Matplotlib

Release 3.11.1

John Hunter
Darren Dale
Eric Firing
Michael Droettboom
and the matplotlib development team

July 18, 2026

CONTENTS

Matplotlib is a comprehensive library for creating static, animated, and interactive visualizations.

Part I

Install

pip

```
pip install matplotlib
```

conda

```
conda install -c conda-forge matplotlib
```

pixi

```
pixi add matplotlib
```

uv

```
uv add matplotlib
```

Warning

uv usually installs its own versions of Python from the python-build-standalone project, and only recent versions of those Python builds (August 2025) work properly with the `tkagg` backend for displaying plots in a window. Please make sure you are using uv 0.8.7 or newer (update with e.g. `uv self update`) and that your bundled Python installs are up to date (with `uv python upgrade --reinstall`). Alternatively, you can use one of the other *supported GUI frameworks*, e.g.

```
uv add matplotlib pyside6
```

other

Install an official release

Third-party distributions

Install a nightly build

Install from source

CHAPTER

ONE

INSTALLATION

pip

```
pip install matplotlib
```

conda

```
conda install -c conda-forge matplotlib
```

pixi

```
pixi add matplotlib
```

uv

```
uv add matplotlib
```

Warning

uv usually installs its own versions of Python from the python-build-standalone project, and only recent versions of those Python builds (August 2025) work properly with the `tkagg` backend for displaying plots in a window. Please make sure you are using uv 0.8.7 or newer (update with e.g. `uv self update`) and that your bundled Python installs are up to date (with `uv python upgrade --reinstall`). Alternatively, you can use one of the other *supported GUI frameworks*, e.g.

```
uv add matplotlib pyside6
```

other

Install an official release

Third-party distributions

Install a nightly build

Install from source

1.1 Install an official release

Matplotlib releases are available as wheel packages for macOS, Windows and Linux on PyPI. Install it using `pip`:

```
python -m pip install -U pip
python -m pip install -U matplotlib
```

If this command results in Matplotlib being compiled from source and there's trouble with the compilation, you can add `--prefer-binary` to select the newest version of Matplotlib for which there is a precompiled wheel for your OS and Python.

Note

The following non-interactive backends work out of the box: Agg, ps, pdf, svg

The TkAgg interactive backend also typically works out of the box. It requires Tk bindings, which are usually provided via the Python standard library's `tkinter` module. On some OSes, you may need to install a separate package like `python3-tk` to add this component of the standard library.

Some tools like `uv` make use of Python builds from the python-build-standalone project, which only gained usable Tk bindings recently (August 2025). If you are having trouble with the TkAgg backend, ensure you have an up-to-date build, e.g. `uv self update && uv python upgrade --reinstall`.

For support of other GUI frameworks, LaTeX rendering, saving animations and a larger selection of file formats, you can install *optional dependencies*.

1.2 Third-party distributions

Various third-parties provide Matplotlib for their environments.

1.2.1 Conda packages

Matplotlib is available both via the *anaconda main channel*

```
conda install matplotlib
```

as well as via the *conda-forge community channel*

```
conda install -c conda-forge matplotlib
```

1.2.2 Python distributions

Matplotlib is part of major Python distributions:

- Anaconda
- ActiveState ActivePython

- WinPython

1.2.3 Linux package manager

If you are using the Python version that comes with your Linux distribution, you can install Matplotlib via your package manager, e.g.:

- Debian / Ubuntu: `sudo apt-get install python3-matplotlib`
- Fedora: `sudo dnf install python3-matplotlib`
- Red Hat: `sudo yum install python3-matplotlib`
- Arch: `sudo pacman -S python-matplotlib`

1.3 Install a nightly build

Matplotlib makes nightly development build wheels available on the scientific-python-nightly-wheels Anaconda Cloud organization. These wheels can be installed with `pip` by specifying scientific-python-nightly-wheels as the package index to query:

```
python -m pip install --upgrade --pre --index-url␣
↪https://pypi.anaconda.org/scientific-python-nightly-wheels/simple --
↪extra-index-url https://pypi.org/simple matplotlib
```

1.4 Install from source

Installing for Development

If you would like to contribute to Matplotlib or otherwise need to install the latest development code, please follow the instructions in *Development setup*.

The following instructions are for installing from source for production use. This is generally *not* recommended; please use prebuilt packages when possible. Proceed with caution because these instructions may result in your build producing unexpected behavior and/or causing local testing to fail.

Before trying to install Matplotlib, please install the *Dependencies*.

To build from a tarball, download the latest *tar.gz* release file from the PyPI files page.

If you are building your own Matplotlib wheels (or sdists) on Windows, note that any DLLs that you copy into the source tree will be packaged too.

1.5 Configure build and behavior defaults

We provide a meson.options file containing options with which you can use to customize the build process. For example, which default backend to use, whether some of the optional libraries that Matplotlib ships with are installed, and so on. These options will be particularly useful to those packaging Matplotlib.

Aspects of some behavioral defaults of the library can be configured via:

1.5.1 Environment variables

HOME

The user's home directory. On Linux, `~` is shorthand for *HOME*.

MPLBACKEND

This optional variable can be set to choose the Matplotlib backend. See *What is a backend?*.

MPLCONFIGDIR

This is the directory used to store user customizations to Matplotlib, as well as some caches to improve performance. If *MPLCONFIGDIR* is not defined, *HOME*`/.config/matplotlib` and *HOME*`/.cache/matplotlib` are used on Linux, and *HOME*`/.matplotlib` on other platforms, if they are writable. Otherwise, the Python standard library's `tempfile.gettempdir` is used to find a base directory in which the `matplotlib` subdirectory is created.

MPL_IGNORE_SYSTEM_FONTS

When this variable is set, Matplotlib will update its font cache only with its own directories. This can be used to limit subprocess usage for querying system fonts.

PATH

The list of directories searched to find executable programs.

PYTHONPATH

The list of directories that are added to Python's standard search list when importing packages and modules.

QT_API

The Python Qt wrapper to prefer when using Qt-based backends. See *the entry in the usage guide* for more information.

Setting environment variables in Linux and macOS

To list the current value of *PYTHONPATH*, which may be empty, try:

```
echo $PYTHONPATH
```

The procedure for setting environment variables in depends on what your default shell is. Common shells include **bash** and **csh**. You should be able to determine which by running at the command prompt:

```
echo $SHELL
```

To create a new environment variable:

```
export PYTHONPATH=~/Python  # bash/ksh
setenv PYTHONPATH ~/Python  # csh/tcsh
```

To prepend to an existing environment variable:

```
export PATH=~/bin:${PATH}  # bash/ksh
setenv PATH ~/bin:${PATH}  # csh/tcsh
```

The search order may be important to you, do you want `~/bin` to be searched first or last? To append to an existing environment variable:

```
export PATH=${PATH}:~/bin  # bash/ksh
setenv PATH ${PATH}:~/bin  # csh/tcsh
```

To make your changes available in the future, add the commands to your `~/.bashrc` or `~/.cshrc` file.

Setting environment variables in Windows

Open the **`Control Panel`** (*Start* □ *Control Panel*), start the **`System`** program. Click the *Advanced* tab and select the *Environment Variables* button. You can edit or add to the *User Variables*.

Default plotting appearance and behavior can be configured via the *rcParams file*.

1.6 Dependencies

Mandatory dependencies should be installed automatically if you install Matplotlib using a package manager such as `pip` or `conda`; therefore this list is primarily for reference and troubleshooting.

1.6.1 Dependencies

Runtime dependencies

Required

When installing through a package manager like `pip` or `conda`, the mandatory dependencies are automatically installed. This list is mainly for reference.

- Python (>= 3.11)
- contourpy (>= 1.0.1)
- cycler (>= 0.10.0)
- dateutil (>= 2.7)
- fontTools (>= 4.28.2)
- kiwisolver (>= 1.3.1)
- NumPy (>= 1.25)
- packaging (>= 20.0)
- Pillow (>= 9.0)
- pyparsing (>= 3)

Note

With **conda packages**, this set of minimal dependencies is realized in the `matplotlib-base` conda package. Other packages in the conda ecosystem that depend on Matplotlib should depend on `matplotlib-base`.

The `matplotlib` conda package additionally comes with `pyside6` to have a working GUI backend out of the box for end users. This should primarily be used to define end-user environments. See also the conda forge documentation.

Optional

The following packages and tools are not required but extend the capabilities of Matplotlib.

Backends

Matplotlib figures can be rendered to various user interfaces. See *What is a backend?* for more details on the optional Matplotlib backends and the capabilities they provide.

- Tk (>= 8.5, != 8.6.0 or 8.6.1): for the Tk-based backends. Tk is part of most standard Python installations, but it's not part of Python itself and thus may not be present in rare cases.
- PyQt6 (>= 6.1), PySide6, PyQt5 (>= 5.12), or PySide2: for the Qt-based backends.
- PyGObject and pycairo (>= 1.14.0): for the GTK-based backends. If using pip (but not conda or system package manager) PyGObject must be built from source; see pygobject documentation.
- pycairo (>= 1.14.0) or cairocffi (>= 0.8): for cairo-based backends.
- wxPython (>= 4): for the wx-based backends. If using pip (but not conda or system package manager) on Linux wxPython wheels must be manually downloaded from https://wxpython.org/pages/downloads/.
- Tornado (>= 5): for the WebAgg backend.
- ipykernel: for the nbagg backend.
- macOS (>= 10.12): for the macosx backend.

Animations

- ffmpeg: for saving movies.
- ImageMagick: for saving animated gifs.

Font handling and rendering

- LaTeX (with cm-super and underscore) and GhostScript (>= 9.0): for rendering text with LaTeX.
- fontconfig (>= 2.7): for detection of system fonts on Linux.

C libraries

Matplotlib brings its own copies of the following libraries:

- `Agg`: the Anti-Grain Geometry C++ rendering engine
- `ttconv`: a TrueType font utility

Additionally, Matplotlib depends on:

- FreeType (>= 2.3): a font rendering library
- QHull (>= 8.0.2): a library for computing triangulations (note that this version is also known as 2020.2)

Download during install

By default, Matplotlib downloads and builds its own copies of Qhull and FreeType. The vendored version of FreeType is necessary to run the test suite, because different versions of FreeType rasterize characters differently.

Use system libraries

To force Matplotlib to use a copy of FreeType or Qhull already installed in your system, you must pass configuration settings to Meson via meson-python:

```
python -m pip install \
  --config-settings=setup-args="-Dsystem-freetype=true" \
  --config-settings=setup-args="-Dsystem-qhull=true" \
  .
```

In this case, you need to install the FreeType and Qhull library and headers. This can be achieved using a package manager, e.g. for FreeType:

```
# Pick ONE of the following:
sudo apt install libfreetype6-dev  # Debian/Ubuntu
sudo dnf install freetype-devel    # Fedora
brew install freetype              # macOS with Homebrew
conda install freetype             # conda, any OS
```

(adapt accordingly for Qhull).

On Linux and macOS, it is also recommended to install pkg-config, a helper tool for locating FreeType:

```
# Pick ONE of the following:
sudo apt install pkg-config  # Debian/Ubuntu
sudo dnf install pkgconf     # Fedora
brew install pkg-config      # macOS with Homebrew
conda install pkg-config     # conda
# Or point the PKG_CONFIG environment variable to the path to␣
```

(continues on next page)

(continued from previous page)

```
 ↪pkg-config:
export PKG_CONFIG=...
```

If not using pkg-config (in particular on Windows), you may need to set the include path (to the library headers) and link path (to the libraries) explicitly, if they are not in standard locations. This can be done using standard environment variables -- on Linux and macOS:

```
export CFLAGS='-I/directory/containing/ft2build.h'
export LDFLAGS='-L/directory/containing/libfreetype.so'
```

and on Windows:

```
set CL=/IC:\directory\containing\ft2build.h
set LINK=/LIBPATH:C:\directory\containing\freetype.lib
```

If you go this route but need to reset and rebuild to change your settings, remember to clear your artifacts before re-building:

```
git clean -xfd
```

From source files

If the automatic download does not work (for example, on air-gapped systems) it is preferable to instead use system libraries. However you can manually download the tarballs into `subprojects/packagecache` at the top level of the checkout repository. The expected SHA256 hashes of the downloaded tarballs are in `subprojects/*.wrap` if you wish to verify them, but they will also be checked by the build system before unpacking.

Minimum pip / manylinux support (linux)

Matplotlib publishes manylinux wheels which have a minimum version of pip which will recognize the wheels

- Python 3.9+: `manylinux2014` / pip >= 19.3

In all cases the required version of pip is embedded in the CPython source.

Build dependencies

Python

`pip` normally builds packages using build isolation, which means that `pip` installs the dependencies listed here for the duration of the build process. However, build isolation is disabled via the the --no-build-isolation flag when *installing Matplotlib for development*, which means that the dependencies must be explicitly installed, either by *creating a virtual environment* (recommended) or by manually installing the following packages:

- meson-python (>= 0.13.1).

- PyBind11 (>= 2.13.2). Used to connect C/C++ code with Python.
- setuptools_scm (>= 7). Used to update the reported `mpl.__version__` based on the current git commit. Also a runtime dependency for editable installs.
- NumPy (>= 1.22). Also a runtime dependency.

Compilers and external build tools

When setting up a virtual environment for development, ninja (>= 1.8.2) may need to be installed separately. This may be available as a pre-built binary or from a package manager or bundled with Meson. Ninja may also be installed via `pip` if otherwise not available.

Compilers

Matplotlib requires a C++ compiler that supports C++17, and each platform has a development environment that must be installed before a compiler can be installed. You may also need to install headers for various libraries used in the compiled extension source files.

Linux

On some Linux systems, you can install a meta-build package. For example, on Ubuntu `apt install build-essential` with elevated privileges.

Otherwise, use the system distribution's package manager to install *gcc*.

macOS

Install Xcode for Apple platform development.

Windows

Install Visual Studio Build Tools

Make sure "Desktop development with C++" is selected, and that the latest MSVC, "C++ CMake tools for Windows," and a Windows SDK compatible with your version of Windows are selected and installed. They should be selected by default under the "Optional" subheading, but are required to build Matplotlib from source.

Alternatively, you can install a Linux-like environment such as CygWin or Windows Subsystem for Linux. If using MinGW-64, we require **v6** of the `Mingw-w64-x86_64-headers`.

We highly recommend that you install a compiler using your platform tool, i.e., Xcode, VS Code or Linux package manager. Choose **one** compiler from this list:

compiler	minimum version	platforms	notes
GCC	**7.2**	Linux, macOS, Windows	gcc 7.2, GCC: Binaries,
Clang (LLVM)	**5**	Linux, macOS	clang 5, LLVM
MSVC++	**16.0**	Windows	Visual Studio 2019 C++

Test dependencies

This section lists the additional software required for *running the tests*.

Required

- pytest (>= 7.0.0)

Optional

In addition to all of the optional dependencies on the main library, for testing the following will be used if they are installed.

Python

These packages are installed when *creating a virtual environment*, otherwise they must be installed manually:

- nbformat and nbconvert used to test the notebook backend
- pandas used to test compatibility with Pandas
- pikepdf used in some tests for the pgf and pdf backends
- psutil used in testing the interactive backends
- pytest-cov (>= 2.3.1) to collect coverage information
- pytest-timeout to limit runtime in case of stuck tests
- pytest-xdist to run tests in parallel
- pytest-xvfb to run tests without windows popping up (Linux)
- pytz used to test pytz int
- sphinx used to test our sphinx extensions
- xarray used to test compatibility with xarray

External tools

- Ghostscript (>= 9.0, to render PDF files)
- Inkscape (to render SVG files)
- WenQuanYi Zen Hei and Noto Sans CJK fonts for testing font fallback and non-Western fonts

If any of these dependencies are not discovered, then the tests that rely on them will be skipped by pytest.

Note

When installing Inkscape on Windows, make sure that you select "Add Inkscape to system PATH", either for all users or current user, or the tests will not find it.

Documentation dependencies

Python

The additional Python packages required to build the *documentation* are listed in `pyproject.toml` and can be installed using

```
pip install --group doc
```

External tools

Required

The documentation requires LaTeX and Graphviz. These are not Python packages and must be installed separately.

- Graphviz
- a LaTeX distribution, e.g. TeX Live or MikTeX

LaTeX dependencies

The following collections must be installed. When using a distribution that does not support collections, the packages listed for each collection must be installed. You may need to install some packages that are not listed here. The complete version of many LaTeX distribution installers, e.g. "texlive-full" or "texlive-all", will often automatically include these collections.

collection	packages
collection-basic	cm, luahbtex
collection-fontsrecommended	cm-super, lm, txfonts
collection-latex	fix-cm, geometry, hyperref, latex, latex-bin, psnfss
collection-latexextra	import, sfmath, type1cm
collection-latexrecommended	fontspec, underscore,
collection-xetex	xetex, xetex-bin

The following packages must also be installed:

- dvipng
- pgf (if using the pgf backend)

Optional

The documentation can be built without these packages, but the build process will raise various warnings:

- Inkscape
- optipng
- ffmpeg

- the font xkcd script or Comic Neue
- the font "Times New Roman"

1.7 Frequently asked questions

1.7.1 Report a compilation problem

See *Get help*.

1.7.2 Matplotlib compiled fine, but nothing shows up when I use it

The first thing to try is a *clean install* and see if that helps. If not, the best way to test your install is by running a script, rather than working interactively from a python shell or an integrated development environment such as **IDLE** which add additional complexities. Open up a UNIX shell or a DOS command prompt and run, for example:

```
python -c "from pylab import *; set_loglevel('DEBUG'); plot(); show()"
```

This will give you additional information about which backends Matplotlib is loading, version information, and more. At this point you might want to make sure you understand Matplotlib's *configuration* process, governed by the `matplotlibrc` configuration file which contains instructions within and the concept of the Matplotlib backend.

If you are still having trouble, see *Get help*.

1.7.3 How to completely remove Matplotlib

Occasionally, problems with Matplotlib can be solved with a clean installation of the package. In order to fully remove an installed Matplotlib:

1. Delete the caches from your *Matplotlib configuration directory*.
2. Delete any Matplotlib directories or eggs from your *installation directory*.

1.7.4 macOS Notes

Which python for macOS?

Apple ships macOS with its own Python, in `/usr/bin/python`, and its own copy of Matplotlib. Unfortunately, the way Apple currently installs its own copies of NumPy, Scipy and Matplotlib means that these packages are difficult to upgrade (see system python packages). For that reason we strongly suggest that you install a fresh version of Python and use that as the basis for installing libraries such as NumPy and Matplotlib. One convenient way to install Matplotlib with other useful Python software is to use the Anaconda Python scientific software collection, which includes Python itself and a wide range of libraries; if you need a library that is not available from the collection, you can install it yourself using standard methods such as *pip*. See the Anaconda web page for installation support.

Other options for a fresh Python install are the standard installer from python.org, or installing Python using a general macOS package management system such as homebrew or macports. Power users on macOS will likely want one of homebrew or macports on their system to install open source software packages, but it

is perfectly possible to use these systems with another source for your Python binary, such as Anaconda or Python.org Python.

Installing macOS binary wheels

If you are using Python from https://www.python.org, Homebrew, or Macports, then you can use the standard pip installer to install Matplotlib binaries in the form of wheels.

pip is installed by default with python.org and Homebrew Python, but needs to be manually installed on Macports with

```
sudo port install py38-pip
```

Once pip is installed, you can install Matplotlib and all its dependencies with from the Terminal.app command line:

```
python3 -m pip install matplotlib
```

You might also want to install IPython or the Jupyter notebook (`python3 -m pip install ipython notebook`).

Checking your installation

The new version of Matplotlib should now be on your Python "path". Check this at the Terminal.app command line:

```
python3 -c 'import matplotlib; print(matplotlib.__version__,␣
↪matplotlib.__file__)'
```

You should see something like

```
3.10.0 /
↪Library/Frameworks/Python.framework/Versions/3.10/lib/python3.10/site-packages/ma
```

where `3.10.0` is the Matplotlib version you just installed, and the path following depends on whether you are using Python.org Python, Homebrew or Macports. If you see another version, or you get an error like

```
Traceback (most recent call last):
  File "<string>", line 1, in <module>
ImportError: No module named matplotlib
```

then check that the Python binary is the one you expected by running

```
which python3
```

If you get a result like `/usr/bin/python...`, then you are getting the Python installed with macOS, which is probably not what you want. Try closing and restarting Terminal.app before running the check again. If that doesn't fix the problem, depending on which Python you wanted to use, consider reinstalling Python.org Python, or check your homebrew or macports setup. Remember that the disk image installer only works for Python.org Python, and will not get picked up by other Pythons. If all these fail, please *let us know*.

1.8 Troubleshooting

1.8.1 Obtaining Matplotlib version

To find out your Matplotlib version number, import it and print the `__version__` attribute:

```
>>> import matplotlib
>>> matplotlib.__version__
'0.98.0'
```

1.8.2 `matplotlib` install location

You can find what directory Matplotlib is installed in by importing it and printing the `__file__` attribute:

```
>>> import matplotlib
>>> matplotlib.__file__
'/
 ↪home/jdhunter/dev/lib64/python2.5/site-packages/matplotlib/__init__.pyc
 ↪'
```

1.8.3 `matplotlib` configuration and cache directory locations

Each user has a Matplotlib configuration directory which may contain a *matplotlibrc* file. To locate your `matplotlib/` configuration directory, use *`matplotlib.get_configdir()`*:

```
>>> import matplotlib as mpl
>>> mpl.get_configdir()
'/home/darren/.config/matplotlib'
```

On Unix-like systems, this directory is generally located in your *HOME* directory under the `.config/` directory.

In addition, users have a cache directory. On Unix-like systems, this is separate from the configuration directory by default. To locate your `.cache/` directory, use *`matplotlib.get_cachedir()`*:

```
>>> import matplotlib as mpl
>>> mpl.get_cachedir()
'/home/darren/.cache/matplotlib'
```

On Windows, both the config directory and the cache directory are the same and are in your `Documents and Settings` or `Users` directory by default:

```
>>> import matplotlib as mpl
>>> mpl.get_configdir()
'C:\\Documents and Settings\\jdhunter\\.matplotlib'
>>> mpl.get_cachedir()
'C:\\Documents and Settings\\jdhunter\\.matplotlib'
```

If you would like to use a different configuration directory, you can do so by specifying the location in your `MPLCONFIGDIR` environment variable -- see *Setting environment variables in Linux and macOS*. Note that `MPLCONFIGDIR` sets the location of both the configuration directory and the cache directory.

Part II

Learn

How to use Matplotlib?

CHAPTER

TWO

QUICK START GUIDE

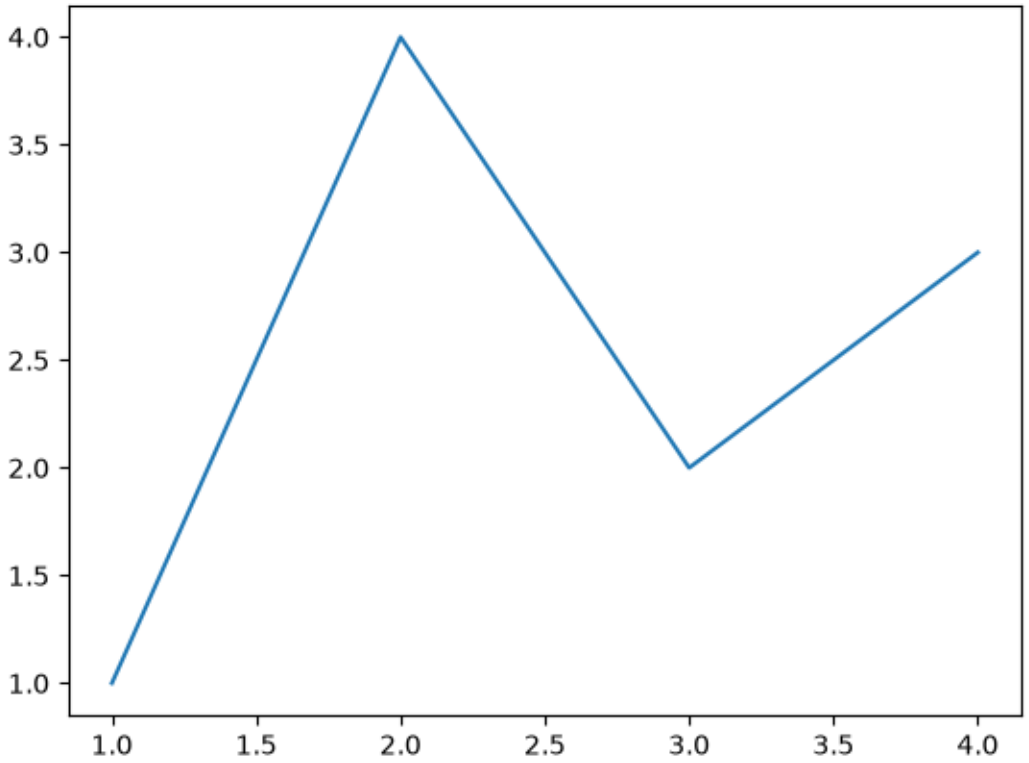
This tutorial covers some basic usage patterns and best practices to help you get started with Matplotlib.

```
import matplotlib.pyplot as plt
import numpy as np
```

2.1 A simple example

Matplotlib graphs your data on *Figure*s (e.g., windows, Jupyter widgets, etc.), each of which can contain one or more *Axes*, an area where points can be specified in terms of x-y coordinates (or theta-r in a polar plot, x-y-z in a 3D plot, etc.). The simplest way of creating a Figure with an Axes is using *pyplot.subplots*. We can then use *Axes.plot* to draw some data on the Axes, and *show* to display the figure:

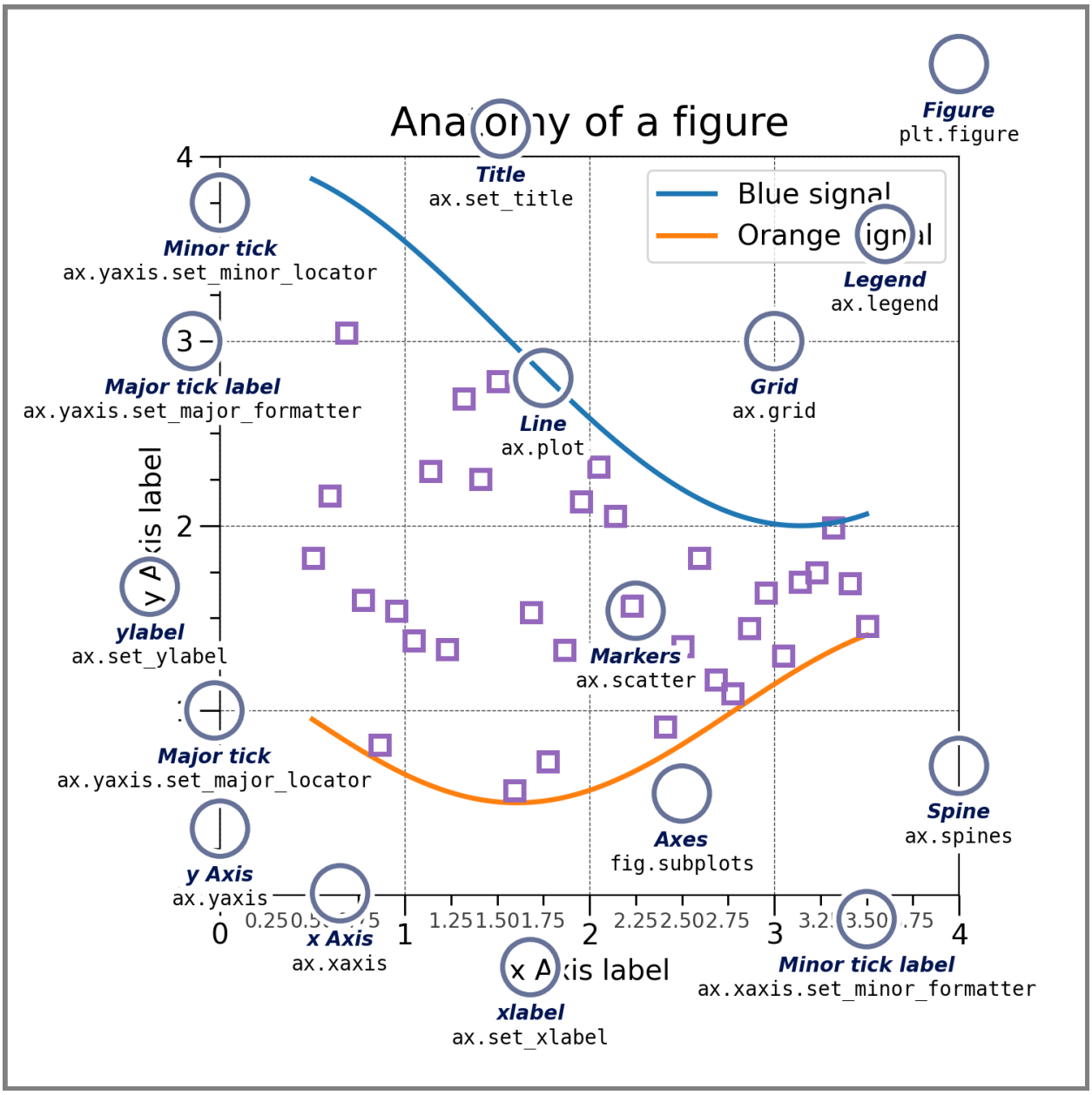
```
fig, ax = plt.subplots()             # Create a figure containing a␣
 ↪single Axes.
ax.plot([1, 2, 3, 4], [1, 4, 2, 3])  # Plot some data on the Axes.
plt.show()                           # Show the figure.
```



Depending on the environment you are working in, `plt.show()` can be left out. This is for example the case with Jupyter notebooks, which automatically show all figures created in a code cell.

2.2 Parts of a Figure

Here are the components of a Matplotlib Figure.



2.2.1 *Figure*

The **whole** figure. The Figure keeps track of all the child *Axes*, a group of 'special' Artists (titles, figure legends, colorbars, etc.), and even nested subfigures.

Typically, you'll create a new Figure through one of the following functions:

```
fig = plt.figure()                # an empty figure with no Axes
fig, ax = plt.subplots()          # a figure with a single Axes
fig, axs = plt.subplots(2, 2)     # a figure with a 2x2 grid of Axes
# a figure with one Axes on the left, and two on the right:
fig, axs = plt.subplot_mosaic([['left', 'right_top'],
```

(continues on next page)

(continued from previous page)

```
                                    ['left', 'right_bottom']])
```

subplots() and *subplot_mosaic* are convenience functions that additionally create Axes objects inside the Figure, but you can also manually add Axes later on.

For more on Figures, including panning and zooming, see *Introduction to Figures*.

2.2.2 *Axes*

An Axes is an Artist attached to a Figure that contains a region for plotting data, and usually includes two (or three in the case of 3D) *Axis* objects (be aware of the difference between **Axes** and **Axis**) that provide ticks and tick labels to provide scales for the data in the Axes. Each *Axes* also has a title (set via *set_title()*), an x-label (set via *set_xlabel()*), and a y-label set via *set_ylabel()*).

The *Axes* methods are the primary interface for configuring most parts of your plot (adding data, controlling axis scales and limits, adding labels etc.).

2.2.3 *Axis*

These objects set the scale and limits and generate ticks (the marks on the Axis) and ticklabels (strings labeling the ticks). The location of the ticks is determined by a *Locator* object and the ticklabel strings are formatted by a *Formatter*. The combination of the correct *Locator* and *Formatter* gives very fine control over the tick locations and labels.

2.2.4 *Artist*

Basically, everything visible on the Figure is an Artist (even *Figure*, *Axes*, and *Axis* objects). This includes *Text* objects, *Line2D* objects, *collections* objects, *Patch* objects, etc. When the Figure is rendered, all of the Artists are drawn to the **canvas**. Most Artists are tied to an Axes; such an Artist cannot be shared by multiple Axes, or moved from one to another.

2.3 Types of inputs to plotting functions

Plotting functions expect `numpy.array` or `numpy.ma.masked_array` as input, or objects that can be passed to `numpy.asarray`. Classes that are similar to arrays ('array-like') such as `pandas` data objects and `numpy.matrix` may not work as intended. Common convention is to convert these to `numpy.array` objects prior to plotting. For example, to convert a `numpy.matrix`

```
b = np.matrix([[1, 2], [3, 4]])
b_asarray = np.asarray(b)
```

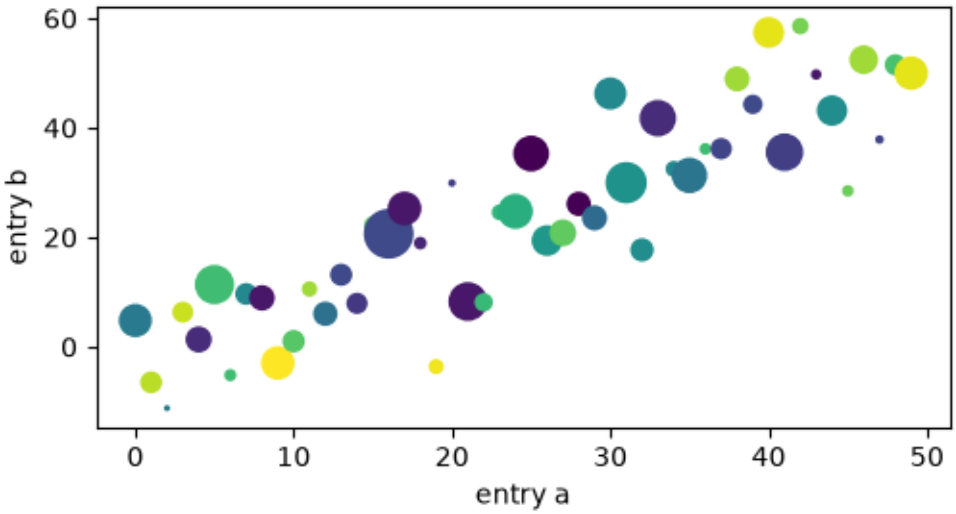
Most methods will also parse a string-indexable object like a *dict*, a structured numpy array, or a `pandas.DataFrame`. Matplotlib allows you to provide the `data` keyword argument and generate plots passing the strings corresponding to the *x* and *y* variables.

```
np.random.seed(19680801)  # seed the random number generator.
data = {'a': np.arange(50),
```

(continues on next page)

(continued from previous page)

```
        'c': np.random.randint(0, 50, 50),
        'd': np.random.randn(50)}
data['b'] = data['a'] + 10 * np.random.randn(50)
data['d'] = np.abs(data['d']) * 100

fig, ax = plt.subplots(figsize=(5, 2.7), layout='constrained')
ax.scatter('a', 'b', c='c', s='d', data=data)
ax.set_xlabel('entry a')
ax.set_ylabel('entry b')
```



2.4 Coding styles

2.4.1 The explicit and the implicit interfaces

As noted above, there are essentially two ways to use Matplotlib:

- Explicitly create Figures and Axes, and call methods on them (the "object-oriented (OO) style").
- Rely on pyplot to implicitly create and manage the Figures and Axes, and use pyplot functions for plotting.

See *Matplotlib Application Interfaces (APIs)* for an explanation of the tradeoffs between the implicit and explicit interfaces.

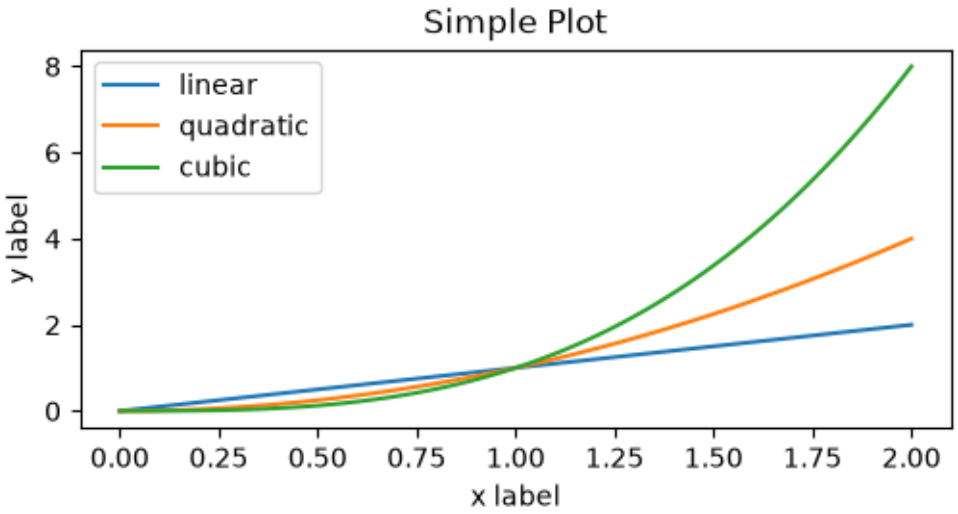
So one can use the OO-style

```
x = np.linspace(0, 2, 100)  # Sample data.

# Note that even in the OO-style, we use `.pyplot.figure` to create␣
↪the Figure.
fig, ax = plt.subplots(figsize=(5, 2.7), layout='constrained')
ax.plot(x, x, label='linear')  # Plot some data on the Axes.
```

(continues on next page)

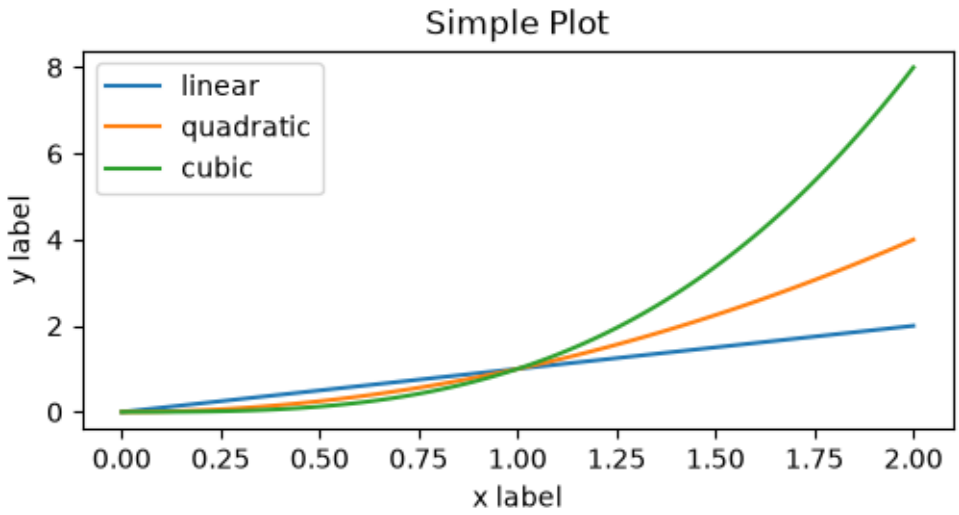
(continued from previous page)

```
ax.plot(x, x**2, label='quadratic')  # Plot more data on the Axes...
ax.plot(x, x**3, label='cubic')  # ... and some more.
ax.set_xlabel('x label')  # Add an x-label to the Axes.
ax.set_ylabel('y label')  # Add a y-label to the Axes.
ax.set_title("Simple Plot")  # Add a title to the Axes.
ax.legend()  # Add a legend.
```



or the pyplot-style:

```
x = np.linspace(0, 2, 100)  # Sample data.

plt.figure(figsize=(5, 2.7), layout='constrained')
plt.plot(x, x, label='linear')  # Plot some data on the (implicit)␣
↪Axes.
plt.plot(x, x**2, label='quadratic')  # etc.
plt.plot(x, x**3, label='cubic')
plt.xlabel('x label')
plt.ylabel('y label')
plt.title("Simple Plot")
plt.legend()
```



(In addition, there is a third approach, for the case when embedding Matplotlib in a GUI application, which completely drops pyplot, even for figure creation. See the corresponding section in the gallery for more info: *Embedding Matplotlib in graphical user interfaces*.)

Matplotlib's documentation and examples use both the OO and the pyplot styles. In general, we suggest using the OO style, particularly for complicated plots, and functions and scripts that are intended to be reused as part of a larger project. However, the pyplot style can be very convenient for quick interactive work.

Note

You may find older examples that use the `pylab` interface, via `from pylab import *`. This approach is strongly deprecated.

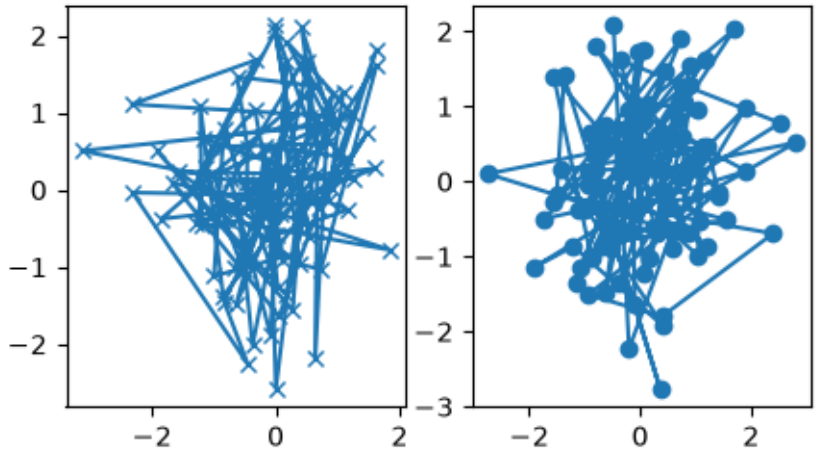
2.4.2 Making a helper functions

If you need to make the same plots over and over again with different data sets, or want to easily wrap Matplotlib methods, use the recommended signature function below.

```
def my_plotter(ax, data1, data2, param_dict):
    """
    A helper function to make a graph.
    """
    out = ax.plot(data1, data2, **param_dict)
    return out
```

which you would then use twice to populate two subplots:

```
data1, data2, data3, data4 = np.random.randn(4, 100)  # make 4 random␣
↪data sets
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(5, 2.7))
my_plotter(ax1, data1, data2, {'marker': 'x'})
my_plotter(ax2, data3, data4, {'marker': 'o'})
```

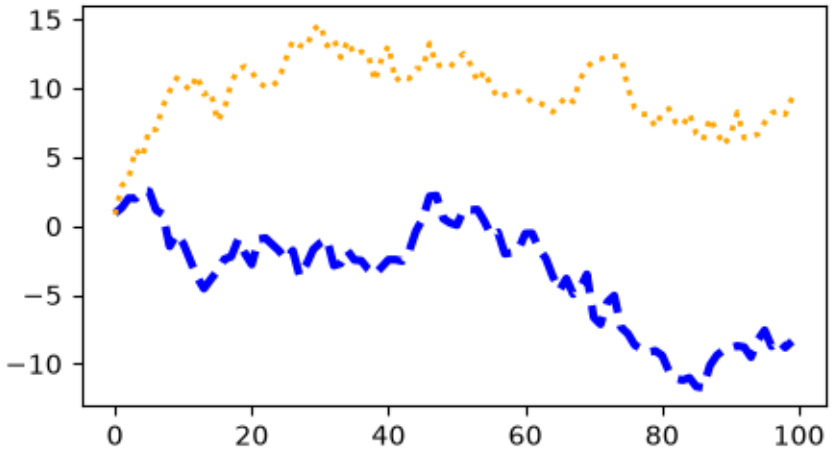


Note that if you want to install these as a python package, or any other customizations you could use one of the many templates on the web; Matplotlib has one at mpl-cookiecutter

2.5 Styling Artists

Most plotting methods have styling options for the Artists, accessible either when a plotting method is called, or from a "setter" on the Artist. In the plot below we manually set the *color*, *linewidth*, and *linestyle* of the Artists created by `plot`, and we set the linestyle of the second line after the fact with `set_linestyle`.

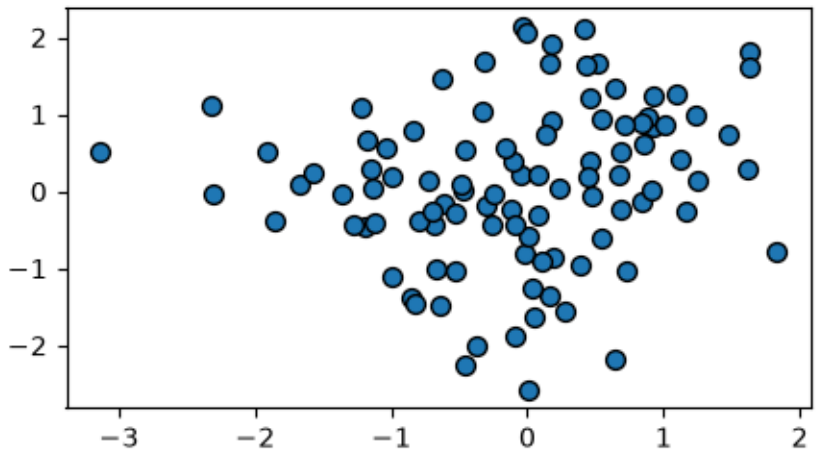
```
fig, ax = plt.subplots(figsize=(5, 2.7))
x = np.arange(len(data1))
ax.plot(x, np.cumsum(data1), color='blue', linewidth=3, linestyle='--')
l, = ax.plot(x, np.cumsum(data2), color='orange', linewidth=2)
l.set_linestyle(':')
```



2.5.1 Colors

Matplotlib has a very flexible array of colors that are accepted for most Artists; see *allowable color definitions* for a list of specifications. Some Artists will take multiple colors. i.e. for a `scatter` plot, the edge of the markers can be different colors from the interior:

```
fig, ax = plt.subplots(figsize=(5, 2.7))
ax.scatter(data1, data2, s=50, facecolor='C0', edgecolor='k')
```

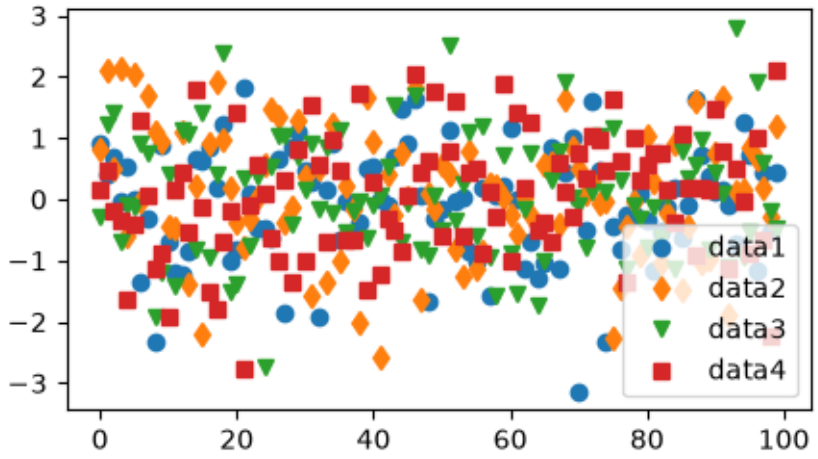


2.5.2 Linewidths, linestyles, and markersizes

Line widths are typically in typographic points (1 pt = 1/72 inch) and available for Artists that have stroked lines. Similarly, stroked lines can have a linestyle. See the *linestyles example*.

Marker size depends on the method being used. `plot` specifies markersize in points, and is generally the "diameter" or width of the marker. `scatter` specifies markersize as approximately proportional to the visual area of the marker. There is an array of markerstyles available as string codes (see `markers`), or users can define their own `MarkerStyle` (see *Marker reference*):

```
fig, ax = plt.subplots(figsize=(5, 2.7))
ax.plot(data1, 'o', label='data1')
ax.plot(data2, 'd', label='data2')
ax.plot(data3, 'v', label='data3')
ax.plot(data4, 's', label='data4')
ax.legend()
```

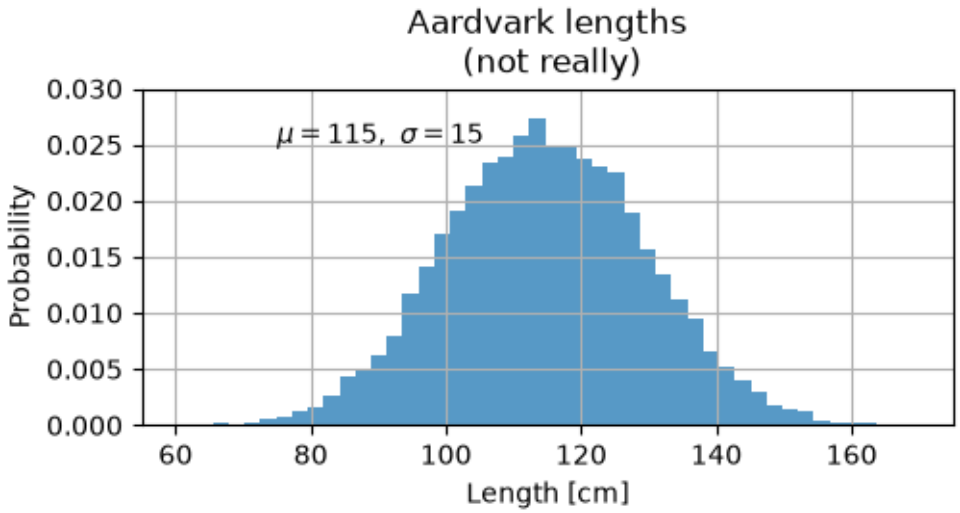


2.6 Labelling plots

2.6.1 Axes labels and text

set_xlabel, *set_ylabel*, and *set_title* are used to add text in the indicated locations (see *Text in Matplotlib* for more discussion). Text can also be directly added to plots using *text*:

```
mu, sigma = 115, 15
x = mu + sigma * np.random.randn(10000)
fig, ax = plt.subplots(figsize=(5, 2.7), layout='constrained')
# the histogram of the data
n, bins, patches = ax.hist(x, 50, density=True, facecolor='C0',␣
 ↪alpha=0.75)

ax.set_xlabel('Length [cm]')
ax.set_ylabel('Probability')
ax.set_title('Aardvark lengths\n (not really)')
ax.text(75, .025, r'$\mu=115,\ \sigma=15$')
ax.axis([55, 175, 0, 0.03])
ax.grid(True)
```



All of the *text* functions return a *matplotlib.text.Text* instance. Just as with lines above, you can customize the properties by passing keyword arguments into the text functions:

```
t = ax.set_xlabel('my data', fontsize=14, color='red')
```

These properties are covered in more detail in *Text properties and layout*.

2.6.2 Using mathematical expressions in text

Matplotlib accepts TeX equation expressions in any text expression. For example to write the expression $\sigma_i = 15$ in the title, you can write a TeX expression surrounded by dollar signs:

```
ax.set_title(r'$\sigma_i=15$')
```

where the `r` preceding the title string signifies that the string is a *raw* string and not to treat backslashes as python escapes. Matplotlib has a built-in TeX expression parser and layout engine, and ships its own math fonts – for details see *Writing mathematical expressions*. You can also use LaTeX directly to format your text and incorporate the output directly into your display figures or saved postscript – see *Text rendering with LaTeX*.

2.6.3 Annotations

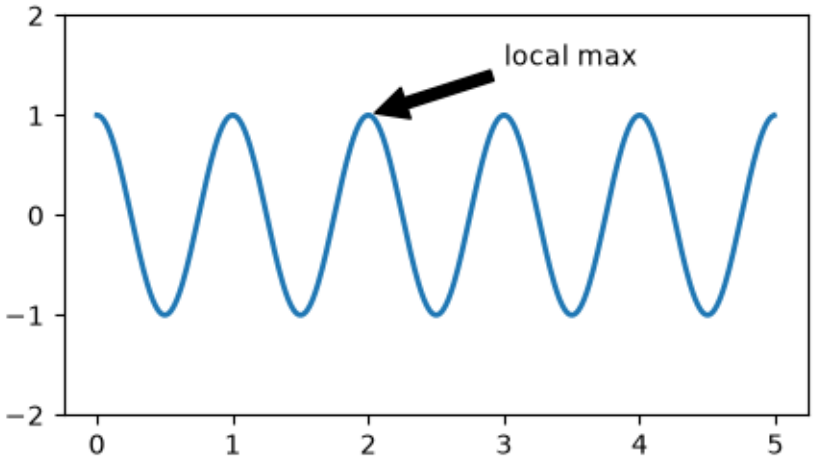
We can also annotate points on a plot, often by connecting an arrow pointing to *xy*, to a piece of text at *xytext*:

```
fig, ax = plt.subplots(figsize=(5, 2.7))

t = np.arange(0.0, 5.0, 0.01)
s = np.cos(2 * np.pi * t)
line, = ax.plot(t, s, lw=2)

ax.annotate('local max', xy=(2, 1), xytext=(3, 1.5),
            arrowprops=dict(facecolor='black', shrink=0.05))
```

(continues on next page)

(continued from previous page)

```
ax.set_ylim(-2, 2)
```

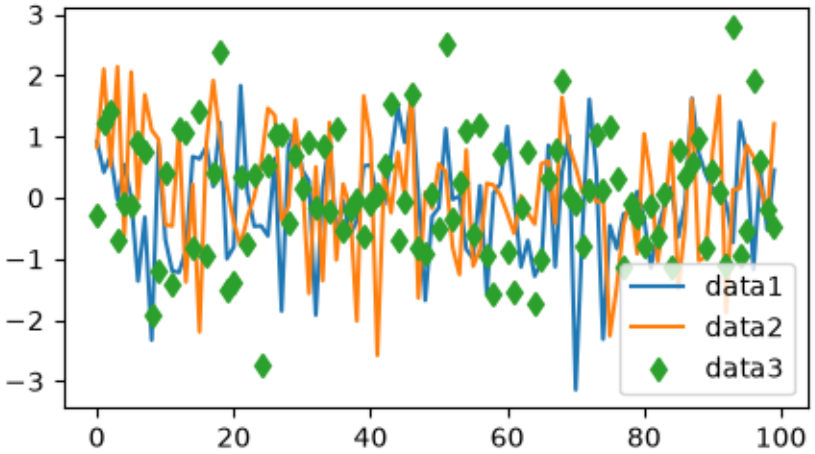


In this basic example, both *xy* and *xytext* are in data coordinates. There are a variety of other coordinate systems one can choose -- see *Basic annotation* and *Advanced annotation* for details. More examples also can be found in *Annotate plots*.

2.6.4 Legends

Often we want to identify lines or markers with a *Axes.legend*:

```
fig, ax = plt.subplots(figsize=(5, 2.7))
ax.plot(np.arange(len(data1)), data1, label='data1')
ax.plot(np.arange(len(data2)), data2, label='data2')
ax.plot(np.arange(len(data3)), data3, 'd', label='data3')
ax.legend()
```



Legends in Matplotlib are quite flexible in layout, placement, and what Artists they can represent. They are discussed in detail in *Legend guide*.

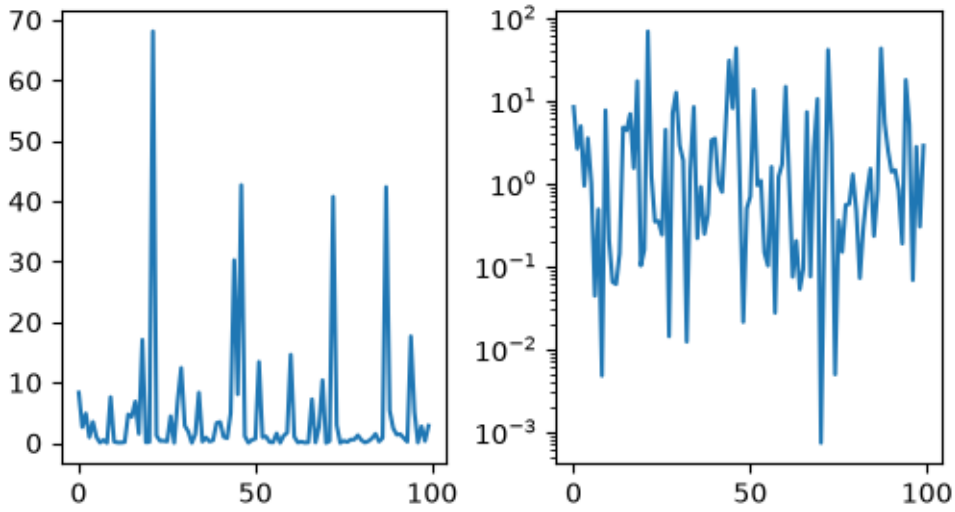
2.7 Axis scales and ticks

Each Axes has two (or three) `Axis` objects representing the x- and y-axis. These control the *scale* of the Axis, the tick *locators* and the tick *formatters*. Additional Axes can be attached to display further Axis objects.

2.7.1 Scales

In addition to the linear scale, Matplotlib supplies non-linear scales, such as a log-scale. Since log-scales are used so much there are also direct methods like `loglog`, `semilogx`, and `semilogy`. There are a number of scales (see *Scales overview* for other examples). Here we set the scale manually:

```
fig, axs = plt.subplots(1, 2, figsize=(5, 2.7), layout='constrained')
xdata = np.arange(len(data1))  # make an ordinal for this
data = 10**data1
axs[0].plot(xdata, data)

axs[1].set_yscale('log')
axs[1].plot(xdata, data)
```



The scale sets the mapping from data values to spacing along the Axis. This happens in both directions, and gets combined into a *transform*, which is the way that Matplotlib maps from data coordinates to Axes, Figure, or screen coordinates. See *Transformations Tutorial*.

2.7.2 Tick locators and formatters

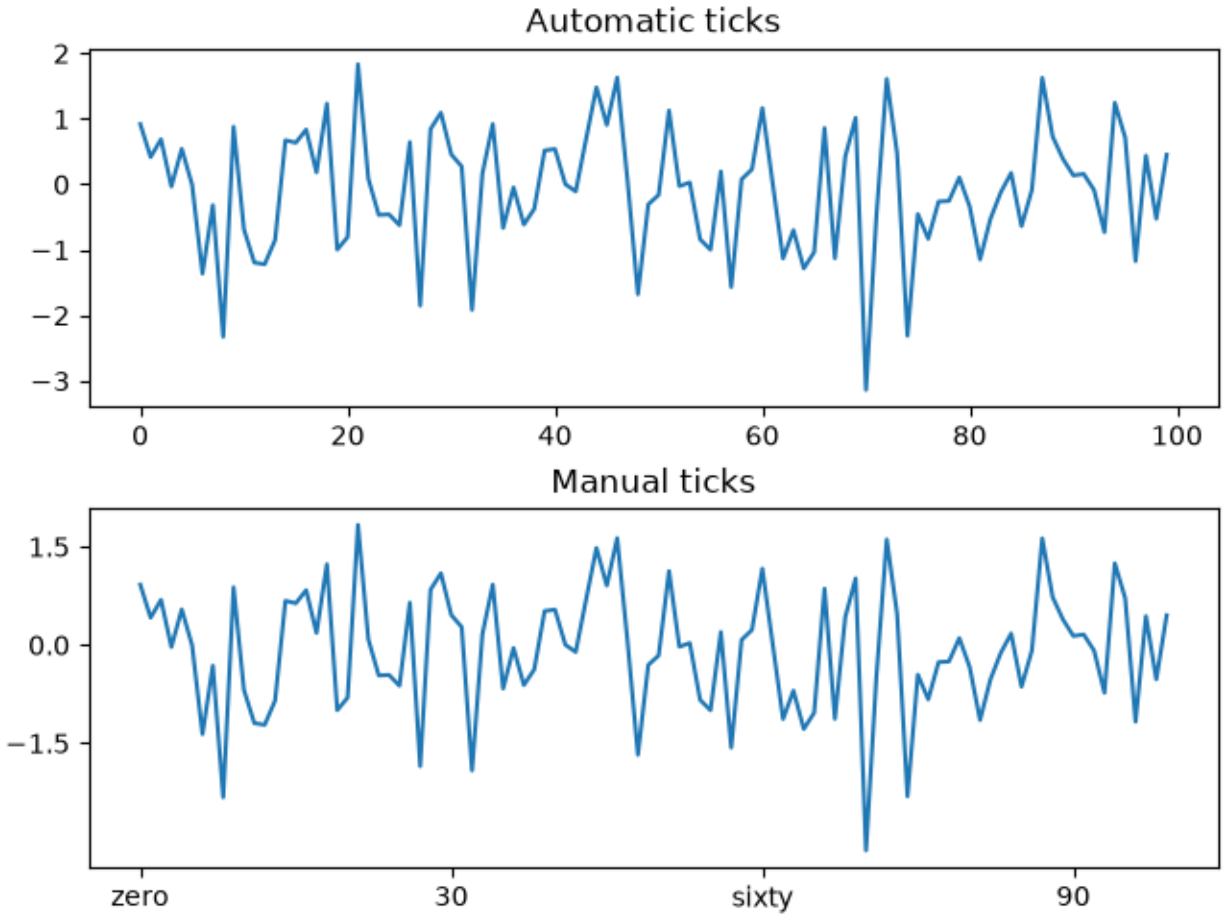
Each Axis has a tick *locator* and *formatter* that choose where along the Axis objects to put tick marks. A simple interface to this is `set_xticks`:

```
fig, axs = plt.subplots(2, 1, layout='constrained')
axs[0].plot(xdata, data1)
```

(continues on next page)

(continued from previous page)

```
axs[0].set_title('Automatic ticks')

axs[1].plot(xdata, data1)
axs[1].set_xticks(np.arange(0, 100, 30), ['zero', '30', 'sixty', '90'])
axs[1].set_yticks([-1.5, 0, 1.5])  # note that we don't need to␣
 ↪specify labels
axs[1].set_title('Manual ticks')
```



Different scales can have different locators and formatters; for instance the log-scale above uses *LogLocator* and *LogFormatter*. See *Tick locators* and *Tick formatters* for other formatters and locators and information for writing your own.

2.7.3 Plotting dates and strings

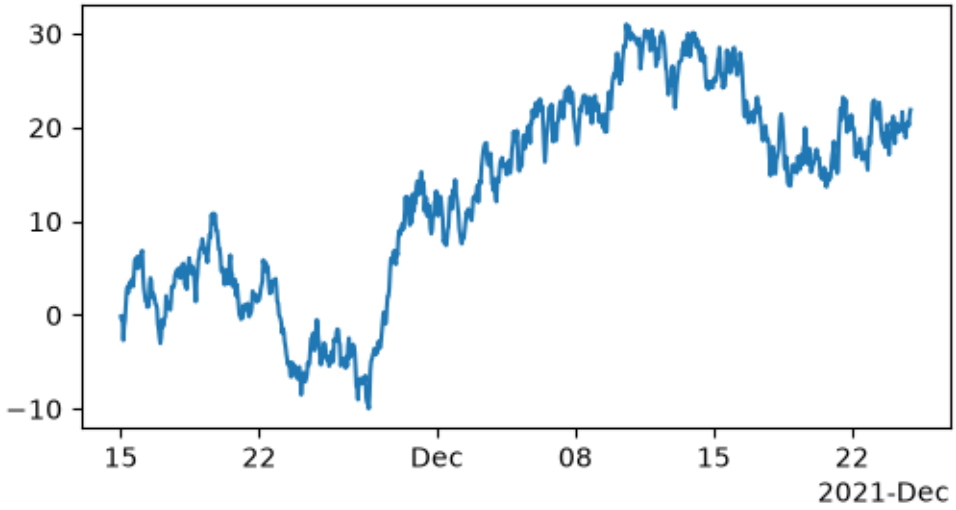
Matplotlib can handle plotting arrays of dates and arrays of strings, as well as floating point numbers. These get special locators and formatters as appropriate. For dates:

```
from matplotlib.dates import ConciseDateFormatter

fig, ax = plt.subplots(figsize=(5, 2.7), layout='constrained')
```

(continues on next page)

(continued from previous page)

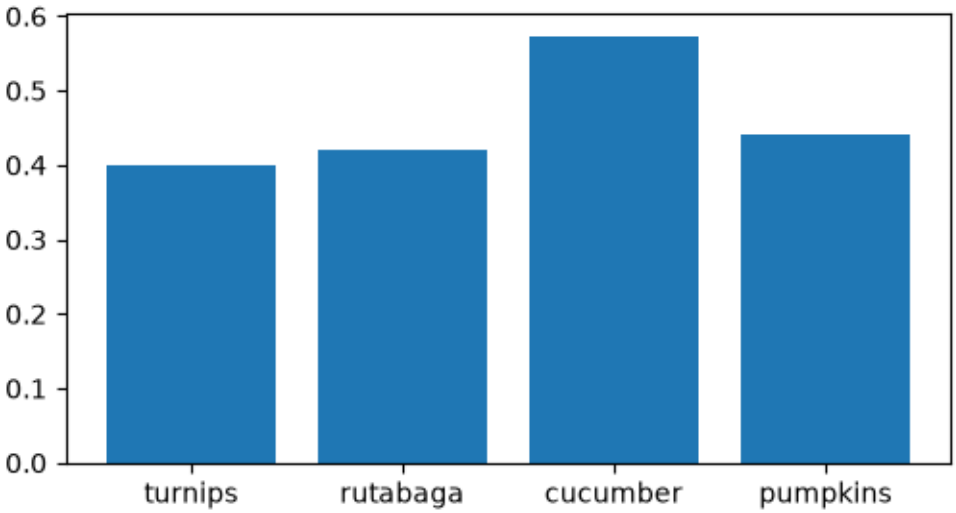
```
dates = np.arange(np.datetime64('2021-11-15'), np.datetime64(
 ↪'2021-12-25'),
                  np.timedelta64(1, 'h'))
data = np.cumsum(np.random.randn(len(dates)))
ax.plot(dates, data)
ax.xaxis.set_major_formatter(ConciseDateFormatter(ax.xaxis.
 ↪get_major_locator()))
```



For more information see the date examples (e.g. *Date tick labels*)

For strings, we get categorical plotting (see: *Plotting categorical variables*).

```
fig, ax = plt.subplots(figsize=(5, 2.7), layout='constrained')
categories = ['turnips', 'rutabaga', 'cucumber', 'pumpkins']

ax.bar(categories, np.random.rand(len(categories)))
```



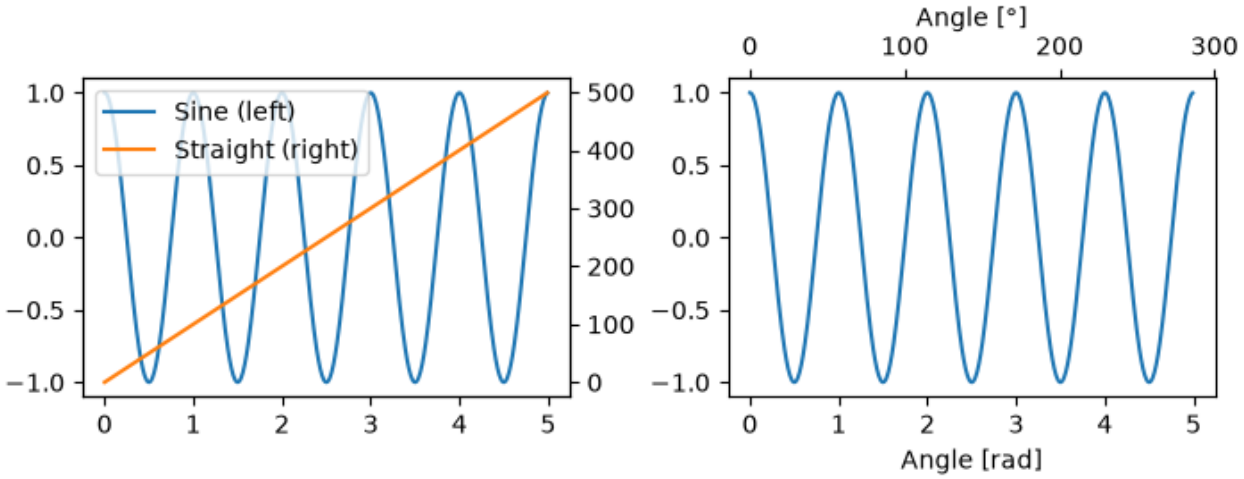
One caveat about categorical plotting is that some methods of parsing text files return a list of strings, even if the strings all represent numbers or dates. If you pass 1000 strings, Matplotlib will think you meant 1000 categories and will add 1000 ticks to your plot!

2.7.4 Additional Axis objects

Plotting data of different magnitude in one chart may require an additional y-axis. Such an Axis can be created by using *twinx* to add a new Axes with an invisible x-axis and a y-axis positioned at the right (analogously for *twiny*). See *Plots with different scales* for another example.

Similarly, you can add a *secondary_xaxis* or *secondary_yaxis* having a different scale than the main Axis to represent the data in different scales or units. See *Secondary Axis* for further examples.

```
fig, (ax1, ax3) = plt.subplots(1, 2, figsize=(7, 2.7), layout=
 ↪'constrained')
l1, = ax1.plot(t, s)
ax2 = ax1.twinx()
l2, = ax2.plot(t, range(len(t)), 'C1')
ax2.legend([l1, l2], ['Sine (left)', 'Straight (right)'])

ax3.plot(t, s)
ax3.set_xlabel('Angle [rad]')
ax4 = ax3.secondary_xaxis('top', (np.rad2deg, np.deg2rad))
ax4.set_xlabel('Angle [°]')
```



2.8 Color mapped data

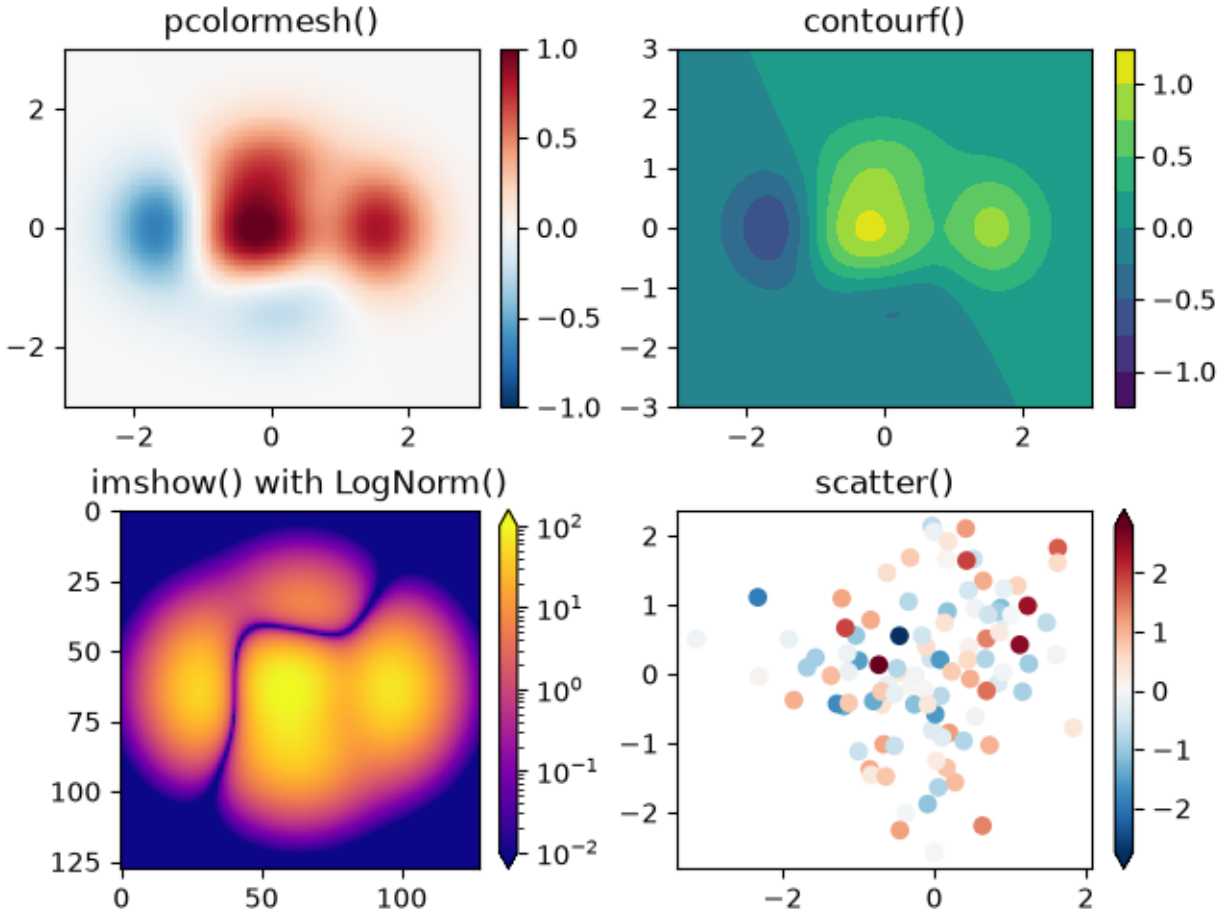
Often we want to have a third dimension in a plot represented by colors in a colormap. Matplotlib has a number of plot types that do this:

```
from matplotlib.colors import LogNorm

X, Y = np.meshgrid(np.linspace(-3, 3, 128), np.linspace(-3, 3, 128))
```

(continues on next page)

(continued from previous page)

```
Z = (1 - X/2 + X**5 + Y**3) * np.exp(-X**2 - Y**2)

fig, axs = plt.subplots(2, 2, layout='constrained')
pc = axs[0, 0].pcolormesh(X, Y, Z, vmin=-1, vmax=1, cmap='RdBu_r')
fig.colorbar(pc, ax=axs[0, 0])
axs[0, 0].set_title('pcolormesh()')

co = axs[0, 1].contourf(X, Y, Z, levels=np.linspace(-1.25, 1.25, 11))
fig.colorbar(co, ax=axs[0, 1])
axs[0, 1].set_title('contourf()')

pc = axs[1, 0].imshow(Z**2 * 100, cmap='plasma',␣
 ↪norm=LogNorm(vmin=0.01, vmax=100))
fig.colorbar(pc, ax=axs[1, 0], extend='both')
axs[1, 0].set_title('imshow() with LogNorm()')

pc = axs[1, 1].scatter(data1, data2, c=data3, cmap='RdBu_r')
fig.colorbar(pc, ax=axs[1, 1], extend='both')
axs[1, 1].set_title('scatter()')
```



2.8.1 Colormaps

These are all examples of Artists that derive from *ScalarMappable* objects. They all can set a linear mapping between *vmin* and *vmax* into the colormap specified by *cmap*. Matplotlib has many colormaps to choose from (*Choosing Colormaps in Matplotlib*) you can make your own (*Creating Colormaps in Matplotlib*) or download as third-party packages.

2.8.2 Normalizations

Sometimes we want a non-linear mapping of the data to the colormap, as in the `LogNorm` example above. We do this by supplying the ScalarMappable with the *norm* argument instead of *vmin* and *vmax*. More normalizations are shown at *Colormap normalization*.

2.8.3 Colorbars

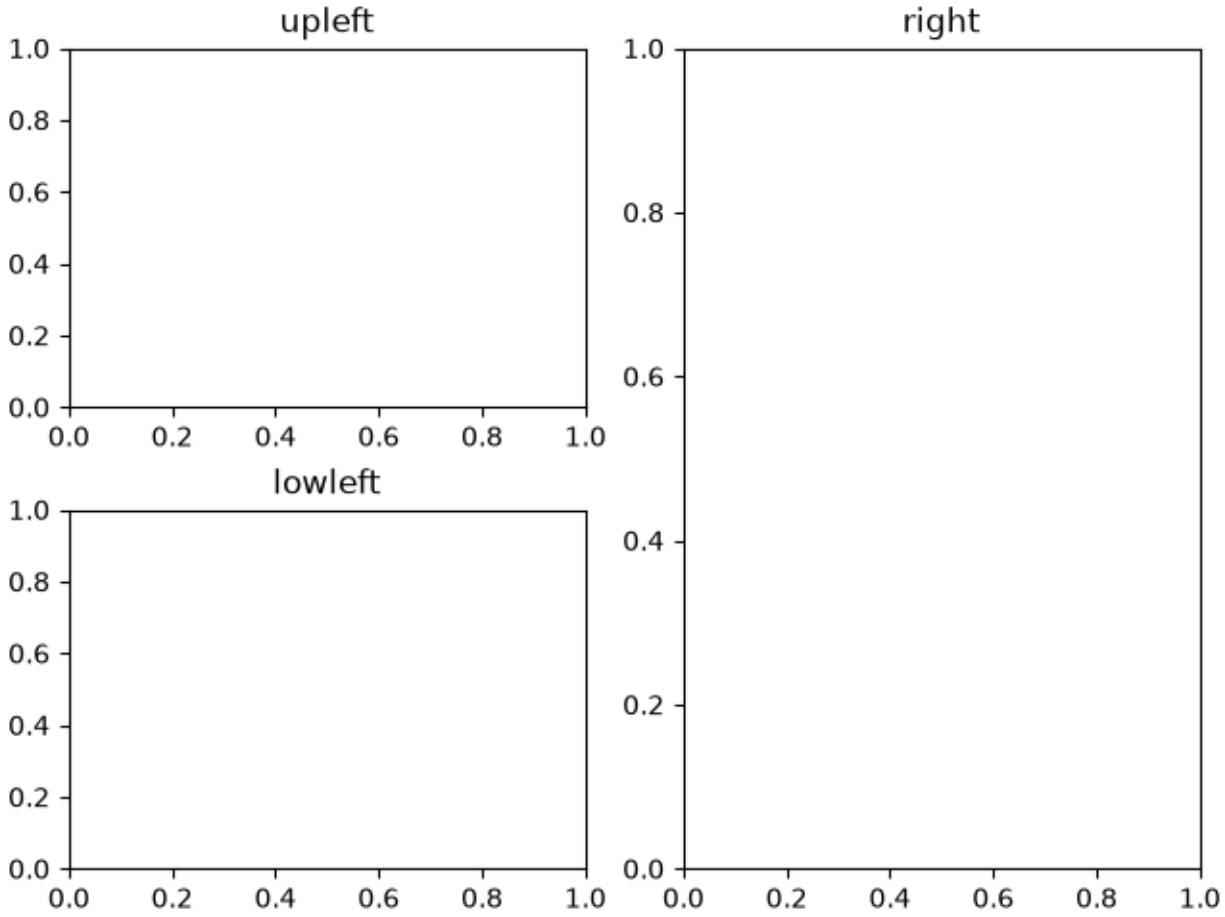
Adding a *colorbar* gives a key to relate the color back to the underlying data. Colorbars are figure-level Artists, and are attached to a ScalarMappable (where they get their information about the norm and colormap) and usually steal space from a parent Axes. Placement of colorbars can be complex: see *Placing colorbars* for details. You can also change the appearance of colorbars with the *extend* keyword to add arrows to the ends, and *shrink* and *aspect* to control the size. Finally, the colorbar will have default locators and formatters appropriate to the norm. These can be changed as for other Axis objects.

2.9 Working with multiple Figures and Axes

You can open multiple Figures with multiple calls to `fig = plt.figure()` or `fig2, ax = plt.subplots()`. By keeping the object references you can add Artists to either Figure.

Multiple Axes can be added a number of ways, but the most basic is `plt.subplots()` as used above. One can achieve more complex layouts, with Axes objects spanning columns or rows, using *subplot_mosaic*.

```
fig, axd = plt.subplot_mosaic([['upleft', 'right'],
                               ['lowleft', 'right']], layout=
 ↪'constrained')
axd['upleft'].set_title('upleft')
axd['lowleft'].set_title('lowleft')
axd['right'].set_title('right')
```



Matplotlib has quite sophisticated tools for arranging Axes: See *Arranging multiple Axes in a Figure* and *Complex and semantic figure composition (subplot_mosaic)*.

2.10 More reading

For more plot types see *Plot types* and the *API reference*, in particular the *Axes API*.

Total running time of the script: (0 minutes 4.987 seconds)

CHAPTER

THREE

USING MATPLOTLIB

3.1 Frequently Asked Questions

3.1.1 I don't see a figure window

Please see *Debugging the figure windows not showing*.

3.1.2 Why do I have so many ticks, and/or why are they out of order?

One common cause for unexpected tick behavior is passing a *list of strings instead of numbers or datetime objects*. This can easily happen without notice when reading in a comma-delimited text file. Matplotlib treats lists of strings as *categorical* variables (*Plotting categorical variables*), and by default puts one tick per category, and plots them in the order in which they are supplied.

```
import matplotlib.pyplot as plt
import numpy as np

fig, ax = plt.subplots(1, 2, layout='constrained', figsize=(6, 2))

ax[0].set_title('Ticks seem out of order / misplaced')
x = ['5', '20', '1', '9']  # strings
y = [5, 20, 1, 9]
ax[0].plot(x, y, 'd')
ax[0].tick_params(axis='x', labelcolor='red', labelsize=14)

ax[1].set_title('Many ticks')
x = [str(xx) for xx in np.arange(100)]  # strings
y = np.arange(100)
ax[1].plot(x, y)
ax[1].tick_params(axis='x', labelcolor='red', labelsize=14)
```

The solution is to convert the list of strings to numbers or datetime objects (often `np.asarray(numeric_strings, dtype='float')` or `np.asarray(datetime_strings, dtype='datetime64[s]')`).

For more information see *Fixing too many ticks*.

3.1.3 Determine the extent of Artists in the Figure

Sometimes we want to know the extent of an Artist. Matplotlib *Artist* objects have a method *Artist.get_window_extent* that will usually return the extent of the artist in pixels. However, some artists, in particular text, must be rendered at least once before their extent is known. Matplotlib supplies *Figure.draw_without_rendering*, which should be called before calling `get_window_extent`.

3.1.4 Check whether a figure is empty

Empty can actually mean different things. Does the figure contain any artists? Does a figure with an empty *Axes* still count as empty? Is the figure empty if it was rendered pure white (there may be artists present, but they could be outside the drawing area or transparent)?

For the purpose here, we define empty as: "The figure does not contain any artists except its background patch." The exception for the background is necessary, because by default every figure contains a *Rectangle* as its background patch. This definition could be checked via:

```
def is_empty(figure):
    """
    Return whether the figure contains no Artists (other than the␣
 ↪default
    background patch).
    """
    contained_artists = figure.get_children()
    return len(contained_artists) <= 1
```

We've decided not to include this as a figure method because this is only one way of defining empty, and checking the above is only rarely necessary. Whether or not something has been added to the figure is usually defined within the context of the program.

The only reliable way to check whether a figure would render empty is to actually perform such a rendering and inspect the result.

3.1.5 Find all objects in a figure of a certain type

Every Matplotlib artist (see *Artist tutorial*) has a method called *findobj()* that can be used to recursively search the artist for any artists it may contain that meet some criteria (e.g., match all *Line2D* instances or match some arbitrary filter function). For example, the following snippet finds every object in the figure which has a `set_color` property and makes the object blue:

```
def myfunc(x):
    return hasattr(x, 'set_color')

for o in fig.findobj(myfunc):
    o.set_color('blue')
```

You can also filter on class instances:

```
import matplotlib.text as text
for o in fig.findobj(text.Text):
    o.set_fontstyle('italic')
```

3.1.6 Prevent ticklabels from having an offset

The default formatter will use an offset to reduce the length of the ticklabels. To turn this feature off on a per-axis basis:

```
ax.xaxis.get_major_formatter().set_useOffset(False)
```

set *rcParams["axes.formatter.useoffset"]* (default: `True`), or use a different formatter. See *ticker* for details.

3.1.7 Save transparent figures

The *savefig()* command has a keyword argument *transparent* which, if 'True', will make the figure and axes backgrounds transparent when saving, but will not affect the displayed image on the screen.

If you need finer grained control, e.g., you do not want full transparency or you want to affect the screen displayed version as well, you can set the alpha properties directly. The figure has a *Rectangle* instance called *patch* and the axes has a Rectangle instance called *patch*. You can set any property on them directly (*facecolor*, *edgecolor*, *linewidth*, *linestyle*, *alpha*). e.g.:

```
fig = plt.figure()
fig.patch.set_alpha(0.5)
ax = fig.add_subplot(111)
ax.patch.set_alpha(0.5)
```

If you need *all* the figure elements to be transparent, there is currently no global alpha setting, but you can set the alpha channel on individual elements, e.g.:

```
ax.plot(x, y, alpha=0.5)
ax.set_xlabel('volts', alpha=0.5)
```

3.1.8 Save multiple plots to one pdf file

Many image file formats can only have one image per file, but some formats support multi-page files. Currently, Matplotlib only provides multi-page output to pdf files, using either the pdf or pgf backends, via the *backend_pdf.PdfPages* and *backend_pgf.PdfPages* classes.

3.1.9 Make room for tick labels

By default, Matplotlib uses fixed percentage margins around subplots. This can lead to labels overlapping or being cut off at the figure boundary. There are multiple ways to fix this:

- Manually adapt the subplot parameters using *Figure.subplots_adjust* / *pyplot.subplots_adjust*.

- Use one of the automatic layout mechanisms:
  - constrained layout (*Constrained layout guide*)
  - tight layout (*Tight layout guide*)
- Calculate good values from the size of the plot elements yourself (*Programmatically control subplot adjustment*)

3.1.10 Align my ylabels across multiple subplots

If you have multiple subplots over one another, and the y data have different scales, you can often get ylabels that do not align vertically across the multiple subplots, which can be unattractive. By default, Matplotlib positions the x location of the ylabel so that it does not overlap any of the y ticks. You can override this default behavior by specifying the coordinates of the label. To learn how, see *Align labels and titles*

3.1.11 Control the draw order of plot elements

The draw order of plot elements, and thus which elements will be on top, is determined by the `set_zorder` property. See *Zorder Demo* for a detailed description.

3.1.12 Make the aspect ratio for plots equal

The Axes property `set_aspect()` controls the aspect ratio of the axes. You can set it to be 'auto', 'equal', or some ratio which controls the ratio:

```
ax = fig.add_subplot(111, aspect='equal')
```

3.1.13 Draw multiple y-axis scales

A frequent request is to have two scales for the left and right y-axis, which is possible using `twinx()` (more than two scales are not currently supported, though it is on the wish list). This works pretty well, though there are some quirks when you are trying to interactively pan and zoom, because both scales do not get the signals.

The approach uses `twinx()` (and its sister `twiny()`) to use *2 different axes*, turning the axes rectangular frame off on the 2nd axes to keep it from obscuring the first, and manually setting the tick locs and labels as desired. You can use separate `matplotlib.ticker` formatters and locators as desired because the two axes are independent.

3.1.14 Generate images without having a window appear

The recommended approach since Matplotlib 3.1 is to explicitly create a Figure instance:

```
from matplotlib.figure import Figure
fig = Figure()
ax = fig.subplots()
ax.plot([1, 2, 3])
fig.savefig('myfig.png')
```

This prevents any interaction with GUI frameworks and the window manager.

It's alternatively still possible to use the pyplot interface: instead of calling *matplotlib.pyplot.show*, call *matplotlib.pyplot.savefig*. In that case, you must close the figure after saving it. Not closing the figure causes a memory leak, because pyplot keeps references to all not-yet-shown figures.

```
import matplotlib.pyplot as plt
plt.plot([1, 2, 3])
plt.savefig('myfig.png')
plt.close()
```

See also

Embed in a web application server (Flask) for information about running matplotlib inside of a web application.

3.1.15 Work with threads

Matplotlib is not thread-safe: in fact, there are known race conditions that affect certain artists. Hence, if you work with threads, it is your responsibility to set up the proper locks to serialize access to Matplotlib artists.

You may be able to work on separate figures from separate threads. However, you must in that case use a *non-interactive backend* (typically Agg), because most GUI backends *require* being run from the main thread as well.

3.1.16 Get help

There are a number of good resources for getting help with Matplotlib. There is a good chance your question has already been asked:

- The mailing list archive.
- GitHub issues.
- Stackoverflow questions tagged matplotlib.

If you are unable to find an answer to your question through search, please provide the following information in your e-mail to the mailing list:

- Your operating system (Linux/Unix users: post the output of `uname -a`).
- Matplotlib version:

  ```
  python -c "import matplotlib; print(matplotlib.__version__)"
  ```

- Where you obtained Matplotlib (e.g., your Linux distribution's packages, GitHub, PyPI, or Anaconda).
- Any customizations to your `matplotlibrc` file (see *Customizing Matplotlib with style sheets and rcParams*).
- If the problem is reproducible, please try to provide a *minimal*, standalone Python script that demonstrates the problem. This is *the* critical step. If you can't post a piece of code that we can run and

reproduce your error, the chances of getting help are significantly diminished. Very often, the mere act of trying to minimize your code to the smallest bit that produces the error will help you find a bug in *your* code that is causing the problem.

- Matplotlib provides debugging information through the `logging` library, and a helper function to set the logging level: one can call

```
plt.set_loglevel("INFO")   # or "DEBUG" for more info
```

to obtain this debugging information.

Standard functions from the `logging` module are also applicable; e.g. one could call `logging.basicConfig(level="DEBUG")` even before importing Matplotlib (this is in particular necessary to get the logging info emitted during Matplotlib's import), or attach a custom handler to the "matplotlib" logger. This may be useful if you use a custom logging configuration.

If you compiled Matplotlib yourself, please also provide:

- your compiler version -- e.g., `gcc --version`.
- the output of:

```
pip install --verbose
```

The beginning of the build output contains lots of details about your platform that are useful for the Matplotlib developers to diagnose your problem.

If you compiled an older version of Matplotlib using the pre-Meson build system, instead provide:

- any changes you have made to `setup.py`/`setupext.py`,
- the output of:

```
rm -rf build
python setup.py build
```

Including this information in your first e-mail to the mailing list will save a lot of time.

You will likely get a faster response writing to the mailing list than filing a bug in the bug tracker. Most developers check the bug tracker only periodically. If your problem has been determined to be a bug and cannot be quickly solved, you may be asked to file a bug in the tracker so the issue doesn't get lost.

3.2 Figures and backends

When looking at Matplotlib visualization, you are almost always looking at Artists placed on a *`Figure`*. In the example below, the figure is the blue region and *`add_subplot`* has added an *`Axes`* artist to the *`Figure`* (see *Parts of a Figure*). A more complicated visualization can add multiple Axes to the Figure, colorbars, legends, annotations, and the Axes themselves can have multiple Artists added to them (e.g. `ax.plot` or `ax.imshow`).

```
fig = plt.figure(figsize=(4, 2), facecolor='lightskyblue',
                 layout='constrained')
```

(continues on next page)

(continued from previous page)

```
fig.suptitle('A nice Matplotlib Figure')
ax = fig.add_subplot()
ax.set_title('Axes', loc='left', fontstyle='oblique', fontsize='medium
↪')
```

3.2.1 Introduction to Figures

```
fig = plt.figure(figsize=(2, 2), facecolor='lightskyblue',
                 layout='constrained')
fig.suptitle('Figure')
ax = fig.add_subplot()
ax.set_title('Axes', loc='left', fontstyle='oblique', fontsize='medium
↪')
```

When looking at Matplotlib visualization, you are almost always looking at Artists placed on a *Figure*. In the example above, the figure is the blue region and *add_subplot* has added an *Axes* artist to the *Figure* (see *Parts of a Figure*). A more complicated visualization can add multiple Axes to the Figure, colorbars, legends, annotations, and the Axes themselves can have multiple Artists added to them (e.g. `ax.plot` or `ax.imshow`).

- *Viewing Figures*
  - *Notebooks and IDEs*
  - *Standalone scripts and interactive use*
- *Creating Figures*
  - *Figure options*
  - *Adding Artists*
- *Saving Figures*

Viewing Figures

We will discuss how to create Figures in more detail below, but first it is helpful to understand how to view a Figure. This varies based on how you are using Matplotlib, and what *Backend* you are using.

Notebooks and IDEs

If you are using a Notebook (e.g. Jupyter) or an IDE that renders Notebooks (PyCharm, VSCode, etc), then they have a backend that will render the Matplotlib Figure when a code cell is executed. The default Jupyter backend (`%matplotlib inline`) creates static plots that by default trim or expand the figure size to have a tight box around Artists added to the Figure (see *Saving Figures*, below). For interactive plots in Jupyter

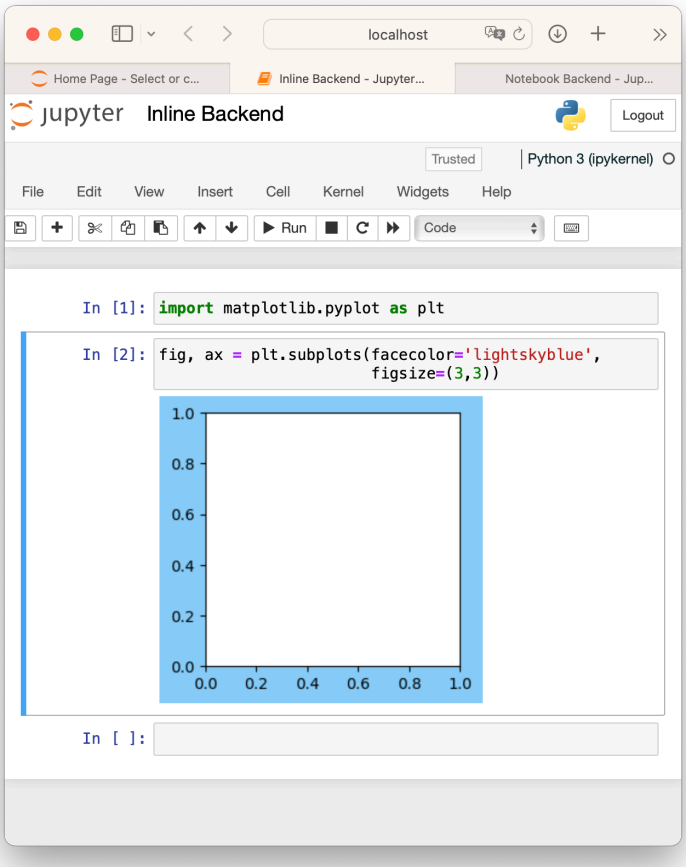


Fig. 1: Screenshot of a Jupyter Notebook, with a figure generated via the default inline backend.

you will need to use an ipython "magic" like `%matplotlib widget` for the ipympl backend in `jupyter lab` or `notebook>=7`, or `%matplotlib notebook` for the Matplotlib *notebook* in `notebook<7` or `nbclassic`.

Note

The ipympl backend is in a separate package, see *Installing ipympl*.

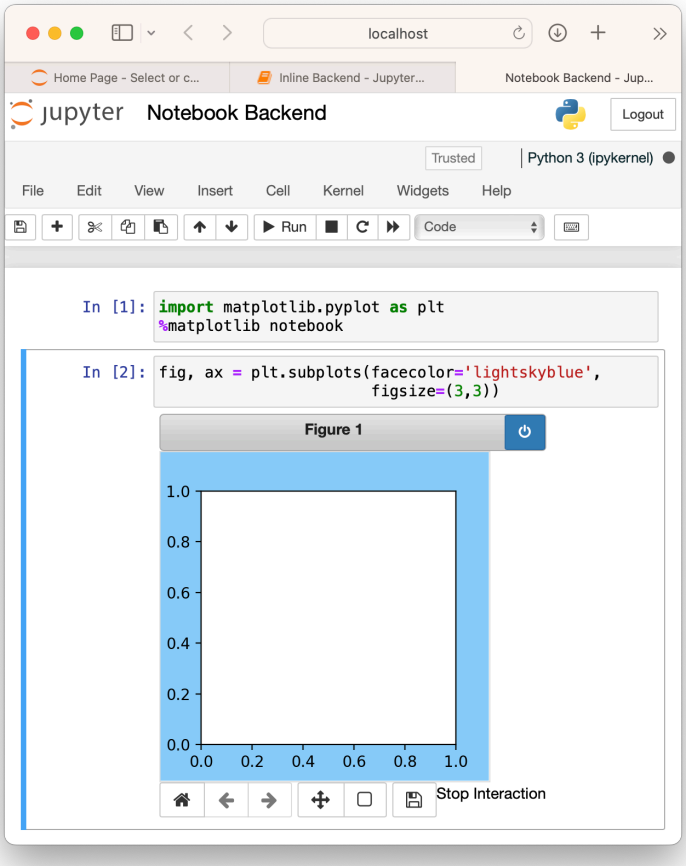


Fig. 2: Screenshot of a Jupyter Notebook with an interactive figure generated via the `%matplotlib notebook` magic. Users should also try the similar widget backend if using JupyterLab.

See also

Interactive figures.

Standalone scripts and interactive use

If the user is on a client with a windowing system, there are a number of *Backends* that can be used to render the Figure to the screen, usually using a Python Qt, Tk, or Wx toolkit, or the native MacOS backend. These are typically chosen either in the user's *matplotlibrc*, or by calling, for example, `matplotlib.use('QtAgg')` at the beginning of a session or script.

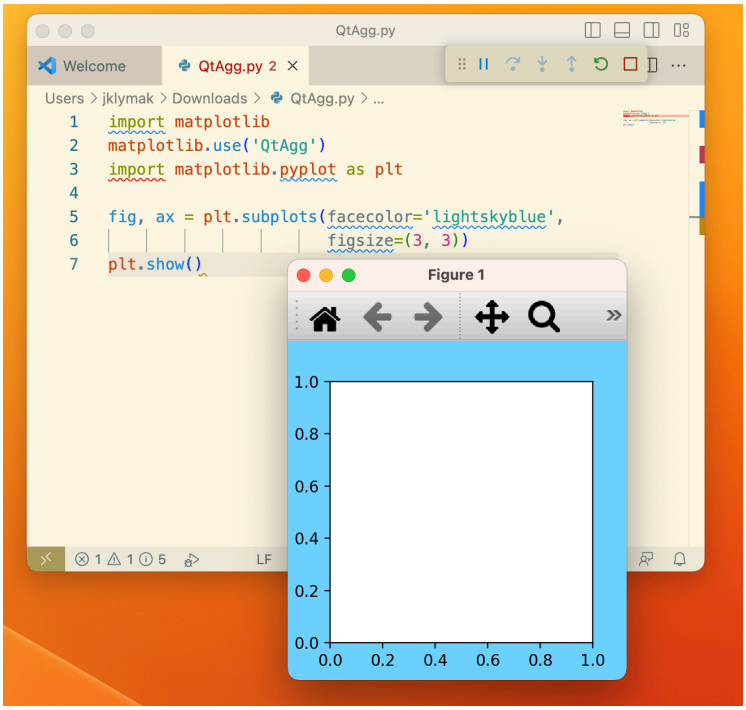


Fig. 3: Screenshot of a Figure generated via a python script and shown using the QtAgg backend.

When run from a script, or interactively (e.g. from an IPython shell) the Figure will not be shown until we call `plt.show()`. The Figure will appear in a new GUI window, and usually will have a toolbar with Zoom, Pan, and other tools for interacting with the Figure. By default, `plt.show()` blocks further interaction from the script or shell until the Figure window is closed, though that can be toggled off for some purposes. For more details, please see *Interactive mode*.

Note that if you are on a client that does not have access to a windowing system, the Figure will fallback to being drawn using the "Agg" backend, and cannot be viewed, though it can be *saved*.

See also

Interactive figures.

Creating Figures

By far the most common way to create a figure is using the *pyplot* interface. As noted in *Matplotlib Application Interfaces (APIs)*, the pyplot interface serves two purposes. One is to spin up the Backend and keep track of GUI windows. The other is a global state for Axes and Artists that allow a short-form API to plotting methods. In the example above, we use pyplot for the first purpose, and create the Figure object, `fig`. As a side effect `fig` is also added to pyplot's global state, and can be accessed via *`gcf`*.

Users typically want an Axes or a grid of Axes when they create a Figure, so in addition to *`figure`*, there are convenience methods that return both a Figure and some Axes. A simple grid of Axes can be achieved with *`pyplot.subplots`* (which simply wraps *`Figure.subplots`*):

```
fig, axs = plt.subplots(2, 2, figsize=(4, 3), layout='constrained')
```

More complex grids can be achieved with *`pyplot.subplot_mosaic`* (which wraps *`Figure.subplot_mosaic`*):

```
fig, axs = plt.subplot_mosaic([['A', 'right'], ['B', 'right']],
                              figsize=(4, 3), layout='constrained')
for ax_name, ax in axs.items():
    ax.text(0.5, 0.5, ax_name, ha='center', va='center')
```

Sometimes we want to have a nested layout in a Figure, with two or more sets of Axes that do not share the same subplot grid. We can use *`add_subfigure`* or *`subfigures`* to create virtual figures inside a parent Figure; see *Figure subfigures* for more details.

```
fig = plt.figure(layout='constrained', facecolor='lightskyblue')
fig.suptitle('Figure')
figL, figR = fig.subfigures(1, 2)
figL.set_facecolor('thistle')
axL = figL.subplots(2, 1, sharex=True)
axL[1].set_xlabel('x [m]')
figL.suptitle('Left subfigure')
figR.set_facecolor('paleturquoise')
axR = figR.subplots(1, 2, sharey=True)
axR[0].set_title('Axes 1')
figR.suptitle('Right subfigure')
```

It is possible to directly instantiate a *`Figure`* instance without using the pyplot interface. This is usually only necessary if you want to create your own GUI application or service that you do not want carrying the

pyplot global state. See the embedding examples in *Embedding Matplotlib in graphical user interfaces* for examples of how to do this.

Figure options

There are a few options available when creating figures. The Figure size on the screen is set by *figsize* and *dpi*. *figsize* is the `(width, height)` of the Figure in inches (or, if preferred, units of 72 typographic points). *dpi* are how many pixels per inch the figure will be rendered at. To make your Figures appear on the screen at the physical size you requested, you should set *dpi* to the same *dpi* as your graphics system. Note that many graphics systems now use a "dpi ratio" to specify how many screen pixels are used to represent a graphics pixel. Matplotlib applies the dpi ratio to the *dpi* passed to the figure to make it have higher resolution, so you should pass the lower number to the figure.

The *facecolor*, *edgecolor*, *linewidth*, and *frameon* options all change the appearance of the figure in expected ways, with *frameon* making the figure transparent if set to *False*.

Finally, the user can specify a layout engine for the figure with the *layout* parameter. Currently Matplotlib supplies *"constrained"*, *"compressed"* and *"tight"* layout engines. These rescale axes inside the Figure to prevent overlap of ticklabels, and try and align axes, and can save significant manual adjustment of artists on a Figure for many common cases.

Adding Artists

The *`Figure`* class has a number of methods for adding artists to a *`Figure`* or a *`SubFigure`*. By far the most common are to add Axes of various configurations (*`add_axes`*, *`add_subplot`*, *`subplots`*, *`subplot_mosaic`*) and subfigures (*`subfigures`*). Colorbars are added to Axes or group of Axes at the Figure level (*`colorbar`*). It is also possible to have a Figure-level legend (*`legend`*). Other Artists include figure-wide labels (*`suptitle`*, *`supxlabel`*, *`supylabel`*) and text (*`text`*). Finally, low-level Artists can be added directly using *`add_artist`* usually with care being taken to use the appropriate transform. Usually these include `Figure.transFigure` which ranges from 0 to 1 in each direction, and represents the fraction of the current Figure size, or `Figure.dpi_scale_trans` which will be in physical units of inches from the bottom left corner of the Figure (see *Transformations Tutorial* for more details).

Saving Figures

Finally, Figures can be saved to disk using the *`savefig`* method. `fig.savefig('MyFigure.png', dpi=200)` will save a PNG formatted figure to the file `MyFigure.png` in the current directory on disk with 200 dots-per-inch resolution. Note that the filename can include a relative or absolute path to any place on the file system.

Many types of output are supported, including raster formats like PNG, GIF, JPEG, TIFF and vector formats like PDF, EPS, and SVG.

By default, the size of the saved Figure is set by the Figure size (in inches) and, for the raster formats, the *dpi*. If *dpi* is not set, then the *dpi* of the Figure is used. Note that *dpi* still has meaning for vector formats like PDF if the Figure includes Artists that have been *rasterized*; the *dpi* specified will be the resolution of the rasterized objects.

It is possible to change the size of the Figure using the *bbox_inches* argument to savefig. This can be specified manually, again in inches. However, by far the most common use is `bbox_inches='tight'`. This option

"shrink-wraps", trimming or expanding as needed, the size of the figure so that it is tight around all the artists in a figure, with a small pad that can be specified by *pad_inches*, which defaults to 0.1 inches. The dashed box in the plot below shows the portion of the figure that would be saved if `bbox_inches='tight'` were used in savefig.

3.2.2 Backends

What is a backend?

Backends are used for displaying Matplotlib figures (see *Introduction to Figures*), on the screen, or for writing to files. A lot of documentation on the website and in the mailing lists refers to the "backend" and many new users are confused by this term. Matplotlib targets many different use cases and output formats. Some people use Matplotlib interactively from the Python shell and have plotting windows pop up when they type commands. Some people run Jupyter notebooks and draw inline plots for quick data analysis. Others embed Matplotlib into graphical user interfaces like PyQt or PyGObject to build rich applications. Some people use Matplotlib in batch scripts to generate postscript images from numerical simulations, and still others run web application servers to dynamically serve up graphs.

To support all of these use cases, Matplotlib can target different outputs, and each of these capabilities is called a backend; the "frontend" is the user facing code, i.e., the plotting code, whereas the "backend" does all the hard work behind-the-scenes to make the figure. There are two types of backends: user interface backends (for use in PyQt/PySide, PyGObject, Tkinter, wxPython, or macOS/Cocoa); also referred to as "interactive backends") and hardcopy backends to make image files (PNG, SVG, PDF, PS; also referred to as "non-interactive backends").

Selecting a backend

There are three ways to configure your backend:

- The *`rcParams["backend"]`* parameter in your `matplotlibrc` file
- The *`MPLBACKEND`* environment variable
- The function *`matplotlib.use()`*

Below is a more detailed description.

If there is more than one configuration present, the last one from the list takes precedence; e.g. calling *`matplotlib.use()`* will override the setting in your `matplotlibrc`.

Without a backend explicitly set, Matplotlib automatically detects a usable backend based on what is available on your system and on whether a GUI event loop is already running. The first usable backend in the following list is selected: MacOSX, QtAgg, GTK4Agg, Gtk3Agg, TkAgg, WxAgg, Agg. The last, Agg, is a non-interactive backend that can only write to files. It is used on Linux, if Matplotlib cannot connect to either an X display or a Wayland display.

Here is a detailed description of the configuration methods:

1. Setting *`rcParams["backend"]`* in your `matplotlibrc` file:

```
backend : qtagg   # use pyqt with antigrain (agg) rendering
```

See also *Customizing Matplotlib with style sheets and rcParams*.

2. Setting the *MPLBACKEND* environment variable:

   You can set the environment variable either for your current shell or for a single script.

   On Unix:

   ```
   > export MPLBACKEND=qtagg
   > python simple_plot.py

   > MPLBACKEND=qtagg python simple_plot.py
   ```

   On Windows, only the former is possible:

   ```
   > set MPLBACKEND=qtagg
   > python simple_plot.py
   ```

   Setting this environment variable will override the `backend` parameter in *any* `matplotlibrc`, even if there is a `matplotlibrc` in your current working directory. Therefore, setting *MPLBACKEND* globally, e.g. in your `.bashrc` or `.profile`, is discouraged as it might lead to counter-intuitive behavior.

3. If your script depends on a specific backend you can use the function *matplotlib.use()*:

   ```
   import matplotlib
   matplotlib.use('qtagg')
   ```

   This should be done before any figure is created, otherwise Matplotlib may fail to switch the backend and raise an ImportError.

   Using *use* will require changes in your code if users want to use a different backend. Therefore, you should avoid explicitly calling *use* unless absolutely necessary.

The builtin backends

By default, Matplotlib should automatically select a default backend which allows both interactive work and plotting from scripts, with output to the screen and/or to a file, so at least initially, you will not need to worry about the backend. The most common exception is if your Python distribution comes without `tkinter` and you have no other GUI toolkit installed. This happens with certain Linux distributions, where you need to install a Linux package named `python-tk` (or similar).

If, however, you want to write graphical user interfaces, or a web application server (*Embed in a web application server (Flask)*), or need a better understanding of what is going on, read on. To make things easily more customizable for graphical user interfaces, Matplotlib separates the concept of the renderer (the thing that actually does the drawing) from the canvas (the place where the drawing goes). The canonical renderer for user interfaces is `Agg` which uses the Anti-Grain Geometry C++ library to make a raster (pixel) image of the figure; it is used by the `QtAgg`, `GTK4Agg`, `GTK3Agg`, `wxAgg`, `TkAgg`, and `macosx` backends. An alternative renderer is based on the Cairo library, used by `QtCairo`, etc.

For the rendering engines, users can also distinguish between vector or raster renderers. Vector graphics languages issue drawing commands like "draw a line from this point to this point" and hence are scale free.

Raster backends generate a pixel representation of the line whose accuracy depends on a DPI setting.

Static backends

Here is a summary of the Matplotlib renderers (there is an eponymous backend for each; these are *non-interactive backends*, capable of writing to a file):

Renderer	Filetypes	Description
AGG	png	raster graphics -- high quality images using the Anti-Grain Geometry engine.
PDF	pdf	vector graphics -- Portable Document Format output.
PS	ps, eps	vector graphics -- PostScript output.
SVG	svg	vector graphics -- Scalable Vector Graphics output.
PGF	pgf, pdf	vector graphics -- using the pgf package.
Cairo	png, ps, pdf, svg	raster or vector graphics -- using the Cairo library (requires pycairo or cairocffi).

To save plots using the non-interactive backends, use the `matplotlib.pyplot.savefig('filename')` method.

Interactive backends

These are the user interfaces and renderer combinations supported; these are *interactive backends*, capable of displaying to the screen and using appropriate renderers from the table above to write to a file:

Backend	Description
QtAgg	Agg rendering in a Qt canvas (requires PyQt or Qt for Python, a.k.a. PySide). This backend can be activated in IPython with `%matplotlib qt`. The Qt binding can be selected via the *QT_API* environment variable; see *Qt Bindings* for more details.
ipympl	Agg rendering embedded in a Jupyter widget (requires ipympl). This backend can be enabled in a Jupyter notebook with `%matplotlib ipympl` or `%matplotlib widget`. Works with Jupyter `lab` and `notebook>=7`.
GTK3	Agg rendering to a GTK 3.x canvas (requires PyGObject and pycairo). This backend can be activated in IPython with `%matplotlib gtk3`.
GTK4	Agg rendering to a GTK 4.x canvas (requires PyGObject and pycairo). This backend can be activated in IPython with `%matplotlib gtk4`.
macosx	Agg rendering into a Cocoa canvas in macOS. This backend can be activated in IPython with `%matplotlib osx`.
TkAgg	Agg rendering to a Tk canvas (requires TkInter). This backend can be activated in IPython with `%matplotlib tk`.
nbAgg	Embed an interactive figure in a Jupyter classic notebook. This backend can be enabled in Jupyter notebooks via `%matplotlib notebook` or `%matplotlib nbagg`. Works with Jupyter `notebook<7` and `nbclassic`.
WebAgg	On `show()` will start a tornado server with an interactive figure.
GTK3	Cairo rendering to a GTK 3.x canvas (requires PyGObject and pycairo).
GTK4	Cairo rendering to a GTK 4.x canvas (requires PyGObject and pycairo).
wxAgg	Agg rendering to a wxWidgets canvas (requires wxPython 4). This backend can be activated in IPython with `%matplotlib wx`.

Note

The names of builtin backends are case-insensitive; e.g., 'QtAgg' and 'qtagg' are equivalent.

ipympl

The ipympl backend is in a separate package that must be explicitly installed if you wish to use it, for example:

```
pip install ipympl
```

or

```
conda install ipympl -c conda-forge
```

See installing ipympl for more details.

Using non-builtin backends

More generally, any importable backend can be selected by using any of the methods above. If `name.of.the.backend` is the module containing the backend, use `module://name.of.the.backend` as the backend name, e.g. `matplotlib.use('module://name.of.the.backend')`.

Information for backend implementers is available at *Writing a backend -- the pyplot interface*.

Backend API versions

Matplotlib aims to maintain backward compatibility on backends. Nevertheless, we want to be able to evolve the backend API to support new features. Defining backend API versions will help to communicate which API is supported by a given version of Matplotlib.

The following backend API versions exist

API version	Supported since	Description
1.0	Matplotlib 3.10	This is the starting point for systematic definition of backend versions. Most of the API will work far back, but there is no benefit in retroactively uncovering all prior the changes.
1.1	Matplotlib 3.11	`RendererBase.draw_path_collection` gained a new optional parameter *hatchcolor*. The presence of the parameter is inferred by introspection, so that matplotlib 3.11+ will still work with backends implementing API version 1.0.

There is currently no plan to remove support for older API versions.

Debugging the figure windows not showing

Sometimes things do not work as expected, usually during an install.

If you are using a Notebook or integrated development environment (see *Notebooks and IDEs*), please consult their documentation for debugging figures not working in their environments.

If you are using one of Matplotlib's graphics backends (see *Standalone scripts and interactive use*), make sure you know which one is being used:

```
import matplotlib

print(matplotlib.get_backend())
```

Try a simple plot to see if the GUI opens:

```
import matplotlib
import matplotlib.pyplot as plt

print(matplotlib.get_backend())
```

(continues on next page)

(continued from previous page)

```
plt.plot((1, 4, 6))
plt.show()
```

If it does not, you perhaps have an installation problem. A good step at this point is to ensure that your GUI toolkit is installed properly, taking Matplotlib out of the testing. Almost all GUI toolkits have a small test program that can be run to test basic functionality. If this test fails, try re-installing.

QtAgg, QtCairo, Qt5Agg, and Qt5Cairo

Test `PyQt6` (if you have `PyQt5`, `PySide2` or `PySide6` installed rather than `PyQt6`, just change the import accordingly):

```
python3 -c "from PyQt6.QtWidgets import *; app = QApplication([]); win␣
↪= QMainWindow(); win.show(); app.exec()"
```

TkAgg and TkCairo

Test `tkinter`:

```
python3 -c "from tkinter import Tk; Tk().mainloop()"
```

GTK3Agg, GTK4Agg, GTK3Cairo, GTK4Cairo

Test `Gtk`:

```
python3 -c "from gi.repository import Gtk; win = Gtk.Window();␣
↪win.connect('destroy', Gtk.main_quit); win.show(); Gtk.main()"
```

wxAgg and wxCairo

Test `wx`:

```
python3 -c "import wx; app = wx.App(); frame = wx.Frame(None);␣
↪frame.Show(); app.MainLoop()"
```

If the test works for your desired backend but you still cannot get Matplotlib to display a figure, then contact us (see *Get help*).

3.2.3 Matplotlib Application Interfaces (APIs)

Matplotlib has two major application interfaces, or styles of using the library:

- An explicit "Axes" interface that uses methods on a Figure or Axes object to create other Artists, and build a visualization step by step. This has also been called an "object-oriented" interface.
- An implicit "pyplot" interface that keeps track of the last Figure and Axes created, and adds Artists to the object it thinks the user wants.

In addition, a number of downstream libraries (like `pandas` and xarray) offer a `plot` method implemented directly on their data classes so that users can call `data.plot()`.

The difference between these interfaces can be a bit confusing, particularly given snippets on the web that use one or the other, or sometimes multiple interfaces in the same example. Here we attempt to point out how the "pyplot" and downstream interfaces relate to the explicit "Axes" interface to help users better navigate the library.

Native Matplotlib interfaces

The explicit "Axes" interface

The "Axes" interface is how Matplotlib is implemented, and many customizations and fine-tuning end up being done at this level.

This interface works by instantiating an instance of a *`Figure`* class (`fig` below), using a *`subplots`* method (or similar) on that object to create one or more *`Axes`* objects (`ax` below), and then calling drawing methods on the Axes (`plot` in this example):

```
import matplotlib.pyplot as plt

fig = plt.figure()
ax = fig.subplots()
ax.plot([1, 2, 3, 4], [0, 0.5, 1, 0.2])
```

We call this an "explicit" interface because each object is explicitly referenced, and used to make the next object. Keeping references to the objects is very flexible, and allows us to customize the objects after they are created, but before they are displayed.

The implicit "pyplot" interface

The *`pyplot`* module shadows most of the *`Axes`* plotting methods to give the equivalent of the above, where the creation of the Figure and Axes is done for the user:

```
import matplotlib.pyplot as plt

plt.plot([1, 2, 3, 4], [0, 0.5, 1, 0.2])
```

This can be convenient, particularly when doing interactive work or simple scripts. A reference to the current Figure can be retrieved using *`gcf`* and to the current Axes by *`gca`*. The *`pyplot`* module retains a list of Figures, and each Figure retains a list of Axes on the figure for the user so that the following:

```
import matplotlib.pyplot as plt

plt.subplot(1, 2, 1)
plt.plot([1, 2, 3], [0, 0.5, 0.2])
```

(continues on next page)

(continued from previous page)

```
plt.subplot(1, 2, 2)
plt.plot([3, 2, 1], [0, 0.5, 0.2])
```

is equivalent to:

```
import matplotlib.pyplot as plt

plt.subplot(1, 2, 1)
ax = plt.gca()
ax.plot([1, 2, 3], [0, 0.5, 0.2])

plt.subplot(1, 2, 2)
ax = plt.gca()
ax.plot([3, 2, 1], [0, 0.5, 0.2])
```

In the explicit interface, this would be:

```
import matplotlib.pyplot as plt

fig, axs = plt.subplots(1, 2)
axs[0].plot([1, 2, 3], [0, 0.5, 0.2])
axs[1].plot([3, 2, 1], [0, 0.5, 0.2])
```

Translating between the Axes interface and the pyplot interface

You may find either interface in existing code, and unfortunately sometimes even mixtures. This section describes the patterns for specific operations in both interfaces and how to translate from one to the other.

- Creating figures is the same for both interfaces: Use the respective *pyplot* functions `plt.figure()`, `plt.subplots()`, `plt.subplot_mosaic()`. For the Axes interface, you typically store the created Figure (and possibly Axes) in variables for later use. When using the pyplot interface, these values are typically not stored. Example:
  - Axes: `fig, ax = plt.subplots()`
  - pyplot: `plt.subplots()`
- "Plotting" functions, i.e. functions that add data, are named the same and have identical parameters on the Axes and in pyplot. Example:
  - Axes: `ax.plot(x, y)`
  - pyplot: `plt.plot(x, y)`
- Functions that retrieve properties are named like the property in pyplot and are prefixed with `get_` on the Axes. Example:

  - Axes: `label = ax.get_xlabel()`
  - pyplot: `label = plt.xlabel()`

- Functions that set properties are named like the property in pyplot and are prefixed with `set_` on the Axes. Example:
  - Axes: `ax.set_xlabel("time")`
  - pyplot: `plt.xlabel("time")`

Here is a short summary of the examples again as a side-by-side comparison:

Operation	Axes interface	pyplot interface
Creating figures	`fig, ax = plt.subplots()`	`plt.subplots()`
Plotting data	`ax.plot(x, y)`	`plt.plot(x, y)`
Getting properties	`label = ax.get_xlabel()`	`label = plt.xlabel()`
Setting properties	`ax.set_xlabel("time")`	`plt.xlabel("time")`

Why be explicit?

What happens if you have to backtrack, and operate on an old axes that is not referenced by `plt.gca()`? One simple way is to call `subplot` again with the same arguments. However, that quickly becomes inelegant. You can also inspect the Figure object and get its list of Axes objects, however, that can be misleading (colorbars are Axes too!). The best solution is probably to save a handle to every Axes you create, but if you do that, why not simply create all the Axes objects at the start?

The first approach is to call `plt.subplot` again:

```
import matplotlib.pyplot as plt

plt.subplot(1, 2, 1)
plt.plot([1, 2, 3], [0, 0.5, 0.2])

plt.subplot(1, 2, 2)
plt.plot([3, 2, 1], [0, 0.5, 0.2])

plt.suptitle('Implicit Interface: re-call subplot')

for i in range(1, 3):
    plt.subplot(1, 2, i)
    plt.xlabel('Boo')
```

The second is to save a handle:

```
import matplotlib.pyplot as plt

axs = []
```

(continues on next page)

(continued from previous page)

```
ax = plt.subplot(1, 2, 1)
axs += [ax]
plt.plot([1, 2, 3], [0, 0.5, 0.2])

ax = plt.subplot(1, 2, 2)
axs += [ax]
plt.plot([3, 2, 1], [0, 0.5, 0.2])

plt.suptitle('Implicit Interface: save handles')

for i in range(2):
    plt.sca(axs[i])
    plt.xlabel('Boo')
```

However, the recommended way would be to be explicit from the outset:

```
import matplotlib.pyplot as plt

fig, axs = plt.subplots(1, 2)
axs[0].plot([1, 2, 3], [0, 0.5, 0.2])
axs[1].plot([3, 2, 1], [0, 0.5, 0.2])
fig.suptitle('Explicit Interface')
for i in range(2):
    axs[i].set_xlabel('Boo')
```

Third-party library "Data-object" interfaces

Some third party libraries have chosen to implement plotting for their data objects, e.g. `data.plot()`, is seen in `pandas`, xarray, and other third-party libraries. For illustrative purposes, a downstream library may implement a simple data container that has `x` and `y` data stored together, and then implements a `plot` method:

```
import matplotlib.pyplot as plt

# supplied by downstream library:
class DataContainer:

    def __init__(self, x, y):
        """
        Proper docstring here!
        """
        self._x = x
        self._y = y
```

(continues on next page)

(continued from previous page)

```
    def plot(self, ax=None, **kwargs):
        if ax is None:
            ax = plt.gca()
        ax.plot(self._x, self._y, **kwargs)
        ax.set_title('Plotted from DataClass!')
        return ax


# what the user usually calls:
data = DataContainer([0, 1, 2, 3], [0, 0.2, 0.5, 0.3])
data.plot()
```

So the library can hide all the nitty-gritty from the user, and can make a visualization appropriate to the data type, often with good labels, choices of colormaps, and other convenient features.

In the above, however, we may not have liked the title the library provided. Thankfully, they pass us back the Axes from the `plot()` method, and understanding the explicit Axes interface, we could call: `ax.set_title('My preferred title')` to customize the title.

Many libraries also allow their `plot` methods to accept an optional *ax* argument. This allows us to place the visualization in an Axes that we have placed and perhaps customized.

Summary

Overall, it is useful to understand the explicit "Axes" interface since it is the most flexible and underlies the other interfaces. A user can usually figure out how to drop down to the explicit interface and operate on the underlying objects. While the explicit interface can be a bit more verbose to setup, complicated plots will often end up simpler than trying to use the implicit "pyplot" interface.

Note

It is sometimes confusing to people that we import `pyplot` for both interfaces. Currently, the `pyplot` module implements the "pyplot" interface, but it also provides top-level Figure and Axes creation methods, and ultimately spins up the graphical user interface, if one is being used. So `pyplot` is still needed regardless of the interface chosen.

Similarly, the declarative interfaces provided by partner libraries use the objects accessible by the "Axes" interface, and often accept these as arguments or pass them back from methods. It is usually essential to use the explicit "Axes" interface to perform any customization of the default visualization, or to unpack the data into NumPy arrays and pass directly to Matplotlib.

Appendix: "Axes" interface with data structures

Most *`Axes`* methods allow yet another API addressing by passing a *data* object to the method and specifying the arguments as strings:

```
import matplotlib.pyplot as plt

data = {'xdat': [0, 1, 2, 3], 'ydat': [0, 0.2, 0.4, 0.1]}
fig, ax = plt.subplots(figsize=(2, 2))
ax.plot('xdat', 'ydat', data=data)
```

Appendix: "pylab" interface

There is one further interface that is highly discouraged, and that is to basically do `from matplotlib.pylab import *`. This imports all the functions from `matplotlib.pyplot`, `numpy`, `numpy.fft`, `numpy.linalg`, and `numpy.random`, and some additional functions into the global namespace.

Such a pattern is considered bad practice in modern python, as it clutters the global namespace. Even more severely, in the case of `pylab`, this will overwrite some builtin functions (e.g. the builtin `sum` will be replaced by `numpy.sum`), which can lead to unexpected behavior.

3.2.4 Interactive figures

Interactivity can be invaluable when exploring plots. The pan/zoom and mouse-location tools built into the Matplotlib GUI windows are often sufficient, but you can also use the event system to build customized data exploration tools.

See also

Introduction to Figures.

Matplotlib ships with *backends* binding to several GUI toolkits (Qt, Tk, Wx, GTK, macOS, JavaScript) and third party packages provide bindings to kivy and Jupyter Lab. For the figures to be responsive to

mouse, keyboard, and paint events, the GUI event loop needs to be integrated with an interactive prompt. We recommend using IPython (see *below*).

The *pyplot* module provides functions for explicitly creating figures that include interactive tools, a toolbar, a tool-tip, and *key bindings*:

pyplot.figure

Creates a new empty *Figure* or selects an existing figure

pyplot.subplots

Creates a new *Figure* and fills it with a grid of *Axes*

pyplot.gcf

Get the current *Figure*. If there is current no figure on the pyplot figure stack, a new figure is created

pyplot.gca

Get the current *Axes*. If there is current no Axes on the Figure, a new one is created

Almost all of the functions in *pyplot* pass through the current *Figure* / *Axes* (or create one) as appropriate.

Matplotlib keeps a reference to all of the open figures created via *pyplot.figure* or *pyplot.subplots* so that the figures will not be garbage collected. *Figure*s can be closed and deregistered from *pyplot* individually via *pyplot.close*; all open *Figure*s can be closed via `plt.close('all')`.

See also

For more discussion of Matplotlib's event system and integrated event loops: - *Interactive figures and asynchronous programming* - *Event handling and picking*

IPython integration

We recommend using IPython for an interactive shell. In addition to all of its features (improved tab-completion, magics, multiline editing, etc), it also ensures that the GUI toolkit event loop is properly integrated with the command line (see *Command prompt integration*).

In this example, we create and modify a figure via an IPython prompt. The figure displays in a QtAgg GUI window. To configure the integration and enable *interactive mode* use the `%matplotlib` magic:

```
In [1]: %matplotlib
Using matplotlib backend: QtAgg

In [2]: import matplotlib.pyplot as plt
```

Create a new figure window:

```
In [3]: fig, ax = plt.subplots()
```

Add a line plot of the data to the window:

```
In [4]: ln, = ax.plot(range(5))
```

Change the color of the line from blue to orange:

```
In [5]: ln.set_color('orange')
```

If you wish to disable automatic redrawing of the plot:

```
In [6]: plt.ioff()
```

If you wish to re-enable automatic redrawing of the plot:

```
In [7]: plt.ion()
```

In recent versions of `Matplotlib` and `IPython`, it is sufficient to import *`matplotlib.pyplot`* and call *`pyplot.ion`*. Using the `%` magic is guaranteed to work in all versions of Matplotlib and IPython.

Interactive mode

`pyplot.ion`	Enable interactive mode.
`pyplot.ioff`	Disable interactive mode.
`pyplot.isinteractive`	Return whether plots are updated after every plotting command.

`pyplot.show`	Display all open figures.
`pyplot.pause`	Run the GUI event loop for *interval* seconds.

Interactive mode controls:

- whether created figures are automatically shown
- whether changes to artists automatically trigger re-drawing existing figures
- when *`pyplot.show()`* returns if given no arguments: immediately, or after all of the figures have been closed

If in interactive mode:

- newly created figures will be displayed immediately
- figures will automatically redraw when elements are changed
- *`pyplot.show()`* displays the figures and immediately returns

If not in interactive mode:

- newly created figures and changes to figures are not displayed until
  - *`pyplot.show()`* is called
  - *`pyplot.pause()`* is called

  - *FigureCanvasBase.flush_events()* is called

- *pyplot.show()* runs the GUI event loop and does not return until all the plot windows are closed

If you are in non-interactive mode (or created figures while in non-interactive mode) you may need to explicitly call *pyplot.show* to display the windows on your screen. If you only want to run the GUI event loop for a fixed amount of time, you can use *pyplot.pause*. This will block the progress of your code as if you had called time.sleep, ensure the current window is shown and re-drawn if needed, and run the GUI event loop for the specified period of time.

The GUI event loop being integrated with your command prompt and the figures being in interactive mode are independent of each other. If you try to use *pyplot.ion* without arranging for the event-loop integration, your figures will appear but will not be interactive while the prompt is waiting for input. You will not be able to pan/zoom and the figure may not even render (the window might appear black, transparent, or as a snapshot of the desktop under it). Conversely, if you configure the event loop integration, displayed figures will be responsive while waiting for input at the prompt, regardless of pyplot's "interactive mode".

No matter what combination of interactive mode setting and event loop integration, figures will be responsive if you use pyplot.show(block=True), *pyplot.pause*, or run the GUI main loop in some other way.

Warning

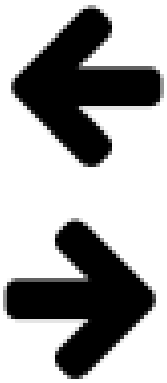
Using *Figure.show*, it is possible to display a figure on the screen without starting the event loop and without being in interactive mode. This may work (depending on the GUI toolkit) but will likely result in a non-responsive figure.

Default UI

The windows created by *pyplot* have an interactive toolbar with navigation buttons and a readout of the data values the cursor is pointing at.

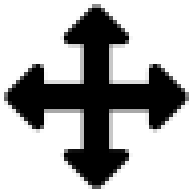
Interactive navigation

All figure windows come with a navigation toolbar, which can be used to navigate through the data set.



The `Home`, `Forward` and `Back` buttons

These are similar to a web browser's home, forward and back controls. `Forward` and `Back` are used to navigate back and forth between previously defined views. They have no meaning unless you have already navigated somewhere else using the pan and zoom buttons. This is analogous to trying to click `Back` on your web browser before visiting a new page or `Forward` before you have gone back to a page -- nothing happens. `Home` takes you to the first, default view of your data.



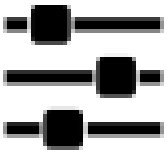
The `Pan/Zoom` button

This button has two modes: pan and zoom. Click the `Pan/Zoom` button to activate panning and zooming, then put your mouse somewhere over an axes. Press the left mouse button and hold it to pan the figure, dragging it to a new position. When you release it, the data under the point where you pressed will be moved to the point where you released. If you press 'x' or 'y' while panning the motion will be constrained to the x or y axis, respectively. Press the right mouse button to zoom, dragging it to a new position. The x axis will be zoomed in proportionately to the rightward movement and zoomed out proportionately to the leftward movement. The same is true for the y axis and up/down motions (up zooms in, down zooms out). The point under your mouse when you begin the zoom remains stationary, allowing you to zoom in or out around that point as much as you wish. You can use the modifier keys 'x', 'y' or 'CONTROL' to constrain the zoom to the x axis, the y axis, or aspect ratio preserve, respectively.

With polar plots, the pan and zoom functionality behaves differently. The radius axis labels can be dragged using the left mouse button. The radius scale can be zoomed in and out using the right mouse button.

The `Zoom-to-Rectangle` button

Put your mouse somewhere over an axes and press a mouse button. Define a rectangular region by dragging the mouse while holding the button to a new location. When using the left mouse button, the axes view limits will be zoomed to the defined region. When using the right mouse button, the axes view limits will be zoomed out, placing the original axes in the defined region.



The `Subplot-configuration` button

Use this button to configure the appearance of the subplot. You can stretch or compress the left, right, top, or bottom side of the subplot, or the space between the rows or space between the columns.

The `Save` button

Click this button to launch a file save dialog. You can save files with the following extensions: `png`, `ps`, `eps`, `svg` and `pdf`.

Navigation keyboard shortcuts

A number of helpful keybindings are registered by default. The following table holds all the default keys, which can be overwritten by use of your *matplotlibrc*.

Command	Default key binding and rcParam
Home/Reset	*rcParams["keymap.home"]* (default: `['h', 'r', 'home']`)
Back	*rcParams["keymap.back"]* (default: `['left', 'c', 'backspace', 'MouseButton.BACK']`)
Forward	*rcParams["keymap.forward"]* (default: `['right', 'v', 'MouseButton.FORWARD']`)
Pan/Zoom	*rcParams["keymap.pan"]* (default: `['p']`)
Zoom-to-rect	*rcParams["keymap.zoom"]* (default: `['o']`)
Save	*rcParams["keymap.save"]* (default: `['s', 'ctrl+s']`)
Toggle fullscreen	*rcParams["keymap.fullscreen"]* (default: `['f', 'ctrl+f']`)
Toggle major grids	*rcParams["keymap.grid"]* (default: `['g']`)
Toggle minor grids	*rcParams["keymap.grid_minor"]* (default: `['G']`)
Toggle x axis scale (log/linear)	*rcParams["keymap.xscale"]* (default: `['k', 'L']`)
Toggle y axis scale (log/linear)	*rcParams["keymap.yscale"]* (default: `['l']`)
Close Figure	*rcParams["keymap.quit"]* (default: `['ctrl+w', 'cmd+w', 'q']`)
Constrain pan/zoom to x axis	hold **x** when panning/zooming with mouse
Constrain pan/zoom to y axis	hold **y** when panning/zooming with mouse
Preserve aspect ratio	hold **CONTROL** when panning/zooming with mouse

Other Python prompts

Interactive mode works in the default Python prompt:

```
>>> import matplotlib.pyplot as plt
>>> plt.ion()
>>>
```

However, this does not ensure that the event hook is properly installed and your figures may not be responsive. Please consult the documentation of your GUI toolkit for details.

Jupyter Notebooks / JupyterLab

To get interactive figures in the 'classic' notebook or Jupyter lab, use the ipympl backend (must be installed separately) which uses the **ipywidget** framework. If `ipympl` is installed use the magic:

```
%matplotlib widget
```

to select and enable it.

If you only need to use the classic notebook (i.e. `notebook<7`), you can use

```
%matplotlib notebook
```

which uses the *backend_nbagg* backend provided by Matplotlib; however, nbagg does not work in Jupyter Lab.

Note

To get the interactive functionality described here, you must be using an interactive backend. The default backend in notebooks, the inline backend, is not. `ipykernel.pylab.backend_inline` renders the figure once and inserts a static image into the notebook when the cell is executed. Because the images are static, they cannot be panned / zoomed, take user input, or be updated from other cells.

GUIs + Jupyter

You can also use one of the non-`ipympl` GUI backends in a Jupyter Notebook. If you are running your Jupyter kernel locally, the GUI window will spawn on your desktop adjacent to your web browser. If you run your notebook on a remote server, the kernel will try to open the GUI window on the remote computer. Unless you have arranged to forward the xserver back to your desktop, you will not be able to see or interact with the window. It may also raise an exception.

PyCharm, Spyder, and VSCode

Many IDEs have built-in integration with Matplotlib, please consult their documentation for configuration details.

3.2.5 Interactive figures and asynchronous programming

Matplotlib supports rich interactive figures by embedding figures into a GUI window. The basic interactions of panning and zooming in an Axes to inspect your data is available out-of-the-box. This is supported by a full mouse and keyboard event handling system that you can use to build sophisticated interactive graphs.

This guide is meant to be an introduction to the low-level details of how Matplotlib integration with a GUI event loop works. For a more practical introduction to the Matplotlib event API see *event handling system*, Interactive Tutorial, and Interactive Applications using Matplotlib.

GUI events

All GUI frameworks (Qt, Wx, Gtk, Tk, macOS, or web) have some method of capturing user interactions and passing them back to the application, but the exact details depend on the toolkit (for example callbacks in Tk or the `Signal` / `Slot` framework in Qt). The Matplotlib *backends* encapsulate the details of the GUI frameworks and provide a framework-independent interface to GUI events through Matplotlib's *event handling system*. By connecting functions to the event handling system (see *FigureCanvasBase.mpl_connect*), you can interactively respond to user actions in a GUI toolkit agnostic way.

Event loops

Fundamentally, all user interaction (and networking) is implemented as an infinite loop waiting for events from the user (via the OS) and then doing something about it. For example, a minimal Read Evaluate Print Loop (REPL) is

```
exec_count = 0
while True:
    inp = input(f"[{exec_count}] > ")          # Read
    ret = eval(inp)                            # Evaluate
    print(ret)                                 # Print
    exec_count += 1                            # Loop
```

This is missing many niceties (for example, it exits on the first exception!), but is representative of the event loops that underlie all terminals, GUIs, and servers[1]. In general the *Read* step is waiting on some sort of I/O -- be it user input or the network -- while the *Evaluate* and *Print* are responsible for interpreting the input and then **doing** something about it.

In practice we interact with a framework that provides a mechanism to register callbacks to be run in response to specific events rather than directly implement the I/O loop[2]. For example "when the user clicks on this button, please run this function" or "when the user hits the 'z' key, please run this other function". This allows users to write reactive, event-driven, programs without having to delve into the nitty-gritty[3] details of I/O. The core event loop is sometimes referred to as "the main loop" and is typically started, depending on the library, by methods with names like `exec`, `run`, or `start`.

Command prompt integration

So far, so good. We have the REPL (like the IPython terminal) that lets us interactively send code to the interpreter and get results back. We also have the GUI toolkit that runs an event loop waiting for user input and lets us register functions to be run when that happens. However, if we want to do both we have a problem: the prompt and the GUI event loop are both infinite loops and cannot run in parallel. In order for both the prompt and the GUI windows to be responsive we need a method to allow the loops to "timeshare" :

1. **Blocking the prompt**: let the GUI main loop block the python process when you want interactive windows
2. **Input hook integration**: let the CLI main loop block the python process and intermittently run the GUI loop
3. **Full embedding**: fully embed python in the GUI (but this is basically writing a full application)

Blocking the prompt

pyplot.show	Display all open figures.

continues on next page

[1] A limitation of this design is that you can only wait for one input, if there is a need to multiplex between multiple sources then the loop would look something like

```
fds = [...]
while True:                     # Loop
    inp = select(fds).read()    # Read
    eval(inp)                   # Evaluate / Print
```

[2] Or you can write your own if you must.

[3] These examples are aggressively dropping many of the complexities that must be dealt with in the real world such as keyboard interrupts, timeouts, bad input, resource allocation and cleanup, etc.

Table 3 – continued from previous page

pyplot.pause	Run the GUI event loop for *interval* seconds.
backend_bases.FigureCanvasBase.start_event_loop	Start a blocking event loop.
backend_bases.FigureCanvasBase.stop_event_loop	Stop the current blocking event loop.

The simplest solution is to start the GUI event loop and let it run exclusively, which results in responsive figure windows. However, the CLI event loop will not run, so that you cannot enter new commands. We call this "blocking" mode. (Your terminal may echo the typed characters, but they will not yet be processed by the CLI event loop because the Python interpreter is busy running the GUI event loop).

It is possible to stop the GUI event loop and return control to the CLI event loop. You can then use the prompt again, but any still open figure windows are non-responsive. Re-starting the GUI event loop will make these figure responsive again (and will process any queued up user interaction).

The typical command to show all figures and run the GUI event loop exclusively until all figures are closed is

```
plt.show()
```

Alternatively, you can start the GUI event loop for a fixed amount of time using *pyplot.pause*.

If you are not using *pyplot* you can start and stop the event loops via *FigureCanvasBase.start_event_loop* and *FigureCanvasBase.stop_event_loop*. However, in most contexts where you would not be using *pyplot* you are embedding Matplotlib in a large GUI application and the GUI event loop should already be running for the application.

Away from the prompt, this technique can be very useful if you want to write a script that pauses for user interaction, or displays a figure between polling for additional data. See *Scripts and functions* for more details.

Input hook integration

While running the GUI event loop in a blocking mode or explicitly handling UI events is useful, we can do better! We really want to be able to have a usable prompt **and** interactive figure windows.

We can do this using the "input hook" feature of the interactive prompt. This hook is called by the prompt as it waits for the user to type (even for a fast typist the prompt is mostly waiting for the human to think and move their fingers). Although the details vary between prompts the logic is roughly

1. start to wait for keyboard input
2. start the GUI event loop
3. as soon as the user hits a key, exit the GUI event loop and handle the key
4. repeat

This gives us the illusion of simultaneously having interactive GUI windows and an interactive prompt. Most of the time the GUI event loop is running, but as soon as the user starts typing the prompt takes over again.

This time-share technique only allows the event loop to run while python is otherwise idle and waiting for user input. If you want the GUI to be responsive during long running code it is necessary to periodically flush the GUI event queue as described in *Explicitly spinning the event loop*. In this case it is your code, not the REPL, which is blocking the process so you need to handle the "time-share" manually. Conversely, a very slow figure draw will block the prompt until it finishes drawing.

Full embedding

It is also possible to go the other direction and fully embed figures (and a Python interpreter) in a rich native application. Matplotlib provides classes for each toolkit which can be directly embedded in GUI applications (this is how the built-in windows are implemented!). See *Embedding Matplotlib in graphical user interfaces* for more details.

Scripts and functions

backend_bases.FigureCanvasBase.flush_events	Flush the GUI events for the figure.
backend_bases.FigureCanvasBase.draw_idle	Request a widget redraw once control returns to the GUI event loop.
figure.Figure.ginput	Blocking call to interact with a figure.
pyplot.ginput	Blocking call to interact with a figure.
pyplot.show	Display all open figures.
pyplot.pause	Run the GUI event loop for *interval* seconds.

There are several use-cases for using interactive figures in scripts:

- capture user input to steer the script
- progress updates as a long running script progresses
- streaming updates from a data source

Blocking functions

If you only need to collect points in an Axes you can use *Figure.ginput*. However if you have written some custom event handling or are using *widgets* you will need to manually run the GUI event loop using the methods described *above*.

You can also use the methods described in *Blocking the prompt* to suspend run the GUI event loop. Once the loop exits your code will resume. In general, any place you would use `time.sleep` you can use *pyplot.pause* instead with the added benefit of interactive figures.

For example, if you want to poll for data you could use something like

```
fig, ax = plt.subplots()
ln, = ax.plot([], [])

while True:
    x, y = get_new_data()
```

(continues on next page)

(continued from previous page)

```
    ln.set_data(x, y)
    plt.pause(1)
```

which would poll for new data and update the figure at 1Hz.

Explicitly spinning the event loop

backend_bases.FigureCanvasBase.flush_events	Flush the GUI events for the figure.
backend_bases.FigureCanvasBase.draw_idle	Request a widget redraw once control returns to the GUI event loop.

If you have open windows that have pending UI events (mouse clicks, button presses, or draws) you can explicitly process those events by calling *FigureCanvasBase.flush_events*. This will run the GUI event loop until all UI events currently waiting have been processed. The exact behavior is backend-dependent but typically events on all figure are processed and only events waiting to be processed (not those added during processing) will be handled.

For example

```
import time
import matplotlib.pyplot as plt
import numpy as np
plt.ion()

fig, ax = plt.subplots()
th = np.linspace(0, 2*np.pi, 512)
ax.set_ylim(-1.5, 1.5)

ln, = ax.plot(th, np.sin(th))

def slow_loop(N, ln):
    for j in range(N):
        time.sleep(.1)  # to simulate some work
        ln.figure.canvas.flush_events()

slow_loop(100, ln)
```

While this will feel a bit laggy (as we are only processing user input every 100ms whereas 20-30ms is what feels "responsive") it will respond.

If you make changes to the plot and want it re-rendered you will need to call *draw_idle* to request that the canvas be re-drawn. This method can be thought of *draw_soon* in analogy to `asyncio.loop.call_soon`.

We can add this to our example above as

```
def slow_loop(N, ln):
    for j in range(N):
        time.sleep(.1)  # to simulate some work
        if j % 10:
            ln.set_ydata(np.sin(((j // 10) % 5 * th)))
            ln.figure.canvas.draw_idle()

        ln.figure.canvas.flush_events()

slow_loop(100, ln)
```

The more frequently you call *FigureCanvasBase.flush_events* the more responsive your figure will feel but at the cost of spending more resources on the visualization and less on your computation.

Stale artists

Artists (as of Matplotlib 1.5) have a **stale** attribute which is `True` if the internal state of the artist has changed since the last time it was rendered. By default the stale state is propagated up to the Artists parents in the draw tree, e.g., if the color of a *Line2D* instance is changed, the *Axes* and *Figure* that contain it will also be marked as "stale". Thus, `fig.stale` will report if any artist in the figure has been modified and is out of sync with what is displayed on the screen. This is intended to be used to determine if `draw_idle` should be called to schedule a re-rendering of the figure.

Each artist has a `Artist.stale_callback` attribute which holds a callback with the signature

```
def callback(self: Artist, val: bool) -> None:
   ...
```

which by default is set to a function that forwards the stale state to the artist's parent. If you wish to suppress a given artist from propagating set this attribute to None.

Figure instances do not have a containing artist and their default callback is `None`. If you call *pyplot.ion* and are not in `IPython` we will install a callback to invoke *draw_idle* whenever the *Figure* becomes stale. In `IPython` we use the `'post_execute'` hook to invoke *draw_idle* on any stale figures after having executed the user's input, but before returning the prompt to the user. If you are not using *pyplot* you can use the callback `Figure.stale_callback` attribute to be notified when a figure has become stale.

Idle draw

backend_bases.FigureCanvasBase.draw	Render the *Figure*.
backend_bases.FigureCanvasBase.draw_idle	Request a widget redraw once control returns to the GUI event loop.
backend_bases.FigureCanvasBase.flush_events	Flush the GUI events for the figure.

In almost all cases, we recommend using *backend_bases.FigureCanvasBase.draw_idle* over *backend_bases.FigureCanvasBase.draw*. `draw` forces a rendering of the figure whereas `draw_idle` schedules a rendering the next time the GUI window is going to re-paint the screen. This improves performance by only rendering pixels that will be shown on the screen. If you want to be sure that the screen is updated as soon as possible do

```
fig.canvas.draw_idle()
fig.canvas.flush_events()
```

Threading

Most GUI frameworks require that all updates to the screen, and hence their main event loop, run on the main thread. This makes pushing periodic updates of a plot to a background thread impossible. Although it seems backwards, it is typically easier to push your computations to a background thread and periodically update the figure on the main thread.

In general Matplotlib is not thread safe. If you are going to update *Artist* objects in one thread and draw from another you should make sure that you are locking in the critical sections.

Event loop integration mechanism

CPython / readline

The Python C API provides a hook, `PyOS_InputHook`, to register a function to be run ("The function will be called when Python's interpreter prompt is about to become idle and wait for user input from the terminal."). This hook can be used to integrate a second event loop (the GUI event loop) with the python input prompt loop. The hook functions typically exhaust all pending events on the GUI event queue, run the main loop for a short fixed amount of time, or run the event loop until a key is pressed on stdin.

Matplotlib does not currently do any management of `PyOS_InputHook` due to the wide range of ways that Matplotlib is used. This management is left to downstream libraries -- either user code or the shell. Interactive figures, even with Matplotlib in "interactive mode", may not work in the vanilla python repl if an appropriate `PyOS_InputHook` is not registered.

Input hooks, and helpers to install them, are usually included with the python bindings for GUI toolkits and may be registered on import. IPython also ships input hook functions for all of the GUI frameworks Matplotlib supports which can be installed via `%matplotlib`. This is the recommended method of integrating Matplotlib and a prompt.

IPython / prompt_toolkit

With IPython >= 5.0 IPython has changed from using CPython's readline based prompt to a `prompt_toolkit` based prompt. `prompt_toolkit` has the same conceptual input hook, which is fed into `prompt_toolkit` via the `IPython.terminal.interactiveshell.TerminalInteractiveShell.inputhook()` method. The source for the `prompt_toolkit` input hooks lives at `IPython.terminal.pt_inputhooks`.

3.2.6 Event handling and picking

Matplotlib works with a number of user interface toolkits (wxpython, tkinter, qt, gtk, and macOS) and in order to support features like interactive panning and zooming of figures, it is helpful to the developers to have an API for interacting with the figure via key presses and mouse movements that is "GUI neutral" so we don't have to repeat a lot of code across the different user interfaces. Although the event handling API is GUI neutral, it is based on the GTK model, which was the first user interface Matplotlib supported. The events that are triggered are also a bit richer vis-a-vis Matplotlib than standard GUI events, including information like which *Axes* the event occurred in. The events also understand the Matplotlib coordinate system, and report event locations in both pixel and data coordinates.

Event connections

To receive events, you need to write a callback function and then connect your function to the event manager, which is part of the *FigureCanvasBase*. Here is a simple example that prints the location of the mouse click and which button was pressed:

```
fig, ax = plt.subplots()
ax.plot(np.random.rand(10))

def onclick(event):
    print('%s click: button=%d, x=%d, y=%d, xdata=%f, ydata=%f' %
          ('double' if event.dblclick else 'single', event.button,
           event.x, event.y, event.xdata, event.ydata))

cid = fig.canvas.mpl_connect('button_press_event', onclick)
```

The *FigureCanvasBase.mpl_connect* method returns a connection id (an integer), which can be used to disconnect the callback via

```
fig.canvas.mpl_disconnect(cid)
```

Note

The canvas retains only weak references to instance methods used as callbacks. Therefore, you need to retain a reference to instances owning such methods. Otherwise the instance will be garbage-collected and the callback will vanish.

This does not affect free functions used as callbacks.

Here are the events that you can connect to, the class instances that are sent back to you when the event occurs, and the event descriptions:

Event name	Class	Description
'button_press_event'	*MouseEvent*	mouse button is pressed
'button_release_event'	*MouseEvent*	mouse button is released
'close_event'	*CloseEvent*	figure is closed
'draw_event'	*DrawEvent*	canvas has been drawn (but screen widget not updated yet)
'key_press_event'	*KeyEvent*	key is pressed
'key_release_event'	*KeyEvent*	key is released
'motion_notify_event'	*MouseEvent*	mouse moves
'pick_event'	*PickEvent*	artist in the canvas is selected
'resize_event'	*ResizeEvent*	figure canvas is resized
'scroll_event'	*MouseEvent*	mouse scroll wheel is rolled
'figure_enter_event'	*LocationEvent*	mouse enters a new figure
'figure_leave_event'	*LocationEvent*	mouse leaves a figure
'axes_enter_event'	*LocationEvent*	mouse enters a new axes
'axes_leave_event'	*LocationEvent*	mouse leaves an axes

Note

When connecting to 'key_press_event' and 'key_release_event' events, you may encounter inconsistencies between the different user interface toolkits that Matplotlib works with. This is due to inconsistencies/limitations of the user interface toolkit. The following table shows some basic examples of what you may expect to receive as key(s) (using a QWERTY keyboard layout) from the different user interface toolkits, where a comma separates different keys:

Key(s) Pressed	Tkinter	Qt	macosx	WebAgg	GTK	WxPython
`Shift+2`	shift, @	shift, @	shift, @	shift, @	shift, @	shift, shift+2
`Shift+F1`	shift, shift+f1	shift, shift+f1	shift, shift+f1	shift, shift+f1	shift, shift+f1	shift, shift+f1
`Shift`	shift	shift	shift	shift	shift	shift
`Control`	control	control	control	control	control	control
`Alt`	alt	alt	alt	alt	alt	alt
`AltGr`	iso_level3_sh	*nothing*		alt	iso_level3_sh	*nothing*
`CapsLock`	caps_lock	caps_lock	caps_lock	caps_lock	caps_lock	caps_lock
`CapsLock+a`	caps_lock, A	caps_lock, a	caps_lock, a	caps_lock, A	caps_lock, A	caps_lock, a
`a`	a	a	a	a	a	a
`Shift+a`	shift, A	shift, A	shift, A	shift, A	shift, A	shift, A
`CapsLock+Sh`	caps_lock, shift, a	caps_lock, shift, A	caps_lock, shift, A	caps_lock, shift, a	caps_lock, shift, a	caps_lock, shift, A
`Ctrl+Shi`	control, ctrl+shift, ctrl+meta	control, ctrl+shift, ctrl+meta	control, ctrl+shift, ctrl+alt+shift	control, ctrl+shift, ctrl+meta	control, ctrl+shift, ctrl+meta	control, ctrl+shift, ctrl+alt
`Ctrl+Shi`	control, ctrl+shift, ctrl+a	control, ctrl+shift, ctrl+A	control, ctrl+shift, ctrl+A	control, ctrl+shift, ctrl+A	control, ctrl+shift, ctrl+A	control, ctrl+shift, ctrl+A
`F1`	f1	f1	f1	f1	f1	f1
`Ctrl+F1`	control, ctrl+f1	control, ctrl+f1	control, *nothing*	control, ctrl+f1	control, ctrl+f1	control, ctrl+f1

Matplotlib attaches some keypress callbacks by default for interactivity; they are documented in the *Navigation keyboard shortcuts* section.

Event attributes

All Matplotlib events inherit from the base class *`matplotlib.backend_bases.Event`*, which stores the attributes:

`name`

the event name

`canvas`

the FigureCanvas instance generating the event

`guiEvent`

the GUI event that triggered the Matplotlib event

The most common events that are the bread and butter of event handling are key press/release events and mouse press/release and movement events. The *KeyEvent* and *MouseEvent* classes that handle these events are both derived from the LocationEvent, which has the following attributes

x, y

mouse x and y position in pixels from left and bottom of canvas

inaxes

the *Axes* instance over which the mouse is, if any; else None

xdata, ydata

mouse x and y position in data coordinates, if the mouse is over an axes

Let's look a simple example of a canvas, where a simple line segment is created every time a mouse is pressed:

```
from matplotlib import pyplot as plt

class LineBuilder:
    def __init__(self, line):
        self.line = line
        self.xs = list(line.get_xdata())
        self.ys = list(line.get_ydata())
        self.cid = line.figure.canvas.mpl_connect('button_press_event',
 ↪ self)

    def __call__(self, event):
        print('click', event)
        if event.inaxes != self.line.axes:
            return
        self.xs.append(event.xdata)
        self.ys.append(event.ydata)
        self.line.set_data(self.xs, self.ys)
        self.line.figure.canvas.draw()

fig, ax = plt.subplots()
ax.set_title('click to build line segments')
line, = ax.plot([0], [0])  # empty line
linebuilder = LineBuilder(line)

plt.show()
```

The *MouseEvent* that we just used is a *LocationEvent*, so we have access to the data and pixel coordinates via `(event.x, event.y)` and `(event.xdata, event.ydata)`. In addition to the `LocationEvent` attributes, it also has:

button

the button pressed: None, *MouseButton*, 'up', or 'down' (up and down are used for scroll events)

key

the key pressed: None, any character, 'shift', 'win', or 'control'

Draggable rectangle exercise

Write a draggable rectangle class that is initialized with a *Rectangle* instance but will move its xy location when dragged.

Hint: You will need to store the original xy location of the rectangle which is stored as rect.xy and connect to the press, motion and release mouse events. When the mouse is pressed, check to see if the click occurs over your rectangle (see .Rectangle.contains) and if it does, store the rectangle xy and the location of the mouse click in data coordinates. In the motion event callback, compute the deltax and deltay of the mouse movement, and add those deltas to the origin of the rectangle you stored, then redraw the figure. On the button release event, just reset all the button press data you stored as None.

Here is the solution:

```
import numpy as np
import matplotlib.pyplot as plt

class DraggableRectangle:
    def __init__(self, rect):
        self.rect = rect
        self.press = None

    def connect(self):
        """Connect to all the events we need."""
        self.cidpress = self.rect.figure.canvas.mpl_connect(
            'button_press_event', self.on_press)
        self.cidrelease = self.rect.figure.canvas.mpl_connect(
            'button_release_event', self.on_release)
        self.cidmotion = self.rect.figure.canvas.mpl_connect(
            'motion_notify_event', self.on_motion)

    def on_press(self, event):
        """Check whether mouse is over us; if so, store some data."""
        if event.inaxes != self.rect.axes:
            return
        contains, attrd = self.rect.contains(event)
        if not contains:
            return
        print('event contains', self.rect.xy)
        self.press = self.rect.xy, (event.xdata, event.ydata)

    def on_motion(self, event):
        """Move the rectangle if the mouse is over us."""
        if self.press is None or event.inaxes != self.rect.axes:
            return
        (x0, y0), (xpress, ypress) = self.press
```

(continues on next page)

(continued from previous page)

```
        dx = event.xdata - xpress
        dy = event.ydata - ypress
        # print(f'x0={x0}, xpress={xpress}, event.xdata={event.xdata},
↪'
        #       f'dx={dx}, x0+dx={x0+dx}')
        self.rect.set_x(x0+dx)
        self.rect.set_y(y0+dy)

        self.rect.figure.canvas.draw()

    def on_release(self, event):
        """Clear button press information."""
        self.press = None
        self.rect.figure.canvas.draw()

    def disconnect(self):
        """Disconnect all callbacks."""
        self.rect.figure.canvas.mpl_disconnect(self.cidpress)
        self.rect.figure.canvas.mpl_disconnect(self.cidrelease)
        self.rect.figure.canvas.mpl_disconnect(self.cidmotion)

fig, ax = plt.subplots()
rects = ax.bar(range(10), 20*np.random.rand(10))
drs = []
for rect in rects:
    dr = DraggableRectangle(rect)
    dr.connect()
    drs.append(dr)

plt.show()
```

Extra credit: Use blitting to make the animated drawing faster and smoother.

Extra credit solution:

```
# Draggable rectangle with blitting.
import numpy as np
import matplotlib.pyplot as plt

class DraggableRectangle:
    lock = None  # only one can be animated at a time

    def __init__(self, rect):
        self.rect = rect
        self.press = None
        self.background = None
```

(continues on next page)

(continued from previous page)

```
    def connect(self):
        """Connect to all the events we need."""
        self.cidpress = self.rect.figure.canvas.mpl_connect(
            'button_press_event', self.on_press)
        self.cidrelease = self.rect.figure.canvas.mpl_connect(
            'button_release_event', self.on_release)
        self.cidmotion = self.rect.figure.canvas.mpl_connect(
            'motion_notify_event', self.on_motion)

    def on_press(self, event):
        """Check whether mouse is over us; if so, store some data."""
        if (event.inaxes != self.rect.axes
                or DraggableRectangle.lock is not None):
            return
        contains, attrd = self.rect.contains(event)
        if not contains:
            return
        print('event contains', self.rect.xy)
        self.press = self.rect.xy, (event.xdata, event.ydata)
        DraggableRectangle.lock = self

        # draw everything but the selected rectangle and store the␣
↪pixel buffer
        canvas = self.rect.figure.canvas
        axes = self.rect.axes
        self.rect.set_animated(True)
        canvas.draw()
        self.background = canvas.copy_from_bbox(self.rect.axes.bbox)

        # now redraw just the rectangle
        axes.draw_artist(self.rect)

        # and blit just the redrawn area
        canvas.blit(axes.bbox)

    def on_motion(self, event):
        """Move the rectangle if the mouse is over us."""
        if (event.inaxes != self.rect.axes
                or DraggableRectangle.lock is not self):
            return
        (x0, y0), (xpress, ypress) = self.press
        dx = event.xdata - xpress
        dy = event.ydata - ypress
        self.rect.set_x(x0+dx)
        self.rect.set_y(y0+dy)
```

(continues on next page)

(continued from previous page)

```
        canvas = self.rect.figure.canvas
        axes = self.rect.axes
        # restore the background region
        canvas.restore_region(self.background)

        # redraw just the current rectangle
        axes.draw_artist(self.rect)

        # blit just the redrawn area
        canvas.blit(axes.bbox)

    def on_release(self, event):
        """Clear button press information."""
        if DraggableRectangle.lock is not self:
            return

        self.press = None
        DraggableRectangle.lock = None

        # turn off the rect animation property and reset the background
        self.rect.set_animated(False)
        self.background = None

        # redraw the full figure
        self.rect.figure.canvas.draw()

    def disconnect(self):
        """Disconnect all callbacks."""
        self.rect.figure.canvas.mpl_disconnect(self.cidpress)
        self.rect.figure.canvas.mpl_disconnect(self.cidrelease)
        self.rect.figure.canvas.mpl_disconnect(self.cidmotion)

fig, ax = plt.subplots()
rects = ax.bar(range(10), 20*np.random.rand(10))
drs = []
for rect in rects:
    dr = DraggableRectangle(rect)
    dr.connect()
    drs.append(dr)

plt.show()
```

Mouse enter and leave

If you want to be notified when the mouse enters or leaves a figure or axes, you can connect to the figure/axes enter/leave events. Here is a simple example that changes the colors of the axes and figure background that the mouse is over:

```
"""
Illustrate the figure and axes enter and leave events by changing the
frame colors on enter and leave
"""
import matplotlib.pyplot as plt

def enter_axes(event):
    print('enter_axes', event.inaxes)
    event.inaxes.patch.set_facecolor('yellow')
    event.canvas.draw()

def leave_axes(event):
    print('leave_axes', event.inaxes)
    event.inaxes.patch.set_facecolor('white')
    event.canvas.draw()

def enter_figure(event):
    print('enter_figure', event.canvas.figure)
    event.canvas.figure.patch.set_facecolor('red')
    event.canvas.draw()

def leave_figure(event):
    print('leave_figure', event.canvas.figure)
    event.canvas.figure.patch.set_facecolor('grey')
    event.canvas.draw()

fig1, axs = plt.subplots(2)
fig1.suptitle('mouse hover over figure or axes to trigger events')

fig1.canvas.mpl_connect('figure_enter_event', enter_figure)
fig1.canvas.mpl_connect('figure_leave_event', leave_figure)
fig1.canvas.mpl_connect('axes_enter_event', enter_axes)
fig1.canvas.mpl_connect('axes_leave_event', leave_axes)

fig2, axs = plt.subplots(2)
fig2.suptitle('mouse hover over figure or axes to trigger events')

fig2.canvas.mpl_connect('figure_enter_event', enter_figure)
fig2.canvas.mpl_connect('figure_leave_event', leave_figure)
fig2.canvas.mpl_connect('axes_enter_event', enter_axes)
fig2.canvas.mpl_connect('axes_leave_event', leave_axes)
```

(continues on next page)

(continued from previous page)

```
plt.show()
```

Object picking

You can enable picking by setting the `picker` property of an *`Artist`* (such as *`Line2D`*, *`Text`*, *`Patch`*, *`Polygon`*, *`AxesImage`*, etc.)

The `picker` property can be set using various types:

`None`

Picking is disabled for this artist (default).

`boolean`

If True, then picking will be enabled and the artist will fire a pick event if the mouse event is over the artist.

`callable`

If picker is a callable, it is a user supplied function which determines whether the artist is hit by the mouse event. The signature is `hit, props = picker(artist, mouseevent)` to determine the hit test. If the mouse event is over the artist, return `hit = True`; `props` is a dictionary of properties that become additional attributes on the *`PickEvent`*.

The artist's `pickradius` property can additionally be set to a tolerance value in points (there are 72 points per inch) that determines how far the mouse can be and still trigger a mouse event.

After you have enabled an artist for picking by setting the `picker` property, you need to connect a handler to the figure canvas pick_event to get pick callbacks on mouse press events. The handler typically looks like

```
def pick_handler(event):
    mouseevent = event.mouseevent
    artist = event.artist
    # now do something with this...
```

The *`PickEvent`* passed to your callback always has the following attributes:

`mouseevent`

The *`MouseEvent`* that generate the pick event. See *event-attributes* for a list of useful attributes on the mouse event.

`artist`

The *`Artist`* that generated the pick event.

Additionally, certain artists like *`Line2D`* and *`PatchCollection`* may attach additional metadata, like the indices of the data that meet the picker criteria (e.g., all the points in the line that are within the specified `pickradius` tolerance).

Simple picking example

In the example below, we enable picking on the line and set a pick radius tolerance in points. The `onpick` callback function will be called when the pick event it within the tolerance distance from the line, and has the indices of the data vertices that are within the pick distance tolerance. Our `onpick` callback function simply prints the data that are under the pick location. Different Matplotlib Artists can attach different data to the PickEvent. For example, `Line2D` attaches the ind property, which are the indices into the line data under the pick point. See `.Line2D.pick` for details on the `PickEvent` properties of the line.

```
import numpy as np
import matplotlib.pyplot as plt

fig, ax = plt.subplots()
ax.set_title('click on points')

line, = ax.plot(np.random.rand(100), 'o',
                picker=True, pickradius=5)  # 5 points tolerance

def onpick(event):
    thisline = event.artist
    xdata = thisline.get_xdata()
    ydata = thisline.get_ydata()
    ind = event.ind
    points = tuple(zip(xdata[ind], ydata[ind]))
    print('onpick points:', points)

fig.canvas.mpl_connect('pick_event', onpick)

plt.show()
```

Picking exercise

Create a data set of 100 arrays of 1000 Gaussian random numbers and compute the sample mean and standard deviation of each of them (hint: NumPy arrays have a mean and std method) and make an xy marker plot of the 100 means vs. the 100 standard deviations. Connect the line created by the plot command to the pick event, and plot the original time series of the data that generated the clicked on points. If more than one point is within the tolerance of the clicked on point, you can use multiple subplots to plot the multiple time series.

Exercise solution:

```
"""
Compute the mean and stddev of 100 data sets and plot mean vs. stddev.
When you click on one of the (mean, stddev) points, plot the raw␣
 ↪dataset
that generated that point.
"""

import numpy as np
```

(continues on next page)

(continued from previous page)

```
import matplotlib.pyplot as plt

X = np.random.rand(100, 1000)
xs = np.mean(X, axis=1)
ys = np.std(X, axis=1)

fig, ax = plt.subplots()
ax.set_title('click on point to plot time series')
line, = ax.plot(xs, ys, 'o', picker=True, pickradius=5)  # 5 points␣
 ↪tolerance


def onpick(event):
    if event.artist != line:
        return
    n = len(event.ind)
    if not n:
        return
    fig, axs = plt.subplots(n, squeeze=False)
    for dataind, ax in zip(event.ind, axs.flat):
        ax.plot(X[dataind])
        ax.text(0.05, 0.9,
                f"$\\mu$={xs[dataind]:1.3f}\n$\\sigma$=
 ↪{ys[dataind]:1.3f}",
                transform=ax.transAxes, verticalalignment='top')
        ax.set_ylim(-0.5, 1.5)
    fig.show()
    return True


fig.canvas.mpl_connect('pick_event', onpick)
plt.show()
```

3.2.7 Writing a backend -- the pyplot interface

This page assumes general understanding of the information in the *Backends* page, and is instead intended as reference for third-party backend implementers. It also only deals with the interaction between backends and *pyplot*, not with the rendering side, which is described in *backend_template*.

There are two APIs for defining backends: a new canvas-based API (introduced in Matplotlib 3.6), and an older function-based API. The new API is simpler to implement because many methods can be inherited from "parent backends". It is recommended if back-compatibility for Matplotlib < 3.6 is not a concern. However, the old API remains supported.

Fundamentally, a backend module needs to provide information to *pyplot*, so that

1. *pyplot.figure()* can create a new *Figure* instance and associate it with an instance of a backend-provided canvas class, itself hosted in an instance of a backend-provided manager class.

2. *pyplot.show()* can show all figures and start the GUI event loop (if any).

To do so, the backend module must define a `backend_module.FigureCanvas` subclass of *FigureCanvasBase*. In the canvas-based API, this is the only strict requirement for backend modules. The function-based API additionally requires many module-level functions to be defined.

Canvas-based API (Matplotlib >= 3.6)

1. **Creating a figure**: *pyplot.figure()* calls `figure = Figure(); FigureCanvas.new_manager(figure, num)` (`new_manager` is a classmethod) to instantiate a canvas and a manager and set up the `figure.canvas` and `figure.canvas.manager` attributes. Figure unpickling uses the same approach, but replaces the newly instantiated `Figure()` by the unpickled figure.

   Interactive backends should customize the effect of `new_manager` by setting the `FigureCanvas.manager_class` attribute to the desired manager class, and additionally (if the canvas cannot be created before the manager, as in the case of the wx backends) by overriding the `FigureManager.create_with_canvas` classmethod. (Non-interactive backends can normally use a trivial `FigureManagerBase` and can therefore skip this step.)

   After a new figure is registered with *pyplot* (either via *pyplot.figure()* or via unpickling), if in interactive mode, *pyplot* will call its canvas' `draw_idle()` method, which can be overridden as desired.

2. **Showing figures**: *pyplot.show()* calls `FigureCanvas.manager_class.pyplot_show()` (a classmethod), forwarding any arguments, to start the main event loop.

   By default, `pyplot_show()` checks whether there are any `managers` registered with *pyplot* (exiting early if not), calls `manager.show()` on all such managers, and then, if called with `block=True` (or with the default `block=None` and out of IPython's pylab mode and not in interactive mode), calls `FigureCanvas.manager_class.start_main_loop()` (a classmethod) to start the main event loop. Interactive backends should therefore override the `FigureCanvas.manager_class.start_main_loop` classmethod accordingly (or alternatively, they may also directly override `FigureCanvas.manager_class.pyplot_show` directly).

Function-based API

1. **Creating a figure**: *pyplot.figure()* calls `new_figure_manager(num, *args, **kwargs)` (which also takes care of creating the new figure as `Figure(*args, **kwargs)`); unpickling calls `new_figure_manager_given_figure(num, figure)`.

   Furthermore, in interactive mode, the first draw of the newly registered figure can be customized by providing a module-level `draw_if_interactive()` function. (In the new canvas-based API, this function is not taken into account anymore.)

2. **Showing figures**: *pyplot.show()* calls a module-level `show()` function, which is typically generated via the `ShowBase` class and its `mainloop` method.

Registering a backend

For a new backend to be usable via `matplotlib.use()` or IPython `%matplotlib` magic command, it must be compatible with one of the three ways supported by the *`BackendRegistry`*:

Built-in

A backend built into Matplotlib must have its name and `FigureCanvas.required_interactive_framework` hard-coded in the *`BackendRegistry`*. If the backend module is not `f"matplotlib.backends.backend_{backend_name.lower()}"` then there must also be an entry in the `BackendRegistry._name_to_module`.

module:// syntax

Any backend in a separate module (not built into Matplotlib) can be used by specifying the path to the module in the form `module://some.backend.module`. An example is `module://mplcairo.qt` for mplcairo. The backend's interactive framework will be taken from its `FigureCanvas.required_interactive_framework`.

Entry point

An external backend module can self-register as a backend using an `entry point` in its `pyproject.toml` such as the one used by `matplotlib-inline`:

```
[project.entry-points."matplotlib.backend"]
inline = "matplotlib_inline.backend_inline"
```

The backend's interactive framework will be taken from its `FigureCanvas.required_interactive_framework`. All entry points are loaded together but only when first needed, such as when a backend name is not recognised as a built-in backend, or when *`list_all()`* is first called.

3.3 Axes and subplots

Matplotlib *`Axes`* are the gateway to creating your data visualizations. Once an Axes is placed on a figure there are many methods that can be used to add data to the Axes. An Axes typically has a pair of *`Axis`* Artists that define the data coordinate system, and include methods to add annotations like x- and y-labels, titles, and legends.

3.3.1 Introduction to Axes (or Subplots)

Matplotlib *`Axes`* are the gateway to creating your data visualizations. Once an Axes is placed on a figure there are many methods that can be used to add data to the Axes. An Axes typically has a pair of *`Axis`* Artists that define the data coordinate system, and include methods to add annotations like x- and y-labels, titles, and legends.

In the picture above, the Axes object was created with `ax = fig.subplots()`. Everything else on the figure was created with methods on this `ax` object, or can be accessed from it. If we want to change

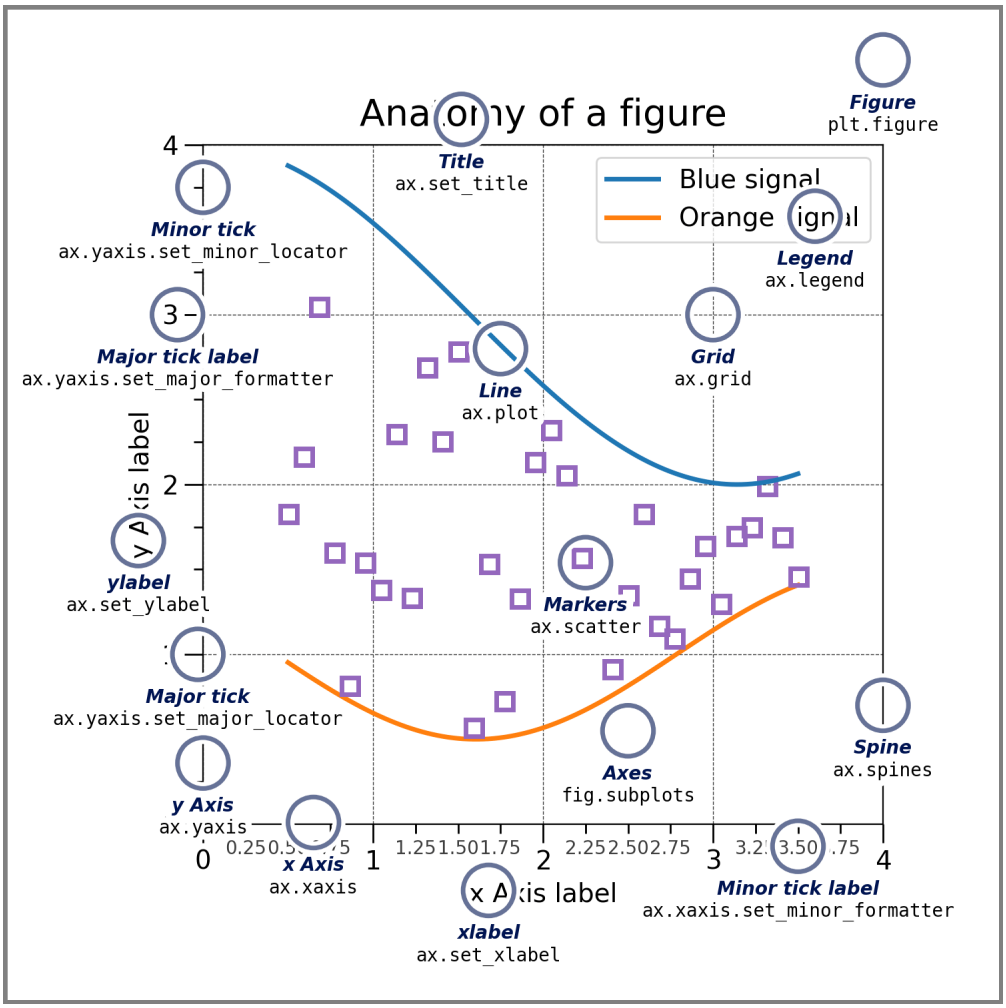


Fig. 4: Anatomy of a Figure

the label on the x-axis, we call `ax.set_xlabel('New Label')`, if we want to plot some data we call `ax.plot(x, y)`. Indeed, in the figure above, the only Artist that is not part of the Axes is the Figure itself, so the *axes.Axes* class is really the gateway to much of Matplotlib's functionality.

Note that Axes are so fundamental to the operation of Matplotlib that a lot of material here is duplicate of that in *Quick start guide*.

Creating Axes

```
import matplotlib.pyplot as plt
import numpy as np

fig, axs = plt.subplots(ncols=2, nrows=2, figsize=(3.5, 2.5),
                        layout="constrained")
# for each Axes, add an artist, in this case a nice label in the␣
 ↪middle...
for row in range(2):
    for col in range(2):
        axs[row, col].annotate(f'axs[{row}, {col}]', (0.5, 0.5),
                               transform=axs[row, col].transAxes,
                               ha='center', va='center', fontsize=18,
                               color='darkgrey')
fig.suptitle('plt.subplots()')
```

Axes are added using methods on *Figure* objects, or via the *pyplot* interface. These methods are discussed in more detail in *Creating Figures* and *Arranging multiple Axes in a Figure*. However, for instance *add_axes* will manually position an Axes on the page. In the example above *subplots* put a grid of subplots on the figure, and `axs` is a (2, 2) array of Axes, each of which can have data added to them.

There are a number of other methods for adding Axes to a Figure:

- *Figure.add_axes*: manually position an Axes. `fig.add_axes((0, 0, 1, 1))` makes an Axes that fills the whole figure.
- *pyplot.subplots* and *Figure.subplots*: add a grid of Axes as in the example above. The pyplot version returns both the Figure object and an array of Axes. Note that `fig, ax = plt.subplots()` adds a single Axes to a Figure.
- *pyplot.subplot_mosaic* and *Figure.subplot_mosaic*: add a grid of named Axes and return a dictionary of axes. For `fig, axs = plt.subplot_mosaic([['left', 'right'], ['bottom', 'bottom']])`, `axs['left']` is an Axes in the top row on the left, and `axs['bottom']` is an Axes that spans both columns on the bottom.

See *Arranging multiple Axes in a Figure* for more detail on how to arrange grids of Axes on a Figure.

Axes plotting methods

Most of the high-level plotting methods are accessed from the *axes.Axes* class. See the API documentation for a full curated list, and *Plot types* for examples. A basic example is *axes.Axes.plot*:

```
fig, ax = plt.subplots(figsize=(4, 3))
np.random.seed(19680801)
t = np.arange(100)
x = np.cumsum(np.random.randn(100))
lines = ax.plot(t, x)
```

Note that `plot` returns a list of *lines* Artists which can subsequently be manipulated, as discussed in *Introduction to Artists*.

A very incomplete list of plotting methods is below. Again, see *Plot types* for more examples, and *axes.Axes* for the full list of methods.

Pairwise data	*plot*, *scatter*, *bar*, *step*,
Array objects	*pcolormesh*, *contour*, *quiver*, *streamplot*, *imshow*
Statistical distributions	*hist*, *errorbar*, *hist2d*, *pie*, *boxplot*, *violinplot*
Irregularly gridded data	*tricontour*, *tripcolor*

Axes labelling and annotation

Usually we want to label the Axes with an xlabel, ylabel, and title, and often we want to have a legend to differentiate plot elements. The *Axes* class has a number of methods to create these annotations.

```
fig, ax = plt.subplots(figsize=(5, 3), layout='constrained')
np.random.seed(19680801)
t = np.arange(200)
x = np.cumsum(np.random.randn(200))
y = np.cumsum(np.random.randn(200))
linesx = ax.plot(t, x, label='Random walk x')
linesy = ax.plot(t, y, label='Random walk y')

ax.set_xlabel('Time [s]')
ax.set_ylabel('Distance [km]')
ax.set_title('Random walk example')
ax.legend()
```

These methods are relatively straight-forward, though there are a number of *Text properties and layout* that can be set on the text objects, like *fontsize*, *fontname*, *horizontalalignment*. Legends can be much more complicated; see *Legend guide* for more details.

Note that text can also be added to axes using *text*, and *annotate*. This can be quite sophisticated: see *Text properties and layout* and *Annotations* for more information.

Axes limits, scales, and ticking

Each Axes has two (or more) *Axis* objects, that can be accessed via `matplotlib.axes.Axes.xaxis` and `matplotlib.axes.Axes.yaxis` properties. These have substantial number of methods on them, and for highly customizable Axis-es it is useful to read the API at *Axis*. However, the Axes class offers a number of helpers for the most common of these methods. Indeed, the *set_xlabel*, discussed above, is a helper for the *set_label_text*.

Other important methods set the extent on the axes (*set_xlim*, *set_ylim*), or more fundamentally the scale of the axes. So for instance, we can make an Axis have a logarithmic scale, and zoom in on a sub-portion of the data:

```
fig, ax = plt.subplots(figsize=(4, 2.5), layout='constrained')
np.random.seed(19680801)
t = np.arange(200)
x = 2**np.cumsum(np.random.randn(200))
linesx = ax.plot(t, x)
ax.set_yscale('log')
ax.set_xlim(20, 180)
```

The Axes class also has helpers to deal with Axis ticks and their labels. Most straight-forward is *set_xticks* and *set_yticks* which manually set the tick locations and optionally their labels. Minor ticks can be toggled with *minorticks_on* or *minorticks_off*.

Many aspects of Axes ticks and tick labeling can be adjusted using *tick_params*. For instance, to label the top of the axes instead of the bottom,color the ticks red, and color the ticklabels green:

```
fig, ax = plt.subplots(figsize=(4, 2.5))
ax.plot(np.arange(10))
ax.tick_params(top=True, labeltop=True, color='red', axis='x',
               labelcolor='green')
```

More fine-grained control on ticks, setting scales, and controlling the Axis can be highly customized beyond these Axes-level helpers.

Axes layout

Sometimes it is important to set the aspect ratio of a plot in data space, which we can do with *set_aspect*:

```
fig, axs = plt.subplots(ncols=2, figsize=(7, 2.5), layout='constrained
↪')
np.random.seed(19680801)
t = np.arange(200)
x = np.cumsum(np.random.randn(200))
axs[0].plot(t, x)
axs[0].set_title('aspect="auto"')

```

(continues on next page)

(continued from previous page)

```
axs[1].plot(t, x)
axs[1].set_aspect(3)
axs[1].set_title('aspect=3')
```

3.3.2 Arranging multiple Axes in a Figure

Often more than one Axes is wanted on a figure at a time, usually organized into a regular grid. Matplotlib has a variety of tools for working with grids of Axes that have evolved over the history of the library. Here we will discuss the tools we think users should use most often, the tools that underpin how Axes are organized, and mention some of the older tools.

Note

Matplotlib uses *Axes* to refer to the drawing area that contains data, x- and y-axis, ticks, labels, title, etc. See *Parts of a Figure* for more details. Another term that is often used is "subplot", which refers to an Axes that is in a grid with other Axes objects.

Overview

Create grid-shaped combinations of Axes

subplots

The primary function used to create figures and a grid of Axes. It creates and places all Axes on the figure at once, and returns an object array with handles for the Axes in the grid. See *Figure.subplots*.

or

subplot_mosaic

A simple way to create figures and a grid of Axes, with the added flexibility that Axes can also span rows or columns. The Axes are returned in a labelled dictionary instead of an array. See also *Figure.subplot_mosaic* and *Complex and semantic figure composition (subplot_mosaic)*.

Sometimes it is natural to have more than one distinct group of Axes grids, in which case Matplotlib has the concept of *SubFigure*:

SubFigure

A virtual figure within a figure.

Underlying tools

Underlying these are the concept of a *GridSpec* and a *SubplotSpec*:

GridSpec

Specifies the geometry of the grid that a subplot will be placed. The number of rows and number of columns of the grid need to be set. Optionally, the subplot layout parameters (e.g., left, right, etc.) can be tuned.

SubplotSpec

Specifies the location of the subplot in the given *GridSpec*.

Adding single Axes at a time

The above functions create all Axes in a single function call. It is also possible to add Axes one at a time, and this was originally how Matplotlib used to work. Doing so is generally less elegant and flexible, though sometimes useful for interactive work or to place an Axes in a custom location:

add_axes

Adds a single Axes at a location specified by `[left, bottom, width, height]` in fractions of figure width or height.

subplot* or *Figure.add_subplot

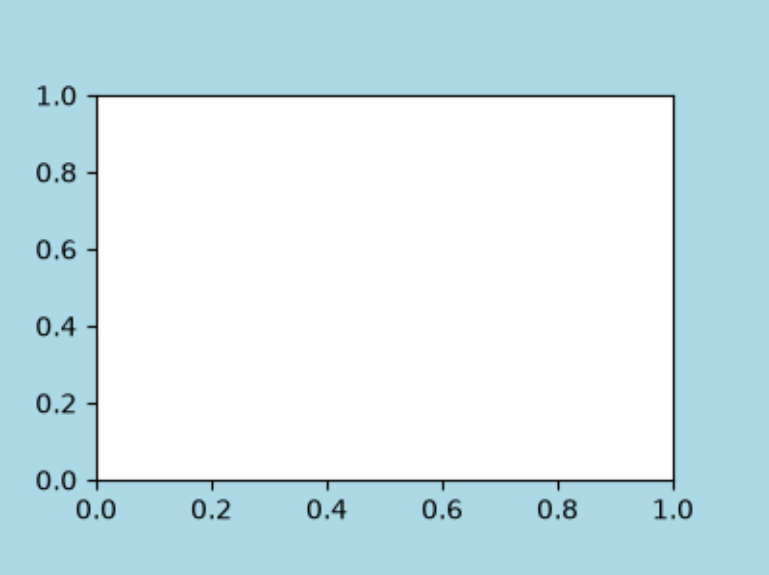
Adds a single subplot on a figure, with 1-based indexing (inherited from Matlab). Columns and rows can be spanned by specifying a range of grid cells.

subplot2grid

Similar to *pyplot.subplot*, but uses 0-based indexing and two-d python slicing to choose cells.

As a simple example of manually adding an Axes *ax*, lets add a 3 inch x 2 inch Axes to a 4 inch x 3 inch figure. Note that the location of the subplot is defined as [left, bottom, width, height] in figure-normalized units:

```
import matplotlib.pyplot as plt
import numpy as np

w, h = 4, 3
margin = 0.5
fig = plt.figure(figsize=(w, h), facecolor='lightblue')
ax = fig.add_axes((margin / w, margin / h,
                   (w - 2 * margin) / w, (h - 2 * margin) / h))
```

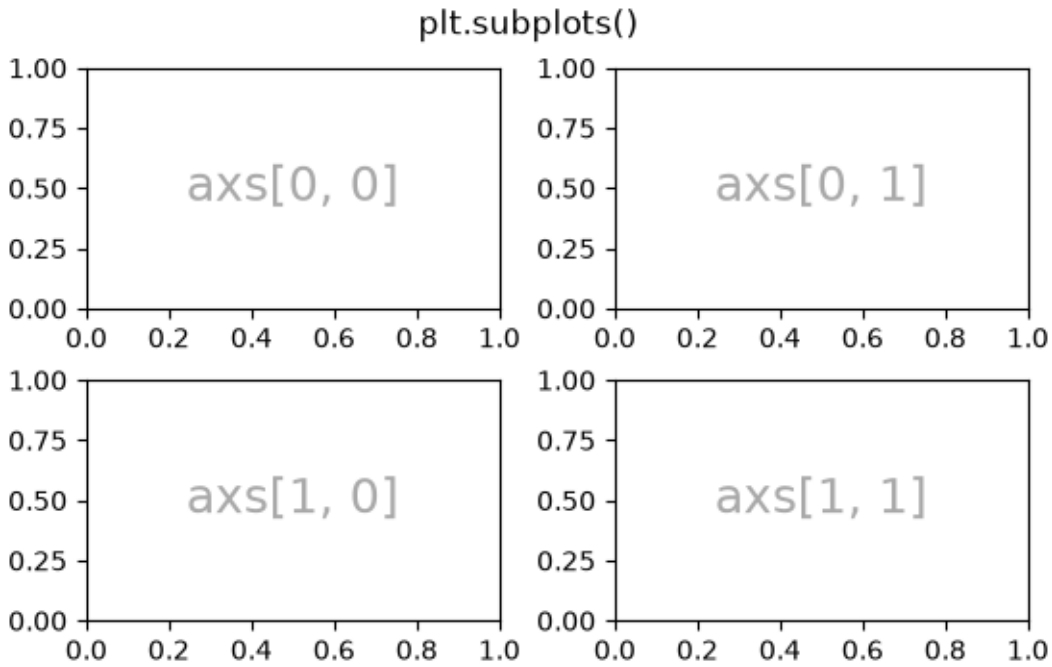


High-level methods for making grids

Basic 2x2 grid

We can create a basic 2-by-2 grid of Axes using *subplots*. It returns a *Figure* instance and an array of *Axes* objects. The Axes objects can be used to access methods to place artists on the Axes; here we use *annotate*, but other examples could be *plot*, *pcolormesh*, etc.

```
fig, axs = plt.subplots(ncols=2, nrows=2, figsize=(5.5, 3.5),
                        layout="constrained")
# add an artist, in this case a nice label in the middle...
for row in range(2):
    for col in range(2):
        axs[row, col].annotate(f'axs[{row}, {col}]', (0.5, 0.5),
                               transform=axs[row, col].transAxes,
                               ha='center', va='center', fontsize=18,
                               color='darkgrey')
fig.suptitle('plt.subplots()')
```

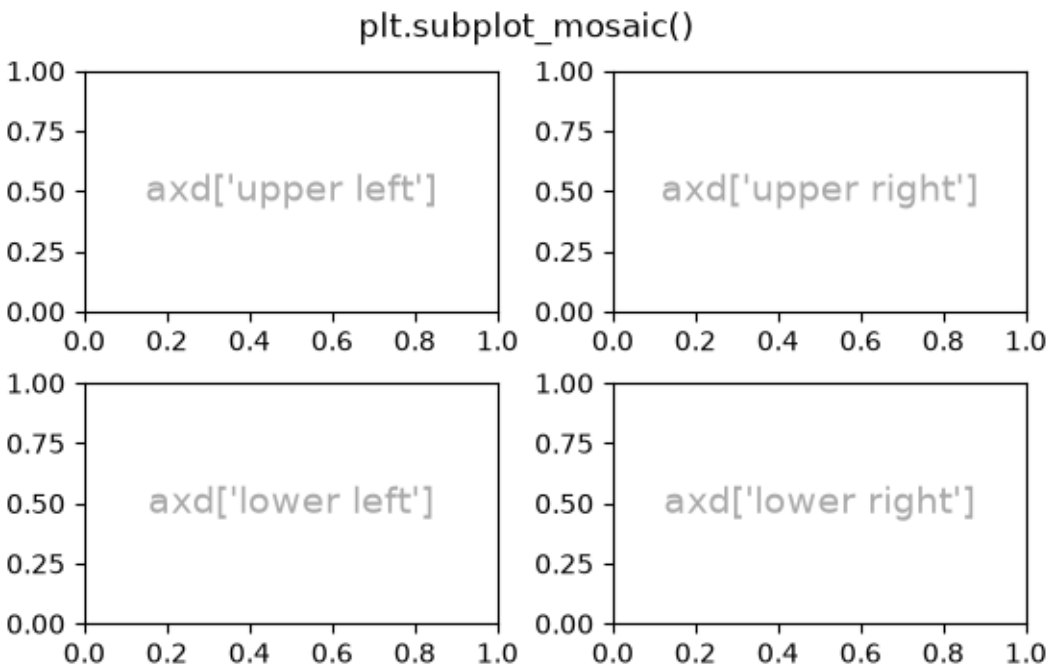


We will annotate a lot of Axes, so let's encapsulate the annotation, rather than having that large piece of annotation code every time we need it:

```
def annotate_axes(ax, text, fontsize=18):
    ax.text(0.5, 0.5, text, transform=ax.transAxes,
            ha="center", va="center", fontsize=fontsize, color=
 ↪"darkgrey")
```

The same effect can be achieved with *subplot_mosaic*, but the return type is a dictionary instead of an array, where the user can give the keys useful meanings. Here we provide two lists, each list representing a row, and each element in the list a key representing the column.

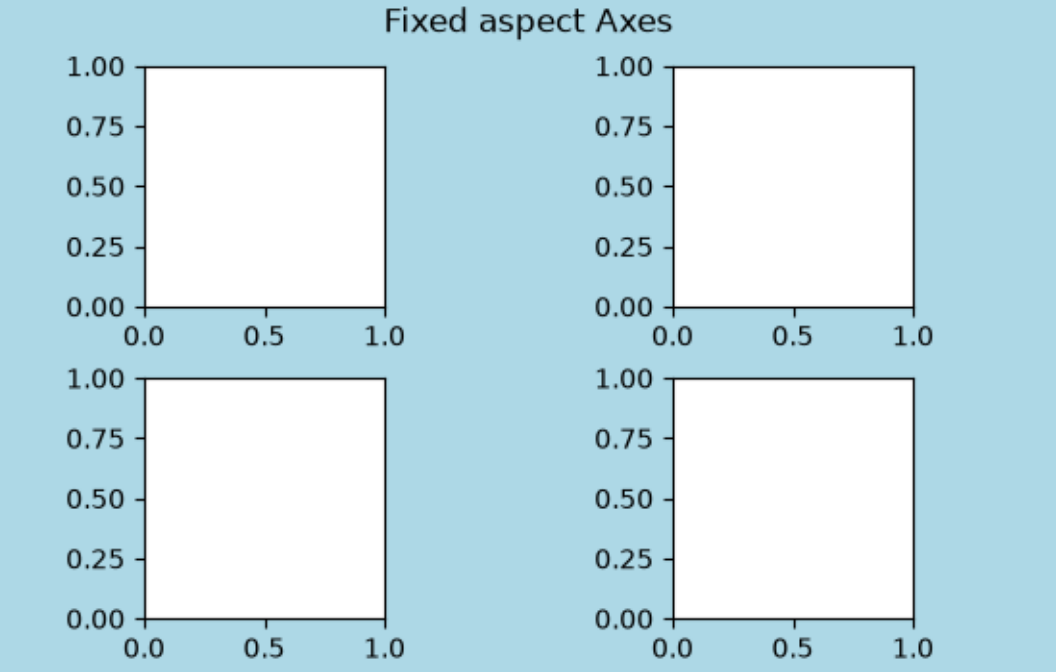
```
fig, axd = plt.subplot_mosaic([['upper left', 'upper right'],
                               ['lower left', 'lower right']],
                              figsize=(5.5, 3.5), layout="constrained")
for k, ax in axd.items():
    annotate_axes(ax, f'axd[{k!r}]', fontsize=14)
fig.suptitle('plt.subplot_mosaic()')
```



Grids of fixed-aspect ratio Axes

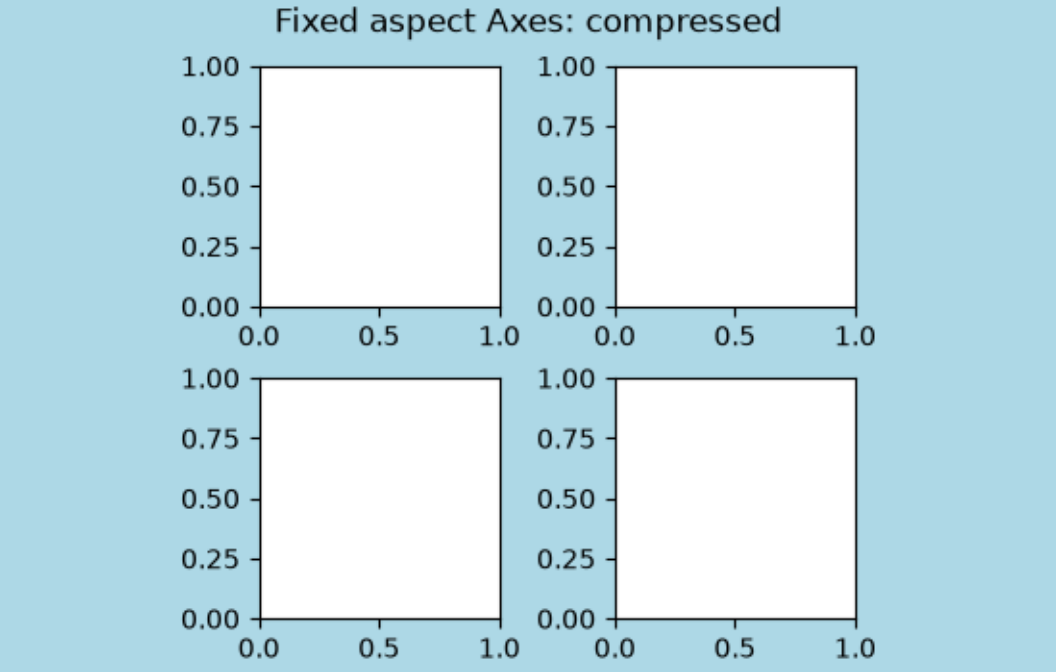
Fixed-aspect ratio Axes are common for images or maps. However, they present a challenge to layout because two sets of constraints are being imposed on the size of the Axes - that they fit in the figure and that they have a set aspect ratio. This leads to large gaps between Axes by default:

```
fig, axs = plt.subplots(2, 2, layout="constrained",
                        figsize=(5.5, 3.5), facecolor='lightblue')
for ax in axs.flat:
    ax.set_aspect(1)
fig.suptitle('Fixed aspect Axes')
```



One way to address this is to change the aspect of the figure to be close to the aspect ratio of the Axes, however that requires trial and error. Matplotlib also supplies `layout="compressed"`, which will work with simple grids to reduce the gaps between Axes. (The `mpl_toolkits` also provides *`ImageGrid`* to accomplish a similar effect, but with a non-standard Axes class).

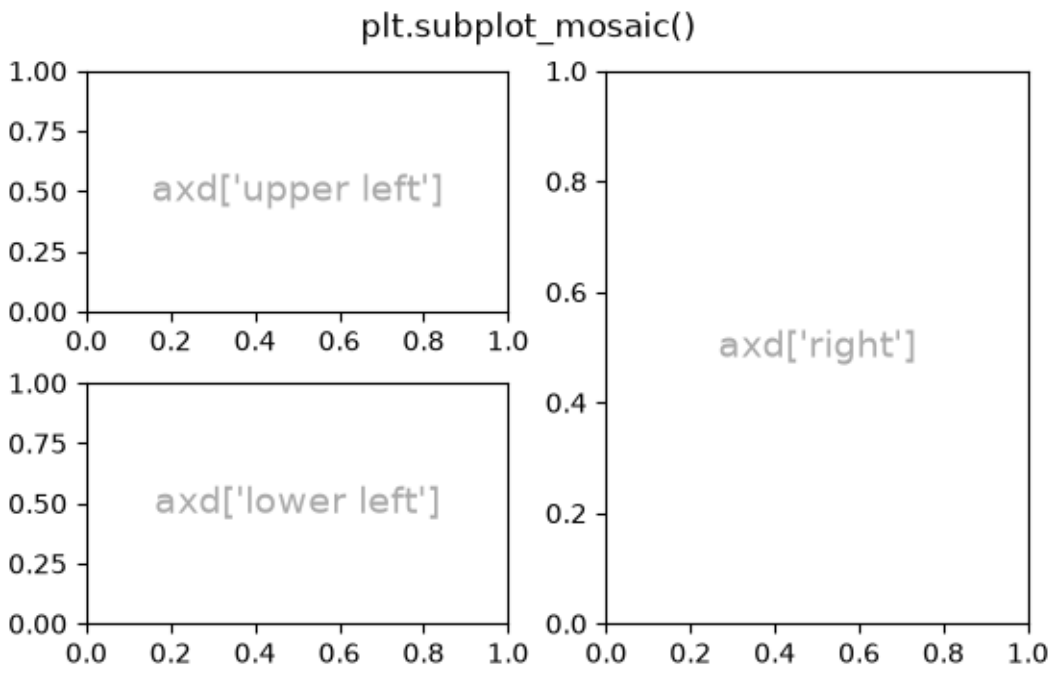
```
fig, axs = plt.subplots(2, 2, layout="compressed", figsize=(5.5, 3.5),
                        facecolor='lightblue')
for ax in axs.flat:
    ax.set_aspect(1)
fig.suptitle('Fixed aspect Axes: compressed')
```



Axes spanning rows or columns in a grid

Sometimes we want Axes to span rows or columns of the grid. There are actually multiple ways to accomplish this, but the most convenient is probably to use *subplot_mosaic* by repeating one of the keys:

```
fig, axd = plt.subplot_mosaic([['upper left', 'right'],
                               ['lower left', 'right']],
                              figsize=(5.5, 3.5), layout="constrained")
for k, ax in axd.items():
    annotate_axes(ax, f'axd[{k!r}]', fontsize=14)
fig.suptitle('plt.subplot_mosaic()')
```

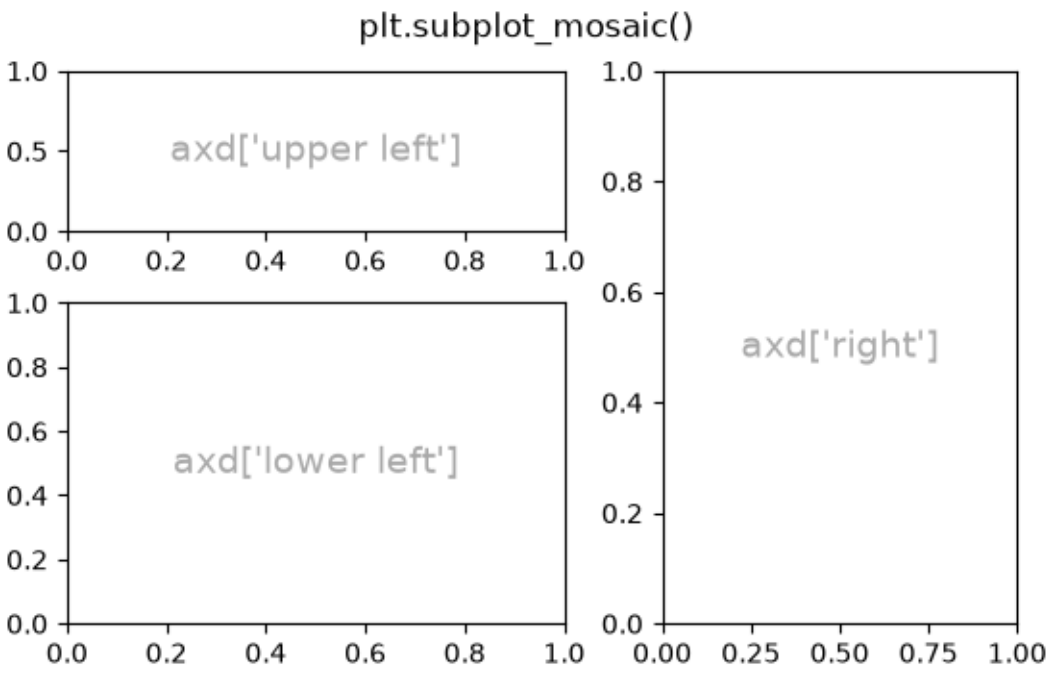


See below for the description of how to do the same thing using *GridSpec* or *subplot2grid*.

Variable widths or heights in a grid

Both *subplots* and *subplot_mosaic* allow the rows in the grid to be different heights, and the columns to be different widths using the *gridspec_kw* keyword argument. Spacing parameters accepted by *GridSpec* can be passed to *subplots* and *subplot_mosaic*:

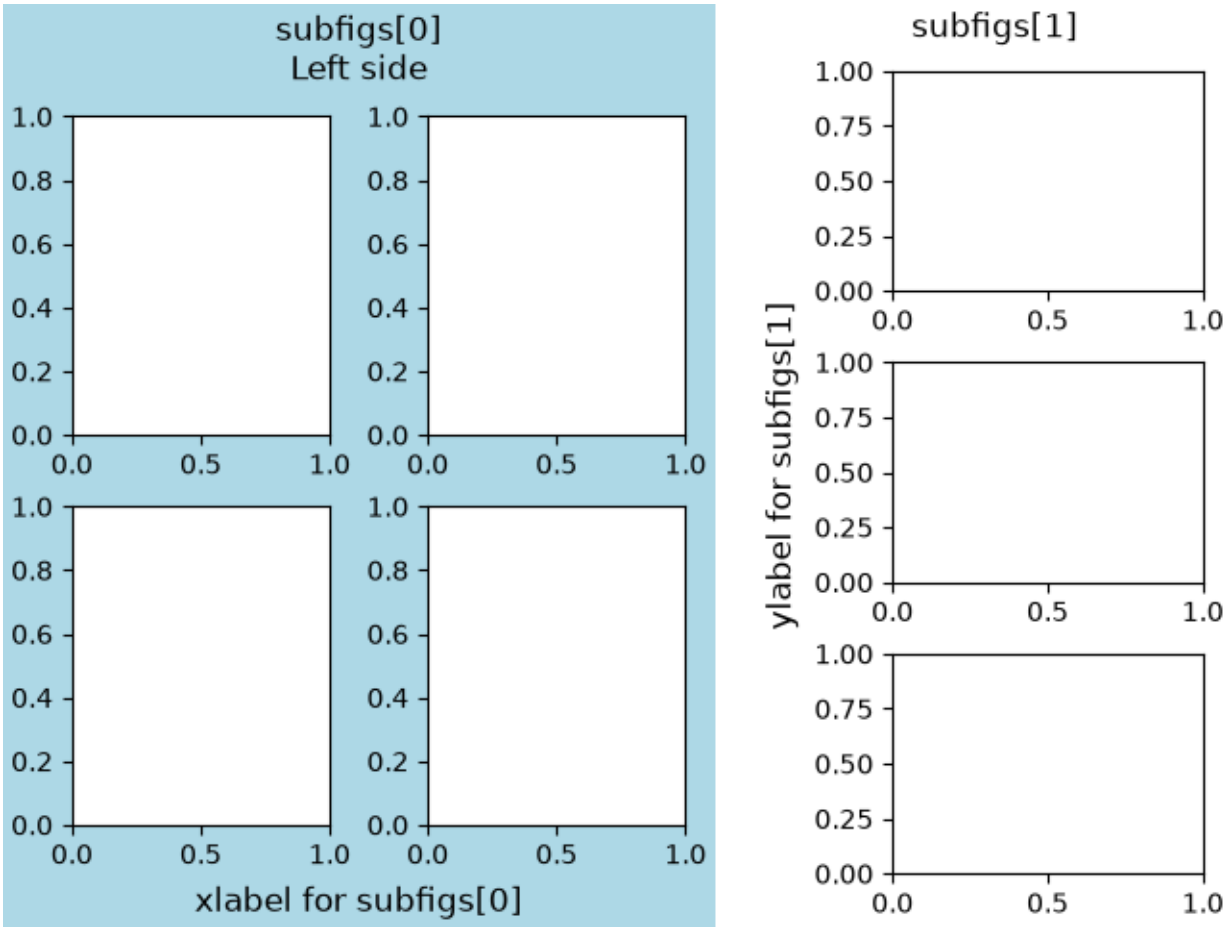
```
gs_kw = dict(width_ratios=[1.4, 1], height_ratios=[1, 2])
fig, axd = plt.subplot_mosaic([['upper left', 'right'],
                               ['lower left', 'right']],
                              gridspec_kw=gs_kw, figsize=(5.5, 3.5),
                              layout="constrained")
for k, ax in axd.items():
    annotate_axes(ax, f'axd[{k!r}]', fontsize=14)
fig.suptitle('plt.subplot_mosaic()')
```



Nested Axes layouts

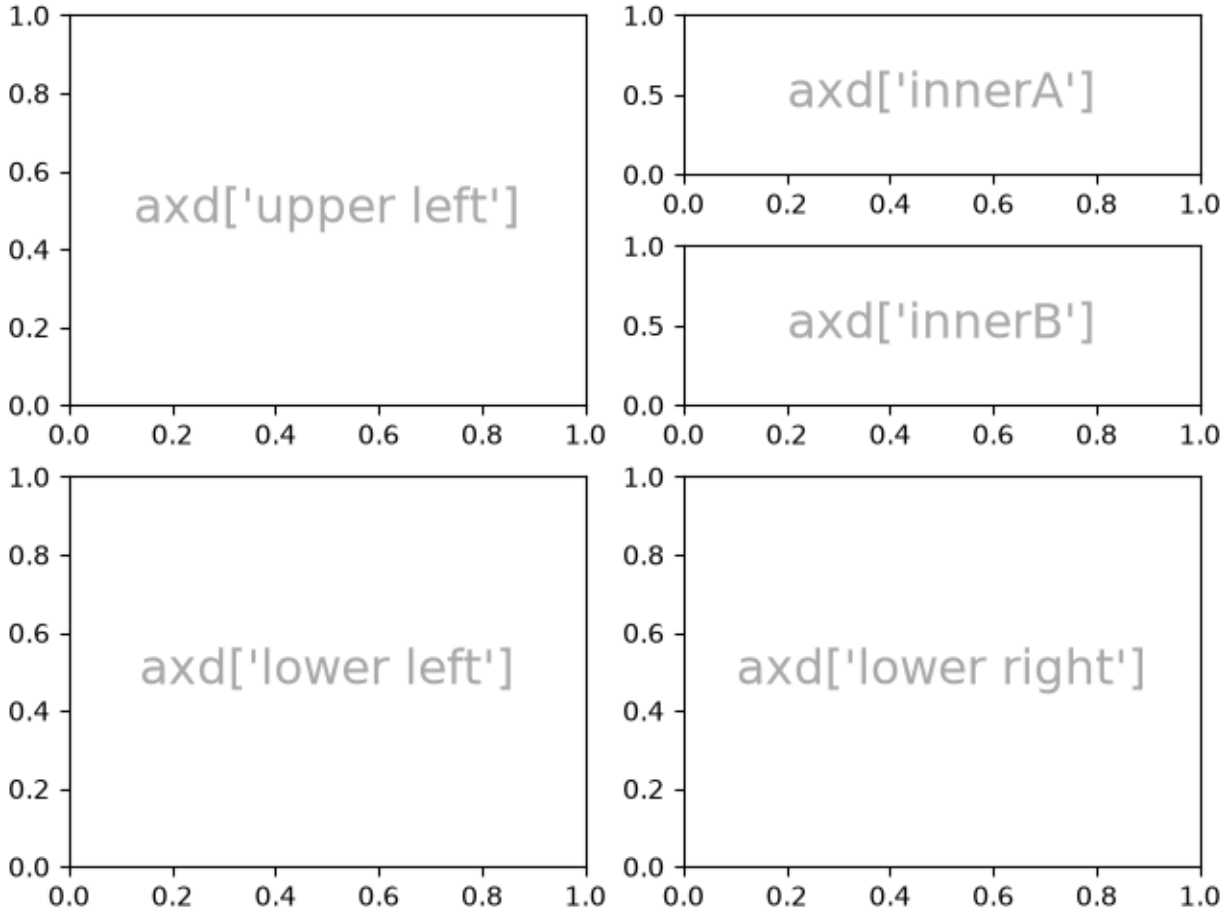
Sometimes it is helpful to have two or more grids of Axes that may not need to be related to one another. The most simple way to accomplish this is to use *Figure.subfigures*. Note that the subfigure layouts are independent, so the Axes spines in each subfigure are not necessarily aligned. See below for a more verbose way to achieve the same effect with *GridSpecFromSubplotSpec*.

```
fig = plt.figure(layout="constrained")
subfigs = fig.subfigures(1, 2, wspace=0.07, width_ratios=[1.5, 1.])
axs0 = subfigs[0].subplots(2, 2)
subfigs[0].set_facecolor('lightblue')
subfigs[0].suptitle('subfigs[0]\nLeft side')
subfigs[0].supxlabel('xlabel for subfigs[0]')

axs1 = subfigs[1].subplots(3, 1)
subfigs[1].suptitle('subfigs[1]')
subfigs[1].supylabel('ylabel for subfigs[1]')
```



It is also possible to nest Axes using *subplot_mosaic* using nested lists. This method does not use subfigures, like above, so lacks the ability to add per-subfigure `suptitle` and `supxlabel`, etc. Rather it is a convenience wrapper around the *subgridspec* method described below.

```
inner = [['innerA'],
         ['innerB']]
outer = [['upper left',  inner],
         ['lower left', 'lower right']]

fig, axd = plt.subplot_mosaic(outer, layout="constrained")
for k, ax in axd.items():
    annotate_axes(ax, f'axd[{k!r}]')
```



Low-level and advanced grid methods

Internally, the arrangement of a grid of Axes is controlled by creating instances of *GridSpec* and *SubplotSpec*. *GridSpec* defines a (possibly non-uniform) grid of cells. Indexing into the *GridSpec* returns a SubplotSpec that covers one or more grid cells, and can be used to specify the location of an Axes.

The following examples show how to use low-level methods to arrange Axes using *GridSpec* objects.

Basic 2x2 grid

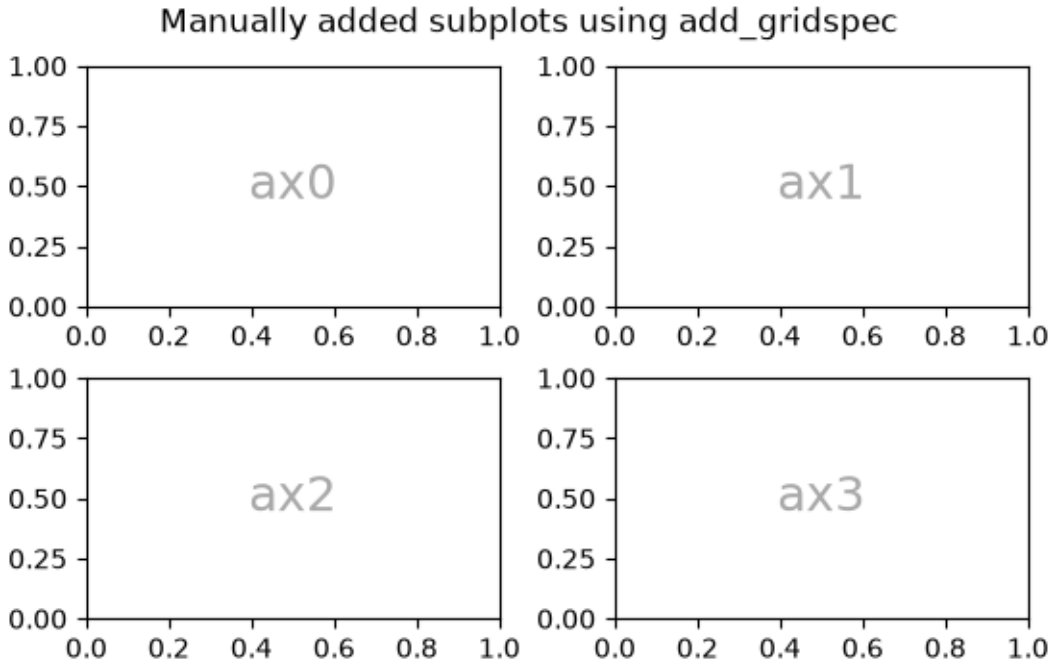
We can accomplish a 2x2 grid in the same manner as `plt.subplots(2, 2)`:

```
fig = plt.figure(figsize=(5.5, 3.5), layout="constrained")
spec = fig.add_gridspec(ncols=2, nrows=2)

ax0 = fig.add_subplot(spec[0, 0])
annotate_axes(ax0, 'ax0')

ax1 = fig.add_subplot(spec[0, 1])
annotate_axes(ax1, 'ax1')
```

(continues on next page)

(continued from previous page)

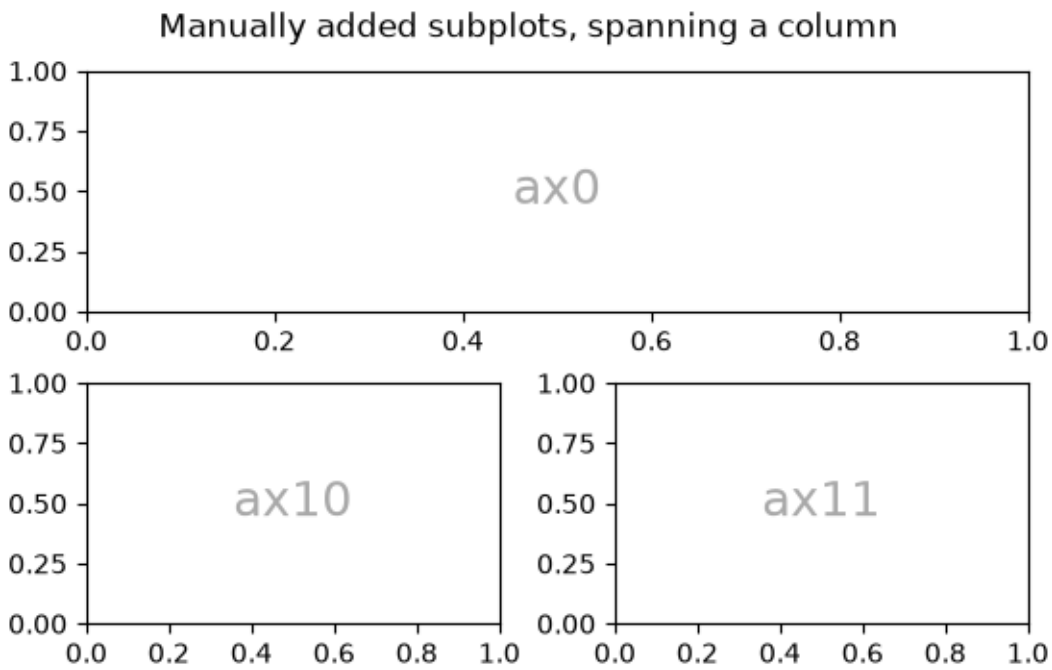
```
ax2 = fig.add_subplot(spec[1, 0])
annotate_axes(ax2, 'ax2')

ax3 = fig.add_subplot(spec[1, 1])
annotate_axes(ax3, 'ax3')

fig.suptitle('Manually added subplots using add_gridspec')
```



Axes spanning rows or grids in a grid

We can index the *spec* array using NumPy slice syntax and the new Axes will span the slice. This would be the same as `fig, axd = plt.subplot_mosaic([['ax0', 'ax0'], ['ax1', 'ax2']], ...)`:

```
fig = plt.figure(figsize=(5.5, 3.5), layout="constrained")
spec = fig.add_gridspec(2, 2)

ax0 = fig.add_subplot(spec[0, :])
annotate_axes(ax0, 'ax0')

ax10 = fig.add_subplot(spec[1, 0])
annotate_axes(ax10, 'ax10')

ax11 = fig.add_subplot(spec[1, 1])
annotate_axes(ax11, 'ax11')

fig.suptitle('Manually added subplots, spanning a column')
```

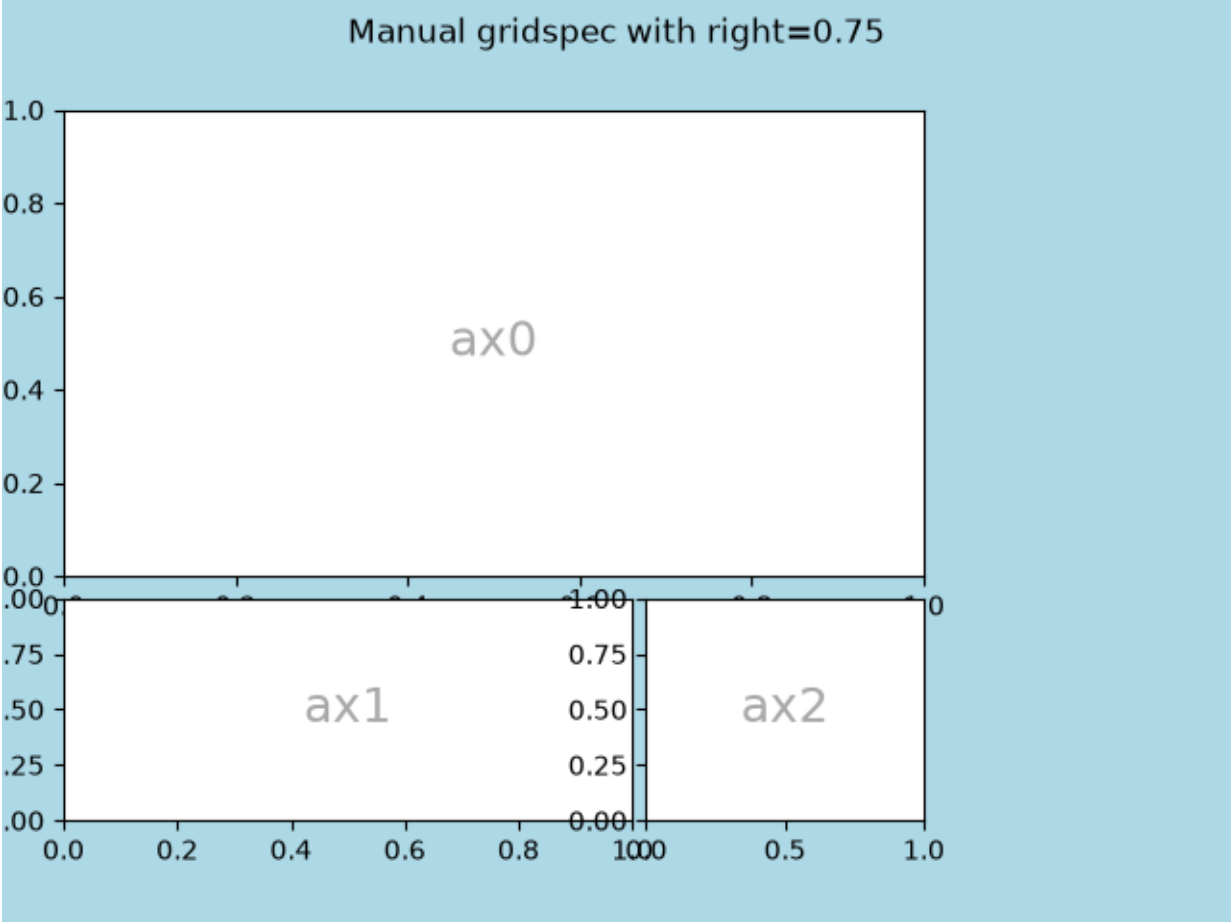


Manual adjustments to a *GridSpec* layout

When a *GridSpec* is explicitly used, you can adjust the layout parameters of subplots that are created from the *GridSpec*. Note this option is not compatible with *constrained layout* or `Figure.tight_layout` which both ignore *left* and *right* and adjust subplot sizes to fill the figure. Usually such manual placement requires iterations to make the Axes tick labels not overlap the Axes.

These spacing parameters can also be passed to `subplots` and `subplot_mosaic` as the *gridspec_kw* argument.

```
fig = plt.figure(layout=None, facecolor='lightblue')
gs = fig.add_gridspec(nrows=3, ncols=3, left=0.05, right=0.75,
                      hspace=0.1, wspace=0.05)
ax0 = fig.add_subplot(gs[:-1, :])
annotate_axes(ax0, 'ax0')
ax1 = fig.add_subplot(gs[-1, :-1])
annotate_axes(ax1, 'ax1')
ax2 = fig.add_subplot(gs[-1, -1])
annotate_axes(ax2, 'ax2')
fig.suptitle('Manual gridspec with right=0.75')
```



Nested layouts with SubplotSpec

You can create nested layout similar to *subfigures* using *subgridspec*. Here the Axes spines *are* aligned.

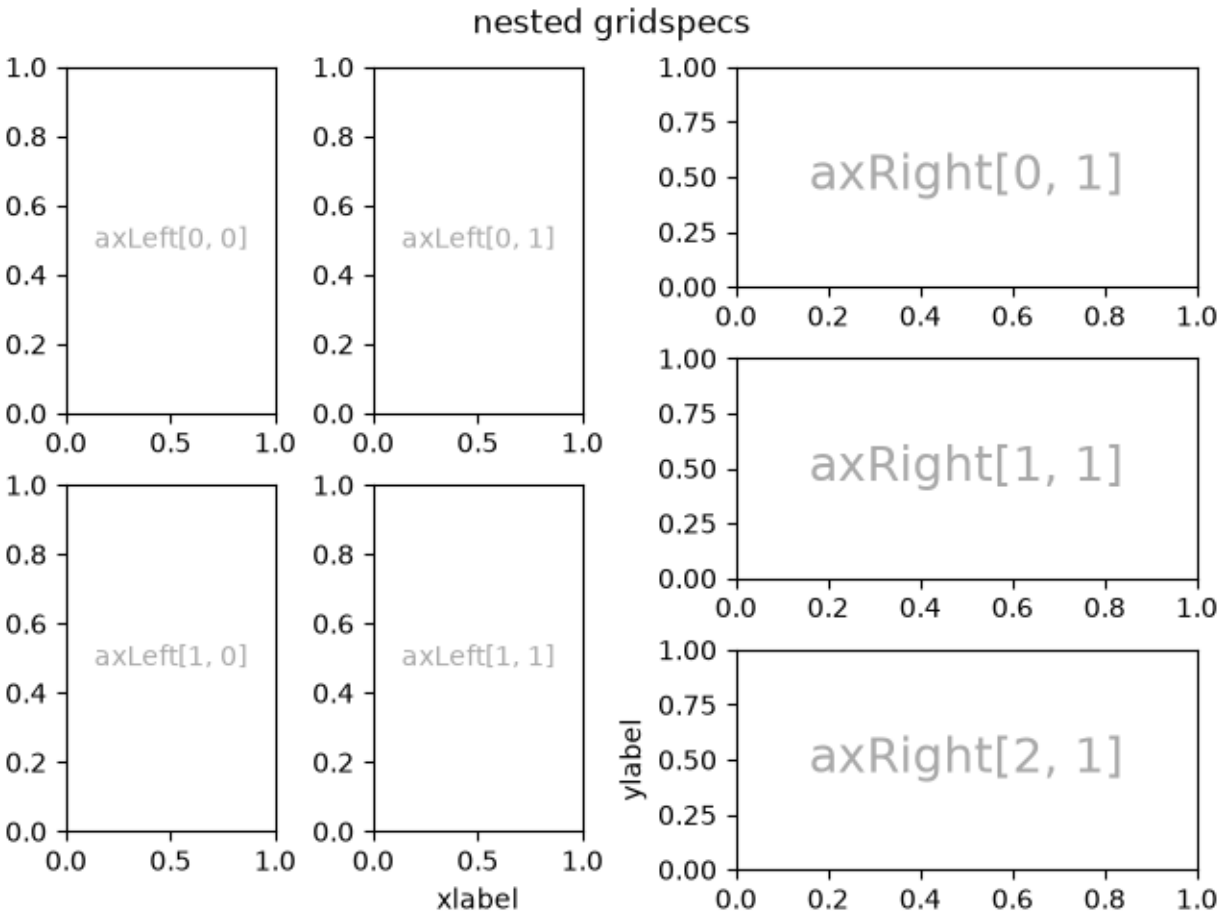
Note this is also available from the more verbose *gridspec.GridSpecFromSubplotSpec*.

```
fig = plt.figure(layout="constrained")
gs0 = fig.add_gridspec(1, 2)

gs00 = gs0[0].subgridspec(2, 2)
gs01 = gs0[1].subgridspec(3, 1)

for a in range(2):
    for b in range(2):
        ax = fig.add_subplot(gs00[a, b])
        annotate_axes(ax, f'axLeft[{a}, {b}]', fontsize=10)
        if a == 1 and b == 1:
            ax.set_xlabel('xlabel')
for a in range(3):
    ax = fig.add_subplot(gs01[a])
```

(continues on next page)

(continued from previous page)

```
    annotate_axes(ax, f'axRight[{a}, {b}]')
    if a == 2:
        ax.set_ylabel('ylabel')

fig.suptitle('nested gridspecs')
```



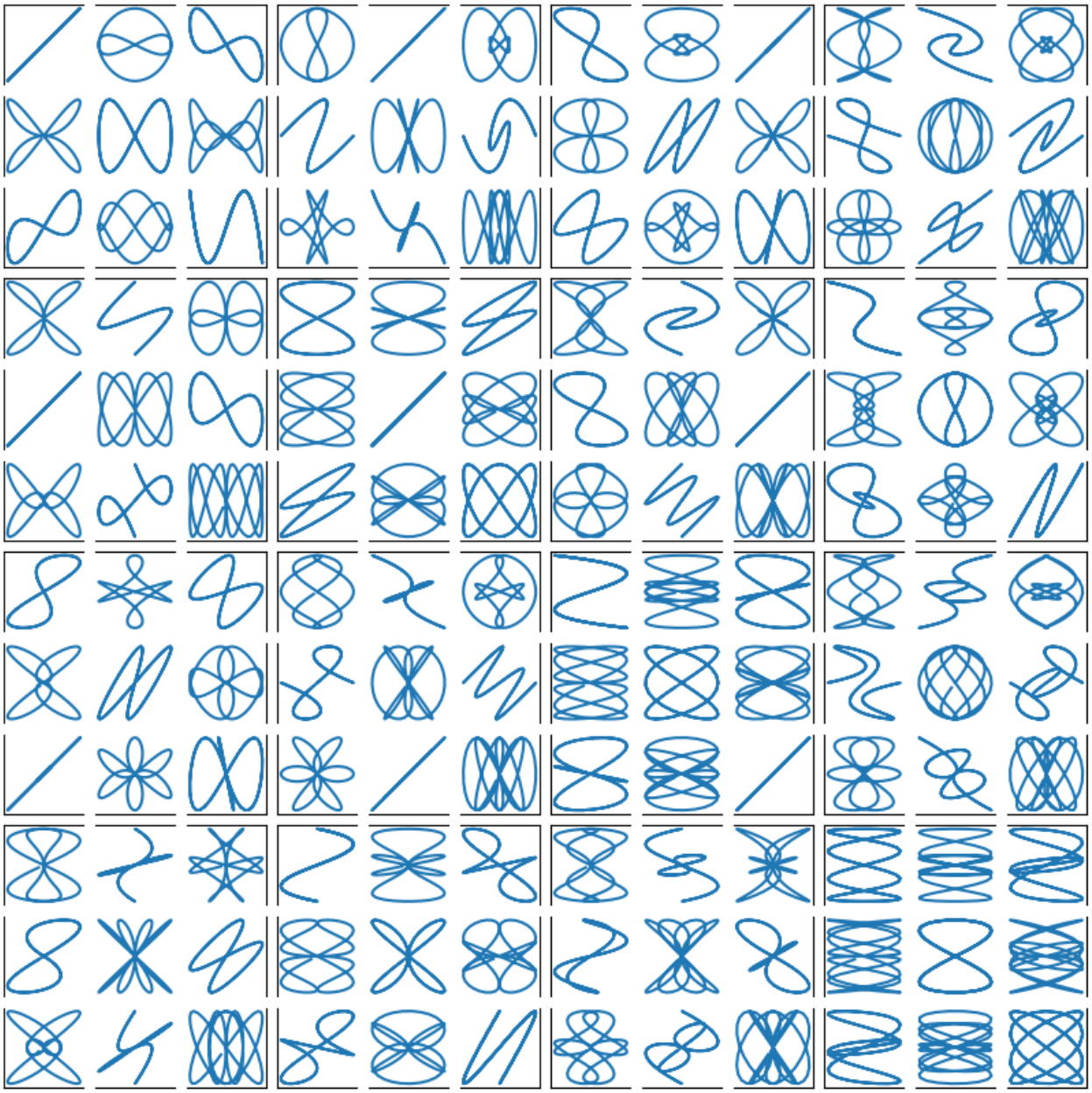
Here's a more sophisticated example of nested *GridSpec*: We create an outer 4x4 grid with each cell containing an inner 3x3 grid of Axes. We outline the outer 4x4 grid by hiding appropriate spines in each of the inner 3x3 grids.

```
def squiggle_xy(a, b, c, d, i=np.arange(0.0, 2*np.pi, 0.05)):
    return np.sin(i*a)*np.cos(i*b), np.sin(i*c)*np.cos(i*d)

fig = plt.figure(figsize=(8, 8), layout='constrained')
outer_grid = fig.add_gridspec(4, 4, wspace=0, hspace=0)

for a in range(4):
    for b in range(4):
        # gridspec inside gridspec
        inner_grid = outer_grid[a, b].subgridspec(3, 3, wspace=0,␣
```

(continues on next page)

(continued from previous page)

```
 ↪hspace=0)
        axs = inner_grid.subplots()  # Create all subplots for the␣
 ↪inner grid.
        for (c, d), ax in np.ndenumerate(axs):
            ax.plot(*squiggle_xy(a + 1, b + 1, c + 1, d + 1))
            ax.set(xticks=[], yticks=[])

# show only the outside spines
for ax in fig.get_axes():
    ss = ax.get_subplotspec()
    ax.spines.top.set_visible(ss.is_first_row())
    ax.spines.bottom.set_visible(ss.is_last_row())
    ax.spines.left.set_visible(ss.is_first_col())
    ax.spines.right.set_visible(ss.is_last_col())

plt.show()
```



More reading

- More details about *subplot mosaic*.
- More details about *constrained layout*, used to align spacing in most of these examples.

References

The use of the following functions, methods, classes and modules is shown in this example:

- `matplotlib.pyplot.subplots`
- `matplotlib.pyplot.subplot_mosaic`

- *matplotlib.figure.Figure.add_gridspec*
- *matplotlib.figure.Figure.add_subplot*
- *matplotlib.gridspec.GridSpec*
- *matplotlib.gridspec.SubplotSpec.subgridspec*
- *matplotlib.gridspec.GridSpecFromSubplotSpec*

Total running time of the script: (0 minutes 8.648 seconds)

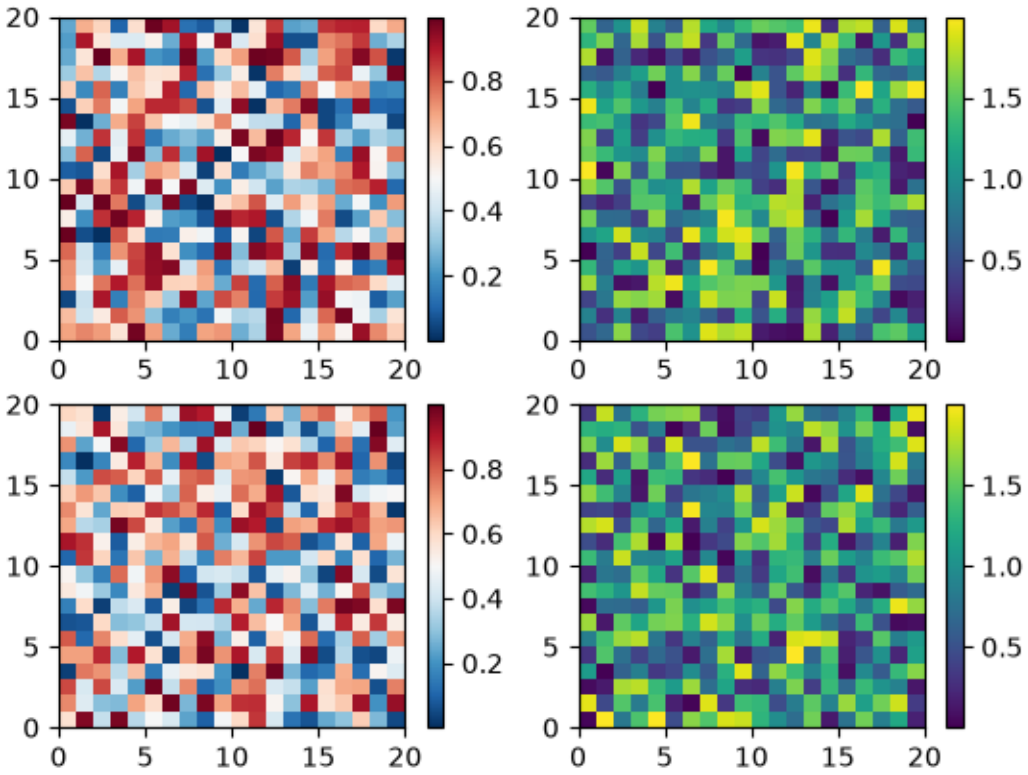
3.3.3 Placing colorbars

Colorbars indicate the quantitative extent of image data. Placing in a figure is non-trivial because room needs to be made for them.

Automatic placement of colorbars

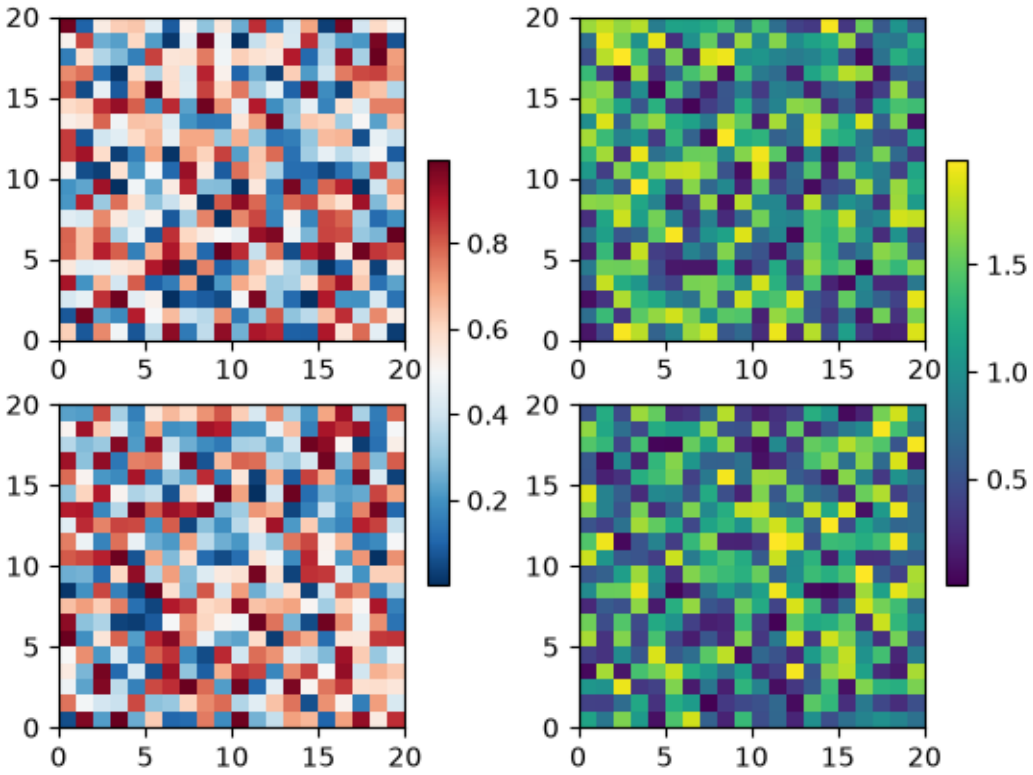
The simplest case is just attaching a colorbar to each Axes. Note in this example that the colorbars steal some space from the parent Axes.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

fig, axs = plt.subplots(2, 2)
cmaps = ['RdBu_r', 'viridis']
for col in range(2):
    for row in range(2):
        ax = axs[row, col]
        pcm = ax.pcolormesh(np.random.random((20, 20)) * (col + 1),
                            cmap=cmaps[col])
        fig.colorbar(pcm, ax=ax)
```



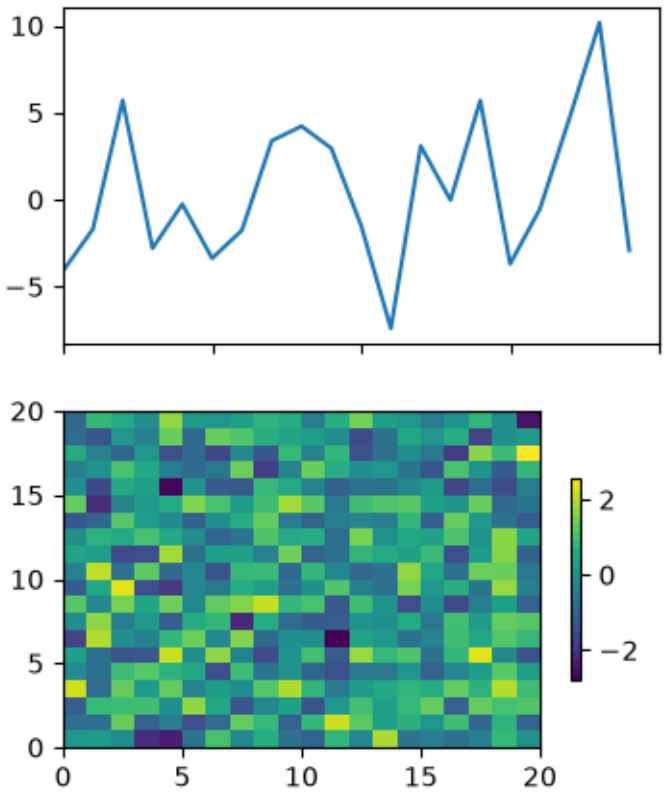
The first column has the same type of data in both rows, so it may be desirable to have just one colorbar. We do this by passing *Figure.colorbar* a list of Axes with the *ax* kwarg.

```
fig, axs = plt.subplots(2, 2)
cmaps = ['RdBu_r', 'viridis']
for col in range(2):
    for row in range(2):
        ax = axs[row, col]
        pcm = ax.pcolormesh(np.random.random((20, 20)) * (col + 1),
                            cmap=cmaps[col])
    fig.colorbar(pcm, ax=axs[:, col], shrink=0.6)
```



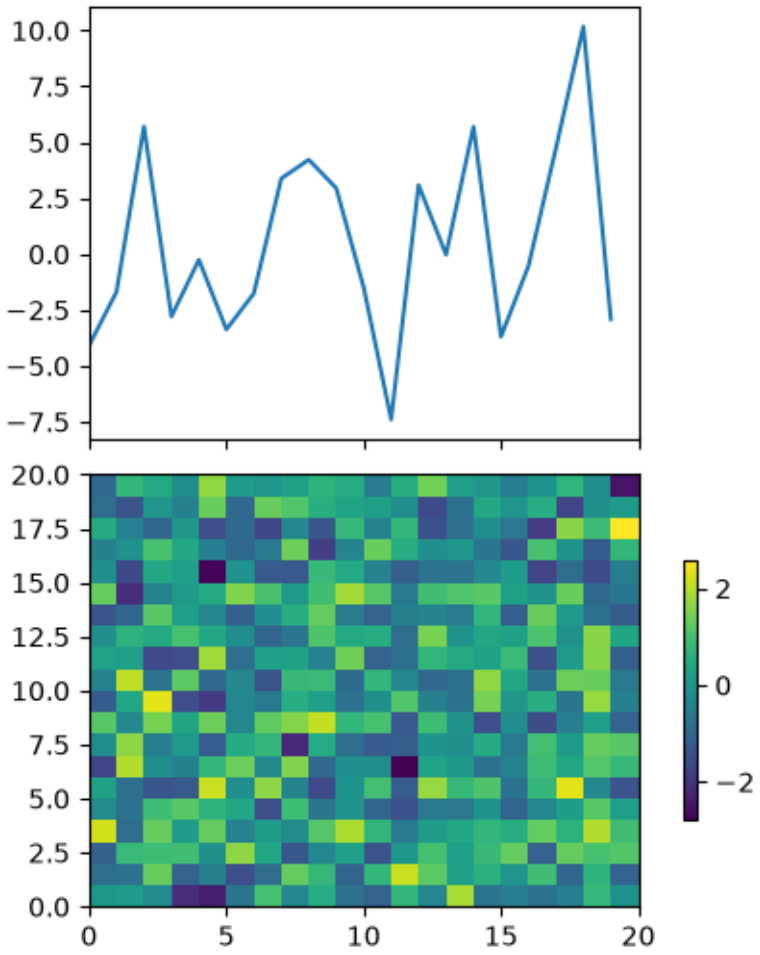
The stolen space can lead to Axes in the same subplot layout being different sizes, which is often undesired if the the x-axis on each plot is meant to be comparable as in the following:

```
fig, axs = plt.subplots(2, 1, figsize=(4, 5), sharex=True)
X = np.random.randn(20, 20)
axs[0].plot(np.sum(X, axis=0))
pcm = axs[1].pcolormesh(X)
fig.colorbar(pcm, ax=axs[1], shrink=0.6)
```



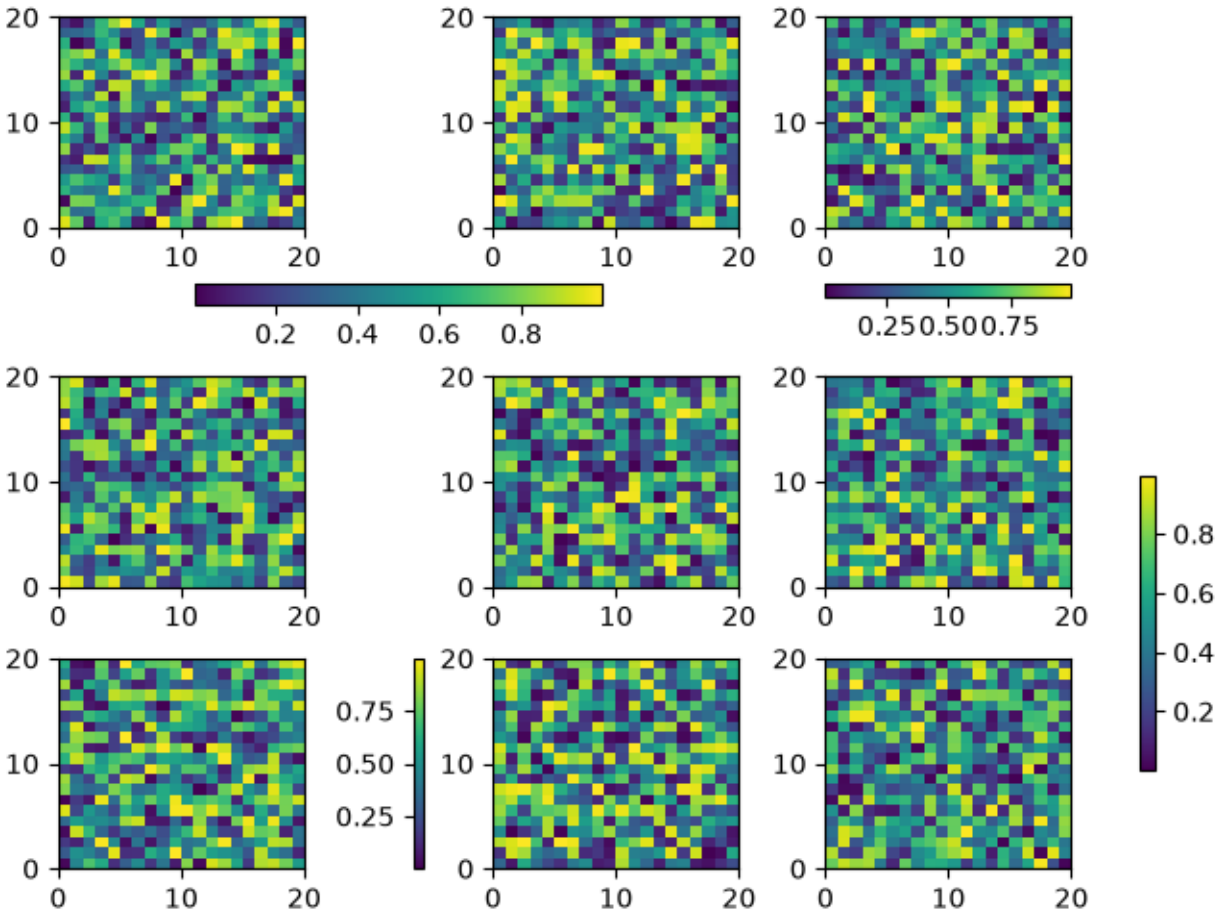
This is usually undesired, and can be worked around in various ways, e.g. adding a colorbar to the other Axes and then removing it. However, the most straightforward is to use *constrained layout*:

```
fig, axs = plt.subplots(2, 1, figsize=(4, 5), sharex=True, layout=
 ↪'constrained')
axs[0].plot(np.sum(X, axis=0))
pcm = axs[1].pcolormesh(X)
fig.colorbar(pcm, ax=axs[1], shrink=0.6)
```



Relatively complicated colorbar layouts are possible using this paradigm. Note that this example works far better with `layout='constrained'`

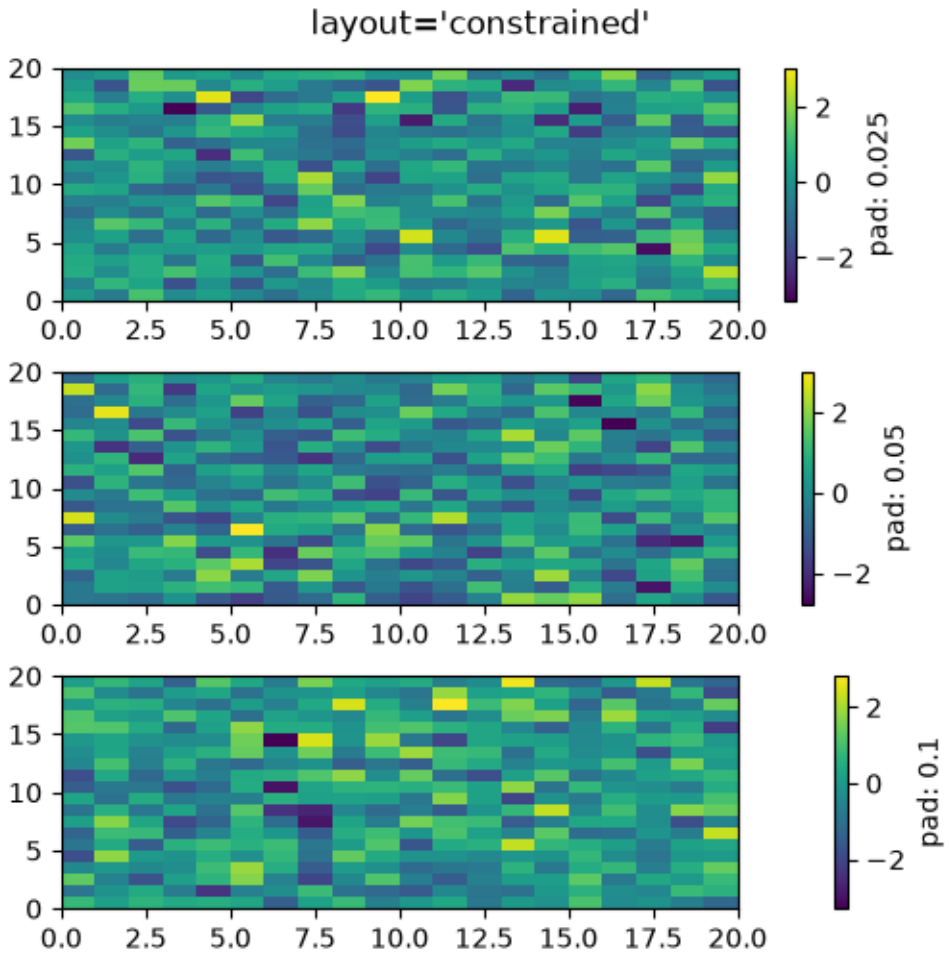
```
fig, axs = plt.subplots(3, 3, layout='constrained')
for ax in axs.flat:
    pcm = ax.pcolormesh(np.random.random((20, 20)))

fig.colorbar(pcm, ax=axs[0, :2], shrink=0.6, location='bottom')
fig.colorbar(pcm, ax=[axs[0, 2]], location='bottom')
fig.colorbar(pcm, ax=axs[1:, :], location='right', shrink=0.6)
fig.colorbar(pcm, ax=[axs[2, 1]], location='left')
```



Adjusting the spacing between colorbars and parent Axes

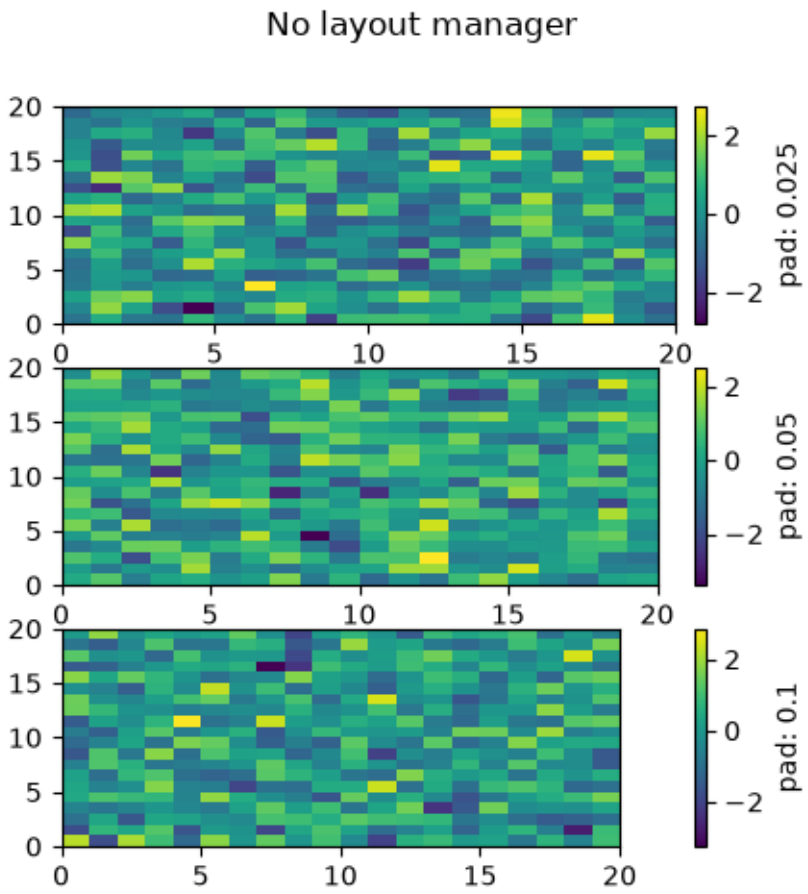
The distance a colorbar is from the parent Axes can be adjusted with the *pad* keyword argument. This is in units of fraction of the parent Axes width, and the default for a vertical Axes is 0.05 (or 0.15 for a horizontal Axes).

```
fig, axs = plt.subplots(3, 1, layout='constrained', figsize=(5, 5))
for ax, pad in zip(axs, [0.025, 0.05, 0.1]):
    pcm = ax.pcolormesh(np.random.randn(20, 20), cmap='viridis')
    fig.colorbar(pcm, ax=ax, pad=pad, label=f'pad: {pad}')
fig.suptitle("layout='constrained'")
```



Note that if you do not use constrained layout, the pad command makes the parent Axes shrink:

```
fig, axs = plt.subplots(3, 1, figsize=(5, 5))
for ax, pad in zip(axs, [0.025, 0.05, 0.1]):
    pcm = ax.pcolormesh(np.random.randn(20, 20), cmap='viridis')
    fig.colorbar(pcm, ax=ax, pad=pad, label=f'pad: {pad}')
fig.suptitle("No layout manager")
```



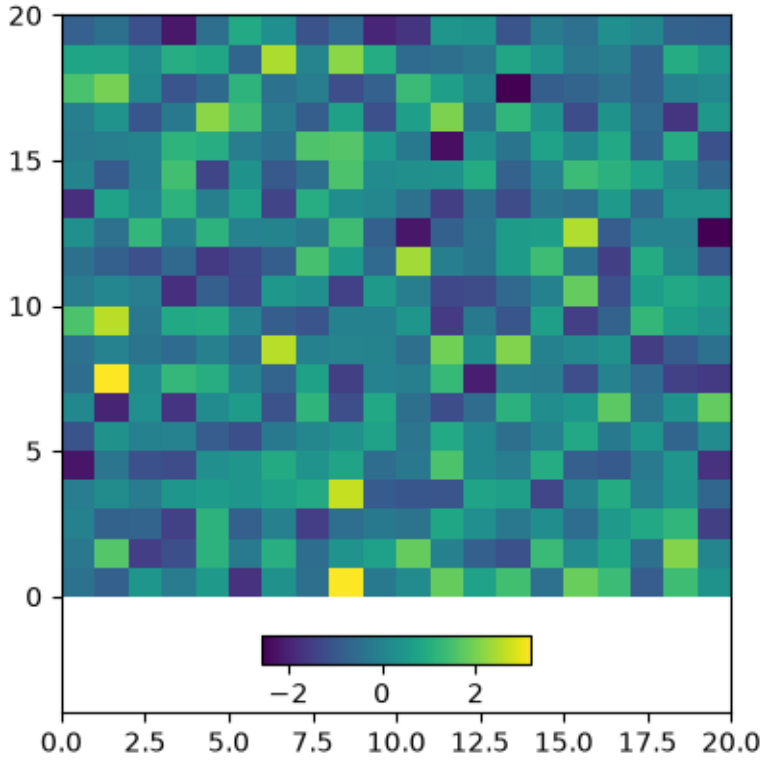
Manual placement of colorbars

Sometimes the automatic placement provided by `colorbar` does not give the desired effect. We can manually create an Axes and tell `colorbar` to use that Axes by passing the Axes to the *cax* keyword argument.

Using `inset_axes`

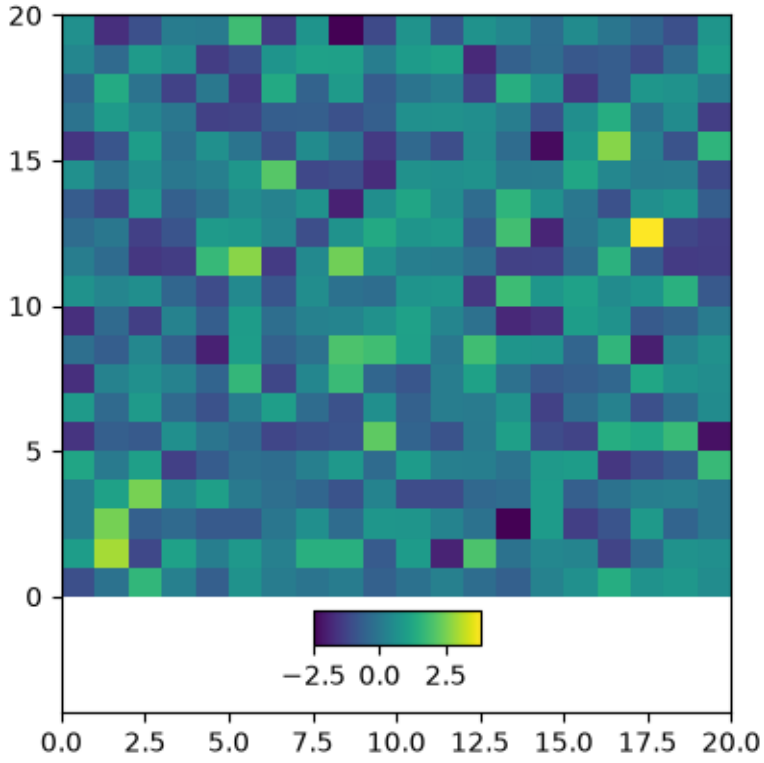
We can manually create any type of Axes for the colorbar to use, but an *`Axes.inset_axes`* is useful because it is a child of the parent Axes and can be positioned relative to the parent. Here we add a colorbar centered near the bottom of the parent Axes.

```
fig, ax = plt.subplots(layout='constrained', figsize=(4, 4))
pcm = ax.pcolormesh(np.random.randn(20, 20), cmap='viridis')
ax.set_ylim([-4, 20])
cax = ax.inset_axes([0.3, 0.07, 0.4, 0.04])
fig.colorbar(pcm, cax=cax, orientation='horizontal')
```



Axes.inset_axes can also specify its position in data coordinates using the *transform* keyword argument if you want your Axes at a certain data position on the graph:

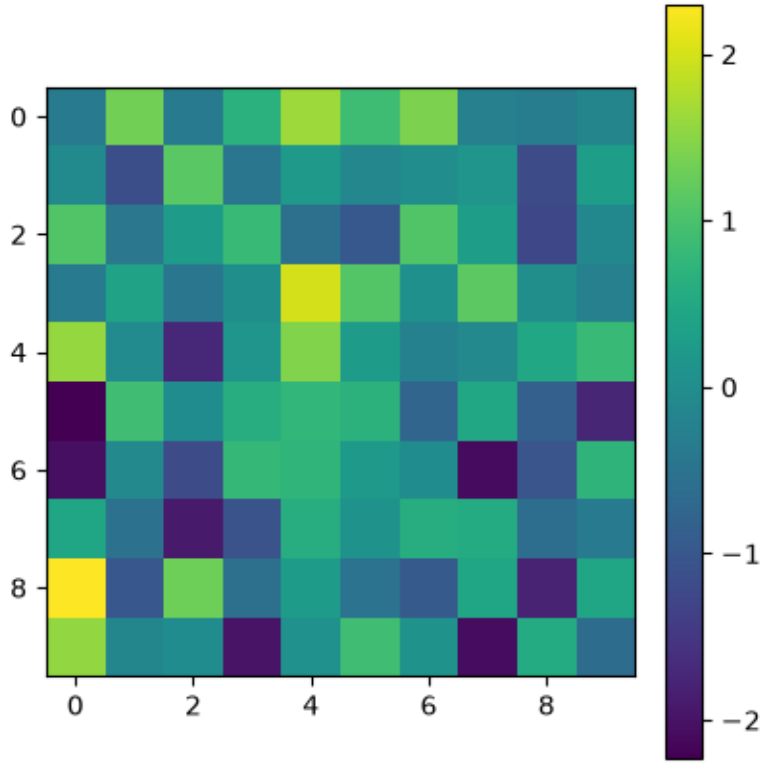
```
fig, ax = plt.subplots(layout='constrained', figsize=(4, 4))
pcm = ax.pcolormesh(np.random.randn(20, 20), cmap='viridis')
ax.set_ylim([-4, 20])
cax = ax.inset_axes([7.5, -1.7, 5, 1.2], transform=ax.transData)
fig.colorbar(pcm, cax=cax, orientation='horizontal')
```



Colorbars attached to fixed-aspect-ratio Axes

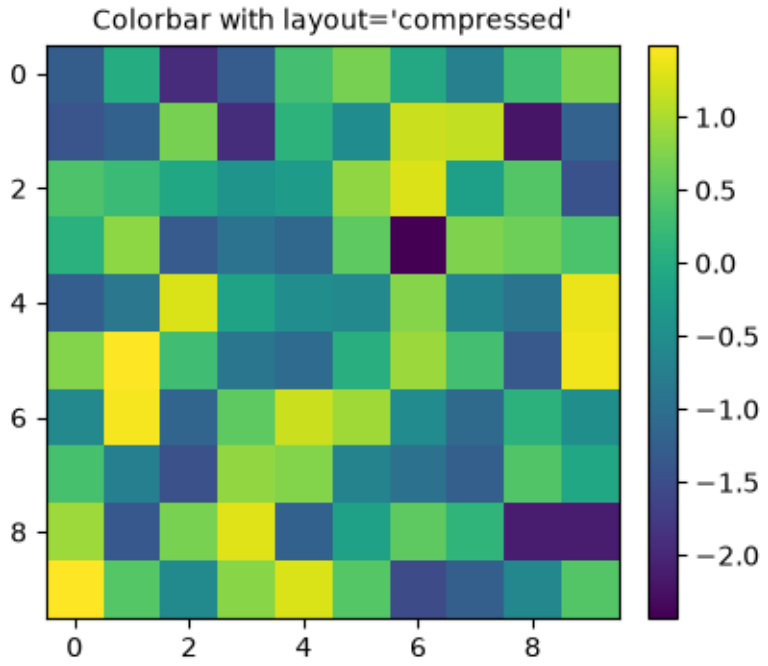
Axes with a fixed aspect ratio may shrink in height to preserve the aspect ratio of the underlying data. This can result in the colorbar becoming taller than the associated Axes, as demonstrated in the following example.

```
fig, ax = plt.subplots(layout='constrained', figsize=(4, 4))
pcm = ax.imshow(np.random.randn(10, 10), cmap='viridis')
fig.colorbar(pcm, ax=ax)
```



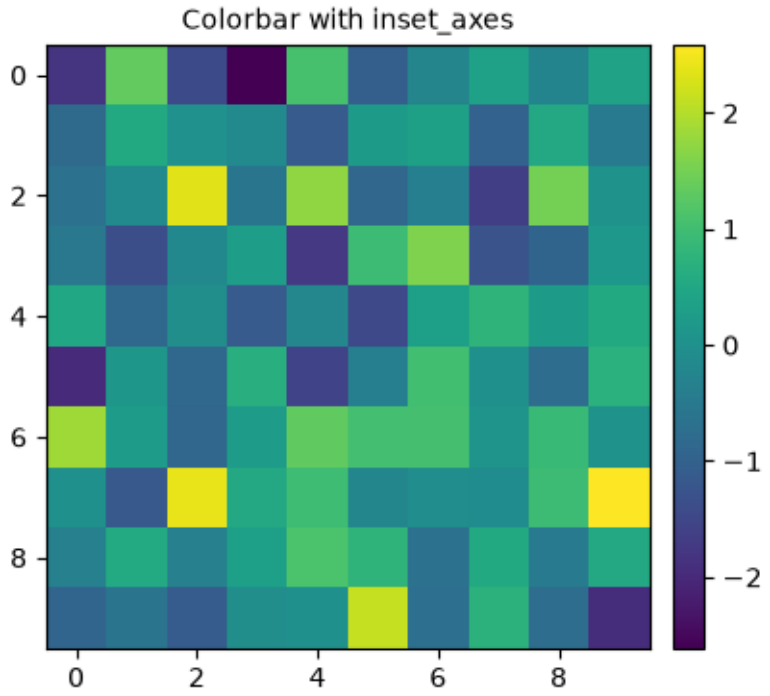
To automatically adjust the colorbar size to match the parent Axes, we can use `layout='compressed'`. This ensures that as the figure is resized or the fixed-aspect-ratio Axes is zoomed in or out, the colorbar dynamically resizes to align with the parent Axes.

```
fig, ax = plt.subplots(layout='compressed', figsize=(4, 4))
pcm = ax.imshow(np.random.randn(10, 10), cmap='viridis')
ax.set_title("Colorbar with layout='compressed'", fontsize='medium')
fig.colorbar(pcm, ax=ax)
```



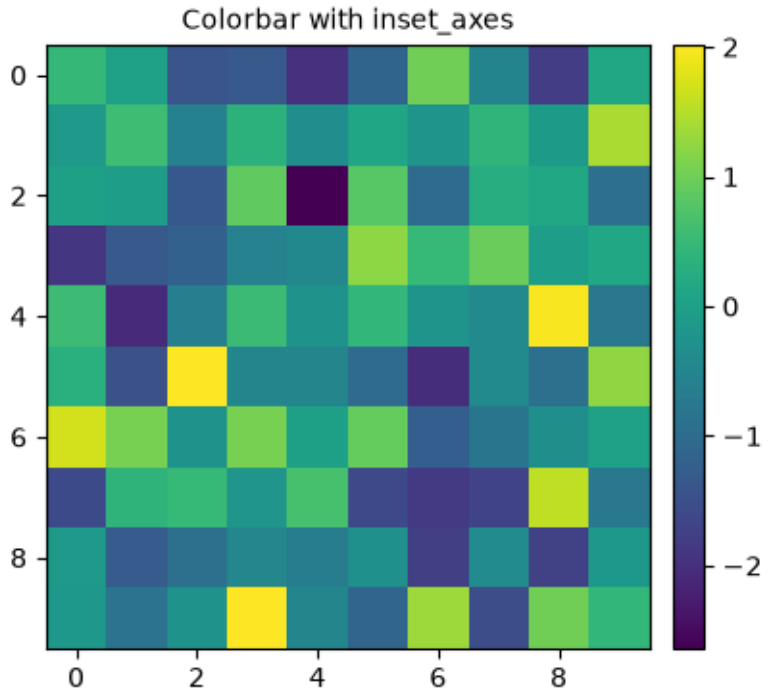
Alternatively, we can manually position the colorbar using *Axes.inset_axes* with axes-relative coordinates. This approach provides precise control over the colorbar's placement. However, without a layout engine, the colorbar might be clipped if it extends beyond the figure boundaries.

```
fig, ax = plt.subplots(layout='constrained', figsize=(4, 4))
pcm = ax.imshow(np.random.randn(10, 10), cmap='viridis')
cax = ax.inset_axes([1.04, 0.0, 0.05, 1.0])  # Positioning the colorbar
ax.set_title('Colorbar with inset_axes', fontsize='medium')
fig.colorbar(pcm, cax=cax)
```



We can also do this manually using an *Axes.inset_axes* using axes-relative coordinates (see *Transformations Tutorial*). Note that if we do not use a layout engine, the colorbar will be clipped off the right side of the figure.

```
fig, ax = plt.subplots(layout='constrained', figsize=(4, 4))
pcm = ax.imshow(np.random.randn(10, 10), cmap='viridis')
cax = ax.inset_axes([1.04, 0.0, 0.05, 1.0])
ax.set_title('Colorbar with inset_axes', fontsize='medium')
fig.colorbar(pcm, cax=cax)
```



See also

The axes_grid1 toolkit has methods for manually creating colorbar Axes as well:

- *Control the position and size of a colorbar with inset_locator.inset_axes*
- *Colorbar with AxesDivider*

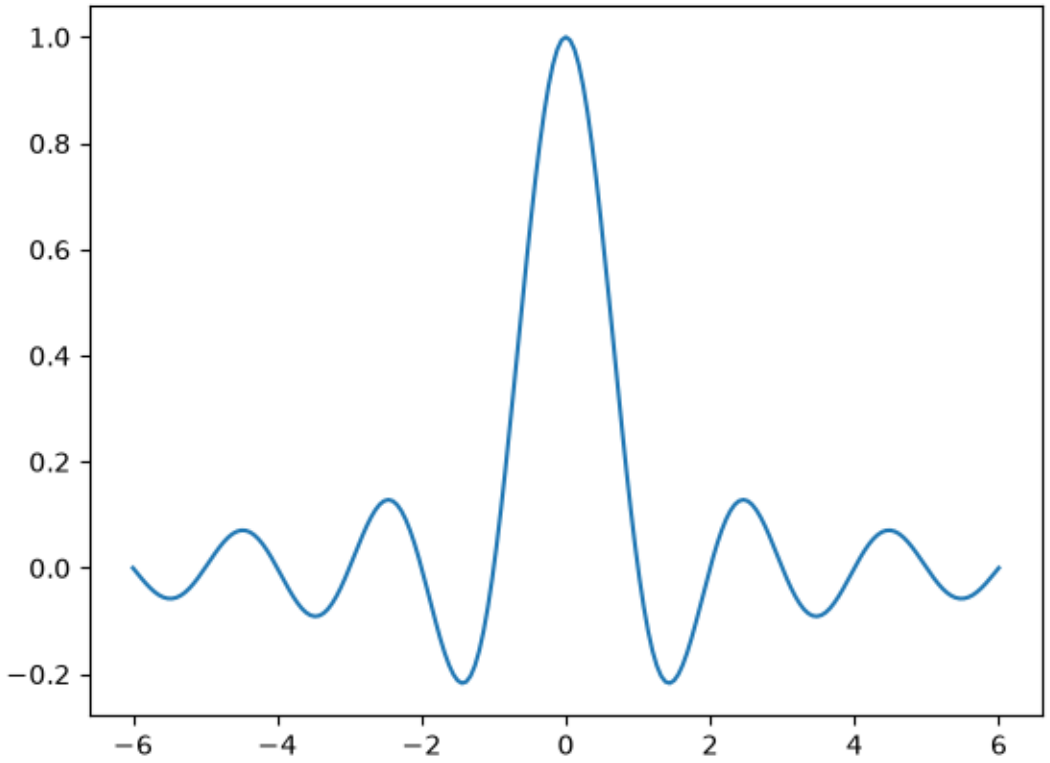
Total running time of the script: (0 minutes 5.327 seconds)

3.3.4 Axis autoscaling

Basic concept

Autoscaling ensures that data is visible within the Axes by automatically adjusting the axis limits. When you plot data, Matplotlib's autoscaling mechanism updates the axis limits accordingly.

```
import matplotlib.pyplot as plt
import numpy as np


x = np.linspace(-6, 6, 201)
y = np.sinc(x)

fig, ax = plt.subplots()
ax.plot(x, y)
```



Margins

To ensure that the data is not at the very edge of the plot, Matplotlib adds a margin around the data limits. Note that the *x* data range in the above plot is [-6, 6], but the x-axis limits are slightly wider due to the margin.

The default margin is 5%, defined via

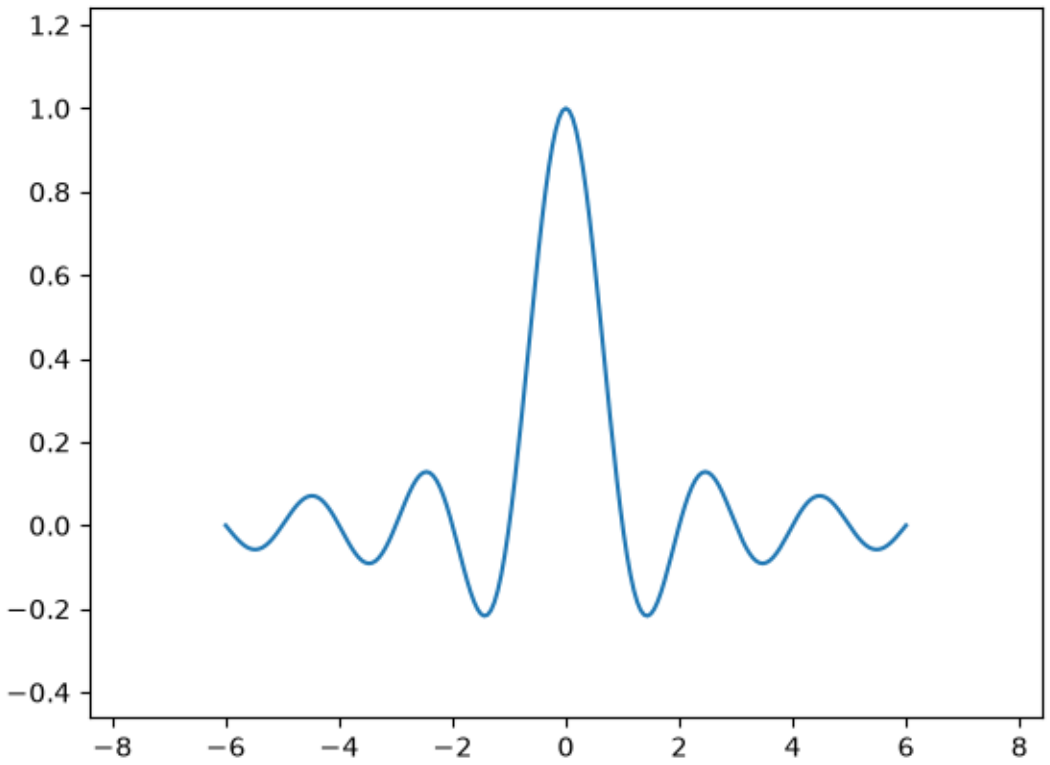
- *rcParams["axes.xmargin"]* (default: `0.05`)
- *rcParams["axes.ymargin"]* (default: `0.05`)
- *rcParams["axes.zmargin"]* (default: `0.05`)

```
print(ax.get_xmargin(), ax.get_ymargin())
```

```
0.05 0.05
```

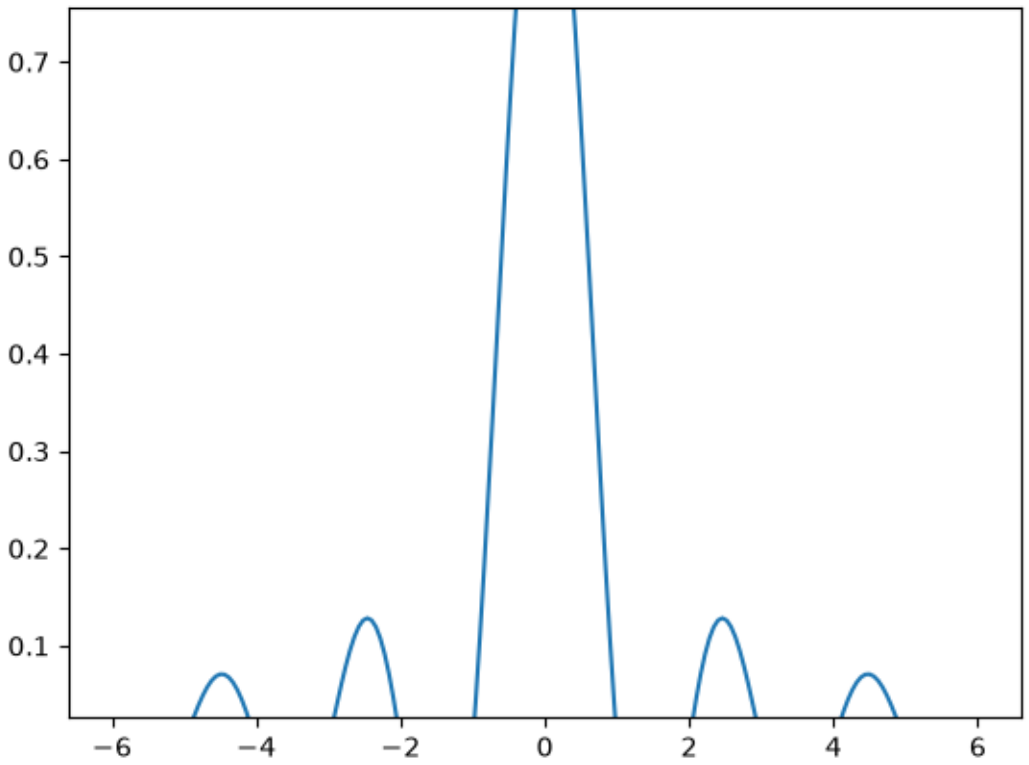
The margin size can be overridden to make them smaller or larger using *margins*:

```
fig, ax = plt.subplots()
ax.plot(x, y)
ax.margins(0.2, 0.2)
```



In general, margins can be in the range (-0.5, ∞), where negative margins set the axes limits to a subrange of the data range, i.e. they clip data. Using a single number for margins affects both axes, a single margin can be customized using keyword arguments `x` or `y`, but positional and keyword interface cannot be combined.

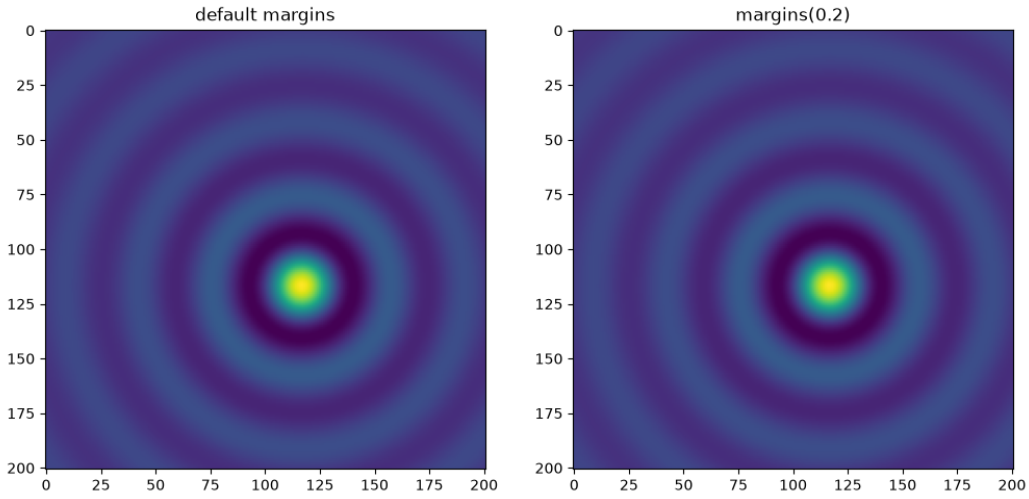
```
fig, ax = plt.subplots()
ax.plot(x, y)
ax.margins(y=-0.2)
```



Sticky edges

There are plot elements (*Artist*s) that are usually used without margins. For example, false-color images (e.g. created with *Axes.imshow*) are not considered in the margins calculation.

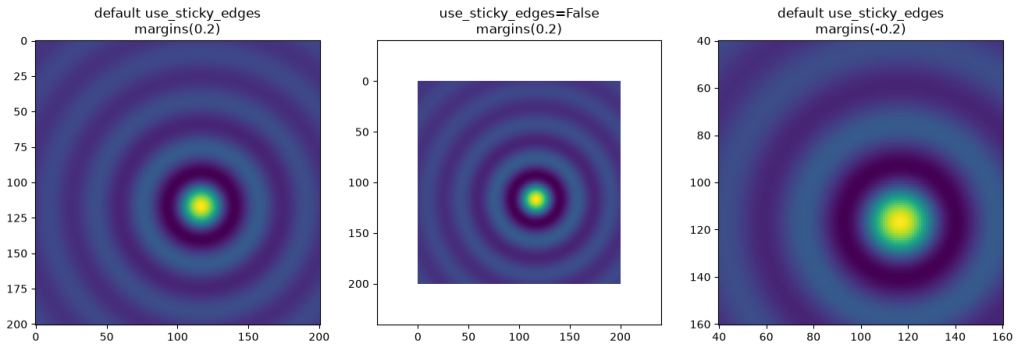
```
xx, yy = np.meshgrid(x, x)
zz = np.sinc(np.sqrt((xx - 1)**2 + (yy - 1)**2))

fig, ax = plt.subplots(ncols=2, figsize=(12, 8))
ax[0].imshow(zz)
ax[0].set_title("default margins")
ax[1].imshow(zz)
ax[1].margins(0.2)
ax[1].set_title("margins(0.2)")
```



This override of margins is determined by "sticky edges", a property of *Artist* class that can suppress adding margins to axis limits. The effect of sticky edges can be disabled on an Axes by changing *use_sticky_edges*. Artists have a property *Artist.sticky_edges*, and the values of sticky edges can be changed by writing to `Artist.sticky_edges.x` or `Artist.sticky_edges.y`.

The following example shows how overriding works and when it is needed.

```
fig, ax = plt.subplots(ncols=3, figsize=(16, 10))
ax[0].imshow(zz)
ax[0].margins(0.2)
ax[0].set_title("default use_sticky_edges\nmargins(0.2)")
ax[1].imshow(zz)
ax[1].margins(0.2)
ax[1].use_sticky_edges = False
ax[1].set_title("use_sticky_edges=False\nmargins(0.2)")
ax[2].imshow(zz)
ax[2].margins(-0.2)
ax[2].set_title("default use_sticky_edges\nmargins(-0.2)")
```



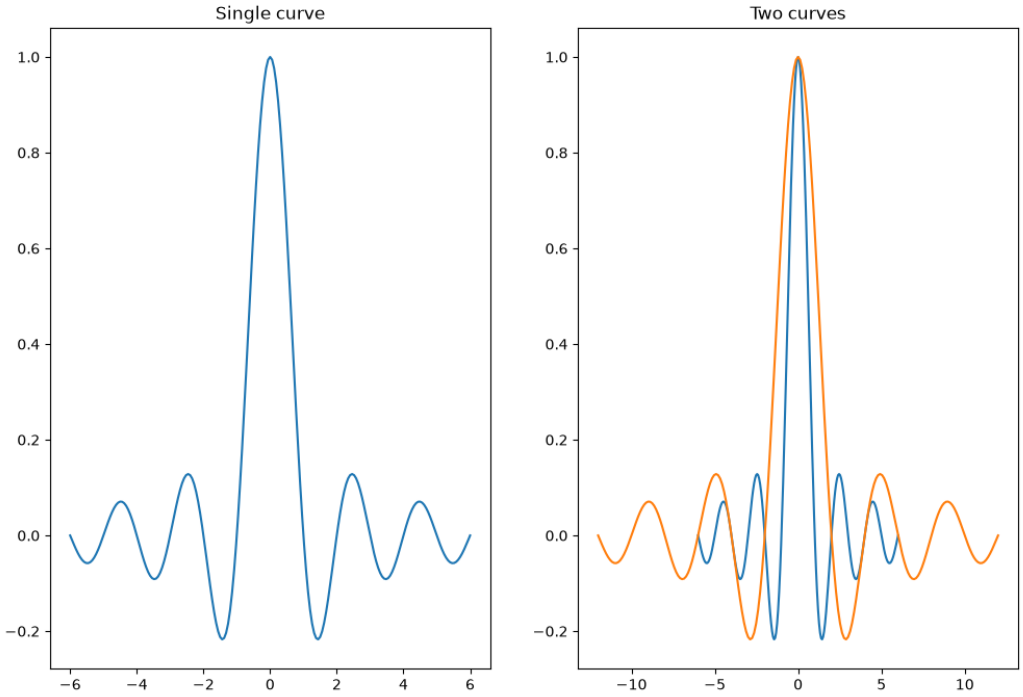
We can see that setting `use_sticky_edges` to *False* renders the image with requested margins.

While sticky edges don't increase the axis limits through extra margins, negative margins are still taken into account. This can be seen in the reduced limits of the third image.

Controlling autoscale

By default, the limits are recalculated every time you add a new curve to the plot:

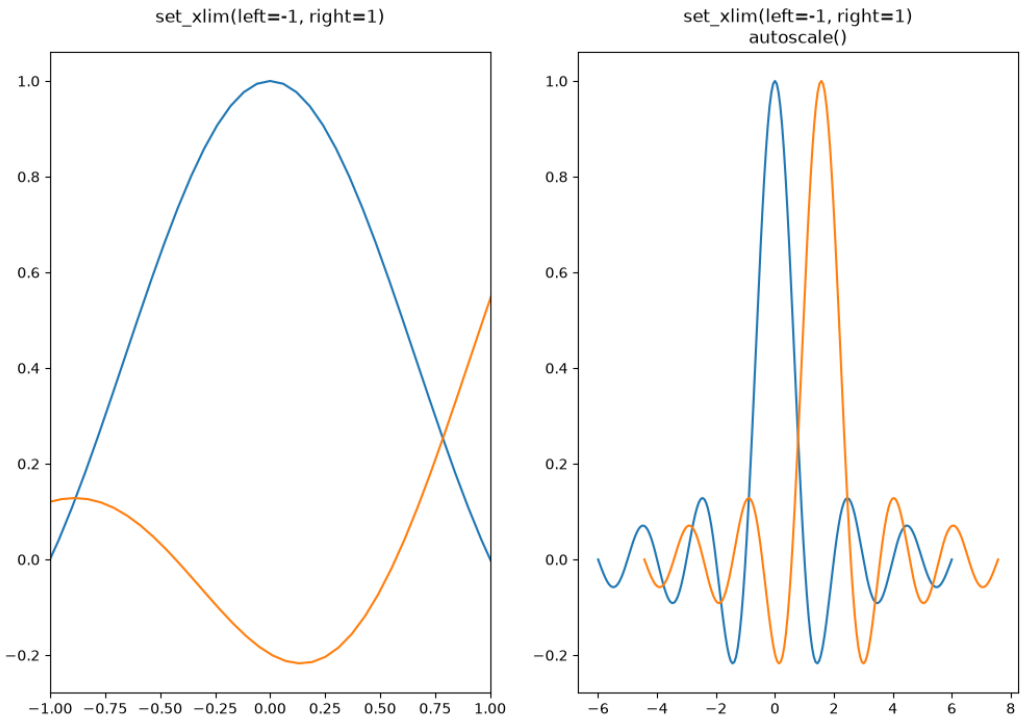
```
fig, ax = plt.subplots(ncols=2, figsize=(12, 8))
ax[0].plot(x, y)
ax[0].set_title("Single curve")
ax[1].plot(x, y)
ax[1].plot(x * 2.0, y)
ax[1].set_title("Two curves")
```



If you don't want automatic updates of the axis limits, either deactivate autoscaling with *autoscale* or set the limits manually with *set_xlim* / *set_ylim*.

Let's say that we want to see only a part of the data in greater detail. Setting the `xlim` persists even if we add more curves to the data. Calling *Axes.autoscale* will re-enable the autoscaling and recalculate the limits to fit all the data.

```
fig, ax = plt.subplots(ncols=2, figsize=(12, 8))
ax[0].plot(x, y)
ax[0].set_xlim(left=-1, right=1)
ax[0].plot(x + np.pi * 0.5, y)
ax[0].set_title("set_xlim(left=-1, right=1)\n")
ax[1].plot(x, y)
ax[1].set_xlim(left=-1, right=1)
ax[1].plot(x + np.pi * 0.5, y)
ax[1].autoscale()
ax[1].set_title("set_xlim(left=-1, right=1)\nautoscale()")
```



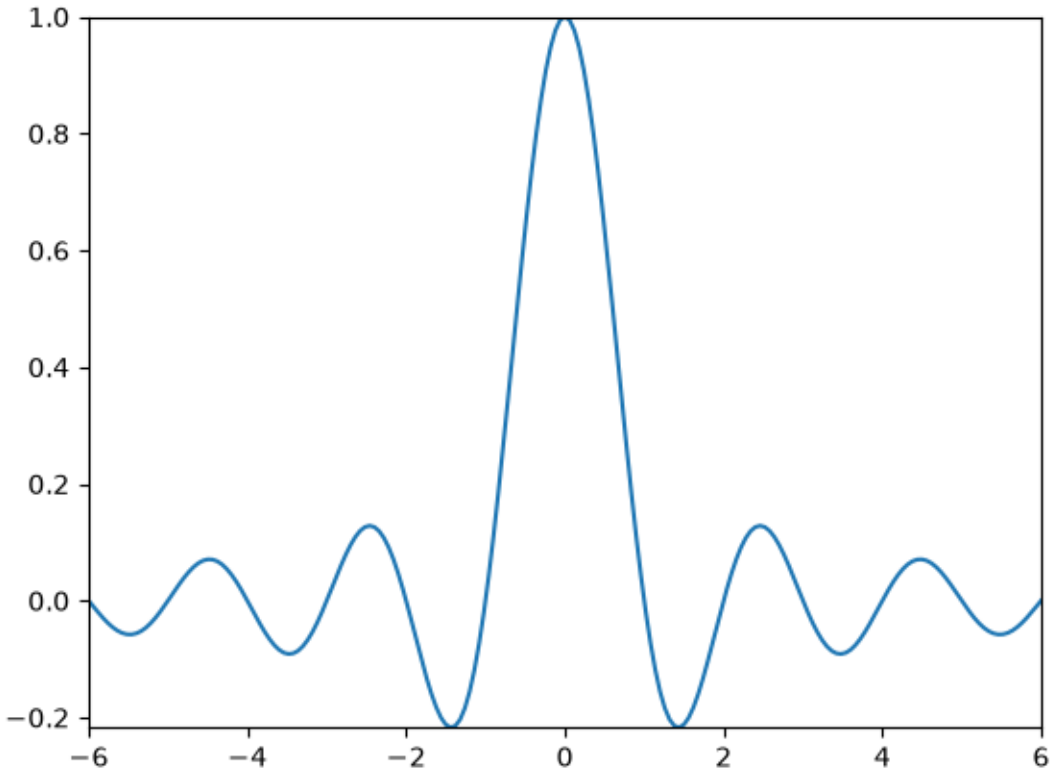
We can check that the first plot has autoscale disabled and that the second plot has it enabled again by using *Axes.get_autoscale_on()*:

```
print(ax[0].get_autoscale_on())   # False means disabled
print(ax[1].get_autoscale_on())   # True means enabled -> recalculated
```

```
False
True
```

Arguments of the autoscale function give us precise control over the process of autoscaling. A combination of arguments `enable`, and `axis` sets the autoscaling feature for the selected axis (or both). The argument `tight` sets the margin of the selected axis to zero. To preserve settings of either `enable` or `tight` you can set the opposite one to *None*, that way it should not be modified. However, setting `enable` to *None* and tight to *True* affects both axes regardless of the `axis` argument.

```
fig, ax = plt.subplots()
ax.plot(x, y)
ax.margins(0.2, 0.2)
ax.autoscale(enable=None, axis="x", tight=True)

print(ax.margins())
```




```
(0, 0)
```

Technical background

This section explains the internal pipeline that runs when autoscaling computes axis limits from data. Understanding the mechanics helps when you encounter surprising behaviour or need to update limits manually.

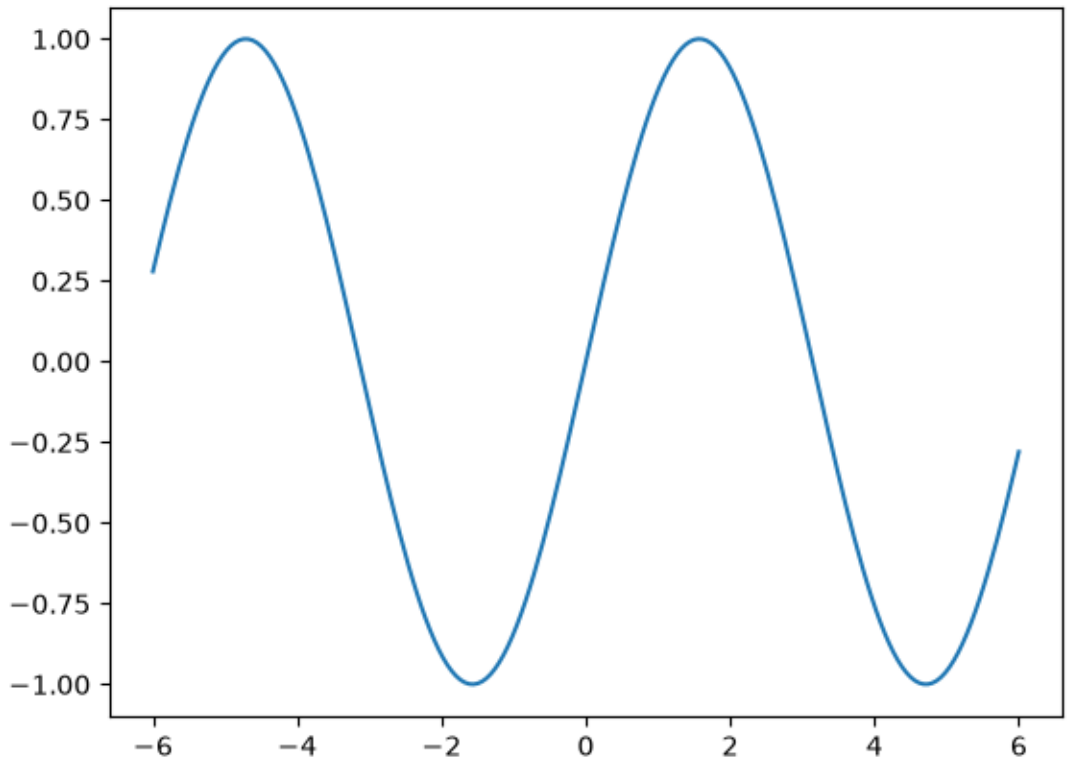
Data limits and view limits

Matplotlib maintains two sets of limits:

- **Data limits** (*`Axes.dataLim`*): the tight bounding box of the raw data.
- **View limits** (*`Axes.viewLim`*): the displayed axis limits. By default, computed from the data limits through the autoscaling mechanism outlined below, but they can be set independently. View limits can alternatively be set explicitly through *`set_xlim`* / *`set_ylim`*, which also disables autoscaling so that the set limits remain fixed.

The following shows the input and output of this process — `dataLim` holds the raw data bounds, `viewLim` the final displayed axis limits.

```
fig, ax = plt.subplots()
x = np.linspace(-6, 6, 201)
y = np.sin(x)
ax.plot(x, y)
print(f"dataLim x: ({ax.dataLim.x0:.3f}, {ax.dataLim.x1:.3f})")
print(f"dataLim y: ({ax.dataLim.y0:.3f}, {ax.dataLim.y1:.3f})")
print(f"viewLim x: ({ax.viewLim.x0:.3f}, {ax.viewLim.x1:.3f})")
print(f"viewLim y: ({ax.viewLim.y0:.3f}, {ax.viewLim.y1:.3f})")
```




```
dataLim x: (-6.000, 6.000)
dataLim y: (-1.000, 1.000)
viewLim x: (-6.600, 6.600)
viewLim y: (-1.100, 1.100)
```

The x data range is [-6, 6] and the default 5% margin adds roughly 0.6 on each side, widening the view to about [-6.6, 6.6]. The same applies to the y axis.

Update logic

Data and view limit updates are handled as separate stages.

Data limits: When an artist is added to an Axes through one of the plotting methods, the data limits are updated through *Axes.update_datalim* to include the new data. This only ever increases the data limits. It is also possible to update *Axes.dataLim* manually, but this is not common. Removal of an artist or change of its data does not trigger any update of the data limits, so they can become out of date. In such cases, it is necessary to explicitly recompute the data limit through *Axes.relim*.

View limits: When autoscaling is enabled, the view limits are automatically computed from the data limit. This update is lazy and only triggered when the view limits are queried or drawn, so that they don't have to be recomputed for every added artist. This is transparent to the user. Explicit changes of the data limits through *Axes.dataLim* or *Axes.relim* do not trigger an update of the view limits, so they can also become out of date. In such cases, it is necessary to explicitly recompute the view limits through *Axes.autoscale_view*.

View limit calculation

Given the data limits, the view limits are derived through these steps:

- scale domain clamping
- margin expansion
- sticky edge clamping
- optional limit rounding

Scale domain clamping

Before margins are applied, the data limits are clipped to the valid domain of the axis scale. This matters for scales like log (positive values only) and logit (values strictly between 0 and 1): if a bound lies outside the domain, it is replaced with a value at the domain boundary.

For this purpose, *Axes.dataLim* tracks not just the ordinary min/max of the data but also `minpos` — the smallest strictly positive value seen. A log-scale lower bound of zero or less is replaced with `minpos` rather than the actual minimum, because only positive values can be displayed.

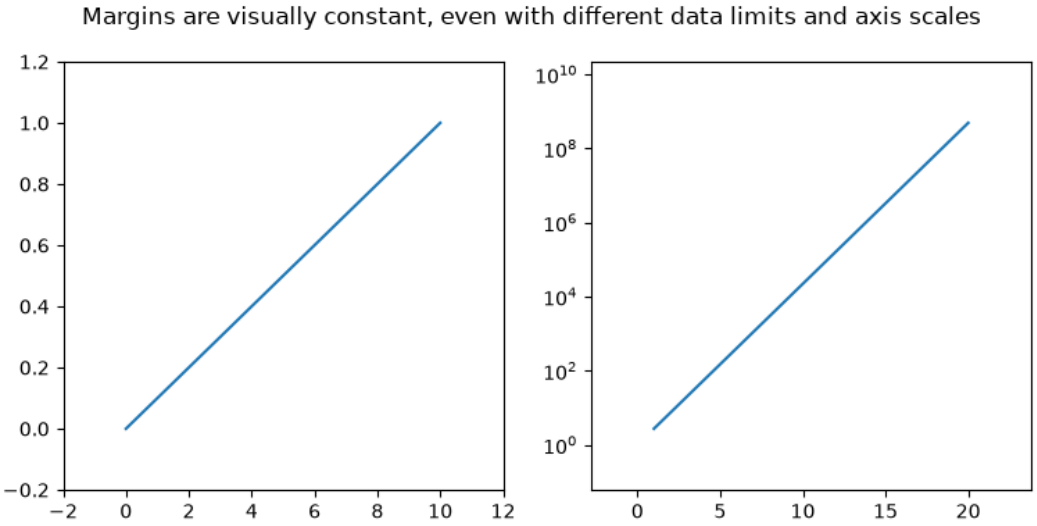
For a logit scale, the upper bound is approximated as `1 - minpos`, since the largest data value below 1 is not tracked separately. This means the autoscaled upper limit may include slightly more headroom than necessary when the data maximum is well below 1.

Margin expansion

The first step is to apply the margins, i.e. widen the view limits beyond the data limits so that data is not at the very edge of the plot. Margins are specified as a fraction of the data span in screen coordinates so that the data-free border area always has the same visual size, irrespective of data ranges or axis scales. The margin is applied symmetrically to both sides of the data limits, so the view is expanded equally in both directions.

This is illustrated in the following example, where the data limits and axis scales are different, but the visual margin is the same in both cases.

```
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(9, 4))
fig.suptitle("Margins are visually constant, "
             "even with different data limits and axis scales")

ax1.plot([0, 10], [0, 1])
ax1.margins(0.2)

x = np.linspace(1, 20)
ax2.semilogy(x, np.exp(x))
ax2.margins(0.2)
```



Sticky edges clamping

Sticky edges are axis values at which margin expansion is clamped. After computing the margin-expanded limits, if an expanded limit would extend beyond a sticky edge, it is pulled back to that edge instead.

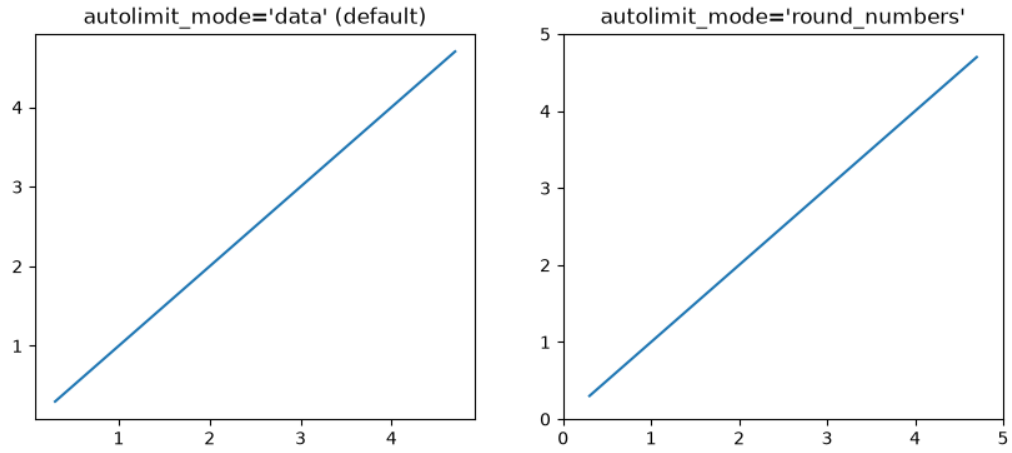
Artists register sticky edges to prevent blank margins at natural data boundaries. *imshow*, for example, registers sticky edges at its four pixel boundaries, which is why images fill the Axes by default without any surrounding margin (as shown in the *Sticky edges* section above). Sticky edges only suppress *outward expansion past the data boundary* — they never shrink limits into the data, and negative margins are not affected. Setting `Axes.use_sticky_edges = False` disables sticky edge clamping on that Axes.

Limit rounding

As a final step, the view limits can optionally be expanded outward to the nearest "nice" tick position, so that the axis edges coincide with tick marks. This is disabled by default, but can be turned on with the "round_numbers" mode of *rcParams["axes.autolimit_mode"]* (default: `'data'`):

- `'data'` (default): keep the limits at the margin-expanded values.
- `'round_numbers'`: expand the limits outward to the nearest "nice" tick position, so the axis edges coincide with tick marks.

```
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 4))
ax1.plot([0.3, 4.7], [0.3, 4.7])
ax1.set_title("autolimit_mode='data' (default)")
with plt.rc_context({'axes.autolimit_mode': 'round_numbers'}):
    ax2.plot([0.3, 4.7], [0.3, 4.7])
    ax2.set_title("autolimit_mode='round_numbers'")
    ax2.autoscale_view()  # force autoscale while round_numbers is␣
 ↪active
```



Total running time of the script: (0 minutes 5.801 seconds)

3.3.5 Axis scales

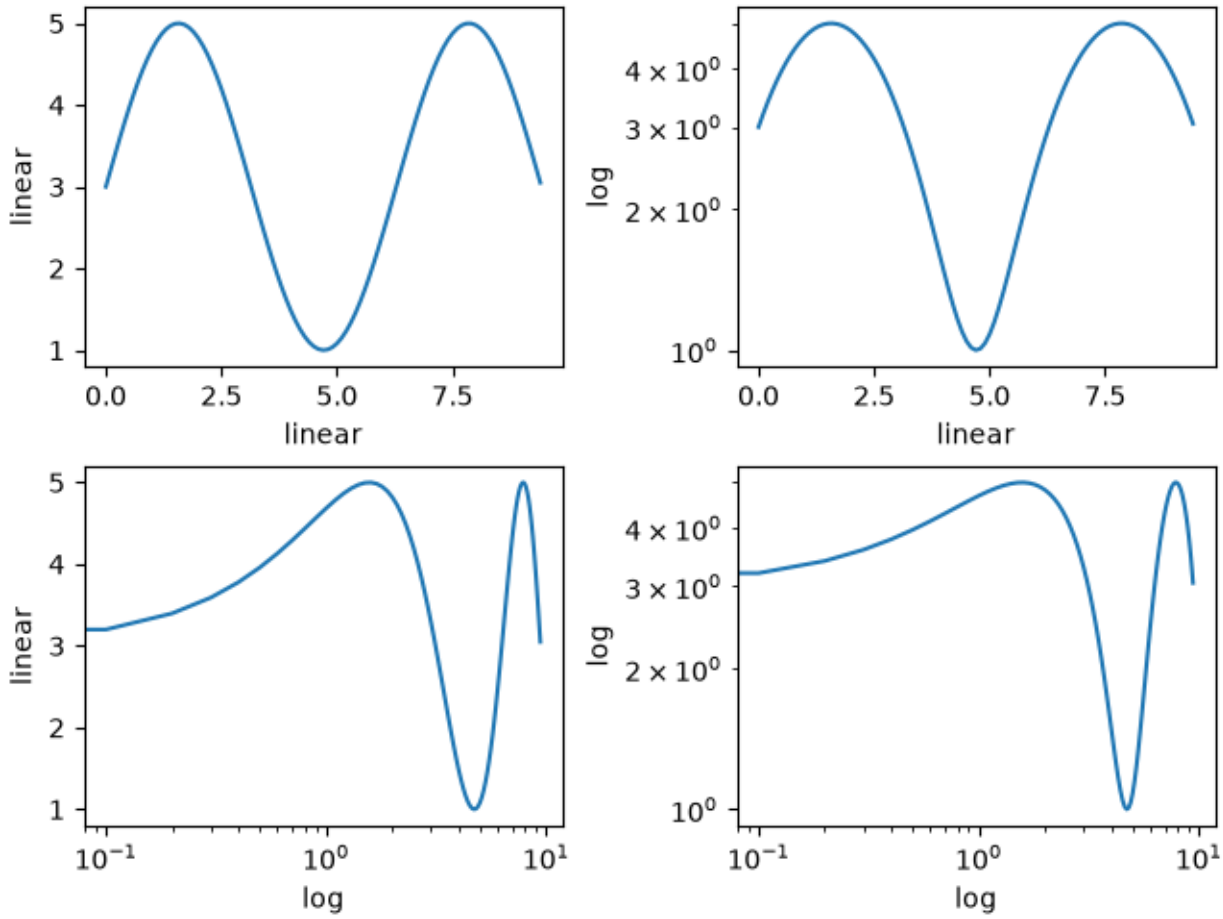
By default Matplotlib displays data on the axis using a linear scale. Matplotlib also supports logarithmic scales, and other less common scales as well. Usually this can be done directly by using the *set_xscale* or *set_yscale* methods.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.scale as mscale
from matplotlib.ticker import FixedLocator, NullFormatter

fig, axs = plt.subplot_mosaic([['linear', 'linear-log'],
                               ['log-linear', 'log-log']], layout=
 ↪'constrained')

x = np.arange(0, 3*np.pi, 0.1)
y = 2 * np.sin(x) + 3

ax = axs['linear']
ax.plot(x, y)
```

(continues on next page)

(continued from previous page)

```
ax.set_xlabel('linear')
ax.set_ylabel('linear')

ax = axs['linear-log']
ax.plot(x, y)
ax.set_yscale('log')
ax.set_xlabel('linear')
ax.set_ylabel('log')

ax = axs['log-linear']
ax.plot(x, y)
ax.set_xscale('log')
ax.set_xlabel('log')
ax.set_ylabel('linear')

ax = axs['log-log']
ax.plot(x, y)
ax.set_xscale('log')
ax.set_yscale('log')
ax.set_xlabel('log')
ax.set_ylabel('log')
```



loglog and semilogx/y

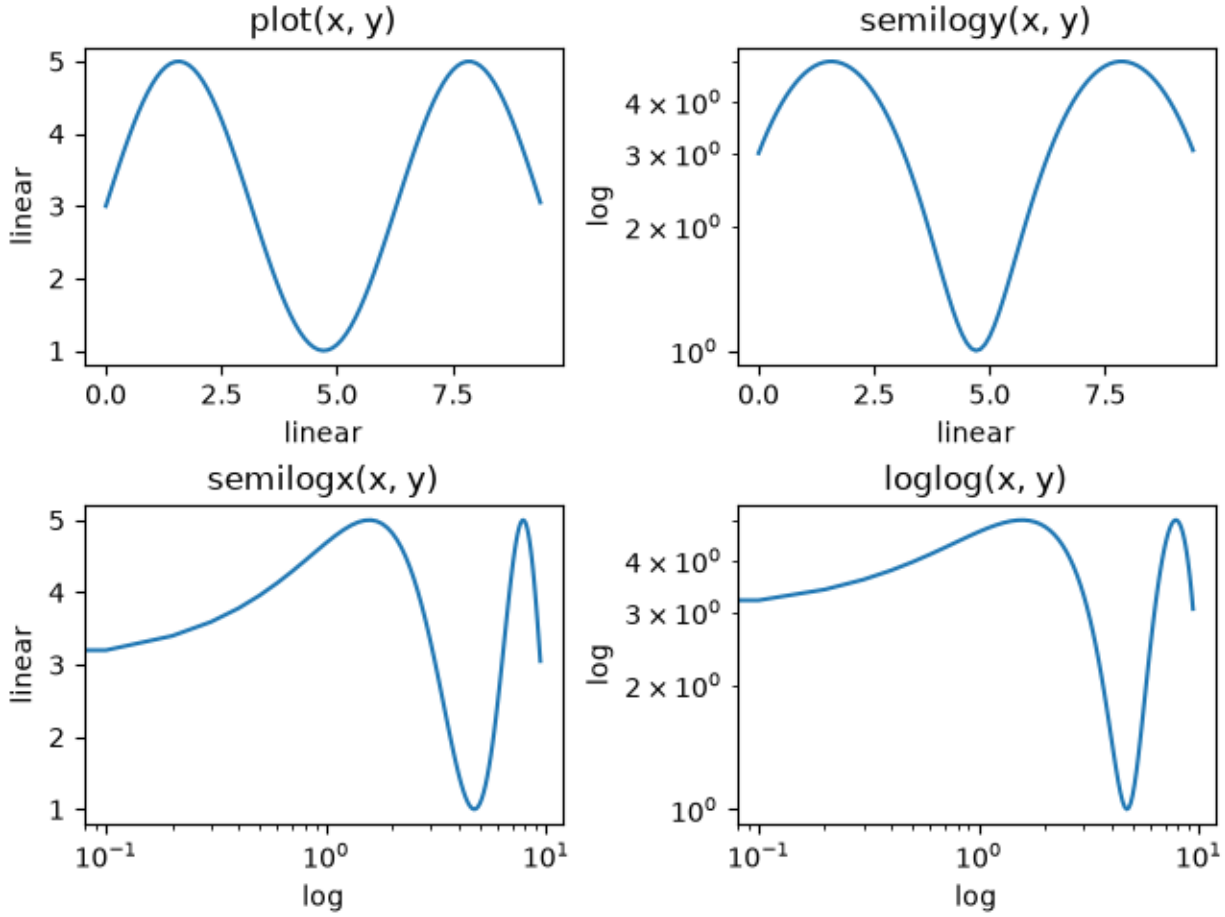
The logarithmic axis is used so often that there are a set helper functions, that do the same thing: *semilogy*, *semilogx*, and *loglog*.

```
fig, axs = plt.subplot_mosaic([['linear', 'linear-log'],
                               ['log-linear', 'log-log']], layout=
 ↪'constrained')

x = np.arange(0, 3*np.pi, 0.1)
y = 2 * np.sin(x) + 3

ax = axs['linear']
ax.plot(x, y)
ax.set_xlabel('linear')
ax.set_ylabel('linear')
ax.set_title('plot(x, y)')

ax = axs['linear-log']
ax.semilogy(x, y)
ax.set_xlabel('linear')
```

(continues on next page)

(continued from previous page)

```
ax.set_ylabel('log')
ax.set_title('semilogy(x, y)')

ax = axs['log-linear']
ax.semilogx(x, y)
ax.set_xlabel('log')
ax.set_ylabel('linear')
ax.set_title('semilogx(x, y)')

ax = axs['log-log']
ax.loglog(x, y)
ax.set_xlabel('log')
ax.set_ylabel('log')
ax.set_title('loglog(x, y)')
```



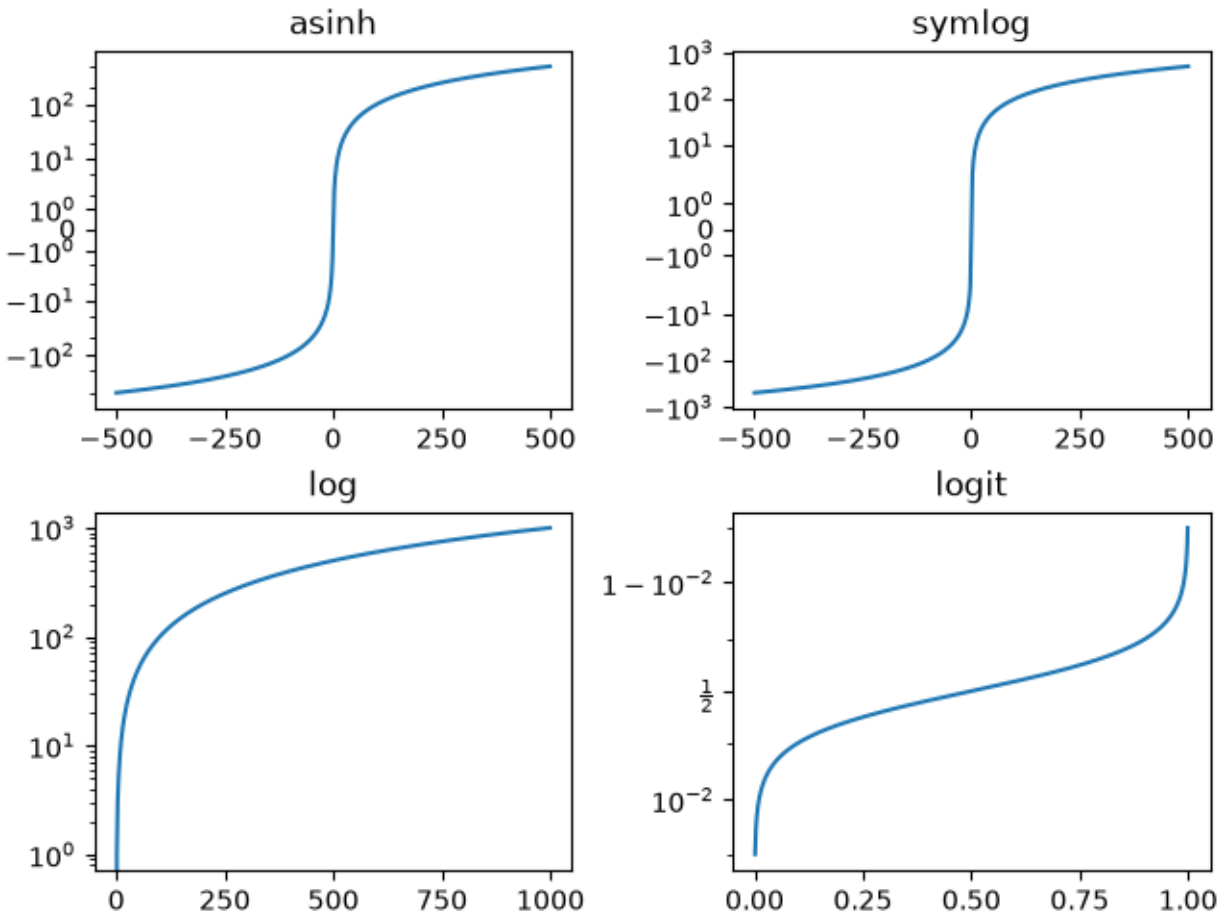
Other built-in scales

There are other scales that can be used. The list of registered scales can be returned from *scale.get_scale_names*:

```
print(mscale.get_scale_names())
```

```
['asinh', 'function', 'functionlog', 'linear', 'log', 'logit', 'symlog
 ↪']
```

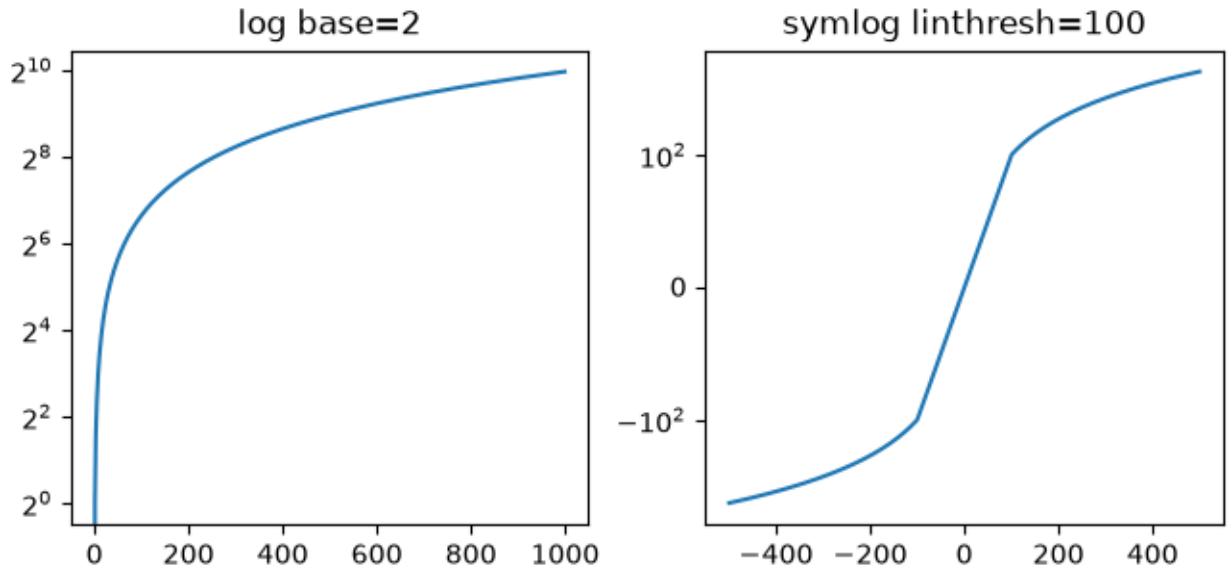
```
fig, axs = plt.subplot_mosaic([['asinh', 'symlog'],
                               ['log', 'logit']], layout='constrained')

x = np.arange(0, 1000)

for name, ax in axs.items():
    if name in ['asinh', 'symlog']:
        yy = x - np.mean(x)
    elif name in ['logit']:
        yy = (x-np.min(x))
        yy = yy / np.max(np.abs(yy))
    else:
        yy = x

    ax.plot(yy, yy)
    ax.set_yscale(name)
    ax.set_title(name)
```



Optional arguments for scales

Some of the default scales have optional arguments. These are documented in the API reference for the respective scales at *scale*. One can change the base of the logarithm being plotted (eg 2 below) or the linear threshold range for `'symlog'`.

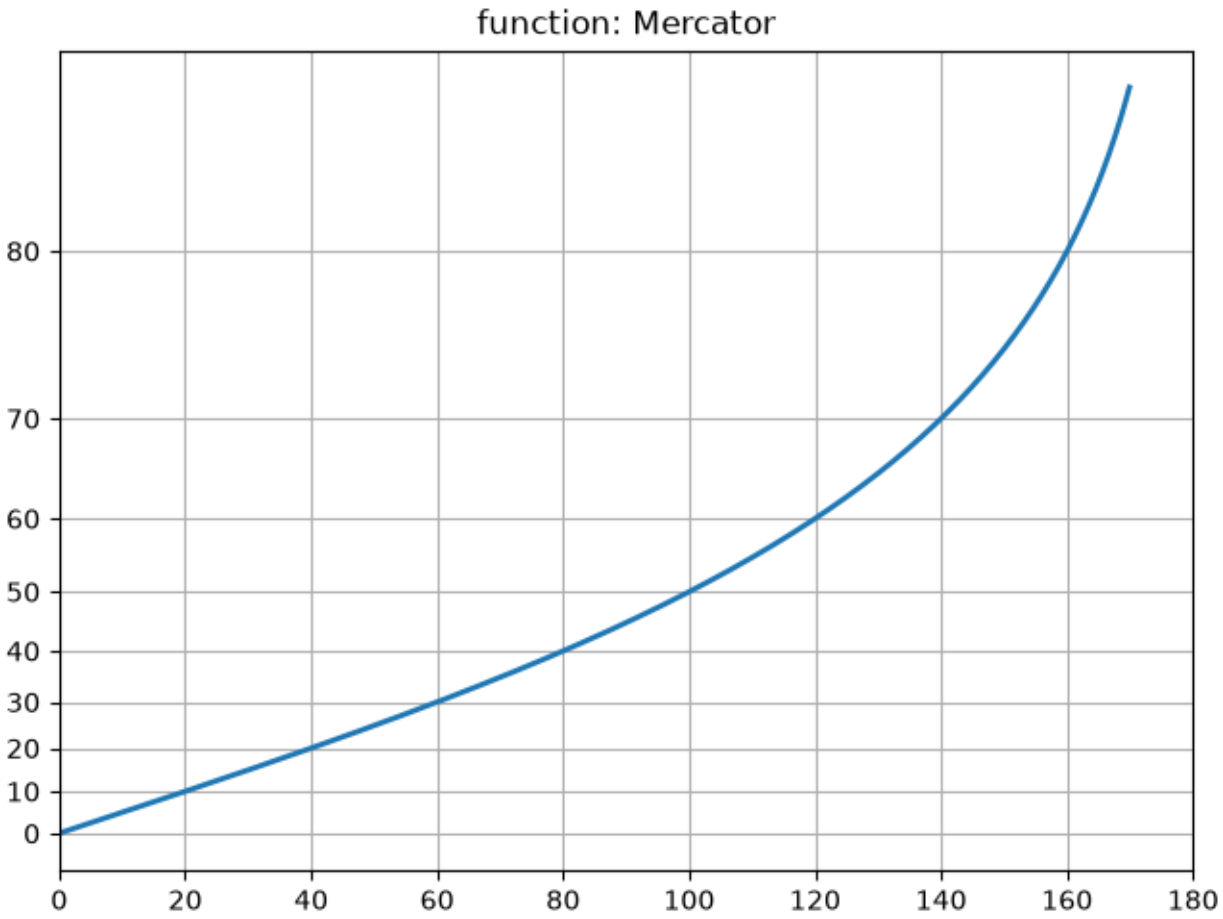
```
fig, axs = plt.subplot_mosaic([['log', 'symlog']], layout='constrained
↪',
                              figsize=(6.4, 3))

for name, ax in axs.items():
    if name in ['log']:
        ax.plot(x, x)
        ax.set_yscale('log', base=2)
        ax.set_title('log base=2')
    else:
        ax.plot(x - np.mean(x), x - np.mean(x))
        ax.set_yscale('symlog', linthresh=100)
        ax.set_title('symlog linthresh=100')
```



Arbitrary function scales

Users can define a full scale class and pass that to *set_xscale* and *set_yscale* (see *Custom scale*). A short cut for this is to use the 'function' scale, and pass as extra arguments a `forward` and an `inverse` function. The following performs a Mercator transform to the y-axis.

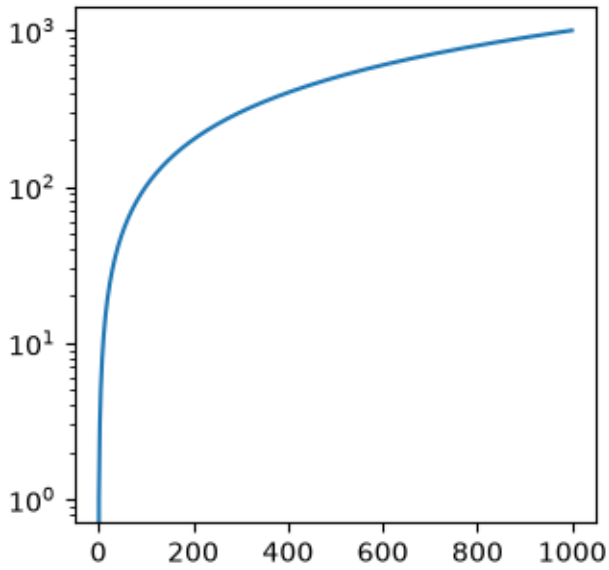
```
# Function Mercator transform
def forward(a):
    a = np.deg2rad(a)
    return np.rad2deg(np.log(np.abs(np.tan(a) + 1.0 / np.cos(a))))


def inverse(a):
    a = np.deg2rad(a)
    return np.rad2deg(np.arctan(np.sinh(a)))


t = np.arange(0, 170.0, 0.1)
s = t / 2.

fig, ax = plt.subplots(layout='constrained')
ax.plot(t, s, '-', lw=2)

ax.set_yscale('function', functions=(forward, inverse))
ax.set_title('function: Mercator')
ax.grid(True)
ax.set_xlim(0, 180)
ax.yaxis.set_minor_formatter(NullFormatter())
ax.yaxis.set_major_locator(FixedLocator(np.arange(0, 90, 10)))
```



What is a "scale"?

A scale is an object that gets attached to an axis. The class documentation is at *scale*. *set_xscale* and *set_yscale* set the scale on the respective Axis objects. You can determine the scale on an axis with *get_scale*:

```
fig, ax = plt.subplots(layout='constrained',
                               figsize=(3.2, 3))
ax.semilogy(x, x)

print(ax.xaxis.get_scale())
print(ax.yaxis.get_scale())
```




```
linear
log
```

Setting a scale does three things. First it defines a transform on the axis that maps between data values to position along the axis. This transform can be accessed via `get_transform`:

```
print(ax.yaxis.get_transform())
```

```
LogTransform(base=10, nonpositive='clip')
```

Transforms on the axis are a relatively low-level concept, but is one of the important roles played by `set_scale`.

Setting the scale also sets default tick locators (*`ticker`*) and tick formatters appropriate for the scale. An axis with a 'log' scale has a *`LogLocator`* to pick ticks at decade intervals, and a *`LogFormatter`* to use scientific notation on the decades.

```
print('X axis')
print(ax.xaxis.get_major_locator())
print(ax.xaxis.get_major_formatter())

print('Y axis')
print(ax.yaxis.get_major_locator())
print(ax.yaxis.get_major_formatter())
```

```
X axis
<matplotlib.ticker.AutoLocator object at 0x7fd014dd40e0>
<matplotlib.ticker.ScalarFormatter object at 0x7fd014549de0>
Y axis
<matplotlib.ticker.LogLocator object at 0x7fd01450b000>
<matplotlib.ticker.LogFormatterSciNotation object at 0x7fd014684650>
```

Total running time of the script: (0 minutes 3.210 seconds)

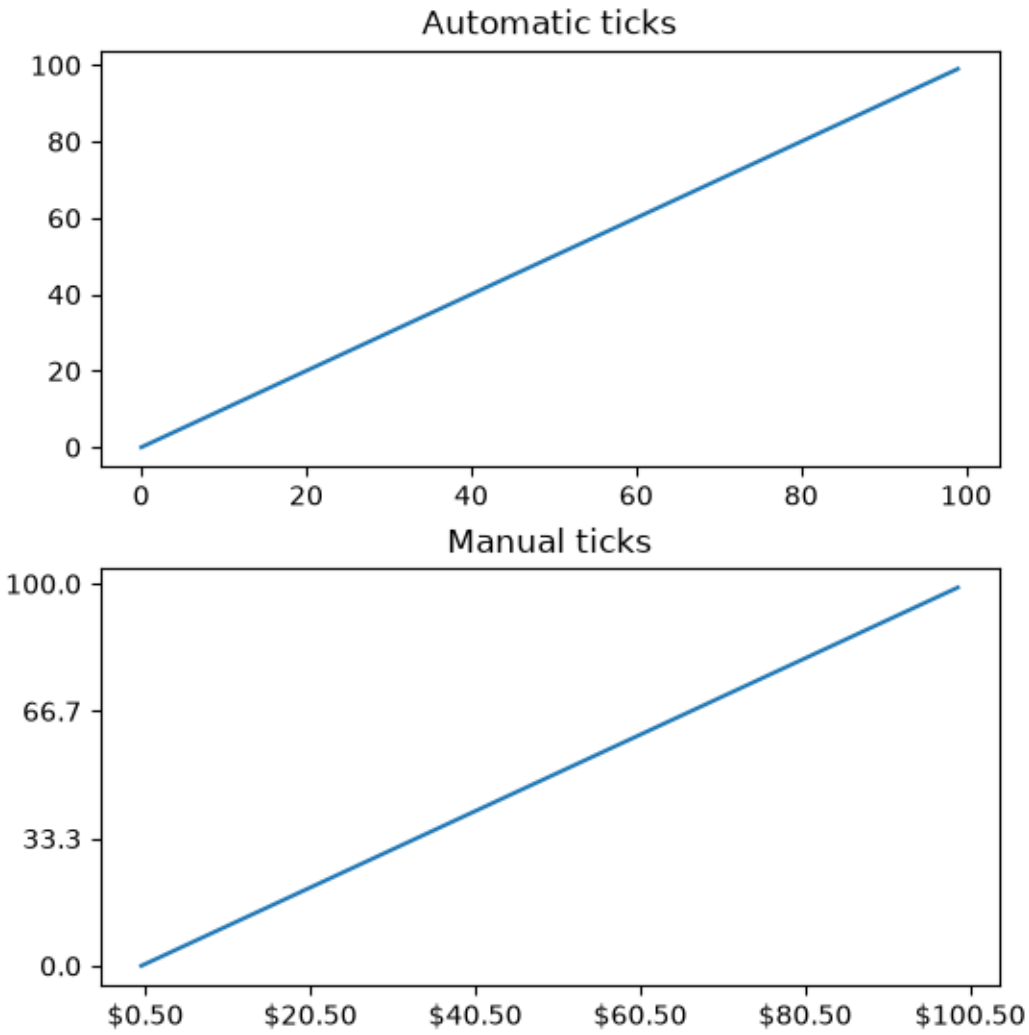
3.3.6 Axis ticks

The x and y Axis on each Axes have default tick "locators" and "formatters" that depend on the scale being used (see *Axis scales*). It is possible to customize the ticks and tick labels with either high-level methods like `set_xticks` or set the locators and formatters directly on the axis.

Manual location and formats

The simplest method to customize the tick locations and formats is to use `set_xticks` and `set_yticks`. These can be used on either the major or the minor ticks.

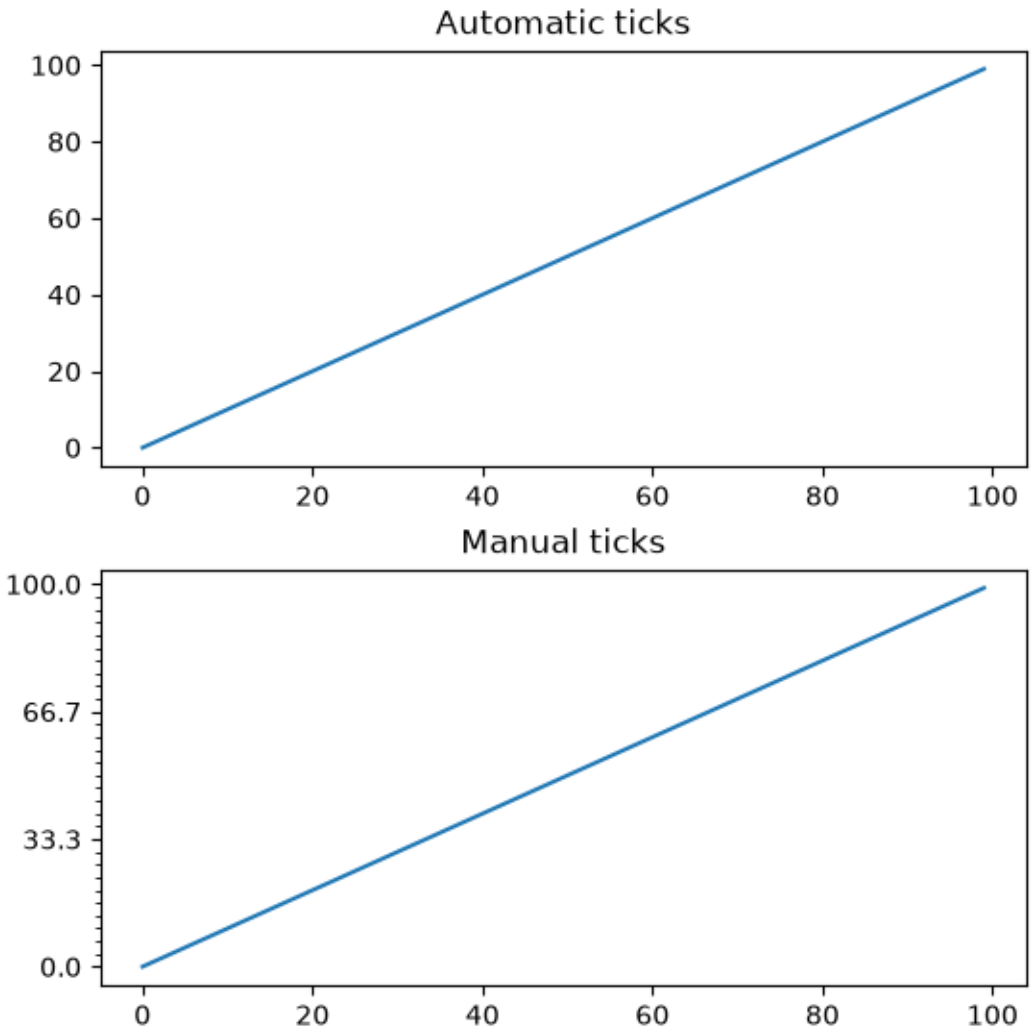
```
import numpy as np
import matplotlib.pyplot as plt

import matplotlib.ticker as ticker


fig, axs = plt.subplots(2, 1, figsize=(5.4, 5.4), layout='constrained')
x = np.arange(100)
for nn, ax in enumerate(axs):
    ax.plot(x, x)
    if nn == 1:
        ax.set_title('Manual ticks')
        ax.set_yticks(np.arange(0, 100.1, 100/3))
        xticks = np.arange(0.50, 101, 20)
        xlabels = [f'\\${x:1.2f}' for x in xticks]
        ax.set_xticks(xticks, labels=xlabels)
    else:
        ax.set_title('Automatic ticks')
```



Note that the length of the `labels` argument must have the same length as the array used to specify the ticks.

By default *`set_xticks`* and *`set_yticks`* act on the major ticks of an Axis, however it is possible to add minor ticks:

```
fig, axs = plt.subplots(2, 1, figsize=(5.4, 5.4), layout='constrained')
x = np.arange(100)
for nn, ax in enumerate(axs):
    ax.plot(x, x)
    if nn == 1:
        ax.set_title('Manual ticks')
        ax.set_yticks(np.arange(0, 100.1, 100/3))
        ax.set_yticks(np.arange(0, 100.1, 100/30), minor=True)
    else:
        ax.set_title('Automatic ticks')
```



Locators and Formatters

Manually setting the ticks as above works well for specific final plots, but does not adapt as the user interacts with the Axes. At a lower level, Matplotlib has `Locators` that are meant to automatically choose ticks depending on the current view limits of the axis, and `Formatters` that are meant to format the tick labels automatically.

The full list of locators provided by Matplotlib are listed at *Tick locating*, and the formatters at *Tick formatting*.

```
def setup(ax, title):
    """Set up common parameters for the Axes in the example."""
    # only show the bottom spine
    ax.yaxis.set_major_locator(ticker.NullLocator())
    ax.spines[['left', 'right', 'top']].set_visible(False)

    ax.xaxis.set_ticks_position('bottom')
    ax.tick_params(which='major', width=1.00, length=5)
    ax.tick_params(which='minor', width=0.75, length=2.5)
```

(continues on next page)

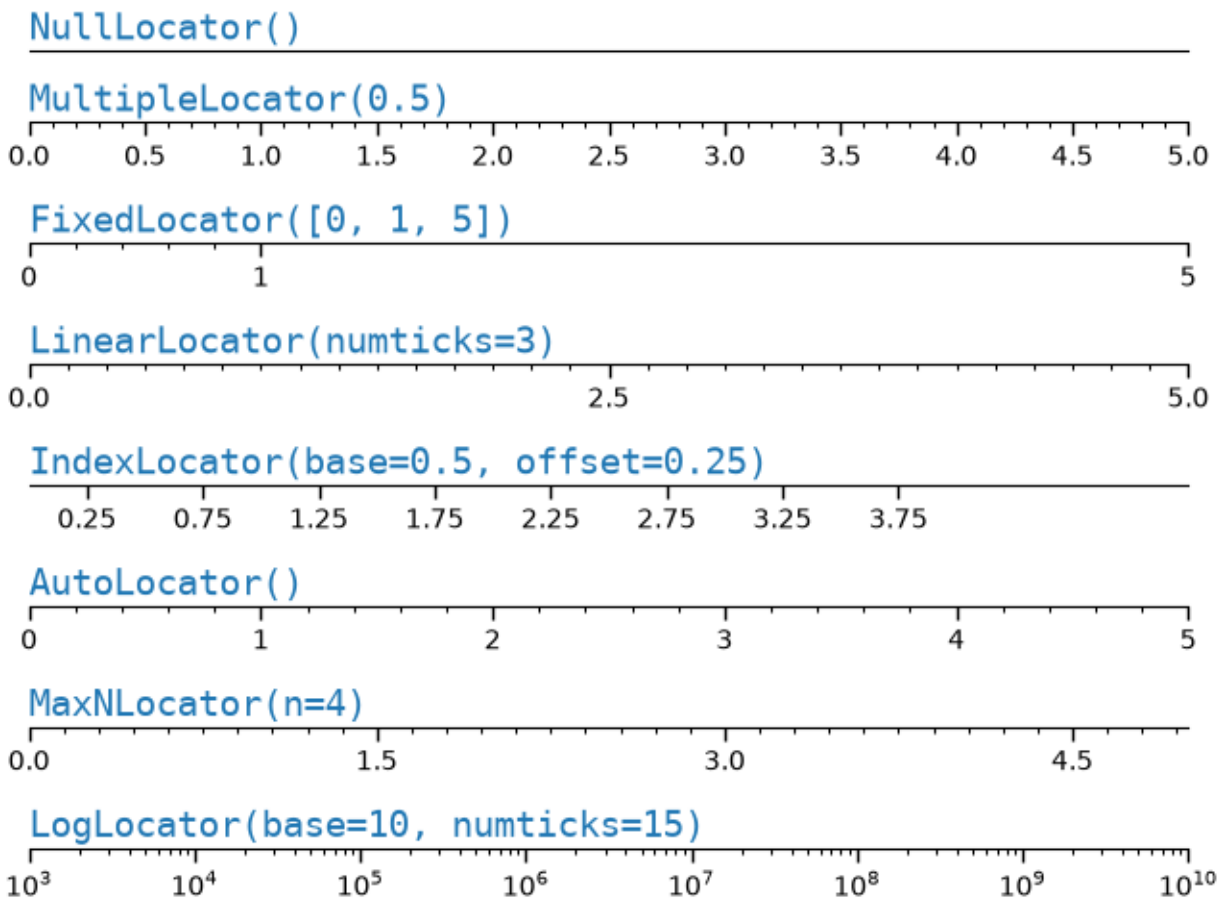
(continued from previous page)

```
    ax.set_xlim(0, 5)
    ax.set_ylim(0, 1)
    ax.text(0.0, 0.2, title, transform=ax.transAxes,
            fontsize=14, fontname='Monospace', color='tab:blue')


fig, axs = plt.subplots(8, 1, layout='constrained')

# Null Locator
setup(axs[0], title="NullLocator()")
axs[0].xaxis.set_major_locator(ticker.NullLocator())
axs[0].xaxis.set_minor_locator(ticker.NullLocator())

# Multiple Locator
setup(axs[1], title="MultipleLocator(0.5)")
axs[1].xaxis.set_major_locator(ticker.MultipleLocator(0.5))
axs[1].xaxis.set_minor_locator(ticker.MultipleLocator(0.1))

# Fixed Locator
setup(axs[2], title="FixedLocator([0, 1, 5])")
axs[2].xaxis.set_major_locator(ticker.FixedLocator([0, 1, 5]))
axs[2].xaxis.set_minor_locator(ticker.FixedLocator(np.linspace(0.2,␣
 ↪0.8, 4)))

# Linear Locator
setup(axs[3], title="LinearLocator(numticks=3)")
axs[3].xaxis.set_major_locator(ticker.LinearLocator(3))
axs[3].xaxis.set_minor_locator(ticker.LinearLocator(31))

# Index Locator
setup(axs[4], title="IndexLocator(base=0.5, offset=0.25)")
axs[4].plot(range(0, 5), [0]*5, color='white')
axs[4].xaxis.set_major_locator(ticker.IndexLocator(base=0.5,␣
 ↪offset=0.25))

# Auto Locator
setup(axs[5], title="AutoLocator()")
axs[5].xaxis.set_major_locator(ticker.AutoLocator())
axs[5].xaxis.set_minor_locator(ticker.AutoMinorLocator())

# MaxN Locator
setup(axs[6], title="MaxNLocator(n=4)")
axs[6].xaxis.set_major_locator(ticker.MaxNLocator(4))
axs[6].xaxis.set_minor_locator(ticker.MaxNLocator(40))

# Log Locator
```

(continues on next page)

(continued from previous page)

```
setup(axs[7], title="LogLocator(base=10, numticks=15)")
axs[7].set_xlim(10**3, 10**10)
axs[7].set_xscale('log')
axs[7].xaxis.set_major_locator(ticker.LogLocator(base=10, numticks=15))
plt.show()
```



Similarly, we can specify "Formatters" for the major and minor ticks on each axis.

The tick format is configured via the function *set_major_formatter* or *set_minor_formatter*. It accepts:

- a format string, which implicitly creates a *StrMethodFormatter*.
- a function, implicitly creates a *FuncFormatter*.
- an instance of a *Formatter* subclass. The most common are
  - *NullFormatter*: No labels on the ticks.
  - *StrMethodFormatter*: Use string `str.format` method.
  - *FormatStrFormatter*: Use %-style formatting.
  - *FuncFormatter*: Define labels through a function.

- *FixedFormatter*: Set the label strings explicitly.
- *ScalarFormatter*: Default formatter for scalars: auto-pick the format string.
- *PercentFormatter*: Format labels as a percentage.

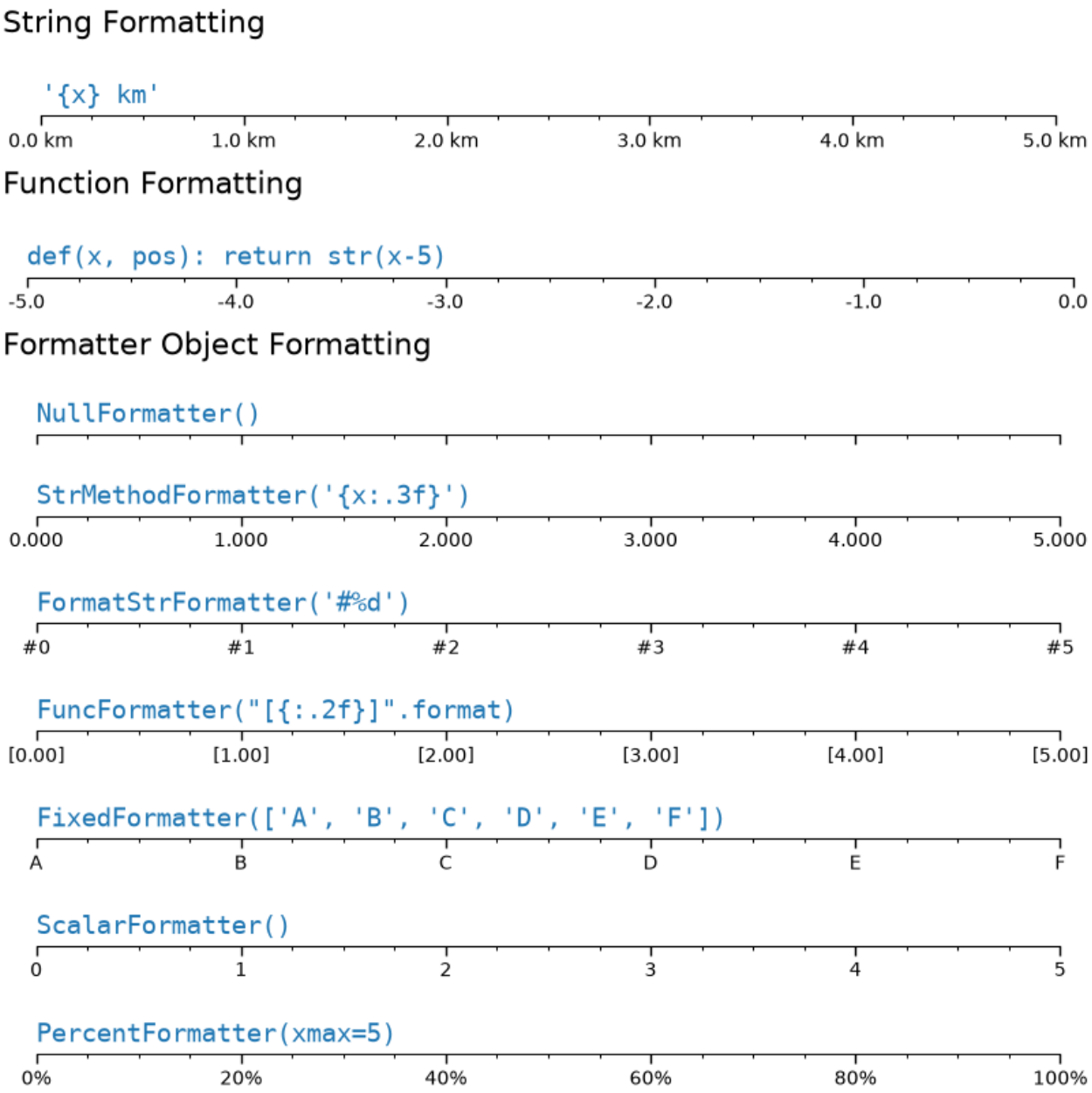
See *Tick formatting* for the complete list.

```
def setup(ax, title):
    """Set up common parameters for the Axes in the example."""
    # only show the bottom spine
    ax.yaxis.set_major_locator(ticker.NullLocator())
    ax.spines[['left', 'right', 'top']].set_visible(False)

    # define tick positions
    ax.xaxis.set_major_locator(ticker.MultipleLocator(1.00))
    ax.xaxis.set_minor_locator(ticker.MultipleLocator(0.25))

    ax.xaxis.set_ticks_position('bottom')
    ax.tick_params(which='major', width=1.00, length=5)
    ax.tick_params(which='minor', width=0.75, length=2.5, labelsize=10)
    ax.set_xlim(0, 5)
    ax.set_ylim(0, 1)
    ax.text(0.0, 0.2, title, transform=ax.transAxes,
            fontsize=14, fontname='Monospace', color='tab:blue')


fig = plt.figure(figsize=(8, 8), layout='constrained')
fig0, fig1, fig2 = fig.subfigures(3, height_ratios=[1.5, 1.5, 7.5])

fig0.suptitle('String Formatting', fontsize=16, x=0, ha='left')
ax0 = fig0.subplots()

setup(ax0, title="'{x} km'")
ax0.xaxis.set_major_formatter('{x} km')

fig1.suptitle('Function Formatting', fontsize=16, x=0, ha='left')
ax1 = fig1.subplots()

setup(ax1, title="def(x, pos): return str(x-5)")
ax1.xaxis.set_major_formatter(lambda x, pos: str(x-5))

fig2.suptitle('Formatter Object Formatting', fontsize=16, x=0, ha='left
 ↪')
axs2 = fig2.subplots(7, 1)

setup(axs2[0], title="NullFormatter()")
axs2[0].xaxis.set_major_formatter(ticker.NullFormatter())
```

(continues on next page)

(continued from previous page)

```
setup(axs2[1], title="StrMethodFormatter('{x:.3f}')")
axs2[1].xaxis.set_major_formatter(ticker.StrMethodFormatter("{x:.3f}"))

setup(axs2[2], title="FormatStrFormatter('#%d')")
axs2[2].xaxis.set_major_formatter(ticker.FormatStrFormatter("#%d"))


def fmt_two_digits(x, pos):
    return f'[{x:.2f}]'


setup(axs2[3], title='FuncFormatter("[{:.2f}]".format)')
axs2[3].xaxis.set_major_formatter(ticker.FuncFormatter(fmt_two_digits))

setup(axs2[4], title="FixedFormatter(['A', 'B', 'C', 'D', 'E', 'F'])")
# FixedFormatter should only be used together with FixedLocator.
# Otherwise, one cannot be sure where the labels will end up.
positions = [0, 1, 2, 3, 4, 5]
labels = ['A', 'B', 'C', 'D', 'E', 'F']
axs2[4].xaxis.set_major_locator(ticker.FixedLocator(positions))
axs2[4].xaxis.set_major_formatter(ticker.FixedFormatter(labels))

setup(axs2[5], title="ScalarFormatter()")
axs2[5].xaxis.set_major_formatter(ticker.
 ↪ScalarFormatter(useMathText=True))

setup(axs2[6], title="PercentFormatter(xmax=5)")
axs2[6].xaxis.set_major_formatter(ticker.PercentFormatter(xmax=5))
```



Styling ticks (tick parameters)

The appearance of ticks can be controlled at a low level by finding the individual *Tick* on the axis. However, usually it is simplest to use *tick_params* to change all the objects at once.

The `tick_params` method can change the properties of ticks:

- length
- direction (in or out of the frame)
- colors
- width and length

- and whether the ticks are drawn at the bottom, top, left, or right of the Axes.

It also can control the tick labels:

- labelsize (fontsize)
- labelcolor (color of the label)
- labelrotation
- labelbottom, labeltop, labelleft, labelright

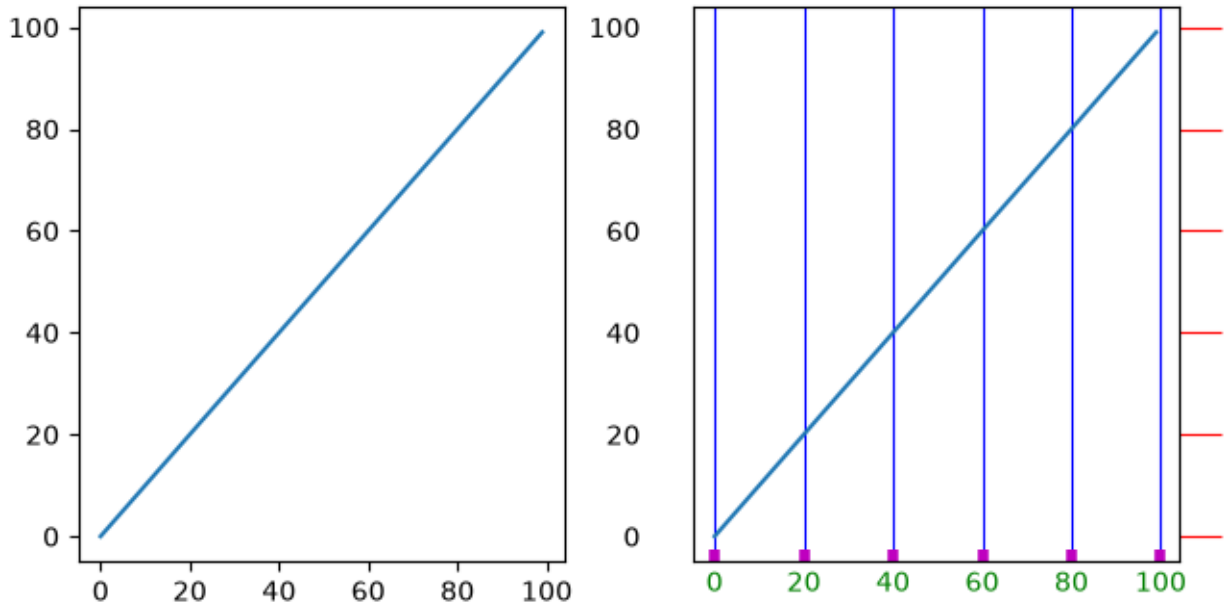
In addition there is a *pad* keyword argument that specifies how far the tick label is from the tick.

Finally, the grid linestyles can be set:

- grid_color
- grid_alpha
- grid_linewidth
- grid_linestyle

All these properties can be restricted to one axis, and can be applied to just the major or minor ticks

```
fig, axs = plt.subplots(1, 2, figsize=(6.4, 3.2), layout='constrained')

for nn, ax in enumerate(axs):
    ax.plot(np.arange(100))
    if nn == 1:
        ax.grid('on')
        ax.tick_params(right=True, left=False, axis='y', color='r',␣
 ↪length=16,
                       grid_color='none')
        ax.tick_params(axis='x', color='m', length=4, direction='in',␣
 ↪width=4,
                       labelcolor='g', grid_color='b')
```



Tick objects

Warning

Ticks are managed through the autoscaling / view limit mechanism, which may create, move and delete ticks as necessary.

Working with tick instances should only be an option of last resort and requires careful handling to not accidentally overwrite any manual changes through this mechanism.

If a tick configuration can be achieved through `Axes.tick_params` (see *Styling ticks (tick parameters)*), that approach should be preferred.

On the technical level, ticks are realized through `Tick` objects. They consist of

- `tick1line` / `tick2line` for the tick lines on either side of the axis.
- `label1` / `label2` for the tick labels on either side of the axis.
- `gridline` for the grid line.

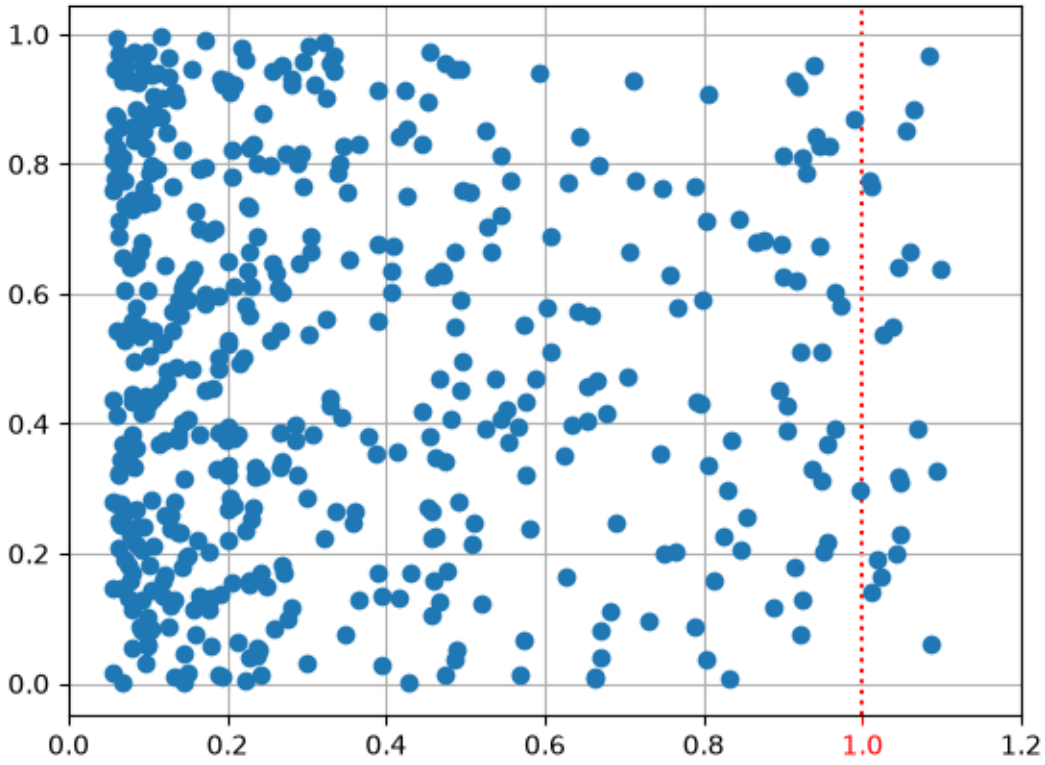
These objects are publicly accessible through *Axes methods* and *Axis methods* and allow extreme customization such as coloring a specific tick line or tick label separately.

```
x = 1.1 * np.exp(-3 * np.random.random(500))
y = np.random.random(500)

fig, ax = plt.subplots()

ax.plot(x, y, 'o')
ax.grid()
```

(continues on next page)

(continued from previous page)

```
ticks = ax.set_xticks([0, 0.2, 0.4, 0.6, 0.8, 1, 1.2])
ticks[5].label1.set_color("red")
ticks[5].tick1line.set_markeredgecolor("red")
ticks[5].gridline.set(visible=True, linestyle=':', linewidth=1.5,␣
↪color='red')
```



Because of the managed nature of ticks, such operations only make sense for static output (e.g., when using the jupyter inline backend or saving the figure to a file) or when you are sure that the view limits of the axis will not change (e.g., when using a fixed locator).

In contrast, *Axes.tick_params* configures the default properties so that they are applied to all current and future ticks.

Total running time of the script: (0 minutes 3.329 seconds)

3.3.7 Plotting dates and strings

The most basic way to use Matplotlib plotting methods is to pass coordinates in as numerical numpy arrays. For example, `plot(x, y)` will work if `x` and `y` are numpy arrays of floats (or integers). Plotting methods will also work if `numpy.asarray` will convert `x` and `y` to an array of floating point numbers; e.g. `x` could be a python list.

Matplotlib also has the ability to convert other data types if a "unit converter" exists for the data type. Matplotlib has two built-in converters, one for dates and the other for lists of strings. Other downstream libraries have their own converters to handle their data types.

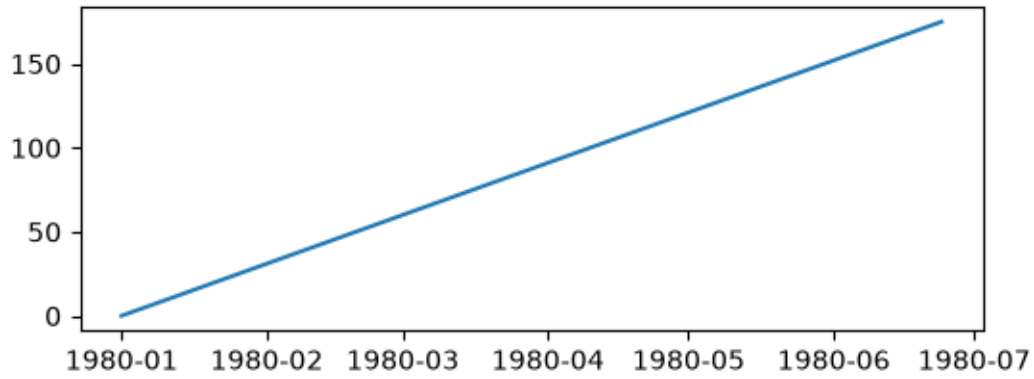
The method to add converters to Matplotlib is described in *matplotlib.units*. Here we briefly overview the built-in date and string converters.

Date conversion

If `x` and/or `y` are a list of `datetime` or an array of `numpy.datetime64`, Matplotlib has a built-in converter that will convert the datetime to a float, and add tick locators and formatters to the axis that are appropriate for dates. See *matplotlib.dates*.

In the following example, the x-axis gains a converter that converts from `numpy.datetime64` to float, and a locator that put ticks at the beginning of the month, and a formatter that label the ticks appropriately:

```
import numpy as np

import matplotlib.dates as mdates
import matplotlib.units as munits

import matplotlib.pyplot as plt

fig, ax = plt.subplots(figsize=(5.4, 2), layout='constrained')
time = np.arange('1980-01-01', '1980-06-25', dtype='datetime64[D]')
x = np.arange(len(time))
ax.plot(time, x)
```



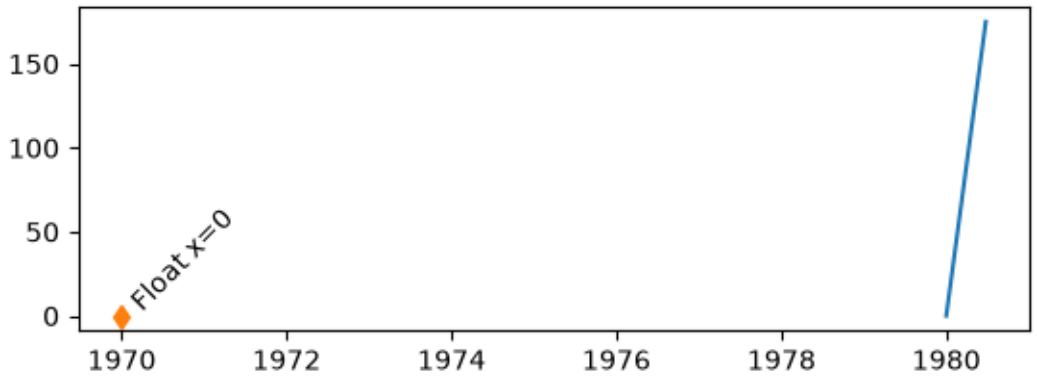
Note that if we try to plot a float on the x-axis, it will be plotted in units of days since the "epoch" for the converter, in this case 1970-01-01 (see *Matplotlib date format*). So when we plot the value 0, the ticks start at 1970-01-01. (The locator also now chooses every two years for a tick instead of every month):

```
fig, ax = plt.subplots(figsize=(5.4, 2), layout='constrained')
time = np.arange('1980-01-01', '1980-06-25', dtype='datetime64[D]')
x = np.arange(len(time))
ax.plot(time, x)
# 0 gets labeled as 1970-01-01
```

(continues on next page)

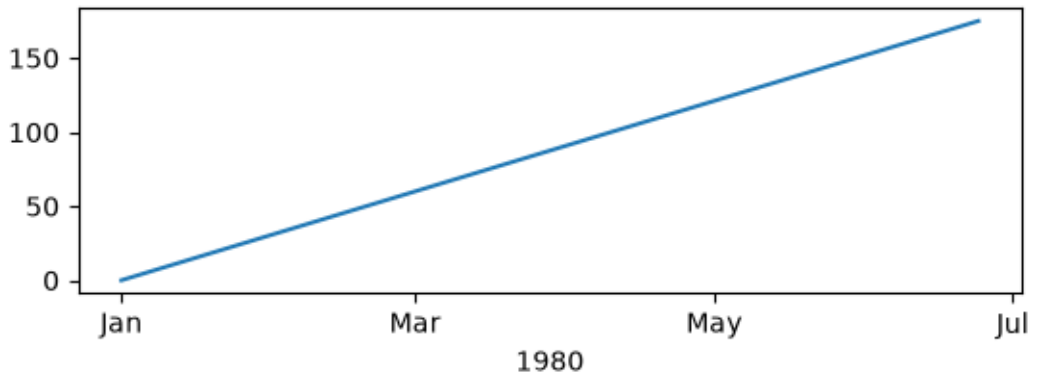
(continued from previous page)

```
ax.plot(0, 0, 'd')
ax.text(0, 0, ' Float x=0', rotation=45)
```



We can customize the locator and the formatter; see *Date tick locators* and *Date formatters* for a complete list, and *Date tick locators and formatters* for examples of them in use. Here we locate by every second month, and format just with the month's 3-letter name using `"%b"` (see `strftime` for format codes):

```
fig, ax = plt.subplots(figsize=(5.4, 2), layout='constrained')
time = np.arange('1980-01-01', '1980-06-25', dtype='datetime64[D]')
x = np.arange(len(time))
ax.plot(time, x)
ax.xaxis.set_major_locator(mdates.MonthLocator(bymonth=np.arange(1, 13,
 ↪ 2)))
ax.xaxis.set_major_formatter(mdates.DateFormatter('%b'))
ax.set_xlabel('1980')
```



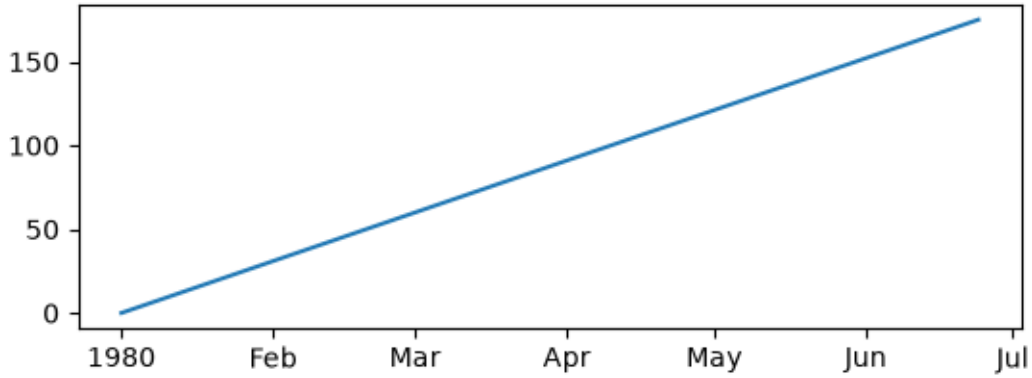
The default locator is the `AutoDateLocator`, and the default Formatter `AutoDateFormatter`. There are also "concise" formatter and locators that give a more compact labelling, and can be set via rcParams. Note how instead of the redundant "Jan" label at the start of the year, "1980" is used instead. See *Format date ticks using ConciseDateFormatter* for more examples.

```
plt.rcParams['date.converter'] = 'concise'

fig, ax = plt.subplots(figsize=(5.4, 2), layout='constrained')
```

(continues on next page)

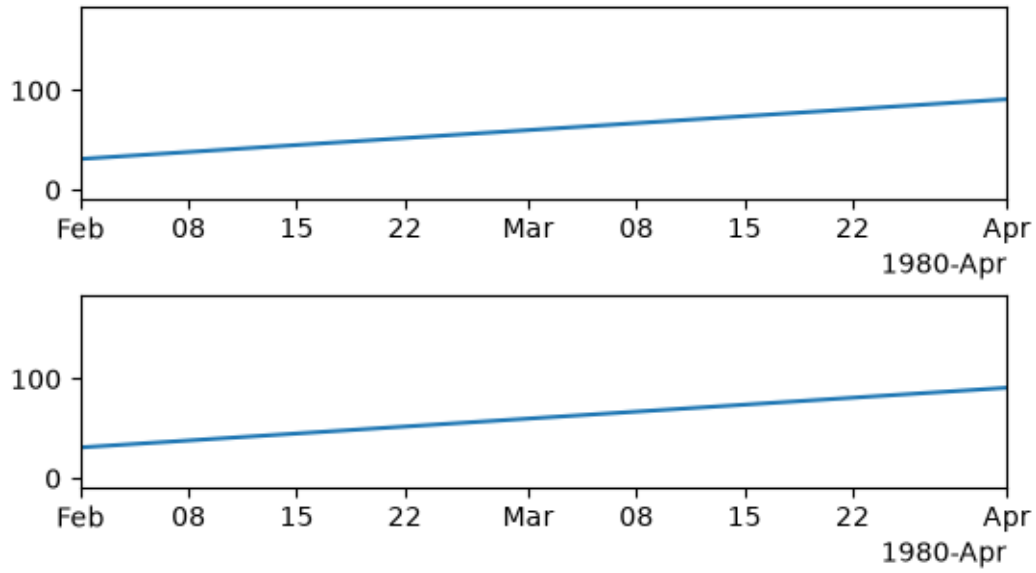
(continued from previous page)

```
time = np.arange('1980-01-01', '1980-06-25', dtype='datetime64[D]')
x = np.arange(len(time))
ax.plot(time, x)
```



We can set the limits on the axis either by passing the appropriate dates as limits, or by passing a floating-point value in the proper units of days since the epoch. If we need it, we can get this value from *date2num*.

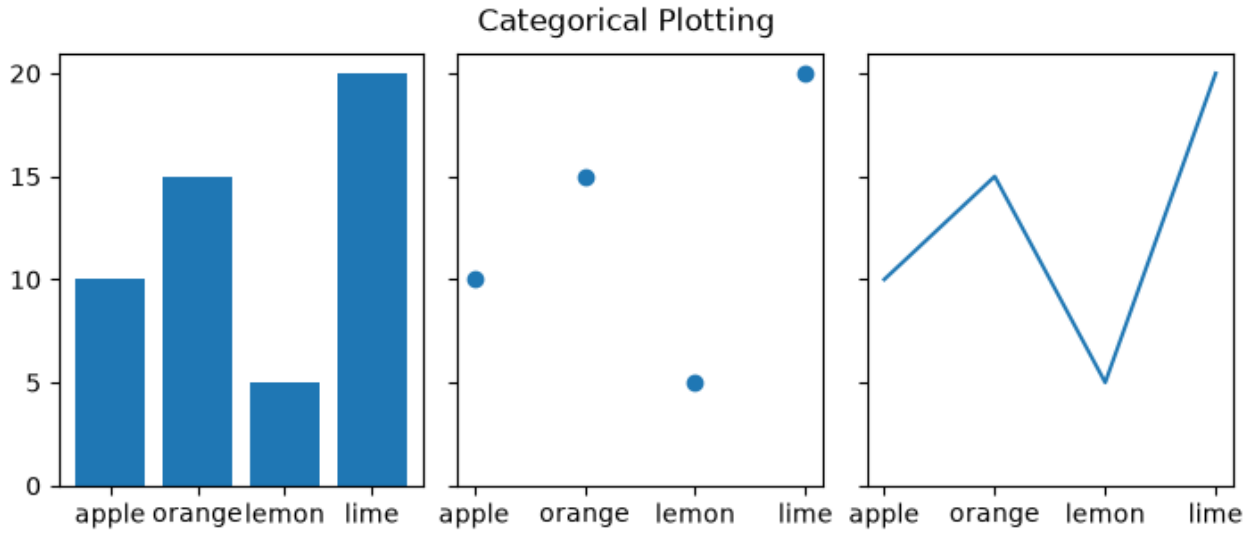
```
fig, axs = plt.subplots(2, 1, figsize=(5.4, 3), layout='constrained')
for ax in axs.flat:
    time = np.arange('1980-01-01', '1980-06-25', dtype='datetime64[D]')
    x = np.arange(len(time))
    ax.plot(time, x)

# set xlim using datetime64:
axs[0].set_xlim(np.datetime64('1980-02-01'), np.datetime64('1980-04-01
 ↪'))

# set xlim using floats:
# Note can get from mdates.date2num(np.datetime64('1980-02-01'))
axs[1].set_xlim(3683, 3683+60)
```



String conversion: categorical plots

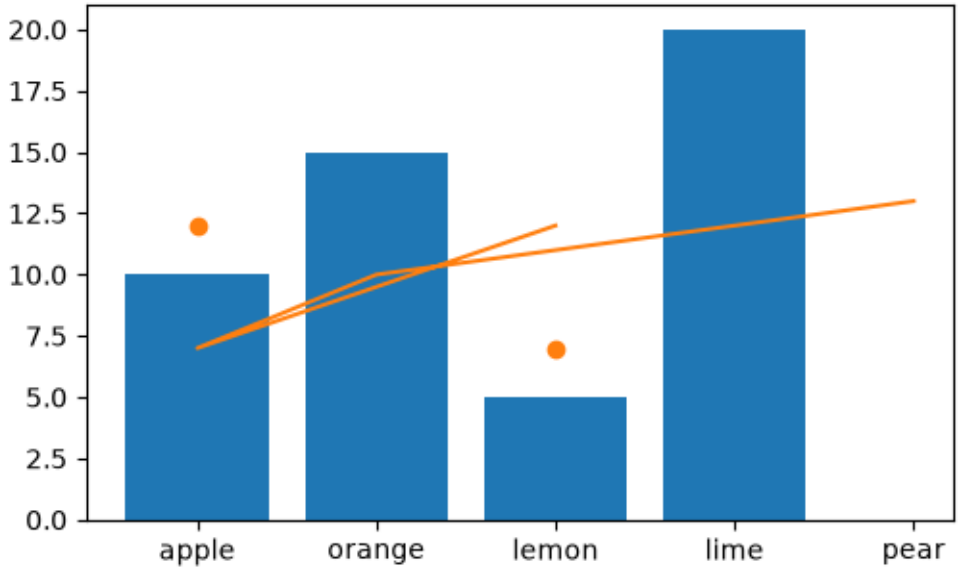
Sometimes we want to label categories on an axis rather than numbers. Matplotlib allows this using a "categorical" converter (see *category*).

```
data = {'apple': 10, 'orange': 15, 'lemon': 5, 'lime': 20}
names = list(data.keys())
values = list(data.values())

fig, axs = plt.subplots(1, 3, figsize=(7, 3), sharey=True, layout=
↪'constrained')
axs[0].bar(names, values)
axs[1].scatter(names, values)
axs[2].plot(names, values)
fig.suptitle('Categorical Plotting')
```



Note that the "categories" are plotted in the order that they are first specified and that subsequent plotting in a different order will not affect the original order. Further, new additions will be added on the end (see "pear" below):

```
fig, ax = plt.subplots(figsize=(5, 3), layout='constrained')
ax.bar(names, values)

# plot in a different order:
ax.scatter(['lemon', 'apple'], [7, 12])

# add a new category, "pear", and put the other categories in a␣
 ↪different order:
ax.plot(['pear', 'orange', 'apple', 'lemon'], [13, 10, 7, 12], color=
 ↪'C1')
```



Note that when using `plot` like in the above, the order of the plotting is mapped onto the original order of the data, so the new line goes in the order specified.

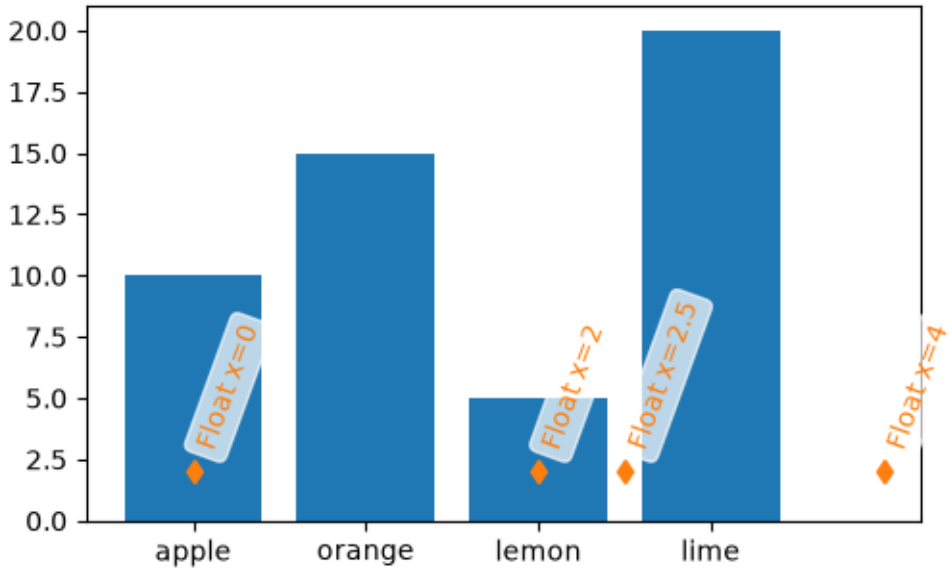
The category converter maps from categories to integers, starting at zero. So data can also be manually added to the axis using a float. Note that if a float is passed in that does not have a "category" associated with it, the data point can still be plotted, but a tick will not be created. In the following, we plot data at 4.0 and 2.5, but no tick is added there because those are not categories.

```
fig, ax = plt.subplots(figsize=(5, 3), layout='constrained')
ax.bar(names, values)
# arguments for styling the labels below:
args = {'rotation': 70, 'color': 'C1',
        'bbox': {'color': 'white', 'alpha': .7, 'boxstyle': 'round'}}


# 0 gets labeled as "apple"
```

(continues on next page)

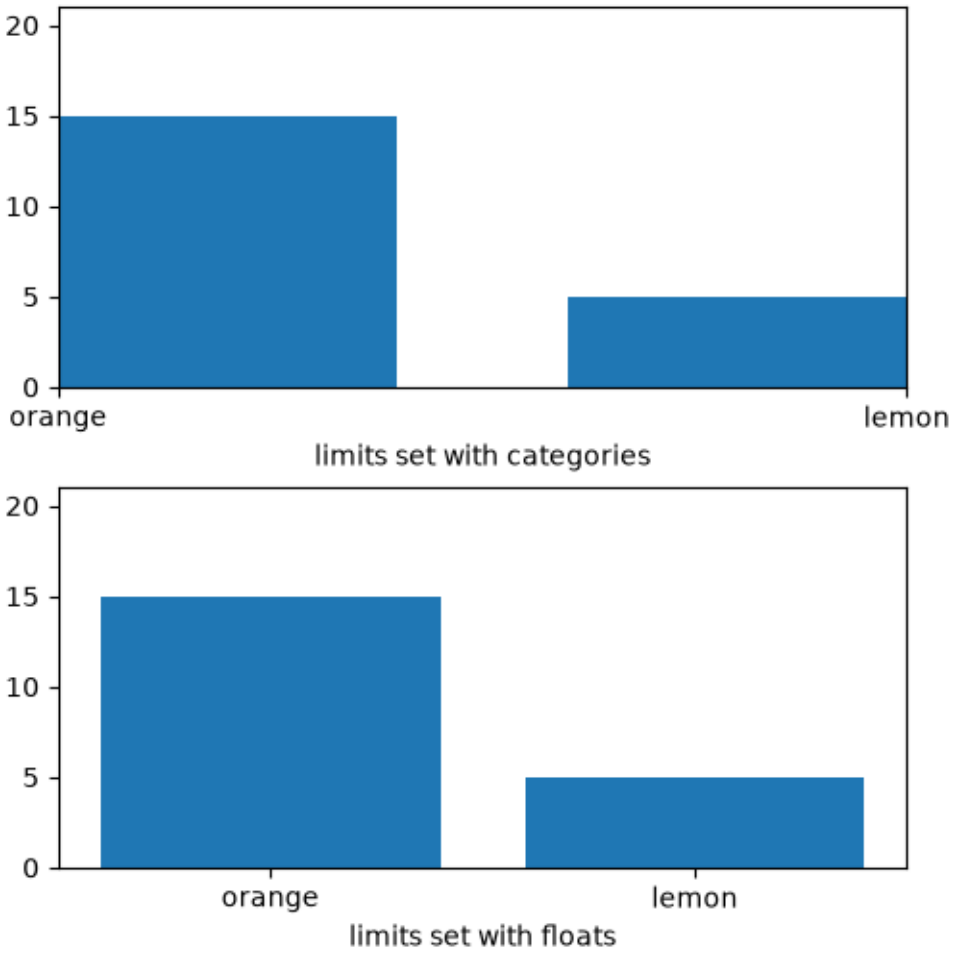
(continued from previous page)

```
ax.plot(0, 2, 'd', color='C1')
ax.text(0, 3, 'Float x=0', **args)

# 2 gets labeled as "lemon"
ax.plot(2, 2, 'd', color='C1')
ax.text(2, 3, 'Float x=2', **args)

# 4 doesn't get a label
ax.plot(4, 2, 'd', color='C1')
ax.text(4, 3, 'Float x=4', **args)

# 2.5 doesn't get a label
ax.plot(2.5, 2, 'd', color='C1')
ax.text(2.5, 3, 'Float x=2.5', **args)
```



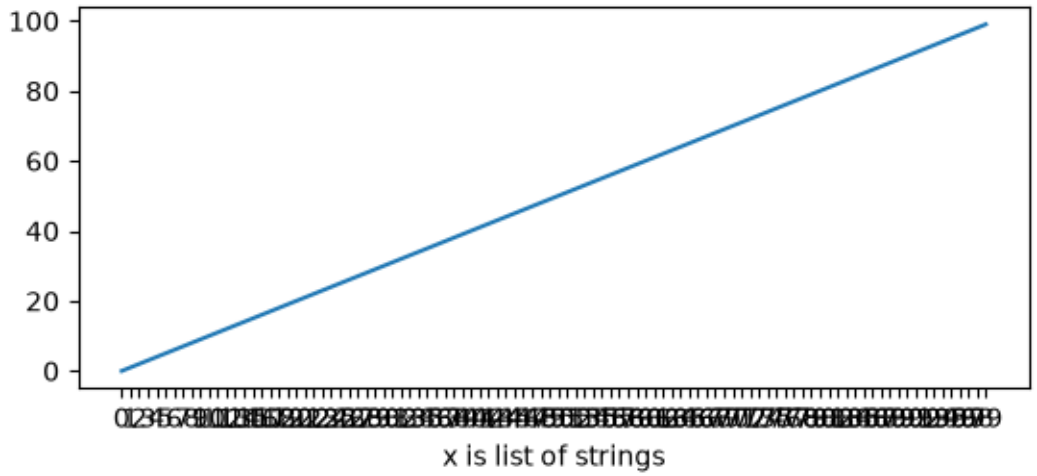
Setting the limits for a category axis can be done by specifying the categories, or by specifying floating point numbers:

```
fig, axs = plt.subplots(2, 1, figsize=(5, 5), layout='constrained')
ax = axs[0]
ax.bar(names, values)
ax.set_xlim('orange', 'lemon')
ax.set_xlabel('limits set with categories')
ax = axs[1]
ax.bar(names, values)
ax.set_xlim(0.5, 2.5)
ax.set_xlabel('limits set with floats')
```



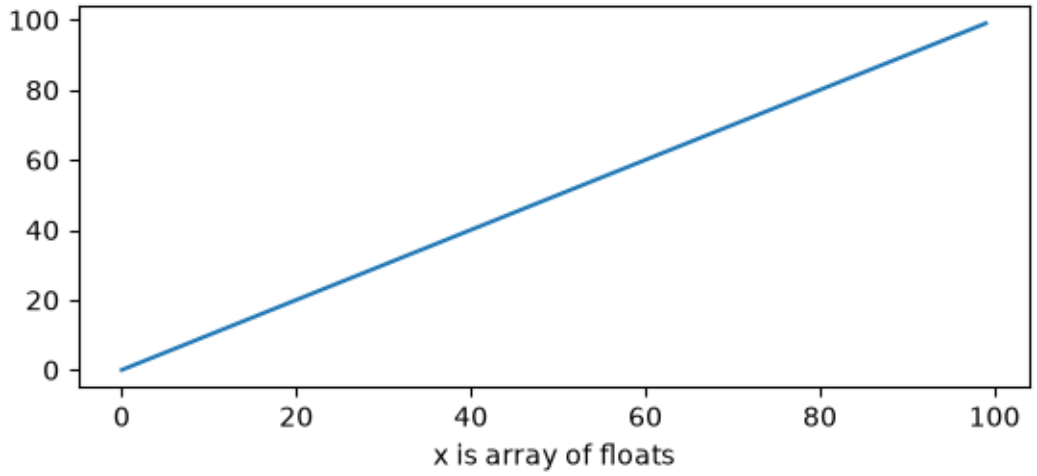
The category axes are helpful for some plot types, but can lead to confusion if data is read in as a list of strings, even if it is meant to be a list of floats or dates. This sometimes happens when reading comma-separated value (CSV) files. The categorical locator and formatter will put a tick at every string value and label each one as well:

```
fig, ax = plt.subplots(figsize=(5.4, 2.5), layout='constrained')
x = [str(xx) for xx in np.arange(100)]  # list of strings
ax.plot(x, np.arange(100))
ax.set_xlabel('x is list of strings')
```



If this is not desired, then simply convert the data to floats before plotting:

```
fig, ax = plt.subplots(figsize=(5.4, 2.5), layout='constrained')
x = np.asarray(x, dtype='float')  # array of float.
ax.plot(x, np.arange(100))
ax.set_xlabel('x is array of floats')
```



Determine converter, formatter, and locator on an axis

Sometimes it is helpful to be able to debug what Matplotlib is using to convert the incoming data. We can do that by querying the `converter` property on the axis. We can also query the formatters and locators using *`get_major_locator`* and *`get_major_formatter`*.

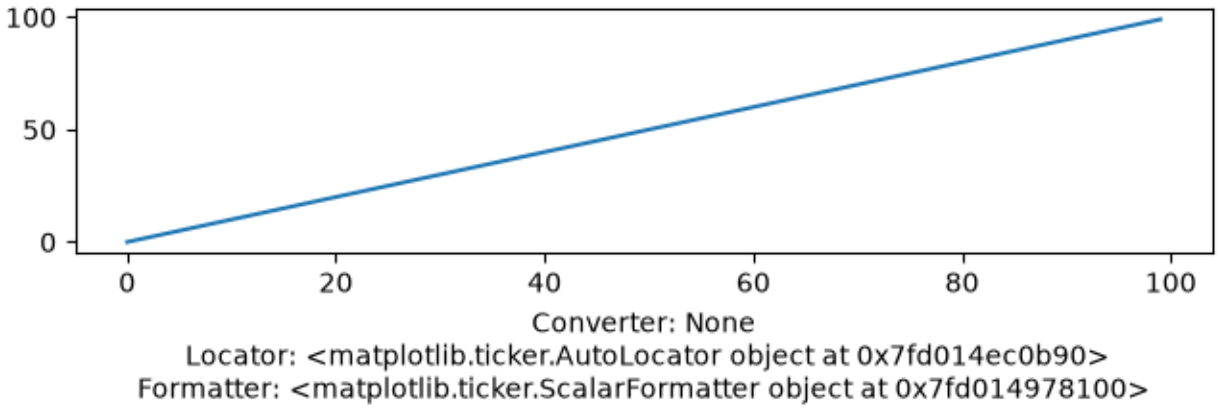
Note that by default the converter is *None*.

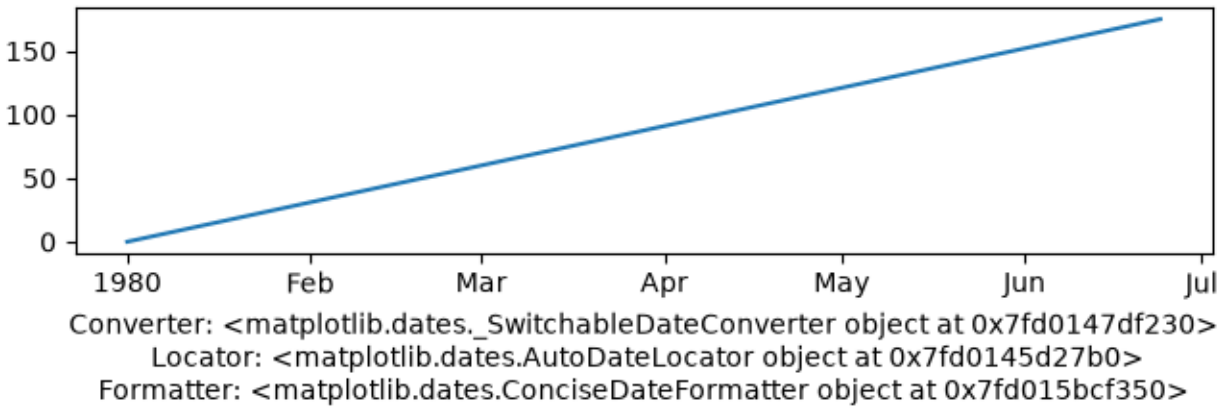
```
fig, axs = plt.subplots(3, 1, figsize=(6.4, 7), layout='constrained')
x = np.arange(100)
ax = axs[0]
ax.plot(x, x)
label = f'Converter: {ax.xaxis.get_converter()}\n '
```

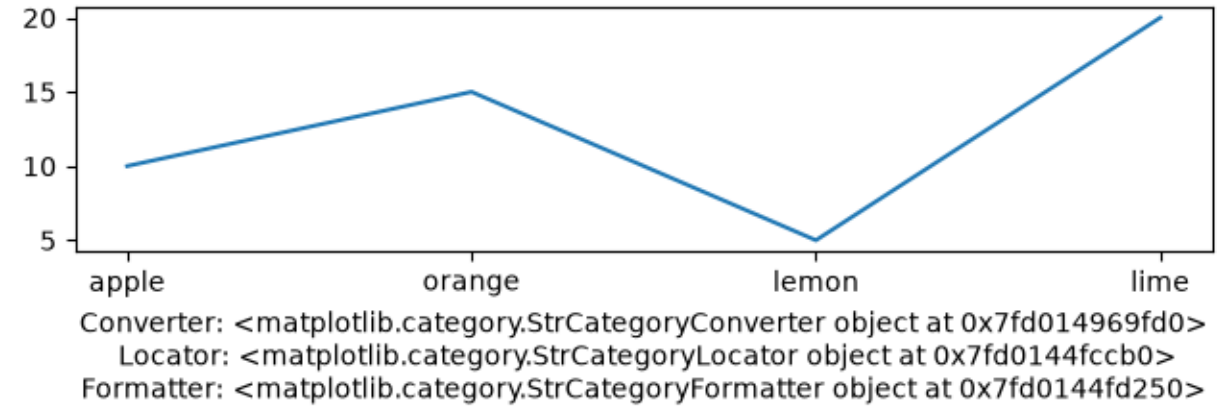
(continues on next page)

(continued from previous page)

```
label += f'Locator: {ax.xaxis.get_major_locator()}\n'
label += f'Formatter: {ax.xaxis.get_major_formatter()}\n'
ax.set_xlabel(label)

ax = axs[1]
time = np.arange('1980-01-01', '1980-06-25', dtype='datetime64[D]')
x = np.arange(len(time))
ax.plot(time, x)
label = f'Converter: {ax.xaxis.get_converter()}\n '
label += f'Locator: {ax.xaxis.get_major_locator()}\n'
label += f'Formatter: {ax.xaxis.get_major_formatter()}\n'
ax.set_xlabel(label)

ax = axs[2]
data = {'apple': 10, 'orange': 15, 'lemon': 5, 'lime': 20}
names = list(data.keys())
values = list(data.values())
ax.plot(names, values)
label = f'Converter: {ax.xaxis.get_converter()}\n '
label += f'Locator: {ax.xaxis.get_major_locator()}\n'
label += f'Formatter: {ax.xaxis.get_major_formatter()}\n'
ax.set_xlabel(label)
```







More about "unit" support

The support for dates and categories is part of "units" support that is built into Matplotlib. This is described at *`matplotlib.units`* and in the *Basic units* example.

Unit support works by querying the type of data passed to the plotting function and dispatching to the first converter in a list that accepts that type of data. So below, if `x` has `datetime` objects in it, the converter will be `_SwitchableDateConverter`; if it has strings in it, it will be sent to the `StrCategoryConverter`.

```
for k, v in munits.registry.items():
    print(f"type: {k};\n    converter: {type(v)}")
```

```
type: <class 'decimal.Decimal'>;
    converter: <class 'matplotlib.units.DecimalConverter'>
type: <class 'numpy.datetime64'>;
    converter: <class 'matplotlib.dates._SwitchableDateConverter'>
type: <class 'datetime.date'>;
    converter: <class 'matplotlib.dates._SwitchableDateConverter'>
type: <class 'datetime.datetime'>;
    converter: <class 'matplotlib.dates._SwitchableDateConverter'>
type: <class 'str'>;
    converter: <class 'matplotlib.category.StrCategoryConverter'>
type: <class 'numpy.str_'>;
    converter: <class 'matplotlib.category.StrCategoryConverter'>
type: <class 'bytes'>;
    converter: <class 'matplotlib.category.StrCategoryConverter'>
type: <class 'numpy.bytes_'>;
    converter: <class 'matplotlib.category.StrCategoryConverter'>
```

There are a number of downstream libraries that provide their own converters with locators and formatters. Physical unit support is provided by astropy, pint, and unyt, among others.

High level libraries like pandas and nc-time-axis (and thus xarray) provide their own datetime support. This support can sometimes be incompatible with Matplotlib native datetime support, so care should be taken when using Matplotlib locators and formatters if these libraries are being used.

Total running time of the script: (0 minutes 3.804 seconds)

3.3.8 Legend guide

This legend guide extends the *legend* docstring - please read it before proceeding with this guide.

This guide makes use of some common terms, which are documented here for clarity:

legend entry

A legend is made up of one or more legend entries. An entry is made up of exactly one key and one label.

legend key

The colored/patterned marker to the left of each legend label.

legend label

The text which describes the handle represented by the key.

legend handle

The original object which is used to generate an appropriate entry in the legend.

Controlling the legend entries

Calling *legend()* with no arguments automatically fetches the legend handles and their associated labels. This functionality is equivalent to:

```
handles, labels = ax.get_legend_handles_labels()
ax.legend(handles, labels)
```

The *get_legend_handles_labels()* function returns a list of handles/artists which exist on the Axes which can be used to generate entries for the resulting legend - it is worth noting however that not all artists can be added to a legend, at which point a "proxy" will have to be created (see *Creating artists specifically for adding to the legend (aka. Proxy artists)* for further details).

Note

Artists with an empty string as label or with a label starting with an underscore, "_", will be ignored.

For full control of what is being added to the legend, it is common to pass the appropriate handles directly to *legend()*:

```
fig, ax = plt.subplots()
line_up, = ax.plot([1, 2, 3], label='Line 2')
line_down, = ax.plot([3, 2, 1], label='Line 1')
ax.legend(handles=[line_up, line_down])
```

Renaming legend entries

When the labels cannot directly be set on the handles, they can be directly passed to *Axes.legend*:

```
fig, ax = plt.subplots()
line_up, = ax.plot([1, 2, 3], label='Line 2')
line_down, = ax.plot([3, 2, 1], label='Line 1')
ax.legend([line_up, line_down], ['Line Up', 'Line Down'])
```

If the handles are not directly accessible, for example when using some Third-party packages, they can be accessed via *Axes.get_legend_handles_labels*. Here we use a dictionary to rename existing labels:

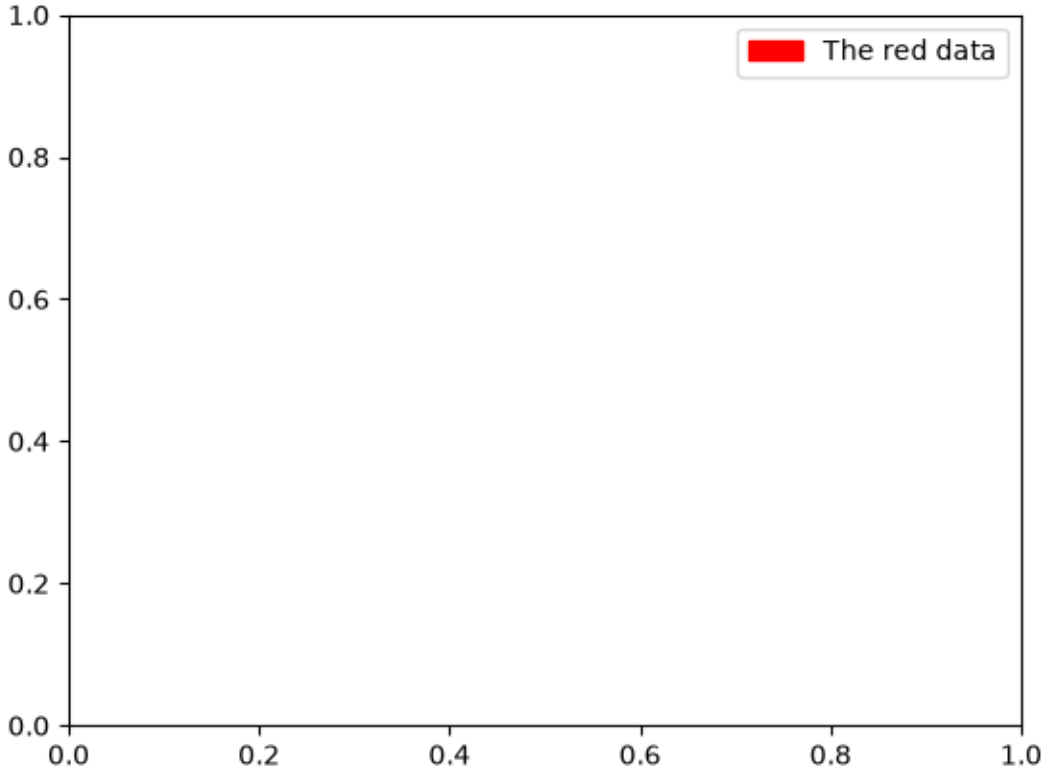
```
my_map = {'Line Up':'Up', 'Line Down':'Down'}

handles, labels = ax.get_legend_handles_labels()
ax.legend(handles, [my_map[l] for l in labels])
```

Creating artists specifically for adding to the legend (aka. Proxy artists)

Not all handles can be turned into legend entries automatically, so it is often necessary to create an artist which *can*. Legend handles don't have to exist on the Figure or Axes in order to be used.

Suppose we wanted to create a legend which has an entry for some data which is represented by a red color:

```
import matplotlib.pyplot as plt

import matplotlib.patches as mpatches

fig, ax = plt.subplots()
red_patch = mpatches.Patch(color='red', label='The red data')
ax.legend(handles=[red_patch])

plt.show()
```



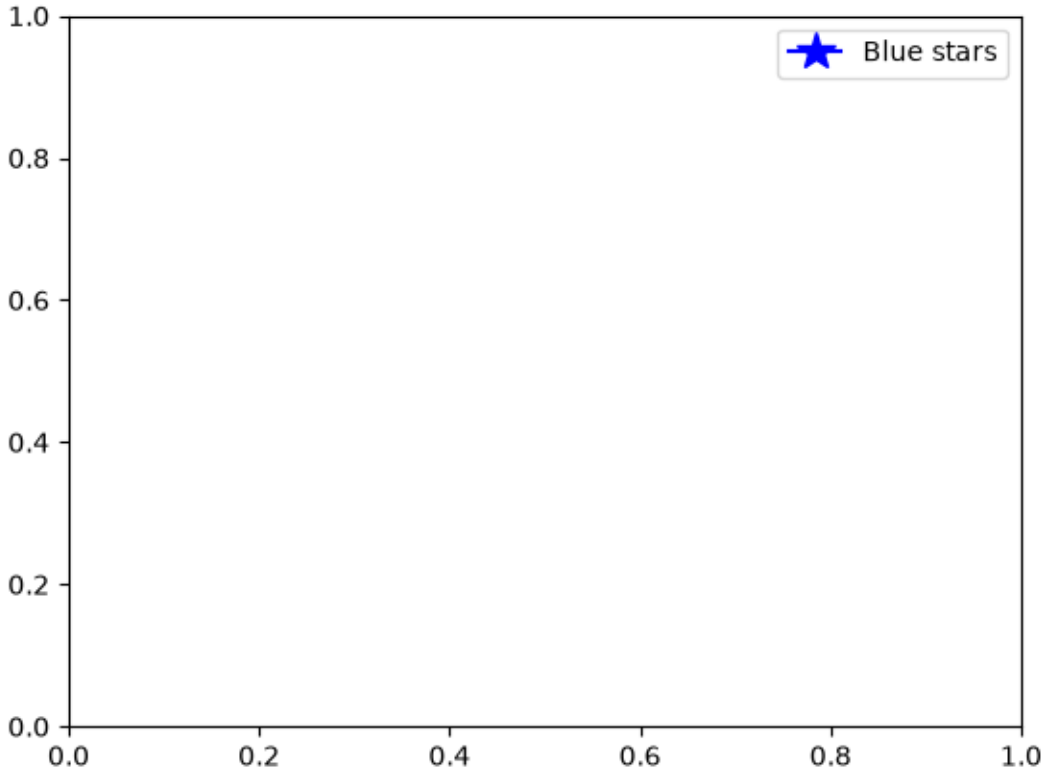
There are many supported legend handles. Instead of creating a patch of color we could have created a line with a marker:

```
import matplotlib.lines as mlines

```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots()
blue_line = mlines.Line2D([], [], color='blue', marker='*',
                          markersize=15, label='Blue stars')
ax.legend(handles=[blue_line])

plt.show()
```



Legend location

The location of the legend can be specified by the keyword argument *loc*. Please see the documentation at `legend()` for more details.

The `bbox_to_anchor` keyword gives a great degree of control for manual legend placement. For example, if you want your Axes legend located at the figure's top right-hand corner instead of the Axes' corner, simply specify the corner's location and the coordinate system of that location:

```
ax.legend(bbox_to_anchor=(1, 1),
          bbox_transform=fig.transFigure)
```

More examples of custom legend placement:

```
fig, ax_dict = plt.subplot_mosaic([['top', 'top'], ['bottom', 'BLANK
↪']],
                                  empty_sentinel="BLANK")
ax_dict['top'].plot([1, 2, 3], label="test1")
ax_dict['top'].plot([3, 2, 1], label="test2")
# Place a legend above this subplot, expanding itself to
# fully use the given bounding box.
ax_dict['top'].legend(bbox_to_anchor=(0., 1.02, 1., .102), loc='lower␣
↪left',
                      ncols=2, mode="expand", borderaxespad=0.)

ax_dict['bottom'].plot([1, 2, 3], label="test1")
ax_dict['bottom'].plot([3, 2, 1], label="test2")
# Place a legend to the right of this smaller subplot.
ax_dict['bottom'].legend(bbox_to_anchor=(1.05, 1),
                         loc='upper left', borderaxespad=0.)
```

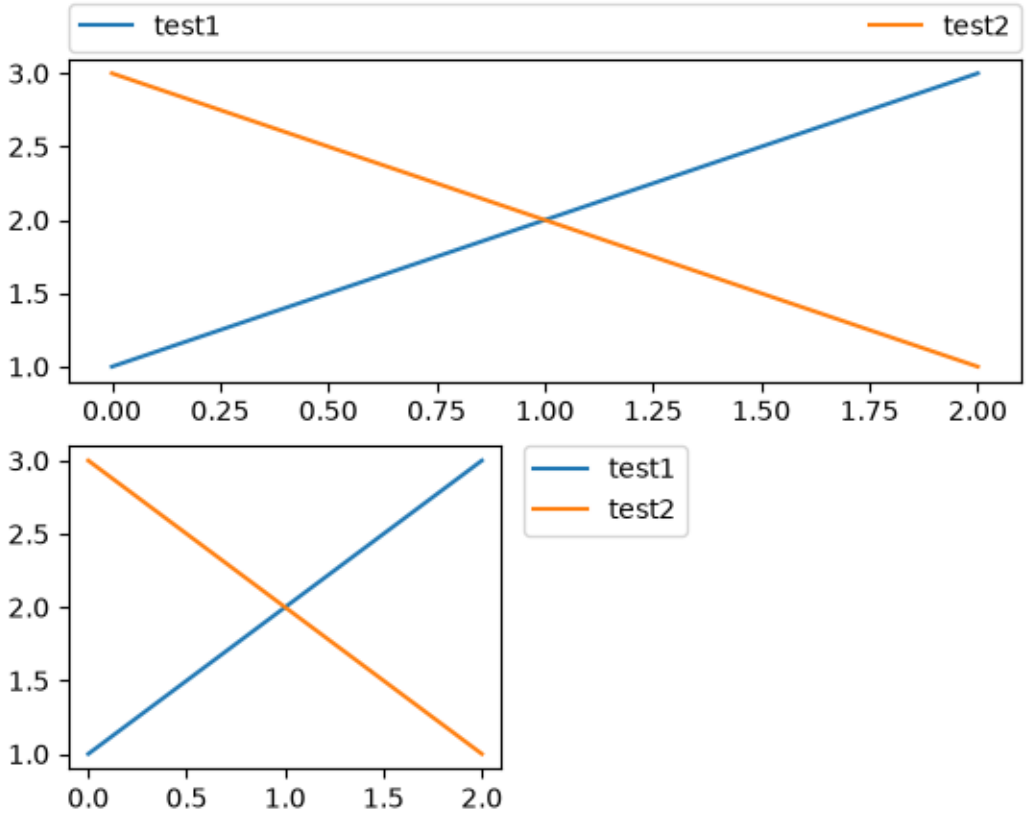
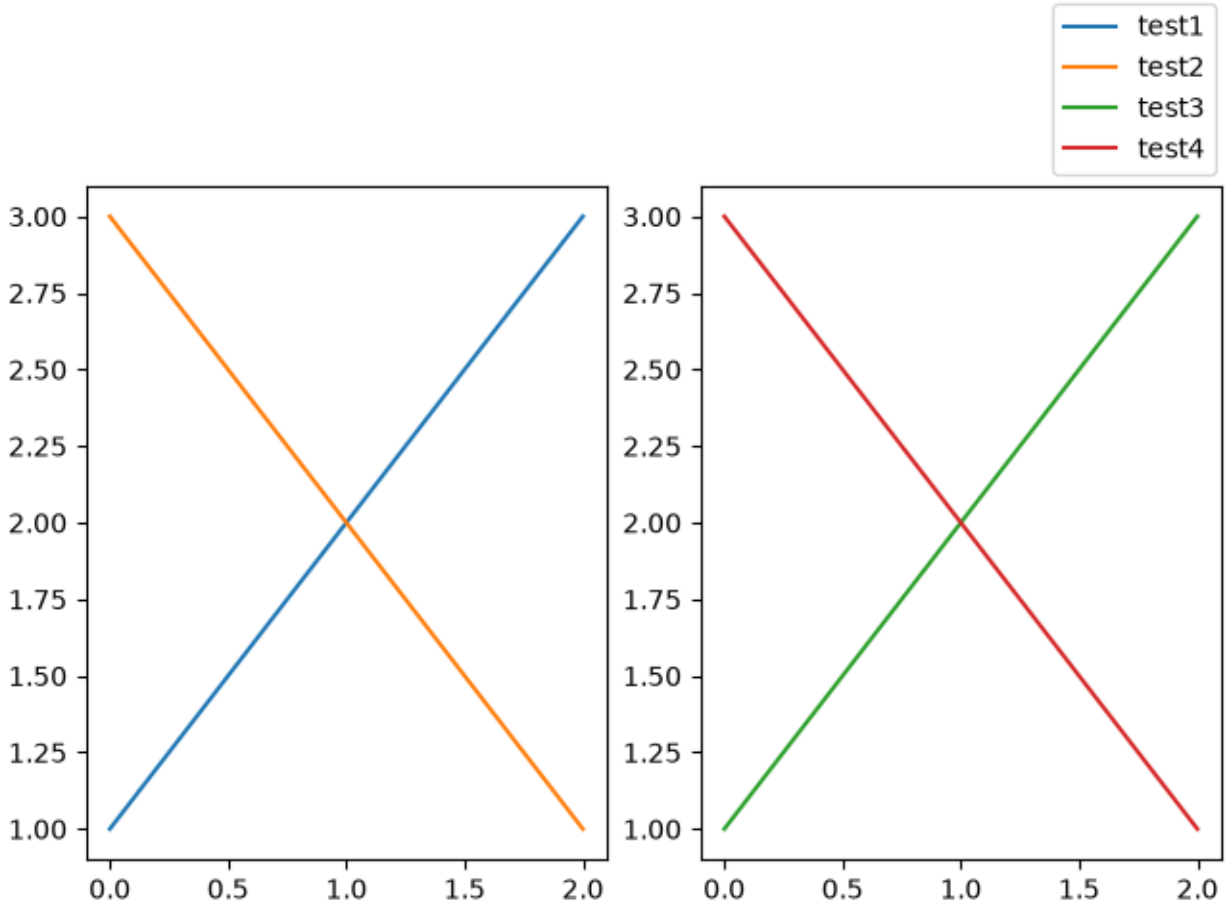


Figure legends

Sometimes it makes more sense to place a legend relative to the (sub)figure rather than individual Axes. By using *constrained layout* and specifying "outside" at the beginning of the *loc* keyword argument, the legend is drawn outside the Axes on the (sub)figure.

```
fig, axs = plt.subplot_mosaic([['left', 'right']], layout='constrained
 ↪')

axs['left'].plot([1, 2, 3], label="test1")
axs['left'].plot([3, 2, 1], label="test2")

axs['right'].plot([1, 2, 3], 'C2', label="test3")
axs['right'].plot([3, 2, 1], 'C3', label="test4")
# Place a legend to the right of this smaller subplot.
fig.legend(loc='outside upper right')
```



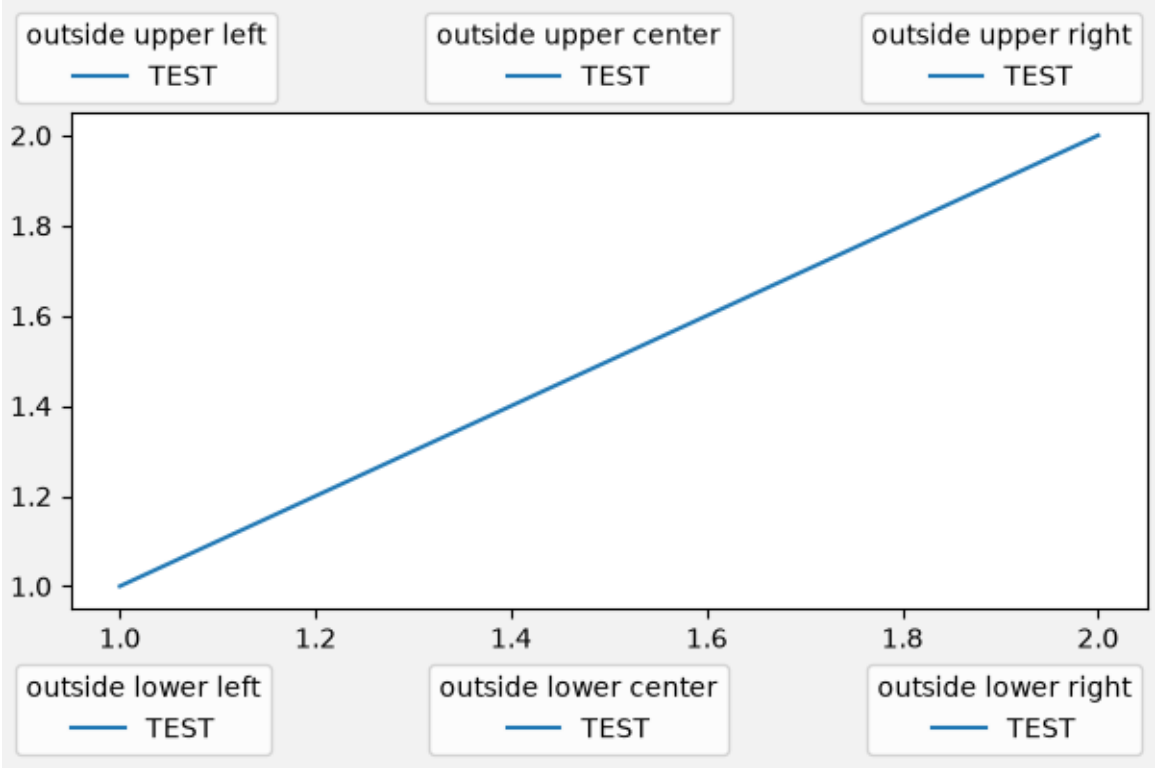
This accepts a slightly different grammar than the normal *loc* keyword, where "outside right upper" is different from "outside upper right".

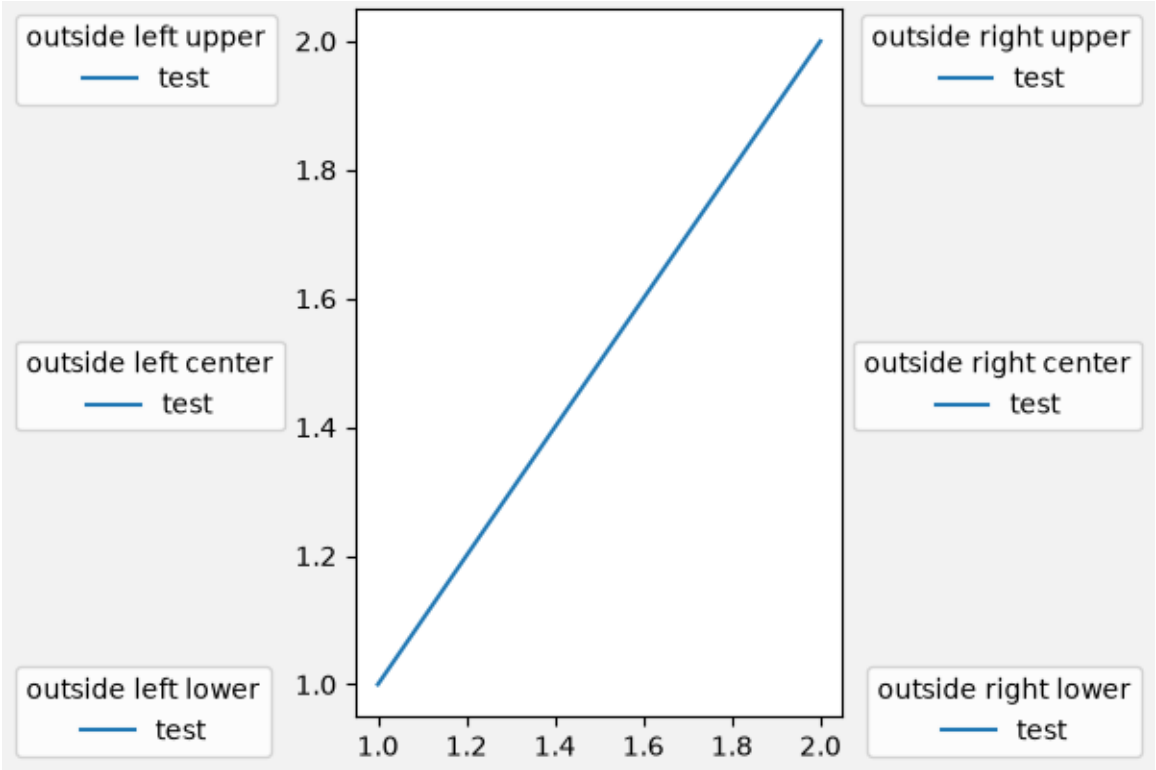
```
ucl = ['upper', 'center', 'lower']
```

(continues on next page)

(continued from previous page)

```
lcr = ['left', 'center', 'right']
fig, ax = plt.subplots(figsize=(6, 4), layout='constrained', facecolor=
 ↪'0.95')

ax.plot([1, 2], [1, 2], label='TEST')
# Place a legend to the right of this smaller subplot.
for loc in [
        'outside upper left',
        'outside upper center',
        'outside upper right',
        'outside lower left',
        'outside lower center',
        'outside lower right']:
    fig.legend(loc=loc, title=loc)

fig, ax = plt.subplots(figsize=(6, 4), layout='constrained', facecolor=
 ↪'0.95')
ax.plot([1, 2], [1, 2], label='test')

for loc in [
        'outside left upper',
        'outside right upper',
        'outside left center',
        'outside right center',
        'outside left lower',
        'outside right lower']:
    fig.legend(loc=loc, title=loc)
```

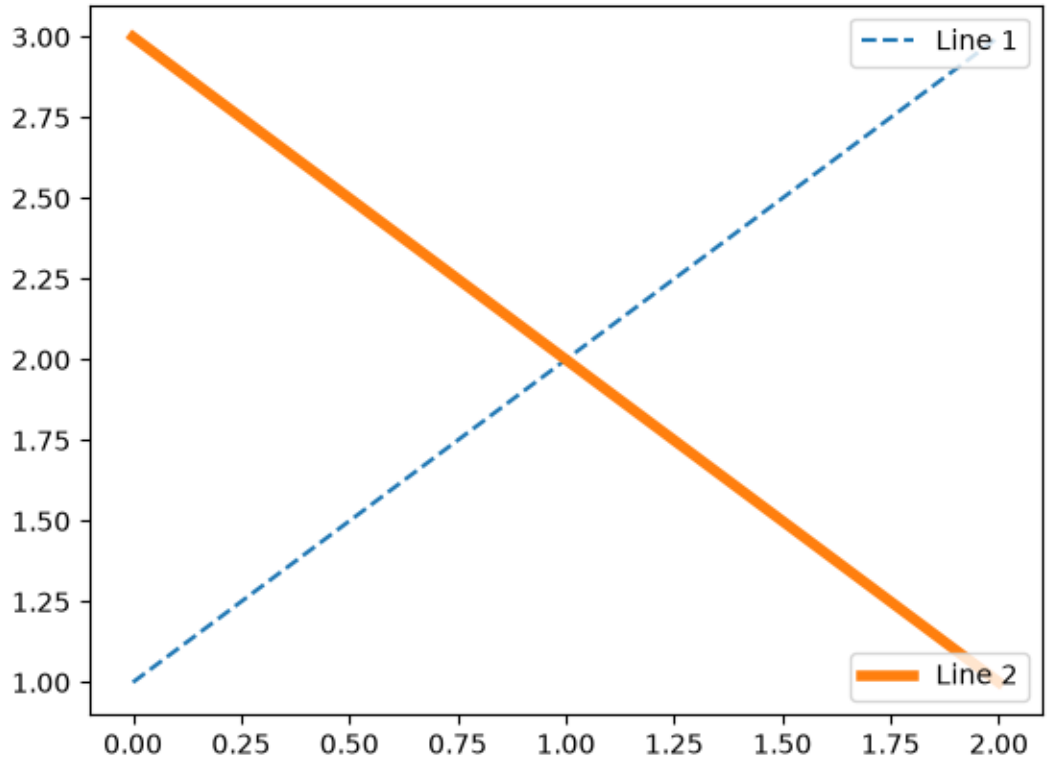
- 
outside upper left
TEST
outside upper center
TEST
outside upper right
TEST
2.0
1.8
1.6
1.4
1.2
1.0
1.0
1.2
1.4
1.6
1.8
2.0
outside lower left
TEST
outside lower center
TEST
outside lower right
TEST

- 
outside left upper
test
outside left center
test
outside left lower
test
2.0
1.8
1.6
1.4
1.2
1.0
1.0
1.2
1.4
1.6
1.8
2.0
outside right upper
test
outside right center
test
outside right lower
test

Multiple legends on the same Axes

Sometimes it is more clear to split legend entries across multiple legends. Whilst the instinctive approach to doing this might be to call the *legend()* function multiple times, you will find that only one legend ever exists on the Axes. This has been done so that it is possible to call *legend()* repeatedly to update the legend to the latest handles on the Axes. To keep old legend instances, we must add them manually to the Axes:

```
fig, ax = plt.subplots()
line1, = ax.plot([1, 2, 3], label="Line 1", linestyle='--')
line2, = ax.plot([3, 2, 1], label="Line 2", linewidth=4)

# Create a legend for the first line.
first_legend = ax.legend(handles=[line1], loc='upper right')

# Add the legend manually to the Axes.
ax.add_artist(first_legend)

# Create another legend for the second line.
ax.legend(handles=[line2], loc='lower right')

plt.show()
```



Legend handlers

In order to create legend entries, handles are given as an argument to an appropriate *HandlerBase* subclass. The choice of handler subclass is determined by the following rules:

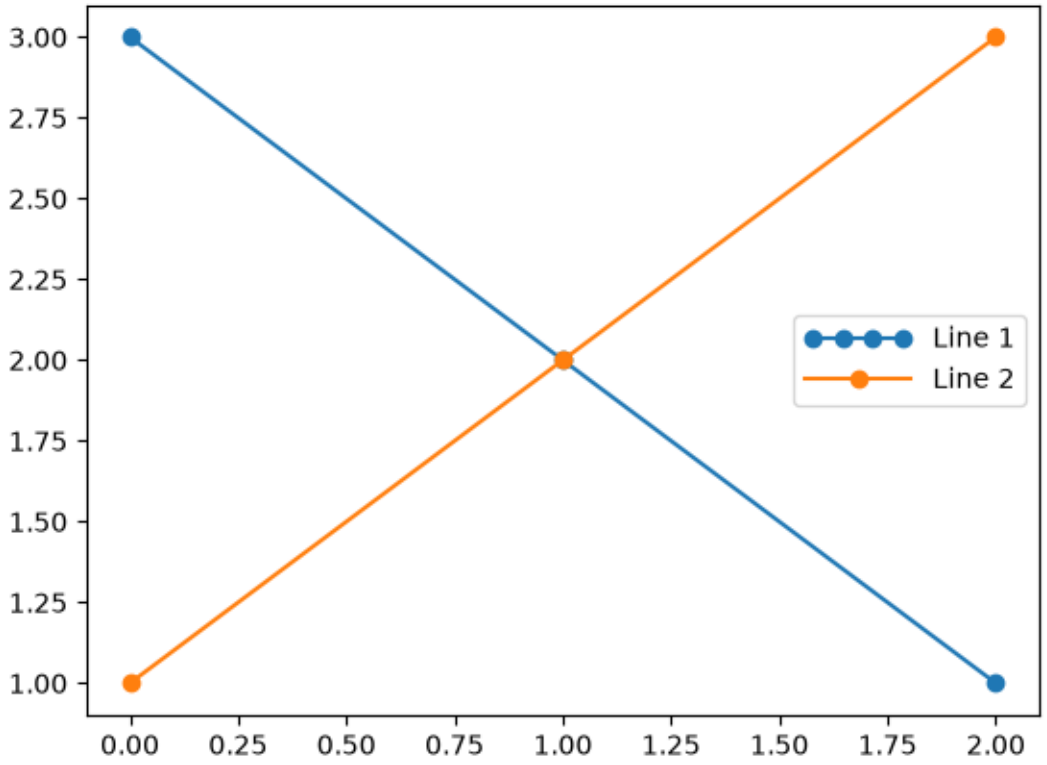
1. Update *get_legend_handler_map()* with the value in the handler_map keyword.
2. Check if the handle is in the newly created handler_map.
3. Check if the type of handle is in the newly created handler_map.
4. Check if any of the types in the handle's mro is in the newly created handler_map.

For completeness, this logic is mostly implemented in *get_legend_handler()*.

All of this flexibility means that we have the necessary hooks to implement custom handlers for our own type of legend key.

The simplest example of using custom handlers is to instantiate one of the existing *legend_handler.HandlerBase* subclasses. For the sake of simplicity, let's choose *legend_handler.HandlerLine2D* which accepts a *numpoints* argument (numpoints is also a keyword on the *legend()* function for convenience). We can then pass the mapping of instance to Handler as a keyword to legend.

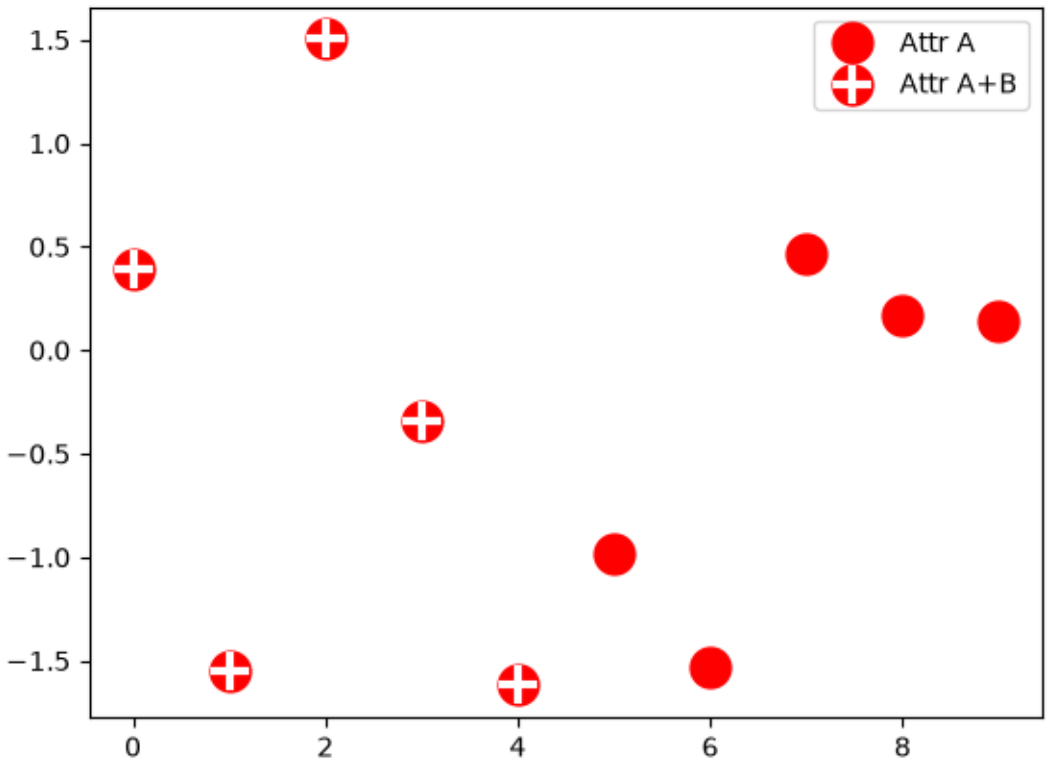
```
from matplotlib.legend_handler import HandlerLine2D

fig, ax = plt.subplots()
line1, = ax.plot([3, 2, 1], marker='o', label='Line 1')
line2, = ax.plot([1, 2, 3], marker='o', label='Line 2')

ax.legend(handler_map={line1: HandlerLine2D(numpoints=4)},␣
 ↪handlelength=4)
```



As you can see, "Line 1" now has 4 marker points, where "Line 2" has 2 (the default). We have also increased the length of the handles with the `handlelength` keyword to fit the larger legend entry. Try the above code, only change the map's key from `line1` to `type(line1)`. Notice how now both *`Line2D`* instances get 4 markers.

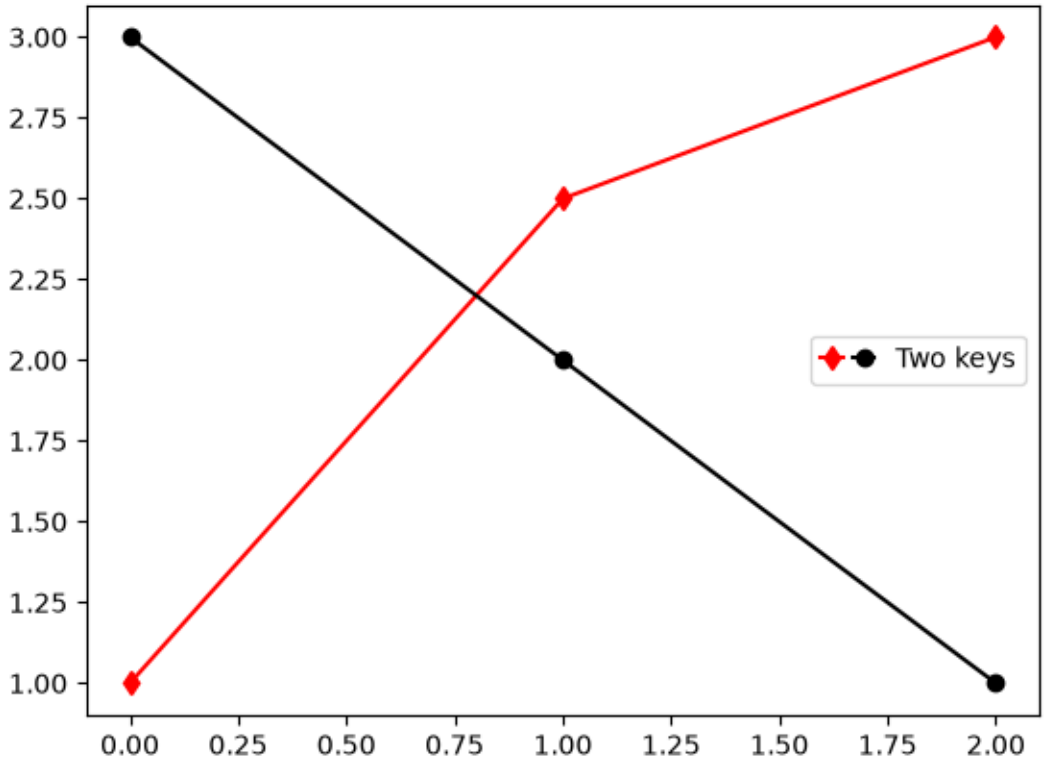
Along with handlers for complex plot types such as errorbars, stem plots and histograms, the default `handler_map` has a special `tuple` handler (*`legend_handler.HandlerTuple`*) which simply plots the handles on top of one another for each item in the given tuple. The following example demonstrates combining two legend keys on top of one another:

```
from numpy.random import randn

z = randn(10)

fig, ax = plt.subplots()
red_dot, = ax.plot(z, "ro", markersize=15)
# Put a white cross over some of the data.
white_cross, = ax.plot(z[:5], "w+", markeredgewidth=3, markersize=15)

ax.legend([red_dot, (red_dot, white_cross)], ["Attr A", "Attr A+B"])
```



The *legend_handler.HandlerTuple* class can also be used to assign several legend keys to the same entry:

```
from matplotlib.legend_handler import HandlerLine2D, HandlerTuple

fig, ax = plt.subplots()
p1, = ax.plot([1, 2.5, 3], 'r-d')
p2, = ax.plot([3, 2, 1], 'k-o')

l = ax.legend([(p1, p2)], ['Two keys'], numpoints=1,
              handler_map={tuple: HandlerTuple(ndivide=None)})
```



Implementing a custom legend handler

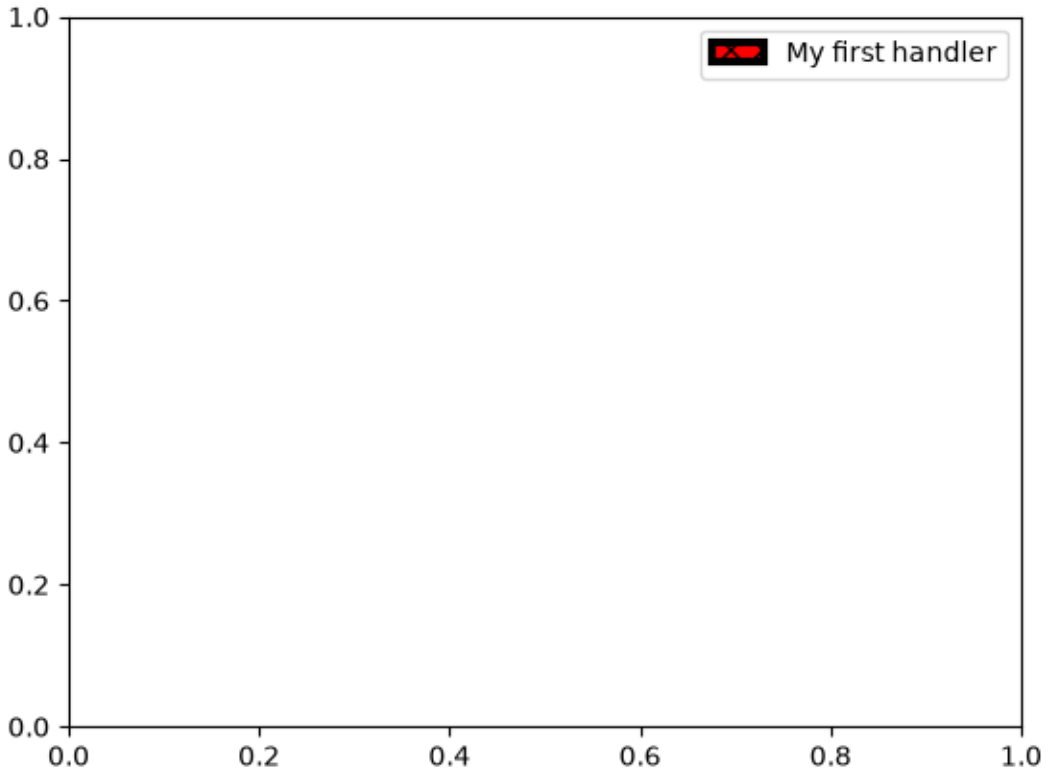
A custom handler can be implemented to turn any handle into a legend key (handles don't necessarily need to be matplotlib artists). The handler must implement a `legend_artist` method which returns a single artist for the legend to use. The required signature for `legend_artist` is documented at *`legend_artist`*.

```
import matplotlib.patches as mpatches


class AnyObject:
    pass


class AnyObjectHandler:
    def legend_artist(self, legend, orig_handle, fontsize, handlebox):
        x0, y0 = handlebox.xdescent, handlebox.ydescent
        width, height = handlebox.width, handlebox.height
        patch = mpatches.Rectangle([x0, y0], width, height, facecolor=
 ↪'red',
                                   edgecolor='black', hatch='xx', lw=3,
```

(continues on next page)

(continued from previous page)

```
                                    transform=handlebox.get_transform())
        handlebox.add_artist(patch)
        return patch

fig, ax = plt.subplots()

ax.legend([AnyObject()], ['My first handler'],
          handler_map={AnyObject: AnyObjectHandler()})
```



Alternatively, had we wanted to globally accept `AnyObject` instances without needing to manually set the *handler_map* keyword all the time, we could have registered the new handler with:

```
from matplotlib.legend import Legend
Legend.update_default_handler_map({AnyObject: AnyObjectHandler()})
```

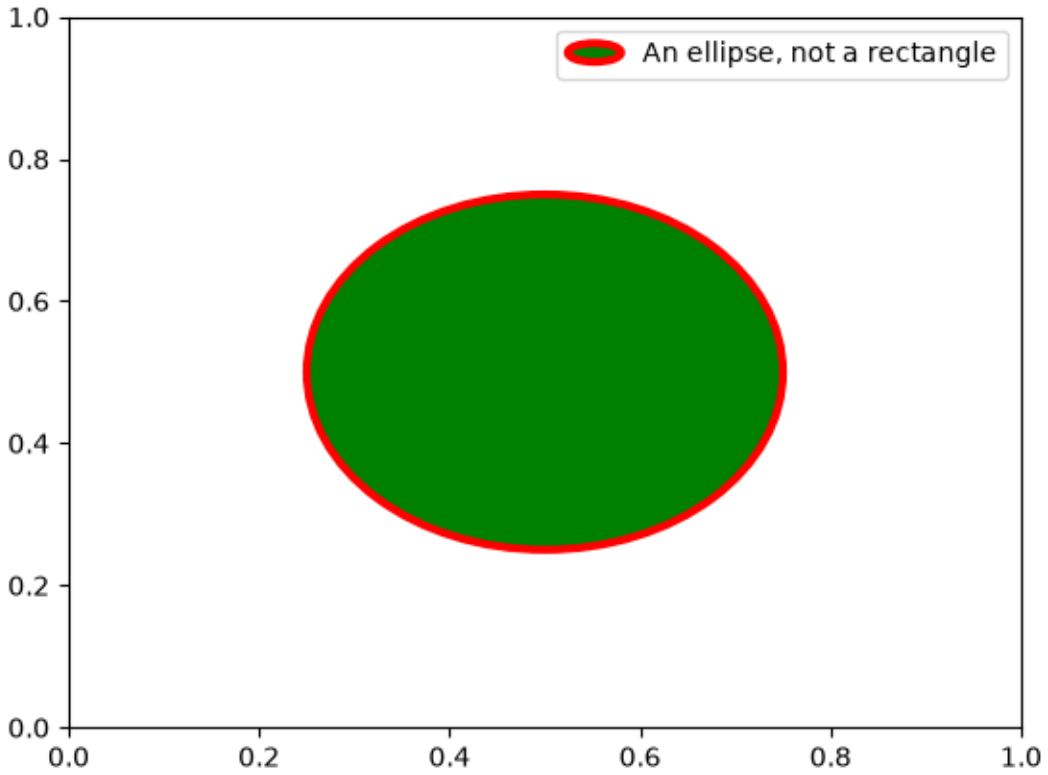
Whilst the power here is clear, remember that there are already many handlers implemented and what you want to achieve may already be easily possible with existing classes. For example, to produce elliptical legend keys, rather than rectangular ones:

```
from matplotlib.legend_handler import HandlerPatch
```

(continues on next page)

(continued from previous page)

```
class HandlerEllipse(HandlerPatch):
    def create_artists(self, legend, orig_handle,
                       xdescent, ydescent, width, height, fontsize,␣
 ↪trans):
        center = 0.5 * width - 0.5 * xdescent, 0.5 * height - 0.5 *␣
 ↪ydescent
        p = mpatches.Ellipse(xy=center, width=width + xdescent,
                             height=height + ydescent)
        self.update_prop(p, orig_handle, legend)
        p.set_transform(trans)
        return [p]


c = mpatches.Circle((0.5, 0.5), 0.25, facecolor="green",
                    edgecolor="red", linewidth=3)

fig, ax = plt.subplots()

ax.add_patch(c)
ax.legend([c], ["An ellipse, not a rectangle"],
          handler_map={mpatches.Circle: HandlerEllipse()})
```



Total running time of the script: (0 minutes 3.566 seconds)

3.3.9 Complex and semantic figure composition (subplot_mosaic)

Laying out Axes in a Figure in a non-uniform grid can be both tedious and verbose. For dense, even grids we have `Figure.subplots` but for more complex layouts, such as Axes that span multiple columns / rows of the layout or leave some areas of the Figure blank, you can use `gridspec.GridSpec` (see *Arranging multiple Axes in a Figure*) or manually place your Axes. `Figure.subplot_mosaic` aims to provide an interface to visually lay out your Axes (as either ASCII art or nested lists) to streamline this process.

This interface naturally supports naming your Axes. `Figure.subplot_mosaic` returns a dictionary keyed on the labels used to lay out the Figure. By returning data structures with names, it is easier to write plotting code that is independent of the Figure layout.

This is inspired by a proposed MEP and the patchwork library for R. While we do not implement the operator overloading style, we do provide a Pythonic API for specifying (nested) Axes layouts.

```
import matplotlib.pyplot as plt
import numpy as np


# Helper function used for visualization in the following examples
```

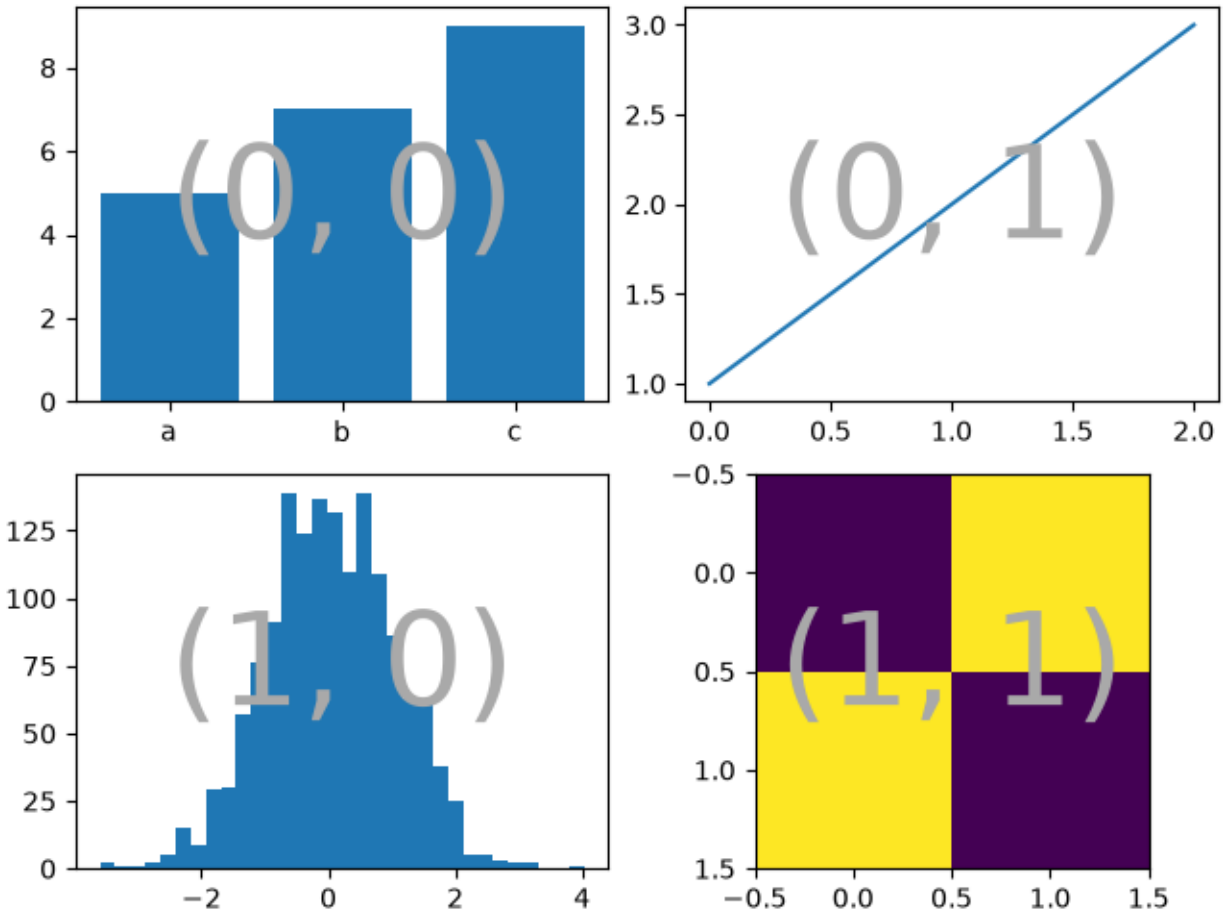
(continues on next page)

(continued from previous page)

```
def identify_axes(ax_dict, fontsize=48):
    """
    Helper to identify the Axes in the examples below.

    Draws the label in a large font in the center of the Axes.

    Parameters
    ----------
    ax_dict : dict[str, Axes]
        Mapping between the title / label and the Axes.
    fontsize : int, optional
        How big the label should be.
    """
    kw = dict(ha="center", va="center", fontsize=fontsize, color=
 ↪"darkgrey")
    for k, ax in ax_dict.items():
        ax.text(0.5, 0.5, k, transform=ax.transAxes, **kw)
```

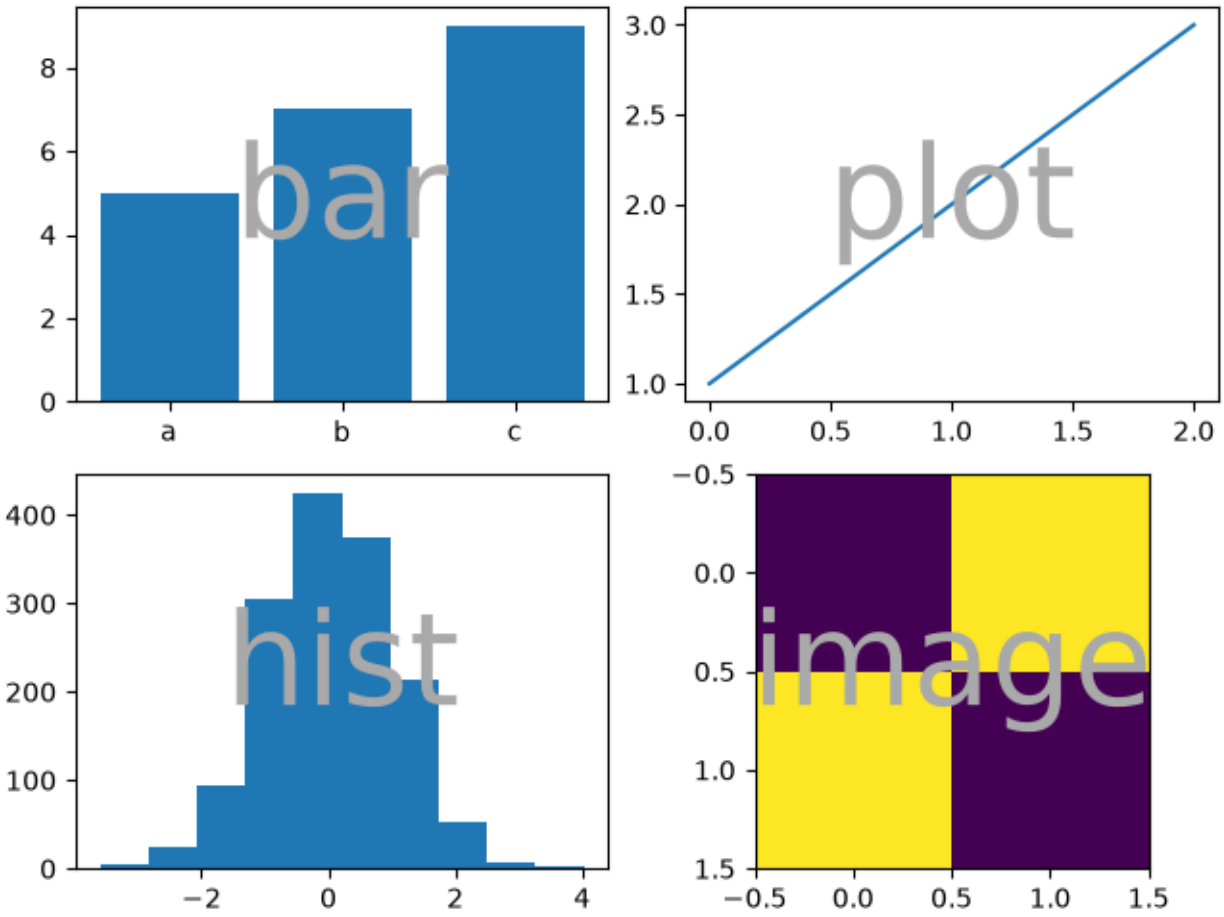
If we want a 2x2 grid we can use *`Figure.subplots`* which returns a 2D array of *`axes.Axes`* which we can index into to do our plotting.

```
np.random.seed(19680801)
hist_data = np.random.randn(1_500)


fig = plt.figure(layout="constrained")
ax_array = fig.subplots(2, 2, squeeze=False)

ax_array[0, 0].bar(["a", "b", "c"], [5, 7, 9])
ax_array[0, 1].plot([1, 2, 3])
ax_array[1, 0].hist(hist_data, bins="auto")
ax_array[1, 1].imshow([[1, 2], [2, 1]])

identify_axes(
    {(j, k): a for j, r in enumerate(ax_array) for k, a in␣
 ↪enumerate(r)},
)
```



Using *Figure.subplot_mosaic* we can produce the same mosaic but give the Axes semantic names

```
fig = plt.figure(layout="constrained")
ax_dict = fig.subplot_mosaic(
    [
        ["bar", "plot"],
        ["hist", "image"],
    ],
)
ax_dict["bar"].bar(["a", "b", "c"], [5, 7, 9])
ax_dict["plot"].plot([1, 2, 3])
ax_dict["hist"].hist(hist_data)
ax_dict["image"].imshow([[1, 2], [2, 1]])
identify_axes(ax_dict)
```



A key difference between *Figure.subplots* and *Figure.subplot_mosaic* is the return value. While the former returns an array for index access, the latter returns a dictionary mapping the labels to the *axes.Axes* instances created

```
print(ax_dict)
```

```
{'bar': <Axes: label='bar'>, 'plot': <Axes: label='plot'>, 'hist':
 ↪<Axes: label='hist'>, 'image': <Axes: label='image'>}
```

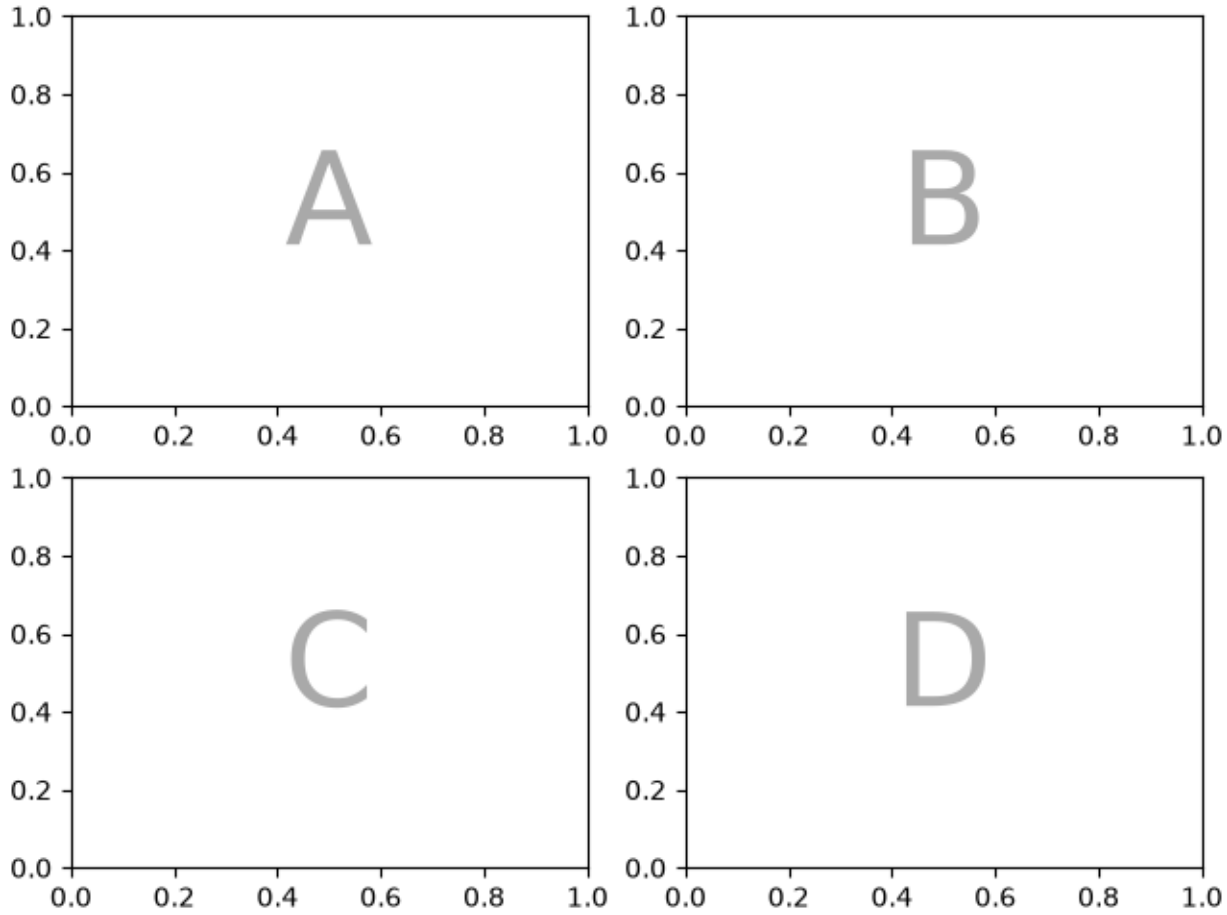
String short-hand

By restricting our Axes labels to single characters we can "draw" the Axes we want as "ASCII art". The following

```
mosaic = """
    AB
    CD
    """
```

will give us 4 Axes laid out in a 2x2 grid and generates the same figure mosaic as above (but now labeled with `{"A", "B", "C", "D"}` rather than `{"bar", "plot", "hist", "image"}`).

```
fig = plt.figure(layout="constrained")
ax_dict = fig.subplot_mosaic(mosaic)
identify_axes(ax_dict)
```

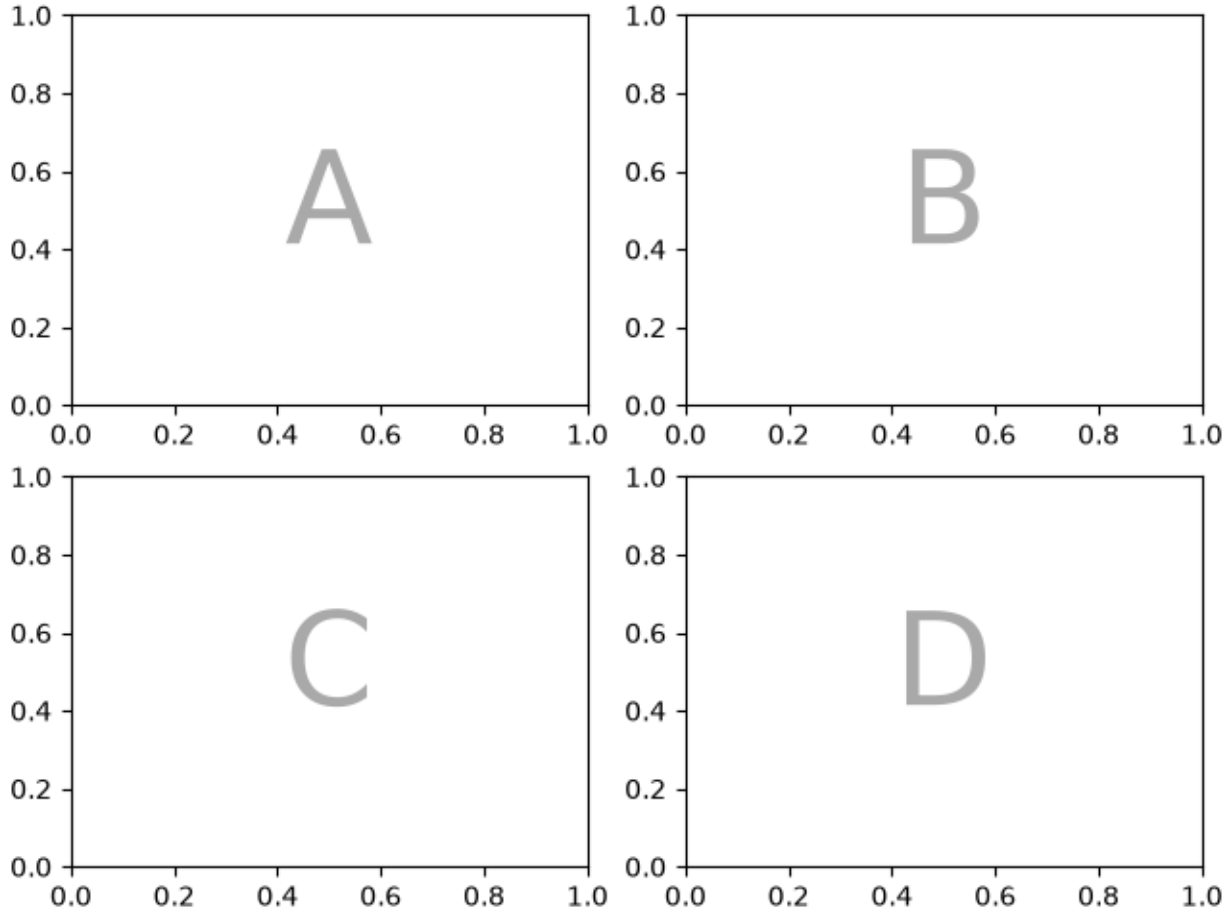


Alternatively, you can use the more compact string notation

```
mosaic = "AB;CD"
```

will give you the same composition, where the `";"` is used as the row separator instead of newline.

```
fig = plt.figure(layout="constrained")
ax_dict = fig.subplot_mosaic(mosaic)
identify_axes(ax_dict)
```

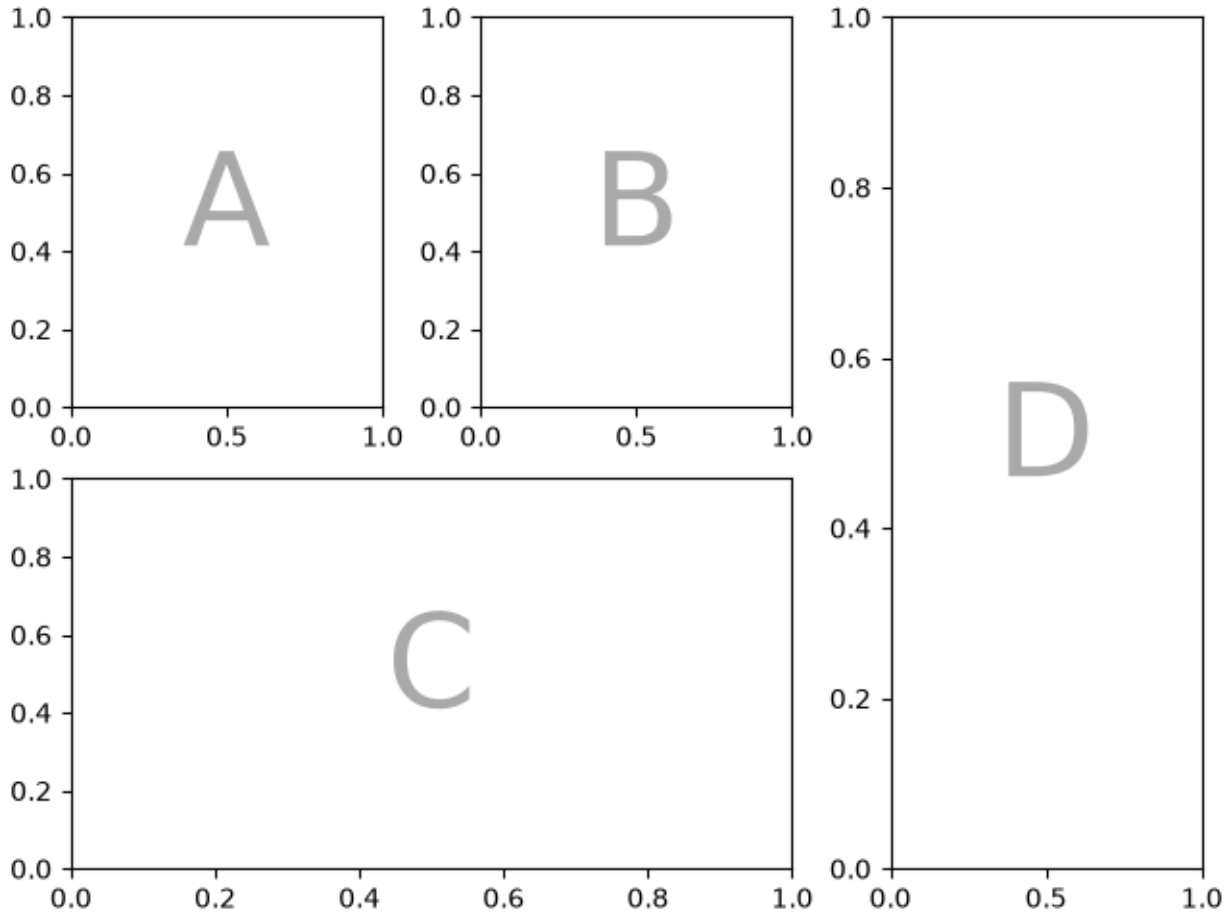


Axes spanning multiple rows/columns

Something we can do with *Figure.subplot_mosaic*, that we cannot do with *Figure.subplots*, is to specify that an Axes should span several rows or columns.

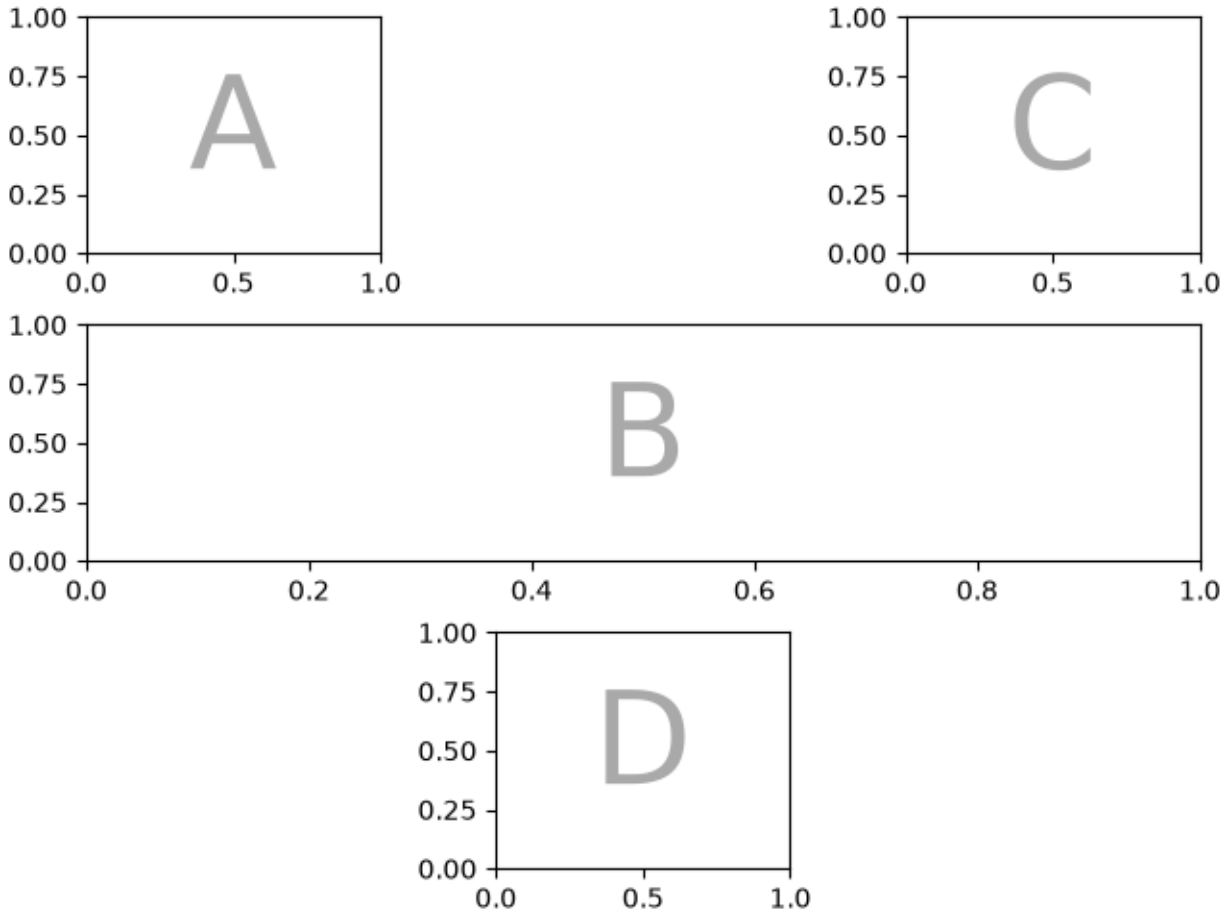
If we want to re-arrange our four Axes to have "C" be a horizontal span on the bottom and "D" be a vertical span on the right we would do

```
axd = plt.figure(layout="constrained").subplot_mosaic(
    """
    ABD
    CCD
    """
)
identify_axes(axd)
```



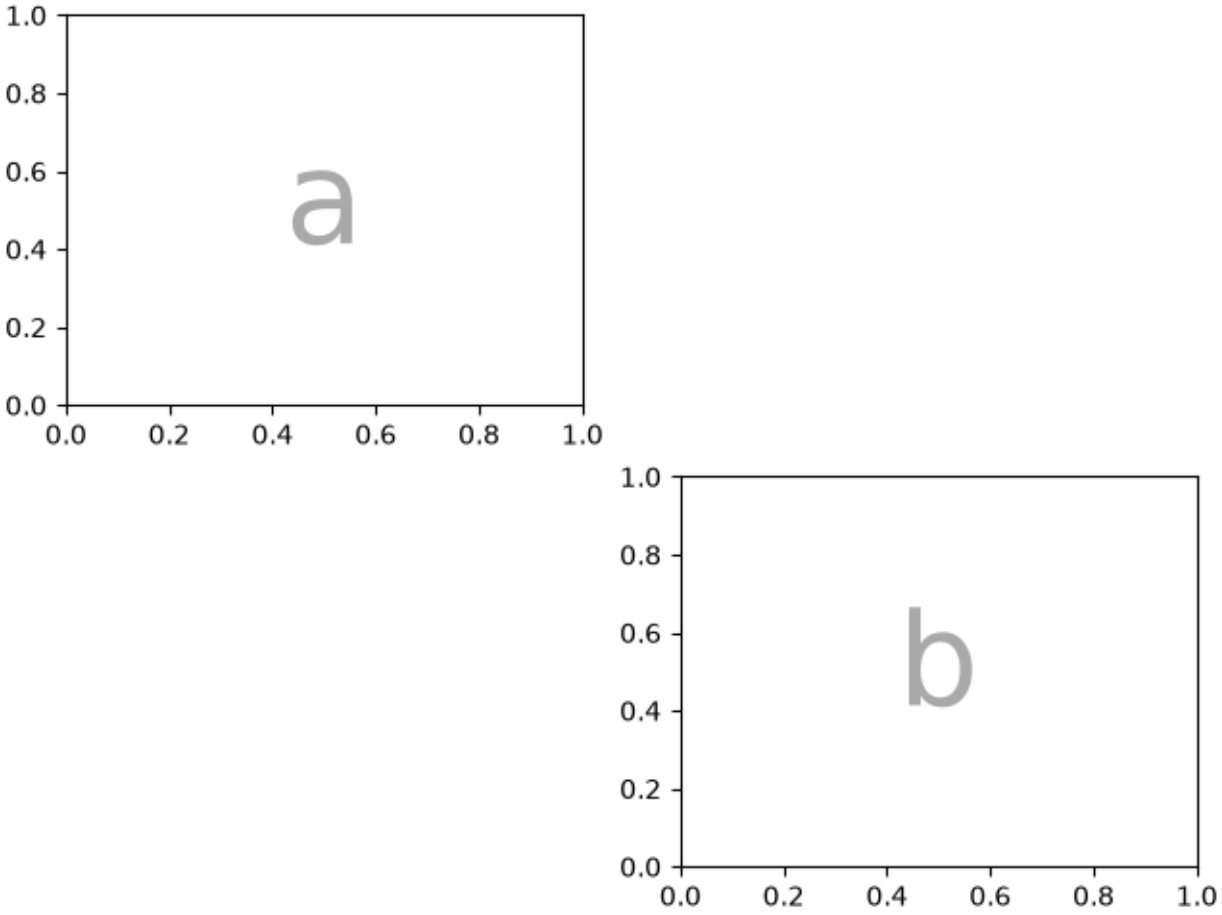
If we do not want to fill in all the spaces in the Figure with Axes, we can specify some spaces in the grid to be blank

```
axd = plt.figure(layout="constrained").subplot_mosaic(
    """
    A.C
    BBB
    .D.
    """
)
identify_axes(axd)
```



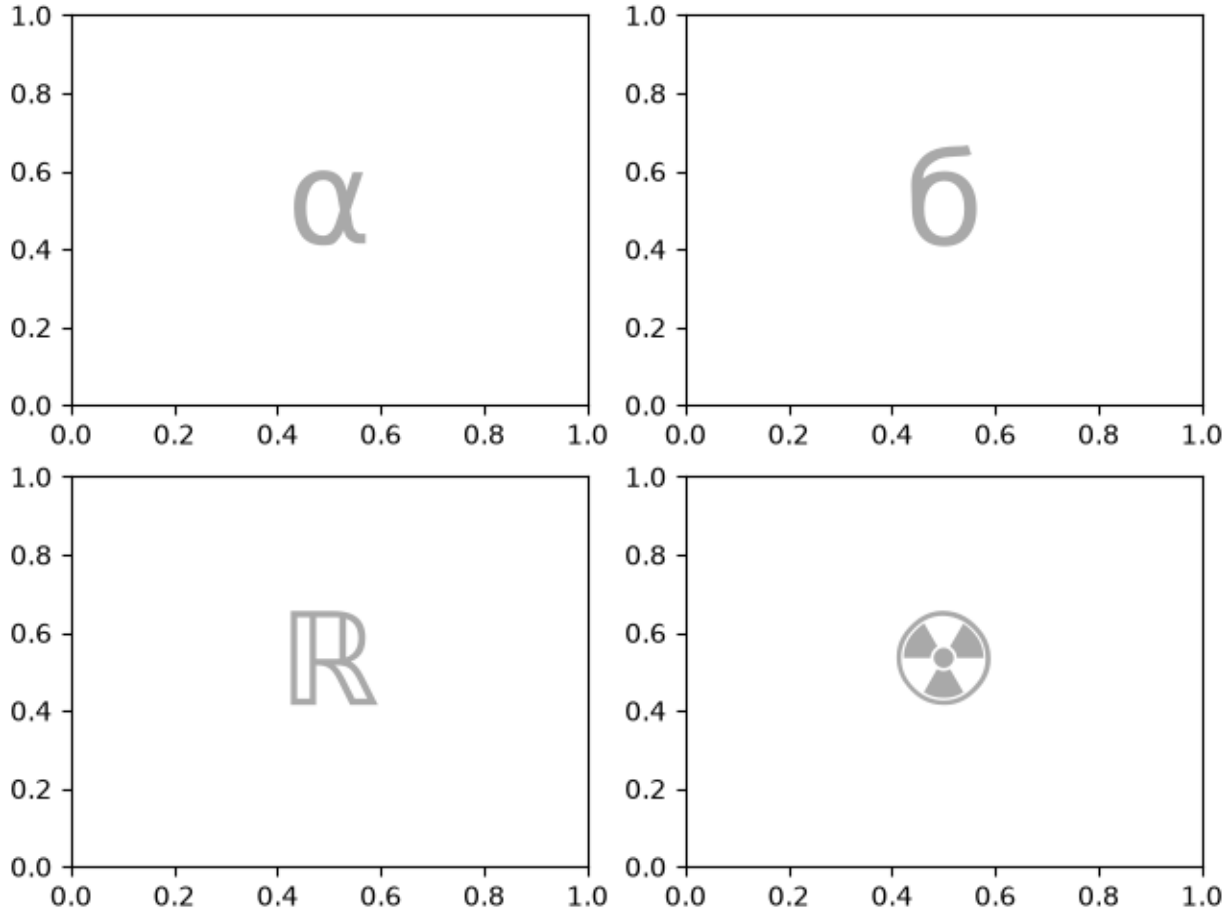
If we prefer to use another character (rather than a period `"."`) to mark the empty space, we can use *empty_sentinel* to specify the character to use.

```
axd = plt.figure(layout="constrained").subplot_mosaic(
    """
    aX
    Xb
    """,
    empty_sentinel="X",
)
identify_axes(axd)
```



Internally there is no meaning attached to the letters we use, any Unicode code point is valid!

```
axd = plt.figure(layout="constrained").subplot_mosaic(
    """аб
       R"""
)
identify_axes(axd)
```



It is not recommended to use white space as either a label or an empty sentinel with the string shorthand because it may be stripped while processing the input.

Controlling mosaic creation

This feature is built on top of *gridspec* and you can pass the keyword arguments through to the underlying *gridspec.GridSpec* (the same as *Figure.subplots*).

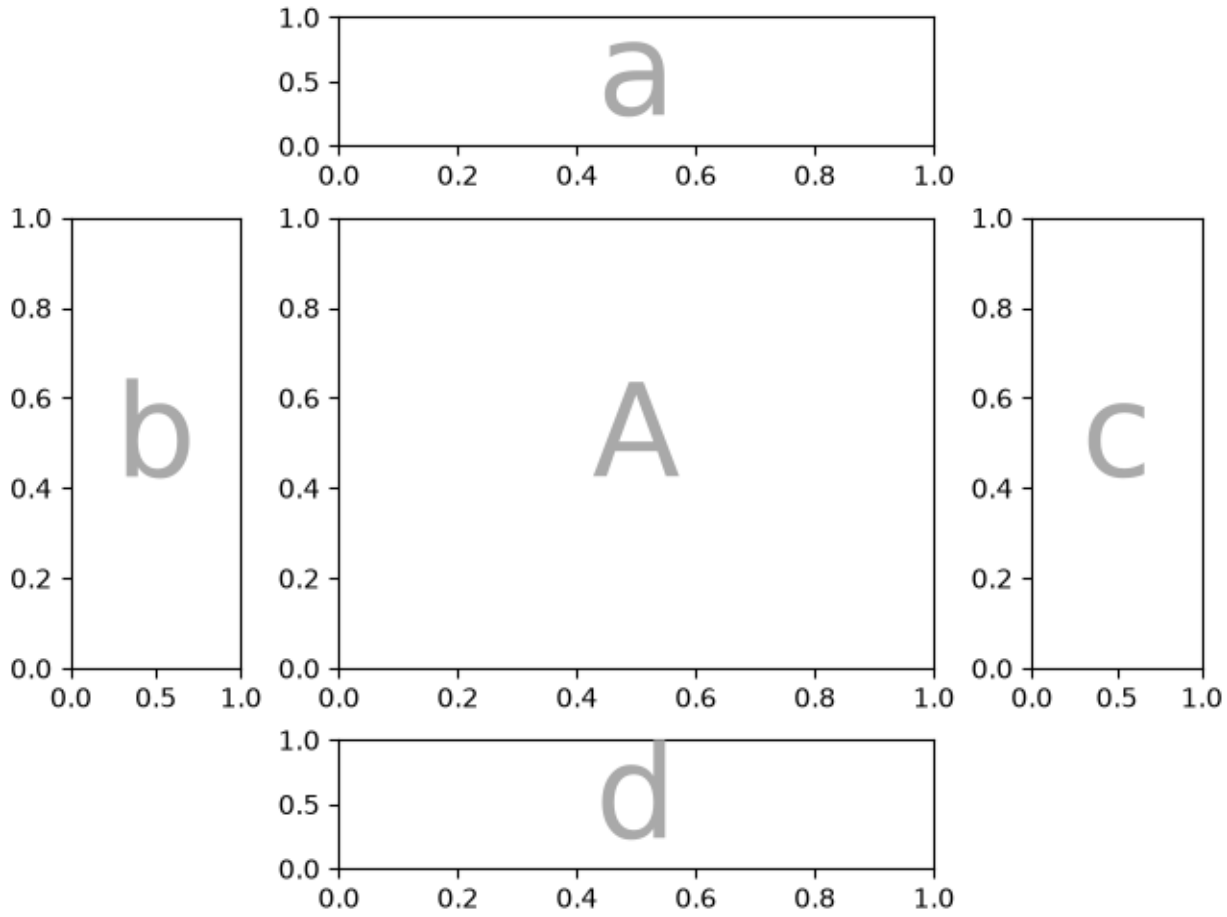
In this case we want to use the input to specify the arrangement, but set the relative widths of the rows / columns. For convenience, *gridspec.GridSpec*'s *height_ratios* and *width_ratios* are exposed in the *Figure.subplot_mosaic* calling sequence.

```
axd = plt.figure(layout="constrained").subplot_mosaic(
    """
    .a.
    bAc
    .d.
    """,
    # set the height ratios between the rows
    height_ratios=[1, 3.5, 1],
    # set the width ratios between the columns
    width_ratios=[1, 3.5, 1],
```

(continues on next page)

(continued from previous page)

```
)
identify_axes(axd)
```



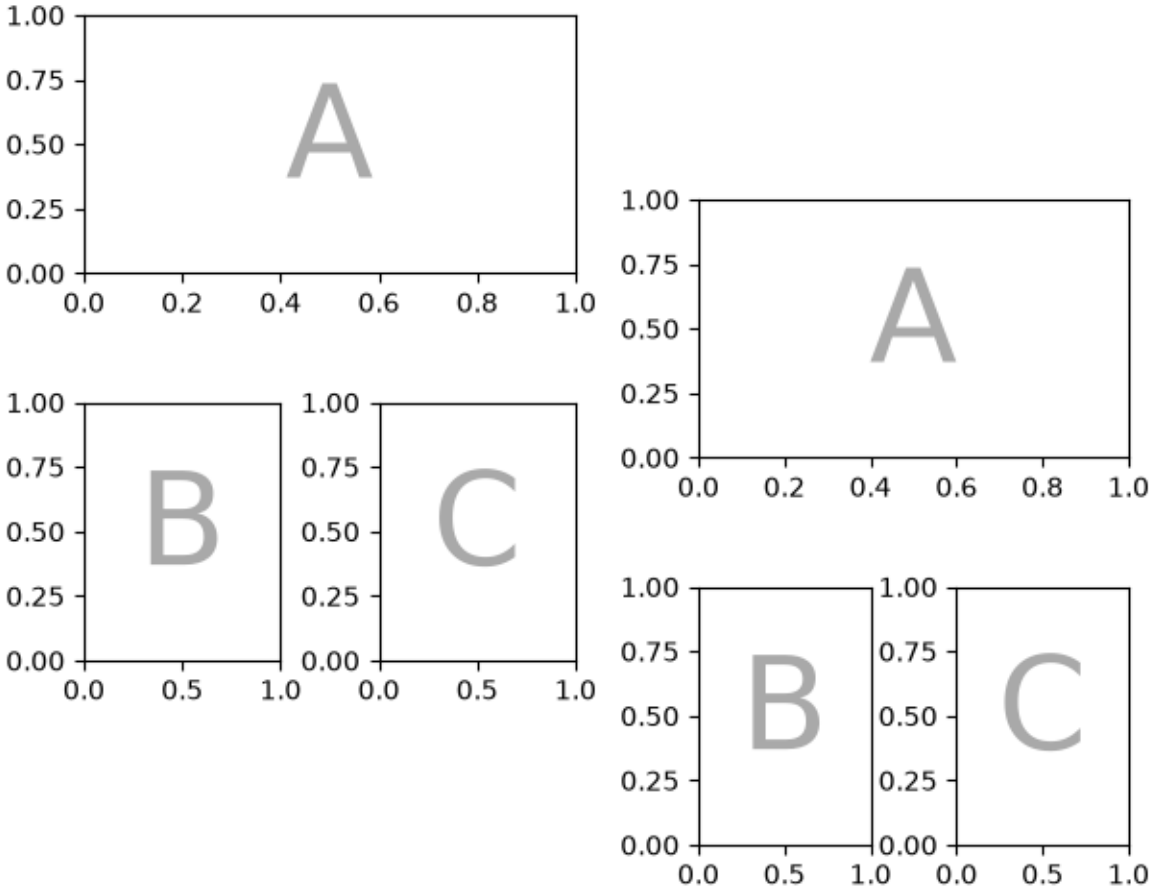
Other `gridspec.GridSpec` keywords can be passed via *gridspec_kw*. For example, use the {*left*, *right*, *bottom*, *top*} keyword arguments to position the overall mosaic to put multiple versions of the same mosaic in a figure.

```
mosaic = """AA
            BC"""
fig = plt.figure()
axd = fig.subplot_mosaic(
    mosaic,
    gridspec_kw={
        "bottom": 0.25,
        "top": 0.95,
        "left": 0.1,
        "right": 0.5,
        "wspace": 0.5,
        "hspace": 0.5,
    },
```

(continues on next page)

(continued from previous page)

```
)
identify_axes(axd)

axd = fig.subplot_mosaic(
    mosaic,
    gridspec_kw={
        "bottom": 0.05,
        "top": 0.75,
        "left": 0.6,
        "right": 0.95,
        "wspace": 0.5,
        "hspace": 0.5,
    },
)
identify_axes(axd)
```



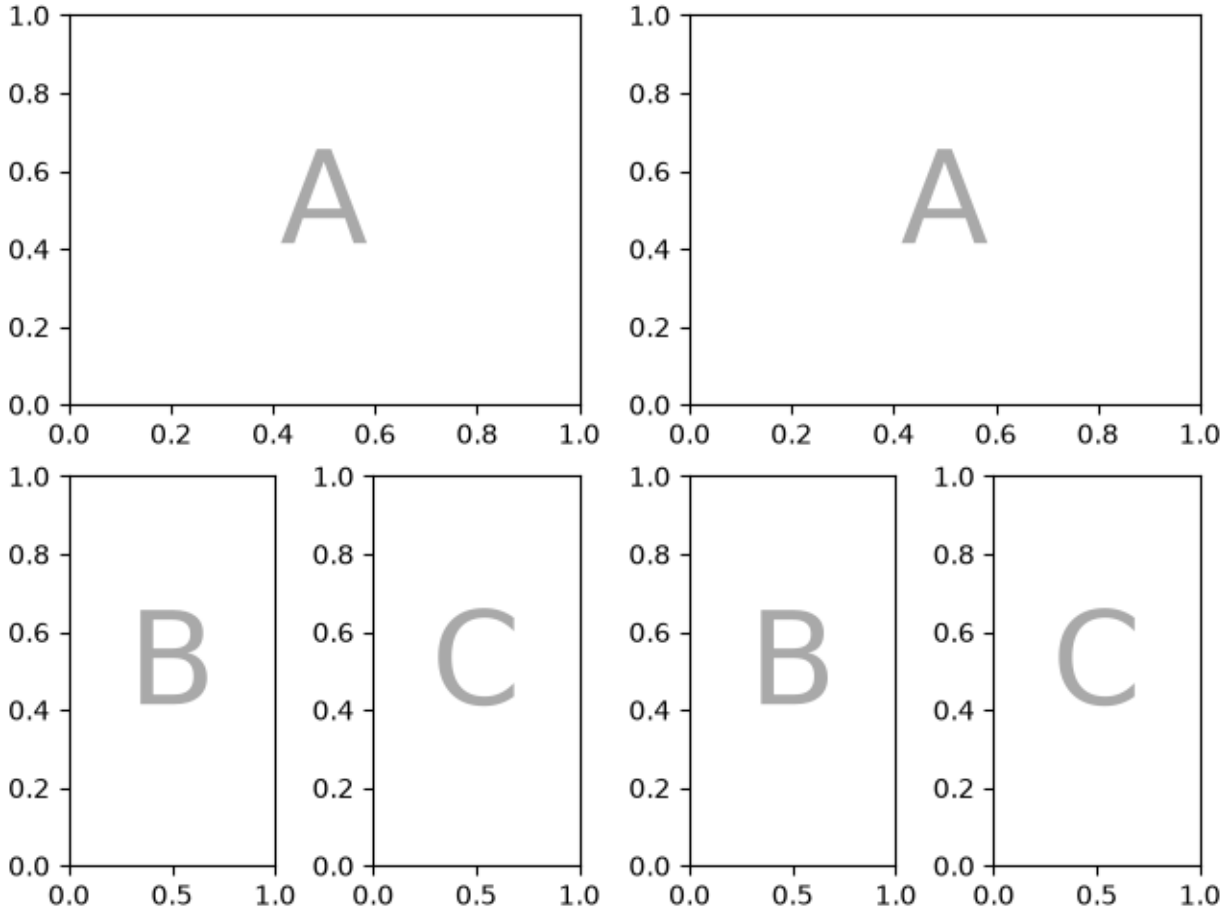
Alternatively, you can use the sub-Figure functionality:

```
mosaic = """AA
            BC"""
```

(continues on next page)

(continued from previous page)

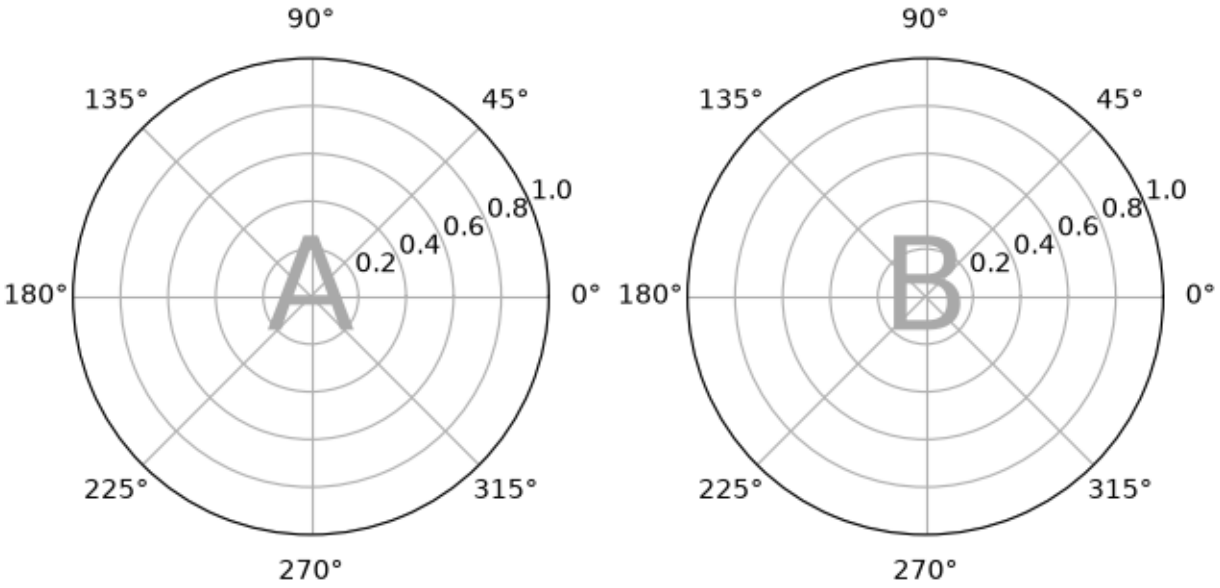
```
fig = plt.figure(layout="constrained")
left, right = fig.subfigures(nrows=1, ncols=2)
axd = left.subplot_mosaic(mosaic)
identify_axes(axd)

axd = right.subplot_mosaic(mosaic)
identify_axes(axd)
```



Controlling subplot creation

We can also pass through arguments used to create the subplots (again, the same as *Figure.subplots*) which will apply to all of the Axes created.

```
axd = plt.figure(layout="constrained").subplot_mosaic(
    "AB", subplot_kw={"projection": "polar"}
)
identify_axes(axd)
```

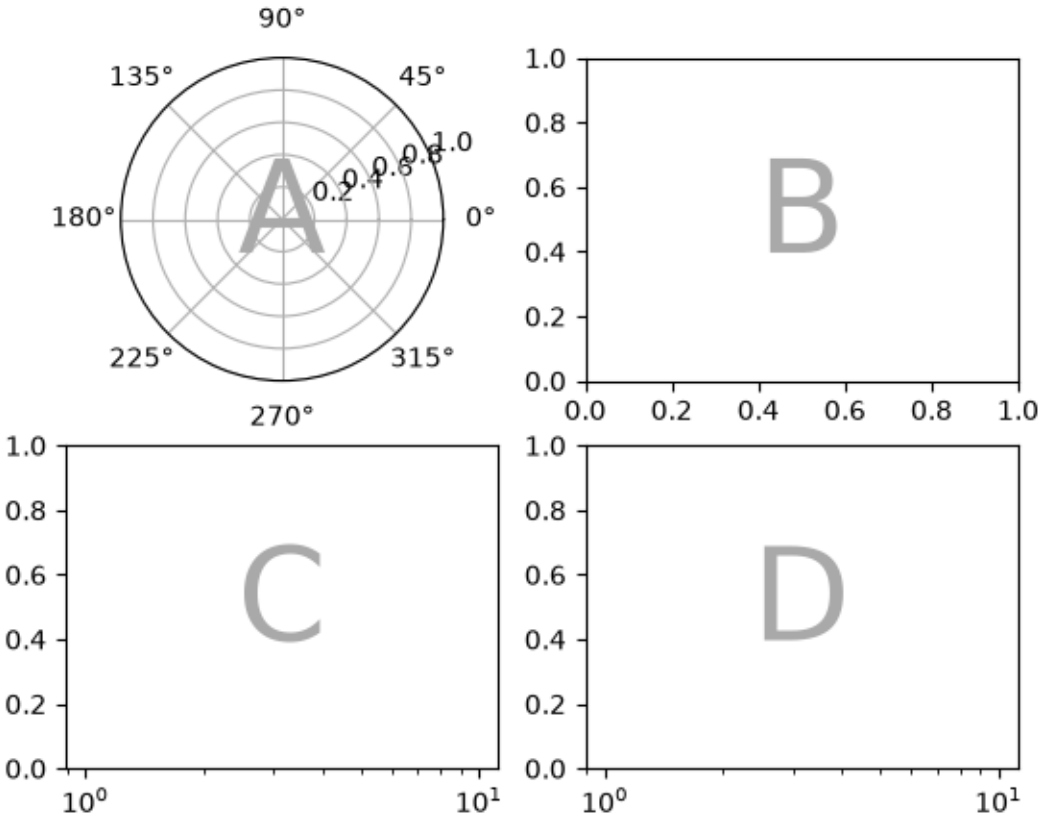


Per-Axes subplot keyword arguments

If you need to control the parameters passed to each subplot individually use *per_subplot_kw* to pass a mapping between the Axes identifiers (or tuples of Axes identifiers) to dictionaries of keywords to be passed.

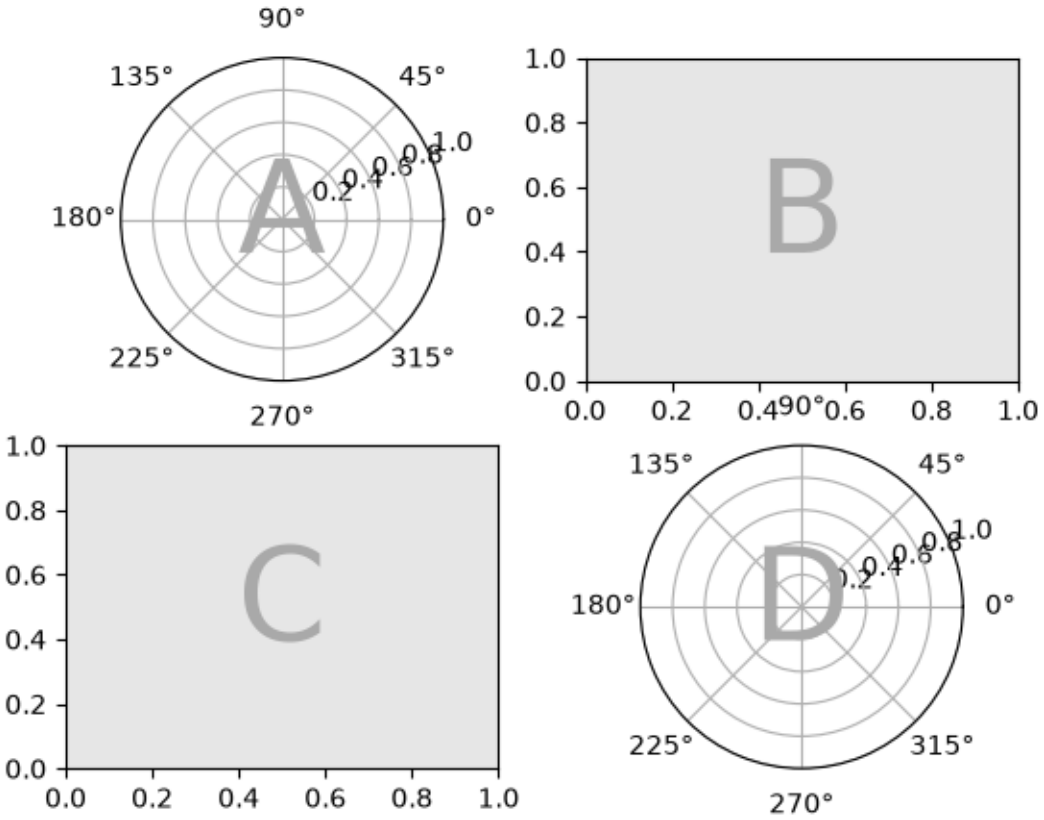
Added in version 3.7.

```
fig, axd = plt.subplot_mosaic(
    "AB;CD",
    per_subplot_kw={
        "A": {"projection": "polar"},
        ("C", "D"): {"xscale": "log"}
    },
)
identify_axes(axd)
```



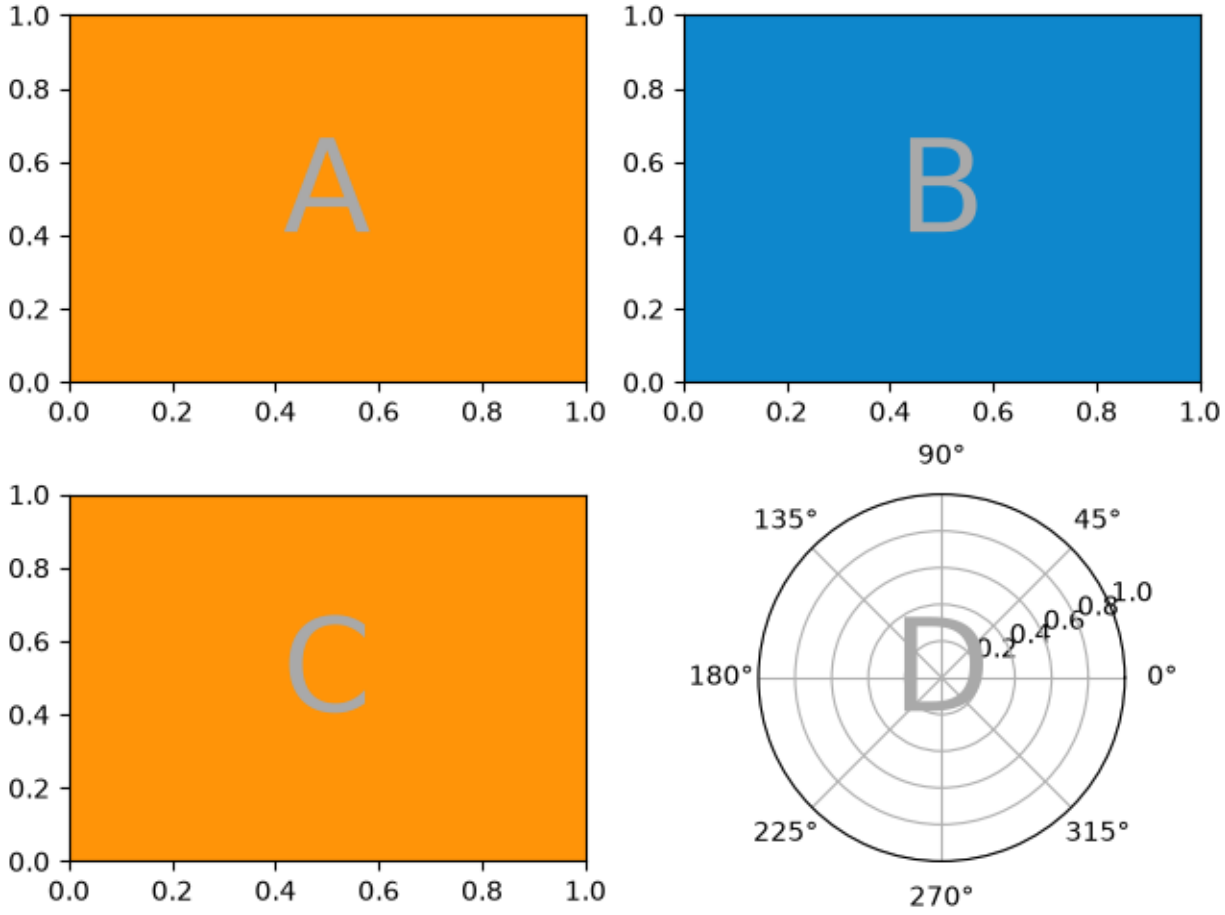
If the layout is specified with the string short-hand, then we know the Axes labels will be one character and can unambiguously interpret longer strings in *per_subplot_kw* to specify a set of Axes to apply the keywords to:

```
fig, axd = plt.subplot_mosaic(
    "AB;CD",
    per_subplot_kw={
        "AD": {"projection": "polar"},
        "BC": {"facecolor": ".9"}
    },
)
identify_axes(axd)
```



If *subplot_kw* and *per_subplot_kw* are used together, then they are merged with *per_subplot_kw* taking priority:

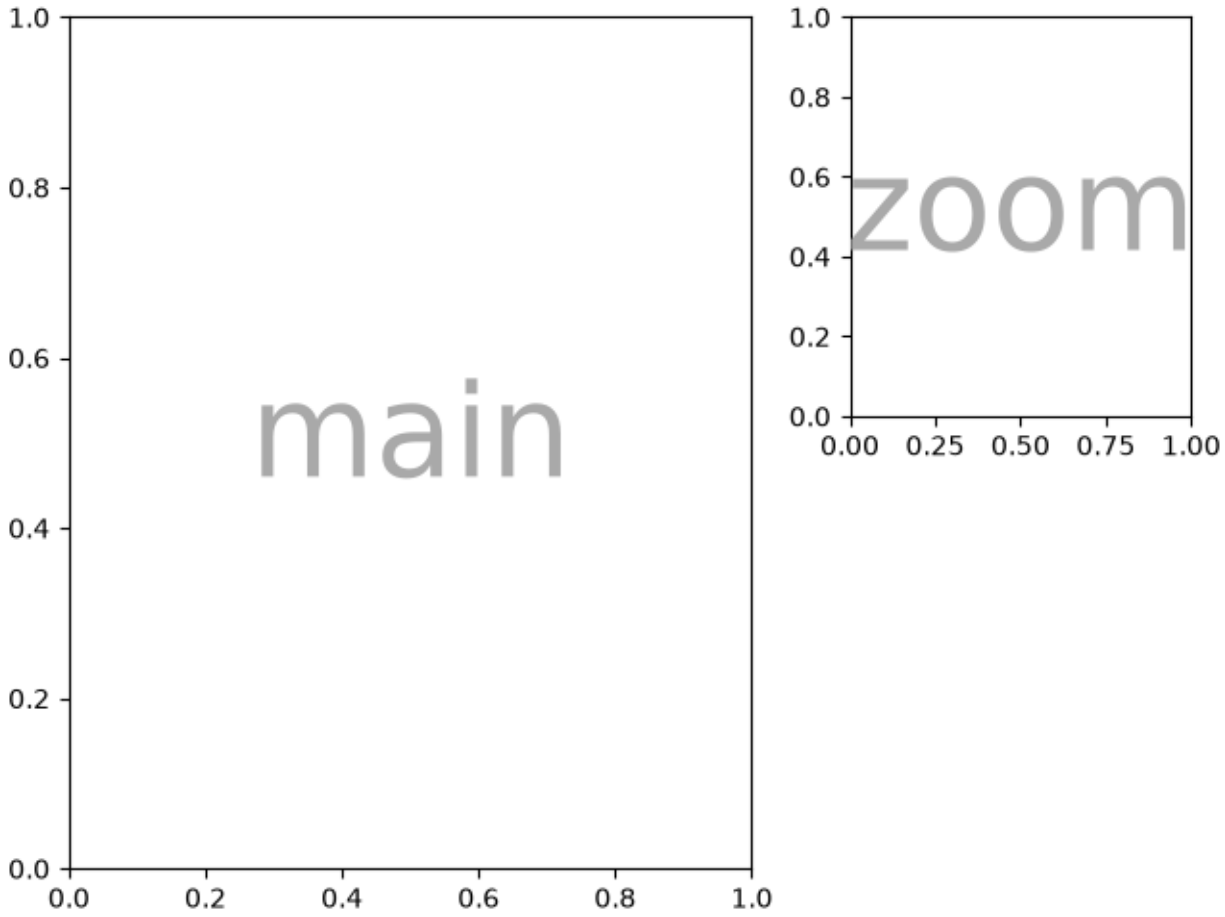
```
axd = plt.figure(layout="constrained").subplot_mosaic(
    "AB;CD",
    subplot_kw={"facecolor": "xkcd:tangerine"},
    per_subplot_kw={
        "B": {"facecolor": "xkcd:water blue"},
        "D": {"projection": "polar", "facecolor": "w"},
    }
)
identify_axes(axd)
```



Nested list input

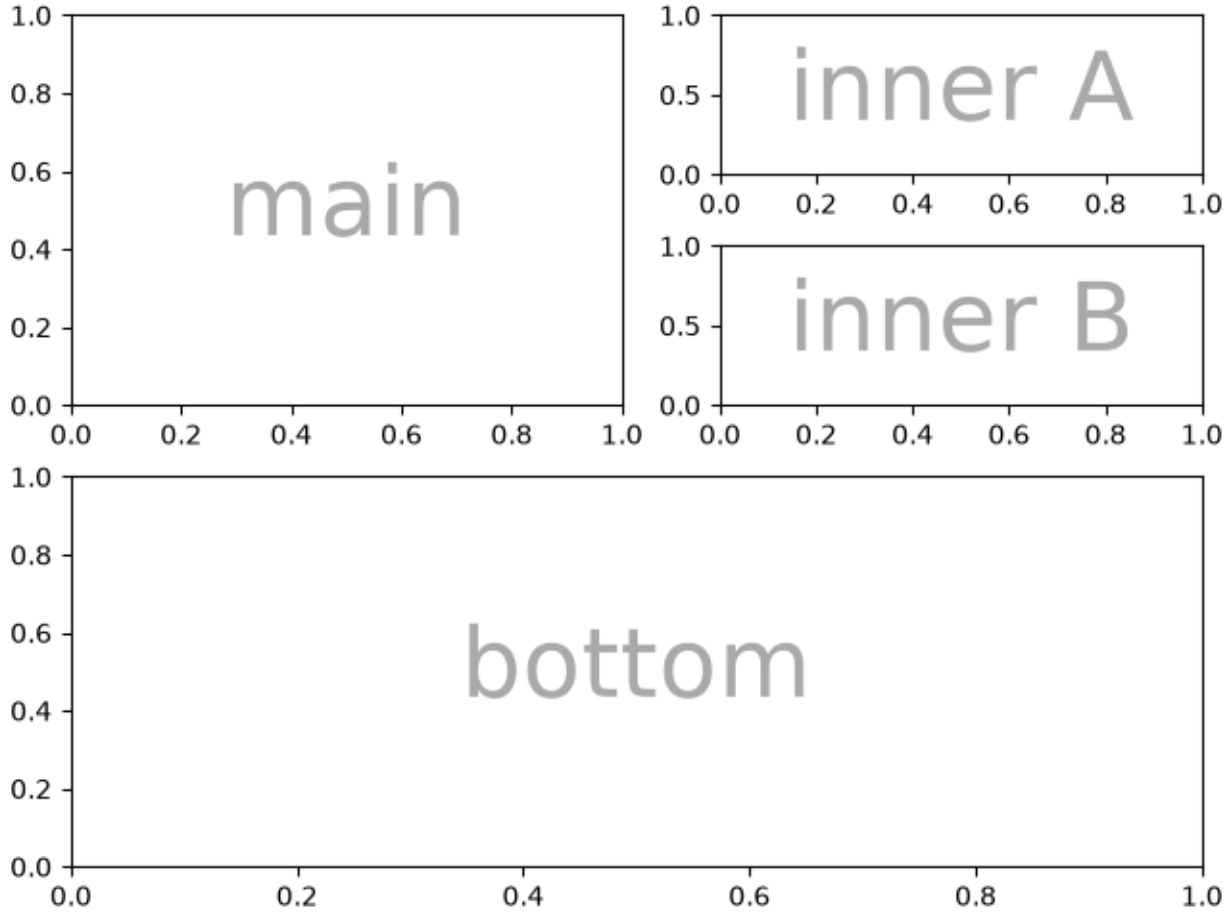
Everything we can do with the string shorthand we can also do when passing in a list (internally we convert the string shorthand to a nested list), for example using spans, blanks, and *gridspec_kw*:

```
axd = plt.figure(layout="constrained").subplot_mosaic(
    [
        ["main", "zoom"],
        ["main", "BLANK"],
    ],
    empty_sentinel="BLANK",
    width_ratios=[2, 1],
)
identify_axes(axd)
```



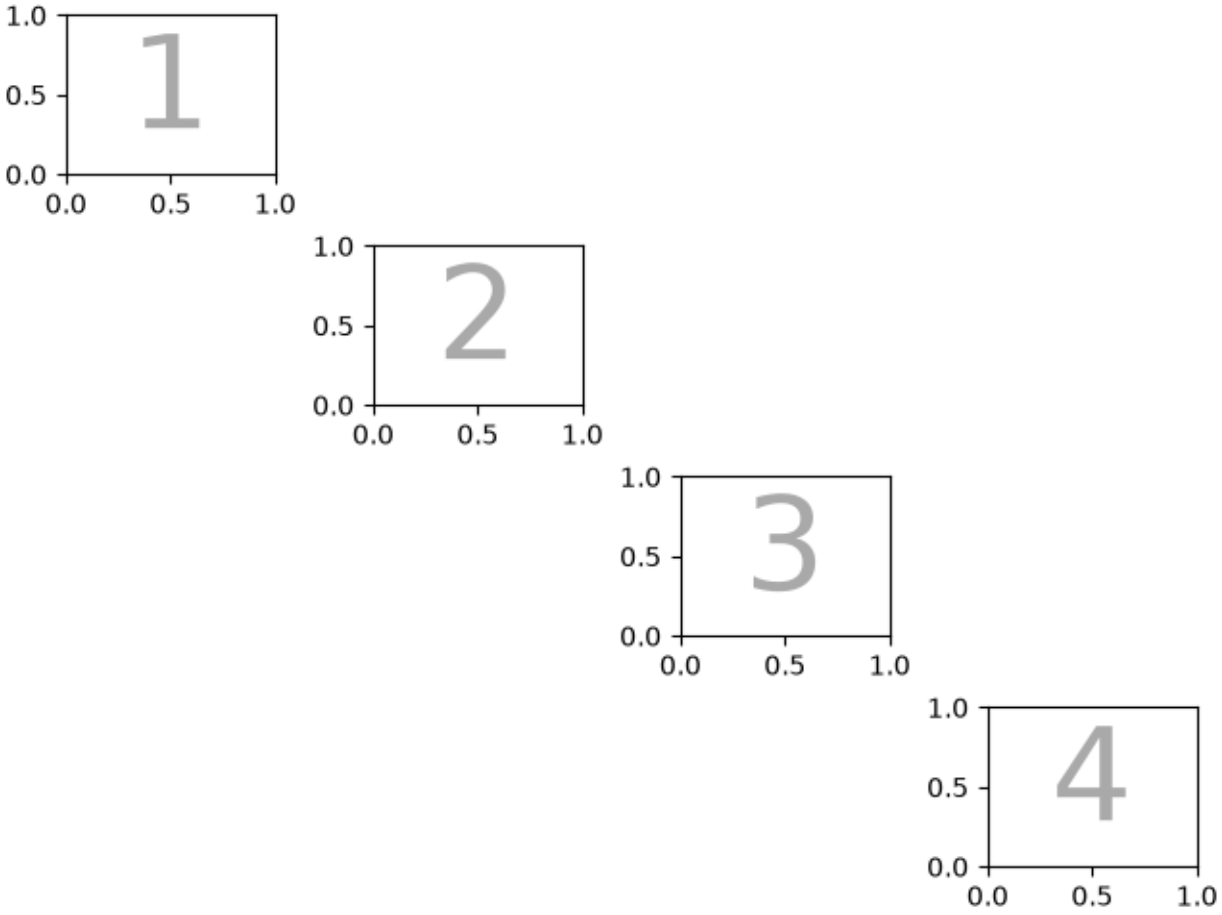
In addition, using the list input we can specify nested mosaics. Any element of the inner list can be another set of nested lists:

```
inner = [
    ["inner A"],
    ["inner B"],
]

outer_nested_mosaic = [
    ["main", inner],
    ["bottom", "bottom"],
]
axd = plt.figure(layout="constrained").subplot_mosaic(
    outer_nested_mosaic, empty_sentinel=None
)
identify_axes(axd, fontsize=36)
```



We can also pass in a 2D NumPy array to do things like

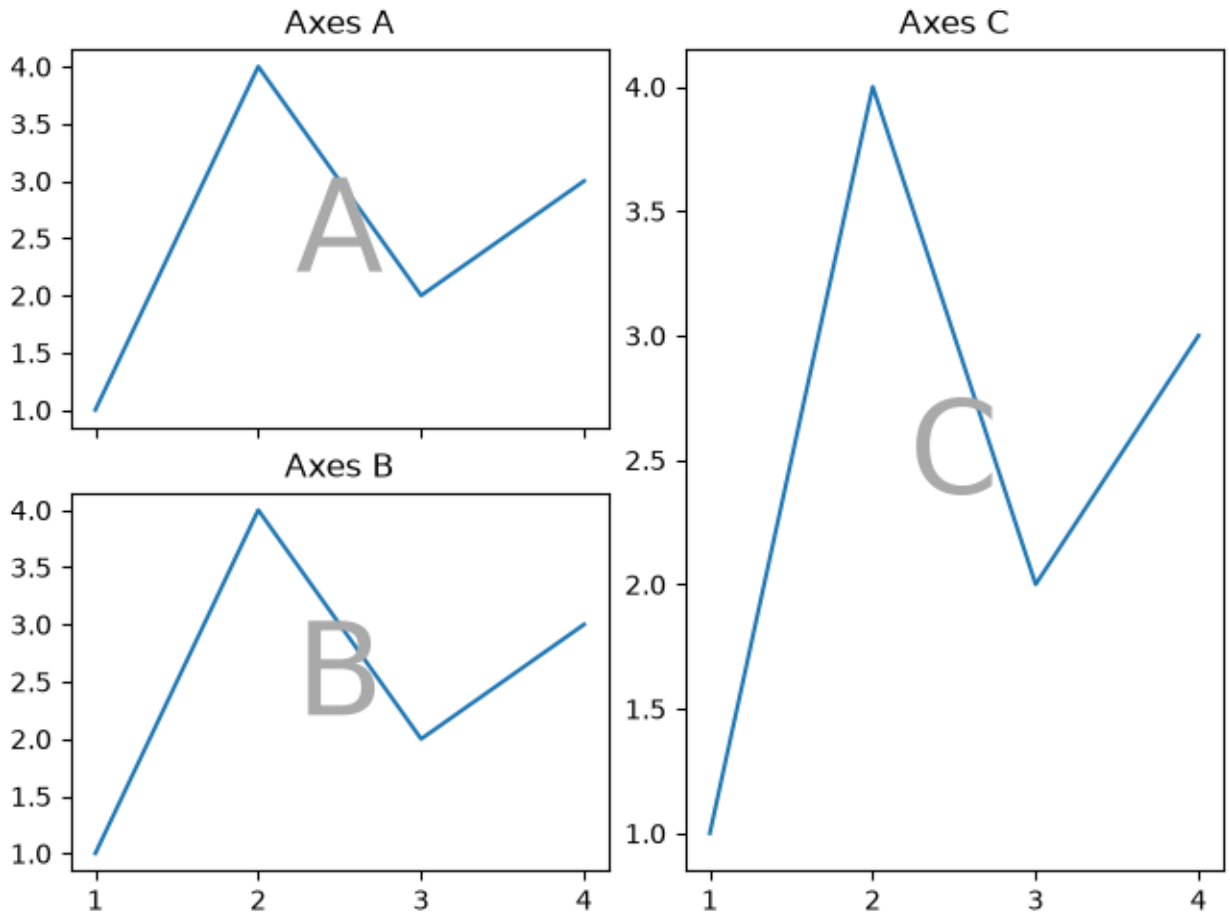
```
mosaic = np.zeros((4, 4), dtype=int)
for j in range(4):
    mosaic[j, j] = j + 1
axd = plt.figure(layout="constrained").subplot_mosaic(
    mosaic,
    empty_sentinel=0,
)
identify_axes(axd)
```



Axis sharing

Figure.subplot_mosaic supports *sharex* and *sharey* as does *Figure.subplots*. When `True`, all Axes in the mosaic share the same x-axis or y-axis, which is useful for directly comparing data across panels.

```
fig = plt.figure(layout="constrained")
axd = fig.subplot_mosaic("AC;BC", sharex=True)
axd["A"].set_title("Axes A")
axd["B"].set_title("Axes B")
axd["C"].set_title("Axes C")
for ax in axd.values():
    ax.plot([1, 2, 3, 4], [1, 4, 2, 3])
identify_axes(axd)
```

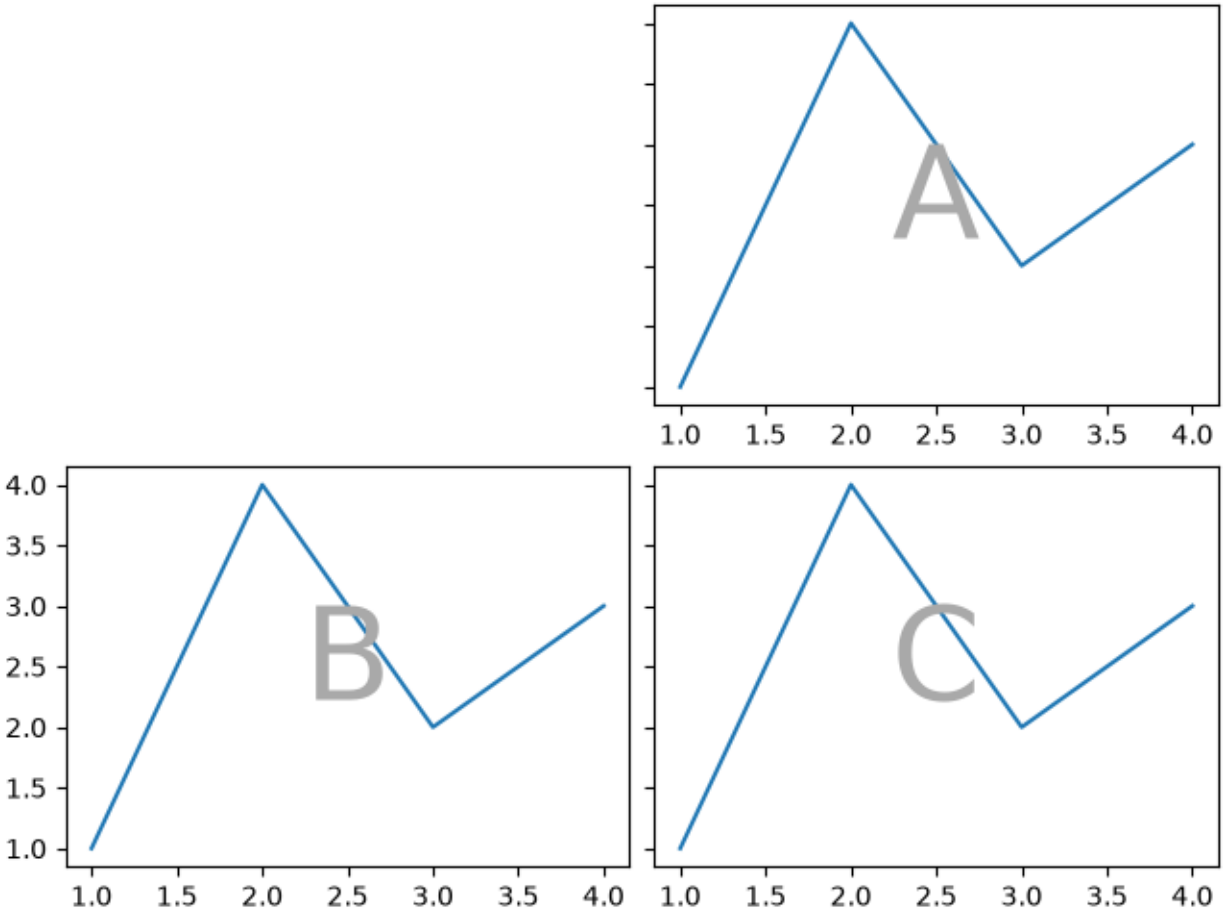


Note that when using `sharex=True` only the bottom row of Axes shows x-axis tick labels, and when using `sharey=True` only the left column shows y-axis tick labels. This is identical to the behavior of *`Figure.subplots`*.

Interaction with empty sentinels

When the mosaic layout has blank spaces (empty sentinels), axis sharing can produce inintended results. In the following example, there are no tick labels in the top row:

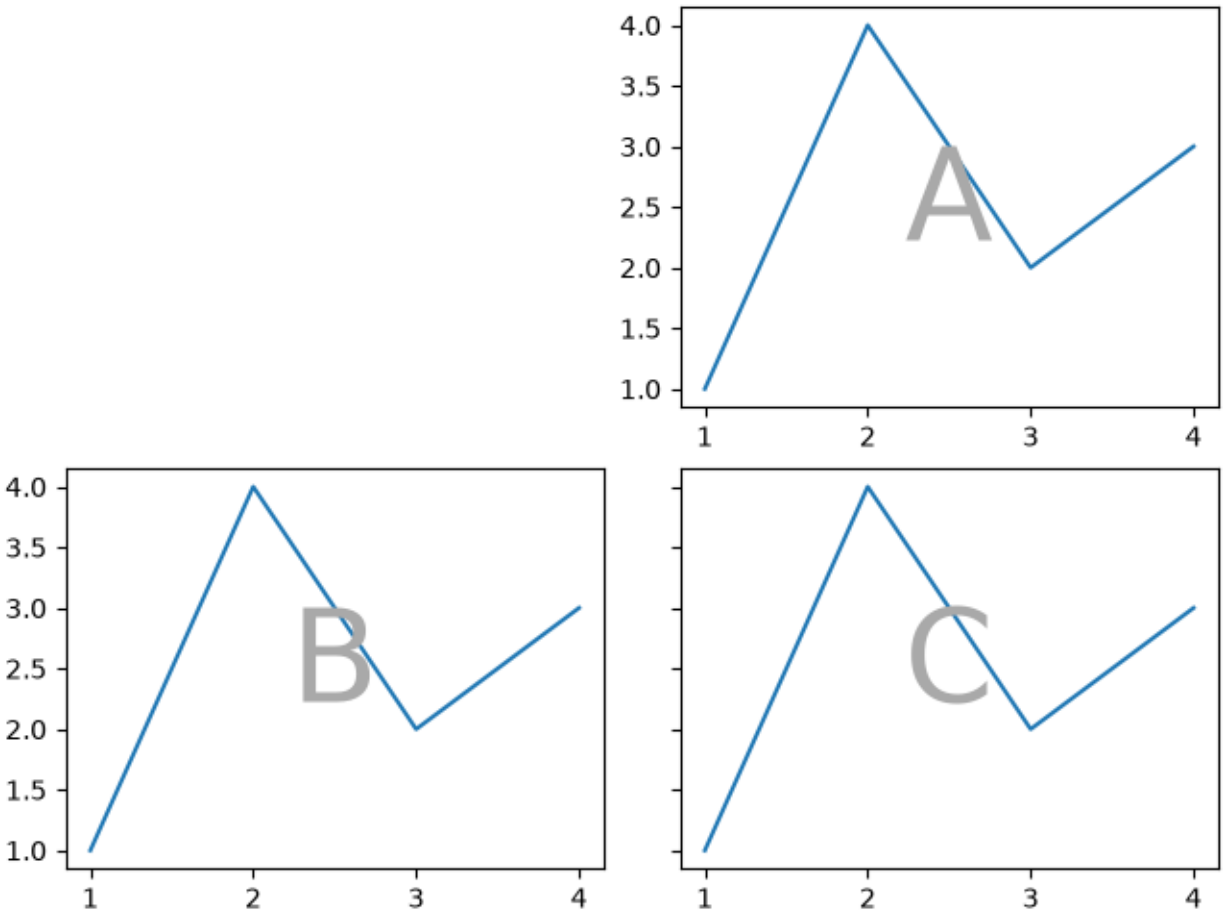
```
fig, axd = plt.subplot_mosaic(".A;BC", sharey=True, layout="constrained
↪")
for ax in axd.values():
    ax.plot([1, 2, 3, 4], [1, 4, 2, 3])
identify_axes(axd)
```



The reason for this behavior is that sharing removes tick labels from all but the most-left / most-bottom grid positions.

The fix is to manually re-enable tick labels on the Axes that should display them using *Axes.tick_params*:

```
fig, axd = plt.subplot_mosaic(".A;BC", sharey=True, layout="constrained
 ↪")
for ax in axd.values():
    ax.plot([1, 2, 3, 4], [1, 4, 2, 3])

# Re-enable y-axis tick labels on Axes "A"
axd["A"].tick_params(labelleft=True)

identify_axes(axd)
```



Total running time of the script: (0 minutes 8.574 seconds)

3.3.10 Constrained layout guide

Use *constrained layout* to fit plots within your figure cleanly.

Constrained layout automatically adjusts subplots so that decorations like tick labels, legends, and colorbars do not overlap, while still preserving the logical layout requested by the user.

Constrained layout is similar to *Tight layout*, but is substantially more flexible. It handles colorbars placed on multiple Axes (*Placing colorbars*) nested layouts (`subfigures`) and Axes that span rows or columns (`subplot_mosaic`), striving to align spines from Axes in the same row or column. In addition, *Compressed layout* will try and move fixed aspect-ratio Axes closer together. These features are described in this document, as well as some *implementation details* discussed at the end.

Constrained layout typically needs to be activated before any Axes are added to a figure. Two ways of doing so are

- using the respective argument to `subplots`, `figure`, `subplot_mosaic` e.g.:

```
plt.subplots(layout="constrained")
```

- activate it via *rcParams*, like:

```
plt.rcParams['figure.constrained_layout.use'] = True
```

Those are described in detail throughout the following sections.

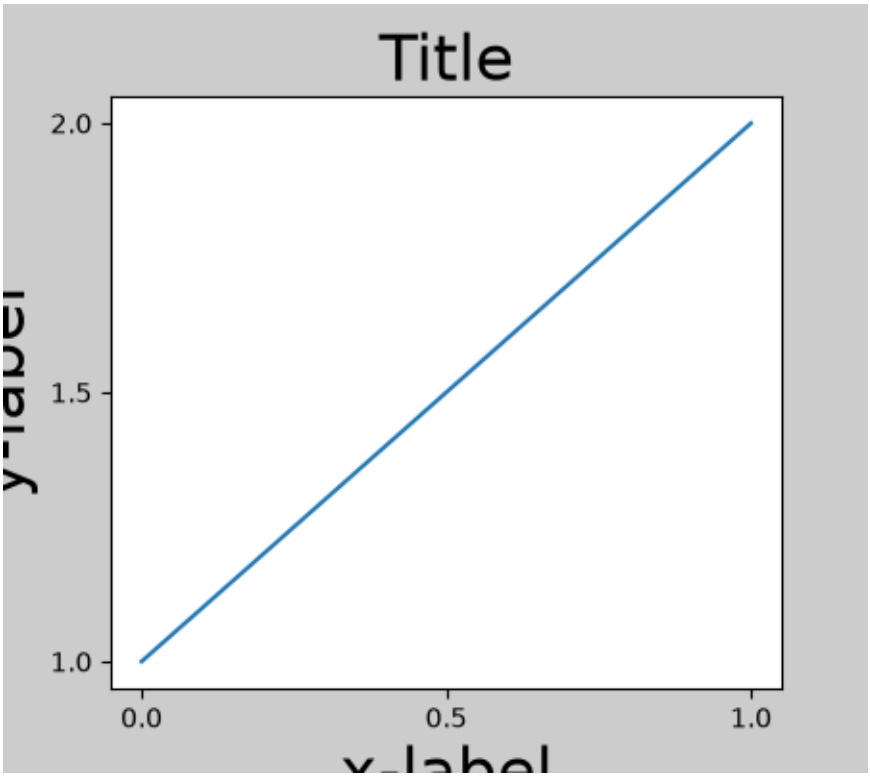
Warning

Calling *tight_layout* will turn off *constrained layout*!

Simple example

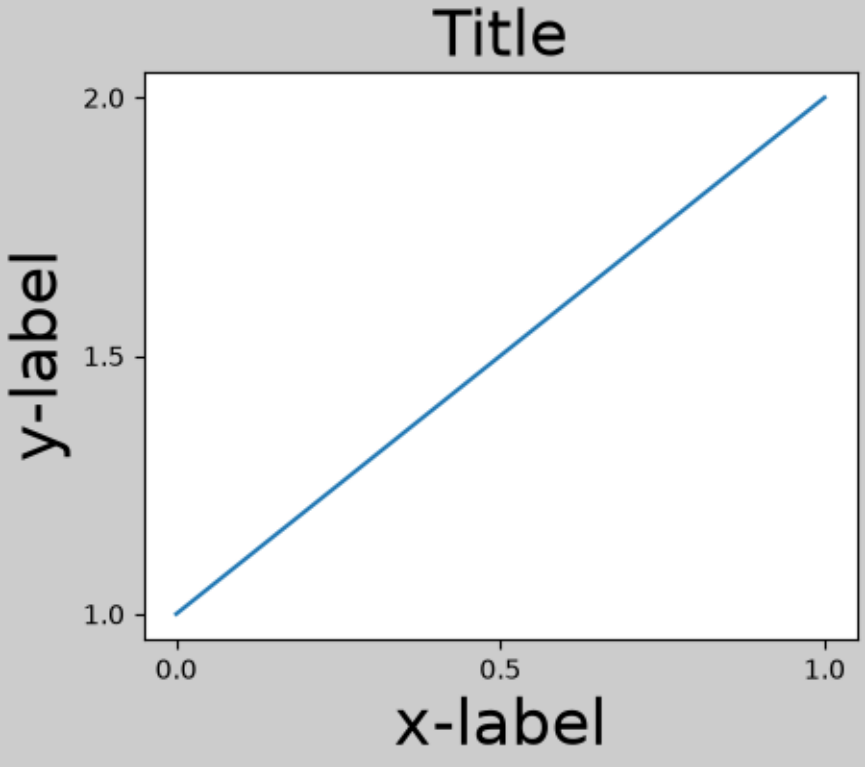
With the default Axes positioning, the axes title, axis labels, or tick labels can sometimes go outside the figure area, and thus get clipped.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.colors as mcolors
import matplotlib.gridspec as gridspec

plt.rcParams['savefig.facecolor'] = "0.8"
plt.rcParams['figure.figsize'] = 4.5, 4.
plt.rcParams['figure.max_open_warning'] = 50


def example_plot(ax, fontsize=12, hide_labels=False):
    ax.plot([1, 2])

    ax.locator_params(nbins=3)
    if hide_labels:
        ax.set_xticklabels([])
        ax.set_yticklabels([])
    else:
        ax.set_xlabel('x-label', fontsize=fontsize)
        ax.set_ylabel('y-label', fontsize=fontsize)
        ax.set_title('Title', fontsize=fontsize)

fig, ax = plt.subplots(layout=None)
example_plot(ax, fontsize=24)
```



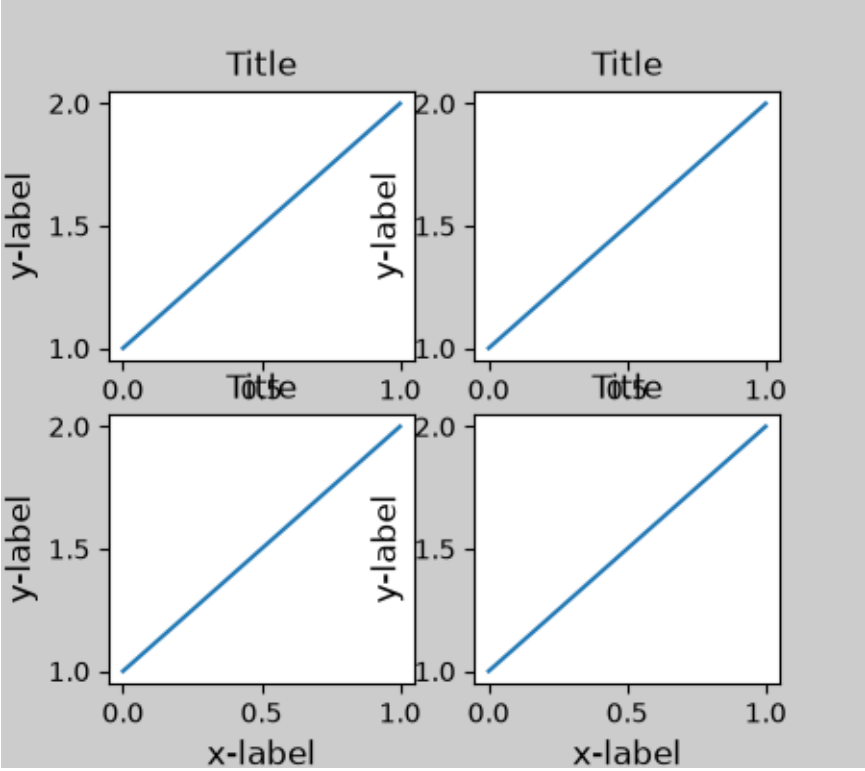
To prevent this, the location of Axes needs to be adjusted. For subplots, this can be done manually by adjusting the subplot parameters using *`Figure.subplots_adjust`*. However, specifying your figure with the `layout="constrained"` keyword argument will do the adjusting automatically.

```
fig, ax = plt.subplots(layout="constrained")
example_plot(ax, fontsize=24)
```



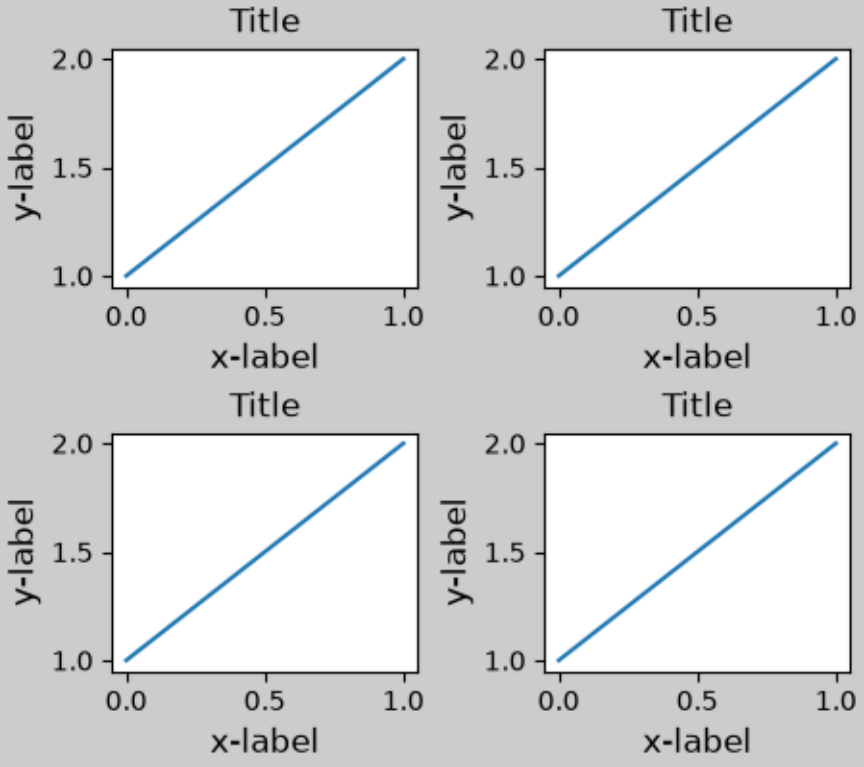
When you have multiple subplots, often you see labels of different Axes overlapping each other.

```
fig, axs = plt.subplots(2, 2, layout=None)
for ax in axs.flat:
    example_plot(ax)
```



Specifying `layout="constrained"` in the call to `plt.subplots` causes the layout to be properly constrained.

```
fig, axs = plt.subplots(2, 2, layout="constrained")
for ax in axs.flat:
    example_plot(ax)
```



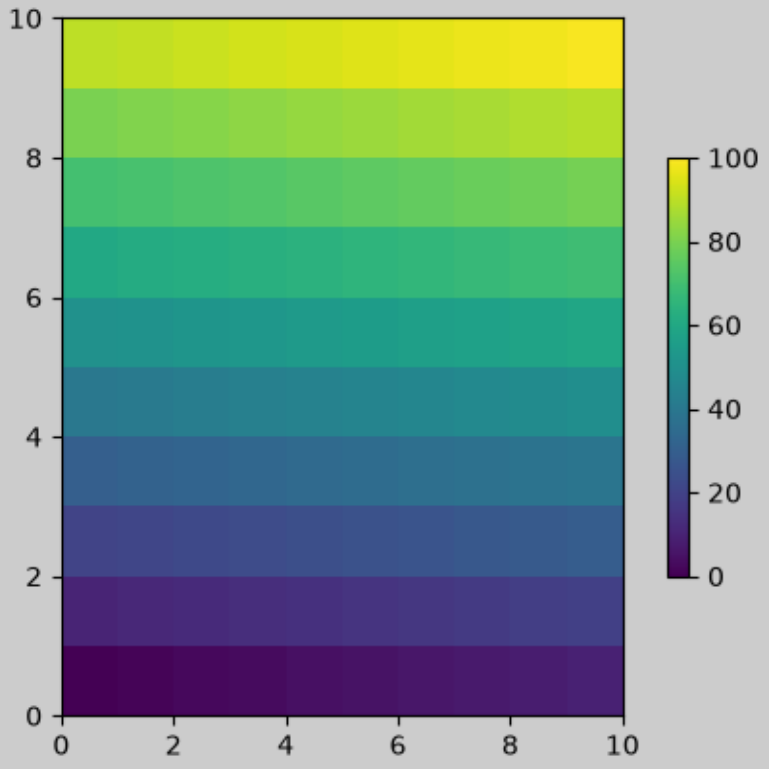
Colorbars

If you create a colorbar with *Figure.colorbar*, you need to make room for it. *Constrained layout* does this automatically. Note that if you specify `use_gridspec=True` it will be ignored because this option is made for improving the layout via `tight_layout`.

Note

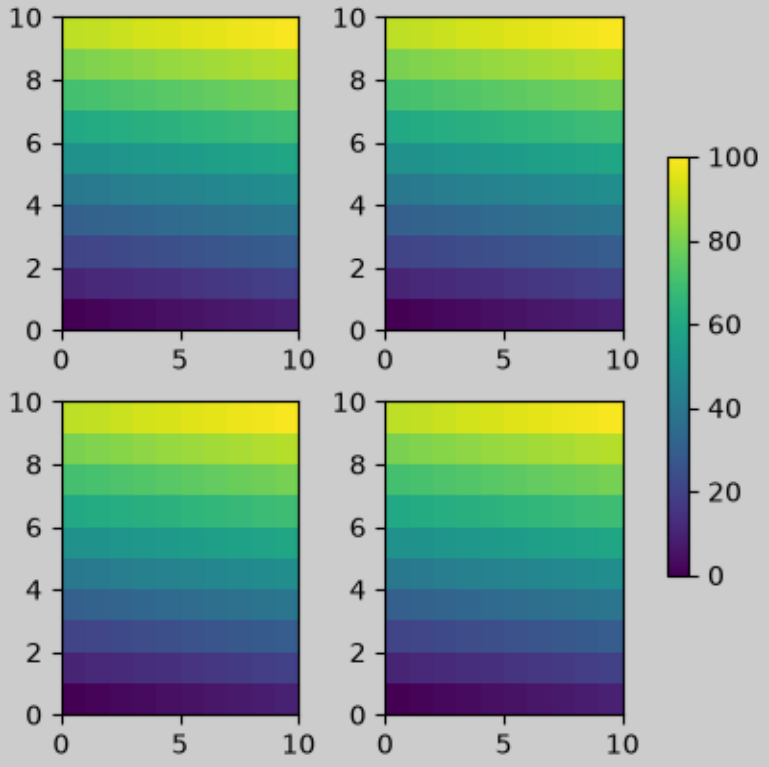
For the *pcolormesh* keyword arguments (`pc_kwargs`) we use a dictionary to keep the calls consistent across this document.

```
arr = np.arange(100).reshape((10, 10))
norm = mcolors.Normalize(vmin=0., vmax=100.)
# see note above: this makes all pcolormesh calls consistent:
pc_kwargs = {'rasterized': True, 'cmap': 'viridis', 'norm': norm}
fig, ax = plt.subplots(figsize=(4, 4), layout="constrained")
im = ax.pcolormesh(arr, **pc_kwargs)
fig.colorbar(im, ax=ax, shrink=0.6)
```



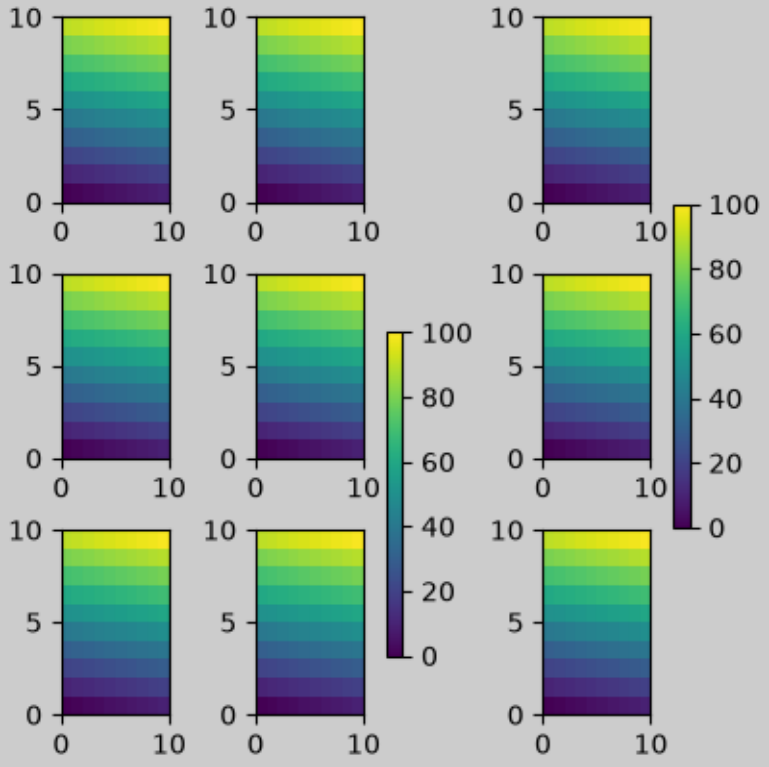
If you specify a list of Axes (or other iterable container) to the `ax` argument of `colorbar`, *constrained layout* will take space from the specified Axes.

```
fig, axs = plt.subplots(2, 2, figsize=(4, 4), layout="constrained")
for ax in axs.flat:
    im = ax.pcolormesh(arr, **pc_kwargs)
fig.colorbar(im, ax=axs, shrink=0.6)
```



If you specify a list of Axes from inside a grid of Axes, the colorbar will steal space appropriately, and leave a gap, but all subplots will still be the same size.

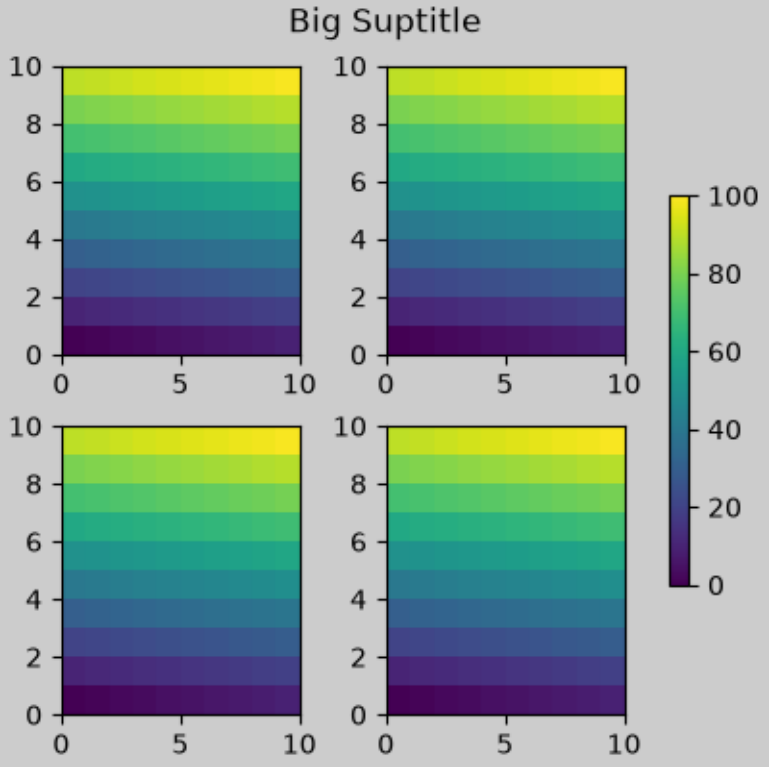
```
fig, axs = plt.subplots(3, 3, figsize=(4, 4), layout="constrained")
for ax in axs.flat:
    im = ax.pcolormesh(arr, **pc_kwargs)
fig.colorbar(im, ax=axs[1:, 1], shrink=0.8)
fig.colorbar(im, ax=axs[:, -1], shrink=0.6)
```



Suptitle

Constrained layout can also make room for `suptitle`.

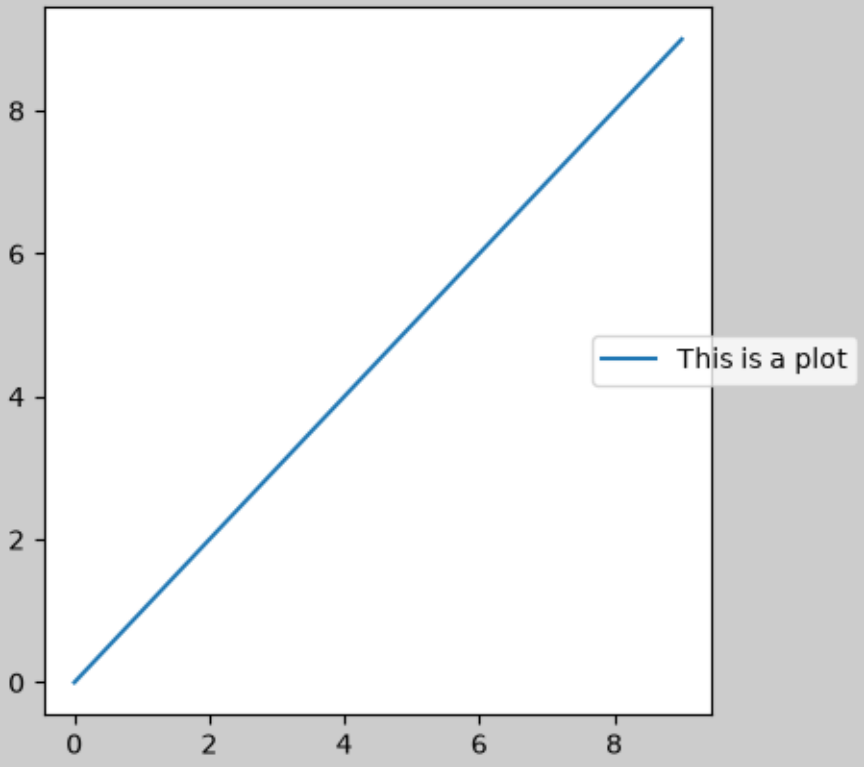
```
fig, axs = plt.subplots(2, 2, figsize=(4, 4), layout="constrained")
for ax in axs.flat:
    im = ax.pcolormesh(arr, **pc_kwargs)
fig.colorbar(im, ax=axs, shrink=0.6)
fig.suptitle('Big Suptitle')
```



Legends

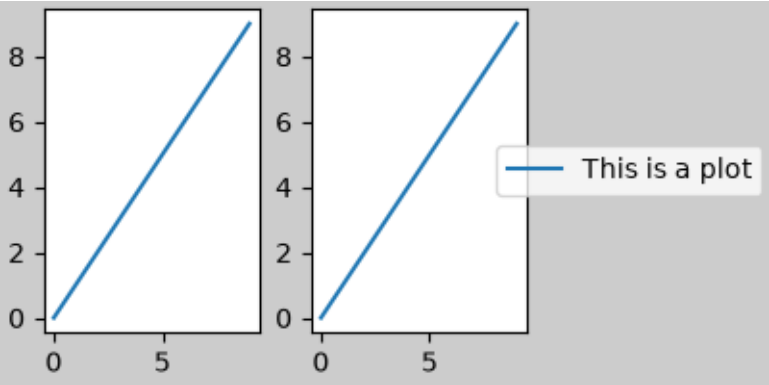
Legends can be placed outside of their parent axes. *Constrained layout* is designed to handle this for `Axes.legend()`. However, *constrained layout* does *not* handle legends being created via `Figure.legend()` (yet).

```
fig, ax = plt.subplots(layout="constrained")
ax.plot(np.arange(10), label='This is a plot')
ax.legend(loc='center left', bbox_to_anchor=(0.8, 0.5))
```



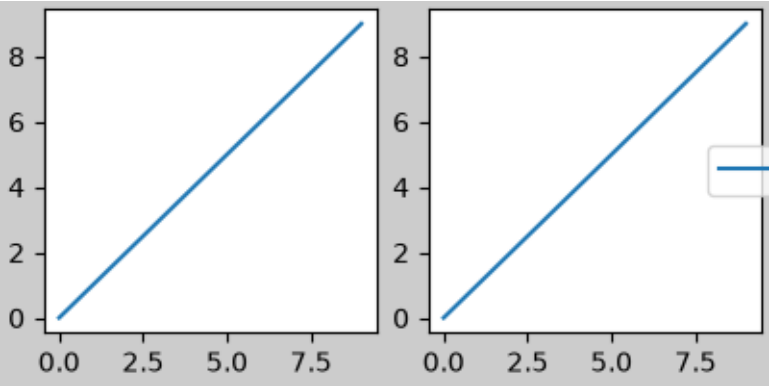
However, this will steal space from a subplot layout:

```
fig, axs = plt.subplots(1, 2, figsize=(4, 2), layout="constrained")
axs[0].plot(np.arange(10))
axs[1].plot(np.arange(10), label='This is a plot')
axs[1].legend(loc='center left', bbox_to_anchor=(0.8, 0.5))
```

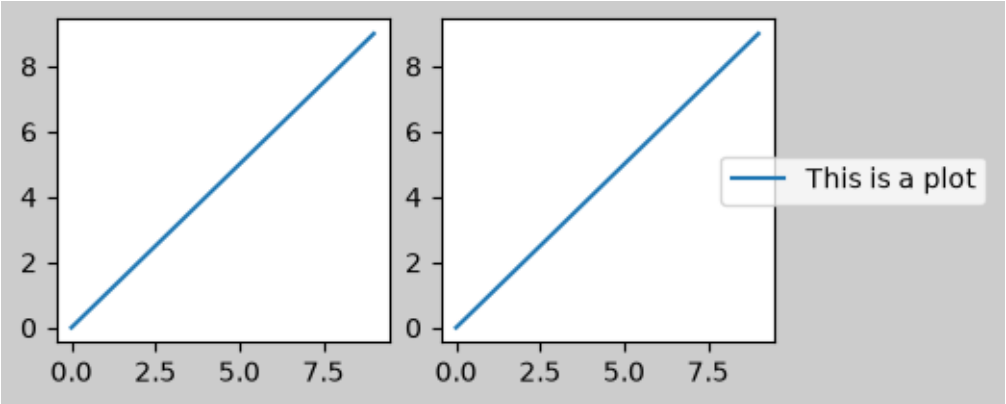


In order for a legend or other artist to *not* steal space from the subplot layout, we can `leg.set_in_layout(False)`. Of course this can mean the legend ends up cropped, but can be useful if the plot is subsequently called with `fig.savefig('outname.png', bbox_inches='tight')`. Note, however, that the legend's `get_in_layout` status will have to be toggled again to make the saved file work, and we must manually trigger a draw if we want *constrained layout* to adjust the size of the Axes before printing.

```
fig, axs = plt.subplots(1, 2, figsize=(4, 2), layout="constrained")

axs[0].plot(np.arange(10))
axs[1].plot(np.arange(10), label='This is a plot')
leg = axs[1].legend(loc='center left', bbox_to_anchor=(0.8, 0.5))
leg.set_in_layout(False)
# trigger a draw so that constrained layout is executed once
# before we turn it off when printing....
fig.canvas.draw()
# we want the legend included in the bbox_inches='tight' calcs.
leg.set_in_layout(True)
# we don't want the layout to change at this point.
fig.set_layout_engine('none')
try:
    fig.savefig('../../../doc/_static/constrained_layout_1b.png',
                bbox_inches='tight', dpi=100)
except FileNotFoundError:
    # this allows the script to keep going if run interactively and
    # the directory above doesn't exist
    pass
```



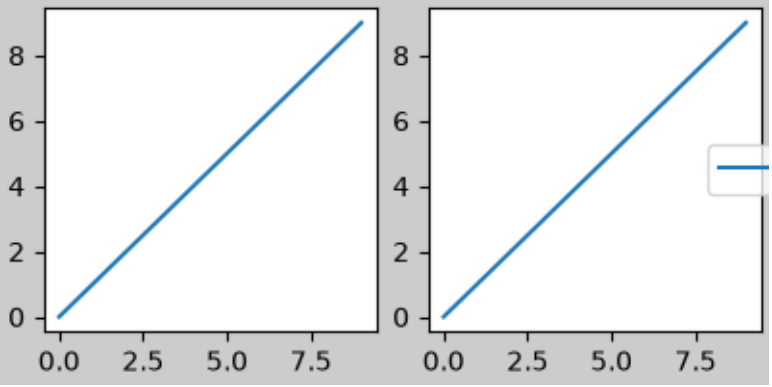
The saved file looks like:



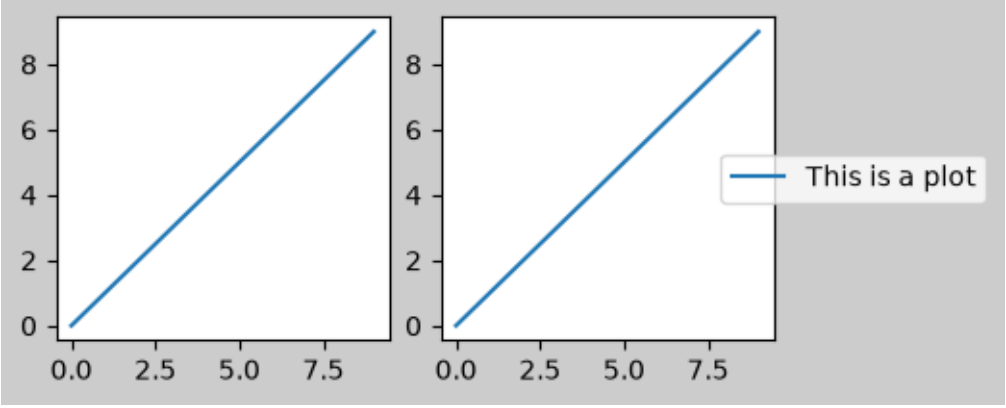
A better way to get around this awkwardness is to simply use the legend method provided by `Figure`.

legend:

```
fig, axs = plt.subplots(1, 2, figsize=(4, 2), layout="constrained")
axs[0].plot(np.arange(10))
lines = axs[1].plot(np.arange(10), label='This is a plot')
labels = [l.get_label() for l in lines]
leg = fig.legend(lines, labels, loc='center left',
                 bbox_to_anchor=(0.8, 0.5), bbox_transform=axs[1].
 ↪transAxes)
try:
    fig.savefig('../../../doc/_static/constrained_layout_2b.png',
                bbox_inches='tight', dpi=100)
except FileNotFoundError:
    # this allows the script to keep going if run interactively and
    # the directory above doesn't exist
    pass
```



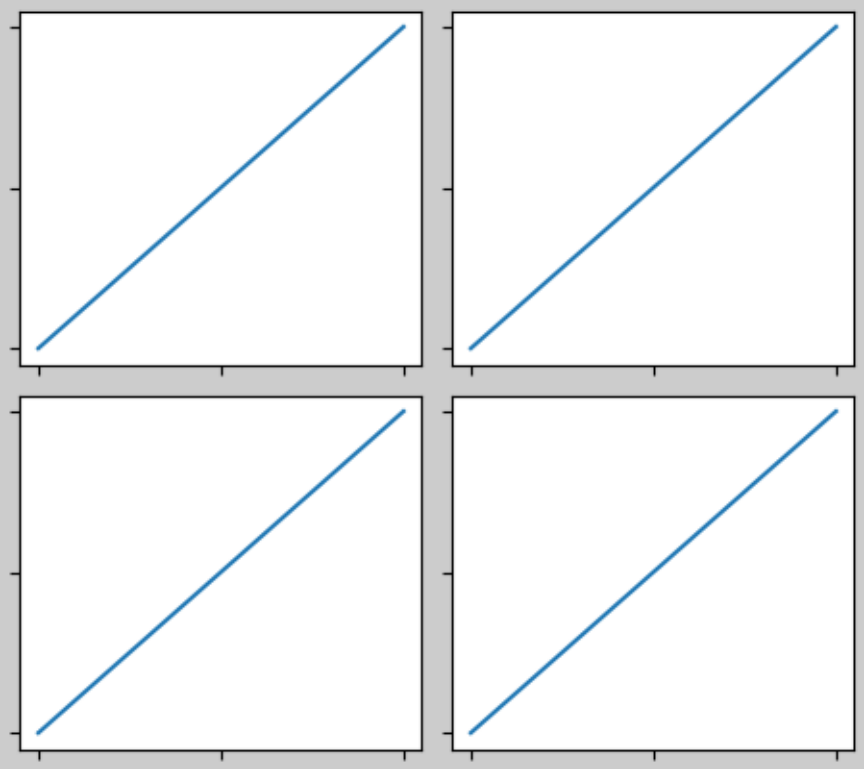
The saved file looks like:



Padding and spacing

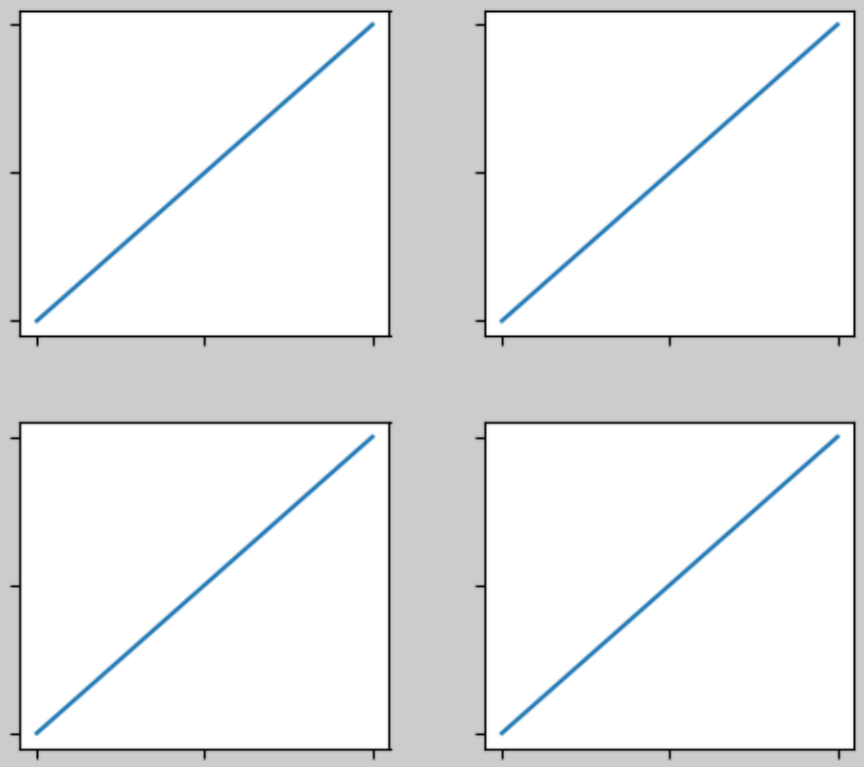
Padding between Axes is controlled in the horizontal by *w_pad* and *wspace*, and vertical by *h_pad* and *hspace*. These can be edited via `set`. *w/h_pad* are the minimum space around the Axes in units of inches:

```
fig, axs = plt.subplots(2, 2, layout="constrained")
for ax in axs.flat:
    example_plot(ax, hide_labels=True)
fig.get_layout_engine().set(w_pad=4 / 72, h_pad=4 / 72, hspace=0,
                            wspace=0)
```



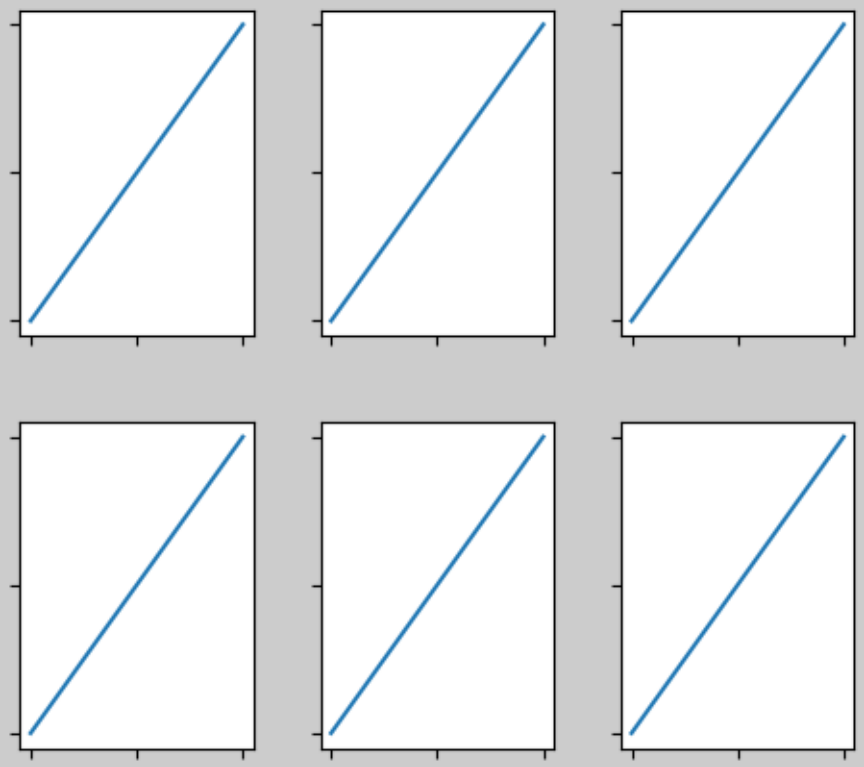
Spacing between subplots is further set by *wspace* and *hspace*. These are specified as a fraction of the size of the subplot group as a whole. If these values are smaller than *w_pad* or *h_pad*, then the fixed pads are used instead. Note in the below how the space at the edges doesn't change from the above, but the space between subplots does.

```
fig, axs = plt.subplots(2, 2, layout="constrained")
for ax in axs.flat:
    example_plot(ax, hide_labels=True)
fig.get_layout_engine().set(w_pad=4 / 72, h_pad=4 / 72, hspace=0.2,
                            wspace=0.2)
```



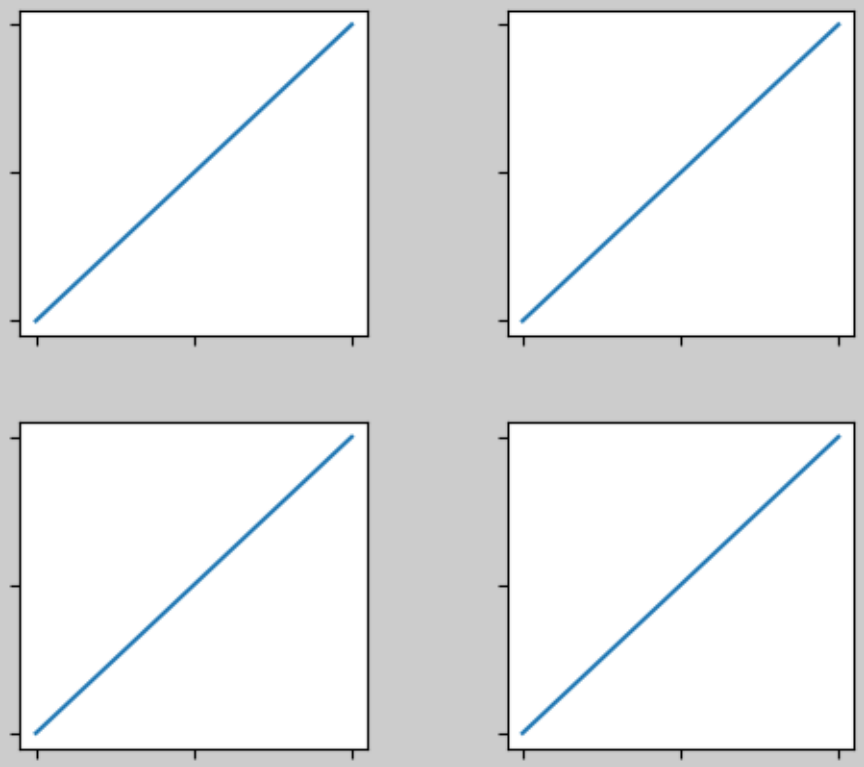
If there are more than two columns, the *wspace* is shared between them, so here the wspace is divided in two, with a *wspace* of 0.1 between each column:

```
fig, axs = plt.subplots(2, 3, layout="constrained")
for ax in axs.flat:
    example_plot(ax, hide_labels=True)
fig.get_layout_engine().set(w_pad=4 / 72, h_pad=4 / 72, hspace=0.2,
                            wspace=0.2)
```



GridSpecs also have optional *hspace* and *wspace* keyword arguments, that will be used instead of the pads set by *constrained layout*:

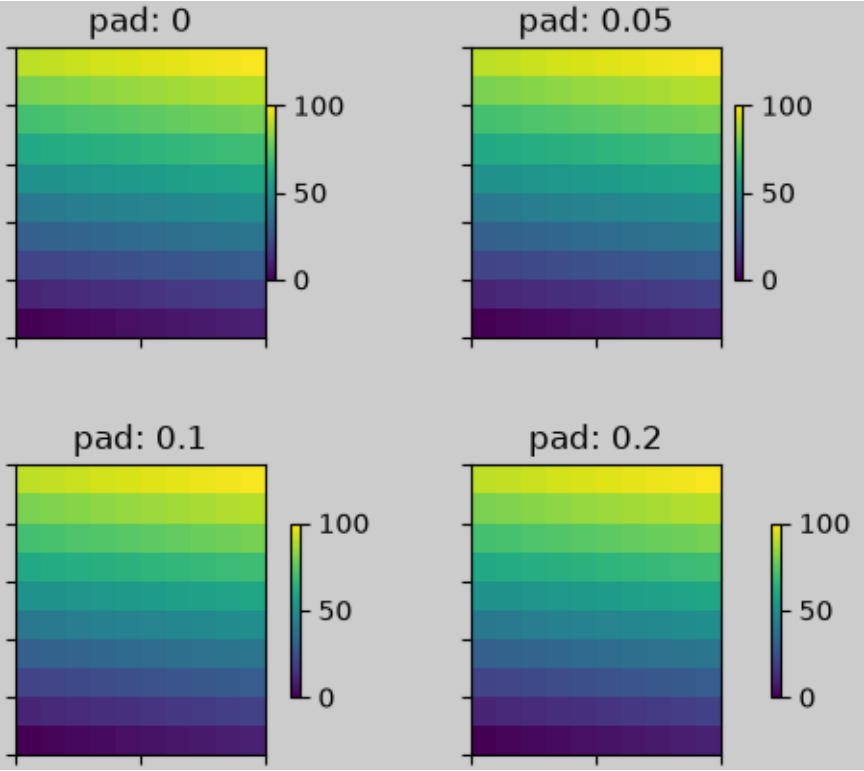
```
fig, axs = plt.subplots(2, 2, layout="constrained",
                        gridspec_kw={'wspace': 0.3, 'hspace': 0.2})
for ax in axs.flat:
    example_plot(ax, hide_labels=True)
# this has no effect because the space set in the gridspec trumps the
# space set in *constrained layout*.
fig.get_layout_engine().set(w_pad=4 / 72, h_pad=4 / 72, hspace=0.0,
                            wspace=0.0)
```



Spacing with colorbars

Colorbars are placed a distance *pad* from their parent, where *pad* is a fraction of the width of the parent(s). The spacing to the next subplot is then given by *w/hspace*.

```
fig, axs = plt.subplots(2, 2, layout="constrained")
pads = [0, 0.05, 0.1, 0.2]
for pad, ax in zip(pads, axs.flat):
    pc = ax.pcolormesh(arr, **pc_kwargs)
    fig.colorbar(pc, ax=ax, shrink=0.6, pad=pad)
    ax.set_xticklabels([])
    ax.set_yticklabels([])
    ax.set_title(f'pad: {pad}')
fig.get_layout_engine().set(w_pad=2 / 72, h_pad=2 / 72, hspace=0.2,
                            wspace=0.2)
```

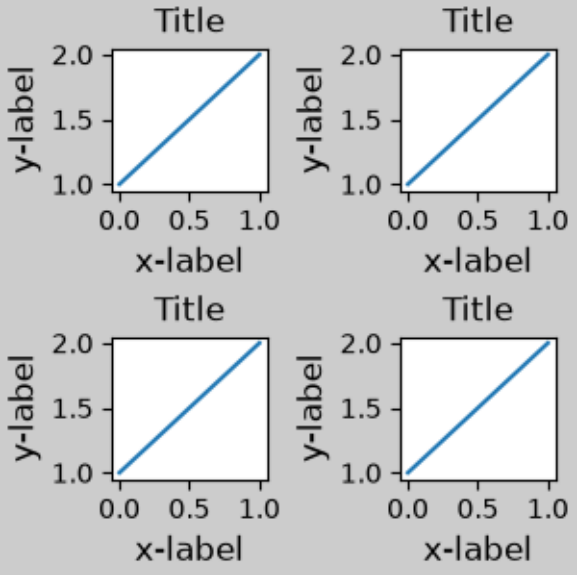


rcParams

There are five *rcParams* that can be set, either in a script or in the `matplotlibrc` file. They all have the prefix `figure.constrained_layout`:

- *use*: Whether to use *constrained layout*. Default is False
- *w_pad*, *h_pad*: Padding around Axes objects. Float representing inches. Default is 3./72. inches (3 pts)
- *wspace*, *hspace*: Space between subplot groups. Float representing a fraction of the subplot widths being separated. Default is 0.02.

```
plt.rcParams['figure.constrained_layout.use'] = True
fig, axs = plt.subplots(2, 2, figsize=(3, 3))
for ax in axs.flat:
    example_plot(ax)
```

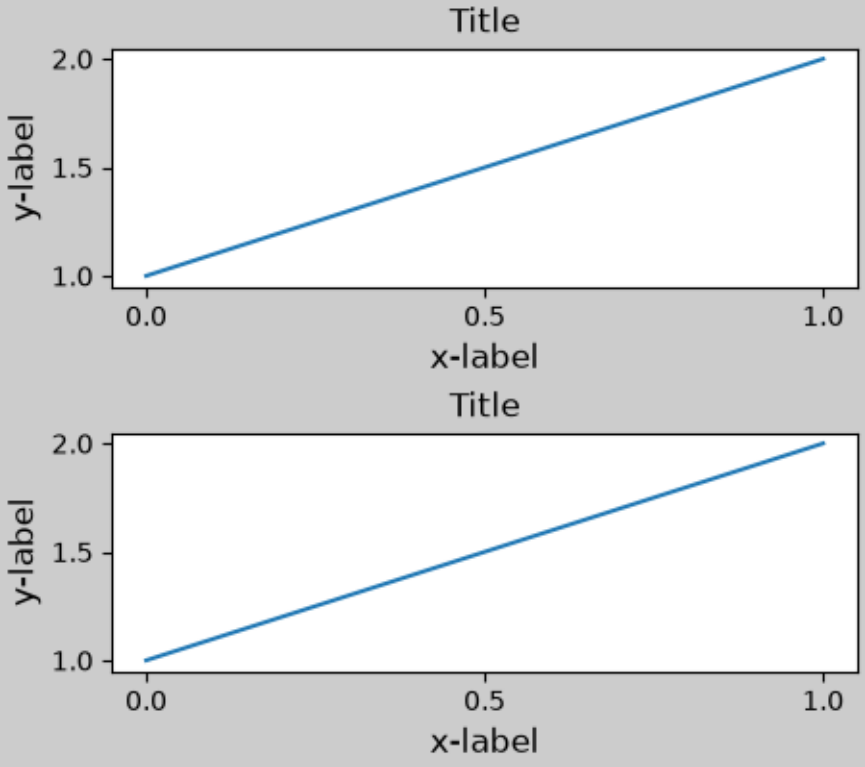


Use with GridSpec

Constrained layout is meant to be used with `subplots()`, `subplot_mosaic()`, or `GridSpec()` with `add_subplot()`.

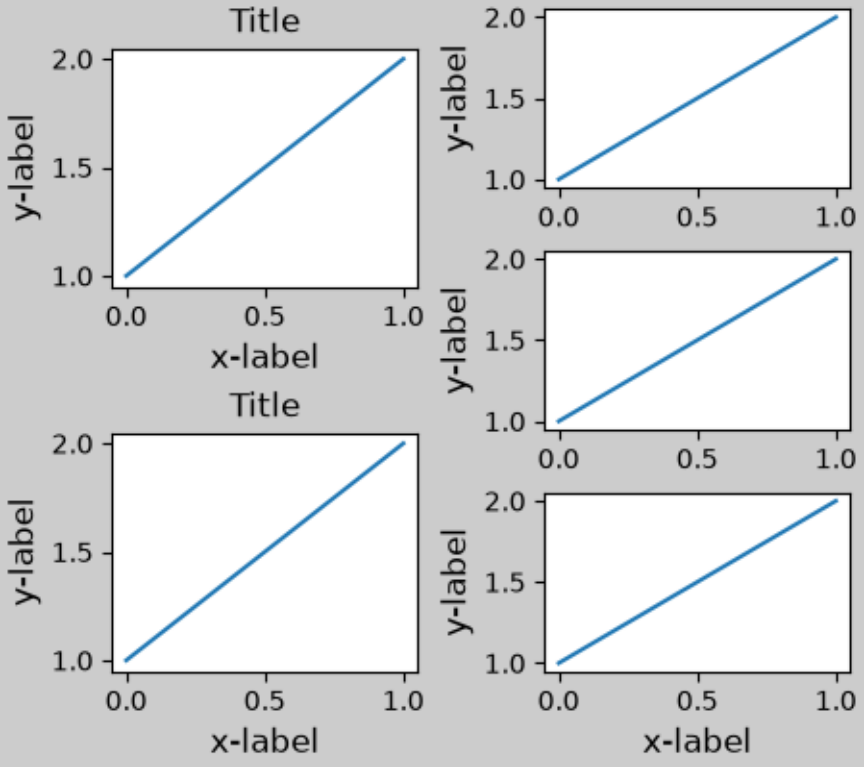
Note that in what follows `layout="constrained"`

```
plt.rcParams['figure.constrained_layout.use'] = False
fig = plt.figure(layout="constrained")

gs1 = gridspec.GridSpec(2, 1, figure=fig)
ax1 = fig.add_subplot(gs1[0])
ax2 = fig.add_subplot(gs1[1])

example_plot(ax1)
example_plot(ax2)
```



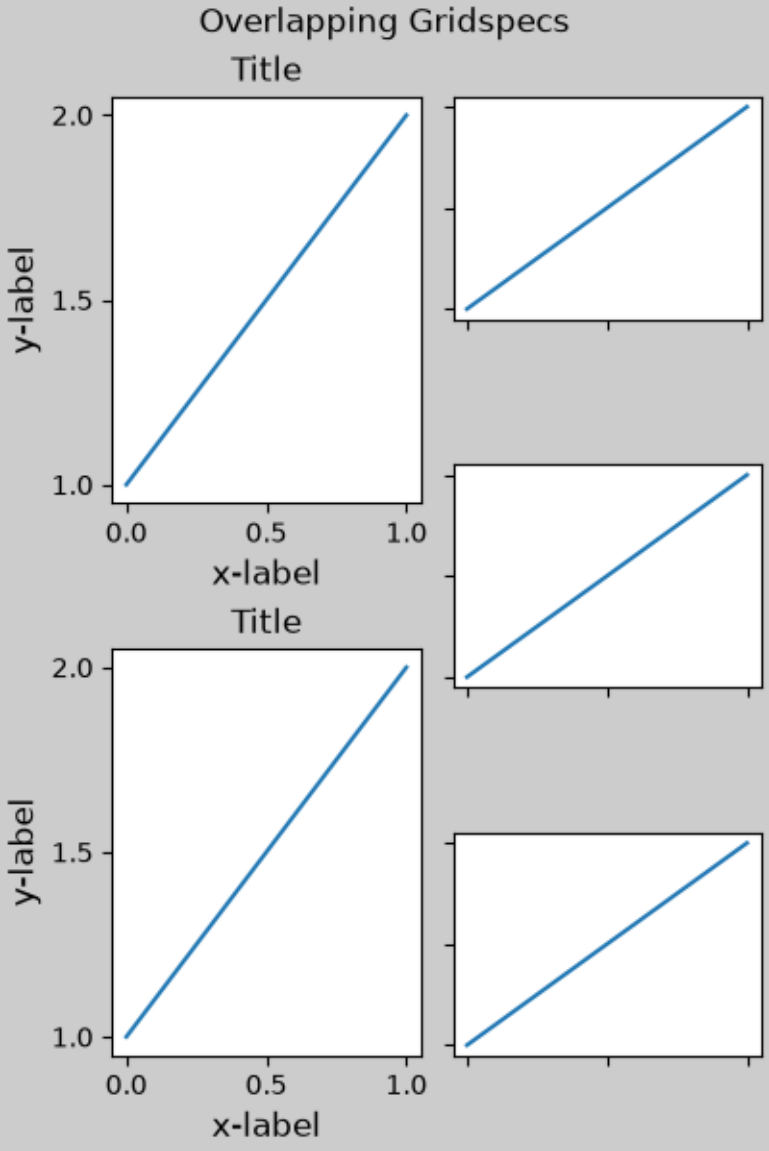
More complicated gridspec layouts are possible. Note here we use the convenience functions *add_gridspec* and *subgridspec*.

```
fig = plt.figure(layout="constrained")

gs0 = fig.add_gridspec(1, 2)

gs1 = gs0[0].subgridspec(2, 1)
ax1 = fig.add_subplot(gs1[0])
ax2 = fig.add_subplot(gs1[1])

example_plot(ax1)
example_plot(ax2)

gs2 = gs0[1].subgridspec(3, 1)

for ss in gs2:
    ax = fig.add_subplot(ss)
    example_plot(ax)
    ax.set_title("")
    ax.set_xlabel("")

ax.set_xlabel("x-label", fontsize=12)
```



Note that in the above the left and right columns don't have the same vertical extent. If we want the top and bottom of the two grids to line up then they need to be in the same gridspec. We need to make this figure larger as well in order for the Axes not to collapse to zero height:

```
fig = plt.figure(figsize=(4, 6), layout="constrained")

gs0 = fig.add_gridspec(6, 2)

ax1 = fig.add_subplot(gs0[:3, 0])
ax2 = fig.add_subplot(gs0[3:, 0])

example_plot(ax1)
example_plot(ax2)

ax = fig.add_subplot(gs0[0:2, 1])
example_plot(ax, hide_labels=True)
ax = fig.add_subplot(gs0[2:4, 1])
example_plot(ax, hide_labels=True)
ax = fig.add_subplot(gs0[4:, 1])
example_plot(ax, hide_labels=True)
fig.suptitle('Overlapping Gridspecs')
```



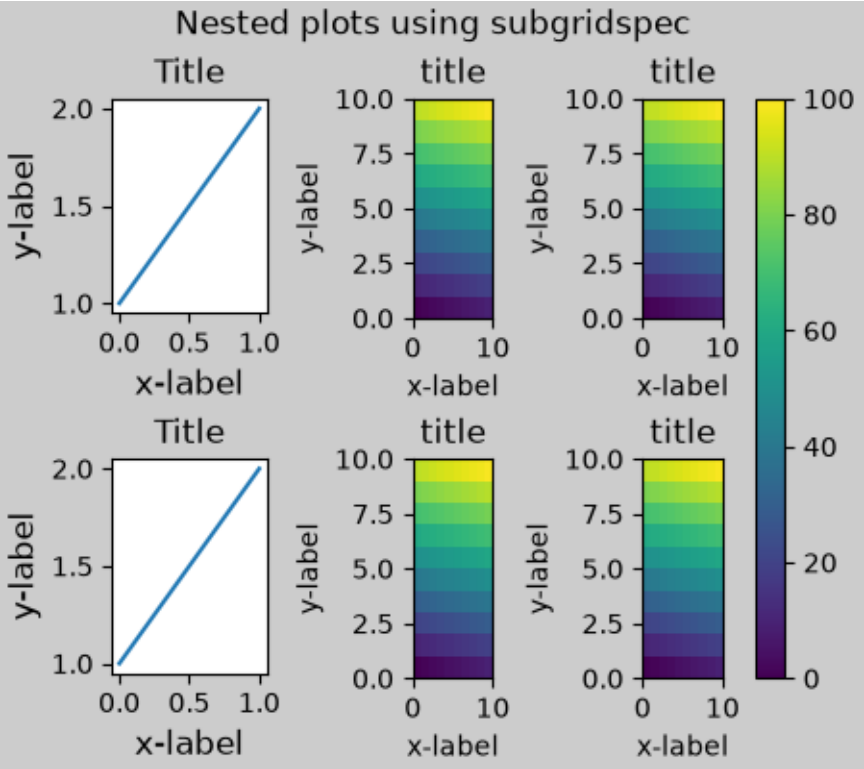
This example uses two gridspecs to have the colorbar only pertain to one set of pcolors. Note how the left column is wider than the two right-hand columns because of this. Of course, if you wanted the subplots to be the same size you only needed one gridspec. Note that the same effect can be achieved using *subfigures*.

```
fig = plt.figure(layout="constrained")
gs0 = fig.add_gridspec(1, 2, figure=fig, width_ratios=[1, 2])
gs_left = gs0[0].subgridspec(2, 1)
gs_right = gs0[1].subgridspec(2, 2)

for gs in gs_left:
    ax = fig.add_subplot(gs)
    example_plot(ax)
axs = []
for gs in gs_right:
```

(continues on next page)

(continued from previous page)

```
    ax = fig.add_subplot(gs)
    pcm = ax.pcolormesh(arr, **pc_kwargs)
    ax.set_xlabel('x-label')
    ax.set_ylabel('y-label')
    ax.set_title('title')
    axs += [ax]
fig.suptitle('Nested plots using subgridspec')
fig.colorbar(pcm, ax=axs)
```



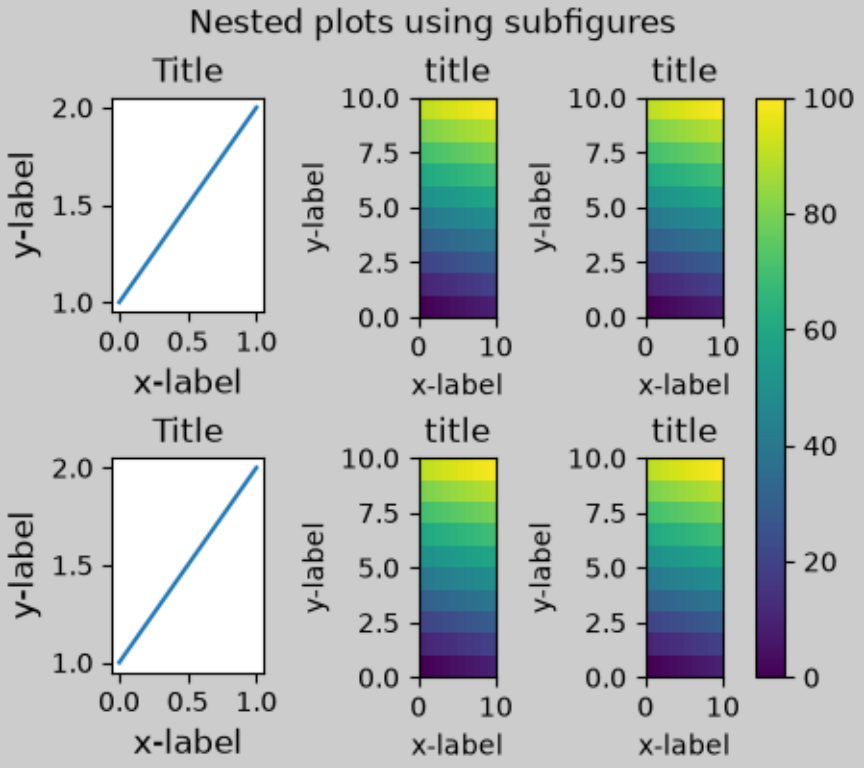
Rather than using subgridspecs, Matplotlib now provides `subfigures` which also work with *constrained layout*:

```
fig = plt.figure(layout="constrained")
sfigs = fig.subfigures(1, 2, width_ratios=[1, 2])

axs_left = sfigs[0].subplots(2, 1)
for ax in axs_left.flat:
    example_plot(ax)

axs_right = sfigs[1].subplots(2, 2)
for ax in axs_right.flat:
    pcm = ax.pcolormesh(arr, **pc_kwargs)
    ax.set_xlabel('x-label')
    ax.set_ylabel('y-label')
```

(continues on next page)

(continued from previous page)

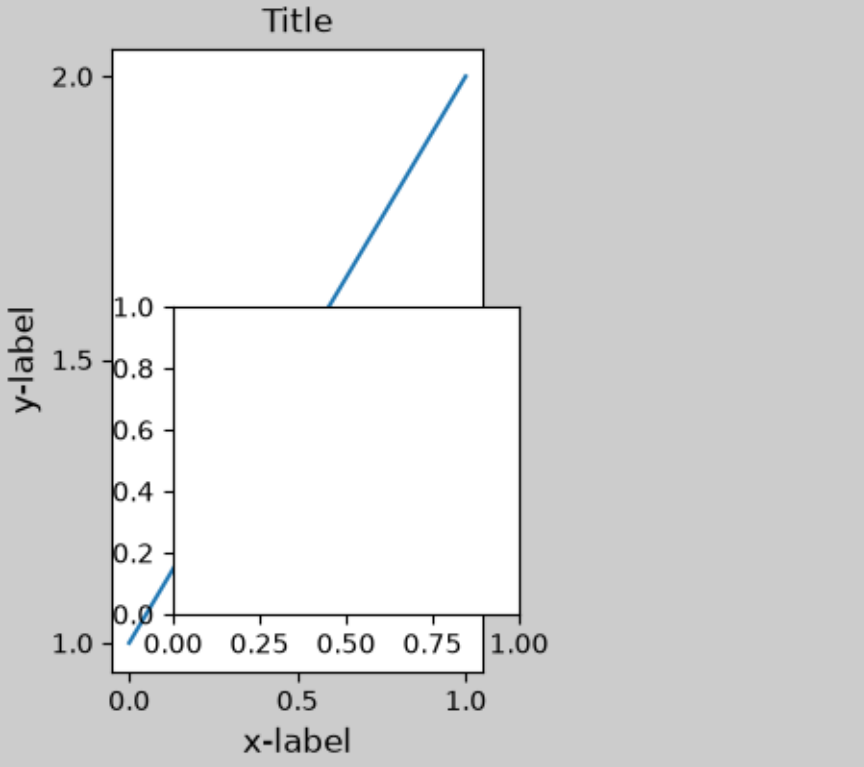
```
    ax.set_title('title')
fig.colorbar(pcm, ax=axs_right)
fig.suptitle('Nested plots using subfigures')
```



Manually setting Axes positions

There can be good reasons to manually set an Axes position. A manual call to `set_position` will set the Axes so *constrained layout* has no effect on it anymore. (Note that *constrained layout* still leaves the space for the Axes that is moved).

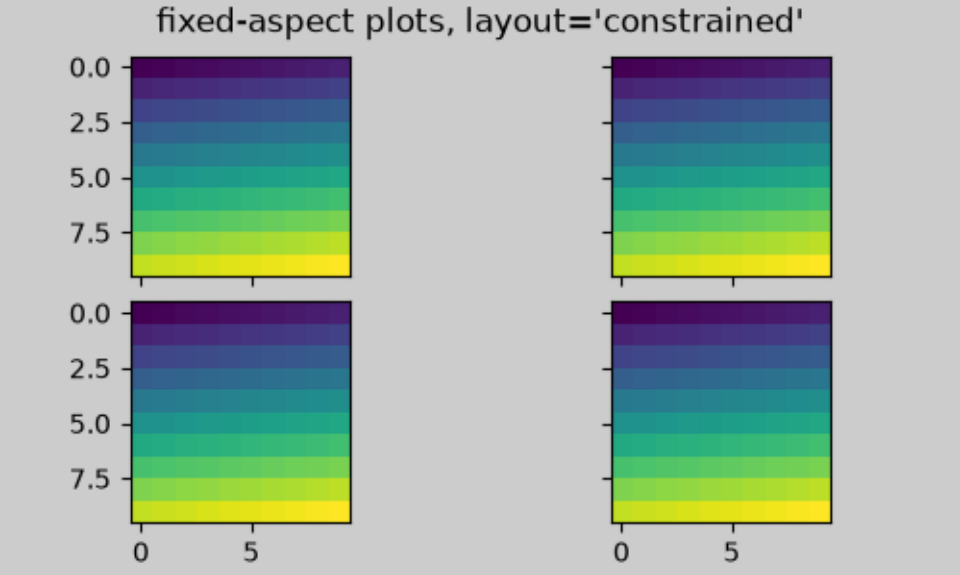
```
fig, axs = plt.subplots(1, 2, layout="constrained")
example_plot(axs[0], fontsize=12)
axs[1].set_position([0.2, 0.2, 0.4, 0.4])
```



Grids of fixed aspect-ratio Axes: "compressed" layout

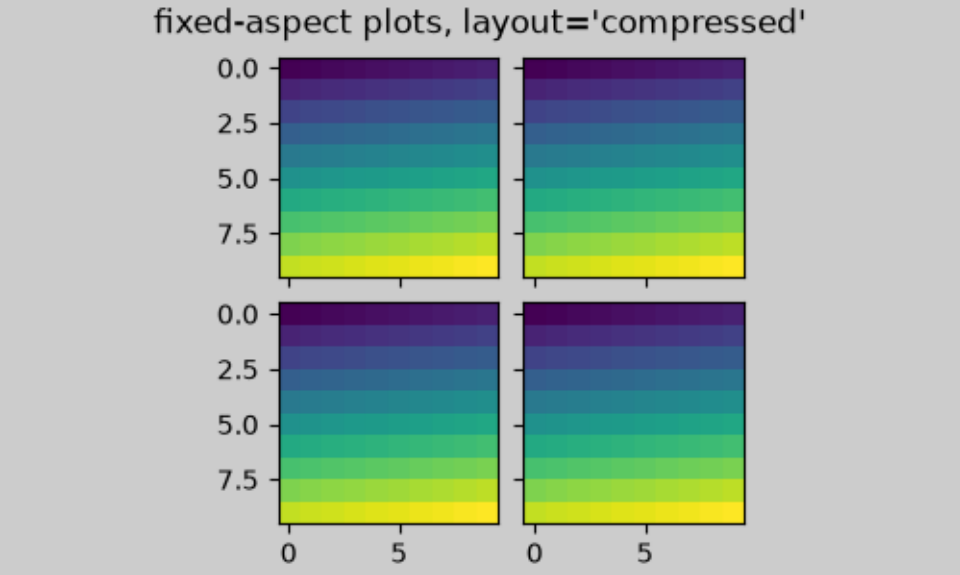
Constrained layout operates on the grid of "original" positions for Axes. However, when Axes have fixed aspect ratios, one side is usually made shorter, and leaves large gaps in the shortened direction. In the following, the Axes are square, but the figure quite wide so there is a horizontal gap:

```
fig, axs = plt.subplots(2, 2, figsize=(5, 3),
                        sharex=True, sharey=True, layout="constrained")
for ax in axs.flat:
    ax.imshow(arr)
fig.suptitle("fixed-aspect plots, layout='constrained'")
```



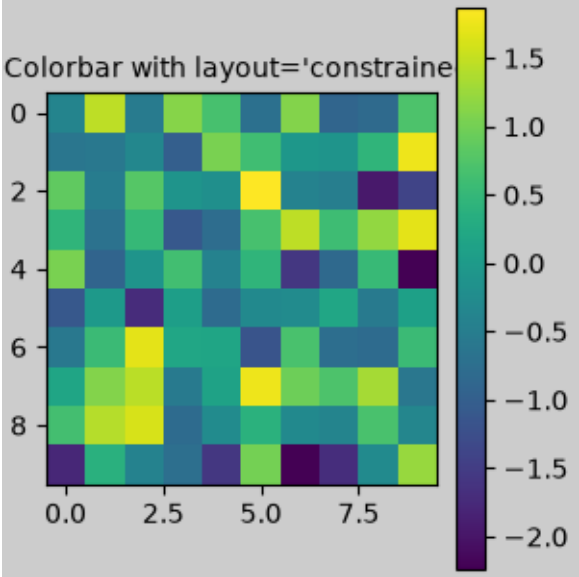
One obvious way of fixing this is to make the figure size more square, however, closing the gaps exactly requires trial and error. For simple grids of Axes we can use `layout="compressed"` to do the job for us:

```
fig, axs = plt.subplots(2, 2, figsize=(5, 3),
                        sharex=True, sharey=True, layout='compressed')
for ax in axs.flat:
    ax.imshow(arr)
fig.suptitle("fixed-aspect plots, layout='compressed'")
```



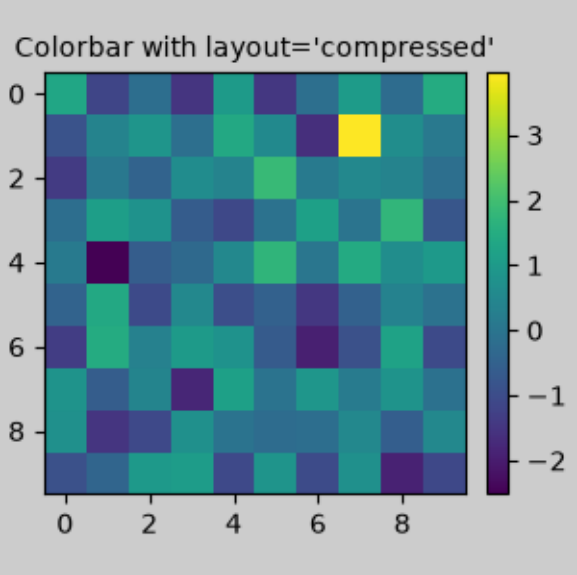
Compressed layout will also attempt to size colorbars to match the size of the fixed-aspect-ratio parent Axes as the figure is resized or the aspect ratio changes. In the following figure, the colorbar is taller than its parent Axes:

```
fig, ax = plt.subplots(layout='constrained', figsize=(3, 3))
pcm = ax.imshow(np.random.randn(10, 10), cmap='viridis')
ax.set_title("Colorbar with layout='constrained'", fontsize='medium')
fig.colorbar(pcm, ax=ax)
```



Compressed layout ensures that the height of the colorbar matches the height of its parent Axes, maintaining a consistent appearance:

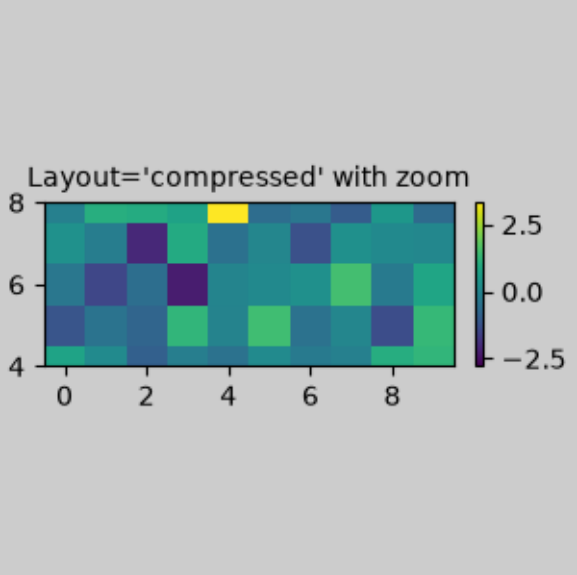
```
fig, ax = plt.subplots(layout='compressed', figsize=(3, 3))
pcm = ax.imshow(np.random.randn(10, 10), cmap='viridis')
ax.set_title("Colorbar with layout='compressed'", fontsize='medium')
fig.colorbar(pcm, ax=ax)
```



If the Axes is zoomed in or out, or the figure is resized, the colorbar will dynamically resize to match the

parent Axes. Whether this behavior is desired depends on the specific application:

```
fig, ax = plt.subplots(layout='compressed', figsize=(3, 3))
pcm = ax.imshow(np.random.randn(10, 10), cmap='viridis')
ax.set_ylim([4, 8])
ax.set_title("Layout='compressed' with zoom", fontsize='medium')
fig.colorbar(pcm, ax=ax)
```



Manually turning off *constrained layout*

Constrained layout usually adjusts the Axes positions on each draw of the figure. If you want to get the spacing provided by *constrained layout* but not have it update, then do the initial draw and then call `fig.set_layout_engine('none')`. This is potentially useful for animations where the tick labels may change length.

Note that *constrained layout* is turned off for `ZOOM` and `PAN` GUI events for the backends that use the toolbar. This prevents the Axes from changing position during zooming and panning.

Limitations

Incompatible functions

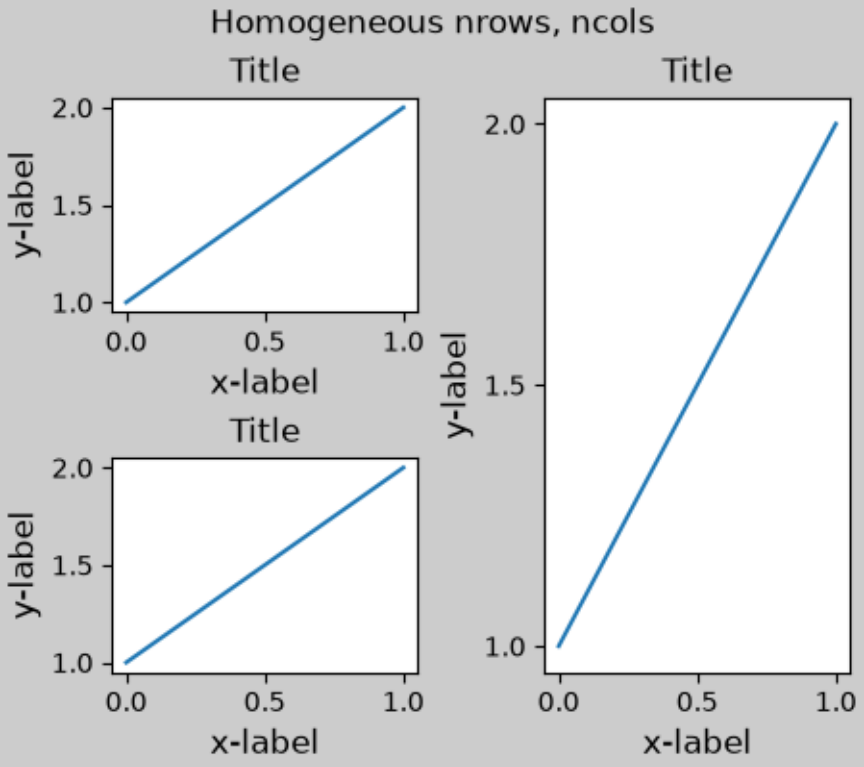
Constrained layout will work with *`pyplot.subplot`*, but only if the number of rows and columns is the same for each call. The reason is that each call to *`pyplot.subplot`* will create a new *`GridSpec`* instance if the geometry is not the same, and *constrained layout*. So the following works fine:

```
fig = plt.figure(layout="constrained")

ax1 = plt.subplot(2, 2, 1)
ax2 = plt.subplot(2, 2, 3)
# third Axes that spans both rows in second column:
ax3 = plt.subplot(2, 2, (2, 4))
```

(continues on next page)

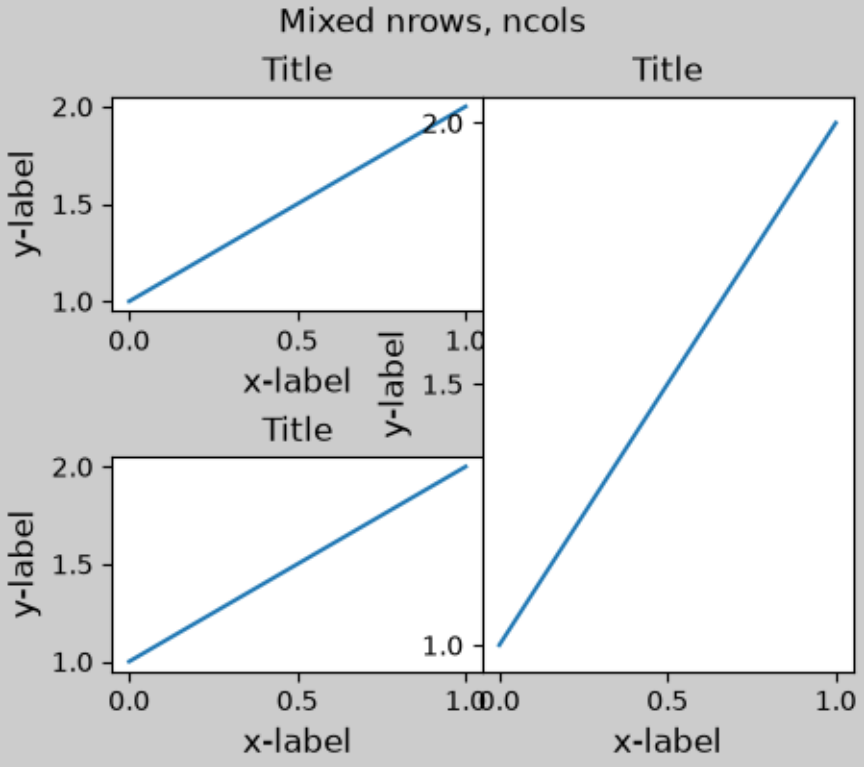
(continued from previous page)

```
example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
plt.suptitle('Homogeneous nrows, ncols')
```



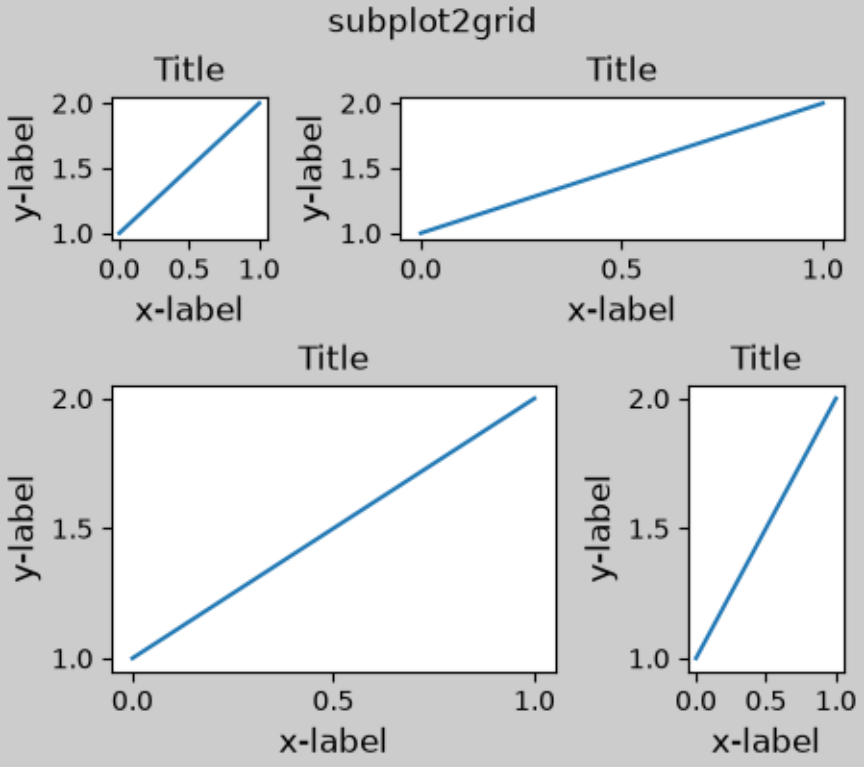
but the following leads to a poor layout:

```
fig = plt.figure(layout="constrained")

ax1 = plt.subplot(2, 2, 1)
ax2 = plt.subplot(2, 2, 3)
ax3 = plt.subplot(1, 2, 2)

example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
plt.suptitle('Mixed nrows, ncols')
```



Similarly, *subplot2grid* works with the same limitation that nrows and ncols cannot change for the layout to look good.

```
fig = plt.figure(layout="constrained")

ax1 = plt.subplot2grid((3, 3), (0, 0))
ax2 = plt.subplot2grid((3, 3), (0, 1), colspan=2)
ax3 = plt.subplot2grid((3, 3), (1, 0), colspan=2, rowspan=2)
ax4 = plt.subplot2grid((3, 3), (1, 2), rowspan=2)

example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
example_plot(ax4)
fig.suptitle('subplot2grid')
```



Other caveats

- *Constrained layout* only considers ticklabels, axis labels, titles, and legends. Thus, other artists may be clipped and also may overlap.
- It assumes that the extra space needed for ticklabels, axis labels, and titles is independent of original location of Axes. This is often true, but there are rare cases where it is not.
- There are small differences in how the backends handle rendering fonts, so the results will not be pixel-identical.
- An artist using Axes coordinates that extend beyond the Axes boundary will result in unusual layouts when added to an Axes. This can be avoided by adding the artist directly to the `Figure` using `add_artist()`. See `ConnectionPatch` for an example.

Debugging

Constrained layout can fail in somewhat unexpected ways. Because it uses a constraint solver the solver can find solutions that are mathematically correct, but that aren't at all what the user wants. The usual failure mode is for all sizes to collapse to their smallest allowable value. If this happens, it is for one of two reasons:

1. There was not enough room for the elements you were requesting to draw.
2. There is a bug - in which case open an issue at https://github.com/matplotlib/matplotlib/issues.

If there is a bug, please report with a self-contained example that does not require outside data or dependencies (other than numpy).

Notes on the algorithm

The algorithm for the constraint is relatively straightforward, but has some complexity due to the complex ways we can lay out a figure.

Layout in Matplotlib is carried out with gridspecs via the *GridSpec* class. A gridspec is a logical division of the figure into rows and columns, with the relative width of the Axes in those rows and columns set by *width_ratios* and *height_ratios*.

In *constrained layout*, each gridspec gets a *layoutgrid* associated with it. The *layoutgrid* has a series of `left` and `right` variables for each column, and `bottom` and `top` variables for each row, and further it has a margin for each of left, right, bottom and top. In each row, the bottom/top margins are widened until all the decorators in that row are accommodated. Similarly, for columns and the left/right margins.

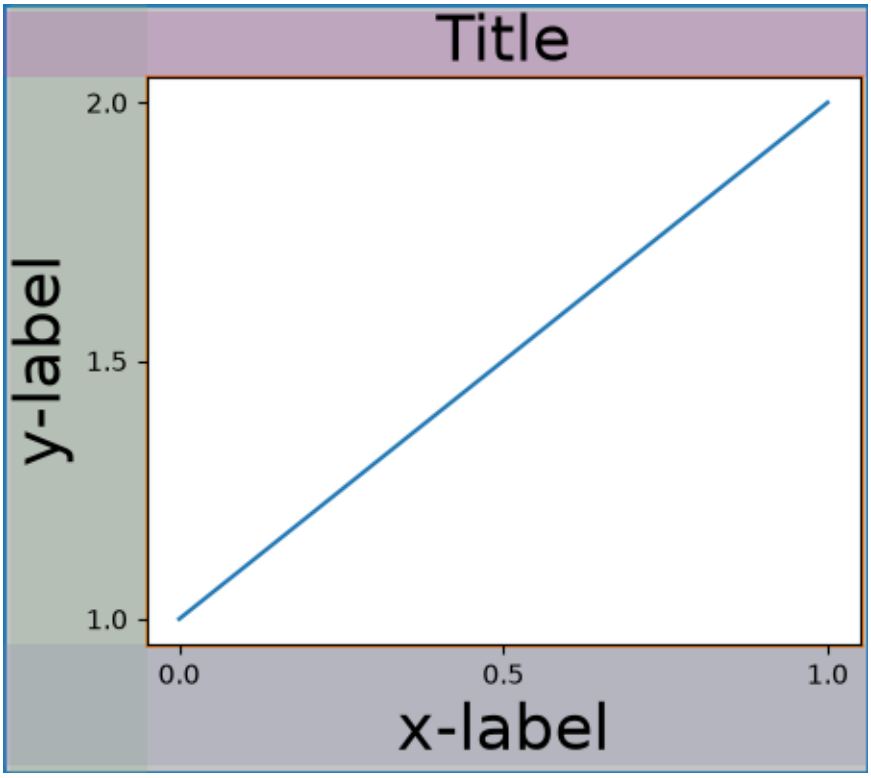
Simple case: one Axes

For a single Axes the layout is straight forward. There is one parent layoutgrid for the figure consisting of one column and row, and a child layoutgrid for the gridspec that contains the Axes, again consisting of one row and column. Space is made for the "decorations" on each side of the Axes. In the code, this is accomplished by the entries in `do_constrained_layout()` like:

```
gridspec._layoutgrid[0, 0].edit_margin_min('left',
      -bbox.x0 + pos.x0 + w_pad)
```

where `bbox` is the tight bounding box of the Axes, and `pos` its position. Note how the four margins encompass the Axes decorations.

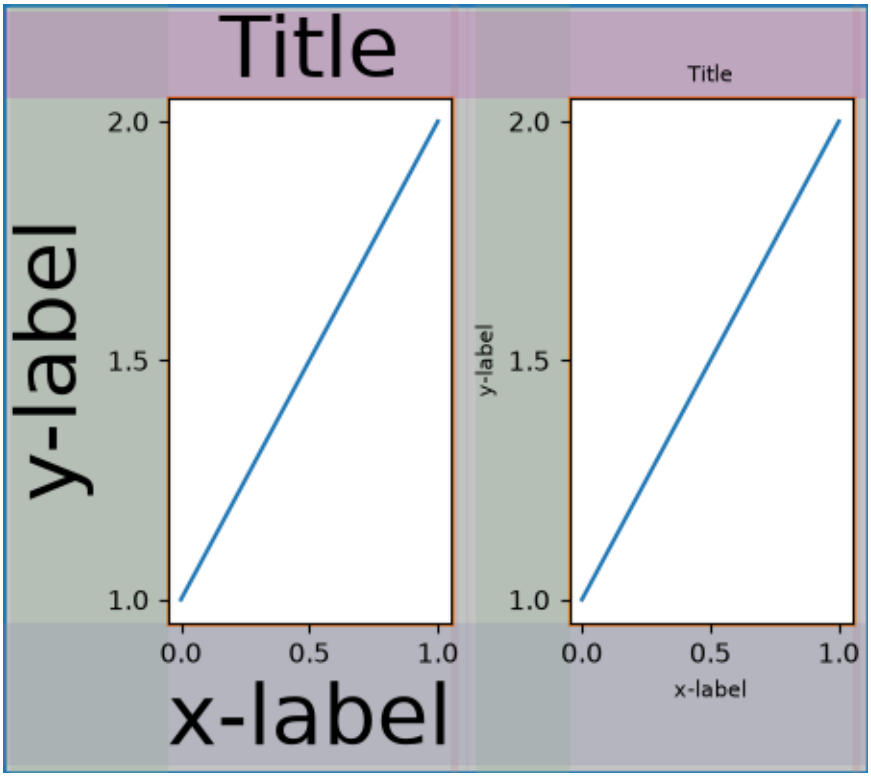
```
from matplotlib._layoutgrid import plot_children

fig, ax = plt.subplots(layout="constrained")
example_plot(ax, fontsize=24)
plot_children(fig)
```



Simple case: two Axes

When there are multiple Axes they have their layouts bound in simple ways. In this example the left Axes has much larger decorations than the right, but they share a bottom margin, which is made large enough to accommodate the larger xlabel. Same with the shared top margin. The left and right margins are not shared, and hence are allowed to be different.

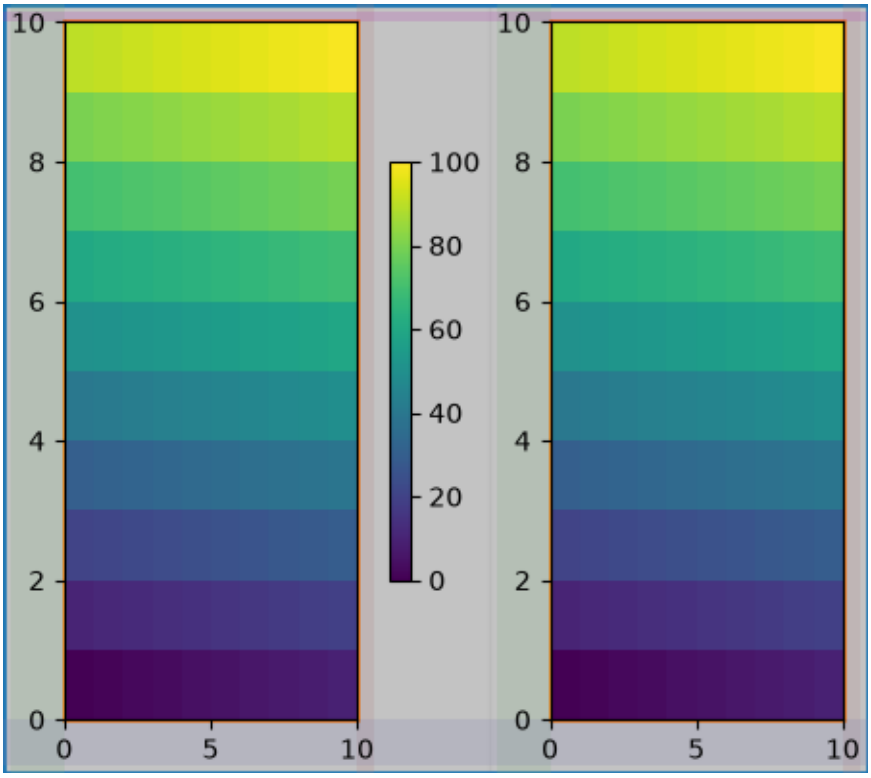
```
fig, ax = plt.subplots(1, 2, layout="constrained")
example_plot(ax[0], fontsize=32)
example_plot(ax[1], fontsize=8)
plot_children(fig)
```



Two Axes and colorbar

A colorbar is simply another item that expands the margin of the parent layoutgrid cell:

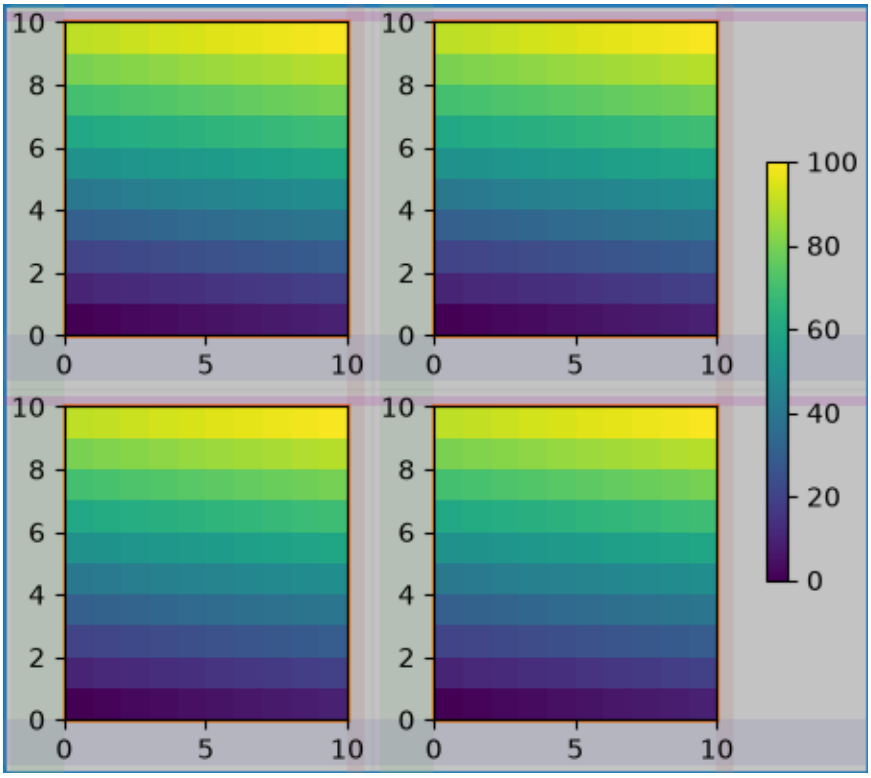
```
fig, ax = plt.subplots(1, 2, layout="constrained")
im = ax[0].pcolormesh(arr, **pc_kwargs)
fig.colorbar(im, ax=ax[0], shrink=0.6)
im = ax[1].pcolormesh(arr, **pc_kwargs)
plot_children(fig)
```



Colorbar associated with a Gridspec

If a colorbar belongs to more than one cell of the grid, then it makes a larger margin for each:

```
fig, axs = plt.subplots(2, 2, layout="constrained")
for ax in axs.flat:
    im = ax.pcolormesh(arr, **pc_kwargs)
fig.colorbar(im, ax=axs, shrink=0.6)
plot_children(fig)
```

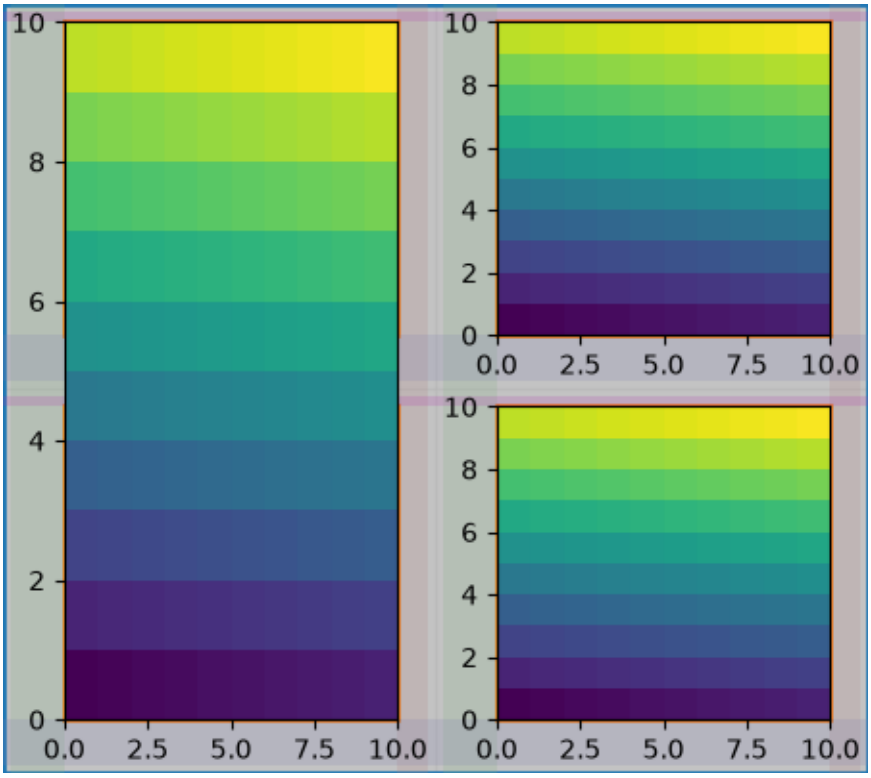


Uneven sized Axes

There are two ways to make Axes have an uneven size in a Gridspec layout, either by specifying them to cross Gridspecs rows or columns, or by specifying width and height ratios.

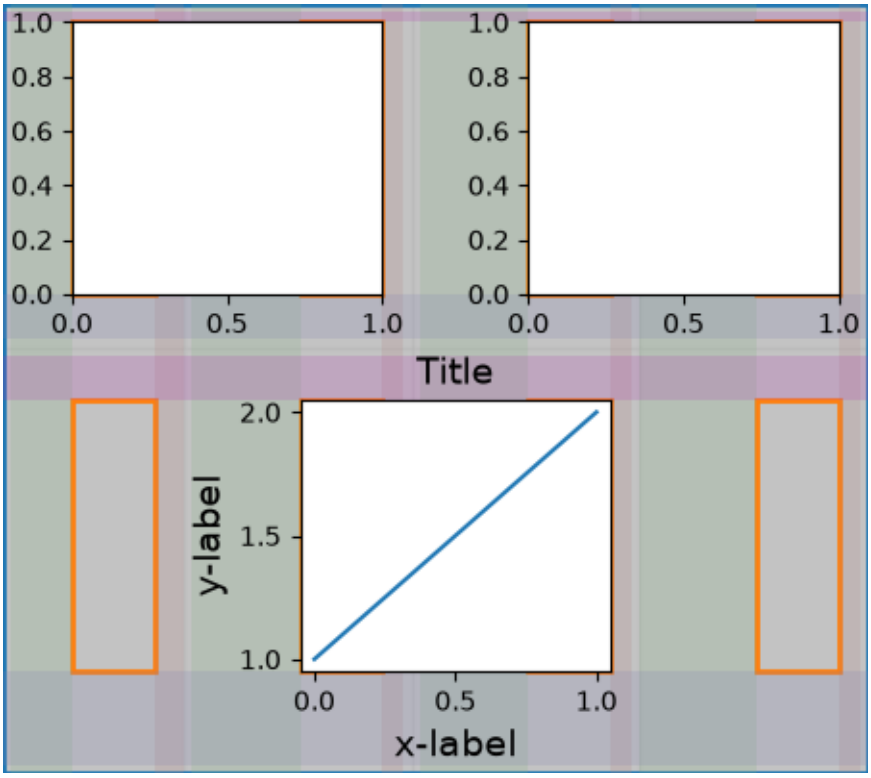
The first method is used here. Note that the middle `top` and `bottom` margins are not affected by the left-hand column. This is a conscious decision of the algorithm, and leads to the case where the two right-hand Axes have the same height, but it is not 1/2 the height of the left-hand Axes. This is consistent with how `gridspec` works without *constrained layout*.

```
fig = plt.figure(layout="constrained")
gs = gridspec.GridSpec(2, 2, figure=fig)
ax = fig.add_subplot(gs[:, 0])
im = ax.pcolormesh(arr, **pc_kwargs)
ax = fig.add_subplot(gs[0, 1])
im = ax.pcolormesh(arr, **pc_kwargs)
ax = fig.add_subplot(gs[1, 1])
im = ax.pcolormesh(arr, **pc_kwargs)
plot_children(fig)
```



One case that requires finessing is if margins do not have any artists constraining their width. In the case below, the right margin for column 0 and the left margin for column 3 have no margin artists to set their width, so we take the maximum width of the margin widths that do have artists. This makes all the Axes have the same size:

```
fig = plt.figure(layout="constrained")
gs = fig.add_gridspec(2, 4)
ax00 = fig.add_subplot(gs[0, 0:2])
ax01 = fig.add_subplot(gs[0, 2:])
ax10 = fig.add_subplot(gs[1, 1:3])
example_plot(ax10, fontsize=14)
plot_children(fig)
plt.show()
```



Total running time of the script: (0 minutes 13.651 seconds)

3.3.11 Tight layout guide

How to use tight-layout to fit plots within your figure cleanly.

Tip

tight_layout was the first layout engine in Matplotlib. The more modern and more capable *Constrained Layout* should typically be used instead.

tight_layout automatically adjusts subplot params so that the subplot(s) fits in to the figure area. This is an experimental feature and may not work for some cases. It only checks the extents of ticklabels, axis labels, and titles.

Simple example

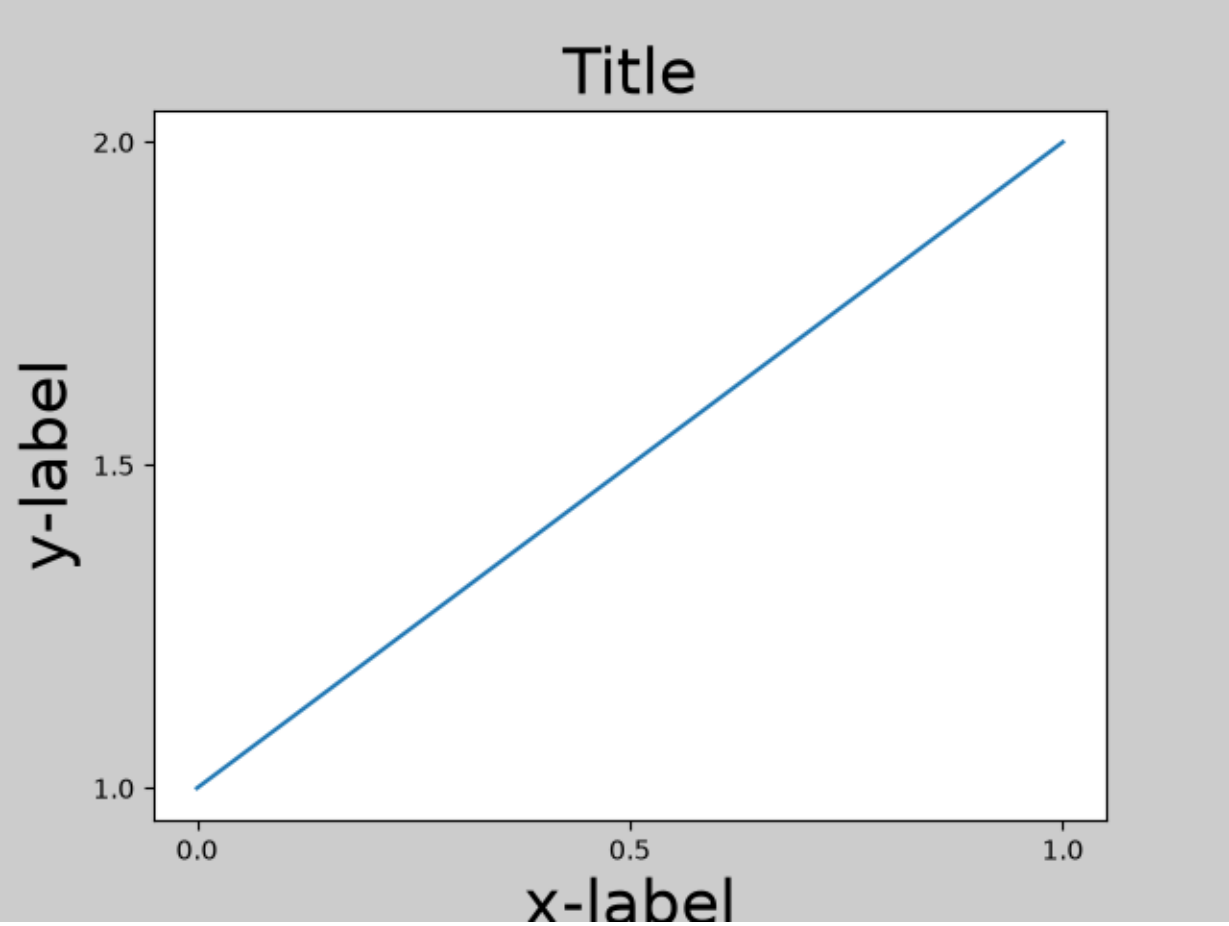
With the default Axes positioning, the axes title, axis labels, or tick labels can sometimes go outside the figure area, and thus get clipped.

```
import matplotlib.pyplot as plt
import numpy as np

plt.rcParams['savefig.facecolor'] = "0.8"
```

(continues on next page)

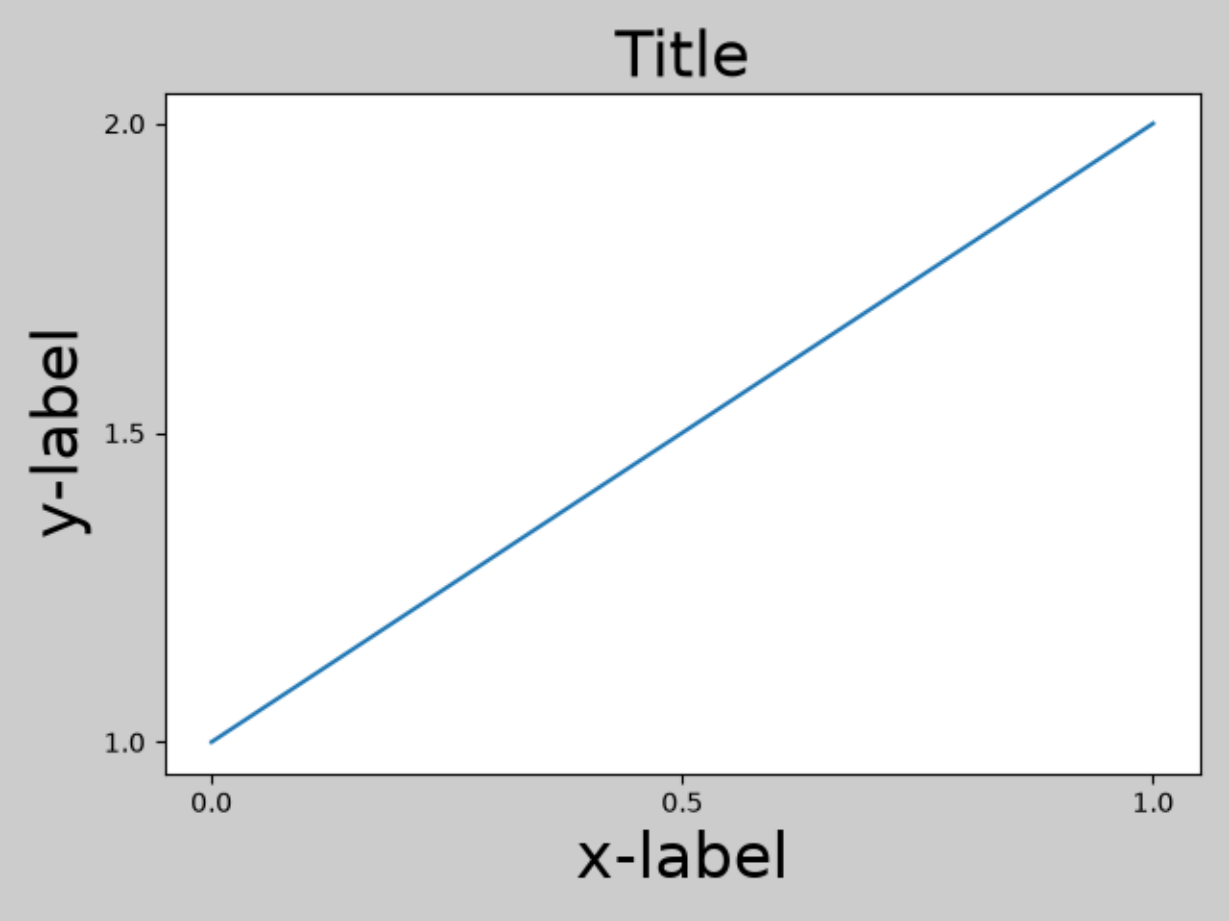
(continued from previous page)

```
def example_plot(ax, fontsize=12):
    ax.plot([1, 2])

    ax.locator_params(nbins=3)
    ax.set_xlabel('x-label', fontsize=fontsize)
    ax.set_ylabel('y-label', fontsize=fontsize)
    ax.set_title('Title', fontsize=fontsize)

plt.close('all')
fig, ax = plt.subplots()
example_plot(ax, fontsize=24)
```



To prevent this, the location of Axes needs to be adjusted. For subplots, this can be done manually by adjusting the subplot parameters using *Figure.subplots_adjust*. *Figure.tight_layout* does this automatically.

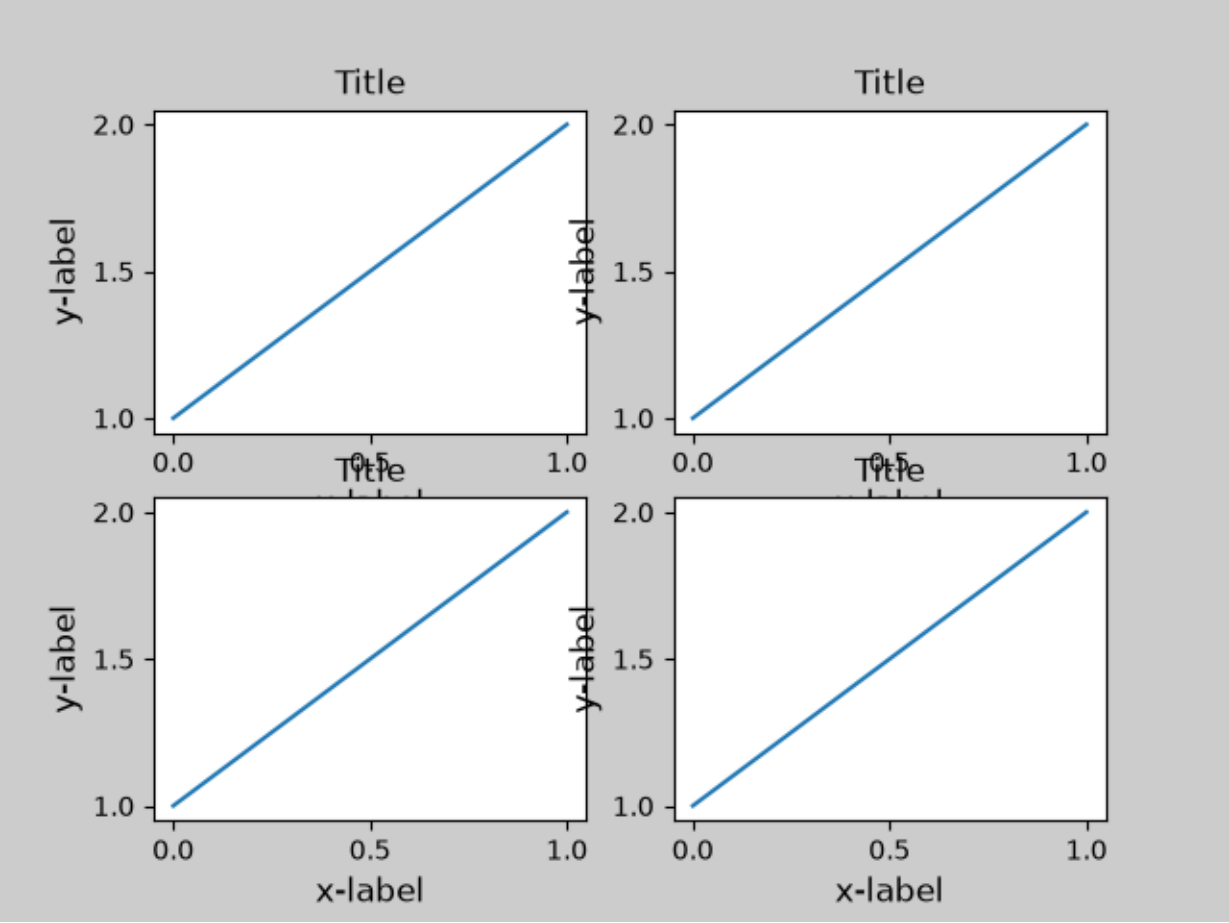
```
fig, ax = plt.subplots()
example_plot(ax, fontsize=24)
plt.tight_layout()
```



Note that *matplotlib.pyplot.tight_layout()* will only adjust the subplot params when it is called. In order to perform this adjustment each time the figure is redrawn, you can call `fig.set_tight_layout(True)`, or, equivalently, set *rcParams["figure.autolayout"]* (default: `False`) to `True`.

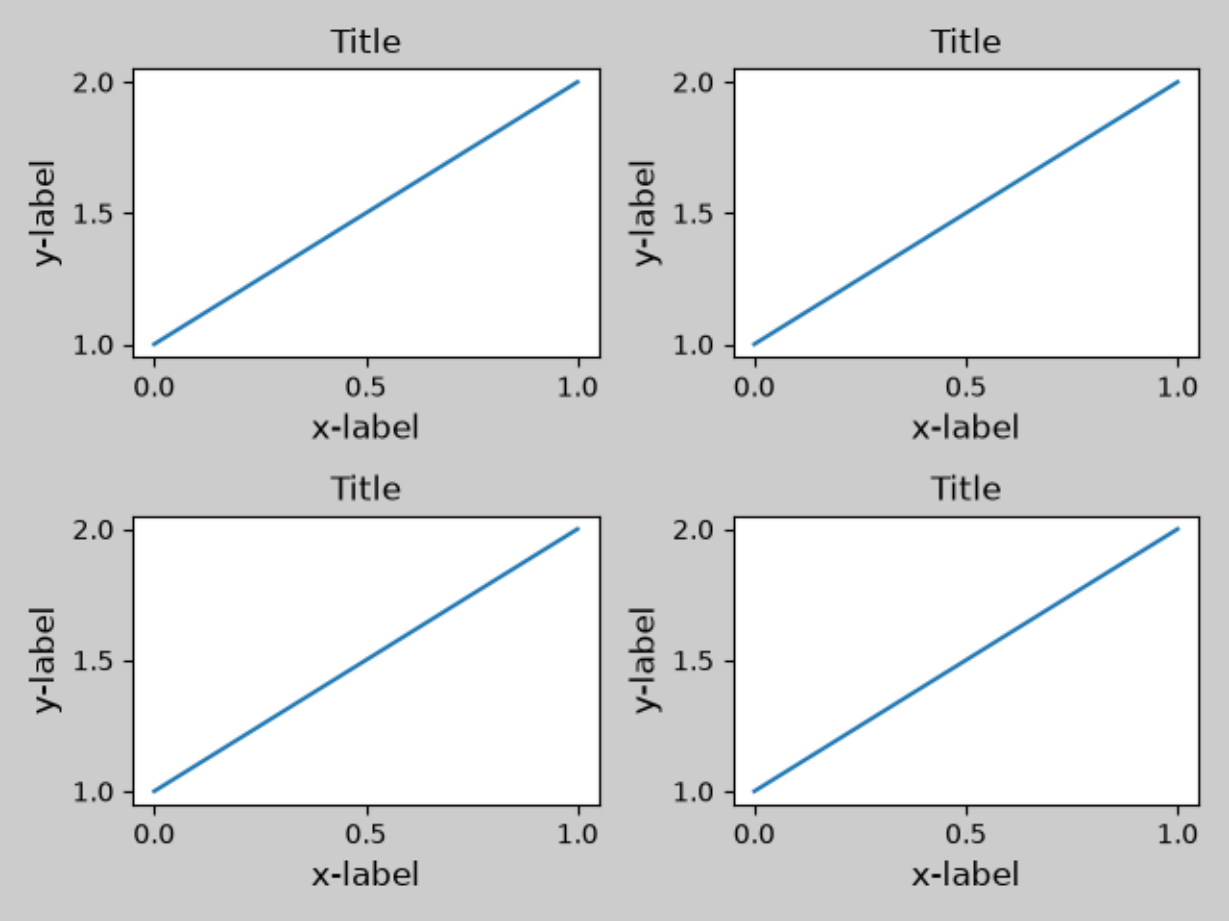
When you have multiple subplots, often you see labels of different Axes overlapping each other.

```
plt.close('all')

fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(nrows=2, ncols=2)
example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
example_plot(ax4)
```



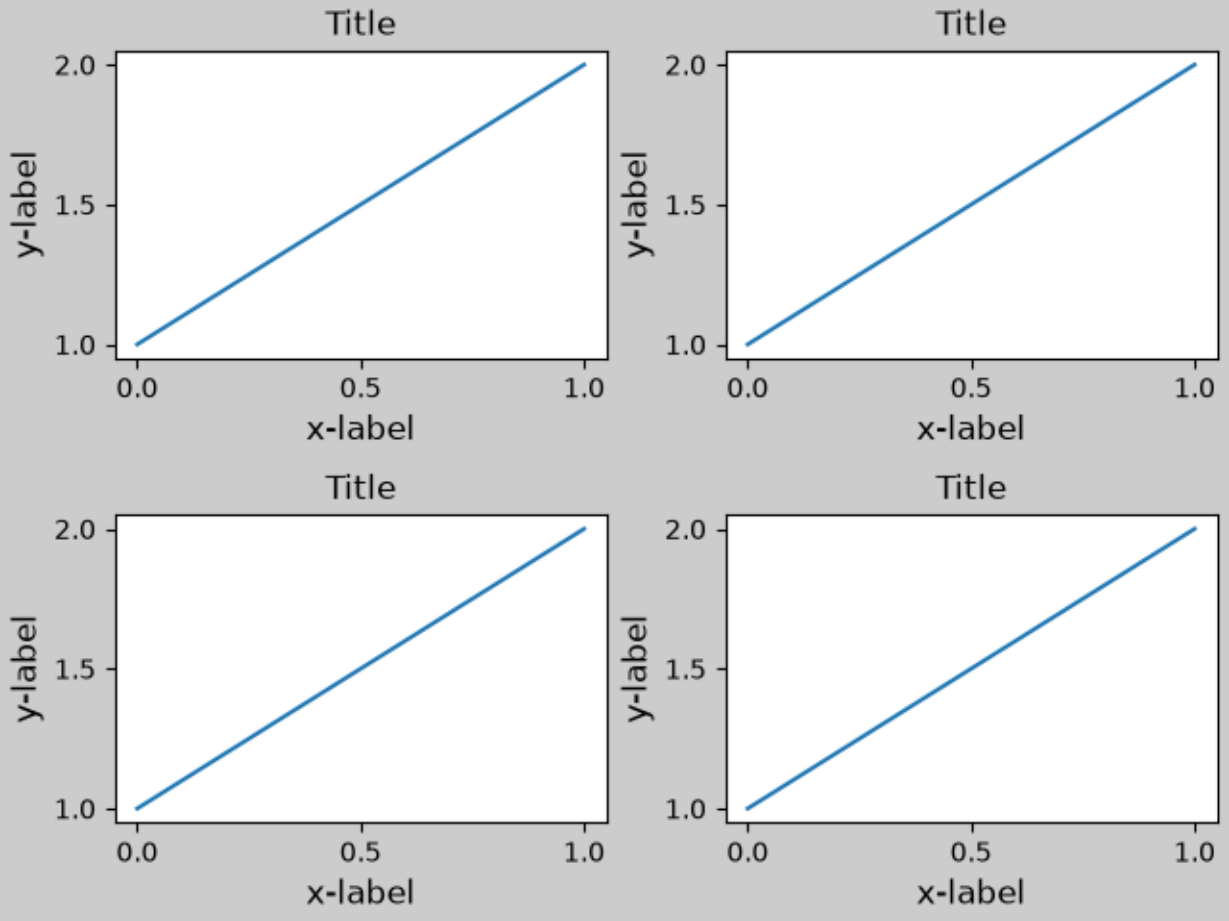
tight_layout() will also adjust spacing between subplots to minimize the overlaps.

```
fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(nrows=2, ncols=2)
example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
example_plot(ax4)
plt.tight_layout()
```



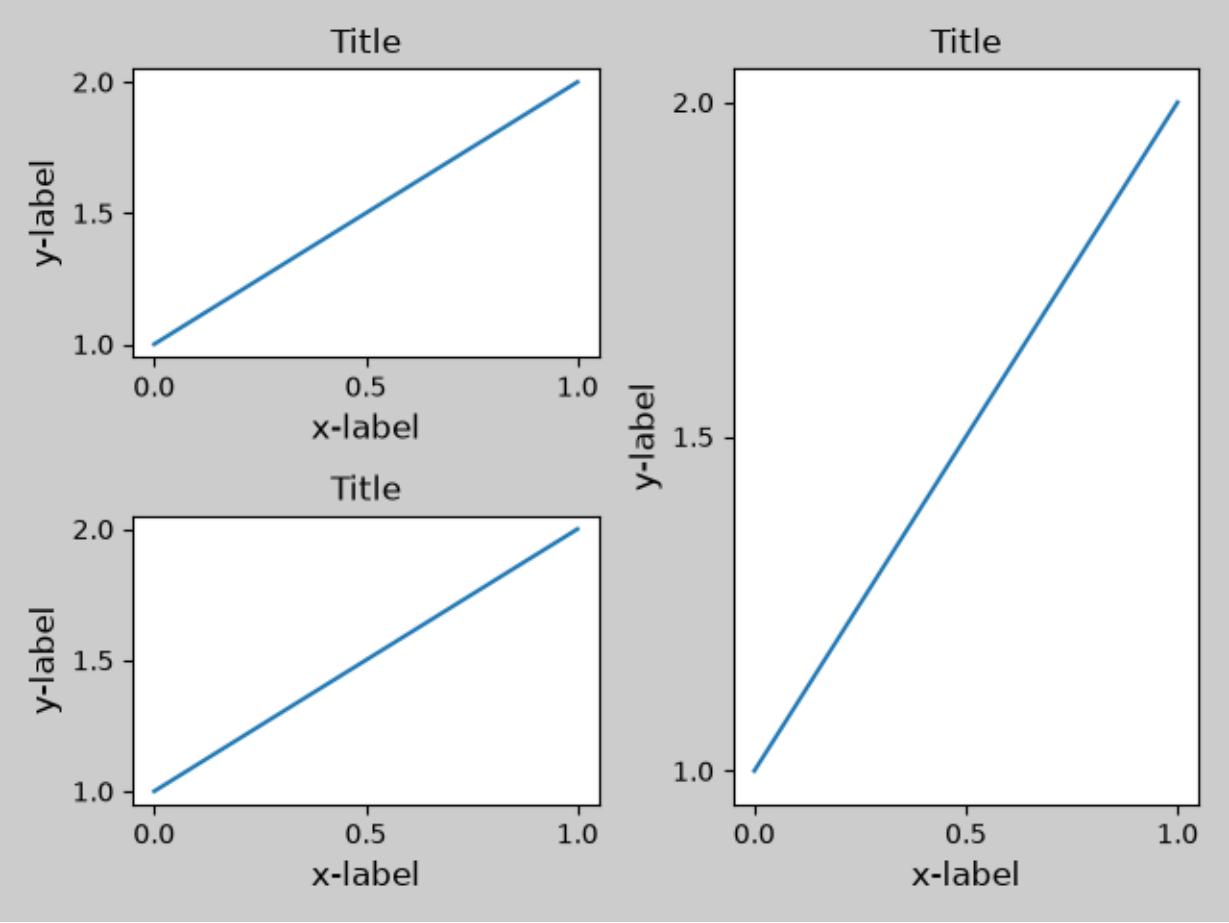
`tight_layout()` can take keyword arguments of *pad*, *w_pad* and *h_pad*. These control the extra padding around the figure border and between subplots. The pads are specified in fraction of fontsize.

```
fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(nrows=2, ncols=2)
example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
example_plot(ax4)
plt.tight_layout(pad=0.4, w_pad=0.5, h_pad=1.0)
```



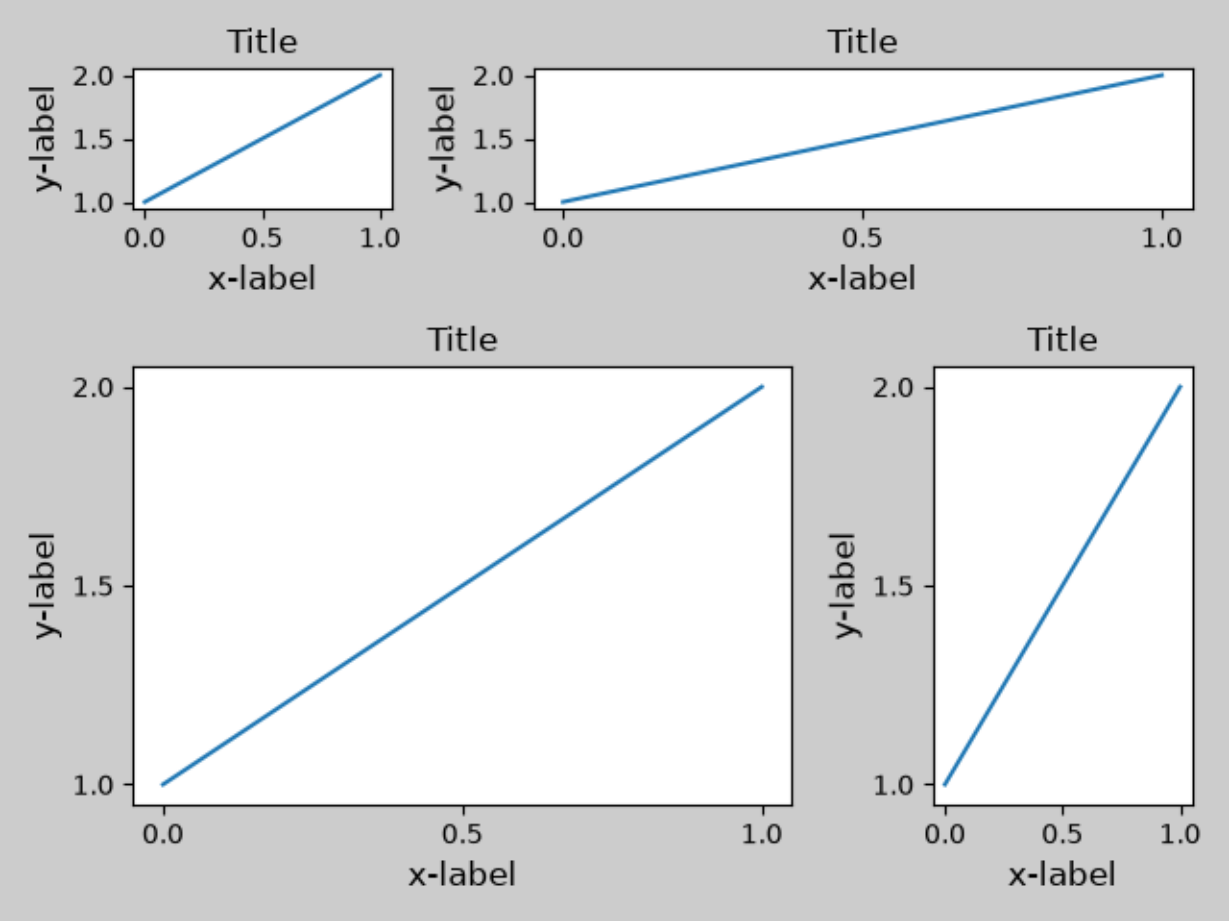
tight_layout() will work even if the sizes of subplots are different as far as their grid specification is compatible. In the example below, *ax1* and *ax2* are subplots of a 2x2 grid, while *ax3* is of a 1x2 grid.

```
plt.close('all')
fig = plt.figure()

ax1 = plt.subplot(221)
ax2 = plt.subplot(223)
ax3 = plt.subplot(122)

example_plot(ax1)
example_plot(ax2)
example_plot(ax3)

plt.tight_layout()
```



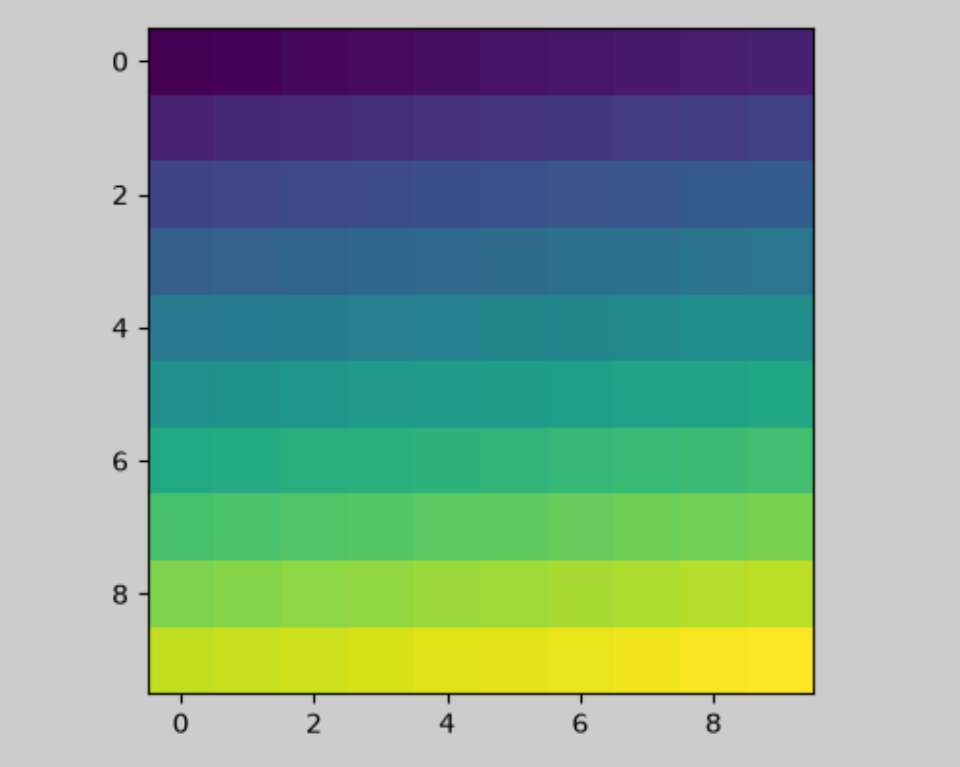
It works with subplots created with *subplot2grid()*. In general, subplots created from the gridspec (*Arranging multiple Axes in a Figure*) will work.

```
plt.close('all')
fig = plt.figure()

ax1 = plt.subplot2grid((3, 3), (0, 0))
ax2 = plt.subplot2grid((3, 3), (0, 1), colspan=2)
ax3 = plt.subplot2grid((3, 3), (1, 0), colspan=2, rowspan=2)
ax4 = plt.subplot2grid((3, 3), (1, 2), rowspan=2)

example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
example_plot(ax4)

plt.tight_layout()
```



Although not thoroughly tested, it seems to work for subplots with aspect != "auto" (e.g., Axes with images).

```
arr = np.arange(100).reshape((10, 10))

plt.close('all')
fig = plt.figure(figsize=(5, 4))

ax = plt.subplot()
im = ax.imshow(arr, interpolation="none")

plt.tight_layout()
```



Caveats

- *tight_layout* considers all artists on the Axes by default. To remove an artist from the layout calculation you can call *Artist.set_in_layout*.
- tight_layout assumes that the extra space needed for artists is independent of the original location of Axes. This is often true, but there are rare cases where it is not.
- pad=0 can clip some texts by a few pixels. This may be a bug or a limitation of the current algorithm, and it is not clear why it happens. Meanwhile, use of pad larger than 0.3 is recommended.
- The algorithm of tight_layout does not necessarily converge, i.e. calling tight_layout multiple times can lead to slight variations in the layout between the calls.

Use with GridSpec

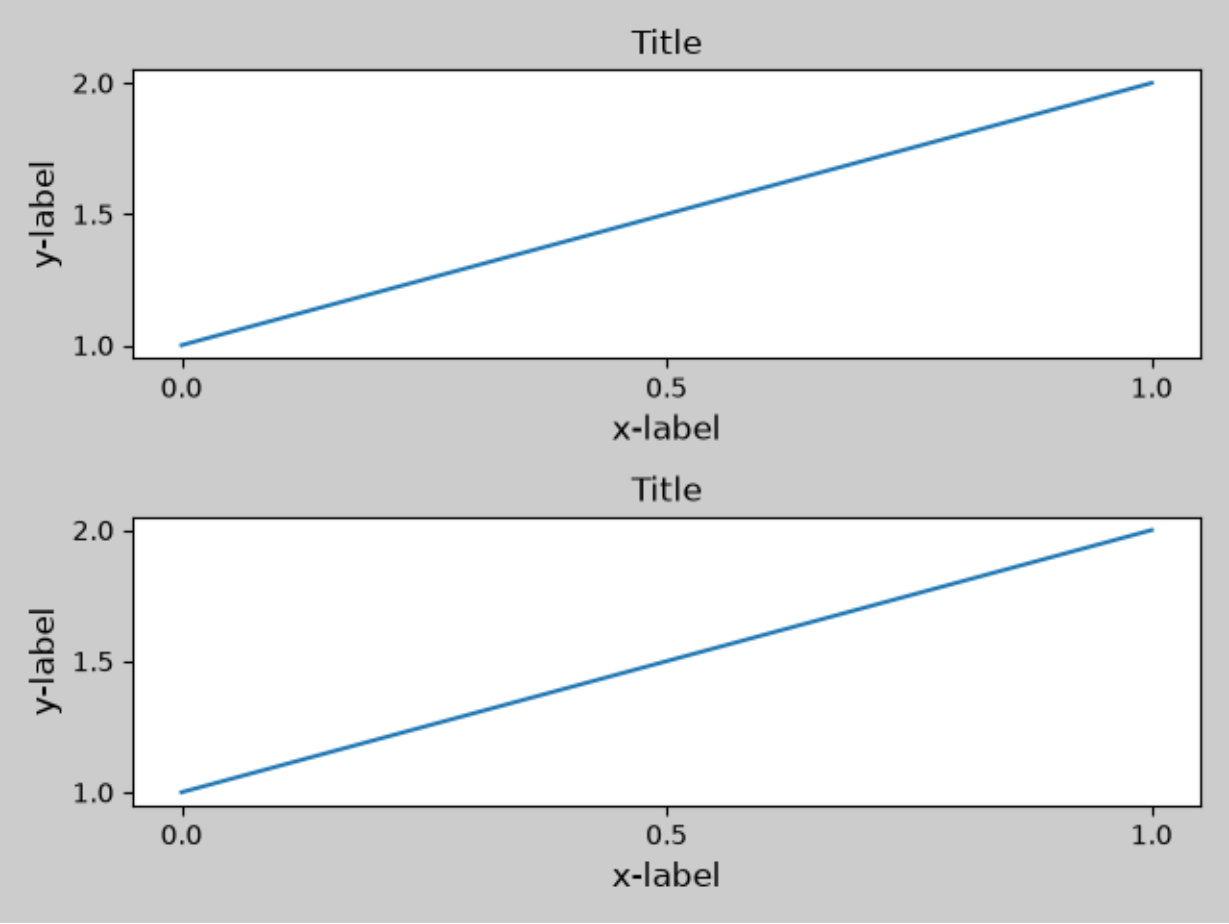
GridSpec has its own *GridSpec.tight_layout* method (the pyplot api *pyplot.tight_layout* also works).

```
import matplotlib.gridspec as gridspec

plt.close('all')
fig = plt.figure()

gs1 = gridspec.GridSpec(2, 1)
ax1 = fig.add_subplot(gs1[0])
ax2 = fig.add_subplot(gs1[1])
```

(continues on next page)

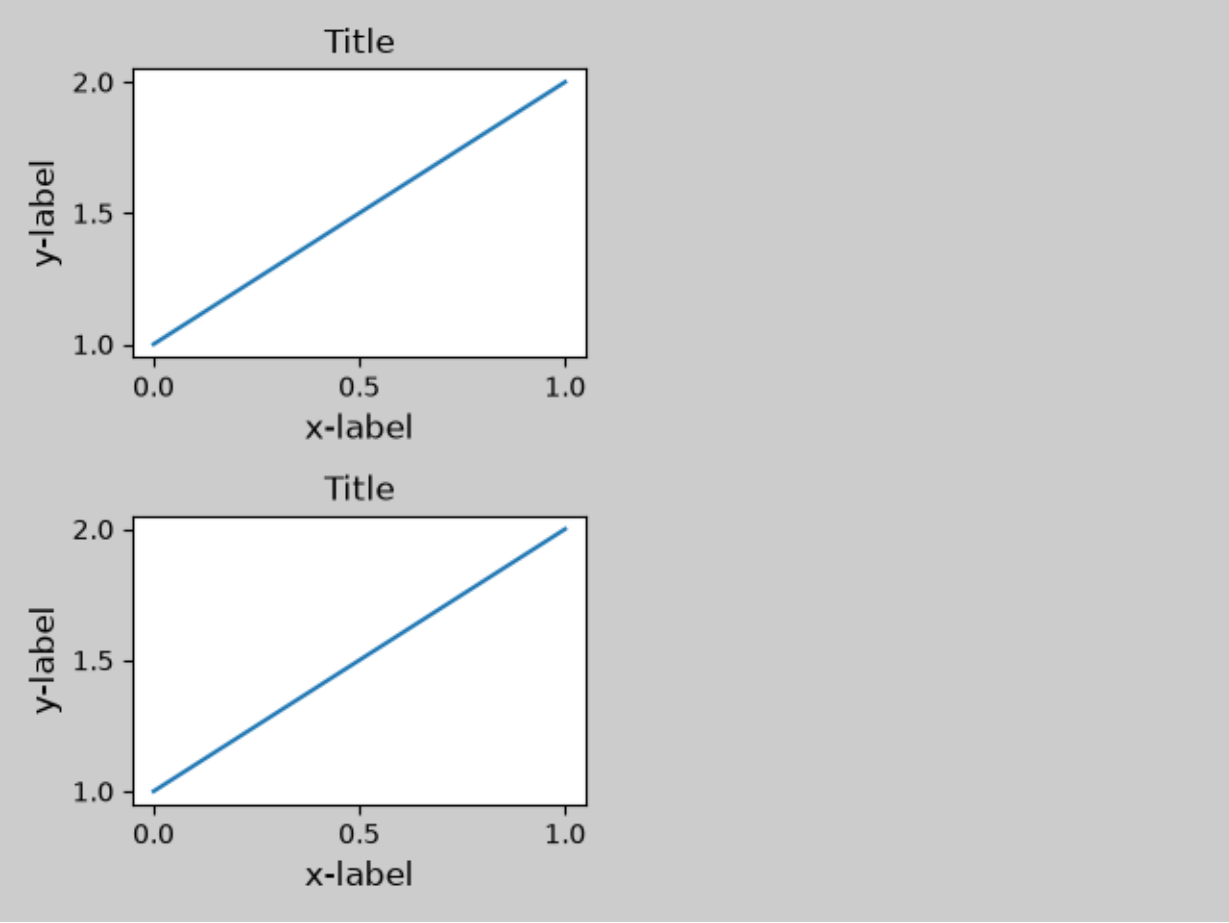
(continued from previous page)

```
example_plot(ax1)
example_plot(ax2)

gs1.tight_layout(fig)
```



You may provide an optional *rect* parameter, which specifies the bounding box that the subplots will be fit inside. The coordinates are in normalized figure coordinates and default to (0, 0, 1, 1) (the whole figure).

```
fig = plt.figure()

gs1 = gridspec.GridSpec(2, 1)
ax1 = fig.add_subplot(gs1[0])
ax2 = fig.add_subplot(gs1[1])

example_plot(ax1)
example_plot(ax2)

gs1.tight_layout(fig, rect=[0, 0, 0.5, 1.0])
```

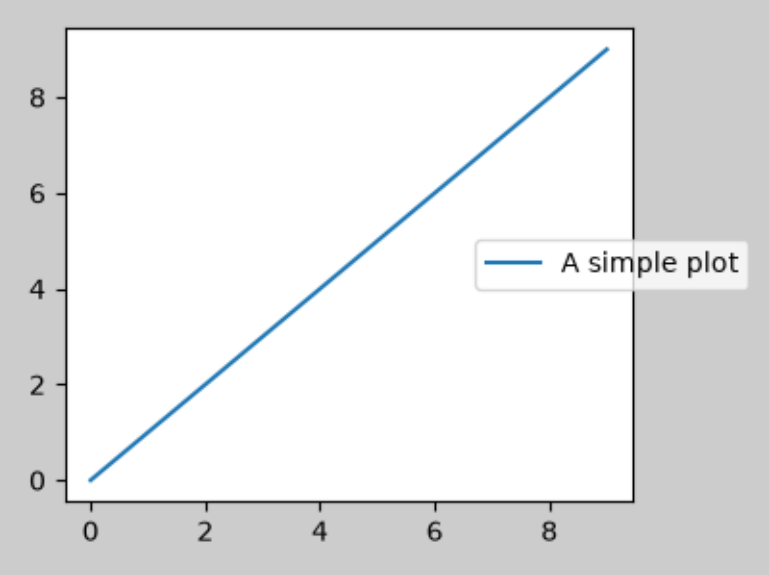


However, we do not recommend that this be used to manually construct more complicated layouts, like having one GridSpec in the left and one in the right side of the figure. For these use cases, one should instead take advantage of *Nested Gridspecs*, or the *Figure subfigures*.

Legends and annotations

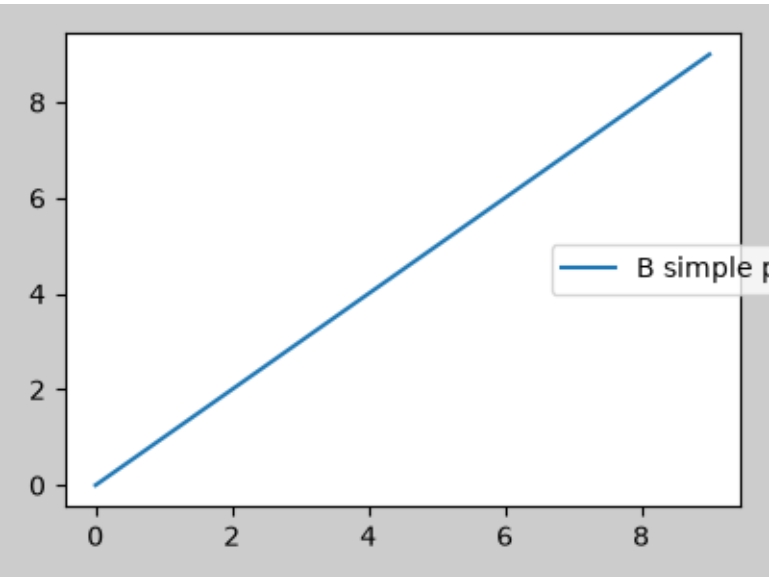
Pre Matplotlib 2.2, legends and annotations were excluded from the bounding box calculations that decide the layout. Subsequently, these artists were added to the calculation, but sometimes it is undesirable to include them. For instance in this case it might be good to have the Axes shrink a bit to make room for the legend:

```
fig, ax = plt.subplots(figsize=(4, 3))
lines = ax.plot(range(10), label='A simple plot')
ax.legend(bbox_to_anchor=(0.7, 0.5), loc='center left',)
fig.tight_layout()
plt.show()
```



However, sometimes this is not desired (quite often when using `fig.savefig('outname.png', bbox_inches='tight')`). In order to remove the legend from the bounding box calculation, we simply set its bounding `leg.set_in_layout(False)` and the legend will be ignored.

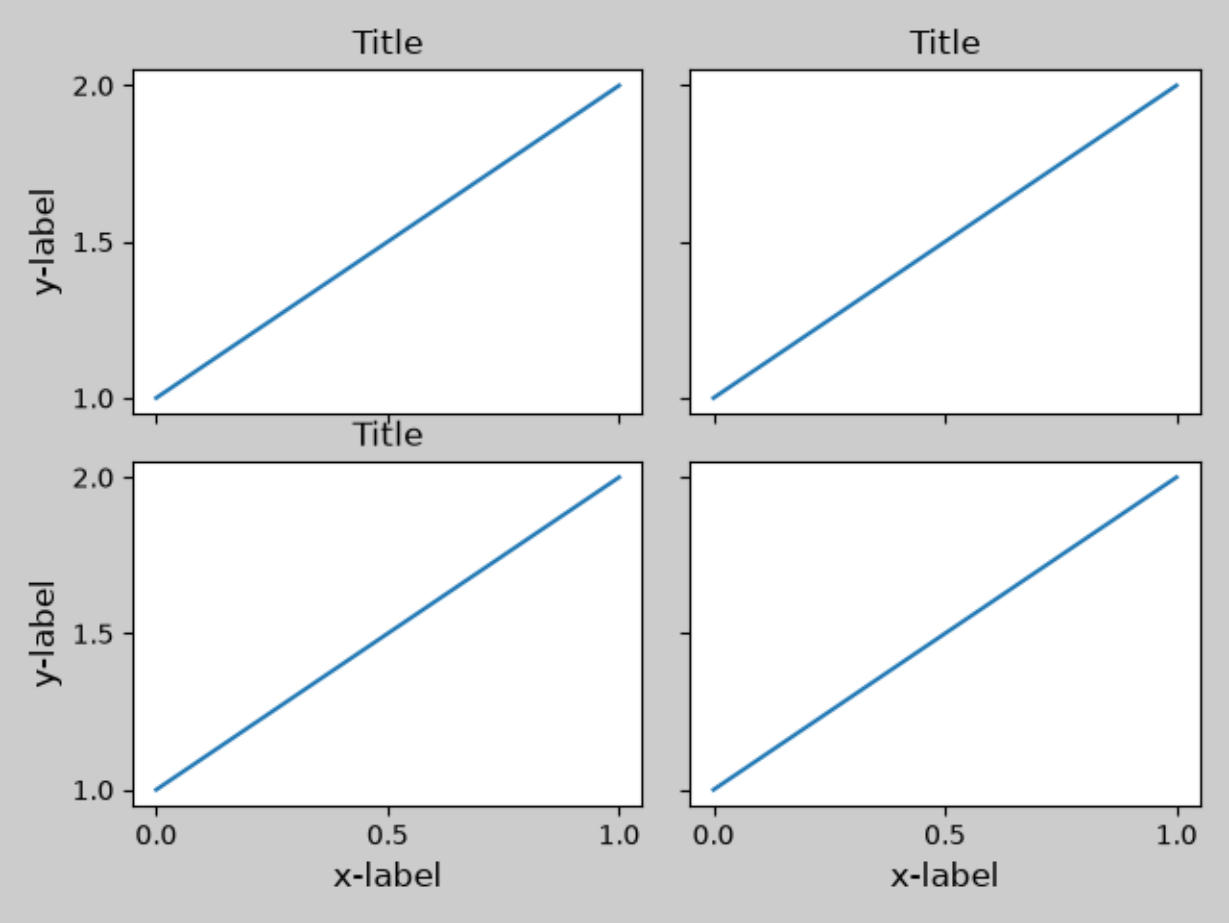
```
fig, ax = plt.subplots(figsize=(4, 3))
lines = ax.plot(range(10), label='B simple plot')
leg = ax.legend(bbox_to_anchor=(0.7, 0.5), loc='center left',)
leg.set_in_layout(False)
fig.tight_layout()
plt.show()
```



Use with AxesGrid1

Limited support for *mpl_toolkits.axes_grid1* is provided.

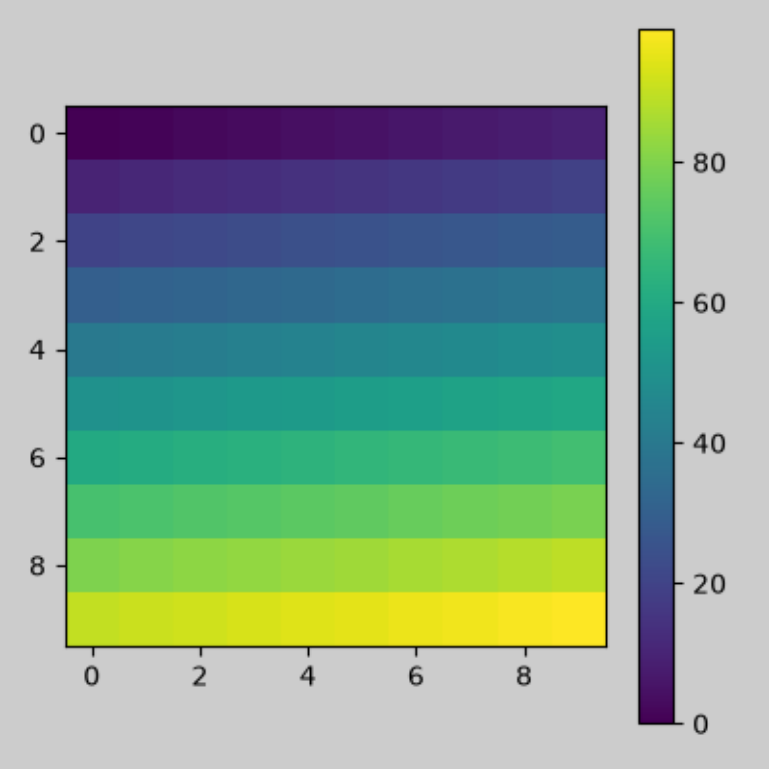
```
from mpl_toolkits.axes_grid1 import Grid

plt.close('all')
fig = plt.figure()
grid = Grid(fig, rect=111, nrows_ncols=(2, 2),
            axes_pad=0.25, label_mode='L',
            )

for ax in grid:
    example_plot(ax)
ax.title.set_visible(False)

plt.tight_layout()
```



Colorbar

If you create a colorbar with *Figure.colorbar*, the created colorbar is drawn in a Subplot as long as the parent Axes is also a Subplot, so *Figure.tight_layout* will work.

```
plt.close('all')
arr = np.arange(100).reshape((10, 10))
fig = plt.figure(figsize=(4, 4))
im = plt.imshow(arr, interpolation="none")

plt.colorbar(im)

plt.tight_layout()
```



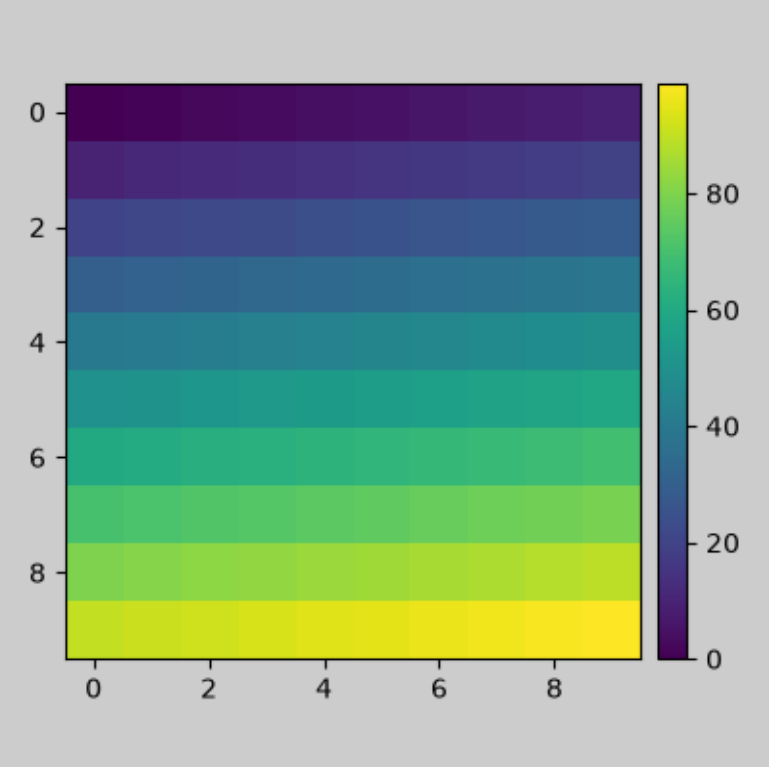
Another option is to use the AxesGrid1 toolkit to explicitly create an Axes for the colorbar.

```
from mpl_toolkits.axes_grid1 import make_axes_locatable

plt.close('all')
arr = np.arange(100).reshape((10, 10))
fig = plt.figure(figsize=(4, 4))
im = plt.imshow(arr, interpolation="none")

divider = make_axes_locatable(plt.gca())
cax = divider.append_axes("right", "5%", pad="3%")
plt.colorbar(im, cax=cax)
```

(continues on next page)

(continued from previous page)

```
plt.tight_layout()
```



Total running time of the script: (0 minutes 4.705 seconds)

3.4 Artists

Almost all objects you interact with on a Matplotlib plot are called "Artist" (and are subclasses of the `Artist` class). *Figure* and *Axes* are Artists, and generally contain `Axis` Artists and Artists that contain data or annotation information.

3.4.1 Introduction to Artists

Almost all objects you interact with on a Matplotlib plot are called "Artist" (and are subclasses of the `Artist` class). *Figure* and *Axes* are Artists, and generally contain `Axis` Artists and Artists that contain data or annotation information.

Creating Artists

Usually we do not instantiate Artists directly, but rather use a plotting method on `Axes`. Some examples of plotting methods and the Artist object they create is given below:

Axes helper method	Artist
annotate - text annotations	*Annotation*
bar - bar charts	*Rectangle*
errorbar - error bar plots	*Line2D* and *Rectangle*
fill - shared area	*Polygon*
hist - histograms	*Rectangle*
imshow - image data	*AxesImage*
legend - Axes legend	*Legend*
plot - xy plots	*Line2D*
scatter - scatter charts	*PolyCollection*
text - text	*Text*

As an example, we can save the Line2D Artist returned from *axes.Axes.plot*:

```
In [209]: import matplotlib.pyplot as plt
In [210]: import matplotlib.artist as martist
In [211]: import numpy as np

In [212]: fig, ax = plt.subplots()
In [213]: x, y = np.random.rand(2, 100)
In [214]: lines = ax.plot(x, y, '-', label='example')
In [215]: print(lines)
[<matplotlib.lines.Line2D at 0xd378b0c>]
```

Note that `plot` returns a _list_ of lines because you can pass in multiple x, y pairs to plot. The line has been added to the Axes, and we can retrieve the Artist via *get_lines()*:

```
In [216]: print(ax.get_lines())
<a list of 1 Line2D objects>
In [217]: print(ax.get_lines()[0])
Line2D(example)
```

Changing Artist properties

Getting the `lines` object gives us access to all the properties of the Line2D object. So if we want to change the *linewidth* after the fact, we can do so using *Artist.set*.

```
fig, ax = plt.subplots(figsize=(4, 2.5))
x = np.arange(0, 13, 0.2)
y = np.sin(x)
lines = ax.plot(x, y, '-', label='example', linewidth=0.2, color='blue
 ↪')
lines[0].set(color='green', linewidth=2)
```

We can interrogate the full list of settable properties with *matplotlib.artist.getp*:

```
In [218]: martist.getp(lines[0])
agg_filter = None
alpha = None
animated = False
antialiased or aa = True
bbox = Bbox(x0=0.004013842290585101, y0=0.013914221641967...
children = []
clip_box = TransformedBbox(     Bbox(x0=0.0, y0=0.0, x1=1.0, ...
clip_on = True
clip_path = None
color or c = blue
dash_capstyle = butt
dash_joinstyle = round
data = (array([0.91377845, 0.58456834, 0.36492019, 0.0379...
drawstyle or ds = default
figure = Figure(550x450)
fillstyle = full
gapcolor = None
gid = None
in_layout = True
label = example
linestyle or ls = -
linewidth or lw = 2.0
marker = None
markeredgecolor or mec = blue
markeredgewidth or mew = 1.0
markerfacecolor or mfc = blue
markerfacecoloralt or mfcalt = none
markersize or ms = 6.0
markevery = None
mouseover = False
path = Path(array([[0.91377845, 0.51224793],        [0.58...
path_effects = []
picker = None
pickradius = 5
rasterized = False
sketch_params = None
snap = None
solid_capstyle = projecting
solid_joinstyle = round
tightbbox = Bbox(x0=70.4609002763619, y0=54.321277798941786, x...
transform = CompositeGenericTransform(     TransformWrapper(  ...
transformed_clip_path_and_affine = (None, None)
url = None
visible = True
window_extent = Bbox(x0=70.4609002763619, y0=54.321277798941786, x...
```

(continues on next page)

(continued from previous page)

```
xdata = [0.91377845 0.58456834 0.36492019 0.03796664 0.884...
xydata = [[0.91377845 0.51224793]  [0.58456834 0.9820474 ] ...
ydata = [0.51224793 0.9820474  0.24469912 0.61647032 0.483...
zorder = 2
```

Note most Artists also have a distinct list of setters; e.g. *Line2D.set_color* or *Line2D.set_linewidth*.

Changing Artist data

In addition to styling properties like *color* and *linewidth*, the Line2D object has a *data* property. You can set the data after the line has been created using *Line2D.set_data*. This is often used for Animations, where the same line is shown evolving over time (see *Animations using Matplotlib*)

```
fig, ax = plt.subplots(figsize=(4, 2.5))
x = np.arange(0, 13, 0.2)
y = np.sin(x)
lines = ax.plot(x, y, '-', label='example')
lines[0].set_data([x, np.cos(x)])
```

Manually adding Artists

Not all Artists have helper methods, or you may want to use a low-level method for some reason. For example the *patches.Circle* Artist does not have a helper, but we can still create and add to an Axes using the *axes.Axes.add_artist* method:

```
import matplotlib.patches as mpatches

fig, ax = plt.subplots(figsize=(4, 2.5))
circle = mpatches.Circle((0.5, 0.5), 0.25, ec="none")
ax.add_artist(circle)
clipped_circle = mpatches.Circle((1, 0.5), 0.125, ec="none", facecolor=
 ↪'C1')
ax.add_artist(clipped_circle)
ax.set_aspect(1)
```

The Circle takes the center and radius of the Circle as arguments to its constructor; optional arguments are passed as keyword arguments.

Note that when we add an Artist manually like this, it doesn't necessarily adjust the axis limits like most of the helper methods do, so the Artists can be clipped, as is the case above for the `clipped_circle` patch.

See *Reference for Matplotlib artists* for other patches.

Removing Artists

Sometimes we want to remove an Artist from a figure without re-specifying the whole figure from scratch. Most Artists have a usable *remove* method that will remove the Artist from its Axes list. For instance `lines[0].remove()` would remove the *Line2D* artist created in the example above.

3.4.2 Styling with cycler

Demo of custom property-cycle settings to control colors and other style properties for multi-line plots.

Note

More complete documentation of the `cycler` API can be found here.

This example demonstrates two different APIs:

1. Setting the rc parameter specifying the default property cycle. This affects all subsequent Axes (but not Axes already created).
2. Setting the property cycle for a single pair of Axes.

```
from cycler import cycler

import matplotlib.pyplot as plt
import numpy as np
```

First we'll generate some sample data, in this case, four offset sine curves.

```
x = np.linspace(0, 2 * np.pi, 50)
offsets = np.linspace(0, 2 * np.pi, 4, endpoint=False)
yy = np.transpose([np.sin(x + phi) for phi in offsets])
```

Now `yy` has shape

```
print(yy.shape)
```

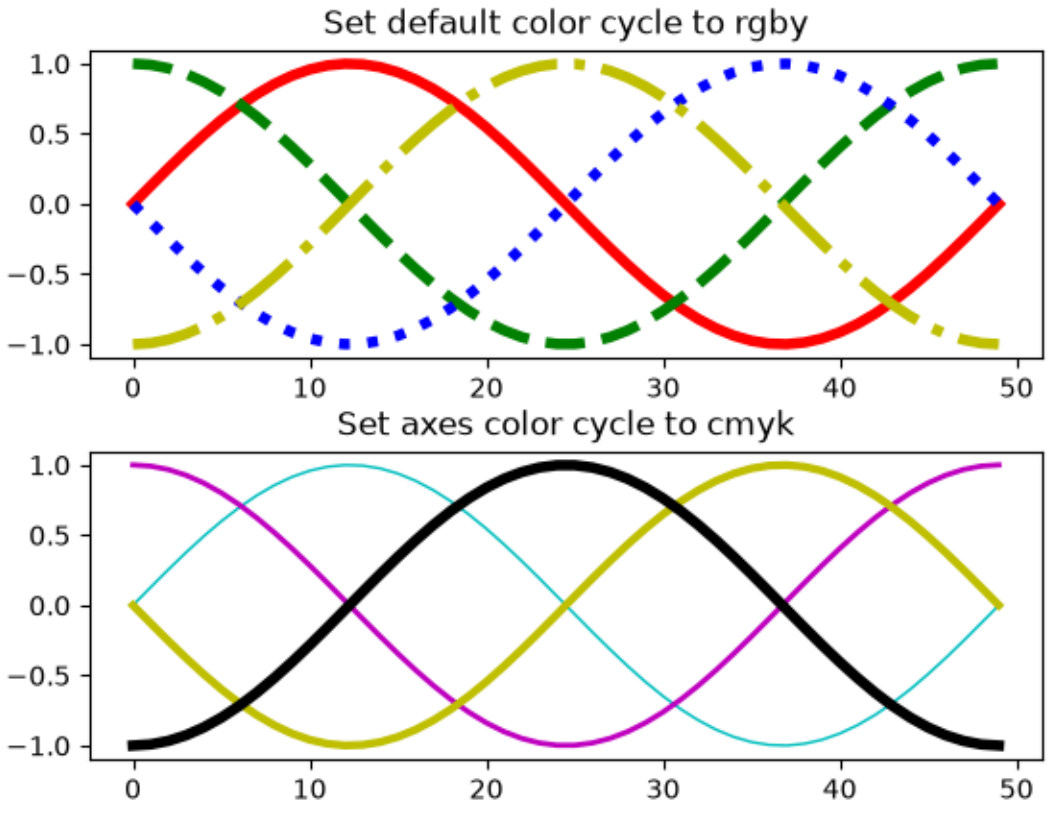
```
(50, 4)
```

So `yy[:, i]` will give you the `i`-th offset sine curve. Let's set the default `prop_cycle` using *`matplotlib.pyplot.rc()`*. We'll combine a color cycler and a linestyle cycler by adding (+) two `cycler`'s together. See the bottom of this tutorial for more information about combining different cyclers.

```
default_cycler = (cycler(color=['r', 'g', 'b', 'y']) +
                  cycler(linestyle=['-', '--', ':', '-.']))

plt.rc('lines', linewidth=4)
plt.rc('axes', prop_cycle=default_cycler)
```

Now we'll generate a figure with two Axes, one on top of the other. On the first axes, we'll plot with the default cycler. On the second axes, we'll set the `prop_cycle` using *`matplotlib.axes.Axes.set_prop_cycle()`*, which will only set the `prop_cycle` for this *`matplotlib.axes.Axes`* instance. We'll use a second `cycler` that combines a color cycler and a linewidth cycler.

```
custom_cycler = (cycler(color=['c', 'm', 'y', 'k']) +
                 cycler(lw=[1, 2, 3, 4]))

fig, (ax0, ax1) = plt.subplots(nrows=2)
ax0.plot(yy)
ax0.set_title('Set default color cycle to rgby')
ax1.set_prop_cycle(custom_cycler)
ax1.plot(yy)
ax1.set_title('Set axes color cycle to cmyk')

# Add a bit more space between the two plots.
fig.subplots_adjust(hspace=0.3)
plt.show()
```



Setting `prop_cycle` in the `matplotlibrc` file or style files

Remember, a custom cycler can be set in your `matplotlibrc` file or a style file (`style.mplstyle`) under `axes.prop_cycle`, e.g.

```
axes.prop_cycle : cycler(color=['red', 'royalblue', 'gray'])
```

For colors, a single string may be used either for one of the *Named color sequences*

```
axes.prop_cycle : cycler(color='Accent')
```

or if each color has a single character name:

```
axes.prop_cycle : cycler(color='bgrcmyk')
```

Cycling through multiple properties

You can add cyclers:

```
from cycler import cycler
cc = (cycler(color=list('rgb')) +
      cycler(linestyle=['-', '--', '-.']))
for d in cc:
    print(d)
```

Results in:

```
{'color': 'r', 'linestyle': '-'}
{'color': 'g', 'linestyle': '--'}
{'color': 'b', 'linestyle': '-.'}
```

You can multiply cyclers:

```
from cycler import cycler
cc = (cycler(color=list('rgb')) *
      cycler(linestyle=['-', '--', '-.']))
for d in cc:
    print(d)
```

Results in:

```
{'color': 'r', 'linestyle': '-'}
{'color': 'r', 'linestyle': '--'}
{'color': 'r', 'linestyle': '-.'}
{'color': 'g', 'linestyle': '-'}
{'color': 'g', 'linestyle': '--'}
{'color': 'g', 'linestyle': '-.'}
{'color': 'b', 'linestyle': '-'}
```

(continues on next page)

(continued from previous page)

```
{'color': 'b', 'linestyle': '--'}
{'color': 'b', 'linestyle': '-.'}
```

3.4.3 Performance

Whether exploring data in interactive mode or programmatically saving lots of plots, rendering performance can be a challenging bottleneck in your pipeline. Matplotlib provides multiple ways to greatly reduce rendering time at the cost of a slight change (to a settable tolerance) in your plot's appearance. The methods available to reduce rendering time depend on the type of plot that is being created.

Line segment simplification

For plots that have line segments (e.g. typical line plots, outlines of polygons, etc.), rendering performance can be controlled by *rcParams["path.simplify"]* (default: `True`) and *rcParams["path.simplify_threshold"]* (default: `0.111111111111`), which can be defined e.g. in the `matplotlibrc` file (see *Customizing Matplotlib with style sheets and rcParams* for more information about the `matplotlibrc` file). *rcParams["path.simplify"]* (default: `True`) is a Boolean indicating whether or not line segments are simplified at all. *rcParams["path.simplify_threshold"]* (default: `0.111111111111`) controls how much line segments are simplified; higher thresholds result in quicker rendering.

The following script will first display the data without any simplification, and then display the same data with simplification. Try interacting with both of them:

```
import numpy as np
import matplotlib.pyplot as plt
import matplotlib as mpl

# Setup, and create the data to plot
y = np.random.rand(100000)
y[50000:] *= 2
y[np.geomspace(10, 50000, 400).astype(int)] = -1
mpl.rcParams['path.simplify'] = True

mpl.rcParams['path.simplify_threshold'] = 0.0
plt.plot(y)
plt.show()

mpl.rcParams['path.simplify_threshold'] = 1.0
plt.plot(y)
plt.show()
```

Matplotlib currently defaults to a conservative simplification threshold of `1/9`. To change default settings to use a different value, change the `matplotlibrc` file. Alternatively, users can create a new style for interactive plotting (with maximal simplification) and another style for publication quality plotting (with minimal simplification) and activate them as necessary. See *Customizing Matplotlib with style sheets and rcParams* for instructions on how to perform these actions.

The simplification works by iteratively merging line segments into a single vector until the next line segment's perpendicular distance to the vector (measured in display-coordinate space) is greater than the `path.simplify_threshold` parameter.

Note

Changes related to how line segments are simplified were made in version 2.1. Rendering time will still be improved by these parameters prior to 2.1, but rendering time for some kinds of data will be vastly improved in versions 2.1 and greater.

Marker subsampling

Markers can also be simplified, albeit less robustly than line segments. Marker subsampling is only available to *`Line2D`* objects (through the `markevery` property). Wherever *`Line2D`* construction parameters are passed through, such as *`pyplot.plot`* and *`Axes.plot`*, the `markevery` parameter can be used:

```
plt.plot(x, y, markevery=10)
```

The `markevery` argument allows for naive subsampling, or an attempt at evenly spaced (along the *x* axis) sampling. See the *Markevery Demo* for more information.

Splitting lines into smaller chunks

If you are using the Agg backend (see *What is a backend?*), then you can make use of *`rcParams["agg.path.chunksize"]`* (default: `0`) This allows users to specify a chunk size, and any lines with greater than that many vertices will be split into multiple lines, each of which has no more than `agg.path.chunksize` many vertices. (Unless `agg.path.chunksize` is zero, in which case there is no chunking.) For some kind of data, chunking the line up into reasonable sizes can greatly decrease rendering time.

The following script will first display the data without any chunk size restriction, and then display the same data with a chunk size of 10,000. The difference can best be seen when the figures are large, try maximizing the GUI and then interacting with them:

```
import numpy as np
import matplotlib.pyplot as plt
import matplotlib as mpl
mpl.rcParams['path.simplify_threshold'] = 1.0

# Setup, and create the data to plot
y = np.random.rand(100000)
y[50000:] *= 2
y[np.geomspace(10, 50000, 400).astype(int)] = -1
mpl.rcParams['path.simplify'] = True

mpl.rcParams['agg.path.chunksize'] = 0
plt.plot(y)
plt.show()
```

(continues on next page)

(continued from previous page)

```
mpl.rcParams['agg.path.chunksize'] = 10000
plt.plot(y)
plt.show()
```

Legends

The default legend behavior for axes attempts to find the location that covers the fewest data points (`loc='best'`). This can be a very expensive computation if there are lots of data points. In this case, you may want to provide a specific location.

Using the *fast* style

The *fast* style can be used to automatically set simplification and chunking parameters to reasonable settings to speed up plotting large amounts of data. The following code runs it:

```
import matplotlib.style as mplstyle
mplstyle.use('fast')
```

It is very lightweight, so it works well with other styles. Be sure the fast style is applied last so that other styles do not overwrite the settings:

```
mplstyle.use(['dark_background', 'ggplot', 'fast'])
```

3.4.4 Path Tutorial

Defining paths in your Matplotlib visualization.

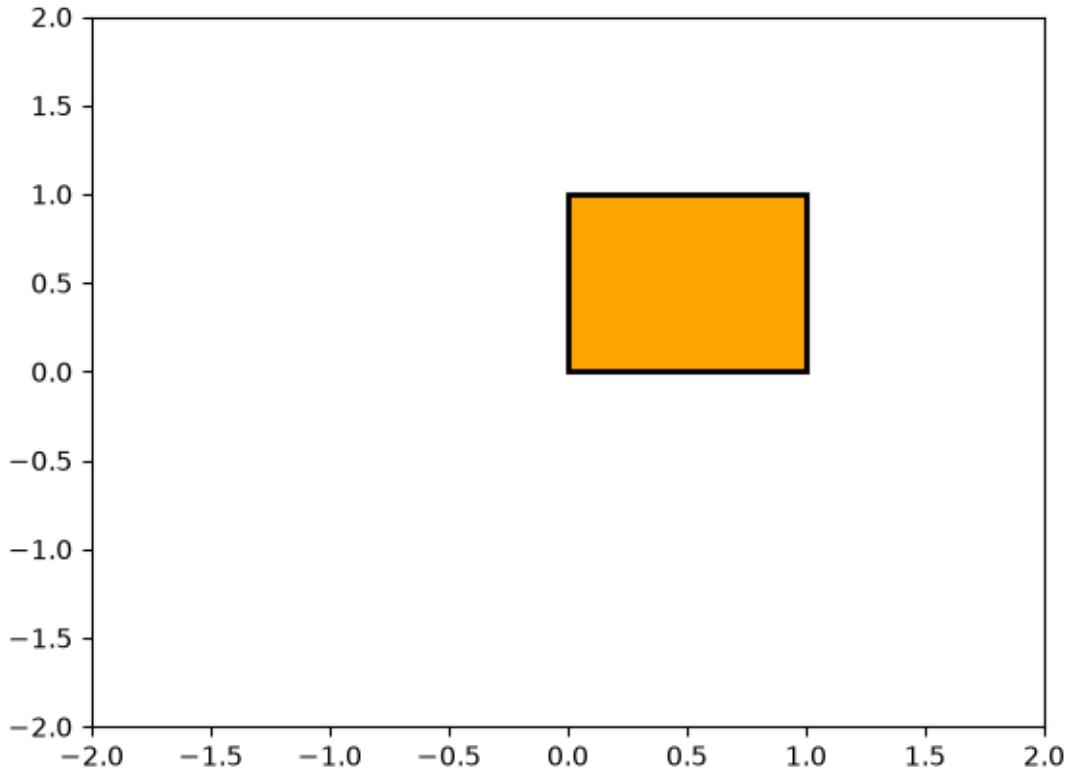
The object underlying all of the *matplotlib.patches* objects is the *Path*, which supports the standard set of moveto, lineto, curveto commands to draw simple and compound outlines consisting of line segments and splines. The `Path` is instantiated with a (N, 2) array of (x, y) vertices, and an N-length array of path codes. For example to draw the unit rectangle from (0, 0) to (1, 1), we could use this code:

```
import numpy as np

import matplotlib.pyplot as plt

import matplotlib.patches as patches
from matplotlib.path import Path

verts = [
   (0., 0.),  # left, bottom
   (0., 1.),  # left, top
   (1., 1.),  # right, top
   (1., 0.),  # right, bottom
   (0., 0.),  # ignored
]
```

(continues on next page)

(continued from previous page)

```
codes = [
    Path.MOVETO,
    Path.LINETO,
    Path.LINETO,
    Path.LINETO,
    Path.CLOSEPOLY,
]

path = Path(verts, codes)

fig, ax = plt.subplots()
patch = patches.PathPatch(path, facecolor='orange', lw=2)
ax.add_patch(patch)
ax.set_xlim(-2, 2)
ax.set_ylim(-2, 2)
plt.show()
```



The following path codes are recognized

Code	Vertices	Description
STOP	1 (ignored)	A marker for the end of the entire path (currently not required and ignored).
MOVETO	1	Pick up the pen and move to the given vertex.
LINETO	1	Draw a line from the current position to the given vertex.
CURVE3	2: 1 control point, 1 end point	Draw a quadratic Bézier curve from the current position, with the given control point, to the given end point.
CURVE4	3: 2 control points, 1 end point	Draw a cubic Bézier curve from the current position, with the given control points, to the given end point.
CLOSEPOLY	1 (the point is ignored)	Draw a line segment to the start point of the current polyline.

Bézier example

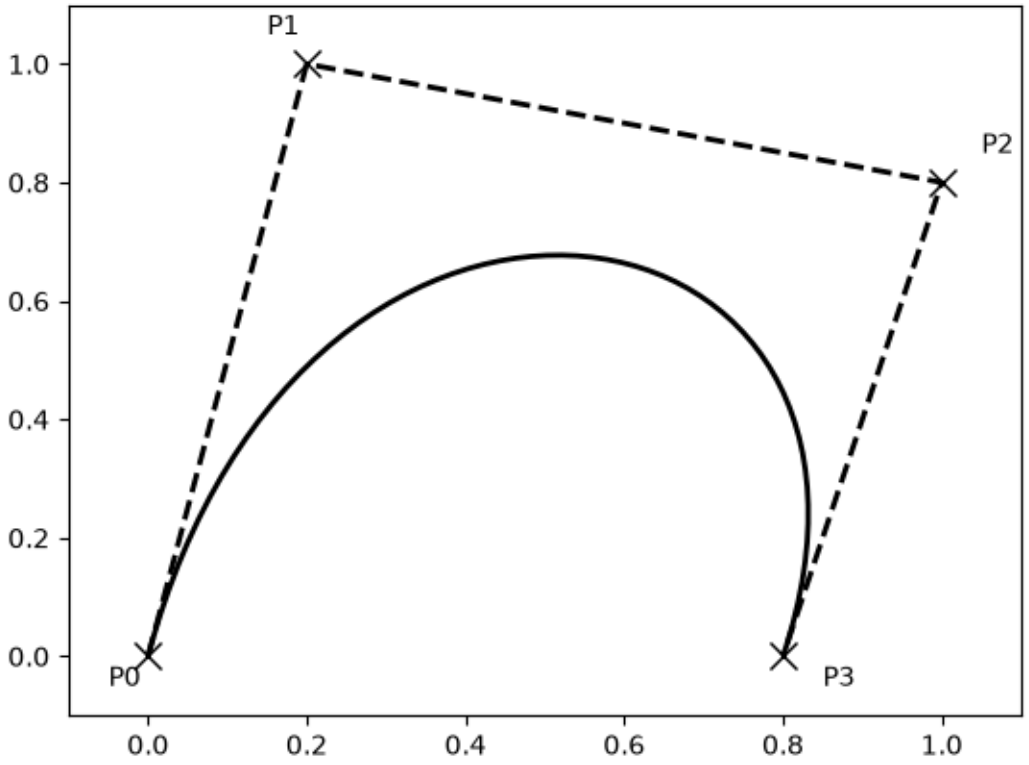
Some of the path components require multiple vertices to specify them: for example CURVE 3 is a Bézier curve with one control point and one end point, and CURVE4 has three vertices for the two control points and the end point. The example below shows a CURVE4 Bézier spline -- the Bézier curve will be contained in the convex hull of the start point, the two control points, and the end point

```
verts = [
   (0., 0.),    # P0
   (0.2, 1.),   # P1
   (1., 0.8),   # P2
   (0.8, 0.),   # P3
]

codes = [
    Path.MOVETO,
    Path.CURVE4,
    Path.CURVE4,
    Path.CURVE4,
]

path = Path(verts, codes)

fig, ax = plt.subplots()
patch = patches.PathPatch(path, facecolor='none', lw=2)
ax.add_patch(patch)

xs, ys = zip(*verts)
ax.plot(xs, ys, 'x--', lw=2, color='black', ms=10)

ax.text(-0.05, -0.05, 'P0')
ax.text(0.15, 1.05, 'P1')
ax.text(1.05, 0.85, 'P2')
```

(continues on next page)

(continued from previous page)

```
ax.text(0.85, -0.05, 'P3')

ax.set_xlim(-0.1, 1.1)
ax.set_ylim(-0.1, 1.1)
plt.show()
```



Compound paths

All of the simple patch primitives in matplotlib, Rectangle, Circle, Polygon, etc, are implemented with simple path. Plotting functions like *hist()* and *bar()*, which create a number of primitives, e.g., a bunch of Rectangles, can usually be implemented more efficiently using a compound path. The reason `bar` creates a list of rectangles and not a compound path is largely historical: the *Path* code is comparatively new and `bar` predates it. While we could change it now, it would break old code, so here we will cover how to create compound paths, replacing the functionality in bar, in case you need to do so in your own code for efficiency reasons, e.g., you are creating an animated bar plot.

We will make the histogram chart by creating a series of rectangles for each histogram bar: the rectangle width is the bin width and the rectangle height is the number of datapoints in that bin. First we'll create some random normally distributed data and compute the histogram. Because NumPy returns the bin edges and not centers, the length of `bins` is one greater than the length of `n` in the example below:

```
# histogram our data with numpy
data = np.random.randn(1000)
n, bins = np.histogram(data, 100)
```

We'll now extract the corners of the rectangles. Each of the `left`, `bottom`, etc., arrays below is `len(n)`, where `n` is the array of counts for each histogram bar:

```
# get the corners of the rectangles for the histogram
left = np.array(bins[:-1])
right = np.array(bins[1:])
bottom = np.zeros(len(left))
top = bottom + n
```

Now we have to construct our compound path, which will consist of a series of `MOVETO`, `LINETO` and `CLOSEPOLY` for each rectangle. For each rectangle, we need five vertices: one for the `MOVETO`, three for the `LINETO`, and one for the `CLOSEPOLY`. As indicated in the table above, the vertex for the closepoly is ignored, but we still need it to keep the codes aligned with the vertices:

```
nverts = nrects*(1+3+1)
verts = np.zeros((nverts, 2))
codes = np.ones(nverts, int) * path.Path.LINETO
codes[0::5] = path.Path.MOVETO
codes[4::5] = path.Path.CLOSEPOLY
verts[0::5, 0] = left
verts[0::5, 1] = bottom
verts[1::5, 0] = left
verts[1::5, 1] = top
verts[2::5, 0] = right
verts[2::5, 1] = top
verts[3::5, 0] = right
verts[3::5, 1] = bottom
```

All that remains is to create the path, attach it to a *PathPatch*, and add it to our Axes:

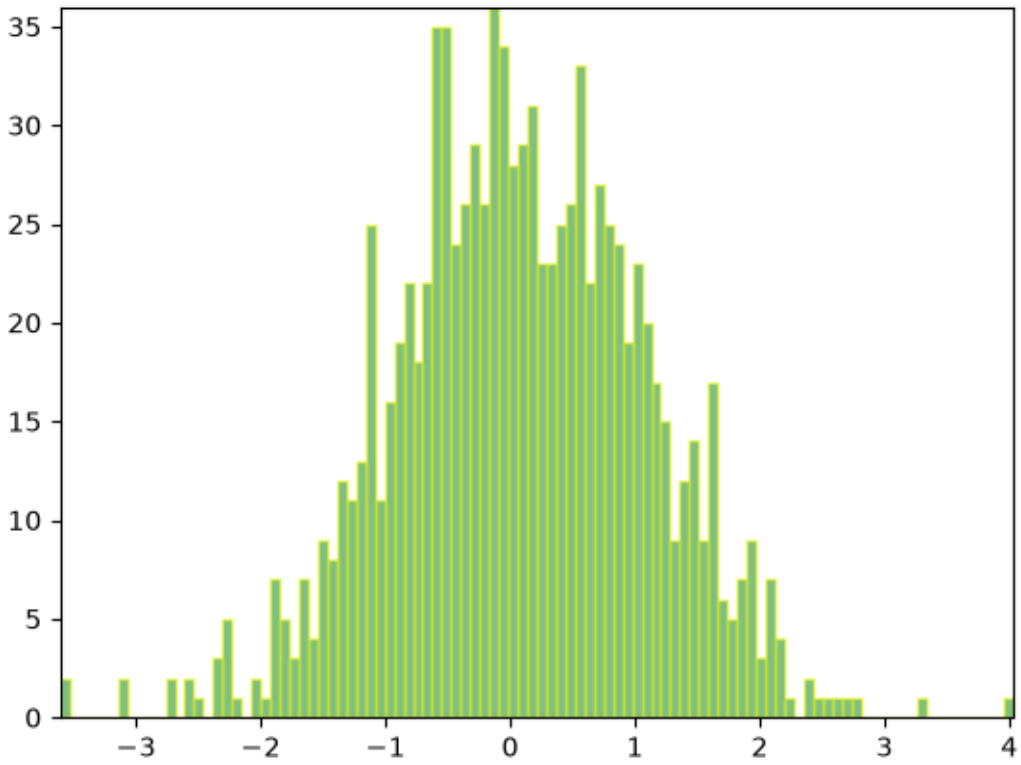
```
barpath = path.Path(verts, codes)
patch = patches.PathPatch(barpath, facecolor='green',
  edgecolor='yellow', alpha=0.5)
ax.add_patch(patch)
```

```
fig, ax = plt.subplots()
# Fixing random state for reproducibility
np.random.seed(19680801)

# histogram our data with numpy
data = np.random.randn(1000)
n, bins = np.histogram(data, 100)
```

(continues on next page)

(continued from previous page)

```
# get the corners of the rectangles for the histogram
left = np.array(bins[:-1])
right = np.array(bins[1:])
bottom = np.zeros(len(left))
top = bottom + n
nrects = len(left)

nverts = nrects*(1+3+1)
verts = np.zeros((nverts, 2))
codes = np.full(nverts, Path.LINETO, dtype=int)
codes[0::5] = Path.MOVETO
codes[4::5] = Path.CLOSEPOLY
verts[0::5, 0] = left
verts[0::5, 1] = bottom
verts[1::5, 0] = left
verts[1::5, 1] = top
verts[2::5, 0] = right
verts[2::5, 1] = top
verts[3::5, 0] = right
verts[3::5, 1] = bottom

barpath = Path(verts, codes)
patch = patches.PathPatch(barpath, facecolor='green',
                          edgecolor='yellow', alpha=0.5)
ax.add_patch(patch)

ax.set_xlim(left[0], right[-1])
ax.set_ylim(bottom.min(), top.max())

plt.show()
```



3.4.5 Path effects guide

Defining paths that objects follow on a canvas.

Matplotlib's *patheffects* module provides functionality to apply a multiple draw stage to any Artist which can be rendered via a *path.Path*.

Artists which can have a path effect applied to them include *patches.Patch*, *lines.Line2D*, *collections.Collection* and even *text.Text*. Each artist's path effects can be controlled via the *Artist.set_path_effects* method, which takes an iterable of *AbstractPathEffect* instances.

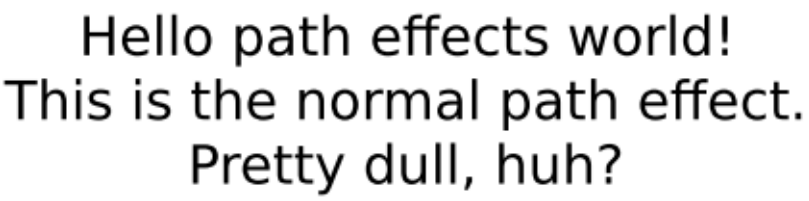
The simplest path effect is the *Normal* effect, which simply draws the artist without any effect:

```
import matplotlib.pyplot as plt

import matplotlib.patheffects as path_effects

fig = plt.figure(figsize=(5, 1.5))
text = fig.text(0.5, 0.5, 'Hello path effects world!\nThis is the␣
 ↪normal '
                          'path effect.\nPretty dull, huh?',
                ha='center', va='center', size=20)
```

(continues on next page)

(continued from previous page)

```
text.set_path_effects([path_effects.Normal()])
plt.show()
```

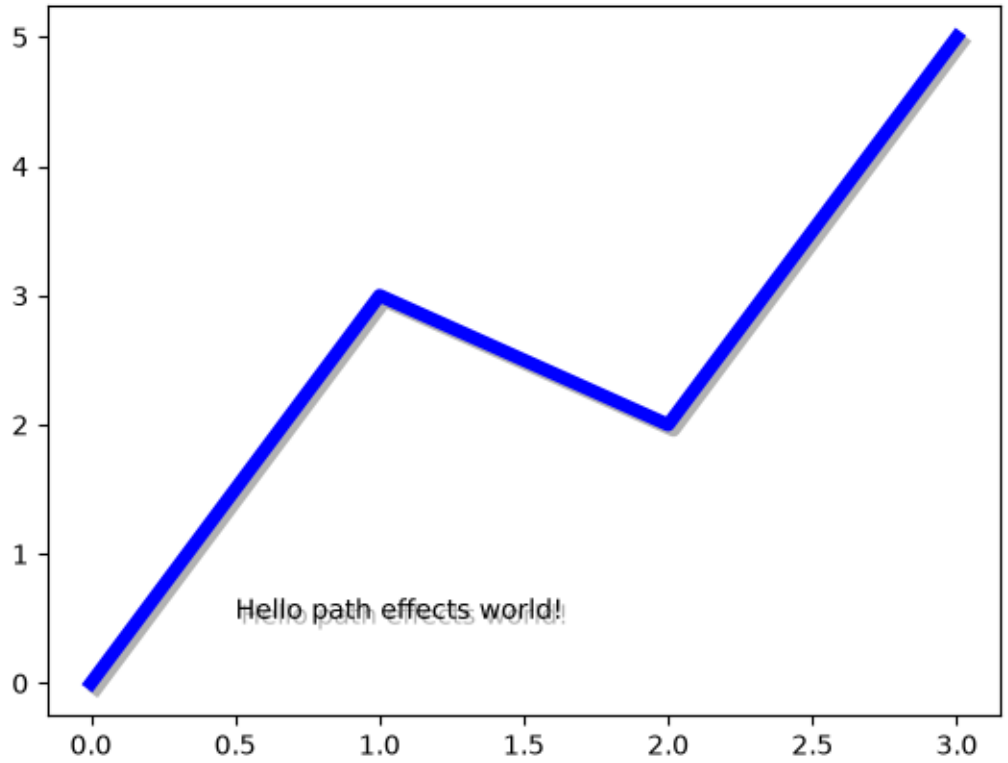


Whilst the plot doesn't look any different to what you would expect without any path effects, the drawing of the text has now been changed to use the path effects framework, opening up the possibilities for more interesting examples.

Adding a shadow

A far more interesting path effect than *Normal* is the drop-shadow, which we can apply to any of our path based artists. The classes *SimplePatchShadow* and *SimpleLineShadow* do precisely this by drawing either a filled patch or a line patch below the original artist:

```
import matplotlib.patheffects as path_effects

text = plt.text(0.5, 0.5, 'Hello path effects world!',
                path_effects=[path_effects.withSimplePatchShadow()])

plt.plot([0, 3, 2, 5], linewidth=5, color='blue',
         path_effects=[path_effects.SimpleLineShadow(),
                       path_effects.Normal()])
plt.show()
```



Notice the two approaches to setting the path effects in this example. The first uses the `with*` classes to include the desired functionality automatically followed with the "normal" effect, whereas the latter explicitly defines the two path effects to draw.

Making an Artist stand out

One nice way of making artists visually stand out is to draw an outline in a bold color below the actual artist. The *`Stroke`* path effect makes this a relatively simple task:

```
fig = plt.figure(figsize=(7, 1))
text = fig.text(0.5, 0.5, 'This text stands out because of\n'
                          'its black border.', color='white',
                          ha='center', va='center', size=30)
text.set_path_effects([path_effects.Stroke(linewidth=3, foreground=
 ↪'black'),
                       path_effects.Normal()])
plt.show()
```

It is important to note that this effect only works because we have drawn the text path twice; once with a thick black line, and then once with the original text path on top.

You may have noticed that the keywords to `Stroke` and `SimplePatchShadow` and `SimpleLineShadow` are not the usual Artist keywords (*facecolor* *edgecolor*, etc.). This is because with these path effects we are operating at lower level of Matplotlib. In fact, the keywords which are accepted are those for a `matplotlib.backend_bases.GraphicsContextBase` instance, which have been designed for making it easy to create new backends - and not for its user interface.

Greater control of the path effect Artist

As already mentioned, some of the path effects operate at a lower level than most users will be used to, meaning that setting keywords such as *facecolor* and *edgecolor* raise an AttributeError. Luckily there is a generic `PathPatchEffect` path effect which creates a `patches.PathPatch` class with the original path. The keywords to this effect are identical to those of `patches.PathPatch`:

```
fig = plt.figure(figsize=(8.5, 1))
t = fig.text(0.02, 0.5, 'Hatch shadow', fontsize=75, weight=1000, va=
 ↪'center')
t.set_path_effects([
    path_effects.PathPatchEffect(
        offset=(4, -4), hatch='xxxx', facecolor='gray'),
    path_effects.PathPatchEffect(
        edgecolor='white', linewidth=1.1, facecolor='black')])
plt.show()
```

3.4.6 Positioning and orientation of `imshow` images

`imshow()` allows you to render an image (either a 2D array which will be color-mapped (based on *norm* and *cmap*) or a 3D RGB(A) array which will be used as-is) to a rectangular region in data space. The orientation of the image in the final rendering is controlled by the *origin* and *extent* keyword arguments (and attributes on the resulting `AxesImage` instance) and the data limits of the Axes.

The *extent* keyword arguments controls the bounding box in data coordinates that the image will fill specified as `(left, right, bottom, top)` in **data coordinates**, the *origin* keyword argument controls how the image fills that bounding box, and the orientation in the final rendered image is also affected by the axes limits.

Hint

Most of the code below is used for adding labels and informative text to the plots. The described effects of *origin* and *extent* can be seen in the plots without the need to follow all code details.

For a quick understanding, you may want to skip the code details below and directly continue with the discussion of the results.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.gridspec import GridSpec


def index_to_coordinate(index, extent, origin):
    """Return the pixel center of an index."""
    left, right, bottom, top = extent

    hshift = 0.5 * np.sign(right - left)
    left, right = left + hshift, right - hshift
    vshift = 0.5 * np.sign(top - bottom)
    bottom, top = bottom + vshift, top - vshift

    if origin == 'upper':
        bottom, top = top, bottom

    return {
        "[0, 0]": (left, bottom),
        "[M', 0]": (left, top),
        "[0, N']": (right, bottom),
        "[M', N']": (right, top),
    }[index]


def get_index_label_pos(index, extent, origin, inverted_xindex):
    """
    Return the desired position and horizontal alignment of an index␣
 ↪label.
    """
    if extent is None:
        extent = lookup_extent(origin)
    left, right, bottom, top = extent
    x, y = index_to_coordinate(index, extent, origin)

    is_x0 = index[-2:] == "0]"
    halign = 'left' if is_x0 ^ inverted_xindex else 'right'
```

(continues on next page)

(continued from previous page)

```
    hshift = 0.5 * np.sign(left - right)
    x += hshift * (1 if is_x0 else -1)
    return x, y, halign


def get_color(index, data, cmap):
    """Return the data color of an index."""
    val = {
        "[0, 0]": data[0, 0],
        "[0, N']": data[0, -1],
        "[M', 0]": data[-1, 0],
        "[M', N']": data[-1, -1],
    }[index]
    return cmap(val / data.max())


def lookup_extent(origin):
    """Return extent for label positioning when not given␣
 ↪explicitly."""
    if origin == 'lower':
        return (-0.5, 6.5, -0.5, 5.5)
    else:
        return (-0.5, 6.5, 5.5, -0.5)


def set_extent_None_text(ax):
    ax.text(3, 2.5, 'equals\nextent=None', size='large',
            ha='center', va='center', color='w')


def plot_imshow_with_labels(ax, data, extent, origin, xlim, ylim):
    """Actually run ``imshow()`` and add extent and index labels."""
    im = ax.imshow(data, origin=origin, extent=extent)

    # extent labels (left, right, bottom, top)
    left, right, bottom, top = im.get_extent()
    if xlim is None or top > bottom:
        upper_string, lower_string = 'top', 'bottom'
    else:
        upper_string, lower_string = 'bottom', 'top'
    if ylim is None or left < right:
        port_string, starboard_string = 'left', 'right'
        inverted_xindex = False
    else:
        port_string, starboard_string = 'right', 'left'
        inverted_xindex = True
```

(continues on next page)

(continued from previous page)

```
    bbox_kwargs = {'fc': 'w', 'alpha': .75, 'boxstyle': "round4"}
    ann_kwargs = {'xycoords': 'axes fraction',
                  'textcoords': 'offset points',
                  'bbox': bbox_kwargs}
    ax.annotate(upper_string, xy=(.5, 1), xytext=(0, -1),
                ha='center', va='top', **ann_kwargs)
    ax.annotate(lower_string, xy=(.5, 0), xytext=(0, 1),
                ha='center', va='bottom', **ann_kwargs)
    ax.annotate(port_string, xy=(0, .5), xytext=(1, 0),
                ha='left', va='center', rotation=90,
                **ann_kwargs)
    ax.annotate(starboard_string, xy=(1, .5), xytext=(-1, 0),
                ha='right', va='center', rotation=-90,
                **ann_kwargs)
    ax.set_title(f'origin: {origin}')

    # index labels
    for index in ["[0, 0]", "[0, N']", "[M', 0]", "[M', N']"]:
        tx, ty, halign = get_index_label_pos(index, extent, origin,
                                             inverted_xindex)
        facecolor = get_color(index, data, im.get_cmap())
        ax.text(tx, ty, index, color='white', ha=halign, va='center',
                bbox={'boxstyle': 'square', 'facecolor': facecolor})
    if xlim:
        ax.set_xlim(*xlim)
    if ylim:
        ax.set_ylim(*ylim)


def generate_imshow_demo_grid(extents, xlim=None, ylim=None):
    N = len(extents)
    fig = plt.figure(tight_layout=True)
    fig.set_size_inches(6, N * (11.25) / 5)
    gs = GridSpec(N, 5, figure=fig)

    columns = {'label': [fig.add_subplot(gs[j, 0]) for j in range(N)],
               'upper': [fig.add_subplot(gs[j, 1:3]) for j in␣
 ↪range(N)],
               'lower': [fig.add_subplot(gs[j, 3:5]) for j in␣
 ↪range(N)]}
    x, y = np.ogrid[0:6, 0:7]
    data = x + y

    for origin in ['upper', 'lower']:
        for ax, extent in zip(columns[origin], extents):
            plot_imshow_with_labels(ax, data, extent, origin, xlim,␣
```

(continues on next page)

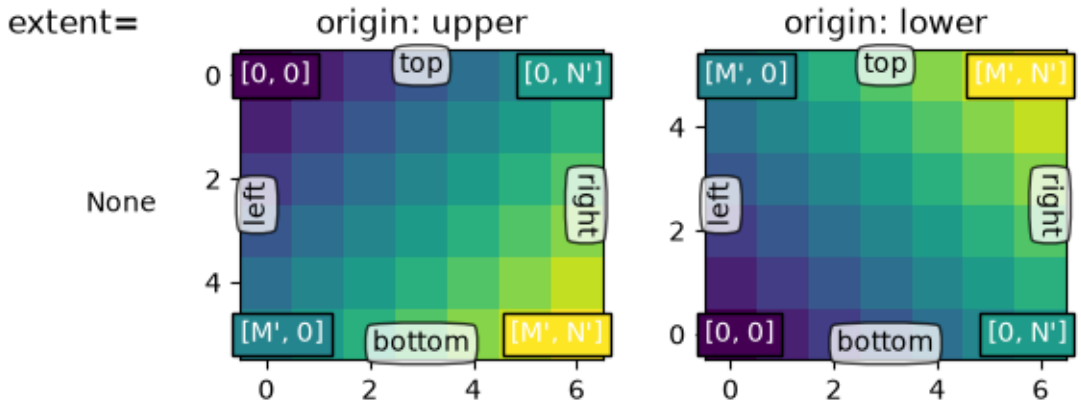
(continued from previous page)

```
↪ylim)

    columns['label'][0].set_title('extent=')
    for ax, extent in zip(columns['label'], extents):
        if extent is None:
            text = 'None'
        else:
            left, right, bottom, top = extent
            text = (f'left: {left:0.1f}\nright: {right:0.1f}\n'
                    f'bottom: {bottom:0.1f}\ntop: {top:0.1f}\n')
        ax.text(1., .5, text, transform=ax.transAxes, ha='right', va=
↪'center')
        ax.axis('off')
    return columns
```

Default extent

First, let's have a look at the default `extent=None`

```
generate_imshow_demo_grid(extents=[None])
```



Generally, for an array of shape (M, N), the first index runs along the vertical, the second index runs along the horizontal. The pixel centers are at integer positions ranging from 0 to `N' = N - 1` horizontally and from 0 to `M' = M - 1` vertically. *origin* determines how the data is filled in the bounding box.

For `origin='lower'`:

- [0, 0] is at (left, bottom)
- [M', 0] is at (left, top)
- [0, N'] is at (right, bottom)
- [M', N'] is at (right, top)

`origin='upper'` reverses the vertical axes direction and filling:

- [0, 0] is at (left, top)
- [M', 0] is at (left, bottom)
- [0, N'] is at (right, top)
- [M', N'] is at (right, bottom)

In summary, the position of the [0, 0] index as well as the extent are influenced by *origin*:

origin	[0, 0] position	extent
upper	top left	`(-0.5, numcols-0.5, numrows-0.5, -0.5)`
lower	bottom left	`(-0.5, numcols-0.5, -0.5, numrows-0.5)`

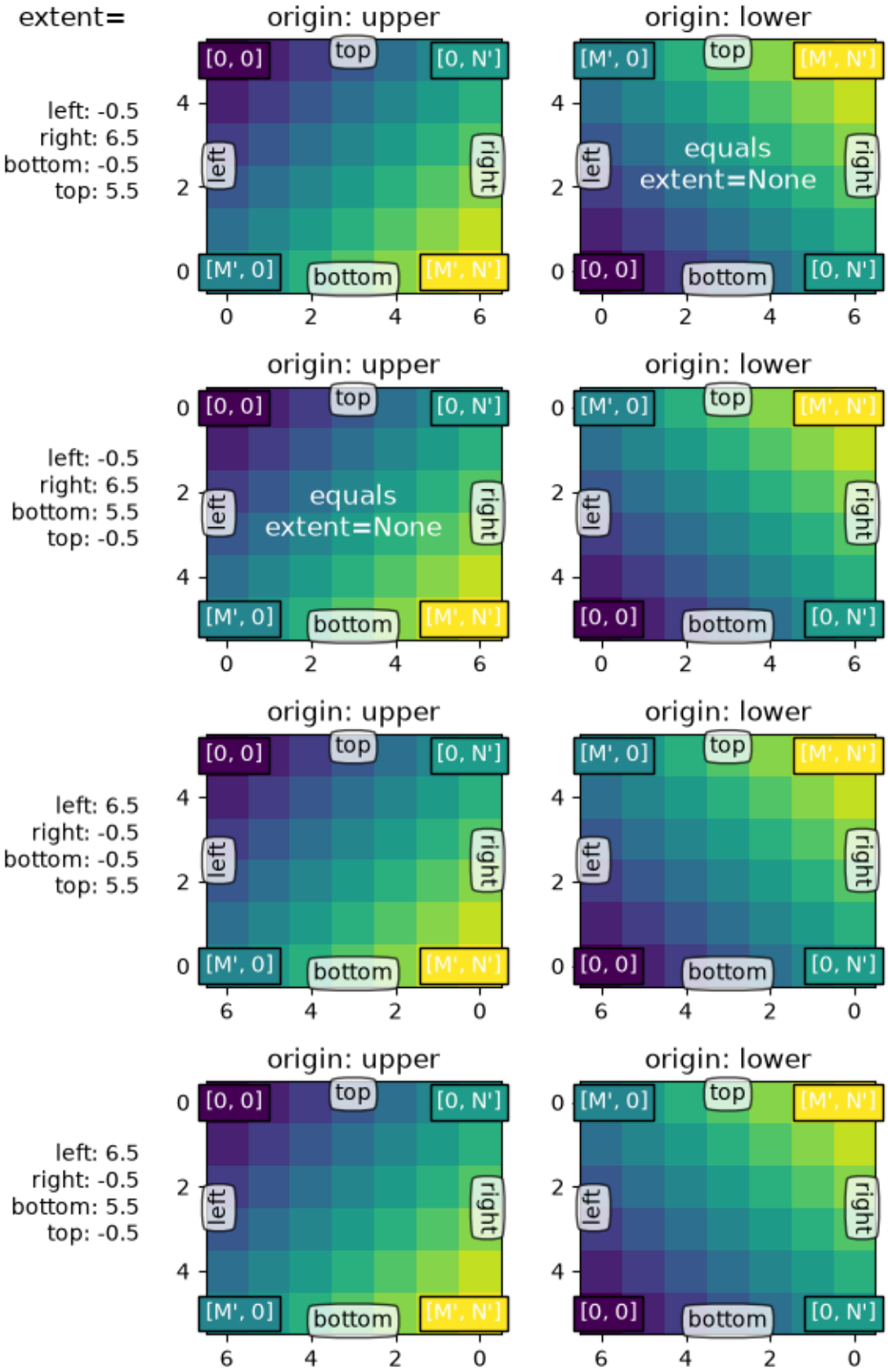
The default value of *origin* is set by *`rcParams["image.origin"]`* (default: `'upper'`) which defaults to `'upper'` to match the matrix indexing conventions in math and computer graphics image indexing conventions.

Explicit extent

By setting *extent* we define the coordinates of the image area. The underlying image data is interpolated/resampled to fill that area.

If the Axes is set to autoscale, then the view limits of the Axes are set to match the *extent* which ensures that the coordinate set by `(left, bottom)` is at the bottom left of the Axes! However, this may invert the axis so they do not increase in the 'natural' direction.

```
extents = [(-0.5, 6.5, -0.5, 5.5),
           (-0.5, 6.5, 5.5, -0.5),
           (6.5, -0.5, -0.5, 5.5),
           (6.5, -0.5, 5.5, -0.5)]

columns = generate_imshow_demo_grid(extents)
set_extent_None_text(columns['upper'][1])
set_extent_None_text(columns['lower'][0])
```


extent=
origin: upper
origin: lower
left: -0.5
right: 6.5
bottom: -0.5
top: 5.5
left: -0.5
right: 6.5
bottom: 5.5
top: -0.5
left: 6.5
right: -0.5
bottom: -0.5
top: 5.5
left: 6.5
right: -0.5
bottom: 5.5
top: -0.5
[0, 0]
[0, N']
[M', 0]
[M', N']
top
bottom
left
right
equals
extent=None

Explicit extent and axes limits

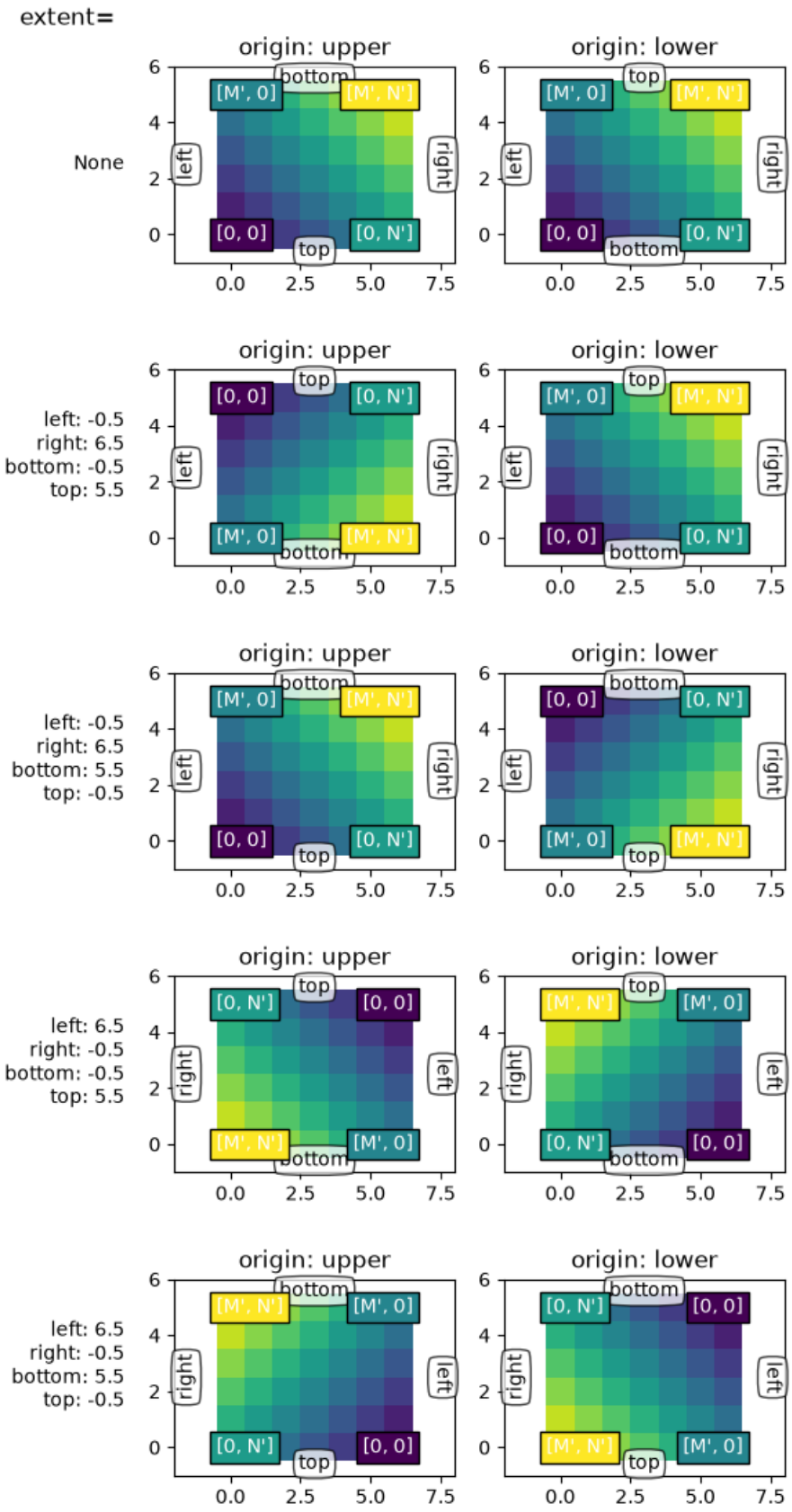
If we fix the axes limits by explicitly setting *set_xlim*/*set_ylim*, we force a certain size and orientation of the Axes. This can decouple the 'left-right' and 'top-bottom' sense of the image from the orientation on the screen.

In the example below we have chosen the limits slightly larger than the extent (note the white areas within the Axes).

While we keep the extents as in the examples before, the coordinate (0, 0) is now explicitly put at the bottom left and values increase to up and to the right (from the viewer's point of view). We can see that:

- The coordinate `(left, bottom)` anchors the image which then fills the box going towards the `(right, top)` point in data space.
- The first column is always closest to the 'left'.
- *origin* controls if the first row is closest to 'top' or 'bottom'.
- The image may be inverted along either direction.
- The 'left-right' and 'top-bottom' sense of the image may be uncoupled from the orientation on the screen.

```
generate_imshow_demo_grid(extents=[None] + extents,
                          xlim=(-2, 8), ylim=(-1, 6))

plt.show()
```


extent=
origin: upper
origin: lower
None
left: -0.5
right: 6.5
bottom: -0.5
top: 5.5
left: -0.5
right: 6.5
bottom: 5.5
top: -0.5
left: 6.5
right: -0.5
bottom: -0.5
top: 5.5
left: 6.5
right: -0.5
bottom: 5.5
top: -0.5
[M', 0]
[M', N']
[0, 0]
[0, N']
bottom
top
left
right
0.0
2.5
5.0
7.5
0
2
4
6

Total running time of the script: (0 minutes 3.039 seconds)

3.4.7 Transformations Tutorial

Like any graphics packages, Matplotlib is built on top of a transformation framework to easily move between coordinate systems, the userland *data* coordinate system, the *axes* coordinate system, the *figure* coordinate system, and the *display* coordinate system. In 95% of your plotting, you won't need to think about this, as it happens under the hood, but as you push the limits of custom figure generation, it helps to have an understanding of these objects, so you can reuse the existing transformations Matplotlib makes available to you, or create your own (see *matplotlib.transforms*). The table below summarizes some useful coordinate systems, a description of each system, and the transformation object for going from each coordinate system to the *display* coordinates. In the "Transformation Object" column, `ax` is a *Axes* instance, `fig` is a *Figure* instance, and `subfigure` is a *SubFigure* instance.

Coordinate system	Description	Transformation object from system to display
data	The coordinate system of the data in the Axes.	`ax.transData`
axes	The coordinate system of the *Axes*; (0, 0) is bottom left of the Axes, and (1, 1) is top right of the Axes.	`ax.transAxes`
subfigure	The coordinate system of the *SubFigure*; (0, 0) is bottom left of the subfigure, and (1, 1) is top right of the subfigure. If a figure has no subfigures, this is the same as `transFigure`.	`subfigure.transSubfigure`
figure	The coordinate system of the *Figure*; (0, 0) is bottom left of the figure, and (1, 1) is top right of the figure.	`fig.transFigure`
figure-inches	The coordinate system of the *Figure* in inches; (0, 0) is bottom left of the figure, and (width, height) is the top right of the figure in inches.	`fig.dpi_scale_trans`
xaxis, *yaxis*	Blended coordinate systems, using data coordinates on one direction and axes coordinates on the other.	`ax.get_xaxis_transform()`, `ax.get_yaxis_transform()`
display	The native coordinate system of the output ; (0, 0) is the bottom left of the window, and (width, height) is top right of the output in "display units". "Display units" depends on the backend. For example, Agg uses pixels, and SVG/PDF use points.	None, or *IdentityTransform()*

The *Transform* objects are naive to the source and destination coordinate systems, however the objects referred to in the table above are constructed to take inputs in their coordinate system, and transform the input to the *display* coordinate system. That is why the *display* coordinate system has None for the "Transformation Object" column -- it already is in *display* coordinates. The naming and destination conventions are an aid to keeping track of the available "standard" coordinate systems and transforms.

The transformations also know how to invert themselves (via *Transform.inverted*) to generate a transform from output coordinate system back to the input coordinate system. For example, `ax.transData`

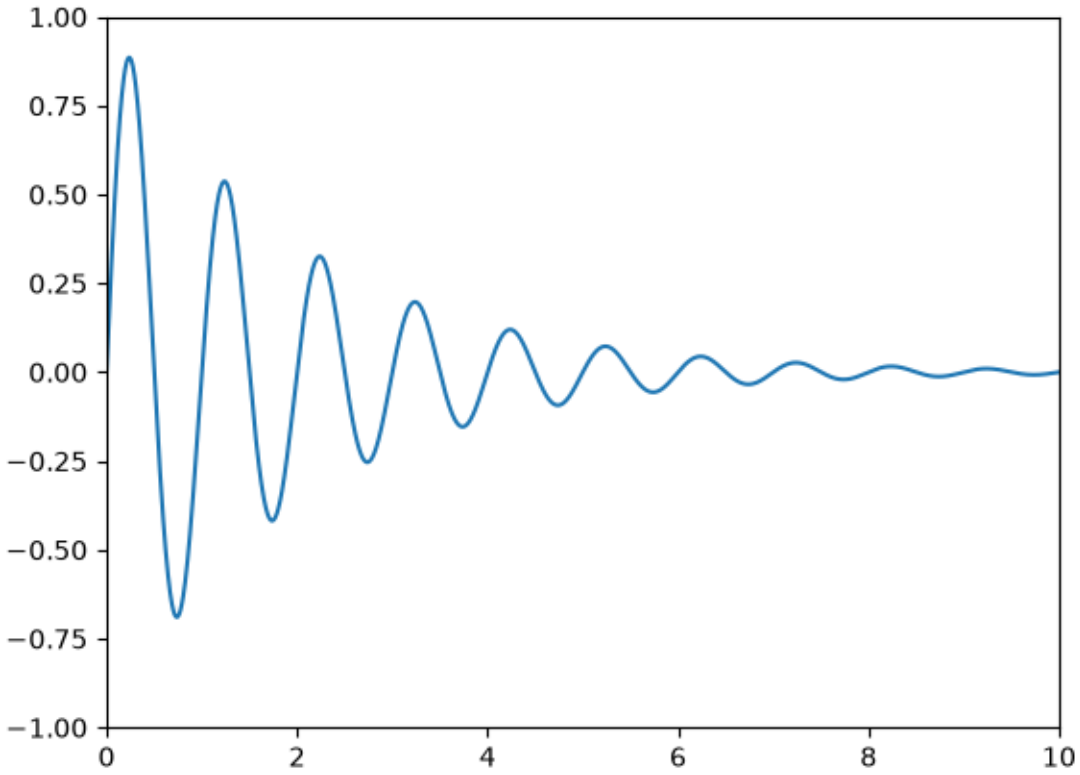
converts values in data coordinates to display coordinates and `ax.transData.inverted()` is a *`matplotlib.transforms.Transform`* that goes from display coordinates to data coordinates. This is particularly useful when processing events from the user interface, which typically occur in display space, and you want to know where the mouse click or key-press occurred in your *data* coordinate system.

Note that specifying the position of Artists in *display* coordinates may change their relative location if the `dpi` or size of the figure changes. This can cause confusion when printing or changing screen resolution, because the object can change location and size. Therefore, it is most common for artists placed in an Axes or figure to have their transform set to something *other* than the *`IdentityTransform()`*; the default when an artist is added to an Axes using *`add_artist`* is for the transform to be `ax.transData` so that you can work and think in *data* coordinates and let Matplotlib take care of the transformation to *display*.

Data coordinates

Let's start with the most commonly used coordinate, the *data* coordinate system. Whenever you add data to the Axes, Matplotlib updates the datalimits, most commonly updated with the *`set_xlim()`* and *`set_ylim()`* methods. For example, in the figure below, the data limits stretch from 0 to 10 on the x-axis, and -1 to 1 on the y-axis.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.patches as mpatches

x = np.arange(0, 10, 0.005)
y = np.exp(-x/2.) * np.sin(2*np.pi*x)

fig, ax = plt.subplots()
ax.plot(x, y)
ax.set_xlim(0, 10)
ax.set_ylim(-1, 1)

plt.show()
```



You can use the `ax.transData` instance to transform from your *data* to your *display* coordinate system, either a single point or a sequence of points as shown below:

```
In [14]: type(ax.transData)
Out[14]: <class 'matplotlib.transforms.CompositeGenericTransform'>

In [15]: ax.transData.transform((5, 0))
Out[15]: array([ 335.175,  247.   ])

In [16]: ax.transData.transform([(5, 0), (1, 2)])
Out[16]:
array([[ 335.175,  247.   ],
       [ 132.435,  642.2  ]])
```

You can use the *`inverted()`* method to create a transform which will take you from *display* to *data* coordinates:

```
In [41]: inv = ax.transData.inverted()

In [42]: type(inv)
Out[42]: <class 'matplotlib.transforms.CompositeGenericTransform'>
```

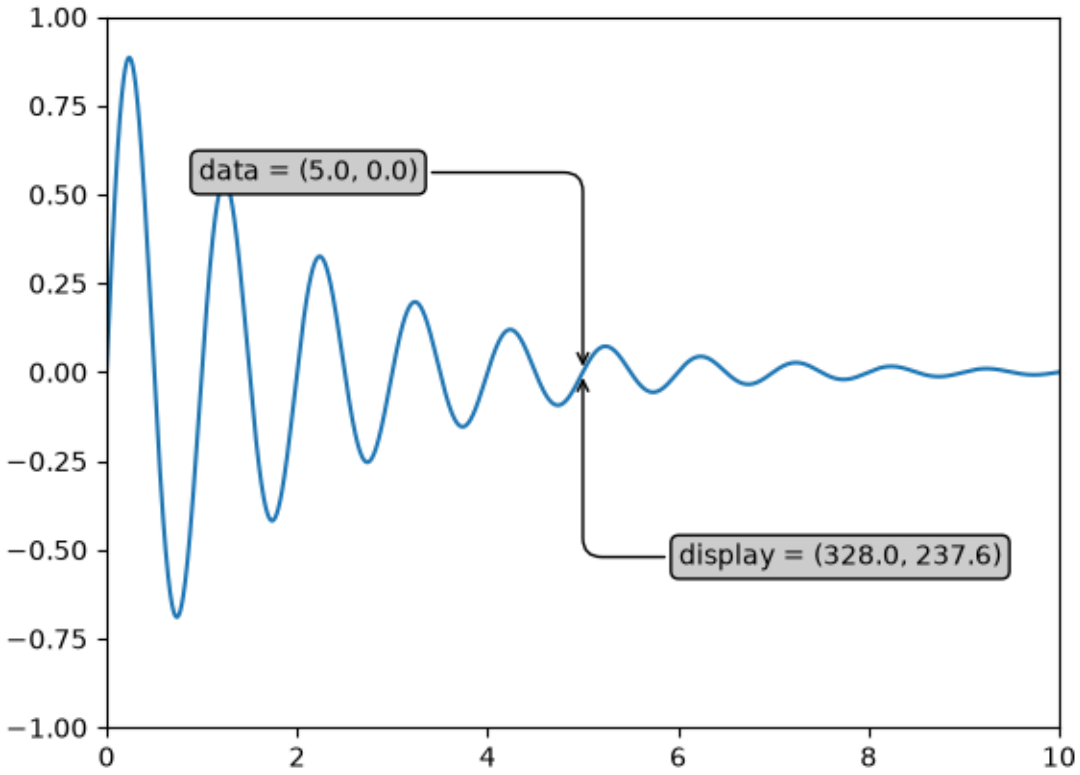
(continues on next page)

(continued from previous page)

```
In [43]: inv.transform((335.175,  247.))
Out[43]: array([ 5.,  0.])
```

If your are typing along with this tutorial, the exact values of the *display* coordinates may differ if you have a different window size or dpi setting. Likewise, in the figure below, the display labeled points are probably not the same as in the ipython session because the documentation figure size defaults are different.

```
x = np.arange(0, 10, 0.005)
y = np.exp(-x/2.) * np.sin(2*np.pi*x)

fig, ax = plt.subplots()
ax.plot(x, y)
ax.set_xlim(0, 10)
ax.set_ylim(-1, 1)

xdata, ydata = 5, 0
# This computing the transform now, if anything
# (figure size, dpi, axes placement, data limits, scales..)
# changes re-calling transform will get a different value.
xdisplay, ydisplay = ax.transData.transform((xdata, ydata))

bbox = dict(boxstyle="round", fc="0.8")
arrowprops = dict(
    arrowstyle="->",
    connectionstyle="angle,angleA=0,angleB=90,rad=10")

offset = 72
ax.annotate(f'data = ({xdata:.1f}, {ydata:.1f})',
            (xdata, ydata), xytext=(-2*offset, offset), textcoords=
 ↪'offset points',
            bbox=bbox, arrowprops=arrowprops)

disp = ax.annotate(f'display = ({xdisplay:.1f}, {ydisplay:.1f})',
                   (xdisplay, ydisplay), xytext=(0.5*offset, -offset),
                   xycoords='figure pixels',
                   textcoords='offset points',
                   bbox=bbox, arrowprops=arrowprops)

plt.show()
```



Warning

If you run the source code in the example above in a GUI backend, you may also find that the two arrows for the *data* and *display* annotations do not point to exactly the same point. This is because the display point was computed before the figure was displayed, and the GUI backend may slightly resize the figure when it is created. The effect is more pronounced if you resize the figure yourself. This is one good reason why you rarely want to work in *display* space, but you can connect to the `'on_draw'` *Event* to update *figure* coordinates on figure draws; see *Event handling and picking*.

When you change the x or y limits of your axes, the data limits are updated so the transformation yields a new display point. Note that when we just change the ylim, only the y-display coordinate is altered, and when we change the xlim too, both are altered. More on this later when we talk about the *Bbox*.

```
In [54]: ax.transData.transform((5, 0))
Out[54]: array([ 335.175,  247.   ])

In [55]: ax.set_ylim(-1, 2)
Out[55]: (-1, 2)

In [56]: ax.transData.transform((5, 0))
```

(continues on next page)

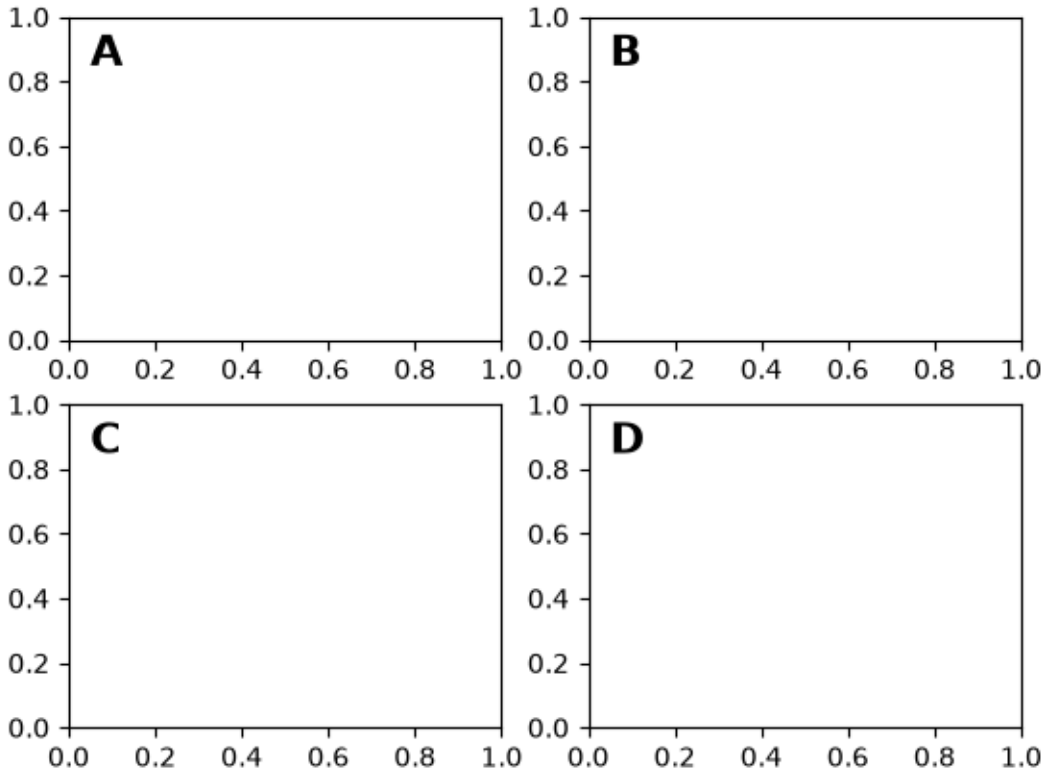
(continued from previous page)

```
Out[56]: array([ 335.175     ,  181.13333333])

In [57]: ax.set_xlim(10, 20)
Out[57]: (10, 20)

In [58]: ax.transData.transform((5, 0))
Out[58]: array([-171.675     ,  181.13333333])
```

Axes coordinates

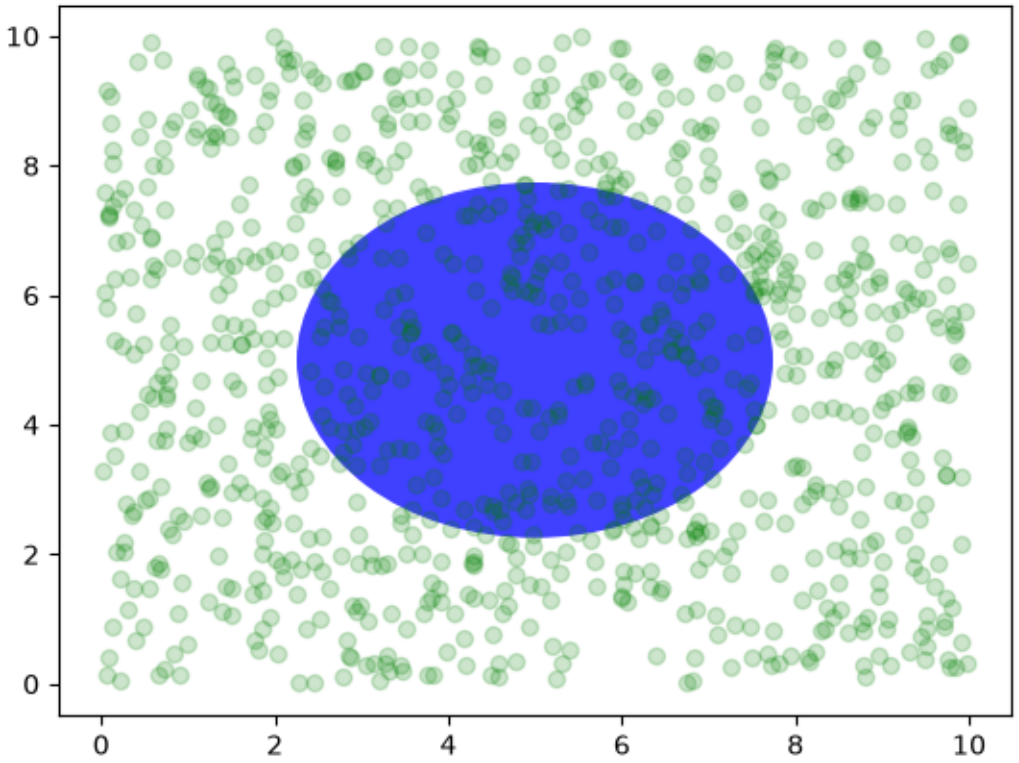
After the *data* coordinate system, *axes* is probably the second most useful coordinate system. Here the point (0, 0) is the bottom left of your Axes or subplot, (0.5, 0.5) is the center, and (1.0, 1.0) is the top right. You can also refer to points outside the range, so (-0.1, 1.1) is to the left and above your Axes. This coordinate system is extremely useful when placing text in your Axes, because you often want a text bubble in a fixed, location, e.g., the upper left of the Axes pane, and have that location remain fixed when you pan or zoom. Here is a simple example that creates four panels and labels them 'A', 'B', 'C', 'D' as you often see in journals. A more sophisticated approach for such labeling is presented at *Labelling subplots*.

```
fig = plt.figure()
for i, label in enumerate(('A', 'B', 'C', 'D')):
    ax = fig.add_subplot(2, 2, i+1)
    ax.text(0.05, 0.95, label, transform=ax.transAxes,
            fontsize=16, fontweight='bold', va='top')

plt.show()
```



You can also make lines or patches in the *axes* coordinate system, but this is less useful in my experience than using `ax.transAxes` for placing text. Nonetheless, here is a silly example which plots some random dots in data space, and overlays a semi-transparent *`Circle`* centered in the middle of the Axes with a radius one quarter of the Axes -- if your Axes does not preserve aspect ratio (see *`set_aspect()`*), this will look like an ellipse. Use the pan/zoom tool to move around, or manually change the data xlim and ylim, and you will see the data move, but the circle will remain fixed because it is not in *data* coordinates and will always remain at the center of the Axes.

```
fig, ax = plt.subplots()
x, y = 10*np.random.rand(2, 1000)
ax.plot(x, y, 'go', alpha=0.2)  # plot some data in data coordinates

circ = mpatches.Circle((0.5, 0.5), 0.25, transform=ax.transAxes,
                       facecolor='blue', alpha=0.75)
ax.add_patch(circ)
plt.show()
```



Blended transformations

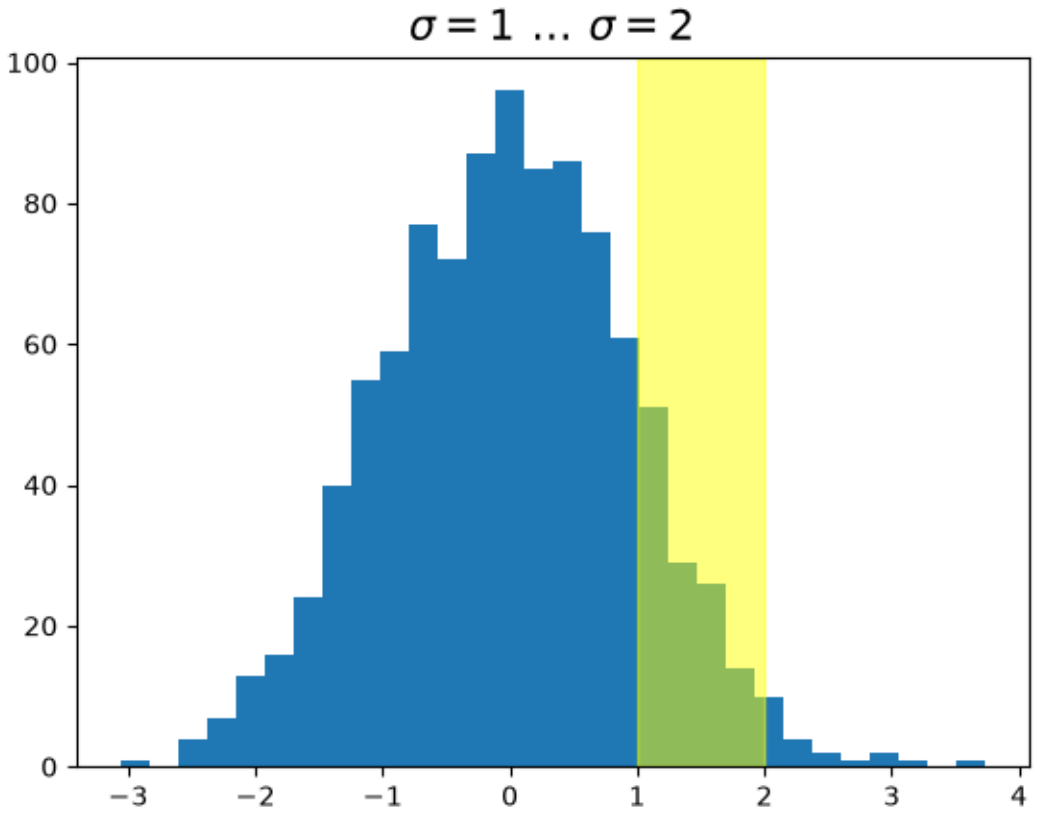
Drawing in *blended* coordinate spaces which mix *axes* with *data* coordinates is extremely useful, for example to create a horizontal span which highlights some region of the y-data but spans across the x-axis regardless of the data limits, pan or zoom level, etc. In fact these blended lines and spans are so useful, we have built-in functions to make them easy to plot (see `axhline()`, `axvline()`, `axhspan()`, `axvspan()`) but for didactic purposes we will implement the horizontal span here using a blended transformation. This trick only works for separable transformations, like you see in normal Cartesian coordinate systems, but not on inseparable transformations like the `PolarTransform`.

```
import matplotlib.transforms as transforms

fig, ax = plt.subplots()
x = np.random.randn(1000)

ax.hist(x, 30)
ax.set_title(r'$\sigma=1 \/ \dots \/ \sigma=2$', fontsize=16)

# the x coords of this transformation are data, and the y coord are␣
 ↪axes
trans = transforms.blended_transform_factory(
```

(continues on next page)

(continued from previous page)

```
    ax.transData, ax.transAxes)
# highlight the 1..2 stddev region with a span.
# We want x to be in data coordinates and y to span from 0..1 in axes␣
 ↪coords.
rect = mpatches.Rectangle((1, 0), width=1, height=1, transform=trans,
                          color='yellow', alpha=0.5)
ax.add_patch(rect)

plt.show()
```



Note

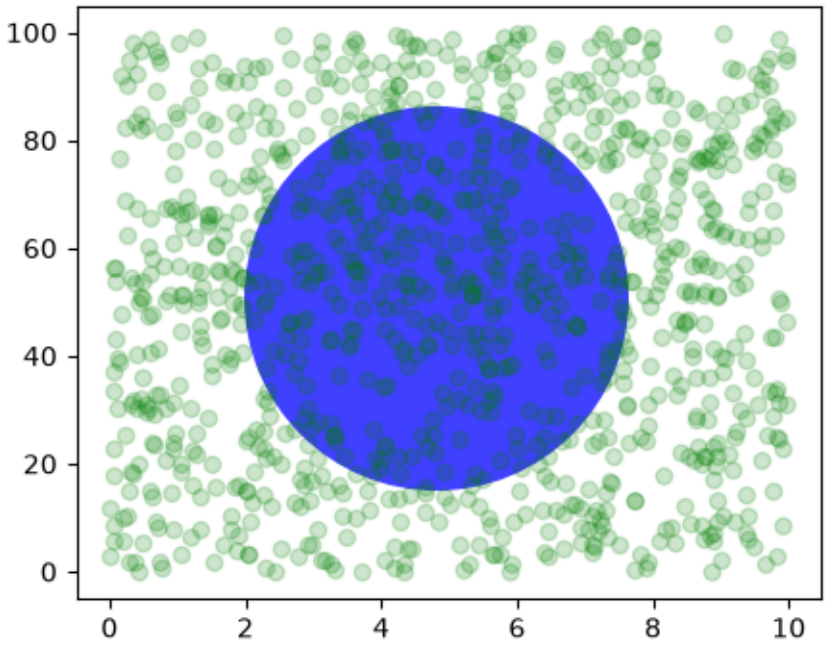
The blended transformations where x is in *data* coords and y in *axes* coordinates is so useful that we have helper methods to return the versions Matplotlib uses internally for drawing ticks, ticklabels, etc. The methods are *matplotlib.axes.Axes.get_xaxis_transform()* and *matplotlib.axes.Axes.get_yaxis_transform()*. So in the example above, the call to *blended_transform_factory()* can be replaced by `get_xaxis_transform`:

```
trans = ax.get_xaxis_transform()
```

Plotting in physical coordinates

Sometimes we want an object to be a certain physical size on the plot. Here we draw the same circle as above, but in physical coordinates. If done interactively, you can see that changing the size of the figure does not change the offset of the circle from the lower-left corner, does not change its size, and the circle remains a circle regardless of the aspect ratio of the Axes.

```
fig, ax = plt.subplots(figsize=(5, 4))
x, y = 10*np.random.rand(2, 1000)
ax.plot(x, y*10., 'go', alpha=0.2)  # plot some data in data␣
 ↪coordinates
# add a circle in fixed-coordinates
circ = mpatches.Circle((2.5, 2), 1.0, transform=fig.dpi_scale_trans,
                       facecolor='blue', alpha=0.75)
ax.add_patch(circ)
plt.show()
```



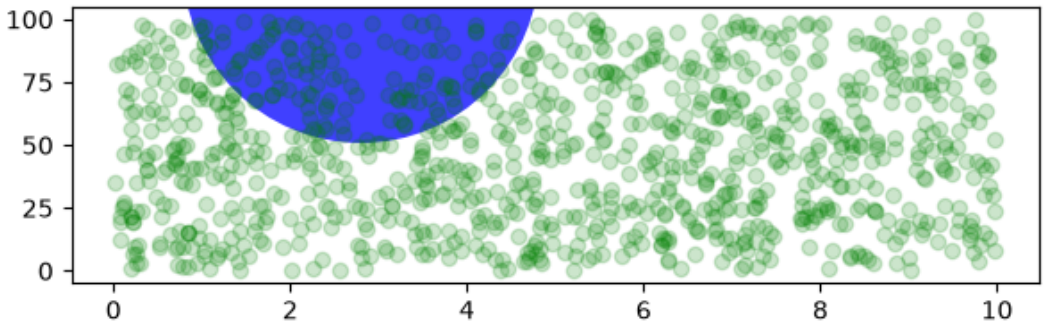
If we change the figure size, the circle does not change its absolute position and is cropped.

```
fig, ax = plt.subplots(figsize=(7, 2))
x, y = 10*np.random.rand(2, 1000)
ax.plot(x, y*10., 'go', alpha=0.2)  # plot some data in data␣
 ↪coordinates
# add a circle in fixed-coordinates
circ = mpatches.Circle((2.5, 2), 1.0, transform=fig.dpi_scale_trans,
                       facecolor='blue', alpha=0.75)
```

(continues on next page)

(continued from previous page)

```
ax.add_patch(circ)
plt.show()
```



Another use is putting a patch with a set physical dimension around a data point on the Axes. Here we add together two transforms. The first sets the scaling of how large the ellipse should be and the second sets its position. The ellipse is then placed at the origin, and then we use the helper transform *ScaledTranslation* to move it to the right place in the `ax.transData` coordinate system. This helper is instantiated with:

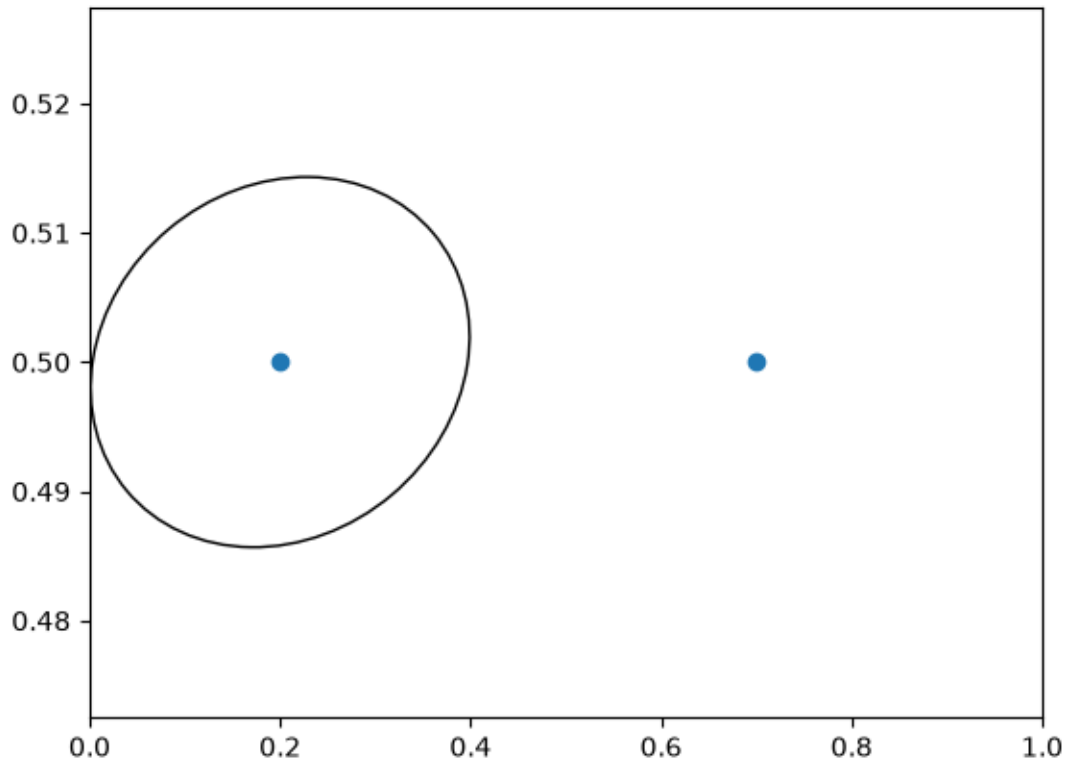
```
trans = ScaledTranslation(xt, yt, scale_trans)
```

where *xt* and *yt* are the translation offsets, and *scale_trans* is a transformation which scales *xt* and *yt* at transformation time before applying the offsets.

Note the use of the plus operator on the transforms below. This code says: first apply the scale transformation `fig.dpi_scale_trans` to make the ellipse the proper size, but still centered at (0, 0), and then translate the data to `xdata[0]` and `ydata[0]` in data space.

In interactive use, the ellipse stays the same size even if the axes limits are changed via zoom.

```
fig, ax = plt.subplots()
xdata, ydata = (0.2, 0.7), (0.5, 0.5)
ax.plot(xdata, ydata, "o")
ax.set_xlim(0, 1)

trans = (fig.dpi_scale_trans +
         transforms.ScaledTranslation(xdata[0], ydata[0], ax.
 ↪transData))

# plot an ellipse around the point that is 150 x 130 points in␣
 ↪diameter...
circle = mpatches.Ellipse((0, 0), 150/72, 130/72, angle=40,
                          fill=None, transform=trans)
ax.add_patch(circle)
plt.show()
```



Note

The order of transformation matters. Here the ellipse is given the right dimensions in display space *first* and then moved in data space to the correct spot. If we had done the `ScaledTranslation` first, then `xdata[0]` and `ydata[0]` would first be transformed to *display* coordinates (`[ 358.4 475.2]` on a 200-dpi monitor) and then those coordinates would be scaled by `fig.dpi_scale_trans` pushing the center of the ellipse well off the screen (i.e. `[ 71680. 95040.]`).

Using offset transforms to create a shadow effect

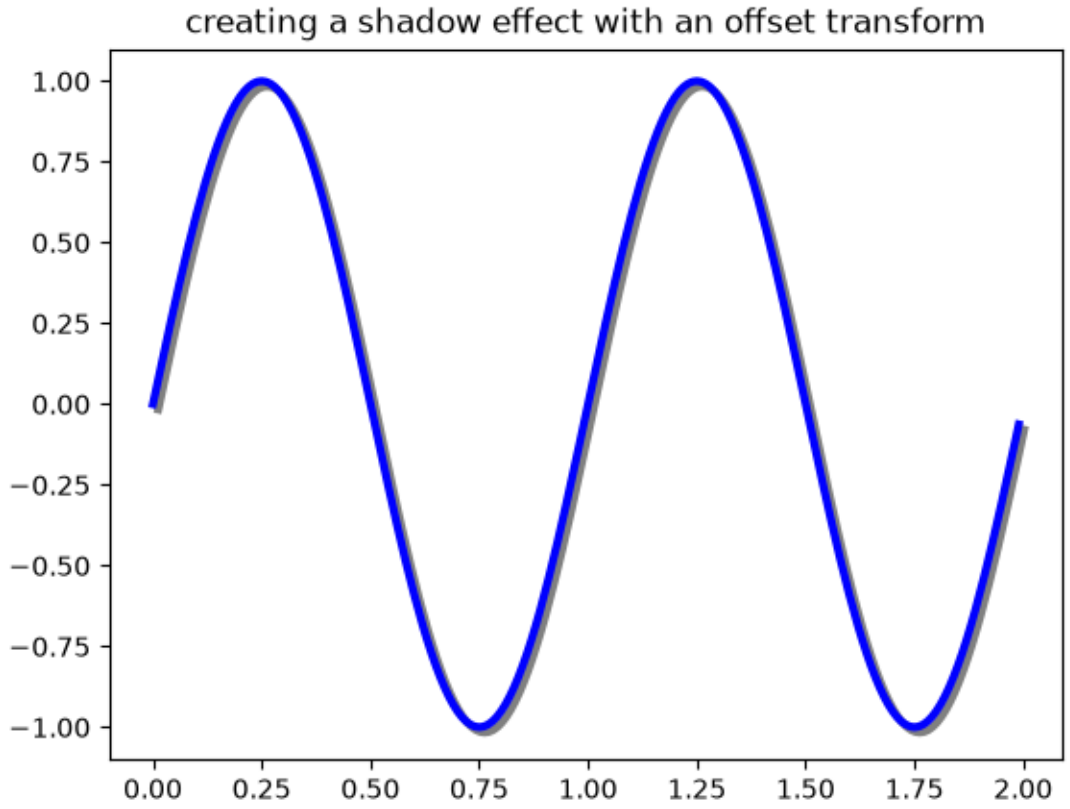
Another use of *`ScaledTranslation`* is to create a new transformation that is offset from another transformation, e.g., to place one object shifted a bit relative to another object. Typically, you want the shift to be in some physical dimension, like points or inches rather than in *data* coordinates, so that the shift effect is constant at different zoom levels and dpi settings.

One use for an offset is to create a shadow effect, where you draw one object identical to the first just to the right of it, and just below it, adjusting the zorder to make sure the shadow is drawn first and then the object it is shadowing above it.

Here we apply the transforms in the *opposite* order to the use of *`ScaledTranslation`* above. The plot is first made in data coordinates (`ax.transData`) and then shifted by `dx` and `dy` points using `fig.`

`dpi_scale_trans`. (In typography, a point is 1/72 inches, and by specifying your offsets in points, your figure will look the same regardless of the dpi resolution it is saved in.)

```
fig, ax = plt.subplots()

# make a simple sine wave
x = np.arange(0., 2., 0.01)
y = np.sin(2*np.pi*x)
line, = ax.plot(x, y, lw=3, color='blue')

# shift the object over 2 points, and down 2 points
dx, dy = 2/72., -2/72.
offset = transforms.ScaledTranslation(dx, dy, fig.dpi_scale_trans)
shadow_transform = ax.transData + offset

# now plot the same data with our offset transform;
# use the zorder to make sure we are below the line
ax.plot(x, y, lw=3, color='gray',
        transform=shadow_transform,
        zorder=0.5*line.get_zorder())

ax.set_title('creating a shadow effect with an offset transform')
plt.show()
```



Note

The dpi and inches offset is a common-enough use case that we have a special helper function to create it in *matplotlib.transforms.offset_copy()*, which returns a new transform with an added offset. So above we could have done:

```
shadow_transform = transforms.offset_copy(ax.transData,
         fig, dx, dy, units='inches')
```

The transformation pipeline

The `ax.transData` transform we have been working with in this tutorial is a composite of three different transformations that comprise the transformation pipeline from *data* -> *display* coordinates. Michael Droettboom implemented the transformations framework, taking care to provide a clean API that segregated the nonlinear projections and scales that happen in polar and logarithmic plots, from the linear affine transformations that happen when you pan and zoom. There is an efficiency here, because you can pan and zoom in your Axes which affects the affine transformation, but you may not need to compute the potentially expensive nonlinear scales or projections on simple navigation events. It is also possible to multiply affine transformation matrices together, and then apply them to coordinates in one step. This is not true of all possible transformations.

Here is how the `ax.transData` instance is defined in the basic separable axis *Axes* class:

```
self.transData = self.transScale + (self.transLimits + self.transAxes)
```

We've been introduced to the `transAxes` instance above in *Axes coordinates*, which maps the (0, 0), (1, 1) corners of the Axes or subplot bounding box to *display* space, so let's look at these other two pieces.

`self.transLimits` is the transformation that takes you from *data* to *axes* coordinates; i.e., it maps your view xlim and ylim to the unit space of the Axes (and `transAxes` then takes that unit space to display space). We can see this in action here

```
In [80]: ax = plt.subplot()

In [81]: ax.set_xlim(0, 10)
Out[81]: (0, 10)

In [82]: ax.set_ylim(-1, 1)
Out[82]: (-1, 1)

In [84]: ax.transLimits.transform((0, -1))
Out[84]: array([ 0.,  0.])

In [85]: ax.transLimits.transform((10, -1))
Out[85]: array([ 1.,  0.])

In [86]: ax.transLimits.transform((10, 1))
Out[86]: array([ 1.,  1.])

In [87]: ax.transLimits.transform((5, 0))
Out[87]: array([ 0.5,  0.5])
```

and we can use this same inverted transformation to go from the unit *axes* coordinates back to *data* coordinates.

```
In [90]: inv.transform((0.25, 0.25))
Out[90]: array([ 2.5, -0.5])
```

The final piece is the `self.transScale` attribute, which is responsible for the optional non-linear scaling of the data, e.g., for logarithmic axes. When an Axes is initially setup, this is just set to the identity transform, since the basic Matplotlib axes has linear scale, but when you call a logarithmic scaling function like *`semilogx()`* or explicitly set the scale to logarithmic with *`set_xscale()`*, then the `ax.transScale` attribute is set to handle the nonlinear projection. The scales transforms are properties of the respective `xaxis` and `yaxis` *Axis* instances. For example, when you call `ax.set_xscale('log')`, the xaxis updates its scale to a *`matplotlib.scale.LogScale`* instance.

For non-separable axes, there are some more pieces to consider, in particular the projection transformation. For example, the `transData` of *`matplotlib.projections.polar.PolarAxes`* is more complex than that of a typical separable Axes:

```
self.transData = (
    self.transScale + self.transShift + self.transProjection +
    (self.transProjectionAffine + self.transWedge + self.transAxes))
```

`transProjection` handles the projection from data coordinates (e.g., latitude and longitude for map data, or radius and theta for polar data), to a separable Cartesian coordinate system. There are several projection examples in the *matplotlib.projections* package, and the best way to learn more is to open the source for those packages and see how to make your own, since Matplotlib supports extensible axes and projections. Michael Droettboom has provided a nice tutorial example of creating a Hammer projection axes; see *Custom projection*.

Total running time of the script: (0 minutes 1.890 seconds)

3.5 Matplotlib configuration - rcParams

Matplotlib's configuration parameters (rcParams) control the behavior and appearance of plots. These parameters are stored in a dict-like variable called *matplotlib.rcParams* (also accessible via `plt.rcParams`).

The following is a comprehensive reference of all available rcParams and their default values.

3.5.1 Backends

webagg.port: `8988`

The port to use for the web server in the WebAgg backend.

webagg.address: `'127.0.0.1'`

The address on which the WebAgg web server should be reachable.

webagg.port_retries: `50`

If webagg.port is unavailable, a number of other random ports will be tried until one that is available is found.

webagg.open_in_browser: `True`

When True, open the web browser to the plot that is shown

backend_fallback: `True`

If you are running pyplot inside a GUI and your backend choice conflicts, we will automatically try to find a compatible one for you if backend_fallback is True

interactive: `False`

no description

figure.hooks: `[]`

list of dotted.module.name:dotted.callable.name

toolbar: `'toolbar2'`

{None, toolbar2, toolmanager}

timezone: `'UTC'`

a pytz timezone string, e.g., US/Central or Europe/Paris

3.5.2 Lines

Default properties for line objects, such as those returned by plot().

lines.linewidth: `1.5`

line width in points

lines.linestyle: `'-'`

solid line

lines.color: `'C0'`

has no affect on plot(); see axes.prop_cycle

lines.marker: `'None'`

the default marker

lines.markerfacecolor: `'auto'`

the default marker face color

lines.markeredgecolor: `'auto'`

the default marker edge color

lines.markeredgewidth: `1.0`

the line width around the marker symbol

lines.markersize: `6.0`

marker size, in points

lines.dash_joinstyle: `'round'`

{miter, round, bevel}

lines.dash_capstyle: `'butt'`

{butt, round, projecting}

lines.solid_joinstyle: `'round'`

{miter, round, bevel}

lines.solid_capstyle: `'projecting'`

{butt, round, projecting}

lines.antialiased: `True`

render lines in antialiased (no jaggies)

lines.dashed_pattern: `[3.7, 1.6]`

The dash pattern for linestyle 'dashed'

lines.dashdot_pattern: `[6.4, 1.6, 1.0, 1.6]`

The dash pattern for linestyle 'dashdot'

lines.dotted_pattern: `[1.0, 1.65]`

The dash pattern for linestyle 'dotted'

lines.scale_dashes: `True`

no description

markers.fillstyle: `'full'`

{full, left, right, bottom, top, none}

pcolor.shading: `'auto'`

no description

pcolormesh.snap: `True`

Whether to snap the mesh to pixel boundaries. This is provided solely to allow old test images to remain unchanged. Set to False to obtain the previous behavior.

3.5.3 Patches

patch.linewidth: `1.0`

edge width in points.

patch.facecolor: `'C0'`

no description

patch.edgecolor: `'black'`

By default, Patches and Collections do not draw edges. This value is only used if facecolor is "none" (an Artist without facecolor and edgecolor would be invisible) or if patch.force_edgecolor is True.

patch.force_edgecolor: `False`

By default, Patches and Collections do not draw edges. Set this to True to draw edges with patch.edgedcolor as the default edgecolor. This is mainly relevant for styles.

patch.antialiased: `True`

render patches in antialiased (no jaggies)

3.5.4 Hatches

hatch.color: `'edge'`

no description

hatch.linewidth: `1.0`

no description

3.5.5 Boxplot

boxplot.notch: `False`

no description

boxplot.vertical: `True`

no description

boxplot.whiskers: `1.5`

no description

boxplot.bootstrap: `None`

no description

boxplot.patchartist: `False`

no description

boxplot.showmeans: `False`

no description

boxplot.showcaps: `True`

no description

boxplot.showbox: `True`

no description

boxplot.showfliers: `True`

no description

boxplot.meanline: `False`

no description

boxplot.flierprops.color: `'black'`

no description

boxplot.flierprops.marker: `'o'`

no description

boxplot.flierprops.markerfacecolor: `'none'`

no description

boxplot.flierprops.markeredgecolor: `'black'`

no description

boxplot.flierprops.markeredgewidth: `1.0`

no description

boxplot.flierprops.markersize: `6.0`

no description

boxplot.flierprops.linestyle: `'none'`

no description

boxplot.flierprops.linewidth: `1.0`

no description

boxplot.boxprops.color: `'black'`

no description

boxplot.boxprops.linewidth: `1.0`

no description

boxplot.boxprops.linestyle: `'-'`

no description

boxplot.whiskerprops.color: `'black'`

no description

boxplot.whiskerprops.linewidth: `1.0`

no description

boxplot.whiskerprops.linestyle: `'-'`

no description

boxplot.capprops.color: `'black'`

no description

boxplot.capprops.linewidth: `1.0`

no description

boxplot.capprops.linestyle: `'-'`

no description

boxplot.medianprops.color: `'C1'`

no description

boxplot.medianprops.linewidth: `1.0`

no description

boxplot.medianprops.linestyle: `'-'`

no description

boxplot.meanprops.color: `'C2'`

no description

boxplot.meanprops.marker: `'^'`

no description

boxplot.meanprops.markerfacecolor: `'C2'`

no description

boxplot.meanprops.markeredgecolor: `'C2'`

no description

boxplot.meanprops.markersize: `6.0`

no description

boxplot.meanprops.linestyle: `'--'`

no description

boxplot.meanprops.linewidth: `1.0`

no description

3.5.6 Font

The font properties used by `Text` See https://matplotlib.org/stable/api/font_manager_api.html for more information on font properties. The 6 font properties used for font matching are given below with their default values.

font.family: `['sans-serif']`

no description

font.style: `'normal'`

no description

font.variant: `'normal'`

no description

font.weight: `'normal'`

no description

font.stretch: `'normal'`

no description

font.size: `10.0`

no description

font.serif: `['DejaVu Serif', 'Bitstream Vera Serif', 'Computer Modern Roman', 'New Century Schoolbook', 'Century Schoolbook L', 'Utopia', 'ITC Bookman', 'Bookman', 'Nimbus Roman No9 L', 'Times New Roman', 'Times', 'Palatino', 'Charter', 'serif']`

no description

font.sans-serif: `['DejaVu Sans', 'Bitstream Vera Sans', 'Computer Modern Sans Serif', 'Lucida Grande', 'Verdana', 'Geneva', 'Lucid', 'Arial', 'Helvetica', 'Avant Garde', 'sans-serif']`

no description

font.cursive: `['Apple Chancery', 'Textile', 'Zapf Chancery', 'Sand', 'Script MT', 'Felipa', 'Comic Neue', 'Comic Sans MS', 'cursive']`

no description

font.fantasy: `['Chicago', 'Charcoal', 'Impact', 'Western', 'xkcd script', 'fantasy']`

no description

font.monospace: `['DejaVu Sans Mono', 'Bitstream Vera Sans Mono', 'Computer Modern Typewriter', 'Andale Mono', 'Nimbus Mono L', 'Courier New', 'Courier', 'Fixed', 'Terminal', 'monospace']`

no description

font.enable_last_resort: `True`

If True, then Unicode Consortium's Last Resort font will be appended to all font selections. This ensures that there will always be a glyph displayed.

3.5.7 Text properties

text.color: `'black'`

no description

text.language: `None`

The language of the text in a format accepted by libraqm, namely a BCP47 language code. If None, then no particular language will be implied, and default font settings will be used.

text.hinting: `'default'`

FreeType hinting flag ("foo" corresponds to FT_LOAD_FOO); may be one of the following (Proprietary Matplotlib-specific synonyms are given in parentheses, but their use is discouraged): - default: Use the font's native hinter if possible, else FreeType's auto-hinter. ("either" is a synonym).- no_autohint: Use the font's native hinter if possible, else don't hint. ("native" is a synonym.)- force_autohint: Use FreeType's auto-hinter. ("auto" is a synonym.)- no_hinting: Disable hinting. ("none" is a synonym.)

text.hinting_factor: `None`

[DEPRECATED] This setting has no effect.

text.kerning_factor: `None`

[DEPRECATED] Specifies the scaling factor for kerning values. This is provided solely to allow old test images to remain unchanged. Set to 6 to obtain previous behavior. Values other than 0 or 6 have no defined meaning.

text.antialiased: `True`

If True (default), the text will be antialiased. This only affects raster outputs.

text.parse_math: `True`

Use mathtext if there is an even number of unescaped dollar signs.

3.5.8 Mathtext and LaTeX

text.usetex: `False`

use latex for all text handling. The following fonts are supported through the usual rc parameter settings: new century schoolbook, bookman, times, palatino, zapf chancery, charter, serif, sans-serif, helvetica, avant garde, courier, monospace, computer modern roman, computer modern sans serif, computer modern typewriter

text.latex.engine: `'latex'`

The TeX engine/format to use. The following values are supported: - 'latex': The classic TeX engine (the current default). All backends render TeX's output by parsing the DVI output into glyphs and boxes and emitting those one by one. - 'latex+dvipng': The same as 'latex', with the exception that Agg-based backends rely on dvipng to rasterize TeX's output. This value was the default up to Matplotlib 3.10.

text.latex.preamble: `''`

IMPROPER USE OF THIS FEATURE WILL LEAD TO LATEX FAILURES AND IS THEREFORE UNSUPPORTED. PLEASE DO NOT ASK FOR HELP IF THIS FEATURE DOES NOT DO WHAT YOU EXPECT IT TO. text.latex.preamble is a single line of LaTeX code that will be passed on to the LaTeX system. It may contain any code that is valid for the LaTeX "preamble", i.e. between the "documentclass" and "begin{document}" statements. Note that it has to be put on a single line, which may become quite long. The following packages are always loaded with usetex, so beware of package collisions: color, fix-cm, geometry, graphicx, textcomp. PostScript (PSNFSS) font packages may also be loaded, depending on your font settings.

mathtext.fontset: `'dejavusans'`

Should be 'dejavusans' (default), 'dejavuserif', 'cm' (Computer Modern), 'stix', 'stixsans' or 'custom'

mathtext.bf: `'sans:bold'`

no description

mathtext.bfit: `'sans:italic:bold'`

no description

mathtext.cal: `'cursive'`

no description

mathtext.it: `'sans:italic'`

no description

mathtext.rm: `'sans'`

no description

mathtext.sf: `'sans'`

no description

mathtext.tt: `'monospace'`

no description

mathtext.fallback: `'cm'`

Select fallback font from ['cm' (Computer Modern), 'stix', 'stixsans'] when a symbol cannot be found in one of the custom math fonts. Select 'None' to not perform fallback and replace the missing character by a dummy symbol.

mathtext.default: `'normal'`

The default font to use for math. Can be any of the LaTeX font names, including the special name "regular" for the same font used in regular text.

3.5.9 Axes

axes.facecolor: `'white'`

axes background color

axes.edgecolor: `'black'`

axes edge color

axes.linewidth: `0.8`

edge line width

axes.grid: `False`

display grid or not

axes.grid.axis: `'both'`

which axis the grid should apply to

axes.grid.which: `'major'`

grid lines at {major, minor, both} ticks

axes.titlelocation: `'center'`

alignment of the title: {left, right, center}

axes.titlesize: `'large'`

font size of the axes title

axes.titleweight: `'normal'`

font weight of title

axes.titlecolor: `'auto'`

color of the axes title, auto falls back to text.color as default value

axes.titley: `None`

position title (axes relative units). None implies auto

axes.titlepad: `6.0`

pad between axes and title in points

axes.labelsize: `'medium'`

font size of the x and y labels

axes.labelpad: `4.0`

space between label and axis

axes.labelweight: `'normal'`

weight of the x and y labels

axes.labelcolor: `'black'`

no description

axes.axisbelow: `'line'`

draw axis gridlines and ticks: - below patches (True) - above patches but below lines ('line') - above all (False)

axes.formatter.limits: `[-5, 6]`

use scientific notation if log10 of the axis range is smaller than the first or larger than the second

axes.formatter.use_locale: `False`

When True, format tick labels according to the user's locale. For example, use ',' as a decimal separator in the fr_FR locale.

axes.formatter.use_mathtext: `False`

When True, use mathtext for scientific notation.

axes.formatter.min_exponent: `0`

minimum exponent to format in scientific notation

axes.formatter.useoffset: `True`

If True, the tick label formatter will default to labeling ticks relative to an offset when the data range is small compared to the minimum absolute value of the data.

axes.formatter.offset_threshold: `4`

When useoffset is True, the offset will be used when it can remove at least this number of significant digits from tick labels.

axes.spines.left: `True`

display axis spines

axes.spines.bottom: `True`

no description

axes.spines.top: `True`

no description

axes.spines.right: `True`

no description

axes.unicode_minus: `True`

use Unicode for the minus symbol rather than hyphen. See https://en.wikipedia.org/wiki/Plus_and_minus_signs#Character_codes

axes.prop_cycle: `cycler('color', [(0.12156862745098039, 0.4666666666666667, 0.7058823529411765), (1.0, 0.4980392156862745, 0.054901960784313725), (0.17254901960784313, 0.6274509803921569, 0.17254901960784313), (0.8392156862745098, 0.15294117647058825, 0.1568627450980392), (0.5803921568627451, 0.403921568627451, 0.7411764705882353), (0.5490196078431373, 0.33725490196078434, 0.29411764705882354), (0.8901960784313725, 0.4666666666666667, 0.7607843137254902), (0.4980392156862745, 0.4980392156862745, 0.4980392156862745), (0.7372549019607844, 0.7411764705882353, 0.13333333333333333), (0.09019607843137255, 0.7450980392156863, 0.8117647058823529)])`

no description

axes.xmargin: `0.05`

x margin. See *margins*

axes.ymargin: `0.05`

y margin. See *margins*

axes.zmargin: `0.05`

z margin. See *margins*

axes.autolimit_mode: `'data'`

If "data", use axes.xmargin and axes.ymargin as is. If "round_numbers", after application of margins, axis limits are further expanded to the nearest "round" number.

Polar Axes

polaraxes.grid: `True`

display grid on polar axes

3D Axes

axes3d.grid: `True`

display grid on 3D axes

axes3d.automargin: `False`

automatically add margin when manually setting 3D axis limits

axes3d.xaxis.panecolor: `(0.95, 0.95, 0.95, 0.5)`

background pane on 3D axes

axes3d.yaxis.panecolor: `(0.9, 0.9, 0.9, 0.5)`

background pane on 3D axes

axes3d.zaxis.panecolor: `(0.925, 0.925, 0.925, 0.5)`

background pane on 3D axes

axes3d.depthshade: `True`

depth shade for 3D scatter plots

axes3d.depthshade_minalpha: `0.3`

minimum alpha value for depth shading

axes3d.mouserotationstyle: `'arcball'`

{azel, trackball, sphere, arcball} See also https://matplotlib.org/stable/api/toolkits/mplot3d/view_angles.html#rotation-with-mouse

axes3d.trackballsize: `0.667`

trackball diameter, in units of the Axes bbox

axes3d.trackballborder: `0.2`

trackball border width, in units of the Axes bbox (only for 'sphere' and 'arcball' style)

3.5.10 Axis

axes3d.snap_rotation: `5.0`

Snap angle (in degrees) for 3D rotation when holding Control.

xaxis.labellocation: `'center'`

alignment of the xaxis label: {left, right, center}

yaxis.labellocation: `'center'`

alignment of the yaxis label: {bottom, top, center}

3.5.11 Dates

Default properties for date tick labels. These are used by the `AutoDateFormatter` when the appropriate time unit is detected.See https://matplotlib.org/stable/api/dates_api.html#date-formatters for more information.

date.autoformatter.year: `'%Y'`

no description

date.autoformatter.month: `'%Y-%m'`

no description

date.autoformatter.day: `'%Y-%m-%d'`

no description

date.autoformatter.hour: `'%m-%d %H'`

no description

date.autoformatter.minute: `'%d %H:%M'`

no description

date.autoformatter.second: `'%H:%M:%S'`

no description

date.autoformatter.microsecond: `'%M:%S.%f'`

no description

date.epoch: `'1970-01-01T00:00:00'`

The reference date for Matplotlib's internal date representation. See https://matplotlib.org/stable/gallery/ticks/date_precision_and_epochs.html

date.converter: `'auto'`

'auto', 'concise'

date.interval_multiples: `True`

For auto converter whether to use interval_multiples

3.5.12 Ticks

xtick.top: `False`

draw ticks on the top side

xtick.bottom: `True`

draw ticks on the bottom side

xtick.labeltop: `False`

draw label on the top

xtick.labelbottom: `True`

draw label on the bottom

xtick.major.size: `3.5`

major tick size in points

xtick.minor.size: `2.0`

minor tick size in points

xtick.major.width: `0.8`

major tick width in points

xtick.minor.width: `0.6`

minor tick width in points

xtick.major.pad: `3.5`

distance to major tick label in points

xtick.minor.pad: `3.4`

distance to the minor tick label in points

xtick.color: `'black'`

color of the ticks

xtick.labelcolor: `'inherit'`

color of the tick labels or inherit from xtick.color

xtick.labelsize: `'medium'`

font size of the tick labels

xtick.direction: `'out'`

direction: {in, out, inout}

xtick.minor.visible: `False`

visibility of minor ticks on x-axis

xtick.major.top: `True`

draw x axis top major ticks

xtick.major.bottom: `True`

draw x axis bottom major ticks

xtick.minor.top: `True`

draw x axis top minor ticks

xtick.minor.bottom: `True`

draw x axis bottom minor ticks

xtick.minor.ndivs: `'auto'`

number of minor ticks between the major ticks on x-axis

xtick.alignment: `'center'`

alignment of xticks

ytick.left: `True`

draw ticks on the left side

ytick.right: `False`

draw ticks on the right side

ytick.labelleft: `True`

draw tick labels on the left side

ytick.labelright: `False`

draw tick labels on the right side

ytick.major.size: `3.5`

major tick size in points

ytick.minor.size: `2.0`

minor tick size in points

ytick.major.width: `0.8`

major tick width in points

ytick.minor.width: `0.6`

minor tick width in points

ytick.major.pad: `3.5`

distance to major tick label in points

ytick.minor.pad: `3.4`

distance to the minor tick label in points

ytick.color: `'black'`

color of the ticks

ytick.labelcolor: `'inherit'`

color of the tick labels or inherit from ytick.color

ytick.labelsize: `'medium'`

font size of the tick labels

ytick.direction: `'out'`

direction: {in, out, inout}

ytick.minor.visible: `False`

visibility of minor ticks on y-axis

ytick.major.left: `True`

draw y axis left major ticks

ytick.major.right: `True`

draw y axis right major ticks

ytick.minor.left: `True`

draw y axis left minor ticks

ytick.minor.right: `True`

draw y axis right minor ticks

ytick.minor.ndivs: `'auto'`

number of minor ticks between the major ticks on y-axis

ytick.alignment: `'center_baseline'`

alignment of yticks

3.5.13 Grid

grid.color: `'#b0b0b0'`

b0b0b0" # grid color

grid.linestyle: `'-'`

solid

grid.linewidth: `0.8`

in points

grid.alpha: `1.0`

transparency, between 0.0 and 1.0

grid.major.color: `None`

If None defaults to grid.color

grid.major.linestyle: `None`

If None defaults to grid.linestyle

grid.major.linewidth: `None`

If None defaults to grid.linewidth

grid.major.alpha: `None`

If None defaults to grid.alpha

grid.minor.color: `None`

If None defaults to grid.color

grid.minor.linestyle: `None`

If None defaults to grid.linestyle

grid.minor.linewidth: `None`

If None defaults to grid.linewidth

grid.minor.alpha: `None`

If None defaults to grid.alpha

3.5.14 Legend

legend.loc: `'best'`

no description

legend.frameon: `True`

if True, draw the legend on a background patch

legend.framealpha: `0.8`

legend patch transparency

legend.facecolor: `'inherit'`

inherit from axes.facecolor; or color spec

legend.edgecolor: `'0.8'`

background patch boundary color

legend.linewidth: `None`

line width of the legend frame, None means inherit from patch.linewidth

legend.fancybox: `True`

if True, use a rounded box for the legend background, else a rectangle

legend.shadow: `False`

if True, give background a shadow effect

legend.numpoints: `1`

the number of marker points in the legend line

legend.scatterpoints: `1`

number of scatter points

legend.markerscale: `1.0`

the relative size of legend markers vs. original

legend.fontsize: `'medium'`

no description

legend.labelcolor: `'None'`

no description

legend.title_fontsize: `None`

None sets to the same as the default axes.

legend.borderpad: `0.4`

border whitespace

legend.labelspacing: `0.5`

the vertical space between the legend entries

legend.handlelength: `2.0`

the length of the legend lines

legend.handleheight: `0.7`

the height of the legend handle

legend.handletextpad: `0.8`

the space between the legend line and legend text

legend.borderaxespad: `0.5`

the border between the axes and legend edge

legend.columnspacing: `2.0`

column separation

3.5.15 Figure

figure.titlesize: `'large'`

size of the figure title (`Figure.suptitle()`)

figure.titleweight: `'normal'`

weight of the figure title

figure.labelsize: `'large'`

size of the figure label (`Figure.sup[x|y]label()`)

figure.labelweight: `'normal'`

weight of the figure label

figure.figsize: `[6.4, 4.8]`

figure size in inches

figure.dpi: `100.0`

figure dots per inch

figure.facecolor: `'white'`

figure face color

figure.edgecolor: `'white'`

figure edge color

figure.frameon: `True`

enable figure frame

figure.max_open_warning: `20`

The maximum number of figures to open through the pyplot interface before emitting a warning. If less than one this feature is disabled.

figure.raise_window: `True`

Raise the GUI window to front when show() is called. If set to False, we currently do not take any further actions and whether the window appears on the front may depend on the GUI framework and window manager.

figure.subplot.left: `0.125`

the left side of the subplots of the figure

figure.subplot.right: `0.9`

the right side of the subplots of the figure

figure.subplot.bottom: `0.11`

the bottom of the subplots of the figure

figure.subplot.top: `0.88`

the top of the subplots of the figure

figure.subplot.wspace: `0.2`

the amount of width reserved for space between subplots, expressed as a fraction of the average axis width

figure.subplot.hspace: `0.2`

the amount of height reserved for space between subplots, expressed as a fraction of the average axis height

figure.autolayout: `False`

When True, automatically adjust subplot parameters to make the plot fit the figure using *tight_layout*

figure.constrained_layout.use: `False`

When True, automatically make plot elements fit on the figure. (Not compatible with "figure.autolayout", above).

figure.constrained_layout.h_pad: `0.04167`

Padding (in inches) around axes; defaults to 3/72 inches, i.e. 3 points

figure.constrained_layout.w_pad: `0.04167`

Padding (in inches) around axes; defaults to 3/72 inches, i.e. 3 points

figure.constrained_layout.hspace: `0.02`

Spacing between subplots, relative to the subplot sizes. Much smaller than for tight_layout (figure.subplot.hspace, figure.subplot.wspace) as constrained_layout already takes surrounding texts (titles, labels, # ticklabels) into account.

figure.constrained_layout.wspace: `0.02`

Spacing between subplots, relative to the subplot sizes. Much smaller than for tight_layout (figure.subplot.hspace, figure.subplot.wspace) as constrained_layout already takes surrounding texts (titles, labels, # ticklabels) into account.

3.5.16 Images

image.aspect: `'equal'`

{equal, auto} or a number

image.interpolation: `'auto'`

see help(imshow) for options

image.interpolation_stage: `'auto'`

see help(imshow) for options

image.cmap: `'viridis'`

A colormap name (plasma, magma, etc.)

image.lut: `256`

the size of the colormap lookup table

image.origin: `'upper'`

{lower, upper}

image.resample: `True`

no description

image.composite_image: `True`

When True, all the images on a set of axes are combined into a single composite image before saving a figure as a vector graphics file, such as a PDF.

3.5.17 Contour plots

contour.negative_linestyle: `'dashed'`

string or on-off ink sequence

contour.corner_mask: `True`

{True, False}

contour.linewidth: `None`

{float, None} Size of the contour line widths. If set to None, it falls back to "line.linewidth".

contour.algorithm: `'mpl2014'`

{mpl2005, mpl2014, serial, threaded}

3.5.18 Errorbar plots

errorbar.capsize: `0.0`

length of end cap on error bars in pixels

errorbar.capthick: `None`

thickness of end cap on error bars in points.

errorbar.elinewidth: `None`

line width of the error bar lines in points.

3.5.19 Histogram plots

hist.bins: `10`

The default number of histogram bins or 'auto'.

3.5.20 Scatter plots

scatter.marker: `'o'`

The default marker type for scatter plots.

scatter.edgecolors: `'face'`

The default edge colors for scatter plots.

3.5.21 AGG rendering

agg.path.chunksize: `0`

0 to disable; values in the range 10000 to 100000 can improve speed slightly and prevent an Agg rendering failure when plotting very large data sets, especially if they are very gappy. It may cause minor artifacts, though. A value of 20000 is probably a good starting point.

3.5.22 Paths

path.simplify: `True`

When True, simplify paths by removing "invisible" points to reduce file size and increase rendering speed

path.simplify_threshold: `0.111111111111`

The threshold of similarity below which vertices will be removed in the simplification process.

path.snap: `True`

When True, rectilinear axis-aligned paths will be snapped to the nearest pixel when certain criteria are met. When False, paths will never be snapped.

path.sketch: `None`

May be None, or a tuple of the form:path.sketch: (scale, length, randomness)- *scale* is the amplitude of the wiggle perpendicular to the line (in pixels).- *length* is the length of the wiggle along the line (in pixels).- *randomness* is the factor by which the length is randomly scaled.

path.effects: `[]`

no description

3.5.23 Saving figures

savefig.dpi: `'figure'`

figure dots per inch or 'figure'

savefig.facecolor: `'auto'`

figure face color when saving

savefig.edgecolor: `'auto'`

figure edge color when saving

savefig.format: `'png'`

{png, ps, pdf, svg}

savefig.bbox: `None`

{tight, standard} 'tight' is incompatible with generating frames for animation

savefig.pad_inches: `0.1`

padding to be used, when bbox is set to 'tight'

savefig.directory: `'~'`

default directory in savefig dialog, gets updated after interactive saves, unless set to the empty string (i.e. the current directory); use '.' to start at the current directory but update after interactive saves

savefig.transparent: `False`

whether figures are saved with a transparent background by default

savefig.orientation: `'portrait'`

orientation of saved figure, for PostScript output only

Mac OSX backend parameters

macosx.window_mode: `'system'`

How to open new figures (system, tab, window) system uses the MacOS system preferences

Tk backend parameters

tk.window_focus: `False`

Maintain shell focus for TkAgg

PS backend parameters

ps.papersize: `'letter'`

{figure, letter, legal, ledger, A0-A10, B0-B10}

ps.useafm: `False`

use AFM fonts, results in small files

ps.usedistiller: `None`

{ghostscript, xpdf, None} Experimental: may produce smaller files. xpdf intended for production of publication quality files, but requires ghostscript, xpdf and ps2eps

ps.distiller.res: `6000`

dpi

ps.fonttype: `3`

Output Type 3 (Type3) or Type 42 (TrueType)

PDF backend parameters

pdf.compression: `6`

integer from 0 to 9 0 disables compression (good for debugging)

pdf.fonttype: `3`

Output Type 3 (Type3) or Type 42 (TrueType)

pdf.use14corefonts: `False`

no description

pdf.inheritcolor: `False`

no description

SVG backend parameters

svg.image_inline: `True`

Write raster image data directly into the SVG file

svg.fonttype: `'path'`

How to handle SVG fonts: path: Embed characters as paths -- supported by most SVG renderersnone: Assume fonts are installed on the machine where the SVG will be viewed.

svg.hashsalt: `None`

If not None, use this string as hash salt instead of uuid4

svg.id: `None`

If not None, use this string as the value for the `id` attribute in the top <svg> tag

PGF parameters

pgf.rcfonts: `True`

no description

pgf.preamble: `''`

See text.latex.preamble for documentation

pgf.texsystem: `'xelatex'`

no description

Docstring parameters

docstring.hardcopy: `False`

set this when you want to generate hardcopy docstring

3.5.24 Interactive keymaps

Default key mappings for interactive navigation. See *Navigation keyboard shortcuts*.

keymap.fullscreen: `['f', 'ctrl+f']`

toggling

keymap.home: `['h', 'r', 'home']`

home or reset mnemonic

keymap.back: `['left', 'c', 'backspace', 'MouseButton.BACK']`

forward / backward keys

keymap.forward: `['right', 'v', 'MouseButton.FORWARD']`

for quick navigation

keymap.pan: `['p']`

pan mnemonic

keymap.zoom: `['o']`

zoom mnemonic

keymap.save: `['s', 'ctrl+s']`

saving current figure

keymap.help: `['f1']`

display help about active tools

keymap.quit: `['ctrl+w', 'cmd+w', 'q']`

close the current figure

keymap.quit_all: `[]`

close all figures

keymap.grid: `['g']`

switching on/off major grids in current axes

keymap.grid_minor: `['G']`

switching on/off minor grids in current axes

keymap.yscale: `['l']`

toggle scaling of y-axes ('log'/'linear')

keymap.xscale: `['k', 'L']`

toggle scaling of x-axes ('log'/'linear')

keymap.copy: `['ctrl+c', 'cmd+c']`

copy figure to clipboard

3.5.25 Animation

animation.html: `'none'`

How to display the animation as HTML in the IPython notebook: - 'html5' uses HTML5 video tag - 'jshtml' creates a JavaScript animation

animation.writer: `'ffmpeg'`

MovieWriter 'backend' to use

animation.codec: `'h264'`

Codec to use for writing movie

animation.bitrate: `-1`

Controls size/quality trade-off for movie. -1 implies let utility auto-determine

animation.frame_format: `'png'`

Controls frame format used by temp files

animation.ffmpeg_path: `'ffmpeg'`

Path to ffmpeg binary. Unqualified paths are resolved by subprocess.Popen.

animation.ffmpeg_args: `[]`

Additional arguments to pass to ffmpeg

animation.convert_path: `'convert'`

Path to ImageMagick's convert binary. Unqualified paths are resolved by subprocess.Popen, except that on Windows, we look up an install of ImageMagick in the registry (as convert is also the name of a system tool).

animation.convert_args: `['-layers', 'OptimizePlus']`

Additional arguments to pass to convert

animation.embed_limit: `20.0`

Limit, in MB, of size of base64 encoded animation in HTML (i.e. IPython notebook)

backend: `None`

no description

3.6 Customizing Matplotlib with style sheets and rcParams

Many aspects of Matplotlib's behavior and default styles can be customized through the use of rc (runtime configuration) settings. The current values are stored in *rcParams*.

There are three ways to customize Matplotlib, all of which effectively change *rcParams*:

1. *Setting rcParams at runtime*.
2. *Using style sheets*.
3. *Changing your matplotlibrc file*.

Setting rcParams at runtime takes precedence over style sheets, style sheets take precedence over `matplotlibrc` files.

3.6.1 Runtime rc settings

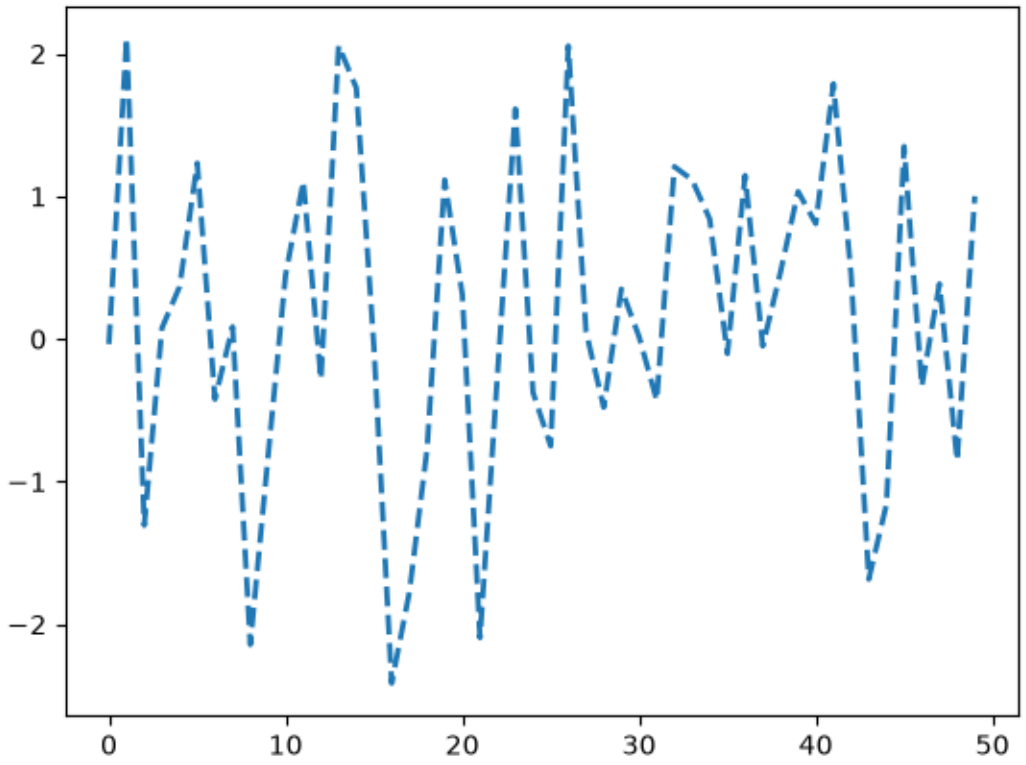
You can dynamically change the default rc (runtime configuration) settings in a python script or interactively from the python shell. All rc settings are stored in a dictionary-like variable called *matplotlib.rcParams*, which is global to the matplotlib package. See *matplotlib.rcParams* for a full list of configurable rcParams. rcParams can be modified directly, for example:

```
from cycler import cycler

import matplotlib.pyplot as plt
```

(continues on next page)

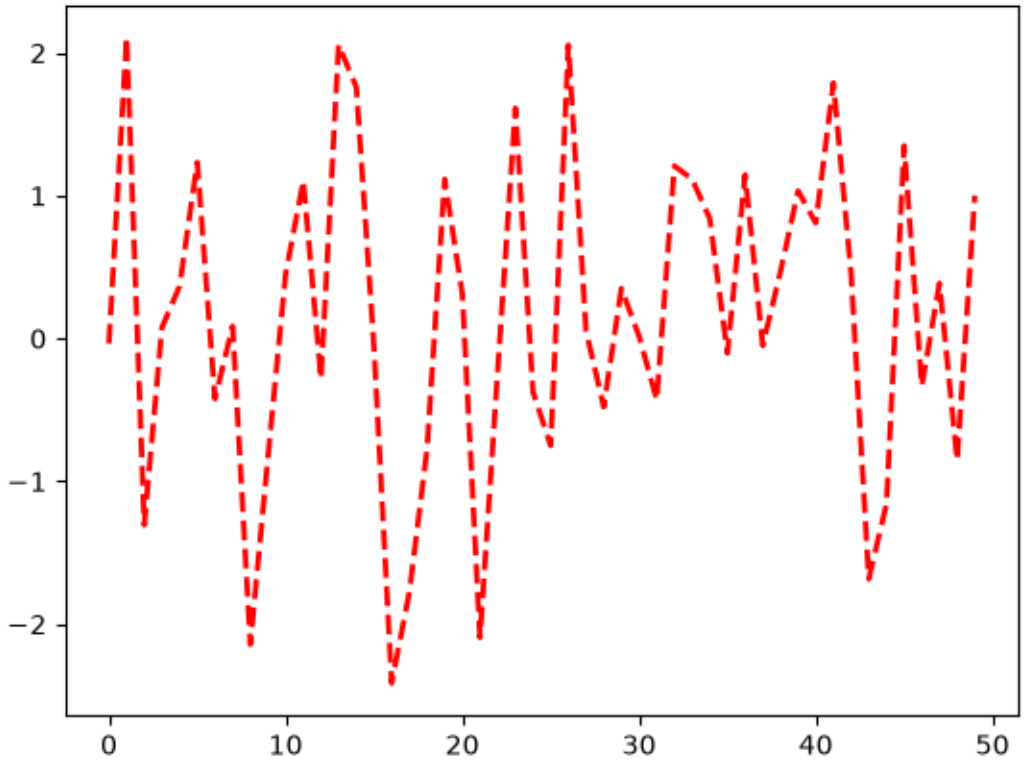
(continued from previous page)

```
import numpy as np

import matplotlib as mpl

mpl.rcParams['lines.linewidth'] = 2
mpl.rcParams['lines.linestyle'] = '--'
data = np.random.randn(50)
plt.plot(data)
```



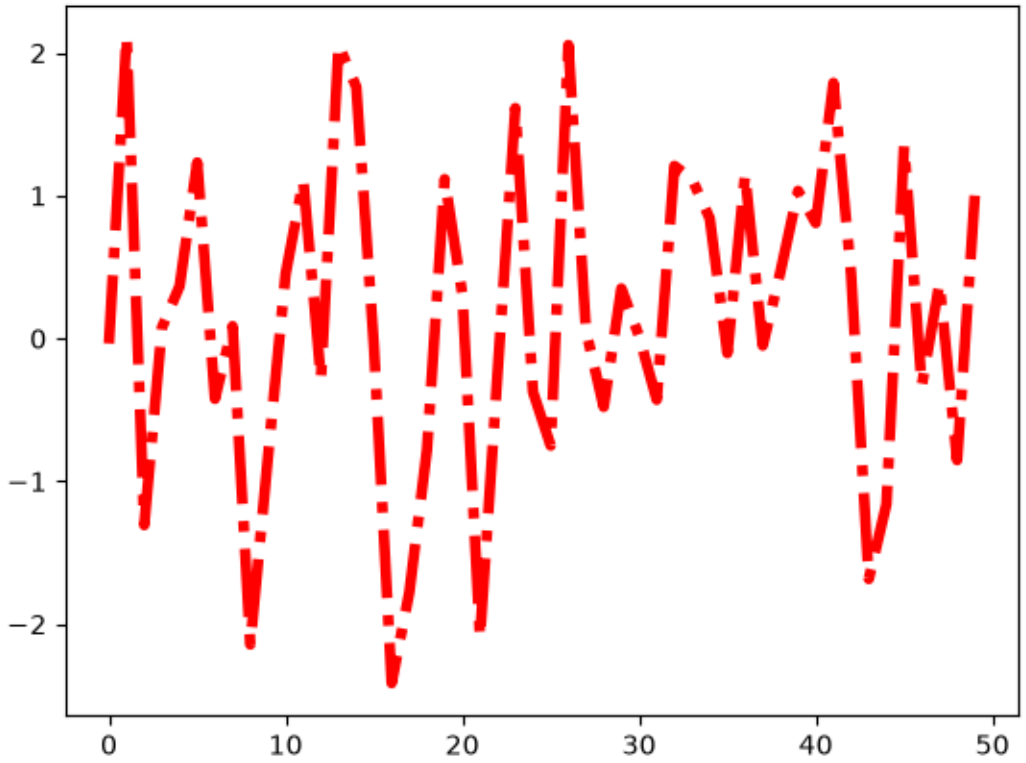
Note, that in order to change the usual `plot` color you have to change the *prop_cycle* property of *axes*:

```
mpl.rcParams['axes.prop_cycle'] = cycler(color=['r', 'g', 'b', 'y'])
plt.plot(data)  # first color is red
```



Matplotlib also provides a couple of convenience functions for modifying rc settings. *matplotlib.rc* can be used to modify multiple settings in a single group at once, using keyword arguments:

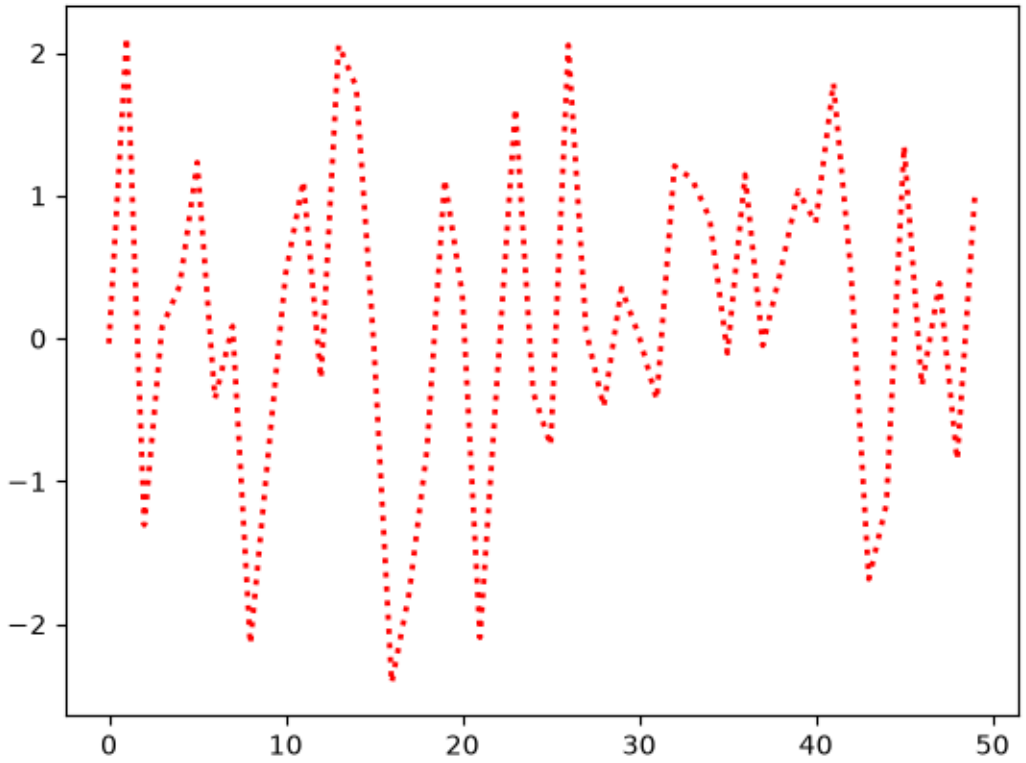
```
mpl.rc('lines', linewidth=4, linestyle='-.')
plt.plot(data)
```



Temporary rc settings

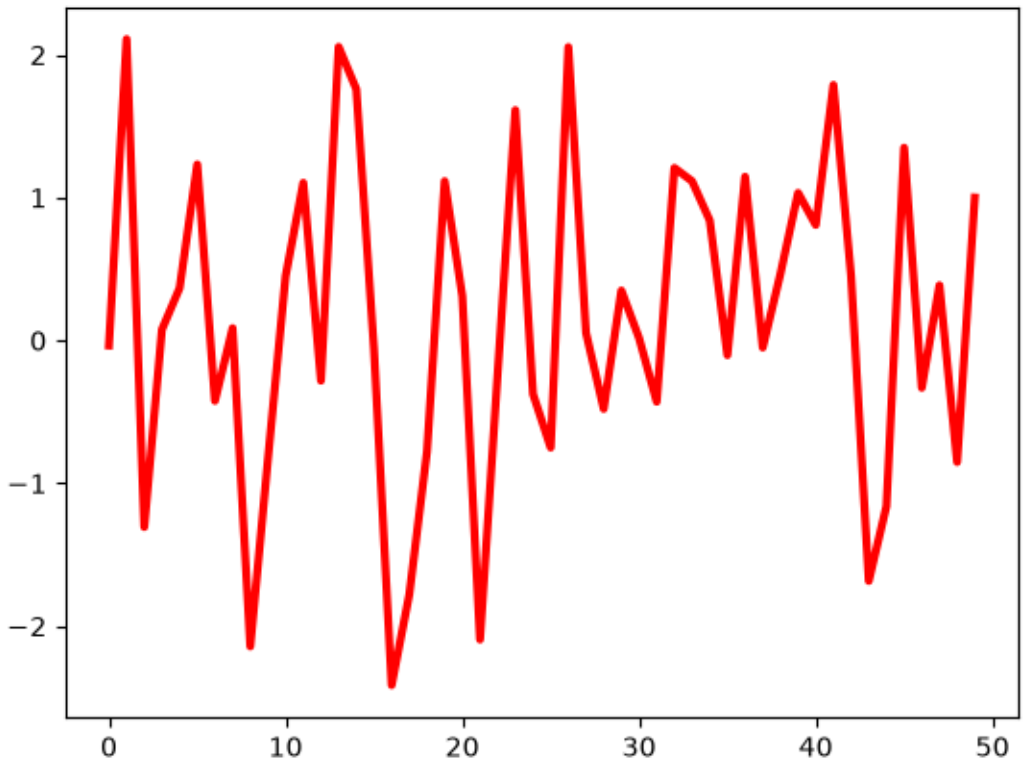
The *matplotlib.rcParams* object can also be changed temporarily using the *matplotlib.rc_context* context manager:

```
with mpl.rc_context({'lines.linewidth': 2, 'lines.linestyle': ':'}):
    plt.plot(data)
```



matplotlib.rc_context can also be used as a decorator to modify the defaults within a function:

```
@mpl.rc_context({'lines.linewidth': 3, 'lines.linestyle': '-'})
def plotting_function():
    plt.plot(data)

plotting_function()
```



`matplotlib.rcdefaults` will restore the standard Matplotlib default settings.

There is some degree of validation when setting the values of rcParams, see `matplotlib.rcsetup` for details.

3.6.2 Using style sheets

Another way to change the visual appearance of plots is to set the rcParams in a so-called style sheet and import that style sheet with `matplotlib.style.use`. In this way you can switch easily between different styles by simply changing the imported style sheet. A style sheets looks the same as a *matplotlibrc* file, but in a style sheet you can only set rcParams that are related to the actual style of a plot. Other rcParams, like *backend*, will be ignored. `matplotlibrc` files support all rcParams. The rationale behind this is to make style sheets portable between different machines without having to worry about dependencies which might or might not be installed on another machine. For a full list of rcParams see `matplotlib.rcParams`. For a list of rcParams that are ignored in style sheets see `matplotlib.style.use`.

There are a number of pre-defined styles *provided by Matplotlib*. For example, there's a pre-defined style called "ggplot", which emulates the aesthetics of ggplot (a popular plotting package for R). To use this style, add:

```
plt.style.use('ggplot')
```

To list all available styles, use:

```
print(plt.style.available)
```

```
['Solarize_Light2', 'bmh', 'classic', 'dark_background', 'fast',
 ↪'fivethirtyeight', 'ggplot', 'grayscale', 'petroff10', 'petroff6',
 ↪'petroff8', 'seaborn-v0_8', 'seaborn-v0_8-bright',
 ↪'seaborn-v0_8-colorblind', 'seaborn-v0_8-dark',
 ↪'seaborn-v0_8-dark-palette', 'seaborn-v0_8-darkgrid',
 ↪'seaborn-v0_8-deep', 'seaborn-v0_8-muted', 'seaborn-v0_8-notebook',
 ↪'seaborn-v0_8-paper', 'seaborn-v0_8-pastel', 'seaborn-v0_8-poster',
 ↪'seaborn-v0_8-talk', 'seaborn-v0_8-ticks', 'seaborn-v0_8-white',
 ↪'seaborn-v0_8-whitegrid', 'tableau-colorblind10']
```

Defining your own style

You can create custom styles and use them by calling *style.use* with the path or URL to the style sheet.

For example, you might want to create `./images/presentation.mplstyle` with the following:

```
axes.titlesize : 24
axes.labelsize : 20
lines.linewidth : 3
lines.markersize : 10
xtick.labelsize : 16
ytick.labelsize : 16
```

Then, when you want to adapt a plot designed for a paper to one that looks good in a presentation, you can just add:

```
>>> import matplotlib.pyplot as plt
>>> plt.style.use('./images/presentation.mplstyle')
```

Distributing styles

You can include style sheets into standard importable Python packages (which can be e.g. distributed on PyPI). If your package is importable as `import mypackage`, with a `mypackage/__init__.py` module, and you add a `mypackage/presentation.mplstyle` style sheet, then it can be used as `plt.style.use("mypackage.presentation")`. Subpackages (e.g. `dotted.package.name`) are also supported.

Alternatively, you can make your style known to Matplotlib by placing your `<style-name>.mplstyle` file into `mpl_configdir/stylelib`. You can then load your custom style sheet with a call to `style.use(<style-name>)`. By default `mpl_configdir` should be `~/.config/matplotlib`, but you can check where yours is with *matplotlib.get_configdir()*; you may need to create this directory. You also can change the directory where Matplotlib looks for the stylelib/ folder by setting the *MPLCONFIGDIR* environment variable, see *matplotlib configuration and cache directory locations*.

Note that a custom style sheet in `mpl_configdir/stylelib` will override a style sheet defined by Matplotlib if the styles have the same name.

Once your `<style-name>.mplstyle` file is in the appropriate `mpl_configdir` you can specify your style with:

```
>>> import matplotlib.pyplot as plt
>>> plt.style.use(<style-name>)
```

Composing styles

Style sheets are designed to be composed together. So you can have a style sheet that customizes colors and a separate style sheet that alters element sizes for presentations. These styles can easily be combined by passing a list of styles:

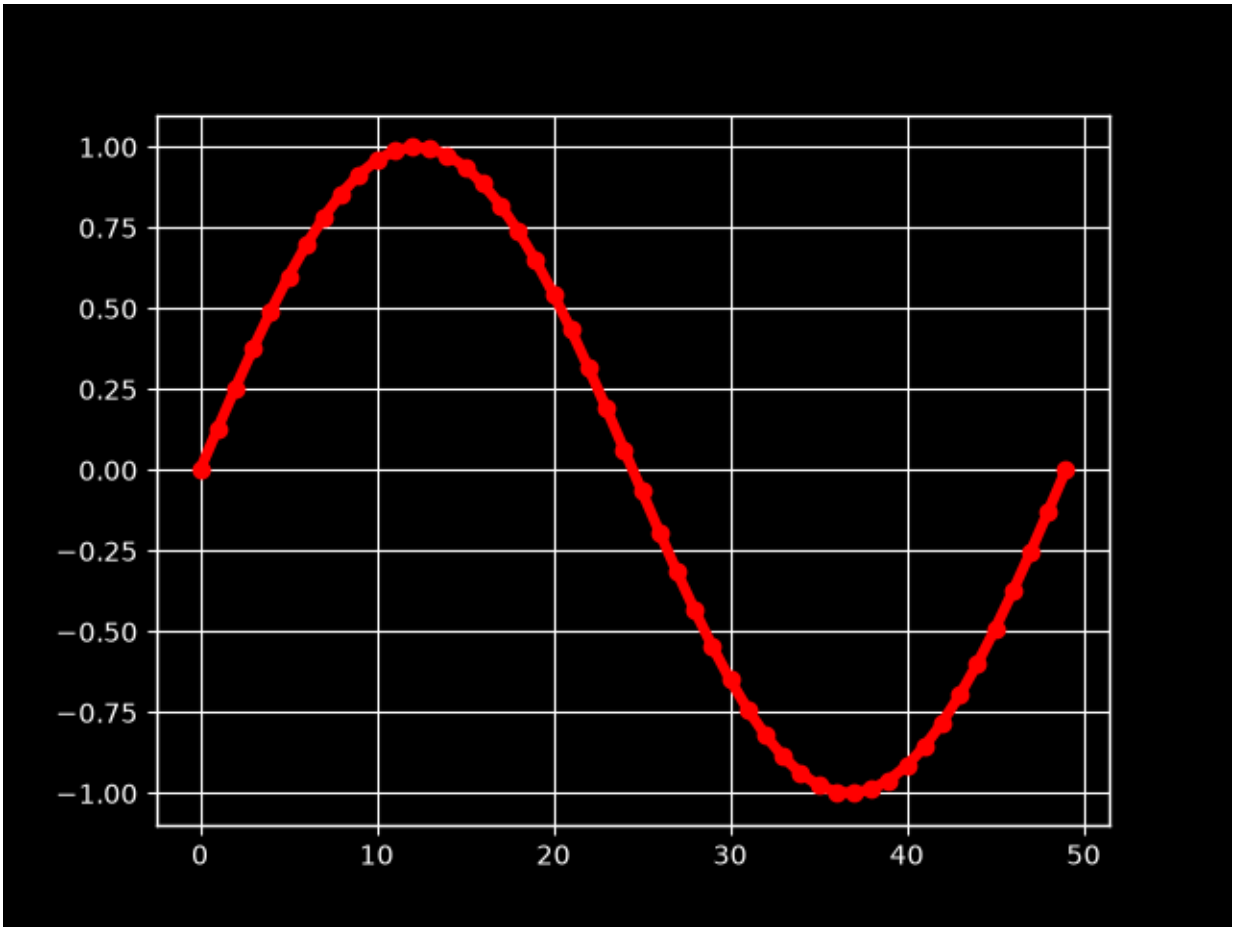
```
>>> import matplotlib.pyplot as plt
>>> plt.style.use(['dark_background', 'presentation'])
```

Note that styles further to the right will overwrite values that are already defined by styles on the left.

Temporary styling

If you only want to use a style for a specific block of code but don't want to change the global styling, the style package provides a context manager for limiting your changes to a specific scope. To isolate your styling changes, you can write something like the following:

```
with plt.style.context('dark_background'):
    plt.plot(np.sin(np.linspace(0, 2 * np.pi)), 'r-o')
plt.show()
```



3.6.3 The `matplotlibrc` file

Matplotlib uses `matplotlibrc` configuration files to customize all kinds of properties, which we call 'rc settings' or 'rc parameters'. You can control the defaults of almost every property in Matplotlib: figure size and DPI, line width, color and style, Axes, axis and grid properties, text and font properties and so on. The `matplotlibrc` is read at startup to configure Matplotlib. Matplotlib looks for `matplotlibrc` in four locations, in the following order:

1. `matplotlibrc` in the current working directory, usually used for specific customizations that you do not want to apply elsewhere.
2. `$MATPLOTLIBRC` if it is a file, else `$MATPLOTLIBRC/matplotlibrc`.
3. It next looks in a user-specific place, depending on your platform:
   - On Linux and FreeBSD, it looks in `.config/matplotlib/matplotlibrc` (or `$XDG_CONFIG_HOME/matplotlib/matplotlibrc`) if you've customized your environment.
   - On other platforms, it looks in `.matplotlib/matplotlibrc`.

   See *matplotlib configuration and cache directory locations*.
4. *`INSTALL`*`/matplotlib/mpl-data/matplotlibrc`, where *`INSTALL`* is something like `/usr/lib/python3.10/site-packages` on Linux, and maybe `C:\Python310\Lib\`

`site-packages` on Windows. Every time you install matplotlib, this file will be overwritten, so if you want your customizations to be saved, please move this file to your user-specific matplotlib directory.

Once a `matplotlibrc` file has been found, it will *not* search any of the other paths. When a *style sheet* is given with `style.use('<path>/<style-name>.mplstyle')`, settings specified in the style sheet take precedence over settings in the `matplotlibrc` file.

To display where the currently active `matplotlibrc` file was loaded from, one can do the following:

```
>>> import matplotlib
>>> matplotlib.matplotlib_fname()
'/home/foo/.config/matplotlib/matplotlibrc'
```

See below for a sample *matplotlibrc file* and see *`matplotlib.rcParams`* for a full list of configurable rcParams.

The default `matplotlibrc` file

```
#### MATPLOTLIBRC FORMAT

## DO NOT EDIT THIS FILE, MAKE A COPY FIRST
##
## This is a sample Matplotlib configuration file - you can find a copy
## of it on your system in␣
 ↪site-packages/matplotlib/mpl-data/matplotlibrc
## (relative to your Python installation location).
## DO NOT EDIT IT!
##
## If you wish to change your default style, copy this file to one of␣
 ↪the
## following locations:
##     Unix/Linux:
##         $HOME/.config/matplotlib/matplotlibrc OR
##         $XDG_CONFIG_HOME/matplotlib/matplotlibrc (if
 ↪$XDG_CONFIG_HOME is set)
##     Other platforms:
##         $HOME/.matplotlib/matplotlibrc
## and edit that copy.
##
## See␣
 ↪https://matplotlib.org/stable/users/explain/customizing.html#customizing-with-mat
## for more details on the paths which are checked for the␣
 ↪configuration file.
##
## Blank lines, or lines starting with a comment symbol, are ignored,␣
 ↪as are
## trailing comments.  Other lines must have the format:
```

(continues on next page)

(continued from previous page)

```
##     key: val  # optional comment
##
## Formatting: Use PEP8-like style (as enforced in the rest of the␣
 ↪codebase).
## All lines start with an additional '#', so that removing all␣
 ↪leading '#'s
## yields a valid style file.
##
## Colors: for the color values below, you can either use
##     - a Matplotlib color string, such as r, k, or b
##     - an RGB tuple, such as (1.0, 0.5, 0.0)
##     - a double-quoted hex string, such as "#ff00ff".
##       The unquoted string ff00ff is also supported for backward
##       compatibility, but is discouraged.
##     - a scalar grayscale intensity such as 0.75
##     - a legal html color name, e.g., red, blue, darkslategray
##
## String values may optionally be enclosed in double quotes, which␣
 ↪allows
## using the comment character # in the string.
##
## This file (and other style files) must be encoded as utf-8.
##
## Matplotlib configuration are currently divided into following parts:
##     - BACKENDS
##     - LINES
##     - PATCHES
##     - HATCHES
##     - BOXPLOT
##     - FONT
##     - TEXT
##     - LaTeX
##     - AXES
##     - DATES
##     - TICKS
##     - GRIDS
##     - LEGEND
##     - FIGURE
##     - IMAGES
##     - CONTOUR PLOTS
##     - ERRORBAR PLOTS
##     - HISTOGRAM PLOTS
##     - SCATTER PLOTS
##     - AGG RENDERING
##     - PATHS
##     - SAVING FIGURES
```

(continues on next page)

(continued from previous page)

```
##     - INTERACTIVE KEYMAPS
##     - ANIMATION

##### CONFIGURATION BEGINS HERE


##␣
 ↪**************************************************************************
## * BACKENDS                                                               ␣
 ↪      *
##␣
 ↪**************************************************************************
## The default backend.  If you omit this parameter, the first working
## backend from the following list is used:
##     MacOSX QtAgg Gtk4Agg Gtk3Agg TkAgg WxAgg Agg
## Other choices include:
##     QtCairo GTK4Cairo GTK3Cairo TkCairo WxCairo Cairo
##     Qt5Agg Qt5Cairo Wx  # deprecated.
##     PS PDF SVG Template
## You can also deploy your own backend outside of Matplotlib by␣
 ↪referring to
## the module name (which must be in the PYTHONPATH) as
 ↪'module://my_backend'.
##backend: Agg

## The port to use for the web server in the WebAgg backend.
#webagg.port: 8988

## The address on which the WebAgg web server should be reachable
#webagg.address: 127.0.0.1

## If webagg.port is unavailable, a number of other random ports will
## be tried until one that is available is found.
#webagg.port_retries: 50

## When True, open the web browser to the plot that is shown
#webagg.open_in_browser: True

## If you are running pyplot inside a GUI and your backend choice
## conflicts, we will automatically try to find a compatible one for
## you if backend_fallback is True
#backend_fallback: True

#interactive: False
#figure.hooks:          # list of␣
 ↪dotted.module.name:dotted.callable.name
```

(continues on next page)

(continued from previous page)

```
#toolbar:     toolbar2  # {None, toolbar2, toolmanager}
#timezone:    UTC       # a pytz timezone string, e.g., US/Central or␣
 ↪Europe/Paris


##␣
 ↪**********************************************************************
## * LINES                                                             ␣
 ↪      *
##␣
 ↪**********************************************************************
## See␣
 ↪https://matplotlib.org/stable/api/artist_api.html#module-matplotlib.lines
## for more information on line properties.
#lines.linewidth: 1.5                # line width in points
#lines.linestyle: -                  # solid line
#lines.color:     C0                 # has no affect on plot(); see␣
 ↪axes.prop_cycle
#lines.marker:          None         # the default marker
#lines.markerfacecolor: auto         # the default marker face color
#lines.markeredgecolor: auto         # the default marker edge color
#lines.markeredgewidth: 1.0          # the line width around the marker␣
 ↪symbol
#lines.markersize:      6            # marker size, in points
#lines.dash_joinstyle:  round        # {miter, round, bevel}
#lines.dash_capstyle:   butt         # {butt, round, projecting}
#lines.solid_joinstyle: round        # {miter, round, bevel}
#lines.solid_capstyle:  projecting   # {butt, round, projecting}
#lines.antialiased: True             # render lines in antialiased (no␣
 ↪jaggies)

## The three standard dash patterns.  These are scaled by the␣
 ↪linewidth.
#lines.dashed_pattern: 3.7, 1.6
#lines.dashdot_pattern: 6.4, 1.6, 1, 1.6
#lines.dotted_pattern: 1, 1.65
#lines.scale_dashes: True

#markers.fillstyle: full  # {full, left, right, bottom, top, none}

#pcolor.shading: auto
#pcolormesh.snap: True  # Whether to snap the mesh to pixel␣
 ↪boundaries. This is
                        # provided solely to allow old test images to␣
 ↪remain
                        # unchanged. Set to False to obtain the␣
```

(continues on next page)

(continued from previous page)

```
 ↪previous behavior.

##␣
 ↪*********************************************************************
## * PATCHES                                                          ␣
 ↪      *
##␣
 ↪*********************************************************************
## Patches are graphical objects that fill 2D space, like polygons or␣
 ↪circles.
## See␣
 ↪https://matplotlib.org/stable/api/artist_api.html#module-matplotlib.patches
## for more information on patch properties.
#patch.linewidth:       1.0     # edge width in points.
#patch.facecolor:       C0
#patch.edgecolor:       black   # By default, Patches and Collections␣
 ↪do not draw edges.
                                # This value is only used if facecolor␣
 ↪is "none"
                                # (an Artist without facecolor and␣
 ↪edgecolor would be
                                # invisible)  or if␣
 ↪patch.force_edgecolor is True.
#patch.force_edgecolor: False   # By default, Patches and Collections␣
 ↪do not draw edges.
                                # Set this to True to draw edges with␣
 ↪patch.edgedcolor
                                # as the default edgecolor.
                                # This is mainly relevant for styles.
#patch.antialiased:     True    # render patches in antialiased (no␣
 ↪jaggies)


##␣
 ↪*********************************************************************
## * HATCHES                                                         ␣
 ↪      *
##␣
 ↪*********************************************************************
#hatch.color:     edge
#hatch.linewidth: 1.0


##␣
 ↪*********************************************************************
## * BOXPLOT                                                         ␣
```

(continues on next page)

(continued from previous page)

```
 ↪       *
##␣
 ↪**********************************************************************
#boxplot.notch:       False
#boxplot.vertical:    True
#boxplot.whiskers:    1.5
#boxplot.bootstrap:   None
#boxplot.patchartist: False
#boxplot.showmeans:   False
#boxplot.showcaps:    True
#boxplot.showbox:     True
#boxplot.showfliers:  True
#boxplot.meanline:    False

#boxplot.flierprops.color:           black
#boxplot.flierprops.marker:          o
#boxplot.flierprops.markerfacecolor: none
#boxplot.flierprops.markeredgecolor: black
#boxplot.flierprops.markeredgewidth: 1.0
#boxplot.flierprops.markersize:      6
#boxplot.flierprops.linestyle:       none
#boxplot.flierprops.linewidth:       1.0

#boxplot.boxprops.color:     black
#boxplot.boxprops.linewidth: 1.0
#boxplot.boxprops.linestyle: -

#boxplot.whiskerprops.color:     black
#boxplot.whiskerprops.linewidth: 1.0
#boxplot.whiskerprops.linestyle: -

#boxplot.capprops.color:     black
#boxplot.capprops.linewidth: 1.0
#boxplot.capprops.linestyle: -

#boxplot.medianprops.color:     C1
#boxplot.medianprops.linewidth: 1.0
#boxplot.medianprops.linestyle: -

#boxplot.meanprops.color:           C2
#boxplot.meanprops.marker:          ^
#boxplot.meanprops.markerfacecolor: C2
#boxplot.meanprops.markeredgecolor: C2
#boxplot.meanprops.markersize:       6
#boxplot.meanprops.linestyle:       --
#boxplot.meanprops.linewidth:       1.0
```

(continues on next page)

(continued from previous page)

```
##␣
 ↪*****************************************************************************
## * FONT                                                                       ␣
 ↪      *
##␣
 ↪*****************************************************************************
## The font properties used by `text.Text`.
## See https://matplotlib.org/stable/api/font_manager_api.html for␣
 ↪more information
## on font properties.  The 6 font properties used for font matching␣
 ↪are
## given below with their default values.
##
## The font.family property can take either a single or multiple␣
 ↪entries of any
## combination of concrete font names (not supported when rendering␣
 ↪text with
## usetex) or the following five generic values:
##     - 'serif' (e.g., Times),
##     - 'sans-serif' (e.g., Helvetica),
##     - 'cursive' (e.g., Zapf-Chancery),
##     - 'fantasy' (e.g., Western), and
##     - 'monospace' (e.g., Courier).
## Each of these values has a corresponding default list of font names
## (font.serif, etc.); the first available font in the list is used. ␣
 ↪Note that
## for font.serif, font.sans-serif, and font.monospace, the first␣
 ↪element of
## the list (a DejaVu font) will always be used because DejaVu is␣
 ↪shipped with
## Matplotlib and is thus guaranteed to be available; the other␣
 ↪entries are
## left as examples of other possible values.
##
## The font.style property has three values: normal (or roman), italic
## or oblique.  The oblique style will be used for italic, if it is not
## present.
##
## The font.variant property has two values: normal or small-caps.  For
## TrueType fonts, which are scalable fonts, small-caps is equivalent
## to using a font size of 'small', or about 83 % of the current font
## size.
##
## The font.weight property has effectively 13 values: normal, bold,
```

(continues on next page)

(continued from previous page)

```
## bolder, lighter, 100, 200, 300, ..., 900.  Normal is the same as
## 400, and bold is 700.  bolder and lighter are relative values with
## respect to the current weight.
##
## The font.stretch property has 11 values: ultra-condensed,
## extra-condensed, condensed, semi-condensed, normal, semi-expanded,
## expanded, extra-expanded, ultra-expanded, wider, and narrower.  This
## property is not currently implemented.
##
## The font.size property is the default font size for text, given in␣
 ↪points.
## 10 pt is the standard value.
##
## Note that font.size controls default text sizes.  To configure
## special text sizes tick labels, axes, labels, title, etc., see the␣
 ↪rc
## settings for axes and ticks.  Special text sizes can be defined
## relative to font.size, using the following values: xx-small,␣
 ↪x-small,
## small, medium, large, x-large, xx-large

#font.family:  sans-serif
#font.style:   normal
#font.variant: normal
#font.weight:  normal
#font.stretch: normal
#font.size:    10.0

#font.serif:      DejaVu Serif, Bitstream Vera Serif, Computer Modern␣
 ↪Roman, New Century Schoolbook, Century Schoolbook L, Utopia, ITC␣
 ↪Bookman, Bookman, Nimbus Roman No9 L, Times New Roman, Times,␣
 ↪Palatino, Charter, serif
#font.sans-serif: DejaVu Sans, Bitstream Vera Sans, Computer Modern␣
 ↪Sans Serif, Lucida Grande, Verdana, Geneva, Lucid, Arial, Helvetica,␣
 ↪Avant Garde, sans-serif
#font.cursive:    Apple Chancery, Textile, Zapf Chancery, Sand, Script␣
 ↪MT, Felipa, Comic Neue, Comic Sans MS, cursive
#font.fantasy:    Chicago, Charcoal, Impact, Western, xkcd script,␣
 ↪fantasy
#font.monospace:  DejaVu Sans Mono, Bitstream Vera Sans Mono, Computer␣
 ↪Modern Typewriter, Andale Mono, Nimbus Mono L, Courier New, Courier,␣
 ↪Fixed, Terminal, monospace

## If font.enable_last_resort is True, then Unicode Consortium's Last␣
 ↪Resort
## font will be appended to all font selections. This ensures that␣
```

(continues on next page)

(continued from previous page)

```
 ↪there will
## always be a glyph displayed.
#font.enable_last_resort: true


##␣
 ↪*****************************************************************************
## * TEXT                                                                     ␣
 ↪      *
##␣
 ↪*****************************************************************************
## The text properties used by `text.Text`.
## See␣
 ↪https://matplotlib.org/stable/api/artist_api.html#module-matplotlib.text
## for more information on text properties
#text.color: black

## The language of the text in a format accepted by libraqm, namely `a␣
 ↪BCP47 language
## code <https://www.w3.org/International/articles/language-tags/>`_.␣
 ↪If None, then no
## particular language will be implied, and default font settings will␣
 ↪be used.
#text.language: None

## FreeType hinting flag ("foo" corresponds to FT_LOAD_FOO); may be␣
 ↪one of the
## following (Proprietary Matplotlib-specific synonyms are given in␣
 ↪parentheses,
## but their use is discouraged):
## - default: Use the font's native hinter if possible, else FreeType
 ↪'s auto-hinter.
##            ("either" is a synonym).
## - no_autohint: Use the font's native hinter if possible, else don't␣
 ↪hint.
##                ("native" is a synonym.)
## - force_autohint: Use FreeType's auto-hinter.  ("auto" is a␣
 ↪synonym.)
## - no_hinting: Disable hinting.  ("none" is a synonym.)
#text.hinting: default

#text.hinting_factor: None  # This setting does nothing and is␣
 ↪deprecated.
#text.kerning_factor: None  # Specifies the scaling factor for kerning␣
 ↪values. Values
                            # other than 0, 6, or None have no defined␣
```

(continues on next page)

(continued from previous page)

```
 ↪meaning.
                            # This setting is deprecated.
#text.antialiased: True  # If True (default), the text will be␣
 ↪antialiased.
                           # This only affects raster outputs.
#text.parse_math: True  # Use mathtext if there is an even number of␣
 ↪unescaped
                          # dollar signs.


##␣
 ↪*****************************************************************************
## * LaTeX                                                                    ␣
 ↪      *
##␣
 ↪*****************************************************************************
## For more information on LaTeX properties, see
## https://matplotlib.org/stable/users/explain/text/usetex.html
#text.usetex: False  # use latex for all text handling. The following␣
 ↪fonts
                     # are supported through the usual rc parameter␣
 ↪settings:
                     # new century schoolbook, bookman, times,␣
 ↪palatino,
                     # zapf chancery, charter, serif, sans-serif,␣
 ↪helvetica,
                     # avant garde, courier, monospace, computer␣
 ↪modern roman,
                     # computer modern sans serif, computer modern␣
 ↪typewriter

## The TeX engine/format to use.  The following values are supported:
## - "latex": The classic TeX engine (the current default).  All␣
 ↪backends render
##    TeX's output by parsing the DVI output into glyphs and boxes and␣
 ↪emitting
##    those one by one.
## - "latex+dvipng": The same as "latex", with the exception that␣
 ↪Agg-based
##   backends rely on dvipng to rasterize TeX's output.  This value␣
 ↪was the
##   default up to Matplotlib 3.10.
#text.latex.engine: latex

#text.latex.preamble:   # IMPROPER USE OF THIS FEATURE WILL LEAD TO␣
 ↪LATEX FAILURES
```

(continues on next page)

(continued from previous page)

```
                        # AND IS THEREFORE UNSUPPORTED. PLEASE DO NOT␣
↪ASK FOR HELP
                        # IF THIS FEATURE DOES NOT DO WHAT YOU EXPECT␣
↪IT TO.
                        # text.latex.preamble is a single line of␣
↪LaTeX code that
                        # will be passed on to the LaTeX system. It␣
↪may contain
                        # any code that is valid for the LaTeX
↪"preamble", i.e.
                        # between the "\documentclass" and "\
↪begin{document}"
                        # statements.
                        # Note that it has to be put on a single line,␣
↪which may
                        # become quite long.
                        # The following packages are always loaded␣
↪with usetex,
                        # so beware of package collisions:
                        #   color, fix-cm, geometry, graphicx,␣
↪textcomp.
                        # PostScript (PSNFSS) font packages may also be
                        # loaded, depending on your font settings.

## The following settings allow you to select the fonts in math mode.
#mathtext.fontset: dejavusans  # Should be 'dejavusans' (default),
                               # 'dejavuserif', 'cm' (Computer␣
↪Modern), 'stix',
                               # 'stixsans' or 'custom'
## "mathtext.fontset: custom" is defined by the mathtext.bf, .cal, .
↪it, ...
## settings which map a TeX font name to a fontconfig font pattern. ␣
↪(These
## settings are not used for other font sets.)
#mathtext.bf:  sans:bold
#mathtext.bfit: sans:italic:bold
#mathtext.cal: cursive
#mathtext.it:  sans:italic
#mathtext.rm:  sans
#mathtext.sf:  sans
#mathtext.tt:  monospace
#mathtext.fallback: cm  # Select fallback font from ['cm' (Computer␣
↪Modern), 'stix'
                        # 'stixsans'] when a symbol cannot be found in␣
↪one of the
                        # custom math fonts. Select 'None' to not␣
```

(continues on next page)

(continued from previous page)

```
 ↪perform fallback
                        # and replace the missing character by a dummy␣
 ↪symbol.
#mathtext.default: normal  # The default font to use for math.
                           # Can be any of the LaTeX font names␣
 ↪(normal, it, bf,
                           # etc.), including the special name
 ↪"regular" for the
                           # same font used in regular text.


##␣
 ↪*********************************************************************
## * AXES                                                              ␣
 ↪      *
##␣
 ↪*********************************************************************
## Following are default face and edge colors, default tick sizes,
## default font sizes for tick labels, and so on.  See
##␣
 ↪https://matplotlib.org/stable/api/axes_api.html#module-matplotlib.axes
#axes.facecolor:     white   # axes background color
#axes.edgecolor:     black   # axes edge color
#axes.linewidth:     0.8     # edge line width
#axes.grid:          False   # display grid or not
#axes.grid.axis:     both    # which axis the grid should apply to
#axes.grid.which:    major   # grid lines at {major, minor, both} ticks
#axes.titlelocation: center  # alignment of the title: {left, right,␣
 ↪center}
#axes.titlesize:     large   # font size of the axes title
#axes.titleweight:   normal  # font weight of title
#axes.titlecolor:    auto    # color of the axes title, auto falls␣
 ↪back to
                             # text.color as default value
#axes.titley:        None    # position title (axes relative units). ␣
 ↪None implies auto
#axes.titlepad:      6.0     # pad between axes and title in points
#axes.labelsize:     medium  # font size of the x and y labels
#axes.labelpad:      4.0     # space between label and axis
#axes.labelweight:   normal  # weight of the x and y labels
#axes.labelcolor:    black
#axes.axisbelow:     line    # draw axis gridlines and ticks:
                             #     - below patches (True)
                             #     - above patches but below lines (
 ↪'line')
                             #     - above all (False)
```

(continues on next page)

(continued from previous page)

```
#axes.formatter.limits: -5, 6  # use scientific notation if log10
                               # of the axis range is smaller than the
                               # first or larger than the second
#axes.formatter.use_locale: False  # When True, format tick labels
                                   # according to the user's locale.
                                   # For example, use ',' as a decimal
                                   # separator in the fr_FR locale.
#axes.formatter.use_mathtext: False  # When True, use mathtext for␣
 ↪scientific
                                     # notation.
#axes.formatter.min_exponent: 0  # minimum exponent to format in␣
 ↪scientific notation
#axes.formatter.useoffset: True  # If True, the tick label formatter
                                 # will default to labeling ticks␣
 ↪relative
                                 # to an offset when the data range is
                                 # small compared to the minimum␣
 ↪absolute
                                 # value of the data.
#axes.formatter.offset_threshold: 4  # When useoffset is True, the␣
 ↪offset
                                     # will be used when it can remove
                                     # at least this number of␣
 ↪significant
                                     # digits from tick labels.

#axes.spines.left:   True  # display axis spines
#axes.spines.bottom: True
#axes.spines.top:    True
#axes.spines.right:  True

#axes.unicode_minus: True  # use Unicode for the minus symbol rather␣
 ↪than hyphen.  See
                           #␣
 ↪https://en.wikipedia.org/wiki/Plus_and_minus_signs#Character_codes
#axes.prop_cycle: cycler(color='tab10')
                  # color cycle for plot lines as either a named color␣
 ↪sequence or a list
                  # of string color specs: single letter, long name,␣
 ↪or web-style hex
                  # As opposed to all other parameters in this file,␣
 ↪the color
                  # values must be enclosed in quotes for this␣
 ↪parameter,
                  # e.g. '1f77b4', instead of 1f77b4.
```

(continues on next page)

(continued from previous page)

```
                   # See also␣
↪https://matplotlib.org/stable/users/explain/artists/color_cycle.html
                   # for more details on prop_cycle usage.
#axes.xmargin:   .05  # x margin.  See `axes.Axes.margins`
#axes.ymargin:   .05  # y margin.  See `axes.Axes.margins`
#axes.zmargin:   .05  # z margin.  See `axes.Axes.margins`
#axes.autolimit_mode: data  # If "data", use axes.xmargin and␣
↪axes.ymargin as is.
                           # If "round_numbers", after application of␣
↪margins, axis
                           # limits are further expanded to the␣
↪nearest "round" number.
#polaraxes.grid:    True   # display grid on polar axes
#axes3d.grid:       True   # display grid on 3D axes
#axes3d.automargin: False  # automatically add margin when manually␣
↪setting 3D axis limits

#axes3d.xaxis.panecolor:    (0.95, 0.95, 0.95, 0.5)  # background pane␣
↪on 3D axes
#axes3d.yaxis.panecolor:    (0.90, 0.90, 0.90, 0.5)  # background pane␣
↪on 3D axes
#axes3d.zaxis.panecolor:    (0.925, 0.925, 0.925, 0.5)  # background␣
↪pane on 3D axes

#axes3d.depthshade: True  # depth shade for 3D scatter plots
#axes3d.depthshade_minalpha: 0.3  # minimum alpha value for depth␣
↪shading

#axes3d.mouserotationstyle: arcball  # {azel, trackball, sphere,␣
↪arcball}
                           # See also␣
↪https://matplotlib.org/stable/api/toolkits/mplot3d/view_angles.html#rotation-with
#axes3d.trackballsize: 0.667  # trackball diameter, in units of the␣
↪Axes bbox
#axes3d.trackballborder: 0.2  # trackball border width, in units of␣
↪the Axes bbox (only for 'sphere' and 'arcball' style)
#axes3d.snap_rotation: 5.0  # Snap angle (degrees) for 3D rotation␣
↪when holding Control.
##␣
↪*********************************************************************
## * AXIS                                                             ␣
↪      *
##␣
↪*********************************************************************
#xaxis.labellocation: center  # alignment of the xaxis label: {left,␣
↪right, center}
```

(continues on next page)

```
#yaxis.labellocation: center  # alignment of the yaxis label: {bottom,␣
 ↪top, center}


##␣
 ↪*********************************************************************
## * DATES                                                             ␣
 ↪      *
##␣
 ↪*********************************************************************
## These control the default format strings used in AutoDateFormatter.
## Any valid format datetime format string can be used (see the python
## `datetime` for details).  For example, by using:
##     - '%x' will use the locale date representation
##     - '%X' will use the locale time representation
##     - '%c' will use the full locale datetime representation
## These values map to the scales:
##     {'year': 365, 'month': 30, 'day': 1, 'hour': 1/24, 'minute': 1 /
 ↪ (24 * 60)}

#date.autoformatter.year:        %Y
#date.autoformatter.month:       %Y-%m
#date.autoformatter.day:         %Y-%m-%d
#date.autoformatter.hour:        %m-%d %H
#date.autoformatter.minute:      %d %H:%M
#date.autoformatter.second:      %H:%M:%S
#date.autoformatter.microsecond: %M:%S.%f
## The reference date for Matplotlib's internal date representation
## See␣
 ↪https://matplotlib.org/stable/gallery/ticks/date_precision_and_epochs.html
#date.epoch: 1970-01-01T00:00:00
## 'auto', 'concise':
#date.converter:                 auto
## For auto converter whether to use interval_multiples:
#date.interval_multiples:        True

##␣
 ↪*********************************************************************
## * TICKS                                                             ␣
 ↪      *
##␣
 ↪*********************************************************************
## See␣
 ↪https://matplotlib.org/stable/api/axis_api.html#matplotlib.axis.Tick
#xtick.top:           False   # draw ticks on the top side
#xtick.bottom:        True    # draw ticks on the bottom side
```

(continues on next page)

(continued from previous page)

```
#xtick.labeltop:      False   # draw label on the top
#xtick.labelbottom:   True    # draw label on the bottom
#xtick.major.size:    3.5     # major tick size in points
#xtick.minor.size:    2       # minor tick size in points
#xtick.major.width:   0.8     # major tick width in points
#xtick.minor.width:   0.6     # minor tick width in points
#xtick.major.pad:     3.5     # distance to major tick label in points
#xtick.minor.pad:     3.4     # distance to the minor tick label in␣
 ↪points
#xtick.color:         black   # color of the ticks
#xtick.labelcolor:    inherit # color of the tick labels or inherit␣
 ↪from xtick.color
#xtick.labelsize:     medium  # font size of the tick labels
#xtick.direction:     out     # direction: {in, out, inout}
#xtick.minor.visible: False   # visibility of minor ticks on x-axis
#xtick.major.top:     True    # draw x axis top major ticks
#xtick.major.bottom:  True    # draw x axis bottom major ticks
#xtick.minor.top:     True    # draw x axis top minor ticks
#xtick.minor.bottom:  True    # draw x axis bottom minor ticks
#xtick.minor.ndivs:   auto    # number of minor ticks between the␣
 ↪major ticks on x-axis
#xtick.alignment:     center  # alignment of xticks

#ytick.left:          True    # draw ticks on the left side
#ytick.right:         False   # draw ticks on the right side
#ytick.labelleft:     True    # draw tick labels on the left side
#ytick.labelright:    False   # draw tick labels on the right side
#ytick.major.size:    3.5     # major tick size in points
#ytick.minor.size:    2       # minor tick size in points
#ytick.major.width:   0.8     # major tick width in points
#ytick.minor.width:   0.6     # minor tick width in points
#ytick.major.pad:     3.5     # distance to major tick label in points
#ytick.minor.pad:     3.4     # distance to the minor tick label in␣
 ↪points
#ytick.color:         black   # color of the ticks
#ytick.labelcolor:    inherit # color of the tick labels or inherit␣
 ↪from ytick.color
#ytick.labelsize:     medium  # font size of the tick labels
#ytick.direction:     out     # direction: {in, out, inout}
#ytick.minor.visible: False   # visibility of minor ticks on y-axis
#ytick.major.left:    True    # draw y axis left major ticks
#ytick.major.right:   True    # draw y axis right major ticks
#ytick.minor.left:    True    # draw y axis left minor ticks
#ytick.minor.right:   True    # draw y axis right minor ticks
#ytick.minor.ndivs:   auto    # number of minor ticks between the␣
 ↪major ticks on y-axis
```

(continues on next page)

(continued from previous page)

```
#ytick.alignment:     center_baseline  # alignment of yticks


##␣
 ↪**********************************************************************
## * GRIDS                                                              ␣
 ↪      *
##␣
 ↪**********************************************************************
#grid.color:     "#b0b0b0"  # grid color
#grid.linestyle: -          # solid
#grid.linewidth: 0.8        # in points
#grid.alpha:     1.0        # transparency, between 0.0 and 1.0

#grid.major.color:     None # If None defaults to grid.color
#grid.major.linestyle: None # If None defaults to grid.linestyle
#grid.major.linewidth: None # If None defaults to grid.linewidth
#grid.major.alpha:     None # If None defaults to grid.alpha

#grid.minor.color:     None # If None defaults to grid.color
#grid.minor.linestyle: None # If None defaults to grid.linestyle
#grid.minor.linewidth: None # If None defaults to grid.linewidth
#grid.minor.alpha:     None # If None defaults to grid.alpha


##␣
 ↪**********************************************************************
## * LEGEND                                                             ␣
 ↪      *
##␣
 ↪**********************************************************************
#legend.loc:           best
#legend.frameon:       True     # if True, draw the legend on a␣
 ↪background patch
#legend.framealpha:    0.8      # legend patch transparency
#legend.facecolor:     inherit  # inherit from axes.facecolor; or␣
 ↪color spec
#legend.edgecolor:     0.8      # background patch boundary color
#legend.linewidth:     None     # line width of the legend frame, None␣
 ↪means inherit from patch.linewidth
#legend.fancybox:      True     # if True, use a rounded box for the
                                # legend background, else a rectangle
#legend.shadow:        False    # if True, give background a shadow␣
 ↪effect
#legend.numpoints:     1        # the number of marker points in the␣
 ↪legend line
```

(continues on next page)

(continued from previous page)

```
#legend.scatterpoints: 1        # number of scatter points
#legend.markerscale:   1.0      # the relative size of legend markers␣
↪vs. original
#legend.fontsize:      medium
#legend.labelcolor:    None
#legend.title_fontsize: None    # None sets to the same as the default␣
↪axes.

## Dimensions as fraction of font size:
#legend.borderpad:     0.4  # border whitespace
#legend.labelspacing:  0.5  # the vertical space between the legend␣
↪entries
#legend.handlelength:  2.0  # the length of the legend lines
#legend.handleheight:  0.7  # the height of the legend handle
#legend.handletextpad: 0.8  # the space between the legend line and␣
↪legend text
#legend.borderaxespad: 0.5  # the border between the axes and legend␣
↪edge
#legend.columnspacing: 2.0  # column separation


##␣
↪*****************************************************************************
## * FIGURE                                                                   ␣
↪      *
##␣
↪*****************************************************************************
## See␣
↪https://matplotlib.org/stable/api/figure_api.html#matplotlib.figure.Figure
#figure.titlesize:   large     # size of the figure title␣
↪(``Figure.suptitle()``)
#figure.titleweight: normal    # weight of the figure title
#figure.labelsize:   large     # size of the figure label␣
↪(``Figure.sup[x|y]label()``)
#figure.labelweight: normal    # weight of the figure label
#figure.figsize:     6.4, 4.8  # figure size in inches
#figure.dpi:         100       # figure dots per inch
#figure.facecolor:   white     # figure face color
#figure.edgecolor:   white     # figure edge color
#figure.frameon:     True      # enable figure frame
#figure.max_open_warning: 20   # The maximum number of figures to open␣
↪through
                               # the pyplot interface before emitting␣
↪a warning.
                               # If less than one this feature is␣
↪disabled.
```

(continues on next page)

(continued from previous page)

```
#figure.raise_window : True    # Raise the GUI window to front when␣
 ↪show() is called.
                               # If set to False, we currently do not␣
 ↪take any further
                               # actions and whether the window␣
 ↪appears on the front
                               # may depend on the GUI framework and␣
 ↪window manager.

## The figure subplot parameters.  All dimensions are a fraction of␣
 ↪the figure width and height.
#figure.subplot.left:   0.125  # the left side of the subplots of the␣
 ↪figure
#figure.subplot.right:  0.9    # the right side of the subplots of the␣
 ↪figure
#figure.subplot.bottom: 0.11   # the bottom of the subplots of the␣
 ↪figure
#figure.subplot.top:    0.88   # the top of the subplots of the figure
#figure.subplot.wspace: 0.2    # the amount of width reserved for␣
 ↪space between subplots,
                               # expressed as a fraction of the␣
 ↪average axis width
#figure.subplot.hspace: 0.2    # the amount of height reserved for␣
 ↪space between subplots,
                               # expressed as a fraction of the␣
 ↪average axis height

## Figure layout
#figure.autolayout: False  # When True, automatically adjust subplot
                           # parameters to make the plot fit the figure
                           # using `tight_layout`
#figure.constrained_layout.use: False  # When True, automatically make␣
 ↪plot
                                       # elements fit on the figure.␣
 ↪(Not
                                       # compatible with `autolayout`,␣
 ↪above).
## Padding (in inches) around axes; defaults to 3/72 inches, i.e. 3␣
 ↪points.
#figure.constrained_layout.h_pad:  0.04167
#figure.constrained_layout.w_pad:  0.04167
## Spacing between subplots, relative to the subplot sizes.  Much␣
 ↪smaller than for
## tight_layout (figure.subplot.hspace, figure.subplot.wspace) as␣
 ↪constrained_layout
## already takes surrounding texts (titles, labels, # ticklabels) into␣
```

(continues on next page)

(continued from previous page)

```
 ↪account.
#figure.constrained_layout.hspace: 0.02
#figure.constrained_layout.wspace: 0.02


##␣
 ↪*********************************************************************
## * IMAGES                                                            ␣
 ↪      *
##␣
 ↪*********************************************************************
#image.aspect:          equal        # {equal, auto} or a number
#image.interpolation:   auto         # see help(imshow) for options
#image.interpolation_stage: auto     # see help(imshow) for options
#image.cmap:            viridis      # A colormap name (plasma, magma,␣
 ↪etc.)
#image.lut:             256          # the size of the colormap lookup␣
 ↪table
#image.origin:          upper        # {lower, upper}
#image.resample:        True
#image.composite_image: True  # When True, all the images on a set of␣
 ↪axes are
                              # combined into a single composite image␣
 ↪before
                              # saving a figure as a vector graphics␣
 ↪file,
                              # such as a PDF.


##␣
 ↪*********************************************************************
## * CONTOUR PLOTS                                                     ␣
 ↪      *
##␣
 ↪*********************************************************************
#contour.negative_linestyle: dashed  # string or on-off ink sequence
#contour.corner_mask:        True    # {True, False}
#contour.linewidth:          None    # {float, None} Size of the␣
 ↪contour line
                                     # widths. If set to None, it␣
 ↪falls back to
                                     # `line.linewidth`.
#contour.algorithm:          mpl2014 # {mpl2005, mpl2014, serial,␣
 ↪threaded}
```

(continues on next page)

(continued from previous page)

```
##␣
 ↪*********************************************************************
## * ERRORBAR PLOTS                                                    ␣
 ↪      *
##␣
 ↪*********************************************************************
#errorbar.capsize: 0  # length of end cap on error bars in pixels
#errorbar.capthick: None  # thickness of end cap on error bars in␣
 ↪points
#errorbar.elinewidth: None  # line width of error bar lines in points


##␣
 ↪*********************************************************************
## * HISTOGRAM PLOTS                                                   ␣
 ↪      *
##␣
 ↪*********************************************************************
#hist.bins: 10  # The default number of histogram bins or 'auto'.


##␣
 ↪*********************************************************************
## * SCATTER PLOTS                                                     ␣
 ↪      *
##␣
 ↪*********************************************************************
#scatter.marker: o         # The default marker type for scatter plots.
#scatter.edgecolors: face  # The default edge colors for scatter plots.


##␣
 ↪*********************************************************************
## * AGG RENDERING                                                     ␣
 ↪      *
##␣
 ↪*********************************************************************
## Warning: experimental, 2008/10/10
#agg.path.chunksize: 0  # 0 to disable; values in the range
                        # 10000 to 100000 can improve speed slightly
                        # and prevent an Agg rendering failure
                        # when plotting very large data sets,
                        # especially if they are very gappy.
                        # It may cause minor artifacts, though.
                        # A value of 20000 is probably a good
                        # starting point.
```

(continues on next page)

(continued from previous page)

```
##␣
 ↪*********************************************************************
## * PATHS                                                             ␣
 ↪      *
##␣
 ↪*********************************************************************
#path.simplify: True  # When True, simplify paths by removing
 ↪"invisible"
                      # points to reduce file size and increase␣
 ↪rendering
                      # speed
#path.simplify_threshold: 0.111111111111  # The threshold of␣
 ↪similarity below
                                          # which vertices will be␣
 ↪removed in
                                          # the simplification process.
#path.snap: True  # When True, rectilinear axis-aligned paths will be␣
 ↪snapped
                  # to the nearest pixel when certain criteria are met.
                  # When False, paths will never be snapped.
#path.sketch: None  # May be None, or a tuple of the form:
                    #  path.sketch: (scale, length, randomness)
                    # - *scale* is the amplitude of the wiggle
                    #    perpendicular to the line (in pixels).
                    # - *length* is the length of the wiggle along the
                    #    line (in pixels).
                    # - *randomness* is the factor by which the length␣
 ↪is
                    #    randomly scaled.
#path.effects:


##␣
 ↪*********************************************************************
## * SAVING FIGURES                                                   ␣
 ↪      *
##␣
 ↪*********************************************************************
## The default savefig parameters can be different from the display␣
 ↪parameters
## e.g., you may want a higher resolution, or to make the figure
## background white
#savefig.dpi:       figure      # figure dots per inch or 'figure'
#savefig.facecolor: auto        # figure face color when saving
```

(continues on next page)

(continued from previous page)

```
#savefig.edgecolor: auto        # figure edge color when saving
#savefig.format:    png         # {png, ps, pdf, svg}
#savefig.bbox:      standard    # {tight, standard}
                                # 'tight' is incompatible with␣
 ↪generating frames
                                # for animation
#savefig.pad_inches:  0.1       # padding to be used, when bbox is set␣
 ↪to 'tight'
#savefig.directory:   ~         # default directory in savefig dialog,␣
 ↪gets updated after
                                # interactive saves, unless set to the␣
 ↪empty string (i.e.
                                # the current directory); use '.' to␣
 ↪start at the current
                                # directory but update after␣
 ↪interactive saves
#savefig.transparent: False     # whether figures are saved with a␣
 ↪transparent
                                # background by default
#savefig.orientation: portrait  # orientation of saved figure, for␣
 ↪PostScript output only

### macosx backend params
#macosx.window_mode : system   # How to open new figures (system, tab,␣
 ↪window)
                               # system uses the MacOS system␣
 ↪preferences

### tk backend params
#tk.window_focus:   False  # Maintain shell focus for TkAgg

### ps backend params
#ps.papersize:      letter  # {figure, letter, legal, ledger, A0-A10,␣
 ↪B0-B10}
#ps.useafm:         False   # use AFM fonts, results in small files
#ps.usedistiller:   False   # {ghostscript, xpdf, None}
                            # Experimental: may produce smaller files.
                            # xpdf intended for production of␣
 ↪publication quality files,
                            # but requires ghostscript, xpdf and ps2eps
#ps.distiller.res:  6000    # dpi
#ps.fonttype:       3       # Output Type 3 (Type3) or Type 42␣
 ↪(TrueType)

### PDF backend params
#pdf.compression:    6  # integer from 0 to 9
```

(continues on next page)

(continued from previous page)

```
                          # 0 disables compression (good for debugging)
#pdf.fonttype:       3  # Output Type 3 (Type3) or Type 42 (TrueType)
#pdf.use14corefonts: False
#pdf.inheritcolor:   False

### SVG backend params
#svg.image_inline: True  # Write raster image data directly into the␣
 ↪SVG file
#svg.fonttype: path      # How to handle SVG fonts:
                         #     path: Embed characters as paths --␣
 ↪supported
                         #           by most SVG renderers
                         #     none: Assume fonts are installed on the
                         #           machine where the SVG will be␣
 ↪viewed.
#svg.hashsalt: None      # If not None, use this string as hash salt␣
 ↪instead of uuid4
#svg.id: None            # If not None, use this string as the value␣
 ↪for the `id`
                         # attribute in the top <svg> tag

### pgf parameter
## See https://matplotlib.org/stable/tutorials/text/pgf.html for more␣
 ↪information.
#pgf.rcfonts: True
#pgf.preamble:  # See text.latex.preamble for documentation
#pgf.texsystem: xelatex

### docstring params
#docstring.hardcopy: False  # set this when you want to generate␣
 ↪hardcopy docstring


##␣
 ↪*****************************************************************************
## * INTERACTIVE KEYMAPS                                                      ␣
 ↪      *
##␣
 ↪*****************************************************************************
## Event keys to interact with figures/plots via keyboard.
## See https://matplotlib.org/stable/users/explain/interactive.html␣
 ↪for more
## details on interactive navigation.  Customize these settings␣
 ↪according to
## your needs. Leave the field(s) empty if you don't need a key-map.␣
 ↪(i.e.,
```

(continues on next page)

(continued from previous page)

```
## fullscreen : '')
#keymap.fullscreen: f, ctrl+f   # toggling
#keymap.home: h, r, home        # home or reset mnemonic
#keymap.back: left, c, backspace, MouseButton.BACK  # forward /␣
↪backward keys
#keymap.forward: right, v, MouseButton.FORWARD      # for quick␣
↪navigation
#keymap.pan: p                  # pan mnemonic
#keymap.zoom: o                 # zoom mnemonic
#keymap.save: s, ctrl+s         # saving current figure
#keymap.help: f1                # display help about active tools
#keymap.quit: ctrl+w, cmd+w, q  # close the current figure
#keymap.quit_all:               # close all figures
#keymap.grid: g                 # switching on/off major grids in␣
↪current axes
#keymap.grid_minor: G           # switching on/off minor grids in␣
↪current axes
#keymap.yscale: l               # toggle scaling of y-axes ('log'/
↪'linear')
#keymap.xscale: k, L            # toggle scaling of x-axes ('log'/
↪'linear')
#keymap.copy: ctrl+c, cmd+c     # copy figure to clipboard


##␣
↪*********************************************************************
## * ANIMATION                                                       ␣
↪      *
##␣
↪*********************************************************************
#animation.html: none  # How to display the animation as HTML in
                       # the IPython notebook:
                       #     - 'html5' uses HTML5 video tag
                       #     - 'jshtml' creates a JavaScript animation
#animation.writer:  ffmpeg        # MovieWriter 'backend' to use
#animation.codec:   h264          # Codec to use for writing movie
#animation.bitrate: -1            # Controls size/quality trade-off␣
↪for movie.
                                  # -1 implies let utility␣
↪auto-determine
#animation.frame_format: png      # Controls frame format used by temp␣
↪files

## Path to ffmpeg binary.  Unqualified paths are resolved by␣
↪subprocess.Popen.
#animation.ffmpeg_path:  ffmpeg
```

(continues on next page)

(continued from previous page)

```
## Additional arguments to pass to ffmpeg.
#animation.ffmpeg_args:

## Path to ImageMagick's convert binary.  Unqualified paths are␣
 ↪resolved by
## subprocess.Popen, except that on Windows, we look up an install of
## ImageMagick in the registry (as convert is also the name of a␣
 ↪system tool).
#animation.convert_path: convert
## Additional arguments to pass to convert.
#animation.convert_args: -layers, OptimizePlus
#
#animation.embed_limit:  20.0     # Limit, in MB, of size of base64␣
 ↪encoded
                                  # animation in HTML (i.e. IPython␣
 ↪notebook)
```

Total running time of the script: (0 minutes 1.802 seconds)

3.7 Colors

Matplotlib has support for visualizing information with a wide array of colors and colormaps. These tutorials cover the basics of how these colormaps look, how you can create your own, and how you can customize colormaps for your use case.

For even more information see the *examples page*.

3.7.1 Customized Colorbars Tutorial

This tutorial shows how to build and customize standalone colorbars, i.e. without an attached plot.

A `colorbar` requires a `matplotlib.colorizer.ColorizingArtist` which contains a `matplotlib.colorizer.Colorizer` that holds the data-to-color pipeline (norm and colormap). To create a colorbar without an attached plot one can directly instantiate the base class `ColorizingArtist`, which has no associated data.

```
import matplotlib.pyplot as plt

import matplotlib as mpl
```

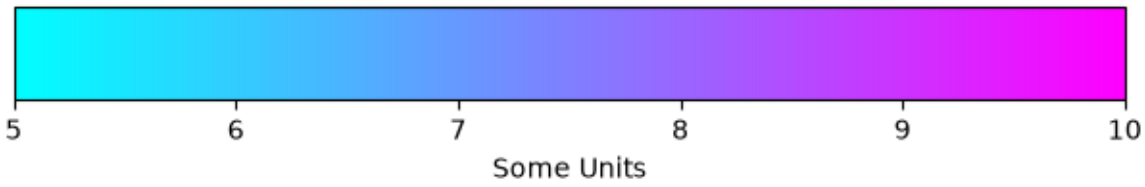
Basic continuous colorbar

Here, we create a basic continuous colorbar with ticks and labels.

The arguments to the `colorbar` call are a `ColorizingArtist`, the axes where the colorbar should be drawn, and the colorbar's orientation. To crate a `ColorizingArtist` one must first make `Colorizer` that holds the desired *norm* and *cmap*.

For more information see the *colorbar* API.

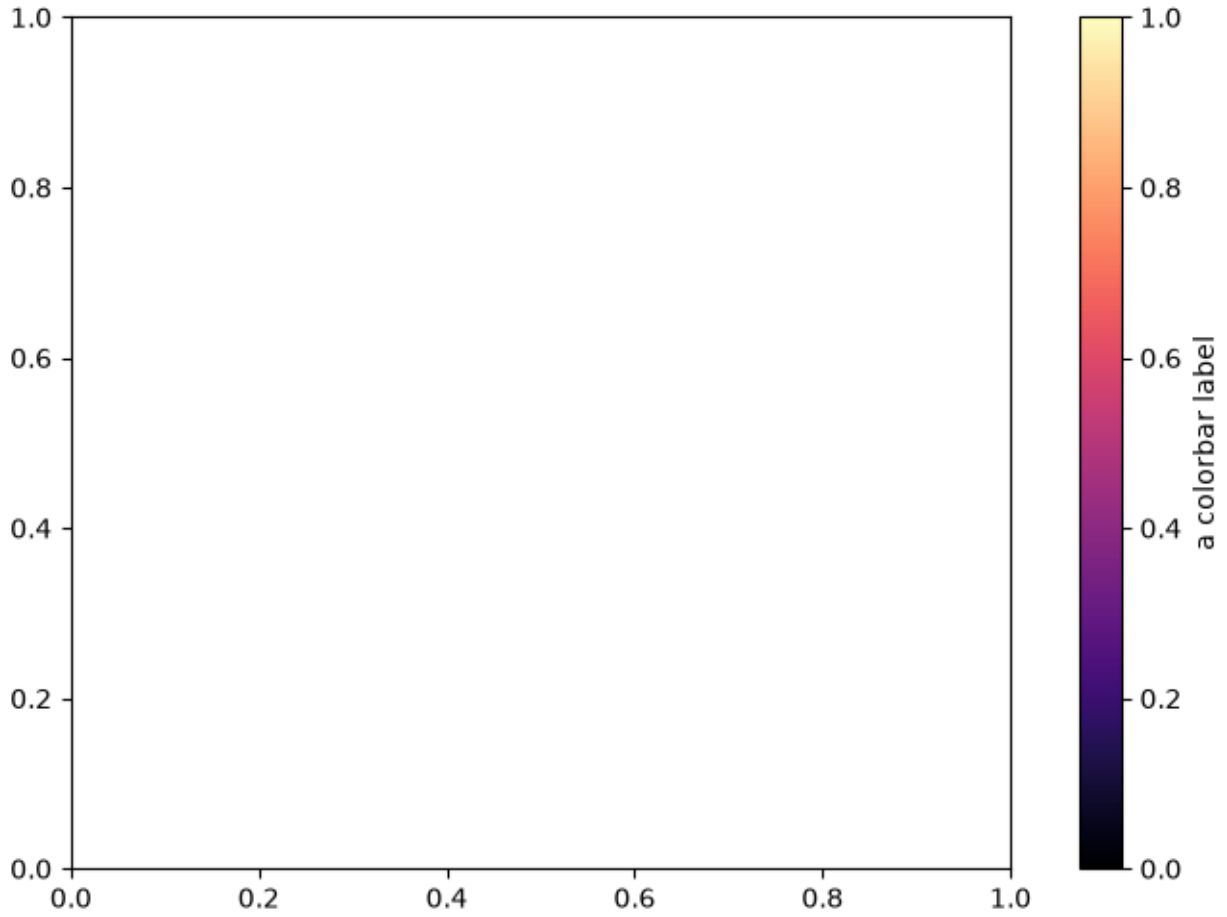
```
fig, ax = plt.subplots(figsize=(6, 1), layout='constrained')

norm = mpl.colors.Normalize(vmin=5, vmax=10)

colorizer = mpl.colorizer.Colorizer(norm=norm, cmap="cool")

fig.colorbar(mpl.colorizer.ColorizingArtist(colorizer),
             cax=ax, orientation='horizontal', label='Some Units')
```



Colorbar attached next to a pre-existing axes

All examples in this tutorial (except this one) show a standalone colorbar on its own figure, but it is possible to display the colorbar *next* to a pre-existing Axes *ax* by passing `ax=ax` to the colorbar() call (meaning "draw the colorbar next to *ax*") rather than `cax=ax` (meaning "draw the colorbar on *ax*").

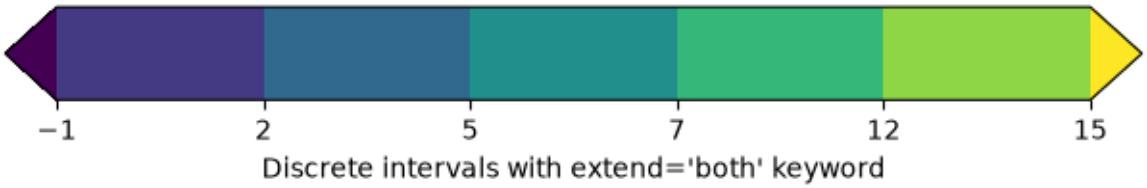
```
fig, ax = plt.subplots(layout='constrained')

colorizer = mpl.colorizer.Colorizer(norm=mpl.colors.Normalize(0, 1),␣
 ↪cmap='magma')

fig.colorbar(mpl.colorizer.ColorizingArtist(colorizer),
             ax=ax, orientation='vertical', label='a colorbar label')
```



Discrete and extended colorbar with continuous colorscale

The following example shows how to make a discrete colorbar based on a continuous cmap. We use *matplotlib.colors.BoundaryNorm* to describe the interval boundaries (which must be in increasing order), and further pass the *extend* argument to it to further display "over" and "under" colors (which are used for data outside of the norm range).

```
fig, ax = plt.subplots(figsize=(6, 1), layout='constrained')

cmap = mpl.colormaps["viridis"]
bounds = [-1, 2, 5, 7, 12, 15]
norm = mpl.colors.BoundaryNorm(bounds, cmap.N, extend='both')

colorizer = mpl.colorizer.Colorizer(norm=norm, cmap='viridis')

fig.colorbar(mpl.colorizer.ColorizingArtist(colorizer),
             cax=ax, orientation='horizontal',
             label="Discrete intervals with extend='both' keyword")
```



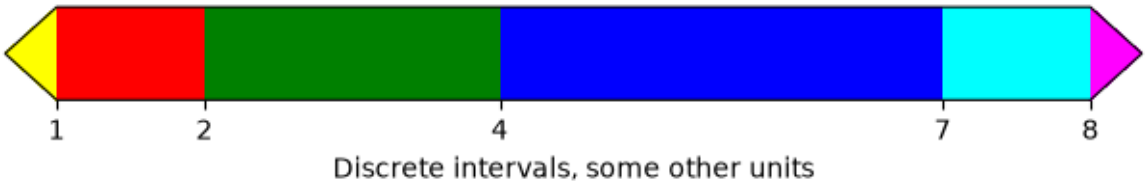
Colorbar with arbitrary colors

The following example still uses a *BoundaryNorm* to describe discrete interval boundaries, but now uses a *matplotlib.colors.ListedColormap* to associate each interval with an arbitrary color (there must be as many intervals than there are colors).

We also pass additional arguments to *colorbar*:

- To display the out-of-range values on the colorbar, we use the *extend* argument in the colorbar() call. (This is equivalent to passing the *extend* argument in the *BoundaryNorm* constructor as done in the previous example.)
- To make the length of each colorbar segment proportional to its corresponding interval, we use the *spacing* argument in the colorbar() call.

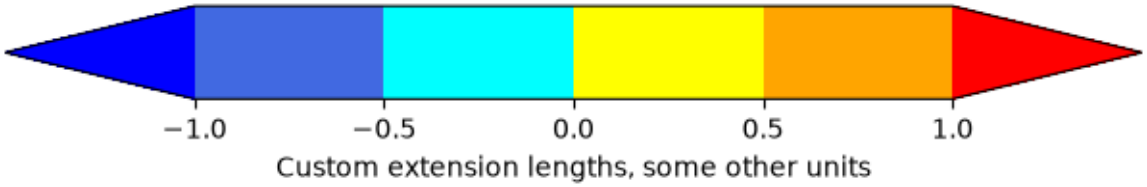
```
fig, ax = plt.subplots(figsize=(6, 1), layout='constrained')

cmap = mpl.colors.ListedColormap(
    ['red', 'green', 'blue', 'cyan'], under='yellow', over='magenta')
bounds = [1, 2, 4, 7, 8]
norm = mpl.colors.BoundaryNorm(bounds, cmap.N)

colorizer = mpl.colorizer.Colorizer(norm=norm, cmap=cmap)

fig.colorbar(
    mpl.colorizer.ColorizingArtist(colorizer),
    cax=ax, orientation='horizontal',
    extend='both',
    spacing='proportional',
    label='Discrete intervals, some other units',
)
```



Colorbar with custom extension lengths

We can customize the length colorbar extensions, on a colorbar with discrete intervals. To make the length of each extension the same as the length of the interior colors, use `extendfrac='auto'`.

```
fig, ax = plt.subplots(figsize=(6, 1), layout='constrained')

cmap = mpl.colors.ListedColormap(
    ['royalblue', 'cyan', 'yellow', 'orange'], over='red', under='blue
 ↪')
bounds = [-1.0, -0.5, 0.0, 0.5, 1.0]
norm = mpl.colors.BoundaryNorm(bounds, cmap.N)

colorizer = mpl.colorizer.Colorizer(norm=norm, cmap=cmap)

fig.colorbar(
    mpl.colorizer.ColorizingArtist(colorizer),
    cax=ax, orientation='horizontal',
    extend='both', extendfrac='auto',
    spacing='uniform',
    label='Custom extension lengths, some other units',
)

plt.show()
```



3.7.2 Creating Colormaps in Matplotlib

Matplotlib has a number of built-in colormaps accessible via *`matplotlib.colormaps`*. There are also external libraries like palettable that have many extra colormaps.

However, we may also want to create or manipulate our own colormaps. This can be done using the class *`ListedColormap`* or *`LinearSegmentedColormap`*. Both colormap classes map values between 0 and 1 to colors. There are however differences, as explained below.

Before manually creating or manipulating colormaps, let us first see how we can obtain colormaps and their colors from existing colormap classes.

Getting colormaps and accessing their values

First, getting a named colormap, most of which are listed in *Choosing Colormaps in Matplotlib*, may be done using *`matplotlib.colormaps`*, which returns a colormap object. The length of the list of colors used internally to define the colormap can be adjusted via *`Colormap.resampled`*. Below we use a modest value of 8 so there are not a lot of values to look at.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib as mpl
from matplotlib.colors import LinearSegmentedColormap, ListedColormap

viridis = mpl.colormaps['viridis'].resampled(8)
```

The object `viridis` is a callable, that when passed a float between 0 and 1 returns an RGBA value from the colormap:

```
print(viridis(0.56))
```

```
(np.float64(0.122312), np.float64(0.633153), np.float64(0.530398),␣
↪np.float64(1.0))
```

ListedColormap

*ListedColormap*s store their color values in a `.colors` attribute. The list of colors that comprise the colormap can be directly accessed using the `colors` property, or it can be accessed indirectly by calling `viridis` with an array of values matching the length of the colormap. Note that the returned list is in the form of an RGBA (N, 4) array, where N is the length of the colormap.

```
print('viridis.colors', viridis.colors)
print('viridis(range(8))', viridis(range(8)))
print('viridis(np.linspace(0, 1, 8))', viridis(np.linspace(0, 1, 8)))
```

```
viridis.colors [[0.267004 0.004874 0.329415 1.      ]
 [0.275191 0.194905 0.496005 1.      ]
 [0.212395 0.359683 0.55171  1.      ]
 [0.153364 0.497    0.557724 1.      ]
 [0.122312 0.633153 0.530398 1.      ]
 [0.288921 0.758394 0.428426 1.      ]
 [0.626579 0.854645 0.223353 1.      ]
 [0.993248 0.906157 0.143936 1.      ]]
viridis(range(8)) [[0.267004 0.004874 0.329415 1.      ]
 [0.275191 0.194905 0.496005 1.      ]
 [0.212395 0.359683 0.55171  1.      ]
 [0.153364 0.497    0.557724 1.      ]
 [0.122312 0.633153 0.530398 1.      ]
 [0.288921 0.758394 0.428426 1.      ]
 [0.626579 0.854645 0.223353 1.      ]
 [0.993248 0.906157 0.143936 1.      ]]
viridis(np.linspace(0, 1, 8)) [[0.267004 0.004874 0.329415 1.      ]
 [0.275191 0.194905 0.496005 1.      ]
 [0.212395 0.359683 0.55171  1.      ]
```

(continues on next page)

(continued from previous page)

```
 [0.153364 0.497    0.557724 1.       ]
 [0.122312 0.633153 0.530398 1.       ]
 [0.288921 0.758394 0.428426 1.       ]
 [0.626579 0.854645 0.223353 1.       ]
 [0.993248 0.906157 0.143936 1.       ]]
```

The colormap is a lookup table, so "oversampling" the colormap returns nearest-neighbor interpolation (note the repeated colors in the list below)

```
print('viridis(np.linspace(0, 1, 12))', viridis(np.linspace(0, 1, 12)))
```

```
viridis(np.linspace(0, 1, 12)) [[0.267004 0.004874 0.329415 1.       ]
 [0.267004 0.004874 0.329415 1.       ]
 [0.275191 0.194905 0.496005 1.       ]
 [0.212395 0.359683 0.55171  1.       ]
 [0.212395 0.359683 0.55171  1.       ]
 [0.153364 0.497    0.557724 1.       ]
 [0.122312 0.633153 0.530398 1.       ]
 [0.288921 0.758394 0.428426 1.       ]
 [0.288921 0.758394 0.428426 1.       ]
 [0.626579 0.854645 0.223353 1.       ]
 [0.993248 0.906157 0.143936 1.       ]
 [0.993248 0.906157 0.143936 1.       ]]
```

LinearSegmentedColormap

*LinearSegmentedColormap*s do not have a `.colors` attribute. However, one may still call the colormap with an integer array, or with a float array between 0 and 1.

```
copper = mpl.colormaps['copper'].resampled(8)

print('copper(range(8))', copper(range(8)))
print('copper(np.linspace(0, 1, 8))', copper(np.linspace(0, 1, 8)))
```

```
copper(range(8)) [[0.         0.         0.         1.        ]
 [0.17647055 0.1116     0.07107143 1.        ]
 [0.35294109 0.2232     0.14214286 1.        ]
 [0.52941164 0.3348     0.21321429 1.        ]
 [0.70588219 0.4464     0.28428571 1.        ]
 [0.88235273 0.558      0.35535714 1.        ]
 [1.         0.6696     0.42642857 1.        ]
 [1.         0.7812     0.4975     1.        ]]
copper(np.linspace(0, 1, 8)) [[0.         0.         0.         1.    ␣
 ↪   ]
 [0.17647055 0.1116     0.07107143 1.        ]
```

(continues on next page)

(continued from previous page)

```
 [0.35294109 0.2232     0.14214286 1.        ]
 [0.52941164 0.3348     0.21321429 1.        ]
 [0.70588219 0.4464     0.28428571 1.        ]
 [0.88235273 0.558      0.35535714 1.        ]
 [1.         0.6696     0.42642857 1.        ]
 [1.         0.7812     0.4975     1.        ]]
```

Creating listed colormaps

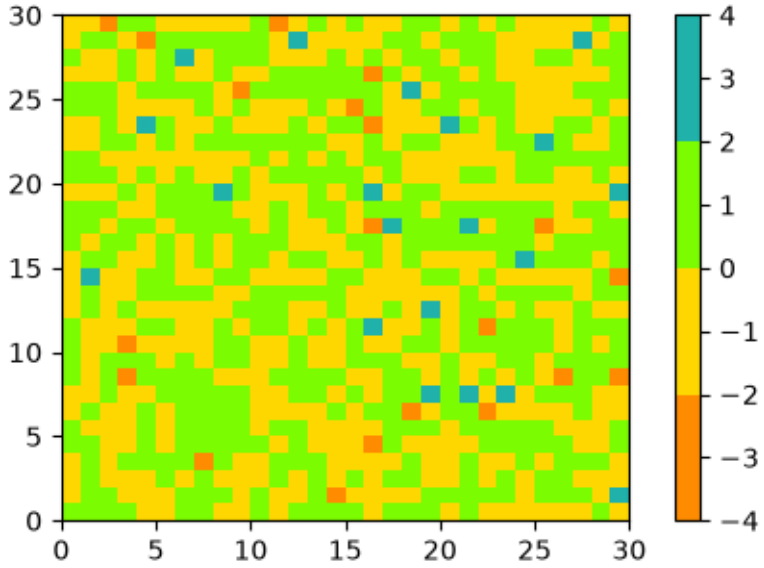
Creating a colormap is essentially the inverse operation of the above where we supply a list or array of color specifications to *ListedColormap* to make a new colormap.

Before continuing with the tutorial, let us define a helper function that takes one of more colormaps as input, creates some random data and applies the colormap(s) to an image plot of that dataset.

```
def plot_examples(colormaps):
    """
    Helper function to plot data with associated colormap.
    """
    np.random.seed(19680801)
    data = np.random.randn(30, 30)
    n = len(colormaps)
    fig, axs = plt.subplots(1, n, figsize=(n * 2 + 2, 3),
                            layout='constrained', squeeze=False)
    for [ax, cmap] in zip(axs.flat, colormaps):
        psm = ax.pcolormesh(data, cmap=cmap, rasterized=True, vmin=-4,␣
 ↪vmax=4)
        fig.colorbar(psm, ax=ax)
    plt.show()
```

In the simplest case we might type in a list of color names to create a colormap from those.

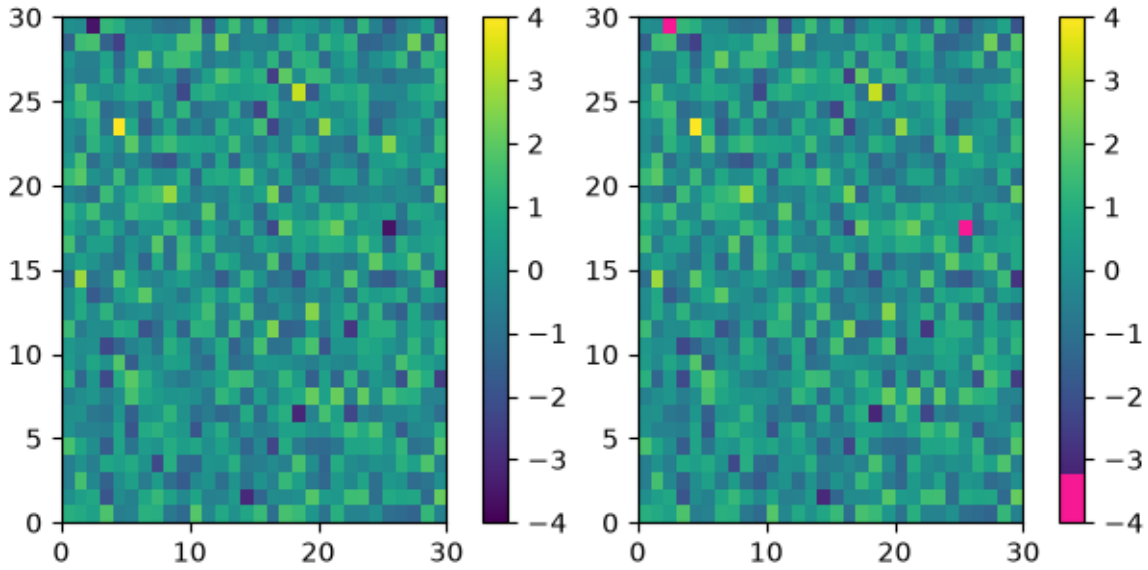
```
cmap = ListedColormap(["darkorange", "gold", "lawngreen",
 ↪"lightseagreen"])
plot_examples([cmap])
```



In fact, that list may contain any valid *Matplotlib color specification*. Particularly useful for creating custom colormaps are (N, 4)-shaped arrays. Because with the variety of numpy operations that we can do on a such an array, carpentry of new colormaps from existing colormaps become quite straight forward.

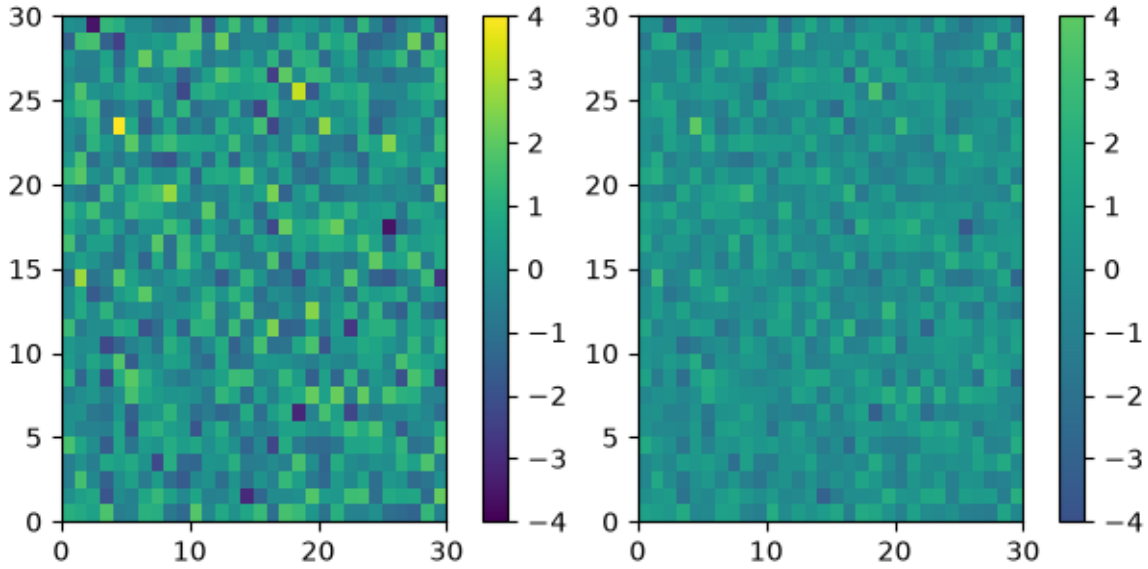
For example, suppose we want to make the first 25 entries of a 256-length "viridis" colormap pink for some reason:

```
viridis = mpl.colormaps['viridis'].resampled(256)
newcolors = viridis(np.linspace(0, 1, 256))
pink = np.array([248/256, 24/256, 148/256, 1])
newcolors[:25, :] = pink
newcmp = ListedColormap(newcolors)

plot_examples([viridis, newcmp])
```



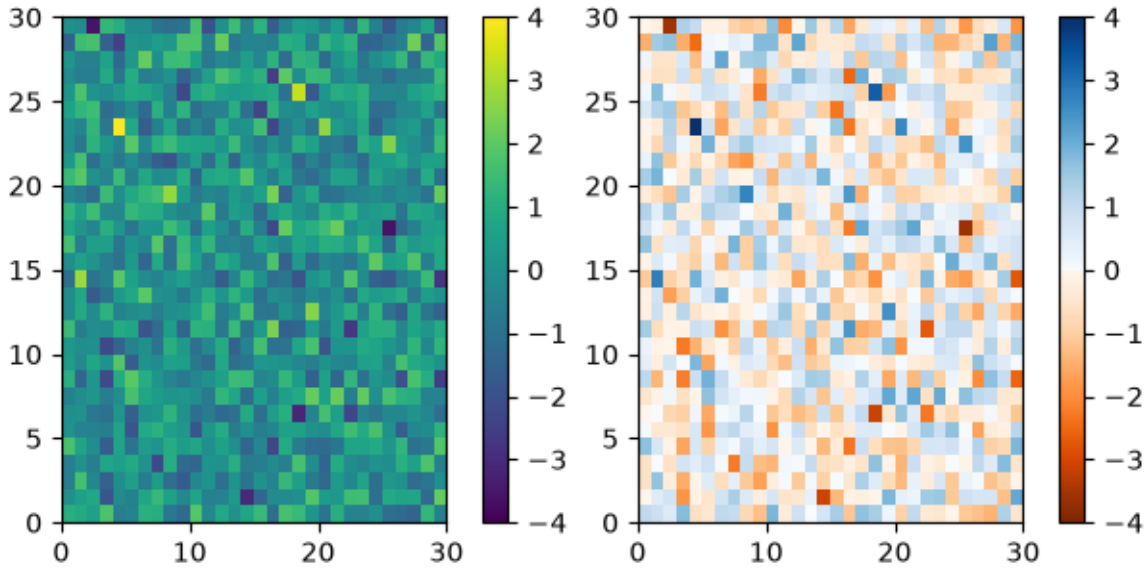
We can reduce the dynamic range of a colormap; here we choose the middle half of the colormap. Note, however, that because viridis is a listed colormap, we will end up with 128 discrete values instead of the 256 values that were in the original colormap. This method does not interpolate in color-space to add new colors.

```
viridis_big = mpl.colormaps['viridis']
newcmp = ListedColormap(viridis_big(np.linspace(0.25, 0.75, 128)))
plot_examples([viridis, newcmp])
```



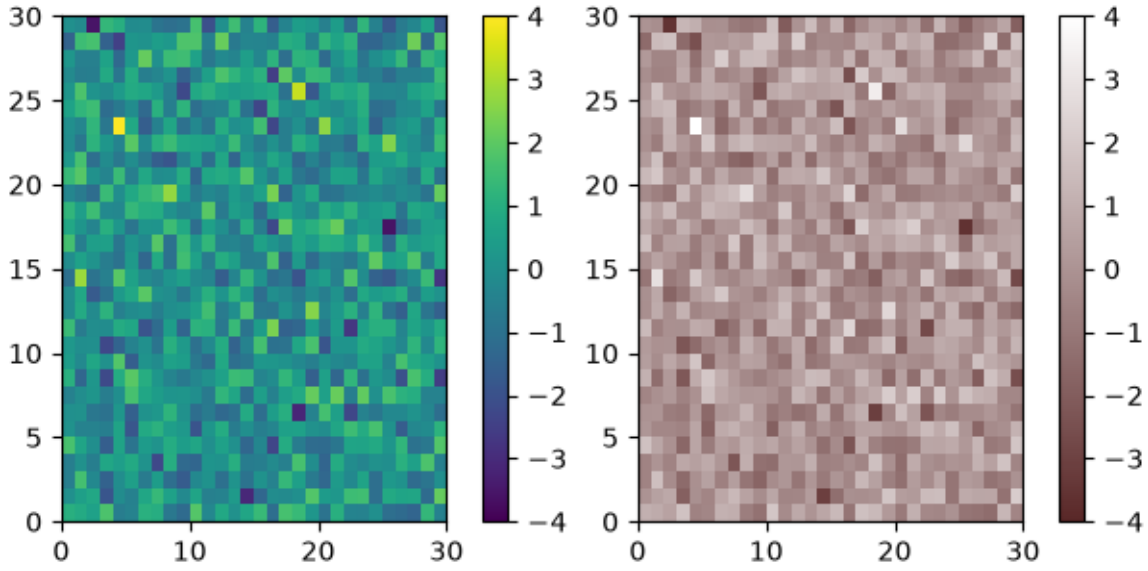
and we can easily concatenate two colormaps:

```
top = mpl.colormaps['Oranges_r'].resampled(128)
bottom = mpl.colormaps['Blues'].resampled(128)

newcolors = np.vstack((top(np.linspace(0, 1, 128)),
                       bottom(np.linspace(0, 1, 128))))
newcmp = ListedColormap(newcolors, name='OrangeBlue')
plot_examples([viridis, newcmp])
```



Of course we need not start from a named colormap, we just need to create the (N, 4) array to pass to *ListedColormap*. Here we create a colormap that goes from brown (RGB: 90, 40, 40) to white (RGB: 255, 255, 255).

```
N = 256
vals = np.ones((N, 4))
vals[:, 0] = np.linspace(90/256, 1, N)
vals[:, 1] = np.linspace(40/256, 1, N)
vals[:, 2] = np.linspace(40/256, 1, N)
newcmp = ListedColormap(vals)
plot_examples([viridis, newcmp])
```



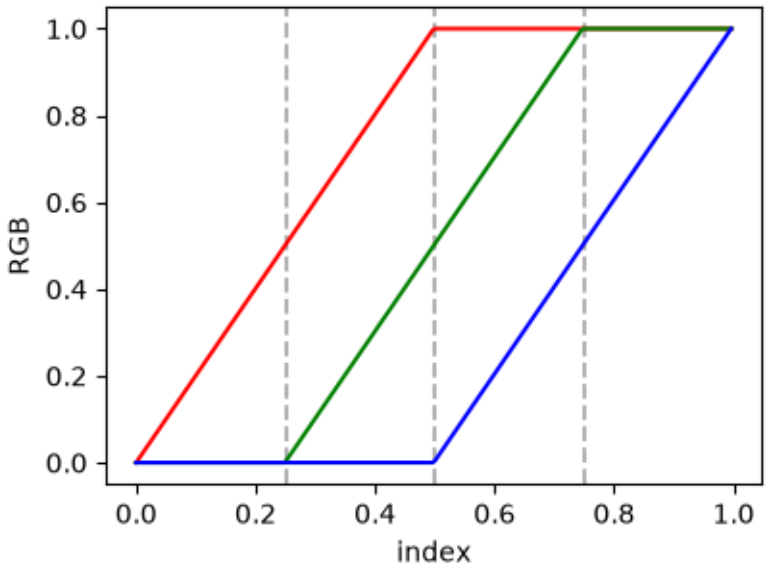
Creating linear segmented colormaps

The *LinearSegmentedColormap* class specifies colormaps using anchor points between which RGB(A) values are interpolated.

The format to specify these colormaps allows discontinuities at the anchor points. Each anchor point is specified as a row in a matrix of the form `[x[i] yleft[i] yright[i]]`, where `x[i]` is the anchor, and `yleft[i]` and `yright[i]` are the values of the color on either side of the anchor point.

If there are no discontinuities, then `yleft[i] == yright[i]`:

```
cdict = {'red':   [[0.0,  0.0, 0.0],
                   [0.5,  1.0, 1.0],
                   [1.0,  1.0, 1.0]],
         'green': [[0.0,  0.0, 0.0],
                   [0.25, 0.0, 0.0],
                   [0.75, 1.0, 1.0],
                   [1.0,  1.0, 1.0]],
         'blue':  [[0.0,  0.0, 0.0],
                   [0.5,  0.0, 0.0],
                   [1.0,  1.0, 1.0]]}


def plot_linearmap(cdict):
    newcmp = LinearSegmentedColormap('testCmap', segmentdata=cdict,␣
 ↪N=256)
    rgba = newcmp(np.linspace(0, 1, 256))
    fig, ax = plt.subplots(figsize=(4, 3), layout='constrained')
    col = ['r', 'g', 'b']
    for xx in [0.25, 0.5, 0.75]:
        ax.axvline(xx, color='0.7', linestyle='--')
    for i in range(3):
        ax.plot(np.arange(256)/256, rgba[:, i], color=col[i])
    ax.set_xlabel('index')
    ax.set_ylabel('RGB')
    plt.show()

plot_linearmap(cdict)
```



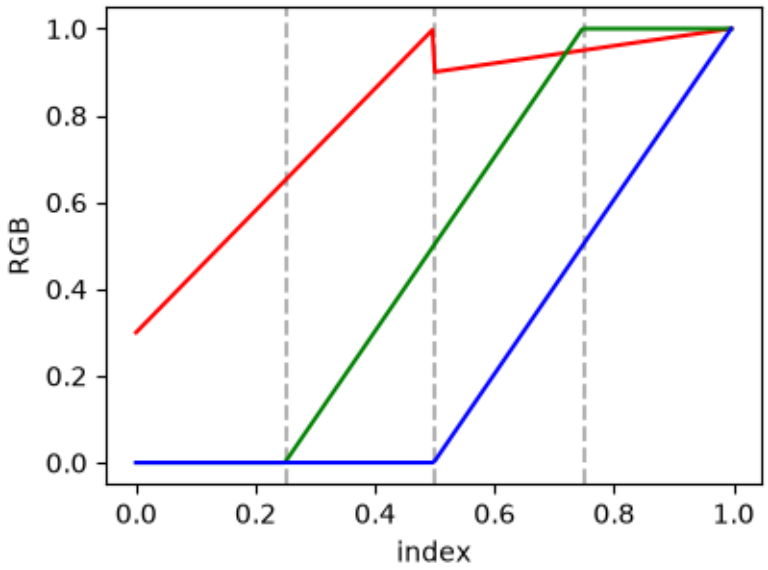
In order to make a discontinuity at an anchor point, the third column is different than the second. The matrix for each of "red", "green", "blue", and optionally "alpha" is set up as:

```
cdict['red'] = [...
                [x[i]       yleft[i]     yright[i]],
                [x[i+1]     yleft[i+1]   yright[i+1]],
               ...]
```

and for values passed to the colormap between `x[i]` and `x[i+1]`, the interpolation is between `yright[i]` and `yleft[i+1]`.

In the example below there is a discontinuity in red at 0.5. The interpolation between 0 and 0.5 goes from 0.3 to 1, and between 0.5 and 1 it goes from 0.9 to 1. Note that `red[0, 1]`, and `red[2, 2]` are both superfluous to the interpolation because `red[0, 1]` (i.e., `yleft[0]`) is the value to the left of 0, and `red[2, 2]` (i.e., `yright[2]`) is the value to the right of 1, which are outside the color mapping domain.

```
cdict['red'] = [[0.0,  0.0, 0.3],
                [0.5,  1.0, 0.9],
                [1.0,  1.0, 1.0]]
plot_linearmap(cdict)
```



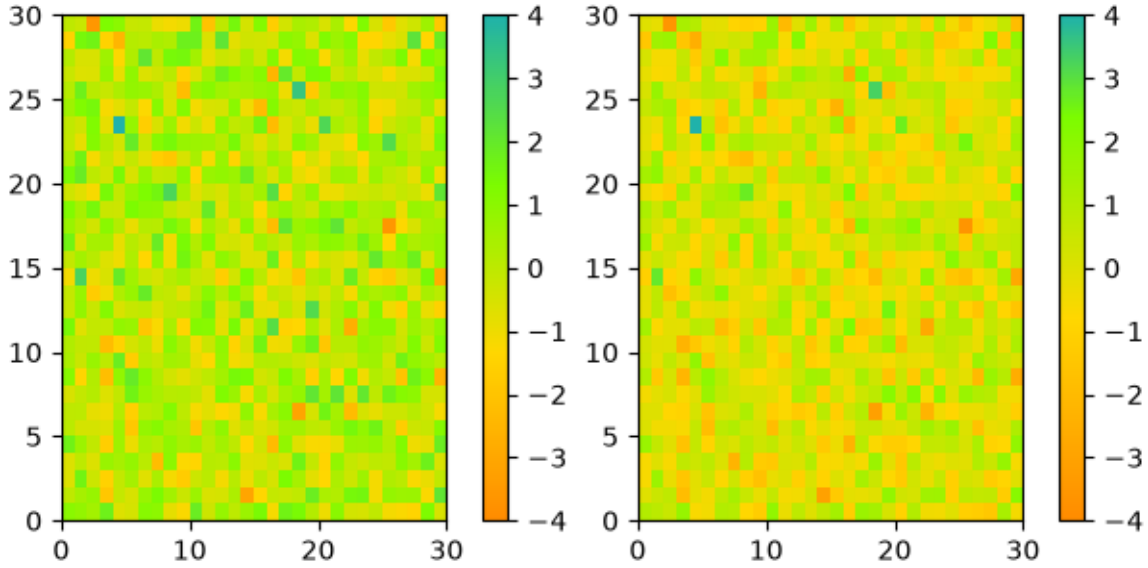
Directly creating a segmented colormap from a list

The approach described above is very versatile, but admittedly a bit cumbersome to implement. For some basic cases, the use of *LinearSegmentedColormap.from_list* may be easier. This creates a segmented colormap with equal spacings from a supplied list of colors.

```
colors = ["darkorange", "gold", "lawngreen", "lightseagreen"]
cmap1 = LinearSegmentedColormap.from_list("mycmap", colors)
```

If desired, the nodes of the colormap can be given as numbers between 0 and 1. For example, one could have the reddish part take more space in the colormap.

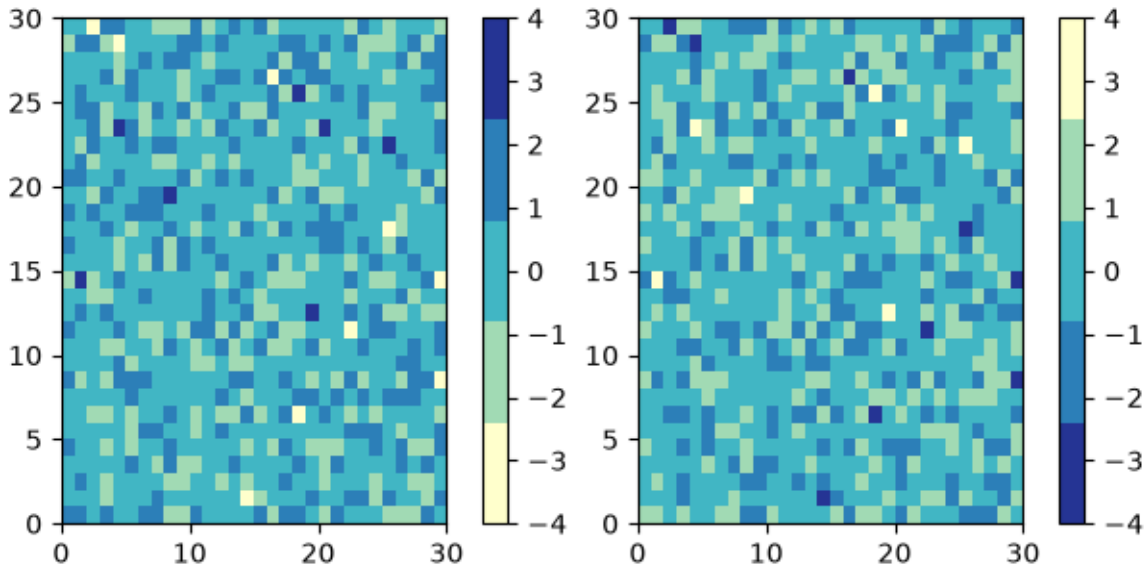
```
nodes = [0.0, 0.4, 0.8, 1.0]
cmap2 = LinearSegmentedColormap.from_list("mycmap", list(zip(nodes,␣
↪colors)))

plot_examples([cmap1, cmap2])
```



Reversing a colormap

`Colormap.reversed` creates a new colormap that is a reversed version of the original colormap.

```
colors = ["#ffffcc", "#a1dab4", "#41b6c4", "#2c7fb8", "#253494"]
my_cmap = ListedColormap(colors, name="my_cmap")

my_cmap_r = my_cmap.reversed()

plot_examples([my_cmap, my_cmap_r])
```

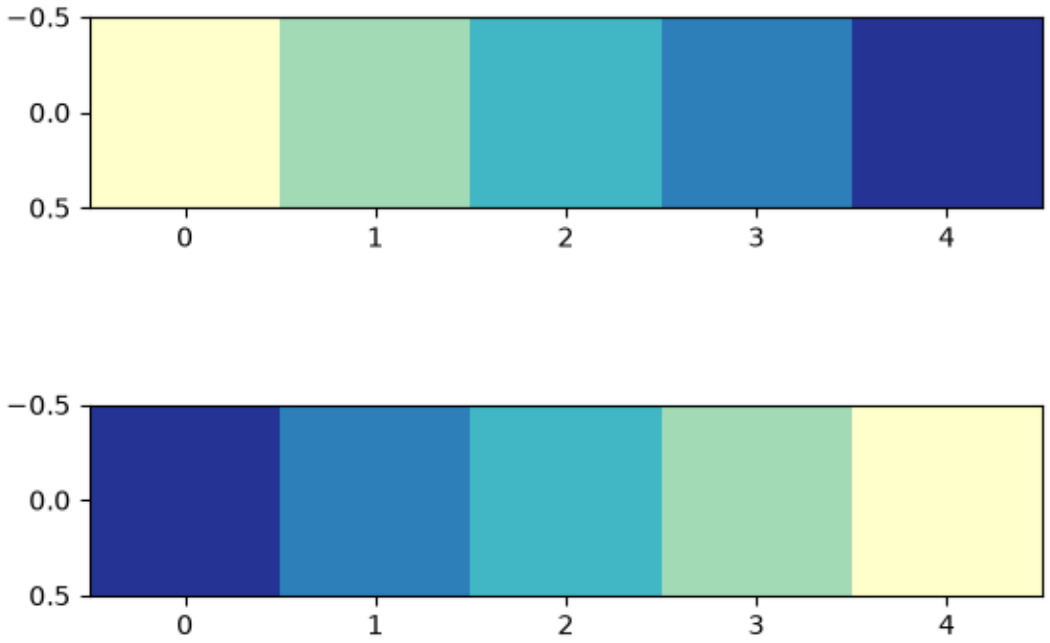


If no name is passed in, `.reversed` also names the copy by *appending '_r'* to the original colormap's name.

Registering a colormap

Colormaps can be added to the *matplotlib.colormaps* list of named colormaps. This allows the colormaps to be accessed by name in plotting functions:

```
# my_cmap, my_cmap_r from reversing a colormap
mpl.colormaps.register(cmap=my_cmap)
mpl.colormaps.register(cmap=my_cmap_r)

data = [[1, 2, 3, 4, 5]]

fig, (ax1, ax2) = plt.subplots(nrows=2)

ax1.imshow(data, cmap='my_cmap')
ax2.imshow(data, cmap='my_cmap_r')

plt.show()
```



Colormaps added to the registry can also be deregistered:

```
mpl.colormaps.unregister(my_cmap.name)
```

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.pcolormesh*
- *matplotlib.figure.Figure.colorbar*
- *matplotlib.colors*
- *matplotlib.colors.LinearSegmentedColormap*
- *matplotlib.colors.ListedColormap*
- *matplotlib.cm*
- *matplotlib.colormaps*

Total running time of the script: (0 minutes 3.281 seconds)

3.7.3 Colormap normalization

Objects that use colormaps by default linearly map the colors in the colormap from data values *vmin* to *vmax*. For example:

```
pcm = ax.pcolormesh(x, y, Z, vmin=-1., vmax=1., cmap='RdBu_r')
```

will map the data in *Z* linearly from -1 to +1, so *Z=0* will give a color at the center of the colormap *RdBu_r* (white in this case).

Matplotlib does this mapping in two steps, with a normalization from the input data to [0, 1] occurring first, and then mapping onto the indices in the colormap. Normalizations are classes defined in the *matplotlib.colors()* module. The default, linear normalization is *matplotlib.colors.Normalize()*.

Artists that map data to color pass the arguments *vmin* and *vmax* to construct a *matplotlib.colors.Normalize()* instance, then call it:

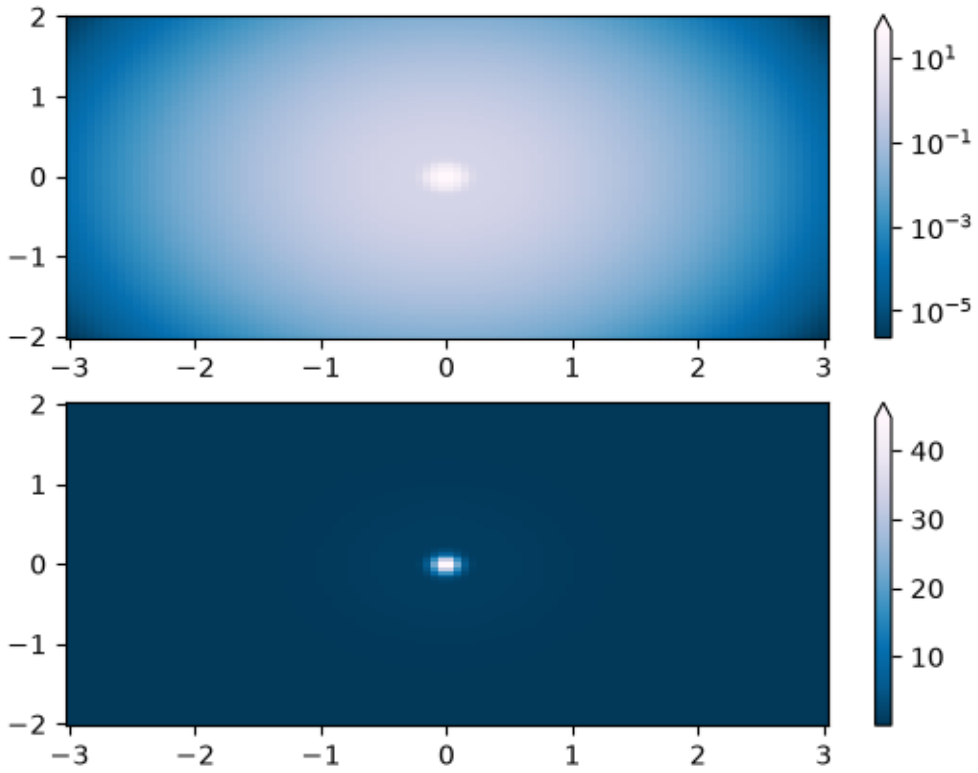
```
>>> import matplotlib as mpl
>>> norm = mpl.colors.Normalize(vmin=-1, vmax=1)
>>> norm(0)
0.5
```

However, there are sometimes cases where it is useful to map data to colormaps in a non-linear fashion.

Logarithmic

One of the most common transformations is to plot data by taking its logarithm (to the base-10). This transformation is useful to display changes across disparate scales. Using *colors.LogNorm* normalizes the data via log_{10}. In the example below, there are two bumps, one much smaller than the other. Using *colors.LogNorm*, the shape and location of each bump can clearly be seen:

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.cbook as cbook
import matplotlib.colors as colors

N = 100
X, Y = np.mgrid[-3:3:complex(0, N), -2:2:complex(0, N)]

# A low hump with a spike coming out of the top right.  Needs to have
# z/colour axis on a log scale, so we see both hump and spike. A linear
# scale only shows the spike.
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X * 10)**2 - (Y * 10)**2)
Z = Z1 + 50 * Z2

fig, ax = plt.subplots(2, 1)

pcm = ax[0].pcolor(X, Y, Z,
                   norm=colors.LogNorm(vmin=Z.min(), vmax=Z.max()),
                   cmap='PuBu_r', shading='auto')
fig.colorbar(pcm, ax=ax[0], extend='max')

pcm = ax[1].pcolor(X, Y, Z, cmap='PuBu_r', shading='auto')
fig.colorbar(pcm, ax=ax[1], extend='max')
plt.show()
```



Centered

In many cases, data is symmetrical around a center, for example, positive and negative anomalies around a center 0. In this case, we would like the center to be mapped to 0.5 and the datapoint with the largest deviation from the center to be mapped to 1.0, if its value is greater than the center, or 0.0 otherwise. The norm *colors.CenteredNorm* creates such a mapping automatically. It is well suited to be combined with a divergent colormap which uses different colors edges that meet in the center at an unsaturated color.

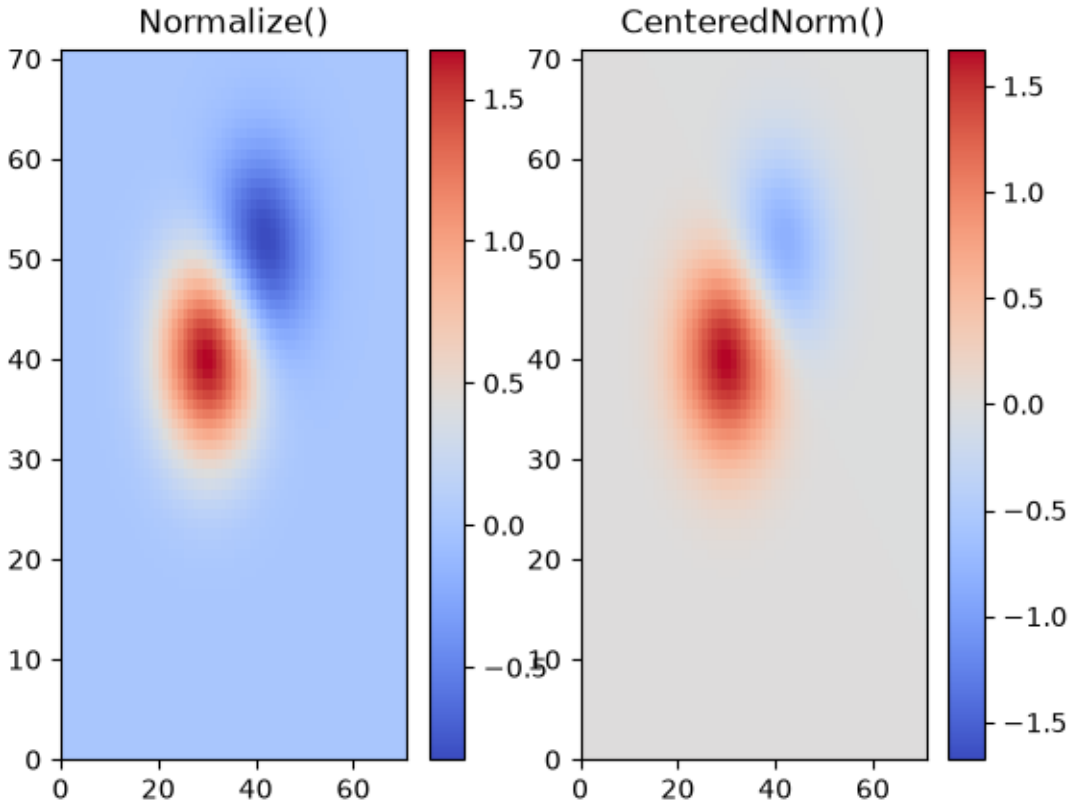
If the center of symmetry is different from 0, it can be set with the *vcenter* argument. For logarithmic scaling on both sides of the center, see *colors.SymLogNorm* below; to apply a different mapping above and below the center, use *colors.TwoSlopeNorm* below.

```
delta = 0.1
x = np.arange(-3.0, 4.001, delta)
y = np.arange(-4.0, 3.001, delta)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (0.9*Z1 - 0.5*Z2) * 2

# select a divergent colormap
```

(continues on next page)

(continued from previous page)

```
cmap = "coolwarm"

fig, (ax1, ax2) = plt.subplots(ncols=2)
pc = ax1.pcolormesh(Z, cmap=cmap)
fig.colorbar(pc, ax=ax1)
ax1.set_title('Normalize()')

pc = ax2.pcolormesh(Z, norm=colors.CenteredNorm(), cmap=cmap)
fig.colorbar(pc, ax=ax2)
ax2.set_title('CenteredNorm()')

plt.show()
```



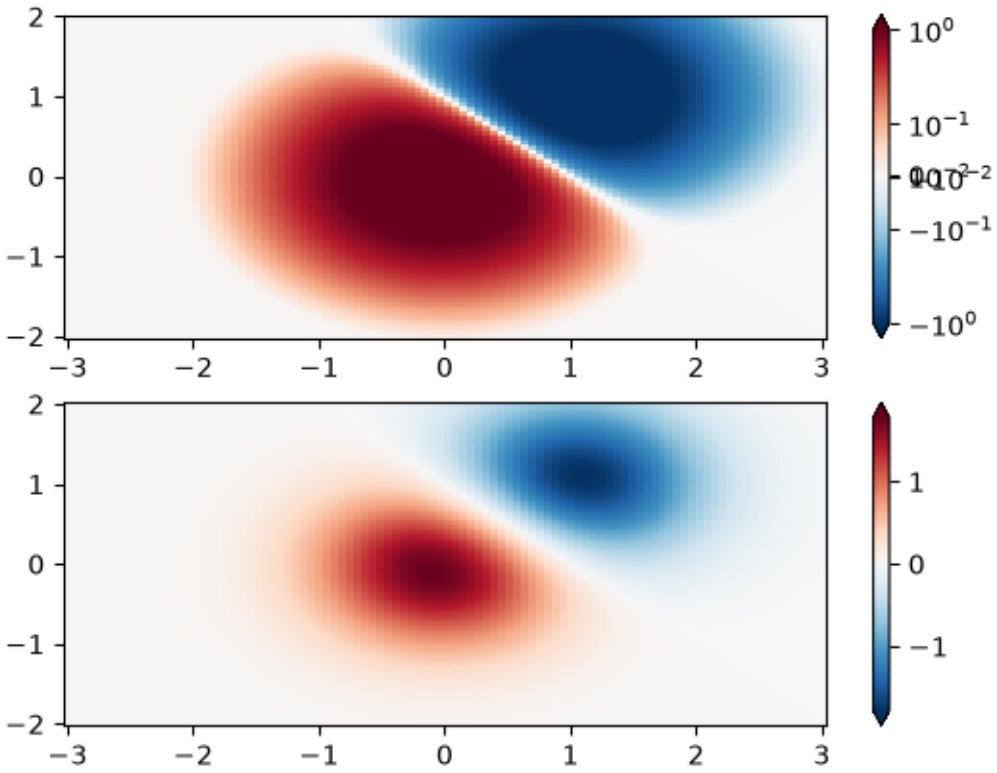
Symmetric logarithmic

Similarly, it sometimes happens that there is data that is positive and negative, but we would still like a logarithmic scaling applied to both. In this case, the negative numbers are also scaled logarithmically, and mapped to smaller numbers; e.g., if `vmin=-vmax`, then the negative numbers are mapped from 0 to 0.5 and the positive from 0.5 to 1.

Since the logarithm of values close to zero tends toward infinity, a small range around zero needs to be mapped

linearly. The parameter *linthresh* allows the user to specify the size of this range (*-linthresh*, *linthresh*). The size of this range in the colormap is set by *linscale*. When *linscale* == 1.0 (the default), the space used for the positive and negative halves of the linear range will be equal to one decade in the logarithmic range.

```
N = 100
X, Y = np.mgrid[-3:3:complex(0, N), -2:2:complex(0, N)]
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2

fig, ax = plt.subplots(2, 1)

pcm = ax[0].pcolormesh(X, Y, Z,
                       norm=colors.SymLogNorm(linthresh=0.03,␣
 ↪linscale=0.03,
                                              vmin=-1.0, vmax=1.0,␣
 ↪base=10),
                       cmap='RdBu_r', shading='auto')
fig.colorbar(pcm, ax=ax[0], extend='both')

pcm = ax[1].pcolormesh(X, Y, Z, cmap='RdBu_r', vmin=-np.max(Z),␣
 ↪shading='auto')
fig.colorbar(pcm, ax=ax[1], extend='both')
plt.show()
```



Power-law

Sometimes it is useful to remap the colors onto a power-law relationship (i.e. $y = x^\gamma$, where γ is the power). For this we use the *colors.PowerNorm*. It takes as an argument *gamma* (*gamma* == 1.0 will just yield the default linear normalization):

Note

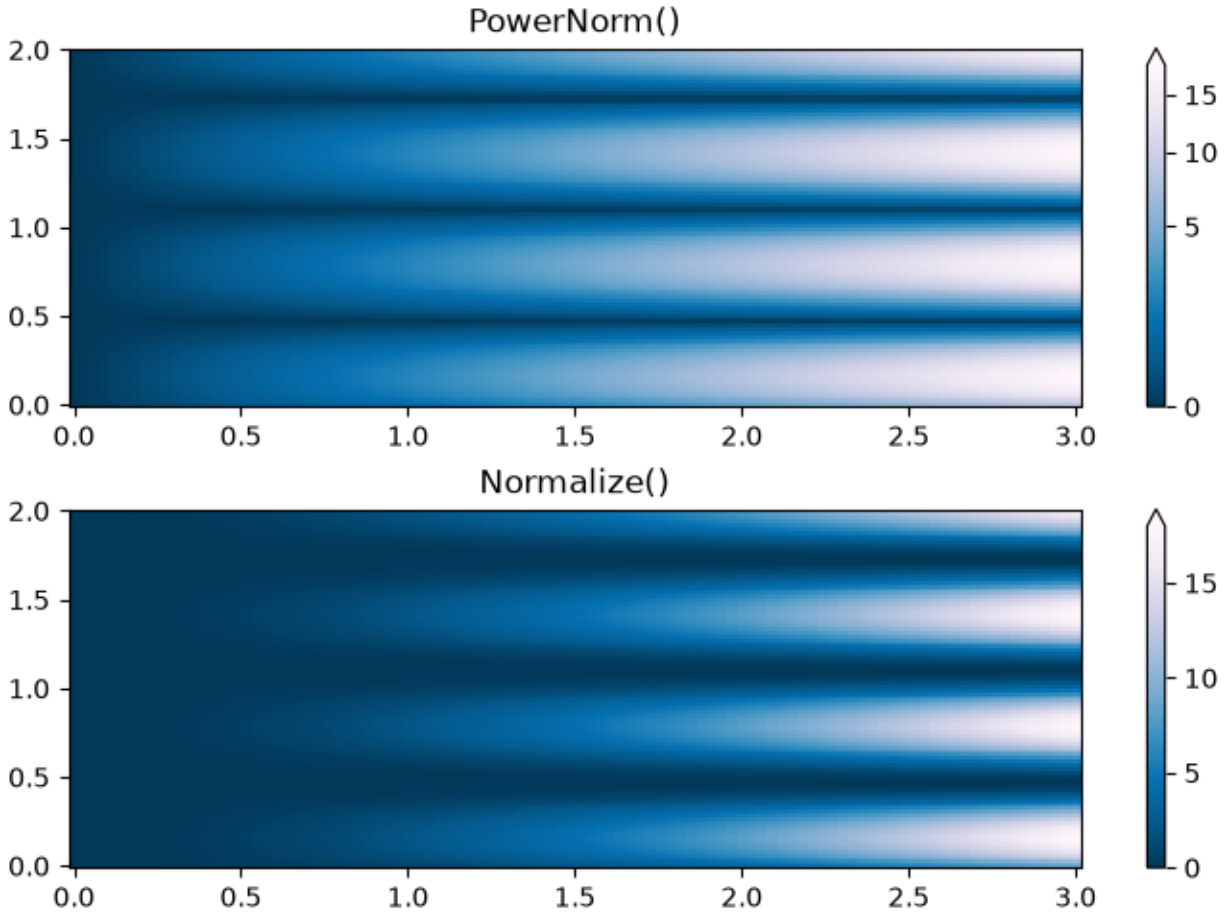
There should probably be a good reason for plotting the data using this type of transformation. Technical viewers are used to linear and logarithmic axes and data transformations. Power laws are less common, and viewers should explicitly be made aware that they have been used.

```
N = 100
X, Y = np.mgrid[0:3:complex(0, N), 0:2:complex(0, N)]
Z1 = (1 + np.sin(Y * 10.)) * X**2

fig, ax = plt.subplots(2, 1, layout='constrained')

pcm = ax[0].pcolormesh(X, Y, Z1, norm=colors.PowerNorm(gamma=0.5),
```

(continues on next page)

(continued from previous page)

```
                        cmap='PuBu_r', shading='auto')
fig.colorbar(pcm, ax=ax[0], extend='max')
ax[0].set_title('PowerNorm()')

pcm = ax[1].pcolormesh(X, Y, Z1, cmap='PuBu_r', shading='auto')
fig.colorbar(pcm, ax=ax[1], extend='max')
ax[1].set_title('Normalize()')
plt.show()
```



Discrete bounds

Another normalization that comes with Matplotlib is *colors.BoundaryNorm*. In addition to *vmin* and *vmax*, this takes as arguments boundaries between which data is to be mapped. The colors are then linearly distributed between these "bounds". It can also take an *extend* argument to add upper and/or lower out-of-bounds values to the range over which the colors are distributed. For instance:

```
>>> import matplotlib.colors as colors
>>> bounds = np.array([-0.25, -0.125, 0, 0.5, 1])
>>> norm = colors.BoundaryNorm(boundaries=bounds, ncolors=4)
>>> print(norm([-0.2, -0.15, -0.02, 0.3, 0.8, 0.99]))
```

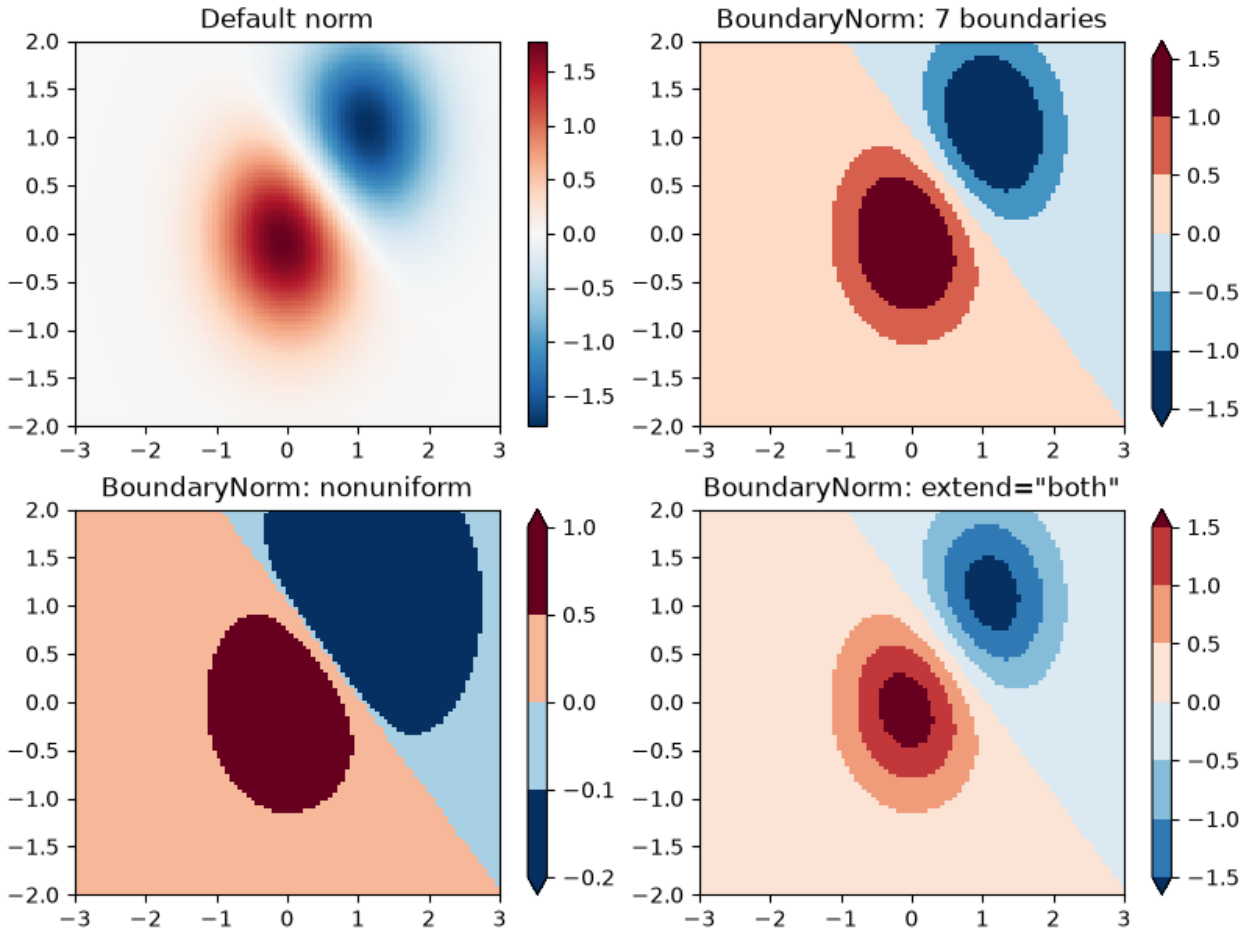
(continues on next page)

(continued from previous page)

```
[0 0 1 2 3 3]
```

Note: Unlike the other norms, this norm returns values from 0 to *ncolors*-1.

```
N = 100
X, Y = np.meshgrid(np.linspace(-3, 3, N), np.linspace(-2, 2, N))
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = ((Z1 - Z2) * 2)[:-1, :-1]

fig, ax = plt.subplots(2, 2, figsize=(8, 6), layout='constrained')
ax = ax.flatten()

# Default norm:
pcm = ax[0].pcolormesh(X, Y, Z, cmap='RdBu_r')
fig.colorbar(pcm, ax=ax[0], orientation='vertical')
ax[0].set_title('Default norm')

# Even bounds give a contour-like effect:
bounds = np.linspace(-1.5, 1.5, 7)
norm = colors.BoundaryNorm(boundaries=bounds, ncolors=256)
pcm = ax[1].pcolormesh(X, Y, Z, norm=norm, cmap='RdBu_r')
fig.colorbar(pcm, ax=ax[1], extend='both', orientation='vertical')
ax[1].set_title('BoundaryNorm: 7 boundaries')

# Bounds may be unevenly spaced:
bounds = np.array([-0.2, -0.1, 0, 0.5, 1])
norm = colors.BoundaryNorm(boundaries=bounds, ncolors=256)
pcm = ax[2].pcolormesh(X, Y, Z, norm=norm, cmap='RdBu_r')
fig.colorbar(pcm, ax=ax[2], extend='both', orientation='vertical')
ax[2].set_title('BoundaryNorm: nonuniform')

# With out-of-bounds colors:
bounds = np.linspace(-1.5, 1.5, 7)
norm = colors.BoundaryNorm(boundaries=bounds, ncolors=256, extend='both
 ↪')
pcm = ax[3].pcolormesh(X, Y, Z, norm=norm, cmap='RdBu_r')
# The colorbar inherits the "extend" argument from BoundaryNorm.
fig.colorbar(pcm, ax=ax[3], orientation='vertical')
ax[3].set_title('BoundaryNorm: extend="both"')
plt.show()
```



TwoSlopeNorm: Different mapping on either side of a center

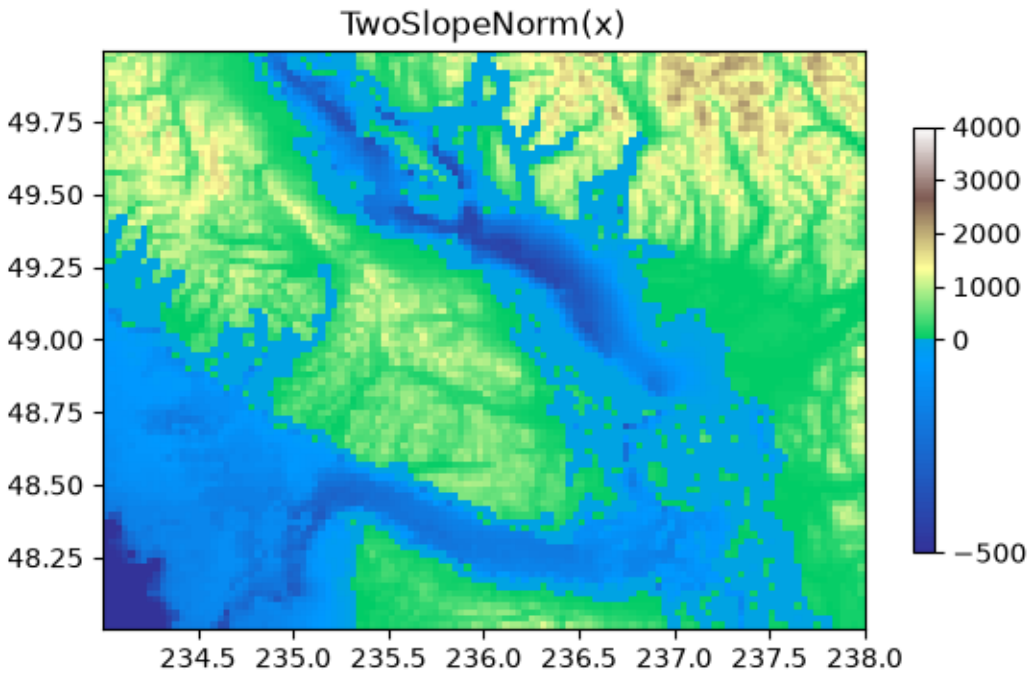
Sometimes we want to have a different colormap on either side of a conceptual center point, and we want those two colormaps to have different linear scales. An example is a topographic map where the land and ocean have a center at zero, but land typically has a greater elevation range than the water has depth range, and they are often represented by a different colormap.

```
dem = cbook.get_sample_data('topobathy.npz')
topo = dem['topo']
longitude = dem['longitude']
latitude = dem['latitude']

fig, ax = plt.subplots()
# make a colormap that has land and ocean clearly delineated and of the
# same length (256 + 256)
colors_undersea = plt.colormaps["terrain"](np.linspace(0, 0.17, 256))
colors_land = plt.colormaps["terrain"](np.linspace(0.25, 1, 256))
all_colors = np.vstack((colors_undersea, colors_land))
terrain_map = colors.LinearSegmentedColormap.from_list(
    'terrain_map', all_colors)
```

(continues on next page)

(continued from previous page)

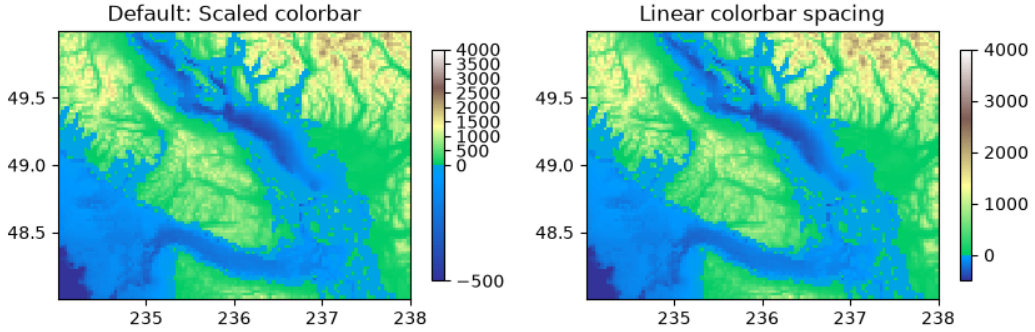
```
# make the norm:  Note the center is offset so that the land has more
# dynamic range:
divnorm = colors.TwoSlopeNorm(vmin=-500., vcenter=0, vmax=4000)

pcm = ax.pcolormesh(longitude, latitude, topo, rasterized=True,␣
 ↪norm=divnorm,
                    cmap=terrain_map, shading='auto')
# Simple geographic plot, set aspect ratio because distance between␣
 ↪lines of
# longitude depends on latitude.
ax.set_aspect(1 / np.cos(np.deg2rad(49)))
ax.set_title('TwoSlopeNorm(x)')
cb = fig.colorbar(pcm, shrink=0.6)
cb.set_ticks([-500, 0, 1000, 2000, 3000, 4000])
plt.show()
```



Using a linear scale on the colormap

By default, colorbars adopt the same axis scaling as their associated norm. For example, for a *TwoSlopeNorm*, colormap segments are distributed linearly and the colorbar ticks positions are spaced non-linearly (as above, and the left-hand colorbar below). To make the tick spacing linear instead, you can change the scale by calling `cb.ax.set_yscale('linear')`, as shown in the right-hand colorbar below. The ticks will then be evenly spaced, the colormap will appear compressed in the smaller of the two slope regions.

```
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 4))
divnorm = colors.TwoSlopeNorm(vmin=-500., vcenter=0, vmax=4000)

for ax, title in zip([ax1, ax2],
                     ['Default: Scaled colorbar', 'Linear colorbar␣
↪spacing']):
    pcm = ax.pcolormesh(longitude, latitude, topo, rasterized=True,␣
↪norm=divnorm,
                        cmap=terrain_map, shading='auto')
    ax.set_aspect(1 / np.cos(np.deg2rad(49)))
    ax.set_title(title)
    cb = fig.colorbar(pcm, ax=ax, shrink=0.6)
    cb.set_ticks(np.arange(-500, 4001, 500))

# Set linear scale for the right colorbar
cb.ax.set_yscale('linear')
```



FuncNorm: Arbitrary function normalization

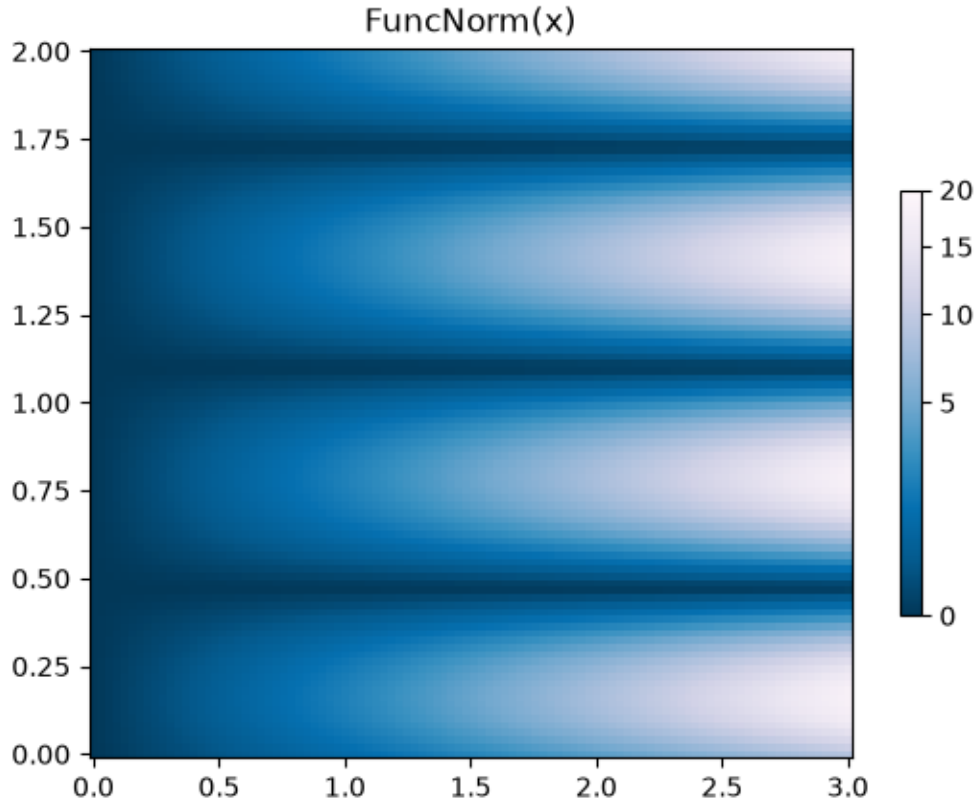
If the above norms do not provide the normalization you want, you can use *FuncNorm* to define your own. Note that this example is the same as *PowerNorm* with a power of 0.5:

```
def _forward(x):
    return np.sqrt(x)
```

(continues on next page)

(continued from previous page)

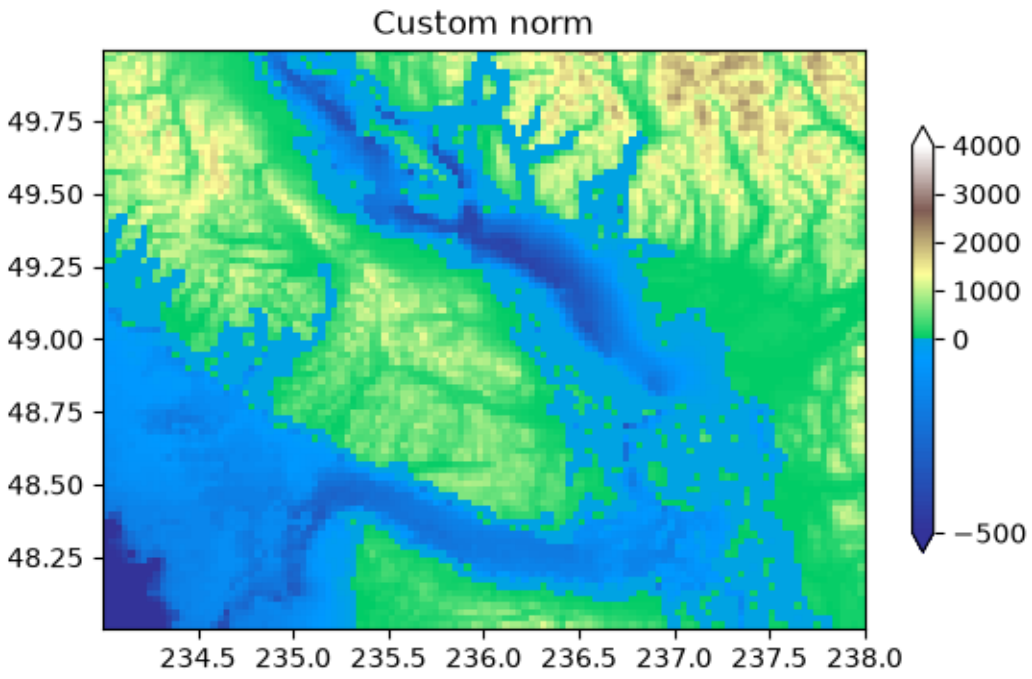
```
def _inverse(x):
    return x**2

N = 100
X, Y = np.mgrid[0:3:complex(0, N), 0:2:complex(0, N)]
Z1 = (1 + np.sin(Y * 10.)) * X**2
fig, ax = plt.subplots()

norm = colors.FuncNorm((_forward, _inverse), vmin=0, vmax=20)
pcm = ax.pcolormesh(X, Y, Z1, norm=norm, cmap='PuBu_r', shading='auto')
ax.set_title('FuncNorm(x)')
fig.colorbar(pcm, shrink=0.6)
plt.show()
```



Custom normalization: Manually implement two linear ranges

The *TwoSlopeNorm* described above makes a useful example for defining your own norm. Note for the colorbar to work, you must define an inverse for your norm:

```
class MidpointNormalize(colors.Normalize):
    def __init__(self, vmin=None, vmax=None, vcenter=None, clip=False):
        self.vcenter = vcenter
        super().__init__(vmin, vmax, clip)

    def __call__(self, value, clip=None):
        # I'm ignoring masked values and all kinds of edge cases to␣
 ↪make a
        # simple example...
        # Note also that we must extrapolate beyond vmin/vmax
        x, y = [self.vmin, self.vcenter, self.vmax], [0, 0.5, 1.]
        return np.ma.masked_array(np.interp(value, x, y,
                                            left=-np.inf, right=np.
 ↪inf))

    def inverse(self, value):
        y, x = [self.vmin, self.vcenter, self.vmax], [0, 0.5, 1]
        return np.interp(value, x, y, left=-np.inf, right=np.inf)


fig, ax = plt.subplots()
midnorm = MidpointNormalize(vmin=-500., vcenter=0, vmax=4000)

pcm = ax.pcolormesh(longitude, latitude, topo, rasterized=True,␣
 ↪norm=midnorm,
                    cmap=terrain_map, shading='auto')
ax.set_aspect(1 / np.cos(np.deg2rad(49)))
ax.set_title('Custom norm')
cb = fig.colorbar(pcm, shrink=0.6, extend='both')
cb.set_ticks([-500, 0, 1000, 2000, 3000, 4000])

plt.show()
```



Total running time of the script: (0 minutes 3.983 seconds)

3.7.4 Choosing Colormaps in Matplotlib

Matplotlib has a number of built-in colormaps accessible via `matplotlib.colormaps`. There are also external libraries that have many extra colormaps, which can be viewed in the Third-party colormaps section of the Matplotlib documentation. Here we briefly discuss how to choose between the many options. For help on creating your own colormaps, see *Creating Colormaps in Matplotlib*.

To get a list of all registered colormaps, you can do:

```
from matplotlib import colormaps
list(colormaps)
```

Overview

The idea behind choosing a good colormap is to find a good representation in 3D colorspace for your data set. The best colormap for any given data set depends on many things including:

- Whether representing form or metric data ([**?**])
- Your knowledge of the data set (*e.g.*, is there a critical value from which the other values deviate?)
- If there is an intuitive color scheme for the parameter you are plotting

- If there is a standard in the field the audience may be expecting

For many applications, a perceptually uniform colormap is the best choice; i.e. a colormap in which equal steps in data are perceived as equal steps in the color space. Researchers have found that the human brain perceives changes in the lightness parameter as changes in the data much better than, for example, changes in hue. Therefore, colormaps which have monotonically increasing lightness through the colormap will be better interpreted by the viewer. Wonderful examples of perceptually uniform colormaps can be found in the Third-party colormaps section as well.

Color can be represented in 3D space in various ways. One way to represent color is using CIELAB. In CIELAB, color space is represented by lightness, L^*; red-green, a^*; and yellow-blue, b^*. The lightness parameter L^* can then be used to learn more about how the matplotlib colormaps will be perceived by viewers.

An excellent starting resource for learning about human perception of colormaps is from [**?**].

Classes of colormaps

Colormaps are often split into several categories based on their function (see, *e.g.*, [**?**]):

1. Sequential: change in lightness and often saturation of color incrementally, often using a single hue; should be used for representing information that has ordering.
2. Diverging: change in lightness and possibly saturation of two different colors that meet in the middle at an unsaturated color; should be used when the information being plotted has a critical middle value, such as topography or when the data deviates around zero.
3. Cyclic: change in lightness of two different colors that meet in the middle and beginning/end at an unsaturated color; should be used for values that wrap around at the endpoints, such as phase angle, wind direction, or time of day.
4. Qualitative: often are miscellaneous colors; should be used to represent information which does not have ordering or relationships.

```
from colorspacious import cspace_converter

import matplotlib.pyplot as plt
import numpy as np

import matplotlib as mpl
```

First, we'll show the range of each colormap. Note that some seem to change more "quickly" than others.

```
cmaps = {}

gradient = np.linspace(0, 1, 256)
gradient = np.vstack((gradient, gradient))


def plot_color_gradients(category, cmap_list):
    # Create figure and adjust figure height to number of colormaps
```

(continues on next page)

(continued from previous page)

```
    nrows = len(cmap_list)
    figh = 0.35 + 0.15 + (nrows + (nrows - 1) * 0.1) * 0.22
    fig, axs = plt.subplots(nrows=nrows + 1, figsize=(6.4, figh))
    fig.subplots_adjust(top=1 - 0.35 / figh, bottom=0.15 / figh,
                        left=0.2, right=0.99)
    axs[0].set_title(f'{category} colormaps', fontsize=14)

    for ax, name in zip(axs, cmap_list):
        ax.imshow(gradient, aspect='auto', cmap=mpl.colormaps[name])
        ax.text(-0.01, 0.5, name, va='center', ha='right', fontsize=10,
                transform=ax.transAxes)

    # Turn off *all* ticks & spines, not just the ones with colormaps.
    for ax in axs:
        ax.set_axis_off()

    # Save colormap list for later.
    cmaps[category] = cmap_list
```

Sequential

For the Sequential plots, the lightness value increases monotonically through the colormaps. This is good. Some of the L^* values in the colormaps span from 0 to 100 (binary and the other grayscale), and others start around $L^* = 20$. Those that have a smaller range of L^* will accordingly have a smaller perceptual range. Note also that the L^* function varies amongst the colormaps: some are approximately linear in L^* and others are more curved.

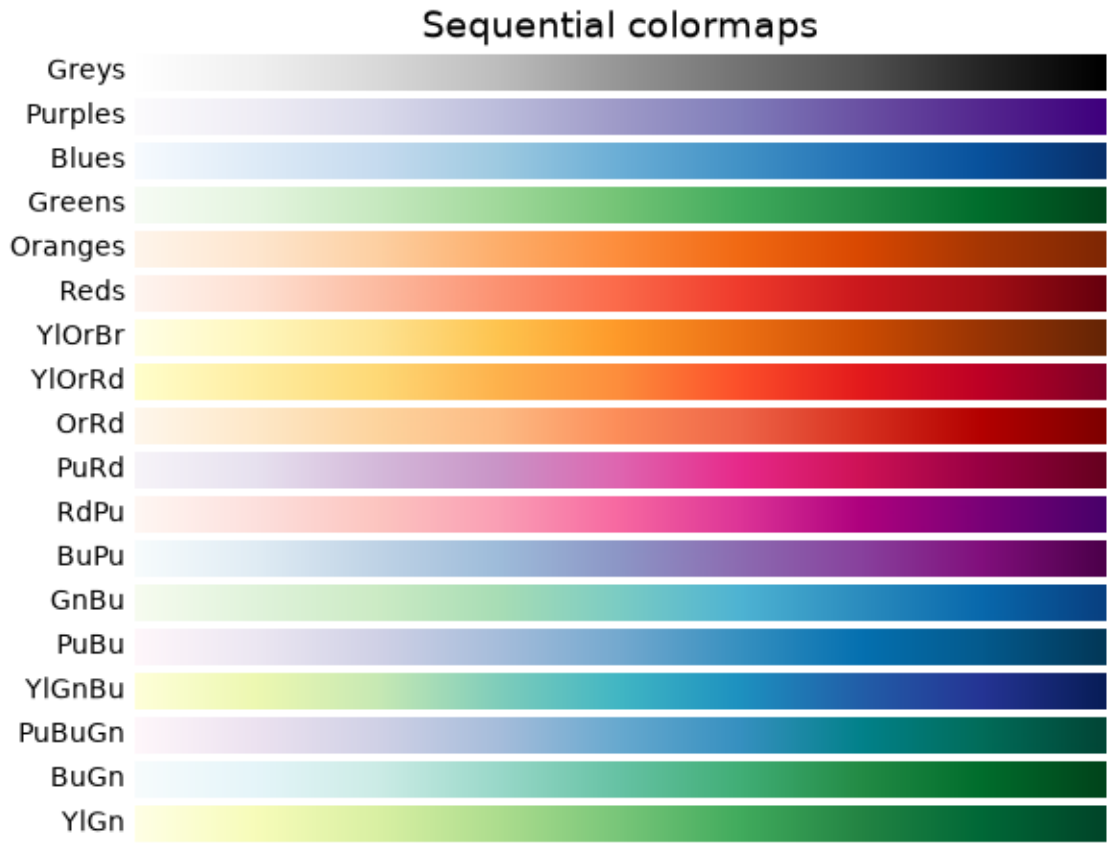
```
plot_color_gradients('Perceptually Uniform Sequential',
                     ['viridis', 'plasma', 'inferno', 'magma', 'cividis
 ↪'])
```

```
plot_color_gradients('Sequential',
                     ['Greys', 'Purples', 'Blues', 'Greens', 'Oranges',
 ↪ 'Reds',
                      'YlOrBr', 'YlOrRd', 'OrRd', 'PuRd', 'RdPu', 'BuPu
 ↪',
```

(continues on next page)

(continued from previous page)

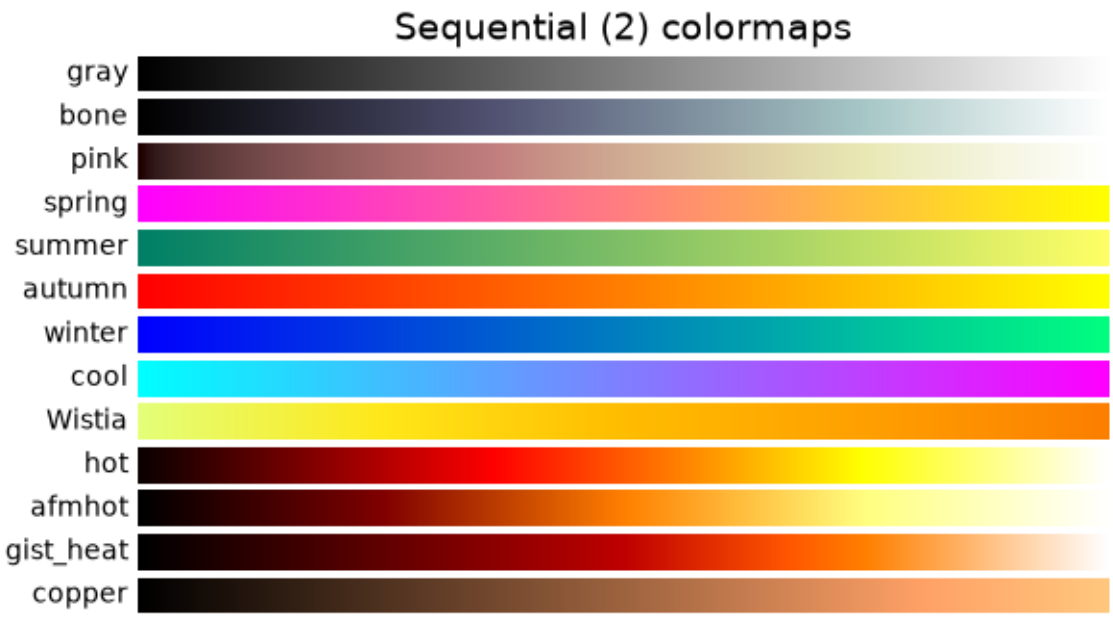
```
                      'GnBu', 'PuBu', 'YlGnBu', 'PuBuGn', 'BuGn', 'YlGn
↪'])
```



Sequential2

Many of the L^* values from the Sequential2 plots are monotonically increasing, but some (autumn, cool, spring, and winter) plateau or even go both up and down in L^* space. Others (afmhot, copper, gist_heat, and hot) have kinks in the L^* functions. Data that is being represented in a region of the colormap that is at a plateau or kink will lead to a perception of banding of the data in those values in the colormap (see [**?**] for an excellent example of this).

```
plot_color_gradients('Sequential (2)',
                     ['gray', 'bone', 'pink', 'spring', 'summer',
↪'autumn',
                      'winter', 'cool', 'Wistia', 'hot', 'afmhot',
↪'gist_heat',
                      'copper'])
```



Discouraged

For backward compatibility we additionally support the following colormap names, which are identical to other builtin colormaps. Their use is discouraged. Use the suggested replacement instead.

Colormap	Use identical replacement instead
gist_gray	gray
gist_yarg	gray_r
binary	gray_r

Diverging

For the Diverging maps, we want to have monotonically increasing L^* values up to a maximum, which should be close to $L^* = 100$, followed by monotonically decreasing L^* values. We are looking for approximately equal minimum L^* values at opposite ends of the colormap. By these measures, BrBG and RdBu are good options. coolwarm is a good option, but it doesn't span a wide range of L^* values (see grayscale section below).

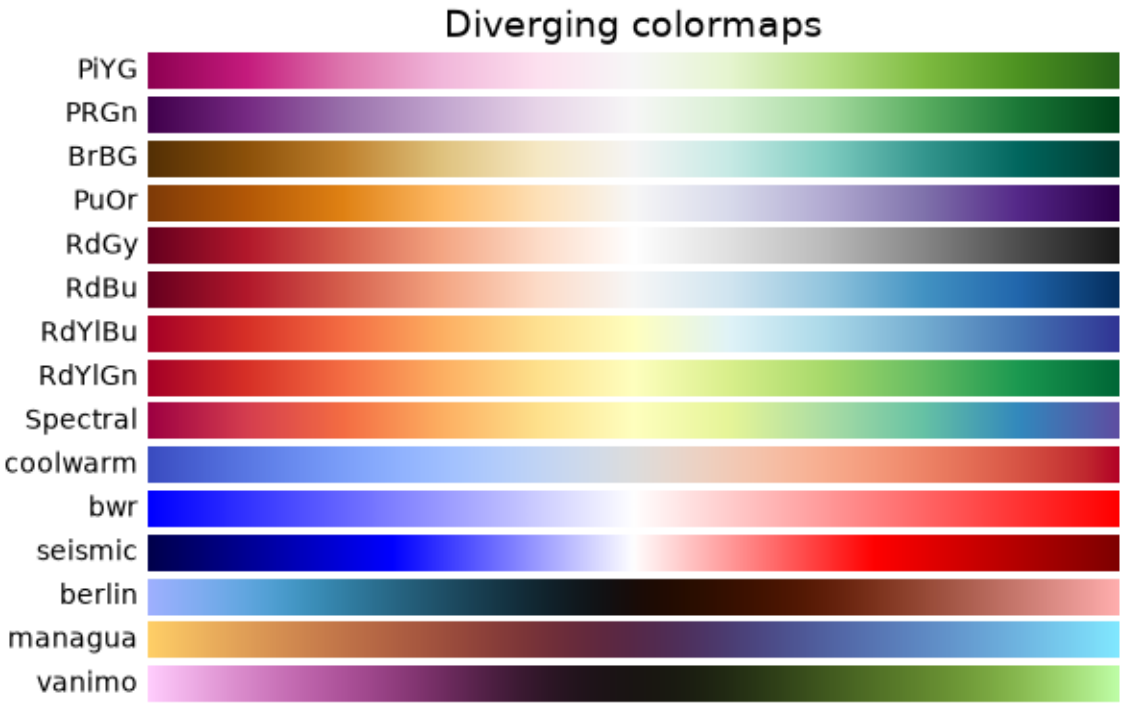
Berlin, Managua, and Vanimo are dark-mode diverging colormaps, with minimum lightness at the center, and maximum at the extremes. These are taken from F. Crameri's [**?**] version 8.0.1.

```
plot_color_gradients('Diverging',
                     ['PiYG', 'PRGn', 'BrBG', 'PuOr', 'RdGy', 'RdBu',
 ↪'RdYlBu',
                      'RdYlGn', 'Spectral', 'coolwarm', 'bwr', 'seismic
```

(continues on next page)

(continued from previous page)

```
↪',
                          'berlin', 'managua', 'vanimo'])
```

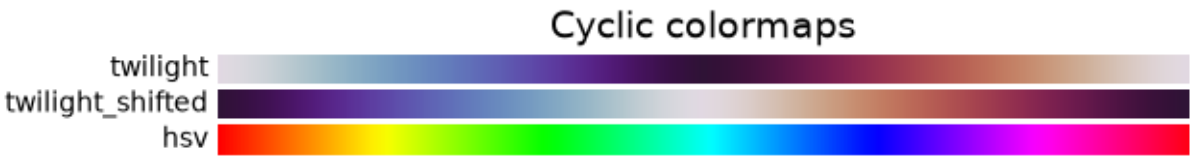


Cyclic

For Cyclic maps, we want to start and end on the same color, and meet a symmetric center point in the middle. L^* should change monotonically from start to middle, and inversely from middle to end. It should be symmetric on the increasing and decreasing side, and only differ in hue. At the ends and middle, L^* will reverse direction, which should be smoothed in L^* space to reduce artifacts. See [**?**] for more information on the design of cyclic maps.

The often-used HSV colormap is included in this set of colormaps, although it is not symmetric to a center point. Additionally, the L^* values vary widely throughout the colormap, making it a poor choice for representing data for viewers to see perceptually. See an extension on this idea at [**?**].

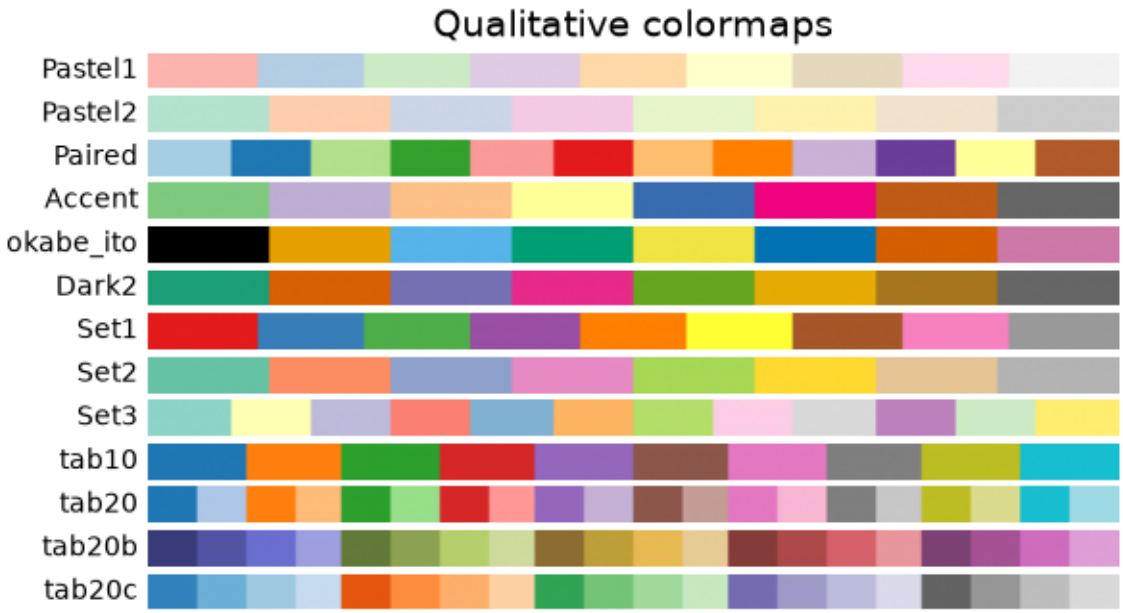
```
plot_color_gradients('Cyclic', ['twilight', 'twilight_shifted', 'hsv'])
```



Qualitative

Qualitative colormaps are not aimed at being perceptual maps, but looking at the lightness parameter can verify that for us. The L^* values move all over the place throughout the colormap, and are clearly not monotonically increasing. These would not be good options for use as perceptual colormaps.

```
plot_color_gradients('Qualitative',
                     ['Pastel1', 'Pastel2', 'Paired', 'Accent',
 ↪'okabe_ito',
                      'Dark2', 'Set1', 'Set2', 'Set3', 'tab10', 'tab20
 ↪',
                      'tab20b', 'tab20c'])
```

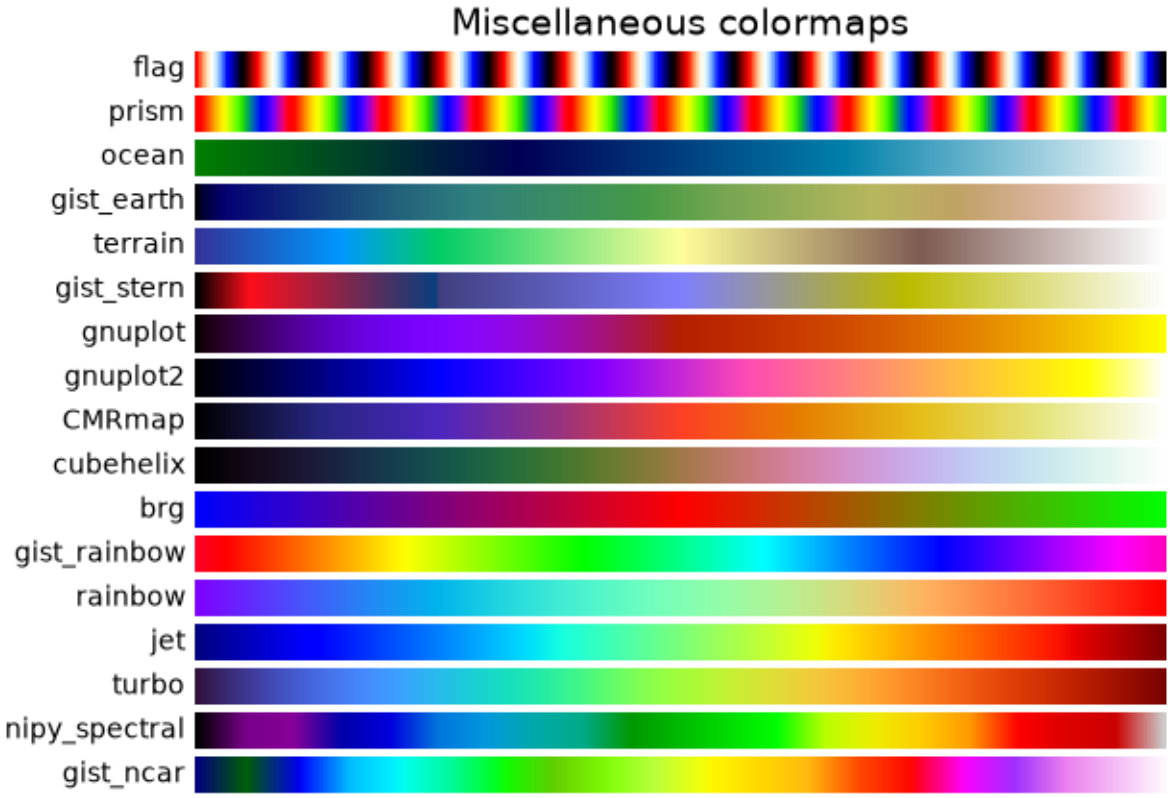


Miscellaneous

Some of the miscellaneous colormaps have particular uses for which they have been created. For example, gist_earth, ocean, and terrain all seem to be created for plotting topography (green/brown) and water depths (blue) together. We would expect to see a divergence in these colormaps, then, but multiple kinks may not be ideal, such as in gist_earth and terrain. CMRmap was created to convert well to grayscale, though it does appear to have some small kinks in L^*. cubehelix was created to vary smoothly in both lightness and hue, but appears to have a small hump in the green hue area. turbo was created to display depth and disparity data.

The often-used jet colormap is included in this set of colormaps. We can see that the L^* values vary widely throughout the colormap, making it a poor choice for representing data for viewers to see perceptually. See an extension on this idea at [**?**] and [**?**].

```
plot_color_gradients('Miscellaneous',
                     ['flag', 'prism', 'ocean', 'gist_earth', 'terrain
 ↪',
                      'gist_stern', 'gnuplot', 'gnuplot2', 'CMRmap',
                      'cubehelix', 'brg', 'gist_rainbow', 'rainbow',
 ↪'jet',
                      'turbo', 'nipy_spectral', 'gist_ncar'])

plt.show()
```



Lightness of Matplotlib colormaps

Here we examine the lightness values of the matplotlib colormaps. Note that some documentation on the colormaps is available ([**?**]).

```
mpl.rcParams.update({'font.size': 12})

# Number of colormap per subplot for particular cmap categories
_DSUBS = {'Perceptually Uniform Sequential': 5, 'Sequential': 6,
          'Sequential (2)': 6, 'Diverging': 6, 'Cyclic': 3,
          'Qualitative': 4, 'Miscellaneous': 6}
```

(continues on next page)

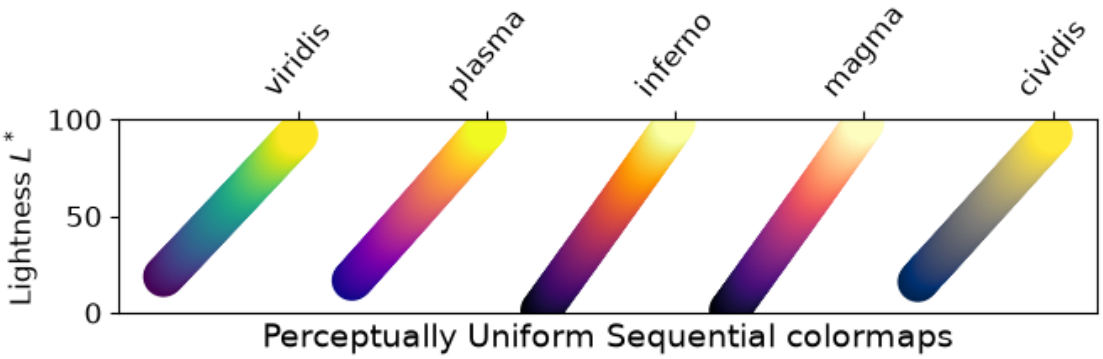
(continued from previous page)

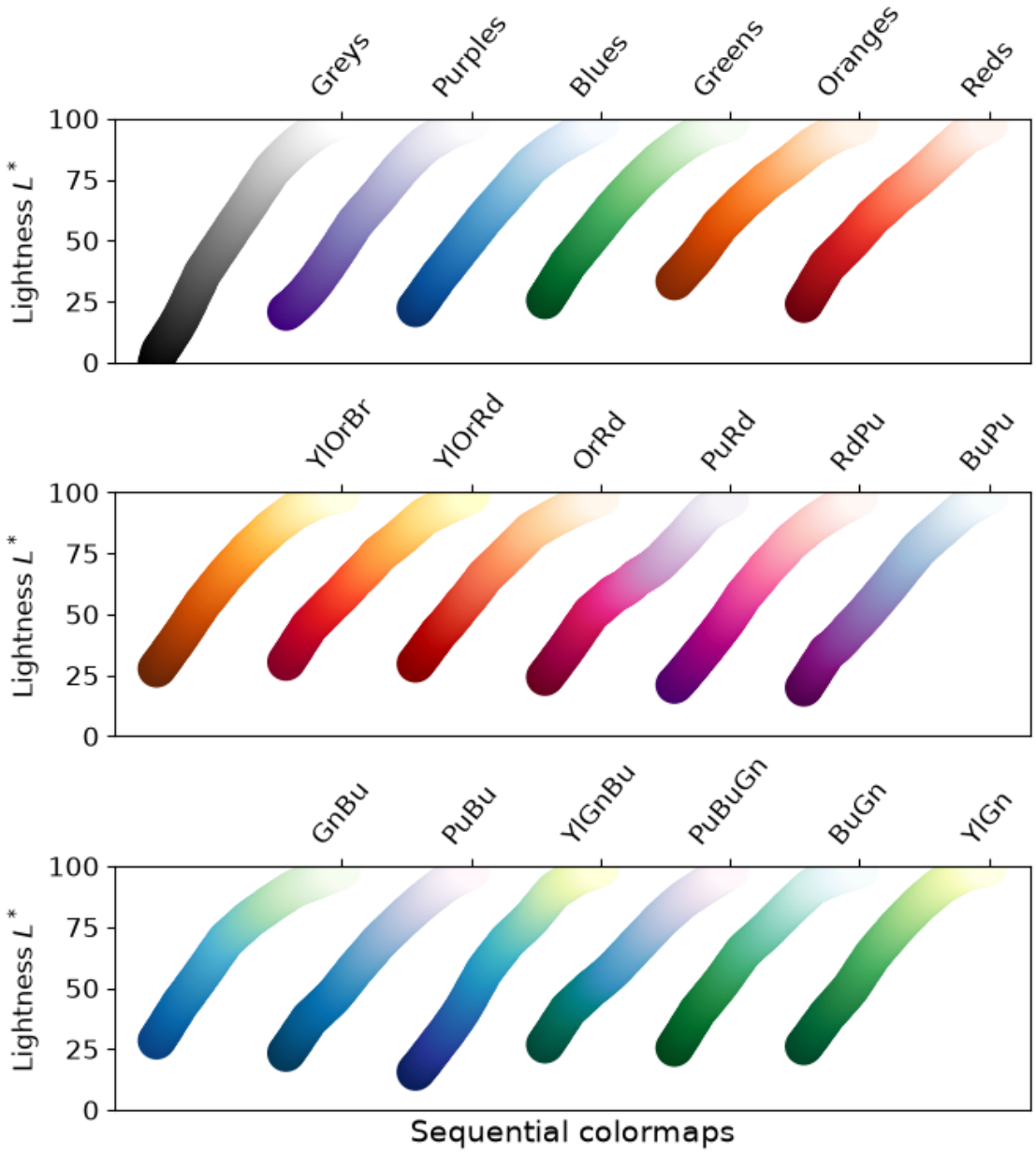
```
# Spacing between the colormaps of a subplot
_DC = {'Perceptually Uniform Sequential': 1.4, 'Sequential': 0.7,
       'Sequential (2)': 1.4, 'Diverging': 1.4, 'Cyclic': 1.4,
       'Qualitative': 1.4, 'Miscellaneous': 1.4}

# Indices to step through colormap
x = np.linspace(0.0, 1.0, 100)

# Do plot
for cmap_category, cmap_list in cmaps.items():

    # Do subplots so that colormaps have enough space.
    # Default is 6 colormaps per subplot.
    dsub = _DSUBS.get(cmap_category, 6)
    nsubplots = int(np.ceil(len(cmap_list) / dsub))

    # squeeze=False to handle similarly the case of a single subplot
    fig, axs = plt.subplots(nrows=nsubplots, squeeze=False,
                            figsize=(7, 2.6*nsubplots))

    for i, ax in enumerate(axs.flat):

        locs = []  # locations for text labels

        for j, cmap in enumerate(cmap_list[i*dsub:(i+1)*dsub]):

            # Get RGB values for colormap and convert the colormap in
            # CAM02-UCS colorspace.  lab[0, :, 0] is the lightness.
            rgb = mpl.colormaps[cmap](x)[np.newaxis, :, :3]
            lab = cspace_converter("sRGB1", "CAM02-UCS")(rgb)

            # Plot colormap L values.  Do separately for each category
            # so each plot can be pretty.  To make scatter markers␣
↪change
            # color along plot:
            # https://stackoverflow.com/q/8202605/

            if cmap_category == 'Sequential':
                # These colormaps all start at high lightness, but we␣
↪want them
                # reversed to look nice in the plot, so reverse the␣
↪order.
                y_ = lab[0, ::-1, 0]
                c_ = x[::-1]
            else:
```

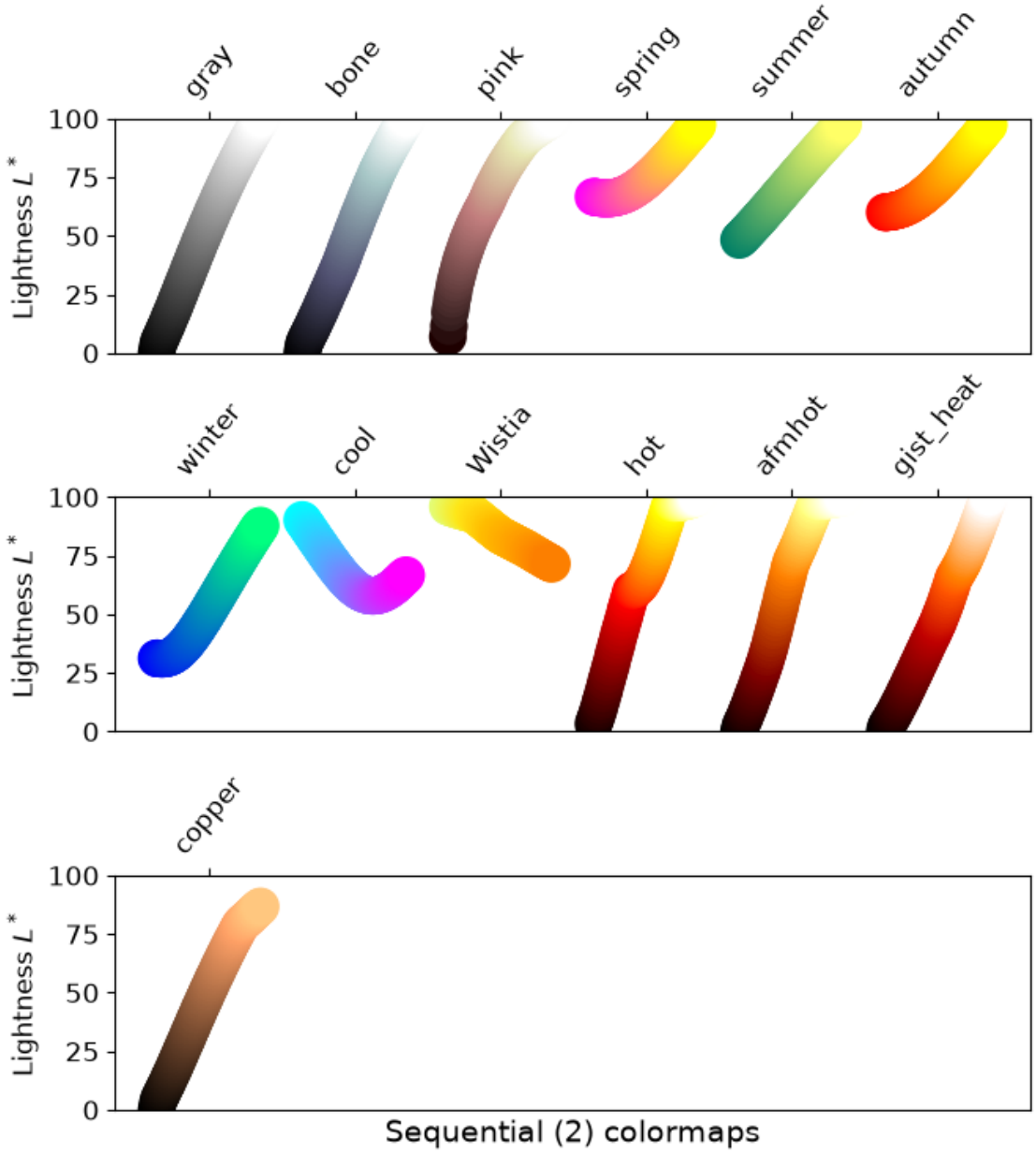
(continues on next page)

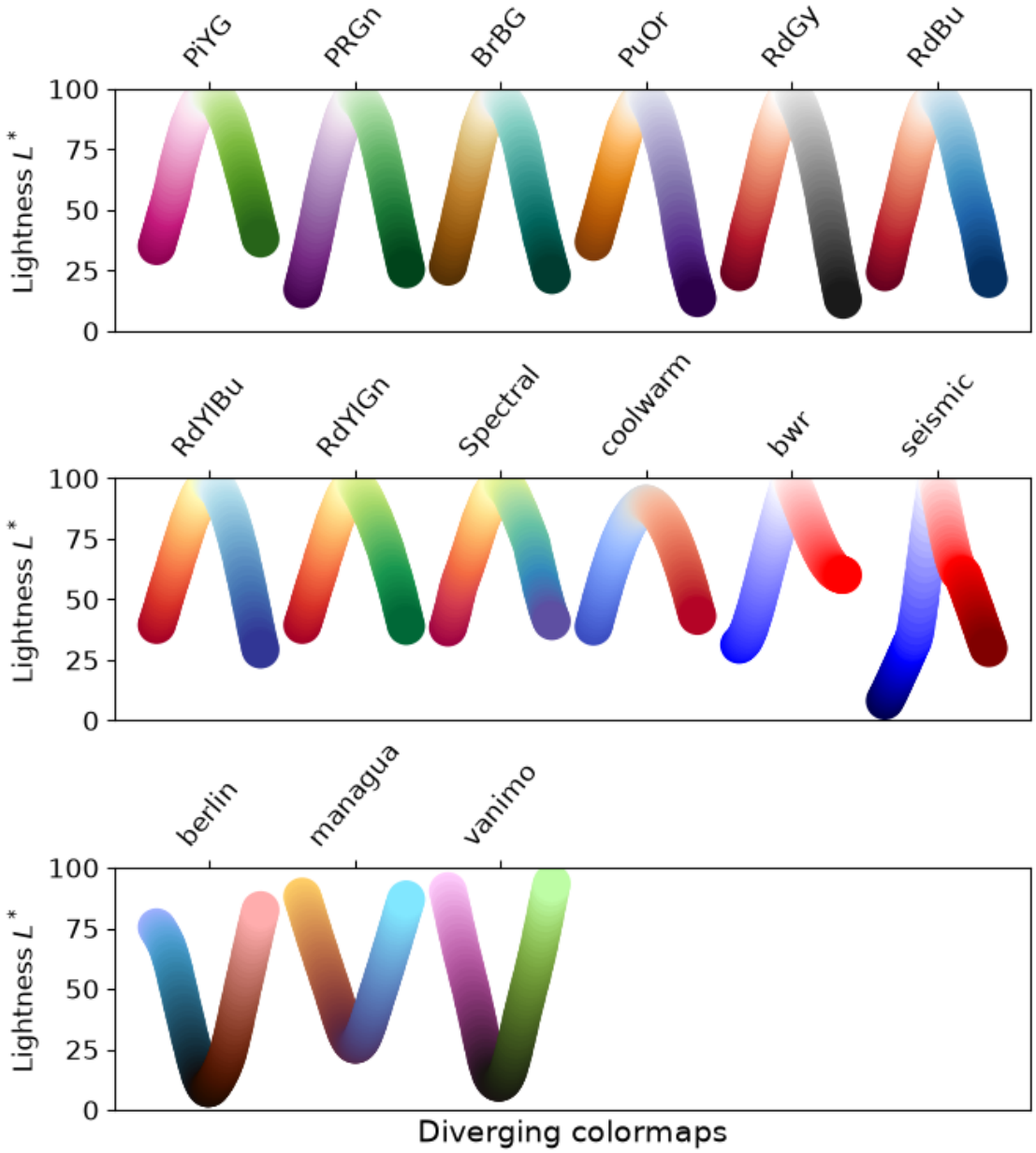
(continued from previous page)

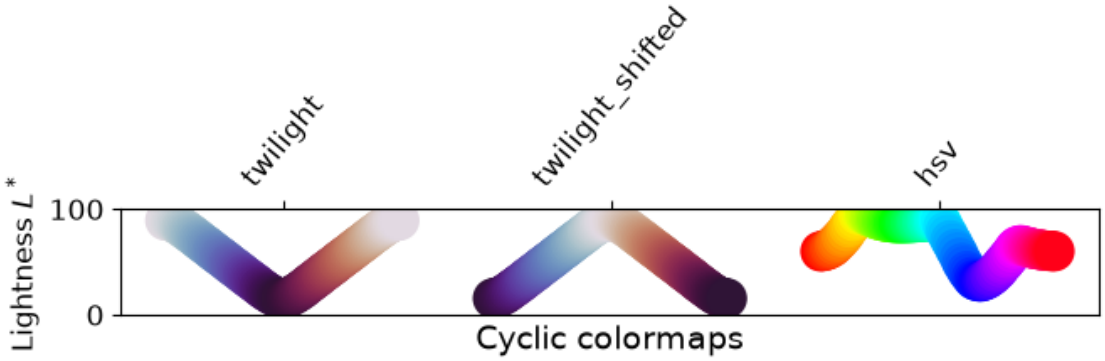
```
                y_ = lab[0, :, 0]
                c_ = x

            dc = _DC.get(cmap_category, 1.4)  # cmaps horizontal␣
↪spacing
            ax.scatter(x + j*dc, y_, c=c_, cmap=cmap, s=300,␣
↪linewidths=0.0)

            # Store locations for colormap labels
            if cmap_category in ('Perceptually Uniform Sequential',
                                 'Sequential'):
                locs.append(x[-1] + j*dc)
            elif cmap_category in ('Diverging', 'Qualitative', 'Cyclic
↪',
                                   'Miscellaneous', 'Sequential (2)'):
                locs.append(x[int(x.size/2.)] + j*dc)

        # Set up the axis limits:
        #   * the 1st subplot is used as a reference for the x-axis␣
↪limits
        #   * lightness values goes from 0 to 100 (y-axis limits)
        ax.set_xlim(axs[0, 0].get_xlim())
        ax.set_ylim(0.0, 100.0)

        # Set up labels for colormaps
        ax.xaxis.set_ticks_position('top')
        ticker = mpl.ticker.FixedLocator(locs)
        ax.xaxis.set_major_locator(ticker)
        formatter = mpl.ticker.
↪FixedFormatter(cmap_list[i*dsub:(i+1)*dsub])
        ax.xaxis.set_major_formatter(formatter)
        ax.xaxis.set_tick_params(rotation=50)
        ax.set_ylabel('Lightness $L^*$', fontsize=12)

    ax.set_xlabel(cmap_category + ' colormaps', fontsize=14)

    fig.tight_layout(h_pad=0.0, pad=1.5)
    plt.show()
```

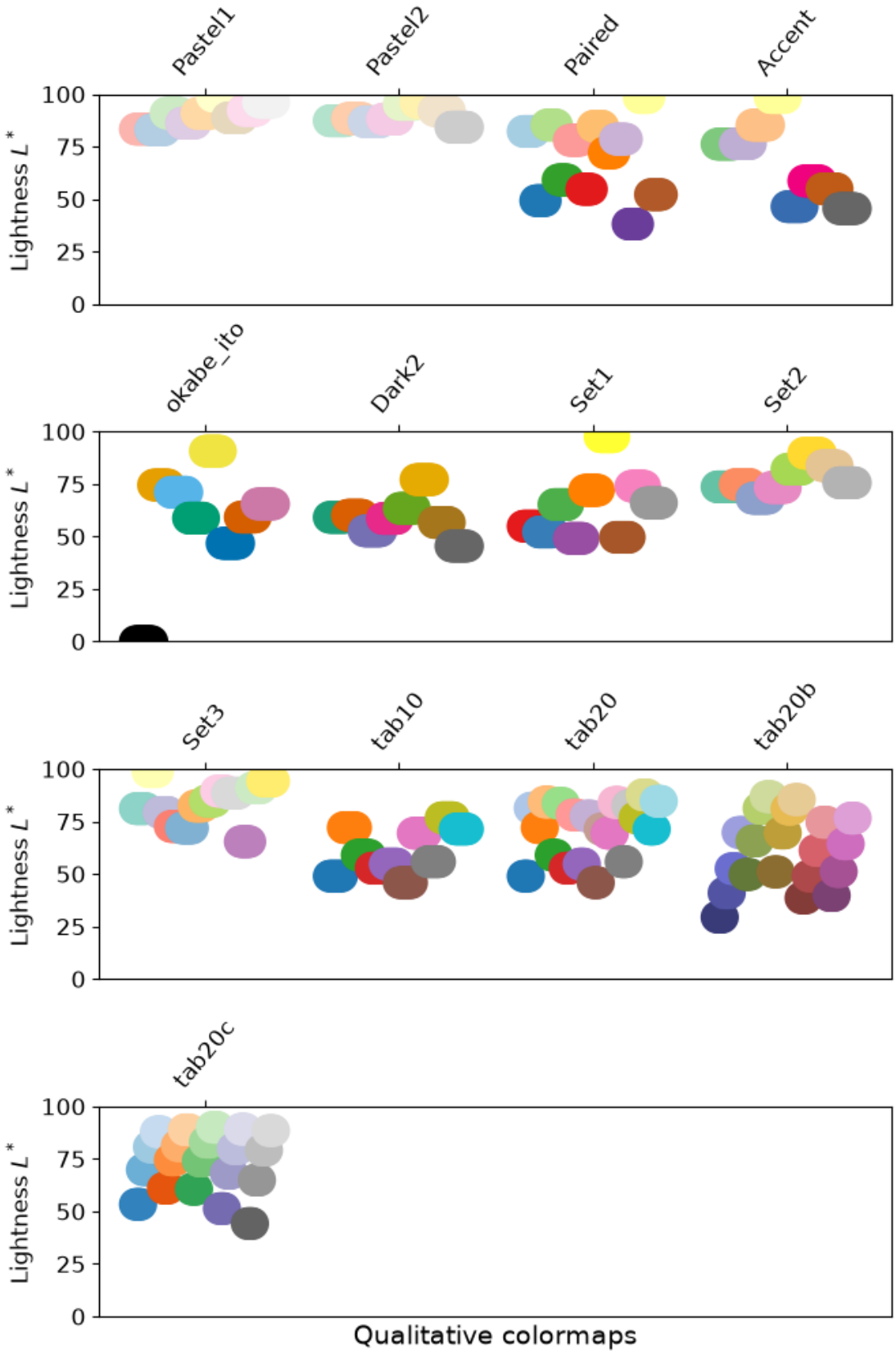

viridis
plasma
inferno
magma
cividis
100
50
0
Lightness L^*
Perceptually Uniform Sequential colormaps

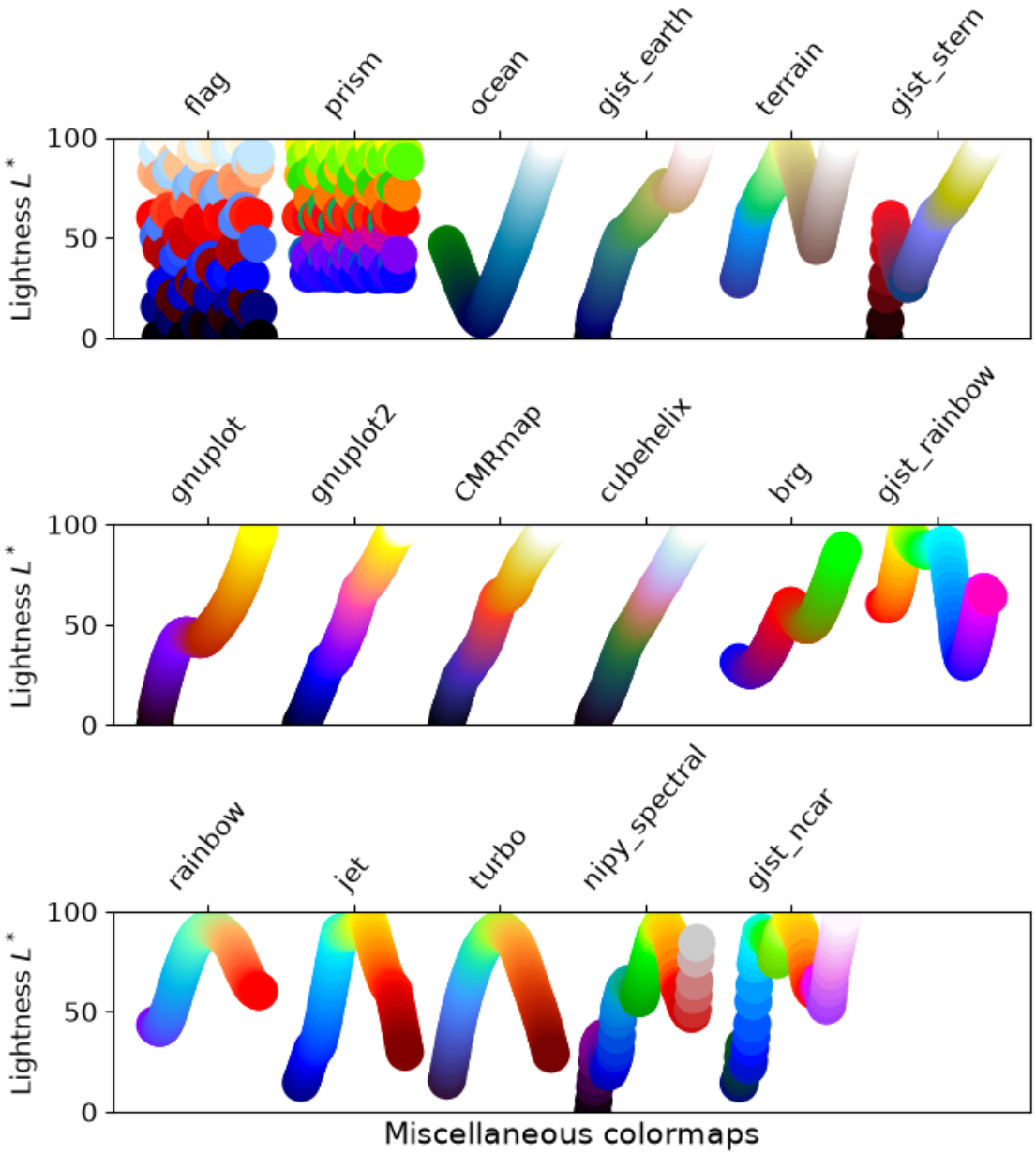

Greys
Purples
Blues
Greens
Oranges
Reds
YlOrBr
YlOrRd
OrRd
PuRd
RdPu
BuPu
GnBu
PuBu
YlGnBu
PuBuGn
BuGn
YlGn
Lightness L^*
100
75
50
25
0
Sequential colormaps


gray
bone
pink
spring
summer
autumn
winter
cool
Wistia
hot
afmhot
gist_heat
copper
Lightness L^*
100
75
50
25
0
Sequential (2) colormaps


PiYG
PRGn
BrBG
PuOr
RdGy
RdBu
RdYlBu
RdYlGn
Spectral
coolwarm
bwr
seismic
berlin
managua
vanimo
Lightness L^*
100
75
50
25
0
Diverging colormaps


twilight
twilight_shifted
hsv
Lightness L^*
100
0
Cyclic colormaps


Pastel1
Pastel2
Paired
Accent
okabe_ito
Dark2
Set1
Set2
Set3
tab10
tab20
tab20b
tab20c
Lightness L^*
100
75
50
25
0
Qualitative colormaps



-

Grayscale conversion

It is important to pay attention to conversion to grayscale for color plots, since they may be printed on black and white printers. If not carefully considered, your readers may end up with indecipherable plots because the grayscale changes unpredictably through the colormap.

Conversion to grayscale is done in many different ways [**?**]. Some of the better ones use a linear combination of the rgb values of a pixel, but weighted according to how we perceive color intensity. A nonlinear method of conversion to grayscale is to use the L^* values of the pixels. In general, similar principles apply for this question as they do for presenting one's information perceptually; that is, if a colormap is chosen that is monotonically increasing in L^* values, it will print in a reasonable manner to grayscale.

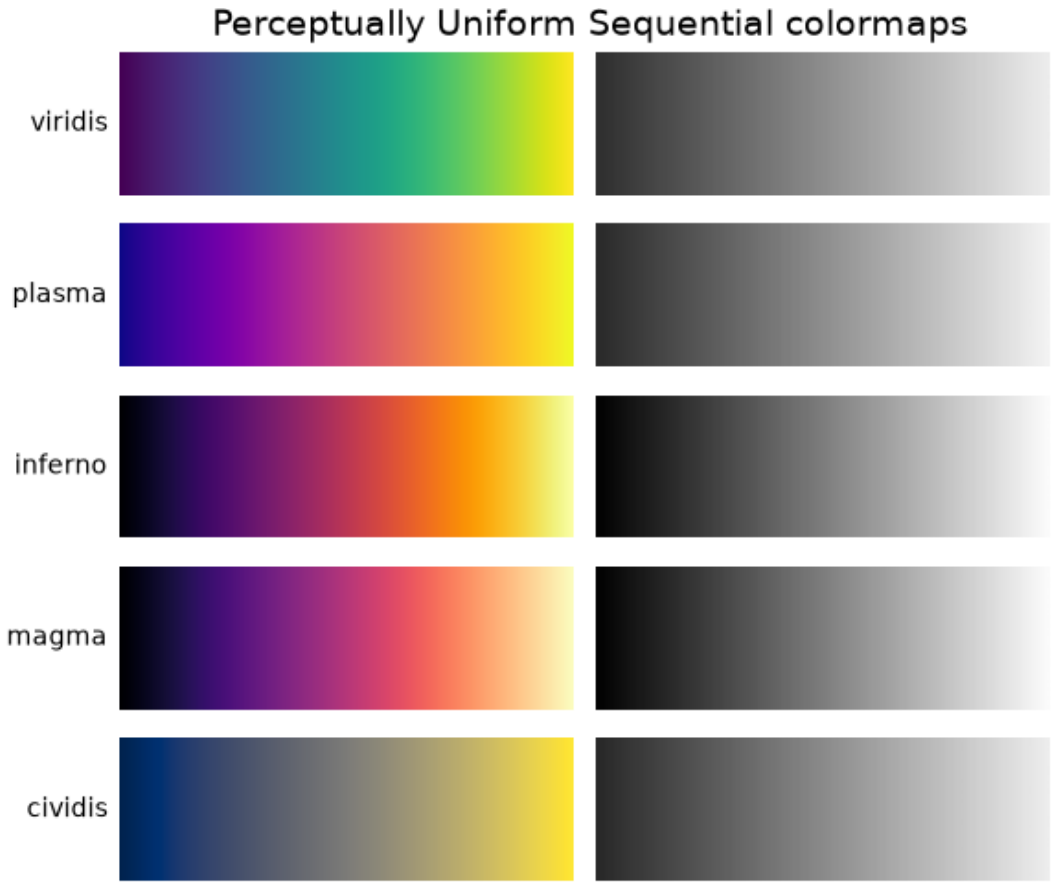
With this in mind, we see that the Sequential colormaps have reasonable representations in grayscale. Some of the Sequential2 colormaps have decent enough grayscale representations, though some (autumn, spring, summer, winter) have very little grayscale change. If a colormap like this was used in a plot and then the plot was printed to grayscale, a lot of the information may map to the same gray values. The Diverging colormaps mostly vary from darker gray on the outer edges to white in the middle. Some (PuOr and seismic) have noticeably darker gray on one side than the other and therefore are not very symmetric. coolwarm has little range of gray scale and would print to a more uniform plot, losing a lot of detail. Note that overlaid, labeled contours could help differentiate between one side of the colormap vs. the other since color cannot be used once a plot is printed to grayscale. Many of the Qualitative and Miscellaneous colormaps, such as Accent, hsv, jet and turbo, change from darker to lighter and back to darker grey throughout the colormap. This would make it impossible for a viewer to interpret the information in a plot once it is printed in grayscale.

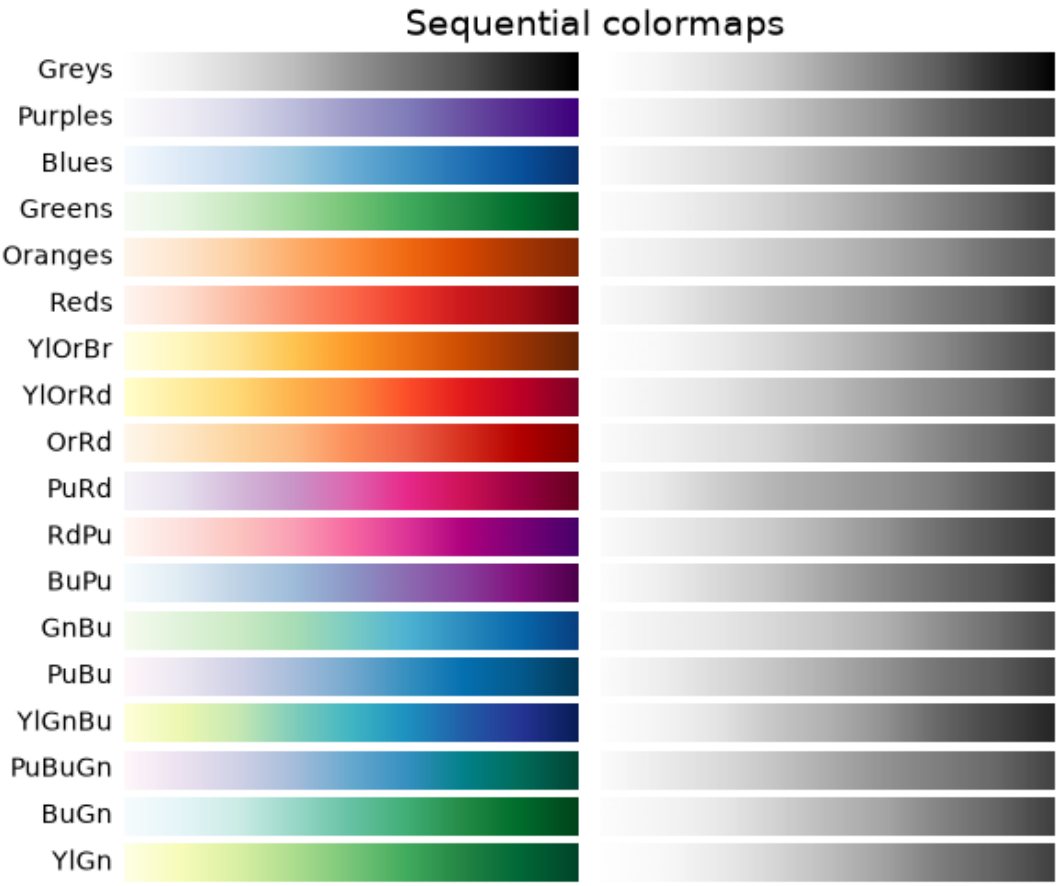
```
mpl.rcParams.update({'font.size': 14})

# Indices to step through colormap.
x = np.linspace(0.0, 1.0, 100)

gradient = np.linspace(0, 1, 256)
gradient = np.vstack((gradient, gradient))


def plot_color_gradients(cmap_category, cmap_list):
    fig, axs = plt.subplots(nrows=len(cmap_list), ncols=2)
    fig.subplots_adjust(top=0.95, bottom=0.01, left=0.2, right=0.99,
                        wspace=0.05)
    fig.suptitle(cmap_category + ' colormaps', fontsize=14, y=1.0,␣
↪x=0.6)

    for ax, name in zip(axs, cmap_list):

        # Get RGB values for colormap.
        rgb = mpl.colormaps[name](x)[np.newaxis, :, :3]

        # Get colormap in CAM02-UCS colorspace. We want the lightness.
        lab = cspace_converter("sRGB1", "CAM02-UCS")(rgb)
        L = lab[0, :, 0]
        L = np.float32(np.vstack((L, L, L)))

        ax[0].imshow(gradient, aspect='auto', cmap=mpl.colormaps[name])
        ax[1].imshow(L, aspect='auto', cmap='binary_r', vmin=0.,␣
↪vmax=100.)
        pos = list(ax[0].get_position().bounds)
        x_text = pos[0] - 0.01
        y_text = pos[1] + pos[3]/2.
        fig.text(x_text, y_text, name, va='center', ha='right',␣
↪fontsize=10)
```

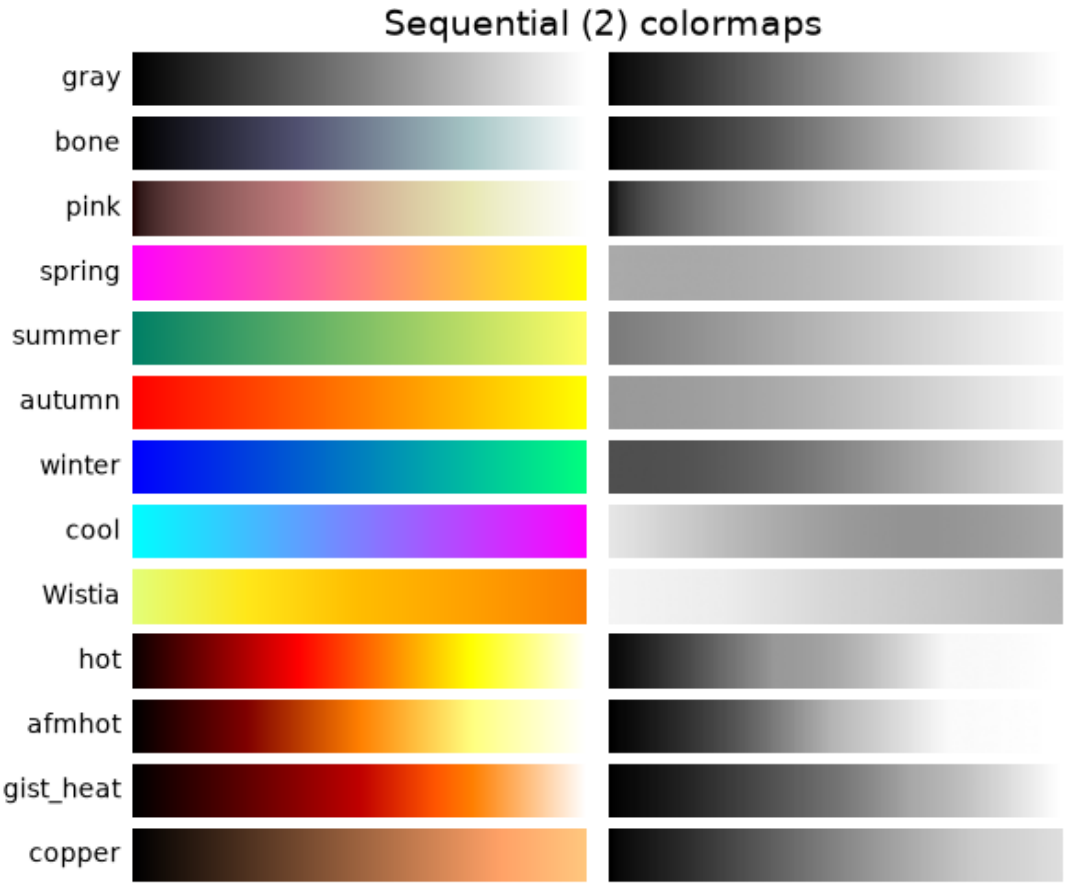
(continues on next page)

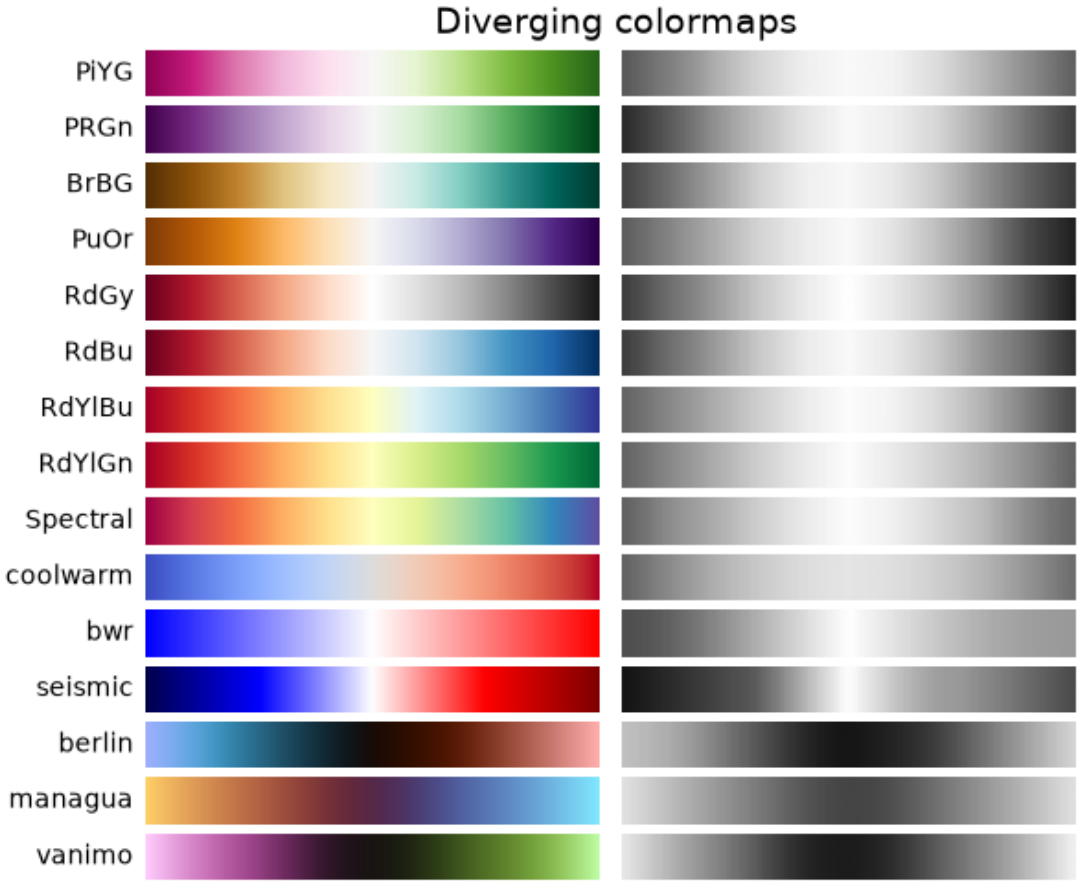
(continued from previous page)

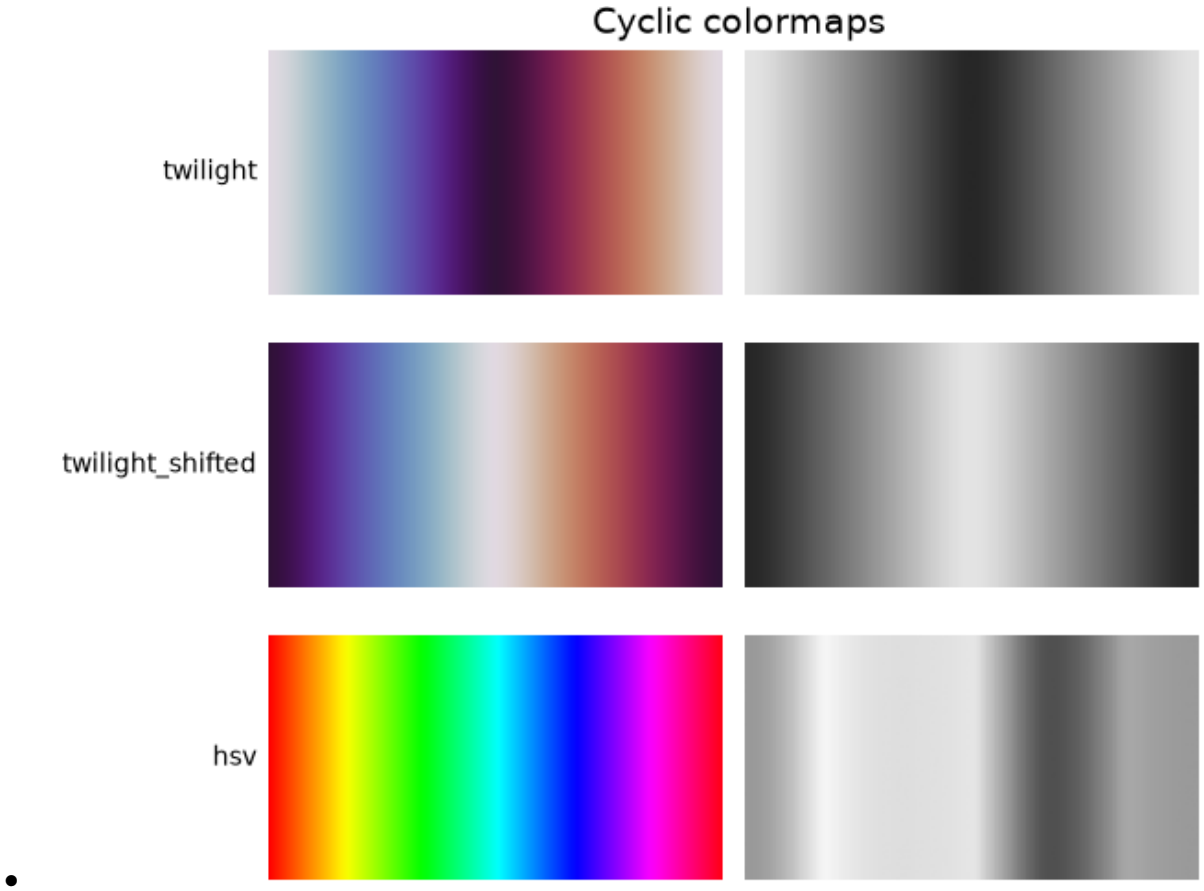
```
    # Turn off *all* ticks & spines, not just the ones with colormaps.
    for ax in axs.flat:
        ax.set_axis_off()

    plt.show()


for cmap_category, cmap_list in cmaps.items():

    plot_color_gradients(cmap_category, cmap_list)
```

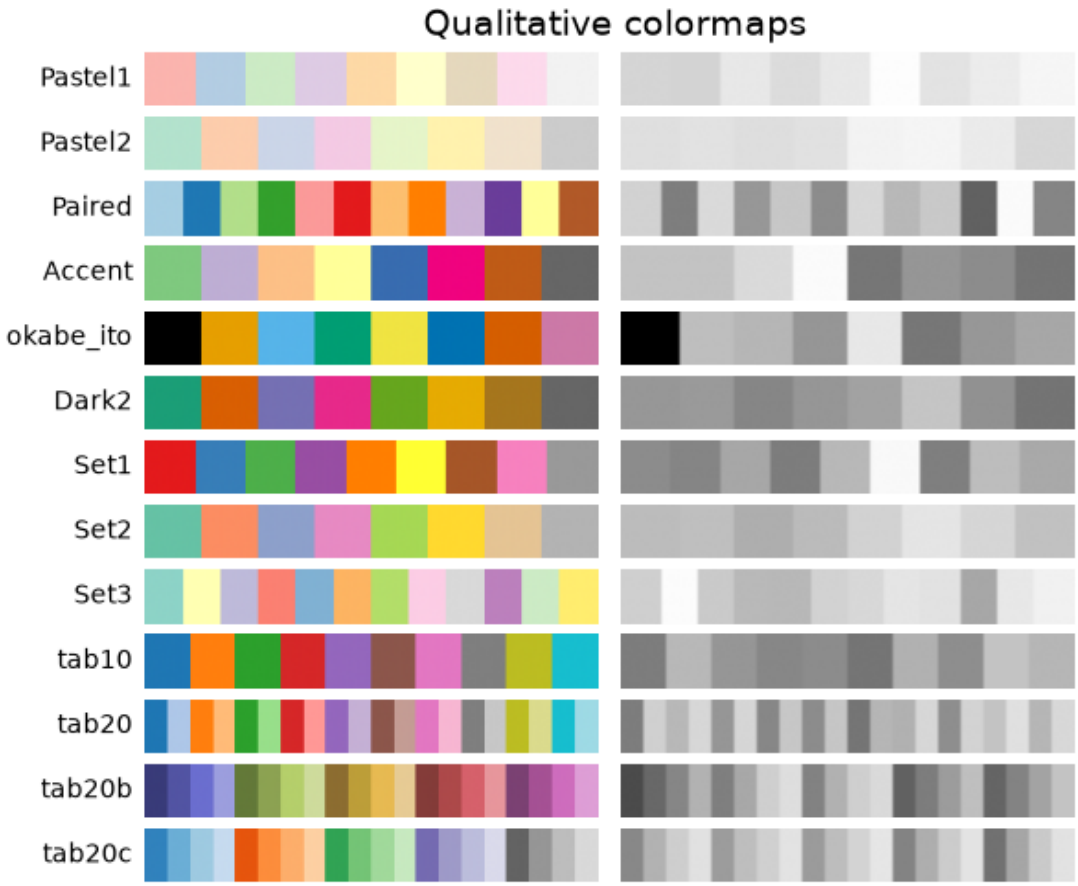


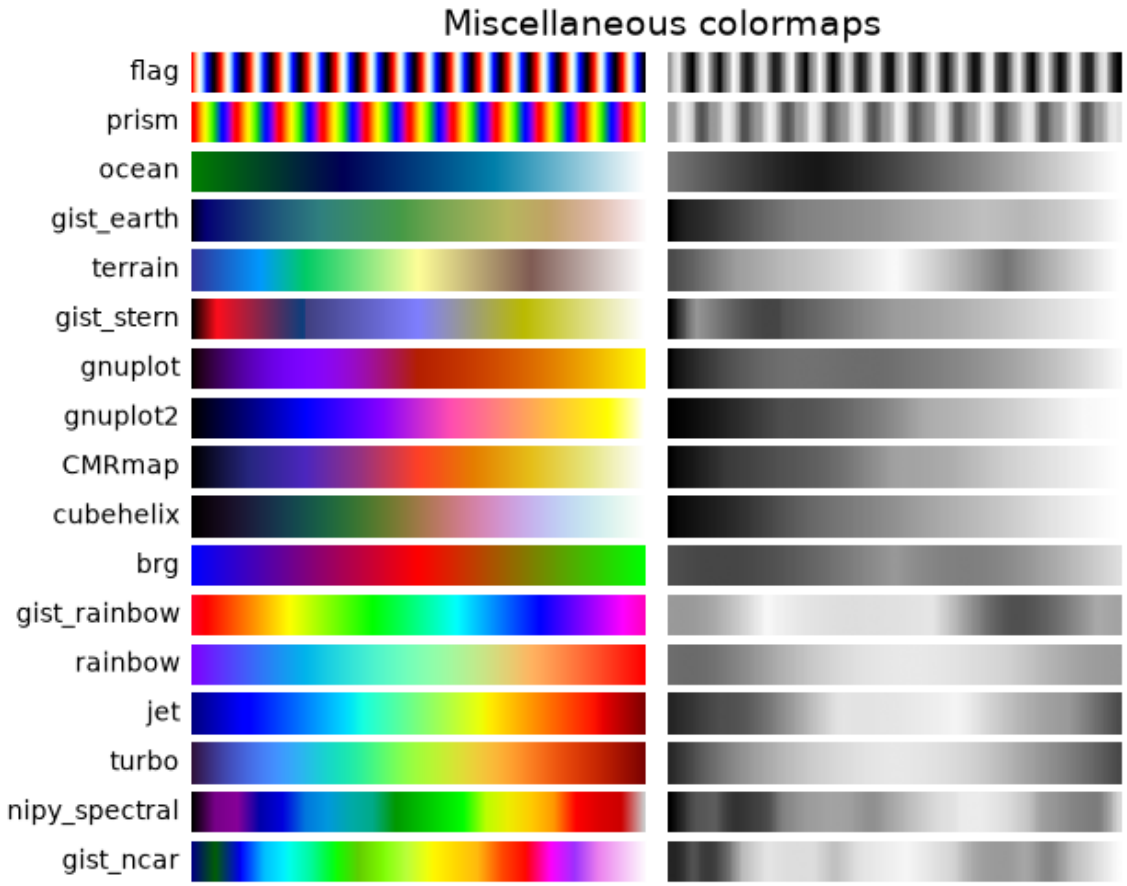

Sequential colormaps
Greys
Purples
Blues
Greens
Oranges
Reds
YlOrBr
YlOrRd
OrRd
PuRd
RdPu
BuPu
GnBu
PuBu
YlGnBu
PuBuGn
BuGn
YlGn


Sequential (2) colormaps
gray
bone
pink
spring
summer
autumn
winter
cool
Wistia
hot
afmhot
gist_heat
copper


Diverging colormaps
PiYG
PRGn
BrBG
PuOr
RdGy
RdBu
RdYlBu
RdYlGn
Spectral
coolwarm
bwr
seismic
berlin
managua
vanimo


Cyclic colormaps
twilight
twilight_shifted
hsv


Qualitative colormaps
Pastel1
Pastel2
Paired
Accent
okabe_ito
Dark2
Set1
Set2
Set3
tab10
tab20
tab20b
tab20c



Color vision deficiencies

There is a lot of information available about color blindness (*e.g.*, [**?**]). Additionally, there are tools available to convert images to how they look for different types of color vision deficiencies.

The most common form of color vision deficiency involves differentiating between red and green. Thus, avoiding colormaps with both red and green will avoid many problems in general.

References

Total running time of the script: (0 minutes 9.893 seconds)

3.7.5 Specifying colors

Color formats

Matplotlib recognizes the following formats to specify a color.

Format	Example
RGB or RGBA (red, green, blue, alpha) tuple of float values in a closed interval [0, 1].	• `(0.1, 0.2, 0.5)` • `(0.1, 0.2, 0.5, 0.3)`
Case-insensitive hex RGB or RGBA string.	• `'#0f0f0f'` • `'#0f0f0f80'`
Case-insensitive RGB or RGBA string equivalent hex shorthand of duplicated characters.	• `'#abc'` as `'#aabbcc'` • `'#fb1'` as `'#ffbb11'`
String representation of float value in closed interval `[0, 1]` for grayscale values.	• `'0'` as black • `'1'` as white • `'0.8'` as light gray
Single character shorthand notation for some basic colors. **Note** The colors green, cyan, magenta, and yellow do not coincide with X11/CSS4 colors. Their particular shades were chosen for better visibility of colored lines against typical backgrounds.	• `'b'` as blue • `'g'` as green • `'r'` as red • `'c'` as cyan • `'m'` as magenta • `'y'` as yellow • `'k'` as black • `'w'` as white
Case-insensitive X11/CSS4 color name with no spaces.	• `'aquamarine'` • `'mediumseagreen'`
Case-insensitive color name from xkcd color survey with `'xkcd:'` prefix.	• `'xkcd:sky blue'` • `'xkcd:eggshell'`
Case-insensitive Tableau Colors from 'T10' categorical palette. **Note** This is the default color cycle.	• `'tab:blue'` • `'tab:orange'` • `'tab:green'` • `'tab:red'` • `'tab:purple'` • `'tab:brown'` • `'tab:pink'` • `'tab:gray'` • `'tab:olive'` • `'tab:cyan'`
"CN" color spec where `'C'` precedes a number acting as an index into the default property cycle. **Note** Matplotlib indexes color at draw time and defaults to black if cycle does not include color.	• `'C0'` • `'C1'`
	rcParams["axes.prop_cycle"] (default: `cycler('color', [(0.12156862745098039, 0.4666666666666667, 0.7058823529411765), (1.0, 0.4980392156862745, 0.054901960784313725), (0.17254901960784313, 0.6274509803921569, 0.17254901960784313), (0.8392156862745098, 0.15294117647058825, 0.1568627450980392), (0.5803921568627451, 0.403921568627451, 0.`

See also

The following links provide more information on colors in Matplotlib.

- *Color Demo* Example
- `matplotlib.colors` API
- *List of named colors* Example

"Red", "Green", and "Blue" are the intensities of those colors. In combination, they represent the colorspace.

Transparency

The *alpha* value of a color specifies its transparency, where 0 is fully transparent and 1 is fully opaque. When a color is semi-transparent, the background color will show through.

The *alpha* value determines the resulting color by blending the foreground color with the background color according to the formula

$$RGB_{result} = RGB_{background} * (1 - \alpha) + RGB_{foreground} * \alpha$$

The following plot illustrates the effect of transparency.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Rectangle

fig, ax = plt.subplots(figsize=(6.5, 1.65), layout='constrained')
ax.add_patch(Rectangle((-0.2, -0.35), 11.2, 0.7, color='C1',␣
 ↪alpha=0.8))
for i, alpha in enumerate(np.linspace(0, 1, 11)):
    ax.add_patch(Rectangle((i, 0.05), 0.8, 0.6, alpha=alpha, zorder=0))
    ax.text(i+0.4, 0.85, f"{alpha:.1f}", ha='center')
    ax.add_patch(Rectangle((i, -0.05), 0.8, -0.6, alpha=alpha,␣
 ↪zorder=2))
ax.set_xlim(-0.2, 13)
ax.set_ylim(-1, 1)
ax.set_title('alpha values')
ax.text(11.3, 0.6, 'zorder=1', va='center', color='C0')
ax.text(11.3, 0, 'zorder=2\nalpha=0.8', va='center', color='C1')
ax.text(11.3, -0.6, 'zorder=3', va='center', color='C0')
ax.axis('off')
```

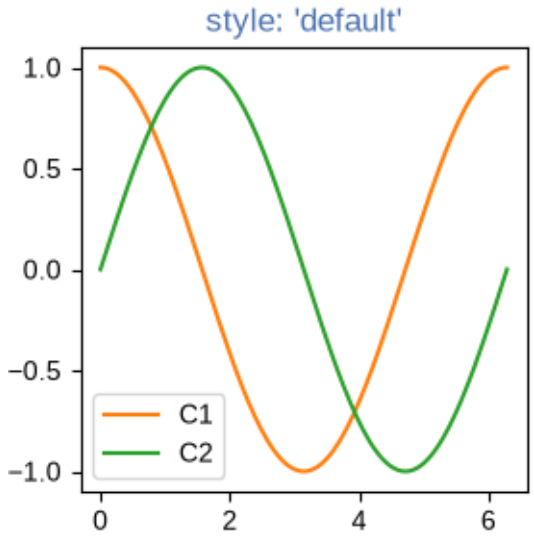
The orange rectangle is semi-transparent with *alpha* = 0.8. The top row of blue squares is drawn below and the bottom row of blue squares is drawn on top of the orange rectangle.

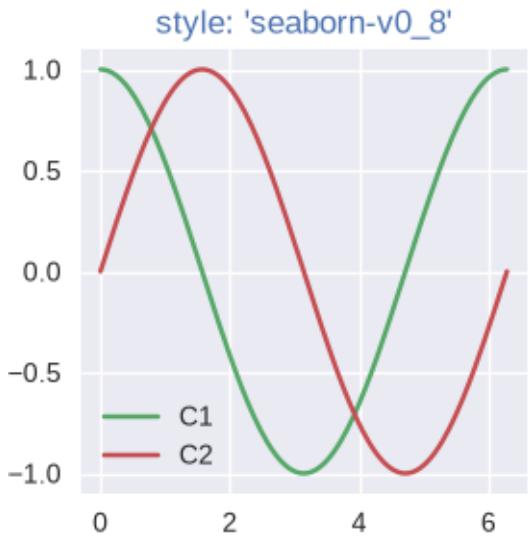
See also *Zorder Demo* to learn more on the drawing order.

"CN" color selection

Matplotlib converts "CN" colors to RGBA when drawing Artists. The *Styling with cycler* section contains additional information about controlling colors and style properties.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib as mpl

th = np.linspace(0, 2*np.pi, 128)


def demo(sty):
    mpl.style.use(sty)
    fig, ax = plt.subplots(figsize=(3, 3))

    ax.set_title(f'style: {sty!r}', color='C0')

    ax.plot(th, np.cos(th), 'C1', label='C1')
    ax.plot(th, np.sin(th), 'C2', label='C2')
    ax.legend()


demo('default')
demo('seaborn-v0_8')
```

- 

- 

The first color `'C0'` is the title. Each plot uses the second and third colors of each style's *rcParams["axes.prop_cycle"]* (default: `cycler('color', [(0.12156862745098039, 0.4666666666666667, 0.7058823529411765), (1.0, 0.4980392156862745, 0.054901960784313725), (0.17254901960784313, 0.6274509803921569, 0.17254901960784313), (0.8392156862745098, 0.15294117647058825, 0.1568627450980392), (0.5803921568627451, 0.403921568627451, 0.7411764705882353), (0.5490196078431373, 0.33725490196078434, 0.29411764705882354), (0.8901960784313725, 0.4666666666666667, 0.7607843137254902), (0.4980392156862745, 0.4980392156862745, 0.4980392156862745), (0.7372549019607844, 0.7411764705882353, 0.13333333333333333), (0.09019607843137255, 0.7450980392156863, 0.8117647058823529)])`). They are `'C1'` and `'C2'`, respectively.

Comparison between X11/CSS4 and xkcd colors

The xkcd colors come from a user survey conducted by the webcomic xkcd.

95 out of the 148 X11/CSS4 color names also appear in the xkcd color survey. Almost all of them map to different color values in the X11/CSS4 and in the xkcd palette. Only 'black', 'white' and 'cyan' are identical.

For example, `'blue'` maps to `'#0000FF'` whereas `'xkcd:blue'` maps to `'#0343DF'`. Due to these name collisions, all xkcd colors have the `'xkcd:'` prefix.

The visual below shows name collisions. Color names where color values agree are in bold.

```
import matplotlib.colors as mcolors
import matplotlib.patches as mpatch

overlap = {name for name in mcolors.CSS4_COLORS
           if f'xkcd:{name}' in mcolors.XKCD_COLORS}

fig = plt.figure(figsize=[9, 5])
ax = fig.add_axes((0, 0, 1, 1))

n_groups = 3
n_rows = len(overlap) // n_groups + 1

for j, color_name in enumerate(sorted(overlap)):
    css4 = mcolors.CSS4_COLORS[color_name]
    xkcd = mcolors.XKCD_COLORS[f'xkcd:{color_name}'].upper()

    # Pick text colour based on perceived luminance.
    rgba = mcolors.to_rgba_array([css4, xkcd])
    luma = 0.299 * rgba[:, 0] + 0.587 * rgba[:, 1] + 0.114 * rgba[:, 2]
    css4_text_color = 'k' if luma[0] > 0.5 else 'w'
    xkcd_text_color = 'k' if luma[1] > 0.5 else 'w'

    col_shift = (j // n_rows) * 3
    y_pos = j % n_rows
    text_args = dict(fontsize=10, weight='bold' if css4 == xkcd else␣
 ↪None)
    ax.add_patch(mpatch.Rectangle((0 + col_shift, y_pos), 1, 1,␣
 ↪color=css4))
    ax.add_patch(mpatch.Rectangle((1 + col_shift, y_pos), 1, 1,␣
 ↪color=xkcd))
    ax.text(0.5 + col_shift, y_pos + .7, css4,
            color=css4_text_color, ha='center', **text_args)
    ax.text(1.5 + col_shift, y_pos + .7, xkcd,
            color=xkcd_text_color, ha='center', **text_args)
    ax.text(2 + col_shift, y_pos + .7, f'  {color_name}', **text_args)

for g in range(n_groups):
```

(continues on next page)

(continued from previous page)

```
    ax.hlines(range(n_rows), 3*g, 3*g + 2.8, color='0.7', linewidth=1)
    ax.text(0.5 + 3*g, -0.3, 'X11/CSS4', ha='center')
    ax.text(1.5 + 3*g, -0.3, 'xkcd', ha='center')

ax.set_xlim(0, 3 * n_groups)
ax.set_ylim(n_rows, -1)
ax.axis('off')

plt.show()
```

X11/CSS4	xkcd	
#00FFFF	#13EAC9	aqua
#7FFFD4	#04D8B2	aquamarine
#F0FFFF	#069AF3	azure
#F5F5DC	#E6DAA6	beige
#000000	#000000	**black**
#0000FF	#0343DF	blue
#A52A2A	#653700	brown
#7FFF00	#C1F80A	chartreuse
#D2691E	#3D1C02	chocolate
#FF7F50	#FC5A50	coral
#DC143C	#8C000F	crimson
#00FFFF	#00FFFF	**cyan**
#00008B	#030764	darkblue
#006400	#054907	darkgreen
#FF00FF	#ED0DD9	fuchsia
#FFD700	#DBB40C	gold
#DAA520	#FAC205	goldenrod

X11/CSS4	xkcd	
#008000	#15B01A	green
#808080	#929591	grey
#4B0082	#380282	indigo
#FFFFF0	#FFFFCB	ivory
#F0E68C	#AAA662	khaki
#E6E6FA	#C79FEF	lavender
#ADD8E6	#7BC8F6	lightblue
#90EE90	#76FF7B	lightgreen
#00FF00	#AAFF32	lime
#FF00FF	#C20078	magenta
#800000	#650021	maroon
#000080	#01153E	navy
#808000	#6E750E	olive
#FFA500	#F97306	orange
#FF4500	#FE420F	orangered
#DA70D6	#C875C4	orchid
#FFC0CB	#FF81C0	pink

X11/CSS4	xkcd	
#DDA0DD	#580F41	plum
#800080	#7E1E9C	purple
#FF0000	#E50000	red
#FA8072	#FF796C	salmon
#A0522D	#A9561E	sienna
#C0C0C0	#C5C9C7	silver
#D2B48C	#D1B26F	tan
#008080	#029386	teal
#FF6347	#EF4026	tomato
#40E0D0	#06C2AC	turquoise
#EE82EE	#9A0EEA	violet
#F5DEB3	#FBDD7E	wheat
#FFFFFF	#FFFFFF	**white**
#FFFF00	#FFFF14	yellow
#9ACD32	#BBF90F	yellowgreen

Total running time of the script: (0 minutes 1.258 seconds)

3.8 Text

Matplotlib has extensive text support, including support for mathematical expressions, TrueType support for raster and vector outputs, newline separated text with arbitrary rotations, and Unicode support. These tutorials cover the basics of working with text in Matplotlib.

For even more information see the *examples page*.

3.8.1 Annotations

Annotations are graphical elements, often pieces of text, that explain, add context to, or otherwise highlight some portion of the visualized data. `annotate` supports a number of coordinate systems for flexibly positioning data and annotations relative to each other and a variety of options of for styling the text. Axes.annotate also provides an optional arrow from the text to the data and this arrow can be styled in various ways. `text` can also be used for simple text annotation, but does not provide as much flexibility in

positioning and styling as `annotate`.

Table of Contents

- *Annotations*
  - *Basic annotation*
    - *Annotating data*
    - *Annotating an Artist*
    - *Annotating with arrows*
    - *Placing text annotations relative to data*
  - *Advanced annotation*
    - *Annotating with boxed text*
    - *Defining custom box styles*
    - *Customizing annotation arrows*
    - *Placing Artist at anchored Axes locations*
    - *Using an Artist as an annotation*
  - *Coordinate systems for annotations*
    - `Transform` *instance*
    - `Artist` *instance*
    - *Callable that returns* `Transform` *of* `BboxBase`
    - *Blended coordinate specification*
    - `text.OffsetFrom`
  - *Non-text annotations*
    - *Using ConnectionPatch*
    - *Zoom effect between Axes*

Basic annotation

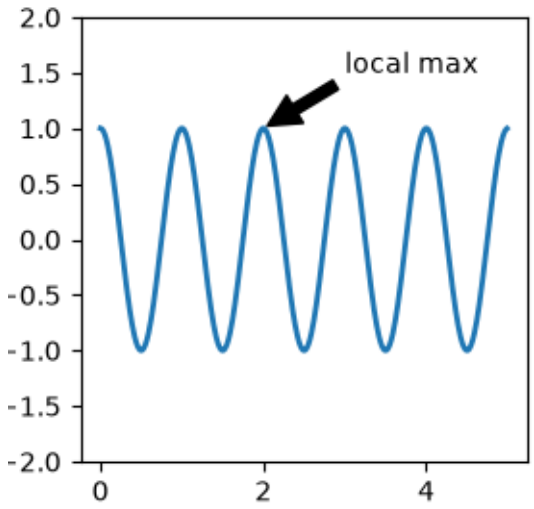
In an annotation, there are two points to consider: the location of the data being annotated *xy* and the location of the annotation text *xytext*. Both of these arguments are `(x, y)` tuples:

```
import matplotlib.pyplot as plt
import numpy as np

fig, ax = plt.subplots(figsize=(3, 3))
```

(continues on next page)

(continued from previous page)

```
t = np.arange(0.0, 5.0, 0.01)
s = np.cos(2*np.pi*t)
line, = ax.plot(t, s, lw=2)

ax.annotate('local max', xy=(2, 1), xytext=(3, 1.5),
            arrowprops=dict(facecolor='black', shrink=0.05))
ax.set_ylim(-2, 2)
```



In this example, both the *xy* (arrow tip) and *xytext* locations (text location) are in data coordinates. There are a variety of other coordinate systems one can choose -- you can specify the coordinate system of *xy* and *xytext* with one of the following strings for *xycoords* and *textcoords* (default is 'data')

argument	coordinate system
'figure points'	points from the lower left corner of the figure
'figure pixels'	pixels from the lower left corner of the figure
'figure fraction'	(0, 0) is lower left of figure and (1, 1) is upper right
'axes points'	points from lower left corner of the Axes
'axes pixels'	pixels from lower left corner of the Axes
'axes fraction'	(0, 0) is lower left of Axes and (1, 1) is upper right
'data'	use the axes data coordinate system

The following strings are also valid arguments for *textcoords*

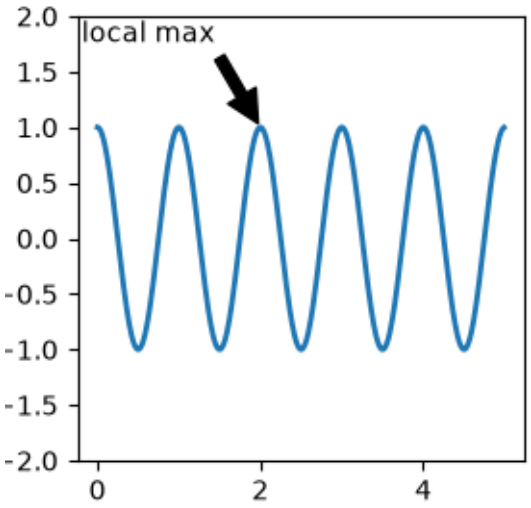
argument	coordinate system
'offset points'	offset (in points) from the xy value
'offset pixels'	offset (in pixels) from the xy value

For physical coordinate systems (points or pixels) the origin is the bottom-left of the figure or Axes. Points are typographic points meaning that they are a physical unit measuring 1/72 of an inch. Points and pixels are discussed in further detail in *Plotting in physical coordinates*.

Annotating data

This example places the text coordinates in fractional axes coordinates:

```
fig, ax = plt.subplots(figsize=(3, 3))

t = np.arange(0.0, 5.0, 0.01)
s = np.cos(2*np.pi*t)
line, = ax.plot(t, s, lw=2)

ax.annotate('local max', xy=(2, 1), xycoords='data',
            xytext=(0.01, .99), textcoords='axes fraction',
            va='top', ha='left',
            arrowprops=dict(facecolor='black', shrink=0.05))
ax.set_ylim(-2, 2)
```



Annotating an Artist

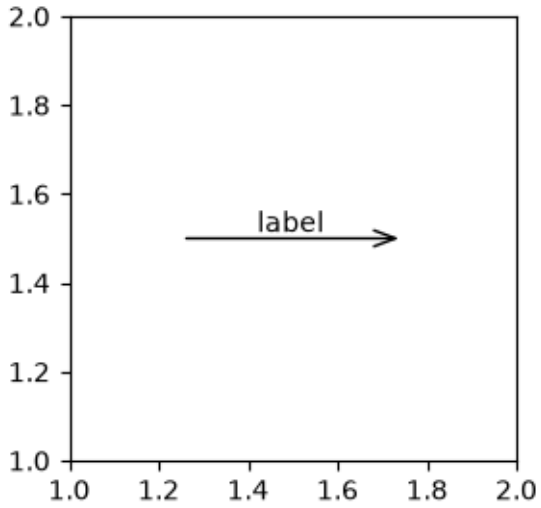
Annotations can be positioned relative to an `Artist` instance by passing that Artist in as *xycoords*. Then *xy* is interpreted as a fraction of the Artist's bounding box.

```
import matplotlib.patches as mpatches

fig, ax = plt.subplots(figsize=(3, 3))
arr = mpatches.FancyArrowPatch((1.25, 1.5), (1.75, 1.5),
                               arrowstyle='->,head_width=.15',␣
```

(continues on next page)

(continued from previous page)

```
 ↪mutation_scale=20)
ax.add_patch(arr)
ax.annotate("label", (.5, .5), xycoords=arr, ha='center', va='bottom')
ax.set(xlim=(1, 2), ylim=(1, 2))
```



Here the annotation is placed at position (.5,.5) relative to the arrow's lower left corner and is vertically and horizontally at that position. Vertically, the bottom aligns to that reference point so that the label is above the line. For an example of chaining annotation Artists, see the *Artist section* of *Coordinate systems for annotations*.

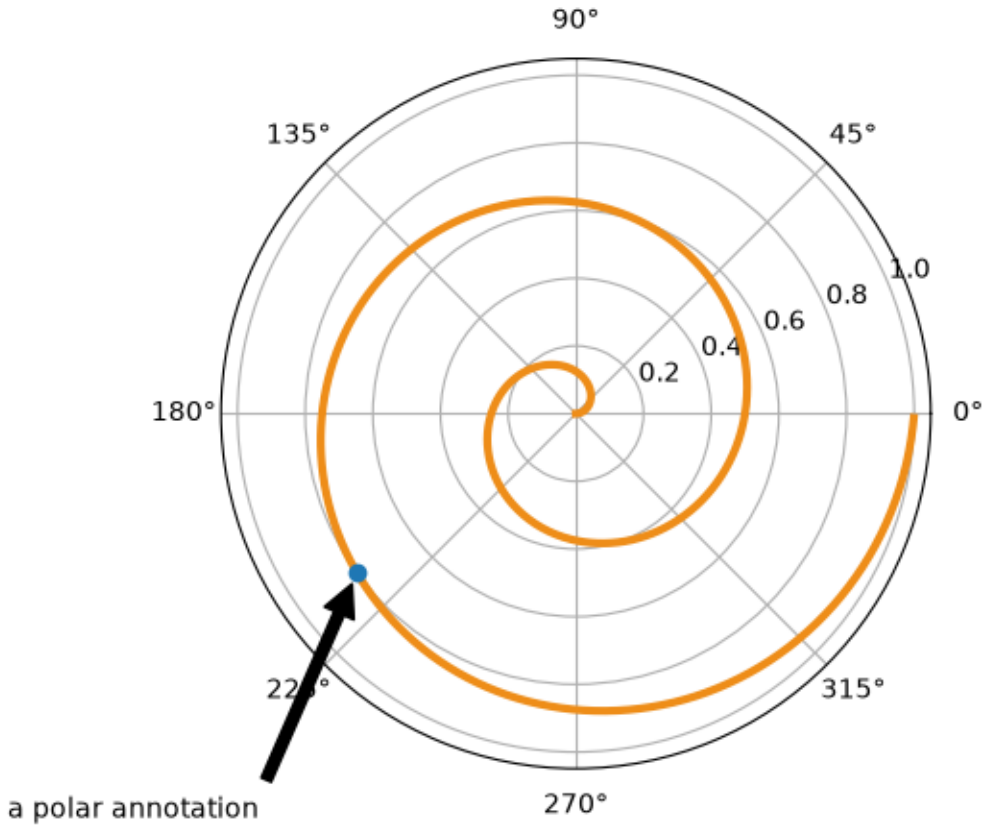
Annotating with arrows

You can enable drawing of an arrow from the text to the annotated point by giving a dictionary of arrow properties in the optional keyword argument *arrowprops*.

arrowprops key	description
width	the width of the arrow in points
frac	the fraction of the arrow length occupied by the head
headwidth	the width of the base of the arrow head in points
shrink	move the tip and base some percent away from the annotated point and text
**kwargs	any key for *matplotlib.patches.Polygon*, e.g., facecolor

In the example below, the *xy* point is in the data coordinate system since *xycoords* defaults to 'data'. For a polar Axes, this is in (theta, radius) space. The text in this example is placed in the fractional figure coordinate system. *matplotlib.text.Text* keyword arguments like *horizontalalignment*, *verticalalignment* and *fontsize* are passed from *annotate* to the Text instance.

```
fig = plt.figure()
ax = fig.add_subplot(projection='polar')
r = np.arange(0, 1, 0.001)
theta = 2 * 2*np.pi * r
line, = ax.plot(theta, r, color='#ee8d18', lw=3)

ind = 800
thisr, thistheta = r[ind], theta[ind]
ax.plot([thistheta], [thisr], 'o')
ax.annotate('a polar annotation',
            xy=(thistheta, thisr),  # theta, radius
            xytext=(0.05, 0.05),    # fraction, fraction
            textcoords='figure fraction',
            arrowprops=dict(facecolor='black', shrink=0.05),
            horizontalalignment='left',
            verticalalignment='bottom')
```

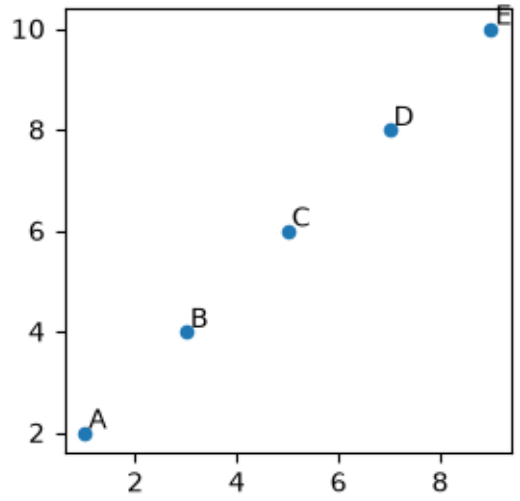


For more on plotting with arrows, see *Customizing annotation arrows*

Placing text annotations relative to data

Annotations can be positioned at a relative offset to the *xy* input to annotation by setting the *textcoords* keyword argument to `'offset points'` or `'offset pixels'`.

```
fig, ax = plt.subplots(figsize=(3, 3))
x = [1, 3, 5, 7, 9]
y = [2, 4, 6, 8, 10]
annotations = ["A", "B", "C", "D", "E"]
ax.scatter(x, y, s=20)

for xi, yi, text in zip(x, y, annotations):
    ax.annotate(text,
                 xy=(xi, yi), xycoords='data',
                 xytext=(1.5, 1.5), textcoords='offset points')
```



The annotations are offset 1.5 points (1.5*1/72 inches) from the *xy* values.

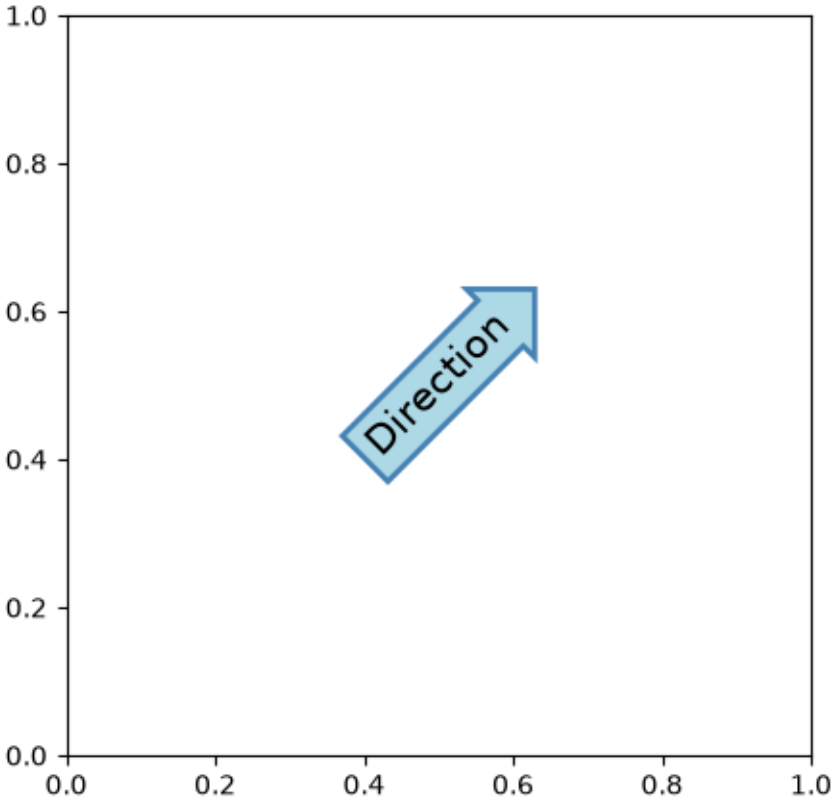
Advanced annotation

We recommend reading *Basic annotation*, `text()` and `annotate()` before reading this section.

Annotating with boxed text

`text` takes a *bbox* keyword argument, which draws a box around the text:

```
fig, ax = plt.subplots(figsize=(5, 5))
t = ax.text(0.5, 0.5, "Direction",
            ha="center", va="center", rotation=45, size=15,
            bbox=dict(boxstyle="rarrow,pad=0.3",
                      fc="lightblue", ec="steelblue", lw=2))
```

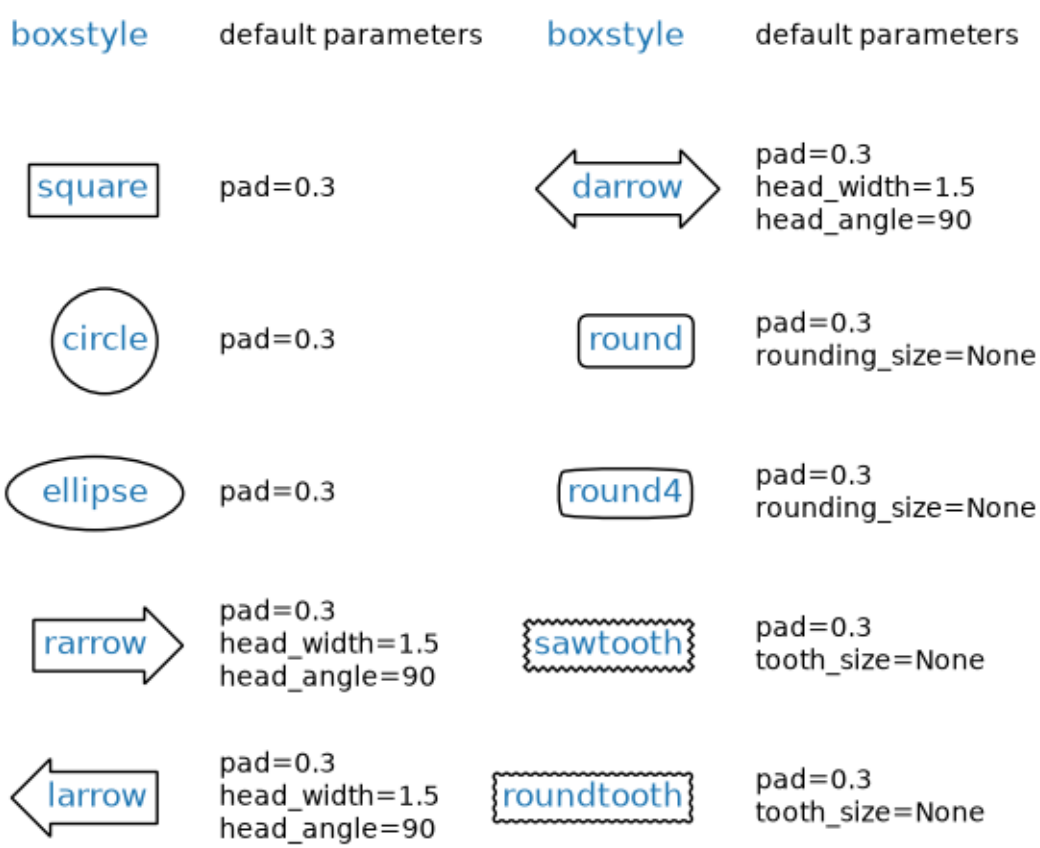


The arguments are the name of the box style with its attributes as keyword arguments. Currently, following box styles are implemented:

Class	Name	Attrs
Circle	`circle`	pad=0.3
DArrow	`darrow`	pad=0.3,head_width=1.5,head_angle=90
Ellipse	`ellipse`	pad=0.3
LArrow	`larrow`	pad=0.3,head_width=1.5,head_angle=90
RArrow	`rarrow`	pad=0.3,head_width=1.5,head_angle=90
Round	`round`	pad=0.3,rounding_size=None
Round4	`round4`	pad=0.3,rounding_size=None
Roundtooth	`roundtooth`	pad=0.3,tooth_size=None
Sawtooth	`sawtooth`	pad=0.3,tooth_size=None
Square	`square`	pad=0.3

The patch object (box) associated with the text can be accessed using:

```
bb = t.get_bbox_patch()
```


boxstyle
default parameters
boxstyle
default parameters
square
pad=0.3
darrow
pad=0.3
head_width=1.5
head_angle=90
circle
pad=0.3
round
pad=0.3
rounding_size=None
ellipse
pad=0.3
round4
pad=0.3
rounding_size=None
rarrow
pad=0.3
head_width=1.5
head_angle=90
sawtooth
pad=0.3
tooth_size=None
larrow
pad=0.3
head_width=1.5
head_angle=90
roundtooth
pad=0.3
tooth_size=None

The return value is a *FancyBboxPatch*; patch properties (facecolor, edgewidth, etc.) can be accessed and modified as usual. *FancyBboxPatch.set_boxstyle* sets the box shape:

```
bb.set_boxstyle("rarrow", pad=0.6)
```

The attribute arguments can also be specified within the style name with separating comma:

```
bb.set_boxstyle("rarrow, pad=0.6")
```

Defining custom box styles

Custom box styles can be implemented as a function that takes arguments specifying both a rectangular box and the amount of "mutation", and returns the "mutated" path. The specific signature is the one of `custom_box_style` below.

Here, we return a new path which adds an "arrow" shape on the left of the box.

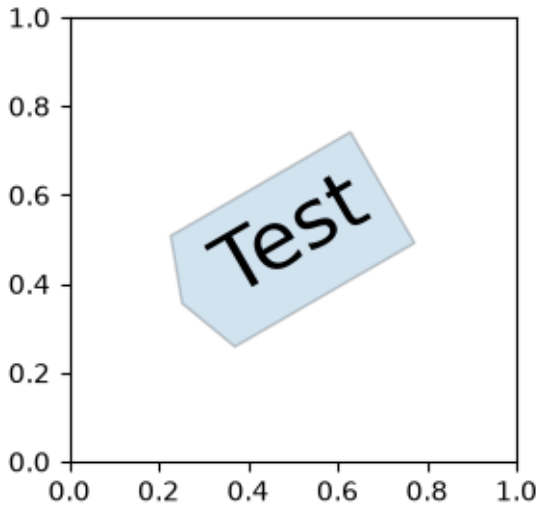
The custom box style can then be used by passing `bbox=dict(boxstyle=custom_box_style, ...)` to *Axes.text*.

```
from matplotlib.path import Path


def custom_box_style(x0, y0, width, height, mutation_size):
    """
    Given the location and size of the box, return the path of the box␣
 ↪around it.

    Rotation is automatically taken care of.

    Parameters
    ----------
    x0, y0, width, height : float
       Box location and size.
    mutation_size : float
        Mutation reference scale, typically the text font size.
    """
    # padding
    mypad = 0.3
    pad = mutation_size * mypad
    # width and height with padding added.
    width = width + 2 * pad
    height = height + 2 * pad
    # boundary of the padded box
    x0, y0 = x0 - pad, y0 - pad
    x1, y1 = x0 + width, y0 + height
    # return the new path
    return Path([(x0, y0), (x1, y0), (x1, y1), (x0, y1),
```

(continues on next page)

(continued from previous page)

```
                  (x0-pad, (y0+y1)/2), (x0, y0), (x0, y0)],
                 closed=True)

fig, ax = plt.subplots(figsize=(3, 3))
ax.text(0.5, 0.5, "Test", size=30, va="center", ha="center",␣
 ↪rotation=30,
        bbox=dict(boxstyle=custom_box_style, alpha=0.2))
```



Likewise, custom box styles can be implemented as classes that implement `__call__`.

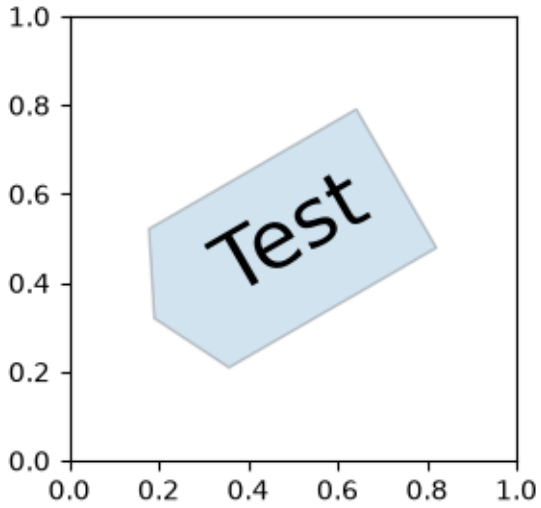
The classes can then be registered into the `BoxStyle._style_list` dict, which allows specifying the box style as a string, `bbox=dict(boxstyle="registered_name,param=value,...", ...)`. Note that this registration relies on internal APIs and is therefore not officially supported.

```
from matplotlib.patches import BoxStyle


class MyStyle:
    """A simple box."""

    def __init__(self, pad=0.3):
        """
        The arguments must be floats and have default values.

        Parameters
        ----------
        pad : float
            amount of padding
        """
        self.pad = pad
```

(continues on next page)

(continued from previous page)

```
        super().__init__()

    def __call__(self, x0, y0, width, height, mutation_size):
        """
        Given the location and size of the box, return the path of the␣
 ↪box around it.

        Rotation is automatically taken care of.

        Parameters
        ----------
        x0, y0, width, height : float
            Box location and size.
        mutation_size : float
            Reference scale for the mutation, typically the text font␣
 ↪size.
        """
        # padding
        pad = mutation_size * self.pad
        # width and height with padding added
        width = width + 2 * pad
        height = height + 2 * pad
        # boundary of the padded box
        x0, y0 = x0 - pad, y0 - pad
        x1, y1 = x0 + width, y0 + height
        # return the new path
        return Path([(x0, y0), (x1, y0), (x1, y1), (x0, y1),
                     (x0-pad, (y0+y1)/2), (x0, y0), (x0, y0)],
                    closed=True)


BoxStyle._style_list["angled"] = MyStyle  # Register the custom style.

fig, ax = plt.subplots(figsize=(3, 3))
ax.text(0.5, 0.5, "Test", size=30, va="center", ha="center",␣
 ↪rotation=30,
        bbox=dict(boxstyle="angled,pad=0.5", alpha=0.2))

del BoxStyle._style_list["angled"]  # Unregister it.
```

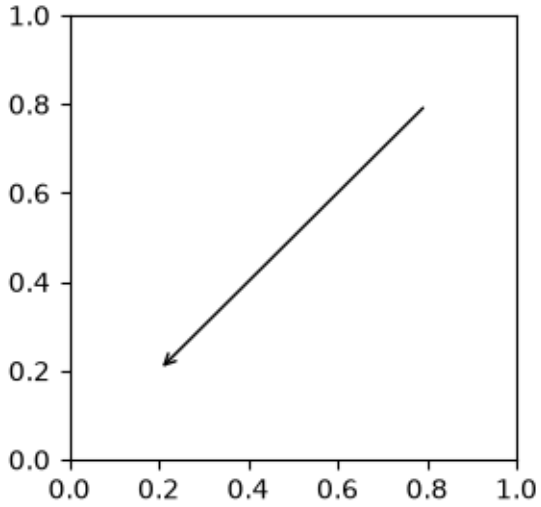


Similarly, you can define a custom *ConnectionStyle* and a custom *ArrowStyle*. View the source code at *patches* to learn how each class is defined.

Customizing annotation arrows

An arrow connecting *xy* to *xytext* can be optionally drawn by specifying the *arrowprops* argument. To draw only an arrow, use empty string as the first argument:

```
fig, ax = plt.subplots(figsize=(3, 3))
ax.annotate("",
            xy=(0.2, 0.2), xycoords='data',
            xytext=(0.8, 0.8), textcoords='data',
            arrowprops=dict(arrowstyle="->", connectionstyle="arc3"))
```



The arrow is drawn as follows:

1. A path connecting the two points is created, as specified by the *connectionstyle* parameter.
2. The path is clipped to avoid patches *patchA* and *patchB*, if these are set.
3. The path is further shrunk by *shrinkA* and *shrinkB* (in pixels).
4. The path is transmuted to an arrow patch, as specified by the *arrowstyle* parameter.

The creation of the connecting path between two points is controlled by `connectionstyle` key and the following styles are available:

Name	Attrs
`angle`	angleA=90,angleB=0,rad=0.0
`angle3`	angleA=90,angleB=0
`arc`	angleA=0,angleB=0,armA=None,armB=None,rad=0.0
`arc3`	rad=0.0
`bar`	armA=0.0,armB=0.0,fraction=0.3,angle=None

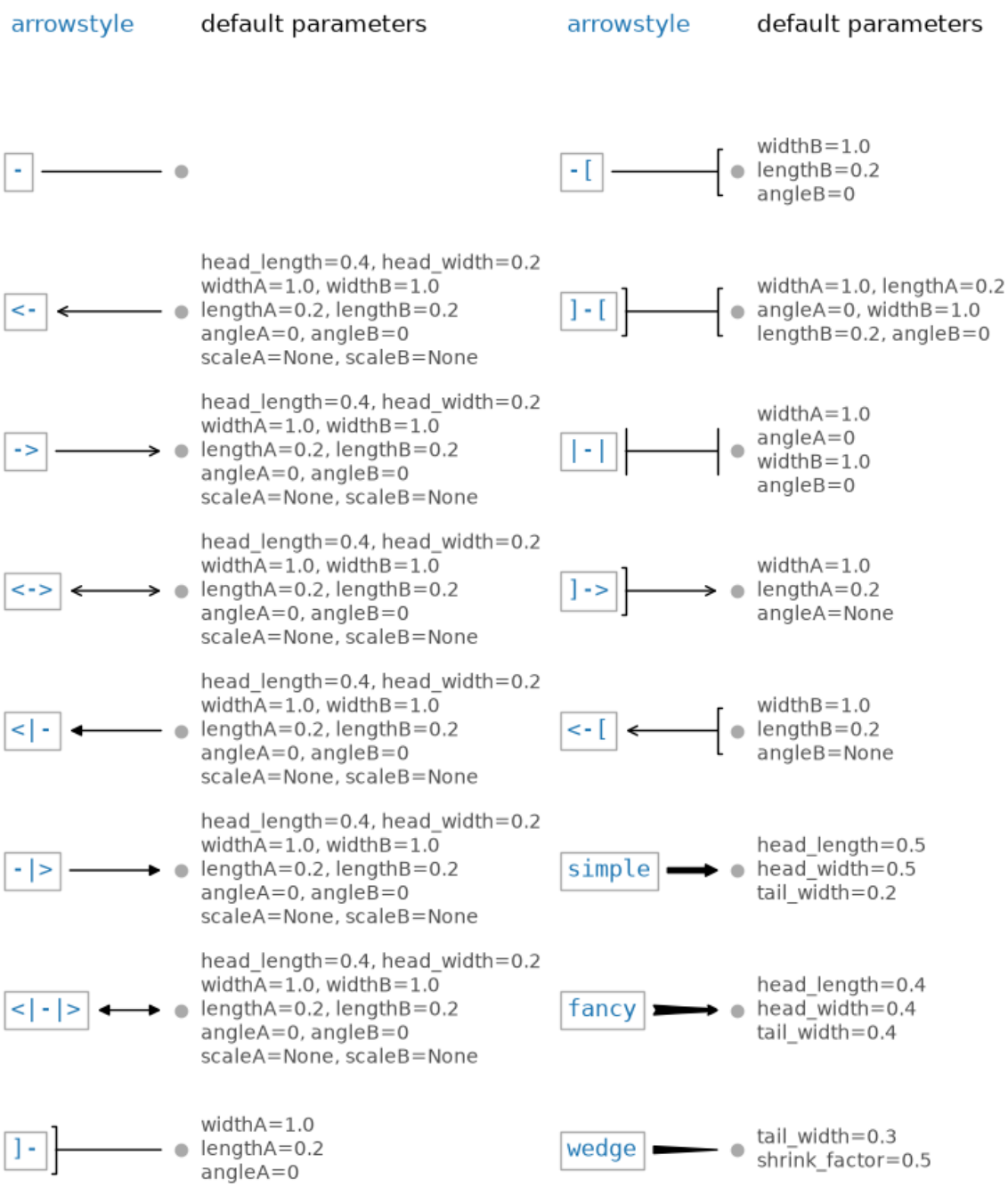
Note that "3" in `angle3` and `arc3` is meant to indicate that the resulting path is a quadratic spline segment (three control points). As will be discussed below, some arrow style options can only be used when the connecting path is a quadratic spline.

The behavior of each connection style is (limitedly) demonstrated in the example below. (Warning: The behavior of the `bar` style is currently not well-defined and may be changed in the future).

The connecting path (after clipping and shrinking) is then mutated to an arrow patch, according to the given `arrowstyle`:

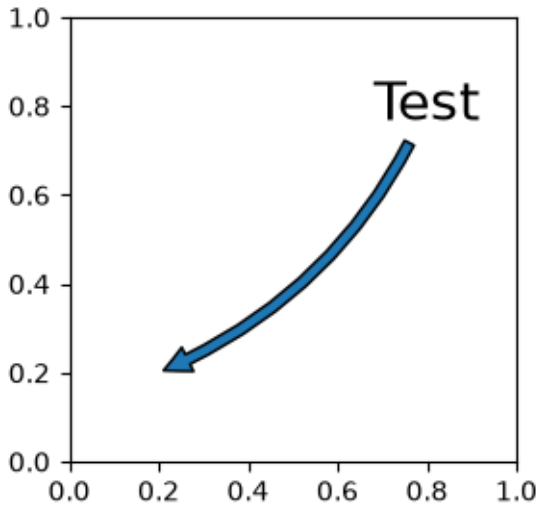
Name	Attrs
`-`	None
`->`	head_length=0.4,head_width=0.2
`-[`	widthB=1.0,lengthB=0.2,angleB=None
`|-|`	widthA=1.0,widthB=1.0
`-|>`	head_length=0.4,head_width=0.2
`<-`	head_length=0.4,head_width=0.2
`<->`	head_length=0.4,head_width=0.2
`<|-`	head_length=0.4,head_width=0.2
`<|-|>`	head_length=0.4,head_width=0.2
`fancy`	head_length=0.4,head_width=0.4,tail_width=0.4
`simple`	head_length=0.5,head_width=0.5,tail_width=0.2
`wedge`	tail_width=0.3,shrink_factor=0.5

Some arrowstyles only work with connection styles that generate a quadratic-spline segment. They are `fancy`, `simple`, and `wedge`. For these arrow styles, you must use the "angle3" or "arc3" connection style.


arrowstyle
default parameters
arrowstyle
default parameters
-
-[
widthB=1.0
lengthB=0.2
angleB=0
<-
head_length=0.4, head_width=0.2
widthA=1.0, widthB=1.0
lengthA=0.2, lengthB=0.2
angleA=0, angleB=0
scaleA=None, scaleB=None
]-[
widthA=1.0, lengthA=0.2
angleA=0, widthB=1.0
lengthB=0.2, angleB=0
->
head_length=0.4, head_width=0.2
widthA=1.0, widthB=1.0
lengthA=0.2, lengthB=0.2
angleA=0, angleB=0
scaleA=None, scaleB=None
|-|
widthA=1.0
angleA=0
widthB=1.0
angleB=0
<->
head_length=0.4, head_width=0.2
widthA=1.0, widthB=1.0
lengthA=0.2, lengthB=0.2
angleA=0, angleB=0
scaleA=None, scaleB=None
]->
widthA=1.0
lengthA=0.2
angleA=None
<|-
head_length=0.4, head_width=0.2
widthA=1.0, widthB=1.0
lengthA=0.2, lengthB=0.2
angleA=0, angleB=0
scaleA=None, scaleB=None
<-[
widthB=1.0
lengthB=0.2
angleB=None
-|>
head_length=0.4, head_width=0.2
widthA=1.0, widthB=1.0
lengthA=0.2, lengthB=0.2
angleA=0, angleB=0
scaleA=None, scaleB=None
simple
head_length=0.5
head_width=0.5
tail_width=0.2
<|-|>
head_length=0.4, head_width=0.2
widthA=1.0, widthB=1.0
lengthA=0.2, lengthB=0.2
angleA=0, angleB=0
scaleA=None, scaleB=None
fancy
head_length=0.4
head_width=0.4
tail_width=0.4
]-
widthA=1.0
lengthA=0.2
angleA=0
wedge
tail_width=0.3
shrink_factor=0.5

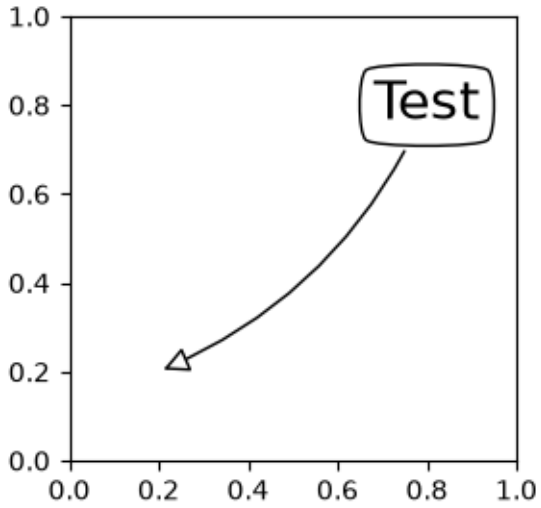
If the annotation string is given, the patch is set to the bbox patch of the text by default.

```
fig, ax = plt.subplots(figsize=(3, 3))

ax.annotate("Test",
            xy=(0.2, 0.2), xycoords='data',
            xytext=(0.8, 0.8), textcoords='data',
            size=20, va="center", ha="center",
            arrowprops=dict(arrowstyle="simple",
                            connectionstyle="arc3,rad=-0.2"))
```



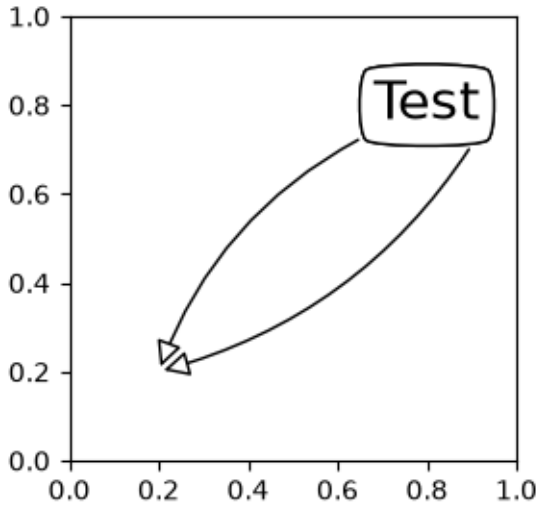
As with *text*, a box around the text can be drawn using the *bbox* argument.

```
fig, ax = plt.subplots(figsize=(3, 3))

ann = ax.annotate("Test",
                  xy=(0.2, 0.2), xycoords='data',
                  xytext=(0.8, 0.8), textcoords='data',
                  size=20, va="center", ha="center",
                  bbox=dict(boxstyle="round4", fc="w"),
                  arrowprops=dict(arrowstyle="-|>",
                                  connectionstyle="arc3,rad=-0.2",
                                  fc="w"))
```



By default, the starting point is set to the center of the text extent. This can be adjusted with `relpos` key value. The values are normalized to the extent of the text. For example, (0, 0) means lower-left corner and (1, 1) means top-right.

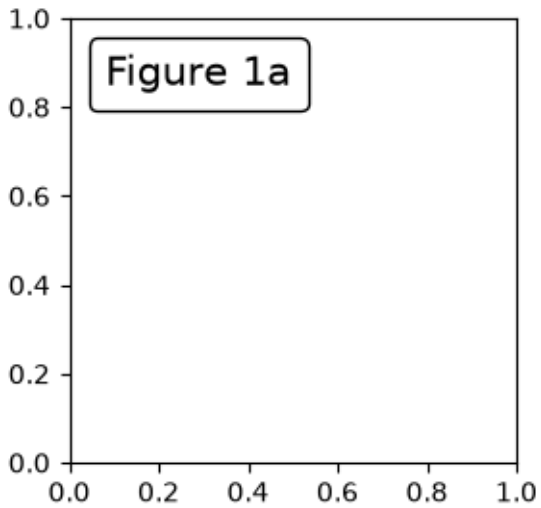
```
fig, ax = plt.subplots(figsize=(3, 3))

ann = ax.annotate("Test",
                  xy=(0.2, 0.2), xycoords='data',
                  xytext=(0.8, 0.8), textcoords='data',
                  size=20, va="center", ha="center",
                  bbox=dict(boxstyle="round4", fc="w"),
                  arrowprops=dict(arrowstyle="-|>",
                                  connectionstyle="arc3,rad=0.2",
                                  relpos=(0., 0.),
                                  fc="w"))

ann = ax.annotate("Test",
                  xy=(0.2, 0.2), xycoords='data',
                  xytext=(0.8, 0.8), textcoords='data',
                  size=20, va="center", ha="center",
                  bbox=dict(boxstyle="round4", fc="w"),
                  arrowprops=dict(arrowstyle="-|>",
                                  connectionstyle="arc3,rad=-0.2",
                                  relpos=(1., 0.),
                                  fc="w"))
```



Placing Artist at anchored Axes locations

There are classes of artists that can be placed at an anchored location in the Axes. A common example is the legend. This type of artist can be created by using the *OffsetBox* class. A few predefined classes are available in *matplotlib.offsetbox* and in *mpl_toolkits.axes_grid1.anchored_artists*.

```
from matplotlib.offsetbox import AnchoredText

fig, ax = plt.subplots(figsize=(3, 3))
at = AnchoredText("Figure 1a",
                  prop=dict(size=15), frameon=True, loc='upper left')
at.patch.set_boxstyle("round,pad=0.,rounding_size=0.2")
ax.add_artist(at)
```

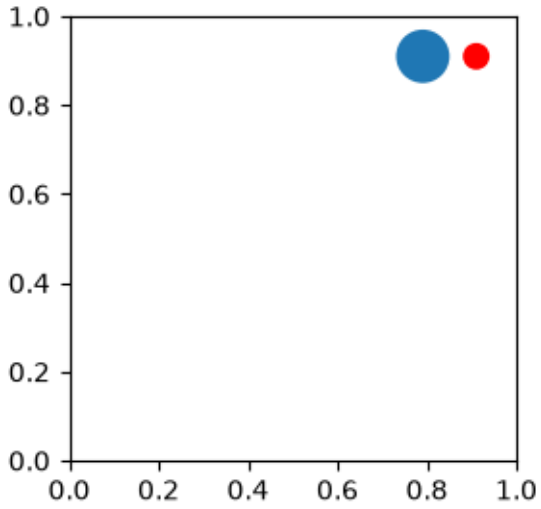


The *loc* keyword has same meaning as in the legend command.

A simple application is when the size of the artist (or collection of artists) is known in pixel size during the time of creation. For example, If you want to draw a circle with fixed size of 20 pixel x 20 pixel (radius = 10 pixel), you can utilize *AnchoredDrawingArea*. The instance is created with a size of the drawing area (in pixels), and arbitrary artists can be added to the drawing area. Note that the extents of the artists that are added to the drawing area are not related to the placement of the drawing area itself. Only the initial size matters.

The artists that are added to the drawing area should not have a transform set (it will be overridden) and the dimensions of those artists are interpreted as a pixel coordinate, i.e., the radius of the circles in above example are 10 pixels and 5 pixels, respectively.

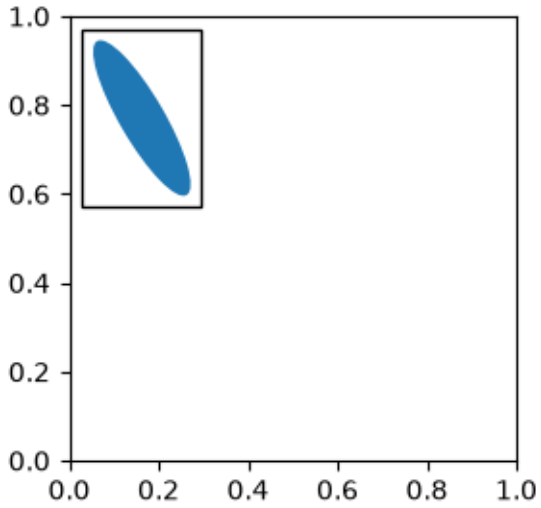
```
from matplotlib.patches import Circle
from mpl_toolkits.axes_grid1.anchored_artists import␣
 ↪AnchoredDrawingArea

fig, ax = plt.subplots(figsize=(3, 3))
ada = AnchoredDrawingArea(40, 20, 0, 0,
                          loc='upper right', pad=0., frameon=False)
p1 = Circle((10, 10), 10)
ada.drawing_area.add_artist(p1)
p2 = Circle((30, 10), 5, fc="r")
ada.drawing_area.add_artist(p2)
ax.add_artist(ada)
```



Sometimes, you want your artists to scale with the data coordinate (or coordinates other than canvas pixels). You can use *AnchoredAuxTransformBox* class. This is similar to *AnchoredDrawingArea* except that the extent of the artist is determined during the drawing time respecting the specified transform.

The ellipse in the example below will have width and height corresponding to 0.1 and 0.4 in data coordinates and will be automatically scaled when the view limits of the Axes change.

```
from matplotlib.patches import Ellipse
from mpl_toolkits.axes_grid1.anchored_artists import␣
 ↪AnchoredAuxTransformBox

fig, ax = plt.subplots(figsize=(3, 3))
box = AnchoredAuxTransformBox(ax.transData, loc='upper left')
el = Ellipse((0, 0), width=0.1, height=0.4, angle=30)  # in data␣
 ↪coordinates!
box.drawing_area.add_artist(el)
ax.add_artist(box)
```



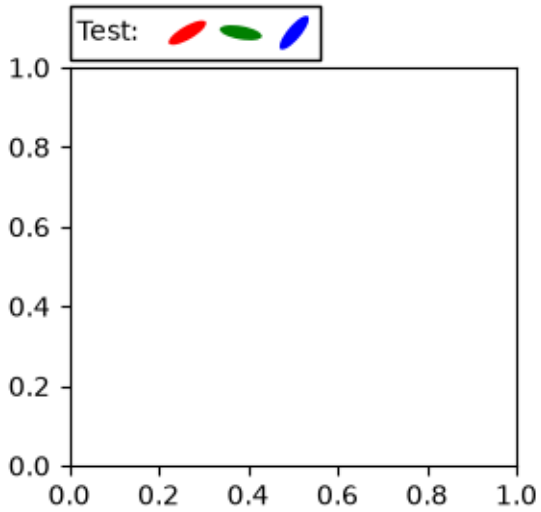
Another method of anchoring an artist relative to a parent Axes or anchor point is via the *bbox_to_anchor* argument of *AnchoredOffsetbox*. This artist can then be automatically positioned relative to another artist using *HPacker* and *VPacker*:

```
from matplotlib.offsetbox import (AnchoredOffsetbox, DrawingArea,␣
 ↪HPacker,
                                  TextArea)

fig, ax = plt.subplots(figsize=(3, 3))

box1 = TextArea(" Test: ", textprops=dict(color="k"))
box2 = DrawingArea(60, 20, 0, 0)

el1 = Ellipse((10, 10), width=16, height=5, angle=30, fc="r")
el2 = Ellipse((30, 10), width=16, height=5, angle=170, fc="g")
el3 = Ellipse((50, 10), width=16, height=5, angle=230, fc="b")
box2.add_artist(el1)
box2.add_artist(el2)
box2.add_artist(el3)
```

(continues on next page)

(continued from previous page)

```
box = HPacker(children=[box1, box2],
              align="center",
              pad=0, sep=5)

anchored_box = AnchoredOffsetbox(loc='lower left',
                                 child=box, pad=0.,
                                 frameon=True,
                                 bbox_to_anchor=(0., 1.02),
                                 bbox_transform=ax.transAxes,
                                 borderpad=0.,)

ax.add_artist(anchored_box)
fig.subplots_adjust(top=0.8)
```



Note that, unlike in *Legend*, the `bbox_transform` is set to *IdentityTransform* by default

Using an Artist as an annotation

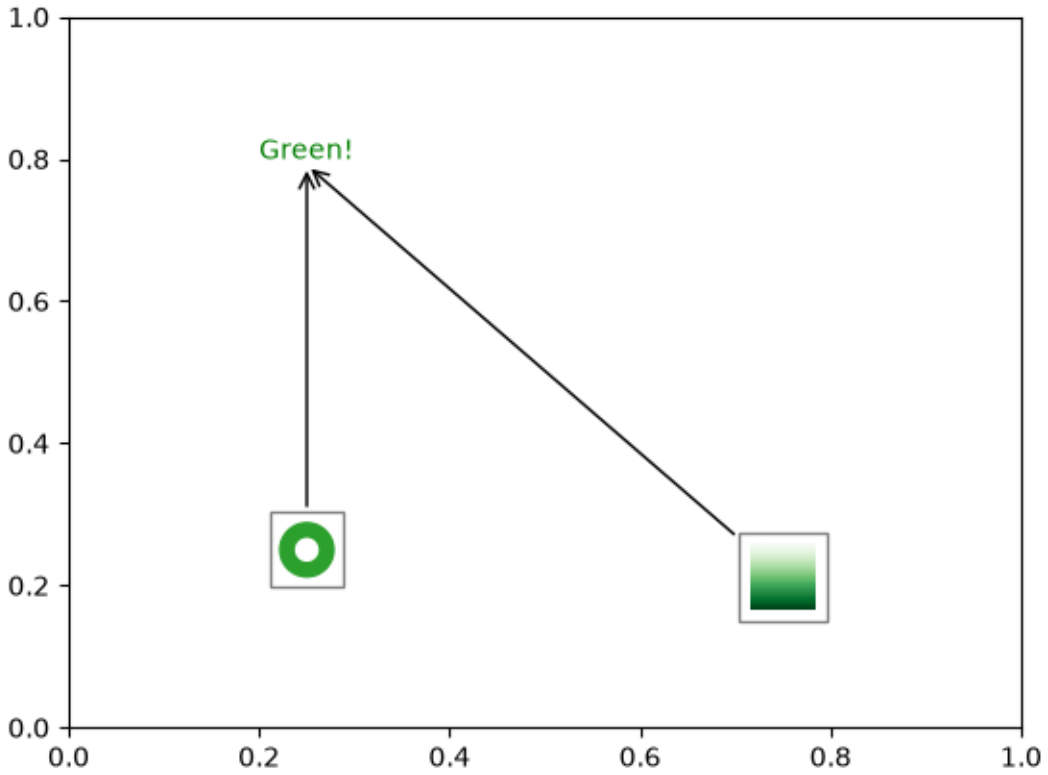
AnnotationBbox uses artists in *OffsetBox* container artists as the annotations and supports positioning these annotations using the same coordinate systems as the other annotation methods. For more examples, see *Artists as annotations*

```
from matplotlib.offsetbox import AnnotationBbox, DrawingArea,␣
 ↪OffsetImage
from matplotlib.patches import Annulus

fig, ax = plt.subplots()
```

(continues on next page)

(continued from previous page)

```
text = ax.text(.2, .8, "Green!", color='green')

da = DrawingArea(20, 20)
annulus = Annulus((10, 10), 10, 5, color='tab:green')
da.add_artist(annulus)

# position annulus relative to text
ab1 = AnnotationBbox(da, xy=(.5, 0),
                     xybox=(.5, .25),
                     xycoords=text,
                     boxcoords=(text, "data"),
                     arrowprops=dict(arrowstyle="->"),
                     bboxprops=dict(alpha=0.5))
ax.add_artist(ab1)

N = 25
arr = np.repeat(np.linspace(0, 1, N), N).reshape(N, N)
im = OffsetImage(arr, cmap='Greens')
im.image.axes = ax

# position gradient relative to text and annulus
ab2 = AnnotationBbox(im, xy=(.5, 0),
                     xybox=(.75, 0),
                     xycoords=text,
                     boxcoords=('data', annulus),
                     arrowprops=dict(arrowstyle="->"),
                     bboxprops=dict(alpha=0.5))
ax.add_artist(ab2)
```



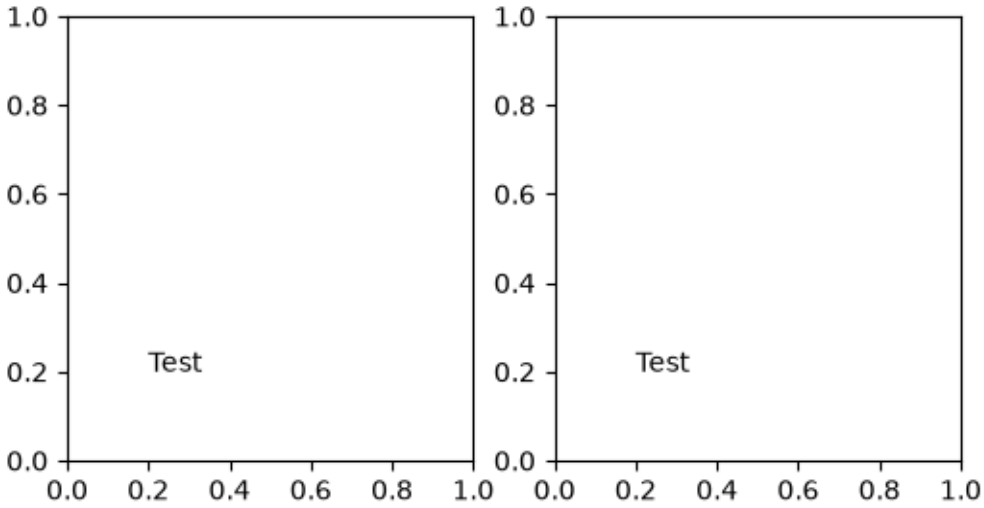
Coordinate systems for annotations

Matplotlib Annotations support several types of coordinate systems. The examples in *Basic annotation* used the `data` coordinate system; Some others more advanced options are:

`Transform` instance

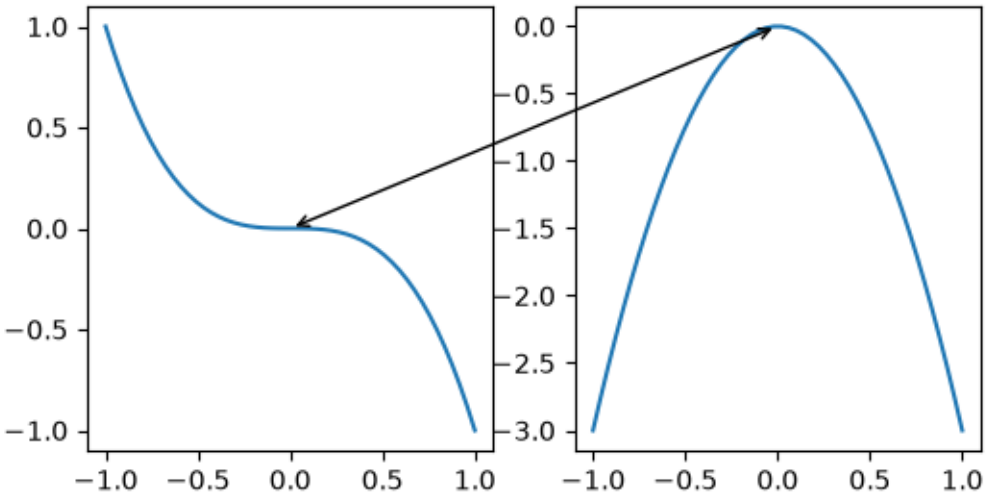
Transforms map coordinates into different coordinate systems, usually the display coordinate system. See *Transformations Tutorial* for a detailed explanation. Here Transform objects are used to identify the coordinate system of the corresponding points. For example, the `Axes.transAxes` transform positions the annotation relative to the Axes coordinates; therefore using it is identical to setting the coordinate system to "axes fraction":

```
fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2, figsize=(6, 3))
ax1.annotate("Test", xy=(0.2, 0.2), xycoords=ax1.transAxes)
ax2.annotate("Test", xy=(0.2, 0.2), xycoords="axes fraction")
```



Another commonly used *Transform* instance is `Axes.transData`. This transform is the coordinate system of the data plotted in the Axes. In this example, it is used to draw an arrow between related data points in two Axes. We have passed an empty text because in this case, the annotation connects data points.

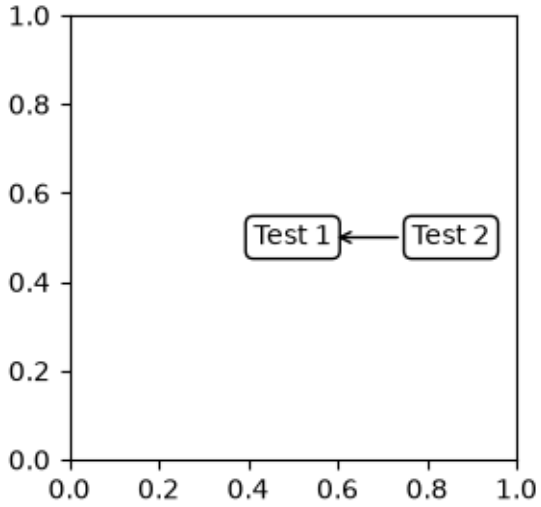
```
x = np.linspace(-1, 1)

fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2, figsize=(6, 3))
ax1.plot(x, -x**3)
ax2.plot(x, -3*x**2)
ax2.annotate("",
             xy=(0, 0), xycoords=ax1.transData,
             xytext=(0, 0), textcoords=ax2.transData,
             arrowprops=dict(arrowstyle="<->"))
```



Artist instance

The *xy* value (or *xytext*) is interpreted as a fractional coordinate of the bounding box (bbox) of the artist:

```
fig, ax = plt.subplots(nrows=1, ncols=1, figsize=(3, 3))
an1 = ax.annotate("Test 1",
                  xy=(0.5, 0.5), xycoords="data",
                  va="center", ha="center",
                  bbox=dict(boxstyle="round", fc="w"))

an2 = ax.annotate("Test 2",
                  xy=(1, 0.5), xycoords=an1,  # (1, 0.5) of an1's bbox
                  xytext=(30, 0), textcoords="offset points",
                  va="center", ha="left",
                  bbox=dict(boxstyle="round", fc="w"),
                  arrowprops=dict(arrowstyle="->"))
```



Note that you must ensure that the extent of the coordinate artist (*an1* in this example) is determined before *an2* gets drawn. Usually, this means that *an2* needs to be drawn after *an1*. The base class for all bounding boxes is *BboxBase*

Callable that returns *Transform* of *BboxBase*

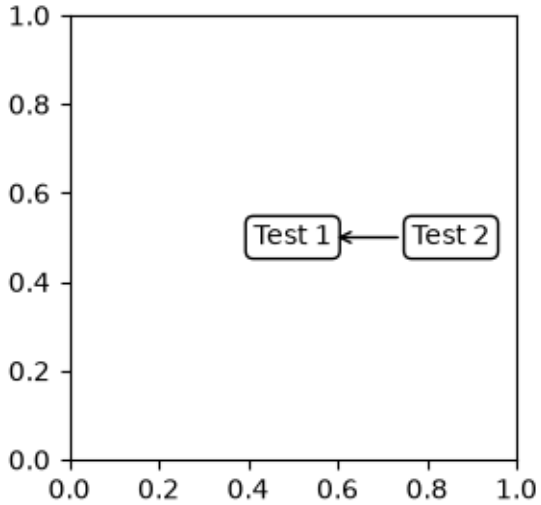
A callable object that takes the renderer instance as single argument, and returns either a *Transform* or a *BboxBase*. For example, the return value of *Artist.get_window_extent* is a bbox, so this method is identical to (2) passing in the artist:

```
fig, ax = plt.subplots(nrows=1, ncols=1, figsize=(3, 3))
an1 = ax.annotate("Test 1",
                  xy=(0.5, 0.5), xycoords="data",
                  va="center", ha="center",
```

(continues on next page)

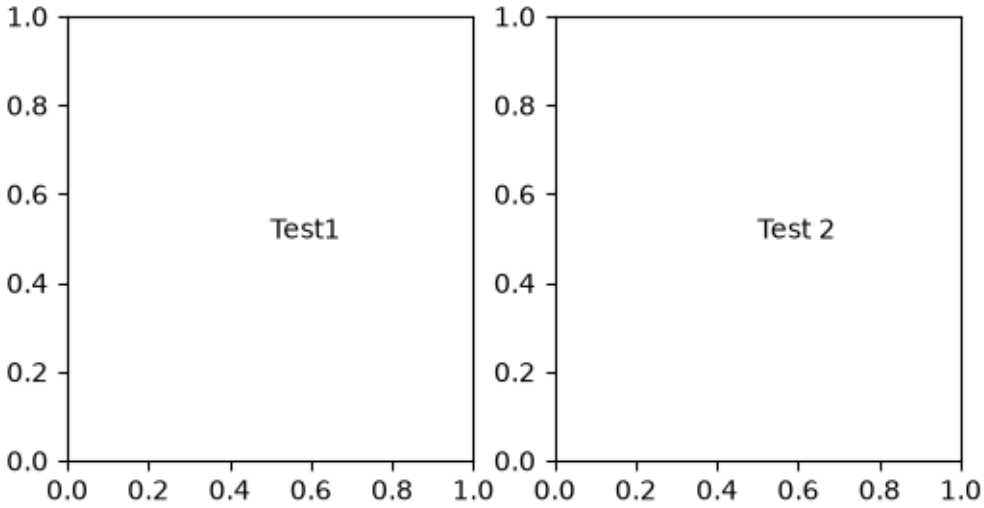
(continued from previous page)

```
                    bbox=dict(boxstyle="round", fc="w"))

an2 = ax.annotate("Test 2",
                    xy=(1, 0.5), xycoords=an1.get_window_extent,
                    xytext=(30, 0), textcoords="offset points",
                    va="center", ha="left",
                    bbox=dict(boxstyle="round", fc="w"),
                    arrowprops=dict(arrowstyle="->"))
```



Artist.get_window_extent is the bounding box of the Axes object and is therefore identical to setting the coordinate system to axes fraction:

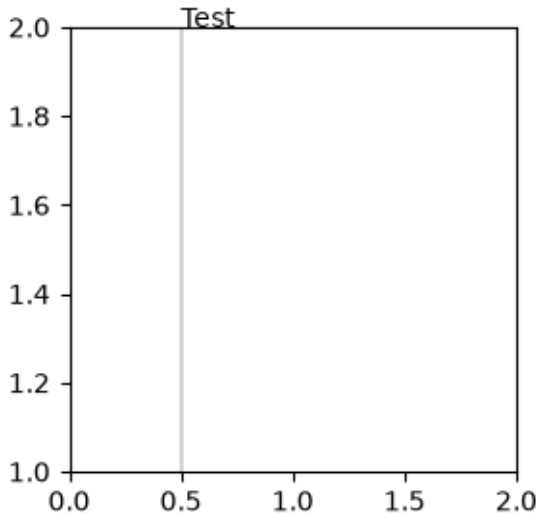
```
fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2, figsize=(6, 3))

an1 = ax1.annotate("Test1", xy=(0.5, 0.5), xycoords="axes fraction")
an2 = ax2.annotate("Test 2", xy=(0.5, 0.5), xycoords=ax2.
 ↪get_window_extent)
```



Blended coordinate specification

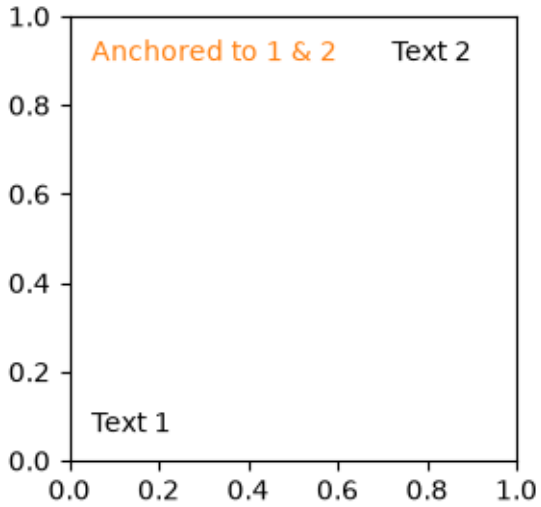
A blended pair of coordinate specifications -- the first for the x-coordinate, and the second is for the y-coordinate. For example, x=0.5 is in data coordinates, and y=1 is in normalized axes coordinates:

```
fig, ax = plt.subplots(figsize=(3, 3))
ax.annotate("Test", xy=(0.5, 1), xycoords=("data", "axes fraction"))
ax.axvline(x=.5, color='lightgray')
ax.set(xlim=(0, 2), ylim=(1, 2))
```



Any of the supported coordinate systems can be used in a blended specification. For example, the text "Anchored to 1 & 2" is positioned relative to the two *Text* Artists:

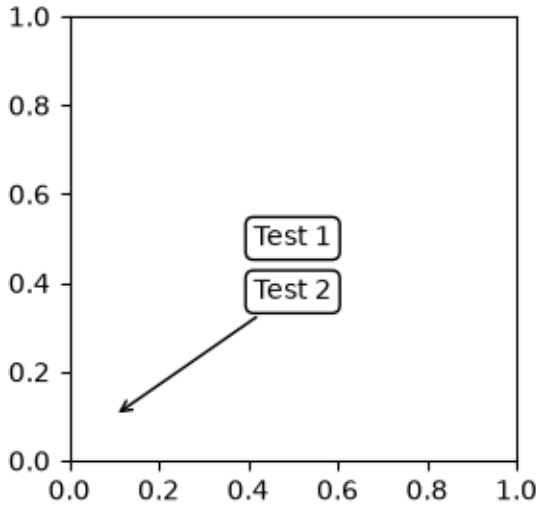
```
fig, ax = plt.subplots(figsize=(3, 3))

t1 = ax.text(0.05, .05, "Text 1", va='bottom', ha='left')
t2 = ax.text(0.90, .90, "Text 2", ha='right')
t3 = ax.annotate("Anchored to 1 & 2", xy=(0, 0), xycoords=(t1, t2),
                 va='bottom', color='tab:orange',)
```



text.OffsetFrom

Sometimes, you want your annotation with some "offset points", not from the annotated point but from some other point or artist. *text.OffsetFrom* is a helper for such cases.

```
from matplotlib.text import OffsetFrom

fig, ax = plt.subplots(figsize=(3, 3))
an1 = ax.annotate("Test 1", xy=(0.5, 0.5), xycoords="data",
                  va="center", ha="center",
                  bbox=dict(boxstyle="round", fc="w"))

offset_from = OffsetFrom(an1, (0.5, 0))
an2 = ax.annotate("Test 2", xy=(0.1, 0.1), xycoords="data",
                  xytext=(0, -10), textcoords=offset_from,
                  # xytext is offset points from "xy=(0.5, 0),␣
 ↪xycoords=an1"
                  va="top", ha="center",
                  bbox=dict(boxstyle="round", fc="w"),
                  arrowprops=dict(arrowstyle="->"))
```

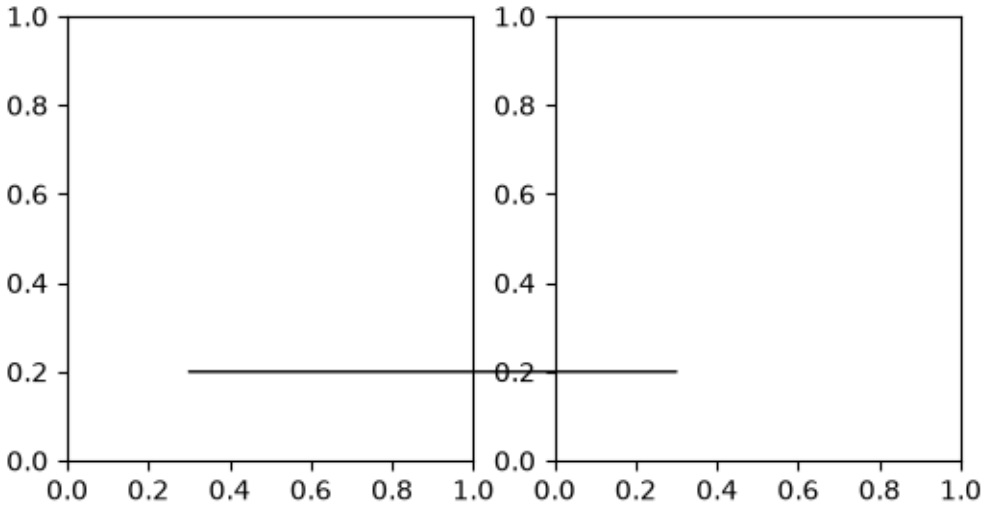


Non-text annotations

Using ConnectionPatch

ConnectionPatch is like an annotation without text. While *annotate* is sufficient in most situations, *ConnectionPatch* is useful when you want to connect points in different Axes. For example, here we connect the point *xy* in the data coordinates of `ax1` to point *xy* in the data coordinates of `ax2`:

```
from matplotlib.patches import ConnectionPatch

fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2, figsize=(6, 3))
xy = (0.3, 0.2)
con = ConnectionPatch(xyA=xy, coordsA=ax1.transData,
                      xyB=xy, coordsB=ax2.transData)

fig.add_artist(con)
```



Here, we added the `ConnectionPatch` to the *figure* (with `add_artist`) rather than to either Axes. This ensures that the ConnectionPatch artist is drawn on top of both Axes, and is also necessary when using *constrained_layout* for positioning the Axes.

Zoom effect between Axes

`mpl_toolkits.axes_grid1.inset_locator` defines some patch classes useful for interconnecting two Axes.

The code for this figure is at *Axes zoom effect* and familiarity with *Transformations Tutorial* is recommended.

Total running time of the script: (0 minutes 2.960 seconds)

3.8.2 Fonts in Matplotlib

Matplotlib needs fonts to work with its text engine, some of which are shipped alongside the installation. The default font is DejaVu Sans which covers most European writing systems. However, users can configure the default fonts, and provide their own custom fonts. See *Customizing text properties* for details and *Text with non-latin glyphs* in particular for glyphs not supported by DejaVu Sans.

Matplotlib also provides an option to offload text rendering to a TeX engine (`usetex=True`), see *Text rendering with LaTeX*.

Fonts in PDF and PostScript

Fonts have a long (and sometimes incompatible) history in computing, leading to different platforms supporting different types of fonts. In practice, Matplotlib supports three font specifications (in addition to pdf 'core fonts', which are explained later in the guide):

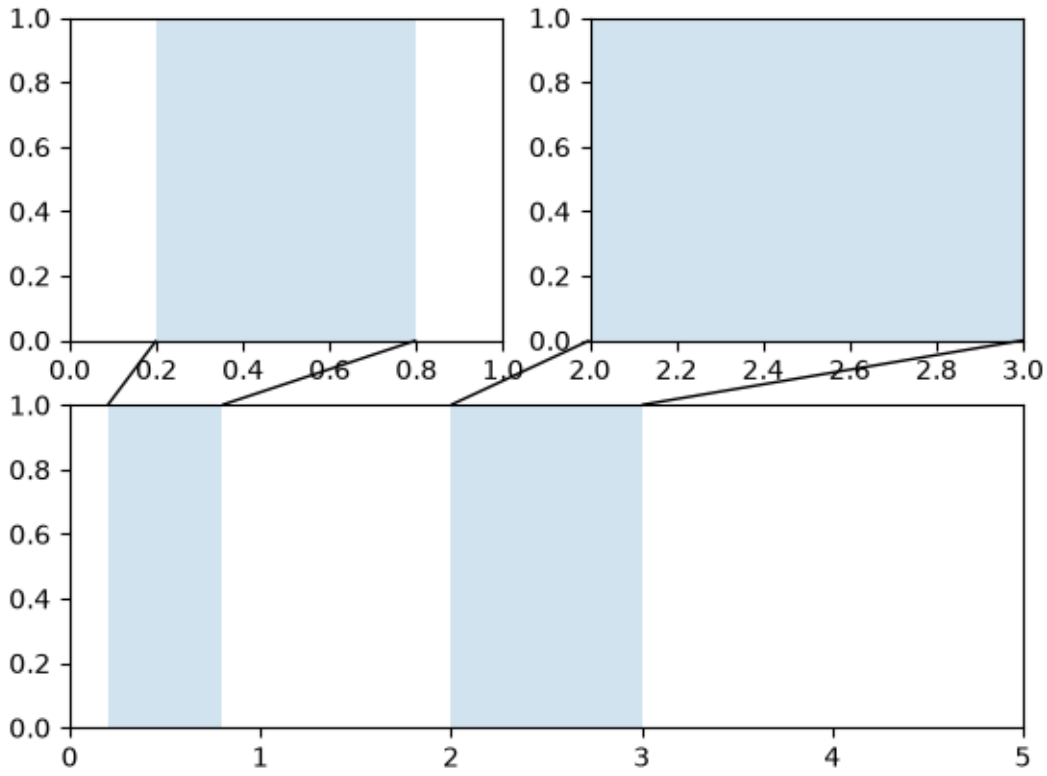

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
2.0
2.2
2.4
2.6
2.8
3.0
0
1
2
3
4
5

Table 7: Types of Fonts

Type 1 (PDF with usetex)	Type 3 (PDF/PS)	TrueType (PDF) / Type 42 (PS)
Old font types introduced by Adobe.		Newer font type introduced by Apple; commonly used today.
Restricted subset of PostScript, charstrings are in bytecode.	Full PostScript language, allows embedding arbitrary code.	Includes a virtual machine that can execute code.
Supports font hinting.	Does not support font hinting.	Supports font hinting, through the virtual machine.
Subsetted by code in *matplotlib._type1font*.	Subsetted via external module fontTools.	

Note

Adobe disabled support for authoring with Type 1 fonts in January 2023. Matplotlib uses Type 1 fonts for compatibility with TeX; when the usetex feature is used with the PDF backend, Matplotlib reads the fonts used by the TeX engine, which are usually Type 1.

Matplotlib also provides limited support for OpenType fonts, a newer standard developed jointly by Adobe and Microsoft; such fonts generally contain a much larger character set.

Font subsetting

The PDF and PostScript formats support embedding fonts in files, allowing the display program to correctly render the text, independent of what fonts are installed on the viewer's computer and without the need to pre-rasterize the text. This ensures that if the output is zoomed or resized the text does not become pixelated. However, embedding full fonts in the file can lead to large output files, particularly with fonts with many glyphs such as those that support CJK (Chinese/Japanese/Korean).

To keep the output size reasonable while using vector fonts, Matplotlib embeds only the glyphs that are actually used in the document. This is known as font subsetting. Computing the font subset and writing the reduced font are both complex problems, which Matplotlib solves in most cases by using the fontTools library.

Core Fonts

In addition to the ability to embed fonts, as part of the PostScript and PDF specification there are 14 Core Fonts that compliant viewers must ensure are available. If you restrict your document to only these fonts you do not have to embed any font information in the document but still get vector text.

This is especially helpful to generate *really lightweight* documents:

```
# trigger core fonts for PDF backend
plt.rcParams["pdf.use14corefonts"] = True
# trigger core fonts for PS backend
plt.rcParams["ps.useafm"] = True
```

(continues on next page)

(continued from previous page)

```
chars = "AFM ftw!"
fig, ax = plt.subplots()
ax.text(0.5, 0.5, chars)

fig.savefig("AFM_PDF.pdf", format="pdf")
fig.savefig("AFM_PS.ps", format="ps")
```

Fonts in SVG

Text can output to SVG in two ways controlled by *rcParams["svg.fonttype"]* (default: `'path'`):

- as a path (`'path'`) in the SVG
- as string in the SVG with font styling on the element (`'none'`)

When saving via `'path'` Matplotlib will compute the path of the glyphs used as vector paths and write those to the output. The advantage of doing so is that the SVG will look the same on all computers independent of what fonts are installed. However the text will not be editable after the fact. In contrast, saving with `'none'` will result in smaller files and the text will appear directly in the markup. However, the appearance may vary based on the SVG viewer and what fonts are available.

Fonts in Agg

To output text to raster formats via Agg, Matplotlib relies on FreeType. Because the exact rendering of the glyphs changes between FreeType versions we pin to a specific version for our image comparison tests.

How Matplotlib selects fonts

Internally, using a font in Matplotlib is a three step process:

1. a *FontProperties* object is created (explicitly or implicitly)
2. based on the *FontProperties* object the methods on *FontManager* are used to select the closest "best" font Matplotlib is aware of (except for `'none'` mode of SVG).
3. the Python proxy for the font object is used by the backend code to render the text -- the exact details depend on the backend via *font_manager.get_font*.

The algorithm to select the "best" font is a modified version of the algorithm specified by the CSS1 Specifications which is used by web browsers. This algorithm takes into account the font family name (e.g. "Arial", "Noto Sans CJK", "Hack", ...), the size, style, and weight. In addition to family names that map directly to fonts there are five "generic font family names" (serif, monospace, fantasy, cursive, and sans-serif) that will internally be mapped to any one of a set of fonts.

Currently the public API for doing step 2 is *FontManager.findfont* (and that method on the global *FontManager* instance is aliased at the module level as *font_manager.findfont*), which will only find a single font and return the absolute path to the font on the filesystem.

Font fallback

There is no font that covers the entire Unicode space thus it is possible for the users to require a mix of glyphs that cannot be satisfied from a single font. While it has been possible to use multiple fonts within a Figure, on distinct *Text* instances, it was not previous possible to use multiple fonts in the same *Text* instance (as a web browser does). As of Matplotlib 3.6 the Agg, SVG, PDF, and PS backends will "fallback" through multiple fonts in a single *Text* instance:

```
fig, ax = plt.subplots()
ax.text(
    .5, .5, "There are 🙈🙉🙊 in between!",
    family=['DejaVu Sans', 'Noto Sans CJK JP', 'Noto Sans TC'],
    ha='center'
)
```

Internally this is implemented by setting The "font family" on *FontProperties* objects to a list of font families. A (currently) private API extracts a list of paths to all of the fonts found and then constructs a single *ft2font.FT2Font* object that is aware of all of the fonts. Each glyph of the string is rendered using the first font in the list that contains that glyph.

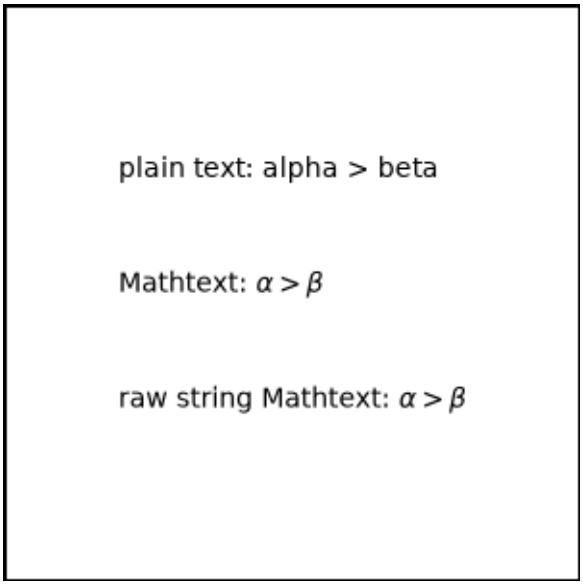
A majority of this work was done by Aitik Gupta supported by Google Summer of Code 2021.

3.8.3 Writing mathematical expressions

Matplotlib implements a lightweight TeX expression parser and layout engine and *Mathtext* is the subset of Tex markup that this engine supports. Note that Matplotlib can also render all text directly using TeX if *rcParams["text.usetex"]* (default: `False`) is *True*; see *Text rendering with LaTeX* for more details. Mathtext support is available if *rcParams["text.usetex"]* (default: `False`) is *False*.

Any string can be processed as Mathtext by placing the string inside a pair of dollar signs `'$'`. Mathtext often contains many backslashes `'\'`; so that the backslashes do not need to be escaped, Mathtext is often written using raw strings. For example:

```
import matplotlib.pyplot as plt

fig = plt.figure(figsize=(3, 3), linewidth=1, edgecolor='black')
fig.text(.2, .7, "plain text: alpha > beta")
fig.text(.2, .5, "Mathtext: $\\alpha > \\beta$")
fig.text(.2, .3, r"raw string Mathtext: $\alpha > \beta$")
```



See also

Mathtext example

TeX does *not* need to be installed to use Mathtext because Matplotlib ships with the Mathtext parser and engine. The Mathtext layout engine is a fairly direct adaptation of the layout algorithms in Donald Knuth's TeX. To render mathematical text using a different TeX engine, see *Text rendering with LaTeX*.

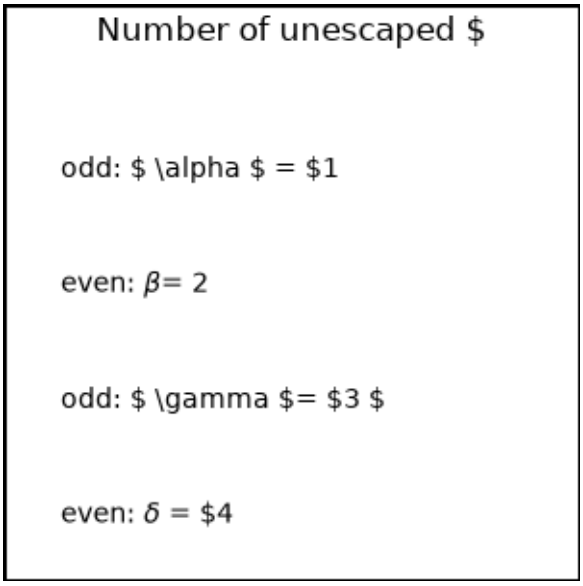
Note

To generate html output in documentation that will exactly match the output generated by `mathtext`, use the *`matplotlib.sphinxext.mathmpl`* Sphinx extension.

Special characters

Mathtext must be placed between a pair of (US) dollar signs `'$'`. A literal dollar symbol `'$'` in a string containing Mathtext must be escaped using a backslash: `'\$'`. A string may contain multiple pairs of dollar signs, resulting in multiple Mathtext expressions. Strings with an odd number of dollar signs are rendered solely as plain text.

```
fig = plt.figure(figsize=(3, 3), linewidth=1, edgecolor='black')
fig.suptitle("Number of unescaped $")
fig.text(.1, .7, r"odd: $ \alpha $ = $1")
fig.text(.1, .5, r"even: $ \beta $= $ 2 $")
fig.text(.1, .3, r'odd: $ \gamma $= \$3 $')
fig.text(.1, .1, r'even: $ \delta $ = $ \$4 $')
```



While Mathtext aims for compatibility with regular TeX, it diverges on when special characters need to be escaped. In TeX the dollar sign must be escaped `'\$'` in non-math text, while in Matplotlib the dollar sign must be escaped when writing Mathtext.

These other special characters are also escaped in non-math TeX, while in Matplotlib their behavior is dependent on how *rcParams["text.usetex"]* (default: `False`) is set:

```
# $ % & ~ _ ^ \ { } \( \) \[ \]
```

See the *usetex tutorial* for more information.

Subscripts and superscripts

To make subscripts and superscripts, use the `'_'` and `'^'` symbols:

```
r'$\alpha_i > \beta_i$'
```

$$\alpha_i > \beta_i$$

To display multi-letter subscripts or superscripts correctly, you should put them in curly braces `{...}`:

```
r'$\alpha^{ic} > \beta_{ic}$'
```

$$\alpha^{ic} > \beta_{ic}$$

Some symbols automatically put their sub/superscripts under and over the operator. For example, to write the sum of x_i from 0 to ∞, you could do:

```
r'$\sum_{i=0}^\infty x_i$'
```

$$\sum_{i=0}^{\infty} x_i$$

Fractions, binomials, and stacked numbers

Fractions, binomials, and stacked numbers can be created with the `\frac{}{}`, `\binom{}{}` and `\genfrac{}{}{}{}{}{}` commands, respectively:

```
r'$\frac{3}{4} \binom{3}{4} \genfrac{}{}{0}{}{3}{4}$'
```

produces

$$\frac{3}{4}\binom{3}{4}\genfrac{}{}{0}{}{3}{4}$$

Fractions can be arbitrarily nested:

```
r'$\frac{5 - \frac{1}{x}}{4}$'
```

produces

$$\frac{5 - \frac{1}{x}}{4}$$

Note that special care needs to be taken to place parentheses and brackets around fractions. Doing things the obvious way produces brackets that are too small:

```
r'$(\frac{5 - \frac{1}{x}}{4})$'
```

$$(\frac{5 - \frac{1}{x}}{4})$$

The solution is to precede the bracket with `\left` and `\right` to inform the parser that those brackets encompass the entire object.:

```
r'$\left(\frac{5 - \frac{1}{x}}{4}\right)$'
```

$$\left(\frac{5 - \frac{1}{x}}{4}\right)$$

Radicals

Radicals can be produced with the `\sqrt[]{}` command. For example:

```
r'$\sqrt{2}$'
```

$$\sqrt{2}$$

Any base can (optionally) be provided inside square brackets. Note that the base must be a simple expression, and cannot contain layout commands such as fractions or sub/superscripts:

```
r'$\sqrt[3]{x}$'
```

$$\sqrt[3]{x}$$

Fonts

The default font is *italics* for mathematical symbols.

This default can be changed using `rcParams["mathtext.default"]` (default: `'normal'`). For setting rcParams, see *Customizing Matplotlib with style sheets and rcParams*. For example, setting the default to `regular` allows you to use the same font for math text and regular non-math text.

To change fonts, e.g., to write "sin" in a Roman font, enclose the text in a font command:

```
r'$s(t) = \mathcal{A}\mathrm{sin}(2 \omega t)$'
```

$$s(t) = \mathcal{A}\mathrm{sin}(2\omega t)$$

More conveniently, many commonly used function names that are typeset in a Roman font have shortcuts. So the expression above could be written as follows:

```
r'$s(t) = \mathcal{A}\sin(2 \omega t)$'
```

$$s(t) = \mathcal{A}\sin(2\omega t)$$

Here "s" and "t" are variable in italics font (default), "sin" is in Roman font, and the amplitude "A" is in calligraphy font. Note in the example above the calligraphy `A` is squished into the `sin`. You can use a spacing command to add a little whitespace between them:

```
r's(t) = \mathcal{A}\/\sin(2 \omega t)'
```

$$s(t) = \mathcal{A}\,\sin(2\omega t)$$

Mathtext can use DejaVu Sans (default), DejaVu Serif, Computer Modern fonts from (La)TeX, STIX fonts which are designed to blend well with Times, or a Unicode font that you provide. The Mathtext font can be selected via `rcParams["mathtext.fontset"]` (default: `'dejavusans'`).

The choices available with all fonts are:

Command	Result
`\mathrm{Roman}`	Roman
`\mathit{Italic}`	*Italic*
`\mathtt{Typewriter}`	`Typewriter`
`\mathcal{CALLIGRAPHY}`	$\mathcal{CALLIGRAPHY}$

When using the STIX fonts, you also have the choice of:

Command	Result
`\mathbb{blackboard}`	$\mathbb{blackboard}$
`\mathrm{\mathbb{blackboard}}`	$\mathrm{\mathbb{blackboard}}$
`\mathfrak{Fraktur}`	$\mathfrak{Fraktur}$
`\mathsf{sansserif}`	$\mathsf{sansserif}$
`\mathrm{\mathsf{sansserif}}`	$\mathrm{\mathsf{sansserif}}$
`\mathbfit{bolditalic}`	$\mathbfit{bolditalic}$

There are also five global "font sets" to choose from, which are selected using the `mathtext.fontset` parameter in *matplotlibrc*.

`dejavusans`: DejaVu Sans

$$\mathscr{R} \prod_{i=\alpha}^{\infty} a_i \sin\left(2\pi f x_i\right) \tag{3.1}$$

`dejavuserif`: DejaVu Serif

$$\mathscr{R} \prod_{i=\alpha}^{\infty} a_i \sin\left(2\pi f x_i\right) \tag{3.2}$$

`cm`: Computer Modern (TeX)

$$\mathscr{R} \prod_{i=\alpha}^{\infty} a_i \sin\left(2\pi f x_i\right) \tag{3.3}$$

`stix`: STIX (designed to blend well with Times)

$$\mathscr{R} \prod_{i=\alpha}^{\infty} a_i \sin\left(2\pi f x_i\right) \tag{3.4}$$

`stixsans`: STIX sans-serif

$$\mathscr{R} \prod_{i=\alpha}^{\infty} a_i \sin\left(2\pi f x_i\right) \tag{3.5}$$

Additionally, you can use `\mathdefault{...}` or its alias `\mathregular{...}` to use the font used for regular text outside of Mathtext. There are a number of limitations to this approach, most notably that far fewer symbols will be available, but it can be useful to make math expressions blend well with other text in the plot.

For compatibility with popular packages, `\text{...}` is available and uses the `\mathrm{...}` font, but otherwise retains spaces and renders - as a dash (not minus).

Custom fonts

Mathtext also provides a way to use custom fonts for math. This method is fairly tricky to use, and should be considered an experimental feature for patient users only. By setting *`rcParams["mathtext.fontset"]`* (default: `'dejavusans'`) to `custom`, you can then set the following parameters, which control which font file to use for a particular set of math characters.

Parameter	Corresponds to
`mathtext.it`	`\mathit{}` or default italic
`mathtext.rm`	`\mathrm{}` Roman (upright)
`mathtext.tt`	`\mathtt{}` Typewriter (monospace)
`mathtext.bf`	`\mathbf{}` bold
`mathtext.bfit`	`\mathbfit{}` bold italic
`mathtext.cal`	`\mathcal{}` calligraphic
`mathtext.sf`	`\mathsf{}` sans-serif

Each parameter should be set to a fontconfig font descriptor, as defined in *Fonts in Matplotlib*. The fonts used should have a Unicode mapping in order to find any non-Latin characters, such as Greek. If you want to use a math symbol that is not contained in your custom fonts, you can set *`rcParams["mathtext.fallback"]`* (default: `'cm'`) to either `'cm'`, `'stix'` or `'stixsans'` which will cause the Mathtext system to use characters from an alternative font whenever a particular character cannot be found in the custom font.

Note that the math glyphs specified in Unicode have evolved over time, and many fonts may not have glyphs in the correct place for Mathtext.

Accents

An accent command may precede any symbol to add an accent above it. There are long and short forms for some of them.

Command	Result
`\acute a` or `\'a`	$\acute{a}$
`\bar a`	$\bar{a}$
`\breve a`	$\breve{a}$
`\dot a` or `\.a`	$\dot{a}$
`\ddot a` or `\''a`	$\ddot{a}$
`\dddot a`	$\dddot{a}$
`\ddddot a`	$\ddddot{a}$
`\grave a` or `\`a`	$\grave{a}$
`\hat a` or `\^a`	$\hat{a}$
`\tilde a` or `\~a`	$\tilde{a}$
`\vec a`	$\vec{a}$
`\overline{abc}`	$\overline{abc}$

In addition, there are two special accents that automatically adjust to the width of the symbols below:

Command	Result
`\widehat{xyz}`	$\widehat{xyz}$
`\widetilde{xyz}`	$\widetilde{xyz}$

Care should be taken when putting accents on lower-case i's and j's. Note that in the following `\imath` is used to avoid the extra dot over the i:

```
r"$\hat i\ \ \hat \imath$"
```

$\hat{i}\ \hat{\imath}$

Symbols

You can also use a large number of the TeX symbols, as in `\infty`, `\leftarrow`, `\sum`, `\int`.

Lower-case Greek

α \alpha	β \beta	γ \gamma	δ \delta
ε \epsilon	ε \varepsilon	ζ \zeta	η \eta
θ \theta	ϑ \vartheta	ι \iota	κ \kappa
ϰ \varkappa	λ \lambda	μ \mu	ν \nu
ξ \xi	π \pi	ϖ \varpi	ρ \rho
ϱ \varrho	σ \sigma	ς \varsigma	τ \tau
υ \upsilon	χ \chi	ψ \psi	ω \omega
ϕ \phi	φ \varphi	ϝ \digamma	

Upper-case Greek

Γ \Gamma	Δ \Delta	Θ \Theta	Λ \Lambda
Ξ \Xi	Π \Pi	Σ \Sigma	Υ \Upsilon
Φ \Phi	Ψ \Psi	Ω \Omega	

Hebrew

ך \daleth	ג \gimel	ב \beth	א \aleph

Latin named characters

Å \AA	Æ \AE	Ð \DH	Ø \O	Þ \Thorn	ß \ss
å \aa	æ \ae	ð \eth	ð \dh	ø \o	þ \thorn
Œ \OE	œ \oe				

Delimiters

(\leftparen	((	))	) \rightparen	. .
/ /	< <	> >	[[	[\lbrack
\ \backslash	∣ |	∣ \vert	]]	] \rbrack
{ \{	{ \leftbrace	{ \lbrace	} \rightbrace	} \rbrace
} \}	‖ \\|	‖ \Vert	↑ \uparrow	↓ \downarrow
↕ \updownarrow	⇑ \Uparrow	⇓ \Downarrow	⇕ \Updownarrow	⌈ \lceil
⌉ \rceil	⌊ \lfloor	⌋ \rfloor	⟨ \langle	⟩ \rangle
(\lgroup	) \rgroup			

Big symbols

∏ \prod	∐ \coprod	∑ \sum	∫ \int	∬ \iint
∭ \iiint	∮ \oint	∯ \oiint	∰ \oiiint	⋀ \bigwedge
⋁ \bigvee	⋂ \bigcap	⋃ \bigcup	⊙ \bigodot	⨁ \bigoplus
⨂ \bigotimes	⨄ \biguplus	⨆ \bigsqcup	⨌ \iiiint	

Standard function names

Pr \Pr	arccos \arccos	arcsin \arcsin	arctan \arctan	arg \arg
cos \cos	cosh \cosh	cot \cot	coth \coth	csc \csc
deg \deg	det \det	dim \dim	exp \exp	gcd \gcd
hom \hom	inf \inf	ker \ker	lg \lg	lim \lim
liminf \liminf	limsup \limsup	ln \ln	log \log	max \max
min \min	sec \sec	sin \sin	sinh \sinh	sup \sup
tan \tan	tanh \tanh			

Binary operation symbols

* *	+ +	- −	± \pm
× \times	÷ \div	† \dagger	‡ \ddagger
− −	∓ \mp	∔ \dotplus	/ \slash
∖ \setminus	∗ \ast	∘ \circ	• \bullet
∧ \wedge	∨ \vee	∩ \cap	∪ \cup
∸ \dotminus	∹ \minuscolon	∺ \dotsminusdots	≀ \wr
⊍ \cupdot	⊎ \uplus	⊓ \sqcap	⊔ \sqcup
⊕ \oplus	⊖ \ominus	⊗ \otimes	⊘ \oslash
⊙ \odot	⊚ \circledcirc	⊛ \circledast	⊝ \circleddash
⊞ \boxplus	⊟ \boxminus	⊠ \boxtimes	⊡ \boxdot
⊴ \unlhd	⊵ \unrhd	⊺ \intercal	⊻ \veebar
⊼ \barwedge	⊽ \barvee	⋄ \diamond	⋅ \cdot
⋆ \star	⋇ \divideontimes	⋋ \leftthreetimes	⋌ \rightthreetimes
⋎ \curlyvee	⋏ \curlywedge	⋒ \Cap	⋓ \Cup
⊼ \doublebarwedge	⊶ \obar	△ \bigtriangleup	▷ \rhd
▷ \triangleright	▽ \bigtriangledown	◁ \triangleleft	◁ \lhd
○ \bigcirc	◫ \boxbar	⨿ \amalg	⩓ \merge

Relation symbols

: :	< <	= =	= \equal
> >	϶ \backepsilon	… \dots	∈ \in
∉ \notin	∈ \smallin	∋ \ni	∌ \notsmallowns
∋ \smallowns	∝ \propto	∝ \varpropto	∟ \rightangle
∣ \mid	∤ \nmid	∥ \parallel	∦ \nparallel
∴ \therefore	∵ \because	∶ \ratio	∼ \sim
∽ \backsim	≁ \nsim	≂ \eqsim	≃ \simeq
≄ \nsimeq	≅ \cong	≆ \simneqq	≇ \ncong
≈ \approx	≉ \napprox	≊ \approxeq	≋ \approxident
≌ \backcong	≍ \asymp	≎ \Bumpeq	≏ \bumpeq
≐ \doteq	≑ \doteqdot	≑ \Doteq	≒ \fallingdotseq
≓ \risingdotseq	≔ \coloneq	≕ \eqcolon	≖ \eqcirc
≗ \circeq	≘ \arceq	≜ \wedgeq	≚ \veeeq
≛ \stareq	≜ \triangleeq	≜ \triangleq	≝ \eqdef
≞ \measeq	≟ \questeq	≠ \ne	≠ \neq
≡ \equiv	≢ \nequiv	≣ \Equiv	≤ \leq
≥ \geq	≦ \leqq	≧ \geqq	≨ \lneqq
≩ \gneqq	≪ \ll	≫ \gg	≬ \between
≮ \nless	≯ \ngtr	≰ \nleq	≱ \ngeq
≲ \lesssim	≳ \gtrsim	≴ \nlesssim	≵ \ngtrsim
≶ \lessgtr	≷ \gtrless	≸ \nlessgtr	≹ \ngtrless
≺ \prec	≻ \succ	≼ \preccurlyeq	≼ \preceq

continues on next page

Table 8 – continued from previous page

⪰ \succeq	⪰ \succcurlyeq	≾ \precsim	≿ \succsim
⊀ \nprec	⊁ \nsucc	⊂ \subset	⊃ \supset
⊄ \nsubset	⊅ \nsupset	⊆ \subseteq	⊇ \supseteq
⊈ \nsubseteq	⊉ \nsupseteq	⊊ \subsetneq	⊋ \supsetneq
⊏ \sqsubset	⊐ \sqsupset	⊑ \sqsubseteq	⊒ \sqsupseteq
⊜ \oequal	⊢ \vdash	⊣ \dashv	⊤ \top
⊥ \bot	⊦ \rightassert	⊨ \models	⊨ \vDash
⊩ \Vdash	⊪ \Vvdash	⊫ \rightModels	⊬ \nvdash
⊭ \nvDash	⊯ \nVdash	⊯ \nVDash	⊱ \scurel
⊴ \trianglelefteq	⊵ \trianglerighteq	⊾ \measuredrightangl	◿ \varlrtriangle
⋈ \bowtie	⋉ \ltimes	⋊ \rtimes	⋍ \backsimeq
⋐ \Subset	⋑ \Supset	⋔ \pitchfork	⋕ \equalparallel
⋖ \lessdot	⋗ \gtrdot	⋘ \lll	⋙ \ggg
⋚ \lesseqgtr	⋛ \gtreqless	⋜ \eqless	⋝ \eqgtr
⋞ \curlyeqprec	⋟ \curlyeqsucc	⋦ \npreccurlyeq	⋩ \nsucccurlyeq
⋢ \nsqsubseteq	⋣ \nsqsupseteq	⋤ \sqsubsetneq	⋥ \sqsupsetneq
⋦ \lnsim	⋧ \gnsim	⋨ \precnsim	⋩ \succnsim
⋪ \ntriangleleft	⋫ \ntriangleright	⋬ \ntrianglelefteq	⋭ \ntrianglerighteq
⋲ \disin	⋳ \isins	⋵ \varisins	⋵̇ \isindot
⋶ \isinobar	⋷ \varisinobar	⋸ \isinvb	⋹ \isinE
⋺ \nisd	⋻ \nis	⋽ \varnis	⋾ \niobar
⋿ \varniobar	⨿ \bagmember	⌢ \frown	⌣ \smile
△ \triangle	▶ \blacktrianglerigh	▷ \triangleright	⊳ \vartriangleright
◀ \blacktriangleleft	◁ \triangleleft	⊲ \vartriangleleft	⊥ \perp
⋈ \Join	⩽ \leqslant	⩾ \geqslant	⪅ \lessapprox
⪆ \gtrapprox	⪉ \lnapprox	⪊ \gnapprox	⪋ \lesseqqgtr
⪌ \gtreqqless	⪽ \eqslantless	⪾ \eqslantgtr	⪷ \precapprox
⪸ \succapprox	⪹ \precnapprox	⪺ \succnapprox	⫅ \subseteqq
⫆ \supseteqq	⫋ \subsetneqq	⫌ \supsetneqq	

Arrow symbols

← \overleftarrow	\overleftrightarrow	← \leftarrow	↑ \uparrow
→ \to	→ \rightarrow	↓ \downarrow	↔ \leftrightarrow
↕ \updownarrow	↖ \nwarrow	↗ \nearrow	↘ \searrow
↙ \swarrow	↚ \nleftarrow	↛ \nrightarrow	↜ \leftsquigarrow
⇝ \rightsquigarrow	↞ \twoheadleftarrow	↟ \twoheaduparrow	↠ \twoheadrightarrow
↡ \twoheaddownarrow	↢ \leftarrowtail	↣ \rightarrowtail	↤ \mapsfrom
↥ \mapsup	↦ \mapsto	↧ \mapsdown	↨ \updownarrowbar
↩ \hookleftarrow	↪ \hookrightarrow	↫ \looparrowleft	↬ \looparrowright
↭ \leftrightsquigarrow	↮ \nleftrightarrow	↯ \downzigzagarrow	↰ \Lsh
↱ \Rsh	↲ \Ldsh	↳ \Rdsh	↶ \curvearrowleft
↷ \curvearrowright	↺ \circlearrowleft	↻ \circlearrowright	↻ \cwopencirclearrow
↼ \leftharpoonup	↽ \leftharpoondown	↾ \upharpoonright	↿ \upharpoonleft
⇀ \rightharpoonup	⇁ \rightharpoondown	⇂ \downharpoonright	⇃ \downharpoonleft
⇄ \rightleftarrows	⇅ \updownarrows	⇆ \leftrightarrows	⇇ \leftleftarrows
⇈ \upuparrows	⇉ \rightrightarrows	⇊ \downdownarrows	⇋ \leftrightharpoons
⇌ \rightleftharpoons	⇍ \nLeftarrow	⇎ \nLeftrightarrow	⇏ \nRightarrow
⇐ \Leftarrow	⇑ \Uparrow	⇒ \Rightarrow	⇓ \Downarrow
⇔ \Leftrightarrow	⇕ \Updownarrow	⇖ \Nwarrow	⇗ \Nearrow
⇘ \Searrow	⇙ \Swarrow	⇚ \Lleftarrow	⇛ \Rrightarrow
⇝ \rightzigzagarrow	⇝ \leadsto	⇤ \barleftarrow	⇥ \rightarrowbar
⊌ \cupleftarrow	⊸ \multimap	⟵ \longleftarrow	⟶ \longrightarrow
⟷ \longleftrightarrow	⟸ \Longleftarrow	⟹ \Longrightarrow	⟺ \Longleftrightarrow
⟼ \longmapsto	⇠ \dashleftarrow	⇢ \dashrightarrow	

Dot symbols

… \ldots	∴ \therefore	∵ \because	∷ \Colon
⋮ \vdots	⋯ \cdots	⋰ \adots	⋱ \ddots

Black-board characters

ℂ \BbbC	ℕ \BbbN	ℙ \BbbP	ℚ \BbbQ	ℝ \BbbR	ℤ \BbbZ

Script characters

𝓰 \scrg	𝓗 \scrH	𝓘 \scrI	𝓛 \scrL	𝓡 \scrR	𝓑 \scrB
e \scre	𝓔 \scrE	𝓕 \scrF	𝓜 \scrM	𝓸 \scro	

Fraktur characters

𝔷 \frakZ	𝔈 \frakC

Miscellaneous symbols

$ \$	¢ \cent	£ \sterling	¥ \yen
§ \S	© \copyright	¬ \neg	® \circledR
° \degree	¶ \P	ℏ \hbar	𝚤 \imath
ı \i	Ł \L	ł \l	ƛ \lambdabar
ȷ \jmath	† \dag	‡ \ddag	‰ \perthousand
′ \prime	‵ \backprime	ℎ \hslash	ℑ \Im
ℓ \ell	℘ \wp	ℜ \Re	℧ \mho
ⅎ \Finv	⅁ \Game	∀ \forall	∁ \complement
∂ \partial	∃ \exists	∄ \nexists	∅ \emptyset
∅ \varnothing	∆ \increment	∇ \nabla	∎ \QED
∞ \infty	∠ \angle	∡ \measuredangle	∢ \sphericalangle
∾ \ac	∿ \sinewave	⊹ \hermitmatrix	Ⓢ \circledS
■ \blacksquare	△ \triangle	▵ \vartriangle	▲ \blacktriangle
▼ \blacktriangledown	▽ \triangledown	★ \bigstar	☡ \danger
♠ \spadesuit	♡ \heartsuit	♢ \diamondsuit	♣ \clubsuit
♧ \clubsuitopen	♭ \flat	♮ \natural	♯ \sharp
✓ \checkmark	✠ \maltese		

If a particular symbol does not have a name (as is true of many of the more obscure symbols in the STIX fonts), Unicode characters can also be used:

```
'$\u23ce$'
```

3.8.4 Text rendering with XeLaTeX/LuaLaTeX via the `pgf` backend

Using the `pgf` backend, Matplotlib can export figures as pgf drawing commands that can be processed with pdflatex, xelatex or lualatex. XeLaTeX and LuaLaTeX have full Unicode support and can use any font that is installed in the operating system, making use of advanced typographic features of OpenType,

AAT and Graphite. Pgf pictures created by `plt.savefig('figure.pgf')` can be embedded as raw commands in LaTeX documents. Figures can also be directly compiled and saved to PDF with `plt.savefig('figure.pdf')` by switching the backend

```
matplotlib.use('pgf')
```

or by explicitly requesting the use of the `pgf` backend

```
plt.savefig('figure.pdf', backend='pgf')
```

or by registering it for handling pdf output

```
from matplotlib.backends.backend_pgf import FigureCanvasPgf
matplotlib.backend_bases.register_backend('pdf', FigureCanvasPgf)
```

The last method allows you to keep using regular interactive backends and to save xelatex, lualatex or pdflatex compiled PDF files from the graphical user interface. Note that, in that case, the interactive display will still use the standard interactive backends (e.g., QtAgg), and in particular use latex to compile relevant text snippets.

Matplotlib's pgf support requires a recent LaTeX installation that includes the TikZ/PGF packages (such as TeXLive), preferably with XeLaTeX or LuaLaTeX installed. If either pdftocairo or ghostscript is present on your system, figures can optionally be saved to PNG images as well. The executables for all applications must be located on your *PATH*.

rcParams that control the behavior of the pgf backend:

Parameter	Documentation
pgf.preamble	Lines to be included in the LaTeX preamble
pgf.rcfonts	Setup fonts from rc params using the fontspec package
pgf.texsystem	Either "xelatex" (default), "lualatex" or "pdflatex"

Note

TeX defines a set of special characters, such as:

```
# $ % & ~ _ ^ \ { }
```

Generally, these characters must be escaped correctly. For convenience, some characters (_, ^, %) are automatically escaped outside of math environments. Other characters are not escaped as they are commonly needed in actual TeX expressions. However, one can configure TeX to treat them as "normal" characters (known as "catcode 12" to TeX) via a custom preamble, such as:

```
plt.rcParams["pgf.preamble"] = (
    r"\AtBeginDocument{\catcode`\&=12\catcode`\#=12}")
```

Multi-Page PDF Files

The pgf backend also supports multipage pdf files using *PdfPages*

```
from matplotlib.backends.backend_pgf import PdfPages
import matplotlib.pyplot as plt

with PdfPages('multipage.pdf', metadata={'author': 'Me'}) as pdf:

    fig1, ax1 = plt.subplots()
    ax1.plot([1, 5, 3])
    pdf.savefig(fig1)

    fig2, ax2 = plt.subplots()
    ax2.plot([1, 5, 3])
    pdf.savefig(fig2)
```

Font specification

The fonts used for obtaining the size of text elements or when compiling figures to PDF are usually defined in the *rcParams*. You can also use the LaTeX default Computer Modern fonts by clearing the lists for *rcParams["font.serif"]* (default: `['DejaVu Serif', 'Bitstream Vera Serif', 'Computer Modern Roman', 'New Century Schoolbook', 'Century Schoolbook L', 'Utopia', 'ITC Bookman', 'Bookman', 'Nimbus Roman No9 L', 'Times New Roman', 'Times', 'Palatino', 'Charter', 'serif']`), *rcParams["font.sans-serif"]* (default: `['DejaVu Sans', 'Bitstream Vera Sans', 'Computer Modern Sans Serif', 'Lucida Grande', 'Verdana', 'Geneva', 'Lucid', 'Arial', 'Helvetica', 'Avant Garde', 'sans-serif']`) or *rcParams["font.monospace"]* (default: `['DejaVu Sans Mono', 'Bitstream Vera Sans Mono', 'Computer Modern Typewriter', 'Andale Mono', 'Nimbus Mono L', 'Courier New', 'Courier', 'Fixed', 'Terminal', 'monospace']`). Please note that the glyph coverage of these fonts is very limited. If you want to keep the Computer Modern font face but require extended Unicode support, consider installing the Computer Modern Unicode fonts *CMU Serif*, *CMU Sans Serif*, etc.

When saving to `.pgf`, the font configuration Matplotlib used for the layout of the figure is included in the header of the text file.

```
import matplotlib.pyplot as plt

plt.rcParams.update({
    "font.family": "serif",
    # Use LaTeX default serif font.
    "font.serif": [],
    # Use specific cursive fonts.
    "font.cursive": ["Comic Neue", "Comic Sans MS"],
})

fig, ax = plt.subplots(figsize=(4.5, 2.5))
```

(continues on next page)

(continued from previous page)

```
ax.plot(range(5))

ax.text(0.5, 3., "serif")
ax.text(0.5, 2., "monospace", family="monospace")
ax.text(2.5, 2., "sans-serif", family="DejaVu Sans")  # Use specific␣
↪sans font.
ax.text(2.5, 1., "comic", family="cursive")
ax.set_xlabel("µ is not $\\mu$")
```

Custom preamble

Full customization is possible by adding your own commands to the preamble. Use *rcParams["pgf.preamble"]* (default: `''`) if you want to configure the math fonts, using `unicode-math` for example, or for loading additional packages. Also, if you want to do the font configuration yourself instead of using the fonts specified in the rc parameters, make sure to disable *rcParams["pgf.rcfonts"]* (default: `True`).

```
import matplotlib as mpl

mpl.use("pgf")
import matplotlib.pyplot as plt

plt.rcParams.update({
    "font.family": "serif",  # use serif/main font for text elements
    "text.usetex": True,     # use inline math for ticks
    "pgf.rcfonts": False,    # don't setup fonts from rc parameters
    "pgf.preamble": "\n".join([
         r"\usepackage{url}",            # load additional packages
         r"\usepackage{unicode-math}",   # unicode math setup
         r"\setmainfont{DejaVu Serif}",  # serif font via preamble
    ])
})

fig, ax = plt.subplots(figsize=(4.5, 2.5))

ax.plot(range(5))

ax.set_xlabel("unicode text: я, ψ, €, ü")
ax.set_ylabel(r"\url{https://matplotlib.org}")
ax.legend(["unicode math: $λ=∑_i^∞ µ_i^2$"])
```

Choosing the TeX system

The TeX system to be used by Matplotlib is chosen by *rcParams["pgf.texsystem"]* (default: `'xelatex'`). Possible values are `'xelatex'` (default), `'lualatex'` and `'pdflatex'`. Please note that when selecting pdflatex, the fonts and Unicode handling must be configured in the preamble.

```
import matplotlib.pyplot as plt

plt.rcParams.update({
    "pgf.texsystem": "pdflatex",
    "pgf.preamble": "\n".join([
         r"\usepackage[utf8x]{inputenc}",
         r"\usepackage[T1]{fontenc}",
         r"\usepackage{cmbright}",
    ]),
})

fig, ax = plt.subplots(figsize=(4.5, 2.5))

ax.plot(range(5))

ax.text(0.5, 3., "serif", family="serif")
ax.text(0.5, 2., "monospace", family="monospace")
ax.text(2.5, 2., "sans-serif", family="sans-serif")
ax.set_xlabel(r"µ is not $\mu$")
```

Troubleshooting

- Make sure LaTeX is working and on your *PATH* (for raster output, pdftocairo or ghostscript is also required). The *PATH* environment variable may need to be modified (in particular on Windows) to include the directories containing the executable. See *Environment variables* and *Setting environment variables in Windows* for details.
- Sometimes the font rendering in figures that are saved to png images is very bad. This happens when the pdftocairo tool is not available and ghostscript is used for the pdf to png conversion.
- Make sure what you are trying to do is possible in a LaTeX document, that your LaTeX syntax is valid and that you are using raw strings if necessary to avoid unintended escape sequences.
- *rcParams["pgf.preamble"]* (default: `''`) provides lots of flexibility, and lots of ways to cause problems. When experiencing problems, try to minimalize or disable the custom preamble.
- Configuring an `unicode-math` environment can be a bit tricky. The TeXLive distribution for example provides a set of math fonts which are usually not installed system-wide. XeLaTeX, unlike LuaLaTeX, cannot find these fonts by their name, which is why you might have to specify `\setmathfont{xits-math.otf}` instead of `\setmathfont{XITS Math}` or alternatively make the fonts available to your OS. See this tex.stackexchange.com question for more details.
- If the font configuration used by Matplotlib differs from the font setting in yout LaTeX document, the alignment of text elements in imported figures may be off. Check the header of your `.pgf` file if you are unsure about the fonts Matplotlib used for the layout.

- Vector images and hence `.pgf` files can become bloated if there are a lot of objects in the graph. This can be the case for image processing or very big scatter graphs. In an extreme case this can cause TeX to run out of memory: "TeX capacity exceeded, sorry" You can configure latex to increase the amount of memory available to generate the `.pdf` image as discussed on tex.stackexchange.com. Another way would be to "rasterize" parts of the graph causing problems using either the `rasterized=True` keyword, or `.set_rasterized(True)` as per *this example*.
- Various math fonts are compiled and rendered only if corresponding font packages are loaded. Specifically, when using `\mathbf{}` on Greek letters, the default computer modern font may not contain them, in which case the letter is not rendered. In such scenarios, the `lmodern` package should be loaded.
- If you still need help, please see *Get help*

3.8.5 Text in Matplotlib

Matplotlib has extensive text support, including support for mathematical expressions, truetype support for raster and vector outputs, newline separated text with arbitrary rotations, and Unicode support.

Because it embeds fonts directly in output documents, e.g., for postscript or PDF, what you see on the screen is what you get in the hardcopy. FreeType support produces very nice, antialiased fonts, that look good even at small raster sizes. Matplotlib includes its own *matplotlib.font_manager* (thanks to Paul Barrett), which implements a cross platform, W3C compliant font finding algorithm.

The user has a great deal of control over text properties (font size, font weight, text location and color, etc.) with sensible defaults set in the *rc file*. And significantly, for those interested in mathematical or scientific figures, Matplotlib implements a large number of TeX math symbols and commands, supporting *mathematical expressions* anywhere in your figure.

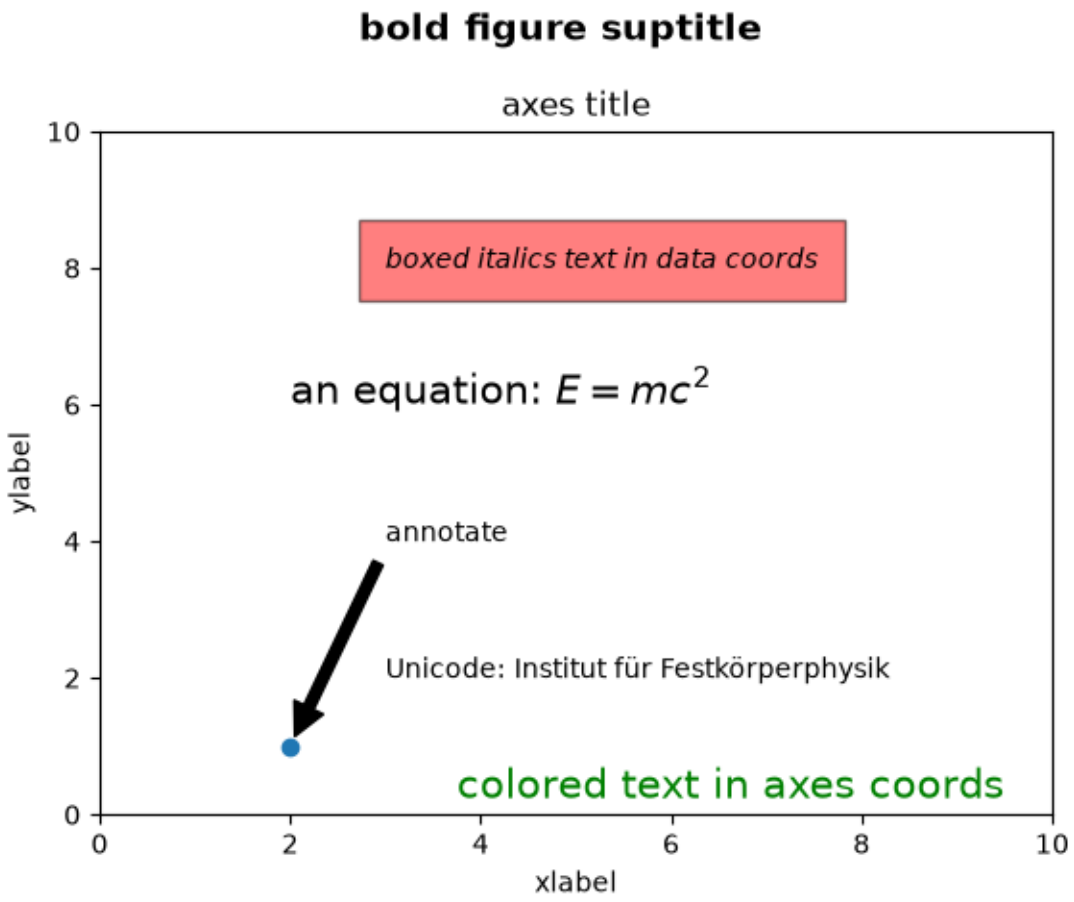
Basic text commands

The following commands are used to create text in the implicit and explicit interfaces (see *Matplotlib Application Interfaces (APIs)* for an explanation of the tradeoffs):

implicit API	explicit API	description
text	*text*	Add text at an arbitrary location of the *Axes*.
annotate	*annotate*	Add an annotation, with an optional arrow, at an arbitrary location of the *Axes*.
xlabel	*set_xlabel*	Add a label to the *Axes*'s x-axis.
ylabel	*set_ylabel*	Add a label to the *Axes*'s y-axis.
title	*set_title*	Add a title to the *Axes*.
figtext	*text*	Add text at an arbitrary location of the *Figure*.
suptitle	*suptitle*	Add a title to the *Figure*.

All of these functions create and return a *Text* instance, which can be configured with a variety of font and other properties. The example below shows all of these commands in action, and more detail is provided in the sections that follow.

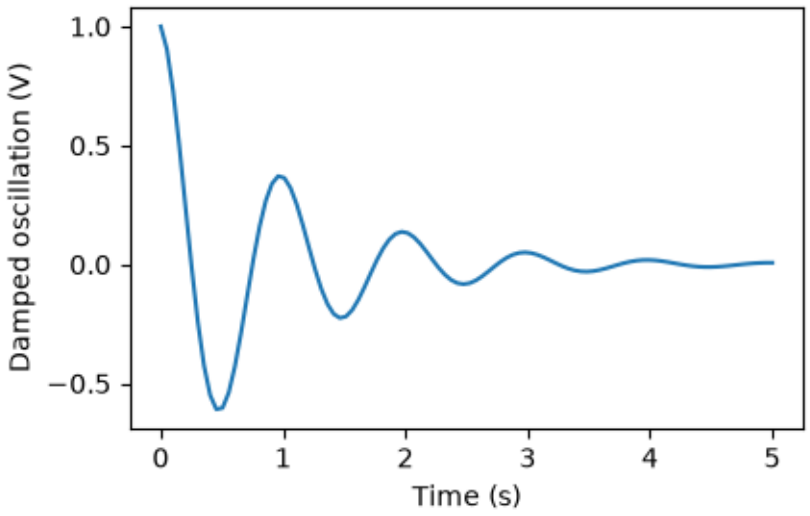
```
import matplotlib.pyplot as plt

import matplotlib

fig = plt.figure()
ax = fig.add_subplot()
fig.subplots_adjust(top=0.85)

# Set titles for the figure and the subplot respectively
fig.suptitle('bold figure suptitle', fontsize=14, fontweight='bold')
ax.set_title('axes title')

ax.set_xlabel('xlabel')
ax.set_ylabel('ylabel')

# Set both x- and y-axis limits to [0, 10] instead of default [0, 1]
ax.axis([0, 10, 0, 10])

ax.text(3, 8, 'boxed italics text in data coords', style='italic',
        bbox={'facecolor': 'red', 'alpha': 0.5, 'pad': 10})

ax.text(2, 6, r'an equation: $E=mc^2$', fontsize=15)

ax.text(3, 2, 'Unicode: Institut für Festkörperphysik')

ax.text(0.95, 0.01, 'colored text in axes coords',
        verticalalignment='bottom', horizontalalignment='right',
        transform=ax.transAxes,
        color='green', fontsize=15)

ax.plot([2], [1], 'o')
ax.annotate('annotate', xy=(2, 1), xytext=(3, 4),
            arrowprops=dict(facecolor='black', shrink=0.05))

plt.show()
```



Labels for x- and y-axis

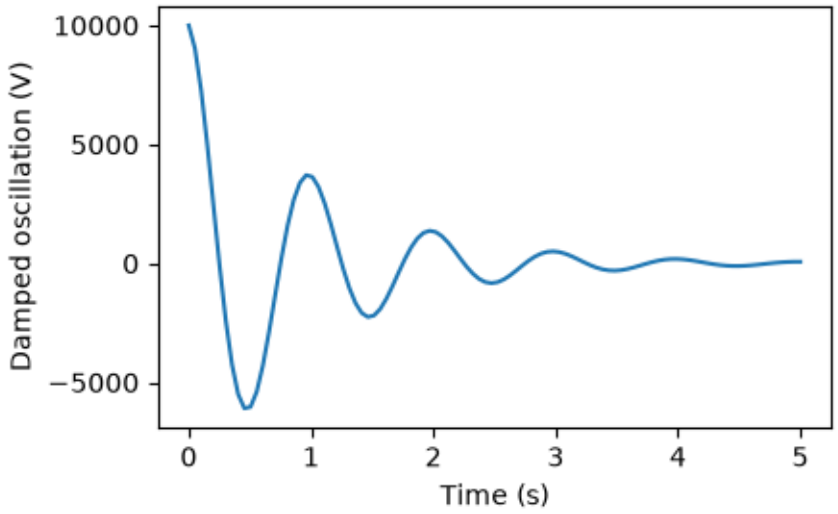
Specifying the labels for the x- and y-axis is straightforward, via the *set_xlabel* and *set_ylabel* methods.

```
import matplotlib.pyplot as plt
import numpy as np

x1 = np.linspace(0.0, 5.0, 100)
y1 = np.cos(2 * np.pi * x1) * np.exp(-x1)

fig, ax = plt.subplots(figsize=(5, 3))
fig.subplots_adjust(bottom=0.15, left=0.2)
ax.plot(x1, y1)
ax.set_xlabel('Time (s)')
ax.set_ylabel('Damped oscillation (V)')

plt.show()
```



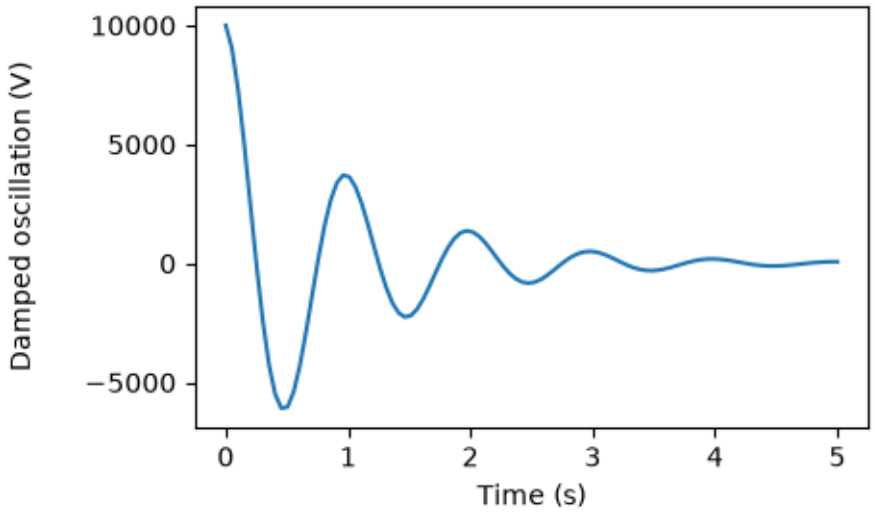
The x- and y-labels are automatically placed so that they clear the x- and y-ticklabels. Compare the plot below with that above, and note the y-label is to the left of the one above.

```
fig, ax = plt.subplots(figsize=(5, 3))
fig.subplots_adjust(bottom=0.15, left=0.2)
ax.plot(x1, y1*10000)
ax.set_xlabel('Time (s)')
ax.set_ylabel('Damped oscillation (V)')

plt.show()
```



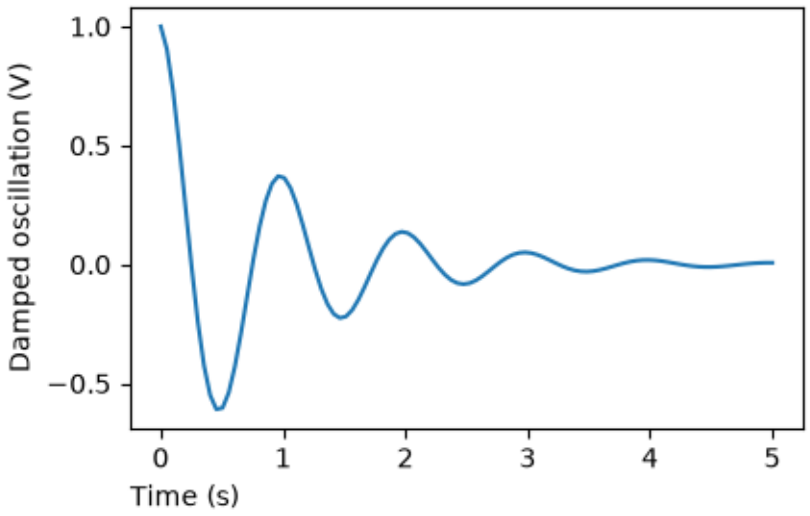
If you want to move the labels, you can specify the *labelpad* keyword argument, where the value is points (1/72", the same unit used to specify font sizes).

```
fig, ax = plt.subplots(figsize=(5, 3))
fig.subplots_adjust(bottom=0.15, left=0.2)
ax.plot(x1, y1*10000)
ax.set_xlabel('Time (s)')
ax.set_ylabel('Damped oscillation (V)', labelpad=18)

plt.show()
```



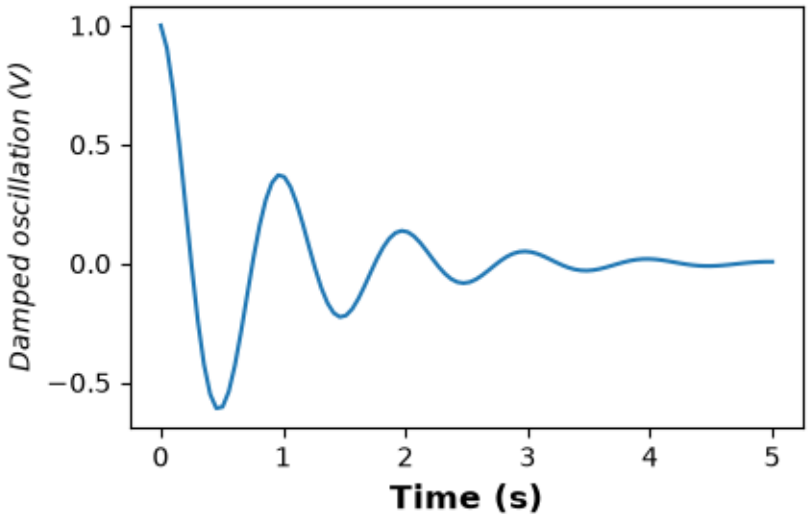
Alternatively, the labels accept all the `Text` keyword arguments, including *position*, via which we can manually specify the label positions. Here we put the xlabel to the far left of the axis. Note, that the y-coordinate of this position has no effect - to adjust the y-position we need to use the *labelpad* keyword argument.

```
fig, ax = plt.subplots(figsize=(5, 3))
fig.subplots_adjust(bottom=0.15, left=0.2)
ax.plot(x1, y1)
ax.set_xlabel('Time (s)', position=(0., 1e6), horizontalalignment='left
 ↪')
ax.set_ylabel('Damped oscillation (V)')

plt.show()
```



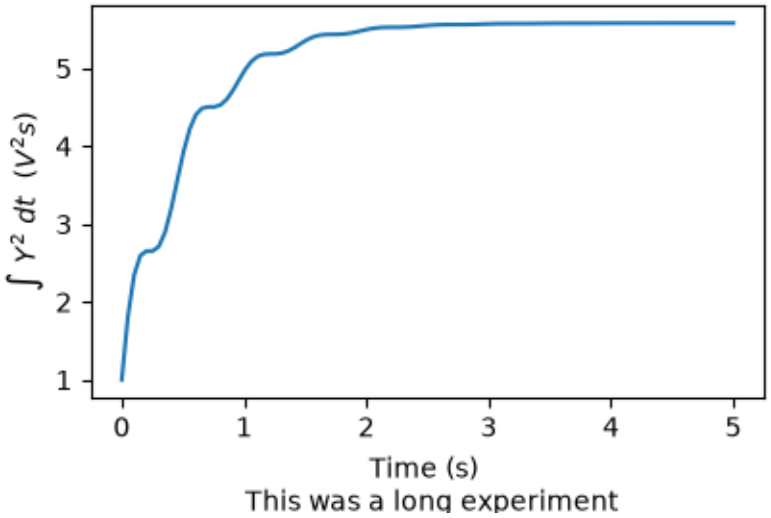
All the labelling in this tutorial can be changed by manipulating the *matplotlib.font_manager.FontProperties* method, or by named keyword arguments to *set_xlabel*.

```
from matplotlib.font_manager import FontProperties

font = FontProperties(family='Times New Roman', style='italic')

fig, ax = plt.subplots(figsize=(5, 3))
fig.subplots_adjust(bottom=0.15, left=0.2)
ax.plot(x1, y1)
ax.set_xlabel('Time (s)', fontsize='large', fontweight='bold')
ax.set_ylabel('Damped oscillation (V)', fontproperties=font)

plt.show()
```



Finally, we can use native TeX rendering in all text objects and have multiple lines:

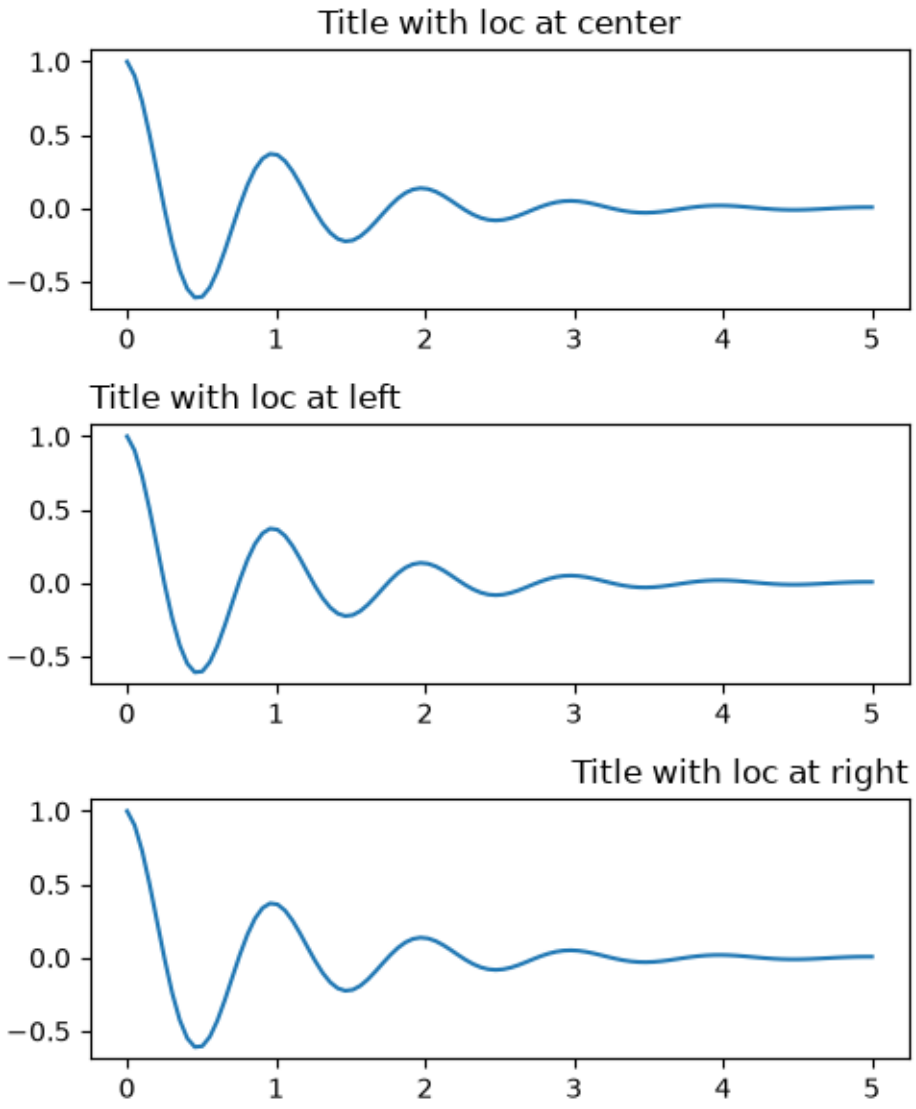
```
fig, ax = plt.subplots(figsize=(5, 3))
fig.subplots_adjust(bottom=0.2, left=0.2)
ax.plot(x1, np.cumsum(y1**2))
ax.set_xlabel('Time (s) \n This was a long experiment')
ax.set_ylabel(r'$\int\ Y^2\ dt\ \ (V^2 s)$')
plt.show()
```



Titles

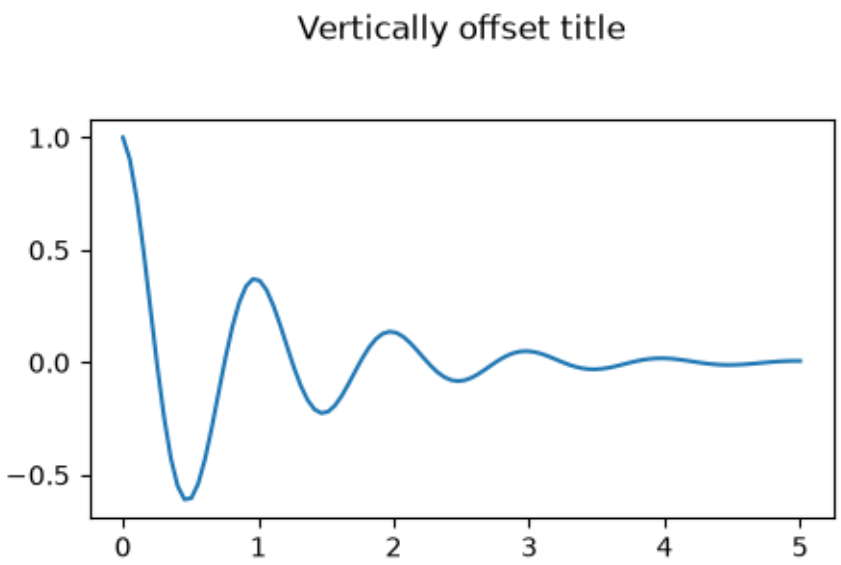
Subplot titles are set in much the same way as labels, but there is the *loc* keyword argument that can change the position and justification (the default value is "center").

```
fig, axs = plt.subplots(3, 1, figsize=(5, 6), tight_layout=True)
locs = ['center', 'left', 'right']
for ax, loc in zip(axs, locs):
    ax.plot(x1, y1)
    ax.set_title('Title with loc at ' + loc, loc=loc)
plt.show()
```



Vertical spacing for titles is controlled via *rcParams["axes.titlepad"]* (default: 6.0). Setting to a different value moves the title.

```
fig, ax = plt.subplots(figsize=(5, 3))
fig.subplots_adjust(top=0.8)
ax.plot(x1, y1)
ax.set_title('Vertically offset title', pad=30)
plt.show()
```



Ticks and ticklabels

Placing ticks and ticklabels is a very tricky aspect of making a figure. Matplotlib does its best to accomplish the task automatically, but it also offers a very flexible framework for determining the choices for tick locations, and how they are labelled.

Terminology

Axes have a *matplotlib.axis.Axis* object for the `ax.xaxis` and `ax.yaxis` that contain the information about how the labels in the axis are laid out.

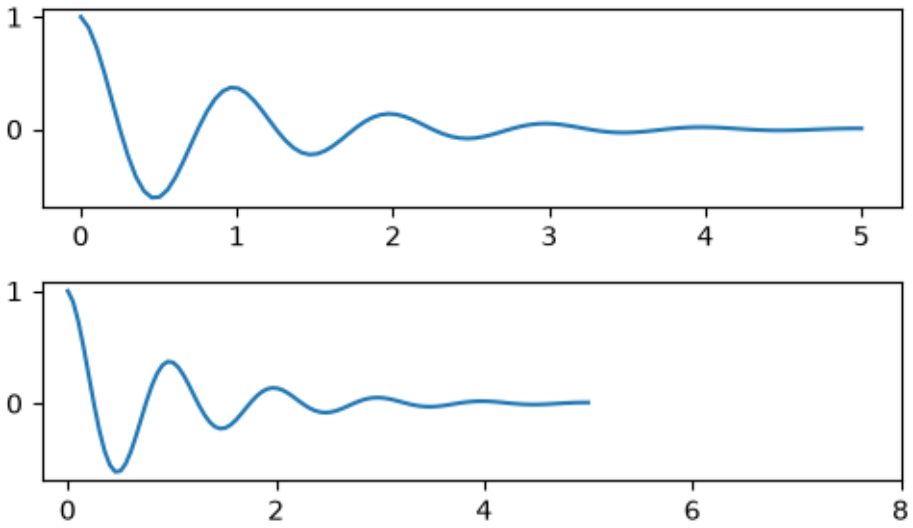
The axis API is explained in detail in the documentation to *axis*.

An Axis object has major and minor ticks. The Axis has *Axis.set_major_locator* and *Axis.set_minor_locator* methods that use the data being plotted to determine the location of major and minor ticks. There are also *Axis.set_major_formatter* and *Axis.set_minor_formatter* methods that format the tick labels.

Simple ticks

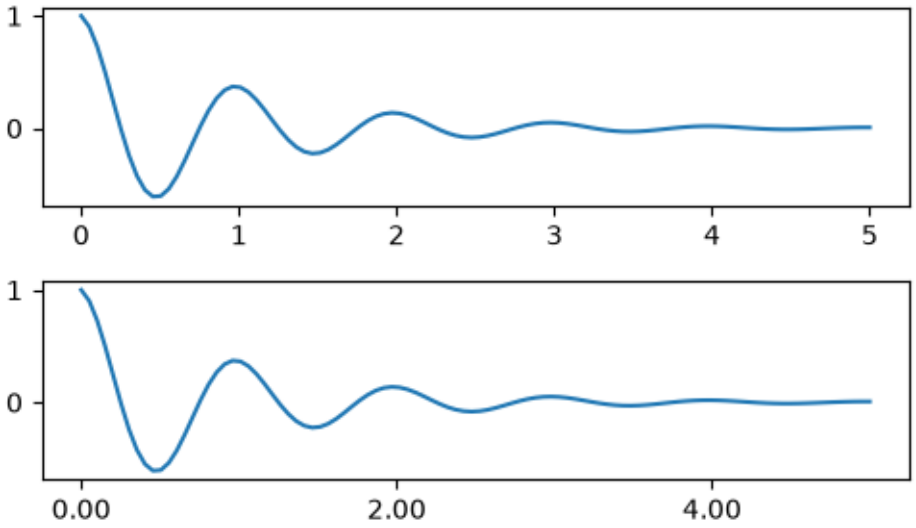
It is often convenient to simply define the tick values, and sometimes the tick labels, overriding the default locators and formatters. However, this is discouraged because it breaks interactive navigation of the plot. It also can reset the axis limits: note that the second plot has the ticks we asked for, including ones that are well outside the automatic view limits.

```
fig, axs = plt.subplots(2, 1, figsize=(5, 3), tight_layout=True)
axs[0].plot(x1, y1)
axs[1].plot(x1, y1)
axs[1].xaxis.set_ticks(np.arange(0., 8.1, 2.))
plt.show()
```



We can of course fix this after the fact, but it does highlight a weakness of hard-coding the ticks. This example also changes the format of the ticks:

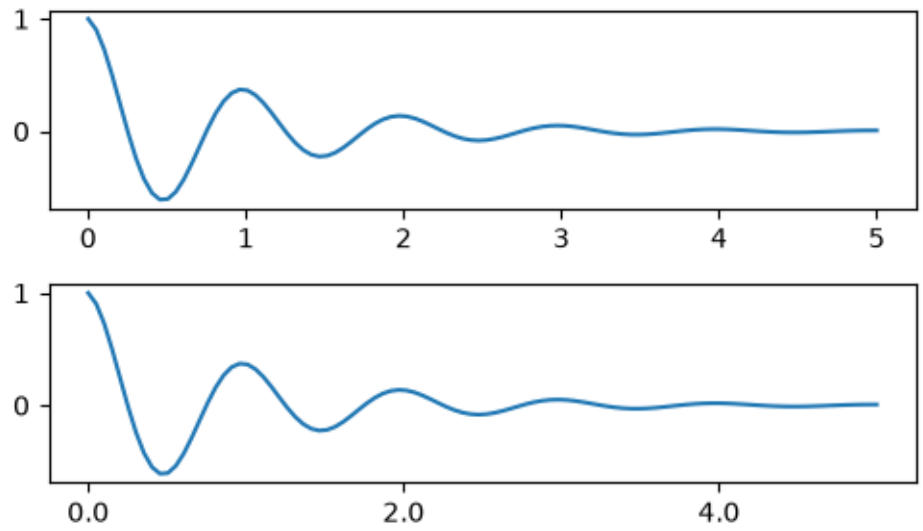
```
fig, axs = plt.subplots(2, 1, figsize=(5, 3), tight_layout=True)
axs[0].plot(x1, y1)
axs[1].plot(x1, y1)
ticks = np.arange(0., 8.1, 2.)
# list comprehension to get all tick labels...
tickla = [f'{tick:1.2f}' for tick in ticks]
axs[1].xaxis.set_ticks(ticks)
axs[1].xaxis.set_ticklabels(tickla)
axs[1].set_xlim(axs[0].get_xlim())
plt.show()
```



Tick locators and formatters

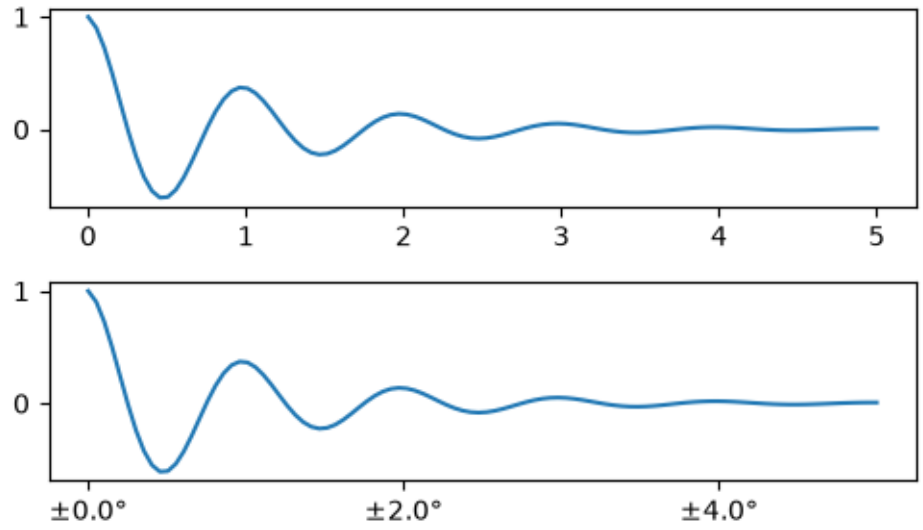
Instead of making a list of all the ticklabels, we could have used *matplotlib.ticker.StrMethodFormatter* (new-style `str.format()` format string) or *matplotlib.ticker.FormatStrFormatter* (old-style '%' format string) and passed it to the `ax.xaxis`. A *matplotlib.ticker.StrMethodFormatter* can also be created by passing a `str` without having to explicitly create the formatter.

```
fig, axs = plt.subplots(2, 1, figsize=(5, 3), tight_layout=True)
axs[0].plot(x1, y1)
axs[1].plot(x1, y1)
ticks = np.arange(0., 8.1, 2.)
axs[1].xaxis.set_ticks(ticks)
axs[1].xaxis.set_major_formatter('{x:1.1f}')
axs[1].set_xlim(axs[0].get_xlim())
plt.show()
```



And of course we could have used a non-default locator to set the tick locations. Note we still pass in the tick values, but the x-limit fix used above is *not* needed.

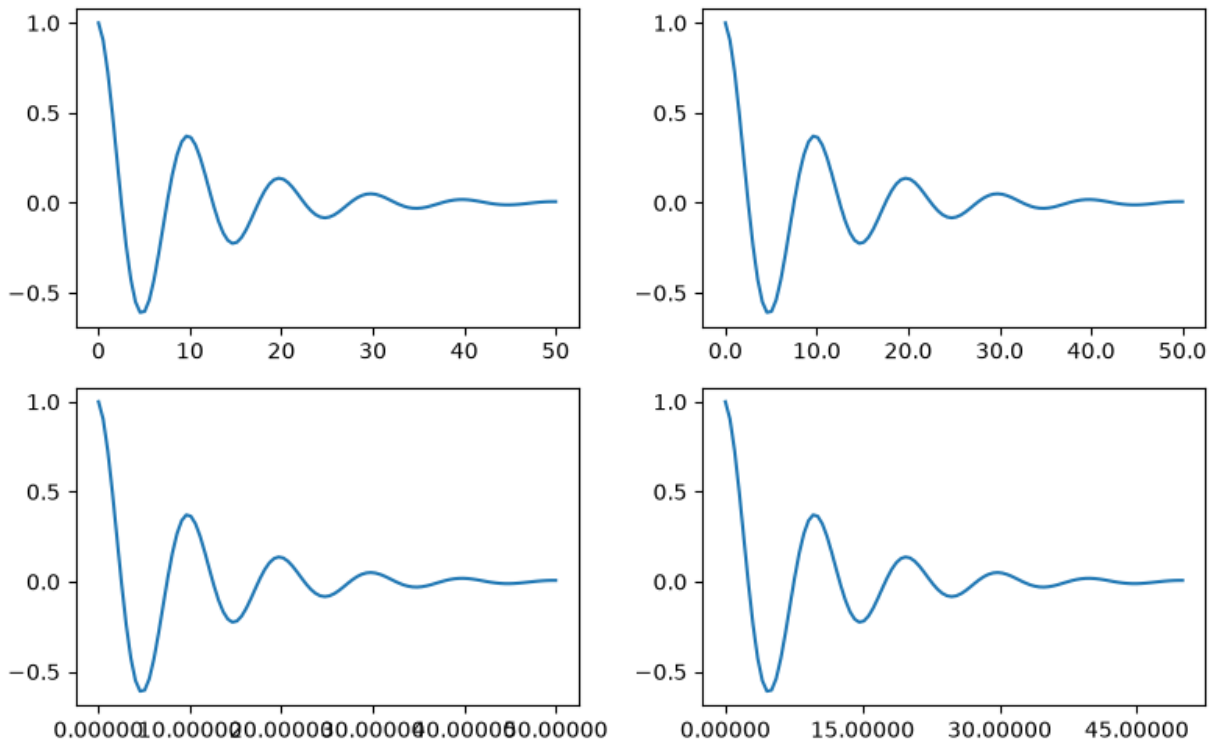
```
fig, axs = plt.subplots(2, 1, figsize=(5, 3), tight_layout=True)
axs[0].plot(x1, y1)
axs[1].plot(x1, y1)
locator = matplotlib.ticker.FixedLocator(ticks)
axs[1].xaxis.set_major_locator(locator)
axs[1].xaxis.set_major_formatter('±{x}°')
plt.show()
```



The default formatter is the *matplotlib.ticker.MaxNLocator* called as `ticker.MaxNLocator(self, nbins='auto', steps=[1, 2, 2.5, 5, 10])`. The `steps` argument contains a list of multiples that can be used for tick values. In this case, 2, 4, 6 would be acceptable ticks, as would 20, 40, 60 or 0.2, 0.4, 0.6. However, 3, 6, 9 would not be acceptable because 3 doesn't appear in the list of steps.

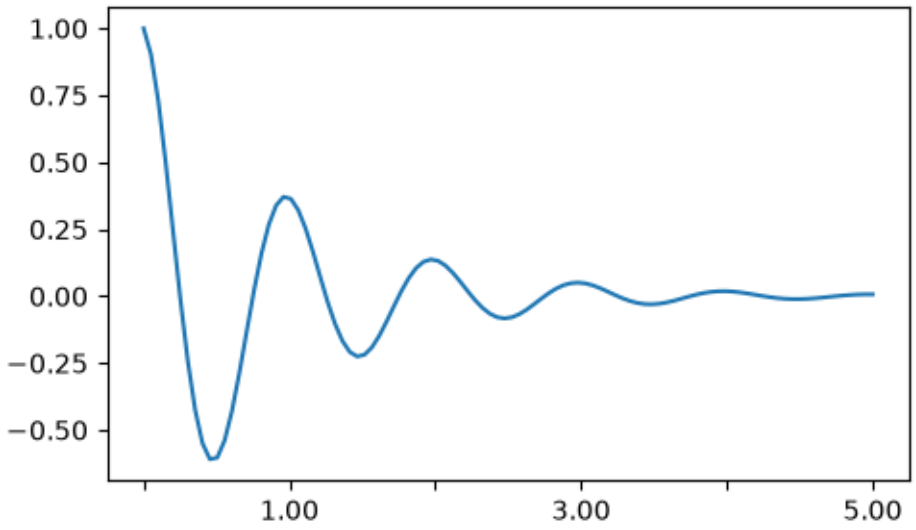
Setting `nbins=auto` uses an algorithm to determine how many ticks will be acceptable based on the axis length. The fontsize of the ticklabel is taken into account, but the length of the tick string is not (because it's not yet known.) In the bottom row, the ticklabels are quite large, so we set `nbins=4` to make the labels fit in the right-hand plot.

```
fig, axs = plt.subplots(2, 2, figsize=(8, 5), tight_layout=True)
for n, ax in enumerate(axs.flat):
    ax.plot(x1*10., y1)

formatter = matplotlib.ticker.FormatStrFormatter('%1.1f')
locator = matplotlib.ticker.MaxNLocator(nbins='auto', steps=[1, 4, 10])
axs[0, 1].xaxis.set_major_locator(locator)
axs[0, 1].xaxis.set_major_formatter(formatter)

formatter = matplotlib.ticker.FormatStrFormatter('%1.5f')
locator = matplotlib.ticker.AutoLocator()
axs[1, 0].xaxis.set_major_formatter(formatter)
axs[1, 0].xaxis.set_major_locator(locator)

formatter = matplotlib.ticker.FormatStrFormatter('%1.5f')
locator = matplotlib.ticker.MaxNLocator(nbins=4)
axs[1, 1].xaxis.set_major_formatter(formatter)
axs[1, 1].xaxis.set_major_locator(locator)

plt.show()
```



Finally, we can specify functions for the formatter using *matplotlib.ticker.FuncFormatter*. Further, like *matplotlib.ticker.StrMethodFormatter*, passing a function will automatically create a *matplotlib.ticker.FuncFormatter*.

```
def formatoddticks(x, pos):
    """Format odd tick positions."""
    if x % 2:
        return f'{x:1.2f}'
    else:
        return ''


fig, ax = plt.subplots(figsize=(5, 3), tight_layout=True)
ax.plot(x1, y1)
locator = matplotlib.ticker.MaxNLocator(nbins=6)
ax.xaxis.set_major_formatter(formatoddticks)
ax.xaxis.set_major_locator(locator)

plt.show()
```

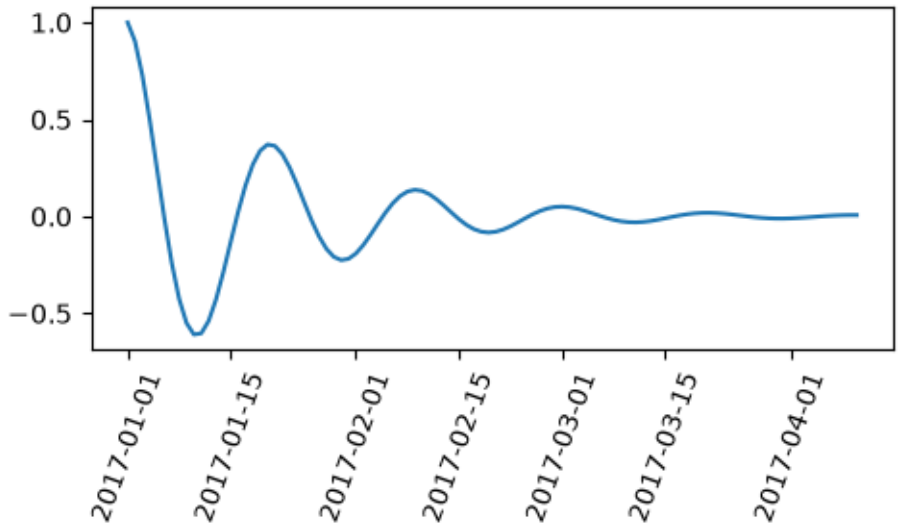


Dateticks

Matplotlib can accept `datetime.datetime` and `numpy.datetime64` objects as plotting arguments. Dates and times require special formatting, which can often benefit from manual intervention. In order to help, dates have special locators and formatters, defined in the *`matplotlib.dates`* module.

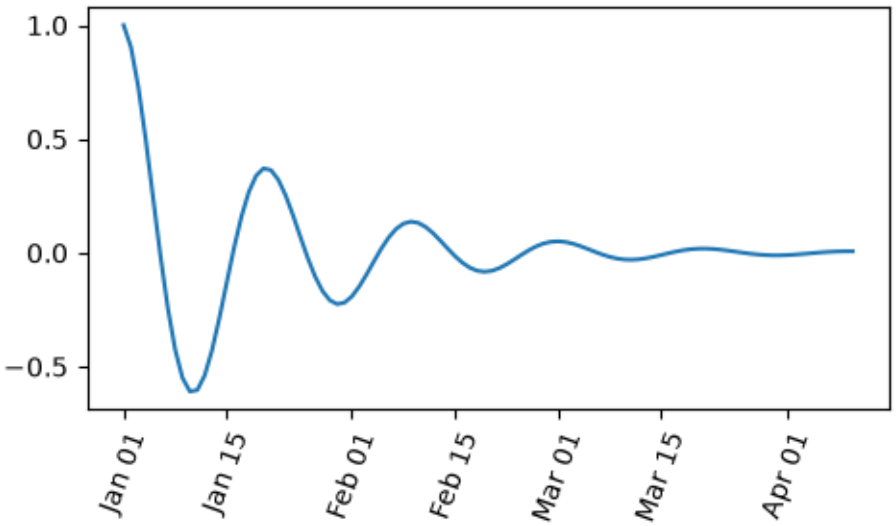
The following simple example illustrates this concept. Note how we rotate the tick labels so that they don't overlap.

```
import datetime

fig, ax = plt.subplots(figsize=(5, 3), tight_layout=True)
base = datetime.datetime(2017, 1, 1, 0, 0, 1)
time = [base + datetime.timedelta(days=x) for x in range(len(x1))]

ax.plot(time, y1)
ax.tick_params(axis='x', rotation=70)
plt.show()
```



We can pass a format to *matplotlib.dates.DateFormatter*. If two tick labels are very close together, we can use the *dates.DayLocator* class, which allows us to specify a list of days of the month to use. Similar formatters are listed in the *matplotlib.dates* module.

```
import matplotlib.dates as mdates

locator = mdates.DayLocator(bymonthday=[1, 15])
formatter = mdates.DateFormatter('%b %d')

fig, ax = plt.subplots(figsize=(5, 3), tight_layout=True)
ax.xaxis.set_major_locator(locator)
ax.xaxis.set_major_formatter(formatter)
ax.plot(time, y1)
ax.tick_params(axis='x', rotation=70)
plt.show()
```



Legends and annotations

- *Legend guide*
- *Annotations*

Total running time of the script: (0 minutes 3.535 seconds)

3.8.6 Text properties and layout

Controlling properties of text and its layout with Matplotlib.

`matplotlib.text.Text` instances have a variety of properties which can be configured via keyword arguments to `set_title`, `set_xlabel`, `text`, etc.

Property	Value Type
alpha	float
backgroundcolor	any matplotlib *color*
bbox	*Rectangle* prop dict plus key 'pad' which is a pad in points
clip_box	a matplotlib.transform.Bbox instance
clip_on	bool
clip_path	a *Path* instance and a *Transform* instance, a *Patch*
color	any matplotlib *color*
family	['serif' | 'sans-serif' | 'cursive' | 'fantasy' | 'monospace']
fontproperties	*FontProperties*
horizontalalignment or ha	['center' | 'right' | 'left']
label	any string
linespacing	float
multialignment	['left' | 'right' | 'center']
name or fontname	string e.g., ['Sans' | 'Courier' | 'Helvetica' ...]
picker	[None|float|bool|callable]
position	(x, y)
rotation	[angle in degrees | 'vertical' | 'horizontal']
size or fontsize	[size in points | relative size, e.g., 'small', 'x-large']
style or fontstyle	['normal' | 'italic' | 'oblique']
text	string or anything printable with '%s' conversion
transform	*Transform* subclass
variant	['normal' | 'small-caps']
verticalalignment or va	['center' | 'top' | 'bottom' | 'baseline']
visible	bool
weight or fontweight	['normal' | 'bold' | 'heavy' | 'light' | 'ultrabold' | 'ultra-light']
x	float
y	float
zorder	any number

Text alignment

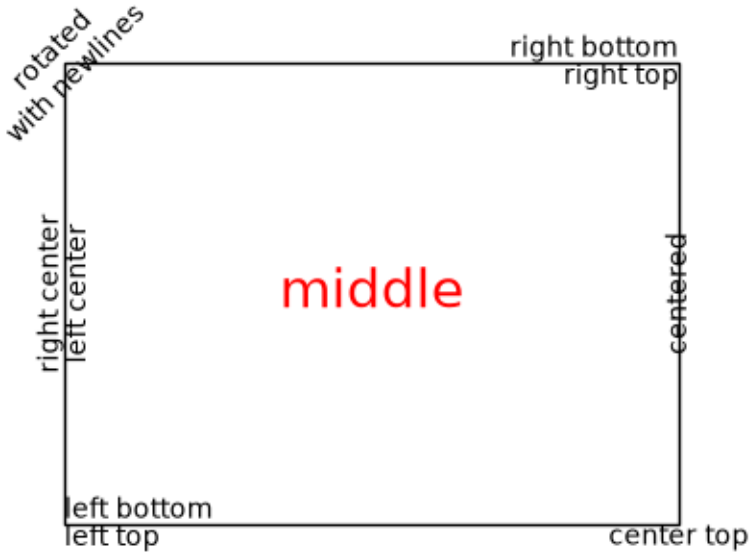
You can lay out text with the alignment arguments `horizontalalignment`, `verticalalignment`, and `multialignment`. `horizontalalignment` controls whether the x positional argument for the text indicates the left, center or right side of the text bounding box. `verticalalignment` controls whether the y positional argument for the text indicates the bottom, center or top side of the text bounding box. `multialignment`, for newline separated strings only, controls whether the different lines are left, center or right justified. Here is an example which uses the *text()* command to show the various alignment possibilities. The use of `transform=ax.transAxes` throughout the code indicates that the coordinates are given relative to the Axes bounding box, with (0, 0) being the lower left of the Axes and (1, 1) the upper right.

```
import matplotlib.pyplot as plt

import matplotlib.patches as patches

# build a rectangle in axes coords
left, width = 0.25, 0.5
bottom, height = 0.25, 0.5
right = left + width
top = bottom + height

fig = plt.figure()
ax = fig.add_axes((0, 0, 1, 1))

# axes coordinates: (0, 0) is bottom left and (1, 1) is upper right
p = patches.Rectangle(
    (left, bottom), width, height,
    fill=False, transform=ax.transAxes, clip_on=False
    )

ax.add_patch(p)

ax.text(left, bottom, 'left top',
        horizontalalignment='left',
        verticalalignment='top',
        transform=ax.transAxes)

ax.text(left, bottom, 'left bottom',
        horizontalalignment='left',
        verticalalignment='bottom',
        transform=ax.transAxes)

ax.text(right, top, 'right bottom',
        horizontalalignment='right',
        verticalalignment='bottom',
        transform=ax.transAxes)

ax.text(right, top, 'right top',
        horizontalalignment='right',
        verticalalignment='top',
        transform=ax.transAxes)

ax.text(right, bottom, 'center top',
        horizontalalignment='center',
        verticalalignment='top',
        transform=ax.transAxes)
```

(continues on next page)

(continued from previous page)

```
ax.text(left, 0.5*(bottom+top), 'right center',
        horizontalalignment='right',
        verticalalignment='center',
        rotation='vertical',
        transform=ax.transAxes)

ax.text(left, 0.5*(bottom+top), 'left center',
        horizontalalignment='left',
        verticalalignment='center',
        rotation='vertical',
        transform=ax.transAxes)

ax.text(0.5*(left+right), 0.5*(bottom+top), 'middle',
        horizontalalignment='center',
        verticalalignment='center',
        fontsize=20, color='red',
        transform=ax.transAxes)

ax.text(right, 0.5*(bottom+top), 'centered',
        horizontalalignment='center',
        verticalalignment='center',
        rotation='vertical',
        transform=ax.transAxes)

ax.text(left, top, 'rotated\nwith newlines',
        horizontalalignment='center',
        verticalalignment='center',
        rotation=45,
        transform=ax.transAxes)

ax.set_axis_off()
plt.show()
```



Relative font sizes

Font sizes can be specified in points, or as a string that indicates the size relative to the default font size. The following are valid values for relative font sizes:

Relative font size	Scaling of default font size
xx-small	0.579
x-small	0.694
small	0.833
medium	1.000
large	1.200
x-large	1.440
xx-large	1.728

3.8.7 Default Font

The base default font is controlled by a set of rcParams. To set the font for mathematical expressions, use the rcParams beginning with `mathtext` (see *mathtext*).

rcParam	usage
`'font.family'`	List of font families (installed on user's machine) and/or `{'cursive', 'fantasy', 'monospace', 'sans', 'sans serif', 'sans-serif', 'serif'}`.
`'font.style'`	The default style, ex `'normal'`, `'italic'`.
`'font.variant'`	Default variant, ex `'normal'`, `'small-caps'` (untested)
`'font.stretch'`	Default stretch, ex `'normal'`, `'condensed'` (incomplete)
`'font.weight'`	Default weight. Either string or integer
`'font.size'`	Default font size in points. Relative font sizes (`'large'`, `'x-small'`) are computed against this size.

Matplotlib can use font families installed on the user's computer, i.e. Helvetica, Times, etc. Font families can also be specified with generic-family aliases like (`{'cursive', 'fantasy', 'monospace', 'sans', 'sans serif', 'sans-serif', 'serif'}`).

Note

To access the full list of available fonts:

```
matplotlib.font_manager.get_font_names()
```

The mapping between the generic family aliases and actual font families (mentioned at *default rcParams*) is controlled by the following rcParams:

CSS-based generic-family alias	rcParam with mappings
`'serif'`	`'font.serif'`
`'monospace'`	`'font.monospace'`
`'fantasy'`	`'font.fantasy'`
`'cursive'`	`'font.cursive'`
`{'sans', 'sans serif', 'sans-serif'}`	`'font.sans-serif'`

If any of generic family names appear in `'font.family'`, we replace that entry by all the entries in the corresponding rcParam mapping. For example:

```
matplotlib.rcParams['font.family'] = ['Family1', 'serif', 'Family2']
matplotlib.rcParams['font.serif'] = ['SerifFamily1', 'SerifFamily2']

# This is effectively translated to:
matplotlib.rcParams['font.family'] = ['Family1', 'SerifFamily1',
 ↪'SerifFamily2', 'Family2']
```

Text with non-latin glyphs

As of v2.0 the *default font*, DejaVu, contains glyphs for many western alphabets, but not other scripts, such as Chinese, Korean, or Japanese.

To set the default font to be one that supports the code points you need, prepend the font name to `'font.family'` (recommended), or to the desired alias lists.

```
# first method
matplotlib.rcParams['font.family'] = ['Source Han Sans TW', 'sans-serif
 ↪']

# second method
matplotlib.rcParams['font.family'] = ['sans-serif']
matplotlib.rcParams['sans-serif'] = ['Source Han Sans TW', ...]
```

The generic family alias lists contain fonts that are either shipped alongside Matplotlib (so they have 100% chance of being found), or fonts which have a very high probability of being present in most systems.

A good practice when setting custom font families is to append a generic-family to the font-family list as a last resort.

You can also set it in your `.matplotlibrc` file:

```
font.family: Source Han Sans TW, Arial, sans-serif
```

To control the font used on per-artist basis use the *name*, *fontname* or *fontproperties* keyword arguments documented in *Text properties and layout*.

On linux, fc-list can be a useful tool to discover the font name; for example

```
$ fc-list :lang=zh family
Noto to Sans Mono CJK TC,Noto Sans Mono CJK TC Bold
Noto Sans CJK TC,Noto Sans CJK TC Medium
Noto Sans CJK TC,Noto Sans CJK TC DemiLight
Noto Sans CJK KR,Noto Sans CJK KR Black
Noto Sans CJK TC,Noto Sans CJK TC Black
Noto Sans Mono CJK TC,Noto Sans Mono CJK TC Regular
Noto Sans CJK SC,Noto Sans CJK SC Light
```

lists all of the fonts that support Chinese.

3.8.8 Text rendering with LaTeX

Matplotlib can use LaTeX to render text. This is activated by setting `text.usetex : True` in your rcParams, or by setting the `usetex` property to True on individual `Text` objects. Text handling through LaTeX is slower than Matplotlib's very capable *mathtext*, but is more flexible, since different LaTeX packages (font packages, math packages, etc.) can be used. The results can be striking, especially when you take care to use the same fonts in your figures as in the main document.

Matplotlib's LaTeX support requires a working LaTeX installation. For the *Agg backends, dvipng is additionally required; for the PS backend, PSfrag, dvips and Ghostscript are additionally required. For the PDF

and SVG backends, if LuaTeX is present, it will be used to speed up some post-processing steps, but note that it is not used to parse the TeX string itself (only LaTeX is supported). The executables for these external dependencies must all be located on your *PATH*.

Only a small number of font families (defined by the PSNFSS scheme) are supported. They are listed here, with the corresponding LaTeX font selection commands and LaTeX packages, which are automatically used.

generic family	fonts
serif (\rmfamily)	Computer Modern Roman, Palatino (mathpazo), Times (mathptmx), Bookman (bookman), New Century Schoolbook (newcent), Charter (charter)
sans-serif (\sffamily)	Computer Modern Serif, Helvetica (helvet), Avant Garde (avant)
cursive (\rmfamily)	Zapf Chancery (chancery)
monospace (\ttfamily)	Computer Modern Typewriter, Courier (courier)

The default font family (which does not require loading any LaTeX package) is Computer Modern. All other families are Adobe fonts. Times and Palatino each have their own accompanying math fonts, while the other Adobe serif fonts make use of the Computer Modern math fonts.

To enable LaTeX and select a font, use e.g.:

```
plt.rcParams.update({
    "text.usetex": True,
    "font.family": "Helvetica"
})
```

or equivalently, set your *matplotlibrc* to:

```
text.usetex : true
font.family : Helvetica
```

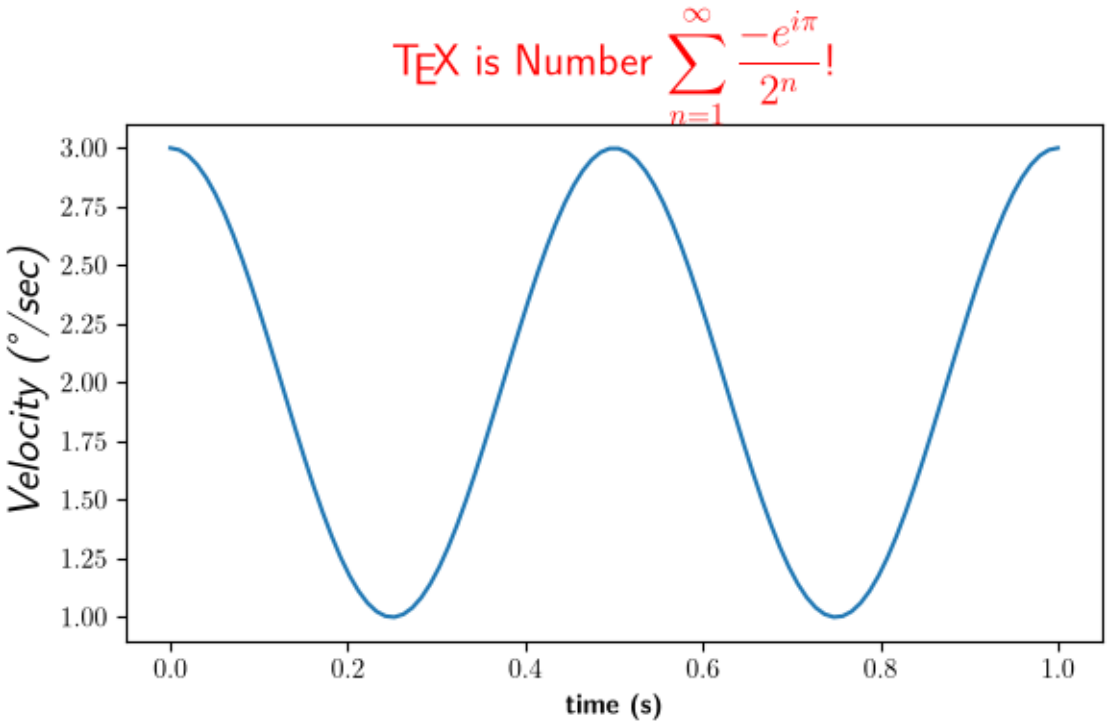
It is also possible to instead set `font.family` to one of the generic family names and then configure the corresponding generic family; e.g.:

```
plt.rcParams.update({
    "text.usetex": True,
    "font.family": "sans-serif",
    "font.sans-serif": "Helvetica",
})
```

(this was the required approach until Matplotlib 3.5).

Here is the standard example, *Render math equations using TeX*:

Note that display math mode (`$$ e=mc^2 $$`) is not supported, but adding the command `\displaystyle`, as in the above demo, will produce the same results.



Non-ASCII characters (e.g. the degree sign in the y-label above) are supported to the extent that they are supported by inputenc.

Note

For consistency with the non-usetex case, Matplotlib special-cases newlines, so that single-newlines yield linebreaks (rather than being interpreted as whitespace in standard LaTeX).

Matplotlib uses the underscore package so that underscores (_) are printed "as-is" in text mode (rather than causing an error as in standard LaTeX). Underscores still introduce subscripts in math mode.

Note

Certain characters require special escaping in TeX, such as:

```
# $ % & ~ ^ \ { } \( \) \[ \]
```

Therefore, these characters will behave differently depending on `rcParams["text.usetex"]` (default: `False`). As noted above, underscores (_) do not require escaping outside of math mode.

Note

LaTeX always defaults to using a serif font for math (even when `rcParams["font.family"] =`

"sans-serif"). If desired, adding \usepackage{sfmath} to rcParams["text.latex.preamble"] lets LaTeX output sans-serif math.

PostScript options

In order to produce encapsulated PostScript (EPS) files that can be embedded in a new LaTeX document, the default behavior of Matplotlib is to distill the output, which removes some PostScript operators used by LaTeX that are illegal in an EPS file. This step produces results which may be unacceptable to some users, because the text is coarsely rasterized and converted to bitmaps, which are not scalable like standard PostScript, and the text is not searchable. One workaround is to set *rcParams["ps.distiller.res"]* (default: 6000) to a higher value (perhaps 6000) in your rc settings, which will produce larger files but may look better and scale reasonably. A better workaround, which requires Poppler or Xpdf, can be activated by changing *rcParams["ps.usedistiller"]* (default: None) to xpdf. This alternative produces PostScript without rasterizing text, so it scales properly, can be edited in Adobe Illustrator, and searched text in pdf documents.

Troubleshooting

- Try deleting your .matplotlib/tex.cache directory. If you don't know where to find .matplotlib, see *matplotlib configuration and cache directory locations*.
- Make sure LaTeX, dvipng, and Ghostscript are each working and on your *PATH*. The *PATH* environment variable may need to be modified (in particular on Windows) to include the directories containing the executables. See *Environment variables* and *Setting environment variables in Windows* for details.
- Make sure what you are trying to do is possible in a LaTeX document, that your LaTeX syntax is valid and that you are using raw strings if necessary to avoid unintended escape sequences.
- *rcParams["text.latex.preamble"]* (default: '') is not officially supported. This option provides lots of flexibility, and lots of ways to cause problems. Please disable this option before reporting problems.
- Using MiKTeX with Computer Modern fonts, if you get odd *Agg and PNG results, go to MiKTeX/Options and update your format files.
- Some required LaTeX packages, such as type1cm, may be missing from minimalist TeX installs. Required packages are listed at *LaTeX dependencies*.
- If you still need help, please see *Get help*.

3.9 Animations using Matplotlib

Based on its plotting functionality, Matplotlib also provides an interface to generate animations using the *animation* module. An animation is a sequence of frames where each frame corresponds to a plot on a *Figure*. This tutorial covers a general guideline on how to create such animations and the different options available.

3.9.1 Animations using Matplotlib

Based on its plotting functionality, Matplotlib also provides an interface to generate animations using the `animation` module. An animation is a sequence of frames where each frame corresponds to a plot on a `Figure`. This tutorial covers a general guideline on how to create such animations and the different options available. More information is available in the API description: `animation`

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation
```

Animation classes

The animation process in Matplotlib can be thought of in 2 different ways:

- `FuncAnimation`: Generate data for first frame and then modify this data for each frame to create an animated plot.
- `ArtistAnimation`: Generate a list (iterable) of artists that will draw in each frame in the animation.

`FuncAnimation` is more efficient in terms of speed and memory as it draws an artist once and then modifies it. On the other hand `ArtistAnimation` is flexible as it allows any iterable of artists to be animated in a sequence.

`FuncAnimation`

The `FuncAnimation` class allows us to create an animation by passing a function that iteratively modifies the data of a plot. This is achieved by using the *setter* methods on various `Artist` (examples: `Line2D`, `PathCollection`, etc.). A usual `FuncAnimation` object takes a `Figure` that we want to animate and a function *func* that modifies the data plotted on the figure. It uses the *frames* parameter to determine the length of the animation. The *interval* parameter is used to determine time in milliseconds between drawing of two frames. Animating using `FuncAnimation` typically requires these steps:

1) Plot the initial figure as you would in a static plot. Save all the created artists, which are returned by the plot functions, in variables so that you can access and modify them later in the animation function.
2) Create an animation function that updates the artists for a given frame. Typically, this calls `set_*` methods of the artists.
3) Create a `FuncAnimation`, passing the `Figure` and the animation function.
4) Save or show the animation using one of the following methods:
   - `pyplot.show` to show the animation in a window
   - `Animation.to_html5_video` to create an HTML `<video>` tag
   - `Animation.to_jshtml` to create HTML code with interactive JavaScript animation controls
   - `Animation.save` to save the animation to a file

The following table shows a few plotting methods, the artists they return and some commonly used `set_*` methods that update the underlying data. While updating data is the most common operation in animations, you can also update other aspects such as color or text position.

Plotting method	Artist	Data set methods
Axes.plot	*lines.Line2D*	*set_data*, *set_xdata*, *set_ydata*
Axes.scatter	*collections.PathCollection*	*set_offsets*
Axes.imshow	*image.AxesImage*	AxesImage.set_data
Axes.annotate	*text.Annotation*	*update_positions*
Axes.barh	*patches.Rectangle*	*set_angle*, *set_bounds*, *set_height*, *set_width*, *set_x*, *set_y*, *set_xy*
Axes.fill	*patches.Polygon*	*set_xy*
Axes.add_patch(*patches.Ellipse*)	*patches.Ellipse*	*set_angle*, *set_center*, *set_height*, *set_width*
Axes.set_title, *Axes.text*	*text.Text*	*set_text*

Covering the set methods for all types of artists is beyond the scope of this tutorial but can be found in their respective documentations. An example of such update methods in use for *Axes.scatter* and *Axes.plot* is as follows.

```
fig, ax = plt.subplots()
t = np.linspace(0, 3, 40)
g = -9.81
v0 = 12
z = g * t**2 / 2 + v0 * t

v02 = 5
z2 = g * t**2 / 2 + v02 * t

scat = ax.scatter(t[0], z[0], c="b", s=5, label=f'v0 = {v0} m/s')
line2 = ax.plot(t[0], z2[0], label=f'v0 = {v02} m/s')[0]
ax.set(xlim=(0, 3), ylim=(-4, 10), xlabel='Time [s]', ylabel='Z [m]')
ax.legend()


def update(frame):
    # for each frame, update the data stored on each artist.
    x = t[:frame]
    y = z[:frame]
    # update the scatter plot:
```

(continues on next page)

(continued from previous page)

```
    data = np.stack([x, y]).T
    scat.set_offsets(data)
    # update the line plot:
    line2.set_xdata(t[:frame])
    line2.set_ydata(z2[:frame])
    return (scat, line2)


ani = animation.FuncAnimation(fig=fig, func=update, frames=40,␣
 ↪interval=30)
plt.show()
```

ArtistAnimation

ArtistAnimation can be used to generate animations if there is data stored on various different artists. This list of artists is then converted frame by frame into an animation. For example, when we use *Axes.barh* to plot a bar-chart, it creates a number of artists for each of the bar and error bars. To update the plot, one would need to update each of the bars from the container individually and redraw them. Instead, *animation.ArtistAnimation* can be used to plot each frame individually and then stitched together to form an animation. A barchart race is a simple example for this.

```
fig, ax = plt.subplots()
rng = np.random.default_rng(19680801)
data = np.array([20, 20, 20, 20])
x = np.array([1, 2, 3, 4])

artists = []
colors = ['tab:blue', 'tab:red', 'tab:green', 'tab:purple']
for i in range(20):
    data += rng.integers(low=0, high=10, size=data.shape)
    container = ax.barh(x, data, color=colors)
    artists.append(container)


ani = animation.ArtistAnimation(fig=fig, artists=artists, interval=400)
plt.show()
```

Animation writers

Animation objects can be saved to disk using various multimedia writers (ex: Pillow, *ffpmeg*, *imagemagick*). Not all video formats are supported by all writers. There are 4 major types of writers:

- *PillowWriter* - Uses the Pillow library to create the animation.
- *HTMLWriter* - Used to create JavaScript-based animations.
- Pipe-based writers - *FFMpegWriter* and *ImageMagickWriter* are pipe based writers. These

writers pipe each frame to the utility (*ffmpeg* / *imagemagick*) which then stitches all of them together to create the animation.

- File-based writers - `FFMpegFileWriter` and `ImageMagickFileWriter` are examples of file-based writers. These writers are slower than their pipe-based alternatives but are more useful for debugging as they save each frame in a file before stitching them together into an animation.

Saving Animations

Writer	Supported Formats
`PillowWriter`	.gif, .apng, .webp
`HTMLWriter`	.htm, .html, .png
`FFMpegWriter` `FFMpegFileWriter`	All formats supported by *ffmpeg*: `ffmpeg -formats`
`ImageMagickWriter` `ImageMagickFileWriter`	All formats supported by *imagemagick*: `magick -list format`

To save animations using any of the writers, we can use the `animation.Animation.save` method. It takes the *filename* that we want to save the animation as and the *writer*, which is either a string or a writer object. It also takes an *fps* argument. This argument is different than the *interval* argument that `FuncAnimation` or `ArtistAnimation` uses. *fps* determines the frame rate that the **saved** animation uses, whereas *interval* determines the frame rate that the **displayed** animation uses.

Below are a few examples that show how to save an animation with different writers.

Pillow writers:

```
ani.save(filename="/tmp/pillow_example.gif", writer="pillow")
ani.save(filename="/tmp/pillow_example.apng", writer="pillow")
```

HTML writers:

```
ani.save(filename="/tmp/html_example.html", writer="html")
ani.save(filename="/tmp/html_example.htm", writer="html")
ani.save(filename="/tmp/html_example.png", writer="html")
```

FFMpegWriter:

```
ani.save(filename="/tmp/ffmpeg_example.mkv", writer="ffmpeg")
ani.save(filename="/tmp/ffmpeg_example.mp4", writer="ffmpeg")
ani.save(filename="/tmp/ffmpeg_example.mjpeg", writer="ffmpeg")
```

Imagemagick writers:

```
ani.save(filename="/tmp/imagemagick_example.gif", writer="imagemagick")
ani.save(filename="/tmp/imagemagick_example.webp", writer="imagemagick
 ↪")
ani.save(filename="apng:/tmp/imagemagick_example.apng",
         writer="imagemagick", extra_args=["-quality", "100"])
```

(the `extra_args` for *apng* are needed to reduce filesize by ~10x)

Note that *ffmpeg* and *imagemagick* need to be separately installed. A cross-platform way to obtain *ffmpeg* is to install the `imageio_ffmpeg` PyPI package, and then to set `rcParams["animation.ffmpeg_path"] = imageio_ffmpeg.get_ffmpeg_exe()`.

Total running time of the script: (0 minutes 9.901 seconds)

3.9.2 Faster rendering by using blitting

Blitting is a standard technique in raster graphics that, in the context of Matplotlib, can be used to (drastically) improve performance of interactive figures. For example, the *animation* and *widgets* modules use blitting internally. Here, we demonstrate how to implement your own blitting, outside of these classes.

Blitting speeds up repetitive drawing by rendering all non-changing graphic elements into a background image once. Then, for every draw, only the changing elements need to be drawn onto this background. For example, if the limits of an Axes have not changed, we can render the empty Axes including all ticks and labels once, and only draw the changing data later.

The strategy is

- Prepare the constant background:
  - Draw the figure, but exclude all artists that you want to animate by marking them as *animated* (see *Artist.set_animated*).
  - Save a copy of the RBGA buffer.
- Render the individual images:
  - Restore the copy of the RGBA buffer.
  - Redraw the animated artists using *Axes.draw_artist* / *Figure.draw_artist*.
  - Show the resulting image on the screen.

One consequence of this procedure is that your animated artists are always drawn on top of the static artists.

Not all backends support blitting. You can check if a given canvas does via the *FigureCanvasBase.supports_blit* property.

Minimal example

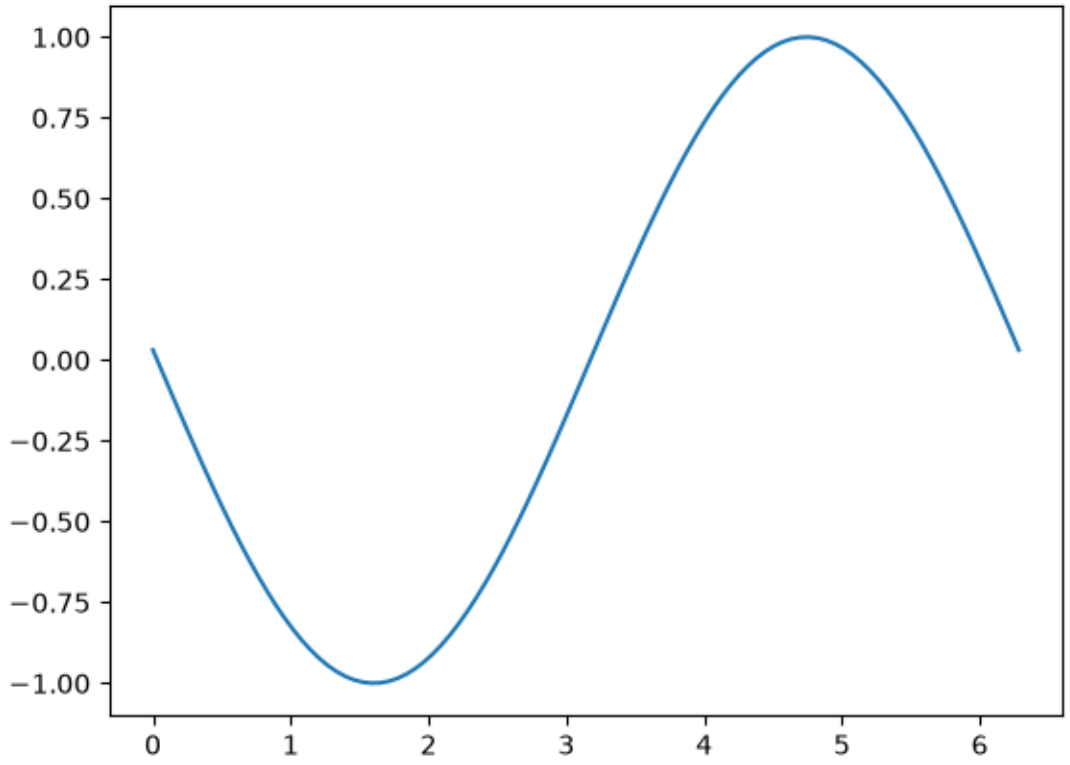
We can use the *FigureCanvasAgg* methods *copy_from_bbox* and *restore_region* in conjunction with setting `animated=True` on our artist to implement a minimal example that uses blitting to accelerate rendering

```
import matplotlib.pyplot as plt
import numpy as np

x = np.linspace(0, 2 * np.pi, 100)

fig, ax = plt.subplots()

# animated=True tells matplotlib to only draw the artist when we
# explicitly request it
(ln,) = ax.plot(x, np.sin(x), animated=True)

# make sure the window is raised, but the script keeps going
plt.show(block=False)

# stop to admire our empty window axes and ensure it is rendered at
# least once.
#
# We need to fully draw the figure at its final size on the screen
# before we continue on so that :
#  a) we have the correctly sized and drawn background to grab
#  b) we have a cached renderer so that ``ax.draw_artist`` works
# so we spin the event loop to let the backend process any pending␣
 ↪operations
plt.pause(0.1)

# get copy of entire figure (everything inside fig.bbox) sans animated␣
 ↪artist
bg = fig.canvas.copy_from_bbox(fig.bbox)
# draw the animated artist, this uses a cached renderer
ax.draw_artist(ln)
# show the result to the screen, this pushes the updated RGBA buffer␣
 ↪from the
# renderer to the GUI framework so you can see it
fig.canvas.blit(fig.bbox)

for j in range(100):
    # reset the background back in the canvas state, screen unchanged
    fig.canvas.restore_region(bg)
    # update the artist, neither the canvas state nor the screen have␣
 ↪changed
    ln.set_ydata(np.sin(x + (j / 100) * np.pi))
    # re-render the artist, updating the canvas state, but not the␣
 ↪screen
    ax.draw_artist(ln)
    # copy the image to the GUI state, but screen might not be changed␣
 ↪yet
```

(continues on next page)

(continued from previous page)

```
    fig.canvas.blit(fig.bbox)
    # flush any pending GUI events, re-painting the screen if needed
    fig.canvas.flush_events()
    # you can put a pause in if you want to slow things down
    # plt.pause(.1)
```



This example works and shows a simple animation, however because we are only grabbing the background once, if the size of the figure in pixels changes (due to either the size or dpi of the figure changing) , the background will be invalid and result in incorrect (but sometimes cool looking!) images. There is also a global variable and a fair amount of boilerplate which suggests we should wrap this in a class.

Class-based example

We can use a class to encapsulate the boilerplate logic and state of restoring the background, drawing the artists, and then blitting the result to the screen. Additionally, we can use the `'draw_event'` callback to capture a new background whenever a full re-draw happens to handle resizes correctly.

```
class BlitManager:
    def __init__(self, canvas, animated_artists=()):
        """
```

(continues on next page)

(continued from previous page)

```
        Parameters
        ----------
        canvas : FigureCanvasAgg
            The canvas to work with, this only works for subclasses of␣
↪the Agg
            canvas which have the `~FigureCanvasAgg.copy_from_bbox` and
            `~FigureCanvasAgg.restore_region` methods.

        animated_artists : Iterable[Artist]
            List of the artists to manage
        """
        self.canvas = canvas
        self._bg = None
        self._artists = []

        for a in animated_artists:
            self.add_artist(a)
        # grab the background on every draw
        self.cid = canvas.mpl_connect("draw_event", self.on_draw)

    def on_draw(self, event):
        """Callback to register with 'draw_event'."""
        cv = self.canvas
        if event is not None:
            if event.canvas != cv:
                raise RuntimeError
        self._bg = cv.copy_from_bbox(cv.figure.bbox)
        self._draw_animated()

    def add_artist(self, art):
        """
        Add an artist to be managed.

        Parameters
        ----------
        art : Artist

            The artist to be added.  Will be set to 'animated' (just
            to be safe).  *art* must be in the figure associated with
            the canvas this class is managing.

        """
        if art.figure != self.canvas.figure:
            raise RuntimeError
        art.set_animated(True)
        self._artists.append(art)
```

(continues on next page)

(continued from previous page)

```
    def _draw_animated(self):
        """Draw all of the animated artists."""
        fig = self.canvas.figure
        for a in self._artists:
            fig.draw_artist(a)

    def update(self):
        """Update the screen with animated artists."""
        cv = self.canvas
        fig = cv.figure
        # paranoia in case we missed the draw event,
        if self._bg is None:
            self.on_draw(None)
        else:
            # restore the background
            cv.restore_region(self._bg)
            # draw all of the animated artists
            self._draw_animated()
            # update the GUI state
            cv.blit(fig.bbox)
        # let the GUI event loop process anything it has to do
        cv.flush_events()
```

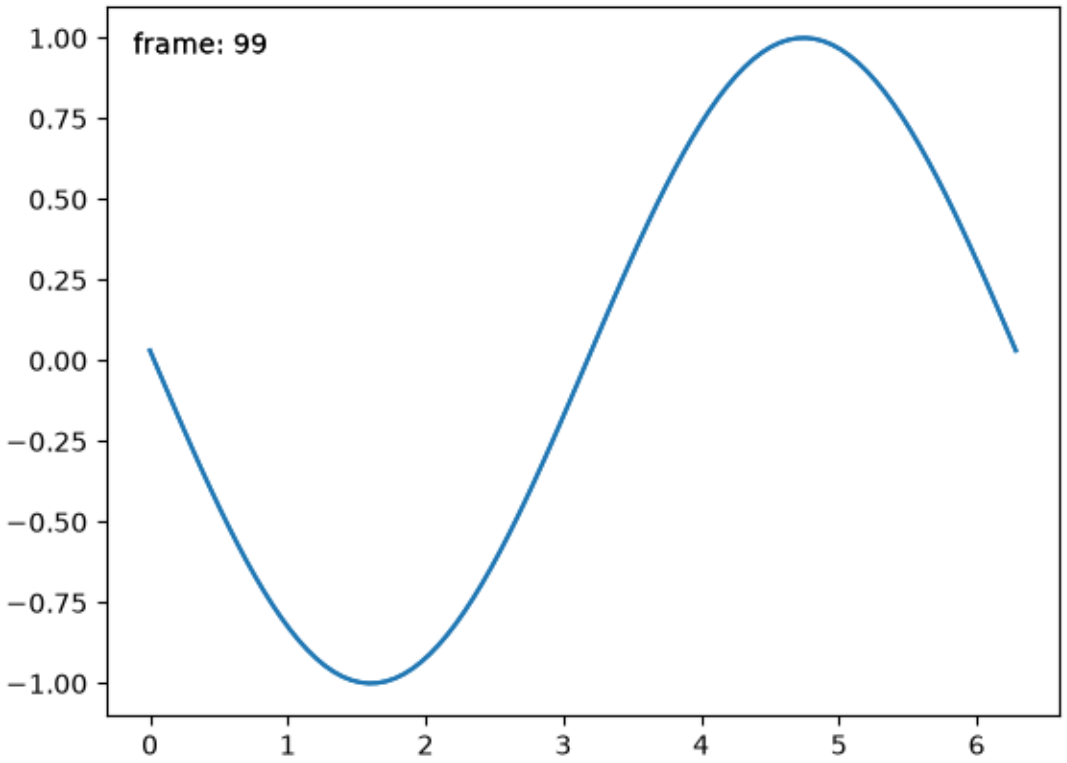
Here is how we would use our class. This is a slightly more complicated example than the first case as we add a text frame counter as well.

```
# make a new figure
fig, ax = plt.subplots()
# add a line
(ln,) = ax.plot(x, np.sin(x), animated=True)
# add a frame number
fr_number = ax.annotate(
    "0",
    (0, 1),
    xycoords="axes fraction",
    xytext=(10, -10),
    textcoords="offset points",
    ha="left",
    va="top",
    animated=True,
)
bm = BlitManager(fig.canvas, [ln, fr_number])
# make sure our window is on the screen and drawn
plt.show(block=False)
plt.pause(.1)
```

(continues on next page)

(continued from previous page)

```
for j in range(100):
    # update the artists
    ln.set_ydata(np.sin(x + (j / 100) * np.pi))
    fr_number.set_text(f"frame: {j}")
    # tell the blitting manager to do its thing
    bm.update()
```



This class does not depend on *pyplot* and is suitable to embed into larger GUI application.

Total running time of the script: (0 minutes 1.324 seconds)

3.10 User Toolkits

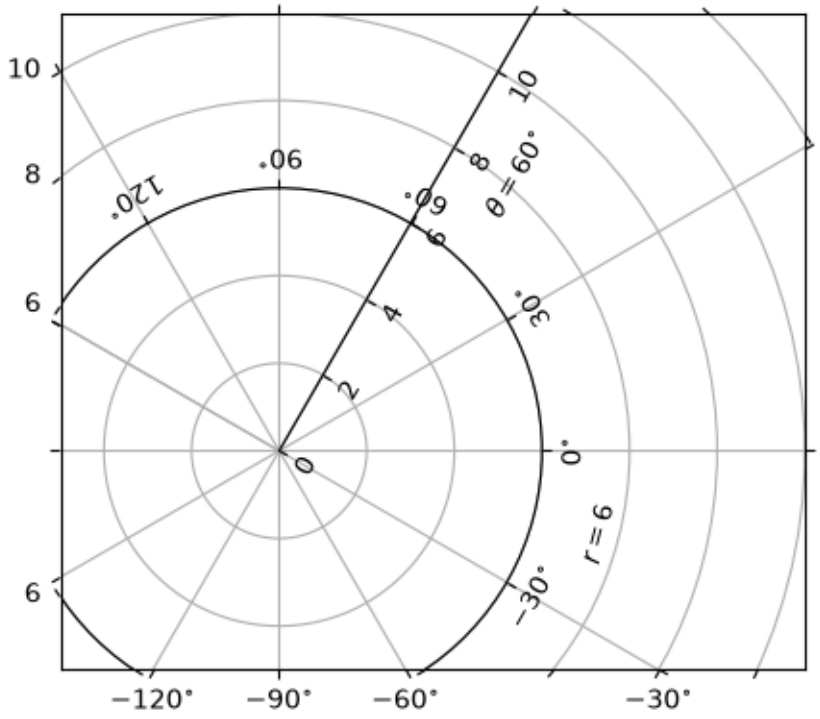
Here you can find examples and explanations of how to use various toolkits available in Matplotlib.

3.10.1 The axisartist toolkit

Warning

axisartist uses a custom Axes class (derived from the Matplotlib's original Axes class). As a side effect, some commands (mostly tick-related) do not work.

The *axisartist* contains a custom Axes class that is meant to support curvilinear grids (e.g., the world coordinate system in astronomy). Unlike Matplotlib's original Axes class which uses Axes.xaxis and Axes.yaxis to draw ticks, ticklines, etc., axisartist uses a special artist (AxisArtist) that can handle ticks, ticklines, etc. for curved coordinate systems.



Since it uses special artists, some Matplotlib commands that work on Axes.xaxis and Axes.yaxis may not work.

axisartist

The *axisartist* module provides a custom (and very experimental) Axes class, where each axis (left, right, top, and bottom) have a separate associated artist which is responsible for drawing the axis-line, ticks, ticklabels, and labels. You can also create your own axis, which can pass through a fixed position in the axes coordinate, or a fixed position in the data coordinate (i.e., the axis floats around when viewlimit changes).

The axes class, by default, has its xaxis and yaxis invisible, and has 4 additional artists which are responsible for drawing the 4 axis spines in "left", "right", "bottom", and "top". They are accessed as ax.axis["left"], ax.axis["right"], and so on, i.e., ax.axis is a dictionary that contains artists (note that ax.axis is still a callable method and it behaves as an original Axes.axis method in Matplotlib).

To create an Axes,

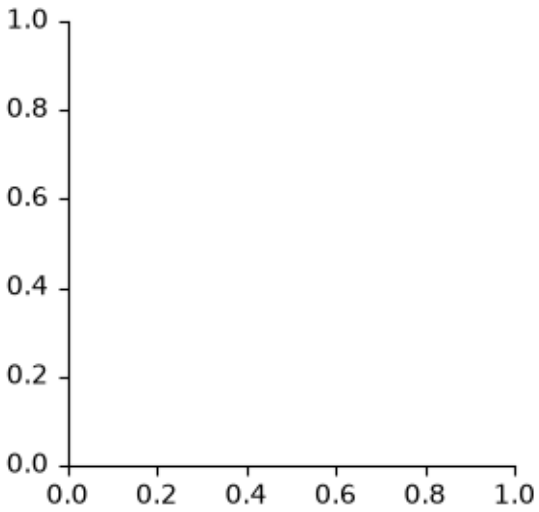
```
import mpl_toolkits.axisartist as AA
fig = plt.figure()
fig.add_axes((0.1, 0.1, 0.8, 0.8), axes_class=AA.Axes)
```

or to create a subplot

```
fig.add_subplot(111, axes_class=AA.Axes)
# Given that 111 is the default, one can also do
fig.add_subplot(axes_class=AA.Axes)
```

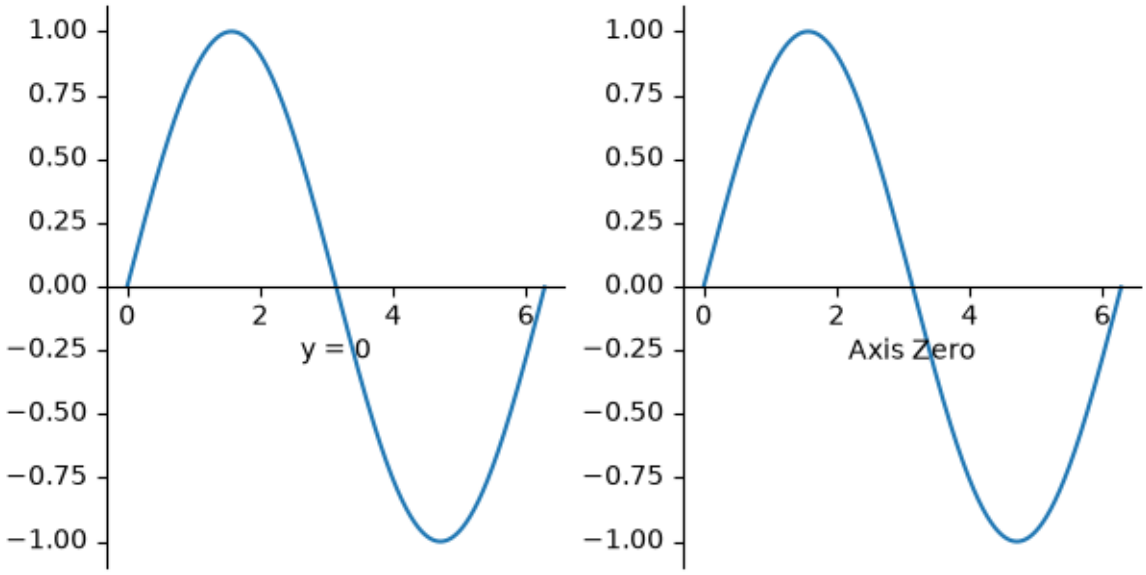
For example, you can hide the right and top spines using:

```
ax.axis["right"].set_visible(False)
ax.axis["top"].set_visible(False)
```



It is also possible to add a horizontal axis. For example, you may have an horizontal axis at y=0 (in data coordinate).

```
ax.axis["y=0"] = ax.new_floating_axis(nth_coord=0, value=0)
```



Or a fixed axis with some offset

```
# make new (right-side) yaxis, but with some offset
ax.axis["right2"] = ax.new_fixed_axis(loc="right", offset=(20, 0))
```

axisartist with ParasiteAxes

Most commands in the axes_grid1 toolkit can take an axes_class keyword argument, and the commands create an Axes of the given class. For example, to create a host subplot with axisartist.Axes,

```
import mpl_toolkits.axisartist as AA
from mpl_toolkits.axes_grid1 import host_subplot

host = host_subplot(111, axes_class=AA.Axes)
```

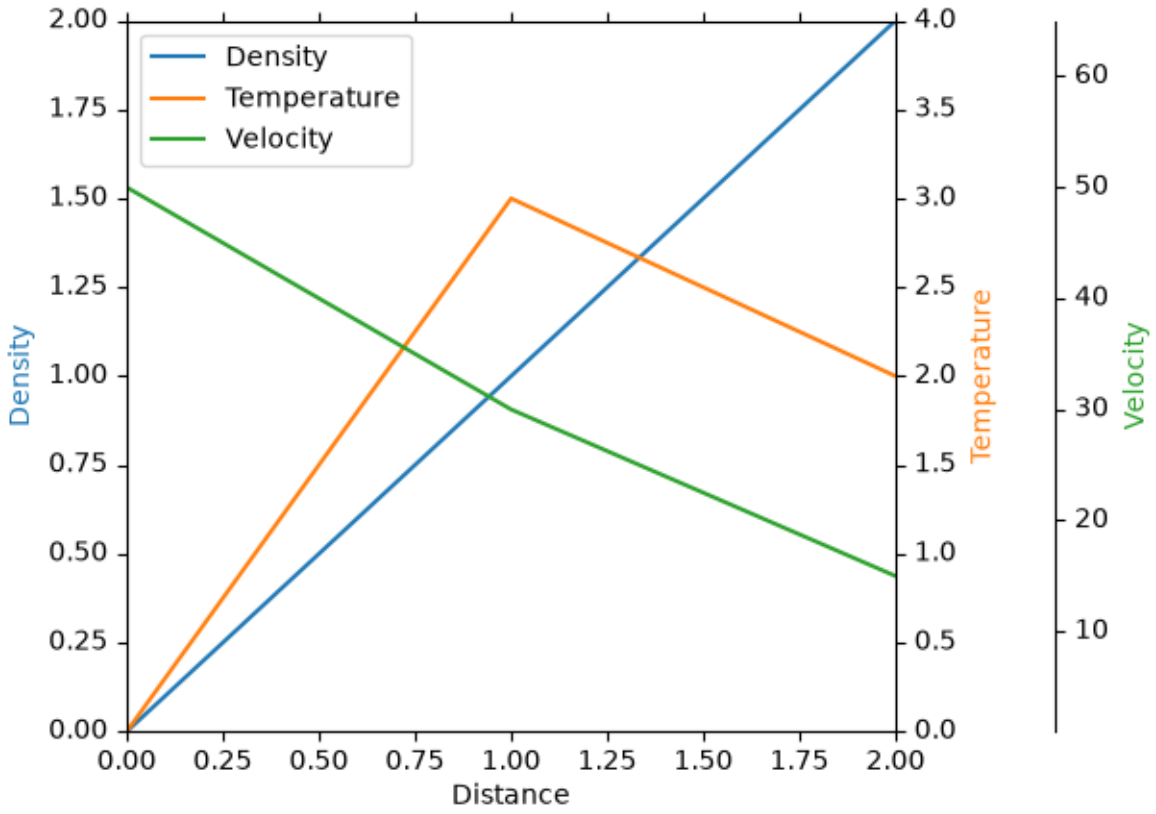
Here is an example that uses ParasiteAxes.

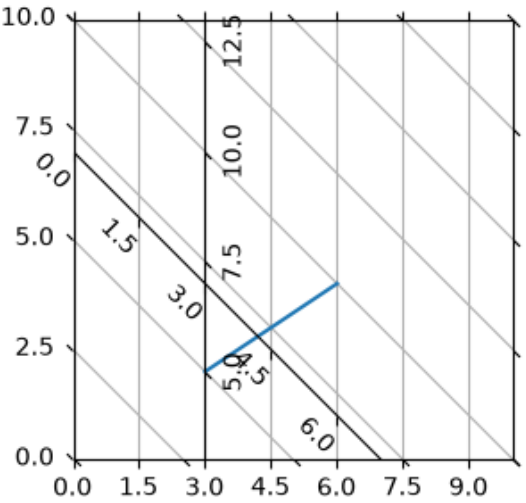
Curvilinear grid

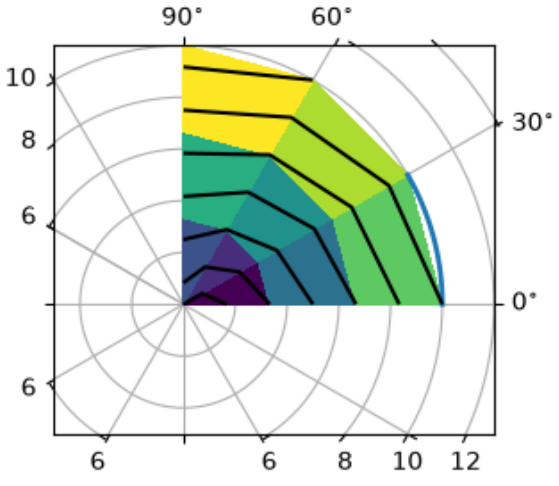
The motivation behind the AxisArtist module is to support a curvilinear grid and ticks.

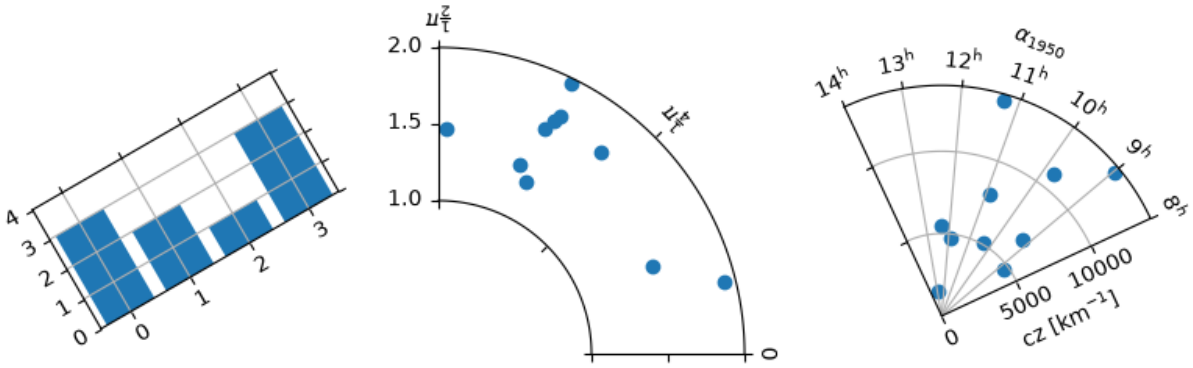
Floating Axes

AxisArtist also supports a Floating Axes whose outer axes are defined as floating axis.


Density
Temperature
Velocity
Distance
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
60
50
40
30
20
10
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00


10.0
7.5
5.0
2.5
0.0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
12.5
10.0
7.5
5.0
4.5
6.0
0.0
1.5
3.0


90°
60°
30°
0°
10
8
6
6
6
8
10
12



axisartist namespace

The *axisartist* namespace includes a derived Axes implementation. The biggest difference is that the artists responsible to draw axis line, ticks, ticklabel and axis labels are separated out from the Matplotlib's Axis class, which are much more than artists in the original Matplotlib. This change was strongly motivated to support curvilinear grid. Here are a few things that mpl_toolkits.axisartist.Axes is different from original Axes from Matplotlib.

- Axis elements (axis line(spine), ticks, ticklabel and axis labels) are drawn by an AxisArtist instance. Unlike Axis, left, right, top and bottom axis are drawn by separate artists. And each of them may have different tick location and different tick labels.
- gridlines are drawn by a Gridlines instance. The change was motivated that in curvilinear coordinate, a gridline may not cross axis-lines (i.e., no associated ticks). In the original Axes class, gridlines are tied to ticks.
- ticklines can be rotated if necessary (i.e, along the gridlines)

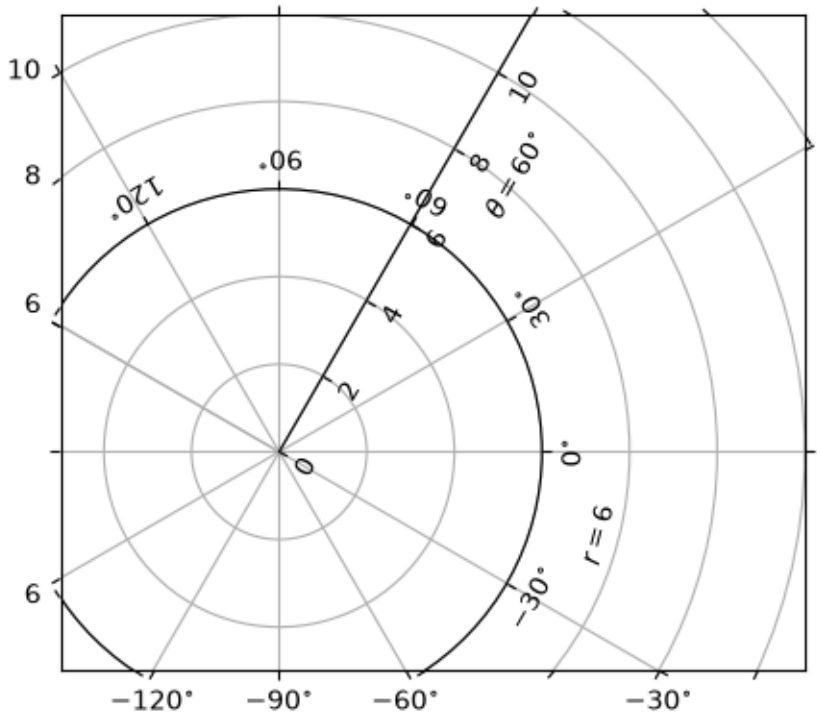
In summary, all these changes was to support

- a curvilinear grid.
- a floating axis

mpl_toolkits.axisartist.Axes class defines a *axis* attribute, which is a dictionary of AxisArtist instances. By default, the dictionary has 4 AxisArtist instances, responsible for drawing of left, right, bottom and top axis.

xaxis and yaxis attributes are still available, however they are set to not visible. As separate artists are used for rendering axis, some axis-related method in Matplotlib may have no effect. In addition to AxisArtist instances, the mpl_toolkits.axisartist.Axes will have *gridlines* attribute (Gridlines), which obviously draws grid lines.

In both AxisArtist and Gridlines, the calculation of tick and grid location is delegated to an instance of GridHelper class. mpl_toolkits.axisartist.Axes class uses GridHelperRectlinear as a grid helper. The Grid-


10
8
6
6
.06
120°
60°
θ = 60°
30°
0°
−30°
r = 6
0
2
4
6
8
10
−120°
−90°
−60°
−30°

HelperRectlinear class is a wrapper around the *xaxis* and *yaxis* of Matplotlib's original Axes, and it was meant to work as the way how Matplotlib's original axes works. For example, tick location changes using set_ticks method and etc. should work as expected. But change in artist properties (e.g., color) will not work in general, although some effort has been made so that some often-change attributes (color, etc.) are respected.

AxisArtist

AxisArtist can be considered as a container artist with following attributes which will draw ticks, labels, etc.

- line
- major_ticks, major_ticklabels
- minor_ticks, minor_ticklabels
- offsetText
- label

line

Derived from Line2D class. Responsible for drawing a spinal(?) line.

major_ticks, minor_ticks

Derived from Line2D class. Note that ticks are markers.

major_ticklabels, minor_ticklabels

Derived from Text. Note that it is not a list of Text artist, but a single artist (similar to a collection).

axislabel

Derived from Text.

Default AxisArtists

By default, following for axis artists are defined.:

```
ax.axis["left"], ax.axis["bottom"], ax.axis["right"], ax.axis["top"]
```

The ticklabels and axislabel of the top and the right axis are set to not visible.

For example, if you want to change the color attributes of major_ticklabels of the bottom x-axis

```
ax.axis["bottom"].major_ticklabels.set_color("b")
```

Similarly, to make ticklabels invisible

```
ax.axis["bottom"].major_ticklabels.set_visible(False)
```

AxisArtist provides a helper method to control the visibility of ticks, ticklabels, and label. To make ticklabel invisible,

```
ax.axis["bottom"].toggle(ticklabels=False)
```

To make all of ticks, ticklabels, and (axis) label invisible

```
ax.axis["bottom"].toggle(all=False)
```

To turn all off but ticks on

```
ax.axis["bottom"].toggle(all=False, ticks=True)
```

To turn all on but (axis) label off

```
ax.axis["bottom"].toggle(all=True, label=False)
```

ax.axis's __getitem__ method can take multiple axis names. For example, to turn ticklabels of "top" and "right" axis on,

```
ax.axis["top", "right"].toggle(ticklabels=True)
```

Note that `ax.axis["top", "right"]` returns a simple proxy object that translate above code to something like below.

```
for n in ["top", "right"]:
    ax.axis[n].toggle(ticklabels=True)
```

So, any return values in the for loop are ignored. And you should not use it anything more than a simple method.

Like the list indexing ":" means all items, i.e.,

```
ax.axis[:].major_ticks.set_color("r")
```

changes tick color in all axis.

HowTo

1. Changing tick locations and label.

   Same as the original Matplotlib's axes:

   ```
   ax.set_xticks([1, 2, 3])
   ```

2. Changing axis properties like color, etc.

   Change the properties of appropriate artists. For example, to change the color of the ticklabels:

   ```
   ax.axis["left"].major_ticklabels.set_color("r")
   ```

3. To change the attributes of multiple axis:

```
ax.axis["left", "bottom"].major_ticklabels.set_color("r")
```

or to change the attributes of all axis:

```
ax.axis[:].major_ticklabels.set_color("r")
```

4. To change the tick size (length), use `axis.major_ticks.set_ticksize`.

   To change the direction of the ticks, use `axis.major_ticks.set_tick_direction`.

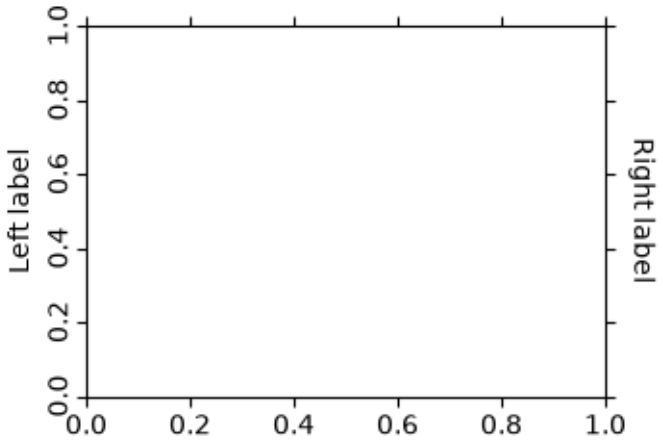
   To change the pad between ticks and ticklabels, use `axis.major_ticklabels.set_pad`.

   To change the pad between ticklabels and axis label, use `axis.label.set_pad`.

Rotation and alignment of TickLabels

This is also quite different from standard Matplotlib and can be confusing. When you want to rotate the ticklabels, first consider using "set_axis_direction" method.

```
ax1.axis["left"].major_ticklabels.set_axis_direction("top")
ax1.axis["right"].label.set_axis_direction("left")
```



The parameter for set_axis_direction is one of ["left", "right", "bottom", "top"].

You must understand some underlying concept of directions.

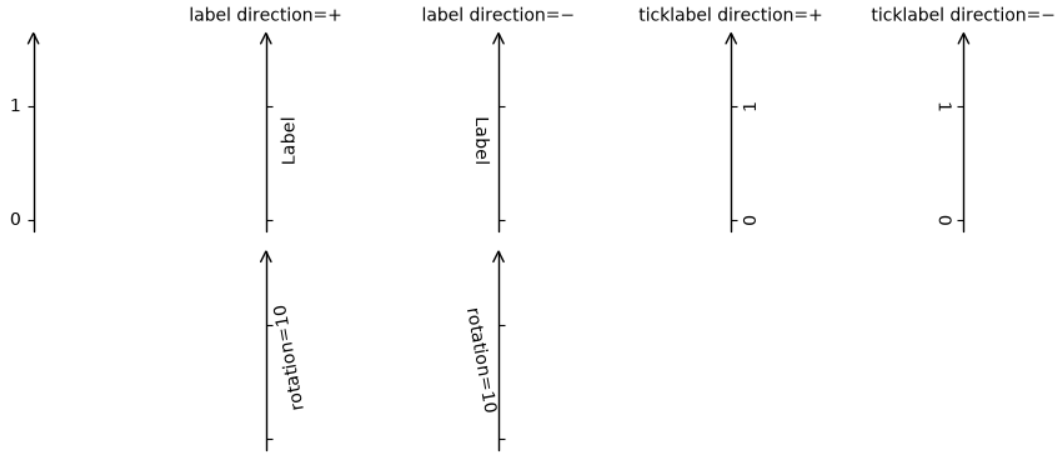
- There is a reference direction which is defined as the direction of the axis line with increasing coordinate. For example, the reference direction of the left x-axis is from bottom to top.

  The direction, text angle, and alignments of the ticks, ticklabels and axis-label is determined with respect to the reference direction

- *label_direction* and *ticklabel_direction* are either the right-hand side (+) of the reference direction or the left-hand side (-).

- ticks are by default drawn toward the opposite direction of the ticklabels.

- text rotation of ticklabels and label is determined in reference to the *ticklabel_direction* or *label_direction*, respectively. The rotation of ticklabels and label is anchored.



On the other hand, there is a concept of "axis_direction". This is a default setting of above properties for each, "bottom", "left", "top", and "right" axis.

Table 9: `axislabel` property defaults

reference direction	label direction	label rotation	horizontal alignment	vertical alignment
left	'-'	180	right	center
bottom	'+'	0	center	top
right	'+'	0	right	center
top	'-'	180	center	bottom

Table 10: `ticklabel` property defaults

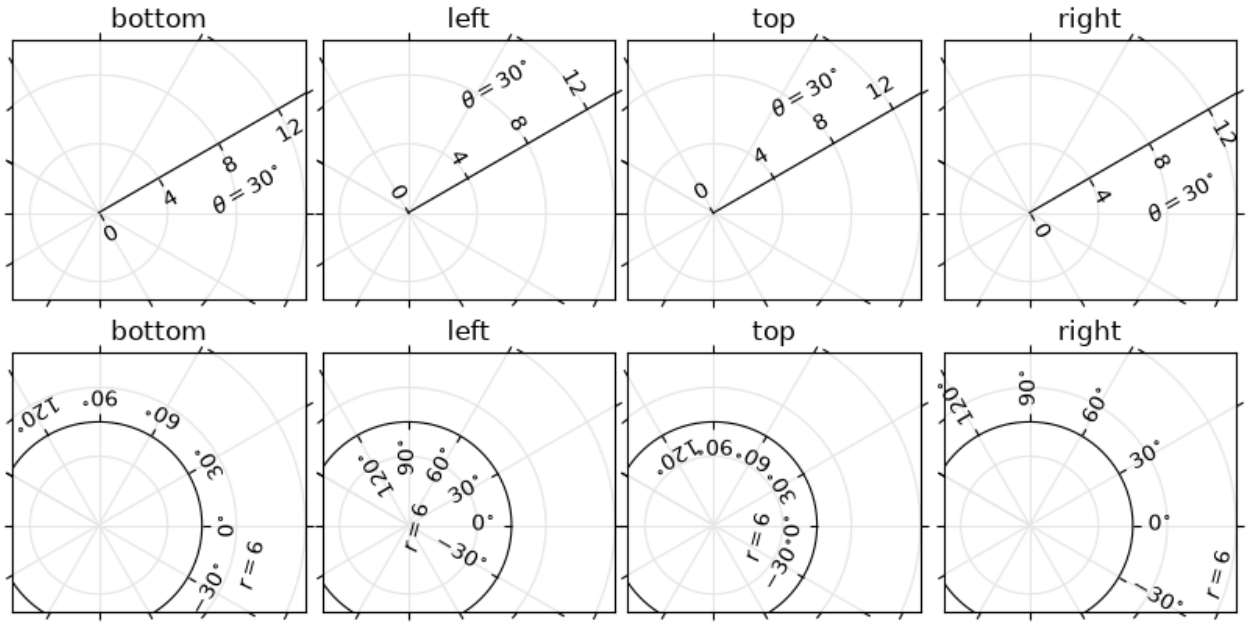
reference direction	label direction	label rotation	horizontal alignment	vertical alignment
left	'-'	90	right	center
bottom	'+'	0	center	baseline
right	'+'	-90	right	center
top	'-'	180	center	baseline

And, 'set_axis_direction("top")' means to adjust the text rotation etc, for settings suitable for "top" axis. The concept of axis direction can be more clear with curved axis.

The axis_direction can be adjusted in the AxisArtist level, or in the level of its child artists, i.e., ticks, ticklabels, and axis-label.

```
ax1.axis["left"].set_axis_direction("top")
```

changes axis_direction of all the associated artist with the "left" axis, while




```
ax1.axis["left"].major_ticklabels.set_axis_direction("top")
```

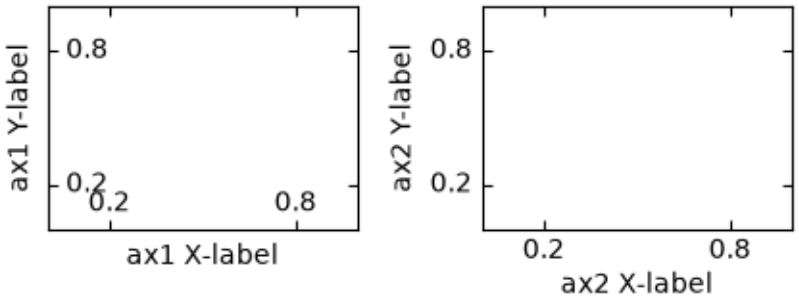
changes the axis_direction of only the major_ticklabels. Note that set_axis_direction in the AxisArtist level changes the ticklabel_direction and label_direction, while changing the axis_direction of ticks, ticklabels, and axis-label does not affect them.

If you want to make ticks outward and ticklabels inside the axes, use *AxisArtist.invert_ticklabel_direction*:

```
ax.axis[:].invert_ticklabel_direction()
```

A related method is *Ticks.set_tick_direction*. It can make ticks point "in", "out", or "inout" (crossing the axis halfway):

```
ax.axis[:].major_ticks.set_tick_direction("inout")
```



So, in summary,

- AxisArtist's methods
  - *set_axis_direction*: "left", "right", "bottom", or "top"
  - *set_ticklabel_direction*: "+" or "-"
  - *set_axislabel_direction*: "+" or "-"
  - *invert_ticklabel_direction*
- Ticks' methods (major_ticks and minor_ticks)
  - *set_tick_direction*: "in", "out", or "inout"
  - *set_ticksize*: size in points
- TickLabels' methods (major_ticklabels and minor_ticklabels)
  - *set_axis_direction*: "left", "right", "bottom", or "top"
  - *set_rotation*: angle with respect to the reference direction
  - *set_horizontalalignment* and *set_verticalalignment*: see below
- AxisLabel' methods (label)
  - *set_axis_direction*: "left", "right", "bottom", or "top"
  - *set_rotation*: angle with respect to the reference direction
  - *set_horizontalalignment* and *set_verticalalignment*

Adjusting ticklabels alignment

Alignment of TickLabels are treated specially. See below

Adjusting pad

To change the pad between ticks and ticklabels

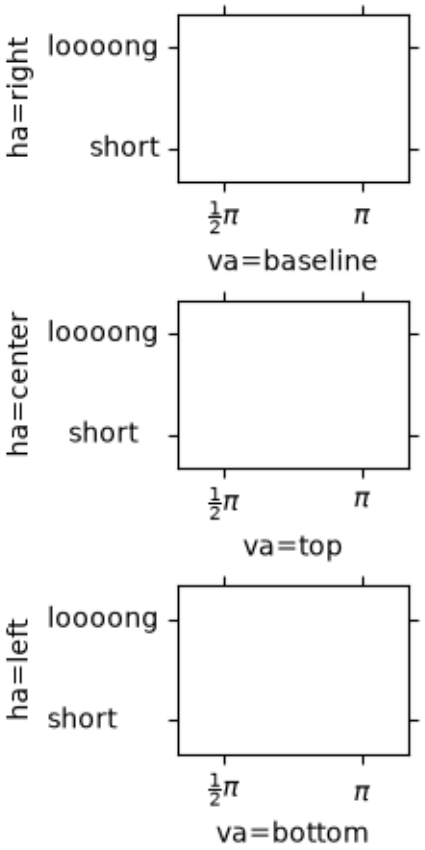
```
ax.axis["left"].major_ticklabels.set_pad(10)
```

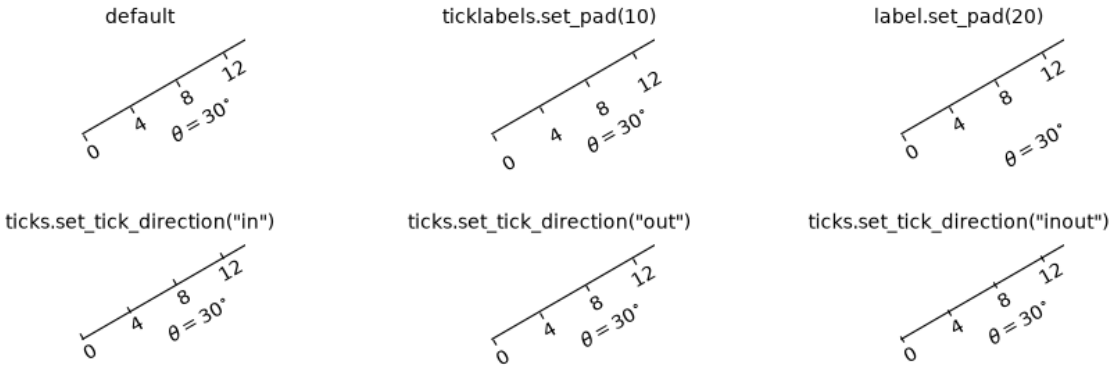
Or ticklabels and axis-label

```
ax.axis["left"].label.set_pad(10)
```

GridHelper

To actually define a curvilinear coordinate, you have to use your own grid helper. A generalised version of grid helper class is supplied and this class should suffice in most of cases. A user may provide two functions which defines a transformation (and its inverse pair) from the curved coordinate to (rectilinear) image coordinate. Note that while ticks and grids are drawn for curved coordinate, the data transform of the axes itself (ax.transData) is still rectilinear (image) coordinate.


ha=right
loooong
short
$\frac{1}{2}\pi$
π
va=baseline
ha=center
loooong
short
$\frac{1}{2}\pi$
π
va=top
ha=left
loooong
short
$\frac{1}{2}\pi$
π
va=bottom


default
0
4
8
12
θ = 30°
ticklabels.set_pad(10)
0
4
8
12
θ = 30°
label.set_pad(20)
0
4
8
12
θ = 30°
ticks.set_tick_direction("in")
0
4
8
12
θ = 30°
ticks.set_tick_direction("out")
0
4
8
12
θ = 30°
ticks.set_tick_direction("inout")
0
4
8
12
θ = 30°

```
from mpl_toolkits.axisartist.grid_helper_curvelinear \
     import GridHelperCurveLinear
from mpl_toolkits.axisartist import Axes

# from curved coordinate to rectlinear coordinate.
def tr(x, y):
    x, y = np.asarray(x), np.asarray(y)
    return x, y-x

# from rectlinear coordinate to curved coordinate.
def inv_tr(x, y):
    x, y = np.asarray(x), np.asarray(y)
    return x, y+x

grid_helper = GridHelperCurveLinear((tr, inv_tr))

fig.add_subplot(axes_class=Axes, grid_helper=grid_helper)
```

You may use Matplotlib's Transform instance instead (but a inverse transformation must be defined). Often, coordinate range in a curved coordinate system may have a limited range, or may have cycles. In those cases, a more customized version of grid helper is required.

```
import mpl_toolkits.axisartist.angle_helper as angle_helper

# PolarAxes.PolarTransform takes radian. However, we want our␣
 ↪coordinate
# system in degree
tr = Affine2D().scale(np.pi/180., 1.) + PolarAxes.PolarTransform()

# extreme finder: find a range of coordinate.
# 20, 20: number of sampling points along x, y direction
# The first coordinate (longitude, but theta in polar)
#   has a cycle of 360 degree.
# The second coordinate (latitude, but radius in polar)  has a minimum␣
 ↪of 0
extreme_finder = angle_helper.ExtremeFinderCycle(20, 20,
                                                 lon_cycle=360,
                                                 lat_cycle=None,
                                                 lon_minmax=None,
                                                 lat_minmax=(0, np.
 ↪inf),
                                                 )

# Find a grid values appropriate for the coordinate (degree,
# minute, second). The argument is an approximate number of grids.
grid_locator1 = angle_helper.LocatorDMS(12)
```

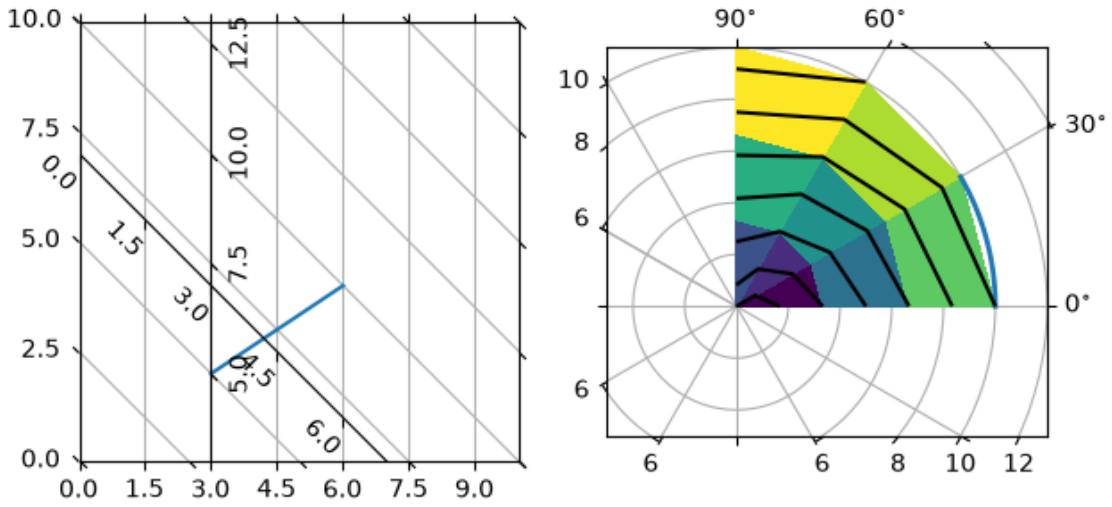
(continues on next page)

(continued from previous page)

```
# And also uses an appropriate formatter.  Note that the acceptable␣
 ↪Locator
# and Formatter classes are different than that of Matplotlib's, and␣
 ↪you
# cannot directly use Matplotlib's Locator and Formatter here (but may␣
 ↪be
# possible in the future).
tick_formatter1 = angle_helper.FormatterDMS()

grid_helper = GridHelperCurveLinear(tr,
                                    extreme_finder=extreme_finder,
                                    grid_locator1=grid_locator1,
                                    tick_formatter1=tick_formatter1
                                    )
```

Again, the *transData* of the axes is still a rectilinear coordinate (image coordinate). You may manually do conversion between two coordinates, or you may use Parasite Axes for convenience.:

```
ax1 = SubplotHost(fig, 1, 2, 2, grid_helper=grid_helper)

# A parasite axes with given transform
ax2 = ax1.get_aux_axes(tr, "equal")
# note that ax2.transData == tr + ax1.transData
# Anything you draw in ax2 will match the ticks and grids of ax1.
```



FloatingAxis

A floating axis is an axis one of whose data coordinate is fixed, i.e, its location is not fixed in Axes coordinate but changes as axes data limits changes. A floating axis can be created using *new_floating_axis* method. However, it is your responsibility that the resulting AxisArtist is properly added to the axes. A recommended way is to add it as an item of Axes's axis attribute.:

```
# floating axis whose first (index starts from 0) coordinate
# (theta) is fixed at 60

ax1.axis["lat"] = axis = ax1.new_floating_axis(0, 60)
axis.label.set_text(r"$\theta = 60^{\circ}$")
axis.label.set_visible(True)
```

See the first example of this page.

Current limitations and TODO's

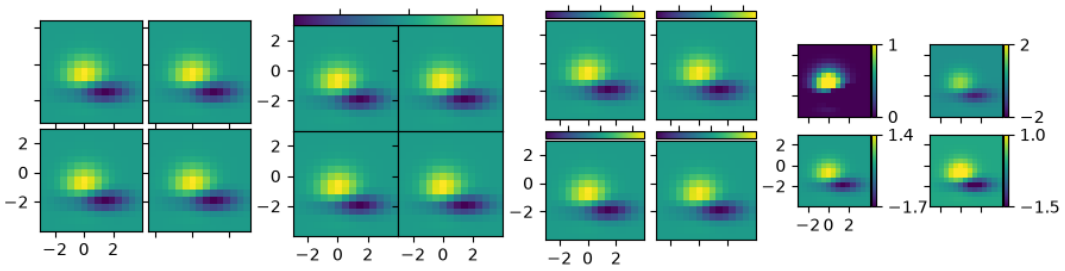
The code need more refinement. Here is an incomplete list of issues and TODO's

- No easy way to support a user customized tick location (for curvilinear grid). A new Locator class needs to be created.
- FloatingAxis may have coordinate limits, e.g., a floating axis of x = 0, but y only spans from 0 to 1.
- The location of axislabel of FloatingAxis needs to be optionally given as a coordinate value. ex, a floating axis of x=0 with label at y=1

3.10.2 The axes_grid1 toolkit

axes_grid1 provides the following features:

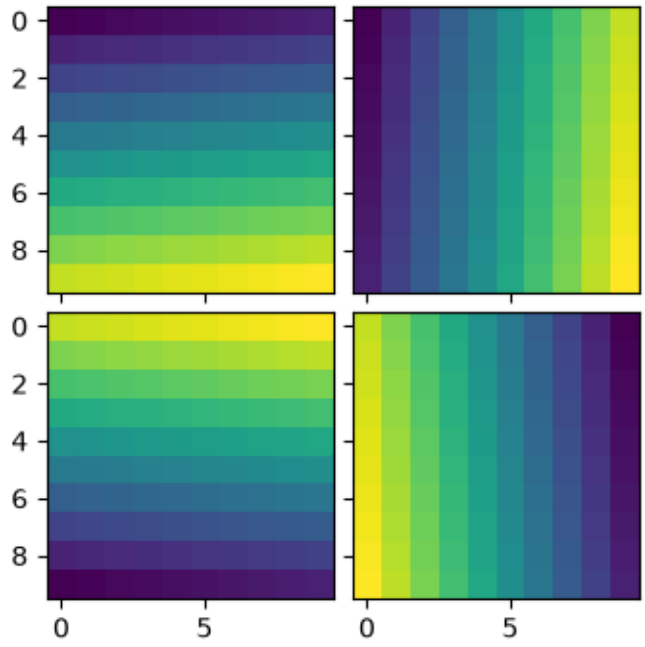
- Helper classes (*ImageGrid*, *RGBAxes*, *AxesDivider*) to ease the layout of axes displaying images with a fixed aspect ratio while satisfying additional constraints (matching the heights of a colorbar and an image, or fixing the padding between images);
- *ParasiteAxes* (twinx/twiny-like features so that you can plot different data (e.g., different y-scale) in a same Axes);
- *AnchoredArtists* (custom artists which are placed at an anchored position, similarly to legends).



axes_grid1

ImageGrid

In Matplotlib, axes location and size are usually specified in normalized figure coordinates (0 = bottom left, 1 = top right), which makes it difficult to achieve a fixed (absolute) padding between images. `ImageGrid` can be used to achieve such a padding; see its docs for detailed API information.



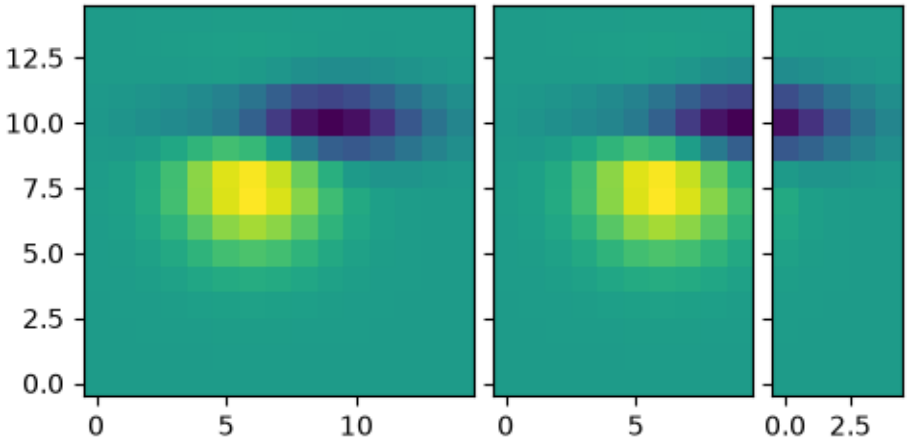
- The position of each axes is determined at the drawing time (see *AxesDivider*), so that the size of the entire grid fits in the given rectangle (like the aspect of axes). Note that in this example, the paddings between axes are fixed even if you change the figure size.
- Axes in the same column share their x-axis, and axes in the same row share their y-axis (in the sense of `sharex`, `sharey`). Additionally, Axes in the same column all have the same width, and axes in the same row all have the same height. These widths and heights are scaled in proportion to the axes' view limits (xlim or ylim).

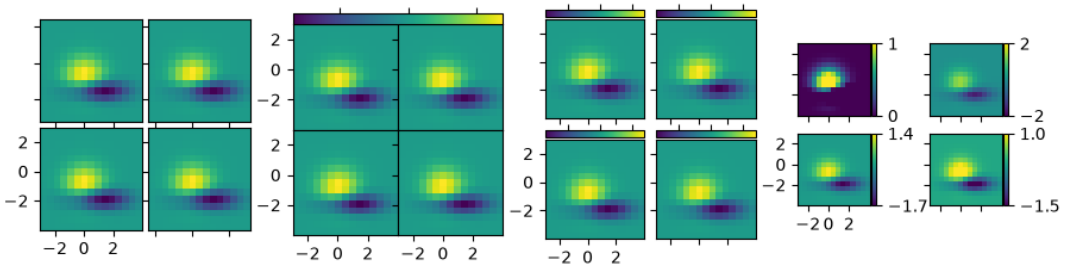
The examples below show what you can do with ImageGrid.

AxesDivider class

Behind the scenes, ImageGrid (and RGBAxes, described below) rely on `AxesDivider`, whose role is to calculate the location of the axes at drawing time.

Users typically do not need to directly instantiate dividers by calling `AxesDivider`; instead, `make_axes_locatable` can be used to create a divider for an Axes:

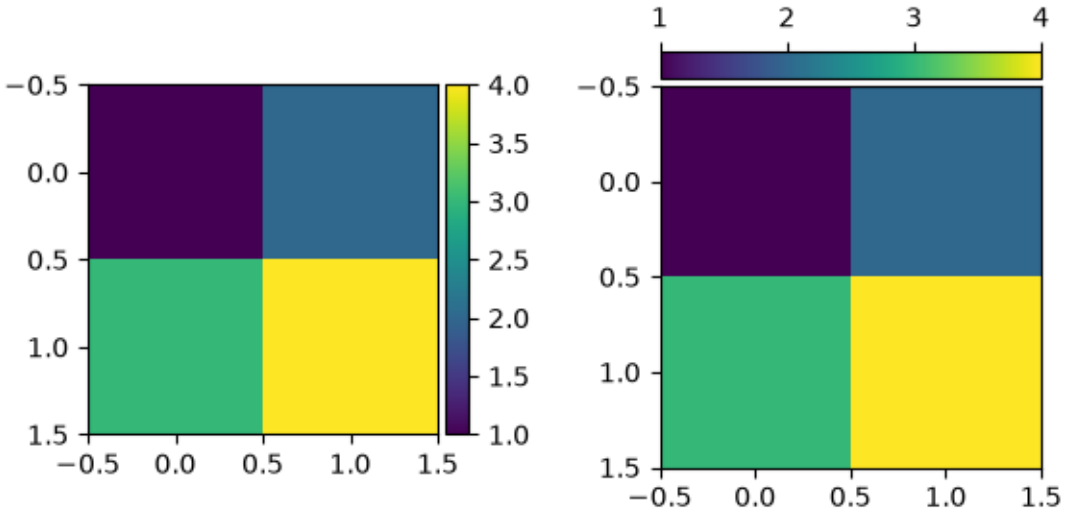

12.5
10.0
7.5
5.0
2.5
0.0
0
5
10
0
5
0.0
2.5


2
0
−2
−2 0 2
1
0
1.4
1.0
−1.7
−1.5

```
ax = subplot(1, 1, 1)
divider = make_axes_locatable(ax)
```

AxesDivider.append_axes can then be used to create a new axes on a given side ("left", "right", "top", "bottom") of the original axes.

colorbar whose height (or width) is in sync with the main axes



scatter_hist.py with AxesDivider

The *Scatter plot with histograms* example can be rewritten using *make_axes_locatable*:

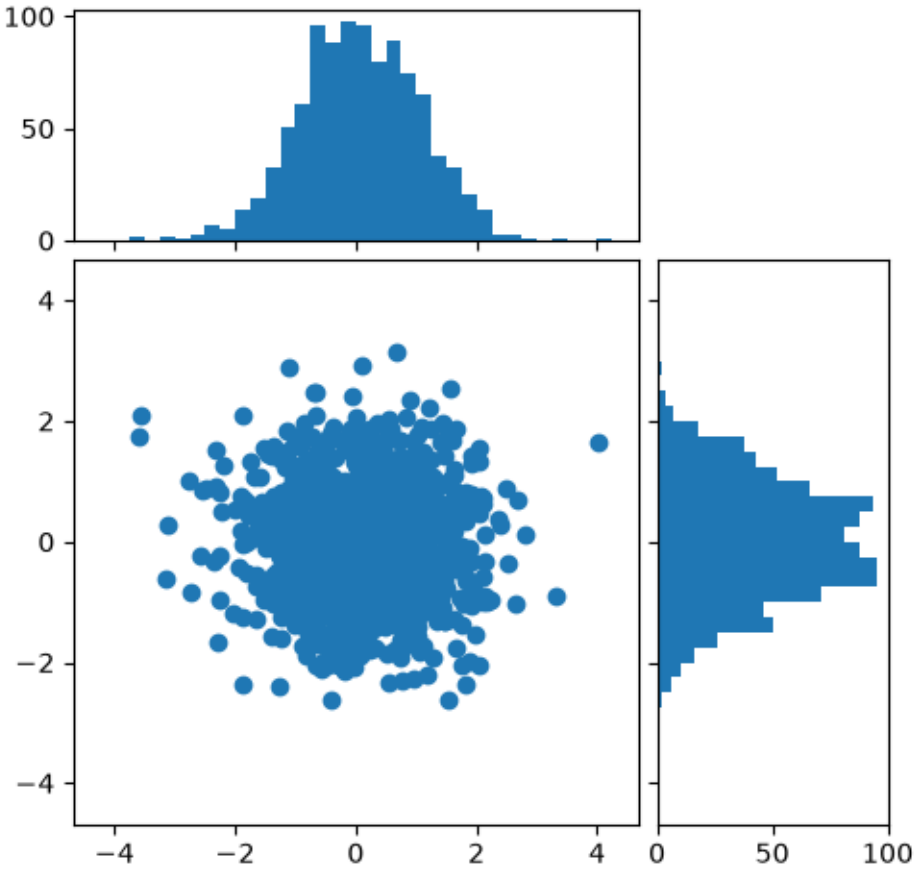
```
axScatter = plt.subplot()
axScatter.scatter(x, y)
axScatter.set_aspect(1.)

# create new axes on the right and on the top of the current axes.
divider = make_axes_locatable(axScatter)
axHistx = divider.append_axes("top", size=1.2, pad=0.1,␣
```

(continues on next page)

(continued from previous page)

```
 ↪sharex=axScatter)
axHisty = divider.append_axes("right", size=1.2, pad=0.1,␣
 ↪sharey=axScatter)

# the scatter plot:
# histograms
bins = np.arange(-lim, lim + binwidth, binwidth)
axHistx.hist(x, bins=bins)
axHisty.hist(y, bins=bins, orientation='horizontal')
```

See the full source code below.



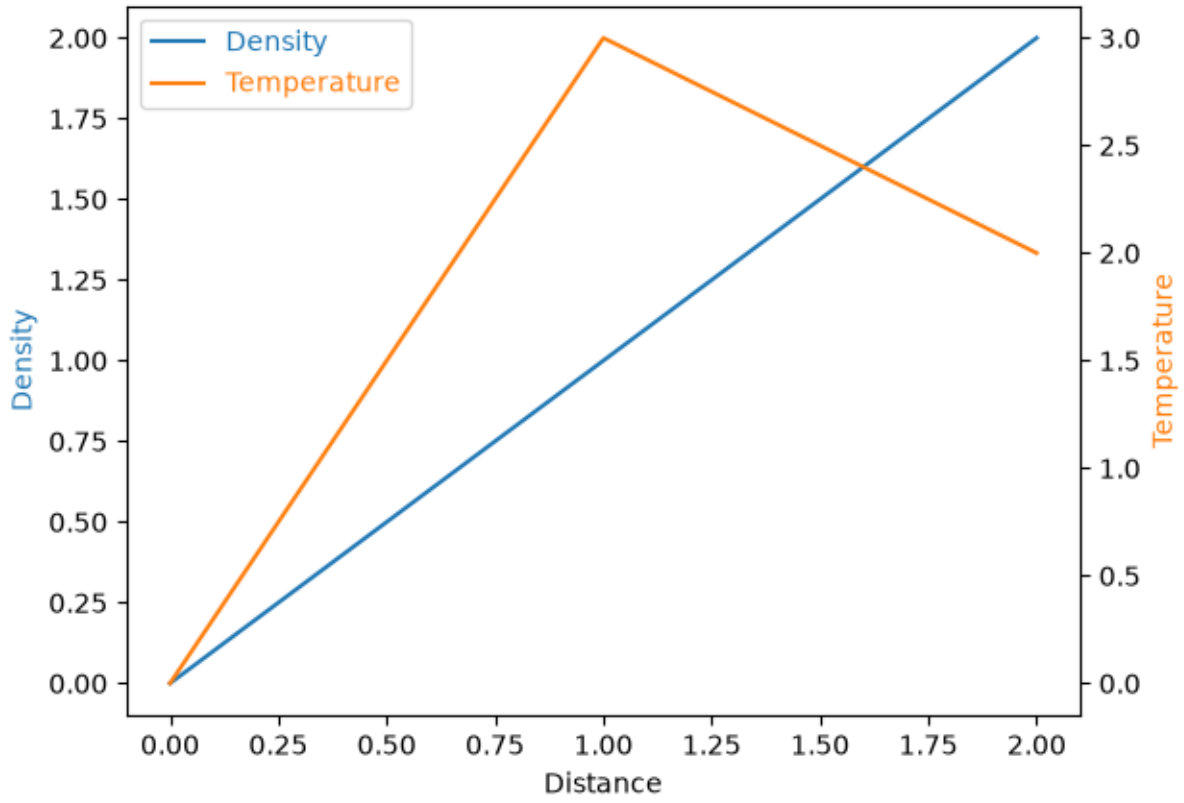
The *Align histogram to scatter plot using locatable Axes* using the AxesDivider has some advantages over the original *Scatter plot with histograms* in Matplotlib. For example, you can set the aspect ratio of the scatter plot, even with the x-axis or y-axis is shared accordingly.

ParasiteAxes

The ParasiteAxes is an Axes whose location is identical to its host axes. The location is adjusted in the drawing time, thus it works even if the host change its location (e.g., images).

In most cases, you first create a host axes, which provides a few methods that can be used to create parasite axes. They are `twinx`, `twiny` (which are similar to `twinx` and `twiny` in the matplotlib) and `twin`. `twin` takes an arbitrary transformation that maps between the data coordinates of the host axes and the parasite axes. The `draw` method of the parasite axes are never called. Instead, host axes collects artists in parasite axes and draws them as if they belong to the host axes, i.e., artists in parasite axes are merged to those of the host axes and then drawn according to their zorder. The host and parasite axes modifies some of the axes behavior. For example, color cycle for plot lines are shared between host and parasites. Also, the legend command in host, creates a legend that includes lines in the parasite axes. To create a host axes, you may use `host_subplot` or `host_axes` command.

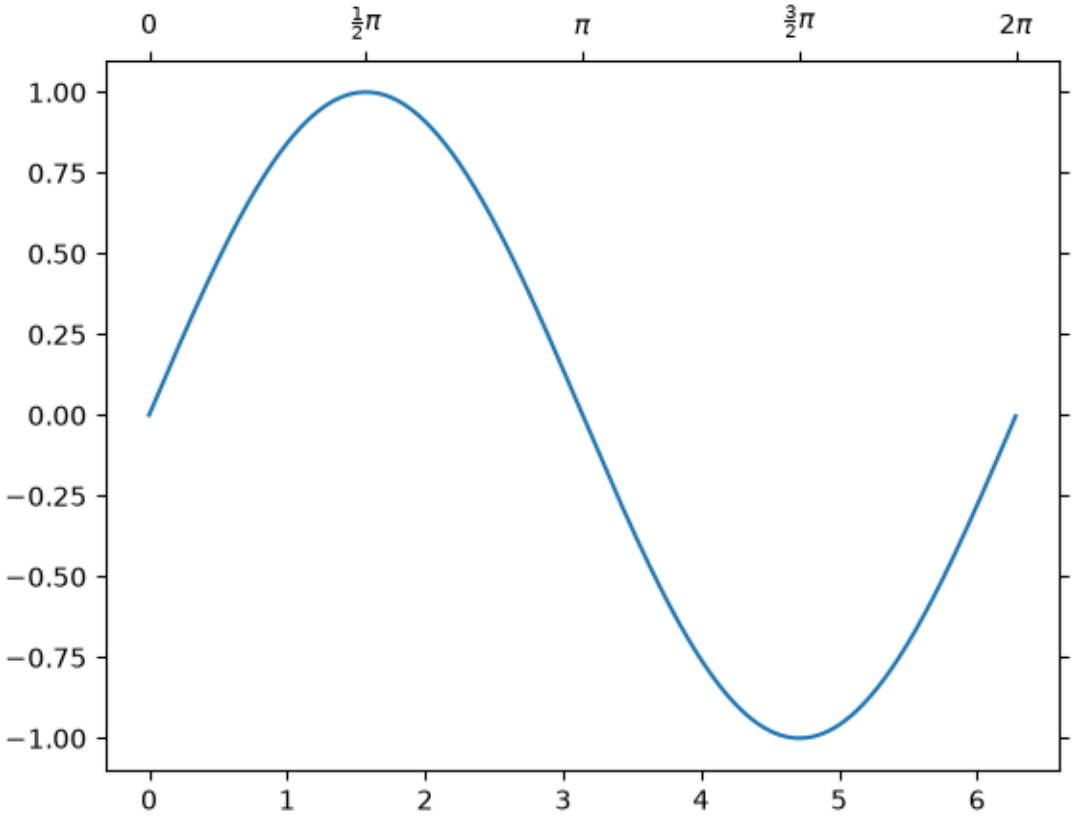
Example 1: twinx



Example 2: twin

`twin` without a transform argument assumes that the parasite axes has the same data transform as the host. This can be useful when you want the top(or right)-axis to have different tick-locations, tick-labels, or tick-formatter for bottom(or left)-axis.

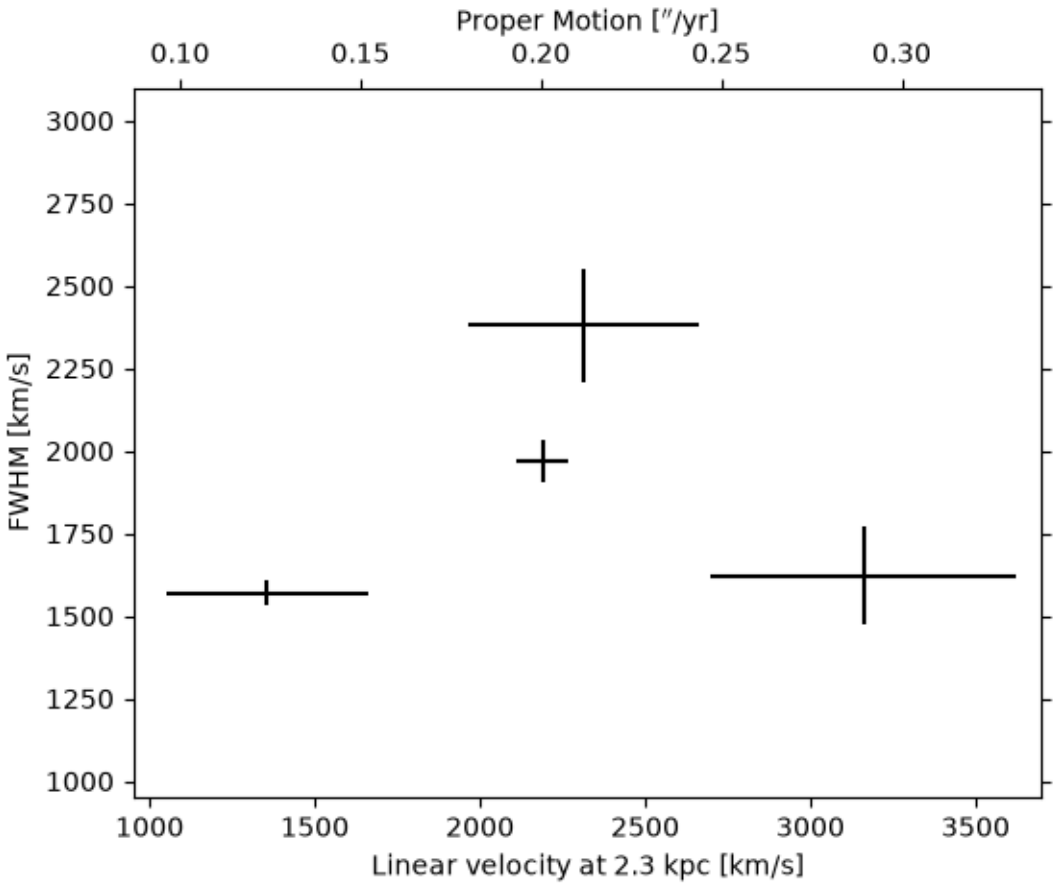
```
ax2 = ax.twin() # now, ax2 is responsible for "top" axis and "right"␣
↪axis
ax2.set_xticks([0., .5*np.pi, np.pi, 1.5*np.pi, 2*np.pi],
               labels=["0", r"$\frac{1}{2}\pi$",
                       r"$\pi$", r"$\frac{3}{2}\pi$", r"$2\pi$"])
```



A more sophisticated example using twin. Note that if you change the x-limit in the host axes, the x-limit of the parasite axes will change accordingly.

AnchoredArtists

`axes_grid1.anchored_artists` is a collection of artists whose location is anchored to the (axes) bbox, similarly to legends. These artists derive from *`offsetbox.OffsetBox`*, and the artist need to be drawn in canvas coordinates. There is limited support for arbitrary transforms. For example, the ellipse in the example below will have width and height in data coordinates.


Proper Motion [″/yr]
0.10
0.15
0.20
0.25
0.30
3000
2750
2500
2250
2000
1750
1500
1250
1000
FWHM [km/s]
1000
1500
2000
2500
3000
3500
Linear velocity at 2.3 kpc [km/s]

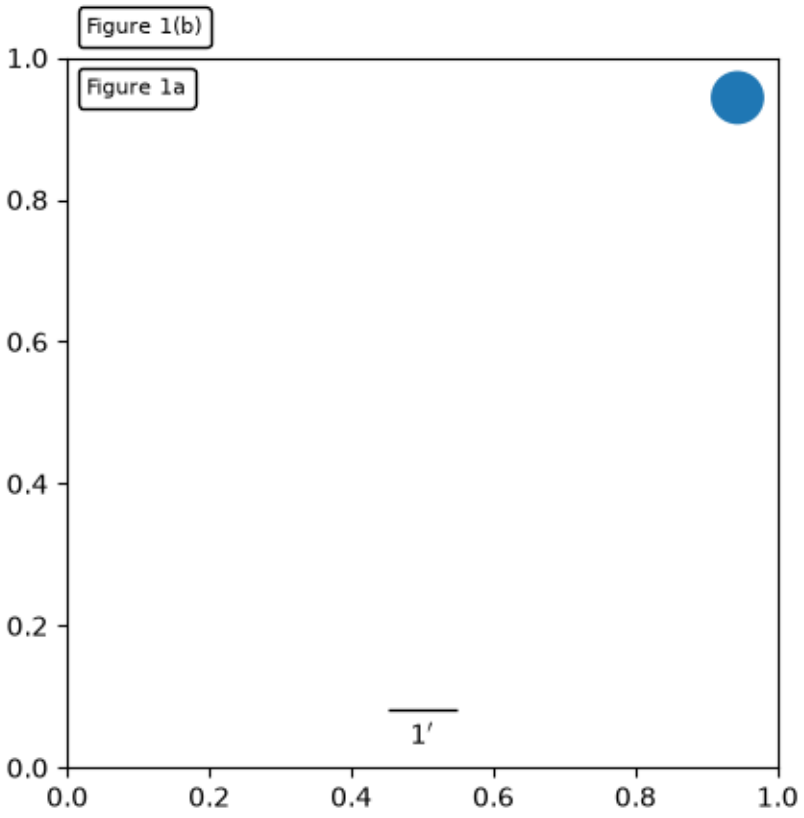


Figure 1(b)
Figure 1a
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1′

InsetLocator

See also

Axes.inset_axes and *Axes.indicate_inset_zoom* in the main library.

axes_grid1.inset_locator provides helper classes and functions to place inset axes at an anchored position of the parent axes, similarly to AnchoredArtist.

inset_locator.inset_axes creates an inset axes whose size is either fixed, or a fixed proportion of the parent axes:

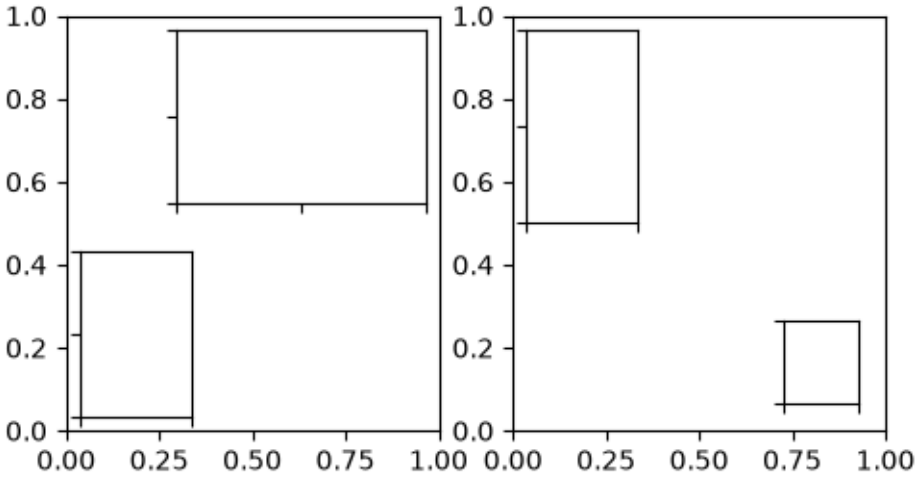
```
inset_axes = inset_axes(parent_axes,
                        width="30%",  # width = 30% of parent_bbox
                        height=1.,  # height = 1 inch
                        loc='lower left')
```

creates an inset axes whose width is 30% of the parent axes and whose height is fixed at 1 inch.

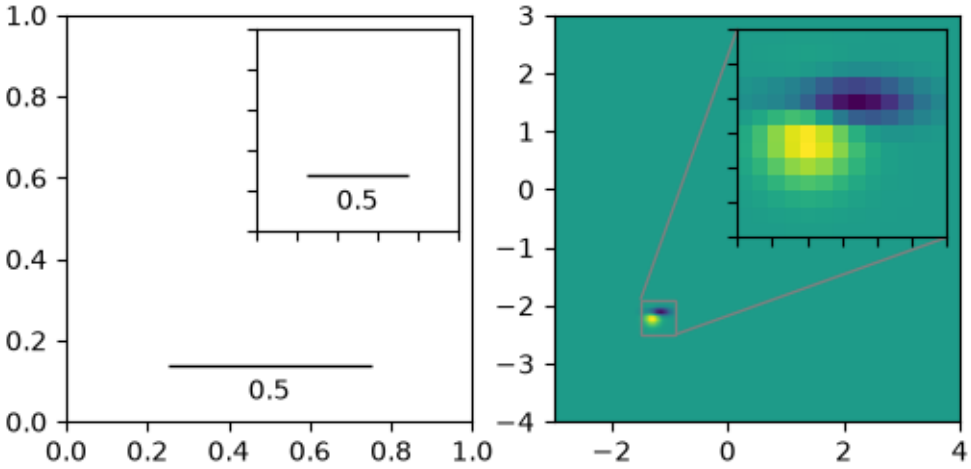
inset_locator.zoomed_inset_axes creates an inset axes whose data scale is that of the parent axes multiplied by some factor, e.g.

```
inset_axes = zoomed_inset_axes(ax,
                               0.5,  # zoom = 0.5
                               loc='upper right')
```

creates an inset axes whose data scale is half of the parent axes. This can be useful to mark the zoomed area on the parent axes:



inset_locator.mark_inset allows marking the location of the area represented by the inset axes:



RGBAxes

RGBAxes is a helper class to conveniently show RGB composite images. Like ImageGrid, the location of axes are adjusted so that the area occupied by them fits in a given rectangle. Also, the xaxis and yaxis of each axes are shared.

```
from mpl_toolkits.axes_grid1.axes_rgb import RGBAxes

fig = plt.figure()
ax = RGBAxes(fig, [0.1, 0.1, 0.8, 0.8], pad=0.0)
r, g, b = get_rgb()  # r, g, b are 2D images.
ax.imshow_rgb(r, g, b)
```

AxesDivider

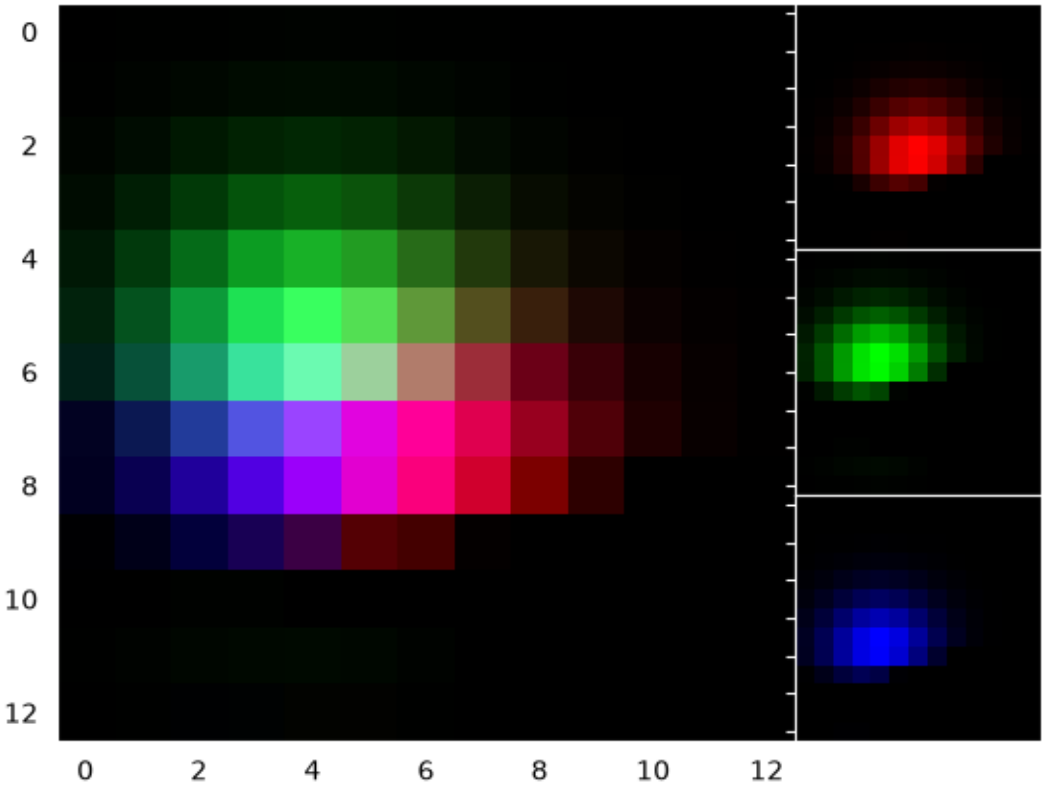
The *mpl_toolkits.axes_grid1.axes_divider* module provides helper classes to adjust the axes positions of a set of images at drawing time.

- *axes_size* provides a class of units that are used to determine the size of each axes. For example, you can specify a fixed size.
- *Divider* is the class that calculates the axes position. It divides the given rectangular area into several areas. The divider is initialized by setting the lists of horizontal and vertical sizes on which the division will be based. Then use *new_locator()*, which returns a callable object that can be used to set the axes_locator of the axes.

Here, we demonstrate how to achieve the following layout: we want to position axes in a 3x4 grid (note that *Divider* makes row indices start from the *bottom*(!) of the grid):

```
┌─────────┬─────────┬─────────┬─────────┐
│ (2, 0)  │ (2, 1)  │ (2, 2)  │ (2, 3)  │
```

(continues on next page)


0
2
4
6
8
10
12
0
2
4
6
8
10
12

(continued from previous page)

```
┌─────────┬─────────┬─────────┬─────────┐
│ (1, 0)  │ (1, 1)  │ (1, 2)  │ (1, 3)  │
├─────────┼─────────┼─────────┼─────────┤
│ (0, 0)  │ (0, 1)  │ (0, 2)  │ (0, 3)  │
└─────────┴─────────┴─────────┴─────────┘
```

such that the bottom row has a fixed height of 2 (inches) and the top two rows have a height ratio of 2 (middle) to 3 (top). (For example, if the grid has a size of 7 inches, the bottom row will be 2 inches, the middle row also 2 inches, and the top row 3 inches.)

These constraints are specified using classes from the *axes_size* module, namely:

```
from mpl_toolkits.axes_grid1.axes_size import Fixed, Scaled
vert = [Fixed(2), Scaled(2), Scaled(3)]
```

(More generally, *axes_size* classes define a `get_size(renderer)` method that returns a pair of floats -- a relative size, and an absolute size. `Fixed(2).get_size(renderer)` returns `(0, 2)`; `Scaled(2).get_size(renderer)` returns `(2, 0)`.)

We use these constraints to initialize a *Divider* object:

```
rect = [0.2, 0.2, 0.6, 0.6]  # Position of the grid in the figure.
vert = [Fixed(2), Scaled(2), Scaled(3)]  # As above.
horiz = [...]  # Some other horizontal constraints.
divider = Divider(fig, rect, horiz, vert)
```

then use *Divider.new_locator* to create an axes locator callable for a given grid entry:

```
locator = divider.new_locator(nx=0, ny=1)  # Grid entry (1, 0).
```

and make it responsible for locating the axes:

```
ax.set_axes_locator(locator)
```

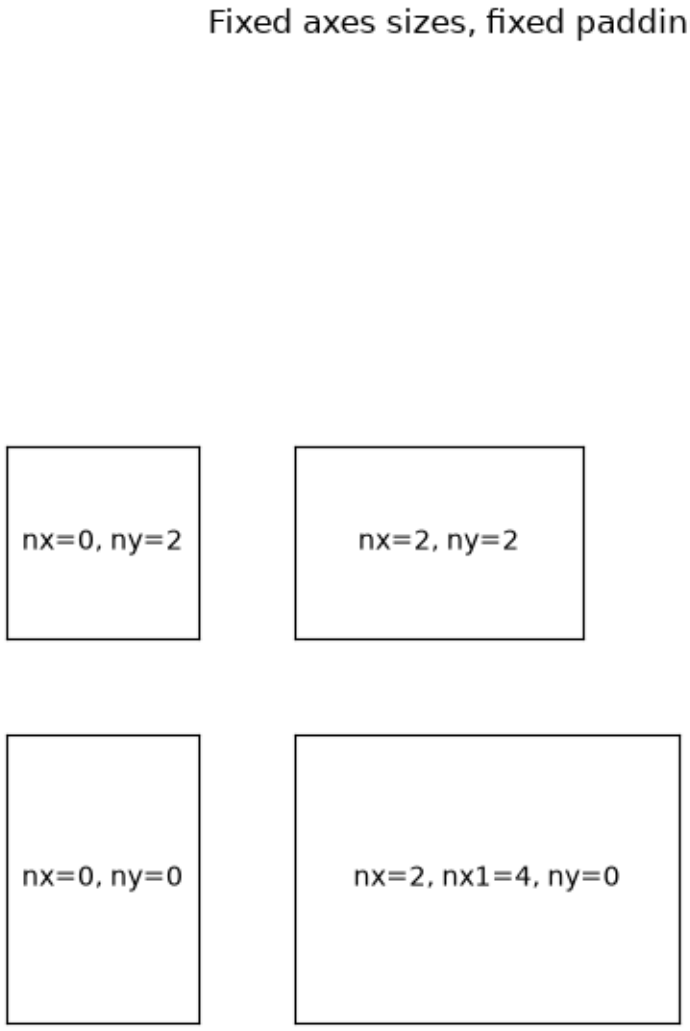
The axes locator callable returns the location and size of the cell at the first column and the second row.

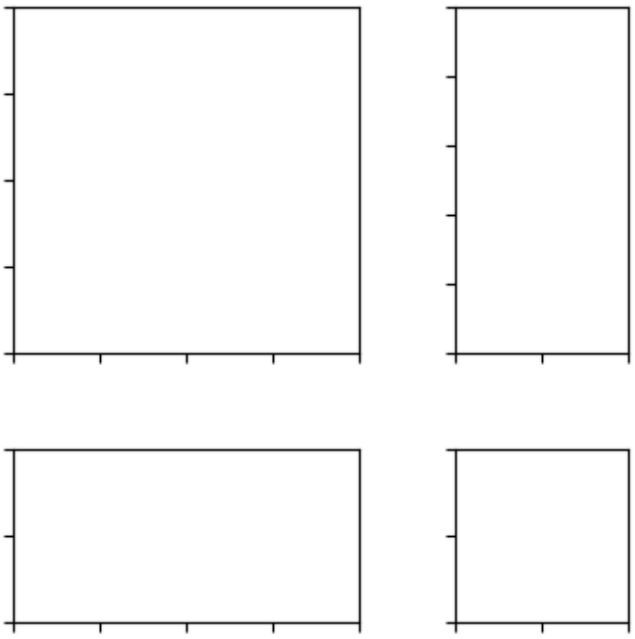
Locators that spans over multiple cells can be created with, e.g.:

```
# Columns #0 and #1 ("0-2 range"), row #1.
locator = divider.new_locator(nx=0, nx1=2, ny=1)
```

See the example,

You can also adjust the size of each axes according to its x or y data limits (AxesX and AxesY).


Fixed axes sizes, fixed paddings
nx=0, ny=2
nx=2, ny=2
nx=0, ny=0
nx=2, nx1=4, ny=0



3.10.3 The mplot3d toolkit

Generating 3D plots using the mplot3d toolkit.

This tutorial showcases various 3D plots. Click on the figures to see each full gallery example with the code that generates the figures.

Contents

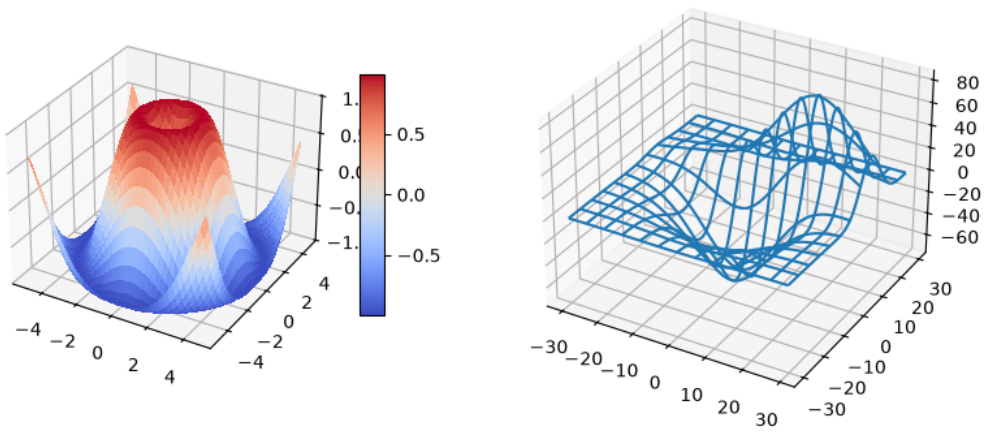
- *The mplot3d toolkit*
  - *Line plots*
  - *Scatter plots*
  - *Wireframe plots*
  - *Surface plots*
  - *Tri-Surface plots*
  - *Contour plots*
  - *Filled contour plots*
  - *Fill between 3D lines*
  - *Polygon plots*

- *Bar plots*
- *Quiver*
- *2D plots in 3D*
- *Text*

3D Axes (of class *Axes3D*) are created by passing the `projection="3d"` keyword argument to *Figure.add_subplot*:

```
import matplotlib.pyplot as plt
fig = plt.figure()
ax = fig.add_subplot(projection='3d')
```

Multiple 3D subplots can be added on the same figure, as for 2D subplots.

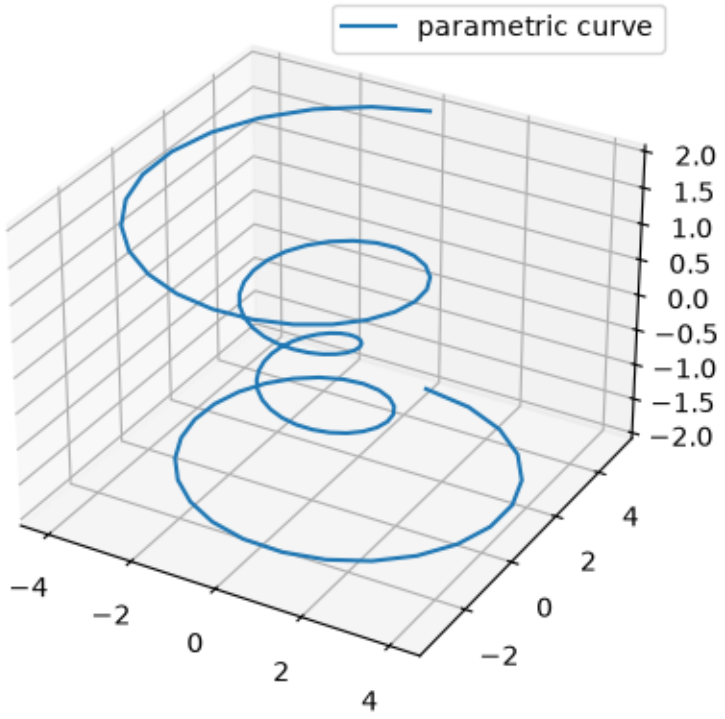


Changed in version 3.2.0: Prior to Matplotlib 3.2.0, it was necessary to explicitly import the *mpl_toolkits.mplot3d* module to make the '3d' projection to *Figure.add_subplot*.

See the *mplot3d FAQ* for more information about the mplot3d toolkit.

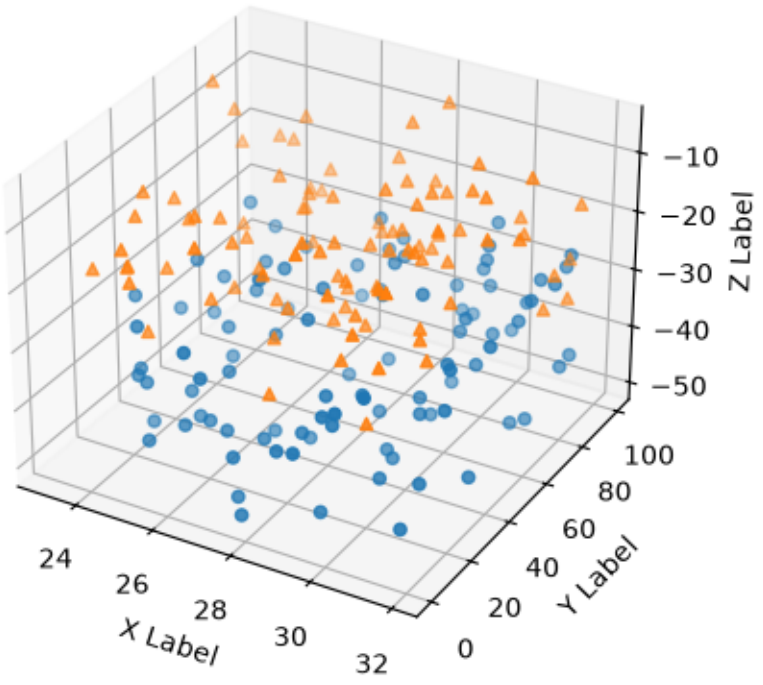
Line plots

See *Axes3D.plot* for API documentation.


parametric curve
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−4
−2
0
2
4
4
2
0
−2

Scatter plots

See *Axes3D.scatter* for API documentation.



Wireframe plots

See *Axes3D.plot_wireframe* for API documentation.

Surface plots

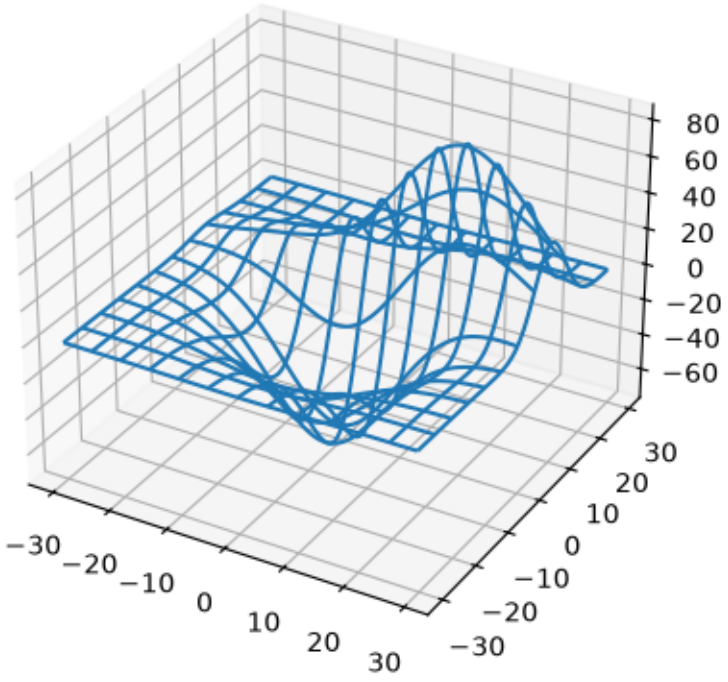
See *Axes3D.plot_surface* for API documentation.

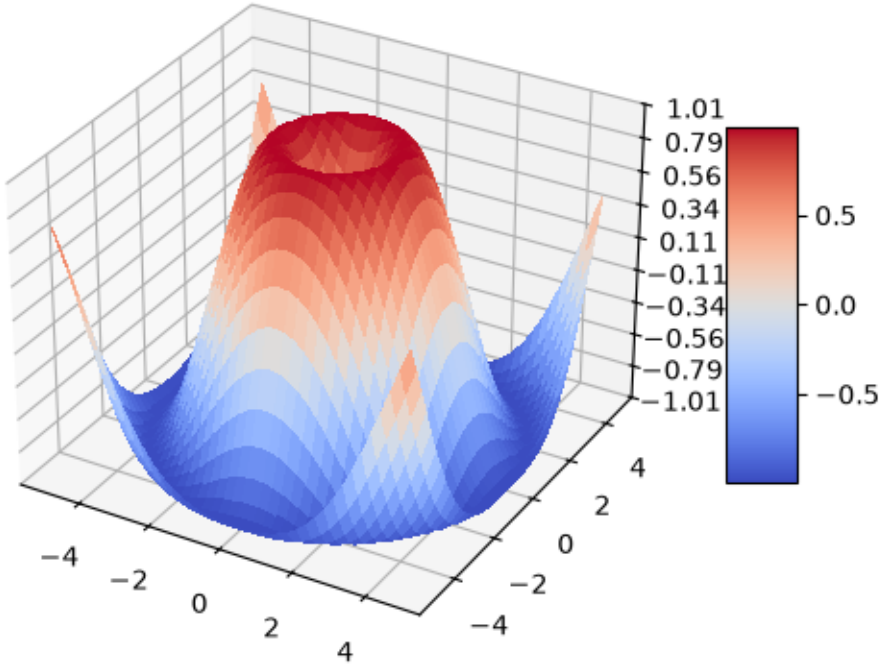
Tri-Surface plots

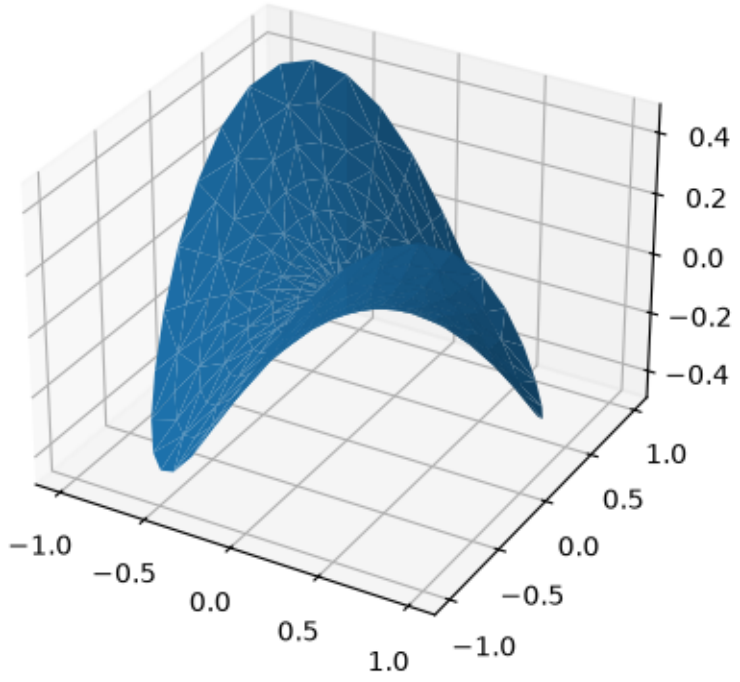
See *Axes3D.plot_trisurf* for API documentation.

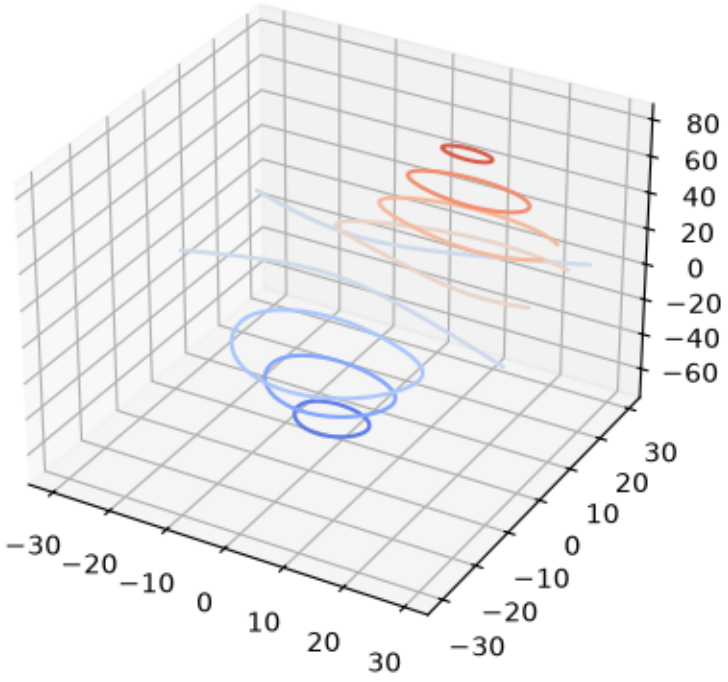
Contour plots

See *Axes3D.contour* for API documentation.


80
60
40
20
0
−20
−40
−60
−30
−20
−10
0
10
20
30
30
20
10
0
−10
−20
−30

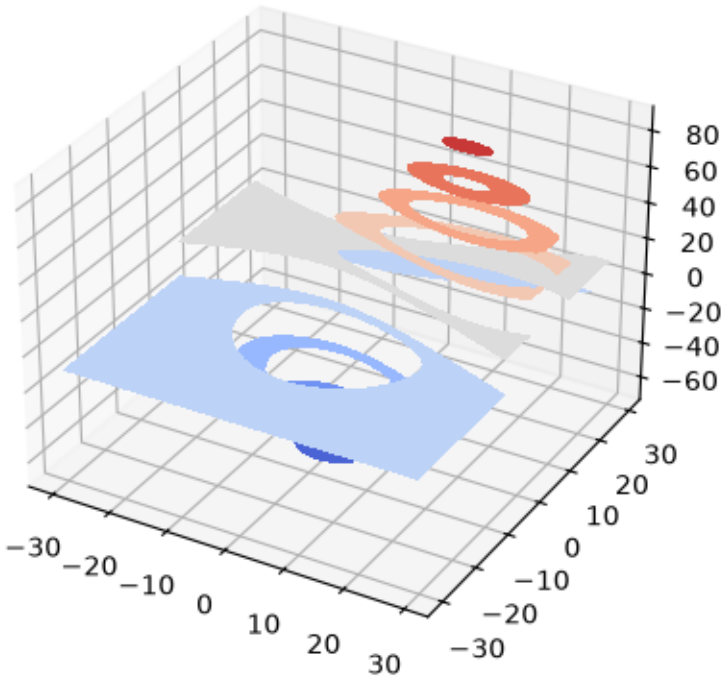

1.01
0.79
0.56
0.34
0.11
−0.11
−0.34
−0.56
−0.79
−1.01
0.5
0.0
−0.5
−4
−2
0
2
4
−4
−2
0
2
4


0.4
0.2
0.0
−0.2
−0.4
1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0


80
60
40
20
0
−20
−40
−60
30
20
10
0
−10
−20
−30
−30
−20
−10
0
10
20
30

Filled contour plots

See *Axes3D.contourf* for API documentation.



Added in version 1.1.0: The feature demoed in the second contourf3d example was enabled as a result of a bugfix for version 1.1.0.

Fill between 3D lines

See *Axes3D.fill_between* for API documentation.

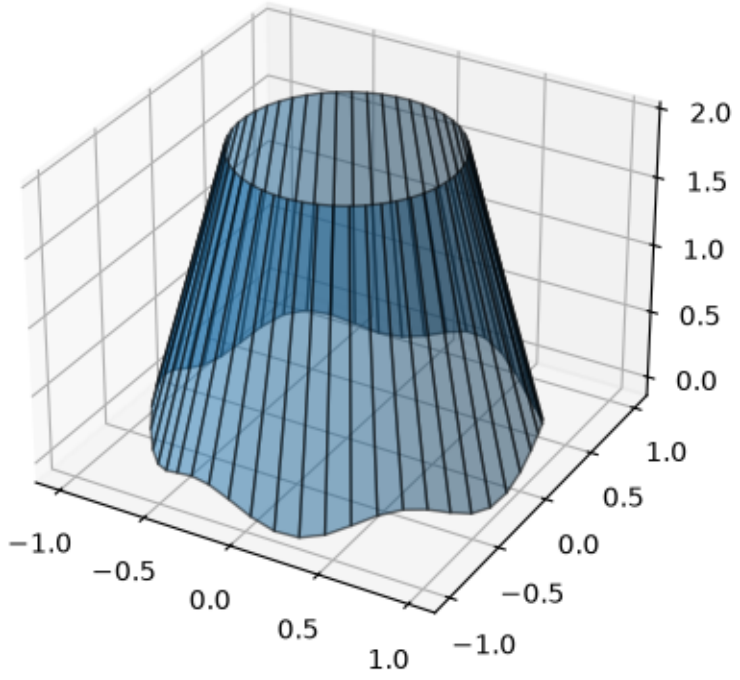
Added in version 3.10.

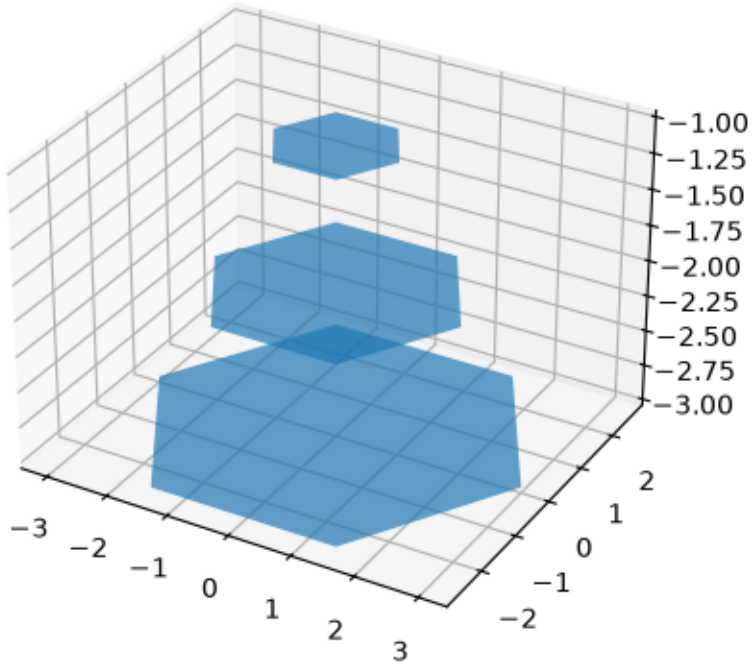
Polygon plots

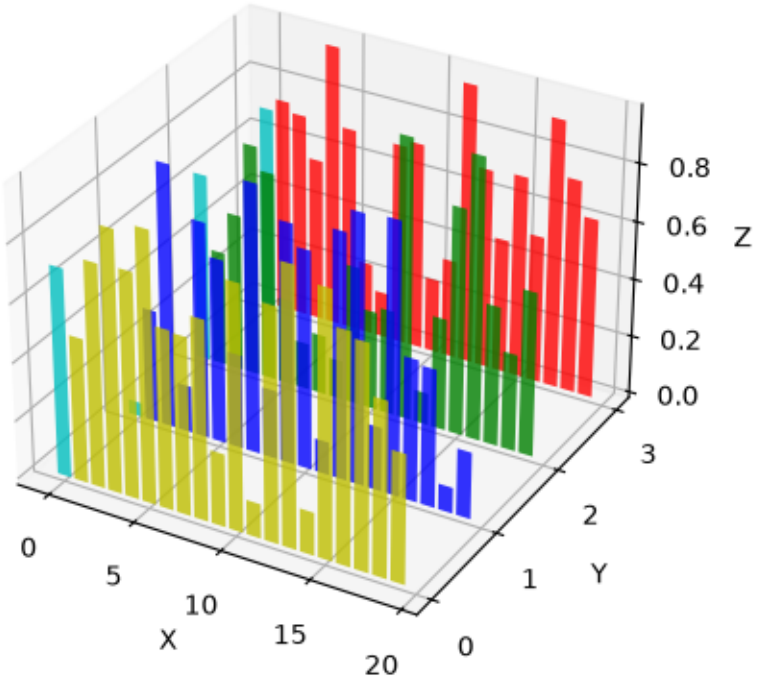
See *Axes3D.add_collection3d* for API documentation.

Bar plots

See *Axes3D.bar* for API documentation.

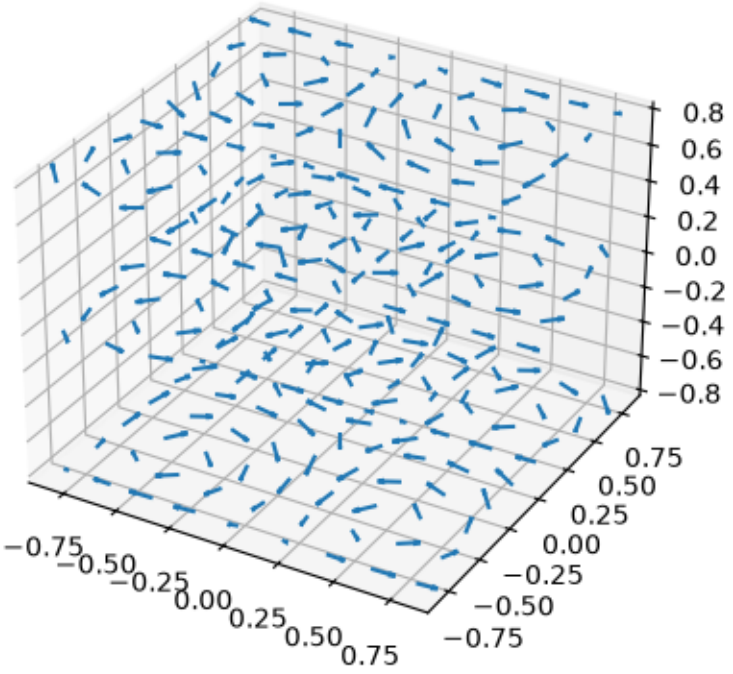

2.0
1.5
1.0
0.5
0.0
1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0


−1.00
−1.25
−1.50
−1.75
−2.00
−2.25
−2.50
−2.75
−3.00
−3
−2
−1
0
1
2
3
2
1
0
−1
−2


0.8
0.6
Z
0.4
0.2
0.0
3
2
1
Y
0
0
5
10
15
20
X

Quiver

See *Axes3D.quiver* for API documentation.



2D plots in 3D

Text

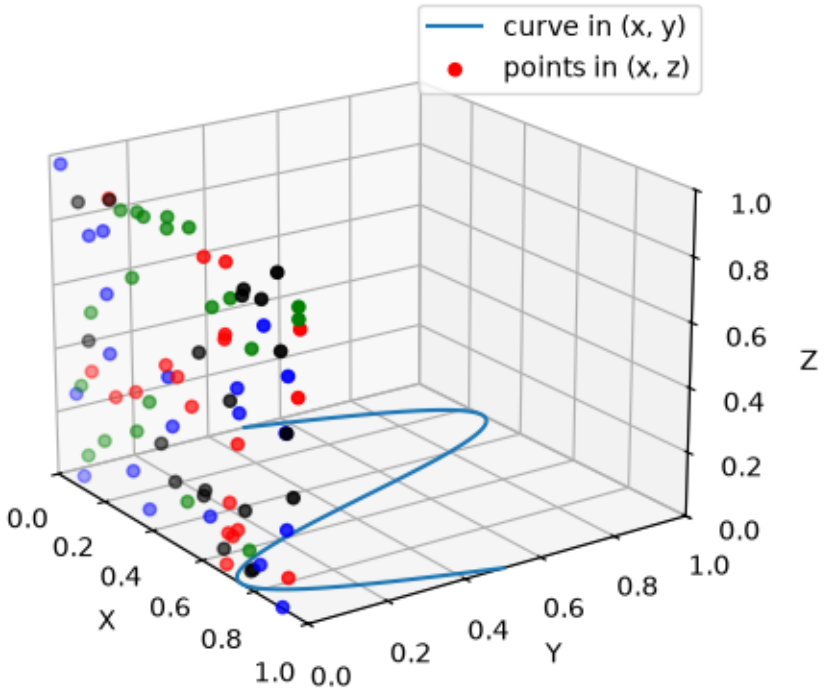
See *Axes3D.text* for API documentation.

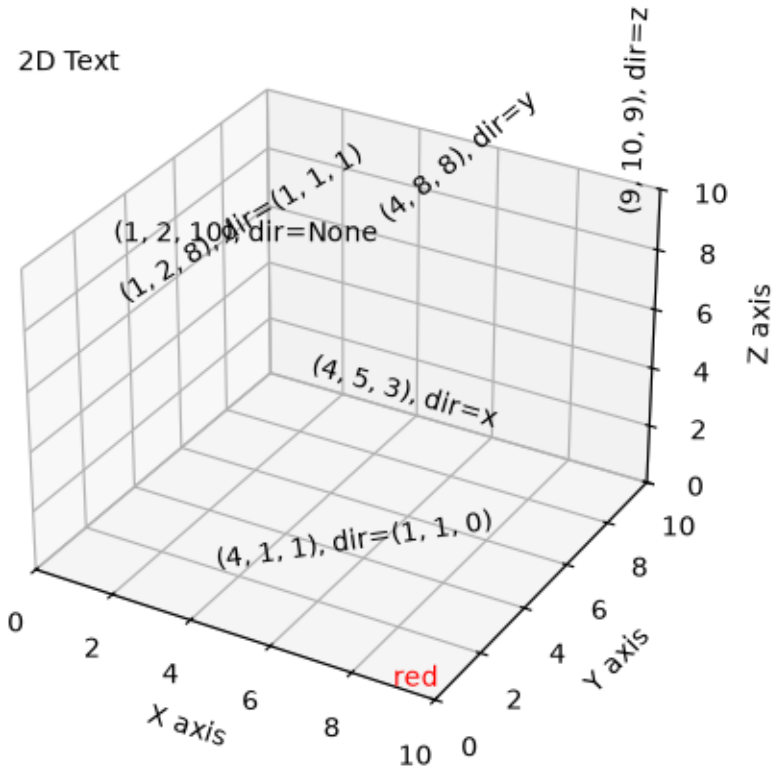
3.11 Getting started

3.11.1 Installation quick-start

pip

```
pip install matplotlib
```


curve in (x, y)
points in (x, z)
1.0
0.8
0.6
0.4
0.2
0.0
Z
0.0
0.2
0.4
0.6
0.8
1.0
X
0.0
0.2
0.4
0.6
0.8
1.0
Y


2D Text
(1, 2, 10), dir=(1, 1, 1)
(1, 2, 8), dir=None
(4, 8, 8), dir=y
(9, 10, 9), dir=z
(4, 5, 3), dir=x
(4, 1, 1), dir=(1, 1, 0)
red
X axis
Y axis
Z axis
0
2
4
6
8
10

conda

```
conda install -c conda-forge matplotlib
```

pixi

```
pixi add matplotlib
```

uv

```
uv add matplotlib
```

Warning

uv usually installs its own versions of Python from the python-build-standalone project, and only recent versions of those Python builds (August 2025) work properly with the `tkagg` backend for displaying plots in a window. Please make sure you are using uv 0.8.7 or newer (update with e.g. `uv self update`) and that your bundled Python installs are up to date (with `uv python upgrade --reinstall`). Alternatively, you can use one of the other *supported GUI frameworks*, e.g.

```
uv add matplotlib pyside6
```

other

Install an official release

Third-party distributions

Install a nightly build

Install from source

3.11.2 Draw a first plot

Here is a minimal example plot:

```
import matplotlib.pyplot as plt
import numpy as np

x = np.linspace(0, 2 * np.pi, 200)
y = np.sin(x)

fig, ax = plt.subplots()
ax.plot(x, y)
plt.show()
```

If a plot does not show up please check *Troubleshooting*.

3.11.3 Where to go next

- Check out *Plot types* to get an overview of the types of plots you can create with Matplotlib.
- Learn Matplotlib from the ground up in the *Quick-start guide*.

3.12 Glossary

This glossary defines concepts and terminology specific to Matplotlib.

Figure

The outermost container for a Matplotlib graphic. Think of this as the canvas to draw on.

This is implemented in the class `Figure`. For more details see *Introduction to Figures*.

Axes

This is a container for what is often colloquially called a plot/chart/graph. It's a data area with *Axis*es, i.e. coordinate directions, and includes data artists like lines, bars etc. as well as decorations like title, axis labels, legend.

Since most "plotting operations" are realized as methods on `Axes` this is the object users will mostly interact with.

Note: The term *Axes* was taken over from MATLAB. Think of this as a container spanned by the *x*- and *y*-axis, including decoration and data.

Axis

A direction with a scale. The scale defines the mapping from data coordinates to screen coordinates. The Axis also includes the ticks and axis label.

Artist

The base class for all graphical element that can be drawn. Examples are Lines, Rectangles, Text, Ticks, Legend, Axes, ...

CHAPTER

FOUR

TUTORIALS

This page contains a few tutorials for using Matplotlib. For the old tutorials, see *below*.

For shorter examples, see our *examples page*. You can also find *external resources* and a *FAQ* in our *user guide*.

4.1 Pyplot tutorial

An introduction to the pyplot interface. Please also see *Quick start guide* for an overview of how Matplotlib works and *Matplotlib Application Interfaces (APIs)* for an explanation of the trade-offs between the supported user APIs.

4.1.1 Introduction to pyplot

matplotlib.pyplot is a collection of functions that make matplotlib work like MATLAB. Each `pyplot` function makes some change to a figure: e.g., creates a figure, creates a plotting area in a figure, plots some lines in a plotting area, decorates the plot with labels, etc.

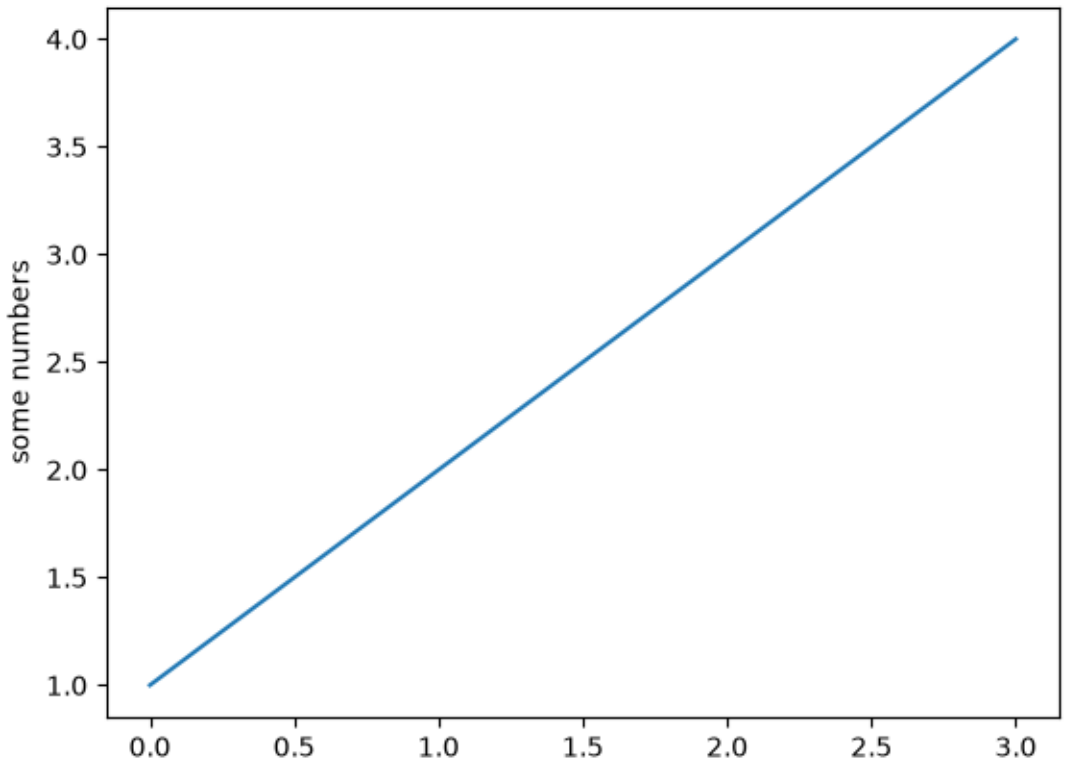
In *matplotlib.pyplot* various states are preserved across function calls, so that it keeps track of things like the current figure and plotting area, and the plotting functions are directed to the current Axes (please note that we use uppercase Axes to refer to the *Axes* concept, which is a central *part of a figure* and not only the plural of *axis*).

Note

The implicit pyplot API is generally less verbose but also not as flexible as the explicit API. Most of the function calls you see here can also be called as methods from an `Axes` object. We recommend browsing the tutorials and examples to see how this works. See *Matplotlib Application Interfaces (APIs)* for an explanation of the trade-off of the supported user APIs.

Generating visualizations with pyplot is very quick:

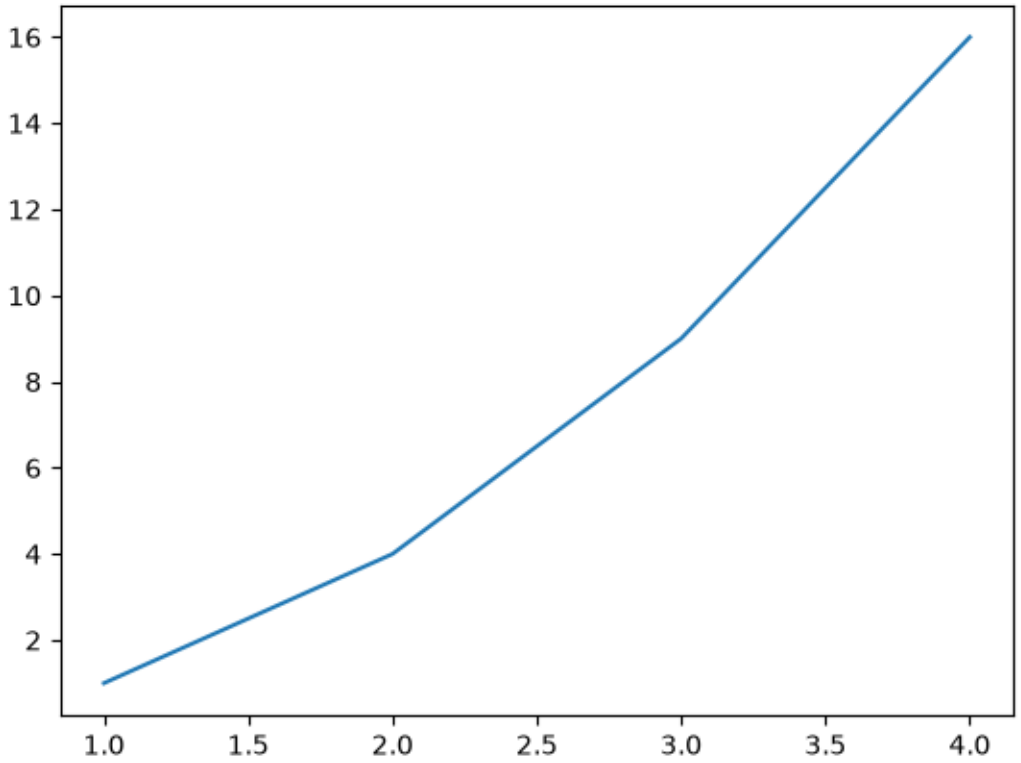
```
import matplotlib.pyplot as plt

plt.plot([1, 2, 3, 4])
plt.ylabel('some numbers')
plt.show()
```



You may be wondering why the x-axis ranges from 0-3 and the y-axis from 1-4. If you provide a single list or array to *plot*, matplotlib assumes it is a sequence of y values, and automatically generates the x values for you. Since python ranges start with 0, the default x vector has the same length as y but starts with 0; therefore, the x data are `[0, 1, 2, 3]`.

plot is a versatile function, and will take an arbitrary number of arguments. For example, to plot x versus y, you can write:

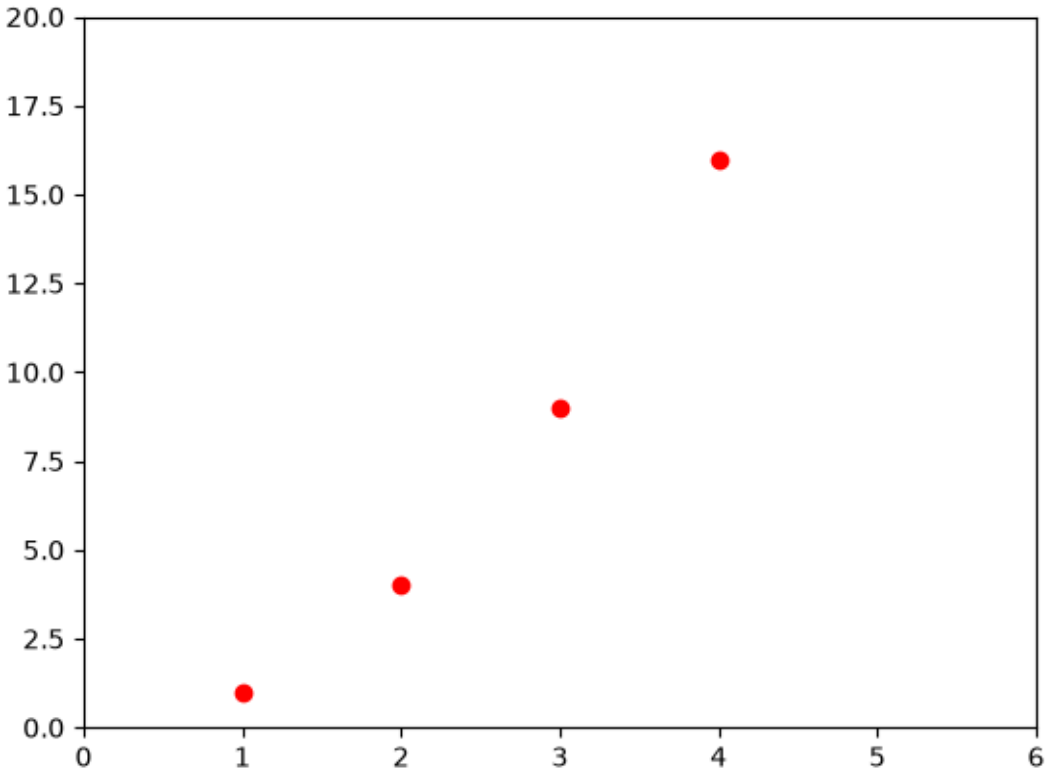
```
plt.plot([1, 2, 3, 4], [1, 4, 9, 16])
```



Formatting the style of your plot

For every x, y pair of arguments, there is an optional third argument which is the format string that indicates the color and line type of the plot. The letters and symbols of the format string are from MATLAB, and you concatenate a color string with a line style string. The default format string is 'b-', which is a solid blue line. For example, to plot the above with red circles, you would issue

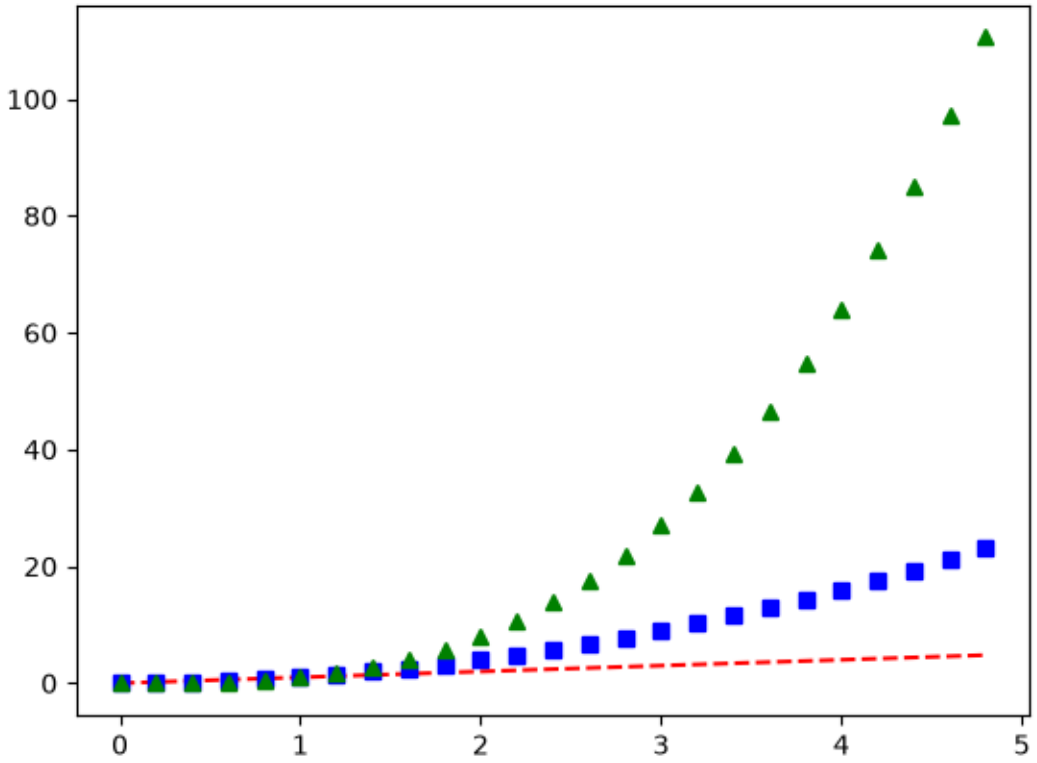
```
plt.plot([1, 2, 3, 4], [1, 4, 9, 16], 'ro')
plt.axis((0, 6, 0, 20))
plt.show()
```



See the *plot* documentation for a complete list of line styles and format strings. The *axis* function in the example above takes a list of `[xmin, xmax, ymin, ymax]` and specifies the viewport of the Axes.

If matplotlib were limited to working with lists, it would be fairly useless for numeric processing. Generally, you will use numpy arrays. In fact, all sequences are converted to numpy arrays internally. The example below illustrates plotting several lines with different format styles in one function call using arrays.

```
import numpy as np

# evenly sampled time at 200ms intervals
t = np.arange(0., 5., 0.2)

# red dashes, blue squares and green triangles
plt.plot(t, t, 'r--', t, t**2, 'bs', t, t**3, 'g^')
plt.show()
```

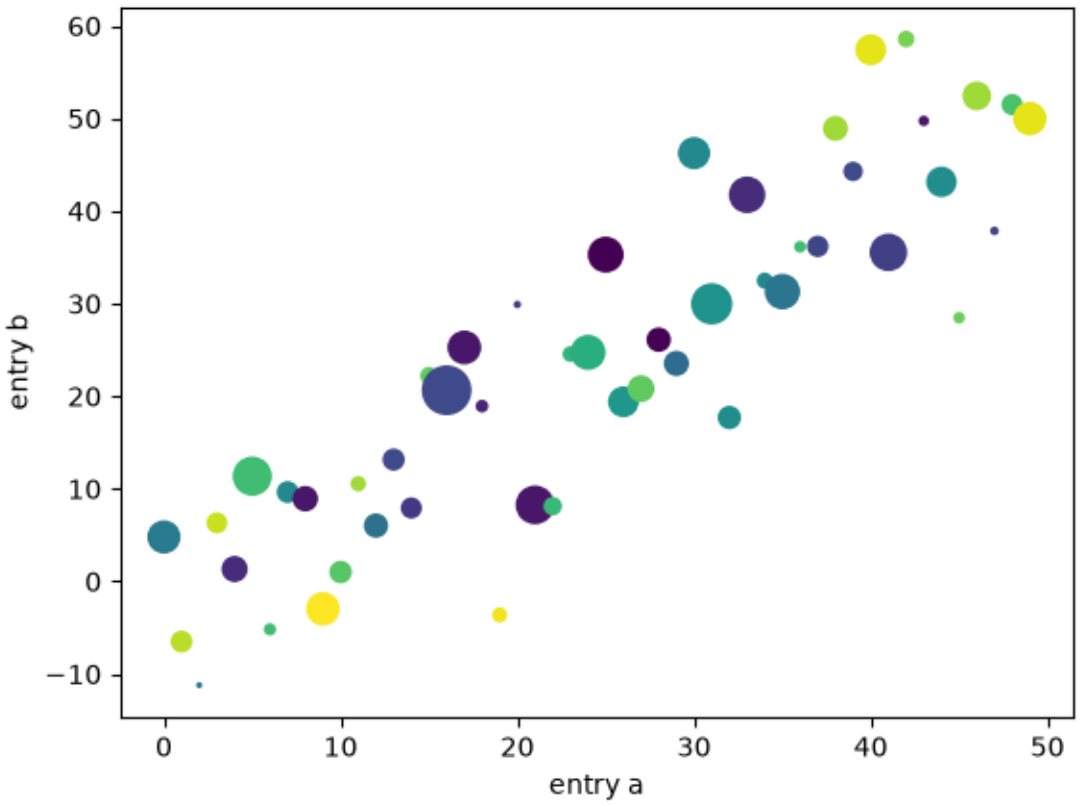


4.1.2 Plotting with keyword strings

There are some instances where you have data in a format that lets you access particular variables with strings. For example, with structured arrays or `pandas.DataFrame`.

Matplotlib allows you to provide such an object with the `data` keyword argument. If provided, then you may generate plots with the strings corresponding to these variables.

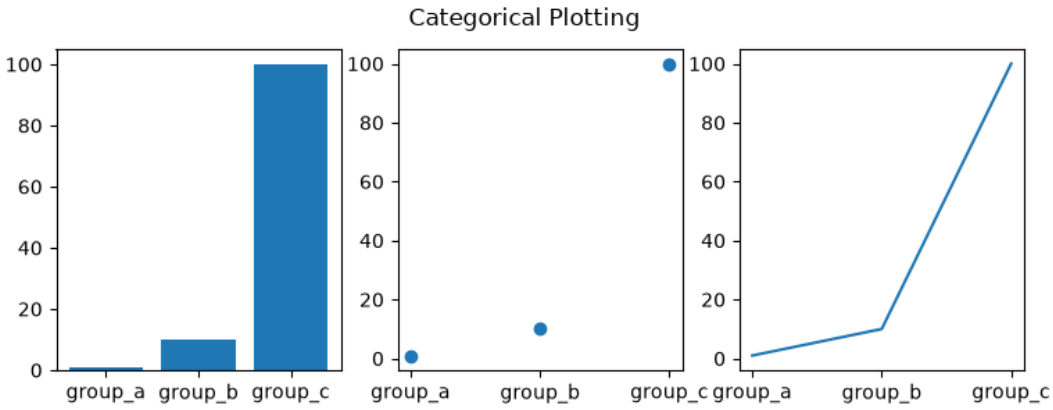
```
data = {'a': np.arange(50),
        'c': np.random.randint(0, 50, 50),
        'd': np.random.randn(50)}
data['b'] = data['a'] + 10 * np.random.randn(50)
data['d'] = np.abs(data['d']) * 100

plt.scatter('a', 'b', c='c', s='d', data=data)
plt.xlabel('entry a')
plt.ylabel('entry b')
plt.show()
```



4.1.3 Plotting with categorical variables

It is also possible to create a plot using categorical variables. Matplotlib allows you to pass categorical variables directly to many plotting functions. For example:

```
names = ['group_a', 'group_b', 'group_c']
values = [1, 10, 100]

plt.figure(figsize=(9, 3))

plt.subplot(131)
plt.bar(names, values)
plt.subplot(132)
plt.scatter(names, values)
plt.subplot(133)
plt.plot(names, values)
plt.suptitle('Categorical Plotting')
plt.show()
```



4.1.4 Controlling line properties

Lines have many attributes that you can set: linewidth, dash style, antialiased, etc; see *matplotlib.lines.Line2D*. There are several ways to set line properties

- Use keyword arguments:

```
plt.plot(x, y, linewidth=2.0)
```

- Use the setter methods of a `Line2D` instance. `plot` returns a list of `Line2D` objects; e.g., `line1, line2 = plot(x1, y1, x2, y2)`. In the code below we will suppose that we have only one line so that the list returned is of length 1. We use tuple unpacking with `line,` to get the first element of that list:

```
line, = plt.plot(x, y, '-')
line.set_antialiased(False) # turn off antialiasing
```

- Use *setp*. The example below uses a MATLAB-style function to set multiple properties on a list of lines. `setp` works transparently with a list of objects or a single object. You can either use python keyword arguments or MATLAB-style string/value pairs:

```
lines = plt.plot(x1, y1, x2, y2)
# use keyword arguments
plt.setp(lines, color='r', linewidth=2.0)
# or MATLAB style string value pairs
plt.setp(lines, 'color', 'r', 'linewidth', 2.0)
```

Here are the available *Line2D* properties.

Property	Value Type
alpha	float
animated	[True | False]
antialiased or aa	[True | False]
clip_box	a matplotlib.transform.Bbox instance

continues on next page

Table 1 – continued from previous page

Property	Value Type
clip_on	[True | False]
clip_path	a Path instance and a Transform instance, a Patch
color or c	any matplotlib color
contains	the hit testing function
dash_capstyle	['butt' | 'round' | 'projecting']
dash_joinstyle	['miter' | 'round' | 'bevel']
dashes	sequence of on/off ink in points
data	(np.array xdata, np.array ydata)
figure	a matplotlib.figure.Figure instance
label	any string
linestyle or ls	['-' | '--' | '-.' | ':' | 'steps' | ...]
linewidth or lw	float value in points
marker	['+' | ',' | '.' | '1' | '2' | '3' | '4']
markeredgecolor or mec	any matplotlib color
markeredgewidth or mew	float value in points
markerfacecolor or mfc	any matplotlib color
markersize or ms	float
markevery	[None | integer | (startind, stride)]
picker	used in interactive line selection
pickradius	the line pick selection radius
solid_capstyle	['butt' | 'round' | 'projecting']
solid_joinstyle	['miter' | 'round' | 'bevel']
transform	a matplotlib.transforms.Transform instance
visible	[True | False]
xdata	np.array
ydata	np.array
zorder	any number

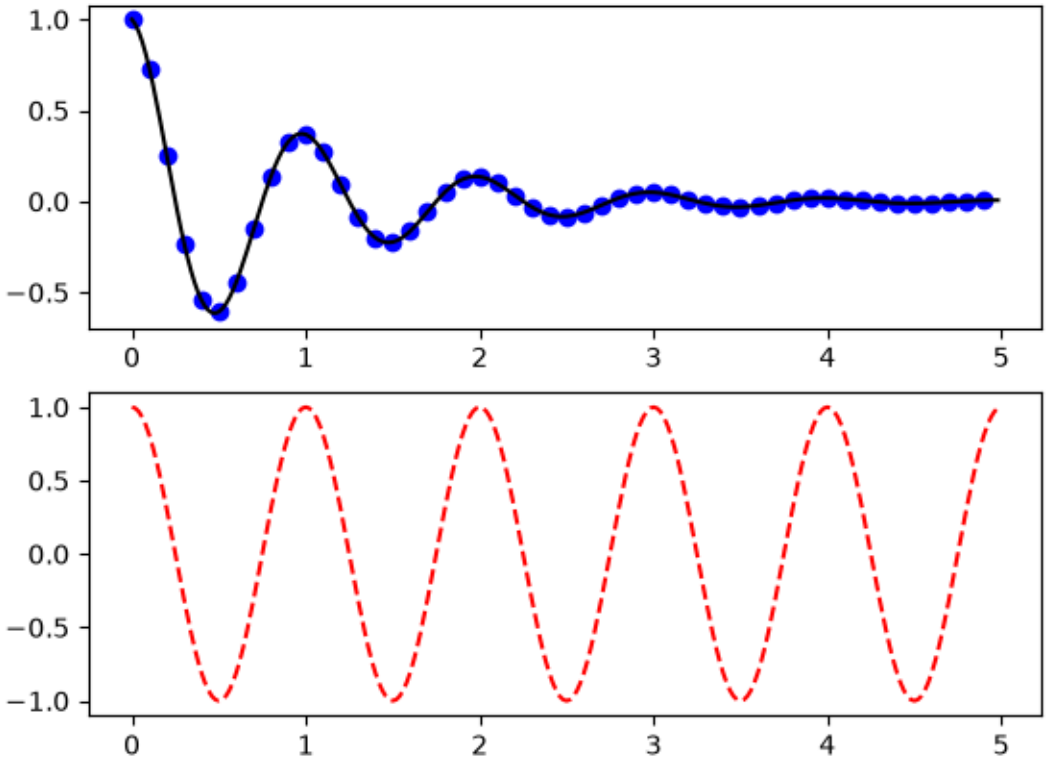
To get a list of settable line properties, call the *setp* function with a line or lines as argument

```
In [69]: lines = plt.plot([1, 2, 3])

In [70]: plt.setp(lines)
  alpha: float
  animated: [True | False]
  antialiased or aa: [True | False]
  ...snip
```

4.1.5 Working with multiple figures and Axes

MATLAB, and *pyplot*, have the concept of the current figure and the current Axes. All plotting functions apply to the current Axes. The function *gca* returns the current Axes (a *matplotlib.axes.Axes* instance), and *gcf* returns the current figure (a *matplotlib.figure.Figure* instance). Normally, you don't have to worry about this, because it is all taken care of behind the scenes. Below is a script to create two subplots.

```
def f(t):
    return np.exp(-t) * np.cos(2*np.pi*t)

t1 = np.arange(0.0, 5.0, 0.1)
t2 = np.arange(0.0, 5.0, 0.02)

plt.figure()
plt.subplot(211)
plt.plot(t1, f(t1), 'bo', t2, f(t2), 'k')

plt.subplot(212)
plt.plot(t2, np.cos(2*np.pi*t2), 'r--')
plt.show()
```



The *figure* call here is optional because a figure will be created if none exists, just as an Axes will be created (equivalent to an explicit `subplot()` call) if none exists. The *subplot* call specifies `numrows, numcols, plot_number` where `plot_number` ranges from 1 to `numrows*numcols`. The commas in the `subplot` call are optional if `numrows*numcols<10`. So `subplot(211)` is identical to `subplot(2, 1, 1)`.

You can create an arbitrary number of subplots and Axes. If you want to place an Axes manually, i.e., not

on a rectangular grid, use *axes*, which allows you to specify the location as `axes([left, bottom, width, height])` where all values are in fractional (0 to 1) coordinates. See *Axes Demo* for an example of placing Axes manually and *Multiple subplots* for an example with lots of subplots.

You can create multiple figures by using multiple *figure* calls with an increasing figure number. Of course, each figure can contain as many Axes and subplots as your heart desires:

```
import matplotlib.pyplot as plt
plt.figure(1)                # the first figure
plt.subplot(211)             # the first subplot in the first figure
plt.plot([1, 2, 3])
plt.subplot(212)             # the second subplot in the first figure
plt.plot([4, 5, 6])


plt.figure(2)                # a second figure
plt.plot([4, 5, 6])          # creates a subplot() by default

plt.figure(1)                # first figure current;
                             # subplot(212) still current
plt.subplot(211)             # make subplot(211) in the first figure
                             # current
plt.title('Easy as 1, 2, 3') # subplot 211 title
```

You can clear the current figure with *clf* and the current Axes with *cla*. If you find it annoying that states (specifically the current image, figure and Axes) are being maintained for you behind the scenes, don't despair: this is just a thin stateful wrapper around an object-oriented API, which you can use instead (see *Artist tutorial*)

If you are making lots of figures, you need to be aware of one more thing: the memory required for a figure is not completely released until the figure is explicitly closed with *close*. Deleting all references to the figure, and/or using the window manager to kill the window in which the figure appears on the screen, is not enough, because pyplot maintains internal references until *close* is called.

4.1.6 Working with text

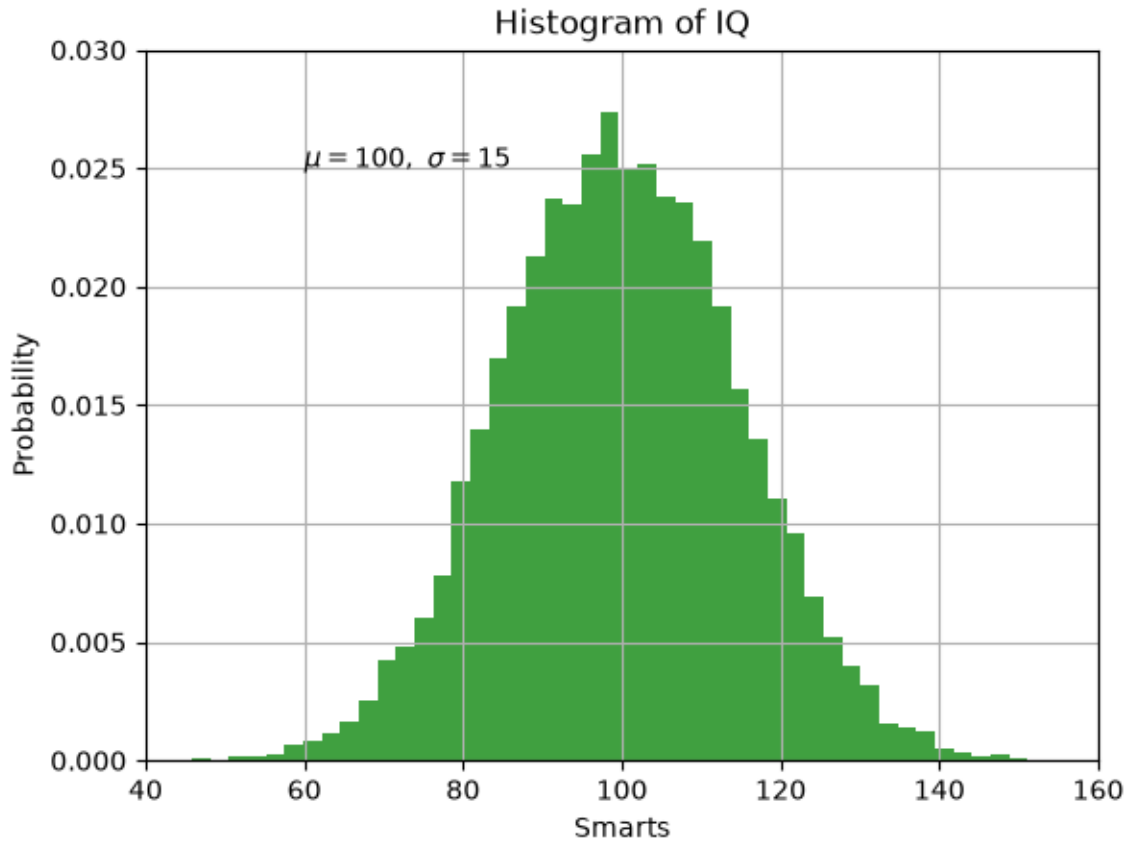
text can be used to add text in an arbitrary location, and *xlabel*, *ylabel* and *title* are used to add text in the indicated locations (see *Text in Matplotlib* for a more detailed example)

```
mu, sigma = 100, 15
x = mu + sigma * np.random.randn(10000)

# the histogram of the data
n, bins, patches = plt.hist(x, 50, density=True, facecolor='g',␣
 ↪alpha=0.75)


plt.xlabel('Smarts')
plt.ylabel('Probability')
```

(continues on next page)

(continued from previous page)

```
plt.title('Histogram of IQ')
plt.text(60, .025, r'$\mu=100,\ \sigma=15$')
plt.axis([40, 160, 0, 0.03])
plt.grid(True)
plt.show()
```



All of the *text* functions return a *matplotlib.text.Text* instance. Just as with lines above, you can customize the properties by passing keyword arguments into the text functions or using *setp*:

```
t = plt.xlabel('my data', fontsize=14, color='red')
```

These properties are covered in more detail in *Text properties and layout*.

Using mathematical expressions in text

Matplotlib accepts TeX equation expressions in any text expression. For example to write the expression $\sigma_i = 15$ in the title, you can write a TeX expression surrounded by dollar signs:

```
plt.title(r'$\sigma_i=15$')
```

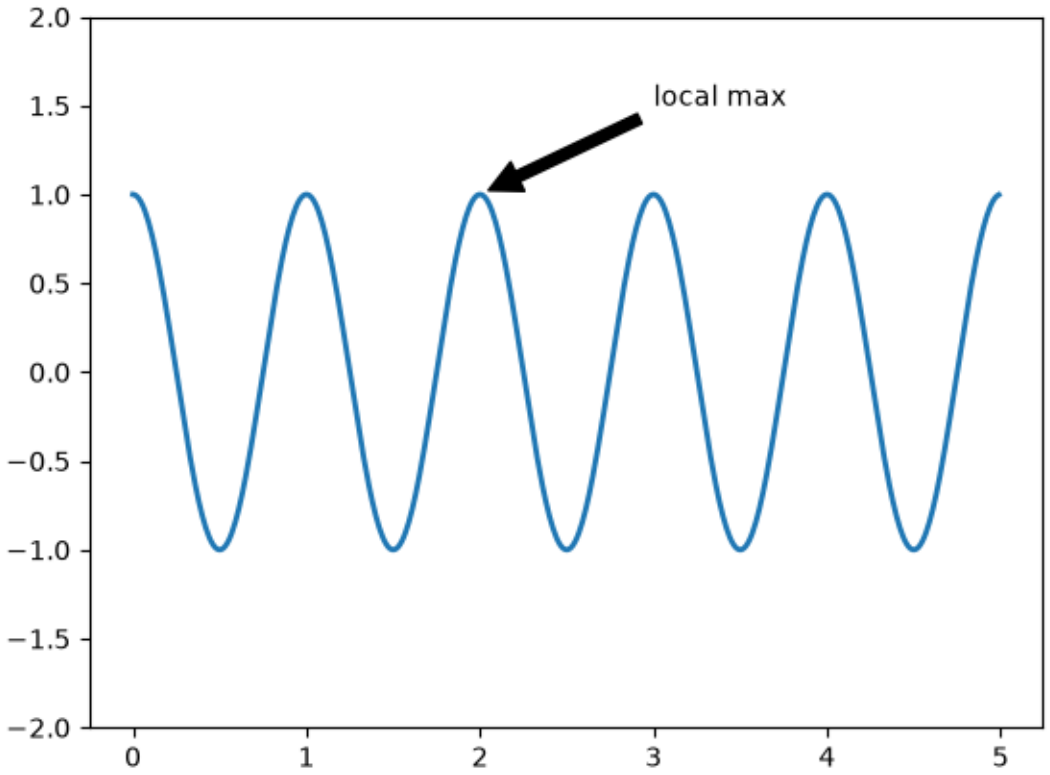
The `r` preceding the title string is important -- it signifies that the string is a *raw* string and not to treat

backslashes as python escapes. matplotlib has a built-in TeX expression parser and layout engine, and ships its own math fonts -- for details see *Writing mathematical expressions*. Thus, you can use mathematical text across platforms without requiring a TeX installation. For those who have LaTeX and dvipng installed, you can also use LaTeX to format your text and incorporate the output directly into your display figures or saved postscript -- see *Text rendering with LaTeX*.

Annotating text

The uses of the basic *text* function above place text at an arbitrary position on the Axes. A common use for text is to annotate some feature of the plot, and the *annotate* method provides helper functionality to make annotations easy. In an annotation, there are two points to consider: the location being annotated represented by the argument `xy` and the location of the text `xytext`. Both of these arguments are `(x, y)` tuples.

```
ax = plt.subplot()

t = np.arange(0.0, 5.0, 0.01)
s = np.cos(2*np.pi*t)
line, = plt.plot(t, s, lw=2)

plt.annotate('local max', xy=(2, 1), xytext=(3, 1.5),
             arrowprops=dict(facecolor='black', shrink=0.05),
             )

plt.ylim(-2, 2)
plt.show()
```



In this basic example, both the `xy` (arrow tip) and `xytext` locations (text location) are in data coordinates. There are a variety of other coordinate systems one can choose -- see *Basic annotation* and *Advanced annotation* for details. More examples can be found in *Annotate plots*.

4.1.7 Logarithmic and other nonlinear axes

`matplotlib.pyplot` supports not only linear axis scales, but also logarithmic and logit scales. This is commonly used if data spans many orders of magnitude. Changing the scale of an axis is easy:

```
plt.xscale('log')
```

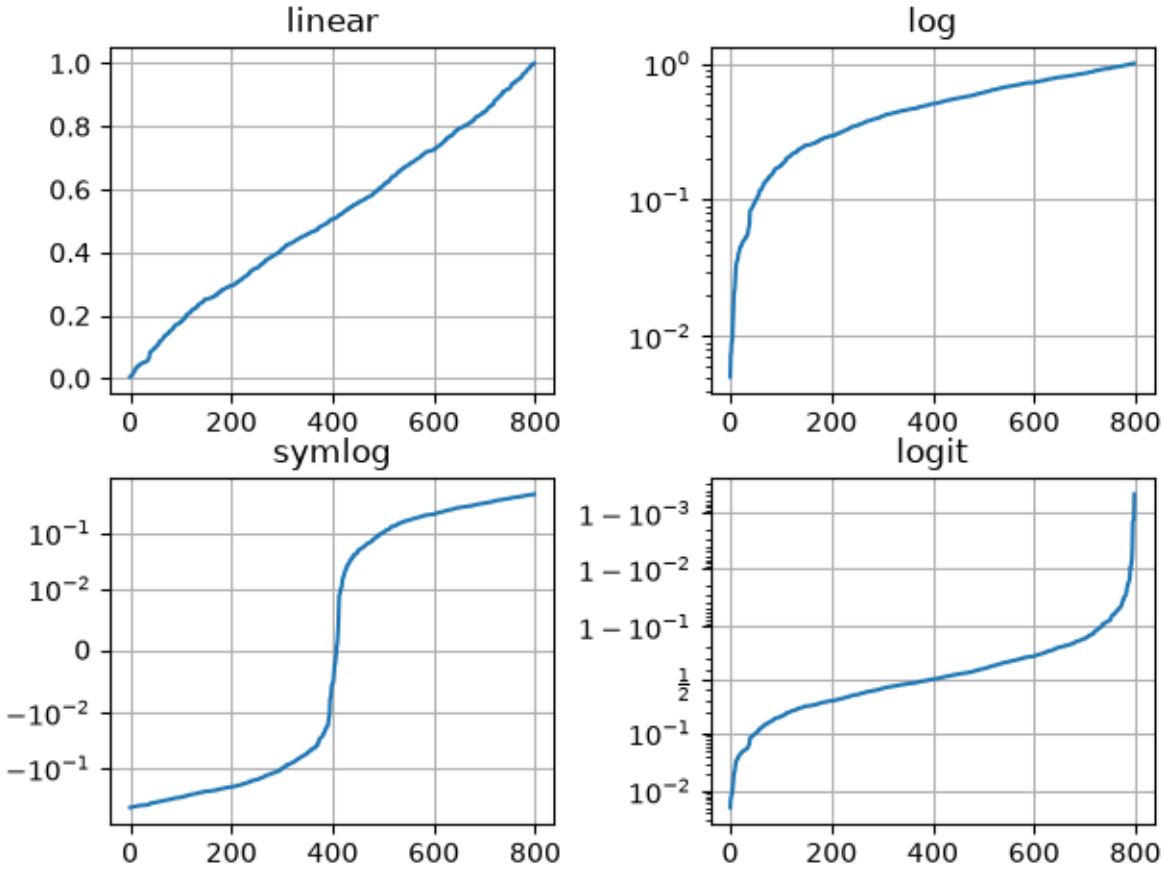
An example of four plots with the same data and different scales for the y-axis is shown below.

```
# Fixing random state for reproducibility
np.random.seed(19680801)

# make up some data in the open interval (0, 1)
y = np.random.normal(loc=0.5, scale=0.4, size=1000)
y = y[(y > 0) & (y < 1)]
y.sort()
x = np.arange(len(y))
```

(continues on next page)

(continued from previous page)

```
# plot with various axes scales
plt.figure()

# linear
plt.subplot(221)
plt.plot(x, y)
plt.yscale('linear')
plt.title('linear')
plt.grid(True)

# log
plt.subplot(222)
plt.plot(x, y)
plt.yscale('log')
plt.title('log')
plt.grid(True)

# symmetric log
plt.subplot(223)
plt.plot(x, y - y.mean())
plt.yscale('symlog', linthresh=0.01)
plt.title('symlog')
plt.grid(True)

# logit
plt.subplot(224)
plt.plot(x, y)
plt.yscale('logit')
plt.title('logit')
plt.grid(True)
# Adjust the subplot layout, because the logit one may take more space
# than usual, due to y-tick labels like "1 - 10^{-3}"
plt.subplots_adjust(top=0.92, bottom=0.08, left=0.10, right=0.95,␣
 ↪hspace=0.25,
                    wspace=0.35)

plt.show()
```



It is also possible to add your own scale, see `matplotlib.scale` for details.

Total running time of the script: (0 minutes 3.045 seconds)

4.2 Coding shortcuts

Matplotlib's primary and universal API is the *Axes interface*. While it is clearly structured and powerful, it can sometimes feel overly verbose and thus cumbersome to write. This page collects patterns for condensing the code of the Axes-based API and achieving the same results with less typing for many simpler plots.

Note

The *pyplot interface* is an alternative more compact interface, and was historically modeled to be similar to MATLAB. It remains a valid approach for those who want to use it. However, it has the disadvantage that it achieves its brevity through implicit assumptions that you have to understand.

Since it follows a different paradigm, switching between the Axes interface and the pyplot interface requires a shift of the mental model, and some code rewrite, if the code develops to a point at which pyplot no longer provides enough flexibility.

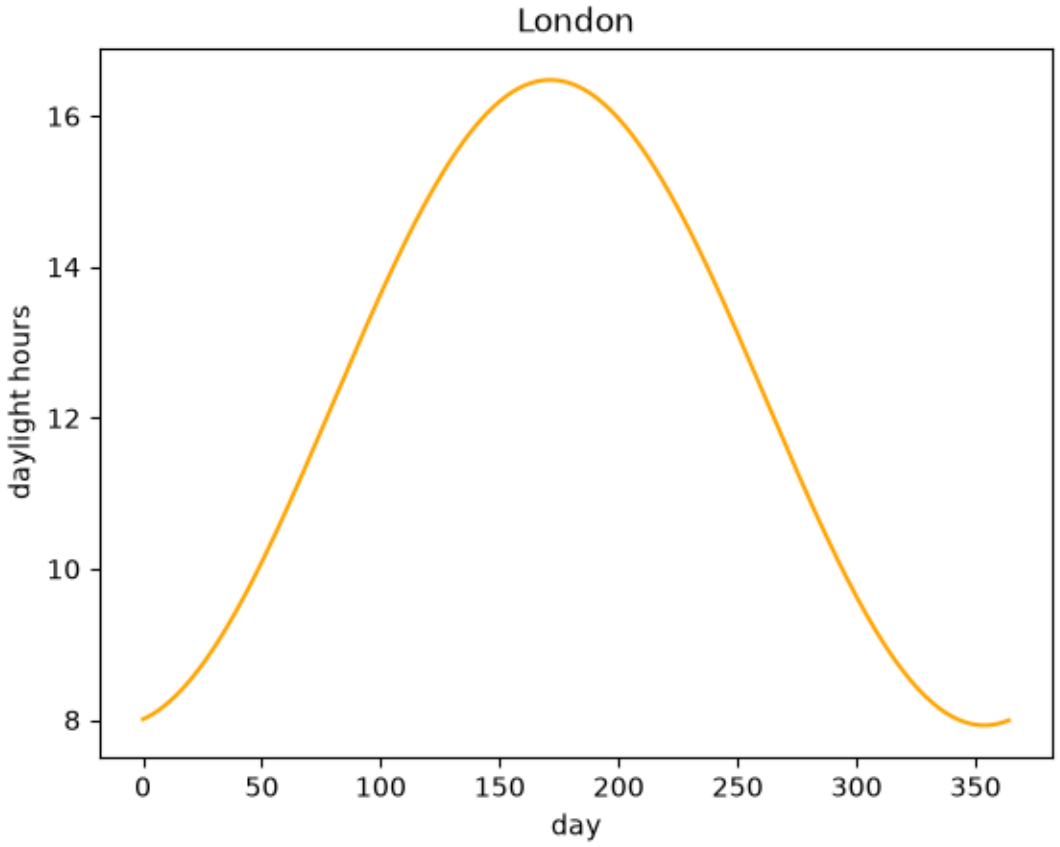
This tutorial goes the other way round, starting from the standard verbose Axes interface and using its capa-

bilities for shortcuts when you don't need all the generality.

Let's assume we want to make a plot of the number of daylight hours per day over the year in London.

The standard approach with the Axes interface looks like this.

```
import matplotlib.pyplot as plt
import numpy as np

day = np.arange(365)
hours = 4.276 * np.sin(2 * np.pi * (day - 80)/365) + 12.203

fig, ax = plt.subplots()
ax.plot(day, hours, color="orange")
ax.set_xlabel("day")
ax.set_ylabel("daylight hours")
ax.set_title("London")
plt.show()
```



Note that we've included `plt.show()` here. This is needed to show the plot window when running from a command line or in a Python script. If you run a Jupyter notebook, this command is automatically executed at the end of each cell.

For the rest of the tutorial, we'll assume that we are in a notebook and leave this out for brevity. Depending on your context you may still need it.

If you instead want to save to a file, use `fig.savefig("daylight.png")`.

4.2.1 Collect Axes properties into a single `set()` call

The properties of Matplotlib Artists can be modified through their respective `set_*()` methods. Artists additionally have a generic `set()` method, that takes keyword arguments and is equivalent to calling all the respective `set_*()` methods.

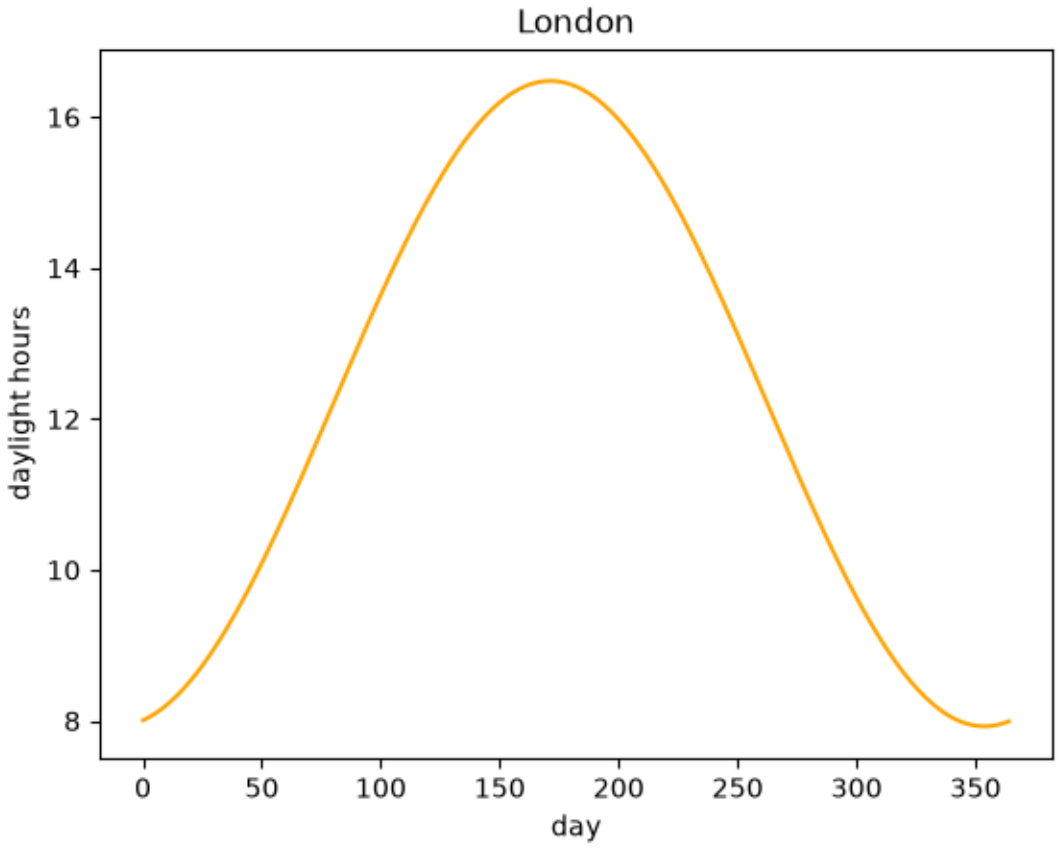
```
ax.set_xlabel("day")
ax.set_ylabel("daylight hours")
```

can also be written as

```
ax.set(xlabel="day", ylabel="daylight hours")
```

This is the most simple and effective reduction you can do. With that we can shorten the above plot to

```
fig, ax = plt.subplots()
ax.plot(day, hours, color="orange")
ax.set(xlabel="day", ylabel="daylight hours", title="London")
```



This works as long as you only need to pass one parameter to the `set_*()` function. The individual functions are still necessary if you want more control, e.g. `set_title("London", fontsize=16)`.

4.2.2 Not storing a reference to the figure

Another nuisance of `fig, ax = plt.subplots()` is that you always create a `fig` variable, even if you don't use it. A slightly shorter version would be using the standard variable for unused value in Python (_): `_, ax = plt.subplots()`. However, that's only marginally better.

You can work around this by separating figure and Axes creation and chaining them

```
ax = plt.figure().add_subplot()
```

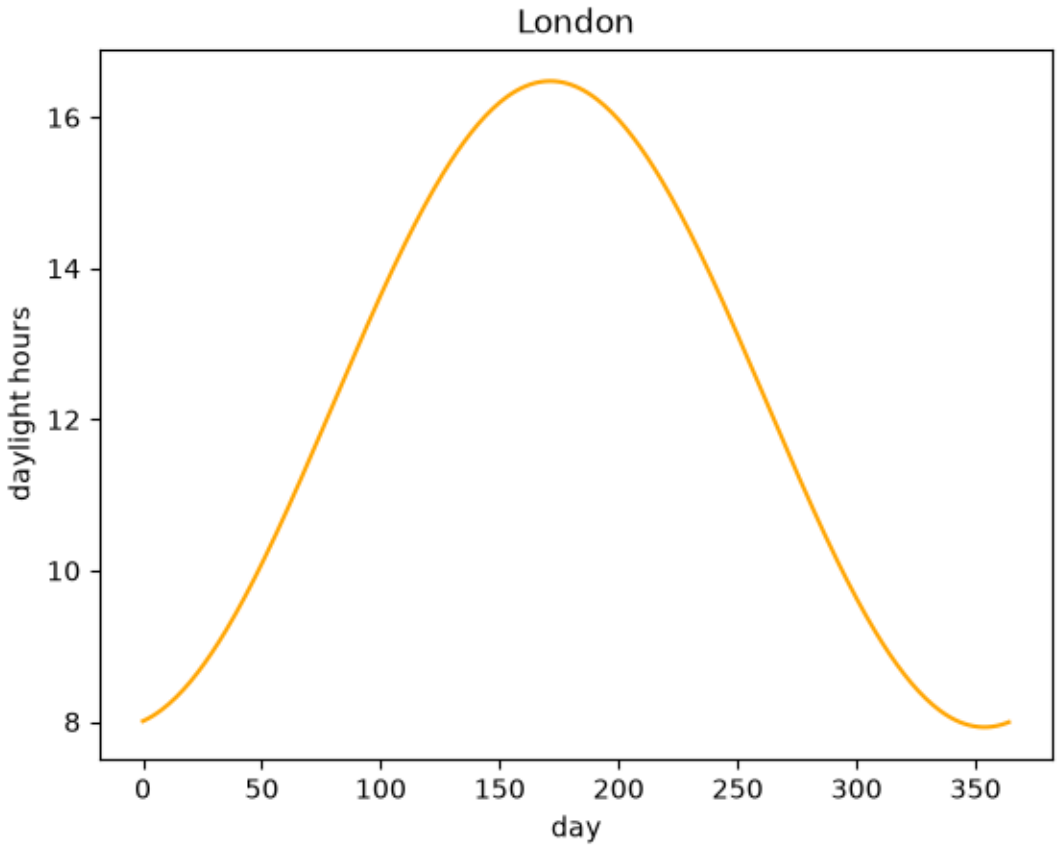
This is a bit cleaner logically and has the slight advantage that you could set figure properties inline as well; e.g. `plt.figure(facecolor="lightgoldenrod")`. But it has the disadvantage that it's longer than `fig, ax = plt.subplots()`.

You can still obtain the figure from the Axes if needed, e.g.

```
ax.figure.savefig("daylight_hours.png")
```

The example code now looks like this:

```
ax = plt.figure().add_subplot()
ax.plot(day, hours, color="orange")
ax.set(xlabel="day", ylabel="daylight hours", title="London")
```



4.2.3 Define Axes properties during axes creation

The `set_*` methods as well as `set` modify existing objects. You can alternatively define them right at creation. Since you typically don't instantiate classes yourself in Matplotlib, but rather call some factory function that creates the object and wires it up correctly with the plot, this may seem less obvious. But in fact you just pass the desired properties to the factory functions. You are likely doing this already in some places without realizing. Consider the function to create a line

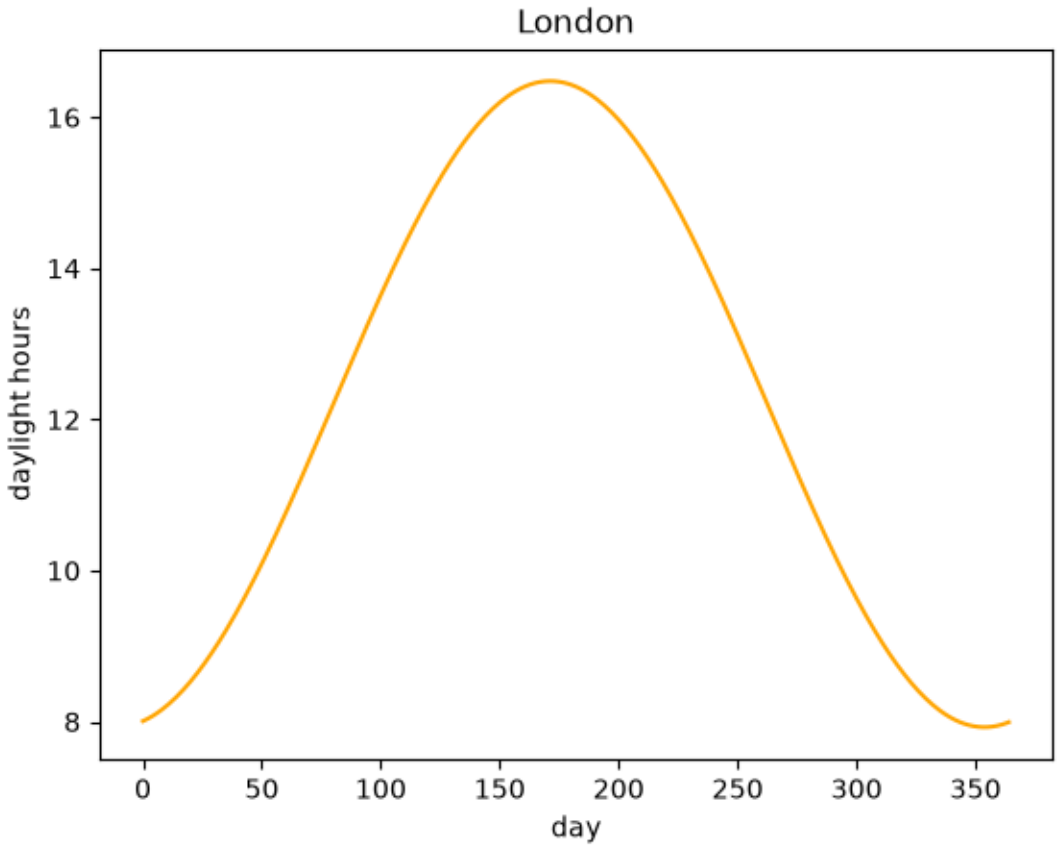
```
ax.plot(x, y, color="orange")
```

This is equivalent to

```
line, = ax.plot(x, y)
line.set_color("orange")
```

The same can be done with functions that create Axes.

```
ax = plt.figure().add_subplot(xlabel="day", ylabel="daylight hours",␣
↪title="London")
ax.plot(day, hours, color="orange")
```



Important

The Axes properties are only accepted as keyword arguments by *`Figure.add_subplot`*, which creates a single Axes.

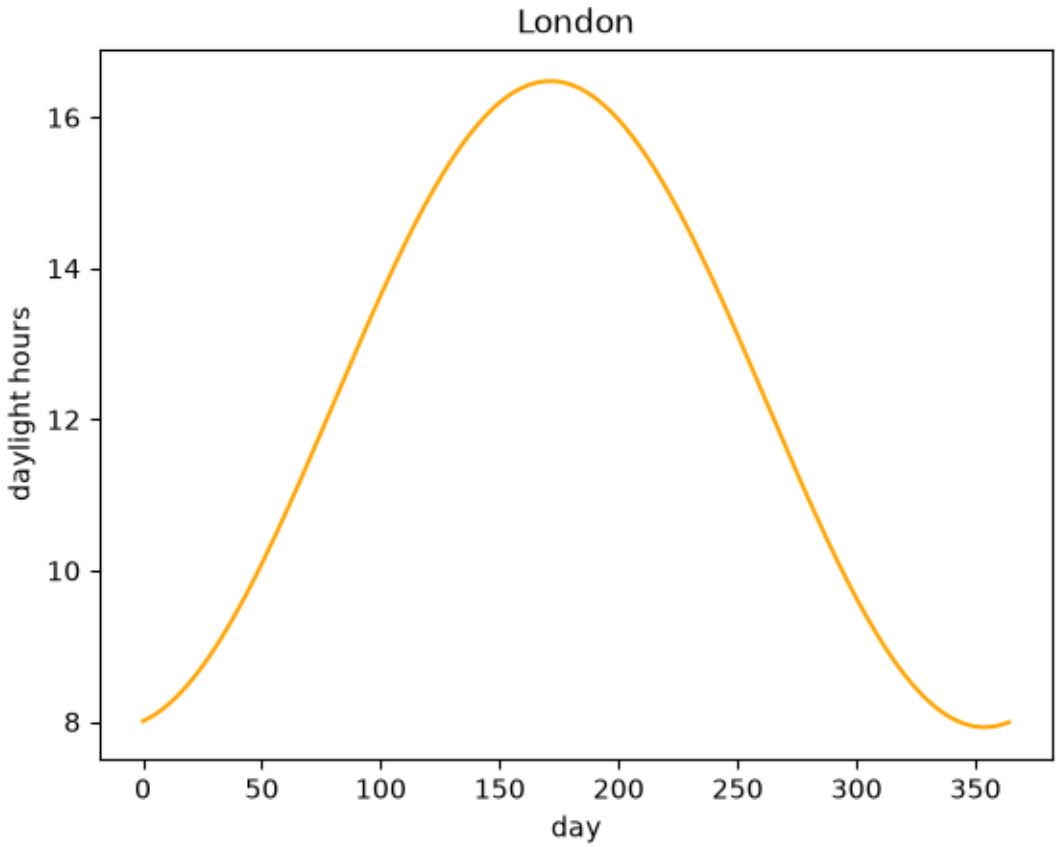
For *`Figure.subplots`* and *`pyplot.subplots`*, you'd have to pass the properties as a dict via the keyword argument `subplot_kw`. The limitation here is that such parameters are given to all Axes. For example, if you need two subplots (`fig, (ax1, ax2) = plt.subplots(1, 2)`) with different labels, you have to set them individually.

Defining Axes properties during creation is best used for single subplots or when all subplots share the same properties.

4.2.4 Using implicit figure creation

You can go even further by tapping into the pyplot logic and use *`pyplot.axes`* to create the axes:

```
ax = plt.axes(xlabel="day", ylabel="daylight hours", title="London")
ax.plot(day, hours, color="orange")
```



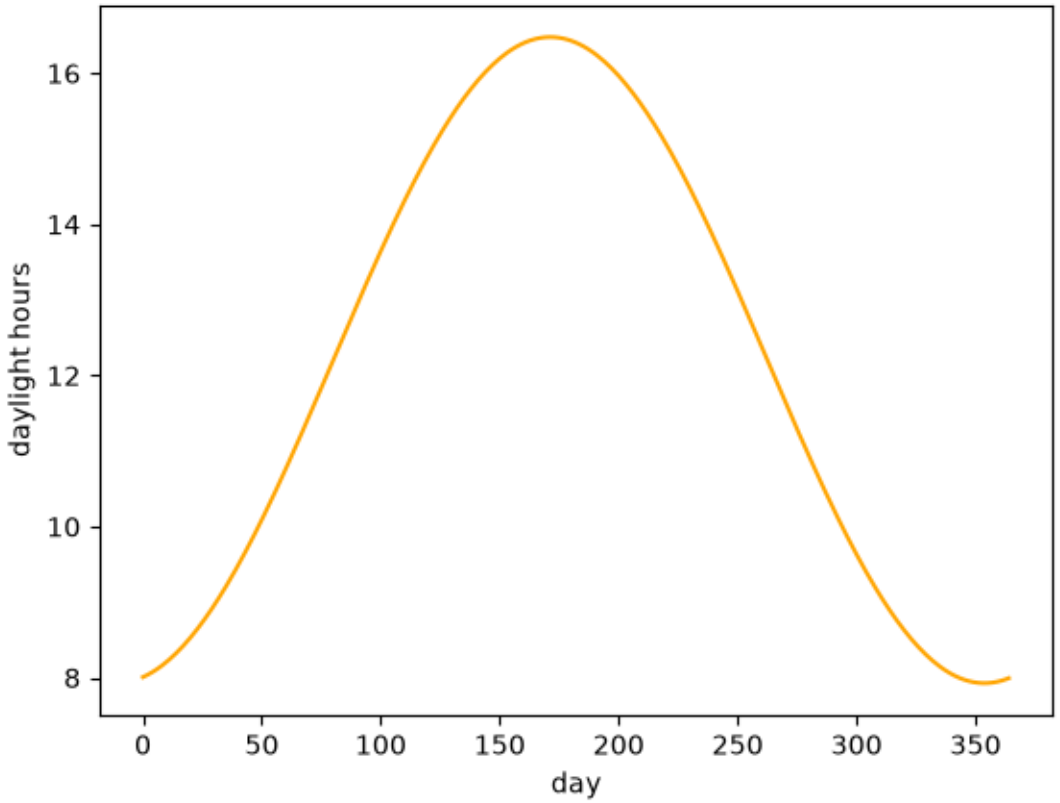
Warning

When using this, you have to be aware of the implicit figure semantics of pyplot. `plt.axes()` will only create a new figure if no figure exists. Otherwise, it will add the Axes to the current existing figure, which is likely not what you want.

4.2.5 Not storing a reference to the Axes

If you only need to visualize one dataset, you can append the plot command directly to the Axes creation. This may be useful e.g. in notebooks, where you want to create a plot with some configuration, but as little distracting code as possible:

```
plt.axes(xlabel="day", ylabel="daylight hours").plot(day, hours, color=
↪"orange")
```



Total running time of the script: (0 minutes 2.101 seconds)

4.3 Image tutorial

This tutorial will use Matplotlib's implicit plotting interface, pyplot. This interface maintains global state, and is very useful for quickly and easily experimenting with various plot settings. The alternative is the explicit, which is more suitable for large application development. For an explanation of the tradeoffs between the implicit and explicit interfaces see *Matplotlib Application Interfaces (APIs)* and the *Quick start guide* to start using the explicit interface. For now, let's get on with the implicit approach:

```
from PIL import Image

import matplotlib.pyplot as plt
import numpy as np
```

4.3.1 Importing image data into Numpy arrays

Matplotlib relies on the Pillow library to load image data.

Here's the image we're going to play with:

It's a 24-bit RGB PNG image (8 bits for each of R, G, B). Depending on where you get your data, the other kinds of image that you'll most likely encounter are RGBA images, which allow for transparency, or single-channel grayscale (luminosity) images. Download stinkbug.png to your computer for the rest of this tutorial.

We use Pillow to open an image (with `PIL.Image.open`), and immediately convert the `PIL.Image.Image` object into an 8-bit (`dtype=uint8`) numpy array.

```
img = np.asarray(Image.open('../../doc/_static/stinkbug.png'))
print(repr(img))
```

```
array([[[104, 104, 104],
        [104, 104, 104],
        [104, 104, 104],
        ...,
        [109, 109, 109],
        [109, 109, 109],
        [109, 109, 109]],

       [[105, 105, 105],
        [105, 105, 105],
        [105, 105, 105],
```

(continues on next page)

(continued from previous page)

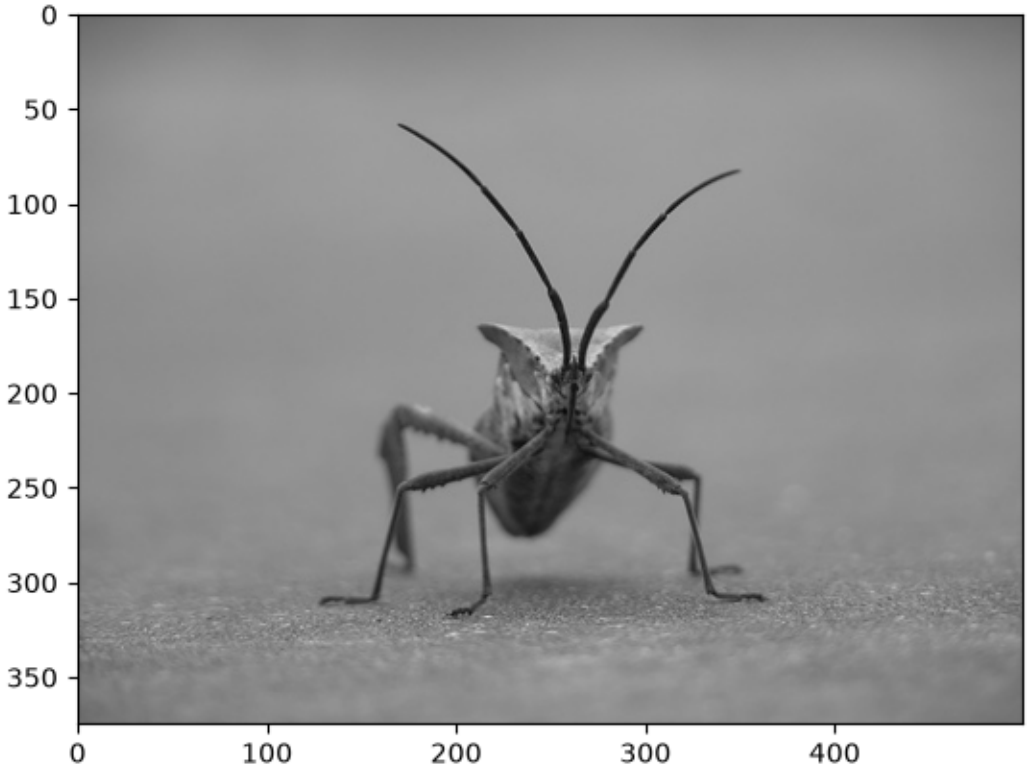
```
        ...,
        [109, 109, 109],
        [109, 109, 109],
        [109, 109, 109]],

       [[107, 107, 107],
        [106, 106, 106],
        [106, 106, 106],
        ...,
        [110, 110, 110],
        [110, 110, 110],
        [110, 110, 110]],

       ...,

       [[112, 112, 112],
        [111, 111, 111],
        [110, 110, 110],
        ...,
        [116, 116, 116],
        [115, 115, 115],
        [115, 115, 115]],

       [[113, 113, 113],
        [113, 113, 113],
        [112, 112, 112],
        ...,
        [115, 115, 115],
        [114, 114, 114],
        [114, 114, 114]],

       [[113, 113, 113],
        [115, 115, 115],
        [115, 115, 115],
        ...,
        [114, 114, 114],
        [114, 114, 114],
        [113, 113, 113]]], shape=(375, 500, 3), dtype=uint8)
```

Each inner list represents a pixel. Here, with an RGB image, there are 3 values. Since it's a black and white image, R, G, and B are all similar. An RGBA (where A is alpha, or transparency) has 4 values per inner list, and a simple luminance image just has one value (and is thus only a 2-D array, not a 3-D array). For RGB and RGBA images, Matplotlib supports float32 and uint8 data types. For grayscale, Matplotlib supports only float32. If your array data does not meet one of these descriptions, you need to rescale it.

4.3.2 Plotting numpy arrays as images

So, you have your data in a numpy array (either by importing it, or by generating it). Let's render it. In Matplotlib, this is performed using the *imshow()* function. Here we'll grab the plot object. This object gives you an easy way to manipulate the plot from the prompt.

```
imgplot = plt.imshow(img)
```



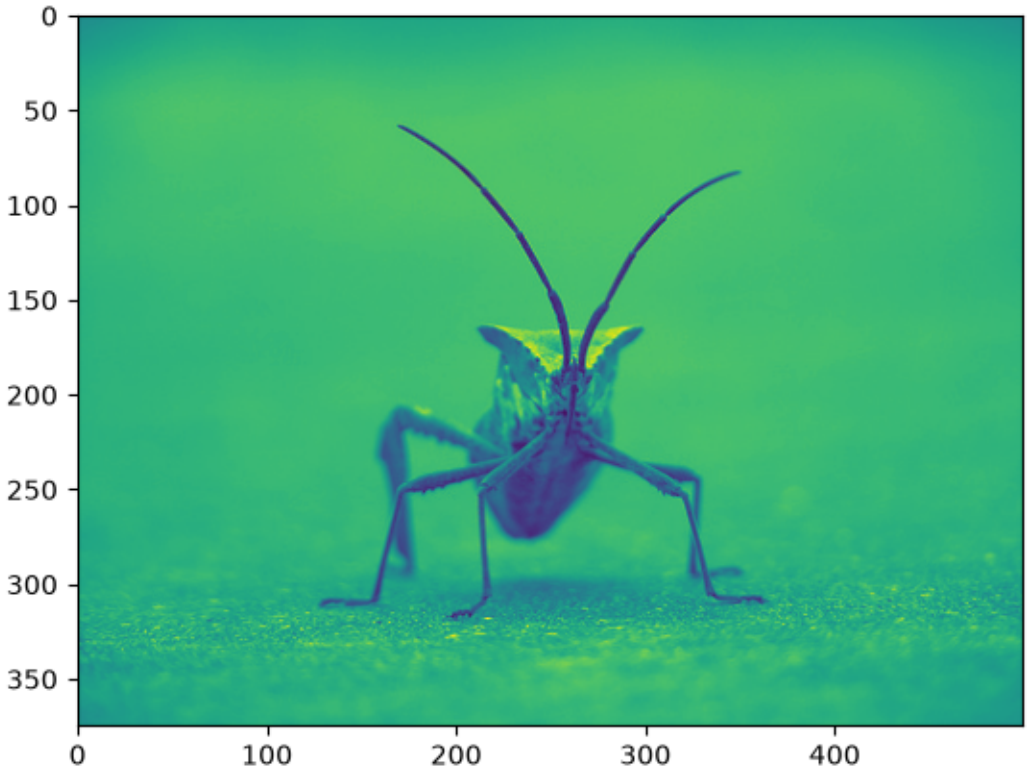
You can also plot any numpy array.

Applying pseudocolor schemes to image plots

Pseudocolor can be a useful tool for enhancing contrast and visualizing your data more easily. This is especially useful when making presentations of your data using projectors - their contrast is typically quite poor.

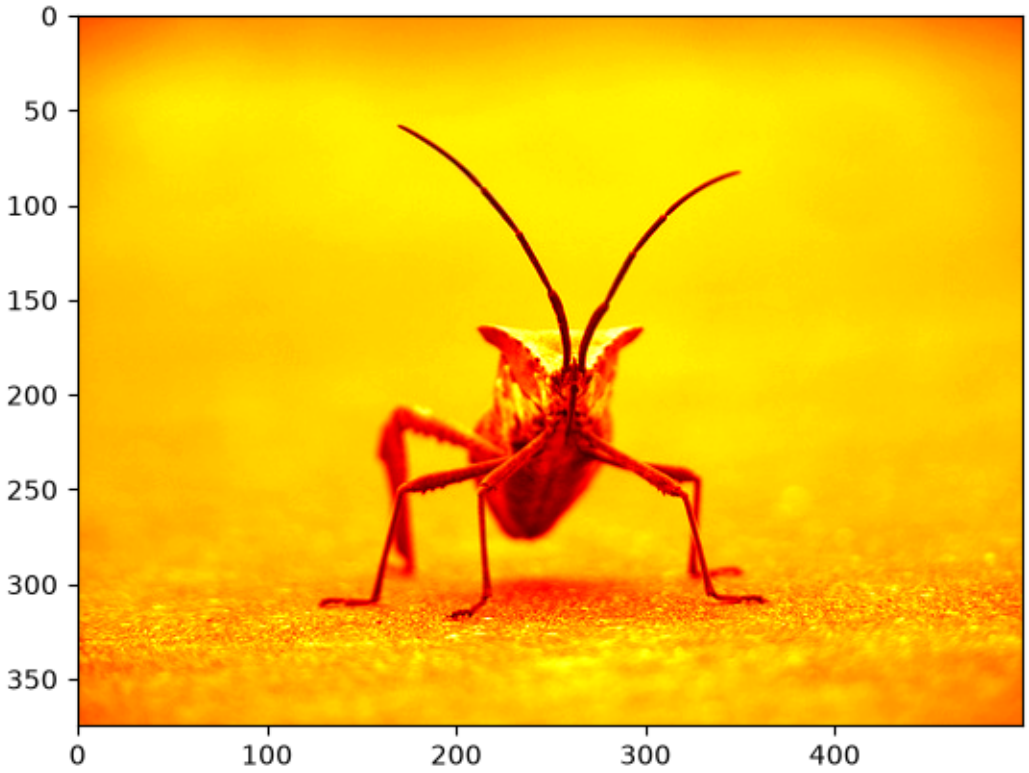
Pseudocolor is only relevant to single-channel, grayscale, luminosity images. We currently have an RGB image. Since R, G, and B are all similar (see for yourself above or in your data), we can just pick one channel of our data using array slicing (you can read more in the Numpy tutorial):

```
lum_img = img[:, :, 0]
plt.imshow(lum_img)
```



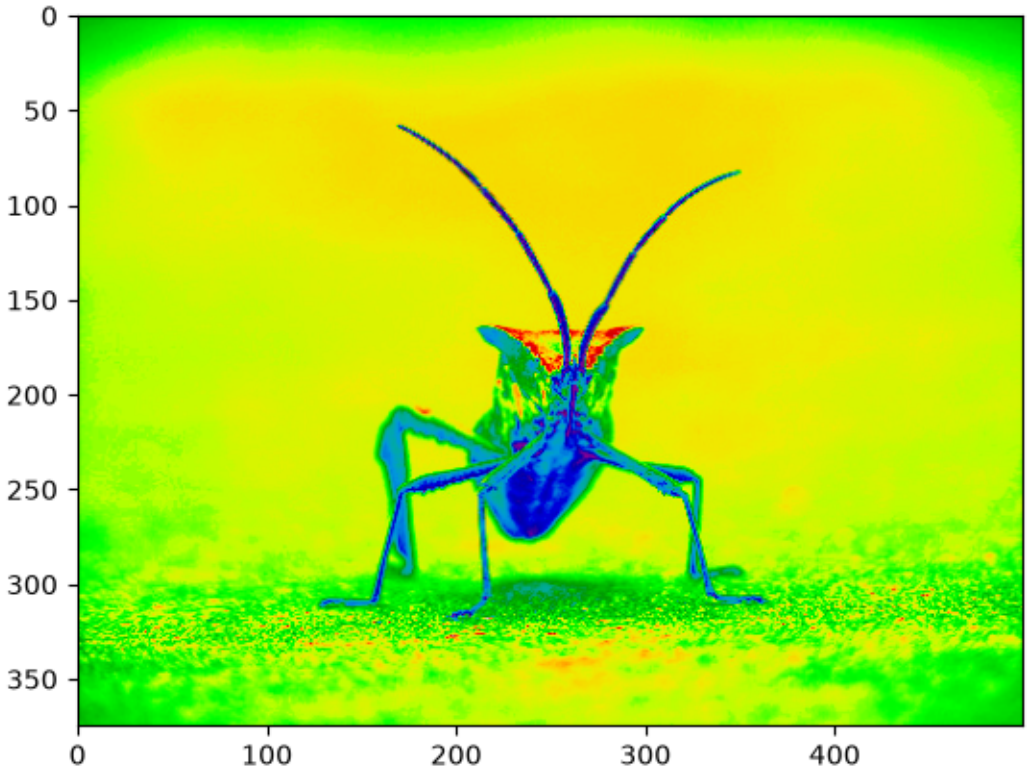
Now, with a luminosity (2D, no color) image, the default colormap (aka lookup table, LUT), is applied. The default is called viridis. There are plenty of others to choose from.

```
plt.imshow(lum_img, cmap="hot")
```



Note that you can also change colormaps on existing plot objects using the *set_cmap()* method:

```
imgplot = plt.imshow(lum_img)
imgplot.set_cmap('nipy_spectral')
```

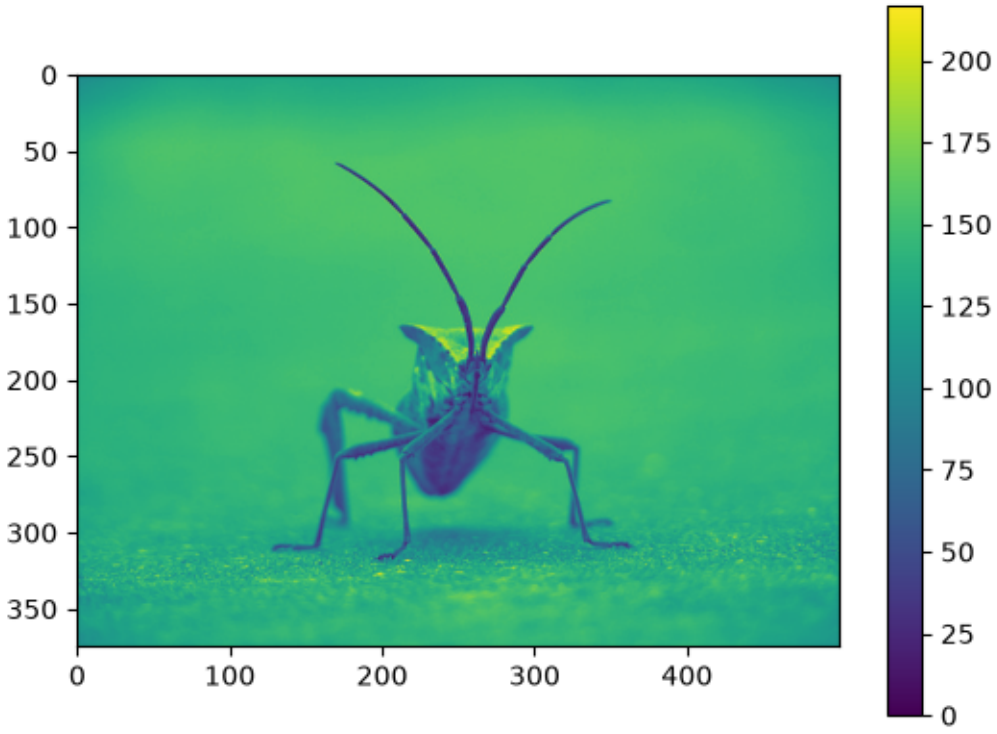


There are many other colormap schemes available. See the *list and images of the colormaps*.

Color scale reference

It's helpful to have an idea of what value a color represents. We can do that by adding a color bar to your figure:

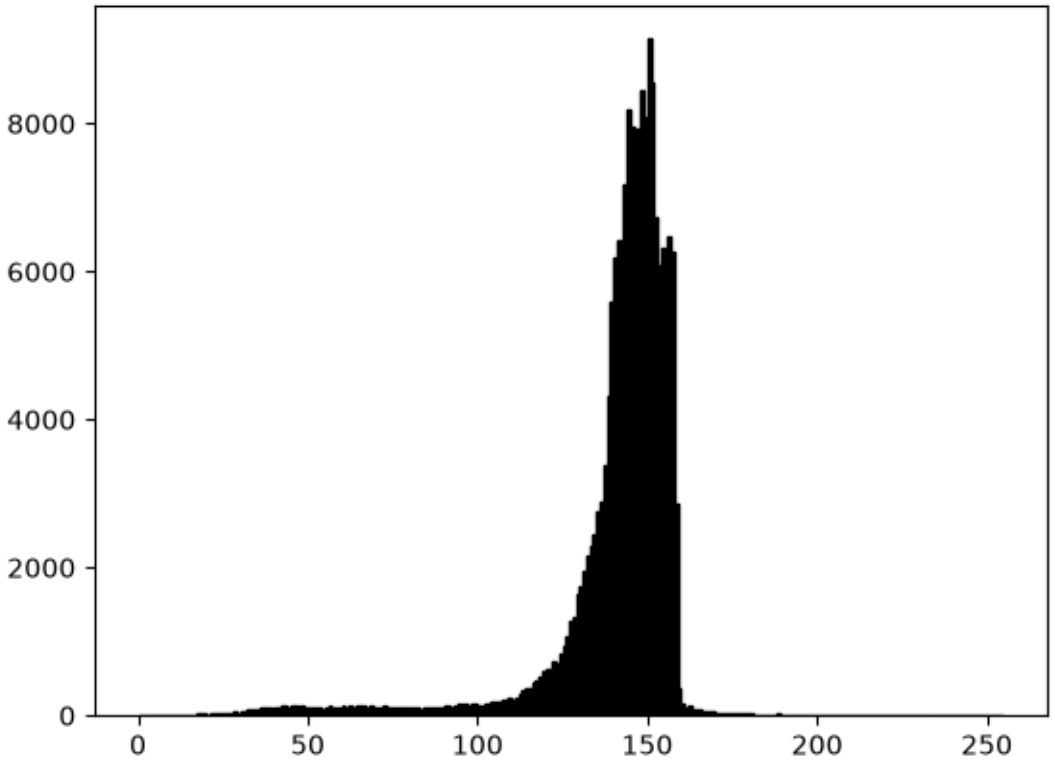
```
imgplot = plt.imshow(lum_img)
plt.colorbar()
```



Examining a specific data range

Sometimes you want to enhance the contrast in your image, or expand the contrast in a particular region while sacrificing the detail in colors that don't vary much, or don't matter. A good tool to find interesting regions is the histogram. To create a histogram of our image data, we use the *hist()* function.

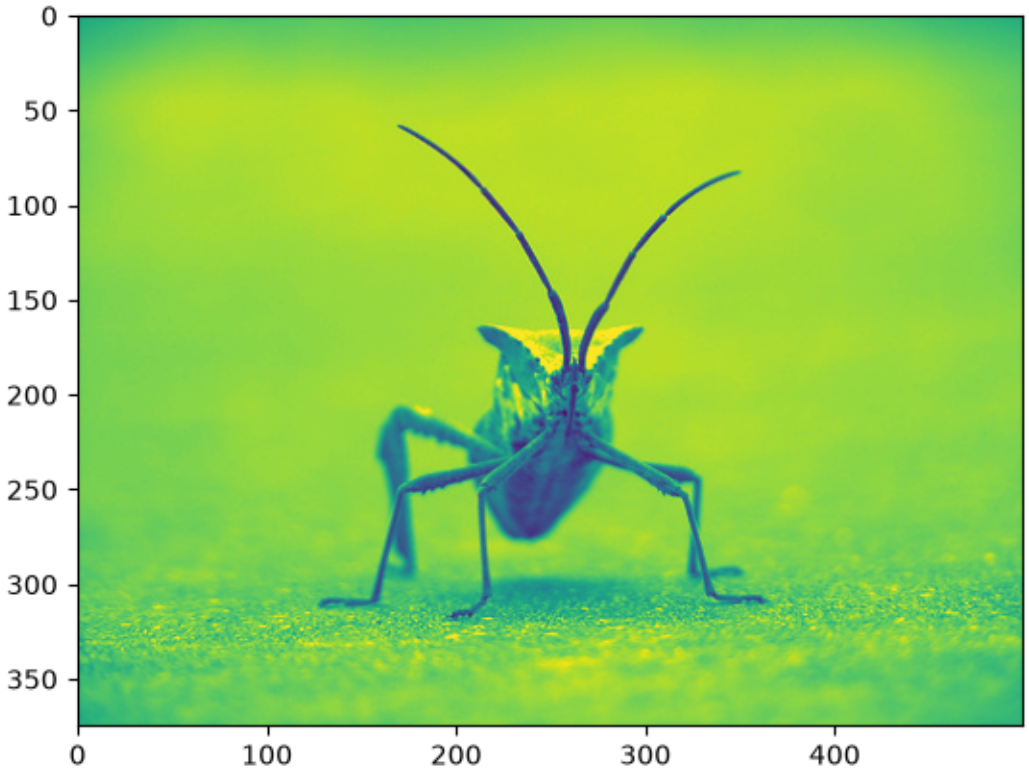
```
plt.hist(lum_img.ravel(), bins=range(256), fc='k', ec='k')
```



Most often, the "interesting" part of the image is around the peak, and you can get extra contrast by clipping the regions above and/or below the peak. In our histogram, it looks like there's not much useful information in the high end (not many white things in the image). Let's adjust the upper limit, so that we effectively "zoom in on" part of the histogram. We do this by setting *clim*, the colormap limits.

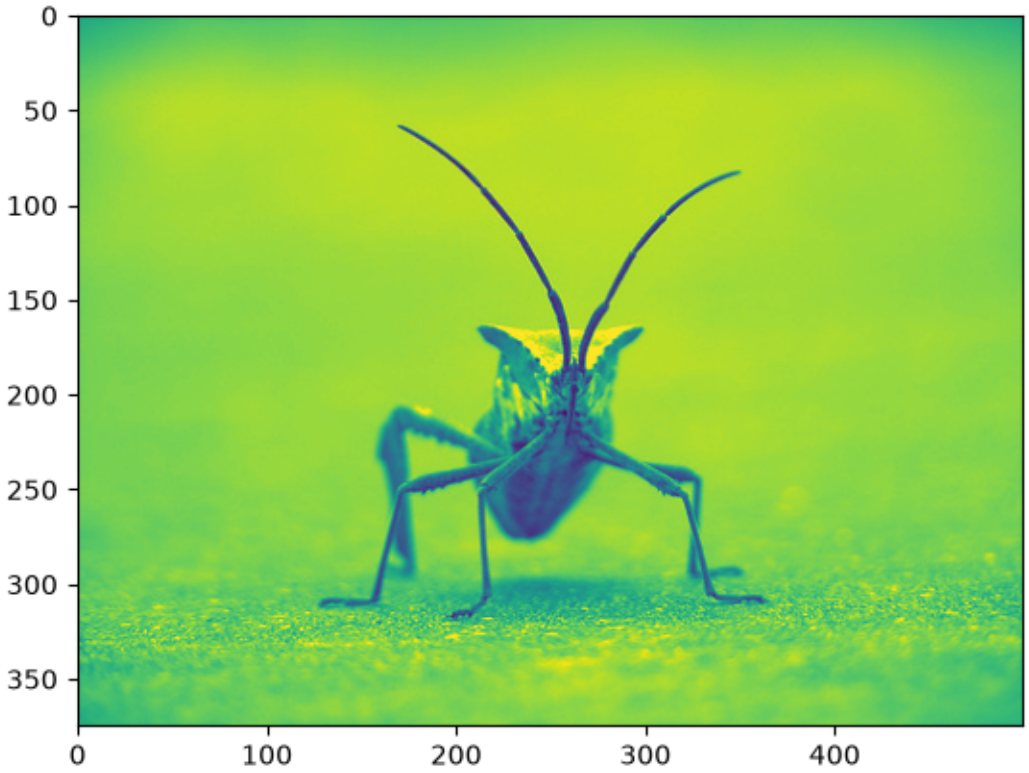
This can be done by passing a *clim* keyword argument in the call to `imshow`.

```
plt.imshow(lum_img, clim=(0, 175))
```



This can also be done by calling the *set_clim()* method of the returned image plot object.

```
imgplot = plt.imshow(lum_img)
imgplot.set_clim(0, 175)
```

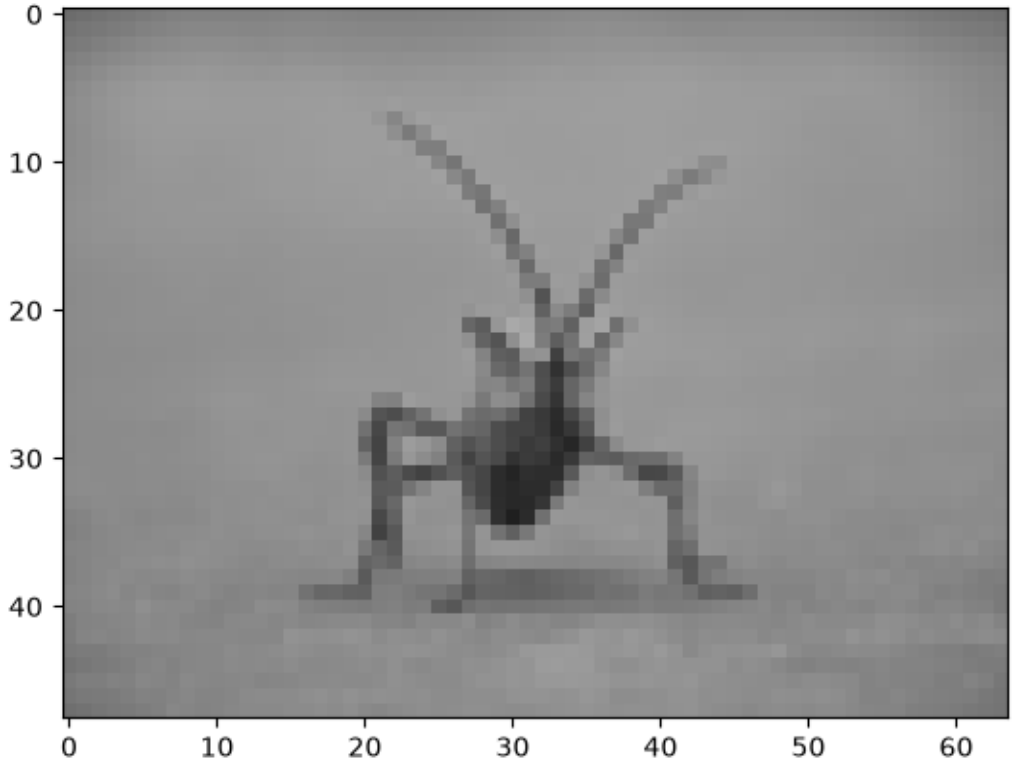


Array Interpolation schemes

Interpolation calculates what the color or value of a pixel "should" be, according to different mathematical schemes. One common place that this happens is when you resize an image. The number of pixels change, but you want the same information. Since pixels are discrete, there's missing space. Interpolation is how you fill that space. This is why your images sometimes come out looking pixelated when you blow them up. The effect is more pronounced when the difference between the original image and the expanded image is greater. Let's take our image and shrink it. We're effectively discarding pixels, only keeping a select few. Now when we plot it, that data gets blown up to the size on your screen. The old pixels aren't there anymore, and the computer has to draw in pixels to fill that space.

We'll use the Pillow library that we used to load the image also to resize the image.

```
img = Image.open('../../doc/_static/stinkbug.png')
img.thumbnail((64, 64))  # resizes image in-place
imgplot = plt.imshow(img)
```



Here we use the default interpolation ("nearest"), since we did not give *imshow()* any interpolation argument.

Let's try some others. Here's "bilinear":

```
imgplot = plt.imshow(img, interpolation="bilinear")
```

and bicubic:

```
imgplot = plt.imshow(img, interpolation="bicubic")
```

Bicubic interpolation is often used when blowing up photos - people tend to prefer blurry over pixelated.

Total running time of the script: (0 minutes 5.021 seconds)

4.4 The Lifecycle of a Plot

This tutorial aims to show the beginning, middle, and end of a single visualization using Matplotlib. We'll begin with some raw data and end by saving a figure of a customized visualization. Along the way we try to highlight some neat features and best-practices using Matplotlib.

Note

This tutorial is based on this excellent blog post by Chris Moffitt. It was transformed into this tutorial by Chris Holdgraf.

4.4.1 Our data

We'll use the data from the post from which this tutorial was derived. It contains sales information for a number of companies.

```
import matplotlib.pyplot as plt
import numpy as np

data = {'Barton LLC': 109438.50,
        'Frami, Hills and Schmidt': 103569.59,
        'Fritsch, Russel and Anderson': 112214.71,
        'Jerde-Hilpert': 112591.43,
        'Keeling LLC': 100934.30,
        'Koepp Ltd': 103660.54,
        'Kulas Inc': 137351.96,
        'Trantow-Barrows': 123381.38,
        'White-Trantow': 135841.99,
        'Will LLC': 104437.60}
group_data = list(data.values())
group_names = list(data.keys())
group_mean = np.mean(group_data)
```

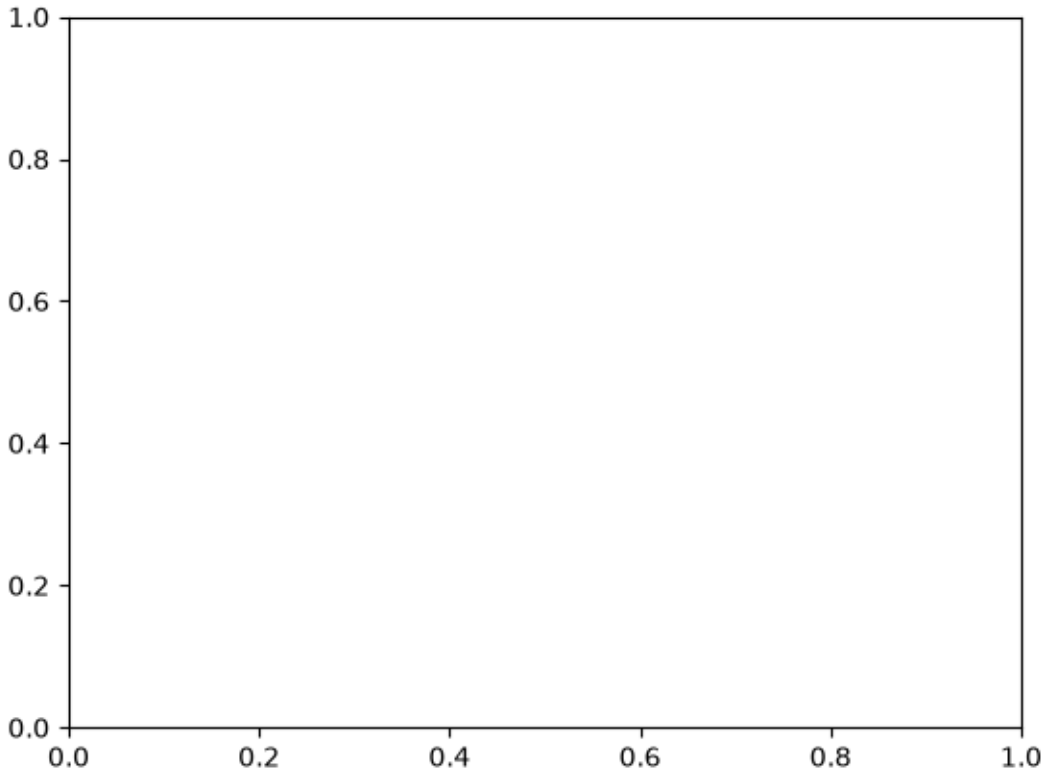
4.4.2 Getting started

This data is naturally visualized as a barplot, with one bar per group. To do this with the object-oriented approach, we first generate an instance of *figure.Figure* and *axes.Axes*. The Figure is like a canvas, and the Axes is a part of that canvas on which we will make a particular visualization.

Note

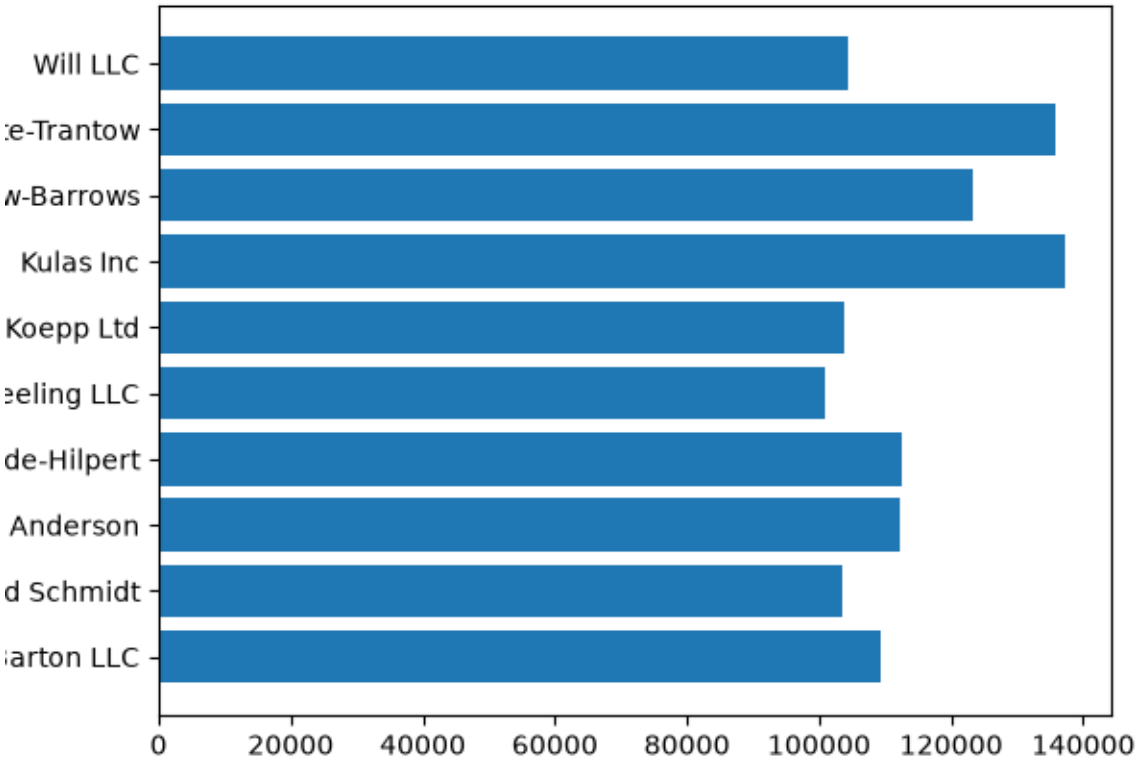
Figures can have multiple Axes on them. For information on how to do this, see the *Tight Layout tutorial*.

```
fig, ax = plt.subplots()
```



Now that we have an Axes instance, we can plot on top of it.

```
fig, ax = plt.subplots()
ax.barh(group_names, group_data)
```



4.4.3 Controlling the style

There are many styles available in Matplotlib in order to let you tailor your visualization to your needs. To see a list of styles, we can use `style`.

```
print(plt.style.available)
```

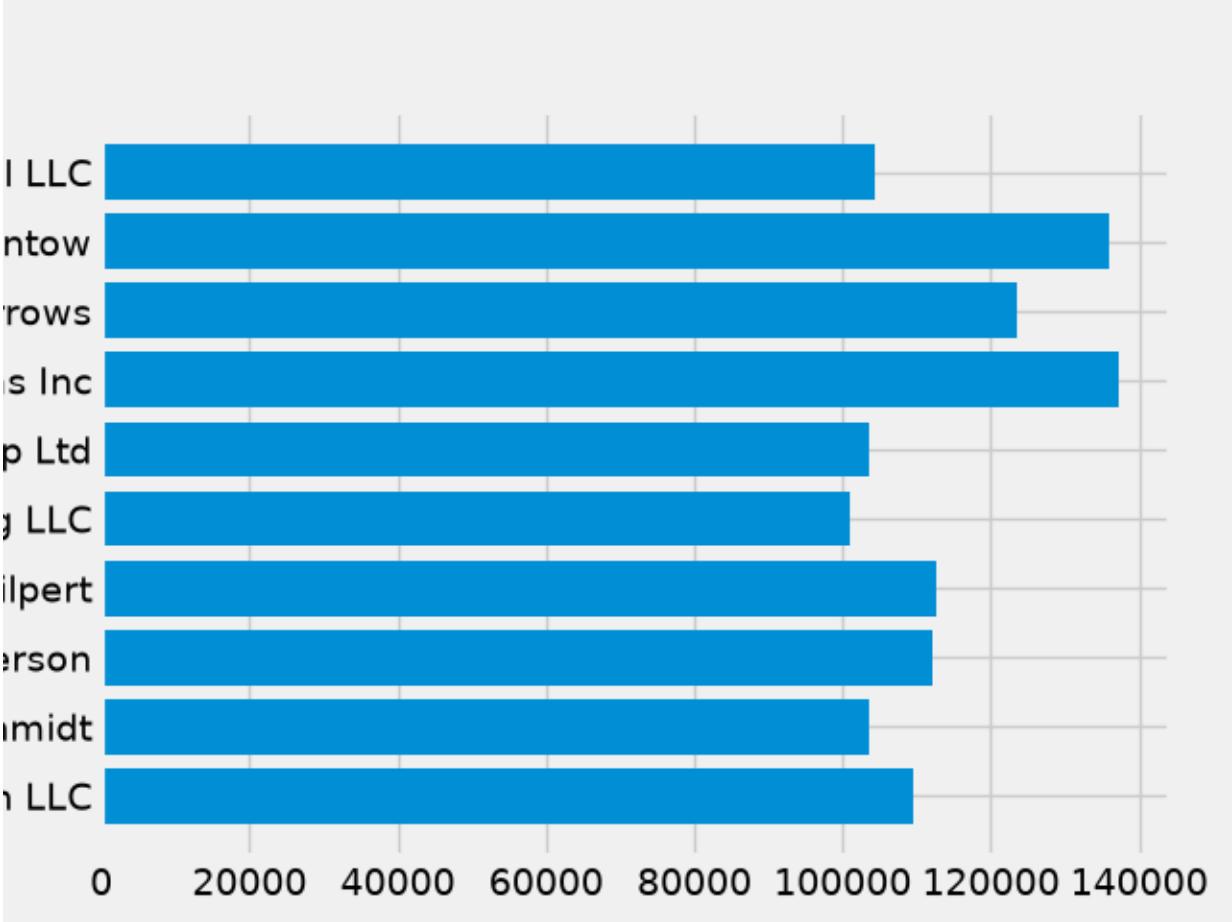
```
['Solarize_Light2', 'bmh', 'classic', 'dark_background', 'fast',
 ↪'fivethirtyeight', 'ggplot', 'grayscale', 'petroff10', 'petroff6',
 ↪'petroff8', 'seaborn-v0_8', 'seaborn-v0_8-bright',
 ↪'seaborn-v0_8-colorblind', 'seaborn-v0_8-dark',
 ↪'seaborn-v0_8-dark-palette', 'seaborn-v0_8-darkgrid',
 ↪'seaborn-v0_8-deep', 'seaborn-v0_8-muted', 'seaborn-v0_8-notebook',
 ↪'seaborn-v0_8-paper', 'seaborn-v0_8-pastel', 'seaborn-v0_8-poster',
 ↪'seaborn-v0_8-talk', 'seaborn-v0_8-ticks', 'seaborn-v0_8-white',
 ↪'seaborn-v0_8-whitegrid', 'tableau-colorblind10']
```

You can activate a style with the following:

```
plt.style.use('fivethirtyeight')
```

Now let's remake the above plot to see how it looks:

```
fig, ax = plt.subplots()
ax.barh(group_names, group_data)
```

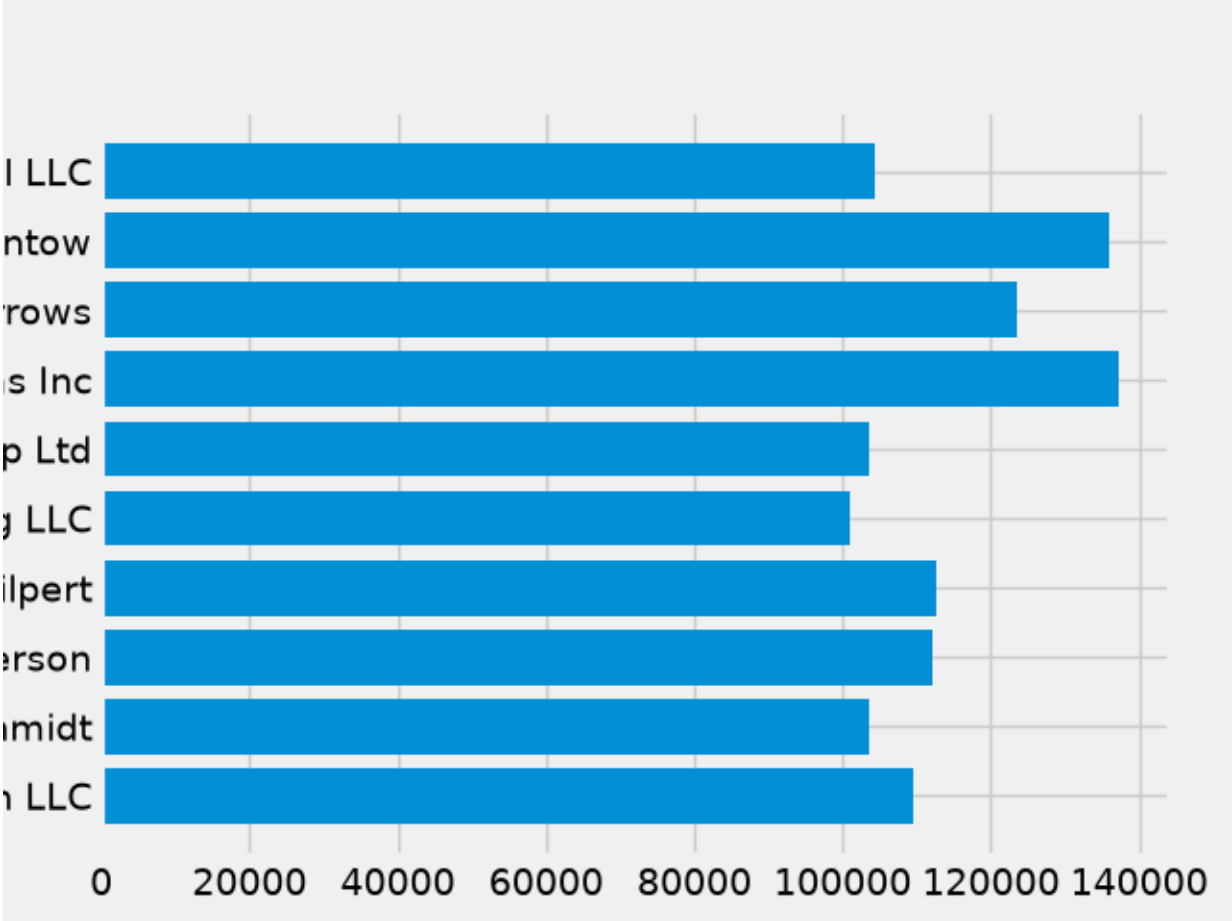


The style controls many things, such as color, linewidths, backgrounds, etc.

4.4.4 Customizing the plot

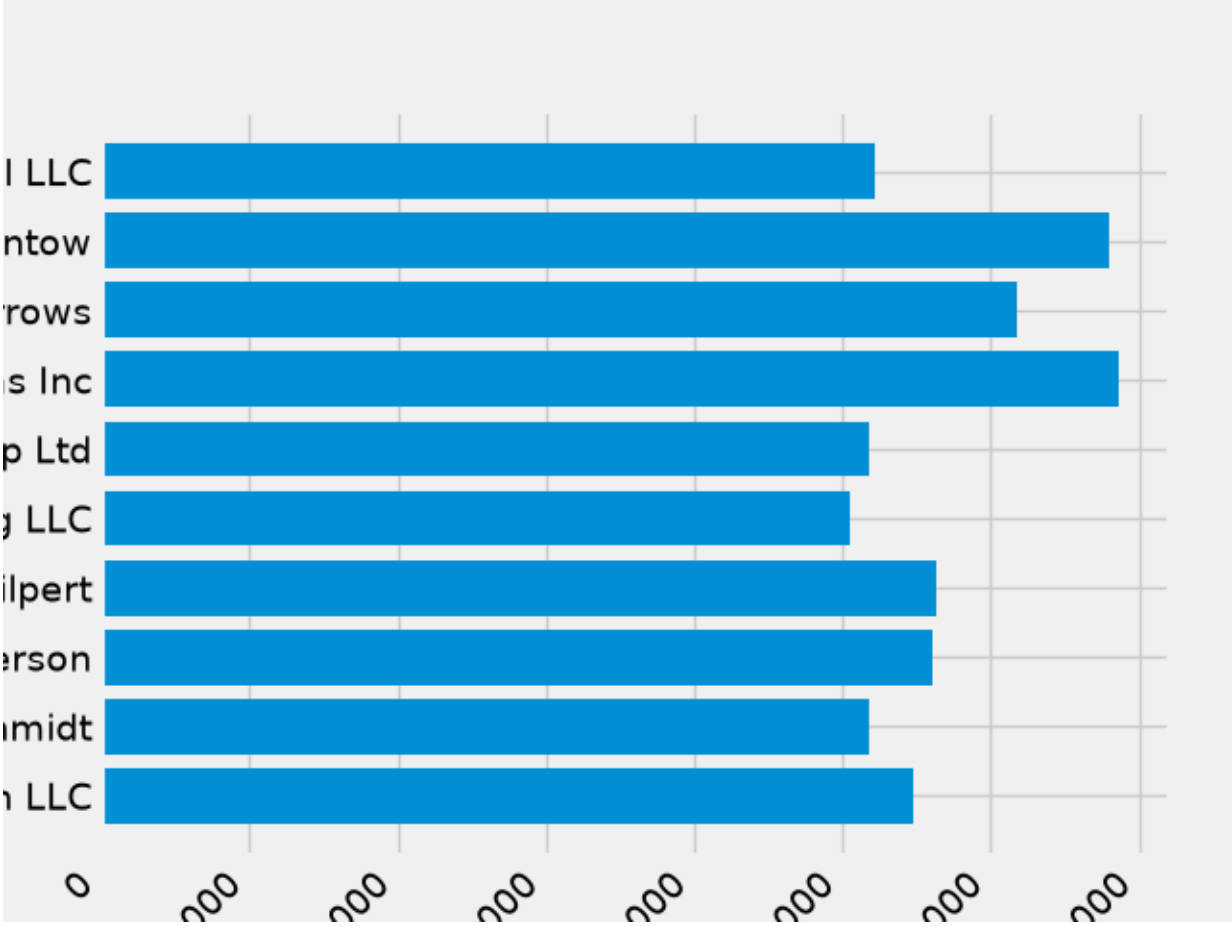
Now we've got a plot with the general look that we want, so let's fine-tune it so that it's ready for print. First let's rotate the labels on the x-axis so that they show up more clearly. We can gain access to these labels with the *axes.Axes.get_xticklabels()* method:

```
fig, ax = plt.subplots()
ax.barh(group_names, group_data)
labels = ax.get_xticklabels()
```



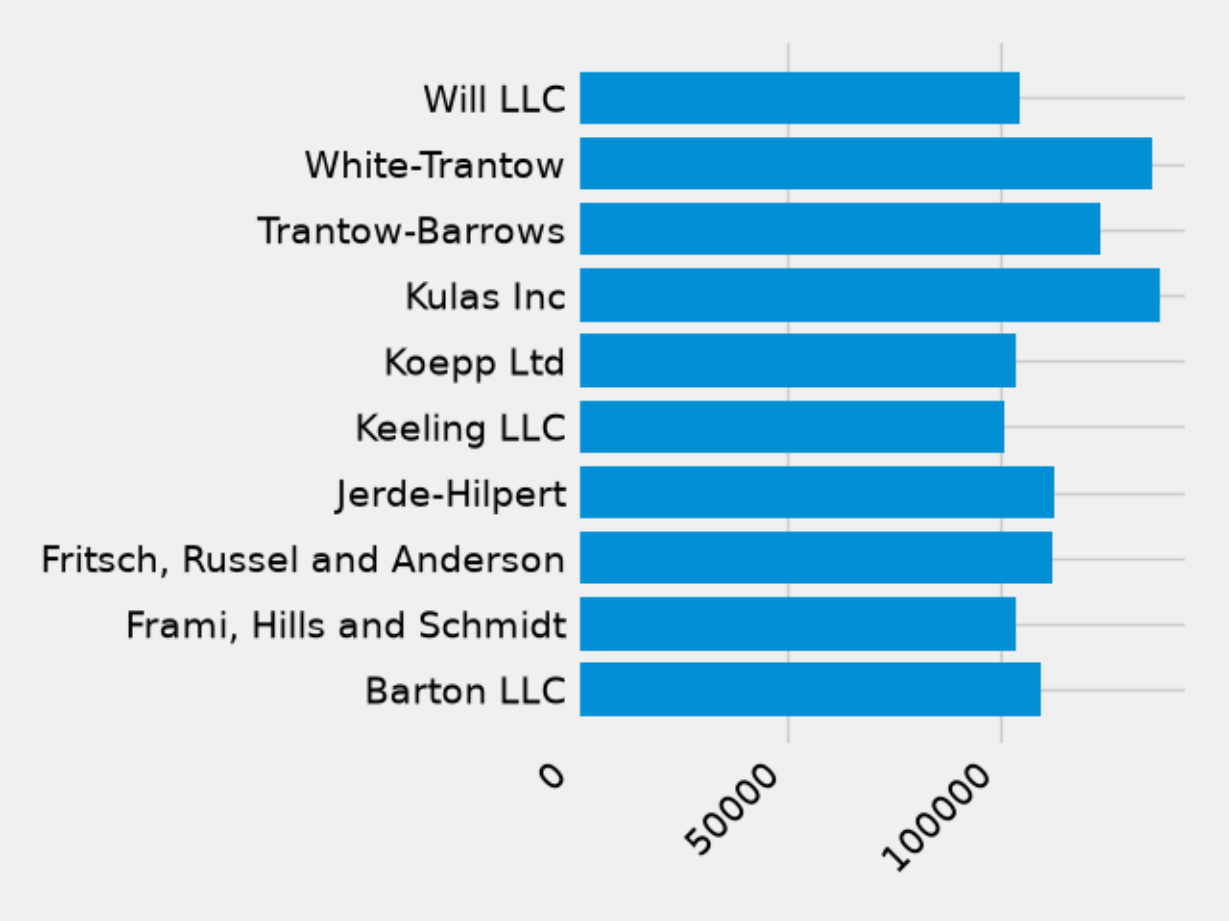
If we'd like to set the property of many items at once, it's useful to use the *pyplot.setp()* function. This will take a list (or many lists) of Matplotlib objects, and attempt to set some style element of each one.

```
fig, ax = plt.subplots()
ax.barh(group_names, group_data)
labels = ax.get_xticklabels()
plt.setp(labels, rotation=45, horizontalalignment='right')
```



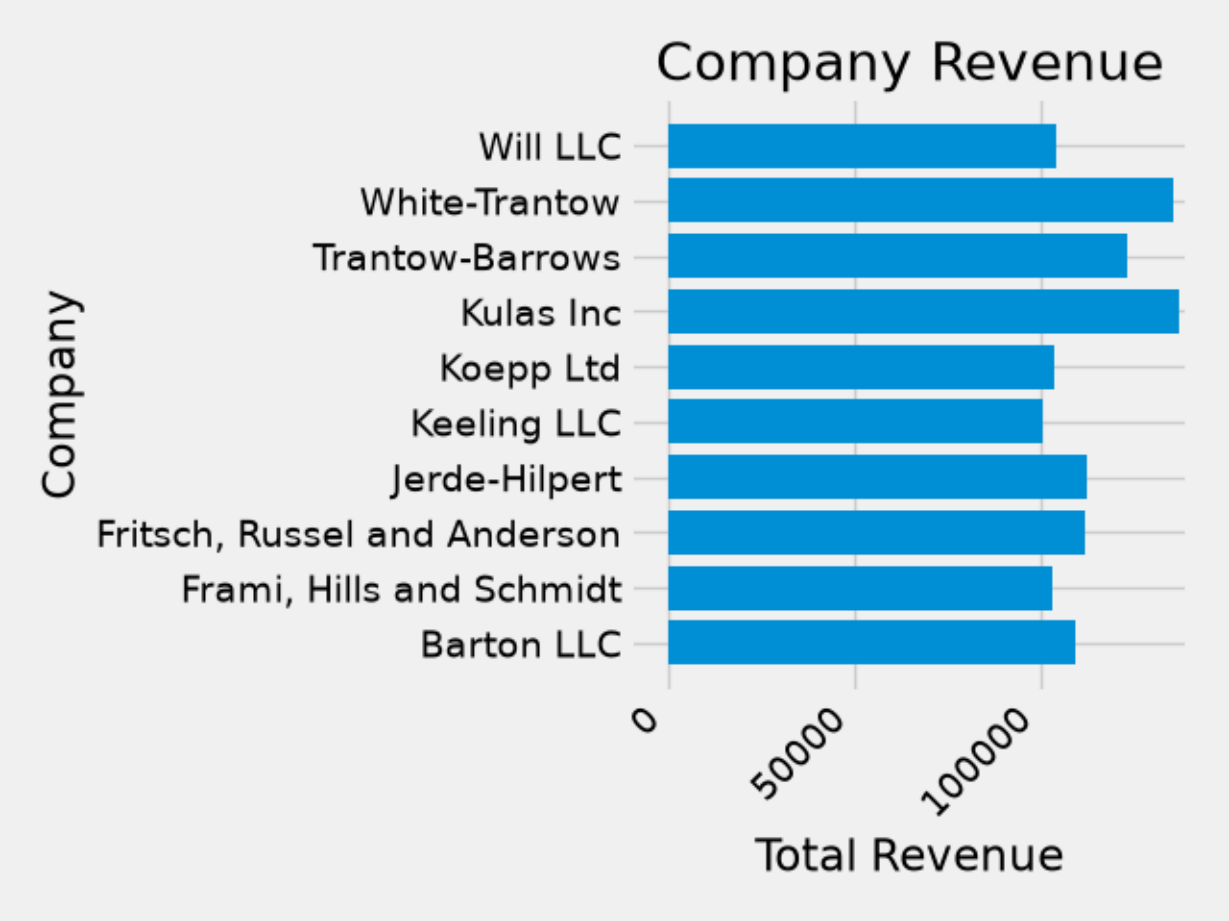
It looks like this cut off some of the labels on the bottom. We can tell Matplotlib to automatically make room for elements in the figures that we create. To do this we set the `autolayout` value of our rcParams. For more information on controlling the style, layout, and other features of plots with rcParams, see *Customizing Matplotlib with style sheets and rcParams*.

```
plt.rcParams.update({'figure.autolayout': True})

fig, ax = plt.subplots()
ax.barh(group_names, group_data)
labels = ax.get_xticklabels()
plt.setp(labels, rotation=45, horizontalalignment='right')
```



Next, we add labels to the plot. To do this with the OO interface, we can use the *Artist.set()* method to set properties of this Axes object.

```
fig, ax = plt.subplots()
ax.barh(group_names, group_data)
labels = ax.get_xticklabels()
plt.setp(labels, rotation=45, horizontalalignment='right')
ax.set(xlim=(-10000, 140000), xlabel='Total Revenue', ylabel='Company',
       title='Company Revenue')
```

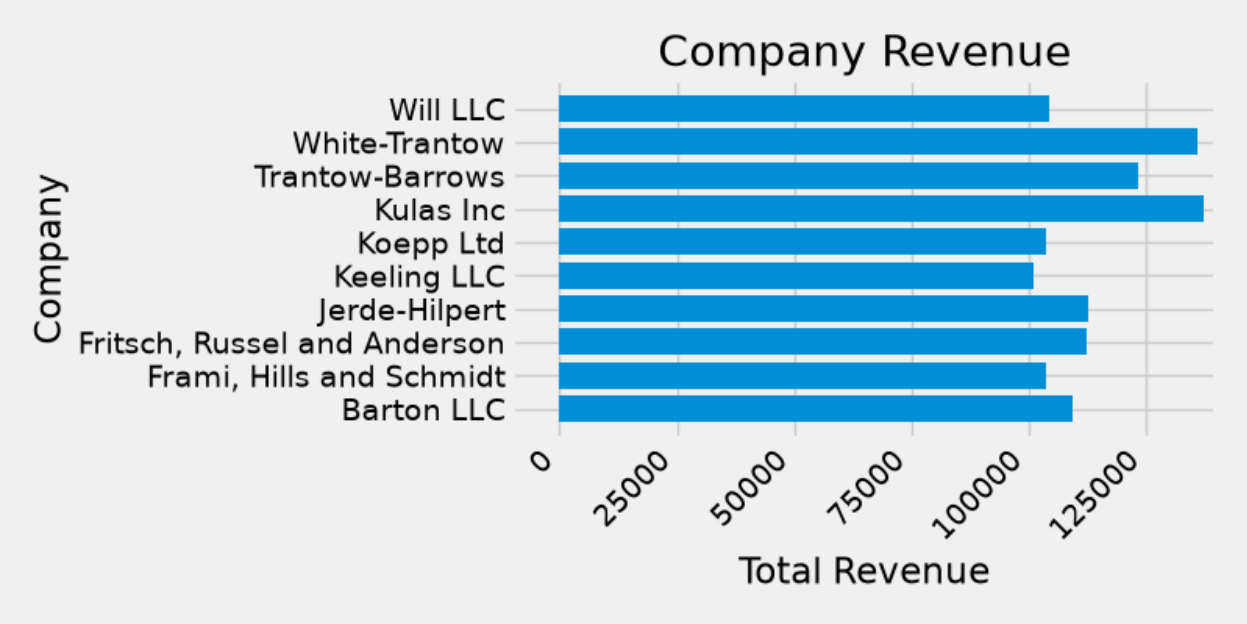


We can also adjust the size of this plot using the `pyplot.subplots()` function. We can do this with the *figsize* keyword argument.

Note

While indexing in NumPy follows the form (row, column), the *figsize* keyword argument follows the form (width, height). This follows conventions in visualization, which unfortunately are different from those of linear algebra.

```
fig, ax = plt.subplots(figsize=(8, 4))
ax.barh(group_names, group_data)
labels = ax.get_xticklabels()
plt.setp(labels, rotation=45, horizontalalignment='right')
ax.set(xlim=(-10000, 140000), xlabel='Total Revenue', ylabel='Company',
       title='Company Revenue')
```



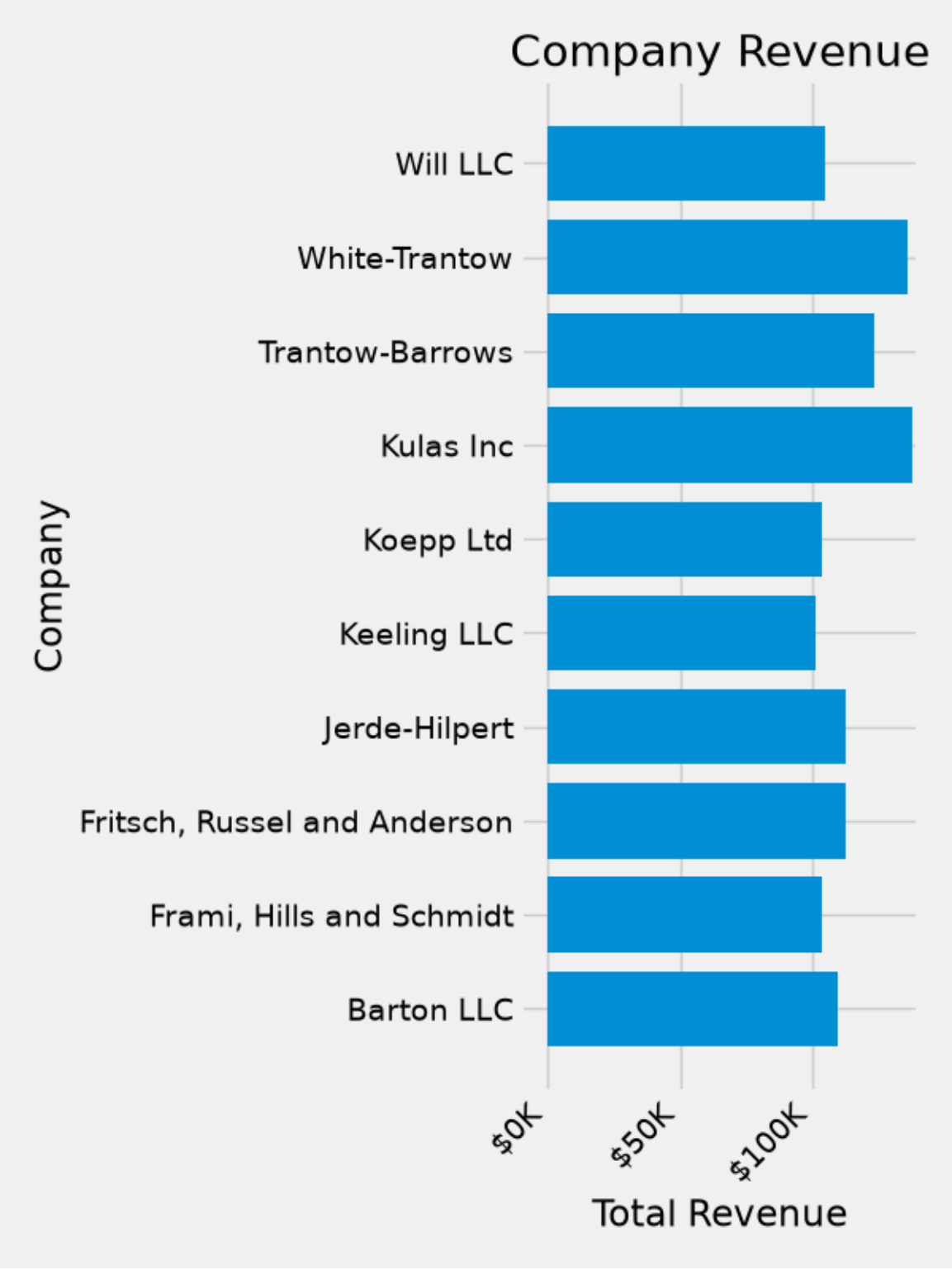
For labels, we can specify custom formatting guidelines in the form of functions. Below we define a function that takes an integer as input, and returns a string as an output. When used with *`Axis.set_major_formatter`* or *`Axis.set_minor_formatter`*, they will automatically create and use a *`ticker.FuncFormatter`* class.

For this function, the `x` argument is the original tick label and `pos` is the tick position. We will only use `x` here but both arguments are needed.

```
def currency(x, pos):
    """The two arguments are the value and tick position"""
    if x >= 1e6:
        s = f'${x*1e-6:1.1f}M'
    else:
        s = f'${x*1e-3:1.0f}K'
    return s
```

We can then apply this function to the labels on our plot. To do this, we use the `xaxis` attribute of our Axes. This lets you perform actions on a specific axis on our plot.

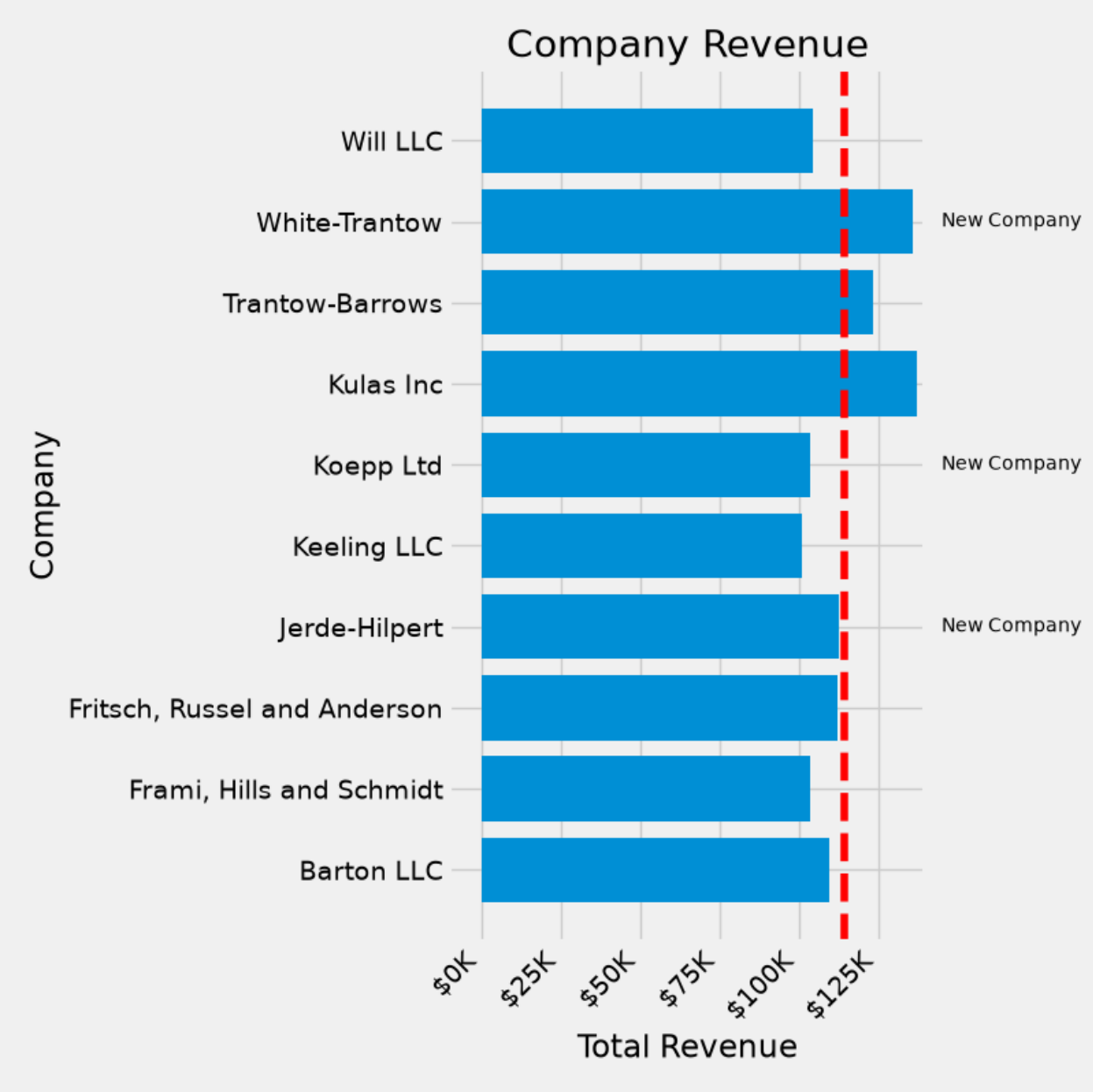
```
fig, ax = plt.subplots(figsize=(6, 8))
ax.barh(group_names, group_data)
labels = ax.get_xticklabels()
plt.setp(labels, rotation=45, horizontalalignment='right')

ax.set(xlim=(-10000, 140000), xlabel='Total Revenue', ylabel='Company',
       title='Company Revenue')
ax.xaxis.set_major_formatter(currency)
```


Company Revenue
Will LLC
White-Trantow
Trantow-Barrows
Kulas Inc
Koepp Ltd
Keeling LLC
Jerde-Hilpert
Fritsch, Russel and Anderson
Frami, Hills and Schmidt
Barton LLC
Company
$0K
$50K
$100K
Total Revenue

4.4.5 Combining multiple visualizations

It is possible to draw multiple plot elements on the same instance of *axes.Axes*. To do this we simply need to call another one of the plot methods on that Axes object.

```
fig, ax = plt.subplots(figsize=(8, 8))
ax.barh(group_names, group_data)
labels = ax.get_xticklabels()
plt.setp(labels, rotation=45, horizontalalignment='right')

# Add a vertical line, here we set the style in the function call
ax.axvline(group_mean, ls='--', color='r')

# Annotate new companies
for group in [3, 5, 8]:
    ax.text(145000, group, "New Company", fontsize=10,
            verticalalignment="center")

# Now we move our title up since it's getting a little cramped
ax.title.set(y=1.05)

ax.set(xlim=(-10000, 140000), xlabel='Total Revenue', ylabel='Company',
       title='Company Revenue')
ax.xaxis.set_major_formatter(currency)
ax.set_xticks([0, 25e3, 50e3, 75e3, 100e3, 125e3])
fig.subplots_adjust(right=.1)

plt.show()
```



4.4.6 Saving our plot

Now that we're happy with the outcome of our plot, we want to save it to disk. There are many file formats we can save to in Matplotlib. To see a list of available options, use:

```
print(fig.canvas.get_supported_filetypes())
```

```
{'eps': 'Encapsulated Postscript', 'gif': 'Graphics Interchange Format
 ↪', 'jpg': 'Joint Photographic Experts Group', 'jpeg': 'Joint␣
 ↪Photographic Experts Group', 'pdf': 'Portable Document Format', 'pgf
 ↪': 'PGF code for LaTeX', 'png': 'Portable Network Graphics', 'ps':
```

(continues on next page)

(continued from previous page)

```
↪'Postscript', 'raw': 'Raw RGBA bitmap', 'rgba': 'Raw RGBA bitmap',
↪'svg': 'Scalable Vector Graphics', 'svgz': 'Scalable Vector Graphics
↪', 'tif': 'Tagged Image File Format', 'tiff': 'Tagged Image File␣
↪Format', 'webp': 'WebP Image Format', 'avif': 'AV1 Image File Format
↪'}
```

We can then use the *figure.Figure.savefig()* in order to save the figure to disk. Note that there are several useful flags we show below:

- `transparent=True` makes the background of the saved figure transparent if the format supports it.
- `dpi=80` controls the resolution (dots per square inch) of the output.
- `bbox_inches="tight"` fits the bounds of the figure to our plot.

```
# Uncomment this line to save the figure.
# fig.savefig('sales.png', transparent=False, dpi=80,␣
↪bbox_inches="tight")
```

Total running time of the script: (0 minutes 3.042 seconds)

4.5 Artist tutorial

Using Artist objects to render on the canvas.

There are three layers to the Matplotlib API.

- the `matplotlib.backend_bases.FigureCanvas` is the area onto which the figure is drawn
- the `matplotlib.backend_bases.Renderer` is the object which knows how to draw on the `matplotlib.backend_bases.FigureCanvas`
- and the *matplotlib.artist.Artist* is the object that knows how to use a renderer to paint onto the canvas.

The `matplotlib.backend_bases.FigureCanvas` and `matplotlib.backend_bases.Renderer` handle all the details of talking to user interface toolkits like wxPython or drawing languages like PostScript®, and the `Artist` handles all the high level constructs like representing and laying out the figure, text, and lines. The typical user will spend 95% of their time working with the `Artists`.

There are two types of `Artists`: primitives and containers. The primitives represent the standard graphical objects we want to paint onto our canvas: *Line2D*, *Rectangle*, *Text*, *AxesImage*, etc., and the containers are places to put them (*Axis*, *Axes* and *Figure*). The standard use is to create a *Figure* instance, use the `Figure` to create one or more *Axes* instances, and use the `Axes` instance helper methods to create the primitives. In the example below, we create a `Figure` instance using *matplotlib.pyplot.figure()*, which is a convenience method for instantiating `Figure` instances and connecting them with a GUI framework so that they can be shown in a window on the screen:

```
import matplotlib.pyplot as plt
fig = plt.figure()
ax = fig.add_subplot(2, 1, 1) # two rows, one column, first plot
```

The *Axes* is probably the most important class in the Matplotlib API, and the one you will be working with most of the time. This is because the `Axes` is the plotting area into which most of the objects go, and the `Axes` has many special helper methods (*plot()*, *text()*, *hist()*, *imshow()*) to create the most common graphics primitives (*Line2D*, *Text*, *Rectangle*, *AxesImage*, respectively). These helper methods will take your data (e.g., `numpy` arrays and strings) and create primitive `Artist` instances as needed (e.g., `Line2D`), add them to the relevant containers, and draw them when requested. If you want to create an `Axes` at an arbitrary location, simply use the *add_axes()* method which takes a list of `[left, bottom, width, height]` values in 0-1 relative figure coordinates:

```
fig2 = plt.figure()
ax2 = fig2.add_axes((0.15, 0.1, 0.7, 0.3))
```

Continuing with our example:

```
import numpy as np
t = np.arange(0.0, 1.0, 0.01)
s = np.sin(2*np.pi*t)
line, = ax.plot(t, s, color='blue', lw=2)
```

In this example, `ax` is the `Axes` instance created by the `fig.add_subplot` call above and when you call `ax.plot`, it creates a `Line2D` instance and adds it to the `Axes`. In the interactive IPython session below, you can see that the `Axes.lines` list is length one and contains the same line that was returned by the `line, = ax.plot...` call:

```
In [101]: ax.lines[0]
Out[101]: <matplotlib.lines.Line2D at 0x19a95710>

In [102]: line
Out[102]: <matplotlib.lines.Line2D at 0x19a95710>
```

If you make subsequent calls to `ax.plot` then additional lines will be added to the list. You can remove a line later by calling its `remove` method:

```
line = ax.lines[0]
line.remove()
```

The Axes also has helper methods to configure and decorate the x-axis and y-axis tick, tick labels and axis labels:

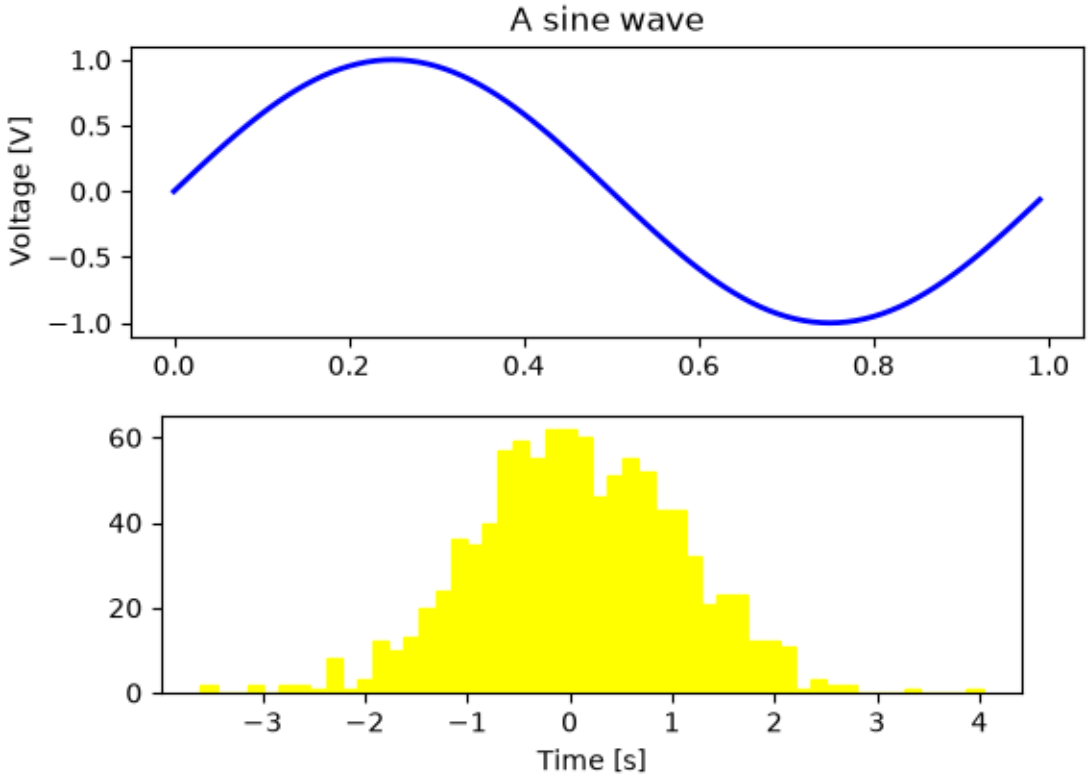
```
xtext = ax.set_xlabel('my xdata')  # returns a Text instance
ytext = ax.set_ylabel('my ydata')
```

When you call *ax.set_xlabel*, it passes the information on the *Text* instance of the *XAxis*. Each `Axes` instance contains an *XAxis* and a *YAxis* instance, which handle the layout and drawing of the ticks,

tick labels and axis labels.

Try creating the figure below.

```
import matplotlib.pyplot as plt
import numpy as np

fig = plt.figure()
fig.subplots_adjust(top=0.8)
ax1 = fig.add_subplot(211)
ax1.set_ylabel('Voltage [V]')
ax1.set_title('A sine wave')

t = np.arange(0.0, 1.0, 0.01)
s = np.sin(2*np.pi*t)
line, = ax1.plot(t, s, color='blue', lw=2)

# Fixing random state for reproducibility
np.random.seed(19680801)

ax2 = fig.add_axes((0.15, 0.1, 0.7, 0.3))
n, bins, patches = ax2.hist(np.random.randn(1000), 50,
                            facecolor='yellow', edgecolor='yellow')
ax2.set_xlabel('Time [s]')

plt.show()
```



4.5.1 Customizing your objects

Every element in the figure is represented by a Matplotlib *Artist*, and each has an extensive list of properties to configure its appearance. The figure itself contains a *Rectangle* exactly the size of the figure, which you can use to set the background color and transparency of the figures. Likewise, each *Axes* bounding box (the standard white box with black edges in the typical Matplotlib plot, has a `Rectangle` instance that determines the color, transparency, and other properties of the Axes. These instances are stored as member variables `Figure.patch` and `Axes.patch` ("Patch" is a name inherited from MATLAB, and is a 2D "patch" of color on the figure, e.g., rectangles, circles and polygons). Every Matplotlib `Artist` has the following properties

Property	Description
alpha	The transparency - a scalar from 0-1
animated	A boolean that is used to facilitate animated drawing
axes	The Axes that the Artist lives in, possibly None
clip_box	The bounding box that clips the Artist
clip_on	Whether clipping is enabled
clip_path	The path the artist is clipped to
contains	A picking function to test whether the artist contains the pick point
figure	The figure instance the artist lives in, possibly None
label	A text label (e.g., for auto-labeling)
picker	A python object that controls object picking
transform	The transformation
visible	A boolean whether the artist should be drawn
zorder	A number which determines the drawing order
rasterized	Boolean; Turns vectors into raster graphics (for compression & EPS transparency)

Each of the properties is accessed with an old-fashioned setter or getter (yes we know this irritates Pythonistas and we plan to support direct access via properties or traits but it hasn't been done yet). For example, to multiply the current alpha by a half:

```
a = o.get_alpha()
o.set_alpha(0.5*a)
```

If you want to set a number of properties at once, you can also use the `set` method with keyword arguments. For example:

```
o.set(alpha=0.5, zorder=2)
```

If you are working interactively at the python shell, a handy way to inspect the `Artist` properties is to use the *`matplotlib.artist.getp()`* function (simply *`getp()`* in pyplot), which lists the properties and their values. This works for classes derived from `Artist` as well, e.g., `Figure` and `Rectangle`. Here are the `Figure` rectangle properties mentioned above:

```
In [149]: matplotlib.artist.getp(fig.patch)
  agg_filter = None
  alpha = None
  animated = False
  antialiased or aa = False
  bbox = Bbox(x0=0.0, y0=0.0, x1=1.0, y1=1.0)
  capstyle = butt
  children = []
  clip_box = None
  clip_on = True
  clip_path = None
  contains = None
  data_transform = BboxTransformTo(     TransformedBbox(
```

(continues on next page)

(continued from previous page)

```
↪Bbox...
 edgecolor or ec = (1.0, 1.0, 1.0, 1.0)
 extents = Bbox(x0=0.0, y0=0.0, x1=640.0, y1=480.0)
 facecolor or fc = (1.0, 1.0, 1.0, 1.0)
 figure = Figure(640x480)
 fill = True
 gid = None
 hatch = None
 height = 1
 in_layout = False
 joinstyle = miter
 label =
 linestyle or ls = solid
 linewidth or lw = 0.0
 patch_transform = CompositeGenericTransform(     BboxTransformTo(    .
↪..
 path = Path(array([[0., 0.],         [1., 0.],         [1.,...
 path_effects = []
 picker = None
 rasterized = None
 sketch_params = None
 snap = None
 transform = CompositeGenericTransform(     CompositeGenericTra...
 transformed_clip_path_and_affine = (None, None)
 url = None
 verts = [[  0.   0.]  [640.   0.]  [640. 480.]  [  0. 480....
 visible = True
 width = 1
 window_extent = Bbox(x0=0.0, y0=0.0, x1=640.0, y1=480.0)
 x = 0
 xy = (0, 0)
 y = 0
 zorder = 1
```

The docstrings for all of the classes also contain the `Artist` properties, so you can consult the interactive "help" or the *matplotlib.artist* for a listing of properties for a given object.

4.5.2 Object containers

Now that we know how to inspect and set the properties of a given object we want to configure, we need to know how to get at that object. As mentioned in the introduction, there are two kinds of objects: primitives and containers. The primitives are usually the things you want to configure (the font of a *`Text`* instance, the width of a *`Line2D`*) although the containers also have some properties as well -- for example the *`Axes Artist`* is a container that contains many of the primitives in your plot, but it also has properties like the `xscale` to control whether the xaxis is 'linear' or 'log'. In this section we'll review where the various container objects store the `Artists` that you want to get at.

Figure container

The top level container `Artist` is the *matplotlib.figure.Figure*, and it contains everything in the figure. The background of the figure is a *Rectangle* which is stored in `Figure.patch`. As you add subplots (*add_subplot()*) and Axes (*add_axes()*) to the figure these will be appended to the *Figure.axes*. These are also returned by the methods that create them:

```
In [156]: fig = plt.figure()

In [157]: ax1 = fig.add_subplot(211)

In [158]: ax2 = fig.add_axes((0.1, 0.1, 0.7, 0.3))

In [159]: ax1
Out[159]: <Axes:>

In [160]: print(fig.axes)
[<Axes: >, <Axes: >]
```

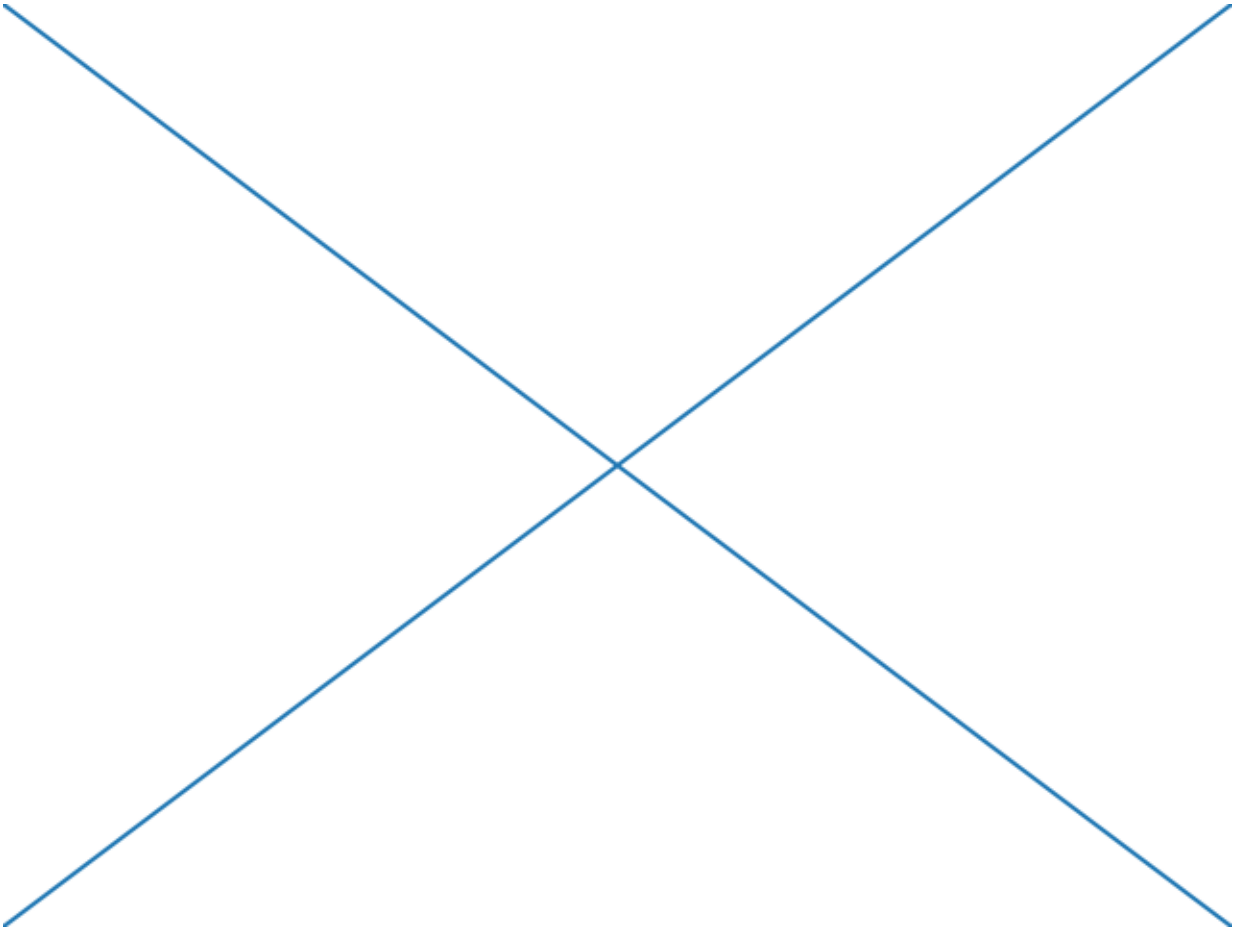
Because the figure maintains the concept of the "current Axes" (see *Figure.gca* and *Figure.sca*) to support the pylab/pyplot state machine, you should not insert or remove Axes directly from the Axes list, but rather use the *add_subplot()* and *add_axes()* methods to insert, and the *Axes.remove* method to delete. You are free however, to iterate over the list of Axes or index into it to get access to `Axes` instances you want to customize. Here is an example which turns all the Axes grids on:

```
for ax in fig.axes:
    ax.grid(True)
```

The figure also has its own `images`, `lines`, `patches` and `text` attributes, which you can use to add primitives directly. When doing so, the default coordinate system for the `Figure` will simply be in pixels (which is not usually what you want). If you instead use Figure-level methods to add Artists (e.g., using *Figure.text* to add text), then the default coordinate system will be "figure coordinates" where (0, 0) is the bottom-left of the figure and (1, 1) is the top-right of the figure.

As with all `Artists`, you can control this coordinate system by setting the transform property. You can explicitly use "figure coordinates" by setting the `Artist` transform to `fig.transFigure`:

```
import matplotlib.lines as lines

fig = plt.figure()

l1 = lines.Line2D([0, 1], [0, 1], transform=fig.transFigure,␣
 ↪figure=fig)
l2 = lines.Line2D([0, 1], [1, 0], transform=fig.transFigure,␣
 ↪figure=fig)
fig.lines.extend([l1, l2])

plt.show()
```



Here is a summary of the Artists the Figure contains

Figure attribute	Description
axes	A list of *Axes* instances
patch	The *Rectangle* background
images	A list of *FigureImage* patches - useful for raw pixel display
legends	A list of Figure *Legend* instances (different from `Axes.get_legend()`)
lines	A list of Figure *Line2D* instances (rarely used, see `Axes.lines`)
patches	A list of Figure *Patch*s (rarely used, see `Axes.patches`)
texts	A list Figure *Text* instances

Axes container

The *matplotlib.axes.Axes* is the center of the Matplotlib universe -- it contains the vast majority of all the `Artists` used in a figure with many helper methods to create and add these `Artists` to itself, as well as helper methods to access and customize the `Artists` it contains. Like the *Figure*, it contains a *Patch* `matplotlib.axes.Axes.patch` which is a *Rectangle* for Cartesian coordinates and a *Circle* for polar coordinates; this patch determines the shape, background and border of the plotting region:

```
ax = fig.add_subplot()
rect = ax.patch  # a Rectangle instance
rect.set_facecolor('green')
```

When you call a plotting method, e.g., the canonical *plot* and pass in arrays or lists of values, the method will create a *matplotlib.lines.Line2D* instance, update the line with all the Line2D properties passed as keyword arguments, add the line to the Axes, and return it to you:

```
In [213]: x, y = np.random.rand(2, 100)

In [214]: line, = ax.plot(x, y, '-', color='blue', linewidth=2)
```

plot returns a list of lines because you can pass in multiple x, y pairs to plot, and we are unpacking the first element of the length one list into the line variable. The line has been added to the Axes.lines list:

```
In [229]: print(ax.lines)
[<matplotlib.lines.Line2D at 0xd378b0c>]
```

Similarly, methods that create patches, like *bar()* creates a list of rectangles, will add the patches to the Axes.patches list:

```
In [233]: n, bins, rectangles = ax.hist(np.random.randn(1000), 50)

In [234]: rectangles
Out[234]: <BarContainer object of 50 artists>

In [235]: print(len(ax.patches))
Out[235]: 50
```

You should not add objects directly to the Axes.lines or Axes.patches lists, because the Axes needs to do a few things when it creates and adds an object:

- It sets the figure and axes property of the Artist;
- It sets the default Axes transformation (unless one is already set);
- It inspects the data contained in the Artist to update the data structures controlling auto-scaling, so that the view limits can be adjusted to contain the plotted data.

You can, nonetheless, create objects yourself and add them directly to the Axes using helper methods like *add_line* and *add_patch*. Here is an annotated interactive session illustrating what is going on:

```
In [262]: fig, ax = plt.subplots()

# create a rectangle instance
In [263]: rect = matplotlib.patches.Rectangle((1, 1), width=5,␣
 ↪height=12)

# by default the Axes instance is None
```

(continues on next page)

(continued from previous page)

```
In [264]: print(rect.axes)
None

# and the transformation instance is set to the "identity transform"
In [265]: print(rect.get_data_transform())
IdentityTransform()

# now we add the Rectangle to the Axes
In [266]: ax.add_patch(rect)

# and notice that the ax.add_patch method has set the Axes
# instance
In [267]: print(rect.axes)
Axes(0.125,0.1;0.775x0.8)

# and the transformation has been set too
In [268]: print(rect.get_data_transform())
CompositeGenericTransform(
    TransformWrapper(
        BlendedAffine2D(
            IdentityTransform(),
            IdentityTransform())),
    CompositeGenericTransform(
        BboxTransformFrom(
            TransformedBbox(
                Bbox(x0=0.0, y0=0.0, x1=1.0, y1=1.0),
                TransformWrapper(
                    BlendedAffine2D(
                        IdentityTransform(),
                        IdentityTransform())))),
        BboxTransformTo(
            TransformedBbox(
                Bbox(x0=0.125, y0=0.10999999999999999, x1=0.9,␣
 ↪y1=0.88),
                BboxTransformTo(
                    TransformedBbox(
                        Bbox(x0=0.0, y0=0.0, x1=6.4, y1=4.8),
                        Affine2D(
                            [[100.   0.   0.]
                             [  0. 100.   0.]
                             [  0.   0.   1.]]))))))))

# the default Axes transformation is ax.transData
In [269]: print(ax.transData)
CompositeGenericTransform(
    TransformWrapper(
```

(continues on next page)

(continued from previous page)

```
        BlendedAffine2D(
            IdentityTransform(),
            IdentityTransform())),
    CompositeGenericTransform(
        BboxTransformFrom(
            TransformedBbox(
                Bbox(x0=0.0, y0=0.0, x1=1.0, y1=1.0),
                TransformWrapper(
                    BlendedAffine2D(
                        IdentityTransform(),
                        IdentityTransform())))),
        BboxTransformTo(
            TransformedBbox(
                Bbox(x0=0.125, y0=0.10999999999999999, x1=0.9,␣
 ↪y1=0.88),
                BboxTransformTo(
                    TransformedBbox(
                        Bbox(x0=0.0, y0=0.0, x1=6.4, y1=4.8),
                        Affine2D(
                            [[100.   0.   0.]
                             [  0. 100.   0.]
                             [  0.   0.   1.]]))))))))

# notice that the xlimits of the Axes have not been changed
In [270]: print(ax.get_xlim())
(0.0, 1.0)

# but the data limits have been updated to encompass the rectangle
In [271]: print(ax.dataLim.bounds)
(1.0, 1.0, 5.0, 12.0)

# we can manually invoke the auto-scaling machinery
In [272]: ax.autoscale_view()

# and now the xlim are updated to encompass the rectangle, plus margins
In [273]: print(ax.get_xlim())
(0.75, 6.25)

# we have to manually force a figure draw
In [274]: fig.canvas.draw()
```

There are many, many `Axes` helper methods for creating primitive `Artists` and adding them to their respective containers. The table below summarizes a small sampling of them, the kinds of `Artist` they create, and where they store them

Axes helper method	Artist	Container
annotate - text annotations	*Annotation*	ax.texts
bar - bar charts	*Rectangle*	ax.patches
errorbar - error bar plots	*Line2D* and *Rectangle*	ax.lines and ax.patches
fill - shared area	*Polygon*	ax.patches
hist - histograms	*Rectangle*	ax.patches
imshow - image data	*AxesImage*	ax.images
legend - Axes legend	*Legend*	ax.get_legend()
plot - xy plots	*Line2D*	ax.lines
scatter - scatter charts	*PolyCollection*	ax.collections
text - text	*Text*	ax.texts

In addition to all of these Artists, the Axes contains two important Artist containers: the *XAxis* and *YAxis*, which handle the drawing of the ticks and labels. These are stored as instance variables matplotlib.axes.Axes.xaxis and matplotlib.axes.Axes.yaxis. The XAxis and YAxis containers will be detailed below, but note that the Axes contains many helper methods which forward calls on to the *Axis* instances, so you often do not need to work with them directly unless you want to. For example, you can set the font color of the XAxis ticklabels using the Axes helper method:

```
ax.tick_params(axis='x', labelcolor='orange')
```

Below is a summary of the Artists that the *Axes* contains

Axes attribute	Description
artists	An *ArtistList* of *Artist* instances
patch	*Rectangle* instance for Axes background
collections	An *ArtistList* of *Collection* instances
images	An *ArtistList* of *AxesImage*
lines	An *ArtistList* of *Line2D* instances
patches	An *ArtistList* of *Patch* instances
texts	An *ArtistList* of *Text* instances
xaxis	A *matplotlib.axis.XAxis* instance
yaxis	A *matplotlib.axis.YAxis* instance

The legend can be accessed by *get_legend*,

Axis containers

The *matplotlib.axis.Axis* instances handle the drawing of the tick lines, the grid lines, the tick labels and the axis label. You can configure the left and right ticks separately for the y-axis, and the upper and lower ticks separately for the x-axis. The Axis also stores the data and view intervals used in auto-scaling, panning and zooming, as well as the *Locator* and *Formatter* instances which control where the ticks are placed and how they are represented as strings.

Each Axis object contains a *label* attribute (this is what *set_xlabel* / *set_ylabel* modifies internally) as well as a list of major and minor ticks. The ticks are *axis.XTick* and *axis.YTick* instances,

which contain the actual line and text primitives that render the ticks and ticklabels. Because the ticks are dynamically created and modified as needed (e.g., when panning and zooming), directly working on the ticks and their parts (tick lines, tick labels, grid lines) is discouraged. Instead, the high-level concepts tick locators, tick formatters and style configuration via *tick_params* should be used. See *Axis ticks* for details.

Here is a summary of some of the useful accessor methods of the `Axis` (these have corresponding setters where useful, such as *set_major_formatter()*.)

Axis accessor method	Description
get_scale	The scale of the Axis, e.g., 'log' or 'linear'
get_view_interval	The interval instance of the Axis view limits
get_data_interval	The interval instance of the Axis data limits
get_label	The Axis label - a *Text* instance
get_major_locator	The *ticker.Locator* instance for major ticks
get_major_formatter	The *ticker.Formatter* instance for major ticks
get_minor_locator	The *ticker.Locator* instance for minor ticks
get_minor_formatter	The *ticker.Formatter* instance for minor ticks
get_tick_params	Styling of ticks, ticklabels and gridlines
grid	Turn the grid on or off for the major or minor ticks

The full Axis API can be found at *matplotlib.axis*.

4.6 User guide tutorials

Many of our tutorials were moved from this section to *Using Matplotlib*:

4.6.1 Introductory

- *Quick start guide*
- *Customizing Matplotlib with style sheets and rcParams*
- *Animations using Matplotlib*

4.6.2 Intermediate

- *Legend guide*
- *Styling with cycler*
- *Constrained layout guide*
- *Tight layout guide*
- *Arranging multiple Axes in a Figure*
- *Axis autoscaling*
- *Positioning and orientation of imshow images*

4.6.3 Advanced

- *Faster rendering by using blitting*
- *Path Tutorial*
- *Path effects guide*
- *Transformations Tutorial*

4.6.4 Colors

See *Colors*.

4.6.5 Text

See *Text*.

4.6.6 Toolkits

See *User Toolkits*.

What can Matplotlib do?

CHAPTER

FIVE

PLOT TYPES

Overview of many common plotting commands provided by Matplotlib.

See the gallery for more examples and the tutorials page for longer examples.

5.1 Pairwise data

Plots of pairwise (x, y), tabular $(var_0, \cdots, var_n)$, and functional $f(x) = y$ data.

5.2 Statistical distributions

Plots of the distribution of at least one variable in a dataset. Some of these methods also compute the distributions.

5.3 Gridded data

Plots of arrays and images $Z_{i,j}$ and fields $U_{i,j}, V_{i,j}$ on regular grids and corresponding coordinate grids $X_{i,j}, Y_{i,j}$.

5.4 Irregularly gridded data

Plots of data $Z_{x,y}$ on unstructured grids , unstructured coordinate grids (x, y), and 2D functions $f(x, y) = z$.

5.5 3D and volumetric data

Plots of three-dimensional (x, y, z), surface $f(x, y) = z$, and volumetric $V_{x,y,z}$ data using the `mpl_toolkits.mplot3d` library.

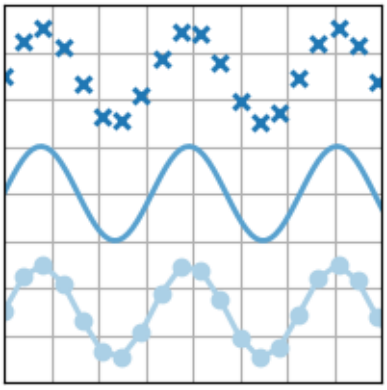
5.5.1 Pairwise data

Plots of pairwise (x, y), tabular $(var_0, \cdots, var_n)$, and functional $f(x) = y$ data.

plot(x, y)

Plot y versus x as lines and/or markers.

See *plot*.

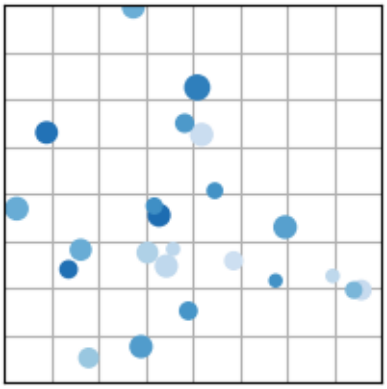


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data
x = np.linspace(0, 10, 100)
y = 4 + 1 * np.sin(2 * x)
x2 = np.linspace(0, 10, 25)
y2 = 4 + 1 * np.sin(2 * x2)

# plot
fig, ax = plt.subplots()

ax.plot(x2, y2 + 2.5, 'x', markeredgewidth=2)
ax.plot(x, y, linewidth=2.0)
ax.plot(x2, y2 - 2.5, 'o-', linewidth=2)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

scatter(x, y)

A scatter plot of y versus x with varying marker size and/or color.

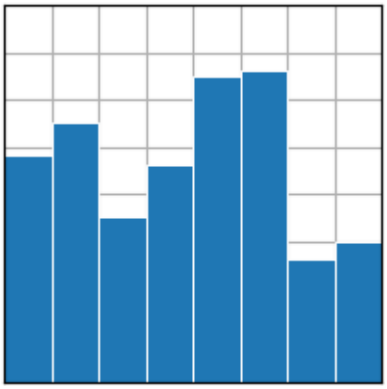
See *scatter*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make the data
np.random.seed(3)
x = 4 + np.random.normal(0, 2, 24)
y = 4 + np.random.normal(0, 2, len(x))
# size and color:
sizes = np.random.uniform(15, 80, len(x))
colors = np.random.uniform(15, 80, len(x))

# plot
fig, ax = plt.subplots()

ax.scatter(x, y, s=sizes, c=colors, vmin=0, vmax=100)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

bar(x, height)

See *bar*.

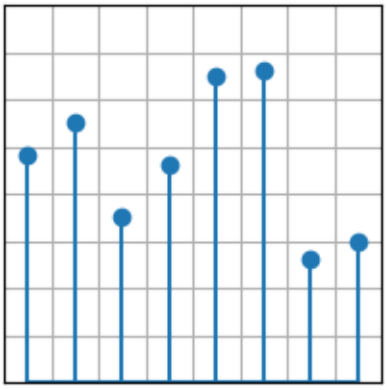


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data:
x = 0.5 + np.arange(8)
y = [4.8, 5.5, 3.5, 4.6, 6.5, 6.6, 2.6, 3.0]

# plot
fig, ax = plt.subplots()

ax.bar(x, y, width=1, edgecolor="white", linewidth=0.7)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

stem(x, y)

Create a stem plot.

See *stem*.

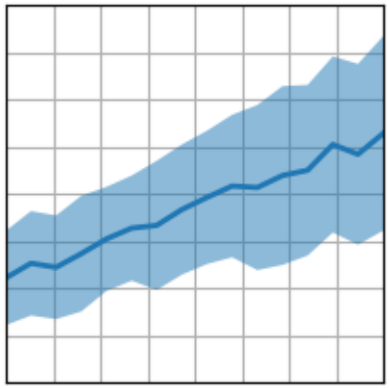


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data
x = 0.5 + np.arange(8)
y = [4.8, 5.5, 3.5, 4.6, 6.5, 6.6, 2.6, 3.0]

# plot
fig, ax = plt.subplots()

ax.stem(x, y)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

fill_between(x, y1, y2)

Fill the area between two horizontal curves.

See *fill_between*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data
np.random.seed(1)
x = np.linspace(0, 8, 16)
y1 = 3 + 4*x/8 + np.random.uniform(0.0, 0.5, len(x))
y2 = 1 + 2*x/8 + np.random.uniform(0.0, 0.5, len(x))
```

(continues on next page)

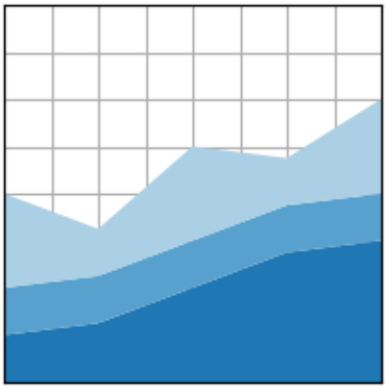
(continued from previous page)

```
# plot
fig, ax = plt.subplots()

ax.fill_between(x, y1, y2, alpha=.5, linewidth=0)
ax.plot(x, (y1 + y2)/2, linewidth=2)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

stackplot(x, y)

Draw a stacked area plot or a streamgraph.

See *stackplot*



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data
x = np.arange(0, 10, 2)
ay = [1, 1.25, 2, 2.75, 3]
by = [1, 1, 1, 1, 1]
cy = [2, 1, 2, 1, 2]
y = np.vstack([ay, by, cy])

# plot
fig, ax = plt.subplots()

ax.stackplot(x, y)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
```

(continues on next page)

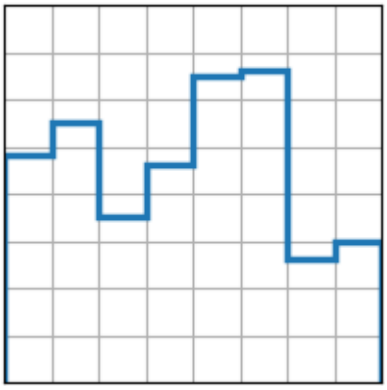
(continued from previous page)

```
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

stairs(values)

Draw a stepwise constant function as a line or a filled plot.

See *stairs* when plotting y between (x_i, x_{i+1}). For plotting y at x, see *step*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data
y = [4.8, 5.5, 3.5, 4.6, 6.5, 6.6, 2.6, 3.0]

# plot
fig, ax = plt.subplots()

ax.stairs(y, linewidth=2.5)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

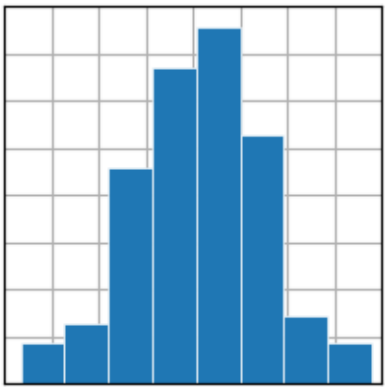
5.5.2 Statistical distributions

Plots of the distribution of at least one variable in a dataset. Some of these methods also compute the distributions.

hist(x)

Compute and plot a histogram.

See *hist*.

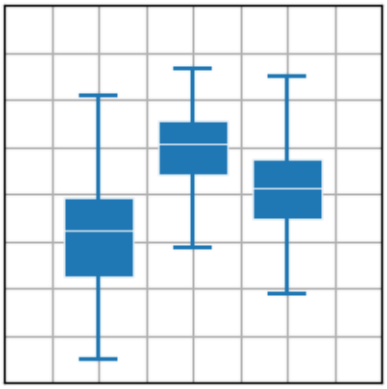


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data
np.random.seed(1)
x = 4 + np.random.normal(0, 1.5, 200)

# plot:
fig, ax = plt.subplots()

ax.hist(x, bins=8, linewidth=0.5, edgecolor="white")

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 56), yticks=np.linspace(0, 56, 9))

plt.show()
```

boxplot(X)

Draw a box and whisker plot.

See *boxplot*.

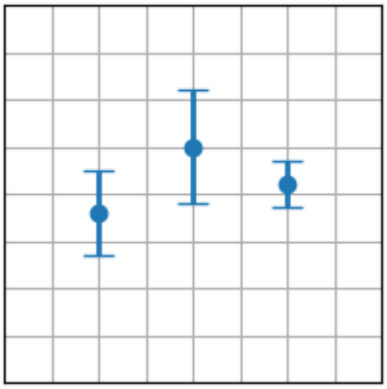


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data:
np.random.seed(10)
D = np.random.normal((3, 5, 4), (1.25, 1.00, 1.25), (100, 3))

# plot
fig, ax = plt.subplots()
VP = ax.boxplot(D, positions=[2, 4, 6], widths=1.5, patch_artist=True,
                showmeans=False, showfliers=False,
                medianprops={"color": "white", "linewidth": 0.5},
                boxprops={"facecolor": "C0", "edgecolor": "white",
                          "linewidth": 0.5},
                whiskerprops={"color": "C0", "linewidth": 1.5},
                capprops={"color": "C0", "linewidth": 1.5})

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

errorbar(x, y, yerr, xerr)

Plot y versus x as lines and/or markers with attached errorbars.

See *errorbar*.

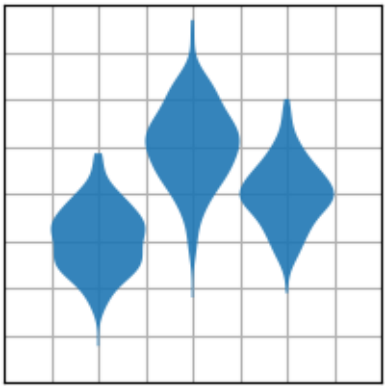


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data:
np.random.seed(1)
x = [2, 4, 6]
y = [3.6, 5, 4.2]
yerr = [0.9, 1.2, 0.5]

# plot:
fig, ax = plt.subplots()

ax.errorbar(x, y, yerr, fmt='o', linewidth=2, capsize=6)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

violinplot(D)

Make a violin plot.

See *violinplot*.

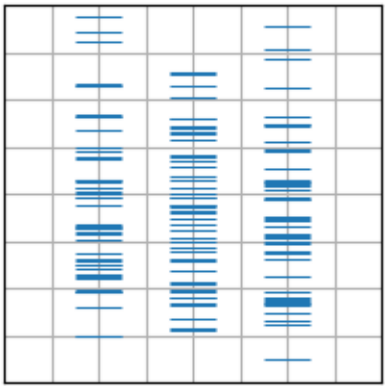


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data:
np.random.seed(10)
D = np.random.normal((3, 5, 4), (0.75, 1.00, 0.75), (200, 3))

# plot:
fig, ax = plt.subplots()

vp = ax.violinplot(D, [2, 4, 6], widths=2,
                   showmeans=False, showmedians=False,␣
 ↪showextrema=False)
# styling:
for body in vp['bodies']:
    body.set_alpha(0.9)
ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

eventplot(D)

Plot identical parallel lines at the given positions.

See *eventplot*.

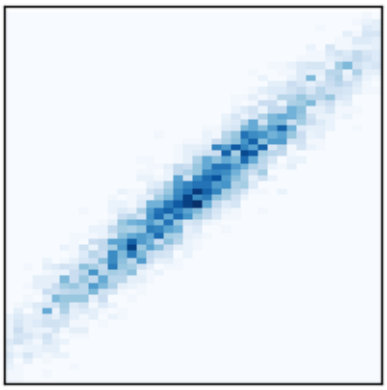


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data:
np.random.seed(1)
x = [2, 4, 6]
D = np.random.gamma(4, size=(3, 50))

# plot:
fig, ax = plt.subplots()

ax.eventplot(D, orientation="vertical", lineoffsets=x, linewidth=0.75)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

hist2d(x, y)

Make a 2D histogram plot.

See *hist2d*.

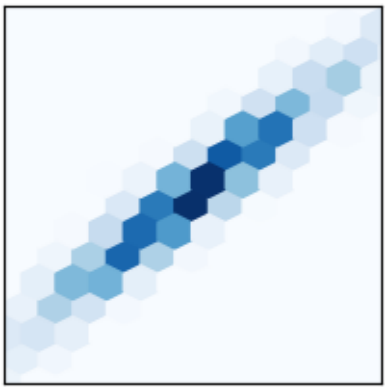


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data: correlated + noise
np.random.seed(1)
x = np.random.randn(5000)
y = 1.2 * x + np.random.randn(5000) / 3

# plot:
fig, ax = plt.subplots()

ax.hist2d(x, y, bins=(np.arange(-3, 3, 0.1), np.arange(-3, 3, 0.1)))

ax.set(xlim=(-2, 2), ylim=(-3, 3))

plt.show()
```

hexbin(x, y, C)

Make a 2D hexagonal binning plot of points x, y.

See *hexbin*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data: correlated + noise
np.random.seed(1)
x = np.random.randn(5000)
y = 1.2 * x + np.random.randn(5000) / 3

# plot:
```

(continues on next page)

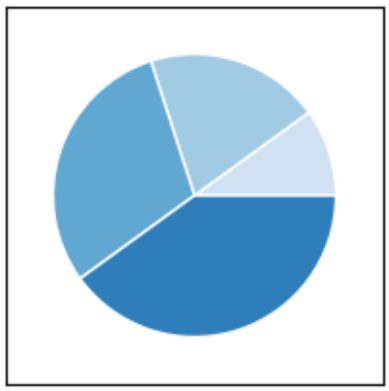
(continued from previous page)

```
fig, ax = plt.subplots()

ax.hexbin(x, y, gridsize=20)

ax.set(xlim=(-2, 2), ylim=(-3, 3))

plt.show()
```

pie(x)

Plot a pie chart.

See *pie*.

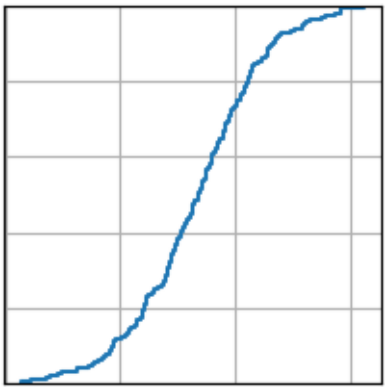


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')


# make data
x = [1, 2, 3, 4]
colors = plt.get_cmap('Blues')(np.linspace(0.2, 0.7, len(x)))

# plot
fig, ax = plt.subplots()
ax.pie(x, colors=colors, radius=3, center=(4, 4),
       wedgeprops={"linewidth": 1, "edgecolor": "white"}, frame=True)

ax.set(xlim=(0, 8), xticks=np.arange(1, 8),
       ylim=(0, 8), yticks=np.arange(1, 8))

plt.show()
```

ecdf(x)

Compute and plot the empirical cumulative distribution function of x.

See *ecdf*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# make data
np.random.seed(1)
x = 4 + np.random.normal(0, 1.5, 200)

# plot:
fig, ax = plt.subplots()
ax.ecdf(x)
plt.show()
```

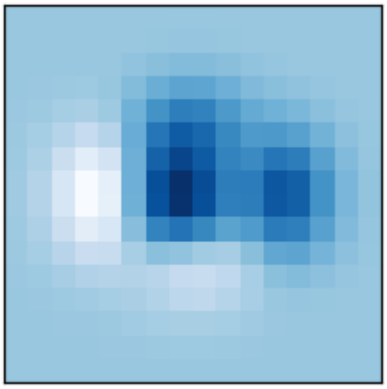
5.5.3 Gridded data

Plots of arrays and images $Z_{i,j}$ and fields $U_{i,j}, V_{i,j}$ on regular grids and corresponding coordinate grids $X_{i,j}, Y_{i,j}$.

imshow(Z)

Display data as an image, i.e., on a 2D regular raster.

See *imshow*.

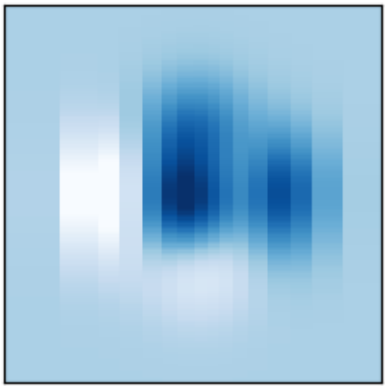


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data
X, Y = np.meshgrid(np.linspace(-3, 3, 16), np.linspace(-3, 3, 16))
Z = (1 - X/2 + X**5 + Y**3) * np.exp(-X**2 - Y**2)

# plot
fig, ax = plt.subplots()

ax.imshow(Z, origin='lower')

plt.show()
```

pcolormesh(X, Y, Z)

Create a pseudocolor plot with a non-regular rectangular grid.

pcolormesh is more flexible than *imshow* in that the x and y vectors need not be equally spaced (indeed they can be skewed).



```
import matplotlib.pyplot as plt
```

(continues on next page)

(continued from previous page)

```
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data with uneven sampling in x
x = [-3, -2, -1.6, -1.2, -.8, -.5, -.2, .1, .3, .5, .8, 1.1, 1.5, 1.9,␣
↪2.3, 3]
X, Y = np.meshgrid(x, np.linspace(-3, 3, 128))
Z = (1 - X/2 + X**5 + Y**3) * np.exp(-X**2 - Y**2)

# plot
fig, ax = plt.subplots()

ax.pcolormesh(X, Y, Z, vmin=-0.5, vmax=1.0)

plt.show()
```

contour(X, Y, Z)

Plot contour lines.

See *contour*.

```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data
X, Y = np.meshgrid(np.linspace(-3, 3, 256), np.linspace(-3, 3, 256))
Z = (1 - X/2 + X**5 + Y**3) * np.exp(-X**2 - Y**2)
levels = np.linspace(np.min(Z), np.max(Z), 7)

# plot
fig, ax = plt.subplots()
```

(continues on next page)

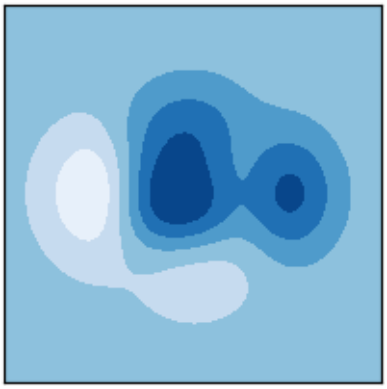
(continued from previous page)

```
ax.contour(X, Y, Z, levels=levels)

plt.show()
```

contourf(X, Y, Z)

Plot filled contours.

See *contourf*.

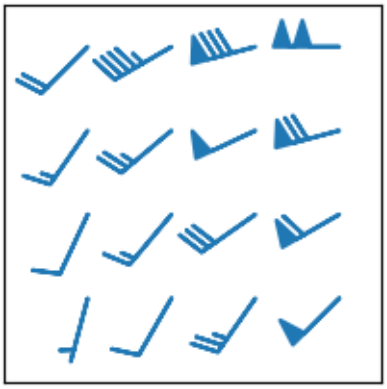


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data
X, Y = np.meshgrid(np.linspace(-3, 3, 256), np.linspace(-3, 3, 256))
Z = (1 - X/2 + X**5 + Y**3) * np.exp(-X**2 - Y**2)
levels = np.linspace(Z.min(), Z.max(), 7)

# plot
fig, ax = plt.subplots()

ax.contourf(X, Y, Z, levels=levels)

plt.show()
```

barbs(X, Y, U, V)

Plot a 2D field of wind barbs.

See *barbs*.

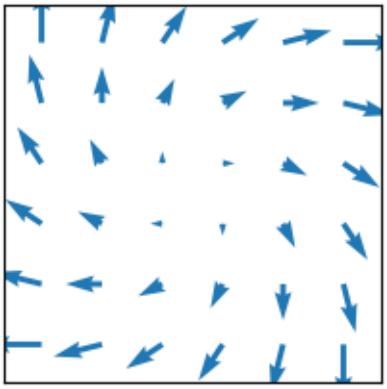


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data:
X, Y = np.meshgrid([1, 2, 3, 4], [1, 2, 3, 4])
angle = np.pi / 180 * np.array([[15., 30, 35, 45],
                                [25., 40, 55, 60],
                                [35., 50, 65, 75],
                                [45., 60, 75, 90]])
amplitude = np.array([[5, 10, 25, 50],
                      [10, 15, 30, 60],
                      [15, 26, 50, 70],
                      [20, 45, 80, 100]])
U = amplitude * np.sin(angle)
V = amplitude * np.cos(angle)

# plot:
fig, ax = plt.subplots()

ax.barbs(X, Y, U, V, barbcolor='C0', flagcolor='C0', length=7,␣
 ↪linewidth=1.5)

ax.set(xlim=(0, 4.5), ylim=(0, 4.5))

plt.show()
```

quiver(X, Y, U, V)

Plot a 2D field of arrows.

See *quiver*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data
x = np.linspace(-4, 4, 6)
y = np.linspace(-4, 4, 6)
X, Y = np.meshgrid(x, y)
U = X + Y
V = Y - X

# plot
fig, ax = plt.subplots()

ax.quiver(X, Y, U, V, color="C0", angles='xy',
          scale_units='xy', scale=5, width=.015)

ax.set(xlim=(-5, 5), ylim=(-5, 5))

plt.show()
```

streamplot(X, Y, U, V)

Draw streamlines of a vector flow.

See *streamplot*.

```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make a stream function:
X, Y = np.meshgrid(np.linspace(-3, 3, 256), np.linspace(-3, 3, 256))
Z = (1 - X/2 + X**5 + Y**3) * np.exp(-X**2 - Y**2)
# make U and V out of the streamfunction:
V = np.diff(Z[1:, :], axis=1)
U = -np.diff(Z[:, 1:], axis=0)

# plot:
fig, ax = plt.subplots()

ax.streamplot(X[1:, 1:], Y[1:, 1:], U, V)

plt.show()
```

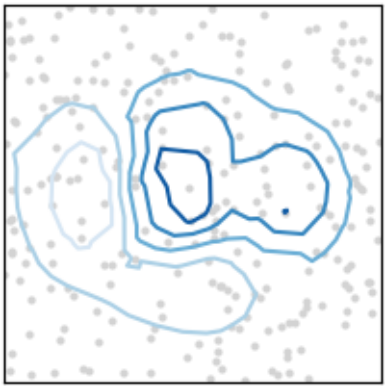
5.5.4 Irregularly gridded data

Plots of data $Z_{x,y}$ on unstructured grids , unstructured coordinate grids (x, y), and 2D functions $f(x, y) = z$.

tricontour(x, y, z)

Draw contour lines on an unstructured triangular grid.

See *tricontour*.

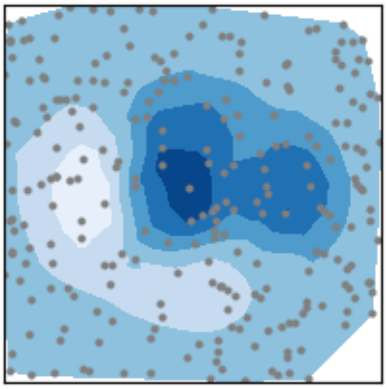


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data:
np.random.seed(1)
x = np.random.uniform(-3, 3, 256)
y = np.random.uniform(-3, 3, 256)
z = (1 - x/2 + x**5 + y**3) * np.exp(-x**2 - y**2)
levels = np.linspace(z.min(), z.max(), 7)

# plot:
fig, ax = plt.subplots()

ax.plot(x, y, 'o', markersize=2, color='lightgrey')
ax.tricontour(x, y, z, levels=levels)

ax.set(xlim=(-3, 3), ylim=(-3, 3))

plt.show()
```

tricontourf(x, y, z)

Draw contour regions on an unstructured triangular grid.

See *tricontourf*.

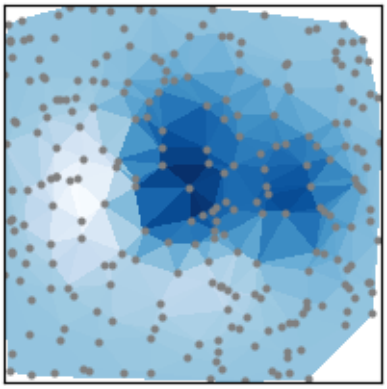


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data:
np.random.seed(1)
x = np.random.uniform(-3, 3, 256)
y = np.random.uniform(-3, 3, 256)
z = (1 - x/2 + x**5 + y**3) * np.exp(-x**2 - y**2)
levels = np.linspace(z.min(), z.max(), 7)

# plot:
fig, ax = plt.subplots()

ax.plot(x, y, 'o', markersize=2, color='grey')
ax.tricontourf(x, y, z, levels=levels)

ax.set(xlim=(-3, 3), ylim=(-3, 3))

plt.show()
```

tripcolor(x, y, z)

Create a pseudocolor plot of an unstructured triangular grid.

See *tripcolor*.

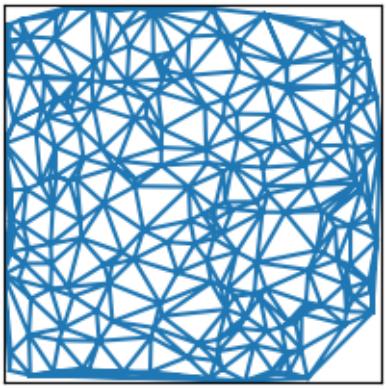


```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data:
np.random.seed(1)
x = np.random.uniform(-3, 3, 256)
y = np.random.uniform(-3, 3, 256)
z = (1 - x/2 + x**5 + y**3) * np.exp(-x**2 - y**2)

# plot:
fig, ax = plt.subplots()

ax.plot(x, y, 'o', markersize=2, color='grey')
ax.tripcolor(x, y, z)

ax.set(xlim=(-3, 3), ylim=(-3, 3))

plt.show()
```

triplot(x, y)

Draw an unstructured triangular grid as lines and/or markers.

See *triplot*.



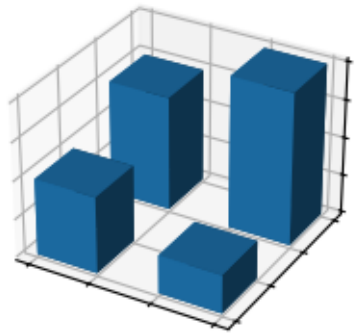
```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery-nogrid')

# make data:
np.random.seed(1)
x = np.random.uniform(-3, 3, 256)
y = np.random.uniform(-3, 3, 256)
z = (1 - x/2 + x**5 + y**3) * np.exp(-x**2 - y**2)

# plot:
fig, ax = plt.subplots()

ax.triplot(x, y)

ax.set(xlim=(-3, 3), ylim=(-3, 3))

plt.show()
```

5.5.5 3D and volumetric data

Plots of three-dimensional (x, y, z), surface $f(x, y) = z$, and volumetric $V_{x,y,z}$ data using the *mpl_toolkits.mplot3d* library.

bar3d(x, y, z, dx, dy, dz)

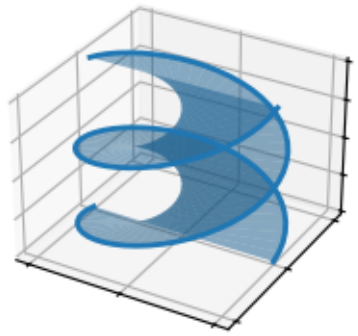
See *bar3d*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# Make data
x = [1, 1, 2, 2]
y = [1, 2, 1, 2]
z = [0, 0, 0, 0]
dx = np.ones_like(x)*0.5
dy = np.ones_like(x)*0.5
dz = [2, 3, 1, 4]

# Plot
fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
ax.bar3d(x, y, z, dx, dy, dz)

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

fill_between(x1, y1, z1, x2, y2, z2)

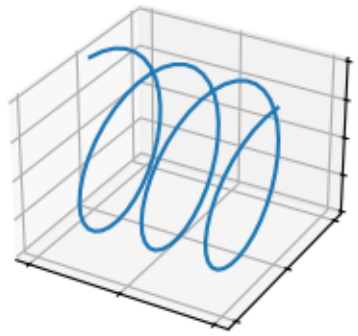
See *fill_between*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# Make data for a double helix
n = 50
theta = np.linspace(0, 2*np.pi, n)
x1 = np.cos(theta)
y1 = np.sin(theta)
z1 = np.linspace(0, 1, n)
x2 = np.cos(theta + np.pi)
y2 = np.sin(theta + np.pi)
z2 = z1

# Plot
fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
ax.fill_between(x1, y1, z1, x2, y2, z2, alpha=0.5)
ax.plot(x1, y1, z1, linewidth=2, color='C0')
ax.plot(x2, y2, z2, linewidth=2, color='C0')

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

plot(xs, ys, zs)

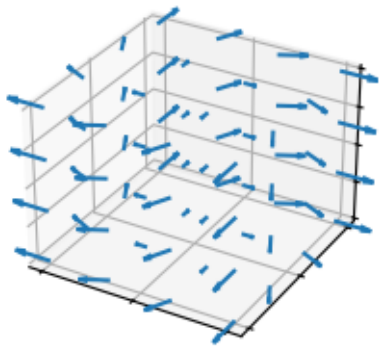
See *plot*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# Make data
n = 100
xs = np.linspace(0, 1, n)
ys = np.sin(xs * 6 * np.pi)
zs = np.cos(xs * 6 * np.pi)

# Plot
fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
ax.plot(xs, ys, zs)

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

quiver(X, Y, Z, U, V, W)

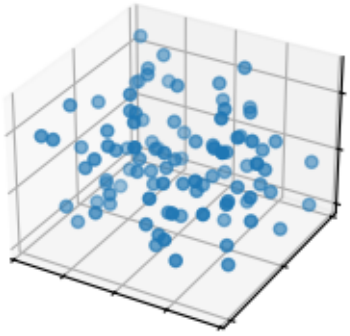
See *quiver*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# Make data
n = 4
x = np.linspace(-1, 1, n)
y = np.linspace(-1, 1, n)
z = np.linspace(-1, 1, n)
X, Y, Z = np.meshgrid(x, y, z)
U = (X + Y)/5
V = (Y - X)/5
W = Z*0


# Plot
fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
ax.quiver(X, Y, Z, U, V, W)

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

scatter(xs, ys, zs)

See *scatter*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')
```

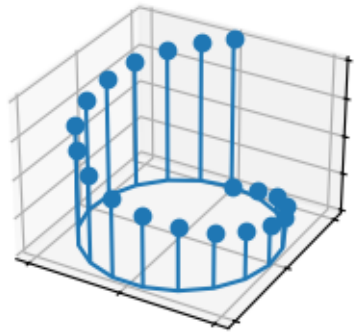
(continues on next page)

(continued from previous page)

```
# Make data
np.random.seed(19680801)
n = 100
rng = np.random.default_rng()
xs = rng.uniform(23, 32, n)
ys = rng.uniform(0, 100, n)
zs = rng.uniform(-50, -25, n)

# Plot
fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
ax.scatter(xs, ys, zs)

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

stem(x, y, z)

See *stem*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# Make data
n = 20
x = np.sin(np.linspace(0, 2*np.pi, n))
y = np.cos(np.linspace(0, 2*np.pi, n))
z = np.linspace(0, 1, n)

# Plot
```

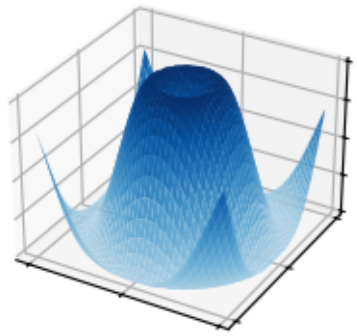
(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
ax.stem(x, y, z)

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

plot_surface(X, Y, Z)

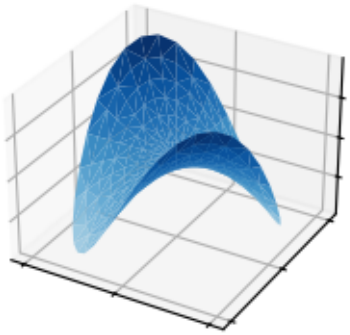
See *plot_surface*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# Make data
X = np.arange(-5, 5, 0.25)
Y = np.arange(-5, 5, 0.25)
X, Y = np.meshgrid(X, Y)
R = np.sqrt(X**2 + Y**2)
Z = np.sin(R)

# Plot the surface
fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
ax.plot_surface(X, Y, Z, vmin=Z.min() * 2, cmap="Blues")

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

plot_trisurf(x, y, z)

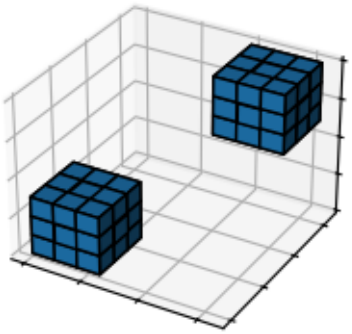
See *plot_trisurf*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

n_radii = 8
n_angles = 36

# Make radii and angles spaces
radii = np.linspace(0.125, 1.0, n_radii)
angles = np.linspace(0, 2*np.pi, n_angles, endpoint=False)[..., np.
 ↪newaxis]

# Convert polar (radii, angles) coords to cartesian (x, y) coords.
x = np.append(0, (radii*np.cos(angles)).flatten())
y = np.append(0, (radii*np.sin(angles)).flatten())
z = np.sin(-x*y)

# Plot
fig, ax = plt.subplots(subplot_kw={'projection': '3d'})
ax.plot_trisurf(x, y, z, vmin=z.min() * 2, cmap="Blues")

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

voxels([x, y, z], filled)

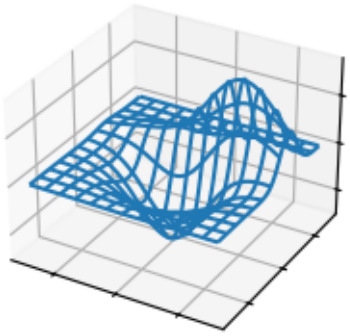
See *voxels*.



```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('_mpl-gallery')

# Prepare some coordinates
x, y, z = np.indices((8, 8, 8))

# Draw cuboids in the top left and bottom right corners
cube1 = (x < 3) & (y < 3) & (z < 3)
cube2 = (x >= 5) & (y >= 5) & (z >= 5)

# Combine the objects into a single boolean array
voxelarray = cube1 | cube2

# Plot
fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
ax.voxels(voxelarray, edgecolor='k')

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

plot_wireframe(X, Y, Z)

See *plot_wireframe*.



```
import matplotlib.pyplot as plt

from mpl_toolkits.mplot3d import axes3d

plt.style.use('_mpl-gallery')

# Make data
X, Y, Z = axes3d.get_test_data(0.05)

# Plot
fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
ax.plot_wireframe(X, Y, Z, rstride=10, cstride=10)

ax.set(xticklabels=[],
       yticklabels=[],
       zticklabels=[])

plt.show()
```

CHAPTER

SIX

EXAMPLES

For an overview of the plotting methods we provide, see *Plot types*

This page contains example plots. Click on any image to see the full image and source code.

For longer tutorials, see our *tutorials page*. You can also find *external resources* and a *FAQ* in our *user guide*.

Tagging!

You can also browse the example gallery by tags.

6.1 Lines, bars and markers

6.2 Images, contours and fields

6.3 Statistics

6.4 Pie and polar charts

6.5 Subplots, axes and figures

6.6 Ticks

6.7 Scales

These examples cover how different scales are handled in Matplotlib.

6.8 Spines

6.9 Text, labels and annotations

6.10 Shapes and collections

6.11 Color

For a description of the colormaps available in Matplotlib, see the *colormaps tutorial*.

6.12 Style sheets

6.13 Module - pyplot

6.14 3D plotting

6.15 Module - axes_grid1

6.16 Module - axisartist

6.17 Animation

6.18 Widgets

Examples of how to write primitive, but GUI agnostic, widgets in matplotlib

6.19 Event handling

Matplotlib supports *event handling* with a GUI neutral event model, so you can connect to Matplotlib events without knowledge of what user interface Matplotlib will ultimately be plugged in to. This has two advantages: the code you write will be more portable, and Matplotlib events are aware of things like data coordinate space and which axes the event occurs in so you don't have to mess with low level transformation details to go from canvas space to data space. Object picking examples are also included.

6.20 Embedding Matplotlib in graphical user interfaces

You can embed Matplotlib directly into a user interface application by following the embedding_in_SOMEGUI.py examples here. Currently Matplotlib supports PyQt/PySide, PyGObject, Tkinter, and wxPython.

When embedding Matplotlib in a GUI, you must use the Matplotlib API directly rather than the pylab/pyplot procedural interface, so take a look at the examples/api directory for some example code working with the API.

6.21 Units

These examples cover the many representations of units in Matplotlib.

6.22 Miscellaneous

6.23 Showcase

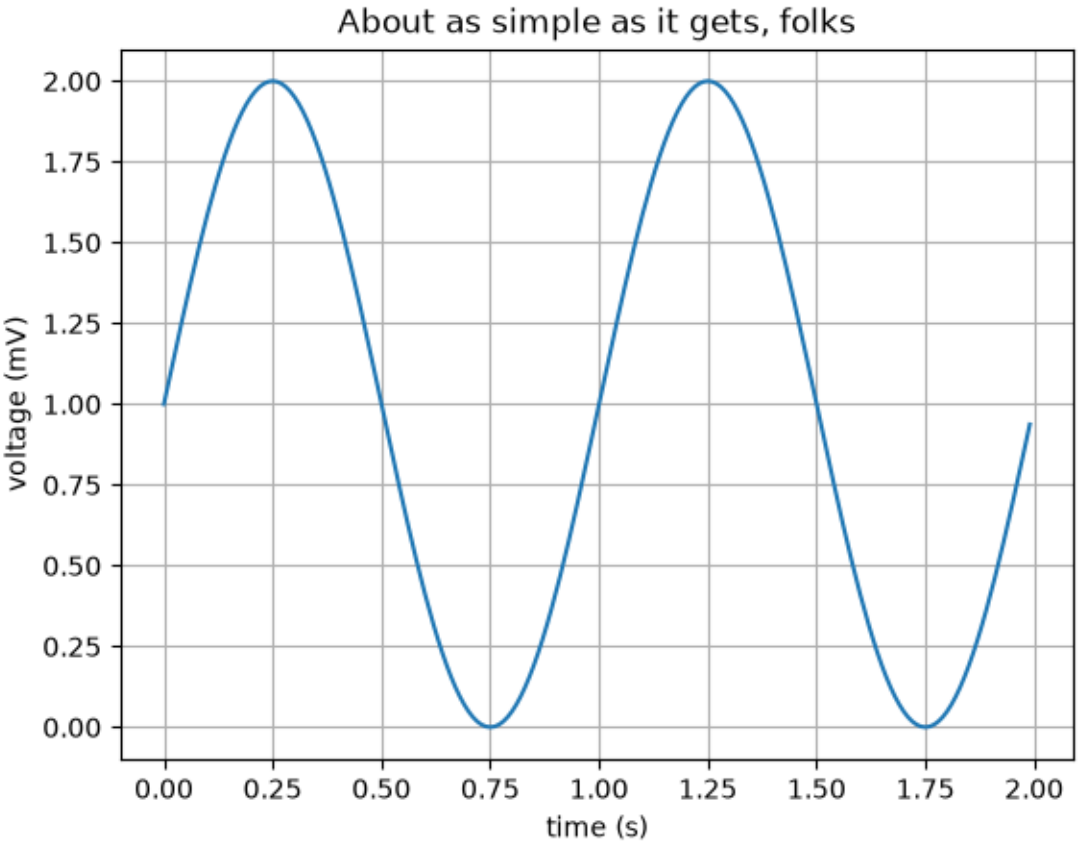
6.24 Specialty plots

6.24.1 Lines, bars and markers

Line plot

Create a basic line plot.

```
import matplotlib.pyplot as plt
import numpy as np

# Data for plotting
t = np.arange(0.0, 2.0, 0.01)
s = 1 + np.sin(2 * np.pi * t)

fig, ax = plt.subplots()
ax.plot(t, s)

ax.set(xlabel='time (s)', ylabel='voltage (mV)',
       title='About as simple as it gets, folks')
ax.grid()

fig.savefig("test.png")
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.plot* / *matplotlib.pyplot.plot*
- *matplotlib.pyplot.subplots*
- *matplotlib.figure.Figure.savefig*

Tags: plot-type: line level: beginner

Linestyles

Simple linestyles can be defined using the strings "solid", "dotted", "dashed" or "dashdot". More refined control can be achieved by providing a dash tuple `(offset, (on_off_seq))`. For example, `(0, (3, 10, 1, 15))` means (3pt line, 10pt space, 1pt line, 15pt space) with no offset, while `(5, (10, 3))`, means (10pt line, 3pt space), but skip the first 5pt line. See also *Line2D.set_linestyle*. The specific on/off sequences of the "dotted", "dashed" and "dashdot" styles are configurable:

- *rcParams["lines.dotted_pattern"]* (default: `[1.0, 1.65]`)
- *rcParams["lines.dashed_pattern"]* (default: `[3.7, 1.6]`)

- *rcParams["lines.dashdot_pattern"]* (default: [6.4, 1.6, 1.0, 1.6])

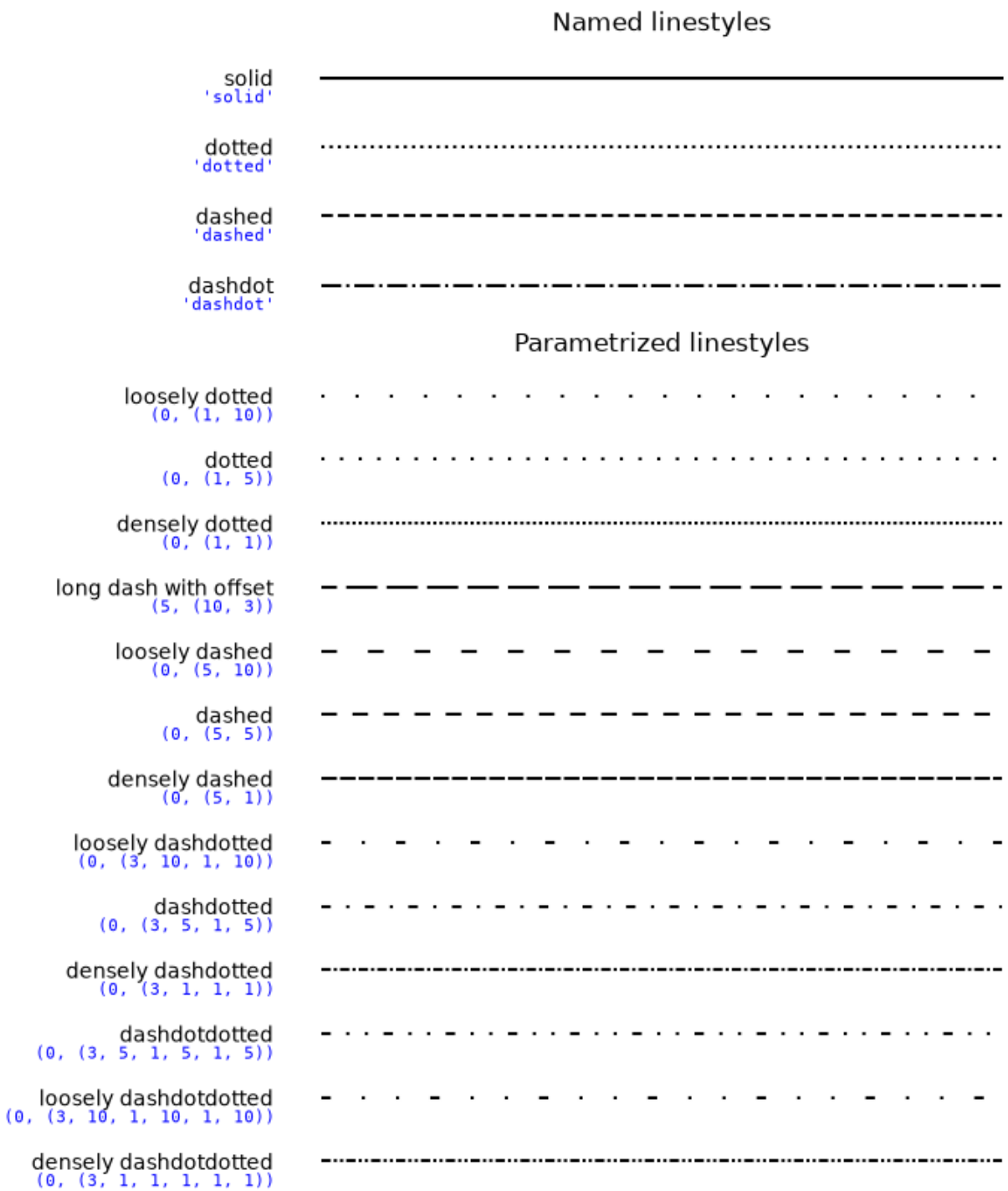
Note: The dash style can also be configured via *Line2D.set_dashes* as shown in *Dashed line style configuration* and passing a list of dash sequences using the keyword *dashes* to the cycler in *property_cycle*.

```
import matplotlib.pyplot as plt
import numpy as np

linestyle_str = [
     ('solid', 'solid'),      # Same as (0, ()) or '-'
     ('dotted', 'dotted'),    # Same as ':'
     ('dashed', 'dashed'),    # Same as '--'
     ('dashdot', 'dashdot')]  # Same as '-.'

linestyle_tuple = [
     ('loosely dotted',         (0, (1, 10))),
     ('dotted',                 (0, (1, 5))),
     ('densely dotted',         (0, (1, 1))),

     ('long dash with offset', (5, (10, 3))),
     ('loosely dashed',         (0, (5, 10))),
     ('dashed',                 (0, (5, 5))),
     ('densely dashed',         (0, (5, 1))),

     ('loosely dashdotted',     (0, (3, 10, 1, 10))),
     ('dashdotted',             (0, (3, 5, 1, 5))),
     ('densely dashdotted',     (0, (3, 1, 1, 1))),

     ('dashdotdotted',          (0, (3, 5, 1, 5, 1, 5))),
     ('loosely dashdotdotted', (0, (3, 10, 1, 10, 1, 10))),
     ('densely dashdotdotted', (0, (3, 1, 1, 1, 1, 1)))]


def plot_linestyles(ax, linestyles, title):
    X, Y = np.linspace(0, 100, 10), np.zeros(10)
    yticklabels = []

    for i, (name, linestyle) in enumerate(linestyles):
        ax.plot(X, Y+i, linestyle=linestyle, linewidth=1.5, color=
↪'black')
        yticklabels.append(name)

    ax.set_title(title)
    ax.set(ylim=(-0.5, len(linestyles)-0.5),
           yticks=np.arange(len(linestyles)),
           yticklabels=yticklabels)
    ax.tick_params(left=False, bottom=False, labelbottom=False)
    ax.spines[:].set_visible(False)
```

(continues on next page)

(continued from previous page)

```
    # For each line style, add a text annotation with a small offset␣
 ↪from
    # the reference point (0 in Axes coords, y tick value in Data␣
 ↪coords).
    for i, (name, linestyle) in enumerate(linestyles):
        ax.annotate(repr(linestyle),
                    xy=(0.0, i), xycoords=ax.get_yaxis_transform(),
                    xytext=(-6, -12), textcoords='offset points',
                    color="blue", fontsize=8, ha="right", family=
 ↪"monospace")


fig, (ax0, ax1) = plt.subplots(2, 1, figsize=(7, 8), height_ratios=[1,␣
 ↪3],
                               layout='constrained')

plot_linestyles(ax0, linestyle_str[::-1], title='Named linestyles')
plot_linestyles(ax1, linestyle_tuple[::-1], title='Parametrized␣
 ↪linestyles')

plt.show()
```



Tags: styling: linestyle purpose: reference

Dashed line style configuration

The dashing of a line is controlled via a dash sequence. It can be modified using *`Line2D.set_dashes`*.

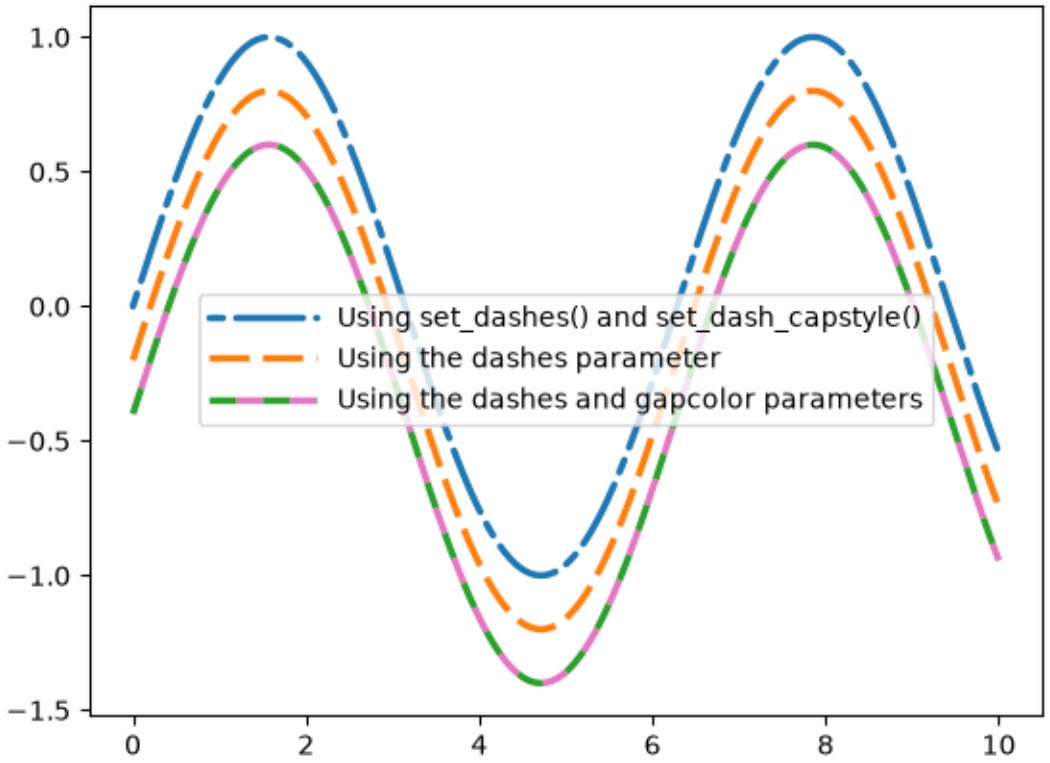
The dash sequence is a series of on/off lengths in points, e.g. `[3, 1]` would be 3pt long lines separated by 1pt spaces.

Some functions like *Axes.plot* support passing Line properties as keyword arguments. In such a case, you can already set the dashing when creating the line.

Note: The dash style can also be configured via a *property_cycle* by passing a list of dash sequences using the keyword *dashes* to the cycler. This is not shown within this example.

Other attributes of the dash may also be set either with the relevant method (*set_dash_capstyle*, *set_dash_joinstyle*, *set_gapcolor*) or by passing the property through a plotting function.

```
import matplotlib.pyplot as plt
import numpy as np

x = np.linspace(0, 10, 500)
y = np.sin(x)

plt.rc('lines', linewidth=2.5)
fig, ax = plt.subplots()

# Using set_dashes() and set_capstyle() to modify dashing of an␣
↪existing line.
line1, = ax.plot(x, y, label='Using set_dashes() and␣
↪set_dash_capstyle()')
line1.set_dashes([2, 2, 10, 2])  # 2pt line, 2pt break, 10pt line, 2pt␣
↪break.
line1.set_dash_capstyle('round')

# Using plot(..., dashes=...) to set the dashing when creating a line.
line2, = ax.plot(x, y - 0.2, dashes=[6, 2], label='Using the dashes␣
↪parameter')

# Using plot(..., dashes=..., gapcolor=...) to set the dashing and
# alternating color when creating a line.
line3, = ax.plot(x, y - 0.4, dashes=[4, 4], gapcolor='tab:pink',
                 label='Using the dashes and gapcolor parameters')

ax.legend(handlelength=4)
plt.show()
```



Tags: styling: linestyle plot-type: line level: beginner

Markevery Demo

The `markevery` property of *`Line2D`* allows drawing markers at a subset of data points.

The list of possible parameters is specified at *`Line2D.set_markevery`*. In short:

- A single integer N draws every N-th marker.
- A tuple of integers (start, N) draws every N-th marker, starting at data index *start*.
- A list of integers draws the markers at the specified indices.
- A slice draws the markers at the sliced indices.
- A float specifies the distance between markers as a fraction of the Axes diagonal in screen space. This will lead to a visually uniform distribution of the points along the line, irrespective of scales and zooming.

```
import matplotlib.pyplot as plt
import numpy as np

# define a list of markevery cases to plot
```

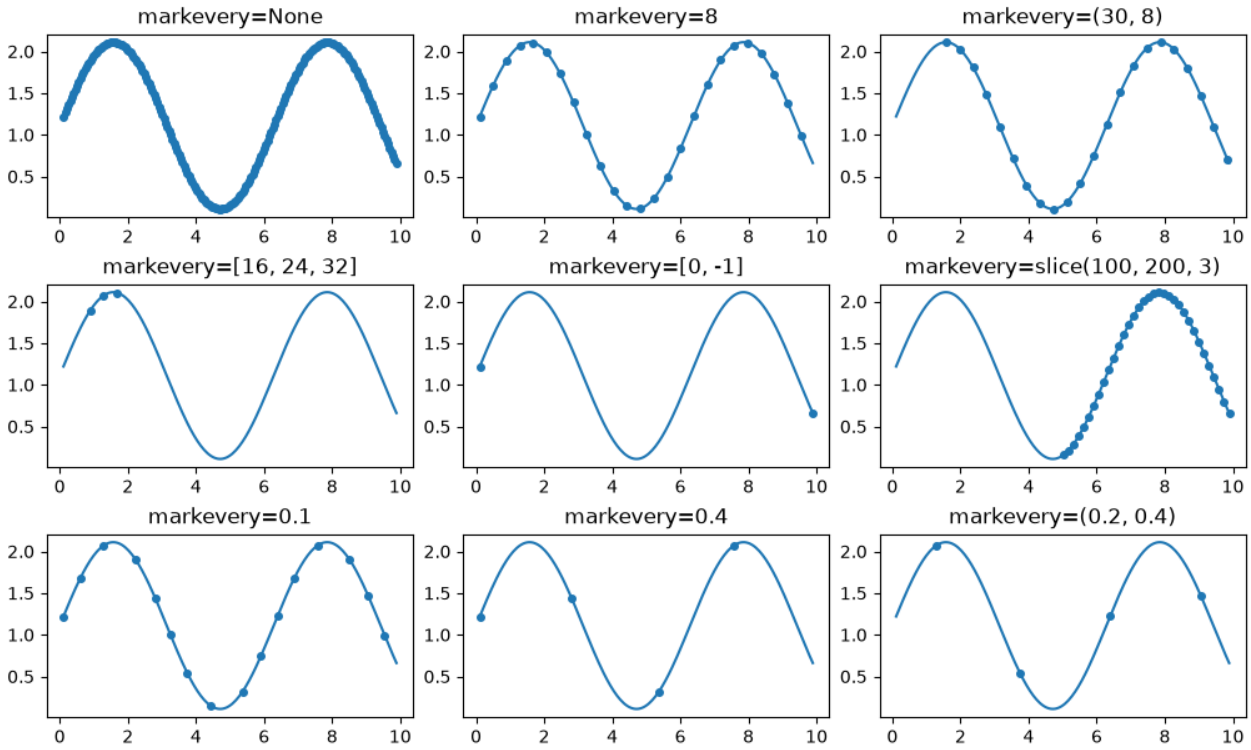
(continues on next page)

(continued from previous page)

```
cases = [
    None,
    8,
    (30, 8),
    [16, 24, 32],
    [0, -1],
    slice(100, 200, 3),
    0.1,
    0.4,
    (0.2, 0.4)
]

# data points
delta = 0.11
x = np.linspace(0, 10 - 2 * delta, 200) + delta
y = np.sin(x) + 1.0 + delta
```

markevery with linear scales

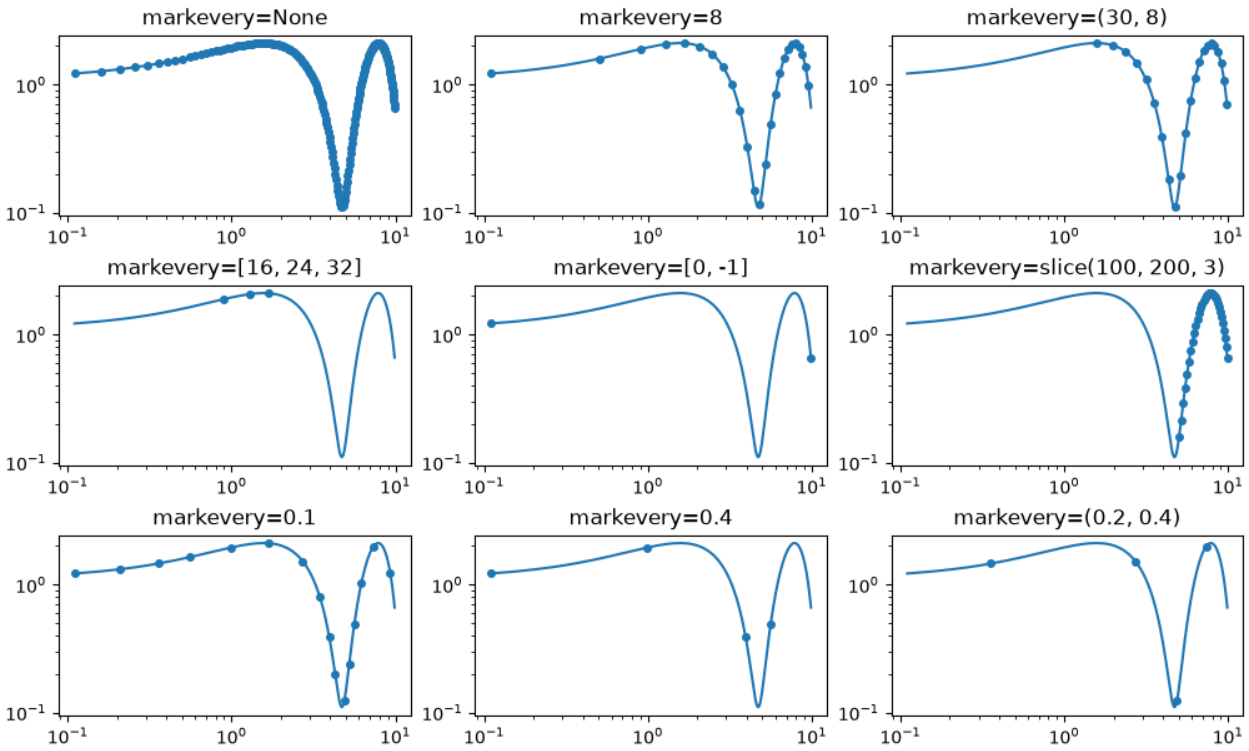
```
fig, axs = plt.subplots(3, 3, figsize=(10, 6), layout='constrained')
for ax, markevery in zip(axs.flat, cases):
    ax.set_title(f'markevery={markevery}')
    ax.plot(x, y, 'o', ls='-', ms=4, markevery=markevery)
```



markevery with log scales

Note that the log scale causes a visual asymmetry in the marker distance for when subsampling the data using an integer. In contrast, subsampling on fraction of figure size creates even distributions, because it's based on fractions of the Axes diagonal, not on data coordinates or data indices.

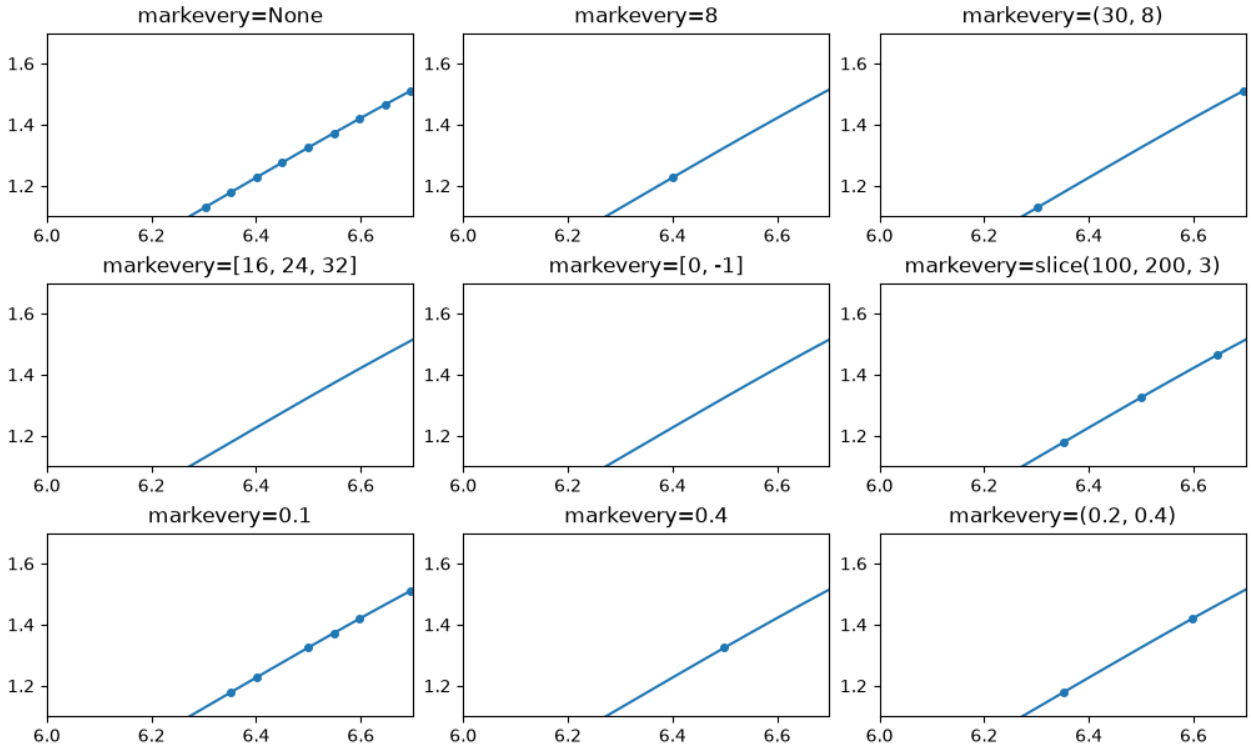
```
fig, axs = plt.subplots(3, 3, figsize=(10, 6), layout='constrained')
for ax, markevery in zip(axs.flat, cases):
    ax.set_title(f'markevery={markevery}')
    ax.set_xscale('log')
    ax.set_yscale('log')
    ax.plot(x, y, 'o', ls='-', ms=4, markevery=markevery)
```



markevery on zoomed plots

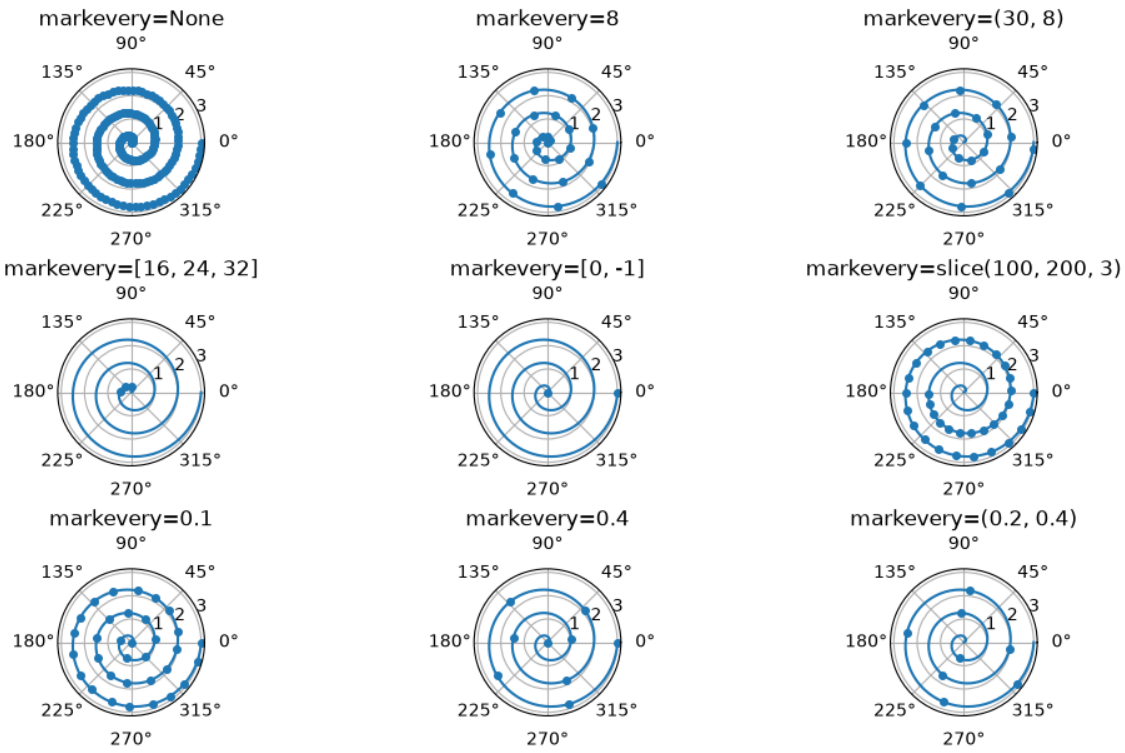
Integer-based *markevery* specifications select points from the underlying data and are independent on the view. In contrast, float-based specifications are related to the Axes diagonal. While zooming does not change the Axes diagonal, it changes the displayed data range, and more points will be displayed when zooming.

```
fig, axs = plt.subplots(3, 3, figsize=(10, 6), layout='constrained')
for ax, markevery in zip(axs.flat, cases):
    ax.set_title(f'markevery={markevery}')
    ax.plot(x, y, 'o', ls='-', ms=4, markevery=markevery)
    ax.set_xlim(6, 6.7)
    ax.set_ylim(1.1, 1.7)
```



markevery on polar plots

```
r = np.linspace(0, 3.0, 200)
theta = 2 * np.pi * r

fig, axs = plt.subplots(3, 3, figsize=(10, 6), layout='constrained',
                        subplot_kw={'projection': 'polar'})
for ax, markevery in zip(axs.flat, cases):
    ax.set_title(f'markevery={markevery}')
    ax.plot(theta, r, 'o', ls='-', ms=4, markevery=markevery)

plt.show()
```



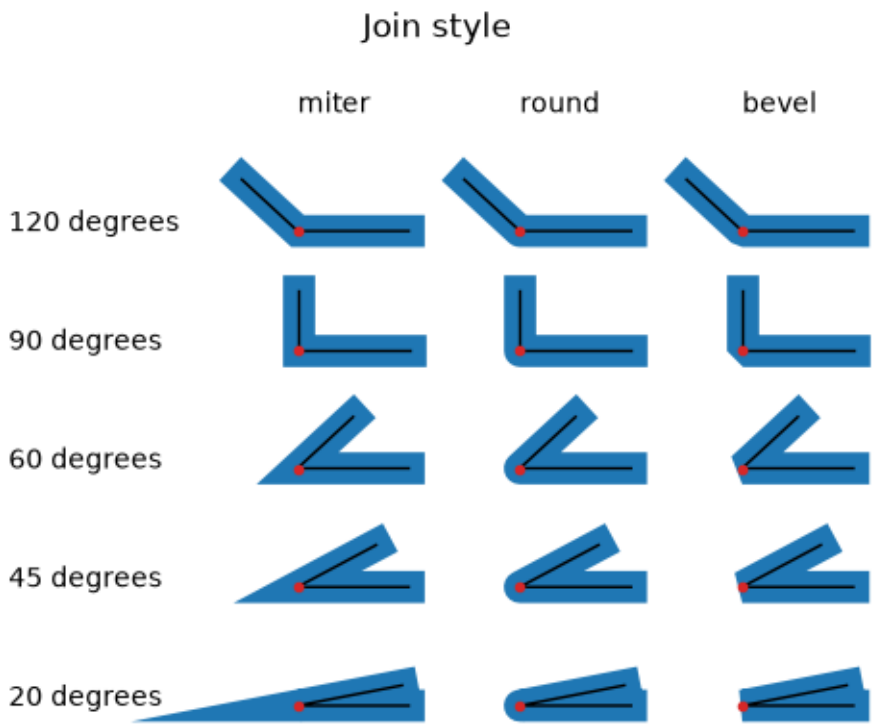
Tags: component: marker plot-type: line level: beginner

Total running time of the script: (0 minutes 5.969 seconds)

JoinStyle

The *matplotlib._enums.JoinStyle* controls how Matplotlib draws the corners where two different line segments meet. For more details, see the *JoinStyle* docs.

```
import matplotlib.pyplot as plt

from matplotlib._enums import JoinStyle

JoinStyle.demo()
plt.show()
```



Tags: purpose: reference styling: linestyle

CapStyle

The *matplotlib._enums.CapStyle* controls how Matplotlib draws the two endpoints (caps) of an unclosed line. For more details, see the *CapStyle* docs.

```
import matplotlib.pyplot as plt

from matplotlib._enums import CapStyle

CapStyle.demo()
plt.show()
```

Tags: purpose: reference

Marker reference

Matplotlib supports multiple categories of markers which are selected using the `marker` parameter of plot commands:

- *Unfilled markers*
- *Filled markers*
- *Markers created from TeX symbols*
- *Markers created from Paths*

For a list of all markers see also the *matplotlib.markers* documentation.

For example usages see *Marker examples*.

```
import matplotlib.pyplot as plt

from matplotlib.lines import Line2D
from matplotlib.markers import MarkerStyle
from matplotlib.transforms import Affine2D

text_style = dict(horizontalalignment='right', verticalalignment=
 ↪'center',
                  fontsize=12, fontfamily='monospace')
marker_style = dict(linestyle=':', color='0.8', markersize=10,
                    markerfacecolor="tab:blue", markeredgecolor=
 ↪"tab:blue")


def format_axes(ax):
    ax.margins(0.2)
    ax.set_axis_off()
    ax.invert_yaxis()


def split_list(a_list):
    i_half = len(a_list) // 2
    return a_list[:i_half], a_list[i_half:]
```

Unfilled markers

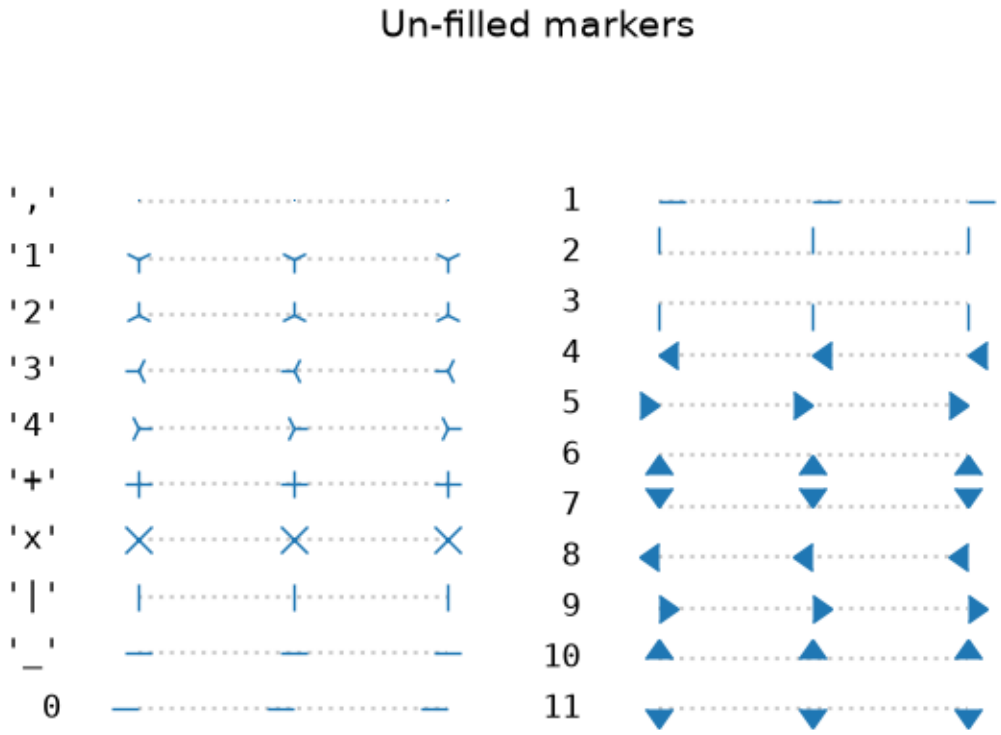
Unfilled markers are single-colored.

```
fig, axs = plt.subplots(ncols=2)
fig.suptitle('Un-filled markers', fontsize=14)

# Filter out filled markers and marker settings that do nothing.
unfilled_markers = [m for m, func in Line2D.markers.items()
```

(continues on next page)

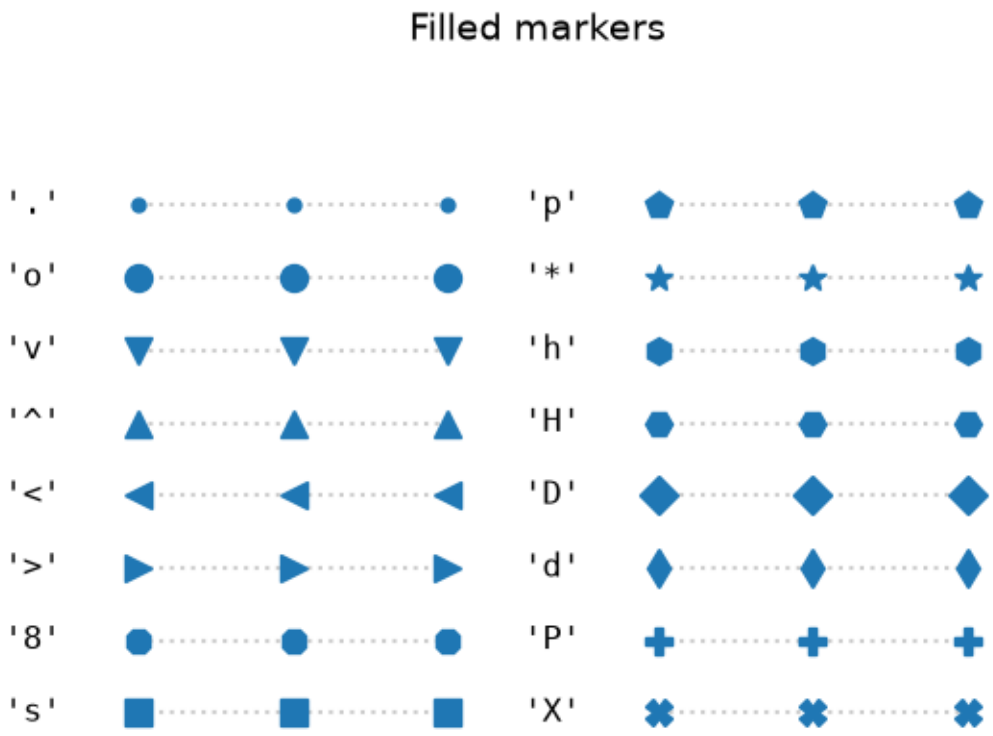
(continued from previous page)

```
                    if func != 'nothing' and m not in Line2D.
↪filled_markers]

for ax, markers in zip(axs, split_list(unfilled_markers)):
    for y, marker in enumerate(markers):
        ax.text(-0.5, y, repr(marker), **text_style)
        ax.plot([y] * 3, marker=marker, **marker_style)
    format_axes(ax)
```



Filled markers

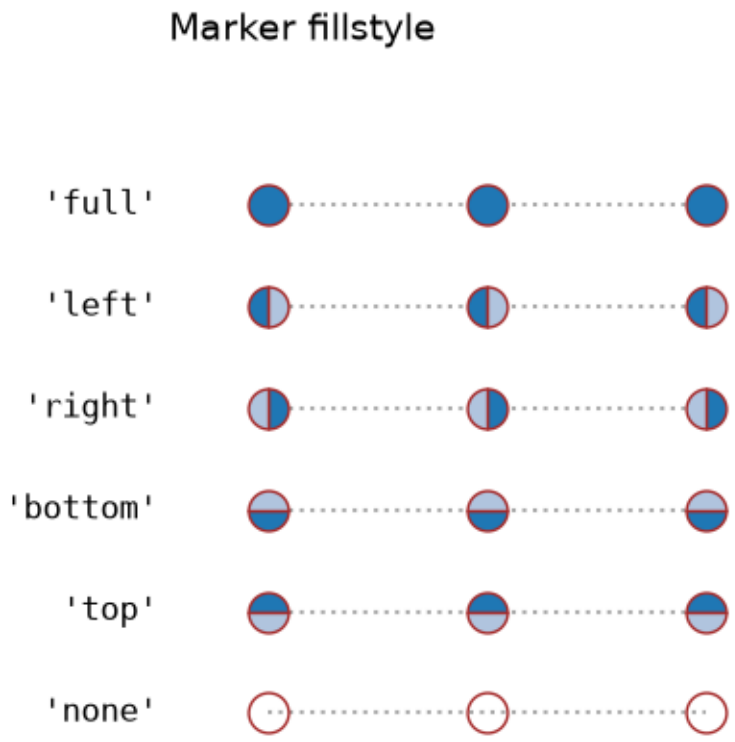
```
fig, axs = plt.subplots(ncols=2)
fig.suptitle('Filled markers', fontsize=14)
for ax, markers in zip(axs, split_list(Line2D.filled_markers)):
    for y, marker in enumerate(markers):
        ax.text(-0.5, y, repr(marker), **text_style)
        ax.plot([y] * 3, marker=marker, **marker_style)
    format_axes(ax)
```



Marker fill styles

The edge color and fill color of filled markers can be specified separately. Additionally, the `fillstyle` can be configured to be unfilled, fully filled, or half-filled in various directions. The half-filled styles use `markerfacecoloralt` as secondary fill color.

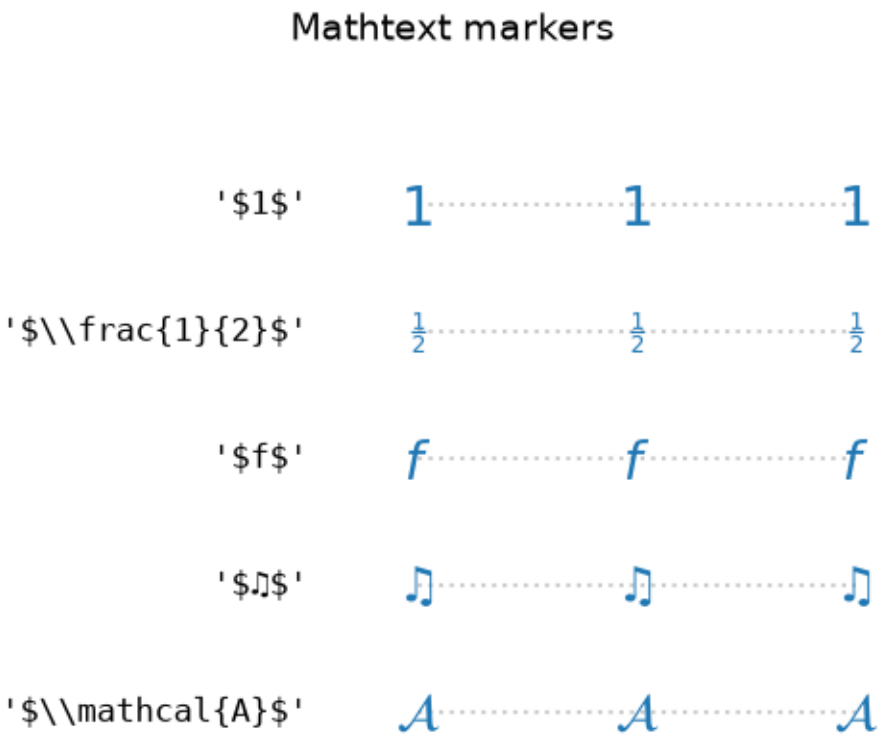
```
fig, ax = plt.subplots()
fig.suptitle('Marker fillstyle', fontsize=14)
fig.subplots_adjust(left=0.4)

filled_marker_style = dict(marker='o', linestyle=':', markersize=15,
                           color='darkgrey',
                           markerfacecolor='tab:blue',
                           markerfacecoloralt='lightsteelblue',
                           markeredgecolor='brown')

for y, fill_style in enumerate(Line2D.fillStyles):
    ax.text(-0.5, y, repr(fill_style), **text_style)
    ax.plot([y] * 3, fillstyle=fill_style, **filled_marker_style)
format_axes(ax)
```



Markers created from TeX symbols

Use *MathText*, to use custom marker symbols, like e.g. `"$\u266B$"`. For an overview over the STIX font symbols refer to the STIX font table. Also see the *STIX Fonts*.

```
fig, ax = plt.subplots()
fig.suptitle('Mathtext markers', fontsize=14)
fig.subplots_adjust(left=0.4)

marker_style.update(markeredgecolor="none", markersize=15)
markers = ["$1$", r"$\frac{1}{2}$", "$f$", "$\u266B$", r"$\mathcal{A}$
 ↪"]

for y, marker in enumerate(markers):
    # Escape dollars so that the text is written "as is", not as␣
 ↪mathtext.
    ax.text(-0.5, y, repr(marker).replace("$", r"\$"), **text_style)
    ax.plot([y] * 3, marker=marker, **marker_style)
format_axes(ax)
```



Markers created from Paths

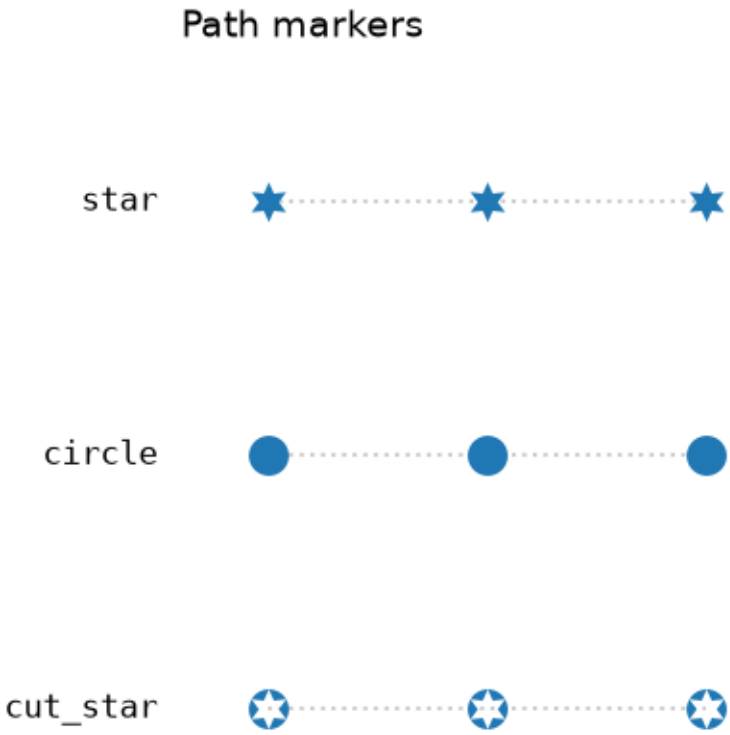
Any `Path` can be used as a marker. The following example shows two simple paths *star* and *circle*, and a more elaborate path of a circle with a cut-out star.

```
import numpy as np

import matplotlib.path as mpath

star = mpath.Path.unit_regular_star(6)
circle = mpath.Path.unit_circle()
# concatenate the circle with an internal cutout of the star
cut_star = mpath.Path(
    vertices=np.concatenate([circle.vertices, star.vertices[::-1, ...
 ↪]]),
    codes=np.concatenate([circle.codes, star.codes]))

fig, ax = plt.subplots()
fig.suptitle('Path markers', fontsize=14)
fig.subplots_adjust(left=0.4)
```

(continues on next page)

(continued from previous page)

```
markers = {'star': star, 'circle': circle, 'cut_star': cut_star}

for y, (name, marker) in enumerate(markers.items()):
    ax.text(-0.5, y, name, **text_style)
    ax.plot([y] * 3, marker=marker, **marker_style)
format_axes(ax)
```



Advanced marker modifications with transform

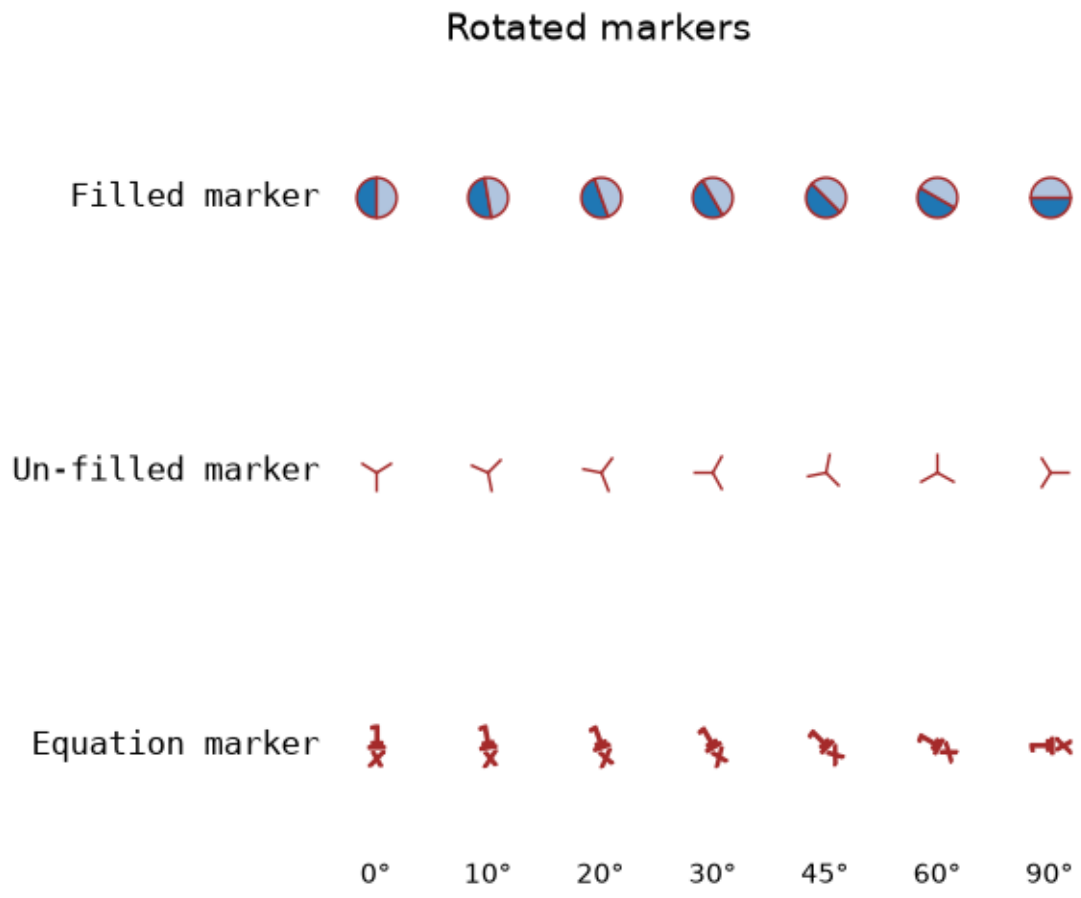
Markers can be modified by passing a transform to the MarkerStyle constructor. Following example shows how a supplied rotation is applied to several marker shapes.

```
common_style = {k: v for k, v in filled_marker_style.items() if k !=
 ↪'marker'}
angles = [0, 10, 20, 30, 45, 60, 90]

fig, ax = plt.subplots()
fig.suptitle('Rotated markers', fontsize=14)
```

(continues on next page)

(continued from previous page)

```
ax.text(-0.5, 0, 'Filled marker', **text_style)
for x, theta in enumerate(angles):
    t = Affine2D().rotate_deg(theta)
    ax.plot(x, 0, marker=MarkerStyle('o', 'left', t), **common_style)

ax.text(-0.5, 1, 'Un-filled marker', **text_style)
for x, theta in enumerate(angles):
    t = Affine2D().rotate_deg(theta)
    ax.plot(x, 1, marker=MarkerStyle('1', 'left', t), **common_style)

ax.text(-0.5, 2, 'Equation marker', **text_style)
for x, theta in enumerate(angles):
    t = Affine2D().rotate_deg(theta)
    eq = r'$\frac{1}{x}$'
    ax.plot(x, 2, marker=MarkerStyle(eq, 'left', t), **common_style)

for x, theta in enumerate(angles):
    ax.text(x, 2.5, f"{theta}°", horizontalalignment="center")
format_axes(ax)

fig.tight_layout()
```



Setting marker cap style and join style

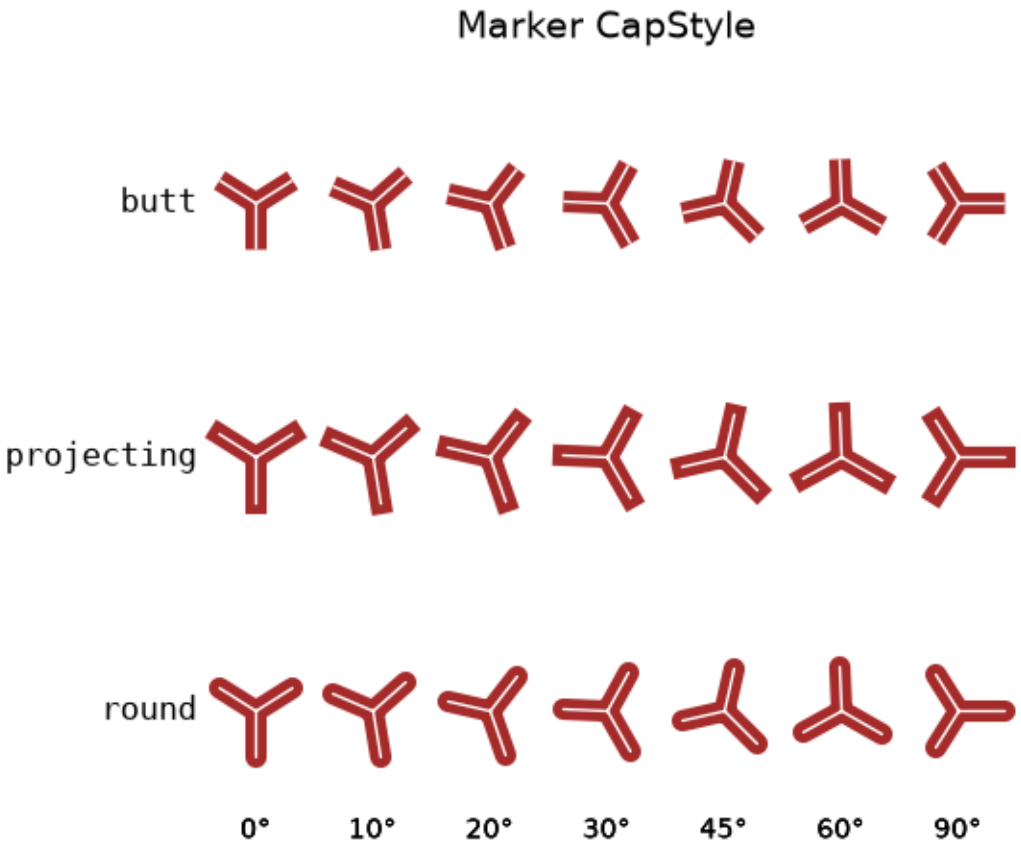
Markers have default cap and join styles, but these can be customized when creating a MarkerStyle.

```
from matplotlib.markers import CapStyle, JoinStyle

marker_inner = dict(markersize=35,
                    markerfacecolor='tab:blue',
                    markerfacecoloralt='lightsteelblue',
                    markeredgecolor='brown',
                    markeredgewidth=8,
                    )

marker_outer = dict(markersize=35,
                    markerfacecolor='tab:blue',
                    markerfacecoloralt='lightsteelblue',
                    markeredgecolor='white',
                    markeredgewidth=1,
                    )
```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots()
fig.suptitle('Marker CapStyle', fontsize=14)
fig.subplots_adjust(left=0.1)

for y, cap_style in enumerate(CapStyle):
    ax.text(-0.5, y, cap_style.name, **text_style)
    for x, theta in enumerate(angles):
        t = Affine2D().rotate_deg(theta)
        m = MarkerStyle('1', transform=t, capstyle=cap_style)
        ax.plot(x, y, marker=m, **marker_inner)
        ax.plot(x, y, marker=m, **marker_outer)
        ax.text(x, len(CapStyle) - .5, f'{theta}°', ha='center')
format_axes(ax)
```



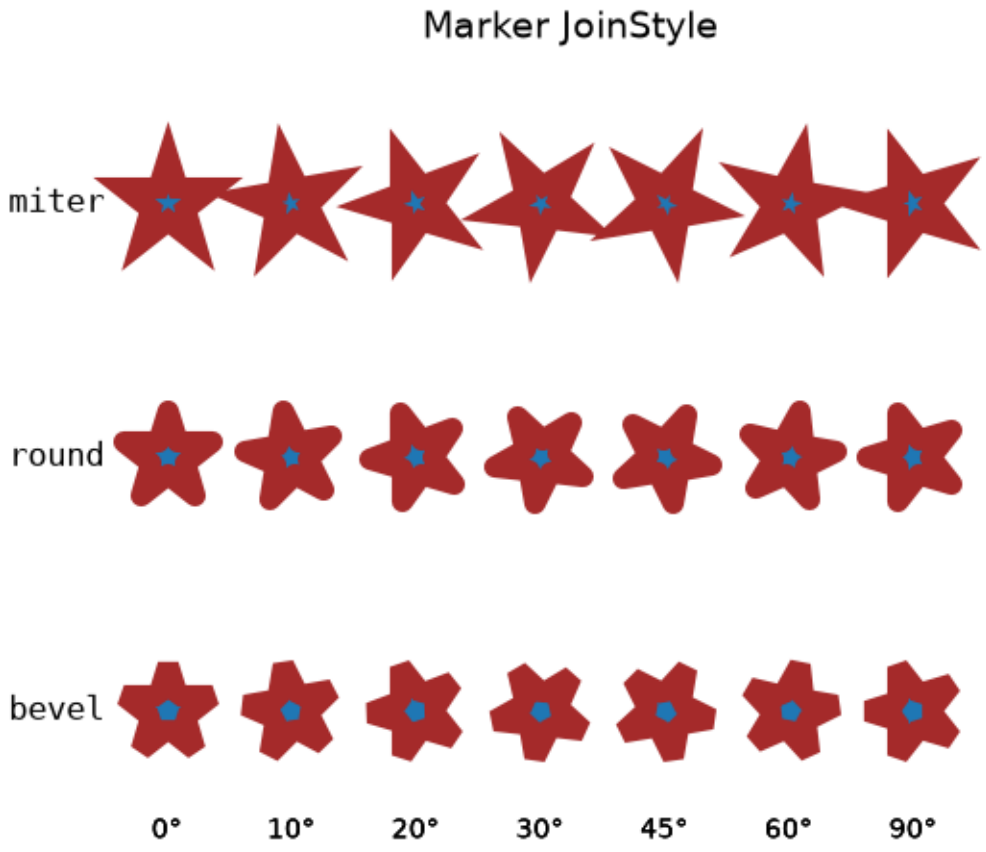
Modifying the join style:

```
fig, ax = plt.subplots()
fig.suptitle('Marker JoinStyle', fontsize=14)
fig.subplots_adjust(left=0.05)
```

(continues on next page)

(continued from previous page)

```
for y, join_style in enumerate(JoinStyle):
    ax.text(-0.5, y, join_style.name, **text_style)
    for x, theta in enumerate(angles):
        t = Affine2D().rotate_deg(theta)
        m = MarkerStyle('*', transform=t, joinstyle=join_style)
        ax.plot(x, y, marker=m, **marker_inner)
        ax.text(x, len(JoinStyle) - .5, f'{theta}°', ha='center')
format_axes(ax)

plt.show()
```



Tags: component: marker purpose: reference

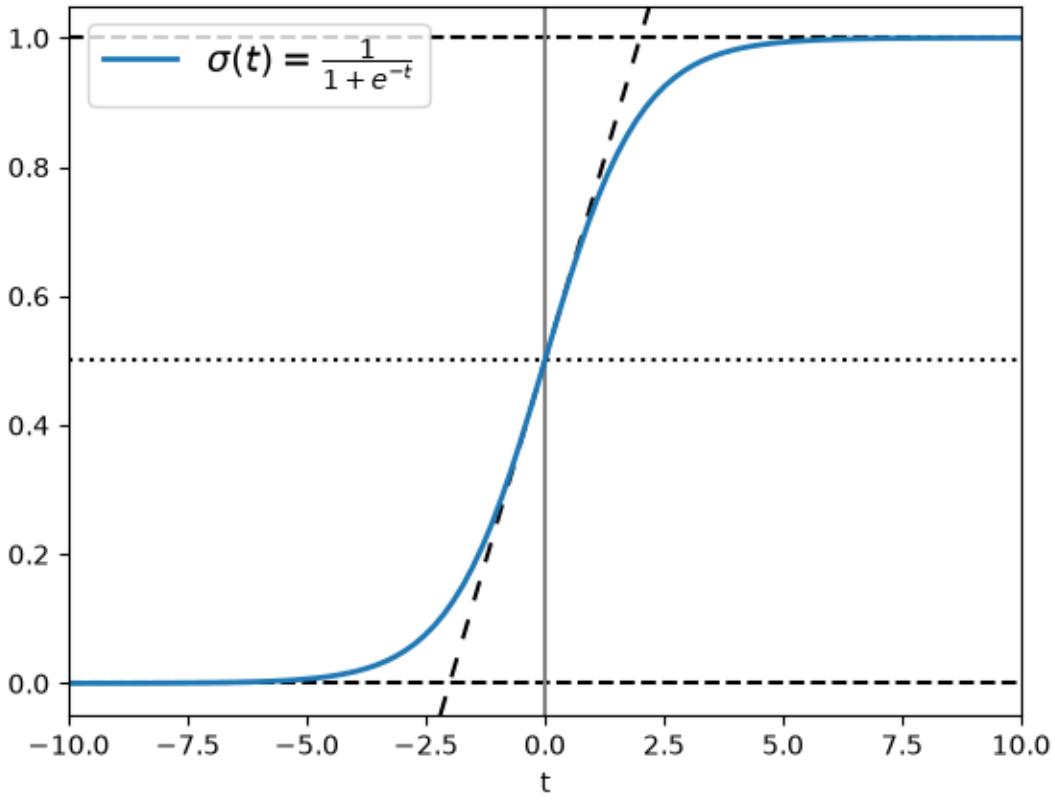
Total running time of the script: (0 minutes 1.585 seconds)

Infinite lines

axvline and *axhline* draw infinite vertical / horizontal lines, at given *x* / *y* positions. They are usually used to mark special data values, e.g. in this example the center and limit values of the sigmoid function.

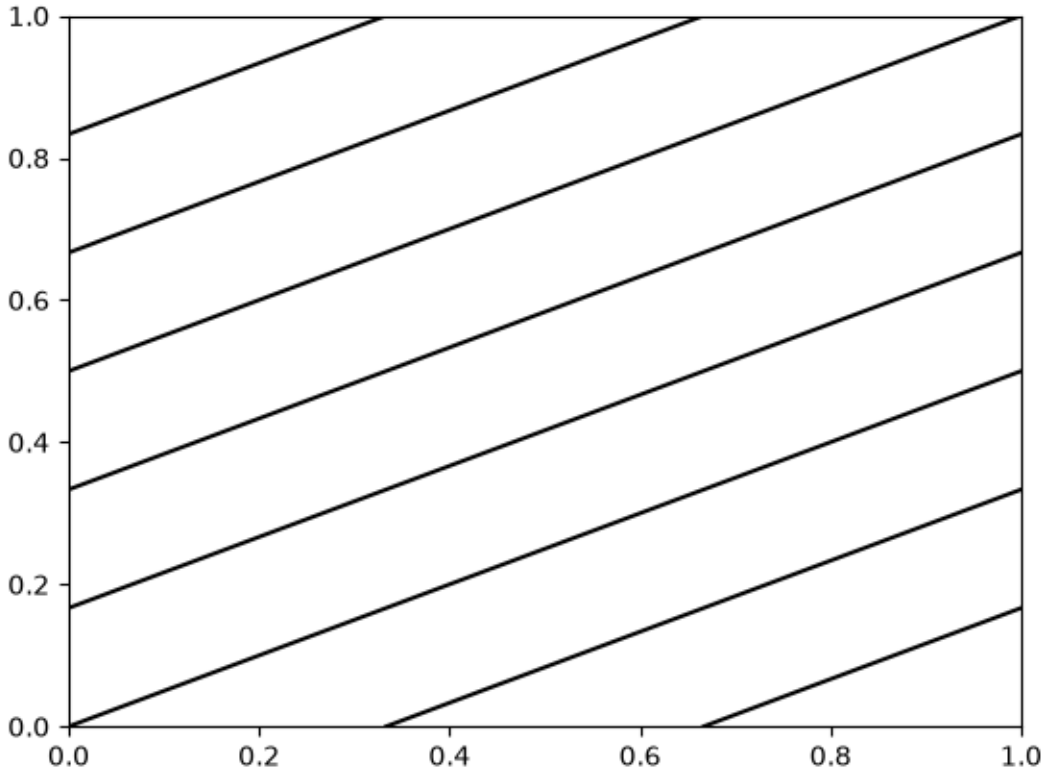
axline draws infinite straight lines defined either by two points or by a point and a slope.

```
import matplotlib.pyplot as plt
import numpy as np

t = np.linspace(-10, 10, 100)
sig = 1 / (1 + np.exp(-t))

fig, ax = plt.subplots()
ax.axhline(y=0, color="black", linestyle="--")
ax.axhline(y=0.5, color="black", linestyle=":")
ax.axhline(y=1.0, color="black", linestyle="--")
ax.axvline(color="grey")
ax.axline((0, 0.5), slope=0.25, color="black", linestyle=(0, (5, 5)))
ax.plot(t, sig, linewidth=2, label=r"$\sigma(t) = \frac{1}{1 + e^{-t}}$
 ↪")
ax.set(xlim=(-10, 10), xlabel="t")
ax.legend(fontsize=14)
plt.show()
```



`axline` can also be used with a *transform* parameter, which applies to the point, but not to the slope. This can be useful for drawing diagonal grid lines with a fixed slope, which stay in place when the plot limits are moved.

```
fig, ax = plt.subplots()
for pos in np.linspace(-2, 1, 10):
    ax.axline((pos, 0), slope=0.5, color='k', transform=ax.transAxes)

ax.set(xlim=(0, 1), ylim=(0, 1))
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.axhline* / *matplotlib.pyplot.axhline*
- *matplotlib.axes.Axes.axvline* / *matplotlib.pyplot.axvline*
- *matplotlib.axes.Axes.axline* / *matplotlib.pyplot.axline*

See also

axhspan, *axvspan* draw rectangles that span the Axes in one direction and are bounded in the other

direction.

Tags: component: annotation

Multicolored lines

The example shows two ways to plot a line with the a varying color defined by a third value. The first example defines the color at each (x, y) point. The second example defines the color between pairs of points, so the length of the color value list is one less than the length of the x and y lists.

Color values at points

```
import warnings

import matplotlib.pyplot as plt
import numpy as np

from matplotlib.collections import LineCollection


def colored_line(x, y, c, ax=None, **lc_kwargs):
    """
    Plot a line with a color specified along the line by a third value.

    It does this by creating a collection of line segments. Each line␣
 ↪segment is
    made up of two straight lines each connecting the current (x, y)␣
 ↪point to the
    midpoints of the lines connecting the current point with its two␣
 ↪neighbors.
    This creates a smooth line with no gaps between the line segments.

    Parameters
    ----------
    x, y : array-like
        The horizontal and vertical coordinates of the data points.
    c : array-like
        The color values, which should be the same size as x and y.
    ax : matplotlib.axes.Axes, optional
        The axes to plot on. If not provided, the current axes will be␣
 ↪used.
    **lc_kwargs
        Any additional arguments to pass to␣
 ↪matplotlib.collections.LineCollection
        constructor. This should not include the array keyword␣
 ↪argument because
```

(continues on next page)

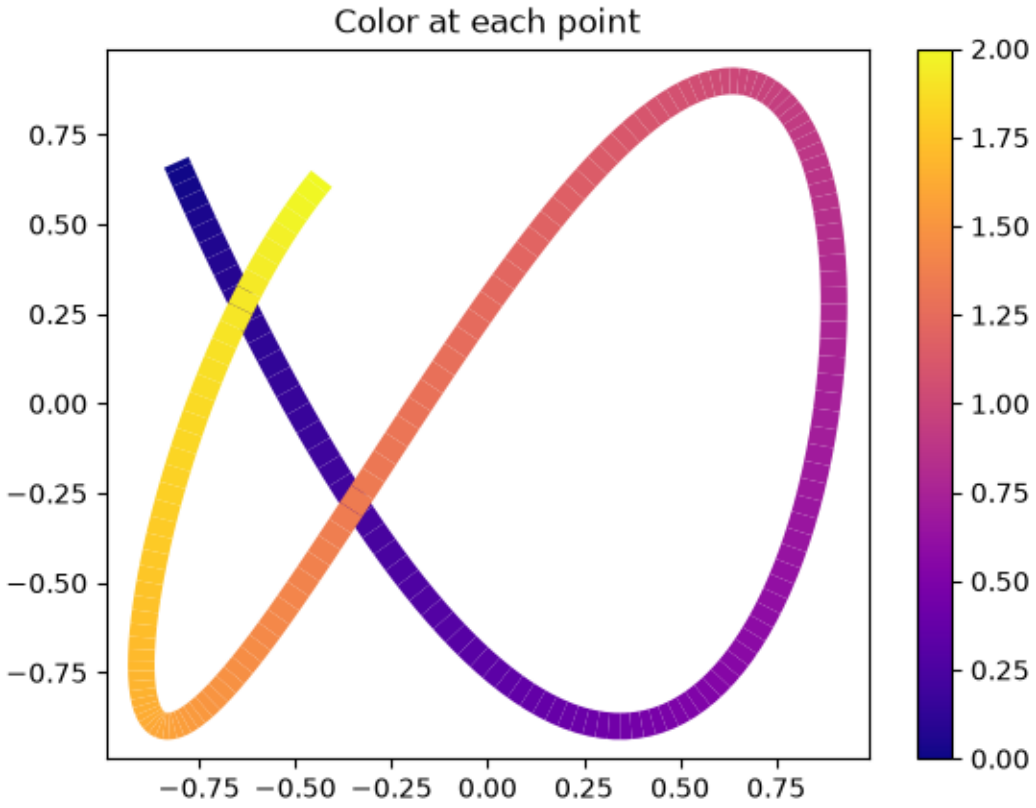
(continued from previous page)

```
        that is set to the color argument. If provided, it will be␣
↪overridden.

    Returns
    -------
    matplotlib.collections.LineCollection
        The generated line collection representing the colored line.
    """
    if "array" in lc_kwargs:
        warnings.warn(
            'The provided "array" keyword argument will be overridden',
            UserWarning,
            stacklevel=2,
        )

    xy = np.stack((x, y), axis=-1)
    xy_mid = np.concat(
        (xy[0, :][None, :], (xy[:-1, :] + xy[1:, :]) / 2, xy[-1,␣
↪:][None, :]), axis=0
    )
    segments = np.stack((xy_mid[:-1, :], xy, xy_mid[1:, :]), axis=-2)
    # Note that
    # segments[0, :, :] is [xy[0, :], xy[0, :], (xy[0, :] + xy[1, :]) /
↪ 2]
    # segments[i, :, :] is [(xy[i - 1, :] + xy[i, :]) / 2, xy[i, :],
    #     (xy[i, :] + xy[i + 1, :]) / 2] if i not in {0, len(x) - 1}
    # segments[-1, :, :] is [(xy[-2, :] + xy[-1, :]) / 2, xy[-1, :],␣
↪xy[-1, :]]

    lc_kwargs["array"] = c
    lc = LineCollection(segments, **lc_kwargs)

    # Plot the line collection to the axes
    ax = ax or plt.gca()
    ax.add_collection(lc)

    return lc


# -------------- Create and show plot --------------
# Some arbitrary function that gives x, y, and color values
t = np.linspace(-7.4, -0.5, 200)
x = 0.9 * np.sin(t)
y = 0.9 * np.cos(1.6 * t)
color = np.linspace(0, 2, t.size)
```

(continues on next page)

(continued from previous page)

```
# Create a figure and plot the line on it
fig1, ax1 = plt.subplots()
lines = colored_line(x, y, color, ax1, linewidth=10, cmap="plasma")
fig1.colorbar(lines)  # add a color legend

ax1.set_title("Color at each point")

plt.show()
```



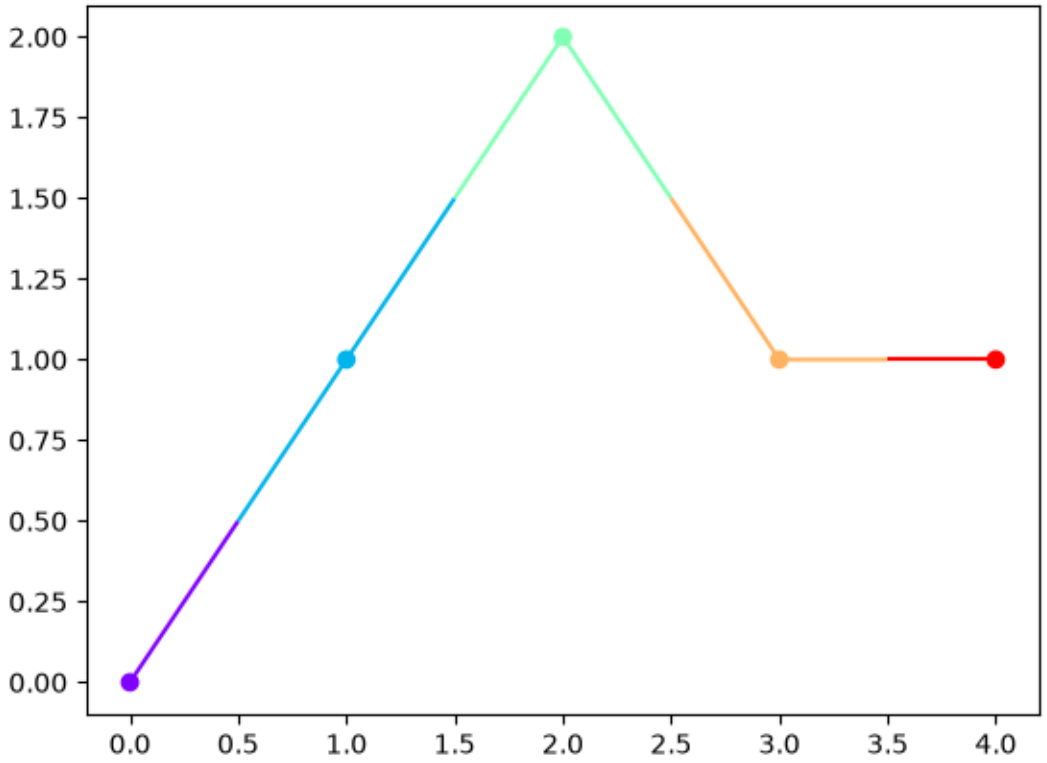
This method is designed to give a smooth impression when distances and color differences between adjacent points are not too large. The following example does not meet this criteria and by that serves to illustrate the segmentation and coloring mechanism.

```
x = [0, 1, 2, 3, 4]
y = [0, 1, 2, 1, 1]
c = [1, 2, 3, 4, 5]
fig, ax = plt.subplots()
ax.scatter(x, y, c=c, cmap='rainbow')
colored_line(x, y, c=c, ax=ax, cmap='rainbow')
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



Color values between points

```
def colored_line_between_pts(x, y, c, ax, **lc_kwargs):
    """
    Plot a line with a color specified between (x, y) points by a␣
↪third value.

    It does this by creating a collection of line segments between␣
↪each pair of
    neighboring points. The color of each segment is determined by the
    made up of two straight lines each connecting the current (x, y)␣
↪point to the
    midpoints of the lines connecting the current point with its two␣
↪neighbors.
    This creates a smooth line with no gaps between the line segments.

    Parameters
```

(continues on next page)

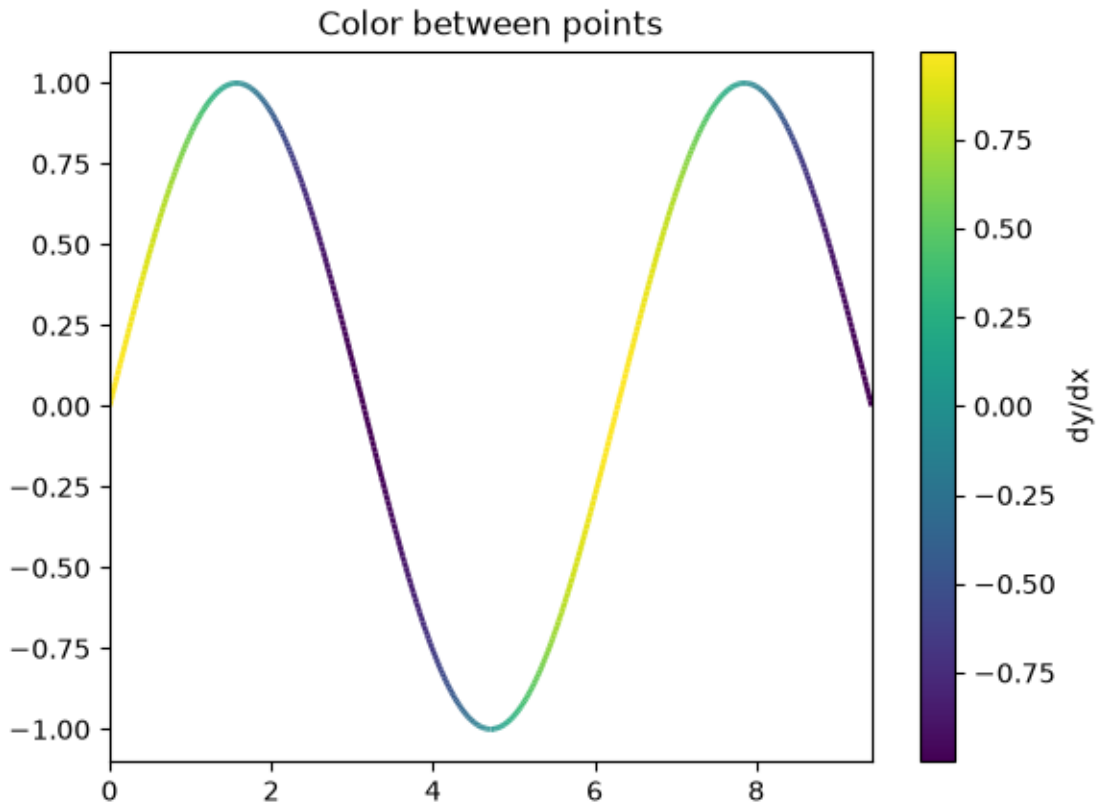
(continued from previous page)

```
    ----------
    x, y : array-like
        The horizontal and vertical coordinates of the data points.
    c : array-like
        The color values, which should have a size one less than that␣
↪of x and y.
    ax : Axes
        Axis object on which to plot the colored line.
    **lc_kwargs
        Any additional arguments to pass to␣
↪matplotlib.collections.LineCollection
        constructor. This should not include the array keyword␣
↪argument because
        that is set to the color argument. If provided, it will be␣
↪overridden.

    Returns
    -------
    matplotlib.collections.LineCollection
        The generated line collection representing the colored line.
    """
    if "array" in lc_kwargs:
        warnings.warn('The provided "array" keyword argument will be␣
↪overridden')

    # Check color array size (LineCollection still works, but values␣
↪are unused)
    if len(c) != len(x) - 1:
        warnings.warn(
            "The c argument should have a length one less than the␣
↪length of x and y. "
            "If it has the same length, use the colored_line function␣
↪instead."
        )

    # Create a set of line segments so that we can color them␣
↪individually
    # This creates the points as an N x 1 x 2 array so that we can␣
↪stack points
    # together easily to get the segments. The segments array for line␣
↪collection
    # needs to be (numlines) x (points per line) x 2 (for x and y)
    points = np.array([x, y]).T.reshape(-1, 1, 2)
    segments = np.concatenate([points[:-1], points[1:]], axis=1)
    lc = LineCollection(segments, **lc_kwargs)
```

(continues on next page)

(continued from previous page)

```
    # Set the values used for colormapping
    lc.set_array(c)

    return ax.add_collection(lc)


# -------------- Create and show plot --------------
x = np.linspace(0, 3 * np.pi, 500)
y = np.sin(x)
dydx = np.cos(0.5 * (x[:-1] + x[1:]))  # first derivative

fig2, ax2 = plt.subplots()
line = colored_line_between_pts(x, y, dydx, ax2, linewidth=2, cmap=
 ↪"viridis")
fig2.colorbar(line, ax=ax2, label="dy/dx")

ax2.set_xlim(x.min(), x.max())
ax2.set_ylim(-1.1, 1.1)
ax2.set_title("Color between points")

plt.show()
```



Tags: styling: color styling: linestyle plot-type: line level: intermediate

Lines with a ticked patheffect

Ticks can be added along a line to mark one side as a barrier using `TickedStroke`. You can control the angle, spacing, and length of the ticks.

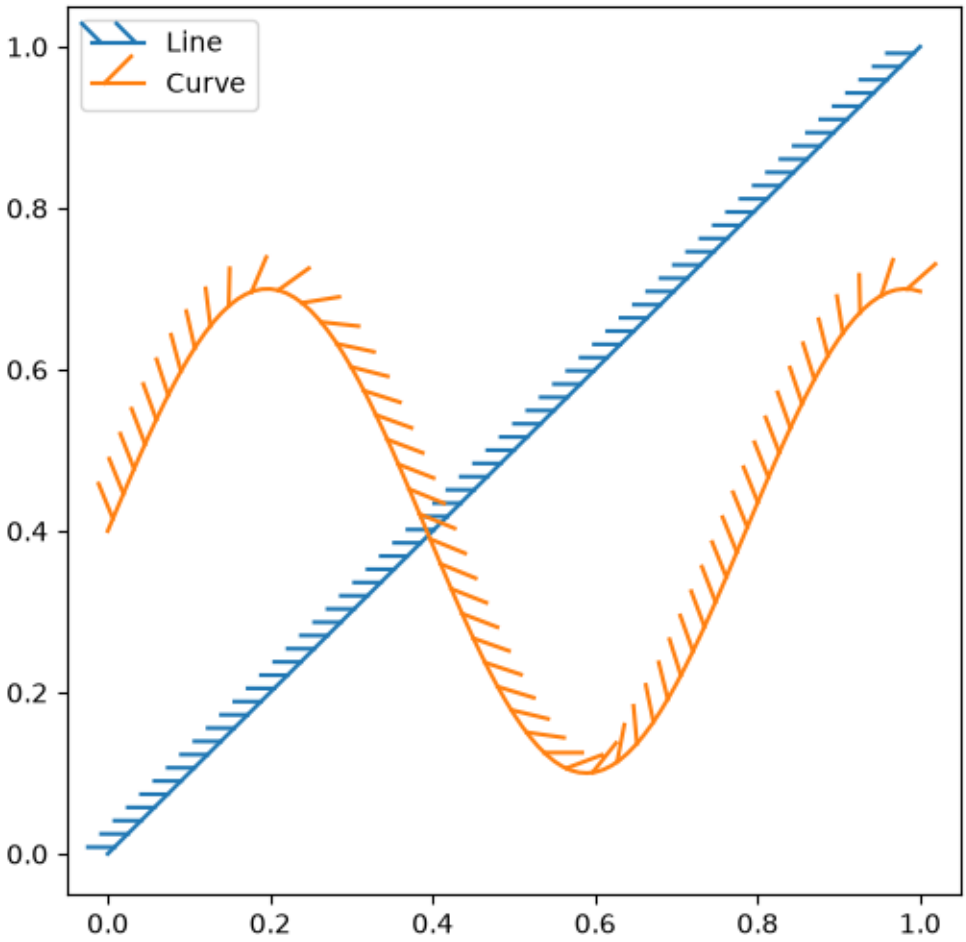
The ticks will also appear appropriately in the legend.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import patheffects

# Plot a straight diagonal line with ticked style path
fig, ax = plt.subplots(figsize=(6, 6))
ax.plot([0, 1], [0, 1], label="Line",
        path_effects=[patheffects.withTickedStroke(spacing=7,␣
 ↪angle=135)])

# Plot a curved line with ticked style path
nx = 101
```

(continues on next page)

(continued from previous page)

```
x = np.linspace(0.0, 1.0, nx)
y = 0.3*np.sin(x*8) + 0.4
ax.plot(x, y, label="Curve", path_effects=[patheffects.
 ↪withTickedStroke()])

ax.legend()

plt.show()
```

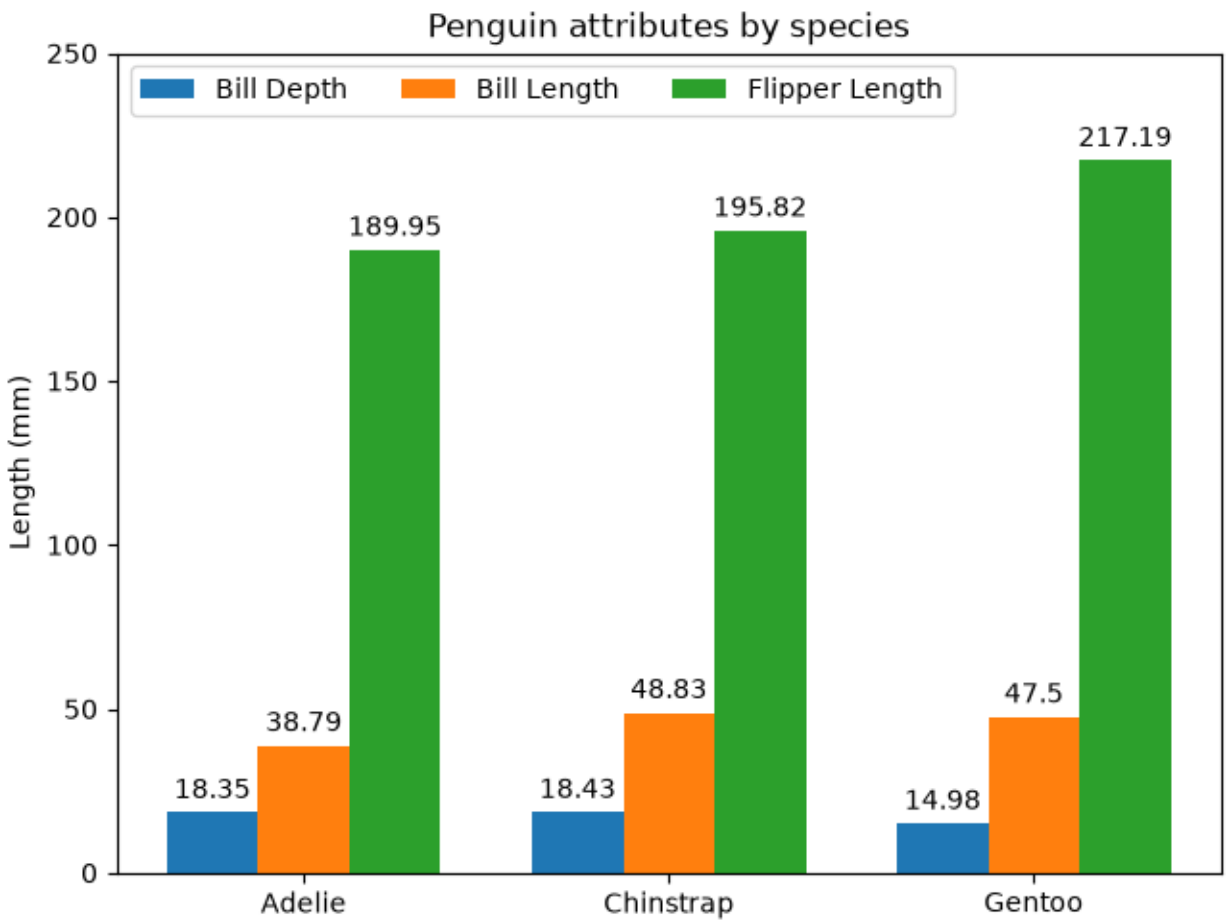


Tags: styling: linestyle plot-type: line level: beginner

Grouped bar chart with labels

This example shows a how to create a grouped bar chart and how to annotate bars with labels.

```
# data from https://allisonhorst.github.io/palmerpenguins/

import matplotlib.pyplot as plt

species = ("Adelie", "Chinstrap", "Gentoo")
penguin_means = {
    'Bill Depth': (18.35, 18.43, 14.98),
    'Bill Length': (38.79, 48.83, 47.50),
    'Flipper Length': (189.95, 195.82, 217.19),
}

fig, ax = plt.subplots(layout='constrained')

res = ax.grouped_bar(penguin_means, tick_labels=species,␣
 ↪group_spacing=1)
for container in res.bar_containers:
    ax.bar_label(container, padding=3)

# Add some text for labels, title, etc.
ax.set_ylabel('Length (mm)')
ax.set_title('Penguin attributes by species')
ax.legend(loc='upper left', ncols=3)
ax.set_ylim(0, 250)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.bar* / *matplotlib.pyplot.bar*
- *matplotlib.axes.Axes.bar_label* / *matplotlib.pyplot.bar_label*

Tags: component: label plot-type: bar level: beginner

Bar chart with labels

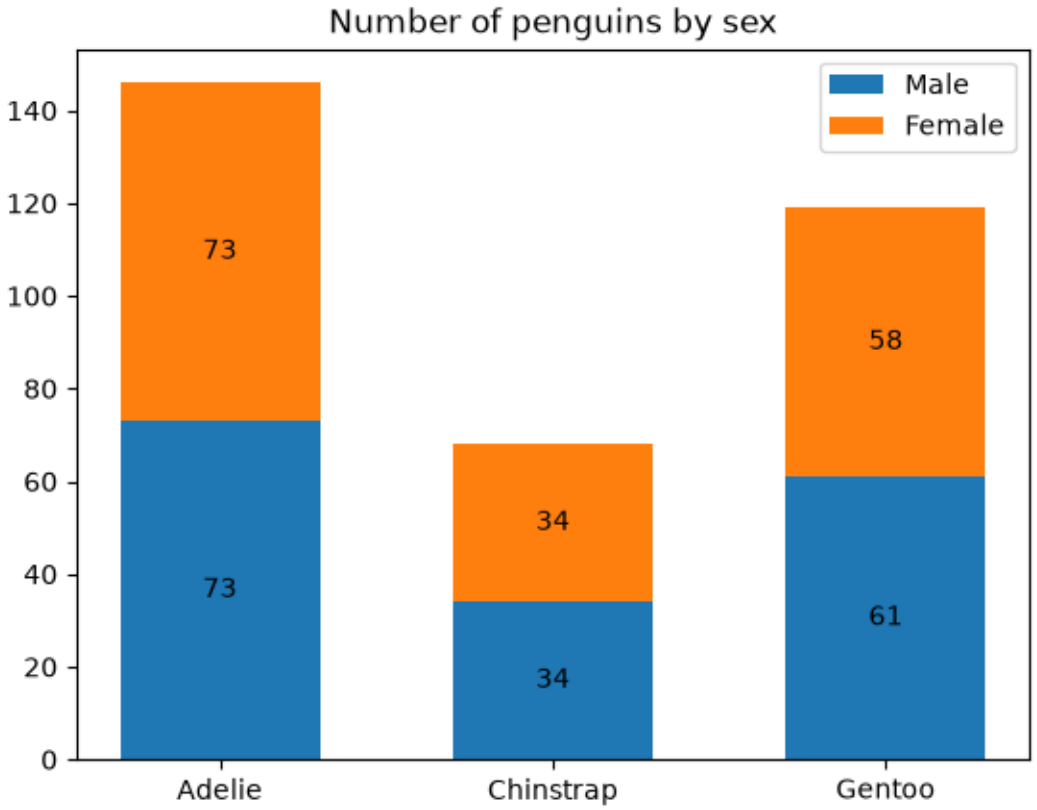
This example shows how to use the *bar_label* helper function to create bar chart labels.

See also the *grouped bar*, *stacked bar* and *horizontal bar chart* examples.

```
import matplotlib.pyplot as plt
import numpy as np
```

data from https://allisonhorst.github.io/palmerpenguins/

```
species = ('Adelie', 'Chinstrap', 'Gentoo')
sex_counts = {
    'Male': np.array([73, 34, 61]),
    'Female': np.array([73, 34, 58]),
}
width = 0.6  # the width of the bars: can also be len(x) sequence


fig, ax = plt.subplots()
bottom = np.zeros(3)

for sex, sex_count in sex_counts.items():
    p = ax.bar(species, sex_count, width, label=sex, bottom=bottom)
    bottom += sex_count

    ax.bar_label(p, label_type='center')

ax.set_title('Number of penguins by sex')
ax.legend()

plt.show()
```



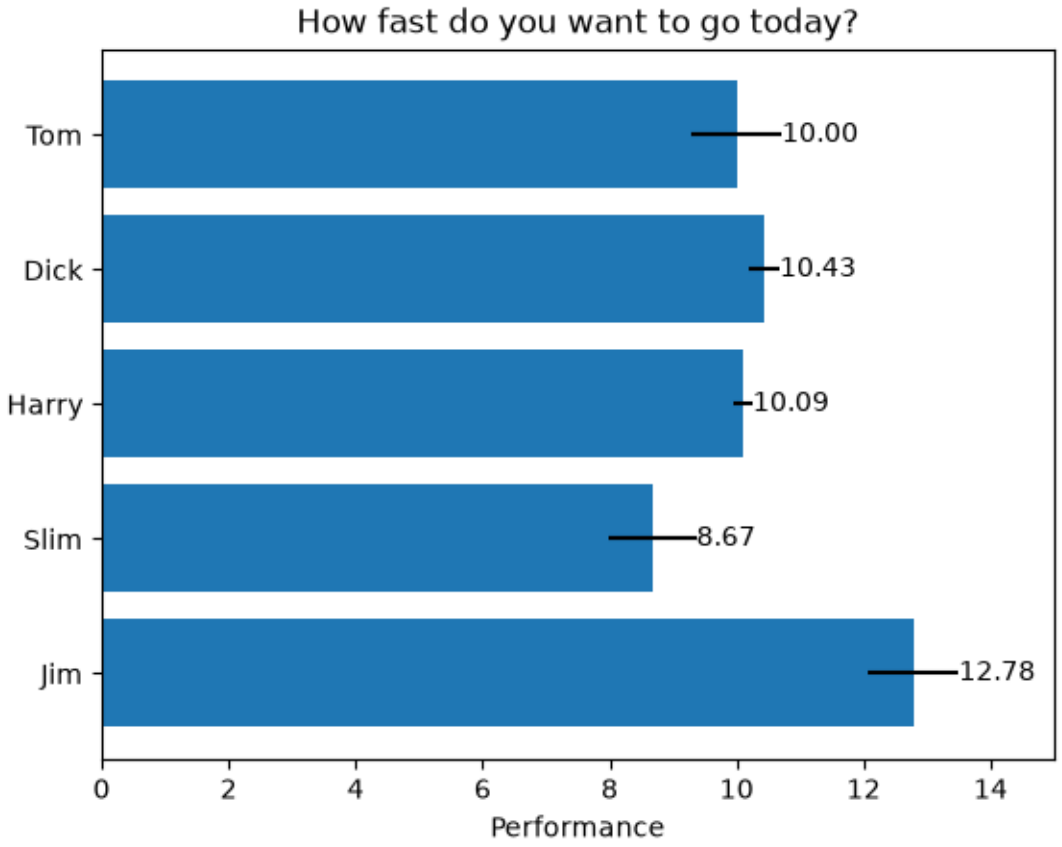
Horizontal bar chart

```
# Fixing random state for reproducibility
np.random.seed(19680801)

# Example data
people = ('Tom', 'Dick', 'Harry', 'Slim', 'Jim')
y_pos = np.arange(len(people))
performance = 3 + 10 * np.random.rand(len(people))
error = np.random.rand(len(people))

fig, ax = plt.subplots()

hbars = ax.barh(y_pos, performance, xerr=error, align='center')
ax.set_yticks(y_pos, labels=people)
ax.invert_yaxis()  # labels read top-to-bottom
ax.set_xlabel('Performance')
ax.set_title('How fast do you want to go today?')

# Label with specially formatted floats
ax.bar_label(hbars, fmt='%.2f')
```

(continues on next page)

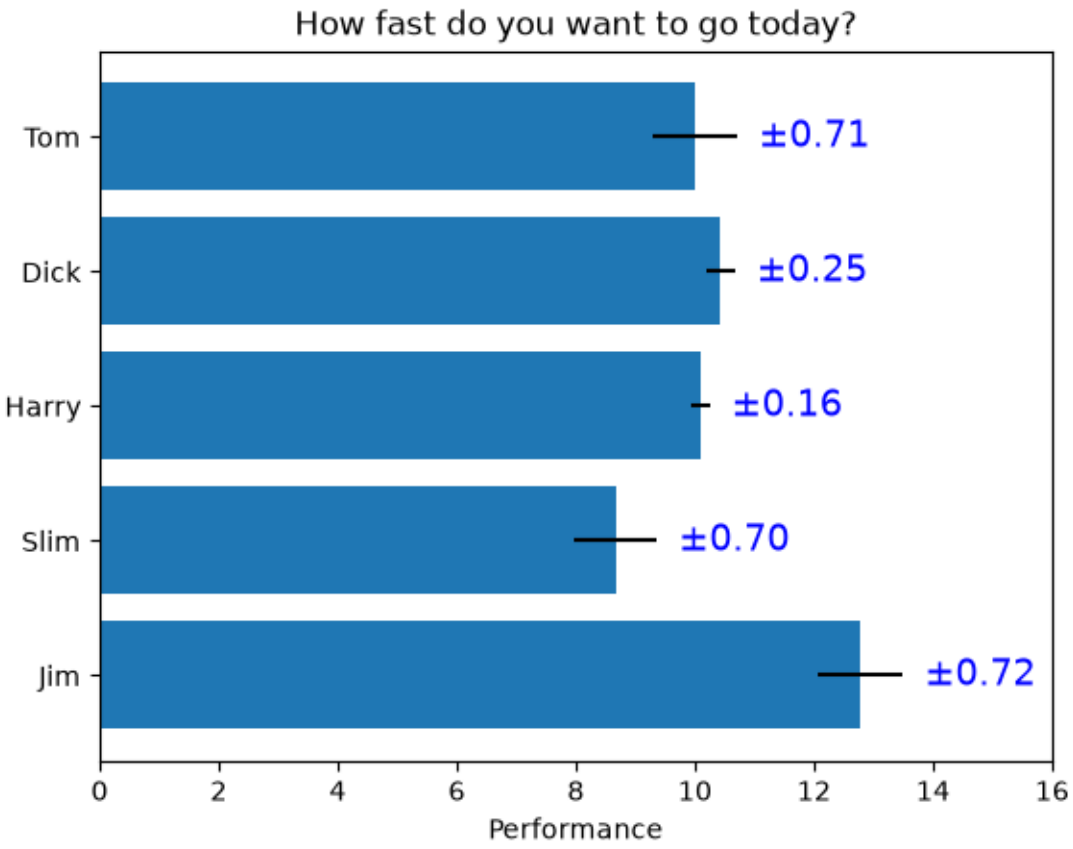
(continued from previous page)

```
ax.set_xlim(right=15)  # adjust xlim to fit labels

plt.show()
```



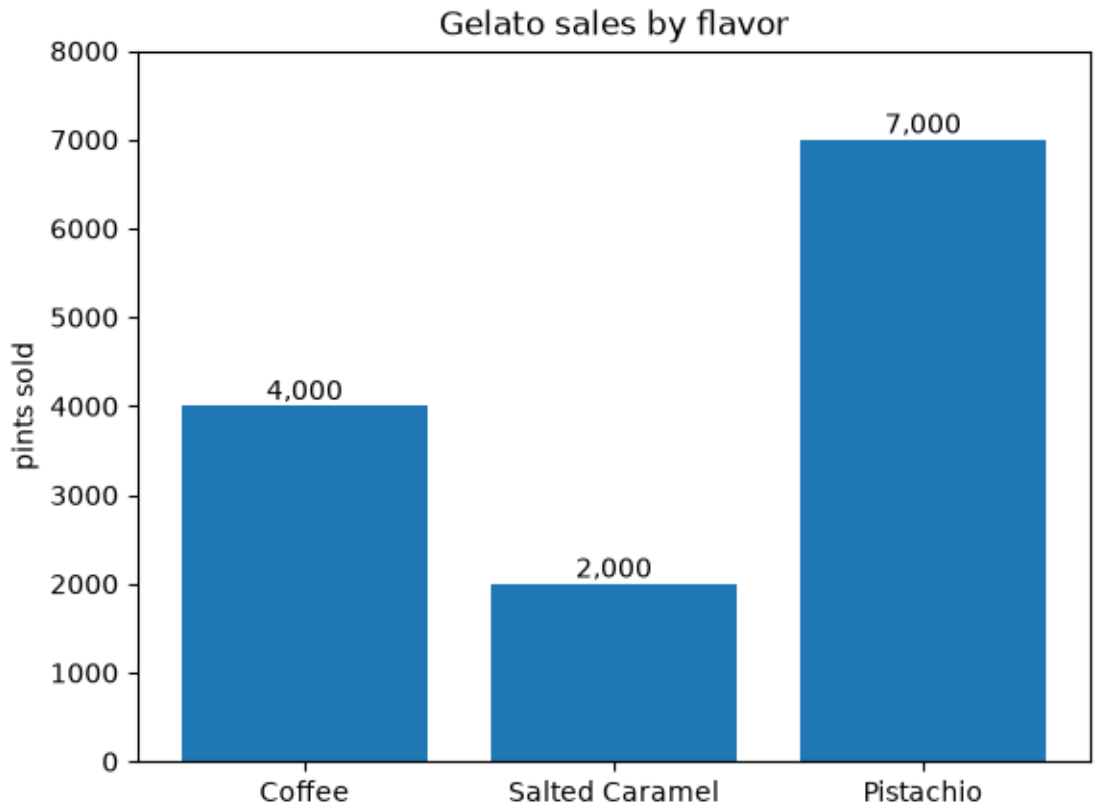
Some of the more advanced things that one can do with bar labels

```
fig, ax = plt.subplots()

hbars = ax.barh(y_pos, performance, xerr=error, align='center')
ax.set_yticks(y_pos, labels=people)
ax.invert_yaxis()  # labels read top-to-bottom
ax.set_xlabel('Performance')
ax.set_title('How fast do you want to go today?')

# Label with given captions, custom padding and annotate options
ax.bar_label(hbars, labels=[f'±{e:.2f}' for e in error],
             padding=8, color='b', fontsize=14)
ax.set_xlim(right=16)

plt.show()
```



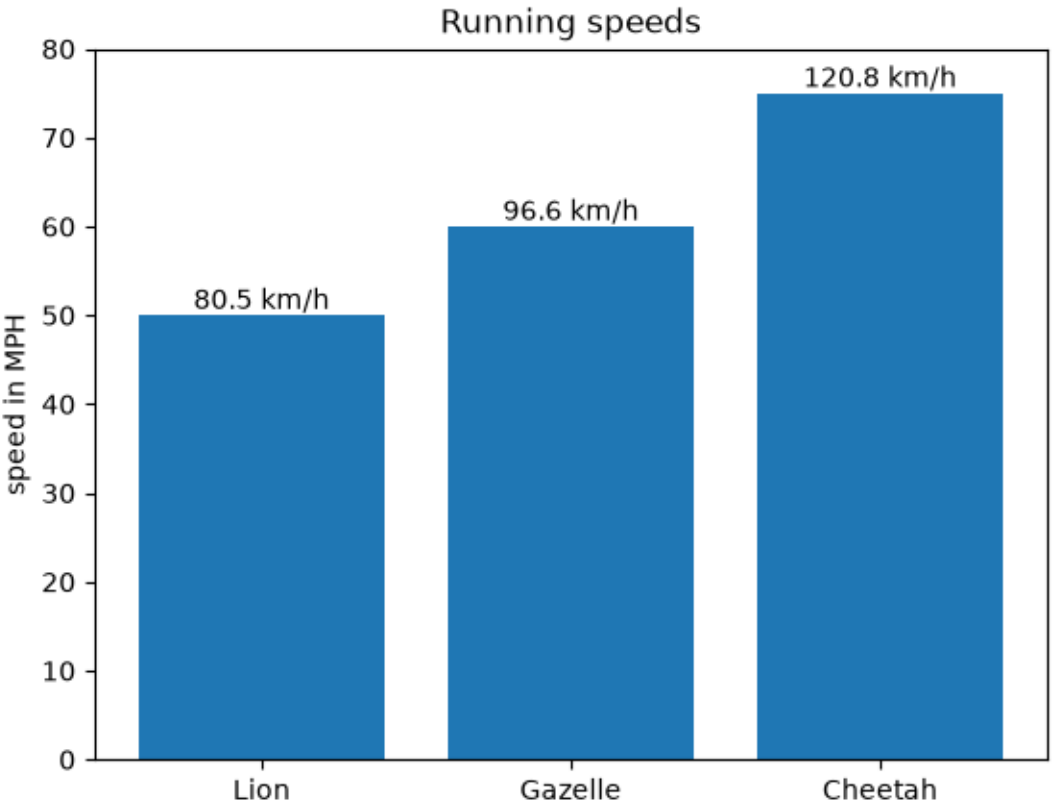
Bar labels using {}-style format string

```
fruit_names = ['Coffee', 'Salted Caramel', 'Pistachio']
fruit_counts = [4000, 2000, 7000]

fig, ax = plt.subplots()
bar_container = ax.bar(fruit_names, fruit_counts)
ax.set(ylabel='pints sold', title='Gelato sales by flavor', ylim=(0,␣
↪8000))
ax.bar_label(bar_container, fmt='{:,.0f}')
```



Bar labels using a callable

```
animal_names = ['Lion', 'Gazelle', 'Cheetah']
mph_speed = [50, 60, 75]

fig, ax = plt.subplots()
bar_container = ax.bar(animal_names, mph_speed)
ax.set(ylabel='speed in MPH', title='Running speeds', ylim=(0, 80))
ax.bar_label(bar_container, fmt=lambda x: f'{x * 1.61:.1f} km/h')
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.bar* / *matplotlib.pyplot.bar*
- *matplotlib.axes.Axes.barh* / *matplotlib.pyplot.barh*
- *matplotlib.axes.Axes.bar_label* / *matplotlib.pyplot.bar_label*

Tags: component: label plot-type: bar level: beginner

Total running time of the script: (0 minutes 1.074 seconds)

Stacked bar chart

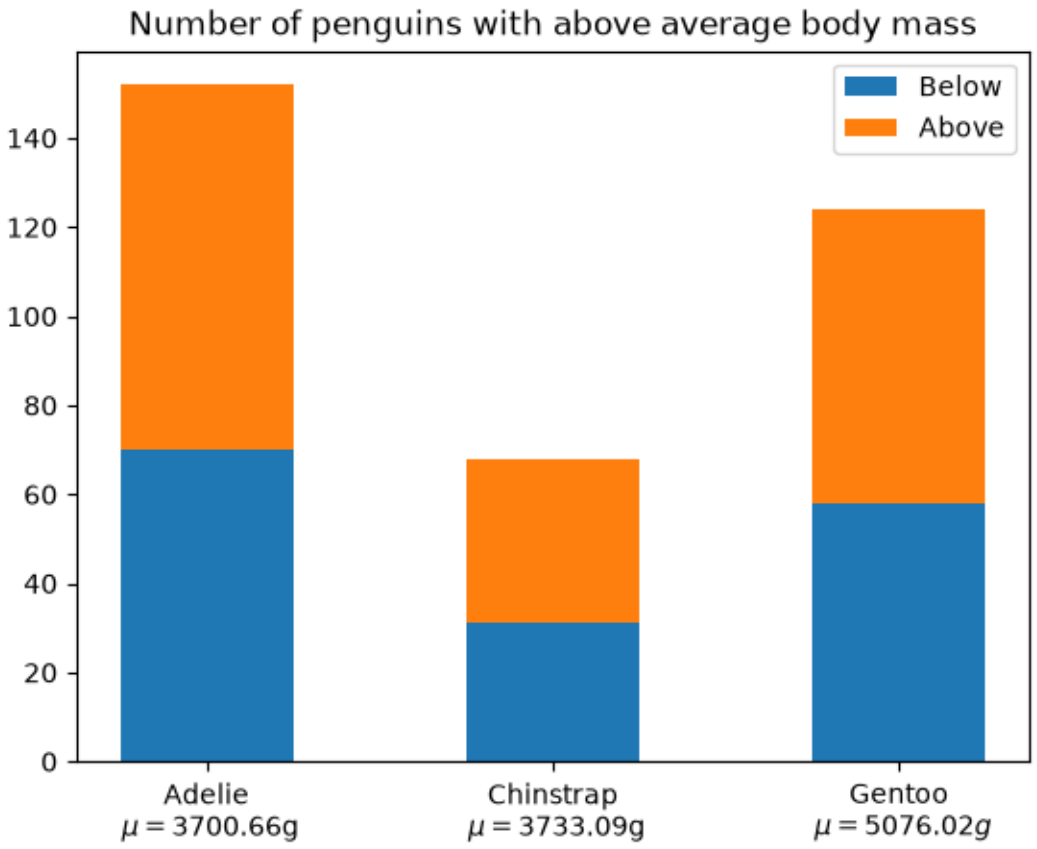
This is an example of creating a stacked bar plot using *bar*.

```
import matplotlib.pyplot as plt
import numpy as np

# data from https://allisonhorst.github.io/palmerpenguins/
```

(continues on next page)

(continued from previous page)

```
species = (
    "Adelie\n $\\mu=$3700.66g",
    "Chinstrap\n $\\mu=$3733.09g",
    "Gentoo\n $\\mu=5076.02g$",
)
weight_counts = {
    "Below": np.array([70, 31, 58]),
    "Above": np.array([82, 37, 66]),
}
width = 0.5

fig, ax = plt.subplots()
bottom = np.zeros(3)

for boolean, weight_count in weight_counts.items():
    p = ax.bar(species, weight_count, width, label=boolean,␣
 ↪bottom=bottom)
    bottom += weight_count

ax.set_title("Number of penguins with above average body mass")
ax.legend(loc="upper right")

plt.show()
```



Tags: plot-type: bar level: beginner

Bar chart with individual bar colors

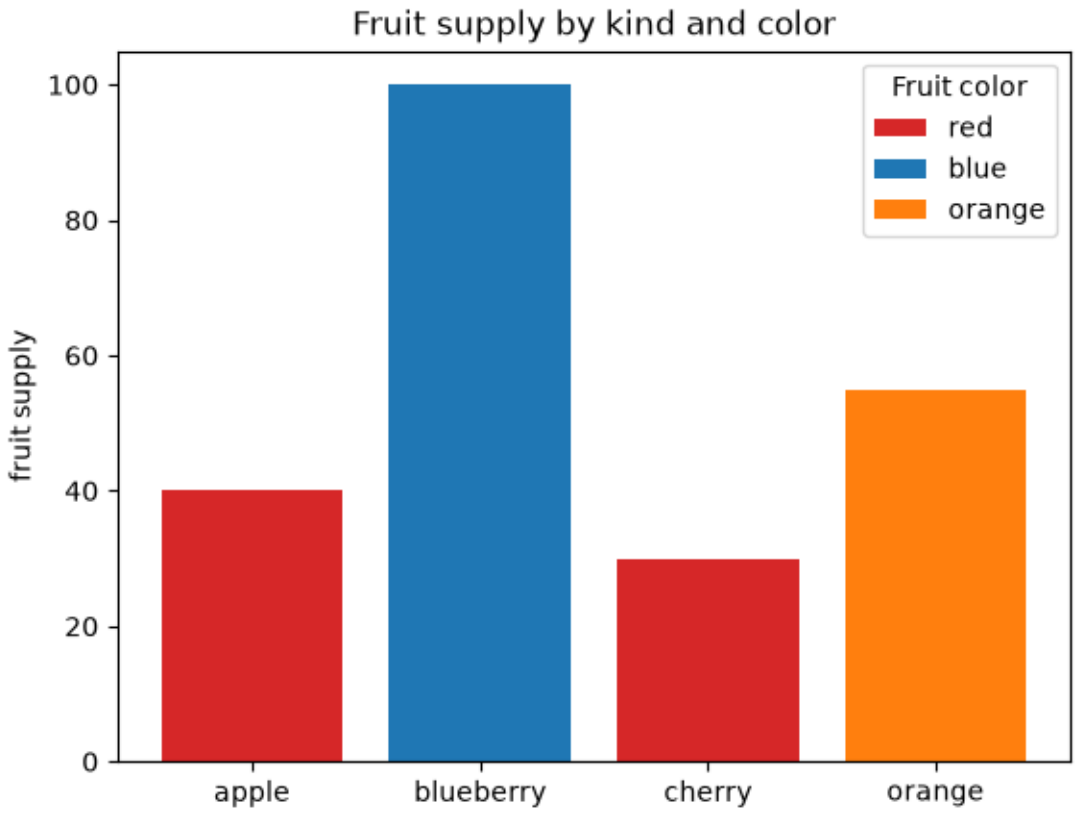
This is an example showing how to control bar color and legend entries using the *color* and *label* parameters of `bar`. Note that labels with a preceding underscore won't show up in the legend.

```
import matplotlib.pyplot as plt

fig, ax = plt.subplots()

fruits = ['apple', 'blueberry', 'cherry', 'orange']
counts = [40, 100, 30, 55]
bar_labels = ['red', 'blue', '_red', 'orange']
bar_colors = ['tab:red', 'tab:blue', 'tab:red', 'tab:orange']

ax.bar(fruits, counts, label=bar_labels, color=bar_colors)

ax.set_ylabel('fruit supply')
ax.set_title('Fruit supply by kind and color')
ax.legend(title='Fruit color')
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



Tags: styling: color plot-type: bar level: beginner

Hat graph

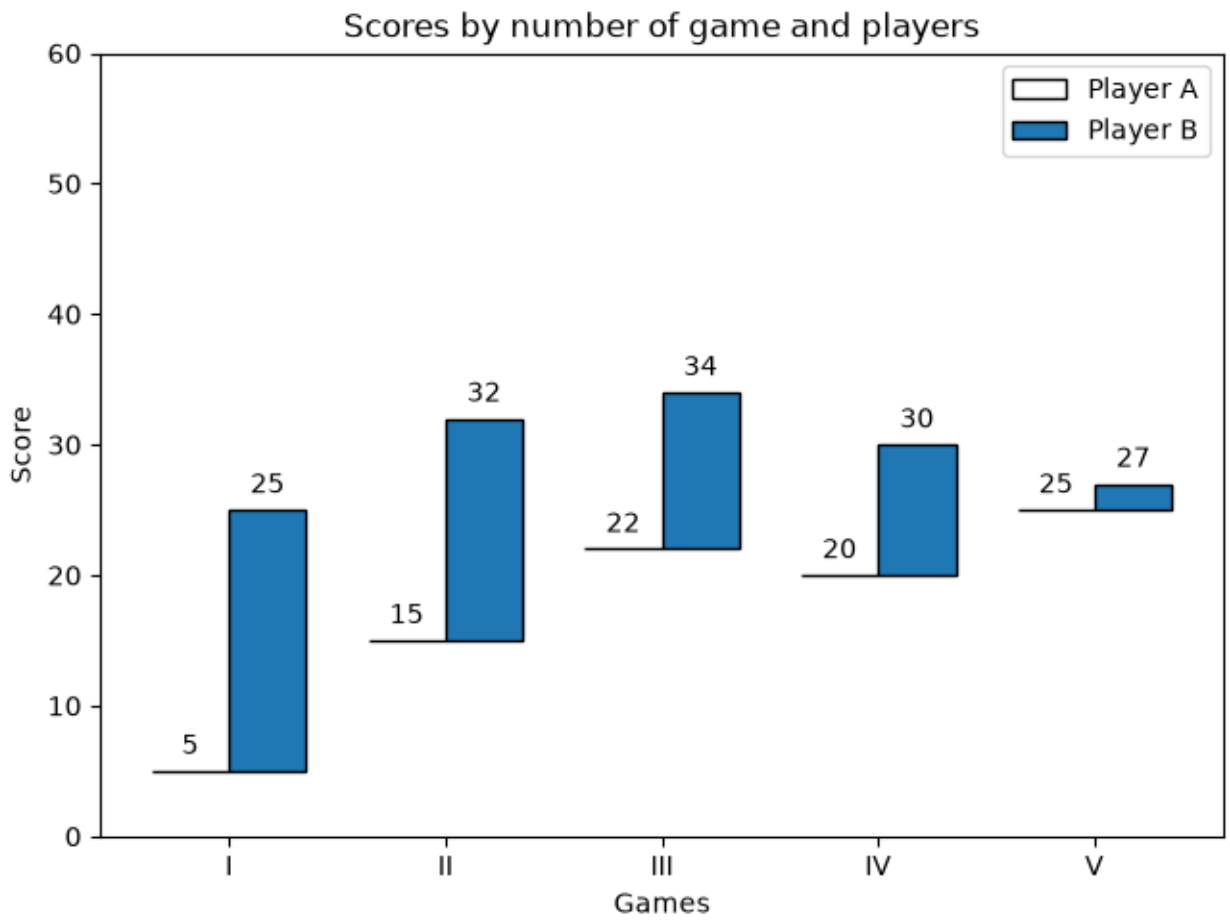
This example shows how to create a hat graph and how to annotate it with labels.

```
import matplotlib.pyplot as plt
import numpy as np


def hat_graph(ax, xlabels, values, group_labels):
    """
    Create a hat graph.

    Parameters
    ----------
    ax : matplotlib.axes.Axes
```

(continues on next page)

(continued from previous page)

```
        The Axes to plot into.
    xlabels : list of str
        The category names to be displayed on the x-axis.
    values : (M, N) array-like
        The data values.
        Rows are the groups (len(group_labels) == M).
        Columns are the categories (len(xlabels) == N).
    group_labels : list of str
        The group labels displayed in the legend.
    """

    values = np.asarray(values)
    color_cycle_colors = plt.rcParams['axes.prop_cycle'].by_key()[
↪'color']

    # Draw the hats
    bars = ax.grouped_bar(
        (values - values[0]).T, bottom=values[0], tick_labels=xlabels,
        labels=group_labels, edgecolor='black', group_spacing=0.8,
        colors=['none'] + color_cycle_colors)

    # Attach a text label on top of each bar
    for bc, heights in zip(bars.bar_containers, values):
        ax.bar_label(bc, heights, padding=4)


# Initialise labels and a numpy array make sure you have
# N labels of N number of values in the array
xlabels = ['I', 'II', 'III', 'IV', 'V']
playerA = np.array([5, 15, 22, 20, 25])
playerB = np.array([25, 32, 34, 30, 27])

fig, ax = plt.subplots(layout='constrained')

hat_graph(ax, xlabels, [playerA, playerB], ['Player A', 'Player B'])

# Add some text for labels, title and custom x-axis tick labels, etc.
ax.set_xlabel('Games')
ax.set_ylabel('Score')
ax.set_ylim(0, 60)
ax.set_title('Scores by number of game and players')
ax.legend()

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.grouped_bar* / *matplotlib.pyplot.grouped_bar*
- *matplotlib.axes.Axes.bar_label* / *matplotlib.pyplot.bar_label*

Tags: component: annotation plot-type: bar level: beginner

Bar chart with gradients

Matplotlib does not natively support gradients. However, we can emulate a gradient-filled rectangle by an *AxesImage* of the right size and coloring.

In particular, we use a colormap to generate the actual colors. It is then sufficient to define the underlying values on the corners of the image and let bicubic interpolation fill out the area. We define the gradient direction by a unit vector v. The values at the corners are then obtained by the lengths of the projections of the corner vectors on v.

A similar approach can be used to create a gradient background for an Axes. In that case, it is helpful to use Axes coordinates (`extent=(0, 1, 0, 1), transform=ax.transAxes`) to be independent of

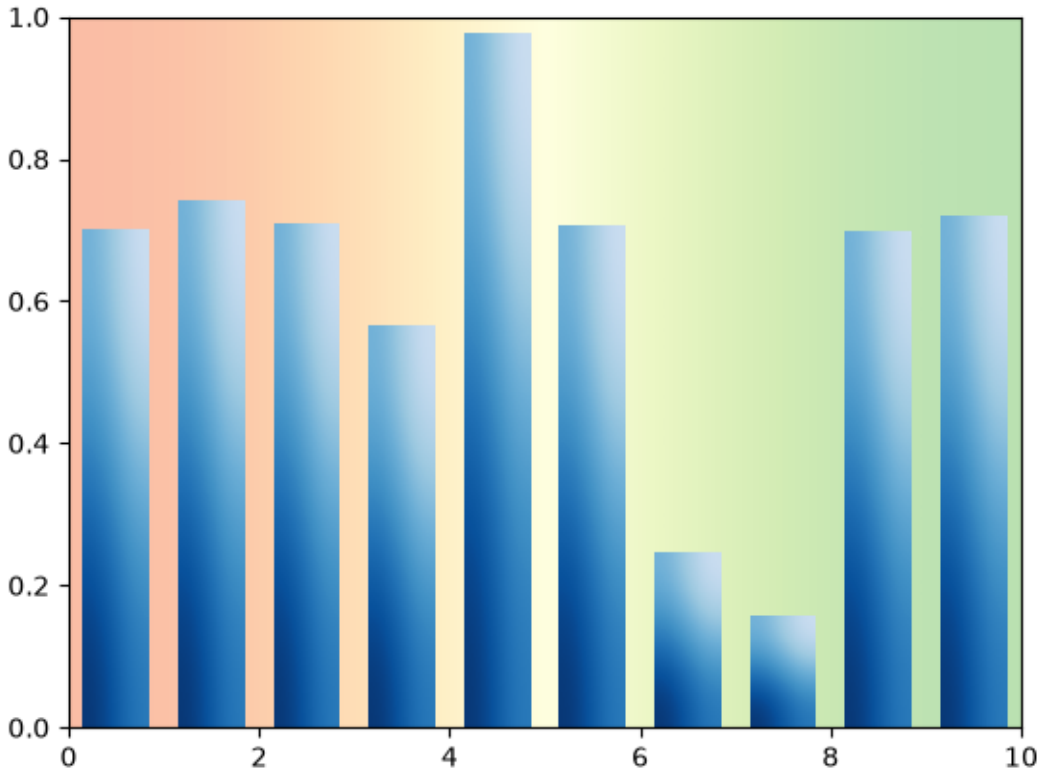
the data coordinates.

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)


def gradient_image(ax, direction=0.3, cmap_range=(0, 1), **kwargs):
    """
    Draw a gradient image based on a colormap.

    Parameters
    ----------
    ax : Axes
        The Axes to draw on.
    direction : float
        The direction of the gradient. This is a number in
        range 0 (=vertical) to 1 (=horizontal).
    cmap_range : float, float
        The fraction (cmin, cmax) of the colormap that should be
        used for the gradient, where the complete colormap is (0, 1).
    **kwargs
        Other parameters are passed on to `.Axes.imshow()`.
        In particular, *cmap*, *extent*, and *transform* may be useful.
    """
    phi = direction * np.pi / 2
    v = np.array([np.cos(phi), np.sin(phi)])
    X = np.array([[v @ [1, 0], v @ [1, 1]],
                  [v @ [0, 0], v @ [0, 1]]])
    a, b = cmap_range
    X = a + (b - a) / X.max() * X
    im = ax.imshow(X, interpolation='bicubic', clim=(0, 1),
                   aspect='auto', **kwargs)
    return im


def gradient_bar(ax, x, y, width=0.5, bottom=0):
    for left, top in zip(x, y):
        right = left + width
        gradient_image(ax, extent=(left, right, bottom, top),
                       cmap="Blues_r", cmap_range=(0, 0.8))


fig, ax = plt.subplots()
ax.set(xlim=(0, 10), ylim=(0, 1))
```

(continues on next page)

(continued from previous page)

```
# background image
gradient_image(ax, direction=1, extent=(0, 1, 0, 1), transform=ax.
 ↪transAxes,
               cmap="RdYlGn", cmap_range=(0.2, 0.8), alpha=0.5)

N = 10
x = np.arange(N) + 0.15
y = np.random.rand(N)
gradient_bar(ax, x, y, width=0.7)
plt.show()
```



Tags: styling: color plot-type: imshow level: intermediate purpose: showcase

Horizontal bar chart

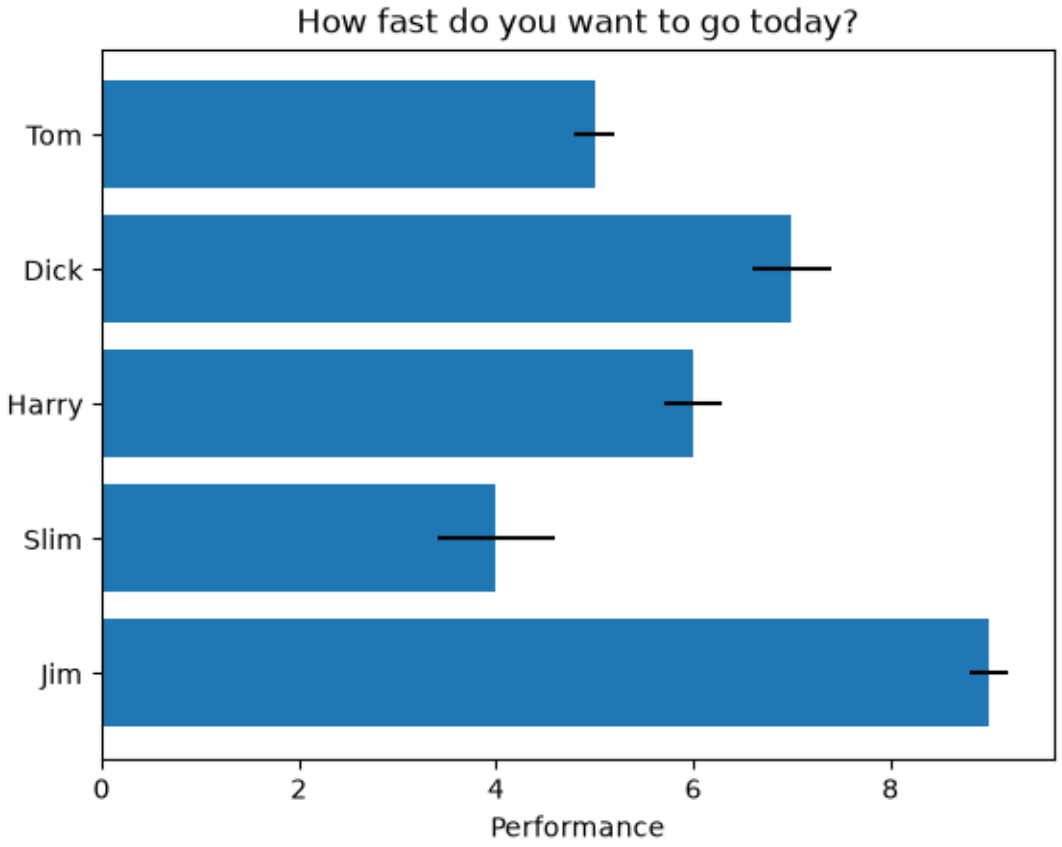
This example showcases a simple horizontal bar chart.

```
import matplotlib.pyplot as plt

fig, ax = plt.subplots()
```

(continues on next page)

(continued from previous page)

```
# Example data
people = ('Tom', 'Dick', 'Harry', 'Slim', 'Jim')
performance = [5, 7, 6, 4, 9]
error = [0.2, 0.4, 0.3, 0.6, 0.2]

ax.barh(people, performance, xerr=error, align='center')
ax.yaxis.set_inverted(True)  # arrange data from top to bottom
ax.set_xlabel('Performance')
ax.set_title('How fast do you want to go today?')

plt.show()
```



Tags: plot-type: bar level: beginner

Discrete distribution as horizontal bar chart

Stacked bar charts can be used to visualize discrete distributions.

This example visualizes the result of a survey in which people could rate their agreement to questions on a five-element scale.

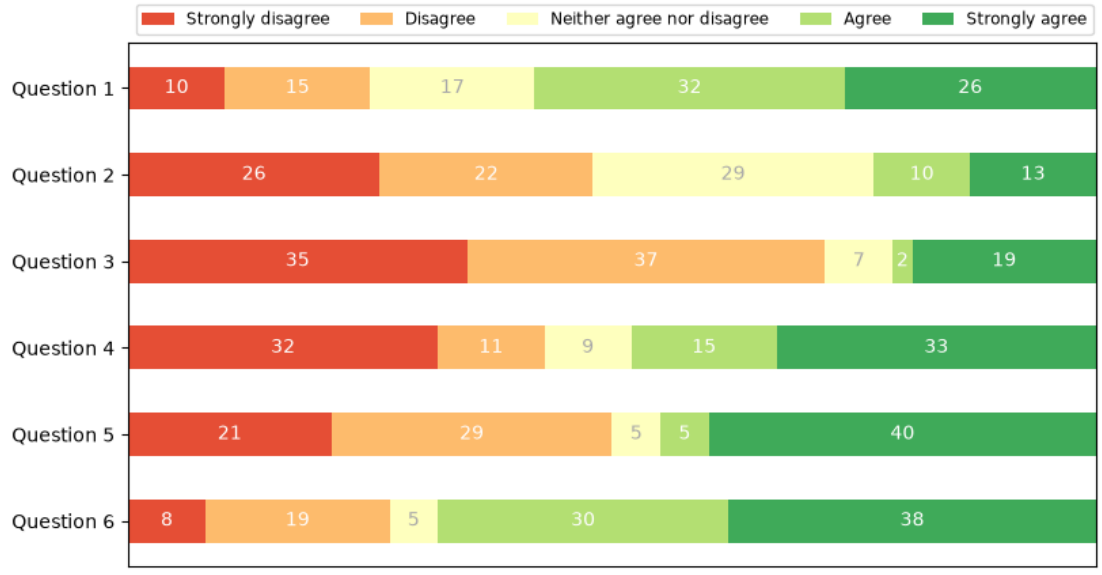
The horizontal stacking is achieved by calling *barh()* for each category and passing the starting point as the cumulative sum of the already drawn bars via the parameter `left`.

```
import matplotlib.pyplot as plt
import numpy as np

category_names = ['Strongly disagree', 'Disagree',
                  'Neither agree nor disagree', 'Agree', 'Strongly␣
 ↪agree']
results = {
    'Question 1': [10, 15, 17, 32, 26],
    'Question 2': [26, 22, 29, 10, 13],
    'Question 3': [35, 37, 7, 2, 19],
    'Question 4': [32, 11, 9, 15, 33],
    'Question 5': [21, 29, 5, 5, 40],
    'Question 6': [8, 19, 5, 30, 38]
}


def survey(results, category_names):
    """
    Parameters
    ----------
    results : dict
        A mapping from question labels to a list of answers per␣
 ↪category.
        It is assumed all lists contain the same number of entries and␣
 ↪that
        it matches the length of *category_names*.
    category_names : list of str
        The category labels.
    """
    labels = list(results.keys())
    data = np.array(list(results.values()))
    data_cum = data.cumsum(axis=1)
    category_colors = plt.colormaps['RdYlGn'](
        np.linspace(0.15, 0.85, data.shape[1]))

    fig, ax = plt.subplots(figsize=(9.2, 5))
    ax.invert_yaxis()
    ax.xaxis.set_visible(False)
```

(continues on next page)

(continued from previous page)

```
    ax.set_xlim(0, np.sum(data, axis=1).max())

    for i, (colname, color) in enumerate(zip(category_names,␣
↪category_colors)):
        widths = data[:, i]
        starts = data_cum[:, i] - widths
        rects = ax.barh(labels, widths, left=starts, height=0.5,
                        label=colname, color=color)

        r, g, b, _ = color
        text_color = 'white' if r * g * b < 0.5 else 'darkgrey'
        ax.bar_label(rects, label_type='center', color=text_color)
    ax.legend(ncols=len(category_names), bbox_to_anchor=(0, 1),
              loc='lower left', fontsize='small')

    return fig, ax


survey(results, category_names)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.barh / matplotlib.pyplot.barh*

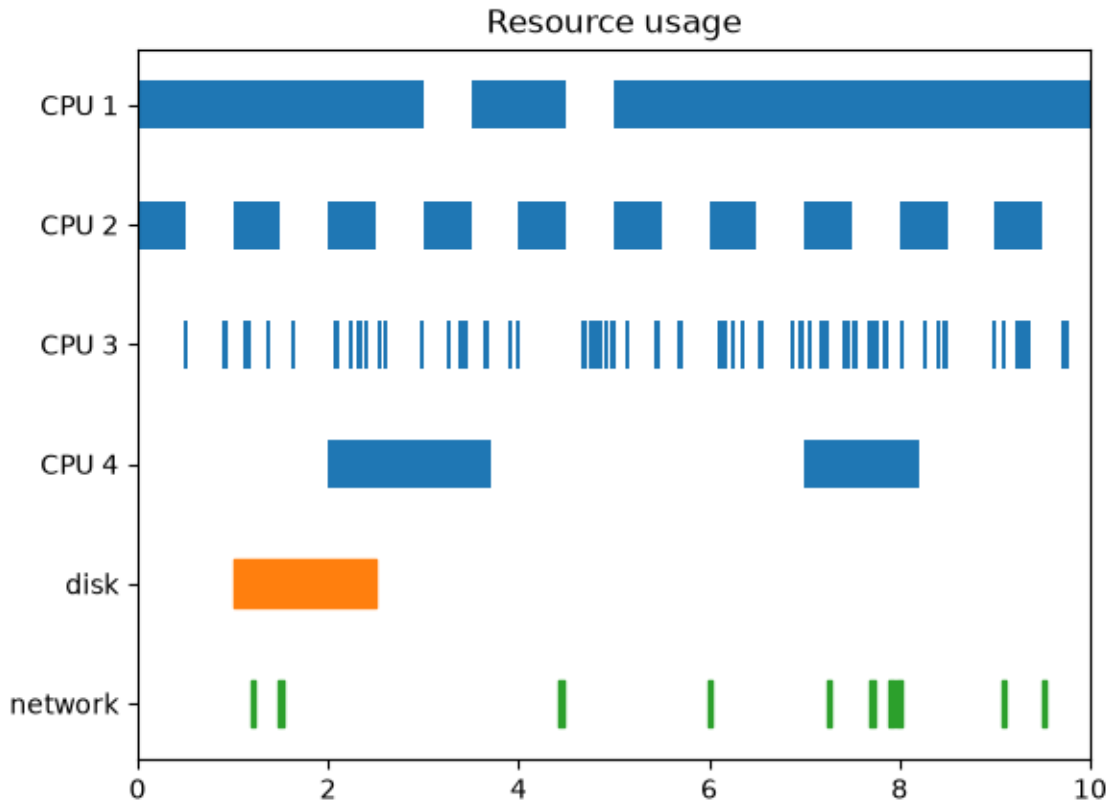
- *matplotlib.axes.Axes.bar_label* / *matplotlib.pyplot.bar_label*
- *matplotlib.axes.Axes.legend* / *matplotlib.pyplot.legend*

Tags: domain: statistics component: label plot-type: bar level: beginner

Broken horizontal bars

broken_barh creates sequences of horizontal bars. This example shows a timing diagram.

```
import matplotlib.pyplot as plt
import numpy as np

# data is a sequence of (start, duration) tuples
cpu_1 = [(0, 3), (3.5, 1), (5, 5)]
cpu_2 = np.column_stack([np.linspace(0, 9, 10), np.full(10, 0.5)])
cpu_3 = np.column_stack([10*np.random.random(61), np.full(61, 0.05)])
cpu_4 = [(2, 1.7), (7, 1.2)]
disk = [(1, 1.5)]
network = np.column_stack([10*np.random.random(10), np.full(10, 0.05)])

fig, ax = plt.subplots()
# broken_barh(xranges, (ypos, height))
ax.broken_barh(cpu_1, ("CPU 1", 0.4), align="center")
ax.broken_barh(cpu_2, ("CPU 2", 0.4), align="center")
ax.broken_barh(cpu_3, ("CPU 3", 0.4), align="center")
ax.broken_barh(cpu_4, ("CPU 4", 0.4), align="center")
ax.broken_barh(disk, ("disk", 0.4), align="center", color="tab:orange")
ax.broken_barh(network, ("network", 0.4), align="center", color=
 ↪"tab:green")
ax.set_xlim(0, 10)
ax.invert_yaxis()  # order the bars from top to bottom
ax.set_title("Resource usage")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.broken_barh* / *matplotlib.pyplot.broken_barh*
- *matplotlib.axes.Axes.invert_yaxis*
- *matplotlib.axes.Axes.set_yticks*

Tags: component: annotation plot-type: bar level: beginner

Scatter Demo2

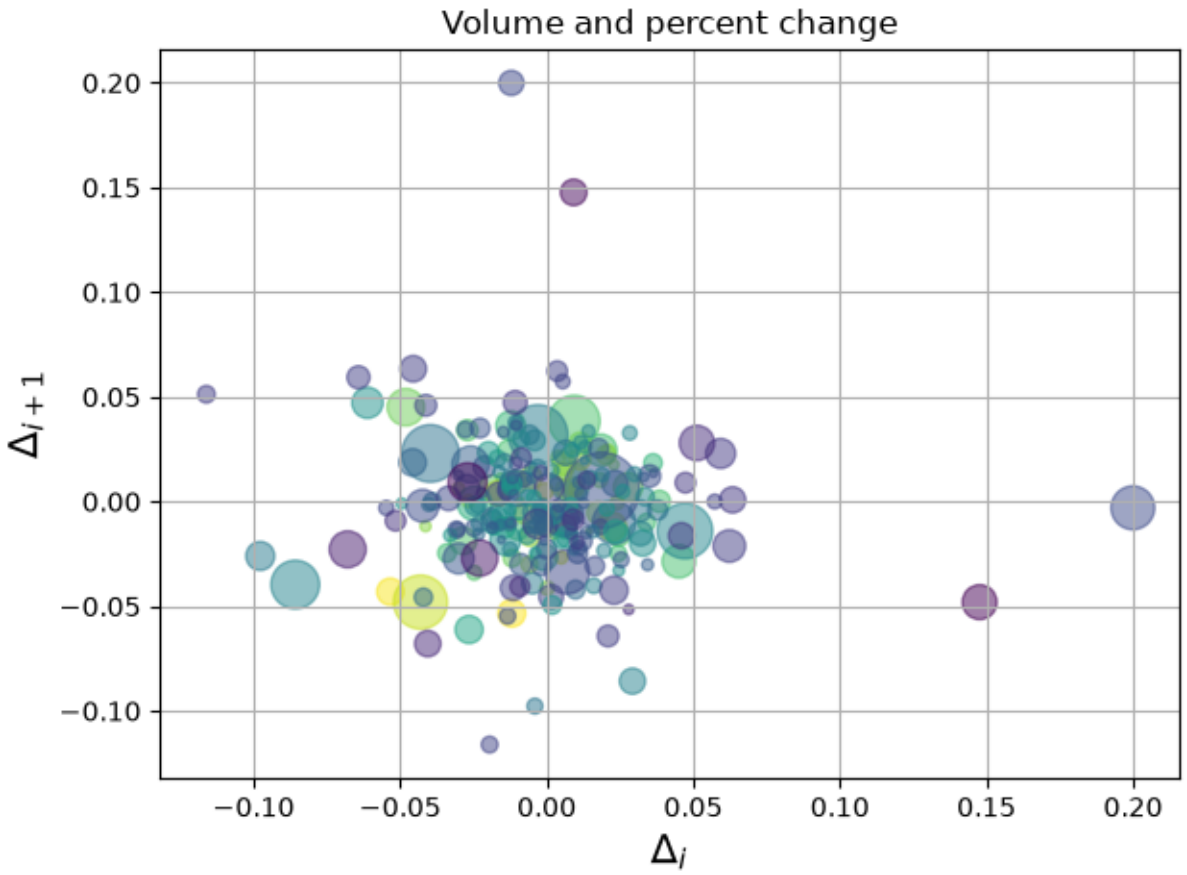
Demo of scatter plot with varying marker colors and sizes.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.cbook as cbook
```

(continues on next page)

(continued from previous page)

```
# Load a numpy record array from yahoo csv data with fields date,␣
 ↪open, high,
# low, close, volume, adj_close from the mpl-data/sample_data␣
 ↪directory. The
# record array stores the date as an np.datetime64 with a day unit ('D
 ↪') in
# the date column.
price_data = cbook.get_sample_data('goog.npz')['price_data']
price_data = price_data[-250:]  # get the most recent 250 trading days

delta1 = np.diff(price_data["adj_close"]) / price_data["adj_close"][:-
 ↪1]

# Marker size in units of points^2
volume = (15 * price_data["volume"][:-2] / price_data["volume"][0])**2
close = 0.003 * price_data["close"][:-2] / 0.003 * price_data["open
 ↪"][:-2]

fig, ax = plt.subplots()
ax.scatter(delta1[:-1], delta1[1:], c=close, s=volume, alpha=0.5)

ax.set_xlabel(r'$\Delta_i$', fontsize=15)
ax.set_ylabel(r'$\Delta_{i+1}$', fontsize=15)
ax.set_title('Volume and percent change')

ax.grid(True)
fig.tight_layout()

plt.show()
```



Tags: component: marker styling: color styling: colormap plot-type: scatter level: beginner

Mapping marker properties to multivariate data

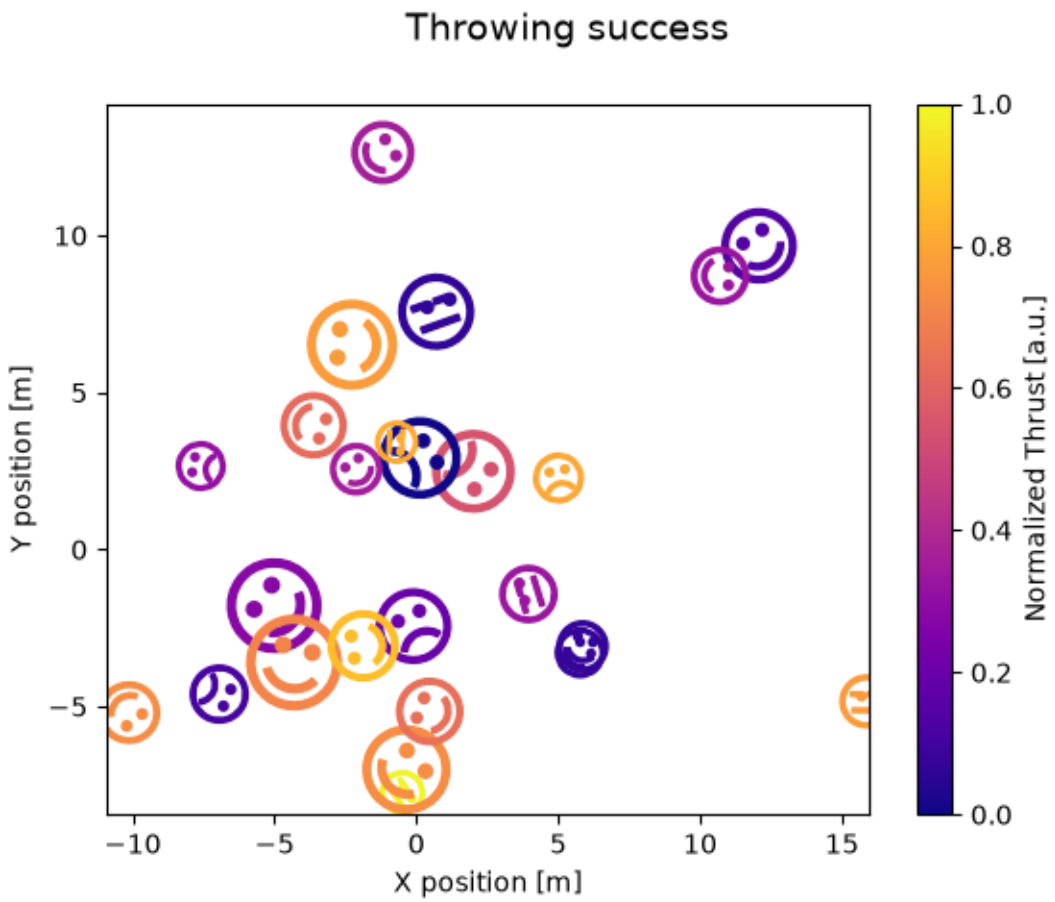
This example shows how to use different properties of markers to plot multivariate datasets. Here we represent a successful baseball throw as a smiley face with marker size mapped to the skill of thrower, marker rotation to the take-off angle, and thrust to the marker color.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.colors import Normalize
from matplotlib.markers import MarkerStyle
from matplotlib.text import TextPath
from matplotlib.transforms import Affine2D

SUCCESS_SYMBOLS = [
    TextPath((0, 0), "☹"),
    TextPath((0, 0), "😐"),
    TextPath((0, 0), "☺"),
]
```

(continues on next page)

(continued from previous page)

```
N = 25
np.random.seed(42)
skills = np.random.uniform(5, 80, size=N) * 0.1 + 5
takeoff_angles = np.random.normal(0, 90, N)
thrusts = np.random.uniform(size=N)
successful = np.random.randint(0, 3, size=N)
positions = np.random.normal(size=(N, 2)) * 5
data = zip(skills, takeoff_angles, thrusts, successful, positions)

cmap = plt.colormaps["plasma"]
fig, ax = plt.subplots()
fig.suptitle("Throwing success", size=14)
for skill, takeoff, thrust, mood, pos in data:
    t = Affine2D().scale(skill).rotate_deg(takeoff)
    m = MarkerStyle(SUCCESS_SYMBOLS[mood], transform=t)
    ax.plot(pos[0], pos[1], marker=m, color=cmap(thrust))
fig.colorbar(plt.cm.ScalarMappable(norm=Normalize(0, 1), cmap="plasma
 ↪"),
             ax=ax, label="Normalized Thrust [a.u.]")
ax.set_xlabel("X position [m]")
ax.set_ylabel("Y position [m]")

plt.show()
```



Tags: component: marker styling: color styling: shape level: beginner purpose: fun

Marker examples

Demonstrates several ways to specify markers in scatter plots, including built-in marker styles and custom marker paths.

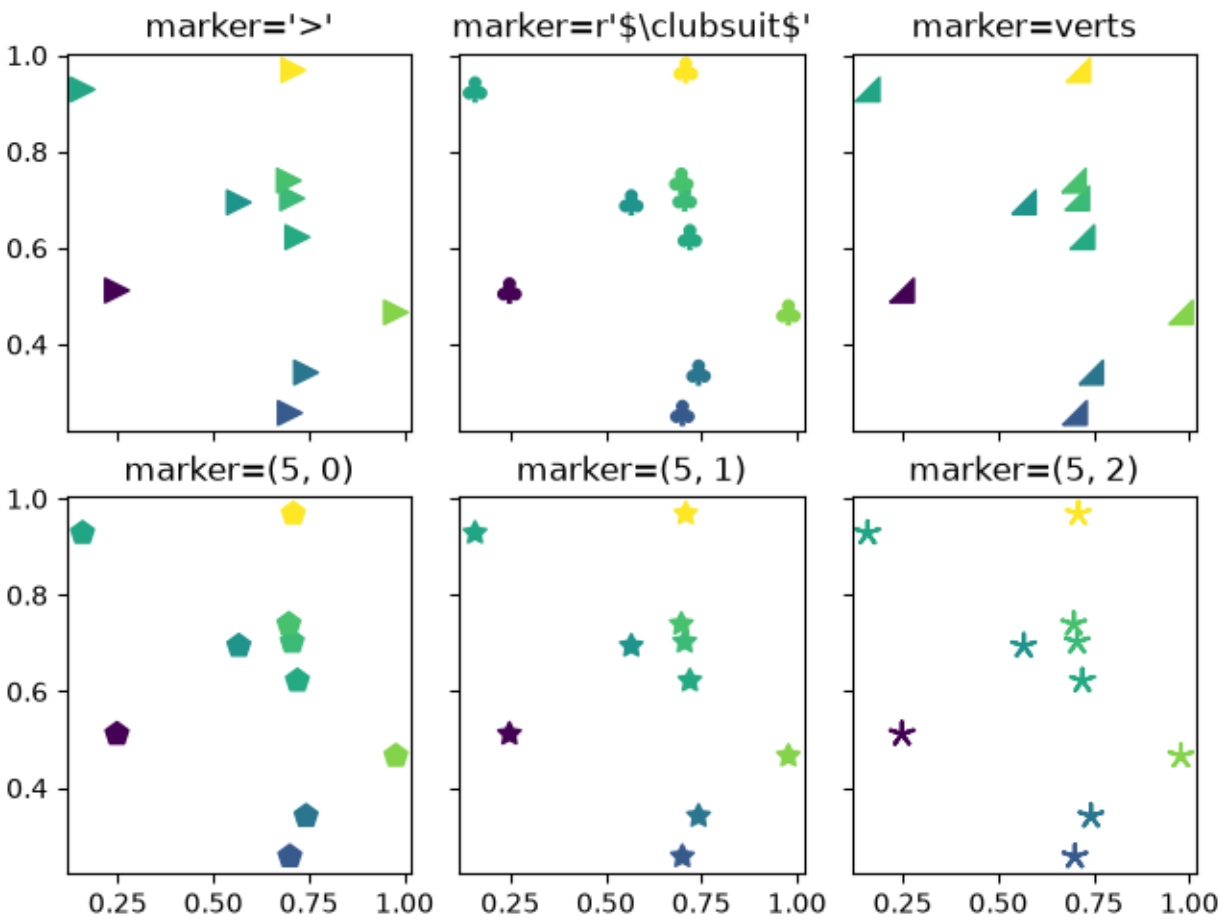
See also the *matplotlib.markers* documentation for a list of all markers and *Marker reference* for more information on configuring markers.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

x = np.random.rand(10)
y = np.random.rand(10)
z = np.sqrt(x**2 + y**2)

fig, axs = plt.subplots(2, 3, sharex=True, sharey=True, layout=
 ↪"constrained")
```

(continues on next page)

(continued from previous page)

```
# Matplotlib marker symbol
axs[0, 0].scatter(x, y, s=80, c=z, marker=">")
axs[0, 0].set_title("marker='>'")

# marker from TeX: passing a TeX symbol name enclosed in $-signs
axs[0, 1].scatter(x, y, s=80, c=z, marker=r"$\clubsuit$")
axs[0, 1].set_title(r"marker=r'\$\clubsuit\$'")

# marker from path: passing a custom path of N vertices as a (N, 2)␣
 ↪array-like
verts = [[-1, -1], [1, -1], [1, 1], [-1, -1]]
axs[0, 2].scatter(x, y, s=80, c=z, marker=verts)
axs[0, 2].set_title("marker=verts")

# regular pentagon marker
axs[1, 0].scatter(x, y, s=80, c=z, marker=(5, 0))
axs[1, 0].set_title("marker=(5, 0)")

# regular 5-pointed star marker
axs[1, 1].scatter(x, y, s=80, c=z, marker=(5, 1))
axs[1, 1].set_title("marker=(5, 1)")

# regular 5-pointed asterisk marker
axs[1, 2].scatter(x, y, s=80, c=z, marker=(5, 2))
axs[1, 2].set_title("marker=(5, 2)")

plt.show()
```



Tags: component: marker level: beginner

Scatter plot with a legend

To create a scatter plot with a legend one may use a loop and create one *scatter* plot per item to appear in the legend and set the `label` accordingly.

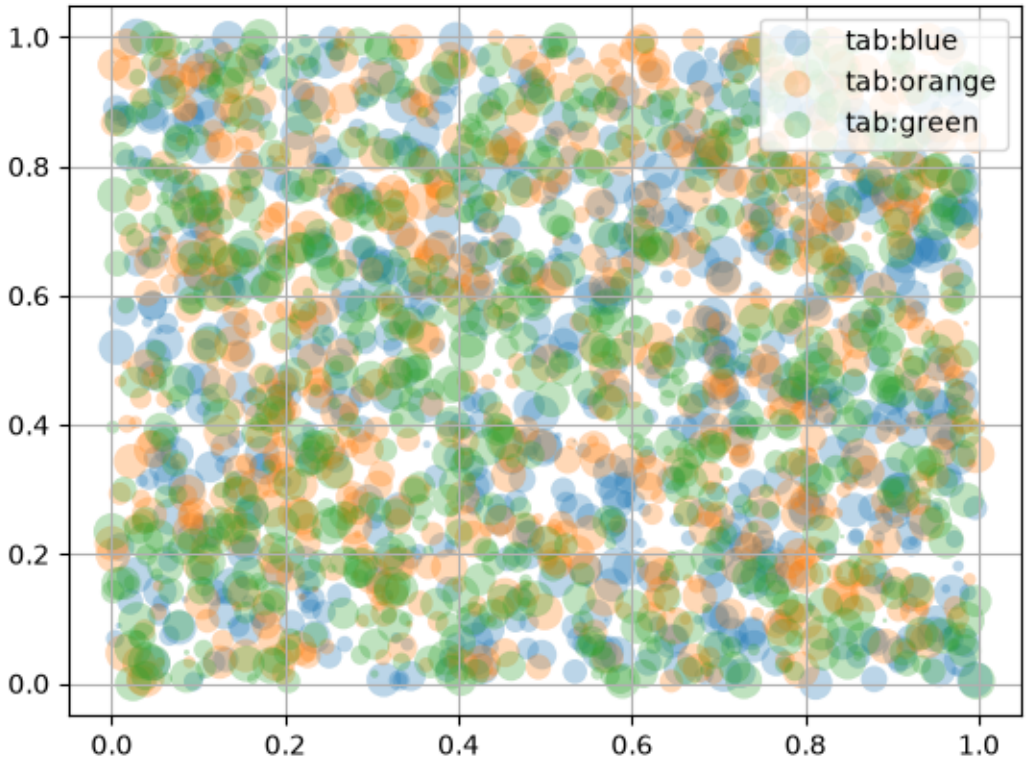
The following also demonstrates how transparency of the markers can be adjusted by giving `alpha` a value between 0 and 1.

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)


fig, ax = plt.subplots()
for color in ['tab:blue', 'tab:orange', 'tab:green']:
    n = 750
    x, y = np.random.rand(2, n)
    scale = 200.0 * np.random.rand(n)
    ax.scatter(x, y, c=color, s=scale, label=color,
```

(continues on next page)

(continued from previous page)

```
                alpha=0.3, edgecolors='none')

ax.legend()
ax.grid(True)

plt.show()
```



Automated legend creation

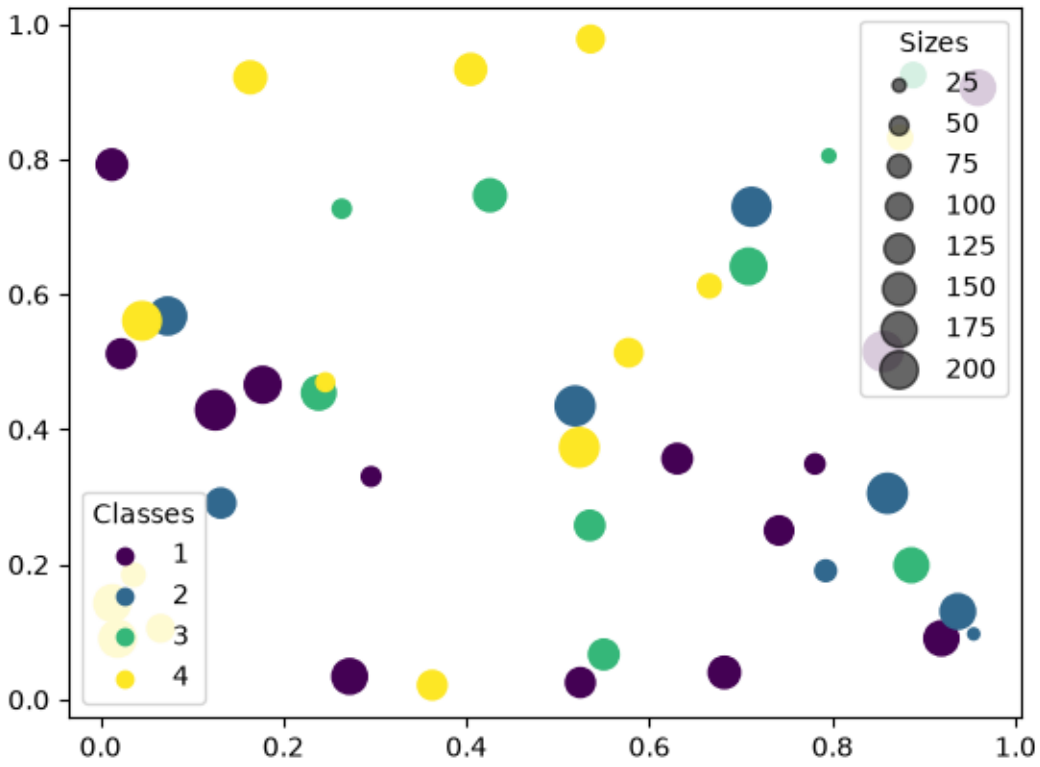
Another option for creating a legend for a scatter is to use the *PathCollection.legend_elements* method. It will automatically try to determine a useful number of legend entries to be shown and return a tuple of handles and labels. Those can be passed to the call to *legend*.

```
N = 45
x, y = np.random.rand(2, N)
c = np.random.randint(1, 5, size=N)
s = np.random.randint(10, 220, size=N)

fig, ax = plt.subplots()
```

(continues on next page)

(continued from previous page)

```
scatter = ax.scatter(x, y, c=c, s=s)

# produce a legend with the unique colors from the scatter
legend1 = ax.legend(*scatter.legend_elements(),
                    loc="lower left", title="Classes")
ax.add_artist(legend1)

# produce a legend with a cross-section of sizes from the scatter
handles, labels = scatter.legend_elements(prop="sizes", alpha=0.6)
legend2 = ax.legend(handles, labels, loc="upper right", title="Sizes")

plt.show()
```



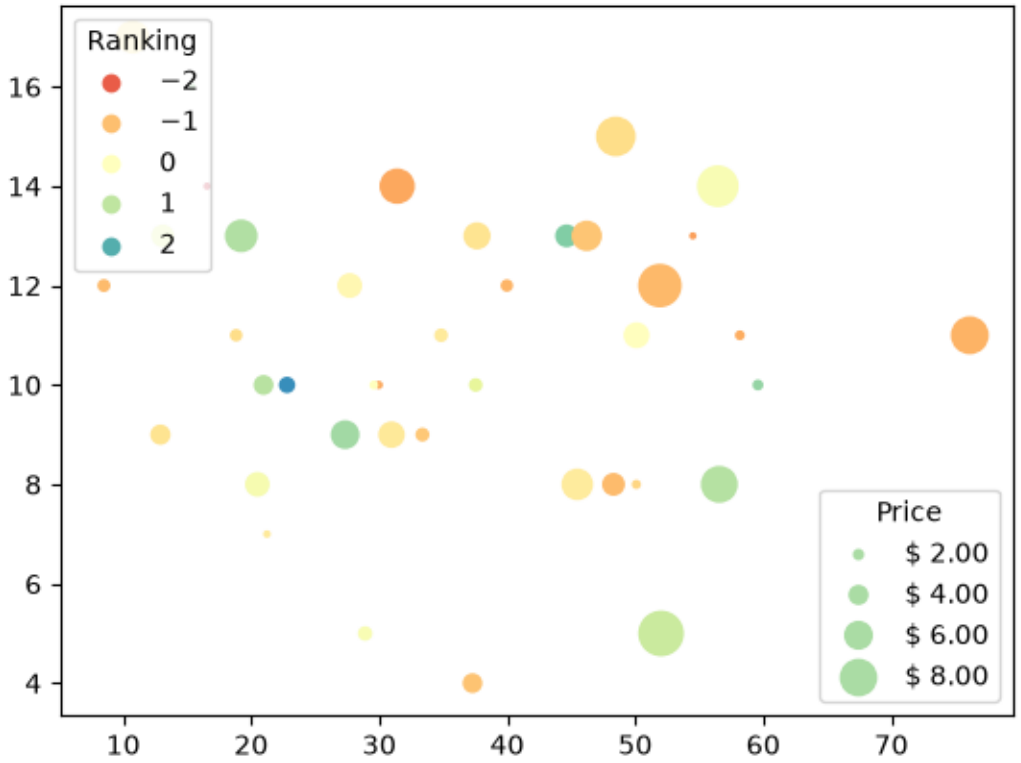
Further arguments to the `PathCollection.legend_elements` method can be used to steer how many legend entries are to be created and how they should be labeled. The following shows how to use some of them.

```
volume = np.random.rayleigh(27, size=40)
amount = np.random.poisson(10, size=40)
```

(continues on next page)

(continued from previous page)

```
ranking = np.random.normal(size=40)
price = np.random.uniform(1, 10, size=40)

fig, ax = plt.subplots()

# Because the price is much too small when being provided as size for␣
 ↪``s``,
# we normalize it to some useful point sizes, s=0.3*(price*3)**2
scatter = ax.scatter(volume, amount, c=ranking, s=0.3*(price*3)**2,
                     vmin=-3, vmax=3, cmap="Spectral")

# Produce a legend for the ranking (colors). Even though there are 40␣
 ↪different
# rankings, we only want to show 5 of them in the legend.
legend1 = ax.legend(*scatter.legend_elements(num=5),
                    loc="upper left", title="Ranking")
ax.add_artist(legend1)

# Produce a legend for the price (sizes). Because we want to show the␣
 ↪prices
# in dollars, we use the *func* argument to supply the inverse of the␣
 ↪function
# used to calculate the sizes from above. The *fmt* ensures to show␣
 ↪the price
# in dollars. Note how we target at 5 elements here, but obtain only 4␣
 ↪in the
# created legend due to the automatic round prices that are chosen for␣
 ↪us.
kw = dict(prop="sizes", num=5, color=scatter.cmap(0.7), fmt="$ {x:.2f}
 ↪",
          func=lambda s: np.sqrt(s/.3)/3)
legend2 = ax.legend(*scatter.legend_elements(**kw),
                    loc="lower right", title="Price")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.scatter* / *matplotlib.pyplot.scatter*
- *matplotlib.axes.Axes.legend* / *matplotlib.pyplot.legend*
- *matplotlib.collections.PathCollection.legend_elements*

Tags: component: legend plot-type: scatter level: intermediate

Total running time of the script: (0 minutes 1.046 seconds)

Scatter plot with masked values

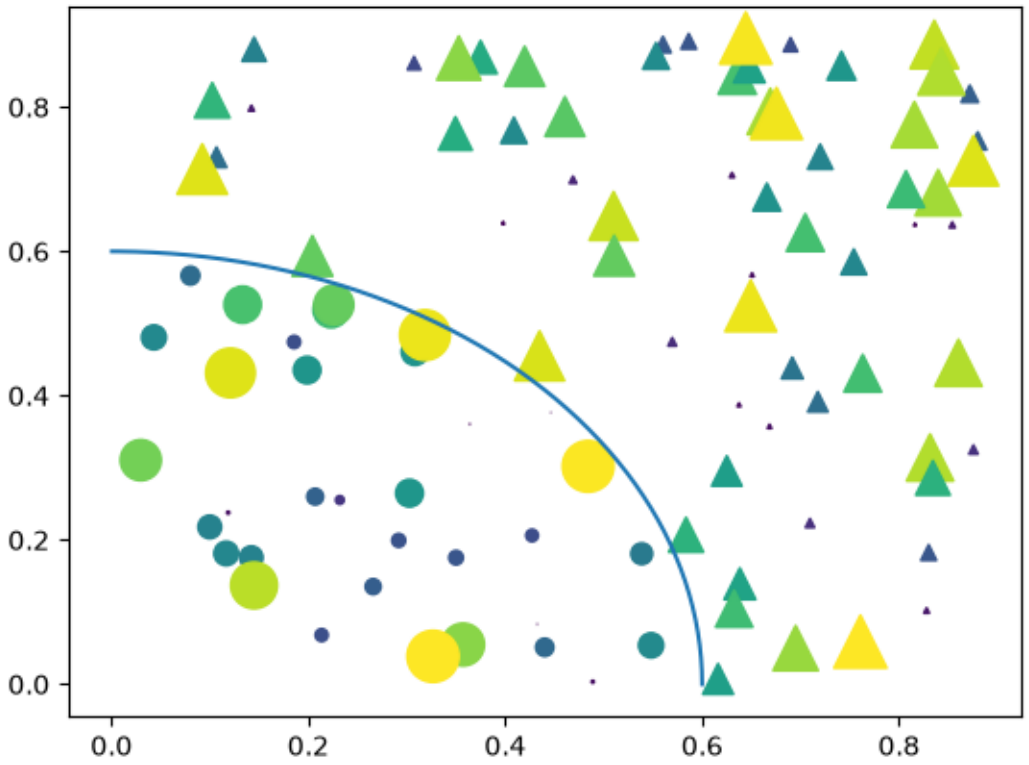
Mask some data points and add a line demarking masked regions.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
```

(continues on next page)

(continued from previous page)

```
np.random.seed(19680801)


N = 100
r0 = 0.6
x = 0.9 * np.random.rand(N)
y = 0.9 * np.random.rand(N)
area = (20 * np.random.rand(N))**2  # 0 to 10 point radii
c = np.sqrt(area)
r = np.sqrt(x ** 2 + y ** 2)
area1 = np.ma.masked_where(r < r0, area)
area2 = np.ma.masked_where(r >= r0, area)
plt.scatter(x, y, s=area1, marker='^', c=c)
plt.scatter(x, y, s=area2, marker='o', c=c)
# Show the boundary between the regions:
theta = np.arange(0, np.pi / 2, 0.01)
plt.plot(r0 * np.cos(theta), r0 * np.sin(theta))

plt.show()
```



Tags: component: marker plot-type: scatter level: beginner

Scatter plot with histograms

Add histograms to the x-axes and y-axes margins of a scatter plot.

This layout features a central scatter plot illustrating the relationship between x and y, a histogram at the top displaying the distribution of x, and a histogram on the right showing the distribution of y.

For a nice alignment of the main Axes with the marginals, two options are shown below:

- *Defining the Axes positions using subplot_mosaic*
- *Defining the Axes positions using inset_axes*

While `Axes.inset_axes` may be a bit more complex, it allows correct handling of main Axes with a fixed aspect ratio.

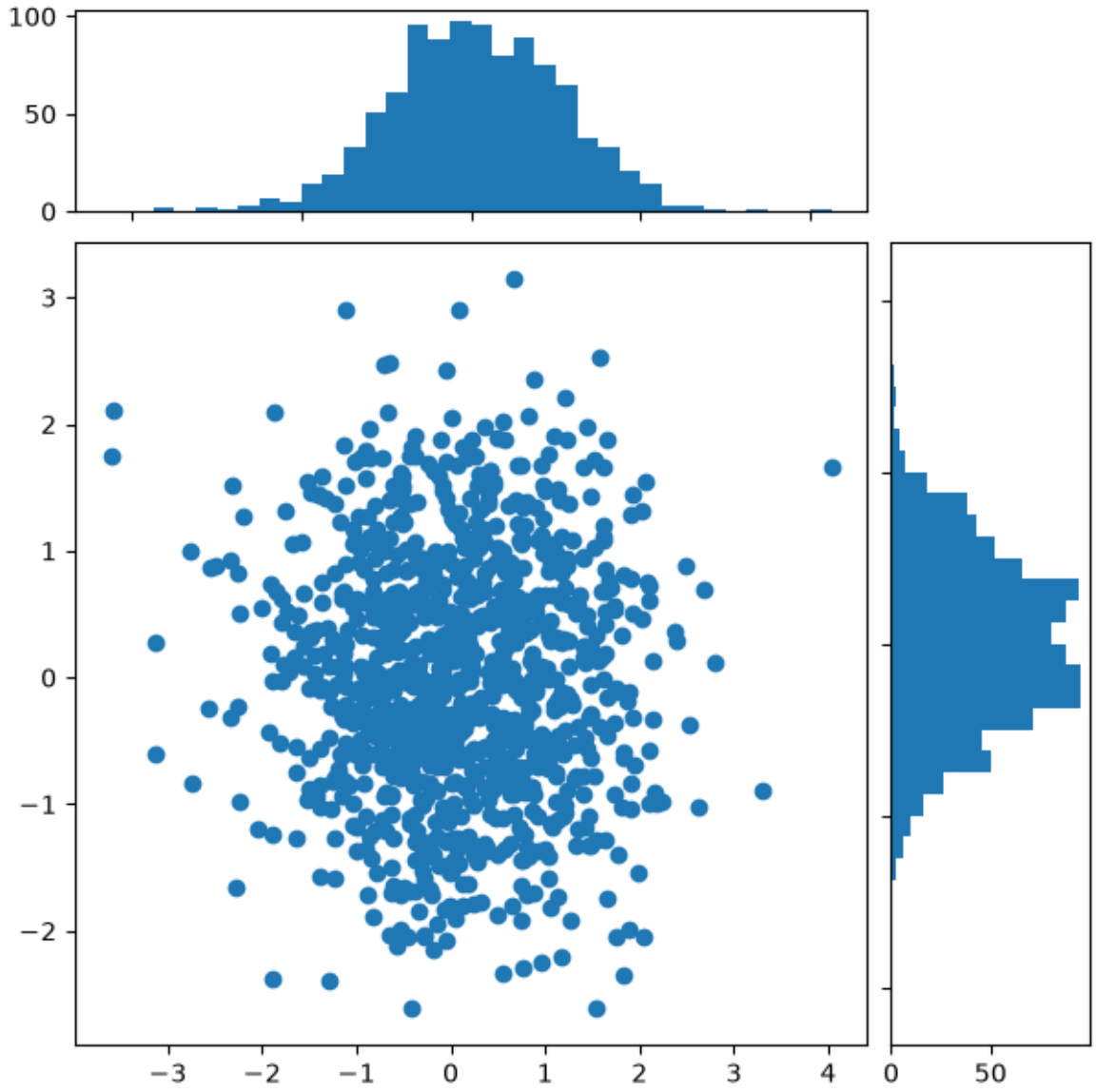
Let us first define a function that takes x and y data as input, as well as three Axes, the main Axes for the scatter, and two marginal Axes. It will then create the scatter and histograms inside the provided Axes.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

# some random data
x = np.random.randn(1000)
y = np.random.randn(1000)


def scatter_hist(x, y, ax, ax_histx, ax_histy):
    # no labels
    ax_histx.tick_params(axis="x", labelbottom=False)
    ax_histy.tick_params(axis="y", labelleft=False)

    # the scatter plot:
    ax.scatter(x, y)

    # now determine nice limits by hand:
    binwidth = 0.25
    xymax = max(np.max(np.abs(x)), np.max(np.abs(y)))
    lim = (int(xymax/binwidth) + 1) * binwidth

    bins = np.arange(-lim, lim + binwidth, binwidth)
    ax_histx.hist(x, bins=bins)
    ax_histy.hist(y, bins=bins, orientation='horizontal')
```

Defining the Axes positions using subplot_mosaic

We use the *subplot_mosaic* function to define the positions and names of the three axes; the empty axes is specified by `'.'`. We manually specify the size of the figure, and can make the different axes have different sizes by specifying the *width_ratios* and *height_ratios* arguments. The *layout* argument is set to `'constrained'` to optimize the spacing between the axes.

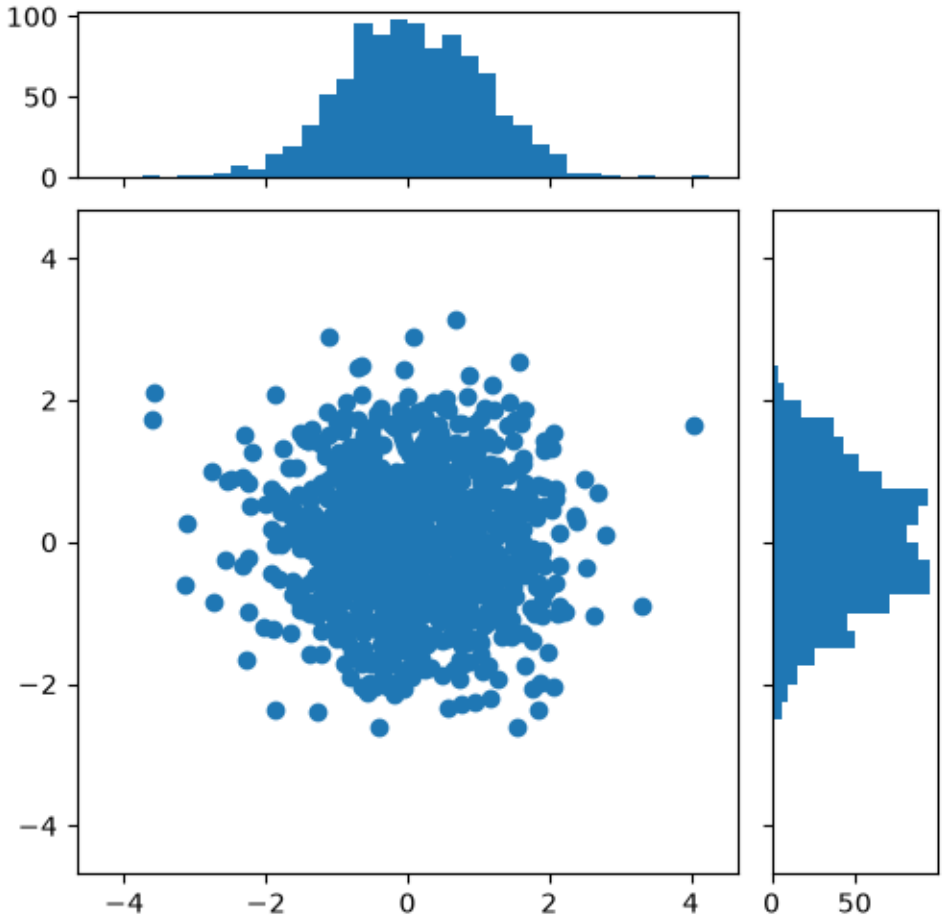
```
fig, axs = plt.subplot_mosaic([['histx', '.'],
                               ['scatter', 'histy']],
                              figsize=(6, 6),
                              width_ratios=(4, 1), height_ratios=(1,␣
↪4),
                              layout='constrained')
scatter_hist(x, y, axs['scatter'], axs['histx'], axs['histy'])
```



Defining the Axes positions using inset_axes

inset_axes can be used to position marginals *outside* the main Axes. The advantage of doing so is that the aspect ratio of the main Axes can be fixed, and the marginals will always be drawn relative to the position of the Axes.

```
# Create a Figure, which doesn't have to be square.
fig = plt.figure(layout='constrained')
# Create the main Axes.
ax = fig.add_subplot()
# The main Axes' aspect can be fixed.
ax.set_aspect('equal')
# Create marginal Axes, which have 25% of the size of the main Axes. ␣
 ↪Note that
# the inset Axes are positioned *outside* (on the right and the top)␣
 ↪of the
# main Axes, by specifying axes coordinates greater than 1.  Axes␣
 ↪coordinates
# less than 0 would likewise specify positions on the left and the␣
 ↪bottom of
# the main Axes.
ax_histx = ax.inset_axes([0, 1.05, 1, 0.25], sharex=ax)
ax_histy = ax.inset_axes([1.05, 0, 0.25, 1], sharey=ax)
# Draw the scatter plot and marginals.
scatter_hist(x, y, ax, ax_histx, ax_histy)

plt.show()
```



While we recommend using one of the two methods described above, there are number of other ways to achieve a similar layout:

- The Axes can be positioned manually in relative coordinates using *add_axes*.
- A gridspec can be used to create the layout (*add_gridspec*) and adding only the three desired axes (*add_subplot*).
- Four subplots can be created using *subplots*, and the unused axes in the upper right can be removed manually.
- The `axes_grid1` toolkit can be used, as shown in *Align histogram to scatter plot using locatable Axes*.

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.figure.Figure.subplot_mosaic*
- *matplotlib.pyplot.subplot_mosaic*
- *matplotlib.figure.Figure.add_subplot*
- *matplotlib.axes.Axes.inset_axes*

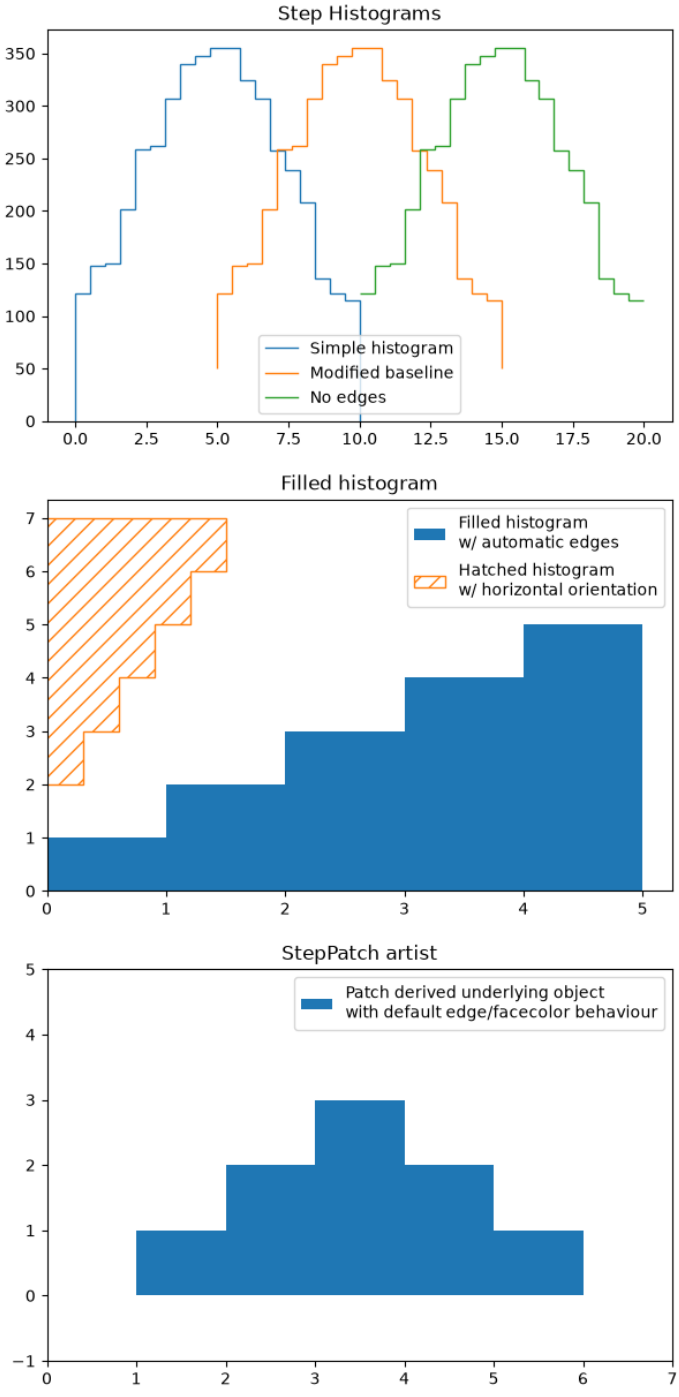
- *matplotlib.axes.Axes.scatter*
- *matplotlib.axes.Axes.hist*

Tags: component: axes plot-type: scatter plot-type: histogram level: intermediate

Stairs Demo

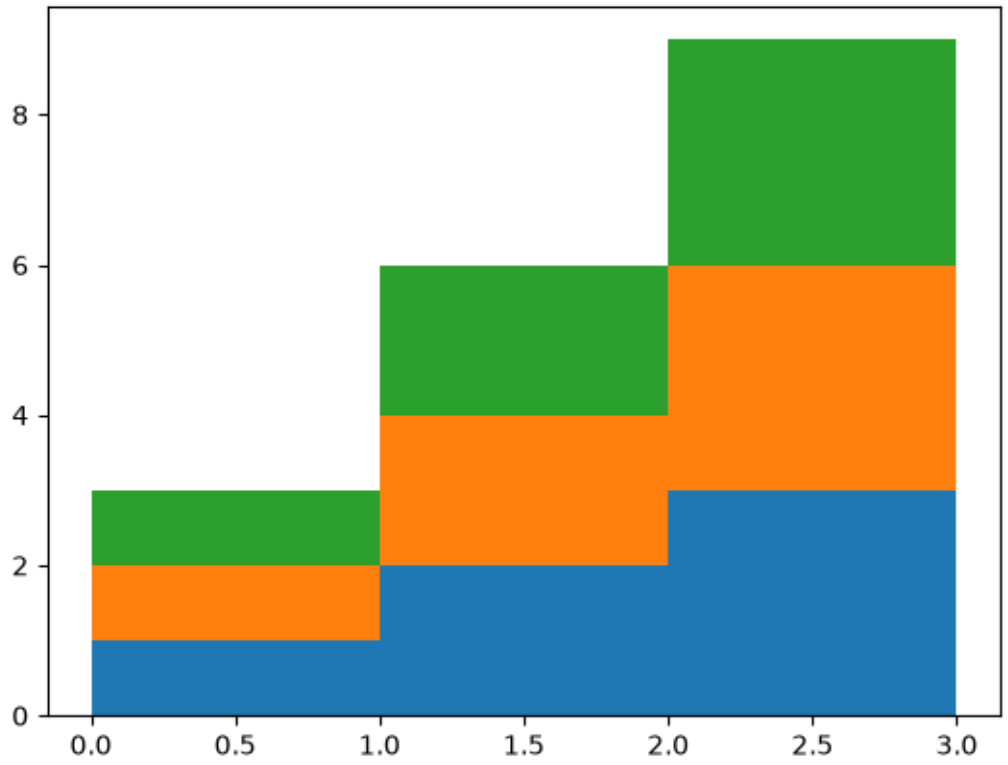
This example demonstrates the use of *stairs* for stepwise constant functions. A common use case is histogram and histogram-like data visualization.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import StepPatch

np.random.seed(0)
h, edges = np.histogram(np.random.normal(5, 3, 5000),
                        bins=np.linspace(0, 10, 20))

fig, axs = plt.subplots(3, 1, figsize=(7, 15))
axs[0].stairs(h, edges, label='Simple histogram')
axs[0].stairs(h, edges + 5, baseline=50, label='Modified baseline')
axs[0].stairs(h, edges + 10, baseline=None, label='No edges')
axs[0].set_title("Step Histograms")

axs[1].stairs(np.arange(1, 6, 1), fill=True,
              label='Filled histogram\nw/ automatic edges')
axs[1].stairs(np.arange(1, 6, 1)*0.3, np.arange(2, 8, 1),
              orientation='horizontal', hatch='//',
              label='Hatched histogram\nw/ horizontal orientation')
axs[1].set_title("Filled histogram")

patch = StepPatch(values=[1, 2, 3, 2, 1],
                  edges=range(1, 7),
                  label=('Patch derived underlying object\n'
                         'with default edge/facecolor behaviour'))
axs[2].add_patch(patch)
axs[2].set_xlim(0, 7)
axs[2].set_ylim(-1, 5)
axs[2].set_title("StepPatch artist")

for ax in axs:
    ax.legend()
plt.show()
```


Step Histograms
Simple histogram
Modified baseline
No edges
Filled histogram
Filled histogram
w/ automatic edges
Hatched histogram
w/ horizontal orientation
StepPatch artist
Patch derived underlying object
with default edge/facecolor behaviour

baseline can take an array to allow for stacked histogram plots

```
A = [[0, 0, 0],
     [1, 2, 3],
     [2, 4, 6],
     [3, 6, 9]]

for i in range(len(A) - 1):
    plt.stairs(A[i+1], baseline=A[i], fill=True)
```



Comparison of *pyplot.step* and *pyplot.stairs*

pyplot.step defines the positions of the steps as single values. The steps extend left/right/both ways from these reference values depending on the parameter *where*. The number of *x* and *y* values is the same.

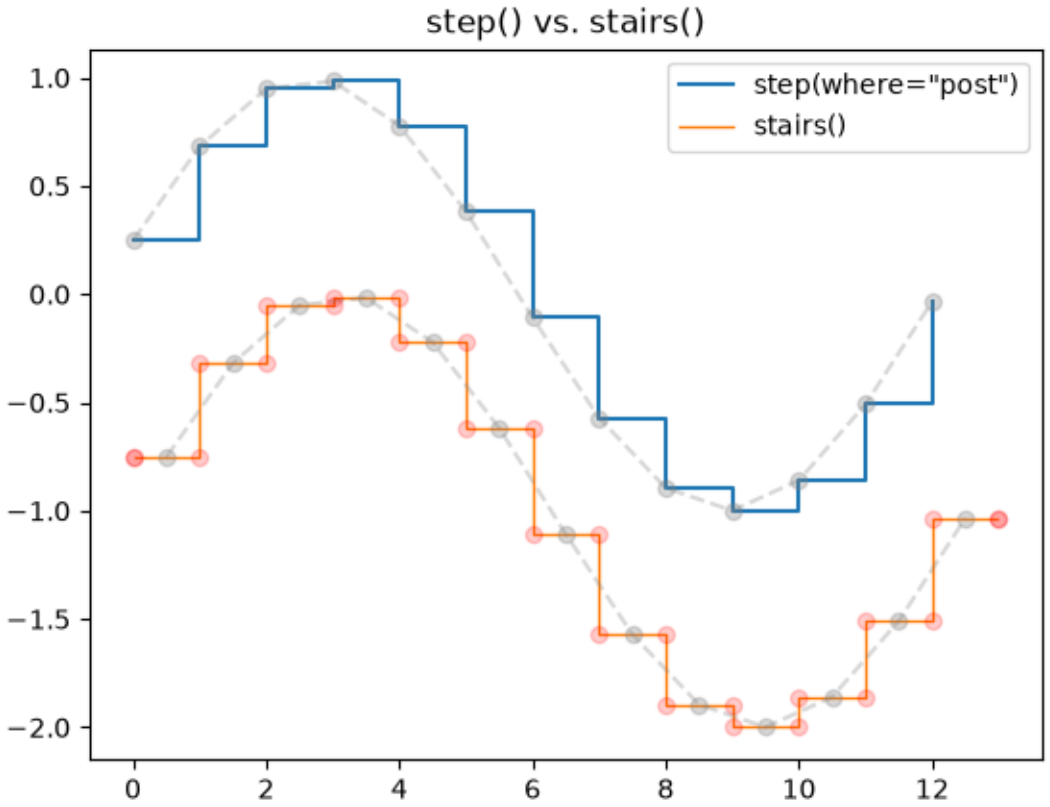
In contrast, *pyplot.stairs* defines the positions of the steps via their bounds *edges*, which is one element longer than the step values.

```
bins = np.arange(14)
centers = bins[:-1] + np.diff(bins) / 2
y = np.sin(centers / 2)
```

(continues on next page)

(continued from previous page)

```
plt.step(bins[:-1], y, where='post', label='step(where="post")')
plt.plot(bins[:-1], y, 'o--', color='grey', alpha=0.3)

plt.stairs(y - 1, bins, baseline=None, label='stairs()')
plt.plot(centers, y - 1, 'o--', color='grey', alpha=0.3)
plt.plot(np.repeat(bins, 2), np.hstack([y[0], np.repeat(y, 2), y[-1]]) -␣
↪1,
         'o', color='red', alpha=0.2)

plt.legend()
plt.title('step() vs. stairs()')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.stairs* / *matplotlib.pyplot.stairs*

- *matplotlib.patches.StepPatch*

Tags: plot-type: stairs level: intermediate

Total running time of the script: (0 minutes 1.005 seconds)

Step Demo

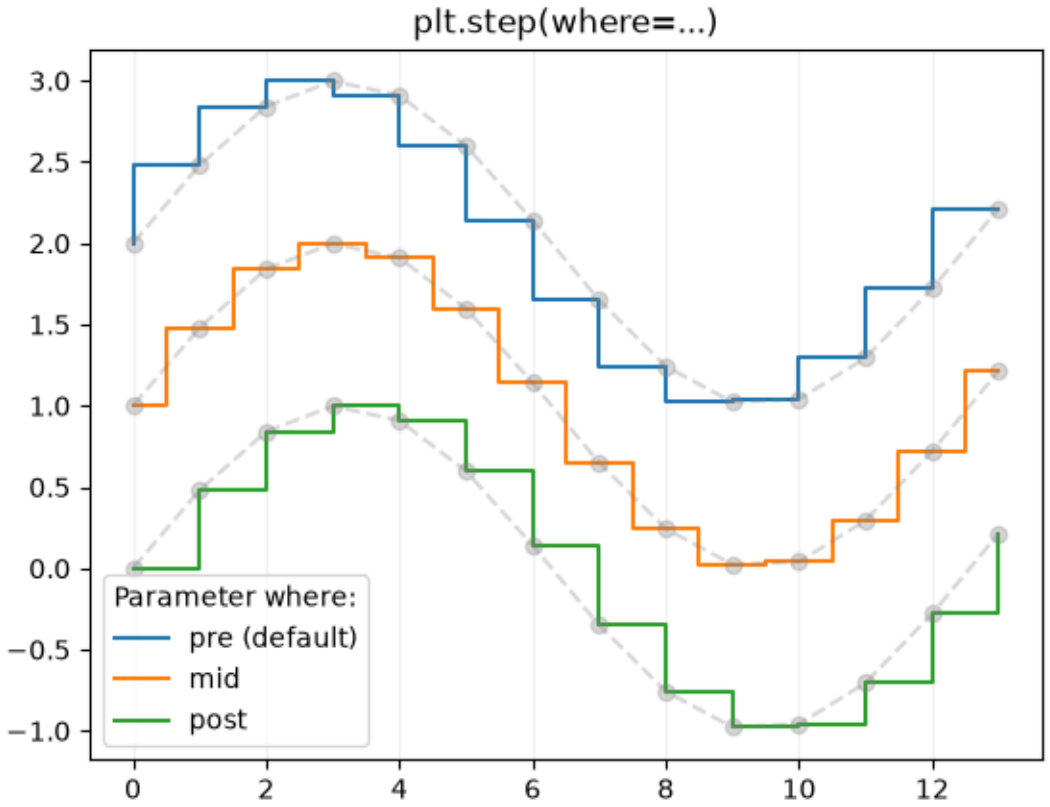
This example demonstrates the use of *pyplot.step* for piece-wise constant curves. In particular, it illustrates the effect of the parameter *where* on the step position.

Note

For the common case that you know the edge positions, use *pyplot.stairs* instead.

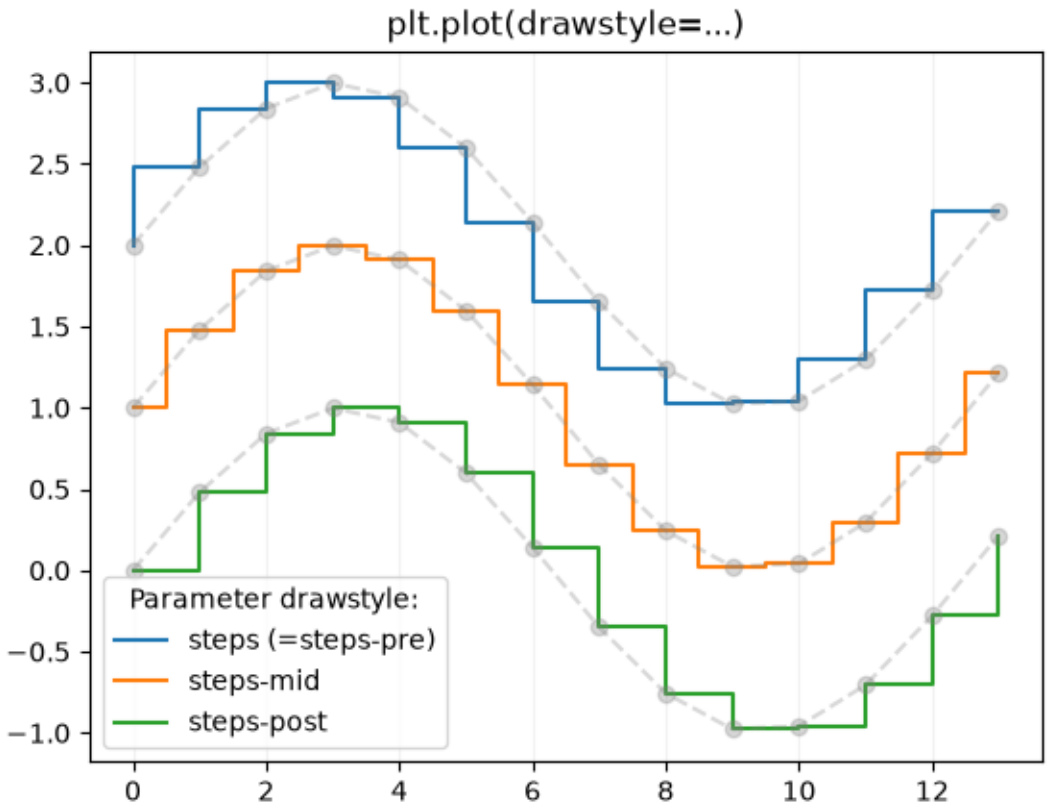
The circular markers created with *pyplot.plot* show the actual data positions so that it's easier to see the effect of *where*.

```
import matplotlib.pyplot as plt
import numpy as np

x = np.arange(14)
y = np.sin(x / 2)

plt.step(x, y + 2, label='pre (default)')
plt.plot(x, y + 2, 'o--', color='grey', alpha=0.3)

plt.step(x, y + 1, where='mid', label='mid')
plt.plot(x, y + 1, 'o--', color='grey', alpha=0.3)

plt.step(x, y, where='post', label='post')
plt.plot(x, y, 'o--', color='grey', alpha=0.3)

plt.grid(axis='x', color='0.95')
plt.legend(title='Parameter where:')
plt.title('plt.step(where=...)')
plt.show()
```



The same behavior can be achieved by using the `drawstyle` parameter of *`pyplot.plot`*.

```
plt.plot(x, y + 2, drawstyle='steps', label='steps (=steps-pre)')
plt.plot(x, y + 2, 'o--', color='grey', alpha=0.3)

plt.plot(x, y + 1, drawstyle='steps-mid', label='steps-mid')
plt.plot(x, y + 1, 'o--', color='grey', alpha=0.3)

plt.plot(x, y, drawstyle='steps-post', label='steps-post')
plt.plot(x, y, 'o--', color='grey', alpha=0.3)

plt.grid(axis='x', color='0.95')
plt.legend(title='Parameter drawstyle:')
plt.title('plt.plot(drawstyle=...)')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.step* / *matplotlib.pyplot.step*
- *matplotlib.axes.Axes.plot* / *matplotlib.pyplot.plot*

Tags: plot-type: step plot-type: line level: beginner

Filled polygon

fill() draws a filled polygon based on lists of point coordinates *x*, *y*.

This example uses the Koch snowflake as an example polygon.

```
import matplotlib.pyplot as plt
import numpy as np


def koch_snowflake(order, scale=10):
```

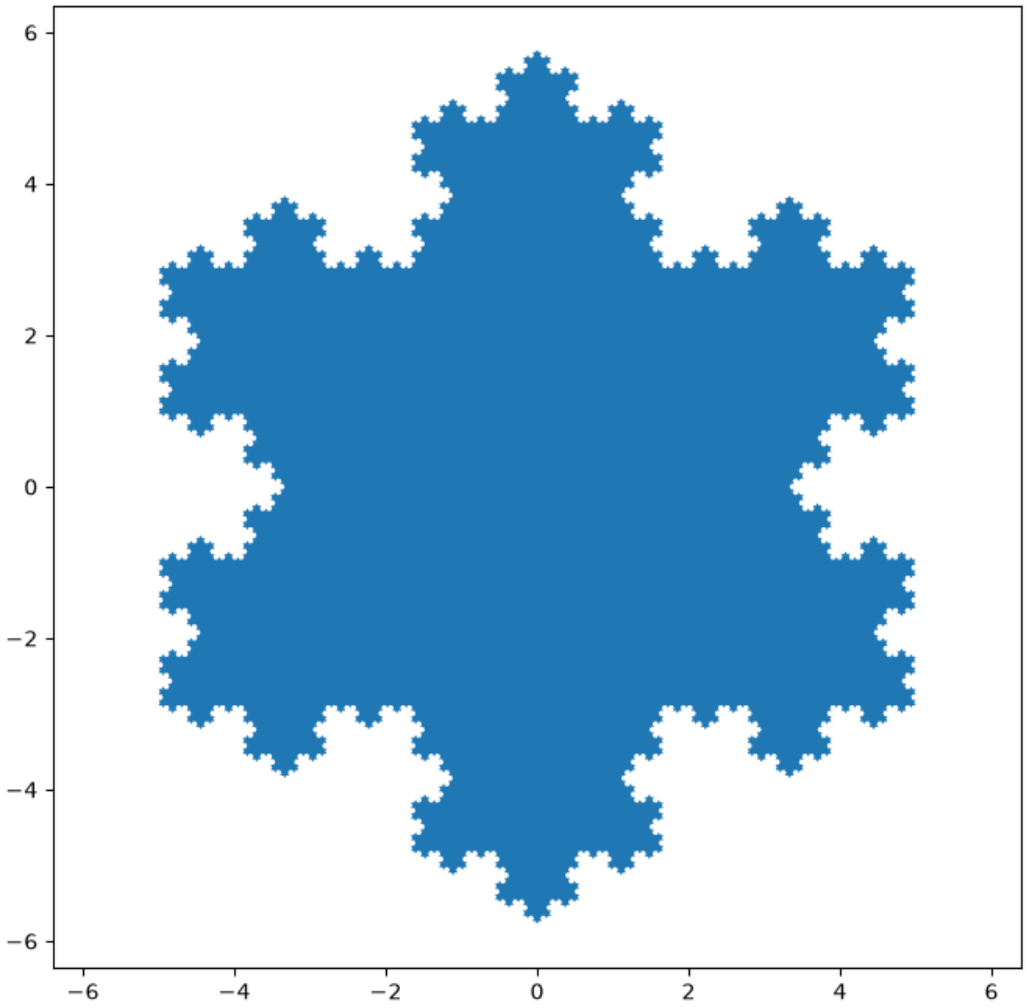
(continues on next page)

(continued from previous page)

```
    """
    Return two lists x, y of point coordinates of the Koch snowflake.

    Parameters
    ----------
    order : int
        The recursion depth.
    scale : float
        The extent of the snowflake (edge length of the base triangle).
    """
    def _koch_snowflake_complex(order):
        if order == 0:
            # initial triangle
            angles = np.array([0, 120, 240]) + 90
            return scale / np.sqrt(3) * np.exp(np.deg2rad(angles) * 1j)
        else:
            ZR = 0.5 - 0.5j * np.sqrt(3) / 3

            p1 = _koch_snowflake_complex(order - 1)  # start points
            p2 = np.roll(p1, shift=-1)  # end points
            dp = p2 - p1  # connection vectors

            new_points = np.empty(len(p1) * 4, dtype=np.complex128)
            new_points[::4] = p1
            new_points[1::4] = p1 + dp / 3
            new_points[2::4] = p1 + dp * ZR
            new_points[3::4] = p1 + dp / 3 * 2
            return new_points

    points = _koch_snowflake_complex(order)
    x, y = points.real, points.imag
    return x, y
```

Basic usage:

```
x, y = koch_snowflake(order=5)

plt.figure(figsize=(8, 8))
plt.axis('equal')
plt.fill(x, y)
plt.show()
```



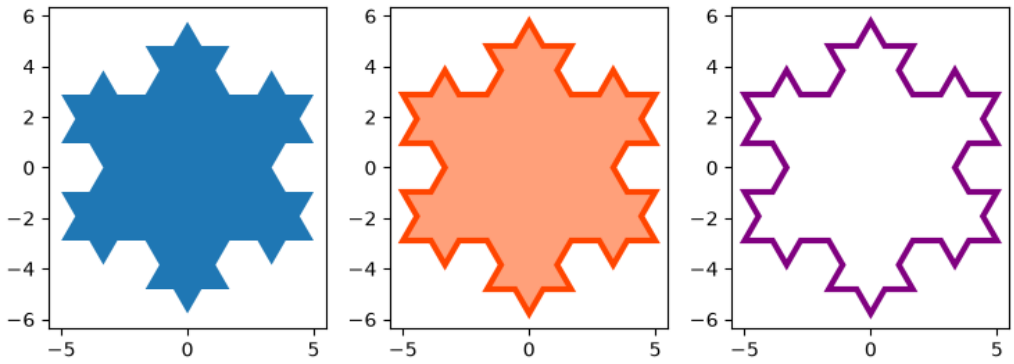
Use keyword arguments *facecolor* and *edgecolor* to modify the colors of the polygon. Since the *linewidth* of the edge is 0 in the default Matplotlib style, we have to set it as well for the edge to become visible.

```
x, y = koch_snowflake(order=2)

fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(9, 3),
                                    subplot_kw={'aspect': 'equal'})
ax1.fill(x, y)
ax2.fill(x, y, facecolor='lightsalmon', edgecolor='orangered',␣
 ↪linewidth=3)
ax3.fill(x, y, facecolor='none', edgecolor='purple', linewidth=3)
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.fill* / *matplotlib.pyplot.fill*
- *matplotlib.axes.Axes.axis* / *matplotlib.pyplot.axis*

Tags: styling: shape level: beginner purpose: showcase

`fill_between` with transparency

The *fill_between* function generates a shaded region between a min and max boundary that is useful for illustrating ranges. It has a very handy `where` argument to combine filling with logical ranges, e.g., to just fill in a curve over some threshold value.

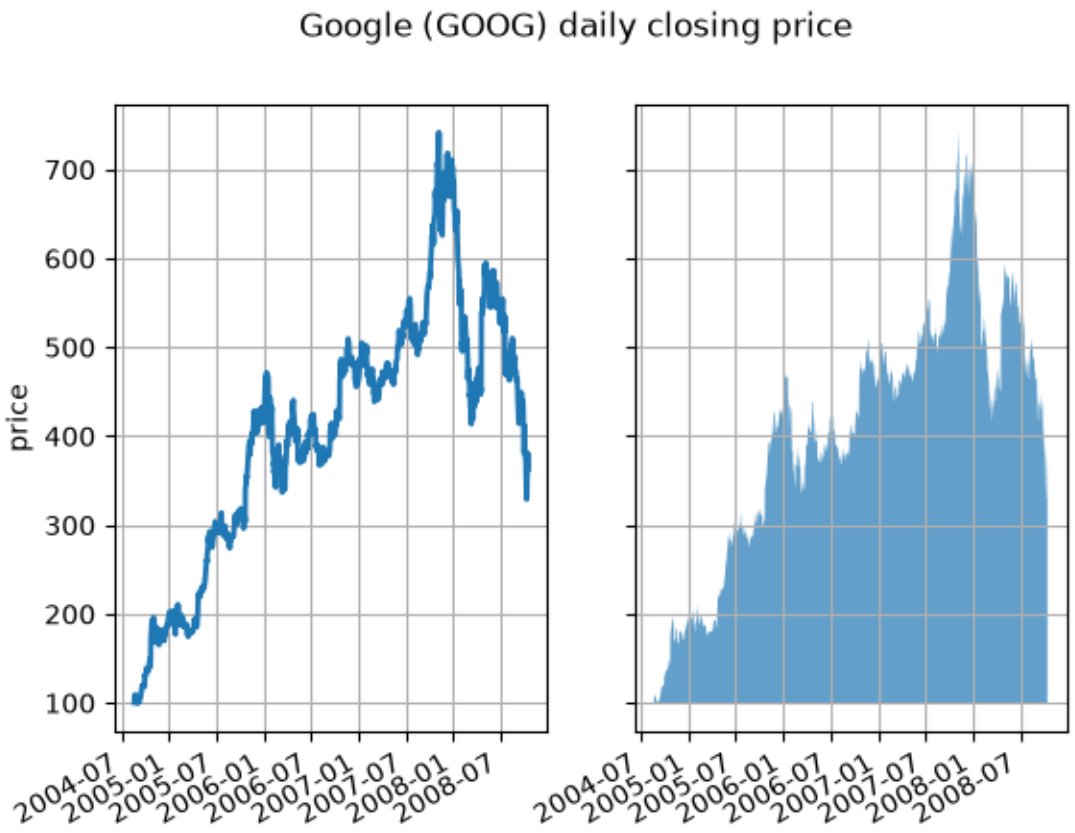
At its most basic level, `fill_between` can be used to enhance a graph's visual appearance. Let's compare two graphs of financial data with a simple line plot on the left and a filled line on the right.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.cbook as cbook

# load up some sample financial data
r = cbook.get_sample_data('goog.npz')['price_data']
# create two subplots with the shared x and y axes
fig, (ax1, ax2) = plt.subplots(1, 2, sharex=True, sharey=True)

pricemin = r["close"].min()

ax1.plot(r["date"], r["close"], lw=2)
```

(continues on next page)

(continued from previous page)

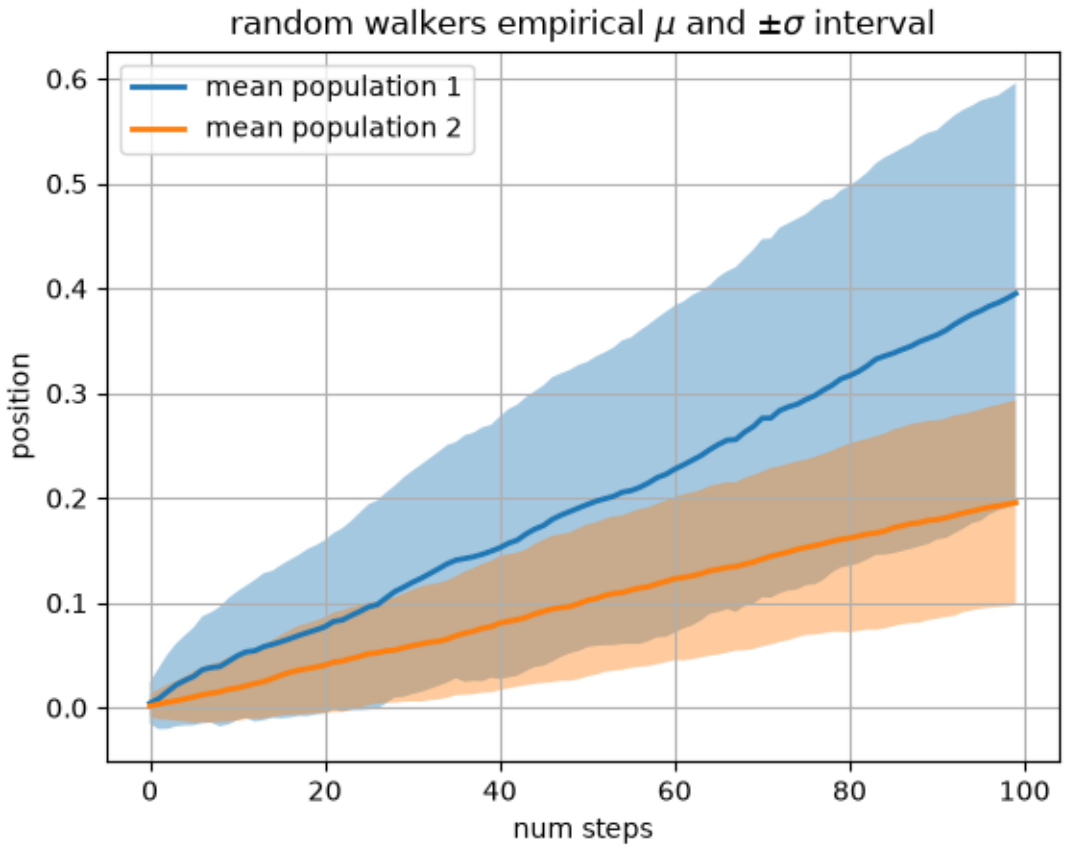
```
ax2.fill_between(r["date"], pricemin, r["close"], alpha=0.7)

for ax in ax1, ax2:
    ax.grid(True)
    ax.label_outer()

ax1.set_ylabel('price')

fig.suptitle('Google (GOOG) daily closing price')
fig.autofmt_xdate()
```



The alpha channel is not necessary here, but it can be used to soften colors for more visually appealing plots. In other examples, as we'll see below, the alpha channel is functionally useful as the shaded regions can overlap and alpha allows you to see both. Note that the postscript format does not support alpha (this is a postscript limitation, not a matplotlib limitation), so when using alpha save your figures in GIF, PNG, PDF or SVG.

Our next example computes two populations of random walkers with a different mean and standard deviation of the normal distributions from which the steps are drawn. We use filled regions to plot +/- one standard deviation of the mean position of the population. Here the alpha channel is useful, not just aesthetic.

```
# Fixing random state for reproducibility
np.random.seed(19680801)

Nsteps, Nwalkers = 100, 250
t = np.arange(Nsteps)

# an (Nsteps x Nwalkers) array of random walk steps
S1 = 0.004 + 0.02*np.random.randn(Nsteps, Nwalkers)
S2 = 0.002 + 0.01*np.random.randn(Nsteps, Nwalkers)

# an (Nsteps x Nwalkers) array of random walker positions
X1 = S1.cumsum(axis=0)
X2 = S2.cumsum(axis=0)


# Nsteps length arrays empirical means and standard deviations of both
# populations over time
mu1 = X1.mean(axis=1)
sigma1 = X1.std(axis=1)
mu2 = X2.mean(axis=1)
sigma2 = X2.std(axis=1)

# plot it!
fig, ax = plt.subplots(1)
ax.plot(t, mu1, lw=2, label='mean population 1')
ax.plot(t, mu2, lw=2, label='mean population 2')
ax.fill_between(t, mu1+sigma1, mu1-sigma1, facecolor='C0', alpha=0.4)
ax.fill_between(t, mu2+sigma2, mu2-sigma2, facecolor='C1', alpha=0.4)
ax.set_title(r'random walkers empirical $\mu$ and $\pm \sigma$ interval
 ↪')
ax.legend(loc='upper left')
ax.set_xlabel('num steps')
ax.set_ylabel('position')
ax.grid()
```



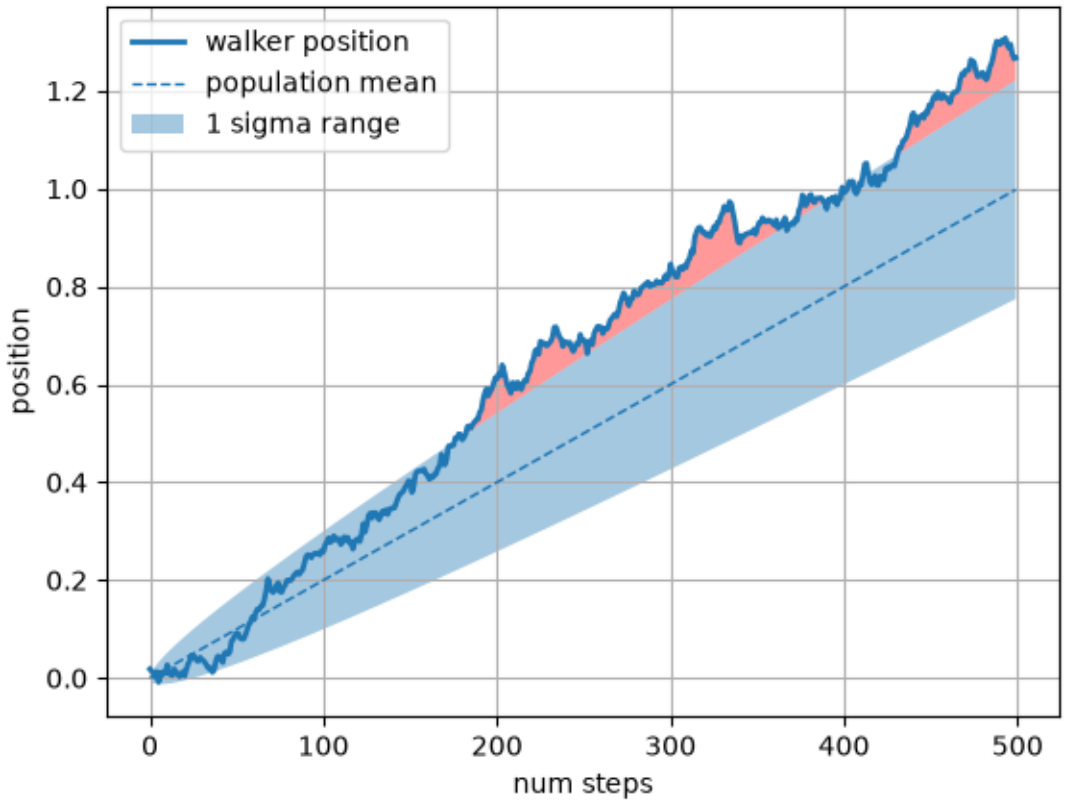
The `where` keyword argument is very handy for highlighting certain regions of the graph. `where` takes a boolean mask the same length as the x, ymin and ymax arguments, and only fills in the region where the boolean mask is True. In the example below, we simulate a single random walker and compute the analytic mean and standard deviation of the population positions. The population mean is shown as the dashed line, and the plus/minus one sigma deviation from the mean is shown as the filled region. We use the where mask `X > upper_bound` to find the region where the walker is outside the one sigma boundary, and shade that region red.

```
# Fixing random state for reproducibility
np.random.seed(1)

Nsteps = 500
t = np.arange(Nsteps)

mu = 0.002
sigma = 0.01

# the steps and position
S = mu + sigma*np.random.randn(Nsteps)
X = S.cumsum()
```

(continues on next page)

(continued from previous page)

```
# the 1 sigma upper and lower analytic population bounds
lower_bound = mu*t - sigma*np.sqrt(t)
upper_bound = mu*t + sigma*np.sqrt(t)

fig, ax = plt.subplots(1)
ax.plot(t, X, lw=2, label='walker position')
ax.plot(t, mu*t, lw=1, label='population mean', color='C0', ls='--')
ax.fill_between(t, lower_bound, upper_bound, facecolor='C0', alpha=0.4,
                label='1 sigma range')
ax.legend(loc='upper left')

# here we use the where argument to only fill the region where the
# walker is above the population 1 sigma boundary
ax.fill_between(t, upper_bound, X, where=X > upper_bound, fc='red',␣
 ↪alpha=0.4)
ax.fill_between(t, lower_bound, X, where=X < lower_bound, fc='red',␣
 ↪alpha=0.4)
ax.set_xlabel('num steps')
ax.set_ylabel('position')
ax.grid()
```



Another handy use of filled regions is to highlight horizontal or vertical spans of an Axes -- for that Matplotlib has the helper functions *axhspan* and *axvspan*. See *Draw regions that span an Axes*.

```
plt.show()
```

Tags: styling: alpha plot-type: fill_between level: intermediate purpose: showcase

Fill the area between two lines

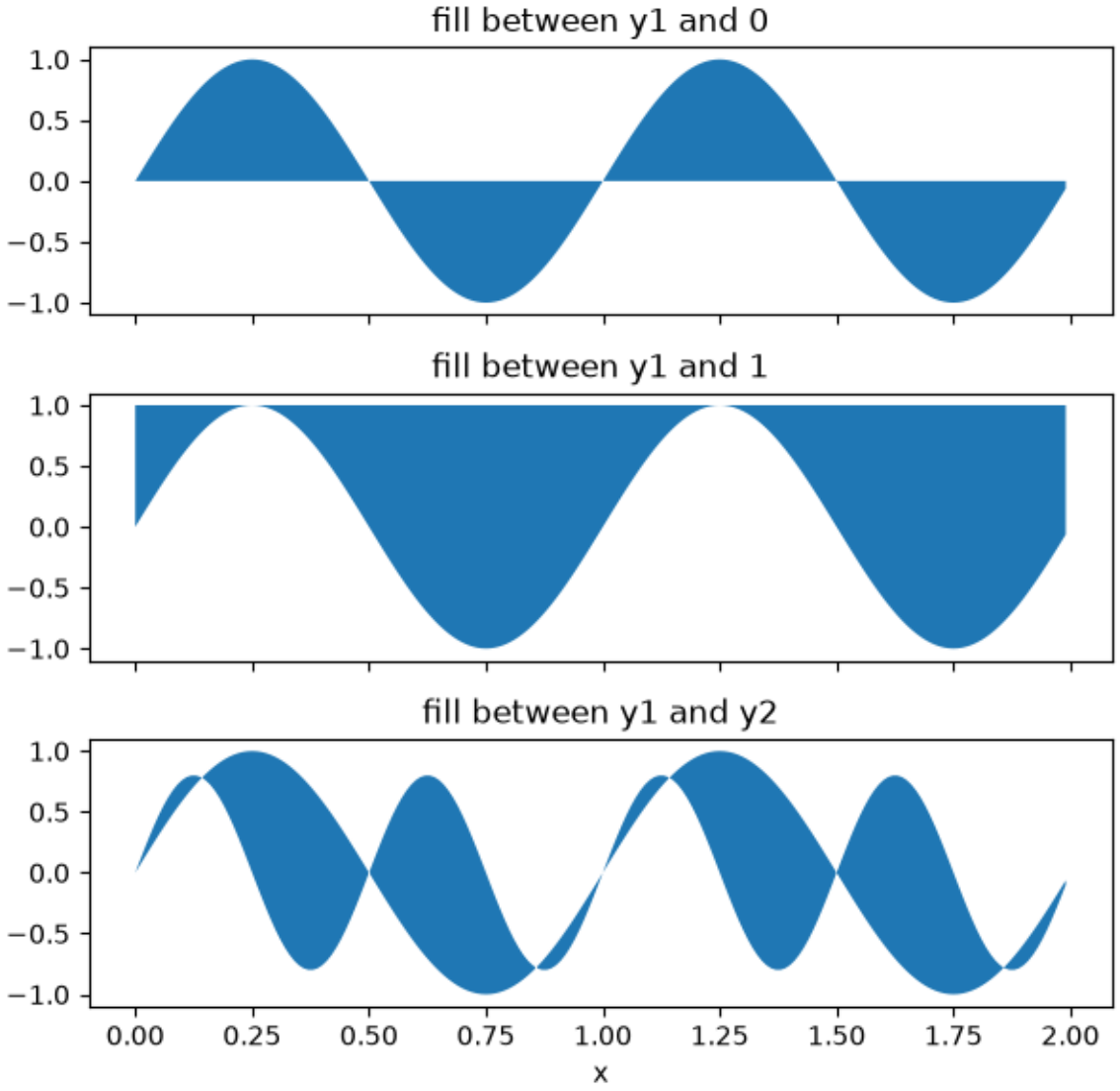
This example shows how to use *fill_between* to color the area between two lines.

```
import matplotlib.pyplot as plt
import numpy as np
```

Basic usage

The parameters *y1* and *y2* can be scalars, indicating a horizontal boundary at the given y-values. If only *y1* is given, *y2* defaults to 0.

```
x = np.arange(0.0, 2, 0.01)
y1 = np.sin(2 * np.pi * x)
y2 = 0.8 * np.sin(4 * np.pi * x)

fig, (ax1, ax2, ax3) = plt.subplots(3, 1, sharex=True, figsize=(6, 6))

ax1.fill_between(x, y1)
ax1.set_title('fill between y1 and 0')

ax2.fill_between(x, y1, 1)
ax2.set_title('fill between y1 and 1')

ax3.fill_between(x, y1, y2)
ax3.set_title('fill between y1 and y2')
ax3.set_xlabel('x')
fig.tight_layout()
```



Example: Confidence bands

A common application for *fill_between* is the indication of confidence bands.

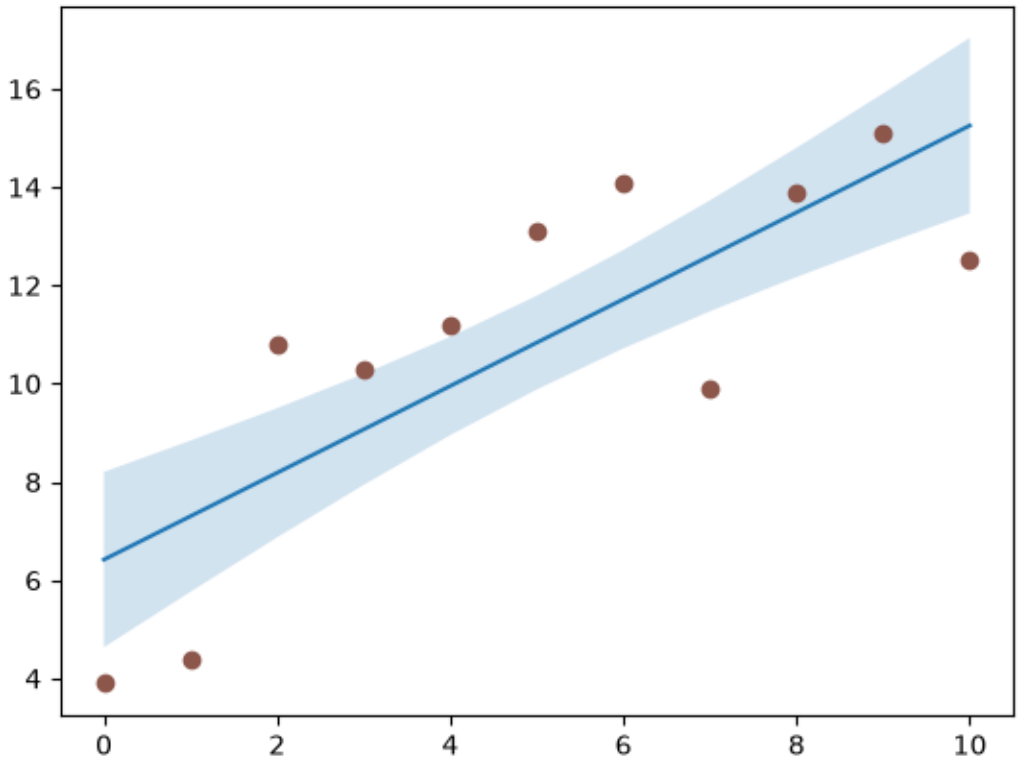
fill_between uses the colors of the color cycle as the fill color. These may be a bit strong when applied to fill areas. It is therefore often a good practice to lighten the color by making the area semi-transparent using *alpha*.

```
N = 21
x = np.linspace(0, 10, 11)
y = [3.9, 4.4, 10.8, 10.3, 11.2, 13.1, 14.1,  9.9, 13.9, 15.1, 12.5]

# fit a linear curve and estimate its y-values and their error.
a, b = np.polyfit(x, y, deg=1)
y_est = a * x + b
```

(continues on next page)

(continued from previous page)

```
y_err = x.std() * np.sqrt(1/len(x) +
                          (x - x.mean())**2 / np.sum((x - x.
 ↪mean())**2))

fig, ax = plt.subplots()
ax.plot(x, y_est, '-')
ax.fill_between(x, y_est - y_err, y_est + y_err, alpha=0.2)
ax.plot(x, y, 'o', color='tab:brown')
```

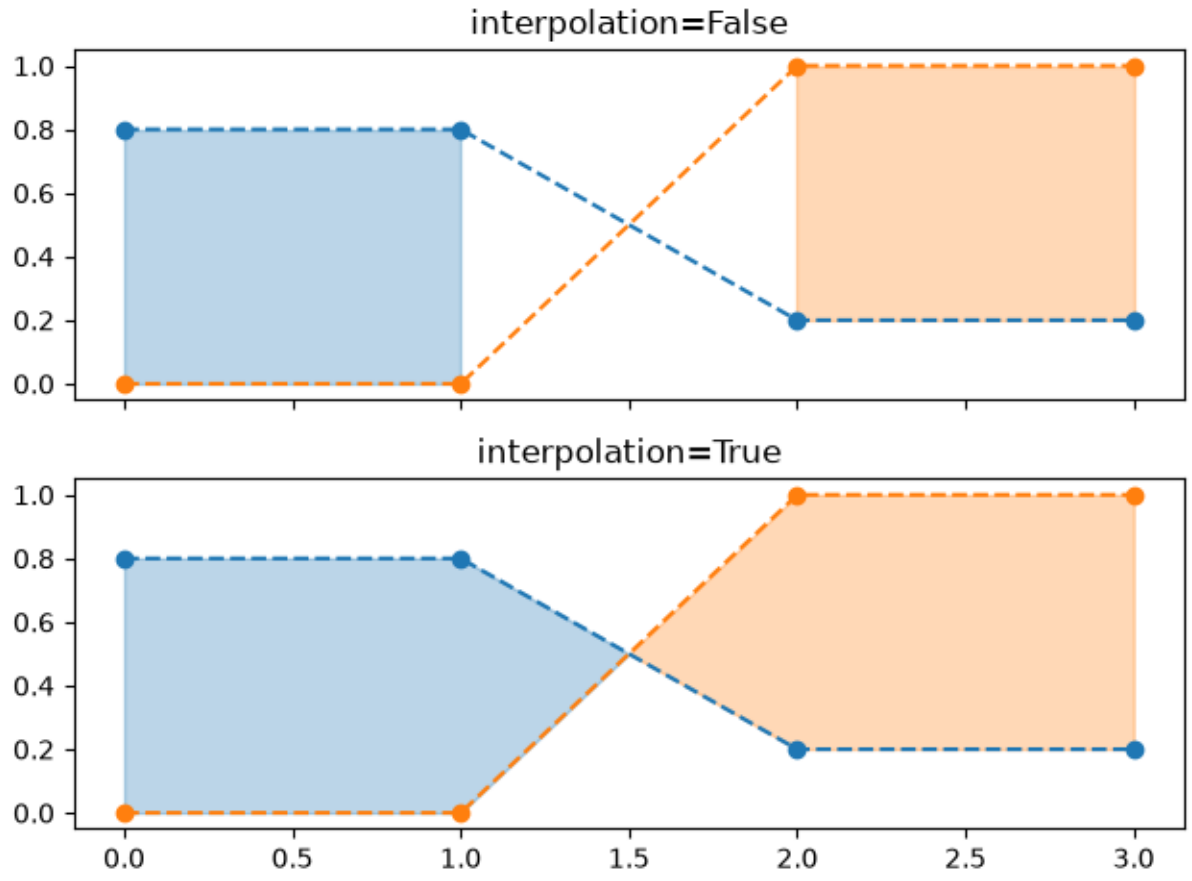


Selectively filling horizontal regions

The parameter *where* allows to specify the x-ranges to fill. It's a boolean array with the same size as *x*.

Only x-ranges of contiguous *True* sequences are filled. As a result the range between neighboring *True* and *False* values is never filled. This often undesired when the data points should represent a contiguous quantity. It is therefore recommended to set `interpolate=True` unless the x-distance of the data points is fine enough so that the above effect is not noticeable. Interpolation approximates the actual x position at which the *where* condition will change and extends the filling up to there.

```
x = np.array([0, 1, 2, 3])
y1 = np.array([0.8, 0.8, 0.2, 0.2])
y2 = np.array([0, 0, 1, 1])

fig, (ax1, ax2) = plt.subplots(2, 1, sharex=True)

ax1.set_title('interpolation=False')
ax1.plot(x, y1, 'o--')
ax1.plot(x, y2, 'o--')
ax1.fill_between(x, y1, y2, where=(y1 > y2), color='C0', alpha=0.3)
ax1.fill_between(x, y1, y2, where=(y1 < y2), color='C1', alpha=0.3)

ax2.set_title('interpolation=True')
ax2.plot(x, y1, 'o--')
ax2.plot(x, y2, 'o--')
ax2.fill_between(x, y1, y2, where=(y1 > y2), color='C0', alpha=0.3,
                 interpolate=True)
ax2.fill_between(x, y1, y2, where=(y1 <= y2), color='C1', alpha=0.3,
                 interpolate=True)
fig.tight_layout()
```



Note

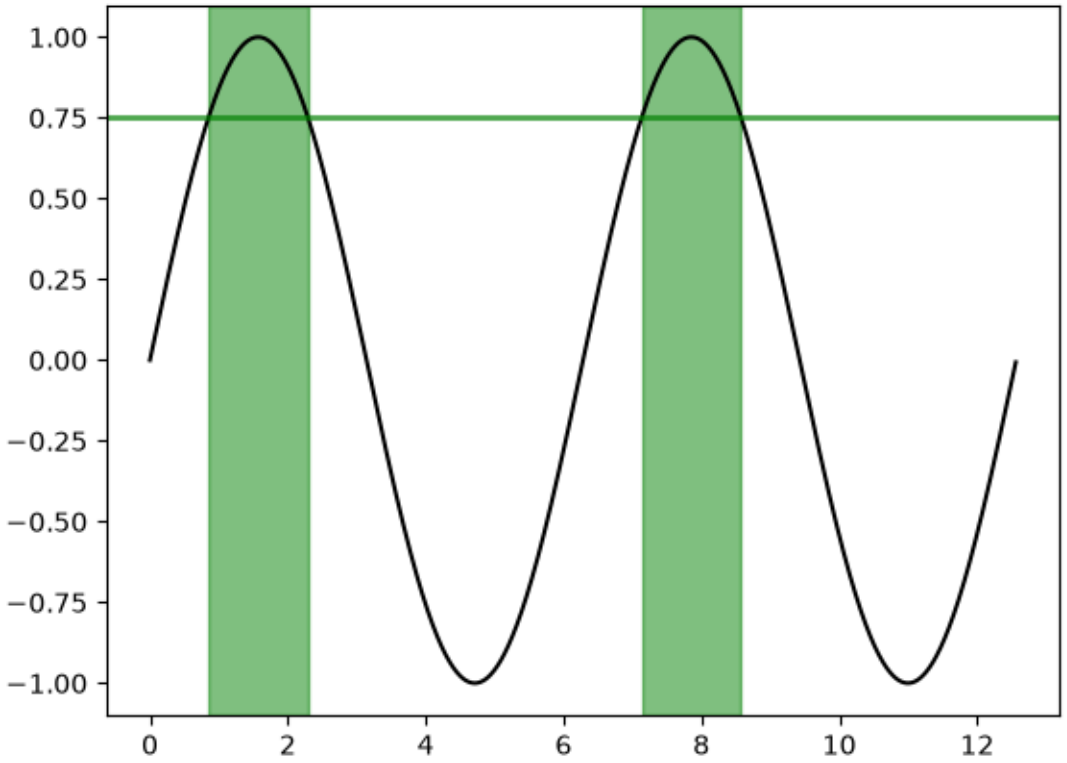
Similar gaps will occur if *y1* or *y2* are masked arrays. Since missing values cannot be approximated, *interpolate* has no effect in this case. The gaps around masked values can only be reduced by adding more data points close to the masked values.

Selectively marking horizontal regions across the whole Axes

The same selection mechanism can be applied to fill the full vertical height of the Axes. To be independent of y-limits, we add a transform that interprets the x-values in data coordinates and the y-values in Axes coordinates.

The following example marks the regions in which the y-data are above a given threshold.

```
fig, ax = plt.subplots()
x = np.arange(0, 4 * np.pi, 0.01)
y = np.sin(x)
ax.plot(x, y, color='black')

threshold = 0.75
ax.axhline(threshold, color='green', lw=2, alpha=0.7)
ax.fill_between(x, 0, 1, where=y > threshold,
                color='green', alpha=0.5, transform=ax.
 ↪get_xaxis_transform())
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.fill_between* / *matplotlib.pyplot.fill_between*
- *matplotlib.axes.Axes.get_xaxis_transform*

Tags: styling: conditional plot-type: fill_between level: beginner purpose: showcase

Total running time of the script: (0 minutes 1.370 seconds)

Fill the area between two vertical lines

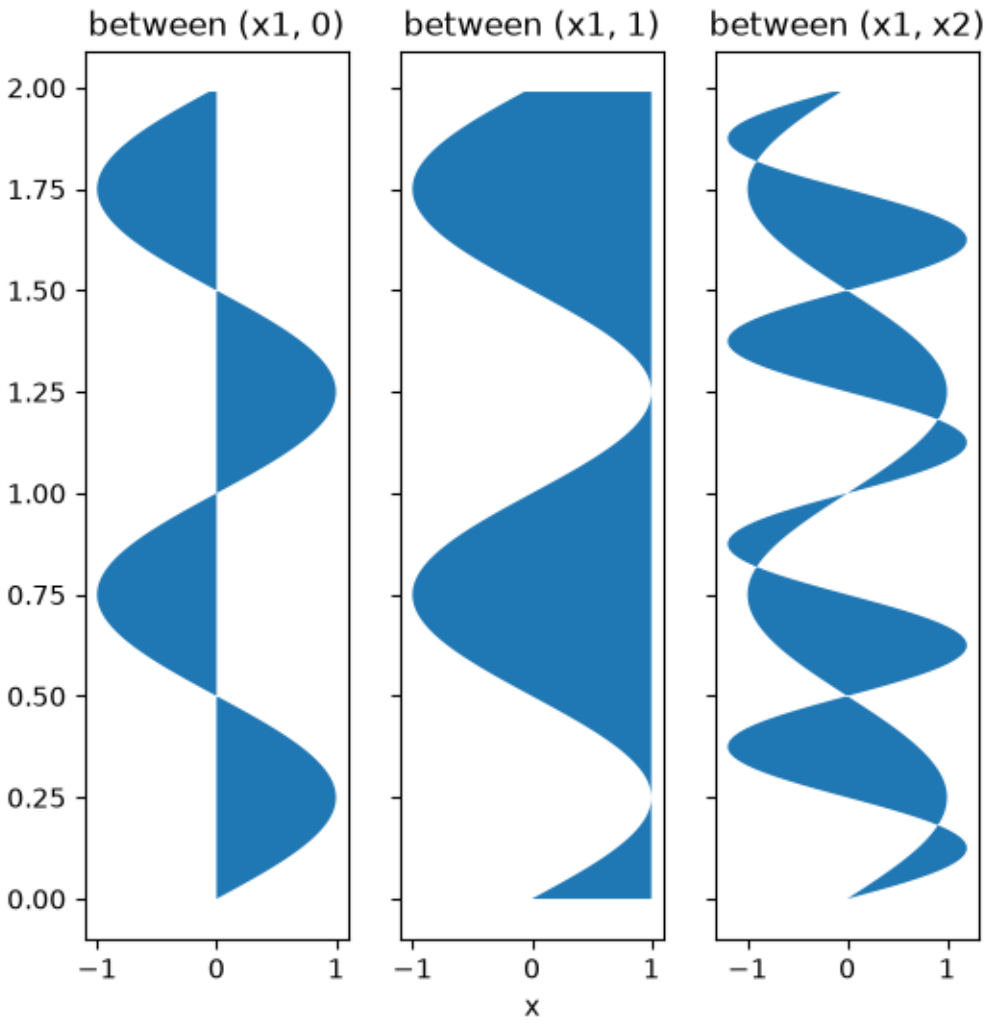
Using *fill_betweenx* to color along the horizontal direction between two curves.

```
import matplotlib.pyplot as plt
import numpy as np

y = np.arange(0.0, 2, 0.01)
x1 = np.sin(2 * np.pi * y)
```

(continues on next page)

(continued from previous page)

```
x2 = 1.2 * np.sin(4 * np.pi * y)

fig, [ax1, ax2, ax3] = plt.subplots(1, 3, sharey=True, figsize=(6, 6))

ax1.fill_betweenx(y, 0, x1)
ax1.set_title('between (x1, 0)')

ax2.fill_betweenx(y, x1, 1)
ax2.set_title('between (x1, 1)')
ax2.set_xlabel('x')

ax3.fill_betweenx(y, x1, x2)
ax3.set_title('between (x1, x2)')
```

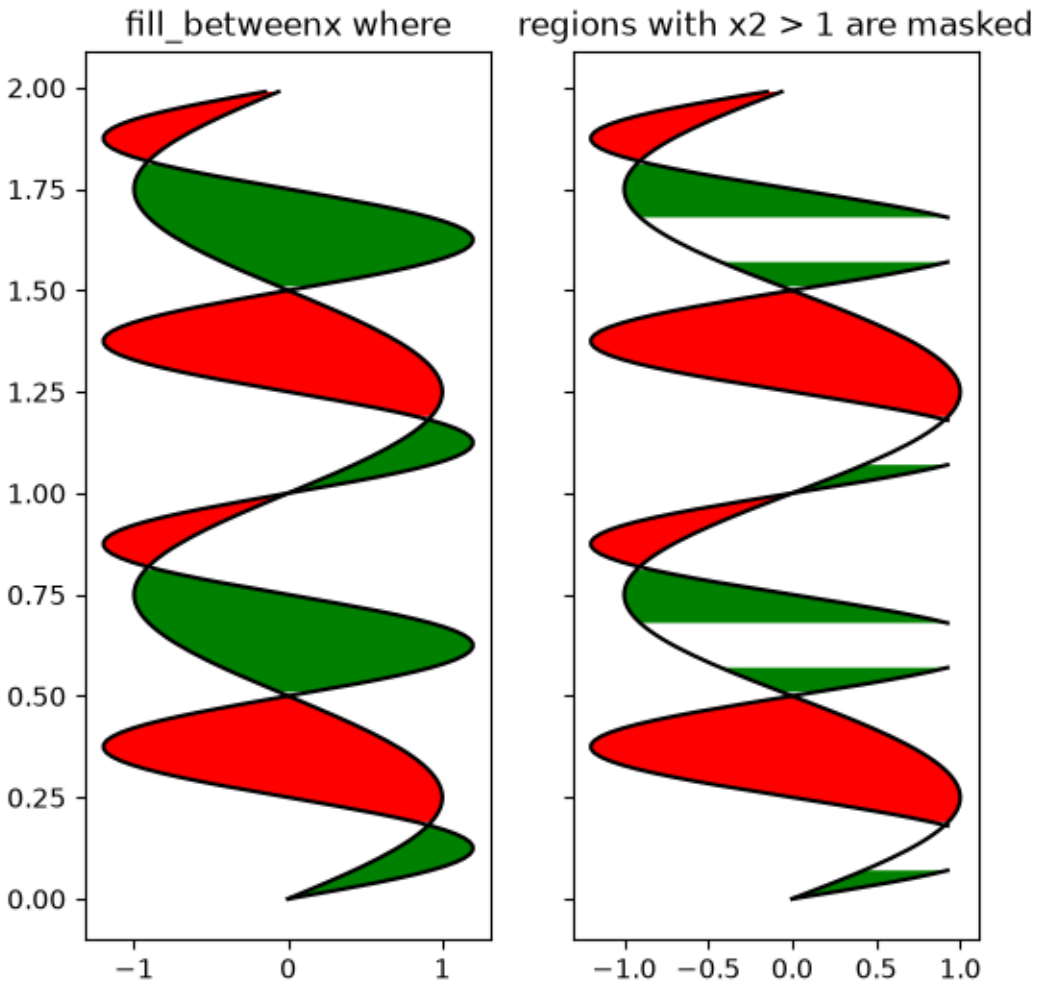


Now fill between x1 and x2 where a logical condition is met. Note this is different than calling:

```
fill_between(y[where], x1[where], x2[where])
```

because of edge effects over multiple contiguous regions.

```
fig, [ax, ax1] = plt.subplots(1, 2, sharey=True, figsize=(6, 6))
ax.plot(x1, y, x2, y, color='black')
ax.fill_betweenx(y, x1, x2, where=x2 >= x1, facecolor='green')
ax.fill_betweenx(y, x1, x2, where=x2 <= x1, facecolor='red')
ax.set_title('fill_betweenx where')

# Test support for masked arrays.
x2 = np.ma.masked_greater(x2, 1.0)
ax1.plot(x1, y, x2, y, color='black')
ax1.fill_betweenx(y, x1, x2, where=x2 >= x1, facecolor='green')
ax1.fill_betweenx(y, x1, x2, where=x2 <= x1, facecolor='red')
ax1.set_title('regions with x2 > 1 are masked')
```



This example illustrates a problem; because of the data gridding, there are undesired unfilled triangles at the crossover points. A brute-force solution would be to interpolate all arrays to a very fine grid before plotting.

```
plt.show()
```

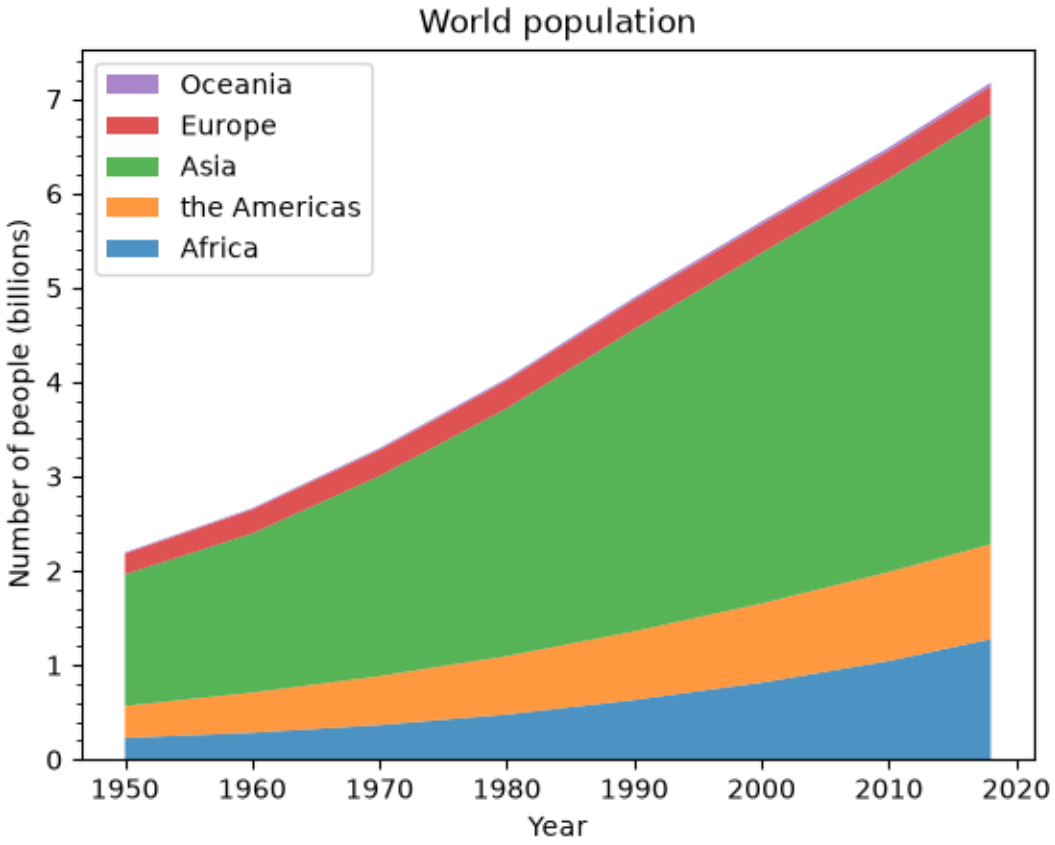
Tags: plot-type: fill_between level: beginner

Stackplots and streamgraphs

Stackplots

Stackplots draw multiple datasets as vertically stacked areas. This is useful when the individual data values and additionally their cumulative value are of interest.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.ticker as mticker

# data from United Nations World Population Prospects (Revision 2019)
# https://population.un.org/wpp/, license: CC BY 3.0 IGO
year = [1950, 1960, 1970, 1980, 1990, 2000, 2010, 2018]
population_by_continent = {
    'Africa': [.228, .284, .365, .477, .631, .814, 1.044, 1.275],
    'the Americas': [.340, .425, .519, .619, .727, .840, .943, 1.006],
    'Asia': [1.394, 1.686, 2.120, 2.625, 3.202, 3.714, 4.169, 4.560],
    'Europe': [.220, .253, .276, .295, .310, .303, .294, .293],
    'Oceania': [.012, .015, .019, .022, .026, .031, .036, .039],
}

fig, ax = plt.subplots()
ax.stackplot(year, population_by_continent.values(),
             labels=population_by_continent.keys(), alpha=0.8)
ax.legend(loc='upper left', reverse=True)
ax.set_title('World population')
ax.set_xlabel('Year')
ax.set_ylabel('Number of people (billions)')
# add tick at every 200 million people
ax.yaxis.set_minor_locator(mticker.MultipleLocator(.2))

plt.show()
```



Streamgraphs

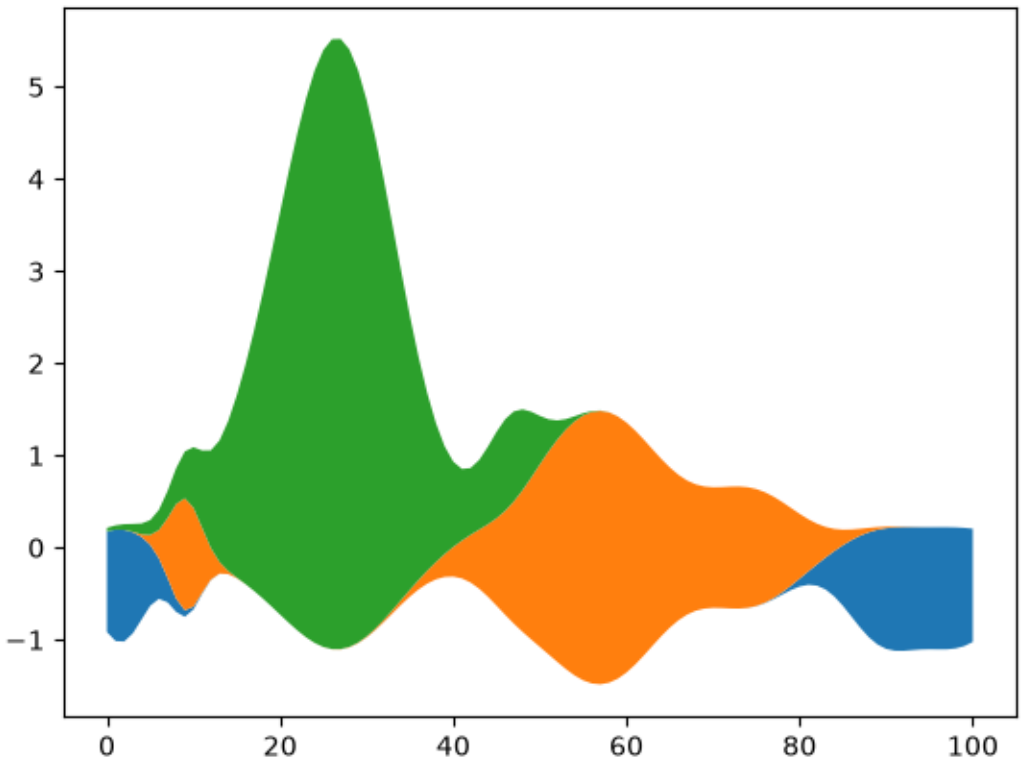
Using the *baseline* parameter, you can turn an ordinary stacked area plot with baseline 0 into a stream graph.

```
# Fixing random state for reproducibility
np.random.seed(19680801)


def gaussian_mixture(x, n=5):
    """Return a random mixture of *n* Gaussians, evaluated at␣
 ↪positions *x*."""
    def add_random_gaussian(a):
        amplitude = 1 / (.1 + np.random.random())
        dx = x[-1] - x[0]
        x0 = (2 * np.random.random() - .5) * dx
        z = 10 / (.1 + np.random.random()) / dx
        a += amplitude * np.exp(-(z * (x - x0))**2)
    a = np.zeros_like(x)
    for j in range(n):
        add_random_gaussian(a)
```

(continues on next page)

(continued from previous page)

```
    return a


x = np.linspace(0, 100, 101)
ys = [gaussian_mixture(x) for _ in range(3)]

fig, ax = plt.subplots()
ax.stackplot(x, ys, baseline='wiggle')
plt.show()
```



Tags: plot-type: stackplot level: intermediate

EventCollection Demo

Plot two curves, then use *EventCollection*s to mark the locations of the x and y data points on the respective Axes for each curve.

```
import matplotlib.pyplot as plt
import numpy as np

```

(continues on next page)

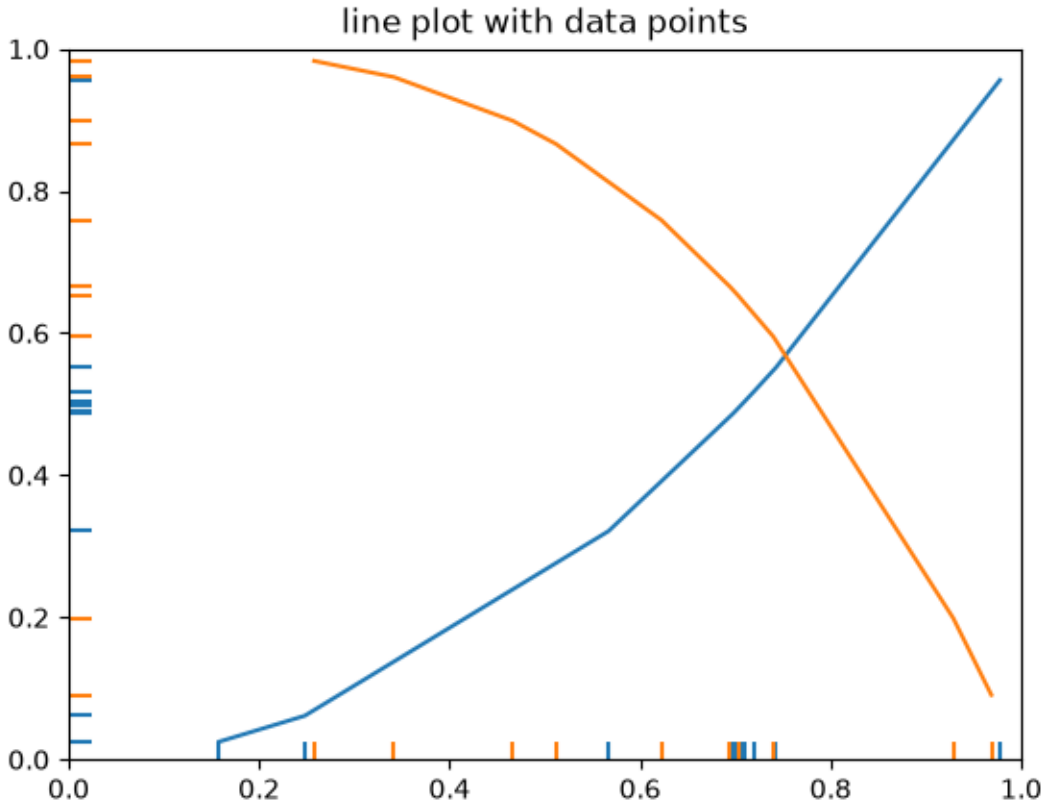
(continued from previous page)

```
from matplotlib.collections import EventCollection

# Fixing random state for reproducibility
np.random.seed(19680801)

# create random data
xdata = np.random.random([2, 10])

# split the data into two parts
xdata1 = xdata[0, :]
xdata2 = xdata[1, :]

# sort the data so it makes clean curves
xdata1.sort()
xdata2.sort()

# create some y data points
ydata1 = xdata1 ** 2
ydata2 = 1 - xdata2 ** 3

# plot the data
fig = plt.figure()
ax = fig.add_subplot(1, 1, 1)
ax.plot(xdata1, ydata1, color='tab:blue')
ax.plot(xdata2, ydata2, color='tab:orange')

# create the events marking the x data points
xevents1 = EventCollection(xdata1, color='tab:blue', linelength=0.05)
xevents2 = EventCollection(xdata2, color='tab:orange', linelength=0.05)

# create the events marking the y data points
yevents1 = EventCollection(ydata1, color='tab:blue', linelength=0.05,
                           orientation='vertical')
yevents2 = EventCollection(ydata2, color='tab:orange', linelength=0.05,
                           orientation='vertical')

# add the events to the axis
ax.add_collection(xevents1)
ax.add_collection(xevents2)
ax.add_collection(yevents1)
ax.add_collection(yevents2)

# set the limits
ax.set_xlim(0, 1)
ax.set_ylim(0, 1)
```

(continues on next page)

(continued from previous page)

```
ax.set_title('line plot with data points')

# display the plot
plt.show()
```



Tags: plot-type: eventplot level: intermediate

Eventplot demo

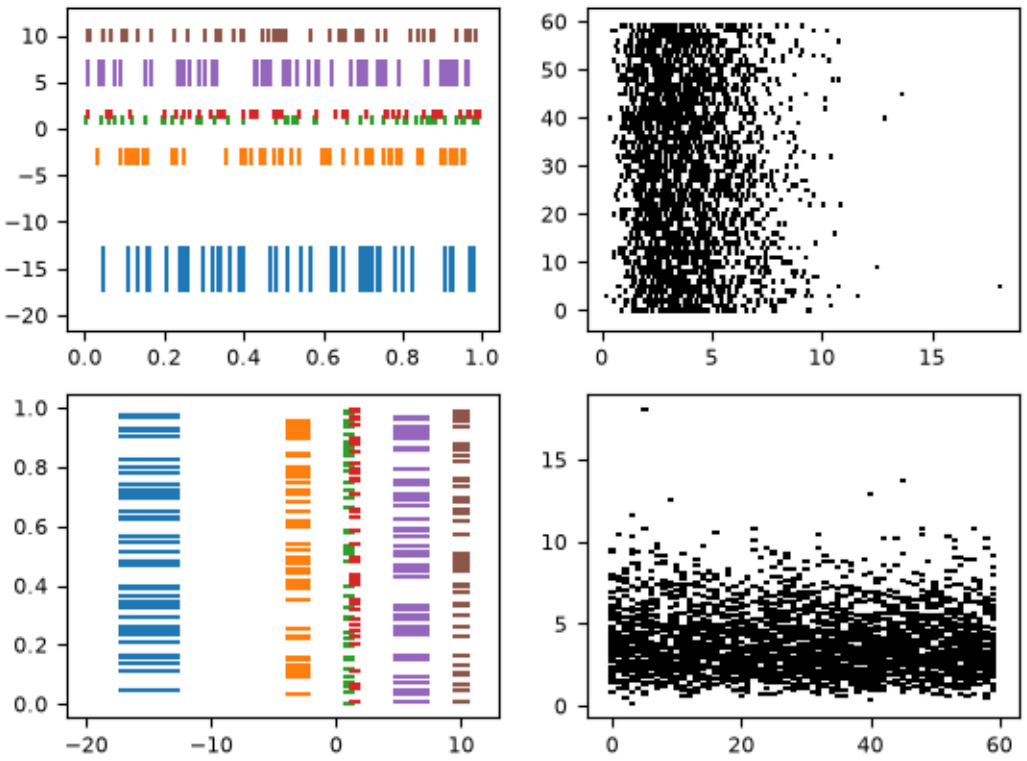
An *eventplot* showing sequences of events with various line properties. The plot is shown in both horizontal and vertical orientations.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib

matplotlib.rcParams['font.size'] = 8.0

# Fixing random state for reproducibility
```

(continues on next page)

(continued from previous page)

```
np.random.seed(19680801)


# create random data
data1 = np.random.random([6, 50])

# set different colors for each set of positions
colors1 = [f'C{i}' for i in range(6)]

# set different line properties for each set of positions
# note that some overlap
lineoffsets1 = [-15, -3, 1, 1.5, 6, 10]
linelengths1 = [5, 2, 1, 1, 3, 1.5]

fig, axs = plt.subplots(2, 2)

# create a horizontal plot
axs[0, 0].eventplot(data1, colors=colors1, lineoffsets=lineoffsets1,
                    linelengths=linelengths1)

# create a vertical plot
axs[1, 0].eventplot(data1, colors=colors1, lineoffsets=lineoffsets1,
                    linelengths=linelengths1, orientation='vertical')

# create another set of random data.
# the gamma distribution is only used for aesthetic purposes
data2 = np.random.gamma(4, size=[60, 50])

# use individual values for the parameters this time
# these values will be used for all data sets (except lineoffsets2,␣
 ↪which
# sets the increment between each data set in this usage)
colors2 = 'black'
lineoffsets2 = 1
linelengths2 = 1

# create a horizontal plot
axs[0, 1].eventplot(data2, colors=colors2, lineoffsets=lineoffsets2,
                    linelengths=linelengths2)


# create a vertical plot
axs[1, 1].eventplot(data2, colors=colors2, lineoffsets=lineoffsets2,
                    linelengths=linelengths2, orientation='vertical')

plt.show()
```



Tags: plot-type: eventplot level: beginner purpose: showcase

Timeline with lines, dates, and text

How to create a simple timeline using Matplotlib release dates.

Timelines can be created with a collection of dates and text. In this example, we show how to create a simple timeline using the dates for recent releases of Matplotlib. First, we'll pull the data from GitHub.

```
from datetime import datetime

import matplotlib.pyplot as plt
import numpy as np

import matplotlib.dates as mdates

try:
    # Try to fetch a list of Matplotlib releases and their dates
    # from https://api.github.com/repos/matplotlib/matplotlib/releases
    import json
    import urllib.request
```

(continues on next page)

(continued from previous page)

```
    url = 'https://api.github.com/repos/matplotlib/matplotlib/releases'
    url += '?per_page=100'
    data = json.loads(urllib.request.urlopen(url, timeout=1).read().
 ↪decode())

    dates = []
    releases = []
    for item in data:
        if 'rc' not in item['tag_name'] and 'b' not in item['tag_name
 ↪']:
            dates.append(item['published_at'].split("T")[0])
            releases.append(item['tag_name'].lstrip("v"))

except Exception:
    # In case the above fails, e.g. because of missing internet␣
 ↪connection
    # use the following lists as fallback.
    releases = ['2.2.4', '3.0.3', '3.0.2', '3.0.1', '3.0.0', '2.2.3',
                '2.2.2', '2.2.1', '2.2.0', '2.1.2', '2.1.1', '2.1.0',
                '2.0.2', '2.0.1', '2.0.0', '1.5.3', '1.5.2', '1.5.1',
                '1.5.0', '1.4.3', '1.4.2', '1.4.1', '1.4.0']
    dates = ['2019-02-26', '2019-02-26', '2018-11-10', '2018-11-10',
             '2018-09-18', '2018-08-10', '2018-03-17', '2018-03-16',
             '2018-03-06', '2018-01-18', '2017-12-10', '2017-10-07',
             '2017-05-10', '2017-05-02', '2017-01-17', '2016-09-09',
             '2016-07-03', '2016-01-10', '2015-10-29', '2015-02-16',
             '2014-10-26', '2014-10-18', '2014-08-26']

dates = [datetime.strptime(d, "%Y-%m-%d") for d in dates]  # Convert␣
 ↪strs to dates.
releases = [tuple(release.split('.')) for release in releases]  #␣
 ↪Split by component.
dates, releases = zip(*sorted(zip(dates, releases)))  # Sort by␣
 ↪increasing date.
```

Next, we'll create a stem plot with some variation in levels as to distinguish even close-by events. We add markers on the baseline for visual emphasis on the one-dimensional nature of the timeline.

For each event, we add a text label via `annotate`, which is offset in units of points from the tip of the event line.

Note that Matplotlib will automatically plot datetime inputs.

```
# Choose some nice levels: alternate meso releases between top and␣
 ↪bottom, and
# progressively shorten the stems for micro releases.
levels = []
```

(continues on next page)

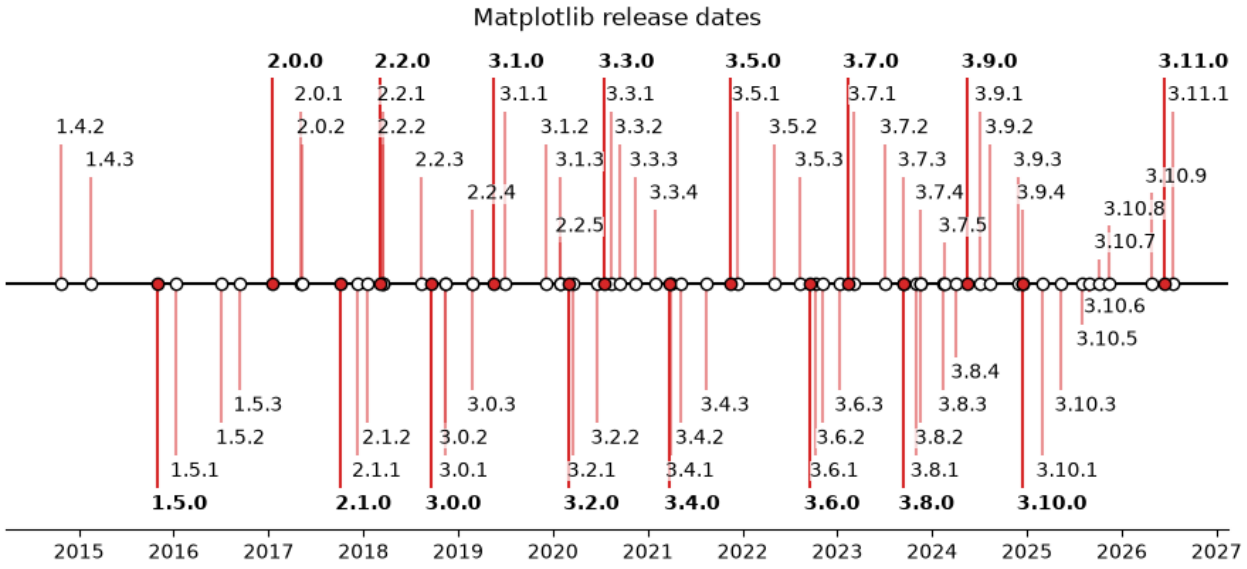
(continued from previous page)

```
macro_meso_releases = sorted({release[:2] for release in releases})
for release in releases:
    macro_meso = release[:2]
    micro = int(release[2])
    h = 1 + 0.8 * (5 - micro)
    level = h if macro_meso_releases.index(macro_meso) % 2 == 0 else -h
    levels.append(level)


def is_feature(release):
    """Return whether a version (split into components) is a feature␣
 ↪release."""
    return release[-1] == '0'


# The figure and the axes.
fig, ax = plt.subplots(figsize=(8.8, 4), layout="constrained")
ax.set(title="Matplotlib release dates")

# The vertical stems.
ax.vlines(dates, 0, levels,
          color=[("tab:red", 1 if is_feature(release) else .5) for␣
 ↪release in releases])
# The baseline.
ax.axhline(0, c="black")
# The markers on the baseline.
meso_dates = [date for date, release in zip(dates, releases) if␣
 ↪is_feature(release)]
micro_dates = [date for date, release in zip(dates, releases)
               if not is_feature(release)]
ax.plot(micro_dates, np.zeros_like(micro_dates), "ko", mfc="white")
ax.plot(meso_dates, np.zeros_like(meso_dates), "ko", mfc="tab:red")

# Annotate the lines.
for date, level, release in zip(dates, levels, releases):
    version_str = '.'.join(release)
    ax.annotate(version_str, xy=(date, level),
                xytext=(-3, np.sign(level)*3), textcoords="offset␣
 ↪points",
                verticalalignment="bottom" if level > 0 else "top",
                weight="bold" if is_feature(release) else "normal",
                bbox=dict(boxstyle='square', pad=0, lw=0, fc=(1, 1, 1,␣
 ↪0.7)))

ax.xaxis.set(major_locator=mdates.YearLocator(),
             major_formatter=mdates.DateFormatter("%Y"))
```

(continues on next page)

(continued from previous page)

```
# Remove the y-axis and some spines.
ax.yaxis.set_visible(False)
ax.spines[["left", "top", "right"]].set_visible(False)

ax.margins(y=0.1)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.annotate*
- *matplotlib.axes.Axes.vlines*
- *matplotlib.axis.Axis.set_major_locator*
- *matplotlib.axis.Axis.set_major_formatter*
- *matplotlib.dates.MonthLocator*
- *matplotlib.dates.DateFormatter*

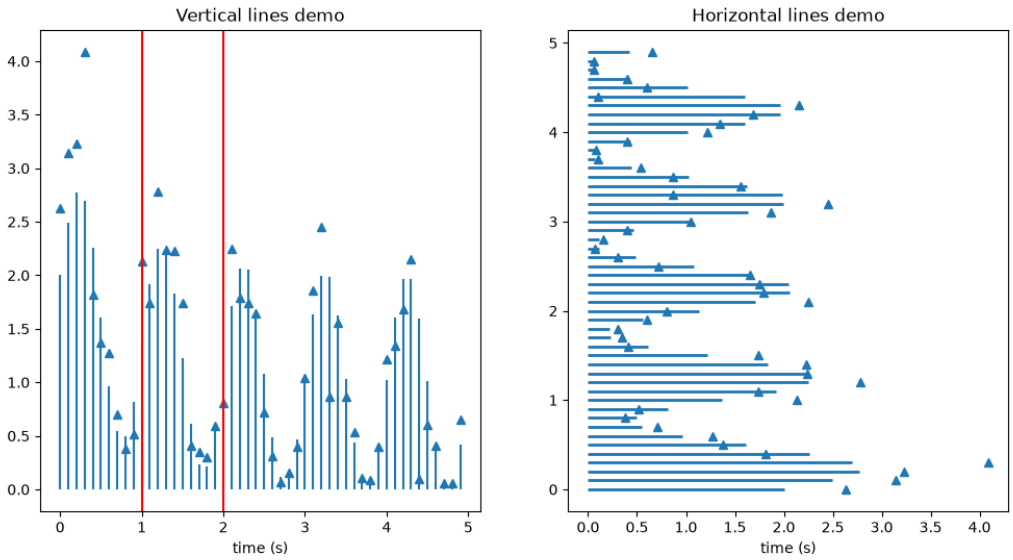
Tags: component: annotation plot-type: line level: intermediate

Total running time of the script: (0 minutes 1.202 seconds)

hlines and vlines

This example showcases the functions hlines and vlines.

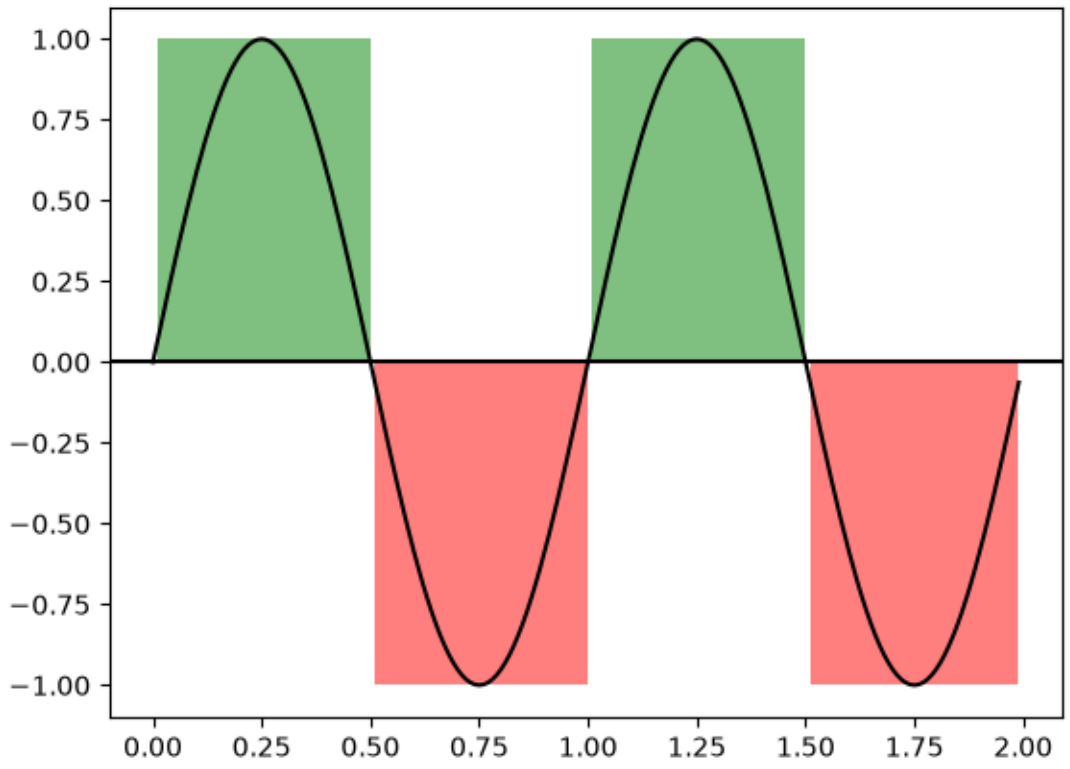
```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

t = np.arange(0.0, 5.0, 0.1)
s = np.exp(-t) + np.sin(2 * np.pi * t) + 1
nse = np.random.normal(0.0, 0.3, t.shape) * s

fig, (vax, hax) = plt.subplots(1, 2, figsize=(12, 6))

vax.plot(t, s + nse, '^')
vax.vlines(t, [0], s)
# By using ``transform=vax.get_xaxis_transform()`` the y coordinates␣
 ↪are scaled
# such that 0 maps to the bottom of the Axes and 1 to the top.
vax.vlines([1, 2], 0, 1, transform=vax.get_xaxis_transform(), colors='r
 ↪')
vax.set_xlabel('time (s)')
vax.set_title('Vertical lines demo')

hax.plot(s + nse, t, '^')
hax.hlines(t, [0], s, lw=2)
hax.set_xlabel('time (s)')
hax.set_title('Horizontal lines demo')

plt.show()
```



Tags: plot-type: line level: beginner

Shade regions defined by a logical mask using fill_between

```
import matplotlib.pyplot as plt
import numpy as np

t = np.arange(0.0, 2, 0.01)
s = np.sin(2*np.pi*t)

fig, ax = plt.subplots()

ax.plot(t, s, color='black')
ax.axhline(0, color='black')

ax.fill_between(t, 1, where=s > 0, facecolor='green', alpha=.5)
ax.fill_between(t, -1, where=s < 0, facecolor='red', alpha=.5)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

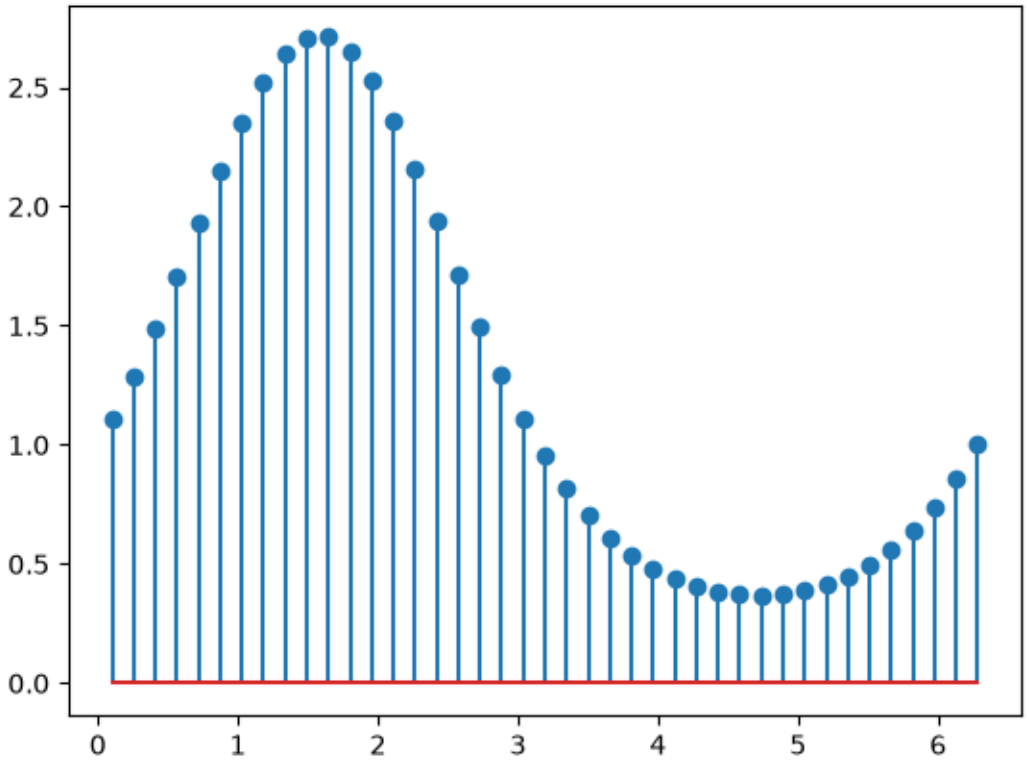
- *matplotlib.axes.Axes.fill_between*

Tags: styling: conditional plot-type: fill_between level: beginner

Stem plot

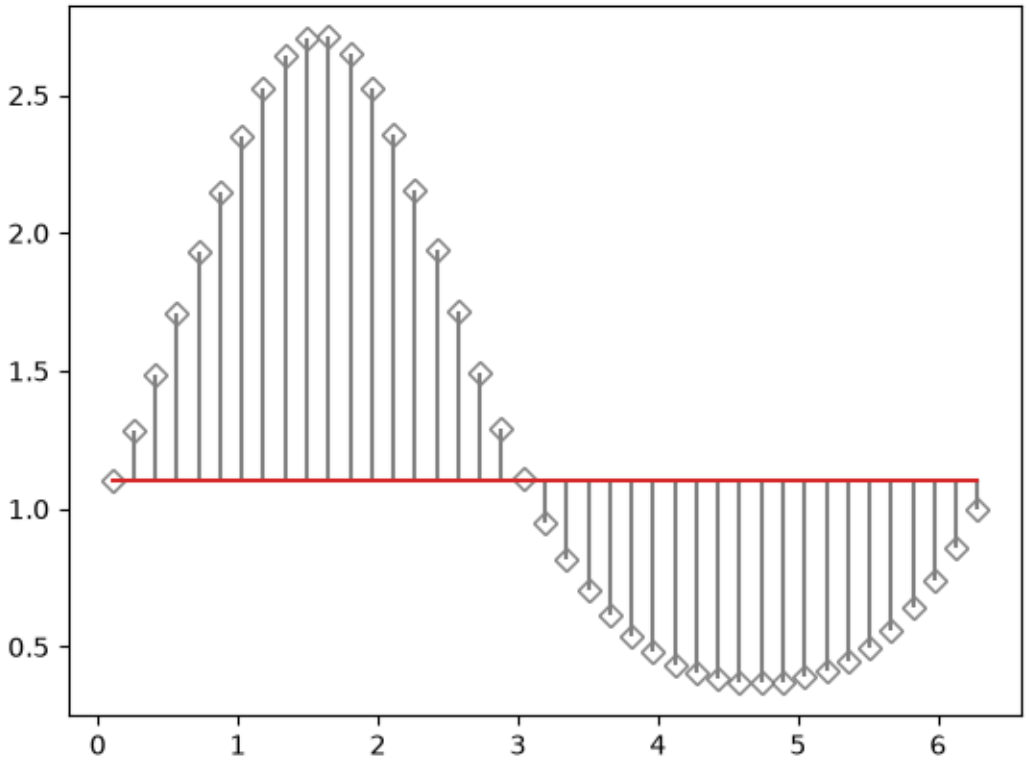
stem plots vertical lines from a baseline to the y-coordinate and places a marker at the tip.

```
import matplotlib.pyplot as plt
import numpy as np

x = np.linspace(0.1, 2 * np.pi, 41)
y = np.exp(np.sin(x))

plt.stem(x, y)
plt.show()
```



The position of the baseline can be adapted using *bottom*. The parameters *linefmt*, *markerfmt*, and *basefmt* control basic format properties of the plot. However, in contrast to `plot` not all properties are configurable via keyword arguments. For more advanced control adapt the line objects returned by `pyplot`.

```
markerline, stemlines, baseline = plt.stem(
    x, y, linefmt='grey', markerfmt='D', bottom=1.1)
markerline.set_markerfacecolor('none')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.stem* / *matplotlib.pyplot.stem*

Tags: plot-type: stem level: beginner

Plotting categorical variables

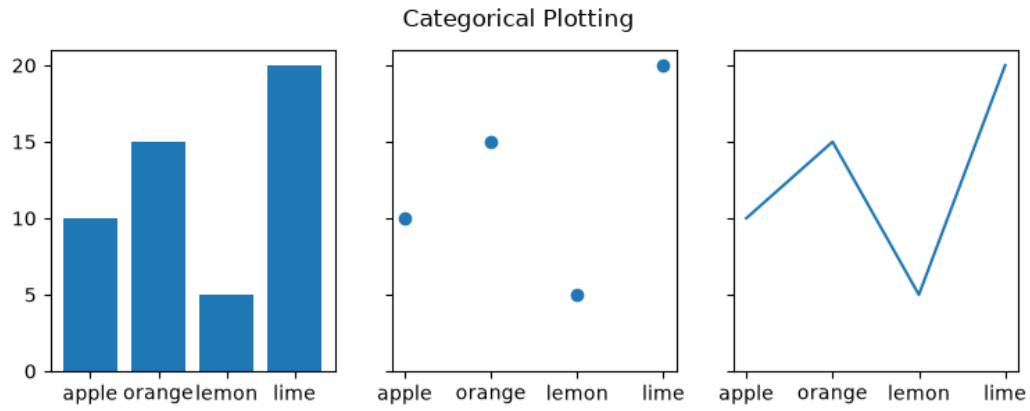
You can pass categorical values (i.e. strings) directly as x- or y-values to many plotting functions:

```
import matplotlib.pyplot as plt

data = {'apple': 10, 'orange': 15, 'lemon': 5, 'lime': 20}
names = list(data.keys())
values = list(data.values())

fig, axs = plt.subplots(1, 3, figsize=(9, 3), sharey=True)
axs[0].bar(names, values)
```

(continues on next page)

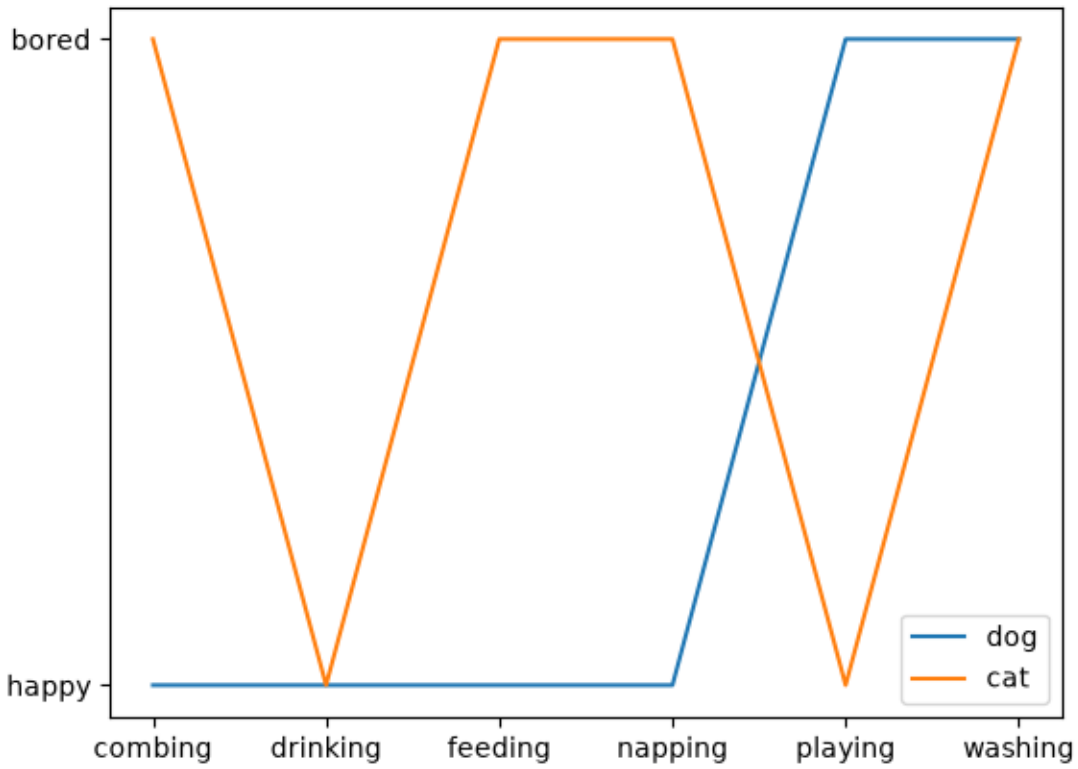
(continued from previous page)

```
axs[1].scatter(names, values)
axs[2].plot(names, values)
fig.suptitle('Categorical Plotting')
```



Categorical values are a mapping from names to positions. This means that values that occur multiple times are mapped to the same position. See the `cat` and `dog` values "happy" and "bored" on the y-axis in the following example.

```
cat = ["bored", "happy", "bored", "bored", "happy", "bored"]
dog = ["happy", "happy", "happy", "happy", "bored", "bored"]
activity = ["combing", "drinking", "feeding", "napping", "playing",
 ↪"washing"]

fig, ax = plt.subplots()
ax.plot(activity, dog, label="dog")
ax.plot(activity, cat, label="cat")
ax.legend()

plt.show()
```



Tags: plot-type: specialty level: beginner

Plotting masked and NaN values

Sometimes you need to plot data with missing values.

One possibility is to simply remove undesired data points. The line plotted through the remaining data will be continuous, and not indicate where the missing data is located.

If it is useful to have gaps in the line where the data is missing, then the undesired points can be indicated using a masked array or by setting their values to NaN. No marker will be drawn where either x or y are masked and, if plotting with a line, it will be broken there.

The following example illustrates the three cases:

1) Removing points.

2) Masking points.

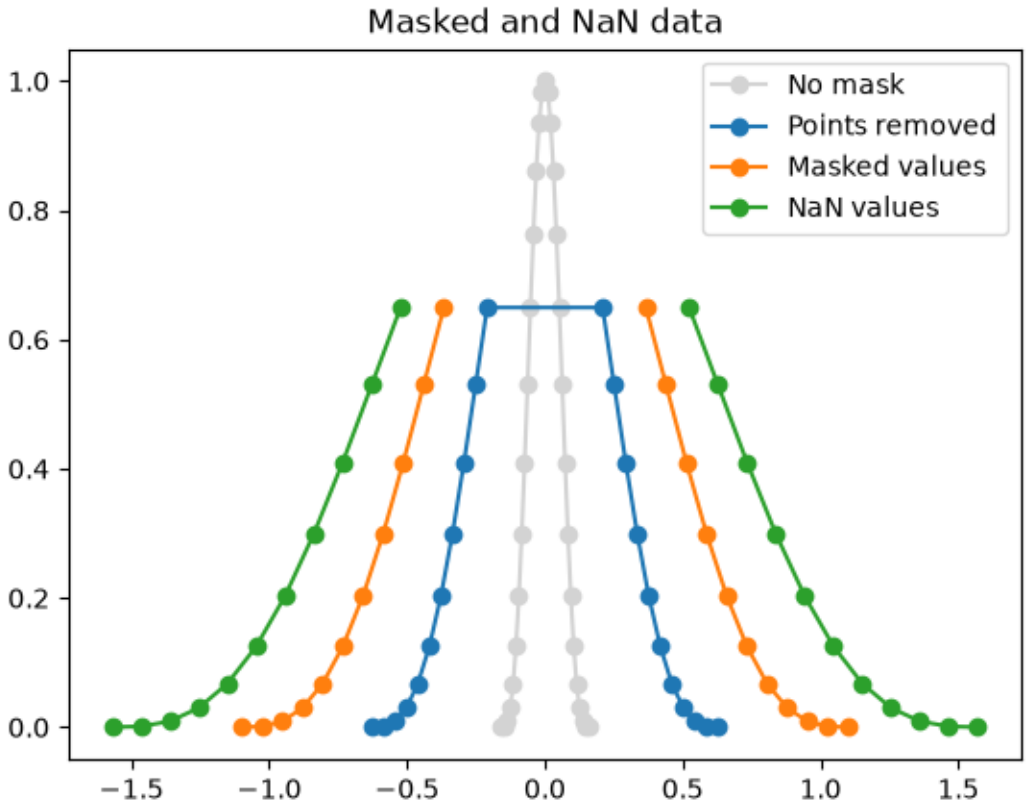
3) Setting to NaN.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
x = np.linspace(-np.pi/2, np.pi/2, 31)
y = np.cos(x)**3

# 1) remove points where y > 0.7
x2 = x[y <= 0.7]
y2 = y[y <= 0.7]

# 2) mask points where y > 0.7
y3 = np.ma.masked_where(y > 0.7, y)

# 3) set to NaN where y > 0.7
y4 = y.copy()
y4[y3 > 0.7] = np.nan

plt.plot(x*0.1, y, 'o-', color='lightgrey', label='No mask')
plt.plot(x2*0.4, y2, 'o-', label='Points removed')
plt.plot(x*0.7, y3, 'o-', label='Masked values')
plt.plot(x*1.0, y4, 'o-', label='NaN values')
plt.legend()
plt.title('Masked and NaN data')
plt.show()
```



Tags: plot-type: line level: intermediate

Spectrum representations

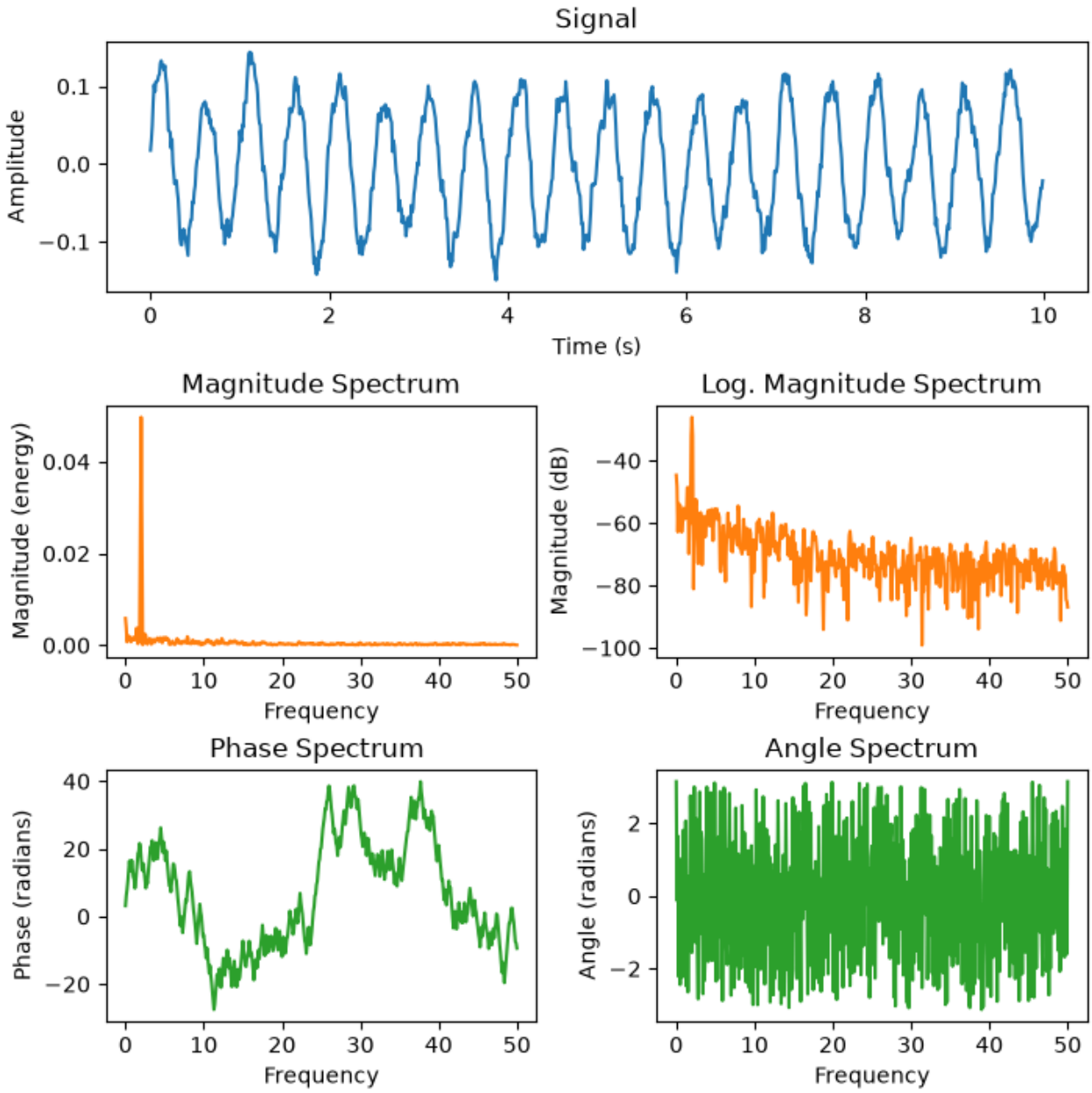
The plots show different spectrum representations of a sine signal with additive noise. A (frequency) spectrum of a discrete-time signal is calculated by utilizing the fast Fourier transform (FFT).

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(0)

dt = 0.01  # sampling interval
Fs = 1 / dt  # sampling frequency
t = np.arange(0, 10, dt)

# generate noise:
nse = np.random.randn(len(t))
r = np.exp(-t / 0.05)
cnse = np.convolve(nse, r) * dt
cnse = cnse[:len(t)]
```

(continues on next page)

(continued from previous page)

```
s = 0.1 * np.sin(4 * np.pi * t) + cnse  # the signal

fig = plt.figure(figsize=(7, 7), layout='constrained')
axs = fig.subplot_mosaic([["signal", "signal"],
                          ["magnitude", "log_magnitude"],
                          ["phase", "angle"]])

# plot time signal:
axs["signal"].set_title("Signal")
axs["signal"].plot(t, s, color='C0')
axs["signal"].set_xlabel("Time (s)")
axs["signal"].set_ylabel("Amplitude")

# plot different spectrum types:
axs["magnitude"].set_title("Magnitude Spectrum")
axs["magnitude"].magnitude_spectrum(s, Fs=Fs, color='C1')

axs["log_magnitude"].set_title("Log. Magnitude Spectrum")
axs["log_magnitude"].magnitude_spectrum(s, Fs=Fs, scale='dB', color='C1
 ↪')

axs["phase"].set_title("Phase Spectrum ")
axs["phase"].phase_spectrum(s, Fs=Fs, color='C2')

axs["angle"].set_title("Angle Spectrum")
axs["angle"].angle_spectrum(s, Fs=Fs, color='C2')

plt.show()
```



Tags: domain: signal-processing plot-type: line level: beginner

6.24.2 Images, contours and fields

Many ways to plot images

The most common way to plot images in Matplotlib is with *imshow*. The following examples demonstrate much of the functionality of imshow and the many images you can create.

```
from PIL import Image

import matplotlib.pyplot as plt
```

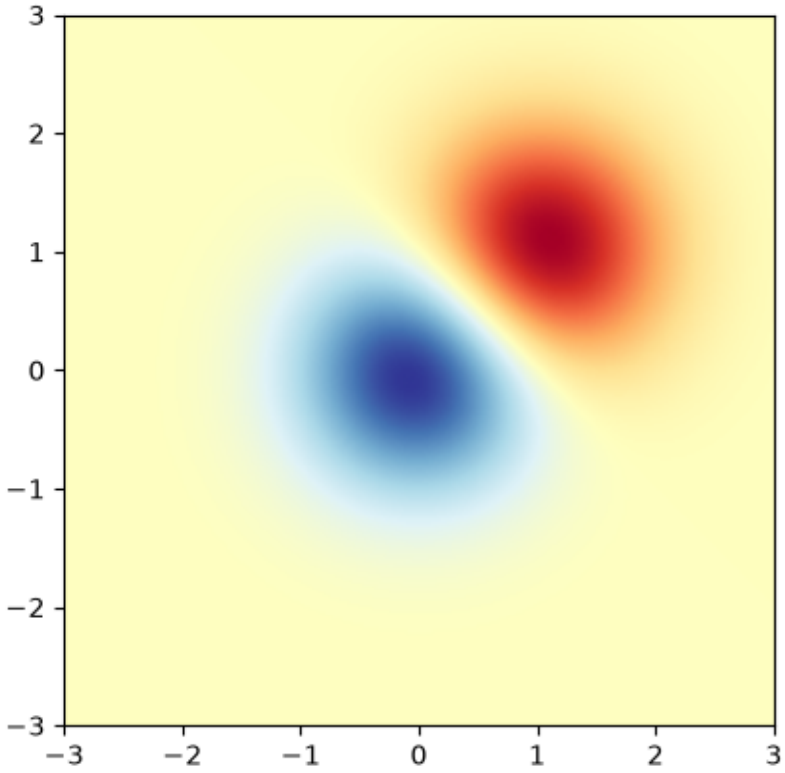
(continues on next page)

(continued from previous page)

```
import numpy as np

import matplotlib.cbook as cbook
from matplotlib.patches import PathPatch
from matplotlib.path import Path

# Fixing random state for reproducibility
np.random.seed(19680801)
```

First we'll generate a simple bivariate normal distribution.

```
delta = 0.025
x = y = np.arange(-3.0, 3.0, delta)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2

fig, ax = plt.subplots()
im = ax.imshow(Z, interpolation='bilinear', cmap="RdYlBu",
               origin='lower', extent=[-3, 3, -3, 3],
               vmax=abs(Z).max(), vmin=-abs(Z).max())

plt.show()
```



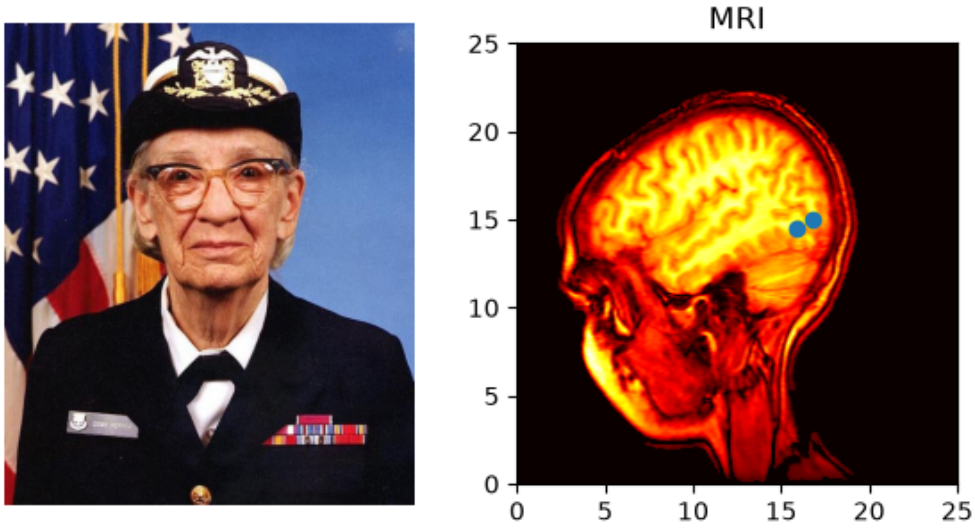
It is also possible to show images of pictures.

```
# A sample image
image = Image.open(cbook.get_sample_data("grace_hopper.jpg"))

# And another image, using 256x256 16-bit integers.
w, h = 256, 256
with cbook.get_sample_data('s1045.ima.gz') as datafile:
    s = datafile.read()
A = np.frombuffer(s, np.uint16).astype(float).reshape((w, h))
extent = (0, 25, 0, 25)

fig, ax = plt.subplot_mosaic([
    ['hopper', 'mri']
], figsize=(7, 3.5))

ax['hopper'].imshow(image)
ax['hopper'].axis('off')  # clear x-axis and y-axis

im = ax['mri'].imshow(A, cmap="hot", origin='upper', extent=extent)
```

(continues on next page)

(continued from previous page)

```
markers = [(15.9, 14.5), (16.8, 15)]
x, y = zip(*markers)
ax['mri'].plot(x, y, 'o')

ax['mri'].set_title('MRI')

plt.show()
```



Interpolating images

It is also possible to interpolate images before displaying them. Be careful, as this may manipulate the way your data looks, but it can be helpful for achieving the look you want. Below we'll display the same (small) array, interpolated with three different interpolation methods.

The center of the pixel at A[i, j] is plotted at (i+0.5, i+0.5). If you are using interpolation='nearest', the region bounded by (i, j) and (i+1, j+1) will have the same color. If you are using interpolation, the pixel center will have the same color as it does with nearest, but other pixels will be interpolated between the neighboring pixels.

To prevent edge effects when doing interpolation, Matplotlib pads the input array with identical pixels around the edge: if you have a 5x5 array with colors a-y as below:

```
a b c d e
f g h i j
k l m n o
p q r s t
u v w x y
```

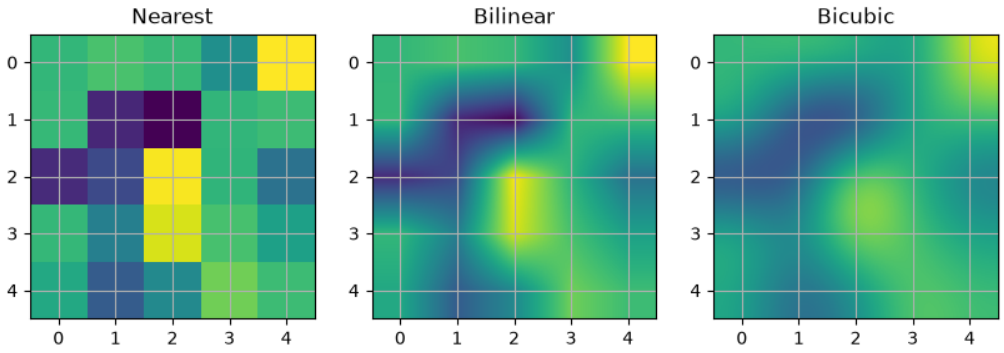
Matplotlib computes the interpolation and resizing on the padded array

```
a a b c d e e
a a b c d e e
f f g h i j j
k k l m n o o
p p q r s t t
o u v w x y y
o u v w x y y
```

and then extracts the central region of the result. (Extremely old versions of Matplotlib (<0.63) did not pad the array, but instead adjusted the view limits to hide the affected edge areas.)

This approach allows plotting the full extent of an array without edge effects, and for example to layer multiple images of different sizes over one another with different interpolation methods -- see *Layer images with alpha blending*. It also implies a performance hit, as this new temporary, padded array must be created. Sophisticated interpolation also implies a performance hit; for maximal performance or very large images, interpolation='nearest' is suggested.

```
A = np.random.rand(5, 5)

fig, axs = plt.subplots(1, 3, figsize=(10, 3))
for ax, interp in zip(axs, ['nearest', 'bilinear', 'bicubic']):
    ax.imshow(A, interpolation=interp)
    ax.set_title(interp.capitalize())
    ax.grid(True)

plt.show()
```



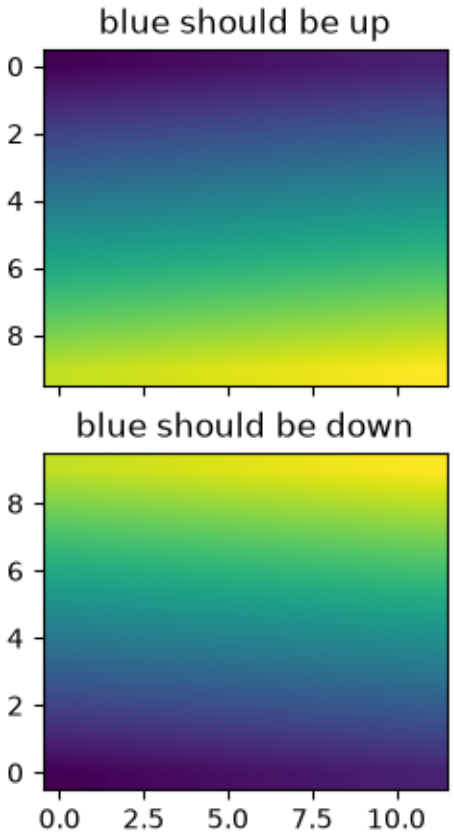
You can specify whether images should be plotted with the array origin x[0, 0] in the upper left or lower right by using the origin parameter. You can also control the default setting image.origin in your *matplotlibrc file*. For more on this topic see the *complete guide on origin and extent*.

```
x = np.arange(120).reshape((10, 12))

interp = 'bilinear'
fig, axs = plt.subplots(nrows=2, sharex=True, figsize=(3, 5))
axs[0].set_title('blue should be up')
```

(continues on next page)

(continued from previous page)

```
axs[0].imshow(x, origin='upper', interpolation=interp)

axs[1].set_title('blue should be down')
axs[1].imshow(x, origin='lower', interpolation=interp)
plt.show()
```



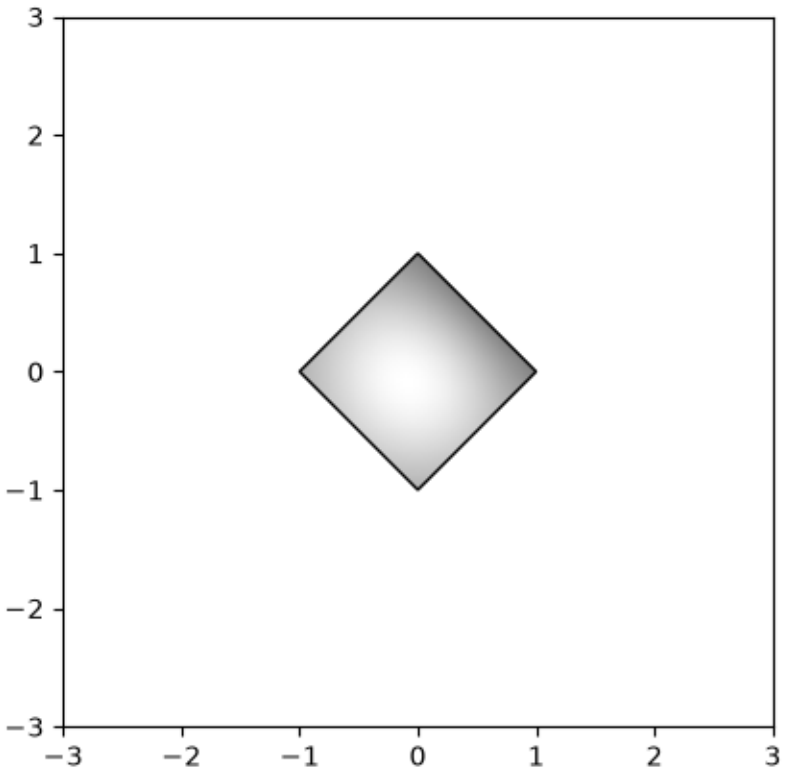
Finally, we'll show an image using a clip path.

```
delta = 0.025
x = y = np.arange(-3.0, 3.0, delta)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2

path = Path([[0, 1], [1, 0], [0, -1], [-1, 0], [0, 1]])
patch = PathPatch(path, facecolor='none')

fig, ax = plt.subplots()
```

(continues on next page)

(continued from previous page)

```
ax.add_patch(patch)

im = ax.imshow(Z, interpolation='bilinear', cmap="gray",
               origin='lower', extent=[-3, 3, -3, 3],
               clip_path=patch, clip_on=True)
im.set_clip_path(patch)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow / matplotlib.pyplot.imshow*
- *matplotlib.artist.Artist.set_clip_path*
- *matplotlib.patches.PathPatch*

Total running time of the script: (0 minutes 1.452 seconds)

Image with masked values

imshow with masked array input and out-of-range colors.

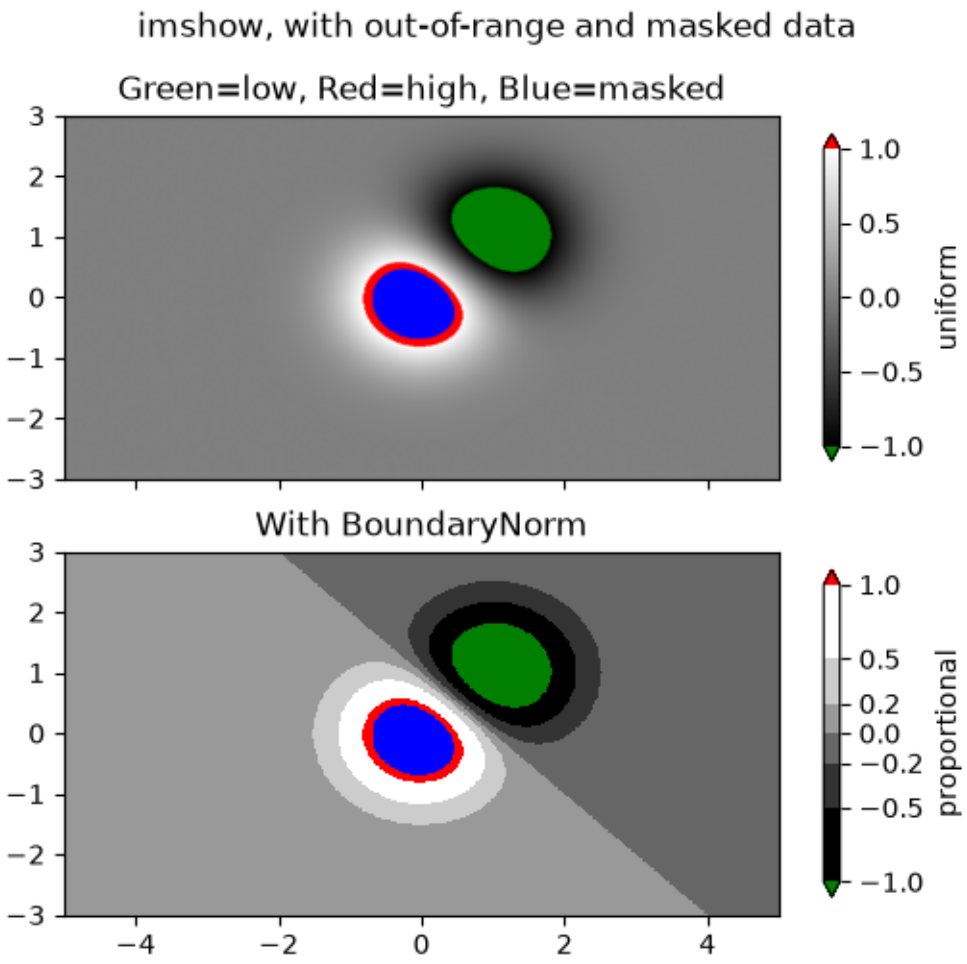
The second subplot illustrates the use of BoundaryNorm to get a filled contour effect.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.colors as colors

# compute some interesting data
x0, x1 = -5, 5
y0, y1 = -3, 3
x = np.linspace(x0, x1, 500)
y = np.linspace(y0, y1, 500)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2

# Set up a colormap:
palette = plt.colormaps["gray"].with_extremes(over='r', under='g', bad=
 ↪'b')
# Alternatively, we could use
# palette.set_bad(alpha = 0.0)
# to make the bad region transparent.  This is the default.
# If you comment out all the palette.set* lines, you will see
# all the defaults; under and over will be colored with the
# first and last colors in the palette, respectively.
Zm = np.ma.masked_where(Z > 1.2, Z)

# By setting vmin and vmax in the norm, we establish the
# range to which the regular palette color scale is applied.
# Anything above that range is colored based on palette.set_over, etc.

# set up the Axes objects
fig, (ax1, ax2) = plt.subplots(nrows=2, figsize=(6, 5.4))

# plot using 'continuous' colormap
im = ax1.imshow(Zm, interpolation='bilinear',
                cmap=palette,
                norm=colors.Normalize(vmin=-1.0, vmax=1.0),
                aspect='auto',
                origin='lower',
                extent=[x0, x1, y0, y1])
ax1.set_title('Green=low, Red=high, Blue=masked')
cbar = fig.colorbar(im, extend='both', shrink=0.9, ax=ax1)
```

(continues on next page)

(continued from previous page)

```
cbar.set_label('uniform')
ax1.tick_params(axis='x', labelbottom=False)

# Plot using a small number of colors, with unevenly spaced boundaries.
im = ax2.imshow(Zm, interpolation='nearest',
                cmap=palette,
                norm=colors.BoundaryNorm([-1, -0.5, -0.2, 0, 0.2, 0.5,␣
 ↪1],
                                         ncolors=palette.N),
                aspect='auto',
                origin='lower',
                extent=[x0, x1, y0, y1])
ax2.set_title('With BoundaryNorm')
cbar = fig.colorbar(im, extend='both', spacing='proportional',
                    shrink=0.9, ax=ax2)
cbar.set_label('proportional')

fig.suptitle('imshow, with out-of-range and masked data')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.colors.BoundaryNorm*
- *matplotlib.colorbar.Colorbar.set_label*

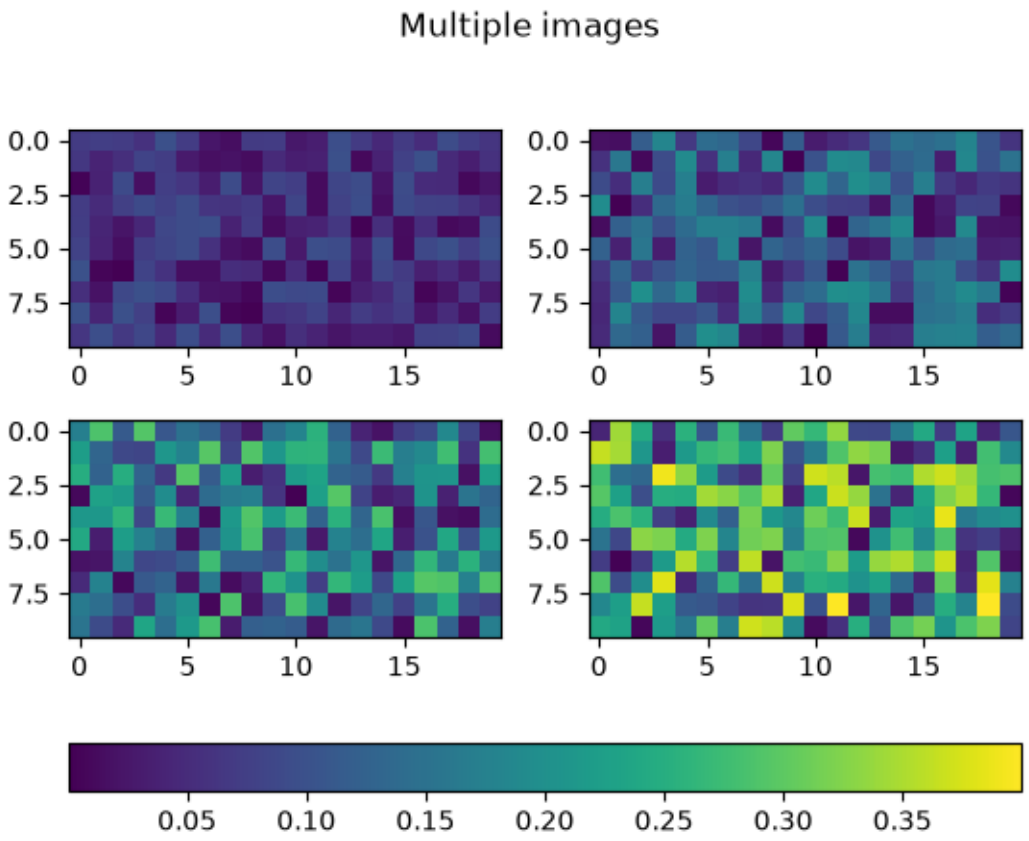
Multiple images with one colorbar

Use a single colorbar for multiple images.

Currently, a colorbar can only be connected to one image. The connection guarantees that the data coloring is consistent with the colormap scale (i.e. the color of value x in the colormap is used for coloring a data value x in the image).

If we want one colorbar to be representative for multiple images, we have to explicitly ensure consistent data coloring by using the same data-to-color pipeline for all the images. We ensure this by explicitly creating a *matplotlib.colorizer.Colorizer* object that we pass to all the image plotting methods.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.colorizer as mcolorizer
import matplotlib.colors as mcolors

np.random.seed(19680801)

datasets = [
    (i+1)/10 * np.random.rand(10, 20)
    for i in range(4)
]

fig, axs = plt.subplots(2, 2)
fig.suptitle('Multiple images')

# create a colorizer with a predefined norm to be shared across all␣
↪images
norm = mcolors.Normalize(vmin=np.min(datasets), vmax=np.max(datasets))
colorizer = mcolorizer.Colorizer(norm=norm)

images = []
for ax, data in zip(axs.flat, datasets):
    images.append(ax.imshow(data, colorizer=colorizer))

fig.colorbar(images[0], ax=axs, orientation='horizontal', fraction=.1)

plt.show()
```



The colors are now kept consistent across all images when changing the scaling, e.g. through zooming in the colorbar or via the "edit axis, curves and images parameters" GUI of the Qt backend. Additionally, if the colormap of the colorizer is changed, (e.g. through the "edit axis, curves and images parameters" GUI of the Qt backend) this change propagates to the other plots and the colorbar.

References

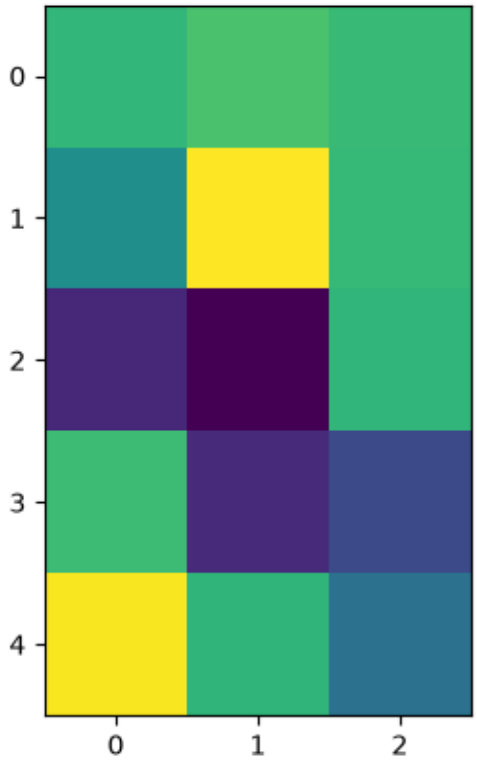
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.colorizer.Colorizer*
- *matplotlib.colors.Normalize*

Modifying the coordinate formatter

Modify the coordinate formatter to report the image "z" value of the nearest pixel given x and y. This functionality is built in by default; this example just showcases how to customize the *format_coord* function.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)


X = 10*np.random.rand(5, 3)

fig, ax = plt.subplots()
ax.imshow(X)


def format_coord(x, y):
    col = round(x)
    row = round(y)
    nrows, ncols = X.shape
    if 0 <= col < ncols and 0 <= row < nrows:
        z = X[row, col]
        return f'x={x:1.4f}, y={y:1.4f}, z={z:1.4f}'
    else:
        return f'x={x:1.4f}, y={y:1.4f}'


ax.format_coord = format_coord
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

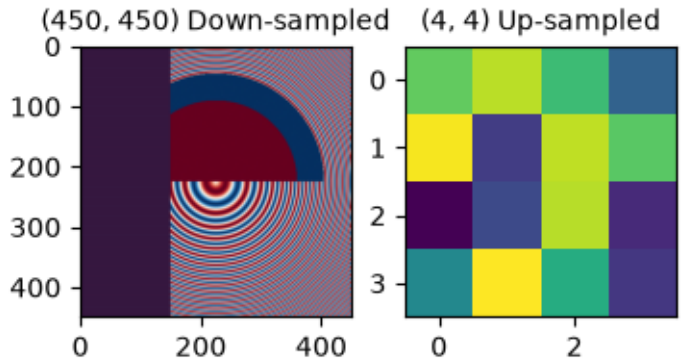
- *matplotlib.axes.Axes.format_coord*
- *matplotlib.axes.Axes.imshow*

Image resampling

Images are represented by discrete pixels assigned color values, either on the screen or in an image file. When a user calls *imshow* with a data array, it is rare that the size of the data array exactly matches the number of pixels allotted to the image in the figure, so Matplotlib resamples or scales the data or image to fit. If the data array is larger than the number of pixels allotted in the rendered figure, then the image will be "down-sampled" and image information will be lost. Conversely, if the data array is smaller than the number of output pixels then each data point will get multiple pixels, and the image is "up-sampled".

In the following figure, the first data array has size (450, 450), but is represented by far fewer pixels in the figure, and hence is down-sampled. The second data array has size (4, 4), and is represented by far more pixels, and hence is up-sampled.

```
import matplotlib.pyplot as plt
import numpy as np

fig, axs = plt.subplots(1, 2, figsize=(4, 2))

# First we generate a 450x450 pixel image with varying frequency␣
 ↪content:
N = 450
x = np.arange(N) / N - 0.5
y = np.arange(N) / N - 0.5
aa = np.ones((N, N))
aa[::2, :] = -1

X, Y = np.meshgrid(x, y)
R = np.sqrt(X**2 + Y**2)
f0 = 5
k = 100
a = np.sin(np.pi * 2 * (f0 * R + k * R**2 / 2))
# make the left hand side of this
a[:int(N / 2), :][R[:int(N / 2), :] < 0.4] = -1
a[:int(N / 2), :][R[:int(N / 2), :] < 0.3] = 1
aa[:, int(N / 3):] = a[:, int(N / 3):]
alarge = aa

axs[0].imshow(alarge, cmap='RdBu_r')
axs[0].set_title('(450, 450) Down-sampled', fontsize='medium')

np.random.seed(19680801+9)
asmall = np.random.rand(4, 4)
axs[1].imshow(asmall, cmap='viridis')
axs[1].set_title('(4, 4) Up-sampled', fontsize='medium')
```



Matplotlib's *imshow* method has two keyword arguments to allow the user to control how resampling is done. The *interpolation* keyword argument allows a choice of the kernel that is used for resampling, allowing either anti-alias filtering if down-sampling, or smoothing of pixels if up-sampling. The *interpolation_stage* keyword argument, determines if this smoothing kernel is applied to the underlying data, or if the kernel is

applied to the RGBA pixels.

`interpolation_stage='rgba'`: Data -> Normalize -> RGBA -> Interpolate/Resample

`interpolation_stage='data'`: Data -> Interpolate/Resample -> Normalize -> RGBA

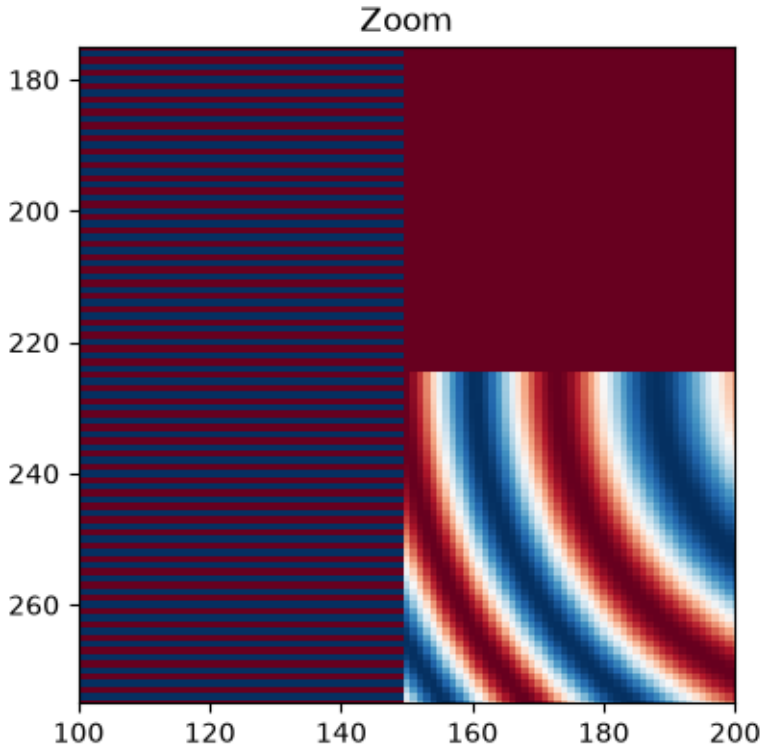
For both keyword arguments, Matplotlib has a default "auto", that is recommended for most situations, and is described below. Note that this default behaves differently if the image is being down- or up-sampled, as described below.

Down-sampling and modest up-sampling

When down-sampling data, we usually want to remove aliasing by smoothing the image first and then sub-sampling it. In Matplotlib, we can do that smoothing before mapping the data to colors, or we can do the smoothing on the RGB(A) image pixels. The differences between these are shown below, and controlled with the *interpolation_stage* keyword argument.

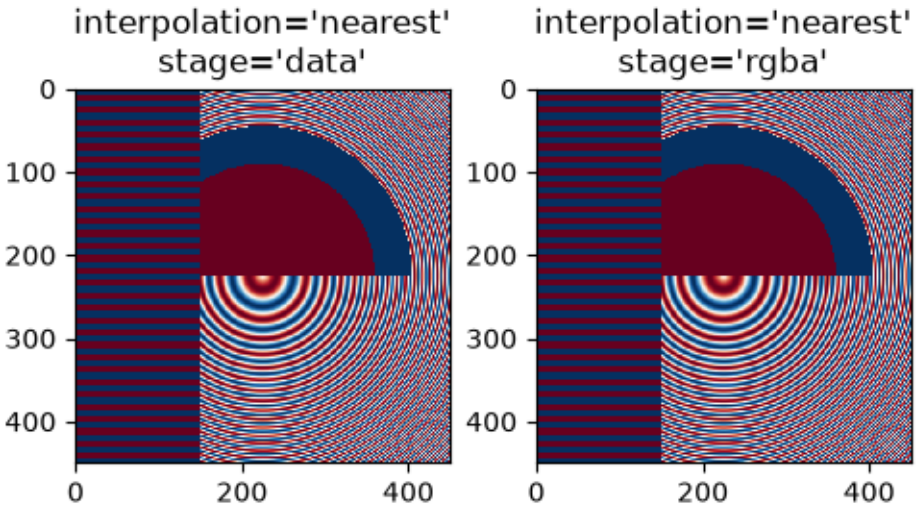
The following images are down-sampled from 450 data pixels to approximately 125 pixels or 250 pixels (depending on your display). The underlying image has alternating +1, -1 stripes on the left side, and a varying wavelength (chirp) pattern in the rest of the image. If we zoom, we can see this detail without any down-sampling:

```
fig, ax = plt.subplots(figsize=(4, 4), layout='compressed')
ax.imshow(alarge, interpolation='nearest', cmap='RdBu_r')
ax.set_xlim(100, 200)
ax.set_ylim(275, 175)
ax.set_title('Zoom')
```



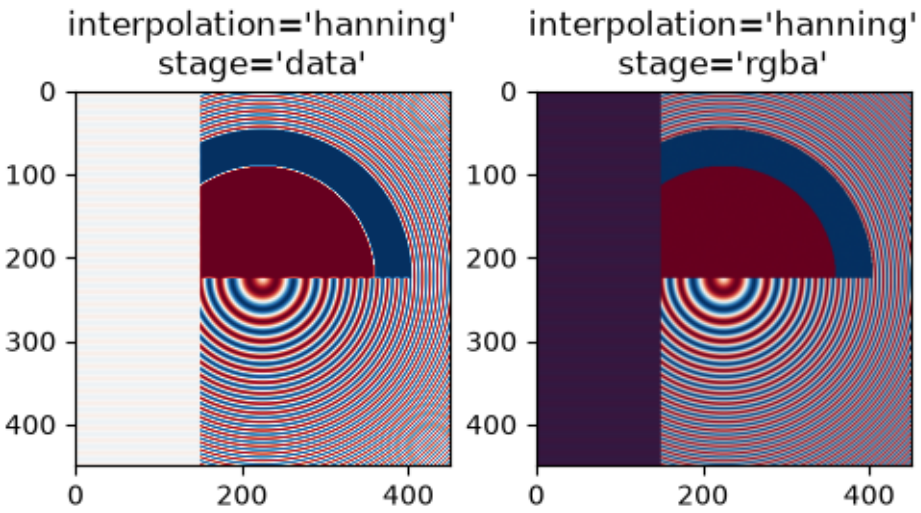
If we down-sample, the simplest algorithm is to decimate the data using nearest-neighbor interpolation. We can do this in either data space or RGBA space:

```
fig, axs = plt.subplots(1, 2, figsize=(5, 2.7), layout='compressed')
for ax, interp, space in zip(axs.flat, ['nearest', 'nearest'],
                                       ['data', 'rgba']):
    ax.imshow(alarge, interpolation=interp, interpolation_stage=space,
              cmap='RdBu_r')
    ax.set_title(f"interpolation='{interp}'\nstage='{space}'")
```



Nearest interpolation is identical in data and RGBA space, and both exhibit Moiré patterns because the high-frequency data is being down-sampled and shows up as lower frequency patterns. We can reduce the Moiré patterns by applying an anti-aliasing filter to the image before rendering:

```
fig, axs = plt.subplots(1, 2, figsize=(5, 2.7), layout='compressed')
for ax, interp, space in zip(axs.flat, ['hanning', 'hanning'],
                                       ['data', 'rgba']):
    ax.imshow(alarge, interpolation=interp, interpolation_stage=space,
              cmap='RdBu_r')
    ax.set_title(f"interpolation='{interp}'\nstage='{space}'")
plt.show()
```

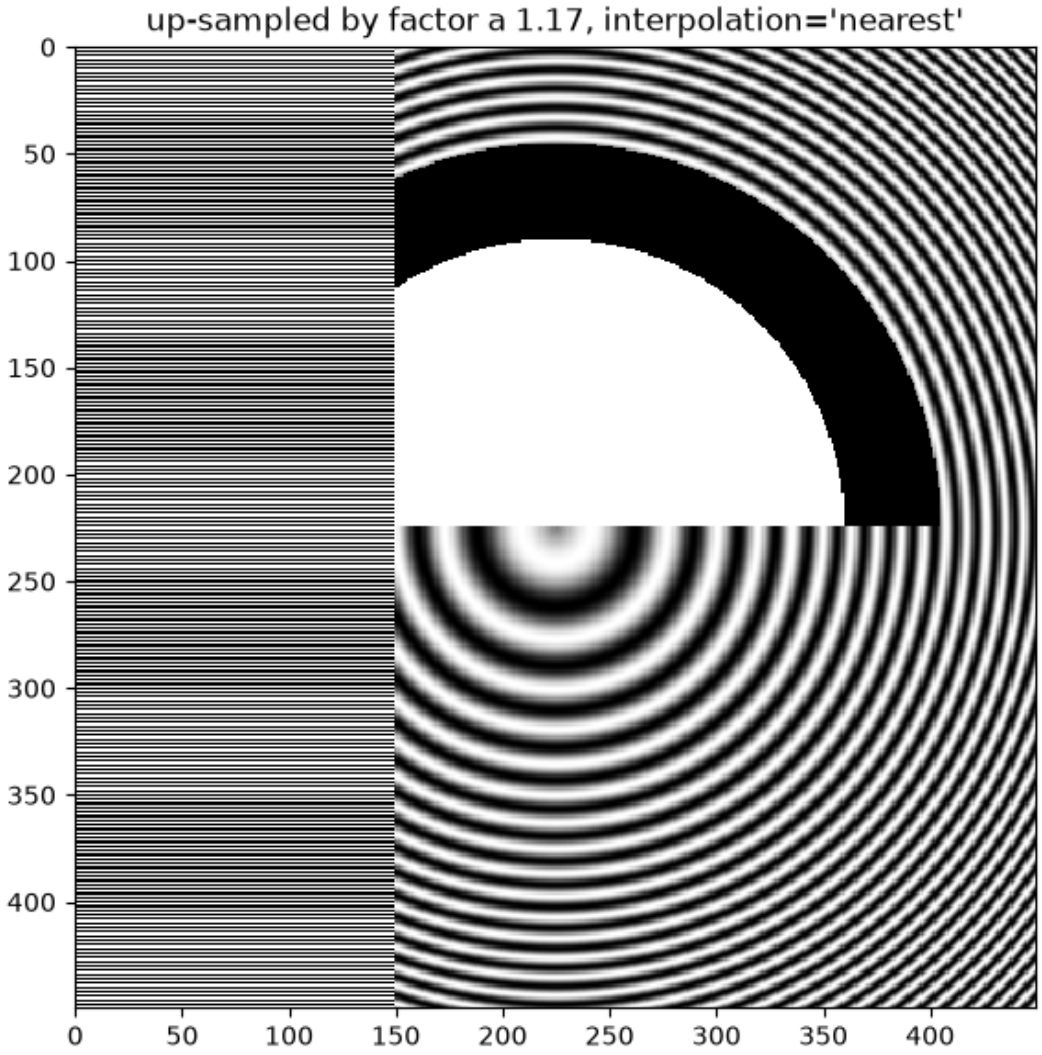


The Hanning filter smooths the underlying data so that each new pixel is a weighted average of the original underlying pixels. This greatly reduces the Moiré patterns. However, when the *interpolation_stage* is set to 'data', it also introduces white regions to the image that are not in the original data, both in the alternating bands on the left hand side of the image, and in the boundary between the red and blue of the large circles in the middle of the image. The interpolation at the 'rgba' stage has a different artifact, with the alternating bands coming out a shade of purple; even though purple is not in the original colormap, it is what we perceive when a blue and red stripe are close to each other.

The default for the *interpolation* keyword argument is 'auto' which will choose a Hanning filter if the image is being down-sampled or up-sampled by less than a factor of three. The default *interpolation_stage* keyword argument is also 'auto', and for images that are down-sampled or up-sampled by less than a factor of three it defaults to 'rgba' interpolation.

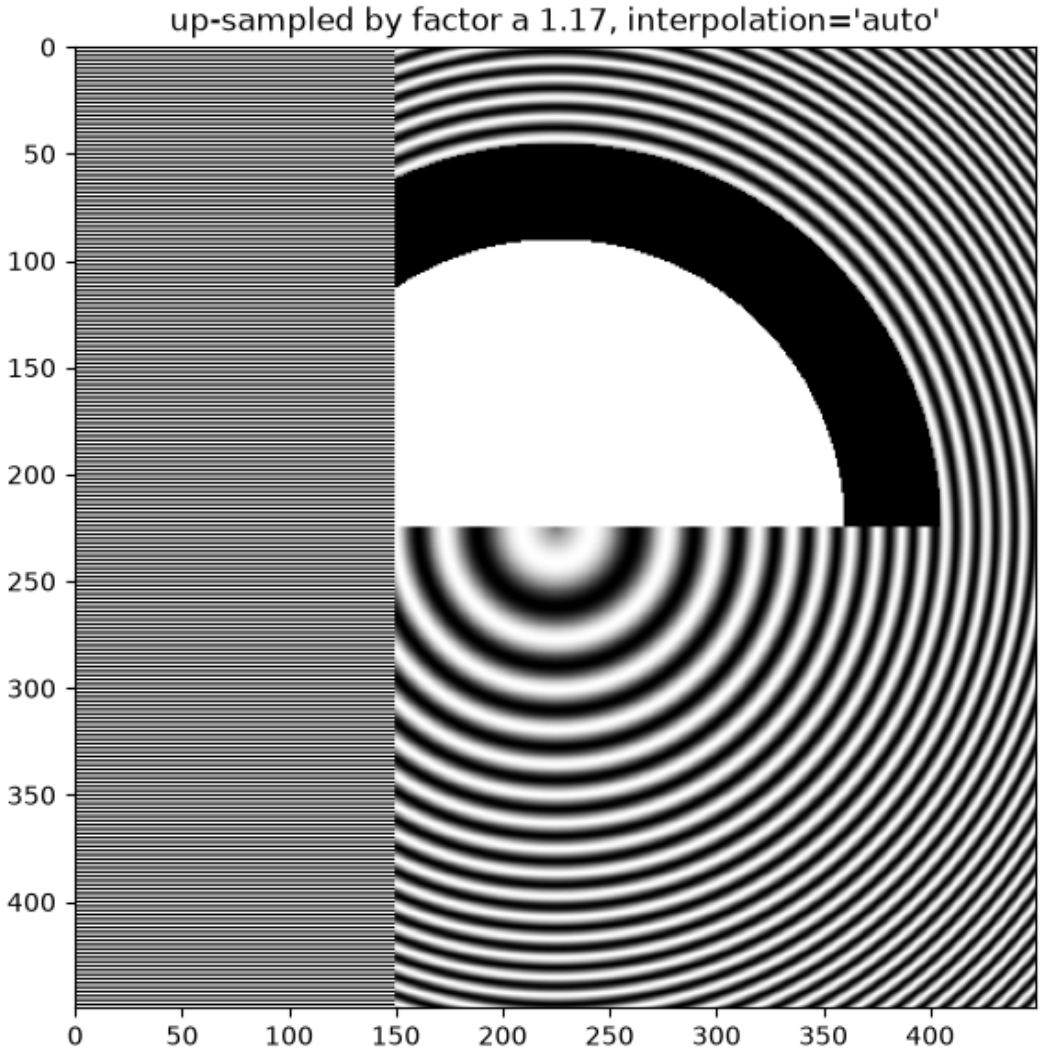
Anti-aliasing filtering is needed, even when up-sampling. The following image up-samples 450 data pixels to 530 rendered pixels. You may note a grid of line-like artifacts which stem from the extra pixels that had to be made up. Since interpolation is 'nearest' they are the same as a neighboring line of pixels and thus stretch the image locally so that it looks distorted.

```
fig, ax = plt.subplots(figsize=(6.8, 6.8))
ax.imshow(alarge, interpolation='nearest', cmap='grey')
ax.set_title("up-sampled by factor a 1.17, interpolation='nearest'")
```



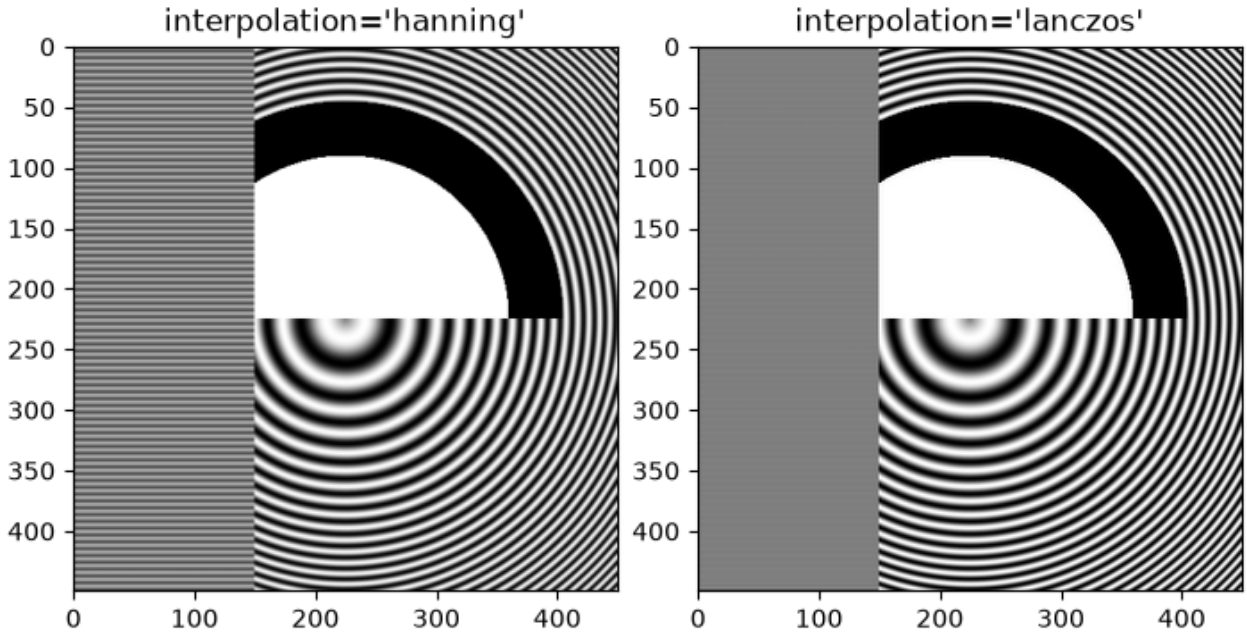
Better anti-aliasing algorithms can reduce this effect:

```
fig, ax = plt.subplots(figsize=(6.8, 6.8))
ax.imshow(alarge, interpolation='auto', cmap='grey')
ax.set_title("up-sampled by factor a 1.17, interpolation='auto'")
```



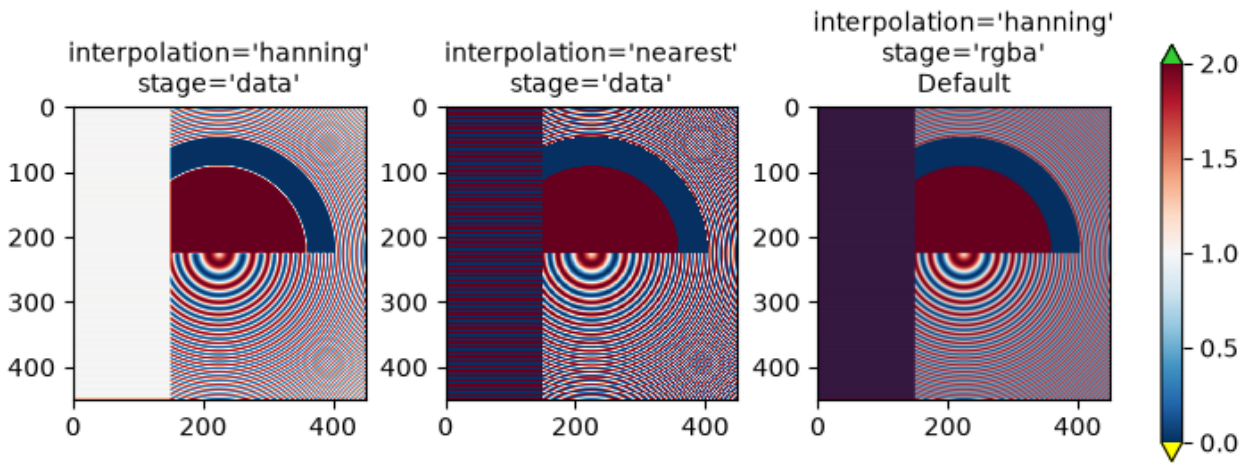
Apart from the default 'hanning' anti-aliasing, *imshow* supports a number of different interpolation algorithms, which may work better or worse depending on the underlying data.

```
fig, axs = plt.subplots(1, 2, figsize=(7, 4), layout='constrained')
for ax, interp in zip(axs, ['hanning', 'lanczos']):
    ax.imshow(alarge, interpolation=interp, cmap='gray')
    ax.set_title(f"interpolation='{interp}'")
```



A final example shows the desirability of performing the anti-aliasing at the RGBA stage when using non-trivial interpolation kernels. In the following, the data in the outer circle is exactly 0.0, and data in the inner circle is exactly 2.0. If we perform the *interpolation_stage* in 'data' space and use an anti-aliasing filter (first panel), then floating point imprecision makes some of the data values just a bit less than zero or a bit more than 2.0, and they get assigned the under- or over- colors. This can be avoided if you do not use an anti-aliasing filter (*interpolation* set to 'nearest'), however, that makes the part of the data susceptible to Moiré patterns much worse (second panel). Therefore, we recommend the default *interpolation* of 'hanning'/'auto', and *interpolation_stage* of 'rgba'/'auto' for most down-sampling situations (last panel).

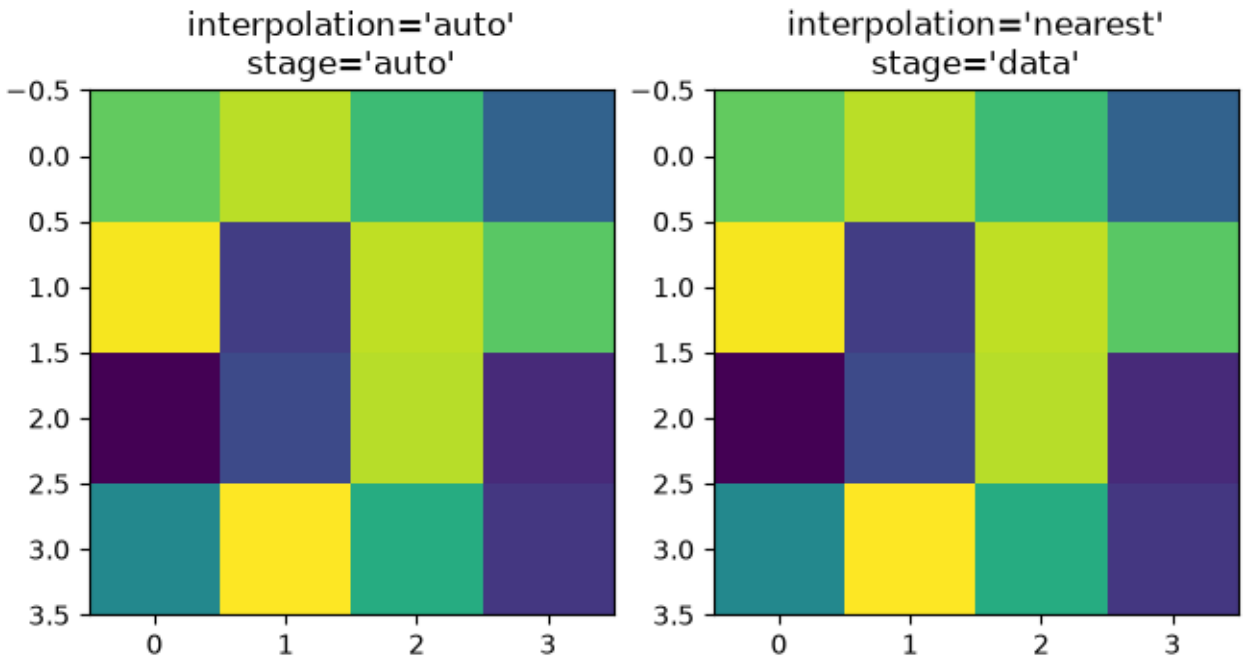
```
a = alarge + 1
cmap = plt.get_cmap('RdBu_r')
cmap.set_under('yellow')
cmap.set_over('limegreen')

fig, axs = plt.subplots(1, 3, figsize=(7, 3), layout='constrained')
for ax, interp, space in zip(axs.flat,
                             ['hanning', 'nearest', 'hanning', ],
                             ['data', 'data', 'rgba']):
    im = ax.imshow(a, interpolation=interp, interpolation_stage=space,
                   cmap=cmap, vmin=0, vmax=2)
    title = f"interpolation='{interp}'\nstage='{space}'"
    if ax == axs[2]:
        title += '\nDefault'
    ax.set_title(title, fontsize='medium')
fig.colorbar(im, ax=axs, extend='both', shrink=0.8)
```



Up-sampling

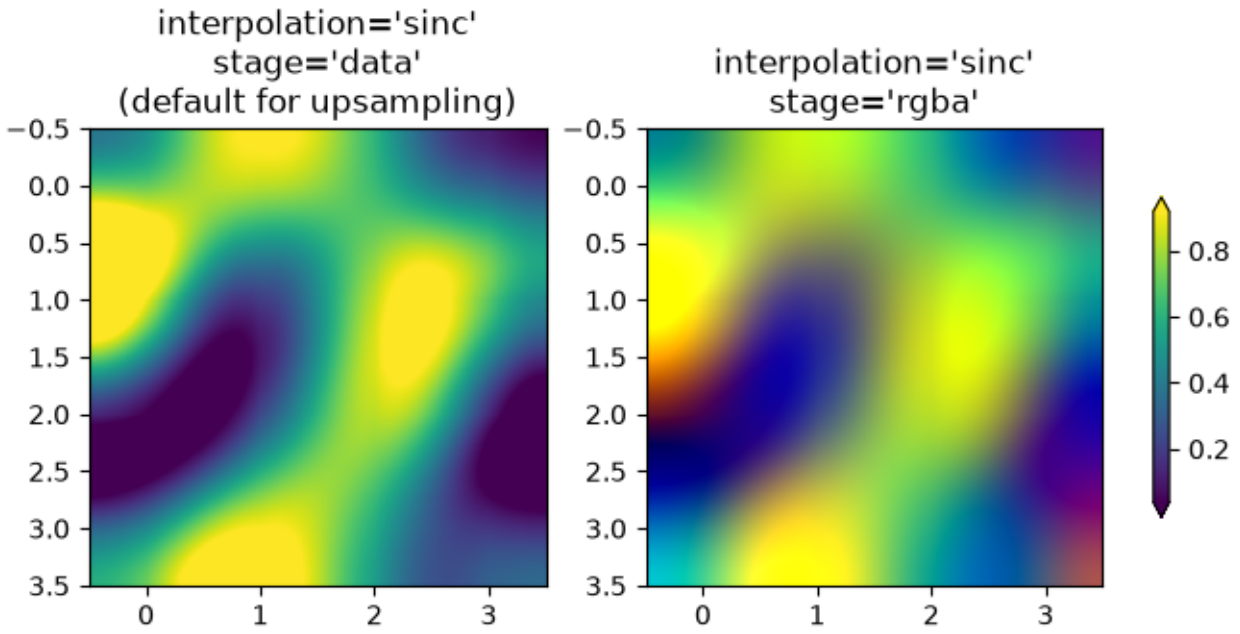
If we up-sample, then we can represent a data pixel by many image or screen pixels. In the following example, we greatly over-sample the small data matrix.

```
np.random.seed(19680801+9)
a = np.random.rand(4, 4)

fig, axs = plt.subplots(1, 2, figsize=(6.5, 4), layout='compressed')
axs[0].imshow(asmall, cmap='viridis')
axs[0].set_title("interpolation='auto'\nstage='auto'")
axs[1].imshow(asmall, cmap='viridis', interpolation="nearest",
              interpolation_stage="data")
axs[1].set_title("interpolation='nearest'\nstage='data'")
plt.show()
```



The *interpolation* keyword argument can be used to smooth the pixels if desired. However, that almost always is better done in data space, rather than in RGBA space where the filters can cause colors that are not in the colormap to be the result of the interpolation. In the following example, note that when the interpolation is 'rgba' there are red colors as interpolation artifacts. Therefore, the default 'auto' choice for *interpolation_stage* is set to be the same as 'data' when up-sampling is greater than a factor of three:

```
fig, axs = plt.subplots(1, 2, figsize=(6.5, 4), layout='compressed')
im = axs[0].imshow(a, cmap='viridis', interpolation='sinc',␣
 ↪interpolation_stage='data')
axs[0].set_title("interpolation='sinc'\nstage='data'\n(default for␣
 ↪upsampling)")
axs[1].imshow(a, cmap='viridis', interpolation='sinc',␣
 ↪interpolation_stage='rgba')
axs[1].set_title("interpolation='sinc'\nstage='rgba'")
fig.colorbar(im, ax=axs, shrink=0.7, extend='both')
```

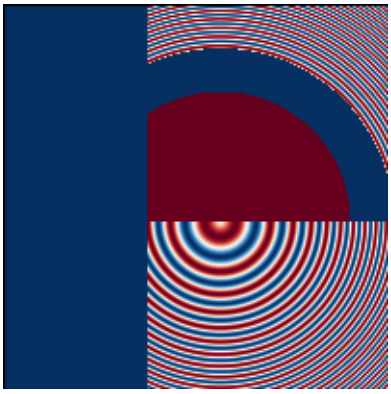


Avoiding resampling

It is possible to avoid resampling data when making an image. One method is to simply save to a vector backend (pdf, eps, svg) and use `interpolation='none'`. Vector backends allow embedded images, however be aware that some vector image viewers may smooth image pixels.

The second method is to exactly match the size of your axes to the size of your data. The following figure is exactly 2 inches by 2 inches, and if the dpi is 200, then the 400x400 data is not resampled at all. If you download this image and zoom in an image viewer you should see the individual stripes on the left hand side (note that if you have a non hiDPI or "retina" screen, the html may serve a 100x100 version of the image, which will be downsampled.)

```
fig = plt.figure(figsize=(2, 2))
ax = fig.add_axes((0, 0, 1, 1))
ax.imshow(aa[:400, :400], cmap='RdBu_r', interpolation='nearest')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow*

Total running time of the script: (0 minutes 4.747 seconds)

Interpolations for imshow

This example displays the difference between interpolation methods for *imshow*.

If *interpolation* is None, it defaults to the *rcParams["image.interpolation"]* (default: `'auto'`). If the interpolation is `'none'`, then no interpolation is performed for the Agg, ps and pdf backends. Other backends will default to `'auto'`.

For the Agg, ps and pdf backends, `interpolation='none'` works well when a big image is scaled down, while `interpolation='nearest'` works well when a small image is scaled up.

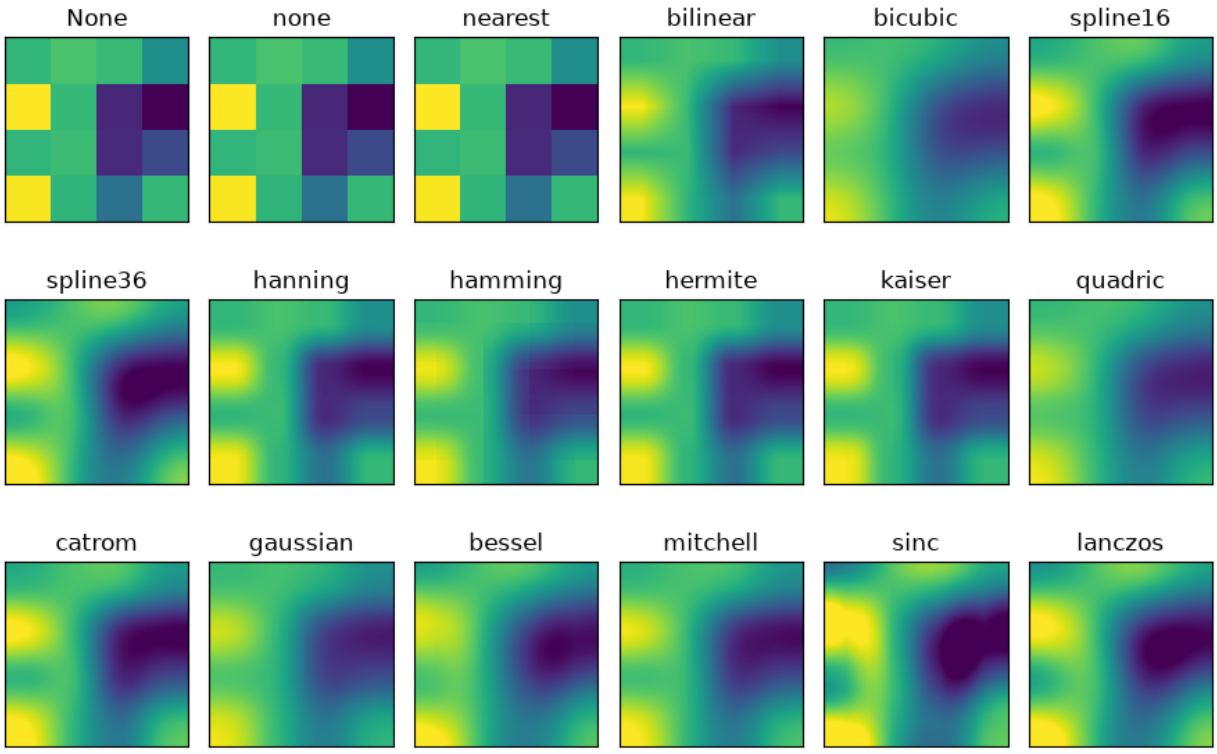
See *Image resampling* for a discussion on the default `interpolation='auto'` option.

```
import matplotlib.pyplot as plt
import numpy as np

methods = [None, 'none', 'nearest', 'bilinear', 'bicubic', 'spline16',
           'spline36', 'hanning', 'hamming', 'hermite', 'kaiser',
 ↪'quadric',
           'catrom', 'gaussian', 'bessel', 'mitchell', 'sinc', 'lanczos
 ↪']

# Fixing random state for reproducibility
np.random.seed(19680801)

grid = np.random.rand(4, 4)

fig, axs = plt.subplots(nrows=3, ncols=6, figsize=(9, 6),
                        subplot_kw={'xticks': [], 'yticks': []})
```

(continues on next page)

(continued from previous page)

```
for ax, interp_method in zip(axs.flat, methods):
    ax.imshow(grid, interpolation=interp_method, cmap='viridis')
    ax.set_title(str(interp_method))

plt.tight_layout()
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*

Layer images with alpha blending

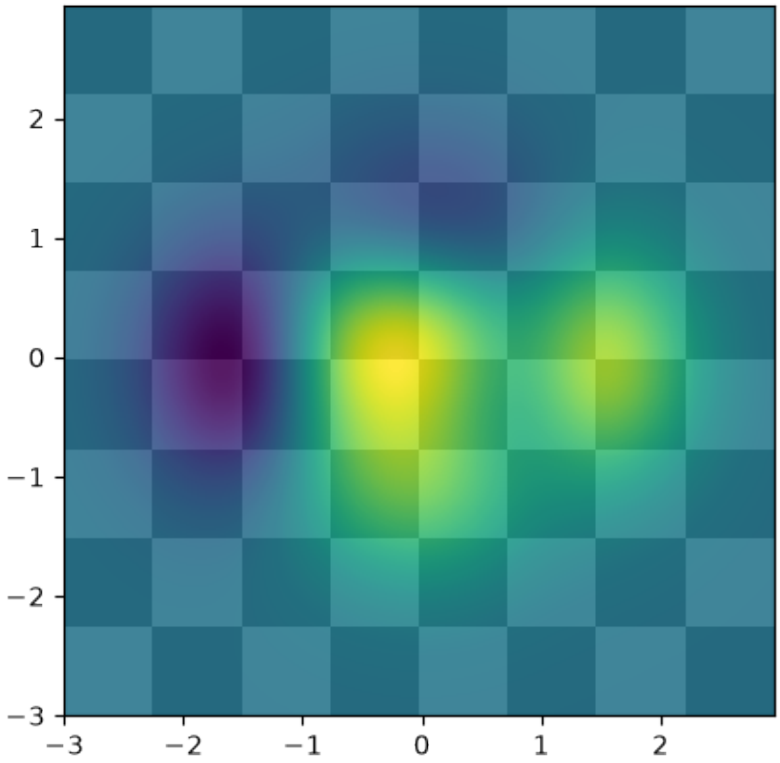
Layer images above one another using alpha blending

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
def func3(x, y):
    return (1 - x / 2 + x**5 + y**3) * np.exp(-(x**2 + y**2))


# make these smaller to increase the resolution
dx, dy = 0.05, 0.05

x = np.arange(-3.0, 3.0, dx)
y = np.arange(-3.0, 3.0, dy)
X, Y = np.meshgrid(x, y)

# when layering multiple images, the images need to have the same
# extent.  This does not mean they need to have the same shape, but
# they both need to render to the same coordinate system determined by
# xmin, xmax, ymin, ymax.  Note if you use different interpolations
# for the images their apparent extent could be different due to
# interpolation edge effects

extent = np.min(x), np.max(x), np.min(y), np.max(y)
fig = plt.figure(frameon=False)

Z1 = np.add.outer(range(8), range(8)) % 2  # chessboard
im1 = plt.imshow(Z1, cmap="gray", interpolation='nearest',
                 extent=extent)

Z2 = func3(X, Y)

im2 = plt.imshow(Z2, cmap="viridis", alpha=.9, interpolation='bilinear
 ↪',
                 extent=extent)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*

Blend transparency with color in 2D images

Blend transparency with color to highlight parts of data with imshow.

A common use for *matplotlib.pyplot.imshow* is to plot a 2D statistical map. The function makes it easy to visualize a 2D matrix as an image and add transparency to the output. For example, one can plot a statistic (such as a t-statistic) and color the transparency of each pixel according to its p-value. This example demonstrates how you can achieve this effect.

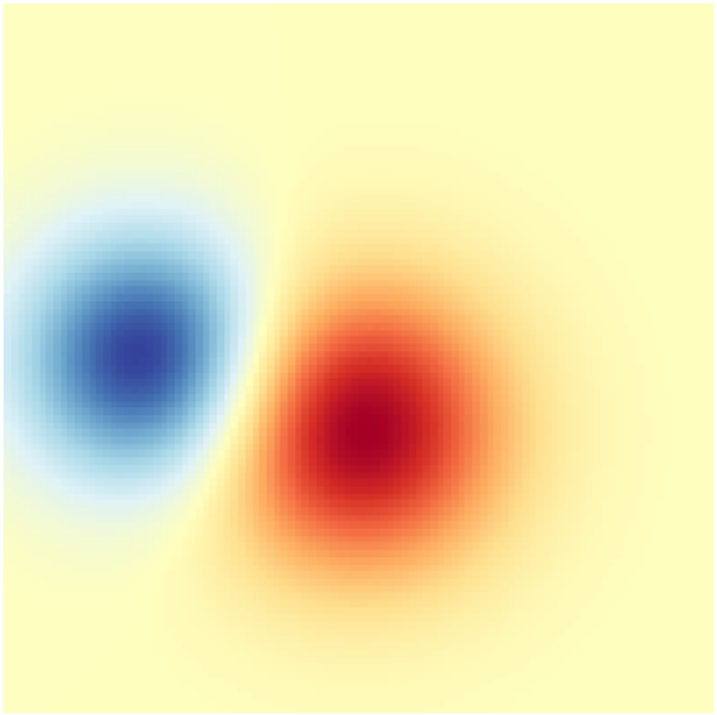
First we will generate some data, in this case, we'll create two 2D "blobs" in a 2D grid. One blob will be positive, and the other negative.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

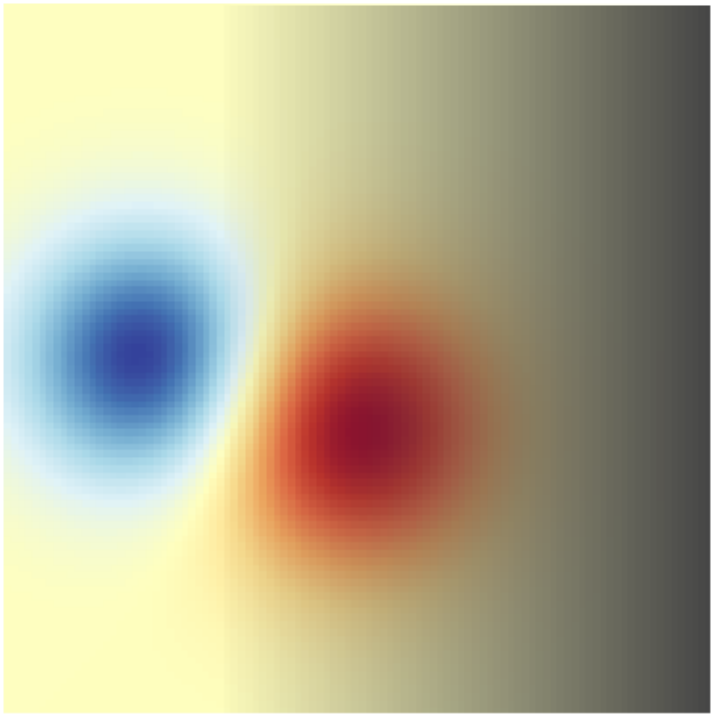
```
from matplotlib.colors import Normalize


def normal_pdf(x, mean, var):
    return np.exp(-(x - mean)**2 / (2*var))


# Generate the space in which the blobs will live
xmin, xmax, ymin, ymax = (0, 100, 0, 100)
n_bins = 100
xx = np.linspace(xmin, xmax, n_bins)
yy = np.linspace(ymin, ymax, n_bins)

# Generate the blobs. The range of the values is roughly -.0002 to .
 ↪0002
means_high = [20, 50]
means_low = [50, 60]
var = [150, 200]

gauss_x_high = normal_pdf(xx, means_high[0], var[0])
gauss_y_high = normal_pdf(yy, means_high[1], var[0])

gauss_x_low = normal_pdf(xx, means_low[0], var[1])
gauss_y_low = normal_pdf(yy, means_low[1], var[1])

weights = (np.outer(gauss_y_high, gauss_x_high)
           - np.outer(gauss_y_low, gauss_x_low))

# We'll also create a grey background into which the pixels will fade
greys = np.full((*weights.shape, 3), 70, dtype=np.uint8)

# First we'll plot these blobs using ``imshow`` without transparency.
vmax = np.abs(weights).max()
imshow_kwargs = {
    'vmax': vmax,
    'vmin': -vmax,
    'cmap': 'RdYlBu',
    'extent': (xmin, xmax, ymin, ymax),
}

fig, ax = plt.subplots()
ax.imshow(greys)
ax.imshow(weights, **imshow_kwargs)
ax.set_axis_off()
```



Blending in transparency

The simplest way to include transparency when plotting data with *matplotlib.pyplot.imshow* is to pass an array matching the shape of the data to the `alpha` argument. For example, we'll create a gradient moving from left to right below.

```
# Create an alpha channel of linearly increasing values moving to the␣
 ↪right.
alphas = np.ones(weights.shape)
alphas[:, 30:] = np.linspace(1, 0, 70)

# Create the figure and image
# Note that the absolute values may be slightly different
fig, ax = plt.subplots()
ax.imshow(greys)
ax.imshow(weights, alpha=alphas, **imshow_kwargs)
ax.set_axis_off()
```



Using transparency to highlight values with high amplitude

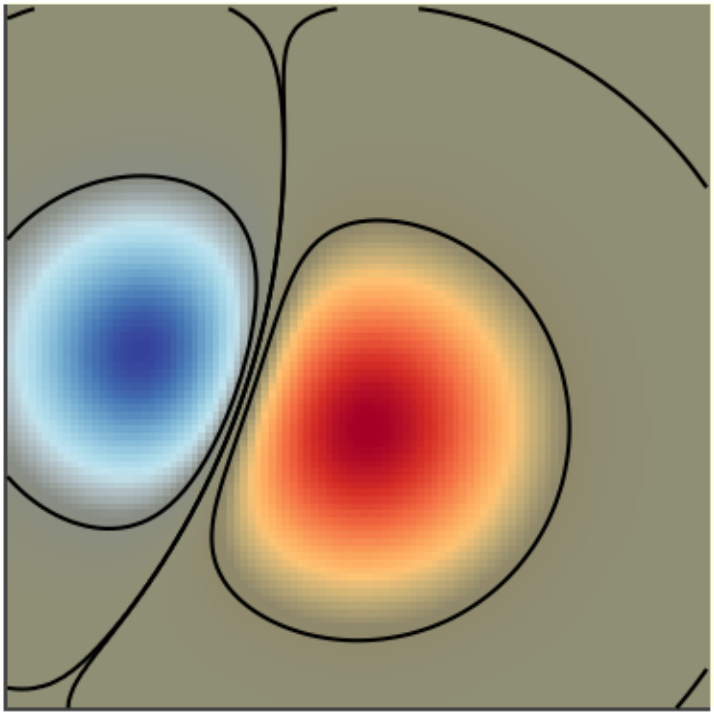
Finally, we'll recreate the same plot, but this time we'll use transparency to highlight the extreme values in the data. This is often used to highlight data points with smaller p-values. We'll also add in contour lines to highlight the image values.

```
# Create an alpha channel based on weight values
# Any value whose absolute value is > .0001 will have zero transparency
alphas = Normalize(0, .3, clip=True)(np.abs(weights))
alphas = np.clip(alphas, .4, 1)  # alpha value clipped at the bottom␣
↪at .4

# Create the figure and image
# Note that the absolute values may be slightly different
fig, ax = plt.subplots()
ax.imshow(greys)
ax.imshow(weights, alpha=alphas, **imshow_kwargs)

# Add contour lines to further highlight different levels.
ax.contour(weights[::-1], levels=[-.1, .1], colors='k', linestyles='-')
```

(continues on next page)

(continued from previous page)

```
ax.set_axis_off()
plt.show()

ax.contour(weights[::-1], levels=[-.0001, .0001], colors='k',␣
 ↪linestyles='-')
ax.set_axis_off()
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow / matplotlib.pyplot.imshow*
- *matplotlib.axes.Axes.contour / matplotlib.pyplot.contour*
- *matplotlib.colors.Normalize*
- *matplotlib.axes.Axes.set_axis_off*

Shading example

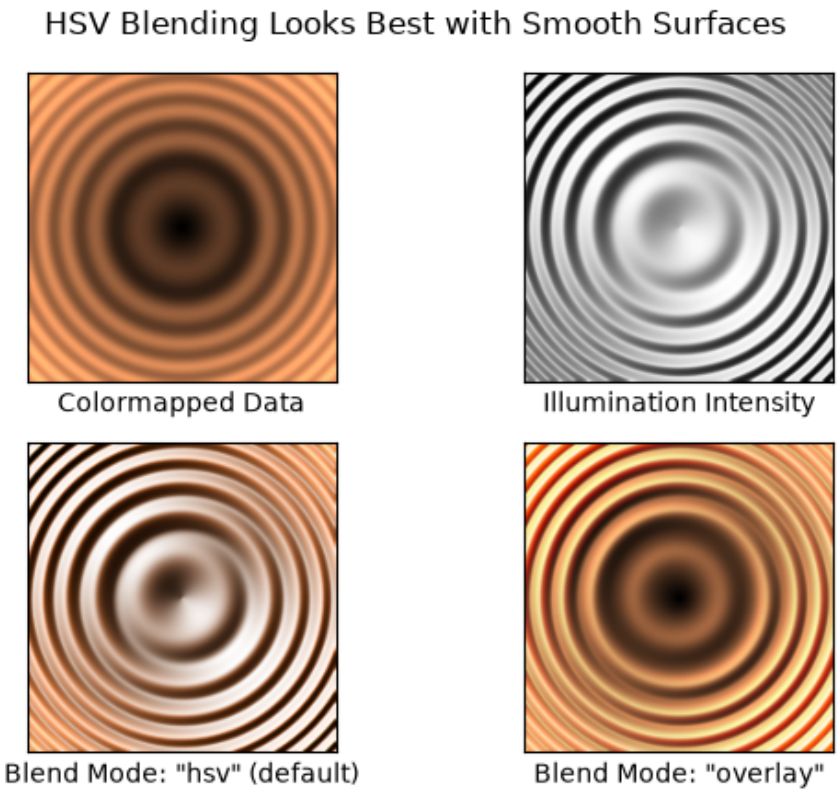
Example showing how to make shaded relief plots like Mathematica or Generic Mapping Tools.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import cbook
from matplotlib.colors import LightSource


def main():
    # Test data
    x, y = np.mgrid[-5:5:0.05, -5:5:0.05]
    z = 5 * (np.sqrt(x**2 + y**2) + np.sin(x**2 + y**2))

    dem = cbook.get_sample_data('jacksboro_fault_dem.npz')
    elev = dem['elevation']

    fig = compare(z, plt.colormaps["copper"])
    fig.suptitle('HSV Blending Looks Best with Smooth Surfaces',␣
 ↪y=0.95)

    fig = compare(elev, plt.colormaps["gist_earth"], ve=0.05)
    fig.suptitle('Overlay Blending Looks Best with Rough Surfaces',␣
 ↪y=0.95)

    plt.show()


def compare(z, cmap, ve=1):
    # Create subplots and hide ticks
    fig, axs = plt.subplots(ncols=2, nrows=2)
    for ax in axs.flat:
        ax.set(xticks=[], yticks=[])
```

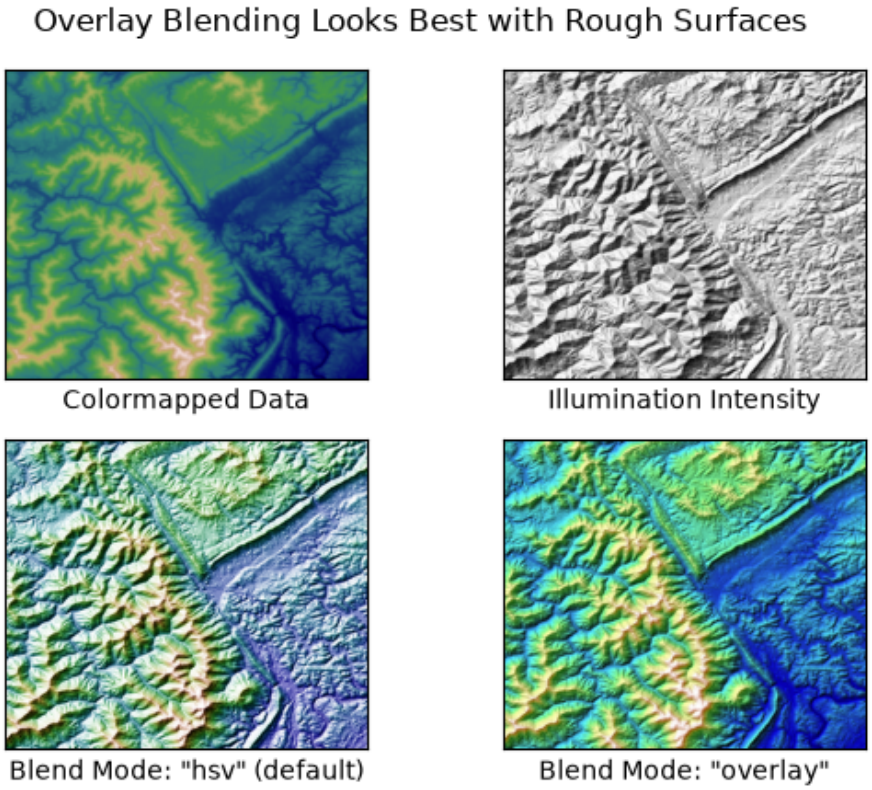
(continues on next page)

(continued from previous page)

```
    # Illuminate the scene from the northwest
    ls = LightSource(azdeg=315, altdeg=45)

    axs[0, 0].imshow(z, cmap=cmap)
    axs[0, 0].set(xlabel='Colormapped Data')

    axs[0, 1].imshow(ls.hillshade(z, vert_exag=ve), cmap='gray')
    axs[0, 1].set(xlabel='Illumination Intensity')

    rgb = ls.shade(z, cmap=cmap, vert_exag=ve, blend_mode='hsv')
    axs[1, 0].imshow(rgb)
    axs[1, 0].set(xlabel='Blend Mode: "hsv" (default)')

    rgb = ls.shade(z, cmap=cmap, vert_exag=ve, blend_mode='overlay')
    axs[1, 1].imshow(rgb)
    axs[1, 1].set(xlabel='Blend Mode: "overlay"')

    return fig


if __name__ == '__main__':
    main()
```


HSV Blending Looks Best with Smooth Surfaces
Colormapped Data
Illumination Intensity
Blend Mode: "hsv" (default)
Blend Mode: "overlay"

-



-

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.colors.LightSource*
- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*

Total running time of the script: (0 minutes 1.194 seconds)

Clipping images with patches

Demo of image that's been clipped by a circular patch.

```
from PIL import Image

import matplotlib.pyplot as plt

import matplotlib.cbook as cbook
import matplotlib.patches as patches

image = Image.open(cbook.get_sample_data("grace_hopper.jpg"))
```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots()
im = ax.imshow(image)
patch = patches.Circle((260, 200), radius=200, transform=ax.transData)
im.set_clip_path(patch)

ax.axis('off')
plt.show()
```

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow / matplotlib.pyplot.imshow*
- *matplotlib.artist.Artist.set_clip_path*

Placing images, preserving relative sizes

By default Matplotlib resamples images created with *imshow* to fit inside the parent *Axes*. This can mean that images that have very different original sizes can end up appearing similar in size.

This example shows how to keep the images the same relative size, or how to make the images keep exactly the same pixels as the original data.

Preserving relative sizes

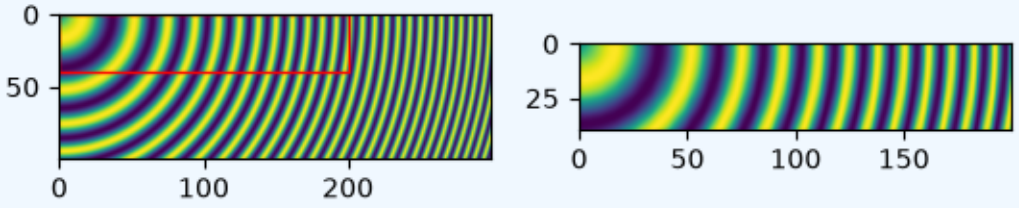
By default the two images are made a similar size, despite one being 1.5 times the width of the other:

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.patches as mpatches

# make the data:
N = 450
x = np.arange(N) / N
y = np.arange(N) / N

X, Y = np.meshgrid(x, y)
R = np.sqrt(X**2 + Y**2)
f0 = 5
k = 100
a = np.sin(np.pi * 2 * (f0 * R + k * R**2 / 2))
A = a[:100, :300]
B = A[:40, :200]

# default layout: both axes have the same size
fig, axs = plt.subplots(1, 2, facecolor='aliceblue')

axs[0].imshow(A, vmin=-1, vmax=1)
axs[1].imshow(B, vmin=-1, vmax=1)


def annotate_rect(ax):
    # add a rectangle that is the size of the B matrix
    rect = mpatches.Rectangle((0, 0), 200, 40, linewidth=1,
```

(continues on next page)

(continued from previous page)

```
                                edgecolor='r', facecolor='none')
    ax.add_patch(rect)
    return rect

annotate_rect(axs[0])
```



Note that both images have an aspect ratio of 1 (i.e. pixels are square), but pixels sizes differ because the images are scaled to the same width.

If the size of the images are amenable, we can preserve the relative sizes of two images by using either the *width_ratio* or *height_ratio* of the subplots. Which one you use depends on the shape of the image and the size of the figure. We can control the relative sizes using the *width_ratios* argument *if* the images are wider than they are tall and shown side by side, as is the case here.

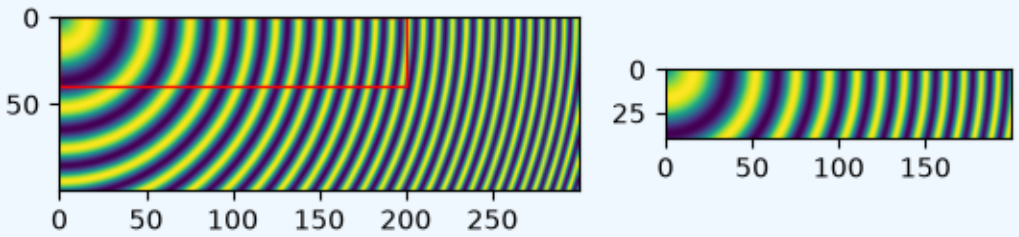
While we are making changes, let us also make the aspect ratio of the figure closer to the aspect ratio of the axes using *figsize* so that the figure does not have so much white space. Note that you could alternatively trim extra blank space when saving a figure by passing `bbox_inches="tight"` to *savefig*.

```
fig, axs = plt.subplots(1, 2, width_ratios=[300/200, 1],
                        figsize=(6.4, 2), facecolor='aliceblue')
```

(continues on next page)

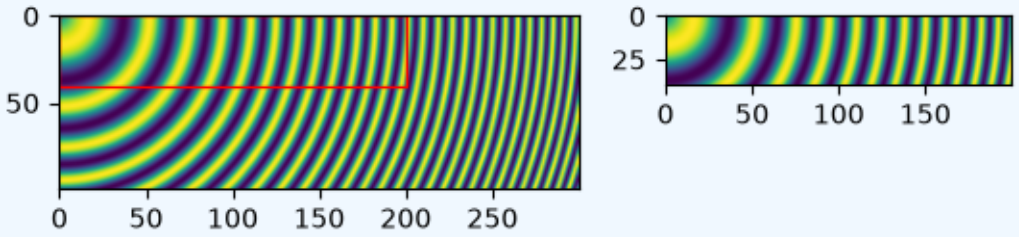
(continued from previous page)

```
axs[0].imshow(A, vmin=-1, vmax=1)
annotate_rect(axs[0])

axs[1].imshow(B, vmin=-1, vmax=1)
```



Given that the data subsample is in the upper left of the larger image, it might make sense if the top of the smaller Axes aligned with the top of the larger. This can be done manually by using *set_anchor*, and using "NW" (for northwest).

```
fig, axs = plt.subplots(1, 2, width_ratios=[300/200, 1],
                        figsize=(6.4, 2), facecolor='aliceblue')

axs[0].imshow(A, vmin=-1, vmax=1)
annotate_rect(axs[0])

axs[0].set_anchor('NW')
axs[1].imshow(B, vmin=-1, vmax=1)
axs[1].set_anchor('NW')
```



Explicit placement

The above approach with adjusting `figsize` and `width_ratios` does not generalize well, because it needs manual parameter tuning, and possibly even code changes to using `height_ratios` instead of `width_ratios` depending on the aspects and layout of the images.

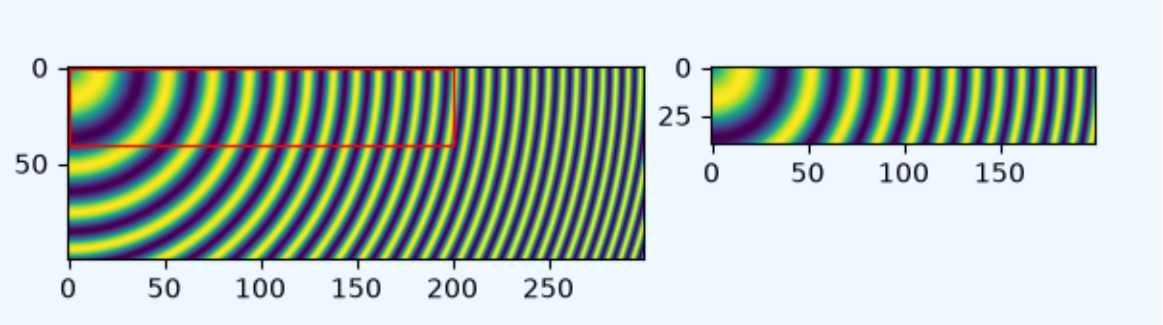
We can alternative calculate positions explicitly and place Axes at absolute coordinates using *`add_axes`*. This takes the position in the form `[left bottom width height]` and is in *figure coordinates*. In the following, we determine figure size and Axes positions so that one image data point is rendered exactly to one figure pixel.

```
dpi = 100  # 100 pixels is one inch

# All variables from here are in pixels:
buffer = 0.35 * dpi  # pixels

# Get the position of A axes
left = buffer
bottom = buffer
ny, nx = np.shape(A)
posA = [left, bottom, nx, ny]
# we know this is tallest, so we can already get the fig height (in␣
 ↪pixels)
fig_height = bottom + ny + buffer

# place the B axes to the right of the A axes
left = left + nx + buffer

ny, nx = np.shape(B)
# align the bottom so that the top lines up with the top of the A axes:
bottom = fig_height - buffer - ny
posB = [left, bottom, nx, ny]

# now we can get the fig width (in pixels)
fig_width = left + nx + buffer

# figsize must be in inches:
fig = plt.figure(figsize=(fig_width / dpi, fig_height / dpi),␣
 ↪facecolor='aliceblue')

# the position posA must be normalized by the figure width and height:
ax = fig.add_axes((posA[0] / fig_width, posA[1] / fig_height,
                   posA[2] / fig_width, posA[3] / fig_height))
ax.imshow(A, vmin=-1, vmax=1)
annotate_rect(ax)

ax = fig.add_axes((posB[0] / fig_width, posB[1] / fig_height,
                   posB[2] / fig_width, posB[3] / fig_height))
```

(continues on next page)

(continued from previous page)

```
ax.imshow(B, vmin=-1, vmax=1)
plt.show()
```



Inspection of the image will show that it is exactly 3* 35 + 300 + 200 = 605 pixels wide, and 2 * 35 + 100 = 170 pixels high (or twice that if the 2x version is used by the browser instead). The images should be rendered with exactly 1 pixel per data point (or four, if 2x).

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow*
- *matplotlib.figure.Figure.add_axes*

Tags: component: figure component: axes styling: position plot-type: image

pcolor images

pcolor generates 2D image-style plots, as illustrated below.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.colors import LogNorm

# Fixing random state for reproducibility
np.random.seed(19680801)
```

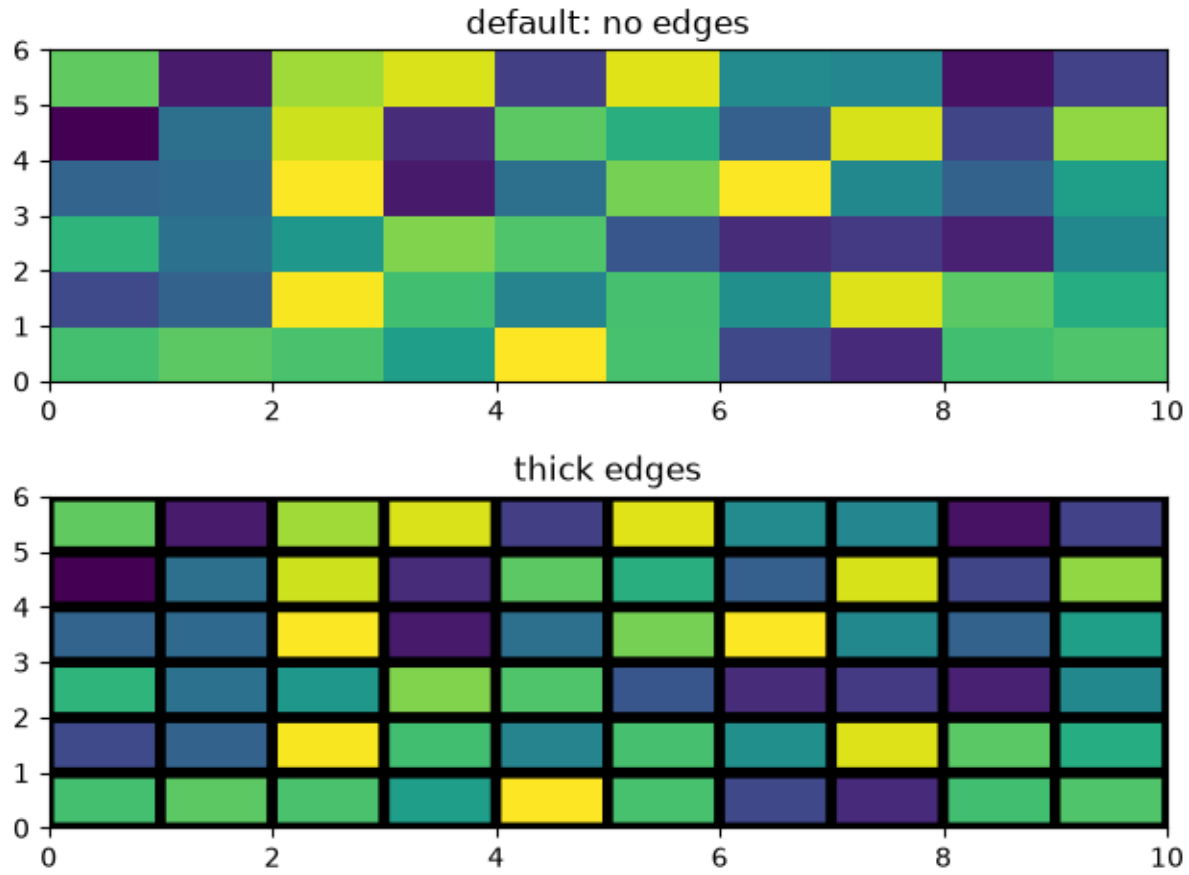
A simple pcolor demo

```
Z = np.random.rand(6, 10)

fig, (ax0, ax1) = plt.subplots(2, 1)

c = ax0.pcolor(Z)
```

(continues on next page)

(continued from previous page)

```
ax0.set_title('default: no edges')

c = ax1.pcolor(Z, edgecolors='k', linewidths=4)
ax1.set_title('thick edges')

fig.tight_layout()
plt.show()
```



Comparing pcolor with similar functions

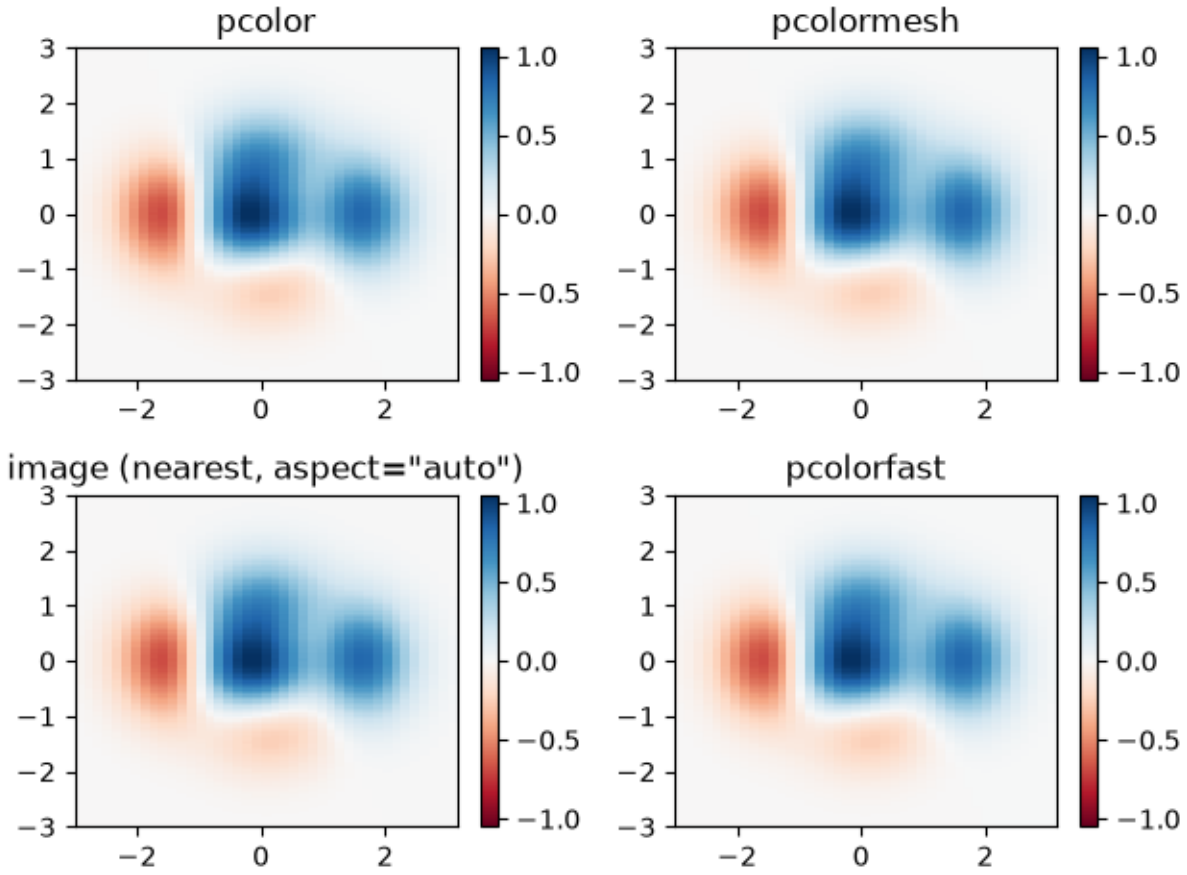
Demonstrates similarities between *pcolor*, *pcolormesh*, *imshow* and *pcolorfast* for drawing quadrilateral grids. Note that we call `imshow` with `aspect="auto"` so that it doesn't force the data pixels to be square (the default is `aspect="equal"`).

```
# make these smaller to increase the resolution
dx, dy = 0.15, 0.05

# generate 2 2d grids for the x & y bounds
y, x = np.mgrid[-3:3+dy:dy, -3:3+dx:dx]
```

(continues on next page)

(continued from previous page)

```
z = (1 - x/2 + x**5 + y**3) * np.exp(-x**2 - y**2)
# x and y are bounds, so z should be the value *inside* those bounds.
# Therefore, remove the last value from the z array.
z = z[:-1, :-1]
z_min, z_max = -abs(z).max(), abs(z).max()

fig, axs = plt.subplots(2, 2)

ax = axs[0, 0]
c = ax.pcolor(x, y, z, cmap='RdBu', vmin=z_min, vmax=z_max)
ax.set_title('pcolor')
fig.colorbar(c, ax=ax)

ax = axs[0, 1]
c = ax.pcolormesh(x, y, z, cmap='RdBu', vmin=z_min, vmax=z_max)
ax.set_title('pcolormesh')
fig.colorbar(c, ax=ax)

ax = axs[1, 0]
c = ax.imshow(z, cmap='RdBu', vmin=z_min, vmax=z_max,
              extent=[x.min(), x.max(), y.min(), y.max()],
              interpolation='nearest', origin='lower', aspect='auto')
ax.set_title('image (nearest, aspect="auto")')
fig.colorbar(c, ax=ax)

ax = axs[1, 1]
c = ax.pcolorfast(x, y, z, cmap='RdBu', vmin=z_min, vmax=z_max)
ax.set_title('pcolorfast')
fig.colorbar(c, ax=ax)

fig.tight_layout()
plt.show()
```



Pcolor with a log scale

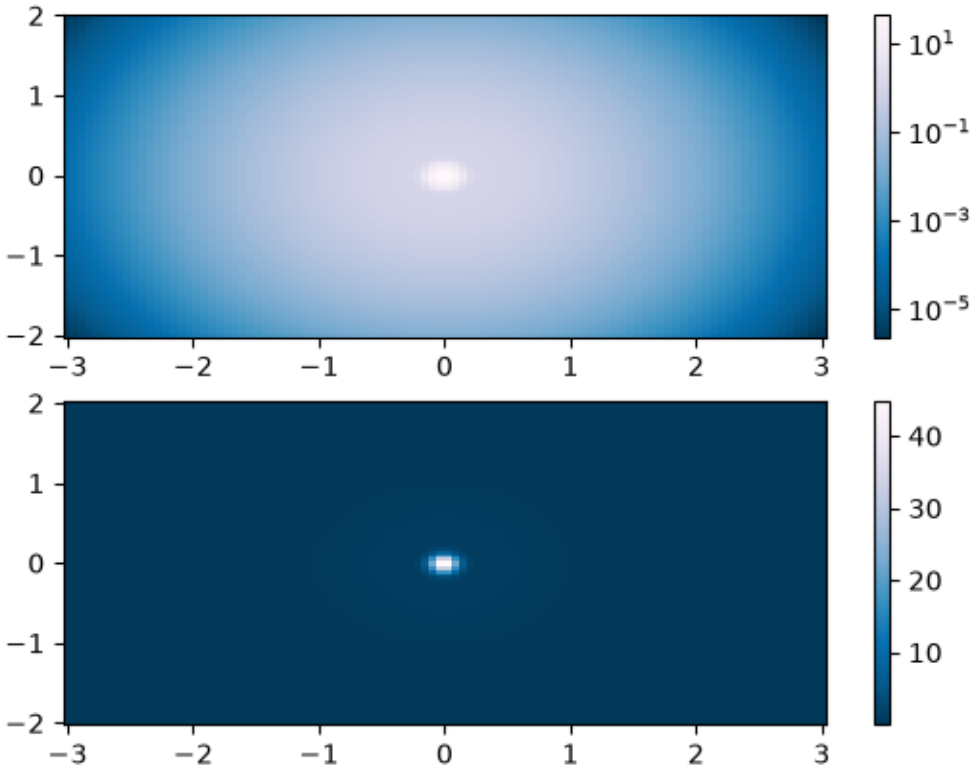
The following shows pcolor plots with a log scale.

```
N = 100
X, Y = np.meshgrid(np.linspace(-3, 3, N), np.linspace(-2, 2, N))

# A low hump with a spike coming out.
# Needs to have z/colour axis on a log scale, so we see both hump and␣
 ↪spike.
# A linear scale only shows the spike.
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X * 10)**2 - (Y * 10)**2)
Z = Z1 + 50 * Z2

fig, (ax0, ax1) = plt.subplots(2, 1)

c = ax0.pcolor(X, Y, Z, shading='auto',
               norm=LogNorm(vmin=Z.min(), vmax=Z.max()), cmap='PuBu_r')
fig.colorbar(c, ax=ax0)
```

(continues on next page)

(continued from previous page)

```
c = ax1.pcolor(X, Y, Z, cmap='PuBu_r', shading='auto')
fig.colorbar(c, ax=ax1)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.pcolor* / *matplotlib.pyplot.pcolor*
- *matplotlib.axes.Axes.pcolormesh* / *matplotlib.pyplot.pcolormesh*
- *matplotlib.axes.Axes.pcolorfast*
- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.colors.LogNorm*

Total running time of the script: (0 minutes 1.954 seconds)

pcolormesh

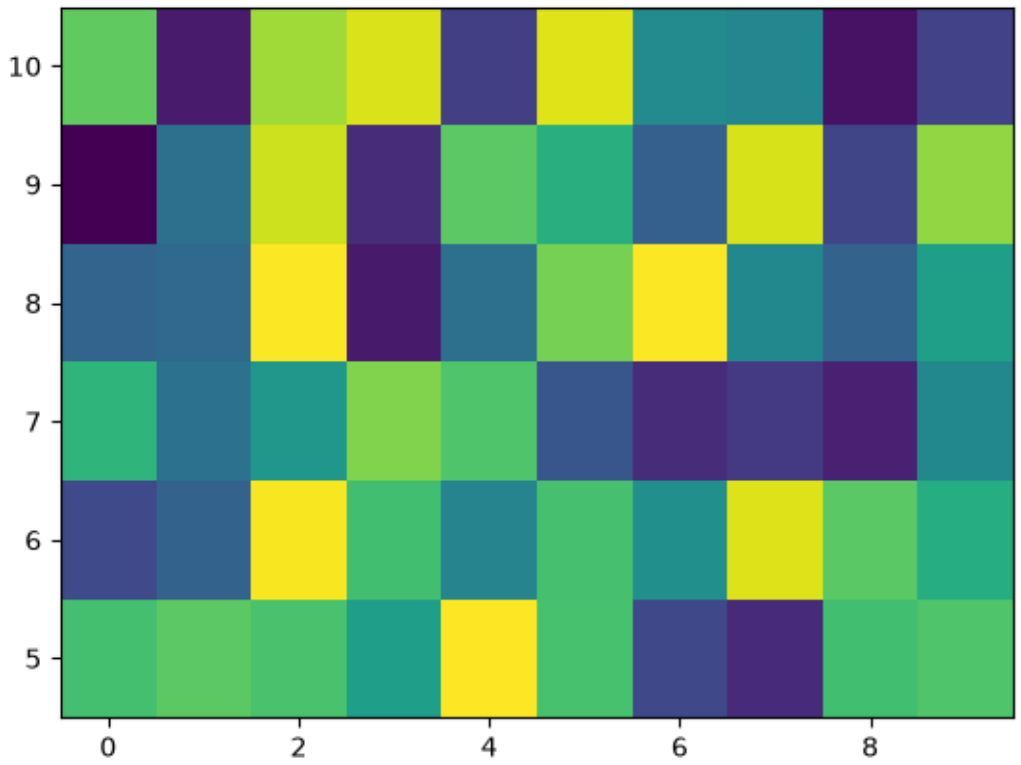
axes.Axes.pcolormesh allows you to generate 2D image-style plots. Note that it is faster than the similar *pcolor*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.colors import BoundaryNorm
from matplotlib.ticker import MaxNLocator
```

Basic pcolormesh

We usually specify a pcolormesh by defining the edge of quadrilaterals and the value of the quadrilateral. Note that here *x* and *y* each have one extra element than Z in the respective dimension.

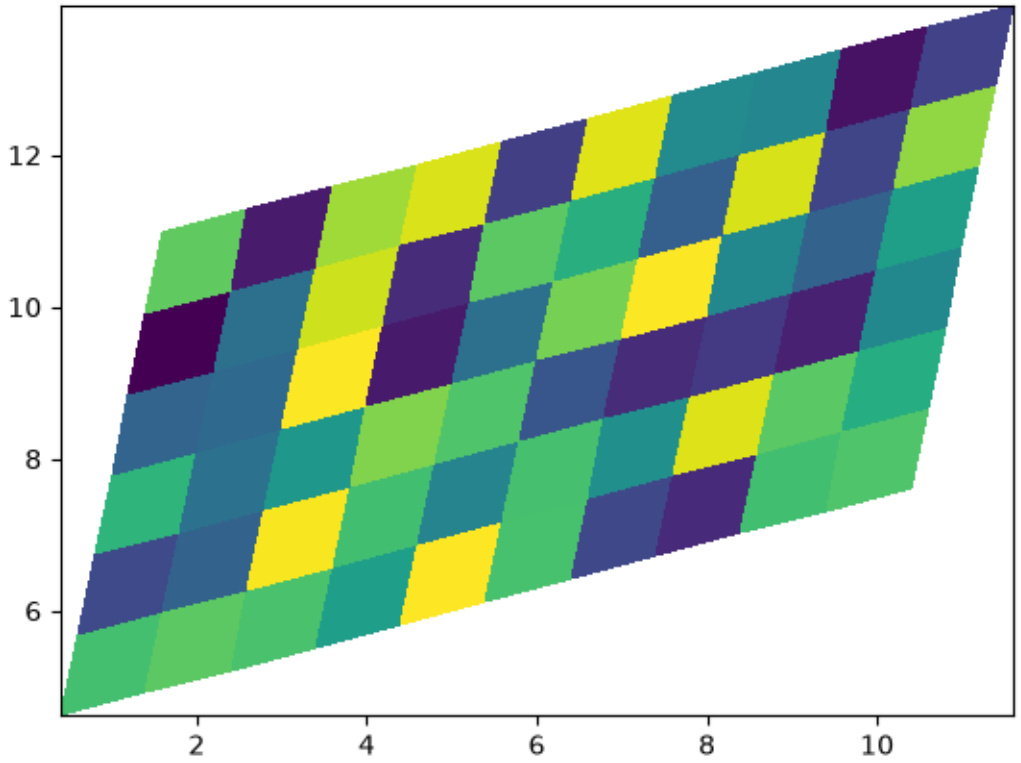
```
np.random.seed(19680801)
Z = np.random.rand(6, 10)
x = np.arange(-0.5, 10, 1)  # len = 11
y = np.arange(4.5, 11, 1)  # len = 7

fig, ax = plt.subplots()
ax.pcolormesh(x, y, Z)
```



Non-rectilinear pcolormesh

Note that we can also specify matrices for X and Y and have non-rectilinear quadrilaterals.

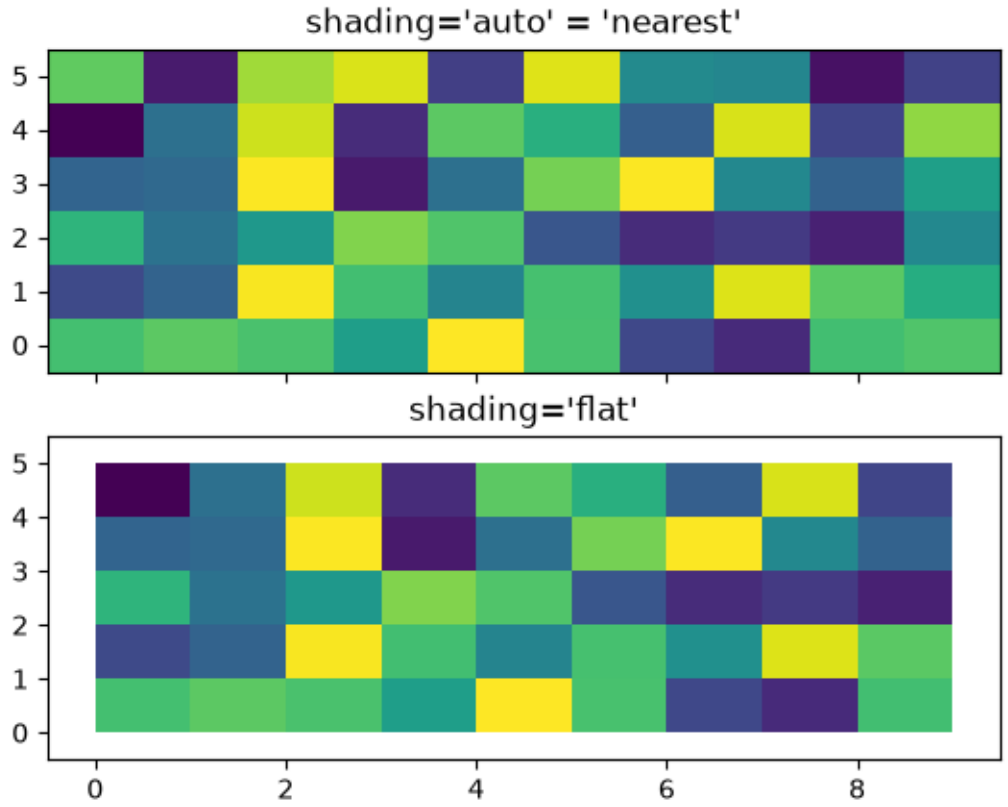
```
x = np.arange(-0.5, 10, 1)  # len = 11
y = np.arange(4.5, 11, 1)  # len = 7
X, Y = np.meshgrid(x, y)
X = X + 0.2 * Y  # tilt the coordinates.
Y = Y + 0.3 * X

fig, ax = plt.subplots()
ax.pcolormesh(X, Y, Z)
```



Centered Coordinates

Often a user wants to pass *X* and *Y* with the same sizes as *Z* to *axes.Axes.pcolormesh*. This is also allowed if `shading='auto'` is passed (default set by *rcParams["pcolor.shading"]* (default: `'auto'`)). Pre Matplotlib 3.3, `shading='flat'` would drop the last column and row of *Z*, but now gives an error. If this is really what you want, then simply drop the last row and column of Z manually:

```
x = np.arange(10)  # len = 10
y = np.arange(6)  # len = 6
X, Y = np.meshgrid(x, y)

fig, axs = plt.subplots(2, 1, sharex=True, sharey=True)
axs[0].pcolormesh(X, Y, Z, vmin=np.min(Z), vmax=np.max(Z), shading=
 ↪'auto')
axs[0].set_title("shading='auto' = 'nearest'")
axs[1].pcolormesh(X, Y, Z[:-1, :-1], vmin=np.min(Z), vmax=np.max(Z),
                  shading='flat')
axs[1].set_title("shading='flat'")
```



Making levels using Norms

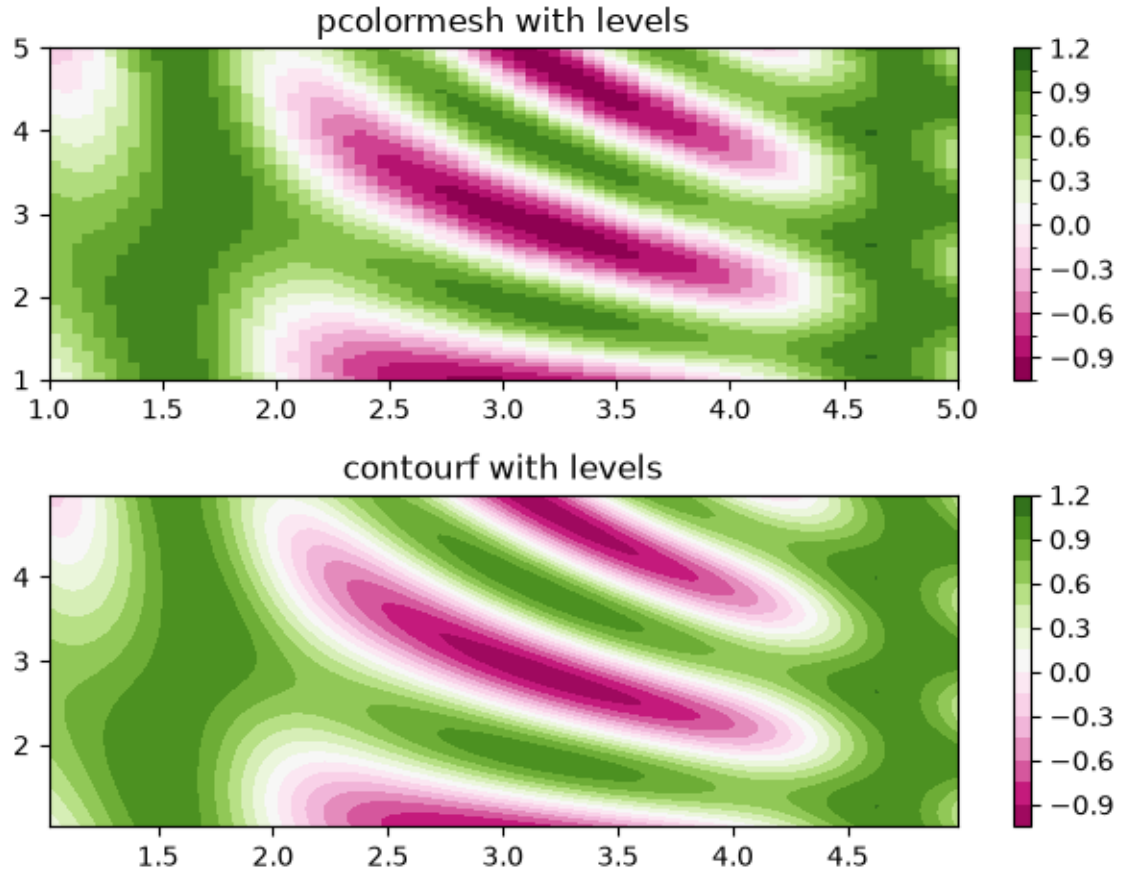
Shows how to combine Normalization and Colormap instances to draw "levels" in *axes.Axes.pcolor*, *axes.Axes.pcolormesh* and *axes.Axes.imshow* type plots in a similar way to the levels keyword argument to contour/contourf.

```
# make these smaller to increase the resolution
dx, dy = 0.05, 0.05

# generate 2 2d grids for the x & y bounds
y, x = np.mgrid[slice(1, 5 + dy, dy),
                slice(1, 5 + dx, dx)]

z = np.sin(x)**10 + np.cos(10 + y*x) * np.cos(x)

# x and y are bounds, so z should be the value *inside* those bounds.
# Therefore, remove the last value from the z array.
z = z[:-1, :-1]
levels = MaxNLocator(nbins=15).tick_values(z.min(), z.max())
```

(continues on next page)

(continued from previous page)

```
# pick the desired colormap, sensible levels, and define a␣
 ↪normalization
# instance which takes data values and translates those into levels.
cmap = plt.colormaps['PiYG']
norm = BoundaryNorm(levels, ncolors=cmap.N, clip=True)

fig, (ax0, ax1) = plt.subplots(nrows=2)

im = ax0.pcolormesh(x, y, z, cmap=cmap, norm=norm)
fig.colorbar(im, ax=ax0)
ax0.set_title('pcolormesh with levels')


# contours are *point* based plots, so convert our bound into point
# centers
cf = ax1.contourf(x[:-1, :-1] + dx/2.,
                  y[:-1, :-1] + dy/2., z, levels=levels,
                  cmap=cmap)
fig.colorbar(cf, ax=ax1)
ax1.set_title('contourf with levels')

# adjust spacing between subplots so `ax1` title and `ax0` tick labels
# don't overlap
fig.tight_layout()

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.pcolormesh* / *matplotlib.pyplot.pcolormesh*
- *matplotlib.axes.Axes.contourf* / *matplotlib.pyplot.contourf*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.colors.BoundaryNorm*
- *matplotlib.ticker.MaxNLocator*

Total running time of the script: (0 minutes 1.356 seconds)

pcolormesh grids and shading

axes.Axes.pcolormesh and *pcolor* have a few options for how grids are laid out and the shading between the grid points.

Generally, if *Z* has shape *(M, N)* then the grid *X* and *Y* can be specified with either shape *(M+1, N+1)* or *(M, N)*, depending on the argument for the `shading` keyword argument. Note that below we specify vectors *x*

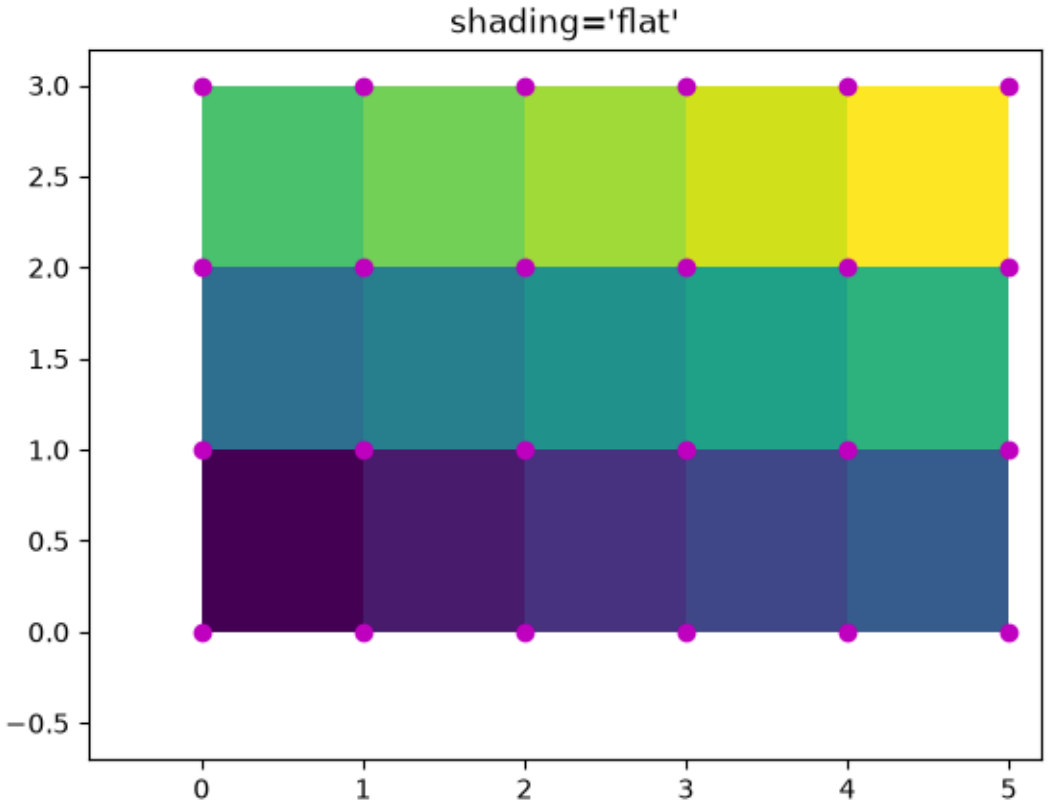
as either length N or N+1 and *y* as length M or M+1, and `pcolormesh` internally makes the mesh matrices *X* and *Y* from the input vectors.

```
import matplotlib.pyplot as plt
import numpy as np
```

Flat Shading

The grid specification with the least assumptions is `shading='flat'` and if the grid is one larger than the data in each dimension, i.e. has shape *(M+1, N+1)*. In that case *X* and *Y* specify the corners of quadrilaterals that are colored with the values in *Z*. Here we specify the edges of the *(3, 5)* quadrilaterals with *X* and *Y* that are *(4, 6)*.

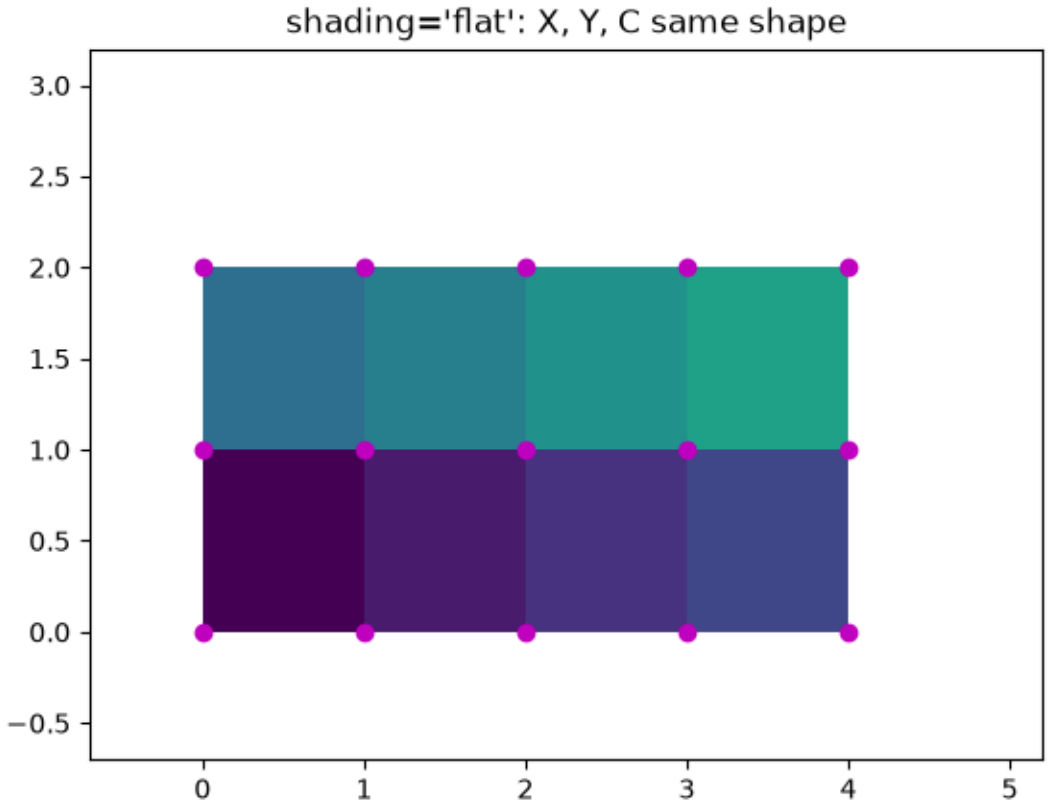
```
nrows = 3
ncols = 5
Z = np.arange(nrows * ncols).reshape(nrows, ncols)
x = np.arange(ncols + 1)
y = np.arange(nrows + 1)

fig, ax = plt.subplots()
ax.pcolormesh(x, y, Z, shading='flat', vmin=Z.min(), vmax=Z.max())


def _annotate(ax, x, y, title):
    # this all gets repeated below:
    X, Y = np.meshgrid(x, y)
    ax.plot(X.flat, Y.flat, 'o', color='m')
    ax.set_xlim(-0.7, 5.2)
    ax.set_ylim(-0.7, 3.2)
    ax.set_title(title)

_annotate(ax, x, y, "shading='flat'")
```



Flat Shading, same shape grid

Often, however, data is provided where X and Y match the shape of Z. While this makes sense for other `shading` types, it is not permitted when `shading='flat'`. Historically, Matplotlib silently dropped the last row and column of Z in this case, to match Matlab's behavior. If this behavior is still desired, simply drop the last row and column manually:

```
x = np.arange(ncols)  # note *not* ncols + 1 as before
y = np.arange(nrows)
fig, ax = plt.subplots()
ax.pcolormesh(x, y, Z[:-1, :-1], shading='flat', vmin=Z.min(), vmax=Z.
 ↪max())
_annotate(ax, x, y, "shading='flat': X, Y, C same shape")
```

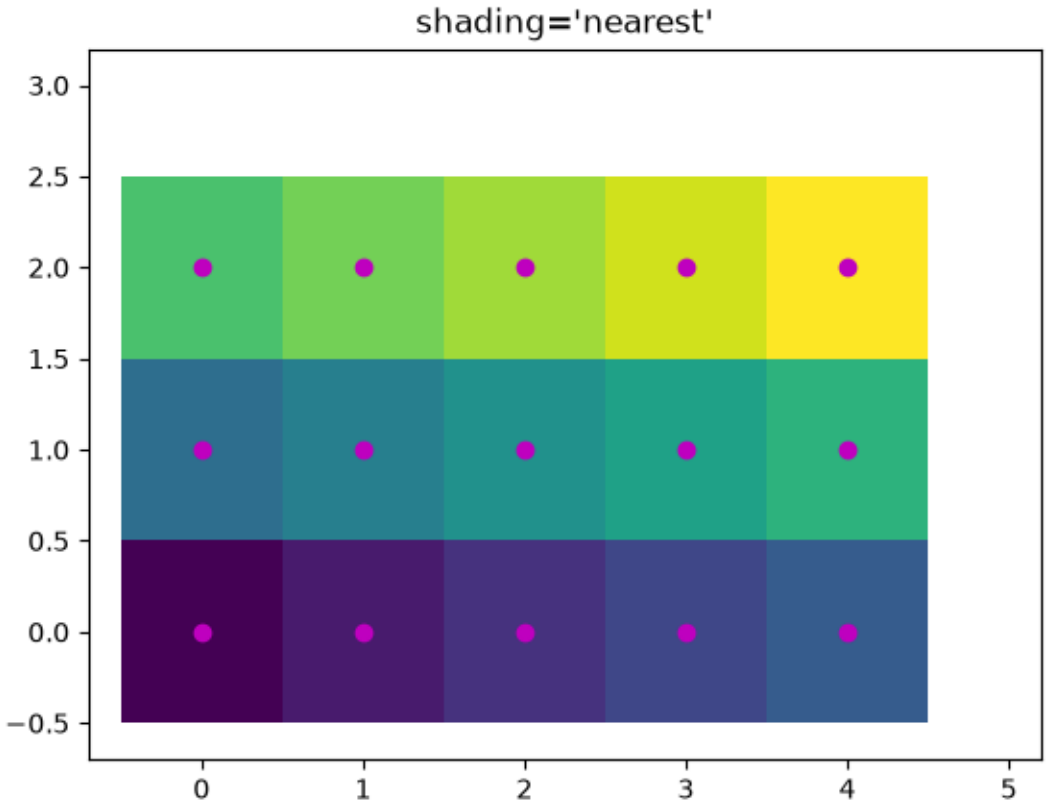


Nearest Shading, same shape grid

Usually, dropping a row and column of data is not what the user means when they make *X*, *Y* and *Z* all the same shape. For this case, Matplotlib allows `shading='nearest'` and centers the colored quadrilaterals on the grid points.

If a grid that is not the correct shape is passed with `shading='nearest'` an error is raised.

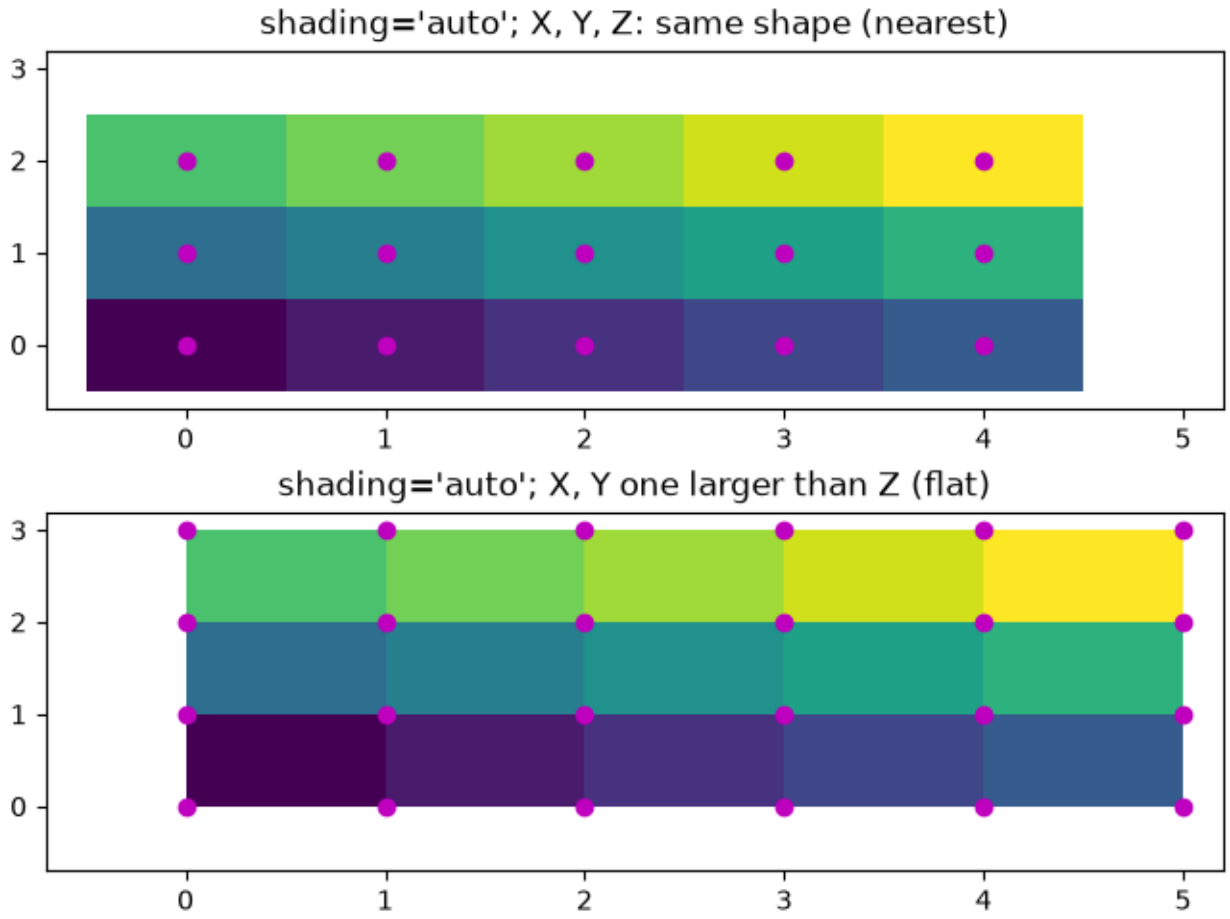
```
fig, ax = plt.subplots()
ax.pcolormesh(x, y, Z, shading='nearest', vmin=Z.min(), vmax=Z.max())
_annotate(ax, x, y, "shading='nearest'")
```



Auto Shading

It's possible that the user would like the code to automatically choose which to use, in this case `shading='auto'` will decide whether to use 'flat' or 'nearest' shading based on the shapes of *X*, *Y* and *Z*.

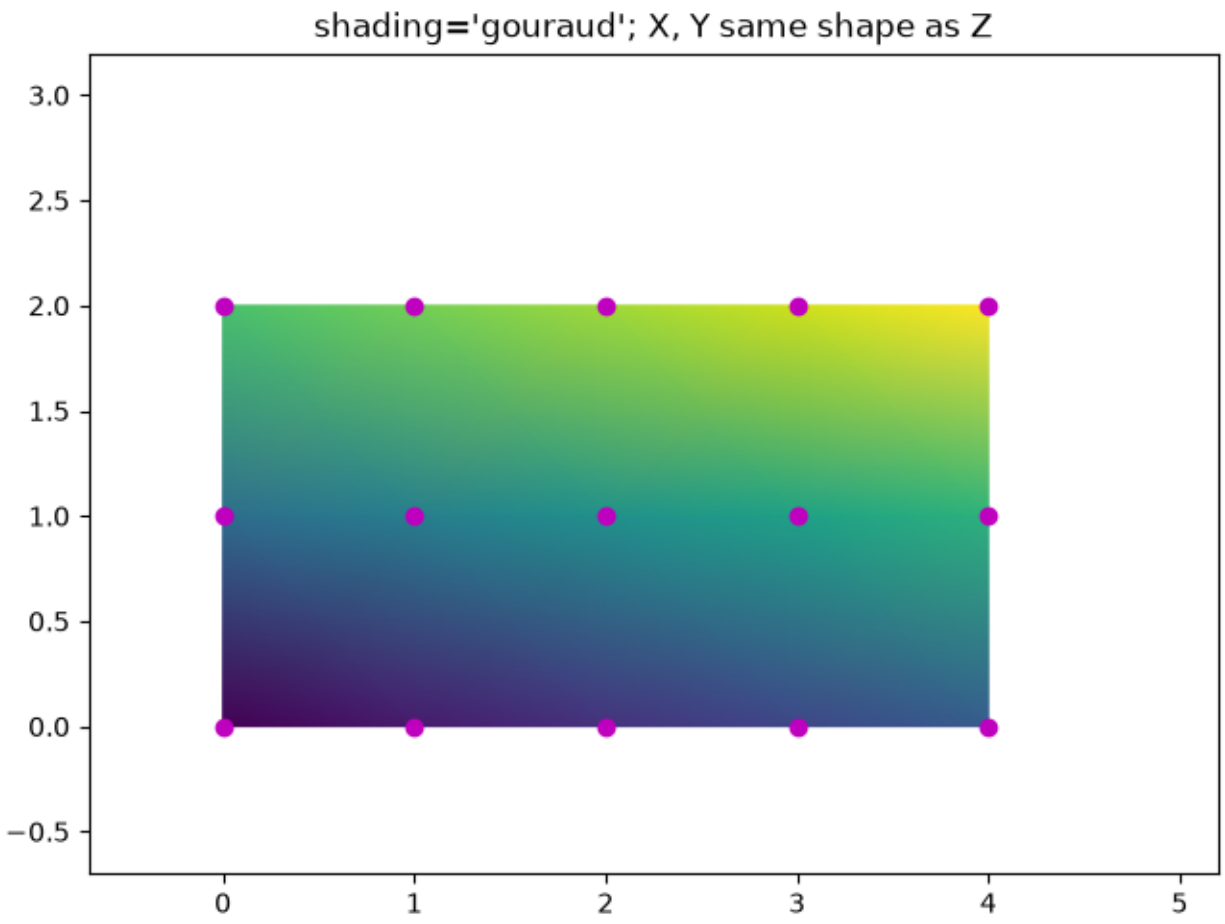
```
fig, axs = plt.subplots(2, 1, layout='constrained')
ax = axs[0]
x = np.arange(ncols)
y = np.arange(nrows)
ax.pcolormesh(x, y, Z, shading='auto', vmin=Z.min(), vmax=Z.max())
_annotate(ax, x, y, "shading='auto'; X, Y, Z: same shape (nearest)")

ax = axs[1]
x = np.arange(ncols + 1)
y = np.arange(nrows + 1)
ax.pcolormesh(x, y, Z, shading='auto', vmin=Z.min(), vmax=Z.max())
_annotate(ax, x, y, "shading='auto'; X, Y one larger than Z (flat)")
```



Gouraud Shading

Gouraud shading can also be specified, where the color in the quadrilaterals is linearly interpolated between the grid points. The shapes of X, Y, Z must be the same.

```
fig, ax = plt.subplots(layout='constrained')
x = np.arange(ncols)
y = np.arange(nrows)
ax.pcolormesh(x, y, Z, shading='gouraud', vmin=Z.min(), vmax=Z.max())
_annotate(ax, x, y, "shading='gouraud'; X, Y same shape as Z")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

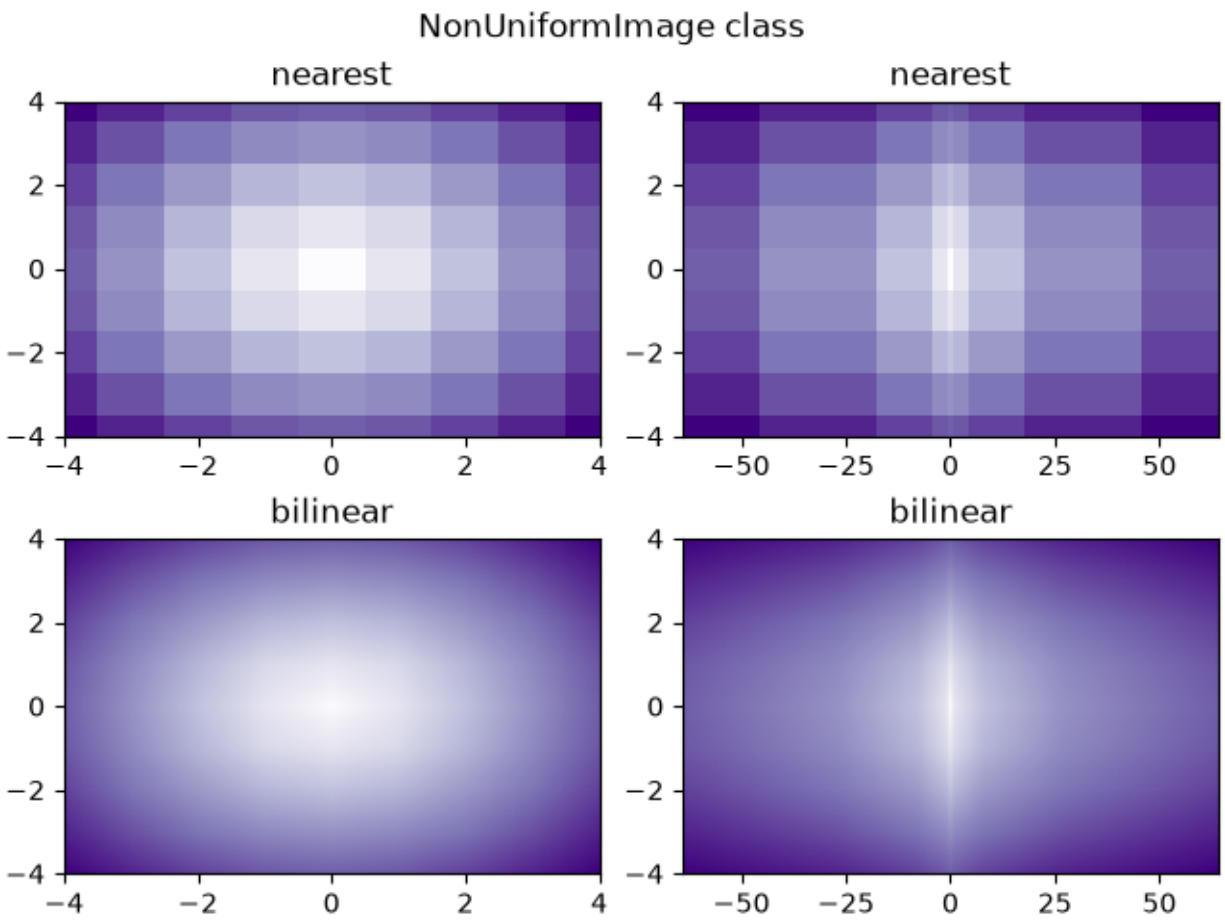
- *matplotlib.axes.Axes.pcolormesh* / *matplotlib.pyplot.pcolormesh*

Total running time of the script: (0 minutes 1.732 seconds)

Image nonuniform

NonUniformImage is a generalized image with pixels on a rectilinear grid, i.e. it allows rows and columns with individual heights / widths.

There is no high-level plotting method on *Axes* or *pyplot* to create a NonUniformImage. Instead, you have to instantiate the image explicitly add it to the Axes using *Axes.add_image*.




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.image import NonUniformImage

interp = 'nearest'

# Linear x array for cell centers:
x = np.linspace(-4, 4, 9)

# Highly nonlinear x array:
x2 = x**3

y = np.linspace(-4, 4, 9)

z = np.sqrt(x[np.newaxis, :]**2 + y[:, np.newaxis]**2)

fig, axs = plt.subplots(nrows=2, ncols=2, layout='constrained')
fig.suptitle('NonUniformImage class', fontsize='large')
ax = axs[0, 0]
```

(continues on next page)

(continued from previous page)

```
im = NonUniformImage(ax, interpolation=interp, extent=(-4, 4, -4, 4),
                     cmap="Purples")
im.set_data(x, y, z)
ax.add_image(im)
ax.set_xlim(-4, 4)
ax.set_ylim(-4, 4)
ax.set_title(interp)

ax = axs[0, 1]
im = NonUniformImage(ax, interpolation=interp, extent=(-64, 64, -4, 4),
                     cmap="Purples")
im.set_data(x2, y, z)
ax.add_image(im)
ax.set_xlim(-64, 64)
ax.set_ylim(-4, 4)
ax.set_title(interp)

interp = 'bilinear'

ax = axs[1, 0]
im = NonUniformImage(ax, interpolation=interp, extent=(-4, 4, -4, 4),
                     cmap="Purples")
im.set_data(x, y, z)
ax.add_image(im)
ax.set_xlim(-4, 4)
ax.set_ylim(-4, 4)
ax.set_title(interp)

ax = axs[1, 1]
im = NonUniformImage(ax, interpolation=interp, extent=(-64, 64, -4, 4),
                     cmap="Purples")
im.set_data(x2, y, z)
ax.add_image(im)
ax.set_xlim(-64, 64)
ax.set_ylim(-4, 4)
ax.set_title(interp)

plt.show()
```

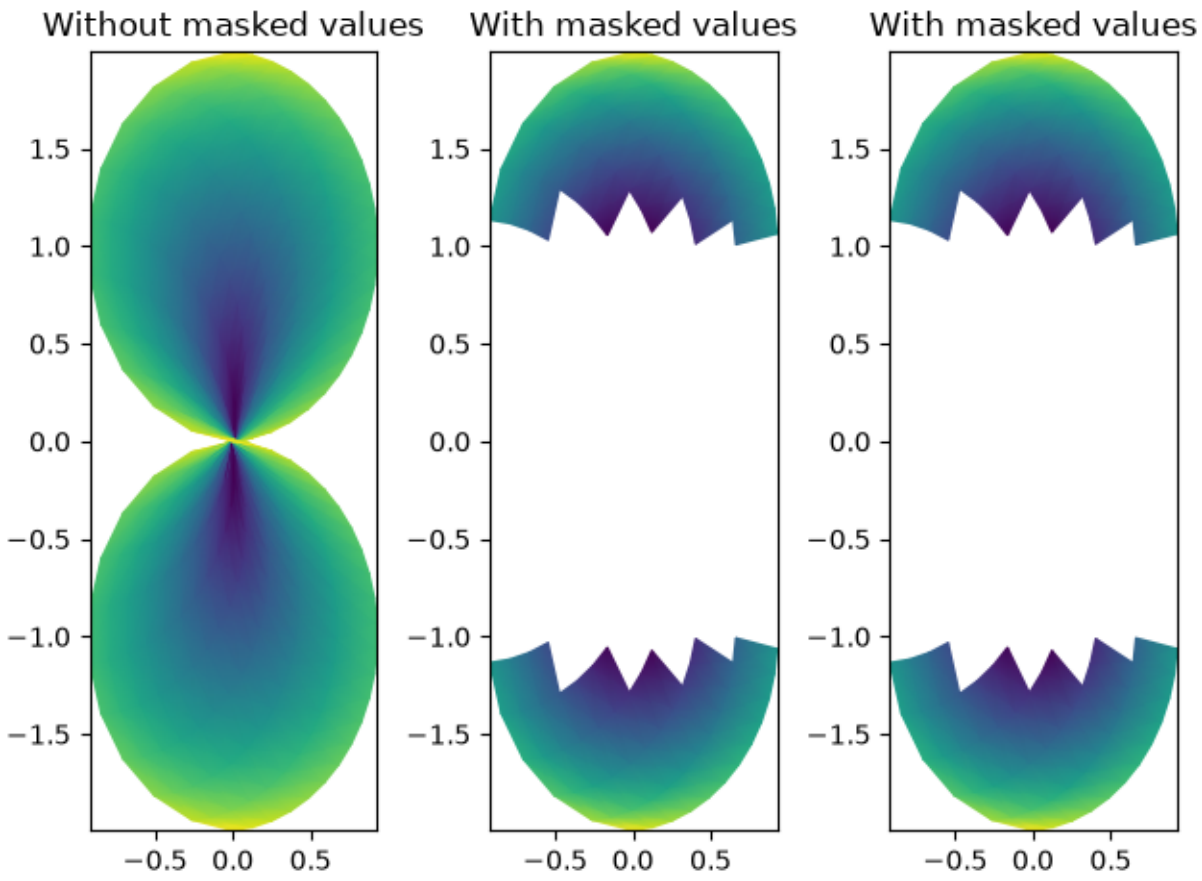
Total running time of the script: (0 minutes 1.173 seconds)

QuadMesh Demo

pcolormesh uses a *QuadMesh*, a faster generalization of *pcolor*, but with some restrictions.

This demo illustrates a bug in quadmesh with masked data.

```
import numpy as np

from matplotlib import pyplot as plt

n = 12
x = np.linspace(-1.5, 1.5, n)
y = np.linspace(-1.5, 1.5, n * 2)
X, Y = np.meshgrid(x, y)
Qx = np.cos(Y) - np.cos(X)
Qz = np.sin(Y) + np.sin(X)
Z = np.sqrt(X**2 + Y**2) / 5
Z = (Z - Z.min()) / (Z.max() - Z.min())

# The color array can include masked values.
Zm = np.ma.masked_where(np.abs(Qz) < 0.5 * np.max(Qz), Z)

fig, axs = plt.subplots(nrows=1, ncols=3)
axs[0].pcolormesh(Qx, Qz, Z, shading='gouraud')
axs[0].set_title('Without masked values')

# You can control the color of the masked region.
cmap = plt.colormaps[plt.rcParams['image.cmap']].with_extremes(bad='y')
axs[1].pcolormesh(Qx, Qz, Zm, shading='gouraud', cmap=cmap)
axs[1].set_title('With masked values')

# Or use the default, which is transparent.
axs[2].pcolormesh(Qx, Qz, Zm, shading='gouraud')
axs[2].set_title('With masked values')

fig.tight_layout()
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.pcolormesh* / *matplotlib.pyplot.pcolormesh*

Triplot Demo

Creating and plotting unstructured triangular grids.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.tri as tri
```

Creating a Triangulation without specifying the triangles results in the Delaunay triangulation of the points.

```
# First create the x and y coordinates of the points.
n_angles = 36
n_radii = 8
```

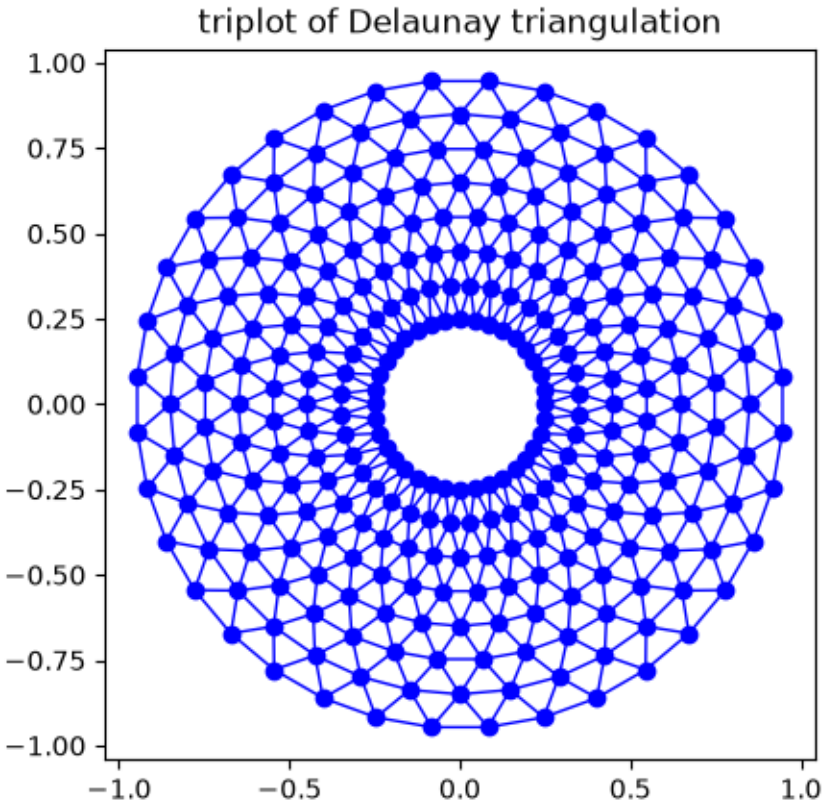
(continues on next page)

(continued from previous page)

```
min_radius = 0.25
radii = np.linspace(min_radius, 0.95, n_radii)

angles = np.linspace(0, 2 * np.pi, n_angles, endpoint=False)
angles = np.repeat(angles[..., np.newaxis], n_radii, axis=1)
angles[:, 1::2] += np.pi / n_angles

x = (radii * np.cos(angles)).flatten()
y = (radii * np.sin(angles)).flatten()

# Create the Triangulation; no triangles so Delaunay triangulation␣
 ↪created.
triang = tri.Triangulation(x, y)

# Mask off unwanted triangles.
triang.set_mask(np.hypot(x[triang.triangles].mean(axis=1),
                         y[triang.triangles].mean(axis=1))
                < min_radius)
```

Plot the triangulation.

```
fig1, ax1 = plt.subplots()
ax1.set_aspect('equal')
ax1.triplot(triang, 'bo-', lw=1)
ax1.set_title('triplot of Delaunay triangulation')
```



You can specify your own triangulation rather than perform a Delaunay triangulation of the points, where each triangle is given by the indices of the three points that make up the triangle, ordered in either a clockwise or anticlockwise manner.

```
xy = np.asarray([
    [-0.101, 0.872], [-0.080, 0.883], [-0.069, 0.888], [-0.054, 0.890],
    [-0.045, 0.897], [-0.057, 0.895], [-0.073, 0.900], [-0.087, 0.898],
    [-0.090, 0.904], [-0.069, 0.907], [-0.069, 0.921], [-0.080, 0.919],
    [-0.073, 0.928], [-0.052, 0.930], [-0.048, 0.942], [-0.062, 0.949],
    [-0.054, 0.958], [-0.069, 0.954], [-0.087, 0.952], [-0.087, 0.959],
    [-0.080, 0.966], [-0.085, 0.973], [-0.087, 0.965], [-0.097, 0.965],
    [-0.097, 0.975], [-0.092, 0.984], [-0.101, 0.980], [-0.108, 0.980],
    [-0.104, 0.987], [-0.102, 0.993], [-0.115, 1.001], [-0.099, 0.996],
    [-0.101, 1.007], [-0.090, 1.010], [-0.087, 1.021], [-0.069, 1.021],
    [-0.052, 1.022], [-0.052, 1.017], [-0.069, 1.010], [-0.064, 1.005],
    [-0.048, 1.005], [-0.031, 1.005], [-0.031, 0.996], [-0.040, 0.987],
    [-0.045, 0.980], [-0.052, 0.975], [-0.040, 0.973], [-0.026, 0.968],
    [-0.020, 0.954], [-0.006, 0.947], [ 0.003, 0.935], [ 0.006, 0.926],
    [ 0.005, 0.921], [ 0.022, 0.923], [ 0.033, 0.912], [ 0.029, 0.905],
    [ 0.017, 0.900], [ 0.012, 0.895], [ 0.027, 0.893], [ 0.019, 0.886],
    [ 0.001, 0.883], [-0.012, 0.884], [-0.029, 0.883], [-0.038, 0.879],
```

(continues on next page)

(continued from previous page)

```
    [-0.057, 0.881], [-0.062, 0.876], [-0.078, 0.876], [-0.087, 0.872],
    [-0.030, 0.907], [-0.007, 0.905], [-0.057, 0.916], [-0.025, 0.933],
    [-0.077, 0.990], [-0.059, 0.993]])
x = np.degrees(xy[:, 0])
y = np.degrees(xy[:, 1])

triangles = np.asarray([
    [67, 66,  1], [65,  2, 66], [ 1, 66,  2], [64,  2, 65], [63,  3,␣
↪64],
    [60, 59, 57], [ 2, 64,  3], [ 3, 63,  4], [ 0, 67,  1], [62,  4,␣
↪63],
    [57, 59, 56], [59, 58, 56], [61, 60, 69], [57, 69, 60], [ 4, 62,␣
↪68],
    [ 6,  5,  9], [61, 68, 62], [69, 68, 61], [ 9,  5, 70], [ 6,  8, ␣
↪7],
    [ 4, 70,  5], [ 8,  6,  9], [56, 69, 57], [69, 56, 52], [70, 10, ␣
↪9],
    [54, 53, 55], [56, 55, 53], [68, 70,  4], [52, 56, 53], [11, 10,␣
↪12],
    [69, 71, 68], [68, 13, 70], [10, 70, 13], [51, 50, 52], [13, 68,␣
↪71],
    [52, 71, 69], [12, 10, 13], [71, 52, 50], [71, 14, 13], [50, 49,␣
↪71],
    [49, 48, 71], [14, 16, 15], [14, 71, 48], [17, 19, 18], [17, 20,␣
↪19],
    [48, 16, 14], [48, 47, 16], [47, 46, 16], [16, 46, 45], [23, 22,␣
↪24],
    [21, 24, 22], [17, 16, 45], [20, 17, 45], [21, 25, 24], [27, 26,␣
↪28],
    [20, 72, 21], [25, 21, 72], [45, 72, 20], [25, 28, 26], [44, 73,␣
↪45],
    [72, 45, 73], [28, 25, 29], [29, 25, 31], [43, 73, 44], [73, 43,␣
↪40],
    [72, 73, 39], [72, 31, 25], [42, 40, 43], [31, 30, 29], [39, 73,␣
↪40],
    [42, 41, 40], [72, 33, 31], [32, 31, 33], [39, 38, 72], [33, 72,␣
↪38],
    [33, 38, 34], [37, 35, 38], [34, 38, 35], [35, 37, 36]])
```

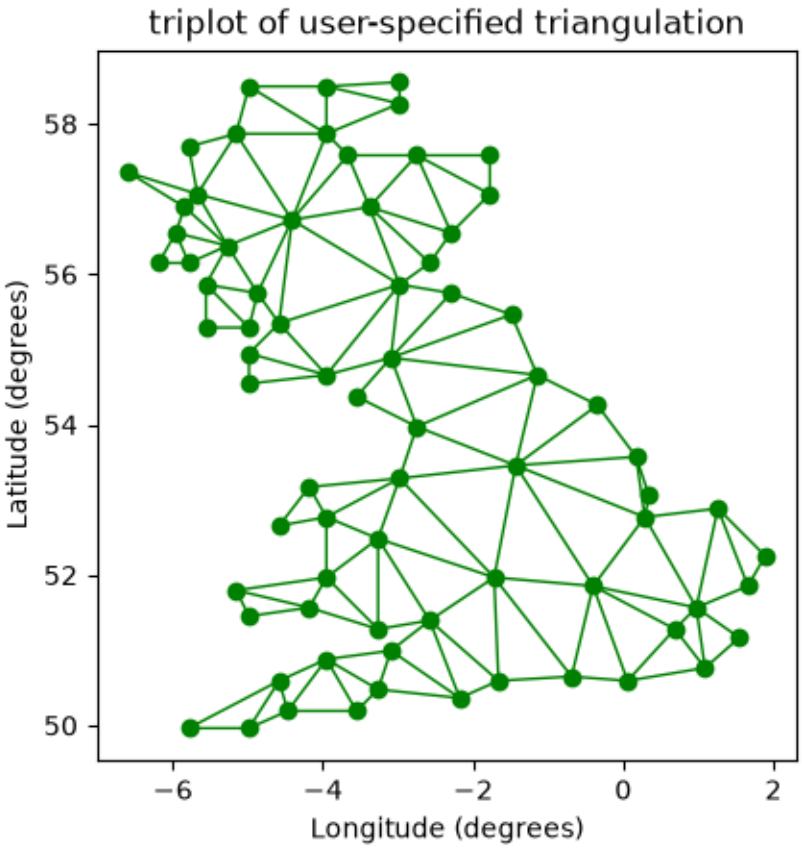
Rather than create a Triangulation object, can simply pass x, y and triangles arrays to triplot directly. It would be better to use a Triangulation object if the same triangulation was to be used more than once to save duplicated calculations.

```
fig2, ax2 = plt.subplots()
ax2.set_aspect('equal')
ax2.triplot(x, y, triangles, 'go-', lw=1.0)
```

(continues on next page)

(continued from previous page)

```
ax2.set_title('triplot of user-specified triangulation')
ax2.set_xlabel('Longitude (degrees)')
ax2.set_ylabel('Latitude (degrees)')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.triplot / matplotlib.pyplot.triplot*
- *matplotlib.tri*
- *matplotlib.tri.Triangulation*

Tripcolor Demo

Pseudocolor plots of unstructured triangular grids.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.tri as tri
```

Creating a Triangulation without specifying the triangles results in the Delaunay triangulation of the points.

```
# First create the x and y coordinates of the points.
n_angles = 36
n_radii = 8
min_radius = 0.25
radii = np.linspace(min_radius, 0.95, n_radii)

angles = np.linspace(0, 2 * np.pi, n_angles, endpoint=False)
angles = np.repeat(angles[..., np.newaxis], n_radii, axis=1)
angles[:, 1::2] += np.pi / n_angles

x = (radii * np.cos(angles)).flatten()
y = (radii * np.sin(angles)).flatten()
z = (np.cos(radii) * np.cos(3 * angles)).flatten()

# Create the Triangulation; no triangles so Delaunay triangulation␣
 ↪created.
triang = tri.Triangulation(x, y)

# Mask off unwanted triangles.
triang.set_mask(np.hypot(x[triang.triangles].mean(axis=1),
                         y[triang.triangles].mean(axis=1))
                < min_radius)
```

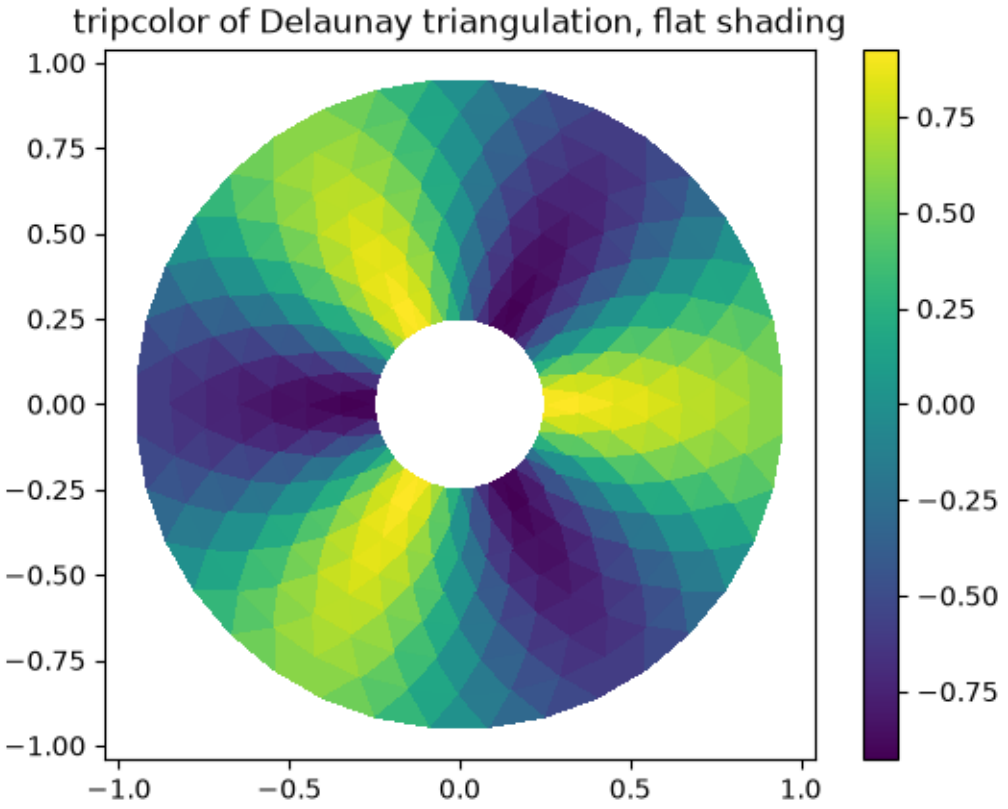
tripcolor plot.

```
fig1, ax1 = plt.subplots()
ax1.set_aspect('equal')
```

(continues on next page)

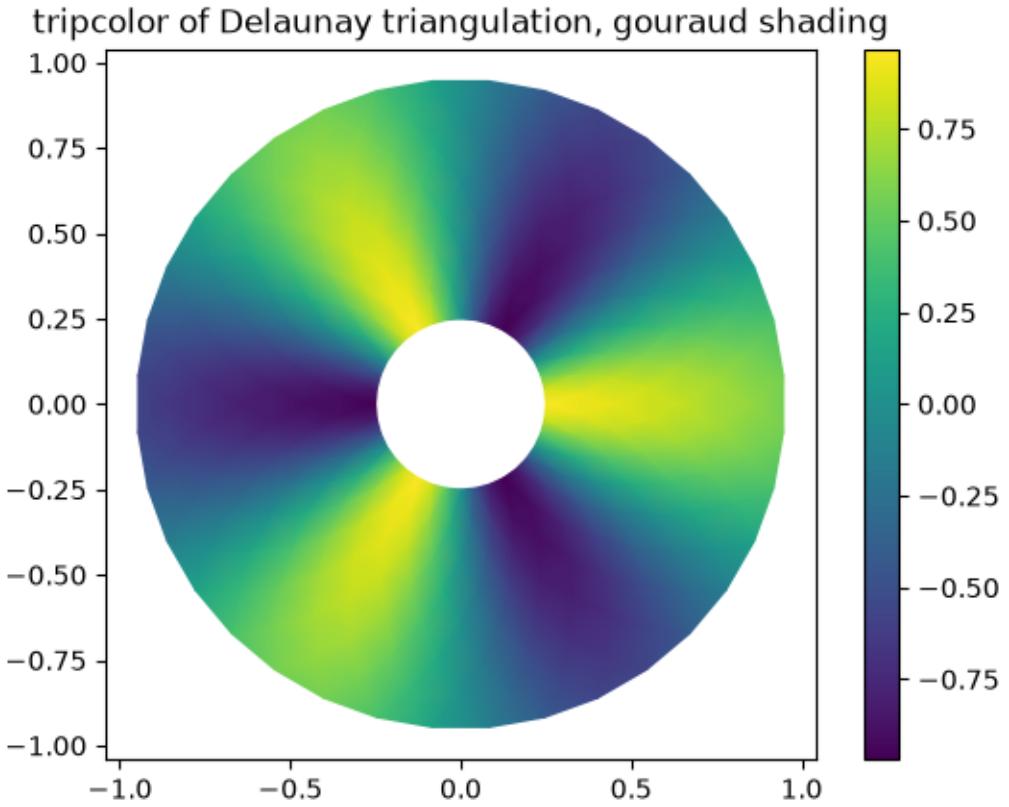
(continued from previous page)

```
tpc = ax1.tripcolor(triang, z, shading='flat')
fig1.colorbar(tpc)
ax1.set_title('tripcolor of Delaunay triangulation, flat shading')
```



Illustrate Gouraud shading.

```
fig2, ax2 = plt.subplots()
ax2.set_aspect('equal')
tpc = ax2.tripcolor(triang, z, shading='gouraud')
fig2.colorbar(tpc)
ax2.set_title('tripcolor of Delaunay triangulation, gouraud shading')
```



You can specify your own triangulation rather than perform a Delaunay triangulation of the points, where each triangle is given by the indices of the three points that make up the triangle, ordered in either a clockwise or anticlockwise manner.

```
xy = np.asarray([
    [-0.101, 0.872], [-0.080, 0.883], [-0.069, 0.888], [-0.054, 0.890],
    [-0.045, 0.897], [-0.057, 0.895], [-0.073, 0.900], [-0.087, 0.898],
    [-0.090, 0.904], [-0.069, 0.907], [-0.069, 0.921], [-0.080, 0.919],
    [-0.073, 0.928], [-0.052, 0.930], [-0.048, 0.942], [-0.062, 0.949],
    [-0.054, 0.958], [-0.069, 0.954], [-0.087, 0.952], [-0.087, 0.959],
    [-0.080, 0.966], [-0.085, 0.973], [-0.087, 0.965], [-0.097, 0.965],
    [-0.097, 0.975], [-0.092, 0.984], [-0.101, 0.980], [-0.108, 0.980],
    [-0.104, 0.987], [-0.102, 0.993], [-0.115, 1.001], [-0.099, 0.996],
    [-0.101, 1.007], [-0.090, 1.010], [-0.087, 1.021], [-0.069, 1.021],
    [-0.052, 1.022], [-0.052, 1.017], [-0.069, 1.010], [-0.064, 1.005],
    [-0.048, 1.005], [-0.031, 1.005], [-0.031, 0.996], [-0.040, 0.987],
    [-0.045, 0.980], [-0.052, 0.975], [-0.040, 0.973], [-0.026, 0.968],
    [-0.020, 0.954], [-0.006, 0.947], [ 0.003, 0.935], [ 0.006, 0.926],
    [ 0.005, 0.921], [ 0.022, 0.923], [ 0.033, 0.912], [ 0.029, 0.905],
    [ 0.017, 0.900], [ 0.012, 0.895], [ 0.027, 0.893], [ 0.019, 0.886],
    [ 0.001, 0.883], [-0.012, 0.884], [-0.029, 0.883], [-0.038, 0.879],
```

(continues on next page)

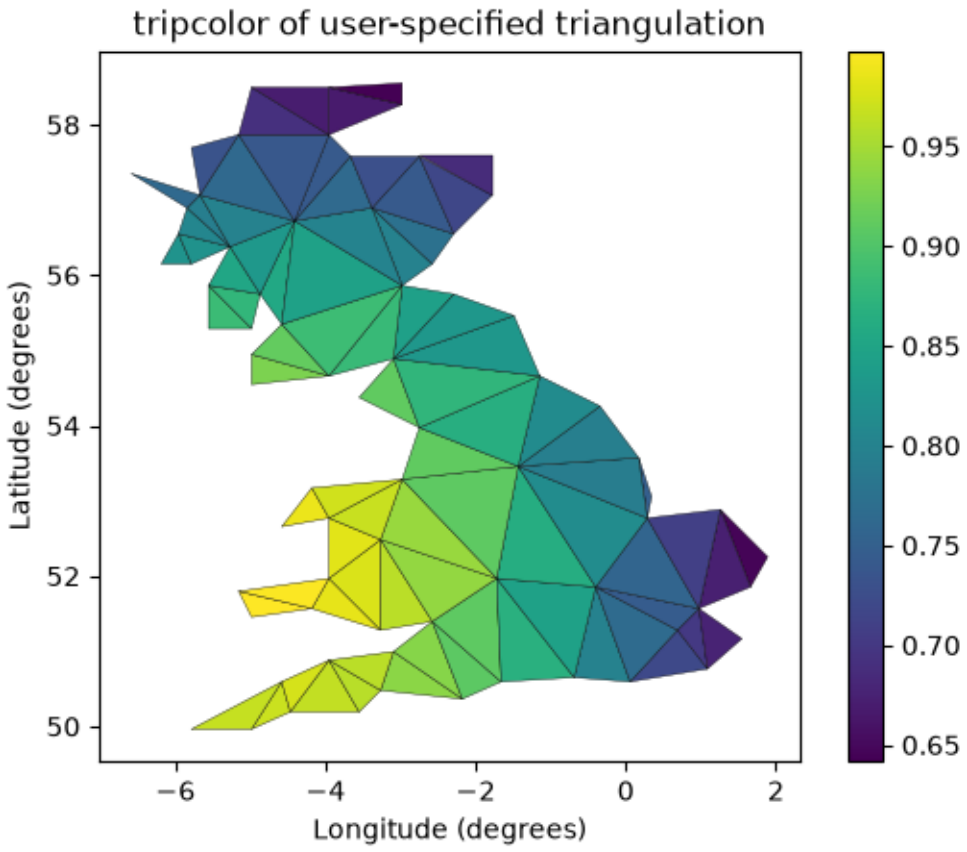
(continued from previous page)

```
    [-0.057, 0.881], [-0.062, 0.876], [-0.078, 0.876], [-0.087, 0.872],
    [-0.030, 0.907], [-0.007, 0.905], [-0.057, 0.916], [-0.025, 0.933],
    [-0.077, 0.990], [-0.059, 0.993]])
x, y = np.rad2deg(xy).T

triangles = np.asarray([
    [67, 66,  1], [65,  2, 66], [ 1, 66,  2], [64,  2, 65], [63,  3,␣
↪64],
    [60, 59, 57], [ 2, 64,  3], [ 3, 63,  4], [ 0, 67,  1], [62,  4,␣
↪63],
    [57, 59, 56], [59, 58, 56], [61, 60, 69], [57, 69, 60], [ 4, 62,␣
↪68],
    [ 6,  5,  9], [61, 68, 62], [69, 68, 61], [ 9,  5, 70], [ 6,  8, ␣
↪7],
    [ 4, 70,  5], [ 8,  6,  9], [56, 69, 57], [69, 56, 52], [70, 10, ␣
↪9],
    [54, 53, 55], [56, 55, 53], [68, 70,  4], [52, 56, 53], [11, 10,␣
↪12],
    [69, 71, 68], [68, 13, 70], [10, 70, 13], [51, 50, 52], [13, 68,␣
↪71],
    [52, 71, 69], [12, 10, 13], [71, 52, 50], [71, 14, 13], [50, 49,␣
↪71],
    [49, 48, 71], [14, 16, 15], [14, 71, 48], [17, 19, 18], [17, 20,␣
↪19],
    [48, 16, 14], [48, 47, 16], [47, 46, 16], [16, 46, 45], [23, 22,␣
↪24],
    [21, 24, 22], [17, 16, 45], [20, 17, 45], [21, 25, 24], [27, 26,␣
↪28],
    [20, 72, 21], [25, 21, 72], [45, 72, 20], [25, 28, 26], [44, 73,␣
↪45],
    [72, 45, 73], [28, 25, 29], [29, 25, 31], [43, 73, 44], [73, 43,␣
↪40],
    [72, 73, 39], [72, 31, 25], [42, 40, 43], [31, 30, 29], [39, 73,␣
↪40],
    [42, 41, 40], [72, 33, 31], [32, 31, 33], [39, 38, 72], [33, 72,␣
↪38],
    [33, 38, 34], [37, 35, 38], [34, 38, 35], [35, 37, 36]])

xmid = x[triangles].mean(axis=1)
ymid = y[triangles].mean(axis=1)
x0 = -5
y0 = 52
zfaces = np.exp(-0.01 * ((xmid - x0) * (xmid - x0) +
                         (ymid - y0) * (ymid - y0)))
```

Rather than create a Triangulation object, can simply pass x, y and triangles arrays to tripcolor directly. It

would be better to use a Triangulation object if the same triangulation was to be used more than once to save duplicated calculations. Can specify one color value per face rather than one per point by using the *facecolors* keyword argument.

```
fig3, ax3 = plt.subplots()
ax3.set_aspect('equal')
tpc = ax3.tripcolor(x, y, triangles, facecolors=zfaces, edgecolors='k')
fig3.colorbar(tpc)
ax3.set_title('tripcolor of user-specified triangulation')
ax3.set_xlabel('Longitude (degrees)')
ax3.set_ylabel('Latitude (degrees)')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.tripcolor* / *matplotlib.pyplot.tripcolor*
- *matplotlib.tri*

- *matplotlib.tri.Triangulation*

Total running time of the script: (0 minutes 1.310 seconds)

Tricontour Demo

Contour plots of unstructured triangular grids.

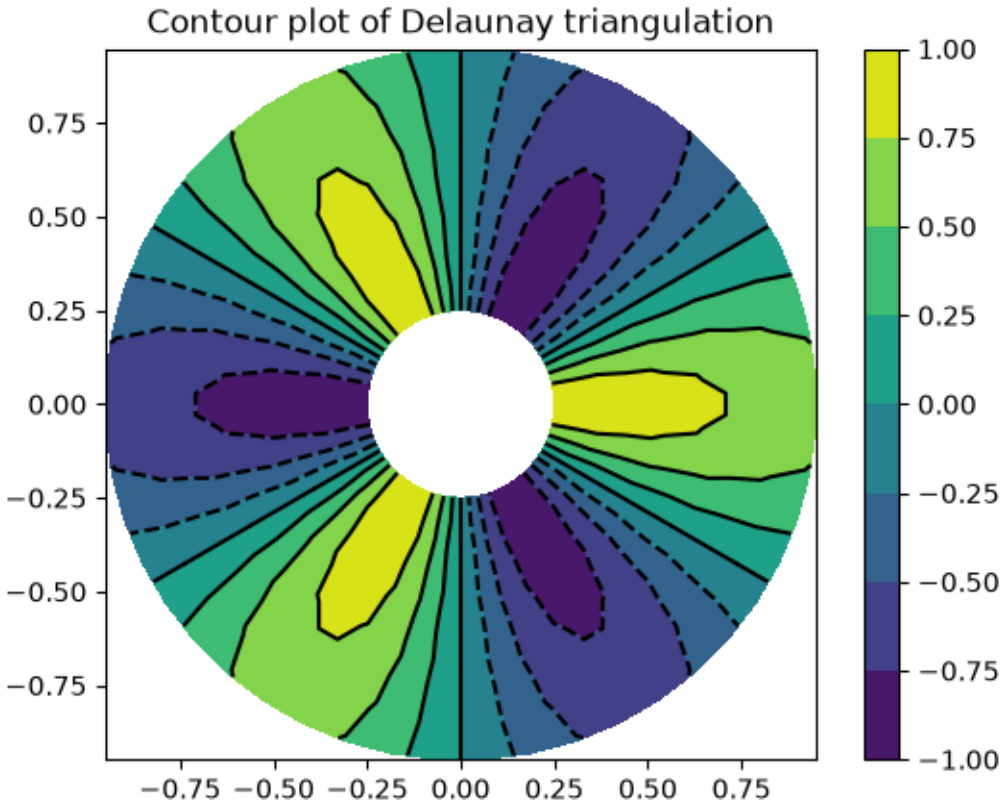
```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.tri as tri
```

Creating a Triangulation without specifying the triangles results in the Delaunay triangulation of the points.

```
# First create the x and y coordinates of the points.
n_angles = 48
n_radii = 8
min_radius = 0.25
radii = np.linspace(min_radius, 0.95, n_radii)

angles = np.linspace(0, 2 * np.pi, n_angles, endpoint=False)
angles = np.repeat(angles[..., np.newaxis], n_radii, axis=1)
angles[:, 1::2] += np.pi / n_angles

x = (radii * np.cos(angles)).flatten()
y = (radii * np.sin(angles)).flatten()
z = (np.cos(radii) * np.cos(3 * angles)).flatten()

# Create the Triangulation; no triangles so Delaunay triangulation␣
 ↪created.
triang = tri.Triangulation(x, y)

# Mask off unwanted triangles.
triang.set_mask(np.hypot(x[triang.triangles].mean(axis=1),
                         y[triang.triangles].mean(axis=1))
                < min_radius)
```

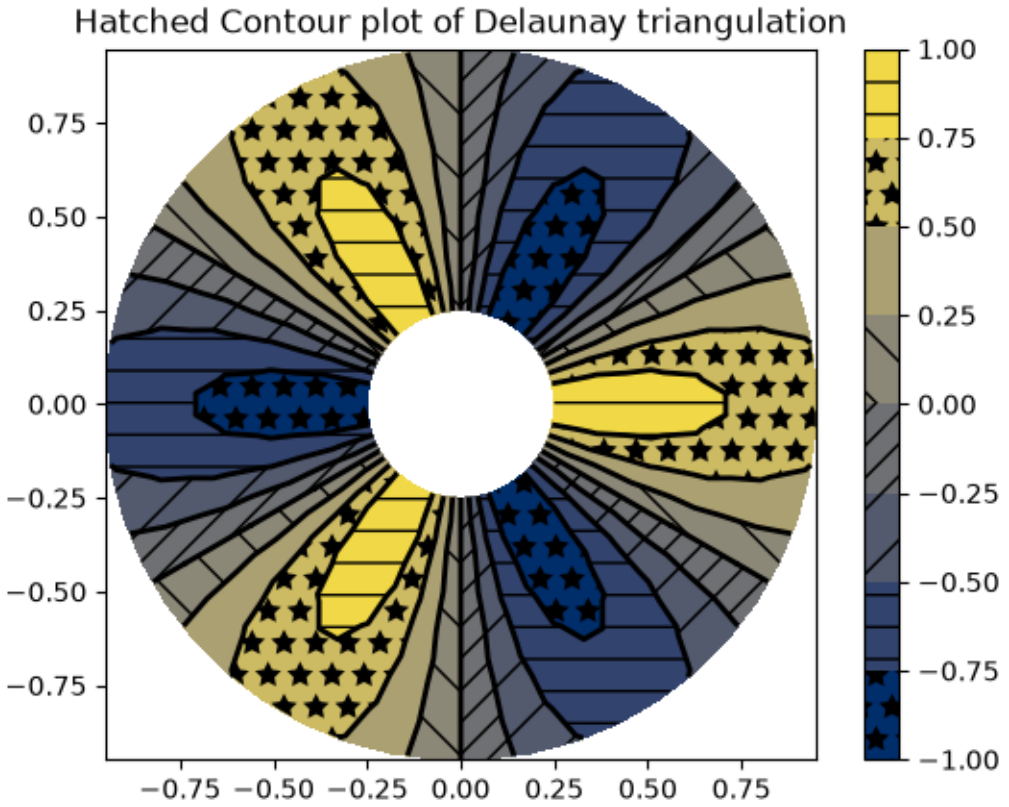
pcolor plot.

```
fig1, ax1 = plt.subplots()
ax1.set_aspect('equal')
tcf = ax1.tricontourf(triang, z)
fig1.colorbar(tcf)
ax1.tricontour(triang, z, colors='k')
ax1.set_title('Contour plot of Delaunay triangulation')
```



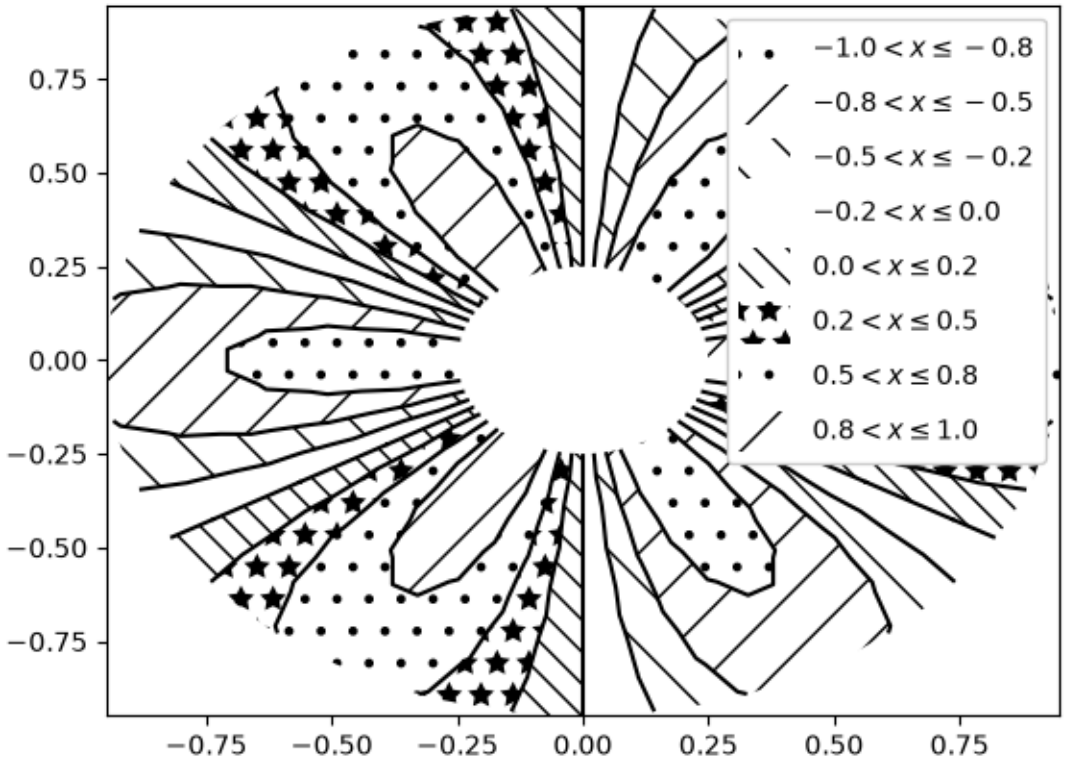
You could also specify hatching patterns along with different cmaps.

```
fig2, ax2 = plt.subplots()
ax2.set_aspect("equal")
tcf = ax2.tricontourf(
    triang,
    z,
    hatches=["*", "-", "/", "//", "\\", None],
    cmap="cividis"
)
fig2.colorbar(tcf)
ax2.tricontour(triang, z, linestyles="solid", colors="k",␣
 ↪linewidths=2.0)
ax2.set_title("Hatched Contour plot of Delaunay triangulation")
```



You could also generate hatching patterns labeled with no color.

```
fig3, ax3 = plt.subplots()
n_levels = 7
tcf = ax3.tricontourf(
    triang,
    z,
    n_levels,
    colors="none",
    hatches=[".", "/", "\\", None, "\\\\", "*"],
)
ax3.tricontour(triang, z, n_levels, colors="black", linestyles="-")


# create a legend for the contour set
artists, labels = tcf.legend_elements(str_format="{:2.1f}".format)
ax3.legend(artists, labels, handleheight=2, framealpha=1)
```



You can specify your own triangulation rather than perform a Delaunay triangulation of the points, where each triangle is given by the indices of the three points that make up the triangle, ordered in either a clockwise or anticlockwise manner.

```
xy = np.asarray([
    [-0.101, 0.872], [-0.080, 0.883], [-0.069, 0.888], [-0.054, 0.890],
    [-0.045, 0.897], [-0.057, 0.895], [-0.073, 0.900], [-0.087, 0.898],
    [-0.090, 0.904], [-0.069, 0.907], [-0.069, 0.921], [-0.080, 0.919],
    [-0.073, 0.928], [-0.052, 0.930], [-0.048, 0.942], [-0.062, 0.949],
    [-0.054, 0.958], [-0.069, 0.954], [-0.087, 0.952], [-0.087, 0.959],
    [-0.080, 0.966], [-0.085, 0.973], [-0.087, 0.965], [-0.097, 0.965],
    [-0.097, 0.975], [-0.092, 0.984], [-0.101, 0.980], [-0.108, 0.980],
    [-0.104, 0.987], [-0.102, 0.993], [-0.115, 1.001], [-0.099, 0.996],
    [-0.101, 1.007], [-0.090, 1.010], [-0.087, 1.021], [-0.069, 1.021],
    [-0.052, 1.022], [-0.052, 1.017], [-0.069, 1.010], [-0.064, 1.005],
    [-0.048, 1.005], [-0.031, 1.005], [-0.031, 0.996], [-0.040, 0.987],
    [-0.045, 0.980], [-0.052, 0.975], [-0.040, 0.973], [-0.026, 0.968],
    [-0.020, 0.954], [-0.006, 0.947], [ 0.003, 0.935], [ 0.006, 0.926],
    [ 0.005, 0.921], [ 0.022, 0.923], [ 0.033, 0.912], [ 0.029, 0.905],
    [ 0.017, 0.900], [ 0.012, 0.895], [ 0.027, 0.893], [ 0.019, 0.886],
    [ 0.001, 0.883], [-0.012, 0.884], [-0.029, 0.883], [-0.038, 0.879],
```

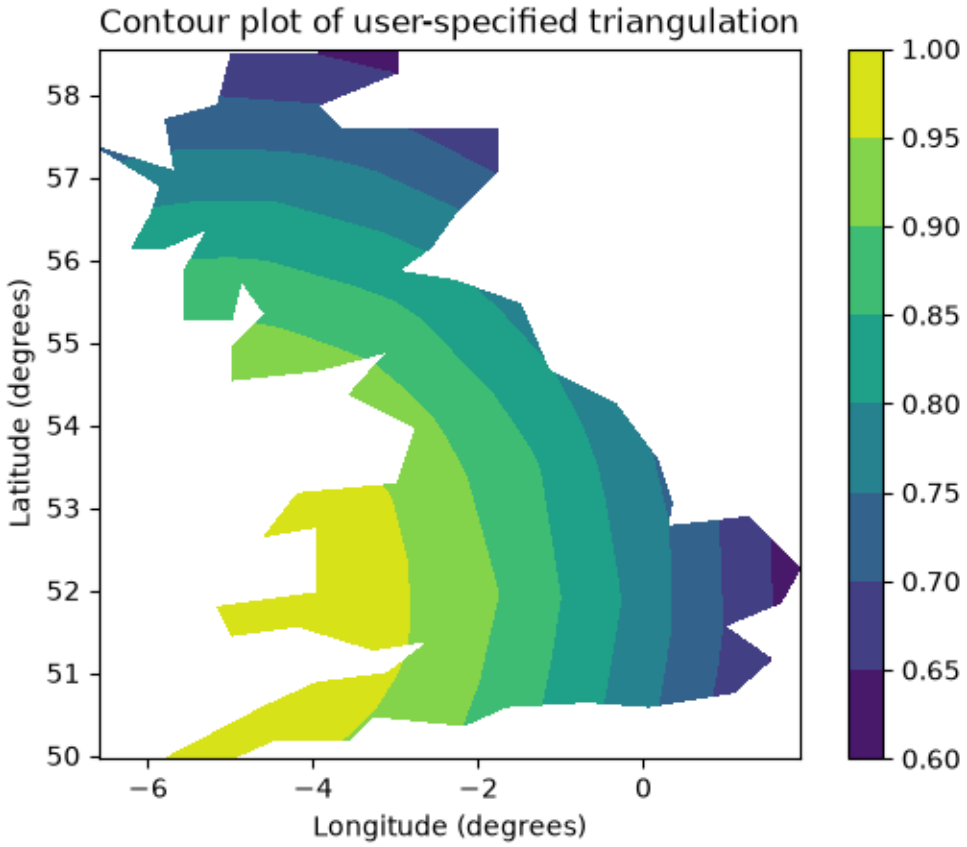
(continues on next page)

(continued from previous page)

```
    [-0.057, 0.881], [-0.062, 0.876], [-0.078, 0.876], [-0.087, 0.872],
    [-0.030, 0.907], [-0.007, 0.905], [-0.057, 0.916], [-0.025, 0.933],
    [-0.077, 0.990], [-0.059, 0.993]])
x = np.degrees(xy[:, 0])
y = np.degrees(xy[:, 1])
x0 = -5
y0 = 52
z = np.exp(-0.01 * ((x - x0) ** 2 + (y - y0) ** 2))

triangles = np.asarray([
    [67, 66,  1], [65,  2, 66], [ 1, 66,  2], [64,  2, 65], [63,  3,␣
↪64],
    [60, 59, 57], [ 2, 64,  3], [ 3, 63,  4], [ 0, 67,  1], [62,  4,␣
↪63],
    [57, 59, 56], [59, 58, 56], [61, 60, 69], [57, 69, 60], [ 4, 62,␣
↪68],
    [ 6,  5,  9], [61, 68, 62], [69, 68, 61], [ 9,  5, 70], [ 6,  8, ␣
↪7],
    [ 4, 70,  5], [ 8,  6,  9], [56, 69, 57], [69, 56, 52], [70, 10, ␣
↪9],
    [54, 53, 55], [56, 55, 53], [68, 70,  4], [52, 56, 53], [11, 10,␣
↪12],
    [69, 71, 68], [68, 13, 70], [10, 70, 13], [51, 50, 52], [13, 68,␣
↪71],
    [52, 71, 69], [12, 10, 13], [71, 52, 50], [71, 14, 13], [50, 49,␣
↪71],
    [49, 48, 71], [14, 16, 15], [14, 71, 48], [17, 19, 18], [17, 20,␣
↪19],
    [48, 16, 14], [48, 47, 16], [47, 46, 16], [16, 46, 45], [23, 22,␣
↪24],
    [21, 24, 22], [17, 16, 45], [20, 17, 45], [21, 25, 24], [27, 26,␣
↪28],
    [20, 72, 21], [25, 21, 72], [45, 72, 20], [25, 28, 26], [44, 73,␣
↪45],
    [72, 45, 73], [28, 25, 29], [29, 25, 31], [43, 73, 44], [73, 43,␣
↪40],
    [72, 73, 39], [72, 31, 25], [42, 40, 43], [31, 30, 29], [39, 73,␣
↪40],
    [42, 41, 40], [72, 33, 31], [32, 31, 33], [39, 38, 72], [33, 72,␣
↪38],
    [33, 38, 34], [37, 35, 38], [34, 38, 35], [35, 37, 36]])
```

Rather than create a Triangulation object, can simply pass x, y and triangles arrays to tripcolor directly. It would be better to use a Triangulation object if the same triangulation was to be used more than once to save duplicated calculations.

```
fig4, ax4 = plt.subplots()
ax4.set_aspect('equal')
tcf = ax4.tricontourf(x, y, triangles, z)
fig4.colorbar(tcf)
ax4.set_title('Contour plot of user-specified triangulation')
ax4.set_xlabel('Longitude (degrees)')
ax4.set_ylabel('Latitude (degrees)')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.tricontourf* / *matplotlib.pyplot.tricontourf*
- *matplotlib.tri.Triangulation*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.axes.Axes.legend* / *matplotlib.pyplot.legend*

- *matplotlib.contour.ContourSet.legend_elements*

Total running time of the script: (0 minutes 1.658 seconds)

Tricontour Smooth User

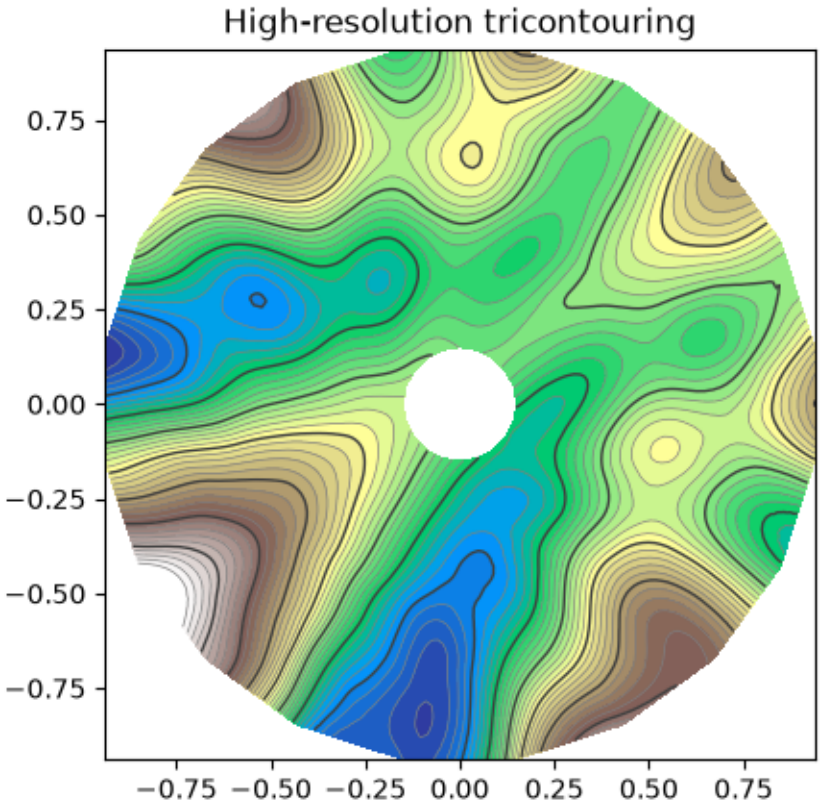
Demonstrates high-resolution tricontouring on user-defined triangular grids with *matplotlib.tri.UniformTriRefiner*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.tri as tri


# -----------------------------------------------------------------------
 ↪-------
# Analytical test function
# -----------------------------------------------------------------------
 ↪-------
def function_z(x, y):
    r1 = np.sqrt((0.5 - x)**2 + (0.5 - y)**2)
    theta1 = np.arctan2(0.5 - x, 0.5 - y)
    r2 = np.sqrt((-x - 0.2)**2 + (-y - 0.2)**2)
    theta2 = np.arctan2(-x - 0.2, -y - 0.2)
    z = -(2 * (np.exp((r1 / 10)**2) - 1) * 30. * np.cos(7. * theta1) +
          (np.exp((r2 / 10)**2) - 1) * 30. * np.cos(11. * theta2) +
          0.7 * (x**2 + y**2))
    return (np.max(z) - z) / (np.max(z) - np.min(z))

# -----------------------------------------------------------------------
 ↪-------
# Creating a Triangulation
# -----------------------------------------------------------------------
 ↪-------
# First create the x and y coordinates of the points.
n_angles = 20
n_radii = 10
min_radius = 0.15
radii = np.linspace(min_radius, 0.95, n_radii)

angles = np.linspace(0, 2 * np.pi, n_angles, endpoint=False)
angles = np.repeat(angles[..., np.newaxis], n_radii, axis=1)
angles[:, 1::2] += np.pi / n_angles

x = (radii * np.cos(angles)).flatten()
```

(continues on next page)

(continued from previous page)

```
y = (radii * np.sin(angles)).flatten()
z = function_z(x, y)

# Now create the Triangulation.
# (Creating a Triangulation without specifying the triangles results␣
 ↪in the
# Delaunay triangulation of the points.)
triang = tri.Triangulation(x, y)

# Mask off unwanted triangles.
triang.set_mask(np.hypot(x[triang.triangles].mean(axis=1),
                         y[triang.triangles].mean(axis=1))
                < min_radius)

# ----------------------------------------------------------------------
 ↪-------
# Refine data
# ----------------------------------------------------------------------
 ↪-------
refiner = tri.UniformTriRefiner(triang)
tri_refi, z_test_refi = refiner.refine_field(z, subdiv=3)

# ----------------------------------------------------------------------
 ↪-------
# Plot the triangulation and the high-res iso-contours
# ----------------------------------------------------------------------
 ↪-------
fig, ax = plt.subplots()
ax.set_aspect('equal')
ax.triplot(triang, lw=0.5, color='white')

levels = np.arange(0., 1., 0.025)
ax.tricontourf(tri_refi, z_test_refi, levels=levels, cmap='terrain')
ax.tricontour(tri_refi, z_test_refi, levels=levels,
              colors=['0.25', '0.5', '0.5', '0.5', '0.5'],
              linewidths=[1.0, 0.5, 0.5, 0.5, 0.5])

ax.set_title("High-resolution tricontouring")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.tricontour* / *matplotlib.pyplot.tricontour*
- *matplotlib.axes.Axes.tricontourf* / *matplotlib.pyplot.tricontourf*
- *matplotlib.tri*
- *matplotlib.tri.Triangulation*
- *matplotlib.tri.UniformTriRefiner*

Tricontour Smooth Delaunay

Demonstrates high-resolution tricontouring of a random set of points; a *matplotlib.tri.TriAnalyzer* is used to improve the plot quality.

The initial data points and triangular grid for this demo are:

- a set of random points is instantiated, inside [-1, 1] x [-1, 1] square
- A Delaunay triangulation of these points is then computed, of which a random subset of triangles is

masked out by the user (based on *init_mask_frac* parameter). This simulates invalidated data.

The proposed generic procedure to obtain a high resolution contouring of such a data set is the following:

1. Compute an extended mask with a *matplotlib.tri.TriAnalyzer*, which will exclude badly shaped (flat) triangles from the border of the triangulation. Apply the mask to the triangulation (using set_mask).
2. Refine and interpolate the data using a *matplotlib.tri.UniformTriRefiner*.
3. Plot the refined data with *tricontour*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.tri import TriAnalyzer, Triangulation,␣
 ↪UniformTriRefiner


# -----------------------------------------------------------------------
 ↪-------
# Analytical test function
# -----------------------------------------------------------------------
 ↪-------
def experiment_res(x, y):
    """An analytic function representing experiment results."""
    x = 2 * x
    r1 = np.sqrt((0.5 - x)**2 + (0.5 - y)**2)
    theta1 = np.arctan2(0.5 - x, 0.5 - y)
    r2 = np.sqrt((-x - 0.2)**2 + (-y - 0.2)**2)
    theta2 = np.arctan2(-x - 0.2, -y - 0.2)
    z = (4 * (np.exp((r1/10)**2) - 1) * 30 * np.cos(3 * theta1) +
         (np.exp((r2/10)**2) - 1) * 30 * np.cos(5 * theta2) +
         2 * (x**2 + y**2))
    return (np.max(z) - z) / (np.max(z) - np.min(z))

# -----------------------------------------------------------------------
 ↪-------
# Generating the initial data test points and triangulation for the␣
 ↪demo
# -----------------------------------------------------------------------
 ↪-------
# User parameters for data test points

# Number of test data points, tested from 3 to 5000 for subdiv=3
n_test = 200

# Number of recursive subdivisions of the initial mesh for smooth␣
 ↪plots.
```

(continues on next page)

(continued from previous page)

```
# Values >3 might result in a very high number of triangles for the␣
 ↪refine
# mesh: new triangles numbering = (4**subdiv)*ntri
subdiv = 3

# Float > 0. adjusting the proportion of (invalid) initial triangles␣
 ↪which will
# be masked out. Enter 0 for no mask.
init_mask_frac = 0.0

# Minimum circle ratio - border triangles with circle ratio below this␣
 ↪will be
# masked if they touch a border. Suggested value 0.01; use -1 to keep␣
 ↪all
# triangles.
min_circle_ratio = .01

# Random points
random_gen = np.random.RandomState(seed=19680801)
x_test = random_gen.uniform(-1., 1., size=n_test)
y_test = random_gen.uniform(-1., 1., size=n_test)
z_test = experiment_res(x_test, y_test)

# meshing with Delaunay triangulation
tri = Triangulation(x_test, y_test)
ntri = tri.triangles.shape[0]

# Some invalid data are masked out
mask_init = np.zeros(ntri, dtype=bool)
masked_tri = random_gen.randint(0, ntri, int(ntri * init_mask_frac))
mask_init[masked_tri] = True
tri.set_mask(mask_init)


# ----------------------------------------------------------------------
 ↪-------
# Improving the triangulation before high-res plots: removing flat␣
 ↪triangles
# ----------------------------------------------------------------------
 ↪-------
# masking badly shaped triangles at the border of the triangular mesh.
mask = TriAnalyzer(tri).get_flat_tri_mask(min_circle_ratio)
tri.set_mask(mask)

# refining the data
refiner = UniformTriRefiner(tri)
```

(continues on next page)

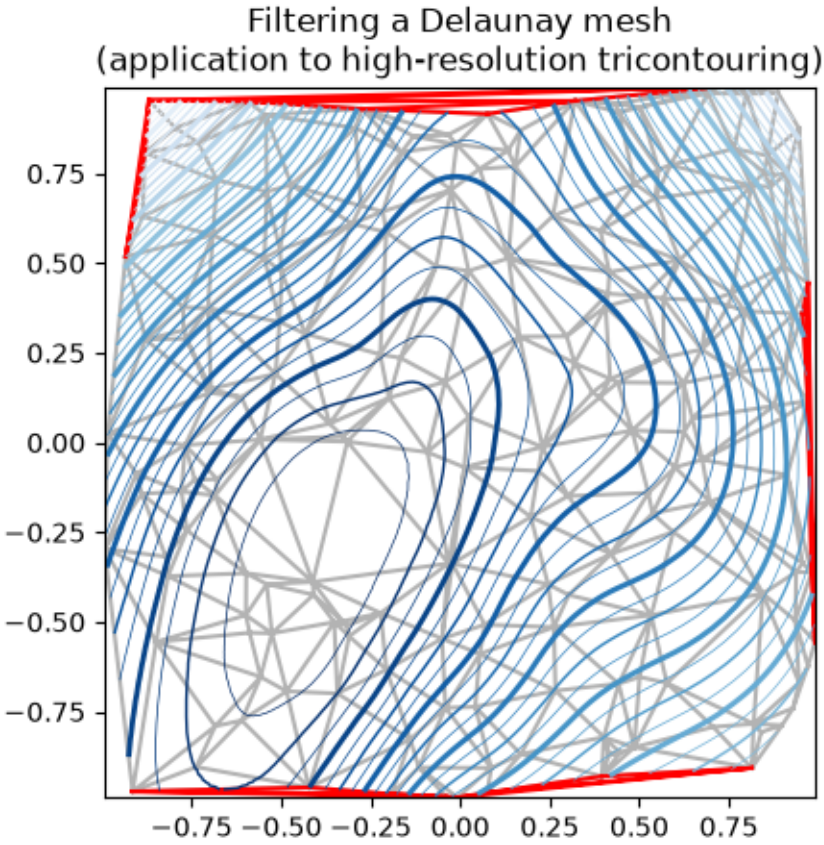
(continued from previous page)

```
tri_refi, z_test_refi = refiner.refine_field(z_test, subdiv=subdiv)

# analytical 'results' for comparison
z_expected = experiment_res(tri_refi.x, tri_refi.y)

# for the demo: loading the 'flat' triangles for plot
flat_tri = Triangulation(x_test, y_test)
flat_tri.set_mask(~mask)


# -----------------------------------------------------------------------
 ↪-------
# Now the plots
# -----------------------------------------------------------------------
 ↪-------
# User options for plots
plot_tri = True          # plot of base triangulation
plot_masked_tri = True   # plot of excessively flat excluded triangles
plot_refi_tri = False    # plot of refined triangulation
plot_expected = False    # plot of analytical function values for␣
 ↪comparison


# Graphical options for tricontouring
levels = np.arange(0., 1., 0.025)

fig, ax = plt.subplots()
ax.set_aspect('equal')
ax.set_title("Filtering a Delaunay mesh\n"
             "(application to high-resolution tricontouring)")

# 1) plot of the refined (computed) data contours:
ax.tricontour(tri_refi, z_test_refi, levels=levels, cmap='Blues',
              linewidths=[2.0, 0.5, 1.0, 0.5])
# 2) plot of the expected (analytical) data contours (dashed):
if plot_expected:
    ax.tricontour(tri_refi, z_expected, levels=levels, cmap='Blues',
                  linestyles='--')
# 3) plot of the fine mesh on which interpolation was done:
if plot_refi_tri:
    ax.triplot(tri_refi, color='0.97')
# 4) plot of the initial 'coarse' mesh:
if plot_tri:
    ax.triplot(tri, color='0.7')
# 4) plot of the unvalidated triangles from naive Delaunay␣
 ↪Triangulation:
```

(continues on next page)

(continued from previous page)

```
if plot_masked_tri:
    ax.triplot(flat_tri, color='red')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.tricontour* / *matplotlib.pyplot.tricontour*
- *matplotlib.axes.Axes.tricontourf* / *matplotlib.pyplot.tricontourf*
- *matplotlib.axes.Axes.triplot* / *matplotlib.pyplot.triplot*
- *matplotlib.tri*
- *matplotlib.tri.Triangulation*
- *matplotlib.tri.TriAnalyzer*
- *matplotlib.tri.UniformTriRefiner*

Trigradient Demo

Demonstrates computation of gradient with *matplotlib.tri.CubicTriInterpolator*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.tri import CubicTriInterpolator, Triangulation,␣
 ↪UniformTriRefiner


# -----------------------------------------------------------------------
 ↪-------
# Electrical potential of a dipole
# -----------------------------------------------------------------------
 ↪-------
def dipole_potential(x, y):
    """The electric dipole potential V, at position *x*, *y*."""
    r_sq = x**2 + y**2
    theta = np.arctan2(y, x)
    z = np.cos(theta)/r_sq
    return (np.max(z) - z) / (np.max(z) - np.min(z))


# -----------------------------------------------------------------------
 ↪-------
# Creating a Triangulation
# -----------------------------------------------------------------------
 ↪-------
# First create the x and y coordinates of the points.
n_angles = 30
n_radii = 10
min_radius = 0.2
radii = np.linspace(min_radius, 0.95, n_radii)

angles = np.linspace(0, 2 * np.pi, n_angles, endpoint=False)
angles = np.repeat(angles[..., np.newaxis], n_radii, axis=1)
angles[:, 1::2] += np.pi / n_angles

x = (radii*np.cos(angles)).flatten()
y = (radii*np.sin(angles)).flatten()
V = dipole_potential(x, y)

# Create the Triangulation; no triangles specified so Delaunay␣
 ↪triangulation
# created.
triang = Triangulation(x, y)
```

(continues on next page)

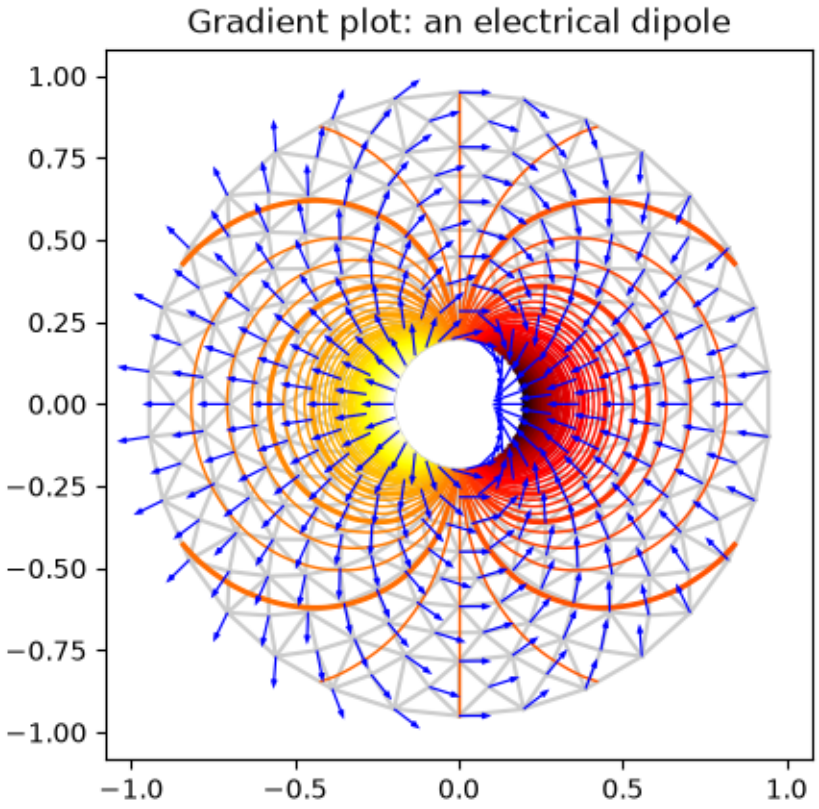
(continued from previous page)

```
# Mask off unwanted triangles.
triang.set_mask(np.hypot(x[triang.triangles].mean(axis=1),
                         y[triang.triangles].mean(axis=1))
                < min_radius)

# ----------------------------------------------------------------------
 ↪-------
# Refine data - interpolates the electrical potential V
# ----------------------------------------------------------------------
 ↪-------
refiner = UniformTriRefiner(triang)
tri_refi, z_test_refi = refiner.refine_field(V, subdiv=3)

# ----------------------------------------------------------------------
 ↪-------
# Computes the electrical field (Ex, Ey) as gradient of electrical␣
 ↪potential
# ----------------------------------------------------------------------
 ↪-------
tci = CubicTriInterpolator(triang, -V)
# Gradient requested here at the mesh nodes but could be anywhere else:
(Ex, Ey) = tci.gradient(triang.x, triang.y)
E_norm = np.sqrt(Ex**2 + Ey**2)

# ----------------------------------------------------------------------
 ↪-------
# Plot the triangulation, the potential iso-contours and the vector␣
 ↪field
# ----------------------------------------------------------------------
 ↪-------
fig, ax = plt.subplots()
ax.set_aspect('equal')
# Enforce the margins, and enlarge them to give room for the vectors.
ax.use_sticky_edges = False
ax.margins(0.07)

ax.triplot(triang, color='0.8')

levels = np.arange(0., 1., 0.01)
ax.tricontour(tri_refi, z_test_refi, levels=levels, cmap='hot',
              linewidths=[2.0, 1.0, 1.0, 1.0])
# Plots direction of the electrical vector field
ax.quiver(triang.x, triang.y, Ex/E_norm, Ey/E_norm,
          units='xy', scale=10., zorder=3, color='blue',
          width=0.007, headwidth=3., headlength=4.)
```

(continues on next page)

(continued from previous page)

```
ax.set_title('Gradient plot: an electrical dipole')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.tricontour* / *matplotlib.pyplot.tricontour*
- *matplotlib.axes.Axes.triplot* / *matplotlib.pyplot.triplot*
- *matplotlib.tri*
- *matplotlib.tri.Triangulation*
- *matplotlib.tri.CubicTriInterpolator*
- *matplotlib.tri.CubicTriInterpolator.gradient*
- *matplotlib.tri.UniformTriRefiner*
- *matplotlib.axes.Axes.quiver* / *matplotlib.pyplot.quiver*

Triinterp Demo

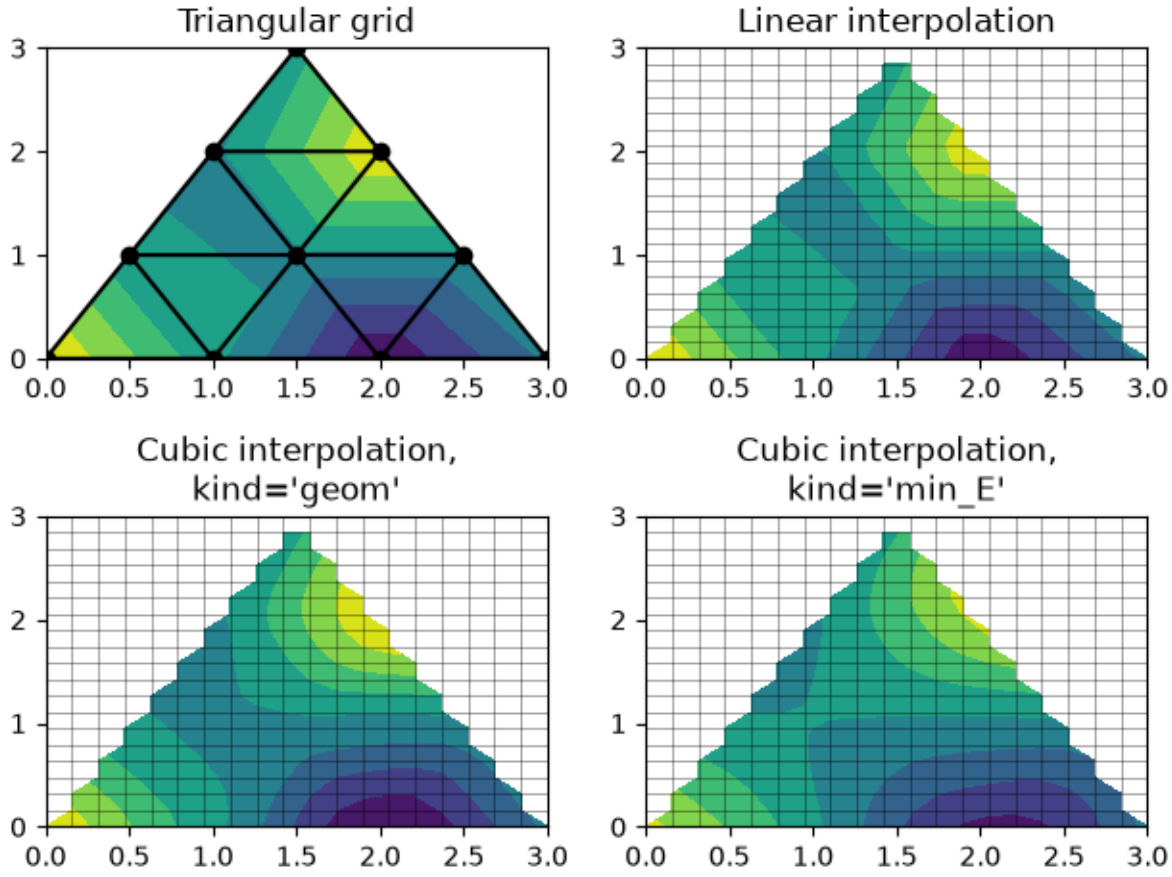
Interpolation from triangular grid to quad grid.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.tri as mtri

# Create triangulation.
x = np.asarray([0, 1, 2, 3, 0.5, 1.5, 2.5, 1, 2, 1.5])
y = np.asarray([0, 0, 0, 0, 1.0, 1.0, 1.0, 2, 2, 3.0])
triangles = [[0, 1, 4], [1, 2, 5], [2, 3, 6], [1, 5, 4], [2, 6, 5], [4,
 ↪ 5, 7],
             [5, 6, 8], [5, 8, 7], [7, 8, 9]]
triang = mtri.Triangulation(x, y, triangles)

# Interpolate to regularly-spaced quad grid.
z = np.cos(1.5 * x) * np.cos(1.5 * y)
xi, yi = np.meshgrid(np.linspace(0, 3, 20), np.linspace(0, 3, 20))

interp_lin = mtri.LinearTriInterpolator(triang, z)
zi_lin = interp_lin(xi, yi)

interp_cubic_geom = mtri.CubicTriInterpolator(triang, z, kind='geom')
zi_cubic_geom = interp_cubic_geom(xi, yi)

interp_cubic_min_E = mtri.CubicTriInterpolator(triang, z, kind='min_E')
zi_cubic_min_E = interp_cubic_min_E(xi, yi)

# Set up the figure
fig, axs = plt.subplots(nrows=2, ncols=2)
axs = axs.flatten()

# Plot the triangulation.
axs[0].tricontourf(triang, z)
axs[0].triplot(triang, 'ko-')
axs[0].set_title('Triangular grid')

# Plot linear interpolation to quad grid.
axs[1].contourf(xi, yi, zi_lin)
axs[1].plot(xi, yi, 'k-', lw=0.5, alpha=0.5)
axs[1].plot(xi.T, yi.T, 'k-', lw=0.5, alpha=0.5)
axs[1].set_title("Linear interpolation")

# Plot cubic interpolation to quad grid, kind=geom
axs[2].contourf(xi, yi, zi_cubic_geom)
```

(continues on next page)

(continued from previous page)

```
axs[2].plot(xi, yi, 'k-', lw=0.5, alpha=0.5)
axs[2].plot(xi.T, yi.T, 'k-', lw=0.5, alpha=0.5)
axs[2].set_title("Cubic interpolation,\nkind='geom'")

# Plot cubic interpolation to quad grid, kind=min_E
axs[3].contourf(xi, yi, zi_cubic_min_E)
axs[3].plot(xi, yi, 'k-', lw=0.5, alpha=0.5)
axs[3].plot(xi.T, yi.T, 'k-', lw=0.5, alpha=0.5)
axs[3].set_title("Cubic interpolation,\nkind='min_E'")

fig.tight_layout()
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.tricontourf* / *matplotlib.pyplot.tricontourf*
- *matplotlib.axes.Axes.triplot* / *matplotlib.pyplot.triplot*

- *matplotlib.axes.Axes.contourf* / *matplotlib.pyplot.contourf*
- *matplotlib.axes.Axes.plot* / *matplotlib.pyplot.plot*
- *matplotlib.tri*
- *matplotlib.tri.LinearTriInterpolator*
- *matplotlib.tri.CubicTriInterpolator*
- *matplotlib.tri.Triangulation*

Contour plot of irregularly spaced data

Comparison of a contour plot of irregularly spaced data interpolated on a regular grid versus a tricontour plot for an unstructured triangular grid.

Since *contour* and *contourf* expect the data to live on a regular grid, plotting a contour plot of irregularly spaced data requires different methods. The two options are:

- Interpolate the data to a regular grid first. This can be done with on-board means, e.g. via *LinearTriInterpolator* or using external functionality e.g. via `scipy.interpolate.griddata`. Then plot the interpolated data with the usual *contour*.
- Directly use *tricontour* or *tricontourf* which will perform a triangulation internally.

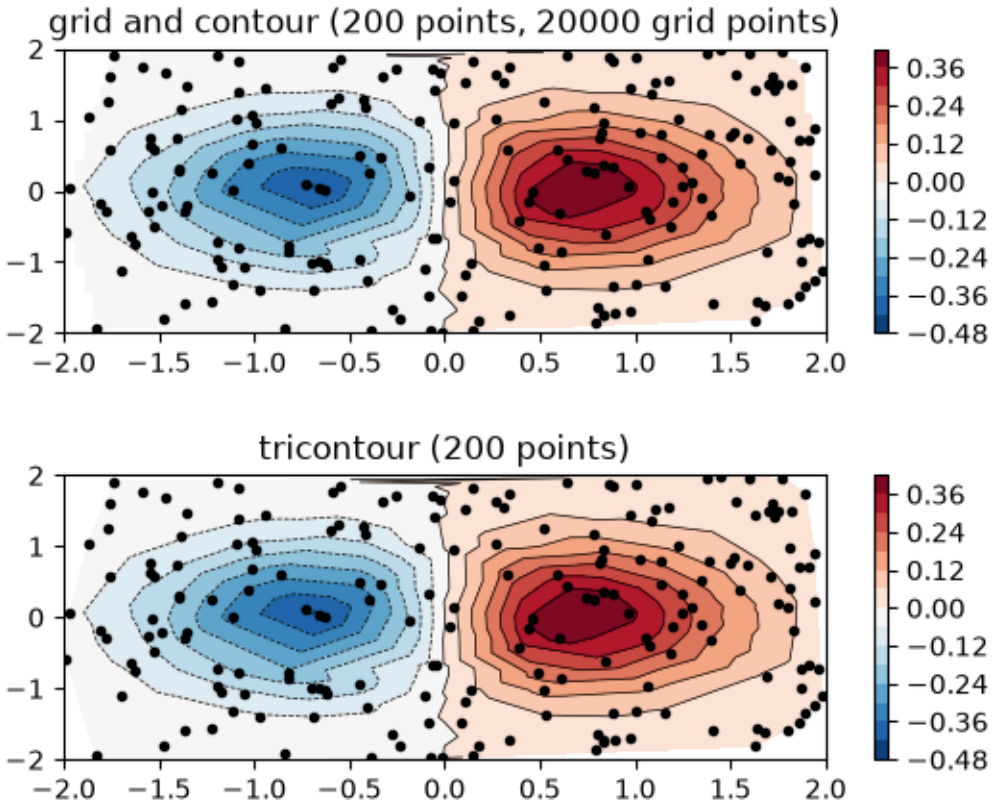
This example shows both methods in action.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.tri as tri

np.random.seed(19680801)
npts = 200
ngridx = 100
ngridy = 200
x = np.random.uniform(-2, 2, npts)
y = np.random.uniform(-2, 2, npts)
z = x * np.exp(-x**2 - y**2)

fig, (ax1, ax2) = plt.subplots(nrows=2)

# ----------------------
# Interpolation on a grid
# ----------------------
# A contour plot of irregularly spaced data coordinates
# via interpolation on a grid.

# Create grid values first.
```

(continues on next page)

(continued from previous page)

```
xi = np.linspace(-2.1, 2.1, ngridx)
yi = np.linspace(-2.1, 2.1, ngridy)

# Linearly interpolate the data (x, y) on a grid defined by (xi, yi).
triang = tri.Triangulation(x, y)
interpolator = tri.LinearTriInterpolator(triang, z)
Xi, Yi = np.meshgrid(xi, yi)
zi = interpolator(Xi, Yi)

# Note that scipy.interpolate provides means to interpolate data on a␣
 ↪grid
# as well. The following would be an alternative to the four lines␣
 ↪above:
# from scipy.interpolate import griddata
# zi = griddata((x, y), z, (xi[None, :], yi[:, None]), method='linear')

ax1.contour(xi, yi, zi, levels=14, linewidths=0.5, colors='k')
cntr1 = ax1.contourf(xi, yi, zi, levels=14, cmap="RdBu_r")

fig.colorbar(cntr1, ax=ax1)
ax1.plot(x, y, 'ko', ms=3)
ax1.set(xlim=(-2, 2), ylim=(-2, 2))
ax1.set_title('grid and contour (%d points, %d grid points)' %
              (npts, ngridx * ngridy))

# ----------
# Tricontour
# ----------
# Directly supply the unordered, irregularly spaced coordinates
# to tricontour.

ax2.tricontour(x, y, z, levels=14, linewidths=0.5, colors='k')
cntr2 = ax2.tricontourf(x, y, z, levels=14, cmap="RdBu_r")

fig.colorbar(cntr2, ax=ax2)
ax2.plot(x, y, 'ko', ms=3)
ax2.set(xlim=(-2, 2), ylim=(-2, 2))
ax2.set_title('tricontour (%d points)' % npts)

plt.subplots_adjust(hspace=0.5)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.contour* / *matplotlib.pyplot.contour*
- *matplotlib.axes.Axes.contourf* / *matplotlib.pyplot.contourf*
- *matplotlib.axes.Axes.tricontour* / *matplotlib.pyplot.tricontour*
- *matplotlib.axes.Axes.tricontourf* / *matplotlib.pyplot.tricontourf*

Contour Demo

Illustrate simple contour plotting, contours on an image with a colorbar for the contours, and labelled contours.

See also the *contour image example*.

```
import matplotlib.pyplot as plt
import numpy as np
```

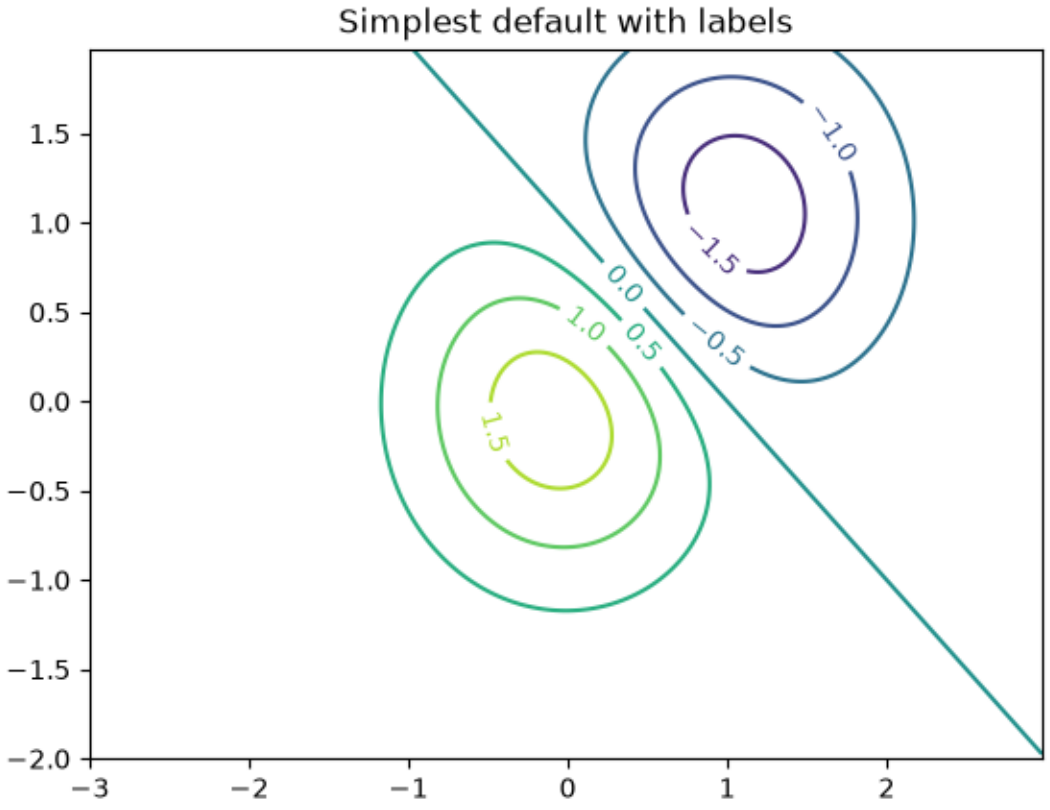
(continues on next page)

(continued from previous page)

```
delta = 0.025
x = np.arange(-3.0, 3.0, delta)
y = np.arange(-2.0, 2.0, delta)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2
```

Create a simple contour plot with labels using default colors. The inline argument to clabel will control whether the labels are draw over the line segments of the contour, removing the lines beneath the label.

```
fig, ax = plt.subplots()
CS = ax.contour(X, Y, Z)
ax.clabel(CS, fontsize=10)
ax.set_title('Simplest default with labels')
```



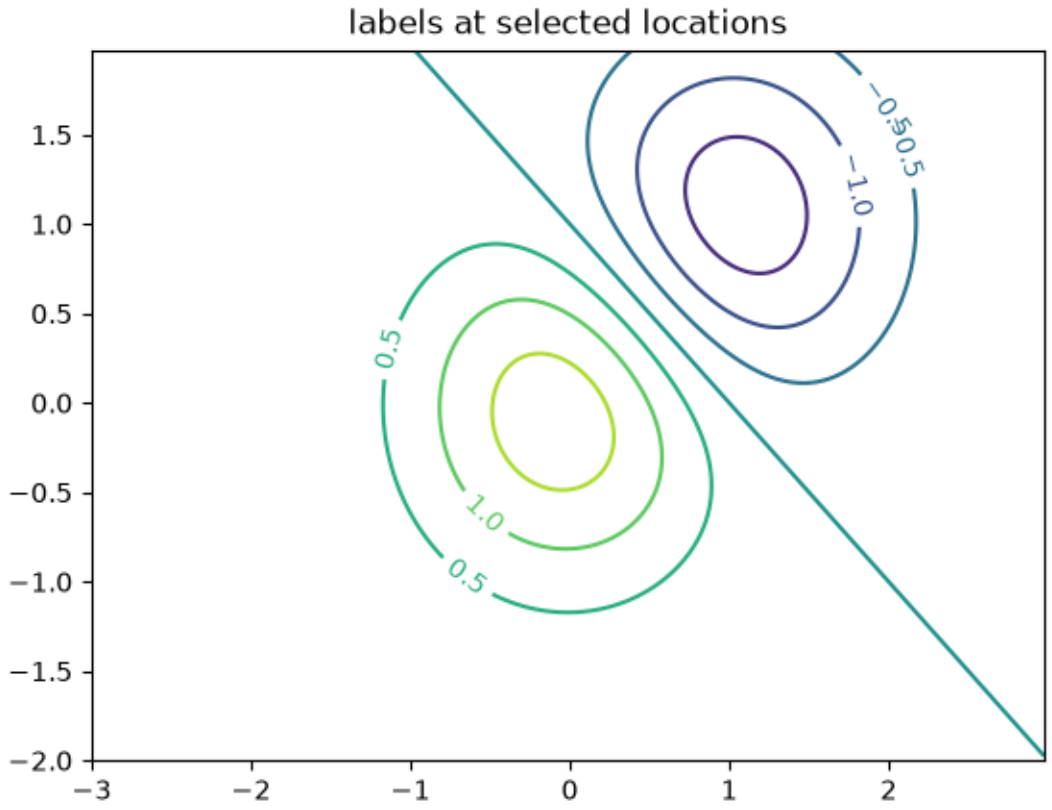
Contour labels can be placed manually by providing list of positions (in data coordinate). See *Interactive functions* for interactive placement.

```
fig, ax = plt.subplots()
```

(continues on next page)

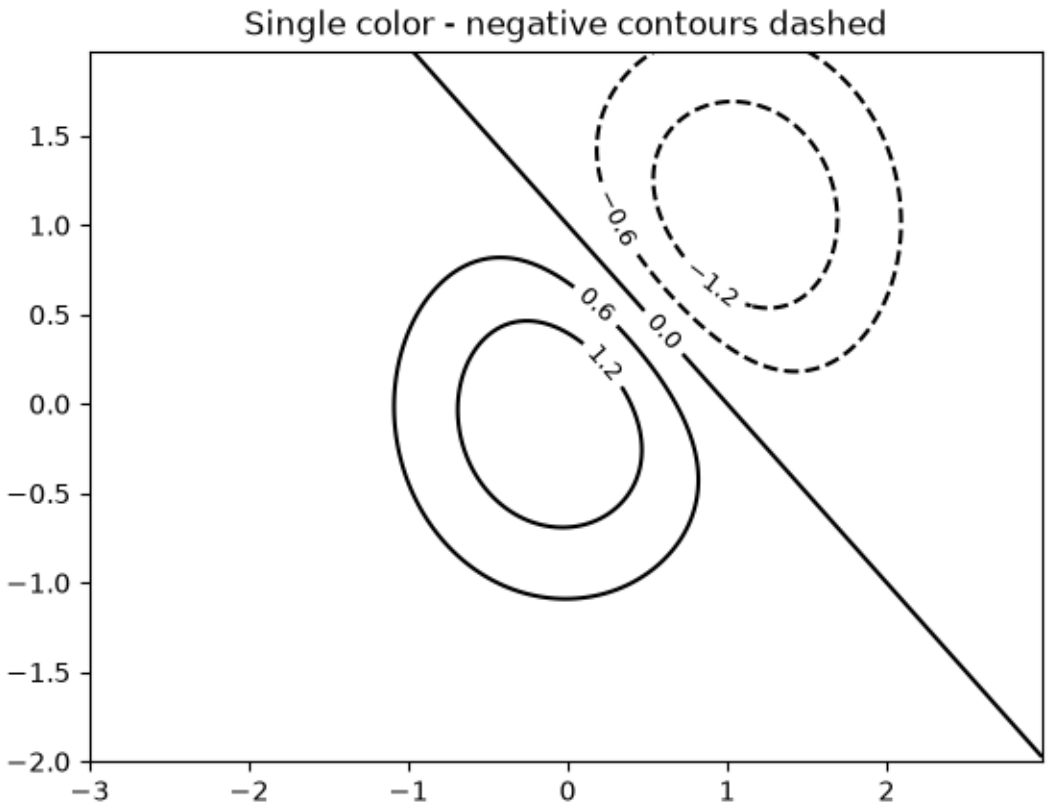
(continued from previous page)

```
CS = ax.contour(X, Y, Z)
manual_locations = [
    (-1, -1.4), (-0.62, -0.7), (-2, 0.5), (1.7, 1.2), (2.0, 1.4), (2.4,
 ↪ 1.7)]
ax.clabel(CS, fontsize=10, manual=manual_locations)
ax.set_title('labels at selected locations')
```



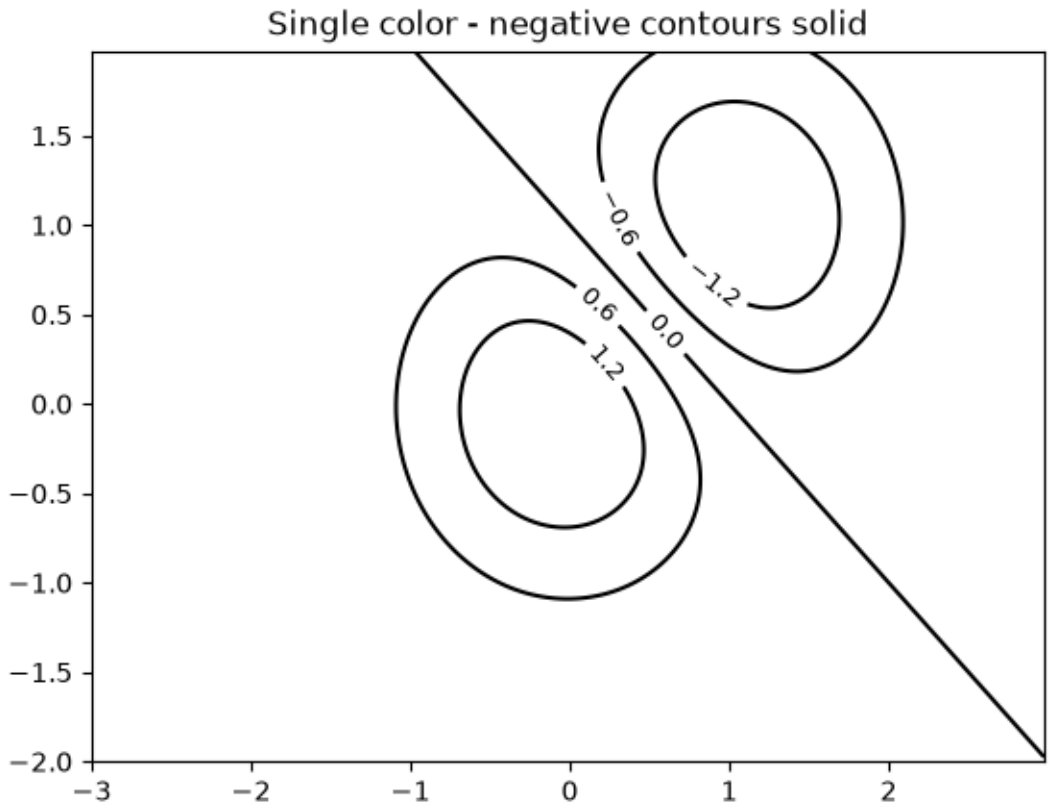
You can force all the contours to be the same color.

```
fig, ax = plt.subplots()
CS = ax.contour(X, Y, Z, 6, colors='k')  # Negative contours default␣
 ↪to dashed.
ax.clabel(CS, fontsize=9)
ax.set_title('Single color - negative contours dashed')
```



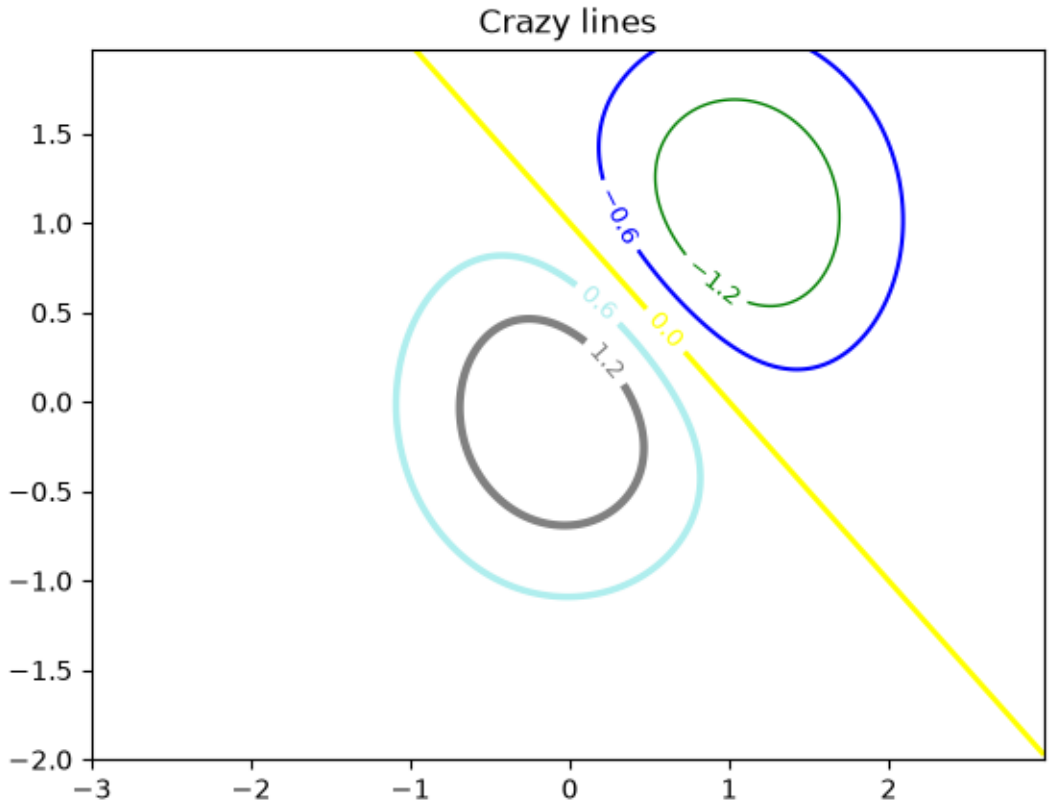
You can set negative contours to be solid instead of dashed:

```
plt.rcParams['contour.negative_linestyle'] = 'solid'
fig, ax = plt.subplots()
CS = ax.contour(X, Y, Z, 6, colors='k')  # Negative contours default␣
↪to dashed.
ax.clabel(CS, fontsize=9)
ax.set_title('Single color - negative contours solid')
```



And you can manually specify the colors of the contour

```
fig, ax = plt.subplots()
CS = ax.contour(X, Y, Z, 6,
                linewidths=np.arange(.5, 4, .5),
                colors=('r', 'green', 'blue', (1, 1, 0), '#afeeee',
 ↪'0.5'),
                )
ax.clabel(CS, fontsize=9)
ax.set_title('Crazy lines')
```



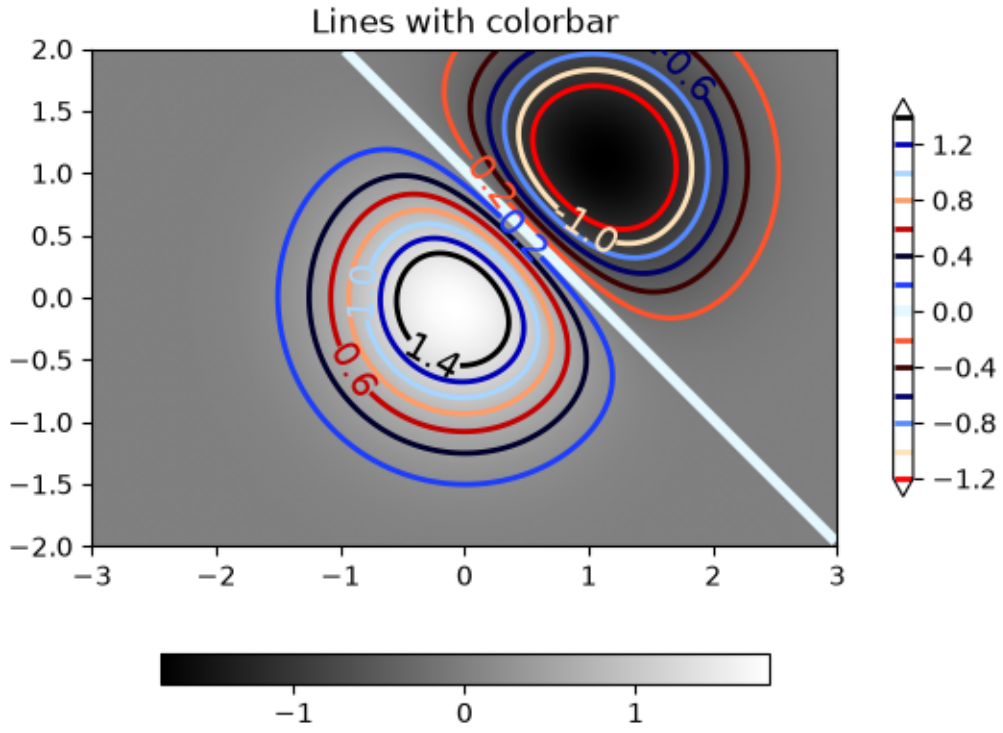
Or you can use a colormap to specify the colors; the default colormap will be used for the contour lines

```
fig, ax = plt.subplots()
im = ax.imshow(Z, interpolation='bilinear', origin='lower',
               cmap="gray", extent=(-3, 3, -2, 2))
levels = np.arange(-1.2, 1.6, 0.2)
CS = ax.contour(Z, levels, origin='lower', cmap='flag', extend='both',
                linewidths=2, extent=(-3, 3, -2, 2))

# Thicken the zero contour.
lws = np.resize(CS.get_linewidth(), len(levels))
lws[6] = 4
CS.set_linewidth(lws)

ax.clabel(CS, levels[1::2],  # label every second level
          fmt='%1.1f', fontsize=14)

# make a colorbar for the contour lines
CB = fig.colorbar(CS, shrink=0.8)

ax.set_title('Lines with colorbar')
```

(continues on next page)

(continued from previous page)

```
# We can still add a colorbar for the image, too.
CBI = fig.colorbar(im, orientation='horizontal', shrink=0.8)

# This makes the original colorbar look a bit out of place,
# so let's improve its position.

l, b, w, h = ax.get_position().bounds
ll, bb, ww, hh = CB.ax.get_position().bounds
CB.ax.set_position([ll, b + 0.1*h, ww, h*0.8])

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.contour / matplotlib.pyplot.contour*
- *matplotlib.figure.Figure.colorbar / matplotlib.pyplot.colorbar*

- *matplotlib.axes.Axes.clabel* / *matplotlib.pyplot.clabel*
- *matplotlib.axes.Axes.get_position*
- *matplotlib.axes.Axes.set_position*

Total running time of the script: (0 minutes 2.083 seconds)

Contour Label Demo

Illustrate some of the more advanced things that one can do with contour labels.

See also the *contour demo example*.

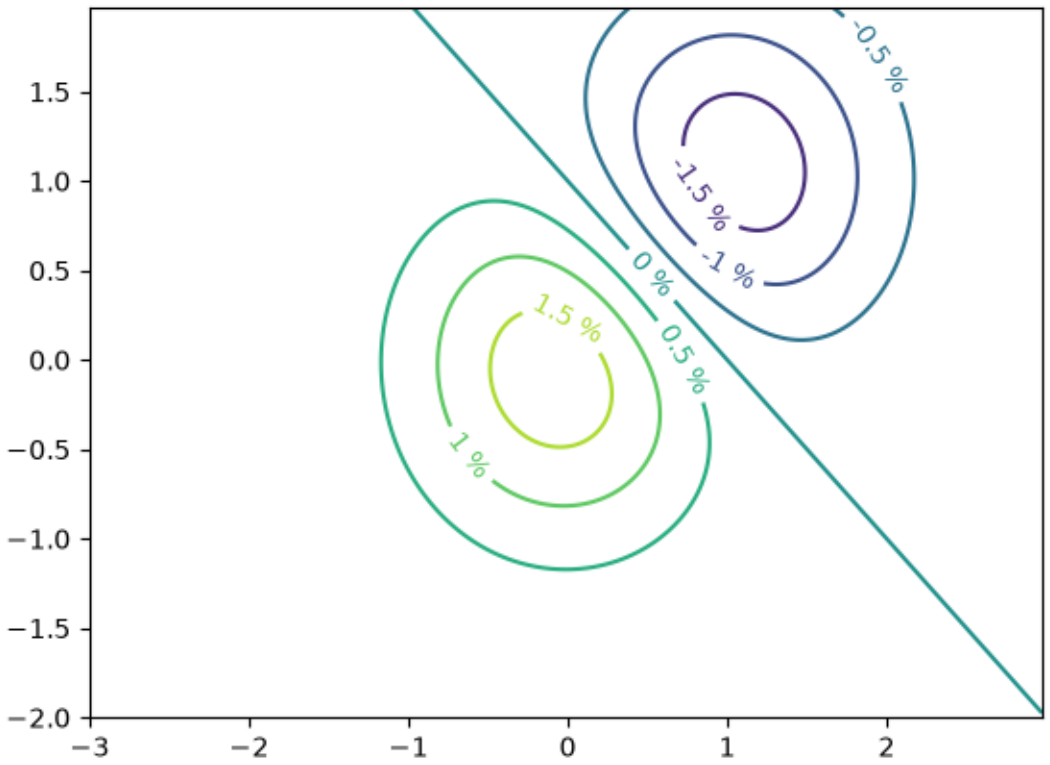
```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.ticker as ticker
```

Define our surface

```
delta = 0.025
x = np.arange(-3.0, 3.0, delta)
y = np.arange(-2.0, 2.0, delta)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2
```

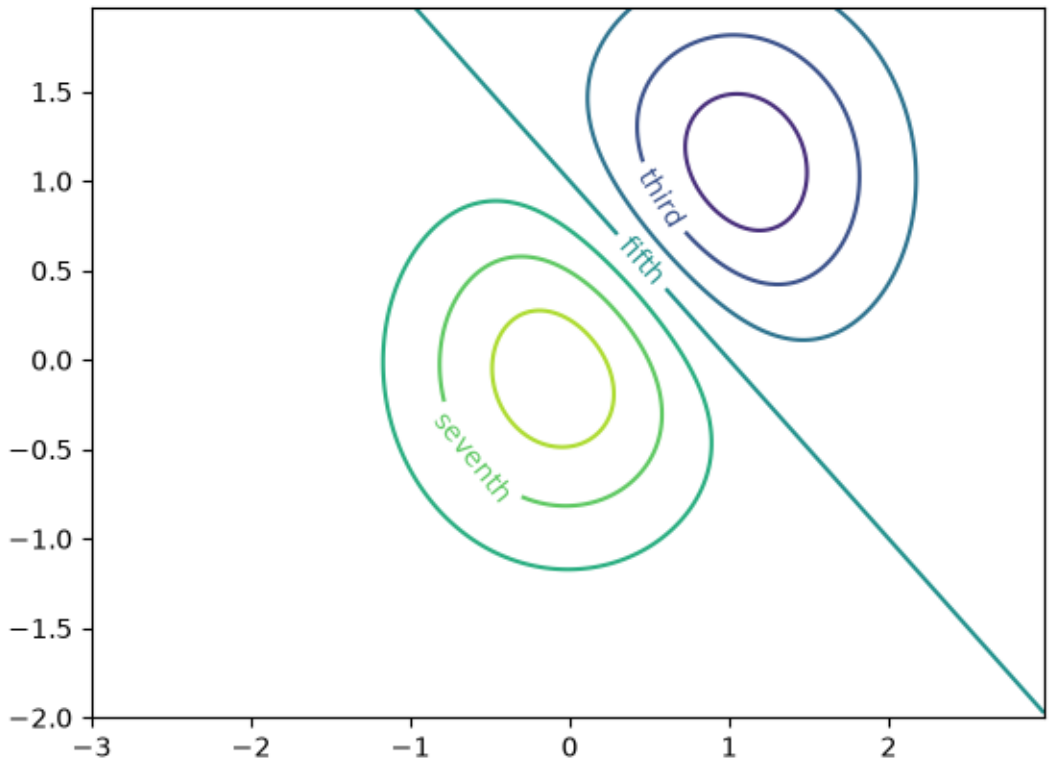
Make contour labels with custom level formatters

```
# This custom formatter removes trailing zeros, e.g. "1.0" becomes
 ↪"1", and
# then adds a percent sign.
def fmt(x):
    s = f"{x:.1f}"
    if s.endswith("0"):
        s = f"{x:.0f}"
    return rf"{s} \%" if plt.rcParams["text.usetex"] else f"{s} %"


# Basic contour plot
fig, ax = plt.subplots()
CS = ax.contour(X, Y, Z)

ax.clabel(CS, CS.levels, fmt=fmt, fontsize=10)
```



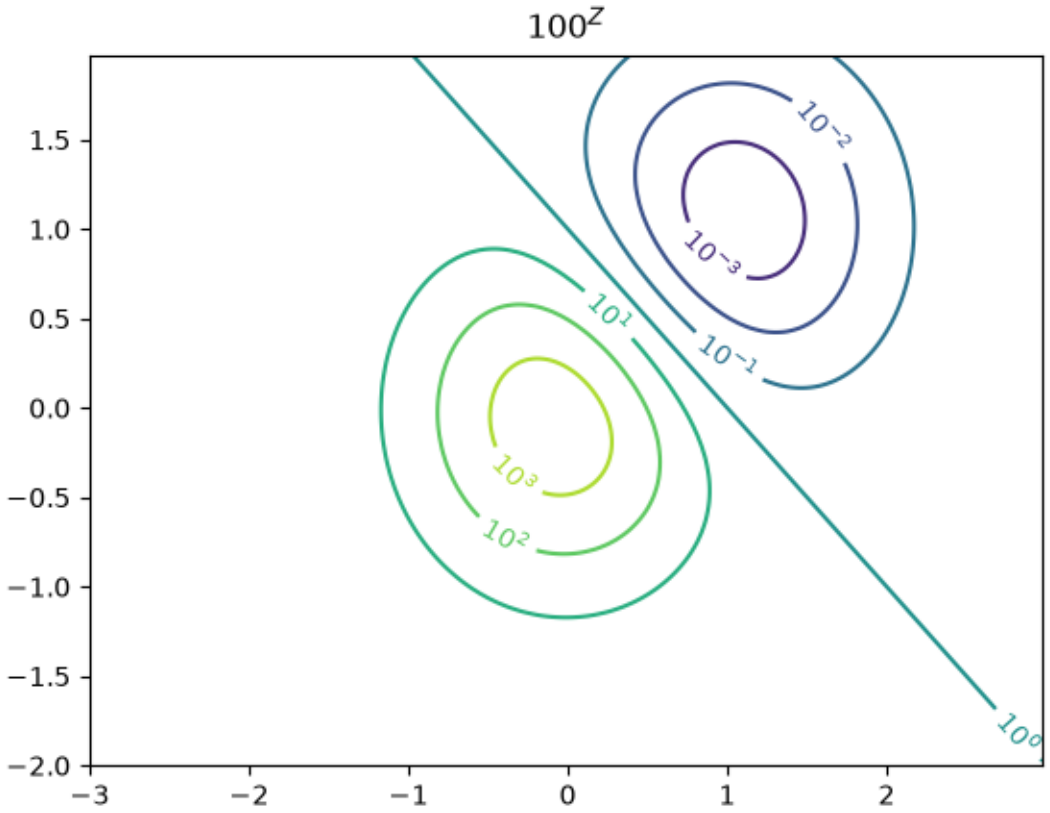
Label contours with arbitrary strings using a dictionary

```
fig1, ax1 = plt.subplots()

# Basic contour plot
CS1 = ax1.contour(X, Y, Z)

fmt = {}
strs = ['first', 'second', 'third', 'fourth', 'fifth', 'sixth',
 ↪'seventh']
for l, s in zip(CS1.levels, strs):
    fmt[l] = s

# Label every other level using strings
ax1.clabel(CS1, CS1.levels[::2], fmt=fmt, fontsize=10)
```



Use a Formatter

```
fig2, ax2 = plt.subplots()

CS2 = ax2.contour(X, Y, 100**Z, locator=plt.LogLocator())
fmt = ticker.LogFormatterMathtext()
fmt.create_dummy_axis()
ax2.clabel(CS2, CS2.levels, fmt=fmt)
ax2.set_title("$100^Z$")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.contour* / *matplotlib.pyplot.contour*
- *matplotlib.axes.Axes.clabel* / *matplotlib.pyplot.clabel*
- *matplotlib.ticker.LogFormatterMathtext*
- *matplotlib.ticker.TickHelper.create_dummy_axis*

Total running time of the script: (0 minutes 1.087 seconds)

Contourf demo

How to use the *axes.Axes.contourf* method to create filled contour plots.

```
import matplotlib.pyplot as plt
import numpy as np

delta = 0.025
```

(continues on next page)

(continued from previous page)

```
x = y = np.arange(-3.0, 3.01, delta)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2

nr, nc = Z.shape

# put NaNs in one corner:
Z[-nr // 6:, -nc // 6:] = np.nan
# contourf will convert these to masked


Z = np.ma.array(Z)
# mask another corner:
Z[:nr // 6, :nc // 6] = np.ma.masked

# mask a circle in the middle:
interior = np.sqrt(X**2 + Y**2) < 0.5
Z[interior] = np.ma.masked
```

Automatic contour levels

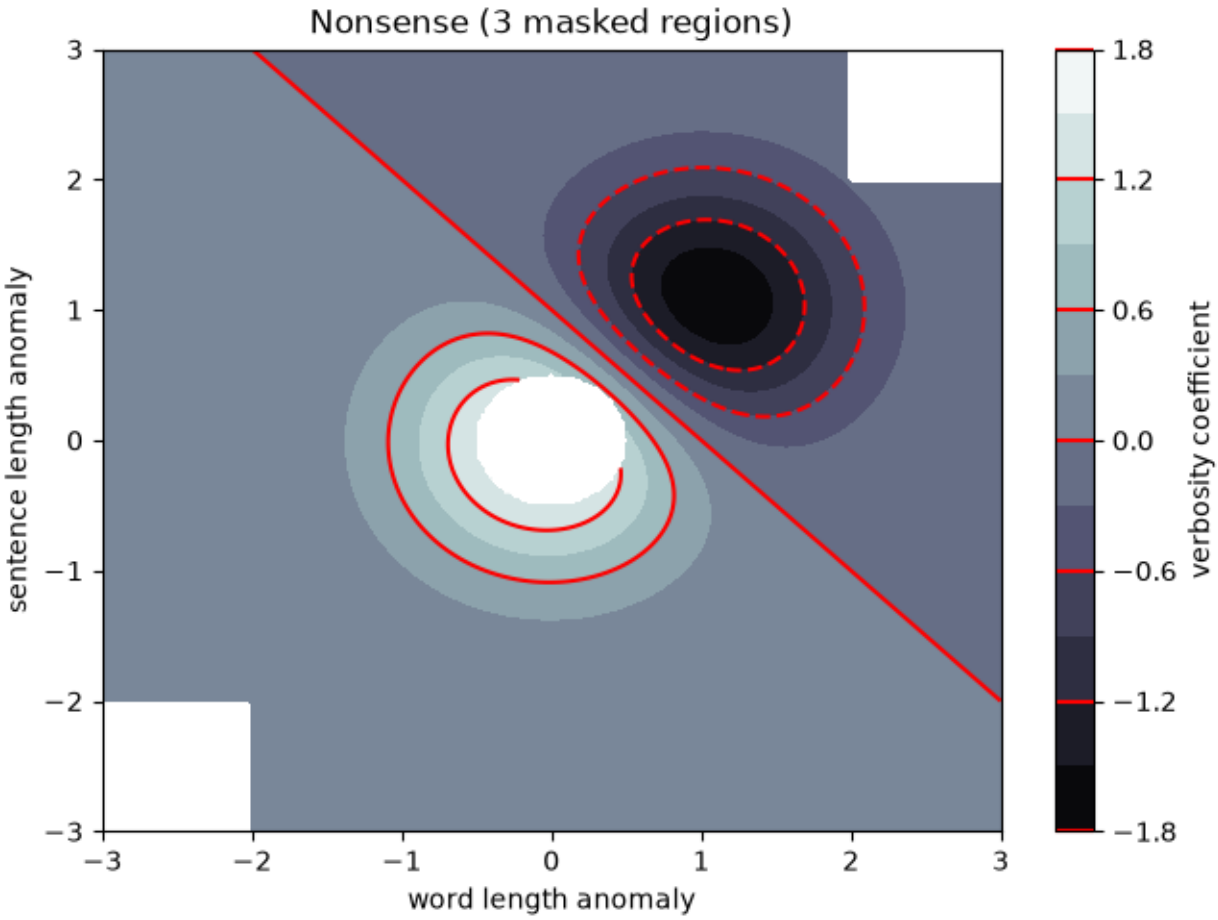
We are using automatic selection of contour levels; this is usually not such a good idea, because they don't occur on nice boundaries, but we do it here for purposes of illustration.

```
fig1, ax2 = plt.subplots(layout='constrained')
CS = ax2.contourf(X, Y, Z, 10, cmap="bone")

# Note that in the following, we explicitly pass in a subset of the␣
 ↪contour
# levels used for the filled contours.  Alternatively, we could pass in
# additional levels to provide extra resolution, or leave out the␣
 ↪*levels*
# keyword argument to use all of the original levels.

CS2 = ax2.contour(CS, levels=CS.levels[::2], colors='r')

ax2.set_title('Nonsense (3 masked regions)')
ax2.set_xlabel('word length anomaly')
ax2.set_ylabel('sentence length anomaly')

# Make a colorbar for the ContourSet returned by the contourf call.
cbar = fig1.colorbar(CS)
```

(continues on next page)

(continued from previous page)

```
cbar.ax.set_ylabel('verbosity coefficient')
# Add the contour line levels to the colorbar
cbar.add_lines(CS2)
```



Explicit contour levels

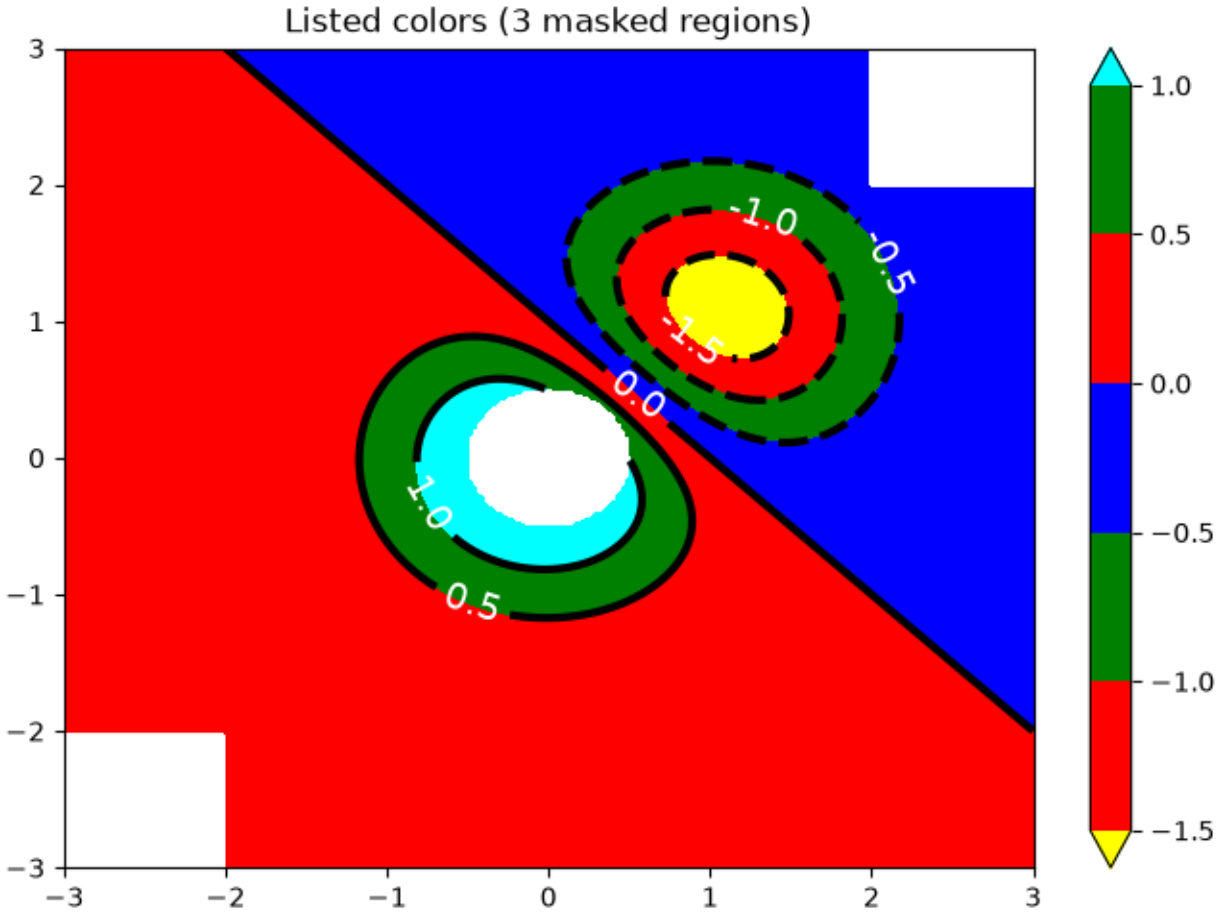
Now make a contour plot with the levels specified, and with the colormap generated automatically from a list of colors.

```
fig2, ax2 = plt.subplots(layout='constrained')
levels = [-1.5, -1, -0.5, 0, 0.5, 1]
CS3 = ax2.contourf(X, Y, Z, levels, colors=('r', 'g', 'b'), extend=
 ↪'both')
# Our data range extends outside the range of levels; make
# data below the lowest contour level yellow, and above the
# highest level cyan:
CS3.cmap.set_under('yellow')
CS3.cmap.set_over('cyan')
```

(continues on next page)

(continued from previous page)

```
CS4 = ax2.contour(X, Y, Z, levels, colors=('k',), linewidths=(3,))
ax2.set_title('Listed colors (3 masked regions)')
ax2.clabel(CS4, fmt='%2.1f', colors='w', fontsize=14)

# Notice that the colorbar gets all the information it
# needs from the ContourSet object, CS3.
fig2.colorbar(CS3)
```



Extension settings

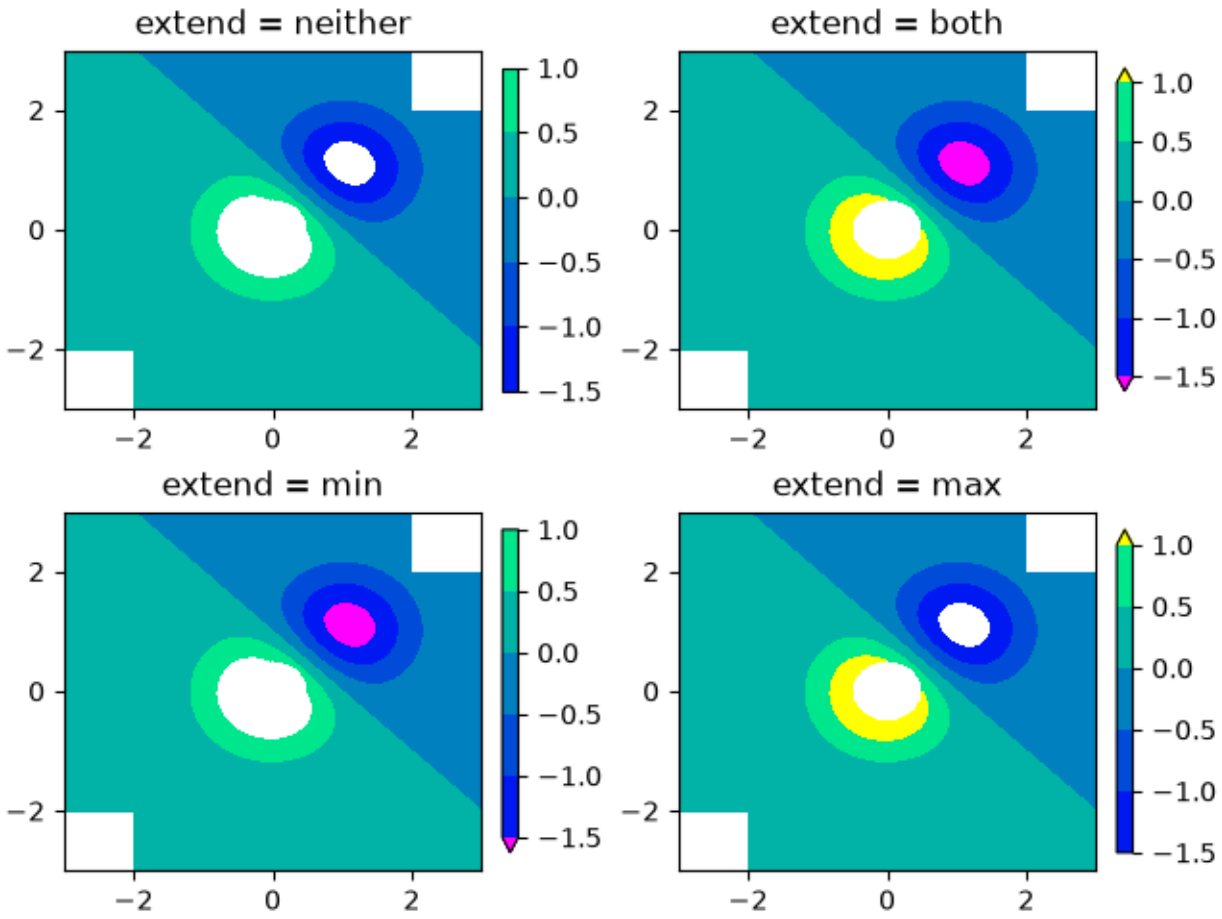
Illustrate all 4 possible "extend" settings:

```
extends = ["neither", "both", "min", "max"]
cmap = plt.colormaps["winter"].with_extremes(under="magenta", over=
 ↪"yellow")
# Note: contouring simply excludes masked or nan regions, so
# instead of using the "bad" colormap value for them, it draws
# nothing at all in them.  Therefore, the following would have
# no effect:
```

(continues on next page)

(continued from previous page)

```
# cmap.set_bad("red")

fig, axs = plt.subplots(2, 2, layout="constrained")

for ax, extend in zip(axs.flat, extends):
    cs = ax.contourf(X, Y, Z, levels, cmap=cmap, extend=extend)
    fig.colorbar(cs, ax=ax, shrink=0.9)
    ax.set_title("extend = %s" % extend)
    ax.locator_params(nbins=4)

plt.show()
```



Orient contour plots using the origin keyword

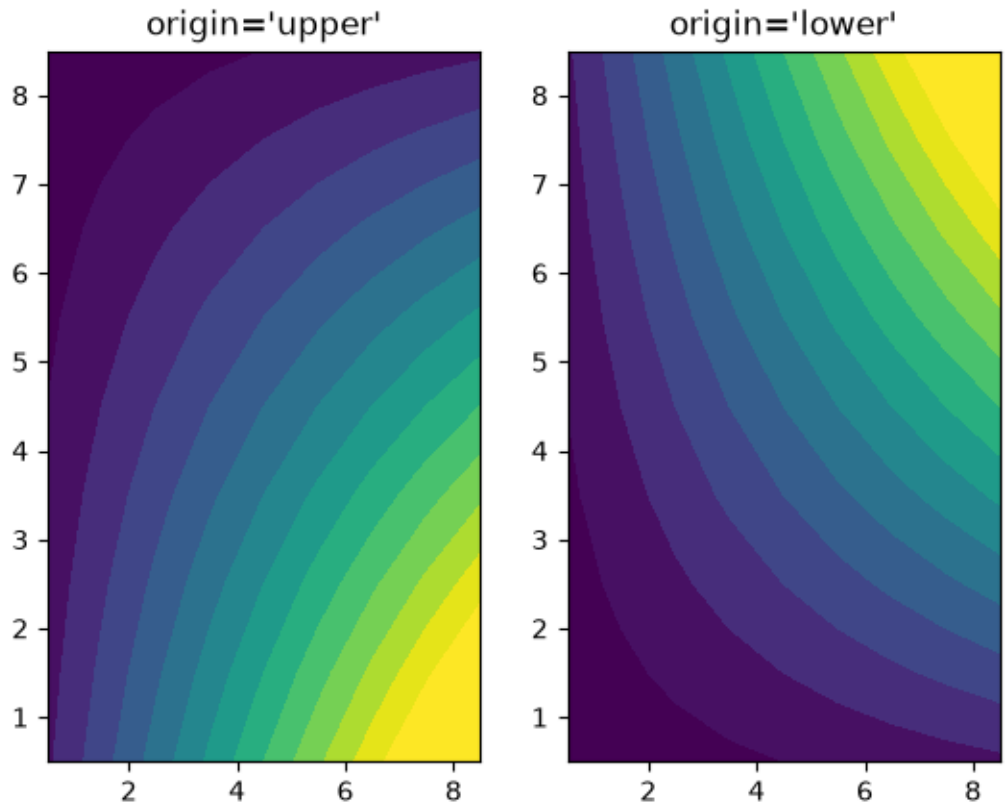
This code demonstrates orienting contour plot data using the "origin" keyword

```
x = np.arange(1, 10)
y = x.reshape(-1, 1)
h = x * y
```

(continues on next page)

(continued from previous page)

```
fig, (ax1, ax2) = plt.subplots(ncols=2)

ax1.set_title("origin='upper'")
ax2.set_title("origin='lower'")
ax1.contourf(h, levels=np.arange(5, 70, 5), extend='both', origin=
 ↪"upper")
ax2.contourf(h, levels=np.arange(5, 70, 5), extend='both', origin=
 ↪"lower")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.contour* / *matplotlib.pyplot.contour*
- *matplotlib.axes.Axes.contourf* / *matplotlib.pyplot.contourf*
- *matplotlib.axes.Axes.clabel* / *matplotlib.pyplot.clabel*

- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.colors.Colormap*
- *matplotlib.colors.Colormap.set_bad*
- *matplotlib.colors.Colormap.set_under*
- *matplotlib.colors.Colormap.set_over*

Total running time of the script: (0 minutes 1.942 seconds)

Contour image

Test combinations of contouring, filled contouring, and image plotting. For contour labelling, see also the *contour demo example*.

The emphasis in this demo is on showing how to make contours register correctly on images, and on how to get both of them oriented as desired. In particular, note the usage of the *"origin" and "extent"* keyword arguments to imshow and contour.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import cm

# Default delta is large because that makes it fast, and it illustrates
# the correct registration between image and contours.
delta = 0.5

extent = (-3, 4, -4, 3)

x = np.arange(-3.0, 4.001, delta)
y = np.arange(-4.0, 3.001, delta)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2

# Boost the upper limit to avoid truncation errors.
levels = np.arange(-2.0, 1.601, 0.4)

norm = cm.colors.Normalize(vmax=abs(Z).max(), vmin=-abs(Z).max())
cmap = plt.colormaps["PRGn"]

fig, _axs = plt.subplots(nrows=2, ncols=2)
fig.subplots_adjust(hspace=0.3)
axs = _axs.flatten()

```

(continues on next page)

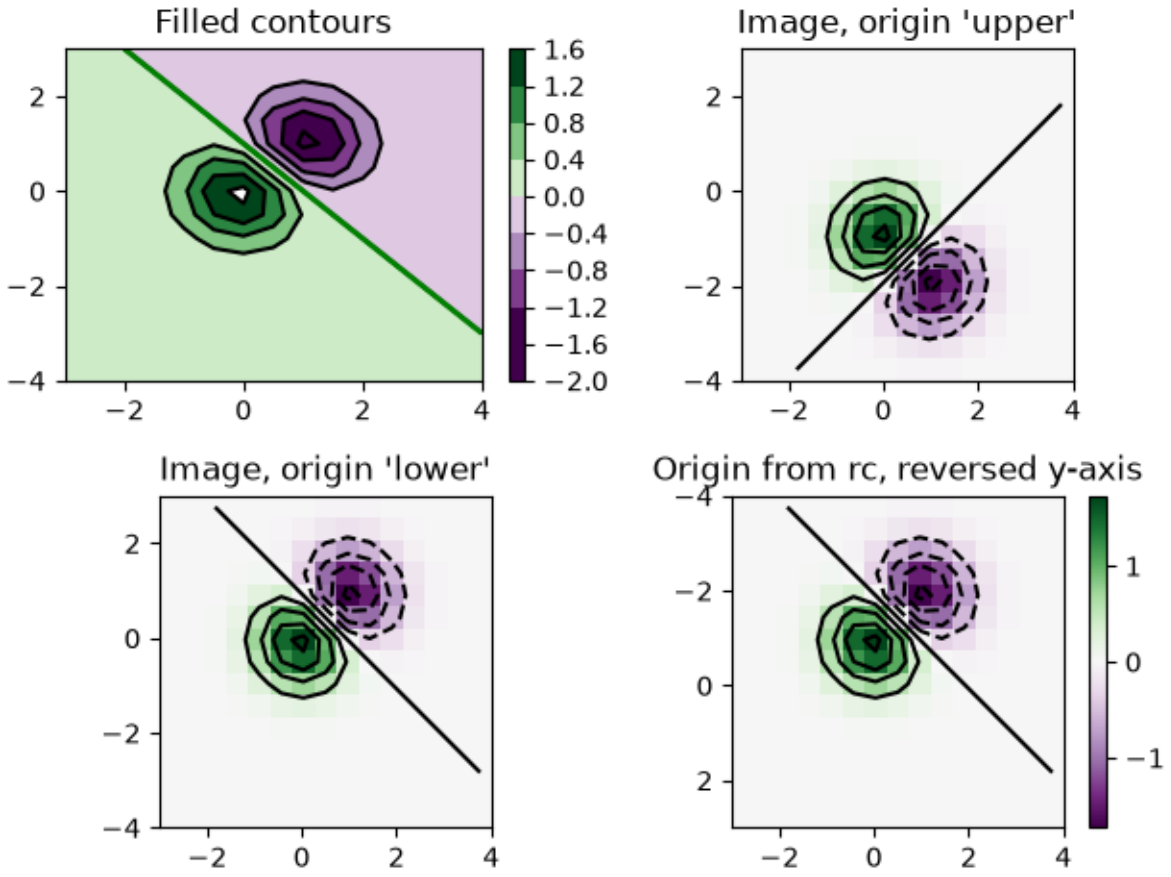
(continued from previous page)

```
cset1 = axs[0].contourf(X, Y, Z, levels, norm=norm,
                        cmap=cmap.resampled(len(levels) - 1))
# It is not necessary, but for the colormap, we need only the
# number of levels minus 1.  To avoid discretization error, use
# either this number or a large number such as the default (256).

# If we want lines as well as filled regions, we need to call
# contour separately; don't try to change the edgecolor or edgewidth
# of the polygons in the collections returned by contourf.
# Use levels output from previous call to guarantee they are the same.

cset2 = axs[0].contour(X, Y, Z, cset1.levels, colors='k')

# We don't really need dashed contour lines to indicate negative
# regions, so let's turn them off.
cset2.set_linestyle('solid')

# It is easier here to make a separate call to contour than
# to set up an array of colors and linewidths.
# We are making a thick green line as a zero contour.
# Specify the zero level as a tuple with only 0 in it.

cset3 = axs[0].contour(X, Y, Z, (0,), colors='g', linewidths=2)
axs[0].set_title('Filled contours')
fig.colorbar(cset1, ax=axs[0])


axs[1].imshow(Z, extent=extent, cmap=cmap, norm=norm)
axs[1].contour(Z, levels, colors='k', origin='upper', extent=extent)
axs[1].set_title("Image, origin 'upper'")

axs[2].imshow(Z, origin='lower', extent=extent, cmap=cmap, norm=norm)
axs[2].contour(Z, levels, colors='k', origin='lower', extent=extent)
axs[2].set_title("Image, origin 'lower'")

# We will use the interpolation "nearest" here to show the actual
# image pixels.
# Note that the contour lines don't extend to the edge of the box.
# This is intentional. The Z values are defined at the center of each
# image pixel (each color block on the following subplot), so the
# domain that is contoured does not extend beyond these pixel centers.
im = axs[3].imshow(Z, interpolation='nearest', extent=extent,
                   cmap=cmap, norm=norm)
axs[3].contour(Z, levels, colors='k', origin='image', extent=extent)
ylim = axs[3].get_ylim()
axs[3].set_ylim(ylim[::-1])
```

(continues on next page)

(continued from previous page)

```
axs[3].set_title("Origin from rc, reversed y-axis")
fig.colorbar(im, ax=axs[3])

fig.tight_layout()
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.contour* / *matplotlib.pyplot.contour*
- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.colors.Normalize*

Contourf and log color scale

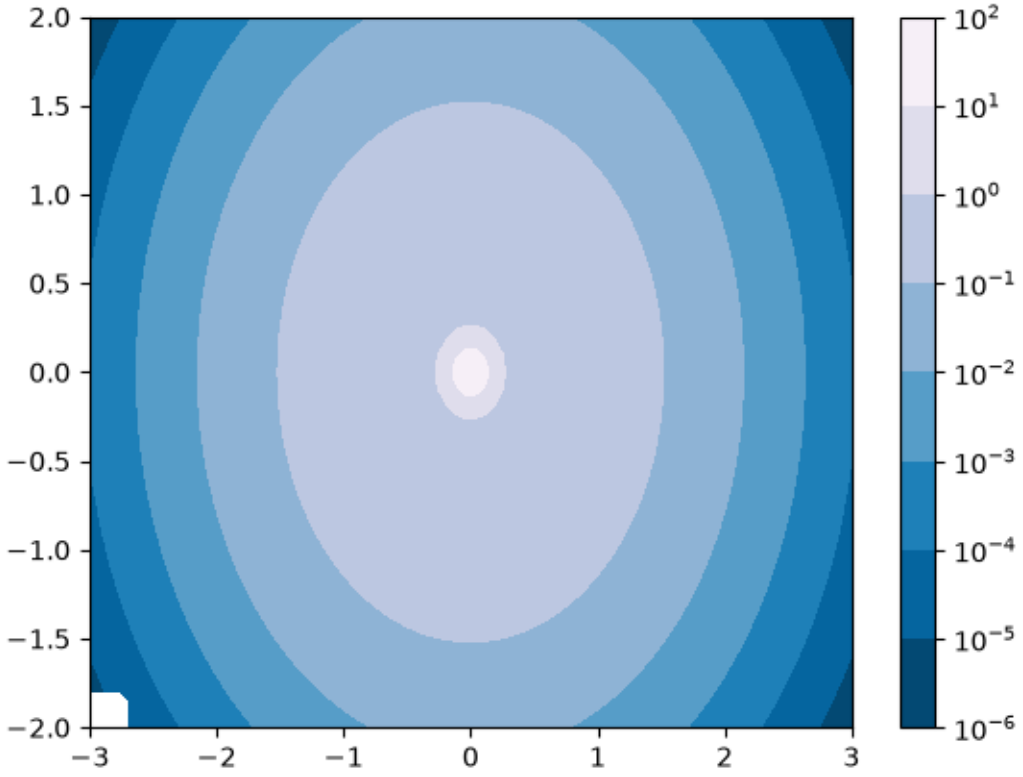
Demonstrate use of a log color scale in contourf

```
import matplotlib.pyplot as plt
import numpy as np
from numpy import ma

from matplotlib import ticker

N = 100
x = np.linspace(-3.0, 3.0, N)
y = np.linspace(-2.0, 2.0, N)

X, Y = np.meshgrid(x, y)

# A low hump with a spike coming out.
# Needs to have z/colour axis on a log scale, so we see both hump and␣
 ↪spike.
# A linear scale only shows the spike.
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X * 10)**2 - (Y * 10)**2)
z = Z1 + 50 * Z2

# Put in some negative values (lower left corner) to cause trouble␣
 ↪with logs:
z[:5, :5] = -1

# The following is not strictly essential, but it will eliminate
# a warning.  Comment it out to see the warning.
z = ma.masked_where(z <= 0, z)


# Automatic selection of levels works; setting the
# log locator tells contourf to use a log scale:
fig, ax = plt.subplots()
```

(continues on next page)

(continued from previous page)

```
cs = ax.contourf(X, Y, z, locator=ticker.LogLocator(), cmap="PuBu_r")

# Alternatively, you can manually set the levels
# and the norm:
# lev_exp = np.arange(np.floor(np.log10(z.min())-1),
#                     np.ceil(np.log10(z.max())+1))
# levs = np.power(10, lev_exp)
# cs = ax.contourf(X, Y, z, levs, norm=colors.LogNorm())

cbar = fig.colorbar(cs)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.contourf* / *matplotlib.pyplot.contourf*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*

- *matplotlib.axes.Axes.legend* / *matplotlib.pyplot.legend*
- *matplotlib.ticker.LogLocator*

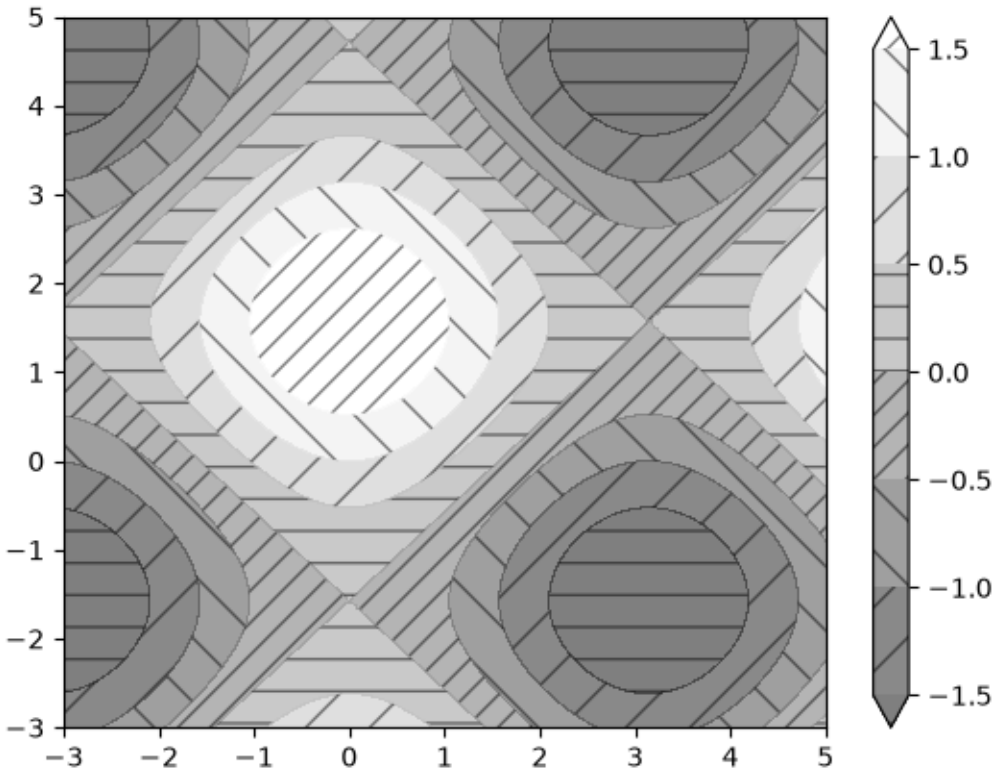
Contourf hatching

Demo filled contour plots with hatched patterns.

```
import matplotlib.pyplot as plt
import numpy as np

# invent some numbers, turning the x and y arrays into simple
# 2d arrays, which make combining them together easier.
x = np.linspace(-3, 5, 150).reshape(1, -1)
y = np.linspace(-3, 5, 120).reshape(-1, 1)
z = np.cos(x) + np.sin(y)

# we no longer need x and y to be 2 dimensional, so flatten them.
x, y = x.flatten(), y.flatten()
```

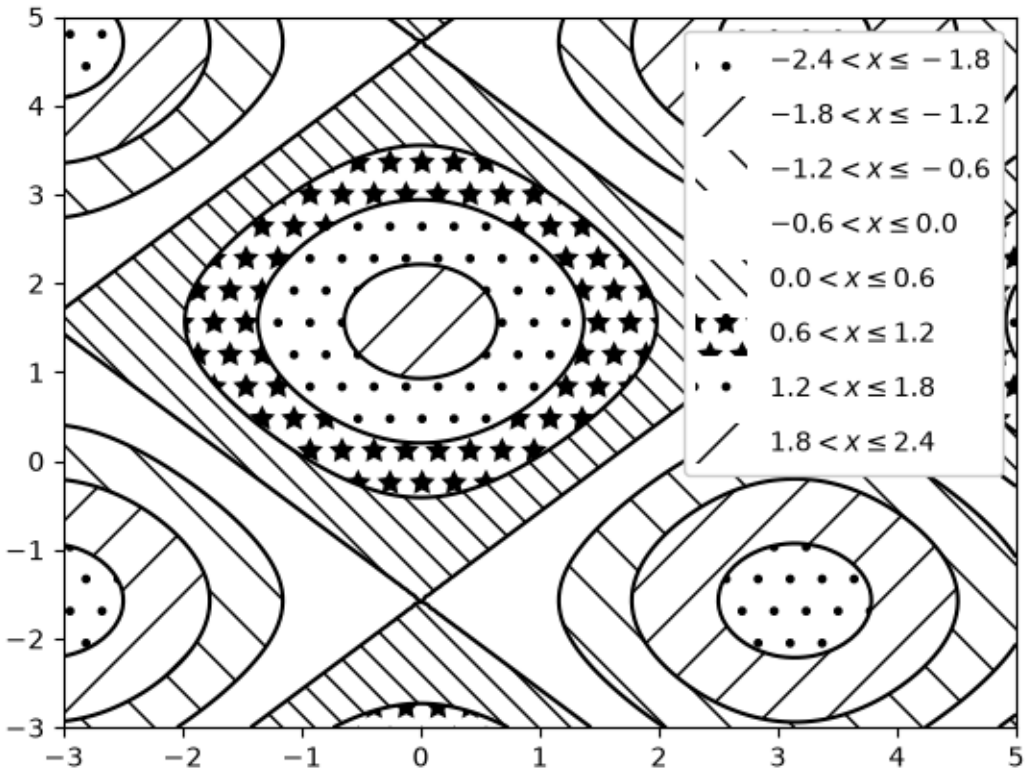
Plot 1: the simplest hatched plot with a colorbar

```
fig1, ax1 = plt.subplots()
cs = ax1.contourf(x, y, z, hatches=['-', '/', '\\', '//'],
                  cmap='gray', extend='both', alpha=0.5)
fig1.colorbar(cs)
```



Plot 2: a plot of hatches without color with a legend

```
fig2, ax2 = plt.subplots()
n_levels = 6
ax2.contour(x, y, z, n_levels, colors='black', linestyles='-')
cs = ax2.contourf(x, y, z, n_levels, colors='none',
                  hatches=['.', '/', '\\', None, '\\\\', '*'],
                  extend='lower')

# create a legend for the contour set
artists, labels = cs.legend_elements(str_format='{:2.1f}'.format)
ax2.legend(artists, labels, handleheight=2, framealpha=1)
plt.show()
```



References

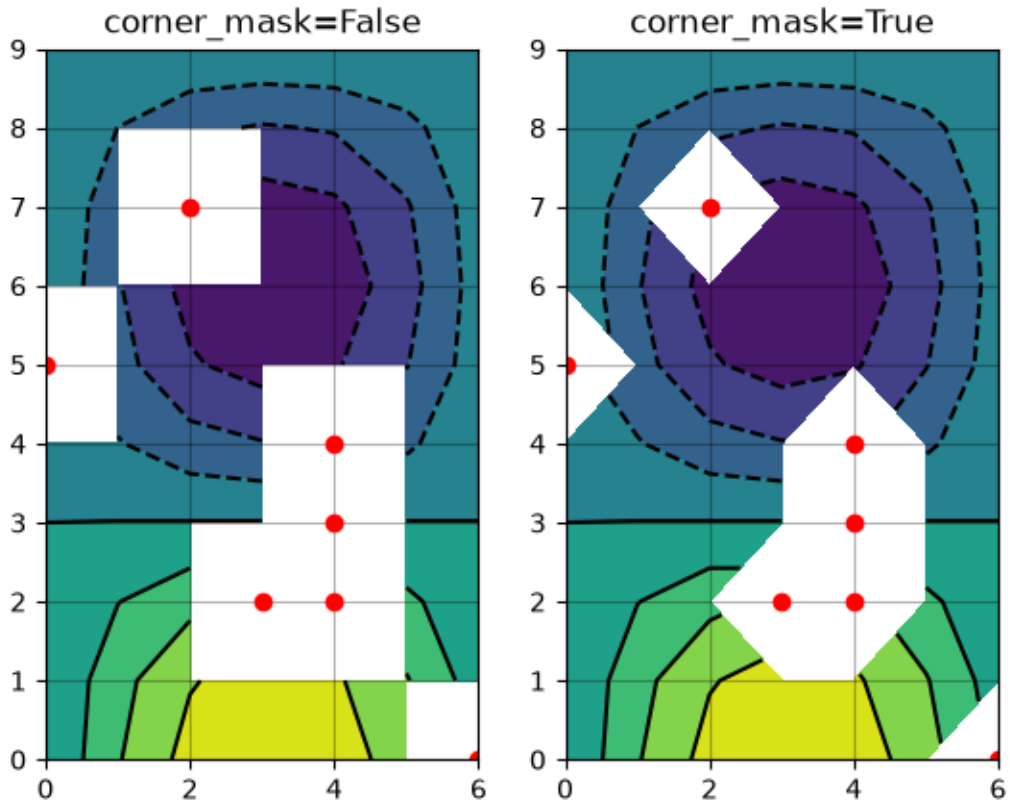
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.contour* / *matplotlib.pyplot.contour*
- *matplotlib.axes.Axes.contourf* / *matplotlib.pyplot.contourf*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.axes.Axes.legend* / *matplotlib.pyplot.legend*
- *matplotlib.contour.ContourSet*
- *matplotlib.contour.ContourSet.legend_elements*

Contour corner mask

Illustrate the difference between `corner_mask=False` and `corner_mask=True` for masked contour plots. The default is controlled by *rcParams["contour.corner_mask"]* (default: `True`).

```
import matplotlib.pyplot as plt
import numpy as np

# Data to plot.
x, y = np.meshgrid(np.arange(7), np.arange(10))
z = np.sin(0.5 * x) * np.cos(0.52 * y)

# Mask various z values.
mask = np.zeros_like(z, dtype=bool)
mask[2, 3:5] = True
mask[3:5, 4] = True
mask[7, 2] = True
mask[5, 0] = True
mask[0, 6] = True
z = np.ma.array(z, mask=mask)

corner_masks = [False, True]
fig, axs = plt.subplots(ncols=2)
for ax, corner_mask in zip(axs, corner_masks):
    cs = ax.contourf(x, y, z, corner_mask=corner_mask)
    ax.contour(cs, colors='k')
    ax.set_title(f'{corner_mask=}')

    # Plot grid.
    ax.grid(c='k', ls='-', alpha=0.3)

    # Indicate masked points with red circles.
    ax.plot(np.ma.array(x, mask=~mask), y, 'ro')

plt.show()
```



References

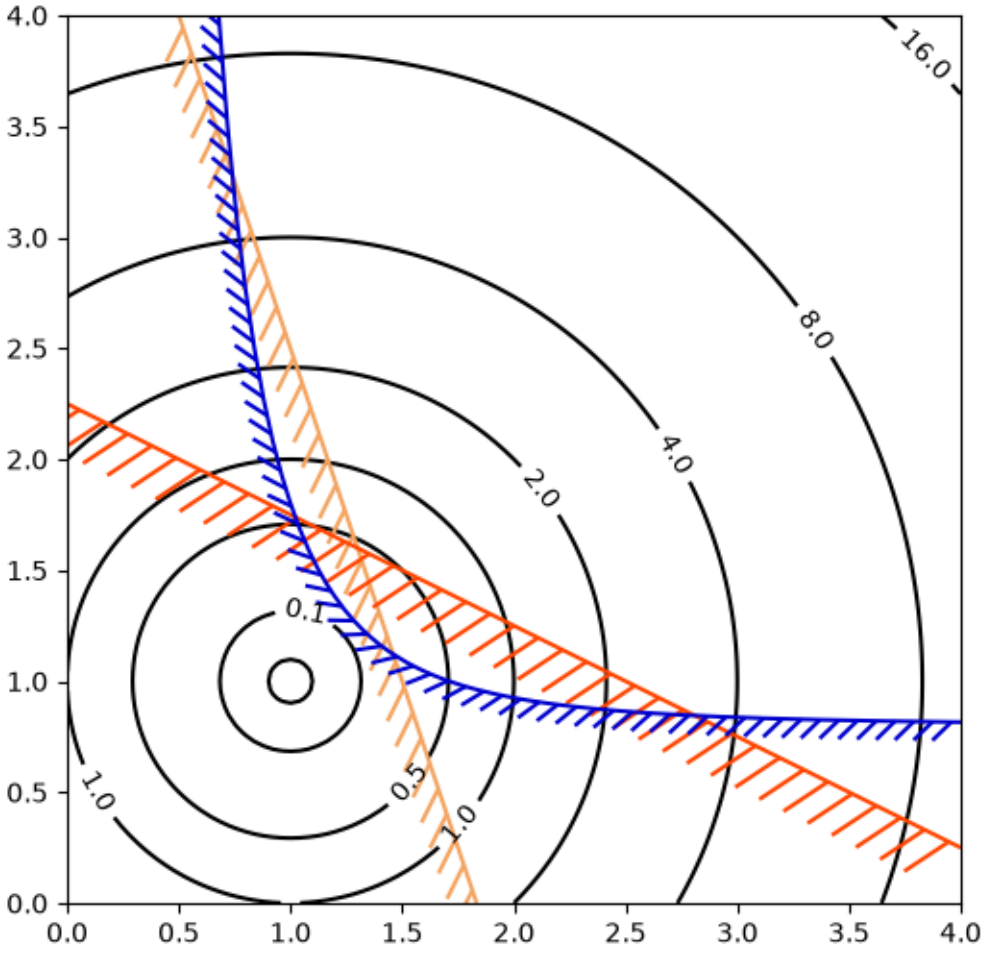
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.contour* / *matplotlib.pyplot.contour*
- *matplotlib.axes.Axes.contourf* / *matplotlib.pyplot.contourf*

Contouring the solution space of optimizations

Contour plotting is particularly handy when illustrating the solution space of optimization problems. Not only can *axes.Axes.contour* be used to represent the topography of the objective function, it can be used to generate boundary curves of the constraint functions. The constraint lines can be drawn with *TickedStroke* to distinguish the valid and invalid sides of the constraint boundaries.

axes.Axes.contour generates curves with larger values to the left of the contour. The angle parameter is measured zero ahead with increasing values to the left. Consequently, when using *TickedStroke* to illustrate a constraint in a typical optimization problem, the angle should be set between zero and 180 degrees.




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import patheffects

fig, ax = plt.subplots(figsize=(6, 6))

nx = 101
ny = 105

# Set up survey vectors
xvec = np.linspace(0.001, 4.0, nx)
yvec = np.linspace(0.001, 4.0, ny)
```

(continues on next page)

(continued from previous page)

```
# Set up survey matrices.  Design disk loading and gear ratio.
x1, x2 = np.meshgrid(xvec, yvec)

# Evaluate some stuff to plot
obj = x1**2 + x2**2 - 2*x1 - 2*x2 + 2
g1 = -(3*x1 + x2 - 5.5)
g2 = -(x1 + 2*x2 - 4.5)
g3 = 0.8 + x1**-3 - x2

cntr = ax.contour(x1, x2, obj, [0.01, 0.1, 0.5, 1, 2, 4, 8, 16],
                  colors='black')
ax.clabel(cntr, fmt="%2.1f", use_clabeltext=True)

cg1 = ax.contour(x1, x2, g1, [0], colors='sandybrown')
cg1.set(path_effects=[patheffects.withTickedStroke(angle=135)])

cg2 = ax.contour(x1, x2, g2, [0], colors='orangered')
cg2.set(path_effects=[patheffects.withTickedStroke(angle=60,␣
 ↪length=2)])

cg3 = ax.contour(x1, x2, g3, [0], colors='mediumblue')
cg3.set(path_effects=[patheffects.withTickedStroke(spacing=7)])

ax.set_xlim(0, 4)
ax.set_ylim(0, 4)

plt.show()
```

Quiver Simple Demo

A simple example of a *quiver* plot with a *quiverkey*.

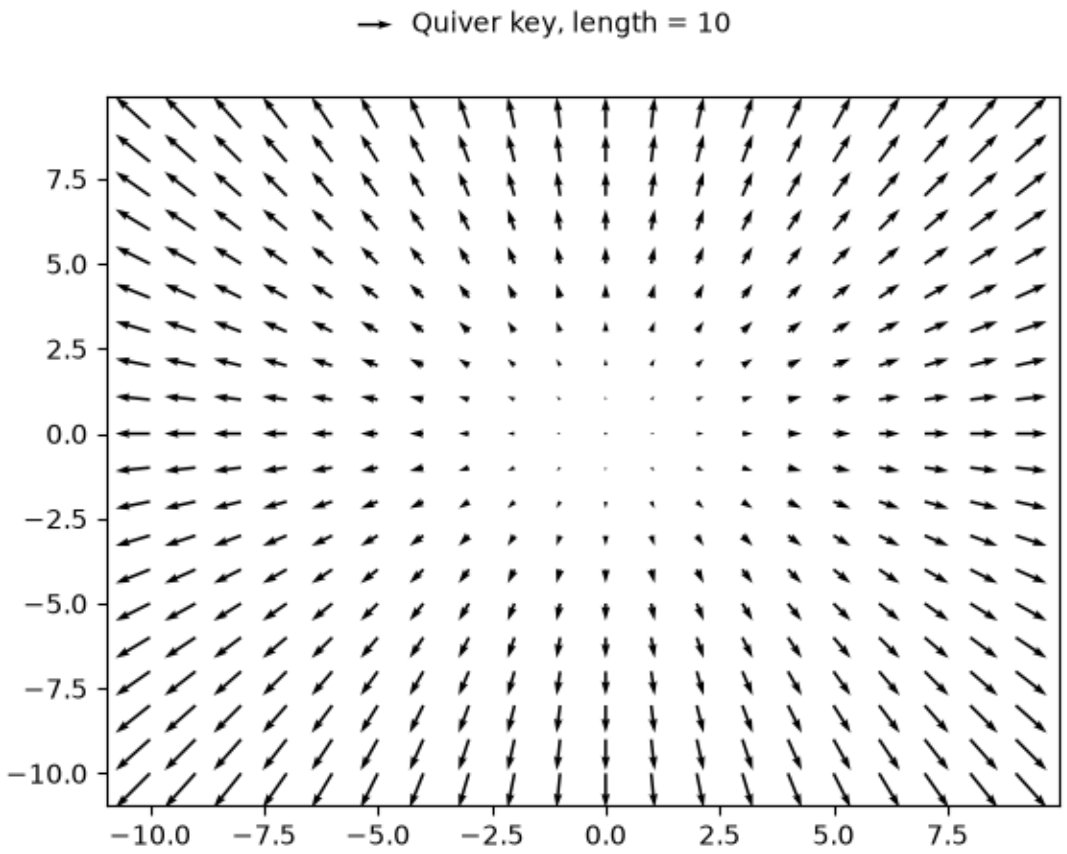
For more advanced options refer to *Advanced quiver and quiverkey functions*.

```
import matplotlib.pyplot as plt
import numpy as np

X = np.arange(-10, 10, 1)
Y = np.arange(-10, 10, 1)
U, V = np.meshgrid(X, Y)

fig, ax = plt.subplots()
q = ax.quiver(X, Y, U, V)
ax.quiverkey(q, X=0.3, Y=1.1, U=10,
             label='Quiver key, length = 10', labelpos='E')
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.quiver* / *matplotlib.pyplot.quiver*
- *matplotlib.axes.Axes.quiverkey* / *matplotlib.pyplot.quiverkey*

Advanced quiver and quiverkey functions

Demonstrates some more advanced options for *quiver*. For a simple example refer to *Quiver Simple Demo*.

Note: The plot autoscaling does not take into account the arrows, so those on the boundaries may reach out of the picture. This is not an easy problem to solve in a perfectly general way. The recommended workaround is to manually set the Axes limits in such a case.

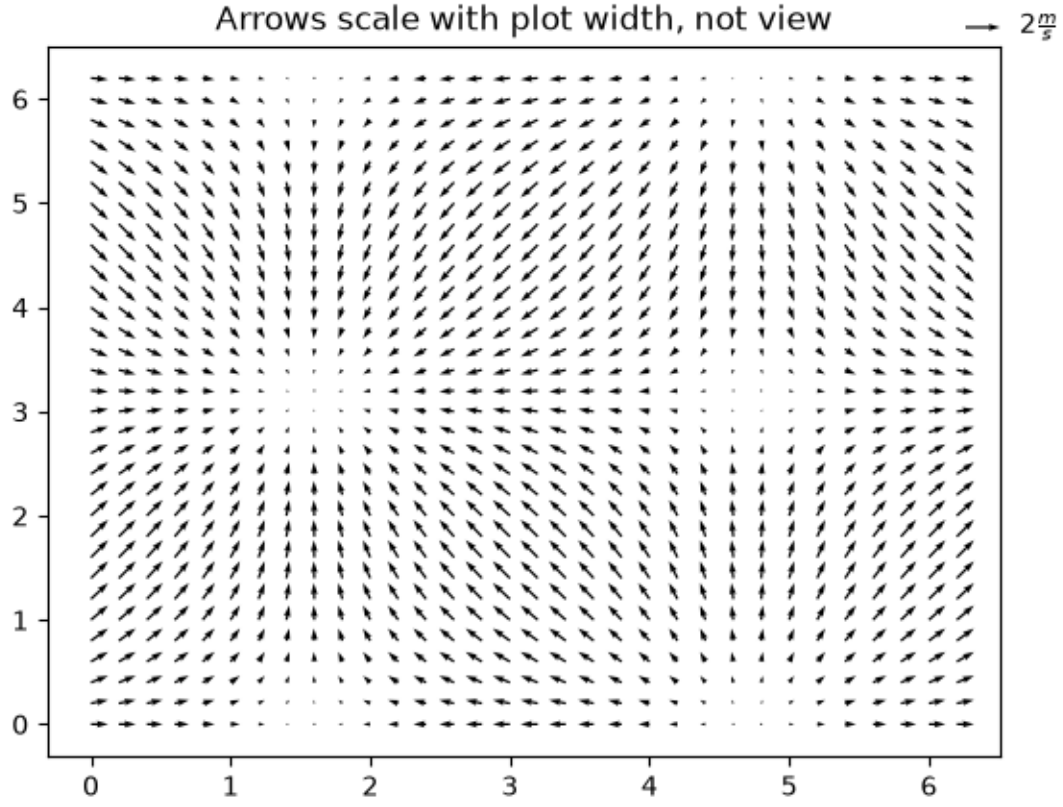
```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

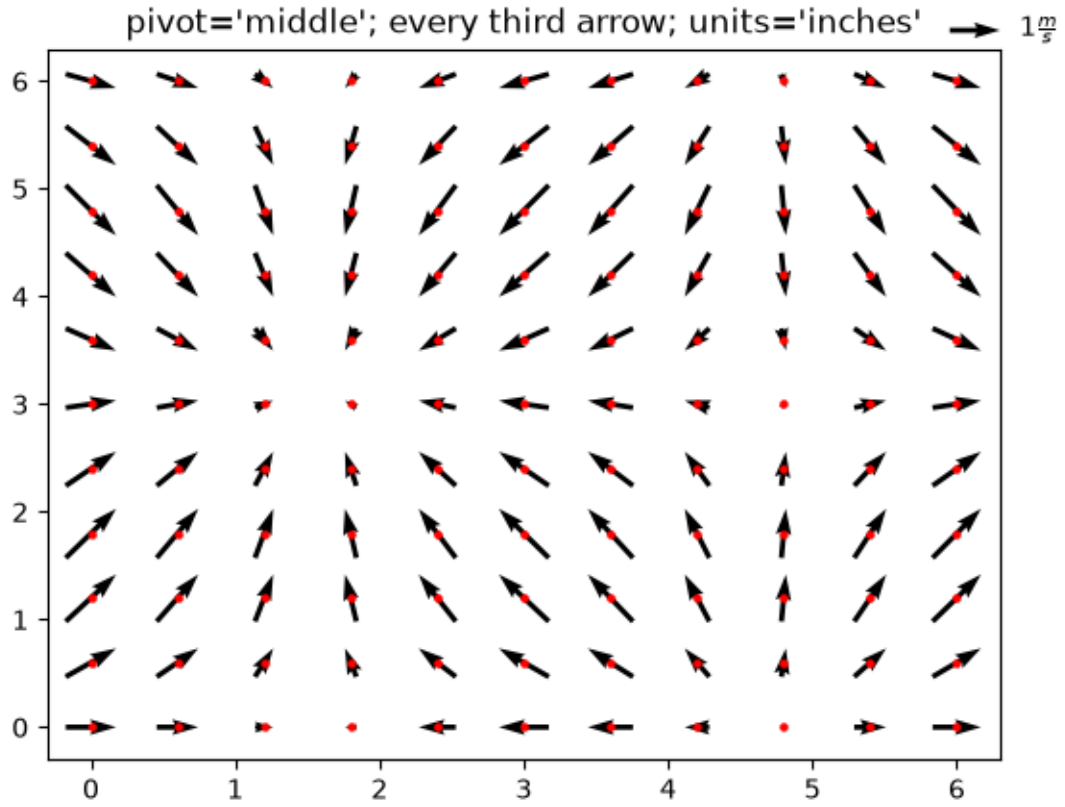
(continued from previous page)

```
X, Y = np.meshgrid(np.arange(0, 2 * np.pi, .2), np.arange(0, 2 * np.
↪pi, .2))
U = np.cos(X)
V = np.sin(Y)
```

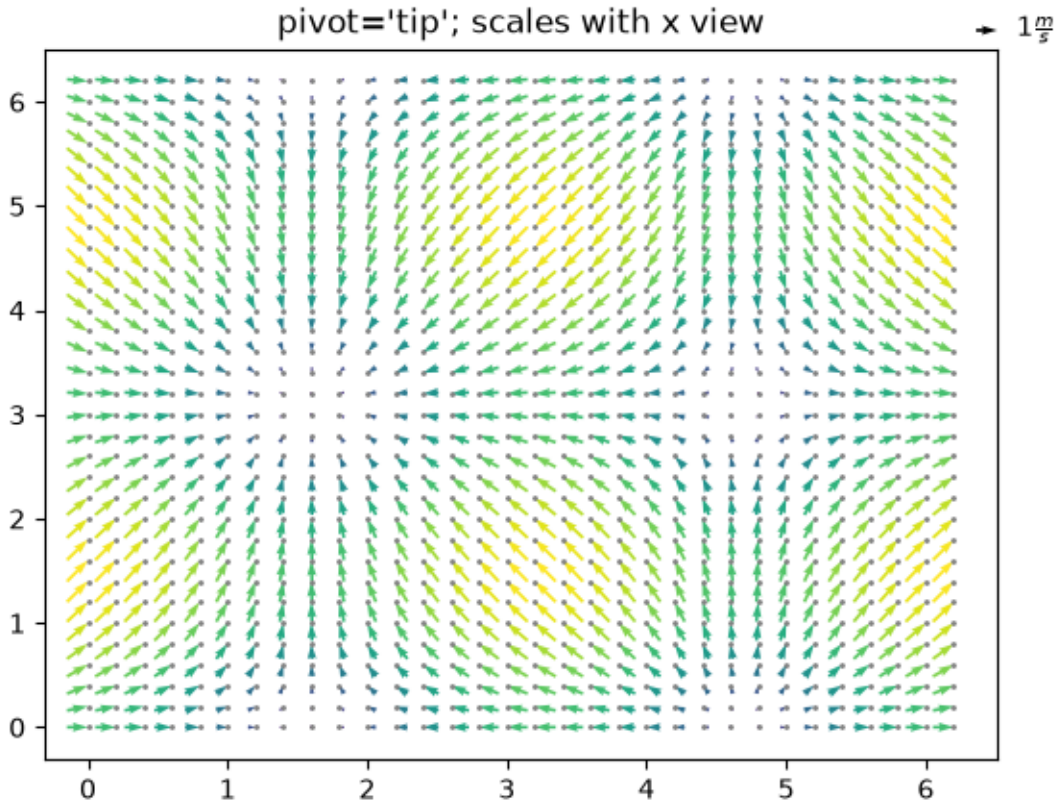
```
fig1, ax1 = plt.subplots()
ax1.set_title('Arrows scale with plot width, not view')
Q = ax1.quiver(X, Y, U, V, units='width')
qk = ax1.quiverkey(Q, 0.9, 0.9, 2, r'$2 \frac{m}{s}$', labelpos='E',
                   coordinates='figure')
```




```
fig2, ax2 = plt.subplots()
ax2.set_title("pivot='middle'; every third arrow; units='inches'")
Q = ax2.quiver(X[::3, ::3], Y[::3, ::3], U[::3, ::3], V[::3, ::3],
               pivot='middle', units='inches')
qk = ax2.quiverkey(Q, 0.9, 0.9, 1, r'$1 \frac{m}{s}$', labelpos='E',
                   coordinates='figure')
ax2.scatter(X[::3, ::3], Y[::3, ::3], color='r', s=5)
```




```
fig3, ax3 = plt.subplots()
ax3.set_title("pivot='tip'; scales with x view")
M = np.hypot(U, V)
Q = ax3.quiver(X, Y, U, V, M, units='x', pivot='tip', width=0.022,
               scale=1 / 0.15)
qk = ax3.quiverkey(Q, 0.9, 0.9, 1, r'$1 \frac{m}{s}$', labelpos='E',
                   coordinates='figure')
ax3.scatter(X, Y, color='0.5', s=1)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.quiver* / *matplotlib.pyplot.quiver*
- *matplotlib.axes.Axes.quiverkey* / *matplotlib.pyplot.quiverkey*

Wind barbs

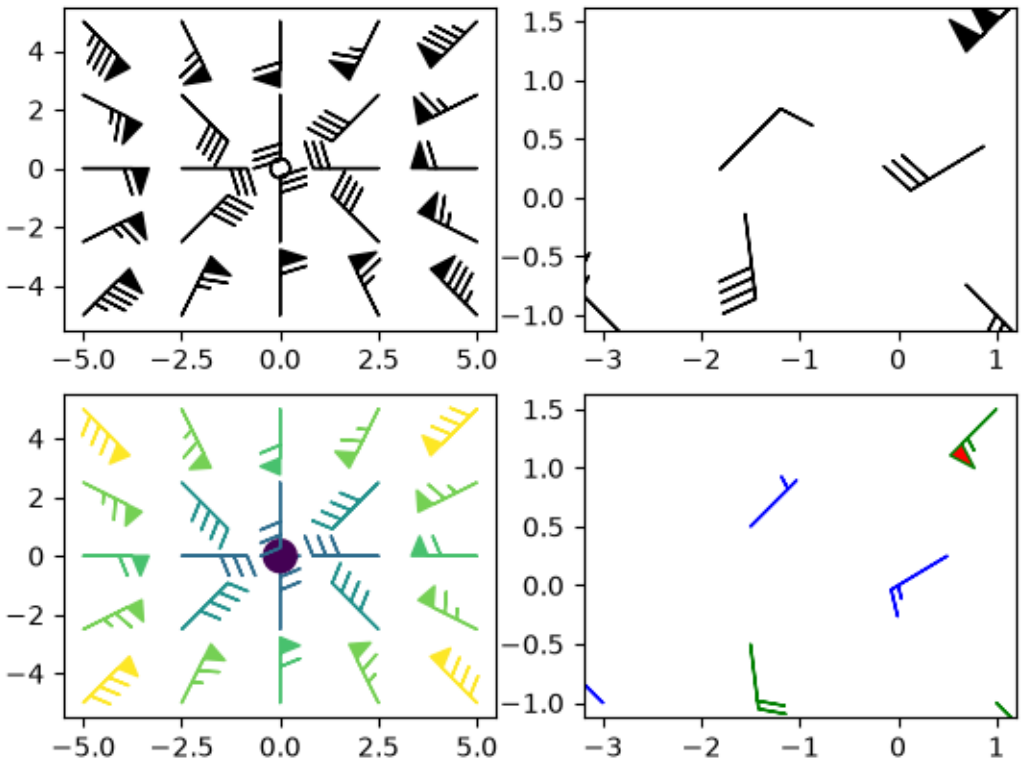
Demonstration of wind barb plots.

```
import matplotlib.pyplot as plt
import numpy as np

x = np.linspace(-5, 5, 5)
X, Y = np.meshgrid(x, x)
U, V = 12 * X, 12 * Y

data = [(-1.5, .5, -6, -6),
```

(continues on next page)

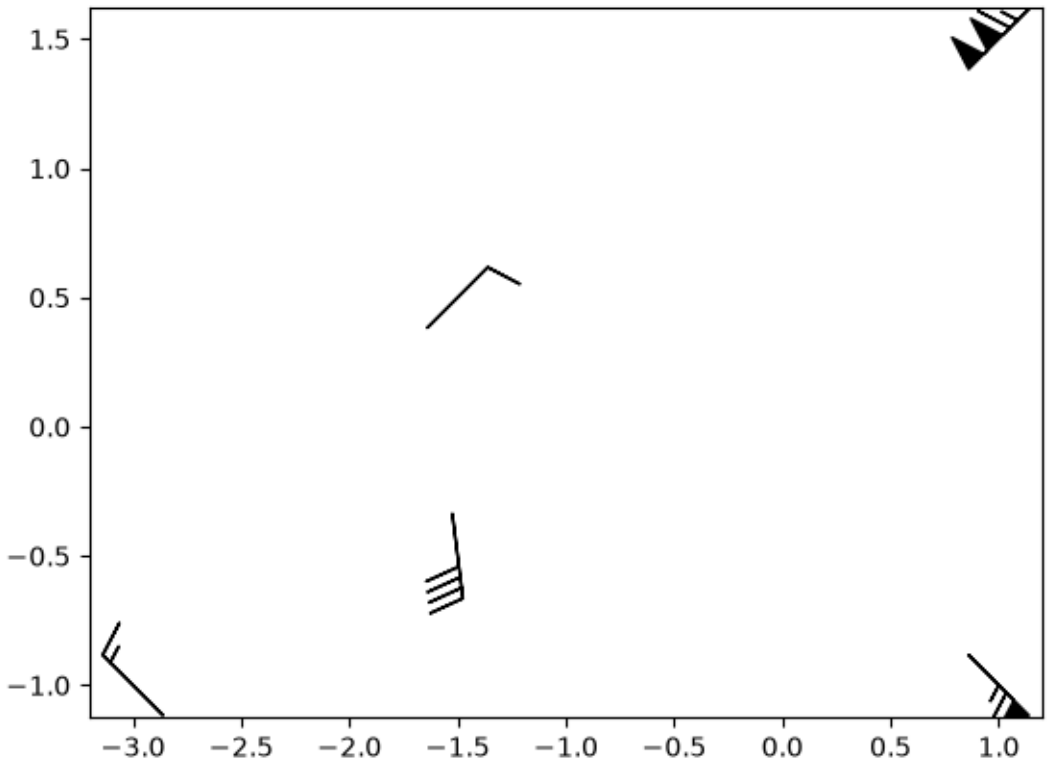
(continued from previous page)

```
        (1, -1, -46, 46),
        (-3, -1, 11, -11),
        (1, 1.5, 80, 80),
        (0.5, 0.25, 25, 15),
        (-1.5, -0.5, -5, 40)]

data = np.array(data, dtype=[('x', np.float32), ('y', np.float32),
                             ('u', np.float32), ('v', np.float32)])

fig1, axs1 = plt.subplots(nrows=2, ncols=2)
# Default parameters, uniform grid
axs1[0, 0].barbs(X, Y, U, V)

# Arbitrary set of vectors, make them longer and change the pivot point
# (point around which they're rotated) to be the middle
axs1[0, 1].barbs(
    data['x'], data['y'], data['u'], data['v'], length=8, pivot='middle
 ↪')

# Showing colormapping with uniform grid.  Fill the circle for an␣
 ↪empty barb,
# don't round the values, and change some of the size parameters
axs1[1, 0].barbs(
    X, Y, U, V, np.sqrt(U ** 2 + V ** 2), fill_empty=True,␣
 ↪rounding=False,
    sizes=dict(emptybarb=0.25, spacing=0.2, height=0.3))

# Change colors as well as the increments for parts of the barbs
axs1[1, 1].barbs(data['x'], data['y'], data['u'], data['v'], flagcolor=
 ↪'r',
                 barbcolor=['b', 'g'], flip_barb=True,
                 barb_increments=dict(half=10, full=20, flag=100))

# Masked arrays are also supported
masked_u = np.ma.masked_array(data['u'])
masked_u[4] = 1000  # Bad value that should not be plotted when masked
masked_u[4] = np.ma.masked
```



Identical plot to panel 2 in the first figure, but with the point at (0.5, 0.25) missing (masked)

```
fig2, ax2 = plt.subplots()
ax2.barbs(data['x'], data['y'], masked_u, data['v'], length=8, pivot=
 ↪'middle')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.barbs* / *matplotlib.pyplot.barbs*

Streamplot

A stream plot, or streamline plot, is used to display 2D vector fields. This example shows a few features of the *streamplot* function:

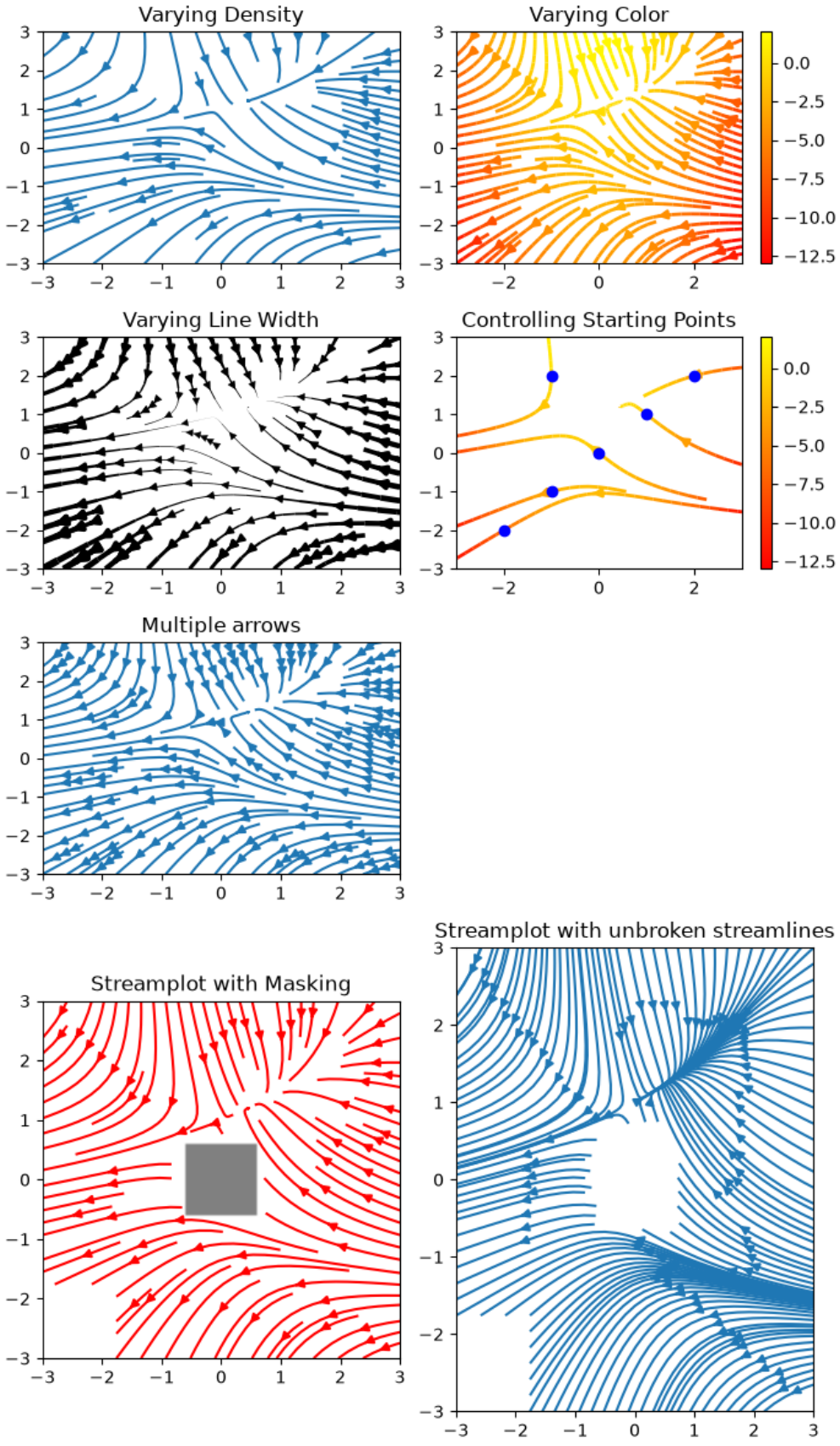
- Varying the color along a streamline.
- Varying the density of streamlines.
- Varying the line width along a streamline.
- Controlling the starting points of streamlines.
- Streamlines skipping masked regions and NaN values.
- Unbroken streamlines even when exceeding the limit of lines within a single grid cell.

```
import time

import matplotlib.pyplot as plt
import numpy as np

w = 3
Y, X = np.mgrid[-w:w:100j, -w:w:100j]
U = -1 - X**2 + Y
V = 1 + X - Y**2
speed = np.sqrt(U**2 + V**2)

fig, axs = plt.subplots(4, 2, figsize=(7, 12), height_ratios=[1, 1, 1,␣
↪2])
axs = axs.flat

#  Varying density along a streamline
axs[0].streamplot(X, Y, U, V, density=[0.5, 1])
axs[0].set_title('Varying Density')

# Varying color along a streamline
strm = axs[1].streamplot(X, Y, U, V, color=U, linewidth=2, cmap='autumn
↪')
fig.colorbar(strm.lines)
axs[1].set_title('Varying Color')

#  Varying line width along a streamline
lw = 5*speed / speed.max()
axs[2].streamplot(X, Y, U, V, density=0.6, color='k', linewidth=lw,␣
↪num_arrows=5)
axs[2].set_title('Varying Line Width')

# Controlling the starting points of the streamlines
seed_points = np.array([[-2, -1, 0, 1, 2, -1], [-2, -1,  0, 1, 2, 2]])

strm = axs[3].streamplot(X, Y, U, V, color=U, linewidth=2,
                         cmap='autumn', start_points=seed_points.T)
fig.colorbar(strm.lines)
axs[3].set_title('Controlling Starting Points')

# Displaying the starting points with blue symbols.
axs[3].plot(seed_points[0], seed_points[1], 'bo')
axs[3].set(xlim=(-w, w), ylim=(-w, w))

# Adding more than one arrow to each streamline
axs[4].streamplot(X, Y, U, V, num_arrows=3)
axs[4].set_title('Multiple arrows')
```

(continues on next page)

(continued from previous page)

```
axs[5].axis("off")

# Create a mask
mask = np.zeros(U.shape, dtype=bool)
mask[40:60, 40:60] = True
U[:20, :20] = np.nan
U = np.ma.array(U, mask=mask)

axs[6].streamplot(X, Y, U, V, color='r')
axs[6].set_title('Streamplot with Masking')

axs[6].imshow(~mask, extent=(-w, w, -w, w), alpha=0.5, cmap='gray',
              aspect='auto')
axs[6].set_aspect('equal')

axs[7].streamplot(X, Y, U, V, broken_streamlines=False)
axs[7].set_title('Streamplot with unbroken streamlines')

plt.tight_layout()
# plt.show()
```


Varying Density
Varying Color
Varying Line Width
Controlling Starting Points
Multiple arrows
Streamplot with Masking
Streamplot with unbroken streamlines

Streamline computation

The streamlines are computed by integrating along the provided vector field from the seed points, which are either automatically generated or manually specified. The accuracy and smoothness of the streamlines can be adjusted using the `integration_max_step_scale` and `integration_max_error_scale` optional parameters. See the *`streamplot`* function documentation for more details.

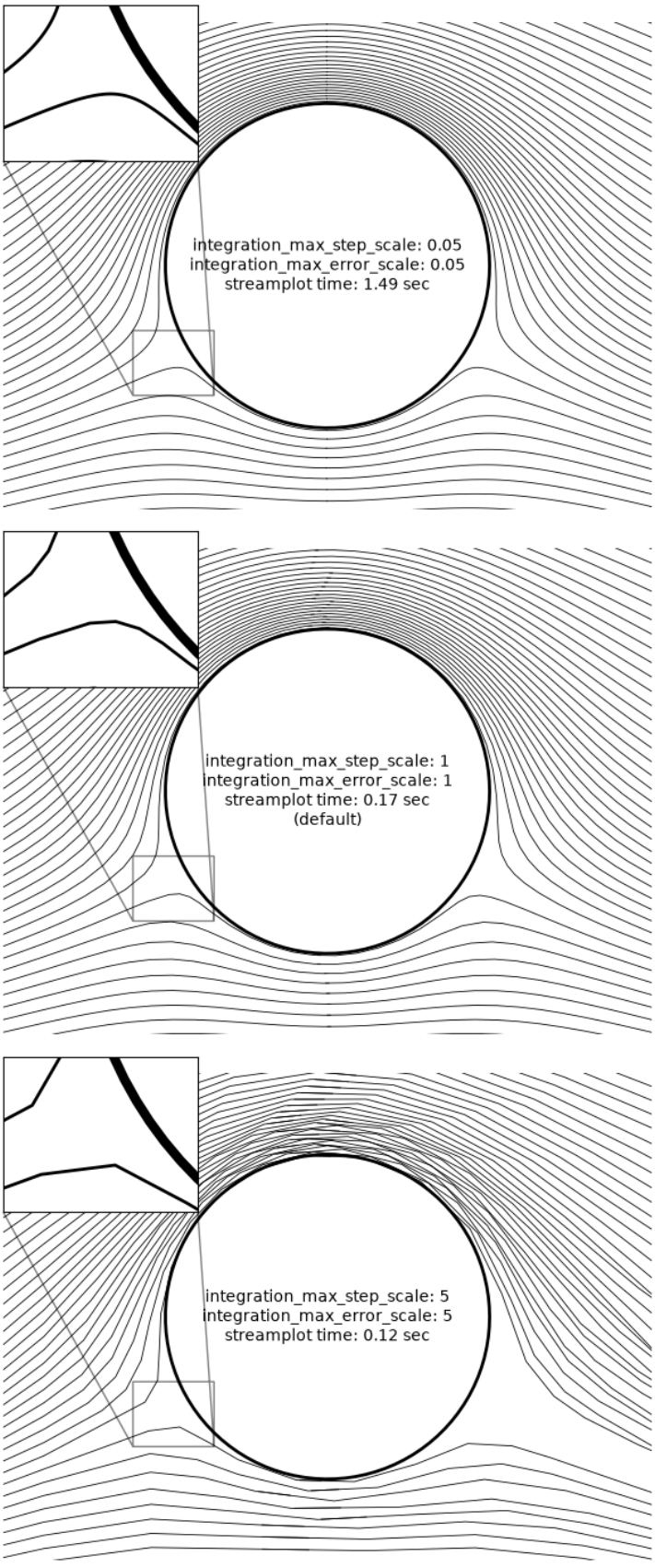
This example shows how adjusting the maximum allowed step size and error for the integrator changes the appearance of the streamline. The differences can be subtle, but can be observed particularly where the streamlines have high curvature (as shown in the zoomed in region).

```
# Linear potential flow over a lifting cylinder
n = 50
x, y = np.meshgrid(np.linspace(-2, 2, n), np.linspace(-3, 3, n))
th = np.arctan2(y, x)
r = np.sqrt(x**2 + y**2)
vr = -np.cos(th) / r**2
vt = -np.sin(th) / r**2 - 1 / r
vx = vr * np.cos(th) - vt * np.sin(th) + 1.0
vy = vr * np.sin(th) + vt * np.cos(th)

# Seed points
n_seed = 50
seed_pts = np.column_stack((np.full(n_seed, -1.75), np.linspace(-2, 2,␣
 ↪n_seed)))

_, axs = plt.subplots(3, 1, figsize=(6, 14))
th_circ = np.linspace(0, 2 * np.pi, 100)
for ax, max_val in zip(axs, [0.05, 1, 5]):
    ax_ins = ax.inset_axes([0.0, 0.7, 0.3, 0.35])
    for ax_curr, is_inset in zip([ax, ax_ins], [False, True]):
        t_start = time.time()
        ax_curr.streamplot(
            x,
            y,
            vx,
            vy,
            start_points=seed_pts,
            broken_streamlines=False,
            arrowsize=1e-10,
            linewidth=2 if is_inset else 0.6,
            color="k",
            integration_max_step_scale=max_val,
            integration_max_error_scale=max_val,
        )
        if is_inset:
            t_total = time.time() - t_start
```

(continues on next page)

(continued from previous page)

```
        # Draw the cylinder
        ax_curr.fill(
            np.cos(th_circ),
            np.sin(th_circ),
            color="w",
            ec="k",
            lw=6 if is_inset else 2,
        )

        # Set axis properties
        ax_curr.set_aspect("equal")

    # Label properties of each circle
    text = f"integration_max_step_scale: {max_val}\n" \
        f"integration_max_error_scale: {max_val}\n" \
        f"streamplot time: {t_total:.2f} sec"
    if max_val == 1:
        text += "\n(default)"
    ax.text(0.0, 0.0, text, ha="center", va="center")

    # Set axis limits and show zoomed region
    ax_ins.set_xlim(-1.2, -0.7)
    ax_ins.set_ylim(-0.8, -0.4)
    ax_ins.set_yticks(())
    ax_ins.set_xticks(())

    ax.set_ylim(-1.5, 1.5)
    ax.axis("off")
    ax.indicate_inset_zoom(ax_ins, ec="k")

plt.tight_layout()
plt.show()
```


integration_max_step_scale: 0.05
integration_max_error_scale: 0.05
streamplot time: 1.49 sec
integration_max_step_scale: 1
integration_max_error_scale: 1
streamplot time: 0.17 sec
(default)
integration_max_step_scale: 5
integration_max_error_scale: 5
streamplot time: 0.12 sec

References

The use of the following functions, methods, classes and modules is shown in this example:

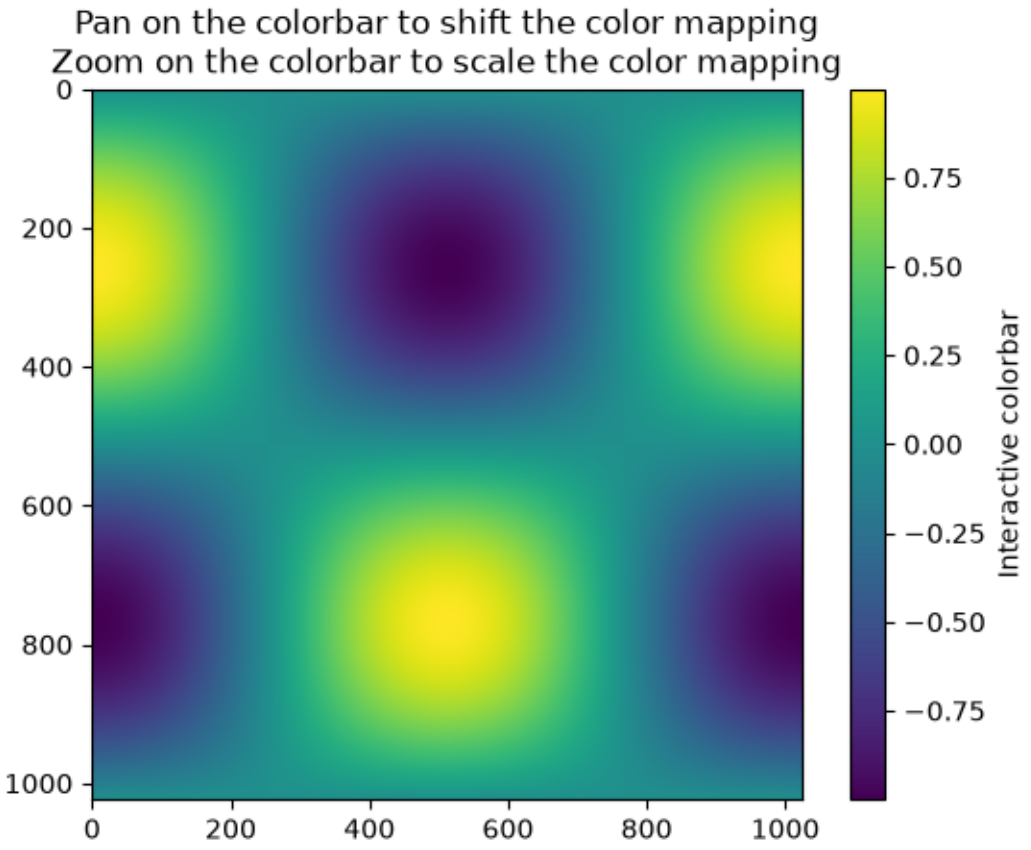
- *matplotlib.axes.Axes.streamplot* / *matplotlib.pyplot.streamplot*
- *matplotlib.gridspec.GridSpec*

Total running time of the script: (0 minutes 10.277 seconds)

Interactive adjustment of colormap range

Demonstration of how a colorbar can be used to interactively adjust the range of colormapping on an image. To use the interactive feature, you must be in either zoom mode (magnifying glass toolbar button) or pan mode (4-way arrow toolbar button) and click inside the colorbar.

When zooming, the bounding box of the zoom region defines the new vmin and vmax of the norm. Zooming using the right mouse button will expand the vmin and vmax proportionally to the selected region, in the same manner that one can zoom out on an axis. When panning, the vmin and vmax of the norm are both shifted according to the direction of movement. The Home/Back/Forward buttons can also be used to get back to a previous state.



```
import matplotlib.pyplot as plt
import numpy as np

t = np.linspace(0, 2 * np.pi, 1024)
data2d = np.sin(t)[:, np.newaxis] * np.cos(t)[np.newaxis, :]

fig, ax = plt.subplots()
im = ax.imshow(data2d)
ax.set_title('Pan on the colorbar to shift the color mapping\n'
             'Zoom on the colorbar to scale the color mapping')

fig.colorbar(im, ax=ax, label='Interactive colorbar')

plt.show()
```

Colormap normalizations

Demonstration of using norm to map colormaps onto data in non-linear ways.

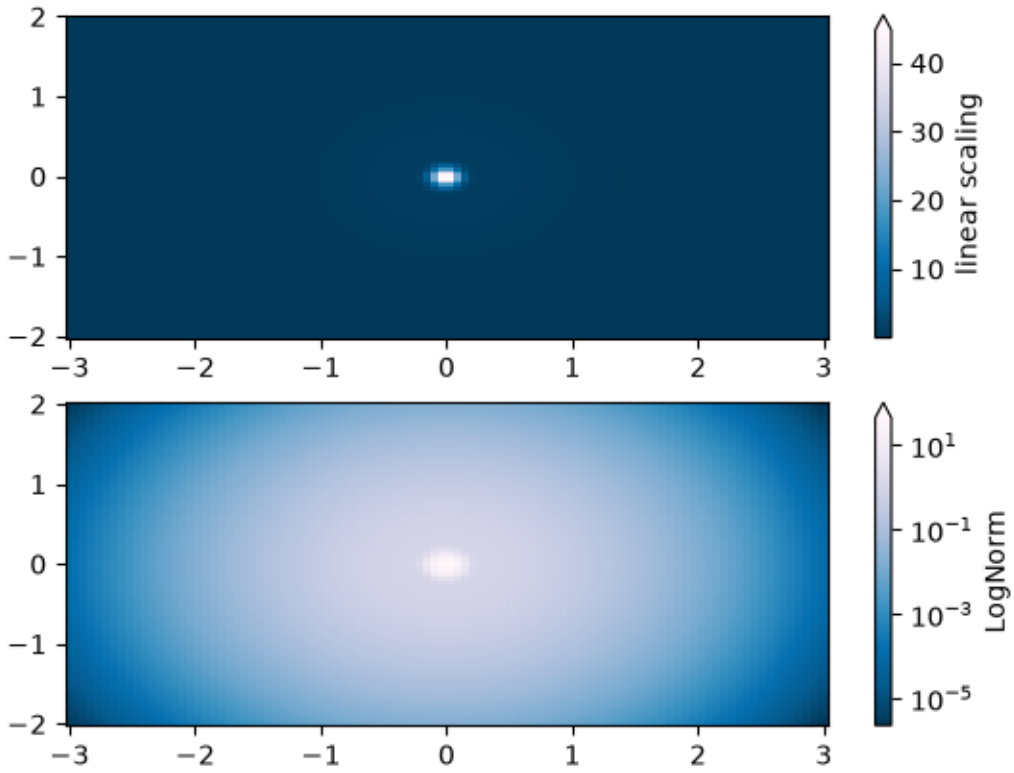
```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.colors as colors

N = 100
```

LogNorm

This example data has a low hump with a spike coming out of its center. If plotted using a linear colour scale, then only the spike will be visible. To see both hump and spike, this requires the z/colour axis on a log scale.

Instead of transforming the data with `pcolor(log10(Z))`, the color mapping can be made logarithmic using a *LogNorm*.

```
X, Y = np.mgrid[-3:3:complex(0, N), -2:2:complex(0, N)]
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X * 10)**2 - (Y * 10)**2)
Z = Z1 + 50 * Z2

fig, ax = plt.subplots(2, 1)

pcm = ax[0].pcolor(X, Y, Z, cmap='PuBu_r', shading='nearest')
fig.colorbar(pcm, ax=ax[0], extend='max', label='linear scaling')

pcm = ax[1].pcolor(X, Y, Z, cmap='PuBu_r', shading='nearest',
                   norm=colors.LogNorm(vmin=Z.min(), vmax=Z.max()))
fig.colorbar(pcm, ax=ax[1], extend='max', label='LogNorm')
```

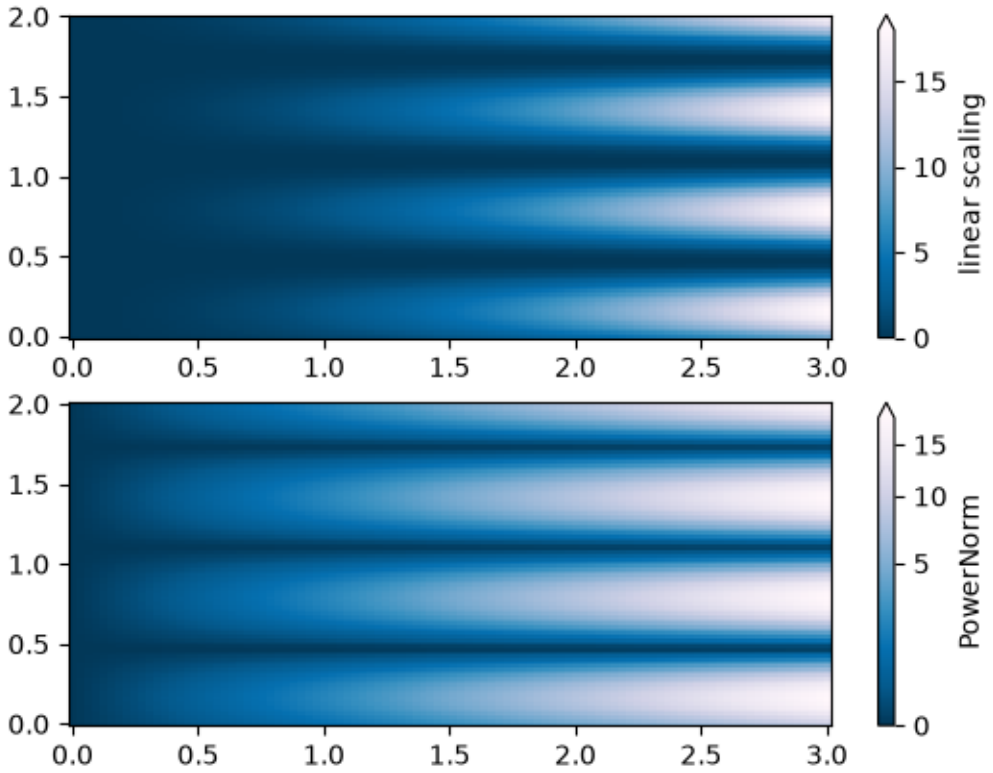


PowerNorm

This example data mixes a power-law trend in X with a rectified sine wave in Y. If plotted using a linear colour scale, then the power-law trend in X partially obscures the sine wave in Y.

The power law can be removed using a *PowerNorm*.

```
X, Y = np.mgrid[0:3:complex(0, N), 0:2:complex(0, N)]
Z = (1 + np.sin(Y * 10)) * X**2

fig, ax = plt.subplots(2, 1)

pcm = ax[0].pcolormesh(X, Y, Z, cmap='PuBu_r', shading='nearest')
fig.colorbar(pcm, ax=ax[0], extend='max', label='linear scaling')

pcm = ax[1].pcolormesh(X, Y, Z, cmap='PuBu_r', shading='nearest',
                       norm=colors.PowerNorm(gamma=0.5))
fig.colorbar(pcm, ax=ax[1], extend='max', label='PowerNorm')
```



SymLogNorm

This example data has two humps, one negative and one positive, The positive hump has 5 times the amplitude of the negative. If plotted with a linear colour scale, then the detail in the negative hump is obscured.

Here we logarithmically scale the positive and negative data separately with *SymLogNorm*.

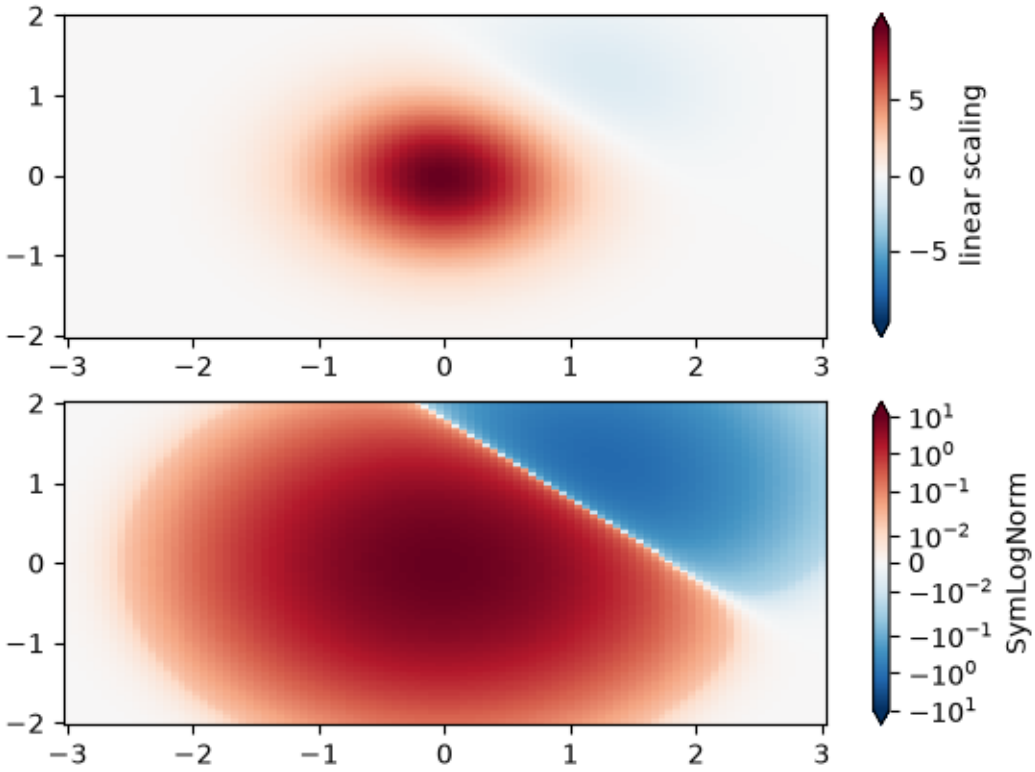
Note that colorbar labels do not come out looking very good.

```
X, Y = np.mgrid[-3:3:complex(0, N), -2:2:complex(0, N)]
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (5 * Z1 - Z2) * 2

fig, ax = plt.subplots(2, 1)

pcm = ax[0].pcolormesh(X, Y, Z, cmap='RdBu_r', shading='nearest',
                       vmin=-np.max(Z))
fig.colorbar(pcm, ax=ax[0], extend='both', label='linear scaling')

pcm = ax[1].pcolormesh(X, Y, Z, cmap='RdBu_r', shading='nearest',
```

(continues on next page)

(continued from previous page)

```
                       norm=colors.SymLogNorm(linthresh=0.015,
                                              vmin=-10.0, vmax=10.0,␣
 ↪base=10))
fig.colorbar(pcm, ax=ax[1], extend='both', label='SymLogNorm')
```



Custom Norm

Alternatively, the above example data can be scaled with a customized normalization. This one normalizes the negative data differently from the positive.

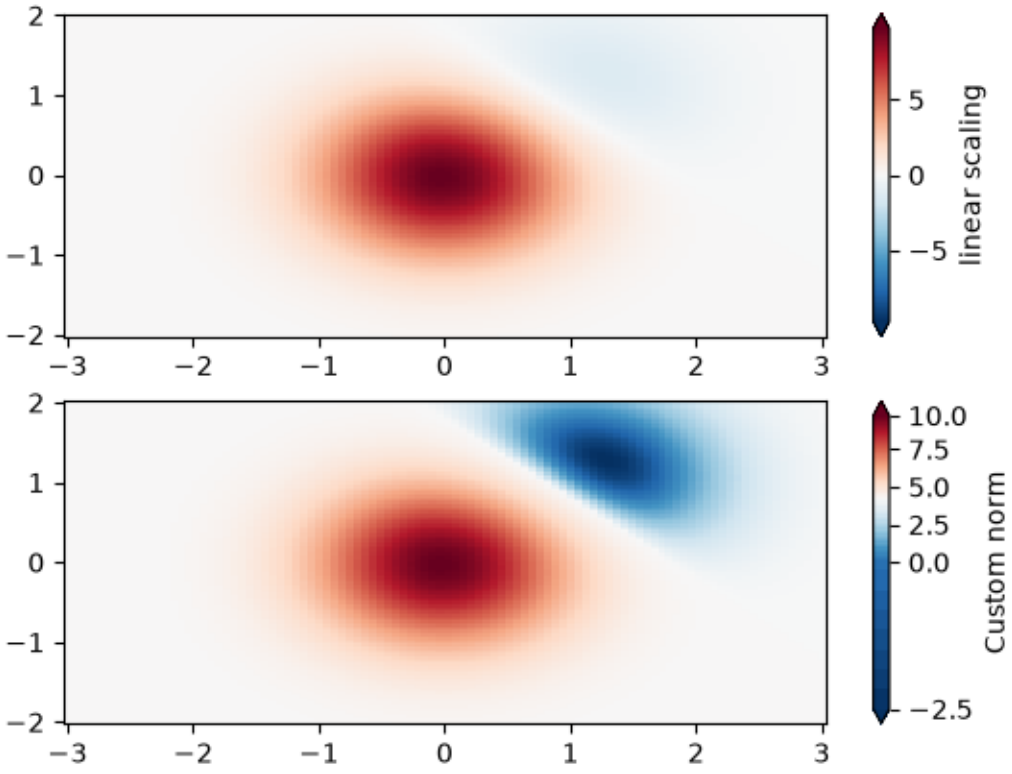
```
# Example of making your own norm.  Also see matplotlib.colors.
# From Joe Kington: This one gives two different linear ramps:
class MidpointNormalize(colors.Normalize):
    def __init__(self, vmin=None, vmax=None, midpoint=None,␣
 ↪clip=False):
        self.midpoint = midpoint
        super().__init__(vmin, vmax, clip)

    def __call__(self, value, clip=None):
```

(continues on next page)

(continued from previous page)

```
        # I'm ignoring masked values and all kinds of edge cases to␣
↪make a
        # simple example...
        x, y = [self.vmin, self.midpoint, self.vmax], [0, 0.5, 1]
        return np.ma.masked_array(np.interp(value, x, y))
```

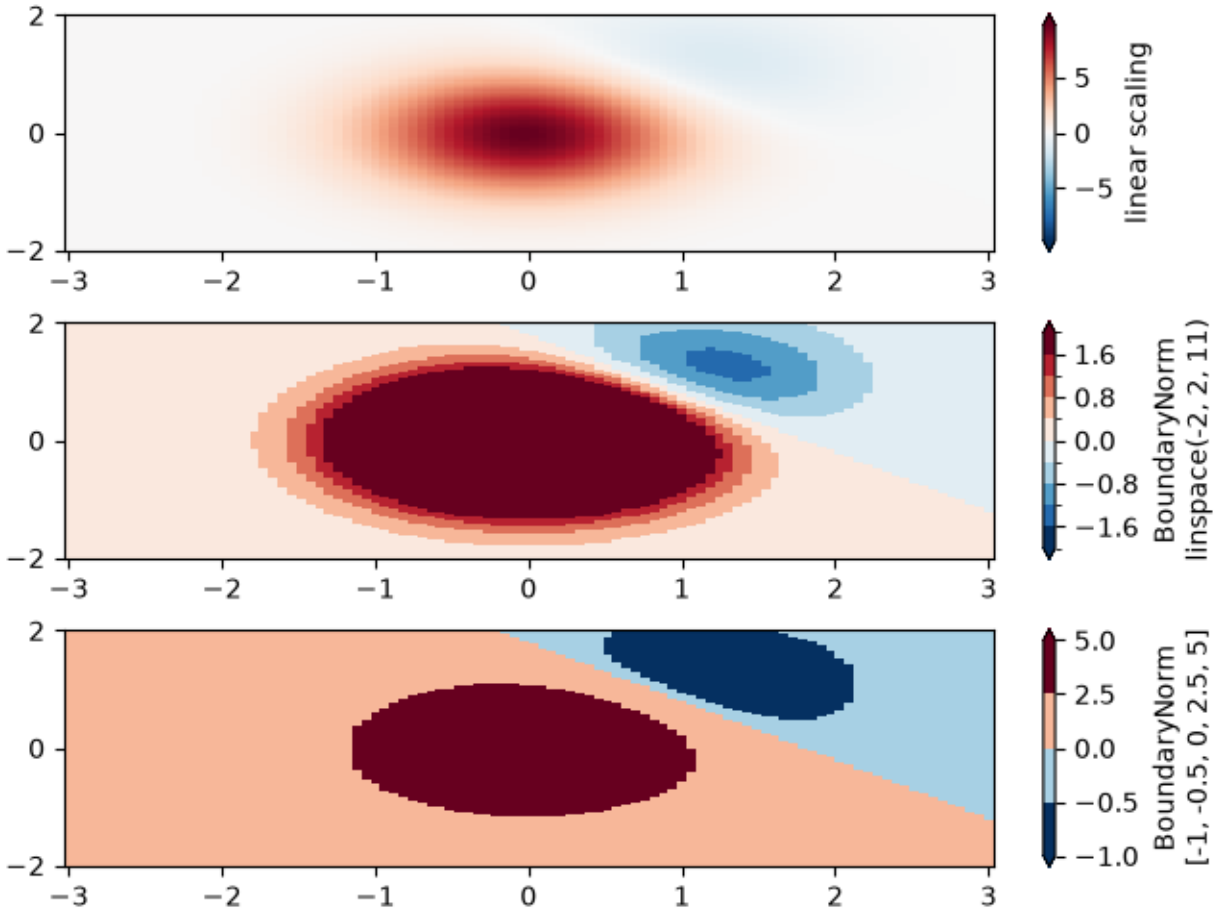
```
fig, ax = plt.subplots(2, 1)

pcm = ax[0].pcolormesh(X, Y, Z, cmap='RdBu_r', shading='nearest',
                       vmin=-np.max(Z))
fig.colorbar(pcm, ax=ax[0], extend='both', label='linear scaling')

pcm = ax[1].pcolormesh(X, Y, Z, cmap='RdBu_r', shading='nearest',
                       norm=MidpointNormalize(midpoint=0))
fig.colorbar(pcm, ax=ax[1], extend='both', label='Custom norm')
```



BoundaryNorm

For arbitrarily dividing the color scale, the *BoundaryNorm* may be used; by providing the boundaries for colors, this norm puts the first color in between the first pair, the second color between the second pair, etc.

```
fig, ax = plt.subplots(3, 1, layout='constrained')

pcm = ax[0].pcolormesh(X, Y, Z, cmap='RdBu_r', shading='nearest',
                       vmin=-np.max(Z))
fig.colorbar(pcm, ax=ax[0], extend='both', orientation='vertical',
             label='linear scaling')

# Evenly-spaced bounds gives a contour-like effect.
bounds = np.linspace(-2, 2, 11)
norm = colors.BoundaryNorm(boundaries=bounds, ncolors=256)
pcm = ax[1].pcolormesh(X, Y, Z, cmap='RdBu_r', shading='nearest',
                       norm=norm)
fig.colorbar(pcm, ax=ax[1], extend='both', orientation='vertical',
             label='BoundaryNorm\nlinspace(-2, 2, 11)')

# Unevenly-spaced bounds changes the colormapping.
bounds = np.array([-1, -0.5, 0, 2.5, 5])
norm = colors.BoundaryNorm(boundaries=bounds, ncolors=256)
pcm = ax[2].pcolormesh(X, Y, Z, cmap='RdBu_r', shading='nearest',
                       norm=norm)
fig.colorbar(pcm, ax=ax[2], extend='both', orientation='vertical',
             label='BoundaryNorm\n[-1, -0.5, 0, 2.5, 5]')

plt.show()
```



Total running time of the script: (0 minutes 2.337 seconds)

Colormap normalizations SymLogNorm

Demonstration of using norm to map colormaps onto data in non-linear ways.

Synthetic dataset consisting of two humps, one negative and one positive, the positive with 8-times the amplitude. Linearly, the negative hump is almost invisible, and it is very difficult to see any detail of its profile. With the logarithmic scaling applied to both positive and negative values, it is much easier to see the shape of each hump.

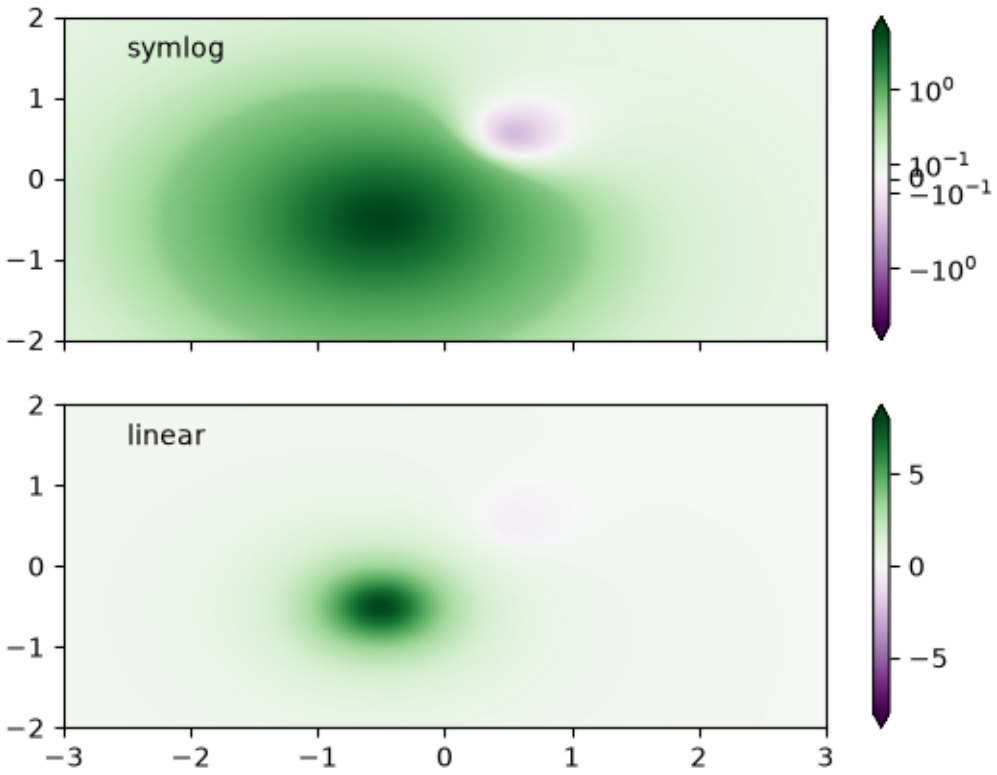
See *SymLogNorm*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.colors as colors


def rbf(x, y):
    return 1.0 / (1 + 5 * ((x ** 2) + (y ** 2)))
```

(continues on next page)

(continued from previous page)

```
N = 200
gain = 8
X, Y = np.mgrid[-3:3:complex(0, N), -2:2:complex(0, N)]
Z1 = rbf(X + 0.5, Y + 0.5)
Z2 = rbf(X - 0.5, Y - 0.5)
Z = gain * Z1 - Z2

shadeopts = {'cmap': 'PRGn', 'shading': 'gouraud'}
colormap = 'PRGn'
lnrwidth = 0.5

fig, ax = plt.subplots(2, 1, sharex=True, sharey=True)

pcm = ax[0].pcolormesh(X, Y, Z,
                       norm=colors.SymLogNorm(linthresh=lnrwidth,␣
 ↪linscale=1,
                                              vmin=-gain, vmax=gain,␣
 ↪base=10),
                       **shadeopts)
fig.colorbar(pcm, ax=ax[0], extend='both')
ax[0].text(-2.5, 1.5, 'symlog')

pcm = ax[1].pcolormesh(X, Y, Z, vmin=-gain, vmax=gain,
                       **shadeopts)
fig.colorbar(pcm, ax=ax[1], extend='both')
ax[1].text(-2.5, 1.5, 'linear')
```



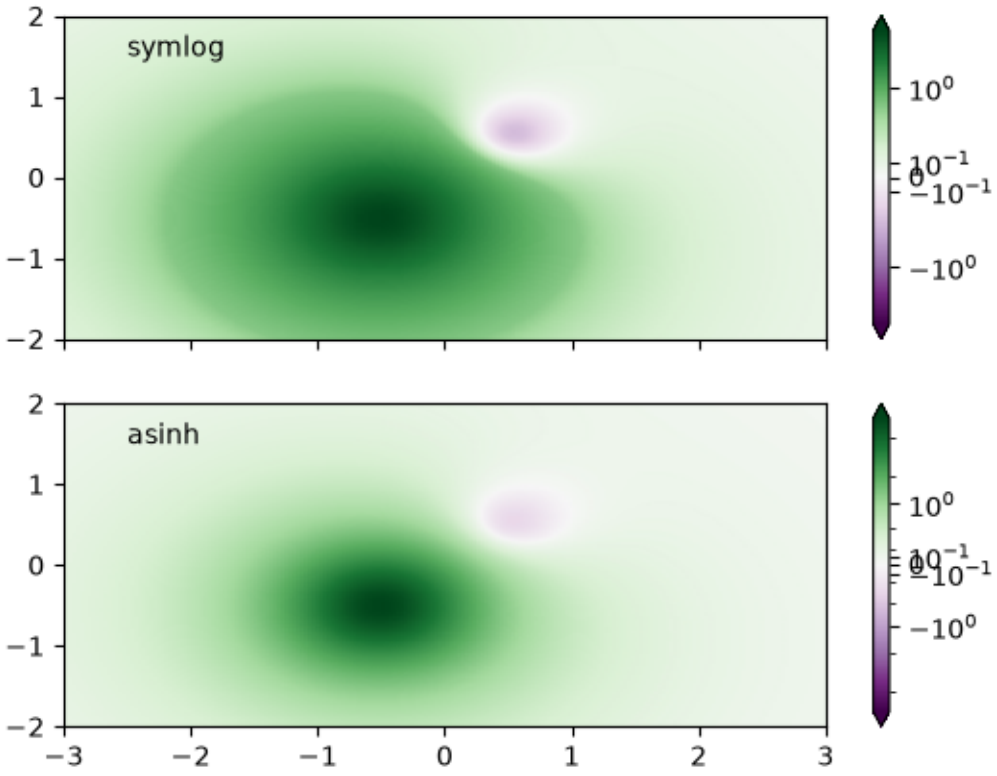
In order to find the best visualization for any particular dataset, it may be necessary to experiment with multiple different color scales. As well as the *SymLogNorm* scaling, there is also the option of using *AsinhNorm* (experimental), which has a smoother transition between the linear and logarithmic regions of the transformation applied to the data values, "Z". In the plots below, it may be possible to see contour-like artifacts around each hump despite there being no sharp features in the dataset itself. The `asinh` scaling shows a smoother shading of each hump.

```
fig, ax = plt.subplots(2, 1, sharex=True, sharey=True)

pcm = ax[0].pcolormesh(X, Y, Z,
                       norm=colors.SymLogNorm(linthresh=lnrwidth,␣
 ↪linscale=1,
                                              vmin=-gain, vmax=gain,␣
 ↪base=10),
                       **shadeopts)
fig.colorbar(pcm, ax=ax[0], extend='both')
ax[0].text(-2.5, 1.5, 'symlog')

pcm = ax[1].pcolormesh(X, Y, Z,
                       norm=colors.AsinhNorm(linear_width=lnrwidth,
                                             vmin=-gain, vmax=gain),
```

(continues on next page)

(continued from previous page)

```
                          **shadeopts)
fig.colorbar(pcm, ax=ax[1], extend='both')
ax[1].text(-2.5, 1.5, 'asinh')


plt.show()
```



Total running time of the script: (0 minutes 1.872 seconds)

Annotated heatmap

It is often desirable to show data which depends on two independent variables as a color coded image plot. This is often referred to as a heatmap. If the data is categorical, this would be called a categorical heatmap.

Matplotlib's *imshow* function makes production of such plots particularly easy.

The following examples show how to create a heatmap with annotations. We will start with an easy example and expand it to be usable as a universal function.

A simple categorical heatmap

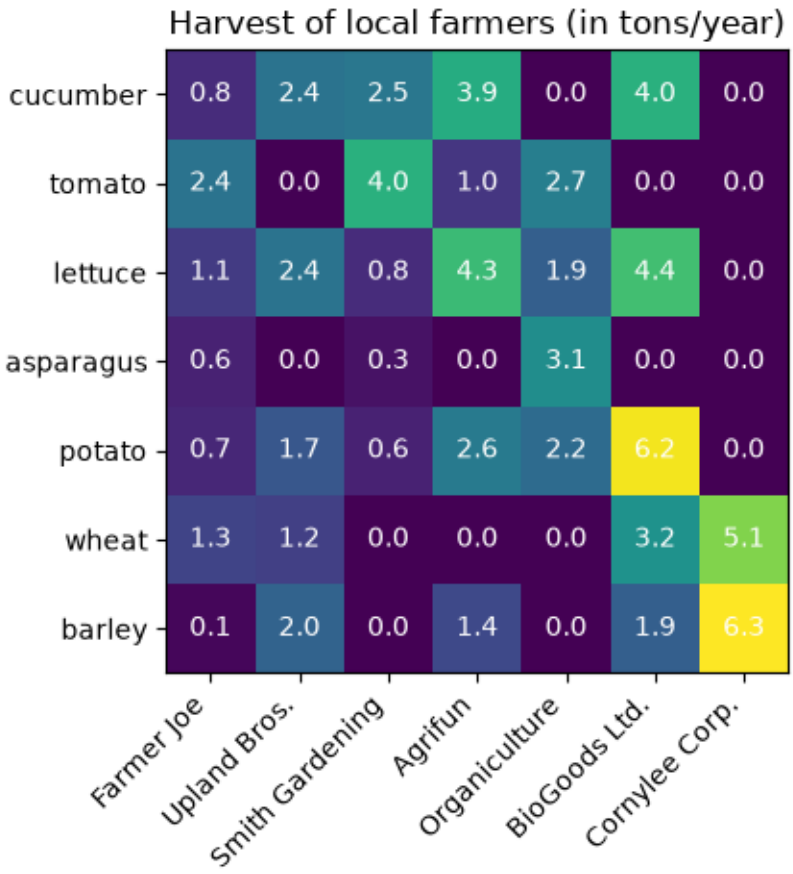
We may start by defining some data. What we need is a 2D list or array which defines the data to color code. We then also need two lists or arrays of categories; of course the number of elements in those lists need to match the data along the respective axes. The heatmap itself is an *imshow* plot with the labels set to the categories we have. Note that it is important to set both, the tick locations (*set_xticks*) as well as the tick labels (*set_xticklabels*), otherwise they would become out of sync. The locations are just the ascending integer numbers, while the ticklabels are the labels to show. Finally, we can label the data itself by creating a *Text* within each cell showing the value of that cell.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib
import matplotlib as mpl


vegetables = ["cucumber", "tomato", "lettuce", "asparagus",
              "potato", "wheat", "barley"]
farmers = ["Farmer Joe", "Upland Bros.", "Smith Gardening",
           "Agrifun", "Organiculture", "BioGoods Ltd.", "Cornylee Corp.
 ↪"]

harvest = np.array([[0.8, 2.4, 2.5, 3.9, 0.0, 4.0, 0.0],
                    [2.4, 0.0, 4.0, 1.0, 2.7, 0.0, 0.0],
                    [1.1, 2.4, 0.8, 4.3, 1.9, 4.4, 0.0],
                    [0.6, 0.0, 0.3, 0.0, 3.1, 0.0, 0.0],
                    [0.7, 1.7, 0.6, 2.6, 2.2, 6.2, 0.0],
                    [1.3, 1.2, 0.0, 0.0, 0.0, 3.2, 5.1],
                    [0.1, 2.0, 0.0, 1.4, 0.0, 1.9, 6.3]])


fig, ax = plt.subplots()
im = ax.imshow(harvest)

# Show all ticks and label them with the respective list entries
ax.set_xticks(range(len(farmers)), labels=farmers,
              rotation=45, rotation_mode="xtick")
ax.set_yticks(range(len(vegetables)), labels=vegetables)

# Loop over data dimensions and create text annotations.
for i in range(len(vegetables)):
    for j in range(len(farmers)):
        text = ax.text(j, i, harvest[i, j],
                       ha="center", va="center", color="w")

ax.set_title("Harvest of local farmers (in tons/year)")
```

(continues on next page)

(continued from previous page)

```
fig.tight_layout()
plt.show()
```



Using the helper function code style

As discussed in the *Coding styles* one might want to reuse such code to create some kind of heatmap for different input data and/or on different axes. We create a function that takes the data and the row and column labels as input, and allows arguments that are used to customize the plot

Here, in addition to the above we also want to create a colorbar and position the labels above of the heatmap instead of below it. The annotations shall get different colors depending on a threshold for better contrast against the pixel color. Finally, we turn the surrounding axes spines off and create a grid of white lines to separate the cells.

```
def heatmap(data, row_labels, col_labels, ax=None,
            cbar_kw=None, cbarlabel="", **kwargs):
    """
    Create a heatmap from a numpy array and two lists of labels.

    Parameters
```

(continues on next page)

(continued from previous page)

```
    ----------
    data
        A 2D numpy array of shape (M, N).
    row_labels
        A list or array of length M with the labels for the rows.
    col_labels
        A list or array of length N with the labels for the columns.
    ax
        A `matplotlib.axes.Axes` instance to which the heatmap is␣
↪plotted.  If
        not provided, use current Axes or create a new one.  Optional.
    cbar_kw
        A dictionary with arguments to `matplotlib.Figure.colorbar`. ␣
↪Optional.
    cbarlabel
        The label for the colorbar.  Optional.
    **kwargs
        All other arguments are forwarded to `imshow`.
    """

    if ax is None:
        ax = plt.gca()

    if cbar_kw is None:
        cbar_kw = {}

    # Plot the heatmap
    im = ax.imshow(data, **kwargs)

    # Create colorbar
    cbar = ax.figure.colorbar(im, ax=ax, **cbar_kw)
    cbar.ax.set_ylabel(cbarlabel, rotation=-90, va="bottom")

    # Show all ticks and label them with the respective list entries.
    ax.set_xticks(range(data.shape[1]), labels=col_labels,
                  rotation=-30, rotation_mode="xtick")
    ax.set_yticks(range(data.shape[0]), labels=row_labels)

    # Let the horizontal axes labeling appear on top.
    ax.tick_params(top=True, bottom=False,
                   labeltop=True, labelbottom=False)

    # Turn spines off and create white grid.
    ax.spines[:].set_visible(False)

    ax.set_xticks(np.arange(data.shape[1]+1)-.5, minor=True)
```

(continues on next page)

(continued from previous page)

```
    ax.set_yticks(np.arange(data.shape[0]+1)-.5, minor=True)
    ax.grid(which="minor", color="w", linestyle='-', linewidth=3)
    ax.tick_params(which="minor", bottom=False, left=False)

    return im, cbar


def annotate_heatmap(im, data=None, valfmt="{x:.2f}",
                     textcolors=("black", "white"),
                     threshold=None, **textkw):
    """
    A function to annotate a heatmap.

    Parameters
    ----------
    im
        The AxesImage to be labeled.
    data
        Data used to annotate.  If None, the image's data is used. ␣
 ↪Optional.
    valfmt
        The format of the annotations inside the heatmap.  This should␣
 ↪either
        use the string format method, e.g. "$ {x:.2f}", or be a
        `matplotlib.ticker.Formatter`.  Optional.
    textcolors
        A pair of colors.  The first is used for values below a␣
 ↪threshold,
        the second for those above.  Optional.
    threshold
        Value in data units according to which the colors from␣
 ↪textcolors are
        applied.  If None (the default) uses the middle of the␣
 ↪colormap as
        separation.  Optional.
    **kwargs
        All other arguments are forwarded to each call to `text` used␣
 ↪to create
        the text labels.
    """

    if not isinstance(data, (list, np.ndarray)):
        data = im.get_array()

    # Normalize the threshold to the images color range.
    if threshold is not None:
```

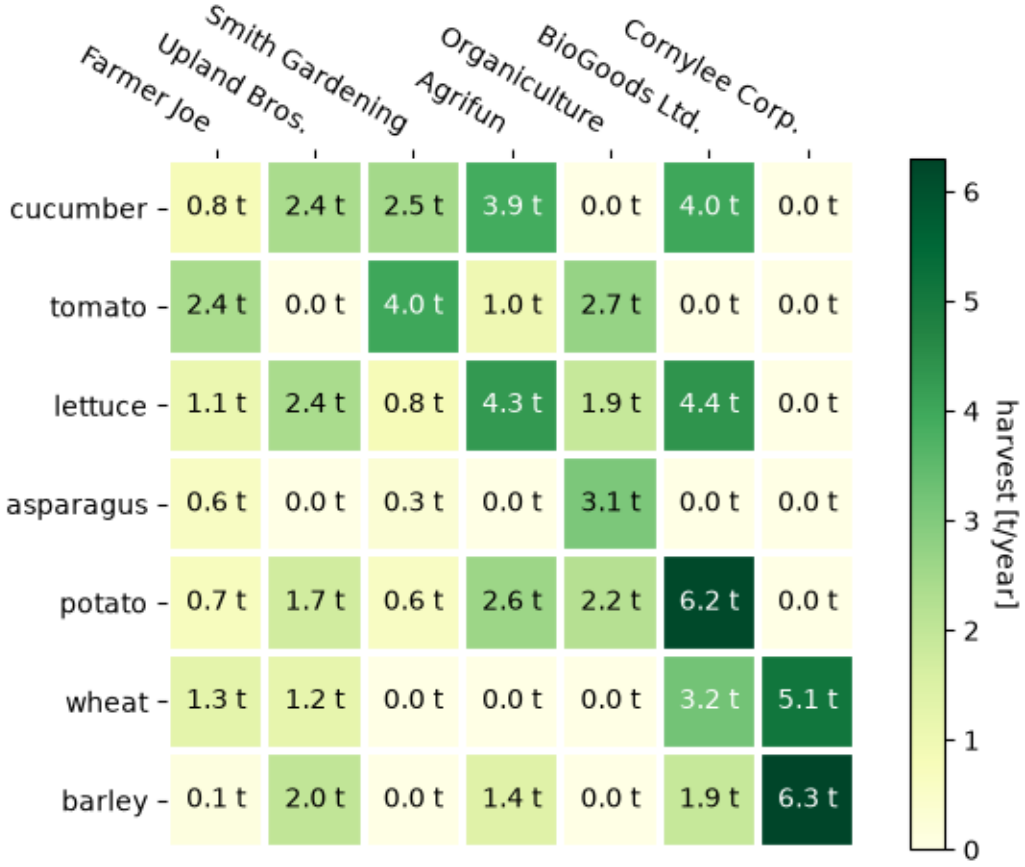
(continues on next page)

(continued from previous page)

```
        threshold = im.norm(threshold)
    else:
        threshold = im.norm(data.max())/2.

    # Set default alignment to center, but allow it to be
    # overwritten by textkw.
    kw = dict(horizontalalignment="center",
              verticalalignment="center")
    kw.update(textkw)

    # Get the formatter in case a string is supplied
    if isinstance(valfmt, str):
        valfmt = matplotlib.ticker.StrMethodFormatter(valfmt)

    # Loop over the data and create a `Text` for each "pixel".
    # Change the text's color depending on the data.
    texts = []
    for i in range(data.shape[0]):
        for j in range(data.shape[1]):
            kw.update(color=textcolors[int(im.norm(data[i, j]) >␣
↪threshold)])
            text = im.axes.text(j, i, valfmt(data[i, j], None), **kw)
            texts.append(text)

    return texts
```

The above now allows us to keep the actual plot creation pretty compact.

```
fig, ax = plt.subplots()

im, cbar = heatmap(harvest, vegetables, farmers, ax=ax,
                   cmap="YlGn", cbarlabel="harvest [t/year]")
texts = annotate_heatmap(im, valfmt="{x:.1f} t")

fig.tight_layout()
plt.show()
```



Some more complex heatmap examples

In the following we show the versatility of the previously created functions by applying it in different cases and using different arguments.

```
np.random.seed(19680801)

fig, ((ax, ax2), (ax3, ax4)) = plt.subplots(2, 2, figsize=(8, 6))

# Replicate the above example with a different font size and colormap.

im, _ = heatmap(harvest, vegetables, farmers, ax=ax,
                cmap="Wistia", cbarlabel="harvest [t/year]")
annotate_heatmap(im, valfmt="{x:.1f}", size=7)

# Create some new data, give further arguments to imshow (vmin),
# use an integer format on the annotations and provide some colors.

data = np.random.randint(2, 100, size=(7, 7))
y = [f"Book {i}" for i in range(1, 8)]
```

(continues on next page)

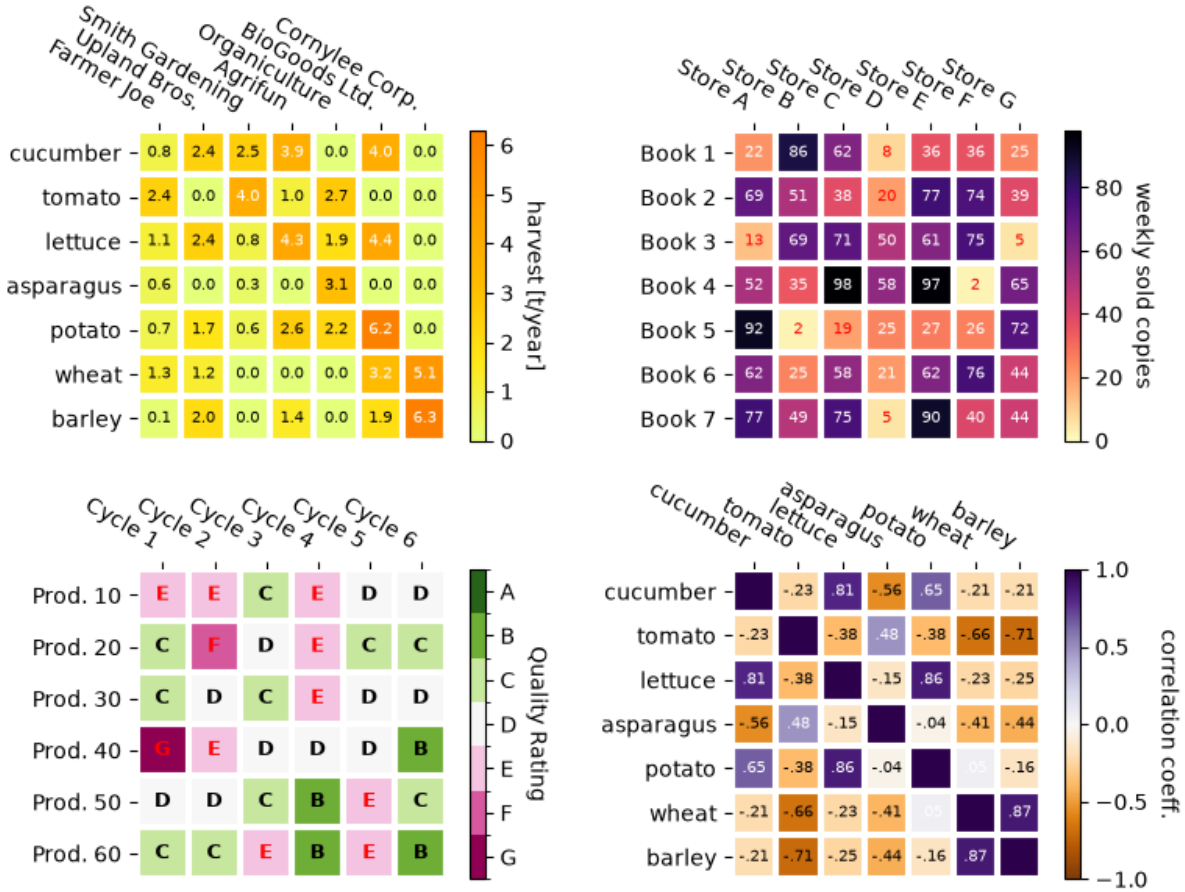
(continued from previous page)

```
x = [f"Store {i}" for i in list("ABCDEFG")]
im, _ = heatmap(data, y, x, ax=ax2, vmin=0,
                cmap="magma_r", cbarlabel="weekly sold copies")
annotate_heatmap(im, valfmt="{x:d}", size=7, threshold=20,
                 textcolors=("red", "white"))

# Sometimes even the data itself is categorical. Here we use a
# `matplotlib.colors.BoundaryNorm` to get the data into classes
# and use this to colorize the plot, but also to obtain the class
# labels from an array of classes.

data = np.random.randn(6, 6)
y = [f"Prod. {i}" for i in range(10, 70, 10)]
x = [f"Cycle {i}" for i in range(1, 7)]

qrates = list("ABCDEFG")
norm = matplotlib.colors.BoundaryNorm(np.linspace(-3.5, 3.5, 8), 7)
fmt = matplotlib.ticker.FuncFormatter(lambda x, pos: qrates[::-
 ↪1][norm(x)])

im, _ = heatmap(data, y, x, ax=ax3,
                cmap=mpl.colormaps["PiYG"].resampled(7), norm=norm,
                cbar_kw=dict(ticks=np.arange(-3, 4), format=fmt),
                cbarlabel="Quality Rating")

annotate_heatmap(im, valfmt=fmt, size=9, fontweight="bold", threshold=-
 ↪1,
                 textcolors=("red", "black"))

# We can nicely plot a correlation matrix. Since this is bound by -1␣
 ↪and 1,
# we use those as vmin and vmax. We may also remove leading zeros and␣
 ↪hide
# the diagonal elements (which are all 1) by using a
# `matplotlib.ticker.FuncFormatter`.

corr_matrix = np.corrcoef(harvest)
im, _ = heatmap(corr_matrix, vegetables, vegetables, ax=ax4,
                cmap="PuOr", vmin=-1, vmax=1,
                cbarlabel="correlation coeff.")


def func(x, pos):
    return f"{x:.2f}".replace("0.", ".").replace("1.00", "")

annotate_heatmap(im, valfmt=matplotlib.ticker.FuncFormatter(func),␣
```

(continues on next page)

(continued from previous page)

```
 ↪size=7)


plt.tight_layout()
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*

Total running time of the script: (0 minutes 2.513 seconds)

Affine transform of an image

Prepending an affine transformation (*Affine2D*) to the *data transform* of an image allows to manipulate the image's shape and orientation. This is an example of the concept of *transform chaining*.

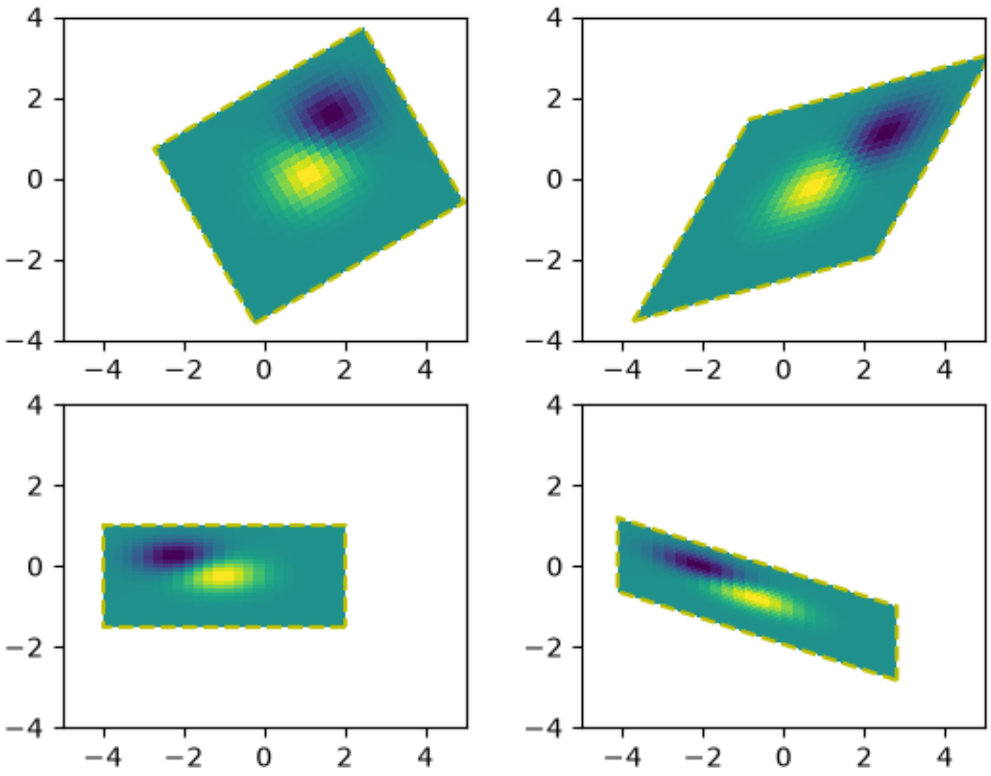
The image of the output should have its boundary match the dashed yellow rectangle.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.transforms as mtransforms


def get_image():
    delta = 0.25
    x = y = np.arange(-3.0, 3.0, delta)
    X, Y = np.meshgrid(x, y)
    Z1 = np.exp(-X**2 - Y**2)
    Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
    Z = (Z1 - Z2)
    return Z


def do_plot(ax, Z, transform):
    im = ax.imshow(Z, interpolation='none',
                   origin='lower',
                   extent=[-2, 4, -3, 2], clip_on=True)

    trans_data = transform + ax.transData
    im.set_transform(trans_data)

    # display intended extent of the image
    x1, x2, y1, y2 = im.get_extent()
    ax.plot([x1, x2, x2, x1, x1], [y1, y1, y2, y2, y1], "y--",
            transform=trans_data)
    ax.set_xlim(-5, 5)
    ax.set_ylim(-4, 4)
```

(continues on next page)

(continued from previous page)

```
# prepare image and figure
fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(2, 2)
Z = get_image()

# image rotation
do_plot(ax1, Z, mtransforms.Affine2D().rotate_deg(30))

# image skew
do_plot(ax2, Z, mtransforms.Affine2D().skew_deg(30, 15))

# scale and reflection
do_plot(ax3, Z, mtransforms.Affine2D().scale(-1, .5))

# everything and a translation
do_plot(ax4, Z, mtransforms.Affine2D().
        rotate_deg(30).skew_deg(30, 15).scale(-1, .5).translate(.5, -
 ↪1))

plt.show()
```



References

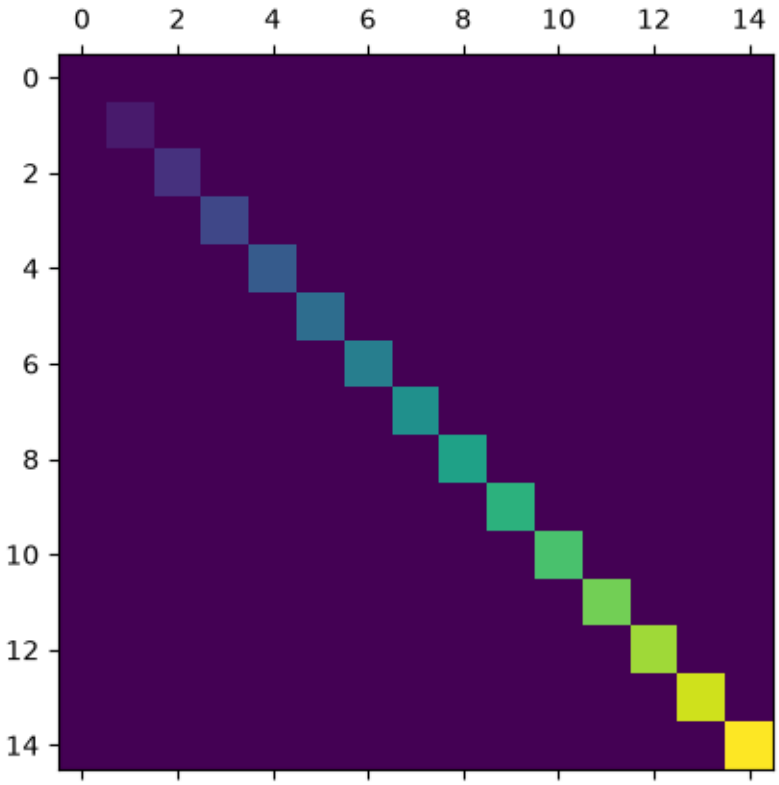
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow / matplotlib.pyplot.imshow*
- *matplotlib.transforms.Affine2D*

Visualize matrices with matshow

matshow visualizes a 2D matrix or array as color-coded image.

```
import matplotlib.pyplot as plt
import numpy as np

# a 2D array with linearly increasing values on the diagonal
a = np.diag(range(15))

plt.matshow(a)

plt.show()
```



References

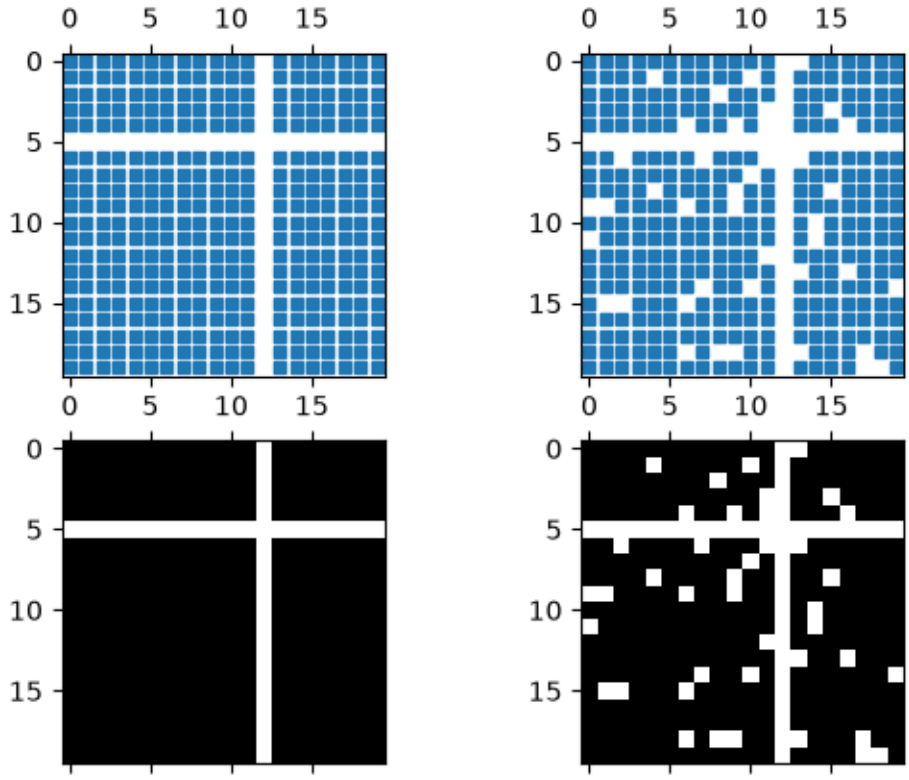
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*

Spy Demos

Plot the sparsity pattern of arrays.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

fig, axs = plt.subplots(2, 2)
ax1 = axs[0, 0]
ax2 = axs[0, 1]
ax3 = axs[1, 0]
ax4 = axs[1, 1]

x = np.random.randn(20, 20)
x[5, :] = 0.
x[:, 12] = 0.

ax1.spy(x, markersize=5)
ax2.spy(x, precision=0.1, markersize=5)

ax3.spy(x)
ax4.spy(x, precision=0.1)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.spy* / *matplotlib.pyplot.spy*

Spectrogram

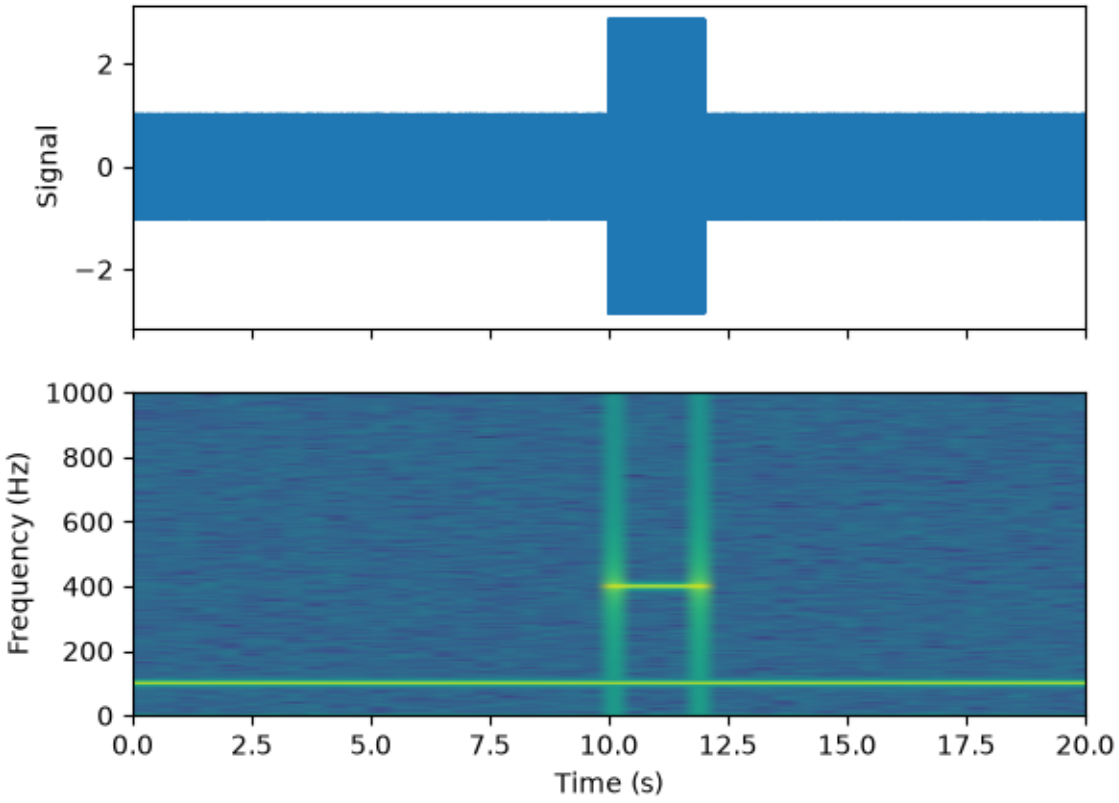
Plotting a spectrogram using *specgram*.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

dt = 0.0005
t = np.arange(0.0, 20.5, dt)
s1 = np.sin(2 * np.pi * 100 * t)
s2 = 2 * np.sin(2 * np.pi * 400 * t)
```

(continues on next page)

(continued from previous page)

```
# create a transient "chirp"
s2[t <= 10] = s2[12 <= t] = 0

# add some noise into the mix
nse = 0.01 * np.random.random(size=len(t))

x = s1 + s2 + nse  # the signal
NFFT = 1024  # the length of the windowing segments
Fs = 1/dt  # the sampling frequency

fig, (ax1, ax2) = plt.subplots(nrows=2, sharex=True)
ax1.plot(t, x)
ax1.set_ylabel('Signal')

Pxx, freqs, bins, im = ax2.specgram(x, NFFT=NFFT, Fs=Fs)
# The `specgram` method returns 4 objects. They are:
# - Pxx: the periodogram
# - freqs: the frequency vector
# - bins: the centers of the time bins
# - im: the .image.AxesImage instance representing the data in the plot
ax2.set_xlabel('Time (s)')
ax2.set_ylabel('Frequency (Hz)')
ax2.set_xlim(0, 20)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.specgram* / *matplotlib.pyplot.specgram*

Barcode

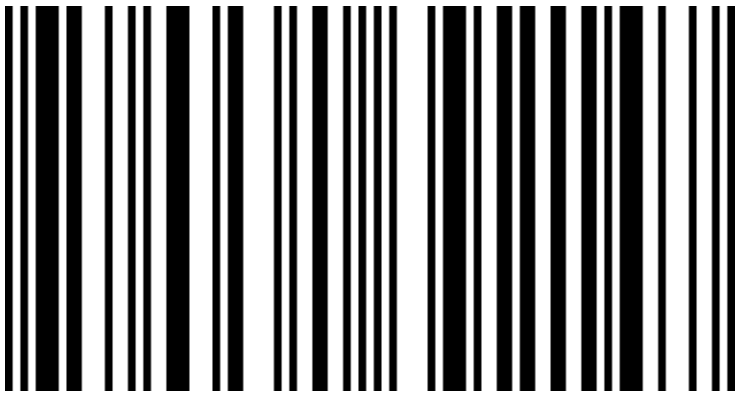
This demo shows how to produce a bar code.

The figure size is calculated so that the width in pixels is a multiple of the number of data points to prevent interpolation artifacts. Additionally, the `Axes` is defined to span the whole figure and all `Axis` are turned off.

The data itself is rendered with *imshow* using

- `code.reshape(1, -1)` to turn the data into a 2D array with one row.
- `imshow(..., aspect='auto')` to allow for non-square pixels.
- `imshow(..., interpolation='nearest')` to prevent blurred edges. This should not happen anyway because we fine-tuned the figure width in pixels, but just to be safe.

```
import matplotlib.pyplot as plt
import numpy as np

code = np.array([
    1, 0, 1, 0, 1, 1, 1, 0, 1, 1, 0, 0, 0, 1, 0, 0, 1, 0, 1, 0, 0, 1,␣
 ↪1, 1,
    0, 0, 0, 1, 0, 1, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0, 1, 1, 0, 0, 1, 0,␣
 ↪1, 0,
    1, 0, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 0, 1, 0, 0, 1, 1, 0, 1, 1, 0,␣
 ↪0, 1,
    1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0,␣
 ↪1])

pixel_per_bar = 4
dpi = 100

fig = plt.figure(figsize=(len(code) * pixel_per_bar / dpi, 2), dpi=dpi)
ax = fig.add_axes((0, 0, 1, 1))  # span the whole figure
ax.set_axis_off()
ax.imshow(code.reshape(1, -1), cmap='binary', aspect='auto',
          interpolation='nearest')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*
- *matplotlib.figure.Figure.add_axes*

Tags: component: axes plot-type: imshow purpose: fun

BboxImage Demo

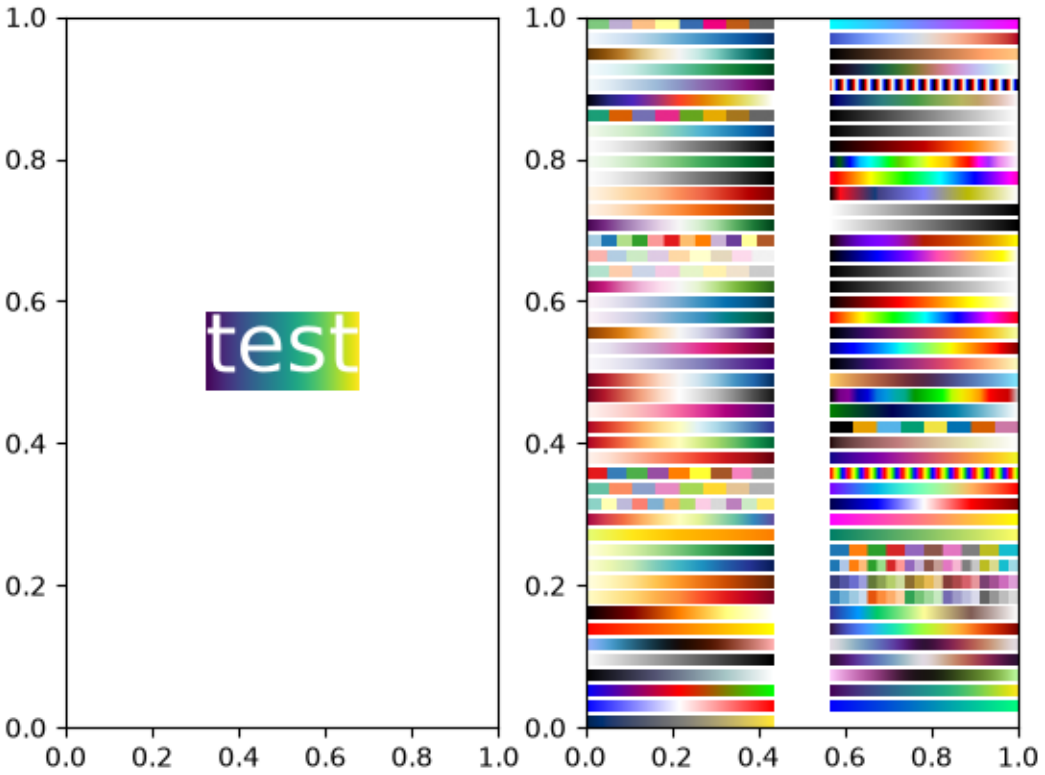
A *BboxImage* can be used to position an image according to a bounding box. This demo shows how to show an image inside a *text.Text*'s bounding box as well as how to manually create a bounding box for the image.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.image import BboxImage
from matplotlib.transforms import Bbox, TransformedBbox

fig, (ax1, ax2) = plt.subplots(ncols=2)

# ----------------------------
# Create a BboxImage with Text
# ----------------------------
txt = ax1.text(0.5, 0.5, "test", size=30, ha="center", color="w")
ax1.add_artist(
    BboxImage(txt.get_window_extent, data=np.arange(256).reshape((1, -
↪1))))

# ------------------------------------
# Create a BboxImage for each colormap
# ------------------------------------
# List of all colormaps; skip reversed colormaps.
cmap_names = sorted(m for m in plt.colormaps if not m.endswith("_r"))

ncol = 2
nrow = len(cmap_names) // ncol + 1

xpad_fraction = 0.3
dx = 1 / (ncol + xpad_fraction * (ncol - 1))

ypad_fraction = 0.3
dy = 1 / (nrow + ypad_fraction * (nrow - 1))

for i, cmap_name in enumerate(cmap_names):
```

(continues on next page)

(continued from previous page)

```
    ix, iy = divmod(i, nrow)
    bbox0 = Bbox.from_bounds(ix*dx*(1+xpad_fraction),
                             1 - iy*dy*(1+ypad_fraction) - dy,
                             dx, dy)
    bbox = TransformedBbox(bbox0, ax2.transAxes)
    ax2.add_artist(
        BboxImage(bbox, cmap=cmap_name, data=np.arange(256).reshape((1,
 ↪ -1))))

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.image.BboxImage*
- *matplotlib.transforms.Bbox*
- *matplotlib.transforms.TransformedBbox*

- *matplotlib.text.Text*

Figimage Demo

This illustrates placing images directly in the figure, with no Axes objects.

```
import matplotlib.pyplot as plt
import numpy as np

fig = plt.figure()
Z = np.arange(10000).reshape((100, 100))
Z[:, 50:] = 1

im1 = fig.figimage(Z, xo=50, yo=0, origin='lower')
im2 = fig.figimage(Z, xo=100, yo=100, alpha=.8, origin='lower')

plt.show()
```

References

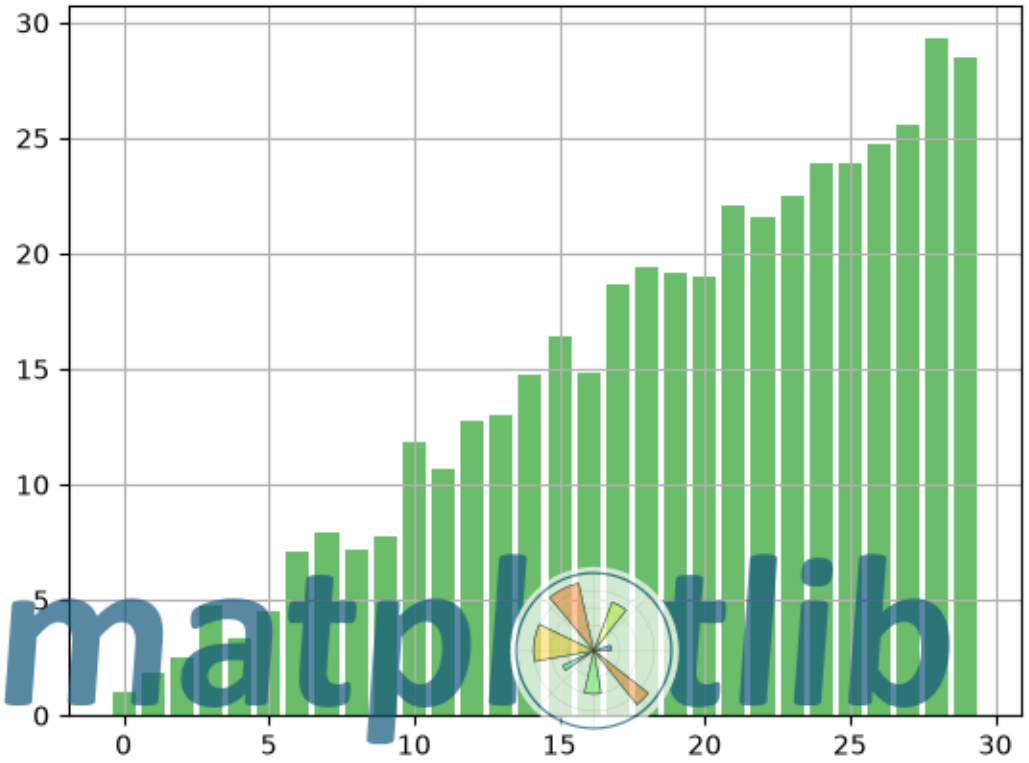
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.figure.Figure*
- *matplotlib.figure.Figure.figimage* / *matplotlib.pyplot.figimage*

Watermark image

Overlay an image on a plot by moving it to the front (`zorder=3`) and making it semi-transparent (`alpha=0.7`).

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.cbook as cbook
import matplotlib.image as image

with cbook.get_sample_data('logo2.png') as file:
    im = image.imread(file)

fig, ax = plt.subplots()

np.random.seed(19680801)
x = np.arange(30)
y = x + np.random.randn(30)
ax.bar(x, y, color='#6bbc6b')
ax.grid()

fig.figimage(im, 25, 25, zorder=3, alpha=.7)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.image*
- *matplotlib.image.imread* / *matplotlib.pyplot.imread*
- *matplotlib.figure.Figure.figimage*

6.24.3 Statistics

Errorbar function

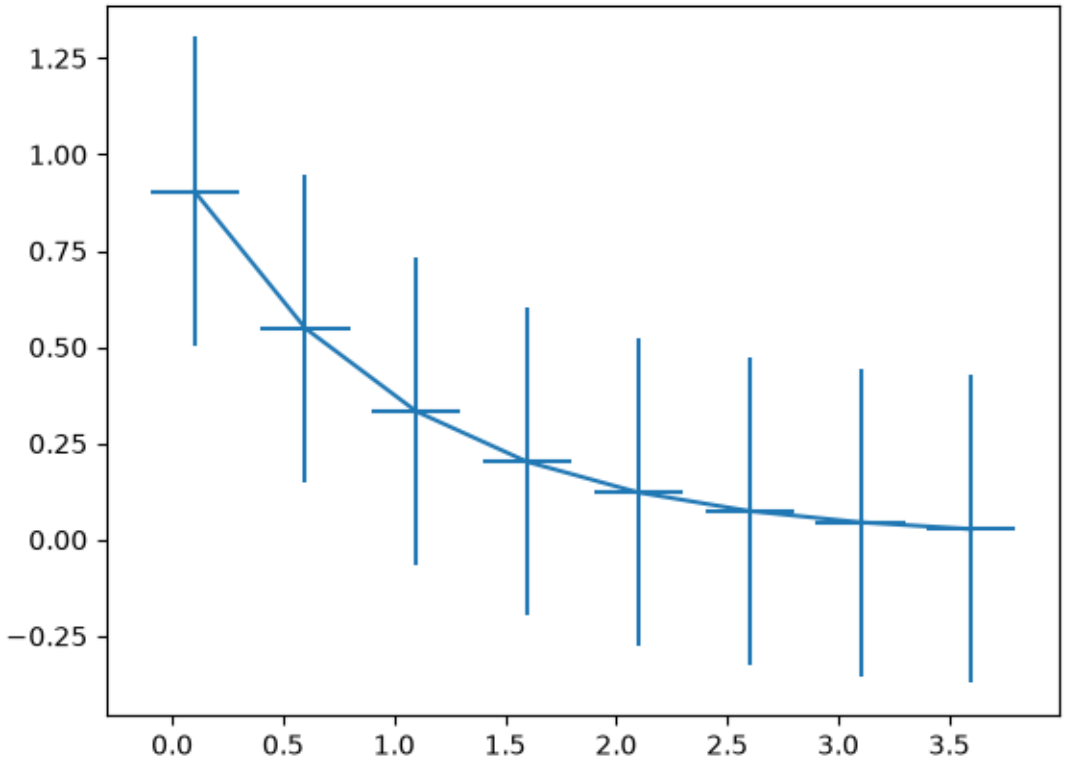
This exhibits the most basic use of the error bar method. In this case, constant values are provided for the error in both the x- and y-directions.

```
import matplotlib.pyplot as plt
import numpy as np

# example data
```

(continues on next page)

(continued from previous page)

```
x = np.arange(0.1, 4, 0.5)
y = np.exp(-x)

fig, ax = plt.subplots()
ax.errorbar(x, y, xerr=0.2, yerr=0.4)
plt.show()
```



Tags: plot-type: errorbar domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.errorbar / matplotlib.pyplot.errorbar*

Different ways of specifying error bars

Errors can be specified as a constant value (as shown in *Errorbar function*). However, this example demonstrates how they vary by specifying arrays of error values.

If the raw `x` and `y` data have length N, there are two options:

Array of shape (N,):

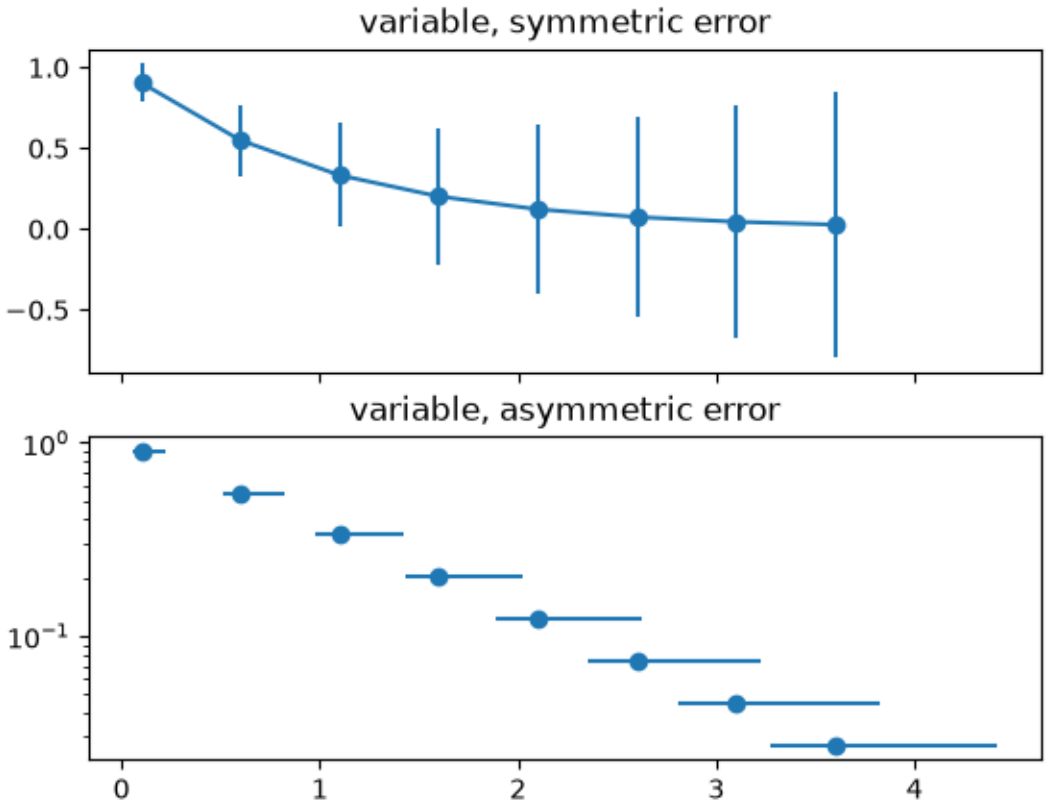
Error varies for each point, but the error values are symmetric (i.e. the lower and upper values are equal).

Array of shape (2, N):

Error varies for each point, and the lower and upper limits (in that order) are different (asymmetric case)

In addition, this example demonstrates how to use log scale with error bars.

```
import matplotlib.pyplot as plt
import numpy as np

# example data
x = np.arange(0.1, 4, 0.5)
y = np.exp(-x)

# example error bar values that vary with x-position
error = 0.1 + 0.2 * x

fig, (ax0, ax1) = plt.subplots(nrows=2, sharex=True)
ax0.errorbar(x, y, yerr=error, fmt='-o')
ax0.set_title('variable, symmetric error')

# error bar values w/ different -/+ errors that
# also vary with the x-position
lower_error = 0.4 * error
upper_error = error
asymmetric_error = [lower_error, upper_error]

ax1.errorbar(x, y, xerr=asymmetric_error, fmt='o')
ax1.set_title('variable, asymmetric error')
ax1.set_yscale('log')
plt.show()
```



Tags: plot-type: errorbar domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.errorbar* / *matplotlib.pyplot.errorbar*

Errorbar subsampling

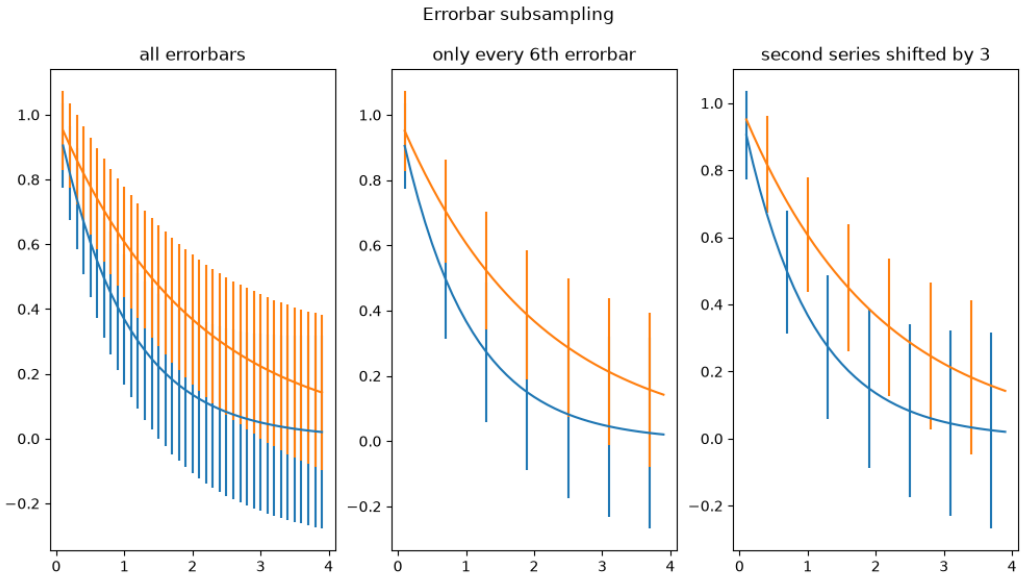
The parameter *errorevery* of *Axes.errorbar* can be used to draw error bars only on a subset of data points. This is particularly useful if there are many data points with similar errors.

```
import matplotlib.pyplot as plt
import numpy as np

# example data
x = np.arange(0.1, 4, 0.1)
y1 = np.exp(-1.0 * x)
y2 = np.exp(-0.5 * x)
```

(continues on next page)

(continued from previous page)

```
# example variable error bar values
y1err = 0.1 + 0.1 * np.sqrt(x)
y2err = 0.1 + 0.1 * np.sqrt(x/2)


fig, (ax0, ax1, ax2) = plt.subplots(nrows=1, ncols=3, sharex=True,
                                    figsize=(12, 6))

ax0.set_title('all errorbars')
ax0.errorbar(x, y1, yerr=y1err)
ax0.errorbar(x, y2, yerr=y2err)

ax1.set_title('only every 6th errorbar')
ax1.errorbar(x, y1, yerr=y1err, errorevery=6)
ax1.errorbar(x, y2, yerr=y2err, errorevery=6)

ax2.set_title('second series shifted by 3')
ax2.errorbar(x, y1, yerr=y1err, errorevery=(0, 6))
ax2.errorbar(x, y2, yerr=y2err, errorevery=(3, 6))

fig.suptitle('Errorbar subsampling')
plt.show()
```



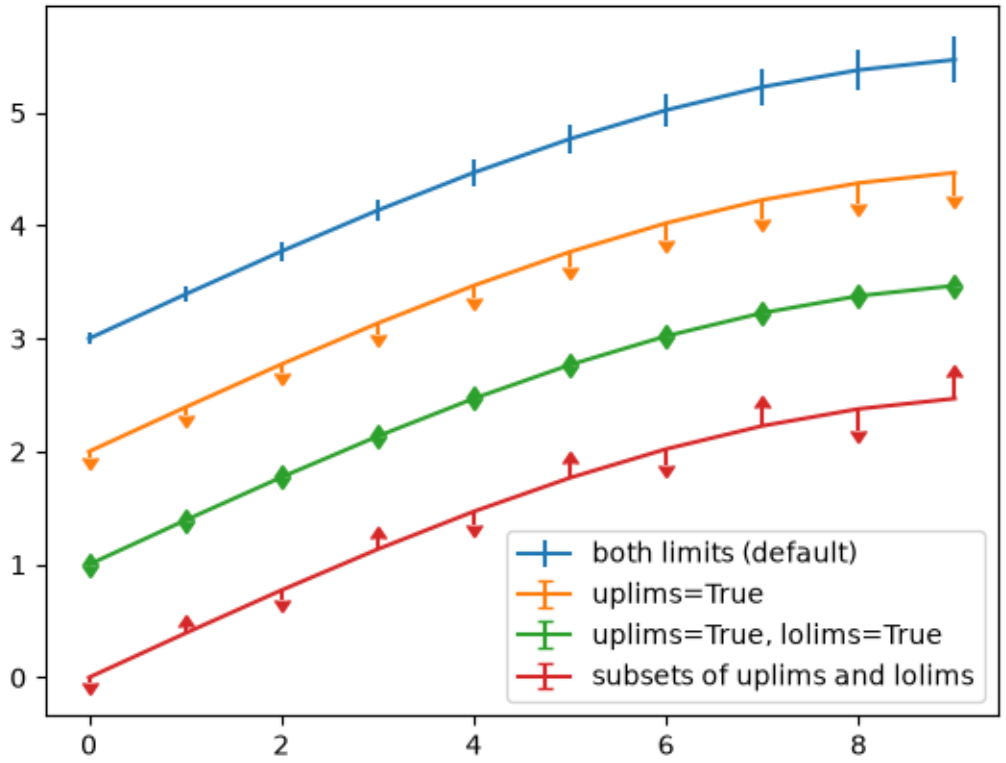
Tags: component: error plot-type: errorbar level: beginner

Errorbar limit selection

Illustration of selectively drawing lower and/or upper limit symbols on errorbars using the parameters `uplims`, `lolims` of *errorbar*.

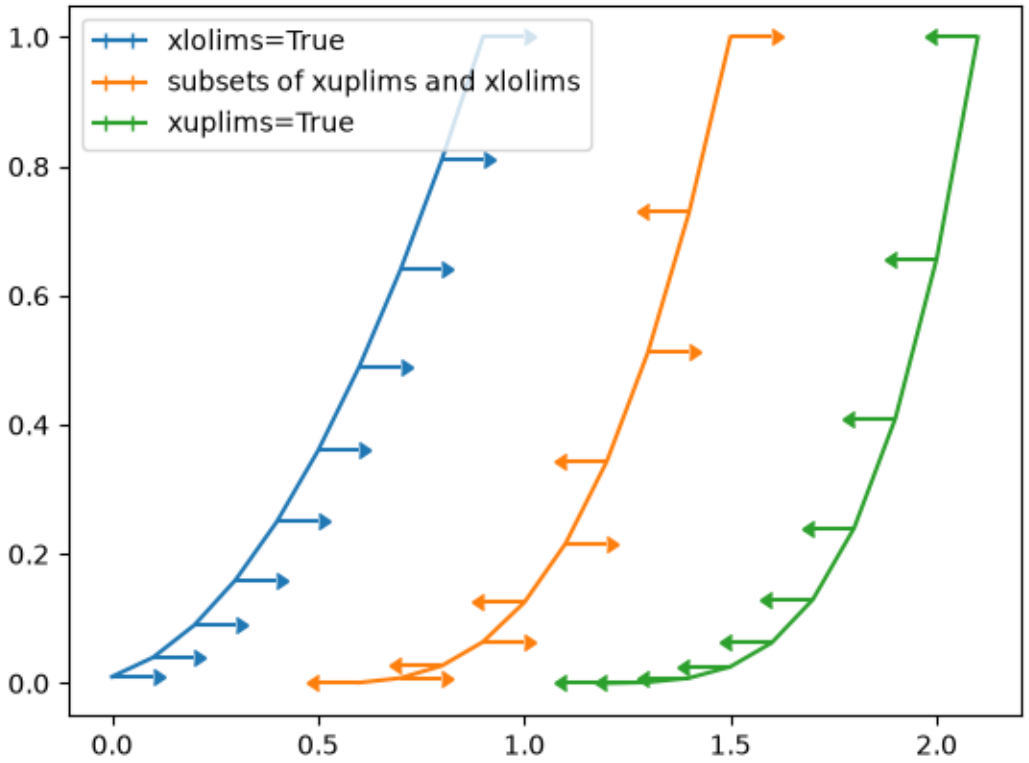
Alternatively, you can use 2xN values to draw errorbars in only one direction.

```
import matplotlib.pyplot as plt
import numpy as np

fig = plt.figure()
x = np.arange(10)
y = 2.5 * np.sin(x / 20 * np.pi)
yerr = np.linspace(0.05, 0.2, 10)

plt.errorbar(x, y + 3, yerr=yerr, label='both limits (default)')

plt.errorbar(x, y + 2, yerr=yerr, uplims=True, label='uplims=True')

plt.errorbar(x, y + 1, yerr=yerr, uplims=True, lolims=True,
             label='uplims=True, lolims=True')

upperlimits = [True, False] * 5
lowerlimits = [False, True] * 5
plt.errorbar(x, y, yerr=yerr, uplims=upperlimits, lolims=lowerlimits,
             label='subsets of uplims and lolims')

plt.legend(loc='lower right')
```



Similarly `xuplims` and `xlolims` can be used on the horizontal `xerr` errorbars.

```
fig = plt.figure()
x = np.arange(10) / 10
y = (x + 0.1)**2

plt.errorbar(x, y, xerr=0.1, xlolims=True, label='xlolims=True')
y = (x + 0.1)**3

plt.errorbar(x + 0.6, y, xerr=0.1, xuplims=upperlimits,␣
 ↪xlolims=lowerlimits,
             label='subsets of xuplims and xlolims')

y = (x + 0.1)**4
plt.errorbar(x + 1.2, y, xerr=0.1, xuplims=True, label='xuplims=True')

plt.legend()
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.errorbar* / *matplotlib.pyplot.errorbar*

Tags: component: error plot-type: errorbar level: beginner

Including upper and lower limits in error bars

In matplotlib, errors bars can have "limits". Applying limits to the error bars essentially makes the error unidirectional. Because of that, upper and lower limits can be applied in both the y- and x-directions via the `uplims`, `lolims`, `xuplims`, and `xlolims` parameters, respectively. These parameters can be scalar or boolean arrays.

For example, if `xlolims` is `True`, the x-error bars will only extend from the data towards increasing values. If `uplims` is an array filled with `False` except for the 4th and 7th values, all of the y-error bars will be bidirectional, except the 4th and 7th bars, which will extend from the data towards decreasing y-values.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

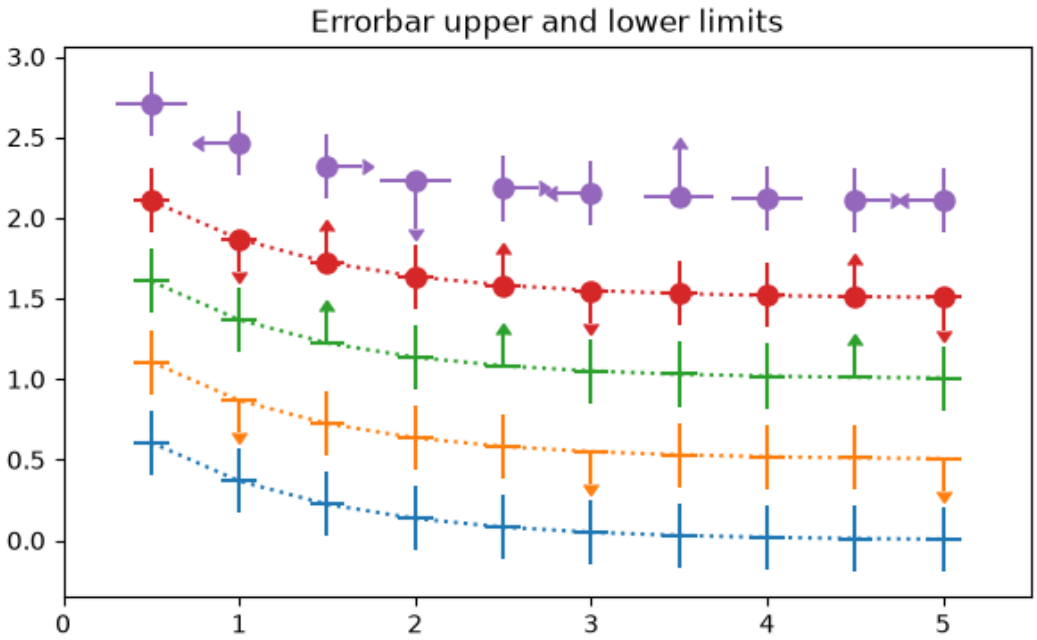
(continued from previous page)

```
# example data
x = np.array([0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0])
y = np.exp(-x)
xerr = 0.1
yerr = 0.2

# lower & upper limits of the error
lolims = np.array([0, 0, 1, 0, 1, 0, 0, 0, 1, 0], dtype=bool)
uplims = np.array([0, 1, 0, 0, 0, 1, 0, 0, 0, 1], dtype=bool)
ls = 'dotted'

fig, ax = plt.subplots(figsize=(7, 4))

# standard error bars
ax.errorbar(x, y, xerr=xerr, yerr=yerr, linestyle=ls)

# including upper limits
ax.errorbar(x, y + 0.5, xerr=xerr, yerr=yerr, uplims=uplims,
            linestyle=ls)

# including lower limits
ax.errorbar(x, y + 1.0, xerr=xerr, yerr=yerr, lolims=lolims,
            linestyle=ls)

# including upper and lower limits
ax.errorbar(x, y + 1.5, xerr=xerr, yerr=yerr,
            lolims=lolims, uplims=uplims,
            marker='o', markersize=8,
            linestyle=ls)

# Plot a series with lower and upper limits in both x & y
# constant x-error with varying y-error
xerr = 0.2
yerr = np.full_like(x, 0.2)
yerr[[3, 6]] = 0.3

# mock up some limits by modifying previous data
xlolims = lolims
xuplims = uplims
lolims = np.zeros_like(x)
uplims = np.zeros_like(x)
lolims[[6]] = True  # only limited at this index
uplims[[3]] = True  # only limited at this index

# do the plotting
```

(continues on next page)

(continued from previous page)

```
ax.errorbar(x, y + 2.1, xerr=xerr, yerr=yerr,
            xlolims=xlolims, xuplims=xuplims,
            uplims=uplims, lolims=lolims,
            marker='o', markersize=8,
            linestyle='none')

# tidy up the figure
ax.set_xlim(0, 5.5)
ax.set_title('Errorbar upper and lower limits')
plt.show()
```



Tags: plot-type: errorbar domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.errorbar* / *matplotlib.pyplot.errorbar*

Create boxes from error bars using PatchCollection

In this example, we snazz up a pretty standard error bar plot by adding a rectangle patch defined by the limits of the bars in both the x- and y- directions. To do this, we have to write our own custom function called `make_error_boxes`. Close inspection of this function will reveal the preferred pattern in writing functions for matplotlib:

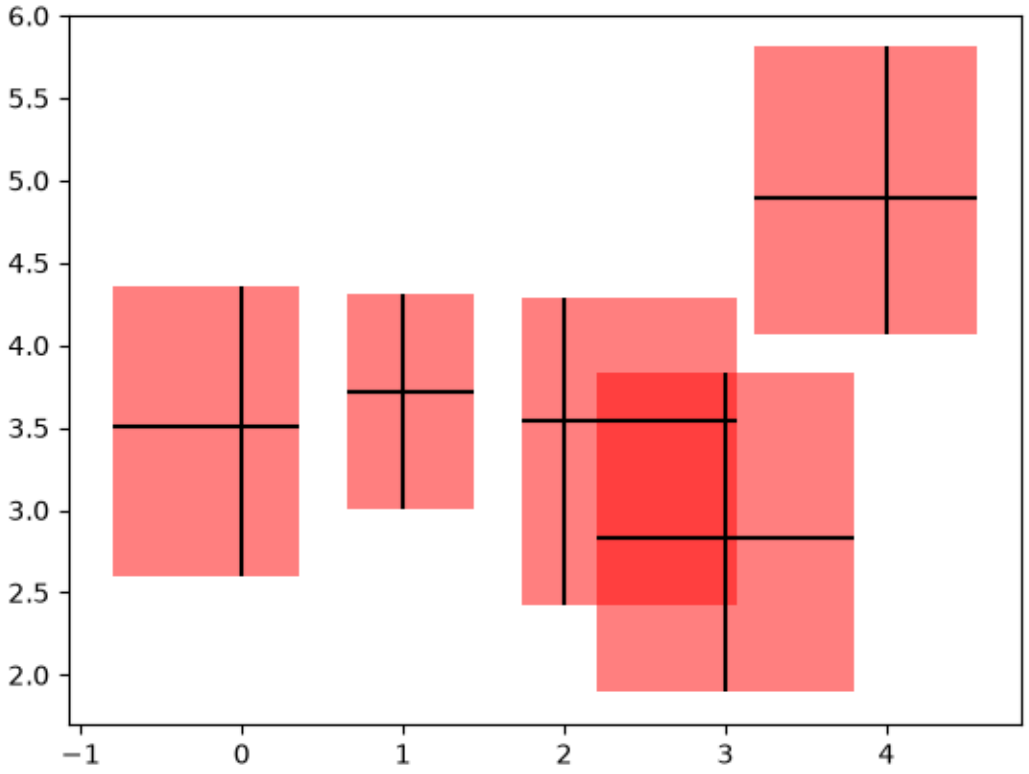
1. an *Axes* object is passed directly to the function
2. the function operates on the `Axes` methods directly, not through the `pyplot` interface
3. plotting keyword arguments that could be abbreviated are spelled out for better code readability in the future (for example we use *facecolor* instead of *fc*)
4. the artists returned by the `Axes` plotting methods are then returned by the function so that, if desired, their styles can be modified later outside of the function (they are not modified in this example).

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.collections import PatchCollection
from matplotlib.patches import Rectangle

# Number of data points
n = 5

# Dummy data
np.random.seed(19680801)
x = np.arange(0, n, 1)
y = np.random.rand(n) * 5.

# Dummy errors (above and below)
xerr = np.random.rand(2, n) + 0.1
yerr = np.random.rand(2, n) + 0.2


def make_error_boxes(ax, xdata, ydata, xerror, yerror, facecolor='r',
                     edgecolor='none', alpha=0.5):

    # Loop over data points; create box from errors at each point
    errorboxes = [Rectangle((x - xe[0], y - ye[0]), xe.sum(), ye.sum())
                  for x, y, xe, ye in zip(xdata, ydata, xerror.T,␣
 ↪yerror.T)]

    # Create patch collection with specified colour/alpha
    pc = PatchCollection(errorboxes, facecolor=facecolor, alpha=alpha,
                         edgecolor=edgecolor)

    # Add collection to Axes
    ax.add_collection(pc)

    # Plot errorbars
    artists = ax.errorbar(xdata, ydata, xerr=xerror, yerr=yerror,
                          fmt='none', ecolor='k')

    return artists
```

(continues on next page)

(continued from previous page)

```
# Create figure and Axes
fig, ax = plt.subplots(1)

# Call function to create error boxes
_ = make_error_boxes(ax, x, y, xerr, yerr)

plt.show()
```



Tags: plot-type: errorbar component: rectangle component: patchcollection domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.errorbar* / *matplotlib.pyplot.errorbar*
- *matplotlib.axes.Axes.add_collection*
- *matplotlib.collections.PatchCollection*

Plot a confidence ellipse of a two-dimensional dataset

This example shows how to plot a confidence ellipse of a two-dimensional dataset, using its pearson correlation coefficient.

The approach that is used to obtain the correct geometry is explained and proved here:

https://carstenschelp.github.io/2018/09/14/Plot_Confidence_Ellipse_001.html

The method avoids the use of an iterative eigen decomposition algorithm and makes use of the fact that a normalized covariance matrix (composed of pearson correlation coefficients and ones) is particularly easy to handle.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Ellipse
import matplotlib.transforms as transforms
```

The plotting function itself

This function plots the confidence ellipse of the covariance of the given array-like variables x and y. The ellipse is plotted into the given Axes object *ax*.

The radiuses of the ellipse can be controlled by n_std which is the number of standard deviations. The default value is 3 which makes the ellipse enclose 98.9% of the points if the data is normally distributed like in these examples (3 standard deviations in 1-D contain 99.7% of the data, which is 98.9% of the data in 2-D).

```
def confidence_ellipse(x, y, ax, n_std=3.0, facecolor='none',␣
↪**kwargs):
    """
    Create a plot of the covariance confidence ellipse of *x* and *y*.

    Parameters
    ----------
    x, y : array-like, shape (n, )
        Input data.

    ax : matplotlib.axes.Axes
        The Axes object to draw the ellipse into.

    n_std : float
        The number of standard deviations to determine the ellipse's␣
↪radiuses.

    **kwargs
        Forwarded to `~matplotlib.patches.Ellipse`

    Returns
```

(continues on next page)

(continued from previous page)

```
    -------
    matplotlib.patches.Ellipse
    """
    if x.size != y.size:
        raise ValueError("x and y must be the same size")

    cov = np.cov(x, y)
    pearson = cov[0, 1]/np.sqrt(cov[0, 0] * cov[1, 1])
    # Using a special case to obtain the eigenvalues of this
    # two-dimensional dataset.
    ell_radius_x = np.sqrt(1 + pearson)
    ell_radius_y = np.sqrt(1 - pearson)
    ellipse = Ellipse((0, 0), width=ell_radius_x * 2,␣
↪height=ell_radius_y * 2,
                      facecolor=facecolor, **kwargs)

    # Calculating the standard deviation of x from
    # the squareroot of the variance and multiplying
    # with the given number of standard deviations.
    scale_x = np.sqrt(cov[0, 0]) * n_std
    mean_x = np.mean(x)

    # calculating the standard deviation of y ...
    scale_y = np.sqrt(cov[1, 1]) * n_std
    mean_y = np.mean(y)

    transf = transforms.Affine2D() \
        .rotate_deg(45) \
        .scale(scale_x, scale_y) \
        .translate(mean_x, mean_y)

    ellipse.set_transform(transf + ax.transData)
    return ax.add_patch(ellipse)
```

A helper function to create a correlated dataset

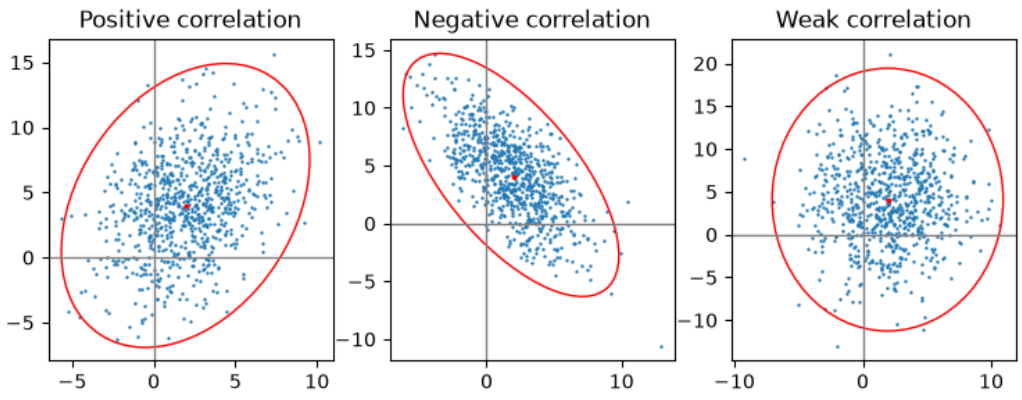
Creates a random two-dimensional dataset with the specified two-dimensional mean (mu) and dimensions (scale). The correlation can be controlled by the param 'dependency', a 2x2 matrix.

```
def get_correlated_dataset(n, dependency, mu, scale):
    latent = np.random.randn(n, 2)
    dependent = latent.dot(dependency)
    scaled = dependent * scale
    scaled_with_offset = scaled + mu
    # return x and y of the new, correlated dataset
    return scaled_with_offset[:, 0], scaled_with_offset[:, 1]
```

Positive, negative and weak correlation

Note that the shape for the weak correlation (right) is an ellipse, not a circle because x and y are differently scaled. However, the fact that x and y are uncorrelated is shown by the axes of the ellipse being aligned with the x- and y-axis of the coordinate system.

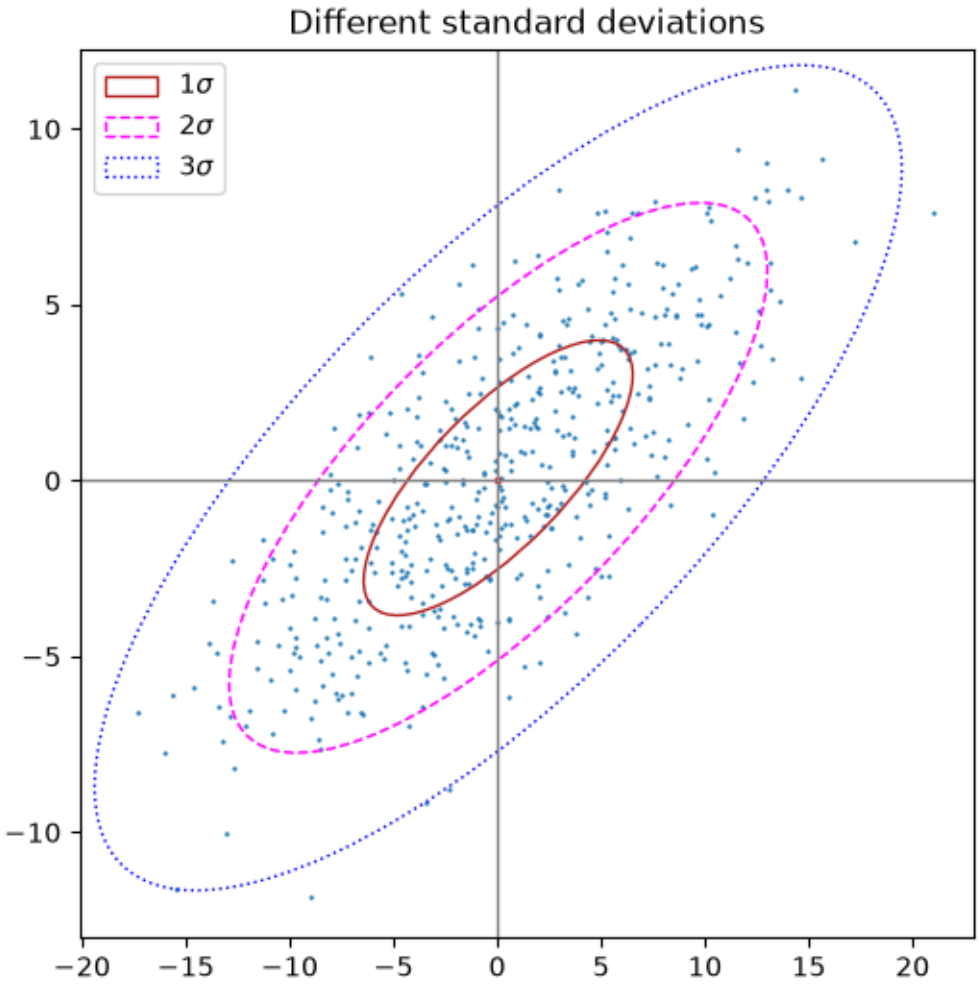
```
np.random.seed(0)

PARAMETERS = {
    'Positive correlation': [[0.85, 0.35],
                             [0.15, -0.65]],
    'Negative correlation': [[0.9, -0.4],
                             [0.1, -0.6]],
    'Weak correlation': [[1, 0],
                         [0, 1]],
}

mu = 2, 4
scale = 3, 5

fig, axs = plt.subplots(1, 3, figsize=(9, 3))
for ax, (title, dependency) in zip(axs, PARAMETERS.items()):
    x, y = get_correlated_dataset(800, dependency, mu, scale)
    ax.scatter(x, y, s=0.5)

    ax.axvline(c='grey', lw=1)
    ax.axhline(c='grey', lw=1)

    confidence_ellipse(x, y, ax, edgecolor='red')

    ax.scatter(mu[0], mu[1], c='red', s=3)
    ax.set_title(title)

plt.show()
```



Different number of standard deviations

A plot with n_std = 3 (blue), 2 (purple) and 1 (red)

```
fig, ax_nstd = plt.subplots(figsize=(6, 6))

dependency_nstd = [[0.8, 0.75],
                   [-0.2, 0.35]]
mu = 0, 0
scale = 8, 5

ax_nstd.axvline(c='grey', lw=1)
ax_nstd.axhline(c='grey', lw=1)

x, y = get_correlated_dataset(500, dependency_nstd, mu, scale)
ax_nstd.scatter(x, y, s=0.5)

confidence_ellipse(x, y, ax_nstd, n_std=1,
                   label=r'$1\sigma$', edgecolor='firebrick')
confidence_ellipse(x, y, ax_nstd, n_std=2,
                   label=r'$2\sigma$', edgecolor='fuchsia', linestyle=
 ↪'--')
confidence_ellipse(x, y, ax_nstd, n_std=3,
                   label=r'$3\sigma$', edgecolor='blue', linestyle=':')

ax_nstd.scatter(mu[0], mu[1], c='red', s=3)
ax_nstd.set_title('Different standard deviations')
ax_nstd.legend()
plt.show()
```



Using the keyword arguments

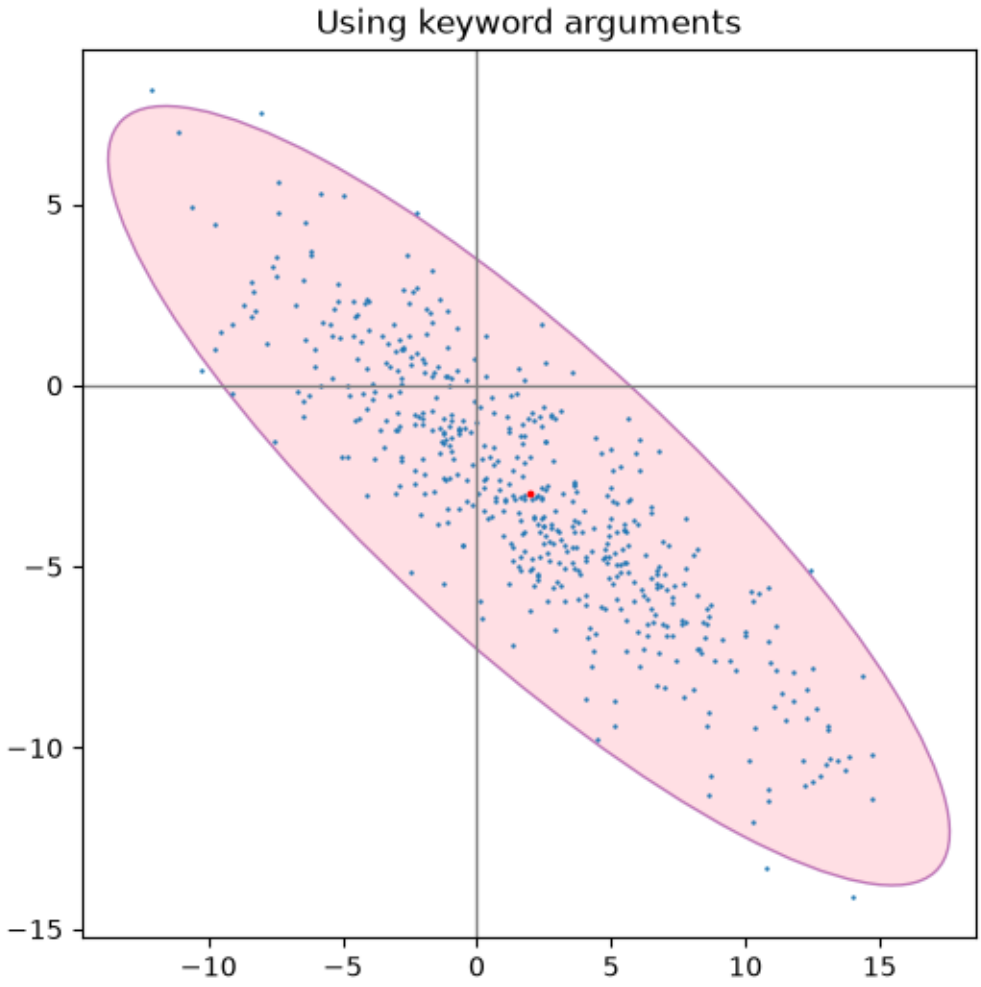
Use the keyword arguments specified for *matplotlib.patches.Patch* in order to have the ellipse rendered in different ways.

```
fig, ax_kwargs = plt.subplots(figsize=(6, 6))
dependency_kwargs = [[-0.8, 0.5],
                     [-0.2, 0.5]]
mu = 2, -3
scale = 6, 5

ax_kwargs.axvline(c='grey', lw=1)
ax_kwargs.axhline(c='grey', lw=1)
```

(continues on next page)

(continued from previous page)

```
x, y = get_correlated_dataset(500, dependency_kwargs, mu, scale)
# Plot the ellipse with zorder=0 in order to demonstrate
# its transparency (caused by the use of alpha).
confidence_ellipse(x, y, ax_kwargs,
                   alpha=0.5, facecolor='pink', edgecolor='purple',␣
 ↪zorder=0)

ax_kwargs.scatter(x, y, s=0.5)
ax_kwargs.scatter(mu[0], mu[1], c='red', s=3)
ax_kwargs.set_title('Using keyword arguments')

fig.subplots_adjust(hspace=0.25)
plt.show()
```



Tags: plot-type: specialty plot-type: scatter component: ellipse component: patch domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

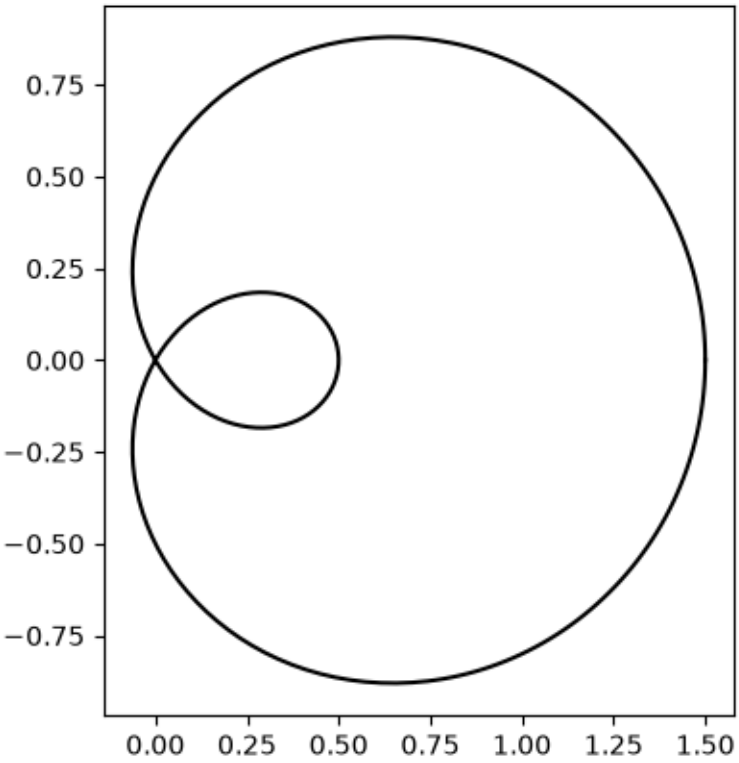
- *matplotlib.transforms.Affine2D*
- *matplotlib.patches.Ellipse*

Curve with error band

This example illustrates how to draw an error band around a parametrized curve.

A parametrized curve x(t), y(t) can directly be drawn using *plot*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import PathPatch
from matplotlib.path import Path

N = 400
t = np.linspace(0, 2 * np.pi, N)
r = 0.5 + np.cos(t)
x, y = r * np.cos(t), r * np.sin(t)

fig, ax = plt.subplots()
ax.plot(x, y, "k")
ax.set(aspect=1)
```



An error band can be used to indicate the uncertainty of the curve. In this example we assume that the error can be given as a scalar *err* that describes the uncertainty perpendicular to the curve in every point.

We visualize this error as a colored band around the path using a `PathPatch`. The patch is created from two path segments *(xp, yp)*, and *(xn, yn)* that are shifted by +/- *err* perpendicular to the curve *(x, y)*.

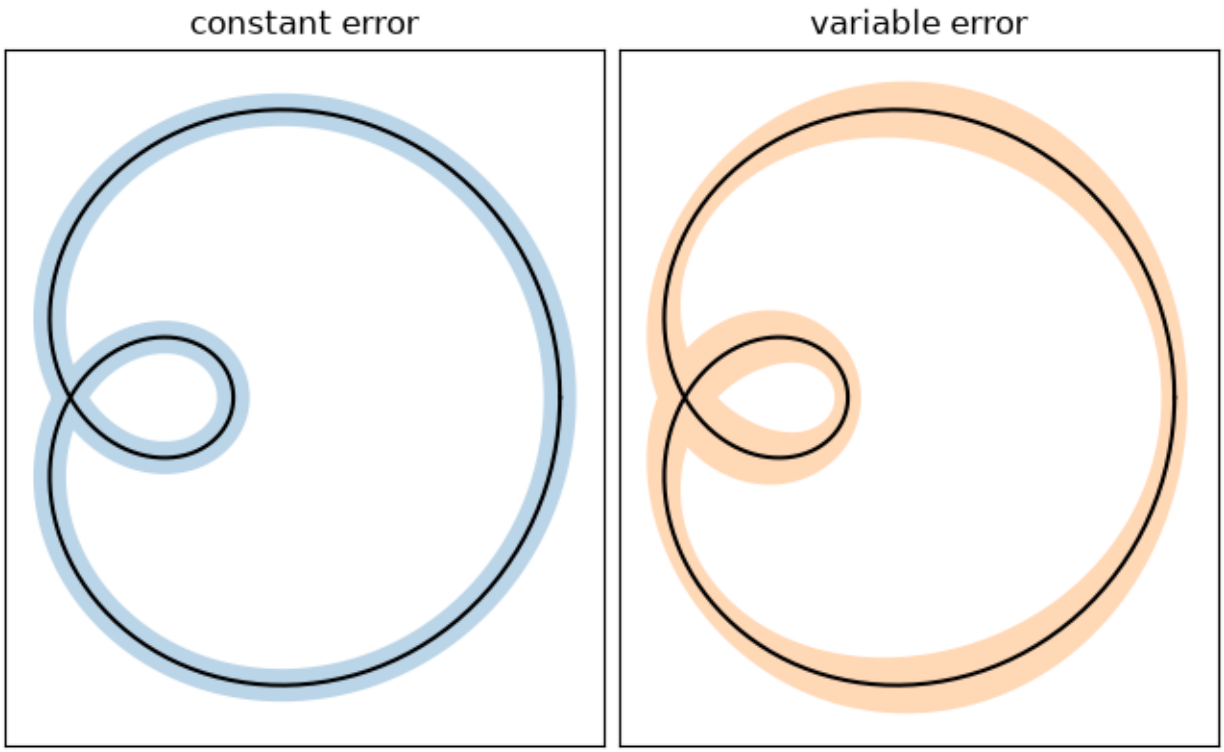
Note: This method of using a `PathPatch` is suited to arbitrary curves in 2D. If you just have a standard y-vs.-x plot, you can use the simpler `fill_between` method (see also *Fill the area between two lines*).

```
def draw_error_band(ax, x, y, err, **kwargs):
    # Calculate normals via centered finite differences (except the␣
 ↪first point
    # which uses a forward difference and the last point which uses a␣
 ↪backward
    # difference).
    dx = np.concatenate([[x[1] - x[0]], x[2:] - x[:-2], [x[-1] - x[-
 ↪2]]])
    dy = np.concatenate([[y[1] - y[0]], y[2:] - y[:-2], [y[-1] - y[-
 ↪2]]])
    l = np.hypot(dx, dy)
    nx = dy / l
    ny = -dx / l
```

(continues on next page)

(continued from previous page)

```
    # end points of errors
    xp = x + nx * err
    yp = y + ny * err
    xn = x - nx * err
    yn = y - ny * err

    vertices = np.block([[xp, xn[::-1]],
                         [yp, yn[::-1]]]).T
    codes = np.full(len(vertices), Path.LINETO)
    codes[0] = codes[len(xp)] = Path.MOVETO
    path = Path(vertices, codes)
    ax.add_patch(PathPatch(path, **kwargs))


_, axs = plt.subplots(1, 2, layout='constrained', sharex=True,␣
↪sharey=True)
errs = [
    (axs[0], "constant error", 0.05),
    (axs[1], "variable error", 0.05 * np.sin(2 * t) ** 2 + 0.04),
]
for i, (ax, title, err) in enumerate(errs):
    ax.set(title=title, aspect=1, xticks=[], yticks=[])
    ax.plot(x, y, "k")
    draw_error_band(ax, x, y, err=err,
                    facecolor=f"C{i}", edgecolor="none", alpha=.3)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches.PathPatch*
- *matplotlib.path.Path*

Tags: component: error plot-type: line level: intermediate

Histograms

How to plot histograms with Matplotlib.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import colors
from matplotlib.ticker import PercentFormatter

# Create a random number generator with a fixed seed for␣
```

(continues on next page)

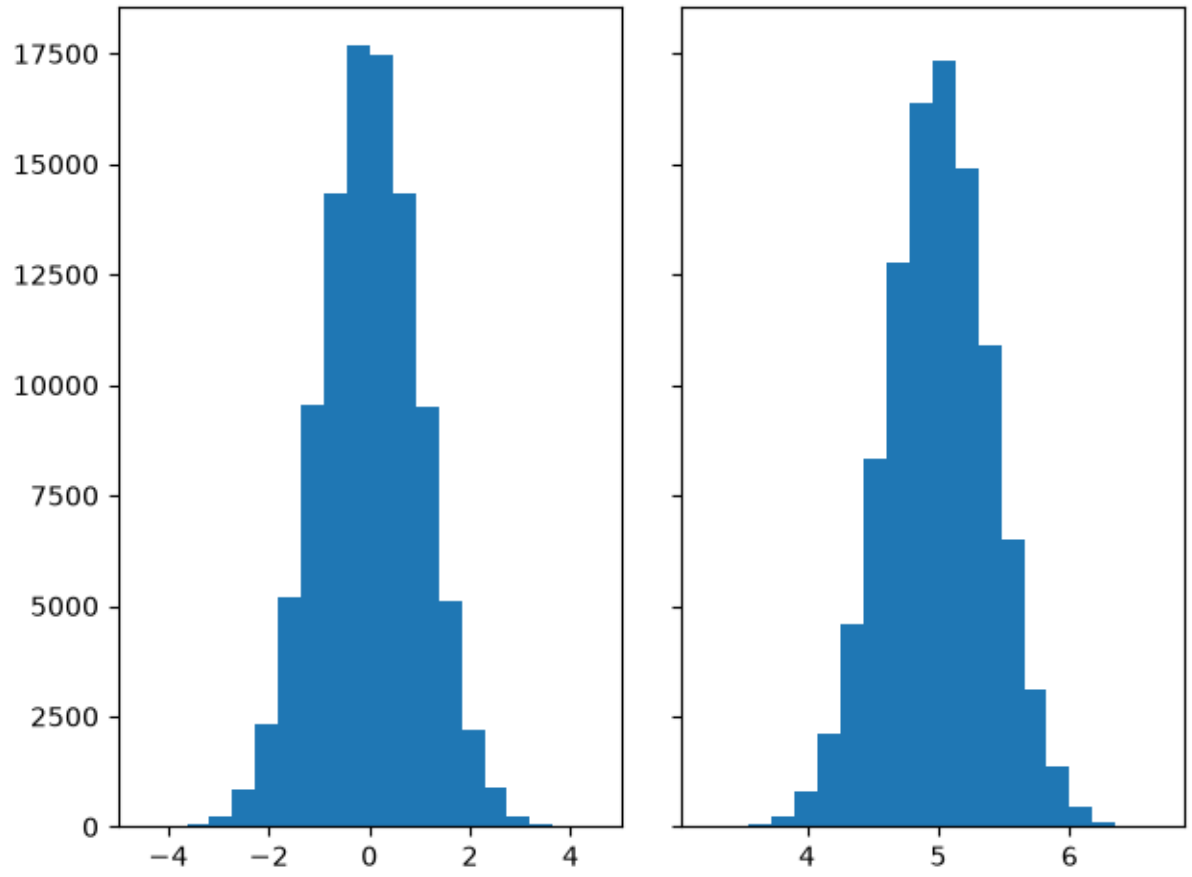
(continued from previous page)

```
 ↪reproducibility
rng = np.random.default_rng(19680801)
```

Generate data and plot a simple histogram

To generate a 1D histogram we only need a single vector of numbers. For a 2D histogram we'll need a second vector. We'll generate both below, and show the histogram for each vector.

```
N_points = 100000
n_bins = 20

# Generate two normal distributions
dist1 = rng.standard_normal(N_points)
dist2 = 0.4 * rng.standard_normal(N_points) + 5

fig, axs = plt.subplots(1, 2, sharey=True, tight_layout=True)

# We can set the number of bins with the *bins* keyword argument.
axs[0].hist(dist1, bins=n_bins)
axs[1].hist(dist2, bins=n_bins)

plt.show()
```



Updating histogram colors

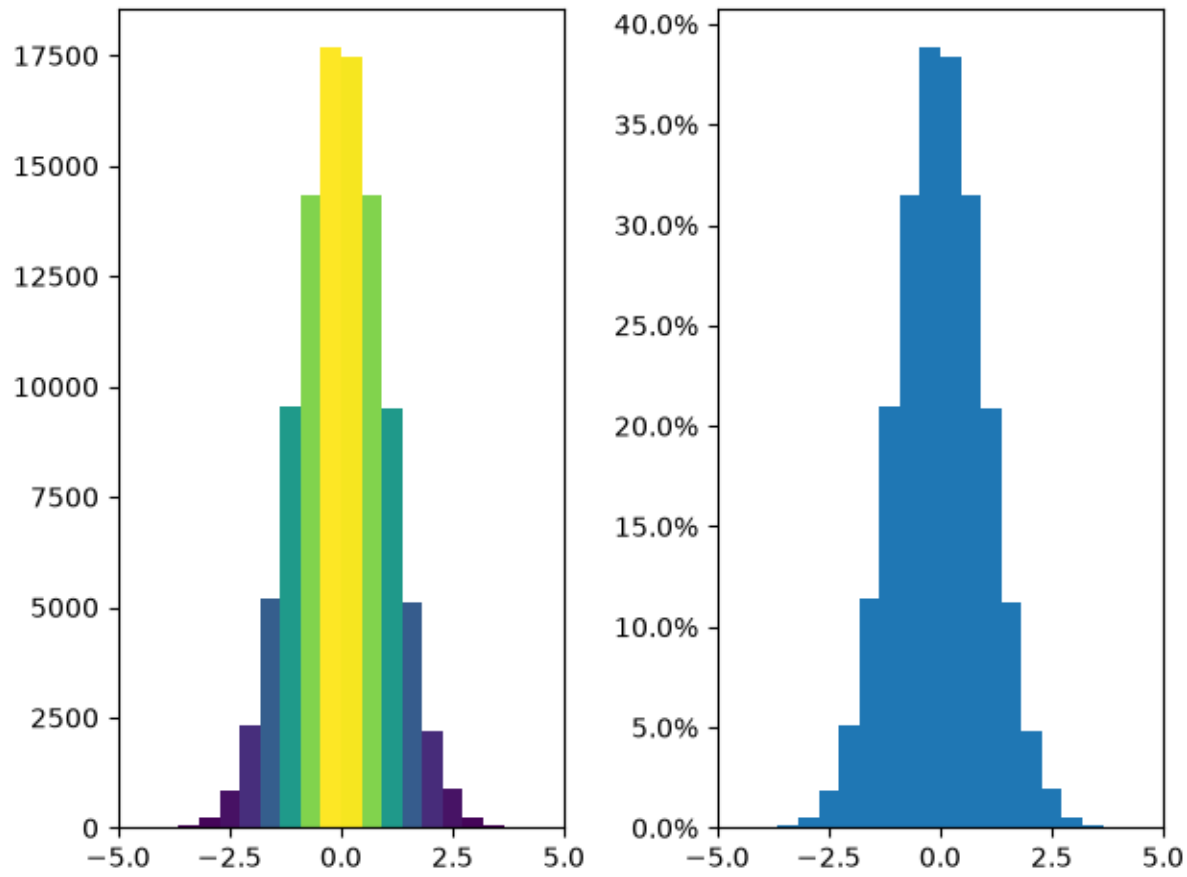
The histogram method returns (among other things) a `patches` object. This gives us access to the properties of the objects drawn. Using this, we can edit the histogram to our liking. Let's change the color of each bar based on its y value.

```
fig, axs = plt.subplots(1, 2, tight_layout=True)

# N is the count in each bin, bins is the lower-limit of the bin
N, bins, patches = axs[0].hist(dist1, bins=n_bins)

# We'll color code by height, but you could use any scalar
fracs = N / N.max()

# we need to normalize the data to 0..1 for the full range of the␣
 ↪colormap
norm = colors.Normalize(fracs.min(), fracs.max())

# Now, we'll loop through our objects and set the color of each␣
 ↪accordingly
```

(continues on next page)

(continued from previous page)

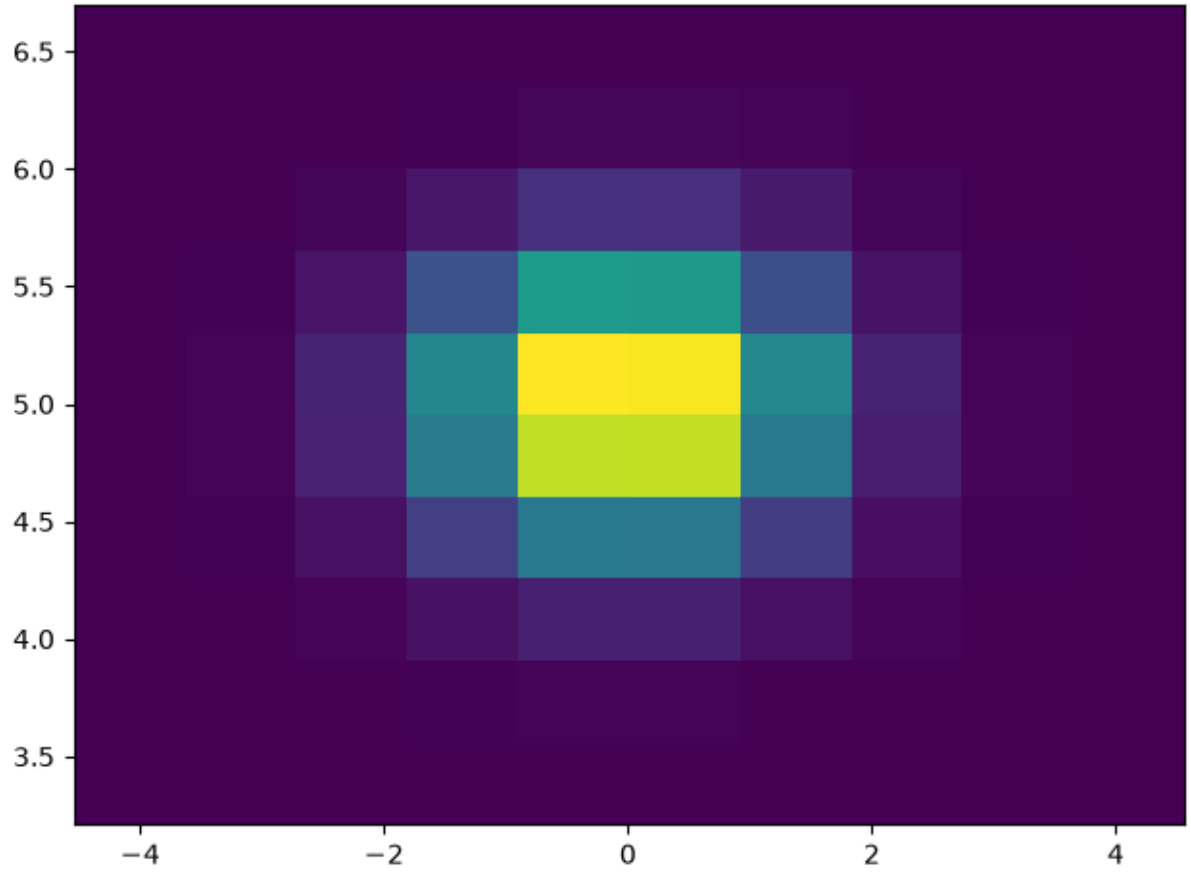
```
for thisfrac, thispatch in zip(fracs, patches):
    color = plt.colormaps["viridis"](norm(thisfrac))
    thispatch.set_facecolor(color)

# We can also normalize our inputs by the total number of counts
axs[1].hist(dist1, bins=n_bins, density=True)

# Now we format the y-axis to display percentage
axs[1].yaxis.set_major_formatter(PercentFormatter(xmax=1))
```



Plot a 2D histogram

To plot a 2D histogram, one only needs two vectors of the same length, corresponding to each axis of the histogram.

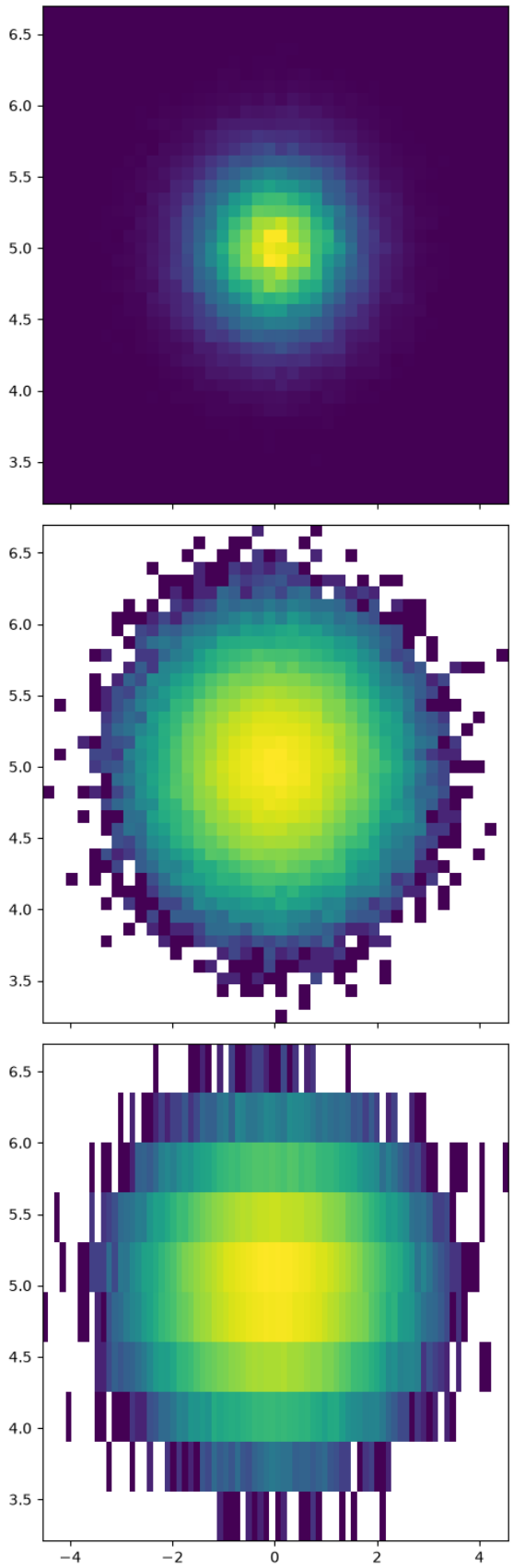
```
fig, ax = plt.subplots(tight_layout=True)
hist = ax.hist2d(dist1, dist2)
```



Customizing your histogram

Customizing a 2D histogram is similar to the 1D case, you can control visual components such as the bin size or color normalization.

```
fig, axs = plt.subplots(3, 1, figsize=(5, 15), sharex=True,␣
 ↪sharey=True,
                        tight_layout=True)

# We can increase the number of bins on each axis
axs[0].hist2d(dist1, dist2, bins=40)

# As well as define normalization of the colors
axs[1].hist2d(dist1, dist2, bins=40, norm=colors.LogNorm())

# We can also define custom numbers of bins for each axis
axs[2].hist2d(dist1, dist2, bins=(80, 10), norm=colors.LogNorm())
```


6.5
6.0
5.5
5.0
4.5
4.0
3.5
6.5
6.0
5.5
5.0
4.5
4.0
3.5
6.5
6.0
5.5
5.0
4.5
4.0
3.5
−4
−2
0
2
4

Tags: plot-type: histogram plot-type: histogram2d domain: statistics styling: color component: normalization component: patch

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.hist / matplotlib.pyplot.hist*
- *matplotlib.pyplot.hist2d*
- *matplotlib.ticker.PercentFormatter*

Total running time of the script: (0 minutes 1.386 seconds)

Demo of the histogram function's different `histtype` settings

- Histogram with step curve that has a color fill.
- Histogram with step curve with no fill.
- Histogram with custom and unequal bin widths.
- Two histograms with stacked bars.

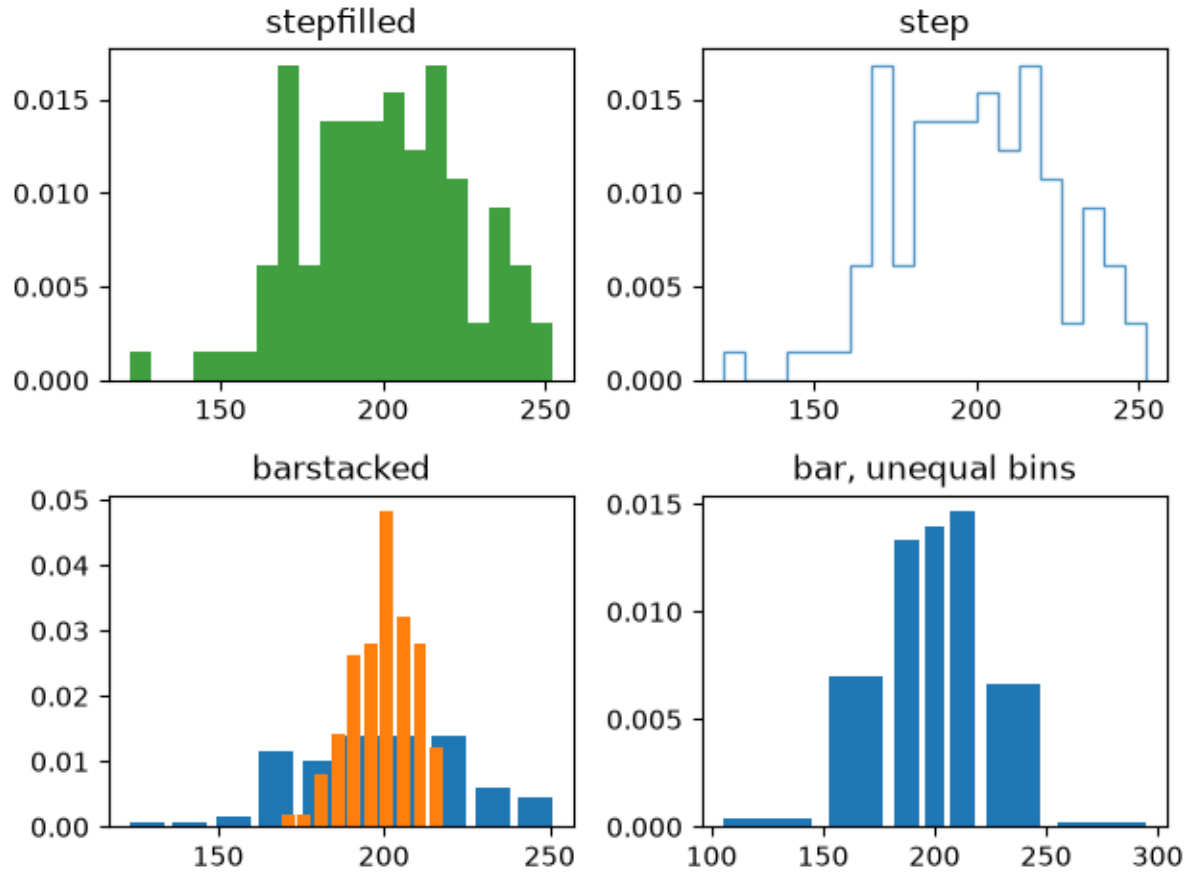
Selecting different bin counts and sizes can significantly affect the shape of a histogram. The Astropy docs have a great section on how to select these parameters: http://docs.astropy.org/en/stable/visualization/histogram.html

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)

mu_x = 200
sigma_x = 25
x = np.random.normal(mu_x, sigma_x, size=100)

mu_w = 200
sigma_w = 10
w = np.random.normal(mu_w, sigma_w, size=100)

fig, axs = plt.subplots(nrows=2, ncols=2)

axs[0, 0].hist(x, 20, density=True, histtype='stepfilled', facecolor='g
↪',
               alpha=0.75)
axs[0, 0].set_title('stepfilled')

axs[0, 1].hist(x, 20, density=True, histtype='step', facecolor='g',
```

(continues on next page)

(continued from previous page)

```
                alpha=0.75)
axs[0, 1].set_title('step')

axs[1, 0].hist(x, density=True, histtype='barstacked', rwidth=0.8)
axs[1, 0].hist(w, density=True, histtype='barstacked', rwidth=0.8)
axs[1, 0].set_title('barstacked')

# Create a histogram by providing the bin edges (unequally spaced).
bins = [100, 150, 180, 195, 205, 220, 250, 300]
axs[1, 1].hist(x, bins, density=True, histtype='bar', rwidth=0.8)
axs[1, 1].set_title('bar, unequal bins')

fig.tight_layout()
plt.show()
```



Tags: plot-type: histogram domain: statistics purpose: reference

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.hist* / *matplotlib.pyplot.hist*

Histogram bins, density, and weight

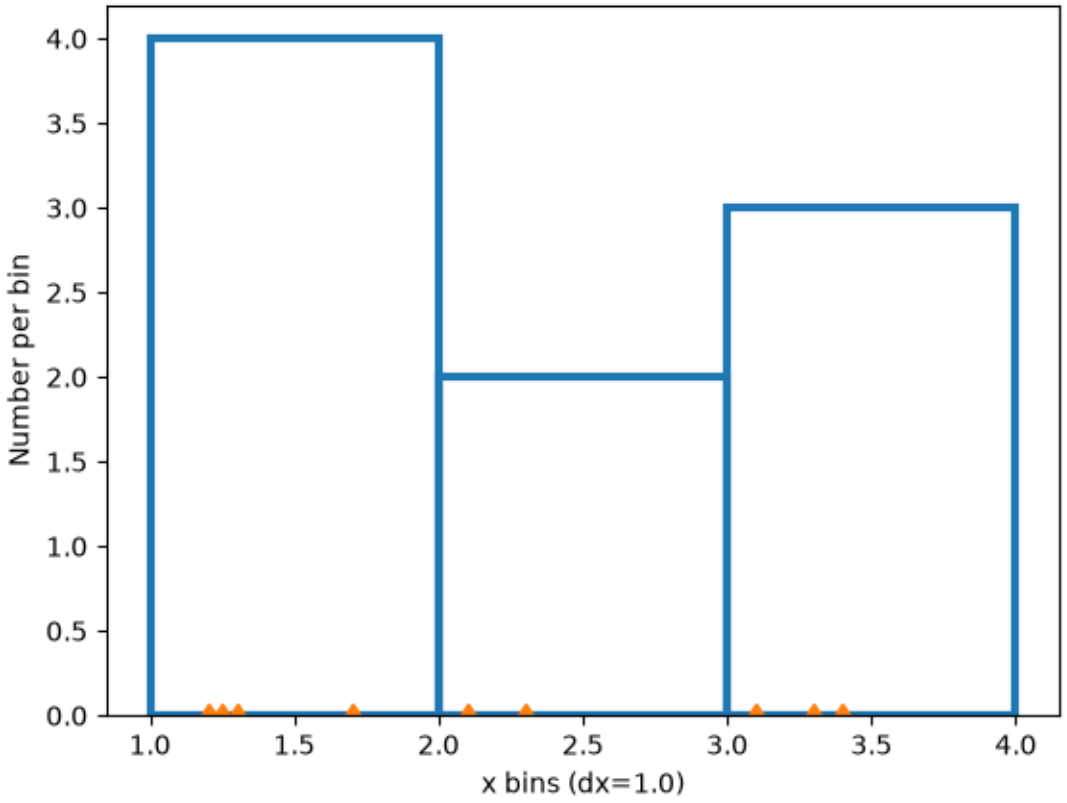
The *Axes.hist* method can flexibly create histograms in a few different ways, which is flexible and helpful, but can also lead to confusion. In particular, you can:

- bin the data as you want, either with an automatically chosen number of bins, or with fixed bin edges,
- normalize the histogram so that its integral is one,
- and assign weights to the data points, so that each data point affects the count in its bin differently.

The Matplotlib `hist` method calls `numpy.histogram` and plots the results, therefore users should consult the numpy documentation for a definitive guide.

Histograms are created by defining bin edges, and taking a dataset of values and sorting them into the bins, and counting or summing how much data is in each bin. In this simple example, 9 numbers between 1 and 4 are sorted into 3 bins:

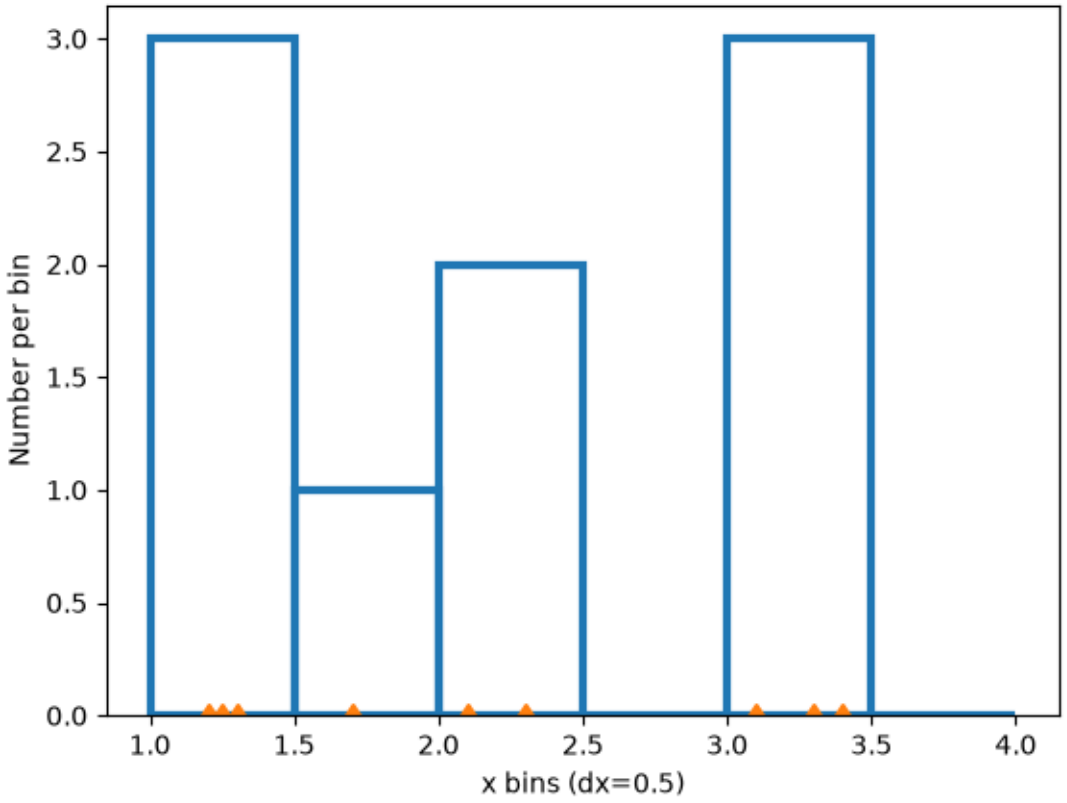
```
import matplotlib.pyplot as plt
import numpy as np

rng = np.random.default_rng(19680801)

xdata = np.array([1.2, 2.3, 3.3, 3.1, 1.7, 3.4, 2.1, 1.25, 1.3])
xbins = np.array([1, 2, 3, 4])

# changing the style of the histogram bars just to make it
# very clear where the boundaries of the bins are:
style = {'facecolor': 'none', 'edgecolor': 'C0', 'linewidth': 3}

fig, ax = plt.subplots()
ax.hist(xdata, bins=xbins, **style)

# plot the xdata locations on the x axis:
ax.plot(xdata, 0*xdata, 'd')
ax.set_ylabel('Number per bin')
ax.set_xlabel('x bins (dx=1.0)')
```



Modifying bins

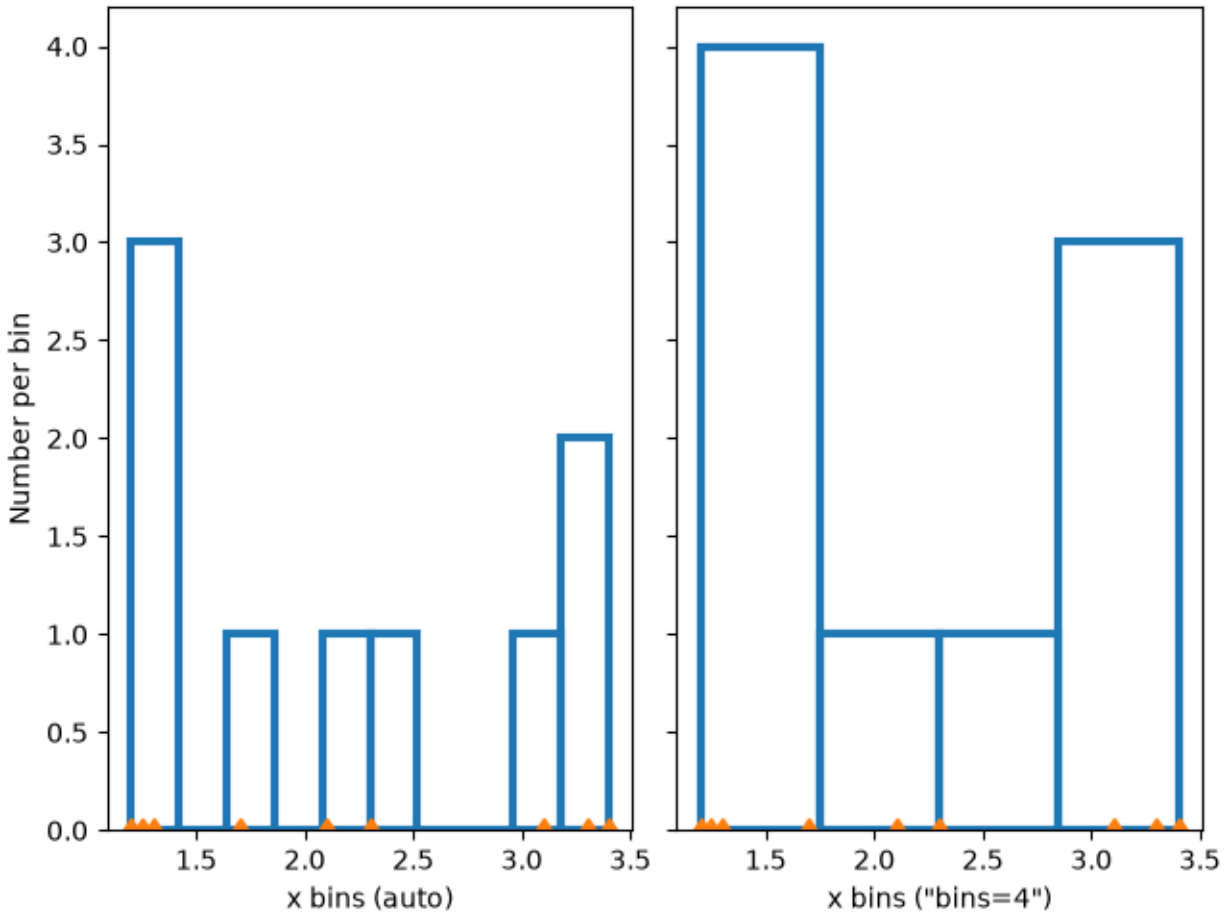
Changing the bin size changes the shape of this sparse histogram, so its a good idea to choose bins with some care with respect to your data. Here we make the bins half as wide.

```
xbins = np.arange(1, 4.5, 0.5)

fig, ax = plt.subplots()
ax.hist(xdata, bins=xbins, **style)
ax.plot(xdata, 0*xdata, 'd')
ax.set_ylabel('Number per bin')
ax.set_xlabel('x bins (dx=0.5)')
```



We can also let numpy (via Matplotlib) choose the bins automatically, or specify a number of bins to choose automatically:

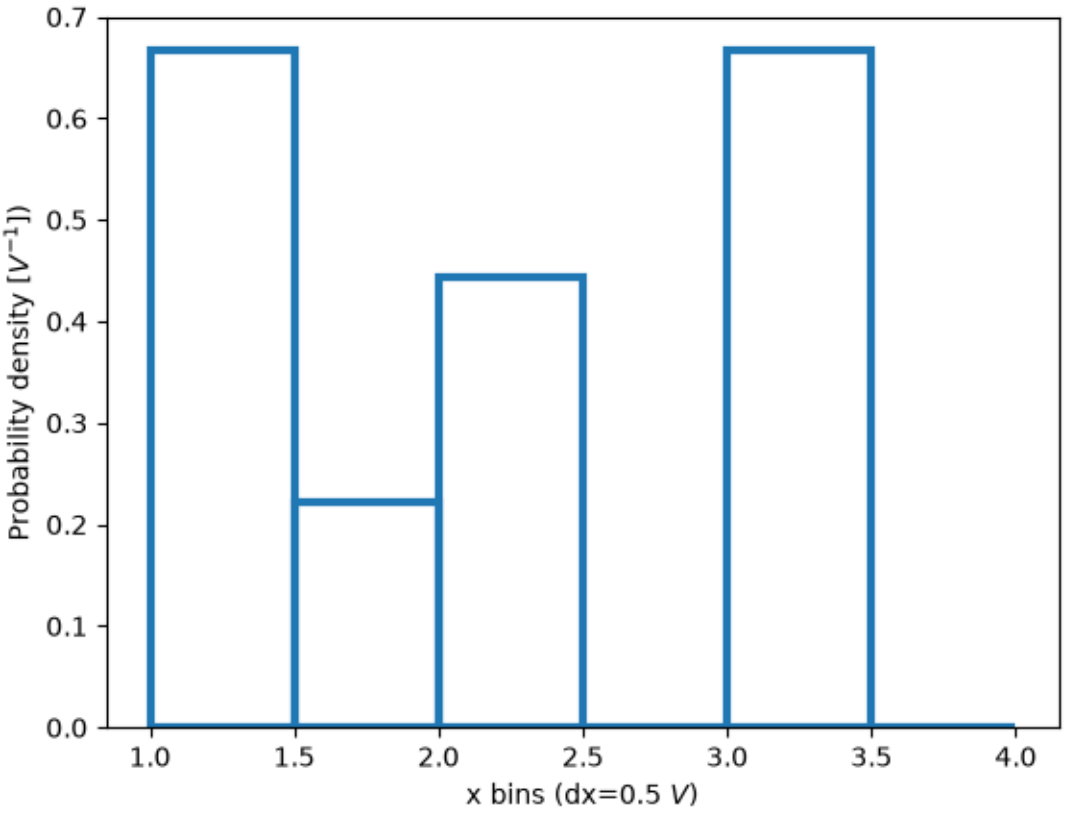
```
fig, ax = plt.subplot_mosaic([['auto', 'n4']],
                             sharex=True, sharey=True, layout=
 ↪'constrained')

ax['auto'].hist(xdata, **style)
ax['auto'].plot(xdata, 0*xdata, 'd')
ax['auto'].set_ylabel('Number per bin')
ax['auto'].set_xlabel('x bins (auto)')

ax['n4'].hist(xdata, bins=4, **style)
ax['n4'].plot(xdata, 0*xdata, 'd')
ax['n4'].set_xlabel('x bins ("bins=4")')
```



Normalizing histograms: density and weight

Counts-per-bin is the default length of each bar in the histogram. However, we can also normalize the bar lengths as a probability density function using the `density` parameter:

```
fig, ax = plt.subplots()
ax.hist(xdata, bins=xbins, density=True, **style)
ax.set_ylabel('Probability density [$V^{-1}$])')
ax.set_xlabel('x bins (dx=0.5 $V$)')
```



This normalization can be a little hard to interpret when just exploring the data. The value attached to each bar is divided by the total number of data points *and* the width of the bin, and thus the values _integrate_ to one when integrating across the full range of data. e.g.

```
density = counts / (sum(counts) * np.diff(bins))
np.sum(density * np.diff(bins)) == 1
```

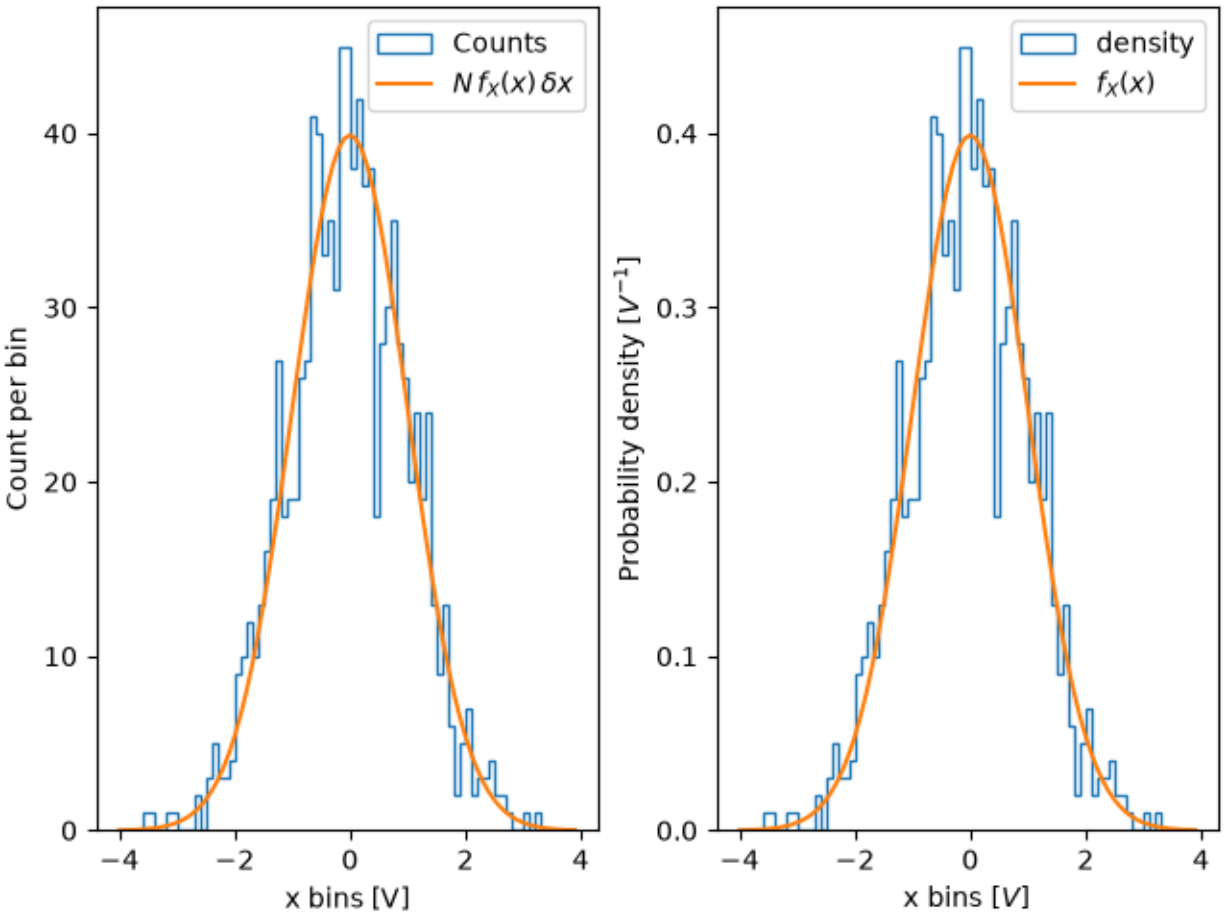
This normalization is how probability density functions are defined in statistics. If X is a random variable on x, then f_X is is the probability density function if $P[a < X < b] = \int_a^b f_X dx$. If the units of x are Volts, then the units of f_X are V^{-1} or probability per change in voltage.

The usefulness of this normalization is a little more clear when we draw from a known distribution and try to compare with theory. So, choose 1000 points from a normal distribution, and also calculate the known probability density function:

```
xdata = rng.normal(size=1000)
xpdf = np.arange(-4, 4, 0.1)
pdf = 1 / (np.sqrt(2 * np.pi)) * np.exp(-xpdf**2 / 2)
```

If we don't use `density=True`, we need to scale the expected probability distribution function by both the length of the data and the width of the bins:

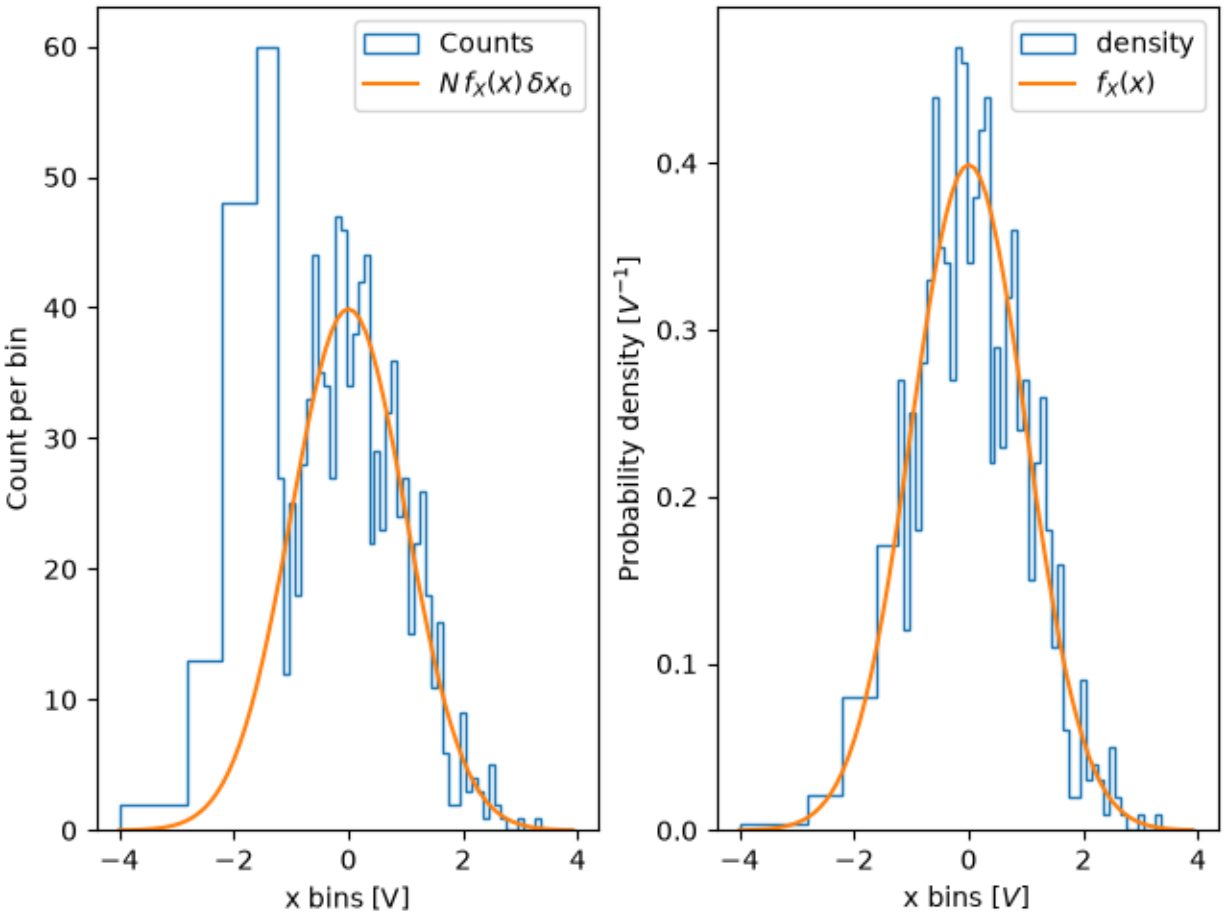
```
fig, ax = plt.subplot_mosaic([['False', 'True']], layout='constrained')
dx = 0.1
xbins = np.arange(-4, 4, dx)
ax['False'].hist(xdata, bins=xbins, density=False, histtype='step',␣
 ↪label='Counts')

# scale and plot the expected pdf:
ax['False'].plot(xpdf, pdf * len(xdata) * dx, label=r'$N\,f_X(x)\,\
 ↪delta x$')
ax['False'].set_ylabel('Count per bin')
ax['False'].set_xlabel('x bins [V]')
ax['False'].legend()

ax['True'].hist(xdata, bins=xbins, density=True, histtype='step',␣
 ↪label='density')
ax['True'].plot(xpdf, pdf, label='$f_X(x)$')
ax['True'].set_ylabel('Probability density [$V^{-1}$]')
ax['True'].set_xlabel('x bins [$V$]')
ax['True'].legend()
```



One advantage of using the density is therefore that the shape and amplitude of the histogram does not

depend on the size of the bins. Consider an extreme case where the bins do not have the same width. In this example, the bins below `x=-1.25` are six times wider than the rest of the bins. By normalizing by density, we preserve the shape of the distribution, whereas if we do not, then the wider bins have much higher counts than the thinner bins:

```
fig, ax = plt.subplot_mosaic([['False', 'True']], layout='constrained')
dx = 0.1
xbins = np.hstack([np.arange(-4, -1.25, 6*dx), np.arange(-1.25, 4,␣
 ↪dx)])
ax['False'].hist(xdata, bins=xbins, density=False, histtype='step',␣
 ↪label='Counts')
ax['False'].plot(xpdf, pdf * len(xdata) * dx, label=r'$N\,f_X(x)\,\
 ↪delta x_0$')
ax['False'].set_ylabel('Count per bin')
ax['False'].set_xlabel('x bins [V]')
ax['False'].legend()

ax['True'].hist(xdata, bins=xbins, density=True, histtype='step',␣
 ↪label='density')
ax['True'].plot(xpdf, pdf, label='$f_X(x)$')
ax['True'].set_ylabel('Probability density [$V^{-1}$]')
ax['True'].set_xlabel('x bins [$V$]')
ax['True'].legend()
```



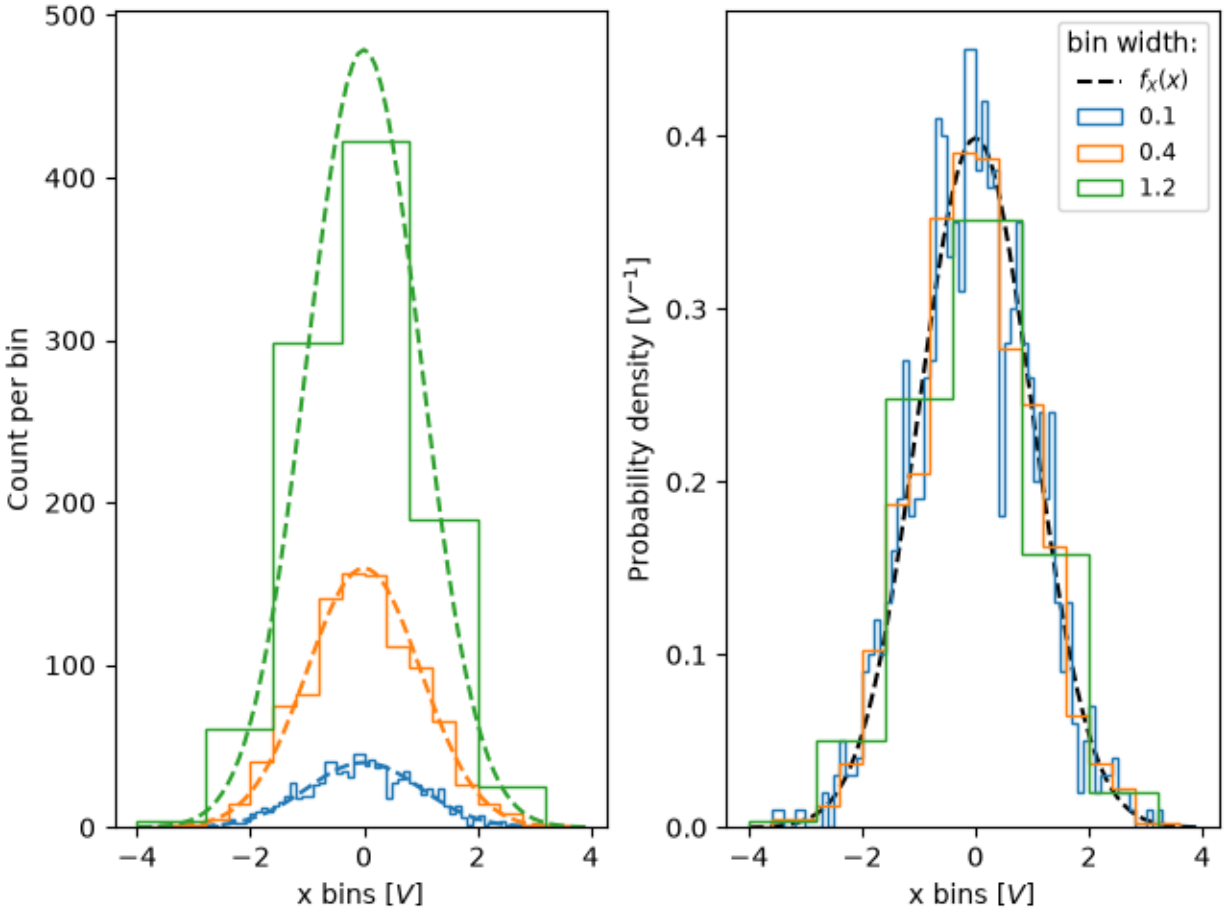
Similarly, if we want to compare histograms with different bin widths, we may want to use `density=True`:

```
fig, ax = plt.subplot_mosaic([['False', 'True']], layout='constrained')

# expected PDF
ax['True'].plot(xpdf, pdf, '--', label='$f_X(x)$', color='k')

for nn, dx in enumerate([0.1, 0.4, 1.2]):
    xbins = np.arange(-4, 4, dx)
    # expected histogram:
    ax['False'].plot(xpdf, pdf*1000*dx, '--', color=f'C{nn}')
    ax['False'].hist(xdata, bins=xbins, density=False, histtype='step')

    ax['True'].hist(xdata, bins=xbins, density=True, histtype='step',␣
 ↪label=dx)

# Labels:
ax['False'].set_xlabel('x bins [$V$]')
ax['False'].set_ylabel('Count per bin')
ax['True'].set_ylabel('Probability density [$V^{-1}$]')
ax['True'].set_xlabel('x bins [$V$]')
```

(continues on next page)

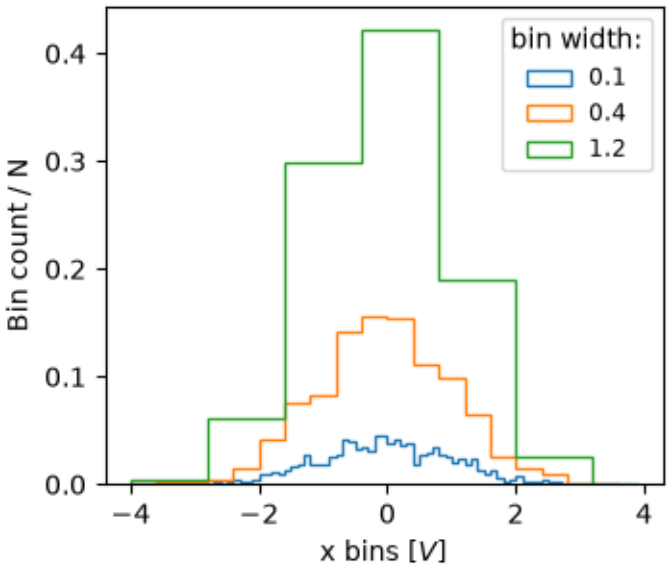
(continued from previous page)

```
ax['True'].legend(fontsize='small', title='bin width:')
```



Sometimes people want to normalize so that the sum of counts is one. This is analogous to a probability mass function for a discrete variable where the sum of probabilities for all the values equals one. Using `hist`, we can get this normalization if we set the *weights* to 1/N. Note that the amplitude of this normalized histogram still depends on width and/or number of the bins:

```
fig, ax = plt.subplots(layout='constrained', figsize=(3.5, 3))

for nn, dx in enumerate([0.1, 0.4, 1.2]):
    xbins = np.arange(-4, 4, dx)
    ax.hist(xdata, bins=xbins, weights=1/len(xdata) * np.
 ↪ones(len(xdata)),
                    histtype='step', label=f'{dx}')
ax.set_xlabel('x bins [$V$]')
ax.set_ylabel('Bin count / N')
ax.legend(fontsize='small', title='bin width:')
```



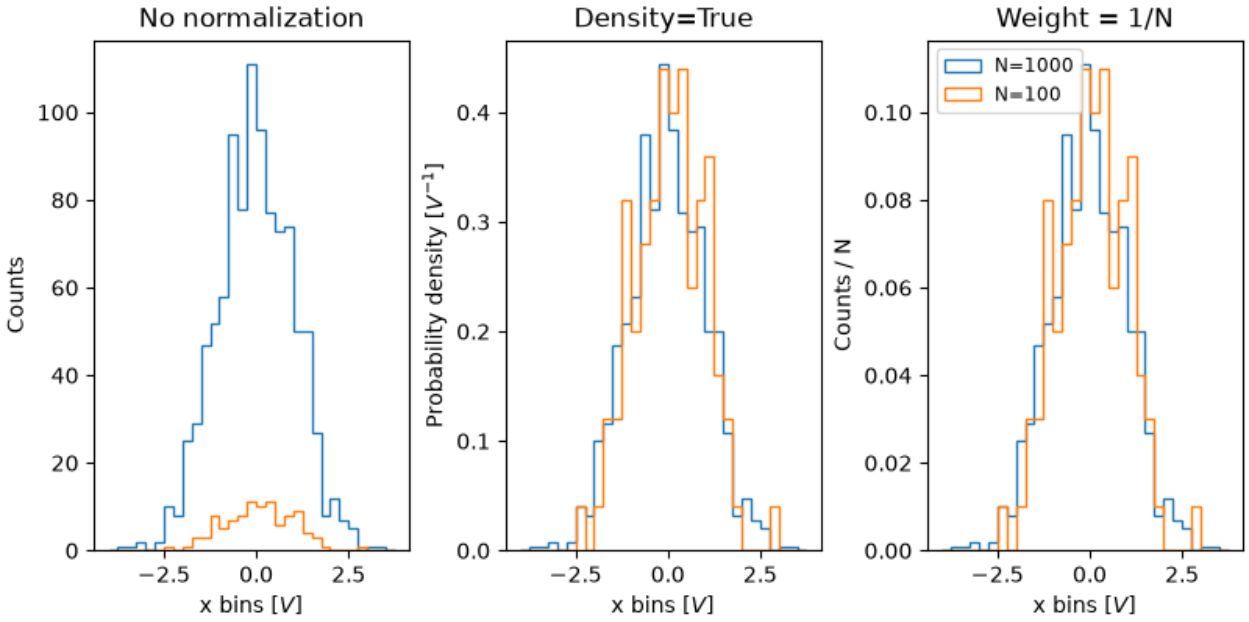
The value of normalizing histograms is comparing two distributions that have different sized populations. Here we compare the distribution of `xdata` with a population of 1000, and `xdata2` with 100 members.

```
xdata2 = rng.normal(size=100)

fig, ax = plt.subplot_mosaic([['no_norm', 'density', 'weight']],
                             layout='constrained', figsize=(8, 4))

xbins = np.arange(-4, 4, 0.25)

ax['no_norm'].hist(xdata, bins=xbins, histtype='step')
ax['no_norm'].hist(xdata2, bins=xbins, histtype='step')
ax['no_norm'].set_ylabel('Counts')
ax['no_norm'].set_xlabel('x bins [$V$]')
ax['no_norm'].set_title('No normalization')

ax['density'].hist(xdata, bins=xbins, histtype='step', density=True)
ax['density'].hist(xdata2, bins=xbins, histtype='step', density=True)
ax['density'].set_ylabel('Probability density [$V^{-1}$]')
ax['density'].set_title('Density=True')
ax['density'].set_xlabel('x bins [$V$]')

ax['weight'].hist(xdata, bins=xbins, histtype='step',
                  weights=1 / len(xdata) * np.ones(len(xdata)),
                  label='N=1000')
ax['weight'].hist(xdata2, bins=xbins, histtype='step',
                  weights=1 / len(xdata2) * np.ones(len(xdata2)),
                  label='N=100')
ax['weight'].set_xlabel('x bins [$V$]')
ax['weight'].set_ylabel('Counts / N')
```

(continues on next page)

(continued from previous page)

```
ax['weight'].legend(fontsize='small')
ax['weight'].set_title('Weight = 1/N')

plt.show()
```



Tags: plot-type: histogram domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.hist / matplotlib.pyplot.hist*
- *matplotlib.axes.Axes.set_title*
- *matplotlib.axes.Axes.set_xlabel*
- *matplotlib.axes.Axes.set_ylabel*
- *matplotlib.axes.Axes.legend*

Total running time of the script: (0 minutes 4.051 seconds)

The histogram (hist) function with multiple data sets

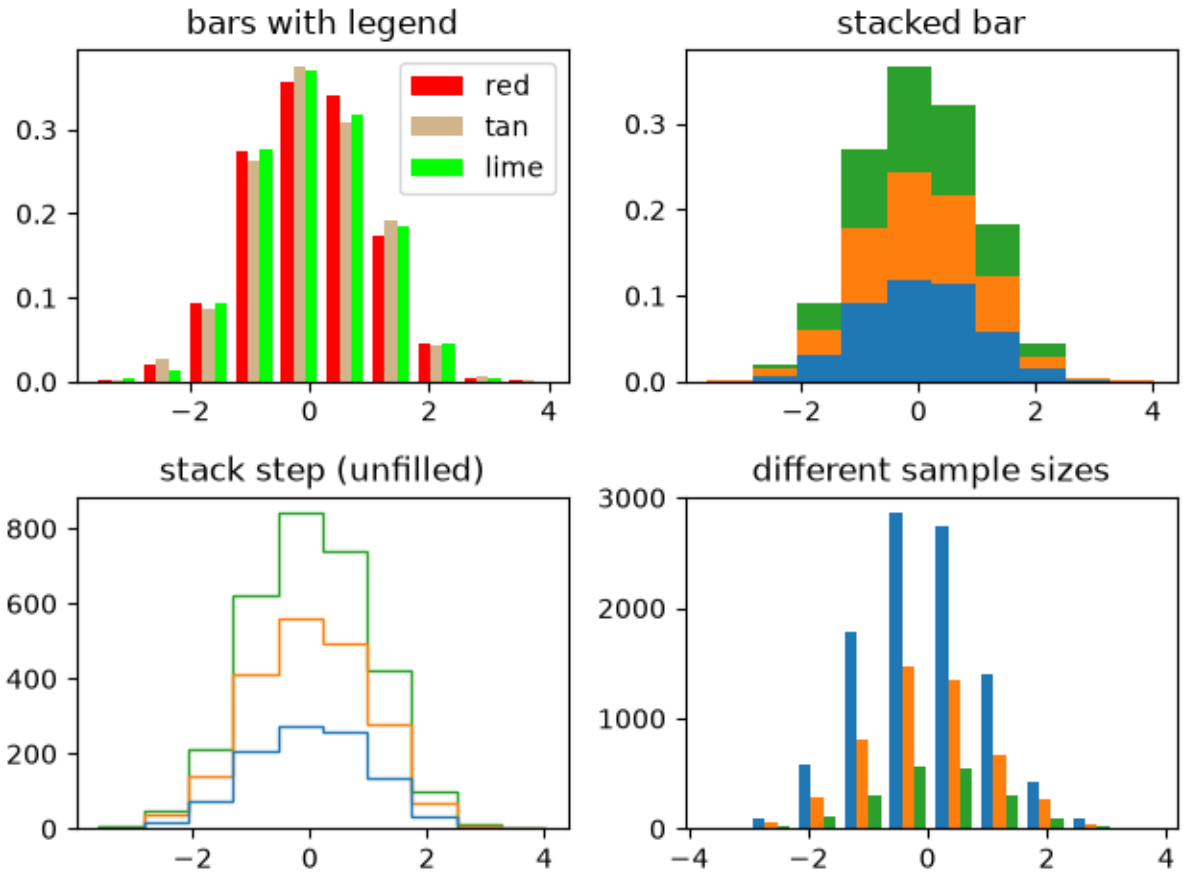
Plot histogram with multiple sample sets and demonstrate:

- Use of legend with multiple sample sets
- Stacked bars
- Step curve with no fill

- Data sets of different sample sizes

Selecting different bin counts and sizes can significantly affect the shape of a histogram. The Astropy docs have a great section on how to select these parameters: http://docs.astropy.org/en/stable/visualization/histogram.html

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)

n_bins = 10
x = np.random.randn(1000, 3)

fig, ((ax0, ax1), (ax2, ax3)) = plt.subplots(nrows=2, ncols=2)

colors = ['red', 'tan', 'lime']
ax0.hist(x, n_bins, density=True, histtype='bar', color=colors,␣
 ↪label=colors)
ax0.legend(prop={'size': 10})
ax0.set_title('bars with legend')

ax1.hist(x, n_bins, density=True, histtype='bar', stacked=True)
ax1.set_title('stacked bar')

ax2.hist(x, n_bins, histtype='step', stacked=True, fill=False)
ax2.set_title('stack step (unfilled)')

# Make a multiple-histogram of data-sets with different length.
x_multi = [np.random.randn(n) for n in [10000, 5000, 2000]]
ax3.hist(x_multi, n_bins, histtype='bar')
ax3.set_title('different sample sizes')

fig.tight_layout()
plt.show()
```



Setting properties for each dataset

You can style the histograms individually by passing a list of values to the following parameters:

- edgecolor
- facecolor
- hatch
- linewidth
- linestyle

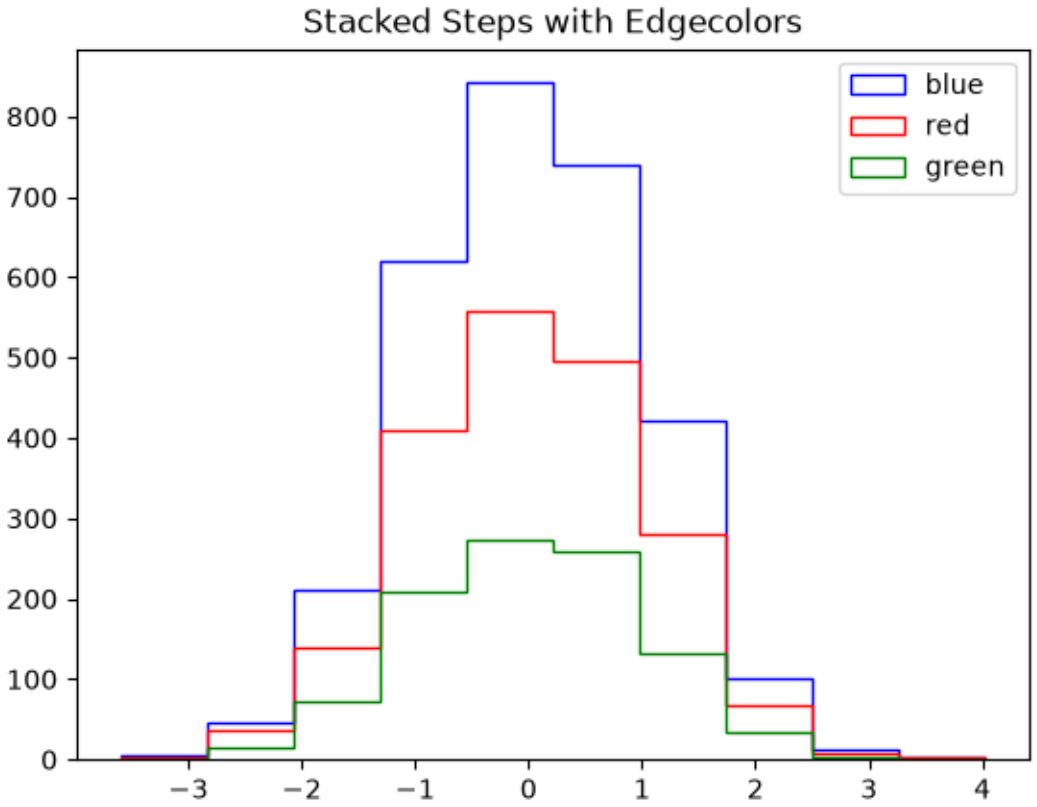
edgecolor

```
fig, ax = plt.subplots()

edgecolors = ['green', 'red', 'blue']

ax.hist(x, n_bins, fill=False, histtype="step", stacked=True,
        edgecolor=edgecolors, label=edgecolors)
```

(continues on next page)

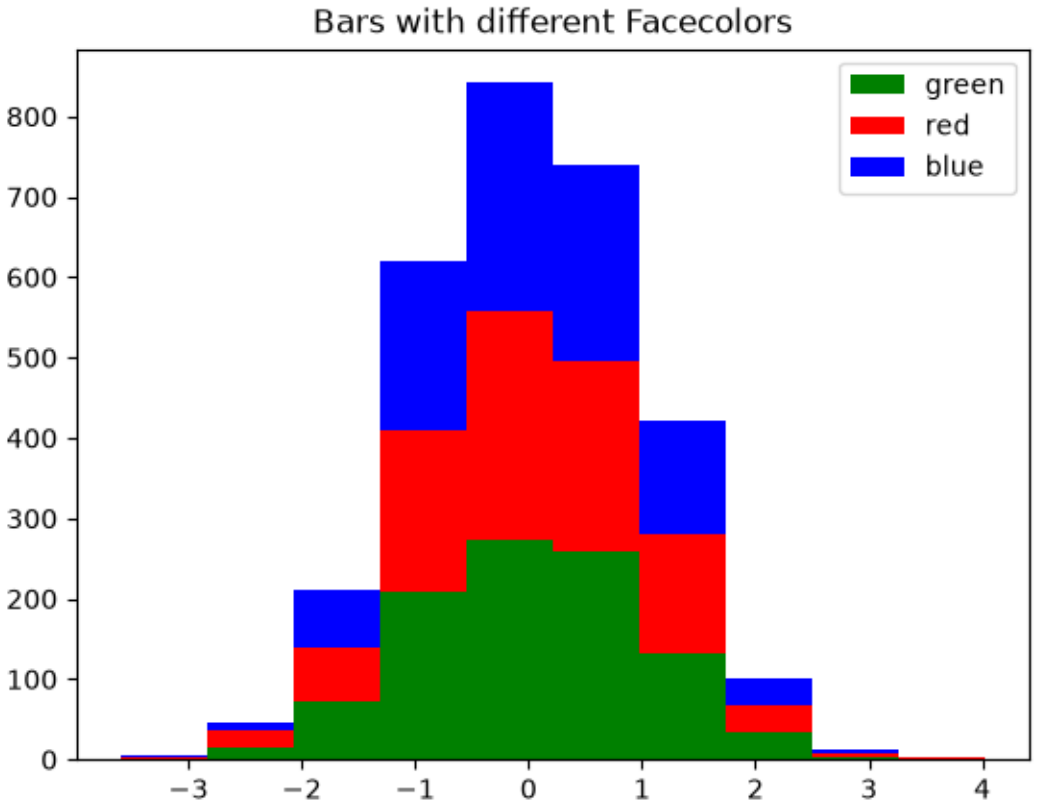
(continued from previous page)

```
ax.legend()
ax.set_title('Stacked Steps with Edgecolors')

plt.show()
```



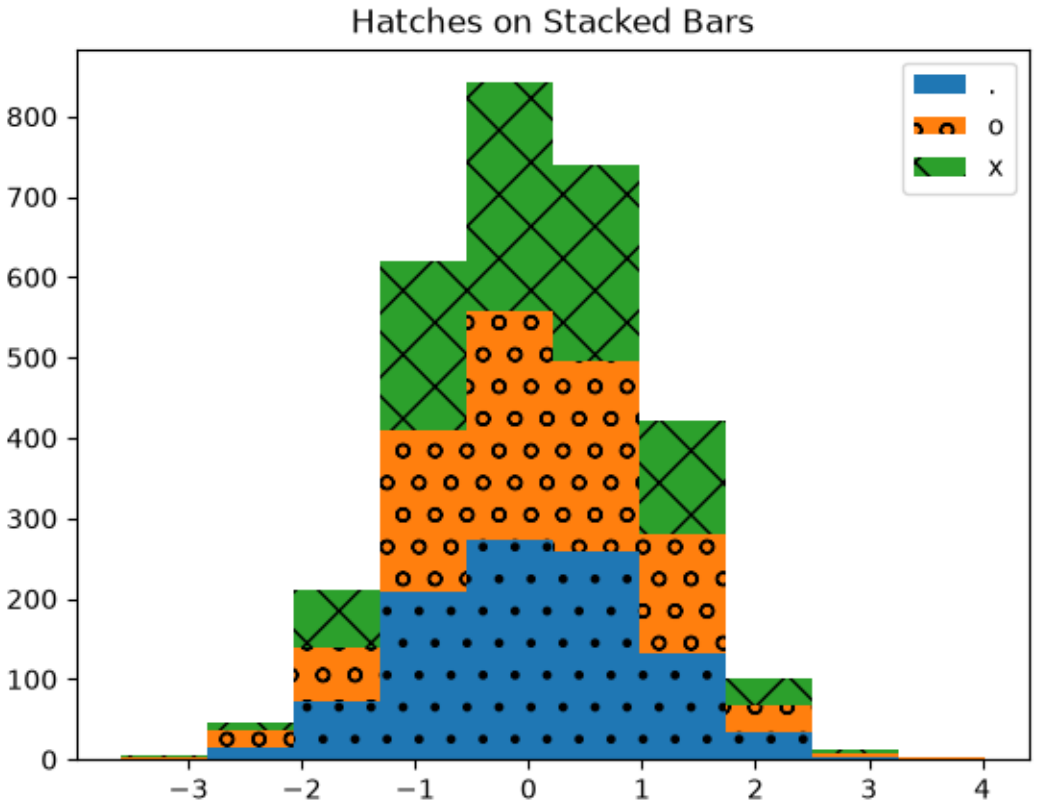
facecolor

```
fig, ax = plt.subplots()

facecolors = ['green', 'red', 'blue']

ax.hist(x, n_bins, histtype="barstacked", facecolor=facecolors,␣
 ↪label=facecolors)
ax.legend()
ax.set_title("Bars with different Facecolors")

plt.show()
```



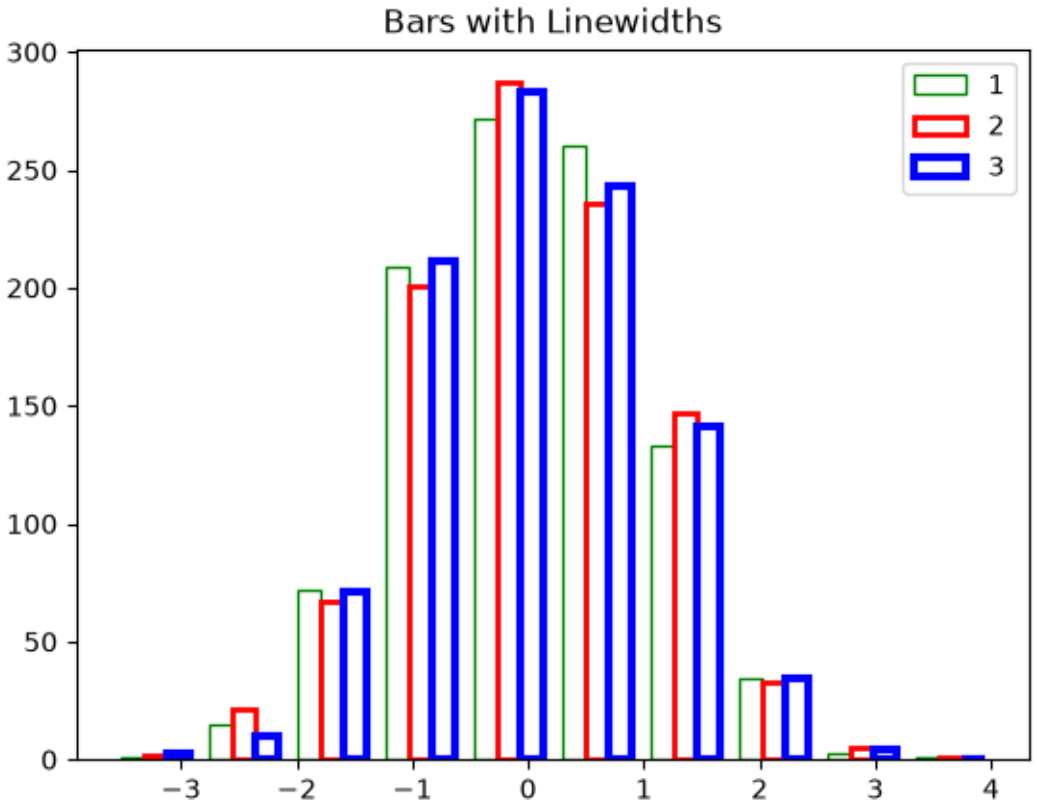
hatch

```
fig, ax = plt.subplots()

hatches = [".", "o", "x"]

ax.hist(x, n_bins, histtype="barstacked", hatch=hatches, label=hatches)
ax.legend()
ax.set_title("Hatches on Stacked Bars")

plt.show()
```



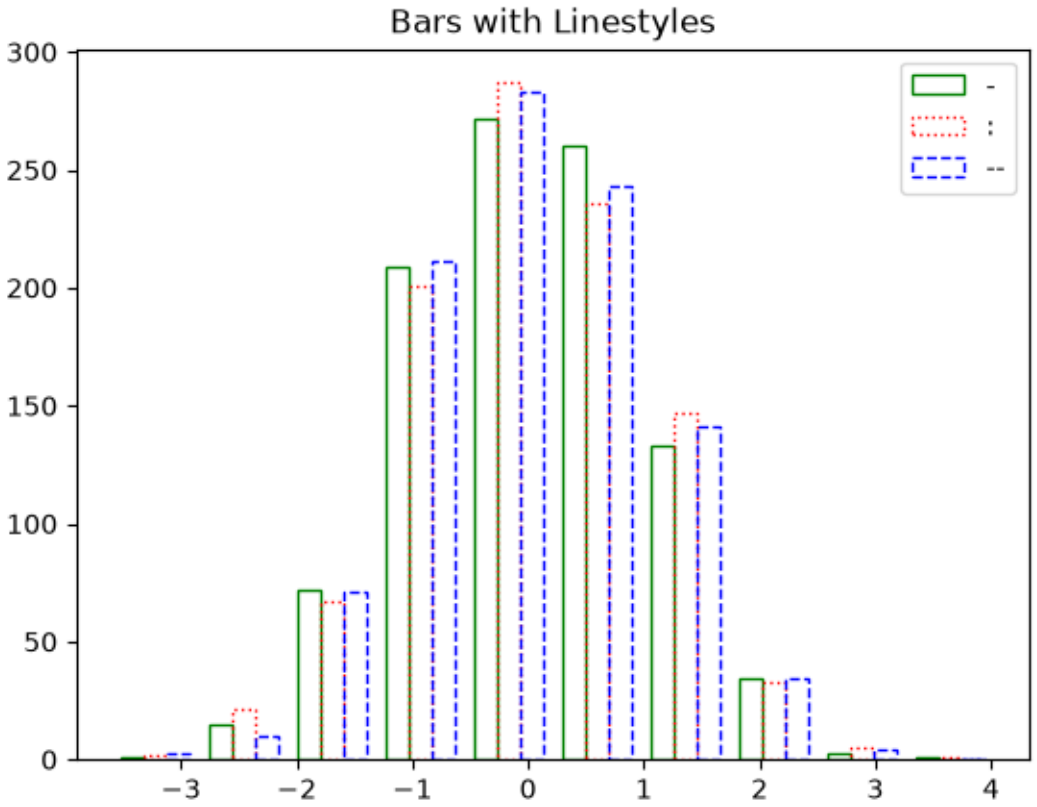
linewidth

```
fig, ax = plt.subplots()

linewidths = [1, 2, 3]
edgecolors = ["green", "red", "blue"]

ax.hist(x, n_bins, fill=False, histtype="bar", linewidth=linewidths,
        edgecolor=edgecolors, label=linewidths)
ax.legend()
ax.set_title("Bars with Linewidths")

plt.show()
```



linestyle

```
fig, ax = plt.subplots()

linestyles = ['-', ':', '--']

ax.hist(x, n_bins, fill=False, histtype='bar', linestyle=linestyles,
        edgecolor=edgecolors, label=linestyles)
ax.legend()
ax.set_title('Bars with Linestyles')

plt.show()
```



Tags: plot-type: histogram domain: statistics purpose: reference

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.hist* / *matplotlib.pyplot.hist*

Total running time of the script: (0 minutes 2.290 seconds)

Multiple histograms side by side

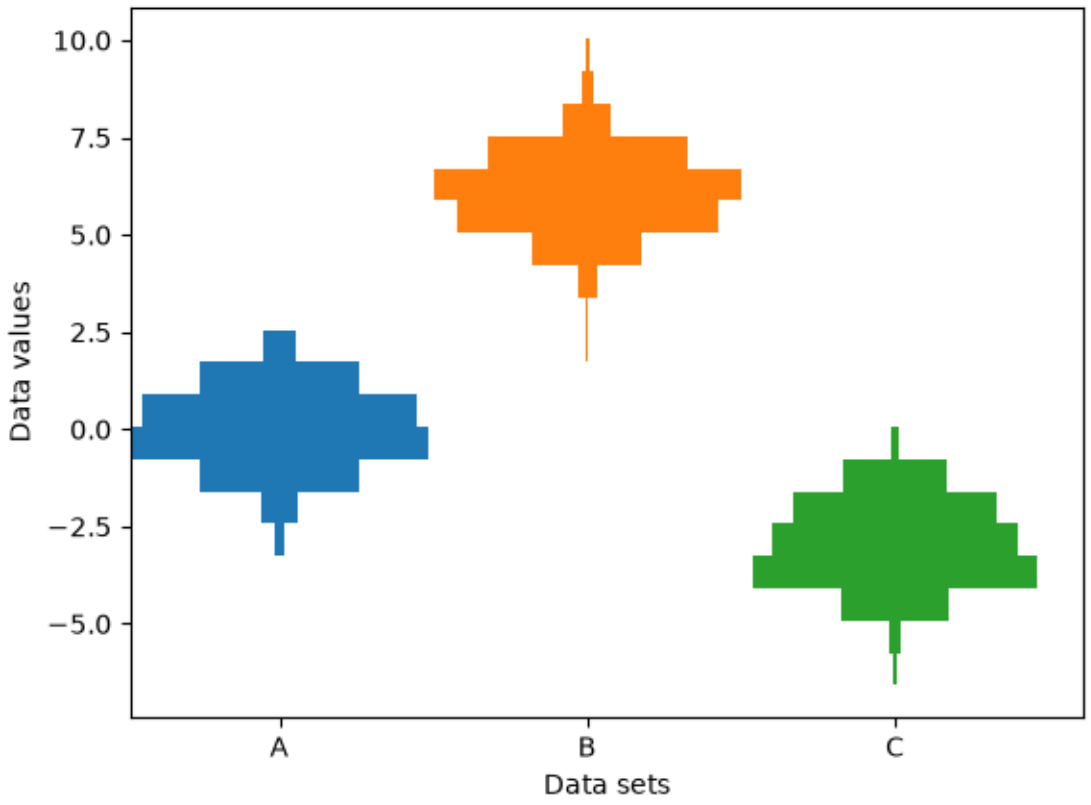
This example plots horizontal histograms of different samples along a categorical x-axis. Additionally, the histograms are plotted to be symmetrical about their x-position, thus making them very similar to violin plots.

To make this highly specialized plot, we can't use the standard `hist` method. Instead, we use `barh` to draw the horizontal bars directly. The vertical positions and lengths of the bars are computed via the `np.histogram` function. The histograms for all the samples are computed using the same range (min and max values) and number of bins, so that the bins for each sample are in the same vertical positions.

Selecting different bin counts and sizes can significantly affect the shape of a histogram. The Astropy

docs have a great section on how to select these parameters: http://docs.astropy.org/en/stable/visualization/histogram.html

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)
number_of_bins = 20

# An example of three data sets to compare
number_of_data_points = 387
labels = ["A", "B", "C"]
data_sets = [np.random.normal(0, 1, number_of_data_points),
             np.random.normal(6, 1, number_of_data_points),
             np.random.normal(-3, 1, number_of_data_points)]

# Computed quantities to aid plotting
hist_range = (np.min(data_sets), np.max(data_sets))
binned_data_sets = [
    np.histogram(d, range=hist_range, bins=number_of_bins)[0]
    for d in data_sets
]
binned_maximums = np.max(binned_data_sets, axis=1)
x_locations = np.arange(0, sum(binned_maximums), np.
 ↪max(binned_maximums))

# The bin_edges are the same for all of the histograms
bin_edges = np.linspace(hist_range[0], hist_range[1], number_of_bins +␣
 ↪1)
heights = np.diff(bin_edges)
centers = bin_edges[:-1] + heights / 2

# Cycle through and plot each histogram
fig, ax = plt.subplots()
for x_loc, binned_data in zip(x_locations, binned_data_sets):
    lefts = x_loc - 0.5 * binned_data
    ax.barh(centers, binned_data, height=heights, left=lefts)

ax.set_xticks(x_locations, labels)

ax.set_ylabel("Data values")
ax.set_xlabel("Data sets")

plt.show()
```



Tags: domain: statistics plot-type: barh plot-type: histogram styling: position

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.barh* / *matplotlib.pyplot.barh*

Bihistogram

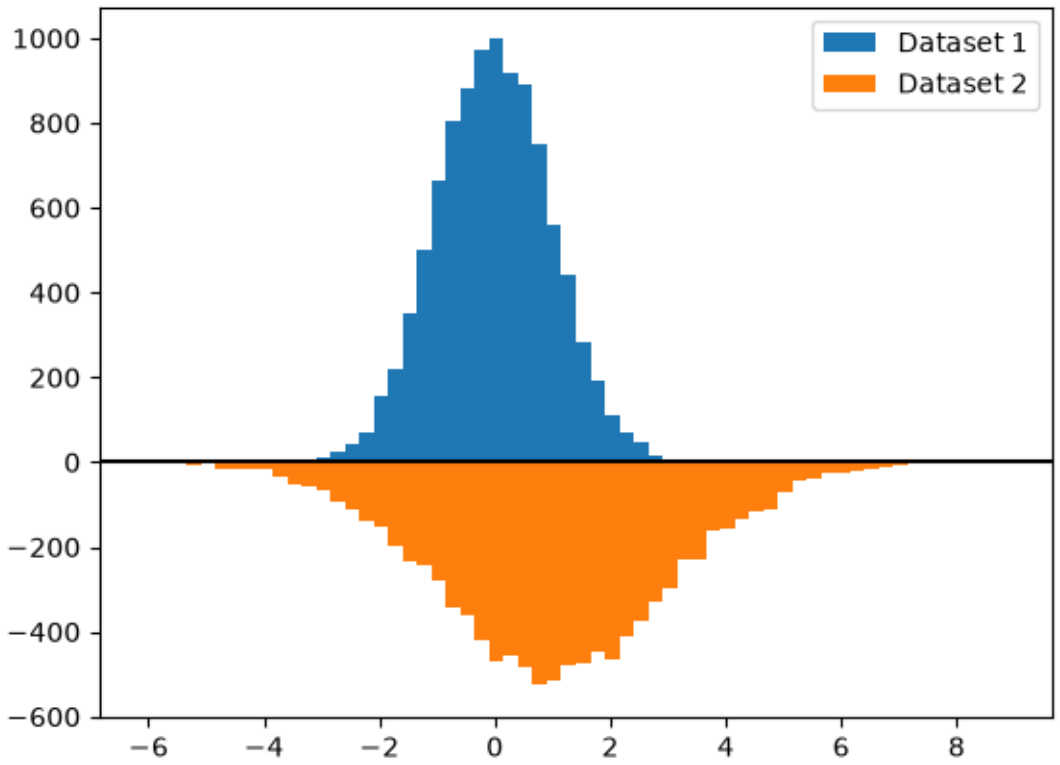
How to plot a bihistogram with Matplotlib.

```
import matplotlib.pyplot as plt
import numpy as np

# Create a random number generator with a fixed seed for␣
 ↪reproducibility
rng = np.random.default_rng(19680801)
```

Generate data and plot a bihistogram

To generate a bihistogram we need two datasets (each being a vector of numbers). We will plot both histograms using plt.hist() and set the weights of the second one to be negative. We'll generate data below and plot the bihistogram.

```
N_points = 10_000

# Generate two normal distributions
dataset1 = np.random.normal(0, 1, size=N_points)
dataset2 = np.random.normal(1, 2, size=N_points)

# Use a constant bin width to make the two histograms easier to␣
 ↪compare visually
bin_width = 0.25
bins = np.arange(np.min([dataset1, dataset2]),
                 np.max([dataset1, dataset2]) + bin_width,␣
 ↪bin_width)

fig, ax = plt.subplots()

# Plot the first histogram
ax.hist(dataset1, bins=bins, label="Dataset 1")

# Plot the second histogram
# (notice the negative weights, which flip the histogram upside down)
ax.hist(dataset2, weights=-np.ones_like(dataset2), bins=bins, label=
 ↪"Dataset 2")
ax.axhline(0, color="k")
ax.legend()

plt.show()
```



Tags: plot-type: histogram domain: statistics purpose: showcase

Cumulative distributions

This example shows how to plot the empirical cumulative distribution function (ECDF) of a sample. We also show the theoretical CDF.

In engineering, ECDFs are sometimes called "non-exceedance" curves: the y-value for a given x-value gives probability that an observation from the sample is below that x-value. For example, the value of 220 on the x-axis corresponds to about 0.80 on the y-axis, so there is an 80% chance that an observation in the sample does not exceed 220. Conversely, the empirical *complementary* cumulative distribution function (the ECCDF, or "exceedance" curve) shows the probability y that an observation from the sample is above a value x.

A direct method to plot ECDFs is `Axes.ecdf`. Passing `complementary=True` results in an ECCDF instead.

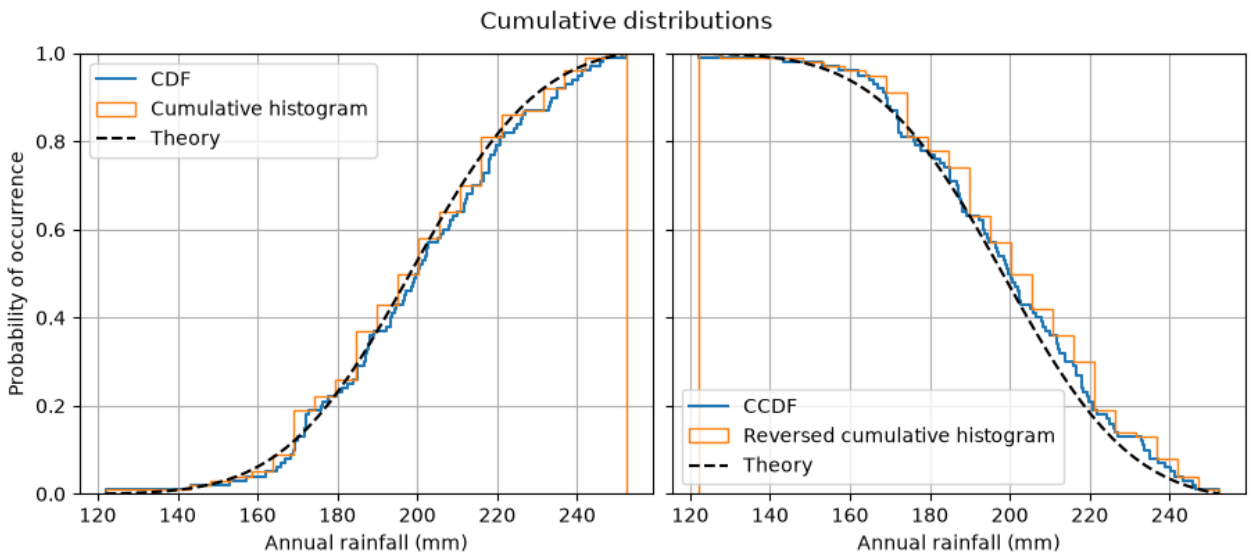
Alternatively, one can use `ax.hist(data, density=True, cumulative=True)` to first bin the data, as if plotting a histogram, and then compute and plot the cumulative sums of the frequencies of entries in each bin. Here, to plot the ECCDF, pass `cumulative=-1`. Note that this approach results in an approximation of the E(C)CDF, whereas `Axes.ecdf` is exact.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
np.random.seed(19680801)

mu = 200
sigma = 25
n_bins = 25
data = np.random.normal(mu, sigma, size=100)

fig = plt.figure(figsize=(9, 4), layout="constrained")
axs = fig.subplots(1, 2, sharex=True, sharey=True)

# Cumulative distributions.
axs[0].ecdf(data, label="CDF")
n, bins, patches = axs[0].hist(data, n_bins, density=True, histtype=
 ↪"step",
                               cumulative=True, label="Cumulative␣
 ↪histogram")
x = np.linspace(data.min(), data.max())
y = ((1 / (np.sqrt(2 * np.pi) * sigma)) *
     np.exp(-0.5 * (1 / sigma * (x - mu))**2))
y = y.cumsum()
y /= y[-1]
axs[0].plot(x, y, "k--", linewidth=1.5, label="Theory")

# Complementary cumulative distributions.
axs[1].ecdf(data, complementary=True, label="CCDF")
axs[1].hist(data, bins=bins, density=True, histtype="step",␣
 ↪cumulative=-1,
            label="Reversed cumulative histogram")
axs[1].plot(x, 1 - y, "k--", linewidth=1.5, label="Theory")

# Label the figure.
fig.suptitle("Cumulative distributions")
for ax in axs:
    ax.grid(True)
    ax.legend()
    ax.set_xlabel("Annual rainfall (mm)")
    ax.set_ylabel("Probability of occurrence")
    ax.label_outer()

plt.show()
```



Tags: plot-type: ecdf plot-type: histogram domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.hist* / *matplotlib.pyplot.hist*
- *matplotlib.axes.Axes.ecdf* / *matplotlib.pyplot.ecdf*

Hexagonal binned plot

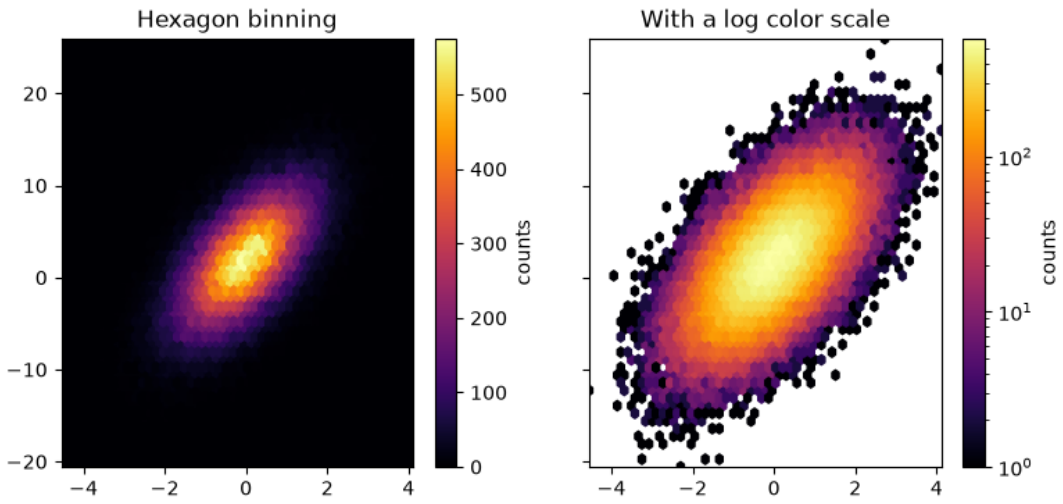
hexbin is a 2D histogram plot, in which the bins are hexagons and the color represents the number of data points within each bin.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

n = 100_000
x = np.random.standard_normal(n)
y = 2.0 + 3.0 * x + 4.0 * np.random.standard_normal(n)
xlim = x.min(), x.max()
ylim = y.min(), y.max()

fig, (ax0, ax1) = plt.subplots(ncols=2, sharey=True, figsize=(9, 4))

hb = ax0.hexbin(x, y, gridsize=50, cmap='inferno')
ax0.set(xlim=xlim, ylim=ylim)
```

(continues on next page)

(continued from previous page)

```
ax0.set_title("Hexagon binning")
cb = fig.colorbar(hb, ax=ax0, label='counts')

hb = ax1.hexbin(x, y, gridsize=50, bins='log', cmap='inferno')
ax1.set(xlim=xlim, ylim=ylim)
ax1.set_title("With a log color scale")
cb = fig.colorbar(hb, ax=ax1, label='counts')

plt.show()
```



Tags: plot-type: histogram plot-type: hexbin domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.hexbin* / *matplotlib.pyplot.hexbin*

Time Series Histogram

This example demonstrates how to efficiently visualize large numbers of time series in a way that could potentially reveal hidden substructure and patterns that are not immediately obvious, and display them in a visually appealing way.

In this example, we generate multiple sinusoidal "signal" series that are buried under a larger number of random walk "noise/background" series. For an unbiased Gaussian random walk with standard deviation of σ, the RMS deviation from the origin after n steps is σ*sqrt(n). So in order to keep the sinusoids visible on the same scale as the random walks, we scale the amplitude by the random walk RMS. In addition, we also introduce a small random offset `phi` to shift the sines left/right, and some additive random noise to shift individual data points up/down to make the signal a bit more "realistic" (you wouldn't expect a perfect sine wave to appear in your data).

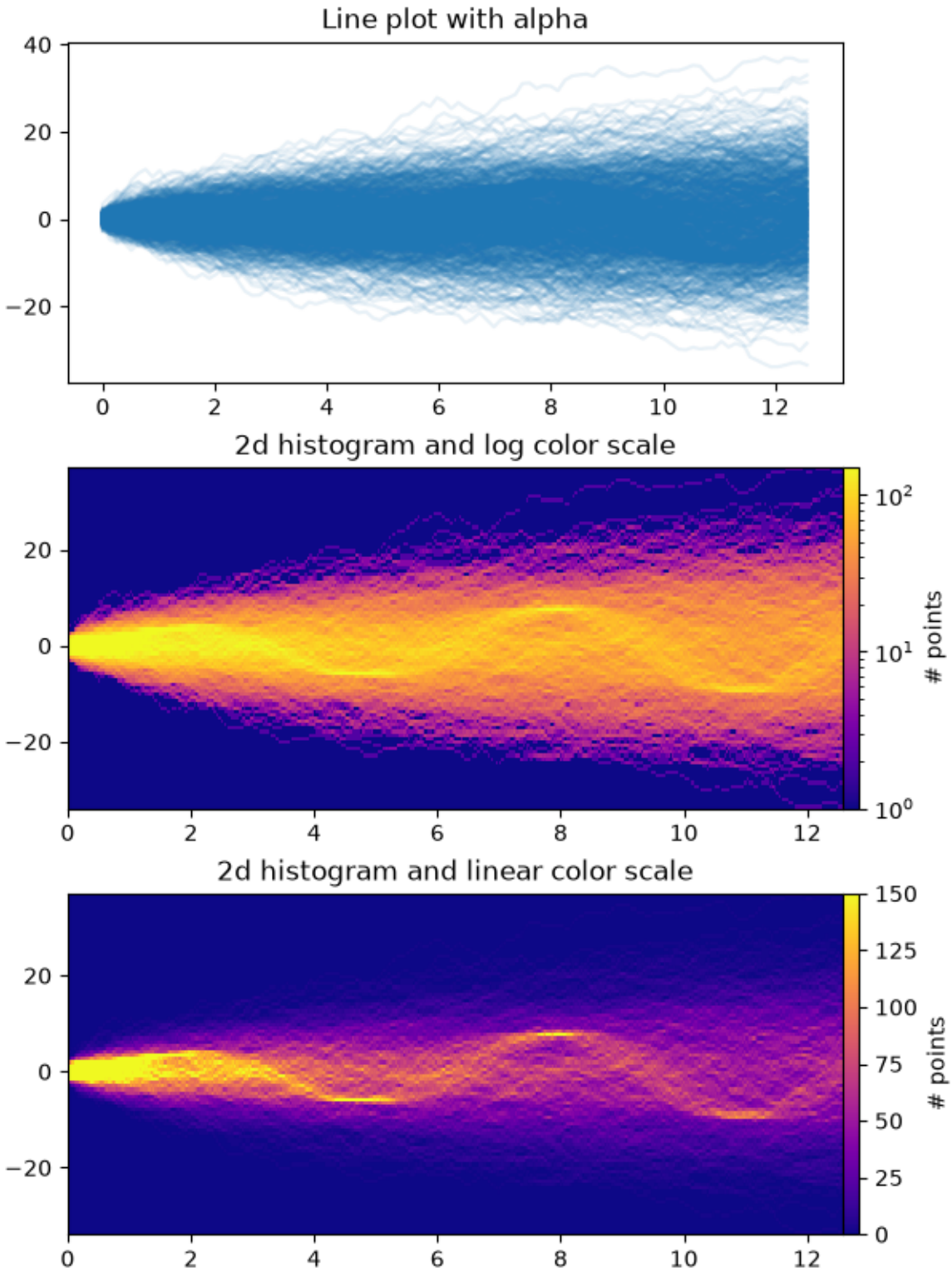
The first plot shows the typical way of visualizing multiple time series by overlaying them on top of each other with `plt.plot` and a small value of `alpha`. The second and third plots show how to reinterpret the data as a 2d histogram, with optional interpolation between data points, by using `np.histogram2d` and `plt.pcolormesh`.

```
import time

import matplotlib.pyplot as plt
import numpy as np

fig, axes = plt.subplots(nrows=3, figsize=(6, 8), layout='constrained')

# Fix random state for reproducibility
np.random.seed(19680801)
# Make some data; a 1D random walk + small fraction of sine waves
num_series = 1000
num_points = 100
SNR = 0.10  # Signal to Noise Ratio
x = np.linspace(0, 4 * np.pi, num_points)
# Generate unbiased Gaussian random walks
Y = np.cumsum(np.random.randn(num_series, num_points), axis=-1)
# Generate sinusoidal signals
num_signal = round(SNR * num_series)
phi = (np.pi / 8) * np.random.randn(num_signal, 1)  # small random␣
 ↪offset
Y[-num_signal:] = (
    np.sqrt(np.arange(num_points))  # random walk RMS scaling factor
    * (np.sin(x - phi)
       + 0.05 * np.random.randn(num_signal, num_points))  # small␣
 ↪random noise
)


# Plot series using `plot` and a small value of `alpha`. With this␣
 ↪view it is
# very difficult to observe the sinusoidal behavior because of how many
# overlapping series there are. It also takes a bit of time to run␣
 ↪because so
# many individual artists need to be generated.
tic = time.time()
axes[0].plot(x, Y.T, color="C0", alpha=0.1)
toc = time.time()
axes[0].set_title("Line plot with alpha")
print(f"{toc-tic:.3f} sec. elapsed")


# Now we will convert the multiple time series into a histogram. Not␣
```

(continues on next page)

(continued from previous page)

```
 ↪only will
# the hidden signal be more visible, but it is also a much quicker␣
 ↪procedure.
tic = time.time()
# Linearly interpolate between the points in each time series
num_fine = 800
x_fine = np.linspace(x.min(), x.max(), num_fine)
y_fine = np.concatenate([np.interp(x_fine, x, y_row) for y_row in Y])
x_fine = np.broadcast_to(x_fine, (num_series, num_fine)).ravel()


# Plot (x, y) points in 2d histogram with log colorscale
# It is pretty evident that there is some kind of structure under the␣
 ↪noise
# You can tune vmax to make signal more visible
cmap = plt.colormaps["plasma"]
cmap = cmap.with_extremes(bad=cmap(0))
h, xedges, yedges = np.histogram2d(x_fine, y_fine, bins=[400, 100])
pcm = axes[1].pcolormesh(xedges, yedges, h.T, cmap=cmap,
                         norm="log", vmax=1.5e2, rasterized=True)
fig.colorbar(pcm, ax=axes[1], label="# points", pad=0)
axes[1].set_title("2d histogram and log color scale")

# Same data but on linear color scale
pcm = axes[2].pcolormesh(xedges, yedges, h.T, cmap=cmap,
                         vmax=1.5e2, rasterized=True)
fig.colorbar(pcm, ax=axes[2], label="# points", pad=0)
axes[2].set_title("2d histogram and linear color scale")

toc = time.time()
print(f"{toc-tic:.3f} sec. elapsed")
plt.show()
```




```
0.347 sec. elapsed
0.097 sec. elapsed
```

Tags: plot-type: histogram2d plot-type: pcolormesh purpose: storytelling styling: color styling: colormap

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.pcolormesh* / *matplotlib.pyplot.pcolormesh*
- *matplotlib.figure.Figure.colorbar*

Total running time of the script: (0 minutes 2.066 seconds)

Boxplots

Visualizing boxplots with matplotlib.

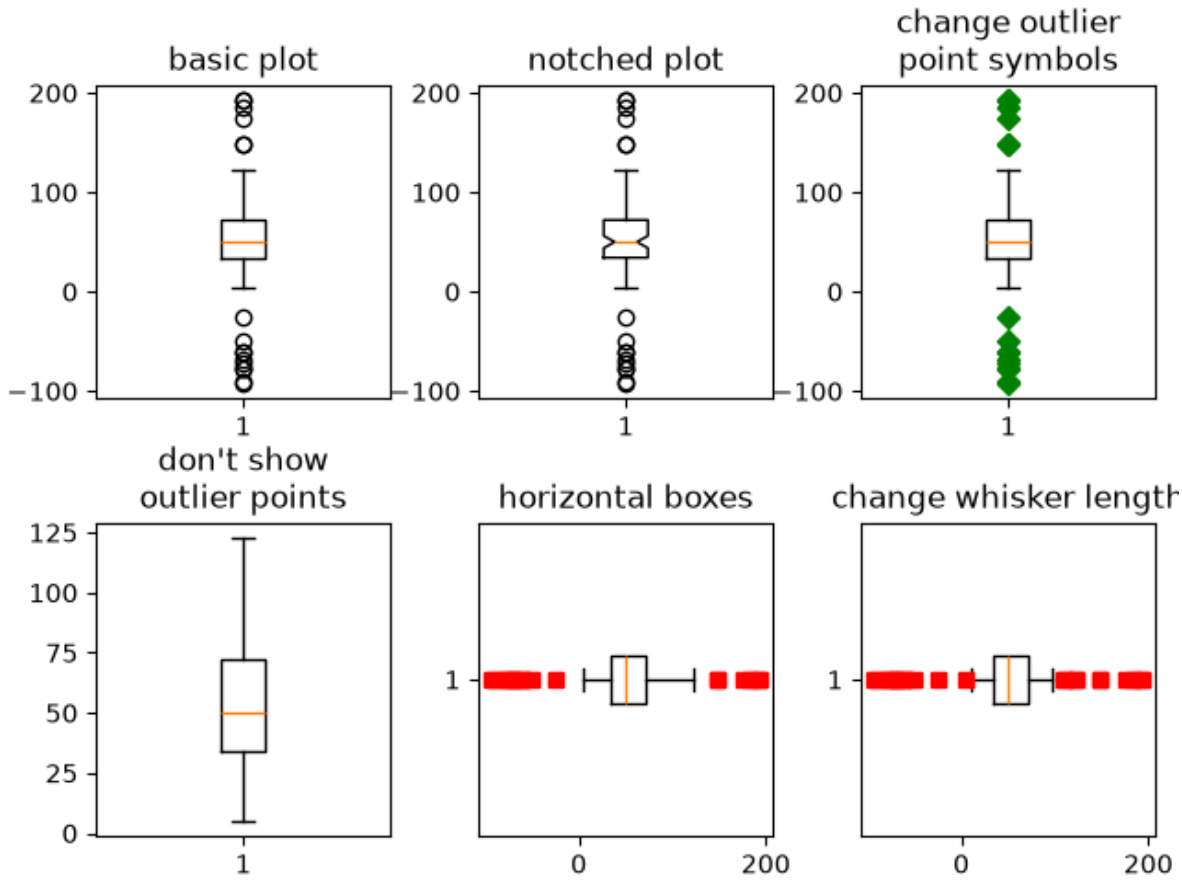
The following examples show off how to visualize boxplots with Matplotlib. There are many options to control their appearance and the statistics that they use to summarize the data.

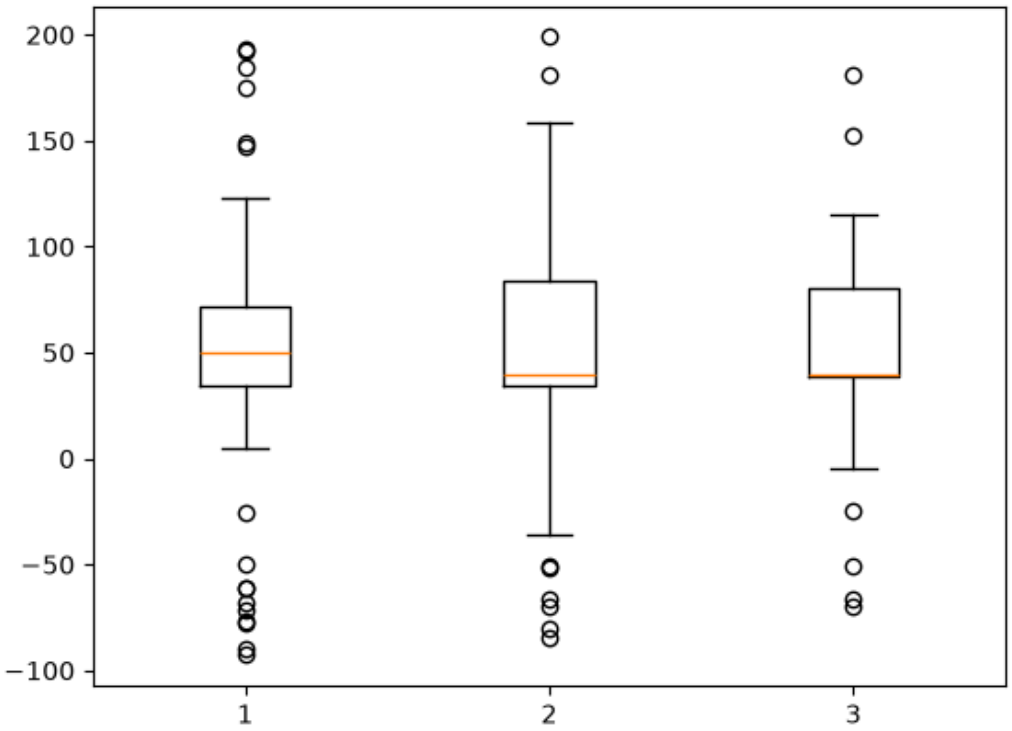
```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Polygon

# Fixing random state for reproducibility
np.random.seed(19680801)

# fake up some data
spread = np.random.rand(50) * 100
center = np.ones(25) * 50
flier_high = np.random.rand(10) * 100 + 100
flier_low = np.random.rand(10) * -100
data = np.concatenate((spread, center, flier_high, flier_low))

fig, axs = plt.subplots(2, 3)

# basic plot
axs[0, 0].boxplot(data)
axs[0, 0].set_title('basic plot')

# notched plot
axs[0, 1].boxplot(data, notch=True)
axs[0, 1].set_title('notched plot')

# change outlier point symbols
axs[0, 2].boxplot(data, sym='gD')
axs[0, 2].set_title('change outlier\npoint symbols')

# don't show outlier points
axs[1, 0].boxplot(data, sym='')
```

(continues on next page)

(continued from previous page)

```
axs[1, 0].set_title("don't show\noutlier points")

# horizontal boxes
axs[1, 1].boxplot(data, sym='rs', orientation='horizontal')
axs[1, 1].set_title('horizontal boxes')

# change whisker length
axs[1, 2].boxplot(data, sym='rs', orientation='horizontal', whis=0.75)
axs[1, 2].set_title('change whisker length')

fig.subplots_adjust(left=0.08, right=0.98, bottom=0.05, top=0.9,
                    hspace=0.4, wspace=0.3)

# fake up some more data
spread = np.random.rand(50) * 100
center = np.ones(25) * 40
flier_high = np.random.rand(10) * 100 + 100
flier_low = np.random.rand(10) * -100
d2 = np.concatenate((spread, center, flier_high, flier_low))
# Making a 2-D array only works if all the columns are the
# same length.  If they are not, then use a list instead.
# This is actually more efficient because boxplot converts
# a 2-D array into a list of vectors internally anyway.
data = [data, d2, d2[::2]]

# Multiple box plots on one Axes
fig, ax = plt.subplots()
ax.boxplot(data)

plt.show()
```

- 
basic plot
notched plot
change outlier
point symbols
200
100
0
−100
1
don't show
outlier points
horizontal boxes
change whisker length
125
100
75
50
25
0
1
0
200



-

Below we'll generate data from five different probability distributions, each with different characteristics. We want to play with how an IID bootstrap resample of the data preserves the distributional properties of the original sample, and a boxplot is one visual tool to make this assessment

```
random_dists = ['Normal(1, 1)', 'Lognormal(1, 1)', 'Exp(1)',
 ↪'Gumbel(6, 4)',
                'Triangular(2, 9, 11)']
N = 500

norm = np.random.normal(1, 1, N)
logn = np.random.lognormal(1, 1, N)
expo = np.random.exponential(1, N)
gumb = np.random.gumbel(6, 4, N)
tria = np.random.triangular(2, 9, 11, N)

# Generate some random indices that we'll use to resample the original␣
 ↪data
# arrays. For code brevity, just use the same random indices for each␣
 ↪array
bootstrap_indices = np.random.randint(0, N, N)
data = [
    norm, norm[bootstrap_indices],
```

(continues on next page)

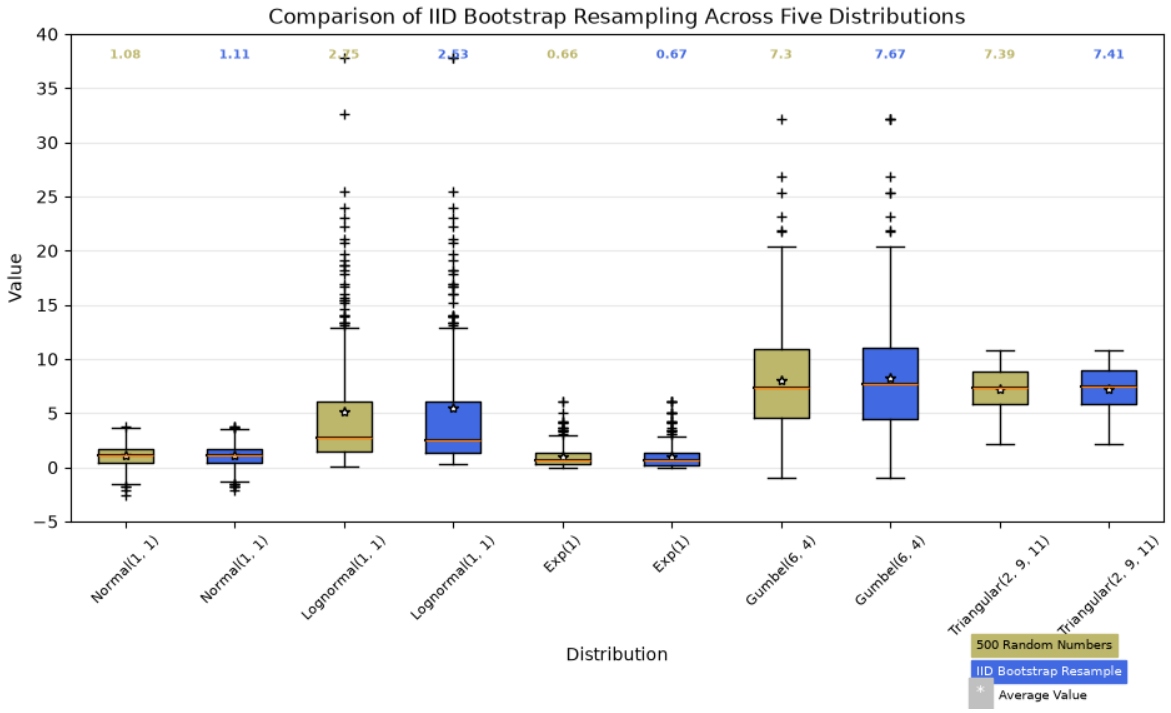
(continued from previous page)

```
    logn, logn[bootstrap_indices],
    expo, expo[bootstrap_indices],
    gumb, gumb[bootstrap_indices],
    tria, tria[bootstrap_indices],
]

fig, ax1 = plt.subplots(figsize=(10, 6))
fig.canvas.manager.set_window_title('A Boxplot Example')
fig.subplots_adjust(left=0.075, right=0.95, top=0.9, bottom=0.25)

bp = ax1.boxplot(data, notch=False, sym='+', orientation='vertical',␣
 ↪whis=1.5)
plt.setp(bp['boxes'], color='black')
plt.setp(bp['whiskers'], color='black')
plt.setp(bp['fliers'], color='red', marker='+')

# Add a horizontal grid to the plot, but make it very light in color
# so we can use it for reading data values but not be distracting
ax1.yaxis.grid(True, linestyle='-', which='major', color='lightgrey',
               alpha=0.5)

ax1.set(
    axisbelow=True,  # Hide the grid behind plot objects
    title='Comparison of IID Bootstrap Resampling Across Five␣
 ↪Distributions',
    xlabel='Distribution',
    ylabel='Value',
)

# Now fill the boxes with desired colors
box_colors = ['darkkhaki', 'royalblue']
num_boxes = len(data)
medians = np.empty(num_boxes)
for i in range(num_boxes):
    box = bp['boxes'][i]
    box_x = []
    box_y = []
    for j in range(5):
        box_x.append(box.get_xdata()[j])
        box_y.append(box.get_ydata()[j])
    box_coords = np.column_stack([box_x, box_y])
    # Alternate between Dark Khaki and Royal Blue
    ax1.add_patch(Polygon(box_coords, facecolor=box_colors[i % 2]))
    # Now draw the median lines back over what we just filled in
    med = bp['medians'][i]
    median_x = []
```

(continues on next page)

(continued from previous page)

```
    median_y = []
    for j in range(2):
        median_x.append(med.get_xdata()[j])
        median_y.append(med.get_ydata()[j])
        ax1.plot(median_x, median_y, 'k')
    medians[i] = median_y[0]
    # Finally, overplot the sample averages, with horizontal alignment
    # in the center of each box
    ax1.plot(np.average(med.get_xdata()), np.average(data[i]),
             color='w', marker='*', markeredgecolor='k')

# Set the axes ranges and axes labels
ax1.set_xlim(0.5, num_boxes + 0.5)
top = 40
bottom = -5
ax1.set_ylim(bottom, top)
ax1.set_xticklabels(np.repeat(random_dists, 2),
                    rotation=45, fontsize=8)

# Due to the Y-axis scale being different across samples, it can be
# hard to compare differences in medians across the samples. Add upper
# X-axis tick labels with the sample medians to aid in comparison
# (just use two decimal places of precision)
pos = np.arange(num_boxes) + 1
upper_labels = [str(round(s, 2)) for s in medians]
weights = ['bold', 'semibold']
for tick, label in zip(range(num_boxes), ax1.get_xticklabels()):
    k = tick % 2
    ax1.text(pos[tick], .95, upper_labels[tick],
             transform=ax1.get_xaxis_transform(),
             horizontalalignment='center', size='x-small',
             weight=weights[k], color=box_colors[k])

# Finally, add a basic legend
fig.text(0.80, 0.08, f'{N} Random Numbers',
         backgroundcolor=box_colors[0], color='black', weight='roman',
         size='x-small')
fig.text(0.80, 0.045, 'IID Bootstrap Resample',
         backgroundcolor=box_colors[1],
         color='white', weight='roman', size='x-small')
fig.text(0.80, 0.015, '*', color='white', backgroundcolor='silver',
         weight='roman', size='medium')
fig.text(0.815, 0.013, ' Average Value', color='black', weight='roman',
         size='x-small')

plt.show()
```



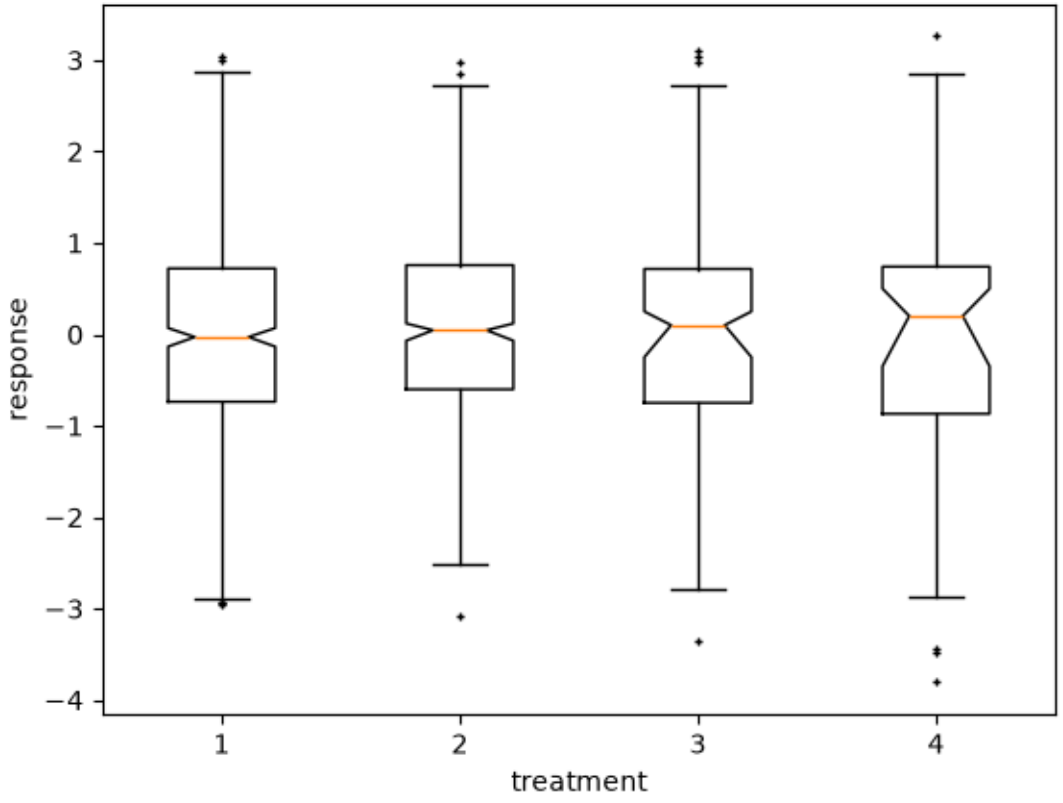
Here we write a custom function to bootstrap confidence intervals. We can then use the boxplot along with this function to show these intervals.

```
def fake_bootstrapper(n):
    """
    This is just a placeholder for the user's method of
    bootstrapping the median and its confidence intervals.

    Returns an arbitrary median and confidence interval packed into a␣
 ↪tuple.
    """
    if n == 1:
        med = 0.1
        ci = (-0.25, 0.25)
    else:
        med = 0.2
        ci = (-0.35, 0.50)
    return med, ci

inc = 0.1
e1 = np.random.normal(0, 1, size=500)
e2 = np.random.normal(0, 1, size=500)
e3 = np.random.normal(0, 1 + inc, size=500)
e4 = np.random.normal(0, 1 + 2*inc, size=500)

treatments = [e1, e2, e3, e4]
```

(continues on next page)

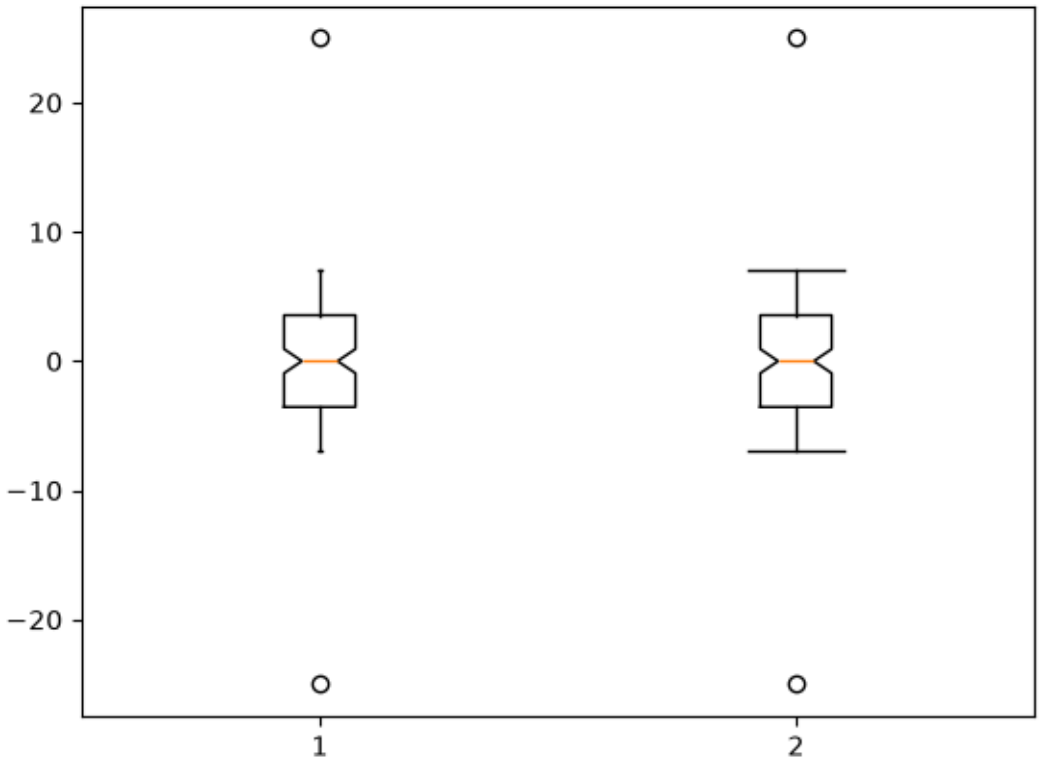
(continued from previous page)

```
med1, ci1 = fake_bootstrapper(1)
med2, ci2 = fake_bootstrapper(2)
medians = [None, None, med1, med2]
conf_intervals = [None, None, ci1, ci2]

fig, ax = plt.subplots()
pos = np.arange(len(treatments)) + 1
bp = ax.boxplot(treatments, sym='k+', positions=pos,
                notch=True, bootstrap=5000,
                usermedians=medians,
                conf_intervals=conf_intervals)

ax.set_xlabel('treatment')
ax.set_ylabel('response')
plt.setp(bp['whiskers'], color='k', linestyle='-')
plt.setp(bp['fliers'], markersize=3.0)
plt.show()
```



Here we customize the widths of the caps .

```
x = np.linspace(-7, 7, 140)
x = np.hstack([-25, x, 25])
fig, ax = plt.subplots()

ax.boxplot([x, x], notch=True, capwidths=[0.01, 0.2])

plt.show()
```



Tags: domain: statistics plot-type: boxplot

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.boxplot* / *matplotlib.pyplot.boxplot*
- *matplotlib.artist.Artist.set* / *matplotlib.pyplot.setp*

Total running time of the script: (0 minutes 2.044 seconds)

Artist customization in box plots

This example demonstrates how to use the various keyword arguments to fully customize box plots. The first figure demonstrates how to remove and add individual components (note that the mean is the only value not shown by default). The second figure demonstrates how the styles of the artists can be customized. It also demonstrates how to set the limit of the whiskers to specific percentiles (lower right Axes)

A good general reference on boxplots and their history can be found here: https://vita.had.co.nz/papers/boxplots.pdf

```
import matplotlib.pyplot as plt
import numpy as np

# fake data
np.random.seed(19680801)
data = np.random.lognormal(size=(37, 4), mean=1.5, sigma=1.75)
labels = list('ABCD')
fs = 10  # fontsize
```

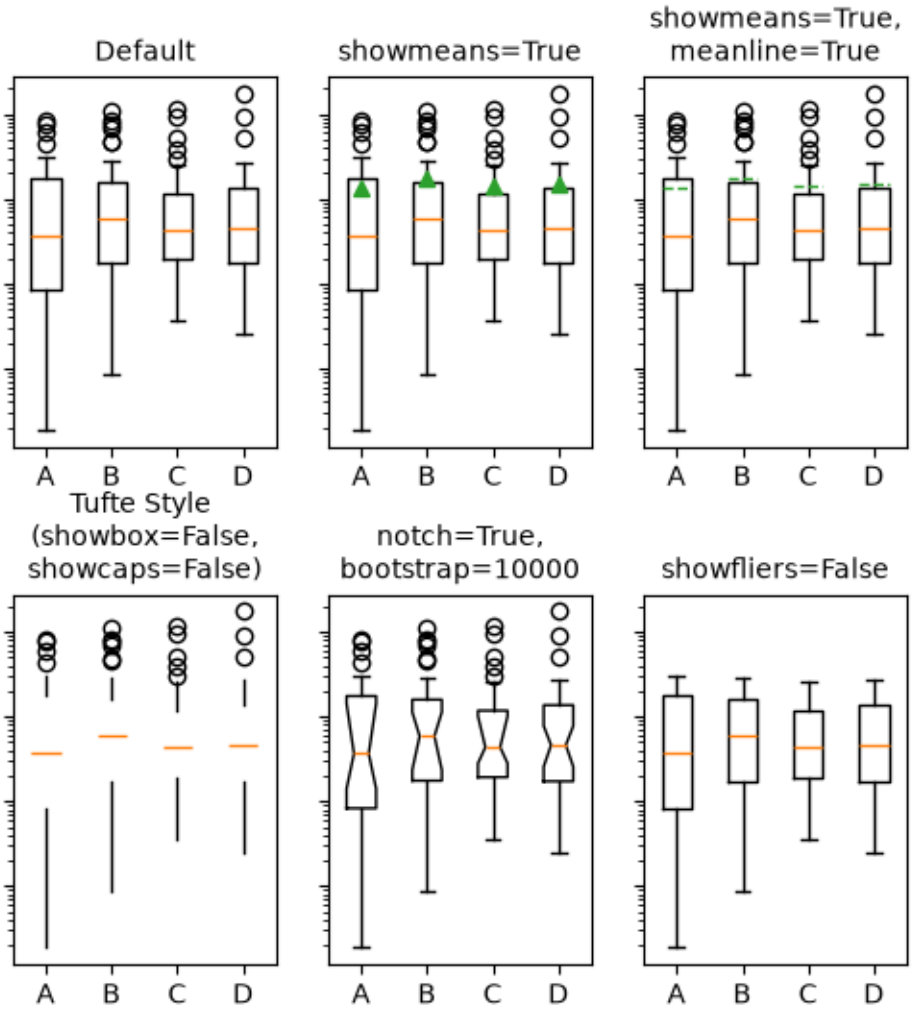
Demonstrate how to toggle the display of different elements:

```
fig, axs = plt.subplots(nrows=2, ncols=3, figsize=(6, 6), sharey=True)
axs[0, 0].boxplot(data, tick_labels=labels)
axs[0, 0].set_title('Default', fontsize=fs)

axs[0, 1].boxplot(data, tick_labels=labels, showmeans=True)
axs[0, 1].set_title('showmeans=True', fontsize=fs)

axs[0, 2].boxplot(data, tick_labels=labels, showmeans=True,␣
↪meanline=True)
axs[0, 2].set_title('showmeans=True,\nmeanline=True', fontsize=fs)

axs[1, 0].boxplot(data, tick_labels=labels, showbox=False,␣
↪showcaps=False)
tufte_title = 'Tufte Style \n(showbox=False,\nshowcaps=False)'
axs[1, 0].set_title(tufte_title, fontsize=fs)

axs[1, 1].boxplot(data, tick_labels=labels, notch=True,␣
```

(continues on next page)

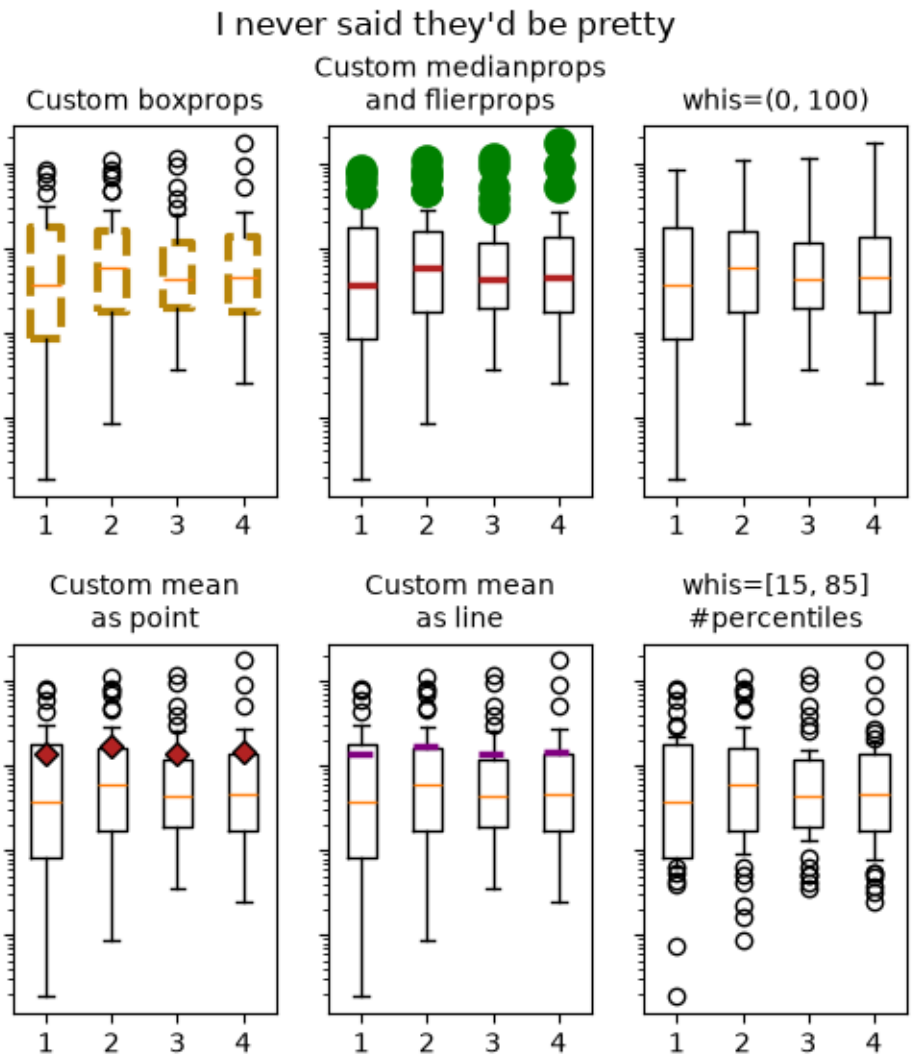
(continued from previous page)

```
 ↪bootstrap=10000)
axs[1, 1].set_title('notch=True,\nbootstrap=10000', fontsize=fs)

axs[1, 2].boxplot(data, tick_labels=labels, showfliers=False)
axs[1, 2].set_title('showfliers=False', fontsize=fs)

for ax in axs.flat:
    ax.set_yscale('log')
    ax.set_yticklabels([])

fig.subplots_adjust(hspace=0.4)
plt.show()
```



Demonstrate how to customize the display different elements:

```
boxprops = dict(linestyle='--', linewidth=3, color='darkgoldenrod')
flierprops = dict(marker='o', markerfacecolor='green', markersize=12,
                  markeredgecolor='none')
medianprops = dict(linestyle='-.', linewidth=2.5, color='firebrick')
meanpointprops = dict(marker='D', markeredgecolor='black',
                      markerfacecolor='firebrick')
meanlineprops = dict(linestyle='--', linewidth=2.5, color='purple')

fig, axs = plt.subplots(nrows=2, ncols=3, figsize=(6, 6), sharey=True)
axs[0, 0].boxplot(data, boxprops=boxprops)
axs[0, 0].set_title('Custom boxprops', fontsize=fs)

axs[0, 1].boxplot(data, flierprops=flierprops, medianprops=medianprops)
axs[0, 1].set_title('Custom medianprops\nand flierprops', fontsize=fs)

axs[0, 2].boxplot(data, whis=(0, 100))
axs[0, 2].set_title('whis=(0, 100)', fontsize=fs)

axs[1, 0].boxplot(data, meanprops=meanpointprops, meanline=False,
                  showmeans=True)
axs[1, 0].set_title('Custom mean\nas point', fontsize=fs)

axs[1, 1].boxplot(data, meanprops=meanlineprops, meanline=True,
                  showmeans=True)
axs[1, 1].set_title('Custom mean\nas line', fontsize=fs)

axs[1, 2].boxplot(data, whis=[15, 85])
axs[1, 2].set_title('whis=[15, 85]\n#percentiles', fontsize=fs)

for ax in axs.flat:
    ax.set_yscale('log')
    ax.set_yticklabels([])

fig.suptitle("I never said they'd be pretty")
fig.subplots_adjust(hspace=0.4)
plt.show()
```



Tags: plot-type: boxplot domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.boxplot* / *matplotlib.pyplot.boxplot*

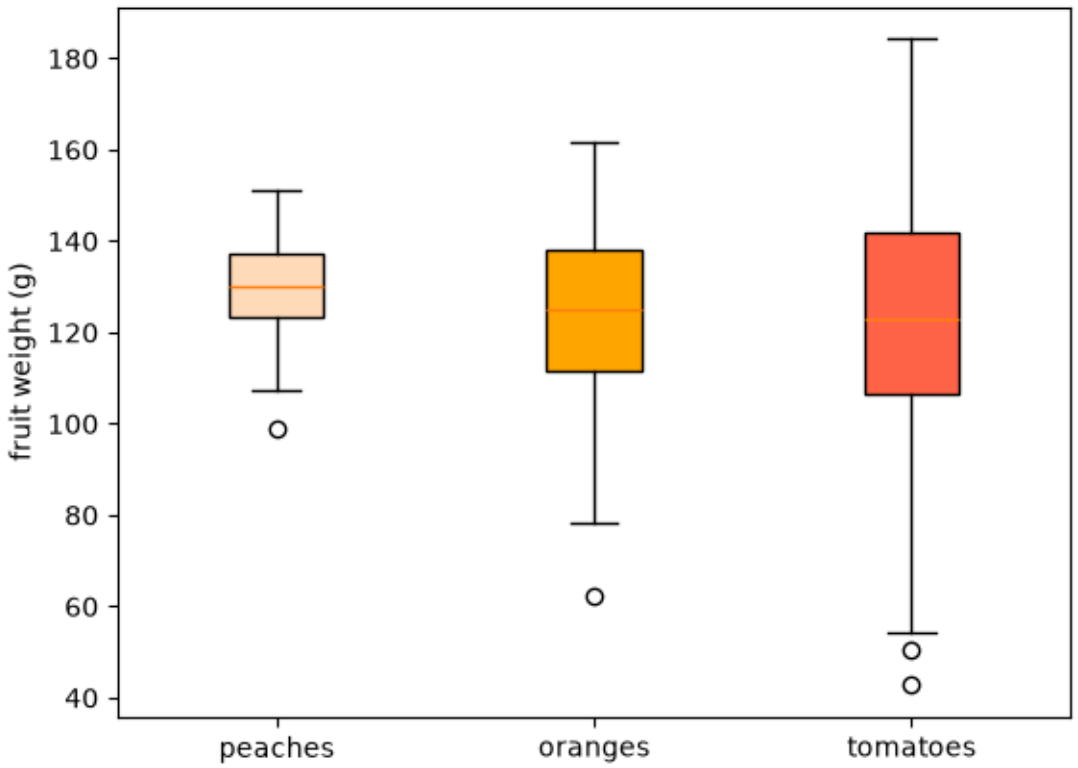
Total running time of the script: (0 minutes 2.169 seconds)

Box plots with custom fill colors

To color each box of a box plot individually:

1) use the keyword argument `patch_artist=True` to create filled boxes.
2) loop through the created boxes and adapt their color.

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)
fruit_weights = [
    np.random.normal(130, 10, size=100),
    np.random.normal(125, 20, size=100),
    np.random.normal(120, 30, size=100),
]
labels = ['peaches', 'oranges', 'tomatoes']
colors = ['peachpuff', 'orange', 'tomato']

fig, ax = plt.subplots()
ax.set_ylabel('fruit weight (g)')

bplot = ax.boxplot(fruit_weights,
                   patch_artist=True,  # fill with color
                   tick_labels=labels)  # will be used to label x-ticks

# fill with colors
for patch, color in zip(bplot['boxes'], colors):
    patch.set_facecolor(color)

plt.show()
```



Tags: styling: color domain: statistics plot-type: boxplot

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.boxplot* / *matplotlib.pyplot.boxplot*

Separate calculation and plotting of boxplots

Drawing a *boxplot* for a given data set, consists of two main operations, that can also be used separately:

1. Calculating the boxplot statistics: *matplotlib.cbook.boxplot_stats*
2. Drawing the boxplot: *matplotlib.axes.Axes.bxp*

Thus, `ax.boxplot(data)` is equivalent to

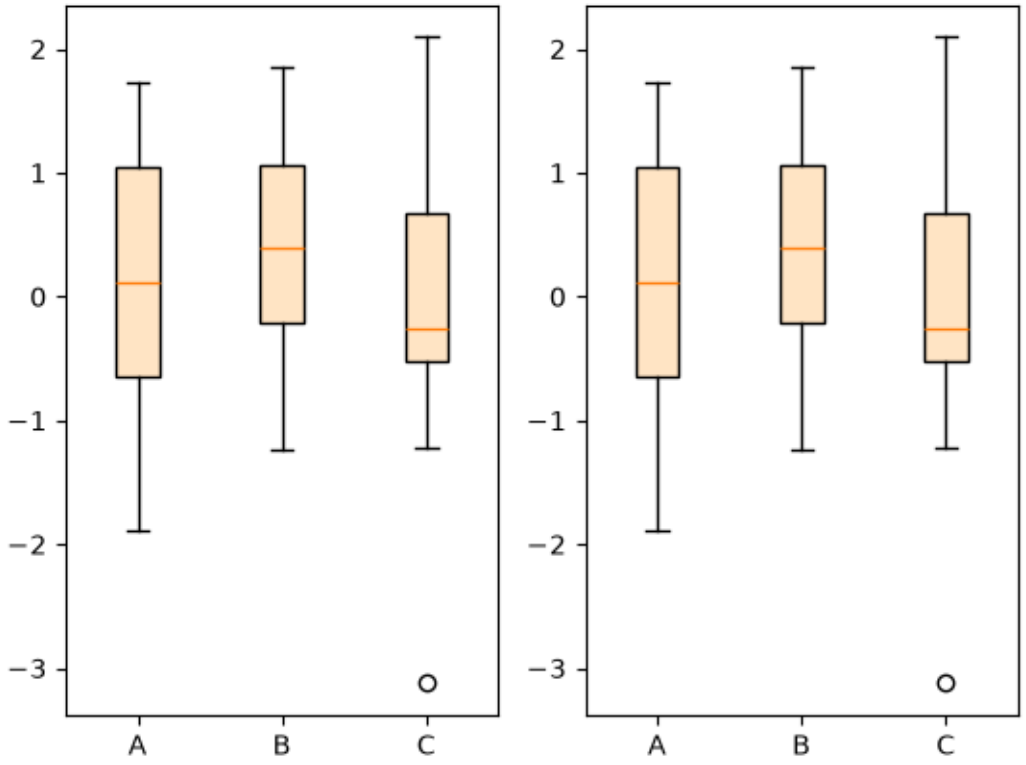
```
stats = cbook.boxplot_stats(data)
ax.bxp(stats)
```

All styling keyword arguments are identical between *boxplot* and *bxp*, and they are passed through from *boxplot* to *bxp*. However, the *tick_labels* parameter of *boxplot* translates to a generic *labels* parameter

in *boxplot_stats*, because the labels are data-related and attached to the returned per-dataset dictionaries.

The following code demonstrates the equivalence between the two methods.

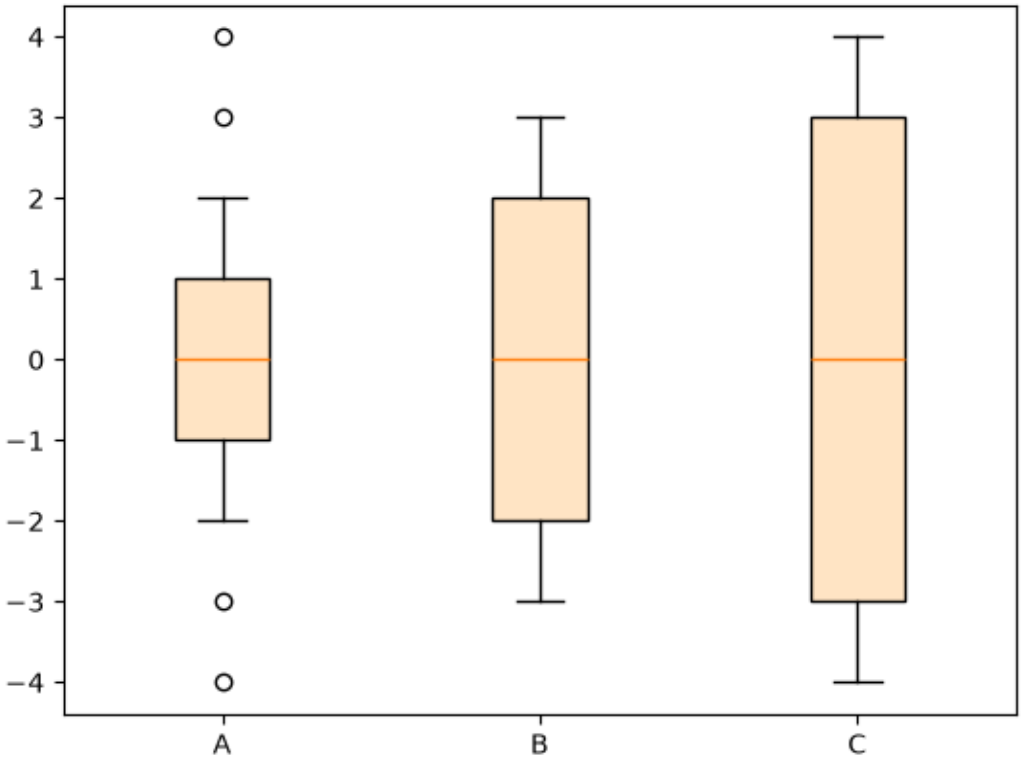
```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import cbook

np.random.seed(19680801)
data = np.random.randn(20, 3)

fig, (ax1, ax2) = plt.subplots(1, 2)

# single boxplot call
ax1.boxplot(data, tick_labels=['A', 'B', 'C'],
            patch_artist=True, boxprops={'facecolor': 'bisque'})

# separate calculation of statistics and plotting
stats = cbook.boxplot_stats(data, labels=['A', 'B', 'C'])
ax2.bxp(stats, patch_artist=True, boxprops={'facecolor': 'bisque'})
```



Using the separate functions allows to pre-calculate statistics, in case you need them explicitly for other purposes, or to reuse the statistics for multiple plots.

Conversely, you can also use the *bxp* function directly, if you already have the statistical parameters:

```
fig, ax = plt.subplots()

stats = [
    dict(med=0, q1=-1, q3=1, whislo=-2, whishi=2, fliers=[-4, -3, 3,␣
 ↪4], label='A'),
    dict(med=0, q1=-2, q3=2, whislo=-3, whishi=3, fliers=[], label='B
 ↪'),
    dict(med=0, q1=-3, q3=3, whislo=-4, whishi=4, fliers=[], label='C
 ↪'),
]

ax.bxp(stats, patch_artist=True, boxprops={'facecolor': 'bisque'})

plt.show()
```



Tags: plot-type: specialty domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.bxp*
- *matplotlib.axes.Axes.boxplot*
- *matplotlib.cbook.boxplot_stats*

Box plot vs. violin plot comparison

Note that although violin plots are closely related to Tukey's (1977) box plots, they add useful information such as the distribution of the sample data (density trace).

By default, box plots show data points outside 1.5 * the inter-quartile range as outliers above or below the whiskers whereas violin plots show the whole range of the data.

A good general reference on boxplots and their history can be found here: https://vita.had.co.nz/papers/boxplots.pdf

Violin plots require matplotlib >= 1.4.

Violin plots show the distribution of the data as a rotated kernel density estimate (KDE) along with summary statistics similar to a box plot.

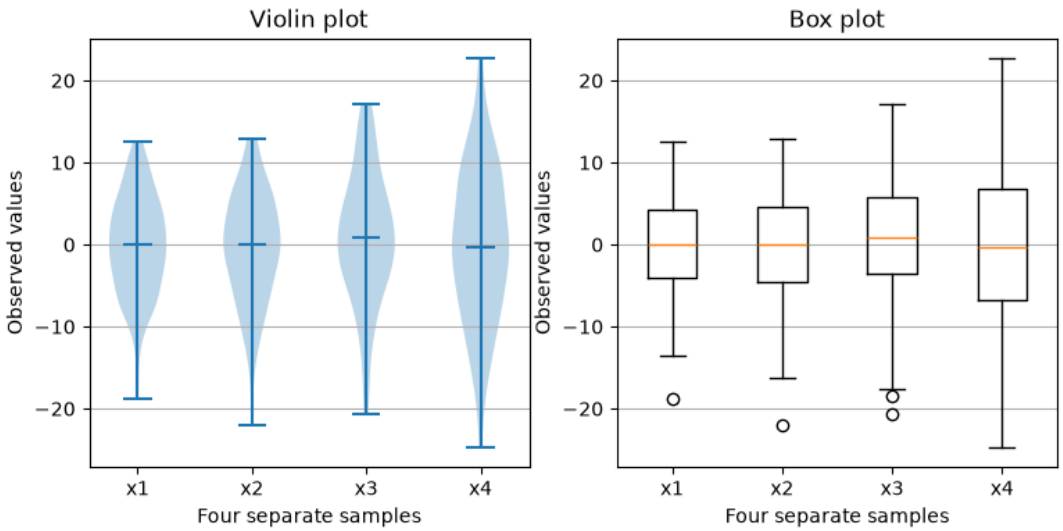
For more information on violin plots, see: https://en.wikipedia.org/wiki/Violin_plot

```
import matplotlib.pyplot as plt
import numpy as np

fig, axs = plt.subplots(nrows=1, ncols=2, figsize=(9, 4))

# Fixing random state for reproducibility
np.random.seed(19680801)


# generate some random test data
all_data = [np.random.normal(0, std, 100) for std in range(6, 10)]

# plot violin plot
axs[0].violinplot(all_data,
                  showmeans=False,
                  showmedians=True)
axs[0].set_title('Violin plot')

# plot box plot
axs[1].boxplot(all_data)
axs[1].set_title('Box plot')
```

(continues on next page)

(continued from previous page)

```
# adding horizontal grid lines
for ax in axs:
    ax.yaxis.grid(True)
    ax.set_xticks([y + 1 for y in range(len(all_data))],
                  labels=['x1', 'x2', 'x3', 'x4'])
    ax.set_xlabel('Four separate samples')
    ax.set_ylabel('Observed values')

plt.show()
```



Tags: plot-type: violin plot-type: boxplot domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.boxplot* / *matplotlib.pyplot.boxplot*
- *matplotlib.axes.Axes.violinplot* / *matplotlib.pyplot.violinplot*

Violin plot basics

Violin plots are similar to histograms and box plots in that they show an abstract representation of the probability distribution of the sample. Rather than showing counts of data points that fall into bins or order statistics, violin plots use kernel density estimation (KDE) to compute an empirical distribution of the sample. That computation is controlled by several parameters. This example demonstrates how to modify the number of points at which the KDE is evaluated (`points`) and how to modify the bandwidth of the KDE (`bw_method`).

For more information on violin plots and KDE, the scikit-learn docs have a great section: https://scikit-learn.org/stable/modules/density.html

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)


# fake data
fs = 10  # fontsize
pos = [1, 2, 4, 5, 7, 8]
data = [np.random.normal(0, std, size=100) for std in pos]

fig, axs = plt.subplots(nrows=2, ncols=6, figsize=(10, 4))

axs[0, 0].violinplot(data, pos, points=20, widths=0.3,
                     showmeans=True, showextrema=True,␣
 ↪showmedians=True)
axs[0, 0].set_title('Custom violin 1', fontsize=fs)

axs[0, 1].violinplot(data, pos, points=40, widths=0.5,
                     showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                     bw_method='silverman')
axs[0, 1].set_title('Custom violin 2', fontsize=fs)

axs[0, 2].violinplot(data, pos, points=60, widths=0.7, showmeans=True,
                     showextrema=True, showmedians=True, bw_method=0.5)
axs[0, 2].set_title('Custom violin 3', fontsize=fs)

axs[0, 3].violinplot(data, pos, points=60, widths=0.7, showmeans=True,
                     showextrema=True, showmedians=True, bw_method=0.5,
                     quantiles=[[0.1], [], [], [0.175, 0.954], [0.75],␣
 ↪[0.25]])
axs[0, 3].set_title('Custom violin 4', fontsize=fs)

axs[0, 4].violinplot(data[-1:], pos[-1:], points=60, widths=0.7,
                     showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                     quantiles=[0.05, 0.1, 0.8, 0.9], bw_method=0.5)
axs[0, 4].set_title('Custom violin 5', fontsize=fs)

axs[0, 5].violinplot(data[-1:], pos[-1:], points=60, widths=0.7,
                     showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                     quantiles=[0.05, 0.1, 0.8, 0.9], bw_method=0.5,␣
 ↪side='low')
```

(continues on next page)

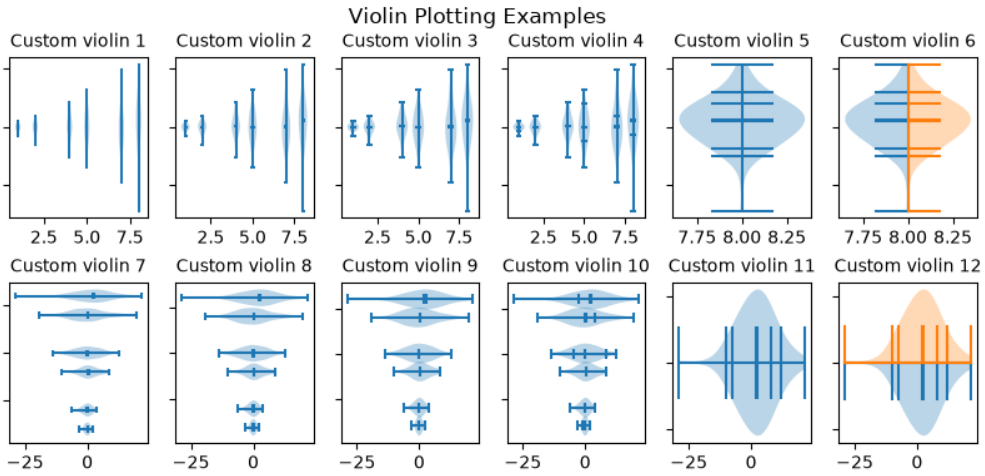
(continued from previous page)

```
axs[0, 5].violinplot(data[-1:], pos[-1:], points=60, widths=0.7,
                     showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                     quantiles=[0.05, 0.1, 0.8, 0.9], bw_method=0.5,␣
 ↪side='high')
axs[0, 5].set_title('Custom violin 6', fontsize=fs)

axs[1, 0].violinplot(data, pos, points=80, orientation='horizontal',␣
 ↪widths=0.7,
                     showmeans=True, showextrema=True,␣
 ↪showmedians=True)
axs[1, 0].set_title('Custom violin 7', fontsize=fs)

axs[1, 1].violinplot(data, pos, points=100, orientation='horizontal',␣
 ↪widths=0.9,
                     showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                     bw_method='silverman')
axs[1, 1].set_title('Custom violin 8', fontsize=fs)

axs[1, 2].violinplot(data, pos, points=200, orientation='horizontal',␣
 ↪widths=1.1,
                     showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                     bw_method=0.5)
axs[1, 2].set_title('Custom violin 9', fontsize=fs)

axs[1, 3].violinplot(data, pos, points=200, orientation='horizontal',␣
 ↪widths=1.1,
                     showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                     quantiles=[[0.1], [], [], [0.175, 0.954], [0.75],␣
 ↪[0.25]],
                     bw_method=0.5)
axs[1, 3].set_title('Custom violin 10', fontsize=fs)

axs[1, 4].violinplot(data[-1:], pos[-1:], points=200, orientation=
 ↪'horizontal',
                     widths=1.1, showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                     quantiles=[0.05, 0.1, 0.8, 0.9], bw_method=0.5)
axs[1, 4].set_title('Custom violin 11', fontsize=fs)

axs[1, 5].violinplot(data[-1:], pos[-1:], points=200, orientation=
 ↪'horizontal',
```

(continues on next page)

(continued from previous page)

```
                      widths=1.1, showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                      quantiles=[0.05, 0.1, 0.8, 0.9], bw_method=0.5,␣
 ↪side='low')

axs[1, 5].violinplot(data[-1:], pos[-1:], points=200, orientation=
 ↪'horizontal',
                      widths=1.1, showmeans=True, showextrema=True,␣
 ↪showmedians=True,
                      quantiles=[0.05, 0.1, 0.8, 0.9], bw_method=0.5,␣
 ↪side='high')
axs[1, 5].set_title('Custom violin 12', fontsize=fs)


for ax in axs.flat:
    ax.set_yticklabels([])

fig.suptitle("Violin Plotting Examples")
fig.subplots_adjust(hspace=0.4)
plt.show()
```



Tags: plot-type: violin domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.violinplot* / *matplotlib.pyplot.violinplot*

Total running time of the script: (0 minutes 1.049 seconds)

Violin plot customization

This example demonstrates how to fully customize violin plots. The first plot shows the default style by providing only the data. The second plot first limits what Matplotlib draws with additional keyword arguments. Then a simplified representation of a box plot is drawn on top. Lastly, the styles of the artists of the violins are modified.

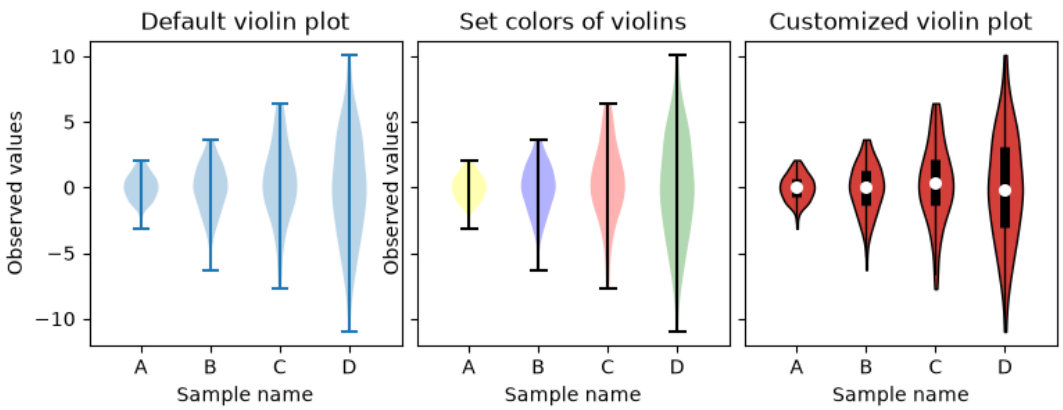
For more information on violin plots, the scikit-learn docs have a great section: https://scikit-learn.org/stable/modules/density.html

```
import matplotlib.pyplot as plt
import numpy as np


def adjacent_values(vals, q1, q3):
    upper_adjacent_value = q3 + (q3 - q1) * 1.5
    upper_adjacent_value = np.clip(upper_adjacent_value, q3, vals[-1])

    lower_adjacent_value = q1 - (q3 - q1) * 1.5
    lower_adjacent_value = np.clip(lower_adjacent_value, vals[0], q1)
    return lower_adjacent_value, upper_adjacent_value


def set_axis_style(ax, labels):
    ax.set_xticks(np.arange(1, len(labels) + 1), labels=labels)
    ax.set_xlim(0.25, len(labels) + 0.75)
    ax.set_xlabel('Sample name')


# create test data
np.random.seed(19680801)
data = [sorted(np.random.normal(0, std, 100)) for std in range(1, 5)]

fig, (ax1, ax2, ax3) = plt.subplots(nrows=1, ncols=3, figsize=(9, 3),␣
 ↪sharey=True)

ax1.set_title('Default violin plot')
ax1.set_ylabel('Observed values')
ax1.violinplot(data)
```

(continues on next page)

(continued from previous page)

```
ax2.set_title('Set colors of violins')
ax2.set_ylabel('Observed values')
ax2.violinplot(
    data,
    facecolor=[('yellow', 0.3), ('blue', 0.3), ('red', 0.3), ('green',␣
 ↪0.3)],
    linecolor='black',
)
# Note that when passing a sequence of colors, the method will repeat␣
 ↪the sequence if
# less colors are provided than data distributions.

ax3.set_title('Customized violin plot')
parts = ax3.violinplot(
        data, showmeans=False, showmedians=False, showextrema=False,
        facecolor='#D43F3A', linecolor='black')

for pc in parts['bodies']:
    pc.set_edgecolor('black')
    pc.set_linewidth(1)
    pc.set_alpha(1)

quartile1, medians, quartile3 = np.percentile(data, [25, 50, 75],␣
 ↪axis=1)
whiskers = np.array([
    adjacent_values(sorted_array, q1, q3)
    for sorted_array, q1, q3 in zip(data, quartile1, quartile3)])
whiskers_min, whiskers_max = whiskers[:, 0], whiskers[:, 1]

inds = np.arange(1, len(medians) + 1)
ax3.scatter(inds, medians, marker='o', color='white', s=30, zorder=3)
ax3.vlines(inds, quartile1, quartile3, color='k', linestyle='-', lw=5)
ax3.vlines(inds, whiskers_min, whiskers_max, color='k', linestyle='-',␣
 ↪lw=1)

# set style for the axes
labels = ['A', 'B', 'C', 'D']
for ax in [ax1, ax2, ax3]:
    set_axis_style(ax, labels)

plt.subplots_adjust(bottom=0.15, wspace=0.05)
plt.show()
```



Tags: plot-type: violin domain: statistics

References

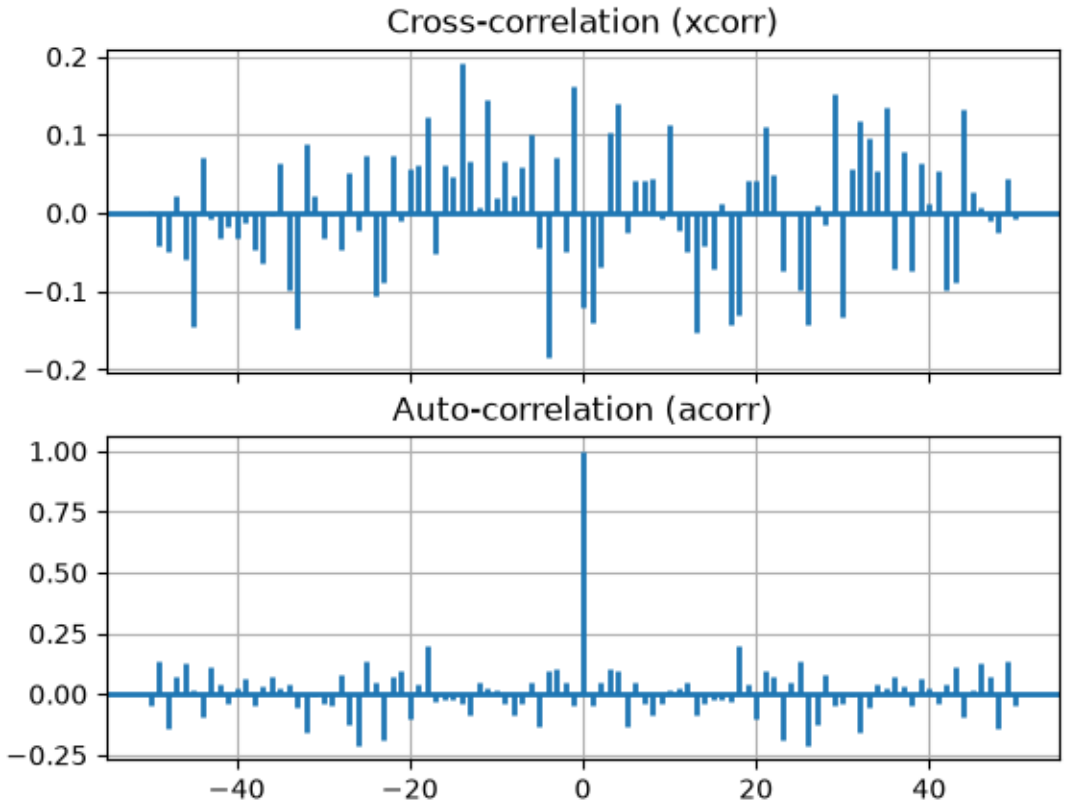
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.violinplot* / *matplotlib.pyplot.violinplot*
- *matplotlib.axes.Axes.vlines* / *matplotlib.pyplot.vlines*

Cross- and auto-correlation

Example use of cross-correlation (*xcorr*) and auto-correlation (*acorr*) plots.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)


x, y = np.random.randn(2, 100)
fig, [ax1, ax2] = plt.subplots(2, 1, sharex=True)
ax1.xcorr(x, y, usevlines=True, maxlags=50, normed=True, lw=2)
ax1.grid(True)
ax1.set_title('Cross-correlation (xcorr)')

ax2.acorr(x, usevlines=True, normed=True, maxlags=50, lw=2)
ax2.grid(True)
ax2.set_title('Auto-correlation (acorr)')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.acorr* / *matplotlib.pyplot.acorr*
- *matplotlib.axes.Axes.xcorr* / *matplotlib.pyplot.xcorr*

Tags: domain: statistics level: beginner

Power spectral density (PSD)

Plotting power spectral density (PSD) using *psd*.

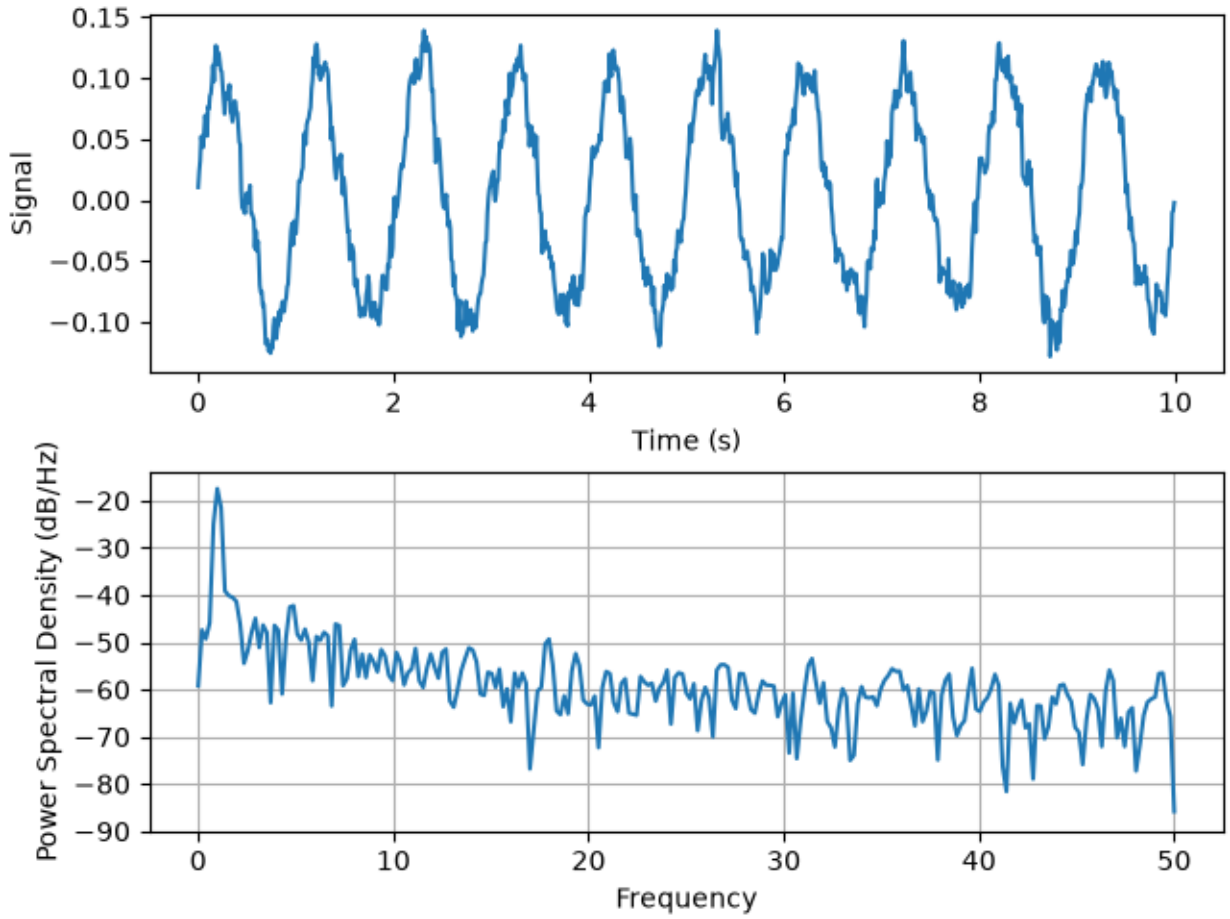
The PSD is a common plot in the field of signal processing. NumPy has many useful libraries for computing a PSD. Below we demo a few examples of how this can be accomplished and visualized with Matplotlib.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.mlab as mlab
```

(continues on next page)

(continued from previous page)

```
# Fixing random state for reproducibility
np.random.seed(19680801)

dt = 0.01
t = np.arange(0, 10, dt)
nse = np.random.randn(len(t))
r = np.exp(-t / 0.05)

cnse = np.convolve(nse, r) * dt
cnse = cnse[:len(t)]
s = 0.1 * np.sin(2 * np.pi * t) + cnse

fig, (ax0, ax1) = plt.subplots(2, 1, layout='constrained')
ax0.plot(t, s)
ax0.set_xlabel('Time (s)')
ax0.set_ylabel('Signal')
ax1.psd(s, NFFT=512, Fs=1 / dt)

plt.show()
```



Compare this with the equivalent Matlab code to accomplish the same thing:

```
dt = 0.01;
t = [0:dt:10];
nse = randn(size(t));
r = exp(-t/0.05);
cnse = conv(nse, r)*dt;
cnse = cnse(1:length(t));
s = 0.1*sin(2*pi*t) + cnse;

subplot(211)
plot(t, s)
subplot(212)
psd(s, 512, 1/dt)
```

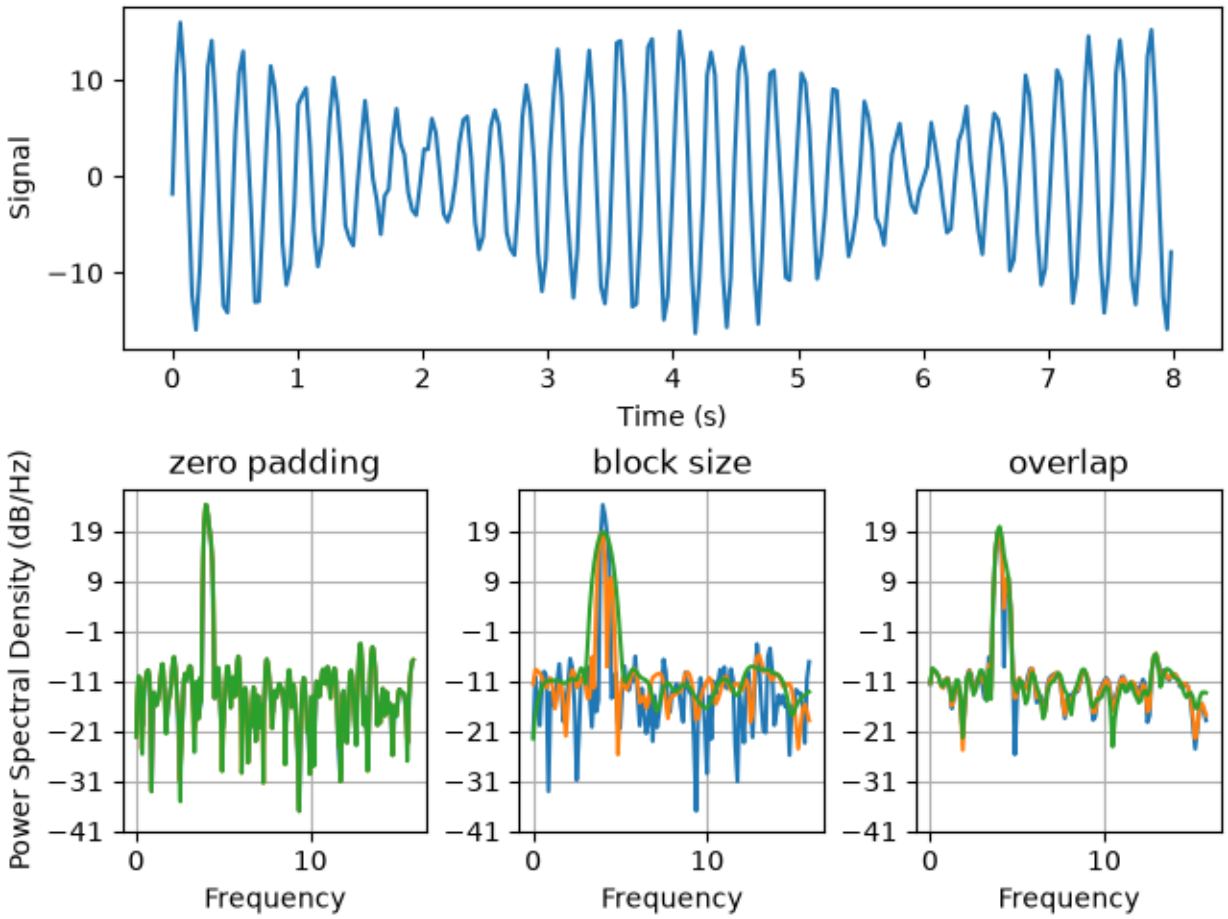
Below we'll show a slightly more complex example that demonstrates how padding affects the resulting PSD.

```
dt = np.pi / 100.
fs = 1. / dt
t = np.arange(0, 8, dt)
y = 10. * np.sin(2 * np.pi * 4 * t) + 5. * np.sin(2 * np.pi * 4.25 * t)
y = y + np.random.randn(*t.shape)

# Plot the raw time series
fig, axs = plt.subplot_mosaic([
    ['signal', 'signal', 'signal'],
    ['zero padding', 'block size', 'overlap'],
], layout='constrained')

axs['signal'].plot(t, y)
axs['signal'].set_xlabel('Time (s)')
axs['signal'].set_ylabel('Signal')

# Plot the PSD with different amounts of zero padding. This uses the␣
 ↪entire
# time series at once
axs['zero padding'].psd(y, NFFT=len(t), pad_to=len(t), Fs=fs)
axs['zero padding'].psd(y, NFFT=len(t), pad_to=len(t) * 2, Fs=fs)
axs['zero padding'].psd(y, NFFT=len(t), pad_to=len(t) * 4, Fs=fs)

# Plot the PSD with different block sizes, Zero pad to the length of␣
 ↪the
# original data sequence.
axs['block size'].psd(y, NFFT=len(t), pad_to=len(t), Fs=fs)
axs['block size'].psd(y, NFFT=len(t) // 2, pad_to=len(t), Fs=fs)
axs['block size'].psd(y, NFFT=len(t) // 4, pad_to=len(t), Fs=fs)
axs['block size'].set_ylabel('')
```

(continues on next page)

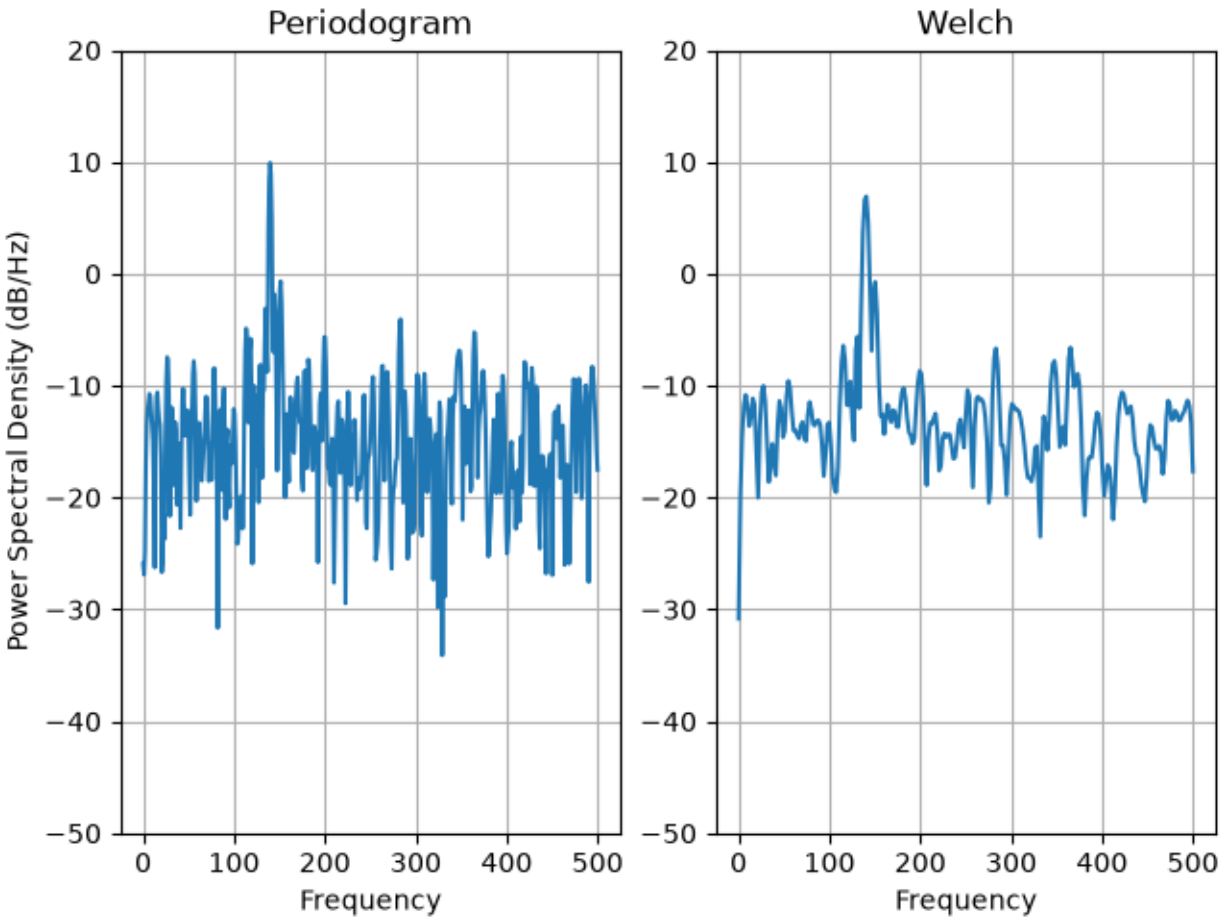
(continued from previous page)

```
# Plot the PSD with different amounts of overlap between blocks
axs['overlap'].psd(y, NFFT=len(t) // 2, pad_to=len(t), noverlap=0,␣
 ↪Fs=fs)
axs['overlap'].psd(y, NFFT=len(t) // 2, pad_to=len(t),
                   noverlap=int(0.025 * len(t)), Fs=fs)
axs['overlap'].psd(y, NFFT=len(t) // 2, pad_to=len(t),
                   noverlap=int(0.1 * len(t)), Fs=fs)
axs['overlap'].set_ylabel('')
axs['overlap'].set_title('overlap')

for title, ax in axs.items():
    if title == 'signal':
        continue

    ax.set_title(title)
    ax.sharex(axs['zero padding'])
    ax.sharey(axs['zero padding'])

plt.show()
```



This is a ported version of a MATLAB example from the signal processing toolbox that showed some difference at one time between Matplotlib's and MATLAB's scaling of the PSD.

```
fs = 1000
t = np.linspace(0, 0.3, 301)
A = np.array([2, 8]).reshape(-1, 1)
f = np.array([150, 140]).reshape(-1, 1)
xn = (A * np.sin(2 * np.pi * f * t)).sum(axis=0)
xn += 5 * np.random.randn(*t.shape)

fig, (ax0, ax1) = plt.subplots(ncols=2, layout='constrained')

yticks = np.arange(-50, 30, 10)
yrange = (yticks[0], yticks[-1])
xticks = np.arange(0, 550, 100)

ax0.psd(xn, NFFT=301, Fs=fs, window=mlab.window_none, pad_to=1024,
        scale_by_freq=True)
ax0.set_title('Periodogram')
ax0.set_yticks(yticks)
ax0.set_xticks(xticks)
ax0.grid(True)
ax0.set_ylim(yrange)

ax1.psd(xn, NFFT=150, Fs=fs, window=mlab.window_none, pad_to=512,␣
 ↪noverlap=75,
        scale_by_freq=True)
ax1.set_title('Welch')
ax1.set_xticks(xticks)
ax1.set_yticks(yticks)
ax1.set_ylabel('')  # overwrite the y-label added by `psd`
ax1.grid(True)
ax1.set_ylim(yrange)

plt.show()
```



This is a ported version of a MATLAB example from the signal processing toolbox that showed some difference at one time between Matplotlib's and MATLAB's scaling of the PSD.

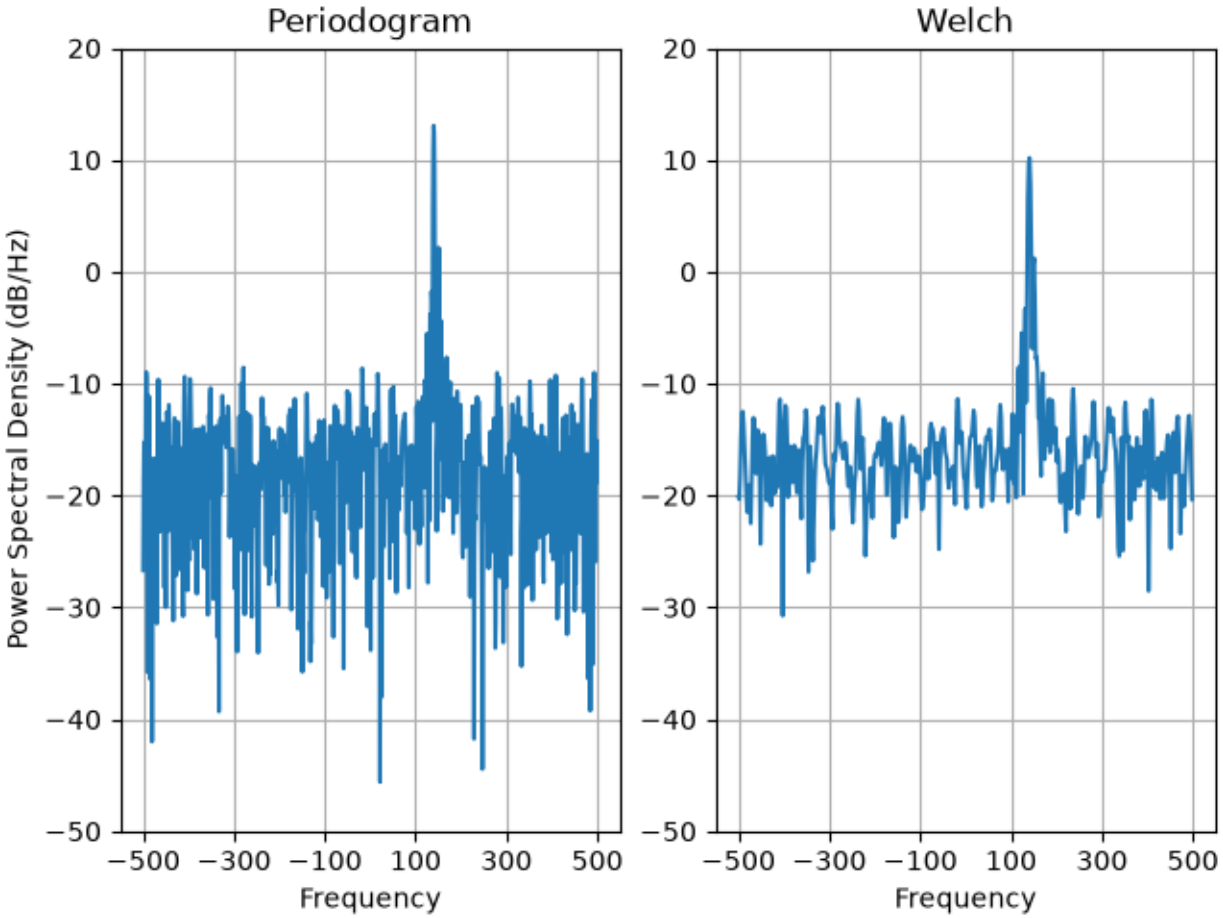
It uses a complex signal so we can see that complex PSD's work properly.

```
prng = np.random.RandomState(19680801)  # to ensure reproducibility

fs = 1000
t = np.linspace(0, 0.3, 301)
A = np.array([2, 8]).reshape(-1, 1)
f = np.array([150, 140]).reshape(-1, 1)
xn = (A * np.exp(2j * np.pi * f * t)).sum(axis=0) + 5 * prng.randn(*t.
 ↪shape)

fig, (ax0, ax1) = plt.subplots(ncols=2, layout='constrained')

yticks = np.arange(-50, 30, 10)
yrange = (yticks[0], yticks[-1])
xticks = np.arange(-500, 550, 200)

ax0.psd(xn, NFFT=301, Fs=fs, window=mlab.window_none, pad_to=1024,
```

(continues on next page)

(continued from previous page)

```
        scale_by_freq=True)
ax0.set_title('Periodogram')
ax0.set_yticks(yticks)
ax0.set_xticks(xticks)
ax0.grid(True)
ax0.set_ylim(yrange)

ax1.psd(xn, NFFT=150, Fs=fs, window=mlab.window_none, pad_to=512,␣
 ↪noverlap=75,
        scale_by_freq=True)
ax1.set_title('Welch')
ax1.set_xticks(xticks)
ax1.set_yticks(yticks)
ax1.set_ylabel('')  # overwrite the y-label added by `psd`
ax1.grid(True)
ax1.set_ylim(yrange)

plt.show()
```



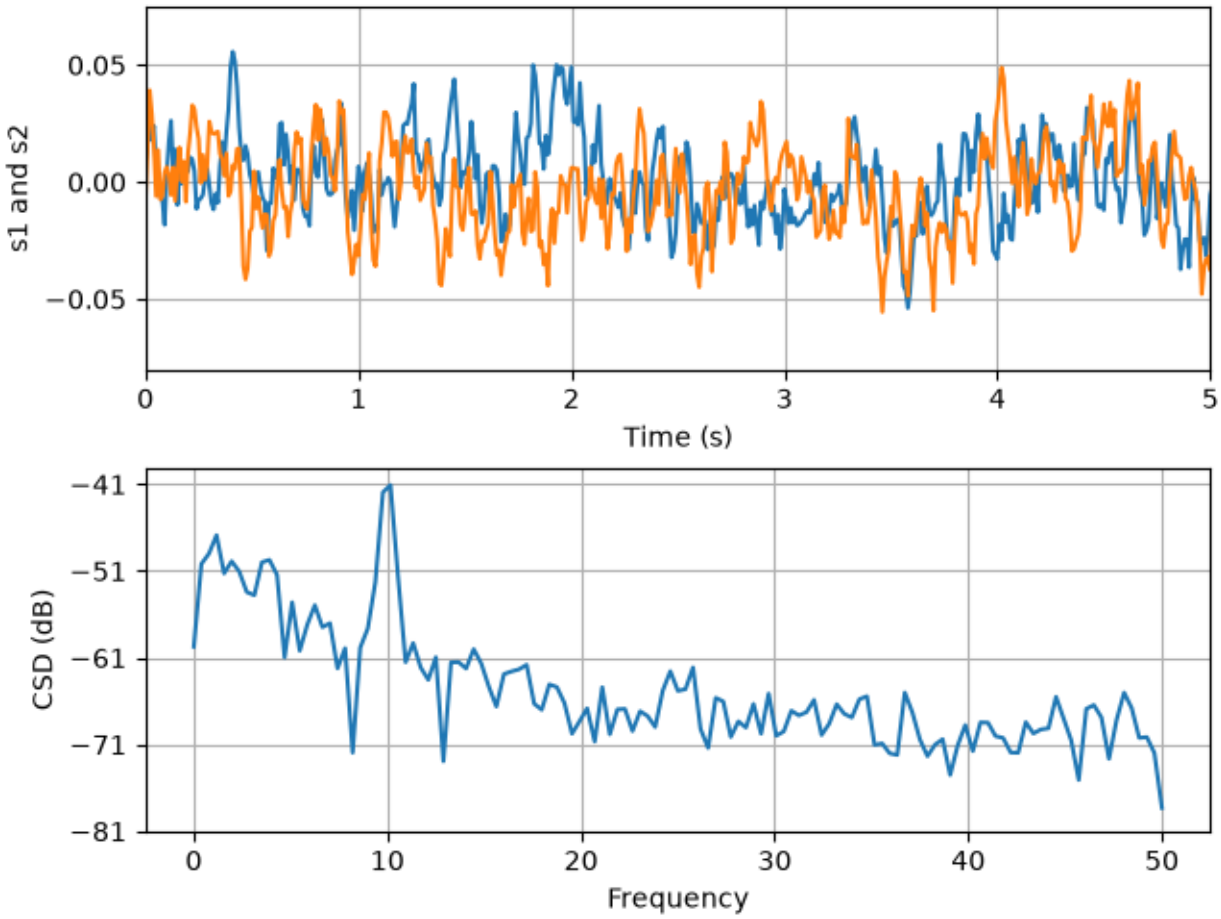
Tags: domain: signal-processing plot-type: line level: intermediate

Total running time of the script: (0 minutes 2.662 seconds)

Cross spectral density (CSD)

Plot the cross spectral density (CSD) of two signals using *csd*.

```
import matplotlib.pyplot as plt
import numpy as np

fig, (ax1, ax2) = plt.subplots(2, 1, layout='constrained')

dt = 0.01
t = np.arange(0, 30, dt)

# Fixing random state for reproducibility
np.random.seed(19680801)


nse1 = np.random.randn(len(t))                 # white noise 1
nse2 = np.random.randn(len(t))                 # white noise 2
r = np.exp(-t / 0.05)

cnse1 = np.convolve(nse1, r, mode='same') * dt   # colored noise 1
cnse2 = np.convolve(nse2, r, mode='same') * dt   # colored noise 2

# two signals with a coherent part and a random part
s1 = 0.01 * np.sin(2 * np.pi * 10 * t) + cnse1
s2 = 0.01 * np.sin(2 * np.pi * 10 * t) + cnse2

ax1.plot(t, s1, t, s2)
ax1.set_xlim(0, 5)
ax1.set_xlabel('Time (s)')
ax1.set_ylabel('s1 and s2')
ax1.grid(True)

cxy, f = ax2.csd(s1, s2, NFFT=256, Fs=1. / dt)
ax2.set_ylabel('CSD (dB)')

plt.show()
```



Tags: domain: signal-processing plot-type: line level: beginner

Plotting the coherence of two signals

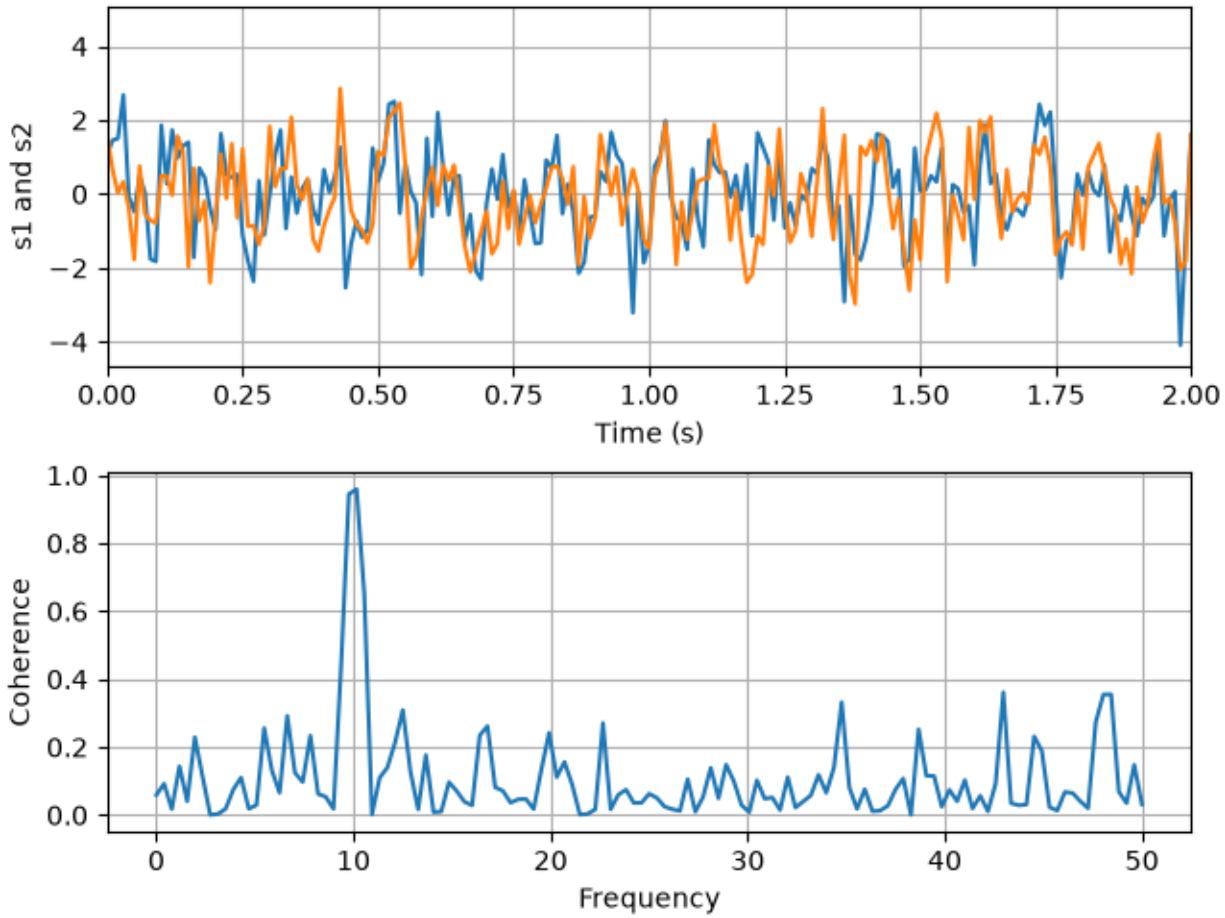
An example showing how to plot the coherence of two signals using *cohere*.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

dt = 0.01
t = np.arange(0, 30, dt)
nse1 = np.random.randn(len(t))                 # white noise 1
nse2 = np.random.randn(len(t))                 # white noise 2

# Two signals with a coherent part at 10 Hz and a random part
s1 = np.sin(2 * np.pi * 10 * t) + nse1
s2 = np.sin(2 * np.pi * 10 * t) + nse2
```

(continues on next page)

(continued from previous page)

```
fig, axs = plt.subplots(2, 1, layout='constrained')
axs[0].plot(t, s1, t, s2)
axs[0].set_xlim(0, 2)
axs[0].set_xlabel('Time (s)')
axs[0].set_ylabel('s1 and s2')
axs[0].grid(True)

cxy, f = axs[1].cohere(s1, s2, NFFT=256, Fs=1. / dt)
axs[1].set_ylabel('Coherence')

plt.show()
```



Tags: domain: signal-processing plot-type: line level: beginner

6.24.4 Pie and polar charts

Pie charts

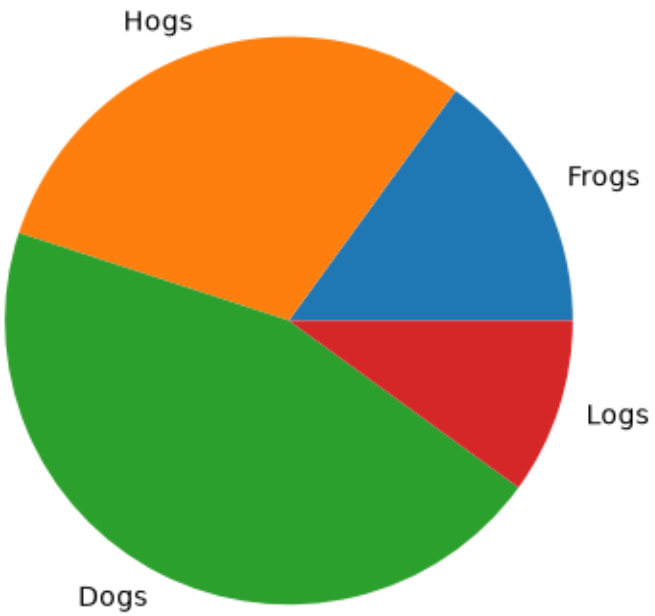
Demo of plotting a pie chart.

This example illustrates various parameters of `pie`.

Label slices

Plot a pie chart of animals and label the slices. To add labels, pass a list of labels to the *labels* parameter

```
import matplotlib.pyplot as plt

labels = 'Frogs', 'Hogs', 'Dogs', 'Logs'
sizes = [15, 30, 45, 10]

fig, ax = plt.subplots()
ax.pie(sizes, labels=labels)
```

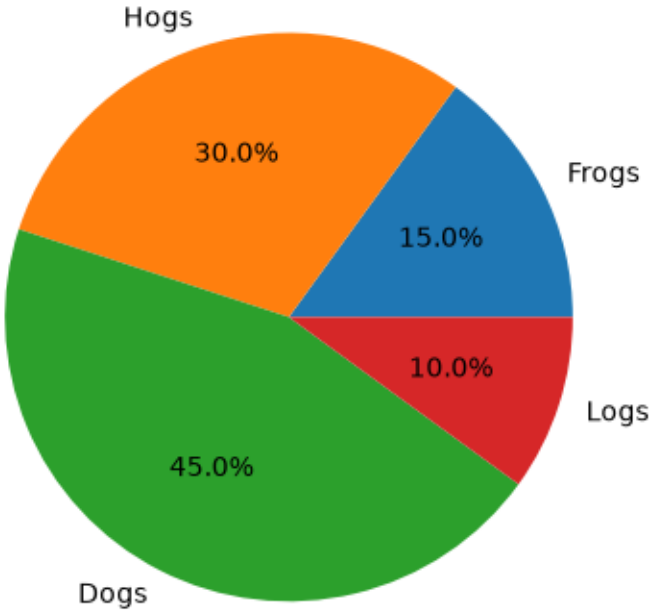


Each slice of the pie chart is a `patches.Wedge` object; therefore in addition to the customizations shown here, each wedge can be customized using the *wedgeprops* argument, as demonstrated in *Nested pie charts*.

Auto-label slices

Pass a function or format string to *autopct* to label slices.

```
fig, ax = plt.subplots()
ax.pie(sizes, labels=labels, autopct='%1.1f%%')
```

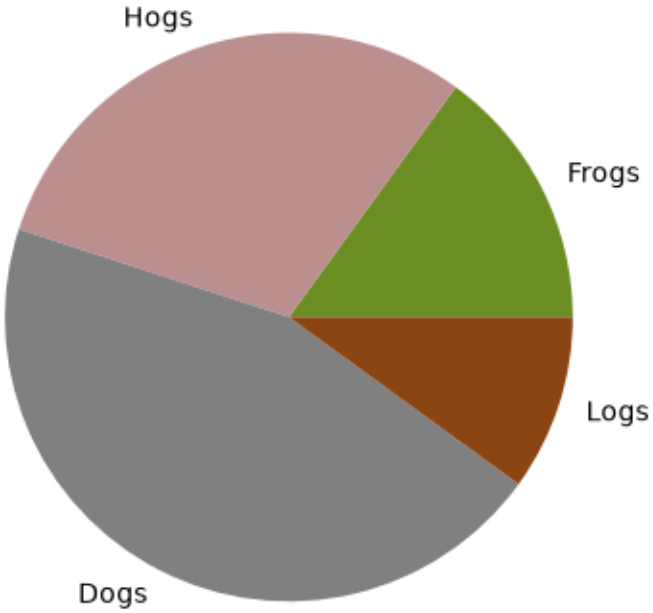


By default, the label values are obtained from the percent size of the slice.

Color slices

Pass a list of colors to *colors* to set the color of each slice.

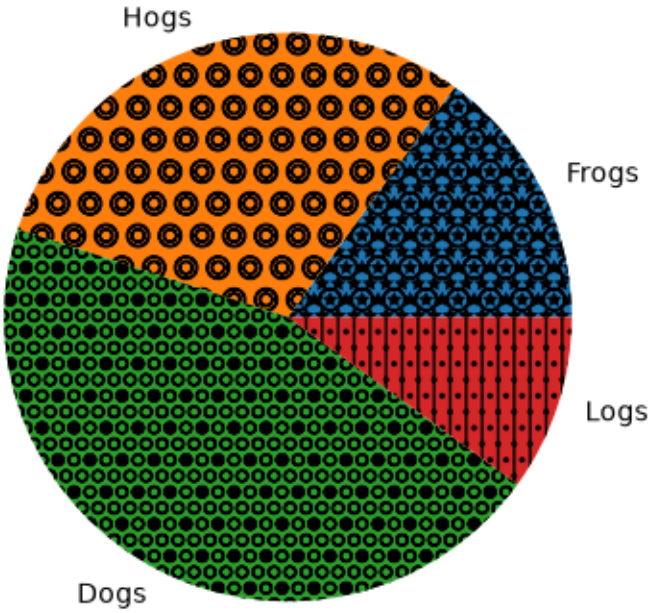
```
fig, ax = plt.subplots()
ax.pie(sizes, labels=labels,
       colors=['olivedrab', 'rosybrown', 'gray', 'saddlebrown'])
```



Hatch slices

Pass a list of hatch patterns to *hatch* to set the pattern of each slice.

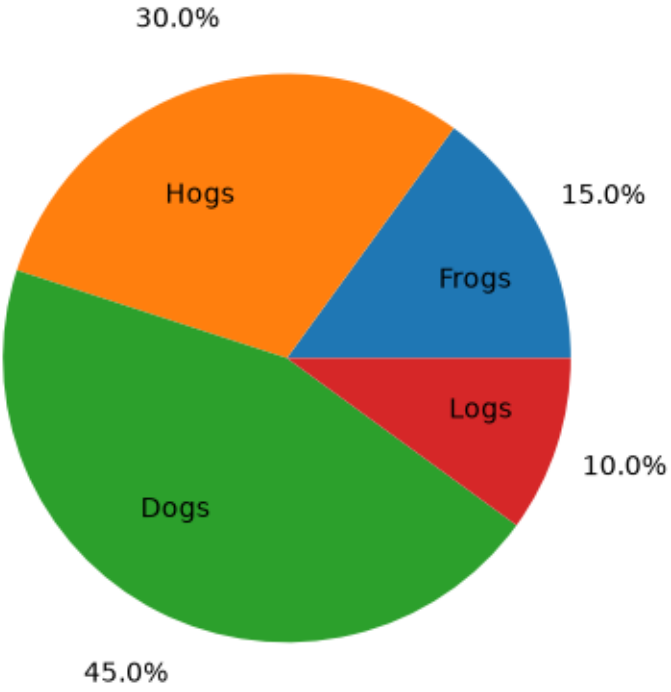
```
fig, ax = plt.subplots()
ax.pie(sizes, labels=labels, hatch=['**O', 'oO', 'O.O', '.||.'])
```



Swap label and autopct text positions

Use the *labeldistance* and *pctdistance* parameters to position the *labels* and *autopct* text respectively.

```
fig, ax = plt.subplots()
ax.pie(sizes, labels=labels, autopct='%1.1f%%',
       pctdistance=1.25, labeldistance=.6)
```



labeldistance and *pctdistance* are ratios of the radius; therefore they vary between `0` for the center of the pie and `1` for the edge of the pie, and can be set to greater than `1` to place text outside the pie.

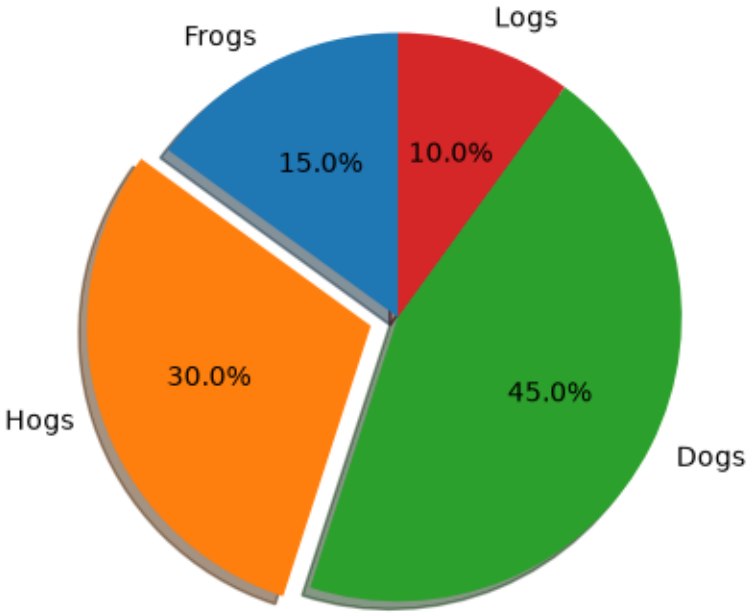
Explode, shade, and rotate slices

In addition to the basic pie chart, this demo shows a few optional features:

- offsetting a slice using *explode*
- add a drop-shadow using *shadow*
- custom start angle using *startangle*

This example orders the slices, separates (explodes) them, and rotates them.

```
explode = (0, 0.1, 0, 0)  # only "explode" the 2nd slice (i.e. 'Hogs')

fig, ax = plt.subplots()
ax.pie(sizes, explode=explode, labels=labels, autopct='%1.1f%%',
       shadow=True, startangle=90)
plt.show()
```

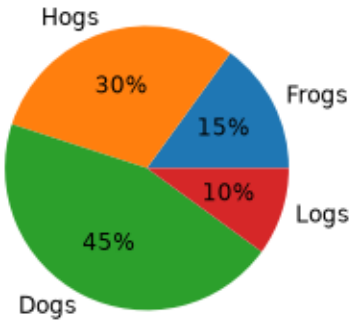


The default *startangle* is 0, which would start the first slice ("Frogs") on the positive x-axis. This example sets `startangle = 90` such that all the slices are rotated counter-clockwise by 90 degrees, and the frog slice starts on the positive y-axis.

Grow or shrink pie

By changing the *radius* parameter, and often the text size for better visual appearance, the pie chart can be scaled.

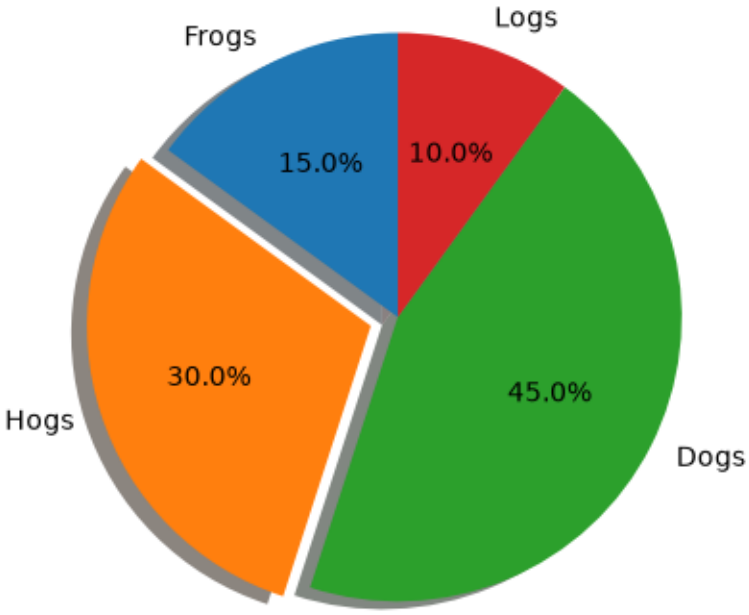
```
fig, ax = plt.subplots()

ax.pie(sizes, labels=labels, autopct='%.0f%%',
       textprops={'size': 'small'}, radius=0.5)
plt.show()
```



Modify shadow

The *shadow* parameter may optionally take a dictionary with arguments to the `Shadow` patch. This can be used to modify the default shadow.

```
fig, ax = plt.subplots()
ax.pie(sizes, explode=explode, labels=labels, autopct='%1.1f%%',
       shadow={'ox': -0.04, 'edgecolor': 'none', 'shade': 0.9},␣
 ↪startangle=90)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.pie / matplotlib.pyplot.pie*

Tags: plot-type: pie level: beginner

Total running time of the script: (0 minutes 2.218 seconds)

Bar of pie

Make a "bar of pie" chart where the first slice of the pie is "exploded" into a bar chart with a further breakdown of said slice's characteristics. The example demonstrates using a figure with multiple sets of Axes and using the Axes patches list to add two ConnectionPatches to link the subplot charts.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import ConnectionPatch

```

(continues on next page)

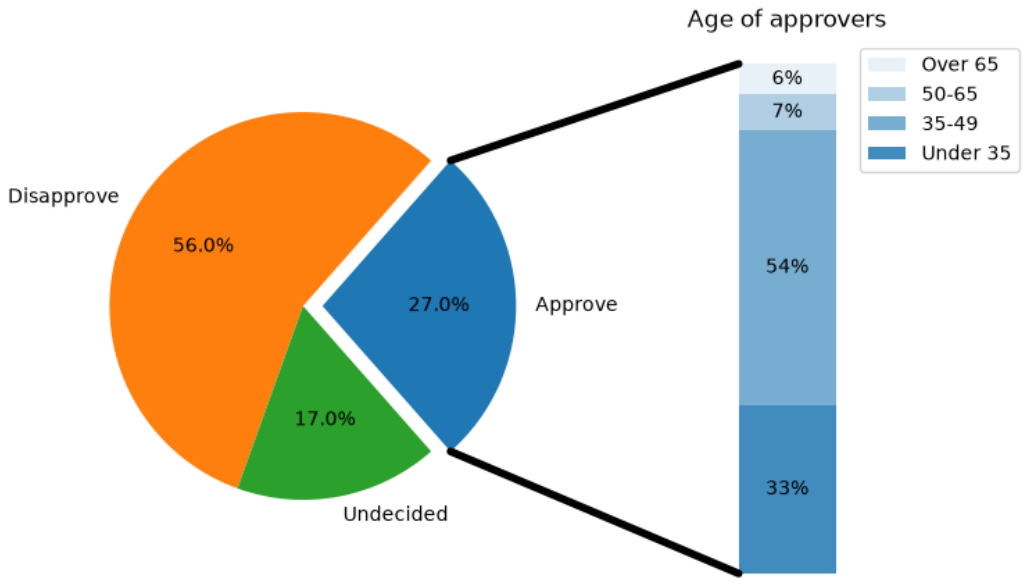
(continued from previous page)

```
# make figure and assign axis objects
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(9, 5))
fig.subplots_adjust(wspace=0)

# pie chart parameters
overall_ratios = [.27, .56, .17]
labels = ['Approve', 'Disapprove', 'Undecided']
explode = [0.1, 0, 0]
# rotate so that first wedge is split by the x-axis
angle = -180 * overall_ratios[0]
pie = ax1.pie(overall_ratios, autopct='%1.1f%%', startangle=angle,
              labels=labels, explode=explode)

# bar chart parameters
age_ratios = [.33, .54, .07, .06]
age_labels = ['Under 35', '35-49', '50-65', 'Over 65']
bottom = 1
width = .2

# Adding from the top matches the legend.
for j, (height, label) in enumerate(reversed([*zip(age_ratios,␣
 ↪age_labels)])):
    bottom -= height
    bc = ax2.bar(0, height, width, bottom=bottom, color='C0',␣
 ↪label=label,
                 alpha=0.1 + 0.25 * j)
    ax2.bar_label(bc, labels=[f"{height:.0%}"], label_type='center')

ax2.set_title('Age of approvers')
ax2.legend()
ax2.axis('off')
ax2.set_xlim(- 2.5 * width, 2.5 * width)

# use ConnectionPatch to draw lines between the two plots
theta1, theta2 = pie.wedges[0].theta1, pie.wedges[0].theta2
center, r = pie.wedges[0].center, pie.wedges[0].r
bar_height = sum(age_ratios)

# draw top connecting line
x = r * np.cos(np.pi / 180 * theta2) + center[0]
y = r * np.sin(np.pi / 180 * theta2) + center[1]
con = ConnectionPatch(xyA=(-width / 2, bar_height), coordsA=ax2.
 ↪transData,
                      xyB=(x, y), coordsB=ax1.transData)
con.set_color([0, 0, 0])
con.set_linewidth(4)
```

(continues on next page)

(continued from previous page)

```
ax2.add_artist(con)

# draw bottom connecting line
x = r * np.cos(np.pi / 180 * theta1) + center[0]
y = r * np.sin(np.pi / 180 * theta1) + center[1]
con = ConnectionPatch(xyA=(-width / 2, 0), coordsA=ax2.transData,
                      xyB=(x, y), coordsB=ax1.transData)
con.set_color([0, 0, 0])
ax2.add_artist(con)
con.set_linewidth(4)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.bar / matplotlib.pyplot.bar*
- *matplotlib.axes.Axes.pie / matplotlib.pyplot.pie*
- *matplotlib.patches.ConnectionPatch*

Tags: component: subplot plot-type: pie plot-type: bar level: intermediate purpose: showcase

Nested pie charts

The following examples show two ways to build a nested pie chart in Matplotlib. Such charts are often referred to as donut charts.

See also the *Left ventricle bullseye* example.

```
import matplotlib.pyplot as plt
import numpy as np
```

The most straightforward way to build a pie chart is to use the *pie* method.

In this case, pie takes values corresponding to counts in a group. We'll first generate some fake data, corresponding to three groups. In the inner circle, we'll treat each number as belonging to its own group. In the outer circle, we'll plot them as members of their original 3 groups.

The effect of the donut shape is achieved by setting a `width` to the pie's wedges through the *wedgeprops* argument.

```
fig, ax = plt.subplots()

size = 0.3
vals = np.array([[60., 32.], [37., 40.], [29., 10.]])

tab20c = plt.color_sequences["tab20c"]
outer_colors = [tab20c[i] for i in [0, 4, 8]]
inner_colors = [tab20c[i] for i in [1, 2, 5, 6, 9, 10]]

ax.pie(vals.sum(axis=1), radius=1, colors=outer_colors,
       wedgeprops=dict(width=size, edgecolor='w'))

ax.pie(vals.flatten(), radius=1-size, colors=inner_colors,
       wedgeprops=dict(width=size, edgecolor='w'))

ax.set(aspect="equal", title='Pie plot with `ax.pie`')
plt.show()
```

However, you can accomplish the same output by using a bar plot on Axes with a polar coordinate system. This may give more flexibility on the exact design of the plot.

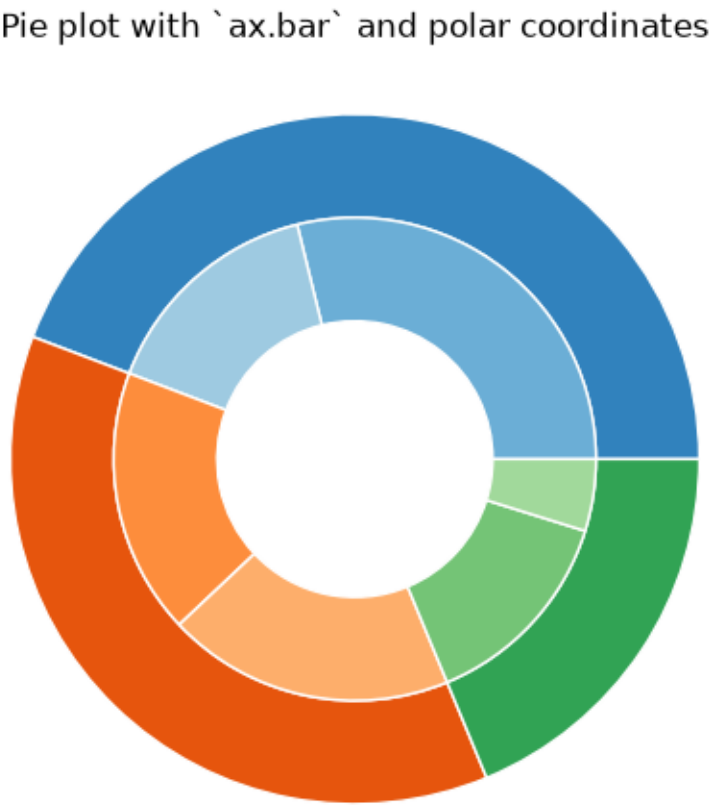
In this case, we need to map x-values of the bar chart onto radians of a circle. The cumulative sum of the values are used as the edges of the bars.

```
fig, ax = plt.subplots(subplot_kw=dict(projection="polar"))

size = 0.3
vals = np.array([[60., 32.], [37., 40.], [29., 10.]])
# Normalize vals to 2 pi
valsnorm = vals/np.sum(vals)*2*np.pi
# Obtain the ordinates of the bar edges
valsleft = np.cumsum(np.append(0, valsnorm.flatten()[:-1])).
 ↪reshape(vals.shape)

cmap = plt.colormaps["tab20c"]
outer_colors = cmap(np.arange(3)*4)
inner_colors = cmap([1, 2, 5, 6, 9, 10])

ax.bar(x=valsleft[:, 0],
```

(continues on next page)

(continued from previous page)

```
       width=valsnorm.sum(axis=1), bottom=1-size, height=size,
       color=outer_colors, edgecolor='w', linewidth=1, align="edge")

ax.bar(x=valsleft.flatten(),
       width=valsnorm.flatten(), bottom=1-2*size, height=size,
       color=inner_colors, edgecolor='w', linewidth=1, align="edge")

ax.set(title="Pie plot with `ax.bar` and polar coordinates")
ax.set_axis_off()
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.pie / matplotlib.pyplot.pie*
- *matplotlib.axes.Axes.bar / matplotlib.pyplot.bar*
- *matplotlib.projections.polar*

- `Axes.set` (*matplotlib.artist.Artist.set*)
- *matplotlib.axes.Axes.set_axis_off*

Tags: plot-type: pie level: beginner purpose: showcase

A pie and a donut with labels

Welcome to the Matplotlib bakery. We will create a pie and a donut chart through the *pie method* and show how to label them with a *legend* as well as with the *pie_label method* and *annotations*.

As usual we would start by defining the imports and create a figure with subplots. Now it's time for the pie. Starting with a pie recipe, we create the data and a list of labels from it.

We then create the pie and store the returned *PieContainer* object for later.

We can provide the *PieContainer* and a format string to the *pie_label* method to automatically label each ingredient's wedge with its weight in grams and percentages.

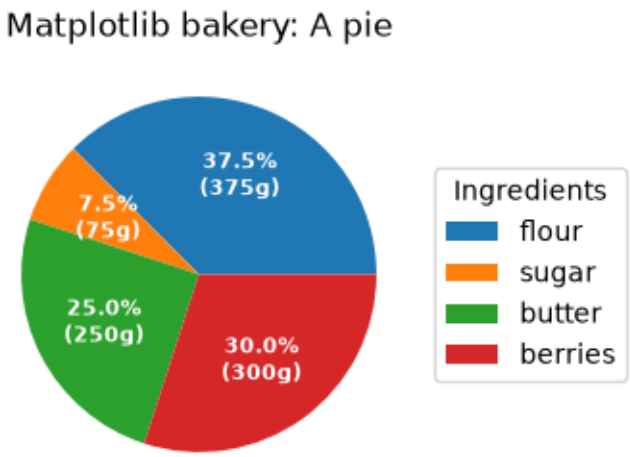
The *PieContainer* has a list of patches as one of its attributes. Those are *matplotlib.patches.Wedge* patches, which can directly be used as the handles for a legend. We can use the legend's `bbox_to_anchor` argument to position the legend outside of the pie. Here we use the axes coordinates `(1, 0, 0.5, 1)` together with the location `"center left"`; i.e. the left central point of the legend will be at the left central point of the bounding box, spanning from `(1, 0)` to `(1.5, 1)` in axes coordinates.

```
import matplotlib.pyplot as plt
import numpy as np

fig, ax = plt.subplots(figsize=(6, 3))

recipe = ["375 g flour",
          "75 g sugar",
          "250 g butter",
          "300 g berries"]

data = [int(x.split()[0]) for x in recipe]
ingredients = [x.split()[-1] for x in recipe]

pie = ax.pie(data)

ax.pie_label(pie, '{frac:.1%}\n({absval:d}g)',
             textprops=dict(color="w", size=8, weight="bold"))

ax.legend(pie.wedges, ingredients,
          title="Ingredients",
          loc="center left",
          bbox_to_anchor=(1, 0, 0.5, 1))
```

(continues on next page)

(continued from previous page)

```
ax.set_title("Matplotlib bakery: A pie")

plt.show()
```



Now it's time for the donut. Starting with a donut recipe, we transcribe the data to numbers (converting 1 egg to 50 g), and directly plot the pie. The pie? Wait... it's going to be donut, is it not? Well, as we see here, the donut is a pie, having a certain `width` set to the wedges, which is different from its radius. It's as easy as it gets. This is done via the `wedgeprops` argument.

We then want to label the wedges via *annotations*. We first create some dictionaries of common properties, which we can later pass as keyword argument. We then iterate over all wedges and for each

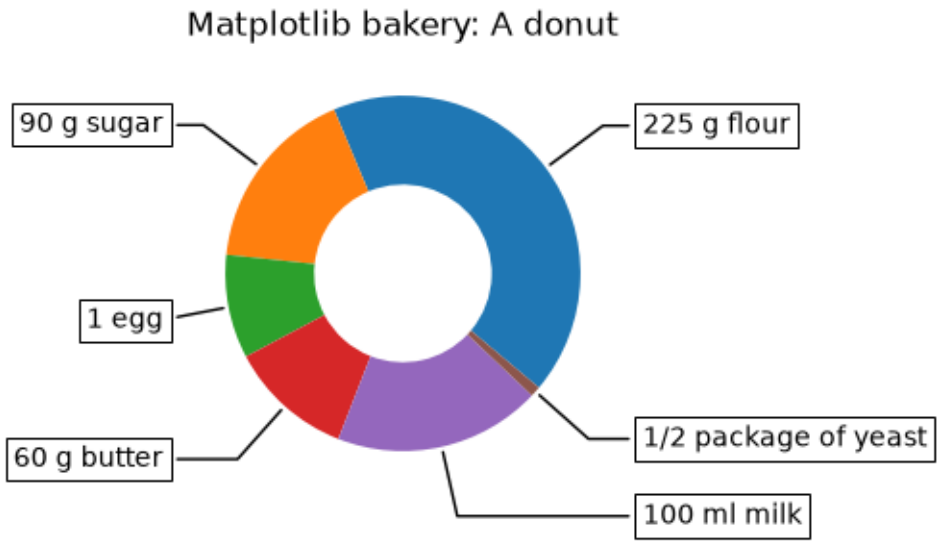
- calculate the angle of the wedge's center,
- from that obtain the coordinates of the point at that angle on the circumference,
- determine the horizontal alignment of the text, depending on which side of the circle the point lies,
- update the connection style with the obtained angle to have the annotation arrow point outwards from the donut,
- finally, create the annotation with all the previously determined parameters.

```
fig, ax = plt.subplots(figsize=(6, 3), subplot_kw=dict(aspect="equal"))

recipe = ["225 g flour",
          "90 g sugar",
          "1 egg",
          "60 g butter",
          "100 ml milk",
          "1/2 package of yeast"]
```

(continues on next page)

(continued from previous page)

```
data = [225, 90, 50, 60, 100, 5]

pie = ax.pie(data, wedgeprops=dict(width=0.5), startangle=-40)

bbox_props = dict(boxstyle="square,pad=0.3", fc="w", ec="k", lw=0.72)
kw = dict(arrowprops=dict(arrowstyle="-"),
          bbox=bbox_props, zorder=0, va="center")

for i, p in enumerate(pie.wedges):
    ang = (p.theta2 - p.theta1)/2. + p.theta1
    y = np.sin(np.deg2rad(ang))
    x = np.cos(np.deg2rad(ang))
    horizontalalignment = {-1: "right", 1: "left"}[int(np.sign(x))]
    connectionstyle = f"angle,angleA=0,angleB={ang}"
    kw["arrowprops"].update({"connectionstyle": connectionstyle})
    ax.annotate(recipe[i], xy=(x, y), xytext=(1.35*np.sign(x), 1.4*y),
                horizontalalignment=horizontalalignment, **kw)

ax.set_title("Matplotlib bakery: A donut")

plt.show()
```



And here it is, the donut. Note however, that if we were to use this recipe, the ingredients would suffice for around 6 donuts - producing one huge donut is untested and might result in kitchen errors.

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.pie / matplotlib.pyplot.pie*

- *matplotlib.axes.Axes.pie_label* / *matplotlib.pyplot.pie_label*
- *matplotlib.axes.Axes.legend* / *matplotlib.pyplot.legend*

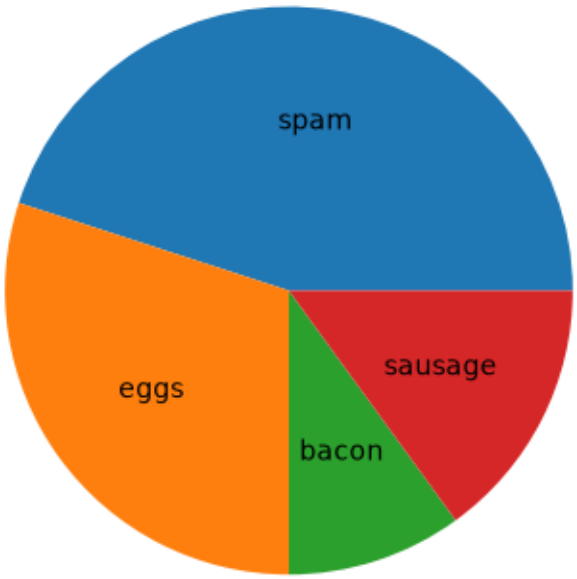
Tags: component: label component: annotation plot-type: pie level: beginner

Labeling pie charts

This example illustrates some features of the *pie_label* method, which adds labels to an existing pie chart created with *pie*.

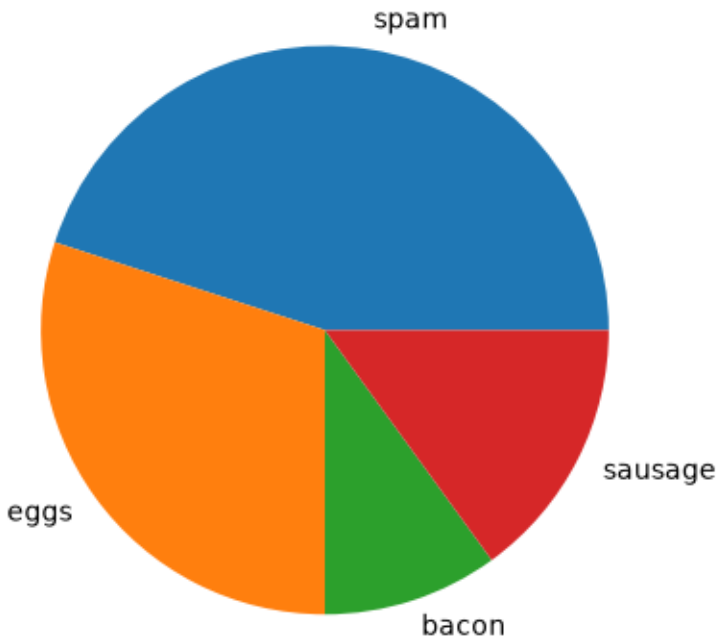
The simplest option is to provide a list of strings to label each slice of the pie.

```
import matplotlib.pyplot as plt

data = [36, 24, 8, 12]
labels = ['spam', 'eggs', 'bacon', 'sausage']

fig, ax = plt.subplots()
pie = ax.pie(data)
ax.pie_label(pie, labels)
```



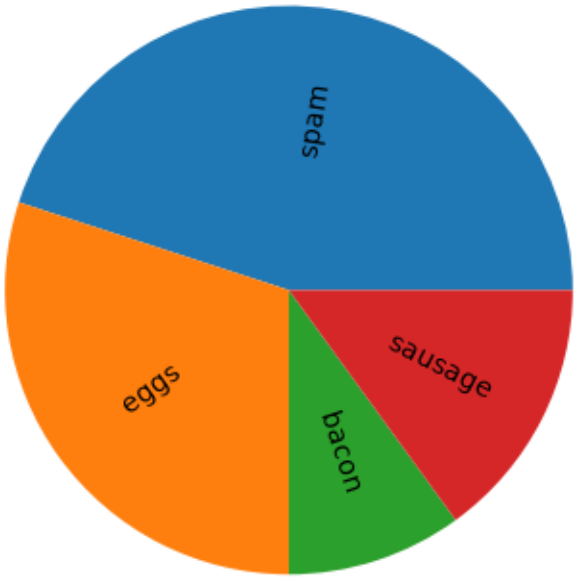
If you want the labels outside the pie, set a *distance* greater than 1. This is the distance from the center of the pie as a fraction of its radius.

```
fig, ax = plt.subplots()
pie = ax.pie(data)
ax.pie_label(pie, labels, distance=1.1)
```



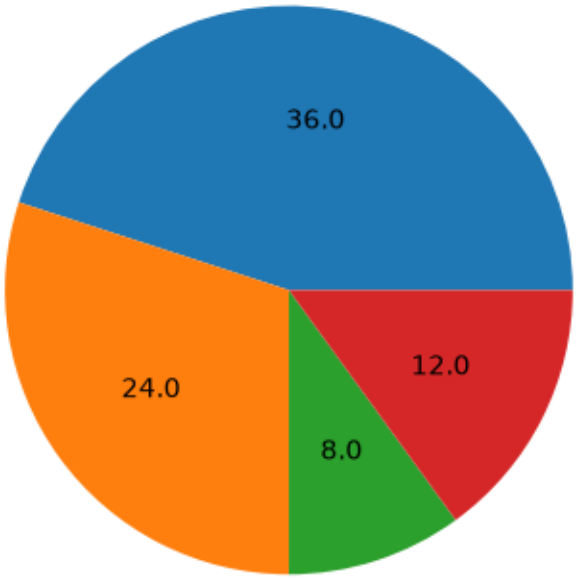
You can also rotate the labels so they are oriented away from the pie center.

```
fig, ax = plt.subplots()
pie = ax.pie(data)
ax.pie_label(pie, labels, rotate=True)
```



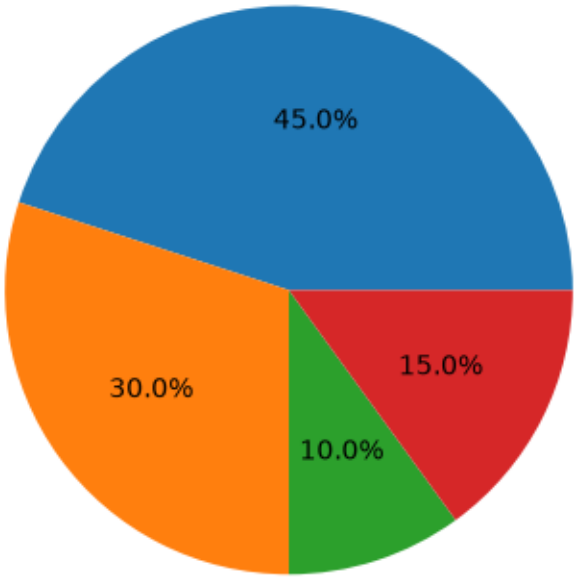
Instead of explicit labels, pass a format string to label slices with their values...

```
fig, ax = plt.subplots()
pie = ax.pie(data)
ax.pie_label(pie, '{absval:.1f}')
```



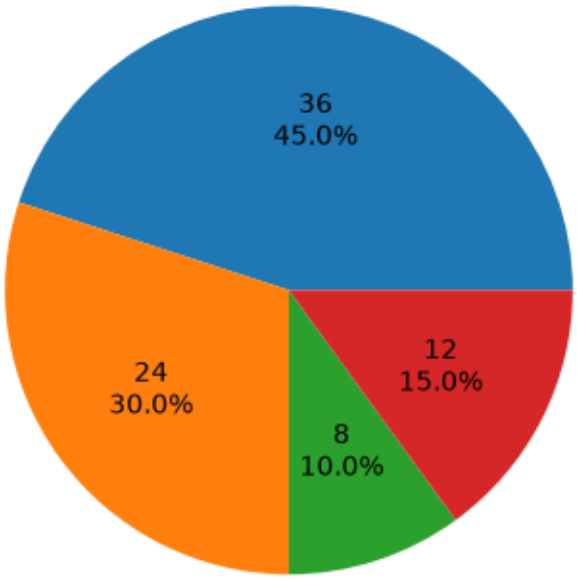
...or with their percentages...

```
fig, ax = plt.subplots()
pie = ax.pie(data)
ax.pie_label(pie, '{frac:.1%}')
```



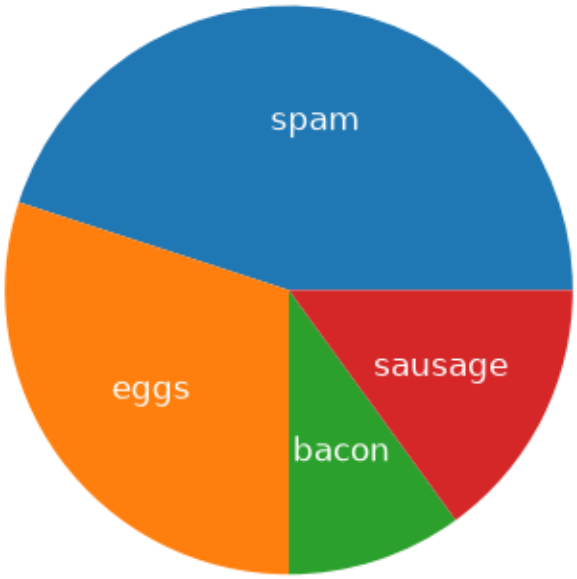
...or both.

```
fig, ax = plt.subplots()
pie = ax.pie(data)
ax.pie_label(pie, '{absval:d}\n{frac:.1%}')
```



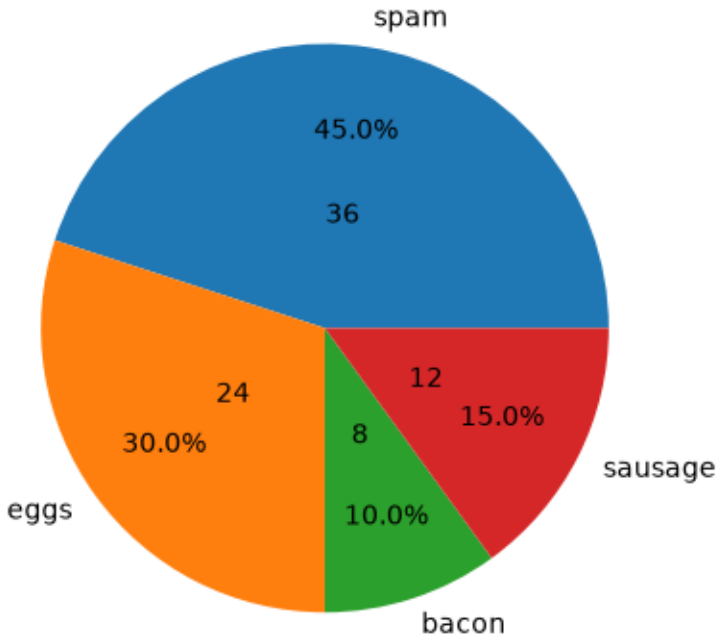
Font styling can be configured by passing a dictionary to the *textprops* parameter.

```
fig, ax = plt.subplots()
pie = ax.pie(data)
ax.pie_label(pie, labels, textprops={'fontsize': 'large', 'color':
 ↪'white'})
```



pie_label can be called repeatedly to add multiple sets of labels.

```
fig, ax = plt.subplots()
pie = ax.pie(data)

ax.pie_label(pie, labels, distance=1.1)
ax.pie_label(pie, '{frac:.1%}', distance=0.7)
ax.pie_label(pie, '{absval:d}', distance=0.4)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.pie* / *matplotlib.pyplot.pie*
- *matplotlib.axes.Axes.pie_label* / *matplotlib.pyplot.pie_label*

Tags: plot-type: pie level: beginner

Total running time of the script: (0 minutes 1.924 seconds)

Bar chart on polar axis

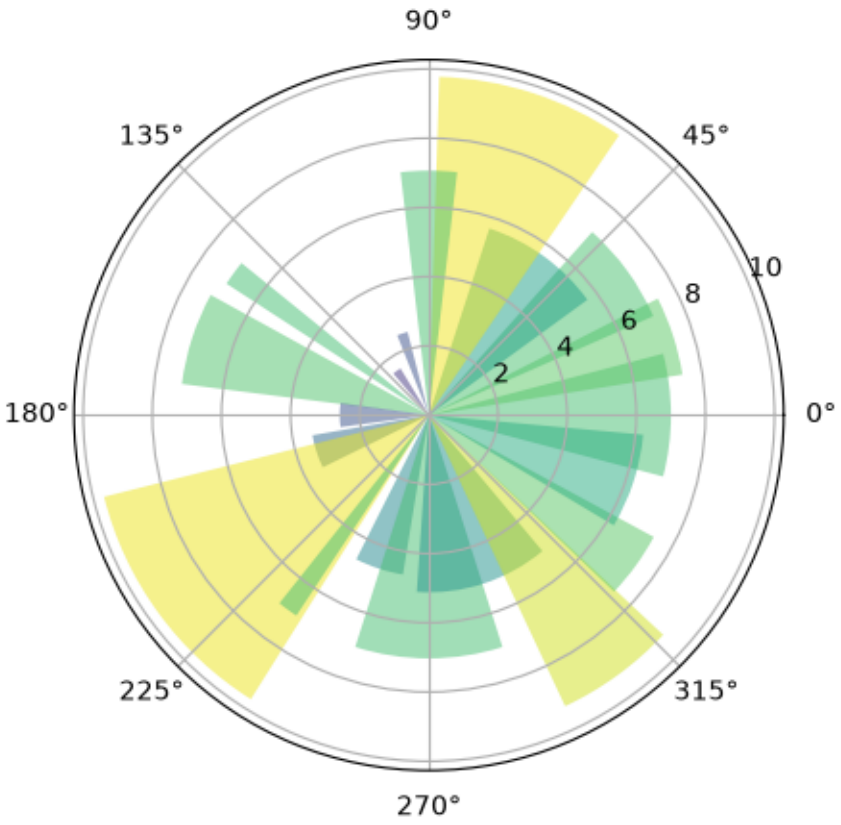
Demo of bar plot on a polar axis.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)
```

(continues on next page)

(continued from previous page)

```
# Compute pie slices
N = 20
theta = np.linspace(0.0, 2 * np.pi, N, endpoint=False)
radii = 10 * np.random.rand(N)
width = np.pi / 4 * np.random.rand(N)
colors = plt.colormaps["viridis"](radii / 10.)

ax = plt.subplot(projection='polar')
ax.bar(theta, radii, width=width, bottom=0.0, color=colors, alpha=0.5)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.bar* / *matplotlib.pyplot.bar*
- *matplotlib.projections.polar*

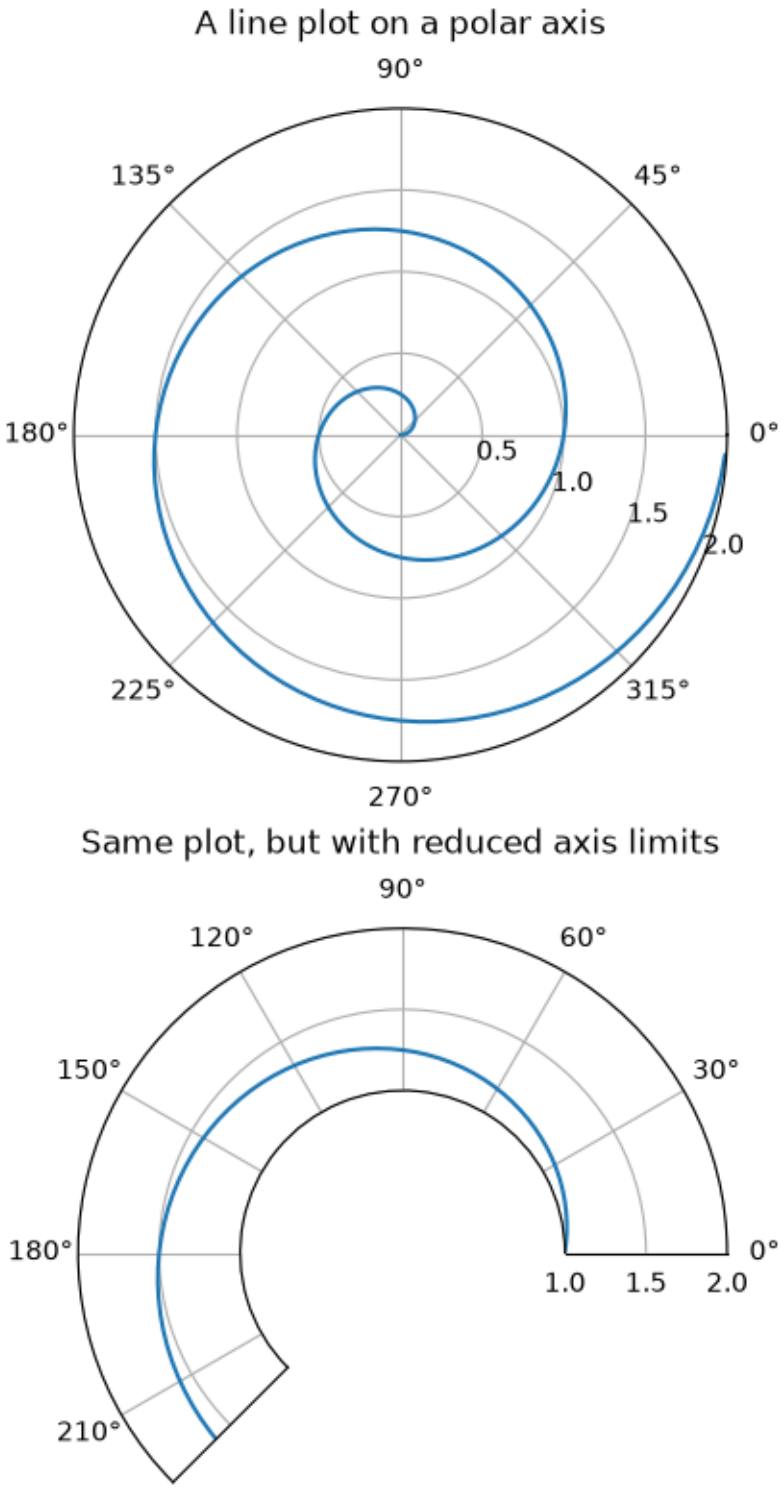
Tags: plot-type: pie plot-type: bar level: beginner purpose: showcase

Polar plot

Demo of a line plot on a polar axis.

The second plot shows the same data, but with the radial axis starting at r=1 and the angular axis starting at 0 degrees and ending at 225 degrees. Setting the origin of the radial axis to 0 allows the radial ticks to be placed at the same location as the first plot.

```
import matplotlib.pyplot as plt
import numpy as np

r = np.arange(0, 2, 0.01)
theta = 2 * np.pi * r

fig, axs = plt.subplots(2, 1, figsize=(5, 8), subplot_kw={'projection
 ↪': 'polar'},
                        layout='constrained')
ax = axs[0]
ax.plot(theta, r)
ax.set_rmax(2)
ax.set_rticks([0.5, 1, 1.5, 2])  # Fewer radial ticks
ax.set_rlabel_position(-22.5)  # Move radial labels away from plotted␣
 ↪line
ax.grid(True)

ax.set_title("A line plot on a polar axis", va='bottom')

ax = axs[1]
ax.plot(theta, r)
ax.set_rmax(2)
ax.set_rmin(1)  # Change the radial axis to only go from 1 to 2
ax.set_rorigin(0)  # Set the origin of the radial axis to 0
ax.set_thetamin(0)
ax.set_thetamax(225)
ax.set_rticks([1, 1.5, 2])  # Fewer radial ticks
ax.set_rlabel_position(-22.5)  # Move radial labels away from plotted␣
 ↪line

ax.grid(True)
ax.set_title("Same plot, but with reduced axis limits", va='bottom')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

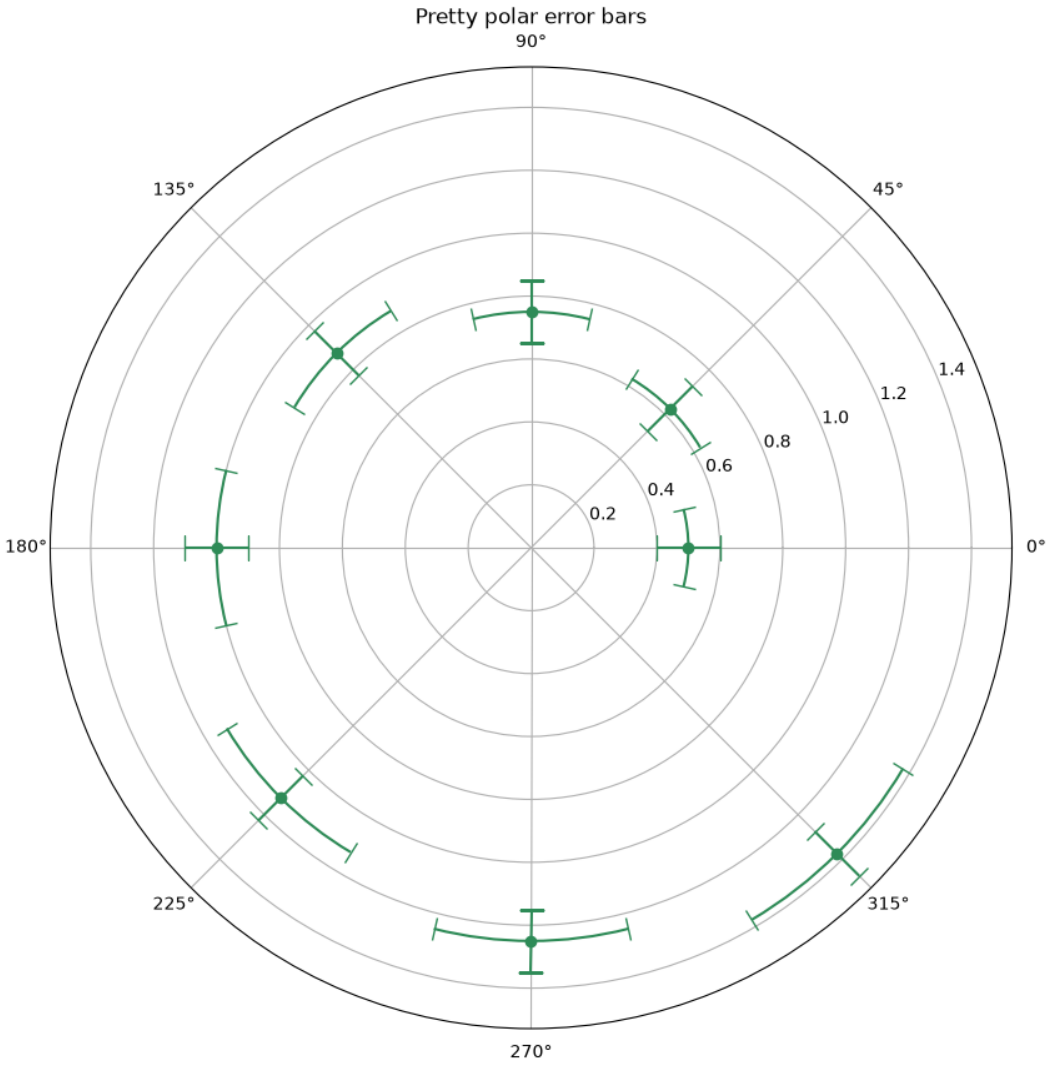
- *matplotlib.axes.Axes.plot / matplotlib.pyplot.plot*
- *matplotlib.projections.polar*
- *matplotlib.projections.polar.PolarAxes*
- *matplotlib.projections.polar.PolarAxes.set_rticks*
- *matplotlib.projections.polar.PolarAxes.set_rmin*
- *matplotlib.projections.polar.PolarAxes.set_rorigin*
- *matplotlib.projections.polar.PolarAxes.set_rmax*
- *matplotlib.projections.polar.PolarAxes.set_rlabel_position*

Tags: plot-type: polar level: beginner

Error bar rendering on polar axis

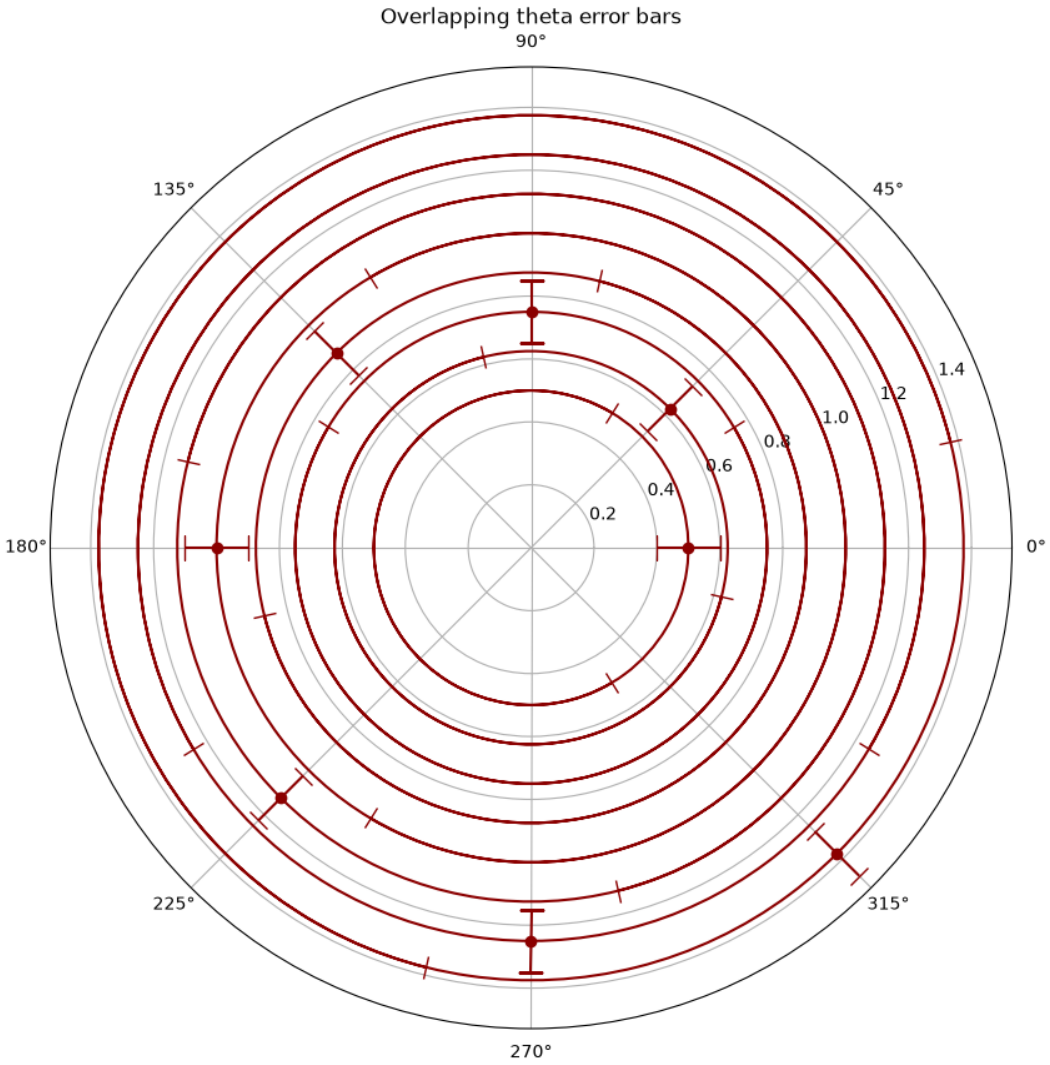
Demo of error bar plot in polar coordinates. Theta error bars are curved lines ended with caps oriented towards the center. Radius error bars are straight lines oriented towards center with perpendicular caps.

```
import matplotlib.pyplot as plt
import numpy as np

theta = np.arange(0, 2 * np.pi, np.pi / 4)
r = theta / np.pi / 2 + 0.5

fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(projection='polar')
ax.errorbar(theta, r, xerr=0.25, yerr=0.1, capsize=7, fmt="o", c=
 ↪"seagreen")
ax.set_title("Pretty polar error bars")
plt.show()
```



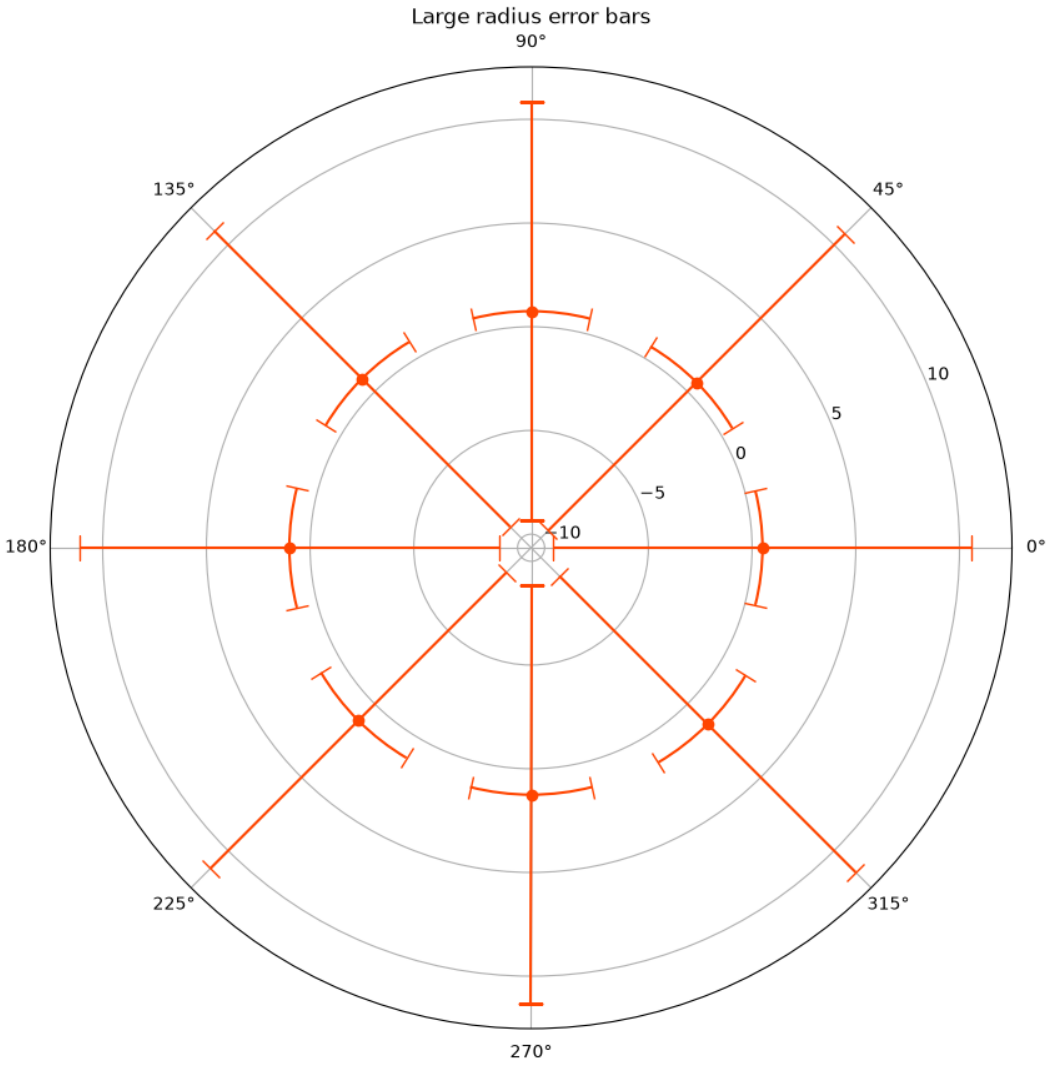
Please acknowledge that large theta error bars will be overlapping. This may reduce readability of the output plot. See example figure below:

```
fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(projection='polar')
ax.errorbar(theta, r, xerr=5.25, yerr=0.1, capsize=7, fmt="o", c=
 ↪"darkred")
ax.set_title("Overlapping theta error bars")
plt.show()
```



On the other hand, large radius error bars will never overlap, they just lead to unwanted scale in the data, reducing the displayed range.

```
fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(projection='polar')
ax.errorbar(theta, r, xerr=0.25, yerr=10.1, capsize=7, fmt="o", c=
 ↪"orangered")
ax.set_title("Large radius error bars")
plt.show()
```


Large radius error bars
90°
135°
45°
180°
0°
225°
315°
270°
10
5
0
−5
10

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.errorbar / matplotlib.pyplot.errorbar*
- *matplotlib.projections.polar*

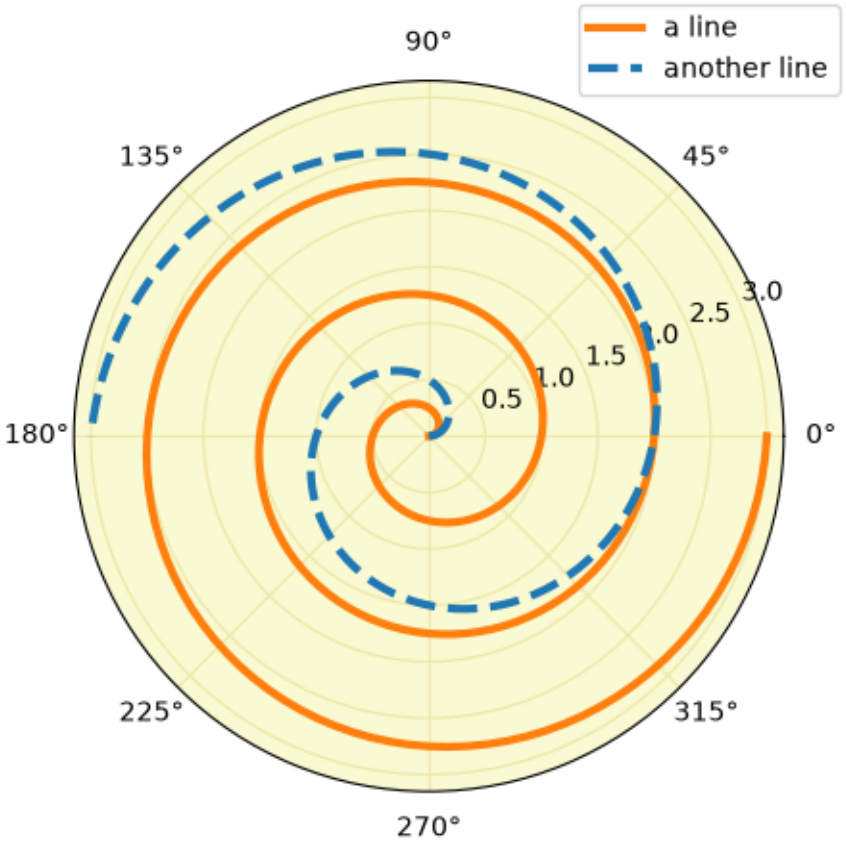
Tags: component: error plot-type: errorbar plot-type: polar level: beginner

Total running time of the script: (0 minutes 2.745 seconds)

Polar legend

Using a legend on a polar-axis plot.

```
import matplotlib.pyplot as plt
import numpy as np

fig = plt.figure()
ax = fig.add_subplot(projection="polar", facecolor=
 ↪"lightgoldenrodyellow")

r = np.linspace(0, 3, 301)
theta = 2 * np.pi * r
ax.plot(theta, r, color="tab:orange", lw=3, label="a line")
ax.plot(0.5 * theta, r, color="tab:blue", ls="--", lw=3, label=
 ↪"another line")
ax.tick_params(grid_color="palegoldenrod")
# For polar Axes, it may be useful to move the legend slightly away␣
 ↪from the
# Axes center, to avoid overlap between the legend and the Axes.  The␣
 ↪following
# snippet places the legend's lower left corner just outside the polar␣
 ↪Axes
# at an angle of 67.5 degrees in polar coordinates.
angle = np.deg2rad(67.5)
ax.legend(loc="lower left",
          bbox_to_anchor=(.5 + np.cos(angle)/2, .5 + np.sin(angle)/2))

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.plot* / *matplotlib.pyplot.plot*
- *matplotlib.axes.Axes.legend* / *matplotlib.pyplot.legend*
- *matplotlib.projections.polar*
- *matplotlib.projections.polar.PolarAxes*

Tags: component: legend plot-type: polar level: beginner

Scatter plot on polar axis

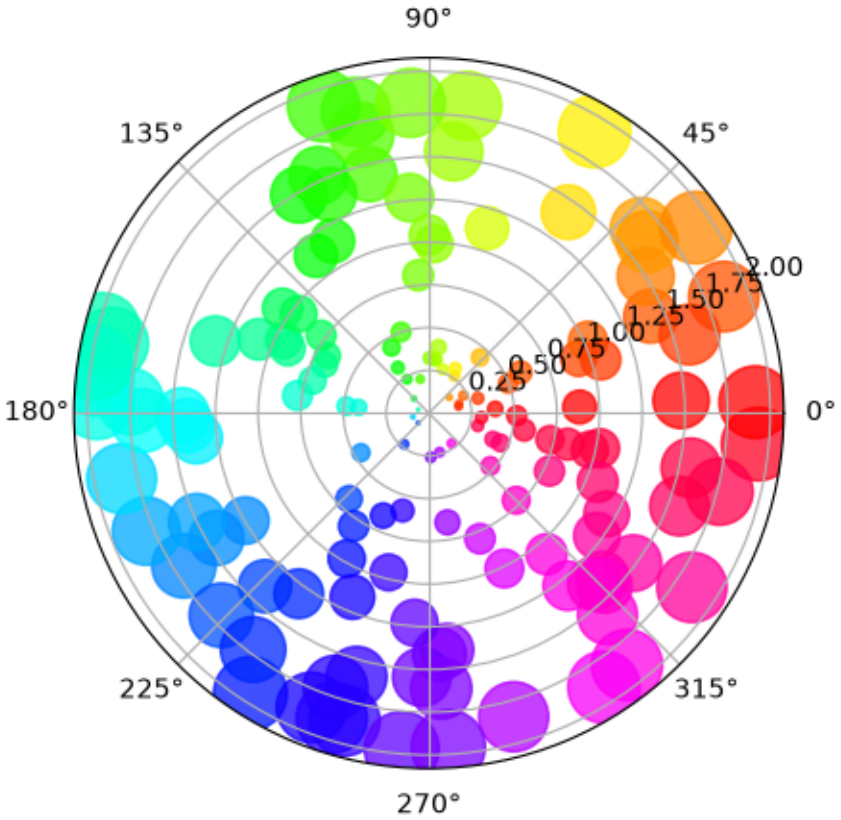
Size increases radially in this example and color increases with angle (just to verify the symbols are being scattered correctly).

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

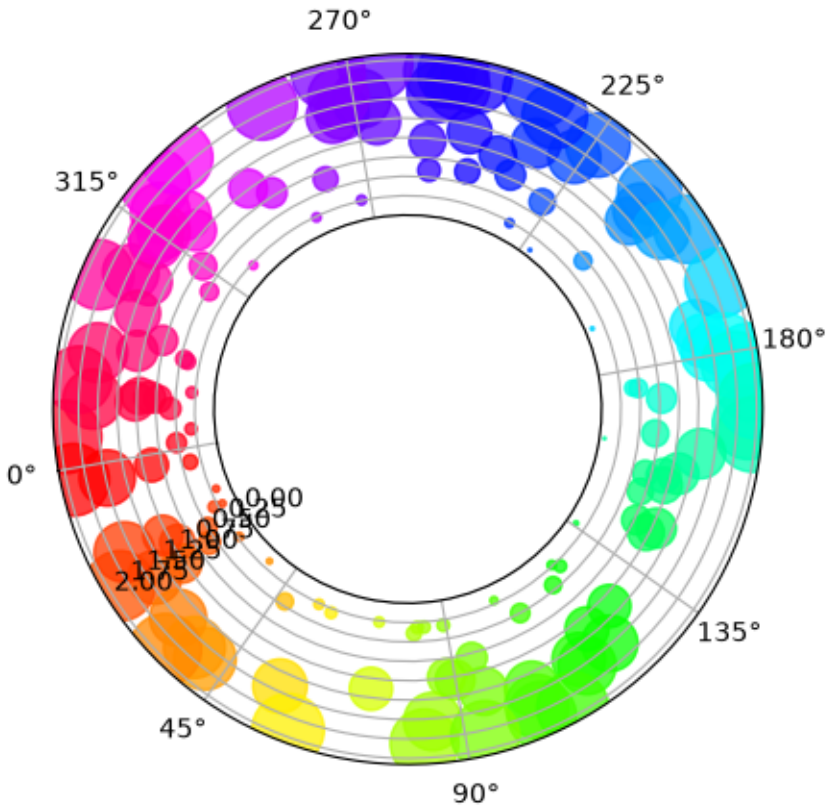
```
# Fixing random state for reproducibility
np.random.seed(19680801)

# Compute areas and colors
N = 150
r = 2 * np.random.rand(N)
theta = 2 * np.pi * np.random.rand(N)
area = 200 * r**2
colors = theta

fig = plt.figure()
ax = fig.add_subplot(projection='polar')
c = ax.scatter(theta, r, c=colors, s=area, cmap='hsv', alpha=0.75)
```



Scatter plot on polar axis, with offset origin

The main difference with the previous plot is the configuration of the origin radius, producing an annulus. Additionally, the theta zero location is set to rotate the plot.

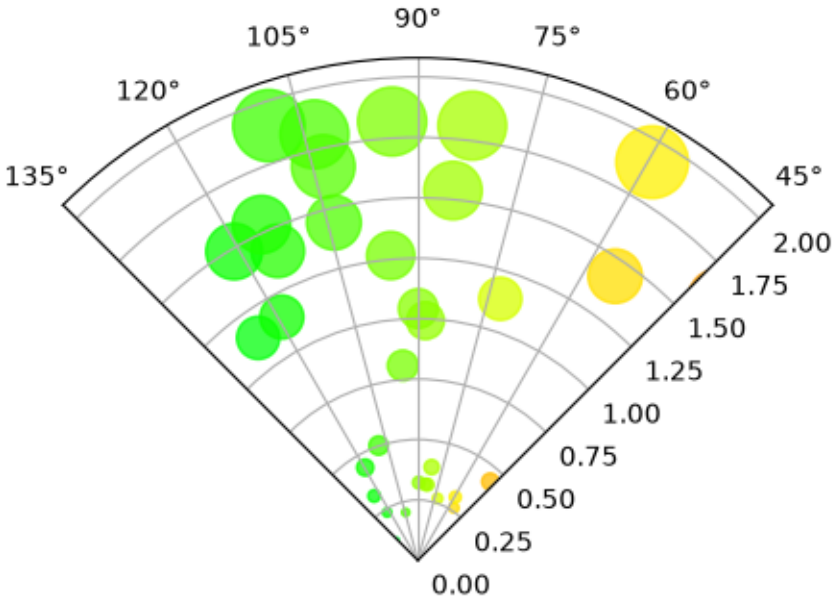
```
fig = plt.figure()
ax = fig.add_subplot(projection='polar')
c = ax.scatter(theta, r, c=colors, s=area, cmap='hsv', alpha=0.75)

ax.set_rorigin(-2.5)
ax.set_theta_zero_location('W', offset=10)
```



Scatter plot on polar axis confined to a sector

The main difference with the previous plots is the configuration of the theta start and end limits, producing a sector instead of a full circle.

```
fig = plt.figure()
ax = fig.add_subplot(projection='polar')
c = ax.scatter(theta, r, c=colors, s=area, cmap='hsv', alpha=0.75)

ax.set_thetamin(45)
ax.set_thetamax(135)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.scatter / matplotlib.pyplot.scatter*
- *matplotlib.projections.polar*
- *matplotlib.projections.polar.PolarAxes.set_rorigin*
- *matplotlib.projections.polar.PolarAxes.set_theta_zero_location*
- *matplotlib.projections.polar.PolarAxes.set_thetamin*
- *matplotlib.projections.polar.PolarAxes.set_thetamax*

Tags: plot-type: polar plot-type: scatter level: beginner

Total running time of the script: (0 minutes 1.096 seconds)

6.24.5 Subplots, axes and figures

Multiple subplots

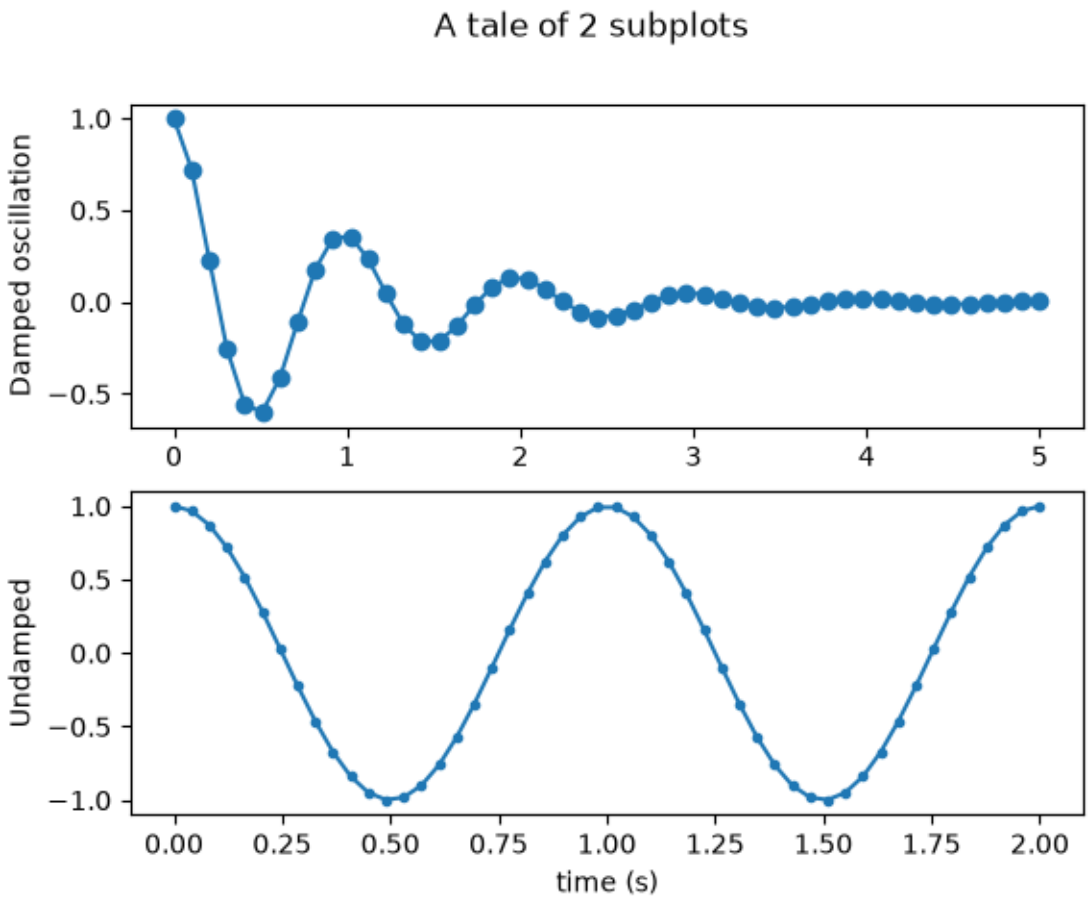
Simple demo with multiple subplots.

For more options, see *Create multiple subplots using plt.subplots*.

```
import matplotlib.pyplot as plt
import numpy as np

# Create some fake data.
x1 = np.linspace(0.0, 5.0)
y1 = np.cos(2 * np.pi * x1) * np.exp(-x1)
x2 = np.linspace(0.0, 2.0)
y2 = np.cos(2 * np.pi * x2)
```

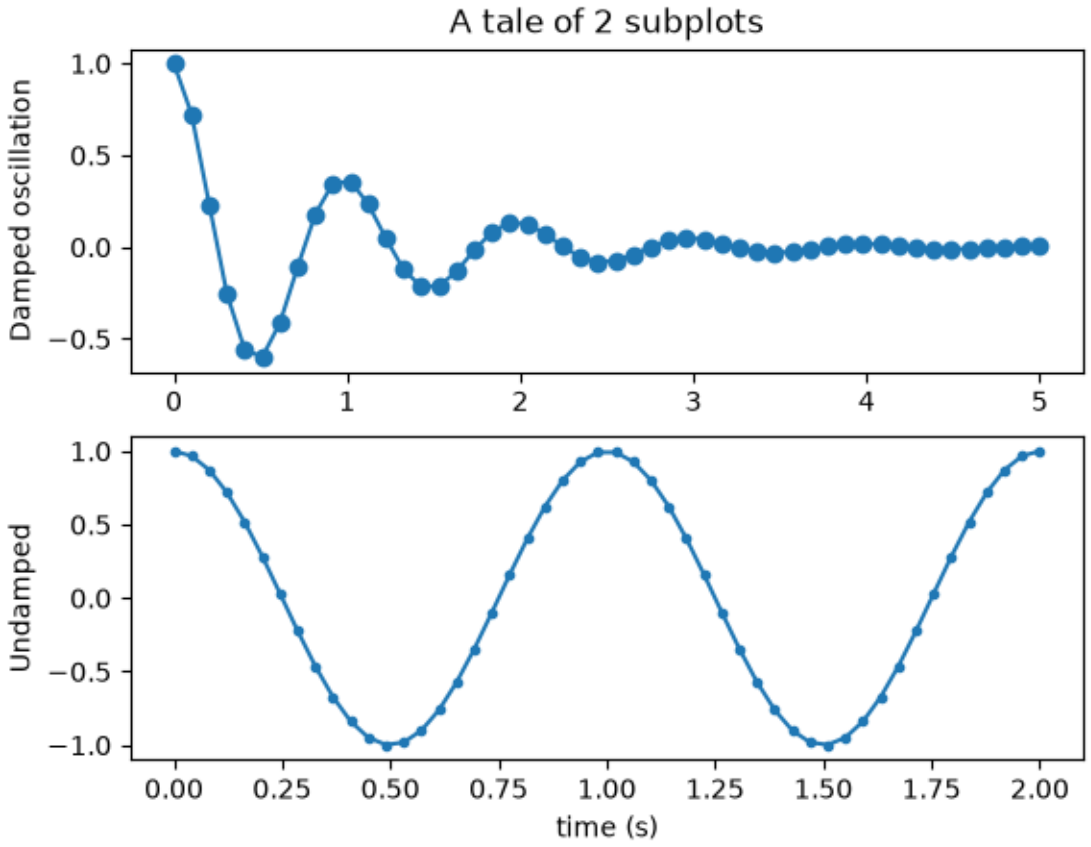
subplots() is the recommended method to generate simple subplot arrangements:

```
fig, (ax1, ax2) = plt.subplots(2, 1)
fig.suptitle('A tale of 2 subplots')

ax1.plot(x1, y1, 'o-')
ax1.set_ylabel('Damped oscillation')

ax2.plot(x2, y2, '.-')
ax2.set_xlabel('time (s)')
ax2.set_ylabel('Undamped')

plt.show()
```



Subplots can also be generated one at a time using *subplot()*:

```
plt.subplot(2, 1, 1)
plt.plot(x1, y1, 'o-')
plt.title('A tale of 2 subplots')
plt.ylabel('Damped oscillation')

plt.subplot(2, 1, 2)
plt.plot(x2, y2, '.-')
plt.xlabel('time (s)')
plt.ylabel('Undamped')

plt.show()
```



Tags: component: subplot plot-type: line level: beginner

Total running time of the script: (0 minutes 1.133 seconds)

Create multiple subplots using `plt.subplots`

pyplot.subplots creates a figure and a grid of subplots with a single call, while providing reasonable control over how the individual plots are created. For more advanced use cases you can use *GridSpec* for a more general subplot layout or *Figure.add_subplot* for adding subplots at arbitrary locations within the figure.

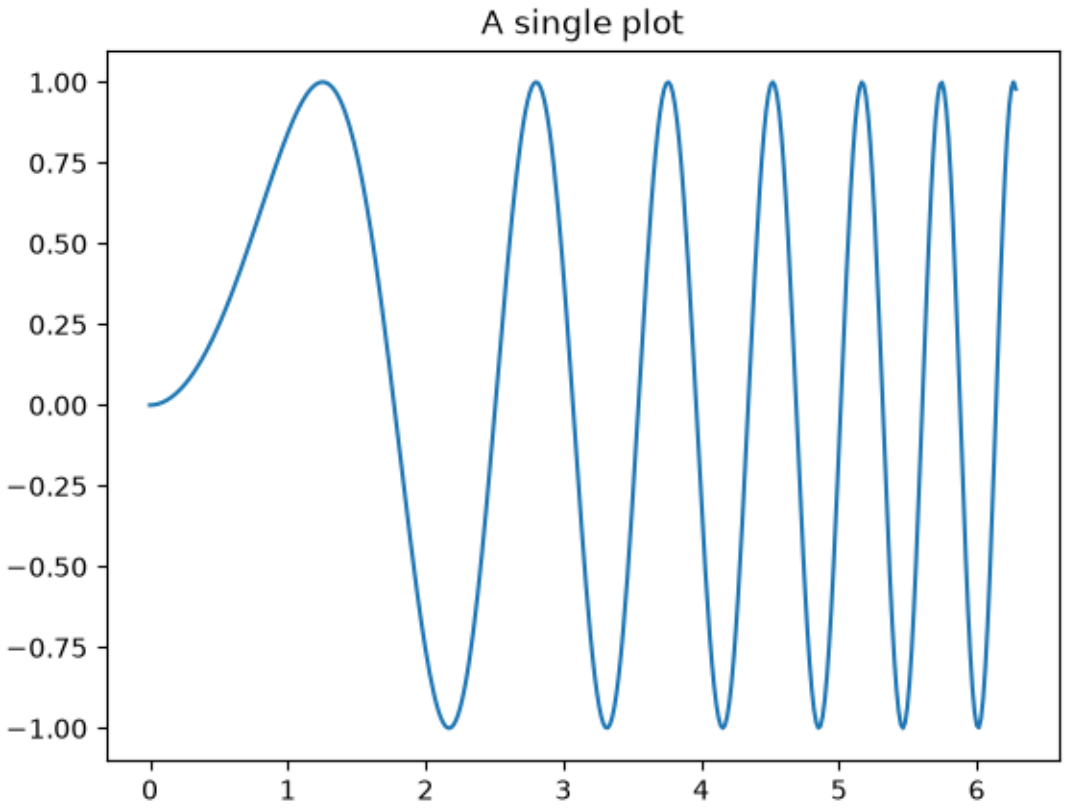
```
import matplotlib.pyplot as plt
import numpy as np

# Some example data to display
x = np.linspace(0, 2 * np.pi, 400)
y = np.sin(x ** 2)
```

A figure with just one subplot

`subplots()` without arguments returns a *`Figure`* and a single *`Axes`*.

This is actually the simplest and recommended way of creating a single Figure and Axes.

```
fig, ax = plt.subplots()
ax.plot(x, y)
ax.set_title('A single plot')
```

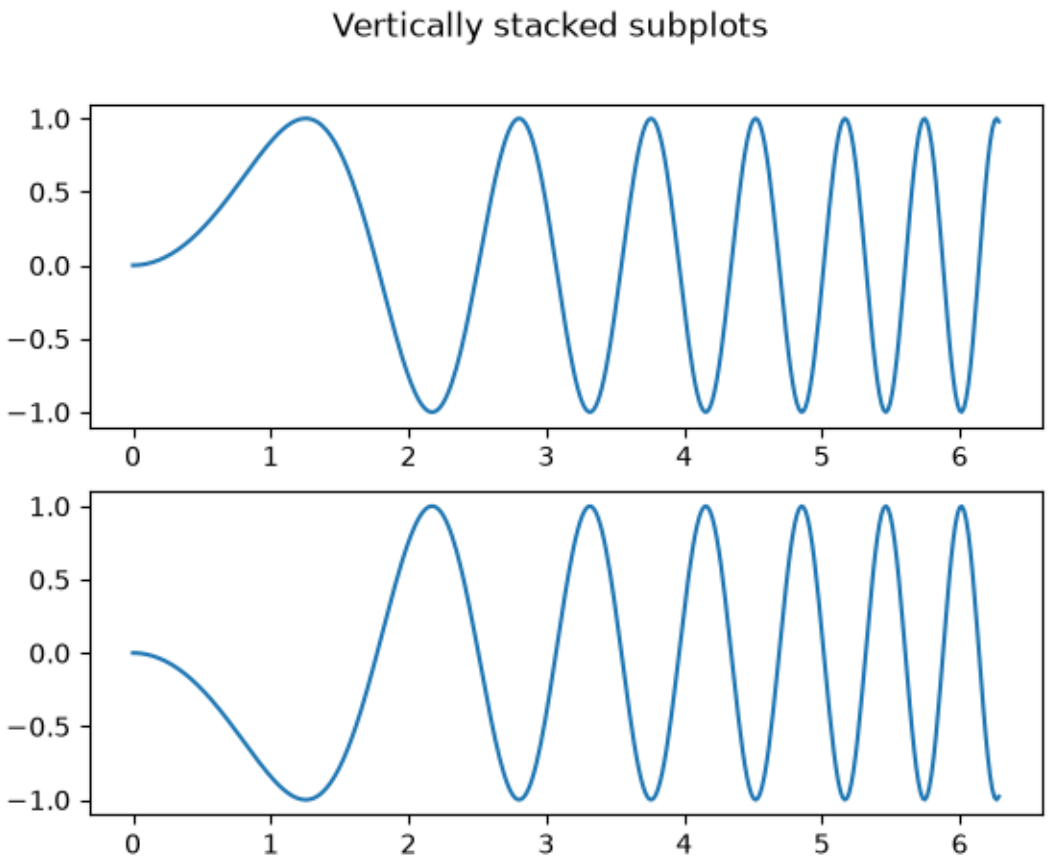


Stacking subplots in one direction

The first two optional arguments of *`pyplot.subplots`* define the number of rows and columns of the subplot grid.

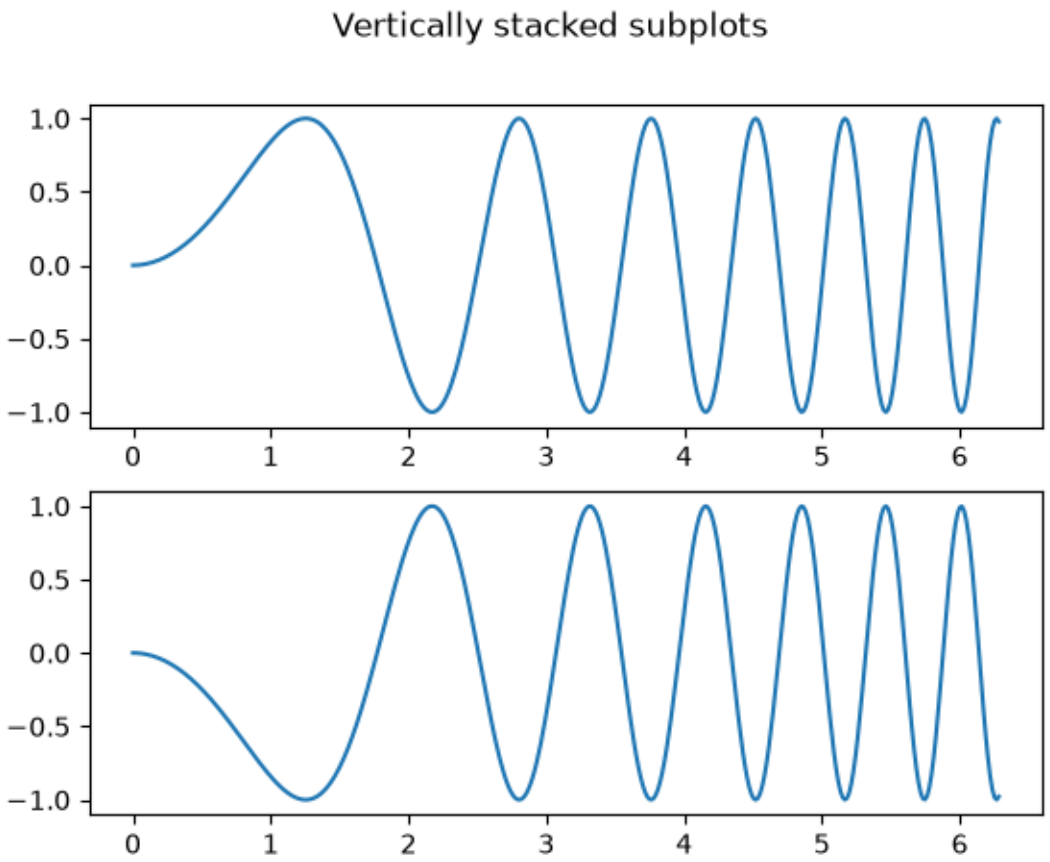
When stacking in one direction only, the returned `axs` is a 1D numpy array containing the list of created Axes.

```
fig, axs = plt.subplots(2)
fig.suptitle('Vertically stacked subplots')
axs[0].plot(x, y)
axs[1].plot(x, -y)
```



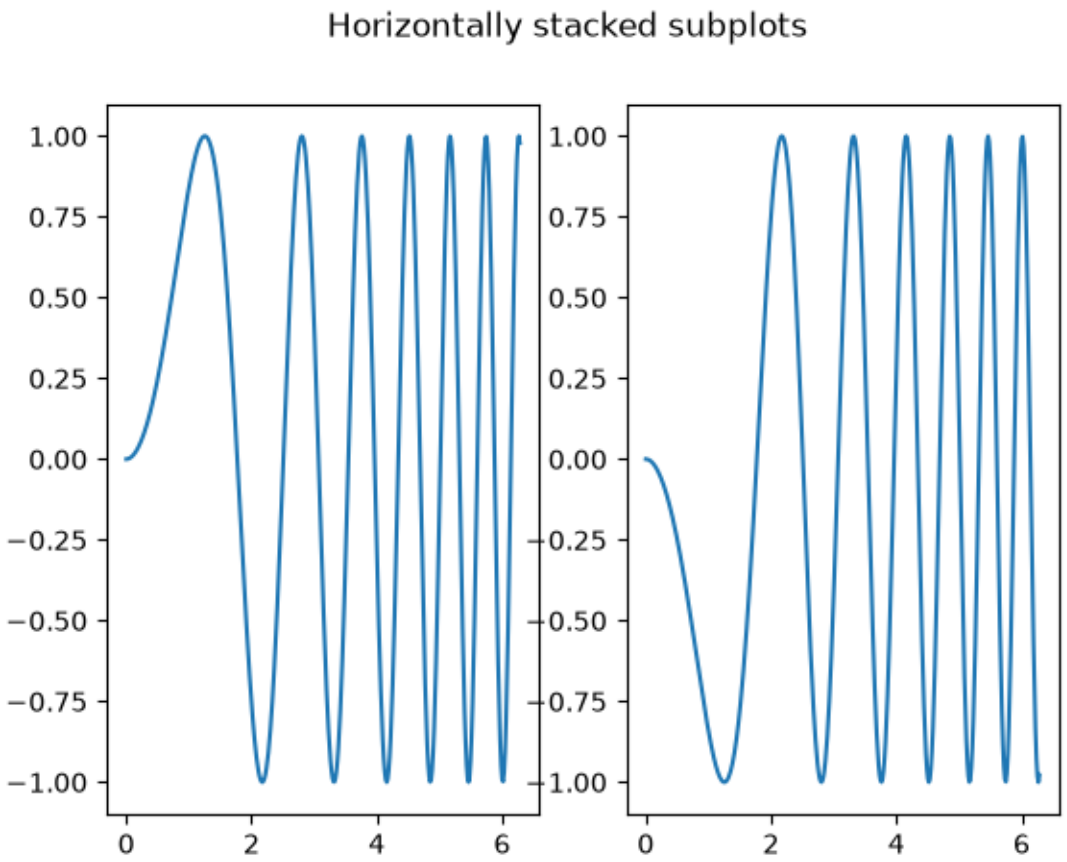
If you are creating just a few Axes, it's handy to unpack them immediately to dedicated variables for each Axes. That way, we can use `ax1` instead of the more verbose `axs[0]`.

```
fig, (ax1, ax2) = plt.subplots(2)
fig.suptitle('Vertically stacked subplots')
ax1.plot(x, y)
ax2.plot(x, -y)
```



To obtain side-by-side subplots, pass parameters `1, 2` for one row and two columns.

```
fig, (ax1, ax2) = plt.subplots(1, 2)
fig.suptitle('Horizontally stacked subplots')
ax1.plot(x, y)
ax2.plot(x, -y)
```



Stacking subplots in two directions

When stacking in two directions, the returned `axs` is a 2D NumPy array.

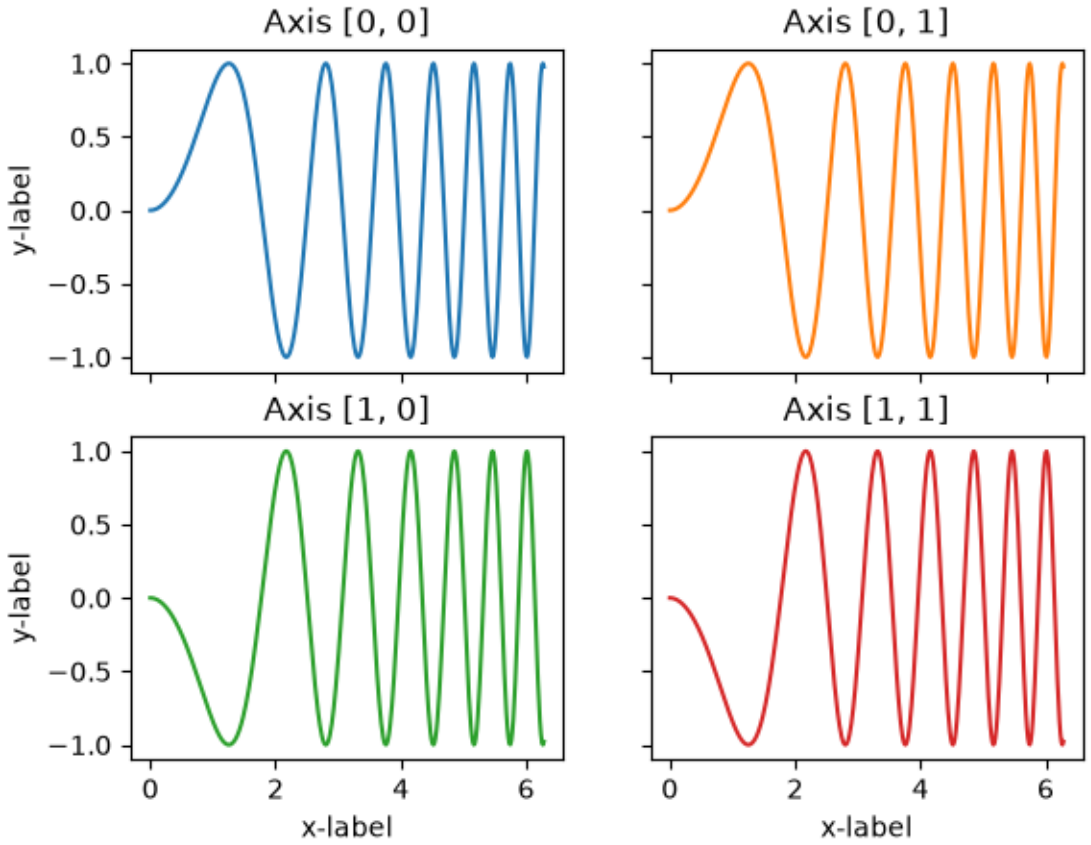
If you have to set parameters for each subplot it's handy to iterate over all subplots in a 2D grid using `for ax in axs.flat:`.

```
fig, axs = plt.subplots(2, 2)
axs[0, 0].plot(x, y)
axs[0, 0].set_title('Axis [0, 0]')
axs[0, 1].plot(x, y, 'tab:orange')
axs[0, 1].set_title('Axis [0, 1]')
axs[1, 0].plot(x, -y, 'tab:green')
axs[1, 0].set_title('Axis [1, 0]')
axs[1, 1].plot(x, -y, 'tab:red')
axs[1, 1].set_title('Axis [1, 1]')

for ax in axs.flat:
    ax.set(xlabel='x-label', ylabel='y-label')

# Hide x labels and tick labels for top plots and y ticks for right␣
```

(continues on next page)

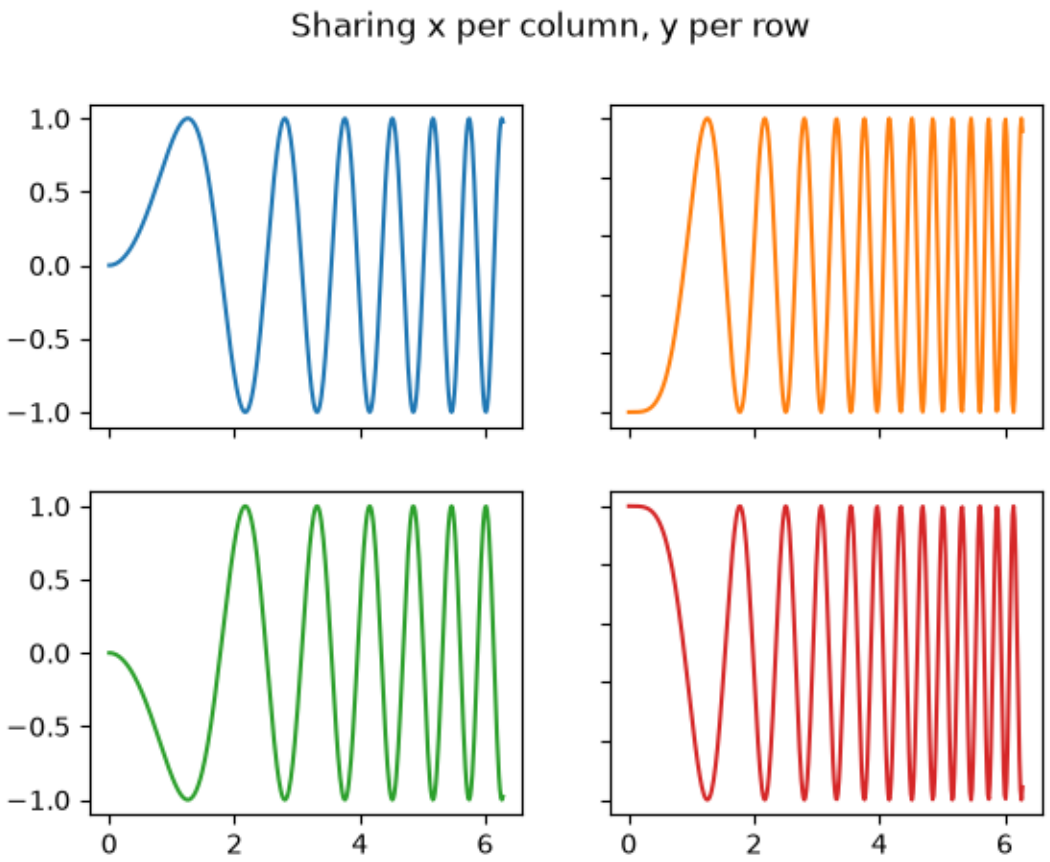
(continued from previous page)

```
↪plots.
for ax in axs.flat:
    ax.label_outer()
```



You can use tuple-unpacking also in 2D to assign all subplots to dedicated variables:

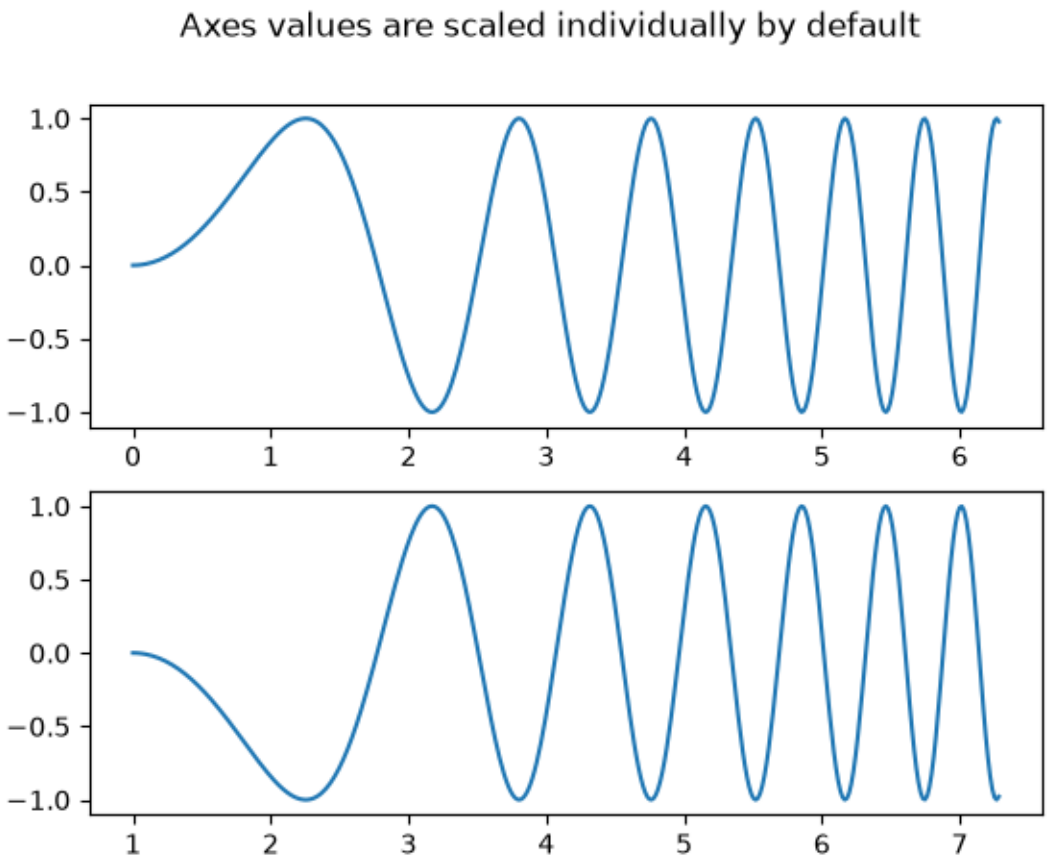
```
fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(2, 2)
fig.suptitle('Sharing x per column, y per row')
ax1.plot(x, y)
ax2.plot(x, y**2, 'tab:orange')
ax3.plot(x, -y, 'tab:green')
ax4.plot(x, -y**2, 'tab:red')

for ax in fig.get_axes():
    ax.label_outer()
```



Sharing axes

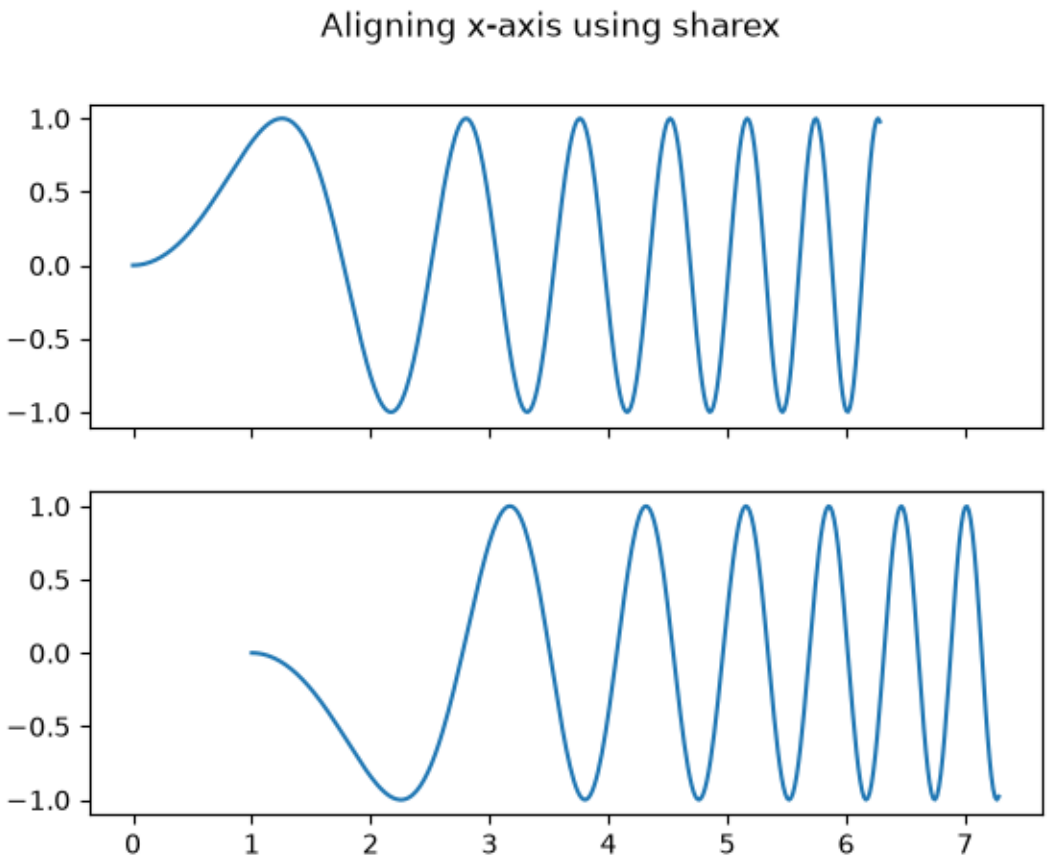
By default, each Axes is scaled individually. Thus, if the ranges are different the tick values of the subplots do not align.

```
fig, (ax1, ax2) = plt.subplots(2)
fig.suptitle('Axes values are scaled individually by default')
ax1.plot(x, y)
ax2.plot(x + 1, -y)
```



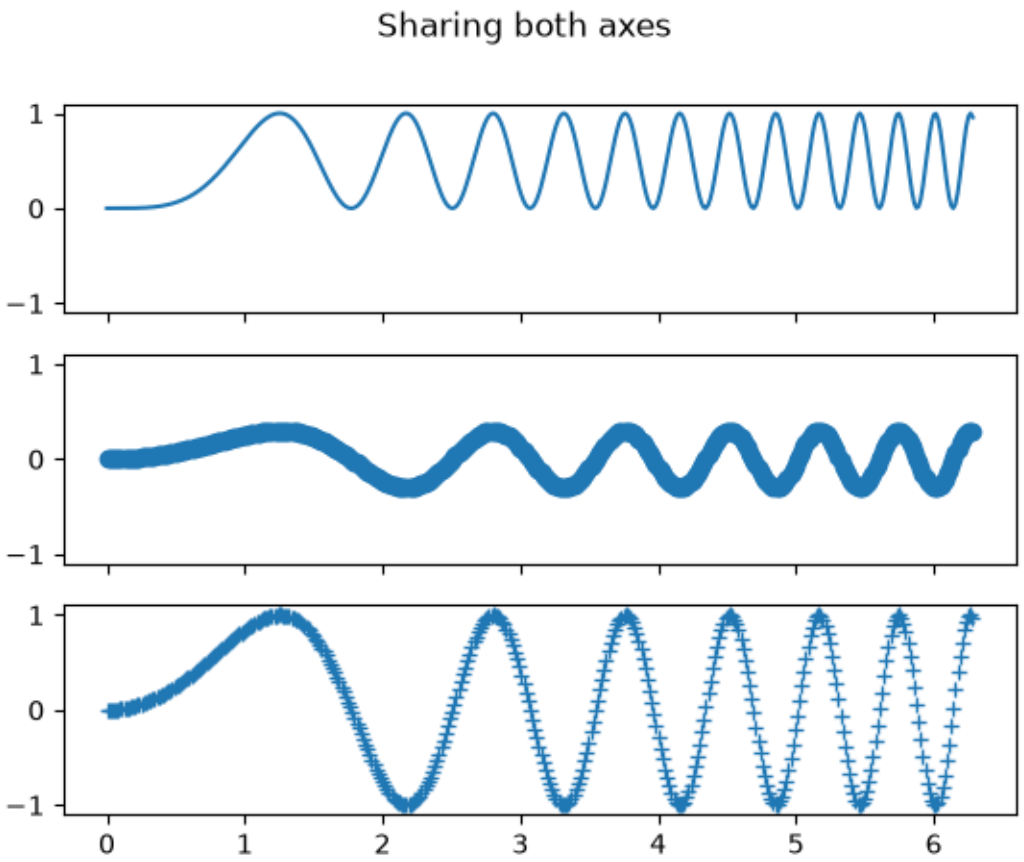
You can use *sharex* or *sharey* to align the horizontal or vertical axis.

```
fig, (ax1, ax2) = plt.subplots(2, sharex=True)
fig.suptitle('Aligning x-axis using sharex')
ax1.plot(x, y)
ax2.plot(x + 1, -y)
```



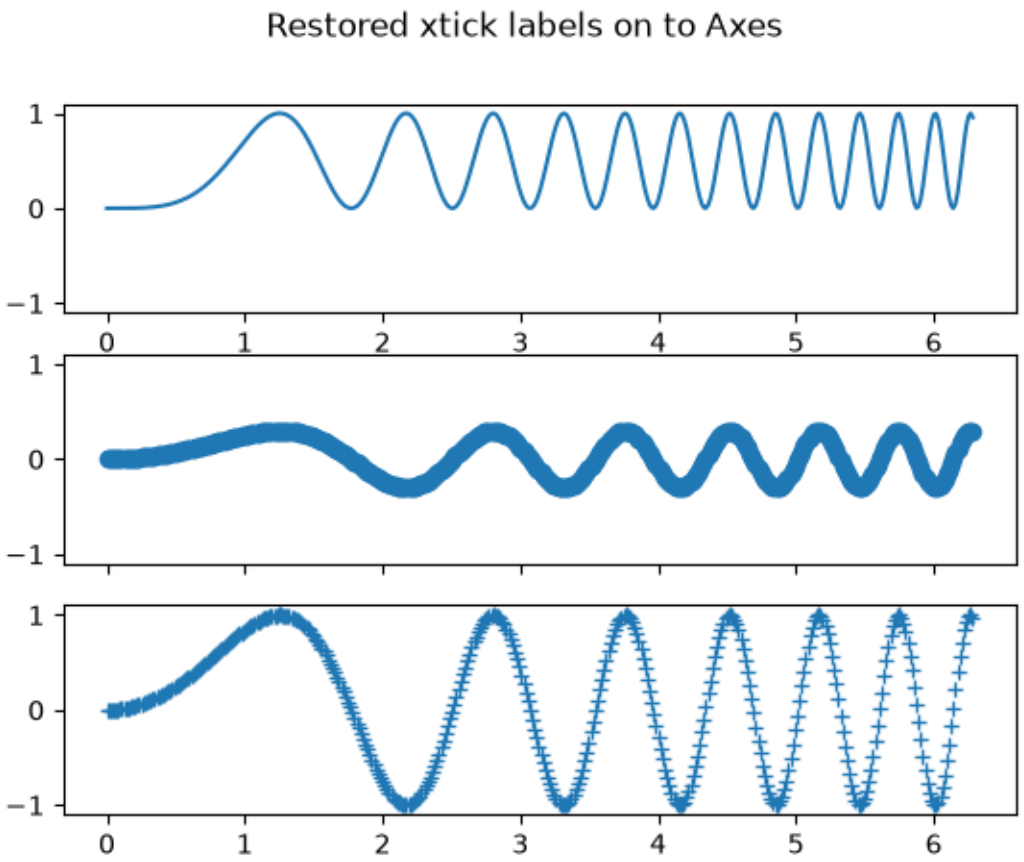
Setting *sharex* or *sharey* to `True` enables global sharing across the whole grid, i.e. also the y-axes of vertically stacked subplots have the same scale when using `sharey=True`.

```
fig, axs = plt.subplots(3, sharex=True, sharey=True)
fig.suptitle('Sharing both axes')
axs[0].plot(x, y ** 2)
axs[1].plot(x, 0.3 * y, 'o')
axs[2].plot(x, y, '+')
```



For subplots that are sharing axes one set of tick labels is enough. Tick labels of inner Axes are automatically removed by *sharex* and *sharey*. You can selectively restore them using `tick_params`.

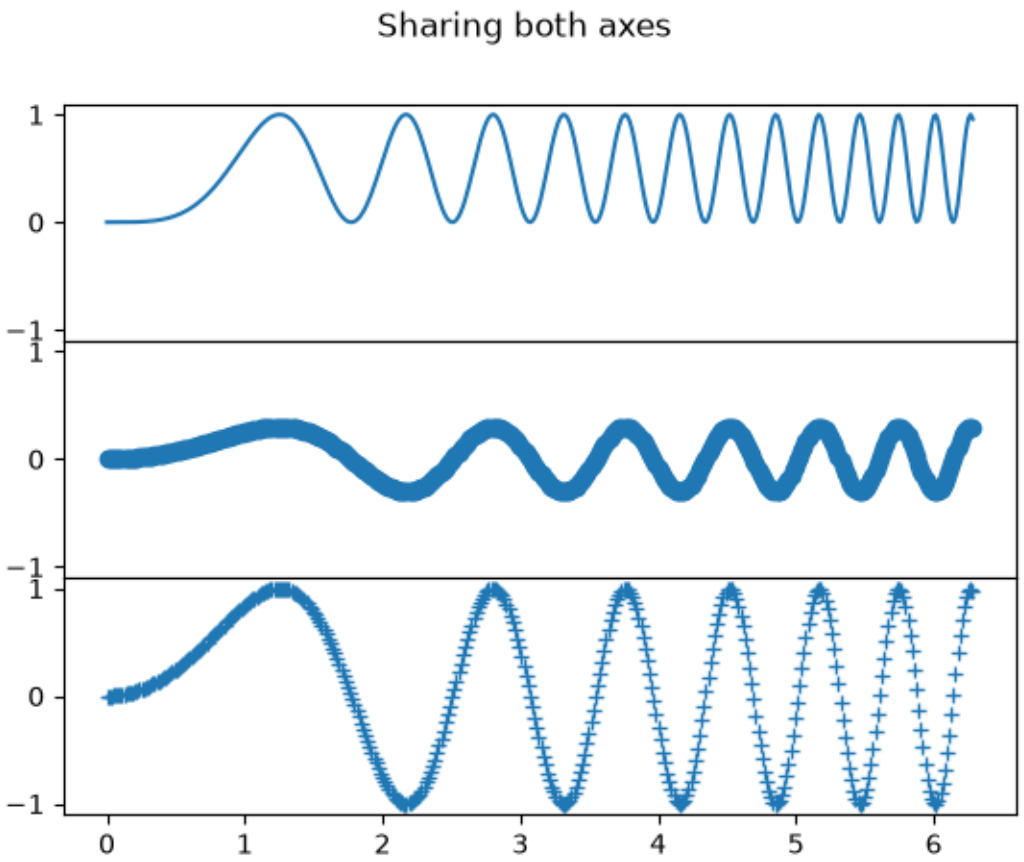
```
fig, axs = plt.subplots(3, sharex=True, sharey=True)
fig.suptitle('Restored xtick labels on to Axes')
axs[0].plot(x, y ** 2)
axs[1].plot(x, 0.3 * y, 'o')
axs[2].plot(x, y, '+')

axs[0].tick_params(labelbottom=True)
```



It is also possible to remove the empty space between the subplots. To precisely control the positioning of the subplots, one can explicitly create a *GridSpec* with *Figure.add_gridspec*, and then call its *subplots* method. For example, we can reduce the height between vertical subplots using `add_gridspec(hspace=0)`.

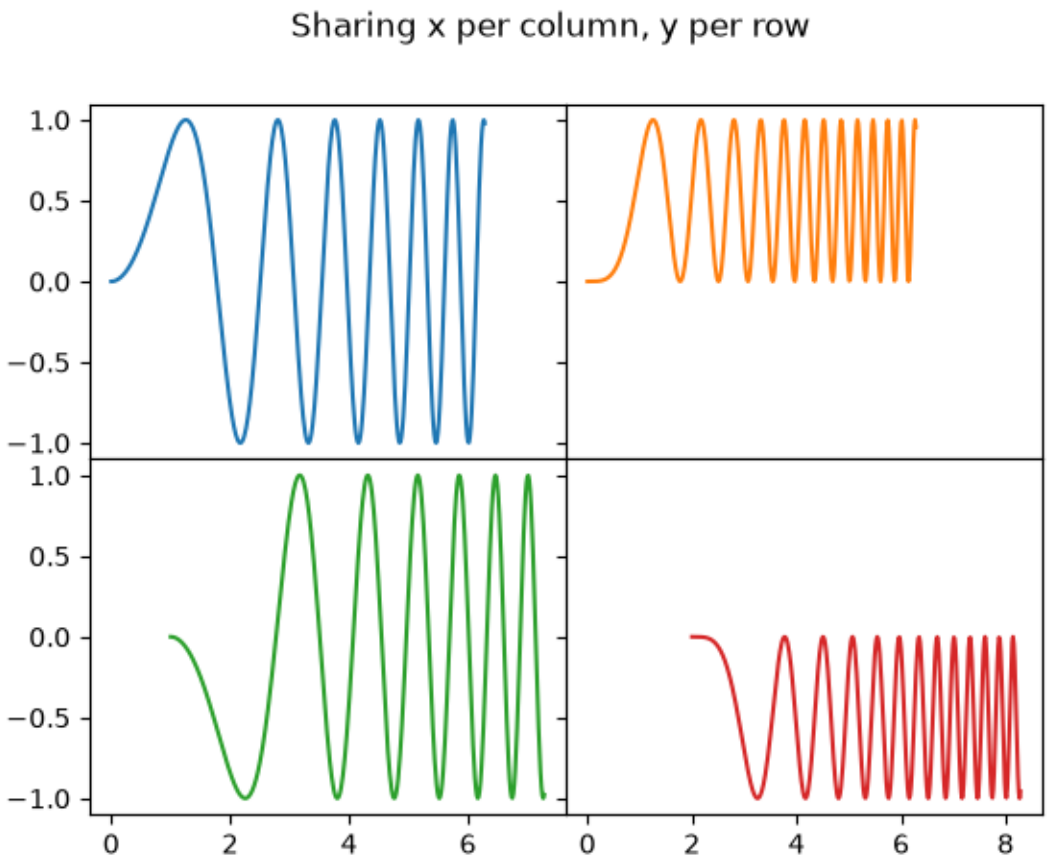
label_outer is a handy method to remove labels and ticks from subplots that are not at the edge of the grid.

```
fig = plt.figure()
gs = fig.add_gridspec(3, hspace=0)
axs = gs.subplots(sharex=True, sharey=True)
fig.suptitle('Sharing both axes')
axs[0].plot(x, y ** 2)
axs[1].plot(x, 0.3 * y, 'o')
axs[2].plot(x, y, '+')

# Hide x labels and tick labels for all but bottom plot.
for ax in axs:
    ax.label_outer()
```



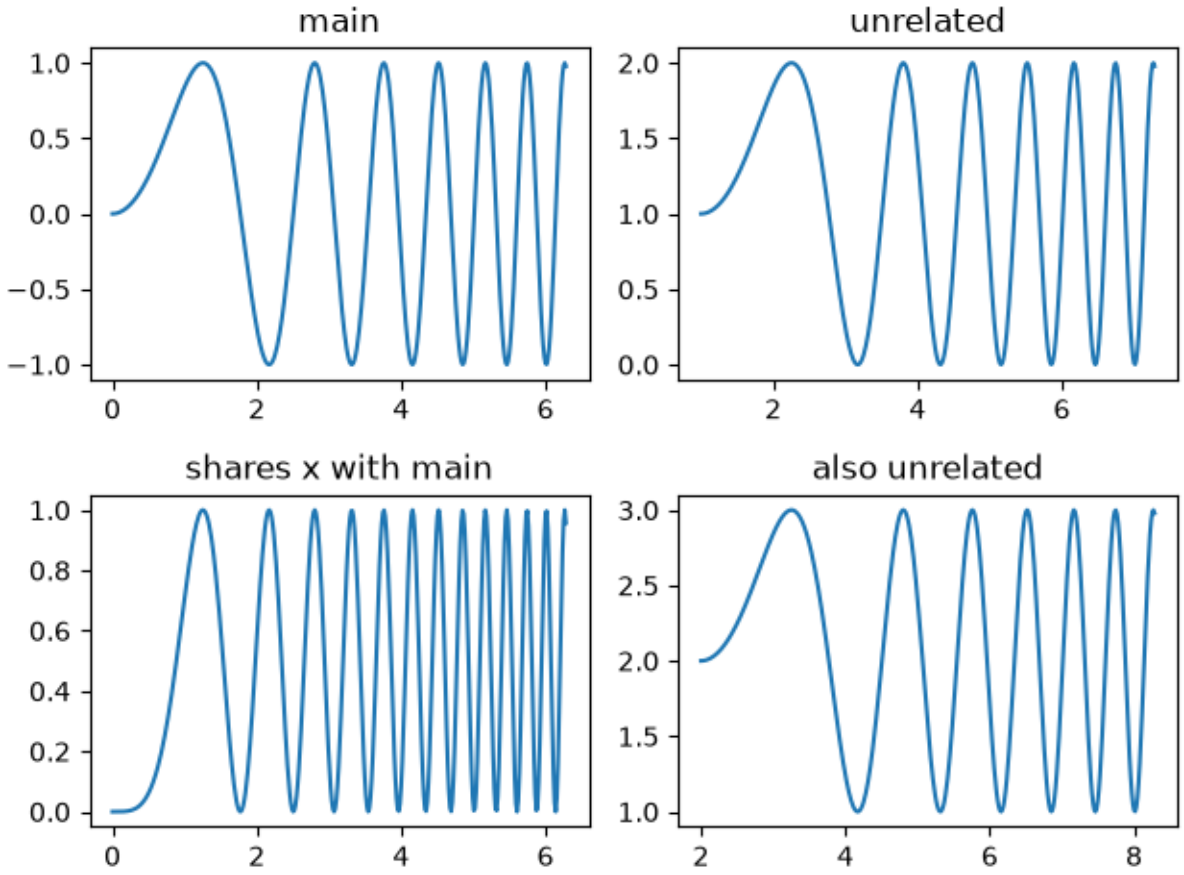
Apart from `True` and `False`, both *sharex* and *sharey* accept the values 'row' and 'col' to share the values only per row or column.

```
fig = plt.figure()
gs = fig.add_gridspec(2, 2, hspace=0, wspace=0)
(ax1, ax2), (ax3, ax4) = gs.subplots(sharex='col', sharey='row')
fig.suptitle('Sharing x per column, y per row')
ax1.plot(x, y)
ax2.plot(x, y**2, 'tab:orange')
ax3.plot(x + 1, -y, 'tab:green')
ax4.plot(x + 2, -y**2, 'tab:red')

for ax in fig.get_axes():
    ax.label_outer()
```



If you want a more complex sharing structure, you can first create the grid of Axes with no sharing, and then call *axes.Axes.sharex* or *axes.Axes.sharey* to add sharing info a posteriori.

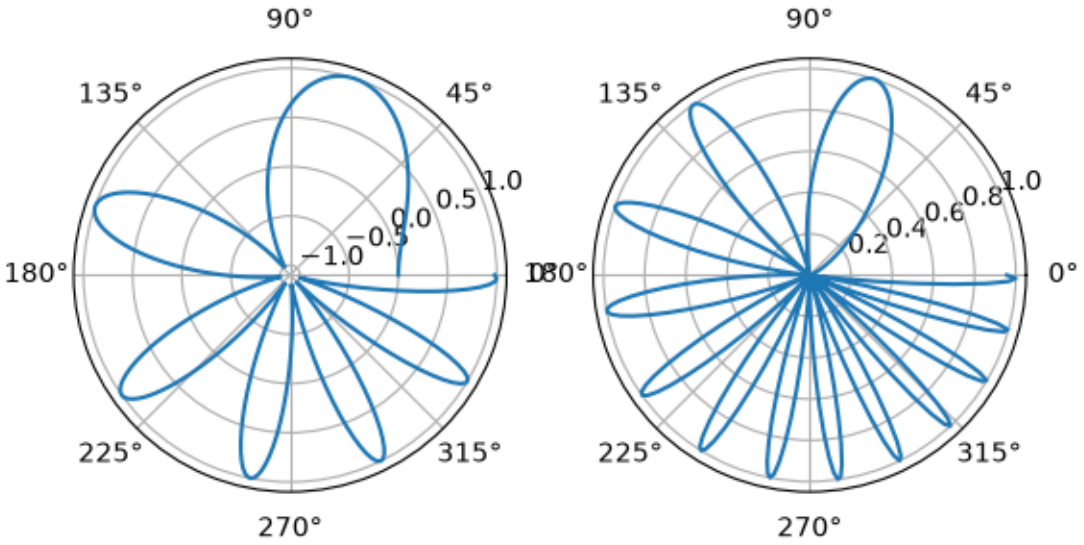
```
fig, axs = plt.subplots(2, 2)
axs[0, 0].plot(x, y)
axs[0, 0].set_title("main")
axs[1, 0].plot(x, y**2)
axs[1, 0].set_title("shares x with main")
axs[1, 0].sharex(axs[0, 0])
axs[0, 1].plot(x + 1, y + 1)
axs[0, 1].set_title("unrelated")
axs[1, 1].plot(x + 2, y + 2)
axs[1, 1].set_title("also unrelated")
fig.tight_layout()
```



Polar Axes

The parameter *subplot_kw* of `pyplot.subplots` controls the subplot properties (see also `Figure.add_subplot`). In particular, this can be used to create a grid of polar Axes.

```
fig, (ax1, ax2) = plt.subplots(1, 2, subplot_kw=dict(projection='polar
 ↪'))
ax1.plot(x, y)
ax2.plot(x, y ** 2)

plt.show()
```



Tags: component: subplot component: axes component: axis plot-type: line plot-type: polar level: beginner purpose: showcase

Total running time of the script: (0 minutes 7.696 seconds)

Axes Demo

Example use of `fig.add_axes` to create inset Axes within the main plot Axes.

Please see also the *Module - axes_grid1* section, and the following three examples:

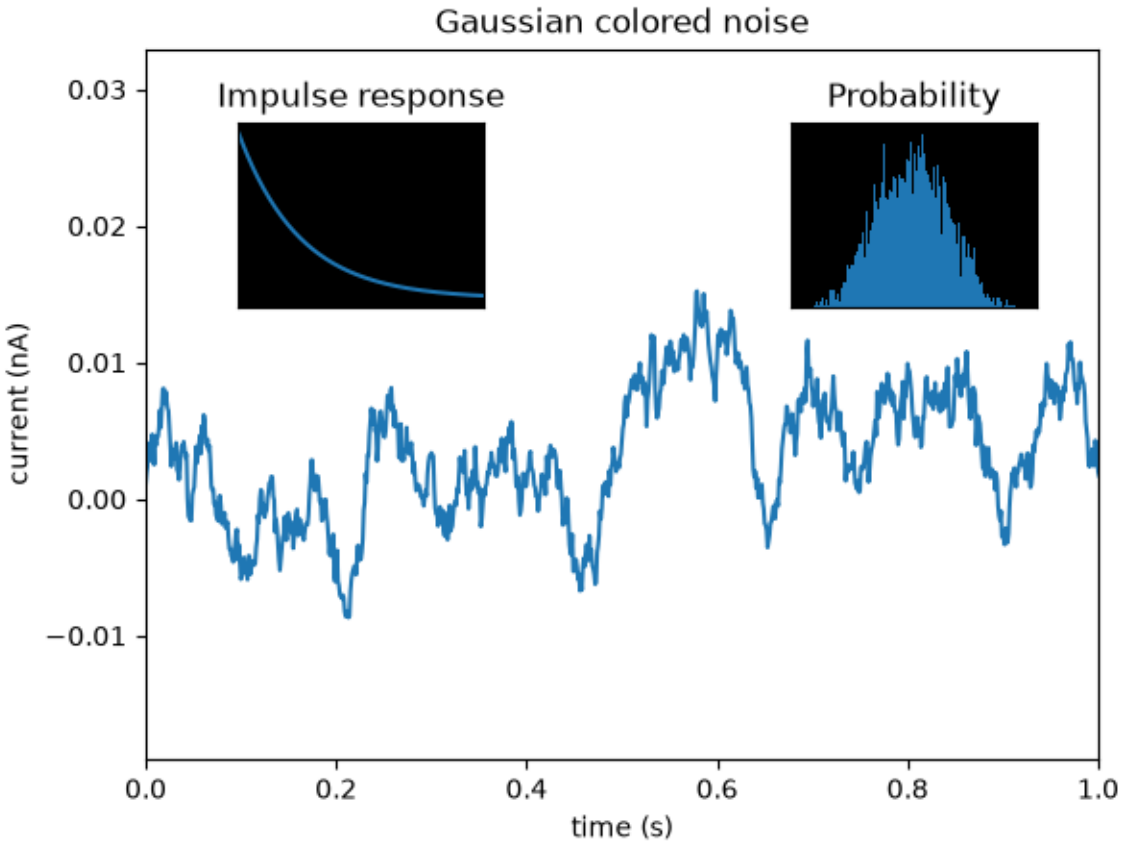
- *Zoom region inset Axes*
- *Inset locator demo*
- *Inset locator demo 2*

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)  # Fixing random state for reproducibility.

# create some data to use for the plot
dt = 0.001
```

(continues on next page)

(continued from previous page)

```
t = np.arange(0.0, 10.0, dt)
r = np.exp(-t[:1000] / 0.05)  # impulse response
x = np.random.randn(len(t))
s = np.convolve(x, r)[:len(x)] * dt  # colored noise

fig, main_ax = plt.subplots()
main_ax.plot(t, s)
main_ax.set_xlim(0, 1)
main_ax.set_ylim(1.1 * np.min(s), 2 * np.max(s))
main_ax.set_xlabel('time (s)')
main_ax.set_ylabel('current (nA)')
main_ax.set_title('Gaussian colored noise')

# this is an inset Axes over the main Axes
right_inset_ax = fig.add_axes((.65, .6, .2, .2), facecolor='k')
right_inset_ax.hist(s, 400, density=True)
right_inset_ax.set(title='Probability', xticks=[], yticks=[])

# this is another inset Axes over the main Axes
left_inset_ax = fig.add_axes((.2, .6, .2, .2), facecolor='k')
left_inset_ax.plot(t[:len(r)], r)
left_inset_ax.set(title='Impulse response', xlim=(0, .2), xticks=[],␣
 ↪yticks=[])

plt.show()
```



Tags: component: axes plot-type: line plot-type: histogram level: beginner

GridSpec with variable sizes and spacing

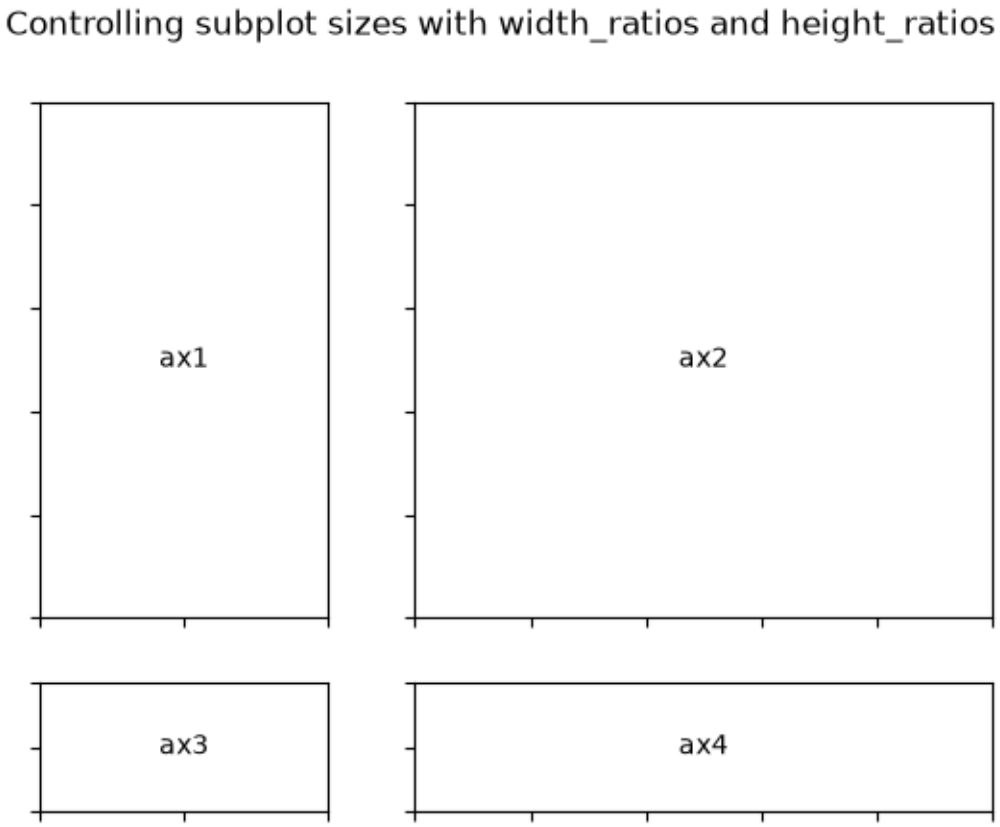
This example demonstrates the use of `GridSpec` to generate subplots, the control of the relative sizes of subplots with *width_ratios* and *height_ratios*, and the control of the spacing around and between subplots using subplot params (*left*, *right*, *bottom*, *top*, *wspace*, and *hspace*).

```
import matplotlib.pyplot as plt

from matplotlib.gridspec import GridSpec


def annotate_axes(fig):
    for i, ax in enumerate(fig.axes):
        ax.text(0.5, 0.5, "ax%d" % (i+1), va="center", ha="center")
        ax.tick_params(labelbottom=False, labelleft=False)


fig = plt.figure()
fig.suptitle("Controlling subplot sizes with width_ratios and␣
```

(continues on next page)

(continued from previous page)

```
 ↪height_ratios")

gs = GridSpec(2, 2, width_ratios=[1, 2], height_ratios=[4, 1])
ax1 = fig.add_subplot(gs[0])
ax2 = fig.add_subplot(gs[1])
ax3 = fig.add_subplot(gs[2])
ax4 = fig.add_subplot(gs[3])

annotate_axes(fig)
```

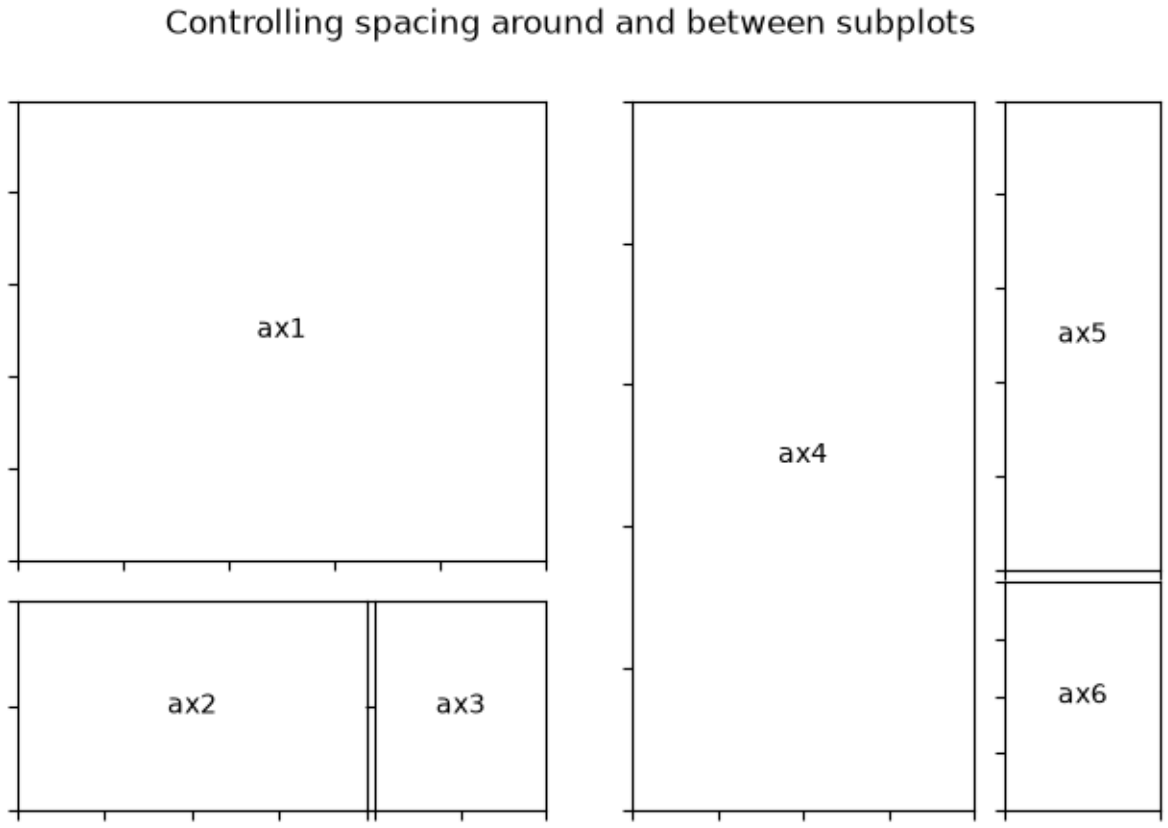



```
fig = plt.figure()
fig.suptitle("Controlling spacing around and between subplots")

gs1 = GridSpec(3, 3, left=0.05, right=0.48, wspace=0.05)
ax1 = fig.add_subplot(gs1[:-1, :])
ax2 = fig.add_subplot(gs1[-1, :-1])
ax3 = fig.add_subplot(gs1[-1, -1])

gs2 = GridSpec(3, 3, left=0.55, right=0.98, hspace=0.05)
```

(continues on next page)

(continued from previous page)

```
ax4 = fig.add_subplot(gs2[:, :-1])
ax5 = fig.add_subplot(gs2[:-1, -1])
ax6 = fig.add_subplot(gs2[-1, -1])

annotate_axes(fig)

plt.show()
```



Gridspec for multi-column/row subplot layouts

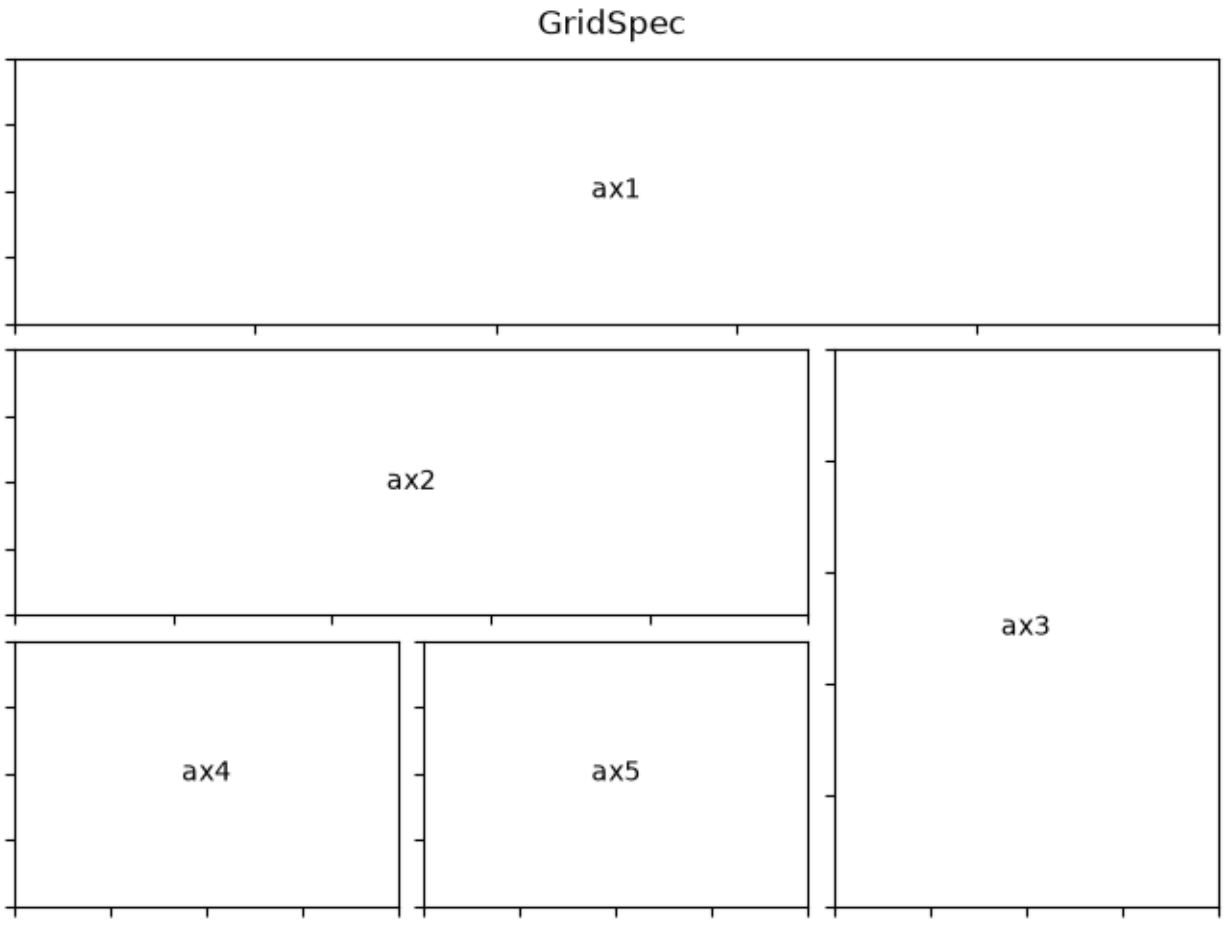
GridSpec is a flexible way to layout subplot grids. Here is an example with a 3x3 grid, and axes spanning all three columns, two columns, and two rows.

```
import matplotlib.pyplot as plt

from matplotlib.gridspec import GridSpec


def format_axes(fig):
    for i, ax in enumerate(fig.axes):
```

(continues on next page)

(continued from previous page)

```
        ax.text(0.5, 0.5, "ax%d" % (i+1), va="center", ha="center")
        ax.tick_params(labelbottom=False, labelleft=False)

fig = plt.figure(layout="constrained")

gs = GridSpec(3, 3, figure=fig)
ax1 = fig.add_subplot(gs[0, :])
# identical to ax1 = plt.subplot(gs.new_subplotspec((0, 0), colspan=3))
ax2 = fig.add_subplot(gs[1, :-1])
ax3 = fig.add_subplot(gs[1:, -1])
ax4 = fig.add_subplot(gs[-1, 0])
ax5 = fig.add_subplot(gs[-1, -2])

fig.suptitle("GridSpec")
format_axes(fig)

plt.show()
```



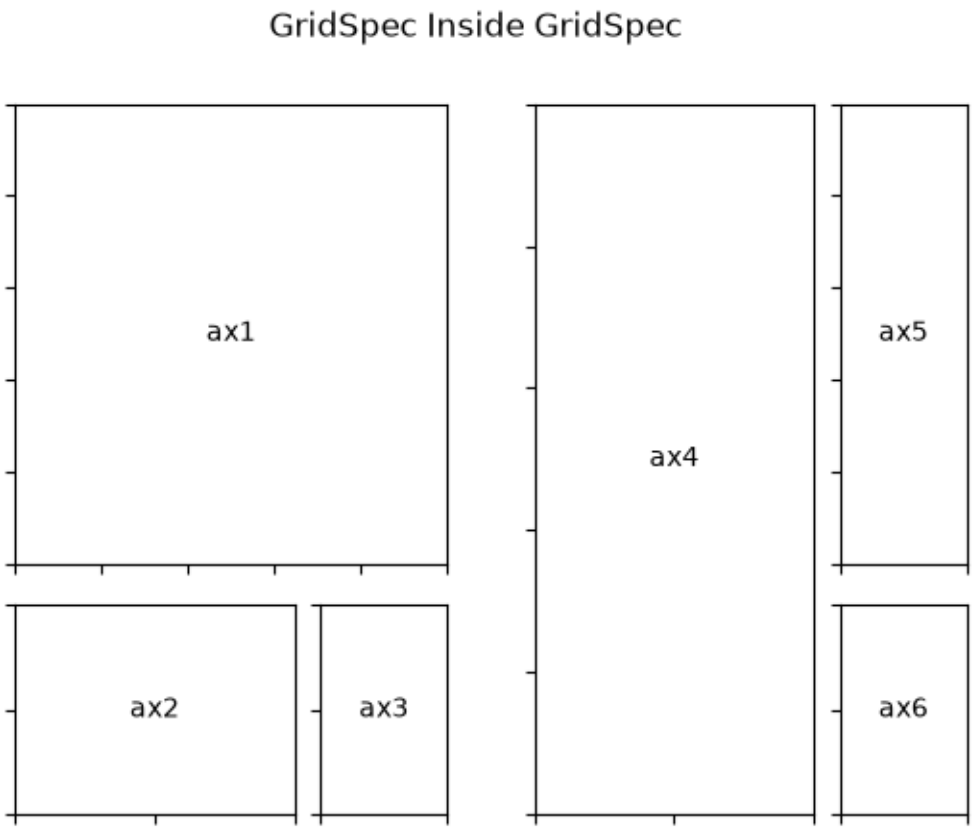
Tags: component: subplot level: intermediate

Nested Gridspecs

GridSpecs can be nested, so that a subplot from a parent GridSpec can set the position for a nested grid of subplots.

Note that the same functionality can be achieved more directly with *subfigures*; see *Figure subfigures*.

```
import matplotlib.pyplot as plt

import matplotlib.gridspec as gridspec


def format_axes(fig):
    for i, ax in enumerate(fig.axes):
        ax.text(0.5, 0.5, "ax%d" % (i+1), va="center", ha="center")
        ax.tick_params(labelbottom=False, labelleft=False)


# gridspec inside gridspec
fig = plt.figure()

gs0 = gridspec.GridSpec(1, 2, figure=fig)

gs00 = gridspec.GridSpecFromSubplotSpec(3, 3, subplot_spec=gs0[0])

ax1 = fig.add_subplot(gs00[:-1, :])
ax2 = fig.add_subplot(gs00[-1, :-1])
ax3 = fig.add_subplot(gs00[-1, -1])

# the following syntax does the same as the GridSpecFromSubplotSpec␣
 ↪call above:
gs01 = gs0[1].subgridspec(3, 3)

ax4 = fig.add_subplot(gs01[:, :-1])
ax5 = fig.add_subplot(gs01[:-1, -1])
ax6 = fig.add_subplot(gs01[-1, -1])

plt.suptitle("GridSpec Inside GridSpec")
format_axes(fig)

plt.show()
```



Tags: component: subplot level: intermediate

Combine two subplots using subplots and GridSpec

Sometimes we want to combine two subplots in an Axes layout created with *subplots*. We can get the *GridSpec* from the Axes and then remove the covered Axes and fill the gap with a new bigger Axes. Here we create a layout with the bottom two Axes in the last column combined.

To start with this layout (rather than removing the overlapping Axes) use *subplot_mosaic*.

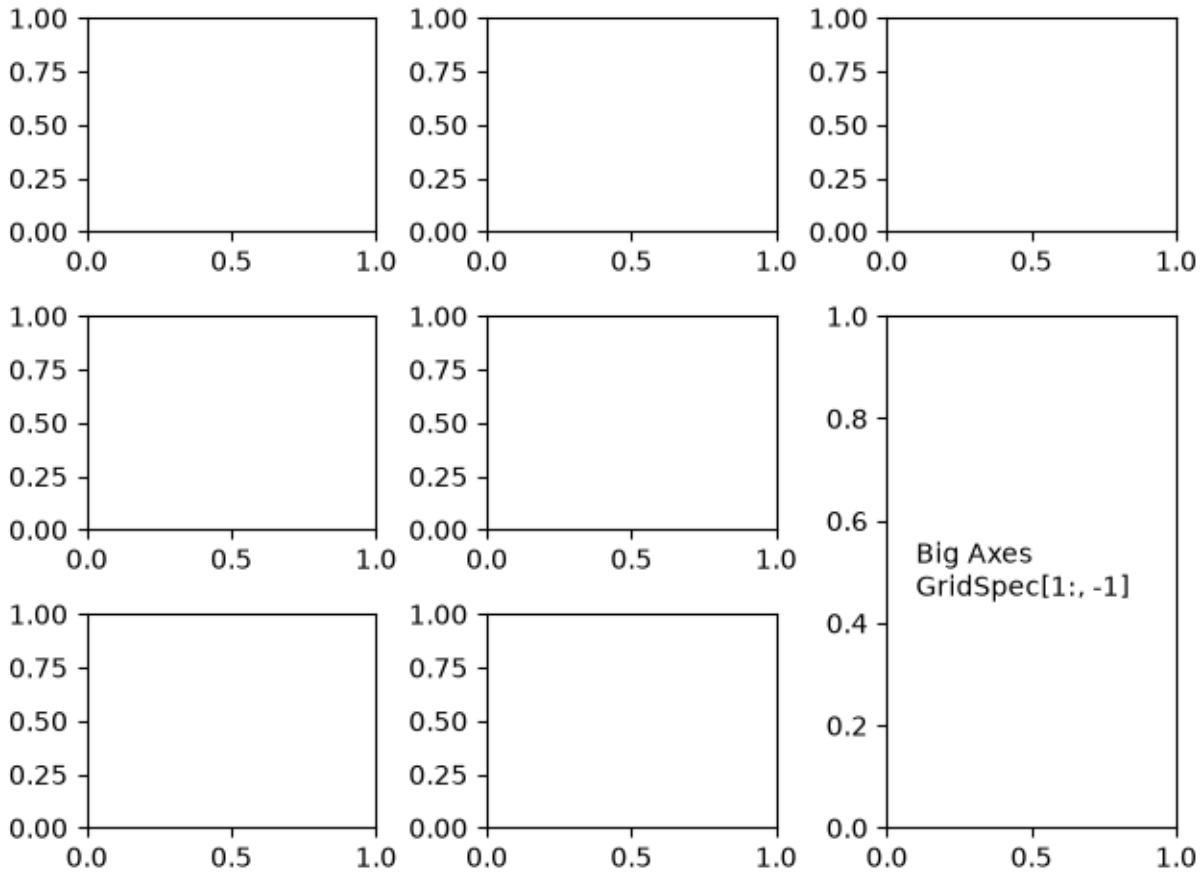
See also *Arranging multiple Axes in a Figure*.

```
import matplotlib.pyplot as plt

fig, axs = plt.subplots(ncols=3, nrows=3)
gs = axs[1, 2].get_gridspec()
# remove the underlying Axes
for ax in axs[1:, -1]:
    ax.remove()
axbig = fig.add_subplot(gs[1:, -1])
axbig.annotate('Big Axes \nGridSpec[1:, -1]', (0.1, 0.5),
               xycoords='axes fraction', va='center')
```

(continues on next page)

(continued from previous page)

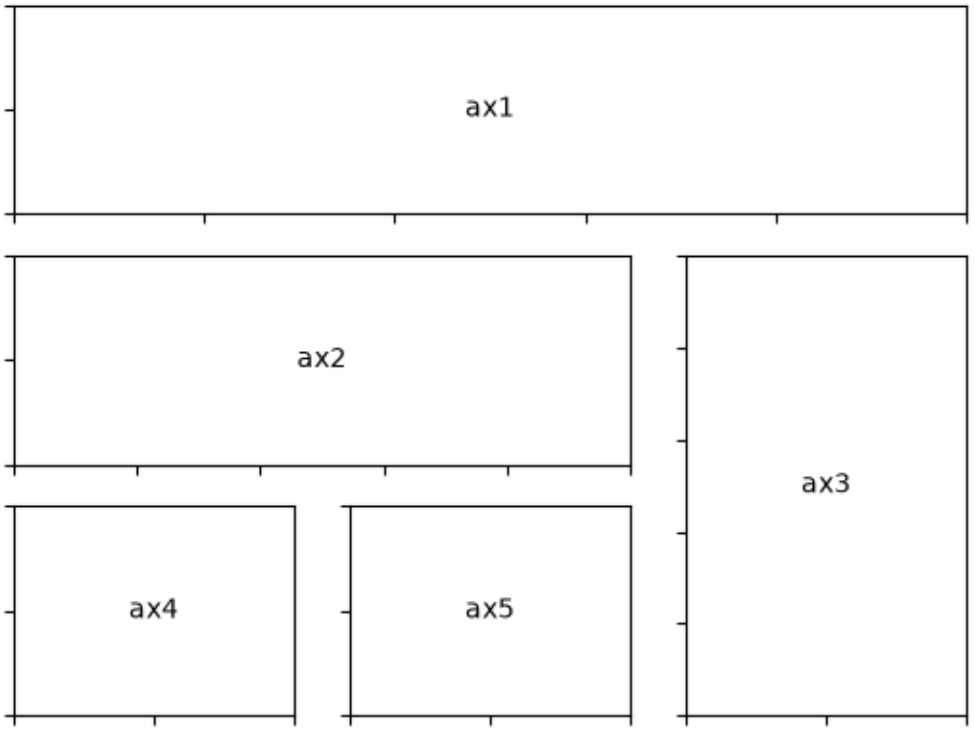
```
fig.tight_layout()

plt.show()
```



Tags: component: subplot level: beginner

subplot2grid

This example demonstrates the use of *pyplot.subplot2grid* to generate subplots. Using *GridSpec*, as demonstrated in *GridSpec with variable sizes and spacing* is generally preferred.




```
import matplotlib.pyplot as plt


def annotate_axes(fig):
    for i, ax in enumerate(fig.axes):
        ax.text(0.5, 0.5, "ax%d" % (i+1), va="center", ha="center")
        ax.tick_params(labelbottom=False, labelleft=False)


fig = plt.figure()
ax1 = plt.subplot2grid((3, 3), (0, 0), colspan=3)
ax2 = plt.subplot2grid((3, 3), (1, 0), colspan=2)
ax3 = plt.subplot2grid((3, 3), (1, 2), rowspan=2)
ax4 = plt.subplot2grid((3, 3), (2, 0))
ax5 = plt.subplot2grid((3, 3), (2, 1))

annotate_axes(fig)

plt.show()
```

Resize Axes with constrained layout

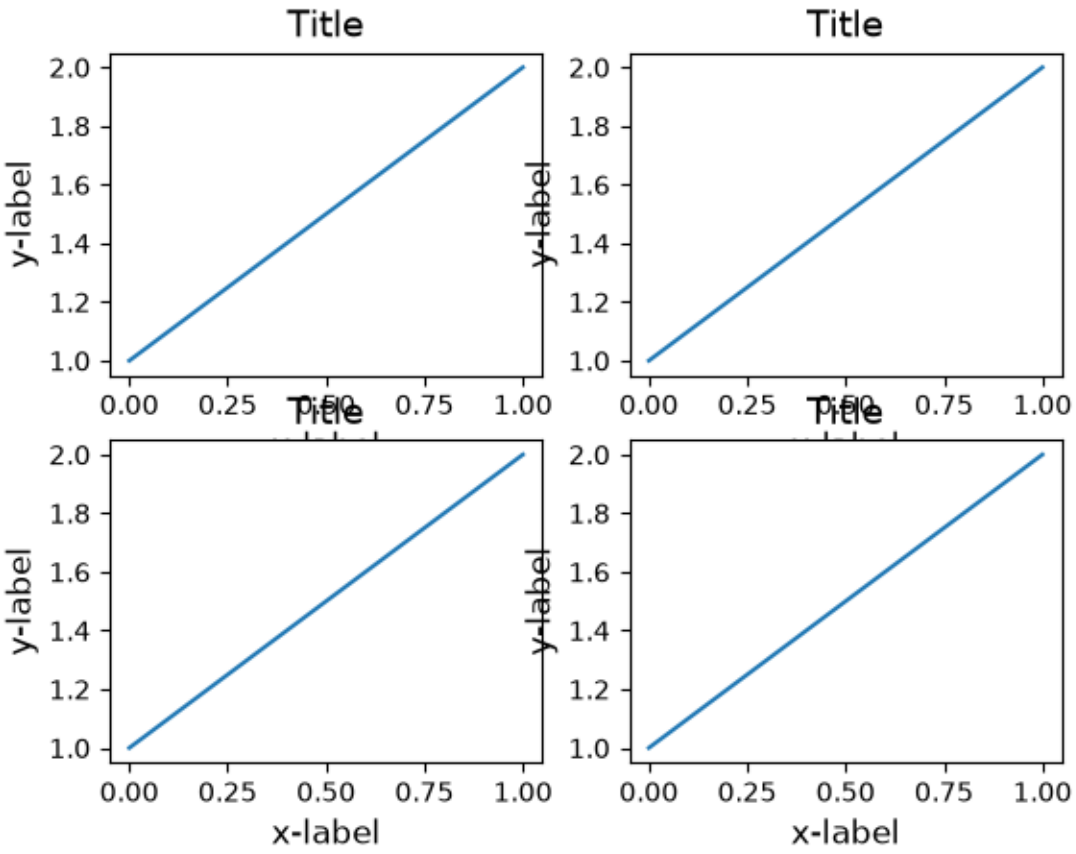
Constrained layout attempts to resize subplots in a figure so that there are no overlaps between Axes objects and labels on the Axes.

See *Constrained layout guide* for more details and *Tight layout guide* for an alternative.

```
import matplotlib.pyplot as plt


def example_plot(ax):
    ax.plot([1, 2])
    ax.set_xlabel('x-label', fontsize=12)
    ax.set_ylabel('y-label', fontsize=12)
    ax.set_title('Title', fontsize=14)
```

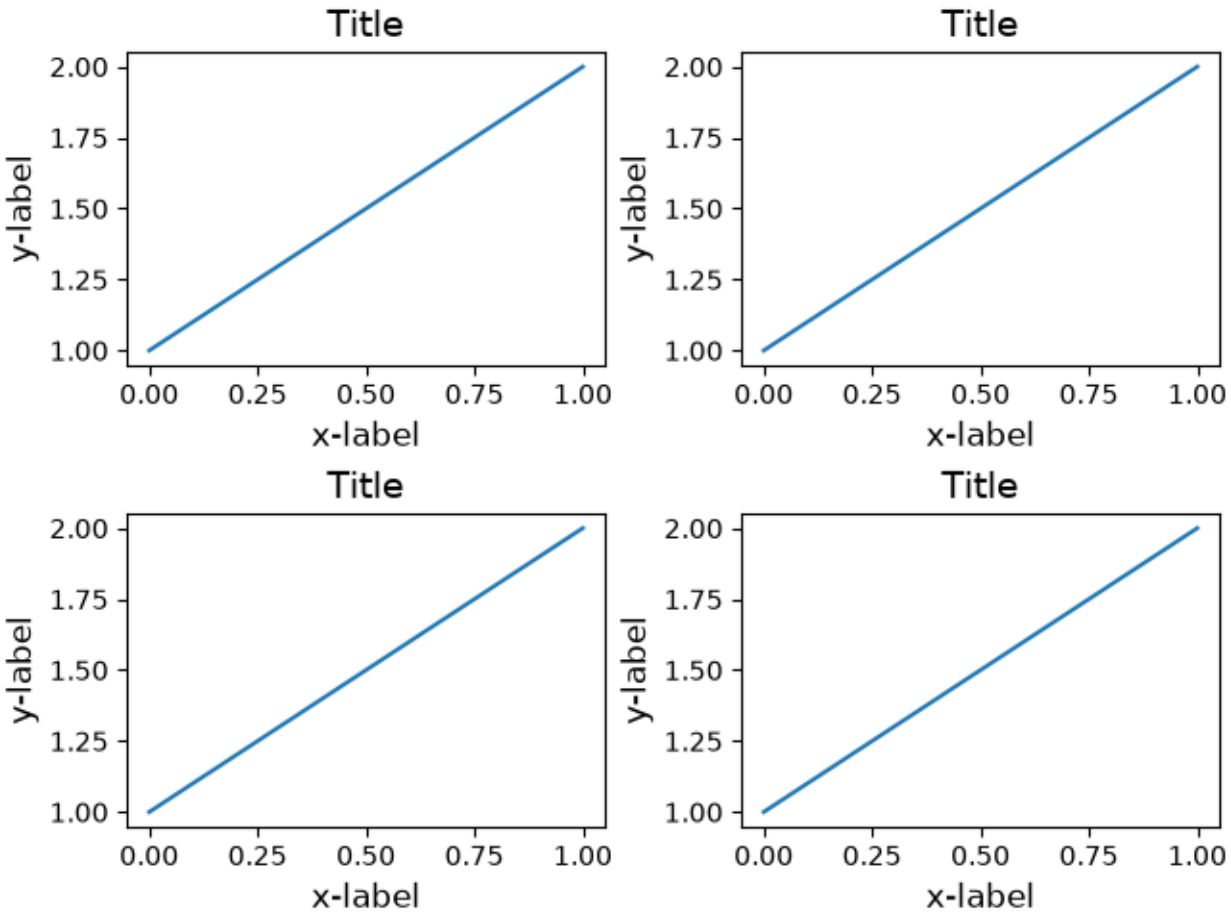
If we don't use *constrained layout*, then labels overlap the Axes

```
fig, axs = plt.subplots(nrows=2, ncols=2, layout=None)

for ax in axs.flat:
    example_plot(ax)
```



adding `layout='constrained'` automatically adjusts.

```
fig, axs = plt.subplots(nrows=2, ncols=2, layout='constrained')

for ax in axs.flat:
    example_plot(ax)
```



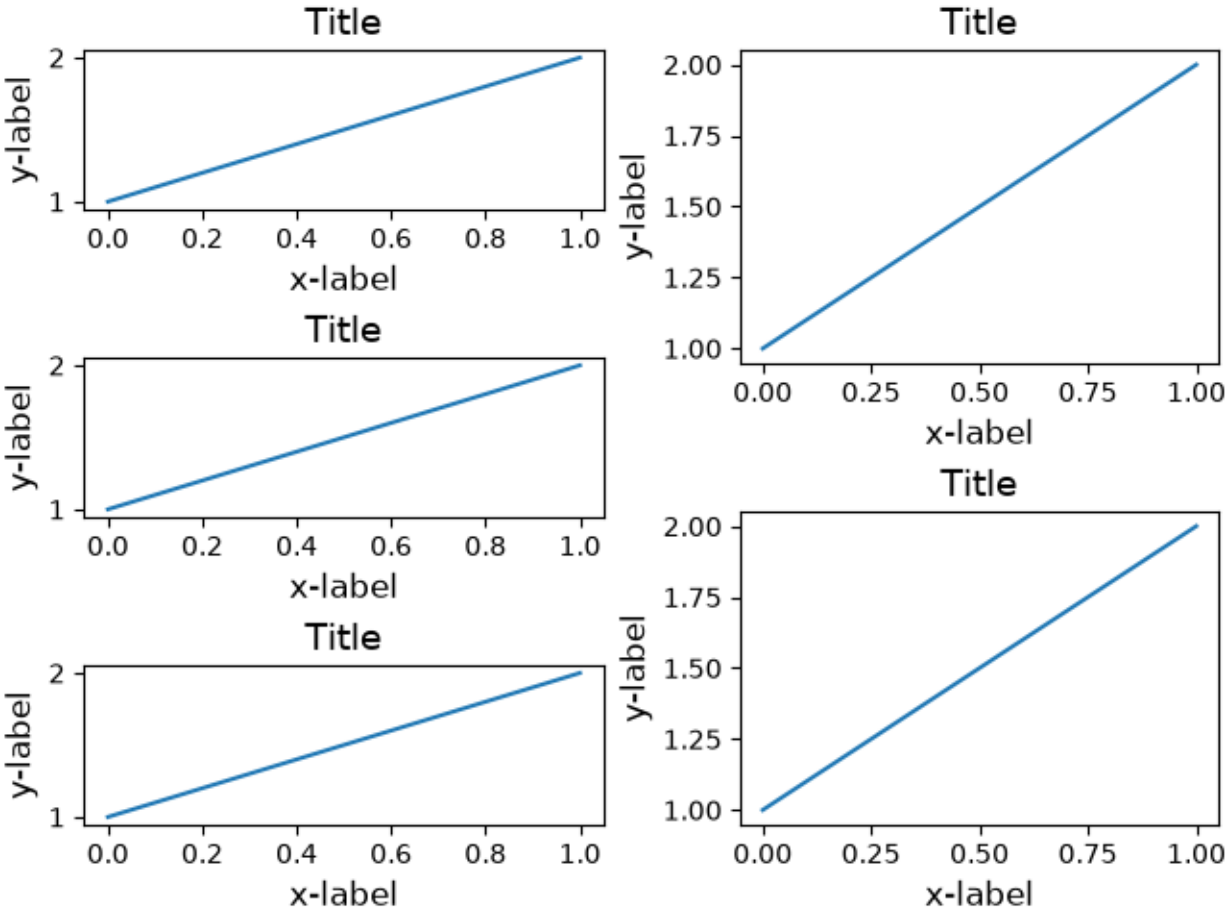
Below is a more complicated example using nested gridspecs.

```
fig = plt.figure(layout='constrained')

import matplotlib.gridspec as gridspec

gs0 = gridspec.GridSpec(1, 2, figure=fig)

gs1 = gridspec.GridSpecFromSubplotSpec(3, 1, subplot_spec=gs0[0])
for n in range(3):
    ax = fig.add_subplot(gs1[n])
    example_plot(ax)
```

(continues on next page)

(continued from previous page)

```
gs2 = gridspec.GridSpecFromSubplotSpec(2, 1, subplot_spec=gs0[1])
for n in range(2):
    ax = fig.add_subplot(gs2[n])
    example_plot(ax)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.gridspec.GridSpec*
- *matplotlib.gridspec.GridSpecFromSubplotSpec*

Tags: component: axes component: subplot styling: size level: beginner

Total running time of the script: (0 minutes 2.759 seconds)

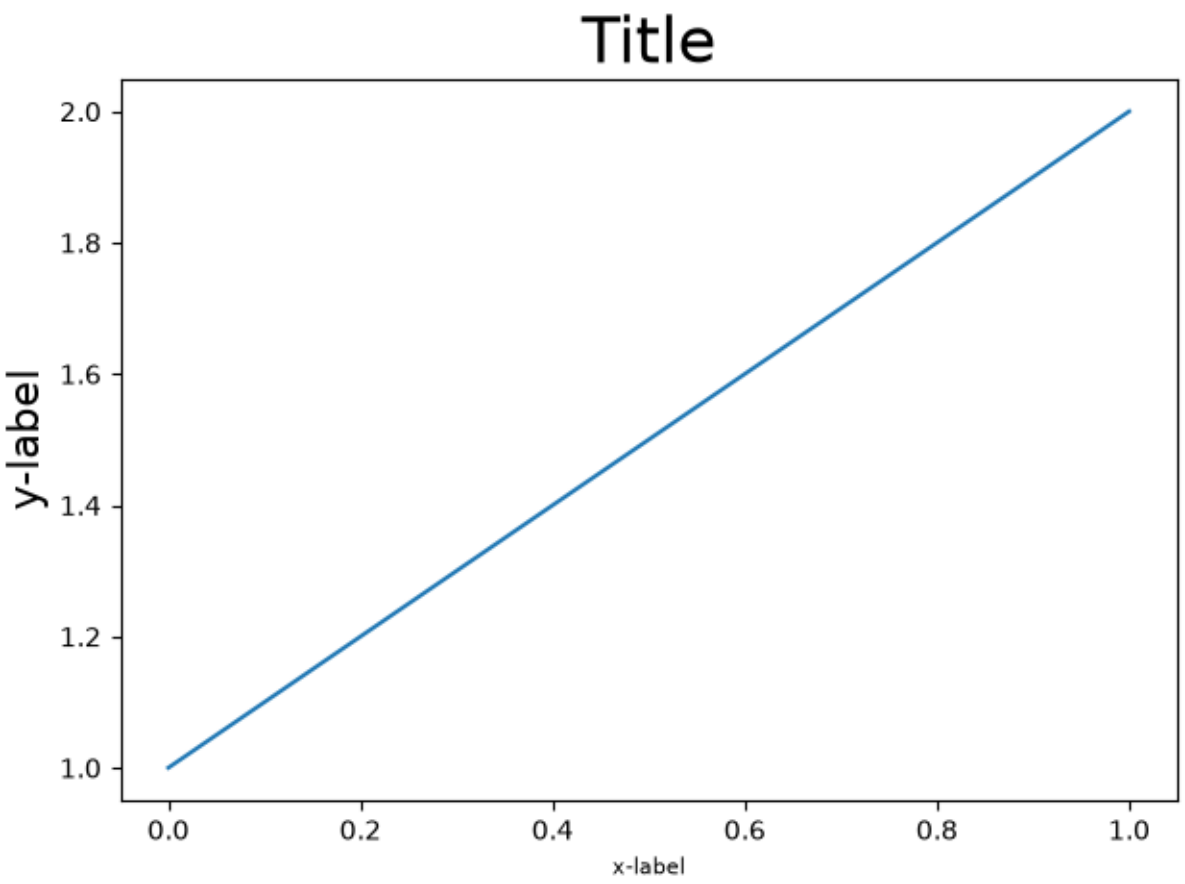
Resize Axes with tight layout

tight_layout attempts to resize subplots in a figure so that there are no overlaps between Axes objects and labels on the Axes.

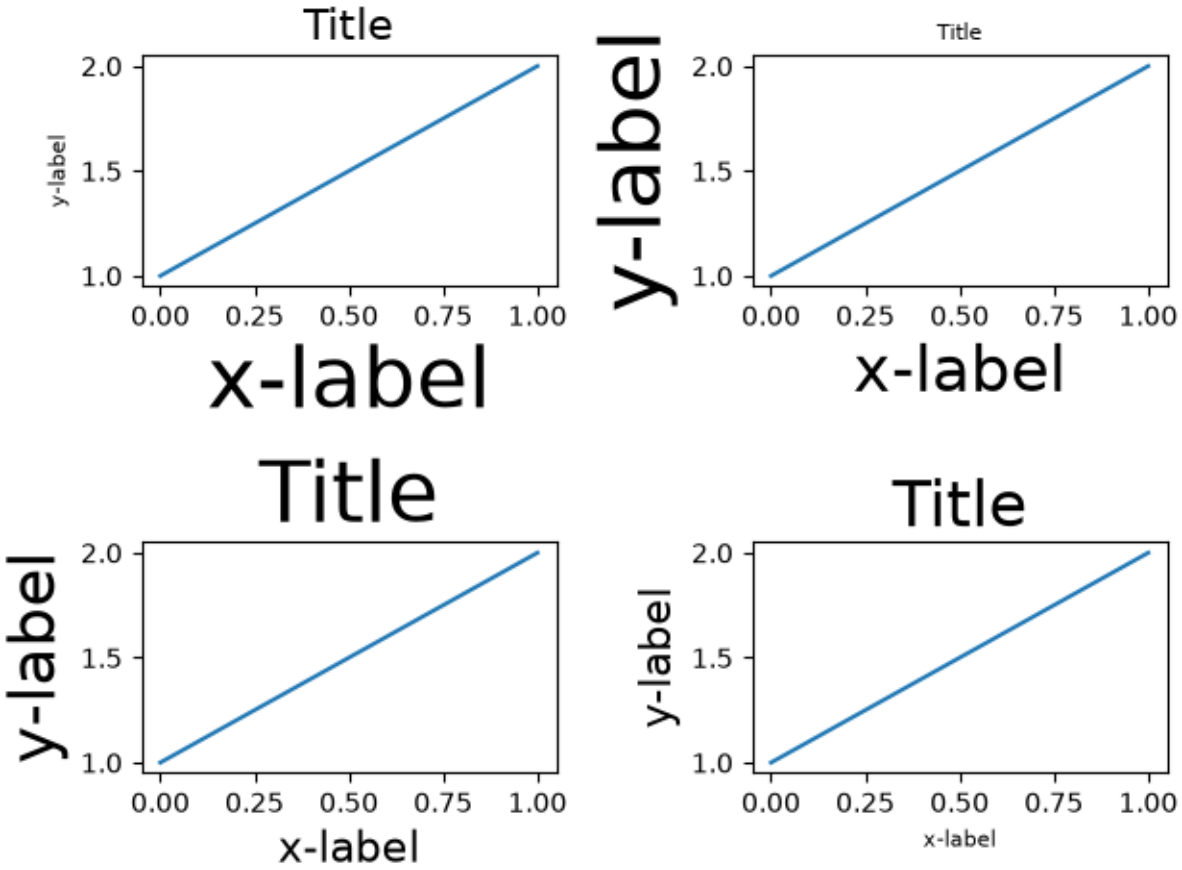
See *Tight layout guide* for more details and *Constrained layout guide* for an alternative.

```
import itertools
import warnings

import matplotlib.pyplot as plt

fontsizes = itertools.cycle([8, 16, 24, 32])


def example_plot(ax):
    ax.plot([1, 2])
    ax.set_xlabel('x-label', fontsize=next(fontsizes))
    ax.set_ylabel('y-label', fontsize=next(fontsizes))
    ax.set_title('Title', fontsize=next(fontsizes))
```

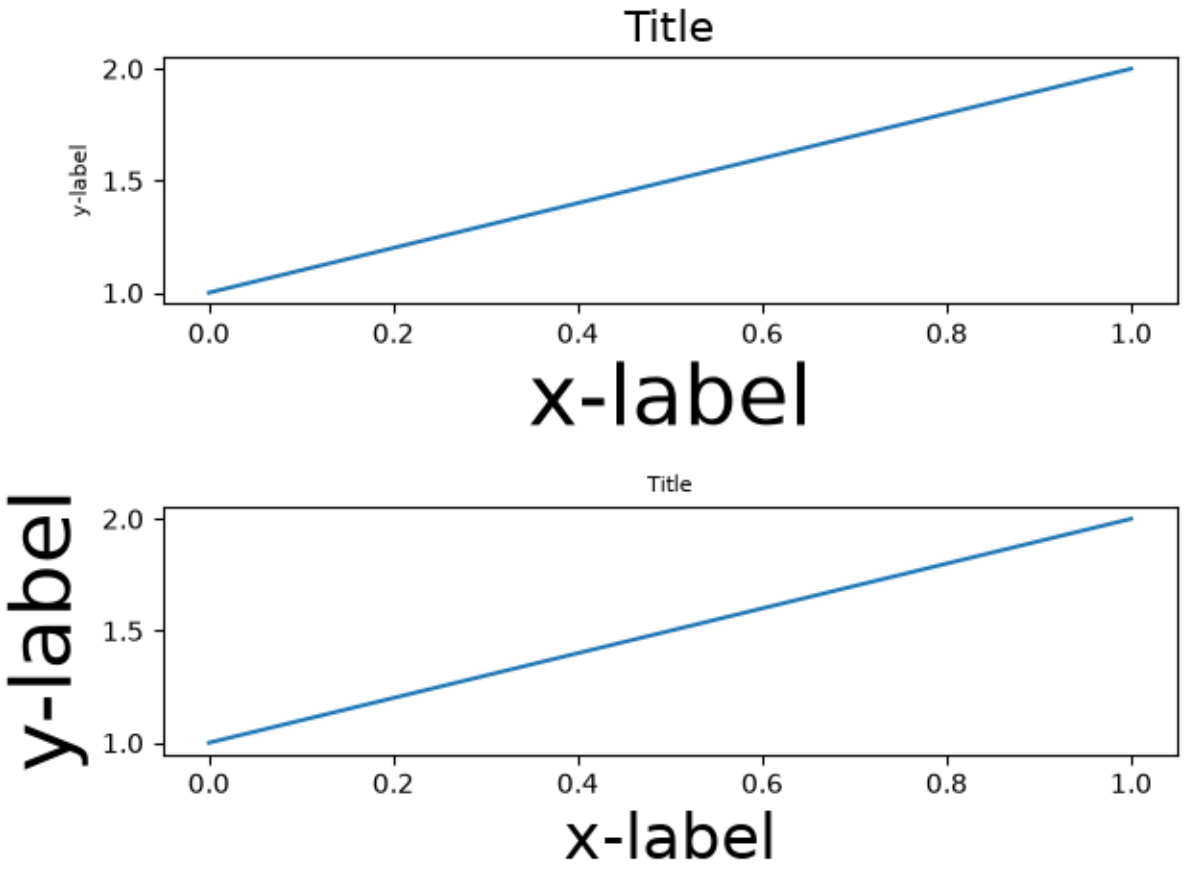
```
fig, ax = plt.subplots()
example_plot(ax)
fig.tight_layout()
```



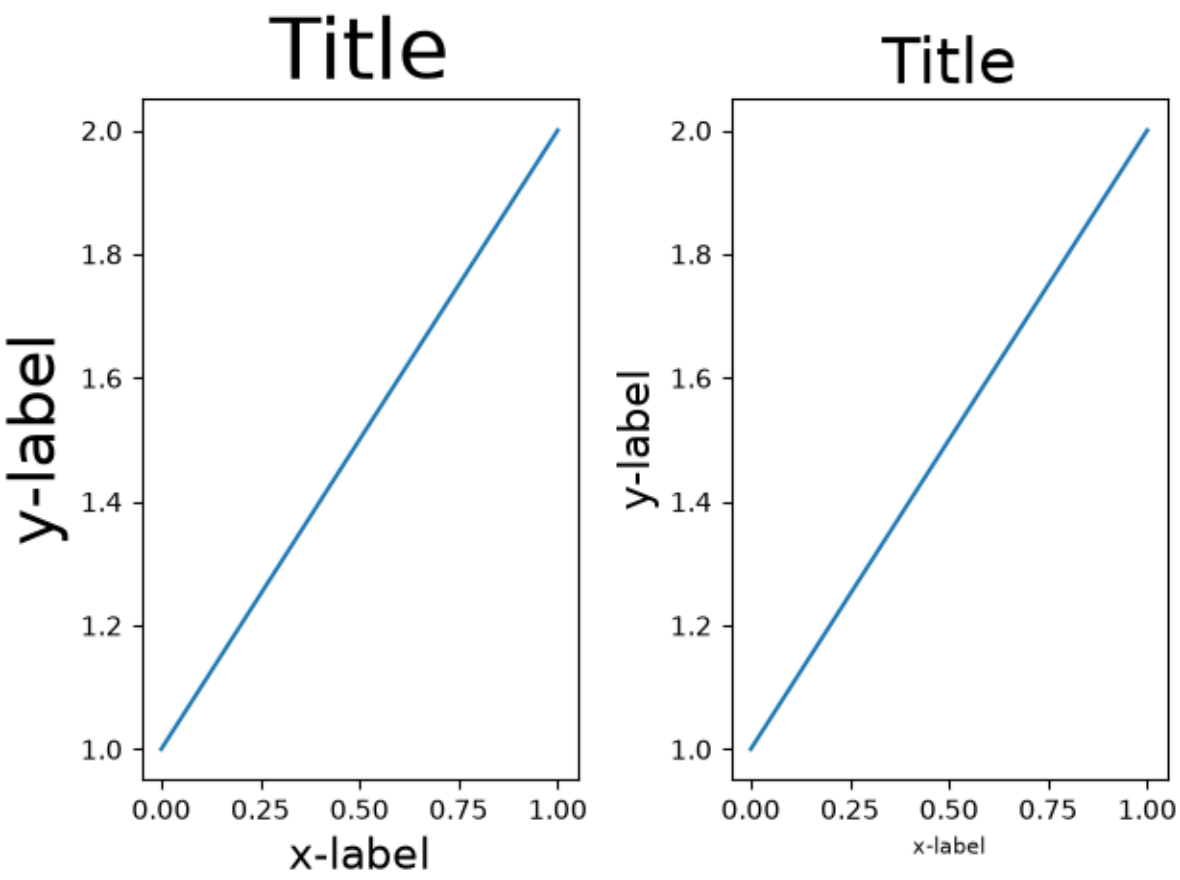

```
fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(nrows=2, ncols=2)
example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
example_plot(ax4)
fig.tight_layout()
```



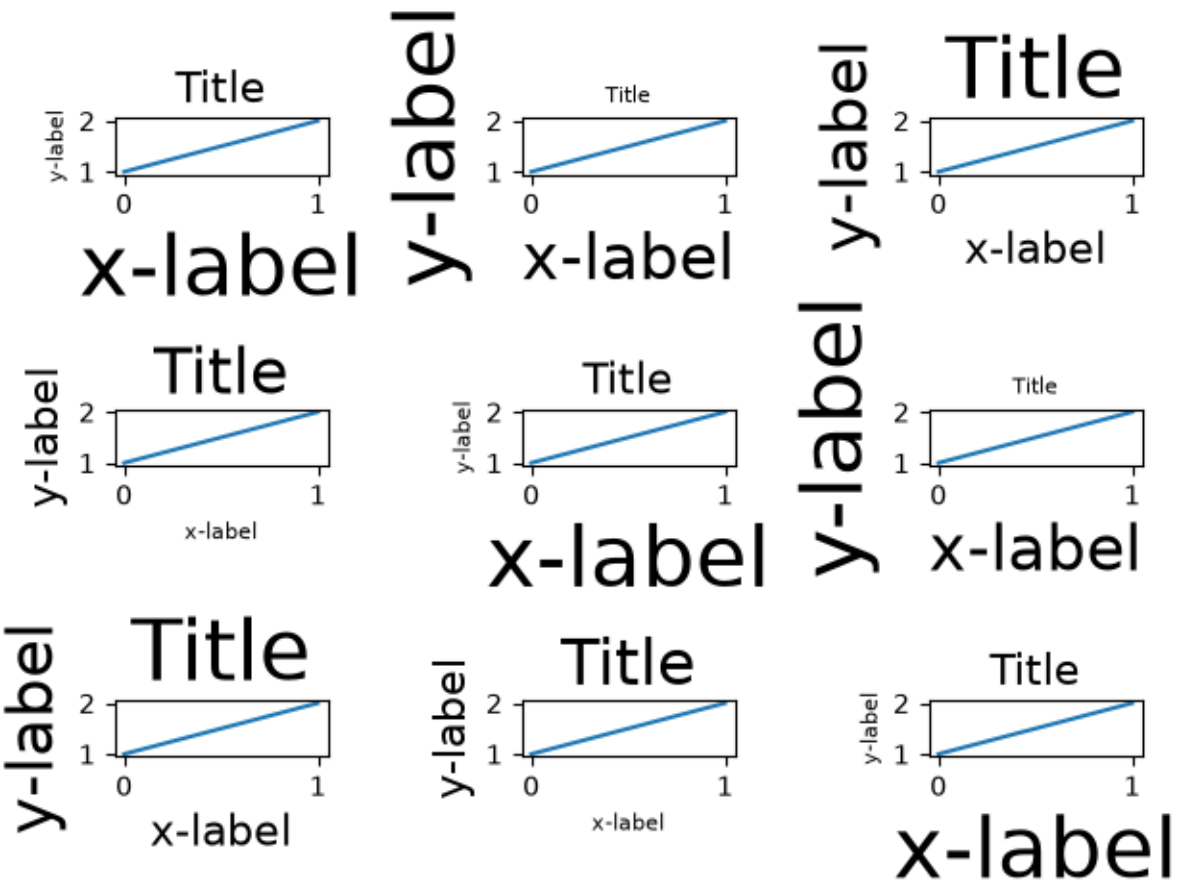

```
fig, (ax1, ax2) = plt.subplots(nrows=2, ncols=1)
example_plot(ax1)
example_plot(ax2)
fig.tight_layout()
```



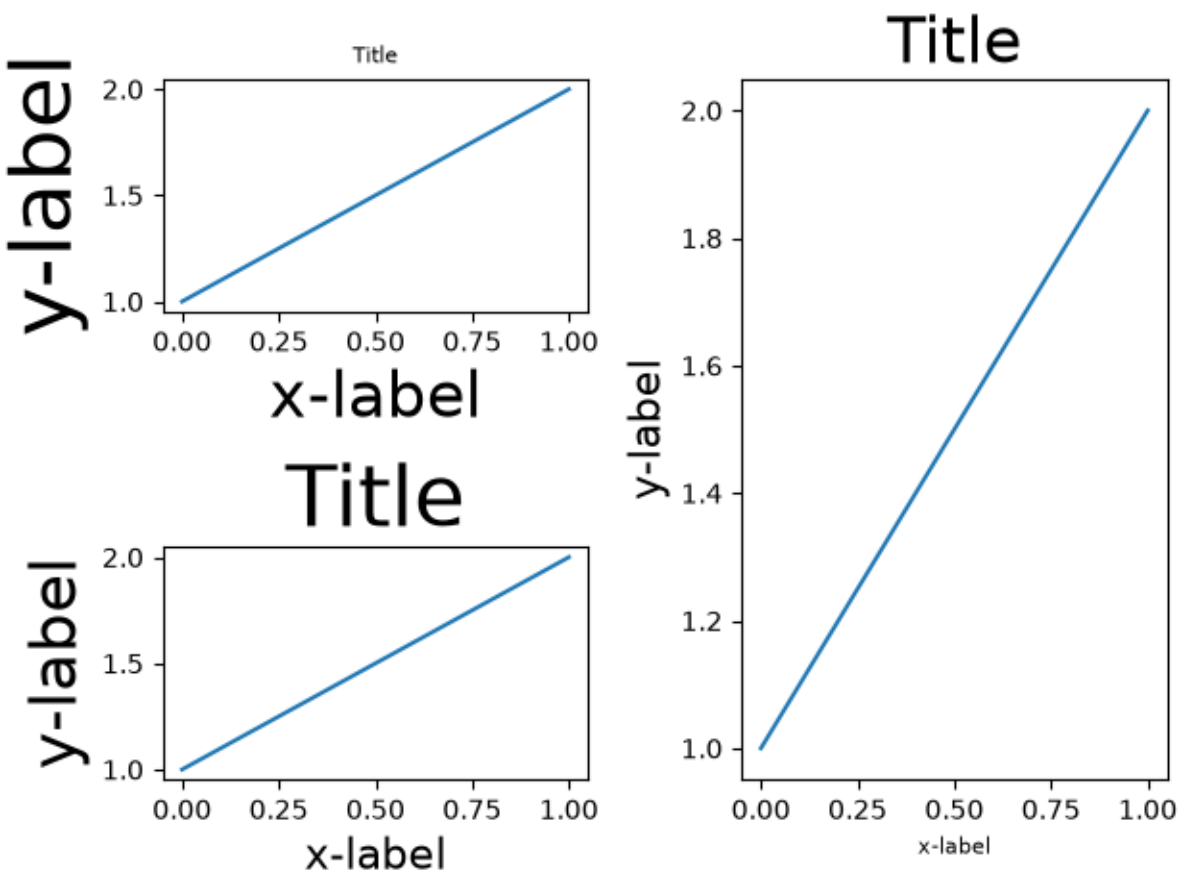

```
fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2)
example_plot(ax1)
example_plot(ax2)
fig.tight_layout()
```



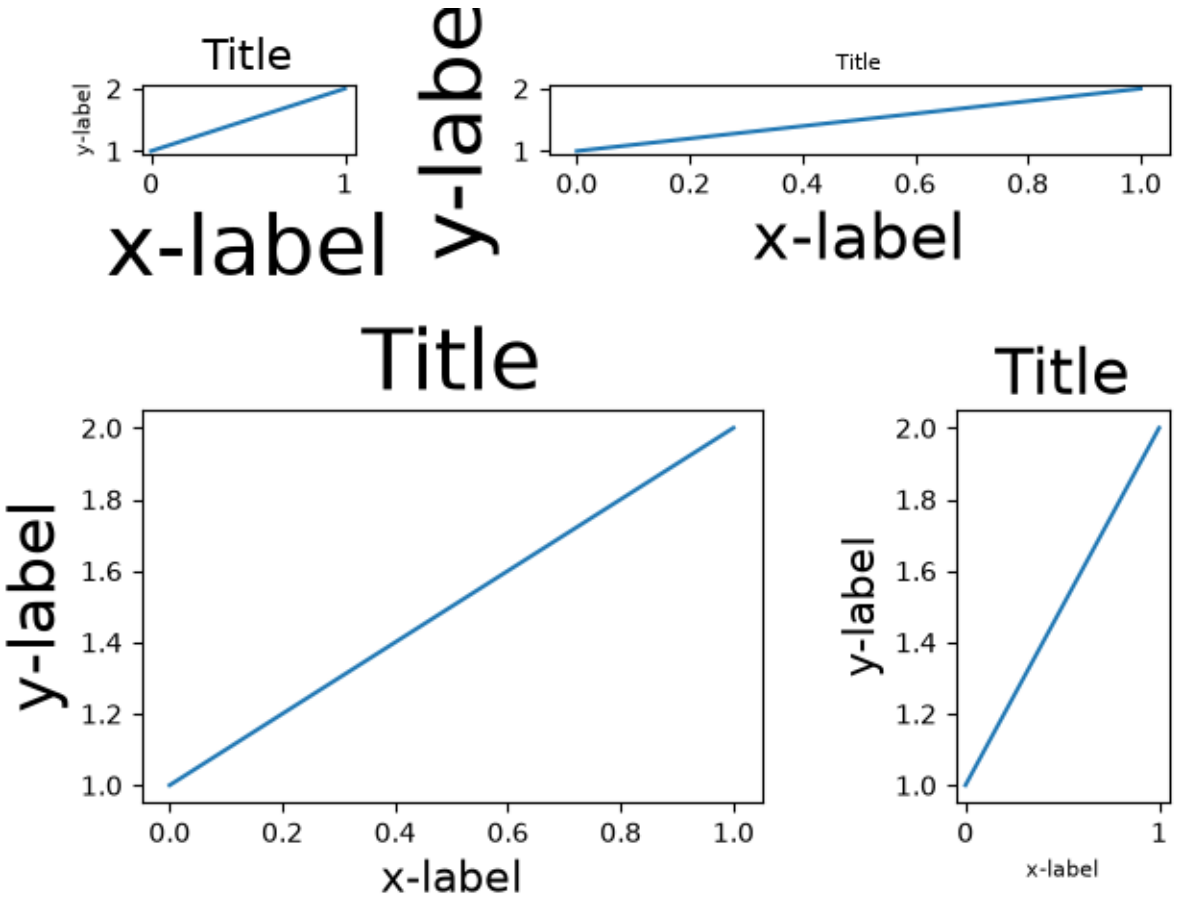

```
fig, axs = plt.subplots(nrows=3, ncols=3)
for ax in axs.flat:
    example_plot(ax)
fig.tight_layout()
```




```
plt.figure()
ax1 = plt.subplot(221)
ax2 = plt.subplot(223)
ax3 = plt.subplot(122)
example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
plt.tight_layout()
```




```
plt.figure()
ax1 = plt.subplot2grid((3, 3), (0, 0))
ax2 = plt.subplot2grid((3, 3), (0, 1), colspan=2)
ax3 = plt.subplot2grid((3, 3), (1, 0), colspan=2, rowspan=2)
ax4 = plt.subplot2grid((3, 3), (1, 2), rowspan=2)
example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
example_plot(ax4)
plt.tight_layout()
```

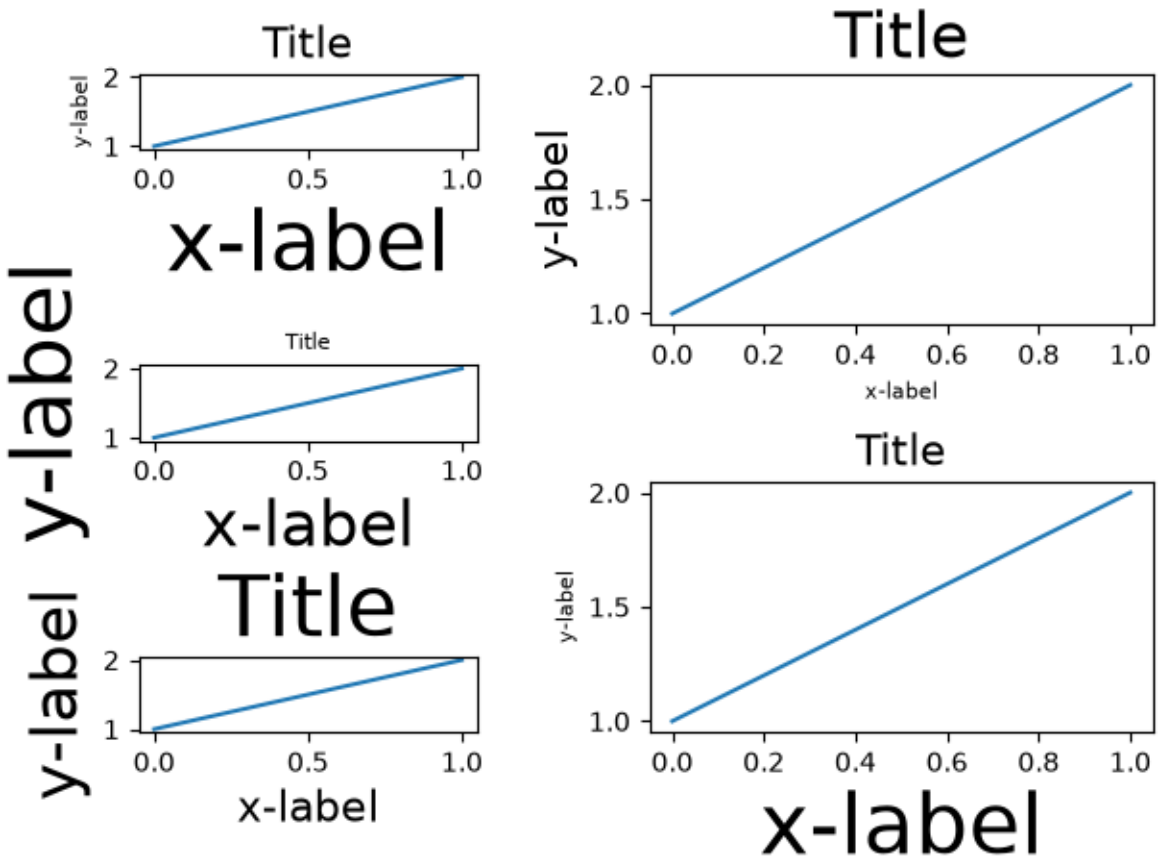



```
fig = plt.figure()

gs1 = fig.add_gridspec(3, 1)
ax1 = fig.add_subplot(gs1[0])
ax2 = fig.add_subplot(gs1[1])
ax3 = fig.add_subplot(gs1[2])
example_plot(ax1)
example_plot(ax2)
example_plot(ax3)
gs1.tight_layout(fig, rect=[None, None, 0.45, None])

gs2 = fig.add_gridspec(2, 1)
ax4 = fig.add_subplot(gs2[0])
ax5 = fig.add_subplot(gs2[1])
example_plot(ax4)
example_plot(ax5)
with warnings.catch_warnings():
    # gs2.tight_layout cannot handle the subplots from the first␣
 ↪gridspec
    # (gs1), so it will raise a warning. We are going to match the␣
```

(continues on next page)

(continued from previous page)

```
↪gridspecs
    # manually so we can filter the warning away.
    warnings.simplefilter("ignore", UserWarning)
    gs2.tight_layout(fig, rect=[0.45, None, None, None])

# now match the top and bottom of two gridspecs.
top = min(gs1.top, gs2.top)
bottom = max(gs1.bottom, gs2.bottom)

gs1.update(top=top, bottom=bottom)
gs2.update(top=top, bottom=bottom)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.figure.Figure.tight_layout* / *matplotlib.pyplot.tight_layout*

- *matplotlib.figure.Figure.add_gridspec*
- *matplotlib.figure.Figure.add_subplot*
- *matplotlib.pyplot.subplot2grid*

Tags: component: axes component: subplot styling: size level: beginner

Total running time of the script: (0 minutes 6.029 seconds)

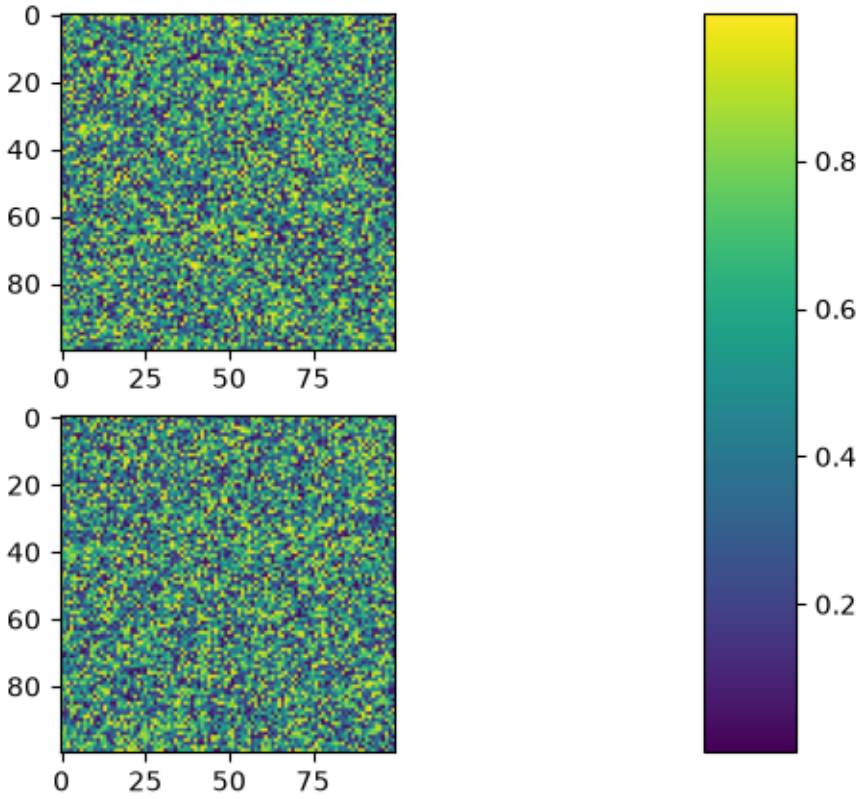
Subplots spacings and margins

Adjusting the spacing of margins and subplots using *pyplot.subplots_adjust*.

Note

There is also a tool window to adjust the margins and spacings of displayed figures interactively. It can be opened via the toolbar or by calling *pyplot.subplot_tool*.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

plt.subplot(211)
plt.imshow(np.random.random((100, 100)))
plt.subplot(212)
plt.imshow(np.random.random((100, 100)))

plt.subplots_adjust(bottom=0.1, right=0.8, top=0.9)
cax = plt.axes((0.85, 0.1, 0.075, 0.8))
plt.colorbar(cax=cax)

plt.show()
```



Tags: component: subplot plot-type: imshow level: beginner

Programmatically control subplot adjustment

Note

This example is primarily intended to show some advanced concepts in Matplotlib.

If you are only looking for having enough space for your labels, it is almost always simpler and good enough to either set the subplot parameters manually using `Figure.subplots_adjust`, or use one of the automatic layout mechanisms (*Constrained layout guide* or *Tight layout guide*).

This example describes a user-defined way to read out Artist sizes and set the subplot parameters accordingly. Its main purpose is to illustrate some advanced concepts like reading out text positions, working with bounding boxes and transforms and using *events*. But it can also serve as a starting point if you want to automate the layouting and need more flexibility than tight layout and constrained layout.

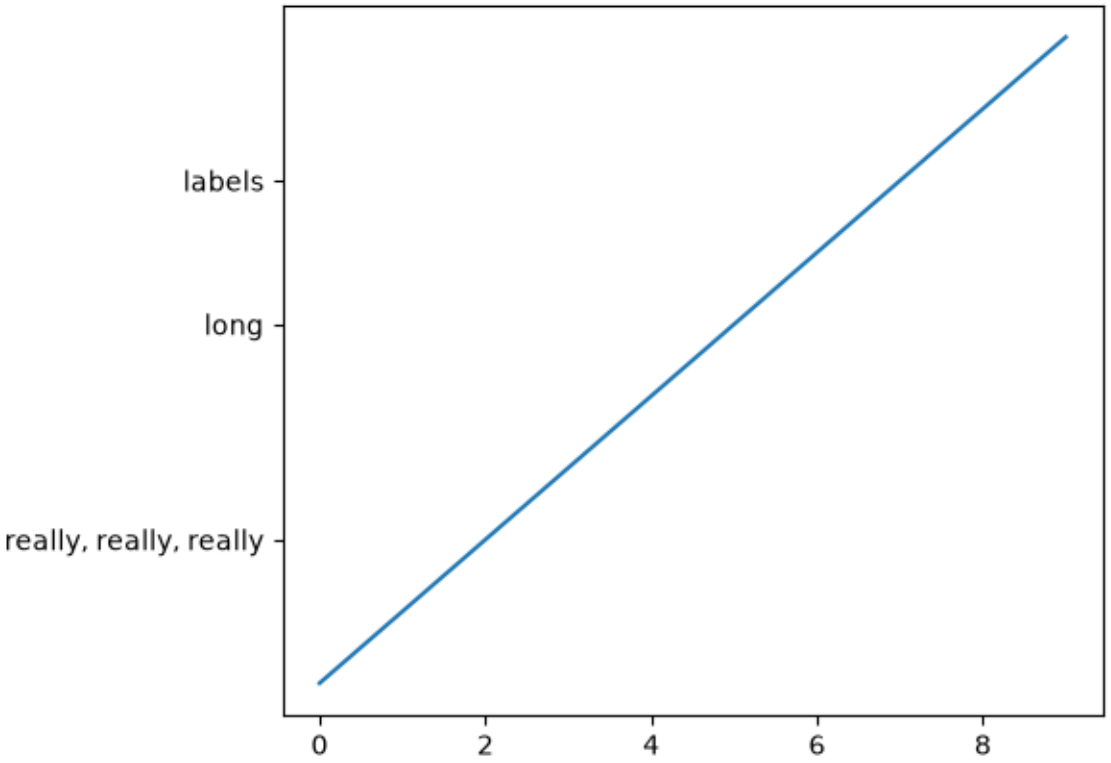
Below, we collect the bounding boxes of all y-labels and move the left border of the subplot to the right so that it leaves enough room for the union of all the bounding boxes.

There's one catch with calculating text bounding boxes: Querying the text bounding boxes (`Text.get_window_extent`) needs a renderer (`RendererBase` instance), to calculate the text size. This

renderer is only available after the figure has been drawn (*Figure.draw*).

A solution to this is putting the adjustment logic in a draw callback. This function is executed after the figure has been drawn. It can now check if the subplot leaves enough room for the text. If not, the subplot parameters are updated and second draw is triggered.

```
import matplotlib.pyplot as plt

import matplotlib.transforms as mtransforms

fig, ax = plt.subplots()
ax.plot(range(10))
ax.set_yticks([2, 5, 7], labels=['really, really, really', 'long',
 ↪'labels'])


def on_draw(event):
    bboxes = []
    for label in ax.get_yticklabels():
        # Bounding box in pixels
        bbox_px = label.get_window_extent()
        # Transform to relative figure coordinates. This is the␣
 ↪inverse of
        # transFigure.
        bbox_fig = bbox_px.transformed(fig.transFigure.inverted())
        bboxes.append(bbox_fig)
    # the bbox that bounds all the bboxes, again in relative figure␣
 ↪coords
    bbox = mtransforms.Bbox.union(bboxes)
    if fig.subplotpars.left < bbox.width:
        # Move the subplot left edge more to the right
        fig.subplots_adjust(left=1.1*bbox.width)  # pad a little
        fig.canvas.draw()


fig.canvas.mpl_connect('draw_event', on_draw)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.artist.Artist.get_window_extent*
- *matplotlib.transforms.Bbox*
- *matplotlib.transforms.BboxBase.transformed*
- *matplotlib.transforms.BboxBase.union*
- *matplotlib.transforms.Transform.inverted*
- *matplotlib.figure.Figure.subplots_adjust*
- *matplotlib.gridspec.SubplotParams*
- *matplotlib.backend_bases.FigureCanvasBase.mpl_connect*

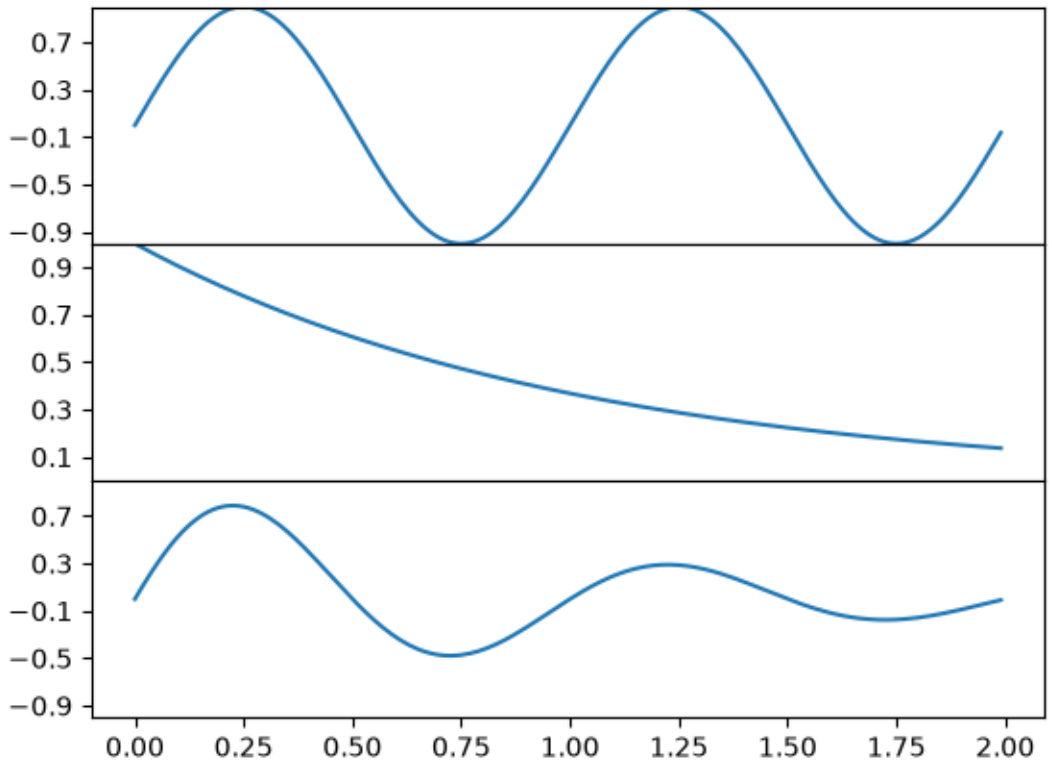
Tags: component: subplot plot-type: line styling: position level: advanced

Adjacent subplots

To create plots that share a common axis (visually) you can set the hspace between the subplots to zero. Passing sharex=True when creating the subplots will automatically turn off all x ticks and labels except those on the bottom axis.

In this example the plots share a common x-axis, but you can follow the same logic to supply a common y-axis.

```
import matplotlib.pyplot as plt
import numpy as np

t = np.arange(0.0, 2.0, 0.01)

s1 = np.sin(2 * np.pi * t)
s2 = np.exp(-t)
s3 = s1 * s2

fig, axs = plt.subplots(3, 1, sharex=True)
# Remove vertical space between Axes
fig.subplots_adjust(hspace=0)

# Plot each graph, and manually set the y tick values
axs[0].plot(t, s1)
axs[0].set_yticks(np.arange(-0.9, 1.0, 0.4))
axs[0].set_ylim(-1, 1)

axs[1].plot(t, s2)
axs[1].set_yticks(np.arange(0.1, 1.0, 0.2))
axs[1].set_ylim(0, 1)

axs[2].plot(t, s3)
axs[2].set_yticks(np.arange(-0.9, 1.0, 0.4))
axs[2].set_ylim(-1, 1)

plt.show()
```



Tags: component: subplot plot-type: line level: beginner

Controlling view limits using margins and sticky_edges

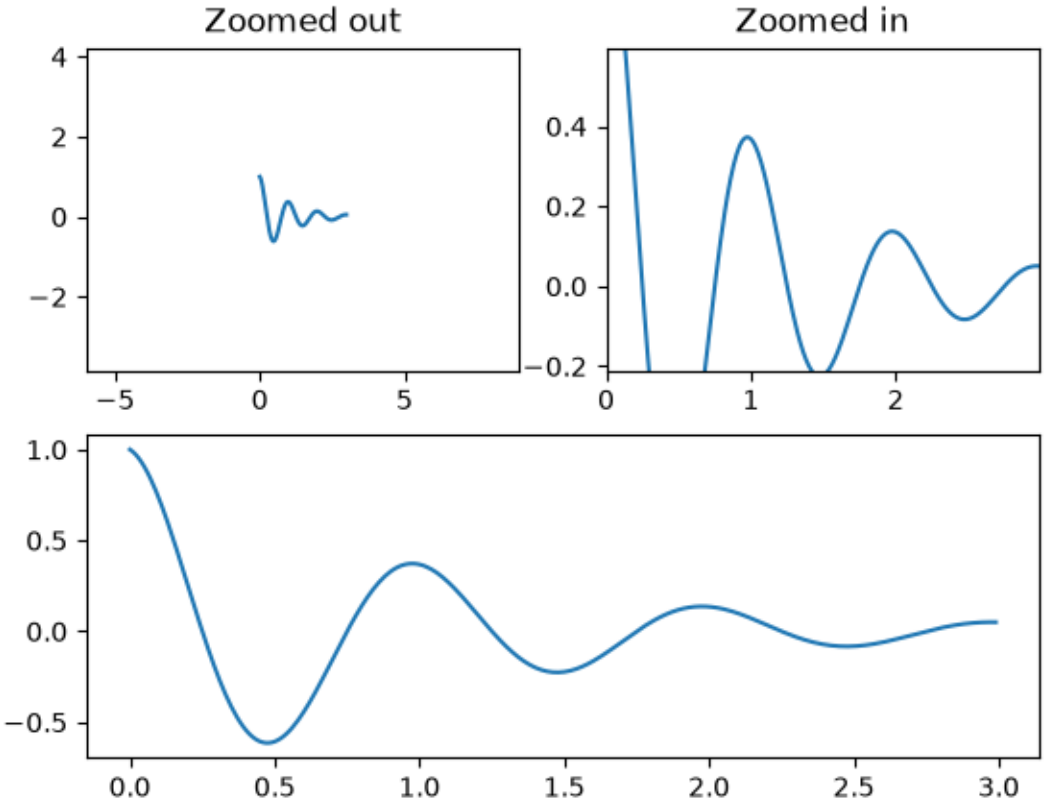
The first figure in this example shows how to zoom in and out of a plot using *margins* instead of *set_xlim* and *set_ylim*. The second figure demonstrates the concept of edge "stickiness" introduced by certain methods and artists and how to effectively work around that.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Polygon


def f(t):
    return np.exp(-t) * np.cos(2*np.pi*t)


t1 = np.arange(0.0, 3.0, 0.01)

ax1 = plt.subplot(212)
```

(continues on next page)

(continued from previous page)

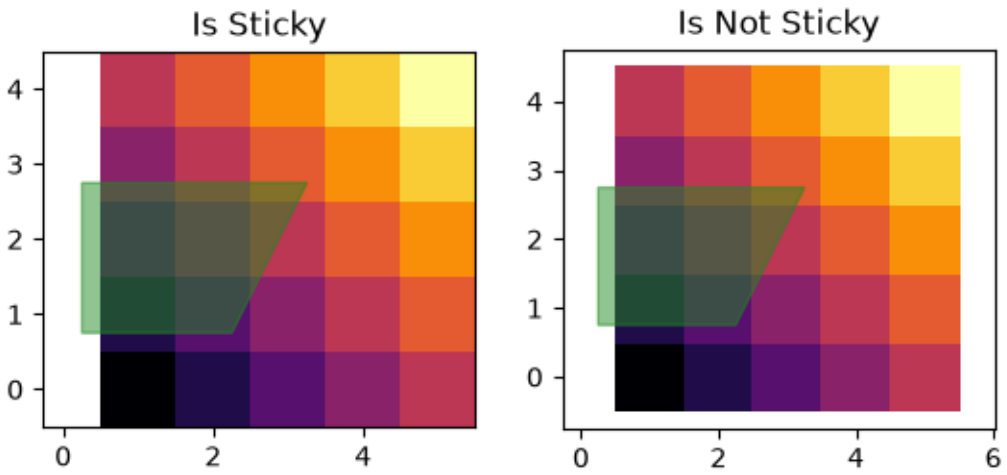
```
ax1.margins(0.05)           # Default margin is 0.05, value 0 means fit
ax1.plot(t1, f(t1))

ax2 = plt.subplot(221)
ax2.margins(2, 2)           # Values >0.0 zoom out
ax2.plot(t1, f(t1))
ax2.set_title('Zoomed out')

ax3 = plt.subplot(222)
ax3.margins(x=0, y=-0.25)   # Values in (-0.5, 0.0) zooms in to center
ax3.plot(t1, f(t1))
ax3.set_title('Zoomed in')

plt.show()
```



On the "stickiness" of certain plotting methods

Some plotting functions make the axis limits "sticky" or immune to the will of the *margins* methods. For instance, *imshow* and *pcolor* expect the user to want the limits to be tight around the pixels shown in the plot. If this behavior is not desired, you need to set *use_sticky_edges* to `False`. Consider the following example:

```
y, x = np.mgrid[:5, 1:6]
poly_coords = [
    (0.25, 2.75), (3.25, 2.75),
    (2.25, 0.75), (0.25, 0.75)
]
fig, (ax1, ax2) = plt.subplots(ncols=2)

# Here we set the stickiness of the Axes object...
# ax1 we'll leave as the default, which uses sticky edges
# and we'll turn off stickiness for ax2
ax2.use_sticky_edges = False

for ax, status in zip((ax1, ax2), ('Is', 'Is Not')):
    cells = ax.pcolor(x, y, x+y, cmap='inferno', shading='auto')  #␣
 ↪sticky
    ax.add_patch(
        Polygon(poly_coords, color='forestgreen', alpha=0.5)
    )  # not sticky
    ax.margins(x=0.1, y=0.05)
    ax.set_aspect('equal')
    ax.set_title(f'{status} Sticky')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.margins* / *matplotlib.pyplot.margins*
- *matplotlib.axes.Axes.use_sticky_edges*
- *matplotlib.axes.Axes.pcolor* / *matplotlib.pyplot.pcolor*
- *matplotlib.patches.Polygon*

Tags: component: axes plot-type: line plot-type: imshow plot-type: pcolor level: beginner

Axes box aspect

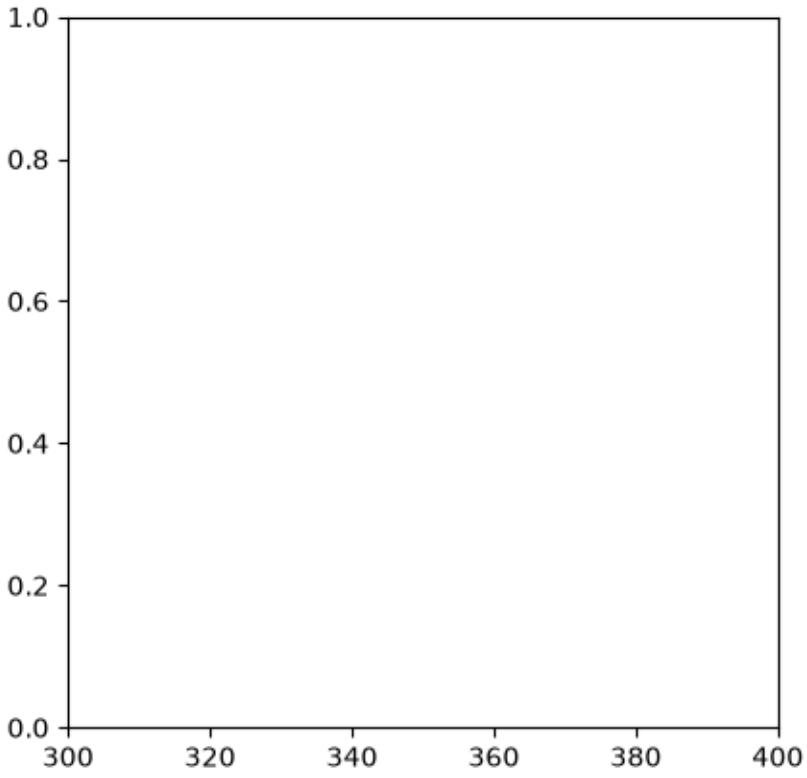
This demo shows how to set the aspect of an Axes box directly via *set_box_aspect*. The box aspect is the ratio between Axes height and Axes width in physical units, independent of the data limits. This is useful to e.g. produce a square plot, independent of the data it contains, or to have a usual plot with the same axes dimensions next to an image plot with fixed (data-)aspect.

The following lists a few use cases for *set_box_aspect*.

A square Axes, independent of data

Produce a square Axes, no matter what the data limits are.

```
import matplotlib.pyplot as plt
import numpy as np

fig1, ax = plt.subplots()

ax.set_xlim(300, 400)
ax.set_box_aspect(1)

plt.show()
```



Shared square Axes

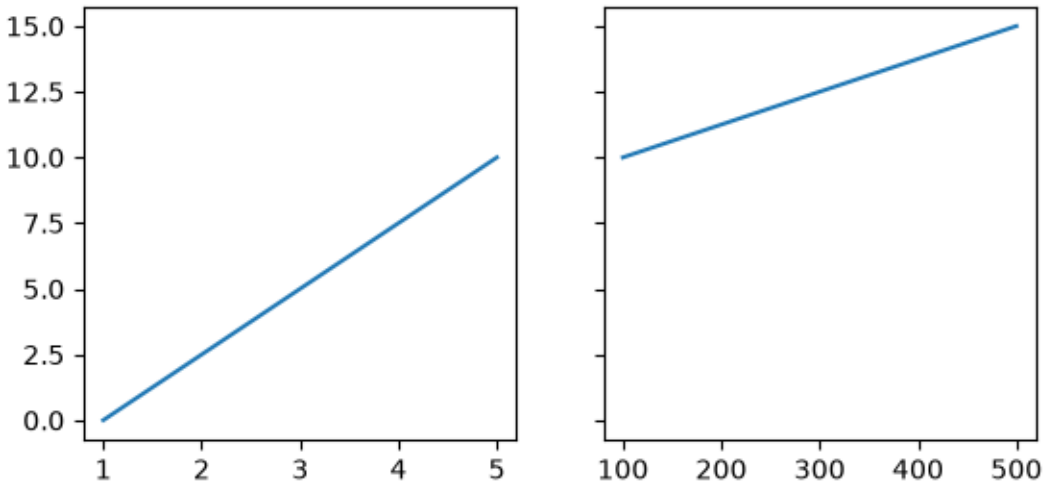
Produce shared subplots that are squared in size.

```
fig2, (ax, ax2) = plt.subplots(ncols=2, sharey=True)

ax.plot([1, 5], [0, 10])
```

(continues on next page)

(continued from previous page)

```
ax2.plot([100, 500], [10, 15])

ax.set_box_aspect(1)
ax2.set_box_aspect(1)

plt.show()
```



Square twin Axes

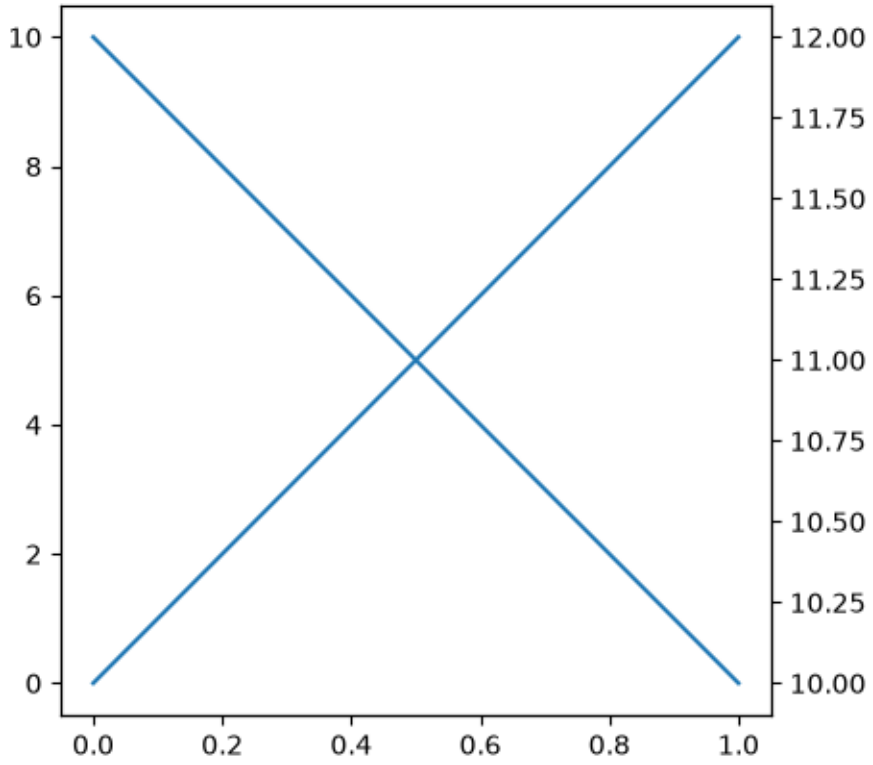
Produce a square Axes, with a twin Axes. The twinned Axes takes over the box aspect of the parent.

```
fig3, ax = plt.subplots()

ax2 = ax.twinx()

ax.plot([0, 10])
ax2.plot([12, 10])

ax.set_box_aspect(1)
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



Normal plot next to image

When creating an image plot with fixed data aspect and the default `adjustable="box"` next to a normal plot, the Axes would be unequal in height. *`set_box_aspect`* provides an easy solution to that by allowing to have the normal plot's Axes use the images dimensions as box aspect.

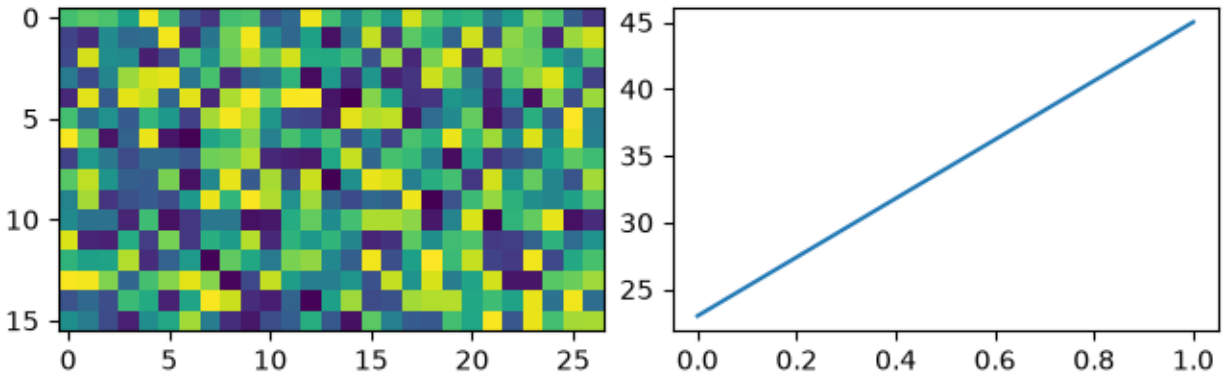
This example also shows that *constrained layout* interplays nicely with a fixed box aspect.

```
fig4, (ax, ax2) = plt.subplots(ncols=2, layout="constrained")

np.random.seed(19680801)  # Fixing random state for reproducibility
im = np.random.rand(16, 27)
ax.imshow(im)

ax2.plot([23, 45])
ax2.set_box_aspect(im.shape[0]/im.shape[1])
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



Square joint/marginal plot

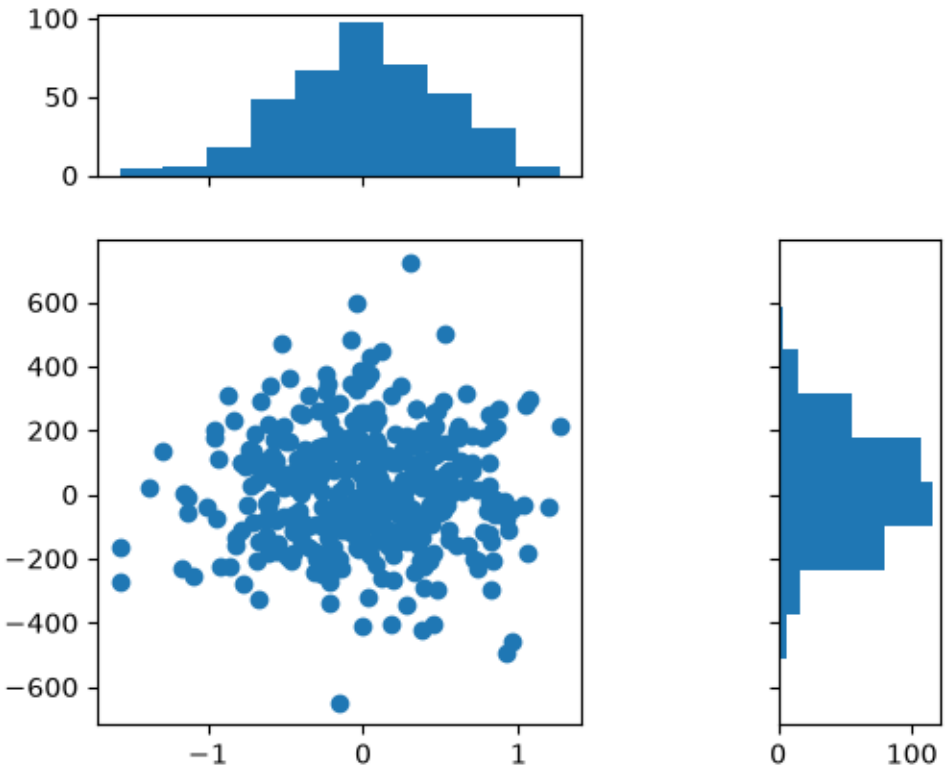
It may be desirable to show marginal distributions next to a plot of joint data. The following creates a square plot with the box aspect of the marginal Axes being equal to the width- and height-ratios of the gridspec. This ensures that all Axes align perfectly, independent on the size of the figure.

```
fig5, axs = plt.subplots(2, 2, sharex="col", sharey="row",
                         gridspec_kw=dict(height_ratios=[1, 3],
                                          width_ratios=[3, 1]))
axs[0, 1].set_visible(False)
axs[0, 0].set_box_aspect(1/3)
axs[1, 0].set_box_aspect(1)
axs[1, 1].set_box_aspect(3/1)

np.random.seed(19680801)  # Fixing random state for reproducibility
x, y = np.random.randn(2, 400) * [[.5], [180]]
axs[1, 0].scatter(x, y)
```

(continues on next page)

(continued from previous page)

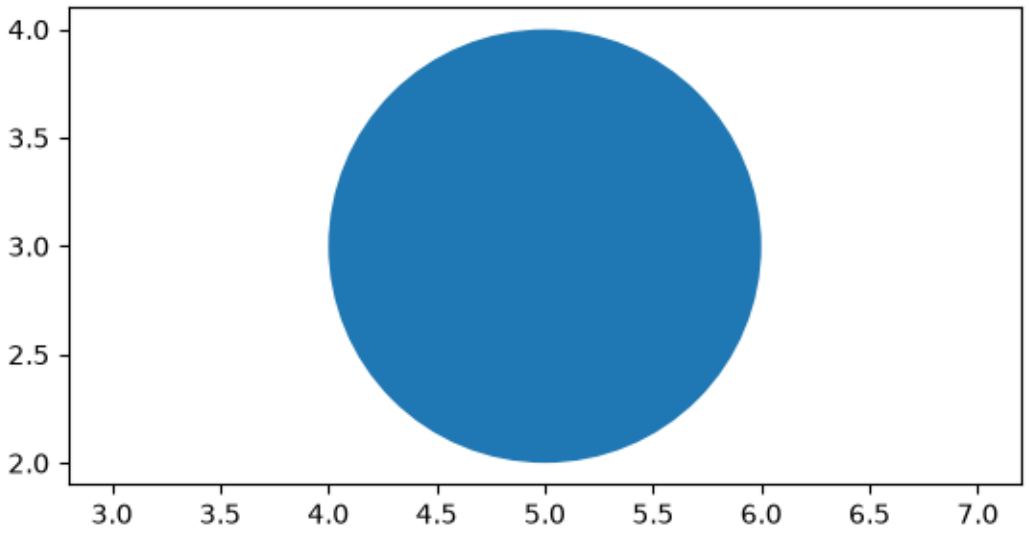
```
axs[0, 0].hist(x)
axs[1, 1].hist(y, orientation="horizontal")

plt.show()
```



Set data aspect with box aspect

When setting the box aspect, one may still set the data aspect as well. Here we create an Axes with a box twice as long as it is tall and use an "equal" data aspect for its contents, i.e. the circle actually stays circular.

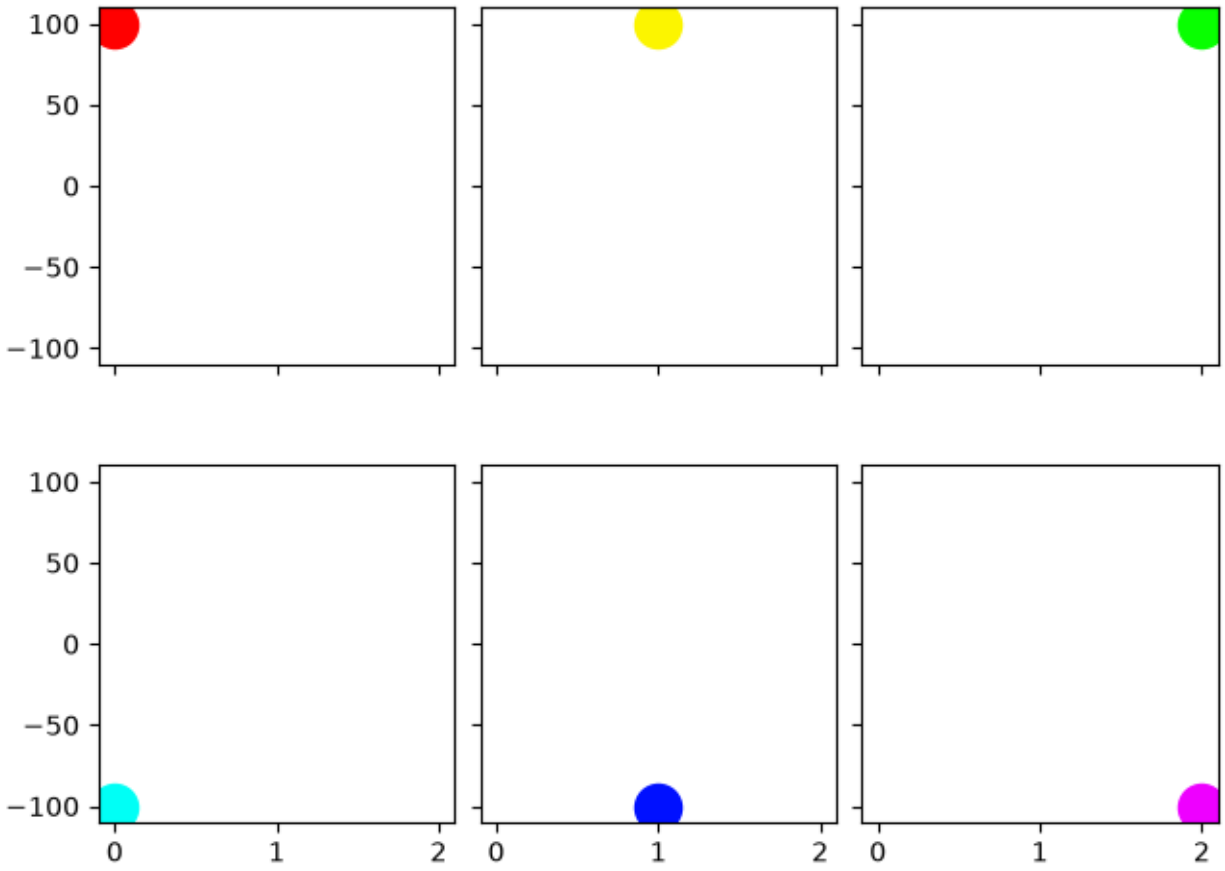
```
fig6, ax = plt.subplots()

ax.add_patch(plt.Circle((5, 3), 1))
ax.set_aspect("equal", adjustable="datalim")
ax.set_box_aspect(0.5)
ax.autoscale()

plt.show()
```



Box aspect for many subplots

It is possible to pass the box aspect to an Axes at initialization. The following creates a 2 by 3 subplot grid with all square Axes.

```
fig7, axs = plt.subplots(2, 3, subplot_kw=dict(box_aspect=1),
                         sharex=True, sharey=True, layout="constrained
 ↪")

for i, ax in enumerate(axs.flat):
    ax.scatter(i % 3, -((i // 3) - 0.5)*200, c=[plt.colormaps["hsv"](i␣
 ↪/ 6)], s=300)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.set_box_aspect*

Tags: component: axes styling: size level: beginner

Total running time of the script: (0 minutes 3.005 seconds)

Equal axis aspect ratio

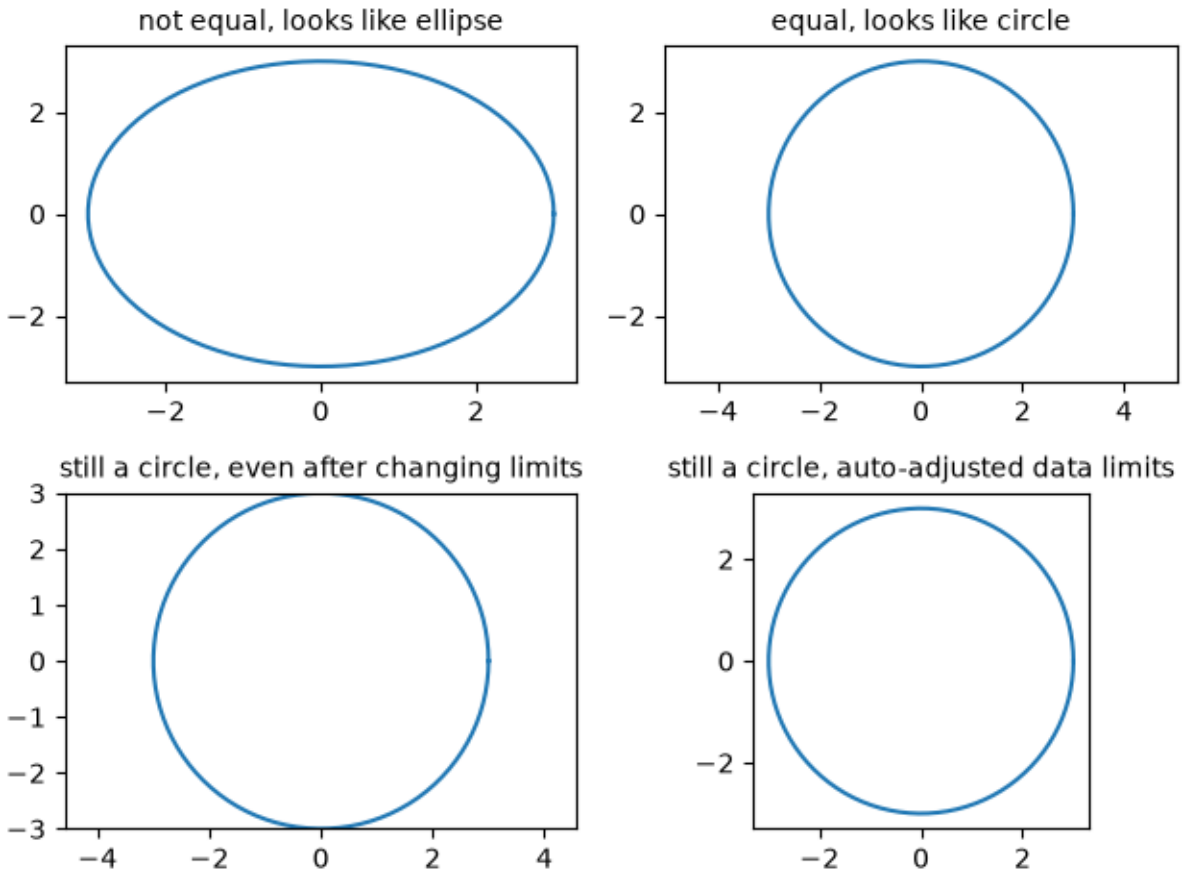
How to set and adjust plots with equal axis aspect ratios.

```
import matplotlib.pyplot as plt
import numpy as np

# Plot circle of radius 3.

an = np.linspace(0, 2 * np.pi, 100)
fig, axs = plt.subplots(2, 2)
```

(continues on next page)

(continued from previous page)

```
axs[0, 0].plot(3 * np.cos(an), 3 * np.sin(an))
axs[0, 0].set_title('not equal, looks like ellipse', fontsize=10)

axs[0, 1].plot(3 * np.cos(an), 3 * np.sin(an))
axs[0, 1].axis('equal')
axs[0, 1].set_title('equal, looks like circle', fontsize=10)

axs[1, 0].plot(3 * np.cos(an), 3 * np.sin(an))
axs[1, 0].axis('equal')
axs[1, 0].set(xlim=(-3, 3), ylim=(-3, 3))
axs[1, 0].set_title('still a circle, even after changing limits',␣
 ↪fontsize=10)

axs[1, 1].plot(3 * np.cos(an), 3 * np.sin(an))
axs[1, 1].set_aspect('equal', 'box')
axs[1, 1].set_title('still a circle, auto-adjusted data limits',␣
 ↪fontsize=10)

fig.tight_layout()

plt.show()
```




```
Ignoring fixed x limits to fulfill fixed data aspect with adjustable␣
↪data limits.
```

Tags: component: axes styling: size plot-type: line level: beginner

Manage multiple figures in pyplot

`matplotlib.pyplot` uses the concept of a *current figure* and *current Axes*. Figures are identified via a figure number that is passed to `figure`. The figure with the given number is set as *current figure*. Additionally, if no figure with the number exists, a new one is created.

Note

We discourage working with multiple figures through the implicit pyplot interface because managing the *current figure* is cumbersome and error-prone. Instead, we recommend using the explicit approach and call methods on Figure and Axes instances. See *Matplotlib Application Interfaces (APIs)* for an explanation of the trade-offs between the implicit and explicit interfaces.

```
import matplotlib.pyplot as plt
import numpy as np
```

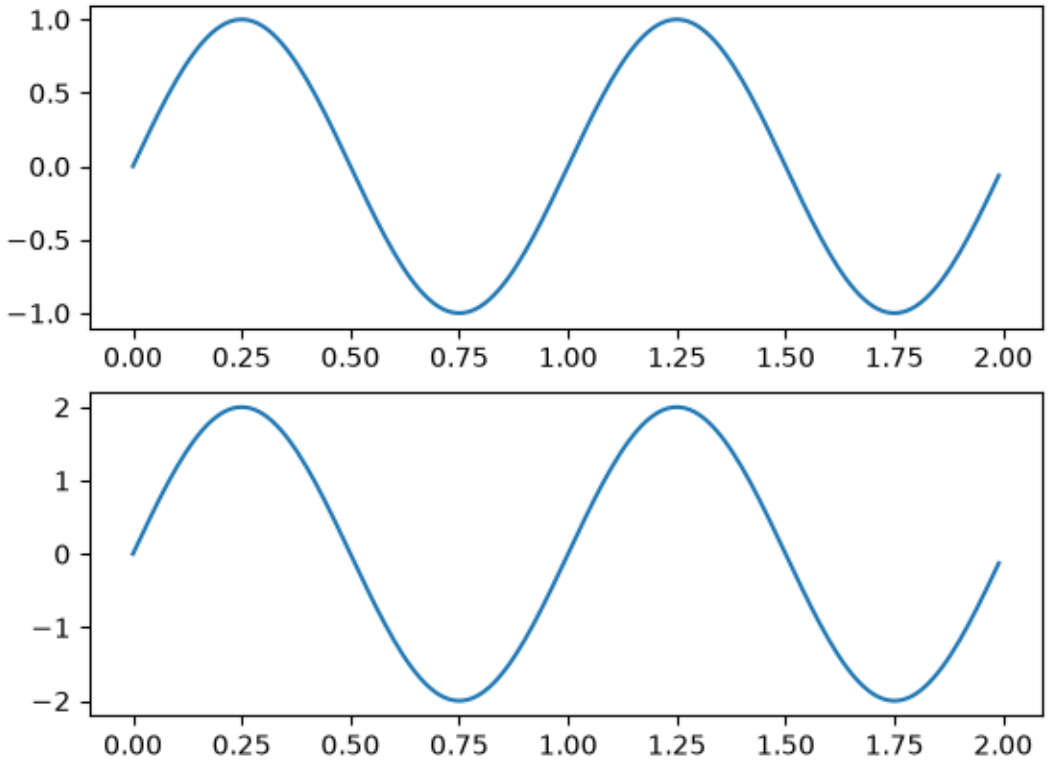
(continues on next page)

(continued from previous page)

```
t = np.arange(0.0, 2.0, 0.01)
s1 = np.sin(2*np.pi*t)
s2 = np.sin(4*np.pi*t)
```

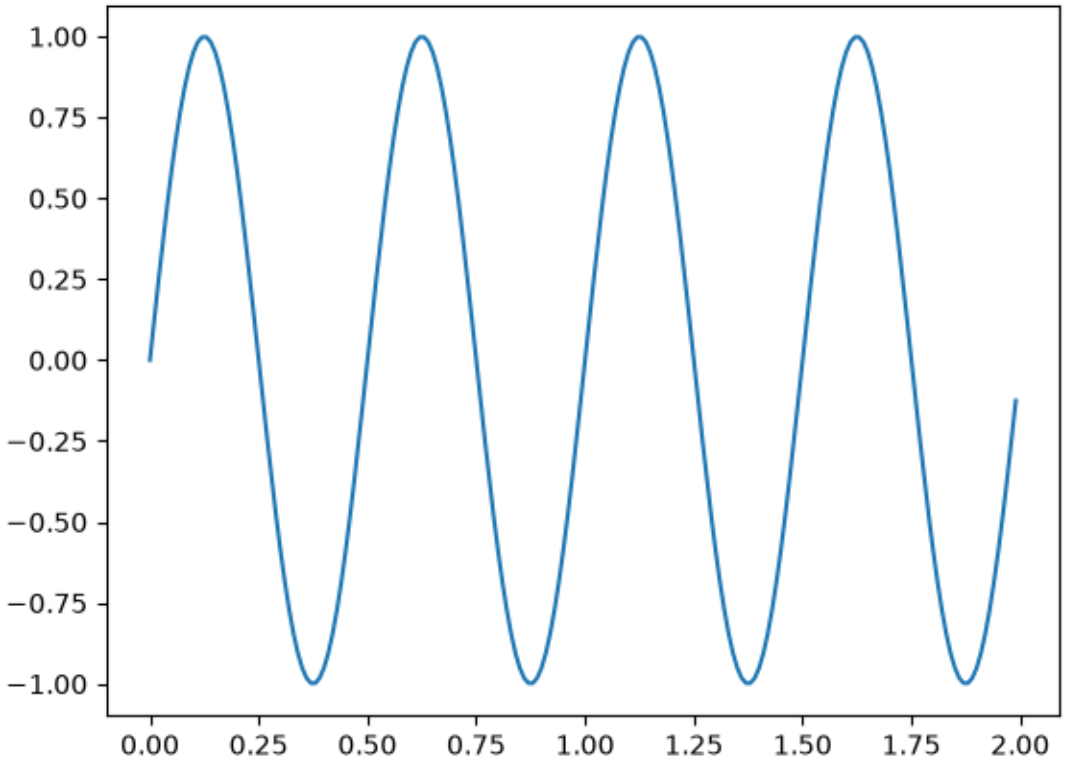
Create figure 1

```
plt.figure(1)
plt.subplot(211)
plt.plot(t, s1)
plt.subplot(212)
plt.plot(t, 2*s1)
```



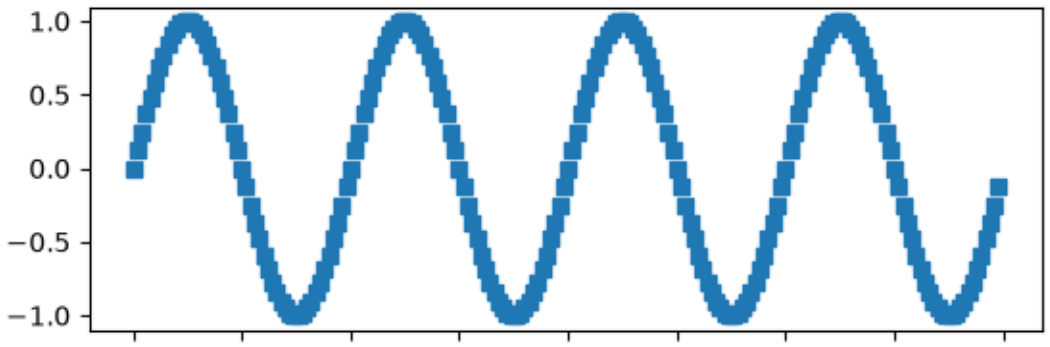
Create figure 2

```
plt.figure(2)
plt.plot(t, s2)
```



Now switch back to figure 1 and make some changes

```
plt.figure(1)
plt.subplot(211)
plt.plot(t, s2, 's')
ax = plt.gca()
ax.set_xticklabels([])

plt.show()
```



Tags: component: figure plot-type: line

Total running time of the script: (0 minutes 1.082 seconds)

Figure size in different units

The native figure size unit in Matplotlib is inches, deriving from print industry standards. However, users may need to specify their figures in other units like centimeters or pixels. This example illustrates how to do this efficiently.

```
import matplotlib.pyplot as plt

text_kwargs = dict(ha='center', va='center', fontsize=28, color='C1')
```

Figure size in inches (default)

```
plt.subplots(figsize=(6, 2))
plt.text(0.5, 0.5, '6 inches x 2 inches', **text_kwargs)
plt.show()
```

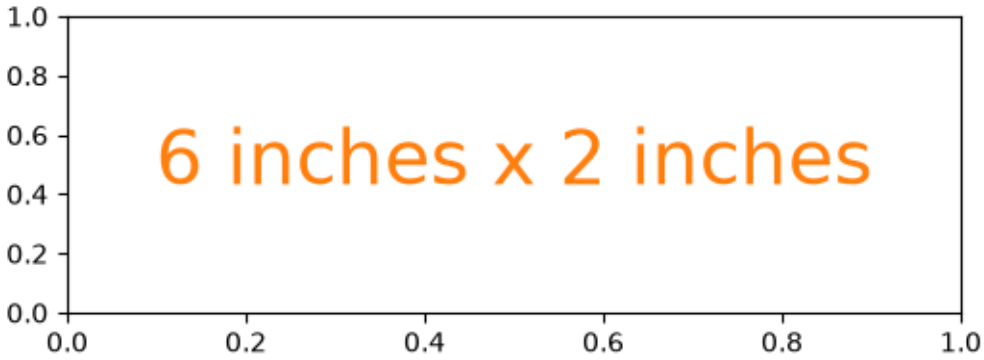


Figure size in centimeter

Multiplying centimeter-based numbers with a conversion factor from cm to inches, gives the right numbers. Naming the conversion factor `cm` makes the conversion almost look like appending a unit to the number, which is nicely readable.

```
cm = 1/2.54  # centimeters in inches
plt.subplots(figsize=(15*cm, 5*cm))
plt.text(0.5, 0.5, '15cm x 5cm', **text_kwargs)
plt.show()
```

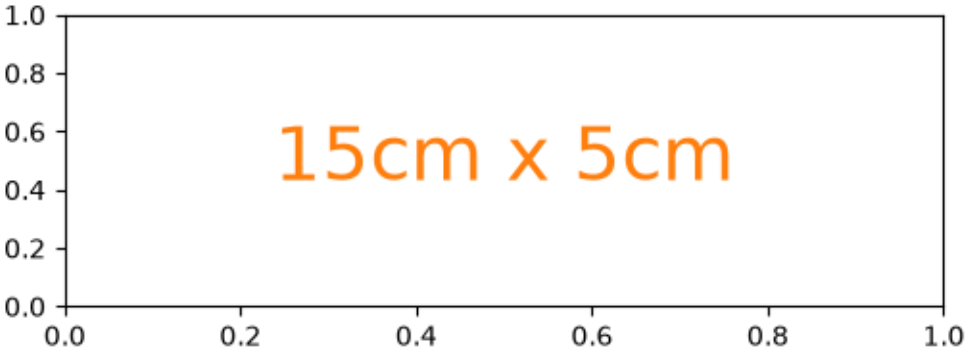
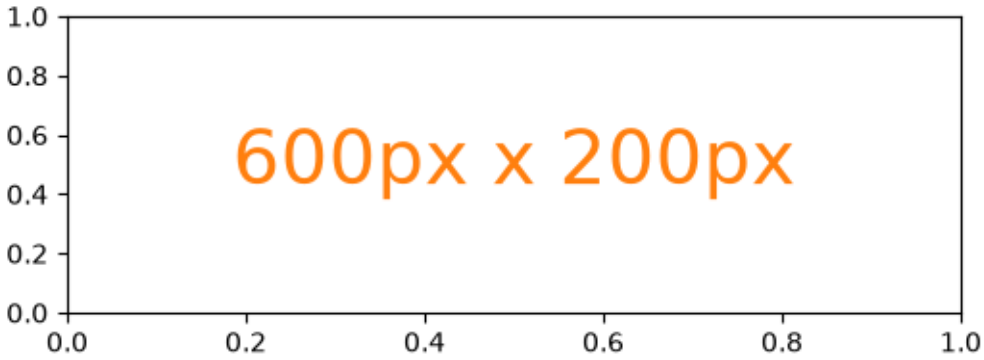


Figure size in pixel

Similarly, one can use a conversion from pixels.

Note that you could break this if you use *savefig* with a different explicit dpi value.

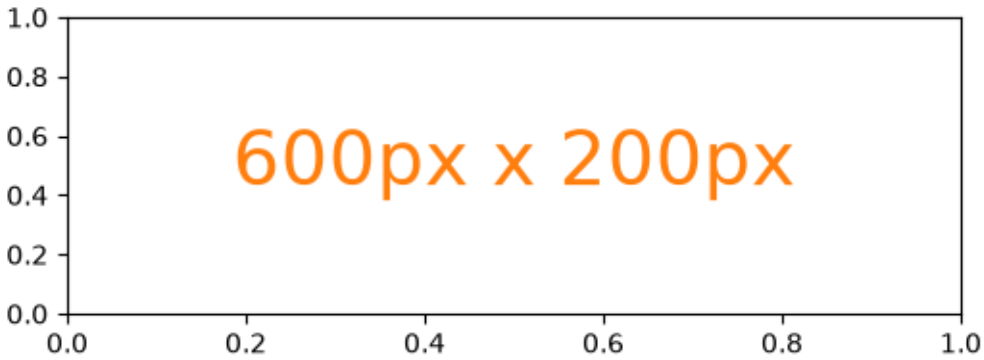
```
px = 1/plt.rcParams['figure.dpi']  # pixel in inches
plt.subplots(figsize=(600*px, 200*px))
plt.text(0.5, 0.5, '600px x 200px', **text_kwargs)
plt.show()
```



Quick interactive work is usually rendered to the screen, making pixels a good size of unit. But defining the conversion factor may feel a little tedious for quick iterations.

Because of the default `rcParams['figure.dpi'] = 100`, one can mentally divide the needed pixel value by 100[1]:

```
plt.subplots(figsize=(6, 2))
plt.text(0.5, 0.5, '600px x 200px', **text_kwargs)
plt.show()
```



[1] Unfortunately, this does not work well for the `matplotlib inline` backend in Jupyter because that backend saves the figure with `bbox_inches='tight'`, which crops the figure and makes the actual size unpredictable.

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.pyplot.figure*
- *matplotlib.pyplot.subplots*
- *matplotlib.pyplot.subplot_mosaic*

Tags: component: figure styling: size level: beginner

Figure subfigures

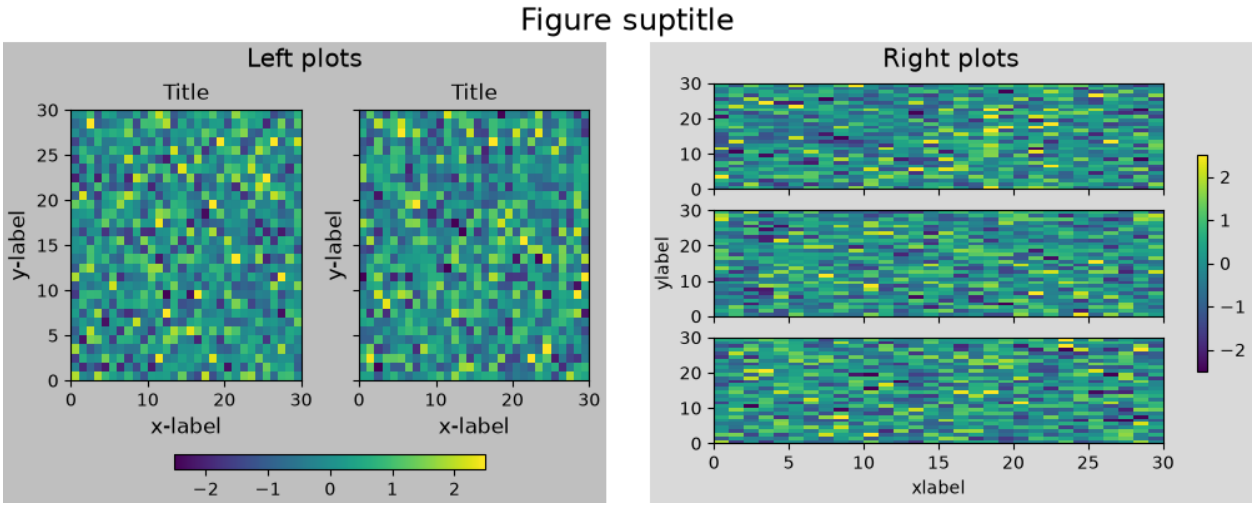
Sometimes it is desirable to have a figure with two different layouts in it. This can be achieved with *nested gridspecs*, but having a virtual figure with its own artists is helpful, so Matplotlib also has "subfigures", accessed by calling *matplotlib.figure.Figure.add_subfigure* in a way that is analogous to *matplotlib.figure.Figure.add_subplot*, or *matplotlib.figure.Figure.subfigures* to make an array of subfigures. Note that subfigures can also have their own child subfigures.

```
import matplotlib.pyplot as plt
import numpy as np


def example_plot(ax, fontsize=12, hide_labels=False):
    pc = ax.pcolormesh(np.random.randn(30, 30), vmin=-2.5, vmax=2.5)
    if not hide_labels:
        ax.set_xlabel('x-label', fontsize=fontsize)
        ax.set_ylabel('y-label', fontsize=fontsize)
        ax.set_title('Title', fontsize=fontsize)
    return pc

np.random.seed(19680808)
# gridspec inside gridspec
fig = plt.figure(layout='constrained', figsize=(10, 4))
subfigs = fig.subfigures(1, 2, wspace=0.07)

axsLeft = subfigs[0].subplots(1, 2, sharey=True)
subfigs[0].set_facecolor('0.75')
for ax in axsLeft:
    pc = example_plot(ax)
subfigs[0].suptitle('Left plots', fontsize='x-large')
subfigs[0].colorbar(pc, shrink=0.6, ax=axsLeft, location='bottom')

axsRight = subfigs[1].subplots(3, 1, sharex=True)
for nn, ax in enumerate(axsRight):
```

(continues on next page)

(continued from previous page)

```
    pc = example_plot(ax, hide_labels=True)
    if nn == 2:
        ax.set_xlabel('xlabel')
    if nn == 1:
        ax.set_ylabel('ylabel')

subfigs[1].set_facecolor('0.85')
subfigs[1].colorbar(pc, shrink=0.6, ax=axsRight)
subfigs[1].suptitle('Right plots', fontsize='x-large')

fig.suptitle('Figure suptitle', fontsize='xx-large')

plt.show()
```



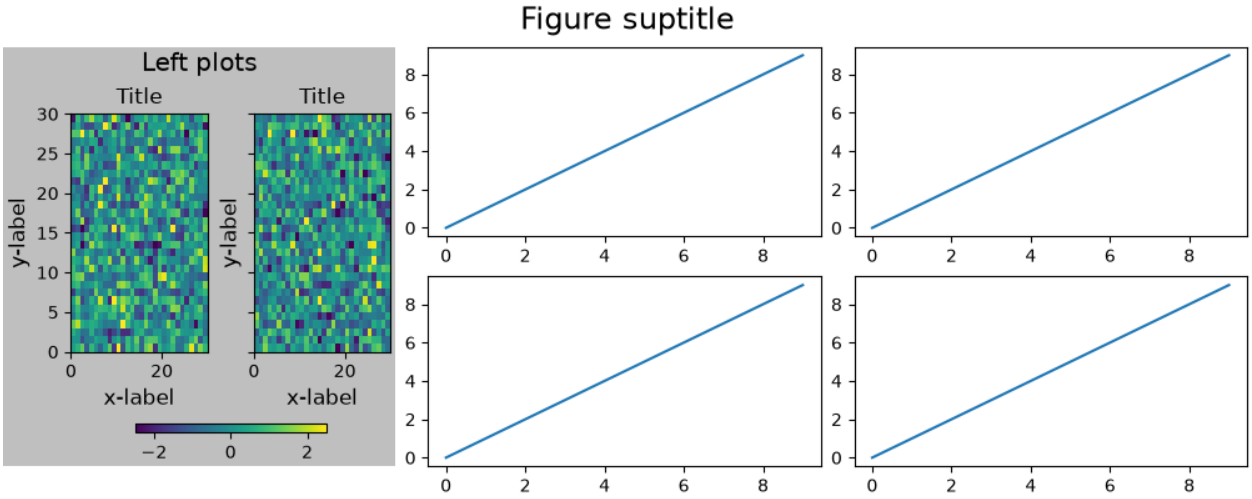
It is possible to mix subplots and subfigures using *matplotlib.figure.Figure.add_subfigure*. This requires getting the gridspec that the subplots are laid out on.

```
fig, axs = plt.subplots(2, 3, layout='constrained', figsize=(10, 4))
gridspec = axs[0, 0].get_subplotspec().get_gridspec()

# clear the left column for the subfigure:
for a in axs[:, 0]:
    a.remove()

# plot data in remaining Axes:
for a in axs[:, 1:].flat:
    a.plot(np.arange(10))

# make the subfigure in the empty gridspec slots:
subfig = fig.add_subfigure(gridspec[:, 0])
```

(continues on next page)

(continued from previous page)

```
axsLeft = subfig.subplots(1, 2, sharey=True)
subfig.set_facecolor('0.75')
for ax in axsLeft:
    pc = example_plot(ax)
subfig.suptitle('Left plots', fontsize='x-large')
subfig.colorbar(pc, shrink=0.6, ax=axsLeft, location='bottom')

fig.suptitle('Figure suptitle', fontsize='xx-large')
plt.show()
```



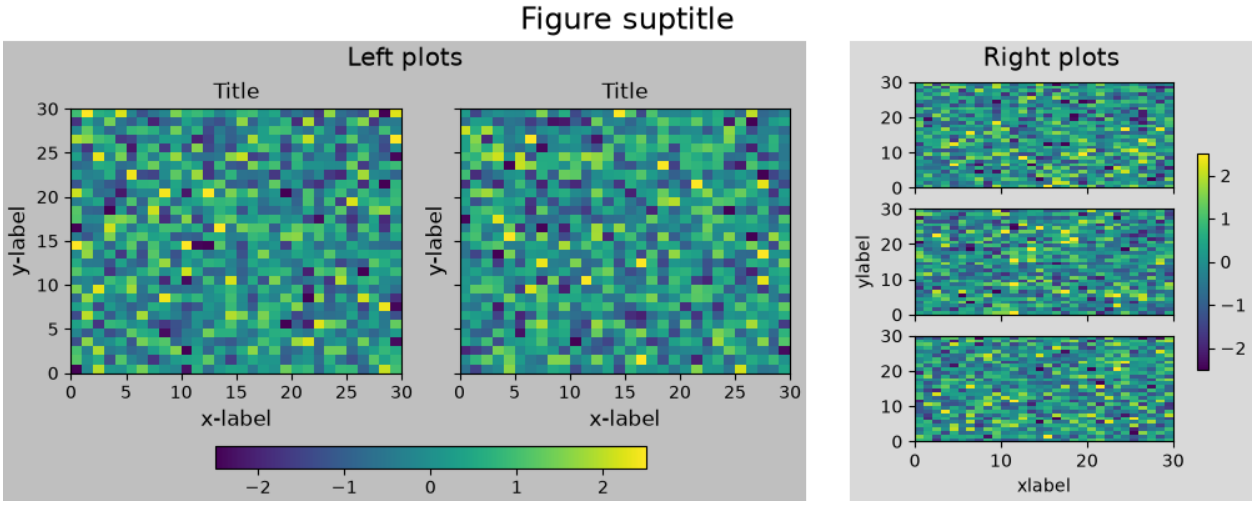
Subfigures can have different widths and heights. This is exactly the same example as the first example, but *width_ratios* has been changed:

```
fig = plt.figure(layout='constrained', figsize=(10, 4))
subfigs = fig.subfigures(1, 2, wspace=0.07, width_ratios=[2, 1])

axsLeft = subfigs[0].subplots(1, 2, sharey=True)
subfigs[0].set_facecolor('0.75')
for ax in axsLeft:
    pc = example_plot(ax)
subfigs[0].suptitle('Left plots', fontsize='x-large')
subfigs[0].colorbar(pc, shrink=0.6, ax=axsLeft, location='bottom')

axsRight = subfigs[1].subplots(3, 1, sharex=True)
for nn, ax in enumerate(axsRight):
    pc = example_plot(ax, hide_labels=True)
    if nn == 2:
        ax.set_xlabel('xlabel')
    if nn == 1:
        ax.set_ylabel('ylabel')
```

(continues on next page)

(continued from previous page)

```
subfigs[1].set_facecolor('0.85')
subfigs[1].colorbar(pc, shrink=0.6, ax=axsRight)
subfigs[1].suptitle('Right plots', fontsize='x-large')

fig.suptitle('Figure suptitle', fontsize='xx-large')

plt.show()
```



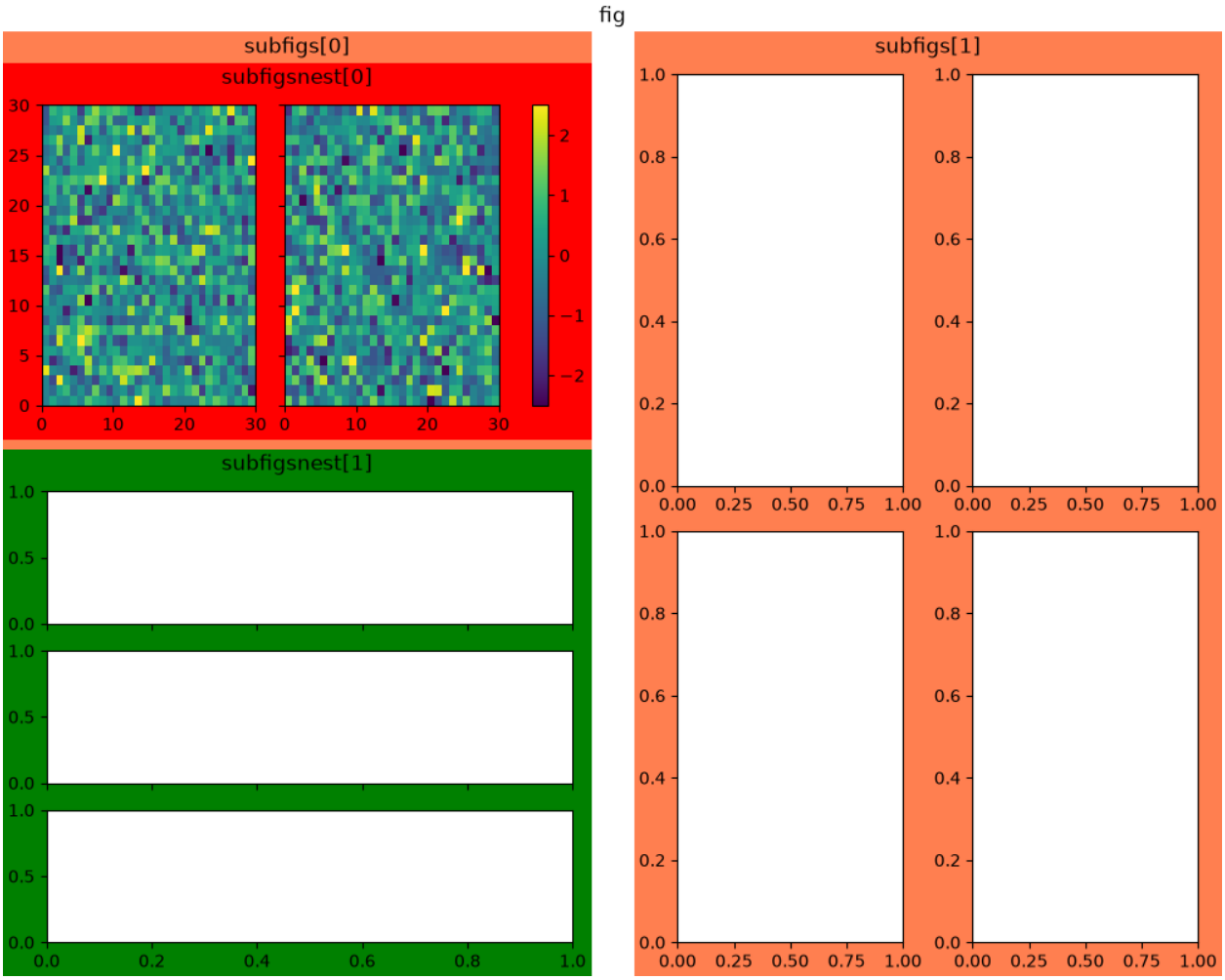
Subfigures can be also be nested:

```
fig = plt.figure(layout='constrained', figsize=(10, 8))

fig.suptitle('fig')

subfigs = fig.subfigures(1, 2, wspace=0.07)

subfigs[0].set_facecolor('coral')
subfigs[0].suptitle('subfigs[0]')

subfigs[1].set_facecolor('coral')
subfigs[1].suptitle('subfigs[1]')

subfigsnest = subfigs[0].subfigures(2, 1, height_ratios=[1, 1.4])
subfigsnest[0].suptitle('subfigsnest[0]')
subfigsnest[0].set_facecolor('r')
axsnest0 = subfigsnest[0].subplots(1, 2, sharey=True)
for nn, ax in enumerate(axsnest0):
    pc = example_plot(ax, hide_labels=True)
subfigsnest[0].colorbar(pc, ax=axsnest0)

subfigsnest[1].suptitle('subfigsnest[1]')
```

(continues on next page)

(continued from previous page)

```
subfigsnest[1].set_facecolor('g')
axsnest1 = subfigsnest[1].subplots(3, 1, sharex=True)

axsRight = subfigs[1].subplots(2, 2)

plt.show()
```



Tags: component: figure plot-type: pcolormesh level: intermediate

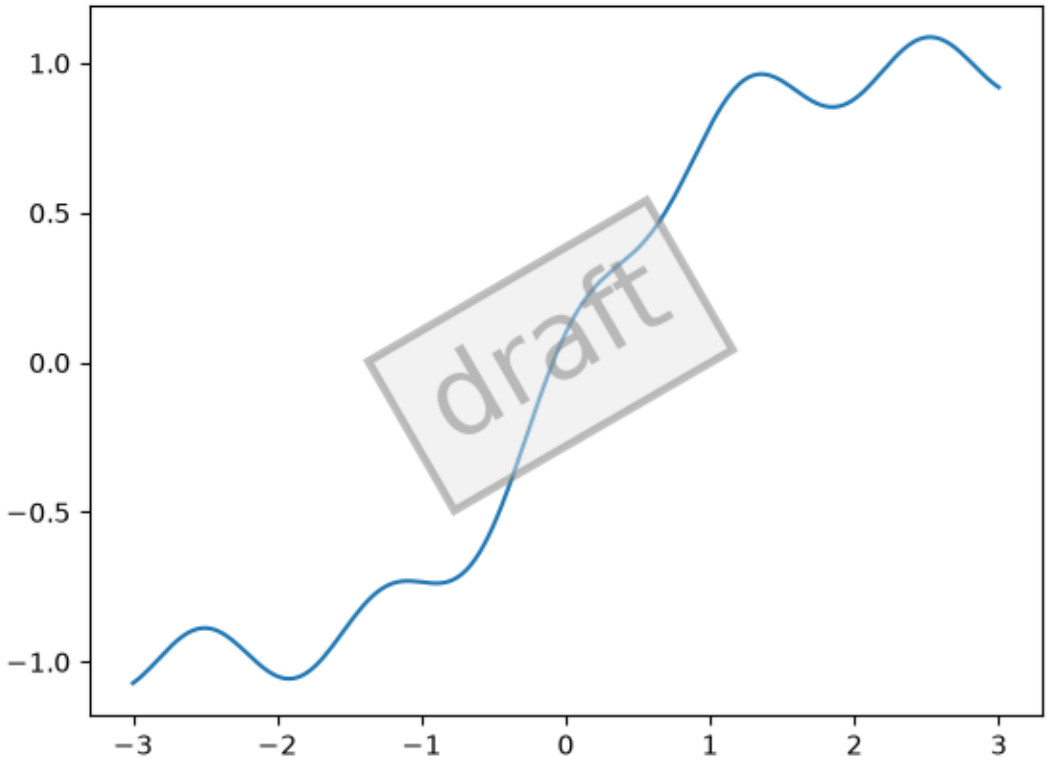
Total running time of the script: (0 minutes 4.142 seconds)

Custom Figure subclasses

You can pass a *Figure* subclass to *pyplot.figure* if you want to change the default behavior of the figure.

This example defines a *Figure* subclass `WatermarkFigure` that accepts an additional parameter `watermark` to display a custom watermark text. The figure is created using the `FigureClass` parameter of *pyplot.figure*. The additional `watermark` parameter is passed on to the subclass constructor.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.figure import Figure


class WatermarkFigure(Figure):
    """A figure with a text watermark."""

    def __init__(self, *args, watermark=None, **kwargs):
        super().__init__(*args, **kwargs)

        if watermark is not None:
            bbox = dict(boxstyle='square', lw=3, ec='gray',
                        fc=(0.9, 0.9, .9, .5), alpha=0.5)
            self.text(0.5, 0.5, watermark,
                      ha='center', va='center', rotation=30,
                      fontsize=40, color='gray', alpha=0.5, bbox=bbox)


x = np.linspace(-3, 3, 201)
y = np.tanh(x) + 0.1 * np.cos(5 * x)

plt.figure(FigureClass=WatermarkFigure, watermark='draft')
plt.plot(x, y)
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.pyplot.figure*
- *matplotlib.figure.Figure*
- *matplotlib.figure.Figure.text*

Tags: component: figure plot-type: line level: intermediate purpose: showcase

Shared axis

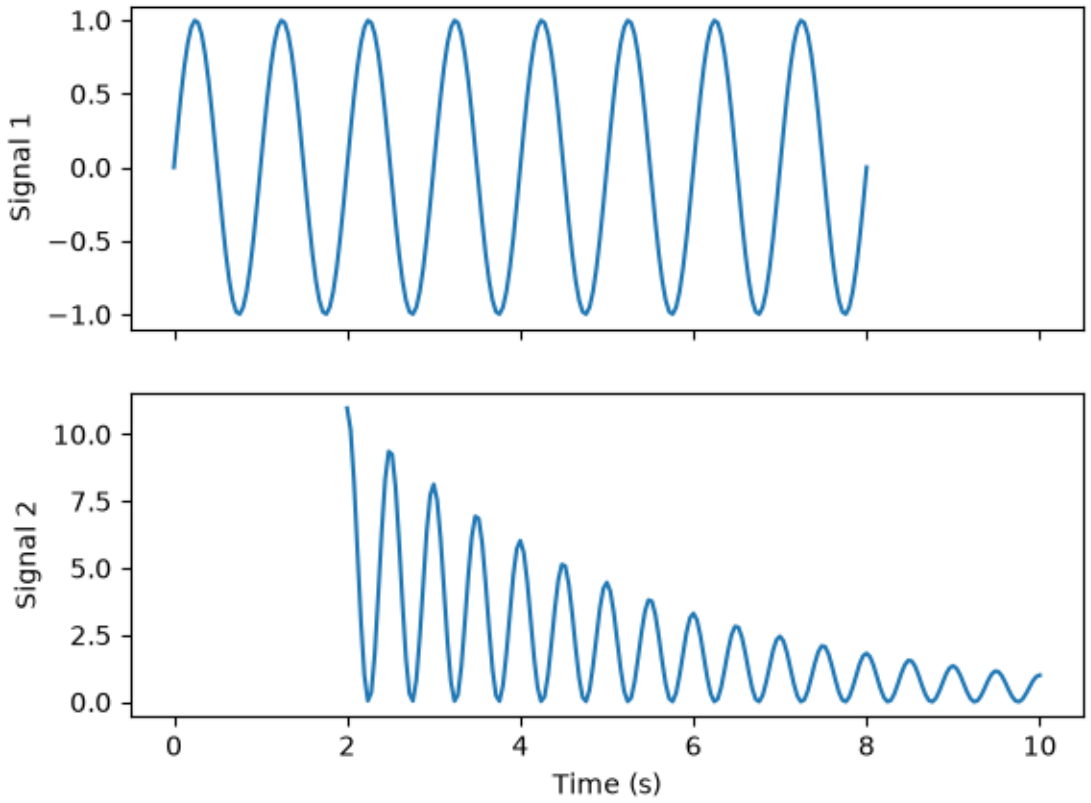
Use axis sharing when you want to compare data across multiple subplots, and want to ensure they are on the same scale. To do so, pass `sharex=True` and/or `sharey=True` to *subplots*.

This ensures the x- or y-axis limits are synchronized across the subplots. Autoscaling considers the data on all Axes; therefore, any limit changes, including interactive zoom and pan, will affect all shared axes.

The plot below illustrates this by showing two different time-series and using *sharex* to ensure the times are aligned.

For more info see *Sharing axes*.

```
import matplotlib.pyplot as plt
import numpy as np

t1 = np.linspace(0, 8, 201)
y1 = np.sin(2 * np.pi * t1)
t2 = np.linspace(2, 10, 201)
y2 = 20 * np.cos(2 * np.pi * t2)**2 * np.exp(-0.3*t2)

fig, (ax1, ax2) = plt.subplots(2, sharex=True)

ax1.plot(t1, y1)
ax1.set_ylabel("Signal 1")

ax2.plot(t2, y2)
ax2.set_ylabel("Signal 2")
ax2.set_xlabel("Time (s)")

plt.show()
```



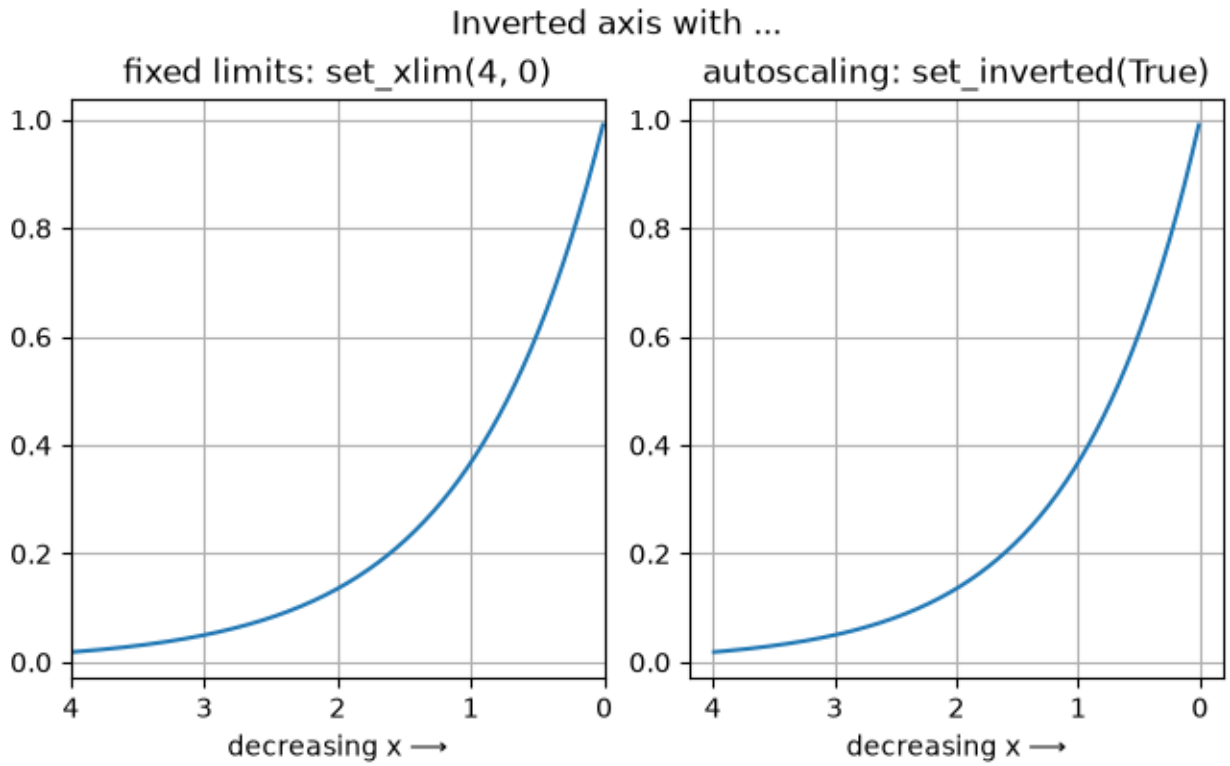
Tags: component: axis plot-type: line level: beginner

Inverted axis

This example demonstrates two ways to invert the direction of an axis:

- If you want to set *explicit axis limits* anyway, e.g. via *set_xlim*, you can swap the limit values: `set_xlim(4, 0)` instead of `set_xlim(0, 4)`.
- Use *Axis.set_inverted* if you only want to invert the axis *without modifying the limits*, i.e. keep existing limits or existing autoscaling behavior.

```
import matplotlib.pyplot as plt
import numpy as np

x = np.arange(0.01, 4.0, 0.01)
y = np.exp(-x)

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(6.4,  4), layout=
 ↪"constrained")
fig.suptitle('Inverted axis with ...')

ax1.plot(x, y)
ax1.set_xlim(4, 0)    # inverted fixed limits
ax1.set_title('fixed limits: set_xlim(4, 0)')
ax1.set_xlabel('decreasing x →')
ax1.grid(True)

ax2.plot(x, y)
ax2.xaxis.set_inverted(True)  # inverted axis with autoscaling
ax2.set_title('autoscaling: set_inverted(True)')
ax2.set_xlabel('decreasing x →')
ax2.grid(True)

plt.show()
```



Tags: component: axis plot-type: line level: beginner

Plots with different scales

Two plots on the same Axes with different left and right scales.

The trick is to use *two different Axes* that share the same *x* axis. You can use separate `matplotlib.ticker` formatters and locators as desired since the two Axes are independent.

Such Axes are generated by calling the `Axes.twinx` method. Likewise, `Axes.twiny` is available to generate Axes that share a *y* axis but have different top and bottom scales.

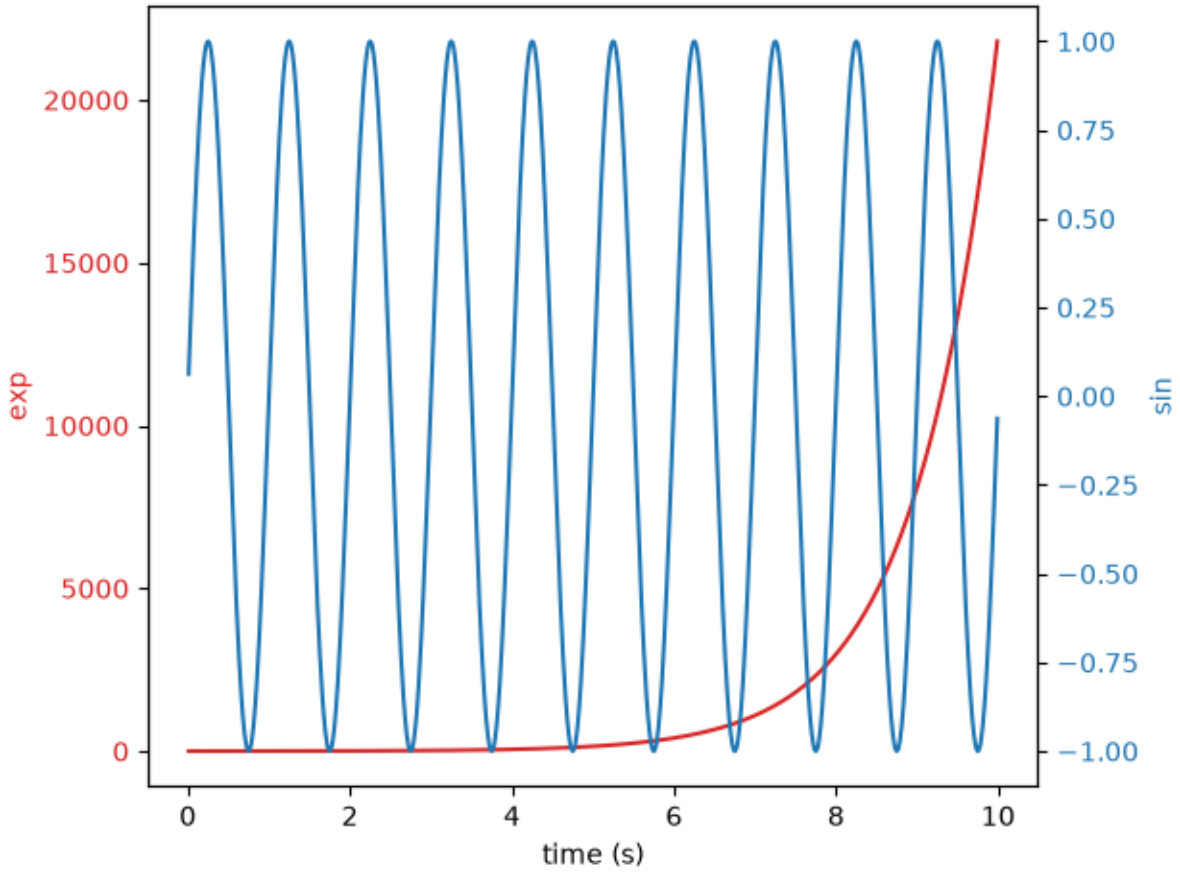
See also *Secondary Axis* for the case where the two scales are not independent, but related (e.g., the same quantity in two different units).

```
import matplotlib.pyplot as plt
import numpy as np

# Create some mock data
t = np.arange(0.01, 10.0, 0.01)
data1 = np.exp(t)
data2 = np.sin(2 * np.pi * t)

fig, ax1 = plt.subplots()

color = 'tab:red'
ax1.set_xlabel('time (s)')
```

(continues on next page)

(continued from previous page)

```
ax1.set_ylabel('exp', color=color)
ax1.plot(t, data1, color=color)
ax1.tick_params(axis='y', labelcolor=color)

ax2 = ax1.twinx()  # instantiate a second Axes that shares the same␣
↪x-axis

color = 'tab:blue'
ax2.set_ylabel('sin', color=color)  # we already handled the x-label␣
↪with ax1
ax2.plot(t, data2, color=color)
ax2.tick_params(axis='y', labelcolor=color)

fig.tight_layout()  # otherwise the right y-label is slightly clipped
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.twinx* / *matplotlib.pyplot.twinx*
- *matplotlib.axes.Axes.twiny* / *matplotlib.pyplot.twiny*
- *matplotlib.axes.Axes.tick_params* / *matplotlib.pyplot.tick_params*

Tags: component: axes plot-type: line level: beginner

Different scales on the same Axes

Demo of how to display two scales on the left and right y-axis.

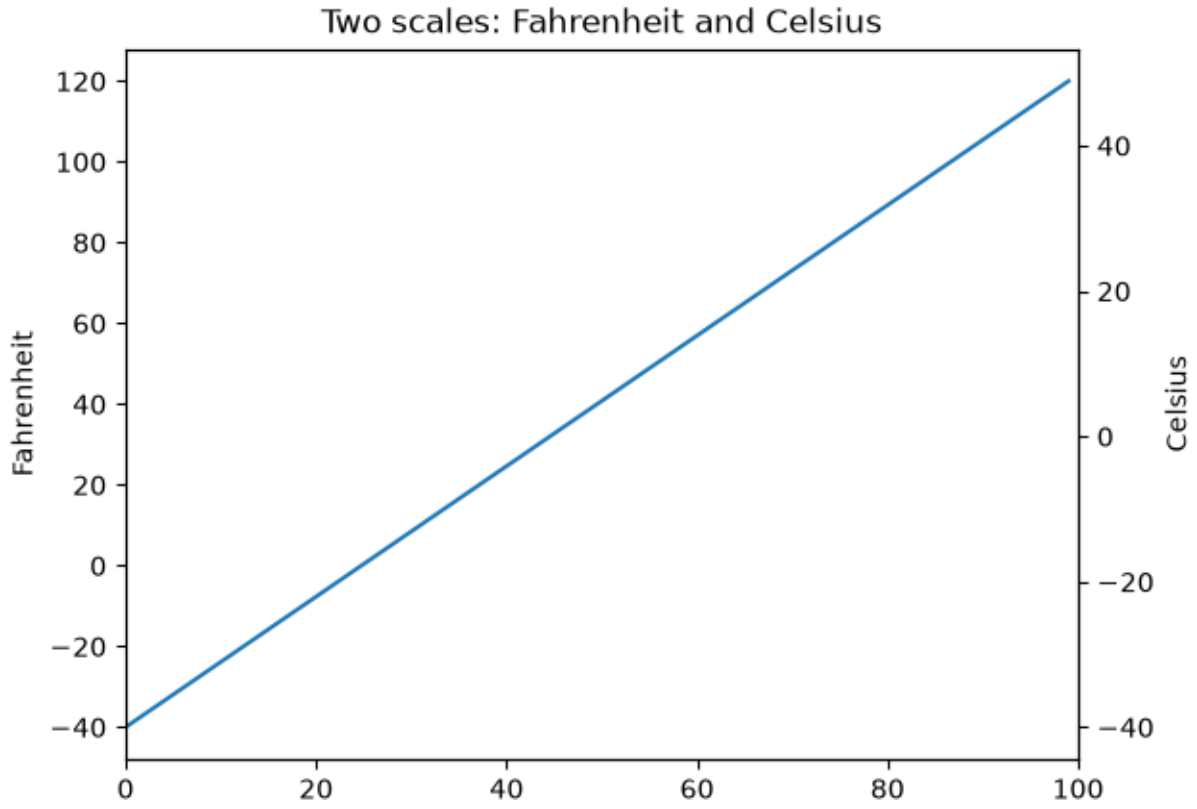
This example uses the Fahrenheit and Celsius scales.

```
import matplotlib.pyplot as plt
import numpy as np


def fahrenheit2celsius(temp):
    """
    Returns temperature in Celsius given Fahrenheit temperature.
    """
    return (5. / 9.) * (temp - 32)


def make_plot():

    # Define a closure function to register as a callback
    def convert_ax_c_to_celsius(ax_f):
        """
        Update second axis according to first axis.
        """
        y1, y2 = ax_f.get_ylim()
        ax_c.set_ylim(fahrenheit2celsius(y1), fahrenheit2celsius(y2))
        ax_c.figure.canvas.draw()

    fig, ax_f = plt.subplots()
    ax_c = ax_f.twinx()

    # automatically update ylim of ax2 when ylim of ax1 changes.
    ax_f.callbacks.connect("ylim_changed", convert_ax_c_to_celsius)
    ax_f.plot(np.linspace(-40, 120, 100))
    ax_f.set_xlim(0, 100)

    ax_f.set_title('Two scales: Fahrenheit and Celsius')
    ax_f.set_ylabel('Fahrenheit')
    ax_c.set_ylabel('Celsius')
```

(continues on next page)

(continued from previous page)

```
    plt.show()

make_plot()
```



Tags: component: axes plot-type: line level: beginner

Multiple y-axis with Spines

Create multiple y axes with a shared x-axis. This is done by creating a *twinx* Axes, turning all spines but the right one invisible and offset its position using *set_position*.

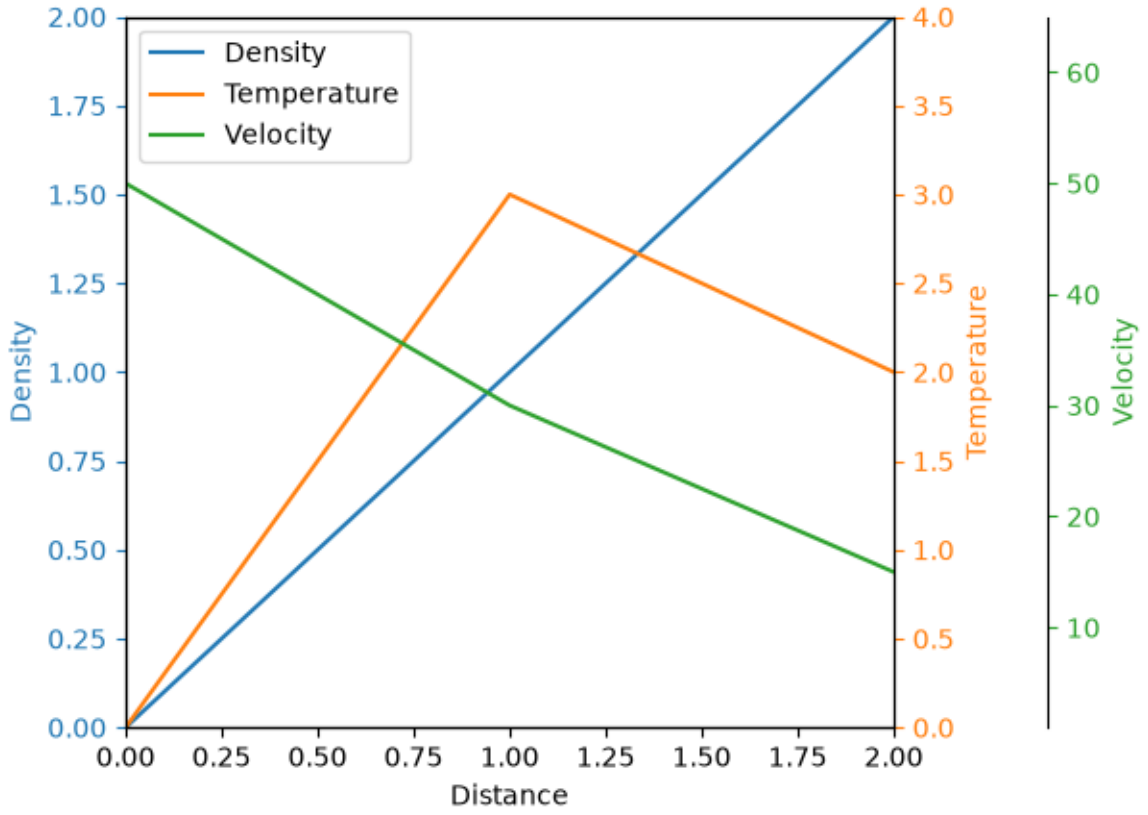
Note that this approach uses *matplotlib.axes.Axes* and their *Spine*s. Alternative approaches using non-standard Axes are shown in the *Parasite Axes demo* and *Parasite axis demo* examples.

```
import matplotlib.pyplot as plt

fig, ax = plt.subplots()
fig.subplots_adjust(right=0.75)

twin1 = ax.twinx()
twin2 = ax.twinx()
```

(continues on next page)

(continued from previous page)

```
# Offset the right spine of twin2.  The ticks and label have already␣
 ↪been
# placed on the right by twinx above.
twin2.spines.right.set_position(("axes", 1.2))

p1, = ax.plot([0, 1, 2], [0, 1, 2], "C0", label="Density")
p2, = twin1.plot([0, 1, 2], [0, 3, 2], "C1", label="Temperature")
p3, = twin2.plot([0, 1, 2], [50, 30, 15], "C2", label="Velocity")

ax.set(xlim=(0, 2), ylim=(0, 2), xlabel="Distance", ylabel="Density")
twin1.set(ylim=(0, 4), ylabel="Temperature")
twin2.set(ylim=(1, 65), ylabel="Velocity")

ax.yaxis.label.set_color(p1.get_color())
twin1.yaxis.label.set_color(p2.get_color())
twin2.yaxis.label.set_color(p3.get_color())

ax.tick_params(axis='y', colors=p1.get_color())
twin1.tick_params(axis='y', colors=p2.get_color())
twin2.tick_params(axis='y', colors=p3.get_color())

ax.legend(handles=[p1, p2, p3])

plt.show()
```

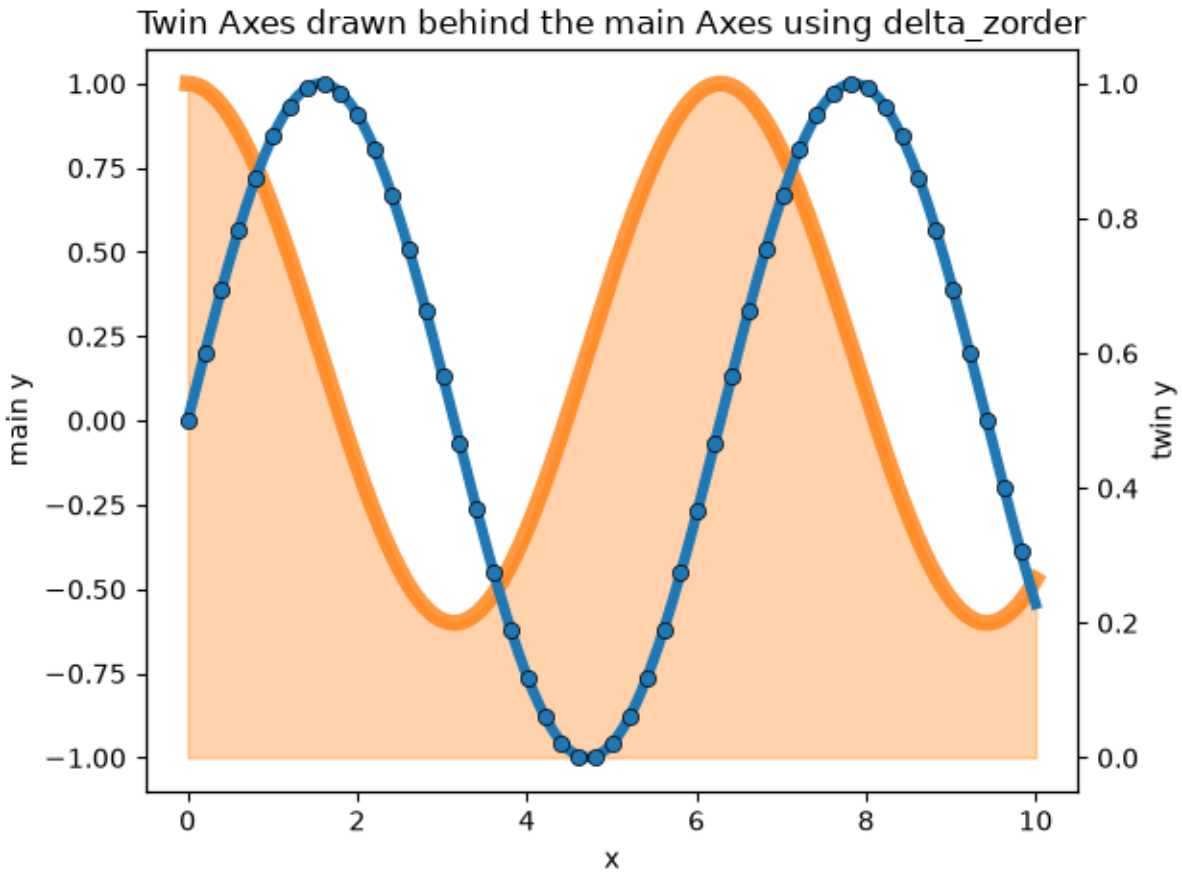


Tags: component: spines

Twin Axes with delta_zorder

`twinx` and `twiny` accept a *delta_zorder* keyword argument (a relative offset added to the original Axes' zorder) that controls whether the twin Axes is drawn in front of or behind the original Axes.

Matplotlib also automatically manages background patch visibility for twinned Axes groups so that only the bottom-most Axes has a visible background patch (respecting `frameon`). This avoids the background of a higher-zorder twin Axes covering artists drawn on the underlying Axes.




```
import matplotlib.pyplot as plt
import numpy as np

x = np.linspace(0, 10, 400)
y_main = np.sin(x)
y_twin = 0.4 * np.cos(x) + 0.6

fig, ax = plt.subplots()

# Put the twin Axes behind the original Axes (relative to the original␣
 ↪zorder).
ax2 = ax.twinx(delta_zorder=-1)

# Draw something broad on the twin Axes so that the stacking is␣
 ↪obvious.
ax2.fill_between(x, 0, y_twin, color="C1", alpha=0.35, label="twin fill
 ↪")
ax2.plot(x, y_twin, color="C1", lw=6, alpha=0.8)

# Draw overlapping artists on the main Axes; they appear on top.
```

(continues on next page)

(continued from previous page)

```
ax.scatter(x[::8], y_main[::8], s=35, color="C0", edgecolor="k",␣
 ↪linewidth=0.5,
           zorder=3, label="main scatter")
ax.plot(x, y_main, color="C0", lw=4)

ax.set_xlabel("x")
ax.set_ylabel("main y")
ax2.set_ylabel("twin y")
ax.set_title("Twin Axes drawn behind the main Axes using delta_zorder")

fig.tight_layout()
plt.show()
```

Secondary Axis

Sometimes we want a secondary axis on a plot, for instance to convert radians to degrees on the same plot. We can do this by making a child axes with only one axis visible via *axes.Axes.secondary_xaxis* and *axes.Axes.secondary_yaxis*. This secondary axis can have a different scale than the main axis by providing both a forward and an inverse conversion function in a tuple to the *functions* keyword argument:

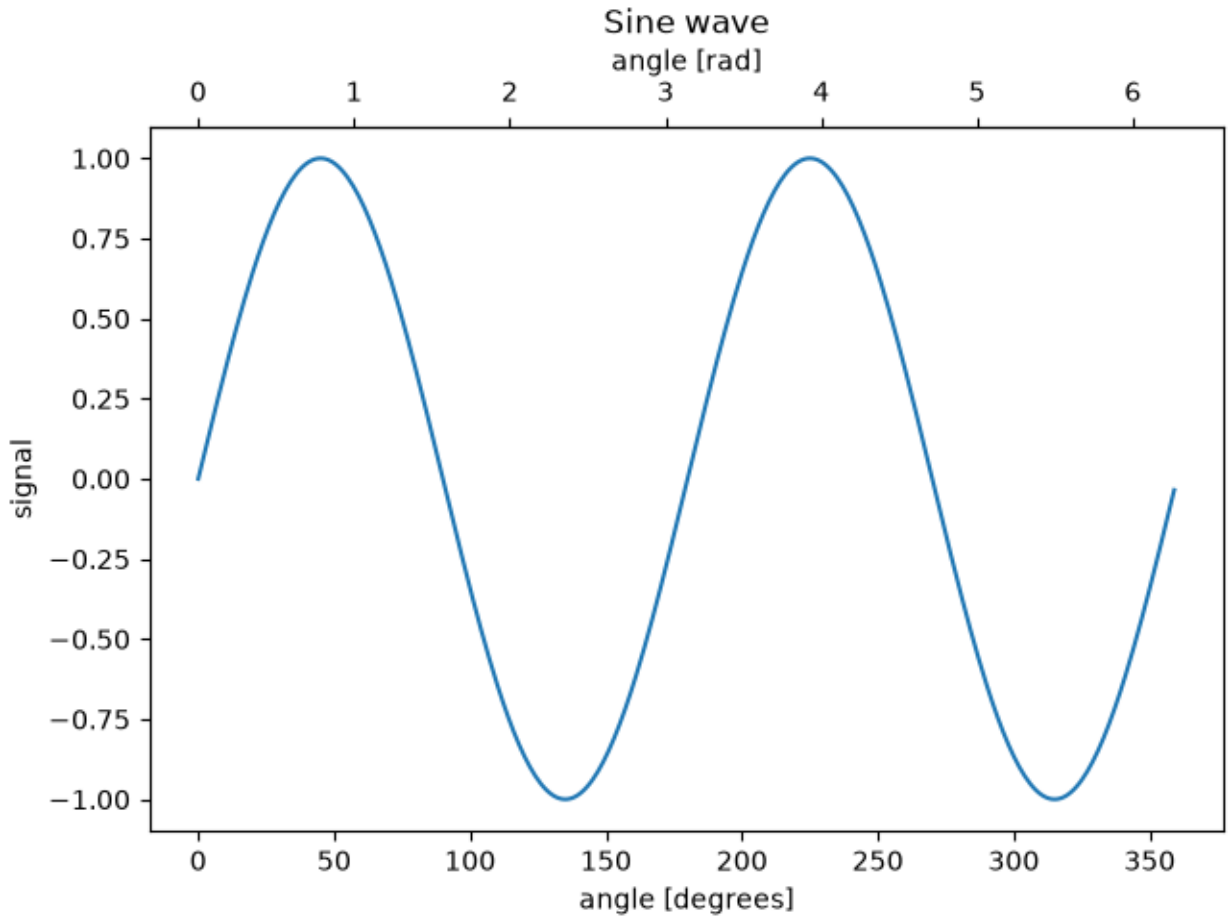
See also *Plots with different scales* for the case where two scales are not related to one another, but independent.

```
import datetime

import matplotlib.pyplot as plt
import numpy as np

import matplotlib.dates as mdates

fig, ax = plt.subplots(layout='constrained')
x = np.arange(0, 360, 1)
y = np.sin(2 * x * np.pi / 180)
ax.plot(x, y)
ax.set_xlabel('angle [degrees]')
ax.set_ylabel('signal')
ax.set_title('Sine wave')


def deg2rad(x):
    return x * np.pi / 180


def rad2deg(x):
    return x * 180 / np.pi
```

(continues on next page)

(continued from previous page)

```
secax = ax.secondary_xaxis('top', functions=(deg2rad, rad2deg))
secax.set_xlabel('angle [rad]')
plt.show()
```



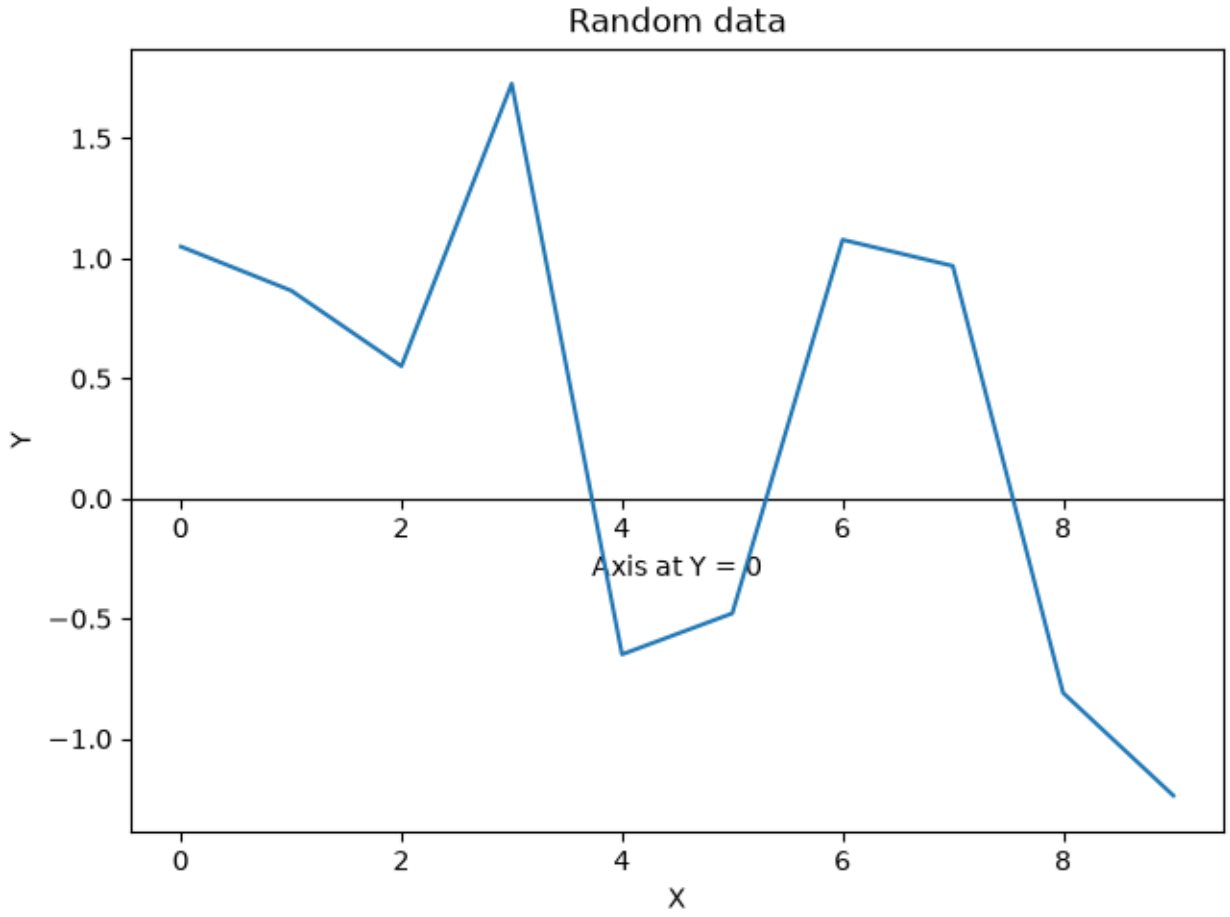
By default, the secondary axis is drawn in the Axes coordinate space. We can also provide a custom transform to place it in a different coordinate space. Here we put the axis at Y = 0 in data coordinates.

```
fig, ax = plt.subplots(layout='constrained')
x = np.arange(0, 10)
np.random.seed(19680801)
y = np.random.randn(len(x))
ax.plot(x, y)
ax.set_xlabel('X')
ax.set_ylabel('Y')
ax.set_title('Random data')

# Pass ax.transData as a transform to place the axis relative to our␣
↪data
secax = ax.secondary_xaxis(0, transform=ax.transData)
```

(continues on next page)

(continued from previous page)

```
secax.set_xlabel('Axis at Y = 0')
plt.show()
```



Here is the case of converting from wavenumber to wavelength in a log-log scale.

Note

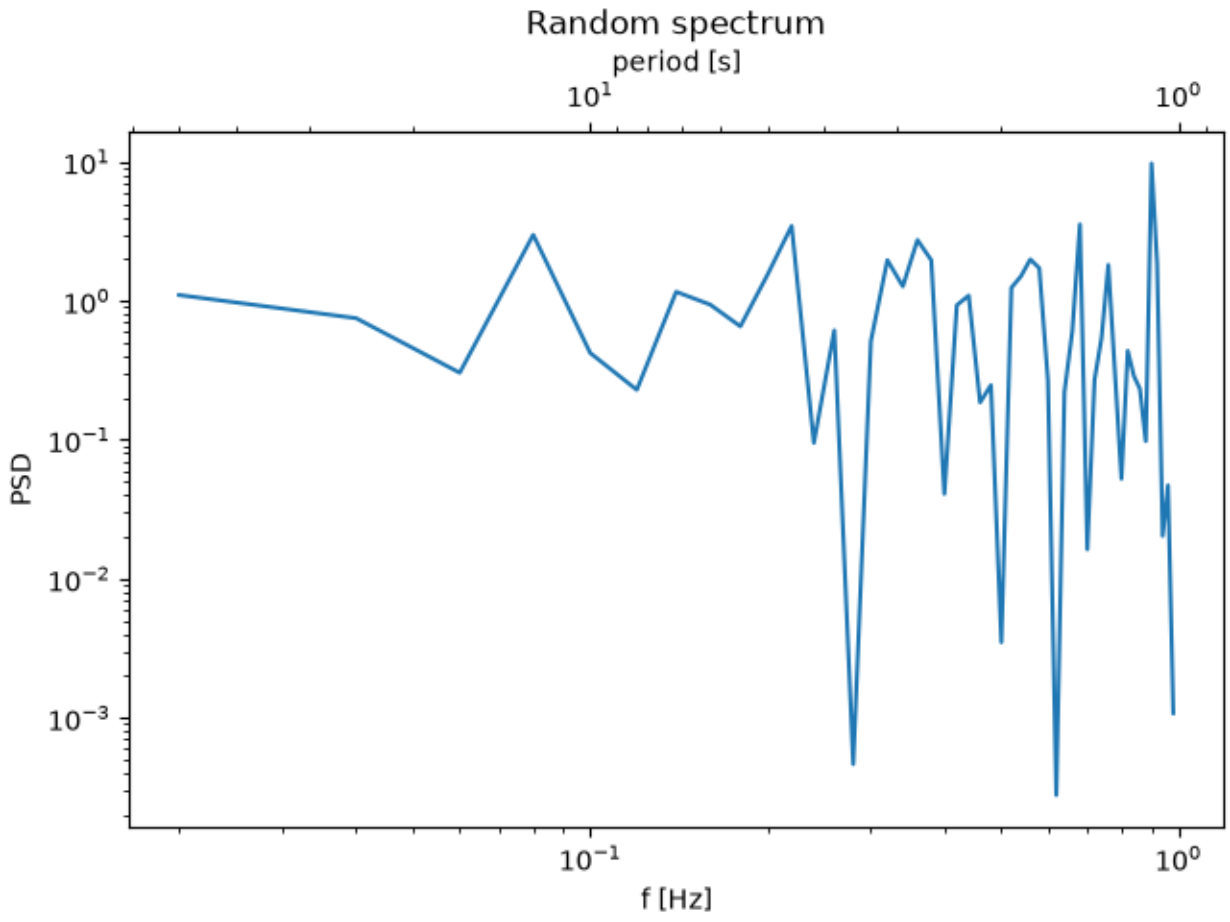
In this case, the xscale of the parent is logarithmic, so the child is made logarithmic as well.

```
fig, ax = plt.subplots(layout='constrained')
x = np.arange(0.02, 1, 0.02)
np.random.seed(19680801)
y = np.random.randn(len(x)) ** 2
ax.loglog(x, y)
ax.set_xlabel('f [Hz]')
ax.set_ylabel('PSD')
ax.set_title('Random spectrum')
```

(continues on next page)

(continued from previous page)

```
def one_over(x):
    """Vectorized 1/x, treating x==0 manually"""
    x = np.array(x, float)
    near_zero = np.isclose(x, 0)
    x[near_zero] = np.inf
    x[~near_zero] = 1 / x[~near_zero]
    return x


# the function "1/x" is its own inverse
inverse = one_over


secax = ax.secondary_xaxis('top', functions=(one_over, inverse))
secax.set_xlabel('period [s]')
plt.show()
```



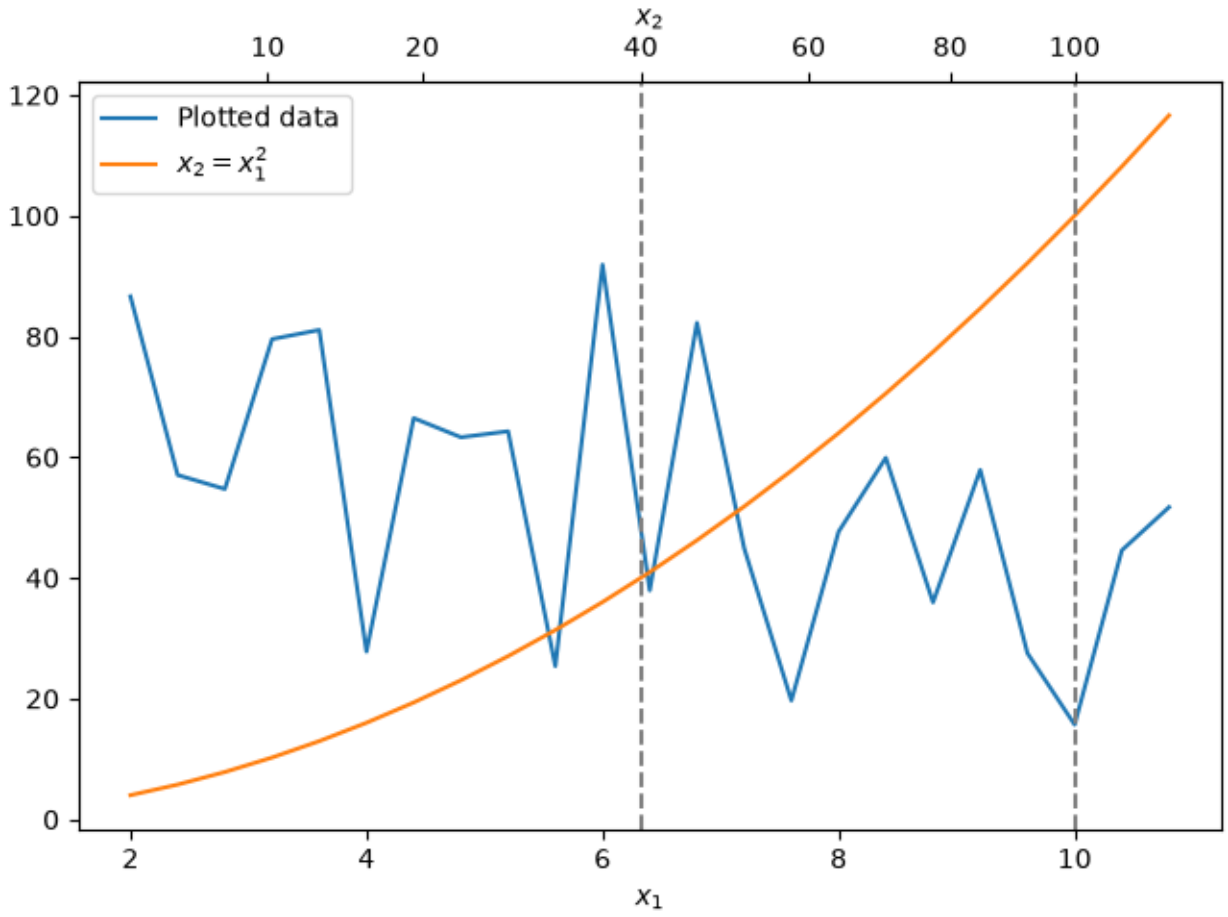
Sometime we want to relate the axes in a transform that is ad-hoc from the data, and is derived empirically. Or, one axis could be a complicated nonlinear function of the other. In these cases we can set the forward and inverse transform functions to be linear interpolations from the one set of independent variables to the

other.

Note

In order to properly handle the data margins, the mapping functions (`forward` and `inverse` in this example) need to be defined beyond the nominal plot limits. This condition can be enforced by extending the interpolation beyond the plotted values, both to the left and the right, see `x1n` and `x2n` below.

```
fig, ax = plt.subplots(layout='constrained')
x1_vals = np.arange(2, 11, 0.4)
# second independent variable is a nonlinear function of the other.
x2_vals = x1_vals ** 2
ydata = 50.0 + 20 * np.random.randn(len(x1_vals))
ax.plot(x1_vals, ydata, label='Plotted data')
ax.plot(x1_vals, x2_vals, label=r'$x_2 = x_1^2$')
ax.set_xlabel(r'$x_1$')
ax.legend()

# the forward and inverse functions must be defined on the complete␣
 ↪visible axis range
x1n = np.linspace(0, 20, 201)
x2n = x1n**2


def forward(x):
    return np.interp(x, x1n, x2n)


def inverse(x):
    return np.interp(x, x2n, x1n)

# use axvline to prove that the derived secondary axis is correctly␣
 ↪plotted
ax.axvline(np.sqrt(40), color="grey", ls="--")
ax.axvline(10, color="grey", ls="--")
secax = ax.secondary_xaxis('top', functions=(forward, inverse))
secax.set_xticks([10, 20, 40, 60, 80, 100])
secax.set_xlabel(r'$x_2$')

plt.show()
```



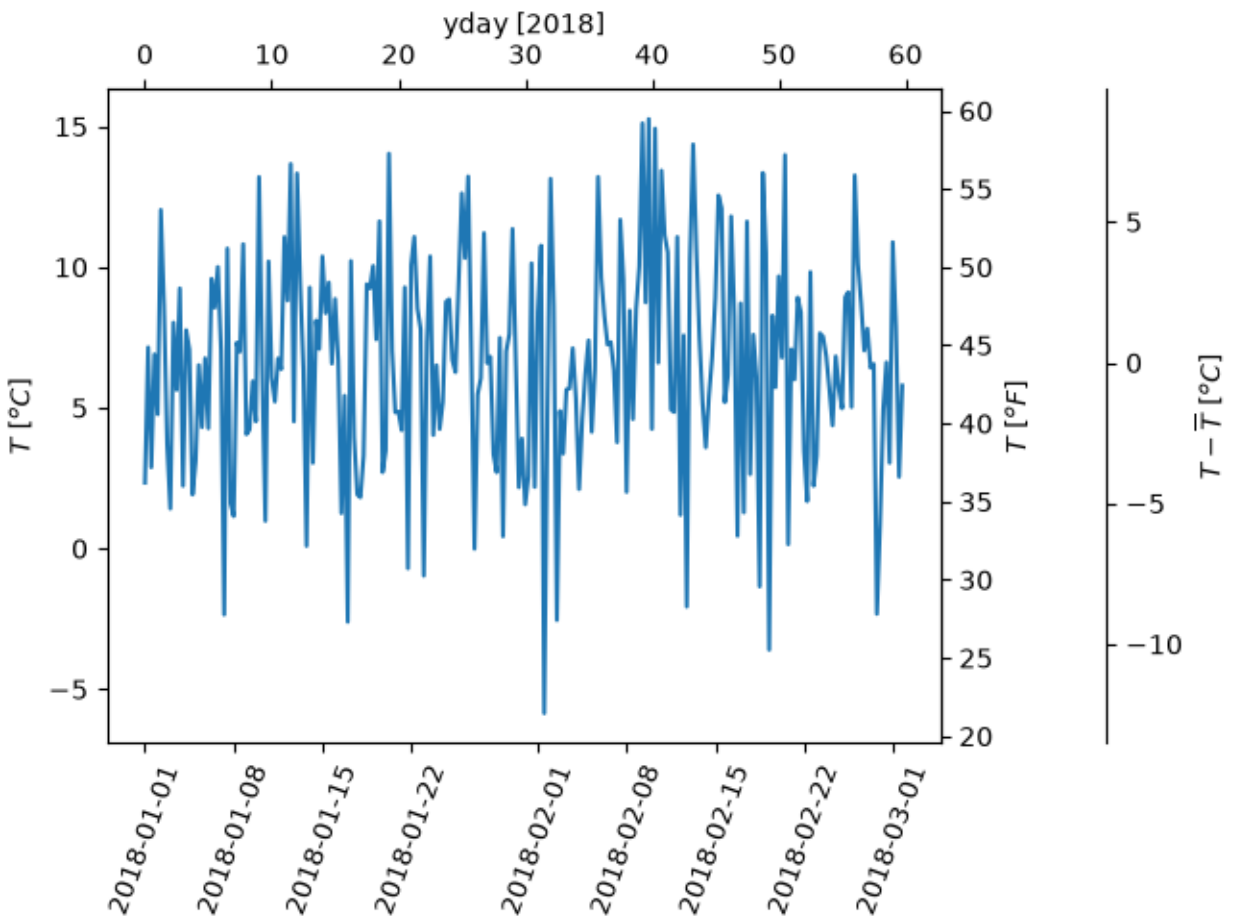
A final example translates np.datetime64 to yearday on the x axis and from Celsius to Fahrenheit on the y axis. Note the addition of a third y axis, and that it can be placed using a float for the location argument

```
dates = [datetime.datetime(2018, 1, 1) + datetime.timedelta(hours=k *␣
↪6)
         for k in range(240)]
temperature = np.random.randn(len(dates)) * 4 + 6.7
fig, ax = plt.subplots(layout='constrained')

ax.plot(dates, temperature)
ax.set_ylabel(r'$T\ [^oC]$')
ax.xaxis.set_tick_params(rotation=70)


def date2yday(x):
    """Convert matplotlib datenum to days since 2018-01-01."""
    y = x - mdates.date2num(datetime.datetime(2018, 1, 1))
    return y


def yday2date(x):
```

(continues on next page)

(continued from previous page)

```
    """Return a matplotlib datenum for *x* days after 2018-01-01."""
    y = x + mdates.date2num(datetime.datetime(2018, 1, 1))
    return y


secax_x = ax.secondary_xaxis('top', functions=(date2yday, yday2date))
secax_x.set_xlabel('yday [2018]')


def celsius_to_fahrenheit(x):
    return x * 1.8 + 32


def fahrenheit_to_celsius(x):
    return (x - 32) / 1.8


secax_y = ax.secondary_yaxis(
    'right', functions=(celsius_to_fahrenheit, fahrenheit_to_celsius))
secax_y.set_ylabel(r'$T\ [^oF]$')


def celsius_to_anomaly(x):
    return (x - np.mean(temperature))


def anomaly_to_celsius(x):
    return (x + np.mean(temperature))


# use of a float for the position:
secax_y2 = ax.secondary_yaxis(
    1.2, functions=(celsius_to_anomaly, anomaly_to_celsius))
secax_y2.set_ylabel(r'$T - \overline{T}\ [^oC]$')


plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.secondary_xaxis*
- *matplotlib.axes.Axes.secondary_yaxis*

Tags: component: axis plot-type: line level: beginner

Total running time of the script: (0 minutes 3.227 seconds)

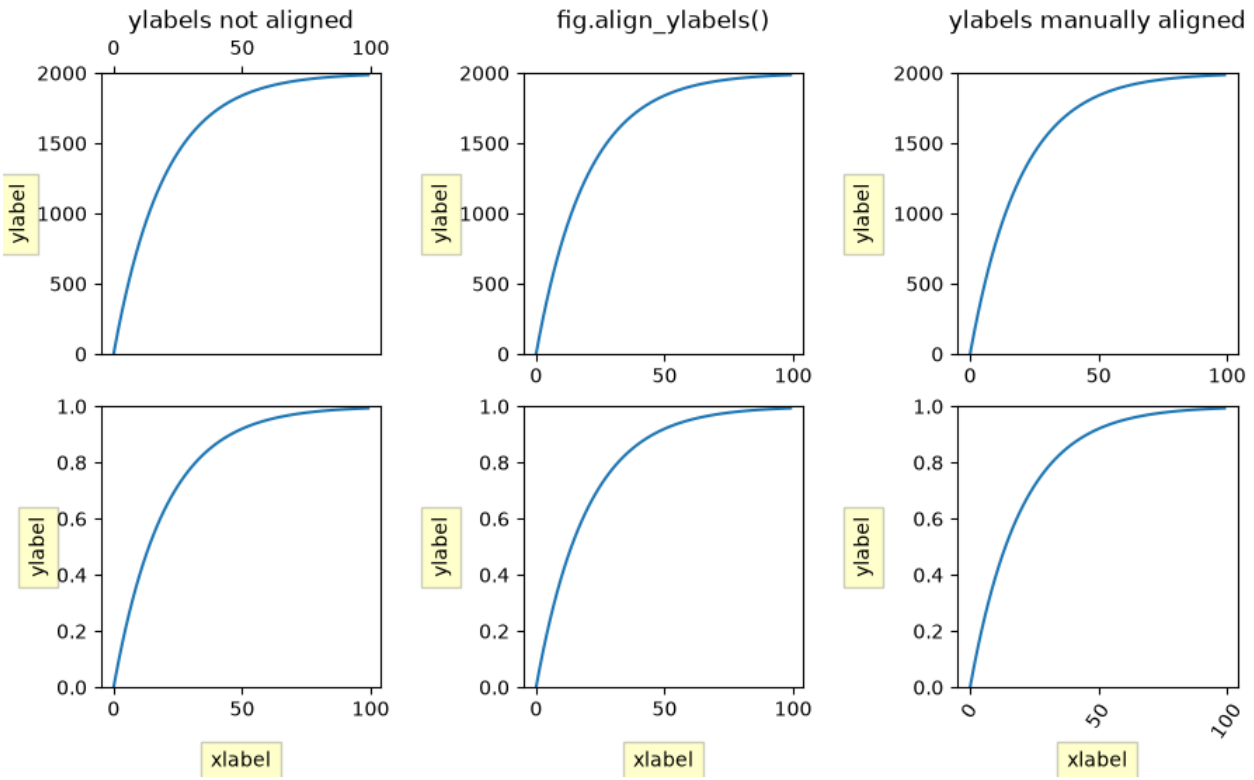
Align labels and titles

Aligning xlabel, ylabel, and title using *Figure.align_xlabels*, *Figure.align_ylabels*, and *Figure.align_titles*.

Figure.align_labels wraps the x and y label functions.

We align the xlabels and ylabels using short calls to *Figure.align_xlabels* and *Figure.align_ylabels*. We also show a manual way to align the ylabels using the *set_label_coords* method of the yaxis object. Note this requires knowing a good offset value which is hardcoded.

```
import matplotlib.pyplot as plt
import numpy as np

fig, axs = plt.subplots(2, 3, figsize=(8.9, 5.5),
                        layout='constrained', gridspec_kw={'wspace':␣
 ↪0.1})

# add sample data and labels
for ax in axs.flat:
    scale = 2000 if ax.get_subplotspec().is_first_row() else 1
    ax.plot(scale * (1 - np.exp(-np.linspace(0, 5, 100))))
    if ax.get_subplotspec().is_last_row():
        ax.set_xlabel('xlabel', bbox=dict(facecolor='yellow', pad=5,␣
 ↪alpha=0.2))
    ax.set_ylabel('ylabel', bbox=dict(facecolor='yellow', pad=5,␣
 ↪alpha=0.2))
    ax.set_ylim(0, scale)

# Modify ticks to get different margins in some plots
axs[0, 0].xaxis.tick_top()
axs[1, 2].tick_params(axis='x', rotation=55)
axs[0, 0].set_title('ylabels not aligned')

# Align labels
fig.align_titles()            # Align titles
fig.align_xlabels()           # Align all x-axis labels
fig.align_ylabels(axs[:, 1])  # Align only the second column's y-labels
axs[0, 1].set_title('fig.align_ylabels()')

# Manually adjust y-labels for the third column
for ax in axs[:, 2]:
    ax.yaxis.set_label_coords(-0.3, 0.5)
axs[0, 2].set_title('ylabels manually aligned')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.figure.Figure.align_xlabels*
- *matplotlib.figure.Figure.align_ylabels*
- *matplotlib.figure.Figure.align_labels*
- *matplotlib.figure.Figure.align_titles*
- *matplotlib.axis.Axis.set_label_coords*
- *matplotlib.axes.Axes.plot* / *matplotlib.pyplot.plot*
- *matplotlib.axes.Axes.set_title*
- *matplotlib.axes.Axes.set_ylabel*
- *matplotlib.axes.Axes.set_ylim*

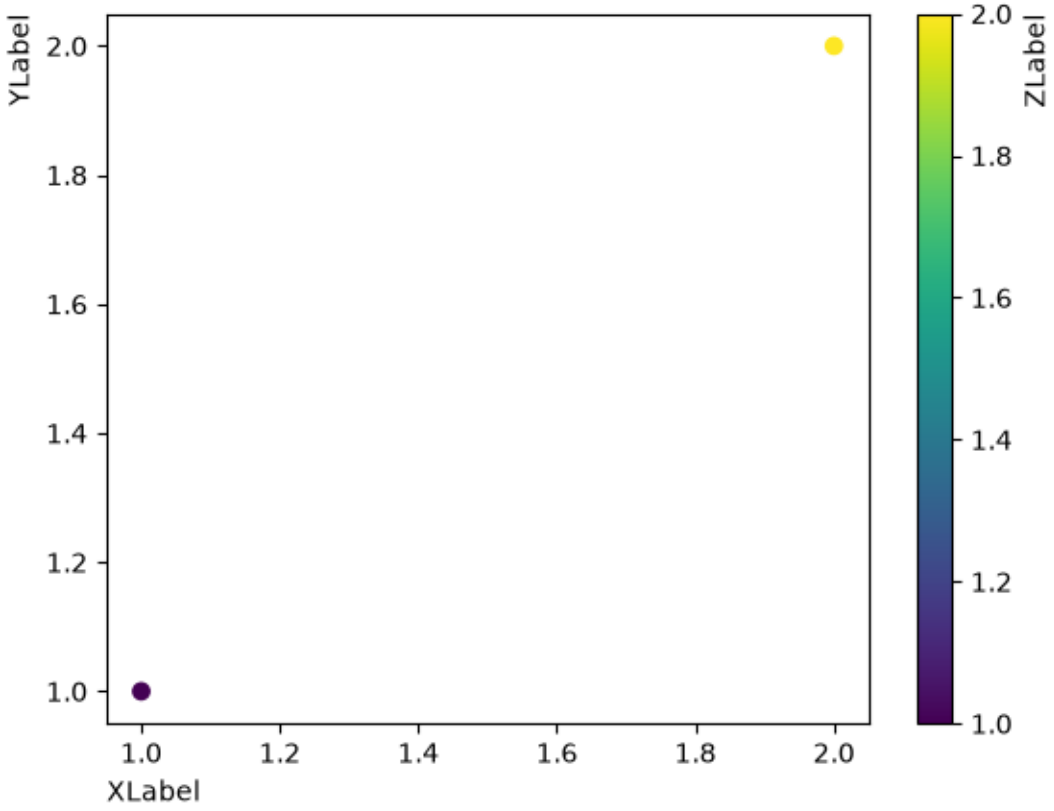
Tags: component: label component: title styling: position level: beginner

Total running time of the script: (0 minutes 1.159 seconds)

Axis label position

Choose axis label position when calling *set_xlabel* and *set_ylabel* as well as for colorbar.

```
import matplotlib.pyplot as plt

fig, ax = plt.subplots()

sc = ax.scatter([1, 2], [1, 2], c=[1, 2])
ax.set_ylabel('YLabel', loc='top')
ax.set_xlabel('XLabel', loc='left')
cbar = fig.colorbar(sc)
cbar.set_label("ZLabel", loc='top')

plt.show()
```

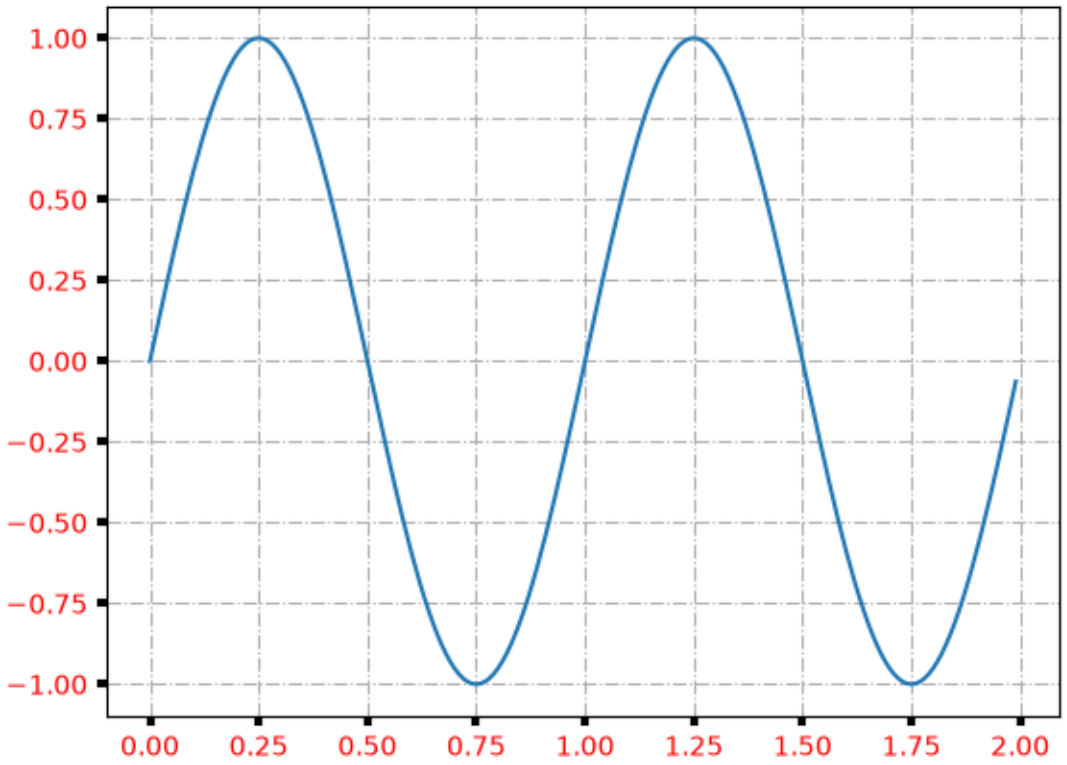


Tags: component: axis styling: position level: beginner

Axes properties

You can control the axis tick and grid properties

```
import matplotlib.pyplot as plt
import numpy as np

t = np.arange(0.0, 2.0, 0.01)
s = np.sin(2 * np.pi * t)

fig, ax = plt.subplots()
ax.plot(t, s)

ax.grid(True, linestyle='-.')
ax.tick_params(labelcolor='r', labelsize='medium', width=3)

plt.show()
```



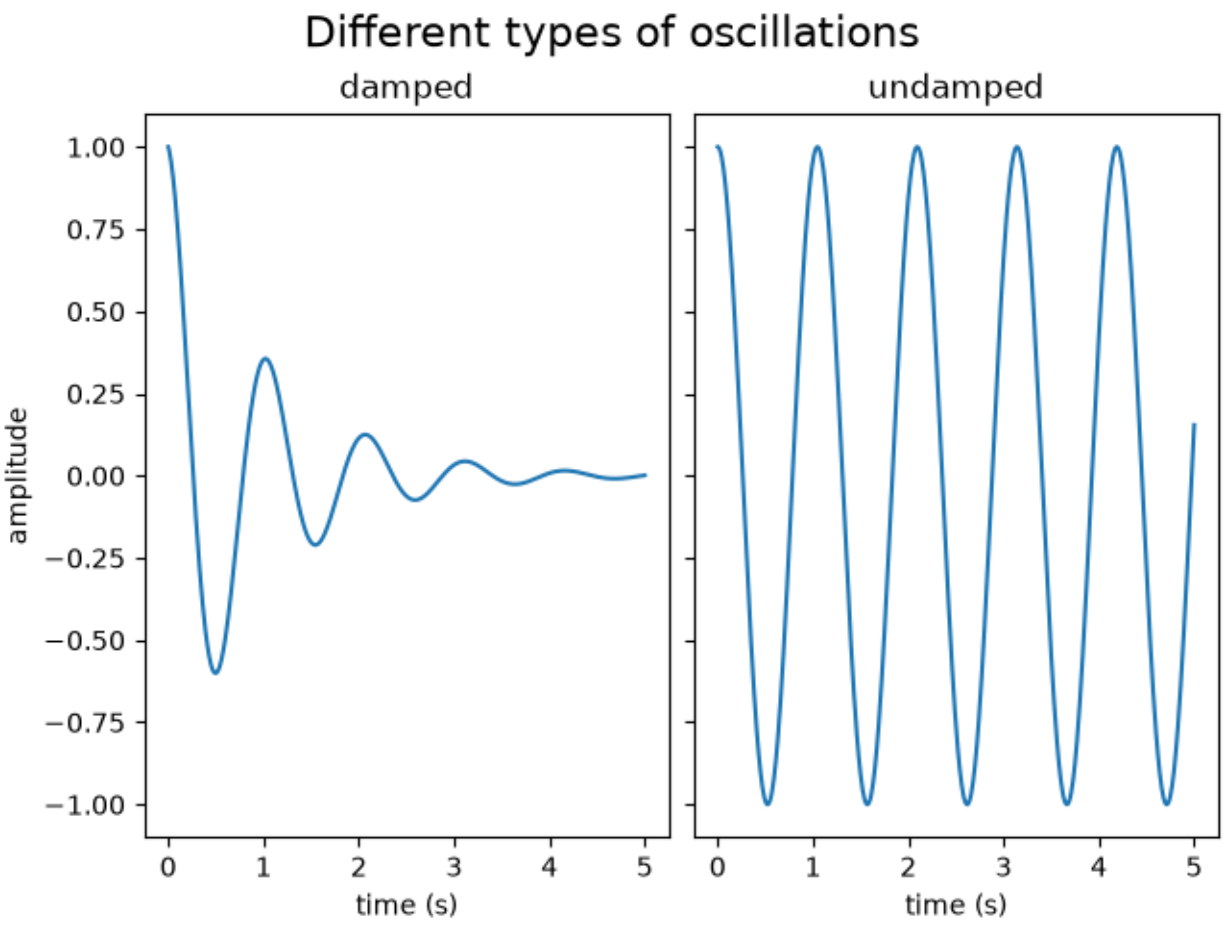
Tags: component: ticks plot-type: line level: beginner

Figure labels: suptitle, supxlabel, supylabel

Each Axes can have a title (or actually three - one each with *loc* "left", "center", and "right"), but is sometimes desirable to give a whole figure (or *SubFigure*) an overall title, using *Figure.suptitle*.

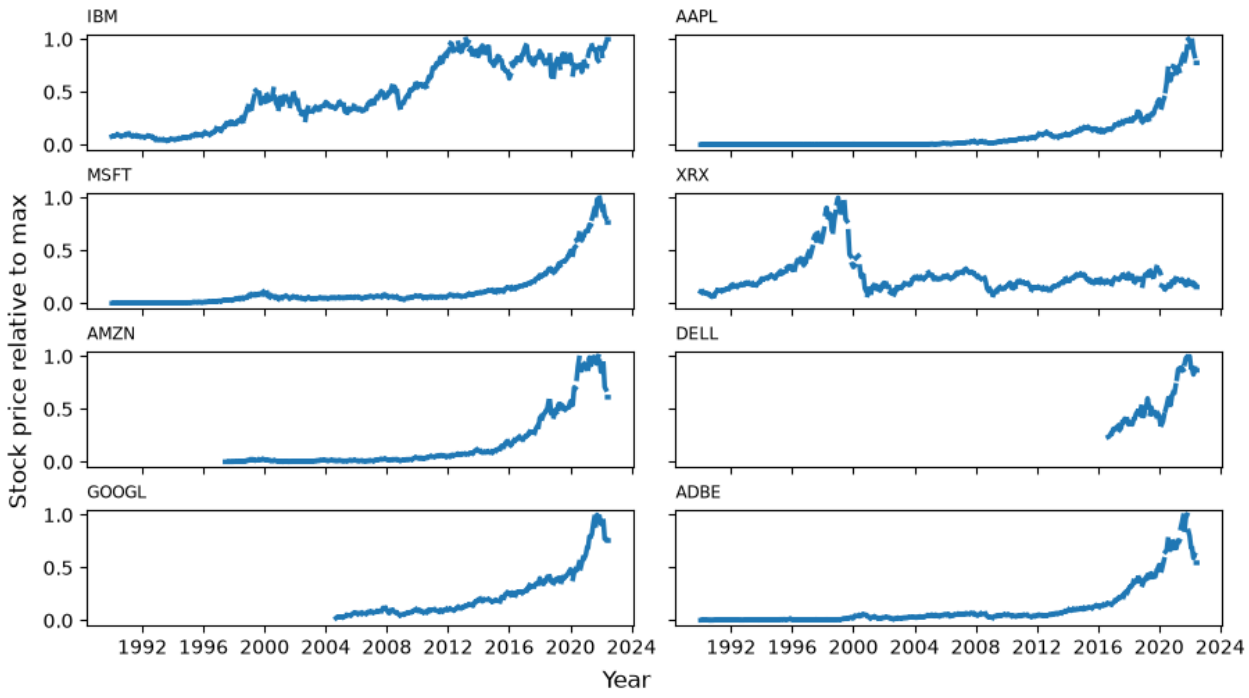
We can also add figure-level x- and y-labels using *Figure.supxlabel* and *Figure.supylabel*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.cbook import get_sample_data

x = np.linspace(0.0, 5.0, 501)

fig, (ax1, ax2) = plt.subplots(1, 2, layout='constrained', sharey=True)
ax1.plot(x, np.cos(6*x) * np.exp(-x))
ax1.set_title('damped')
ax1.set_xlabel('time (s)')
ax1.set_ylabel('amplitude')

ax2.plot(x, np.cos(6*x))
ax2.set_xlabel('time (s)')
ax2.set_title('undamped')

fig.suptitle('Different types of oscillations', fontsize=16)
```



A global x- or y-label can be set using the *Figure.supxlabel* and *Figure.supylabel* methods.

```
with get_sample_data('Stocks.csv') as file:
    stocks = np.genfromtxt(
        file, delimiter=',', names=True, dtype=None,
        converters={0: lambda x: np.datetime64(x, 'D')}, skip_header=1)

fig, axs = plt.subplots(4, 2, figsize=(9, 5), layout='constrained',
                        sharex=True, sharey=True)
for nn, ax in enumerate(axs.flat):
    column_name = stocks.dtype.names[1+nn]
    y = stocks[column_name]
    line, = ax.plot(stocks['Date'], y / np.nanmax(y), lw=2.5)
    ax.set_title(column_name, fontsize='small', loc='left')
fig.supxlabel('Year')
fig.supylabel('Stock price relative to max')

plt.show()
```



Tags: component: figure component: title plot-type: line level: beginner

Total running time of the script: (0 minutes 2.167 seconds)

Axes zoom effect

```
import matplotlib.pyplot as plt

from matplotlib.transforms import Bbox, TransformedBbox,␣
 ↪blended_transform_factory
from mpl_toolkits.axes_grid1.inset_locator import (BboxConnector,␣
 ↪BboxConnectorPatch,
                                                   BboxPatch)


def connect_bbox(bbox1, bbox2,
                 loc1a, loc2a, loc1b, loc2b,
                 prop_lines, prop_patches=None):
    if prop_patches is None:
        prop_patches = {
            **prop_lines,
            "alpha": prop_lines.get("alpha", 1) * 0.2,
            "clip_on": False,
        }

    c1 = BboxConnector(
        bbox1, bbox2, loc1=loc1a, loc2=loc2a, clip_on=False,␣
```

(continues on next page)

(continued from previous page)

```
↪**prop_lines)
    c2 = BboxConnector(
        bbox1, bbox2, loc1=loc1b, loc2=loc2b, clip_on=False,␣
↪**prop_lines)

    bbox_patch1 = BboxPatch(bbox1, **prop_patches)
    bbox_patch2 = BboxPatch(bbox2, **prop_patches)

    p = BboxConnectorPatch(bbox1, bbox2,
                           loc1a=loc1a, loc2a=loc2a, loc1b=loc1b,␣
↪loc2b=loc2b,
                           clip_on=False,
                           **prop_patches)

    return c1, c2, bbox_patch1, bbox_patch2, p


def zoom_effect01(ax1, ax2, xmin, xmax, **kwargs):
    """
    Connect *ax1* and *ax2*. The *xmin*-to-*xmax* range in both Axes␣
↪will
    be marked.

    Parameters
    ----------
    ax1
        The main Axes.
    ax2
        The zoomed Axes.
    xmin, xmax
        The limits of the colored area in both plot Axes.
    **kwargs
        Arguments passed to the patch constructor.
    """

    bbox = Bbox.from_extents(xmin, 0, xmax, 1)

    mybbox1 = TransformedBbox(bbox, ax1.get_xaxis_transform())
    mybbox2 = TransformedBbox(bbox, ax2.get_xaxis_transform())

    prop_patches = {**kwargs, "ec": "none", "alpha": 0.2}

    c1, c2, bbox_patch1, bbox_patch2, p = connect_bbox(
        mybbox1, mybbox2,
        loc1a=3, loc2a=2, loc1b=4, loc2b=1,
        prop_lines=kwargs, prop_patches=prop_patches)
```

(continues on next page)

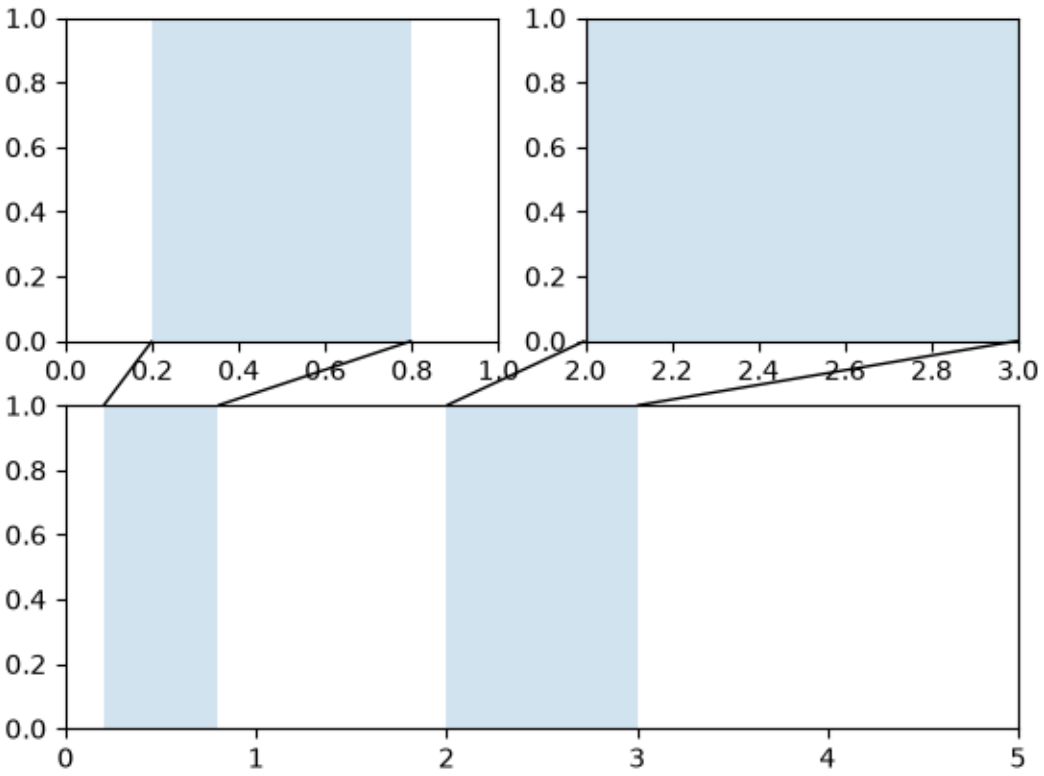
(continued from previous page)

```
    ax1.add_patch(bbox_patch1)
    ax2.add_patch(bbox_patch2)
    ax2.add_patch(c1)
    ax2.add_patch(c2)
    ax2.add_patch(p)

    return c1, c2, bbox_patch1, bbox_patch2, p


def zoom_effect02(ax1, ax2, **kwargs):
    """
    ax1 : the main Axes
    ax1 : the zoomed Axes

    Similar to zoom_effect01.  The xmin & xmax will be taken from the
    ax1.viewLim.
    """

    tt = ax1.transScale + (ax1.transLimits + ax2.transAxes)
    trans = blended_transform_factory(ax2.transData, tt)

    mybbox1 = ax1.bbox
    mybbox2 = TransformedBbox(ax1.viewLim, trans)

    prop_patches = {**kwargs, "ec": "none", "alpha": 0.2}

    c1, c2, bbox_patch1, bbox_patch2, p = connect_bbox(
        mybbox1, mybbox2,
        loc1a=3, loc2a=2, loc1b=4, loc2b=1,
        prop_lines=kwargs, prop_patches=prop_patches)

    ax1.add_patch(bbox_patch1)
    ax2.add_patch(bbox_patch2)
    ax2.add_patch(c1)
    ax2.add_patch(c2)
    ax2.add_patch(p)

    return c1, c2, bbox_patch1, bbox_patch2, p


axs = plt.figure().subplot_mosaic([
    ["zoom1", "zoom2"],
    ["main", "main"],
])
```

(continues on next page)

(continued from previous page)

```
axs["main"].set(xlim=(0, 5))
zoom_effect01(axs["zoom1"], axs["main"], 0.2, 0.8)
axs["zoom2"].set(xlim=(2, 3))
zoom_effect02(axs["zoom2"], axs["main"])

plt.show()
```



Tags: component: subplot component: transform level: advanced

Zoom region inset Axes

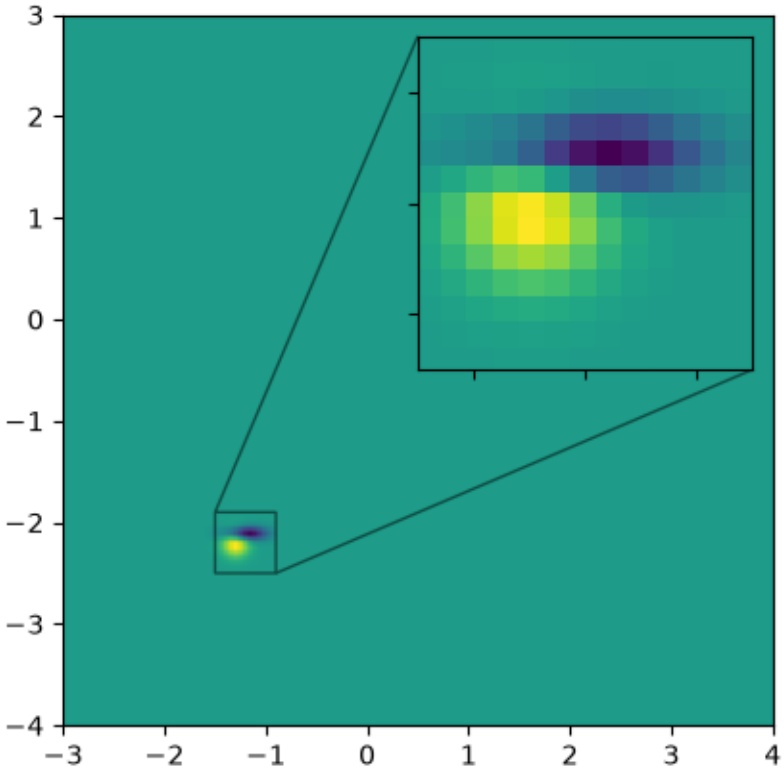
Example of an inset Axes and a rectangle showing where the zoom is located.

```
import numpy as np

from matplotlib import cbook
from matplotlib import pyplot as plt

fig, ax = plt.subplots()
```

(continues on next page)

(continued from previous page)

```
# make data
Z = cbook.get_sample_data("axes_grid/bivariate_normal.npy")  # 15x15␣
 ↪array
Z2 = np.zeros((150, 150))
ny, nx = Z.shape
Z2[30:30+ny, 30:30+nx] = Z
extent = (-3, 4, -4, 3)

ax.imshow(Z2, extent=extent, origin="lower")

# inset Axes....
x1, x2, y1, y2 = -1.5, -0.9, -2.5, -1.9  # subregion of the original␣
 ↪image
axins = ax.inset_axes(
    [0.5, 0.5, 0.47, 0.47],
    xlim=(x1, x2), ylim=(y1, y2), xticklabels=[], yticklabels=[])
axins.imshow(Z2, extent=extent, origin="lower")

ax.indicate_inset_zoom(axins, edgecolor="black")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.inset_axes*
- *matplotlib.axes.Axes.indicate_inset_zoom*
- *matplotlib.axes.Axes.imshow*

Tags: component: axes plot-type: imshow level: intermediate

Broken axis

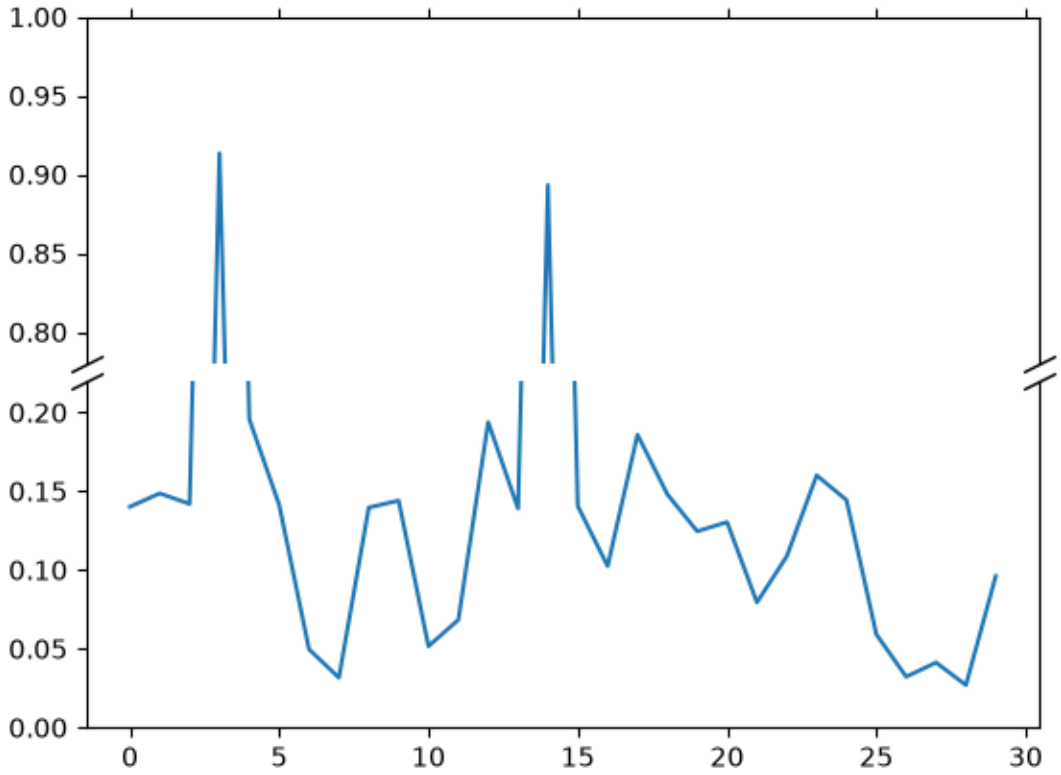
Broken axis example, where the y-axis will have a portion cut out.

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)
```

(continues on next page)

(continued from previous page)

```
pts = np.random.rand(30)*.2
# Now let's make two outlier points which are far away from everything.
pts[[3, 14]] += .8

# If we were to simply plot pts, we'd lose most of the interesting
# details due to the outliers. So let's 'break' or 'cut-out' the y-axis
# into two portions - use the top (ax1) for the outliers, and the␣
 ↪bottom
# (ax2) for the details of the majority of our data
fig, (ax1, ax2) = plt.subplots(2, 1, sharex=True)
fig.subplots_adjust(hspace=0.05)  # adjust space between Axes

# plot the same data on both Axes
ax1.plot(pts)
ax2.plot(pts)

# zoom-in / limit the view to different portions of the data
ax1.set_ylim(.78, 1.)  # outliers only
ax2.set_ylim(0, .22)  # most of the data

# hide the spines between ax and ax2
ax1.spines.bottom.set_visible(False)
ax2.spines.top.set_visible(False)
ax1.xaxis.tick_top()
ax1.tick_params(labeltop=False)  # don't put tick labels at the top
ax2.xaxis.tick_bottom()

# Now, let's turn towards the cut-out slanted lines.
# We create line objects in axes coordinates, in which (0,0), (0,1),
# (1,0), and (1,1) are the four corners of the Axes.
# The slanted lines themselves are markers at those locations, such␣
 ↪that the
# lines keep their angle and position, independent of the Axes size or␣
 ↪scale
# Finally, we need to disable clipping.

d = .5  # proportion of vertical to horizontal extent of the slanted␣
 ↪line
kwargs = dict(marker=[(-1, -d), (1, d)], markersize=12,
              linestyle="none", color='k', mec='k', mew=1,␣
 ↪clip_on=False)
ax1.plot([0, 1], [0, 0], transform=ax1.transAxes, **kwargs)
ax2.plot([0, 1], [1, 1], transform=ax2.transAxes, **kwargs)


plt.show()
```



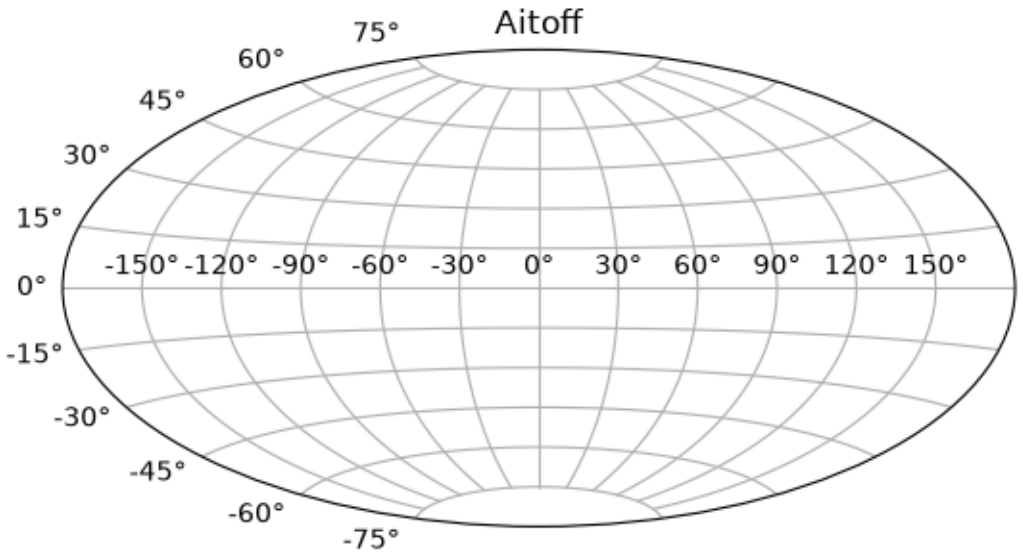
Tags: component: axis plot-type: line level: intermediate

Geographic Projections

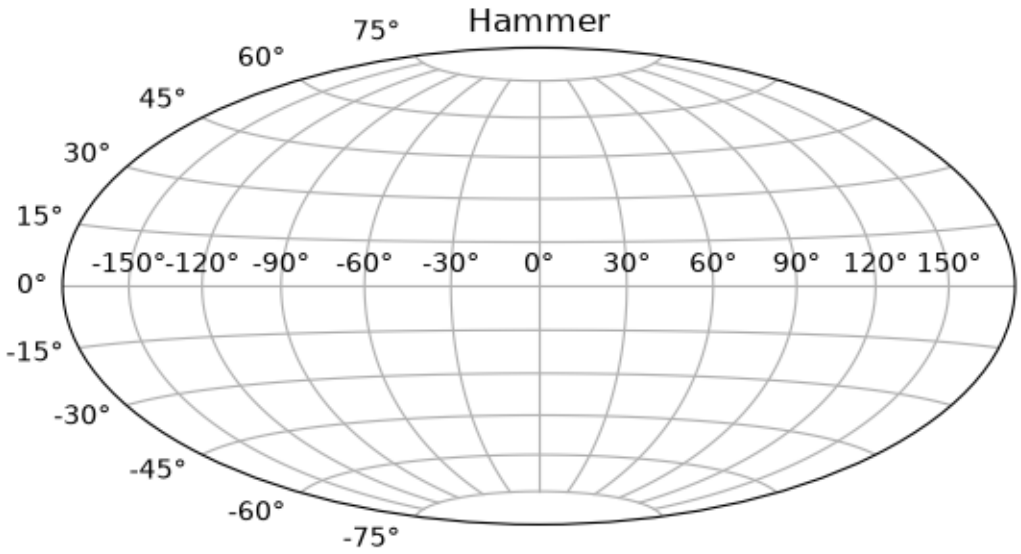
This shows 4 possible geographic projections. Cartopy supports more projections.

```
import matplotlib.pyplot as plt
```

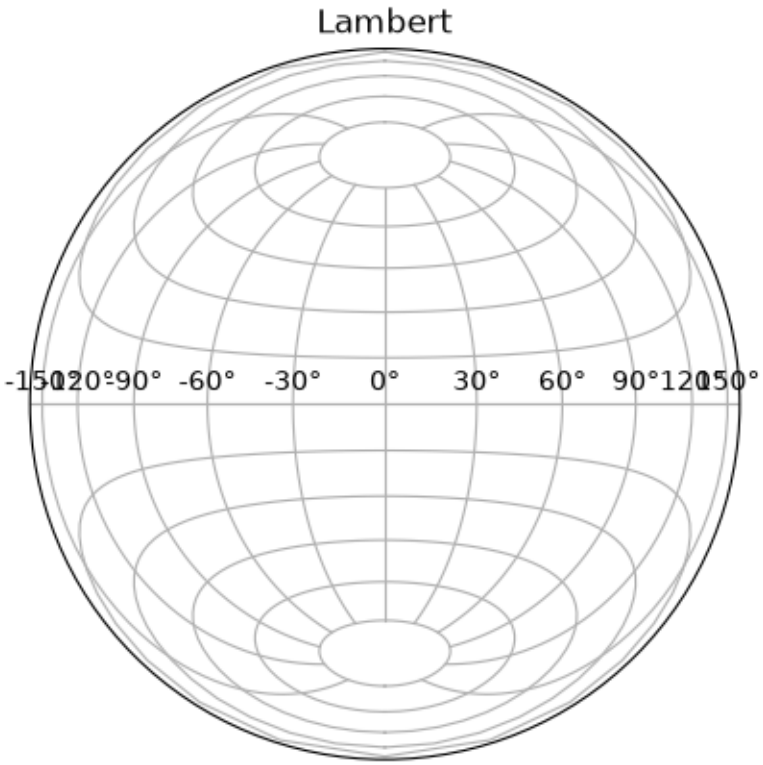
```
plt.figure()
plt.subplot(projection="aitoff")
plt.title("Aitoff")
plt.grid(True)
```



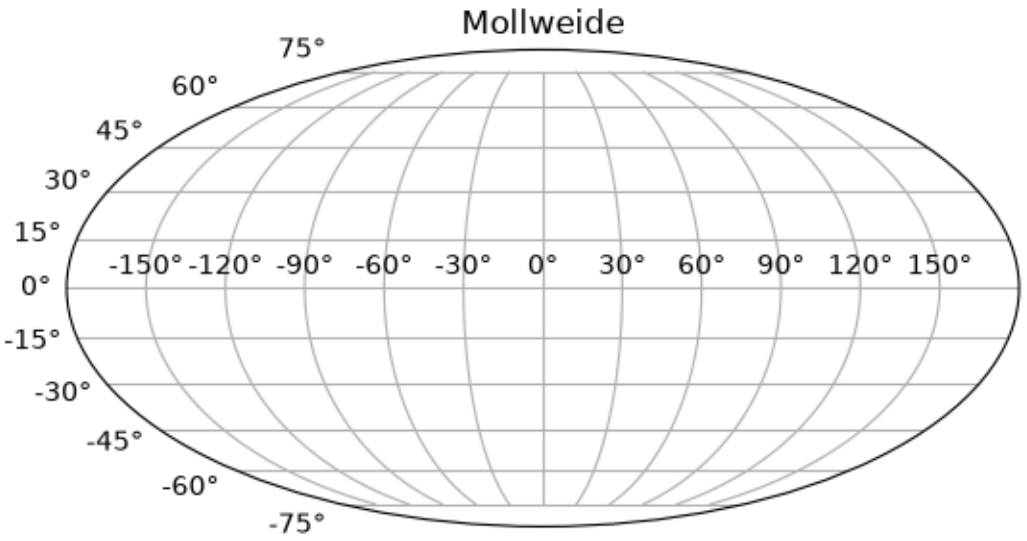

```
plt.figure()
plt.subplot(projection="hammer")
plt.title("Hammer")
plt.grid(True)
```




```
plt.figure()
plt.subplot(projection="lambert")
plt.title("Lambert")
plt.grid(True)
```




```
plt.figure()
plt.subplot(projection="mollweide")
plt.title("Mollweide")
plt.grid(True)

plt.show()
```



Tags: plot-type: specialty component: projection domain: cartography

Draw regions that span an Axes

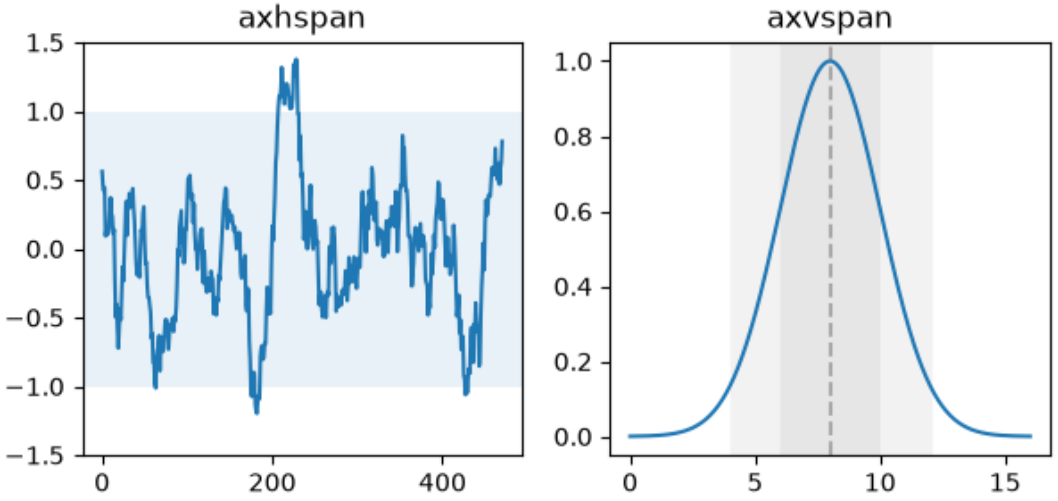
axhspan and *axvspan* draw rectangles that span the Axes in either the horizontal or vertical direction and are bounded in the other direction. They are often used to highlight data regions.

```
import matplotlib.pyplot as plt
import numpy as np

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(7, 3))

np.random.seed(19680801)
s = 2.9 * np.convolve(np.random.randn(500), np.ones(30) / 30, mode=
 ↪'valid')
ax1.plot(s)
ax1.axhspan(-1, 1, alpha=0.1)
ax1.set(ylim=(-1.5, 1.5), title="axhspan")


mu = 8
```

(continues on next page)

(continued from previous page)

```
sigma = 2
x = np.linspace(0, 16, 401)
y = np.exp(-((x-mu)**2)/(2*sigma**2))
ax2.axvspan(mu-2*sigma, mu-sigma, color='0.95')
ax2.axvspan(mu-sigma, mu+sigma, color='0.9')
ax2.axvspan(mu+sigma, mu+2*sigma, color='0.95')
ax2.axvline(mu, color='darkgrey', linestyle='--')
ax2.plot(x, y)
ax2.set(title="axvspan")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.axhspan* / *matplotlib.pyplot.axhspan*
- *matplotlib.axes.Axes.axvspan* / *matplotlib.pyplot.axvspan*

See also

axhline, *axvline*, *axline* draw infinite lines.

Tags: styling: shape plot-type: line level: beginner

6.24.6 Ticks

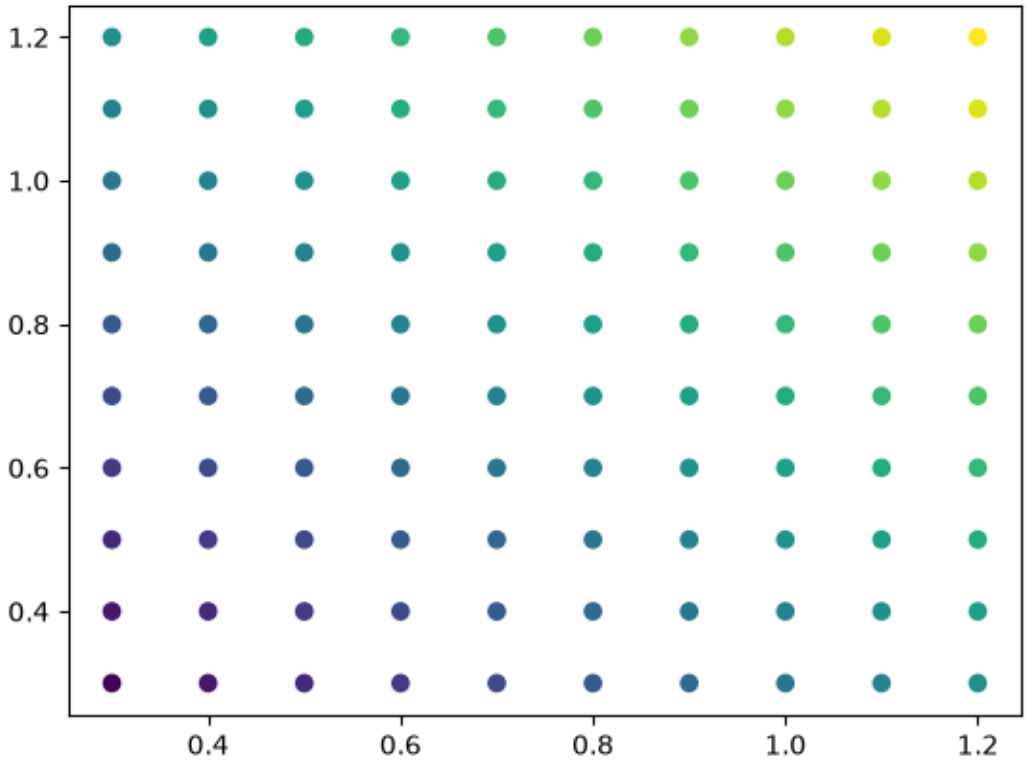
Automatically setting tick positions

Setting the behavior of tick auto-placement.

By default, Matplotlib will choose the number of ticks and tick positions so that there is a reasonable number of ticks on the axis and they are located at "round" numbers.

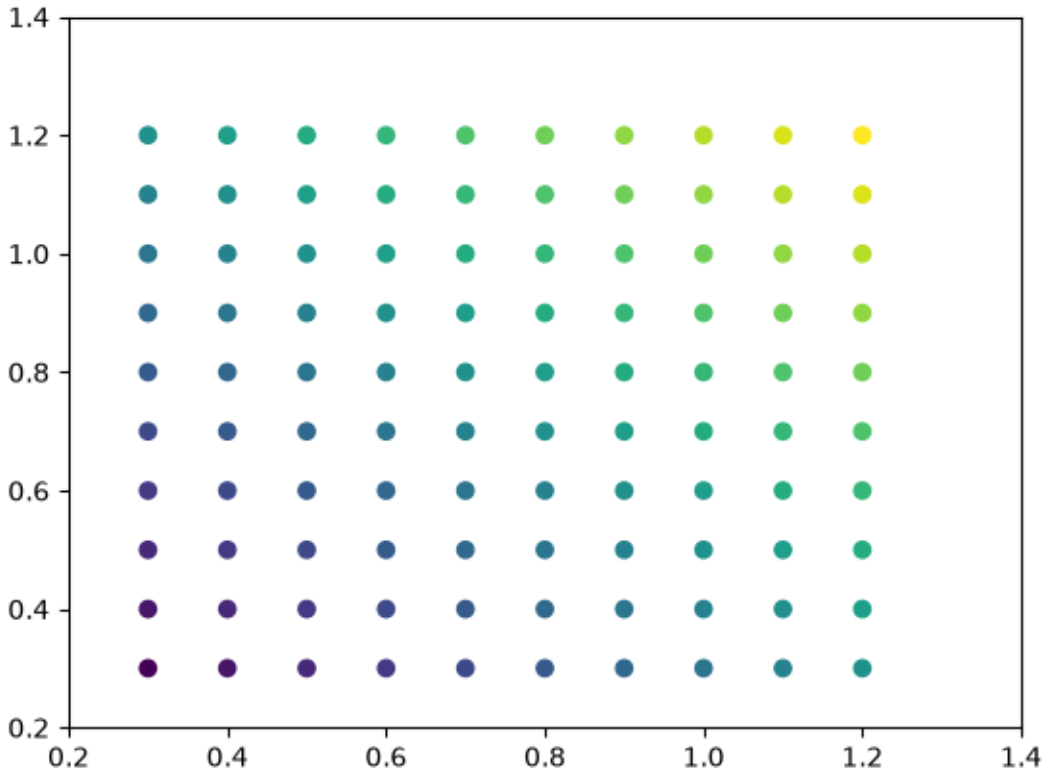
As a result, there may be no ticks on the edges of the plot.

```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)

fig, ax = plt.subplots()
dots = np.linspace(0.3, 1.2, 10)
X, Y = np.meshgrid(dots, dots)
x, y = X.ravel(), Y.ravel()
ax.scatter(x, y, c=x+y)
plt.show()
```



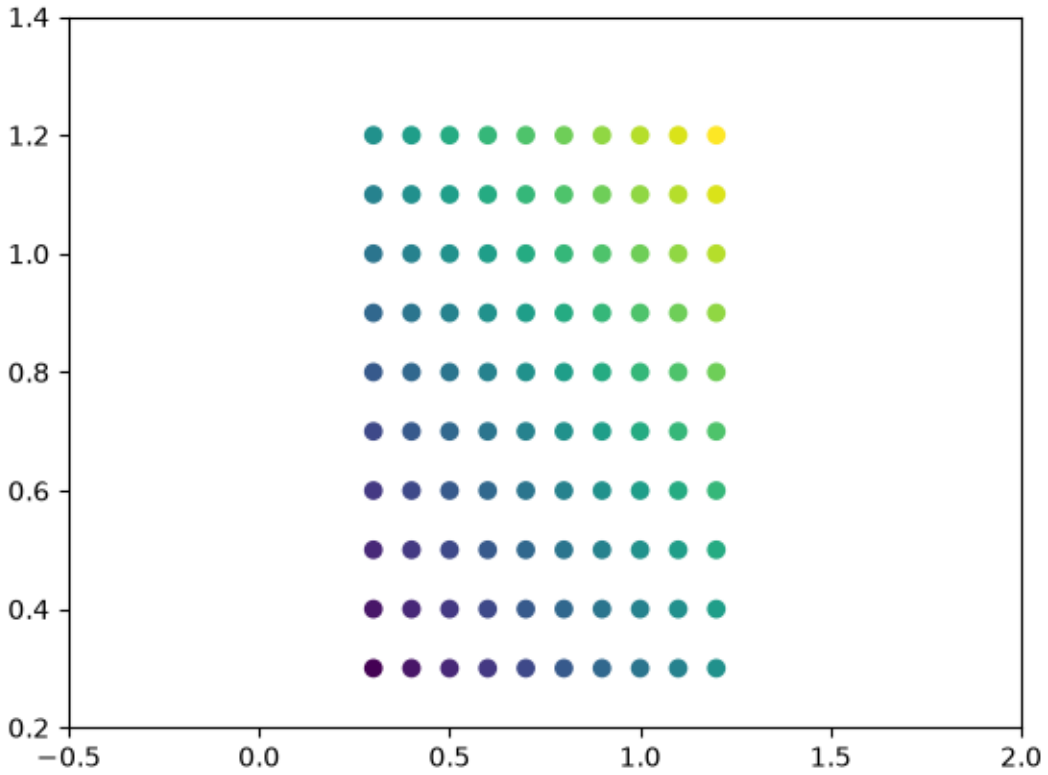
If you want to keep ticks at round numbers, and also have ticks at the edges you can switch *rcParams["axes.autolimit_mode"]* (default: `'data'`) to 'round_numbers'. This expands the axis limits to the next round number.

```
plt.rcParams['axes.autolimit_mode'] = 'round_numbers'

# Note: The limits are calculated at draw-time. Therefore, when using
# :rc:`axes.autolimit_mode` in a context manager, it is important that
# the ``show()`` command is within the context.

fig, ax = plt.subplots()
ax.scatter(x, y, c=x+y)
plt.show()
```



The round numbers autolimit_mode is still respected if you set an additional margin around the data using *Axes.set_xmargin* / *Axes.set_ymargin*:

```
fig, ax = plt.subplots()
ax.scatter(x, y, c=x+y)
ax.set_xmargin(0.8)
plt.show()
```



Tick locators

Tick locators define the position of the ticks.

This example illustrates the usage and effect of the most common locators.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.ticker as ticker


def setup(ax, title):
    """Set up common parameters for the Axes in the example."""
    # only show the bottom spine
    ax.yaxis.set_major_locator(ticker.NullLocator())
    ax.spines[['left', 'right', 'top']].set_visible(False)

    ax.xaxis.set_ticks_position('bottom')
    ax.tick_params(which='major', width=1.00, length=5)
    ax.tick_params(which='minor', width=0.75, length=2.5)
```

(continues on next page)

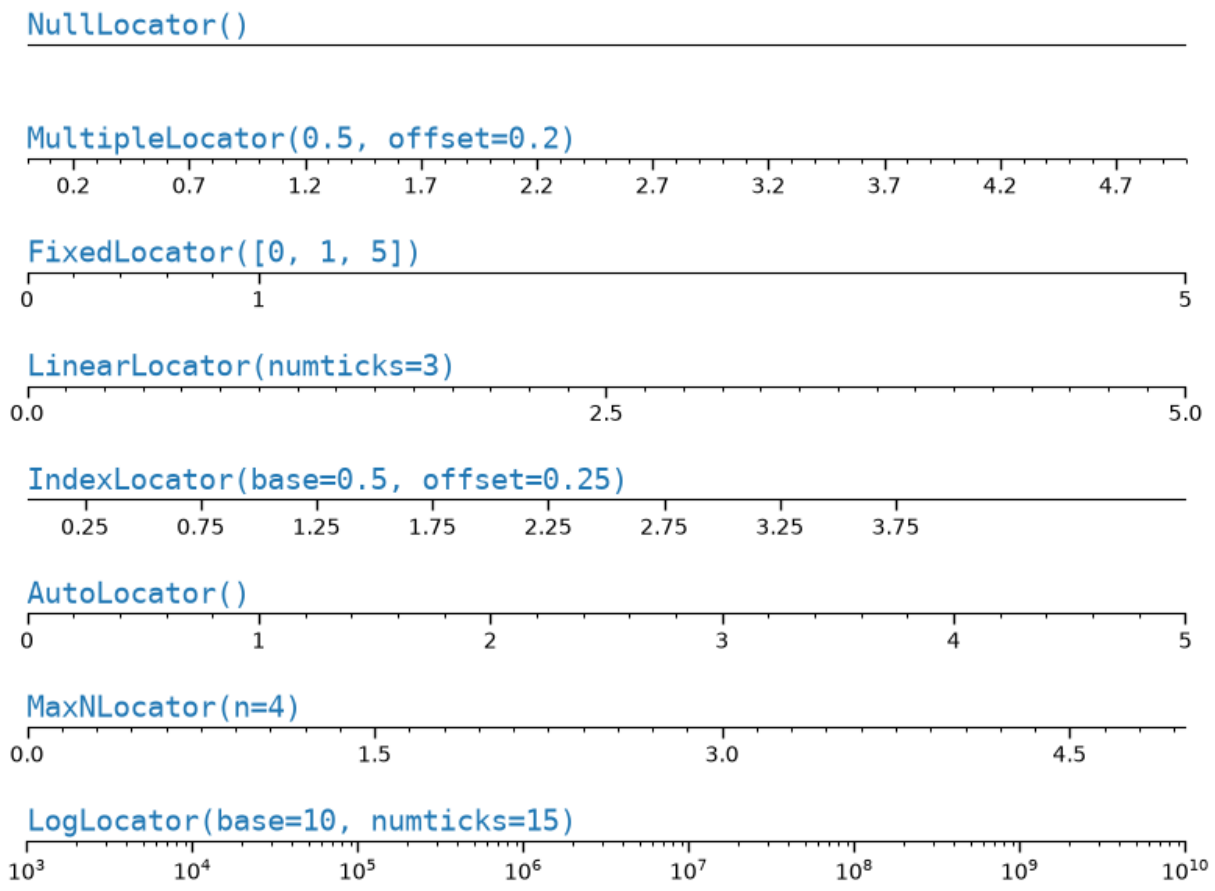
(continued from previous page)

```
    ax.set_xlim(0, 5)
    ax.set_ylim(0, 1)
    ax.text(0.0, 0.2, title, transform=ax.transAxes,
            fontsize=14, fontname='Monospace', color='tab:blue')


fig, axs = plt.subplots(8, 1, figsize=(8, 6))

# Null Locator
setup(axs[0], title="NullLocator()")
axs[0].xaxis.set_major_locator(ticker.NullLocator())
axs[0].xaxis.set_minor_locator(ticker.NullLocator())

# Multiple Locator
setup(axs[1], title="MultipleLocator(0.5, offset=0.2)")
axs[1].xaxis.set_major_locator(ticker.MultipleLocator(0.5, offset=0.2))
axs[1].xaxis.set_minor_locator(ticker.MultipleLocator(0.1))

# Fixed Locator
setup(axs[2], title="FixedLocator([0, 1, 5])")
axs[2].xaxis.set_major_locator(ticker.FixedLocator([0, 1, 5]))
axs[2].xaxis.set_minor_locator(ticker.FixedLocator(np.linspace(0.2,␣
 ↪0.8, 4)))

# Linear Locator
setup(axs[3], title="LinearLocator(numticks=3)")
axs[3].xaxis.set_major_locator(ticker.LinearLocator(3))
axs[3].xaxis.set_minor_locator(ticker.LinearLocator(31))

# Index Locator
setup(axs[4], title="IndexLocator(base=0.5, offset=0.25)")
axs[4].plot([0]*5, color='white')
axs[4].xaxis.set_major_locator(ticker.IndexLocator(base=0.5,␣
 ↪offset=0.25))

# Auto Locator
setup(axs[5], title="AutoLocator()")
axs[5].xaxis.set_major_locator(ticker.AutoLocator())
axs[5].xaxis.set_minor_locator(ticker.AutoMinorLocator())

# MaxN Locator
setup(axs[6], title="MaxNLocator(n=4)")
axs[6].xaxis.set_major_locator(ticker.MaxNLocator(4))
axs[6].xaxis.set_minor_locator(ticker.MaxNLocator(40))

# Log Locator
```

(continues on next page)

(continued from previous page)

```
setup(axs[7], title="LogLocator(base=10, numticks=15)")
axs[7].set_xlim(10**3, 10**10)
axs[7].set_xscale('log')
axs[7].xaxis.set_major_locator(ticker.LogLocator(base=10, numticks=15))

plt.tight_layout()
plt.show()
```



References

The following functions, methods, classes and modules are used in this example:

- *matplotlib.axis.Axis.set_major_locator*
- *matplotlib.axis.Axis.set_minor_locator*
- *matplotlib.ticker.NullLocator*
- *matplotlib.ticker.MultipleLocator*
- *matplotlib.ticker.FixedLocator*

- *matplotlib.ticker.LinearLocator*
- *matplotlib.ticker.IndexLocator*
- *matplotlib.ticker.AutoLocator*
- *matplotlib.ticker.MaxNLocator*
- *matplotlib.ticker.LogLocator*

Tags: component: ticks purpose: reference

Total running time of the script: (0 minutes 1.128 seconds)

Major and minor ticks

Demonstrate how to use major and minor tickers.

The two relevant classes are *Locator*s and *Formatter*s. Locators determine where the ticks are, and formatters control the formatting of tick labels.

Minor ticks are off by default (using *NullLocator* and *NullFormatter*). Minor ticks can be turned on without labels by setting the minor locator. Minor tick labels can be turned on by setting the minor formatter.

MultipleLocator places ticks on multiples of some base. *StrMethodFormatter* uses a format string (e.g., `'{x:d}'` or `'{x:1.2f}'` or `'{x:1.1f} cm'`) to format the tick labels (the variable in the format string must be `'x'`). For a *StrMethodFormatter*, the string can be passed directly to *Axis.set_major_formatter* or *Axis.set_minor_formatter*. An appropriate *StrMethodFormatter* will be created and used automatically.

pyplot.grid changes the grid settings of the major ticks of the x- and y-axis together. If you want to control the grid of the minor ticks for a given axis, use for example

```
ax.xaxis.grid(True, which='minor')
```

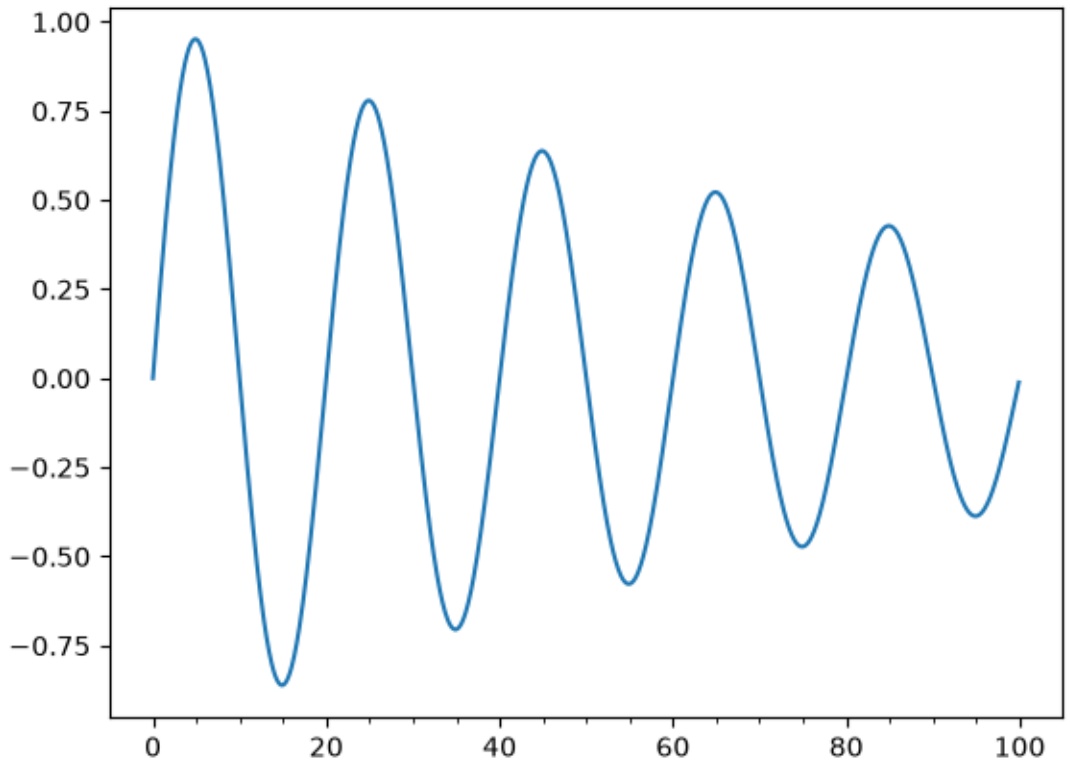
Note that a given locator or formatter instance can only be used on a single axis (because the locator stores references to the axis data and view limits).

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.ticker import AutoMinorLocator, MultipleLocator

t = np.arange(0.0, 100.0, 0.1)
s = np.sin(0.1 * np.pi * t) * np.exp(-t * 0.01)

fig, ax = plt.subplots()
ax.plot(t, s)

# Make a plot with major ticks that are multiples of 20 and minor␣
 ↪ticks that
```

(continues on next page)

(continued from previous page)

```
# are multiples of 5.  Label major ticks with '.0f' formatting but don
 ↪'t label
# minor ticks.  The string is used directly, the `StrMethodFormatter`␣
 ↪is
# created automatically.
ax.xaxis.set_major_locator(MultipleLocator(20))
ax.xaxis.set_major_formatter('{x:.0f}')

# For the minor ticks, use no labels; default NullFormatter.
ax.xaxis.set_minor_locator(MultipleLocator(5))

plt.show()
```

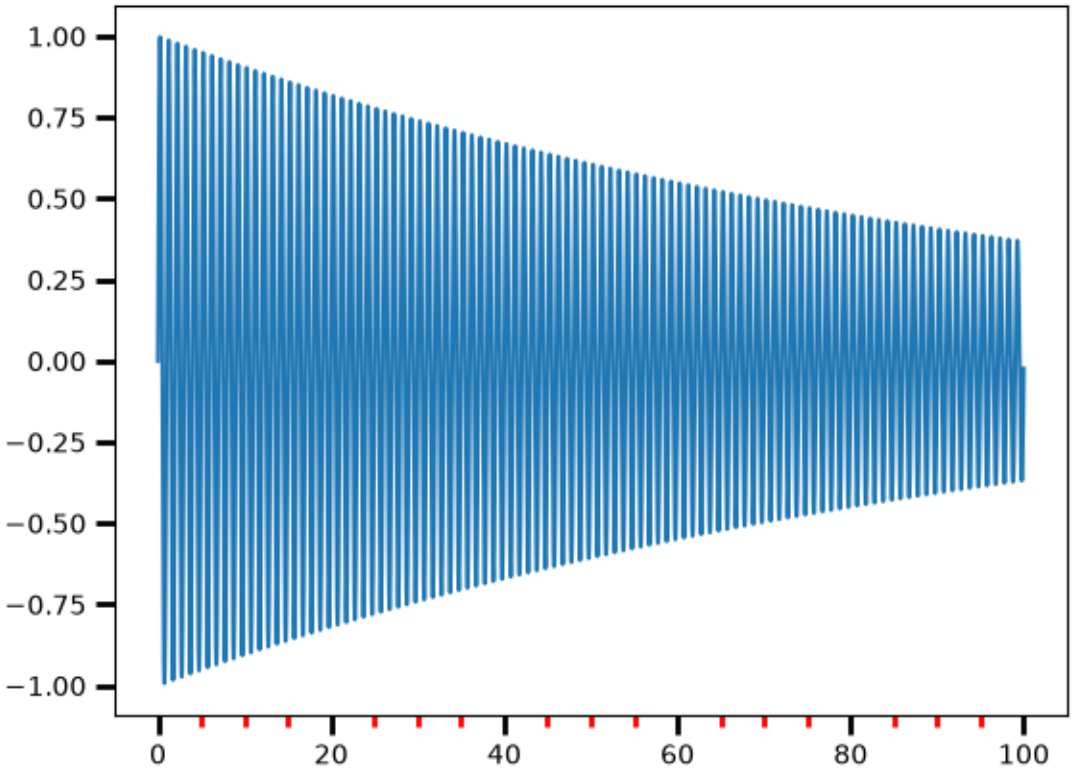


Automatic tick selection for major and minor ticks.

Use interactive pan and zoom to see how the tick intervals change. There will be either 4 or 5 minor tick intervals per major interval, depending on the major interval.

One can supply an argument to `AutoMinorLocator` to specify a fixed number of minor intervals per major interval, e.g. `AutoMinorLocator(2)` would lead to a single minor tick between major ticks.

```
t = np.arange(0.0, 100.0, 0.01)
s = np.sin(2 * np.pi * t) * np.exp(-t * 0.01)

fig, ax = plt.subplots()
ax.plot(t, s)

ax.xaxis.set_minor_locator(AutoMinorLocator())

ax.tick_params(which='both', width=2)
ax.tick_params(which='major', length=7)
ax.tick_params(which='minor', length=4, color='r')

plt.show()
```



References

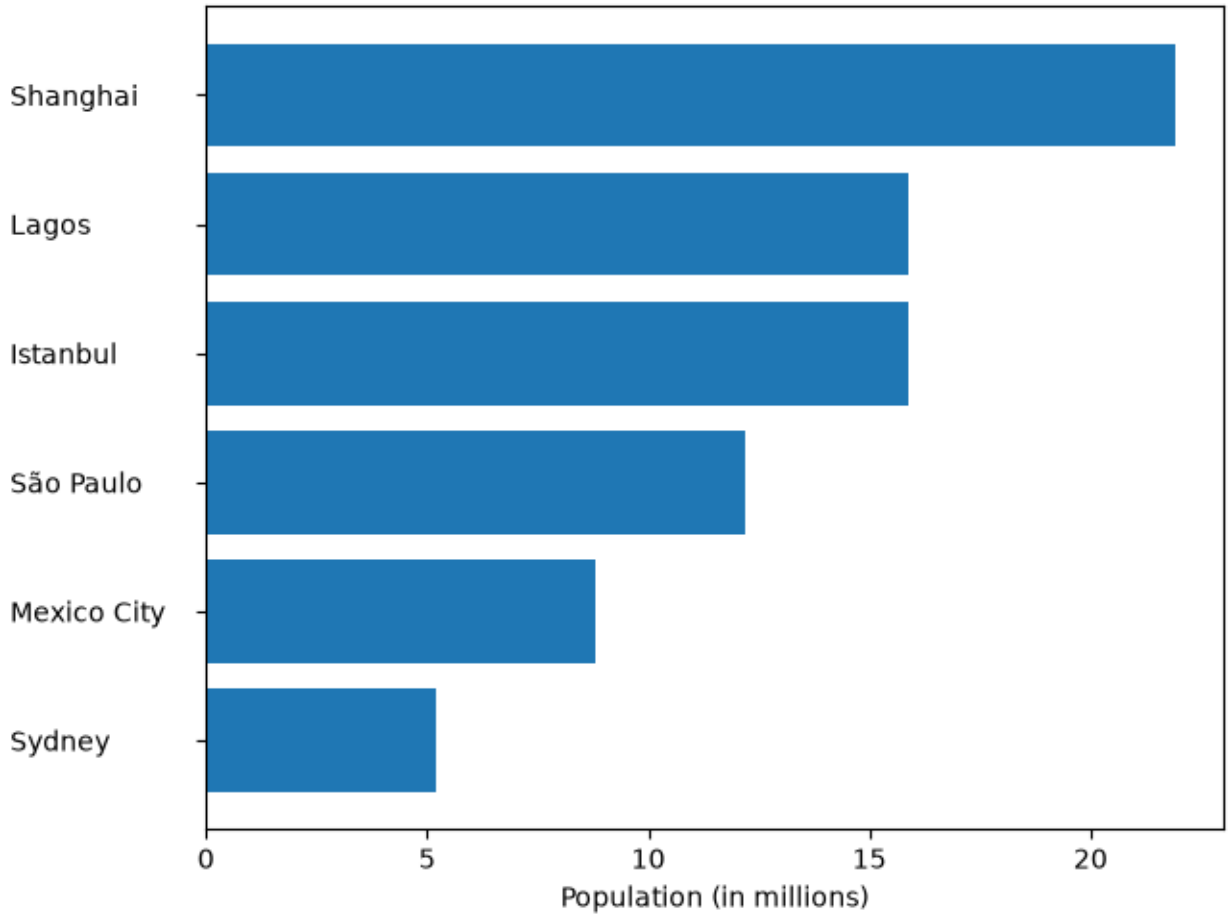
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.pyplot.subplots*
- *matplotlib.axis.Axis.set_major_formatter*

- *matplotlib.axis.Axis.set_major_locator*
- *matplotlib.axis.Axis.set_minor_locator*
- *matplotlib.ticker.AutoMinorLocator*
- *matplotlib.ticker.MultipleLocator*
- *matplotlib.ticker.StrMethodFormatter*

Align tick labels

By default, tick labels are aligned towards the axis. This means the set of *y* tick labels appear right-aligned. Because the alignment reference point is on the axis, left-aligned tick labels would overlap the plotting area. To achieve a good-looking left-alignment, you have to additionally increase the padding.




```
import matplotlib.pyplot as plt

population = {
    "Sydney": 5.2,
    "Mexico City": 8.8,
    "São Paulo": 12.2,
```

(continues on next page)

(continued from previous page)

```
    "Istanbul": 15.9,
    "Lagos": 15.9,
    "Shanghai": 21.9,
}

fig, ax = plt.subplots(layout="constrained")
ax.barh(population.keys(), population.values())
ax.set_xlabel('Population (in millions)')

# left-align all ticklabels
for ticklabel in ax.get_yticklabels():
    ticklabel.set_horizontalalignment("left")

# increase padding
ax.tick_params("y", pad=70)
```

Move x/y-axis ticks and labels on top and right

axes.Axes.tick_params can be used to move tick marks and tick labels to the top or right side of the Axes:

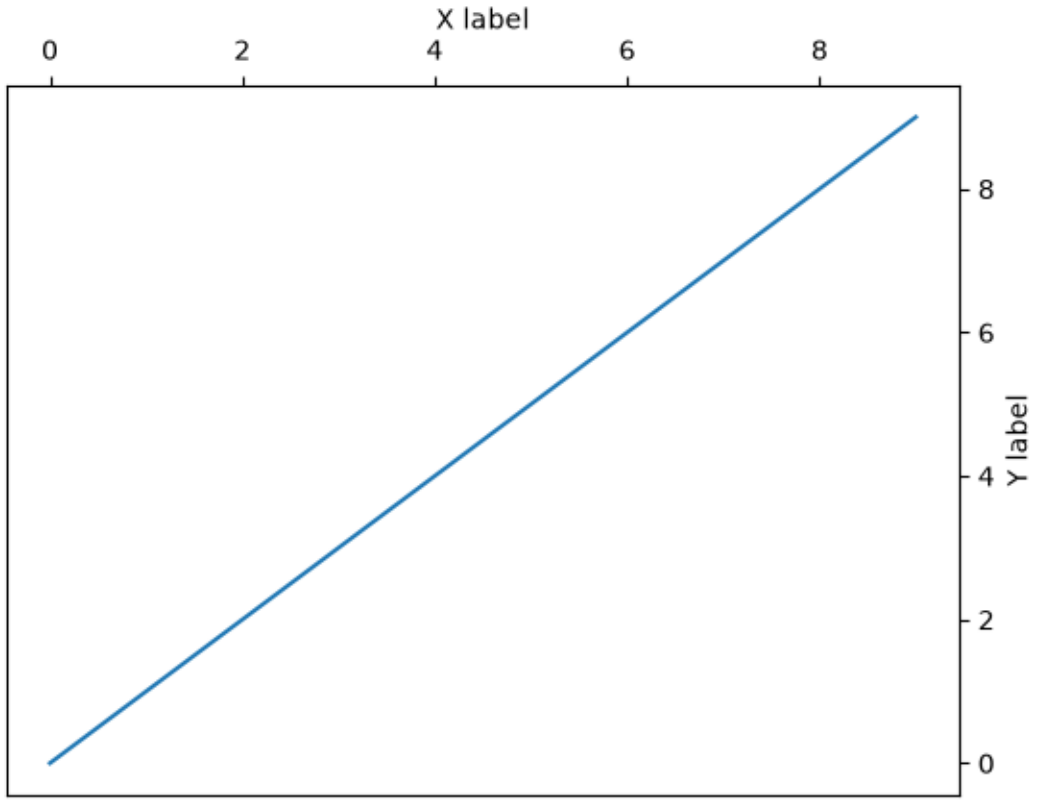
```
ax.tick_params(top=True, labeltop=True, bottom=False,␣
↪labelbottom=False)
ax.tick_params(right=True, labelright=True, left=False,␣
↪labelleft=False)
```

To also reposition the axes labels (xlabel/ylabel), use `Axes.xaxis.set_label_position` and `Axes.yaxis.set_label_position`.

Note

To apply this globally for all future plots, set the rcParams:

- *rcParams["xtick.top"]* (default: `False`)
- *rcParams["xtick.labeltop"]* (default: `False`)
- *rcParams["xtick.bottom"]* (default: `True`)
- *rcParams["xtick.labelbottom"]* (default: `True`)
- *rcParams["ytick.right"]* (default: `False`)
- *rcParams["ytick.labelright"]* (default: `False`)
- *rcParams["ytick.left"]* (default: `True`)
- *rcParams["ytick.labelleft"]* (default: `True`)




```
import matplotlib.pyplot as plt

fig, ax = plt.subplots()
ax.plot(range(10))

# Move ticks marks and tick labels
ax.tick_params(
    top=True, labeltop=True,
    bottom=False, labelbottom=False,
    right=True, labelright=True,
    left=False, labelleft=False,
)

# Move axis labels
ax.xaxis.set_label_position("top")
ax.yaxis.set_label_position("right")

ax.set_xlabel("X label")
ax.set_ylabel("Y label")

plt.show()
```

Center labels between ticks

Tick labels are aligned relative to their associated tick, and are by default centered.

However, there is no direct way to center the labels between ticks. To fake this behavior, one can place a minor tick in between the major ticks. Then label the minor tick, and hide the minor tick lines and the major tick labels.

Here is an example that labels the months, centered between the ticks.

```
import matplotlib.pyplot as plt

import matplotlib.cbook as cbook
import matplotlib.dates as dates
import matplotlib.ticker as ticker

# Load some financial data; Google's stock price
r = cbook.get_sample_data('goog.npz')['price_data']
r = r[-250:]  # get the last 250 days

fig, ax = plt.subplots()
ax.plot(r["date"], r["adj_close"])
```

(continues on next page)

(continued from previous page)

```
ax.xaxis.set_major_locator(dates.MonthLocator())
# 16 is a slight approximation since months differ in number of days.
ax.xaxis.set_minor_locator(dates.MonthLocator(bymonthday=16))

# The NullFormatter removes the major tick labels
ax.xaxis.set_major_formatter(ticker.NullFormatter())
ax.xaxis.set_minor_formatter(dates.DateFormatter('%b'))

# Remove the minor tick lines
ax.tick_params(axis='x', which='minor', tick1On=False, tick2On=False)

imid = len(r) // 2
ax.set_xlabel(str(r["date"][imid].item().year))
plt.show()
```

Rotated tick labels

Rotating tick labels can be useful when the labels are long and overlap with each other. Adjust the tick properties using *tick_params*: Set the angle in degrees via the *rotation* parameter. Set the *rotation_mode* parameter to "xtick" / "ytick" to make the text point towards the tick, see also *set_rotation_mode*.

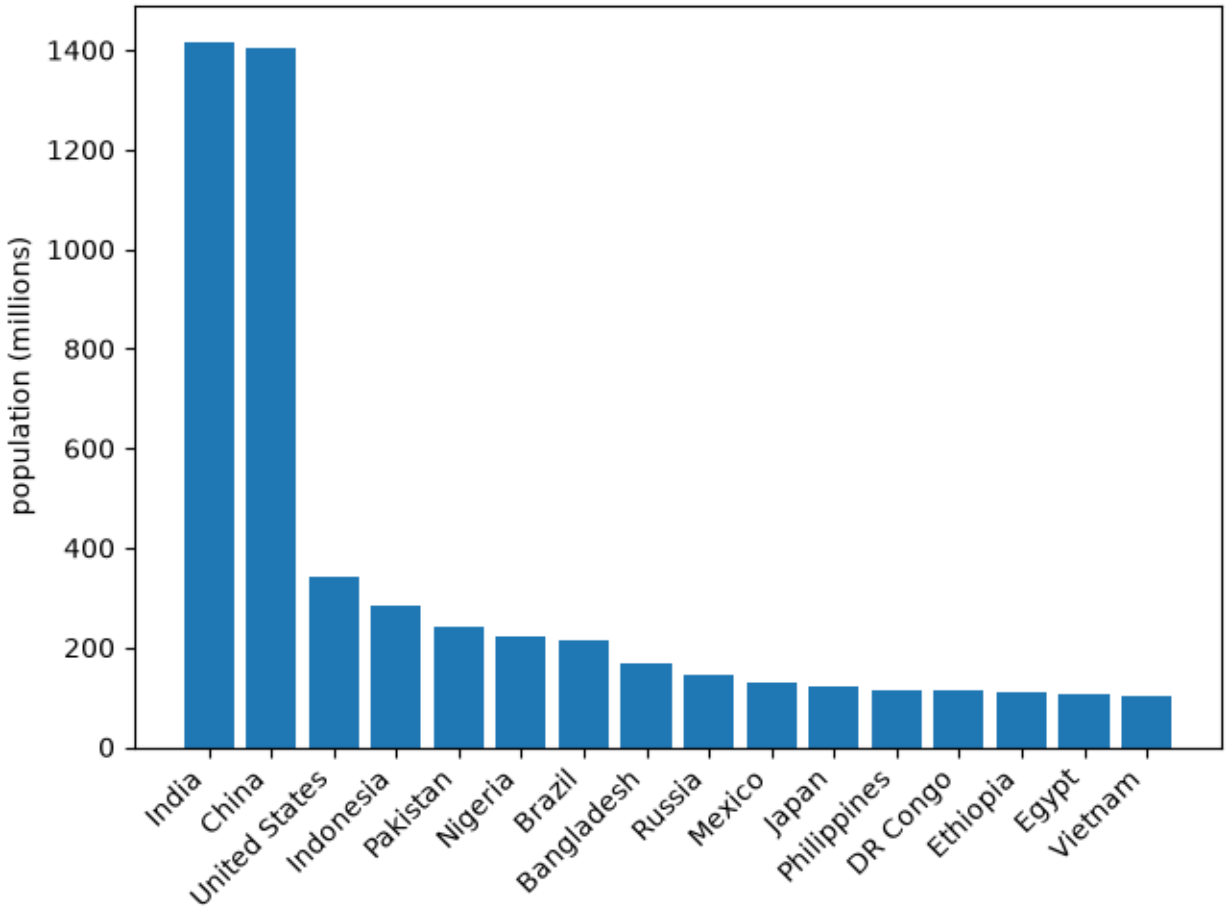
Note: We use `layout="constrained"` to make sure there is enough space for the tick labels so that they are not cut off.

```
import matplotlib.pyplot as plt

population = {
    'India': 1417.492,
    'China': 1404.89,
    'United States': 341.784857,
    'Indonesia': 284.438782,
    'Pakistan': 241.499431,
    'Nigeria': 223.8,
    'Brazil': 213.421037,
    'Bangladesh': 169.828911,
    'Russia': 146.028325,
    'Mexico': 131.001723,
    'Japan': 122.95,
    'Philippines': 114.1236,
    'DR Congo': 112.832,
    'Ethiopia': 111.652998,
    'Egypt': 107.868296,
    'Vietnam': 102.3,
}
```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots(layout="constrained")
ax.bar(population.keys(), population.values())
ax.tick_params("x", rotation=45, rotation_mode="xtick")
ax.set_ylabel("population (millions)")
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.tick_params* / *matplotlib.pyplot.tick_params*

Tags: component: ticks plot-type: bar

Multilevel (nested) ticks

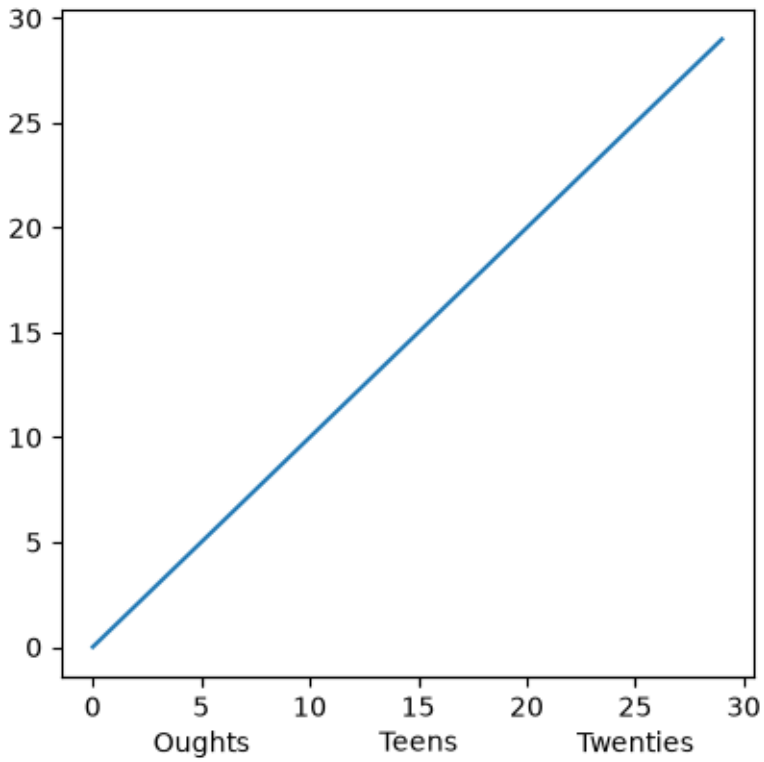
Sometimes we want another level of tick labels on an axis, perhaps to indicate a grouping of the ticks.

Matplotlib does not provide an automated way to do this, but it is relatively straightforward to annotate below the main axis.

These examples use *Axes.secondary_xaxis*, which is one approach. It has the advantage that we can use Matplotlib Locators and Formatters on the axis that does the grouping if we want.

This first example creates a secondary xaxis and manually adds the ticks and labels using *Axes.set_xticks*. Note that the tick labels have a newline (e.g. "\nOughts") at the beginning of them to put the second-level tick labels below the main tick labels.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.dates as mdates

rng = np.random.default_rng(19680801)

fig, ax = plt.subplots(layout='constrained', figsize=(4, 4))

ax.plot(np.arange(30))

sec = ax.secondary_xaxis(location=0)
sec.set_xticks([5, 15, 25], labels=['\nOughts', '\nTeens', '\nTwenties
↪'])
```

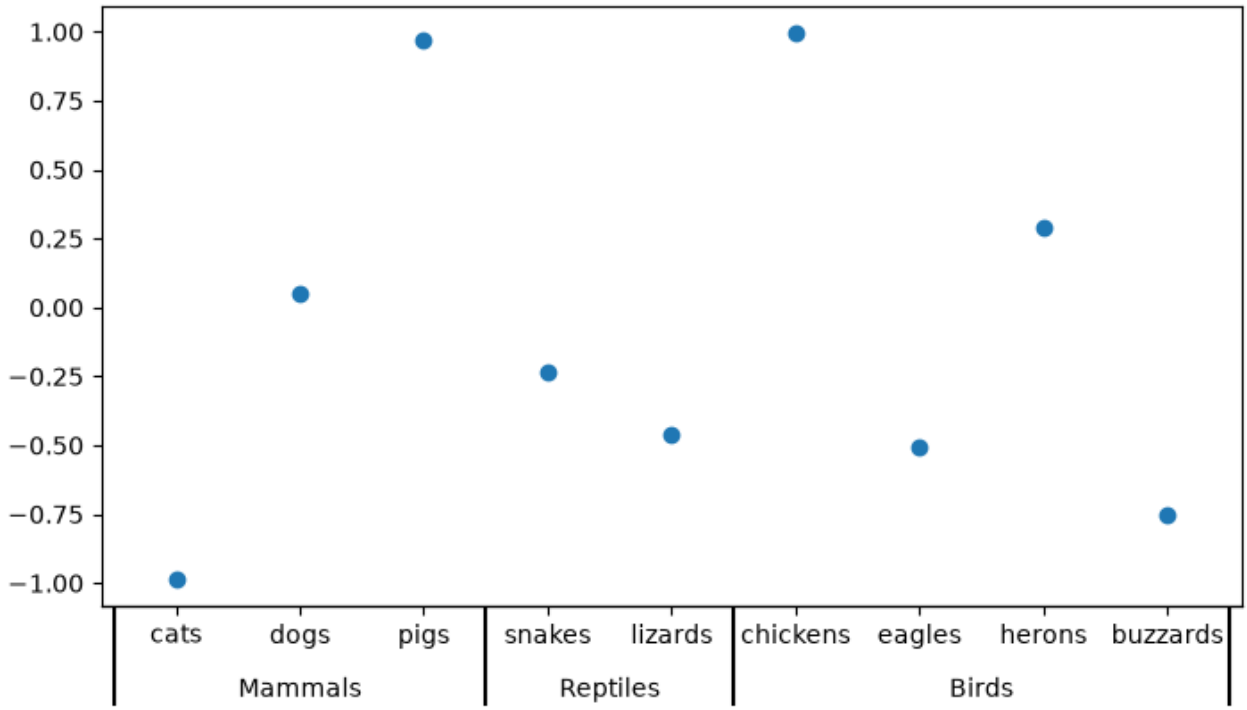


This second example adds a second level of annotation to a categorical axis. Here we need to note that each animal (category) is assigned an integer, so `cats` is at x=0, `dogs` at x=1 etc. Then we place the ticks on the second level on an x that is at the middle of the animal class we are trying to delineate.

This example also adds tick marks between the classes by adding a second secondary xaxis, and placing long,

wide ticks at the boundaries between the animal classes.

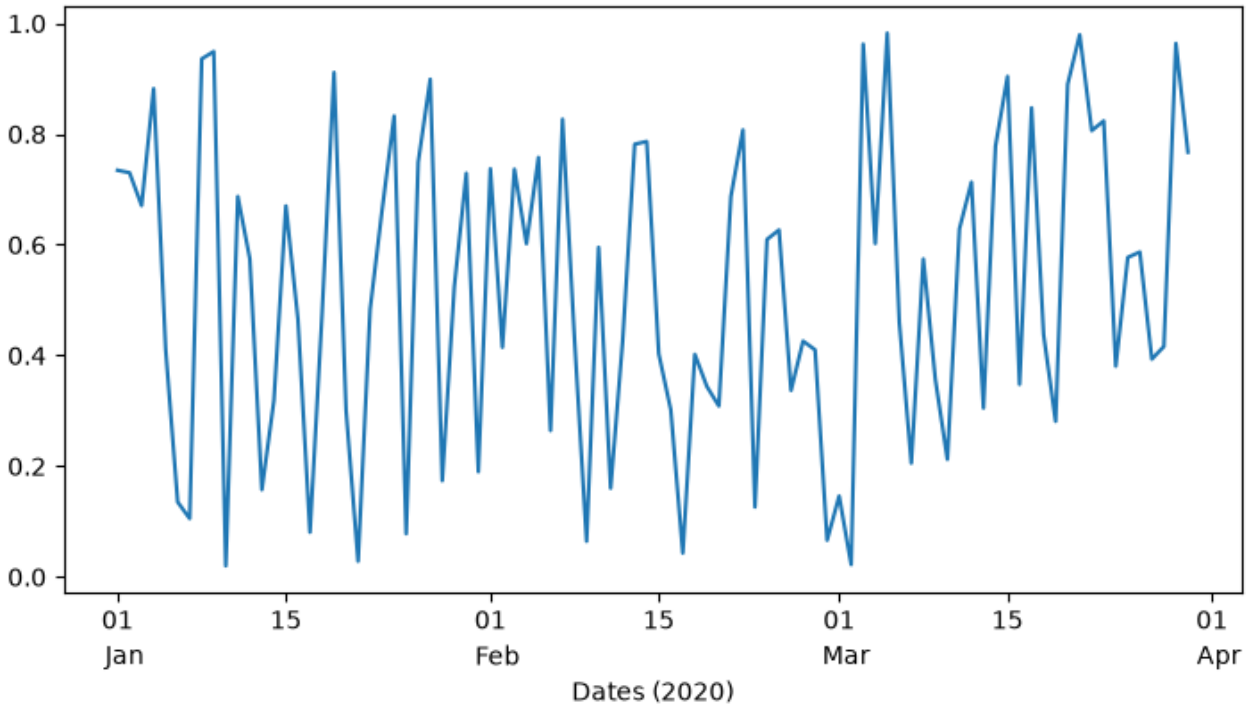
```
fig, ax = plt.subplots(layout='constrained', figsize=(7, 4))

ax.plot(['cats', 'dogs', 'pigs', 'snakes', 'lizards', 'chickens',
         'eagles', 'herons', 'buzzards'],
        rng.normal(size=9), 'o')

# label the classes:
sec = ax.secondary_xaxis(location=0)
sec.set_xticks([1, 3.5, 6.5], labels=['\n\nMammals', '\n\nReptiles', '\
 ↪n\nBirds'])
sec.tick_params('x', length=0)

# lines between the classes:
sec2 = ax.secondary_xaxis(location=0)
sec2.set_xticks([-0.5, 2.5, 4.5, 8.5], labels=[])
sec2.tick_params('x', length=40, width=1.5)
ax.set_xlim(-0.6, 8.6)
```



Dates are another common place where we may want to have a second level of tick labels. In this last example, we take advantage of the ability to add an automatic locator and formatter to the secondary xaxis, which means we do not need to set the ticks manually.

This example also differs from the above, in that we placed it at a location below the main axes `location=-0.075` and then we hide the spine by setting the line width to zero. That means that our formatter no longer needs the carriage returns of the previous two examples.

```
fig, ax = plt.subplots(layout='constrained', figsize=(7, 4))

time = np.arange(np.datetime64('2020-01-01'), np.datetime64('2020-03-31
 ↪'),
                 np.timedelta64(1, 'D'))

ax.plot(time, rng.random(size=len(time)))

# just format the days:
ax.xaxis.set_major_formatter(mdates.DateFormatter('%d'))

# label the months:
sec = ax.secondary_xaxis(location=-0.075)
sec.xaxis.set_major_locator(mdates.MonthLocator(bymonthday=1))

# note the extra spaces in the label to align the month label inside␣
 ↪the month.
# Note that this could have been done by changing ``bymonthday`` above␣
 ↪as well:
sec.xaxis.set_major_formatter(mdates.DateFormatter('  %b'))
sec.tick_params('x', length=0)
sec.spines['bottom'].set_linewidth(0)

# label the xaxis, but note for this to look good, it needs to be on␣
 ↪the
# secondary xaxis.
sec.set_xlabel('Dates (2020)')

plt.show()
```

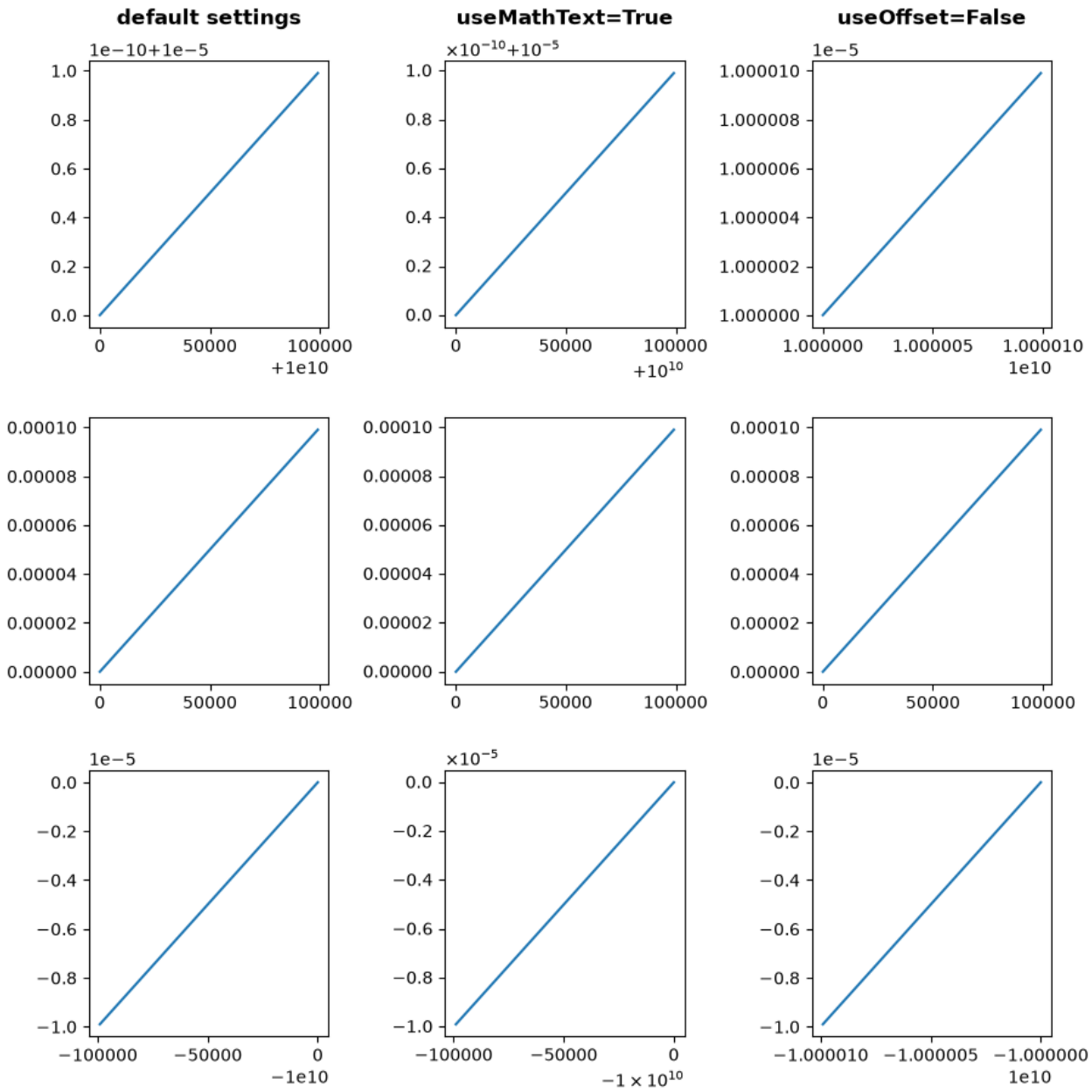


Total running time of the script: (0 minutes 1.054 seconds)

The default tick formatter

By default, tick labels are formatted using a *ScalarFormatter*, which can be configured via *ticklabel_format*. This example illustrates some possible configurations:

- Default.
- `useMathText=True`: Fancy formatting of mathematical expressions.
- `useOffset=False`: Do not use offset notation; see *ScalarFormatter.set_useOffset*.




```
import matplotlib.pyplot as plt
import numpy as np

x = np.arange(0, 1, .01)
fig, axs = plt.subplots(
    3, 3, figsize=(9, 9), layout="constrained", gridspec_kw={"hspace":␣
 ↪0.1})

for col in axs.T:
    col[0].plot(x * 1e5 + 1e10, x * 1e-10 + 1e-5)
    col[1].plot(x * 1e5, x * 1e-4)
```

(continues on next page)

(continued from previous page)

```
    col[2].plot(-x * 1e5 - 1e10, -x * 1e-5 - 1e-10)

for ax in axs[:, 1]:
    ax.ticklabel_format(useMathText=True)
for ax in axs[:, 2]:
    ax.ticklabel_format(useOffset=False)

plt.rcParams.update({"axes.titleweight": "bold", "axes.titley": 1.1})
axs[0, 0].set_title("default settings")
axs[0, 1].set_title("useMathText=True")
axs[0, 2].set_title("useOffset=False")

plt.show()
```

Total running time of the script: (0 minutes 1.797 seconds)

Tick formatters

Tick formatters define how the numeric value associated with a tick on an axis is formatted as a string.

This example illustrates the usage and effect of the most common formatters.

The tick format is configured via the function *set_major_formatter* or *set_minor_formatter*. It accepts:

- a format string, which implicitly creates a *StrMethodFormatter*.
- a function, implicitly creates a *FuncFormatter*.
- an instance of a *Formatter* subclass. The most common are
  - *NullFormatter*: No labels on the ticks.
  - *StrMethodFormatter*: Use string `str.format` method.
  - *FormatStrFormatter*: Use %-style formatting.
  - *FuncFormatter*: Define labels through a function.
  - *FixedFormatter*: Set the label strings explicitly.
  - *ScalarFormatter*: Default formatter for scalars: auto-pick the format string.
  - *PercentFormatter*: Format labels as a percentage.

  See *Tick formatting* for a complete list.

```
import matplotlib.pyplot as plt

from matplotlib import ticker


def setup(ax, title):
```

(continues on next page)

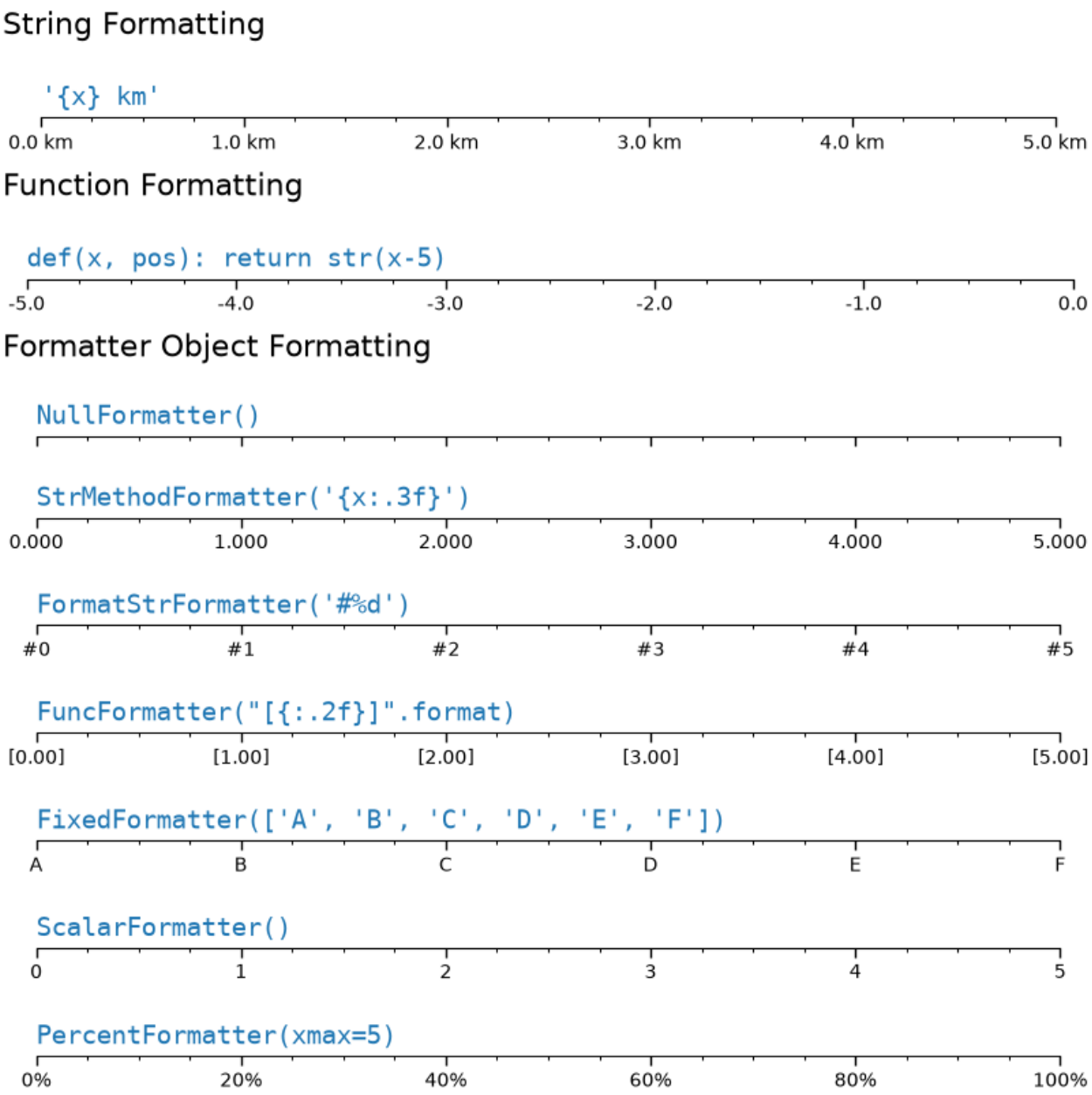
(continued from previous page)

```
    """Set up common parameters for the Axes in the example."""
    # only show the bottom spine
    ax.yaxis.set_major_locator(ticker.NullLocator())
    ax.spines[['left', 'right', 'top']].set_visible(False)

    # define tick positions
    ax.xaxis.set_major_locator(ticker.MultipleLocator(1.00))
    ax.xaxis.set_minor_locator(ticker.MultipleLocator(0.25))

    ax.xaxis.set_ticks_position('bottom')
    ax.tick_params(which='major', width=1.00, length=5)
    ax.tick_params(which='minor', width=0.75, length=2.5, labelsize=10)
    ax.set_xlim(0, 5)
    ax.set_ylim(0, 1)
    ax.text(0.0, 0.2, title, transform=ax.transAxes,
            fontsize=14, fontname='Monospace', color='tab:blue')


fig = plt.figure(figsize=(8, 8), layout='constrained')
fig0, fig1, fig2 = fig.subfigures(3, height_ratios=[1.5, 1.5, 7.5])

fig0.suptitle('String Formatting', fontsize=16, x=0, ha='left')
ax0 = fig0.subplots()

setup(ax0, title="'{x} km'")
ax0.xaxis.set_major_formatter('{x} km')


fig1.suptitle('Function Formatting', fontsize=16, x=0, ha='left')
ax1 = fig1.subplots()

setup(ax1, title="def(x, pos): return str(x-5)")
ax1.xaxis.set_major_formatter(lambda x, pos: str(x-5))


fig2.suptitle('Formatter Object Formatting', fontsize=16, x=0, ha='left
 ↪')
axs2 = fig2.subplots(7, 1)

setup(axs2[0], title="NullFormatter()")
axs2[0].xaxis.set_major_formatter(ticker.NullFormatter())

setup(axs2[1], title="StrMethodFormatter('{x:.3f}')")
axs2[1].xaxis.set_major_formatter(ticker.StrMethodFormatter("{x:.3f}"))

setup(axs2[2], title="FormatStrFormatter('#%d')")
```

(continues on next page)

(continued from previous page)

```
axs2[2].xaxis.set_major_formatter(ticker.FormatStrFormatter("#%d"))


def fmt_two_digits(x, pos):
    return f'[{x:.2f}]'


setup(axs2[3], title='FuncFormatter("[{:.2f}]".format)')
axs2[3].xaxis.set_major_formatter(ticker.FuncFormatter(fmt_two_digits))

setup(axs2[4], title="FixedFormatter(['A', 'B', 'C', 'D', 'E', 'F'])")
# FixedFormatter should only be used together with FixedLocator.
# Otherwise, one cannot be sure where the labels will end up.
positions = [0, 1, 2, 3, 4, 5]
labels = ['A', 'B', 'C', 'D', 'E', 'F']
axs2[4].xaxis.set_major_locator(ticker.FixedLocator(positions))
axs2[4].xaxis.set_major_formatter(ticker.FixedFormatter(labels))

setup(axs2[5], title="ScalarFormatter()")
axs2[5].xaxis.set_major_formatter(ticker.
 ↪ScalarFormatter(useMathText=True))

setup(axs2[6], title="PercentFormatter(xmax=5)")
axs2[6].xaxis.set_major_formatter(ticker.PercentFormatter(xmax=5))

plt.show()
```



Tags: component: ticks purpose: reference

Total running time of the script: (0 minutes 1.298 seconds)

Custom Ticker

The *matplotlib.ticker* module defines many preset tickers, but was primarily designed for extensibility, i.e., to support user customized ticking.

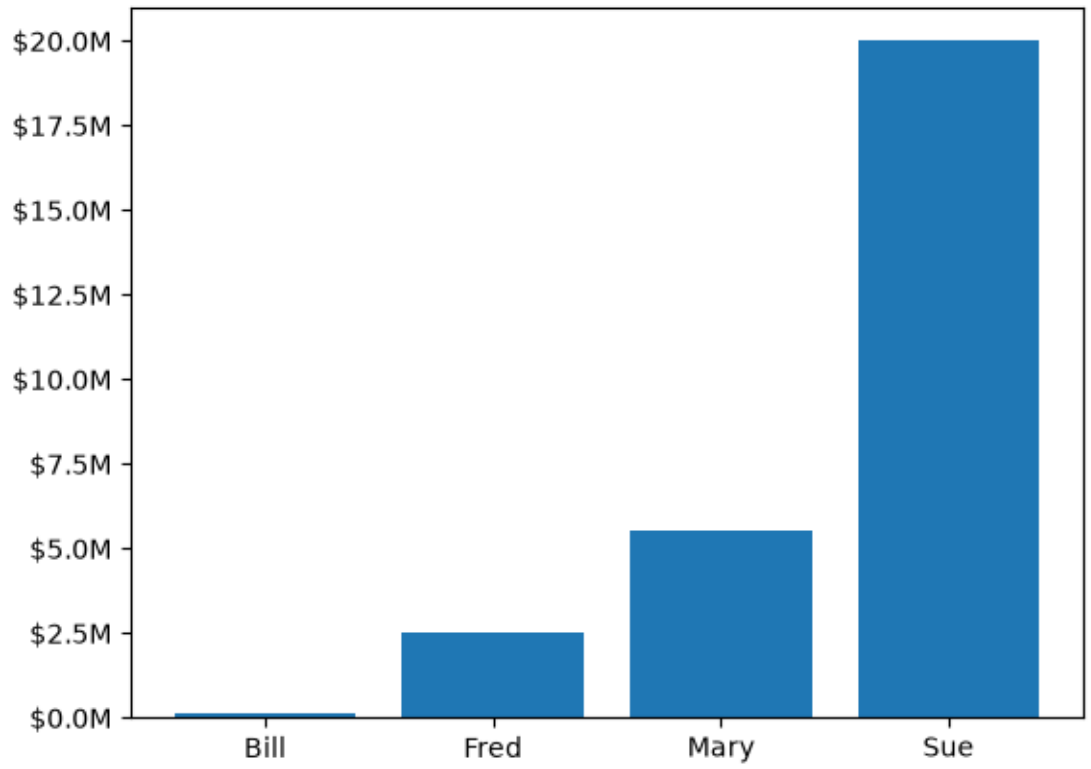
In this example, a user defined function is used to format the ticks in millions of dollars on the y-axis.

```
import matplotlib.pyplot as plt
```

(continues on next page)

(continued from previous page)

```
def millions(x, pos):
    """The two arguments are the value and tick position."""
    return f'${x*1e-6:1.1f}M'


fig, ax = plt.subplots()
# set_major_formatter internally creates a FuncFormatter from the␣
 ↪callable.
ax.yaxis.set_major_formatter(millions)
money = [1.5e5, 2.5e6, 5.5e6, 2.0e7]
ax.bar(['Bill', 'Fred', 'Mary', 'Sue'], money)
plt.show()
```



References

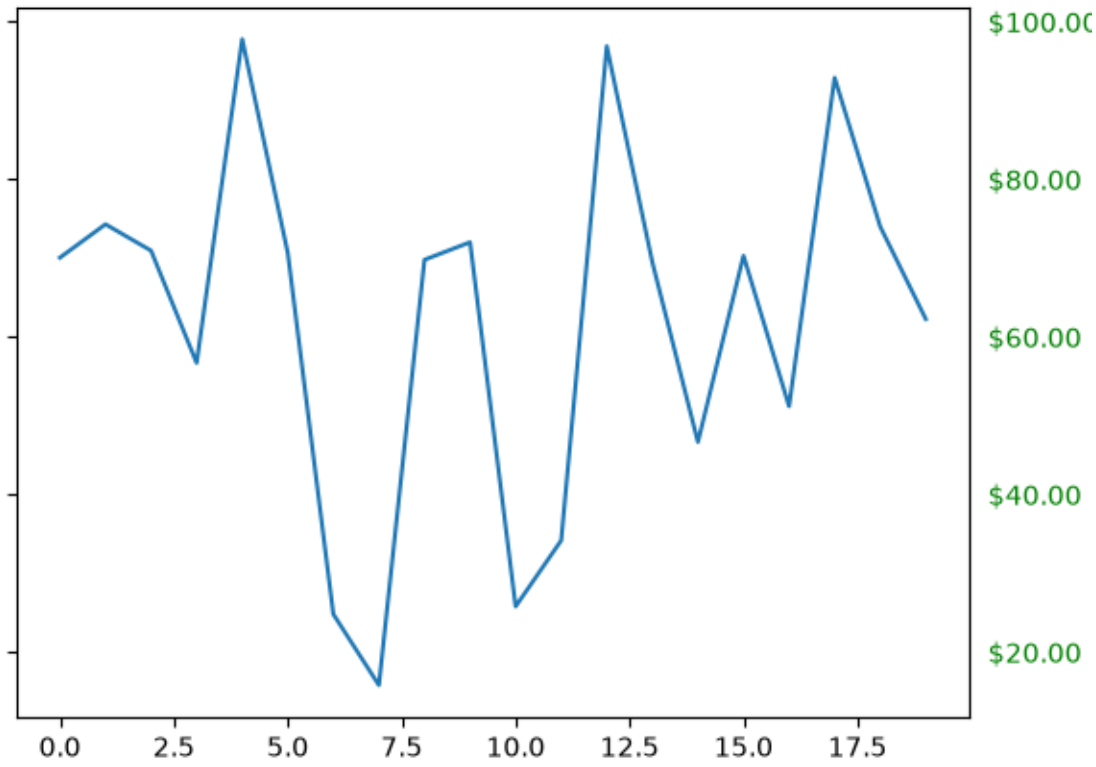
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axis.Axis.set_major_formatter*

Dollar ticks

Use a format string to prepend dollar signs on y-axis labels.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

fig, ax = plt.subplots()
ax.plot(100*np.random.rand(20))

# Use automatic StrMethodFormatter
ax.yaxis.set_major_formatter('${x:1.2f}')

ax.yaxis.set_tick_params(which='major', labelcolor='green',
                         labelleft=False, labelright=True)

plt.show()
```



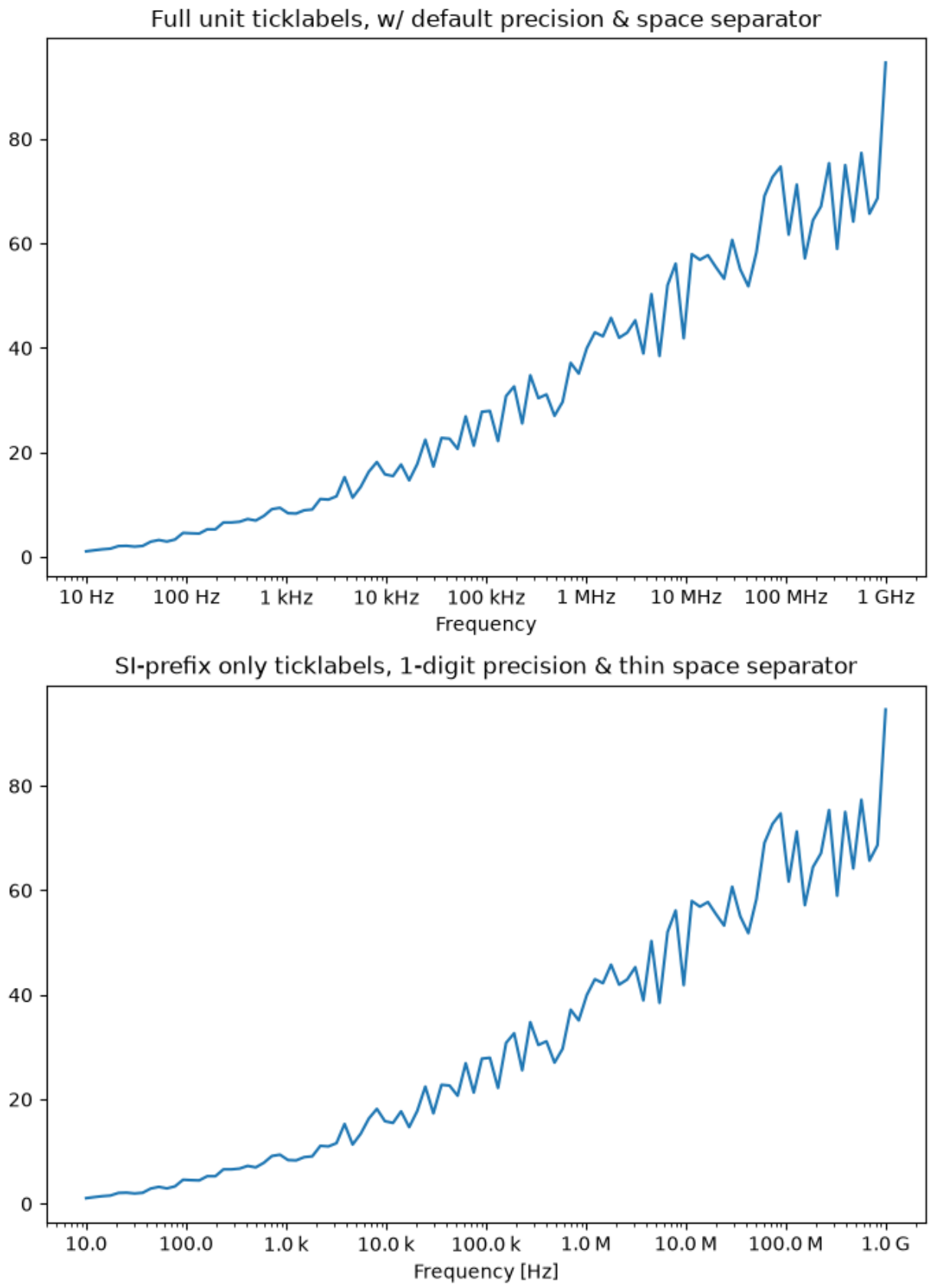
References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.pyplot.subplots*
- *matplotlib.axis.Axis.set_major_formatter*
- *matplotlib.axis.Axis.set_tick_params*
- *matplotlib.axis.Tick*
- *matplotlib.ticker.StrMethodFormatter*

Format ticks using engineering notation

Use of the engineering Formatter.


Full unit ticklabels, w/ default precision & space separator
0
20
40
60
80
10 Hz
100 Hz
1 kHz
10 kHz
100 kHz
1 MHz
10 MHz
100 MHz
1 GHz
Frequency
SI-prefix only ticklabels, 1-digit precision & thin space separator
0
20
40
60
80
10.0
100.0
1.0 k
10.0 k
100.0 k
1.0 M
10.0 M
100.0 M
1.0 G
Frequency [Hz]

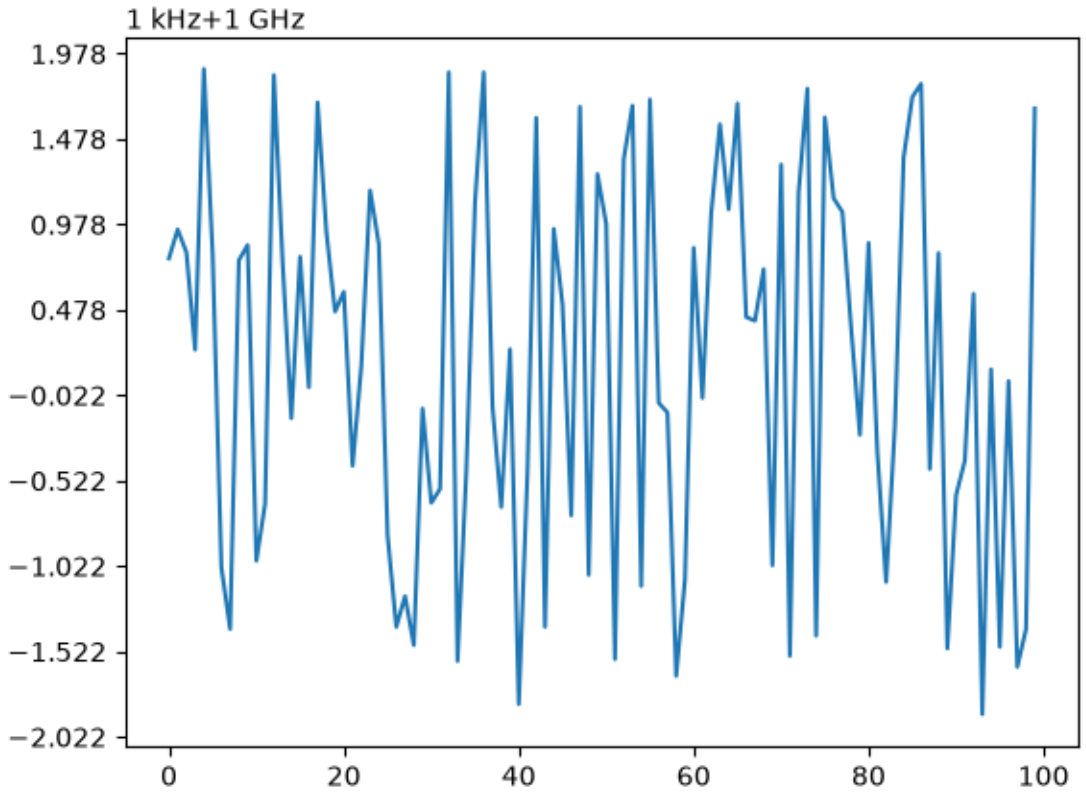
```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.ticker import EngFormatter

# Fixing random state for reproducibility
prng = np.random.RandomState(19680801)

# Create artificial data to plot.
# The x data span over several decades to demonstrate several SI␣
 ↪prefixes.
xs = np.logspace(1, 9, 100)
ys = (0.8 + 0.4 * prng.uniform(size=100)) * np.log10(xs)**2

# Figure width is doubled (2*6.4) to display nicely 2 subplots side by␣
 ↪side.
fig, (ax0, ax1) = plt.subplots(nrows=2, figsize=(7, 9.6))
for ax in (ax0, ax1):
    ax.set_xscale('log')

# Demo of the default settings, with a user-defined unit label.
ax0.set_title('Full unit ticklabels, w/ default precision & space␣
 ↪separator')
formatter0 = EngFormatter(unit='Hz')
ax0.xaxis.set_major_formatter(formatter0)
ax0.plot(xs, ys)
ax0.set_xlabel('Frequency')

# Demo of the options `places` (number of digit after decimal point)␣
 ↪and
# `sep` (separator between the number and the prefix/unit).
ax1.set_title('SI-prefix only ticklabels, 1-digit precision & '
              'thin space separator')
formatter1 = EngFormatter(places=1, sep="\N{THIN SPACE}")  # U+2009
ax1.xaxis.set_major_formatter(formatter1)
ax1.plot(xs, ys)
ax1.set_xlabel('Frequency [Hz]')

plt.tight_layout()
plt.show()
```

Total running time of the script: (0 minutes 1.171 seconds)

SI prefixed offsets and natural order of magnitudes

matplotlib.ticker.EngFormatter is capable of computing a natural offset for your axis data, and presenting it with a standard SI prefix automatically calculated.

Below is an examples of such a plot:




```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.ticker as mticker

# Fixing random state for reproducibility
np.random.seed(19680801)

UNIT = "Hz"

fig, ax = plt.subplots()
ax.yaxis.set_major_formatter(mticker.EngFormatter(
    useOffset=True,
    unit=UNIT
))
```

(continues on next page)

(continued from previous page)

```
size = 100
measurement = np.full(size, 1e9)
noise = np.random.uniform(low=-2e3, high=2e3, size=size)
ax.plot(measurement + noise)
plt.show()
```

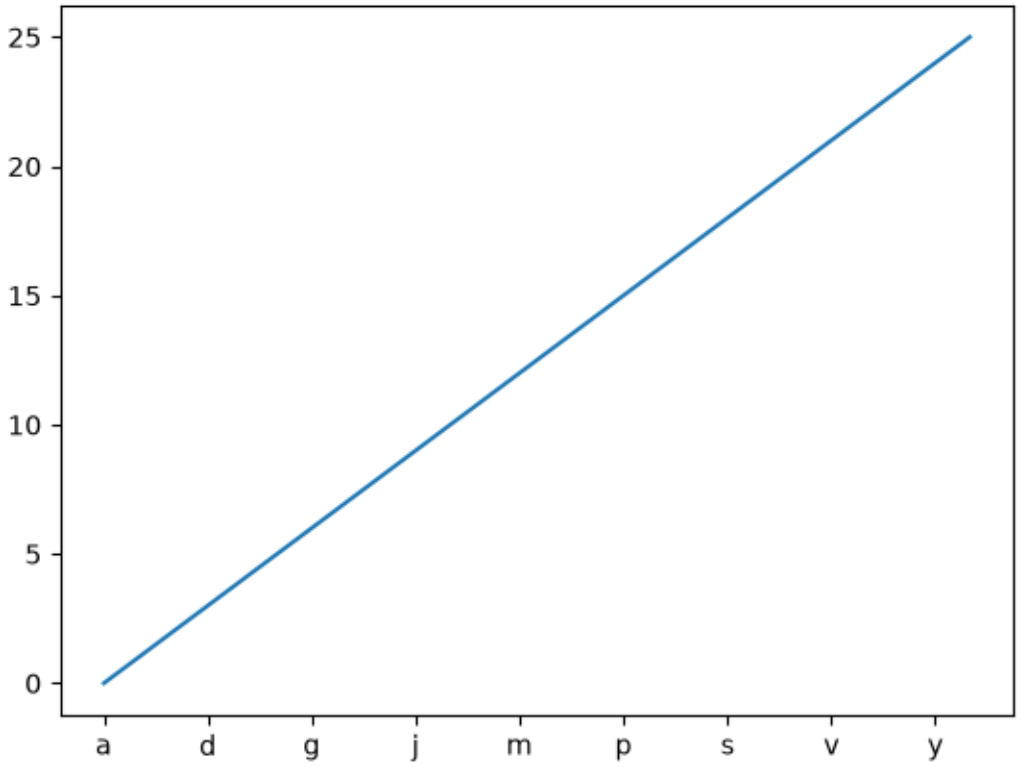
Setting tick labels from a list of values

Using *Axes.set_xticks* causes the tick labels to be set on the currently chosen ticks. However, you may want to allow matplotlib to dynamically choose the number of ticks and their spacing.

In this case it may be better to determine the tick label from the value at the tick. The following example shows how to do this.

NB: The *ticker.MaxNLocator* is used here to ensure that the tick values take integer values.

```
import matplotlib.pyplot as plt

from matplotlib.ticker import MaxNLocator

fig, ax = plt.subplots()
xs = range(26)
ys = range(26)
labels = list('abcdefghijklmnopqrstuvwxyz')


def format_fn(tick_val, tick_pos):
    if int(tick_val) in xs:
        return labels[int(tick_val)]
    else:
        return ''


# A FuncFormatter is created automatically.
ax.xaxis.set_major_formatter(format_fn)
ax.xaxis.set_major_locator(MaxNLocator(integer=True))
ax.plot(xs, ys)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

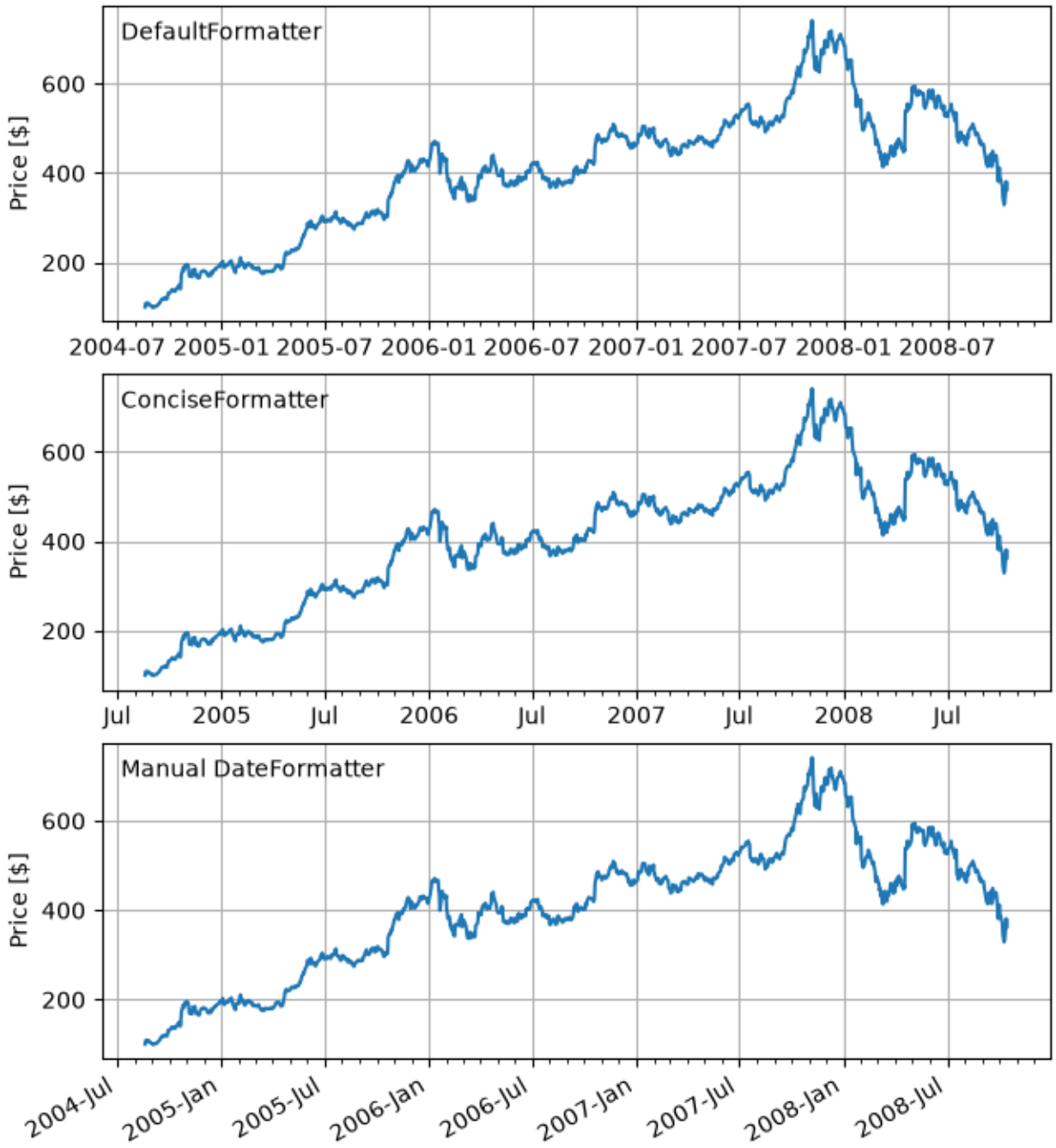
- *matplotlib.pyplot.subplots*
- *matplotlib.axis.Axis.set_major_formatter*
- *matplotlib.axis.Axis.set_major_locator*
- *matplotlib.ticker.FuncFormatter*
- *matplotlib.ticker.MaxNLocator*

Date tick labels

Matplotlib date plotting is done by converting date instances into days since an epoch (by default 1970-01-01T00:00:00). The *matplotlib.dates* module provides the converter functions *date2num* and *num2date* that convert datetime.datetime and numpy.datetime64 objects to and from Matplotlib's internal representation. These data types are registered with the unit conversion mechanism described in *matplotlib.units*, so the conversion happens automatically for the user. The registration process also sets the default tick locator and formatter for the axis to be *AutoDateLocator* and

AutoDateFormatter.

An alternative formatter is the *ConciseDateFormatter*, used in the second Axes below (see *Format date ticks using ConciseDateFormatter*), which often removes the need to rotate the tick labels. The last Axes formats the dates manually, using *DateFormatter* to format the dates using the format strings documented at datetime.date.strftime.




```
import matplotlib.pyplot as plt

import matplotlib.cbook as cbook
```

(continues on next page)

(continued from previous page)

```
import matplotlib.dates as mdates

# Load a numpy record array from yahoo csv data with fields date,␣
 ↪open, high,
# low, close, volume, adj_close from the mpl-data/sample_data␣
 ↪directory. The
# record array stores the date as an np.datetime64 with a day unit ('D
 ↪') in
# the date column.
data = cbook.get_sample_data('goog.npz')['price_data']

fig, axs = plt.subplots(3, 1, figsize=(6.4, 7), layout='constrained')
# common to all three:
for ax in axs:
    ax.plot('date', 'adj_close', data=data)
    # Major ticks every half year, minor ticks every month,
    ax.xaxis.set_major_locator(mdates.MonthLocator(bymonth=(1, 7)))
    ax.xaxis.set_minor_locator(mdates.MonthLocator())
    ax.grid(True)
    ax.set_ylabel(r'Price [\$]')

# different formats:
ax = axs[0]
ax.set_title('DefaultFormatter', loc='left', y=0.85, x=0.02, fontsize=
 ↪'medium')

ax = axs[1]
ax.set_title('ConciseFormatter', loc='left', y=0.85, x=0.02, fontsize=
 ↪'medium')
ax.xaxis.set_major_formatter(
    mdates.ConciseDateFormatter(ax.xaxis.get_major_locator()))

ax = axs[2]
ax.set_title('Manual DateFormatter', loc='left', y=0.85, x=0.02,
             fontsize='medium')
# Text in the x-axis will be displayed in 'YYYY-mm' format.
ax.xaxis.set_major_formatter(mdates.DateFormatter('%Y-%b'))
# Rotates and right-aligns the x labels so they don't crowd each other.
ax.xaxis.set_tick_params(rotation=30, rotation_mode='xtick')

plt.show()
```

Total running time of the script: (0 minutes 1.191 seconds)

Date tick locators and formatters

This example illustrates the usage and effect of the various date locators and formatters.

```
import matplotlib.pyplot as plt
import numpy as np

# While these appear unused directly, they are used from eval'd␣
 ↪strings.
from matplotlib.dates import (FR, MO, MONTHLY, SA, SU, TH, TU, WE,␣
 ↪AutoDateFormatter,
                              AutoDateLocator, ConciseDateFormatter,␣
 ↪DateFormatter,
                              DayLocator, HourLocator,␣
 ↪MicrosecondLocator,
                              MinuteLocator, MonthLocator,␣
 ↪RRuleLocator, SecondLocator,
                              WeekdayLocator, YearLocator,␣
 ↪rrulewrapper)
import matplotlib.ticker as ticker


def plot_axis(ax, locator=None, xmax='2002-02-01', fmt=None,␣
 ↪formatter=None):
    """Set up common parameters for the Axes in the example."""
    ax.spines[['left', 'right', 'top']].set_visible(False)
    ax.yaxis.set_major_locator(ticker.NullLocator())
    ax.tick_params(which='major', width=1.00, length=5)
    ax.tick_params(which='minor', width=0.75, length=2.5)
    ax.set_xlim(np.datetime64('2000-02-01'), np.datetime64(xmax))
    if locator:
        ax.xaxis.set_major_locator(eval(locator))
        ax.xaxis.set_major_formatter(DateFormatter(fmt))
    else:
        ax.xaxis.set_major_formatter(eval(formatter))
    ax.text(0.0, 0.2, locator or formatter, transform=ax.transAxes,
            fontsize=14, fontname='Monospace', color='tab:blue')
```

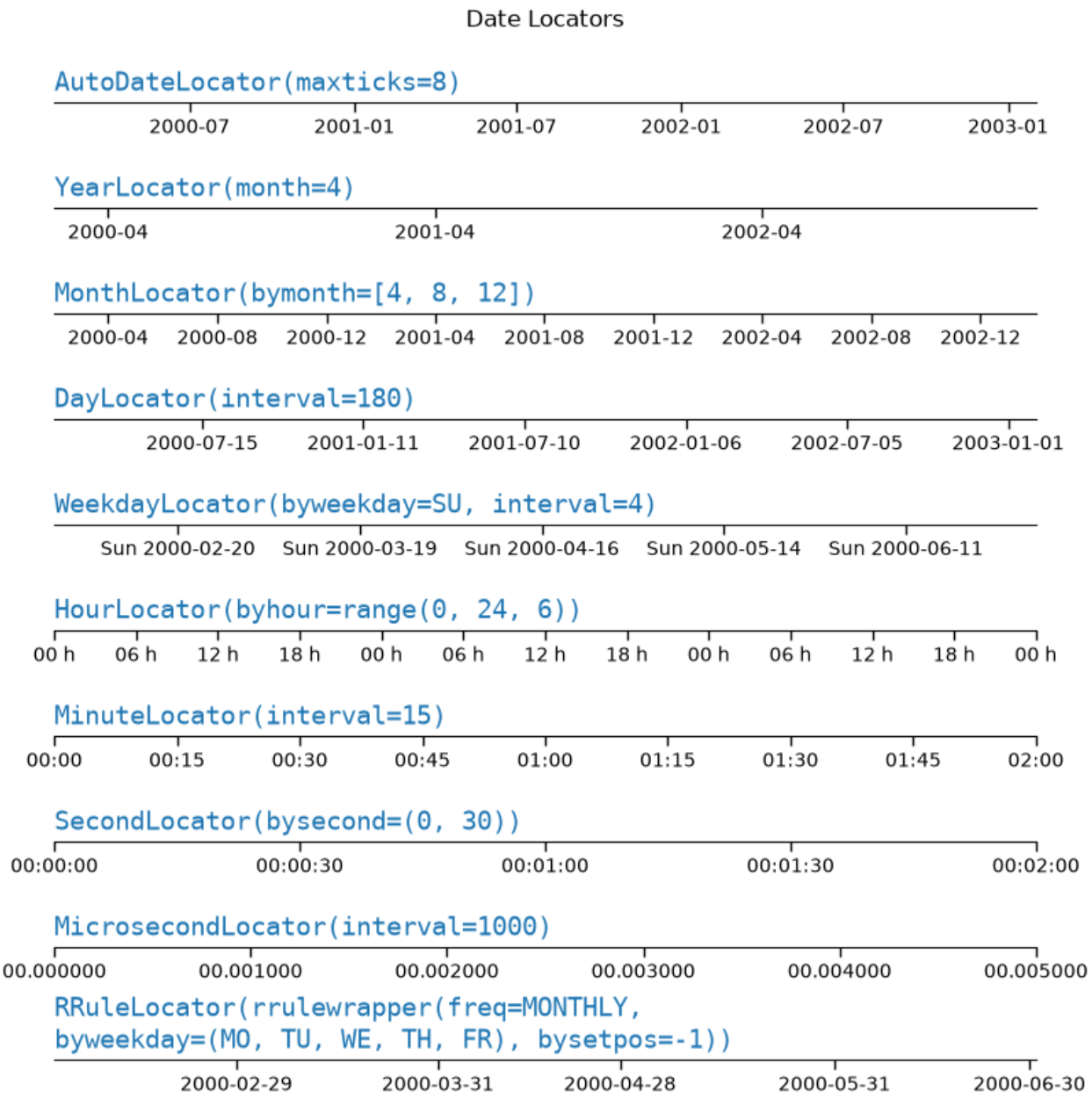
Date tick locators

```
locators = [
    # locator as str, xmax, fmt
    ('AutoDateLocator(maxticks=8)', '2003-02-01', '%Y-%m'),
    ('YearLocator(month=4)', '2003-02-01', '%Y-%m'),
    ('MonthLocator(bymonth=[4, 8, 12])', '2003-02-01', '%Y-%m'),
    ('DayLocator(interval=180)', '2003-02-01', '%Y-%m-%d'),
    ('WeekdayLocator(byweekday=SU, interval=4)', '2000-07-01', '%a %Y-
```

(continues on next page)

(continued from previous page)

```
 ↪%m-%d'),
    ('HourLocator(byhour=range(0, 24, 6))', '2000-02-04', '%H h'),
    ('MinuteLocator(interval=15)', '2000-02-01 02:00', '%H:%M'),
    ('SecondLocator(bysecond=(0, 30))', '2000-02-01 00:02', '%H:%M:%S
 ↪'),
    ('MicrosecondLocator(interval=1000)', '2000-02-01 00:00:00.005', '
 ↪%S.%f'),
    ('RRuleLocator(rrulewrapper(freq=MONTHLY, \nbyweekday=(MO, TU, WE,␣
 ↪TH, FR), '
     'bysetpos=-1))', '2000-07-01', '%Y-%m-%d'),
]

fig, axs = plt.subplots(len(locators), 1, figsize=(8, len(locators) * .
 ↪8),
                        layout='constrained')
fig.suptitle('Date Locators')
for ax, (locator, xmax, fmt) in zip(axs, locators):
    plot_axis(ax, locator, xmax, fmt)
```



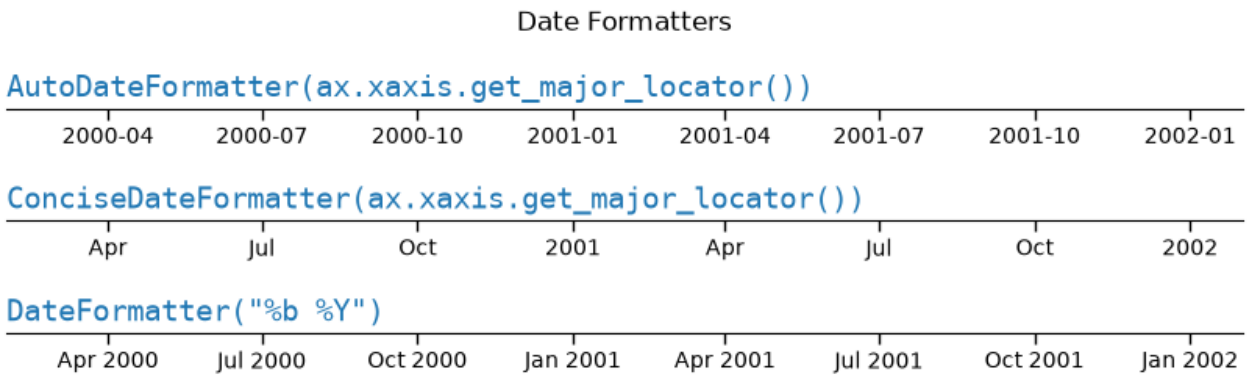
Date formatters

```
formatters = [
    'AutoDateFormatter(ax.xaxis.get_major_locator())',
    'ConciseDateFormatter(ax.xaxis.get_major_locator())',
    'DateFormatter("%b %Y")',
]

fig, axs = plt.subplots(len(formatters), 1, figsize=(8,␣
↪len(formatters) * .8),
                        layout='constrained')
```

(continues on next page)

(continued from previous page)

```
fig.suptitle('Date Formatters')
for ax, fmt in zip(axs, formatters):
    plot_axis(ax, formatter=fmt)
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.dates.AutoDateLocator*
- *matplotlib.dates.YearLocator*
- *matplotlib.dates.MonthLocator*
- *matplotlib.dates.DayLocator*
- *matplotlib.dates.WeekdayLocator*
- *matplotlib.dates.HourLocator*
- *matplotlib.dates.MinuteLocator*
- *matplotlib.dates.SecondLocator*
- *matplotlib.dates.MicrosecondLocator*
- *matplotlib.dates.RRuleLocator*
- *matplotlib.dates.rrulewrapper*
- *matplotlib.dates.DateFormatter*
- *matplotlib.dates.AutoDateFormatter*
- *matplotlib.dates.ConciseDateFormatter*

Tags: component: ticks purpose: reference

Total running time of the script: (0 minutes 1.531 seconds)

Format date ticks using ConciseDateFormatter

Finding good tick values and formatting the ticks for an axis that has date data is often a challenge. *ConciseDateFormatter* is meant to improve the strings chosen for the ticklabels, and to minimize the strings used in those tick labels as much as possible.

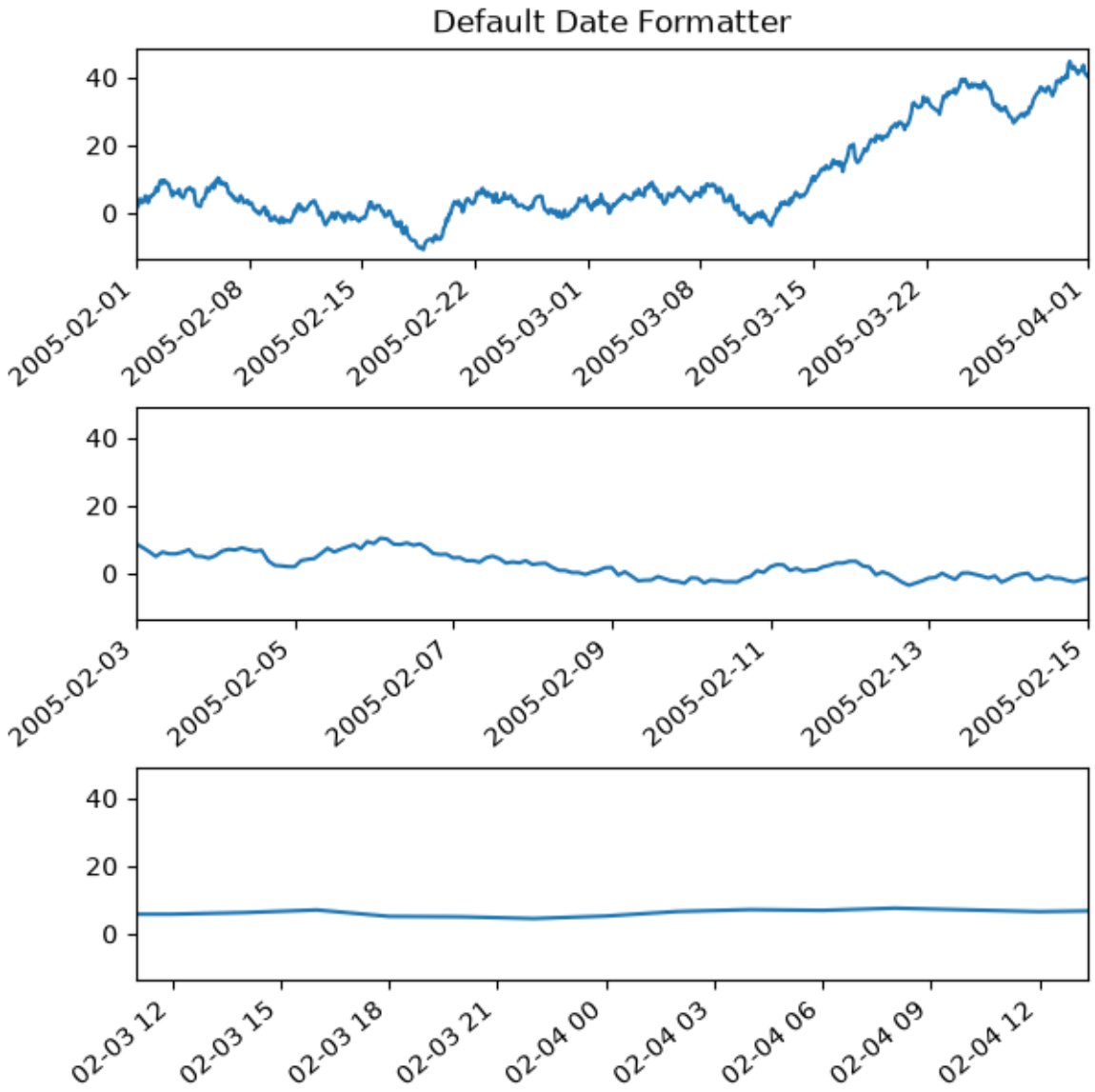
Note

This formatter is a candidate to become the default date tick formatter in future versions of Matplotlib. Please report any issues or suggestions for improvement to the GitHub repository or mailing list.

```
import datetime

import matplotlib.pyplot as plt
import numpy as np

import matplotlib.dates as mdates
```

First, the default formatter.

```
base = datetime.datetime(2005, 2, 1)
dates = [base + datetime.timedelta(hours=(2 * i)) for i in range(732)]
N = len(dates)
np.random.seed(19680801)
y = np.cumsum(np.random.randn(N))

fig, axs = plt.subplots(3, 1, layout='constrained', figsize=(6, 6))
lims = [(np.datetime64('2005-02'), np.datetime64('2005-04')),
        (np.datetime64('2005-02-03'), np.datetime64('2005-02-15')),
        (np.datetime64('2005-02-03 11:00'), np.datetime64('2005-02-04␣
 ↪13:20'))]
for nn, ax in enumerate(axs):
    ax.plot(dates, y)
    ax.set_xlim(lims[nn])
    ax.tick_params(axis='x', rotation=40, rotation_mode='xtick')
axs[0].set_title('Default Date Formatter')
plt.show()
```



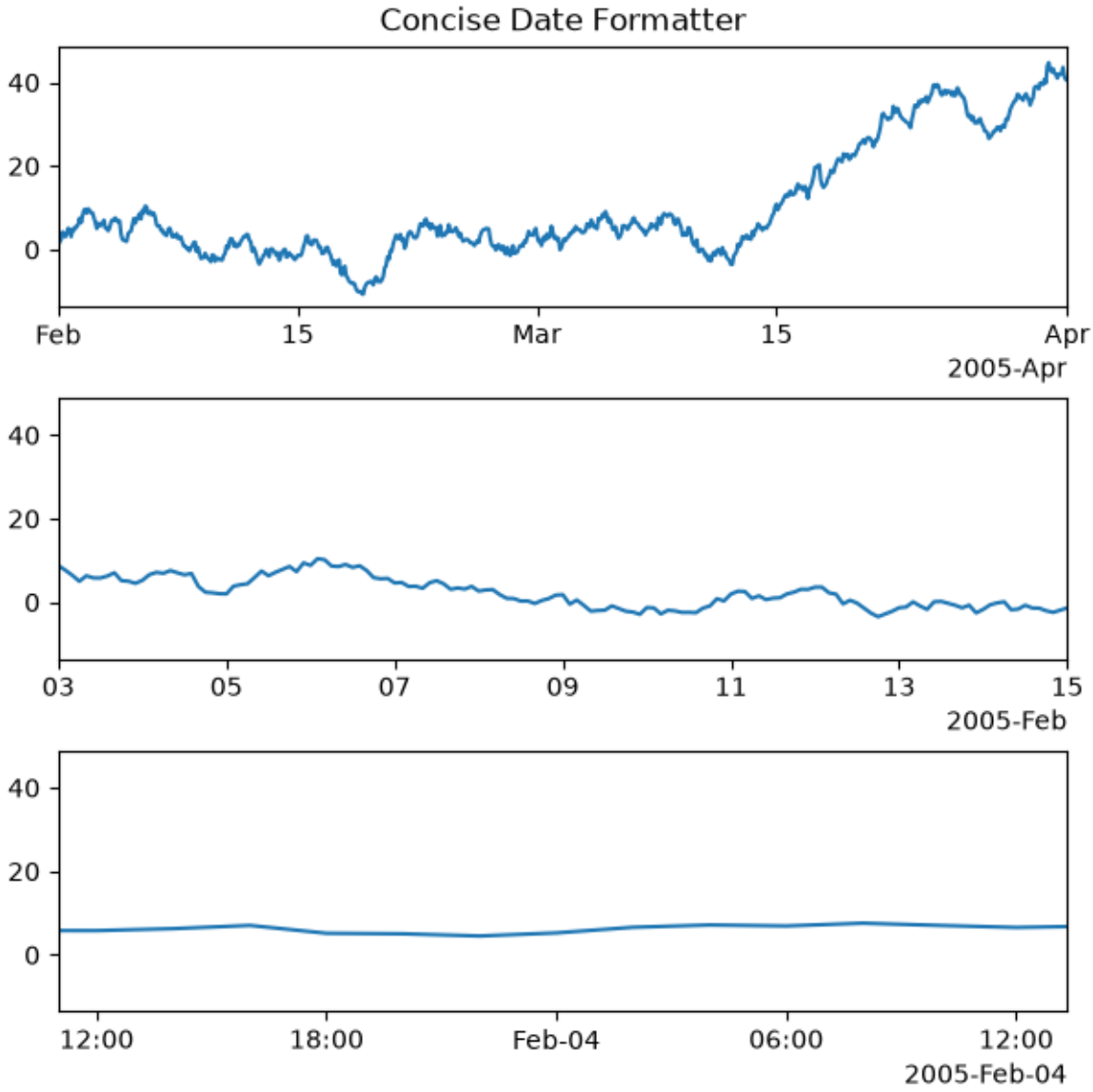
The default date formatter is quite verbose, so we have the option of using *ConciseDateFormatter*, as shown below. Note that for this example the labels do not need to be rotated as they do for the default formatter because the labels are as small as possible.

```
fig, axs = plt.subplots(3, 1, layout='constrained', figsize=(6, 6))
for nn, ax in enumerate(axs):
    locator = mdates.AutoDateLocator(minticks=3, maxticks=7)
    formatter = mdates.ConciseDateFormatter(locator)
    ax.xaxis.set_major_locator(locator)
    ax.xaxis.set_major_formatter(formatter)

    ax.plot(dates, y)
    ax.set_xlim(lims[nn])
axs[0].set_title('Concise Date Formatter')
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



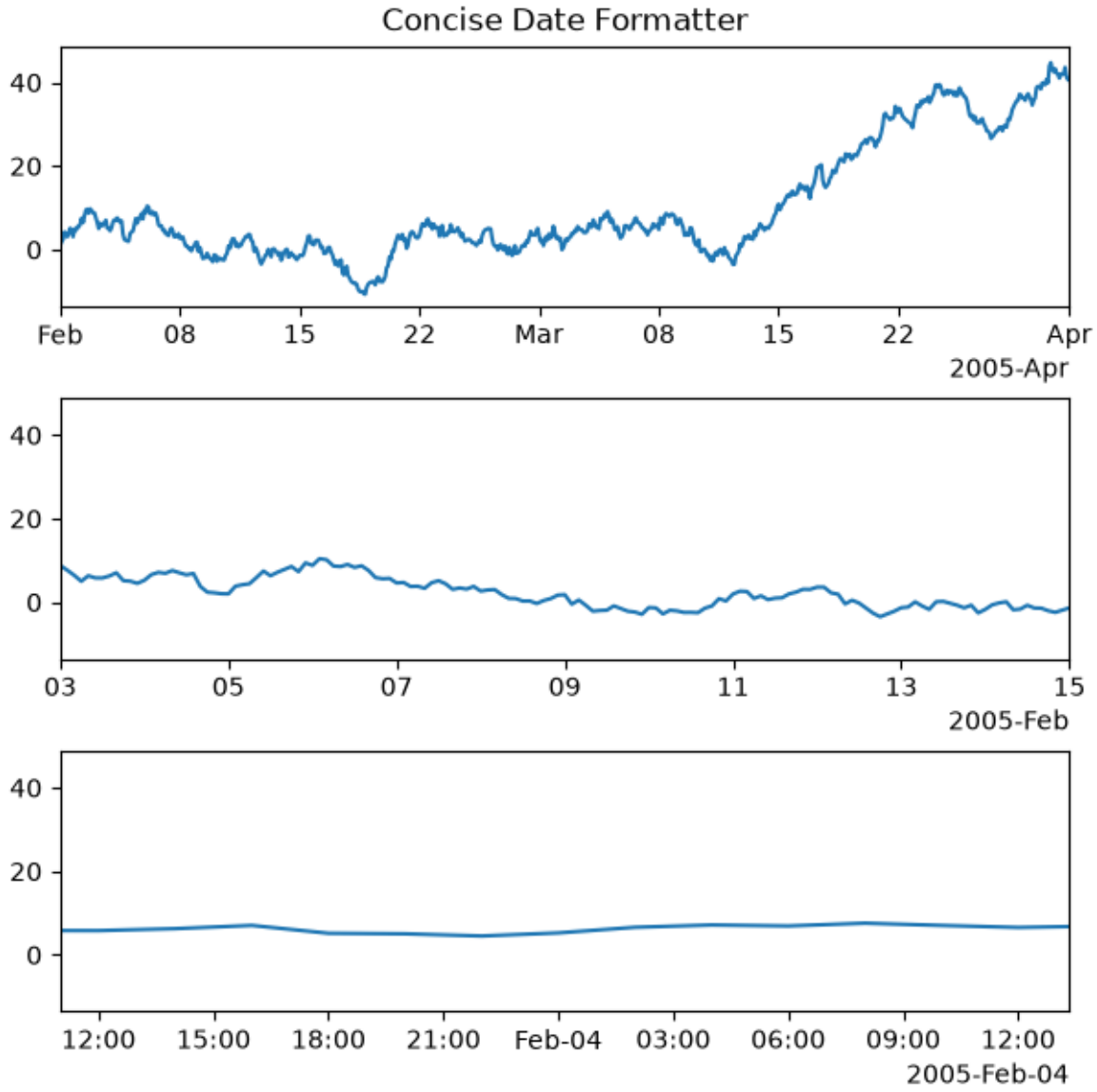
If all calls to axes that have dates are to be made using this converter, it is probably most convenient to use the units registry where you do imports:

```
import matplotlib.units as munits

converter = mdates.ConciseDateConverter()
munits.registry[np.datetime64] = converter
munits.registry[datetime.date] = converter
munits.registry[datetime.datetime] = converter
```

(continues on next page)

(continued from previous page)

```
fig, axs = plt.subplots(3, 1, figsize=(6, 6), layout='constrained')
for nn, ax in enumerate(axs):
    ax.plot(dates, y)
    ax.set_xlim(lims[nn])
axs[0].set_title('Concise Date Formatter')

plt.show()
```



Localization of date formats

Dates formats can be localized if the default formats are not desirable by manipulating one of three lists of strings.

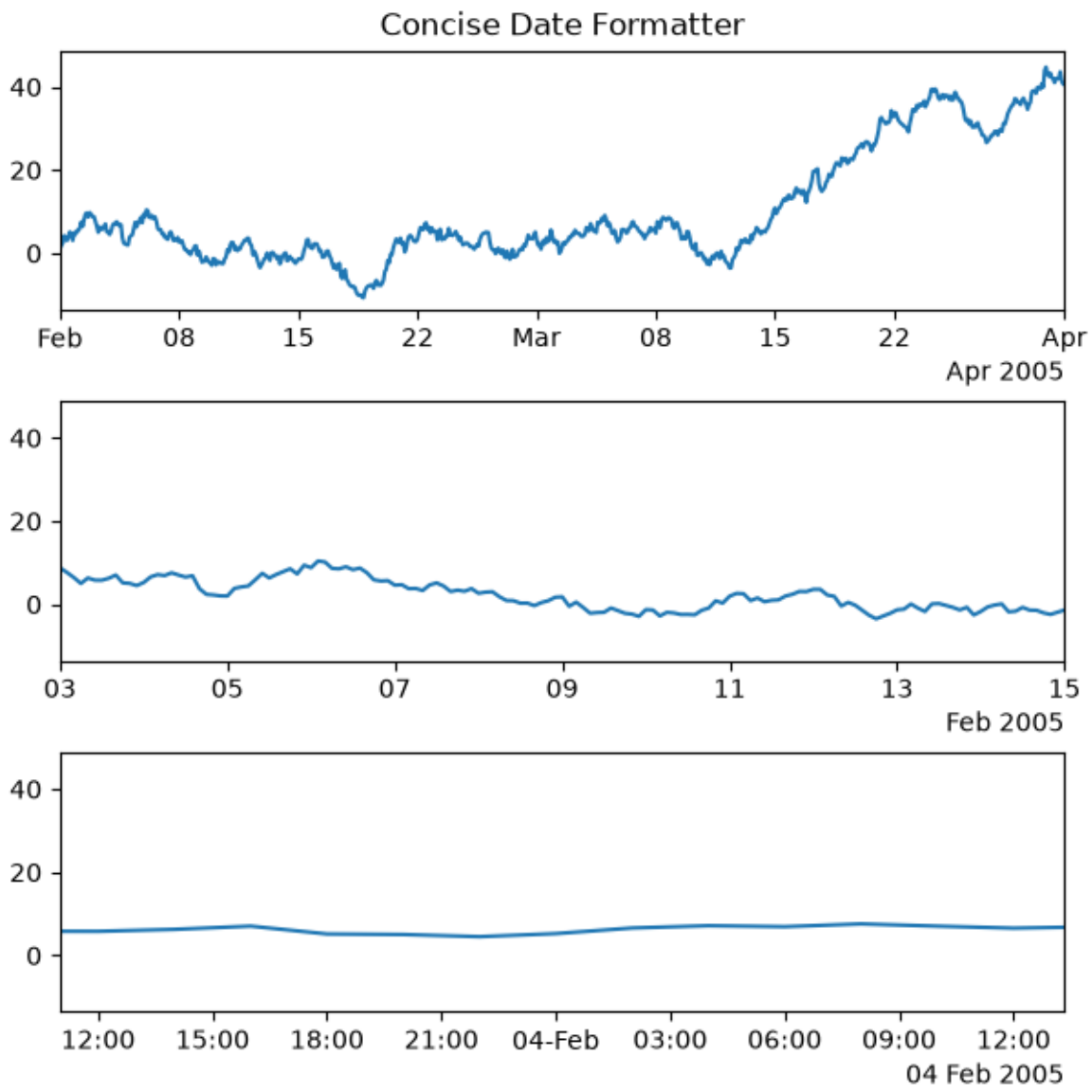
The `formatter.formats` list of formats is for the normal tick labels, There are six levels: years, months,

days, hours, minutes, seconds. The `formatter.offset_formats` is how the "offset" string on the right of the axis is formatted. This is usually much more verbose than the tick labels. Finally, the `formatter.zero_formats` are the formats of the ticks that are "zeros". These are tick values that are either the first of the year, month, or day of month, or the zeroth hour, minute, or second. These are usually the same as the format of the ticks a level above. For example if the axis limits mean the ticks are mostly days, then we label 1 Mar 2005 simply with a "Mar". If the axis limits are mostly hours, we label Feb 4 00:00 as simply "Feb-4".

Note that these format lists can also be passed to *ConciseDateFormatter* as optional keyword arguments.

Here we modify the labels to be "day month year", instead of the ISO "year month day":

```
fig, axs = plt.subplots(3, 1, layout='constrained', figsize=(6, 6))

for nn, ax in enumerate(axs):
    locator = mdates.AutoDateLocator()
    formatter = mdates.ConciseDateFormatter(locator)
    formatter.formats = ['%y',  # ticks are mostly years
                         '%b',        # ticks are mostly months
                         '%d',        # ticks are mostly days
                         '%H:%M',     # hrs
                         '%H:%M',     # min
                         '%S.%f', ]  # secs
    # these are mostly just the level above...
    formatter.zero_formats = [''] + formatter.formats[:-1]
    # ...except for ticks that are mostly hours, then it is nice to␣
 ↪have
    # month-day:
    formatter.zero_formats[3] = '%d-%b'

    formatter.offset_formats = ['',
                                '%Y',
                                '%b %Y',
                                '%d %b %Y',
                                '%d %b %Y',
                                '%d %b %Y %H:%M', ]
    ax.xaxis.set_major_locator(locator)
    ax.xaxis.set_major_formatter(formatter)

    ax.plot(dates, y)
    ax.set_xlim(lims[nn])
axs[0].set_title('Concise Date Formatter')

plt.show()
```



Registering a converter with localization

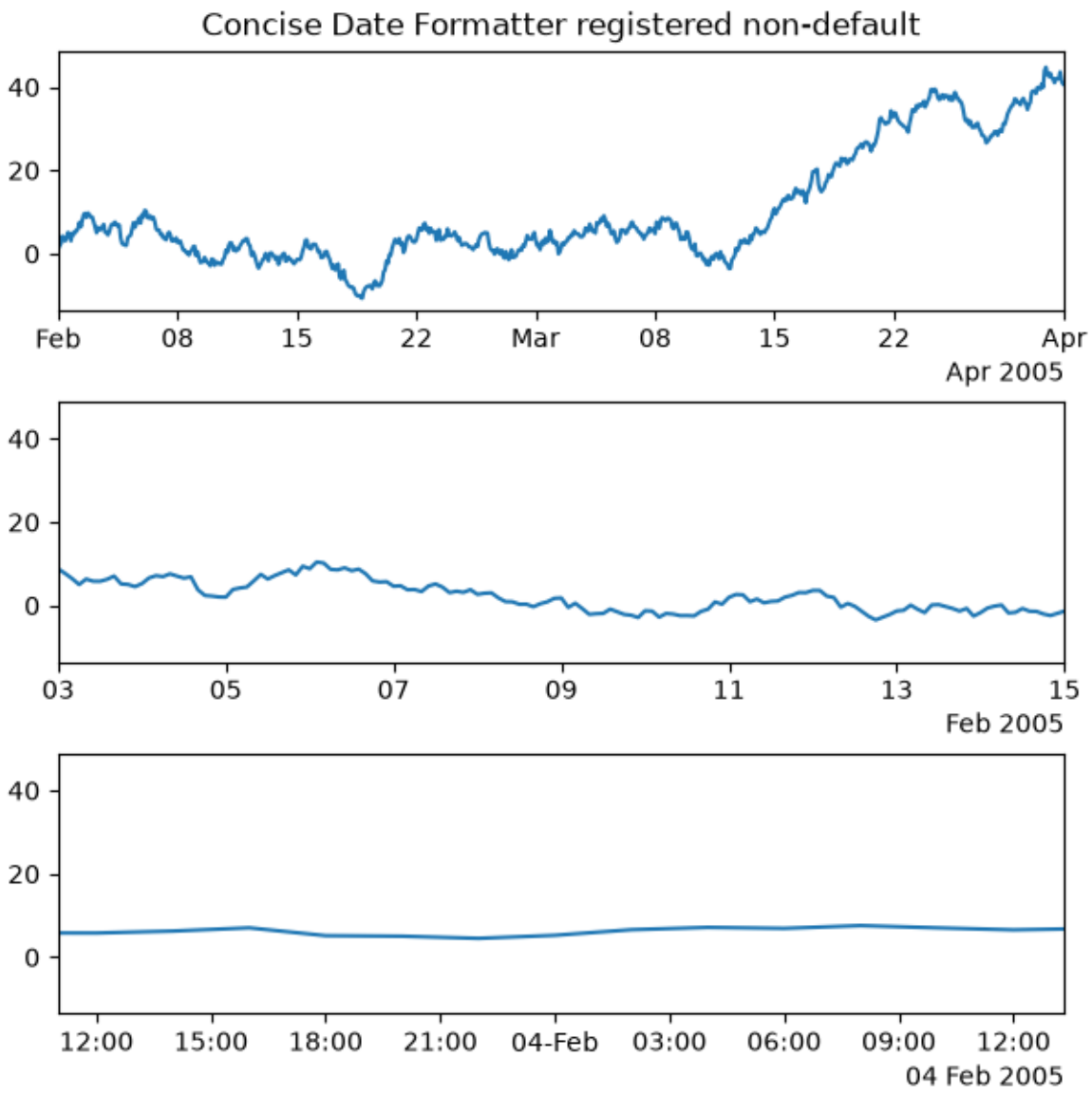
`ConciseDateFormatter` doesn't have rcParams entries, but localization can be accomplished by passing keyword arguments to `ConciseDateConverter` and registering the datatypes you will use with the units registry:

```
import datetime

formats = ['%y',          # ticks are mostly years
           '%b',      # ticks are mostly months
           '%d',      # ticks are mostly days
           '%H:%M',   # hrs
           '%H:%M',   # min
           '%S.%f', ]  # secs
```

(continues on next page)

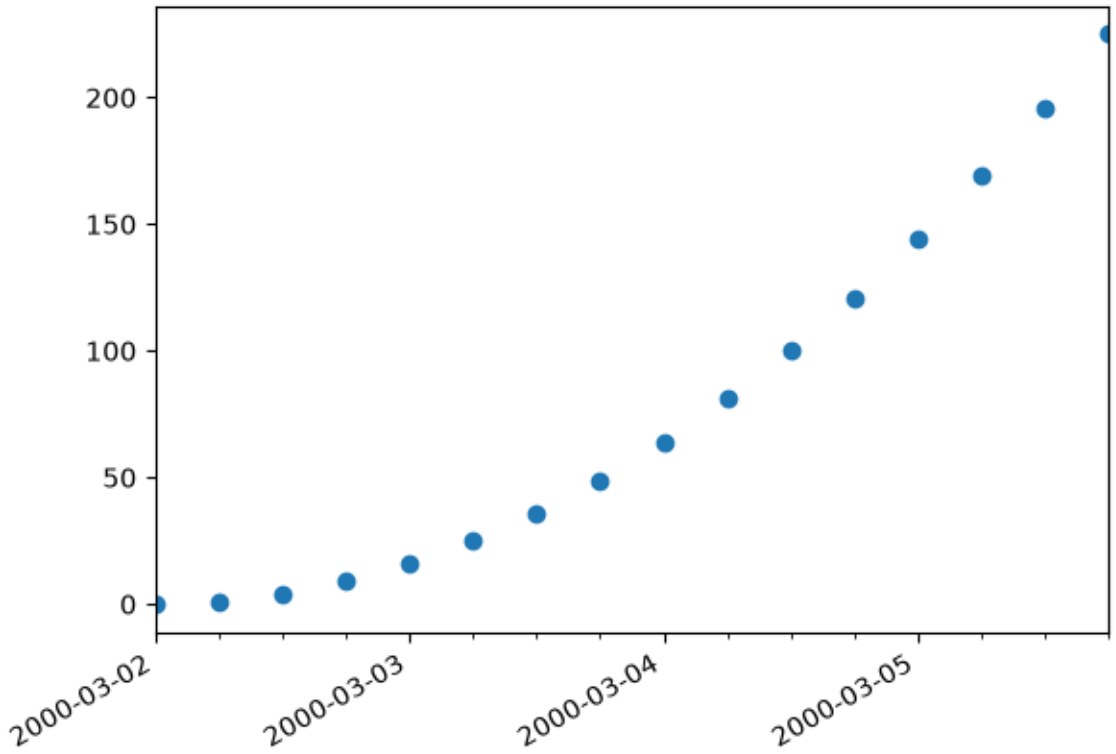
(continued from previous page)

```
# these can be the same, except offset by one level....
zero_formats = [''] + formats[:-1]
# ...except for ticks that are mostly hours, then it's nice to have␣
 ↪month-day
zero_formats[3] = '%d-%b'
offset_formats = ['',
                  '%Y',
                  '%b %Y',
                  '%d %b %Y',
                  '%d %b %Y',
                  '%d %b %Y %H:%M', ]

converter = mdates.ConciseDateConverter(
    formats=formats, zero_formats=zero_formats,␣
 ↪offset_formats=offset_formats)

munits.registry[np.datetime64] = converter
munits.registry[datetime.date] = converter
munits.registry[datetime.datetime] = converter

fig, axs = plt.subplots(3, 1, layout='constrained', figsize=(6, 6))
for nn, ax in enumerate(axs):
    ax.plot(dates, y)
    ax.set_xlim(lims[nn])
axs[0].set_title('Concise Date Formatter registered non-default')

plt.show()
```



Total running time of the script: (0 minutes 2.727 seconds)

Date converter demo




```
import datetime

import matplotlib.pyplot as plt
import numpy as np

from matplotlib.dates import DateFormatter, DayLocator, HourLocator,␣
 ↪drange

date1 = datetime.datetime(2000, 3, 2)
date2 = datetime.datetime(2000, 3, 6)
delta = datetime.timedelta(hours=6)
dates = drange(date1, date2, delta)

y = np.arange(len(dates))

fig, ax = plt.subplots()
ax.plot(dates, y**2, 'o')

# This is superfluous, since the autoscaler should get it right, but
```

(continues on next page)

(continued from previous page)

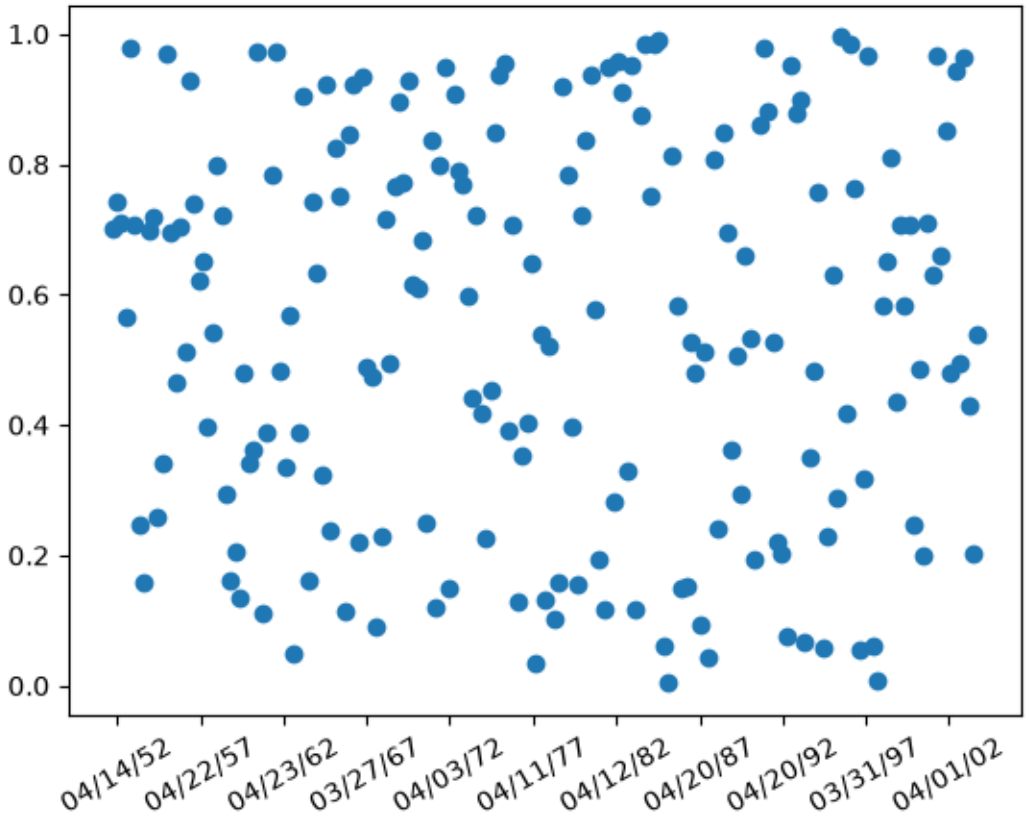
```
# use date2num and num2date to convert between dates and floats if
# you want; both date2num and num2date convert an instance or sequence.
ax.set_xlim(dates[0], dates[-1])

# The hour locator takes the hour or sequence of hours you want to
# tick, not the base multiple.
ax.xaxis.set_major_locator(DayLocator())
ax.xaxis.set_minor_locator(HourLocator(range(0, 25, 6)))
ax.xaxis.set_major_formatter(DateFormatter('%Y-%m-%d'))

ax.fmt_xdata = DateFormatter('%Y-%m-%d %H:%M:%S')
fig.autofmt_xdate()

plt.show()
```

Placing date ticks using recurrence rules

The iCalender RFC specifies *recurrence rules* (rrules), that define date sequences. You can use rrules in Matplotlib to place date ticks.

This example sets custom date ticks on every 5th easter.

See https://dateutil.readthedocs.io/en/stable/rrule.html for help with rrules.




```
import datetime

import matplotlib.pyplot as plt
import numpy as np

from matplotlib.dates import YEARLY, DateFormatter, RRuleLocator,␣
 ↪drange, rrulewrapper

# Fixing random state for reproducibility
np.random.seed(19680801)


# tick every 5th easter
rule = rrulewrapper(YEARLY, byeaster=1, interval=5)
loc = RRuleLocator(rule)
formatter = DateFormatter('%m/%d/%y')
date1 = datetime.date(1952, 1, 1)
date2 = datetime.date(2004, 4, 12)
delta = datetime.timedelta(days=100)
```

(continues on next page)

(continued from previous page)

```
dates = drange(date1, date2, delta)
s = np.random.rand(len(dates))  # make up some random y values


fig, ax = plt.subplots()
plt.plot(dates, s, 'o')
ax.xaxis.set_major_locator(loc)
ax.xaxis.set_major_formatter(formatter)
ax.xaxis.set_tick_params(rotation=30, labelsize=10)

plt.show()
```

Custom tick formatter for time series

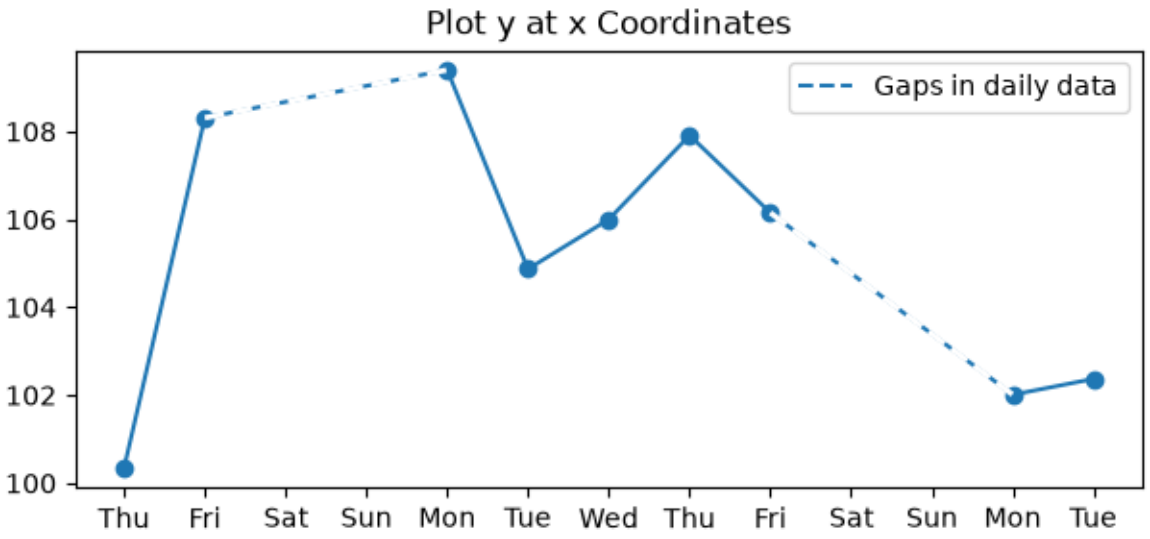
When plotting daily data, e.g., financial time series, one often wants to leave out days on which there is no data, for instance weekends, so that the data are plotted at regular intervals without extra spaces for the days with no data. The example shows how to use an 'index formatter' to achieve the desired plot.

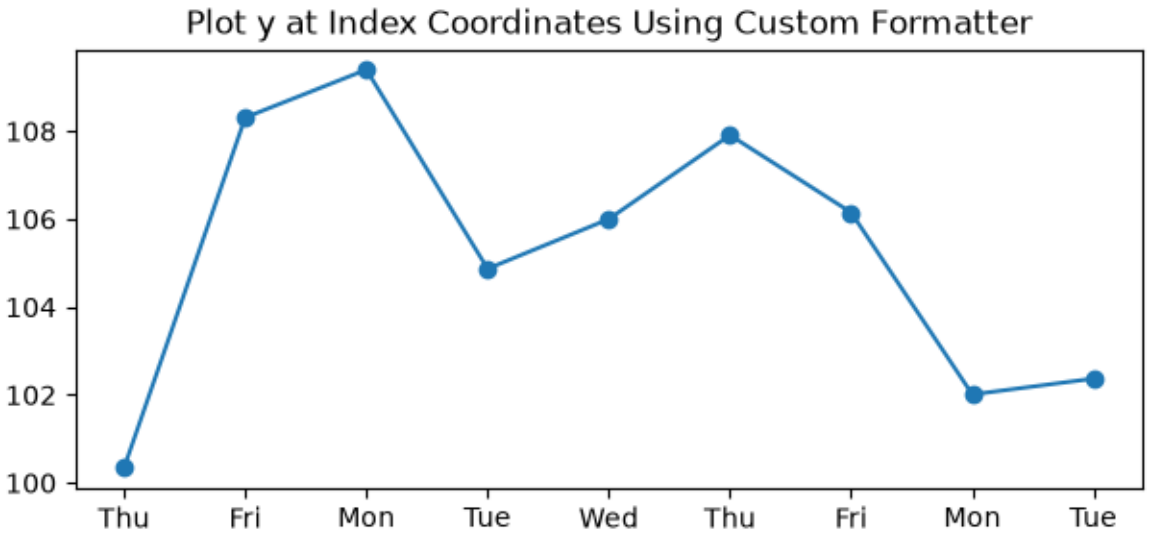
```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.cbook as cbook
from matplotlib.dates import DateFormatter, DayLocator
import matplotlib.lines as ml
from matplotlib.ticker import Formatter

# Load a structured numpy array from yahoo csv data with fields date,␣
 ↪open, high,
# low, close, volume, adj_close from the mpl-data/sample_data␣
 ↪directory. The
# record array stores the date as an np.datetime64 with a day unit ('D
 ↪') in
# the date column (``r['date']``).
r = cbook.get_sample_data('goog.npz')['price_data']
r = r[:9]  # get the first 9 days

fig, (ax1, ax2) = plt.subplots(nrows=2, figsize=(6, 6), layout=
 ↪'constrained')
fig.get_layout_engine().set(hspace=0.15)

# First we'll do it the default way, with gaps on weekends
ax1.plot(r["date"], r["adj_close"], 'o-')

# Highlight gaps in daily data
gaps = np.flatnonzero(np.diff(r["date"]) > np.timedelta64(1, 'D'))
for gap in r[['date', 'adj_close']][np.stack((gaps, gaps + 1)).T]:
```

(continues on next page)

(continued from previous page)

```
    ax1.plot(gap['date'], gap['adj_close'], 'w--', lw=2)
ax1.legend(handles=[ml.Line2D([], [], ls='--', label='Gaps in daily␣
 ↪data')])

ax1.set_title("Plot y at x Coordinates")
ax1.xaxis.set_major_locator(DayLocator())
ax1.xaxis.set_major_formatter(DateFormatter('%a'))


# Next we'll write a custom index formatter. Below we will plot
# the data against an index that goes from 0, 1,  ... len(data). ␣
 ↪Instead of
# formatting the tick marks as integers, we format as times.
def format_date(x, _):
    try:
        # convert datetime64 to datetime, and use datetime's strftime:
        return r["date"][round(x)].item().strftime('%a')
    except IndexError:
        pass

# Create an index plot (x defaults to range(len(y)) if omitted)
ax2.plot(r["adj_close"], 'o-')

ax2.set_title("Plot y at Index Coordinates Using Custom Formatter")
ax2.xaxis.set_major_formatter(format_date)  # internally creates␣
 ↪FuncFormatter
```





Instead of passing a function into *Axis.set_major_formatter* you can use any other callable, e.g. an instance of a class that implements __call__:

```
class MyFormatter(Formatter):
    def __init__(self, dates, fmt='%a'):
        self.dates = dates
        self.fmt = fmt

    def __call__(self, x, pos=0):
        """Return the label for time x at position pos."""
        try:
            return self.dates[round(x)].item().strftime(self.fmt)
        except IndexError:
            pass
```

(continues on next page)

(continued from previous page)

```
ax2.xaxis.set_major_formatter(MyFormatter(r["date"], '%a'))

plt.show()
```

Date precision and epochs

Matplotlib can handle `datetime` objects and `numpy.datetime64` objects using a unit converter that recognizes these dates and converts them to floating point numbers.

Before Matplotlib 3.3, the default for this conversion returns a float that was days since "0000-12-31T00:00:00". As of Matplotlib 3.3, the default is days from "1970-01-01T00:00:00". This allows more resolution for modern dates. "2020-01-01" with the old epoch converted to 730120, and a 64-bit floating point number has a resolution of 2^{-52}, or approximately 14 microseconds, so microsecond precision was lost. With the new default epoch "2020-01-01" is 10957.0, so the achievable resolution is 0.21 microseconds.

```
import datetime

import matplotlib.pyplot as plt
import numpy as np

import matplotlib.dates as mdates


def _reset_epoch_for_tutorial():
    """
    Users (and downstream libraries) should not use the private method␣
 ↪of
    resetting the epoch.
    """
    mdates._reset_epoch_test_example()
```

Datetime

Python `datetime` objects have microsecond resolution, so with the old default matplotlib dates could not round-trip full-resolution datetime objects.

```
old_epoch = '0000-12-31T00:00:00'
new_epoch = '1970-01-01T00:00:00'

_reset_epoch_for_tutorial()  # Don't do this.  Just for this tutorial.
mdates.set_epoch(old_epoch)  # old epoch (pre MPL 3.3)

date1 = datetime.datetime(2000, 1, 1, 0, 10, 0, 12,
                          tzinfo=datetime.timezone.utc)
```

(continues on next page)

(continued from previous page)

```
mdate1 = mdates.date2num(date1)
print('Before Roundtrip: ', date1, 'Matplotlib date:', mdate1)
date2 = mdates.num2date(mdate1)
print('After Roundtrip:  ', date2)
```

```
Before Roundtrip:  2000-01-01 00:10:00.000012+00:00 Matplotlib date:␣
↪730120.0069444446
After Roundtrip:   2000-01-01 00:10:00.000020+00:00
```

Note this is only a round-off error, and there is no problem for dates closer to the old epoch:

```
date1 = datetime.datetime(10, 1, 1, 0, 10, 0, 12,
                          tzinfo=datetime.timezone.utc)
mdate1 = mdates.date2num(date1)
print('Before Roundtrip: ', date1, 'Matplotlib date:', mdate1)
date2 = mdates.num2date(mdate1)
print('After Roundtrip:  ', date2)
```

```
Before Roundtrip:  0010-01-01 00:10:00.000012+00:00 Matplotlib date:␣
↪3288.006944444583
After Roundtrip:   0010-01-01 00:10:00.000012+00:00
```

If a user wants to use modern dates at microsecond precision, they can change the epoch using *set_epoch*. However, the epoch has to be set before any date operations to prevent confusion between different epochs. Trying to change the epoch later will raise a RuntimeError.

```
try:
    mdates.set_epoch(new_epoch)  # this is the new MPL 3.3 default.
except RuntimeError as e:
    print('RuntimeError:', str(e))
```

```
RuntimeError: set_epoch must be called before dates plotted.
```

For this tutorial, we reset the sentinel using a private method, but users should just set the epoch once, if at all.

```
_reset_epoch_for_tutorial()  # Just being done for this tutorial.
mdates.set_epoch(new_epoch)

date1 = datetime.datetime(2020, 1, 1, 0, 10, 0, 12,
                          tzinfo=datetime.timezone.utc)
mdate1 = mdates.date2num(date1)
print('Before Roundtrip: ', date1, 'Matplotlib date:', mdate1)
date2 = mdates.num2date(mdate1)
print('After Roundtrip:  ', date2)
```

```
Before Roundtrip:  2020-01-01 00:10:00.000012+00:00 Matplotlib date:␣
 ↪18262.006944444583
After Roundtrip:   2020-01-01 00:10:00.000012+00:00
```

datetime64

`numpy.datetime64` objects have microsecond precision for a much larger timespace than `datetime` objects. However, currently Matplotlib time is only converted back to datetime objects, which have microsecond resolution, and years that only span 0000 to 9999.

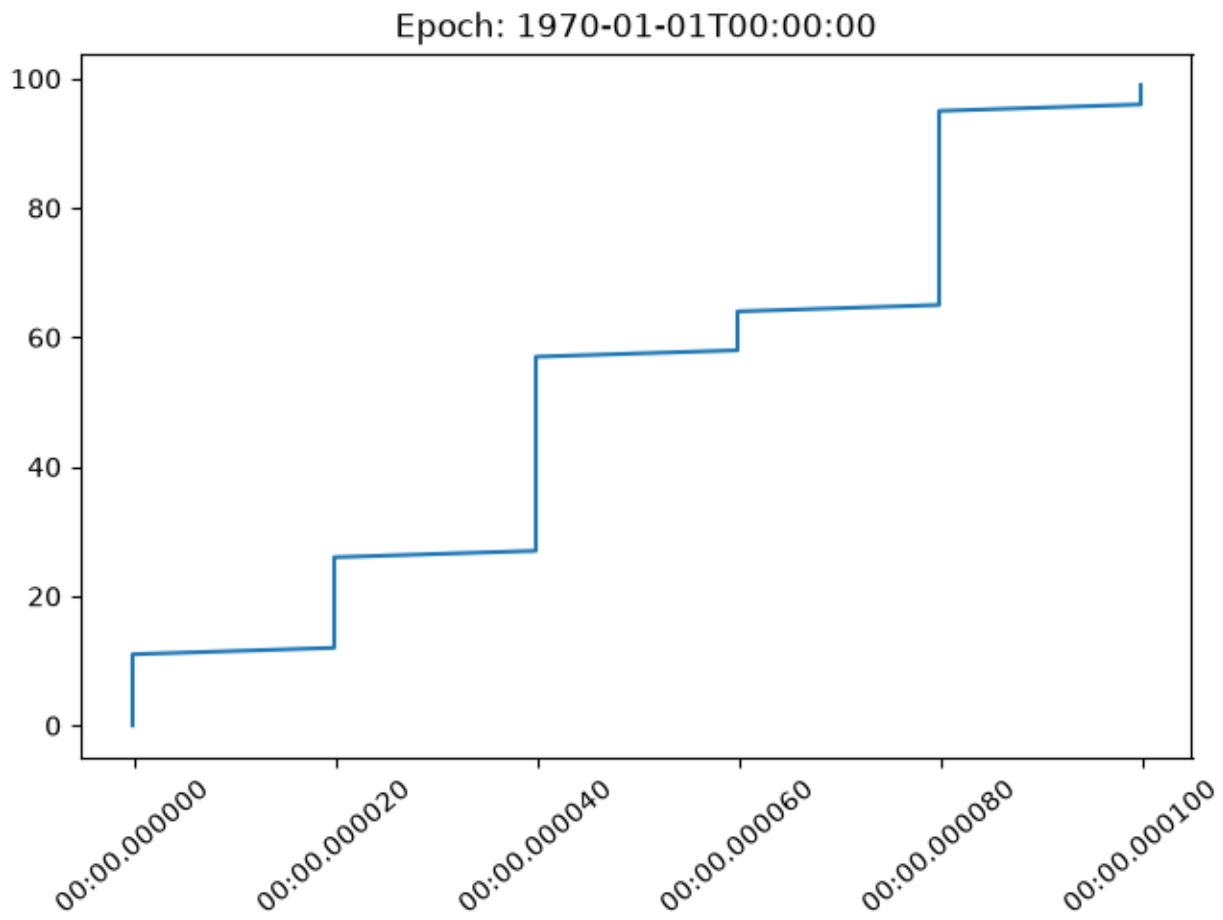
```
_reset_epoch_for_tutorial()  # Don't do this.  Just for this tutorial.
mdates.set_epoch(new_epoch)

date1 = np.datetime64('2000-01-01T00:10:00.000012')
mdate1 = mdates.date2num(date1)
print('Before Roundtrip: ', date1, 'Matplotlib date:', mdate1)
date2 = mdates.num2date(mdate1)
print('After Roundtrip:  ', date2)
```

```
Before Roundtrip:  2000-01-01T00:10:00.000012 Matplotlib date:␣
 ↪10957.006944444583
After Roundtrip:   2000-01-01 00:10:00.000012+00:00
```

Plotting

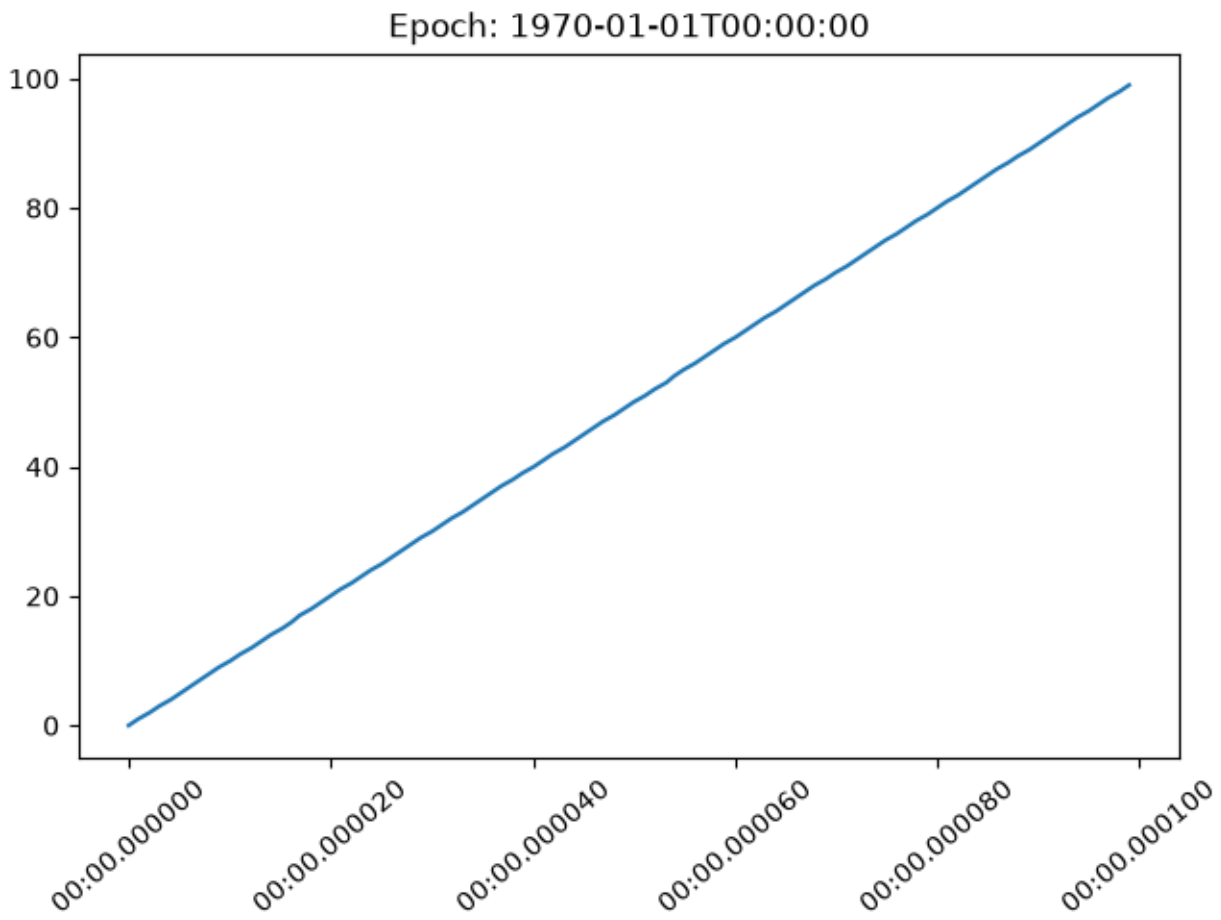
This all of course has an effect on plotting. With the old default epoch the times were rounded during the internal `date2num` conversion, leading to jumps in the data:

```
_reset_epoch_for_tutorial()  # Don't do this.  Just for this tutorial.
mdates.set_epoch(old_epoch)

x = np.arange('2000-01-01T00:00:00.0', '2000-01-01T00:00:00.000100',
              dtype='datetime64[us]')
# simulate the plot being made using the old epoch
xold = np.array([mdates.num2date(mdates.date2num(d)) for d in x])
y = np.arange(0, len(x))

# resetting the Epoch so plots are comparable
_reset_epoch_for_tutorial()  # Don't do this.  Just for this tutorial.
mdates.set_epoch(new_epoch)

fig, ax = plt.subplots(layout='constrained')
ax.plot(xold, y)
ax.set_title('Epoch: ' + mdates.get_epoch())
ax.xaxis.set_tick_params(rotation=40)
plt.show()
```



For dates plotted using the more recent epoch, the plot is smooth:

```
fig, ax = plt.subplots(layout='constrained')
ax.plot(x, y)
ax.set_title('Epoch: ' + mdates.get_epoch())
ax.xaxis.set_tick_params(rotation=40)
plt.show()

_reset_epoch_for_tutorial()  # Don't do this.  Just for this tutorial.
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.dates.num2date*
- *matplotlib.dates.date2num*
- *matplotlib.dates.set_epoch*

Colorbar Tick labelling

Vertical colorbars have ticks, tick labels, and labels visible on the *y* axis, horizontal colorbars on the *x* axis. The `ticks` parameter can be used to set the ticks and the `format` parameter can be used to format the tick labels of the visible colorbar Axes. For further adjustments, the `yaxis` or `xaxis` Axes of the colorbar can be retrieved using its `ax` property.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.ticker as mticker
```

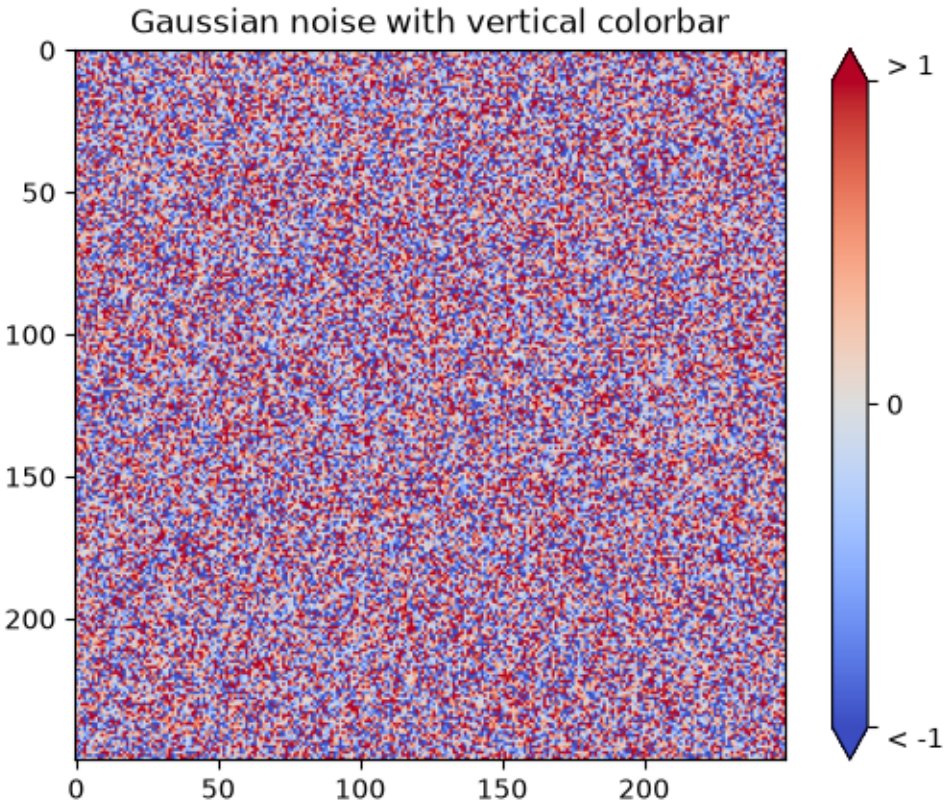
(continues on next page)

(continued from previous page)

```
# Fixing random state for reproducibility
rng = np.random.default_rng(seed=19680801)
```

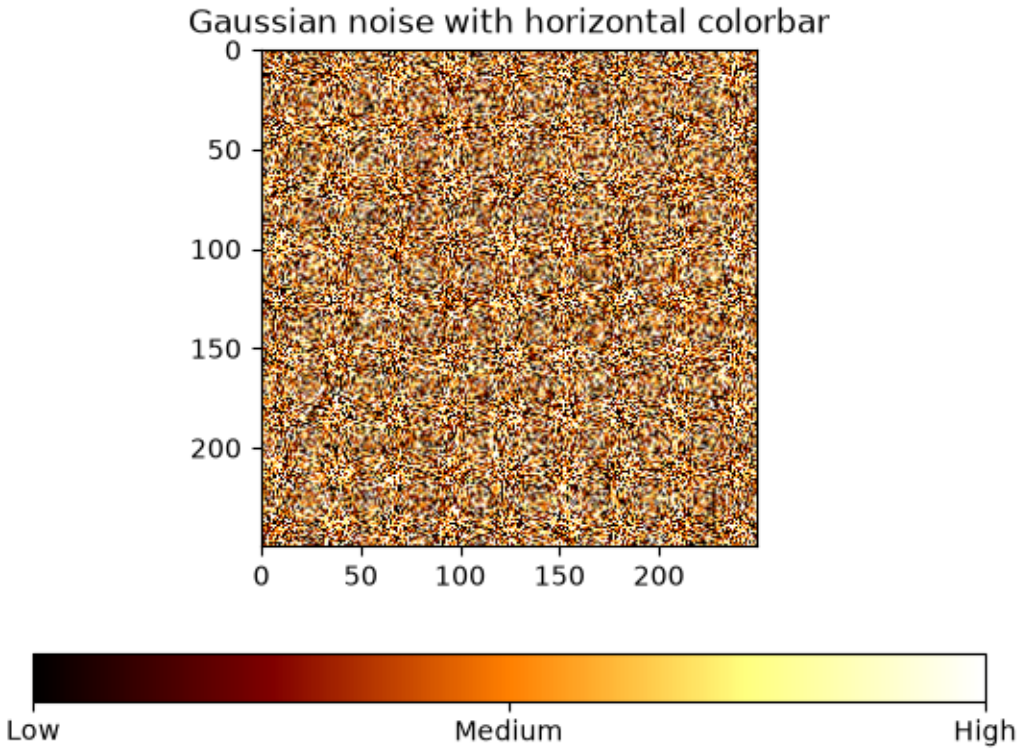
Make plot with vertical (default) colorbar

```
fig, ax = plt.subplots()

data = rng.standard_normal((250, 250))

cax = ax.imshow(data, vmin=-1, vmax=1, cmap='coolwarm')
ax.set_title('Gaussian noise with vertical colorbar')

# Add colorbar, make sure to specify tick locations to match desired␣
↪ticklabels
cbar = fig.colorbar(cax,
                    ticks=[-1, 0, 1],
                    format=mticker.FixedFormatter(['< -1', '0', '> 1
↪']),
                    extend='both'
                    )
labels = cbar.ax.get_yticklabels()
labels[0].set_verticalalignment('top')
labels[-1].set_verticalalignment('bottom')
```



Make plot with horizontal colorbar

```
fig, ax = plt.subplots()

data = np.clip(data, -1, 1)

cax = ax.imshow(data, cmap='afmhot')
ax.set_title('Gaussian noise with horizontal colorbar')

# Add colorbar and adjust ticks afterwards
cbar = fig.colorbar(cax, orientation='horizontal')
cbar.set_ticks(ticks=[-1, 0, 1], labels=['Low', 'Medium', 'High'])

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.colorbar.Colorbar.set_ticks*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*

Customizing figure and axes appearance

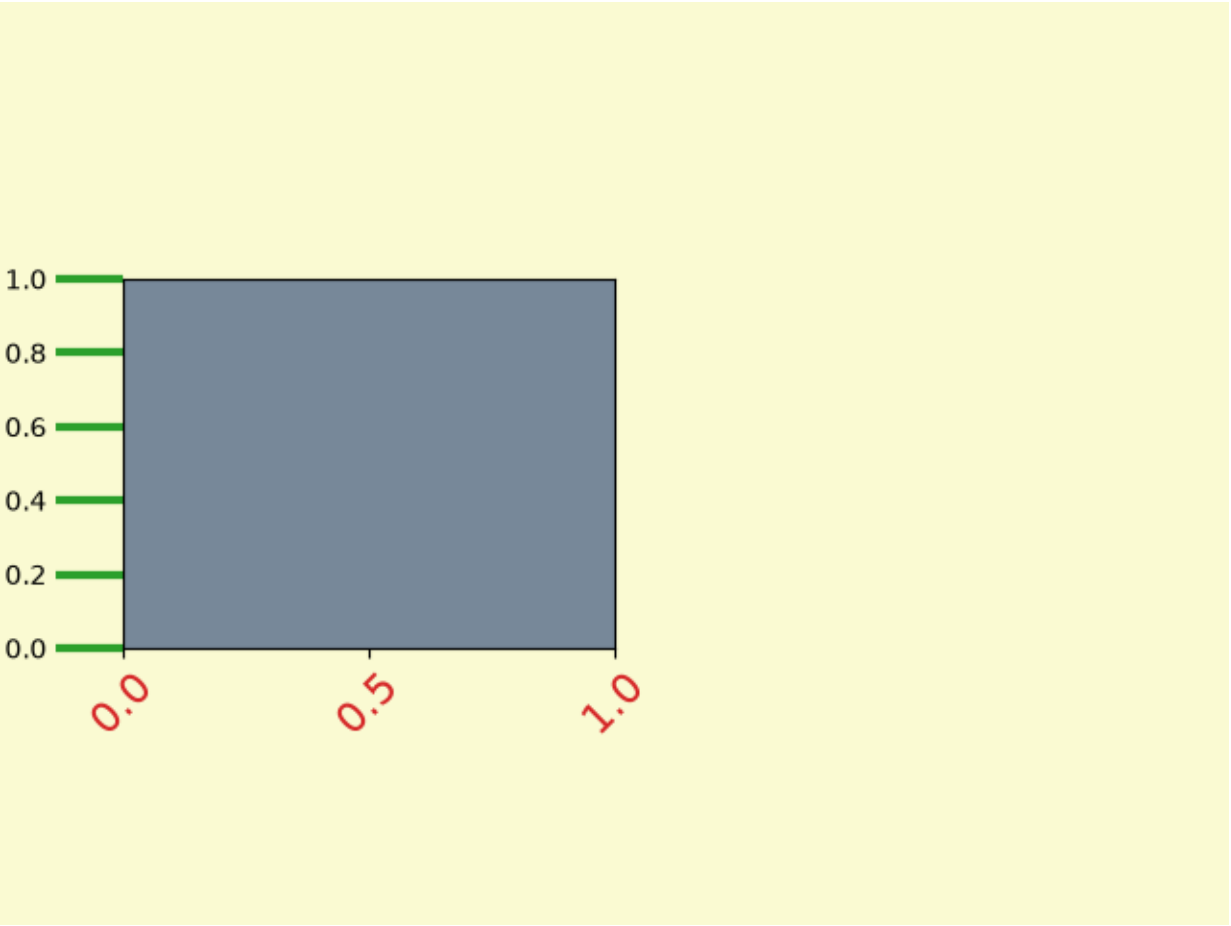
Customize the background, labels and ticks of a simple plot.

```
import matplotlib.pyplot as plt

fig = plt.figure()
fig.patch.set_facecolor('lightgoldenrodyellow')

ax1 = fig.add_axes((0.1, 0.3, 0.4, 0.4))
ax1.patch.set_facecolor('lightslategray')
```

(continues on next page)

(continued from previous page)

```
ax1.tick_params(axis='x', labelcolor='tab:red', labelrotation=45,␣
 ↪labelsize=16)
ax1.tick_params(axis='y', color='tab:green', size=25, width=3)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.tick_params*
- *matplotlib.patches.Patch.set_facecolor*

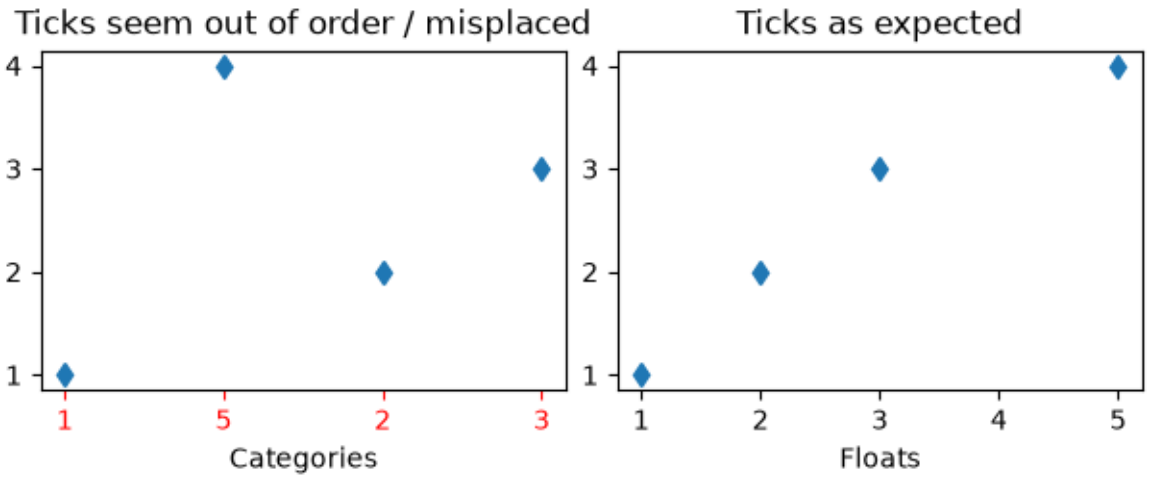
Fixing too many ticks

One common cause for unexpected tick behavior is passing a list of strings instead of numbers or datetime objects. This can easily happen without notice when reading in a comma-delimited text file. Matplotlib treats lists of strings as *categorical* variables (*Plotting categorical variables*), and by default puts one tick per category, and plots them in the order in which they are supplied. If this is not desired, the solution is to

convert the strings to a numeric type as in the following examples.

Example 1: Strings can lead to an unexpected order of number ticks

```
import matplotlib.pyplot as plt
import numpy as np

fig, ax = plt.subplots(1, 2, layout='constrained', figsize=(6, 2.5))
x = ['1', '5', '2', '3']
y = [1, 4, 2, 3]
ax[0].plot(x, y, 'd')
ax[0].tick_params(axis='x', color='r', labelcolor='r')
ax[0].set_xlabel('Categories')
ax[0].set_title('Ticks seem out of order / misplaced')

# convert to numbers:
x = np.asarray(x, dtype='float')
ax[1].plot(x, y, 'd')
ax[1].set_xlabel('Floats')
ax[1].set_title('Ticks as expected')
```



Example 2: Strings can lead to very many ticks

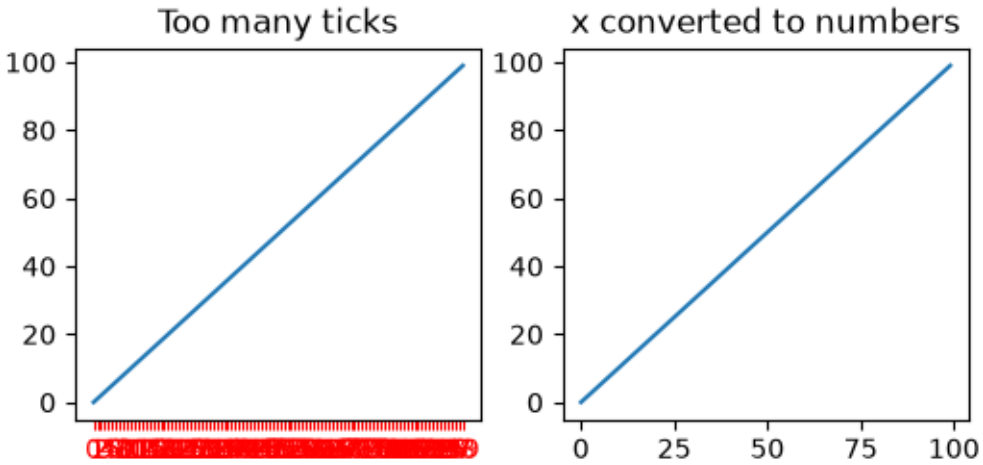
If *x* has 100 elements, all strings, then we would have 100 (unreadable) ticks, and again the solution is to convert the strings to floats:

```
fig, ax = plt.subplots(1, 2, figsize=(6, 2.5))
x = [f'{xx}' for xx in np.arange(100)]
y = np.arange(100)
ax[0].plot(x, y)
ax[0].tick_params(axis='x', color='r', labelcolor='r')
ax[0].set_title('Too many ticks')
ax[0].set_xlabel('Categories')
```

(continues on next page)

(continued from previous page)

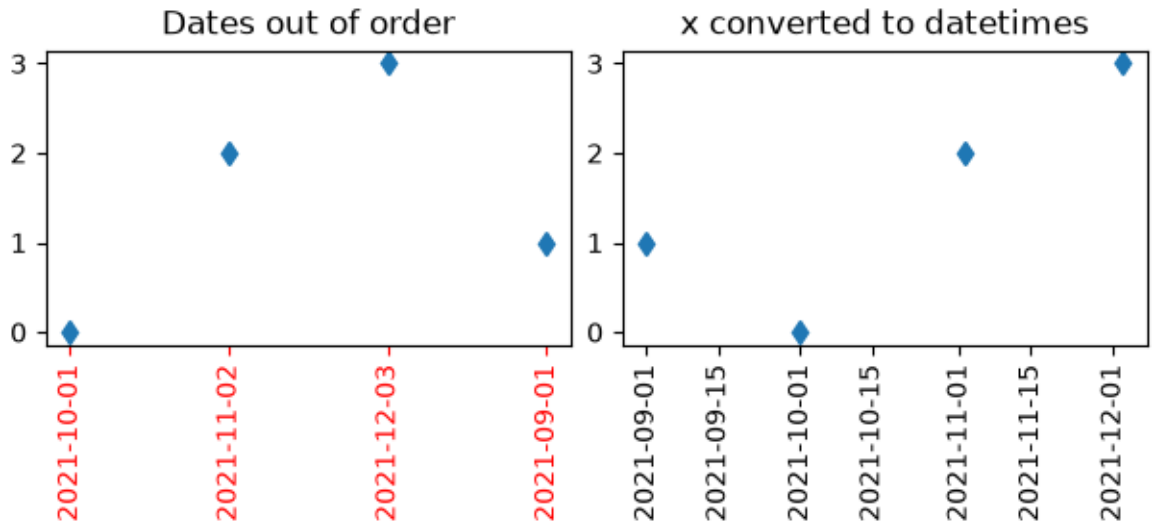
```
ax[1].plot(np.asarray(x, float), y)
ax[1].set_title('x converted to numbers')
ax[1].set_xlabel('Floats')
```



Example 3: Strings can lead to an unexpected order of datetime ticks

A common case is when dates are read from a CSV file, they need to be converted from strings to datetime objects to get the proper date locators and formatters.

```
fig, ax = plt.subplots(1, 2, layout='constrained', figsize=(6, 2.75))
x = ['2021-10-01', '2021-11-02', '2021-12-03', '2021-09-01']
y = [0, 2, 3, 1]
ax[0].plot(x, y, 'd')
ax[0].tick_params(axis='x', labelrotation=90, color='r', labelcolor='r
 ↪')
ax[0].set_title('Dates out of order')

# convert to datetime64
x = np.asarray(x, dtype='datetime64[s]')
ax[1].plot(x, y, 'd')
ax[1].tick_params(axis='x', labelrotation=90)
ax[1].set_title('x converted to datetimes')

plt.show()
```



6.24.7 Scales

These examples cover how different scales are handled in Matplotlib.

Scales overview

Illustrate the scale transformations applied to axes, e.g. log, symlog, logit.

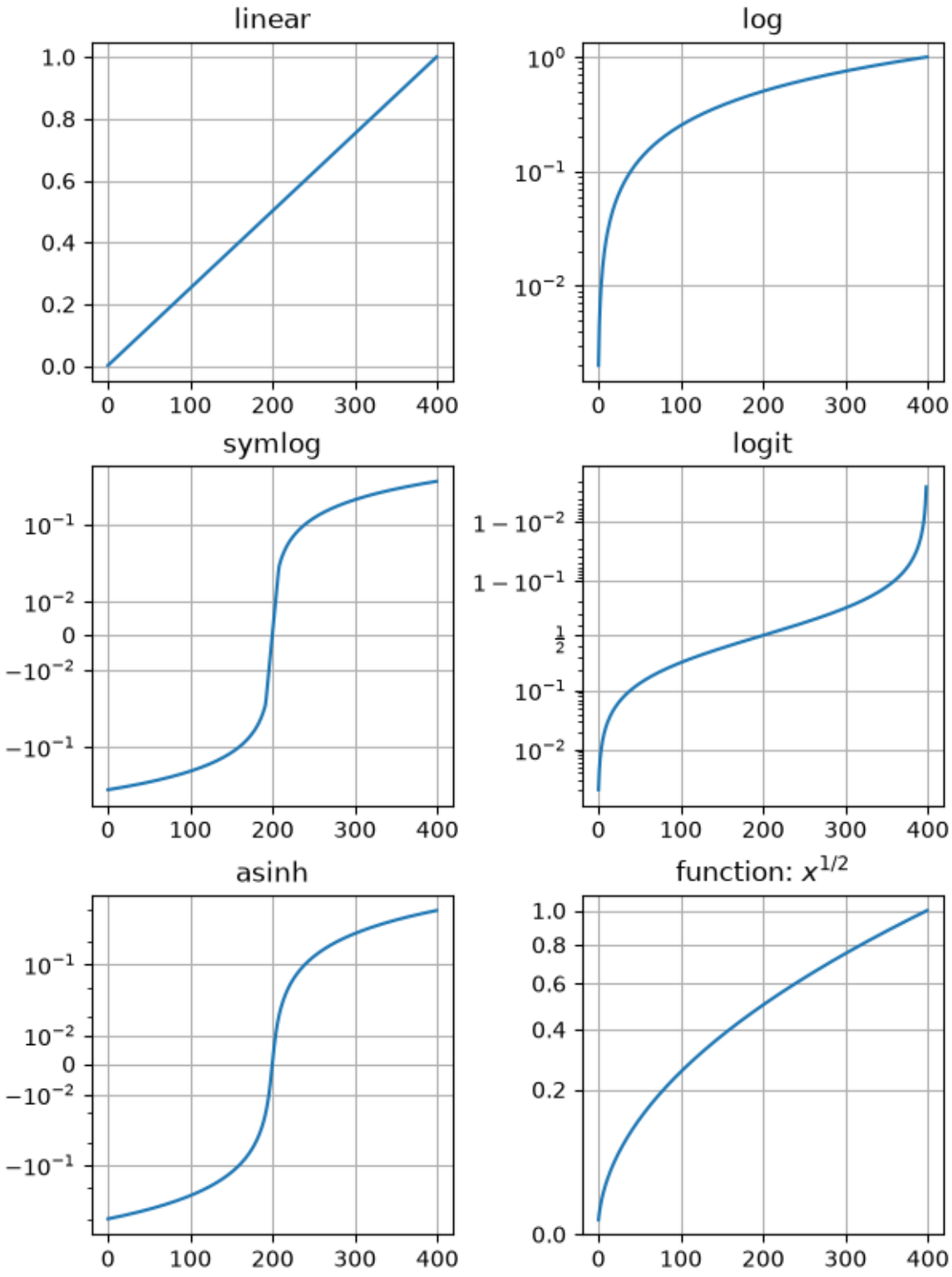
See `matplotlib.scale` for a full list of built-in scales, *Custom scale* for how to create your own scale, and *Scales on 3D (Log, Symlog, etc.)* for using scales on 3D axes.

```
import matplotlib.pyplot as plt
import numpy as np

x = np.arange(400)
y = np.linspace(0.002, 1, 400)

fig, axs = plt.subplots(3, 2, figsize=(6, 8), layout='constrained')

axs[0, 0].plot(x, y)
axs[0, 0].set_yscale('linear')
axs[0, 0].set_title('linear')
axs[0, 0].grid(True)

axs[0, 1].plot(x, y)
axs[0, 1].set_yscale('log')
axs[0, 1].set_title('log')
axs[0, 1].grid(True)

axs[1, 0].plot(x, y - y.mean())
axs[1, 0].set_yscale('symlog', linthresh=0.02)
axs[1, 0].set_title('symlog')
```

(continues on next page)

(continued from previous page)

```
axs[1, 0].grid(True)

axs[1, 1].plot(x, y)
axs[1, 1].set_yscale('logit')
axs[1, 1].set_title('logit')
axs[1, 1].grid(True)

axs[2, 0].plot(x, y - y.mean())
axs[2, 0].set_yscale('asinh', linear_width=0.01)
axs[2, 0].set_title('asinh')
axs[2, 0].grid(True)


# Function x**(1/2)
def forward(x):
    return x**(1/2)


def inverse(x):
    return x**2


axs[2, 1].plot(x, y)
axs[2, 1].set_yscale('function', functions=(forward, inverse))
axs[2, 1].set_title('function: $x^{1/2}$')
axs[2, 1].grid(True)
axs[2, 1].set_yticks(np.arange(0, 1.2, 0.2))

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.set_xscale*
- *matplotlib.axes.Axes.set_yscale*
- *matplotlib.scale.LinearScale*
- *matplotlib.scale.LogScale*
- *matplotlib.scale.SymmetricalLogScale*
- *matplotlib.scale.LogitScale*
- *matplotlib.scale.FuncScale*

Total running time of the script: (0 minutes 1.140 seconds)

Asinh scale

Illustration of the *asinh* axis scaling, which uses the transformation

$$a \to a_0 \sinh^{-1}(a/a_0)$$

For coordinate values close to zero (i.e. much smaller than the "linear width" a_0), this leaves values essentially unchanged:

$$a \to a + \mathcal{O}(a^3)$$

but for larger values (i.e. $|a| \gg a_0$, this is asymptotically

$$a \to a_0 \operatorname{sgn}(a) \ln |a| + \mathcal{O}(1)$$

As with the *symlog* scaling, this allows one to plot quantities that cover a very wide dynamic range that includes both positive and negative values. However, `symlog` involves a transformation that has discontinuities in its gradient because it is built from *separate* linear and logarithmic transformations. The `asinh` scaling uses a transformation that is smooth for all (finite) values, which is both mathematically cleaner and reduces visual artifacts associated with an abrupt transition between linear and logarithmic regions of the plot.

Note

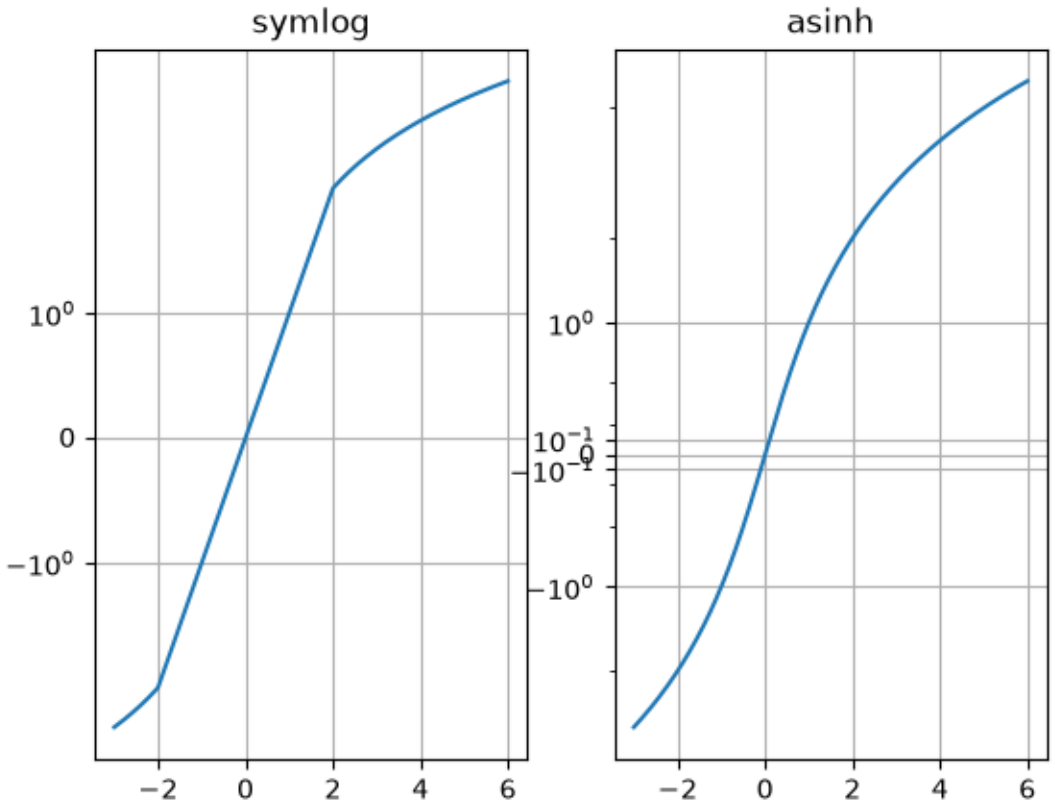
scale.AsinhScale is experimental, and the API may change.

See *AsinhScale*, *SymmetricalLogScale*.

```
import matplotlib.pyplot as plt
import numpy as np

# Prepare sample values for variations on y=x graph:
x = np.linspace(-3, 6, 500)
```

Compare "symlog" and "asinh" behaviour on sample y=x graph, where there is a discontinuous gradient in "symlog" near y=2:

```
fig1 = plt.figure()
ax0, ax1 = fig1.subplots(1, 2, sharex=True)

ax0.plot(x, x)
ax0.set_yscale('symlog')
ax0.grid()
ax0.set_title('symlog')

ax1.plot(x, x)
ax1.set_yscale('asinh')
ax1.grid()
ax1.set_title('asinh')
```



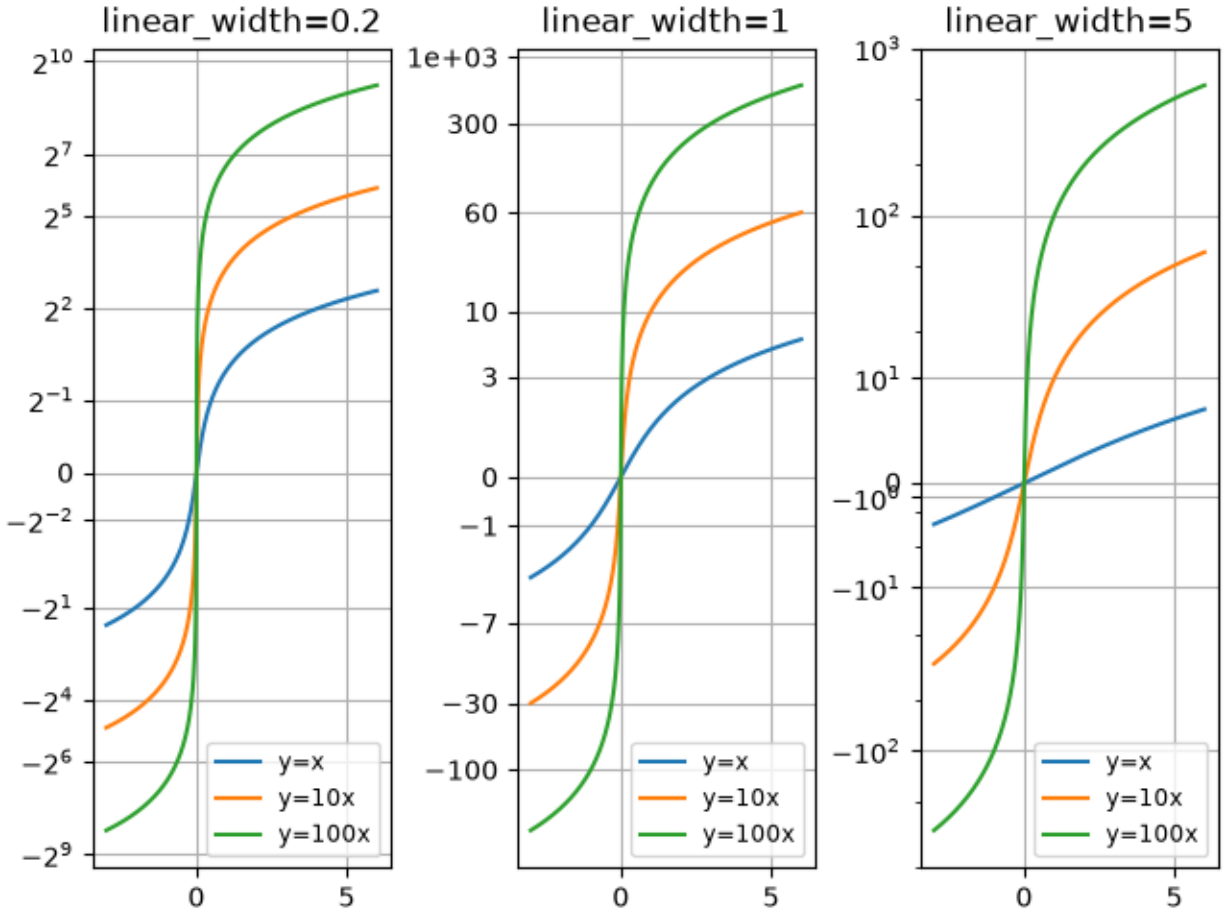
Compare "asinh" graphs with different scale parameter "linear_width":

```
fig2 = plt.figure(layout='constrained')
axs = fig2.subplots(1, 3, sharex=True)
for ax, (a0, base) in zip(axs, ((0.2, 2), (1.0, 0), (5.0, 10))):
```

(continues on next page)

(continued from previous page)

```
    ax.set_title(f'linear_width={a0:.3g}')
    ax.plot(x, x, label='y=x')
    ax.plot(x, 10*x, label='y=10x')
    ax.plot(x, 100*x, label='y=100x')
    ax.set_yscale('asinh', linear_width=a0, base=base)
    ax.grid()
    ax.legend(loc='best', fontsize='small')
```



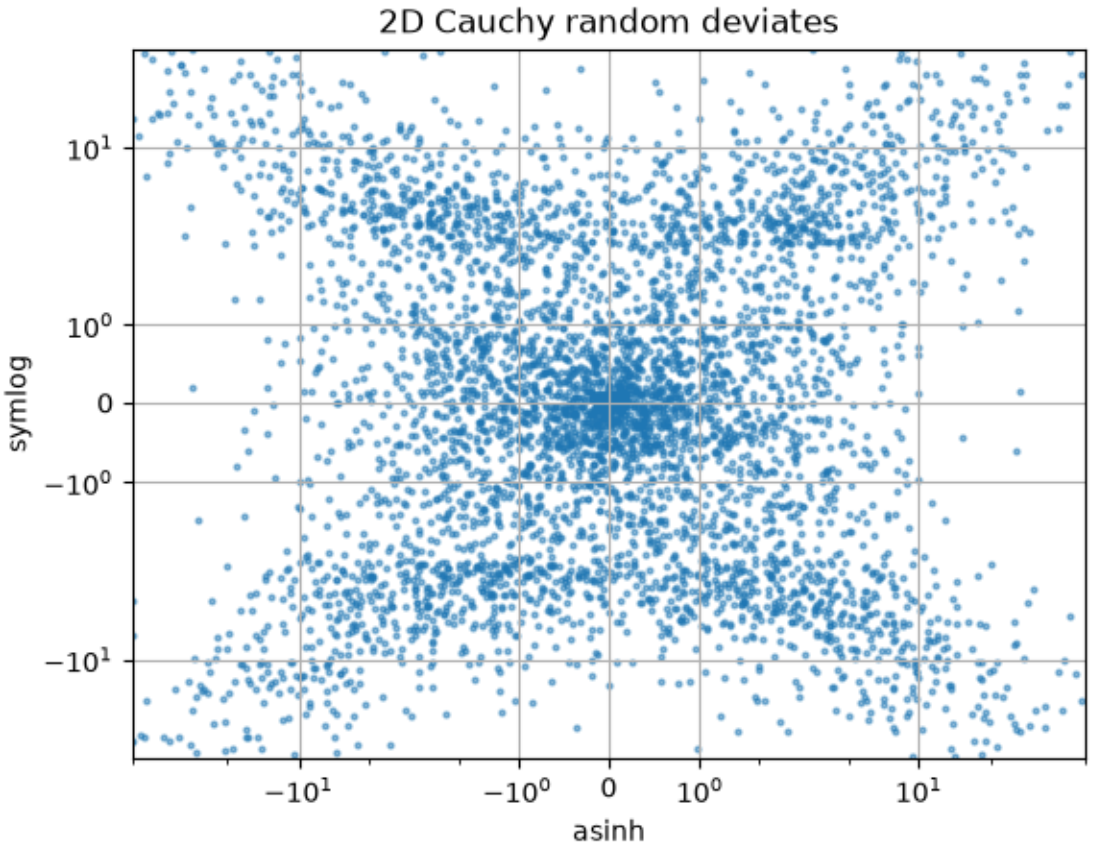
Compare "symlog" and "asinh" scalings on 2D Cauchy-distributed random numbers, where one may be able to see more subtle artifacts near y=2 due to the gradient-discontinuity in "symlog":

```
fig3 = plt.figure()
ax = fig3.subplots(1, 1)
r = 3 * np.tan(np.random.uniform(-np.pi / 2.02, np.pi / 2.02,
                                 size=(5000,)))
th = np.random.uniform(0, 2*np.pi, size=r.shape)

ax.scatter(r * np.cos(th), r * np.sin(th), s=4, alpha=0.5)
ax.set_xscale('asinh')
ax.set_yscale('symlog')
```

(continues on next page)

(continued from previous page)

```
ax.set_xlabel('asinh')
ax.set_ylabel('symlog')
ax.set_title('2D Cauchy random deviates')
ax.set_xlim(-50, 50)
ax.set_ylim(-50, 50)
ax.grid()

plt.show()
```

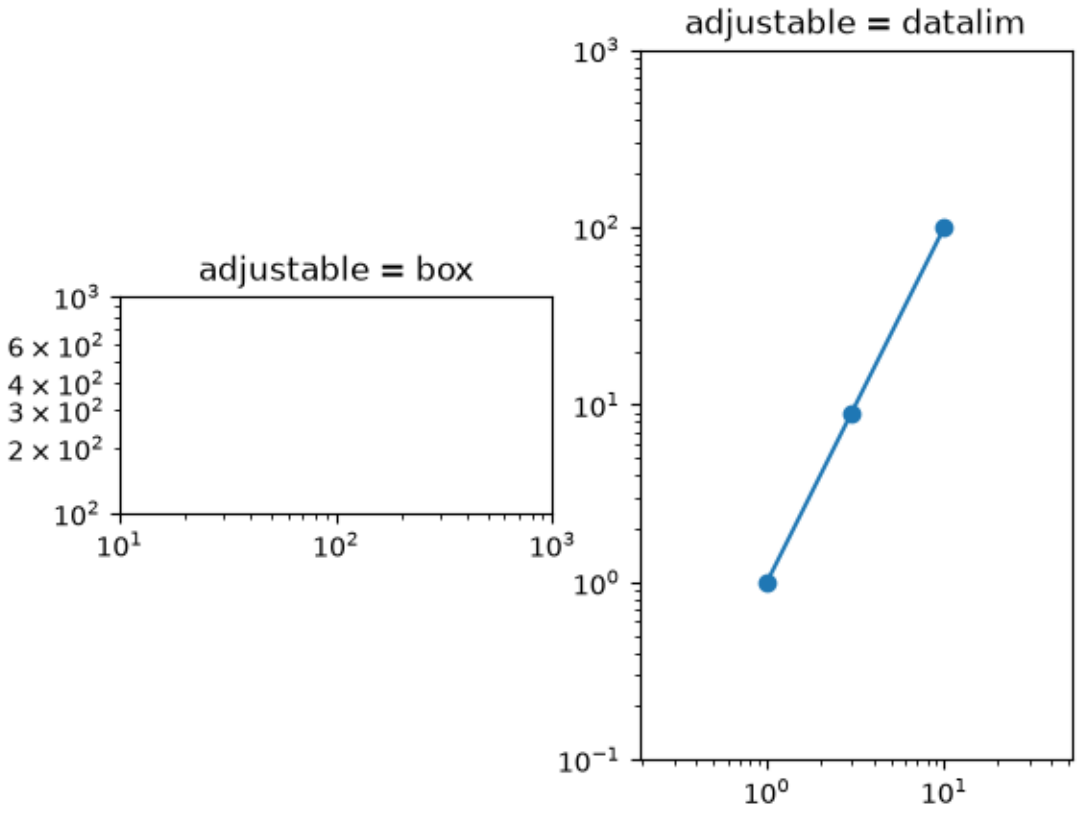


References

- *matplotlib.scale.AsinhScale*
- *matplotlib.ticker.AsinhLocator*
- *matplotlib.scale.SymmetricalLogScale*

Total running time of the script: (0 minutes 1.353 seconds)

Loglog aspect




```
import matplotlib.pyplot as plt

fig, (ax1, ax2) = plt.subplots(1, 2)
ax1.set_xscale("log")
ax1.set_yscale("log")
ax1.set_xlim(1e1, 1e3)
ax1.set_ylim(1e2, 1e3)
ax1.set_aspect(1)
ax1.set_title("adjustable = box")
```

(continues on next page)

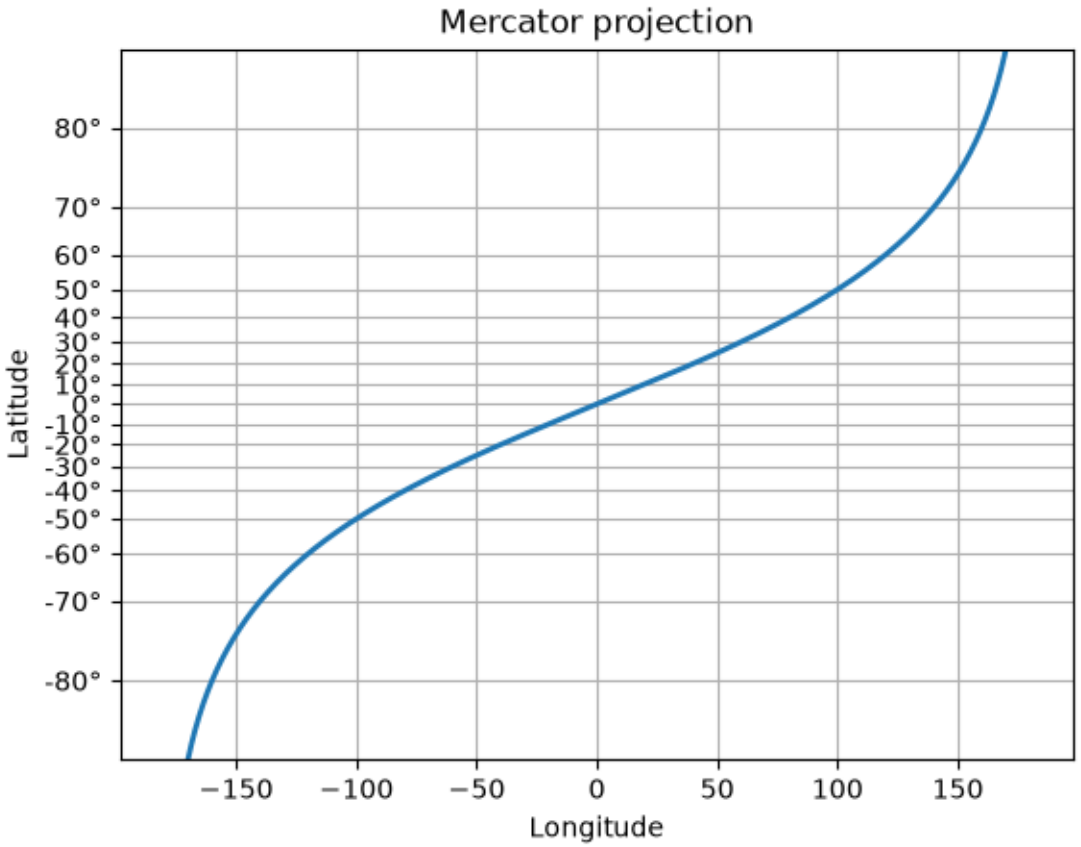
(continued from previous page)

```
ax2.set_xscale("log")
ax2.set_yscale("log")
ax2.set_adjustable("datalim")
ax2.plot([1, 3, 10], [1, 9, 100], "o-")
ax2.set_xlim(1e-1, 1e2)
ax2.set_ylim(1e-1, 1e3)
ax2.set_aspect(1)
ax2.set_title("adjustable = datalim")

plt.show()
```

Custom scale

Custom scales can be created in two ways

1. For simple cases, use *FuncScale* and the 'function' option of *set_xscale* and *set_yscale*. See the last example in *Scales overview*.
2. Create a custom scale class such as the one in this example, which implements the scaling use for latitude data in a Mercator Projection. This more complicated approach is useful when
   - You are making special use of the *Transform* class, such as the special handling of values beyond the threshold in MercatorLatitudeTransform below.
   - You want to override the default locators and formatters for the axis (set_default_locators_and_formatters below).
   - You want to limit the range of the axis (limit_range_for_scale below).




```
import numpy as np
from numpy import ma

from matplotlib import scale as mscale
from matplotlib import transforms as mtransforms
from matplotlib.ticker import FixedLocator, FuncFormatter


class MercatorLatitudeScale(mscale.ScaleBase):
    """
    Scales data in range -pi/2 to pi/2 (-90 to 90 degrees) using
    the system used to scale latitudes in a Mercator__ projection.

    The scale function:
      ln(tan(y) + sec(y))

    The inverse scale function:
      atan(sinh(y))

    Since the Mercator scale tends to infinity at +/- 90 degrees,
```

(continues on next page)

(continued from previous page)

```
    there is user-defined threshold, above and below which nothing
    will be plotted.  This defaults to +/- 85 degrees.

    __ https://en.wikipedia.org/wiki/Mercator_projection
    """

    # The scale class must have a member ``name`` that defines the␣
↪string used
    # to select the scale.  For example, ``ax.set_yscale("mercator")``␣
↪would be
    # used to select this scale.
    name = 'mercator'

    def __init__(self, axis, *, thresh=np.deg2rad(85), **kwargs):
        """
        Any keyword arguments passed to ``set_xscale`` and␣
↪``set_yscale`` will
        be passed along to the scale's constructor.

        thresh: The degree above which to crop the data.
        """
        super().__init__(axis)
        if thresh >= np.pi / 2:
            raise ValueError("thresh must be less than pi/2")
        self.thresh = thresh

    def get_transform(self):
        """
        Override this method to return a new instance that does the
        actual transformation of the data.

        The MercatorLatitudeTransform class is defined below as a
        nested class of this one.
        """
        return self.MercatorLatitudeTransform(self.thresh)

    def set_default_locators_and_formatters(self, axis):
        """
        Override to set up the locators and formatters to use with the
        scale.  This is only required if the scale requires custom
        locators and formatters.  Writing custom locators and
        formatters is rather outside the scope of this example, but
        there are many helpful examples in :mod:`.ticker`.

        In our case, the Mercator example uses a fixed locator from -
↪90 to 90
```

(continues on next page)

(continued from previous page)

```
        degrees and a custom formatter to convert the radians to␣
↪degrees and
        put a degree symbol after the value.
        """
        fmt = FuncFormatter(
            lambda x, pos=None: f"{np.degrees(x):.0f}\N{DEGREE SIGN}")
        axis.set(major_locator=FixedLocator(np.radians(range(-90, 90,␣
↪10))),
                 major_formatter=fmt, minor_formatter=fmt)

    def limit_range_for_scale(self, vmin, vmax, minpos):
        """
        Override to limit the bounds of the axis to the domain of the
        transform.  In the case of Mercator, the bounds should be
        limited to the threshold that was passed in.  Unlike the
        autoscaling provided by the tick locators, this range limiting
        will always be adhered to, whether the axis range is set
        manually, determined automatically or changed through panning
        and zooming.
        """
        return max(vmin, -self.thresh), min(vmax, self.thresh)

    class MercatorLatitudeTransform(mtransforms.Transform):
        # There are two value members that must be defined.
        # ``input_dims`` and ``output_dims`` specify number of input
        # dimensions and output dimensions to the transformation.
        # These are used by the transformation framework to do some
        # error checking and prevent incompatible transformations from
        # being connected together.  When defining transforms for a
        # scale, which are, by definition, separable and have only one
        # dimension, these members should always be set to 1.
        input_dims = output_dims = 1

        def __init__(self, thresh):
            mtransforms.Transform.__init__(self)
            self.thresh = thresh

        def transform_non_affine(self, a):
            """
            This transform takes a numpy array and returns a␣
↪transformed copy.
            Since the range of the Mercator scale is limited by the
            user-specified threshold, the input array must be masked to
            contain only valid values.  Matplotlib will handle masked␣
↪arrays
            and remove the out-of-range data from the plot.  However,␣
```

(continues on next page)

(continued from previous page)

```
↪the
            returned array *must* have the same shape as the input␣
↪array, since
            these values need to remain synchronized with values in␣
↪the other
            dimension.
            """
            masked = ma.masked_where((a < -self.thresh) | (a > self.
↪thresh), a)
            if masked.mask.any():
                return ma.log(np.abs(ma.tan(masked) + 1 / ma.
↪cos(masked)))
            else:
                return np.log(np.abs(np.tan(a) + 1 / np.cos(a)))

        def inverted(self):
            """
            Override this method so Matplotlib knows how to get the
            inverse transform for this transform.
            """
            return MercatorLatitudeScale.
↪InvertedMercatorLatitudeTransform(
                self.thresh)

    class InvertedMercatorLatitudeTransform(mtransforms.Transform):
        input_dims = output_dims = 1

        def __init__(self, thresh):
            mtransforms.Transform.__init__(self)
            self.thresh = thresh

        def transform_non_affine(self, a):
            return np.arctan(np.sinh(a))

        def inverted(self):
            return MercatorLatitudeScale.
↪MercatorLatitudeTransform(self.thresh)


# Now that the Scale class has been defined, it must be registered so
# that Matplotlib can find it.
mscale.register_scale(MercatorLatitudeScale)


if __name__ == '__main__':
    import matplotlib.pyplot as plt
```

(continues on next page)

(continued from previous page)

```
    t = np.arange(-180.0, 180.0, 0.1)
    s = np.radians(t)/2.

    plt.plot(t, s, '-', lw=2)
    plt.yscale('mercator')

    plt.xlabel('Longitude')
    plt.ylabel('Latitude')
    plt.title('Mercator projection')
    plt.grid(True)

    plt.show()
```

Log scale

Examples of plots with logarithmic axes.

You can set the x/y axes to be logarithmic by passing "log" to *set_xscale* / *set_yscale*.

Convenience functions `semilogx`, `semilogy`, and `loglog`

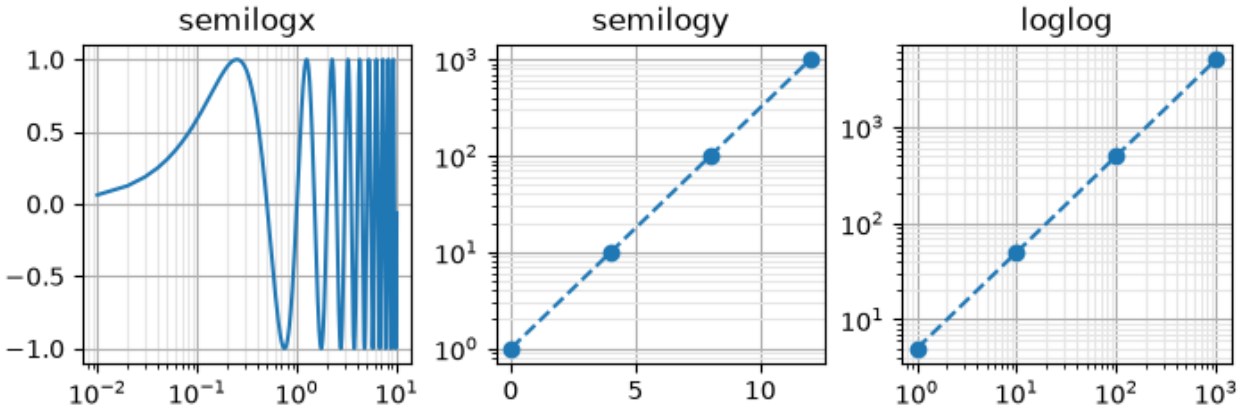
Since plotting data on semi-logarithmic or double-logarithmic scales is very common, the functions *semilogx*, *semilogy*, and *loglog* are shortcuts for setting the scale and plotting data; e.g. `ax.semilogx(x, y)` is equivalent to `ax.set_xscale('log'); ax.plot(x, y)`.

```
import matplotlib.pyplot as plt
import numpy as np

fig, (ax1, ax2, ax3) = plt.subplots(1, 3, layout='constrained',␣
 ↪figsize=(7, 7/3))
# log x axis
t = np.arange(0.01, 10.0, 0.01)
ax1.semilogx(t, np.sin(2 * np.pi * t))
ax1.set(title='semilogx')
ax1.grid()
ax1.grid(which="minor", color="0.9")

# log y axis
x = np.arange(4)
ax2.semilogy(4*x, 10**x, 'o--')
ax2.set(title='semilogy')
ax2.grid()
ax2.grid(which="minor", color="0.9")

# log x and y axis
```

(continues on next page)

(continued from previous page)

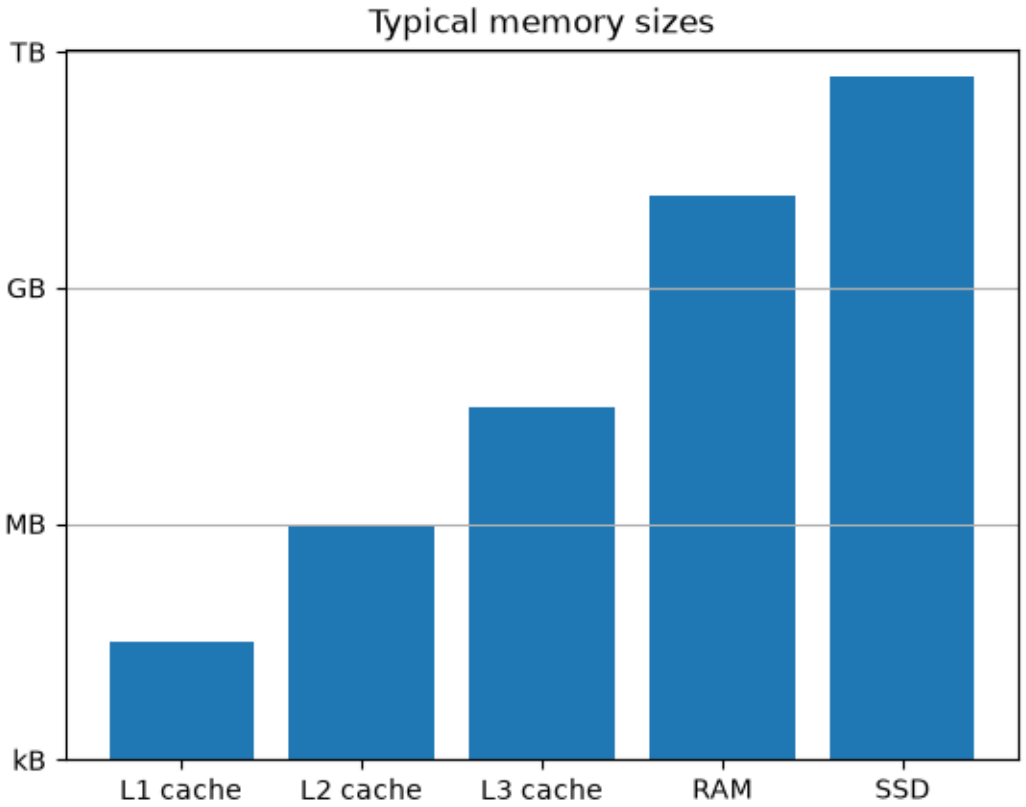
```
x = np.array([1, 10, 100, 1000])
ax3.loglog(x, 5 * x, 'o--')
ax3.set(title='loglog')
ax3.grid()
ax3.grid(which="minor", color="0.9")
```



Logarithms with other bases

By default, the log scale is to the base 10. One can change this via the *base* parameter.

```
fig, ax = plt.subplots()
ax.bar(["L1 cache", "L2 cache", "L3 cache", "RAM", "SSD"],
       [32, 1_000, 32_000, 16_000_000, 512_000_000])
ax.set_yscale('log', base=2)
ax.set_yticks([1, 2**10, 2**20, 2**30], labels=['kB', 'MB', 'GB', 'TB
↪'])
ax.set_title("Typical memory sizes")
ax.yaxis.grid()
```



Dealing with negative values

Non-positive values cannot be displayed on a log scale. The scale has two options to handle these. Either mask the values so that they are ignored, or clip them to a small positive value. Which one is more suited depends on the type of the data and the visualization.

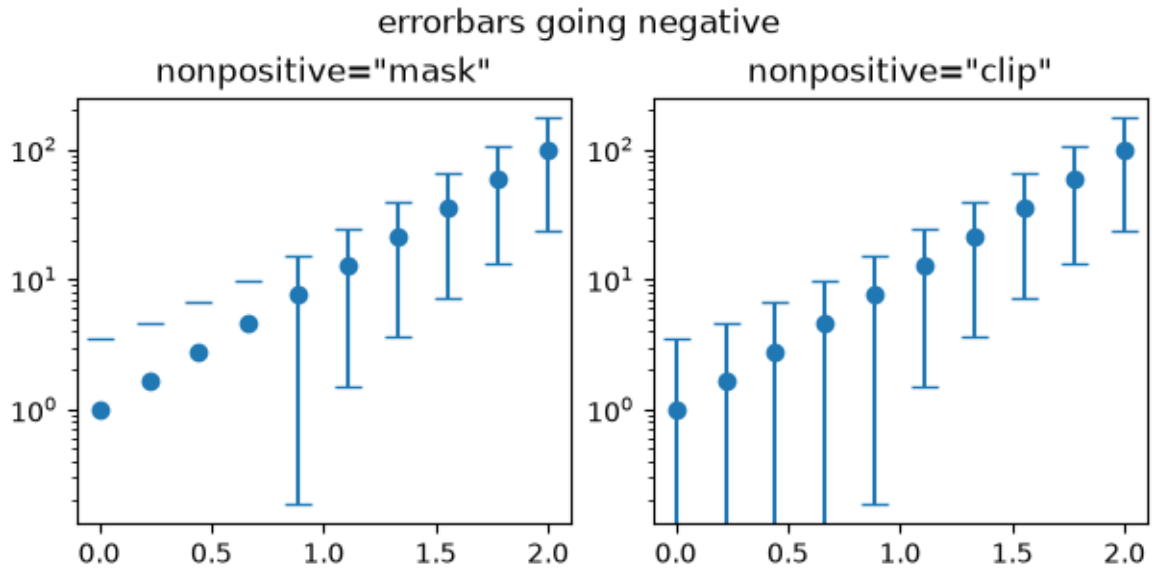
The following example contains errorbars going negative. If we mask these values, the bar vanishes, which is not desirable. In contrast, clipping makes the value small positive (but well below the used scale) so that the error bar is drawn to the edge of the Axes.

```
x = np.linspace(0.0, 2.0, 10)
y = 10**x
yerr = 1.75 + 0.75*y

fig, (ax1, ax2) = plt.subplots(1, 2, layout="constrained", figsize=(6,␣
↪3))
fig.suptitle("errorbars going negative")
ax1.set_yscale("log", nonpositive='mask')
ax1.set_title('nonpositive="mask"')
ax1.errorbar(x, y, yerr=yerr, fmt='o', capsize=5)
```

(continues on next page)

(continued from previous page)

```
ax2.set_yscale("log", nonpositive='clip')
ax2.set_title('nonpositive="clip"')
ax2.errorbar(x, y, yerr=yerr, fmt='o', capsize=5)

plt.show()
```



Total running time of the script: (0 minutes 1.423 seconds)

Logit scale

Examples of plots with logit axes.

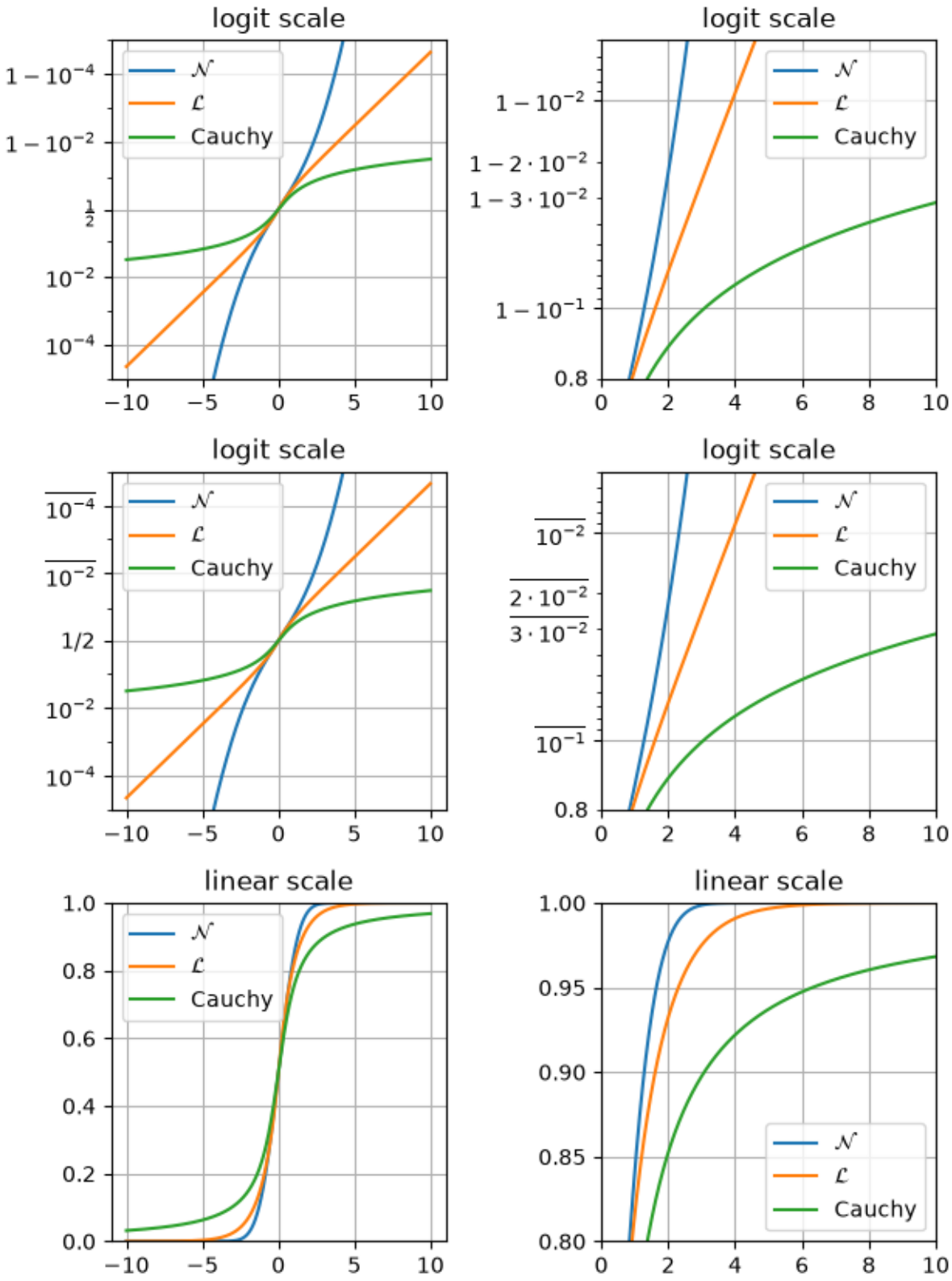
This example visualises how `set_yscale("logit")` works on probability plots by generating three distributions: normal, laplacian, and cauchy in one plot.

The advantage of logit scale is that it effectively spreads out values close to 0 and 1.

In a linear scale plot, probability values near 0 and 1 appear compressed, making it difficult to see differences in those regions.

In a logit scale plot, the transformation expands these regions, making the graph cleaner and easier to compare across different probability values.

This makes the logit scale especially useful when visalising probabilities in logistic regression, classification models, and cumulative distribution functions.


logit scale
$1-10^{-4}$
$1-10^{-2}$
$\frac{1}{2}$
10^{-2}
10^{-4}
−10
−5
0
5
10
$\mathcal{N}$
$\mathcal{L}$
Cauchy
logit scale
$1-10^{-2}$
$1-2\cdot10^{-2}$
$1-3\cdot10^{-2}$
$1-10^{-1}$
0.8
0
2
4
6
8
10
$\mathcal{N}$
$\mathcal{L}$
Cauchy
logit scale
10^{-4}
10^{-2}
1/2
10^{-2}
10^{-4}
−10
−5
0
5
10
$\mathcal{N}$
$\mathcal{L}$
Cauchy
logit scale
10^{-2}
$2\cdot10^{-2}$
$3\cdot10^{-2}$
10^{-1}
0.8
0
2
4
6
8
10
$\mathcal{N}$
$\mathcal{L}$
Cauchy
linear scale
1.0
0.8
0.6
0.4
0.2
0.0
−10
−5
0
5
10
$\mathcal{N}$
$\mathcal{L}$
Cauchy
linear scale
1.00
0.95
0.90
0.85
0.80
0
2
4
6
8
10
$\mathcal{N}$
$\mathcal{L}$
Cauchy

```
import math

import matplotlib.pyplot as plt
import numpy as np

xmax = 10
x = np.linspace(-xmax, xmax, 10000)
cdf_norm = [math.erf(w / np.sqrt(2)) / 2 + 1 / 2 for w in x]
cdf_laplacian = np.where(x < 0, 1 / 2 * np.exp(x), 1 - 1 / 2 * np.exp(-
 ↪x))
cdf_cauchy = np.arctan(x) / np.pi + 1 / 2

fig, axs = plt.subplots(nrows=3, ncols=2, figsize=(6.4, 8.5))

# Common part, for the example, we will do the same plots on all graphs
for i in range(3):
    for j in range(2):
        axs[i, j].plot(x, cdf_norm, label=r"$\mathcal{N}$")
        axs[i, j].plot(x, cdf_laplacian, label=r"$\mathcal{L}$")
        axs[i, j].plot(x, cdf_cauchy, label="Cauchy")
        axs[i, j].legend()
        axs[i, j].grid()

# First line, logitscale, with standard notation
axs[0, 0].set(title="logit scale")
axs[0, 0].set_yscale("logit")
axs[0, 0].set_ylim(1e-5, 1 - 1e-5)

axs[0, 1].set(title="logit scale")
axs[0, 1].set_yscale("logit")
axs[0, 1].set_xlim(0, xmax)
axs[0, 1].set_ylim(0.8, 1 - 5e-3)

# Second line, logitscale, with survival notation (with␣
 ↪`use_overline`), and
# other format display 1/2
axs[1, 0].set(title="logit scale")
axs[1, 0].set_yscale("logit", one_half="1/2", use_overline=True)
axs[1, 0].set_ylim(1e-5, 1 - 1e-5)

axs[1, 1].set(title="logit scale")
axs[1, 1].set_yscale("logit", one_half="1/2", use_overline=True)
axs[1, 1].set_xlim(0, xmax)
axs[1, 1].set_ylim(0.8, 1 - 5e-3)

# Third line, linear scale
```

(continues on next page)

(continued from previous page)

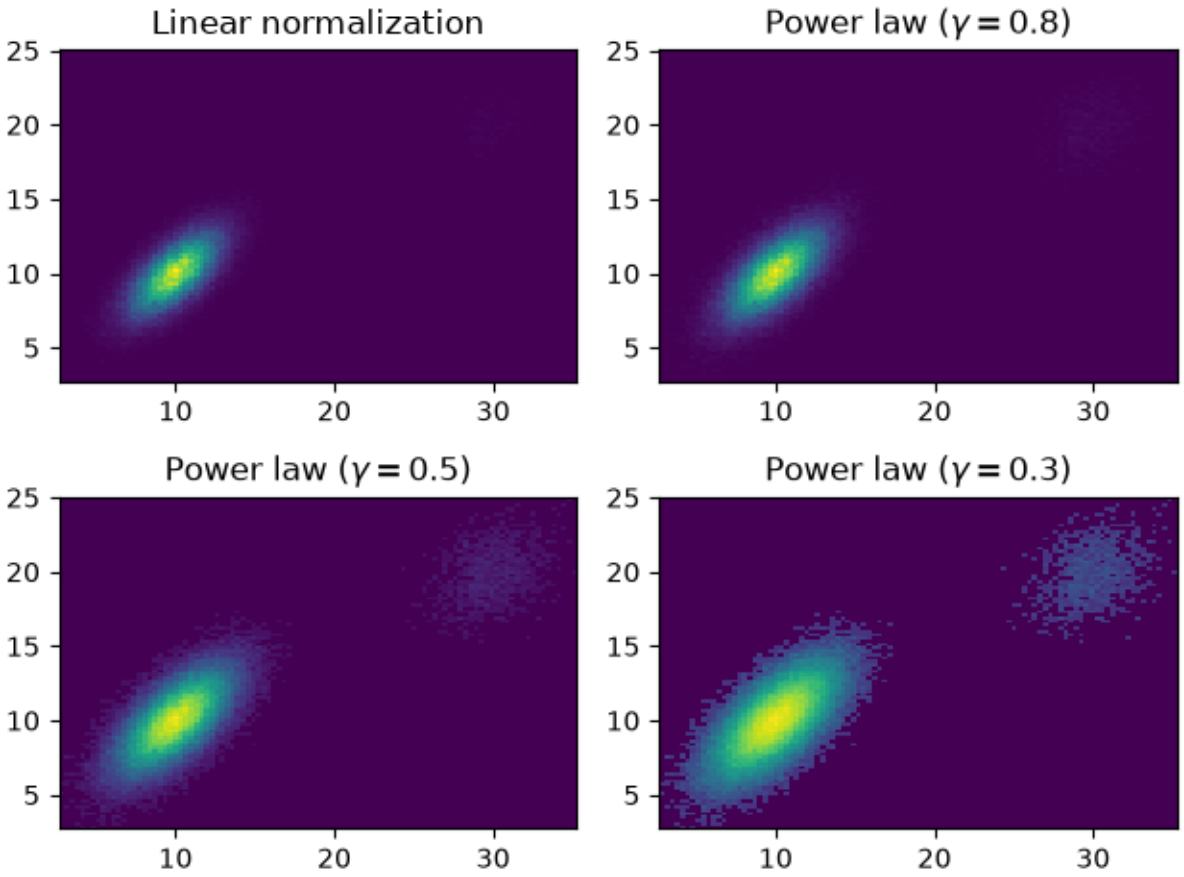
```
axs[2, 0].set(title="linear scale")
axs[2, 0].set_ylim(0, 1)

axs[2, 1].set(title="linear scale")
axs[2, 1].set_xlim(0, xmax)
axs[2, 1].set_ylim(0.8, 1)

fig.tight_layout()
plt.show()
```

Total running time of the script: (0 minutes 1.468 seconds)

Exploring normalizations

Various normalization on a multivariate normal distribution.

```
import matplotlib.pyplot as plt
import numpy as np
from numpy.random import multivariate_normal

import matplotlib.colors as mcolors

# Fixing random state for reproducibility.
np.random.seed(19680801)

data = np.vstack([
    multivariate_normal([10, 10], [[3, 2], [2, 3]], size=100000),
    multivariate_normal([30, 20], [[3, 1], [1, 3]], size=1000)
])

gammas = [0.8, 0.5, 0.3]

fig, axs = plt.subplots(nrows=2, ncols=2)

axs[0, 0].set_title('Linear normalization')
axs[0, 0].hist2d(data[:, 0], data[:, 1], bins=100)

for ax, gamma in zip(axs.flat[1:], gammas):
    ax.set_title(r'Power law $(\gamma=%1.1f)$' % gamma)
    ax.hist2d(data[:, 0], data[:, 1], bins=100, norm=mcolors.
 ↪PowerNorm(gamma))

fig.tight_layout()

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.colors*
- *matplotlib.colors.PowerNorm*
- *matplotlib.axes.Axes.hist2d*
- *matplotlib.pyplot.hist2d*

Symlog scale

The symmetric logarithmic scale is an extension of the logarithmic scale that also covers negative values. As with the logarithmic scale, it is particularly useful for numerical data that spans a broad range of values, especially when there are significant differences between the magnitudes of the numbers involved.

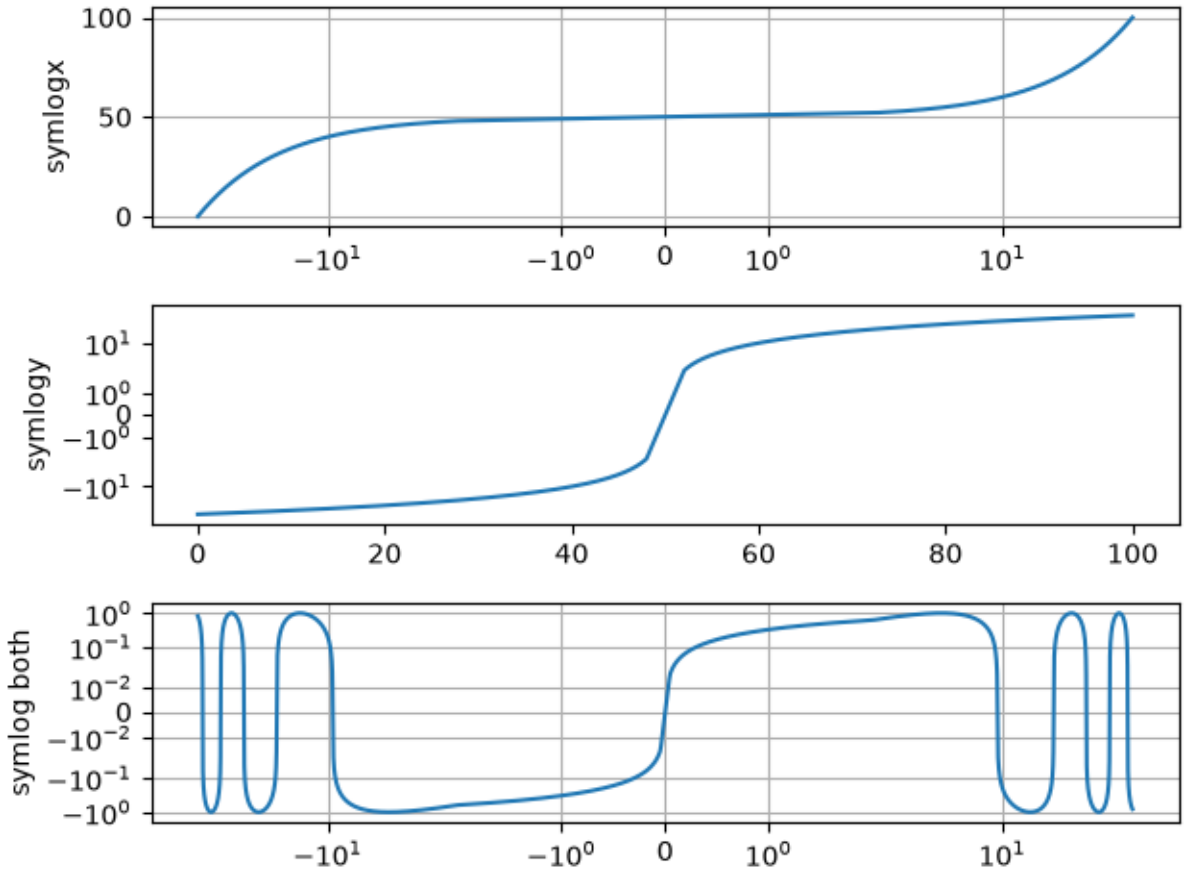
Example use of symlog (symmetric log) axis scaling.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
dt = 0.01
x = np.arange(-50.0, 50.0, dt)
y = np.arange(0, 100.0, dt)

fig, (ax0, ax1, ax2) = plt.subplots(nrows=3)

ax0.plot(x, y)
ax0.set_xscale('symlog')
ax0.set_ylabel('symlogx')
ax0.grid()
ax0.xaxis.grid(which='minor')  # minor grid on too

ax1.plot(y, x)
ax1.set_yscale('symlog')
ax1.set_ylabel('symlogy')

ax2.plot(x, np.sin(x / 3.0))
ax2.set_xscale('symlog')
ax2.set_yscale('symlog', linthresh=0.015)
ax2.grid()
ax2.set_ylabel('symlog both')

fig.tight_layout()
plt.show()
```



Linear threshold

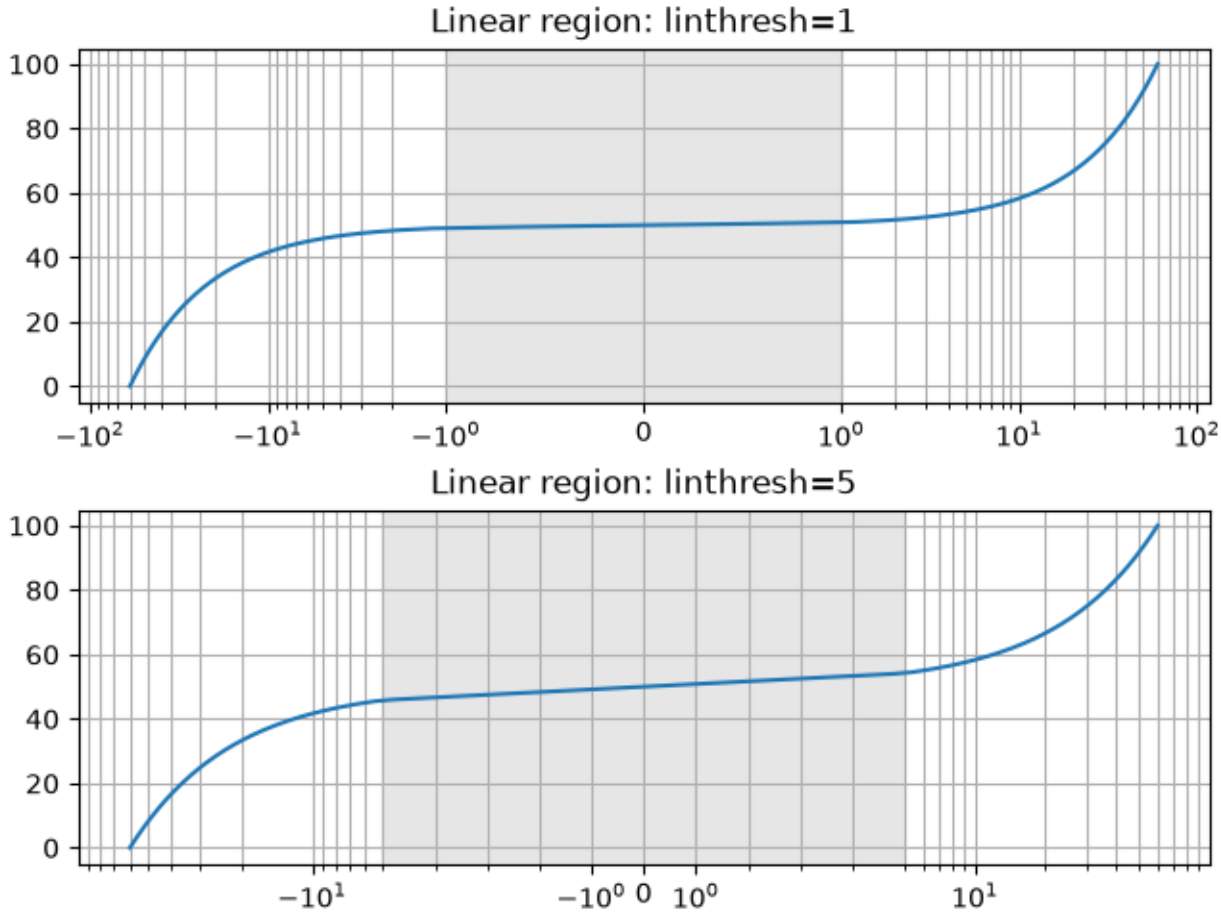
Since each decade on a logarithmic scale covers the same amount of visual space and there are infinitely many decades between a given number and zero, the symlog scale must deviate from logarithmic mapping in a small range *(-linthresh, linthresh)*, so that the range is mapped to a finite visual space.

```
def format_axes(ax, title=None):
    """A helper function to better visualize properties of the symlog␣
↪scale."""
    ax.xaxis.get_minor_locator().set_params(subs=[2, 3, 4, 5, 6, 7, 8,␣
↪9])
    ax.grid()
    ax.xaxis.grid(which='minor')  # minor grid on too
    linthresh = ax.xaxis.get_transform().linthresh
    linscale = ax.xaxis.get_transform().linscale
    ax.axvspan(-linthresh, linthresh, color='0.9')
    if title:
        ax.set_title(title.format(linthresh=linthresh,␣
↪linscale=linscale))
```

(continues on next page)

(continued from previous page)

```
x = np.linspace(-60, 60, 201)
y = np.linspace(0, 100.0, 201)

fig, (ax1, ax2) = plt.subplots(nrows=2, layout="constrained")

ax1.plot(x, y)
ax1.set_xscale('symlog', linthresh=1)
format_axes(ax1, title='Linear region: linthresh={linthresh}')

ax2.plot(x, y)
ax2.set_xscale('symlog', linthresh=5)
format_axes(ax2, title='Linear region: linthresh={linthresh}')
```

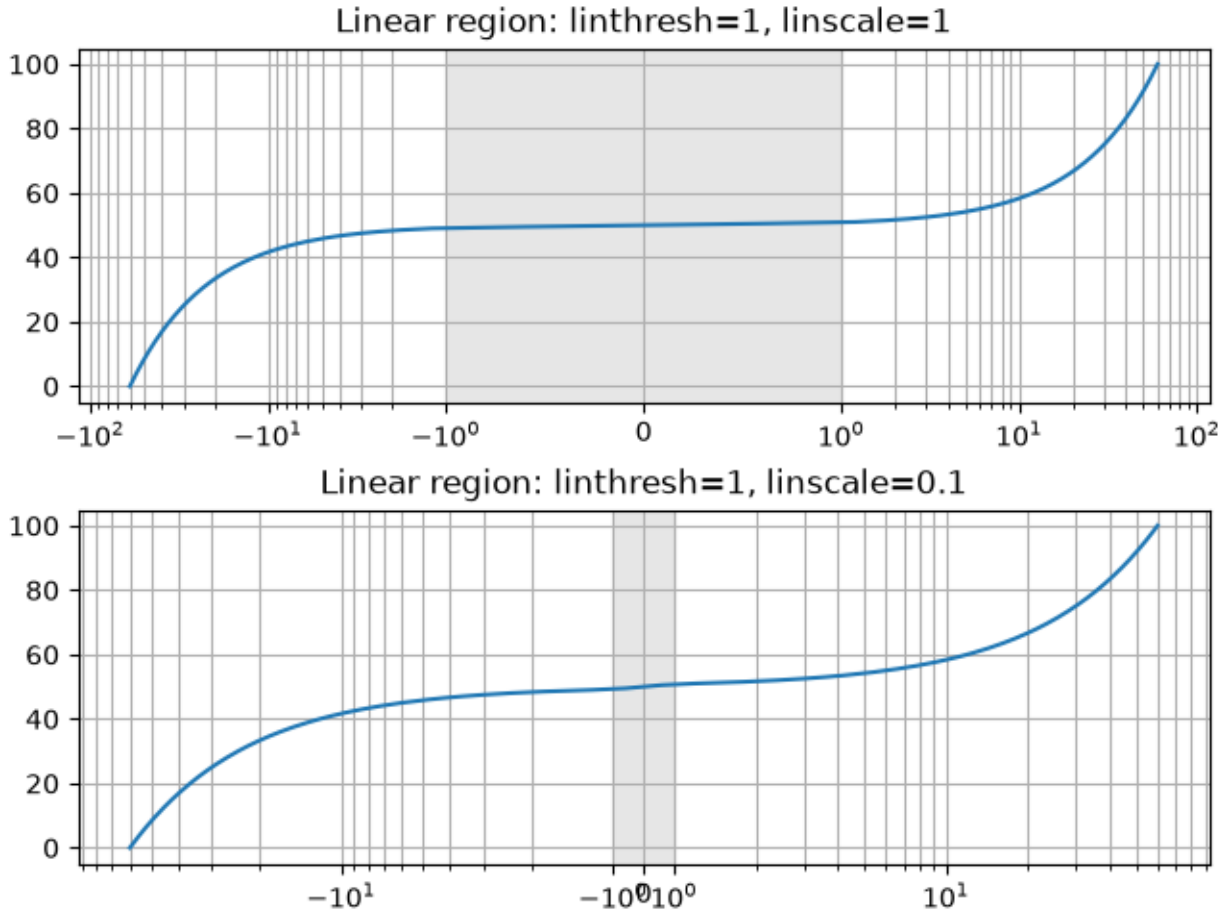


Generally, *linthresh* should be chosen so that no or only a few data points are in the linear region. As a rule of thumb, $linthresh \approx \min|x|$.

Linear scale

Additionally, the *linscale* parameter determines how much visual space should be used for the linear range. More precisely, it defines the ratio of visual space of the region (0, linthresh) relative to one decade.

```
fig, (ax1, ax2) = plt.subplots(nrows=2, layout="constrained")

ax1.plot(x, y)
ax1.set_xscale('symlog', linthresh=1)
format_axes(ax1, title='Linear region: linthresh={linthresh}, linscale=
 ↪{linscale}')

ax2.plot(x, y)
ax2.set_xscale('symlog', linthresh=1, linscale=0.1)
format_axes(ax2, title='Linear region: linthresh={linthresh}, linscale=
 ↪{linscale}')
```

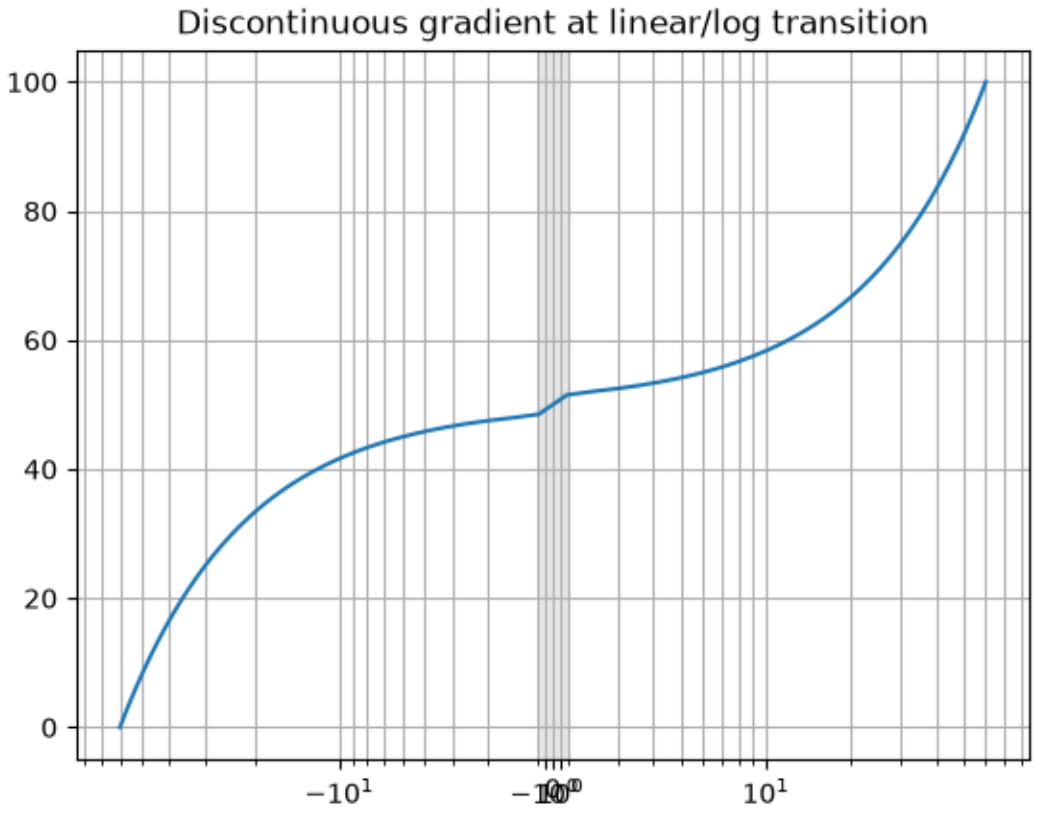


The suitable value for linscale depends on the dynamic range of data. As most data will be outside the linear region, you typically the linear region only to cover a small fraction of the visual area.

Limitations and alternatives

The coordinate transform used by `symlog` has a discontinuous gradient at the transition between its linear and logarithmic regions. Depending on data and scaling, this will be more or less obvious in the plot.

```
fig, ax = plt.subplots()
ax.plot(x, y)
ax.set_xscale('symlog', linscale=0.05)
format_axes(ax, title="Discontinuous gradient at linear/log transition
 ↪")
```



The `asinh` axis scale is an alternative transformation that supports a wide dynamic range with a smooth gradient and thus may avoid such visual artifacts. See *Asinh scale*.

References

- *matplotlib.scale.SymmetricalLogScale*
- *matplotlib.ticker.SymmetricalLogLocator*
- *matplotlib.scale.AsinhScale*

Total running time of the script: (0 minutes 2.038 seconds)

6.24.8 Spines

Spines

This demo compares:

- normal Axes, with spines on all four sides;
- an Axes with spines only on the left and bottom;
- an Axes using custom bounds to limit the extent of the spine.

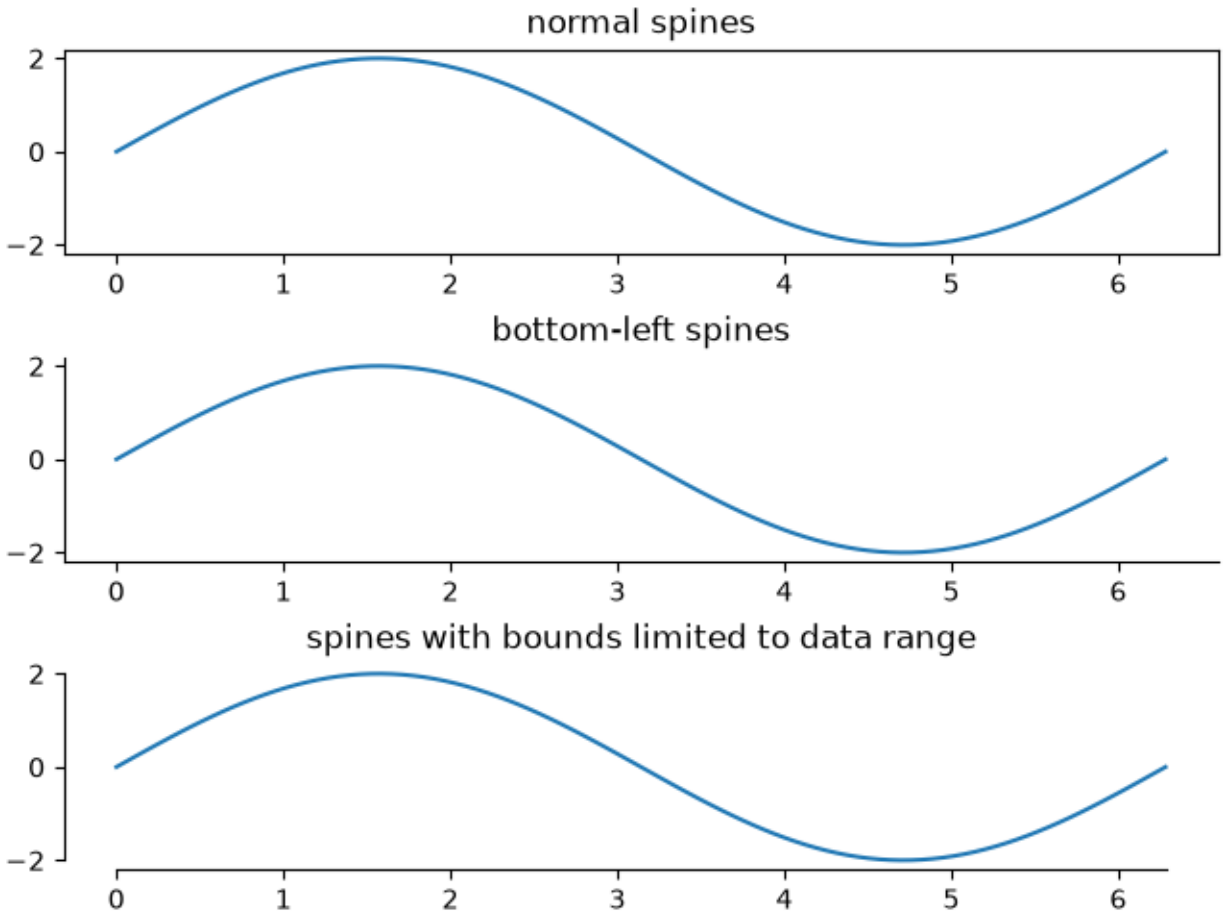
Each *axes.Axes* has a list of *Spine* objects, accessible via the container `ax.spines`.

```
import matplotlib.pyplot as plt
import numpy as np

x = np.linspace(0, 2 * np.pi, 100)
y = 2 * np.sin(x)

# Constrained layout makes sure the labels don't overlap the Axes.
fig, (ax0, ax1, ax2) = plt.subplots(nrows=3, layout='constrained')

ax0.plot(x, y)
ax0.set_title('normal spines')

ax1.plot(x, y)
ax1.set_title('bottom-left spines')

# Hide the right and top spines
ax1.spines.right.set_visible(False)
ax1.spines.top.set_visible(False)

ax2.plot(x, y)
ax2.set_title('spines with bounds limited to data range')

# Only draw spines for the data range, not in the margins
ax2.spines.bottom.set_bounds(x.min(), x.max())
ax2.spines.left.set_bounds(y.min(), y.max())
# Hide the right and top spines
```

(continues on next page)

(continued from previous page)

```
ax2.spines.right.set_visible(False)
ax2.spines.top.set_visible(False)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.artist.Artist.set_visible*
- *matplotlib.spines.Spine.set_bounds*

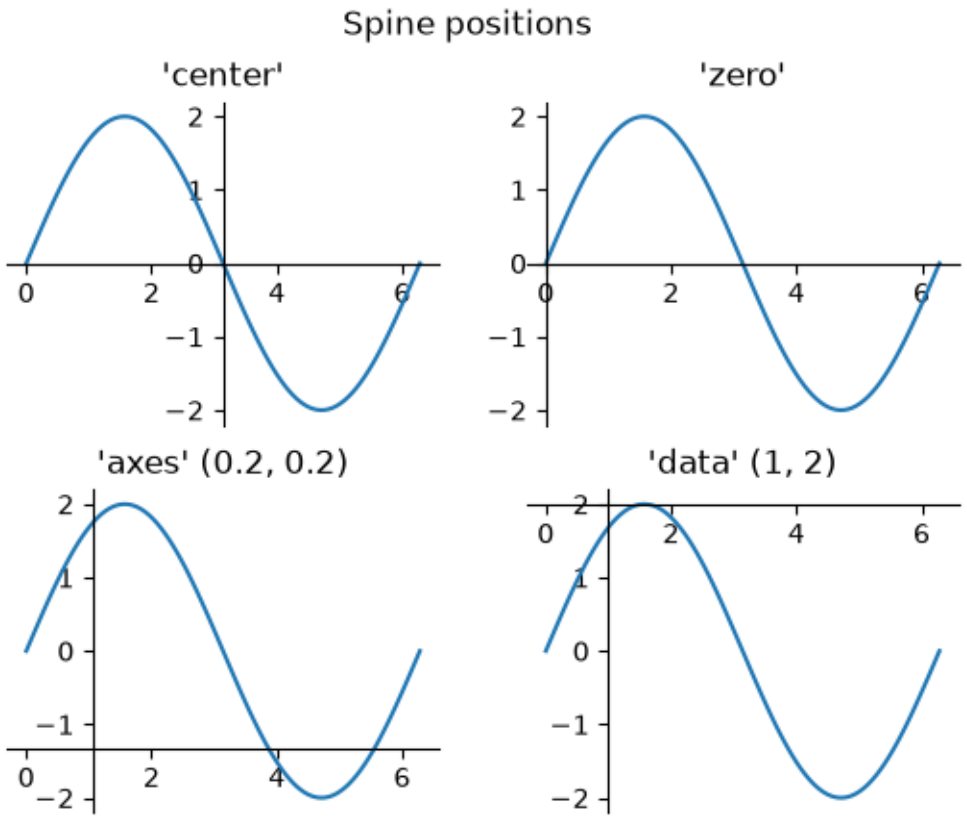
Spine placement

The position of the axis spines can be influenced using *set_position*.

Note: If you want to obtain arrow heads at the ends of the axes, also check out the *Centered spines with arrows* example.

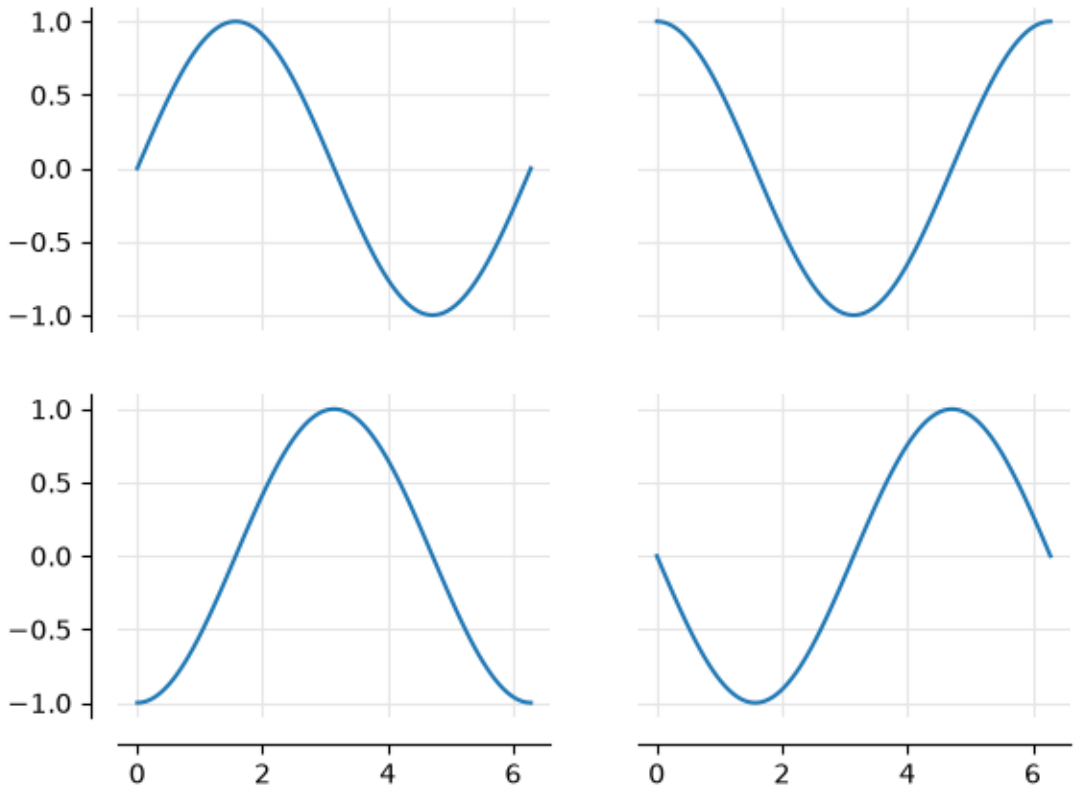
```
import matplotlib.pyplot as plt
import numpy as np
```

```
x = np.linspace(0, 2*np.pi, 100)
y = 2 * np.sin(x)

fig, ax_dict = plt.subplot_mosaic(
    [['center', 'zero'],
     ['axes', 'data']]
)
fig.suptitle('Spine positions')


ax = ax_dict['center']
ax.set_title("'center'")
ax.plot(x, y)
ax.spines[['left', 'bottom']].set_position('center')
ax.spines[['top', 'right']].set_visible(False)

ax = ax_dict['zero']
ax.set_title("'zero'")
ax.plot(x, y)
ax.spines[['left', 'bottom']].set_position('zero')
ax.spines[['top', 'right']].set_visible(False)

ax = ax_dict['axes']
ax.set_title("'axes' (0.2, 0.2)")
ax.plot(x, y)
ax.spines.left.set_position(('axes', 0.2))
ax.spines.bottom.set_position(('axes', 0.2))
ax.spines[['top', 'right']].set_visible(False)

ax = ax_dict['data']
ax.set_title("'data' (1, 2)")
ax.plot(x, y)
ax.spines.left.set_position(('data', 1))
ax.spines.bottom.set_position(('data', 2))
ax.spines[['top', 'right']].set_visible(False)

plt.show()
```



Dropped spines

Demo of spines offset from the axes (a.k.a. "dropped spines").




```
import matplotlib.pyplot as plt
import numpy as np


def adjust_spines(ax, visible_spines):
    ax.label_outer(remove_inner_ticks=True)
    ax.grid(color='0.9')

    for loc, spine in ax.spines.items():
        if loc in visible_spines:
            spine.set_position(('outward', 10))  # outward by 10 points
        else:
            spine.set_visible(False)


x = np.linspace(0, 2 * np.pi, 100)

fig, axs = plt.subplots(2, 2)

axs[0, 0].plot(x, np.sin(x))
```

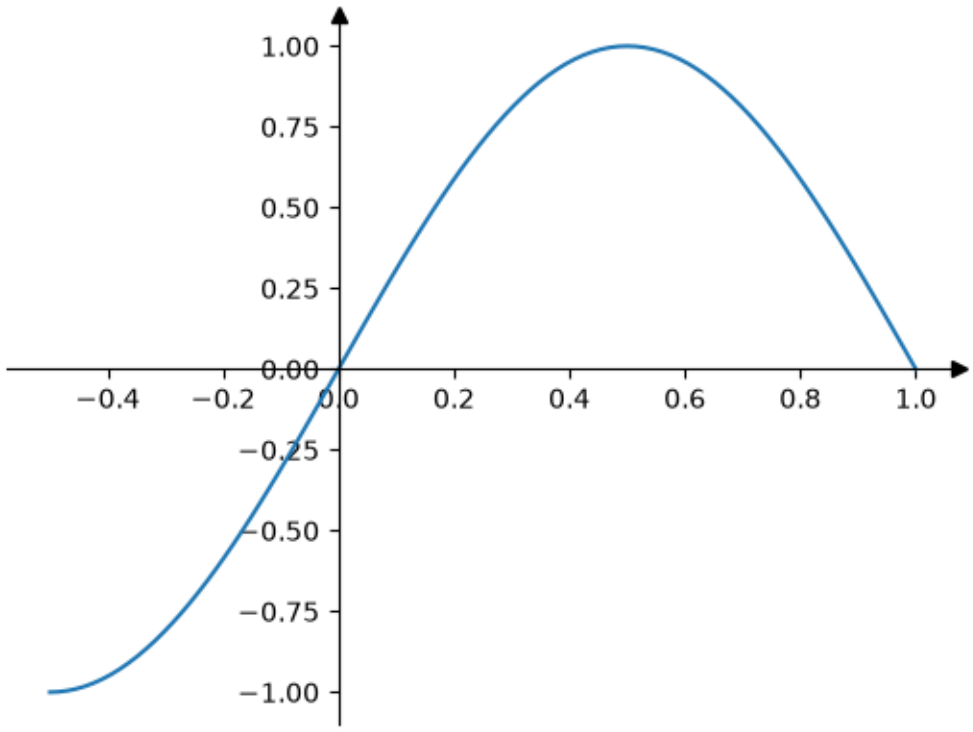
(continues on next page)

(continued from previous page)

```
axs[0, 1].plot(x, np.cos(x))
axs[1, 0].plot(x, -np.cos(x))
axs[1, 1].plot(x, -np.sin(x))

adjust_spines(axs[0, 0], ['left'])
adjust_spines(axs[0, 1], [])
adjust_spines(axs[1, 0], ['left', 'bottom'])
adjust_spines(axs[1, 1], ['bottom'])

plt.show()
```

Centered spines with arrows

This example shows a way to draw a "math textbook" style plot, where the spines ("axes lines") are drawn at `x = 0` and `y = 0`, and have arrows at their ends.




```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots()
# Move the left and bottom spines to x = 0 and y = 0, respectively.
ax.spines[["left", "bottom"]].set_position(("data", 0))
# Hide the top and right spines.
ax.spines[["top", "right"]].set_visible(False)

# Draw arrows (as black triangles: ">k"/"^k") at the end of the axes. ␣
 ↪In each
# case, one of the coordinates (0) is a data coordinate (i.e., y = 0␣
 ↪or x = 0,
# respectively) and the other one (1) is an axes coordinate (i.e., at␣
 ↪the very
# right/top of the axes).  Also, disable clipping (clip_on=False) as␣
 ↪the marker
# actually spills out of the Axes.
ax.plot(1, 0, ">k", transform=ax.get_yaxis_transform(), clip_on=False)
ax.plot(0, 1, "^k", transform=ax.get_xaxis_transform(), clip_on=False)

# Some sample data.
x = np.linspace(-0.5, 1., 100)
ax.plot(x, np.sin(x*np.pi))

plt.show()
```

6.24.9 Text, labels and annotations

Text properties

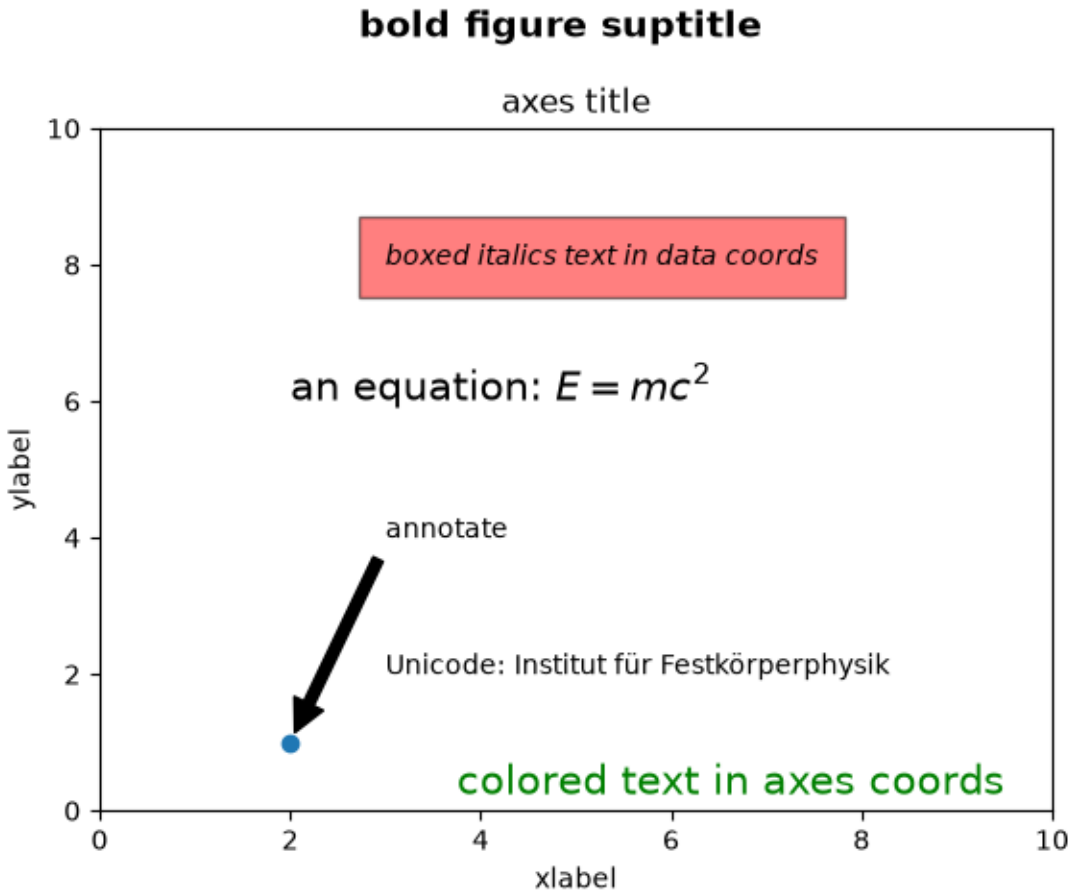
Plotting text of many different kinds.

```
import matplotlib.pyplot as plt

fig = plt.figure()
fig.suptitle('bold figure suptitle', fontsize=14, fontweight='bold')

ax = fig.add_subplot()
fig.subplots_adjust(top=0.85)
ax.set_title('axes title')

ax.set_xlabel('xlabel')
ax.set_ylabel('ylabel')

ax.text(3, 8, 'boxed italics text in data coords', style='italic',
        bbox={'facecolor': 'red', 'alpha': 0.5, 'pad': 10})

ax.text(2, 6, r'an equation: $E=mc^2$', fontsize=15)
```

(continues on next page)

(continued from previous page)

```
ax.text(3, 2, 'Unicode: Institut f\374r Festk\366rperphysik')

ax.text(0.95, 0.01, 'colored text in axes coords',
        verticalalignment='bottom', horizontalalignment='right',
        transform=ax.transAxes,
        color='green', fontsize=15)


ax.plot([2], [1], 'o')
ax.annotate('annotate', xy=(2, 1), xytext=(3, 4),
            arrowprops=dict(facecolor='black', shrink=0.05))

ax.set(xlim=(0, 10), ylim=(0, 10))

plt.show()
```



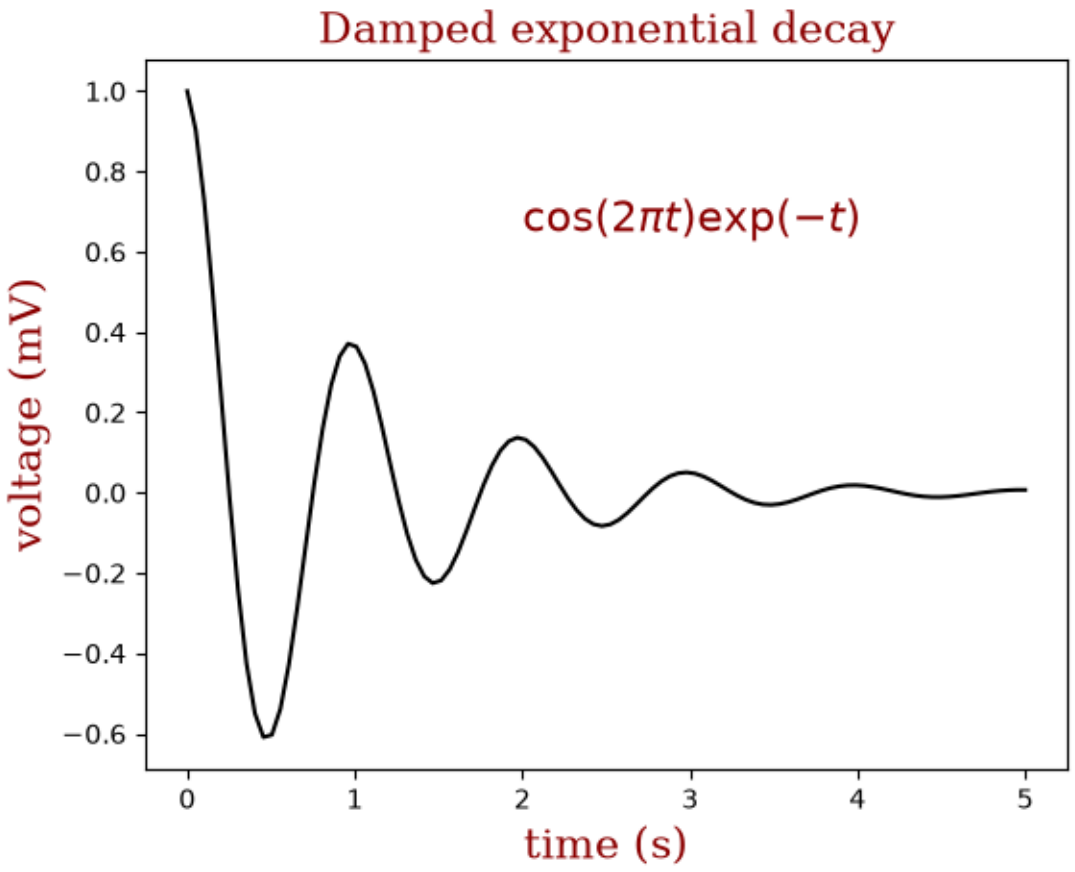
References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.figure.Figure.suptitle*
- *matplotlib.figure.Figure.add_subplot*
- *matplotlib.figure.Figure.subplots_adjust*
- *matplotlib.axes.Axes.set_title*
- *matplotlib.axes.Axes.set_xlabel*
- *matplotlib.axes.Axes.set_ylabel*
- *matplotlib.axes.Axes.text*
- *matplotlib.axes.Axes.annotate*

Controlling style of text and labels using a dictionary

This example shows how to share parameters across many text objects and labels by creating a dictionary of options passed across several functions.



```
import matplotlib.pyplot as plt
import numpy as np

font = {'family': 'serif',
        'color':  'darkred',
        'weight': 'normal',
        'size': 16,
        }

x = np.linspace(0.0, 5.0, 100)
y = np.cos(2*np.pi*x) * np.exp(-x)

plt.plot(x, y, 'k')
plt.title('Damped exponential decay', fontdict=font)
plt.text(2, 0.65, r'$\cos(2 \pi t) \exp(-t)$', fontdict=font)
plt.xlabel('time (s)', fontdict=font)
plt.ylabel('voltage (mV)', fontdict=font)

# Tweak spacing to prevent clipping of ylabel
plt.subplots_adjust(left=0.15)
plt.show()
```

Text alignment

Texts are aligned relative to their anchor point depending on the properties `horizontalalignment` (default: `left`) and `verticalalignment` (default: `baseline`.)

The following plot uses this to align text relative to a plotted rectangle.

```
import matplotlib.pyplot as plt

fig, ax = plt.subplots()

# Build a rectangle in axes coords
left, width = .25, .5
bottom, height = .25, .5
right = left + width
top = bottom + height
p = plt.Rectangle((left, bottom), width, height, fill=False)
p.set_transform(ax.transAxes)
p.set_clip_on(False)
ax.add_patch(p)

ax.text(left, bottom, 'left top',
        horizontalalignment='left',
        verticalalignment='top',
```

(continues on next page)

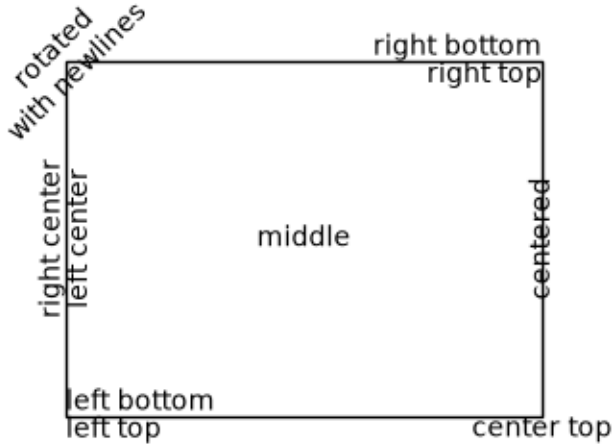
(continued from previous page)

```
        transform=ax.transAxes)

ax.text(left, bottom, 'left bottom',
        horizontalalignment='left',
        verticalalignment='bottom',
        transform=ax.transAxes)

ax.text(right, top, 'right bottom',
        horizontalalignment='right',
        verticalalignment='bottom',
        transform=ax.transAxes)

ax.text(right, top, 'right top',
        horizontalalignment='right',
        verticalalignment='top',
        transform=ax.transAxes)

ax.text(right, bottom, 'center top',
        horizontalalignment='center',
        verticalalignment='top',
        transform=ax.transAxes)

ax.text(left, 0.5 * (bottom + top), 'right center',
        horizontalalignment='right',
        verticalalignment='center',
        rotation='vertical',
        transform=ax.transAxes)

ax.text(left, 0.5 * (bottom + top), 'left center',
        horizontalalignment='left',
        verticalalignment='center',
        rotation='vertical',
        transform=ax.transAxes)

ax.text(0.5 * (left + right), 0.5 * (bottom + top), 'middle',
        horizontalalignment='center',
        verticalalignment='center',
        transform=ax.transAxes)

ax.text(right, 0.5 * (bottom + top), 'centered',
        horizontalalignment='center',
        verticalalignment='center',
        rotation='vertical',
        transform=ax.transAxes)

ax.text(left, top, 'rotated\nwith newlines',
```

(continues on next page)

(continued from previous page)

```
        horizontalalignment='center',
        verticalalignment='center',
        rotation=45,
        transform=ax.transAxes)

ax.set_axis_off()

plt.show()
```



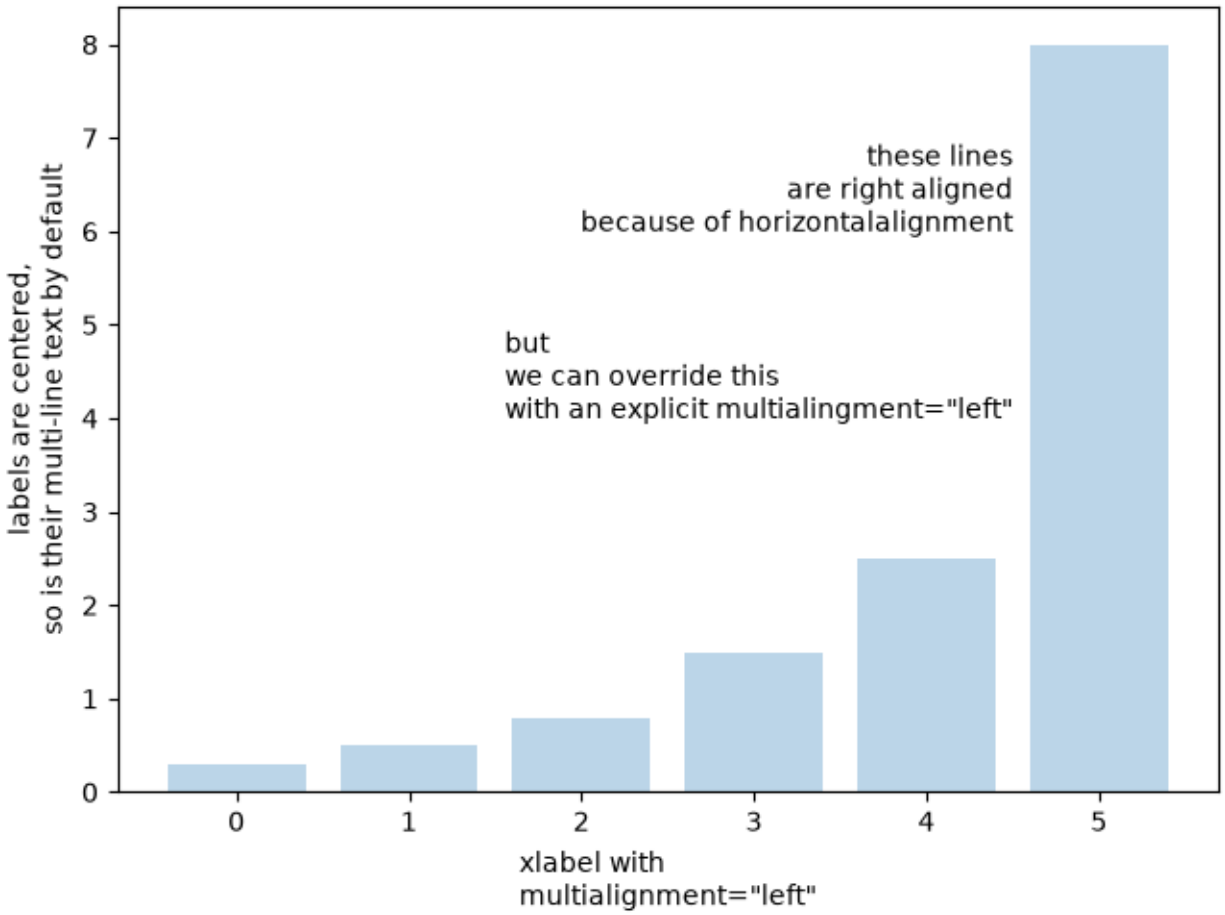
Multiline text

Texts may contain newlines to create multiline text.

The text alignment of the individual lines can be controlled by the `multialignment` parameter. If not set, the alignment of the lines is inferred from the `horizontalalignment` and `verticalalignment` parameters, which primarily control the alignment of the bounding box of the text to its anchor point; e.g. if the text has the anchor point to its right, all text lines will be aligned to the right so that they pick up that anchor point.

When using mutli-line labels, it is recommended to use a layout manager (e.g. `layout="constrained"`) to ensure that there is enough space for the labels..

```
import matplotlib.pyplot as plt

fig, ax = plt.subplots(layout="constrained")

ax.bar(range(6), [0.3, 0.5, 0.8, 1.5, 2.5, 8], alpha=0.3)

ax.set_ylabel('labels are centered,\nso is their multi-line text by␣
 ↪default')
ax.set_xlabel('xlabel with\nmultialignment="left"', multialignment=
 ↪"left")

ax.text(
    4.5, 6,
    'these lines\n'
    'are right aligned\n'
    'because of horizontalalignment',
    horizontalalignment='right',
)

ax.text(
    4.5, 4,
    'but\n'
    'we can override this\n'
    'with an explicit multialingment="left"',
    horizontalalignment='right',
    multialignment='left',
)

plt.show()
```



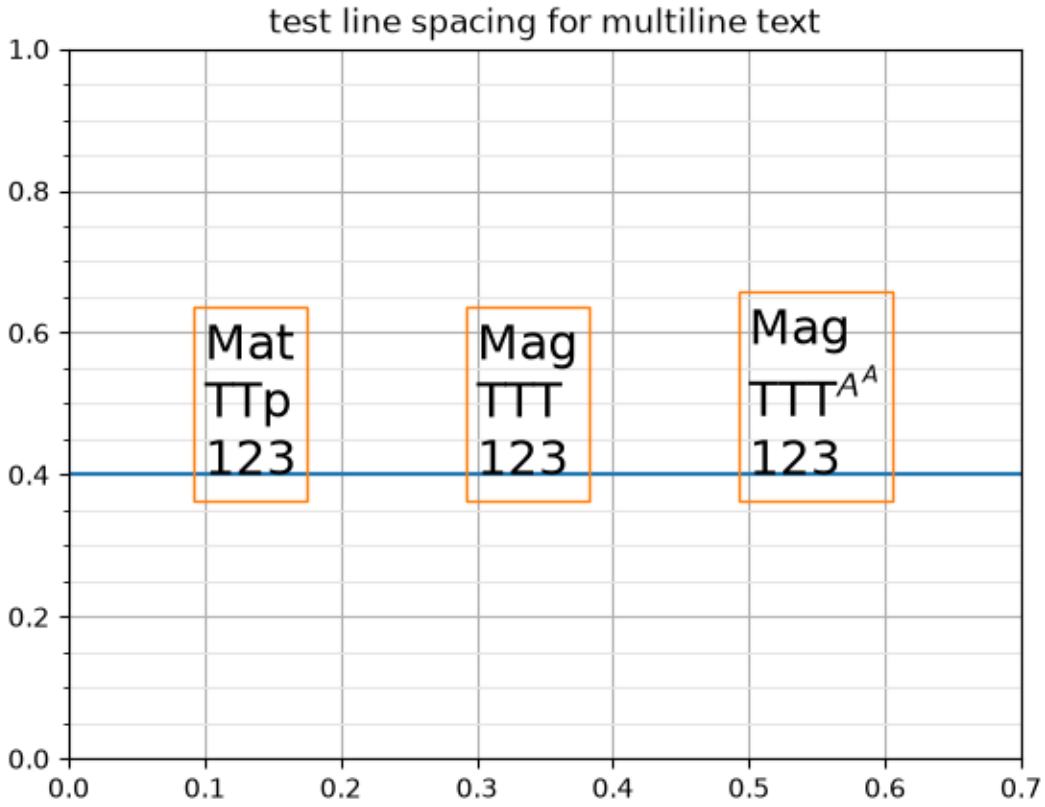
Each line has the same height irrespective of the used characters unless there is math text involved, which may need more vertical space

```
fig, ax = plt.subplots()

ax.text(0.1, 0.4, "Mat\nTTp\n123", size=18,
        va="baseline", bbox=dict(fc="none", ec="tab:orange"))

ax.text(0.3, 0.4, "Mag\nTTT\n123", size=18,
        va="baseline", bbox=dict(fc="none", ec="tab:orange"))

ax.text(0.5, 0.4, "Mag\nTTT$^{A^A}$\n123", size=18,
        va="baseline", bbox=dict(fc="none", ec="tab:orange"))

ax.axhline(0.4)
ax.set_title("test line spacing for multiline text")
ax.set_xlim(0, 0.7)
ax.yaxis.minorticks_on()
ax.yaxis.set_tick_params(which="minor", grid_color="0.9")
ax.grid(which="both")
```

(continues on next page)

(continued from previous page)

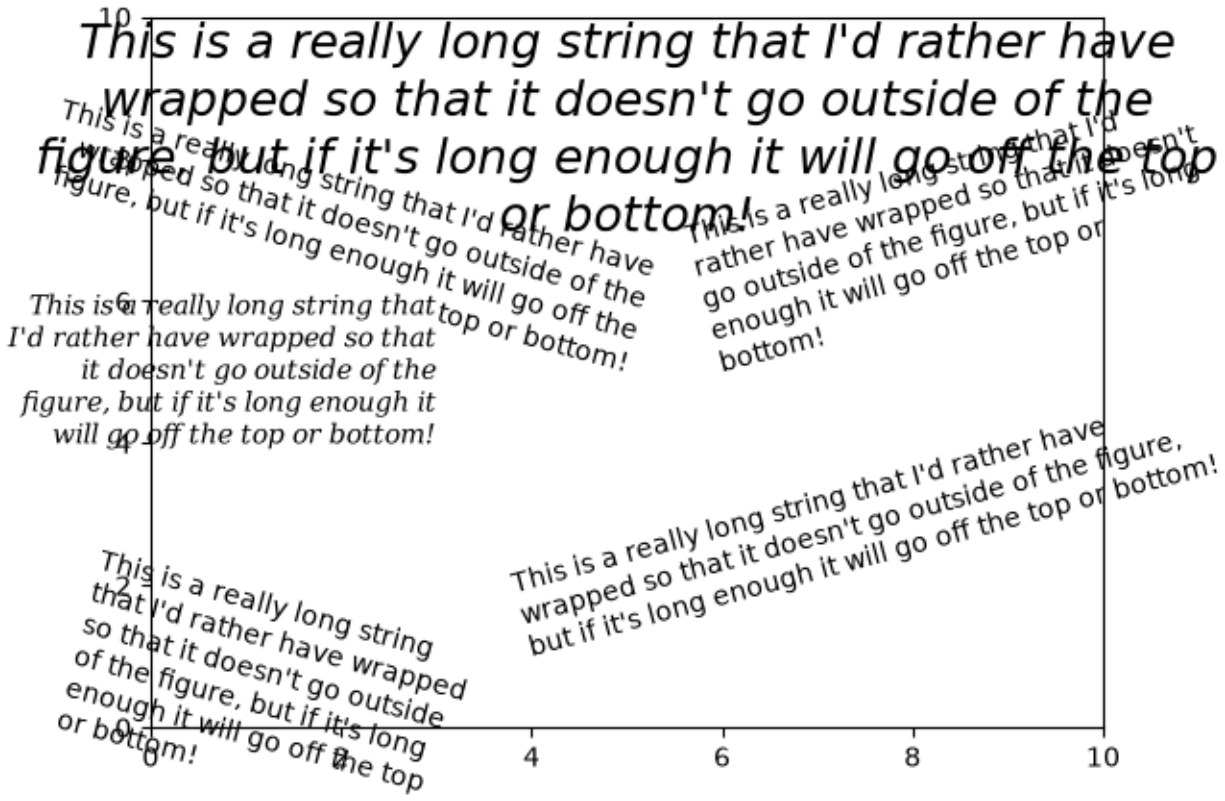
```
plt.show()
```



Auto-wrap text

Matplotlib can wrap text automatically, but if it's too long, the text will still be displayed slightly outside the boundaries of the axis.

Note: Auto-wrapping does not work together with `savefig(..., bbox_inches='tight')`. The 'tight' setting rescales the canvas to accommodate all content and happens before wrapping. This affects `%matplotlib inline` in IPython and Jupyter notebooks where the inline setting uses `bbox_inches='tight'` by default when saving the image to embed.




```
import matplotlib.pyplot as plt

fig = plt.figure()
plt.axis((0, 10, 0, 10))
t = ("This is a really long string that I'd rather have wrapped so␣
 ↪that it "
     "doesn't go outside of the figure, but if it's long enough it␣
 ↪will go "
     "off the top or bottom!")
plt.text(4, 1, t, ha='left', rotation=15, wrap=True)
plt.text(6, 5, t, ha='left', rotation=15, wrap=True)
plt.text(5, 5, t, ha='right', rotation=-15, wrap=True)
plt.text(5, 10, t, fontsize=18, style='oblique', ha='center',
         va='top', wrap=True)
plt.text(3, 4, t, family='serif', style='italic', ha='right',␣
 ↪wrap=True)
plt.text(-1, 0, t, ha='left', rotation=-15, wrap=True)

plt.show()
```

Text rotation mode

This example illustrates the effect of `rotation_mode` on the positioning of rotated text.

Rotated *Texts* are created by passing the parameter `rotation` to the constructor or the Axes' method *text*.

The actual positioning depends on the additional parameters `horizontalalignment`, `verticalalignment` and `rotation_mode`. `rotation_mode` determines the order of rotation and alignment:

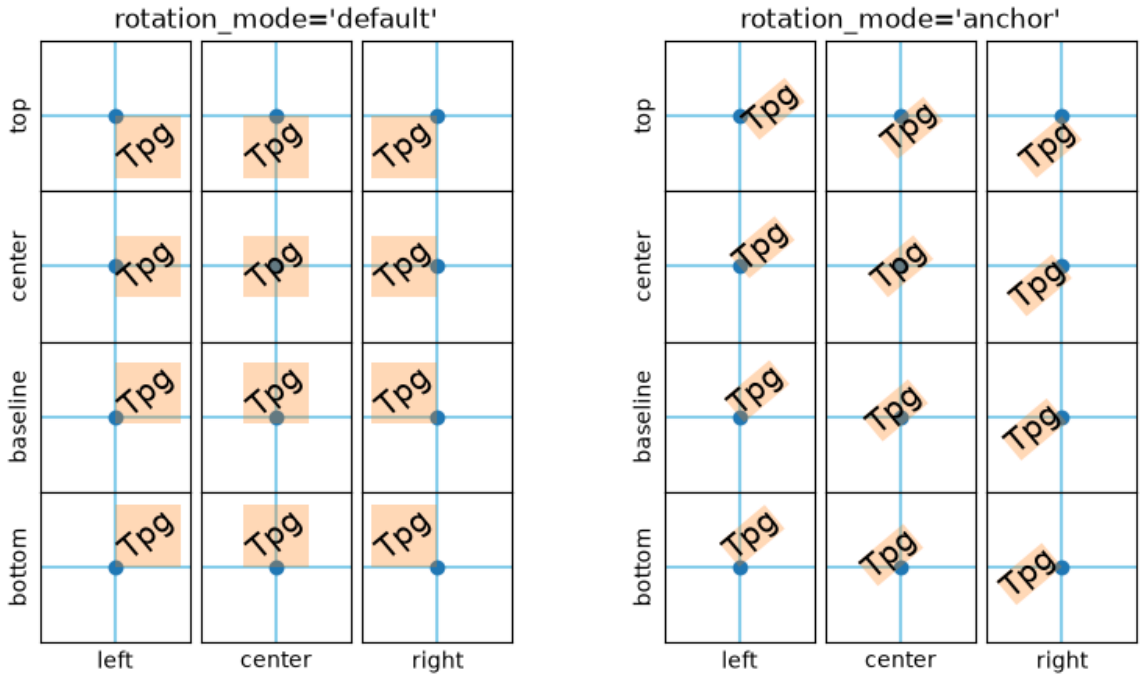
- `rotation_mode='default'` (or None) first rotates the text and then aligns the bounding box of the rotated text.
- `rotation_mode='anchor'` aligns the unrotated text and then rotates the text around the point of alignment.

```
import matplotlib.pyplot as plt


def test_rotation_mode(fig, mode):
    ha_list = ["left", "center", "right"]
    va_list = ["top", "center", "baseline", "bottom"]
    axs = fig.subplots(len(va_list), len(ha_list), sharex=True,␣
 ↪sharey=True,
                       subplot_kw=dict(aspect=1),
                       gridspec_kw=dict(hspace=0, wspace=0))

    # labels and title
    for ha, ax in zip(ha_list, axs[-1, :]):
        ax.set_xlabel(ha)
    for va, ax in zip(va_list, axs[:, 0]):
        ax.set_ylabel(va)
    axs[0, 1].set_title(f"rotation_mode='{mode}'", size="large")

    kw = (
        {} if mode == "default" else
        {"bbox": dict(boxstyle="square,pad=0.", ec="none", fc="C1",␣
 ↪alpha=0.3)}
    )

    texts = {}

    # use a different text alignment in each Axes
    for i, va in enumerate(va_list):
        for j, ha in enumerate(ha_list):
            ax = axs[i, j]
            # prepare Axes layout
            ax.set(xticks=[], yticks=[])
```

(continues on next page)

(continued from previous page)

```
            ax.axvline(0.5, color="skyblue", zorder=0)
            ax.axhline(0.5, color="skyblue", zorder=0)
            ax.plot(0.5, 0.5, color="C0", marker="o", zorder=1)
            # add text with rotation and alignment settings
            tx = ax.text(0.5, 0.5, "Tpg",
                         size="x-large", rotation=40,
                         horizontalalignment=ha, verticalalignment=va,
                         rotation_mode=mode, **kw)
            texts[ax] = tx

    if mode == "default":
        # highlight bbox
        fig.canvas.draw()
        for ax, text in texts.items():
            bb = text.get_window_extent().transformed(ax.transData.
 ↪inverted())
            rect = plt.Rectangle((bb.x0, bb.y0), bb.width, bb.height,
                                 facecolor="C1", alpha=0.3, zorder=2)
            ax.add_patch(rect)


fig = plt.figure(figsize=(8, 5))
subfigs = fig.subfigures(1, 2)
test_rotation_mode(subfigs[0], "default")
test_rotation_mode(subfigs[1], "anchor")
plt.show()
```



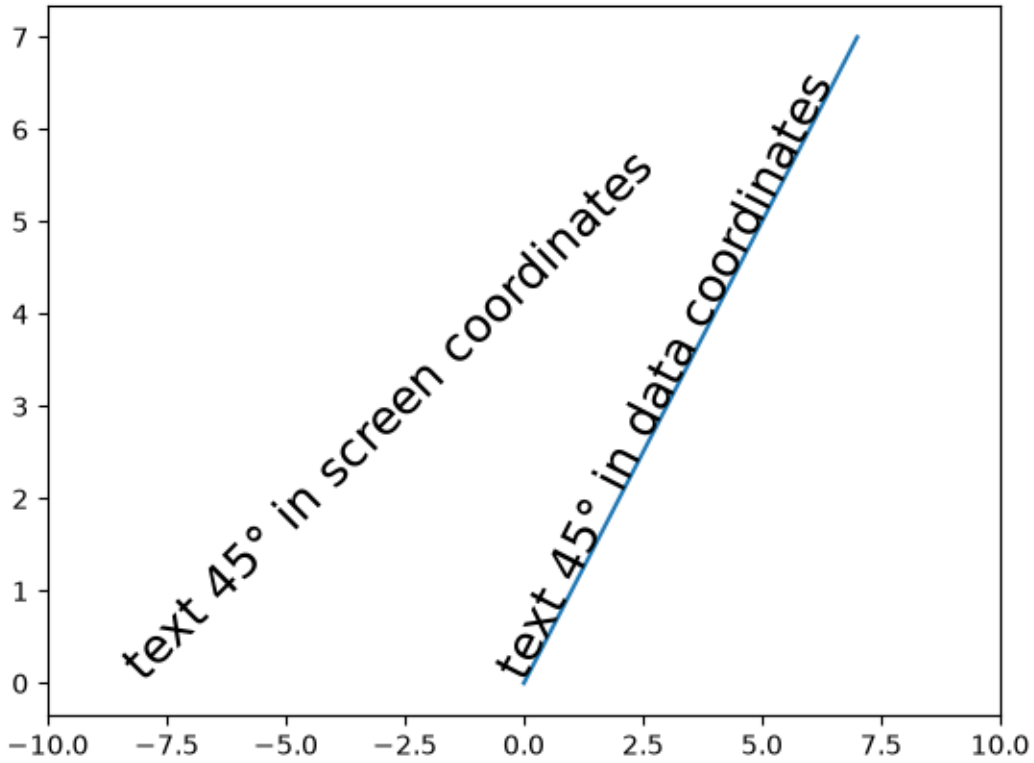
References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.text* / *matplotlib.pyplot.text*

Text rotation angle in data coordinates

Text objects in matplotlib are normally rotated with respect to the screen coordinate system (i.e., 45 degrees rotation plots text along a line that is in between horizontal and vertical no matter how the axes are changed). However, at times one wants to rotate text with respect to something on the plot. In this case, the correct angle won't be the angle of that object in the plot coordinate system, but the angle that that object APPEARS in the screen coordinate system. This angle can be determined automatically by setting the parameter *transform_rotates_text*, as shown in the example below.




```
import matplotlib.pyplot as plt

fig, ax = plt.subplots()

# Plot diagonal line (45 degrees in data coordinates)
ax.plot(range(0, 8), range(0, 8))
ax.set_xlim([-10, 10])

# Plot text
ax.text(-8, 0, 'text 45° in screen coordinates', fontsize=18,
        rotation=45, rotation_mode='anchor')
ax.text(0, 0, 'text 45° in data coordinates', fontsize=18,
        rotation=45, rotation_mode='anchor',
        transform_rotates_text=True)

plt.show()
```

Concatenate text objects with different properties

The example strings together several Text objects with different properties (e.g., color or font), positioning each one after the other. The first Text is created directly using *text*; all subsequent ones are created with *annotate*, which allows positioning the Text's lower left corner at the lower right corner (`xy=(1, 0)`) of the previous one (`xycoords=text`).

```
import matplotlib.pyplot as plt

plt.rcParams["font.size"] = 20
ax = plt.figure().add_subplot(xticks=[], yticks=[])

# The first word, created with text().
text = ax.text(.1, .5, "Matplotlib", color="red")
# Subsequent words, positioned with annotate(), relative to the␣
 ↪preceding one.
text = ax.annotate(
    " says,", xycoords=text, xy=(1, 0), verticalalignment="bottom",
    color="gold", weight="bold")  # custom properties
text = ax.annotate(
    " hello", xycoords=text, xy=(1, 0), verticalalignment="bottom",
```

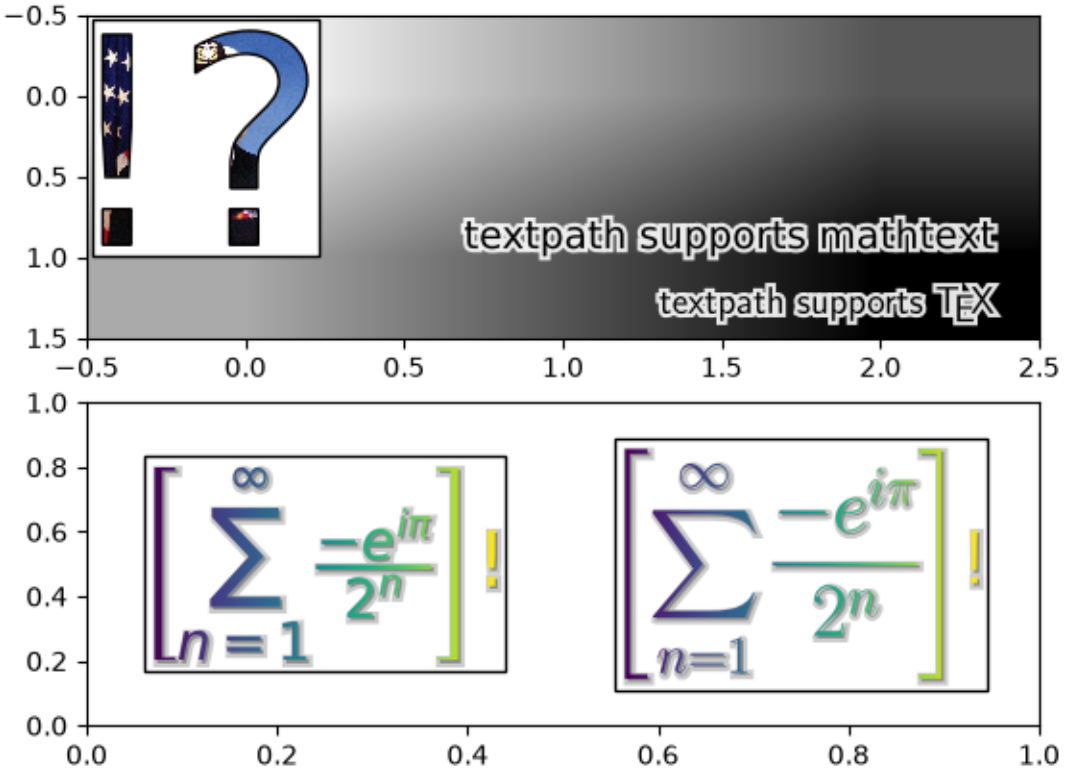
(continues on next page)

(continued from previous page)

```
    color="green", style="italic")  # custom properties
text = ax.annotate(
    " world!", xycoords=text, xy=(1, 0), verticalalignment="bottom",
    color="blue", family="serif")  # custom properties

plt.show()
```

Using a text as a Path

`TextPath` creates a `Path` that is the outline of the characters of a text. The resulting path can be employed e.g. as a clip path for an image.




```
from PIL import Image

import matplotlib.pyplot as plt
import numpy as np

from matplotlib.cbook import get_sample_data
from matplotlib.image import BboxImage
```

(continues on next page)

(continued from previous page)

```
from matplotlib.offsetbox import AnchoredOffsetbox, AnnotationBbox,␣
↪AuxTransformBox
from matplotlib.patches import PathPatch, Shadow
from matplotlib.text import TextPath
from matplotlib.transforms import IdentityTransform


class PathClippedImagePatch(PathPatch):
    """
    The given image is used to draw the face of the patch. Internally,
    it uses BboxImage whose clippath set to the path of the patch.

    FIXME : The result is currently dpi dependent.
    """

    def __init__(self, path, bbox_image, **kwargs):
        super().__init__(path, **kwargs)
        self.bbox_image = BboxImage(
            self.get_window_extent, norm=None, origin=None)
        self.bbox_image.set_data(bbox_image)

    def set_facecolor(self, color):
        """Simply ignore facecolor."""
        super().set_facecolor("none")

    def draw(self, renderer=None):
        # the clip path must be updated every draw. any solution? -JJ
        self.bbox_image.set_clip_path(self._path, self.get_transform())
        self.bbox_image.draw(renderer)
        super().draw(renderer)


if __name__ == "__main__":

    fig, (ax1, ax2) = plt.subplots(2)

    # EXAMPLE 1

    arr = Image.open(get_sample_data("grace_hopper.jpg"))

    text_path = TextPath((0, 0), "!?", size=150)
    p = PathClippedImagePatch(text_path, arr, ec="k")

    # make offset box
    offsetbox = AuxTransformBox(IdentityTransform())
    offsetbox.add_artist(p)
```

(continues on next page)

(continued from previous page)

```
    # make anchored offset box
    ao = AnchoredOffsetbox(loc='upper left', child=offsetbox,␣
↪frameon=True,
                           borderpad=0.2)
    ax1.add_artist(ao)

    # another text
    for usetex, ypos, string in [
            (False, 0.25, r"textpath supports mathtext"),
            (True, 0.05, r"textpath supports \TeX"),
    ]:
        text_path = TextPath((0, 0), string, size=20, usetex=usetex)

        p1 = PathPatch(text_path, ec="w", lw=3, fc="w", alpha=0.9)
        p2 = PathPatch(text_path, ec="none", fc="k")

        offsetbox2 = AuxTransformBox(IdentityTransform())
        offsetbox2.add_artist(p1)
        offsetbox2.add_artist(p2)

        ab = AnnotationBbox(offsetbox2, (0.95, ypos),
                            xycoords='axes fraction',
                            boxcoords="offset points",
                            box_alignment=(1., 0.),
                            frameon=False,
                            )
        ax1.add_artist(ab)

    ax1.imshow([[0, 1, 2], [1, 2, 3]], cmap="gist_gray_r",
               interpolation="bilinear", aspect="auto")

    # EXAMPLE 2

    arr = np.arange(256).reshape(1, 256)

    for usetex, xpos, string in [
            (False, 0.25,
             r"$\left[\sum_{n=1}^\infty\frac{-e^{i\pi}}{2^n}\right]$!
↪"),
            (True, 0.75,
             r"$\displaystyle\left[\sum_{n=1}^\infty"
             r"\frac{-e^{i\pi}}{2^n}\right]$!"),
    ]:
        text_path = TextPath((0, 0), string, size=40, usetex=usetex)
        text_patch = PathClippedImagePatch(text_path, arr, ec="none")
```

(continues on next page)

(continued from previous page)

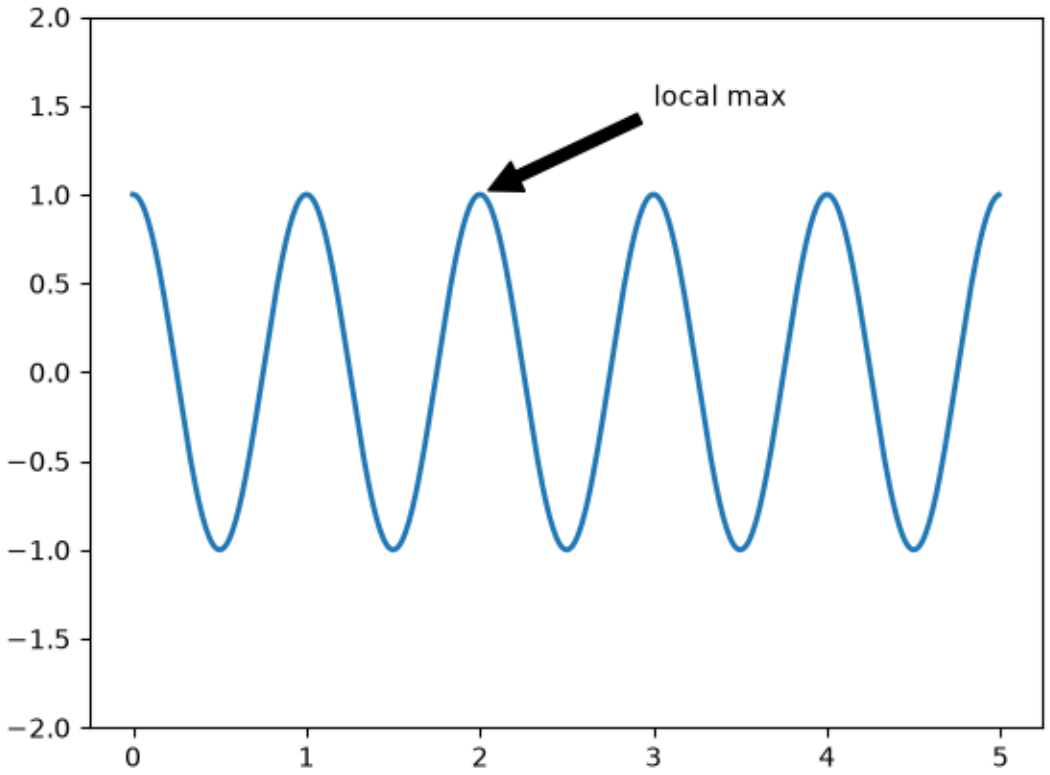
```
        shadow1 = Shadow(text_patch, 1, -1, fc="none", ec="0.6", lw=3)
        shadow2 = Shadow(text_patch, 1, -1, fc="0.3", ec="none")

        # make offset box
        offsetbox = AuxTransformBox(IdentityTransform())
        offsetbox.add_artist(shadow1)
        offsetbox.add_artist(shadow2)
        offsetbox.add_artist(text_patch)

        # place the anchored offset box using AnnotationBbox
        ab = AnnotationBbox(offsetbox, (xpos, 0.5), box_alignment=(0.5,
↪ 0.5))

        ax2.add_artist(ab)

    ax2.set_xlim(0, 1)
    ax2.set_ylim(0, 1)

    plt.show()
```

Annotating a plot

This example shows how to annotate a plot with an arrow pointing to provided coordinates. We modify the defaults of the arrow, to "shrink" it.

For a complete overview of the annotation capabilities, also see the *annotation tutorial*.

```
import matplotlib.pyplot as plt
import numpy as np

fig, ax = plt.subplots()

t = np.arange(0.0, 5.0, 0.01)
s = np.cos(2*np.pi*t)
line, = ax.plot(t, s, lw=2)

ax.annotate('local max', xy=(2, 1), xytext=(3, 1.5),
            arrowprops=dict(facecolor='black', shrink=0.05),
            )
ax.set_ylim(-2, 2)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.annotate* / *matplotlib.pyplot.annotate*

Annotate plots

The following examples show ways to annotate plots in Matplotlib. This includes highlighting specific points of interest and using various visual tools to call attention to this point. For a more complete and in-depth description of the annotation and text tools in Matplotlib, see the *tutorial on annotation*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Ellipse
from matplotlib.text import OffsetFrom
```

Specifying text points and annotation points

You must specify an annotation point `xy=(x, y)` to annotate this point. Additionally, you may specify a text point `xytext=(x, y)` for the location of the text for this annotation. Optionally, you can specify the coordinate system of *xy* and *xytext* with one of the following strings for *xycoords* and *textcoords* (default is 'data'):

```
'figure points'   : points from the lower left corner of the figure
'figure pixels'   : pixels from the lower left corner of the figure
'figure fraction' : (0, 0) is lower left of figure and (1, 1) is upper␣
 ↪right
'axes points'     : points from lower left corner of the Axes
'axes pixels'     : pixels from lower left corner of the Axes
'axes fraction'   : (0, 0) is lower left of Axes and (1, 1) is upper␣
 ↪right
'offset points'   : Specify an offset (in points) from the xy value
'offset pixels'   : Specify an offset (in pixels) from the xy value
'data'            : use the Axes data coordinate system
```

Note: for physical coordinate systems (points or pixels) the origin is the (bottom, left) of the figure or Axes.

Optionally, you can specify arrow properties which draws and arrow from the text to the annotated point by giving a dictionary of arrow properties

Valid keys are:

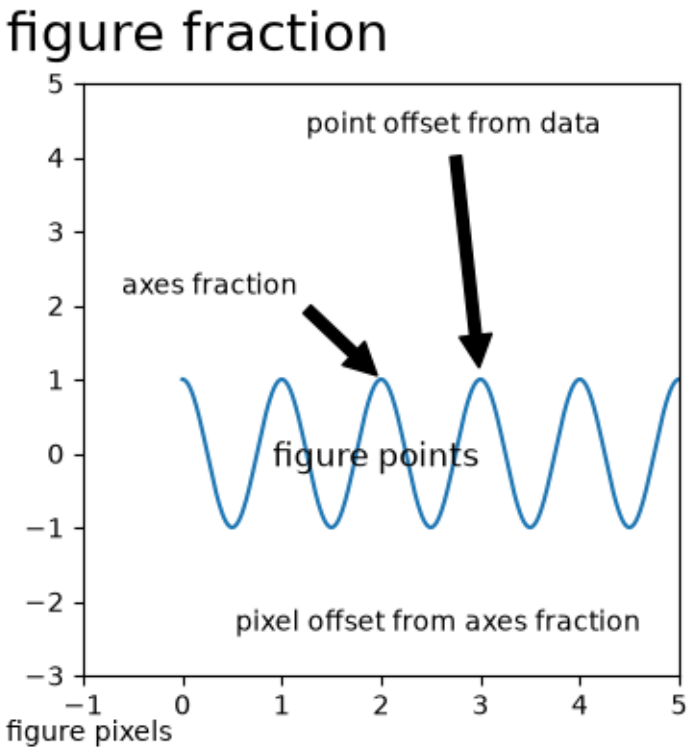
```
width : the width of the arrow in points
frac  : the fraction of the arrow length occupied by the head
headwidth : the width of the base of the arrow head in points
shrink : move the tip and base some percent away from the
         annotated point and text
any key for matplotlib.patches.polygon  (e.g., facecolor)
```

```
# Create our figure and data we'll use for plotting
fig, ax = plt.subplots(figsize=(4, 4))

t = np.arange(0.0, 5.0, 0.01)
s = np.cos(2*np.pi*t)

# Plot a line and add some simple annotations
line, = ax.plot(t, s)
ax.annotate('figure pixels',
            xy=(10, 10), xycoords='figure pixels')
ax.annotate('figure points',
            xy=(107, 110), xycoords='figure points',
            fontsize=12)
ax.annotate('figure fraction',
            xy=(.025, .975), xycoords='figure fraction',
```

(continues on next page)

(continued from previous page)

```
            horizontalalignment='left', verticalalignment='top',
            fontsize=20)

# The following examples show off how these arrows are drawn.

ax.annotate('point offset from data',
            xy=(3, 1), xycoords='data',
            xytext=(-10, 90), textcoords='offset points',
            arrowprops=dict(facecolor='black', shrink=0.05),
            horizontalalignment='center', verticalalignment='bottom')

ax.annotate('axes fraction',
            xy=(2, 1), xycoords='data',
            xytext=(0.36, 0.68), textcoords='axes fraction',
            arrowprops=dict(facecolor='black', shrink=0.05),
            horizontalalignment='right', verticalalignment='top')

# You may also use negative points or pixels to specify from (right,␣
 ↪top).
# E.g., (-10, 10) is 10 points to the left of the right side of the␣
 ↪Axes and 10
# points above the bottom

ax.annotate('pixel offset from axes fraction',
            xy=(1, 0), xycoords='axes fraction',
            xytext=(-20, 20), textcoords='offset pixels',
            horizontalalignment='right',
            verticalalignment='bottom')

ax.set(xlim=(-1, 5), ylim=(-3, 5))
```

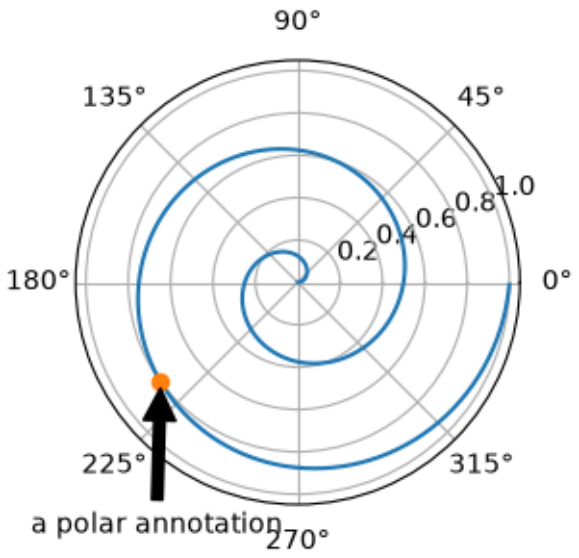


Using multiple coordinate systems and axis types

You can specify the *xypoint* and the *xytext* in different positions and coordinate systems, and optionally turn on a connecting line and mark the point with a marker. Annotations work on polar Axes too.

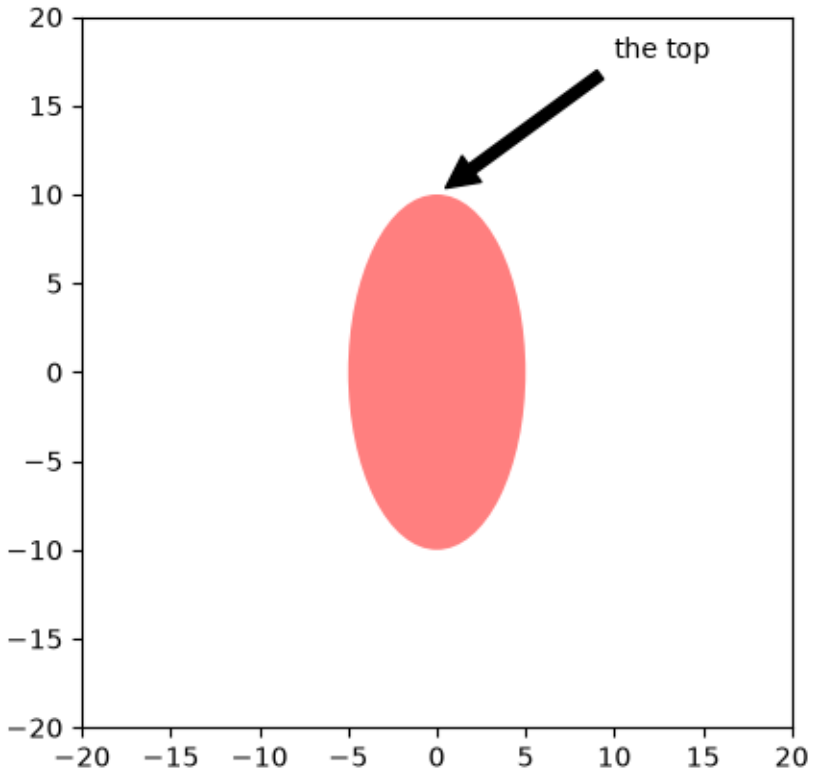
In the example below, the *xy* point is in native coordinates (*xycoords* defaults to 'data'). For a polar Axes, this is in (theta, radius) space. The text in the example is placed in the fractional figure coordinate system. Text keyword arguments like horizontal and vertical alignment are respected.

```
fig, ax = plt.subplots(subplot_kw=dict(projection='polar'), figsize=(3,
 ↪ 3))
r = np.arange(0, 1, 0.001)
theta = 2*2*np.pi*r
line, = ax.plot(theta, r)

ind = 800
thisr, thistheta = r[ind], theta[ind]
ax.plot([thistheta], [thisr], 'o')
ax.annotate('a polar annotation',
            xy=(thistheta, thisr),  # theta, radius
            xytext=(0.05, 0.05),    # fraction, fraction
            textcoords='figure fraction',
            arrowprops=dict(facecolor='black', shrink=0.05),
            horizontalalignment='left',
            verticalalignment='bottom')
```



You can also use polar notation on a cartesian Axes. Here the native coordinate system ('data') is cartesian, so you need to specify the xycoords and textcoords as 'polar' if you want to use (theta, radius).

```
el = Ellipse((0, 0), 10, 20, facecolor='r', alpha=0.5)

fig, ax = plt.subplots(subplot_kw=dict(aspect='equal'))
ax.add_artist(el)
el.set_clip_box(ax.bbox)
ax.annotate('the top',
            xy=(np.pi/2., 10.),      # theta, radius
            xytext=(np.pi/3, 20.),   # theta, radius
            xycoords='polar',
            textcoords='polar',
            arrowprops=dict(facecolor='black', shrink=0.05),
            horizontalalignment='left',
            verticalalignment='bottom',
            clip_on=True)  # clip to the Axes bounding box

ax.set(xlim=[-20, 20], ylim=[-20, 20])
```



Customizing arrow and bubble styles

The arrow between *xytext* and the annotation point, as well as the bubble that covers the annotation text, are highly customizable. Below are a few parameter options as well as their resulting output.

```
fig, ax = plt.subplots(figsize=(8, 5))

t = np.arange(0.0, 5.0, 0.01)
s = np.cos(2*np.pi*t)
line, = ax.plot(t, s, lw=3)

ax.annotate(
    'straight',
    xy=(0, 1), xycoords='data',
    xytext=(-50, 30), textcoords='offset points',
    arrowprops=dict(arrowstyle="->"))
ax.annotate(
    'arc3,\nrad 0.2',
    xy=(0.5, -1), xycoords='data',
    xytext=(-80, -60), textcoords='offset points',
```

(continues on next page)

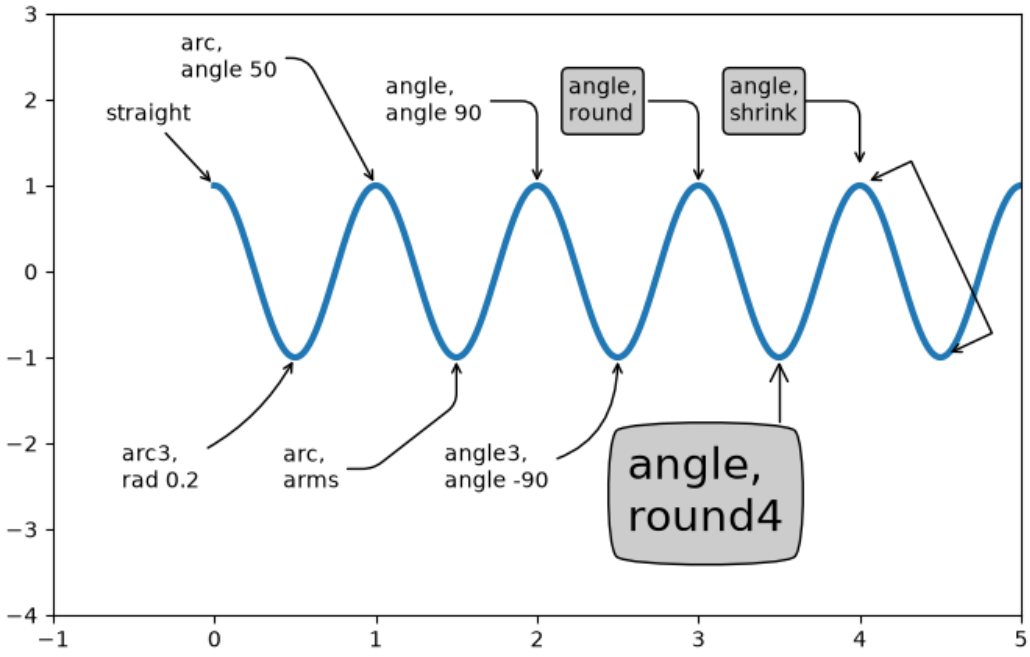
(continued from previous page)

```
    arrowprops=dict(arrowstyle="->",
                    connectionstyle="arc3,rad=.2"))
ax.annotate(
    'arc,\nangle 50',
    xy=(1., 1), xycoords='data',
    xytext=(-90, 50), textcoords='offset points',
    arrowprops=dict(arrowstyle="->",
                    connectionstyle="arc,angleA=0,armA=50,rad=10"))
ax.annotate(
    'arc,\narms',
    xy=(1.5, -1), xycoords='data',
    xytext=(-80, -60), textcoords='offset points',
    arrowprops=dict(
        arrowstyle="->",
        connectionstyle="arc,angleA=0,armA=40,angleB=-90,armB=30,rad=7
 ↪"))
ax.annotate(
    'angle,\nangle 90',
    xy=(2., 1), xycoords='data',
    xytext=(-70, 30), textcoords='offset points',
    arrowprops=dict(arrowstyle="->",
                    connectionstyle="angle,angleA=0,angleB=90,rad=10"))
ax.annotate(
    'angle3,\nangle -90',
    xy=(2.5, -1), xycoords='data',
    xytext=(-80, -60), textcoords='offset points',
    arrowprops=dict(arrowstyle="->",
                    connectionstyle="angle3,angleA=0,angleB=-90"))
ax.annotate(
    'angle,\nround',
    xy=(3., 1), xycoords='data',
    xytext=(-60, 30), textcoords='offset points',
    bbox=dict(boxstyle="round", fc="0.8"),
    arrowprops=dict(arrowstyle="->",
                    connectionstyle="angle,angleA=0,angleB=90,rad=10"))
ax.annotate(
    'angle,\nround4',
    xy=(3.5, -1), xycoords='data',
    xytext=(-70, -80), textcoords='offset points',
    size=20,
    bbox=dict(boxstyle="round4,pad=.5", fc="0.8"),
    arrowprops=dict(arrowstyle="->",
                    connectionstyle="angle,angleA=0,angleB=-90,rad=10
 ↪"))
ax.annotate(
    'angle,\nshrink',
```

(continues on next page)

(continued from previous page)

```
    xy=(4., 1), xycoords='data',
    xytext=(-60, 30), textcoords='offset points',
    bbox=dict(boxstyle="round", fc="0.8"),
    arrowprops=dict(arrowstyle="->",
                    shrinkA=0, shrinkB=10,
                    connectionstyle="angle,angleA=0,angleB=90,rad=10"))
# You can pass an empty string to get only annotation arrows rendered
ax.annotate('', xy=(4., 1.), xycoords='data',
            xytext=(4.5, -1), textcoords='data',
            arrowprops=dict(arrowstyle="<->",
                            connectionstyle="bar",
                            ec="k",
                            shrinkA=5, shrinkB=5))

ax.set(xlim=(-1, 5), ylim=(-4, 3))
```



We'll create another figure so that it doesn't get too cluttered

```
fig, ax = plt.subplots()

el = Ellipse((2, -1), 0.5, 0.5)
ax.add_patch(el)

ax.annotate('$->$',
```

(continues on next page)

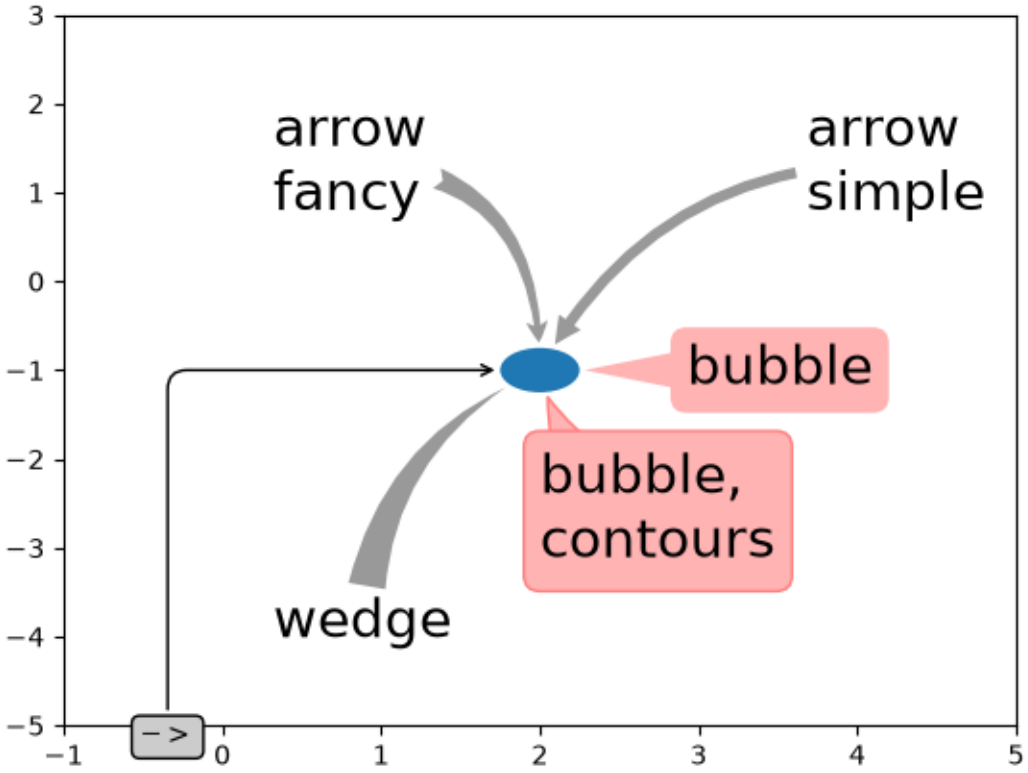
(continued from previous page)

```
            xy=(2., -1), xycoords='data',
            xytext=(-150, -140), textcoords='offset points',
            bbox=dict(boxstyle="round", fc="0.8"),
            arrowprops=dict(arrowstyle="->",
                            patchB=el,
                            connectionstyle=
 ↪"angle,angleA=90,angleB=0,rad=10"))
ax.annotate('arrow\nfancy',
            xy=(2., -1), xycoords='data',
            xytext=(-100, 60), textcoords='offset points',
            size=20,
            arrowprops=dict(arrowstyle="fancy",
                            fc="0.6", ec="none",
                            patchB=el,
                            connectionstyle="angle3,angleA=0,angleB=-90
 ↪"))
ax.annotate('arrow\nsimple',
            xy=(2., -1), xycoords='data',
            xytext=(100, 60), textcoords='offset points',
            size=20,
            arrowprops=dict(arrowstyle="simple",
                            fc="0.6", ec="none",
                            patchB=el,
                            connectionstyle="arc3,rad=0.3"))
ax.annotate('wedge',
            xy=(2., -1), xycoords='data',
            xytext=(-100, -100), textcoords='offset points',
            size=20,
            arrowprops=dict(arrowstyle="wedge,tail_width=0.7",
                            fc="0.6", ec="none",
                            patchB=el,
                            connectionstyle="arc3,rad=-0.3"))
ax.annotate('bubble,\ncontours',
            xy=(2., -1), xycoords='data',
            xytext=(0, -70), textcoords='offset points',
            size=20,
            bbox=dict(boxstyle="round",
                      fc=(1.0, 0.7, 0.7),
                      ec=(1., .5, .5)),
            arrowprops=dict(arrowstyle="wedge,tail_width=1.",
                            fc=(1.0, 0.7, 0.7), ec=(1., .5, .5),
                            patchA=None,
                            patchB=el,
                            relpos=(0.2, 0.8),
                            connectionstyle="arc3,rad=-0.1"))
ax.annotate('bubble',
```

(continues on next page)

(continued from previous page)

```
            xy=(2., -1), xycoords='data',
            xytext=(55, 0), textcoords='offset points',
            size=20, va="center",
            bbox=dict(boxstyle="round", fc=(1.0, 0.7, 0.7), ec="none"),
            arrowprops=dict(arrowstyle="wedge,tail_width=1.",
                            fc=(1.0, 0.7, 0.7), ec="none",
                            patchA=None,
                            patchB=el,
                            relpos=(0.2, 0.5)))

ax.set(xlim=(-1, 5), ylim=(-5, 3))
```



More examples of coordinate systems

Below we'll show a few more examples of coordinate systems and how the location of annotations may be specified.

```
fig, (ax1, ax2) = plt.subplots(1, 2)
```

(continues on next page)

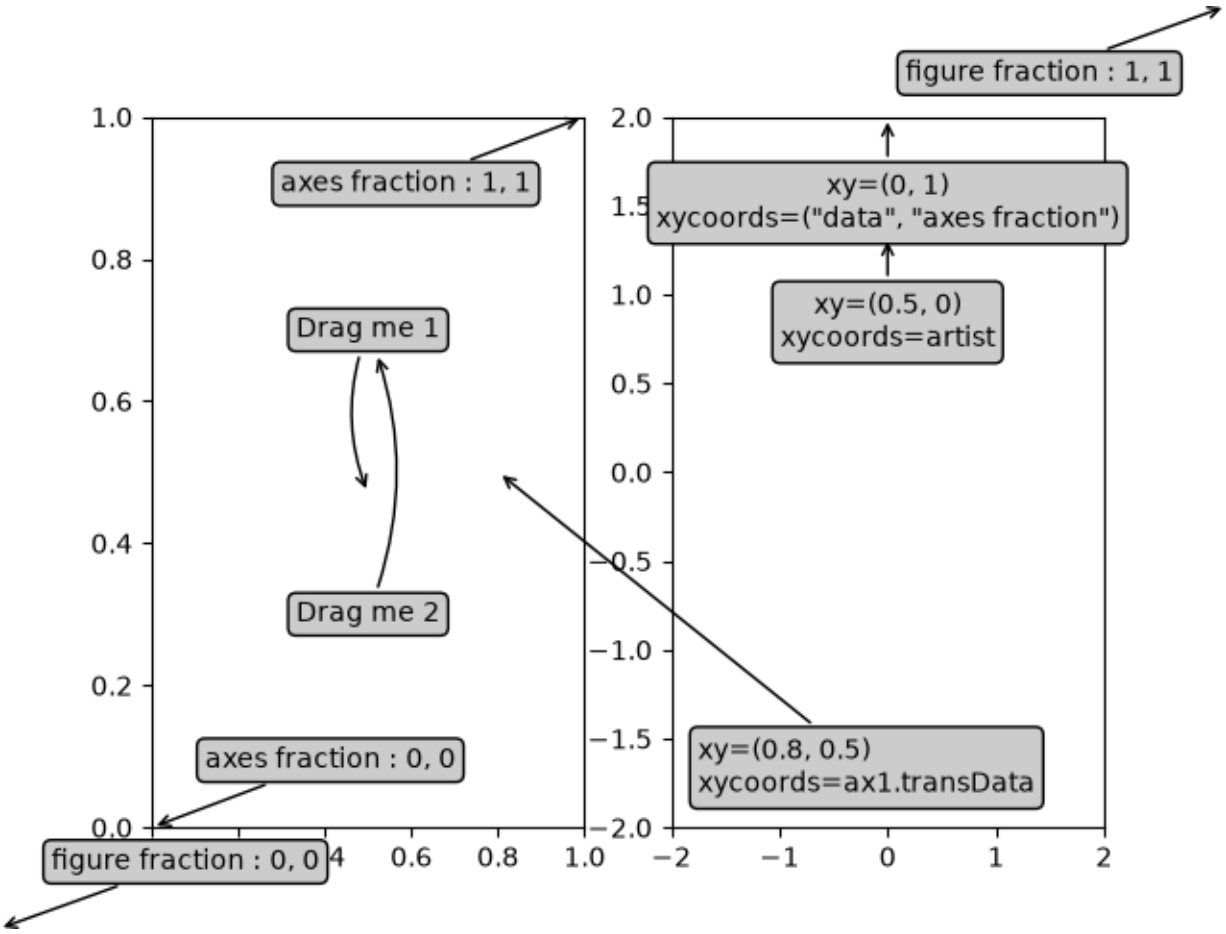
(continued from previous page)

```
bbox_args = dict(boxstyle="round", fc="0.8")
arrow_args = dict(arrowstyle="->")

# Here we'll demonstrate the extents of the coordinate system and how
# we place annotating text.

ax1.annotate('figure fraction : 0, 0', xy=(0, 0), xycoords='figure␣
↪fraction',
             xytext=(20, 20), textcoords='offset points',
             ha="left", va="bottom",
             bbox=bbox_args,
             arrowprops=arrow_args)

ax1.annotate('figure fraction : 1, 1', xy=(1, 1), xycoords='figure␣
↪fraction',
             xytext=(-20, -20), textcoords='offset points',
             ha="right", va="top",
             bbox=bbox_args,
             arrowprops=arrow_args)

ax1.annotate('axes fraction : 0, 0', xy=(0, 0), xycoords='axes fraction
↪',
             xytext=(20, 20), textcoords='offset points',
             ha="left", va="bottom",
             bbox=bbox_args,
             arrowprops=arrow_args)

ax1.annotate('axes fraction : 1, 1', xy=(1, 1), xycoords='axes fraction
↪',
             xytext=(-20, -20), textcoords='offset points',
             ha="right", va="top",
             bbox=bbox_args,
             arrowprops=arrow_args)

# It is also possible to generate draggable annotations

an1 = ax1.annotate('Drag me 1', xy=(.5, .7), xycoords='data',
                   ha="center", va="center",
                   bbox=bbox_args)

an2 = ax1.annotate('Drag me 2', xy=(.5, .5), xycoords=an1,
                   xytext=(.5, .3), textcoords='axes fraction',
                   ha="center", va="center",
                   bbox=bbox_args,
                   arrowprops=dict(patchB=an1.get_bbox_patch(),
                                   connectionstyle="arc3,rad=0.2",
```

(continues on next page)

(continued from previous page)

```
                                    **arrow_args))
an1.draggable()
an2.draggable()

an3 = ax1.annotate('', xy=(.5, .5), xycoords=an2,
                   xytext=(.5, .5), textcoords=an1,
                   ha="center", va="center",
                   bbox=bbox_args,
                   arrowprops=dict(patchA=an1.get_bbox_patch(),
                                   patchB=an2.get_bbox_patch(),
                                   connectionstyle="arc3,rad=0.2",
                                   **arrow_args))

# Finally we'll show off some more complex annotation and placement

text = ax2.annotate('xy=(0, 1)\nxycoords=("data", "axes fraction")',
                    xy=(0, 1), xycoords=("data", 'axes fraction'),
                    xytext=(0, -20), textcoords='offset points',
                    ha="center", va="top",
                    bbox=bbox_args,
                    arrowprops=arrow_args)

ax2.annotate('xy=(0.5, 0)\nxycoords=artist',
             xy=(0.5, 0.), xycoords=text,
             xytext=(0, -20), textcoords='offset points',
             ha="center", va="top",
             bbox=bbox_args,
             arrowprops=arrow_args)

ax2.annotate('xy=(0.8, 0.5)\nxycoords=ax1.transData',
             xy=(0.8, 0.5), xycoords=ax1.transData,
             xytext=(10, 10),
             textcoords=OffsetFrom(ax2.bbox, (0, 0), "points"),
             ha="left", va="bottom",
             bbox=bbox_args,
             arrowprops=arrow_args)

ax2.set(xlim=[-2, 2], ylim=[-2, 2])
plt.show()
```



Total running time of the script: (0 minutes 1.848 seconds)

Annotate polar plots

This example shows how to create an annotation on a polar graph.

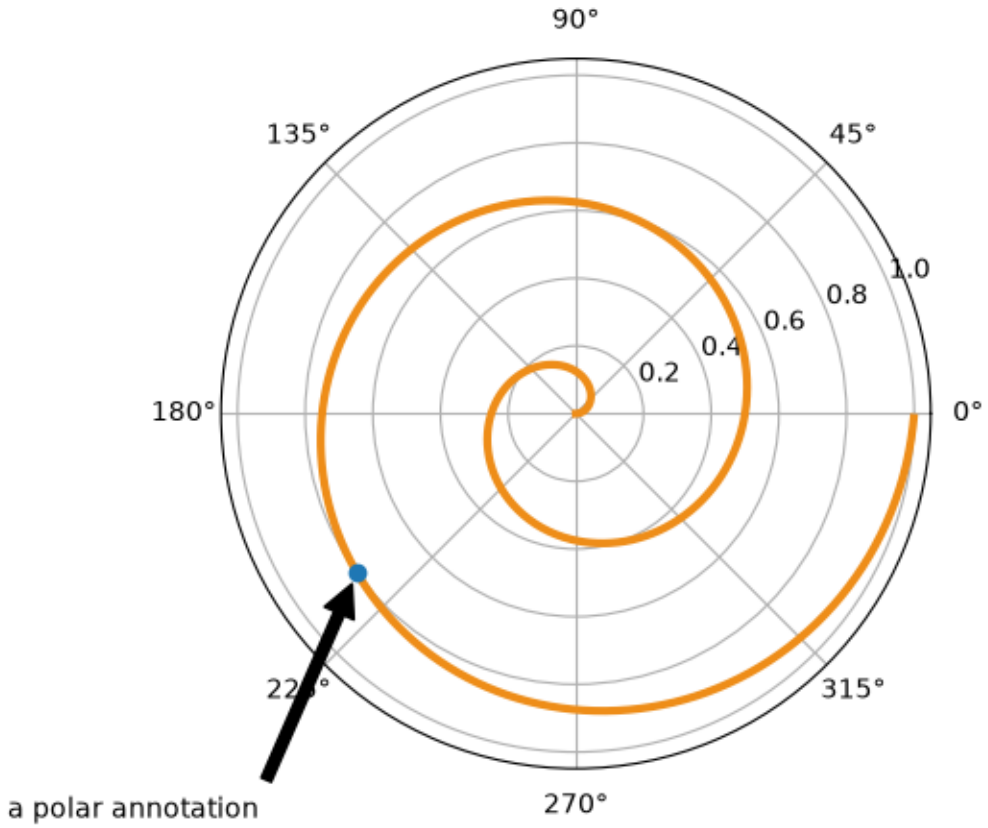
For a complete overview of the annotation capabilities, also see the *Annotations*.

```
import matplotlib.pyplot as plt
import numpy as np

fig = plt.figure()
ax = fig.add_subplot(projection='polar')
r = np.arange(0, 1, 0.001)
theta = 2 * 2*np.pi * r
line, = ax.plot(theta, r, color='#ee8d18', lw=3)

ind = 800
thisr, thistheta = r[ind], theta[ind]
ax.plot([thistheta], [thisr], 'o')
ax.annotate('a polar annotation',
            xy=(thistheta, thisr),  # theta, radius
```

(continues on next page)

(continued from previous page)

```
            xytext=(0.05, 0.05),    # fraction, fraction
            textcoords='figure fraction',
            arrowprops=dict(facecolor='black', shrink=0.05),
            horizontalalignment='left',
            verticalalignment='bottom',
            )
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.projections.polar*
- *matplotlib.axes.Axes.annotate* / *matplotlib.pyplot.annotate*

Angle annotations on bracket arrows

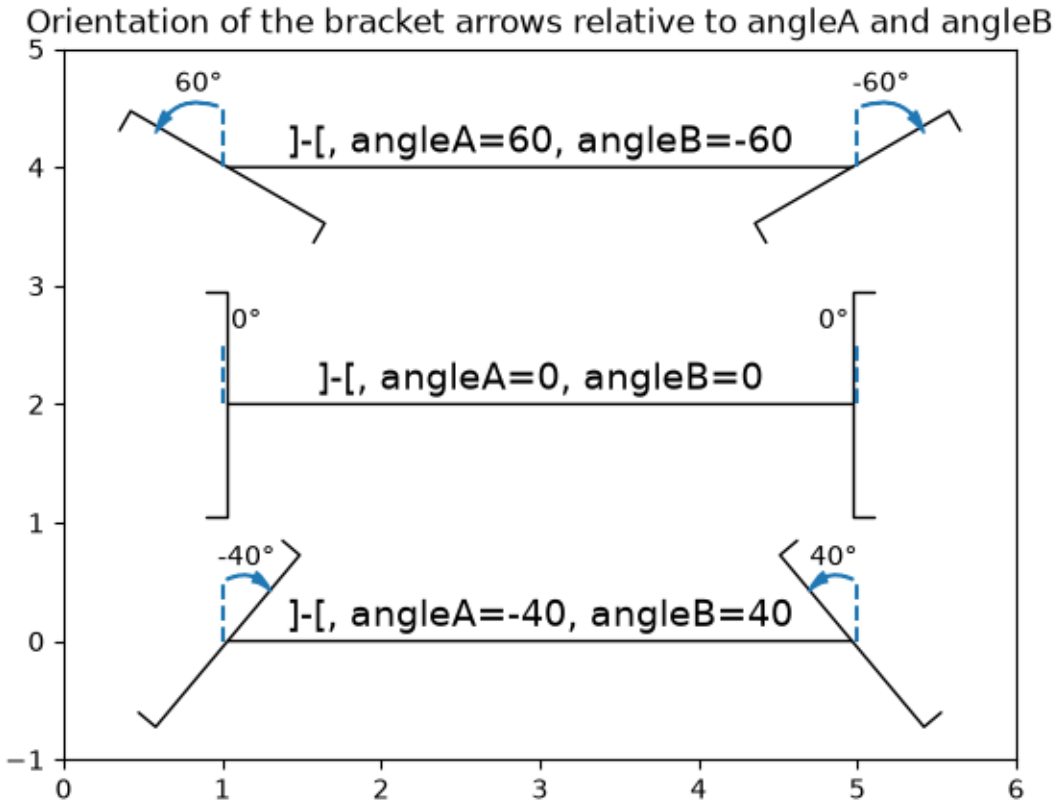
This example shows how to add angle annotations to bracket arrow styles created using *FancyArrowPatch*. *angleA* and *angleB* are measured from a vertical line as positive (to the left) or negative (to the right). Blue *FancyArrowPatch* arrows indicate the directions of *angleA* and *angleB* from the vertical and axes text annotate the angle sizes.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import FancyArrowPatch


def get_point_of_rotated_vertical(origin, line_length, degrees):
    """Return xy coordinates of the vertical line end rotated by␣
 ↪degrees."""
    rad = np.deg2rad(-degrees)
    return [origin[0] + line_length * np.sin(rad),
            origin[1] + line_length * np.cos(rad)]


fig, ax = plt.subplots()
ax.set(xlim=(0, 6), ylim=(-1, 5))
ax.set_title("Orientation of the bracket arrows relative to angleA and␣
 ↪angleB")

style = ']-['
for i, angle in enumerate([-40, 0, 60]):
    y = 2*i
    arrow_centers = ((1, y), (5, y))
    vlines = ((1, y + 0.5), (5, y + 0.5))
    anglesAB = (angle, -angle)
    bracketstyle = f"{style}, angleA={anglesAB[0]}, angleB=
 ↪{anglesAB[1]}"
    bracket = FancyArrowPatch(*arrow_centers, arrowstyle=bracketstyle,
                              mutation_scale=42)
    ax.add_patch(bracket)
    ax.text(3, y + 0.05, bracketstyle, ha="center", va="bottom",␣
 ↪fontsize=14)
```

(continues on next page)

(continued from previous page)

```
    ax.vlines([line[0] for line in vlines], [y, y], [line[1] for line␣
↪in vlines],
              linestyles="--", color="C0")
    # Get the top coordinates for the drawn patches at A and B
    patch_tops = [get_point_of_rotated_vertical(center, 0.5, angle)
                  for center, angle in zip(arrow_centers, anglesAB)]
    # Define the connection directions for the annotation arrows
    connection_dirs = (1, -1) if angle > 0 else (-1, 1)
    # Add arrows and annotation text
    arrowstyle = "Simple, tail_width=0.5, head_width=4, head_length=8"
    for vline, dir, patch_top, angle in zip(vlines, connection_dirs,
                                            patch_tops, anglesAB):
        kw = dict(connectionstyle=f"arc3,rad={dir * 0.5}",
                  arrowstyle=arrowstyle, color="C0")
        ax.add_patch(FancyArrowPatch(vline, patch_top, **kw))
        ax.text(vline[0] - dir * 0.15, y + 0.7, f'{angle}°', ha="center
↪",
                va="center")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches.ArrowStyle*

Annotation arrow style reference

Overview of the available *ArrowStyle* settings. These are used for the *arrowstyle* parameter of *annotate* and *FancyArrowPatch*.

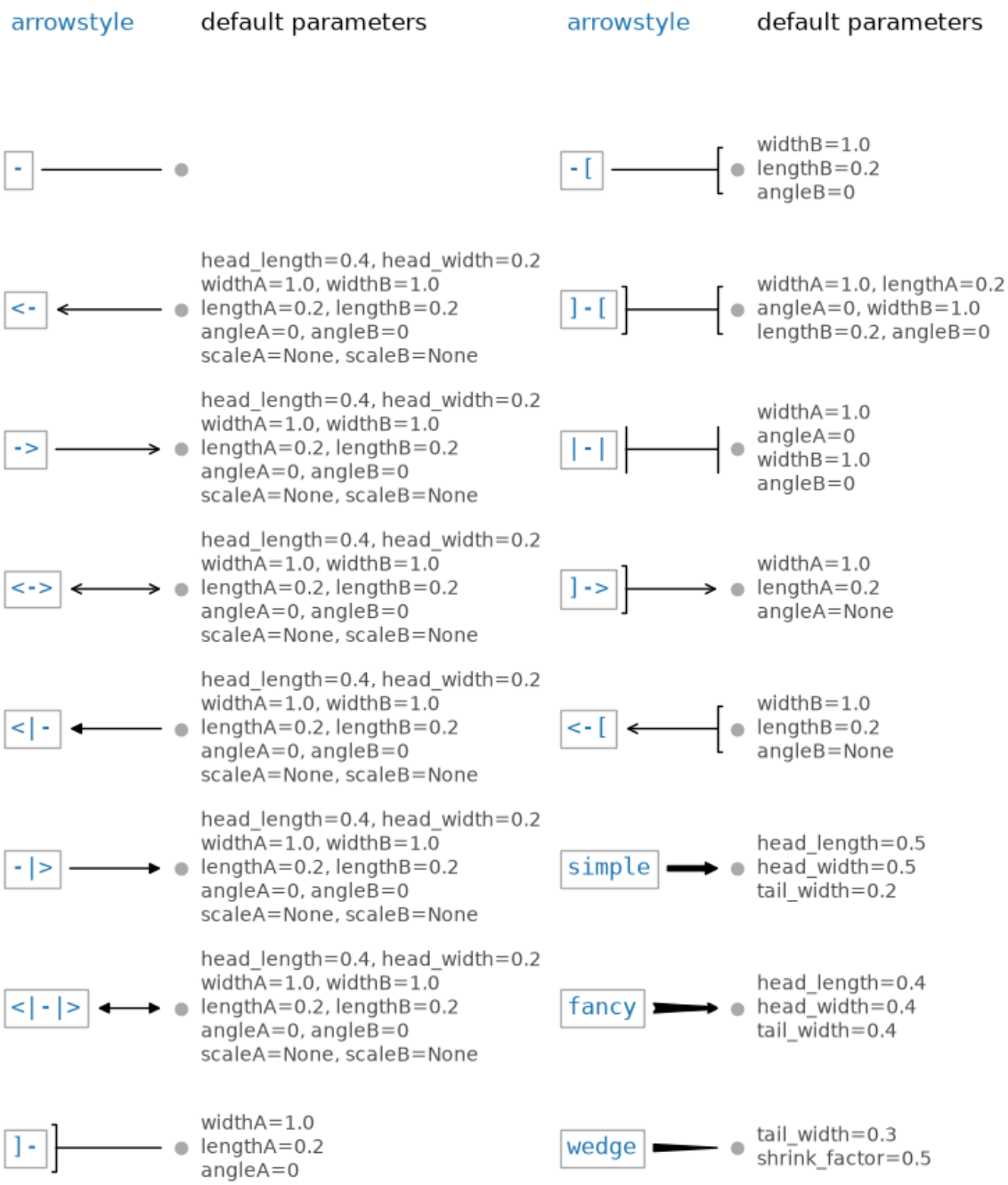
Each style can be configured with a set of parameters, which are stated along with their default values.

```
import inspect
import itertools
import re

import matplotlib.pyplot as plt

from matplotlib.patches import ArrowStyle

styles = ArrowStyle.get_styles()
ncol = 2
nrow = (len(styles) + 1) // ncol
gridspec_kw = dict(wspace=0, hspace=0.05, left=0, right=1, bottom=0,␣
 ↪top=1)
fig, axs = plt.subplots(1 + nrow, ncol,
                        figsize=(4 * ncol, 1 + nrow),␣
 ↪gridspec_kw=gridspec_kw)
for ax in axs.flat:
    ax.set_xlim(-0.1, 4)
    ax.set_axis_off()
for ax in axs[0, :]:
    ax.text(0, 0.5, "arrowstyle", size="large", color="tab:blue")
    ax.text(1.4, .5, "default parameters", size="large")
for ax, (stylename, stylecls) in zip(axs[1:, :].T.flat, styles.
 ↪items()):
    # draw dot and annotation with arrowstyle
    l, = ax.plot(1.25, 0, "o", color="darkgrey")
    ax.annotate(stylename, (1.25, 0), (0, 0),
                size="large", color="tab:blue", va="center", family=
 ↪"monospace",
                arrowprops=dict(
                    arrowstyle=stylename, connectionstyle="arc3,rad=0",
                    color="black", shrinkA=5, shrinkB=5, patchB=l,
                ),
                bbox=dict(boxstyle="square", fc="w", ec="darkgrey"))
```

(continues on next page)

(continued from previous page)

```
    # draw default parameters
    # wrap at every nth comma (n = 1 or 2, depending on text length)
    s = str(inspect.signature(stylecls))[1:-1]
    n = 2 if s.count(',') > 3 else 1
    ax.text(1.4, 0,
            re.sub(', ', lambda m, c=itertools.count(1): m.group()
                   if next(c) % n else '\n', s),
            verticalalignment="center", color="0.3")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

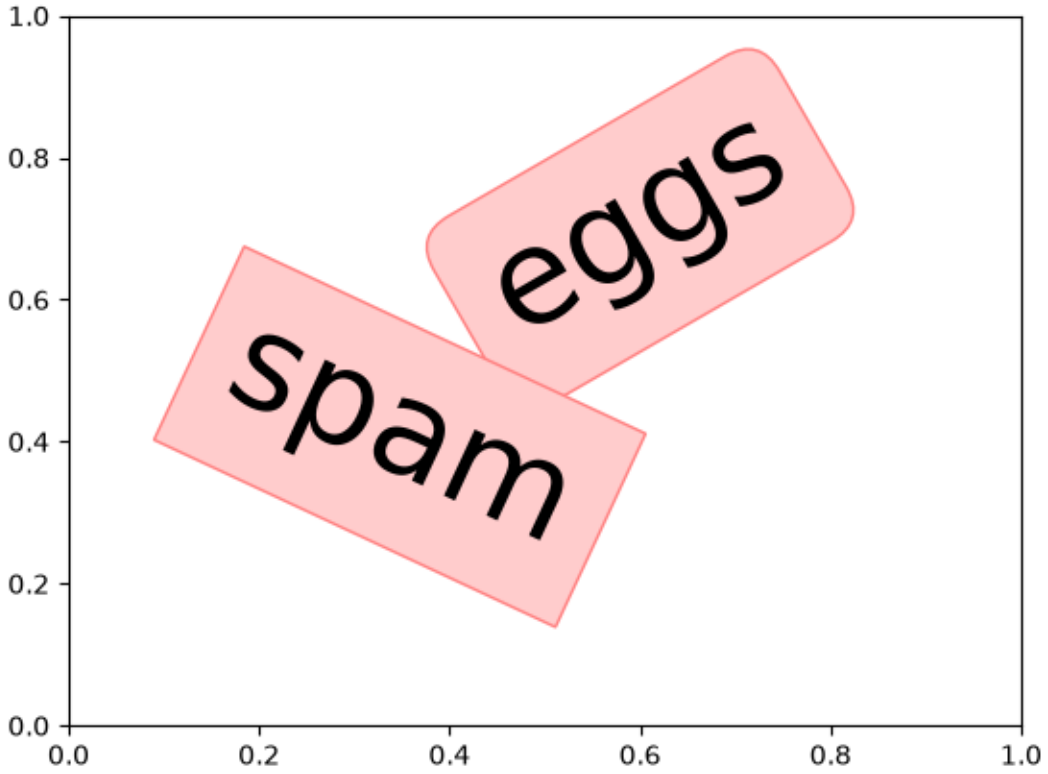
- *matplotlib.patches*
- *matplotlib.patches.ArrowStyle*

- `matplotlib.patches.ArrowStyle.get_styles`
- *`matplotlib.axes.Axes.annotate`*

Total running time of the script: (0 minutes 1.045 seconds)

Styling text boxes

This example shows how to style text boxes using *bbox* parameters.




```
import matplotlib.pyplot as plt

plt.text(0.6, 0.7, "eggs", size=50, rotation=30.,
         ha="center", va="center",
         bbox=dict(boxstyle="round",
                   ec=(1., 0.5, 0.5),
                   fc=(1., 0.8, 0.8),
                   )
         )

plt.text(0.55, 0.6, "spam", size=50, rotation=-25.,
```

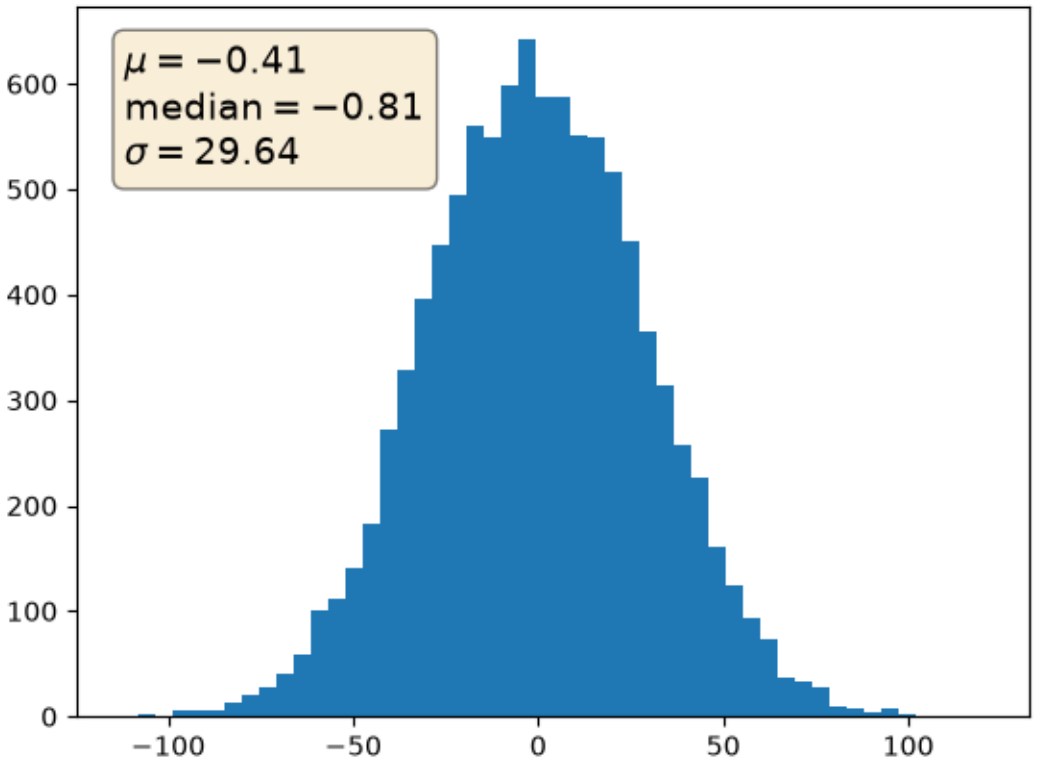
(continues on next page)

(continued from previous page)

```
        ha="right", va="top",
        bbox=dict(boxstyle="square",
                  ec=(1., 0.5, 0.5),
                  fc=(1., 0.8, 0.8),
                  )
        )

plt.show()
```

Placing text boxes

When decorating Axes with text boxes, two useful tricks are to place the text in axes coordinates (see *Transformations Tutorial*), so the text doesn't move around with changes in x or y limits. You can also use the `bbox` property of text to surround the text with a `Patch` instance -- the `bbox` keyword argument takes a dictionary with keys that are Patch properties.




```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
np.random.seed(19680801)

fig, ax = plt.subplots()
x = 30*np.random.randn(10000)
mu = x.mean()
median = np.median(x)
sigma = x.std()
textstr = '\n'.join((
    r'$\mu=%.2f$' % (mu, ),
    r'$\mathrm{median}=%.2f$' % (median, ),
    r'$\sigma=%.2f$' % (sigma, )))

ax.hist(x, 50)
# these are matplotlib.patch.Patch properties
props = dict(boxstyle='round', facecolor='wheat', alpha=0.5)

# place a text box in upper left in axes coords
ax.text(0.05, 0.95, textstr, transform=ax.transAxes, fontsize=14,
        verticalalignment='top', bbox=props)

plt.show()
```

Labelling subplots

Labelling subplots is relatively straightforward, and varies, so Matplotlib does not have a general method for doing this.

We showcase two methods to position text at a given physical offset (in fontsize units or in points) away from a corner of the Axes: one using *annotate*, and one using *ScaledTranslation*.

For convenience, this example uses *pyplot.subplot_mosaic* and subplot labels as keys for the subplots. However, the approach also works with *pyplot.subplots* or keys that are different from what you want to label the subplot with.

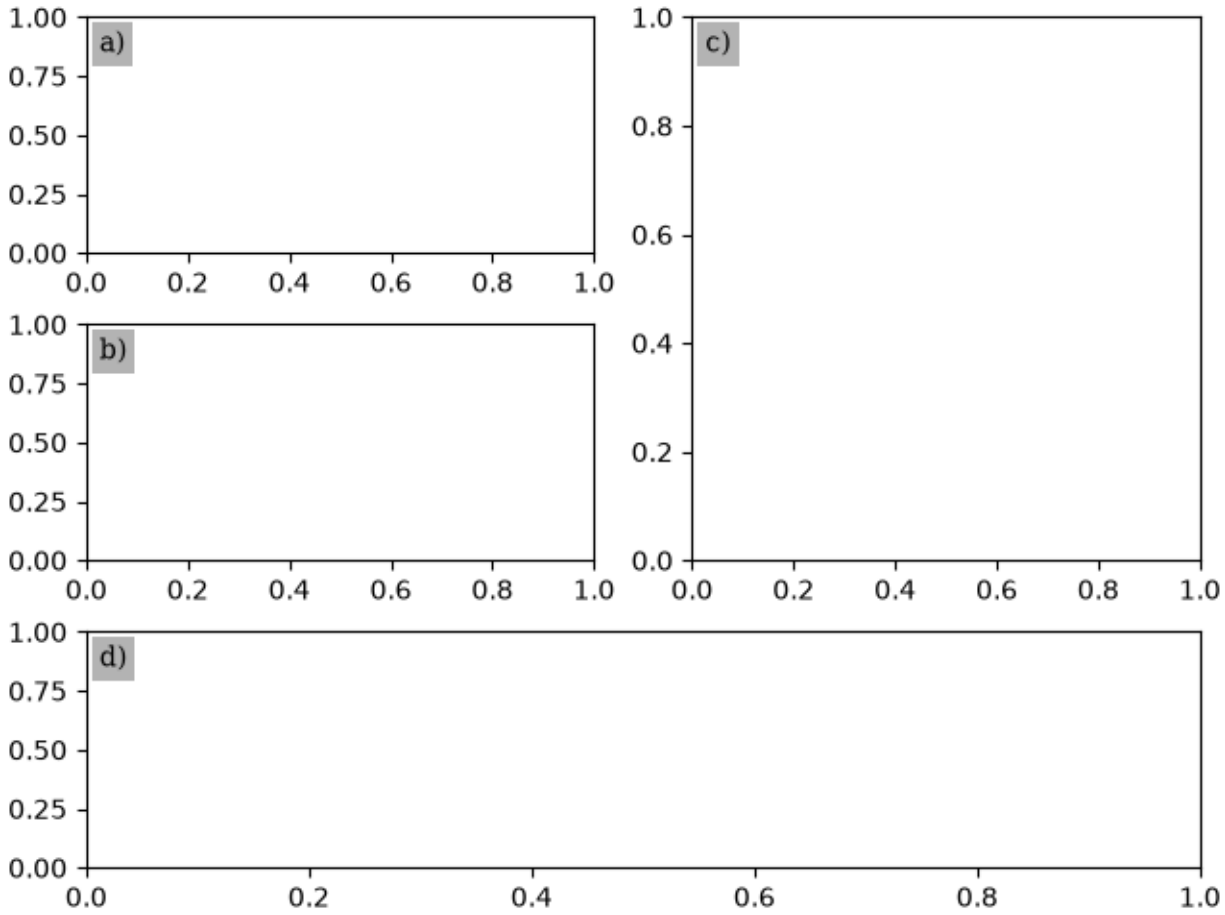
```
import matplotlib.pyplot as plt

from matplotlib.transforms import ScaledTranslation
```

```
fig, axs = plt.subplot_mosaic([['a)', 'c)'], ['b)', 'c)'], ['d)', 'd)
 ↪']],
                              layout='constrained')
for label, ax in axs.items():
    # Use Axes.annotate to put the label
    # - at the top left corner (axes fraction (0, 1)),
    # - offset half-a-fontsize right and half-a-fontsize down
    #   (offset fontsize (+0.5, -0.5)),
```

(continues on next page)

(continued from previous page)

```
    # i.e. just inside the axes.
    ax.annotate(
        label,
        xy=(0, 1), xycoords='axes fraction',
        xytext=(+0.5, -0.5), textcoords='offset fontsize',
        fontsize='medium', verticalalignment='top', fontfamily='serif',
        bbox=dict(facecolor='0.7', edgecolor='none', pad=3.0))
```

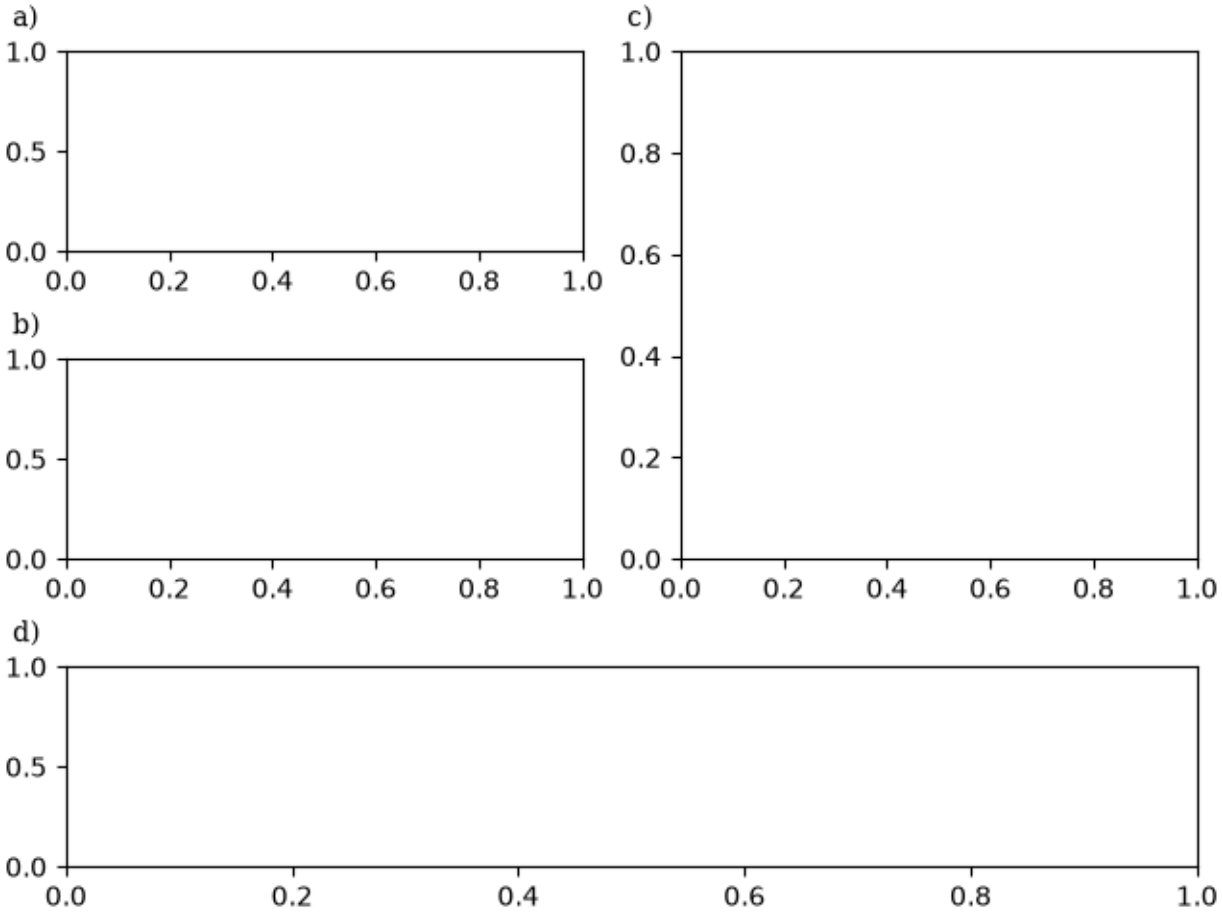



```
fig, axs = plt.subplot_mosaic([['a)', 'c)'], ['b)', 'c)'], ['d)', 'd)
↪']],
                              layout='constrained')
for label, ax in axs.items():
    # Use ScaledTranslation to put the label
    # - at the top left corner (axes fraction (0, 1)),
    # - offset 20 pixels left and 7 pixels up (offset points (-20,␣
↪+7)),
    # i.e. just outside the axes.
    ax.text(
        0.0, 1.0, label, transform=(
```

(continues on next page)

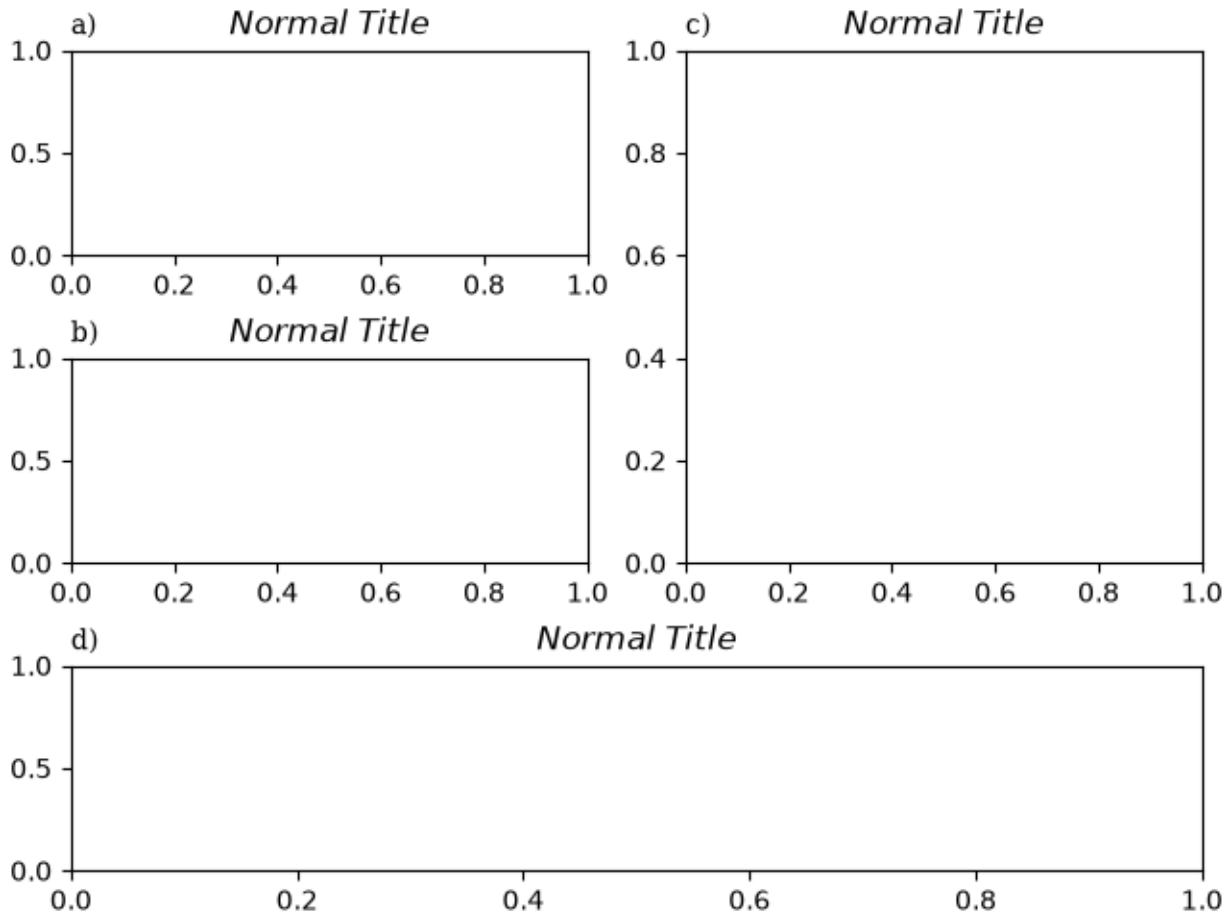
(continued from previous page)

```
            ax.transAxes + ScaledTranslation(-20/72, +7/72, fig.
↪dpi_scale_trans)),
        fontsize='medium', va='bottom', fontfamily='serif')
```



If we want it aligned with the title, either incorporate in the title or use the *loc* keyword argument:

```
fig, axs = plt.subplot_mosaic([['a)', 'c)'], ['b)', 'c)'], ['d)', 'd)
↪']],
                              layout='constrained')
for label, ax in axs.items():
    ax.set_title('Normal Title', fontstyle='italic')
    ax.set_title(label, fontfamily='serif', loc='left', fontsize=
↪'medium')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- `matplotlib.figure.Figure.subplot_mosaic` / `matplotlib.pyplot.subplot_mosaic`
- `matplotlib.axes.Axes.set_title`
- `matplotlib.axes.Axes.annotate`

Total running time of the script: (0 minutes 1.372 seconds)

Artists as annotations

`AnnotationBbox` facilitates using arbitrary artists as annotations, i.e. data at position *xy* is annotated by a box containing an artist at position *xybox*. The coordinate systems for these points are set via the *xycoords* and *boxcoords* parameters, respectively; see the *xycoords* and *textcoords* parameters of `Axes.annotate` for a full listing of supported coordinate systems. The box containing the artist is a subclass of `OffsetBox`, which is a container artist for positioning an artist relative to a parent artist.

```
from pathlib import Path

import PIL

import matplotlib.pyplot as plt
import numpy as np

from matplotlib import get_data_path
from matplotlib.offsetbox import AnnotationBbox, DrawingArea,␣
 ↪OffsetImage, TextArea
from matplotlib.patches import Annulus, Circle, ConnectionPatch
```

Text

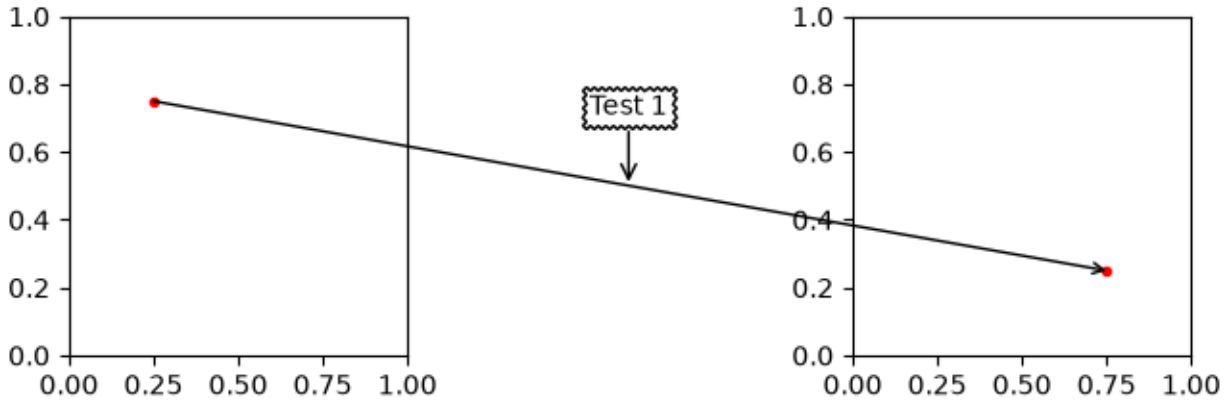
AnnotationBbox supports positioning annotations relative to data, Artists, and callables, as described in *Annotations*. The *TextArea* is used to create a textbox that is not explicitly attached to an axes, which allows it to be used for annotating figure objects. When annotating an axes element (such as a plot) with text, use *Axes.annotate* because it will create the text artist for you.

```
fig, axd = plt.subplot_mosaic([['t1', '.', 't2']], layout='compressed')

# Define a 1st position to annotate (display it with a marker)
xy1 = (.25, .75)
xy2 = (.75, .25)
axd['t1'].plot(*xy1, ".r")
axd['t2'].plot(*xy2, ".r")
axd['t1'].set(xlim=(0, 1), ylim=(0, 1), aspect='equal')
axd['t2'].set(xlim=(0, 1), ylim=(0, 1), aspect='equal')

# Draw a connection patch arrow between the points
c = ConnectionPatch(xyA=xy1, xyB=xy2,
                    coordsA=axd['t1'].transData, coordsB=axd['t2'].
 ↪transData,
                    arrowstyle='->')
fig.add_artist(c)

# Annotate the ConnectionPatch position ('Test 1')
offsetbox = TextArea("Test 1")

# place the annotation above the midpoint of c
ab1 = AnnotationBbox(offsetbox,
                     xy=(.5, .5),
                     xybox=(0, 30),
                     xycoords=c,
                     boxcoords="offset points",
                     arrowprops=dict(arrowstyle="->"),
```

(continues on next page)

(continued from previous page)

```
                      bboxprops=dict(boxstyle="sawtooth"))
fig.add_artist(ab1)
```



Images

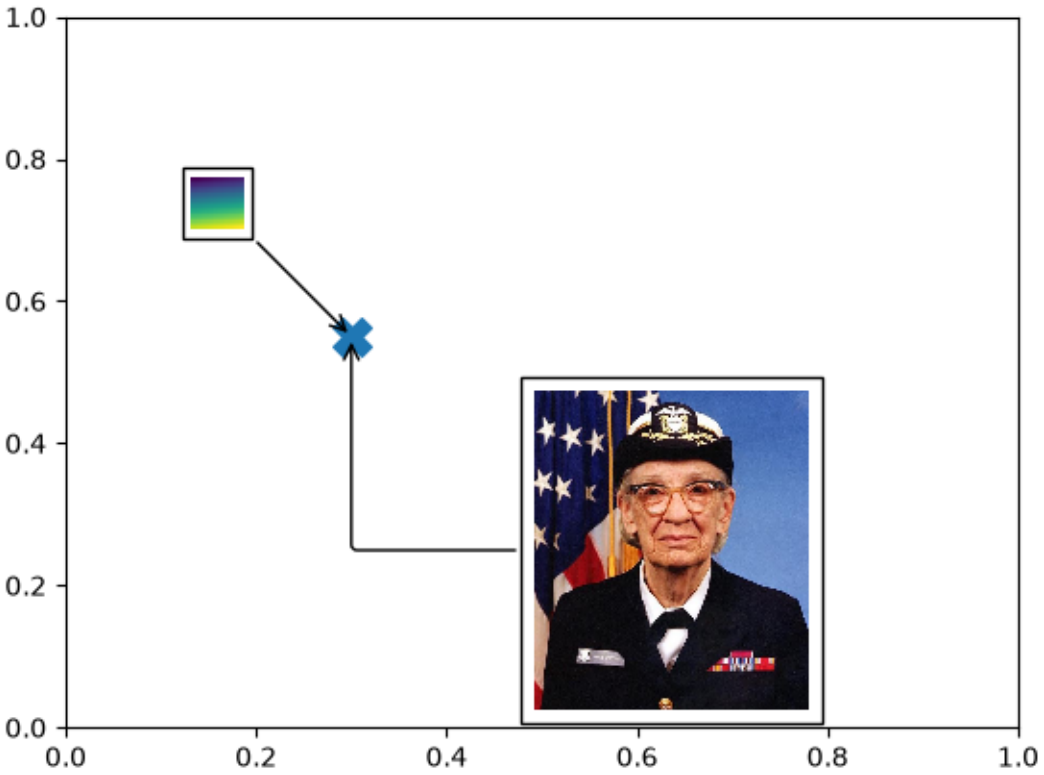
The *OffsetImage* container facilitates using images as annotations

```
fig, ax = plt.subplots()
# Define a position to annotate
xy = (0.3, 0.55)
ax.scatter(*xy, s=200, marker='X')

# Annotate a position with an image generated from an array of pixels
arr = np.arange(100).reshape((10, 10))
im = OffsetImage(arr, zoom=2, cmap='viridis')
im.image.axes = ax

# place the image NW of xy
ab = AnnotationBbox(im, xy=xy,
```

(continues on next page)

(continued from previous page)

```
                    xybox=(-50., 50.),
                    xycoords='data',
                    boxcoords="offset points",
                    pad=0.3,
                    arrowprops=dict(arrowstyle="->"))
ax.add_artist(ab)

# Annotate the position with an image from file (a Grace Hopper␣
 ↪portrait)
img_fp = Path(get_data_path(), "sample_data", "grace_hopper.jpg")
with PIL.Image.open(img_fp) as arr_img:
    imagebox = OffsetImage(arr_img, zoom=0.2)

imagebox.image.axes = ax

# place the image SE of xy
ab = AnnotationBbox(imagebox, xy=xy,
                    xybox=(120., -80.),
                    xycoords='data',
                    boxcoords="offset points",
                    pad=0.5,
                    arrowprops=dict(
                        arrowstyle="->",
                        connectionstyle="angle,angleA=0,angleB=90,rad=3
 ↪")
                    )

ax.add_artist(ab)

# Fix the display limits to see everything
ax.set(xlim=(0, 1), ylim=(0, 1))

plt.show()
```



Arbitrary Artists

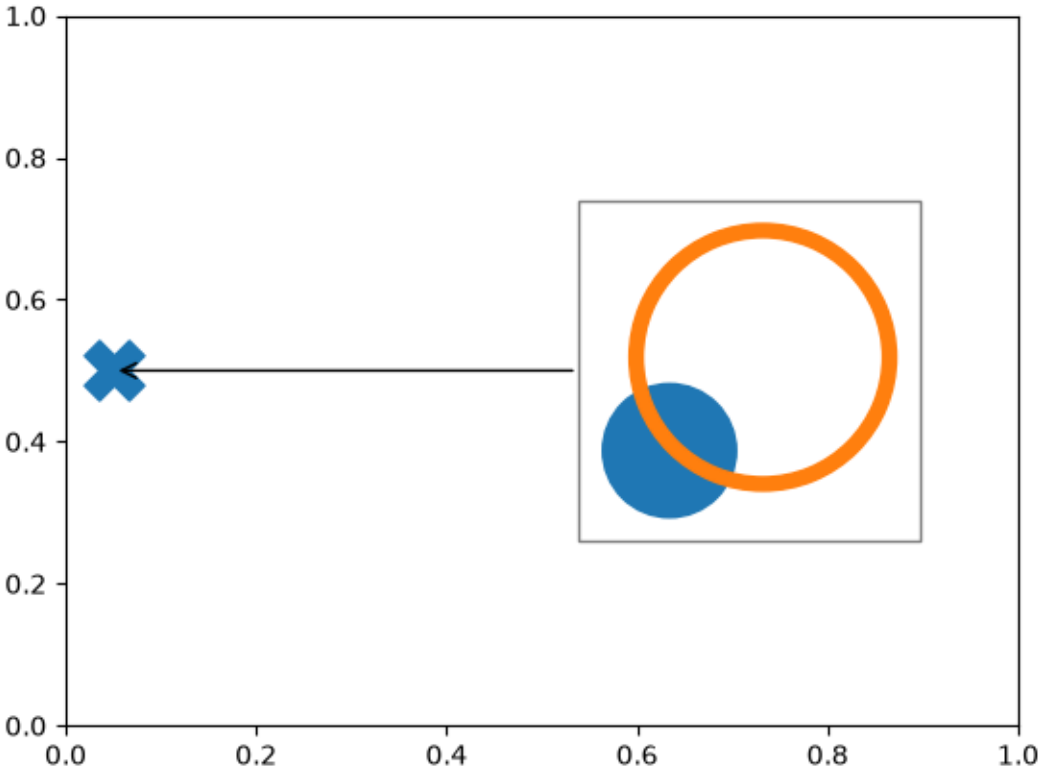
Multiple and arbitrary artists can be placed inside a *DrawingArea*.

```
# make this the thumbnail image
fig, ax = plt.subplots()

# Define a position to annotate
xy = (0.05, 0.5)
ax.scatter(*xy, s=500, marker='X')

# Annotate the position with a circle and annulus
da = DrawingArea(120, 120)
p = Circle((30, 30), 25, color='C0')
da.add_artist(p)
q = Annulus((65, 65), 50, 5, color='C1')
da.add_artist(q)


# Use the drawing area as an annotation
```

(continues on next page)

(continued from previous page)

```
ab = AnnotationBbox(da, xy=xy,
                    xybox=(.55, xy[1]),
                    xycoords='data',
                    boxcoords=("axes fraction", "data"),
                    box_alignment=(0, 0.5),
                    arrowprops=dict(arrowstyle="->"),
                    bboxprops=dict(alpha=0.5))

ax.add_artist(ab)

# Fix the display limits to see everything
ax.set(xlim=(0, 1), ylim=(0, 1))

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

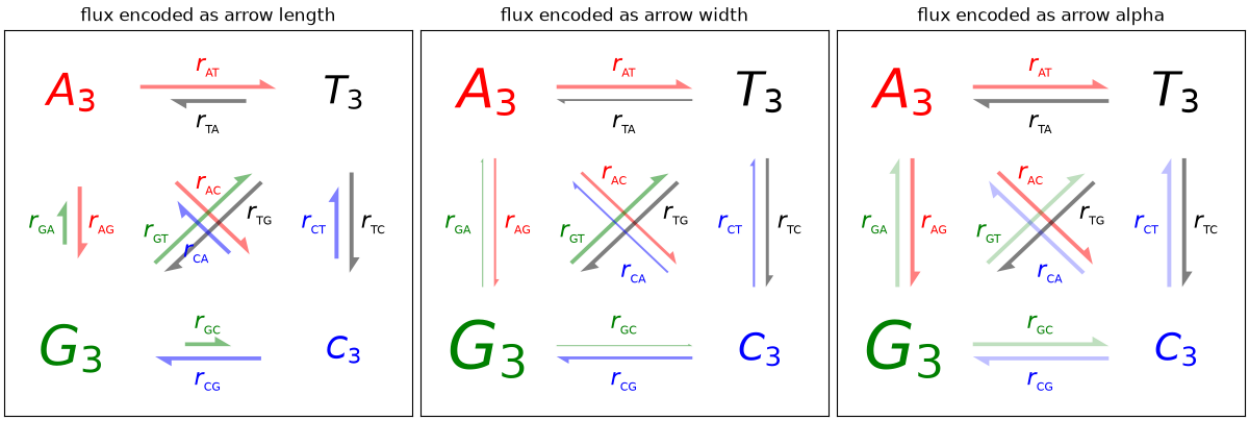
- *matplotlib.offsetbox.TextArea*

- *matplotlib.offsetbox.DrawingArea*
- *matplotlib.offsetbox.OffsetImage*
- *matplotlib.offsetbox.AnnotationBbox*

Tags: component: annotation styling: position

Arrow Demo

Three ways of drawing arrows to encode arrow "strength" (e.g., transition probabilities in a Markov model) using arrow length, width, or alpha (opacity).




```
import itertools

import matplotlib.pyplot as plt
import numpy as np


def make_arrow_graph(ax, data, size=4, display='length', shape='right',
                     max_arrow_width=0.03, arrow_sep=0.02, alpha=0.5,
                     normalize_data=False, ec=None, labelcolor=None,
                     **kwargs):
    """
    Makes an arrow plot.

    Parameters
    ----------
    ax
        The Axes where the graph is drawn.
    data
        Dict with probabilities for the bases and pair transitions.
    size
        Size of the plot, in inches.
    display : {'length', 'width', 'alpha'}
```

(continues on next page)

(continued from previous page)

```
        The arrow property to change.
    shape : {'full', 'left', 'right'}
        For full or half arrows.
    max_arrow_width : float
        Maximum width of an arrow, in data coordinates.
    arrow_sep : float
        Separation between arrows in a pair, in data coordinates.
    alpha : float
        Maximum opacity of arrows.
    **kwargs
        `.FancyArrow` properties, e.g. *linewidth* or *edgecolor*.
    """

    ax.set(xlim=(-0.25, 1.25), ylim=(-0.25, 1.25), xticks=[], yticks=[],
           title=f'flux encoded as arrow {display}')
    max_text_size = size * 12
    min_text_size = size
    label_text_size = size * 4

    bases = 'ATGC'
    coords = {
        'A': np.array([0, 1]),
        'T': np.array([1, 1]),
        'G': np.array([0, 0]),
        'C': np.array([1, 0]),
    }
    colors = {'A': 'r', 'T': 'k', 'G': 'g', 'C': 'b'}

    for base in bases:
        fontsize = np.clip(max_text_size * data[base]**(1/2),
                           min_text_size, max_text_size)
        ax.text(*coords[base], f'${base}_3$',
                color=colors[base], size=fontsize,
                horizontalalignment='center', verticalalignment='center',
                weight='bold')

    arrow_h_offset = 0.25  # data coordinates, empirically determined
    max_arrow_length = 1 - 2 * arrow_h_offset
    max_head_width = 2.5 * max_arrow_width
    max_head_length = 2 * max_arrow_width
    sf = 0.6  # max arrow size represents this in data coords

    if normalize_data:
        # find maximum value for rates, i.e. where keys are 2 chars
```

(continues on next page)

(continued from previous page)

```
↪long
        max_val = max((v for k, v in data.items() if len(k) == 2),␣
↪default=0)
        # divide rates by max val, multiply by arrow scale factor
        for k, v in data.items():
            data[k] = v / max_val * sf

    # iterate over strings 'AT', 'TA', 'AG', 'GA', etc.
    for pair in map(''.join, itertools.permutations(bases, 2)):
        # set the length of the arrow
        if display == 'length':
            length = (max_head_length
                      + data[pair] / sf * (max_arrow_length -␣
↪max_head_length))
        else:
            length = max_arrow_length
        # set the transparency of the arrow
        if display == 'alpha':
            alpha = min(data[pair] / sf, alpha)
        # set the width of the arrow
        if display == 'width':
            scale = data[pair] / sf
            width = max_arrow_width * scale
            head_width = max_head_width * scale
            head_length = max_head_length * scale
        else:
            width = max_arrow_width
            head_width = max_head_width
            head_length = max_head_length

        fc = colors[pair[0]]

        cp0 = coords[pair[0]]
        cp1 = coords[pair[1]]
        # unit vector in arrow direction
        delta = cos, sin = (cp1 - cp0) / np.hypot(*(cp1 - cp0))
        x_pos, y_pos = (
            (cp0 + cp1) / 2  # midpoint
            - delta * length / 2  # half the arrow length
            + np.array([-sin, cos]) * arrow_sep  # shift outwards by␣
↪arrow_sep
        )
        ax.arrow(
            x_pos, y_pos, cos * length, sin * length,
            fc=fc, ec=ec or fc, alpha=alpha, width=width,
            head_width=head_width, head_length=head_length,␣
```

(continues on next page)

(continued from previous page)

```
↪shape=shape,
            length_includes_head=True,
            **kwargs
        )

        # figure out coordinates for text:
        # if drawing relative to base: x and y are same as for arrow
        # dx and dy are one arrow width left and up
        orig_positions = {
            'base': [3 * max_arrow_width, 3 * max_arrow_width],
            'center': [length / 2, 3 * max_arrow_width],
            'tip': [length - 3 * max_arrow_width, 3 * max_arrow_width],
        }
        # for diagonal arrows, put the label at the arrow base
        # for vertical or horizontal arrows, center the label
        where = 'base' if (cp0 != cp1).all() else 'center'
        # rotate based on direction of arrow (cos, sin)
        M = [[cos, -sin], [sin, cos]]
        x, y = np.dot(M, orig_positions[where]) + [x_pos, y_pos]
        label = r'$r_{_{\mathrm{%s}}}$' % (pair,)
        ax.text(x, y, label, size=label_text_size, ha='center', va=
↪'center',
                color=labelcolor or fc)


if __name__ == '__main__':
    data = {  # test data
        'A': 0.4, 'T': 0.3, 'G': 0.6, 'C': 0.2,
        'AT': 0.4, 'AC': 0.3, 'AG': 0.2,
        'TA': 0.2, 'TC': 0.3, 'TG': 0.4,
        'CT': 0.2, 'CG': 0.3, 'CA': 0.2,
        'GA': 0.1, 'GT': 0.4, 'GC': 0.1,
    }

    size = 4
    fig = plt.figure(figsize=(3 * size, size), layout="constrained")
    axs = fig.subplot_mosaic([["length", "width", "alpha"]])

    for display, ax in axs.items():
        make_arrow_graph(
            ax, data, display=display, linewidth=0.001, edgecolor=None,
            normalize_data=True, size=size)

    plt.show()
```

Scale invariant angle label

This example shows how to create a scale invariant angle annotation. It is often useful to mark angles between lines or inside shapes with a circular arc. While Matplotlib provides an *Arc*, an inherent problem when directly using it for such purposes is that an arc being circular in data space is not necessarily circular in display space. Also, the arc's radius is often best defined in a coordinate system which is independent of the actual data coordinates - at least if you want to be able to freely zoom into your plot without the annotation growing to infinity.

This calls for a solution where the arc's center is defined in data space, but its radius in a physical unit like points or pixels, or as a ratio of the Axes dimension. The following `AngleAnnotation` class provides such solution.

The example below serves two purposes:

- It provides a ready-to-use solution for the problem of easily drawing angles in graphs.
- It shows how to subclass a Matplotlib artist to enhance its functionality, as well as giving a hands-on example on how to use Matplotlib's *transform system*.

If mainly interested in the former, you may copy the below class and jump to the *Usage* section.

AngleAnnotation class

The essential idea here is to subclass *Arc* and set its transform to the *IdentityTransform*, making the parameters of the arc defined in pixel space. We then override the `Arc`'s attributes `_center`, `theta1`, `theta2`, `width` and `height` and make them properties, coupling to internal methods that calculate the respective parameters each time the attribute is accessed and thereby ensuring that the arc in pixel space stays synchronized with the input points and size. For example, each time the arc's drawing method would query its `_center` attribute, instead of receiving the same number all over again, it will instead receive the result of the `get_center_in_pixels` method we defined in the subclass. This method transforms the center in data coordinates to pixels via the Axes transform `ax.transData`. The size and the angles are calculated in a similar fashion, such that the arc changes its shape automatically when e.g. zooming or panning interactively.

The functionality of this class allows to annotate the arc with a text. This text is a *Annotation* stored in an attribute `text`. Since the arc's position and radius are defined only at draw time, we need to update the text's position accordingly. This is done by reimplementing the `Arc`'s `draw()` method to let it call an updating method for the text.

The arc and the text will be added to the provided Axes at instantiation: it is hence not strictly necessary to keep a reference to it.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Arc
from matplotlib.transforms import Bbox, IdentityTransform,␣
 ↪TransformedBbox
```

(continues on next page)

(continued from previous page)

```
class AngleAnnotation(Arc):
    """
    Draws an arc between two vectors which appears circular in display␣
↪space.
    """
    def __init__(self, xy, p1, p2, size=75, unit="points", ax=None,
                 text="", textposition="inside", text_kw=None,␣
↪**kwargs):
        """
        Parameters
        ----------
        xy, p1, p2 : tuple or array of two floats
            Center position and two points. Angle annotation is drawn␣
↪between
            the two vectors connecting *p1* and *p2* with *xy*,␣
↪respectively.
            Units are data coordinates.

        size : float
            Diameter of the angle annotation in units specified by␣
↪*unit*.

        unit : str
            One of the following strings to specify the unit of *size*:

            * "pixels": pixels
            * "points": points, use points instead of pixels to not␣
↪have a
              dependence on the DPI
            * "axes width", "axes height": relative units of Axes␣
↪width, height
            * "axes min", "axes max": minimum or maximum of relative␣
↪Axes
              width, height

        ax : `matplotlib.axes.Axes`
            The Axes to add the angle annotation to.

        text : str
            The text to mark the angle with.

        textposition : {"inside", "outside", "edge"}
            Whether to show the text in- or outside the arc. "edge"␣
↪can be used
            for custom positions anchored at the arc's edge.
```

(continues on next page)

(continued from previous page)

```
        text_kw : dict
            Dictionary of arguments passed to the Annotation.

        **kwargs
            Further parameters are passed to `matplotlib.patches.Arc`. Use this
            to specify, color, linewidth etc. of the arc.

        """
        self.ax = ax or plt.gca()
        self._xydata = xy  # in data coordinates
        self.vec1 = p1
        self.vec2 = p2
        self.size = size
        self.unit = unit
        self.textposition = textposition

        super().__init__(self._xydata, size, size, angle=0.0,
                         theta1=self.theta1, theta2=self.theta2, **kwargs)

        self.set_transform(IdentityTransform())
        self.ax.add_patch(self)

        self.kw = dict(ha="center", va="center",
                       xycoords=IdentityTransform(),
                       xytext=(0, 0), textcoords="offset points",
                       annotation_clip=True)
        self.kw.update(text_kw or {})
        self.text = ax.annotate(text, xy=self._center, **self.kw)

    def get_size(self):
        factor = 1.
        if self.unit == "points":
            factor = self.ax.figure.dpi / 72.
        elif self.unit[:4] == "axes":
            b = TransformedBbox(Bbox.unit(), self.ax.transAxes)
            dic = {"max": max(b.width, b.height),
                   "min": min(b.width, b.height),
                   "width": b.width, "height": b.height}
            factor = dic[self.unit[5:]]
        return self.size * factor

    def set_size(self, size):
        self.size = size
```

(continues on next page)

(continued from previous page)

```
    def get_center_in_pixels(self):
        """return center in pixels"""
        return self.ax.transData.transform(self._xydata)

    def set_center(self, xy):
        """set center in data coordinates"""
        self._xydata = xy

    def get_theta(self, vec):
        vec_in_pixels = self.ax.transData.transform(vec) - self._center
        return np.rad2deg(np.arctan2(vec_in_pixels[1],␣
↪vec_in_pixels[0]))

    def get_theta1(self):
        return self.get_theta(self.vec1)

    def get_theta2(self):
        return self.get_theta(self.vec2)

    def set_theta(self, angle):
        pass

    # Redefine attributes of the Arc to always give values in pixel␣
↪space
    _center = property(get_center_in_pixels, set_center)
    theta1 = property(get_theta1, set_theta)
    theta2 = property(get_theta2, set_theta)
    width = property(get_size, set_size)
    height = property(get_size, set_size)

    # The following two methods are needed to update the text position.
    def draw(self, renderer):
        self.update_text()
        super().draw(renderer)

    def update_text(self):
        c = self._center
        s = self.get_size()
        angle_span = (self.theta2 - self.theta1) % 360
        angle = np.deg2rad(self.theta1 + angle_span / 2)
        r = s / 2
        if self.textposition == "inside":
            r = s / np.interp(angle_span, [60, 90, 135, 180],
                                          [3.3, 3.5, 3.8, 4])
        self.text.xy = c + r * np.array([np.cos(angle), np.sin(angle)])
        if self.textposition == "outside":
```

(continues on next page)

(continued from previous page)

```
            def R90(a, r, w, h):
                if a < np.arctan(h/2/(r+w/2)):
                    return np.sqrt((r+w/2)**2 + (np.tan(a)*(r+w/2))**2)
                else:
                    c = np.sqrt((w/2)**2+(h/2)**2)
                    T = np.arcsin(c * np.cos(np.pi/2 - a + np.arcsin(h/
↪2/c))/r)
                    xy = r * np.array([np.cos(a + T), np.sin(a + T)])
                    xy += np.array([w/2, h/2])
                    return np.sqrt(np.sum(xy**2))

            def R(a, r, w, h):
                aa = (a % (np.pi/4))*((a % (np.pi/2)) <= np.pi/4) + \
                     (np.pi/4 - (a % (np.pi/4)))*((a % (np.pi/2)) >=␣
↪np.pi/4)
                return R90(aa, r, *[w, h][::int(np.sign(np.cos(2*a)))])

            bbox = self.text.get_window_extent()
            X = R(angle, r, bbox.width, bbox.height)
            trans = self.ax.figure.dpi_scale_trans.inverted()
            offs = trans.transform(((X-s/2), 0))[0] * 72
            self.text.set_position([offs*np.cos(angle), offs*np.
↪sin(angle)])
```

Usage

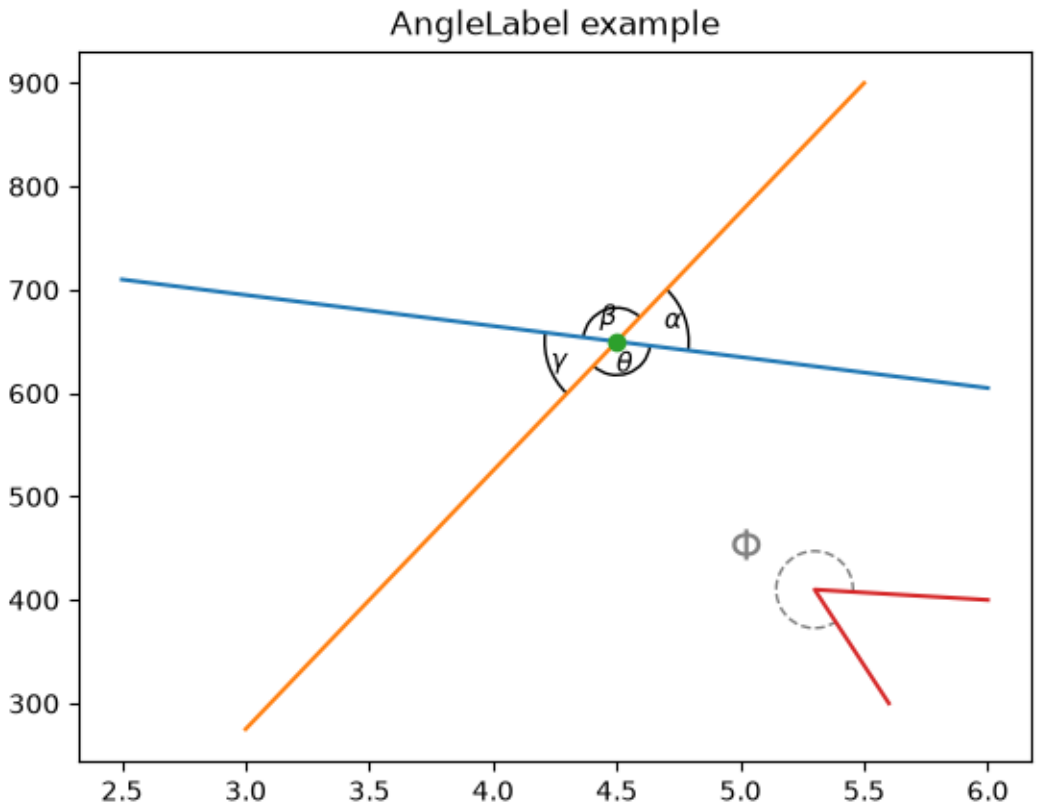
Required arguments to `AngleAnnotation` are the center of the arc, *xy*, and two points, such that the arc spans between the two vectors connecting *p1* and *p2* with *xy*, respectively. Those are given in data coordinates. Further arguments are the *size* of the arc and its *unit*. Additionally, a *text* can be specified, that will be drawn either in- or outside of the arc, according to the value of *textposition*. Usage of those arguments is shown below.

```
fig, ax = plt.subplots()
fig.canvas.draw()  # Need to draw the figure to define renderer
ax.set_title("AngleLabel example")

# Plot two crossing lines and label each angle between them with the␣
↪above
# ``AngleAnnotation`` tool.
center = (4.5, 650)
p1 = [(2.5, 710), (6.0, 605)]
p2 = [(3.0, 275), (5.5, 900)]
line1, = ax.plot(*zip(*p1))
line2, = ax.plot(*zip(*p2))
point, = ax.plot(*center, marker="o")
```

(continues on next page)

(continued from previous page)

```
am1 = AngleAnnotation(center, p1[1], p2[1], ax=ax, size=75, text=r"$\
 ↪alpha$")
am2 = AngleAnnotation(center, p2[1], p1[0], ax=ax, size=35, text=r"$\
 ↪beta$")
am3 = AngleAnnotation(center, p1[0], p2[0], ax=ax, size=75, text=r"$\
 ↪gamma$")
am4 = AngleAnnotation(center, p2[0], p1[1], ax=ax, size=35, text=r"$\
 ↪theta$")


# Showcase some styling options for the angle arc, as well as the text.
p = [(6.0, 400), (5.3, 410), (5.6, 300)]
ax.plot(*zip(*p))
am5 = AngleAnnotation(p[1], p[0], p[2], ax=ax, size=40, text=r"$\Phi$",
                      linestyle="--", color="gray", textposition=
 ↪"outside",
                      text_kw=dict(fontsize=16, color="gray"))
```



`AngleLabel` options

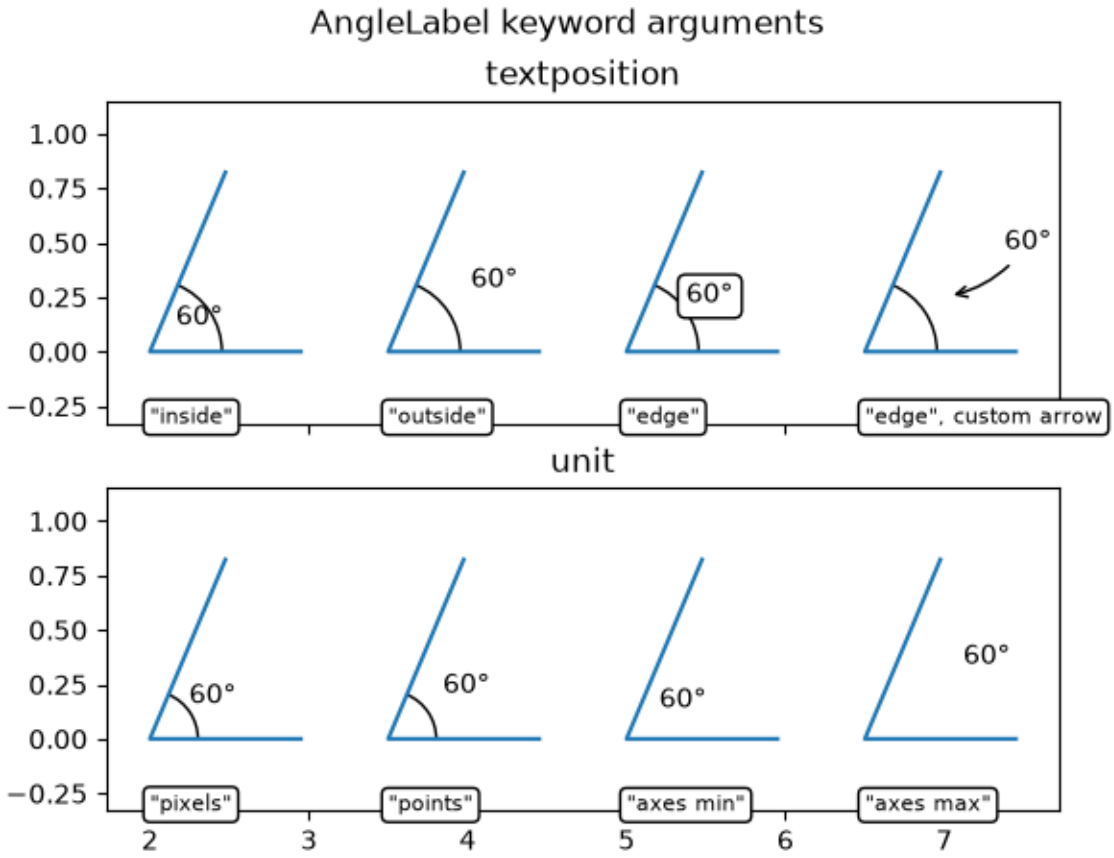
The *textposition* and *unit* keyword arguments may be used to modify the location of the text label, as shown below:

```
# Helper function to draw angle easily.
def plot_angle(ax, pos, angle, length=0.95, acol="C0", **kwargs):
    vec2 = np.array([np.cos(np.deg2rad(angle)), np.sin(np.
 ↪deg2rad(angle))])
    xy = np.c_[[length, 0], [0, 0], vec2*length].T + np.array(pos)
    ax.plot(*xy.T, color=acol)
    return AngleAnnotation(pos, xy[0], xy[2], ax=ax, **kwargs)


fig, (ax1, ax2) = plt.subplots(nrows=2, sharex=True)
fig.suptitle("AngleLabel keyword arguments")
fig.canvas.draw()  # Need to draw the figure to define renderer

# Showcase different text positions.
ax1.margins(y=0.4)
ax1.set_title("textposition")
kw = dict(size=75, unit="points", text=r"$60°$")

am6 = plot_angle(ax1, (2.0, 0), 60, textposition="inside", **kw)
am7 = plot_angle(ax1, (3.5, 0), 60, textposition="outside", **kw)
am8 = plot_angle(ax1, (5.0, 0), 60, textposition="edge",
                 text_kw=dict(bbox=dict(boxstyle="round", fc="w")),␣
 ↪**kw)
am9 = plot_angle(ax1, (6.5, 0), 60, textposition="edge",
                 text_kw=dict(xytext=(30, 20),␣
 ↪arrowprops=dict(arrowstyle="->",
                                  connectionstyle="arc3,rad=-0.2")), **kw)

for x, text in zip([2.0, 3.5, 5.0, 6.5], ['"inside"', '"outside"', '
 ↪"edge"',
                                           '"edge", custom arrow']):
    ax1.annotate(text, xy=(x, 0), xycoords=ax1.get_xaxis_transform(),
                 bbox=dict(boxstyle="round", fc="w"), ha="left",␣
 ↪fontsize=8,
                 annotation_clip=True)

# Showcase different size units. The effect of this can best be␣
 ↪observed
# by interactively changing the figure size
ax2.margins(y=0.4)
ax2.set_title("unit")
kw = dict(text=r"$60°$", textposition="outside")
```

(continues on next page)

(continued from previous page)

```
am10 = plot_angle(ax2, (2.0, 0), 60, size=50, unit="pixels", **kw)
am11 = plot_angle(ax2, (3.5, 0), 60, size=50, unit="points", **kw)
am12 = plot_angle(ax2, (5.0, 0), 60, size=0.25, unit="axes min", **kw)
am13 = plot_angle(ax2, (6.5, 0), 60, size=0.25, unit="axes max", **kw)

for x, text in zip([2.0, 3.5, 5.0, 6.5], ['"pixels"', '"points"',
                                          '"axes min"', '"axes max"']):
    ax2.annotate(text, xy=(x, 0), xycoords=ax2.get_xaxis_transform(),
                 bbox=dict(boxstyle="round", fc="w"), ha="left",␣
 ↪fontsize=8,
                 annotation_clip=True)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches.Arc*

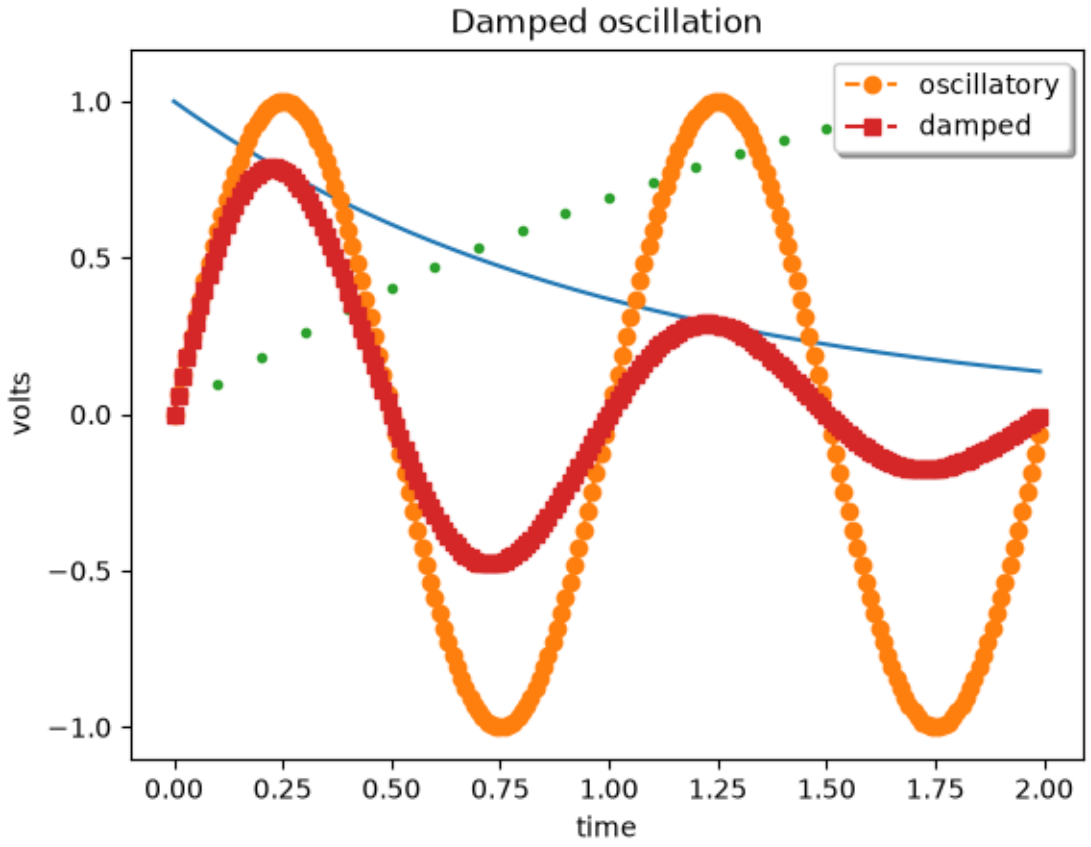
- *matplotlib.axes.Axes.annotate* / *matplotlib.pyplot.annotate*
- *matplotlib.text.Annotation*
- *matplotlib.transforms.IdentityTransform*
- *matplotlib.transforms.TransformedBbox*
- *matplotlib.transforms.Bbox*

Legend Demo

There are many ways to create and customize legends in Matplotlib. Below we'll show a few examples for how to do so.

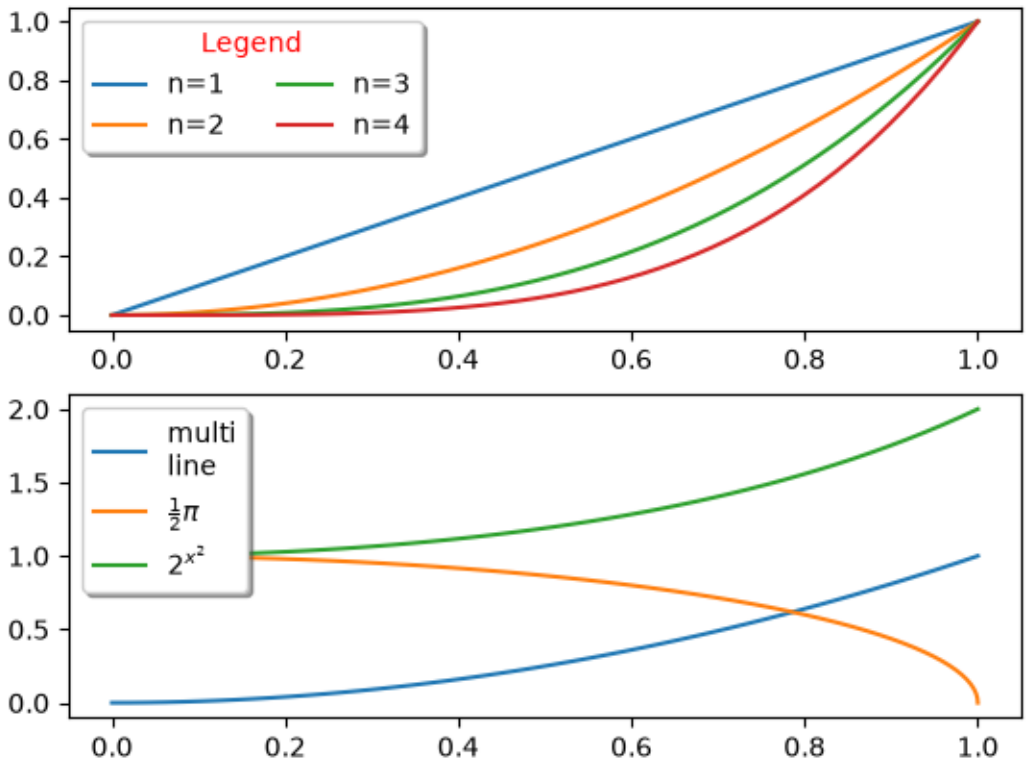
First we'll show off how to make a legend for specific lines.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.collections as mcol
from matplotlib.legend_handler import HandlerLineCollection,␣
 ↪HandlerTuple
from matplotlib.lines import Line2D

t1 = np.arange(0.0, 2.0, 0.1)
t2 = np.arange(0.0, 2.0, 0.01)

fig, ax = plt.subplots()

# note that plot returns a list of lines.  The "l1, = plot" usage
# extracts the first element of the list into l1 using tuple
# unpacking.  So l1 is a Line2D instance, not a sequence of lines
l1, = ax.plot(t2, np.exp(-t2))
l2, l3 = ax.plot(t2, np.sin(2 * np.pi * t2), '--o', t1, np.log(1 +␣
 ↪t1), '.')
l4, = ax.plot(t2, np.exp(-t2) * np.sin(2 * np.pi * t2), 's-.')

ax.legend((l2, l4), ('oscillatory', 'damped'), loc='upper right',␣
 ↪shadow=True)
ax.set_xlabel('time')
ax.set_ylabel('volts')
ax.set_title('Damped oscillation')
plt.show()
```



Next we'll demonstrate plotting more complex labels.

```
x = np.linspace(0, 1)

fig, (ax0, ax1) = plt.subplots(2, 1)

# Plot the lines y=x**n for n=1..4.
for n in range(1, 5):
    ax0.plot(x, x**n, label=f"{n=}")
leg = ax0.legend(loc="upper left", bbox_to_anchor=[0, 1],
                 ncols=2, shadow=True, title="Legend", fancybox=True)
leg.get_title().set_color("red")

# Demonstrate some more complex labels.
ax1.plot(x, x**2, label="multi\nline")
half_pi = np.linspace(0, np.pi / 2)
ax1.plot(np.sin(half_pi), np.cos(half_pi), label=r"$\frac{1}{2}\pi$")
ax1.plot(x, 2**(x**2), label="$2^{x^2}$")
ax1.legend(shadow=True, fancybox=True)

plt.show()
```



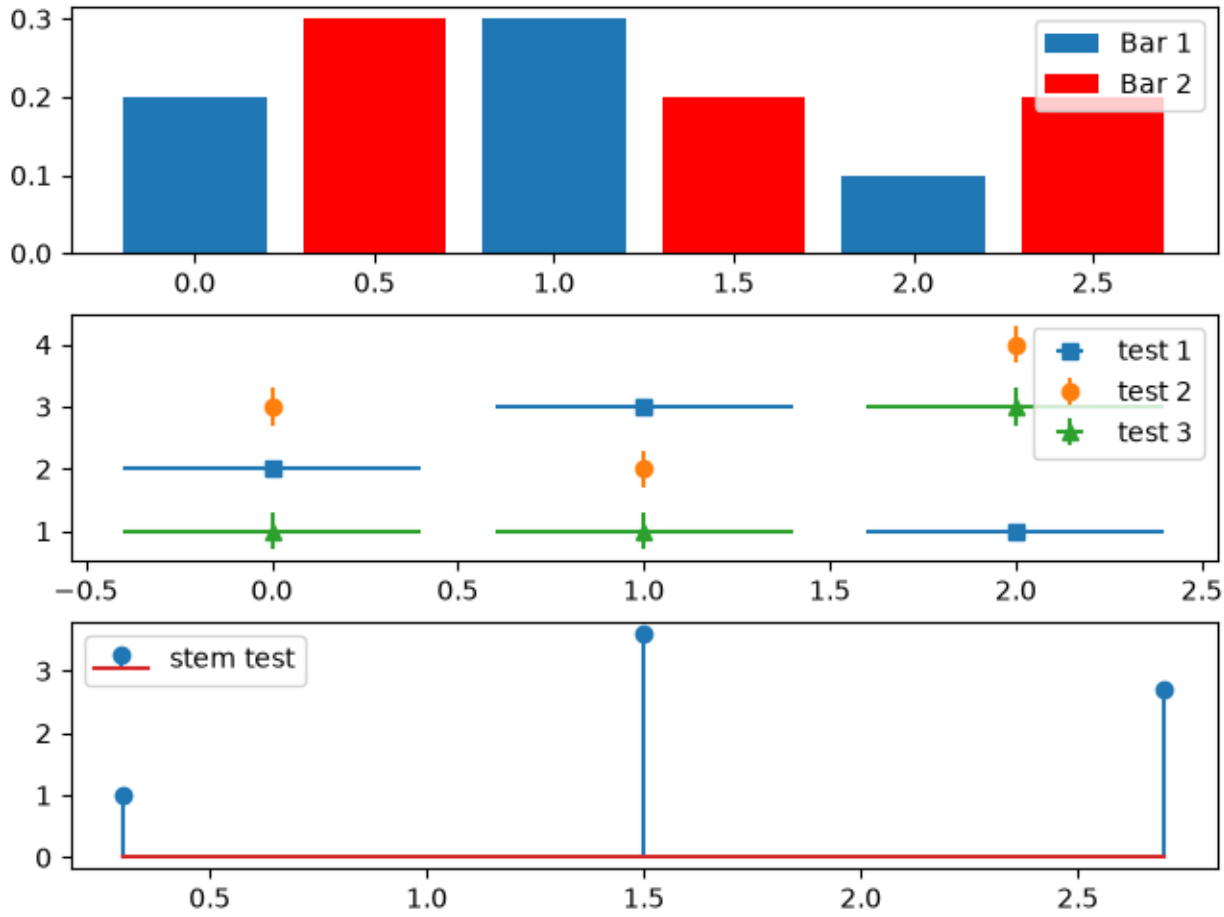
Here we attach legends to more complex plots.

```
fig, axs = plt.subplots(3, 1, layout="constrained")
top_ax, middle_ax, bottom_ax = axs

top_ax.bar([0, 1, 2], [0.2, 0.3, 0.1], width=0.4, label="Bar 1",
           align="center")
top_ax.bar([0.5, 1.5, 2.5], [0.3, 0.2, 0.2], color="red", width=0.4,
           label="Bar 2", align="center")
top_ax.legend()

middle_ax.errorbar([0, 1, 2], [2, 3, 1], xerr=0.4, fmt="s", label=
 ↪"test 1")
middle_ax.errorbar([0, 1, 2], [3, 2, 4], yerr=0.3, fmt="o", label=
 ↪"test 2")
middle_ax.errorbar([0, 1, 2], [1, 1, 3], xerr=0.4, yerr=0.3, fmt="^",
                   label="test 3")
middle_ax.legend()

bottom_ax.stem([0.3, 1.5, 2.7], [1, 3.6, 2.7], label="stem test")
bottom_ax.legend()
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



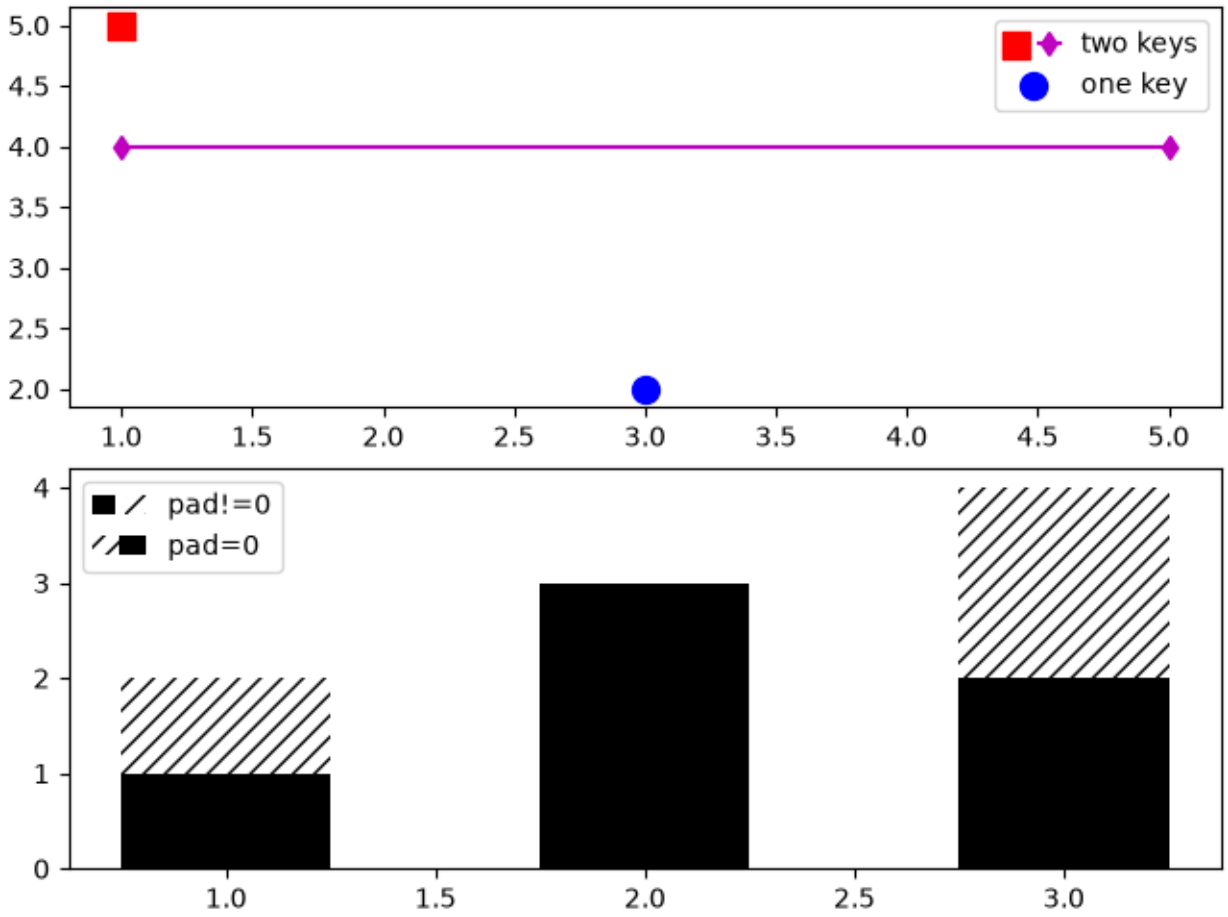
Now we'll showcase legend entries with more than one legend key.

```
fig, (ax1, ax2) = plt.subplots(2, 1, layout='constrained')

# First plot: two legend keys for a single entry
p1 = ax1.scatter([1], [5], c='r', marker='s', s=100)
p2 = ax1.scatter([3], [2], c='b', marker='o', s=100)
# `plot` returns a list, but we want the handle - thus the comma on␣
 ↪the left
p3, = ax1.plot([1, 5], [4, 4], 'm-d')

# Assign two of the handles to the same legend entry by putting them␣
 ↪in a tuple
# and using a generic handler map (which would be used for any␣
 ↪additional
# tuples of handles like (p1, p3)).
l = ax1.legend([(p1, p3), p2], ['two keys', 'one key'],␣
```

(continues on next page)

(continued from previous page)

```
 ↪scatterpoints=1,
                numpoints=1, handler_map={tuple:␣
 ↪HandlerTuple(ndivide=None)})

# Second plot: plot two bar charts on top of each other and change the␣
 ↪padding
# between the legend keys
x_left = [1, 2, 3]
y_pos = [1, 3, 2]
y_neg = [2, 1, 4]

rneg = ax2.bar(x_left, y_neg, width=0.5, color='w', hatch='///', label=
 ↪'-1')
rpos = ax2.bar(x_left, y_pos, width=0.5, color='k', label='+1')

# Treat each legend entry differently by using specific `HandlerTuple`s
l = ax2.legend([(rpos, rneg), (rneg, rpos)], ['pad!=0', 'pad=0'],
                handler_map={(rpos, rneg): HandlerTuple(ndivide=None),
                             (rneg, rpos): HandlerTuple(ndivide=None,␣
 ↪pad=0.)})
plt.show()
```



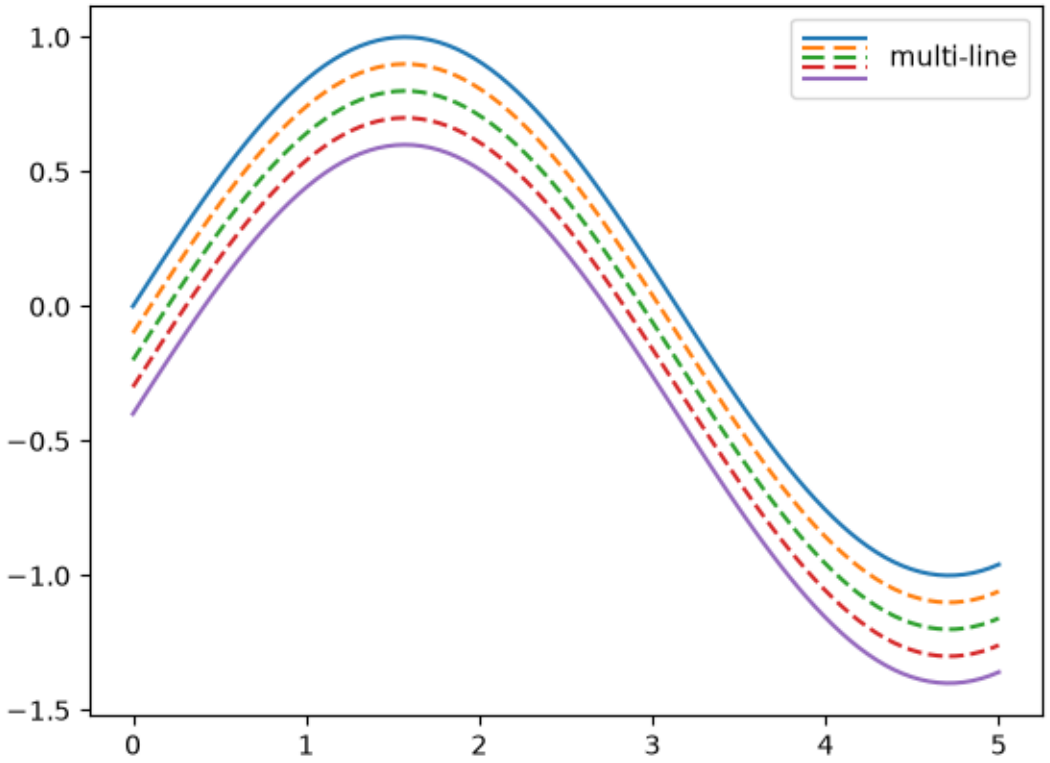
Finally, it is also possible to write custom classes that define how to stylize legends.

```
class HandlerDashedLines(HandlerLineCollection):
    """
    Custom Handler for LineCollection instances.
    """
    def create_artists(self, legend, orig_handle,
                       xdescent, ydescent, width, height, fontsize,␣
↪trans):
        # figure out how many lines there are
        numlines = len(orig_handle.get_segments())
        xdata, xdata_marker = self.get_xdata(legend, xdescent,␣
↪ydescent,
                                             width, height, fontsize)
        leglines = []
        # divide the vertical space where the lines will go
        # into equal parts based on the number of lines
        ydata = np.full_like(xdata, height / (numlines + 1))
        # for each line, create the line at the proper location
        # and set the dash pattern
        for i in range(numlines):
```

(continues on next page)

(continued from previous page)

```
            legline = Line2D(xdata, ydata * (numlines - i) - ydescent)
            self.update_prop(legline, orig_handle, legend)
            # set color, dash pattern, and linewidth to that
            # of the lines in linecollection
            try:
                color = orig_handle.get_colors()[i]
            except IndexError:
                color = orig_handle.get_colors()[0]
            try:
                dashes = orig_handle.get_dashes()[i]
            except IndexError:
                dashes = orig_handle.get_dashes()[0]
            try:
                lw = orig_handle.get_linewidths()[i]
            except IndexError:
                lw = orig_handle.get_linewidths()[0]
            if dashes[1] is not None:
                legline.set_dashes(dashes[1])
            legline.set_color(color)
            legline.set_transform(trans)
            legline.set_linewidth(lw)
            leglines.append(legline)
        return leglines

x = np.linspace(0, 5, 100)

fig, ax = plt.subplots()
colors = plt.rcParams['axes.prop_cycle'].by_key()['color'][:5]
styles = ['solid', 'dashed', 'dashed', 'dashed', 'solid']
for i, color, style in zip(range(5), colors, styles):
    ax.plot(x, np.sin(x) - .1 * i, c=color, ls=style)

# make proxy artists
# make list of one line -- doesn't matter what the coordinates are
line = [[(0, 0)]]
# set up the proxy artist
lc = mcol.LineCollection(5 * line, linestyles=styles, colors=colors)
# create the legend
ax.legend([lc], ['multi-line'], handler_map={type(lc):␣
 ↪HandlerDashedLines()},
          handlelength=2.5, handleheight=3)

plt.show()
```



See also

The *Legend guide* contains an in depth discussion on the configuration options for legends.

Total running time of the script: (0 minutes 1.621 seconds)

Legend using pre-defined labels

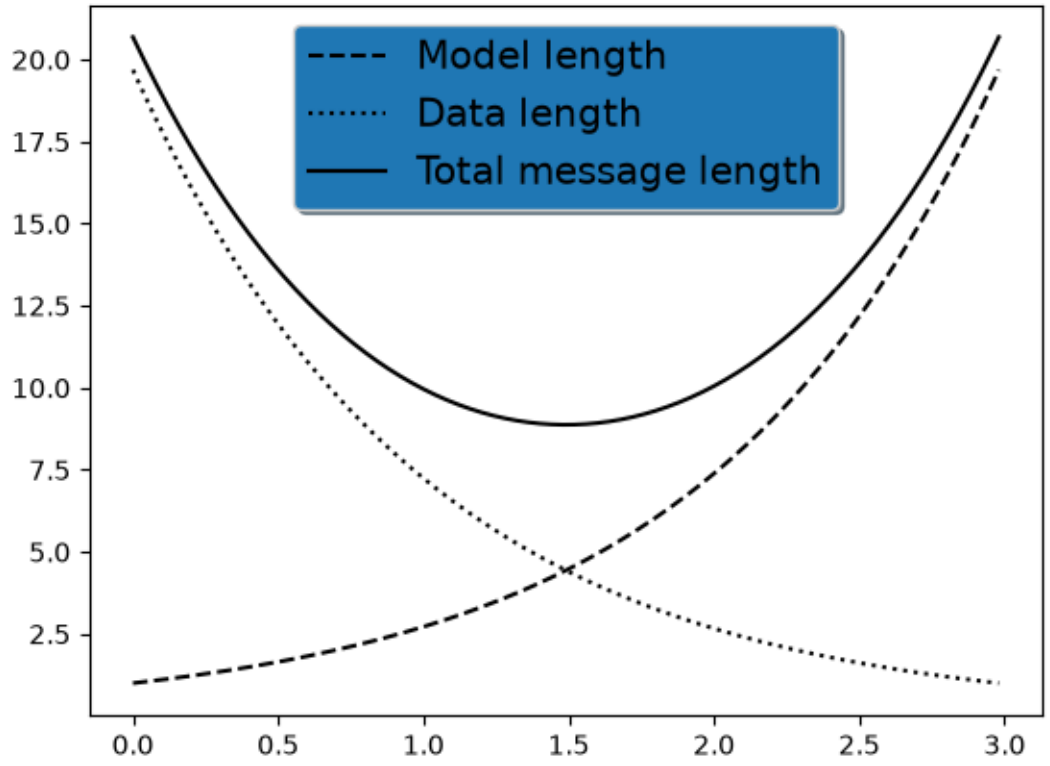
Defining legend labels with plots.

```
import matplotlib.pyplot as plt
import numpy as np

# Make some fake data.
a = b = np.arange(0, 3, .02)
c = np.exp(a)
d = c[::-1]

# Create plots with pre-defined labels.
fig, ax = plt.subplots()
```

(continues on next page)

(continued from previous page)

```
ax.plot(a, c, 'k--', label='Model length')
ax.plot(a, d, 'k:', label='Data length')
ax.plot(a, c + d, 'k', label='Total message length')

legend = ax.legend(loc='upper center', shadow=True, fontsize='x-large')

# Put a nicer background color on the legend.
legend.get_frame().set_facecolor('C0')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.plot* / *matplotlib.pyplot.plot*
- *matplotlib.axes.Axes.legend* / *matplotlib.pyplot.legend*

See also

The *Legend guide* contains an in depth discussion on the configuration options for legends.

Compose custom legends

Composing custom legends piece-by-piece.

Note

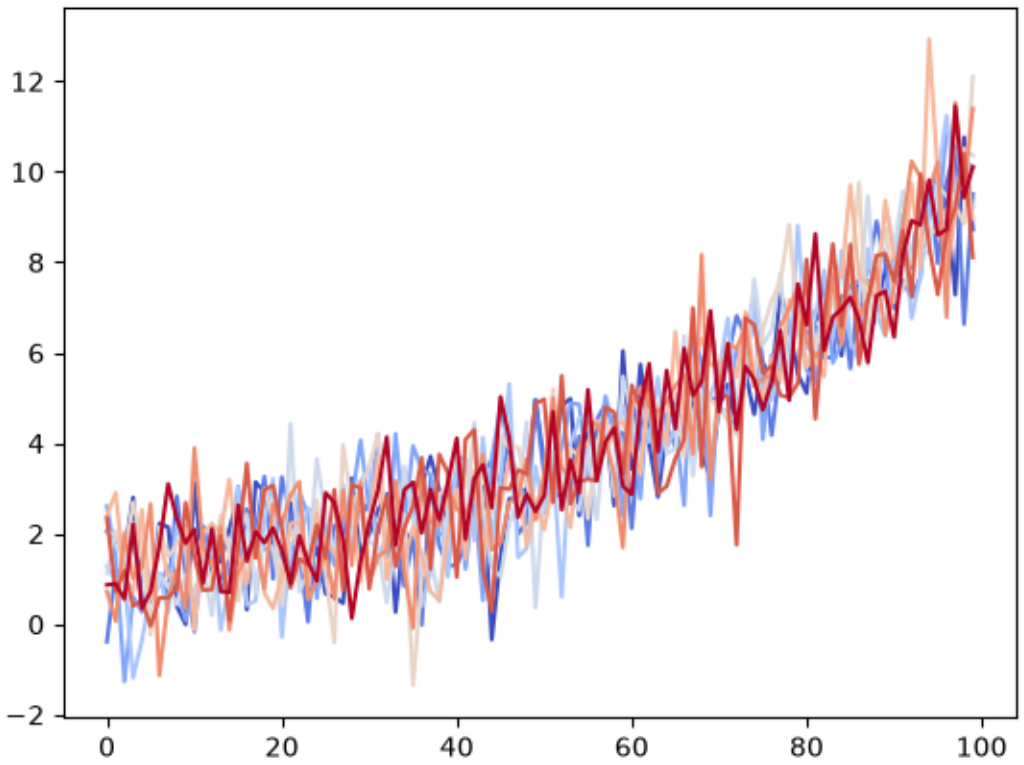
For more information on creating and customizing legends, see the following pages:

- *Legend guide*
- *Legend Demo*

Sometimes you don't want a legend that is explicitly tied to data that you have plotted. For example, say you have plotted 10 lines, but don't want a legend item to show up for each one. If you simply plot the lines and call `ax.legend()`, you will get the following:

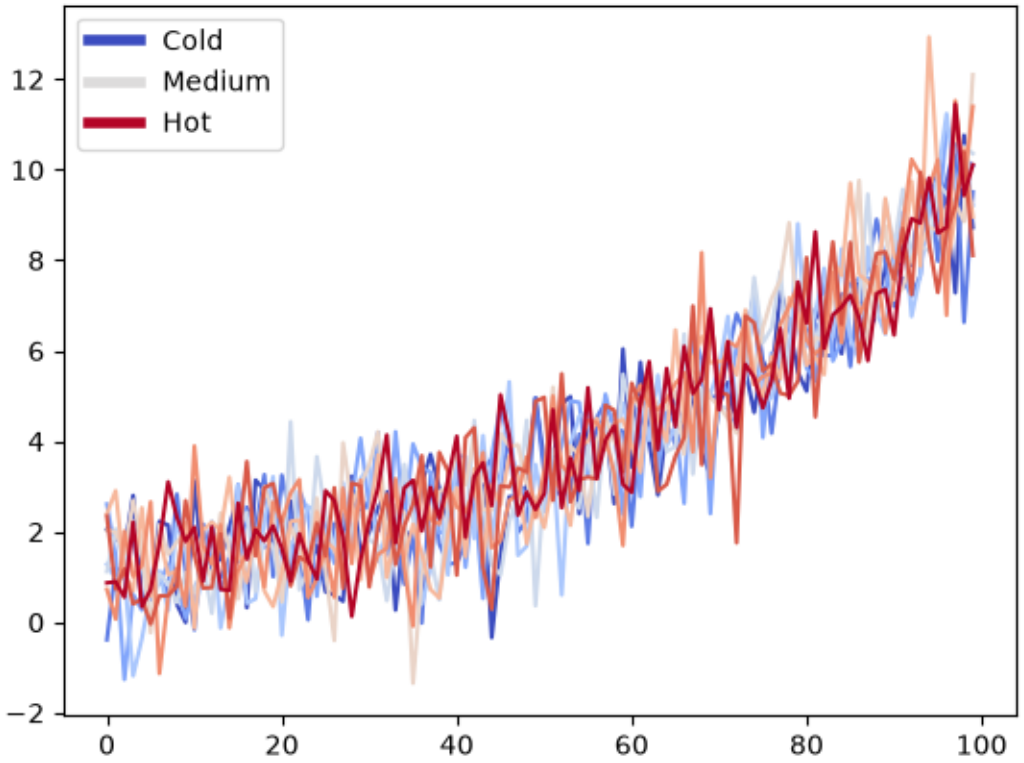
```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib as mpl
from matplotlib import cycler

# Fixing random state for reproducibility
np.random.seed(19680801)
```

```
N = 10
data = (np.geomspace(1, 10, 100) + np.random.randn(N, 100)).T
cmap = plt.colormaps["coolwarm"]
mpl.rcParams['axes.prop_cycle'] = cycler(color=cmap(np.linspace(0, 1,␣
 ↪N)))

fig, ax = plt.subplots()
lines = ax.plot(data)
```



Since the data does not have any labels, creating a legend requires us to define the icons and labels. In this case, we can compose a legend using Matplotlib objects that aren't explicitly tied to the data that was plotted. For example:

```
from matplotlib.lines import Line2D

custom_lines = [Line2D([0], [0], color=cmap(0.), lw=4),
                Line2D([0], [0], color=cmap(.5), lw=4),
                Line2D([0], [0], color=cmap(1.), lw=4)]

fig, ax = plt.subplots()
lines = ax.plot(data)
ax.legend(custom_lines, ['Cold', 'Medium', 'Hot'])
```



There are many other Matplotlib objects that can be used in this way. In the code below we've listed a few common ones.

```
from matplotlib.lines import Line2D
from matplotlib.patches import Patch

legend_elements = [Line2D([0], [0], color='b', lw=4, label='Line'),
                   Line2D([0], [0], marker='o', color='w', label=
 ↪'Scatter',
                          markerfacecolor='g', markersize=15),
                   Patch(facecolor='orange', edgecolor='r',
                         label='Color Patch')]

# Create the figure
fig, ax = plt.subplots()
ax.legend(handles=legend_elements, loc='center')

plt.show()
```

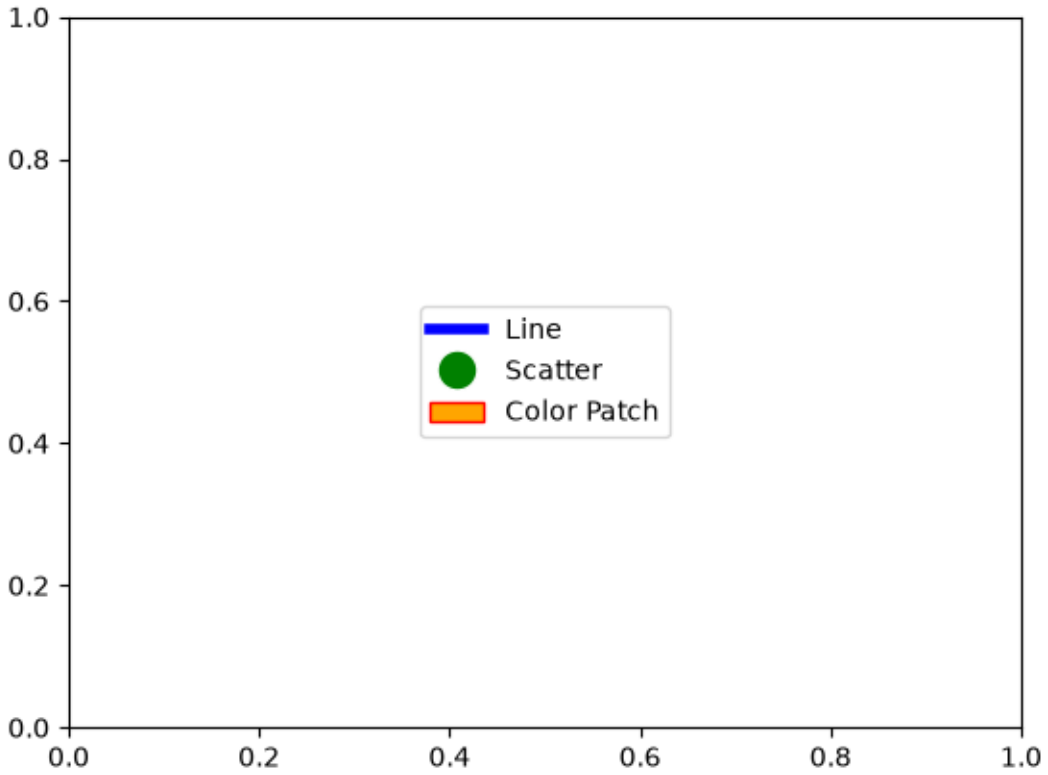
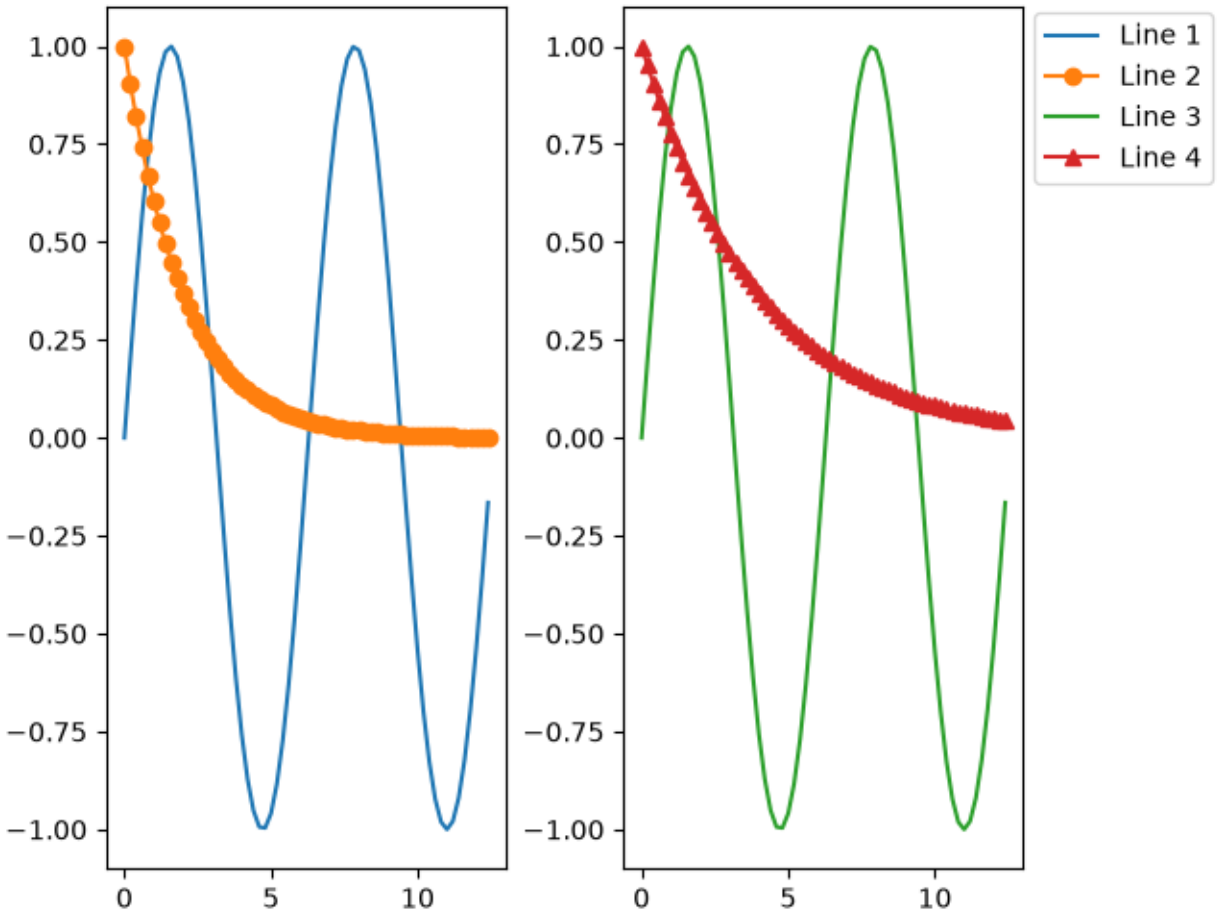


Figure legend demo

Rather than plotting a legend on each axis, a legend for all the artists on all the sub-axes of a figure can be plotted instead.

```
import matplotlib.pyplot as plt
import numpy as np

fig, axs = plt.subplots(1, 2, layout='constrained')

x = np.arange(0.0, 4*np.pi, 0.2)
axs[0].plot(x, np.sin(x), label='Line 1')
axs[0].plot(x, np.exp(-x/2), marker='o', label='Line 2')
axs[1].plot(x, np.sin(x), color='tab:green', label='Line 3')
axs[1].plot(x, np.exp(-x/4), color='tab:red', marker='^', label='Line 4
 ↪')

fig.legend(loc='outside right upper')

plt.show()
```



The outside positioning is discussed in detail here: https://matplotlib.org/stable/users/explain/axes/legend_guide.html#figure-legends

See also

The *Legend guide* contains an in depth discussion on the configuration options for legends.

Accented text

Matplotlib supports accented characters via TeX mathtext or Unicode.

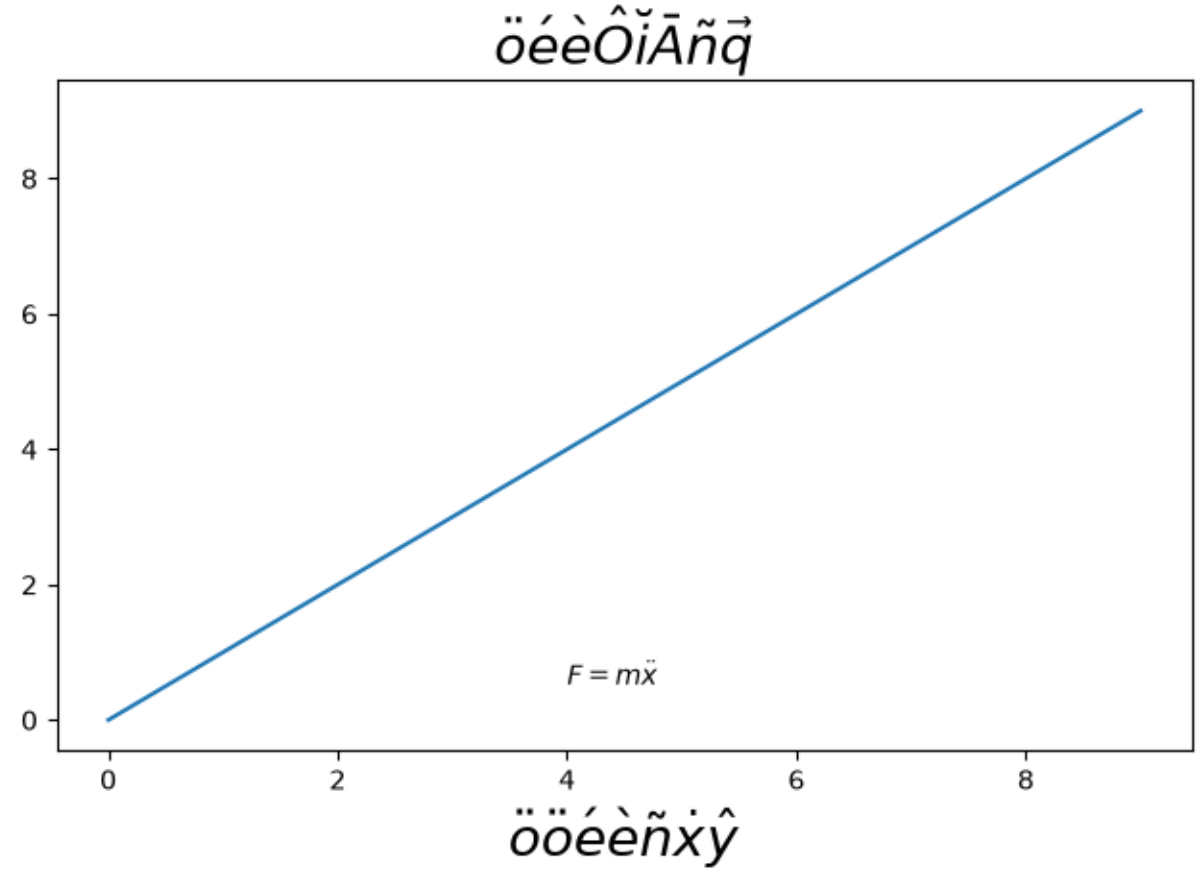
Using mathtext, the following accents are provided: \hat, \breve, \grave, \bar, \acute, \tilde, \vec, \dot, \ddot. All of them have the same syntax, e.g. \bar{o} yields "o overbar", \ddot{o} yields "o umlaut". Shortcuts such as \"o \'e \`e \~n \.x \^y are also supported.

```
import matplotlib.pyplot as plt

# Mathtext demo
fig, ax = plt.subplots()
ax.plot(range(10))
```

(continues on next page)

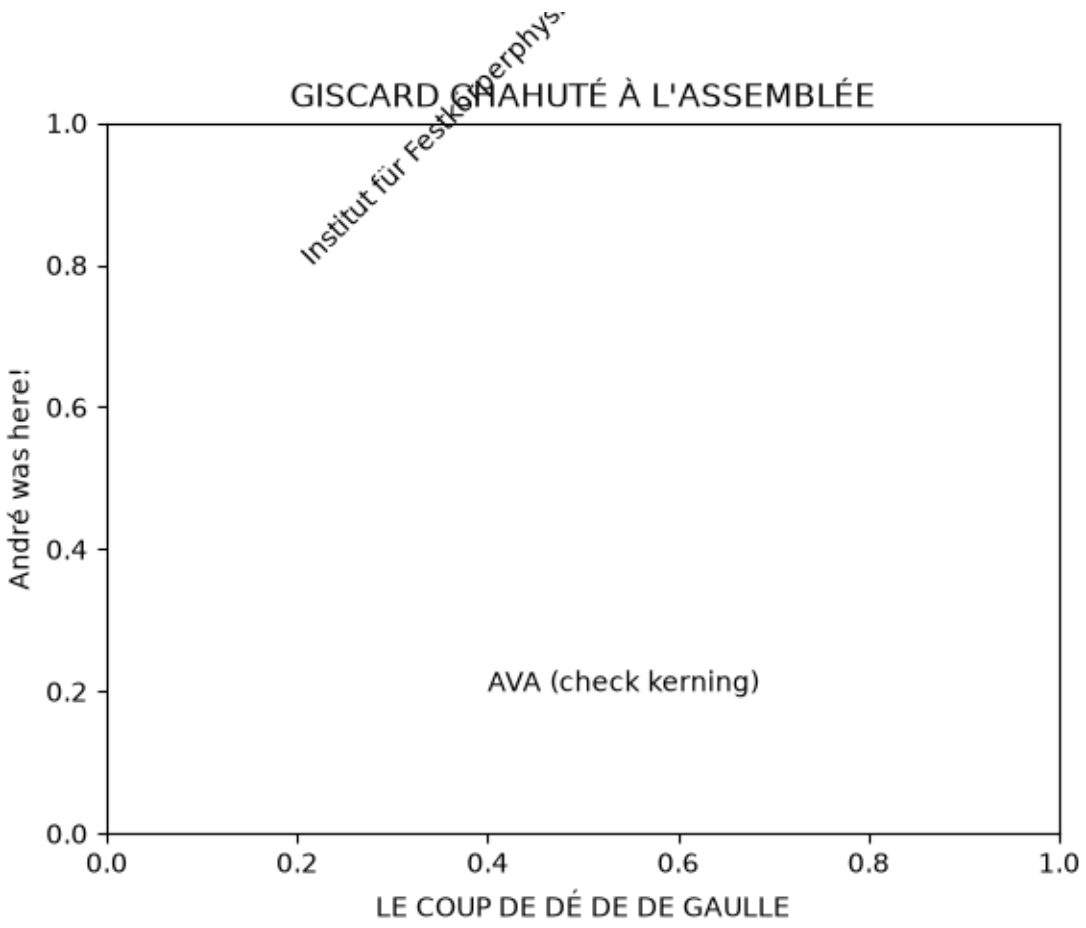
(continued from previous page)

```
ax.set_title(r'$\ddot{o}\acute{e}\grave{e}\hat{O}'
             r'\breve{i}\bar{A}\tilde{n}\vec{q}$', fontsize=20)

# Shorthand is also supported and curly braces are optional
ax.set_xlabel(r"""$\"o\ddot o \'e\`e\~n\.x\^y$""", fontsize=20)
ax.text(4, 0.5, r"$F=m\ddot{x}$")
fig.tight_layout()
```



You can also use Unicode characters directly in strings.

```
fig, ax = plt.subplots()
ax.set_title("GISCARD CHAHUTÉ À L'ASSEMBLÉE")
ax.set_xlabel("LE COUP DE DÉ DE DE GAULLE")
ax.set_ylabel('André was here!')
ax.text(0.2, 0.8, 'Institut für Festkörperphysik', rotation=45)
ax.text(0.4, 0.2, 'AVA (check kerning)')

plt.show()
```



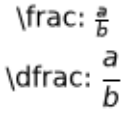
The difference between \dfrac and \frac

In this example, the differences between the \dfrac and \frac TeX macros are illustrated; in particular, the difference between display style and text style fractions when using Mathtext.

Added in version 2.1.

Note

To use \dfrac with the LaTeX engine (text.usetex : True), you need to import the amsmath package with `rcParams["text.latex.preamble"]` (default: `''`), which is an unsupported feature; therefore, it is probably a better idea to just use the \displaystyle option before the \frac macro to get this behavior with the LaTeX engine.




```
import matplotlib.pyplot as plt
```

(continues on next page)

(continued from previous page)

```
fig = plt.figure(figsize=(5.25, 0.75))
fig.text(0.5, 0.3, r'\dfrac: $\dfrac{a}{b}$',
         horizontalalignment='center', verticalalignment='center')
fig.text(0.5, 0.7, r'\frac: $\frac{a}{b}$',
         horizontalalignment='center', verticalalignment='center')
plt.show()
```

Configure the font family

You can explicitly set which font family is picked up, either by specifying family names of fonts installed on user's system, or generic-families (e.g., 'serif', 'sans-serif', 'monospace', 'fantasy' or 'cursive'), or a combination of both. (see *Text properties and layout*)

In the example below, we are overriding the default sans-serif generic family to include a specific (Tahoma) font. (Note that the best way to achieve this would simply be to prepend 'Tahoma' in 'font.family')

The default family is set with the font.family rcparam, e.g.

```
rcParams['font.family'] = 'sans-serif'
```

and for the font.family you set a list of font styles to try to find in order:

```
rcParams['font.sans-serif'] = ['Tahoma', 'DejaVu Sans',
                               'Lucida Grande', 'Verdana']
```

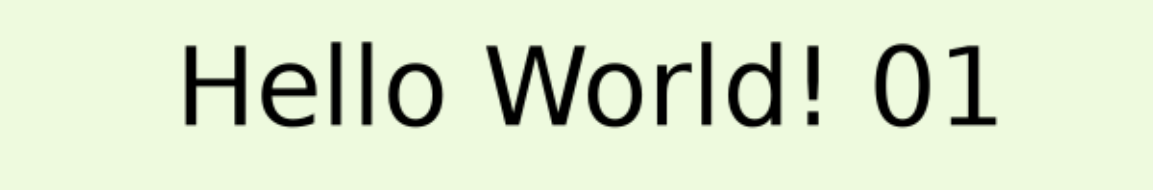
The `font.family` defaults are OS dependent and can be viewed with:

```
import matplotlib.pyplot as plt

print(plt.rcParams["font.sans-serif"][0])
print(plt.rcParams["font.monospace"][0])
```

```
DejaVu Sans
DejaVu Sans Mono
```

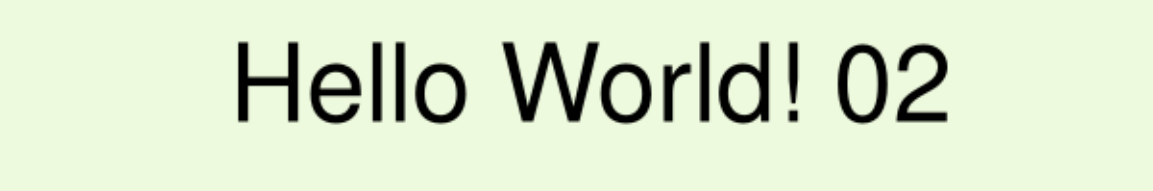
Choose default sans-serif font

```
def print_text(text):
    fig, ax = plt.subplots(figsize=(6, 1), facecolor="#eefade")
    ax.text(0.5, 0.5, text, ha='center', va='center', size=40)
    ax.axis("off")
    plt.show()


plt.rcParams["font.family"] = "sans-serif"
print_text("Hello World! 01")
```



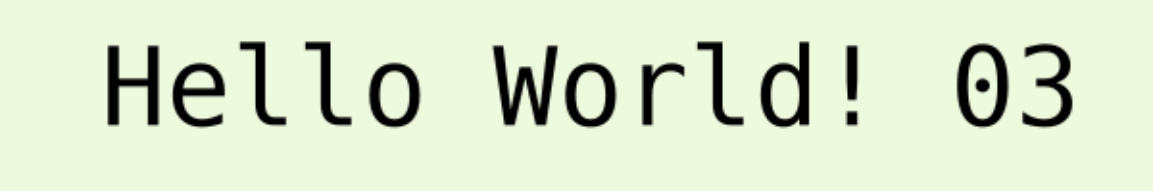
Choose sans-serif font and specify to it to "Nimbus Sans"

```
plt.rcParams["font.family"] = "sans-serif"
plt.rcParams["font.sans-serif"] = ["Nimbus Sans"]
print_text("Hello World! 02")
```



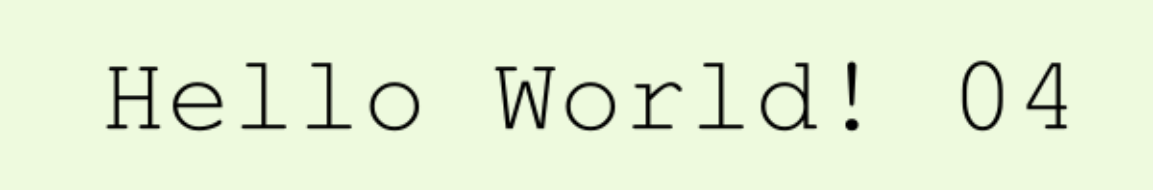
Choose default monospace font

```
plt.rcParams["font.family"] = "monospace"
print_text("Hello World! 03")
```



Choose monospace font and specify to it to "FreeMono"

```
plt.rcParams["font.family"] = "monospace"
plt.rcParams["font.monospace"] = ["FreeMono"]
print_text("Hello World! 04")
```



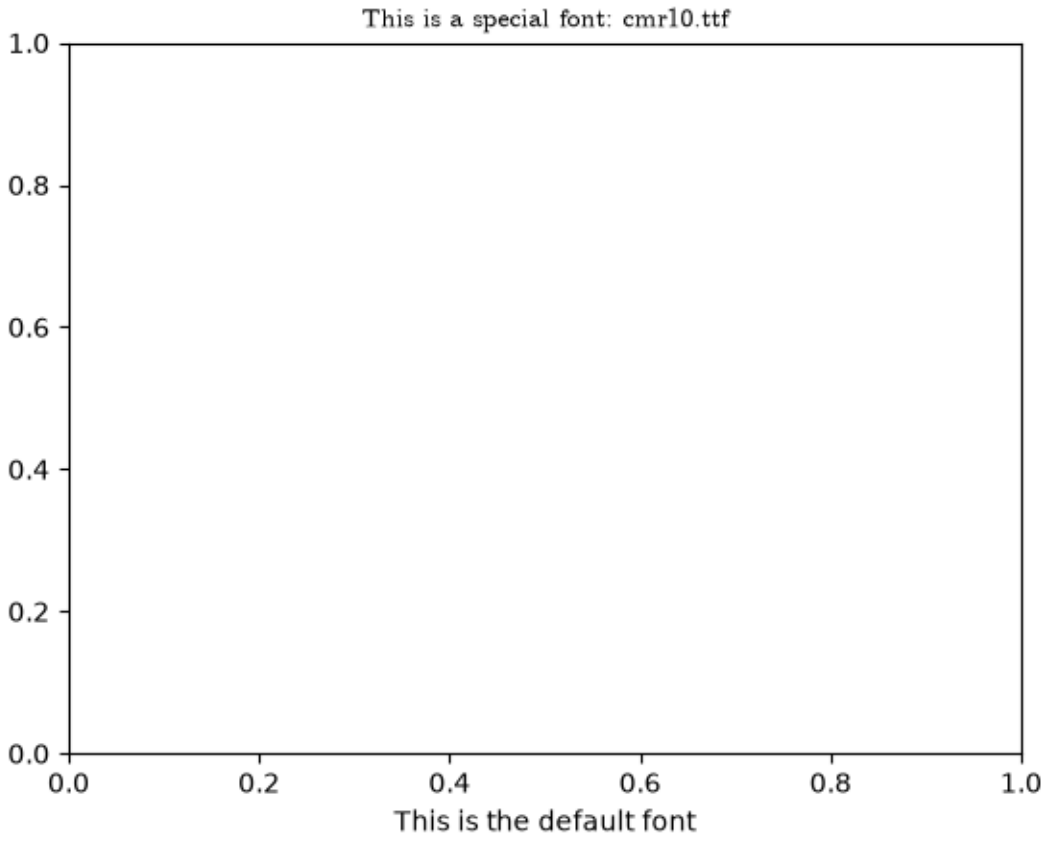
Using ttf font files

Although it is usually not a good idea to explicitly point to a single ttf file for a font instance, you can do so by passing a `pathlib.Path` instance as the *font* parameter. Note that passing paths as `str`s is intentionally not supported, but you can simply wrap `str`s in `pathlib.Path`s as needed.

Here, we use the Computer Modern roman font (`cmr10`) shipped with Matplotlib.

For a more flexible solution, see *Configure the font family* and *Fonts demo (object-oriented style)*.

```
from pathlib import Path

import matplotlib.pyplot as plt

import matplotlib as mpl

fig, ax = plt.subplots()

fpath = Path(mpl.get_data_path(), "fonts/ttf/cmr10.ttf")
ax.set_title(f'This is a special font: {fpath.name}', font=fpath)
ax.set_xlabel('This is the default font')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.set_title*

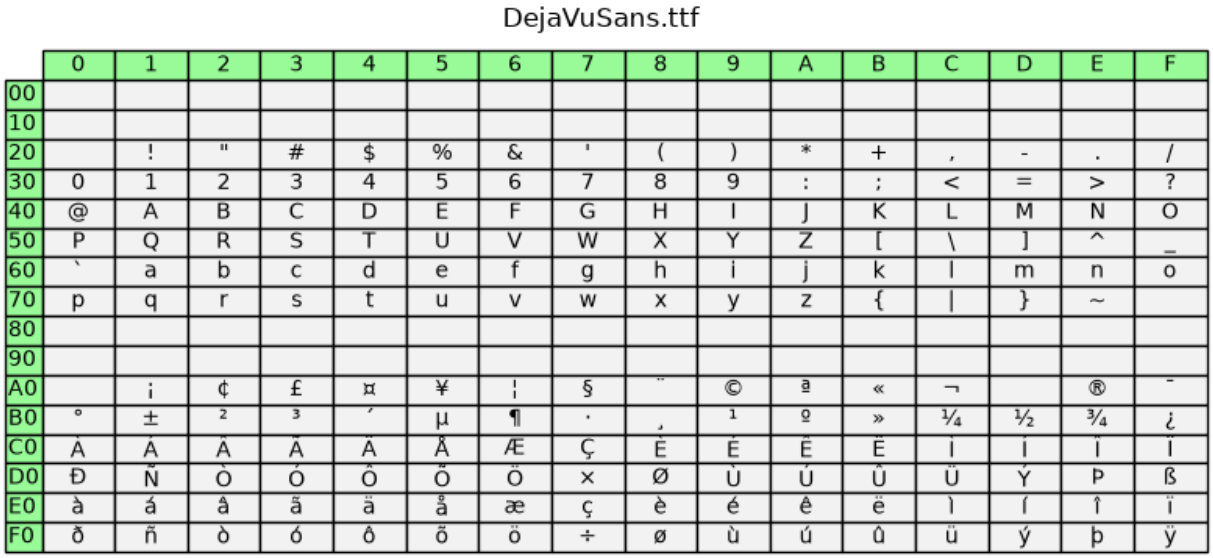
Font table

Matplotlib's font support is provided by the FreeType library.

Here, we use *table* to draw a table that shows the glyphs by Unicode codepoint. For brevity, the table only contains the first 256 glyphs.

The example is a full working script. You can download it and use it to investigate a font by running

```
python font_table.py /path/to/font/file
```




```
import os
from pathlib import Path
import unicodedata

import matplotlib.pyplot as plt

import matplotlib.font_manager as fm
from matplotlib.ft2font import FT2Font


def print_glyphs(path):
    """
```

(continues on next page)

(continued from previous page)

```
    Print the all glyphs in the given font file to stdout.

    Parameters
    ----------
    path : str or None
        The path to the font file.  If None, use Matplotlib's default␣
↪font.
    """
    if path is None:
        path = fm.findfont(fm.FontProperties())  # The default font.

    font = FT2Font(path)

    charmap = font.get_charmap()
    max_indices_len = len(str(max(charmap.values())))

    print("The font face contains the following glyphs:")
    for char_code, glyph_index in charmap.items():
        char = chr(char_code)
        name = unicodedata.name(
                char,
                f"{char_code:#x} ({font.get_glyph_name(glyph_index)})")
        print(f"{glyph_index:>{max_indices_len}} {char} {name}")


def draw_font_table(path):
    """
    Draw a font table of the first 255 chars of the given font.

    Parameters
    ----------
    path : str or None
        The path to the font file.  If None, use Matplotlib's default␣
↪font.
    """
    if path is None:
        path = fm.findfont(fm.FontProperties())  # The default font.

    font = FT2Font(path)
    # A charmap is a mapping of "character codes" (in the sense of a␣
↪character
    # encoding, e.g. latin-1) to glyph indices (i.e. the internal␣
↪storage table
    # of the font face).
    # In FreeType>=2.1, a Unicode charmap (i.e. mapping Unicode␣
↪codepoints)
```

(continues on next page)

(continued from previous page)

```
    # is selected by default.  Moreover, recent versions of FreeType␣
↪will
    # automatically synthesize such a charmap if the font does not␣
↪include one
    # (this behavior depends on the font format; for example it is␣
↪present
    # since FreeType 2.0 for Type 1 fonts but only since FreeType 2.8␣
↪for
    # TrueType (actually, SFNT) fonts).
    # The code below (specifically, the ``chr(char_code)`` call)␣
↪assumes that
    # we have indeed selected a Unicode charmap.
    codes = font.get_charmap().items()

    labelc = [f"{i:X}" for i in range(16)]
    labelr = [f"{i:02X}" for i in range(0, 16*16, 16)]
    chars = [["" for c in range(16)] for r in range(16)]

    for char_code, glyph_index in codes:
        if char_code >= 256:
            continue
        row, col = divmod(char_code, 16)
        chars[row][col] = chr(char_code)

    fig, ax = plt.subplots(figsize=(8, 4))
    ax.set_title(os.path.basename(path))
    ax.set_axis_off()

    table = ax.table(
        cellText=chars,
        rowLabels=labelr,
        colLabels=labelc,
        rowColours=["palegreen"] * 16,
        colColours=["palegreen"] * 16,
        cellColours=[[".95" for c in range(16)] for r in range(16)],
        cellLoc='center',
        loc='upper left',
    )
    for key, cell in table.get_celld().items():
        row, col = key
        if row > 0 and col > -1:  # Beware of table's idiosyncratic␣
↪indexing...
            cell.set_text_props(font=Path(path))

    fig.tight_layout()
    plt.show()
```

(continues on next page)

(continued from previous page)

```
if __name__ == "__main__":
    from argparse import ArgumentParser

    parser = ArgumentParser(description="Display a font table.")
    parser.add_argument("path", nargs="?", help="Path to the font file.
 ↪")
    parser.add_argument("--print-all", action="store_true",
                        help="Additionally, print all chars to stdout.
 ↪")
    args = parser.parse_args()

    if args.print_all:
        print_glyphs(args.path)
    draw_font_table(args.path)
```

Total running time of the script: (0 minutes 1.416 seconds)

Fonts demo (object-oriented style)

Set font properties using setters.

See *Fonts demo (keyword arguments)* to achieve the same effect using keyword arguments.

```
import matplotlib.pyplot as plt

from matplotlib.font_manager import FontProperties

fig = plt.figure()
alignment = {'horizontalalignment': 'center', 'verticalalignment':
 ↪'baseline'}
yp = [0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2]
heading_font = FontProperties(size='large')

# Show family options
fig.text(0.1, 0.9, 'family', fontproperties=heading_font, **alignment)
families = ['serif', 'sans-serif', 'cursive', 'fantasy', 'monospace']
for k, family in enumerate(families):
    font = FontProperties(family=[family])
    fig.text(0.1, yp[k], family, fontproperties=font, **alignment)

# Show style options
styles = ['normal', 'italic', 'oblique']
fig.text(0.3, 0.9, 'style', fontproperties=heading_font, **alignment)
```

(continues on next page)

(continued from previous page)

```
for k, style in enumerate(styles):
    font = FontProperties(family='sans-serif', style=style)
    fig.text(0.3, yp[k], style, fontproperties=font, **alignment)

# Show variant options
variants = ['normal', 'small-caps']
fig.text(0.5, 0.9, 'variant', fontproperties=heading_font, **alignment)
for k, variant in enumerate(variants):
    font = FontProperties(family='serif', variant=variant)
    fig.text(0.5, yp[k], variant, fontproperties=font, **alignment)

# Show weight options
weights = ['light', 'normal', 'medium', 'semibold', 'bold', 'heavy',
 ↪'black']
fig.text(0.7, 0.9, 'weight', fontproperties=heading_font, **alignment)
for k, weight in enumerate(weights):
    font = FontProperties(weight=weight)
    fig.text(0.7, yp[k], weight, fontproperties=font, **alignment)

# Show size options
sizes = [
    'xx-small', 'x-small', 'small', 'medium', 'large', 'x-large',
 ↪'xx-large']
fig.text(0.9, 0.9, 'size', fontproperties=heading_font, **alignment)
for k, size in enumerate(sizes):
    font = FontProperties(size=size)
    fig.text(0.9, yp[k], size, fontproperties=font, **alignment)

# Show bold italic
font = FontProperties(style='italic', weight='bold', size='x-small')
fig.text(0.3, 0.1, 'bold italic', fontproperties=font, **alignment)
font = FontProperties(style='italic', weight='bold', size='medium')
fig.text(0.3, 0.2, 'bold italic', fontproperties=font, **alignment)
font = FontProperties(style='italic', weight='bold', size='x-large')
fig.text(0.3, 0.3, 'bold italic', fontproperties=font, **alignment)

plt.show()
```

Fonts demo (keyword arguments)

Set font properties using keyword arguments.

See *Fonts demo (object-oriented style)* to achieve the same effect using setters.

```
import matplotlib.pyplot as plt

fig = plt.figure()
alignment = {'horizontalalignment': 'center', 'verticalalignment':
 ↪'baseline'}
yp = [0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2]

# Show family options
fig.text(0.1, 0.9, 'family', size='large', **alignment)
families = ['serif', 'sans-serif', 'cursive', 'fantasy', 'monospace']
for k, family in enumerate(families):
    fig.text(0.1, yp[k], family, family=family, **alignment)

# Show style options
fig.text(0.3, 0.9, 'style', **alignment)
styles = ['normal', 'italic', 'oblique']
for k, style in enumerate(styles):
    fig.text(0.3, yp[k], style, family='sans-serif', style=style,␣
 ↪**alignment)
```

(continues on next page)

(continued from previous page)

```
# Show variant options
fig.text(0.5, 0.9, 'variant', **alignment)
variants = ['normal', 'small-caps']
for k, variant in enumerate(variants):
    fig.text(0.5, yp[k], variant, family='serif', variant=variant,␣
 ↪**alignment)

# Show weight options
fig.text(0.7, 0.9, 'weight', **alignment)
weights = ['light', 'normal', 'medium', 'semibold', 'bold', 'heavy',
 ↪'black']
for k, weight in enumerate(weights):
    fig.text(0.7, yp[k], weight, weight=weight, **alignment)

# Show size options
fig.text(0.9, 0.9, 'size', **alignment)
sizes = [
    'xx-small', 'x-small', 'small', 'medium', 'large', 'x-large',
 ↪'xx-large']
for k, size in enumerate(sizes):
    fig.text(0.9, yp[k], size, size=size, **alignment)

# Show bold italic
fig.text(0.3, 0.1, 'bold italic',
         style='italic', weight='bold', size='x-small', **alignment)
fig.text(0.3, 0.2, 'bold italic',
         style='italic', weight='bold', size='medium', **alignment)
fig.text(0.3, 0.3, 'bold italic',
         style='italic', weight='bold', size='x-large', **alignment)

plt.show()
```

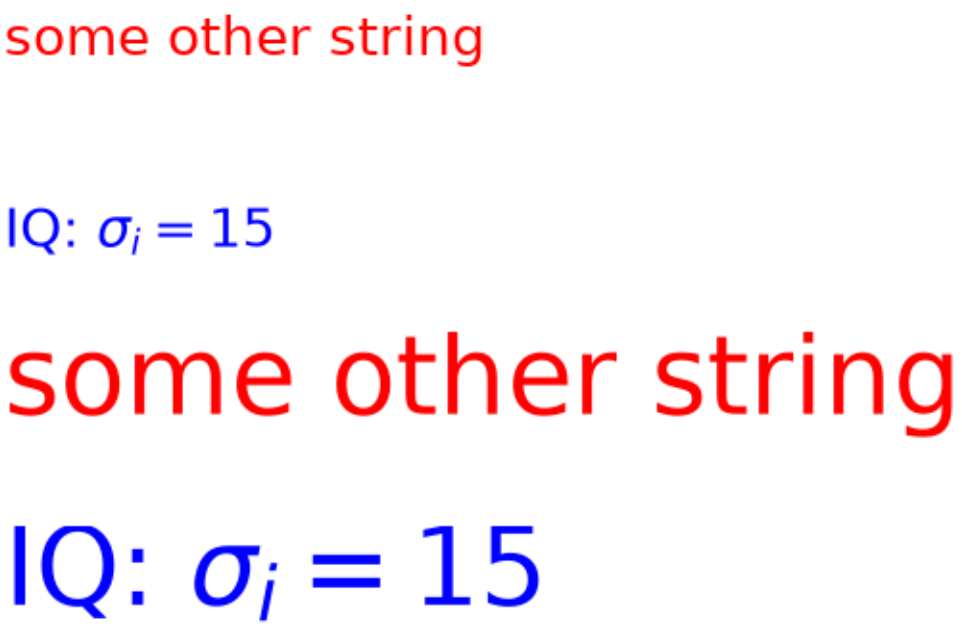
Convert texts to images

```
from io import BytesIO

from PIL import Image

import matplotlib.pyplot as plt
import numpy as np

from matplotlib.figure import Figure
from matplotlib.transforms import IdentityTransform
```

(continues on next page)

(continued from previous page)

```
def text_to_rgba(s, *, dpi, **kwargs):
    # To convert a text string to an image, we can:
    # - draw it on an empty and transparent figure;
    # - save the figure to a temporary buffer using␣
 ↪``bbox_inches="tight",
    #   pad_inches=0`` which will pick the correct area to save;
    # - load the buffer using ``PIL.Image.open``.
    #
    # (If desired, one can also directly save the image to the␣
 ↪filesystem.)
    fig = Figure(facecolor="none")
    fig.text(0, 0, s, **kwargs)
    with BytesIO() as buf:
        fig.savefig(buf, dpi=dpi, format="png", bbox_inches="tight",
                    pad_inches=0)
        buf.seek(0)
        rgba = np.asarray(Image.open(buf))
    return rgba


fig = plt.figure()
rgba1 = text_to_rgba(r"IQ: $\sigma_i=15$", color="blue", fontsize=20,␣
 ↪dpi=200)
rgba2 = text_to_rgba(r"some other string", color="red", fontsize=20,␣
 ↪dpi=200)
# One can then draw such text images to a Figure using `.
 ↪Figure.figimage`.
fig.figimage(rgba1, 100, 50)
fig.figimage(rgba2, 100, 150)

# One can also directly draw texts to a figure with positioning
# in pixel coordinates by using `.Figure.text` together with
# `.transforms.IdentityTransform`.
fig.text(100, 250, r"IQ: $\sigma_i=15$", color="blue", fontsize=20,
         transform=IdentityTransform())
fig.text(100, 350, r"some other string", color="red", fontsize=20,
         transform=IdentityTransform())

plt.show()
```



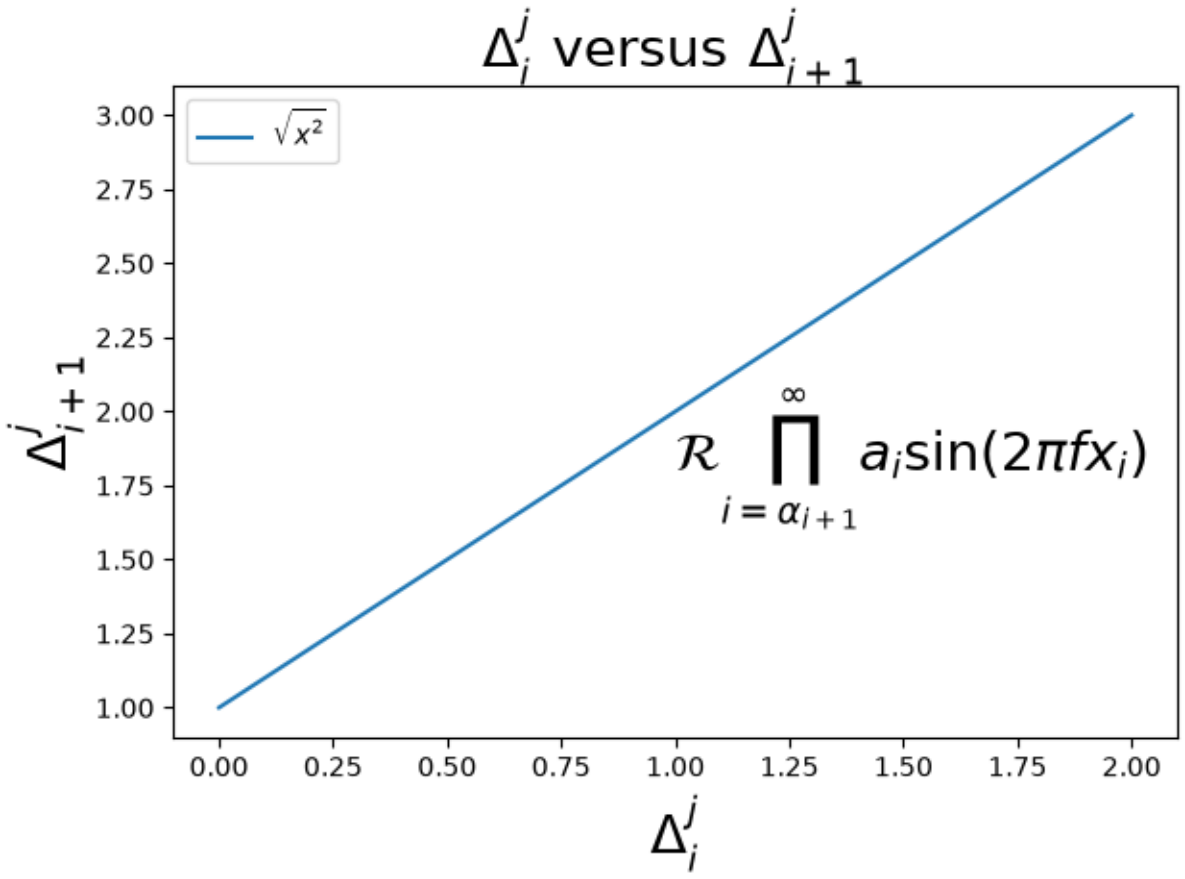
References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.figure.Figure.figimage*
- *matplotlib.figure.Figure.text*
- *matplotlib.transforms.IdentityTransform*
- *matplotlib.image.imread*

Mathtext

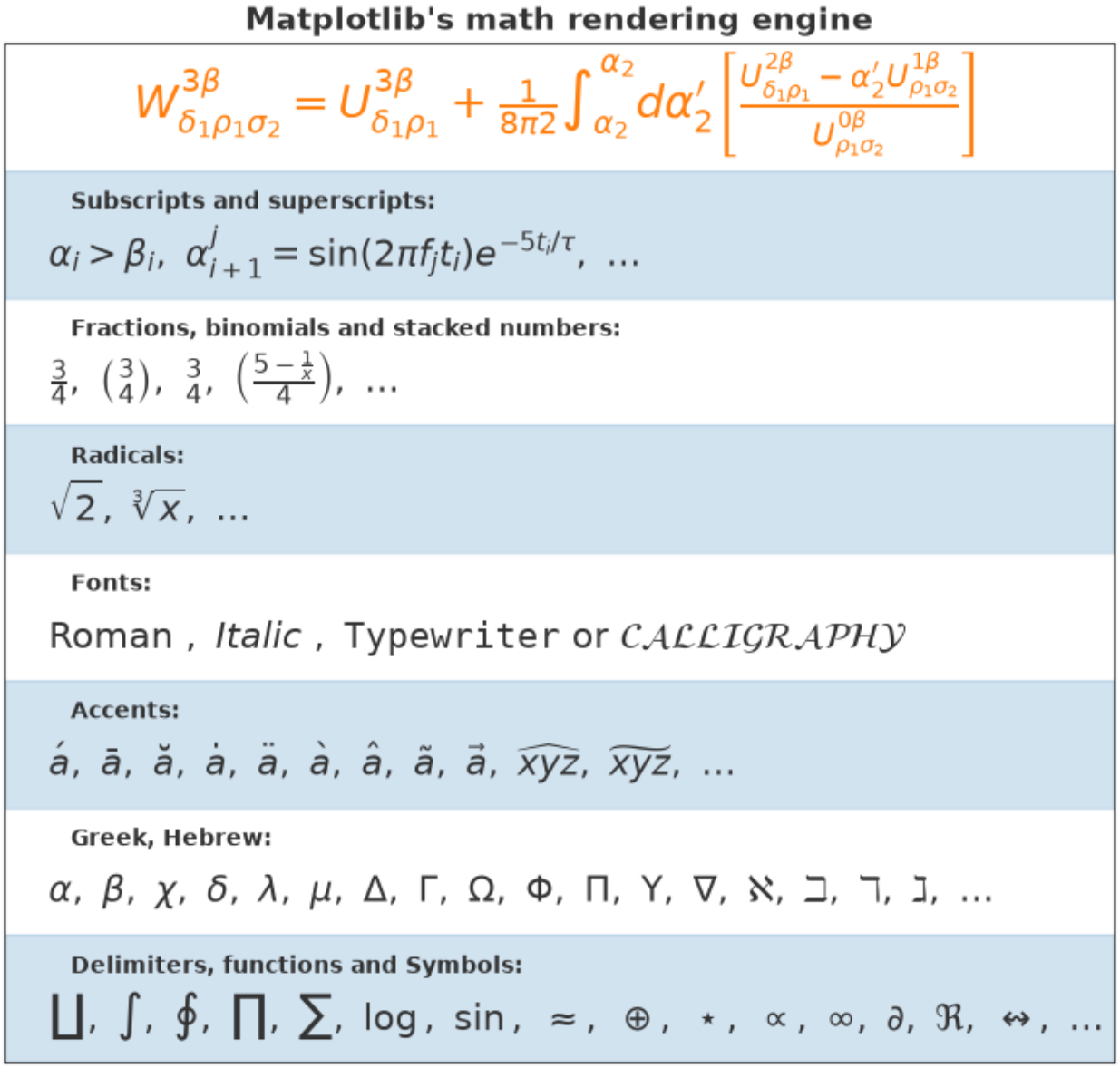
Use Matplotlib's internal LaTeX parser and layout engine. For true LaTeX rendering, see the text.usetex option.




```
import matplotlib.pyplot as plt

fig, ax = plt.subplots()

ax.plot([1, 2, 3], label=r'$\sqrt{x^2}$')
ax.legend()

ax.set_xlabel(r'$\Delta_i^j$', fontsize=20)
ax.set_ylabel(r'$\Delta_{i+1}^j$', fontsize=20)
ax.set_title(r'$\Delta_i^j \hspace{0.4} \mathrm{versus} \hspace{0.4} '
             r'\Delta_{i+1}^j$', fontsize=20)

tex = r'$\mathcal{R}\prod_{i=\alpha_{i+1}}^\infty a_i\sin(2 \pi f x_i)$
 ↪'
ax.text(1, 1.6, tex, fontsize=20, va='bottom')

fig.tight_layout()
plt.show()
```

Mathematical expressions

Selected features of Matplotlib's math rendering engine.




```
0 $W^{3\beta}_{\delta_1 \rho_1 \sigma_2} = U^{3\beta}_{\delta_1 \
 ↪rho_1} + \frac{1}{8 \pi 2} \int^{\alpha_2}_{\alpha_2} d \
 ↪alpha^\prime_2 \left[\frac{ U^{2\beta}_{\delta_1 \rho_1} - \
 ↪alpha^\prime_2U^{1\beta}_{\rho_1 \sigma_2} }{U^{0\beta}_{\rho_1 \
 ↪sigma_2}}\right]$
1 $\alpha_i > \beta_i,\ \alpha_{i+1}^j = {\rm sin}(2\pi f_j t_i) e^{-5␣
 ↪t_i/\tau},\ \ldots$
2 $\frac{3}{4},\ \binom{3}{4},\ \genfrac{}{}{0}{}{3}{4},\ \
```

(continues on next page)

(continued from previous page)

```
 ↪left(\frac{5 - \frac{1}{x}}{4}\right),\ \ldots$
3 $\sqrt{2},\ \sqrt[3]{x},\ \ldots$
4 $\mathrm{Roman}\ , \ \mathit{Italic}\ , \ \mathtt{Typewriter} \ \
 ↪mathrm{or}\ \mathcal{CALLIGRAPHY}$
5 $\acute a,\ \bar a,\ \breve a,\ \dot a,\ \ddot a, \ \grave a, \ \hat␣
 ↪a,\ \tilde a,\ \vec a,\ \widehat{xyz},\ \widetilde{xyz},\ \ldots$
6 $\alpha,\ \beta,\ \chi,\ \delta,\ \lambda,\ \mu,\ \Delta,\ \Gamma,\ \
 ↪Omega,\ \Phi,\ \Pi,\ \Upsilon,\ \nabla,\ \aleph,\ \beth,\ \daleth,\ \
 ↪gimel,\ \ldots$
7 $\coprod,\ \int,\ \oint,\ \prod,\ \sum,\ \log,\ \sin,\ \approx,\ \
 ↪oplus,\ \star,\ \varpropto,\ \infty,\ \partial,\ \Re,\ \
 ↪leftrightsquigarrow, \ \ldots$
```

```
import re
import subprocess
import sys

import matplotlib.pyplot as plt

# Selection of features following "Writing mathematical expressions"␣
 ↪tutorial,
# with randomly picked examples.
mathtext_demos = {
    "Header demo":
        r"$W^{3\beta}_{\delta_1 \rho_1 \sigma_2} = "
        r"U^{3\beta}_{\delta_1 \rho_1} + \frac{1}{8 \pi 2} "
        r"\int^{\alpha_2}_{\alpha_2} d \alpha^\prime_2 \left[\frac{ "
        r"U^{2\beta}_{\delta_1 \rho_1} - \alpha^\prime_2U^{1\beta}_"
        r"{\rho_1 \sigma_2} }{U^{0\beta}_{\rho_1 \sigma_2}}\right]$",

    "Subscripts and superscripts":
        r"$\alpha_i > \beta_i,\ "
        r"\alpha_{i+1}^j = {\rm sin}(2\pi f_j t_i) e^{-5 t_i/\tau},\ "
        r"\ldots$",

    "Fractions, binomials and stacked numbers":
        r"$\frac{3}{4},\ \binom{3}{4},\ \genfrac{}{}{0}{}{3}{4},\ "
        r"\left(\frac{5 - \frac{1}{x}}{4}\right),\ \ldots$",

    "Radicals":
        r"$\sqrt{2},\ \sqrt[3]{x},\ \ldots$",
```

(continues on next page)

(continued from previous page)

```
    "Fonts":
        r"$\mathrm{Roman}\ , \ \mathit{Italic}\ , \ \mathtt
↪{Typewriter} \ "
        r"\mathrm{or}\ \mathcal{CALLIGRAPHY}$",

    "Accents":
        r"$\acute a,\ \bar a,\ \breve a,\ \dot a,\ \ddot a, \ \grave␣
↪a, \ "
        r"\hat a,\ \tilde a,\ \vec a,\ \widehat{xyz},\ \widetilde{xyz},
↪\ "
        r"\ldots$",

    "Greek, Hebrew":
        r"$\alpha,\ \beta,\ \chi,\ \delta,\ \lambda,\ \mu,\ "
        r"\Delta,\ \Gamma,\ \Omega,\ \Phi,\ \Pi,\ \Upsilon,\ \nabla,\ "
        r"\aleph,\ \beth,\ \daleth,\ \gimel,\ \ldots$",

    "Delimiters, functions and Symbols":
        r"$\coprod,\ \int,\ \oint,\ \prod,\ \sum,\ "
        r"\log,\ \sin,\ \approx,\ \oplus,\ \star,\ \varpropto,\ "
        r"\infty,\ \partial,\ \Re,\ \leftrightsquigarrow, \ \ldots$",
}
n_lines = len(mathtext_demos)


def doall():
    # Colors used in Matplotlib online documentation.
    mpl_grey_rgb = (51 / 255, 51 / 255, 51 / 255)

    # Creating figure and axis.
    fig = plt.figure(figsize=(7, 7))
    ax = fig.add_axes((0.01, 0.01, 0.98, 0.90),
                      facecolor="white", frameon=True)
    ax.set_xlim(0, 1)
    ax.set_ylim(0, 1)
    ax.set_title("Matplotlib's math rendering engine",
                 color=mpl_grey_rgb, fontsize=14, weight='bold')
    ax.set_xticks([])
    ax.set_yticks([])

    # Gap between lines in axes coords
    line_axesfrac = 1 / n_lines

    # Plot header demonstration formula.
    full_demo = mathtext_demos['Header demo']
```

(continues on next page)

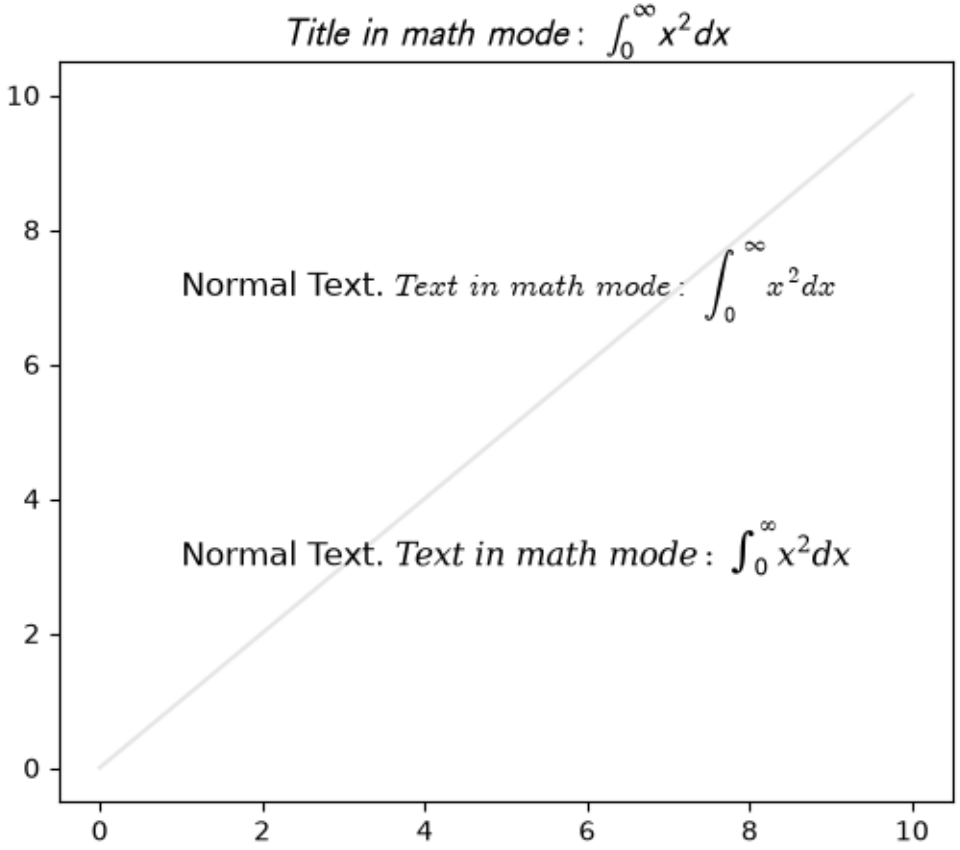
(continued from previous page)

```
    ax.annotate(full_demo,
                xy=(0.5, 1. - 0.59 * line_axesfrac),
                color='tab:orange', ha='center', fontsize=20)

    # Plot feature demonstration formulae.
    for i_line, (title, demo) in enumerate(mathtext_demos.items()):
        print(i_line, demo)
        if i_line == 0:
            continue

        baseline = 1 - i_line * line_axesfrac
        baseline_next = baseline - line_axesfrac
        fill_color = ['white', 'tab:blue'][i_line % 2]
        ax.axhspan(baseline, baseline_next, color=fill_color,␣
↪alpha=0.2)
        ax.annotate(f'{title}:',
                    xy=(0.06, baseline - 0.3 * line_axesfrac),
                    color=mpl_grey_rgb, weight='bold')
        ax.annotate(demo,
                    xy=(0.04, baseline - 0.75 * line_axesfrac),
                    color=mpl_grey_rgb, fontsize=16)

    plt.show()


if '--latex' in sys.argv:
    # Run: python mathtext_examples.py --latex
    # Need amsmath and amssymb packages.
    with open("mathtext_examples.ltx", "w") as fd:
        fd.write("\\documentclass{article}\n")
        fd.write("\\usepackage{amsmath, amssymb}\n")
        fd.write("\\begin{document}\n")
        fd.write("\\begin{enumerate}\n")

        for s in mathtext_demos.values():
            s = re.sub(r"(?<!\\)\$", "$$", s)
            fd.write("\\item %s\n" % s)

        fd.write("\\end{enumerate}\n")
        fd.write("\\end{document}\n")

    subprocess.call(["pdflatex", "mathtext_examples.ltx"])
else:
    doall()
```

Math fontfamily

A simple example showcasing the new *math_fontfamily* parameter that can be used to change the family of fonts for each individual text element in a plot.

If no parameter is set, the global value *rcParams["mathtext.fontset"]* (default: `'dejavusans'`) will be used.




```
import matplotlib.pyplot as plt

fig, ax = plt.subplots(figsize=(6, 5))

# A simple plot for the background.
ax.plot(range(11), color="0.9")

# A text mixing normal text and math text.
msg = (r"Normal Text. $Text\ in\ math\ mode:\ "
       r"\int_{0}^{\infty } x^2 dx$")

# Set the text in the plot.
ax.text(1, 7, msg, size=12, math_fontfamily='cm')
```

(continues on next page)

(continued from previous page)

```
# Set another font for the next text.
ax.text(1, 3, msg, size=12, math_fontfamily='dejavuserif')

# *math_fontfamily* can be used in most places where there is text,
# like in the title:
ax.set_title(r"$Title\ in\ math\ mode:\ \int_{0}^{\infty } x^2 dx$",
             math_fontfamily='stixsans', size=14)

# Note that the normal text is not changed by *math_fontfamily*.
plt.show()
```

STIX Fonts

Demonstration of STIX Fonts used in LaTeX rendering.

①②③ ①②③ ❶❷❸

SansΩ SansΩ SansΩ

Monospace

CALLIGRAPHIC

Blackboard π

Blackboard π

Blackboard π

Fraktur **Fraktur**

Script

```
import matplotlib.pyplot as plt

circle123 = "\N{CIRCLED DIGIT ONE}\N{CIRCLED DIGIT TWO}\N{CIRCLED␣
 ↪DIGIT THREE}"

tests = [
    r'$%s\;\mathrm{%s}\;\mathbf{%s}$' % ((circle123,) * 3),
    r'$\mathsf{Sans \Omega}\;\mathrm{\mathsf{Sans \Omega}}\;'
    r'\mathbf{\mathsf{Sans \Omega}}$',
    r'$\mathtt{Monospace}$',
    r'$\mathcal{CALLIGRAPHIC}$',
    r'$\mathbb{Blackboard\;\pi}$',
    r'$\mathrm{\mathbb{Blackboard\;\pi}}$',
    r'$\mathbf{\mathbb{Blackboard\;\pi}}$',
    r'$\mathfrak{Fraktur}\;\mathbf{\mathfrak{Fraktur}}$',
    r'$\mathscr{Script}$',
]

fig = plt.figure(figsize=(8, len(tests) + 2))
for i, s in enumerate(tests[::-1]):
    fig.text(0, (i + .5) / len(tests), s, fontsize=32)

plt.show()
```

Render math equations using TeX

You can use TeX to render all of your Matplotlib text by setting *rcParams["text.usetex"]* (default: `False`) to True. This requires that you have TeX and the other dependencies described in the *Text rendering with LaTeX* tutorial properly installed on your system. Matplotlib caches processed TeX expressions, so that only the first occurrence of an expression triggers a TeX compilation. Later occurrences reuse the rendered image from the cache and are thus faster.

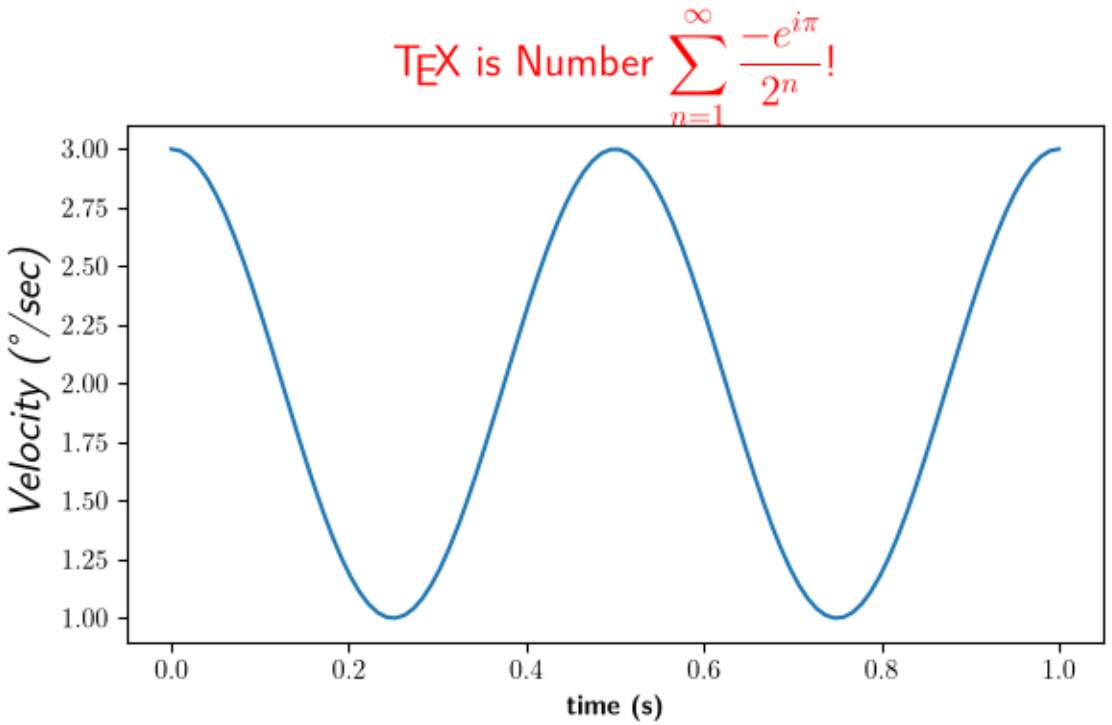
Unicode input is supported, e.g. for the y-axis label in this example.

```
import matplotlib.pyplot as plt
import numpy as np

plt.rcParams['text.usetex'] = True


t = np.linspace(0.0, 1.0, 100)
s = np.cos(4 * np.pi * t) + 2

fig, ax = plt.subplots(figsize=(6, 4), tight_layout=True)
ax.plot(t, s)

ax.set_xlabel(r'\textbf{time (s)}')
```

(continues on next page)

(continued from previous page)

```
ax.set_ylabel('\\textit{Velocity (\N{DEGREE SIGN}/sec)}', fontsize=16)
ax.set_title(r'\TeX\ is Number $\displaystyle\sum_{n=1}^\infty'
             r'\frac{-e^{i\pi}}{2^n}$!', fontsize=16, color='r')
```



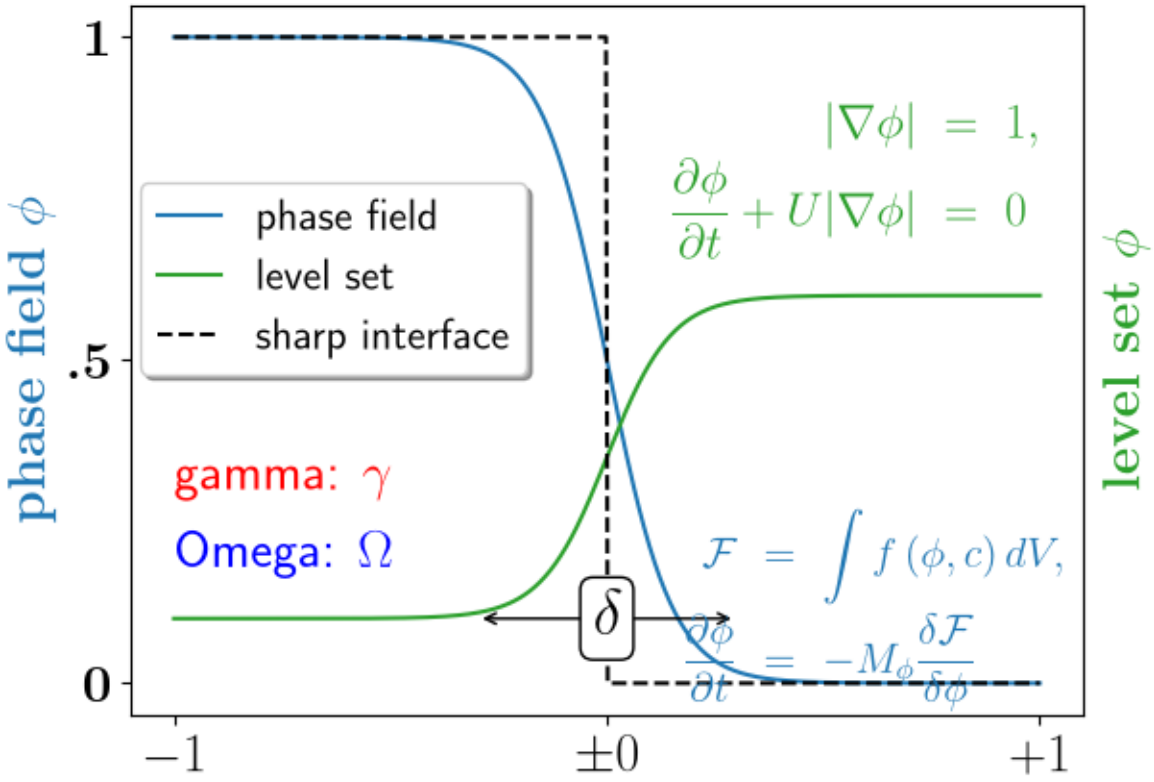
A more complex example.

```
fig, ax = plt.subplots()
# interface tracking profiles
N = 500
delta = 0.6
X = np.linspace(-1, 1, N)
ax.plot(X, (1 - np.tanh(4 * X / delta)) / 2,     # phase field tanh␣
 ↪profiles
        X, (1.4 + np.tanh(4 * X / delta)) / 4, "C2",  # composition␣
 ↪profile
        X, X < 0, "k--")                          # sharp interface

# legend
ax.legend(("phase field", "level set", "sharp interface"),
          shadow=True, loc=(0.01, 0.48), handlelength=1.5, fontsize=16)

# the arrow
ax.annotate("", xy=(-delta / 2., 0.1), xytext=(delta / 2., 0.1),
            arrowprops=dict(arrowstyle="<->", connectionstyle="arc3"))
```

(continues on next page)

(continued from previous page)

```
ax.text(0, 0.1, r"$\delta$",
        color="black", fontsize=24,
        horizontalalignment="center", verticalalignment="center",
        bbox=dict(boxstyle="round", fc="white", ec="black", pad=0.2))

# Use tex in labels
ax.set_xticks([-1, 0, 1])
ax.set_xticklabels(["$-1$", r"$\pm 0$", "$+1$"], color="k", size=20)

# Left Y-axis labels, combine math mode and text mode
ax.set_ylabel(r"\bf{phase field} $\phi$", color="C0", fontsize=20)
ax.set_yticks([0, 0.5, 1])
ax.set_yticklabels([r"\bf{0}", r"\bf{.5}", r"\bf{1}"], color="k",␣
 ↪size=20)

# Right Y-axis labels
ax.text(1.02, 0.5, r"\bf{level set} $\phi$",
        color="C2", fontsize=20, rotation=90,
        horizontalalignment="left", verticalalignment="center",
        clip_on=False, transform=ax.transAxes)

# Use multiline environment inside a `text`.
# level set equations
eq1 = (r"\begin{eqnarray*}"
       r"|\nabla\phi| &=& 1,\\"
       r"\frac{\partial \phi}{\partial t} + U|\nabla \phi| &=& 0 "
       r"\end{eqnarray*}")
ax.text(1, 0.9, eq1, color="C2", fontsize=18,
        horizontalalignment="right", verticalalignment="top")

# phase field equations
eq2 = (r"\begin{eqnarray*}"
       r"\mathcal{F} &=& \int f\left( \phi, c \right) dV, \\ "
       r"\frac{ \partial \phi } { \partial t } &=& -M_{ \phi } "
       r"\frac{ \delta \mathcal{F} } { \delta \phi }"
       r"\end{eqnarray*}")
ax.text(0.18, 0.18, eq2, color="C0", fontsize=16)

ax.text(-1, .30, r"gamma: $\gamma$", color="r", fontsize=20)
ax.text(-1, .18, r"Omega: $\Omega$", color="b", fontsize=20)

plt.show()
```

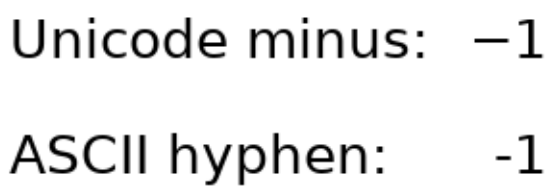


Unicode minus

By default, tick labels at negative values are rendered using a Unicode minus (U+2212) rather than an ASCII hyphen (U+002D). This can be controlled by setting *rcParams["axes.unicode_minus"]* (default: `True`).

The replacement is performed at draw time of the tick labels (usually during a *pyplot.show()* or *pyplot.savefig()* call). Therefore, all tick labels of the figure follow the same setting and we cannot demonstrate both glyphs on real tick labels of the same figure simultaneously.

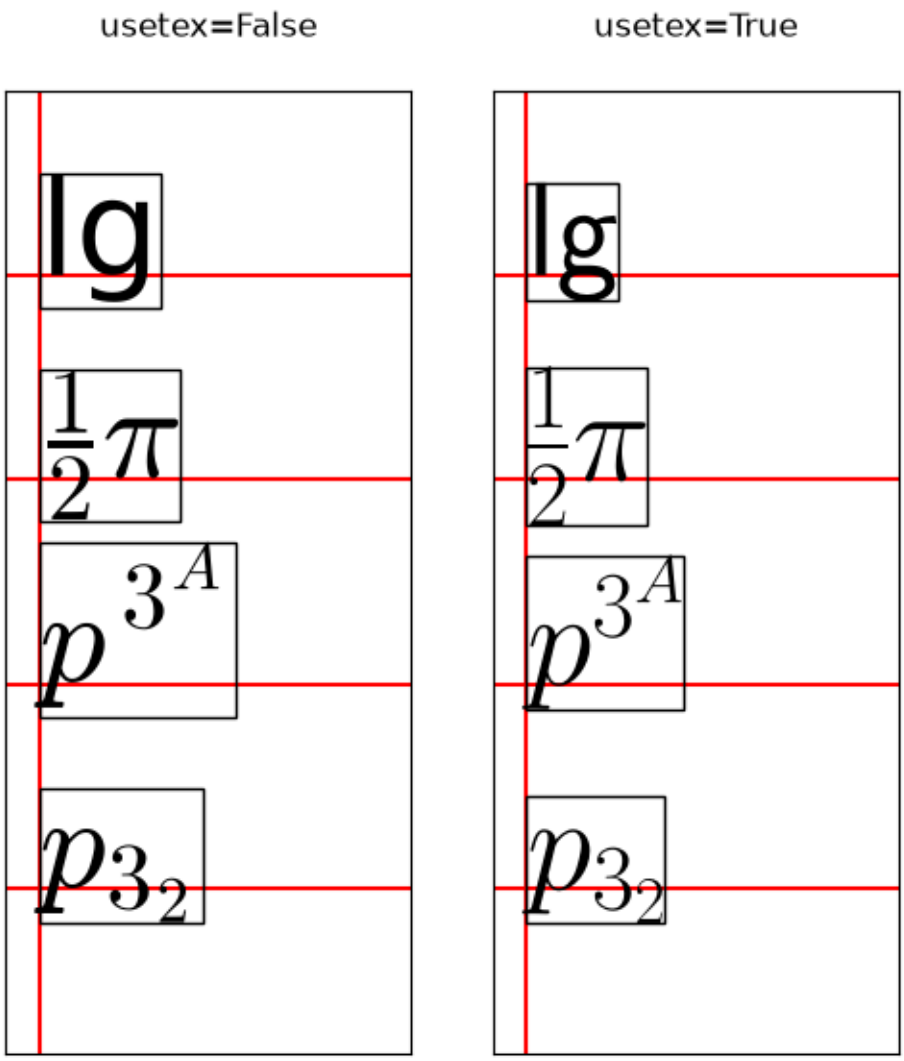
Instead, this example simply showcases the difference between the two glyphs in a magnified font.



```
import matplotlib.pyplot as plt

fig = plt.figure(figsize=(4, 2))
fig.text(.15, .6, "Unicode minus:", fontsize=20)
fig.text(.85, .6, "\N{MINUS SIGN}1", ha='right', fontsize=20)
fig.text(.15, .3, "ASCII hyphen:", fontsize=20)
fig.text(.85, .3, "-1", ha='right', fontsize=20)
plt.show()
```

Usetex text baseline

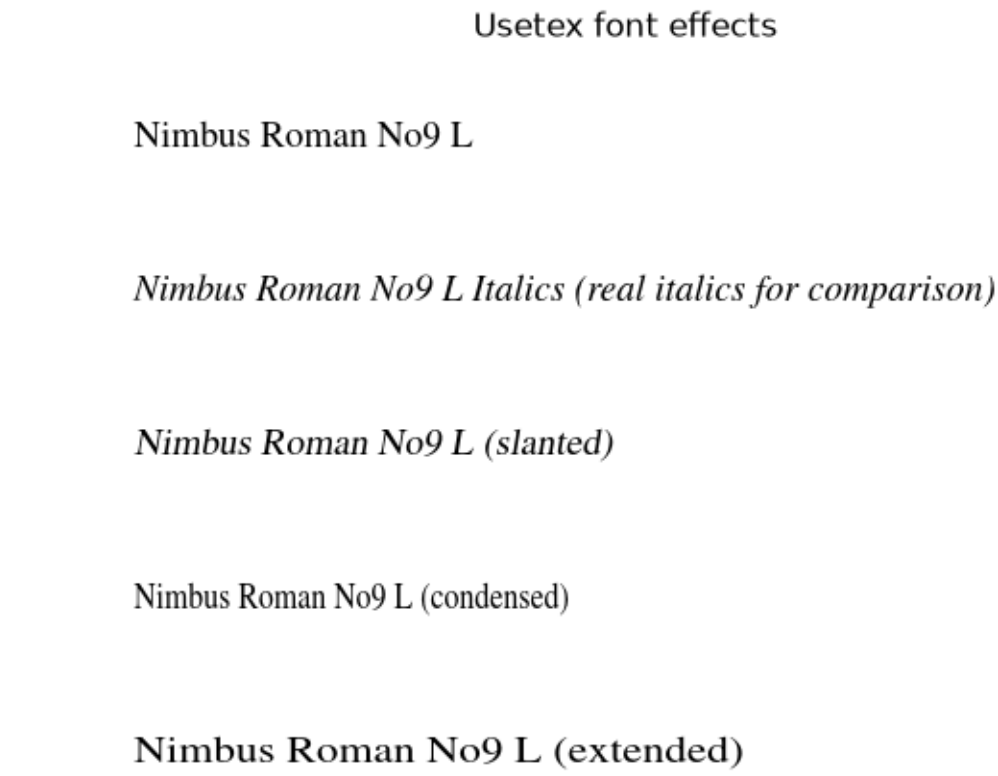
Comparison of text baselines computed for mathtext and usetex.



```
import matplotlib.pyplot as plt

plt.rcParams.update({"mathtext.fontset": "cm", "mathtext.rm": "serif"})
axs = plt.figure(figsize=(2 * 3, 6.5)).subplots(1, 2)
for ax, usetex in zip(axs, [False, True]):
    ax.axvline(0, color="r")
    test_strings = ["lg", r"$\frac{1}{2}\pi$", r"$p^{3^A}$", r"$p_{3_2}
 ↪$"]
    for i, s in enumerate(test_strings):
        ax.axhline(i, color="r")
        ax.text(0., 3 - i, s,
                usetex=usetex,
                verticalalignment="baseline",
                size=50,
                bbox=dict(pad=0, ec="k", fc="none"))
    ax.set(xlim=(-0.1, 1.1), ylim=(-.8, 3.9), xticks=[], yticks=[],
           title=f"usetex={usetex}\n")
plt.show()
```

Usetex font effects

This script demonstrates that font effects specified in your pdftex.map are now supported in usetex mode.




```
import matplotlib.pyplot as plt


def setfont(font):
    return rf'\font\a {font} at 14pt\a '


fig = plt.figure()
for y, font, text in zip(
    range(5),
    ['ptmr8r', 'ptmri8r', 'ptmro8r', 'ptmr8rn', 'ptmrr8re'],
    [f'Nimbus Roman No9 L {x}'
     for x in ['', 'Italics (real italics for comparison)',
               '(slanted)', '(condensed)', '(extended)']],
):
    fig.text(.1, 1 - (y + 1) / 6, setfont(font) + text, usetex=True)

fig.suptitle('Usetex font effects')
# Would also work if saving to pdf.
plt.show()
```

Artist within an artist

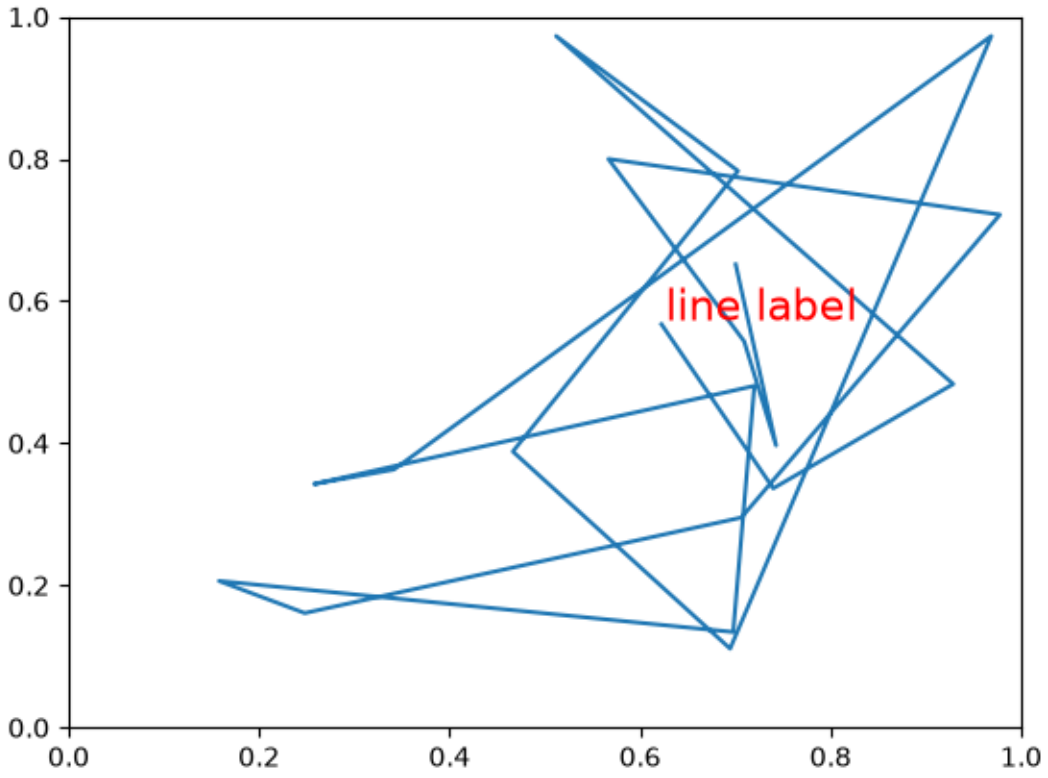
Override basic methods so an artist can contain another artist. In this case, the line contains a Text instance to label it.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.lines as lines
import matplotlib.text as mtext
import matplotlib.transforms as mtransforms


class MyLine(lines.Line2D):
    def __init__(self, *args, **kwargs):
        # we'll update the position when the line data is set
        self.text = mtext.Text(0, 0, '')
        super().__init__(*args, **kwargs)

        # we can't access the label attr until *after* the line is
        # initiated
        self.text.set_text(self.get_label())

    def set_figure(self, figure):
        self.text.set_figure(figure)
        super().set_figure(figure)

    # Override the Axes property setter to set Axes on our children as␣
↪well.
    @lines.Line2D.axes.setter
    def axes(self, new_axes):
        self.text.axes = new_axes
        lines.Line2D.axes.fset(self, new_axes)  # Call the superclass␣
↪property setter.

    def set_transform(self, transform):
        # 2 pixel offset
        texttrans = transform + mtransforms.Affine2D().translate(2, 2)
        self.text.set_transform(texttrans)
        super().set_transform(transform)

    def set_data(self, x, y):
        if len(x):
            self.text.set_position((x[-1], y[-1]))

        super().set_data(x, y)
```

(continues on next page)

(continued from previous page)

```
    def draw(self, renderer):
        # draw my label at the end of the line with 2 pixel offset
        super().draw(renderer)
        self.text.draw(renderer)

# Fixing random state for reproducibility
np.random.seed(19680801)


fig, ax = plt.subplots()
x, y = np.random.rand(2, 20)
line = MyLine(x, y, mfc='red', ms=12, label='line label')
line.text.set_color('red')
line.text.set_fontsize(16)

ax.add_line(line)

plt.show()
```



References

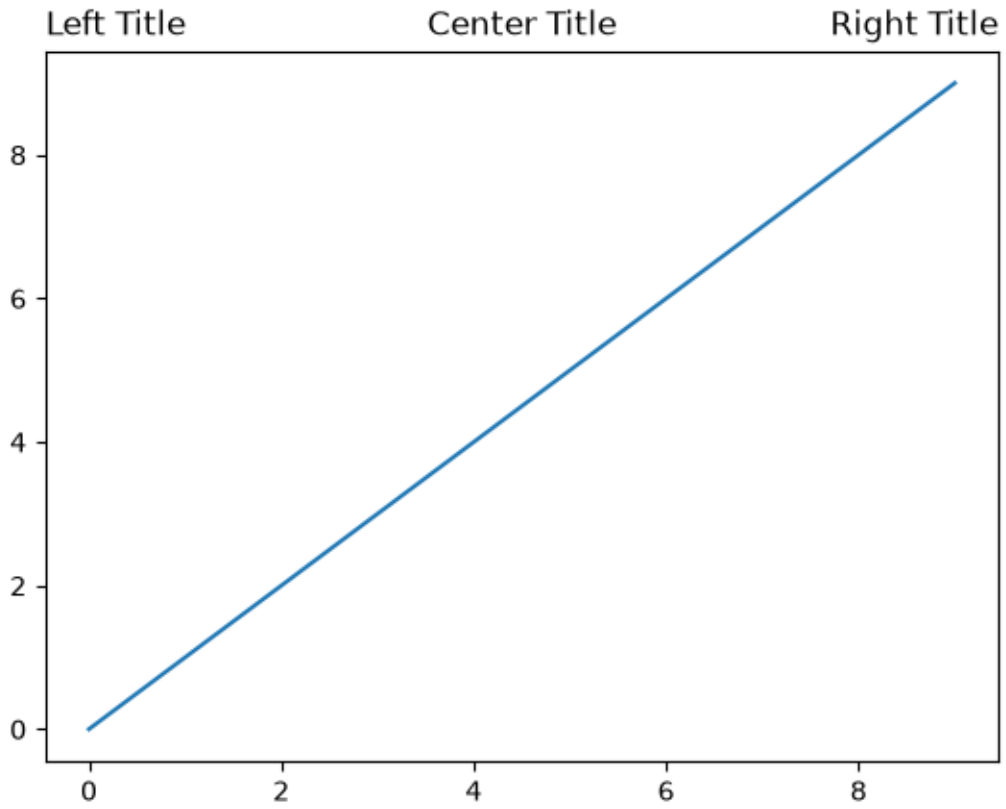
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.lines*
- *matplotlib.lines.Line2D*
- *matplotlib.lines.Line2D.set_data*
- *matplotlib.artist*
- *matplotlib.artist.Artist*
- *matplotlib.artist.Artist.draw*
- *matplotlib.artist.Artist.set_transform*
- *matplotlib.text*
- *matplotlib.text.Text*
- *matplotlib.text.Text.set_color*
- *matplotlib.text.Text.set_fontsize*
- *matplotlib.text.Text.set_position*
- *matplotlib.axes.Axes.add_line*
- *matplotlib.transforms*
- *matplotlib.transforms.Affine2D*

Title positioning

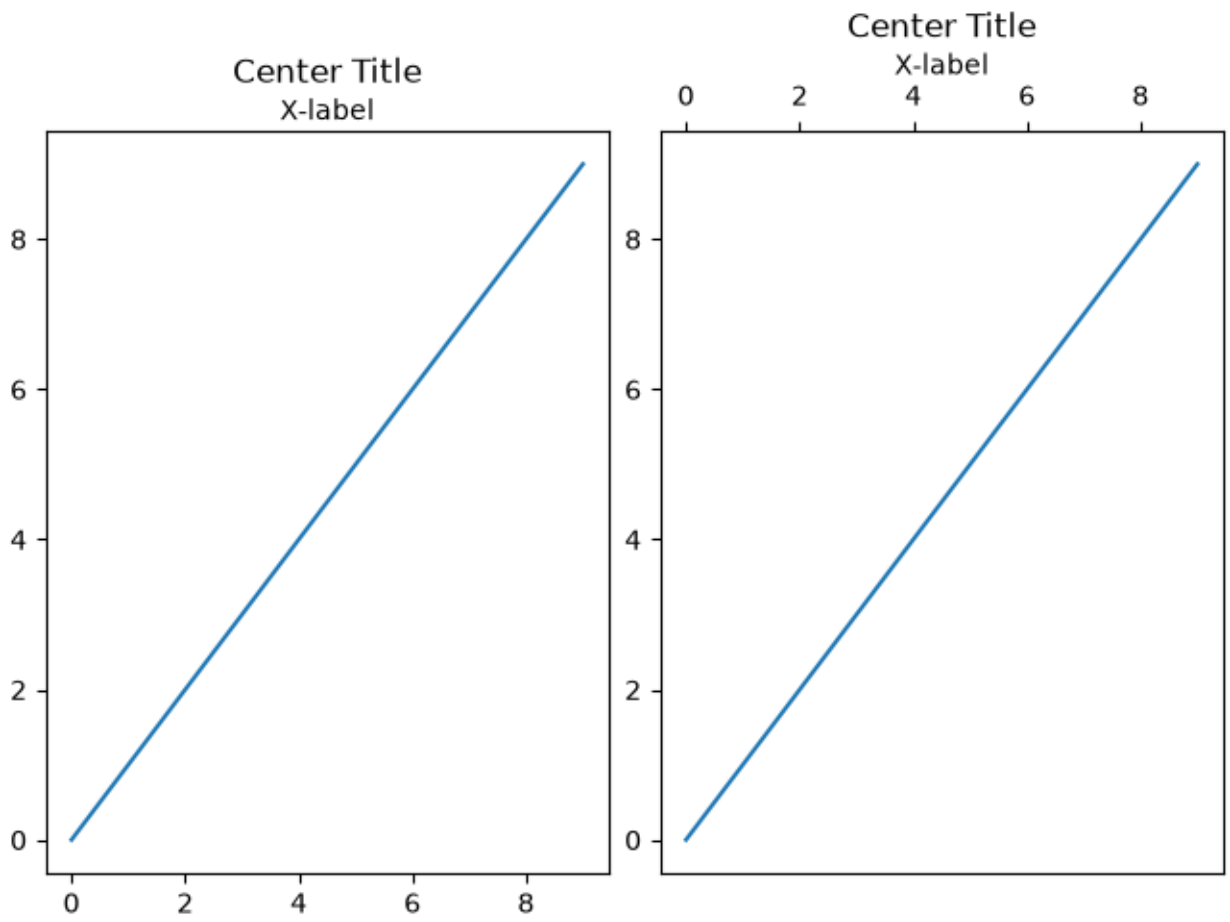
Matplotlib can display plot titles centered, flush with the left side of a set of Axes, and flush with the right side of a set of Axes.

```
import matplotlib.pyplot as plt

plt.plot(range(10))

plt.title('Center Title')
plt.title('Left Title', loc='left')
plt.title('Right Title', loc='right')

plt.show()
```



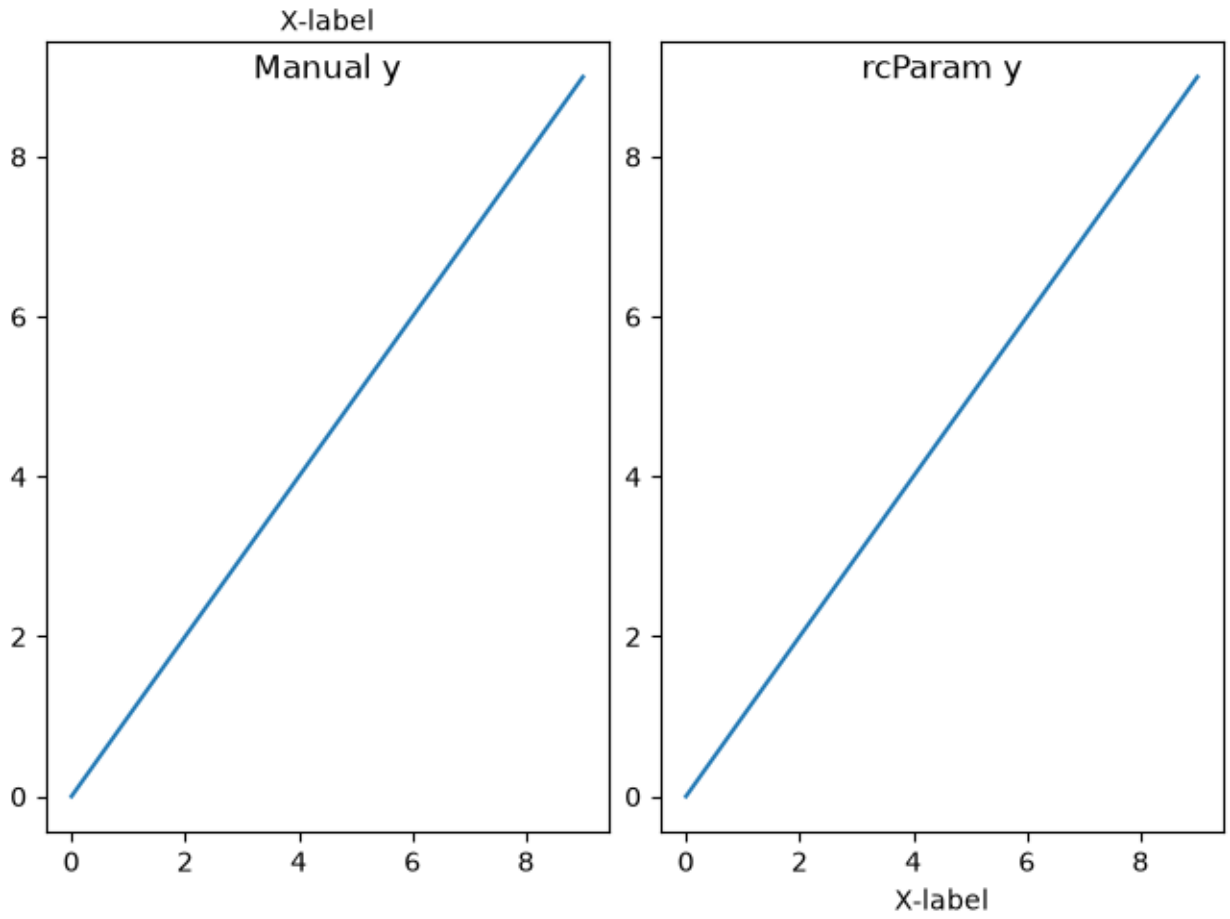
The vertical position is automatically chosen to avoid decorations (i.e. labels and ticks) on the topmost x-axis:

```
fig, axs = plt.subplots(1, 2, layout='constrained')

ax = axs[0]
ax.plot(range(10))
ax.xaxis.set_label_position('top')
ax.set_xlabel('X-label')
ax.set_title('Center Title')

ax = axs[1]
ax.plot(range(10))
ax.xaxis.set_label_position('top')
ax.xaxis.tick_top()
ax.set_xlabel('X-label')
ax.set_title('Center Title')
plt.show()
```



Automatic positioning can be turned off by manually specifying the *y* keyword argument for the title or setting *rcParams["axes.titley"]* (default: None) in the rcParams.

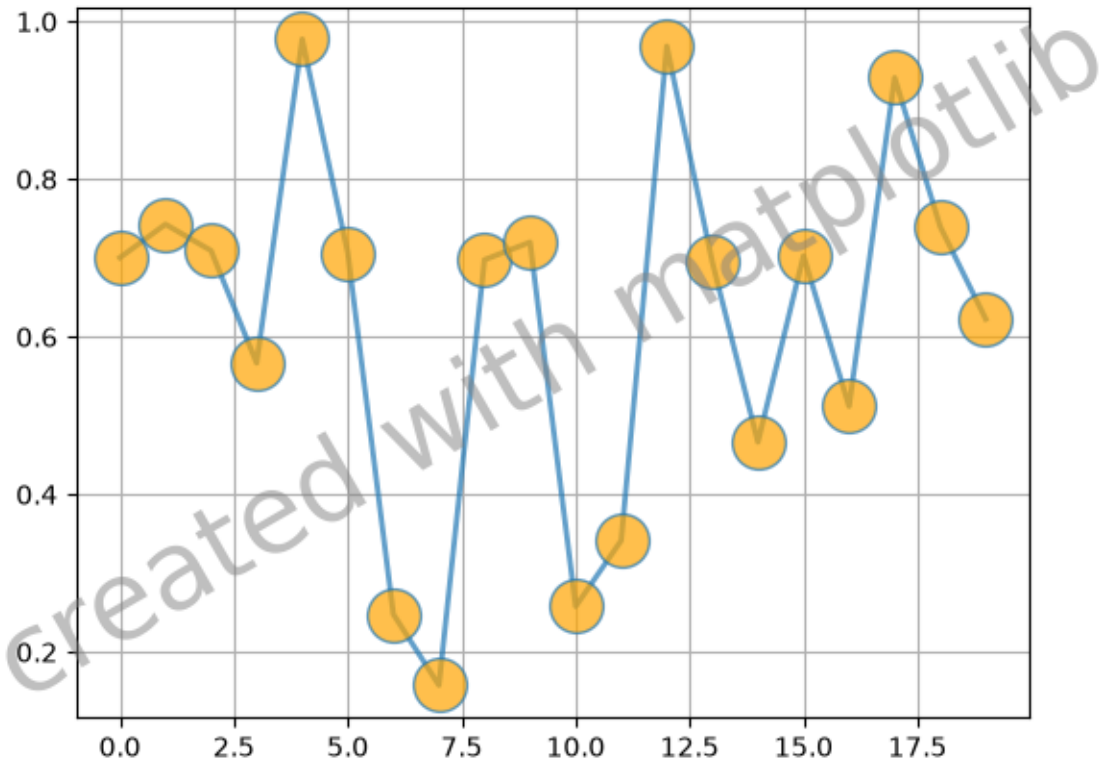
```
fig, axs = plt.subplots(1, 2, layout='constrained')

ax = axs[0]
ax.plot(range(10))
ax.xaxis.set_label_position('top')
ax.set_xlabel('X-label')
ax.set_title('Manual y', y=1.0, pad=-14)

plt.rcParams['axes.titley'] = 1.0    # y is in axes-relative␣
 ↪coordinates.
plt.rcParams['axes.titlepad'] = -14  # pad is in points...
ax = axs[1]
ax.plot(range(10))
ax.set_xlabel('X-label')
ax.set_title('rcParam y')

plt.show()
```



Text watermark

A watermark effect can be achieved by drawing a semi-transparent text.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)


fig, ax = plt.subplots()
ax.plot(np.random.rand(20), '-o', ms=20, lw=2, alpha=0.7, mfc='orange')
ax.grid()

ax.text(0.5, 0.5, 'created with matplotlib', transform=ax.transAxes,
        fontsize=40, color='gray', alpha=0.5,
        ha='center', va='center', rotation=30)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.figure.Figure.text*

6.24.10 Shapes and collections

Arrow guide

Adding arrow patches to plots.

Arrows are often used to annotate plots. This tutorial shows how to plot arrows that behave differently when the data limits on a plot are changed. In general, points on a plot can either be fixed in "data space" or "display space". Something plotted in data space moves when the data limits are altered - an example would be the points in a scatter plot. Something plotted in display space stays static when data limits are altered - an example would be a figure title or the axis labels.

Arrows consist of a head (and possibly a tail) and a stem drawn between a start point and end point, called 'anchor points' from now on. Here we show three use cases for plotting arrows, depending on whether the head or anchor points need to be fixed in data or display space:

1. Head shape fixed in display space, anchor points fixed in data space
2. Head shape and anchor points fixed in display space
3. Entire patch fixed in data space

Below each use case is presented in turn.

```
import matplotlib.pyplot as plt

import matplotlib.patches as mpatches

x_tail = 0.1
y_tail = 0.5
x_head = 0.9
y_head = 0.8
dx = x_head - x_tail
dy = y_head - y_tail
```

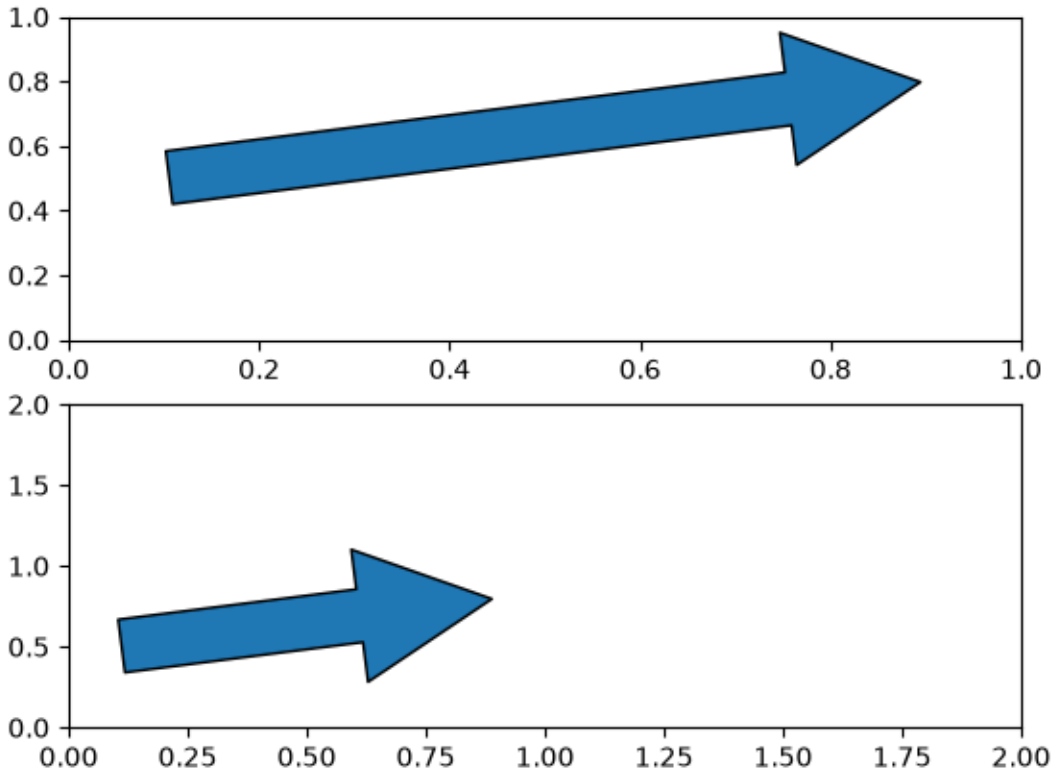
Head shape fixed in display space and anchor points fixed in data space

This is useful if you are annotating a plot, and don't want the arrow to change shape or position if you pan or scale the plot.

In this case we use *patches.FancyArrowPatch*.

Note that when the axis limits are changed, the arrow shape stays the same, but the anchor points move.

```
fig, axs = plt.subplots(nrows=2)
arrow = mpatches.FancyArrowPatch((x_tail, y_tail), (x_head, y_head),
                                 mutation_scale=100)
axs[0].add_patch(arrow)

arrow = mpatches.FancyArrowPatch((x_tail, y_tail), (x_head, y_head),
                                 mutation_scale=100)
axs[1].add_patch(arrow)
axs[1].set(xlim=(0, 2), ylim=(0, 2))
```



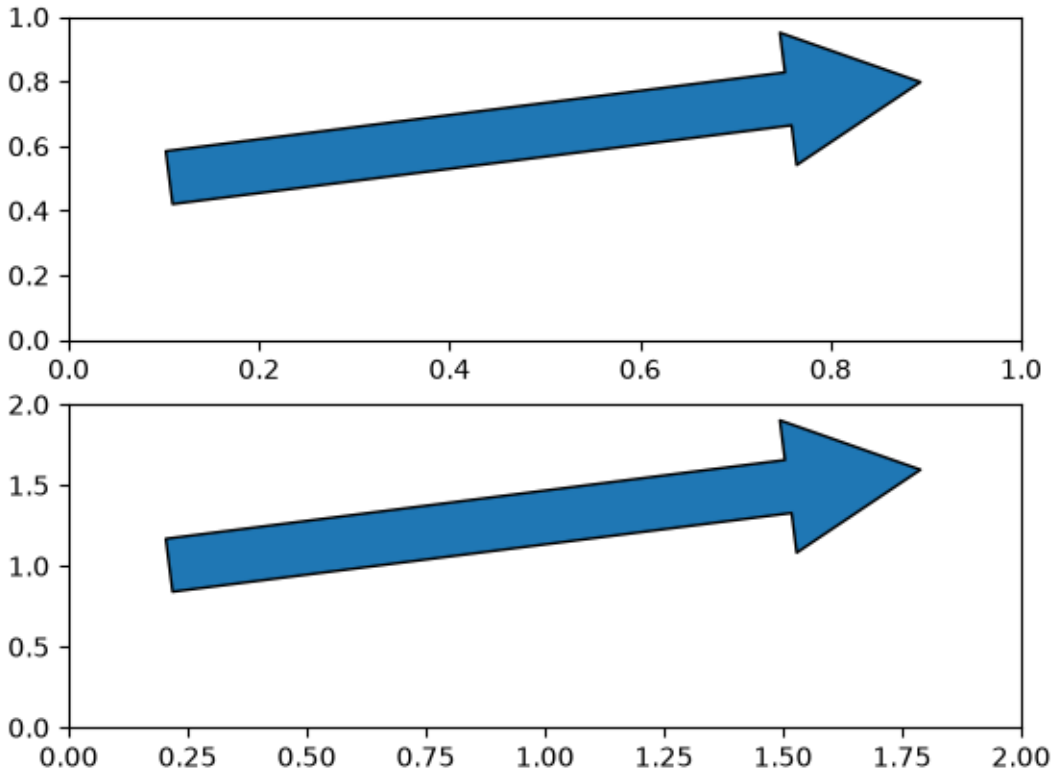
Head shape and anchor points fixed in display space

This is useful if you are annotating a plot, and don't want the arrow to change shape or position if you pan or scale the plot.

In this case we use *patches.FancyArrowPatch*, and pass the keyword argument `transform=ax.transAxes` where `ax` is the Axes we are adding the patch to.

Note that when the axis limits are changed, the arrow shape and location stay the same.

```
fig, axs = plt.subplots(nrows=2)
arrow = mpatches.FancyArrowPatch((x_tail, y_tail), (x_head, y_head),
                                 mutation_scale=100,
                                 transform=axs[0].transAxes)
axs[0].add_patch(arrow)

arrow = mpatches.FancyArrowPatch((x_tail, y_tail), (x_head, y_head),
                                 mutation_scale=100,
                                 transform=axs[1].transAxes)
axs[1].add_patch(arrow)
axs[1].set(xlim=(0, 2), ylim=(0, 2))
```



Head shape and anchor points fixed in data space

In this case we use *patches.Arrow*, or *patches.FancyArrow* (the latter is in orange).

Note that when the axis limits are changed, the arrow shape and location change.

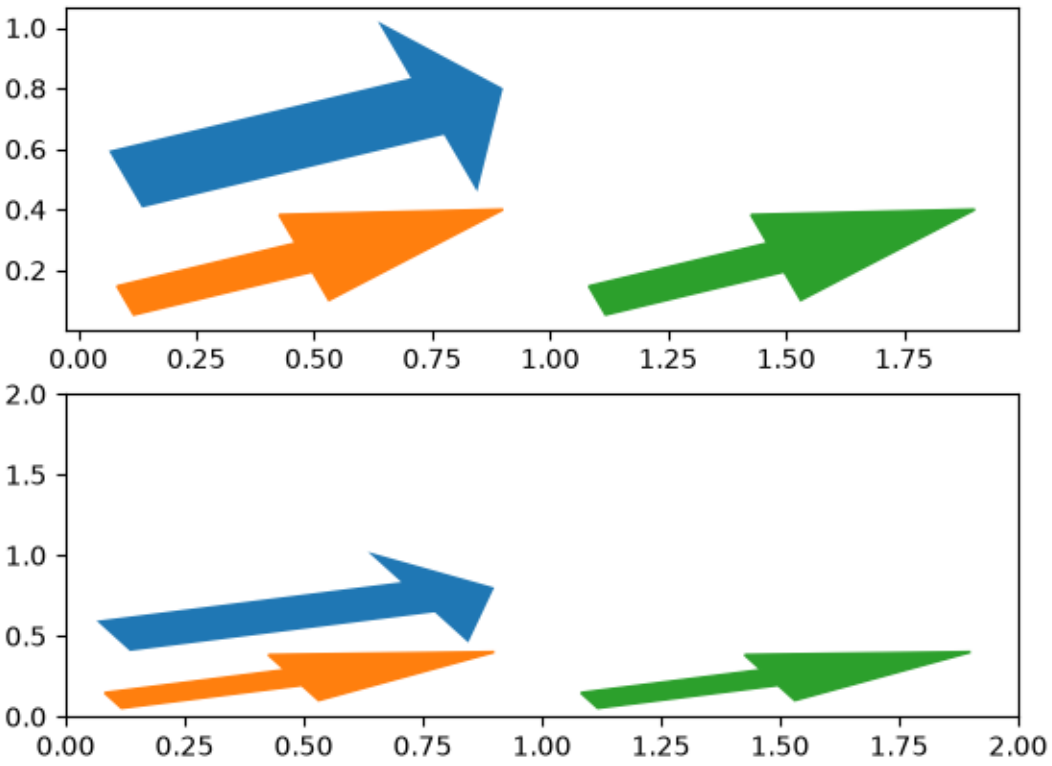
FancyArrow's API is relatively awkward, and requires in particular passing `length_includes_head=True` so that the arrow *tip* is `(dx, dy)` away from the arrow start. It is only included in this reference because it is the arrow class returned by *Axes.arrow* (in green).

```
fig, axs = plt.subplots(nrows=2)

arrow = mpatches.Arrow(x_tail, y_tail, dx, dy)
axs[0].add_patch(arrow)
arrow = mpatches.FancyArrow(x_tail, y_tail - .4, dx, dy,
                            width=.1, length_includes_head=True, color=
 ↪"C1")
axs[0].add_patch(arrow)
axs[0].arrow(x_tail + 1, y_tail - .4, dx, dy,
             width=.1, length_includes_head=True, color="C2")
```

(continues on next page)

(continued from previous page)

```
arrow = mpatches.Arrow(x_tail, y_tail, dx, dy)
axs[1].add_patch(arrow)
arrow = mpatches.FancyArrow(x_tail, y_tail - .4, dx, dy,
                            width=.1, length_includes_head=True, color=
 ↪"C1")
axs[1].add_patch(arrow)
axs[1].arrow(x_tail + 1, y_tail - .4, dx, dy,
             width=.1, length_includes_head=True, color="C2")
axs[1].set(xlim=(0, 2), ylim=(0, 2))
```




```
plt.show()
```

Reference for Matplotlib artists

This example displays several of Matplotlib's graphics primitives (artists). A full list of artists is documented at *the artist API*.

See also *Circles, Wedges and Polygons*, which groups all artists into a single `PatchCollection` instead.

Copyright (c) 2010, Bartosz Telenczuk BSD License

```
import matplotlib.pyplot as plt

import matplotlib as mpl
import matplotlib.lines as mlines
import matplotlib.patches as mpatches
import matplotlib.path as mpath

# Prepare the data for the PathPatch below.
Path = mpath.Path
codes, verts = zip(*[
    (Path.MOVETO, [0.018, -0.11]),
    (Path.CURVE4, [-0.031, -0.051]),
    (Path.CURVE4, [-0.115, 0.073]),
    (Path.CURVE4, [-0.03, 0.073]),
    (Path.LINETO, [-0.011, 0.039]),
    (Path.CURVE4, [0.043, 0.121]),
    (Path.CURVE4, [0.075, -0.005]),
    (Path.CURVE4, [0.035, -0.027]),
    (Path.CLOSEPOLY, [0.018, -0.11])])

artists = [
    mpatches.Circle((0, 0), 0.1, ec="none"),
    mpatches.Rectangle((-0.025, -0.05), 0.05, 0.1, ec="none"),
    mpatches.Wedge((0, 0), 0.1, 30, 270, ec="none"),
    mpatches.RegularPolygon((0, 0), 5, radius=0.1),
    mpatches.Ellipse((0, 0), 0.2, 0.1),
    mpatches.Arrow(-0.05, -0.05, 0.1, 0.1, width=0.1),
    mpatches.PathPatch(mpath.Path(verts, codes), ec="none"),
    mpatches.FancyBboxPatch((-0.025, -0.05), 0.05, 0.1, ec="none",
                            boxstyle=mpatches.BoxStyle("Round",␣
 ↪pad=0.02)),
    mlines.Line2D([-0.06, 0.0, 0.1], [0.05, -0.05, 0.05], lw=5),
]

axs = plt.figure(figsize=(6, 6), layout="constrained").subplots(3, 3)
for i, (ax, artist) in enumerate(zip(axs.flat, artists)):
    artist.set(color=mpl.colormaps["hsv"](i / len(artists)))
    ax.add_artist(artist)
    ax.set(title=type(artist).__name__,
           aspect=1, xlim=(-.2, .2), ylim=(-.2, .2))
    ax.set_axis_off()
plt.show()
```

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.path*
- *matplotlib.path.Path*
- *matplotlib.lines*
- *matplotlib.lines.Line2D*
- *matplotlib.patches*
- *matplotlib.patches.Circle*
- *matplotlib.patches.Ellipse*

- *matplotlib.patches.Wedge*
- *matplotlib.patches.Rectangle*
- *matplotlib.patches.Arrow*
- *matplotlib.patches.PathPatch*
- *matplotlib.patches.FancyBboxPatch*
- *matplotlib.patches.RegularPolygon*
- *matplotlib.axes.Axes.add_artist*

Line, Poly and RegularPoly Collection

For the first two subplots, we will use spirals. Their size will be set in plot units, not data units. Their positions will be set in data units by using the *offsets* and *offset_transform* keyword arguments of the *LineCollection* and *PolyCollection*.

The third subplot will make regular polygons, with the same type of scaling and positioning as in the first two.

The last subplot illustrates the use of `offsets=(xo, yo)`, that is, a single tuple instead of a list of tuples, to generate successively offset curves, with the offset given in data units. This behavior is available only for the LineCollection.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import collections, transforms

nverts = 50
npts = 100

# Make some spirals
r = np.arange(nverts)
theta = np.linspace(0, 2*np.pi, nverts)
xx = r * np.sin(theta)
yy = r * np.cos(theta)
spiral = np.column_stack([xx, yy])

# Fixing random state for reproducibility
rs = np.random.RandomState(19680801)

# Make some offsets
xyo = rs.randn(npts, 2)

# Make a list of colors from the default color cycle.
colors = plt.rcParams['axes.prop_cycle'].by_key()['color']
```

(continues on next page)

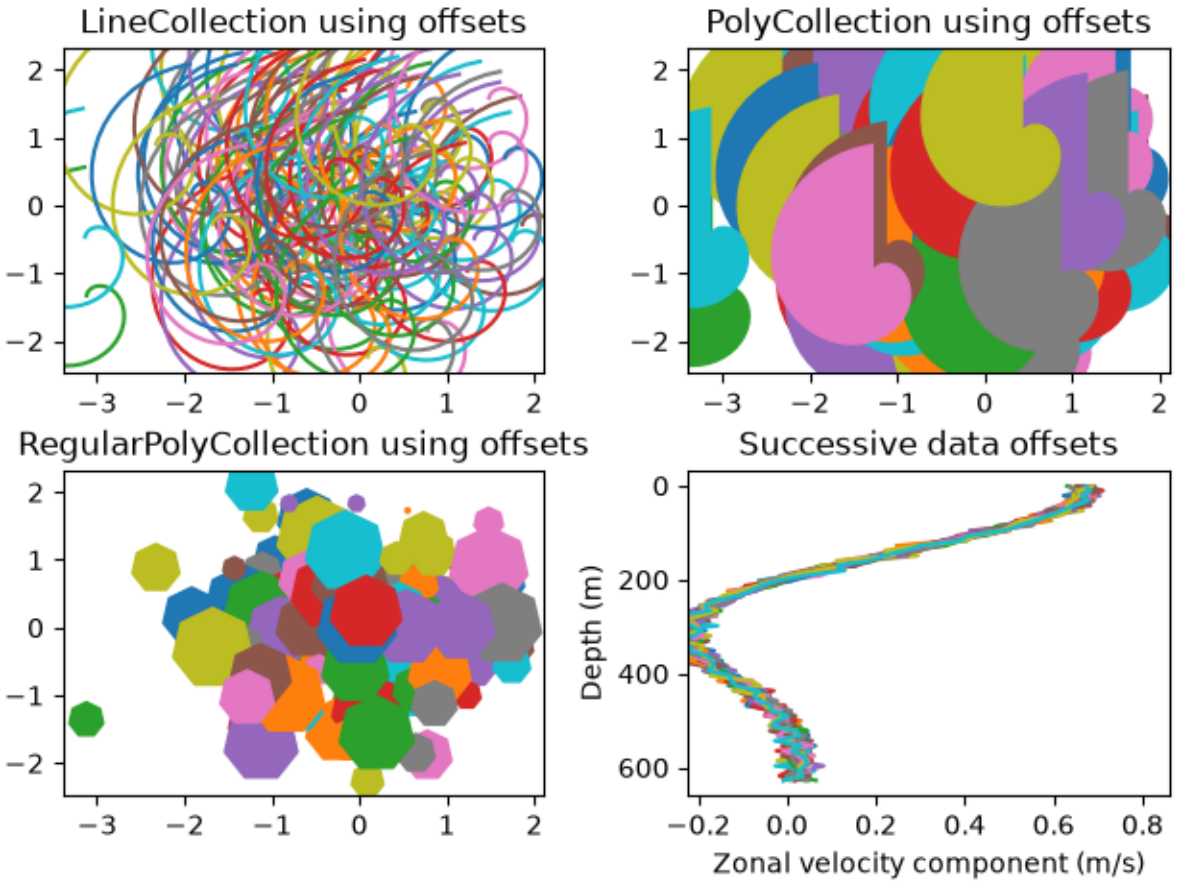
(continued from previous page)

```
fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(2, 2)
fig.subplots_adjust(top=0.92, left=0.07, right=0.97,
                    hspace=0.3, wspace=0.3)


col = collections.LineCollection(
    [spiral], offsets=xyo, offset_transform=ax1.transData,␣
 ↪color=colors)
# transform the line segments such that their size is given in points
trans = fig.dpi_scale_trans + transforms.Affine2D().scale(1.0/72.0)
col.set_transform(trans)  # the points to pixels transform
ax1.add_collection(col)
ax1.set_title('LineCollection using offsets')


# The same data as above, but fill the curves.
col = collections.PolyCollection(
    [spiral], offsets=xyo, offset_transform=ax2.transData,␣
 ↪color=colors)
trans = transforms.Affine2D().scale(fig.dpi/72.0)
col.set_transform(trans)  # the points to pixels transform
ax2.add_collection(col)
ax2.set_title('PolyCollection using offsets')


# 7-sided regular polygons
col = collections.RegularPolyCollection(
    7, sizes=np.abs(xx) * 10.0, offsets=xyo, offset_transform=ax3.
 ↪transData,
    color=colors)
trans = transforms.Affine2D().scale(fig.dpi / 72.0)
col.set_transform(trans)  # the points to pixels transform
ax3.add_collection(col)
ax3.set_title('RegularPolyCollection using offsets')


# Simulate a series of ocean current profiles, successively
# offset by 0.1 m/s so that they form what is sometimes called
# a "waterfall" plot or a "stagger" plot.
nverts = 60
ncurves = 20
offs = (0.1, 0.0)

yy = np.linspace(0, 2*np.pi, nverts)
ym = np.max(yy)
```

(continues on next page)

(continued from previous page)

```
xx = (0.2 + (ym - yy) / ym) ** 2 * np.cos(yy - 0.4) * 0.5
segs = []
for i in range(ncurves):
    xxx = xx + 0.02*rs.randn(nverts)
    curve = np.column_stack([xxx, yy * 100])
    segs.append(curve)

col = collections.LineCollection(segs, offsets=offs, color=colors)
ax4.add_collection(col)
ax4.set_title('Successive data offsets')
ax4.set_xlabel('Zonal velocity component (m/s)')
ax4.set_ylabel('Depth (m)')
ax4.invert_yaxis()  # so that depth increases downward

plt.show()
```



References

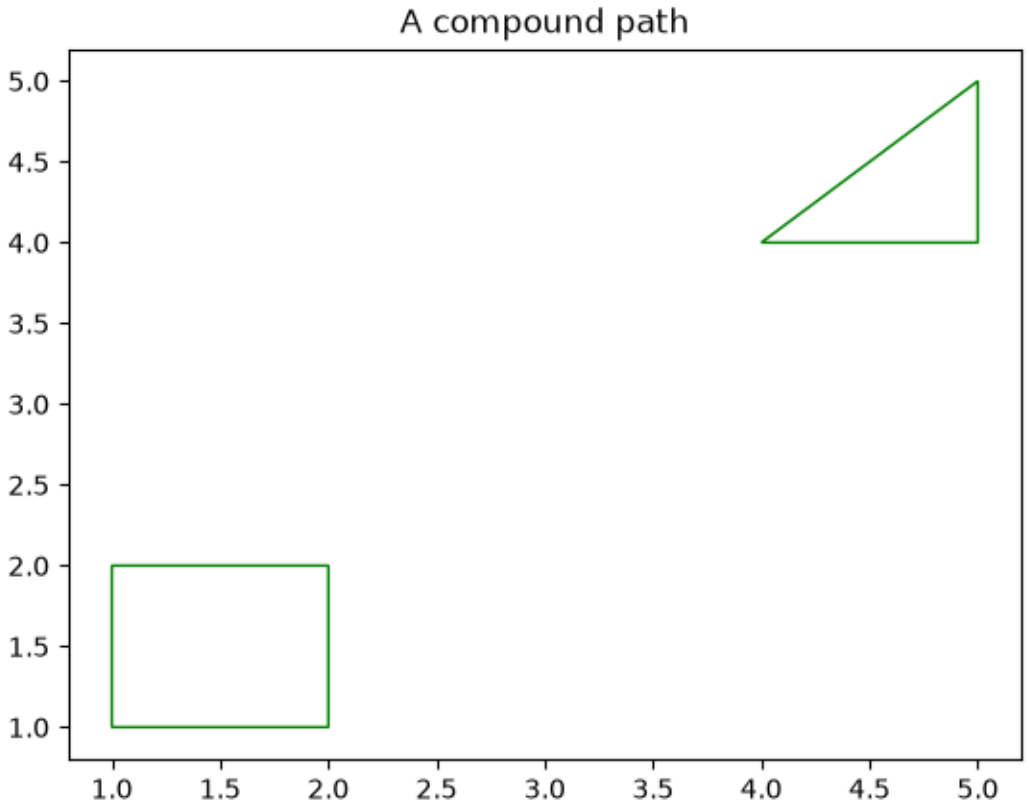
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.figure.Figure*
- *matplotlib.collections*
- *matplotlib.collections.LineCollection*
- *matplotlib.collections.RegularPolyCollection*
- *matplotlib.axes.Axes.add_collection*
- *matplotlib.transforms.Affine2D*
- *matplotlib.transforms.Affine2D.scale*

Compound path

Make a compound path -- in this case two simple polygons, a rectangle and a triangle. Use `CLOSEPOLY` and `MOVETO` for the different parts of the compound path

```
import matplotlib.pyplot as plt

from matplotlib.patches import PathPatch
from matplotlib.path import Path

vertices = []
codes = []

codes = [Path.MOVETO] + [Path.LINETO]*3 + [Path.CLOSEPOLY]
vertices = [(1, 1), (1, 2), (2, 2), (2, 1), (0, 0)]

codes += [Path.MOVETO] + [Path.LINETO]*2 + [Path.CLOSEPOLY]
vertices += [(4, 4), (5, 5), (5, 4), (0, 0)]

path = Path(vertices, codes)

pathpatch = PathPatch(path, facecolor='none', edgecolor='green')

fig, ax = plt.subplots()
ax.add_patch(pathpatch)
ax.set_title('A compound path')

ax.autoscale_view()

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.path*
- *matplotlib.path.Path*
- *matplotlib.patches*
- *matplotlib.patches.PathPatch*
- *matplotlib.axes.Axes.add_patch*
- *matplotlib.axes.Axes.autoscale_view*

Dolphins

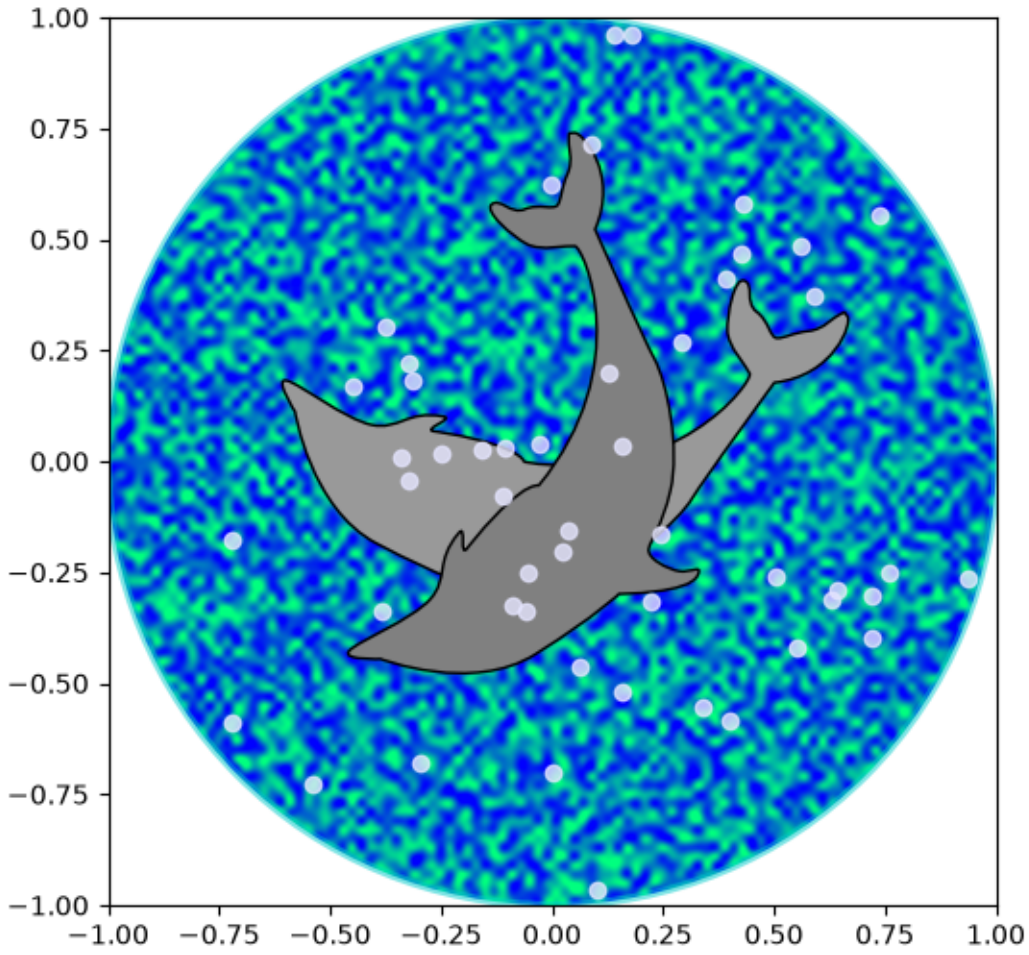
This example shows how to draw, and manipulate shapes given vertices and nodes using the *Path*, *PathPatch* and *transforms* classes.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Circle, PathPatch
from matplotlib.path import Path
from matplotlib.transforms import Affine2D

# Fixing random state for reproducibility
np.random.seed(19680801)


r = np.random.rand(50)
t = np.random.rand(50) * np.pi * 2.0
x = r * np.cos(t)
y = r * np.sin(t)

fig, ax = plt.subplots(figsize=(6, 6))
circle = Circle((0, 0), 1, facecolor='none',
                edgecolor=(0, 0.8, 0.8), linewidth=3, alpha=0.5)
ax.add_patch(circle)

im = plt.imshow(np.random.random((100, 100)),
                origin='lower', cmap="winter",
                interpolation='spline36',
                extent=(-1, 1, -1, 1))
im.set_clip_path(circle)

plt.plot(x, y, 'o', color=(0.9, 0.9, 1.0), alpha=0.8)

# Dolphin from OpenClipart library by Andy Fitzsimon (Public Domain).

dolphin = """
M -0.59739425,160.18173 C -0.62740401,160.18885 -0.57867129,160.11183
-0.57867129,160.11183 C -0.57867129,160.11183 -0.5438361,159.89315
-0.39514638,159.81496 C -0.24645668,159.73678 -0.18316813,159.71981
-0.18316813,159.71981 C -0.18316813,159.71981 -0.10322971,159.58124
-0.057804323,159.58725 C -0.029723983,159.58913 -0.061841603,159.60356
-0.071265813,159.62815 C -0.080250183,159.65325 -0.082918513,159.70554
-0.061841203,159.71248 C -0.040763903,159.7194 -0.0066711426,159.71091
0.077336307,159.73612 C 0.16879567,159.76377 0.28380306,159.86448
0.31516668,159.91533 C 0.3465303,159.96618 0.5011127,160.1771
0.5011127,160.1771 C 0.63668998,160.19238 0.67763022,160.31259
0.66556395,160.32668 C 0.65339985,160.34212 0.66350443,160.33642
0.64907098,160.33088 C 0.63463742,160.32533 0.61309688,160.297
0.5789627,160.29339 C 0.54348657,160.28968 0.52329693,160.27674
0.50728856,160.27737 C 0.49060916,160.27795 0.48965803,160.31565
```

(continues on next page)

(continued from previous page)

```
0.46114204,160.33673 C 0.43329696,160.35786 0.4570711,160.39871
0.43309565,160.40685 C 0.4105108,160.41442 0.39416631,160.33027
0.3954995,160.2935 C 0.39683269,160.25672 0.43807996,160.21522
0.44567915,160.19734 C 0.45327833,160.17946 0.27946869,159.9424
-0.061852613,159.99845 C -0.083965233,160.0427 -0.26176109,160.06683
-0.26176109,160.06683 C -0.30127962,160.07028 -0.21167141,160.09731
-0.24649368,160.1011 C -0.32642366,160.11569 -0.34521187,160.06895
-0.40622293,160.0819 C -0.467234,160.09485 -0.56738444,160.17461
-0.59739425,160.18173
"""

vertices = []
codes = []
parts = dolphin.split()
i = 0
code_map = {
    'M': Path.MOVETO,
    'C': Path.CURVE4,
    'L': Path.LINETO,
}

while i < len(parts):
    path_code = code_map[parts[i]]
    npoints = Path.NUM_VERTICES_FOR_CODE[path_code]
    codes.extend([path_code] * npoints)
    vertices.extend([[*map(float, y.split(','))]
                     for y in parts[i + 1:][:npoints]])
    i += npoints + 1
vertices = np.array(vertices)
vertices[:, 1] -= 160

dolphin_path = Path(vertices, codes)
dolphin_patch = PathPatch(dolphin_path, facecolor=(0.6, 0.6, 0.6),
                          edgecolor=(0.0, 0.0, 0.0))
ax.add_patch(dolphin_patch)

vertices = Affine2D().rotate_deg(60).transform(vertices)
dolphin_path2 = Path(vertices, codes)
dolphin_patch2 = PathPatch(dolphin_path2, facecolor=(0.5, 0.5, 0.5),
                           edgecolor=(0.0, 0.0, 0.0))
ax.add_patch(dolphin_patch2)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.path*
- *matplotlib.path.Path*
- *matplotlib.patches*
- *matplotlib.patches.PathPatch*
- *matplotlib.patches.Circle*
- *matplotlib.axes.Axes.add_patch*
- *matplotlib.transforms*

- *matplotlib.transforms.Affine2D*
- *matplotlib.transforms.Affine2D.rotate_deg*

Tags: component: patch styling: shape purpose: fun

Mmh Donuts!!!

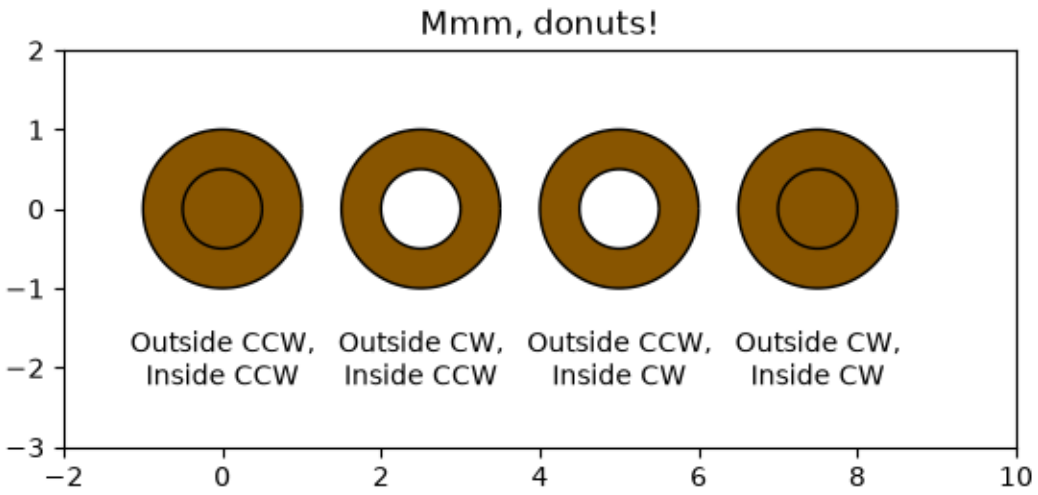
Draw donuts (miam!) using *Path*s and *PathPatch*es. This example shows the effect of the path's orientations in a compound path.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.patches as mpatches
import matplotlib.path as mpath


def wise(v):
    return {+1: "CCW", -1: "CW"}[v]


def make_circle(r):
    t = np.arange(0, np.pi * 2.0, 0.01)
    x = r * np.cos(t)
    y = r * np.sin(t)
    return np.column_stack((x, y))


fig, ax = plt.subplots()

inside_vertices = make_circle(0.5)
outside_vertices = make_circle(1.0)
codes = np.full(len(inside_vertices), mpath.Path.LINETO)
codes[0] = mpath.Path.MOVETO

for i, (inside, outside) in enumerate(((1, 1), (1, -1), (-1, 1), (-1, -
 ↪1))):
    # Concatenate the inside and outside subpaths together, changing␣
 ↪their
    # order as needed
    vertices = np.concatenate((outside_vertices[::outside],
                               inside_vertices[::inside]))
    # Shift the path
    vertices += (i * 2.5, 0)
    # The codes will be all "LINETO" commands, except for "MOVETO"s at␣
 ↪the
```

(continues on next page)

(continued from previous page)

```
    # beginning of each subpath
    all_codes = np.concatenate((codes, codes))
    # Create the Path object
    path = mpath.Path(vertices, all_codes)
    # And plot it
    patch = mpatches.PathPatch(path, facecolor='#885500', edgecolor=
↪'black')
    ax.add_patch(patch)

    ax.annotate(f"Outside {wise(outside)},\nInside {wise(inside)}",
                (i * 2.5, -1.5), va="top", ha="center")

ax.set(xlim=(-2, 10), ylim=(-3, 2), aspect=1, title="Mmm, donuts!")
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.path*

- *matplotlib.path.Path*
- *matplotlib.patches*
- *matplotlib.patches.PathPatch*
- *matplotlib.patches.Circle*
- *matplotlib.axes.Axes.add_patch*
- *matplotlib.axes.Axes.annotate*
- *matplotlib.axes.Axes.set_aspect*
- *matplotlib.axes.Axes.set_xlim*
- *matplotlib.axes.Axes.set_ylim*
- *matplotlib.axes.Axes.set_title*

Tags: component: patch styling: shape purpose: fun

Ellipse with orientation arrow demo

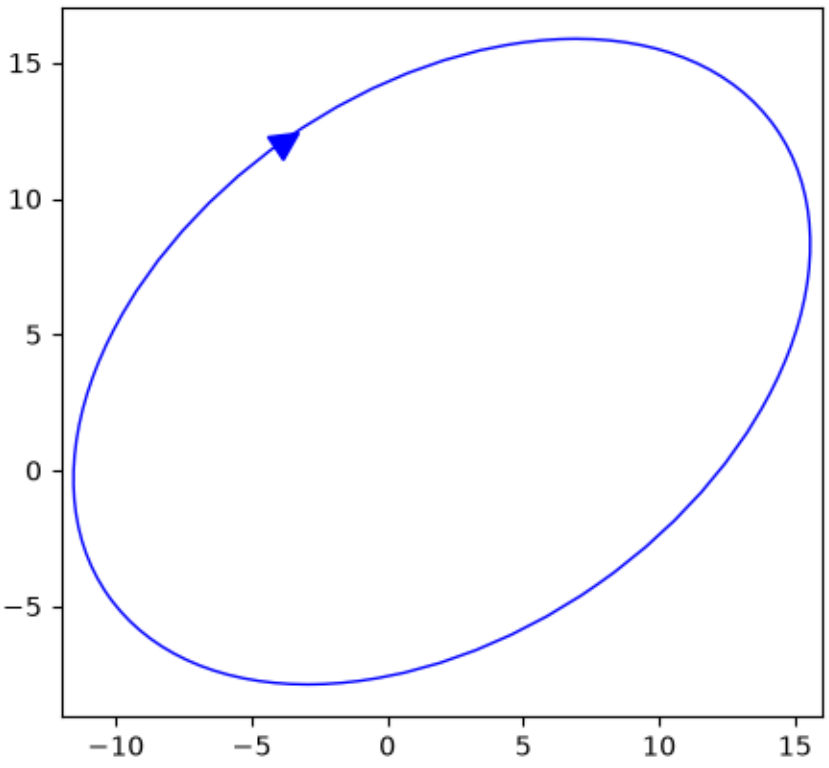
This demo shows how to draw an ellipse with an orientation arrow (clockwise or counterclockwise). Compare this to the *Ellipse collection example*.

```
import matplotlib.pyplot as plt

from matplotlib.markers import MarkerStyle
from matplotlib.patches import Ellipse
from matplotlib.transforms import Affine2D

# Create a figure and axis
fig, ax = plt.subplots(subplot_kw={"aspect": "equal"})

ellipse = Ellipse(
    xy=(2, 4),
    width=30,
    height=20,
    angle=35,
    facecolor="none",
    edgecolor="b"
)
ax.add_patch(ellipse)

# Plot an arrow marker at the end point of minor axis
vertices = ellipse.get_co_vertices()
t = Affine2D().rotate_deg(ellipse.angle)
ax.plot(
    vertices[0][0],
```

(continues on next page)

(continued from previous page)

```
    vertices[0][1],
    color="b",
    marker=MarkerStyle(">", "full", t),
    markersize=10
)
# Note: To reverse the orientation arrow, switch the marker type from >
 ↪ to <.

plt.show()
```



References

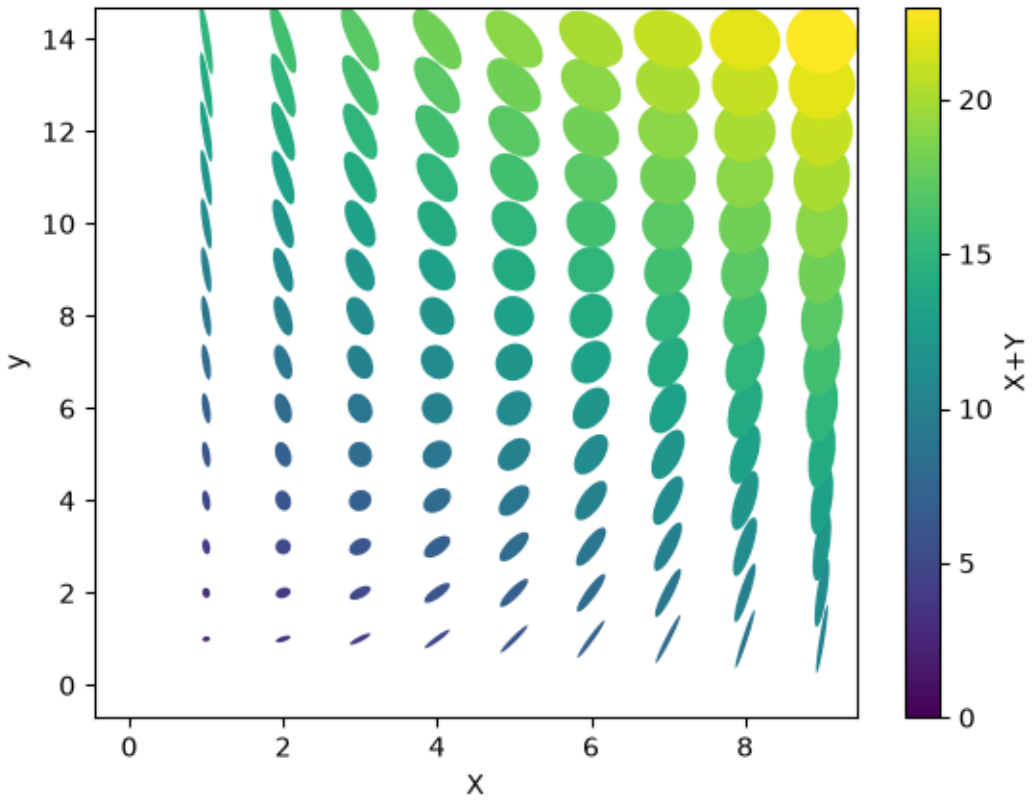
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches*
- *matplotlib.patches.Ellipse*

Ellipse Collection

Drawing a collection of ellipses. While this would equally be possible using a *EllipseCollection* or *PathCollection*, the use of an *EllipseCollection* allows for much shorter code.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.collections import EllipseCollection

x = np.arange(10)
y = np.arange(15)
X, Y = np.meshgrid(x, y)

XY = np.column_stack((X.ravel(), Y.ravel()))

ww = X / 10.0
hh = Y / 15.0
aa = X * 9


fig, ax = plt.subplots()

ec = EllipseCollection(ww, hh, aa, units='x', offsets=XY,
                       offset_transform=ax.transData)
ec.set_array((X + Y).ravel())
ax.add_collection(ec)
ax.set_xlabel('X')
ax.set_ylabel('y')
cbar = plt.colorbar(ec)
cbar.set_label('X+Y')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.collections*
- *matplotlib.collections.EllipseCollection*
- *matplotlib.axes.Axes.add_collection*
- *matplotlib.cm.ScalarMappable.set_array*

Ellipse Demo

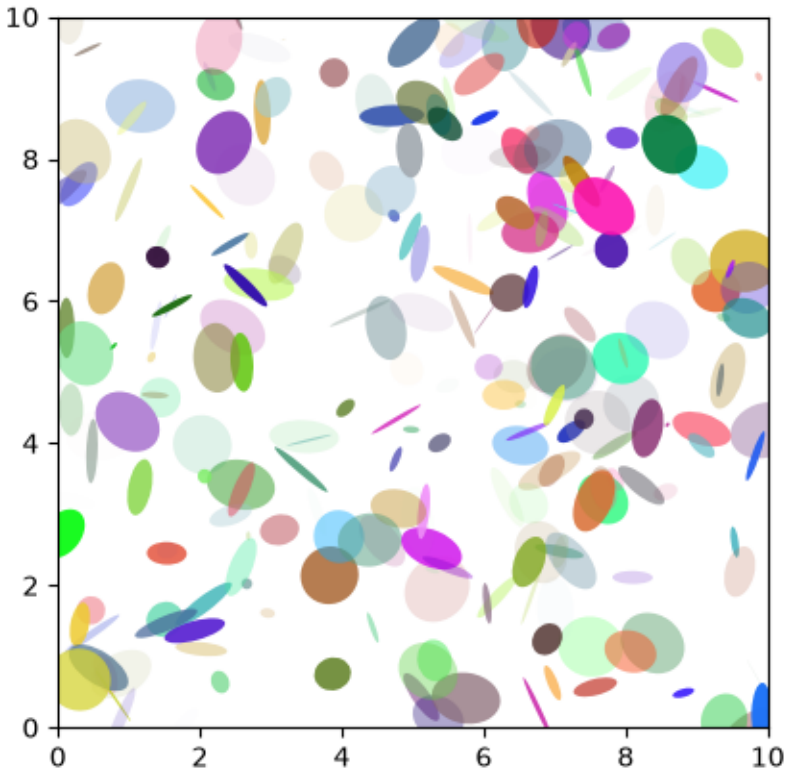
Draw many ellipses. Here individual ellipses are drawn. Compare this to the *Ellipse collection example*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Ellipse
```

(continues on next page)

(continued from previous page)

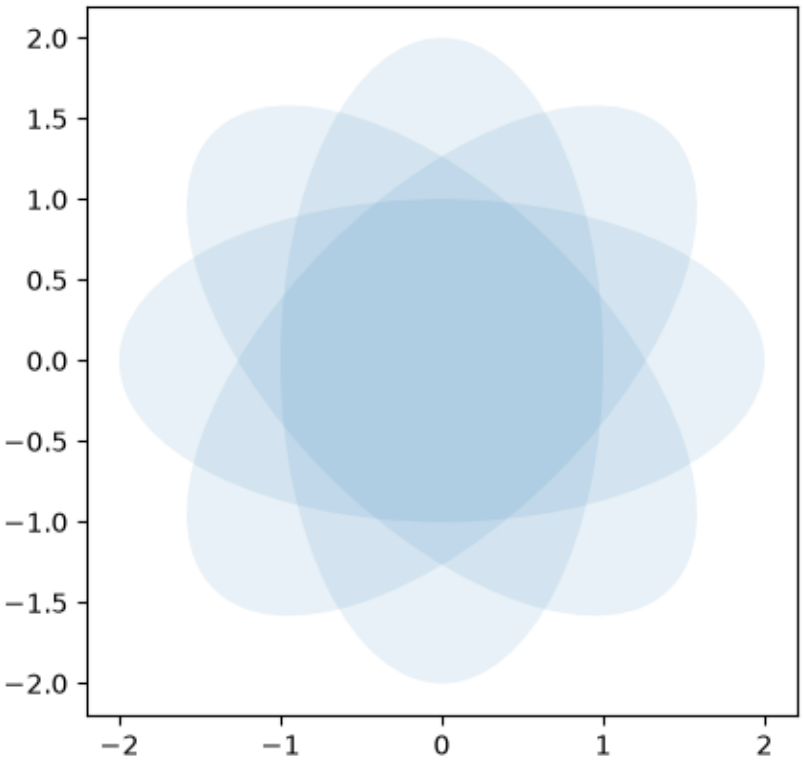
```
# Fixing random state for reproducibility
np.random.seed(19680801)

NUM = 250

ells = [Ellipse(xy=np.random.rand(2) * 10,
                width=np.random.rand(), height=np.random.rand(),
                angle=np.random.rand() * 360)
        for i in range(NUM)]

fig, ax = plt.subplots()
ax.set(xlim=(0, 10), ylim=(0, 10), aspect="equal")

for e in ells:
    ax.add_artist(e)
    e.set_clip_box(ax.bbox)
    e.set_alpha(np.random.rand())
    e.set_facecolor(np.random.rand(3))

plt.show()
```



Ellipse Rotated

Draw many ellipses with different angles.

```
angle_step = 45  # degrees
angles = np.arange(0, 180, angle_step)

fig, ax = plt.subplots()
ax.set(xlim=(-2.2, 2.2), ylim=(-2.2, 2.2), aspect="equal")

for angle in angles:
    ellipse = Ellipse((0, 0), 4, 2, angle=angle, alpha=0.1)
    ax.add_artist(ellipse)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches*

- *matplotlib.patches.Ellipse*
- *matplotlib.axes.Axes.add_artist*
- *matplotlib.artist.Artist.set_clip_box*
- *matplotlib.artist.Artist.set_alpha*
- *matplotlib.patches.Patch.set_facecolor*

Drawing fancy boxes

The following examples show how to plot boxes (*FancyBboxPatch*) with different visual properties.

```
import inspect

import matplotlib.pyplot as plt

import matplotlib.patches as mpatch
from matplotlib.patches import FancyBboxPatch
import matplotlib.transforms as mtransforms
```

Box styles

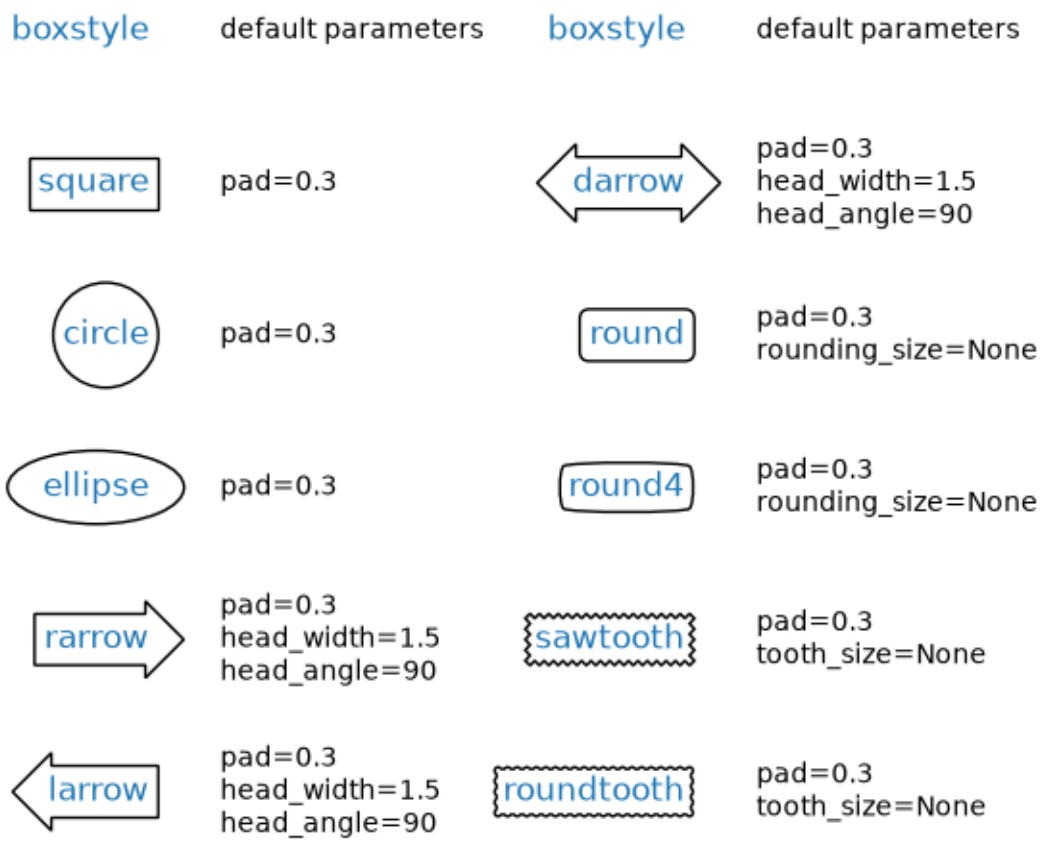
FancyBboxPatch supports different *BoxStyle*s. Note that *text* allows to draw a box around the text by adding the bbox parameter. Therefore, you don't see explicit *FancyBboxPatch* and *BoxStyle* calls in the following example.

```
styles = mpatch.BoxStyle.get_styles()
ncol = 2
nrow = (len(styles) + 1) // ncol
axs = (plt.figure(figsize=(3 * ncol, 1 + nrow))
       .add_gridspec(1 + nrow, ncol, wspace=.5).subplots())
for ax in axs.flat:
    ax.set_axis_off()
for ax in axs[0, :]:
    ax.text(.2, .5, "boxstyle",
            transform=ax.transAxes, size="large", color="tab:blue",
            horizontalalignment="right", verticalalignment="center")
    ax.text(.4, .5, "default parameters",
            transform=ax.transAxes,
            horizontalalignment="left", verticalalignment="center")
for ax, (stylename, stylecls) in zip(axs[1:, :].T.flat, styles.
↪items()):
    ax.text(.2, .5, stylename, bbox=dict(boxstyle=stylename, fc="w",␣
↪ec="k"),
            transform=ax.transAxes, size="large", color="tab:blue",
            horizontalalignment="right", verticalalignment="center")
```

(continues on next page)

(continued from previous page)

```
    ax.text(.4, .5, str(inspect.signature(stylecls))[1:-1].replace(",
↪", "\n"),
            transform=ax.transAxes,
            horizontalalignment="left", verticalalignment="center")
```



Parameters for modifying the box

*BoxStyle*s have additional parameters to configure their appearance. For example, "round" boxes can have `pad` and `rounding`.

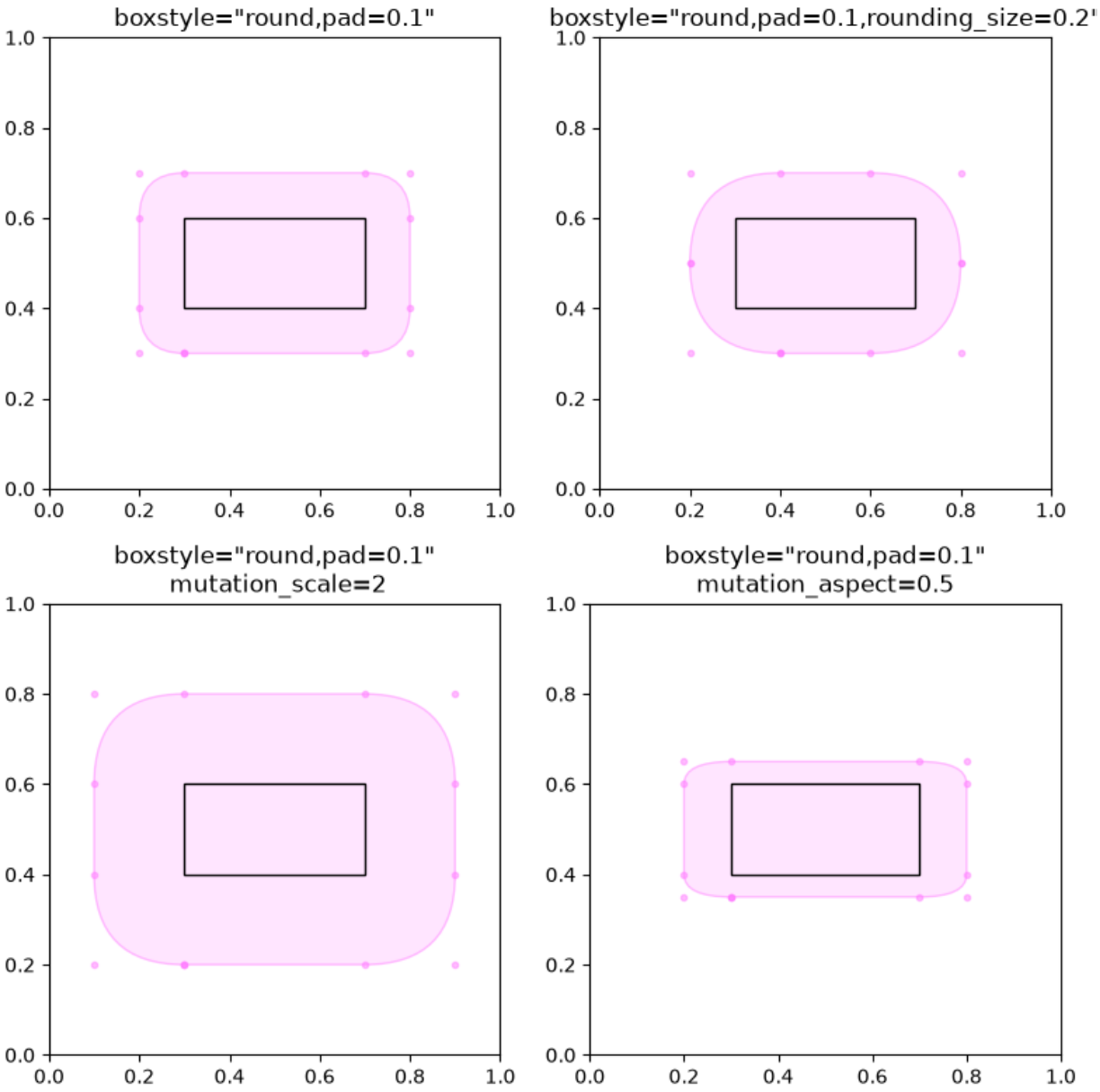
Additionally, the *FancyBboxPatch* parameters `mutation_scale` and `mutation_aspect` scale the box appearance.

```
def add_fancy_patch_around(ax, bb, **kwargs):
    kwargs = {
        'facecolor': (1, 0.8, 1, 0.5),
        'edgecolor': (1, 0.5, 1, 0.5),
        **kwargs
    }
    fancy = FancyBboxPatch(bb.p0, bb.width, bb.height, **kwargs)
    ax.add_patch(fancy)
    return fancy


def draw_control_points_for_patches(ax):
    for patch in ax.patches:
        patch.axes.plot(*patch.get_path().vertices.T, ".",
                        c=patch.get_edgecolor())


fig, axs = plt.subplots(2, 2, figsize=(8, 8))

# Bbox object around which the fancy box will be drawn.
bb = mtransforms.Bbox([[0.3, 0.4], [0.7, 0.6]])

ax = axs[0, 0]
# a fancy box with round corners. pad=0.1
add_fancy_patch_around(ax, bb, boxstyle="round,pad=0.1")
ax.set(xlim=(0, 1), ylim=(0, 1), aspect=1,
       title='boxstyle="round,pad=0.1"')

ax = axs[0, 1]
# bbox=round has two optional arguments: pad and rounding_size.
# They can be set during the initialization.
fancy = add_fancy_patch_around(ax, bb, boxstyle="round,pad=0.1")
# The boxstyle and its argument can be later modified with␣
 ↪set_boxstyle().
# Note that the old attributes are simply forgotten even if the␣
 ↪boxstyle name
# is same.
fancy.set_boxstyle("round,pad=0.1,rounding_size=0.2")
# or: fancy.set_boxstyle("round", pad=0.1, rounding_size=0.2)
ax.set(xlim=(0, 1), ylim=(0, 1), aspect=1,
       title='boxstyle="round,pad=0.1,rounding_size=0.2"')

ax = axs[1, 0]
# mutation_scale determines the overall scale of the mutation, i.e.␣
 ↪both pad
# and rounding_size is scaled according to this value.
```

(continues on next page)

(continued from previous page)

```
add_fancy_patch_around(ax, bb, boxstyle="round,pad=0.1",␣
 ↪mutation_scale=2)
ax.set(xlim=(0, 1), ylim=(0, 1), aspect=1,
       title='boxstyle="round,pad=0.1"\n mutation_scale=2')

ax = axs[1, 1]
# mutation_aspect scales the vertical influence of the parameters␣
 ↪(technically,
# it scales the height of the box down by mutation_aspect, applies the␣
 ↪box parameters
# and scales the result back up). In effect, the vertical pad is␣
 ↪scaled to
# pad * mutation_aspect, e.g. mutation_aspect=0.5 halves the vertical␣
 ↪pad.
add_fancy_patch_around(ax, bb, boxstyle="round,pad=0.1",␣
 ↪mutation_aspect=0.5)
ax.set(xlim=(0, 1), ylim=(0, 1),
       title='boxstyle="round,pad=0.1"\nmutation_aspect=0.5')

for ax in axs.flat:
    draw_control_points_for_patches(ax)
    # Draw the original bbox (using boxstyle=square with pad=0).
    add_fancy_patch_around(ax, bb, boxstyle="square,pad=0",
                           edgecolor="black", facecolor="none",␣
 ↪zorder=10)

fig.tight_layout()


plt.show()
```



Creating visually constant padding on non-equal aspect Axes

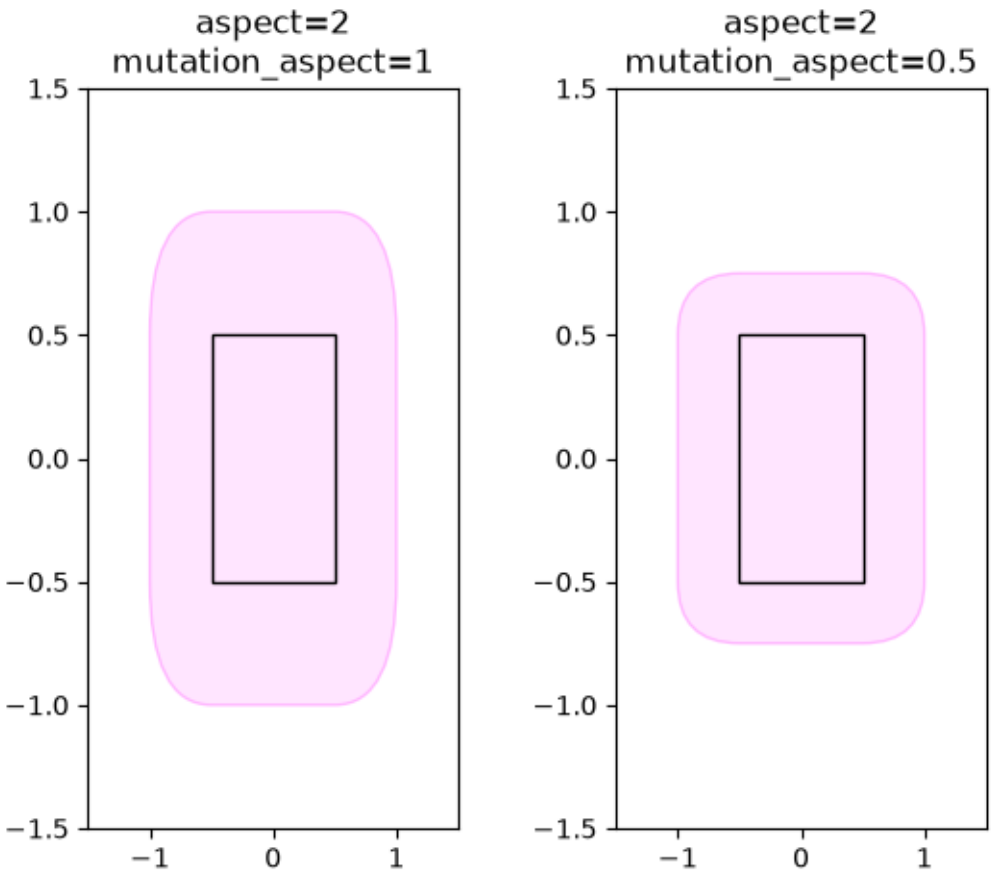
Since padding is in box coordinates, i.e. usually data coordinates, a given padding is rendered to different visual sizes if the Axes aspect is not 1. To get visually equal vertical and horizontal padding, set the mutation_aspect to the inverse of the Axes aspect. This scales the vertical padding appropriately.

```
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(6.5, 5))

# original boxes
bb = mtransforms.Bbox([[-0.5, -0.5], [0.5, 0.5]])
add_fancy_patch_around(ax1, bb, boxstyle="square,pad=0",
```

(continues on next page)

(continued from previous page)

```
                        edgecolor="black", facecolor="none", zorder=10)
add_fancy_patch_around(ax2, bb, boxstyle="square,pad=0",
                        edgecolor="black", facecolor="none", zorder=10)
ax1.set(xlim=(-1.5, 1.5), ylim=(-1.5, 1.5), aspect=2)
ax2.set(xlim=(-1.5, 1.5), ylim=(-1.5, 1.5), aspect=2)


fancy = add_fancy_patch_around(
    ax1, bb, boxstyle="round,pad=0.5")
ax1.set_title("aspect=2\nmutation_aspect=1")

fancy = add_fancy_patch_around(
    ax2, bb, boxstyle="round,pad=0.5", mutation_aspect=0.5)
ax2.set_title("aspect=2\nmutation_aspect=0.5")
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches*
- *matplotlib.patches.FancyBboxPatch*
- *matplotlib.patches.BoxStyle*
- matplotlib.patches.BoxStyle.get_styles
- *matplotlib.transforms.Bbox*
- *matplotlib.figure.Figure.text*
- *matplotlib.axes.Axes.text*

Total running time of the script: (0 minutes 1.528 seconds)

Hatch demo

Hatches can be added to most polygons in Matplotlib, including *bar*, *fill_between*, *contourf*, and children of *Polygon*. They are currently supported in the PS, PDF, SVG, macosx, and Agg backends. The WX and Cairo backends do not currently support hatching.

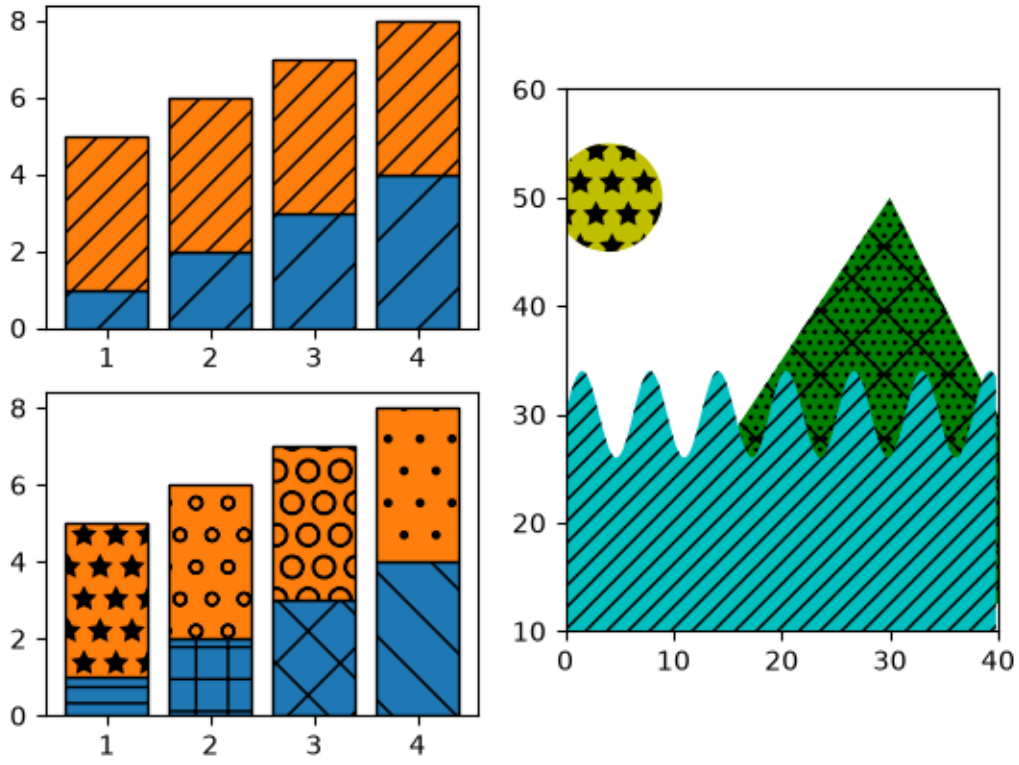
See also *Contourf hatching* for an example using *contourf*, and *Hatch style reference* for swatches of the existing hatches.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Ellipse, Polygon

x = np.arange(1, 5)
y1 = np.arange(1, 5)
y2 = np.ones(y1.shape) * 4

fig = plt.figure()
axs = fig.subplot_mosaic([['bar1', 'patches'], ['bar2', 'patches']])

axs['bar1'].bar(x, y1, edgecolor='black', hatch="/")
axs['bar1'].bar(x, y2, bottom=y1, edgecolor='black', hatch='//')

axs['bar2'].bar(x, y1, edgecolor='black', hatch=['--', '+', 'x', '\\'])
axs['bar2'].bar(x, y2, bottom=y1, edgecolor='black',
                hatch=['*', 'o', 'O', '.'])

x = np.arange(0, 40, 0.2)
axs['patches'].fill_between(x, np.sin(x) * 4 + 30, y2=0,
                            hatch='///', zorder=2, fc='c')
axs['patches'].add_patch(Ellipse((4, 50), 10, 10, fill=True,
                                 hatch='*', facecolor='y'))
axs['patches'].add_patch(Polygon([(10, 20), (30, 50), (50, 10)],
```

(continues on next page)

(continued from previous page)

```
                                    hatch='\\/...', facecolor='g'))
axs['patches'].set_xlim(0, 40)
axs['patches'].set_ylim(10, 60)
axs['patches'].set_aspect(1)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

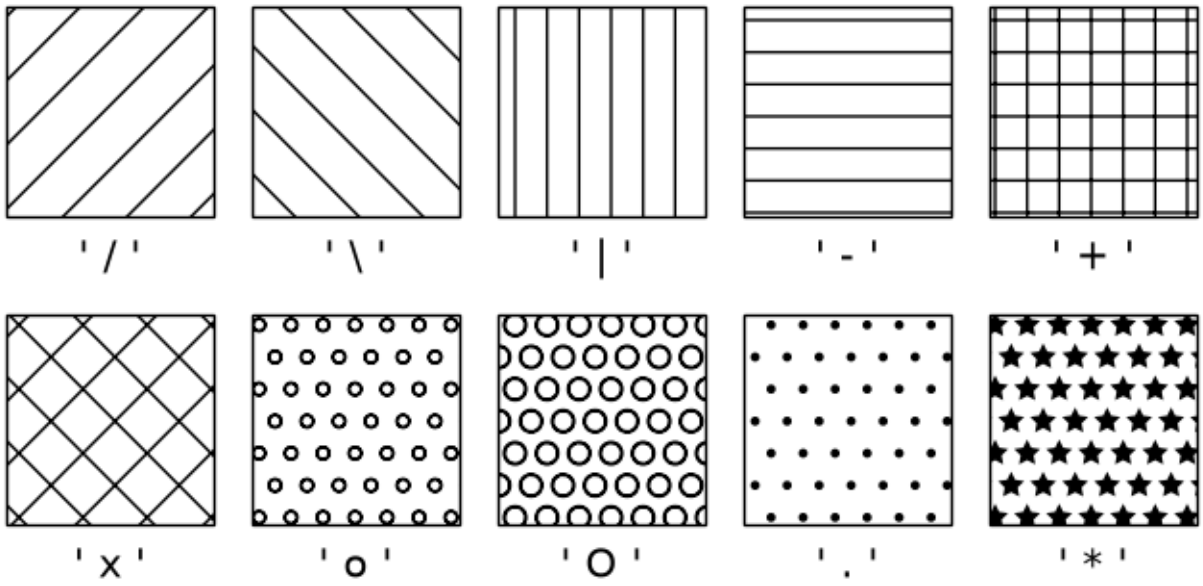
- *matplotlib.patches*
- *matplotlib.patches.Ellipse*
- *matplotlib.patches.Polygon*
- *matplotlib.axes.Axes.add_patch*
- *matplotlib.patches.Patch.set_hatch*
- *matplotlib.axes.Axes.bar* / *matplotlib.pyplot.bar*

Hatch style reference

Hatches can be added to most polygons in Matplotlib, including *bar*, *fill_between*, *contourf*, and children of *Polygon*. They are currently supported in the PS, PDF, SVG, macosx, and Agg backends. The WX and Cairo backends do not currently support hatching.

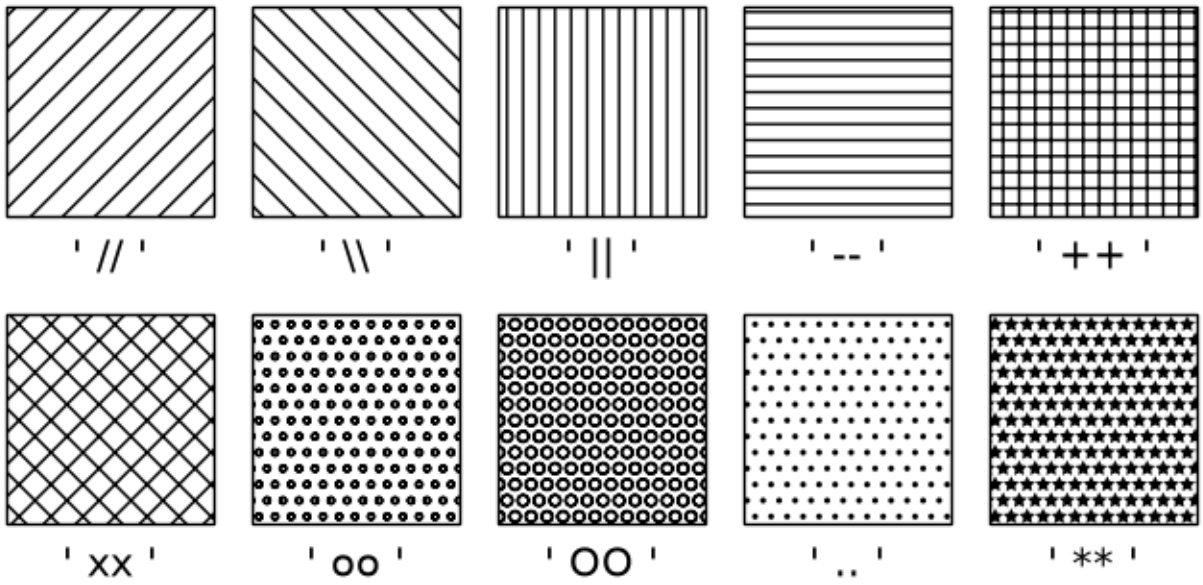
See also *Contourf hatching* for an example using *contourf*, and *Hatch demo* for more usage examples.

```
import matplotlib.pyplot as plt

from matplotlib.patches import Rectangle

fig, axs = plt.subplots(2, 5, layout='constrained', figsize=(6.4, 3.2))

hatches = ['/', '\\', '|', '-', '+', 'x', 'o', 'O', '.', '*']


def hatches_plot(ax, h):
    ax.add_patch(Rectangle((0, 0), 2, 2, fill=False, hatch=h))
    ax.text(1, -0.5, f"' {h} '", size=15, ha="center")
    ax.axis('equal')
    ax.axis('off')

for ax, h in zip(axs.flat, hatches):
    hatches_plot(ax, h)
```



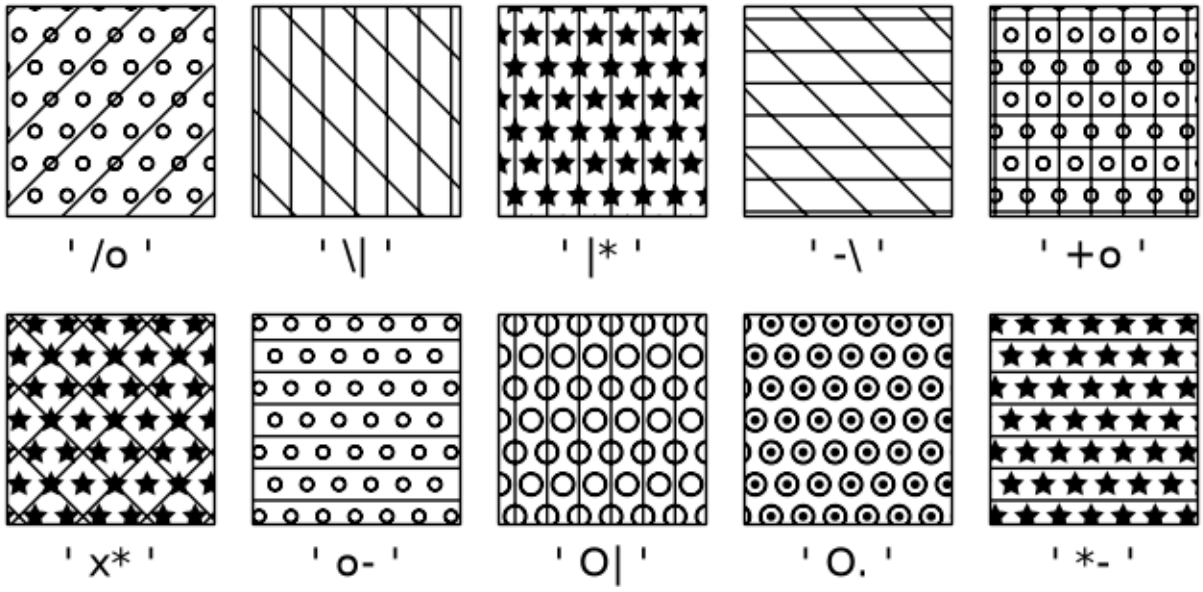
Hatching patterns can be repeated to increase the density.

```
fig, axs = plt.subplots(2, 5, layout='constrained', figsize=(6.4, 3.2))

hatches = ['//', '\\\\', '||', '--', '++', 'xx', 'oo', 'OO', '..', '**
 ↪']

for ax, h in zip(axs.flat, hatches):
    hatches_plot(ax, h)
```



Hatching patterns can be combined to create additional patterns.

```
fig, axs = plt.subplots(2, 5, layout='constrained', figsize=(6.4, 3.2))

hatches = ['/o', '\\|', '|*', '-\\', '+o', 'x*', 'o-', 'O|', 'O.', '*-
 ↪']

for ax, h in zip(axs.flat, hatches):
    hatches_plot(ax, h)
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches*
- *matplotlib.patches.Rectangle*
- *matplotlib.axes.Axes.add_patch*
- *matplotlib.axes.Axes.text*

Tags: purpose: reference

Hatchcolor Demo

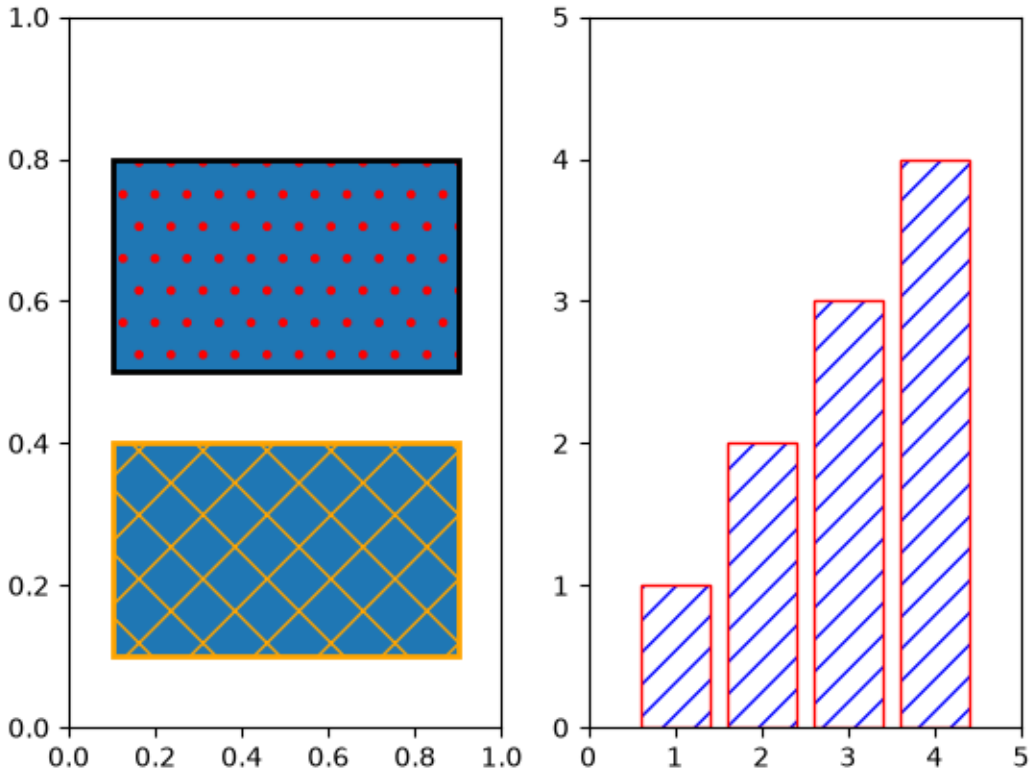
The color of the hatch can be set using the *hatchcolor* parameter. The following examples show how to use the *hatchcolor* parameter to set the color of the hatch in *Patch* and *Collection*.

See also *Hatch demo* for more usage examples of hatching.

Patch Hatchcolor

This example shows how to use the *hatchcolor* parameter to set the color of the hatch in a rectangle and a bar plot. The *hatchcolor* parameter is available for `Patch`, child classes of Patch, and methods that pass through to Patch.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.cm as cm
from matplotlib.patches import Rectangle

fig, (ax1, ax2) = plt.subplots(1, 2)

# Rectangle with red hatch color and black edge color
ax1.add_patch(Rectangle((0.1, 0.5), 0.8, 0.3, hatch=".", hatchcolor=
 ↪'red',
                        edgecolor='black', lw=2))
# If hatchcolor is not passed, the hatch will match the edge color
ax1.add_patch(Rectangle((0.1, 0.1), 0.8, 0.3, hatch='x', edgecolor=
 ↪'orange', lw=2))

x = np.arange(1, 5)
y = np.arange(1, 5)

ax2.bar(x, y, facecolor='none', edgecolor='red', hatch='//',␣
 ↪hatchcolor='blue')
ax2.set_xlim(0, 5)
ax2.set_ylim(0, 5)
```



Collection Hatchcolor

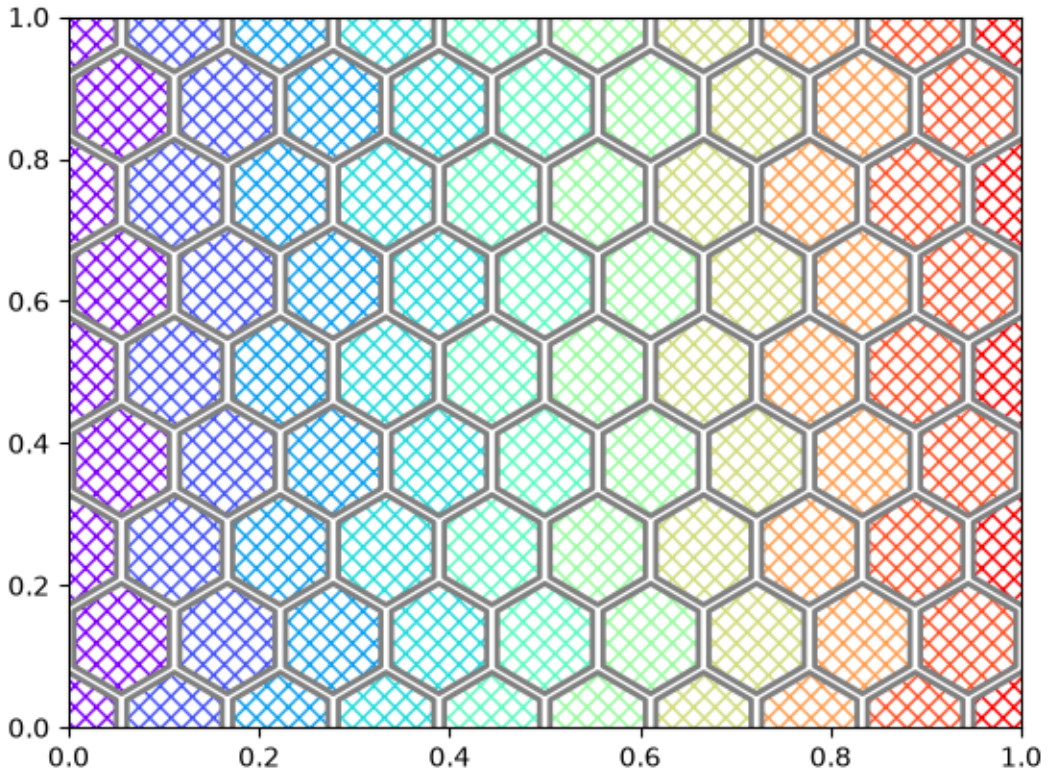
The following example shows how to use the *hatchcolor* parameter to set the color of the hatch in a scatter plot. The *hatchcolor* parameter can also be passed to `Collection`, child classes of Collection, and methods that pass through to Collection.

```
fig, ax = plt.subplots()

num_points_x = 10
num_points_y = 9
x = np.linspace(0, 1, num_points_x)
y = np.linspace(0, 1, num_points_y)

X, Y = np.meshgrid(x, y)
X[1::2, :] += (x[1] - x[0]) / 2  # stagger every alternate row

# As ax.scatter (PathCollection) is drawn row by row, setting␣
 ↪hatchcolors to the
# first row is enough, as the colors will be cycled through for the␣
 ↪next rows.
```

(continues on next page)

(continued from previous page)

```
colors = [cm.rainbow(val) for val in x]

ax.scatter(
    X.ravel(),
    Y.ravel(),
    s=1700,
    facecolor="none",
    edgecolor="gray",
    linewidth=2,
    marker="h",  # Use hexagon as marker
    hatch="xxx",
    hatchcolor=colors,
)
ax.set_xlim(0, 1)
ax.set_ylim(0, 1)

plt.show()
```



References

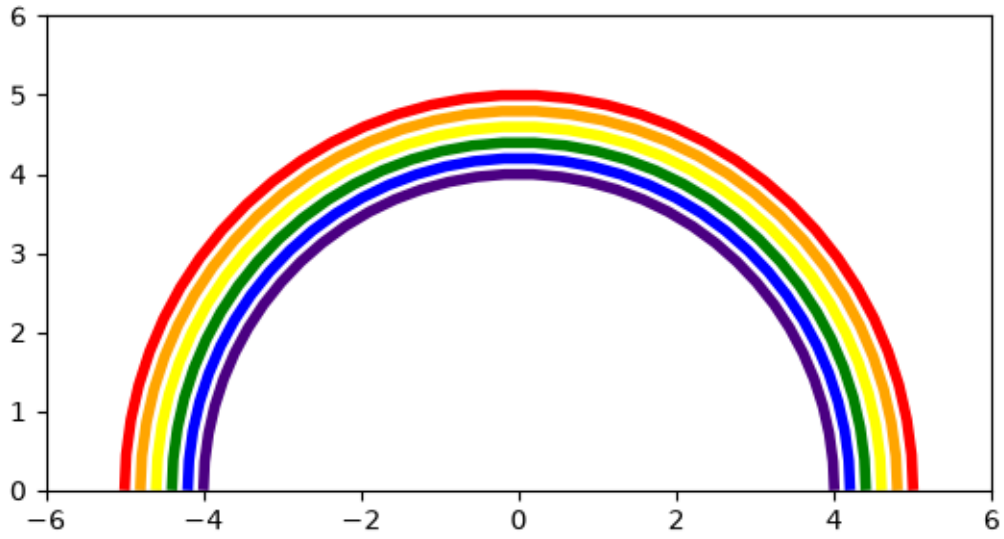
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches*
- *matplotlib.patches.Polygon*
- *matplotlib.axes.Axes.add_patch*
- *matplotlib.axes.Axes.bar* / *matplotlib.pyplot.bar*
- *matplotlib.collections*
- *matplotlib.axes.Axes.scatter* / *matplotlib.pyplot.scatter*

Plot multiple lines using a LineCollection

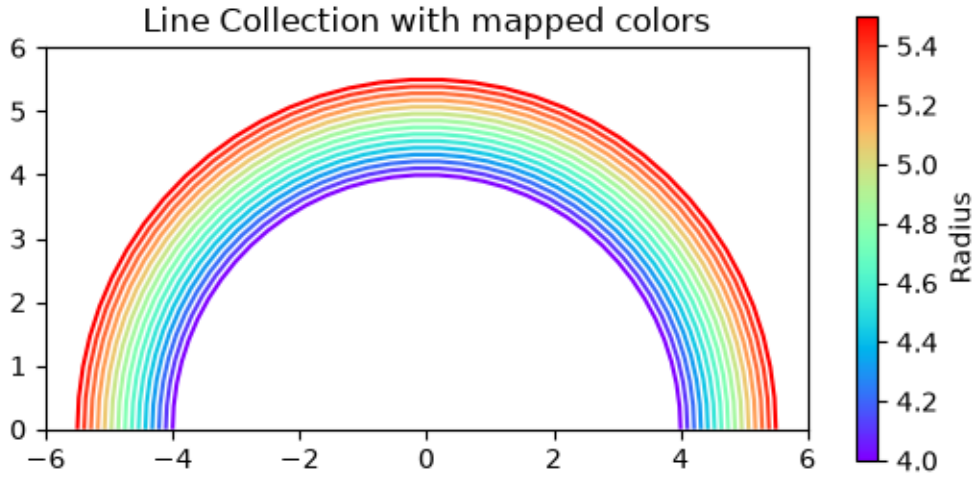
Matplotlib can efficiently draw multiple lines at once using a *LineCollection*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.collections import LineCollection

colors = ["indigo", "blue", "green", "yellow", "orange", "red"]

# create a list of half-circles with varying radii
theta = np.linspace(0, np.pi, 36)
radii = np.linspace(4, 5, num=len(colors))
arcs = [np.column_stack([r * np.cos(theta), r * np.sin(theta)]) for r␣
 ↪in radii]

fig, ax = plt.subplots(figsize=(6.4, 3.2))
# set axes limits manually because Collections do not take part in␣
 ↪autoscaling
ax.set_xlim(-6, 6)
ax.set_ylim(0, 6)
ax.set_aspect("equal")  # to make the arcs look circular

# create a LineCollection with the half-circles
# its properties can be set per line by passing a sequence (here used␣
 ↪for *colors*)
# or they can be set for all lines by passing a scalar (here used for␣
 ↪*linewidths*)
line_collection = LineCollection(arcs, colors=colors, linewidths=4)
ax.add_collection(line_collection)

plt.show()
```



Instead of passing a list of colors (`colors=colors`), we can alternatively use colormapping. The lines are then color-coded based on an additional array of values passed to the *array* parameter. In the below example, we color the lines based on their radius by passing `array=radii`.

```
num_arcs = 15
theta = np.linspace(0, np.pi, 36)
radii = np.linspace(4, 5.5, num=num_arcs)
arcs = [np.column_stack([r * np.cos(theta), r * np.sin(theta)]) for r␣
 ↪in radii]

fig, ax = plt.subplots(figsize=(6.4, 3))
# set axes limits manually because Collections do not take part in␣
 ↪autoscaling
ax.set_xlim(-6, 6)
ax.set_ylim(0, 6)
ax.set_aspect("equal")  # to make the arcs look circular

# create a LineCollection with the half-circles and color mapping
line_collection = LineCollection(arcs, array=radii, cmap="rainbow")
ax.add_collection(line_collection)

fig.colorbar(line_collection, label="Radius")
ax.set_title("Line Collection with mapped colors")

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.collections.LineCollection*
- *matplotlib.collections.Collection.set_array*
- *matplotlib.axes.Axes.add_collection*
- *matplotlib.figure.Figure.colorbar / matplotlib.pyplot.colorbar*

Circles, Wedges and Polygons

This example demonstrates how to use *collections.PatchCollection*.

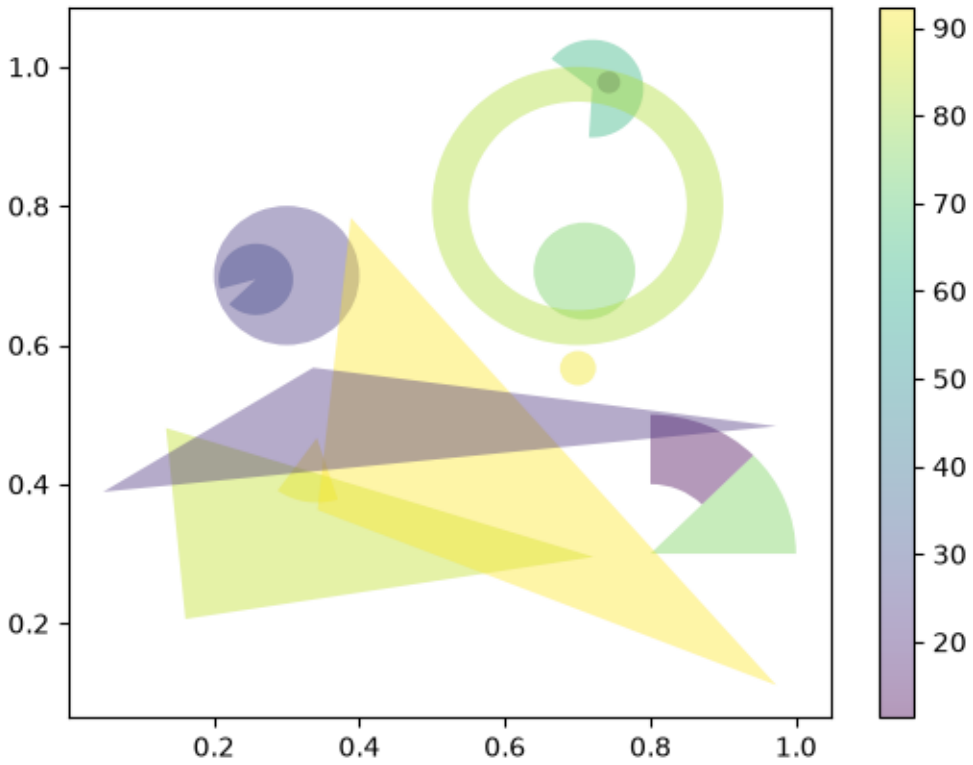
See also *Reference for Matplotlib artists*, which instead adds each artist separately to its own Axes.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.collections import PatchCollection
from matplotlib.patches import Circle, Polygon, Wedge

# Fixing random state for reproducibility
np.random.seed(19680801)


fig, ax = plt.subplots()

resolution = 50  # the number of vertices
N = 3
```

(continues on next page)

(continued from previous page)

```
x = np.random.rand(N)
y = np.random.rand(N)
radii = 0.1*np.random.rand(N)
patches = []
for x1, y1, r in zip(x, y, radii):
    circle = Circle((x1, y1), r)
    patches.append(circle)

x = np.random.rand(N)
y = np.random.rand(N)
radii = 0.1*np.random.rand(N)
theta1 = 360.0*np.random.rand(N)
theta2 = 360.0*np.random.rand(N)
for x1, y1, r, t1, t2 in zip(x, y, radii, theta1, theta2):
    wedge = Wedge((x1, y1), r, t1, t2)
    patches.append(wedge)

# Some limiting conditions on Wedge
patches += [
    Wedge((.3, .7), .1, 0, 360),             # Full circle
    Wedge((.7, .8), .2, 0, 360, width=0.05),  # Full ring
    Wedge((.8, .3), .2, 0, 45),              # Full sector
    Wedge((.8, .3), .2, 45, 90, width=0.10),  # Ring sector
]

for i in range(N):
    polygon = Polygon(np.random.rand(N, 2), closed=True)
    patches.append(polygon)

colors = 100 * np.random.rand(len(patches))
p = PatchCollection(patches, alpha=0.4)
p.set_array(colors)
ax.add_collection(p)
fig.colorbar(p, ax=ax)

plt.show()
```



References

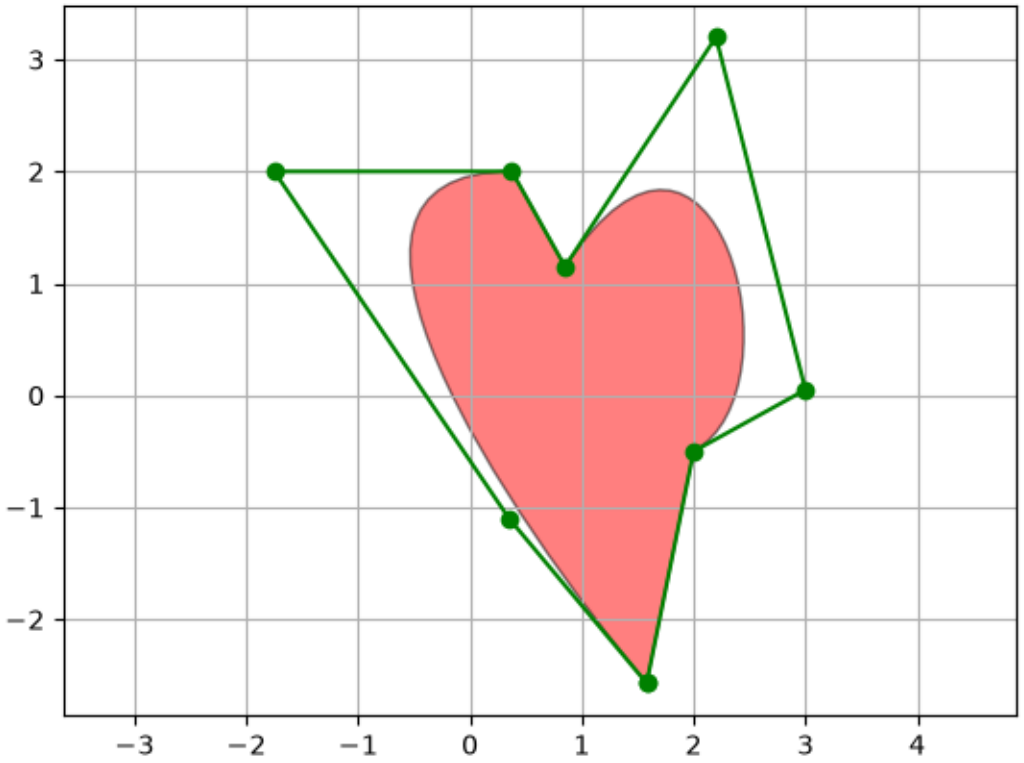
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches*
- *matplotlib.patches.Circle*
- *matplotlib.patches.Wedge*
- *matplotlib.patches.Polygon*
- *matplotlib.collections.PatchCollection*
- *matplotlib.collections.Collection.set_array*
- *matplotlib.axes.Axes.add_collection*
- *matplotlib.figure.Figure.colorbar*

PathPatch object

This example shows how to create *Path* and *PathPatch* objects through Matplotlib's API.

```
import matplotlib.pyplot as plt

import matplotlib.patches as mpatches
import matplotlib.path as mpath

fig, ax = plt.subplots()

Path = mpath.Path
path_data = [
    (Path.MOVETO, (1.58, -2.57)),
    (Path.CURVE4, (0.35, -1.1)),
    (Path.CURVE4, (-1.75, 2.0)),
    (Path.CURVE4, (0.375, 2.0)),
    (Path.LINETO, (0.85, 1.15)),
    (Path.CURVE4, (2.2, 3.2)),
    (Path.CURVE4, (3, 0.05)),
    (Path.CURVE4, (2.0, -0.5)),
    (Path.CLOSEPOLY, (1.58, -2.57)),
    ]
codes, verts = zip(*path_data)
path = mpath.Path(verts, codes)
patch = mpatches.PathPatch(path, facecolor='r', alpha=0.5)
ax.add_patch(patch)

# plot control points and connecting lines
x, y = zip(*path.vertices)
line, = ax.plot(x, y, 'go-')

ax.grid()
ax.axis('equal')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.path*
- *matplotlib.path.Path*
- *matplotlib.patches*
- *matplotlib.patches.PathPatch*
- *matplotlib.axes.Axes.add_patch*

Bezier curve

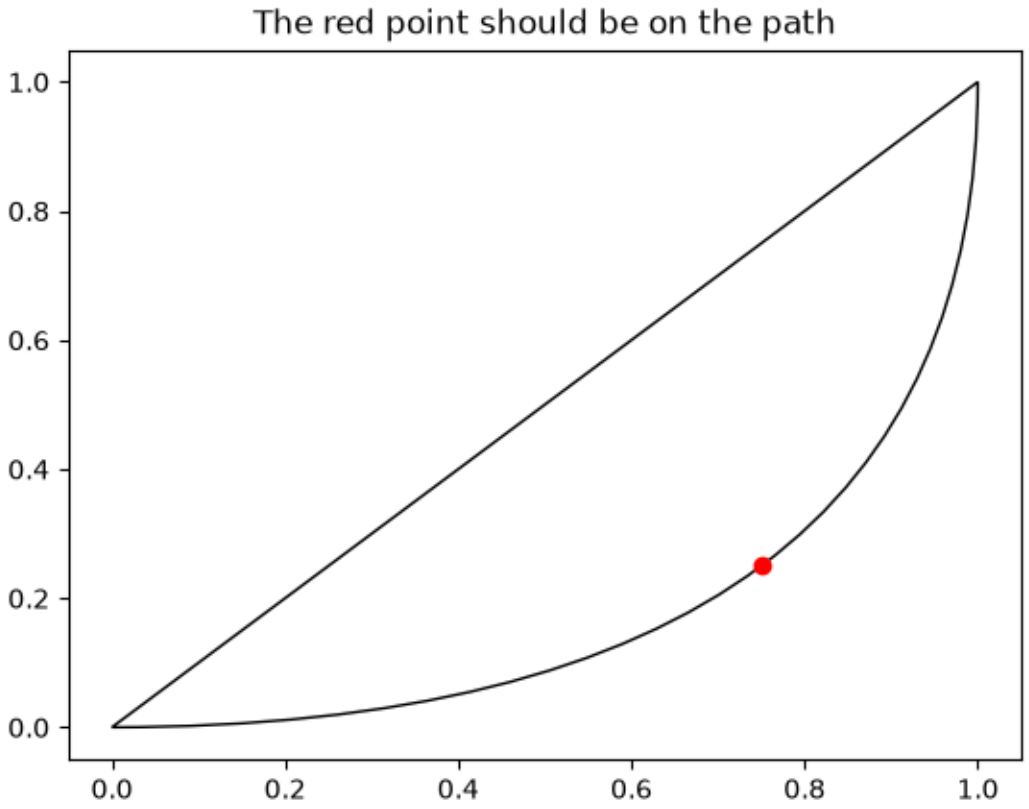
This example showcases the *PathPatch* object to create a Bezier polycurve path patch.

```
import matplotlib.pyplot as plt

import matplotlib.patches as mpatches
import matplotlib.path as mpath
```

(continues on next page)

(continued from previous page)

```
Path = mpath.Path

fig, ax = plt.subplots()
pp1 = mpatches.PathPatch(
    Path([(0, 0), (1, 0), (1, 1), (0, 0)],
         [Path.MOVETO, Path.CURVE3, Path.CURVE3, Path.CLOSEPOLY]),
    fc="none", transform=ax.transData)

ax.add_patch(pp1)
ax.plot([0.75], [0.25], "ro")
ax.set_title('The red point should be on the path')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

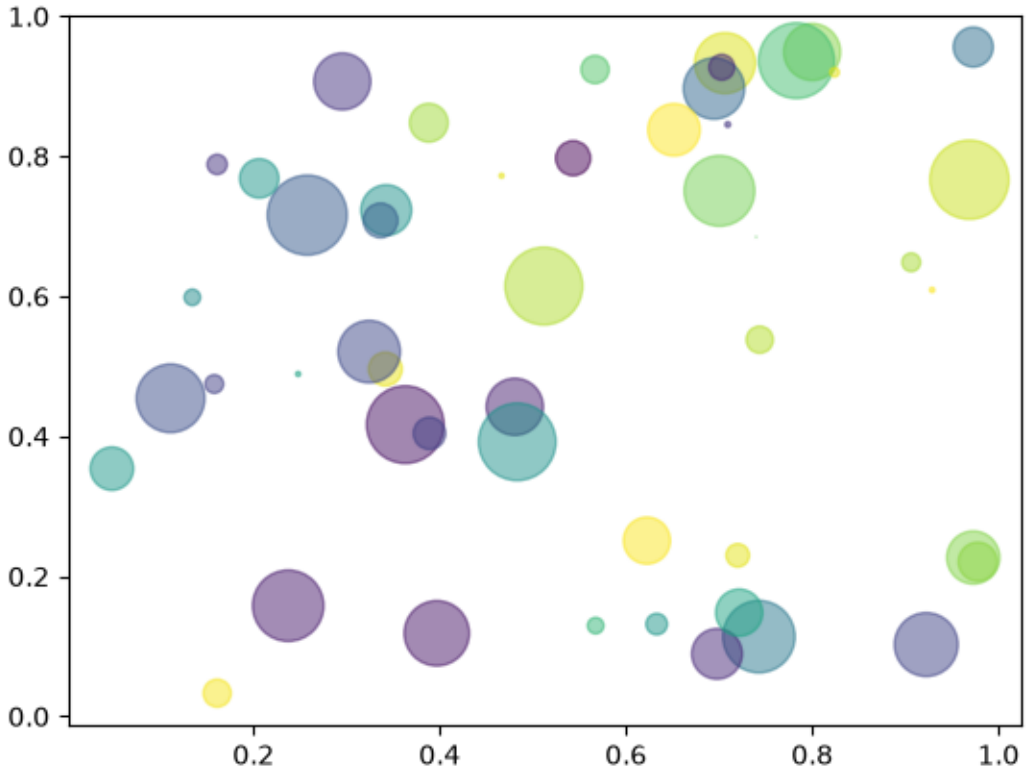
- *matplotlib.path*

- *matplotlib.path.Path*
- *matplotlib.patches*
- *matplotlib.patches.PathPatch*
- *matplotlib.axes.Axes.add_patch*

Scatter plot

This example showcases a simple scatter plot.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)


N = 50
x = np.random.rand(N)
y = np.random.rand(N)
colors = np.random.rand(N)
area = (30 * np.random.rand(N))**2  # 0 to 15 point radii

plt.scatter(x, y, s=area, c=colors, alpha=0.5)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.scatter / matplotlib.pyplot.scatter*

6.24.11 Color

For a description of the colormaps available in Matplotlib, see the *colormaps tutorial*.

Color Demo

Matplotlib recognizes the following formats to specify a color:

1) an RGB or RGBA tuple of float values in `[0, 1]` (e.g. `(0.1, 0.2, 0.5)` or `(0.1, 0.2, 0.5, 0.3)`). RGBA is short for Red, Green, Blue, Alpha;
2) a hex RGB or RGBA string (e.g., `'#0F0F0F'` or `'#0F0F0F0F'`);
3) a shorthand hex RGB or RGBA string, equivalent to the hex RGB or RGBA string obtained by duplicating each character, (e.g., `'#abc'`, equivalent to `'#aabbcc'`, or `'#abcd'`, equivalent to `'#aabbccdd'`);

4) a string representation of a float value in `[0, 1]` inclusive for gray level (e.g., `'0.5'`);

5) a single letter string, i.e. one of `{'b', 'g', 'r', 'c', 'm', 'y', 'k', 'w'}`, which are short-hand notations for shades of blue, green, red, cyan, magenta, yellow, black, and white;

6) an X11/CSS4 ("html") color name, e.g. `"blue"`;

7) a name from the xkcd color survey, prefixed with `'xkcd:'` (e.g., `'xkcd:sky blue'`);

8) a "Cn" color spec, i.e. `'C'` followed by a number, which is an index into the default property cycle (*`rcParams["axes.prop_cycle"]`* (default: `cycler('color', [(0.12156862745098039, 0.4666666666666667, 0.7058823529411765), (1.0, 0.4980392156862745, 0.054901960784313725), (0.17254901960784313, 0.6274509803921569, 0.17254901960784313), (0.8392156862745098, 0.15294117647058825, 0.1568627450980392), (0.5803921568627451, 0.403921568627451, 0.7411764705882353), (0.5490196078431373, 0.33725490196078434, 0.29411764705882354), (0.8901960784313725, 0.4666666666666667, 0.7607843137254902), (0.4980392156862745, 0.4980392156862745, 0.4980392156862745), (0.7372549019607844, 0.7411764705882353, 0.13333333333333333), (0.09019607843137255, 0.7450980392156863, 0.8117647058823529)])`); the indexing is intended to occur at rendering time, and defaults to black if the cycle does not include color.

9) one of `{'tab:blue', 'tab:orange', 'tab:green', 'tab:red', 'tab:purple', 'tab:brown', 'tab:pink', 'tab:gray', 'tab:olive', 'tab:cyan'}` which are the Tableau Colors from the 'tab10' categorical palette (which is the default color cycle);

For more information on colors in matplotlib see

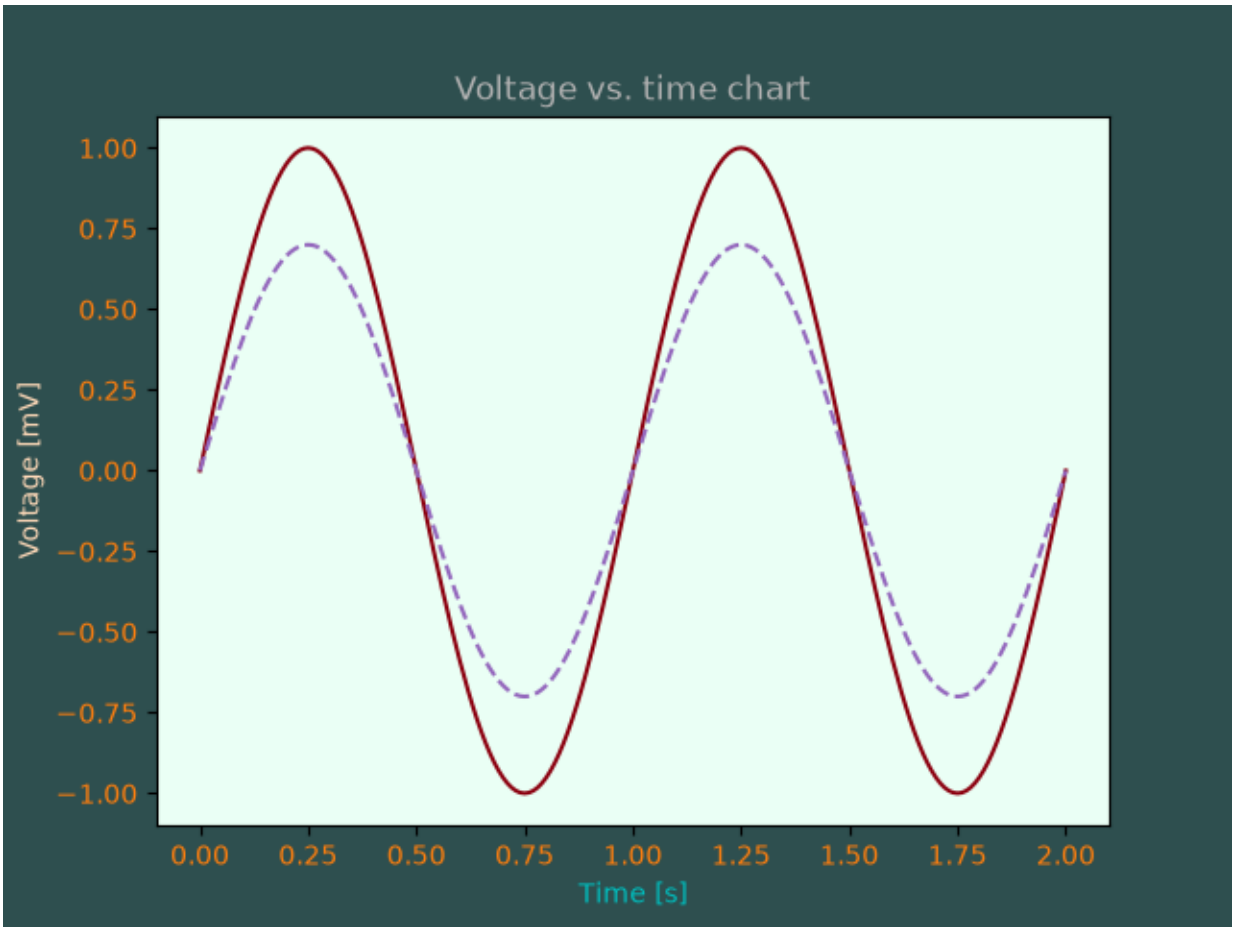
- the *Specifying colors* tutorial;
- the *`matplotlib.colors`* API;
- the *List of named colors* example.

```
import matplotlib.pyplot as plt
import numpy as np

t = np.linspace(0.0, 2.0, 201)
s = np.sin(2 * np.pi * t)

# 1) RGB tuple:
fig, ax = plt.subplots(facecolor=(.18, .31, .31))
# 2) hex string:
ax.set_facecolor('#eafff5')
# 3) gray level string:
ax.set_title('Voltage vs. time chart', color='0.7')
# 4) single letter color string
ax.set_xlabel('Time [s]', color='c')
# 5) a named color:
ax.set_ylabel('Voltage [mV]', color='peachpuff')
# 6) a named xkcd color:
```

(continues on next page)

(continued from previous page)

```
ax.plot(t, s, 'xkcd:crimson')
# 7) Cn notation:
ax.plot(t, .7*s, color='C4', linestyle='--')
# 8) tab notation:
ax.tick_params(labelcolor='tab:orange')


plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.colors*
- *matplotlib.axes.Axes.plot*
- *matplotlib.axes.Axes.set_facecolor*
- *matplotlib.axes.Axes.set_title*
- *matplotlib.axes.Axes.set_xlabel*

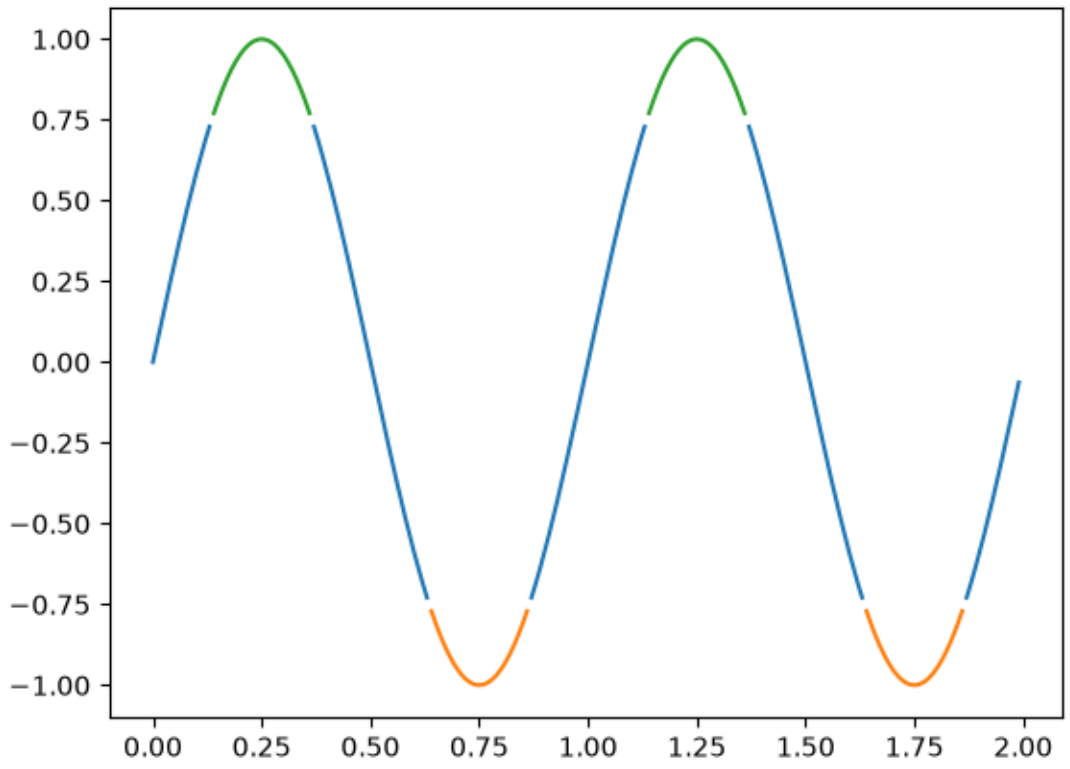
- *matplotlib.axes.Axes.set_ylabel*
- *matplotlib.axes.Axes.tick_params*

Tags: styling: color plot-type: line level: beginner

Color by y-value

Use masked arrays to plot a line with different colors by y-value.

```
import matplotlib.pyplot as plt
import numpy as np

t = np.arange(0.0, 2.0, 0.01)
s = np.sin(2 * np.pi * t)

upper = 0.77
lower = -0.77

supper = np.ma.masked_where(s < upper, s)
slower = np.ma.masked_where(s > lower, s)
smiddle = np.ma.masked_where((s < lower) | (s > upper), s)

fig, ax = plt.subplots()
ax.plot(t, smiddle, t, slower, t, supper)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.plot* / *matplotlib.pyplot.plot*

Tags: styling: color styling: conditional plot-type: line level: beginner

Colors in the default property cycle

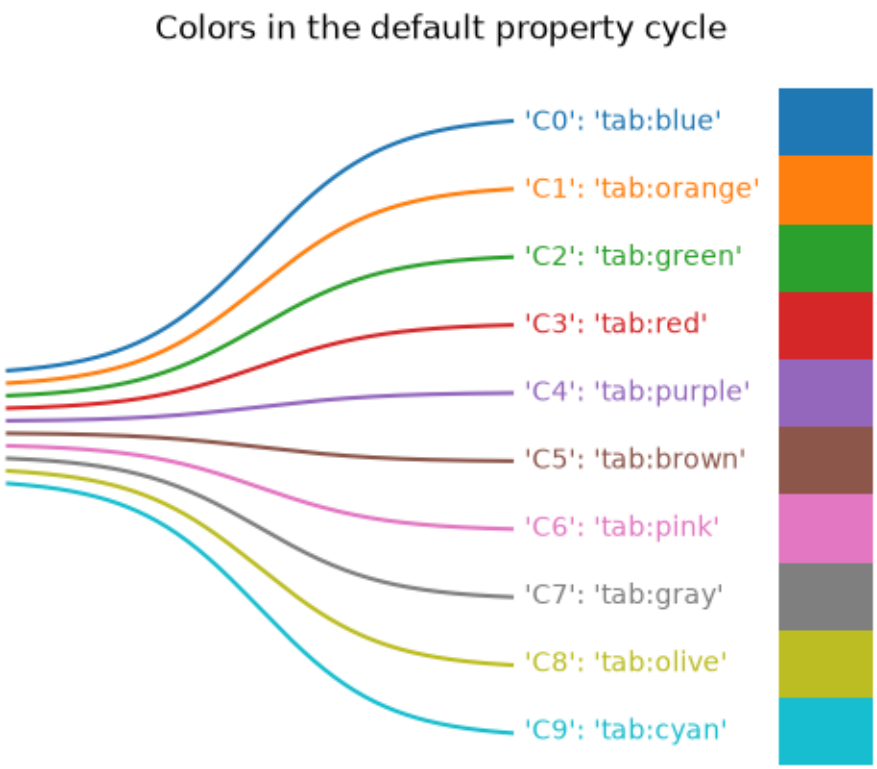
Display the colors from the default prop_cycle, which is obtained from the *rc parameters*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.colors import TABLEAU_COLORS, same_color


def f(x, a):
    """A nice sigmoid-like parametrized curve, ending approximately at␣
```

(continues on next page)

(continued from previous page)

```
 ↪*a*."""
    return 0.85 * a * (1 / (1 + np.exp(-x)) + 0.2)


fig, ax = plt.subplots()
ax.axis('off')
ax.set_title("Colors in the default property cycle")

prop_cycle = plt.rcParams['axes.prop_cycle']
colors = prop_cycle.by_key()['color']
x = np.linspace(-4, 4, 200)

for i, (color, color_name) in enumerate(zip(colors, TABLEAU_COLORS)):
    assert same_color(color, color_name)
    pos = 4.5 - i
    ax.plot(x, f(x, pos))
    ax.text(4.2, pos, f"'C{i}': '{color_name}'", color=color, va=
 ↪"center")
    ax.bar(9, 1, width=1.5, bottom=pos-0.5)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.axis*
- *matplotlib.axes.Axes.text*
- *matplotlib.colors.same_color*
- cycler.Cycler

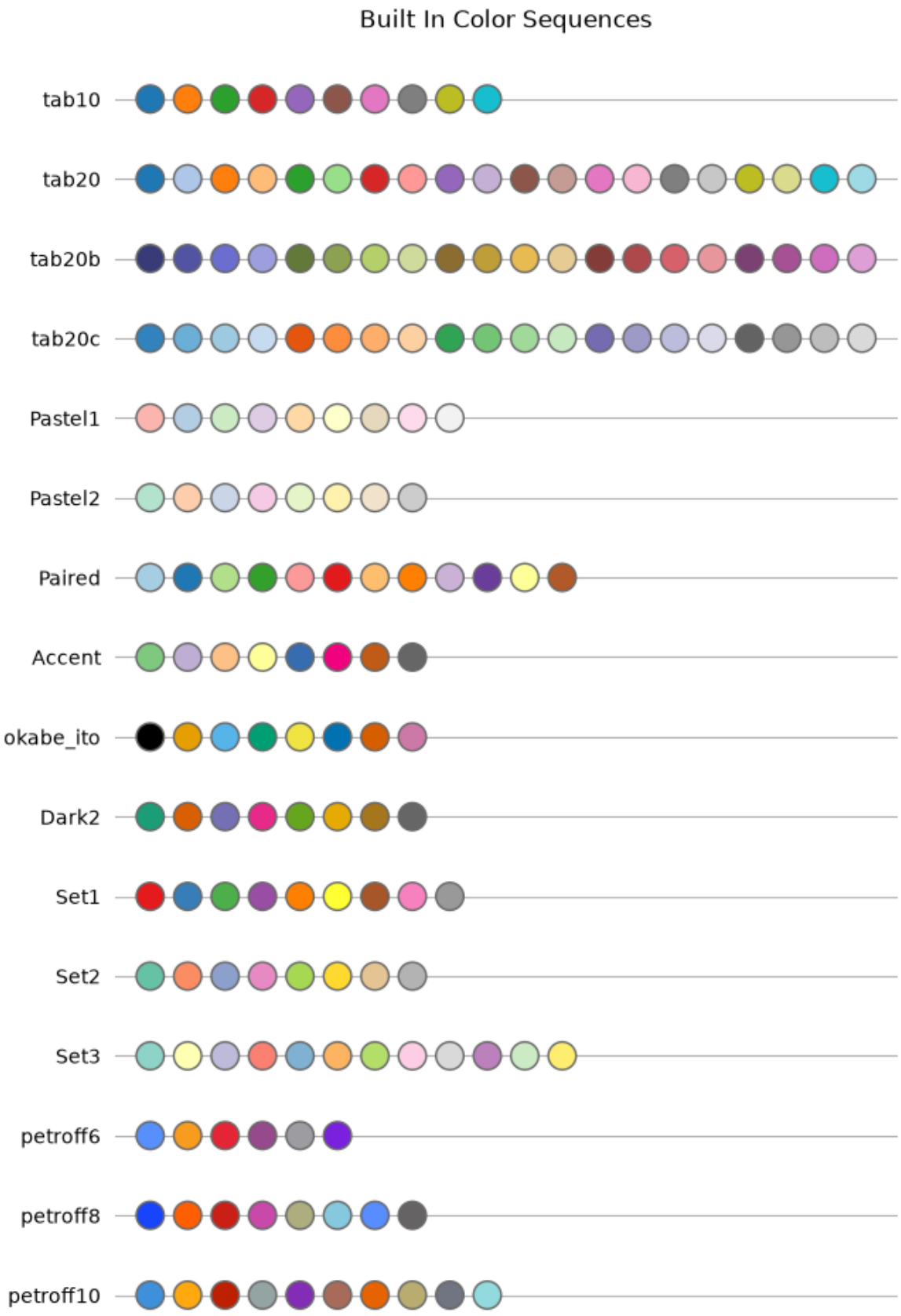
Tags: styling: color purpose: reference plot-type: line level: beginner

Named color sequences

Matplotlib's *ColorSequenceRegistry* allows access to predefined lists of colors by name e.g. `colors = matplotlib.color_sequences['Set1']`. This example shows all of the built in color sequences.

User-defined sequences can be added via *ColorSequenceRegistry.register*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib as mpl


def plot_color_sequences(names, ax):
    # Display each named color sequence horizontally on the supplied␣
 ↪axes.

    for n, name in enumerate(names):
        colors = mpl.color_sequences[name]
        n_colors = len(colors)
        x = np.arange(n_colors)
        y = np.full_like(x, n)

        ax.scatter(x, y, facecolor=colors, edgecolor='dimgray', s=200,␣
 ↪zorder=2)

    ax.set_yticks(range(len(names)), labels=names)
    ax.grid(visible=True, axis='y')
    ax.yaxis.set_inverted(True)
    ax.xaxis.set_visible(False)
    ax.spines[:].set_visible(False)
    ax.tick_params(left=False)


built_in_color_sequences = [
    'tab10', 'tab20', 'tab20b', 'tab20c', 'Pastel1', 'Pastel2', 'Paired
 ↪',
    'Accent', 'okabe_ito', 'Dark2', 'Set1', 'Set2', 'Set3', 'petroff6',
    'petroff8', 'petroff10']


fig, ax = plt.subplots(figsize=(6.4, 9.6), layout='constrained')

plot_color_sequences(built_in_color_sequences, ax)
ax.set_title('Built In Color Sequences')

plt.show()
```


Built In Color Sequences
tab10
tab20
tab20b
tab20c
Pastel1
Pastel2
Paired
Accent
okabe_ito
Dark2
Set1
Set2
Set3
petroff6
petroff8
petroff10

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.colors.ColorSequenceRegistry*
- *matplotlib.axes.Axes.scatter*

Tags: styling: color purpose: reference

Colorbar

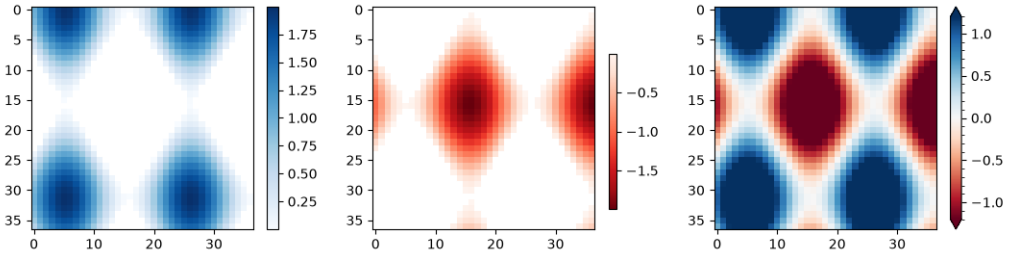
Use *colorbar* by specifying the mappable object (here the *AxesImage* returned by *imshow*) and the Axes to attach the colorbar to.

```
import matplotlib.pyplot as plt
import numpy as np

# setup some generic data
N = 37
x, y = np.mgrid[:N, :N]
Z = (np.cos(x*0.2) + np.sin(y*0.3))

# mask out the negative and positive values, respectively
Zpos = np.ma.masked_less(Z, 0)
Zneg = np.ma.masked_greater(Z, 0)

fig, (ax1, ax2, ax3) = plt.subplots(figsize=(13, 3), ncols=3)

# plot just the positive data and save the
# color "mappable" object returned by ax1.imshow
pos = ax1.imshow(Zpos, cmap='Blues', interpolation='none')

# add the colorbar using the figure's method,
# telling which mappable we're talking about and
# which Axes object it should be near
fig.colorbar(pos, ax=ax1)

# repeat everything above for the negative data
# you can specify location, anchor and shrink the colorbar
neg = ax2.imshow(Zneg, cmap='Reds_r', interpolation='none')
fig.colorbar(neg, ax=ax2, location='right', anchor=(0, 0.3),␣
 ↪shrink=0.7)

# Plot both positive and negative values between +/- 1.2
pos_neg_clipped = ax3.imshow(Z, cmap='RdBu', vmin=-1.2, vmax=1.2,
                             interpolation='none')
# Add minorticks on the colorbar to make it easy to read the
```

(continues on next page)

(continued from previous page)

```
# values off the colorbar.
cbar = fig.colorbar(pos_neg_clipped, ax=ax3, extend='both')
cbar.minorticks_on()
plt.show()
```



References

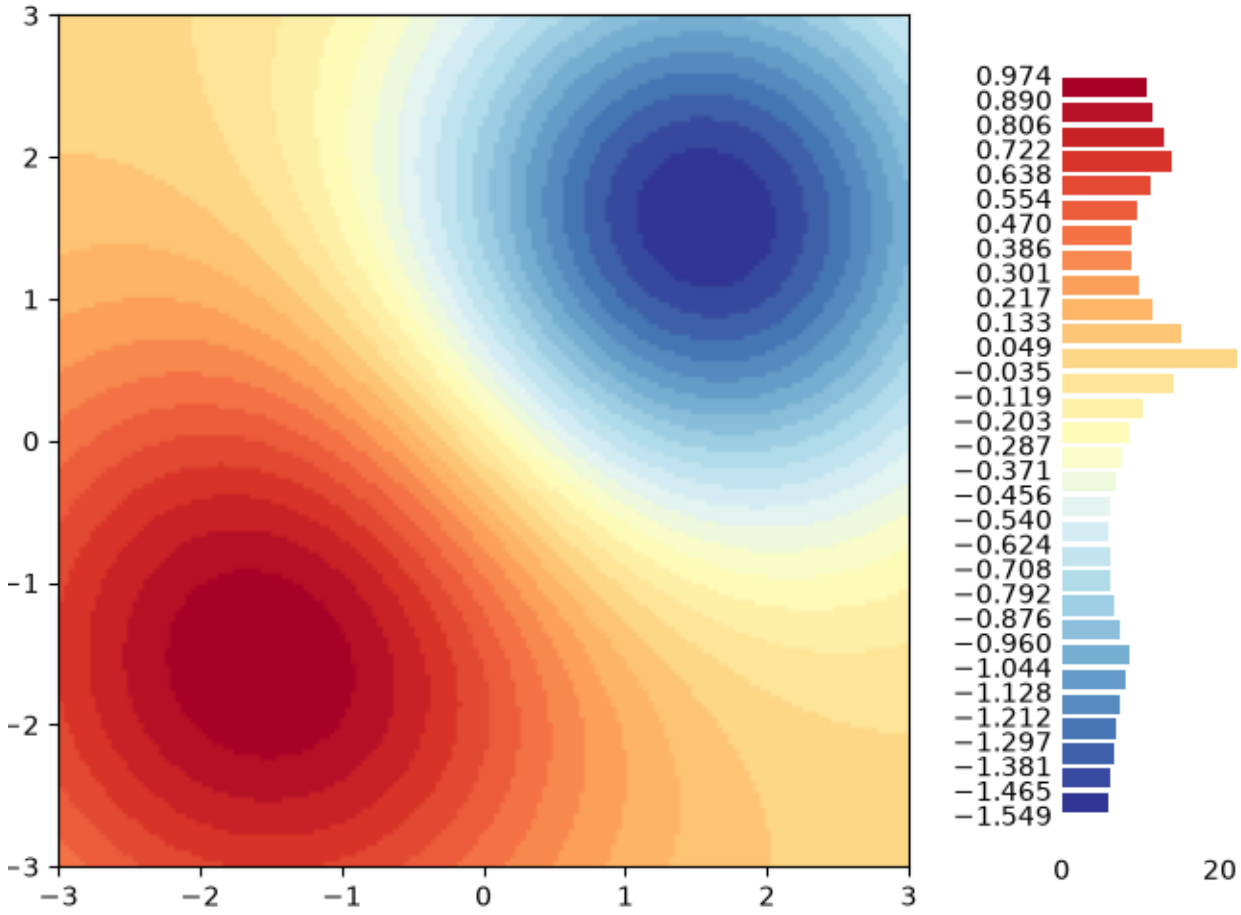
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.colorbar.Colorbar.minorticks_on*
- *matplotlib.colorbar.Colorbar.minorticks_off*

Tags: component: colorbar styling: color plot-type: imshow level: beginner

Histogram as colorbar

This example demonstrates how to use a colored histogram instead of a colorbar to not only show the color-to-value mapping, but also visualize the distribution of values.




```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.colors as mcolors

# surface data
delta = 0.025
x = y = np.arange(-2.0, 2.0, delta)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-(((X + 1) * 1.3) ** 2) - ((Y + 1) * 1.3) ** 2)
Z2 = 2.5 * np.exp(-((X - 1) ** 2) - (Y - 1) ** 2)
Z = Z1**0.25 - Z2**0.5

# colormap & normalization
bins = 30
cmap = plt.get_cmap("RdYlBu_r")
bin_edges = np.linspace(Z.min(), Z.max(), bins + 1)
norm = mcolors.BoundaryNorm(bin_edges, cmap.N)

# main plot
```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots(layout="constrained")
im = ax.imshow(Z, cmap=cmap, origin="lower", extent=[-3, 3, -3, 3],␣
 ↪norm=norm)

# inset histogram
cax = ax.inset_axes([1.18, 0.02, 0.25, 0.95])  # left, bottom, width,␣
 ↪height

# plot histogram
counts, _ = np.histogram(Z, bins=bin_edges)
midpoints = (bin_edges[:-1] + bin_edges[1:]) / 2
distance = midpoints[1] - midpoints[0]
cax.barh(midpoints, counts, height=0.8 * distance,␣
 ↪color=cmap(norm(midpoints)))

# styling
cax.spines[:].set_visible(False)
cax.set_yticks(bin_edges)
cax.tick_params(axis="both", which="both", length=0)

plt.show()
```

Colormap reference

Reference for colormaps included with Matplotlib.

A reversed version of each of these colormaps is available by appending `_r` to the name, as shown in *Reversed colormaps*.

See *Choosing Colormaps in Matplotlib* for an in-depth discussion about colormaps, including colorblind-friendliness, and *Creating Colormaps in Matplotlib* for a guide to creating colormaps.

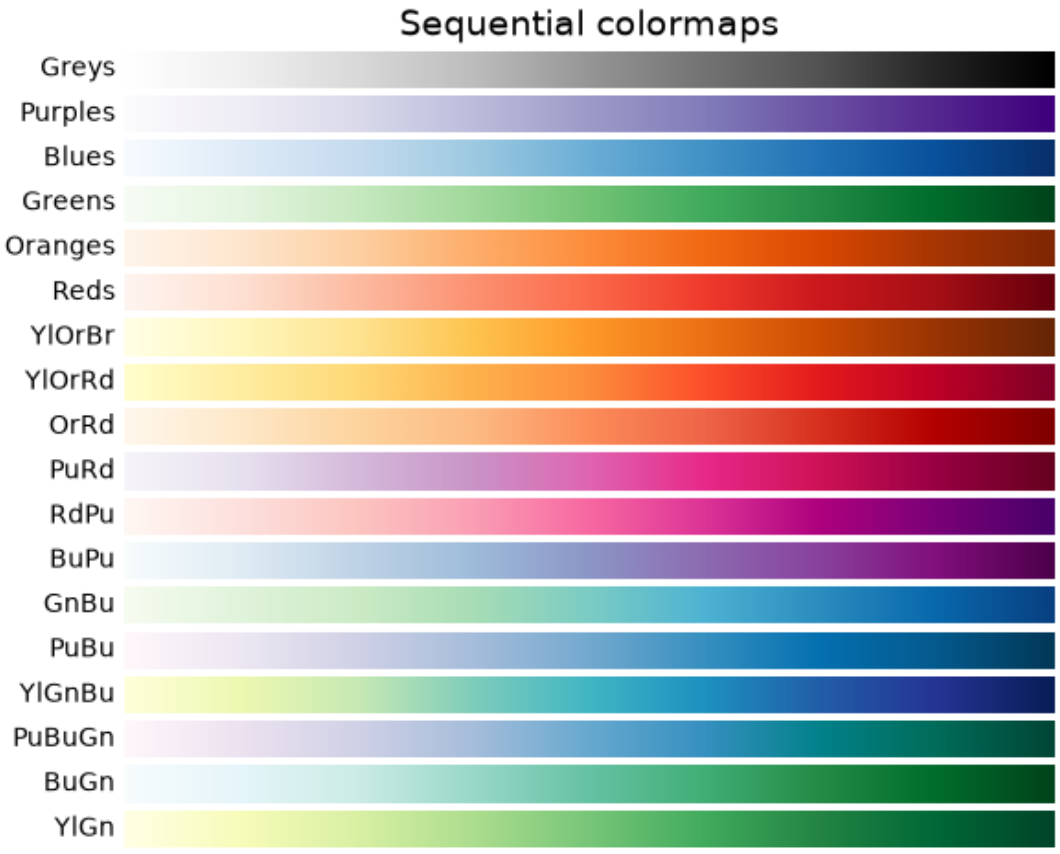
```
import matplotlib.pyplot as plt
import numpy as np

cmaps = [('Perceptually Uniform Sequential', [
            'viridis', 'plasma', 'inferno', 'magma', 'cividis']),
         ('Sequential', [
            'Greys', 'Purples', 'Blues', 'Greens', 'Oranges', 'Reds',
            'YlOrBr', 'YlOrRd', 'OrRd', 'PuRd', 'RdPu', 'BuPu',
            'GnBu', 'PuBu', 'YlGnBu', 'PuBuGn', 'BuGn', 'YlGn']),
         ('Sequential (2)', [
            'gray', 'bone', 'pink', 'spring', 'summer', 'autumn',
 ↪'winter',
            'cool', 'Wistia', 'hot', 'afmhot', 'gist_heat', 'copper']),
         ('Diverging', [
            'PiYG', 'PRGn', 'BrBG', 'PuOr', 'RdGy', 'RdBu',
```

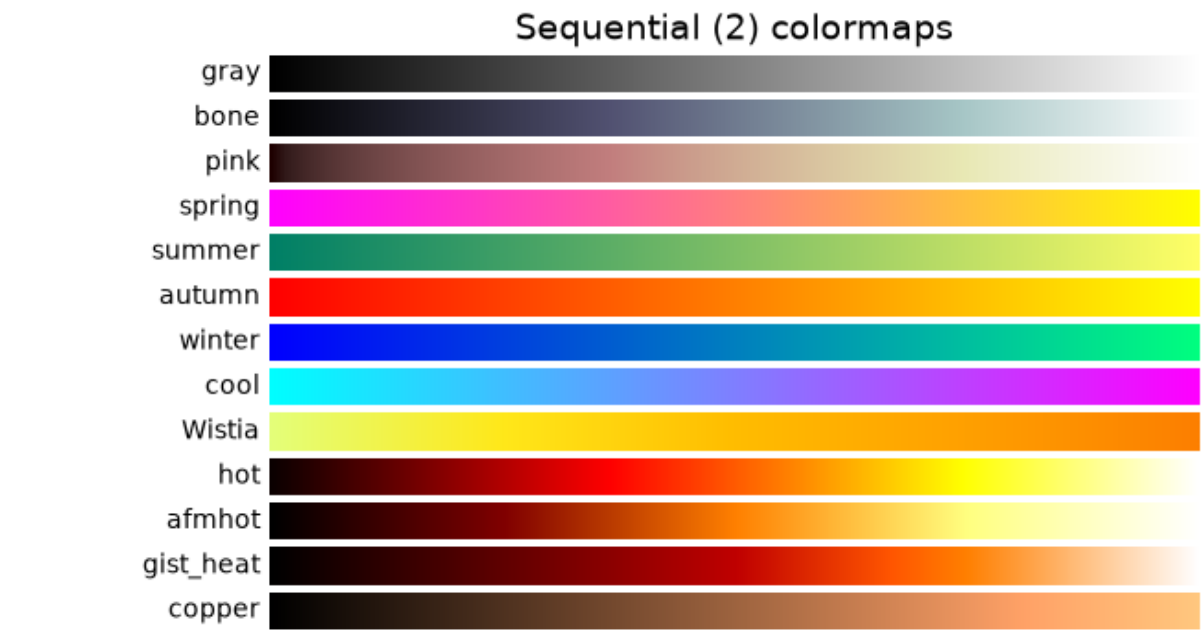
(continues on next page)

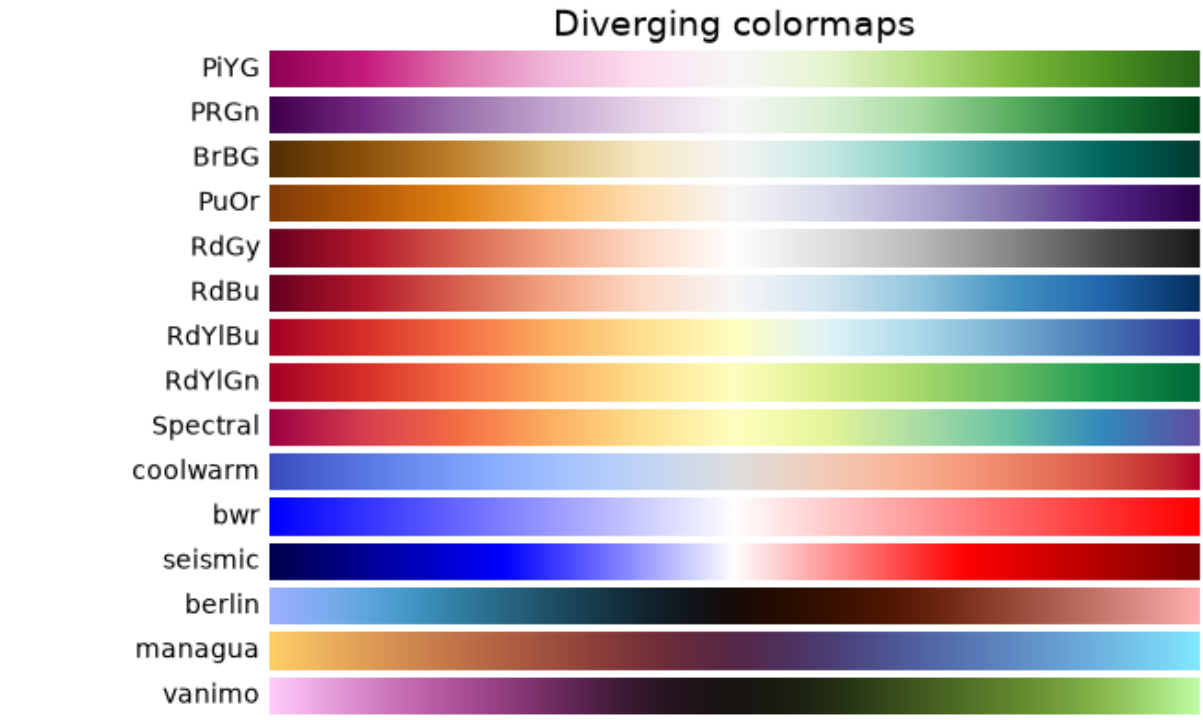
(continued from previous page)

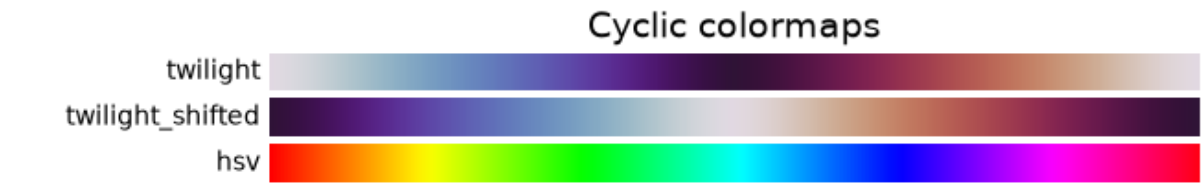
```
            'RdYlBu', 'RdYlGn', 'Spectral', 'coolwarm', 'bwr', 'seismic
↪',
            'berlin', 'managua', 'vanimo']),
        ('Cyclic', ['twilight', 'twilight_shifted', 'hsv']),
        ('Qualitative', [
            'Pastel1', 'Pastel2', 'Paired', 'Accent', 'okabe_ito',
            'Dark2', 'Set1', 'Set2', 'Set3',
            'tab10', 'tab20', 'tab20b', 'tab20c']),
        ('Miscellaneous', [
            'flag', 'prism', 'ocean', 'gist_earth', 'terrain',
↪'gist_stern',
            'gnuplot', 'gnuplot2', 'CMRmap', 'cubehelix', 'brg',
            'gist_rainbow', 'rainbow', 'jet', 'turbo', 'nipy_spectral',
            'gist_ncar'])]

gradient = np.linspace(0, 1, 256)
gradient = np.vstack((gradient, gradient))


def plot_color_gradients(cmap_category, cmap_list):
    # Create figure and adjust figure height to number of colormaps
    nrows = len(cmap_list)
    figh = 0.35 + 0.15 + (nrows + (nrows-1)*0.1)*0.22
    fig, axs = plt.subplots(nrows=nrows, figsize=(6.4, figh))
    fig.subplots_adjust(top=1-.35/figh, bottom=.15/figh, left=0.2,␣
↪right=0.99)

    axs[0].set_title(f"{cmap_category} colormaps", fontsize=14)

    for ax, cmap_name in zip(axs, cmap_list):
        ax.imshow(gradient, aspect='auto', cmap=cmap_name)
        ax.text(-.01, .5, cmap_name, va='center', ha='right',␣
↪fontsize=10,
                transform=ax.transAxes)

    # Turn off *all* ticks & spines, not just the ones with colormaps.
    for ax in axs:
        ax.set_axis_off()


for cmap_category, cmap_list in cmaps:
    plot_color_gradients(cmap_category, cmap_list)
```

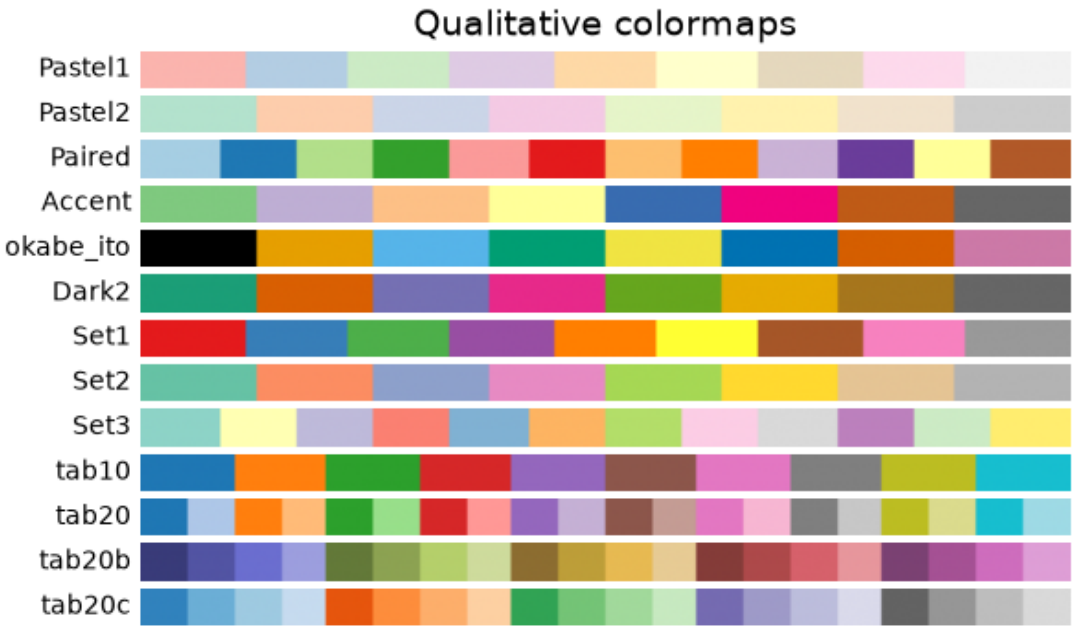
-
Perceptually Uniform Sequential colormaps
viridis
plasma
inferno
magma
cividis

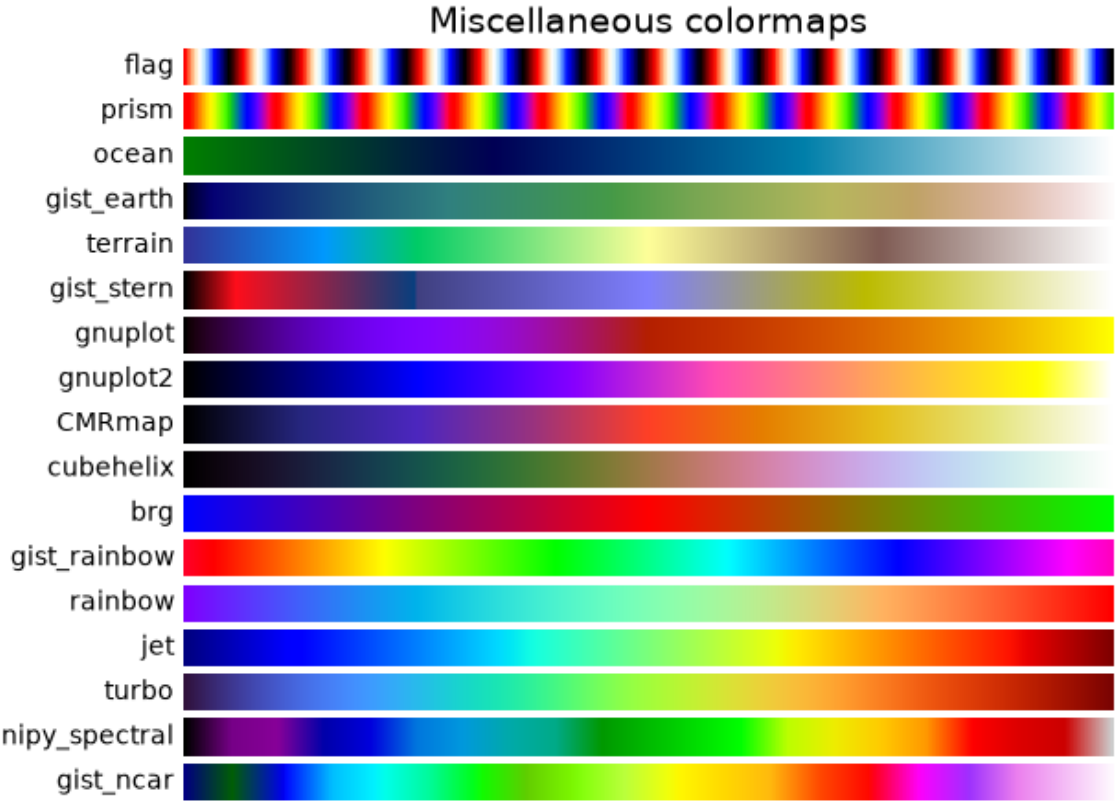
- 
Sequential colormaps
Greys
Purples
Blues
Greens
Oranges
Reds
YlOrBr
YlOrRd
OrRd
PuRd
RdPu
BuPu
GnBu
PuBu
YlGnBu
PuBuGn
BuGn
YlGn


Sequential (2) colormaps
gray
bone
pink
spring
summer
autumn
winter
cool
Wistia
hot
afmhot
gist_heat
copper


Diverging colormaps
PiYG
PRGn
BrBG
PuOr
RdGy
RdBu
RdYlBu
RdYlGn
Spectral
coolwarm
bwr
seismic
berlin
managua
vanimo


Cyclic colormaps
twilight
twilight_shifted
hsv





Discouraged

For backward compatibility we additionally support the following colormap names, which are identical

to other builtin colormaps. Their use is discouraged. Use the suggested replacement instead.

Colormap	Use identical replacement instead
gist_gray	gray
gist_yarg	gray_r
binary	gray_r

Reversed colormaps

Append `_r` to the name of any built-in colormap to get the reversed version:

```
plot_color_gradients("Original and reversed ", ['viridis', 'viridis_r
↪'])
```

The built-in reversed colormaps are generated using *`Colormap.reversed`*. For an example, see *Reversing a colormap*

References

The use of the following functions, methods, classes and modules is shown in this example:

- *`matplotlib.colors`*
- *`matplotlib.axes.Axes.imshow`*
- *`matplotlib.figure.Figure.text`*
- *`matplotlib.axes.Axes.set_axis_off`*

Tags: styling: colormap purpose: reference

Total running time of the script: (0 minutes 2.403 seconds)

Create a colormap from a list of colors

For more detail on creating and manipulating colormaps see *Creating Colormaps in Matplotlib*.

Creating a *colormap* from a list of colors can be done with the *`LinearSegmentedColormap.from_list`* method. You must pass a list of RGB tuples that define the mixture of colors from 0 to 1.

Creating custom colormaps

It is also possible to create a custom mapping for a colormap. This is accomplished by creating dictionary that specifies how the RGB channels change from one end of the cmap to the other.

Example: suppose you want red to increase from 0 to 1 over the bottom half, green to do the same over the middle half, and blue over the top half. Then you would use:

```
cdict = {
    'red': (
        (0.0,  0.0, 0.0),
        (0.5,  1.0, 1.0),
        (1.0,  1.0, 1.0),
    ),
    'green': (
        (0.0,  0.0, 0.0),
        (0.25, 0.0, 0.0),
        (0.75, 1.0, 1.0),
        (1.0,  1.0, 1.0),
    ),
    'blue': (
        (0.0,  0.0, 0.0),
        (0.5,  0.0, 0.0),
        (1.0,  1.0, 1.0),
    )
}
```

If, as in this example, there are no discontinuities in the r, g, and b components, then it is quite simple: the second and third element of each tuple, above, is the same -- call it "`y`". The first element ("`x`") defines interpolation intervals over the full range of 0 to 1, and it must span that whole range. In other words, the values of `x` divide the 0-to-1 range into a set of segments, and `y` gives the end-point color values for each segment.

Now consider the green, `cdict['green']` is saying that for:

- 0 <= `x` <= 0.25, `y` is zero; no green.
- 0.25 < `x` <= 0.75, `y` varies linearly from 0 to 1.
- 0.75 < `x` <= 1, `y` remains at 1, full green.

If there are discontinuities, then it is a little more complicated. Label the 3 elements in each row in the `cdict` entry for a given color as `(x, y0, y1)`. Then for values of `x` between `x[i]` and `x[i+1]` the color value is interpolated between `y1[i]` and `y0[i+1]`.

Going back to a cookbook example:

```
cdict = {
    'red': (
        (0.0,  0.0, 0.0),
        (0.5,  1.0, 0.7),
```

(continues on next page)

(continued from previous page)

```
        (1.0,  1.0, 1.0),
    ),
    'green': (
        (0.0,  0.0, 0.0),
        (0.5,  1.0, 0.0),
        (1.0,  1.0, 1.0),
    ),
    'blue': (
        (0.0,  0.0, 0.0),
        (0.5,  0.0, 0.0),
        (1.0,  1.0, 1.0),
    )
}
```

and look at `cdict['red'][1]`; because `y0 != y1`, it is saying that for `x` from 0 to 0.5, red increases from 0 to 1, but then it jumps down, so that for `x` from 0.5 to 1, red increases from 0.7 to 1. Green ramps from 0 to 1 as `x` goes from 0 to 0.5, then jumps back to 0, and ramps back to 1 as `x` goes from 0.5 to 1.

```
row i:   x  y0  y1
               /
              /
row i+1: x  y0  y1
```

Above is an attempt to show that for `x` in the range `x[i]` to `x[i+1]`, the interpolation is between `y1[i]` and `y0[i+1]`. So, `y0[0]` and `y1[-1]` are never used.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib as mpl
from matplotlib.colors import LinearSegmentedColormap

# Make some illustrative fake data:

x = np.arange(0, np.pi, 0.1)
y = np.arange(0, 2 * np.pi, 0.1)
X, Y = np.meshgrid(x, y)
Z = np.cos(X) * np.sin(Y) * 10
```

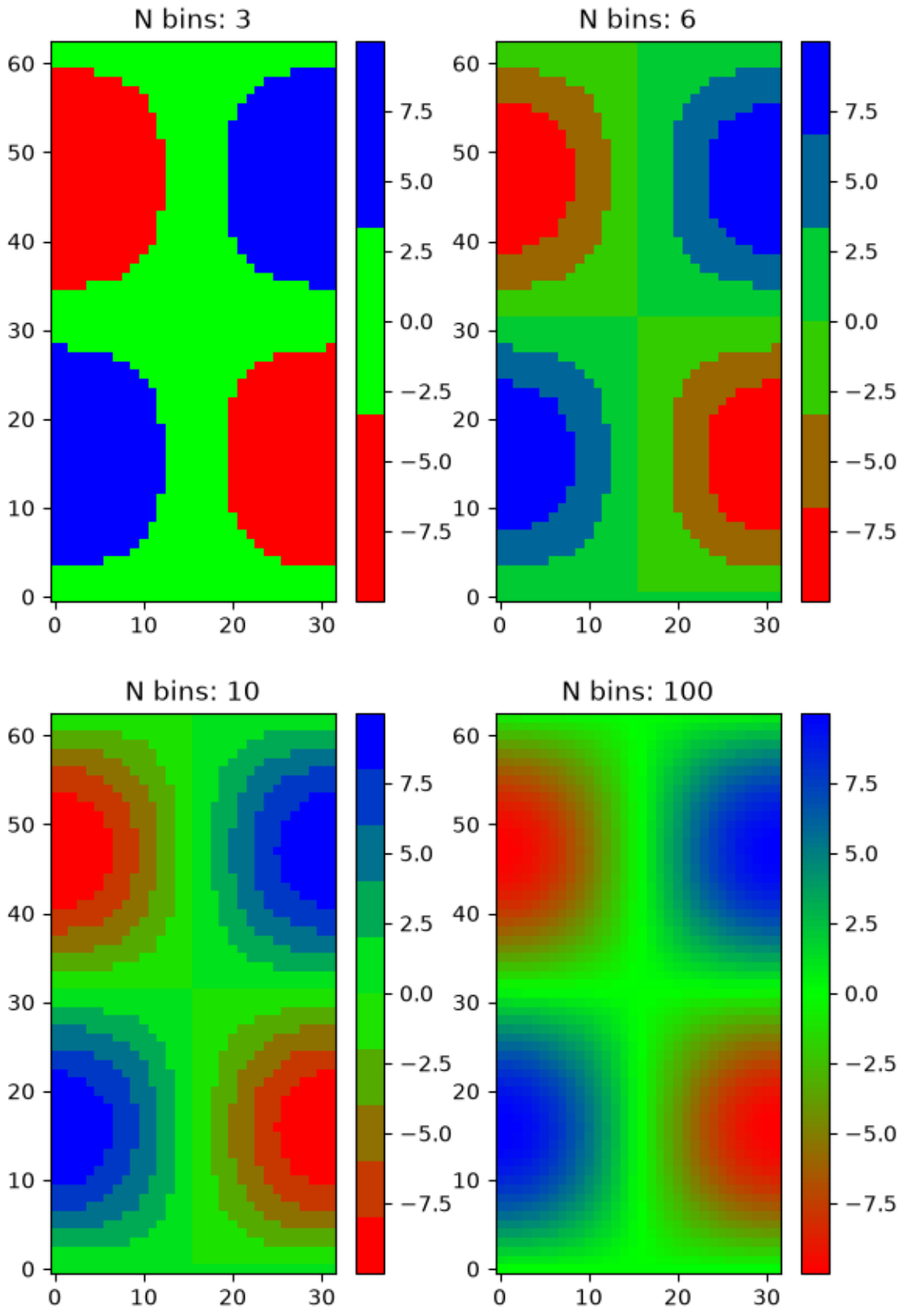
Colormaps from a list

```
colors = [(1, 0, 0), (0, 1, 0), (0, 0, 1)]  # R -> G -> B
n_bins = [3, 6, 10, 100]  # Discretizes the interpolation into bins
cmap_name = 'my_list'
fig, axs = plt.subplots(2, 2, figsize=(6, 9))
```

(continues on next page)

(continued from previous page)

```
fig.subplots_adjust(left=0.02, bottom=0.06, right=0.95, top=0.94,␣
 ↪wspace=0.05)
for n_bin, ax in zip(n_bins, axs.flat):
    # Create the colormap
    cmap = LinearSegmentedColormap.from_list(cmap_name, colors,␣
 ↪N=n_bin)
    # Fewer bins will result in "coarser" colomap interpolation
    im = ax.imshow(Z, origin='lower', cmap=cmap)
    ax.set_title("N bins: %s" % n_bin)
    fig.colorbar(im, ax=ax)
```


N bins: 3
N bins: 6
N bins: 10
N bins: 100
0
10
20
30
40
50
60
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5

Custom colormaps

```
cdict1 = {
    'red': (
        (0.0, 0.0, 0.0),
        (0.5, 0.0, 0.1),
        (1.0, 1.0, 1.0),
    ),
    'green': (
        (0.0, 0.0, 0.0),
        (1.0, 0.0, 0.0),
    ),
    'blue': (
        (0.0, 0.0, 1.0),
        (0.5, 0.1, 0.0),
        (1.0, 0.0, 0.0),
    )
}

cdict2 = {
    'red': (
        (0.0, 0.0, 0.0),
        (0.5, 0.0, 1.0),
        (1.0, 0.1, 1.0),
    ),
    'green': (
        (0.0, 0.0, 0.0),
        (1.0, 0.0, 0.0),
    ),
    'blue': (
        (0.0, 0.0, 0.1),
        (0.5, 1.0, 0.0),
        (1.0, 0.0, 0.0),
    )
}

cdict3 = {
    'red': (
        (0.0, 0.0, 0.0),
        (0.25, 0.0, 0.0),
        (0.5, 0.8, 1.0),
        (0.75, 1.0, 1.0),
        (1.0, 0.4, 1.0),
    ),
    'green': (
        (0.0, 0.0, 0.0),
        (0.25, 0.0, 0.0),
```

(continues on next page)

(continued from previous page)

```
        (0.5, 0.9, 0.9),
        (0.75, 0.0, 0.0),
        (1.0, 0.0, 0.0),
    ),
    'blue': (
        (0.0, 0.0, 0.4),
        (0.25, 1.0, 1.0),
        (0.5, 1.0, 0.8),
        (0.75, 0.0, 0.0),
        (1.0, 0.0, 0.0),
    )
}

# Make a modified version of cdict3 with some transparency
# in the middle of the range.
cdict4 = {
    **cdict3,
    'alpha': (
        (0.0, 1.0, 1.0),
        # (0.25, 1.0, 1.0),
        (0.5, 0.3, 0.3),
        # (0.75, 1.0, 1.0),
        (1.0, 1.0, 1.0),
    ),
}
```

Now we will use this example to illustrate 2 ways of handling custom colormaps. First, the most direct and explicit:

```
blue_red1 = LinearSegmentedColormap('BlueRed1', cdict1)
```

Second, create the map explicitly and register it. Like the first method, this method works with any kind of Colormap, not just a LinearSegmentedColormap:

```
mpl.colormaps.register(LinearSegmentedColormap('BlueRed2', cdict2))
mpl.colormaps.register(LinearSegmentedColormap('BlueRed3', cdict3))
mpl.colormaps.register(LinearSegmentedColormap('BlueRedAlpha', cdict4))
```

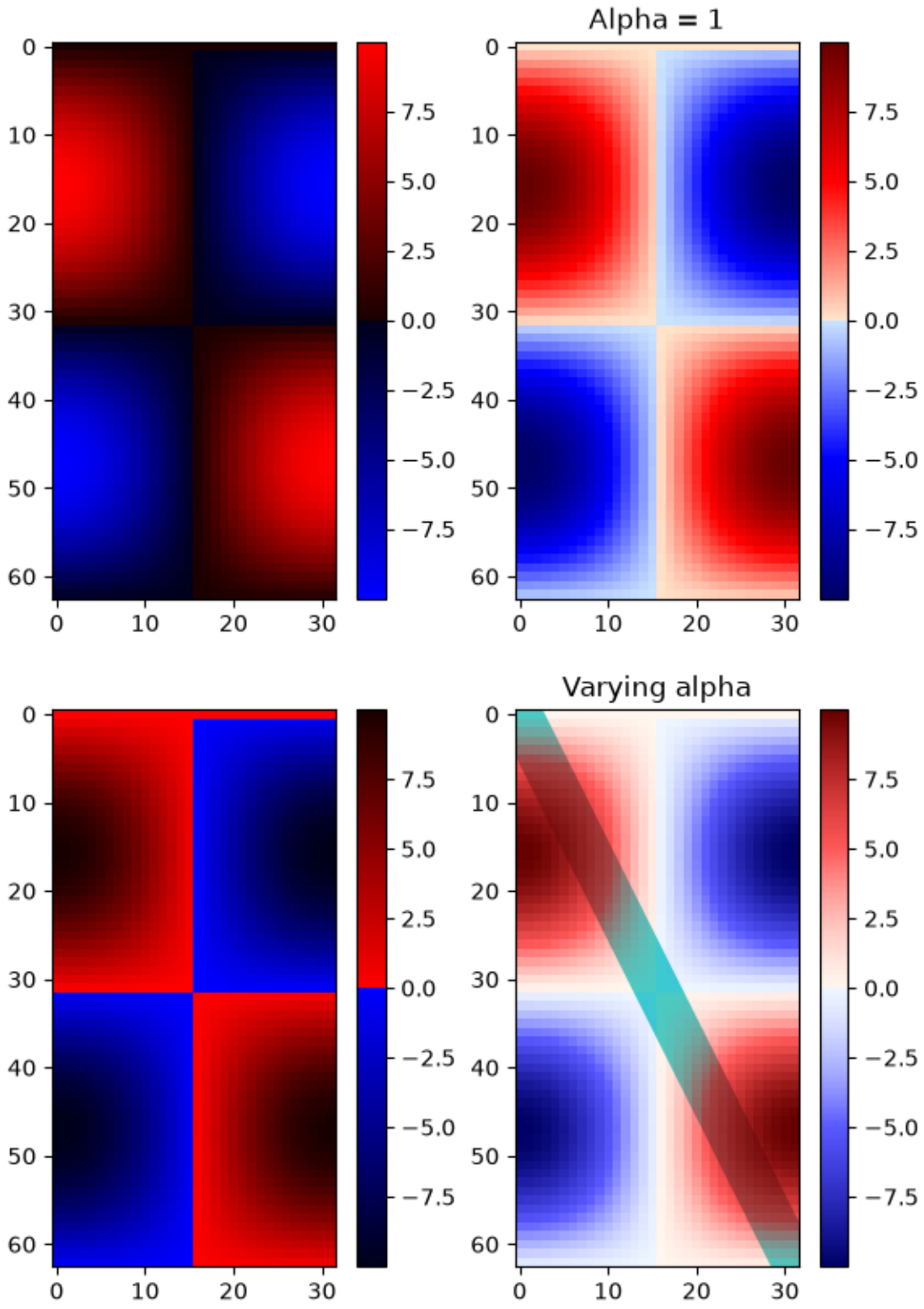
Make the figure, with 4 subplots:

```
fig, axs = plt.subplots(2, 2, figsize=(6, 9))
fig.subplots_adjust(left=0.02, bottom=0.06, right=0.95, top=0.94,␣
 ↪wspace=0.05)

im1 = axs[0, 0].imshow(Z, cmap=blue_red1)
fig.colorbar(im1, ax=axs[0, 0])
```

(continues on next page)

(continued from previous page)

```
im2 = axs[1, 0].imshow(Z, cmap='BlueRed2')
fig.colorbar(im2, ax=axs[1, 0])

# Now we will set the third cmap as the default.  One would
# not normally do this in the middle of a script like this;
# it is done here just to illustrate the method.

plt.rcParams['image.cmap'] = 'BlueRed3'

im3 = axs[0, 1].imshow(Z)
fig.colorbar(im3, ax=axs[0, 1])
axs[0, 1].set_title("Alpha = 1")

# Or as yet another variation, we can replace the rcParams
# specification *before* the imshow with the following *after*
# imshow.
# This sets the new default *and* sets the colormap of the last
# image-like item plotted via pyplot, if any.
#

# Draw a line with low zorder so it will be behind the image.
axs[1, 1].plot([0, 10 * np.pi], [0, 20 * np.pi], color='c', lw=20,␣
 ↪zorder=-1)

im4 = axs[1, 1].imshow(Z)
fig.colorbar(im4, ax=axs[1, 1])

# Here it is: changing the colormap for the current image and its
# colorbar after they have been plotted.
im4.set_cmap('BlueRedAlpha')
axs[1, 1].set_title("Varying alpha")

fig.suptitle('Custom Blue-Red colormaps', fontsize=16)
fig.subplots_adjust(top=0.9)

plt.show()
```


Custom Blue-Red colormaps
Alpha = 1
Varying alpha
0
10
20
30
40
50
60
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.imshow* / *matplotlib.pyplot.imshow*
- *matplotlib.figure.Figure.colorbar* / *matplotlib.pyplot.colorbar*
- *matplotlib.colors*
- *matplotlib.colors.LinearSegmentedColormap*
- *matplotlib.colors.LinearSegmentedColormap.from_list*
- *matplotlib.cm*
- *matplotlib.cm.ScalarMappable.set_cmap*
- *matplotlib.cm.ColormapRegistry.register*

Tags: styling: colormap plot-type: imshow level: intermediate

Total running time of the script: (0 minutes 1.686 seconds)

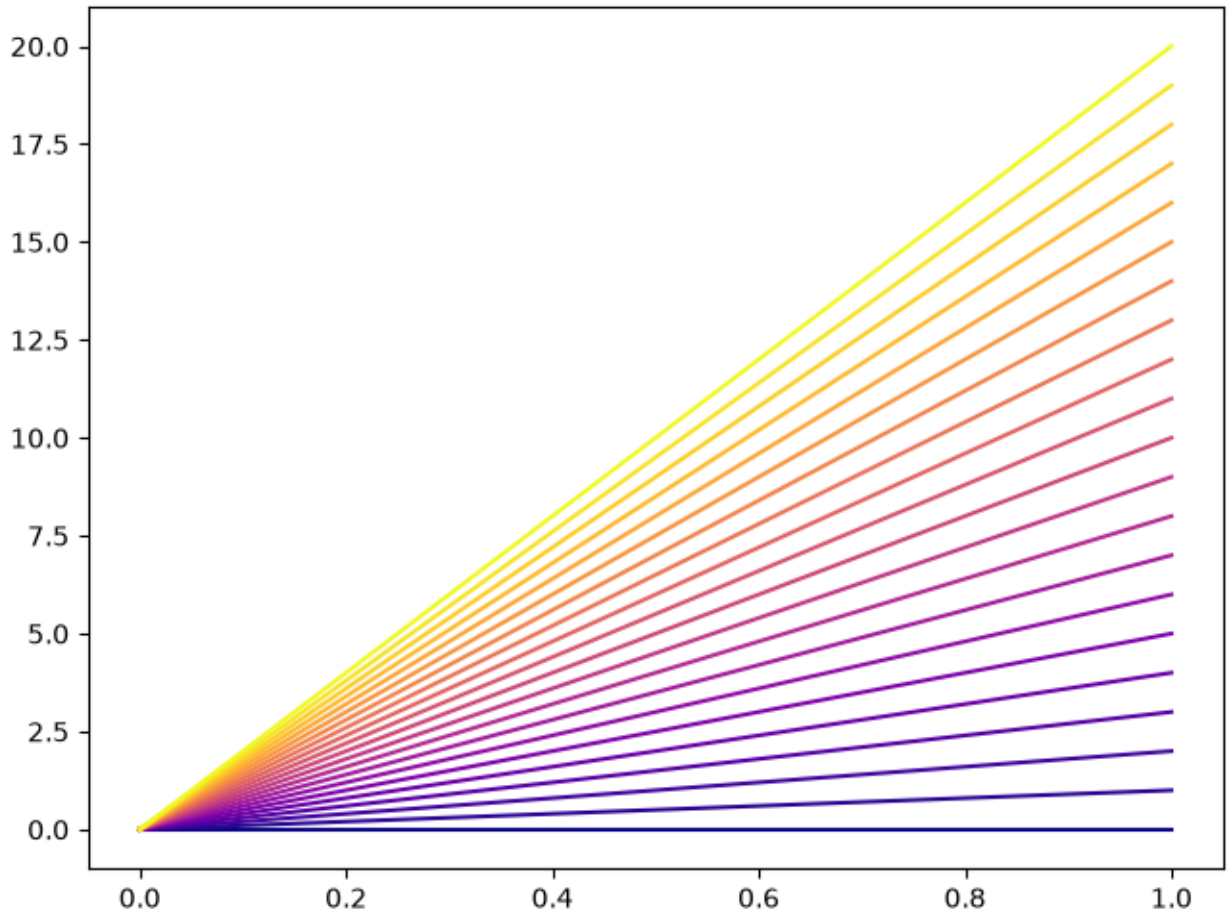
Selecting individual colors from a colormap

Sometimes we want to use more colors or a different set of colors than the default color cycle provides. Selecting individual colors from one of the provided colormaps can be a convenient way to do this.

We can retrieve colors from any *Colormap* by calling it with a float or a list of floats in the range [0, 1]; e.g. `cmap(0.5)` will give the middle color. See also *Colormap.__call__*.

Extracting colors from a continuous colormap

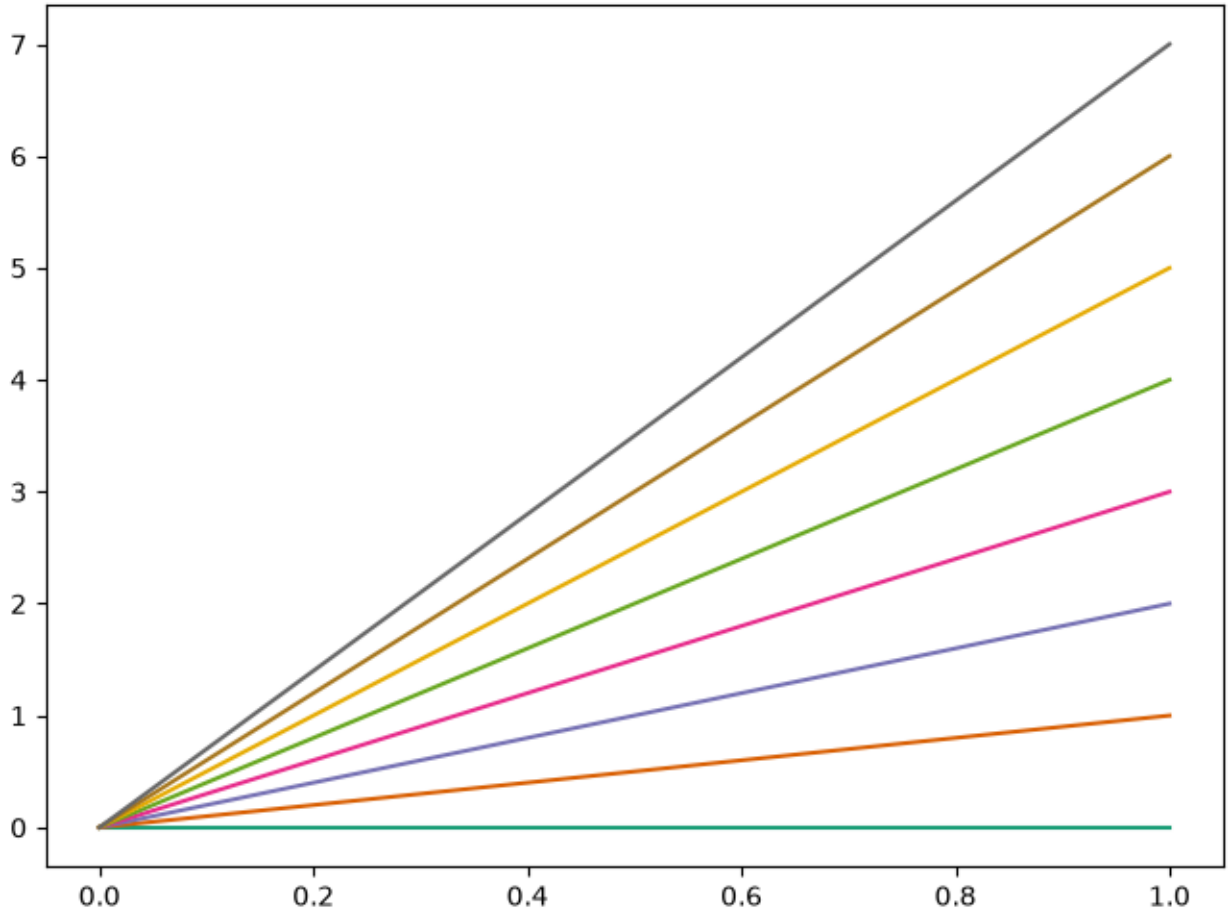
```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib as mpl

n_lines = 21
cmap = mpl.colormaps['plasma']

# Take colors at regular intervals spanning the colormap.
colors = cmap(np.linspace(0, 1, n_lines))

fig, ax = plt.subplots(layout='constrained')

for i, color in enumerate(colors):
    ax.plot([0, i], color=color)

plt.show()
```



Extracting colors from a discrete colormap

The list of all colors in a *ListedColormap* is available as the `colors` attribute. Note that all the colors from Matplotlib's qualitative color maps are also available as color sequences, so may be accessed more directly from the color sequence registry. See *Named color sequences*.

```
colors = mpl.colormaps['Dark2'].colors

fig, ax = plt.subplots(layout='constrained')

for i, color in enumerate(colors):
    ax.plot([0, i], color=color)

plt.show()
```



See Also

For more details about manipulating colormaps, see *Creating Colormaps in Matplotlib*. To change the default color cycle, see *Styling with cycler*.

References

The use of the following functions, methods, classes and modules is shown in this example:

- `matplotlib.colors.Colormap`
- `matplotlib.colors.Colormap.resampled`

Tags: styling: colormap styling: color plot-type: line level: intermediate

List of named colors

This plots a list of the named colors supported by Matplotlib. For more information on colors in matplotlib see

- the *Specifying colors* tutorial;
- the `matplotlib.colors` API;

- the *Color Demo*.

Helper Function for Plotting

First we define a helper function for making a table of colors, then we use it on some common color categories.

```
import math

import matplotlib.pyplot as plt

import matplotlib.colors as mcolors
from matplotlib.patches import Rectangle


def plot_colortable(colors, *, ncols=4, sort_colors=True):

    cell_width = 212
    cell_height = 22
    swatch_width = 48
    margin = 12

    # Sort colors by hue, saturation, value and name.
    if sort_colors is True:
        names = sorted(
            colors, key=lambda c: tuple(mcolors.rgb_to_hsv(mcolors.
 ↪to_rgb(c))))
    else:
        names = list(colors)

    n = len(names)
    nrows = math.ceil(n / ncols)

    width = cell_width * ncols + 2 * margin
    height = cell_height * nrows + 2 * margin
    dpi = 72

    fig, ax = plt.subplots(figsize=(width / dpi, height / dpi),␣
 ↪dpi=dpi)
    fig.subplots_adjust(margin/width, margin/height,
                        (width-margin)/width, (height-margin)/height)
    ax.set_xlim(0, cell_width * ncols)
    ax.set_ylim(cell_height * (nrows-0.5), -cell_height/2.)
    ax.yaxis.set_visible(False)
    ax.xaxis.set_visible(False)
    ax.set_axis_off()

    for i, name in enumerate(names):
```

(continues on next page)

(continued from previous page)

```
        row = i % nrows
        col = i // nrows
        y = row * cell_height

        swatch_start_x = cell_width * col
        text_pos_x = cell_width * col + swatch_width + 7

        ax.text(text_pos_x, y, name, fontsize=14,
                horizontalalignment='left',
                verticalalignment='center')

        ax.add_patch(
            Rectangle(xy=(swatch_start_x, y-9), width=swatch_width,
                      height=18, facecolor=colors[name], edgecolor='0.7
↪')
        )

    return fig
```

Base colors

```
plot_colortable(mcolors.BASE_COLORS, ncols=3, sort_colors=False)
```

Tableau Palette

```
plot_colortable(mcolors.TABLEAU_COLORS, ncols=2, sort_colors=False)
```

CSS Colors

```
plot_colortable(mcolors.CSS4_COLORS)
plt.show()
```

XKCD Colors

Matplotlib supports colors from the xkcd color survey, e.g. `"xkcd:sky blue"`. Since this contains almost 1000 colors, a figure of this would be very large and is thus omitted here. You can use the following code to generate the overview yourself

```
xkcd_fig = plot_colortable(mcolors.XKCD_COLORS)
xkcd_fig.savefig("XKCD_Colors.png")
```

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.colors*
- *matplotlib.colors.rgb_to_hsv*
- *matplotlib.colors.to_rgba*
- *matplotlib.figure.Figure.get_size_inches*
- *matplotlib.figure.Figure.subplots_adjust*
- *matplotlib.axes.Axes.text*
- *matplotlib.patches.Rectangle*

Tags: styling: color purpose: reference

Total running time of the script: (0 minutes 1.526 seconds)

Ways to set a color's alpha value

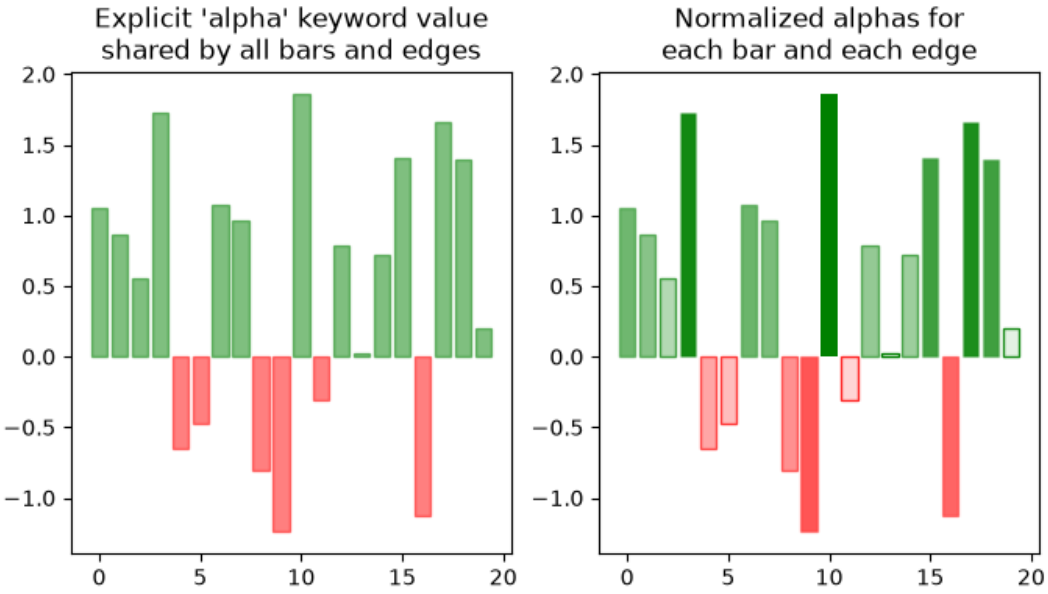
Compare setting alpha by the *alpha* keyword argument and by one of the Matplotlib color formats. Often, the *alpha* keyword is the only tool needed to add transparency to a color. In some cases, the *(matplotlib_color, alpha)* color format provides an easy way to fine-tune the appearance of a Figure.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility.
np.random.seed(19680801)

fig, (ax1, ax2) = plt.subplots(ncols=2, figsize=(8, 4))

x_values = [n for n in range(20)]
y_values = np.random.randn(20)

facecolors = ['green' if y > 0 else 'red' for y in y_values]
edgecolors = facecolors

ax1.bar(x_values, y_values, color=facecolors, edgecolor=edgecolors,␣
 ↪alpha=0.5)
ax1.set_title("Explicit 'alpha' keyword value\nshared by all bars and␣
 ↪edges")


# Normalize y values to get distinct face alpha values.
abs_y = [abs(y) for y in y_values]
face_alphas = [n / max(abs_y) for n in abs_y]
```

(continues on next page)

(continued from previous page)

```
edge_alphas = [1 - alpha for alpha in face_alphas]

colors_with_alphas = list(zip(facecolors, face_alphas))
edgecolors_with_alphas = list(zip(edgecolors, edge_alphas))

ax2.bar(x_values, y_values, color=colors_with_alphas,
        edgecolor=edgecolors_with_alphas)
ax2.set_title('Normalized alphas for\neach bar and each edge')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.axes.Axes.bar*
- *matplotlib.pyplot.subplots*

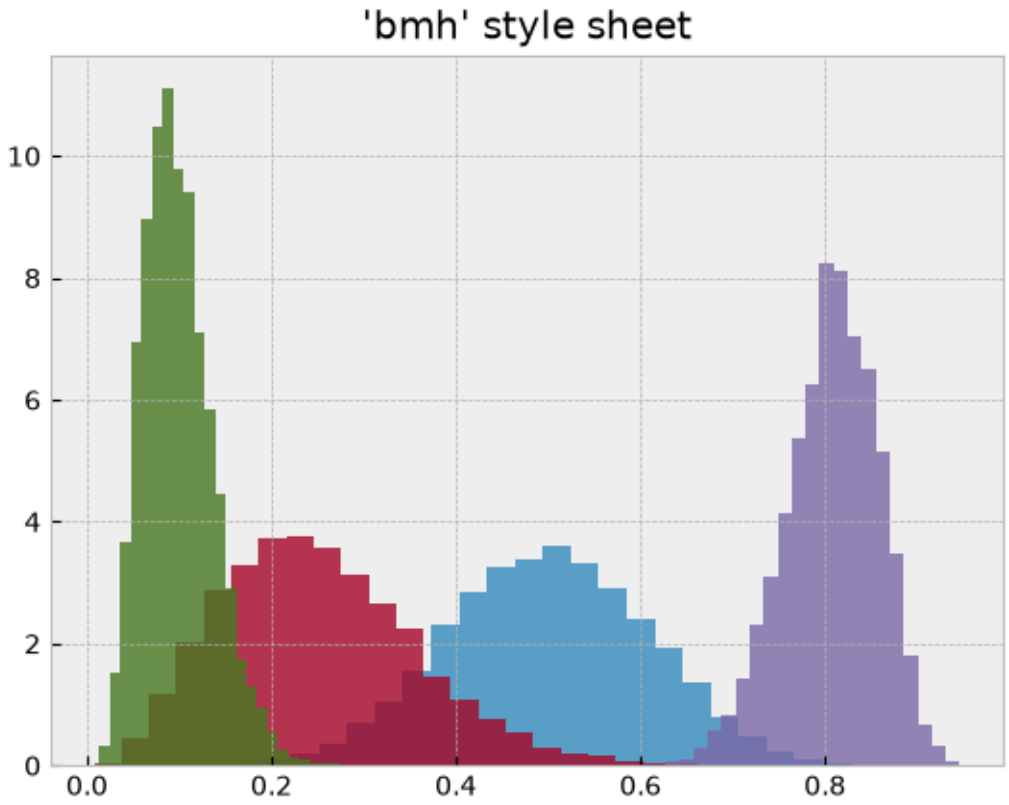
Tags: styling: color plot-type: bar level: beginner

6.24.12 Style sheets

Bayesian Methods for Hackers style sheet

This example demonstrates the style used in the Bayesian Methods for Hackers[1] online book.

[1] http://camdavidsonpilon.github.io/Probabilistic-Programming-and-Bayesian-Methods-for-Hackers/




```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

plt.style.use('bmh')


def plot_beta_hist(ax, a, b):
    ax.hist(np.random.beta(a, b, size=10000),
            histtype="stepfilled", bins=25, alpha=0.8, density=True)


fig, ax = plt.subplots()
plot_beta_hist(ax, 10, 10)
plot_beta_hist(ax, 4, 12)
plot_beta_hist(ax, 50, 12)
plot_beta_hist(ax, 6, 55)
ax.set_title("'bmh' style sheet")
```

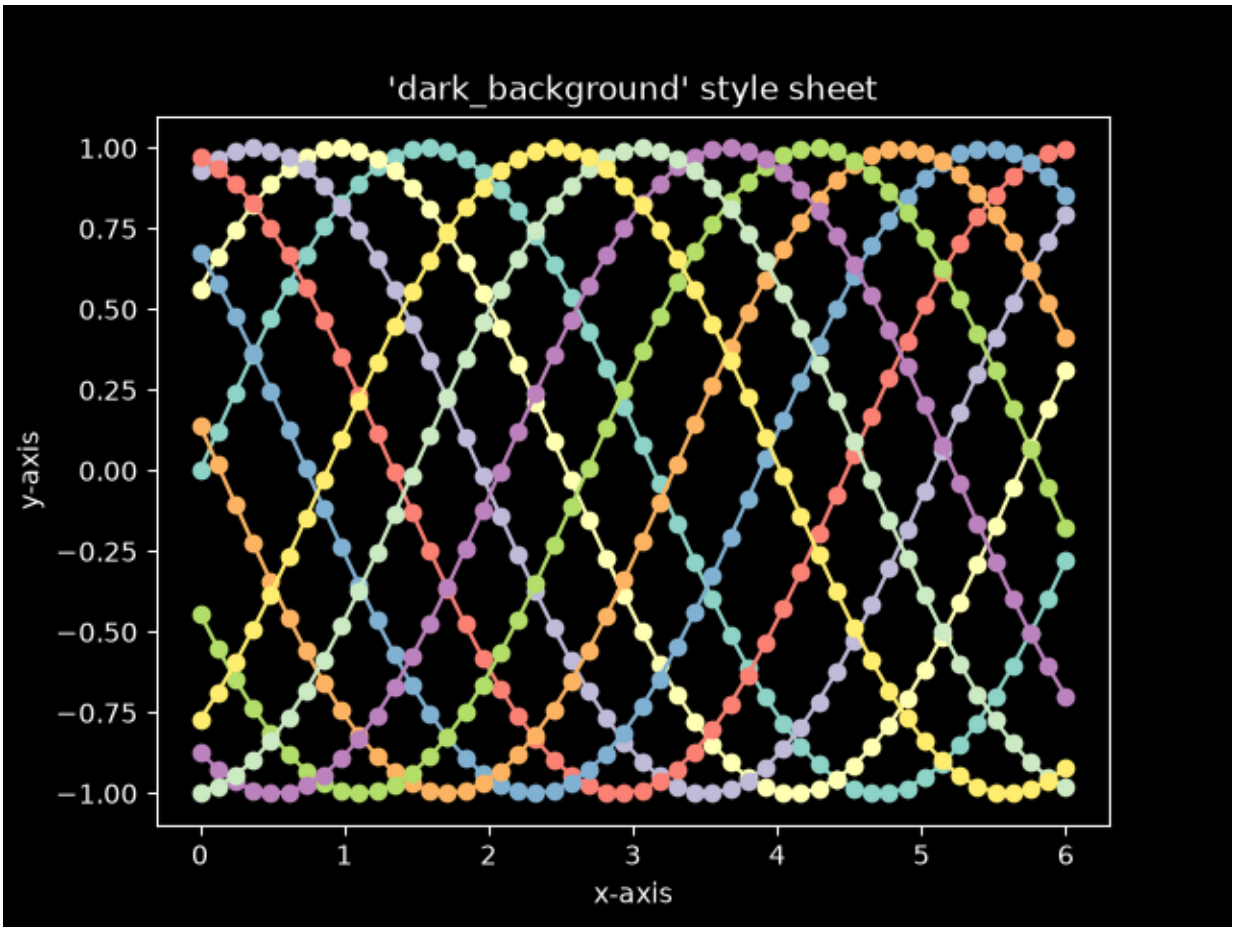
(continues on next page)

(continued from previous page)

```
plt.show()
```

Dark background style sheet

This example demonstrates the "dark_background" style, which uses white for elements that are typically black (text, borders, etc). Note that not all plot elements default to colors defined by an rc parameter.




```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('dark_background')

fig, ax = plt.subplots()

L = 6
x = np.linspace(0, L)
ncolors = len(plt.rcParams['axes.prop_cycle'])
shift = np.linspace(0, L, ncolors, endpoint=False)
```

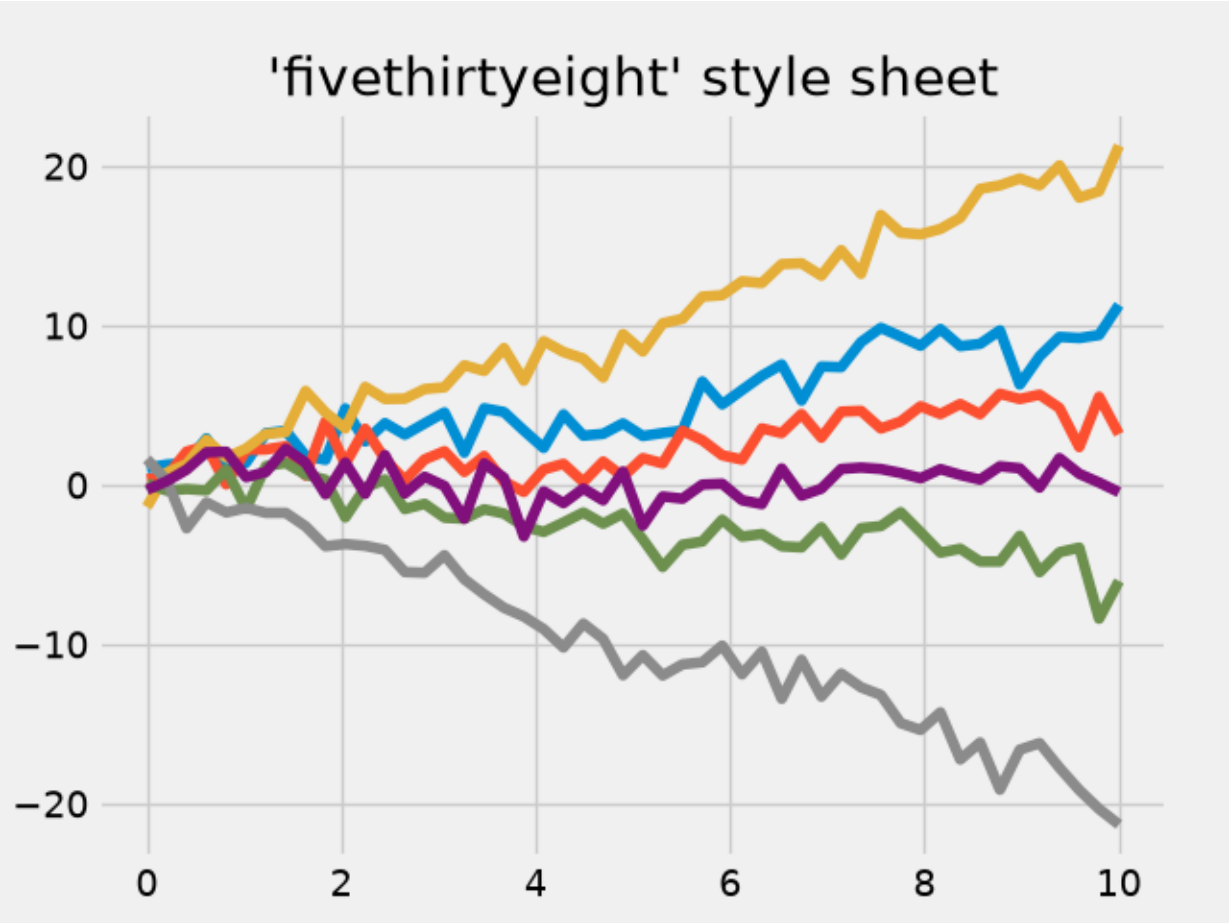
(continues on next page)

(continued from previous page)

```
for s in shift:
    ax.plot(x, np.sin(x + s), 'o-')
ax.set_xlabel('x-axis')
ax.set_ylabel('y-axis')
ax.set_title("'dark_background' style sheet")

plt.show()
```

FiveThirtyEight style sheet

This shows an example of the "fivethirtyeight" styling, which tries to replicate the styles from FiveThirtyEight.com.




```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('fivethirtyeight')

x = np.linspace(0, 10)
```

(continues on next page)

(continued from previous page)

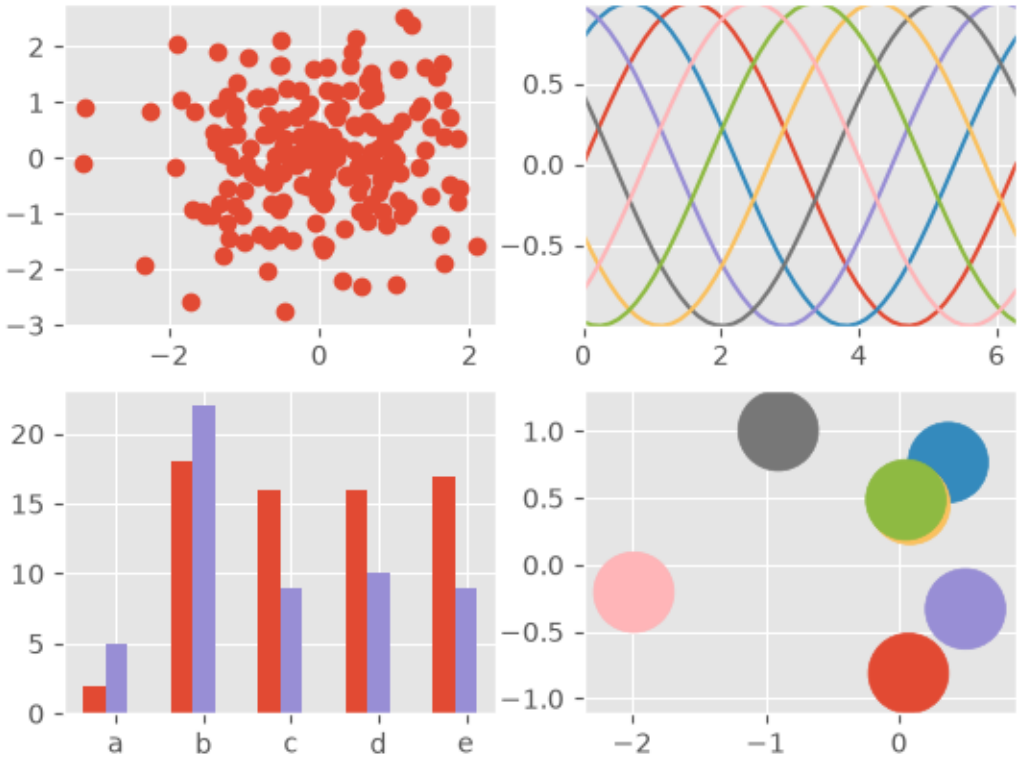
```
# Fixing random state for reproducibility
np.random.seed(19680801)

fig, ax = plt.subplots()

ax.plot(x, np.sin(x) + x + np.random.randn(50))
ax.plot(x, np.sin(x) + 0.5 * x + np.random.randn(50))
ax.plot(x, np.sin(x) + 2 * x + np.random.randn(50))
ax.plot(x, np.sin(x) - 0.5 * x + np.random.randn(50))
ax.plot(x, np.sin(x) - 2 * x + np.random.randn(50))
ax.plot(x, np.sin(x) + np.random.randn(50))
ax.set_title("'fivethirtyeight' style sheet")

plt.show()
```

ggplot style sheet

This example demonstrates the "ggplot" style, which adjusts the style to emulate ggplot (a popular plotting package for R).

These settings were shamelessly stolen from[1] (with permission).

[1] https://everyhue.me/posts/sane-color-scheme-for-matplotlib/




```
import matplotlib.pyplot as plt
import numpy as np

plt.style.use('ggplot')

# Fixing random state for reproducibility
np.random.seed(19680801)

fig, axs = plt.subplots(ncols=2, nrows=2)
ax1, ax2, ax3, ax4 = axs.flat

# scatter plot (Note: `plt.scatter` doesn't use default colors)
x, y = np.random.normal(size=(2, 200))
ax1.plot(x, y, 'o')

# sinusoidal lines with colors from default color cycle
L = 2*np.pi
x = np.linspace(0, L)
ncolors = len(plt.rcParams['axes.prop_cycle'])
shift = np.linspace(0, L, ncolors, endpoint=False)
```

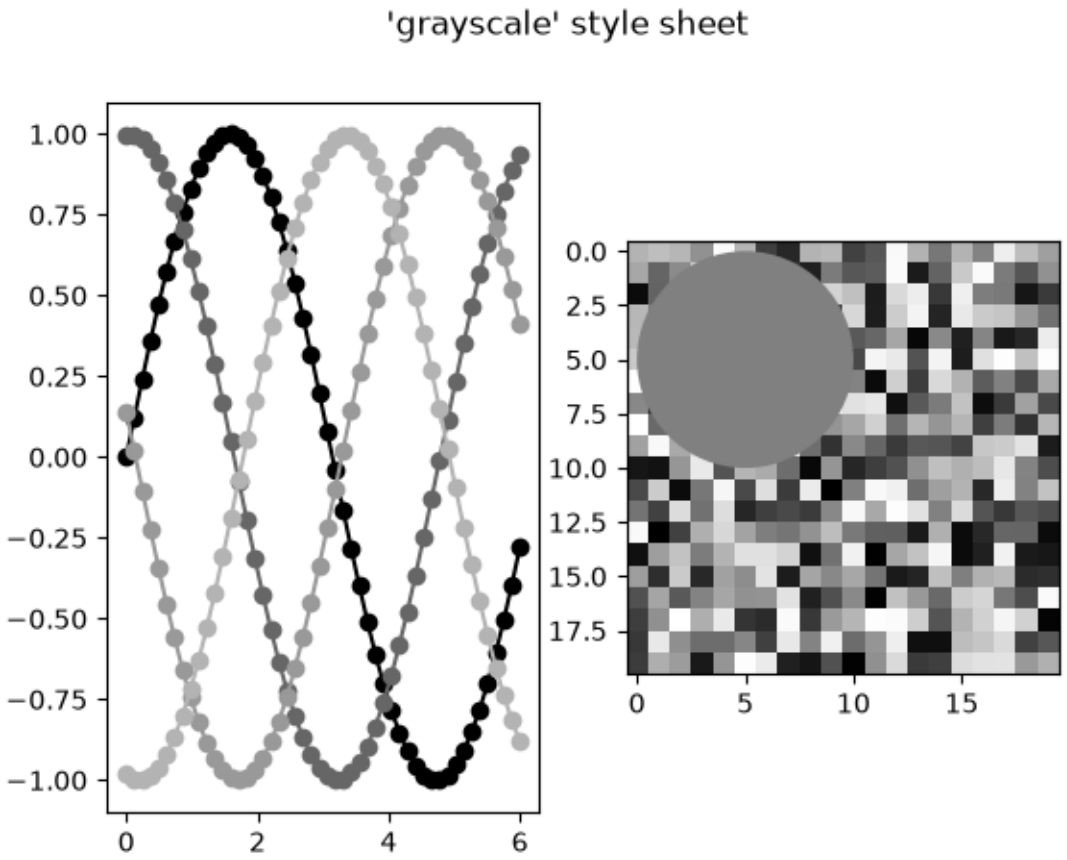
(continues on next page)

(continued from previous page)

```
for s in shift:
    ax2.plot(x, np.sin(x + s), '-')
ax2.margins(0)

# bar graphs
x = np.arange(5)
y1, y2 = np.random.randint(1, 25, size=(2, 5))
width = 0.25
ax3.bar(x, y1, width)
ax3.bar(x + width, y2, width,
        color=list(plt.rcParams['axes.prop_cycle'])[2]['color'])
ax3.set_xticks(x + width, labels=['a', 'b', 'c', 'd', 'e'])

# circles with colors from default color cycle
for i, color in enumerate(plt.rcParams['axes.prop_cycle']):
    xy = np.random.normal(size=2)
    ax4.add_patch(plt.Circle(xy, radius=0.3, color=color['color']))
ax4.axis('equal')
ax4.margins(0)

plt.show()
```

Grayscale style sheet

This example demonstrates the "grayscale" style sheet, which changes all colors that are defined as *rcParams* to grayscale. Note, however, that not all plot elements respect *rcParams*.




```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)


def color_cycle_example(ax):
    L = 6
    x = np.linspace(0, L)
    ncolors = len(plt.rcParams['axes.prop_cycle'])
    shift = np.linspace(0, L, ncolors, endpoint=False)
    for s in shift:
        ax.plot(x, np.sin(x + s), 'o-')


def image_and_patch_example(ax):
    ax.imshow(np.random.random(size=(20, 20)), interpolation='none')
    c = plt.Circle((5, 5), radius=5, label='patch')
    ax.add_patch(c)
```

(continues on next page)

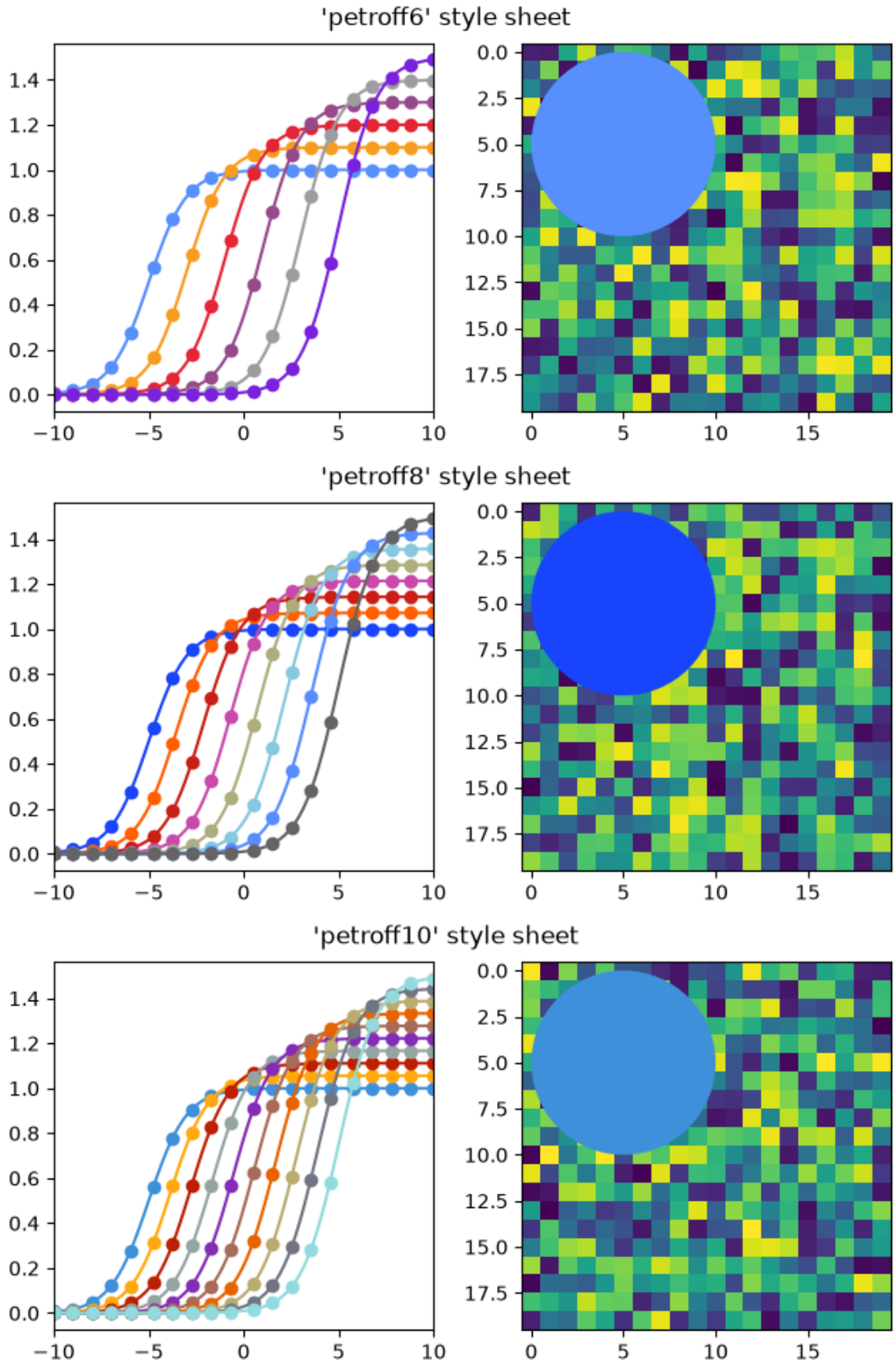
(continued from previous page)

```
plt.style.use('grayscale')

fig, (ax1, ax2) = plt.subplots(ncols=2)
fig.suptitle("'grayscale' style sheet")

color_cycle_example(ax1)
image_and_patch_example(ax2)

plt.show()
```

Petroff style sheets

This example demonstrates the "petroffN" styles, which implement the 6-, 8- and 10-color sequences developed by Matthew A. Petroff[1] for accessible data visualization. The styles balance aesthetics with accessibility considerations, making them suitable for various types of plots while ensuring readability and distinction between data series.

[1] https://arxiv.org/abs/2107.02270


'petroff6' style sheet
'petroff8' style sheet
'petroff10' style sheet

```
import matplotlib.pyplot as plt
import numpy as np


def colored_lines_example(ax):
    t = np.linspace(-10, 10, 100)
    nb_colors = len(plt.rcParams['axes.prop_cycle'])
    shifts = np.linspace(-5, 5, nb_colors)
    amplitudes = np.linspace(1, 1.5, nb_colors)
    for t0, a in zip(shifts, amplitudes):
        y = a / (1 + np.exp(-(t - t0)))
        line, = ax.plot(t, y, '-')
        point_indices = np.linspace(0, len(t) - 1, 20, dtype=int)
        ax.plot(t[point_indices], y[point_indices], 'o', color=line.
 ↪get_color())
    ax.set_xlim(-10, 10)


def image_and_patch_example(ax):
    ax.imshow(np.random.random(size=(20, 20)), interpolation='none')
    c = plt.Circle((5, 5), radius=5, label='patch')
    ax.add_patch(c)


fig = plt.figure(figsize=(6.4, 9.6), layout='compressed')
sfigs = fig.subfigures(nrows=3)

for style, sfig in zip(['petroff6', 'petroff8', 'petroff10'], sfigs):
    sfig.suptitle(f"'{style}' style sheet")
    with plt.style.context(style):
        ax1, ax2 = sfig.subplots(ncols=2)
        colored_lines_example(ax1)
        image_and_patch_example(ax2)

plt.show()
```

Total running time of the script: (0 minutes 1.001 seconds)

Solarized Light stylesheet

This shows an example of "Solarized_Light" styling, which tries to replicate the styles of:

- https://ethanschoonover.com/solarized/
- https://github.com/jrnold/ggthemes
- http://www.pygal.org/en/stable/documentation/builtin_styles.html#light-solarized

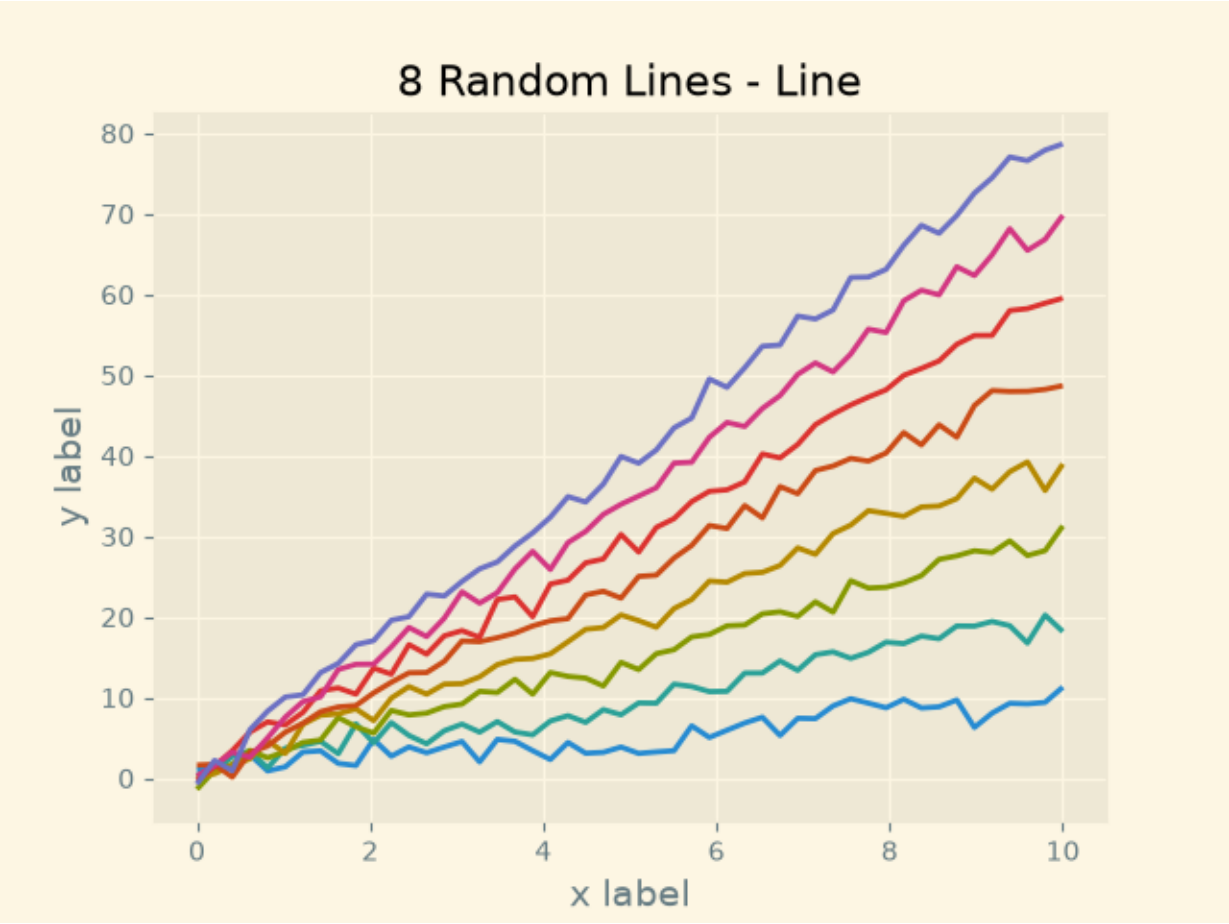
and work of:

- https://github.com/tonysyu/mpltools

using all 8 accents of the color palette - starting with blue

Still TODO:

- Create alpha values for bar and stacked charts. .33 or .5
- Apply Layout Rules




```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

x = np.linspace(0, 10)
with plt.style.context('Solarize_Light2'):
    plt.plot(x, np.sin(x) + x + np.random.randn(50))
    plt.plot(x, np.sin(x) + 2 * x + np.random.randn(50))
    plt.plot(x, np.sin(x) + 3 * x + np.random.randn(50))
    plt.plot(x, np.sin(x) + 4 * x + np.random.randn(50))
    plt.plot(x, np.sin(x) + 5 * x + np.random.randn(50))
```

(continues on next page)

(continued from previous page)

```
    plt.plot(x, np.sin(x) + 6 * x + np.random.randn(50))
    plt.plot(x, np.sin(x) + 7 * x + np.random.randn(50))
    plt.plot(x, np.sin(x) + 8 * x + np.random.randn(50))
    # Number of accent colors in the color scheme
    plt.title('8 Random Lines - Line')
    plt.xlabel('x label', fontsize=14)
    plt.ylabel('y label', fontsize=14)

plt.show()
```

Style sheets reference

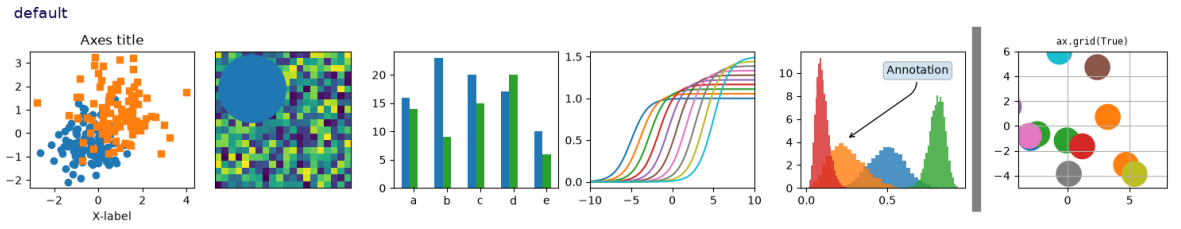
This script demonstrates the different available style sheets on a common set of example plots: scatter plot, image, bar graph, patches, line plot and histogram.

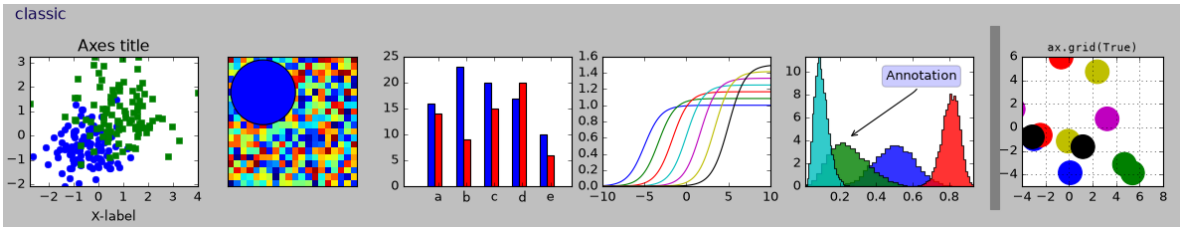
Any of these style sheets can be imported (i.e. activated) by its name. For example for the ggplot style:

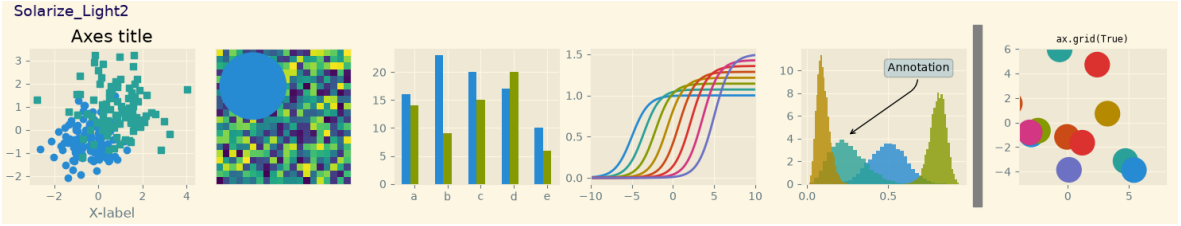
```
>>> plt.style.use('ggplot')
```

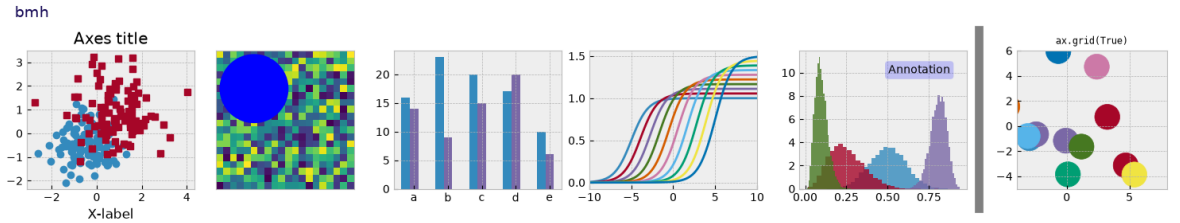
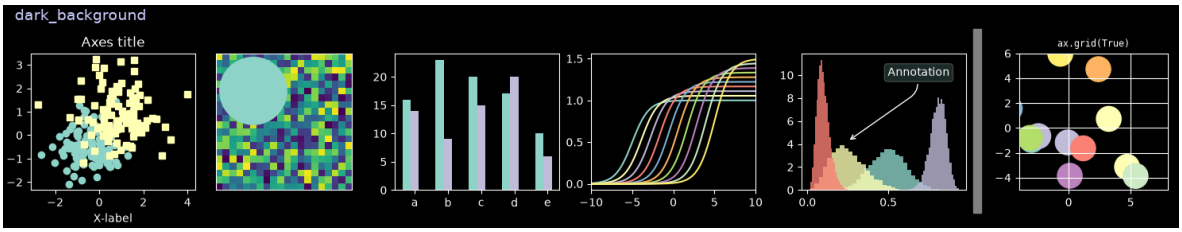
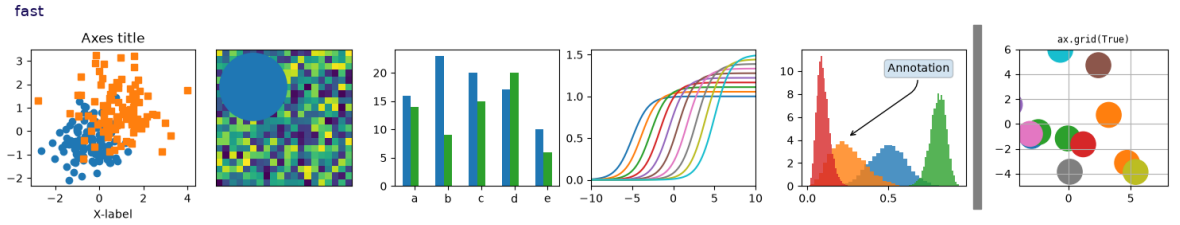
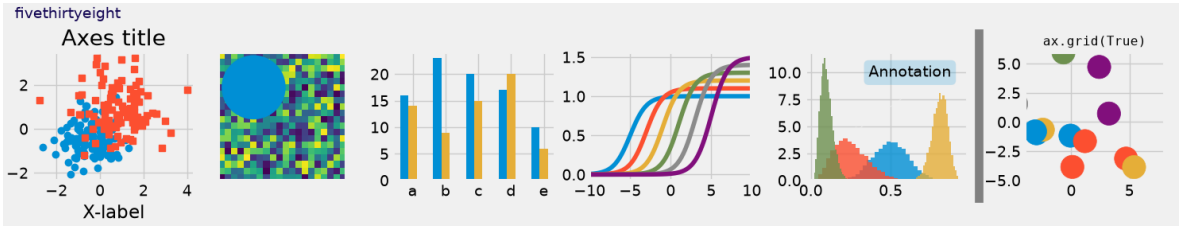
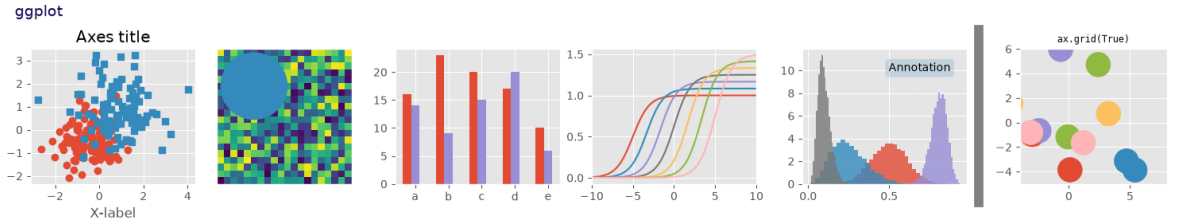
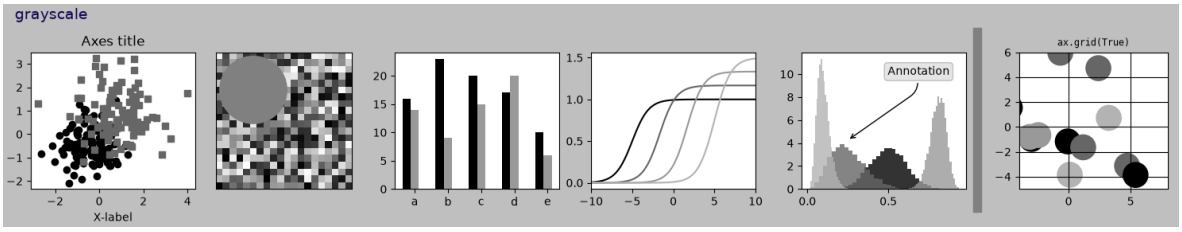
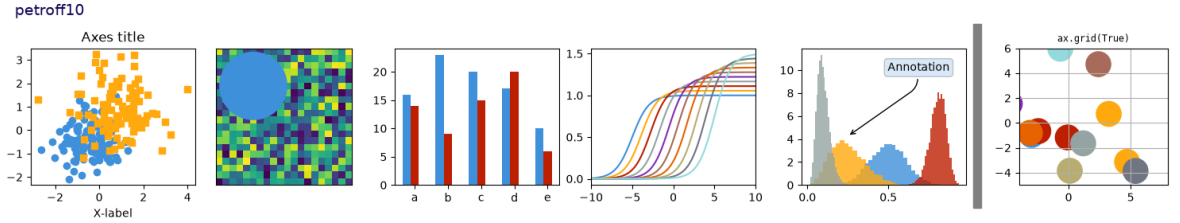
The names of the available style sheets can be found in the list `matplotlib.style.available` (they are also printed in the corner of each plot below).

See more details in *Customizing Matplotlib using style sheets*.

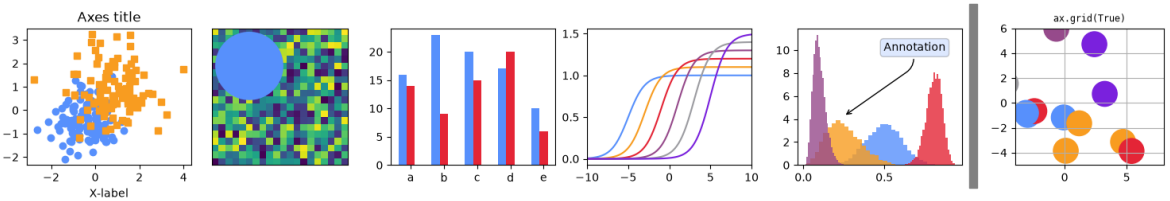
- 

- 

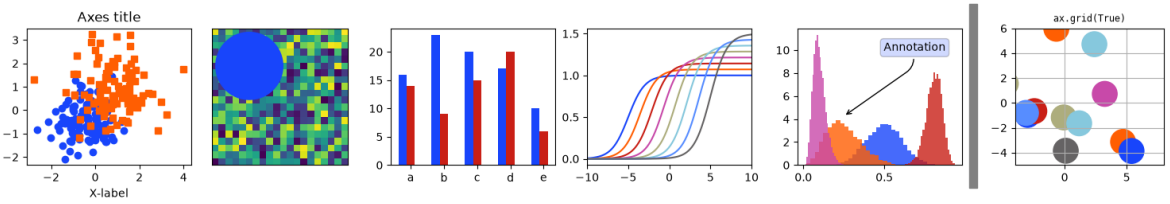
- 

- 
bmh
Axes title
X-label
Annotation
ax.grid(True)
- 
dark_background
Axes title
X-label
Annotation
ax.grid(True)
- 
fast
Axes title
X-label
Annotation
ax.grid(True)
- 
fivethirtyeight
Axes title
X-label
Annotation
ax.grid(True)
- 
ggplot
Axes title
X-label
Annotation
ax.grid(True)
- 
grayscale
Axes title
X-label
Annotation
ax.grid(True)
- 
petroff10
Axes title
X-label
Annotation
ax.grid(True)

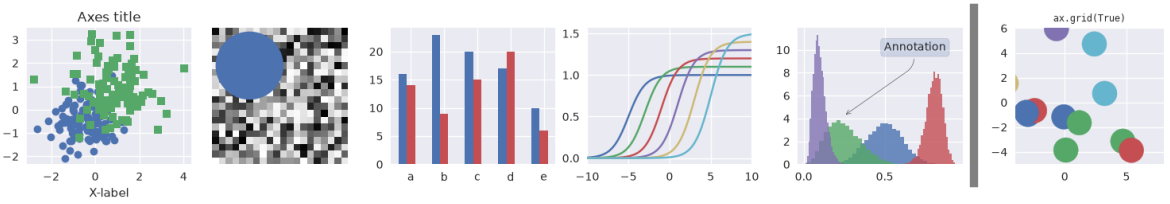
- petroff6



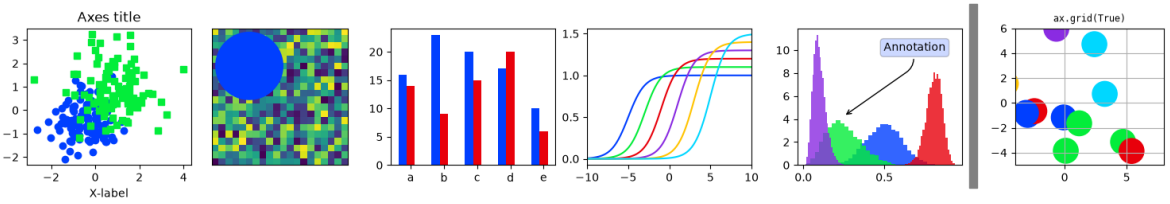
- petroff8



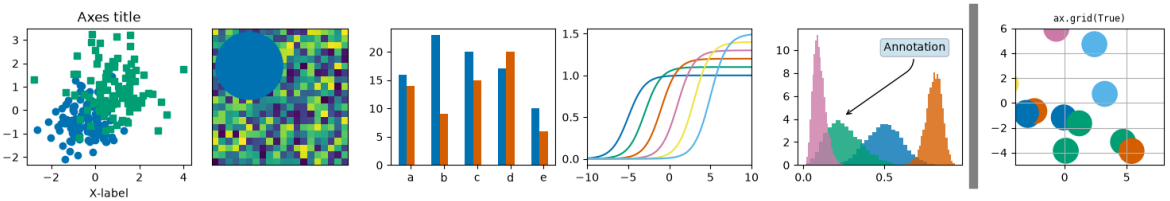
- seaborn-v0_8



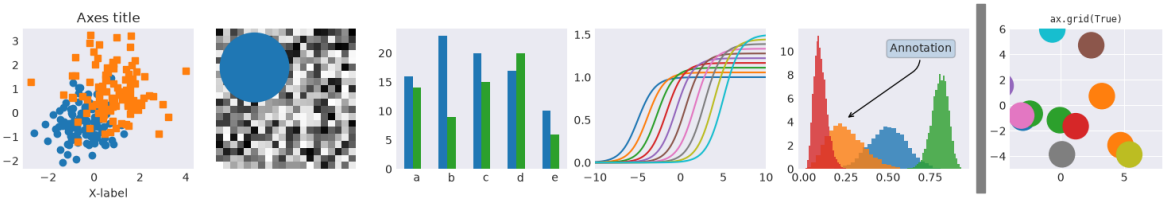
- seaborn-v0_8-bright



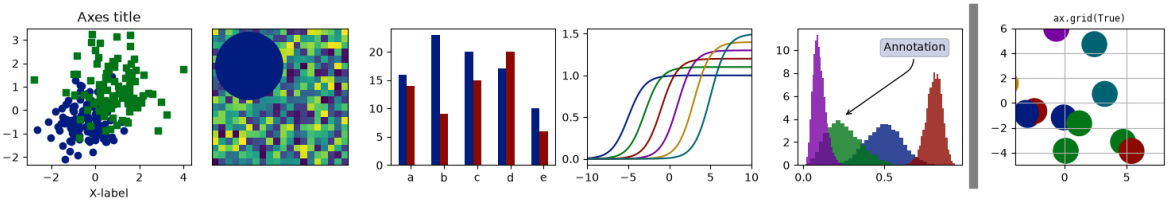
- seaborn-v0_8-colorblind



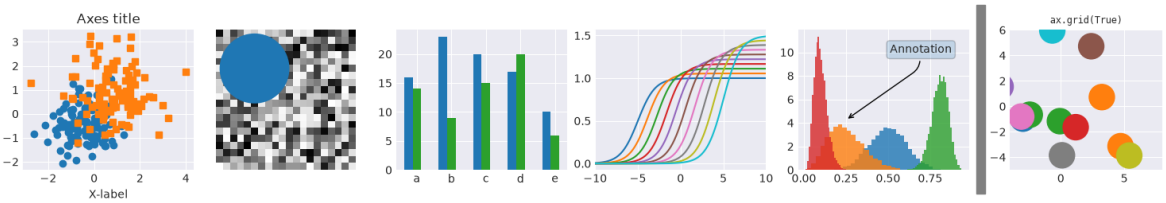
- seaborn-v0_8-dark



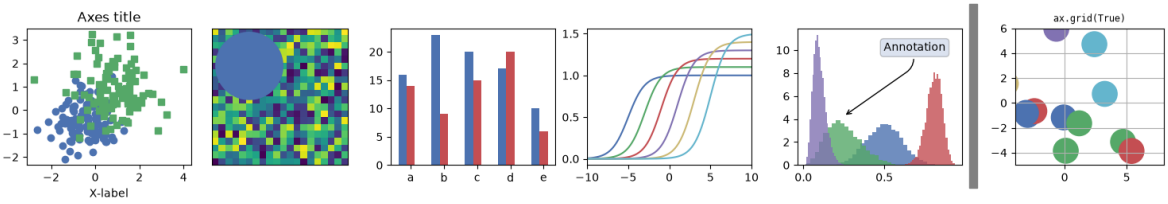
- seaborn-v0_8-dark-palette



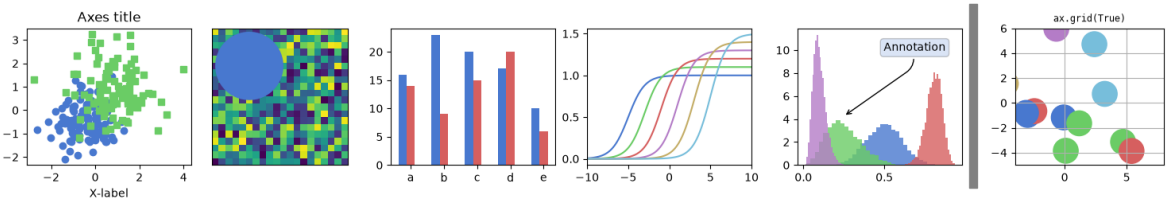
- seaborn-v0_8-darkgrid



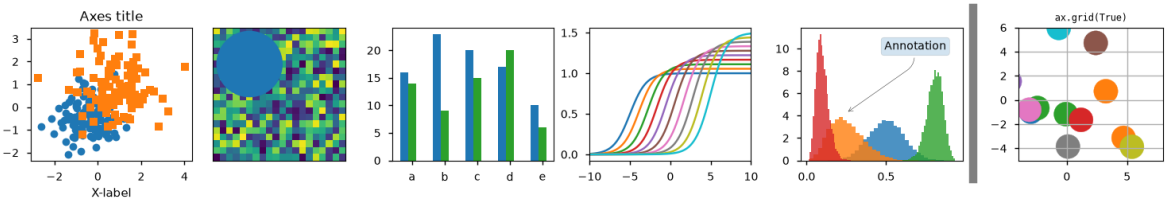
- seaborn-v0_8-deep



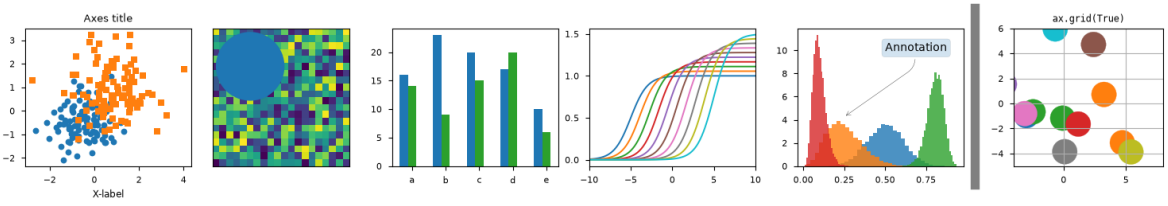
- seaborn-v0_8-muted



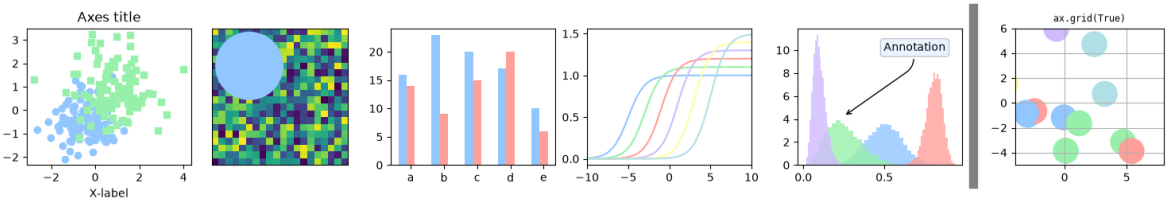
- seaborn-v0_8-notebook



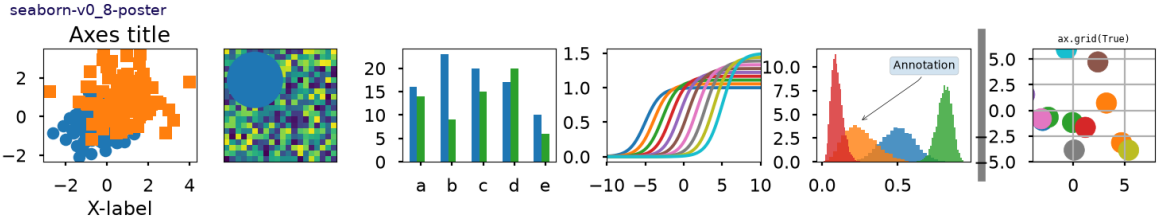
- seaborn-v0_8-paper



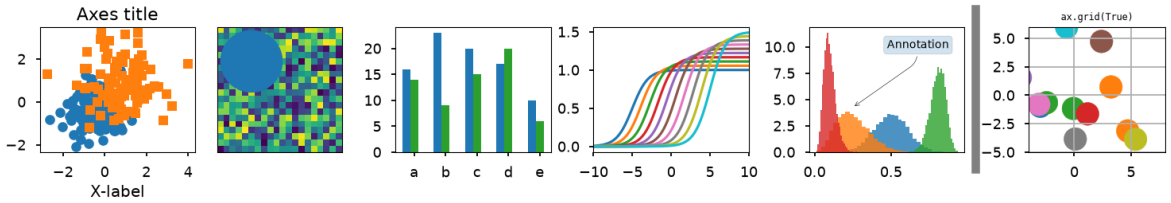
- seaborn-v0_8-pastel



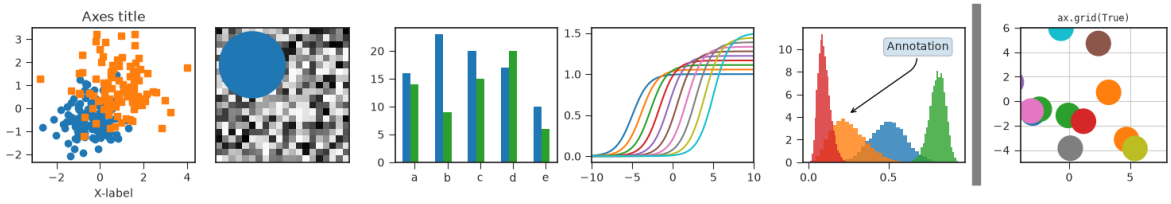
- seaborn-v0_8-poster



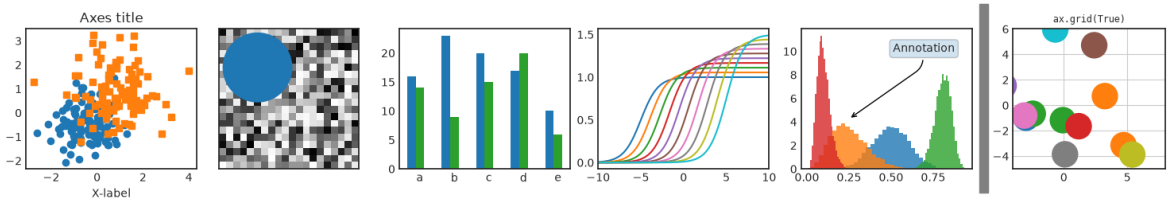
- seaborn-v0_8-talk



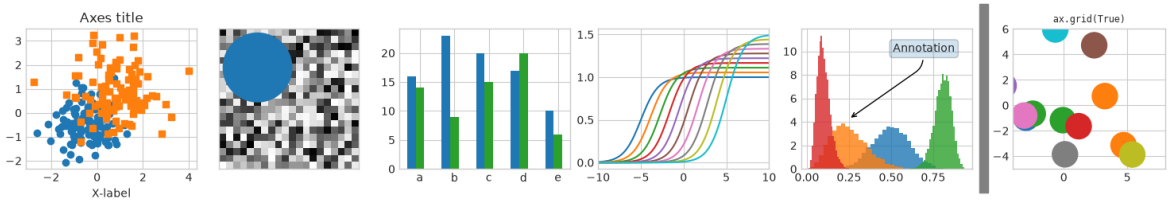
- seaborn-v0_8-ticks



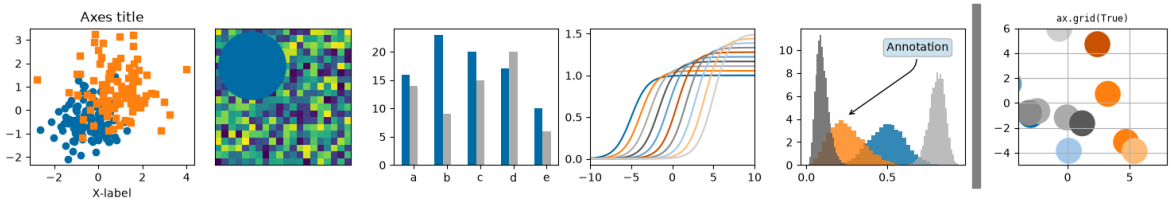
- seaborn-v0_8-white



- seaborn-v0_8-whitegrid



- tableau-colorblind10




```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.colors as mcolors
from matplotlib.patches import Rectangle

# Fixing random state for reproducibility
np.random.seed(19680801)


def plot_scatter(ax, prng, nb_samples=100):
    """Scatter plot."""
    for mu, sigma, marker in [(-.5, 0.75, 'o'), (0.75, 1., 's')]:
```

(continues on next page)

(continued from previous page)

```
        x, y = prng.normal(loc=mu, scale=sigma, size=(2, nb_samples))
        ax.plot(x, y, ls='none', marker=marker)
    ax.set_xlabel('X-label')
    ax.set_title('Axes title')
    return ax


def plot_colored_lines(ax):
    """Plot lines with colors following the style color cycle."""
    t = np.linspace(-10, 10, 100)

    def sigmoid(t, t0):
        return 1 / (1 + np.exp(-(t - t0)))

    nb_colors = len(plt.rcParams['axes.prop_cycle'])
    shifts = np.linspace(-5, 5, nb_colors)
    amplitudes = np.linspace(1, 1.5, nb_colors)
    for t0, a in zip(shifts, amplitudes):
        ax.plot(t, a * sigmoid(t, t0), '-')
    ax.set_xlim(-10, 10)
    return ax


def plot_bar_graphs(ax, prng, min_value=5, max_value=25, nb_samples=5):
    """Plot two bar graphs side by side, with letters as x-tick␣
 ↪labels."""
    x = np.arange(nb_samples)
    ya, yb = prng.randint(min_value, max_value, size=(2, nb_samples))
    width = 0.25
    ax.bar(x, ya, width)
    ax.bar(x + width, yb, width, color='C2')
    ax.set_xticks(x + width, labels=['a', 'b', 'c', 'd', 'e'])
    return ax


def plot_colored_circles(ax, prng, nb_samples=15):
    """
    Plot circle patches.

    NB: draws a fixed amount of samples, rather than using the length␣
 ↪of
    the color cycle, because different styles may have different␣
 ↪numbers
    of colors.
    """
    for sty_dict, j in zip(plt.rcParams['axes.prop_cycle'](),
```

(continues on next page)

(continued from previous page)

```
                                range(nb_samples)):
        ax.add_patch(plt.Circle(prng.normal(scale=3, size=2),
                                radius=1.0, color=sty_dict['color']))
    ax.grid(visible=True)

    # Add title for enabling grid
    plt.title('ax.grid(True)', family='monospace', fontsize='small')

    ax.set_xlim([-4, 8])
    ax.set_ylim([-5, 6])
    ax.set_aspect('equal', adjustable='box')  # to plot circles as␣
 ↪circles
    return ax


def plot_image_and_patch(ax, prng, size=(20, 20)):
    """Plot an image with random values and superimpose a circular␣
 ↪patch."""
    values = prng.random_sample(size=size)
    ax.imshow(values, interpolation='none')
    c = plt.Circle((5, 5), radius=5, label='patch')
    ax.add_patch(c)
    # Remove ticks
    ax.set_xticks([])
    ax.set_yticks([])


def plot_histograms(ax, prng, nb_samples=10000):
    """Plot 4 histograms and a text annotation."""
    params = ((10, 10), (4, 12), (50, 12), (6, 55))
    for a, b in params:
        values = prng.beta(a, b, size=nb_samples)
        ax.hist(values, histtype="stepfilled", bins=30,
                alpha=0.8, density=True)

    # Add a small annotation.
    ax.annotate('Annotation', xy=(0.25, 4.25),
                xytext=(0.9, 0.9), textcoords=ax.transAxes,
                va="top", ha="right",
                bbox=dict(boxstyle="round", alpha=0.2),
                arrowprops=dict(
                          arrowstyle="->",
                          connectionstyle=
 ↪"angle,angleA=-95,angleB=35,rad=10"),
                )
    return ax
```

(continues on next page)

(continued from previous page)

```
def plot_figure(style_label=""):
    """Setup and plot the demonstration figure with a given style."""
    # Use a dedicated RandomState instance to draw the same "random"␣
 ↪values
    # across the different figures.
    prng = np.random.RandomState(96917002)

    fig, axs = plt.subplots(ncols=6, nrows=1, num=style_label,
                            figsize=(14.8, 2.8), layout='constrained')

    # make a suptitle, in the same style for all subfigures,
    # except those with dark backgrounds, which get a lighter color:
    background_color = mcolors.rgb_to_hsv(
        mcolors.to_rgb(plt.rcParams['figure.facecolor']))[2]
    if background_color < 0.5:
        title_color = [0.8, 0.8, 1]
    else:
        title_color = np.array([19, 6, 84]) / 256
    fig.suptitle(style_label, x=0.01, ha='left', color=title_color,
                 fontsize=14, fontfamily='DejaVu Sans', fontweight=
 ↪'normal')

    plot_scatter(axs[0], prng)
    plot_image_and_patch(axs[1], prng)
    plot_bar_graphs(axs[2], prng)
    plot_colored_lines(axs[3])
    plot_histograms(axs[4], prng)
    plot_colored_circles(axs[5], prng)

    # add divider
    rec = Rectangle((1 + 0.025, -2), 0.05, 16,
                    clip_on=False, color='gray')

    axs[4].add_artist(rec)

if __name__ == "__main__":

    # Set up a list of all available styles, in alphabetical order but
    # the `default` and `classic` ones, which will be forced resp. in
    # first and second position.
    # styles with leading underscores are for internal use such as␣
 ↪testing
    # and plot types gallery. These are excluded here.
    style_list = ['default', 'classic'] + sorted(
```

(continues on next page)

(continued from previous page)

```
        style for style in plt.style.available
        if style != 'classic' and not style.startswith('_'))

    # Plot a demonstration figure for every available style sheet.
    for style_label in style_list:
        with plt.rc_context({"figure.max_open_warning":␣
↪len(style_list)}):
            with plt.style.context(style_label):
                plot_figure(style_label=style_label)

    plt.show()
```

Total running time of the script: (0 minutes 18.508 seconds)

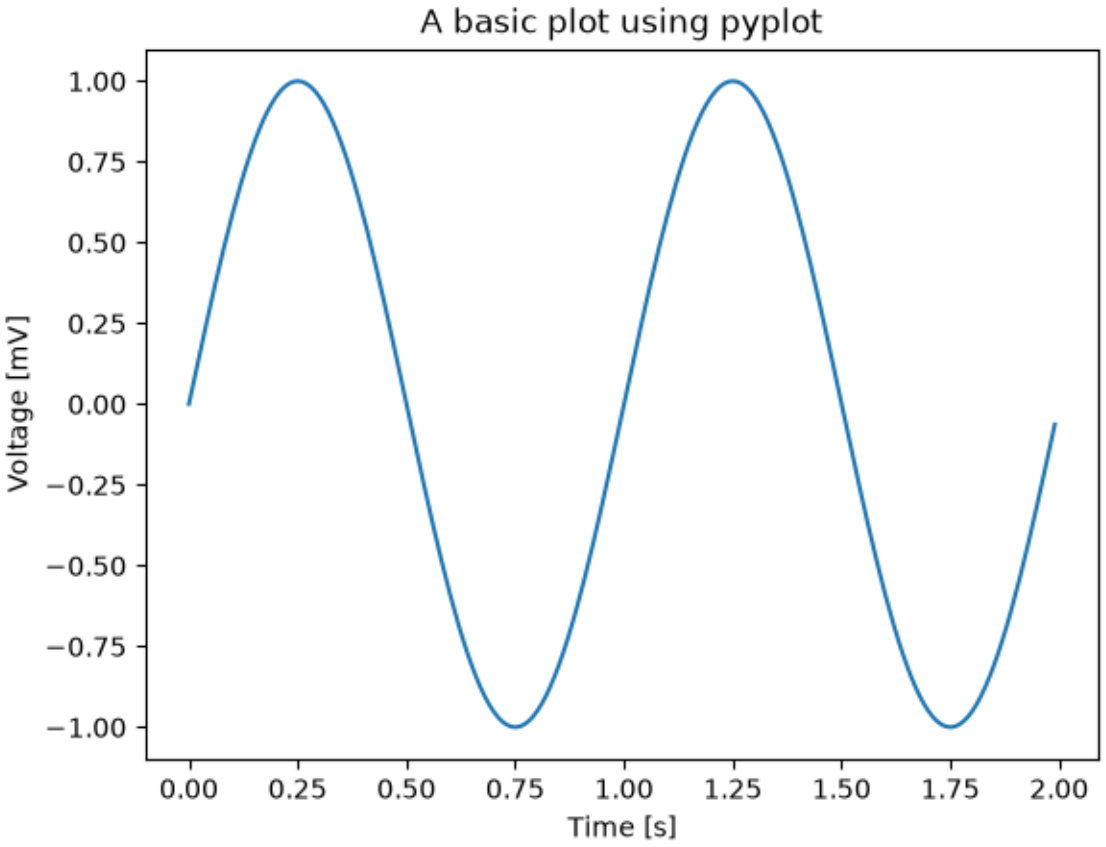
6.24.13 Module - pyplot

Basic plot

A basic plot using the *The implicit "pyplot" interface*.

- *plot* plots the data y versus x as lines and/or markers.
- *title*, *xlabel* and *ylabel* set the title, x-axis label and y-axis label.
- *show* displays the plot.

```
import matplotlib.pyplot as plt
import numpy as np

x = np.arange(0.0, 2.0, 0.01)
y = np.sin(2 * np.pi * x)

plt.plot(x, y)
plt.title("A basic plot using pyplot")
plt.xlabel('Time [s]')
plt.ylabel('Voltage [mV]')
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.pyplot.plot*
- *matplotlib.pyplot.title*
- *matplotlib.pyplot.ylabel*
- *matplotlib.pyplot.ylabel*
- *matplotlib.pyplot.show*

Two subplots using pyplot

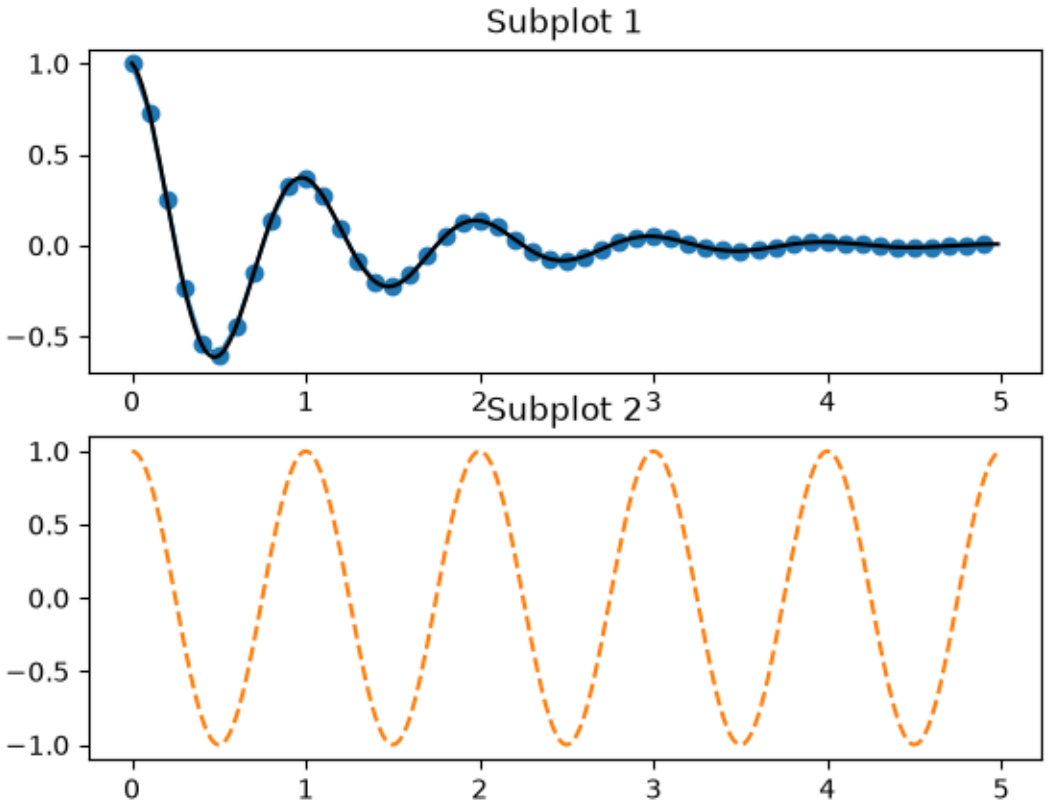
A typical pyplot usage pattern is to create subplots incrementally through *subplot*.

The three-digit number passed to *subplot* specifies the position of the subplot in the grid of subplots. `211` means "in a grid of 2 rows and 1 column, create this subplot in the 1st position". `212` likewise means "in a grid of 2 rows and 1 column, create this subplot in the 2nd position".

After calling `subplot()` all following pyplot commands will modify that subplot until a new subplot is

created.

```
import matplotlib.pyplot as plt
import numpy as np


def f(t):
    return np.exp(-t) * np.cos(2*np.pi*t)


t1 = np.arange(0.0, 5.0, 0.1)
t2 = np.arange(0.0, 5.0, 0.02)

plt.figure()
plt.subplot(211)
plt.plot(t1, f(t1), color='tab:blue', marker='o')
plt.plot(t2, f(t2), color='black')
plt.title("Subplot 1")

plt.subplot(212)
plt.plot(t2, np.cos(2*np.pi*t2), color='tab:orange', linestyle='--')
plt.title("Subplot 2")
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.pyplot.figure*
- *matplotlib.pyplot.subplot*

6.24.14 3D plotting

Plot 2D data on 3D plot

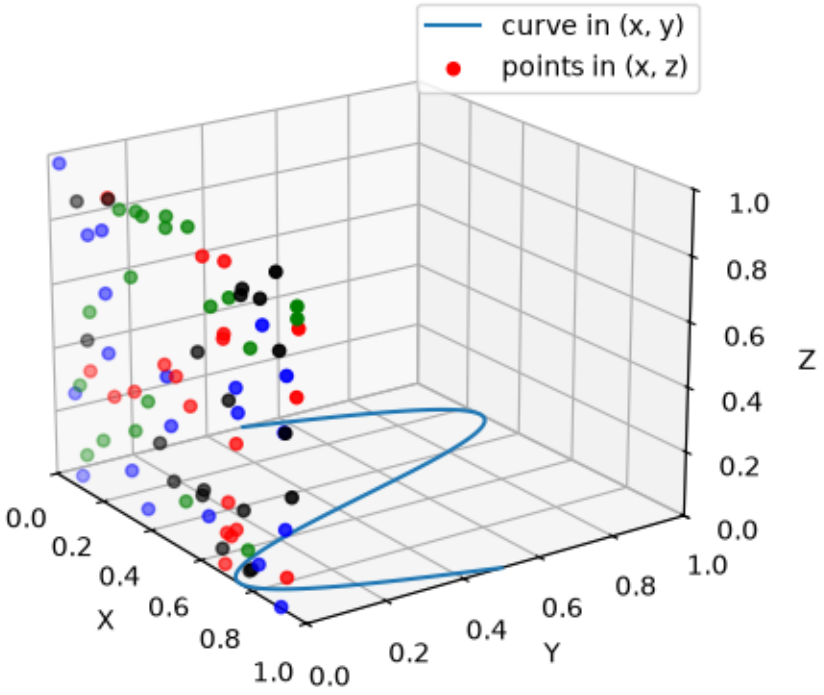
Demonstrates using ax.plot's *zdir* keyword to plot 2D data on selective axes of a 3D plot.

```
import matplotlib.pyplot as plt
import numpy as np

ax = plt.figure().add_subplot(projection='3d')

# Plot a sin curve using the x and y axes.
x = np.linspace(0, 1, 100)
```

(continues on next page)

(continued from previous page)

```
y = np.sin(x * 2 * np.pi) / 2 + 0.5
ax.plot(x, y, zs=0, zdir='z', label='curve in (x, y)')

# Plot scatterplot data (20 2D points per colour) on the x and z axes.
colors = ('r', 'g', 'b', 'k')

# Fixing random state for reproducibility
np.random.seed(19680801)

x = np.random.sample(20 * len(colors))
y = np.random.sample(20 * len(colors))
c_list = []
for c in colors:
    c_list.extend([c] * 20)
# By using zdir='y', the y value of these points is fixed to the zs␣
 ↪value 0
# and the (x, y) points are plotted on the x and z axes.
ax.scatter(x, y, zs=0, zdir='y', c=c_list, label='points in (x, z)')

# Make legend, set axes limits and labels
ax.legend()
ax.set_xlim(0, 1)
ax.set_ylim(0, 1)
ax.set_zlim(0, 1)
ax.set_xlabel('X')
ax.set_ylabel('Y')
ax.set_zlabel('Z')

# Customize the view angle so it's easier to see that the scatter␣
 ↪points lie
# on the plane y=0
ax.view_init(elev=20., azim=-35, roll=0)

plt.show()
```



Tags: plot-type: 3D plot-type: scatter plot-type: line component: axes level: intermediate

Demo of 3D bar charts

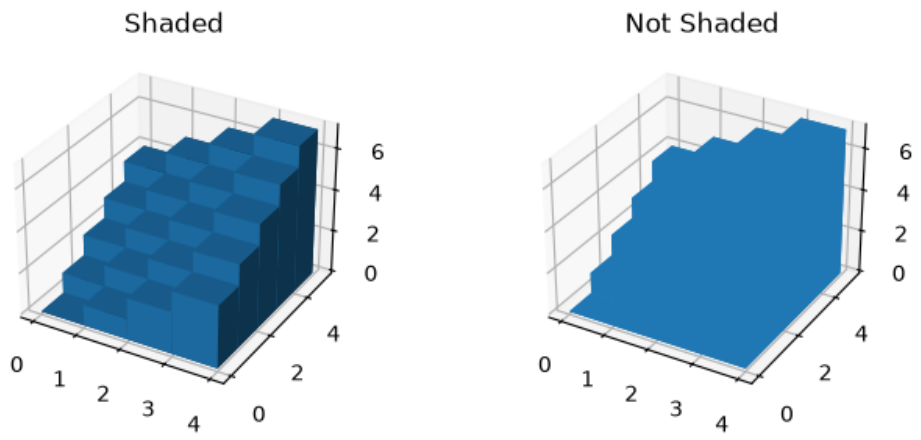
A basic demo of how to plot 3D bars with and without shading.

```
import matplotlib.pyplot as plt
import numpy as np

# set up the figure and Axes
fig = plt.figure(figsize=(8, 3))
ax1 = fig.add_subplot(121, projection='3d')
ax2 = fig.add_subplot(122, projection='3d')

# fake data
_x = np.arange(4)
_y = np.arange(5)
_xx, _yy = np.meshgrid(_x, _y)
x, y = _xx.ravel(), _yy.ravel()

top = x + y
```

(continues on next page)

(continued from previous page)

```
bottom = np.zeros_like(top)
width = depth = 1

ax1.bar3d(x, y, bottom, width, depth, top, shade=True)
ax1.set_title('Shaded')

ax2.bar3d(x, y, bottom, width, depth, top, shade=False)
ax2.set_title('Not Shaded')

plt.show()
```



Tags: plot-type: 3D styling: texture plot-type: bar level: beginner

Clip the data to the axes view limits

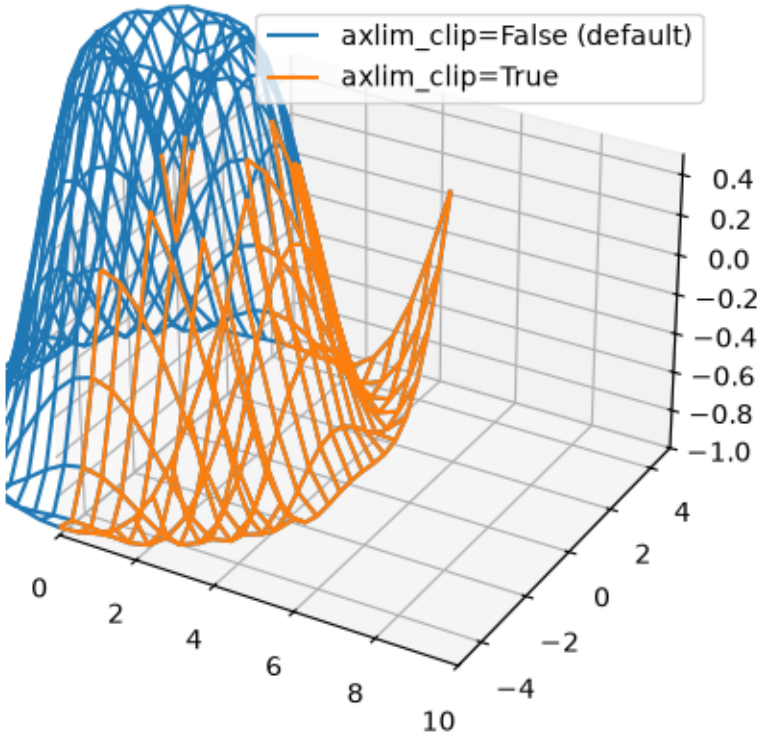
Demonstrate clipping of line and marker data to the axes view limits. The `axlim_clip` keyword argument can be used in any of the 3D plotting functions.

```
import matplotlib.pyplot as plt
import numpy as np

fig, ax = plt.subplots(subplot_kw={"projection": "3d"})

# Make the data
x = np.arange(-5, 5, 0.5)
y = np.arange(-5, 5, 0.5)
X, Y = np.meshgrid(x, y)
R = np.sqrt(X**2 + Y**2)
Z = np.sin(R)

# Default behavior is axlim_clip=False
ax.plot_wireframe(X, Y, Z, color='C0')
```

(continues on next page)

(continued from previous page)

```
# When axlim_clip=True, note that when a line segment has one vertex␣
 ↪outside
# the view limits, the entire line is hidden. The same is true for 3D␣
 ↪patches
# if one of their vertices is outside the limits (not shown).
ax.plot_wireframe(X, Y, Z, color='C1', axlim_clip=True)

# In this example, data where x < 0 or z > 0.5 is clipped
ax.set(xlim=(0, 10), ylim=(-5, 5), zlim=(-1, 0.5))
ax.legend(['axlim_clip=False (default)', 'axlim_clip=True'])

plt.show()
```

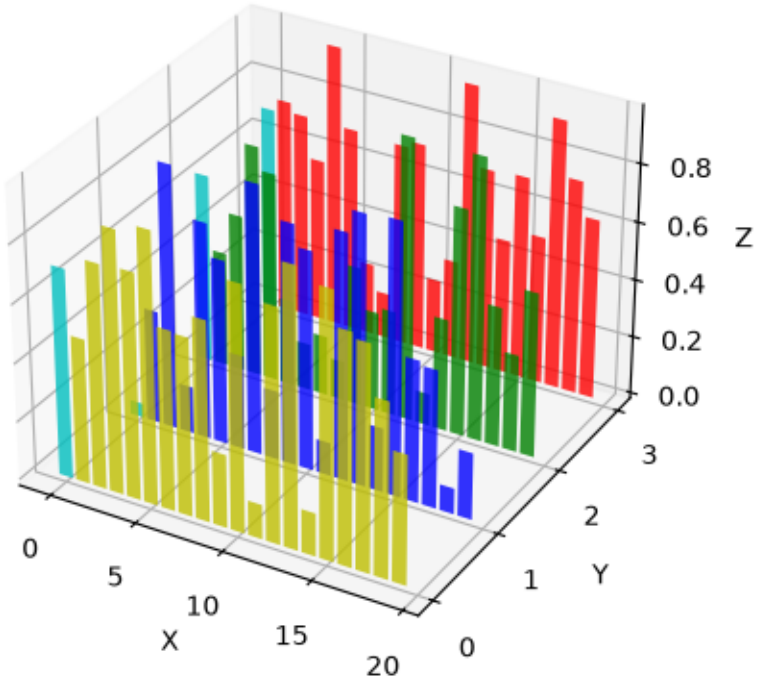


Tags: plot-type: 3D level: beginner

Create 2D bar graphs in different planes

Demonstrates making a 3D plot which has 2D bar graphs projected onto planes y=0, y=1, etc.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)


fig = plt.figure()
ax = fig.add_subplot(projection='3d')

colors = ['r', 'g', 'b', 'y']
yticks = [3, 2, 1, 0]
for c, k in zip(colors, yticks):
    # Generate the random data for the y=k 'layer'.
    xs = np.arange(20)
    ys = np.random.rand(20)

    # You can provide either a single color or an array with the same␣
 ↪length as
    # xs and ys. To demonstrate this, we color the first bar of each␣
 ↪set cyan.
    cs = [c] * len(xs)
    cs[0] = 'c'

    # Plot the bar graph given by xs and ys on the plane y=k with 80%␣
 ↪opacity.
    ax.bar(xs, ys, zs=k, zdir='y', color=cs, alpha=0.8)

ax.set_xlabel('X')
ax.set_ylabel('Y')
ax.set_zlabel('Z')

# On the y-axis let's only label the discrete values that we have data␣
 ↪for.
ax.set_yticks(yticks)

plt.show()
```



Tags: plot-type: 3D plot-type: bar styling: color level: beginner

3D box surface plot

Given data on a gridded volume `X`, `Y`, `Z`, this example plots the data values on the volume surfaces.

The strategy is to select the data from each surface and plot contours separately using *`axes3d.Axes3D.contourf`* with appropriate parameters *zdir* and *offset*.

```
import matplotlib.pyplot as plt
import numpy as np

# Define dimensions
Nx, Ny, Nz = 100, 300, 500
X, Y, Z = np.meshgrid(np.arange(Nx), np.arange(Ny), -np.arange(Nz))

# Create fake data
data = (((X+100)**2 + (Y-20)**2 + 2*Z)/1000+1)

kw = {
    'vmin': data.min(),
    'vmax': data.max(),
```

(continues on next page)

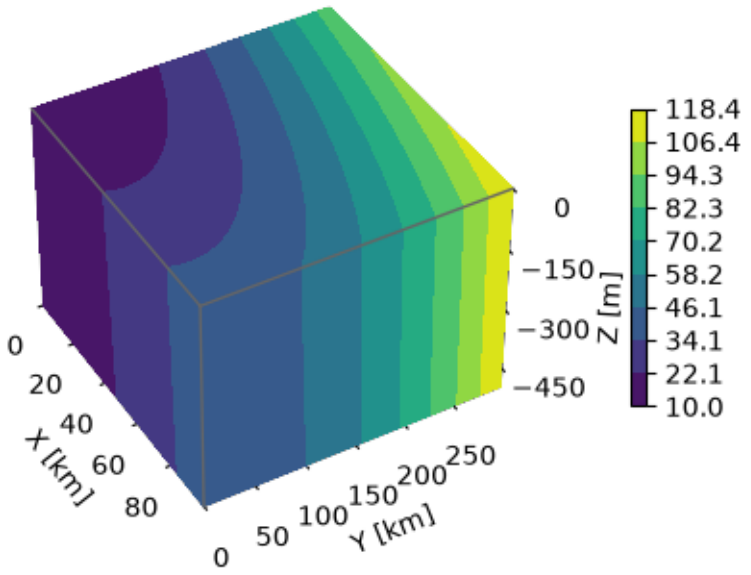
(continued from previous page)

```
    'levels': np.linspace(data.min(), data.max(), 10),
}

# Create a figure with 3D ax
fig = plt.figure(figsize=(5, 4))
ax = fig.add_subplot(111, projection='3d')

# Plot contour surfaces
_ = ax.contourf(
    X[:, :, 0], Y[:, :, 0], data[:, :, 0],
    zdir='z', offset=0, **kw
)
_ = ax.contourf(
    X[0, :, :], data[0, :, :], Z[0, :, :],
    zdir='y', offset=0, **kw
)
C = ax.contourf(
    data[:, -1, :], Y[:, -1, :], Z[:, -1, :],
    zdir='x', offset=X.max(), **kw
)
# --


# Set limits of the plot from coord limits
xmin, xmax = X.min(), X.max()
ymin, ymax = Y.min(), Y.max()
zmin, zmax = Z.min(), Z.max()
ax.set(xlim=(xmin, xmax), ylim=(ymin, ymax), zlim=(zmin, zmax))

# Plot edges
edges_kw = dict(color='0.4', linewidth=1, zorder=1e3)
ax.plot([xmax, xmax], [ymin, ymax], 0, **edges_kw)
ax.plot([xmin, xmax], [ymin, ymin], 0, **edges_kw)
ax.plot([xmax, xmax], [ymin, ymin], [zmin, zmax], **edges_kw)

# Set labels and zticks
ax.set(
    xlabel='X [km]',
    ylabel='Y [km]',
    zlabel='Z [m]',
    zticks=[0, -150, -300, -450],
)

# Set zoom and angle view
ax.view_init(40, -30, 0)
ax.set_box_aspect(None, zoom=0.9)
```

(continues on next page)

(continued from previous page)

```
# Colorbar
fig.colorbar(C, ax=ax, fraction=0.02, pad=0.1, label='Name [units]')

# Show Figure
plt.show()
```



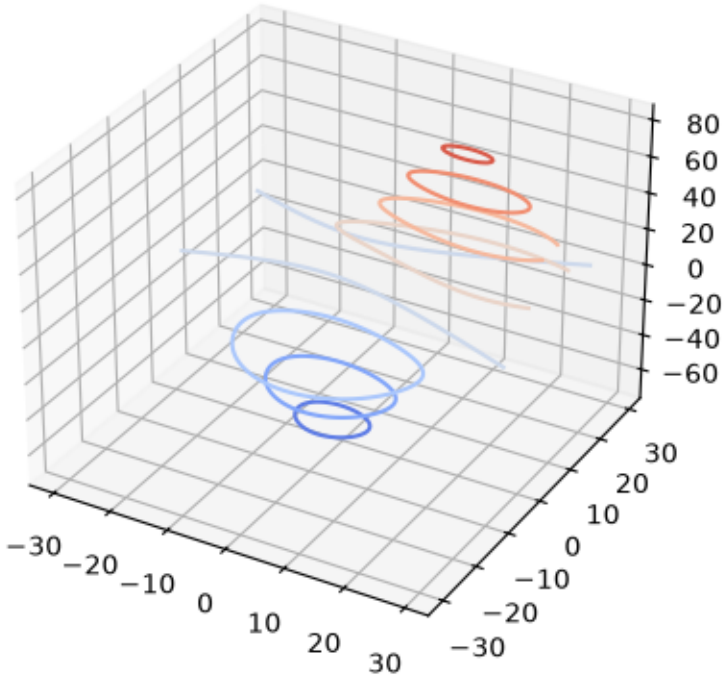
Tags: plot-type: 3D level: intermediate

Total running time of the script: (0 minutes 2.918 seconds)

Plot contour (level) curves in 3D

This is like a contour plot in 2D except that the `f(x, y)=c` curve is plotted on the plane `z=c`.

```
import matplotlib.pyplot as plt

from mpl_toolkits.mplot3d import axes3d

ax = plt.figure().add_subplot(projection='3d')
X, Y, Z = axes3d.get_test_data(0.05)

ax.contour(X, Y, Z, cmap="coolwarm")  # Plot contour curves

plt.show()
```

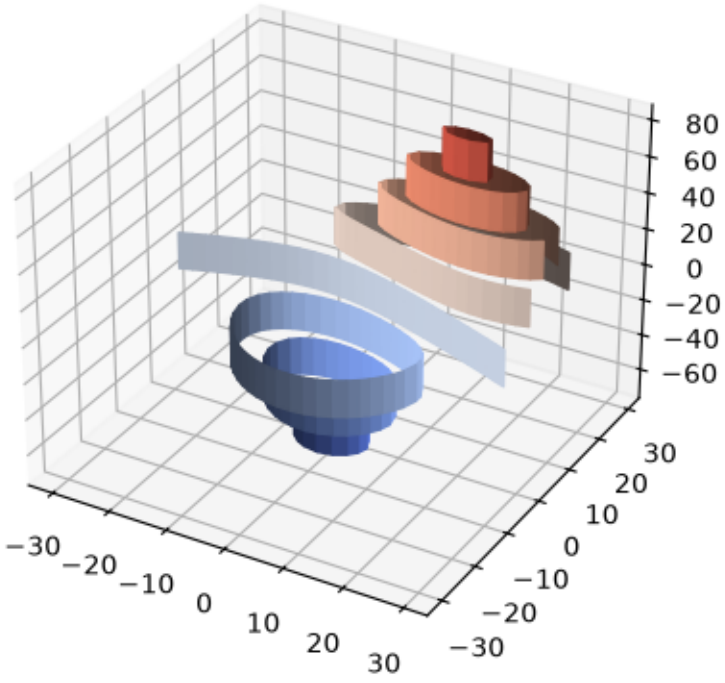


Tags: plot-type: 3D level: beginner

Plot contour (level) curves in 3D using the extend3d option

This modification of the *Plot contour (level) curves in 3D* example uses `extend3d=True` to extend the curves vertically into 'ribbons'.

```
import matplotlib.pyplot as plt

from mpl_toolkits.mplot3d import axes3d

ax = plt.figure().add_subplot(projection='3d')
X, Y, Z = axes3d.get_test_data(0.05)
ax.contour(X, Y, Z, extend3d=True, cmap="coolwarm")

plt.show()
```



Tags: plot-type: 3D level: beginner

Project contour profiles onto a graph

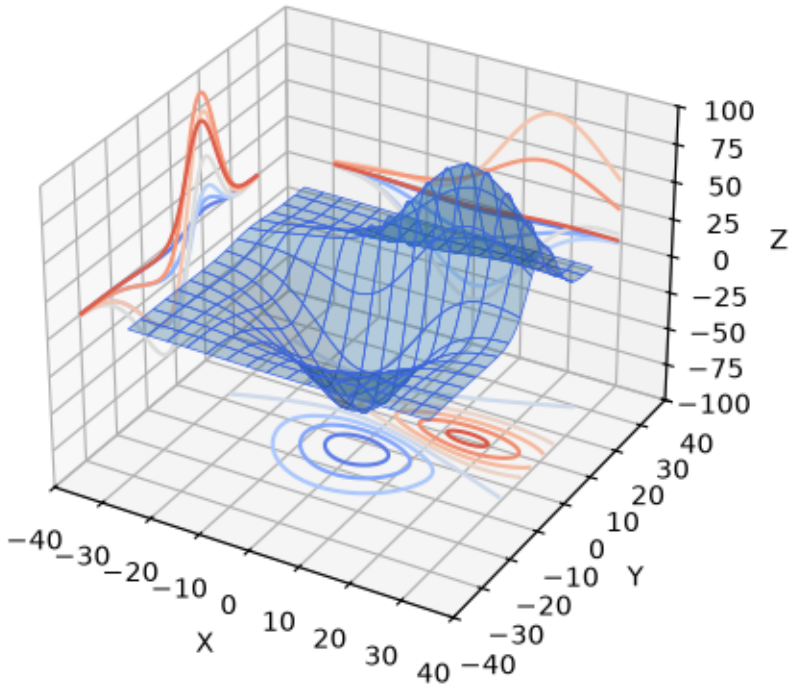
Demonstrates displaying a 3D surface while also projecting contour 'profiles' onto the 'walls' of the graph. See *Project filled contour onto a graph* for the filled version.

```
import matplotlib.pyplot as plt

from mpl_toolkits.mplot3d import axes3d

ax = plt.figure().add_subplot(projection='3d')
X, Y, Z = axes3d.get_test_data(0.05)

# Plot the 3D surface
ax.plot_surface(X, Y, Z, edgecolor='royalblue', lw=0.5, rstride=8,␣
 ↪cstride=8,
                alpha=0.3)

# Plot projections of the contours for each dimension.  By choosing␣
 ↪offsets
```

(continues on next page)

(continued from previous page)

```
# that match the appropriate axes limits, the projected contours will␣
 ↪sit on
# the 'walls' of the graph.
ax.contour(X, Y, Z, zdir='z', offset=-100, cmap='coolwarm')
ax.contour(X, Y, Z, zdir='x', offset=-40, cmap='coolwarm')
ax.contour(X, Y, Z, zdir='y', offset=40, cmap='coolwarm')

ax.set(xlim=(-40, 40), ylim=(-40, 40), zlim=(-100, 100),
       xlabel='X', ylabel='Y', zlabel='Z')

plt.show()
```



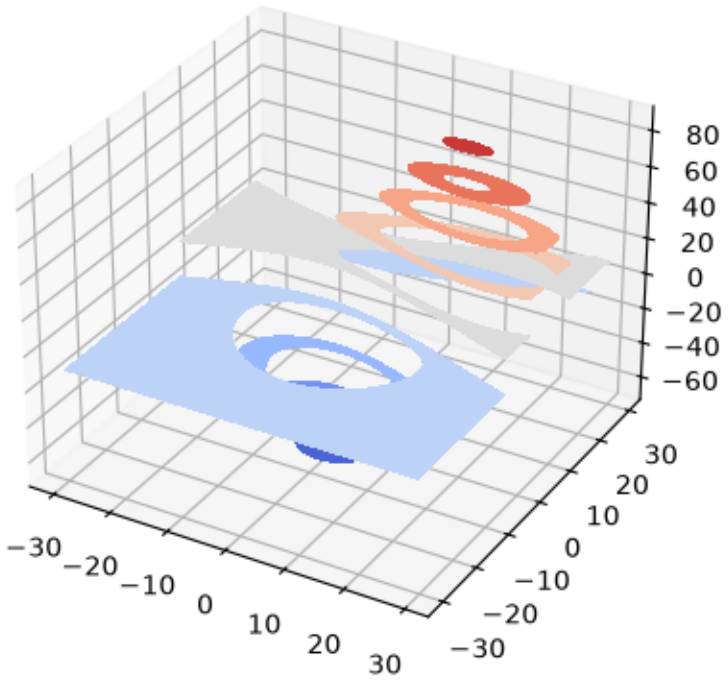
Tags: plot-type: 3D component: axes level: intermediate

Filled contours

Axes3D.contourf differs from *Axes3D.contour* in that it creates filled contours, i.e. a discrete number of colours are used to shade the domain.

This is like a *Axes.contourf* plot in 2D except that the shaded region corresponding to the level c is graphed on the plane `z=c`.

```
import matplotlib.pyplot as plt

from mpl_toolkits.mplot3d import axes3d

ax = plt.figure().add_subplot(projection='3d')
X, Y, Z = axes3d.get_test_data(0.05)
ax.contourf(X, Y, Z, cmap="coolwarm")

plt.show()
```



Tags: plot-type: 3D level: beginner

Project filled contour onto a graph

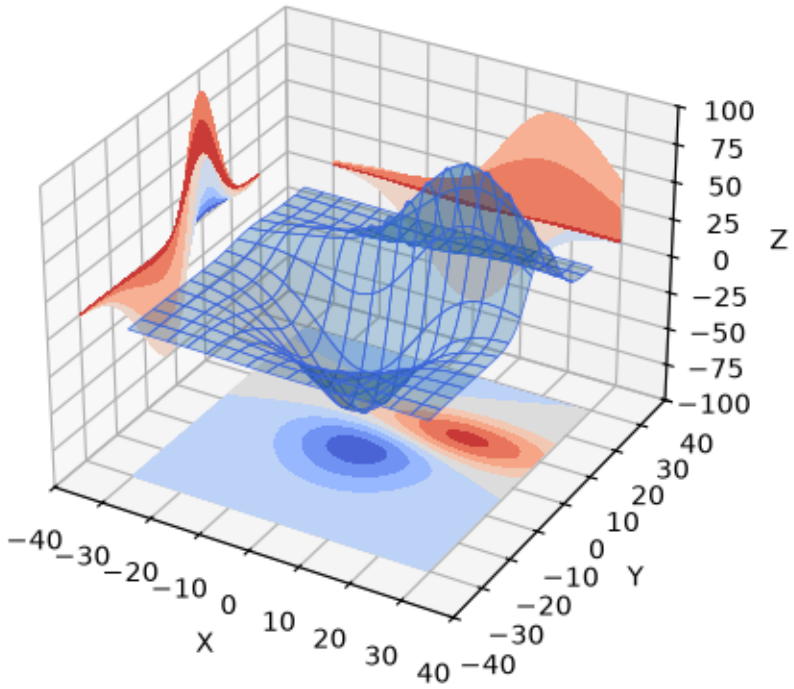
Demonstrates displaying a 3D surface while also projecting filled contour 'profiles' onto the 'walls' of the graph. See *Project contour profiles onto a graph* for the unfilled version.

```
import matplotlib.pyplot as plt

from mpl_toolkits.mplot3d import axes3d

```

(continues on next page)

(continued from previous page)

```
ax = plt.figure().add_subplot(projection='3d')
X, Y, Z = axes3d.get_test_data(0.05)

# Plot the 3D surface
ax.plot_surface(X, Y, Z, edgecolor='royalblue', lw=0.5, rstride=8,␣
 ↪cstride=8,
                alpha=0.3)

# Plot projections of the contours for each dimension.  By choosing␣
 ↪offsets
# that match the appropriate axes limits, the projected contours will␣
 ↪sit on
# the 'walls' of the graph
ax.contourf(X, Y, Z, zdir='z', offset=-100, cmap='coolwarm')
ax.contourf(X, Y, Z, zdir='x', offset=-40, cmap='coolwarm')
ax.contourf(X, Y, Z, zdir='y', offset=40, cmap='coolwarm')

ax.set(xlim=(-40, 40), ylim=(-40, 40), zlim=(-100, 100),
       xlabel='X', ylabel='Y', zlabel='Z')

plt.show()
```



Tags: plot-type: 3D component: axes level: intermediate

Custom hillshading in a 3D surface plot

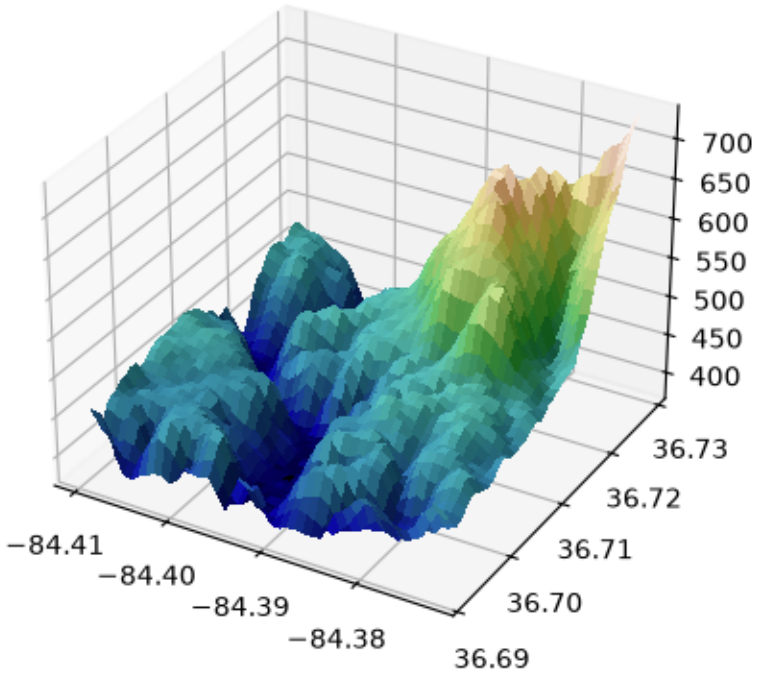
Demonstrates using custom hillshading in a 3D surface plot.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import cbook
from matplotlib.colors import LightSource

# Load and format data
dem = cbook.get_sample_data('jacksboro_fault_dem.npz')
z = dem['elevation']
nrows, ncols = z.shape
x = np.linspace(dem['xmin'], dem['xmax'], ncols)
y = np.linspace(dem['ymin'], dem['ymax'], nrows)
x, y = np.meshgrid(x, y)

region = np.s_[5:50, 5:50]
```

(continues on next page)

(continued from previous page)

```
x, y, z = x[region], y[region], z[region]

# Set up plot
fig, ax = plt.subplots(subplot_kw=dict(projection='3d'))

ls = LightSource(270, 45)
# To use a custom hillshading mode, override the built-in shading and␣
 ↪pass
# in the rgb colors of the shaded surface calculated from "shade".
rgb = ls.shade(z, cmap=plt.colormaps["gist_earth"], vert_exag=0.1,␣
 ↪blend_mode='soft')
surf = ax.plot_surface(x, y, z, rstride=1, cstride=1, facecolors=rgb,
                       linewidth=0, antialiased=False, shade=False)

plt.show()
```

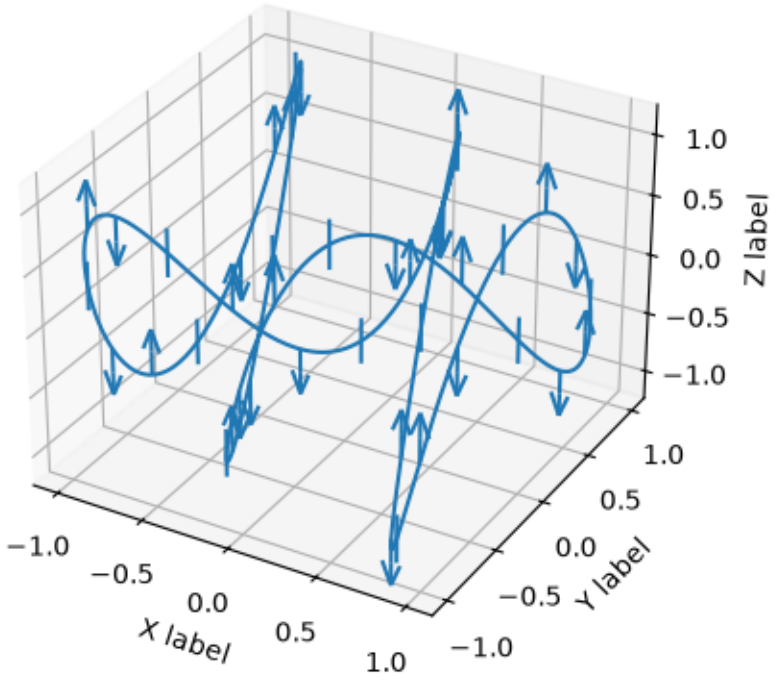


Tags: plot-type: 3D level: intermediate domain: cartography

3D errorbars

An example of using errorbars with upper and lower limits in mplot3d.

```
import matplotlib.pyplot as plt
import numpy as np

ax = plt.figure().add_subplot(projection='3d')

# setting up a parametric curve
t = np.arange(0, 2*np.pi+.1, 0.01)
x, y, z = np.sin(t), np.cos(3*t), np.sin(5*t)

estep = 15
i = np.arange(t.size)
zuplims = (i % estep == 0) & (i // estep % 3 == 0)
zlolims = (i % estep == 0) & (i // estep % 3 == 2)

ax.errorbar(x, y, z, 0.2, zuplims=zuplims, zlolims=zlolims,␣
 ↪errorevery=estep)

ax.set_xlabel("X label")
ax.set_ylabel("Y label")
ax.set_zlabel("Z label")

plt.show()
```



Tags: plot-type: 3D component: error level: beginner

Fill between 3D lines

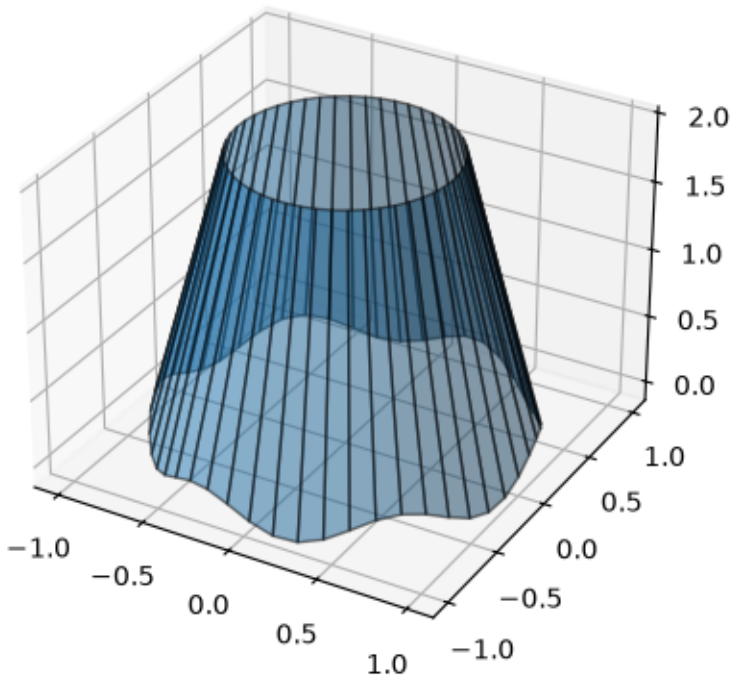
Demonstrate how to fill the space between 3D lines with surfaces. Here we create a sort of "lampshade" shape.

```
import matplotlib.pyplot as plt
import numpy as np

N = 50
theta = np.linspace(0, 2*np.pi, N)

x1 = np.cos(theta)
y1 = np.sin(theta)
z1 = 0.1 * np.sin(6 * theta)

x2 = 0.6 * np.cos(theta)
y2 = 0.6 * np.sin(theta)
z2 = 2  # Note that scalar values work in addition to length N arrays
```

(continues on next page)

(continued from previous page)

```
fig = plt.figure()
ax = fig.add_subplot(projection='3d')
ax.fill_between(x1, y1, z1, x2, y2, z2, alpha=0.5, edgecolor='k')

plt.show()
```



Tags: plot-type: 3D plot-type: fill_between level: beginner

Fill under 3D line graphs

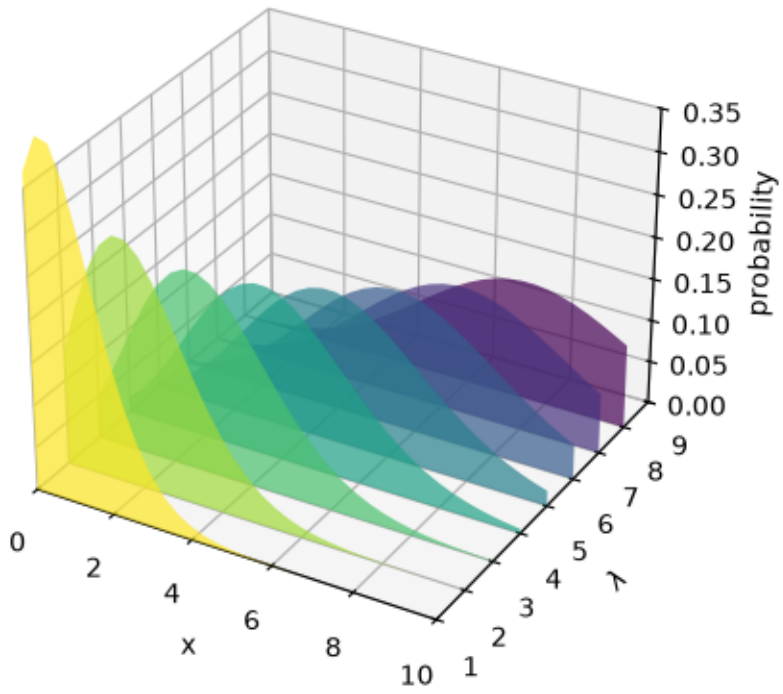
Demonstrate how to create polygons which fill the space under a line graph. In this example polygons are semi-transparent, creating a sort of 'jagged stained glass' effect.

```
import math

import matplotlib.pyplot as plt
import numpy as np

gamma = np.vectorize(math.gamma)
N = 31
```

(continues on next page)

(continued from previous page)

```
x = np.linspace(0., 10., N)
lambdas = range(1, 9)

ax = plt.figure().add_subplot(projection='3d')

facecolors = plt.colormaps['viridis_r'](np.linspace(0, 1,␣
 ↪len(lambdas)))

for i, l in enumerate(lambdas):
    # Note fill_between can take coordinates as length N vectors, or␣
 ↪scalars
    ax.fill_between(x, l, l**x * np.exp(-l) / gamma(x + 1),
                    x, l, 0,
                    facecolors=facecolors[i], alpha=.7)

ax.set(xlim=(0, 10), ylim=(1, 9), zlim=(0, 0.35),
       xlabel='x', ylabel=r'$\lambda$', zlabel='probability')

plt.show()
```

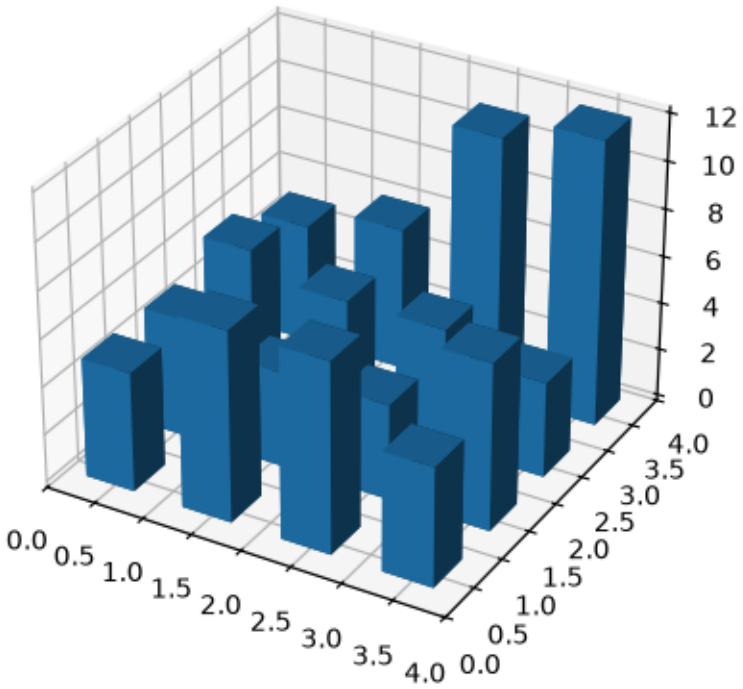


Tags: plot-type: 3D plot-type: fill_between level: beginner

Create 3D histogram of 2D data

Demo of a histogram for 2D data as a bar graph in 3D.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)


fig = plt.figure()
ax = fig.add_subplot(projection='3d')
x, y = np.random.rand(2, 100) * 4
hist, xedges, yedges = np.histogram2d(x, y, bins=4, range=[[0, 4], [0,␣
 ↪4]])

# Construct arrays for the anchor positions of the 16 bars.
xpos, ypos = np.meshgrid(xedges[:-1] + 0.25, yedges[:-1] + 0.25,␣
 ↪indexing="ij")
xpos = xpos.ravel()
ypos = ypos.ravel()
zpos = 0

# Construct arrays with the dimensions for the 16 bars.
dx = dy = 0.5 * np.ones_like(zpos)
dz = hist.ravel()

ax.bar3d(xpos, ypos, zpos, dx, dy, dz, zsort='average')

plt.show()
```



Tags: plot-type: 3D plot-type: histogram level: beginner

2D images in 3D

This example demonstrates how to plot 2D color coded images (similar to *Axes.imshow*) as a plane in 3D.

Matplotlib does not have a native function for this. Below we build one by relying on *Axes3D.plot_surface*. For simplicity, there are some differences to *Axes.imshow*: This function does not set the aspect of the Axes, hence pixels are not necessarily square. Also, pixel edges are on integer values rather than pixel centers. Furthermore, many optional parameters of *Axes.imshow* are not implemented.

Multiple calls of `imshow3d` use independent norms and thus different color scales by default. If you want to have a single common color scale, you need to construct a suitable norm beforehand and pass it to all `imshow3d` calls.

A fundamental limitation of the 3D plotting engine is that intersecting objects cannot be drawn correctly. One object will always be drawn after the other. Therefore, multiple image planes can well be used in the background as shown in this example. But this approach is not suitable if the planes intersect.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

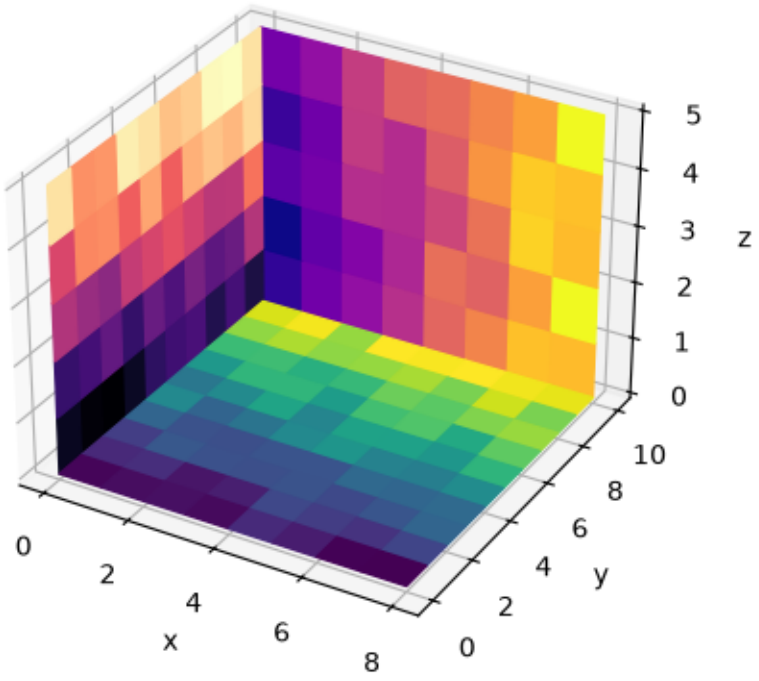
(continued from previous page)

```
from matplotlib.colors import Normalize


def imshow3d(ax, array, value_direction='z', pos=0, norm=None,␣
 ↪cmap=None):
    """
    Display a 2D array as a  color-coded 2D image embedded in 3d.

    The image will be in a plane perpendicular to the coordinate axis␣
 ↪*value_direction*.

    Parameters
    ----------
    ax : Axes3D
        The 3D Axes to plot into.
    array : 2D numpy array
        The image values.
    value_direction : {'x', 'y', 'z'}
        The axis normal to the image plane.
    pos : float
        The numeric value on the *value_direction* axis at which the␣
 ↪image plane is
        located.
    norm : `~matplotlib.colors.Normalize`, default: Normalize
        The normalization method used to scale scalar data. See␣
 ↪`imshow()`.
    cmap : str or `~matplotlib.colors.Colormap`, default:␣
 ↪:rc:`image.cmap`
        The Colormap instance or registered colormap name used to map␣
 ↪scalar data
        to colors.
    """
    if norm is None:
        norm = Normalize()
    colors = plt.get_cmap(cmap)(norm(array))

    if value_direction == 'x':
        nz, ny = array.shape
        zi, yi = np.mgrid[0:nz + 1, 0:ny + 1]
        xi = np.full_like(yi, pos)
    elif value_direction == 'y':
        nx, nz = array.shape
        xi, zi = np.mgrid[0:nx + 1, 0:nz + 1]
        yi = np.full_like(zi, pos)
    elif value_direction == 'z':
        ny, nx = array.shape
```

(continues on next page)

(continued from previous page)

```
        yi, xi = np.mgrid[0:ny + 1, 0:nx + 1]
        zi = np.full_like(xi, pos)
    else:
        raise ValueError(f"Invalid value_direction: {value_direction!r}
 ↪")
    ax.plot_surface(xi, yi, zi, rstride=1, cstride=1,␣
 ↪facecolors=colors, shade=False)


fig = plt.figure()
ax = fig.add_subplot(projection='3d')
ax.set(xlabel="x", ylabel="y", zlabel="z")

nx, ny, nz = 8, 10, 5
data_xy = np.arange(ny * nx).reshape(ny, nx) + 15 * np.random.
 ↪random((ny, nx))
data_yz = np.arange(nz * ny).reshape(nz, ny) + 10 * np.random.
 ↪random((nz, ny))
data_zx = np.arange(nx * nz).reshape(nx, nz) + 8 * np.random.
 ↪random((nx, nz))

imshow3d(ax, data_xy)
imshow3d(ax, data_yz, value_direction='x', cmap='magma')
imshow3d(ax, data_zx, value_direction='y', pos=ny, cmap='plasma')

plt.show()
```



Tags: plot-type: 3D styling: colormap level: advanced

Intersecting planes

This examples demonstrates drawing intersecting planes in 3D. It is a generalization of *2D images in 3D*.

Drawing intersecting planes in `mplot3d` is complicated, because `mplot3d` is not a real 3D renderer, but only projects the Artists into 3D and draws them in the right order. This does not work correctly if Artists overlap each other mutually. In this example, we lift the problem of mutual overlap by segmenting the planes at their intersections, making four parts out of each plane.

This examples only works correctly for planes that cut each other in halves. This limitation is intentional to keep the code more readable. Cutting at arbitrary positions would of course be possible but makes the code even more complex. Thus, this example is more a demonstration of the concept how to work around limitations of the 3D visualization, it's not a refined solution for drawing arbitrary intersecting planes, which you can copy-and-paste as is.

```
import matplotlib.pyplot as plt
import numpy as np


def plot_quadrants(ax, array, fixed_coord, cmap):
```

(continues on next page)

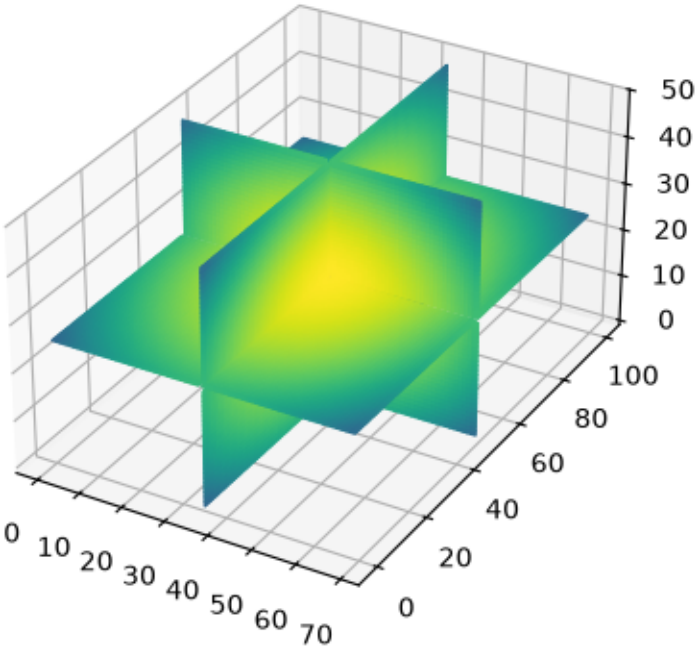
(continued from previous page)

```
    """For a given 3d *array* plot a plane with *fixed_coord*, using␣
↪four quadrants."""
    nx, ny, nz = array.shape
    index = {
        'x': (nx // 2, slice(None), slice(None)),
        'y': (slice(None), ny // 2, slice(None)),
        'z': (slice(None), slice(None), nz // 2),
    }[fixed_coord]
    plane_data = array[index]

    n0, n1 = plane_data.shape
    quadrants = [
        plane_data[:n0 // 2, :n1 // 2],
        plane_data[:n0 // 2, n1 // 2:],
        plane_data[n0 // 2:, :n1 // 2],
        plane_data[n0 // 2:, n1 // 2:]
    ]

    min_val = array.min()
    max_val = array.max()

    cmap = plt.get_cmap(cmap)

    for i, quadrant in enumerate(quadrants):
        facecolors = cmap((quadrant - min_val) / (max_val - min_val))
        if fixed_coord == 'x':
            Y, Z = np.mgrid[0:ny // 2, 0:nz // 2]
            X = nx // 2 * np.ones_like(Y)
            Y_offset = (i // 2) * ny // 2
            Z_offset = (i % 2) * nz // 2
            ax.plot_surface(X, Y + Y_offset, Z + Z_offset, rstride=1,␣
↪cstride=1,
                            facecolors=facecolors, shade=False)
        elif fixed_coord == 'y':
            X, Z = np.mgrid[0:nx // 2, 0:nz // 2]
            Y = ny // 2 * np.ones_like(X)
            X_offset = (i // 2) * nx // 2
            Z_offset = (i % 2) * nz // 2
            ax.plot_surface(X + X_offset, Y, Z + Z_offset, rstride=1,␣
↪cstride=1,
                            facecolors=facecolors, shade=False)
        elif fixed_coord == 'z':
            X, Y = np.mgrid[0:nx // 2, 0:ny // 2]
            Z = nz // 2 * np.ones_like(X)
            X_offset = (i // 2) * nx // 2
            Y_offset = (i % 2) * ny // 2
```

(continues on next page)

(continued from previous page)

```
            ax.plot_surface(X + X_offset, Y + Y_offset, Z, rstride=1,␣
 ↪cstride=1,
                            facecolors=facecolors, shade=False)


def figure_3D_array_slices(array, cmap=None):
    """Plot a 3d array using three intersecting centered planes."""
    fig = plt.figure()
    ax = fig.add_subplot(projection='3d')
    ax.set_box_aspect(array.shape)
    plot_quadrants(ax, array, 'x', cmap=cmap)
    plot_quadrants(ax, array, 'y', cmap=cmap)
    plot_quadrants(ax, array, 'z', cmap=cmap)
    return fig, ax


nx, ny, nz = 70, 100, 50
r_square = (np.mgrid[-1:1:1j * nx, -1:1:1j * ny, -1:1:1j * nz] ** 2).
 ↪sum(0)

figure_3D_array_slices(r_square, cmap='viridis_r')
plt.show()
```



Tags: plot-type: 3D level: advanced

Total running time of the script: (0 minutes 2.031 seconds)

Parametric curve

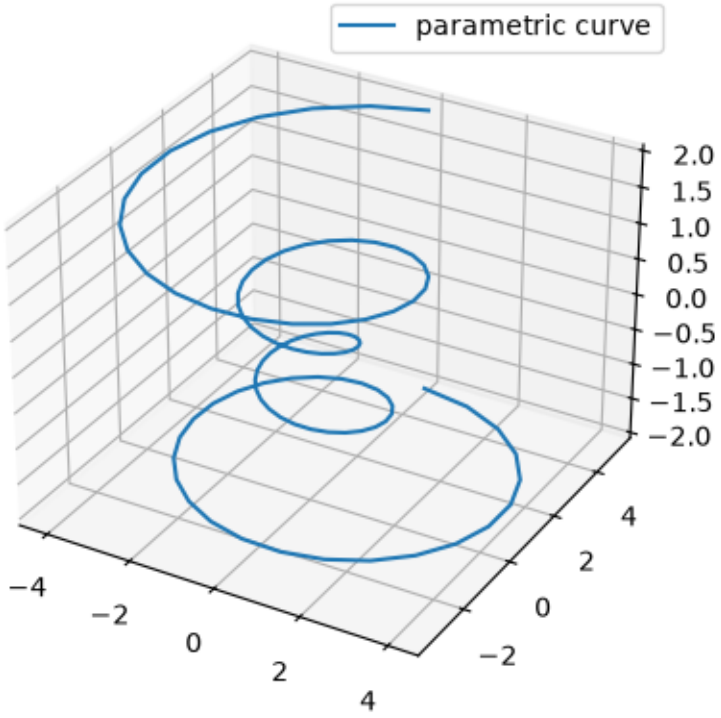
This example demonstrates plotting a parametric curve in 3D.

```
import matplotlib.pyplot as plt
import numpy as np

ax = plt.figure().add_subplot(projection='3d')

# Prepare arrays x, y, z
theta = np.linspace(-4 * np.pi, 4 * np.pi, 100)
z = np.linspace(-2, 2, 100)
r = z**2 + 1
x = r * np.sin(theta)
y = r * np.cos(theta)

ax.plot(x, y, z, label='parametric curve')
ax.legend()
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



Tags: plot-type: 3D level: beginner

Lorenz attractor

This is an example of plotting Edward Lorenz's 1963 "Deterministic Nonperiodic Flow" in a 3-dimensional space using mplot3d.

Note

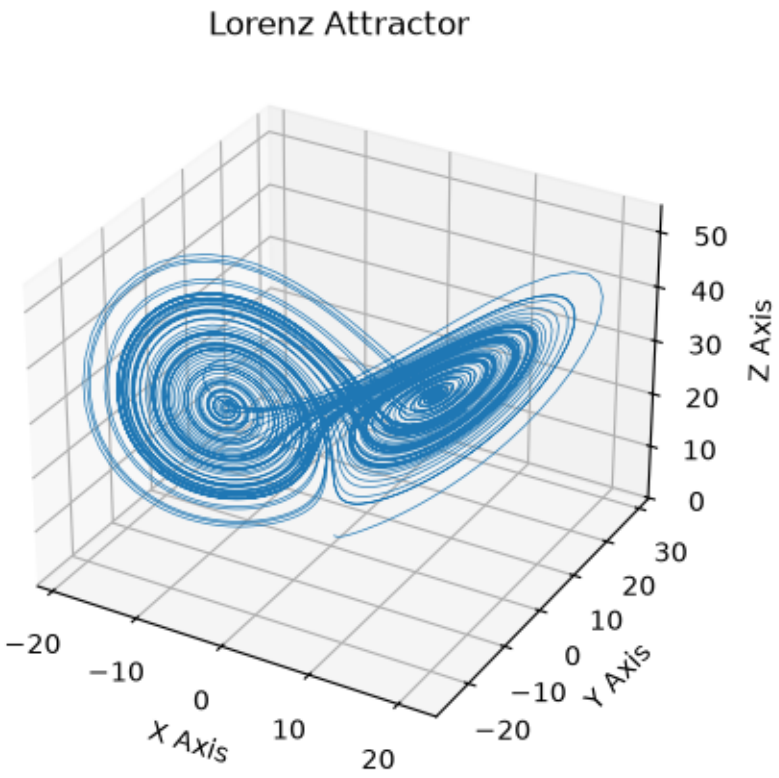
Because this is a simple non-linear ODE, it would be more easily done using SciPy's ODE solver, but this approach depends only upon NumPy.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
def lorenz(xyz, *, s=10, r=28, b=2.667):
    """
    Parameters
    ----------
    xyz : array-like, shape (3,)
       Point of interest in three-dimensional space.
    s, r, b : float
       Parameters defining the Lorenz attractor.

    Returns
    -------
    xyz_dot : array, shape (3,)
       Values of the Lorenz attractor's partial derivatives at *xyz*.
    """
    x, y, z = xyz
    x_dot = s*(y - x)
    y_dot = r*x - y - x*z
    z_dot = x*y - b*z
    return np.array([x_dot, y_dot, z_dot])


dt = 0.01
num_steps = 10000

xyzs = np.empty((num_steps + 1, 3))  # Need one more for the initial␣
 ↪values
xyzs[0] = (0., 1., 1.05)  # Set initial values
# Step through "time", calculating the partial derivatives at the␣
 ↪current point
# and using them to estimate the next point
for i in range(num_steps):
    xyzs[i + 1] = xyzs[i] + lorenz(xyzs[i]) * dt

# Plot
ax = plt.figure().add_subplot(projection='3d')

ax.plot(*xyzs.T, lw=0.5)
ax.set_xlabel("X Axis")
ax.set_ylabel("Y Axis")
ax.set_zlabel("Z Axis")
ax.set_title("Lorenz Attractor")

plt.show()
```



Tags: plot-type: 3D level: intermediate

2D and 3D Axes in same figure

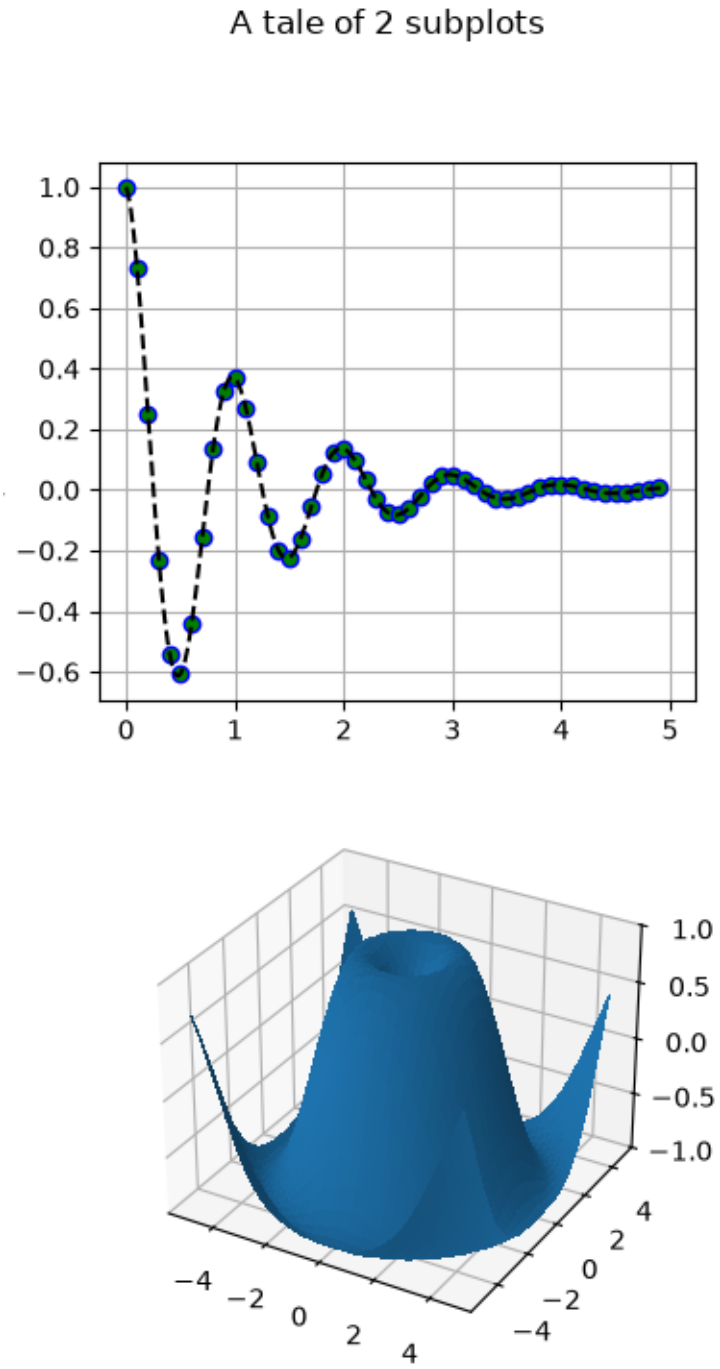
This example shows a how to plot a 2D and a 3D plot on the same figure.

```
import matplotlib.pyplot as plt
import numpy as np


def f(t):
    return np.cos(2*np.pi*t) * np.exp(-t)


# Set up a figure twice as tall as it is wide
fig = plt.figure(figsize=plt.figaspect(2.))
fig.suptitle('A tale of 2 subplots')

# First subplot
ax = fig.add_subplot(2, 1, 1)
```

(continues on next page)

(continued from previous page)

```
t1 = np.arange(0.0, 5.0, 0.1)
t2 = np.arange(0.0, 5.0, 0.02)
t3 = np.arange(0.0, 2.0, 0.01)

ax.plot(t1, f(t1), 'bo',
        t2, f(t2), 'k--', markerfacecolor='green')
ax.grid(True)
ax.set_ylabel('Damped oscillation')

# Second subplot
ax = fig.add_subplot(2, 1, 2, projection='3d')

X = np.arange(-5, 5, 0.25)
Y = np.arange(-5, 5, 0.25)
X, Y = np.meshgrid(X, Y)
R = np.sqrt(X**2 + Y**2)
Z = np.sin(R)

surf = ax.plot_surface(X, Y, Z, rstride=1, cstride=1,
                       linewidth=0, antialiased=False)
ax.set_zlim(-1, 1)

plt.show()
```



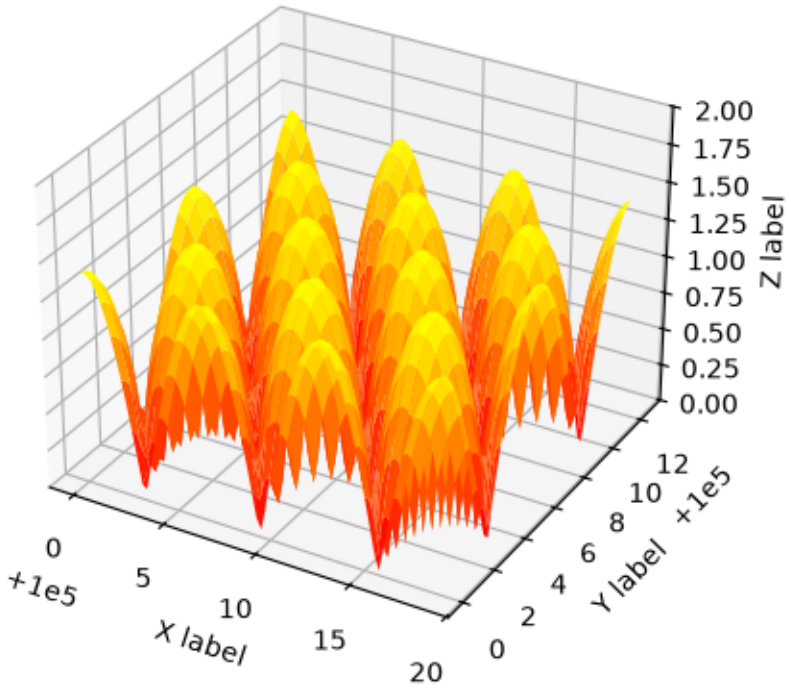
Tags: plot-type: 3D component: subplot level: beginner

Automatic text offsetting

This example demonstrates mplot3d's offset text display. As one rotates the 3D figure, the offsets should remain oriented the same way as the axis label, and should also be located "away" from the center of the plot.

This demo triggers the display of the offset text for the x- and y-axis by adding 1e5 to X and Y. Anything less would not automatically trigger it.

```
import matplotlib.pyplot as plt
import numpy as np

ax = plt.figure().add_subplot(projection='3d')

X, Y = np.mgrid[0:6*np.pi:0.25, 0:4*np.pi:0.25]
Z = np.sqrt(np.abs(np.cos(X) + np.cos(Y)))

ax.plot_surface(X + 1e5, Y + 1e5, Z, cmap='autumn', cstride=2,␣
 ↪rstride=2)

ax.set_xlabel("X label")
ax.set_ylabel("Y label")
ax.set_zlabel("Z label")
ax.set_zlim(0, 2)

plt.show()
```



Tags: plot-type: 3D component: label interactivity: pan level: beginner

Draw flat objects in 3D plot

Demonstrate using *pathpatch_2d_to_3d* to 'draw' shapes and text on a 3D plot.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Circle, PathPatch
from matplotlib.text import TextPath
from matplotlib.transforms import Affine2D
import mpl_toolkits.mplot3d.art3d as art3d


def text3d(ax, xyz, s, zdir="z", size=None, angle=0, usetex=False,␣
 ↪**kwargs):
    """
    Plots the string *s* on the Axes *ax*, with position *xyz*, size␣
 ↪*size*,
    and rotation angle *angle*. *zdir* gives the axis which is to be␣
```

(continues on next page)

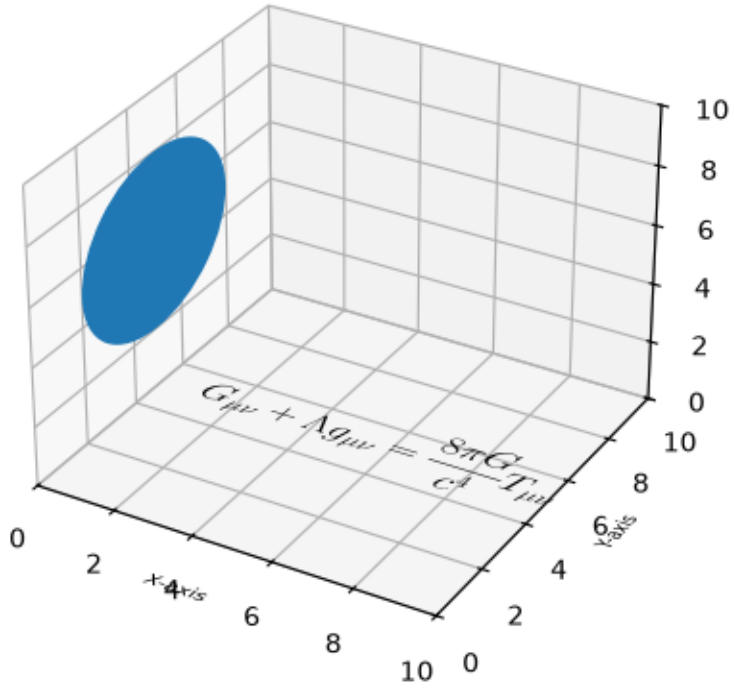
(continued from previous page)

```
 ↪treated as
    the third dimension. *usetex* is a boolean indicating whether the␣
 ↪string
    should be run through a LaTeX subprocess or not.  Any additional␣
 ↪keyword
    arguments are forwarded to `.transform_path`.

    Note: zdir affects the interpretation of xyz.
    """
    x, y, z = xyz
    if zdir == "y":
        xy1, z1 = (x, z), y
    elif zdir == "x":
        xy1, z1 = (y, z), x
    else:
        xy1, z1 = (x, y), z

    text_path = TextPath((0, 0), s, size=size, usetex=usetex)
    trans = Affine2D().rotate(angle).translate(xy1[0], xy1[1])

    p1 = PathPatch(trans.transform_path(text_path), **kwargs)
    ax.add_patch(p1)
    art3d.pathpatch_2d_to_3d(p1, z=z1, zdir=zdir)


fig = plt.figure()
ax = fig.add_subplot(projection='3d')

# Draw a circle on the x=0 'wall'
p = Circle((5, 5), 3)
ax.add_patch(p)
art3d.pathpatch_2d_to_3d(p, z=0, zdir="x")

# Manually label the axes
text3d(ax, (4, -2, 0), "X-axis", zdir="z", size=.5, usetex=False,
       ec="none", fc="k")
text3d(ax, (12, 4, 0), "Y-axis", zdir="z", size=.5, usetex=False,
       angle=np.pi / 2, ec="none", fc="k")
text3d(ax, (12, 10, 4), "Z-axis", zdir="y", size=.5, usetex=False,
       angle=np.pi / 2, ec="none", fc="k")

# Write a Latex formula on the z=0 'floor'
text3d(ax, (1, 5, 0),
       r"$\displaystyle G_{\mu\nu} + \Lambda g_{\mu\nu} = "
       r"\frac{8\pi G}{c^4} T_{\mu\nu}  $",
       zdir="z", size=1, usetex=True,
```

(continues on next page)

(continued from previous page)

```
        ec="none", fc="k")

ax.set_xlim(0, 10)
ax.set_ylim(0, 10)
ax.set_zlim(0, 10)

plt.show()
```



Tags: plot-type: 3D component: label level: advanced

Generate 3D polygons

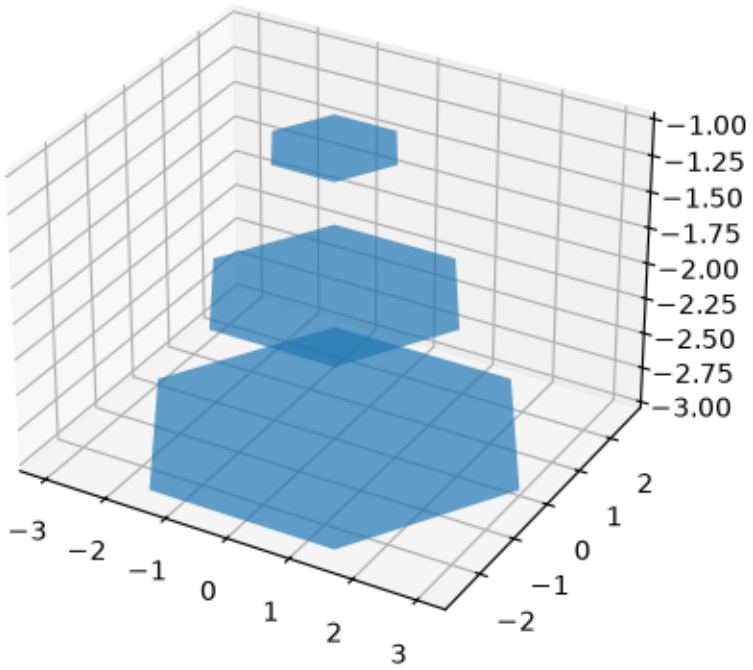
Demonstrate how to create polygons in 3D. Here we stack 3 hexagons.

```
import matplotlib.pyplot as plt
import numpy as np

from mpl_toolkits.mplot3d.art3d import Poly3DCollection

# Coordinates of a hexagon
```

(continues on next page)

(continued from previous page)

```
angles = np.linspace(0, 2 * np.pi, 6, endpoint=False)
x = np.cos(angles)
y = np.sin(angles)
zs = [-3, -2, -1]

# Close the hexagon by repeating the first vertex
x = np.append(x, x[0])
y = np.append(y, y[0])

verts = []
for z in zs:
    verts.append(list(zip(x*z, y*z, np.full_like(x, z))))
verts = np.array(verts)

ax = plt.figure().add_subplot(projection='3d')

poly = Poly3DCollection(verts, alpha=.7)
ax.add_collection3d(poly)
ax.set_aspect('equalxy')

plt.show()
```



Tags: plot-type: 3D styling: colormap level: intermediate

3D plot projection types

Demonstrates the different camera projections for 3D plots, and the effects of changing the focal length for a perspective projection. Note that Matplotlib corrects for the 'zoom' effect of changing the focal length.

The default focal length of 1 corresponds to a Field of View (FOV) of 90 deg. An increased focal length between 1 and infinity "flattens" the image, while a decreased focal length between 1 and 0 exaggerates the perspective and gives the image more apparent depth. In the limiting case, a focal length of infinity corresponds to an orthographic projection after correction of the zoom effect.

You can calculate focal length from a FOV via the equation:

$$1/\tan(\mathrm{FOV}/2)$$

Or vice versa:

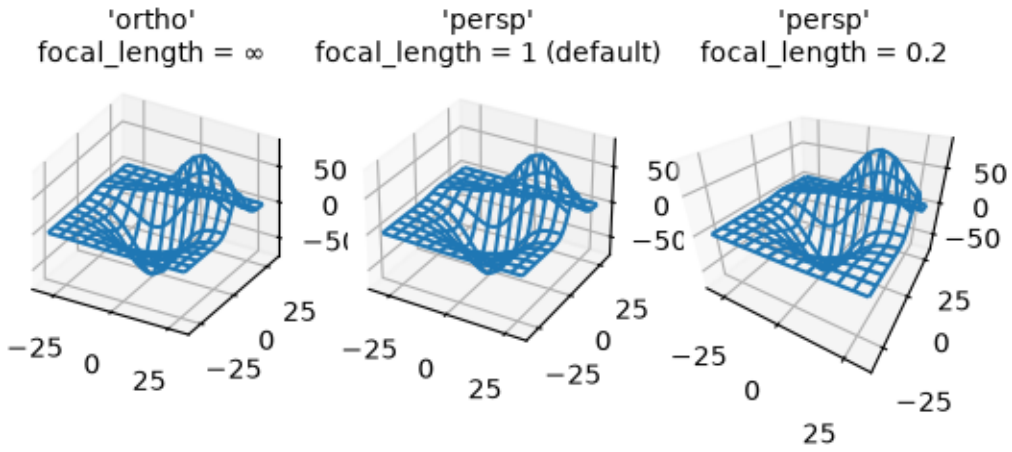
$$\mathrm{FOV} = 2\arctan(1/\mathrm{focallength})$$

```
import matplotlib.pyplot as plt
```

(continues on next page)

(continued from previous page)

```
from mpl_toolkits.mplot3d import axes3d

fig, axs = plt.subplots(1, 3, subplot_kw={'projection': '3d'})

# Get the test data
X, Y, Z = axes3d.get_test_data(0.05)

# Plot the data
for ax in axs:
    ax.plot_wireframe(X, Y, Z, rstride=10, cstride=10)

# Set the orthographic projection.
axs[0].set_proj_type('ortho')  # FOV = 0 deg
axs[0].set_title("'ortho'\nfocal_length = ∞", fontsize=10)

# Set the perspective projections
axs[1].set_proj_type('persp')  # FOV = 90 deg
axs[1].set_title("'persp'\nfocal_length = 1 (default)", fontsize=10)

axs[2].set_proj_type('persp', focal_length=0.2)  # FOV = 157.4 deg
axs[2].set_title("'persp'\nfocal_length = 0.2", fontsize=10)

plt.show()
```



Tags: plot-type: 3D styling: small-multiples component: subplot level: intermediate

3D quiver plot

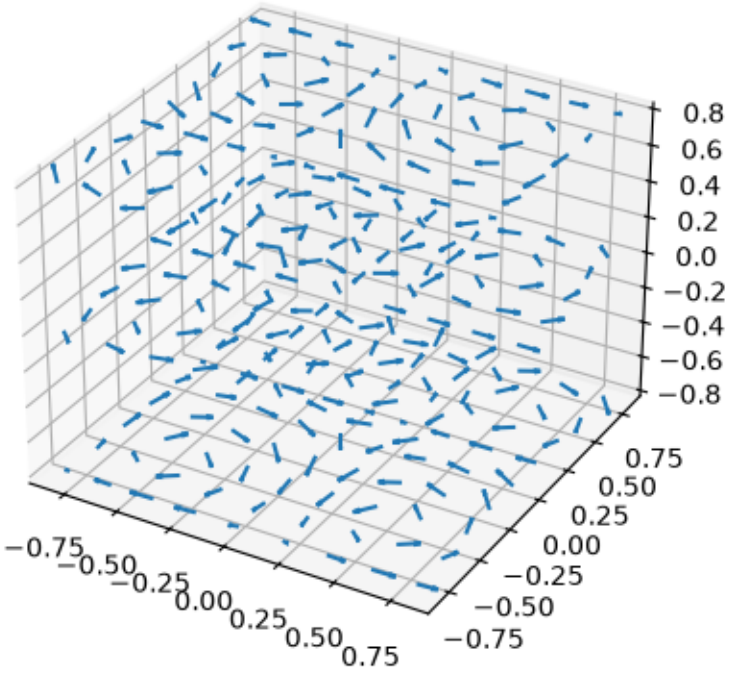
Demonstrates plotting directional arrows at points on a 3D meshgrid.

```
import matplotlib.pyplot as plt
import numpy as np

ax = plt.figure().add_subplot(projection='3d')

# Make the grid
x, y, z = np.meshgrid(np.arange(-0.8, 1, 0.2),
                      np.arange(-0.8, 1, 0.2),
                      np.arange(-0.8, 1, 0.8))

# Make the direction data for the arrows
u = np.sin(np.pi * x) * np.cos(np.pi * y) * np.cos(np.pi * z)
v = -np.cos(np.pi * x) * np.sin(np.pi * y) * np.cos(np.pi * z)
w = (np.sqrt(2.0 / 3.0) * np.cos(np.pi * x) * np.cos(np.pi * y) *
     np.sin(np.pi * z))
```

(continues on next page)

(continued from previous page)

```
ax.quiver(x, y, z, u, v, w, length=0.1, normalize=True)

plt.show()
```



Tags: plot-type: 3D level: beginner

Rotating a 3D plot

A very simple animation of a rotating 3D plot about all three axes.

See *Animate a 3D wireframe plot* for another example of animating a 3D plot.

(This example is skipped when building the documentation gallery because it intentionally takes a long time to run)

```
import matplotlib.pyplot as plt

from matplotlib import animation
from mpl_toolkits.mplot3d import axes3d

```

(continues on next page)

(continued from previous page)

```
fig = plt.figure()
ax = fig.add_subplot(projection='3d')

# Grab some example data and plot a basic wireframe.
X, Y, Z = axes3d.get_test_data(0.05)
ax.plot_wireframe(X, Y, Z, rstride=10, cstride=10)

# Set the axis labels
ax.set_xlabel('x')
ax.set_ylabel('y')
ax.set_zlabel('z')


# Rotate the axes and update
def animate(angle):
    # Normalize the angle to the range [-180, 180] for display
    angle_norm = (angle + 180) % 360 - 180

    # Cycle through a full rotation of elevation, then azimuth, roll,␣
 ↪and all
    elev = azim = roll = 0
    if angle <= 360:
        elev = angle_norm
    elif angle <= 360*2:
        azim = angle_norm
    elif angle <= 360*3:
        roll = angle_norm
    else:
        elev = azim = roll = angle_norm

    # Update the axis view and title
    ax.view_init(elev, azim, roll)
    ax.set_title(f'Elevation: {elev}°, Azimuth: {azim}°, Roll: {roll}°
 ↪')


ani = animation.FuncAnimation(fig, animate, interval=25, frames=360*4)

plt.show()
```

Tags: plot-type: 3D component: animation level: advanced internal: high-bandwidth

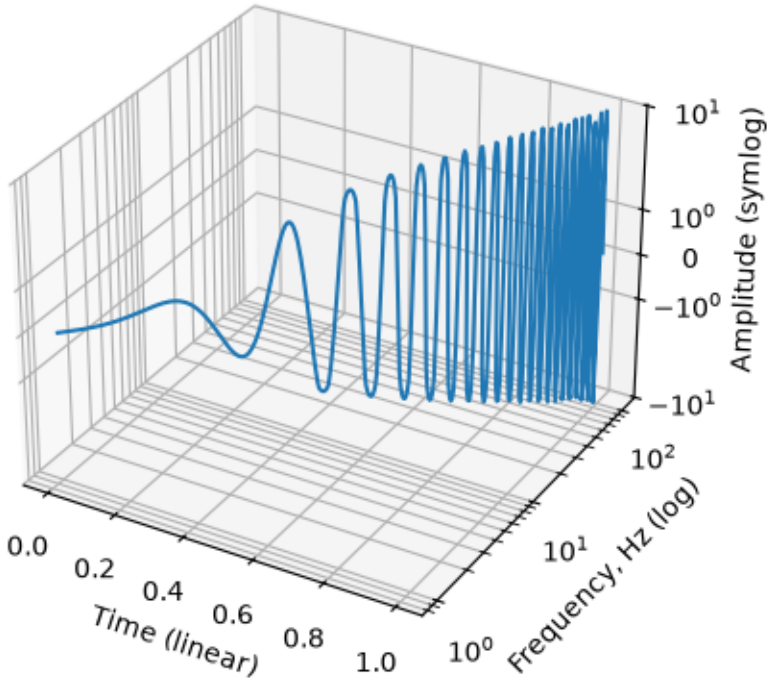
Scales on 3D (Log, Symlog, etc.)

Demonstrate how to use non-linear scales such as logarithmic scales on 3D axes.

3D axes support the same axis scales as 2D plots: 'linear', 'log', 'symlog', 'logit', 'asinh', and custom 'function' scales. This example shows a mix of scales: linear on X, log on Y, and symlog on Z.

For a complete list of built-in scales, see *matplotlib.scale*. For an overview of scale transformations, see *Scales overview*.

```
import matplotlib.pyplot as plt
import numpy as np

# A sine chirp with increasing frequency and amplitude
x = np.linspace(0, 1, 400)  # time
y = 10 ** (2 * x)  # frequency, growing exponentially from 1 to 100 Hz
phase = 2 * np.pi * (10 ** (2 * x) - 1) / (2 * np.log(10))
z = np.sin(phase) * x **2 * 10  # amplitude, growing quadratically

fig = plt.figure()
ax = fig.add_subplot(projection='3d')
ax.plot(x, y, z)

ax.set_xlabel('Time (linear)')
ax.set_ylabel('Frequency, Hz (log)')
ax.set_zlabel('Amplitude (symlog)')

ax.set_yscale('log')
ax.set_zscale('symlog')

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *mpl_toolkits.mplot3d.axes3d.Axes3D.set_xscale*
- *mpl_toolkits.mplot3d.axes3d.Axes3D.set_yscale*
- *mpl_toolkits.mplot3d.axes3d.Axes3D.set_zscale*
- *matplotlib.scale*

Tags: plot-type: 3D level: beginner

3D scatterplot

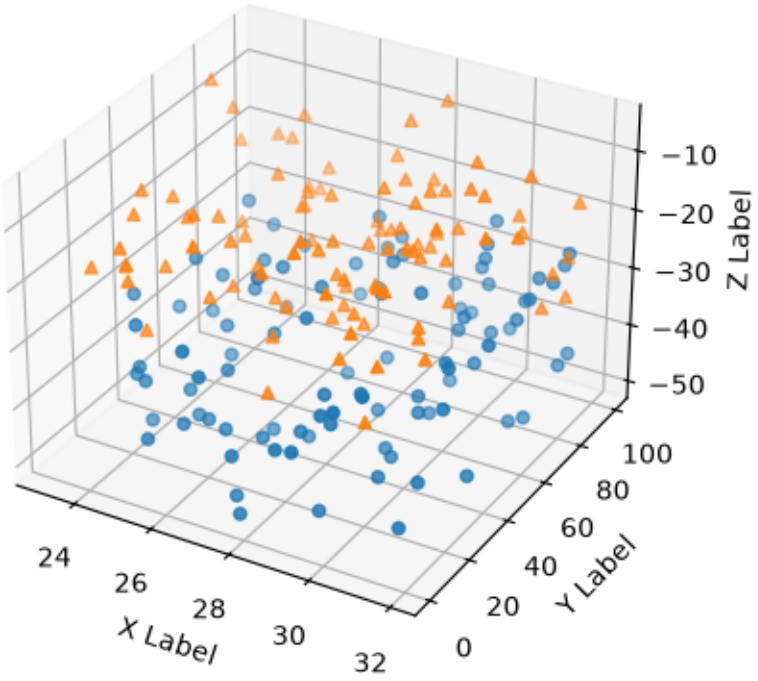
Demonstration of a basic scatterplot in 3D.

```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
```

(continues on next page)

(continued from previous page)

```
np.random.seed(19680801)


def randrange(n, vmin, vmax):
    """
    Helper function to make an array of random numbers having shape␣
 ↪(n, )
    with each number distributed Uniform(vmin, vmax).
    """
    return (vmax - vmin)*np.random.rand(n) + vmin

fig = plt.figure()
ax = fig.add_subplot(projection='3d')

n = 100

# For each set of style and range settings, plot n random points in␣
 ↪the box
# defined by x in [23, 32], y in [0, 100], z in [zlow, zhigh].
for m, zlow, zhigh in [('o', -50, -25), ('^', -30, -5)]:
    xs = randrange(n, 23, 32)
    ys = randrange(n, 0, 100)
    zs = randrange(n, zlow, zhigh)
    ax.scatter(xs, ys, zs, marker=m)

ax.set_xlabel('X Label')
ax.set_ylabel('Y Label')
ax.set_zlabel('Z Label')

plt.show()
```

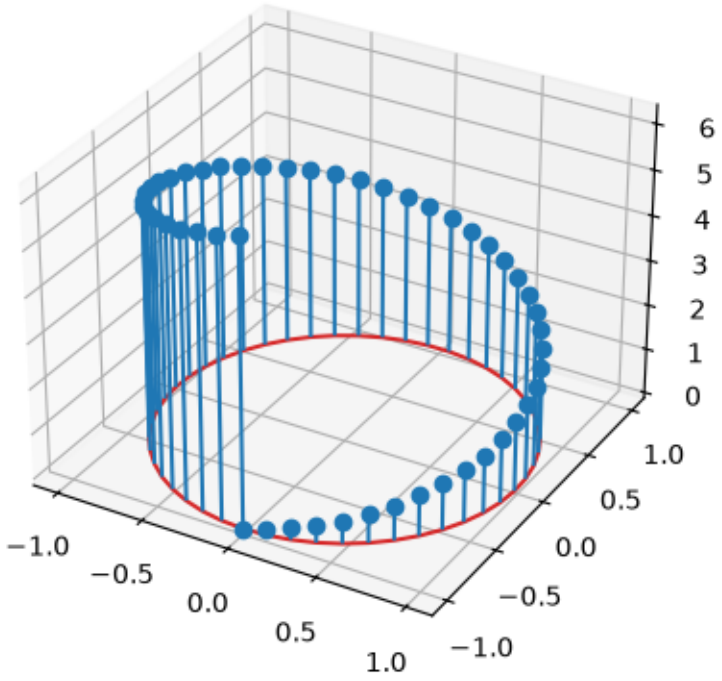


Tags: plot-type: 3D plot-type: scatter level: beginner

3D stem

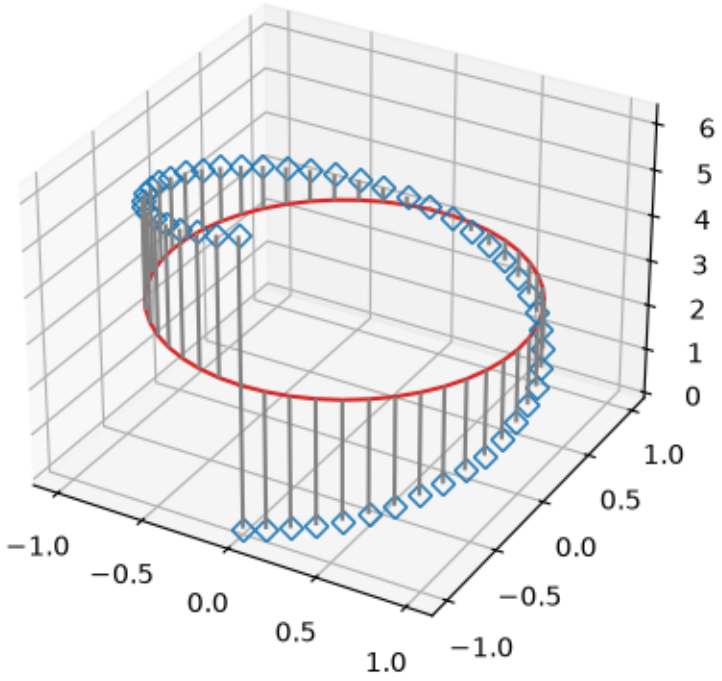
Demonstration of a stem plot in 3D, which plots vertical lines from a baseline to the z-coordinate and places a marker at the tip.

```
import matplotlib.pyplot as plt
import numpy as np

theta = np.linspace(0, 2*np.pi)
x = np.cos(theta - np.pi/2)
y = np.sin(theta - np.pi/2)
z = theta

fig, ax = plt.subplots(subplot_kw=dict(projection='3d'))
ax.stem(x, y, z)

plt.show()
```



The position of the baseline can be adapted using *bottom*. The parameters *linefmt*, *markerfmt*, and *basefmt* control basic format properties of the plot. However, in contrast to `plot` not all properties are configurable via keyword arguments. For more advanced control adapt the line objects returned by `stem`.

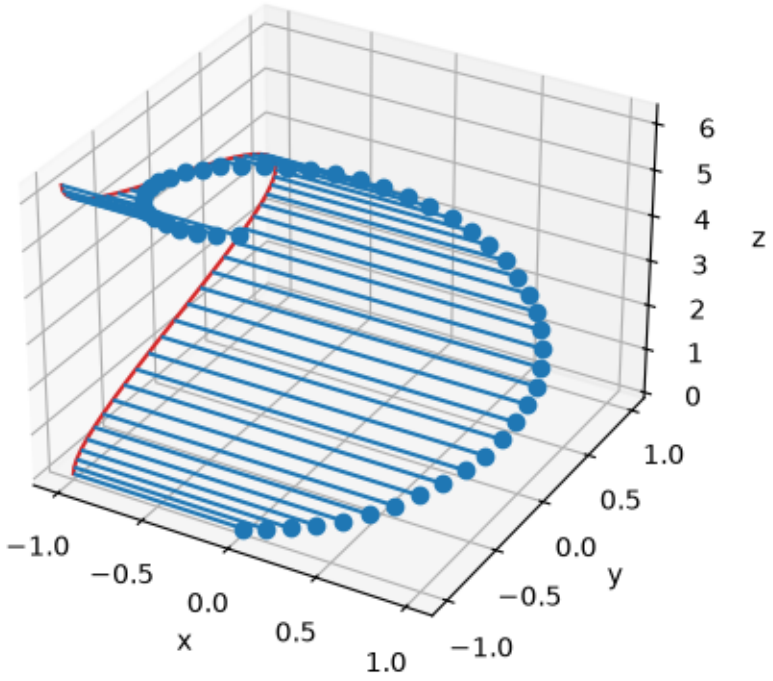
```
fig, ax = plt.subplots(subplot_kw=dict(projection='3d'))
markerline, stemlines, baseline = ax.stem(
    x, y, z, linefmt='grey', markerfmt='D', bottom=np.pi)
markerline.set_markerfacecolor('none')

plt.show()
```



The orientation of the stems and baseline can be changed using *orientation*. This determines in which direction the stems are projected from the head points, towards the *bottom* baseline.

For examples, by setting `orientation='x'`, the stems are projected along the *x*-direction, and the baseline is in the *yz*-plane.

```
fig, ax = plt.subplots(subplot_kw=dict(projection='3d'))
markerline, stemlines, baseline = ax.stem(x, y, z, bottom=-1,␣
 ↪orientation='x')
ax.set(xlabel='x', ylabel='y', zlabel='z')

plt.show()
```



Tags: plot-type: 3D plot-type: specialty level: beginner

Total running time of the script: (0 minutes 1.097 seconds)

3D plots as subplots

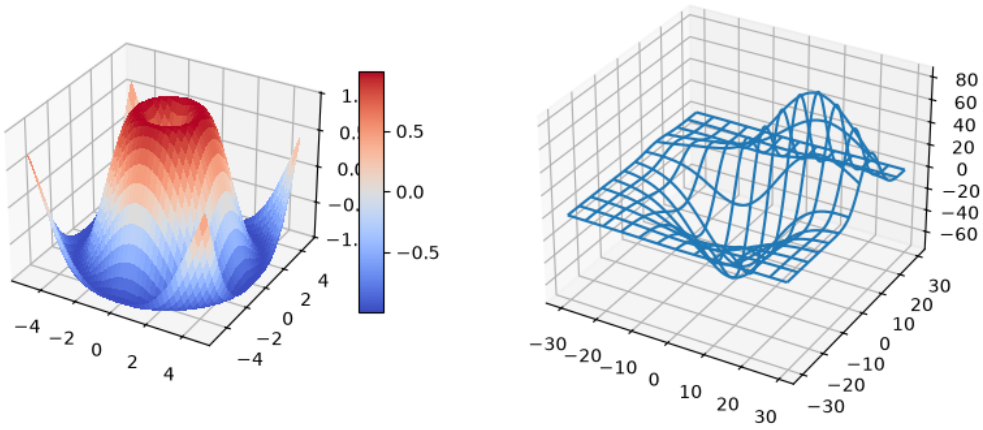
Demonstrate including 3D plots as subplots.

```
import matplotlib.pyplot as plt
import numpy as np

from mpl_toolkits.mplot3d.axes3d import get_test_data

# set up a figure twice as wide as it is tall
fig = plt.figure(figsize=plt.figaspect(0.5))

# =============
# First subplot
# =============
# set up the Axes for the first plot
ax = fig.add_subplot(1, 2, 1, projection='3d')
```

(continues on next page)

(continued from previous page)

```
# plot a 3D surface like in the example mplot3d/surface3d_demo
X = np.arange(-5, 5, 0.25)
Y = np.arange(-5, 5, 0.25)
X, Y = np.meshgrid(X, Y)
R = np.sqrt(X**2 + Y**2)
Z = np.sin(R)
surf = ax.plot_surface(X, Y, Z, rstride=1, cstride=1, cmap="coolwarm",
                       linewidth=0, antialiased=False)
ax.set_zlim(-1.01, 1.01)
fig.colorbar(surf, shrink=0.5, aspect=10)

# ==============
# Second subplot
# ==============
# set up the Axes for the second plot
ax = fig.add_subplot(1, 2, 2, projection='3d')

# plot a 3D wireframe like in the example mplot3d/wire3d_demo
X, Y, Z = get_test_data(0.05)
ax.plot_wireframe(X, Y, Z, rstride=10, cstride=10)

plt.show()
```



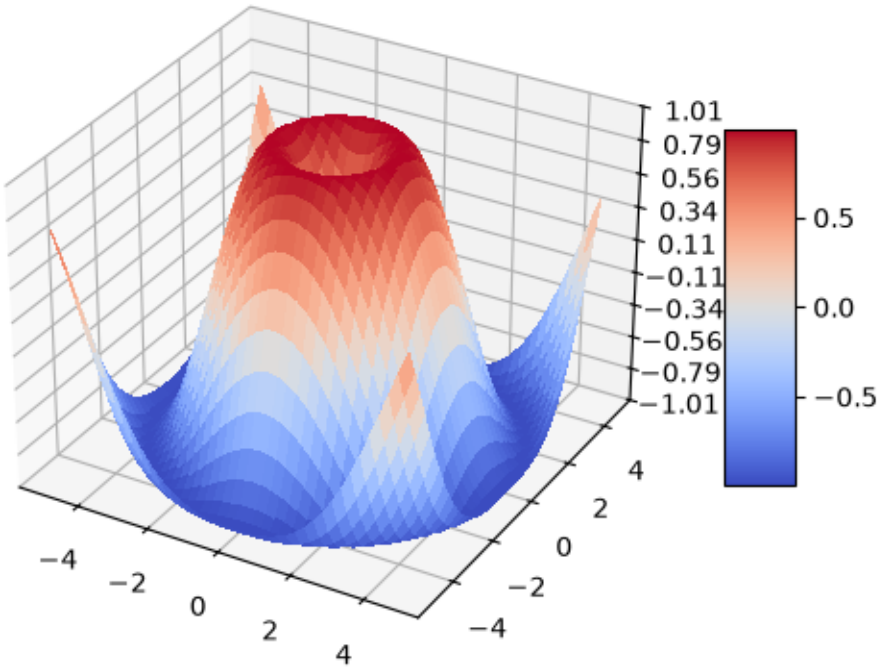
Tags: plot-type: 3D component: subplot level: advanced

3D surface (colormap)

Demonstrates plotting a 3D surface colored with the coolwarm colormap. The surface is made opaque by using `antialiased=False`.

Also demonstrates using the *`LinearLocator`* and custom formatting for the z axis tick labels.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.ticker import LinearLocator

fig, ax = plt.subplots(subplot_kw={"projection": "3d"})

# Make data.
X = np.arange(-5, 5, 0.25)
Y = np.arange(-5, 5, 0.25)
X, Y = np.meshgrid(X, Y)
R = np.sqrt(X**2 + Y**2)
Z = np.sin(R)

# Plot the surface.
surf = ax.plot_surface(X, Y, Z, cmap="coolwarm",
                       linewidth=0, antialiased=False)

# Customize the z axis.
ax.set_zlim(-1.01, 1.01)
ax.zaxis.set_major_locator(LinearLocator(10))
# A StrMethodFormatter is used automatically
ax.zaxis.set_major_formatter('{x:.02f}')

# Add a color bar which maps values to colors.
fig.colorbar(surf, shrink=0.5, aspect=5)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.pyplot.subplots*
- *matplotlib.axis.Axis.set_major_formatter*
- *matplotlib.axis.Axis.set_major_locator*
- *matplotlib.ticker.LinearLocator*
- *matplotlib.ticker.StrMethodFormatter*

Tags: plot-type: 3D styling: colormap level: advanced

3D surface (solid color)

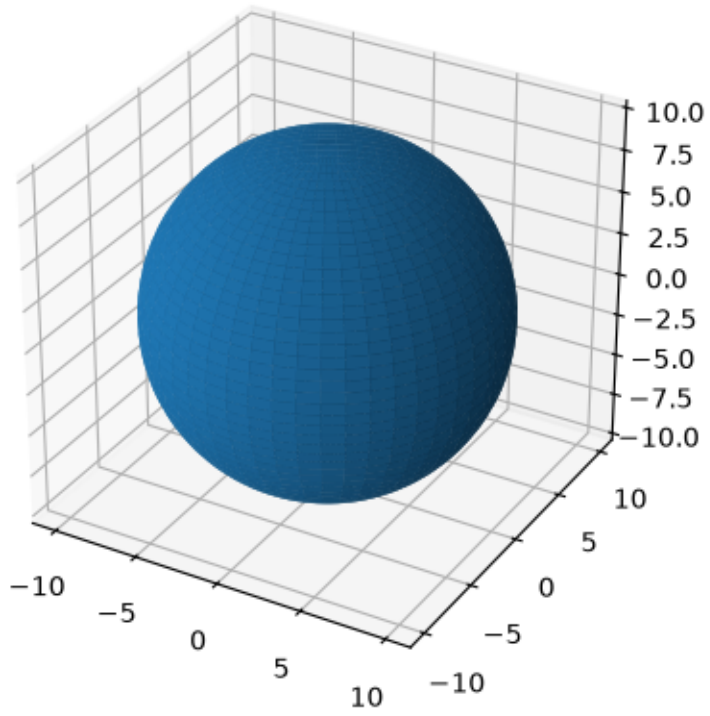
Demonstrates a very basic plot of a 3D surface using a solid color.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
fig = plt.figure()
ax = fig.add_subplot(projection='3d')

# Make data
u = np.linspace(0, 2 * np.pi, 100)
v = np.linspace(0, np.pi, 100)
x = 10 * np.outer(np.cos(u), np.sin(v))
y = 10 * np.outer(np.sin(u), np.sin(v))
z = 10 * np.outer(np.ones(np.size(u)), np.cos(v))

# Plot the surface
ax.plot_surface(x, y, z)

# Set an equal aspect ratio
ax.set_aspect('equal')

plt.show()
```

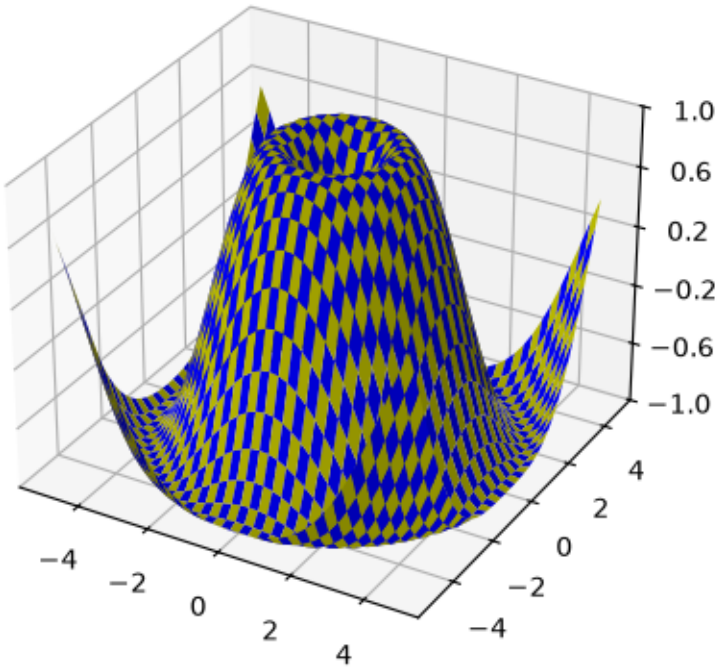


Tags: plot-type: 3D level: beginner

3D surface (checkerboard)

Demonstrates plotting a 3D surface colored in a checkerboard pattern.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.ticker import LinearLocator

ax = plt.figure().add_subplot(projection='3d')

# Make data.
X = np.arange(-5, 5, 0.25)
xlen = len(X)
Y = np.arange(-5, 5, 0.25)
ylen = len(Y)
X, Y = np.meshgrid(X, Y)
R = np.sqrt(X**2 + Y**2)
Z = np.sin(R)

# Create an empty array of strings with the same shape as the␣
 ↪meshgrid, and
# populate it with two colors in a checkerboard pattern.
colortuple = ('y', 'b')
colors = np.empty(X.shape, dtype=str)
for y in range(ylen):
    for x in range(xlen):
        colors[y, x] = colortuple[(x + y) % len(colortuple)]

# Plot the surface with face colors taken from the array we made.
surf = ax.plot_surface(X, Y, Z, facecolors=colors, linewidth=0)

# Customize the z axis.
ax.set_zlim(-1, 1)
ax.zaxis.set_major_locator(LinearLocator(6))

plt.show()
```



Tags: plot-type: 3D styling: color styling: texture level: intermediate

3D surface with polar coordinates

Demonstrates plotting a surface defined in polar coordinates. Uses the reversed version of the YlGnBu colormap. Also demonstrates writing axis labels with latex math mode.

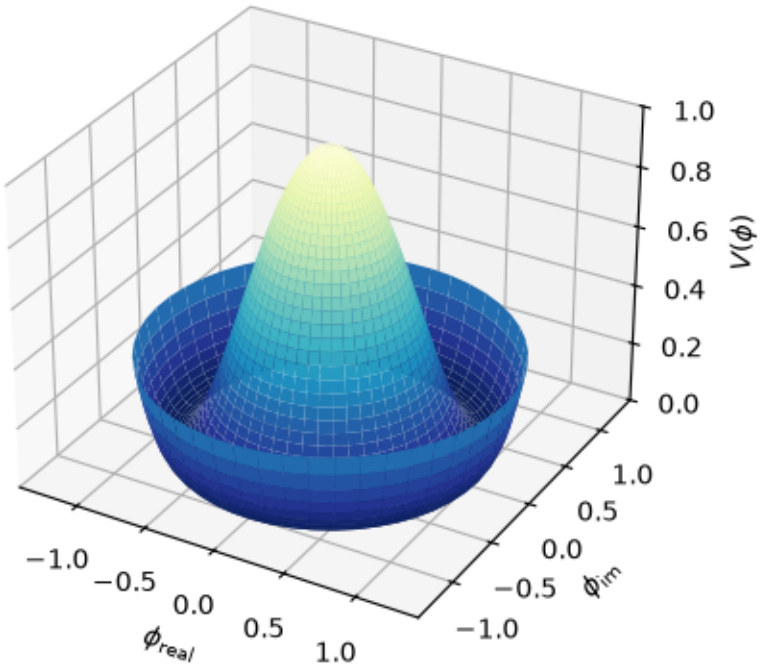
Example contributed by Armin Moser.

```
import matplotlib.pyplot as plt
import numpy as np

fig = plt.figure()
ax = fig.add_subplot(projection='3d')

# Create the mesh in polar coordinates and compute corresponding Z.
r = np.linspace(0, 1.25, 50)
p = np.linspace(0, 2*np.pi, 50)
R, P = np.meshgrid(r, p)
Z = ((R**2 - 1)**2)

# Express the mesh in the cartesian system.
```

(continues on next page)

(continued from previous page)

```
X, Y = R*np.cos(P), R*np.sin(P)

# Plot the surface.
ax.plot_surface(X, Y, Z, cmap="YlGnBu_r")

# Tweak the limits and add latex math labels.
ax.set_zlim(0, 1)
ax.set_xlabel(r'$\phi_\mathrm{real}$')
ax.set_ylabel(r'$\phi_\mathrm{im}$')
ax.set_zlabel(r'$V(\phi)$')

plt.show()
```



Tags: plot-type: 3D plot-type: polar level: beginner

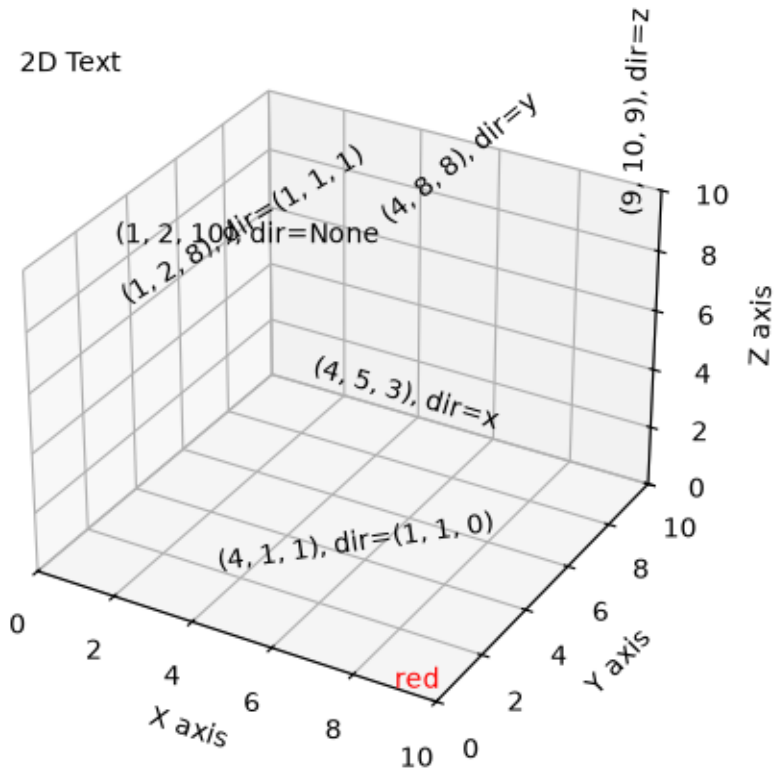
Text annotations in 3D

Demonstrates the placement of text annotations on a 3D plot.

Functionality shown:

- Using the *text* function with three types of *zdir* values: None, an axis name (ex. 'x'), or a direction tuple (ex. (1, 1, 0)).
- Using the *text* function with the color keyword.
- Using the *text2D* function to place text on a fixed position on the ax object.

```
import matplotlib.pyplot as plt

ax = plt.figure().add_subplot(projection='3d')

# Demo 1: zdir
zdirs = (None, 'x', 'y', 'z', (1, 1, 0), (1, 1, 1))
xs = (1, 4, 4, 9, 4, 1)
ys = (2, 5, 8, 10, 1, 2)
zs = (10, 3, 8, 9, 1, 8)

for zdir, x, y, z in zip(zdirs, xs, ys, zs):
    label = '(%d, %d, %d), dir=%s' % (x, y, z, zdir)
    ax.text(x, y, z, label, zdir)

# Demo 2: color
ax.text(9, 0, 0, "red", color='red')

# Demo 3: text2D
# Placement 0, 0 would be the bottom left, 1, 1 would be the top right.
ax.text2D(0.05, 0.95, "2D Text", transform=ax.transAxes)

# Tweaking display region and labels
ax.set_xlim(0, 10)
ax.set_ylim(0, 10)
ax.set_zlim(0, 10)
ax.set_xlabel('X axis')
ax.set_ylabel('Y axis')
ax.set_zlabel('Z axis')

plt.show()
```



Tags: plot-type: 3D component: annotation level: beginner

Triangular 3D contour plot

Contour plots of unstructured triangular grids.

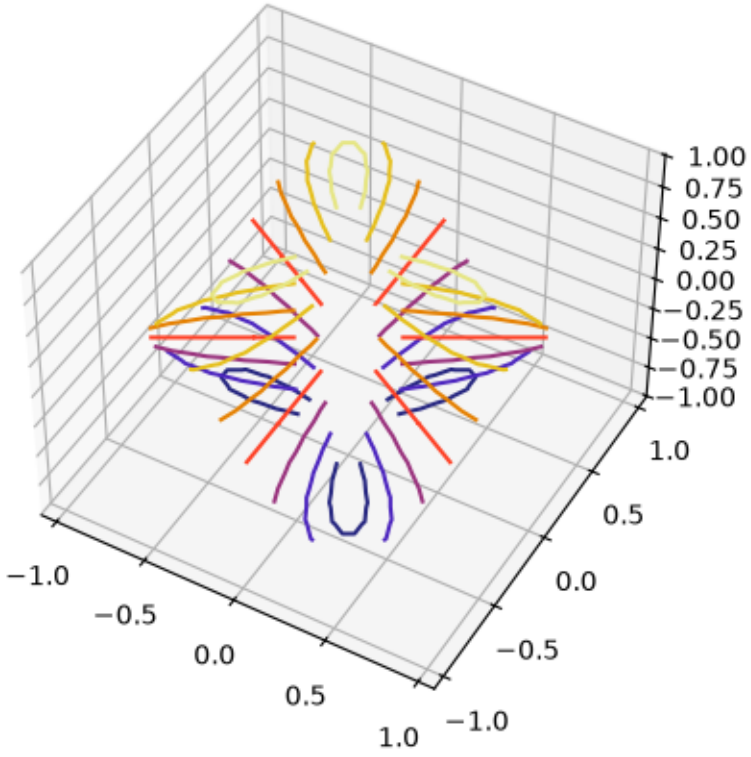
The data used is the same as in the second plot of *More triangular 3D surfaces*. *Triangular 3D filled contour plot* shows the filled version of this example.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.tri as tri

n_angles = 48
n_radii = 8
min_radius = 0.25

# Create the mesh in polar coordinates and compute x, y, z.
radii = np.linspace(min_radius, 0.95, n_radii)
angles = np.linspace(0, 2*np.pi, n_angles, endpoint=False)
angles = np.repeat(angles[..., np.newaxis], n_radii, axis=1)
```

(continues on next page)

(continued from previous page)

```
angles[:, 1::2] += np.pi/n_angles

x = (radii*np.cos(angles)).flatten()
y = (radii*np.sin(angles)).flatten()
z = (np.cos(radii)*np.cos(3*angles)).flatten()

# Create a custom triangulation.
triang = tri.Triangulation(x, y)

# Mask off unwanted triangles.
triang.set_mask(np.hypot(x[triang.triangles].mean(axis=1),
                         y[triang.triangles].mean(axis=1))
                < min_radius)

ax = plt.figure().add_subplot(projection='3d')
ax.tricontour(triang, z, cmap="CMRmap")

# Customize the view angle so it's easier to understand the plot.
ax.view_init(elev=45.)

plt.show()
```



Tags: plot-type: 3D plot-type: specialty level: intermediate

Triangular 3D filled contour plot

Filled contour plots of unstructured triangular grids.

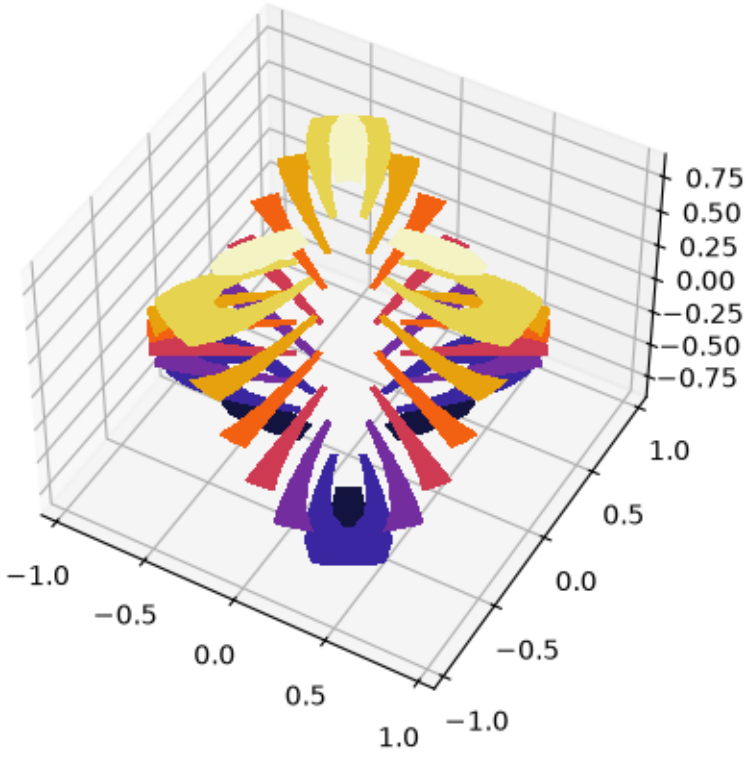
The data used is the same as in the second plot of *More triangular 3D surfaces*. *Triangular 3D contour plot* shows the unfilled version of this example.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.tri as tri

# First create the x, y, z coordinates of the points.
n_angles = 48
n_radii = 8
min_radius = 0.25

# Create the mesh in polar coordinates and compute x, y, z.
radii = np.linspace(min_radius, 0.95, n_radii)
angles = np.linspace(0, 2*np.pi, n_angles, endpoint=False)
```

(continues on next page)

(continued from previous page)

```
angles = np.repeat(angles[..., np.newaxis], n_radii, axis=1)
angles[:, 1::2] += np.pi/n_angles

x = (radii*np.cos(angles)).flatten()
y = (radii*np.sin(angles)).flatten()
z = (np.cos(radii)*np.cos(3*angles)).flatten()

# Create a custom triangulation.
triang = tri.Triangulation(x, y)

# Mask off unwanted triangles.
triang.set_mask(np.hypot(x[triang.triangles].mean(axis=1),
                         y[triang.triangles].mean(axis=1))
                < min_radius)

ax = plt.figure().add_subplot(projection='3d')
ax.tricontourf(triang, z, cmap="CMRmap")

# Customize the view angle so it's easier to understand the plot.
ax.view_init(elev=45.)

plt.show()
```



Tags: plot-type: 3D plot-type: specialty level: intermediate

Triangular 3D surfaces

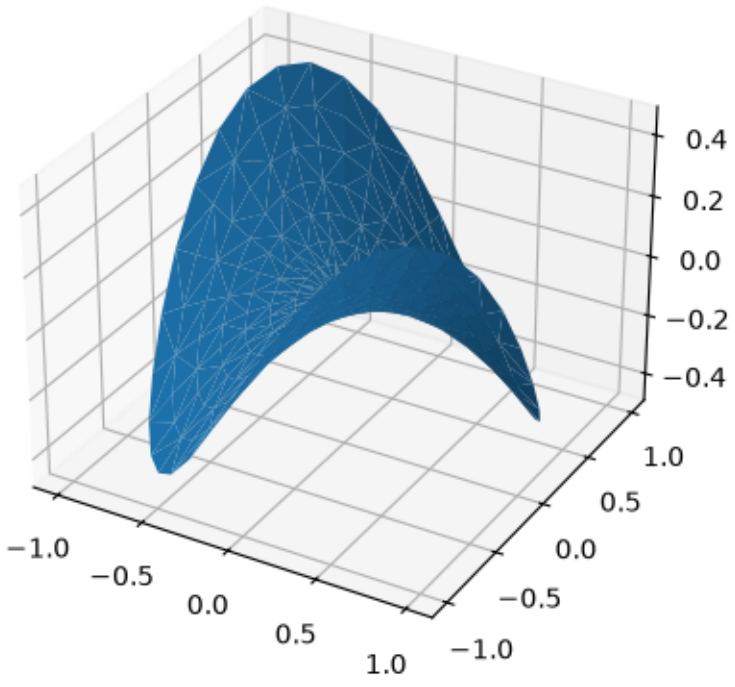
Plot a 3D surface with a triangular mesh.

```
import matplotlib.pyplot as plt
import numpy as np

n_radii = 8
n_angles = 36

# Make radii and angles spaces (radius r=0 omitted to eliminate␣
 ↪duplication).
radii = np.linspace(0.125, 1.0, n_radii)
angles = np.linspace(0, 2*np.pi, n_angles, endpoint=False)[..., np.
 ↪newaxis]

# Convert polar (radii, angles) coords to cartesian (x, y) coords.
# (0, 0) is manually added at this stage,  so there will be no␣
 ↪duplicate
```

(continues on next page)

(continued from previous page)

```
# points in the (x, y) plane.
x = np.append(0, (radii*np.cos(angles)).flatten())
y = np.append(0, (radii*np.sin(angles)).flatten())

# Compute z to make the pringle surface.
z = np.sin(-x*y)

ax = plt.figure().add_subplot(projection='3d')

ax.plot_trisurf(x, y, z, linewidth=0.2, antialiased=True)

plt.show()
```



Tags: plot-type: 3D level: intermediate

More triangular 3D surfaces

Two additional examples of plotting surfaces with triangular mesh.

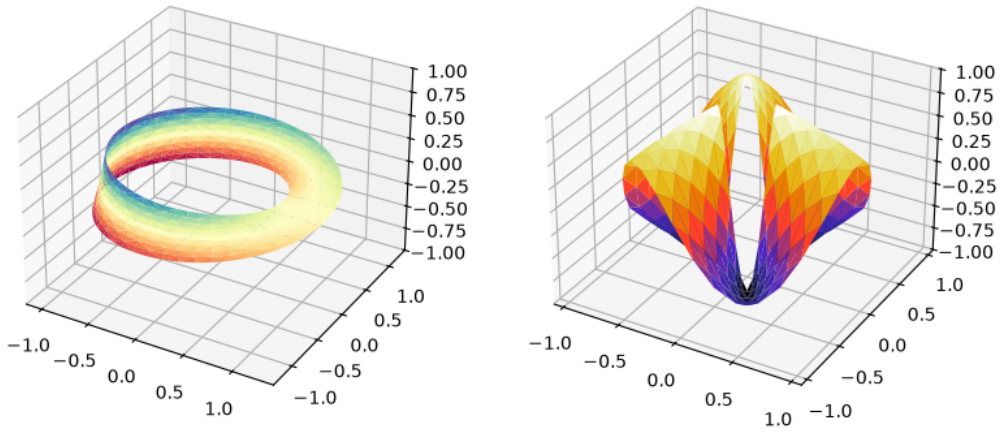
The first demonstrates use of plot_trisurf's triangles argument, and the second sets a *Triangulation* object's mask and passes the object directly to plot_trisurf.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.tri as mtri

fig = plt.figure(figsize=plt.figaspect(0.5))

# ==========
# First plot
# ==========

# Make a mesh in the space of parameterisation variables u and v
u = np.linspace(0, 2.0 * np.pi, endpoint=True, num=50)
v = np.linspace(-0.5, 0.5, endpoint=True, num=10)
u, v = np.meshgrid(u, v)
u, v = u.flatten(), v.flatten()

# This is the Mobius mapping, taking a u, v pair and returning an x,␣
 ↪y, z
# triple
x = (1 + 0.5 * v * np.cos(u / 2.0)) * np.cos(u)
y = (1 + 0.5 * v * np.cos(u / 2.0)) * np.sin(u)
z = 0.5 * v * np.sin(u / 2.0)

# Triangulate parameter space to determine the triangles
tri = mtri.Triangulation(u, v)

# Plot the surface.  The triangles in parameter space determine which␣
 ↪x, y, z
# points are connected by an edge.
ax = fig.add_subplot(1, 2, 1, projection='3d')
ax.plot_trisurf(x, y, z, triangles=tri.triangles, cmap="Spectral")
ax.set_zlim(-1, 1)


# ===========
# Second plot
# ===========

# Make parameter spaces radii and angles.
n_angles = 36
```

(continues on next page)

(continued from previous page)

```
n_radii = 8
min_radius = 0.25
radii = np.linspace(min_radius, 0.95, n_radii)

angles = np.linspace(0, 2*np.pi, n_angles, endpoint=False)
angles = np.repeat(angles[..., np.newaxis], n_radii, axis=1)
angles[:, 1::2] += np.pi/n_angles

# Map radius, angle pairs to x, y, z points.
x = (radii*np.cos(angles)).flatten()
y = (radii*np.sin(angles)).flatten()
z = (np.cos(radii)*np.cos(3*angles)).flatten()

# Create the Triangulation; no triangles so Delaunay triangulation␣
 ↪created.
triang = mtri.Triangulation(x, y)

# Mask off unwanted triangles.
xmid = x[triang.triangles].mean(axis=1)
ymid = y[triang.triangles].mean(axis=1)
mask = xmid**2 + ymid**2 < min_radius**2
triang.set_mask(mask)

# Plot the surface.
ax = fig.add_subplot(1, 2, 2, projection='3d')
ax.plot_trisurf(triang, z, cmap="CMRmap")


plt.show()
```



Tags: plot-type: 3D plot-type: specialty level: intermediate

Primary 3D view planes

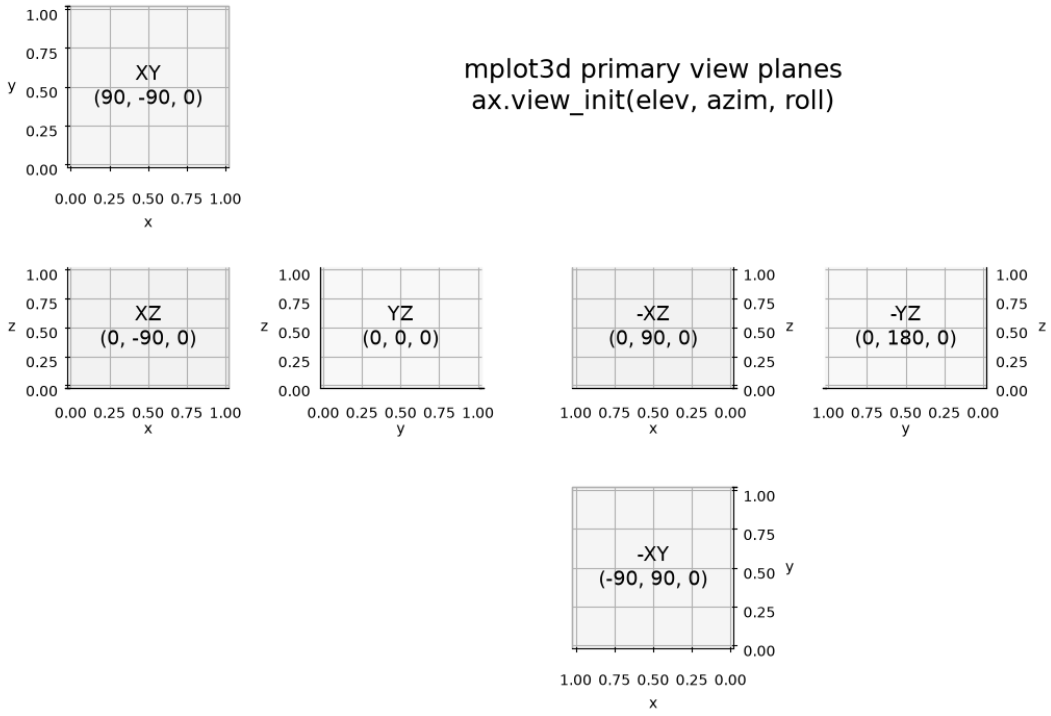
This example generates an "unfolded" 3D plot that shows each of the primary 3D view planes. The elevation, azimuth, and roll angles required for each view are labeled. You could print out this image and fold it into a box where each plane forms a side of the box.

```
import matplotlib.pyplot as plt


def annotate_axes(ax, text, fontsize=18):
    ax.text(x=0.5, y=0.5, z=0.5, s=text,
            va="center", ha="center", fontsize=fontsize, color="black")

# (plane, (elev, azim, roll))
views = [('XY',    (90, -90, 0)),
         ('XZ',     (0, -90, 0)),
         ('YZ',     (0,   0, 0)),
         ('-XY', (-90,  90, 0)),
         ('-XZ',    (0,  90, 0)),
         ('-YZ',    (0, 180, 0))]

layout = [['XY',  '.',   'L',   '.'],
          ['XZ', 'YZ', '-XZ', '-YZ'],
          ['.',   '.', '-XY',   '.']]
fig, axd = plt.subplot_mosaic(layout, subplot_kw={'projection': '3d'},
                              figsize=(12, 8.5))
for plane, angles in views:
```

(continues on next page)

(continued from previous page)

```
    axd[plane].set_xlabel('x')
    axd[plane].set_ylabel('y')
    axd[plane].set_zlabel('z')
    axd[plane].set_proj_type('ortho')
    axd[plane].view_init(elev=angles[0], azim=angles[1],␣
 ↪roll=angles[2])
    axd[plane].set_box_aspect(None, zoom=1.25)

    label = f'{plane}\n{angles}'
    annotate_axes(axd[plane], label, fontsize=14)

for plane in ('XY', '-XY'):
    axd[plane].set_zticklabels([])
    axd[plane].set_zlabel('')
for plane in ('XZ', '-XZ'):
    axd[plane].set_yticklabels([])
    axd[plane].set_ylabel('')
for plane in ('YZ', '-YZ'):
    axd[plane].set_xticklabels([])
    axd[plane].set_xlabel('')

label = 'mplot3d primary view planes\n' + 'ax.view_init(elev, azim,␣
 ↪roll)'
annotate_axes(axd['L'], label, fontsize=18)
axd['L'].set_axis_off()

plt.show()
```



Tags: plot-type: 3D component: axes component: subplot level: beginner

3D voxel / volumetric plot

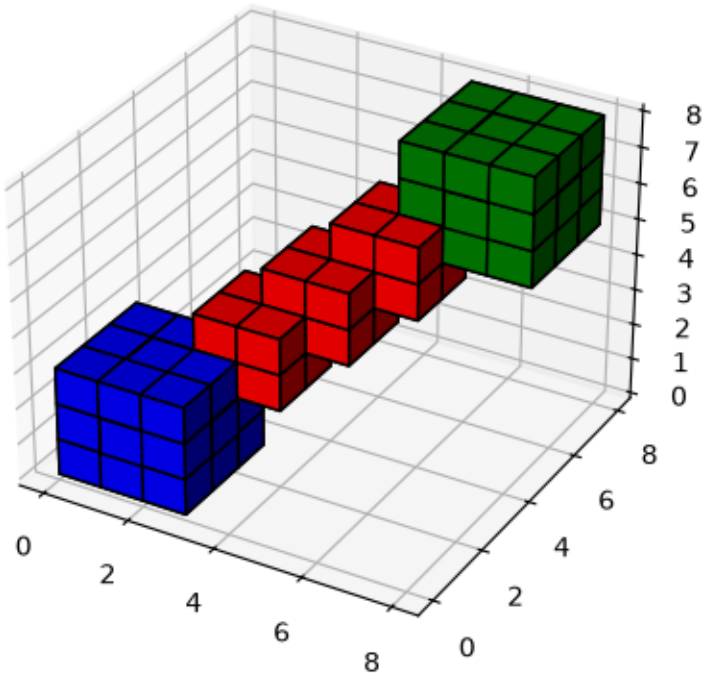
Demonstrates plotting 3D volumetric objects with *Axes3D.voxels*.

```
import matplotlib.pyplot as plt
import numpy as np

# prepare some coordinates
x, y, z = np.indices((8, 8, 8))

# draw cuboids in the top left and bottom right corners, and a link␣
 ↪between
# them
cube1 = (x < 3) & (y < 3) & (z < 3)
cube2 = (x >= 5) & (y >= 5) & (z >= 5)
link = abs(x - y) + abs(y - z) + abs(z - x) <= 2

# combine the objects into a single boolean array
voxelarray = cube1 | cube2 | link
```

(continues on next page)

(continued from previous page)

```
# set the colors of each object
colors = np.empty(voxelarray.shape, dtype=object)
colors[link] = 'red'
colors[cube1] = 'blue'
colors[cube2] = 'green'

# and plot everything
ax = plt.figure().add_subplot(projection='3d')
ax.voxels(voxelarray, facecolors=colors, edgecolor='k')

plt.show()
```



Tags: plot-type: 3D level: beginner

3D voxel plot of the NumPy logo

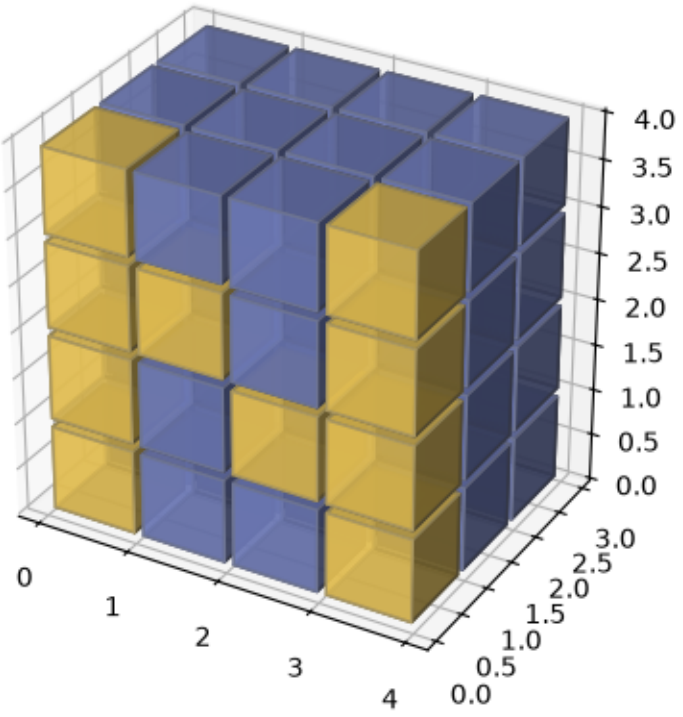
Demonstrates using *Axes3D.voxels* with uneven coordinates.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
def explode(data):
    size = np.array(data.shape)*2
    data_e = np.zeros(size - 1, dtype=data.dtype)
    data_e[::2, ::2, ::2] = data
    return data_e

# build up the numpy logo
n_voxels = np.zeros((4, 3, 4), dtype=bool)
n_voxels[0, 0, :] = True
n_voxels[-1, 0, :] = True
n_voxels[1, 0, 2] = True
n_voxels[2, 0, 1] = True
facecolors = np.where(n_voxels, '#FFD65DC0', '#7A88CCC0')
edgecolors = np.where(n_voxels, '#BFAB6E', '#7D84A6')
filled = np.ones(n_voxels.shape)

# upscale the above voxel image, leaving gaps
filled_2 = explode(filled)
fcolors_2 = explode(facecolors)
ecolors_2 = explode(edgecolors)

# Shrink the gaps
x, y, z = np.indices(np.array(filled_2.shape) + 1).astype(float) // 2
x[0::2, :, :] += 0.05
y[:, 0::2, :] += 0.05
z[:, :, 0::2] += 0.05
x[1::2, :, :] += 0.95
y[:, 1::2, :] += 0.95
z[:, :, 1::2] += 0.95

ax = plt.figure().add_subplot(projection='3d')
ax.voxels(x, y, z, filled_2, facecolors=fcolors_2,␣
 ↪edgecolors=ecolors_2)
ax.set_aspect('equal')

plt.show()
```



Tags: plot-type: 3D level: beginner purpose: fun

3D voxel / volumetric plot with RGB colors

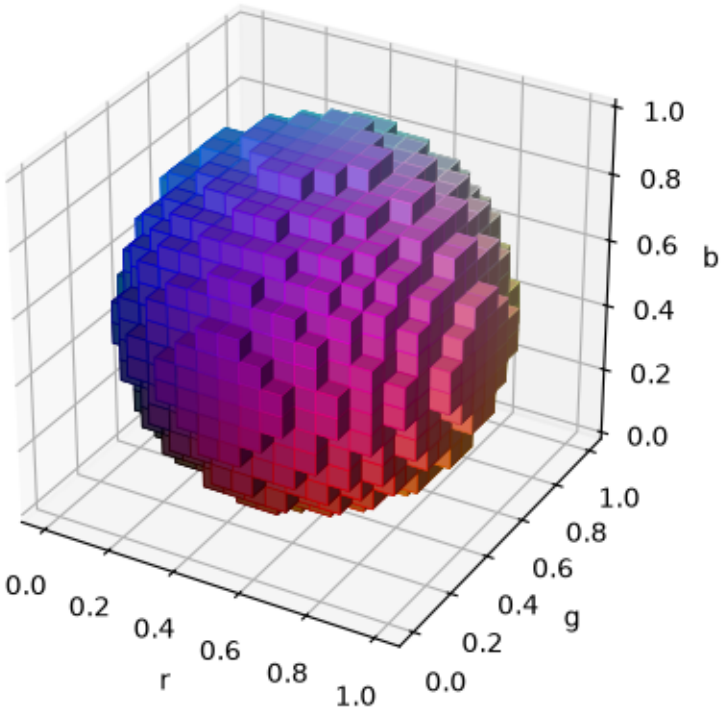
Demonstrates using *Axes3D.voxels* to visualize parts of a color space.

```
import matplotlib.pyplot as plt
import numpy as np


def midpoints(x):
    sl = ()
    for _ in range(x.ndim):
        x = (x[sl + np.index_exp[:-1]] + x[sl + np.index_exp[1:]]) /␣
 ↪2.0
        sl += np.index_exp[:]
    return x

# prepare some coordinates, and attach rgb values to each
r, g, b = np.indices((17, 17, 17)) / 16.0
rc = midpoints(r)
```

(continues on next page)

(continued from previous page)

```
gc = midpoints(g)
bc = midpoints(b)

# define a sphere about [0.5, 0.5, 0.5]
sphere = (rc - 0.5)**2 + (gc - 0.5)**2 + (bc - 0.5)**2 < 0.5**2

# combine the color components
colors = np.zeros(sphere.shape + (3,))
colors[..., 0] = rc
colors[..., 1] = gc
colors[..., 2] = bc

# and plot everything
ax = plt.figure().add_subplot(projection='3d')
ax.voxels(r, g, b, sphere,
          facecolors=colors,
          edgecolors=np.clip(2*colors - 0.5, 0, 1),  # brighter
          linewidth=0.5)
ax.set(xlabel='r', ylabel='g', zlabel='b')
ax.set_aspect('equal')

plt.show()
```



Tags: plot-type: 3D styling: color

Total running time of the script: (0 minutes 2.228 seconds)

3D voxel / volumetric plot with cylindrical coordinates

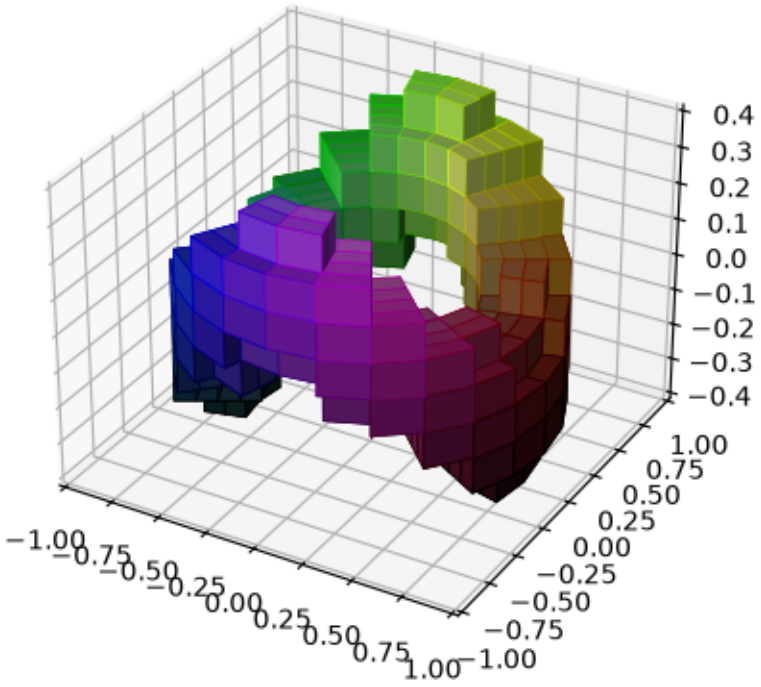
Demonstrates using the *x*, *y*, *z* parameters of *Axes3D.voxels*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.colors


def midpoints(x):
    sl = ()
    for i in range(x.ndim):
        x = (x[sl + np.index_exp[:-1]] + x[sl + np.index_exp[1:]]) /␣
 ↪2.0
        sl += np.index_exp[:]
    return x
```

(continues on next page)

(continued from previous page)

```
# prepare some coordinates, and attach rgb values to each
r, theta, z = np.mgrid[0:1:11j, 0:np.pi*2:25j, -0.5:0.5:11j]
x = r*np.cos(theta)
y = r*np.sin(theta)

rc, thetac, zc = midpoints(r), midpoints(theta), midpoints(z)

# define a wobbly torus about [0.7, *, 0]
sphere = (rc - 0.7)**2 + (zc + 0.2*np.cos(thetac*2))**2 < 0.2**2

# combine the color components
hsv = np.zeros(sphere.shape + (3,))
hsv[..., 0] = thetac / (np.pi*2)
hsv[..., 1] = rc
hsv[..., 2] = zc + 0.5
colors = matplotlib.colors.hsv_to_rgb(hsv)

# and plot everything
ax = plt.figure().add_subplot(projection='3d')
ax.voxels(x, y, z, sphere,
          facecolors=colors,
          edgecolors=np.clip(2*colors - 0.5, 0, 1),  # brighter
          linewidth=0.5)

plt.show()
```



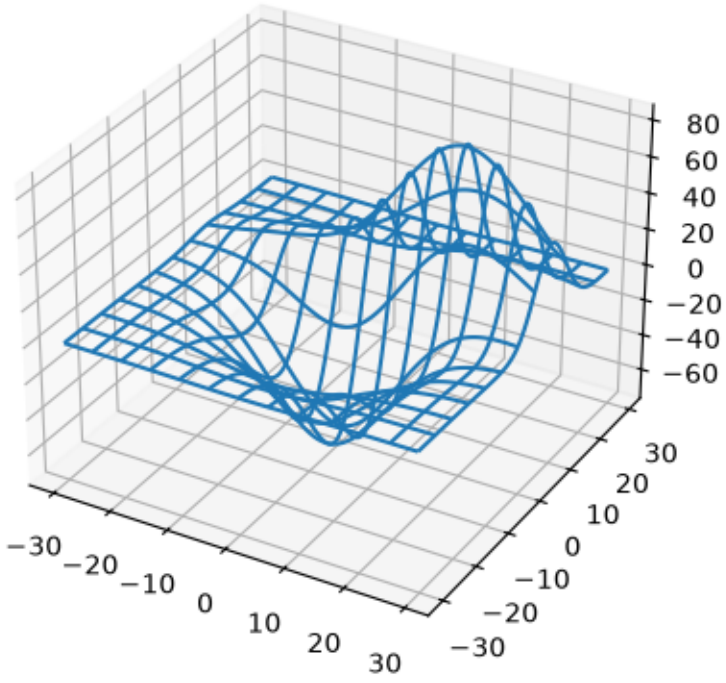
Tags: plot-type: 3D styling: color level: intermediate

Total running time of the script: (0 minutes 1.141 seconds)

3D wireframe plot

A very basic demonstration of a wireframe plot.

```
import matplotlib.pyplot as plt

from mpl_toolkits.mplot3d import axes3d

fig = plt.figure()
ax = fig.add_subplot(projection='3d')

# Grab some test data.
X, Y, Z = axes3d.get_test_data(0.05)

# Plot a basic wireframe.
ax.plot_wireframe(X, Y, Z, rstride=10, cstride=10)

plt.show()
```



Tags: plot-type: 3D level: beginner

Animate a 3D wireframe plot

A very simple "animation" of a 3D plot. See also *Rotating a 3D plot*.

```
import time

import matplotlib.pyplot as plt
import numpy as np

from matplotlib import animation

FRAMES = 25
FPS = 25

fig = plt.figure()
ax = fig.add_subplot(projection='3d')

# Make the X, Y meshgrid.
xs = np.linspace(-1, 1, 50)
```

(continues on next page)

(continued from previous page)

```
ys = np.linspace(-1, 1, 50)
X, Y = np.meshgrid(xs, ys)

# Set the z axis limits, so they aren't recalculated each frame.
ax.set_zlim(-1, 1)

# Begin plotting.
wframe = None
tstart = time.time()


def animate(i):
    global wframe
    # If a line collection is already there, remove it before drawing.
    if wframe:
        wframe.remove()
    # Generate data.
    phi = i / FRAMES * 2 * np.pi
    Z = np.cos(2 * np.pi * X + phi) * (1 - np.hypot(X, Y))
    # Plot the new wireframe.
    wframe = ax.plot_wireframe(X, Y, Z, rstride=2, cstride=2)
    if i == FRAMES - 1:  # Print FPS at the end of the loop.
        global tstart
        fps = FRAMES / (time.time() - tstart)
        print(f'Expected FPS: {FPS}; Average FPS: {fps}')
        tstart = time.time()


ani = animation.FuncAnimation(fig, animate, interval=1000 / FPS,␣
 ↪frames=FRAMES)

plt.show()
```

Tags: plot-type: 3D component: animation level: beginner

Total running time of the script: (0 minutes 6.351 seconds)

3D wireframe plots in one direction

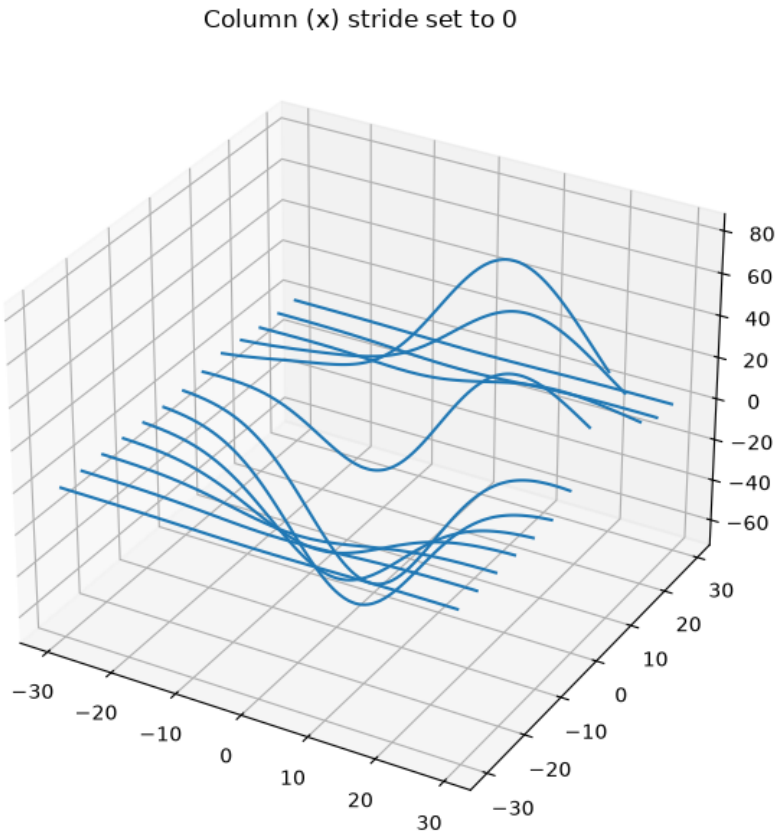
Demonstrates that setting *rstride* or *cstride* to 0 causes wires to not be generated in the corresponding direction.

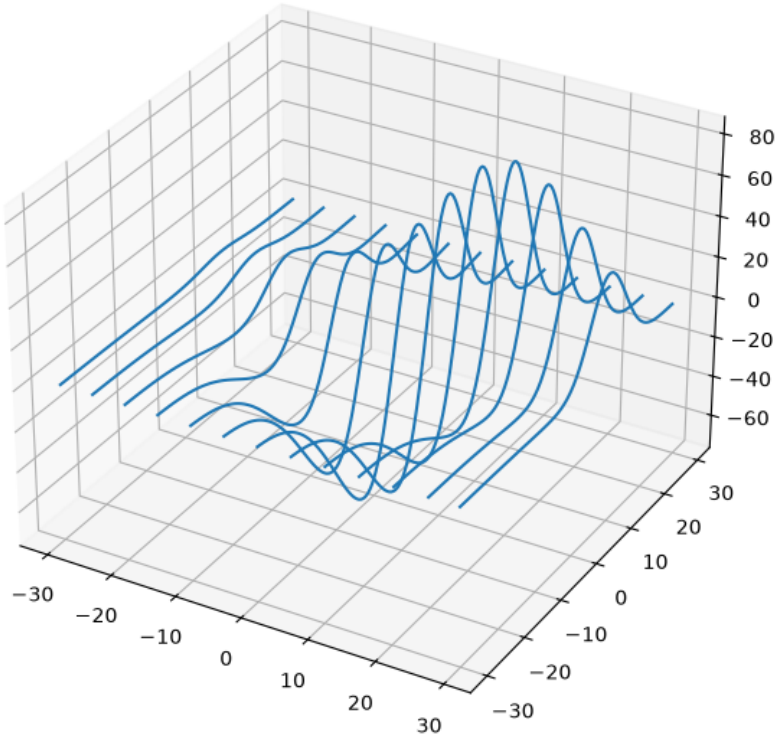
```
import matplotlib.pyplot as plt

from mpl_toolkits.mplot3d import axes3d

fig, (ax1, ax2) = plt.subplots(
```

(continues on next page)

(continued from previous page)

```
    2, 1, figsize=(8, 12), subplot_kw={'projection': '3d'})

# Get the test data
X, Y, Z = axes3d.get_test_data(0.05)

# Give the first plot only wireframes of the type y = c
ax1.plot_wireframe(X, Y, Z, rstride=10, cstride=0)
ax1.set_title("Column (x) stride set to 0")

# Give the second plot only wireframes of the type x = c
ax2.plot_wireframe(X, Y, Z, rstride=0, cstride=10)
ax2.set_title("Row (y) stride set to 0")

plt.tight_layout()
plt.show()
```


Column (x) stride set to 0
80
60
40
20
0
−20
−40
−60
−30
−20
−10
0
10
20
30
30
20
10
0
−10
−20
−30

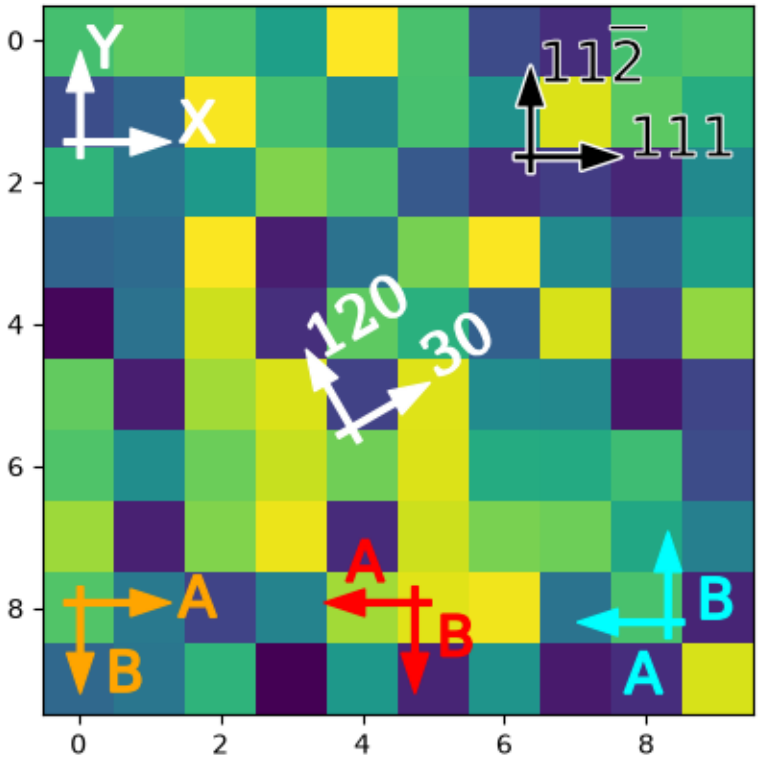

Row (y) stride set to 0
80
60
40
20
0
−20
−40
−60
−30
−20
−10
0
10
20
30
30
20
10
0
−10
−20
−30

Tags: plot-type: 3D level: intermediate

Total running time of the script: (0 minutes 1.058 seconds)

6.24.15 Module - axes_grid1

Anchored Direction Arrow




```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.font_manager as fm
from mpl_toolkits.axes_grid1.anchored_artists import␣
 ↪AnchoredDirectionArrows

# Fixing random state for reproducibility
np.random.seed(19680801)

fig, ax = plt.subplots()
ax.imshow(np.random.random((10, 10)))
```

(continues on next page)

(continued from previous page)

```
# Simple example
simple_arrow = AnchoredDirectionArrows(ax.transAxes, 'X', 'Y')
ax.add_artist(simple_arrow)

# High contrast arrow
high_contrast_part_1 = AnchoredDirectionArrows(
                           ax.transAxes,
                           '111', r'11$\overline{2}$',
                           loc='upper right',
                           arrow_props={'ec': 'w', 'fc': 'none',
 ↪'alpha': 1,
                                        'lw': 2}
                           )
ax.add_artist(high_contrast_part_1)

high_contrast_part_2 = AnchoredDirectionArrows(
                           ax.transAxes,
                           '111', r'11$\overline{2}$',
                           loc='upper right',
                           arrow_props={'ec': 'none', 'fc': 'k'},
                           text_props={'ec': 'w', 'fc': 'k', 'lw':␣
 ↪0.4}
                           )
ax.add_artist(high_contrast_part_2)

# Rotated arrow
fontprops = fm.FontProperties(family='serif')

rotated_arrow = AnchoredDirectionArrows(
                    ax.transAxes,
                    '30', '120',
                    loc='center',
                    color='w',
                    angle=30,
                    fontproperties=fontprops
                    )
ax.add_artist(rotated_arrow)

# Altering arrow directions
a1 = AnchoredDirectionArrows(
        ax.transAxes, 'A', 'B', loc='lower center',
        length=-0.15,
        sep_x=0.03, sep_y=0.03,
        color='r'
    )
ax.add_artist(a1)
```

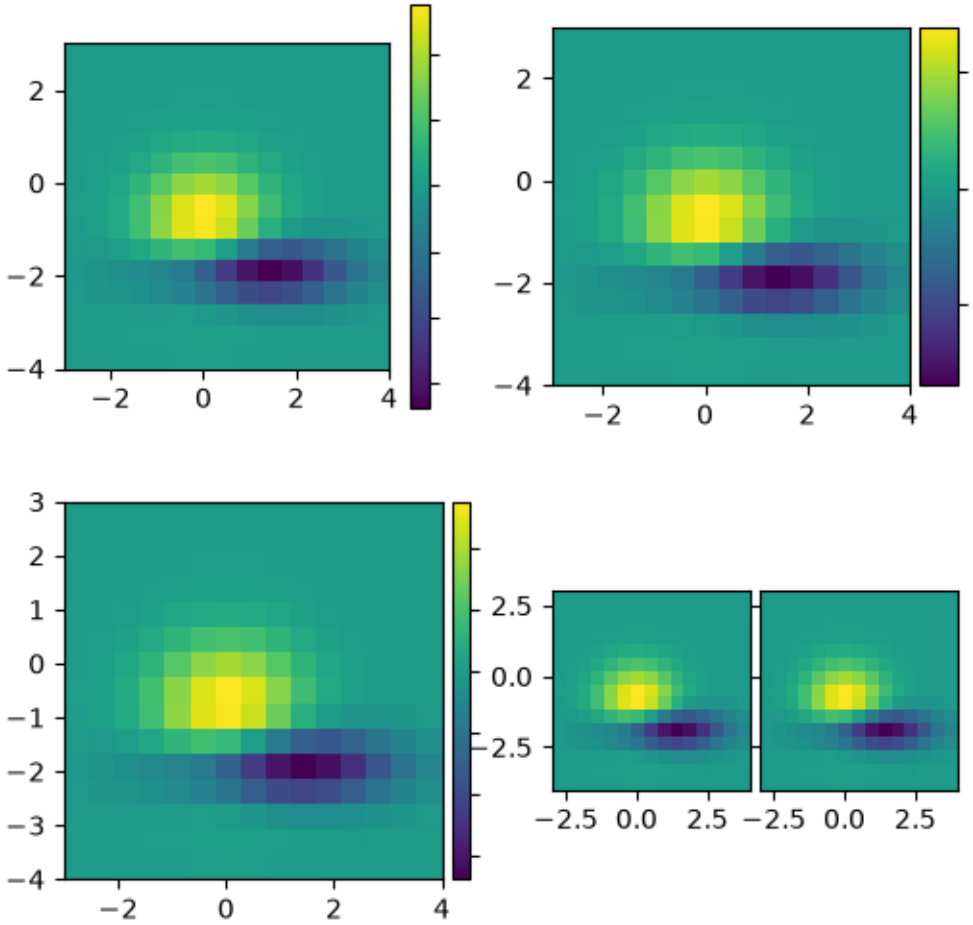
(continues on next page)

(continued from previous page)

```
a2 = AnchoredDirectionArrows(
        ax.transAxes, 'A', ' B', loc='lower left',
        aspect_ratio=-1,
        sep_x=0.01, sep_y=-0.02,
        color='orange'
        )
ax.add_artist(a2)


a3 = AnchoredDirectionArrows(
        ax.transAxes, ' A', 'B', loc='lower right',
        length=-0.15,
        aspect_ratio=-1,
        sep_y=-0.1, sep_x=0.04,
        color='cyan'
        )
ax.add_artist(a3)

plt.show()
```

Axes divider

Axes divider to calculate location of Axes and create a divider for them using existing Axes instances.




```
import matplotlib.pyplot as plt

from matplotlib import cbook


def get_demo_image():
    z = cbook.get_sample_data("axes_grid/bivariate_normal.npy")   #␣
 ↪15x15 array
    return z, (-3, 4, -4, 3)


def demo_simple_image(ax):
    Z, extent = get_demo_image()
```

(continues on next page)

(continued from previous page)

```
    im = ax.imshow(Z, extent=extent)
    cb = plt.colorbar(im)
    cb.ax.yaxis.set_tick_params(labelright=False)


def demo_locatable_axes_hard(fig):
    from mpl_toolkits.axes_grid1 import Size, SubplotDivider

    divider = SubplotDivider(fig, 2, 2, 2, aspect=True)

    # Axes for image
    ax = fig.add_subplot(axes_locator=divider.new_locator(nx=0, ny=0))
    # Axes for colorbar
    ax_cb = fig.add_subplot(axes_locator=divider.new_locator(nx=2,␣
 ↪ny=0))

    divider.set_horizontal([
        Size.AxesX(ax),  # main Axes
        Size.Fixed(0.05),  # padding, 0.1 inch
        Size.Fixed(0.2),  # colorbar, 0.3 inch
    ])
    divider.set_vertical([Size.AxesY(ax)])

    Z, extent = get_demo_image()

    im = ax.imshow(Z, extent=extent)
    plt.colorbar(im, cax=ax_cb)
    ax_cb.yaxis.set_tick_params(labelright=False)


def demo_locatable_axes_easy(ax):
    from mpl_toolkits.axes_grid1 import make_axes_locatable

    divider = make_axes_locatable(ax)

    ax_cb = divider.append_axes("right", size="5%", pad=0.05)
    fig = ax.get_figure()
    fig.add_axes(ax_cb)

    Z, extent = get_demo_image()
    im = ax.imshow(Z, extent=extent)

    plt.colorbar(im, cax=ax_cb)
    ax_cb.yaxis.tick_right()
    ax_cb.yaxis.set_tick_params(labelright=False)
```

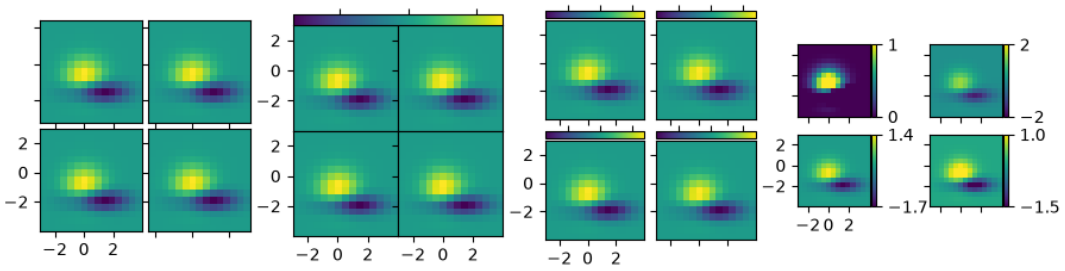
(continues on next page)

(continued from previous page)

```
def demo_images_side_by_side(ax):
    from mpl_toolkits.axes_grid1 import make_axes_locatable

    divider = make_axes_locatable(ax)

    Z, extent = get_demo_image()
    ax2 = divider.append_axes("right", size="100%", pad=0.05)
    fig1 = ax.get_figure()
    fig1.add_axes(ax2)

    ax.imshow(Z, extent=extent)
    ax2.imshow(Z, extent=extent)
    ax2.yaxis.set_tick_params(labelleft=False)


def demo():
    fig = plt.figure(figsize=(6, 6))

    # PLOT 1
    # simple image & colorbar
    ax = fig.add_subplot(2, 2, 1)
    demo_simple_image(ax)

    # PLOT 2
    # image and colorbar with draw-time positioning -- a hard way
    demo_locatable_axes_hard(fig)

    # PLOT 3
    # image and colorbar with draw-time positioning -- an easy way
    ax = fig.add_subplot(2, 2, 3)
    demo_locatable_axes_easy(ax)

    # PLOT 4
    # two images side by side with fixed padding.
    ax = fig.add_subplot(2, 2, 4)
    demo_images_side_by_side(ax)

    plt.show()


demo()
```

Demo Axes Grid

Grid of 2x2 images with a single colorbar or with one colorbar per Axes.



```
import matplotlib.pyplot as plt

from matplotlib import cbook
from mpl_toolkits.axes_grid1 import ImageGrid

fig = plt.figure(figsize=(10.5, 2.5))
Z = cbook.get_sample_data("axes_grid/bivariate_normal.npy")  # 15x15␣
 ↪array
extent = (-3, 4, -4, 3)


# A grid of 2x2 images with 0.05 inch pad between images and only the
# lower-left Axes is labeled.
grid = ImageGrid(
    fig, 141,  # similar to fig.add_subplot(141).
     nrows_ncols=(2, 2), axes_pad=0.05, label_mode="1")
for ax in grid:
    ax.imshow(Z, extent=extent)
# This only affects Axes in first column and second row as␣
 ↪share_all=False.
grid.axes_llc.set(xticks=[-2, 0, 2], yticks=[-2, 0, 2])


# A grid of 2x2 images with a single colorbar.
grid = ImageGrid(
    fig, 142,  # similar to fig.add_subplot(142).
    nrows_ncols=(2, 2), axes_pad=0.0, label_mode="L", share_all=True,
    cbar_location="top", cbar_mode="single")
for ax in grid:
    im = ax.imshow(Z, extent=extent)
grid.cbar_axes[0].colorbar(im)
for cax in grid.cbar_axes:
    cax.tick_params(labeltop=False)
# This affects all Axes as share_all = True.
grid.axes_llc.set(xticks=[-2, 0, 2], yticks=[-2, 0, 2])
```

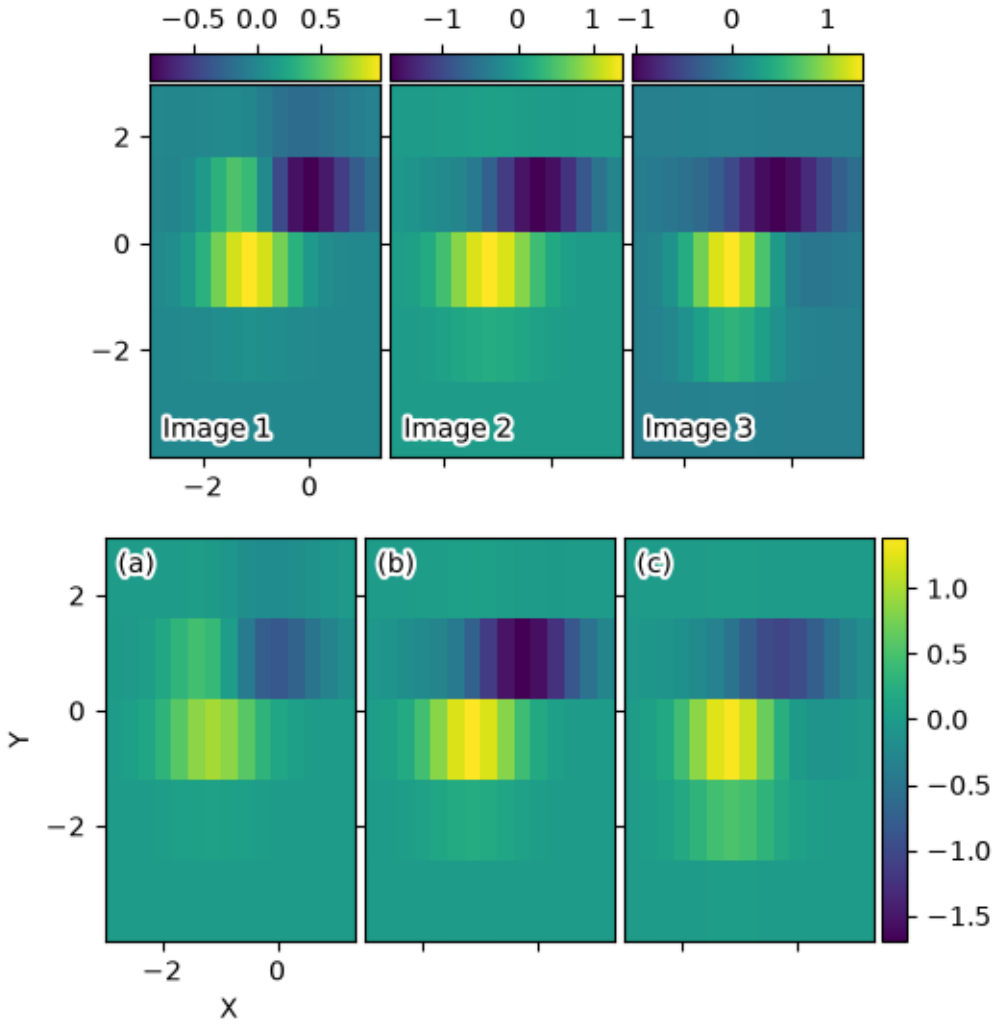
(continues on next page)

(continued from previous page)

```
# A grid of 2x2 images. Each image has its own colorbar.
grid = ImageGrid(
    fig, 143,  # similar to fig.add_subplot(143).
    nrows_ncols=(2, 2), axes_pad=0.1, label_mode="1", share_all=True,
    cbar_location="top", cbar_mode="each", cbar_size="7%", cbar_pad="2%
 ↪")
for ax, cax in zip(grid, grid.cbar_axes):
    im = ax.imshow(Z, extent=extent)
    cax.colorbar(im)
    cax.tick_params(labeltop=False)
# This affects all Axes as share_all = True.
grid.axes_llc.set(xticks=[-2, 0, 2], yticks=[-2, 0, 2])


# A grid of 2x2 images. Each image has its own colorbar.
grid = ImageGrid(
    fig, 144,  # similar to fig.add_subplot(144).
    nrows_ncols=(2, 2), axes_pad=(0.45, 0.15), label_mode="1",␣
 ↪share_all=True,
    cbar_location="right", cbar_mode="each", cbar_size="7%", cbar_pad=
 ↪"2%")
# Use a different colorbar range every time
limits = ((0, 1), (-2, 2), (-1.7, 1.4), (-1.5, 1))
for ax, cax, vlim in zip(grid, grid.cbar_axes, limits):
    im = ax.imshow(Z, extent=extent, vmin=vlim[0], vmax=vlim[1])
    cb = cax.colorbar(im)
    cb.set_ticks((vlim[0], vlim[1]))
# This affects all Axes as share_all = True.
grid.axes_llc.set(xticks=[-2, 0, 2], yticks=[-2, 0, 2])


plt.show()
```

Axes Grid2

Grid of images with shared xaxis and yaxis.




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import cbook
from mpl_toolkits.axes_grid1 import ImageGrid


def add_inner_title(ax, title, loc, **kwargs):
    from matplotlib.offsetbox import AnchoredText
    from matplotlib.patheffects import withStroke
    prop = dict(path_effects=[withStroke(foreground='w', linewidth=3)],
                size=plt.rcParams['legend.fontsize'])
    at = AnchoredText(title, loc=loc, prop=prop,
                      pad=0., borderpad=0.5,
```

(continues on next page)

(continued from previous page)

```
                          frameon=False, **kwargs)
    ax.add_artist(at)
    return at


fig = plt.figure(figsize=(6, 6))

# Prepare images
Z = cbook.get_sample_data("axes_grid/bivariate_normal.npy")
extent = (-3, 4, -4, 3)
ZS = [Z[i::3, :] for i in range(3)]
extent = extent[0], extent[1]/3., extent[2], extent[3]

# *** Demo 1: colorbar at each Axes ***
grid = ImageGrid(
    # 211 = at the position of fig.add_subplot(211)
    fig, 211, nrows_ncols=(1, 3), axes_pad=0.05, label_mode="1",␣
 ↪share_all=True,
    cbar_location="top", cbar_mode="each", cbar_size="7%", cbar_pad="1%
 ↪")
grid[0].set(xticks=[-2, 0], yticks=[-2, 0, 2])

for i, (ax, z) in enumerate(zip(grid, ZS)):
    im = ax.imshow(z, origin="lower", extent=extent)
    cb = ax.cax.colorbar(im)
    # Changing the colorbar ticks
    if i in [1, 2]:
        cb.set_ticks([-1, 0, 1])

for ax, im_title in zip(grid, ["Image 1", "Image 2", "Image 3"]):
    add_inner_title(ax, im_title, loc='lower left')

# *** Demo 2: shared colorbar ***
grid2 = ImageGrid(
    fig, 212, nrows_ncols=(1, 3), axes_pad=0.05, label_mode="1",␣
 ↪share_all=True,
    cbar_location="right", cbar_mode="single", cbar_size="10%",␣
 ↪cbar_pad=0.05)
grid2[0].set(xlabel="X", ylabel="Y", xticks=[-2, 0], yticks=[-2, 0, 2])

clim = (np.min(ZS), np.max(ZS))
for ax, z in zip(grid2, ZS):
    im = ax.imshow(z, clim=clim, origin="lower", extent=extent)

# With cbar_mode="single", cax attribute of all Axes are identical.
ax.cax.colorbar(im)
```

(continues on next page)

(continued from previous page)

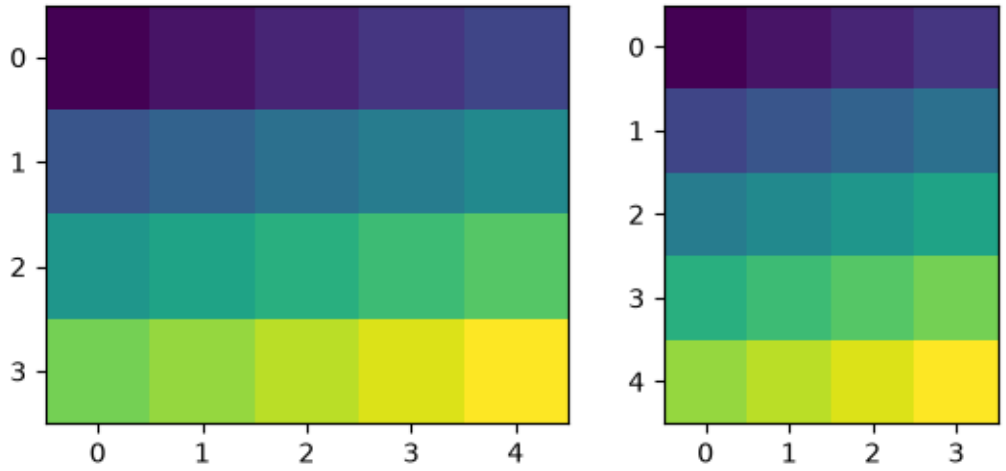
```
for ax, im_title in zip(grid2, ["(a)", "(b)", "(c)"]):
    add_inner_title(ax, im_title, loc='upper left')

plt.show()
```

HBoxDivider and VBoxDivider demo

Using an *HBoxDivider* to arrange subplots.

Note that both Axes' location are adjusted so that they have equal heights while maintaining their aspect ratios.

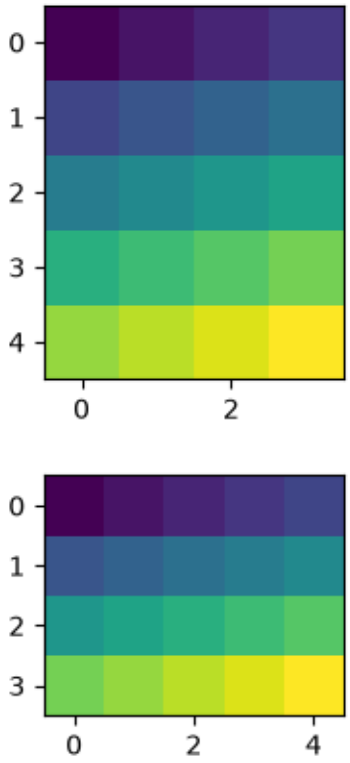
```
import matplotlib.pyplot as plt
import numpy as np

from mpl_toolkits.axes_grid1.axes_divider import HBoxDivider,␣
 ↪VBoxDivider
import mpl_toolkits.axes_grid1.axes_size as Size

arr1 = np.arange(20).reshape((4, 5))
arr2 = np.arange(20).reshape((5, 4))

fig, (ax1, ax2) = plt.subplots(1, 2)
ax1.imshow(arr1)
ax2.imshow(arr2)

pad = 0.5  # pad in inches
divider = HBoxDivider(
    fig, 111,
    horizontal=[Size.AxesX(ax1), Size.Fixed(pad), Size.AxesX(ax2)],
    vertical=[Size.AxesY(ax1), Size.Scaled(1), Size.AxesY(ax2)])
ax1.set_axes_locator(divider.new_locator(0))
ax2.set_axes_locator(divider.new_locator(2))

plt.show()
```



Using a *VBoxDivider* to arrange subplots.

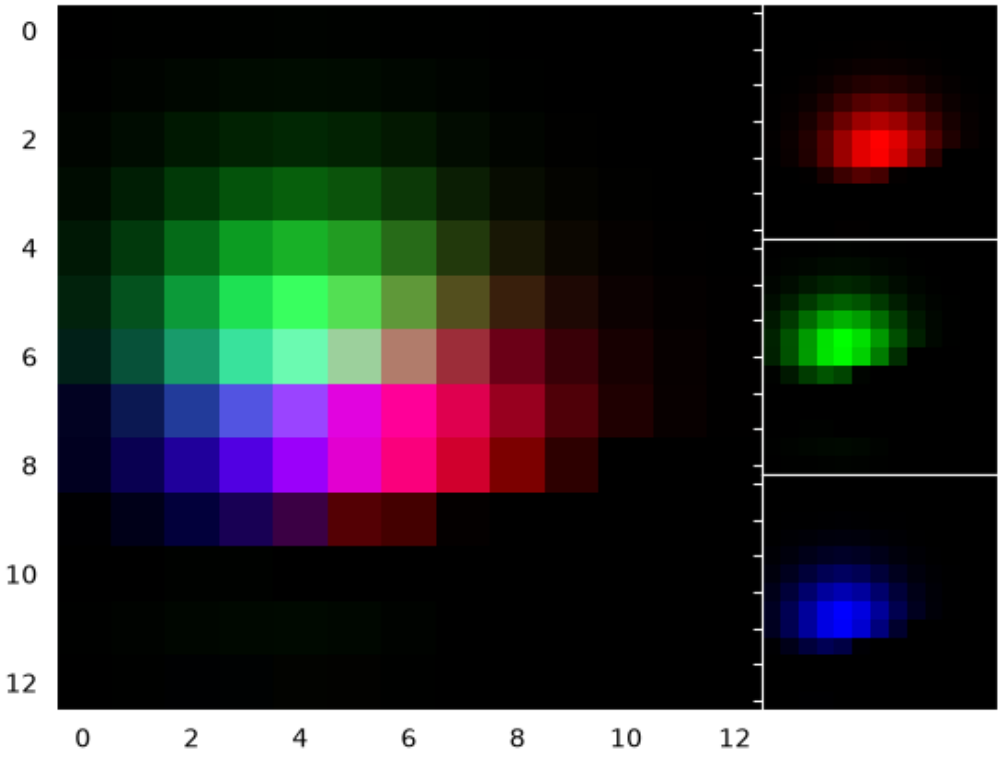
Note that both Axes' location are adjusted so that they have equal widths while maintaining their aspect ratios.

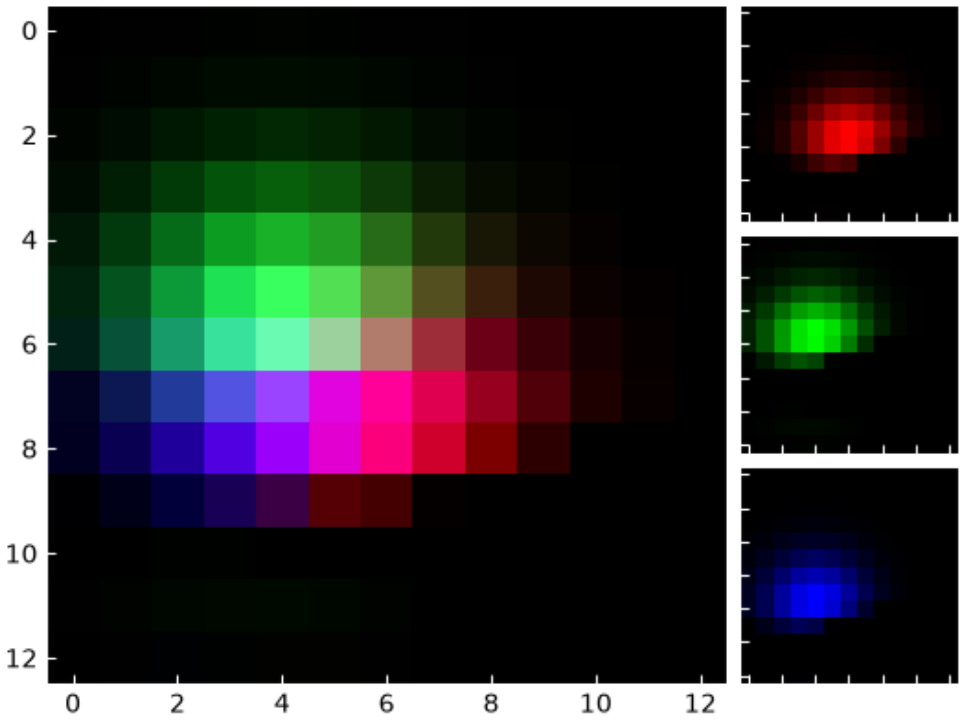
```
fig, (ax1, ax2) = plt.subplots(2, 1)
ax1.imshow(arr1)
ax2.imshow(arr2)

divider = VBoxDivider(
    fig, 111,
    horizontal=[Size.AxesX(ax1), Size.Scaled(1), Size.AxesX(ax2)],
    vertical=[Size.AxesY(ax1), Size.Fixed(pad), Size.AxesY(ax2)])

ax1.set_axes_locator(divider.new_locator(0))
ax2.set_axes_locator(divider.new_locator(2))

plt.show()
```



Show RGB channels using RGBAxes

`RGBAxes` creates a layout of 4 Axes for displaying RGB channels: one large Axes for the RGB image and 3 smaller Axes for the R, G, B channels.


0
2
4
6
8
10
12
0
2
4
6
8
10
12



-

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import cbook
from mpl_toolkits.axes_grid1.axes_rgb import RGBAxes, make_rgb_axes


def get_rgb():
    Z = cbook.get_sample_data("axes_grid/bivariate_normal.npy")
    Z[Z < 0] = 0.
    Z = Z / Z.max()

    R = Z[:13, :13]
    G = Z[2:, 2:]
    B = Z[:13, 2:]

    return R, G, B


def make_cube(r, g, b):
    ny, nx = r.shape
```

(continues on next page)

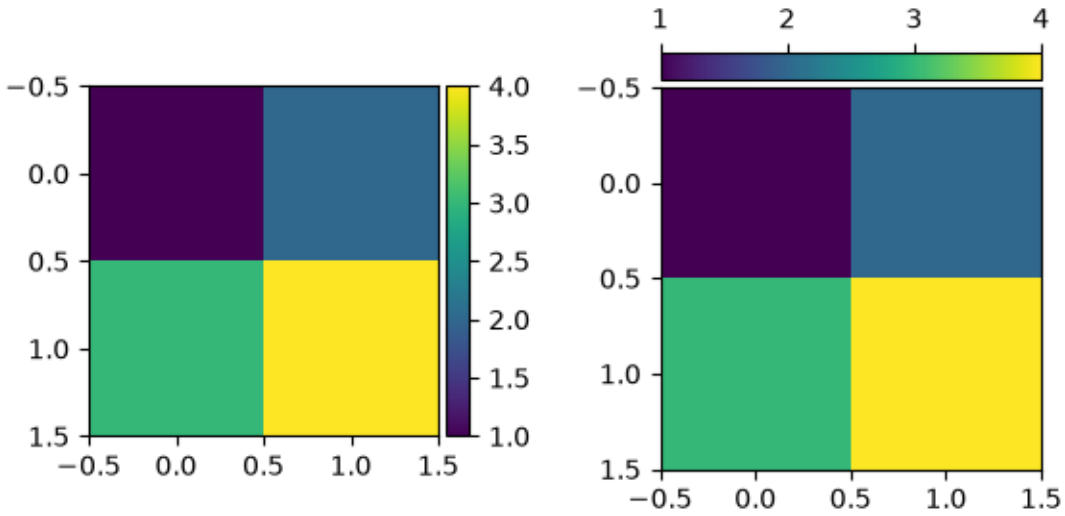
(continued from previous page)

```
    R = np.zeros((ny, nx, 3))
    R[:, :, 0] = r
    G = np.zeros_like(R)
    G[:, :, 1] = g
    B = np.zeros_like(R)
    B[:, :, 2] = b

    RGB = R + G + B

    return R, G, B, RGB


def demo_rgb1():
    fig = plt.figure()
    ax = RGBAxes(fig, [0.1, 0.1, 0.8, 0.8], pad=0.0)
    r, g, b = get_rgb()
    ax.imshow_rgb(r, g, b)


def demo_rgb2():
    fig, ax = plt.subplots()
    ax_r, ax_g, ax_b = make_rgb_axes(ax, pad=0.02)

    r, g, b = get_rgb()
    im_r, im_g, im_b, im_rgb = make_cube(r, g, b)
    ax.imshow(im_rgb)
    ax_r.imshow(im_r)
    ax_g.imshow(im_g)
    ax_b.imshow(im_b)

    for ax in fig.axes:
        ax.tick_params(direction='in', color='w')
        ax.spines[:].set_color("w")


demo_rgb1()
demo_rgb2()

plt.show()
```

Colorbar with AxesDivider

The *axes_divider.make_axes_locatable* function takes an existing Axes, adds it to a new *AxesDivider* and returns the *AxesDivider*. The *append_axes* method of the *AxesDivider* can then be used to create a new Axes on a given side ("top", "right", "bottom", or "left") of the original Axes. This example uses *append_axes* to add colorbars next to Axes.

Users should consider simply passing the main Axes to the *ax* keyword argument of `colorbar` instead of creating a locatable Axes manually like this. See *Placing colorbars*.




```
import matplotlib.pyplot as plt

from mpl_toolkits.axes_grid1.axes_divider import make_axes_locatable

fig, (ax1, ax2) = plt.subplots(1, 2)
fig.subplots_adjust(wspace=0.5)

im1 = ax1.imshow([[1, 2], [3, 4]])
ax1_divider = make_axes_locatable(ax1)
# Add an Axes to the right of the main Axes.
cax1 = ax1_divider.append_axes("right", size="7%", pad="2%")
cb1 = fig.colorbar(im1, cax=cax1)

im2 = ax2.imshow([[1, 2], [3, 4]])
ax2_divider = make_axes_locatable(ax2)
# Add an Axes above the main Axes.
cax2 = ax2_divider.append_axes("top", size="7%", pad="2%")
cb2 = fig.colorbar(im2, cax=cax2, orientation="horizontal")
```

(continues on next page)

(continued from previous page)

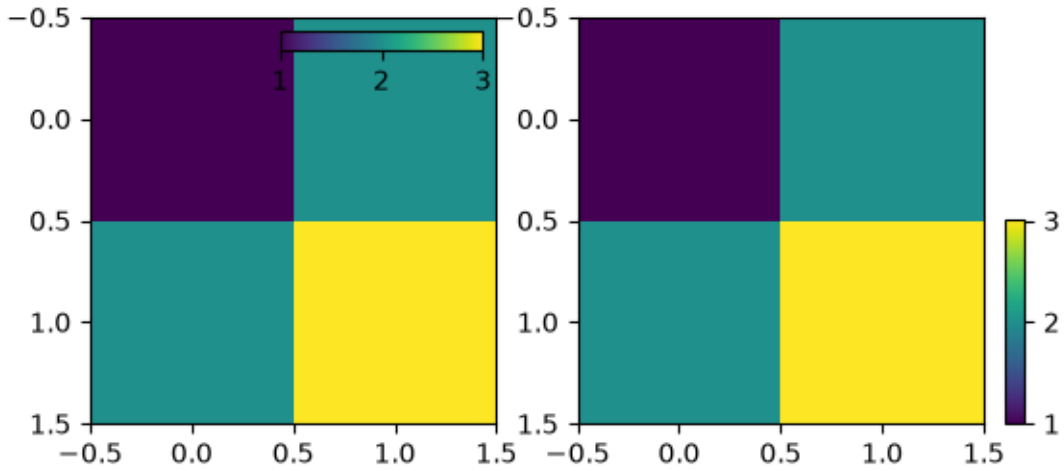
```
# Change tick position to top (with the default tick position
 ↪"bottom", ticks
# overlap the image).
cax2.xaxis.set_ticks_position("top")

plt.show()
```

Control the position and size of a colorbar with inset_locator.inset_axes

This example shows how to control the position, height, and width of colorbars using *inset_locator.inset_axes*.

inset_locator.inset_axes placement is controlled as for legends: either by providing a *loc* option ("upper right", "best", ...), or by providing a locator with respect to the parent bbox. Parameters such as *bbox_to_anchor* and *borderpad* likewise work in the same way, and are also demonstrated here.

Users should consider using *Axes.inset_axes* instead (see *Placing colorbars*).




```
import matplotlib.pyplot as plt

from mpl_toolkits.axes_grid1 import inset_locator

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=[6, 3])

im1 = ax1.imshow([[1, 2], [2, 3]])
axins1 = inset_locator.inset_axes(
    ax1,
    width="50%",  # width: 50% of parent_bbox width
    height="5%",  # height: 5%
    loc="upper right",
```

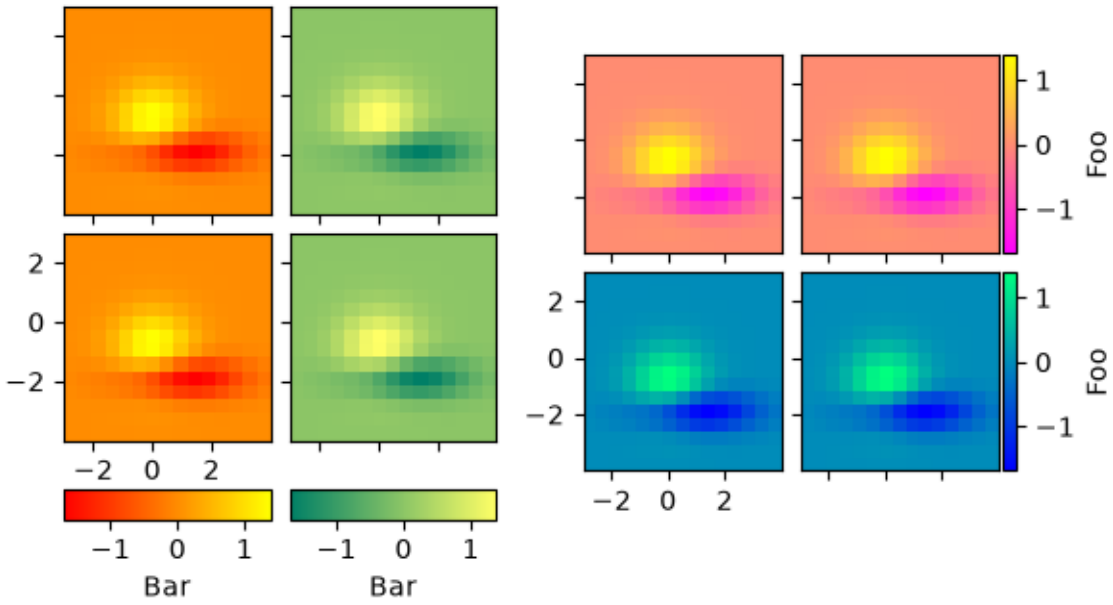
(continues on next page)

(continued from previous page)

```
)
axins1.xaxis.set_ticks_position("bottom")
fig.colorbar(im1, cax=axins1, orientation="horizontal", ticks=[1, 2,␣
↪3])

im = ax2.imshow([[1, 2], [2, 3]])
axins = inset_locator.inset_axes(
    ax2,
    width="5%",  # width: 5% of parent_bbox width
    height="50%",  # height: 50%
    loc="lower left",
    bbox_to_anchor=(1.05, 0., 1, 1),
    bbox_transform=ax2.transAxes,
    borderpad=0,
)
fig.colorbar(im, cax=axins, ticks=[1, 2, 3])

plt.show()
```

Per-row or per-column colorbars

This example shows how to use one common colorbar for each row or column of an image grid.




```
import matplotlib.pyplot as plt

from matplotlib import cbook
from mpl_toolkits.axes_grid1 import AxesGrid


def get_demo_image():
    z = cbook.get_sample_data("axes_grid/bivariate_normal.npy")   #␣
 ↪15x15 array
    return z, (-3, 4, -4, 3)


def demo_bottom_cbar(fig):
    """
    A grid of 2x2 images with a colorbar for each column.
    """
    grid = AxesGrid(fig, 121,  # similar to subplot(121)
                    nrows_ncols=(2, 2),
                    axes_pad=0.10,
                    share_all=True,
```

(continues on next page)

(continued from previous page)

```
                    label_mode="1",
                    cbar_location="bottom",
                    cbar_mode="edge",
                    cbar_pad=0.25,
                    cbar_size="15%",
                    direction="column"
                    )

    Z, extent = get_demo_image()
    cmaps = ["autumn", "summer"]
    for i in range(4):
        im = grid[i].imshow(Z, extent=extent, cmap=cmaps[i//2])
        if i % 2:
            grid.cbar_axes[i//2].colorbar(im)

    for cax in grid.cbar_axes:
        cax.axis[cax.orientation].set_label("Bar")

    # This affects all Axes as share_all = True.
    grid.axes_llc.set_xticks([-2, 0, 2])
    grid.axes_llc.set_yticks([-2, 0, 2])


def demo_right_cbar(fig):
    """
    A grid of 2x2 images. Each row has its own colorbar.
    """
    grid = AxesGrid(fig, 122,  # similar to subplot(122)
                    nrows_ncols=(2, 2),
                    axes_pad=0.10,
                    label_mode="1",
                    share_all=True,
                    cbar_location="right",
                    cbar_mode="edge",
                    cbar_size="7%",
                    cbar_pad="2%",
                    )
    Z, extent = get_demo_image()
    cmaps = ["spring", "winter"]
    for i in range(4):
        im = grid[i].imshow(Z, extent=extent, cmap=cmaps[i//2])
        if i % 2:
            grid.cbar_axes[i//2].colorbar(im)

    for cax in grid.cbar_axes:
        cax.axis[cax.orientation].set_label('Foo')
```

(continues on next page)

(continued from previous page)

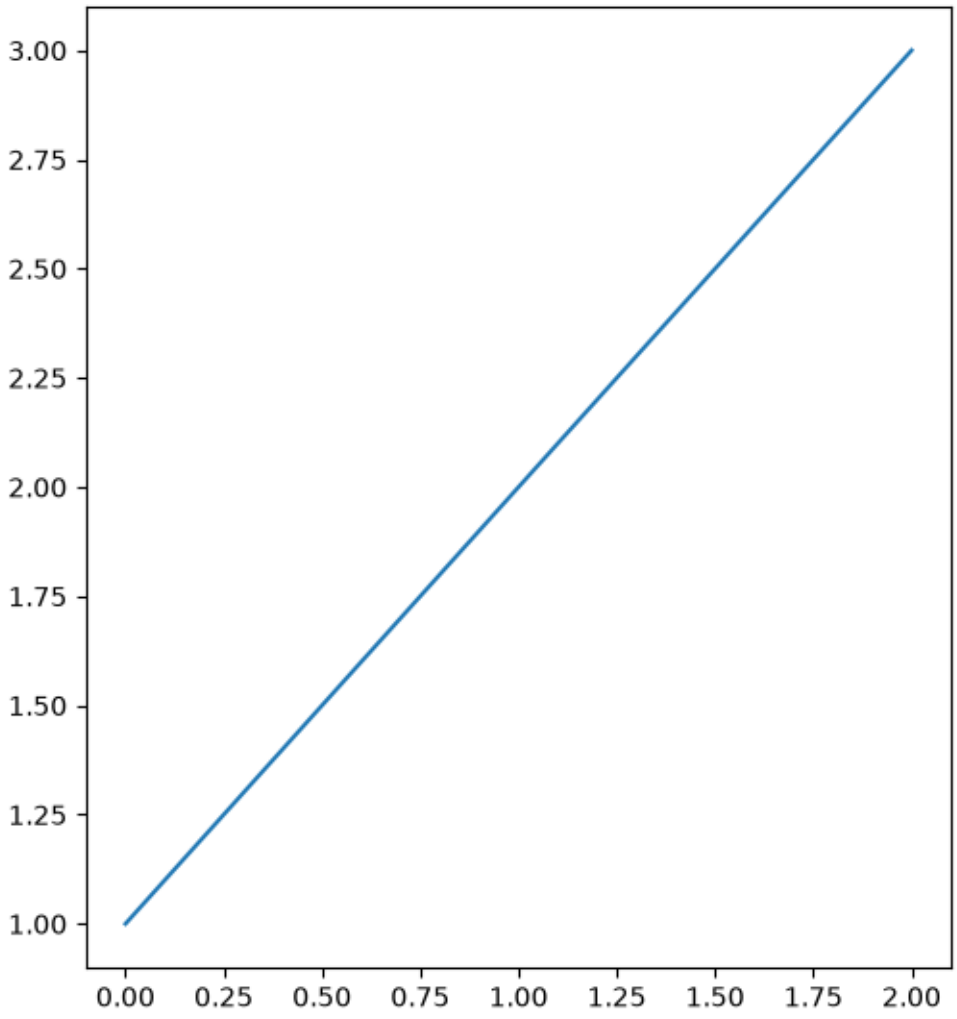
```
    # This affects all Axes because we set share_all = True.
    grid.axes_llc.set_xticks([-2, 0, 2])
    grid.axes_llc.set_yticks([-2, 0, 2])


fig = plt.figure()

demo_bottom_cbar(fig)
demo_right_cbar(fig)

plt.show()
```

Axes with a fixed physical size

Note that this can be accomplished with the main library for Axes on Figures that do not change size: *Adding single Axes at a time*

```
import matplotlib.pyplot as plt

from mpl_toolkits.axes_grid1 import Divider, Size
```

```
fig = plt.figure(figsize=(6, 6))

# The first items are for padding and the second items are for the␣
 ↪Axes.
# sizes are in inch.
h = [Size.Fixed(1.0), Size.Fixed(4.5)]
v = [Size.Fixed(0.7), Size.Fixed(5.)]

divider = Divider(fig, (0, 0, 1, 1), h, v, aspect=False)
# The width and height of the rectangle are ignored.

ax = fig.add_axes(divider.get_position(),
                  axes_locator=divider.new_locator(nx=1, ny=1))

ax.plot([1, 2, 3])
```

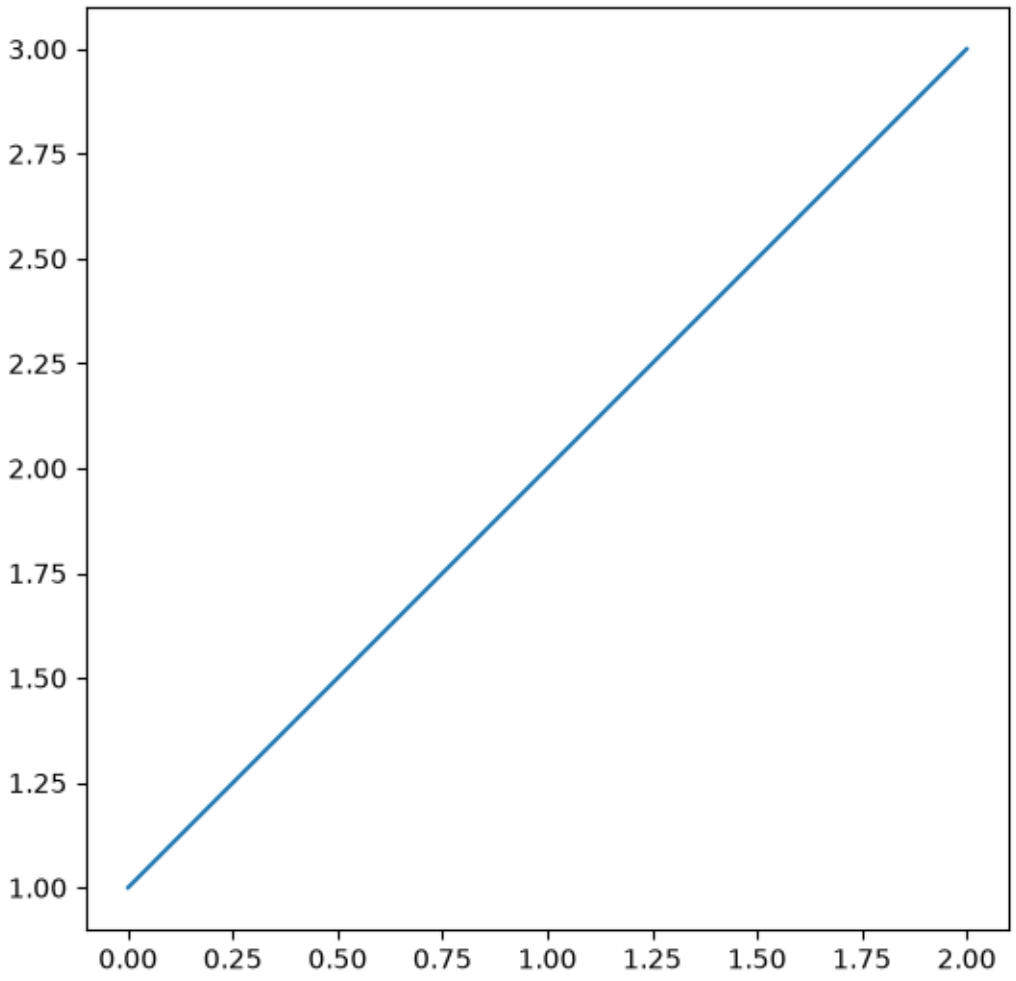



```
fig = plt.figure(figsize=(6, 6))

# The first & third items are for padding and the second items are for␣
 ↪the
# Axes. Sizes are in inches.
h = [Size.Fixed(1.0), Size.Scaled(1.), Size.Fixed(.2)]
v = [Size.Fixed(0.7), Size.Scaled(1.), Size.Fixed(.5)]

divider = Divider(fig, (0, 0, 1, 1), h, v, aspect=False)
# The width and height of the rectangle are ignored.

ax = fig.add_axes(divider.get_position(),
                  axes_locator=divider.new_locator(nx=1, ny=1))
```

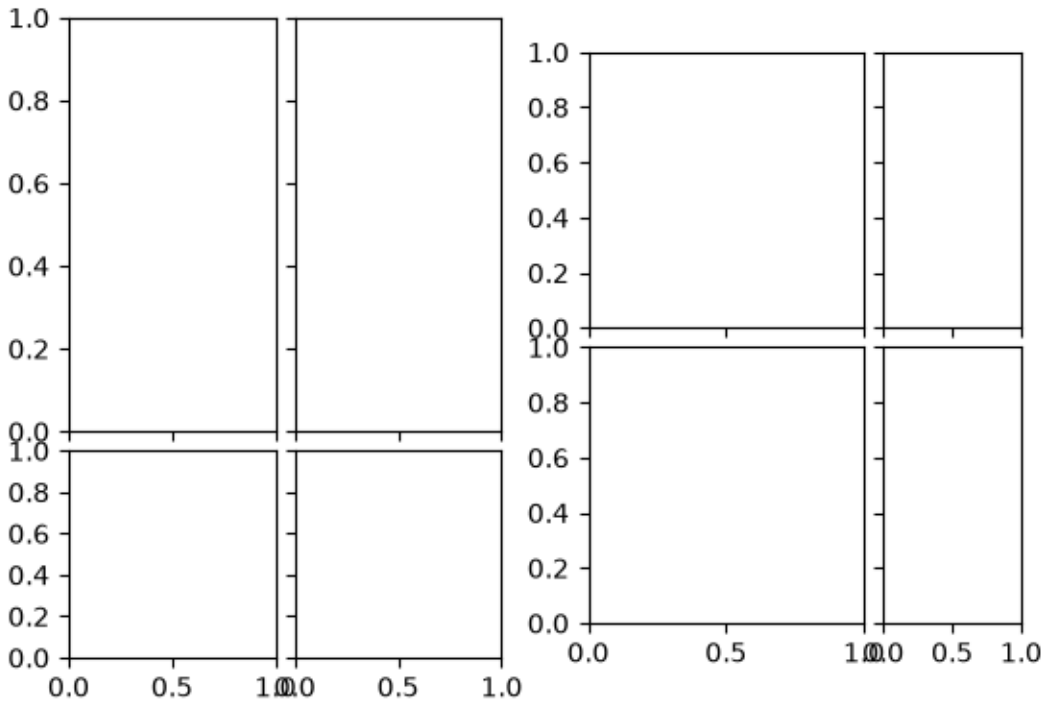
(continues on next page)

(continued from previous page)

```
ax.plot([1, 2, 3])

plt.show()
```



ImageGrid cells with a fixed aspect ratio

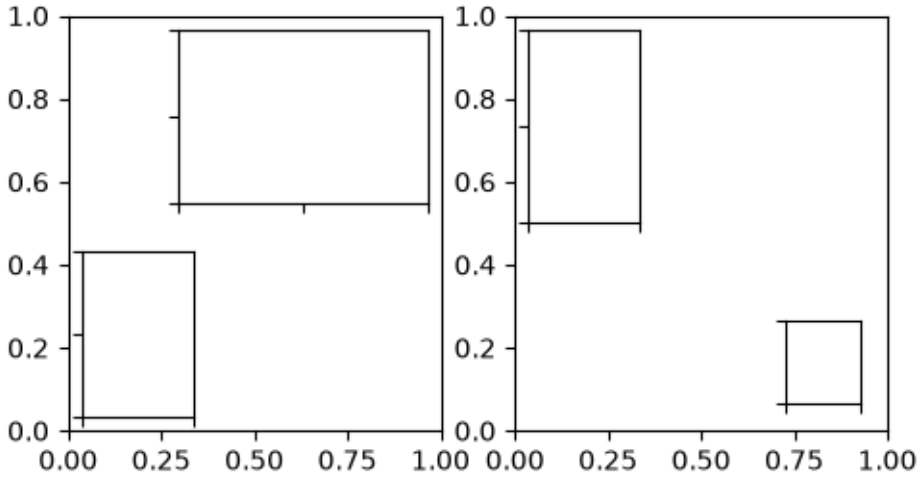



```
import matplotlib.pyplot as plt

from mpl_toolkits.axes_grid1 import ImageGrid

fig = plt.figure()

grid1 = ImageGrid(fig, 121, (2, 2), axes_pad=0.1,
                  aspect=True, share_all=True)
for i in [0, 1]:
    grid1[i].set_aspect(2)

grid2 = ImageGrid(fig, 122, (2, 2), axes_pad=0.1,
                  aspect=True, share_all=True)
for i in [1, 3]:
    grid2[i].set_aspect(2)

plt.show()
```

Inset locator demo

The *inset_locator*'s *inset_axes* allows easily placing insets in the corners of the Axes by specifying a width and height and optionally a location (loc) that accepts locations as codes, similar to *legend*. By default, the inset is offset by some points from the axes, controlled via the *borderpad* parameter.

```
import matplotlib.pyplot as plt

from mpl_toolkits.axes_grid1.inset_locator import inset_axes

fig, (ax, ax2) = plt.subplots(1, 2, figsize=[5.5, 2.8])

# Create inset of width 1.3 inches and height 0.9 inches
# at the default upper right location.
axins = inset_axes(ax, width=1.3, height=0.9)

# Create inset of width 30% and height 40% of the parent Axes'␣
↪bounding box
# at the lower left corner.
axins2 = inset_axes(ax, width="30%", height="40%", loc="lower left")

# Create inset of mixed specifications in the second subplot;
# width is 30% of parent Axes' bounding box and
# height is 1 inch at the upper left corner.
axins3 = inset_axes(ax2, width="30%", height=1., loc="upper left")

# Create an inset in the lower right corner with borderpad=1, i.e.
# 10 points padding (as 10pt is the default fontsize) to the parent␣
↪Axes.
axins4 = inset_axes(ax2, width="20%", height="20%", loc="lower right",␣
↪borderpad=1)

# Turn ticklabels of insets off
for axi in [axins, axins2, axins3, axins4]:
    axi.tick_params(labelleft=False, labelbottom=False)

plt.show()
```



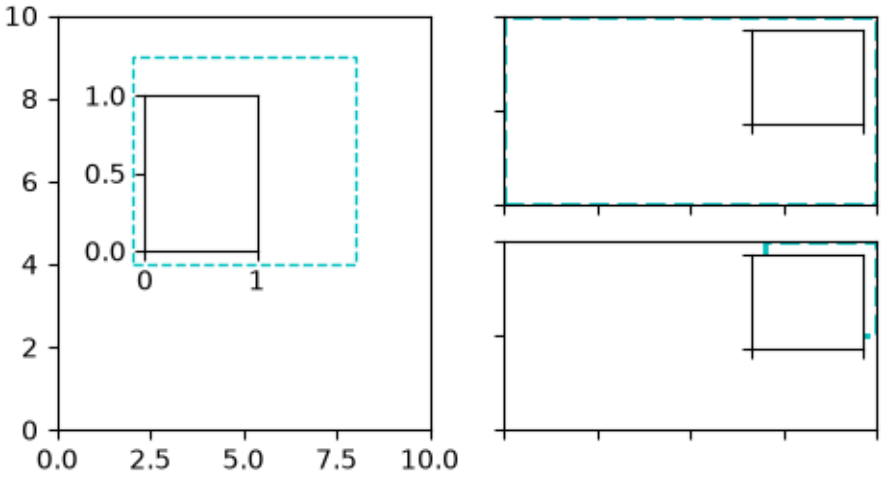
The parameters *bbox_to_anchor* and *bbox_transform* can be used for a more fine-grained control over the inset position and size or even to position the inset at completely arbitrary positions. The *bbox_to_anchor* sets the bounding box in coordinates according to the *bbox_transform*.

```
fig = plt.figure(figsize=[5.5, 2.8])
ax = fig.add_subplot(121)

# We use the Axes transform as bbox_transform. Therefore, the bounding␣
 ↪box
# needs to be specified in axes coordinates ((0, 0) is the lower left␣
 ↪corner
# of the Axes, (1, 1) is the upper right corner).
# The bounding box (.2, .4, .6, .5) starts at (.2, .4) and ranges to␣
 ↪(.8, .9)
# in those coordinates.
# Inside this bounding box an inset of half the bounding box' width and
# three quarters of the bounding box' height is created. The lower␣
 ↪left corner
# of the inset is aligned to the lower left corner of the bounding box.
# The inset is then offset by the default 0.5 in units of the font␣
 ↪size.

axins = inset_axes(ax, width="50%", height="75%",
                   bbox_to_anchor=(.2, .4, .6, .5),
                   bbox_transform=ax.transAxes, loc="lower left")

# For visualization purposes we mark the bounding box by a rectangle
ax.add_patch(plt.Rectangle((.2, .4), .6, .5, ls="--", ec="c", fc="none
 ↪",
                           transform=ax.transAxes))
```

(continues on next page)

(continued from previous page)

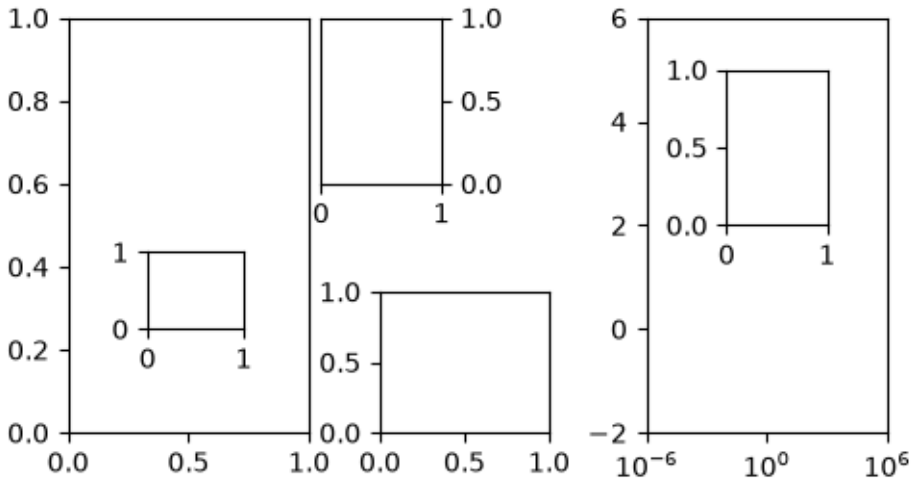
```
# We set the axis limits to something other than the default, in order␣
 ↪to not
# distract from the fact that axes coordinates are used here.
ax.set(xlim=(0, 10), ylim=(0, 10))


# Note how the two following insets are created at the same positions,␣
 ↪one by
# use of the default parent Axes' bbox and the other via a bbox in Axes
# coordinates and the respective transform.
ax2 = fig.add_subplot(222)
axins2 = inset_axes(ax2, width="30%", height="50%")

ax3 = fig.add_subplot(224)
axins3 = inset_axes(ax3, width="100%", height="100%",
                    bbox_to_anchor=(.7, .5, .3, .5),
                    bbox_transform=ax3.transAxes)

# For visualization purposes we mark the bounding box by a rectangle
ax2.add_patch(plt.Rectangle((0, 0), 1, 1, ls="--", lw=2, ec="c", fc=
 ↪"none"))
ax3.add_patch(plt.Rectangle((.7, .5), .3, .5, ls="--", lw=2,
                            ec="c", fc="none"))

# Turn ticklabels off
for axi in [axins2, axins3, ax2, ax3]:
    axi.tick_params(labelleft=False, labelbottom=False)

plt.show()
```



In the above the Axes transform together with 4-tuple bounding boxes has been used as it mostly is useful

to specify an inset relative to the Axes it is an inset to. However, other use cases are equally possible. The following example examines some of those.

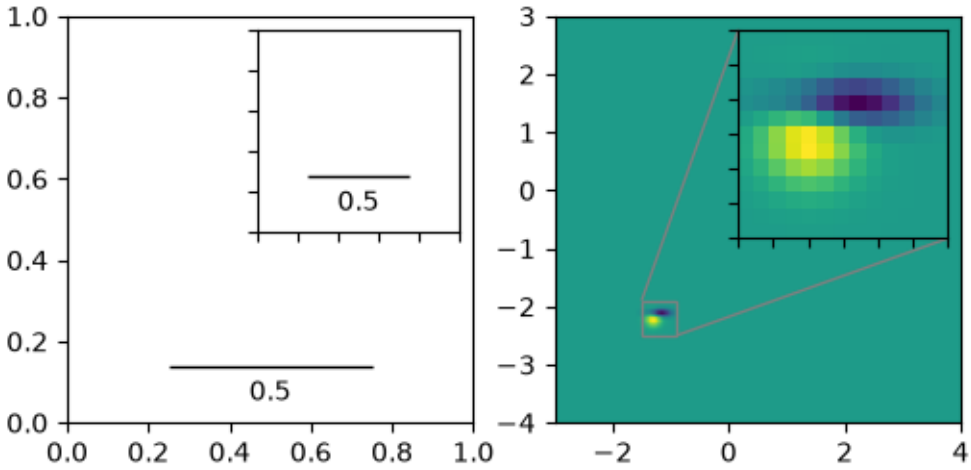
```
fig = plt.figure(figsize=[5.5, 2.8])
ax = fig.add_subplot(131)

# Create an inset outside the Axes
axins = inset_axes(ax, width="100%", height="100%",
                   bbox_to_anchor=(1.05, .6, .5, .4),
                   bbox_transform=ax.transAxes, loc="upper left",␣
 ↪borderpad=0)
axins.tick_params(left=False, right=True, labelleft=False,␣
 ↪labelright=True)

# Create an inset with a 2-tuple bounding box. Note that this creates a
# bbox without extent. This hence only makes sense when specifying
# width and height in absolute units (inches).
axins2 = inset_axes(ax, width=0.5, height=0.4,
                    bbox_to_anchor=(0.33, 0.25),
                    bbox_transform=ax.transAxes, loc="lower left",␣
 ↪borderpad=0)


ax2 = fig.add_subplot(133)
ax2.set_xscale("log")
ax2.set(xlim=(1e-6, 1e6), ylim=(-2, 6))

# Create inset in data coordinates using ax.transData as transform
axins3 = inset_axes(ax2, width="100%", height="100%",
                    bbox_to_anchor=(1e-2, 2, 1e3, 3),
                    bbox_transform=ax2.transData, loc="upper left",␣
 ↪borderpad=0)

# Create an inset horizontally centered in figure coordinates and␣
 ↪vertically
# bound to line up with the Axes.
from matplotlib.transforms import blended_transform_factory  # noqa

transform = blended_transform_factory(fig.transFigure, ax2.transAxes)
axins4 = inset_axes(ax2, width="16%", height="34%",
                    bbox_to_anchor=(0, 0, 1, 1),
                    bbox_transform=transform, loc="lower center",␣
 ↪borderpad=0)

plt.show()
```



Inset locator demo 2

This demo shows how to create a zoomed inset via *zoomed_inset_axes*. In the first subplot an *AnchoredSizeBar* shows the zoom effect. In the second subplot a connection to the region of interest is created via *mark_inset*.

A version of the second subplot, not using the toolkit, is available in *Zoom region inset Axes*.



```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import cbook
from mpl_toolkits.axes_grid1.anchored_artists import AnchoredSizeBar
from mpl_toolkits.axes_grid1.inset_locator import mark_inset,␣
 ↪zoomed_inset_axes
```

(continues on next page)

(continued from previous page)

```
fig, (ax, ax2) = plt.subplots(ncols=2, figsize=[6, 3])


# First subplot, showing an inset with a size bar.
ax.set_aspect(1)

axins = zoomed_inset_axes(ax, zoom=0.5, loc='upper right')
# fix the number of ticks on the inset Axes
axins.yaxis.get_major_locator().set_params(nbins=7)
axins.xaxis.get_major_locator().set_params(nbins=7)
axins.tick_params(labelleft=False, labelbottom=False)


def add_sizebar(ax, size):
    asb = AnchoredSizeBar(ax.transData,
                          size,
                          str(size),
                          loc="lower center",
                          pad=0.1, borderpad=0.5, sep=5,
                          frameon=False)
    ax.add_artist(asb)

add_sizebar(ax, 0.5)
add_sizebar(axins, 0.5)


# Second subplot, showing an image with an inset zoom and a marked␣
 ↪inset
Z = cbook.get_sample_data("axes_grid/bivariate_normal.npy")  # 15x15␣
 ↪array
extent = (-3, 4, -4, 3)
Z2 = np.zeros((150, 150))
ny, nx = Z.shape
Z2[30:30+ny, 30:30+nx] = Z

ax2.imshow(Z2, extent=extent, origin="lower")

axins2 = zoomed_inset_axes(ax2, zoom=6, loc="upper right")
axins2.imshow(Z2, extent=extent, origin="lower")

# subregion of the original image
x1, x2, y1, y2 = -1.5, -0.9, -2.5, -1.9
axins2.set_xlim(x1, x2)
axins2.set_ylim(y1, y2)
# fix the number of ticks on the inset Axes
```

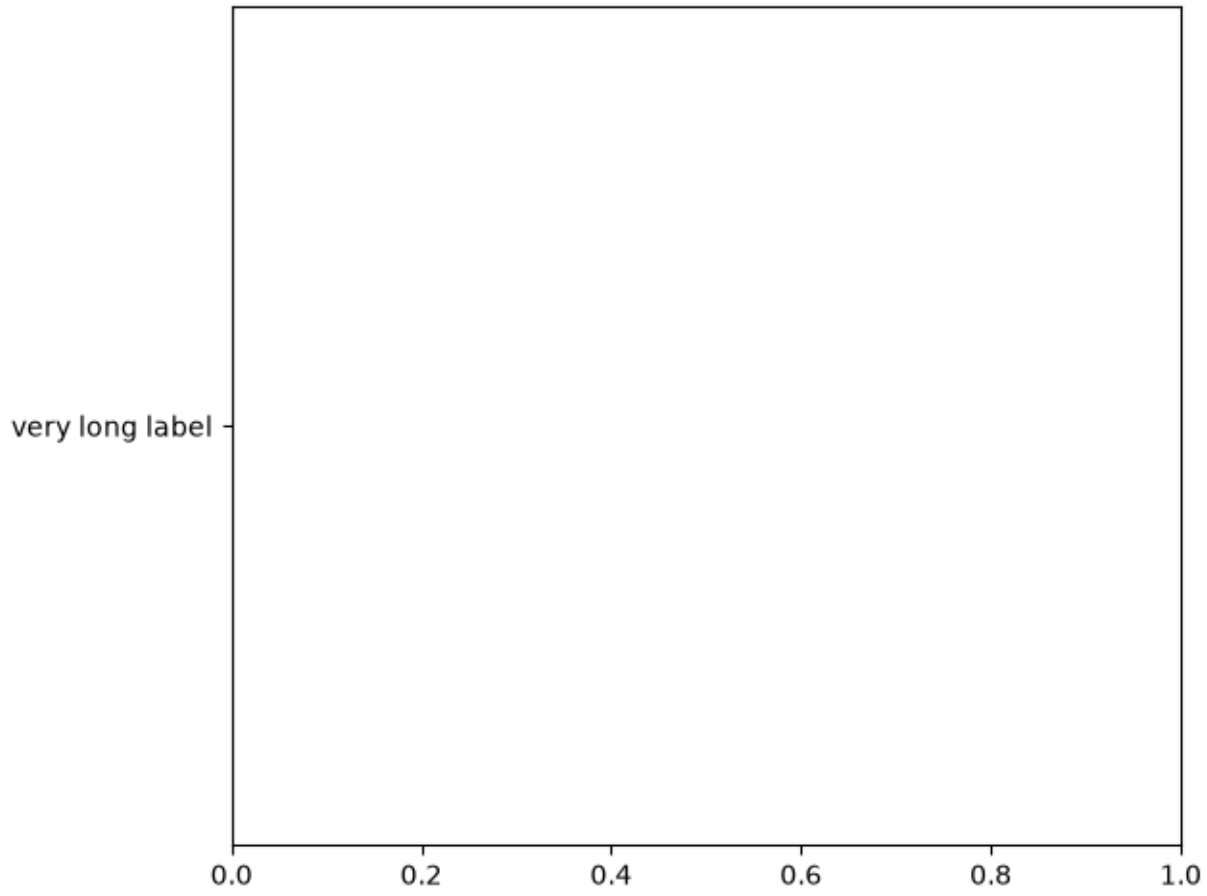
(continues on next page)

(continued from previous page)

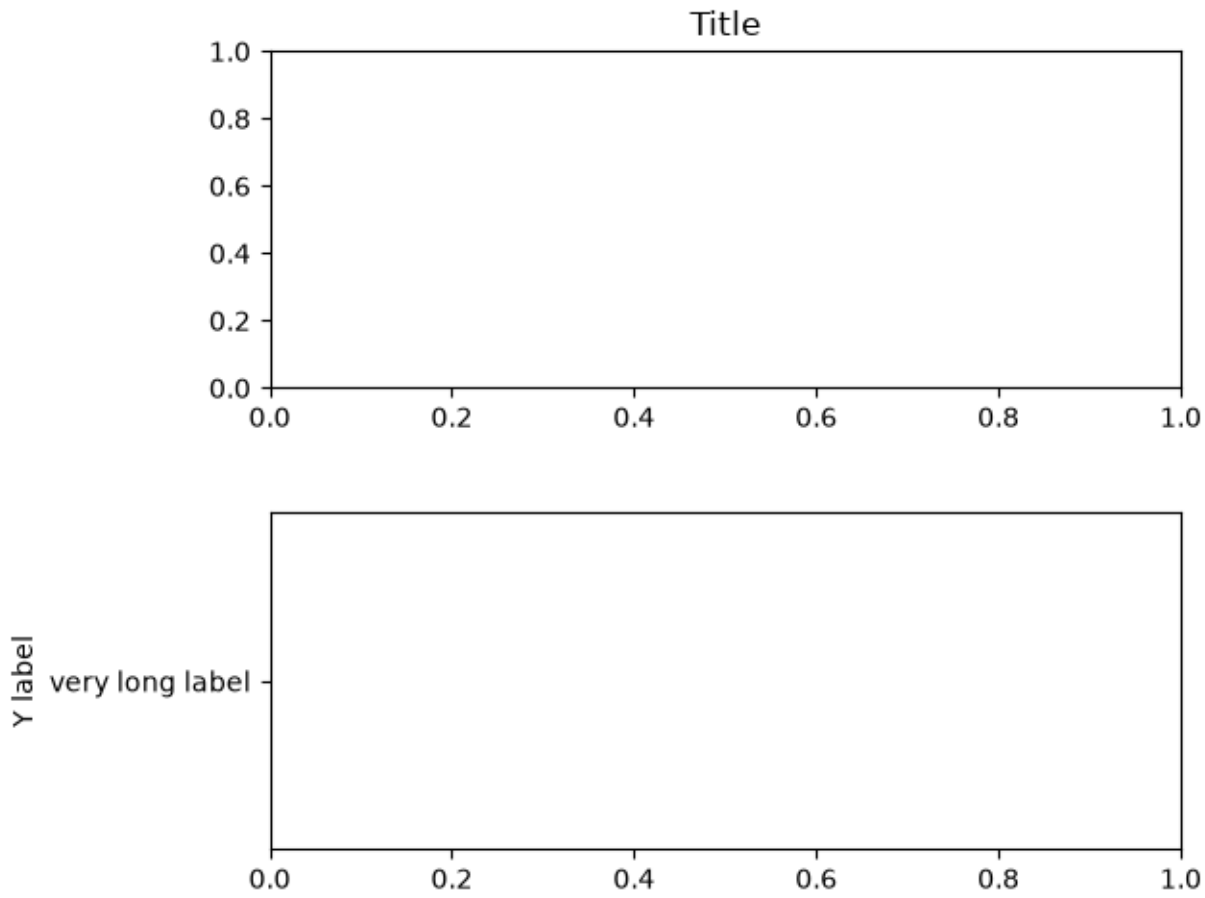
```
axins2.yaxis.get_major_locator().set_params(nbins=7)
axins2.xaxis.get_major_locator().set_params(nbins=7)
axins2.tick_params(labelleft=False, labelbottom=False)

# draw a bbox of the region of the inset Axes in the parent Axes and
# connecting lines between the bbox and the inset Axes area
mark_inset(ax2, axins2, loc1=2, loc2=4, fc="none", ec="0.5")

plt.show()
```

Make room for ylabel using axes_grid

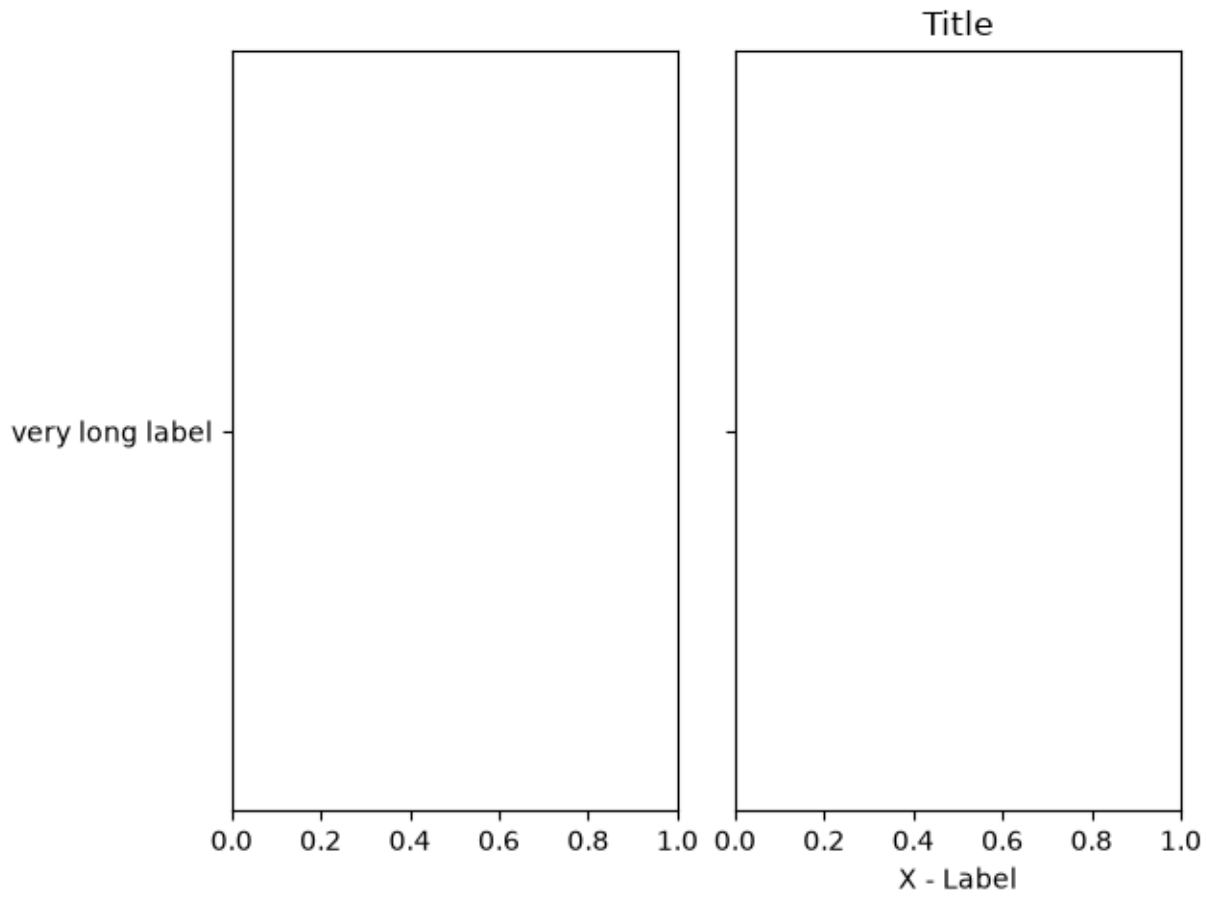
```
import matplotlib.pyplot as plt

from mpl_toolkits.axes_grid1 import make_axes_locatable
from mpl_toolkits.axes_grid1.axes_divider import␣
 ↪make_axes_area_auto_adjustable

fig = plt.figure()
ax = fig.add_axes((0, 0, 1, 1))

ax.set_yticks([0.5], labels=["very long label"])

make_axes_area_auto_adjustable(ax)
```




```
fig = plt.figure()
ax1 = fig.add_axes((0, 0, 1, 0.5))
ax2 = fig.add_axes((0, 0.5, 1, 0.5))

ax1.set_yticks([0.5], labels=["very long label"])
ax1.set_ylabel("Y label")

ax2.set_title("Title")

make_axes_area_auto_adjustable(ax1, pad=0.1, use_axes=[ax1, ax2])
make_axes_area_auto_adjustable(ax2, pad=0.1, use_axes=[ax1, ax2])
```

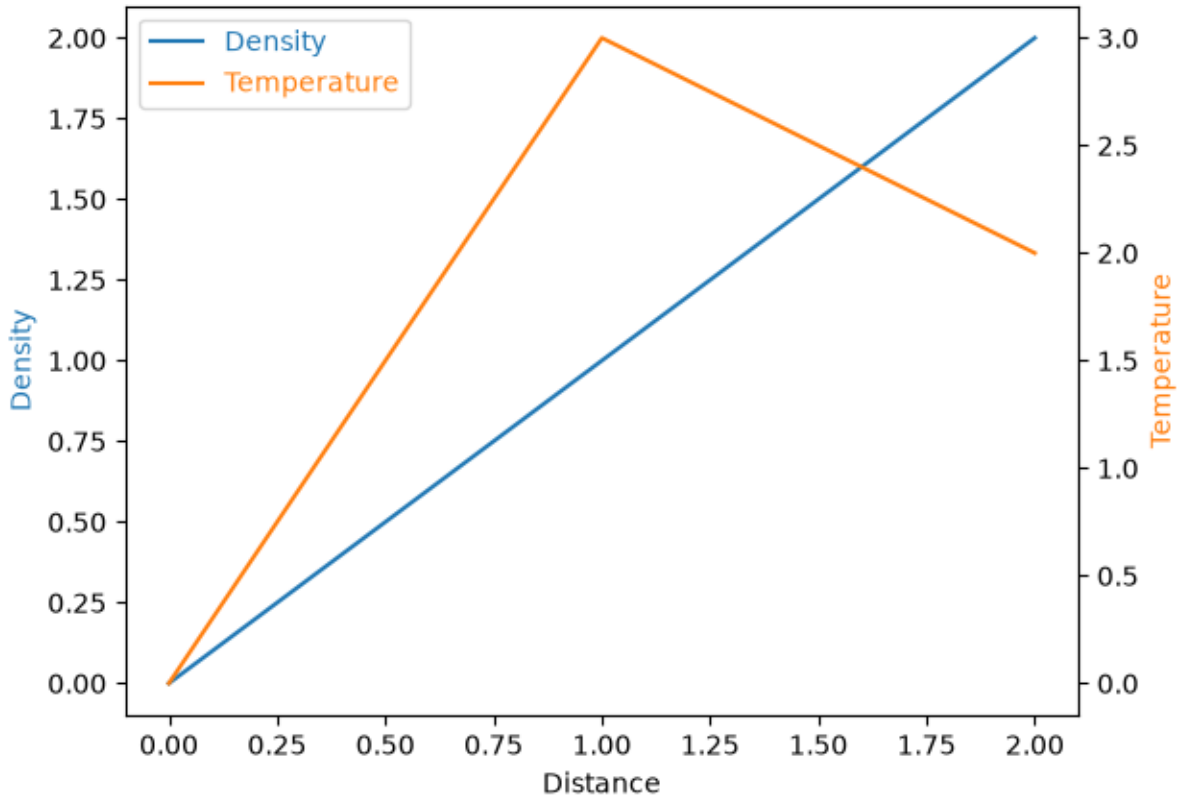



```
fig = plt.figure()
ax1 = fig.add_axes((0, 0, 1, 1))
divider = make_axes_locatable(ax1)

ax2 = divider.append_axes("right", "100%", pad=0.3, sharey=ax1)
ax2.tick_params(labelleft=False)
fig.add_axes(ax2)

divider.add_auto_adjustable_area(use_axes=[ax1], pad=0.1,
                                 adjust_dirs=["left"])
divider.add_auto_adjustable_area(use_axes=[ax2], pad=0.1,
                                 adjust_dirs=["right"])
divider.add_auto_adjustable_area(use_axes=[ax1, ax2], pad=0.1,
                                 adjust_dirs=["top", "bottom"])

ax1.set_yticks([0.5], labels=["very long label"])

ax2.set_title("Title")
ax2.set_xlabel("X - Label")

plt.show()
```



Total running time of the script: (0 minutes 1.192 seconds)

Parasite Simple



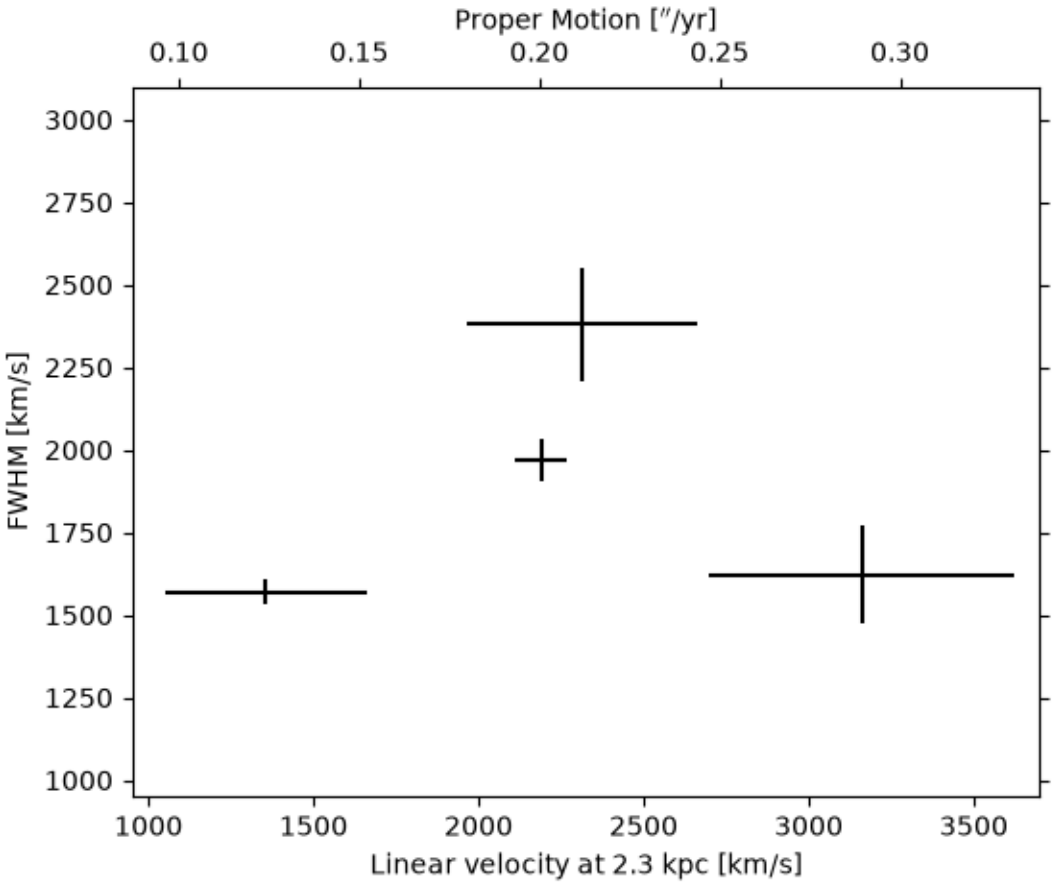

```
import matplotlib.pyplot as plt

from mpl_toolkits.axes_grid1 import host_subplot

host = host_subplot(111)
par = host.twinx()

host.set_xlabel("Distance")
host.set_ylabel("Density")
par.set_ylabel("Temperature")

p1, = host.plot([0, 1, 2], [0, 1, 2], label="Density")
p2, = par.plot([0, 1, 2], [0, 3, 2], label="Temperature")

host.legend(labelcolor="linecolor")

host.yaxis.label.set_color(p1.get_color())
par.yaxis.label.set_color(p2.get_color())
```

(continues on next page)

(continued from previous page)

```
plt.show()
```

Parasite Simple2




```
import matplotlib.pyplot as plt

import matplotlib.transforms as mtransforms
from mpl_toolkits.axes_grid1.parasite_axes import HostAxes

obs = [["01_S1", 3.88, 0.14, 1970, 63],
       ["01_S4", 5.6, 0.82, 1622, 150],
       ["02_S1", 2.4, 0.54, 1570, 40],
       ["03_S1", 4.1, 0.62, 2380, 170]]


fig = plt.figure()

ax_kms = fig.add_subplot(axes_class=HostAxes, aspect=1)
```

(continues on next page)

(continued from previous page)

```
# angular proper motion("/yr) to linear velocity(km/s) at␣
 ↪distance=2.3kpc
pm_to_kms = 1./206265.*2300*3.085e18/3.15e7/1.e5

aux_trans = mtransforms.Affine2D().scale(pm_to_kms, 1.)
ax_pm = ax_kms.twin(aux_trans)

for n, ds, dse, w, we in obs:
    time = ((2007 + (10. + 4/30.)/12) - 1988.5)
    v = ds / time * pm_to_kms
    ve = dse / time * pm_to_kms
    ax_kms.errorbar([v], [w], xerr=[ve], yerr=[we], color="k")


ax_kms.axis["bottom"].set_label("Linear velocity at 2.3 kpc [km/s]")
ax_kms.axis["left"].set_label("FWHM [km/s]")
ax_pm.axis["top"].set_label(r"Proper Motion [$''$/yr]")
ax_pm.axis["top"].label.set_visible(True)
ax_pm.axis["right"].major_ticklabels.set_visible(False)

ax_kms.set_xlim(950, 3700)
ax_kms.set_ylim(950, 3100)
# xlim and ylim of ax_pms will be automatically adjusted.

plt.show()
```

Align histogram to scatter plot using locatable Axes

Show the marginal distributions of a scatter plot as histograms at the sides of the plot.

For a nice alignment of the main Axes with the marginals, the Axes positions are defined by a `Divider`, produced via *`make_axes_locatable`*. Note that the `Divider` API allows setting Axes sizes and pads in inches, which is its main feature.

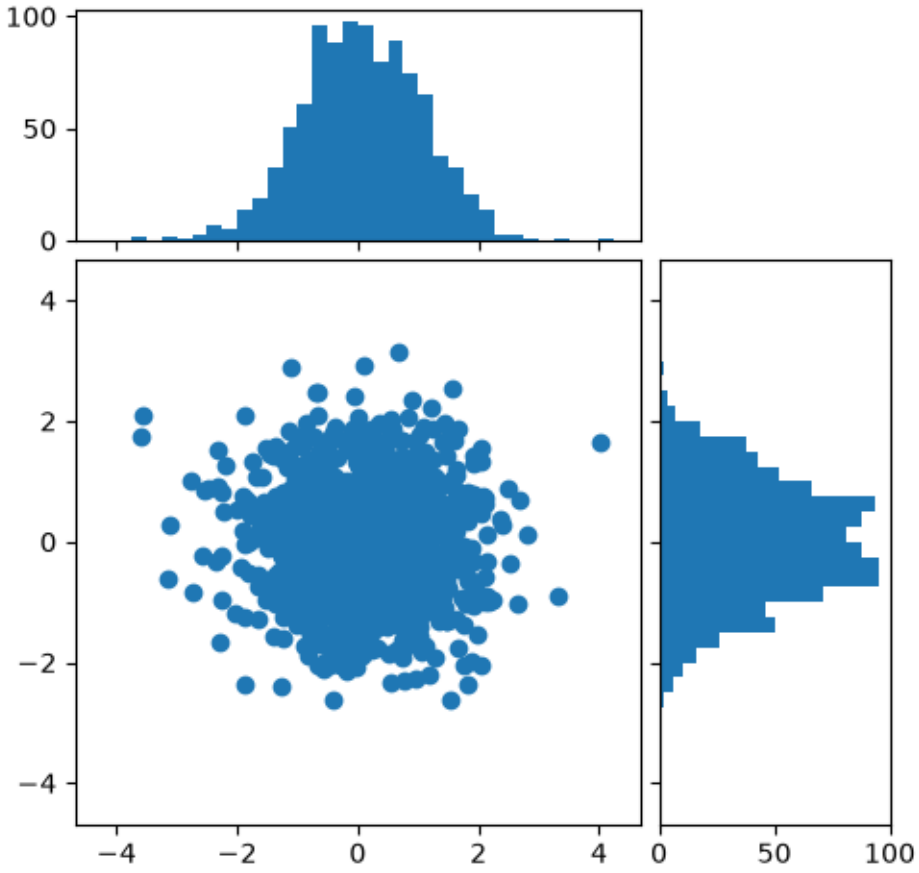
If one wants to set Axes sizes and pads relative to the main Figure, see the *Scatter plot with histograms* example.

```
import matplotlib.pyplot as plt
import numpy as np

from mpl_toolkits.axes_grid1 import make_axes_locatable

# Fixing random state for reproducibility
np.random.seed(19680801)

# the random data
x = np.random.randn(1000)
```

(continues on next page)

(continued from previous page)

```
y = np.random.randn(1000)


fig, ax = plt.subplots(figsize=(5.5, 5.5))

# the scatter plot:
ax.scatter(x, y)

# Set aspect of the main Axes.
ax.set_aspect(1.)

# create new Axes on the right and on the top of the current Axes
divider = make_axes_locatable(ax)
# below height and pad are in inches
ax_histx = divider.append_axes("top", 1.2, pad=0.1, sharex=ax)
ax_histy = divider.append_axes("right", 1.2, pad=0.1, sharey=ax)

# make some labels invisible
ax_histx.xaxis.set_tick_params(labelbottom=False)
ax_histy.yaxis.set_tick_params(labelleft=False)

# now determine nice limits by hand:
binwidth = 0.25
xymax = max(np.max(np.abs(x)), np.max(np.abs(y)))
lim = (int(xymax/binwidth) + 1)*binwidth

bins = np.arange(-lim, lim + binwidth, binwidth)
ax_histx.hist(x, bins=bins)
ax_histy.hist(y, bins=bins, orientation='horizontal')

# the xaxis of ax_histx and yaxis of ax_histy are shared with ax,
# thus there is no need to manually adjust the xlim and ylim of these
# axis.

ax_histx.set_yticks([0, 50, 100])
ax_histy.set_xticks([0, 50, 100])

plt.show()
```



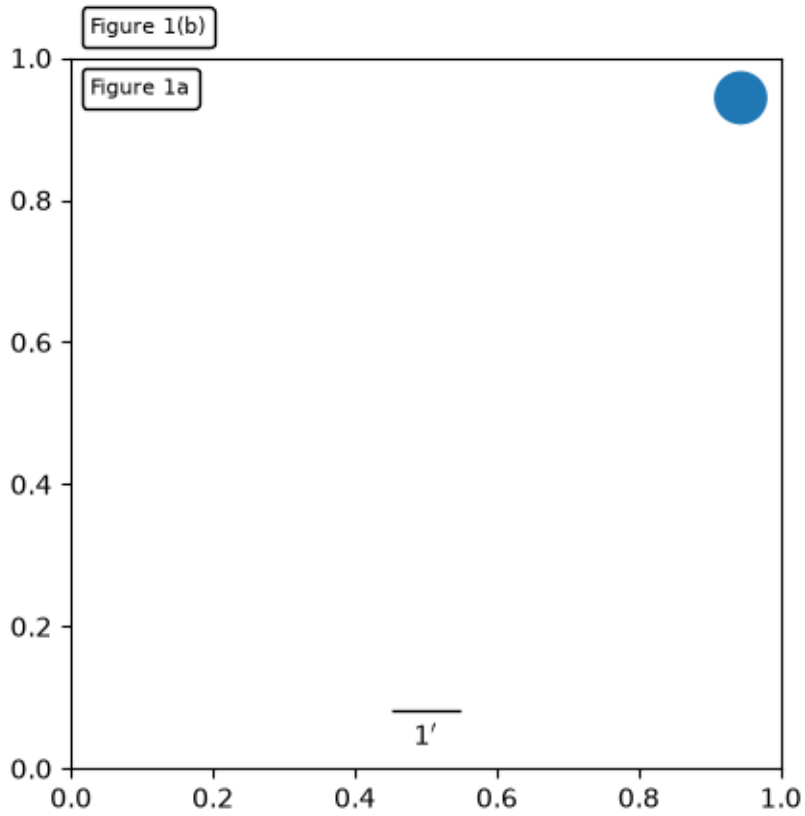
References

The use of the following functions, methods, classes and modules is shown in this example:

- *mpl_toolkits.axes_grid1.axes_divider.make_axes_locatable*
- *matplotlib.axes.Axes.set_aspect*
- *matplotlib.axes.Axes.scatter*
- *matplotlib.axes.Axes.hist*

Simple Anchored Artists

This example illustrates the use of the anchored helper classes found in *matplotlib.offsetbox* and in *mpl_toolkits.axes_grid1*. An implementation of a similar figure, but without use of the toolkit, can be found in *Anchored Artists*.




```
import matplotlib.pyplot as plt


def draw_text(ax):
    """
    Draw two text-boxes, anchored by different corners to the␣
 ↪upper-left
    corner of the figure.
    """
    from matplotlib.offsetbox import AnchoredText
    at = AnchoredText("Figure 1a",
                      loc='upper left', prop=dict(size=8),␣
 ↪frameon=True,
                      )
    at.patch.set_boxstyle("round,pad=0.,rounding_size=0.2")
    ax.add_artist(at)

    at2 = AnchoredText("Figure 1(b)",
                       loc='lower left', prop=dict(size=8),␣
 ↪frameon=True,
```

(continues on next page)

(continued from previous page)

```
                        bbox_to_anchor=(0., 1.),
                        bbox_transform=ax.transAxes
                        )
    at2.patch.set_boxstyle("round,pad=0.,rounding_size=0.2")
    ax.add_artist(at2)


def draw_circle(ax):
    """
    Draw a circle in axis coordinates
    """
    from matplotlib.patches import Circle
    from mpl_toolkits.axes_grid1.anchored_artists import␣
 ↪AnchoredDrawingArea
    ada = AnchoredDrawingArea(20, 20, 0, 0,
                              loc='upper right', pad=0., frameon=False)
    p = Circle((10, 10), 10)
    ada.da.add_artist(p)
    ax.add_artist(ada)


def draw_sizebar(ax):
    """
    Draw a horizontal bar with length of 0.1 in data coordinates,
    with a fixed label underneath.
    """
    from mpl_toolkits.axes_grid1.anchored_artists import␣
 ↪AnchoredSizeBar
    asb = AnchoredSizeBar(ax.transData,
                          0.1,
                          r"1$^{\prime}$",
                          loc='lower center',
                          pad=0.1, borderpad=0.5, sep=5,
                          frameon=False)
    ax.add_artist(asb)


fig, ax = plt.subplots()
ax.set_aspect(1.)

draw_text(ax)
draw_circle(ax)
draw_sizebar(ax)

plt.show()
```

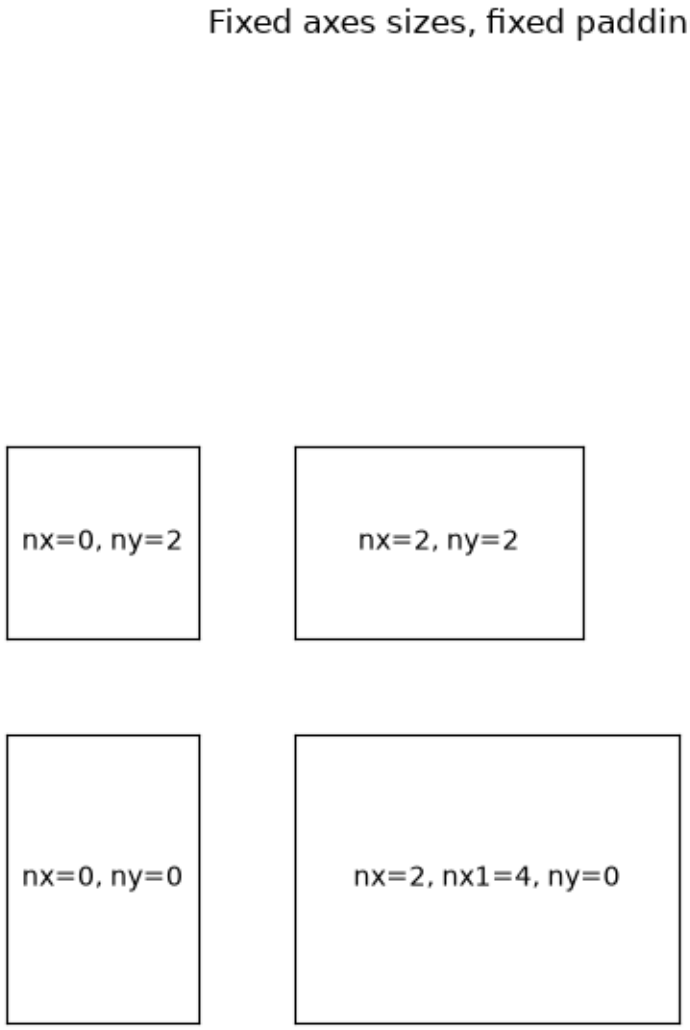
Simple Axes Divider 1

See also *The axes_grid1 toolkit*.

```
import matplotlib.pyplot as plt

from mpl_toolkits.axes_grid1 import Divider, Size


def label_axes(ax, text):
    """Place a label at the center of an Axes, and remove the axis␣
 ↪ticks."""
    ax.text(.5, .5, text, transform=ax.transAxes,
            horizontalalignment="center", verticalalignment="center")
    ax.tick_params(bottom=False, labelbottom=False,
                   left=False, labelleft=False)
```

Fixed Axes sizes; fixed paddings.

```
fig = plt.figure(figsize=(6, 6))
fig.suptitle("Fixed axes sizes, fixed paddings")

# Sizes are in inches.
horiz = [Size.Fixed(1.), Size.Fixed(.5), Size.Fixed(1.5), Size.Fixed(.
 ↪5)]
vert = [Size.Fixed(1.5), Size.Fixed(.5), Size.Fixed(1.)]

rect = (0.1, 0.1, 0.8, 0.8)
# Divide the Axes rectangle into a grid with sizes specified by horiz␣
 ↪* vert.
div = Divider(fig, rect, horiz, vert, aspect=False)

# The rect parameter will actually be ignored and overridden by␣
 ↪axes_locator.
ax1 = fig.add_axes(rect, axes_locator=div.new_locator(nx=0, ny=0))
label_axes(ax1, "nx=0, ny=0")
ax2 = fig.add_axes(rect, axes_locator=div.new_locator(nx=0, ny=2))
label_axes(ax2, "nx=0, ny=2")
ax3 = fig.add_axes(rect, axes_locator=div.new_locator(nx=2, ny=2))
label_axes(ax3, "nx=2, ny=2")
ax4 = fig.add_axes(rect, axes_locator=div.new_locator(nx=2, nx1=4,␣
 ↪ny=0))
label_axes(ax4, "nx=2, nx1=4, ny=0")
```



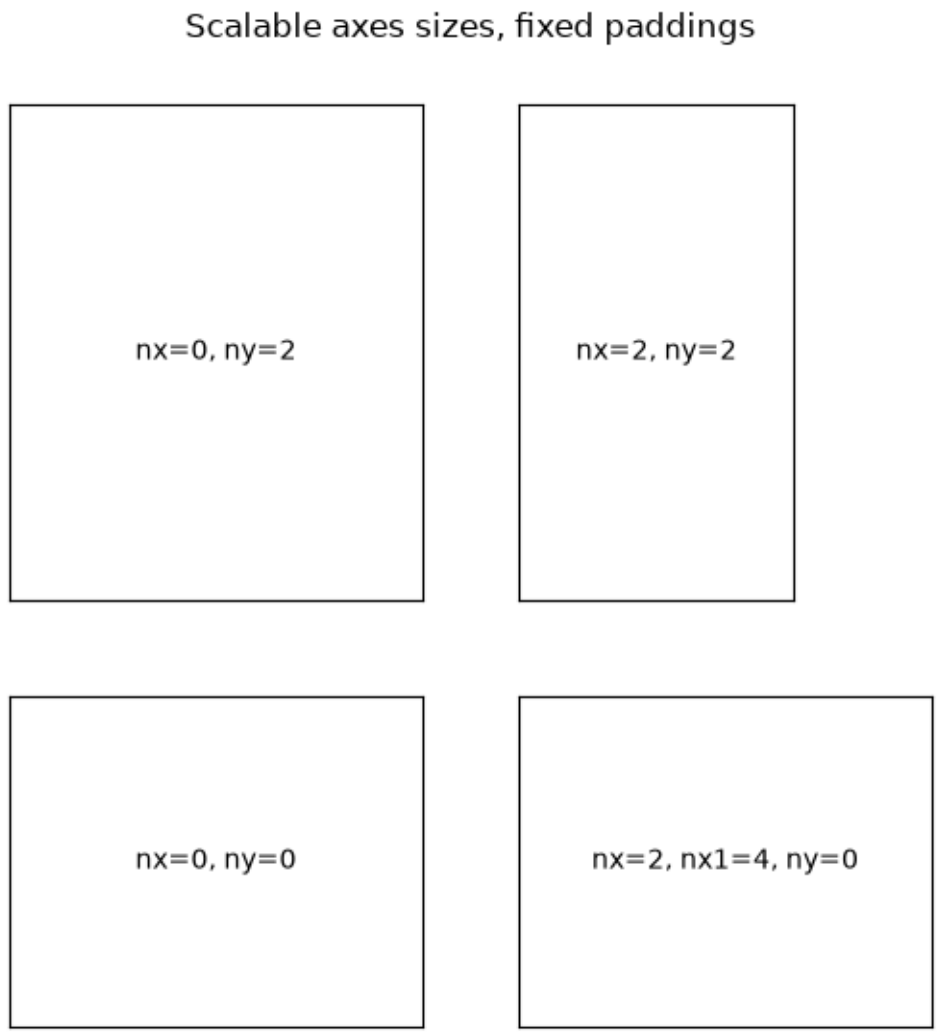
Axes sizes that scale with the figure size; fixed paddings.

```
fig = plt.figure(figsize=(6, 6))
fig.suptitle("Scalable axes sizes, fixed paddings")

horiz = [Size.Scaled(1.5), Size.Fixed(.5), Size.Scaled(1.), Size.
 ↪Scaled(.5)]
vert = [Size.Scaled(1.), Size.Fixed(.5), Size.Scaled(1.5)]

rect = (0.1, 0.1, 0.8, 0.8)
# Divide the Axes rectangle into a grid with sizes specified by horiz␣
 ↪* vert.
div = Divider(fig, rect, horiz, vert, aspect=False)
```

(continues on next page)

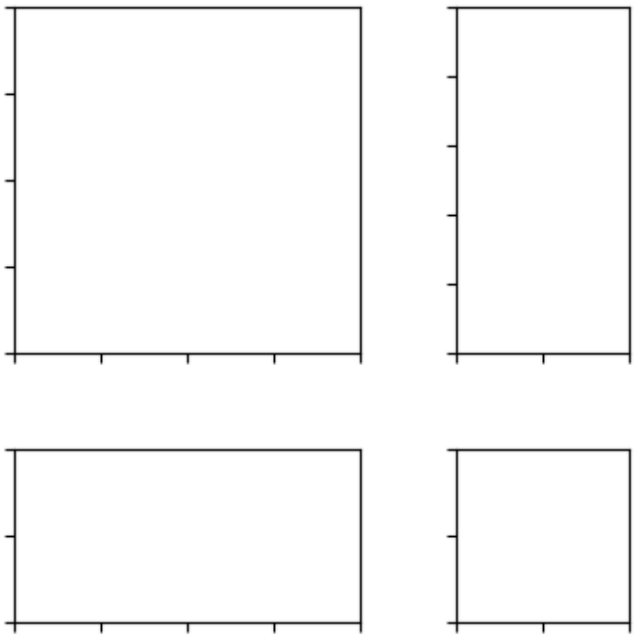
(continued from previous page)

```
# The rect parameter will actually be ignored and overridden by␣
 ↪axes_locator.
ax1 = fig.add_axes(rect, axes_locator=div.new_locator(nx=0, ny=0))
label_axes(ax1, "nx=0, ny=0")
ax2 = fig.add_axes(rect, axes_locator=div.new_locator(nx=0, ny=2))
label_axes(ax2, "nx=0, ny=2")
ax3 = fig.add_axes(rect, axes_locator=div.new_locator(nx=2, ny=2))
label_axes(ax3, "nx=2, ny=2")
ax4 = fig.add_axes(rect, axes_locator=div.new_locator(nx=2, nx1=4,␣
 ↪ny=0))
label_axes(ax4, "nx=2, nx1=4, ny=0")

plt.show()
```



Simple axes divider 3

See also *The axes_grid1 toolkit*.



```
import matplotlib.pyplot as plt

from mpl_toolkits.axes_grid1 import Divider
import mpl_toolkits.axes_grid1.axes_size as Size

fig = plt.figure(figsize=(5.5, 4))

# the rect parameter will be ignored as we will set axes_locator
rect = (0.1, 0.1, 0.8, 0.8)
ax = [fig.add_axes(rect, label="%d" % i) for i in range(4)]


horiz = [Size.AxesX(ax[0]), Size.Fixed(.5), Size.AxesX(ax[1])]
vert = [Size.AxesY(ax[0]), Size.Fixed(.5), Size.AxesY(ax[2])]

# divide the Axes rectangle into grid whose size is specified by horiz␣
 ↪* vert
divider = Divider(fig, rect, horiz, vert, aspect=False)


ax[0].set_axes_locator(divider.new_locator(nx=0, ny=0))
```

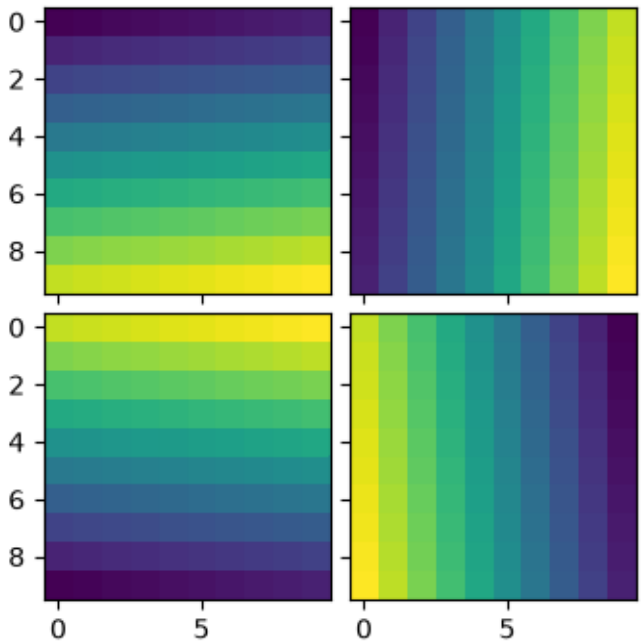
(continues on next page)

(continued from previous page)

```
ax[1].set_axes_locator(divider.new_locator(nx=2, ny=0))
ax[2].set_axes_locator(divider.new_locator(nx=0, ny=2))
ax[3].set_axes_locator(divider.new_locator(nx=2, ny=2))

ax[0].set_xlim(0, 2)
ax[1].set_xlim(0, 1)

ax[0].set_ylim(0, 1)
ax[2].set_ylim(0, 2)

divider.set_aspect(1.)

for ax1 in ax:
    ax1.tick_params(labelbottom=False, labelleft=False)

plt.show()
```

Simple ImageGrid

Align multiple images using *ImageGrid*.




```
import matplotlib.pyplot as plt
import numpy as np
```

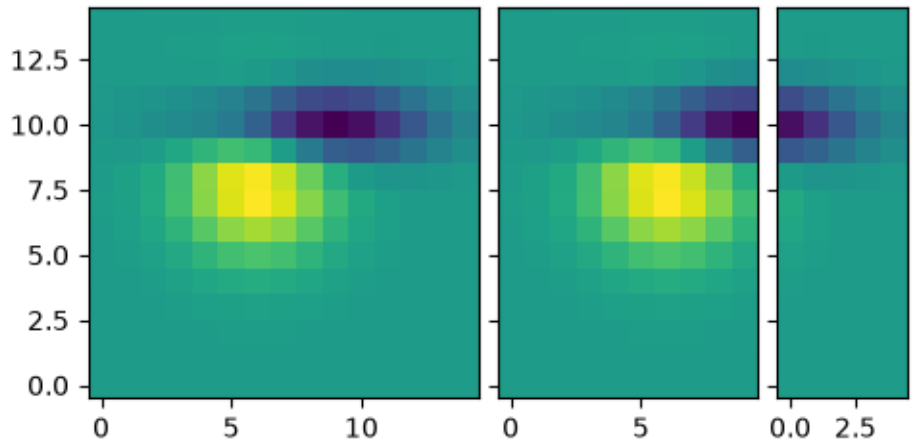
(continues on next page)

(continued from previous page)

```
from mpl_toolkits.axes_grid1 import ImageGrid

im1 = np.arange(100).reshape((10, 10))
im2 = im1.T
im3 = np.flipud(im1)
im4 = np.fliplr(im2)

fig = plt.figure(figsize=(4., 4.))
grid = ImageGrid(fig, 111,  # similar to subplot(111)
                 nrows_ncols=(2, 2),  # creates 2x2 grid of Axes
                 axes_pad=0.1,  # pad between Axes in inch.
                 )

for ax, im in zip(grid, [im1, im2, im3, im4]):
    # Iterating over the grid returns the Axes.
    ax.imshow(im)

plt.show()
```

Simple ImageGrid 2

Align multiple images of different sizes using *ImageGrid*.



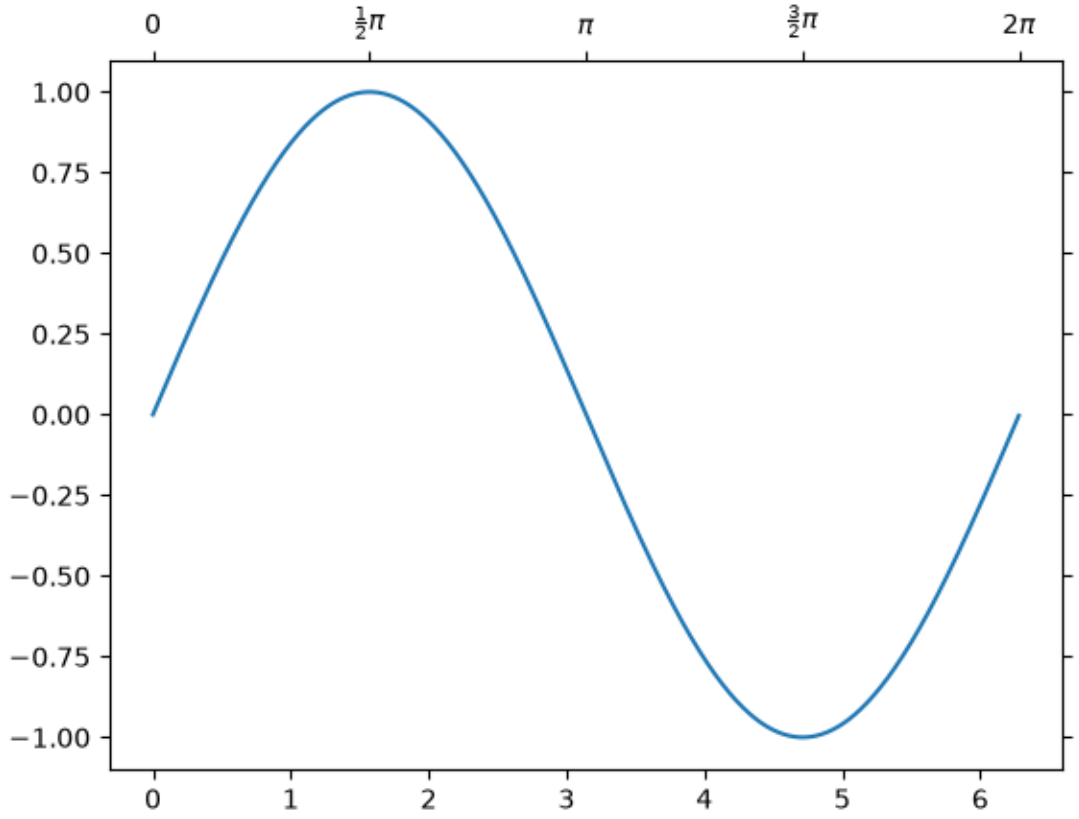

```
import matplotlib.pyplot as plt

from matplotlib import cbook
```

(continues on next page)

(continued from previous page)

```
from mpl_toolkits.axes_grid1 import ImageGrid

fig = plt.figure(figsize=(5.5, 3.5))
grid = ImageGrid(fig, 111,  # similar to subplot(111)
                 nrows_ncols=(1, 3),
                 axes_pad=0.1,
                 label_mode="L",
                 )

# demo image
Z = cbook.get_sample_data("axes_grid/bivariate_normal.npy")
im1 = Z
im2 = Z[:, :10]
im3 = Z[:, 10:]
vmin, vmax = Z.min(), Z.max()
for ax, im in zip(grid, [im1, im2, im3]):
    ax.imshow(im, origin="lower", vmin=vmin, vmax=vmax)

plt.show()
```

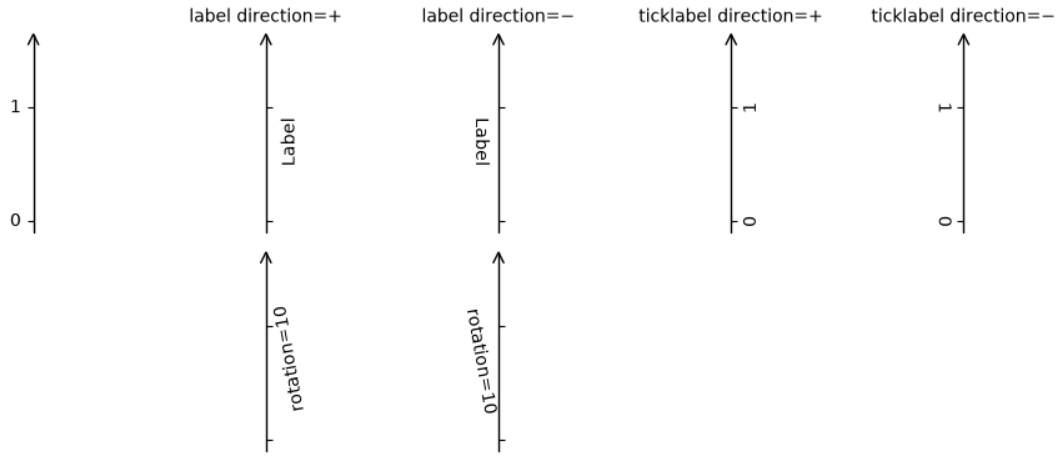
Simple Axisline4




```
import matplotlib.pyplot as plt
import numpy as np

from mpl_toolkits.axes_grid1 import host_subplot

ax = host_subplot(111)
xx = np.arange(0, 2*np.pi, 0.01)
ax.plot(xx, np.sin(xx))

ax2 = ax.twin()  # ax2 is responsible for "top" axis and "right" axis
ax2.set_xticks([0., .5*np.pi, np.pi, 1.5*np.pi, 2*np.pi],
               labels=["$0$", r"$\frac{1}{2}\pi$",
                       r"$\pi$", r"$\frac{3}{2}\pi$", r"$2\pi$"])

ax2.axis["right"].major_ticklabels.set_visible(False)
ax2.axis["top"].major_ticklabels.set_visible(True)

plt.show()
```

6.24.16 Module - axisartist

Axis Direction



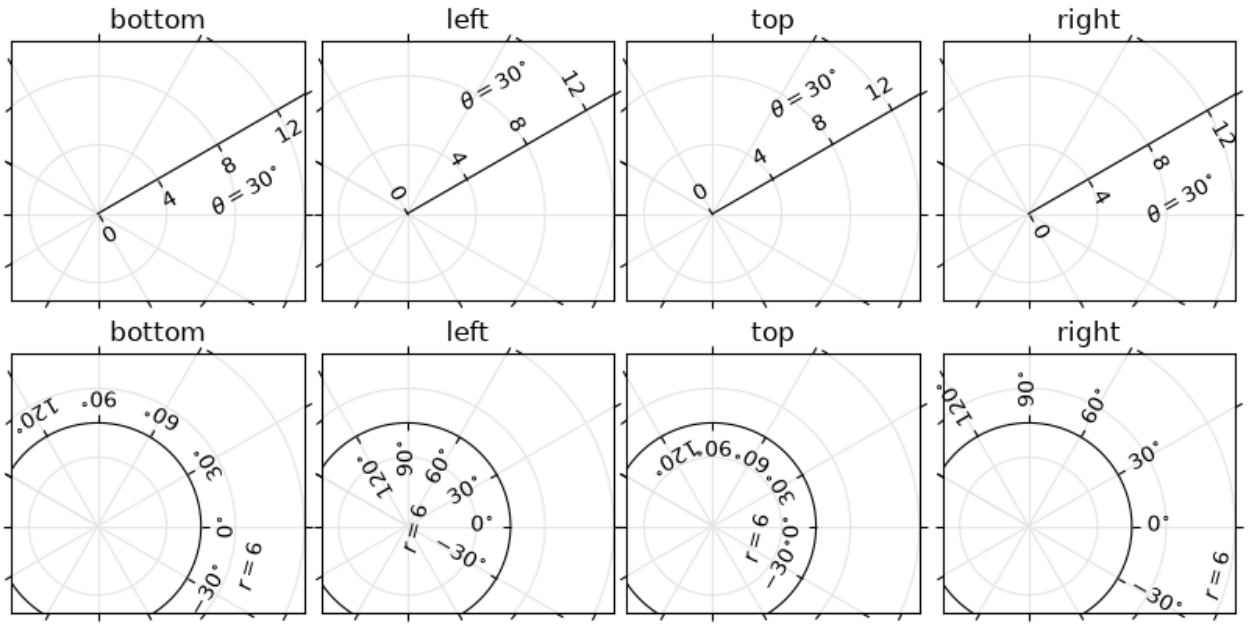

```
import matplotlib.pyplot as plt

import mpl_toolkits.axisartist as axisartist


def setup_axes(fig, pos):
    ax = fig.add_subplot(pos, axes_class=axisartist.Axes)

    ax.set_ylim(-0.1, 1.5)
    ax.set_yticks([0, 1])

    ax.axis[:].set_visible(False)

    ax.axis["x"] = ax.new_floating_axis(1, 0.5)
    ax.axis["x"].set_axisline_style("->", size=1.5)

    return ax


plt.rcParams.update({
    "axes.titlesize": "medium",
    "axes.titley": 1.1,
})

fig = plt.figure(figsize=(10, 4))
fig.subplots_adjust(bottom=0.1, top=0.9, left=0.05, right=0.95)

ax1 = setup_axes(fig, 251)
ax1.axis["x"].set_axis_direction("left")
```

(continues on next page)

(continued from previous page)

```
ax2 = setup_axes(fig, 252)
ax2.axis["x"].label.set_text("Label")
ax2.axis["x"].toggle(ticklabels=False)
ax2.axis["x"].set_axislabel_direction("+")
ax2.set_title("label direction=$+$")

ax3 = setup_axes(fig, 253)
ax3.axis["x"].label.set_text("Label")
ax3.axis["x"].toggle(ticklabels=False)
ax3.axis["x"].set_axislabel_direction("-")
ax3.set_title("label direction=$-$")

ax4 = setup_axes(fig, 254)
ax4.axis["x"].set_ticklabel_direction("+")
ax4.set_title("ticklabel direction=$+$")

ax5 = setup_axes(fig, 255)
ax5.axis["x"].set_ticklabel_direction("-")
ax5.set_title("ticklabel direction=$-$")

ax7 = setup_axes(fig, 257)
ax7.axis["x"].label.set_text("rotation=10")
ax7.axis["x"].label.set_rotation(10)
ax7.axis["x"].toggle(ticklabels=False)

ax8 = setup_axes(fig, 258)
ax8.axis["x"].set_axislabel_direction("-")
ax8.axis["x"].label.set_text("rotation=10")
ax8.axis["x"].label.set_rotation(10)
ax8.axis["x"].toggle(ticklabels=False)

plt.show()
```

axis_direction demo




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.projections import PolarAxes
from matplotlib.transforms import Affine2D
import mpl_toolkits.axisartist as axisartist
from mpl_toolkits.axisartist import angle_helper, grid_finder
from mpl_toolkits.axisartist.grid_helper_curvelinear import␣
 ↪GridHelperCurveLinear


def setup_axes(fig, rect):
    """Polar projection, but in a rectangular box."""
    # see demo_curvelinear_grid.py for details
    grid_helper = GridHelperCurveLinear(
        Affine2D().scale(np.pi/180., 1.) + PolarAxes.PolarTransform(),
        extreme_finder=angle_helper.ExtremeFinderCycle(
            20, 20,
            lon_cycle=360, lat_cycle=None,
            lon_minmax=None, lat_minmax=(0, np.inf),
        ),
        grid_locator1=angle_helper.LocatorDMS(12),
        grid_locator2=grid_finder.MaxNLocator(5),
        tick_formatter1=angle_helper.FormatterDMS(),
    )
    ax = fig.add_subplot(
        rect, axes_class=axisartist.Axes, grid_helper=grid_helper,
```

(continues on next page)

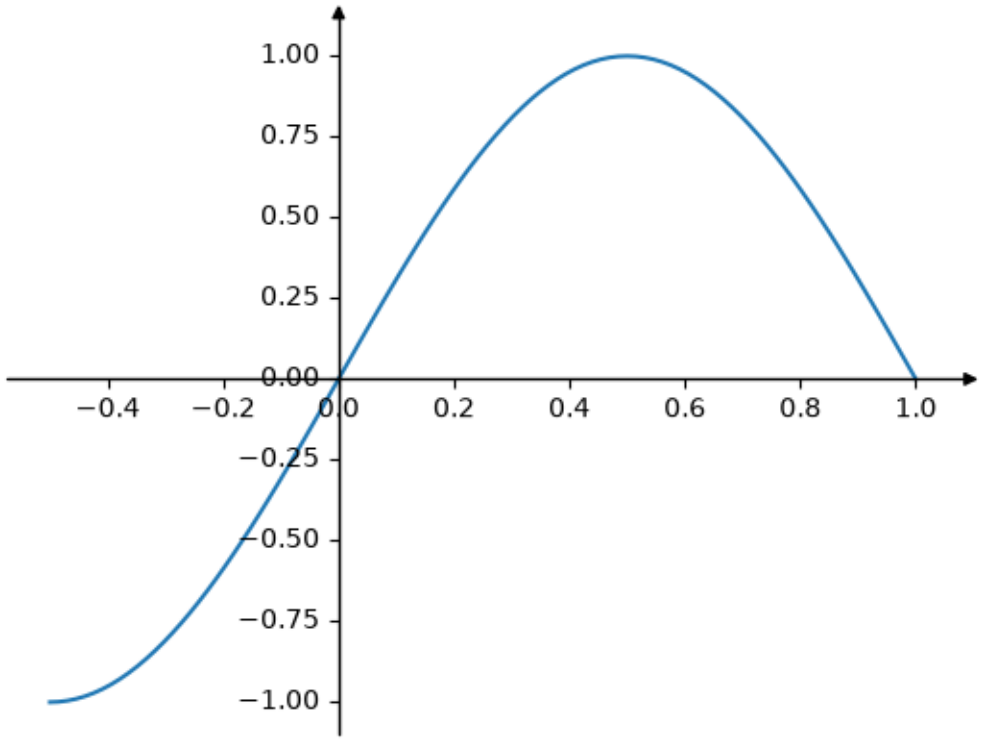
(continued from previous page)

```
        aspect=1, xlim=(-5, 12), ylim=(-5, 10))
    ax.axis[:].toggle(ticklabels=False)
    ax.grid(color=".9")
    return ax


def add_floating_axis1(ax):
    ax.axis["lat"] = axis = ax.new_floating_axis(0, 30)
    axis.label.set_text(r"$\theta = 30^{\circ}$")
    axis.label.set_visible(True)
    return axis


def add_floating_axis2(ax):
    ax.axis["lon"] = axis = ax.new_floating_axis(1, 6)
    axis.label.set_text(r"$r = 6$")
    axis.label.set_visible(True)
    return axis


fig = plt.figure(figsize=(8, 4), layout="constrained")

for i, d in enumerate(["bottom", "left", "top", "right"]):
    ax = setup_axes(fig, rect=241+i)
    axis = add_floating_axis1(ax)
    axis.set_axis_direction(d)
    ax.set(title=d)

for i, d in enumerate(["bottom", "left", "top", "right"]):
    ax = setup_axes(fig, rect=245+i)
    axis = add_floating_axis2(ax)
    axis.set_axis_direction(d)
    ax.set(title=d)

plt.show()
```

Axis line styles

This example shows some configurations for axis style.

Note: The *mpl_toolkits.axisartist* Axes classes may be confusing for new users. If the only aim is to obtain arrow heads at the ends of the axes, rather check out the *Centered spines with arrows* example.




```
import matplotlib.pyplot as plt
import numpy as np

from mpl_toolkits.axisartist.axislines import AxesZero

fig = plt.figure()
ax = fig.add_subplot(axes_class=AxesZero)

for direction in ["xzero", "yzero"]:
    # adds arrows at the ends of each axis
    ax.axis[direction].set_axisline_style("-|>")

    # adds X and Y-axis from the origin
    ax.axis[direction].set_visible(True)

for direction in ["left", "right", "bottom", "top"]:
    # hides borders
    ax.axis[direction].set_visible(False)

x = np.linspace(-0.5, 1., 100)
```

(continues on next page)

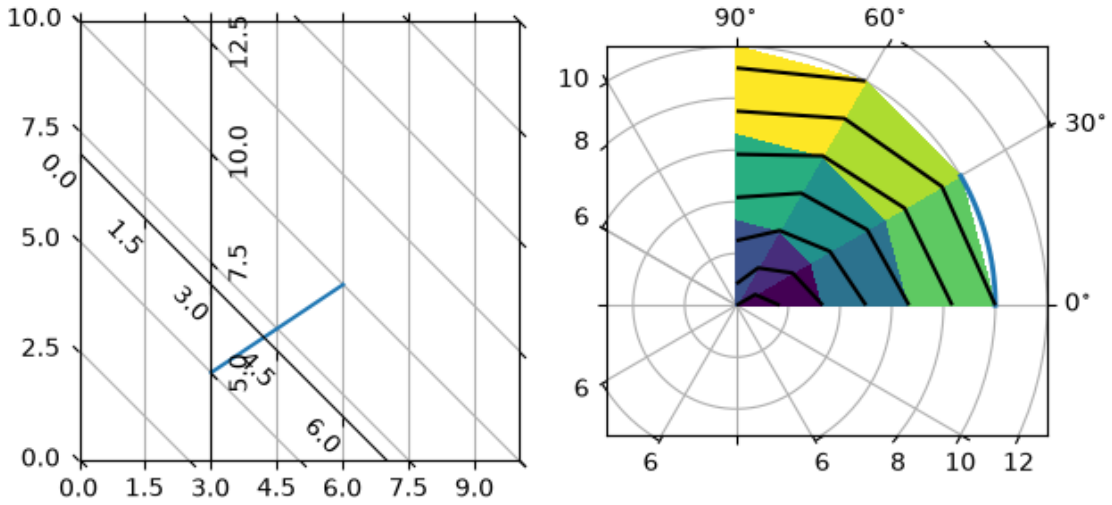
(continued from previous page)

```
ax.plot(x, np.sin(x*np.pi))

plt.show()
```

Curvilinear grid demo

Custom grid and ticklines.

This example demonstrates how to use *GridHelperCurveLinear* to define custom grids and ticklines by applying a transformation on the grid. This can be used, as shown on the second plot, to create polar projections in a rectangular box.




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.projections import PolarAxes
from matplotlib.transforms import Affine2D
from mpl_toolkits.axisartist import Axes, HostAxes, angle_helper
from mpl_toolkits.axisartist.grid_helper_curvelinear import␣
 ↪GridHelperCurveLinear


def curvelinear_test1(fig):
    """
    Grid for custom transform.
    """
```

(continues on next page)

(continued from previous page)

```
    def tr(x, y): return x, y - x
    def inv_tr(x, y): return x, y + x

    grid_helper = GridHelperCurveLinear((tr, inv_tr))

    ax1 = fig.add_subplot(1, 2, 1, axes_class=Axes,␣
↪grid_helper=grid_helper)
    # ax1 will have ticks and gridlines defined by the given transform␣
↪(+
    # transData of the Axes).  Note that the transform of the Axes␣
↪itself
    # (i.e., transData) is not affected by the given transform.
    xx, yy = tr(np.array([3, 6]), np.array([5, 10]))
    ax1.plot(xx, yy)

    ax1.set_aspect(1)
    ax1.set_xlim(0, 10)
    ax1.set_ylim(0, 10)

    ax1.axis["t"] = ax1.new_floating_axis(0, 3)
    ax1.axis["t2"] = ax1.new_floating_axis(1, 7)
    ax1.grid(True, zorder=0)


def curvelinear_test2(fig):
    """
    Polar projection, but in a rectangular box.
    """

    # PolarAxes.PolarTransform takes radian. However, we want our␣
↪coordinate
    # system in degree
    tr = Affine2D().scale(np.pi/180, 1) + PolarAxes.PolarTransform()
    # Polar projection, which involves cycle, and also has limits in
    # its coordinates, needs a special method to find the extremes
    # (min, max of the coordinate within the view).
    extreme_finder = angle_helper.ExtremeFinderCycle(
        nx=20, ny=20,  # Number of sampling points in each direction.
        lon_cycle=360, lat_cycle=None,
        lon_minmax=None, lat_minmax=(0, np.inf),
    )
    # Find grid values appropriate for the coordinate (degree, minute,␣
↪second).
    grid_locator1 = angle_helper.LocatorDMS(12)
    # Use an appropriate formatter.  Note that the acceptable Locator␣
```

(continues on next page)

(continued from previous page)

```
↪and
    # Formatter classes are a bit different than that of Matplotlib,␣
↪which
    # cannot directly be used here (this may be possible in the␣
↪future).
    tick_formatter1 = angle_helper.FormatterDMS()

    grid_helper = GridHelperCurveLinear(
        tr, extreme_finder=extreme_finder,
        grid_locator1=grid_locator1, tick_formatter1=tick_formatter1)
    ax1 = fig.add_subplot(
        1, 2, 2, axes_class=HostAxes, grid_helper=grid_helper)

    # make ticklabels of right and top axis visible.
    ax1.axis["right"].major_ticklabels.set_visible(True)
    ax1.axis["top"].major_ticklabels.set_visible(True)
    # let right axis shows ticklabels for 1st coordinate (angle)
    ax1.axis["right"].get_helper().nth_coord_ticks = 0
    # let bottom axis shows ticklabels for 2nd coordinate (radius)
    ax1.axis["bottom"].get_helper().nth_coord_ticks = 1

    ax1.set_aspect(1)
    ax1.set_xlim(-5, 12)
    ax1.set_ylim(-5, 10)

    ax1.grid(True, zorder=0)

    # A parasite Axes with given transform
    ax2 = ax1.get_aux_axes(tr)
    # note that ax2.transData == tr + ax1.transData
    # Anything you draw in ax2 will match the ticks and grids of ax1.
    ax2.plot(np.linspace(0, 30, 51), np.linspace(10, 10, 51),␣
↪linewidth=2)

    ax2.pcolor(np.linspace(0, 90, 4), np.linspace(0, 10, 4),
               np.arange(9).reshape((3, 3)))
    ax2.contour(np.linspace(0, 90, 4), np.linspace(0, 10, 4),
                np.arange(16).reshape((4, 4)), colors="k")


if __name__ == "__main__":
    fig = plt.figure(figsize=(7, 4))

    curvelinear_test1(fig)
    curvelinear_test2(fig)
```

(continues on next page)

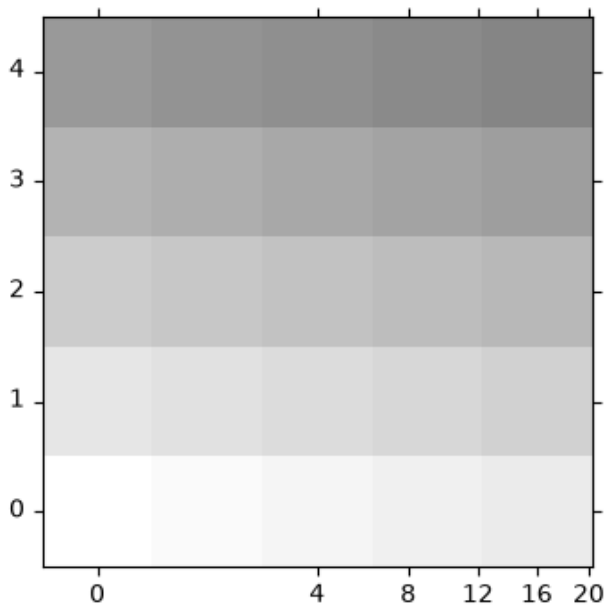
(continued from previous page)

```
    plt.show()
```

Demo CurveLinear Grid2

Custom grid and ticklines.

This example demonstrates how to use GridHelperCurveLinear to define custom grids and ticklines by applying a transformation on the grid. As showcase on the plot, a 5x5 matrix is displayed on the Axes.




```
import matplotlib.pyplot as plt
import numpy as np

from mpl_toolkits.axisartist.axislines import Axes
from mpl_toolkits.axisartist.grid_finder import ExtremeFinderSimple,␣
 ↪MaxNLocator
from mpl_toolkits.axisartist.grid_helper_curvelinear import␣
 ↪GridHelperCurveLinear


def curvelinear_test1(fig):
    """Grid for custom transform."""

    def tr(x, y):
        return np.sign(x)*abs(x)**.5, y

    def inv_tr(x, y):
```

(continues on next page)

(continued from previous page)

```
        return np.sign(x)*x**2, y

    grid_helper = GridHelperCurveLinear(
        (tr, inv_tr),
        extreme_finder=ExtremeFinderSimple(20, 20),
        # better tick density
        grid_locator1=MaxNLocator(nbins=6),␣
 ↪grid_locator2=MaxNLocator(nbins=6))

    ax1 = fig.add_subplot(axes_class=Axes, grid_helper=grid_helper)
    # ax1 will have a ticks and gridlines defined by the given
    # transform (+ transData of the Axes). Note that the transform of␣
 ↪the Axes
    # itself (i.e., transData) is not affected by the given transform.

    ax1.imshow(np.arange(25).reshape(5, 5),
               vmax=50, cmap="gray_r", origin="lower")


if __name__ == "__main__":
    fig = plt.figure(figsize=(7, 4))
    curvelinear_test1(fig)
    plt.show()
```

`floating_axes` features

Demonstration of features of the *floating_axes* module:

- Using *scatter* and *bar* with changing the shape of the plot.
- Using *GridHelperCurveLinear* to rotate the plot and set the plot boundary.
- Using *add_subplot* to create a subplot using the return value from *GridHelperCurveLinear*.
- Making a sector plot by adding more features to *GridHelperCurveLinear*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.projections import PolarAxes
from matplotlib.transforms import Affine2D
import mpl_toolkits.axisartist.angle_helper as angle_helper
import mpl_toolkits.axisartist.floating_axes as floating_axes
from mpl_toolkits.axisartist.grid_finder import DictFormatter,␣
 ↪FixedLocator, MaxNLocator

# Fixing random state for reproducibility
np.random.seed(19680801)
```

(continues on next page)

(continued from previous page)

```
def setup_axes1(fig, rect):
    """
    A simple one.
    """
    tr = Affine2D().scale(2, 1).rotate_deg(30)

    grid_helper = floating_axes.GridHelperCurveLinear(
        tr, extremes=(-0.5, 3.5, 0, 4),
        grid_locator1=MaxNLocator(nbins=4),
        grid_locator2=MaxNLocator(nbins=4))

    ax1 = fig.add_subplot(
        rect, axes_class=floating_axes.FloatingAxes,␣
 ↪grid_helper=grid_helper)
    ax1.grid()

    aux_ax = ax1.get_aux_axes(tr)

    return ax1, aux_ax


def setup_axes2(fig, rect):
    """
    With custom locator and formatter.
    Note that the extreme values are swapped.
    """
    tr = PolarAxes.PolarTransform()

    pi = np.pi
    angle_ticks = {
        0: r"$0$",
        pi/4: r"$\frac{1}{4}\pi$",
        pi/2: r"$\frac{1}{2}\pi$",
    }
    grid_helper = floating_axes.GridHelperCurveLinear(
        tr, extremes=(.5*pi, 0, 2, 1),
        grid_locator1=FixedLocator([*angle_ticks]),
        tick_formatter1=DictFormatter(angle_ticks),
        grid_locator2=MaxNLocator(2),
        tick_formatter2=None,
    )
    ax1 = fig.add_subplot(
        rect, axes_class=floating_axes.FloatingAxes,␣
 ↪grid_helper=grid_helper)
```

(continues on next page)

(continued from previous page)

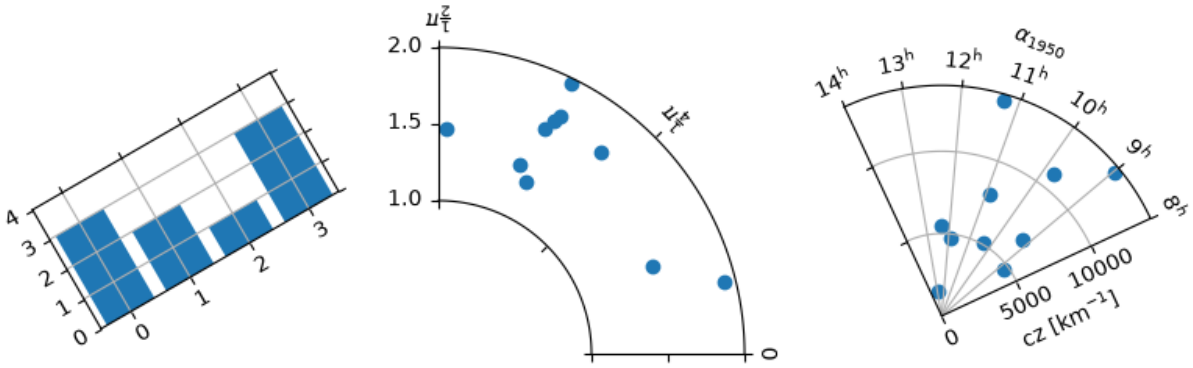
```
    ax1.grid()

    # create a parasite Axes whose transData in RA, cz
    aux_ax = ax1.get_aux_axes(tr)

    aux_ax.patch = ax1.patch  # for aux_ax to have a clip path as in ax
    ax1.patch.zorder = 0.9  # but this has a side effect that the␣
↪patch is
    # drawn twice, and possibly over some other
    # artists. So, we decrease the zorder a bit to
    # prevent this.

    return ax1, aux_ax


def setup_axes3(fig, rect):
    """
    Sometimes, things like axis_direction need to be adjusted.
    """

    tr_rotate = Affine2D().translate(-95, 0)  # rotate a bit for␣
↪better orientation
    tr_scale = Affine2D().scale(np.pi/180., 1.)  # scale degree to␣
↪radians
    tr = tr_rotate + tr_scale + PolarAxes.PolarTransform()

    # Specify theta limits in degrees
    ra0, ra1 = 8.*15, 14.*15
    # Specify radial limits
    cz0, cz1 = 0, 14000

    grid_helper = floating_axes.GridHelperCurveLinear(
        tr, extremes=(ra0, ra1, cz0, cz1),
        grid_locator1=angle_helper.LocatorHMS(4),
        tick_formatter1=angle_helper.FormatterHMS(),
        grid_locator2=MaxNLocator(3),
        tick_formatter2=None,
    )
    ax1 = fig.add_subplot(
        rect, axes_class=floating_axes.FloatingAxes,␣
↪grid_helper=grid_helper)

    # adjust axis
    ax1.axis["left"].set_axis_direction("bottom")
    ax1.axis["right"].set_axis_direction("top")
```

(continues on next page)

(continued from previous page)

```
    ax1.axis["bottom"].set_visible(False)
    ax1.axis["top"].set_axis_direction("bottom")
    ax1.axis["top"].toggle(ticklabels=True, label=True)
    ax1.axis["top"].major_ticklabels.set_axis_direction("top")
    ax1.axis["top"].label.set_axis_direction("top")

    ax1.axis["left"].label.set_text(r"cz [km$^{-1}$]")
    ax1.axis["top"].label.set_text(r"$\alpha_{1950}$")
    ax1.grid()

    # create a parasite Axes whose transData in RA, cz
    aux_ax = ax1.get_aux_axes(tr)

    aux_ax.patch = ax1.patch  # for aux_ax to have a clip path as in ax
    ax1.patch.zorder = 0.9  # but this has a side effect that the␣
↪patch is
    # drawn twice, and possibly over some other
    # artists. So, we decrease the zorder a bit to
    # prevent this.

    return ax1, aux_ax
```

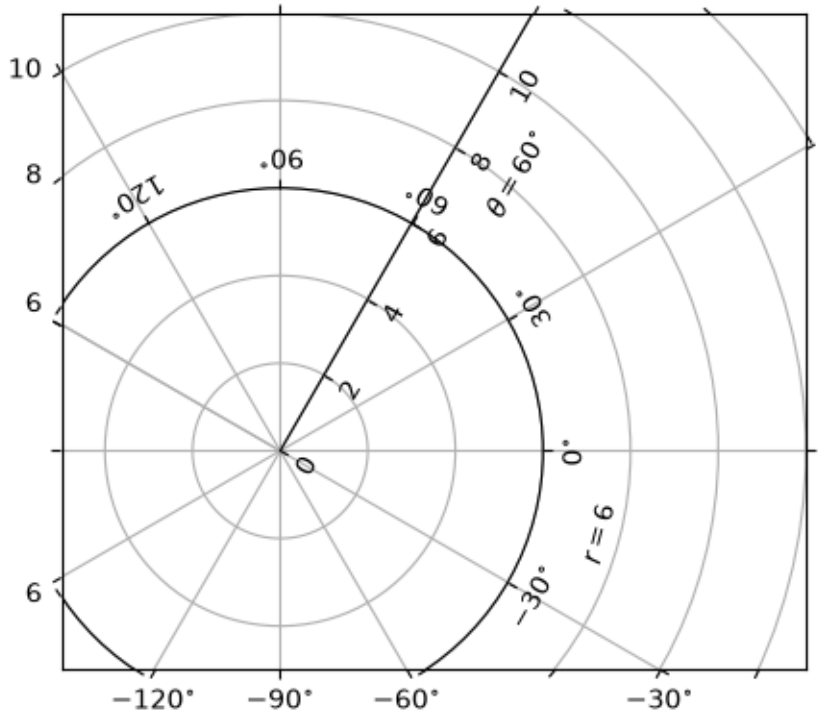
```
fig = plt.figure(figsize=(8, 4))
fig.subplots_adjust(wspace=0.3, left=0.05, right=0.95)

ax1, aux_ax1 = setup_axes1(fig, 131)
aux_ax1.bar([0, 1, 2, 3], [3, 2, 1, 3])

ax2, aux_ax2 = setup_axes2(fig, 132)
theta = np.random.rand(10)*.5*np.pi
radius = np.random.rand(10) + 1.
aux_ax2.scatter(theta, radius)

ax3, aux_ax3 = setup_axes3(fig, 133)

theta = (8 + np.random.rand(10)*(14 - 8))*15.  # in degrees
radius = np.random.rand(10)*14000.
aux_ax3.scatter(theta, radius)

plt.show()
```



floating_axis demo

Axis within rectangular frame.

The following code demonstrates how to put a floating polar curve within a rectangular box. In order to get a better sense of polar curves, please look at *Curvilinear grid demo*.




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.projections import PolarAxes
from matplotlib.transforms import Affine2D
from mpl_toolkits.axisartist import GridHelperCurveLinear, HostAxes
import mpl_toolkits.axisartist.angle_helper as angle_helper


def curvelinear_test2(fig):
    """Polar projection, but in a rectangular box."""
    # see demo_curvelinear_grid.py for details
    grid_helper = GridHelperCurveLinear(
        Affine2D().scale(np.pi / 180., 1.) + PolarAxes.
 ↪PolarTransform(),
        extreme_finder=angle_helper.ExtremeFinderCycle(
            20, 20,
            lon_cycle=360, lat_cycle=None,
            lon_minmax=None, lat_minmax=(0, np.inf),
```

(continues on next page)

(continued from previous page)

```
        ),
        grid_locator1=angle_helper.LocatorDMS(12),
        tick_formatter1=angle_helper.FormatterDMS(),
    )
    ax1 = fig.add_subplot(axes_class=HostAxes, grid_helper=grid_helper)

    # Now create floating axis

    # floating axis whose first coordinate (theta) is fixed at 60
    ax1.axis["lat"] = axis = ax1.new_floating_axis(0, 60)
    axis.label.set_text(r"$\theta = 60^{\circ}$")
    axis.label.set_visible(True)

    # floating axis whose second coordinate (r) is fixed at 6
    ax1.axis["lon"] = axis = ax1.new_floating_axis(1, 6)
    axis.label.set_text(r"$r = 6$")

    ax1.set_aspect(1.)
    ax1.set_xlim(-5, 12)
    ax1.set_ylim(-5, 10)

    ax1.grid(True)


fig = plt.figure(figsize=(5, 5))
curvelinear_test2(fig)
plt.show()
```

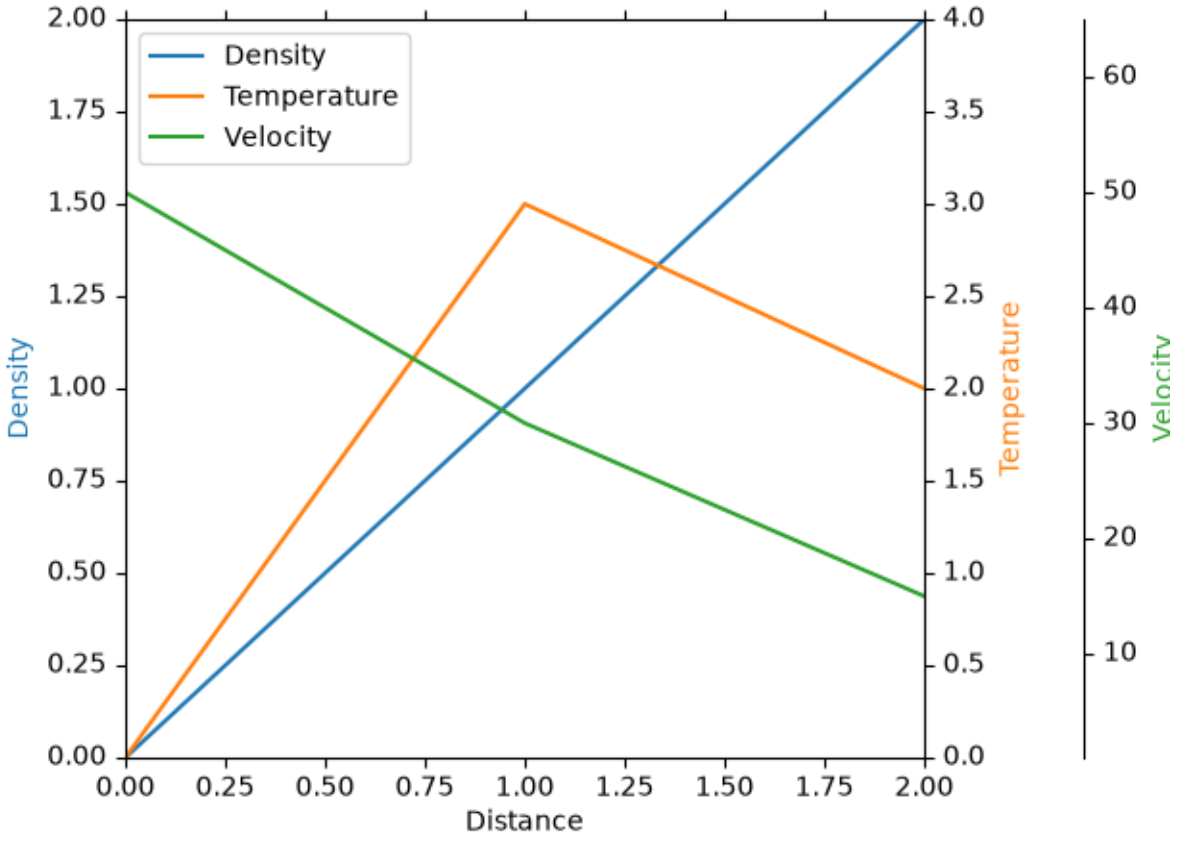
Parasite Axes demo

Create a parasite Axes. Such Axes would share the x scale with a host Axes, but show a different scale in y direction.

This approach uses *mpl_toolkits.axes_grid1.parasite_axes.HostAxes* and *mpl_toolkits.axes_grid1.parasite_axes.ParasiteAxes*.

The standard and recommended approach is to use instead standard Matplotlib axes, as shown in the *Multiple y-axis with Spines* example.

An alternative approach using *mpl_toolkits.axes_grid1* and *mpl_toolkits.axisartist* is shown in the *Parasite axis demo* example.




```
import matplotlib.pyplot as plt

from mpl_toolkits.axisartist.parasite_axes import HostAxes

fig = plt.figure()

host = fig.add_axes((0.15, 0.1, 0.65, 0.8), axes_class=HostAxes)
par1 = host.get_aux_axes(viewlim_mode=None, sharex=host)
par2 = host.get_aux_axes(viewlim_mode=None, sharex=host)

host.axis["right"].set_visible(False)

par1.axis["right"].set_visible(True)
par1.axis["right"].major_ticklabels.set_visible(True)
par1.axis["right"].label.set_visible(True)

par2.axis["right2"] = par2.new_fixed_axis(loc="right", offset=(60, 0))

p1, = host.plot([0, 1, 2], [0, 1, 2], label="Density")
p2, = par1.plot([0, 1, 2], [0, 3, 2], label="Temperature")
```

(continues on next page)

(continued from previous page)

```
p3, = par2.plot([0, 1, 2], [50, 30, 15], label="Velocity")

host.set(xlim=(0, 2), ylim=(0, 2), xlabel="Distance", ylabel="Density")
par1.set(ylim=(0, 4), ylabel="Temperature")
par2.set(ylim=(1, 65), ylabel="Velocity")

host.legend()

host.axis["left"].label.set_color(p1.get_color())
par1.axis["right"].label.set_color(p2.get_color())
par2.axis["right2"].label.set_color(p3.get_color())

plt.show()
```

Parasite axis demo

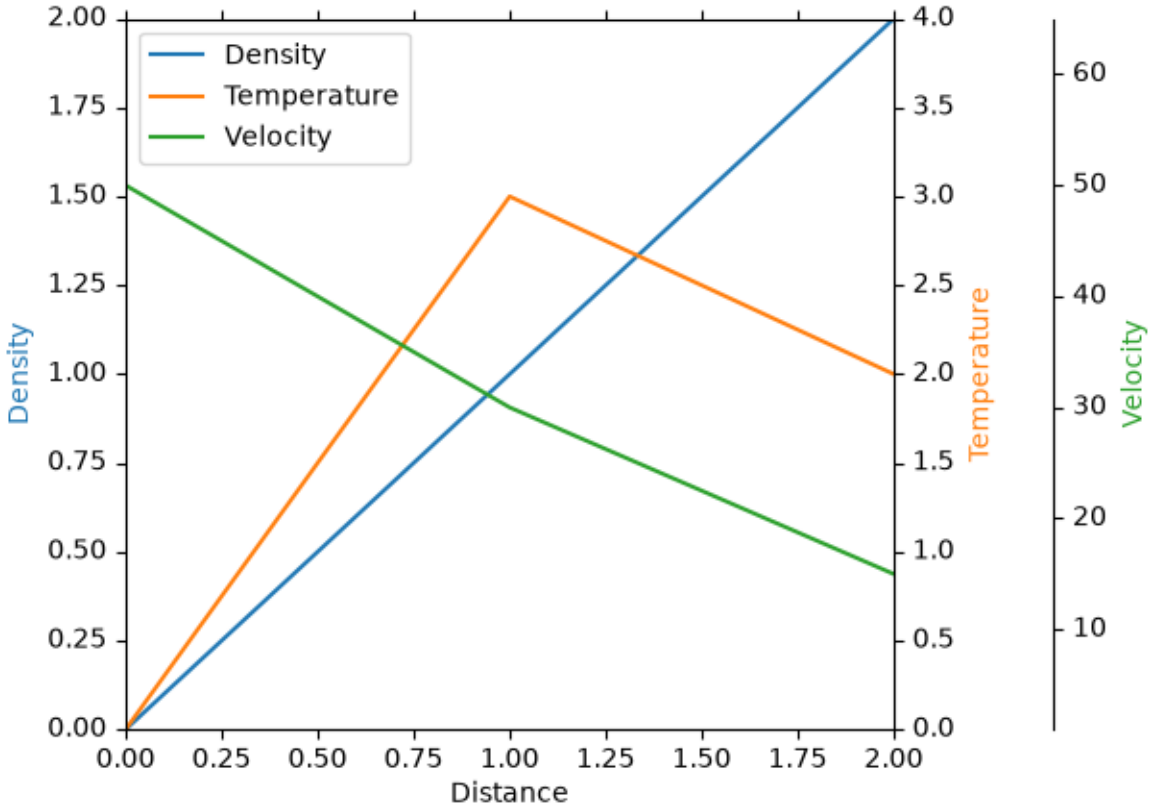
This example demonstrates the use of parasite axis to plot multiple datasets onto one single plot.

Notice how in this example, *par1* and *par2* are both obtained by calling `twinx()`, which ties their x-limits with the host's x-axis. From there, each of those two axis behave separately from each other: different datasets can be plotted, and the y-limits are adjusted separately.

This approach uses *mpl_toolkits.axes_grid1.parasite_axes.host_subplot* and *mpl_toolkits.axisartist.axislines.Axes*.

The standard and recommended approach is to use instead standard Matplotlib axes, as shown in the *Multiple y-axis with Spines* example.

An alternative approach using *mpl_toolkits.axes_grid1.parasite_axes.HostAxes* and *mpl_toolkits.axes_grid1.parasite_axes.ParasiteAxes* is shown in the *Parasite Axes demo* example.



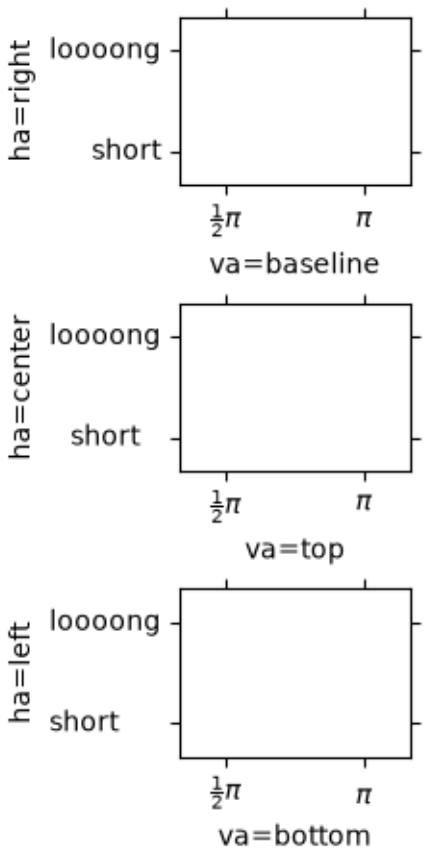

```
import matplotlib.pyplot as plt

from mpl_toolkits import axisartist
from mpl_toolkits.axes_grid1 import host_subplot

host = host_subplot(111, axes_class=axisartist.Axes)
plt.subplots_adjust(right=0.75)

par1 = host.twinx()
par2 = host.twinx()

par2.axis["right"] = par2.new_fixed_axis(loc="right", offset=(60, 0))

par1.axis["right"].toggle(all=True)
par2.axis["right"].toggle(all=True)

p1, = host.plot([0, 1, 2], [0, 1, 2], label="Density")
p2, = par1.plot([0, 1, 2], [0, 3, 2], label="Temperature")
p3, = par2.plot([0, 1, 2], [50, 30, 15], label="Velocity")
```

(continues on next page)

(continued from previous page)

```
host.set(xlim=(0, 2), ylim=(0, 2), xlabel="Distance", ylabel="Density")
par1.set(ylim=(0, 4), ylabel="Temperature")
par2.set(ylim=(1, 65), ylabel="Velocity")

host.legend()

host.axis["left"].label.set_color(p1.get_color())
par1.axis["right"].label.set_color(p2.get_color())
par2.axis["right"].label.set_color(p3.get_color())

plt.show()
```

Ticklabel alignment



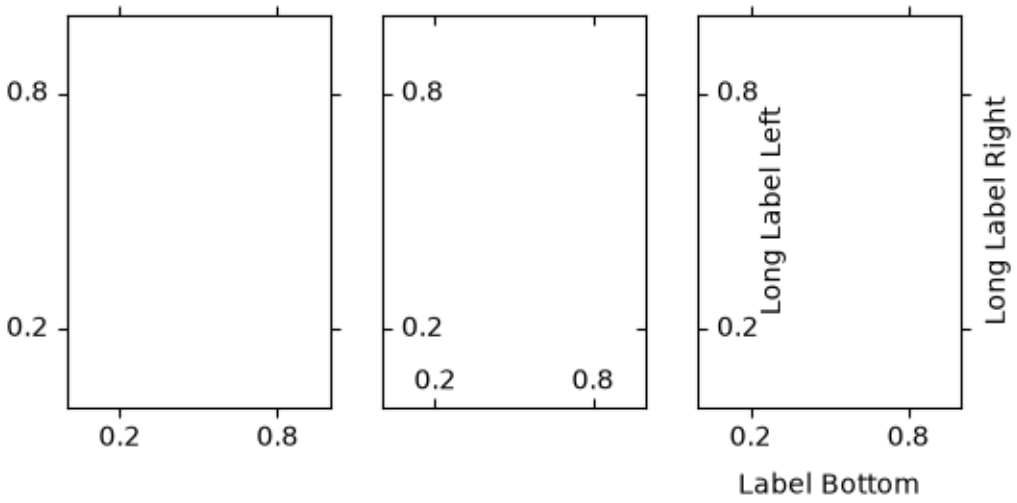

```
import matplotlib.pyplot as plt

import mpl_toolkits.axisartist as axisartist
```

(continues on next page)

(continued from previous page)

```
def setup_axes(fig, pos):
    ax = fig.add_subplot(pos, axes_class=axisartist.Axes)
    ax.set_yticks([0.2, 0.8], labels=["short", "loooong"])
    ax.set_xticks([0.2, 0.8], labels=[r"$\frac{1}{2}\pi$", r"$\pi$"])
    return ax


fig = plt.figure(figsize=(3, 5))
fig.subplots_adjust(left=0.5, hspace=0.7)

ax = setup_axes(fig, 311)
ax.set_ylabel("ha=right")
ax.set_xlabel("va=baseline")

ax = setup_axes(fig, 312)
ax.axis["left"].major_ticklabels.set_ha("center")
ax.axis["bottom"].major_ticklabels.set_va("top")
ax.set_ylabel("ha=center")
ax.set_xlabel("va=top")

ax = setup_axes(fig, 313)
ax.axis["left"].major_ticklabels.set_ha("left")
ax.axis["bottom"].major_ticklabels.set_va("bottom")
ax.set_ylabel("ha=left")
ax.set_xlabel("va=bottom")

plt.show()
```

Ticklabel direction



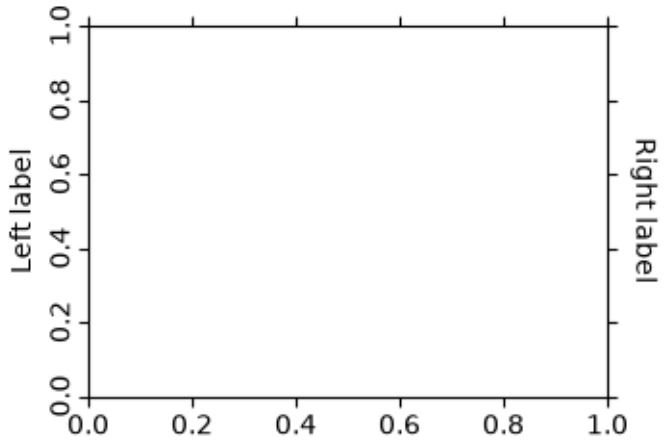

```
import matplotlib.pyplot as plt

import mpl_toolkits.axisartist.axislines as axislines


def setup_axes(fig, pos):
    ax = fig.add_subplot(pos, axes_class=axislines.Axes)
    ax.set_yticks([0.2, 0.8])
    ax.set_xticks([0.2, 0.8])
    return ax


fig = plt.figure(figsize=(6, 3))
fig.subplots_adjust(bottom=0.2)

ax = setup_axes(fig, 131)
for axis in ax.axis.values():
    axis.major_ticks.set_tick_out(True)
# or you can simply do "ax.axis[:].major_ticks.set_tick_out(True)"

ax = setup_axes(fig, 132)
ax.axis["left"].set_axis_direction("right")
ax.axis["bottom"].set_axis_direction("top")
ax.axis["right"].set_axis_direction("left")
ax.axis["top"].set_axis_direction("bottom")

ax = setup_axes(fig, 133)
ax.axis["left"].set_axis_direction("right")
```

(continues on next page)

(continued from previous page)

```
ax.axis[:].major_ticks.set_tick_out(True)

ax.axis["left"].label.set_text("Long Label Left")
ax.axis["bottom"].label.set_text("Label Bottom")
ax.axis["right"].label.set_text("Long Label Right")
ax.axis["right"].label.set_visible(True)
ax.axis["left"].label.set_pad(0)
ax.axis["bottom"].label.set_pad(10)

plt.show()
```

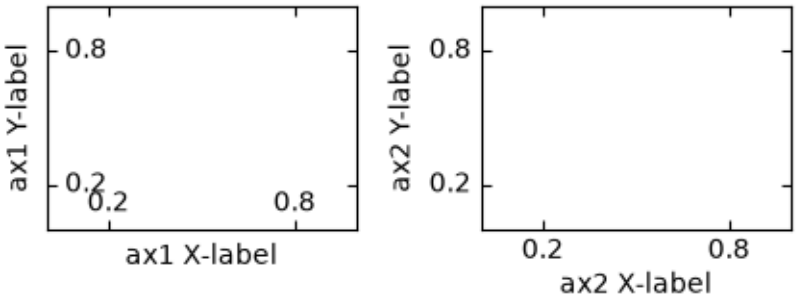
Simple axis direction




```
import matplotlib.pyplot as plt

import mpl_toolkits.axisartist as axisartist

fig = plt.figure(figsize=(4, 2.5))
ax1 = fig.add_subplot(axes_class=axisartist.Axes)
fig.subplots_adjust(right=0.8)

ax1.axis["left"].major_ticklabels.set_axis_direction("top")
ax1.axis["left"].label.set_text("Left label")

ax1.axis["right"].label.set_visible(True)
ax1.axis["right"].label.set_text("Right label")
ax1.axis["right"].label.set_axis_direction("left")

plt.show()
```

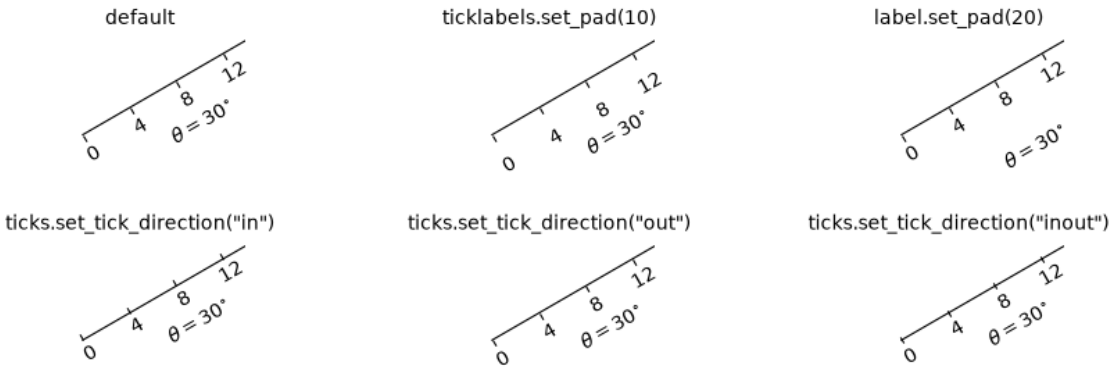
Simple axis tick label and tick directions

First subplot moves the tick labels to inside the spines. Second subplot moves the ticks to inside the spines. These effects can be obtained for a standard Axes by *tick_params*.




```
import matplotlib.pyplot as plt

import mpl_toolkits.axisartist as axisartist


def setup_axes(fig, pos):
    ax = fig.add_subplot(pos, axes_class=axisartist.Axes)
    ax.set_yticks([0.2, 0.8])
    ax.set_xticks([0.2, 0.8])
    return ax


fig = plt.figure(figsize=(5, 2))
fig.subplots_adjust(wspace=0.4, bottom=0.3)

ax1 = setup_axes(fig, 121)
ax1.set_xlabel("ax1 X-label")
ax1.set_ylabel("ax1 Y-label")

ax1.axis[:].invert_ticklabel_direction()

ax2 = setup_axes(fig, 122)
ax2.set_xlabel("ax2 X-label")
ax2.set_ylabel("ax2 Y-label")

ax2.axis[:].major_ticks.set_tick_out(False)

plt.show()
```

Simple axis pad




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.projections import PolarAxes
from matplotlib.transforms import Affine2D
import mpl_toolkits.axisartist as axisartist
from mpl_toolkits.axisartist import angle_helper, grid_finder
from mpl_toolkits.axisartist.grid_helper_curvelinear import␣
 ↪GridHelperCurveLinear


def setup_axes(fig, rect):
    """Polar projection, but in a rectangular box."""
    # see demo_curvelinear_grid.py for details
    grid_helper = GridHelperCurveLinear(
        Affine2D().scale(np.pi/180., 1.) + PolarAxes.PolarTransform(),
        extreme_finder=angle_helper.ExtremeFinderCycle(
            20, 20,
            lon_cycle=360, lat_cycle=None,
            lon_minmax=None, lat_minmax=(0, np.inf),
        ),
        grid_locator1=angle_helper.LocatorDMS(12),
        grid_locator2=grid_finder.MaxNLocator(5),
        tick_formatter1=angle_helper.FormatterDMS(),
    )
    ax = fig.add_subplot(
        rect, axes_class=axisartist.Axes, grid_helper=grid_helper,
        aspect=1, xlim=(-5, 12), ylim=(-5, 10))
    ax.axis[:].set_visible(False)
    return ax


def add_floating_axis1(ax1):
```

(continues on next page)

(continued from previous page)

```
    ax1.axis["lat"] = axis = ax1.new_floating_axis(0, 30)
    axis.label.set_text(r"$\theta = 30^{\circ}$")
    axis.label.set_visible(True)

    return axis


def add_floating_axis2(ax1):
    ax1.axis["lon"] = axis = ax1.new_floating_axis(1, 6)
    axis.label.set_text(r"$r = 6$")
    axis.label.set_visible(True)

    return axis


fig = plt.figure(figsize=(9, 3.))
fig.subplots_adjust(left=0.01, right=0.99, bottom=0.01, top=0.99,
                    wspace=0.01, hspace=0.01)


def ann(ax1, d):
    ax1.annotate(d, (0.5, 1), (5, -5),
                 xycoords="axes fraction", textcoords="offset points",
                 va="top", ha="center")


ax1 = setup_axes(fig, rect=231)
axis = add_floating_axis1(ax1)
ann(ax1, "default")

ax1 = setup_axes(fig, rect=232)
axis = add_floating_axis1(ax1)
axis.major_ticklabels.set_pad(10)
ann(ax1, "ticklabels.set_pad(10)")

ax1 = setup_axes(fig, rect=233)
axis = add_floating_axis1(ax1)
axis.label.set_pad(20)
ann(ax1, "label.set_pad(20)")

ax1 = setup_axes(fig, rect=234)
axis = add_floating_axis1(ax1)
axis.major_ticks.set_tick_direction("in")
ann(ax1, 'ticks.set_tick_direction("in")')

ax1 = setup_axes(fig, rect=235)
```

(continues on next page)

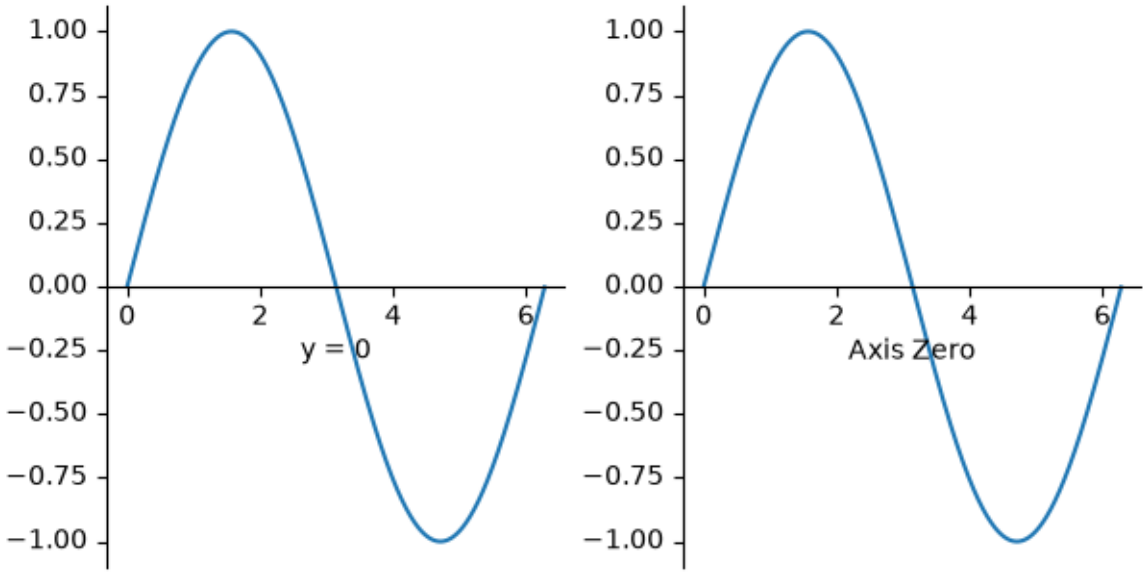
(continued from previous page)

```
axis = add_floating_axis1(ax1)
axis.major_ticks.set_tick_direction("out")
ann(ax1, 'ticks.set_tick_direction("out")')

ax1 = setup_axes(fig, rect=236)
axis = add_floating_axis1(ax1)
axis.major_ticks.set_tick_direction("inout")
ann(ax1, 'ticks.set_tick_direction("inout")')

plt.show()
```

Custom spines with axisartist

This example showcases the use of *axisartist* to draw spines at custom positions (here, at `y = 0`).

Note, however, that it is simpler to achieve this effect using standard *Spine* methods, as demonstrated in *Centered spines with arrows*.



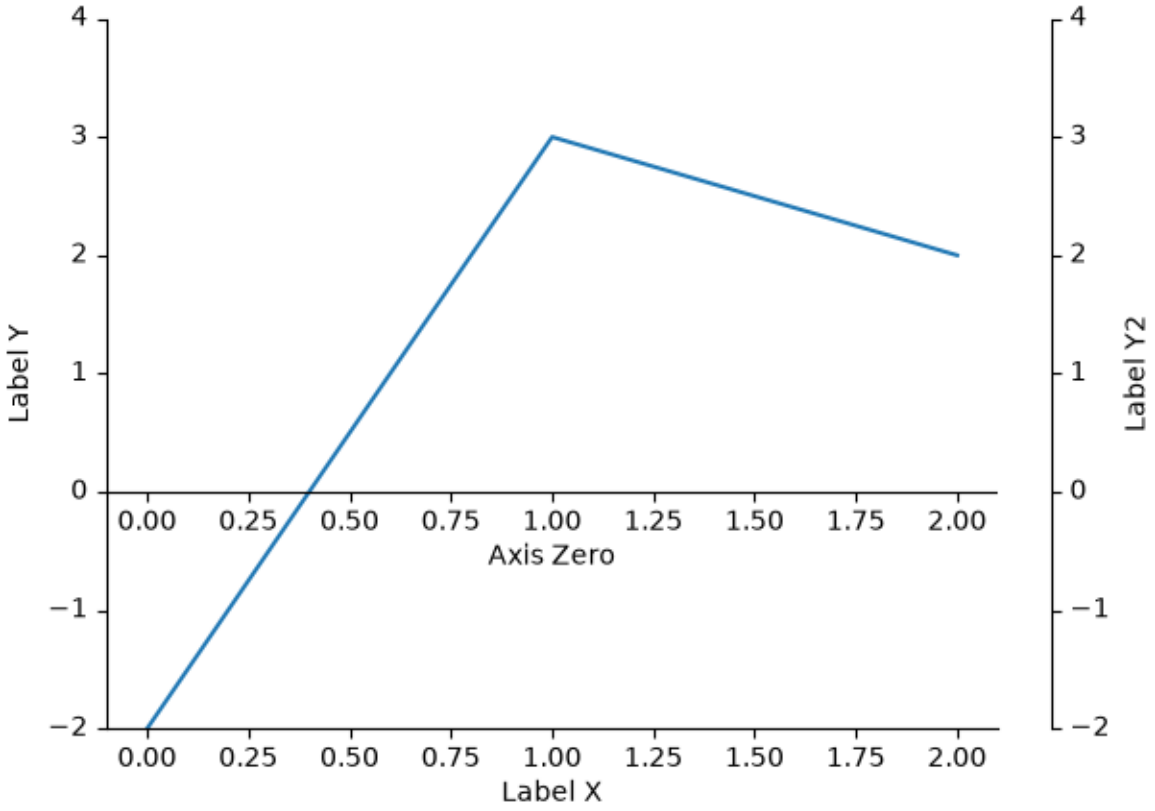

```
import matplotlib.pyplot as plt
import numpy as np

from mpl_toolkits import axisartist

fig = plt.figure(figsize=(6, 3), layout="constrained")
# To construct Axes of two different classes, we need to use gridspec␣
 ↪(or
# MATLAB-style add_subplot calls).
gs = fig.add_gridspec(1, 2)
```

(continues on next page)

(continued from previous page)

```
ax0 = fig.add_subplot(gs[0, 0], axes_class=axisartist.Axes)
# Make a new axis along the first (x) axis which passes through y=0.
ax0.axis["y=0"] = ax0.new_floating_axis(nth_coord=0, value=0,
                                        axis_direction="bottom")
ax0.axis["y=0"].toggle(all=True)
ax0.axis["y=0"].label.set_text("y = 0")
# Make other axis invisible.
ax0.axis["bottom", "top", "right"].set_visible(False)


# Alternatively, one can use AxesZero, which automatically sets up two
# additional axis, named "xzero" (the y=0 axis) and "yzero" (the x=0␣
 ↪axis).
ax1 = fig.add_subplot(gs[0, 1], axes_class=axisartist.axislines.
 ↪AxesZero)
# "xzero" and "yzero" default to invisible; make xzero axis visible.
ax1.axis["xzero"].set_visible(True)
ax1.axis["xzero"].label.set_text("Axis Zero")
# Make other axis invisible.
ax1.axis["bottom", "top", "right"].set_visible(False)


# Draw some sample data.
x = np.arange(0, 2*np.pi, 0.01)
ax0.plot(x, np.sin(x))
ax1.plot(x, np.sin(x))

plt.show()
```

Simple Axisline



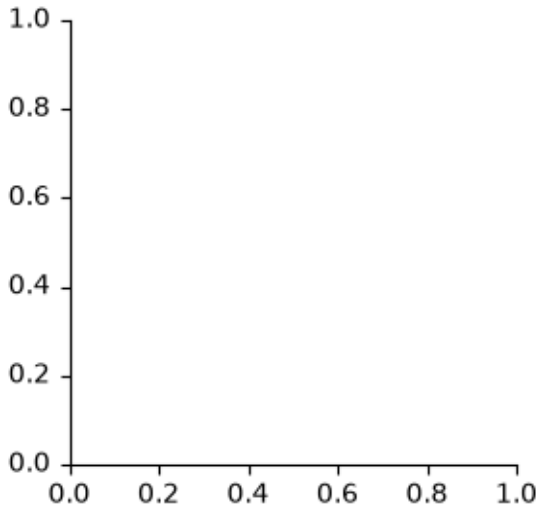

```
import matplotlib.pyplot as plt

from mpl_toolkits.axisartist.axislines import AxesZero

fig = plt.figure()
fig.subplots_adjust(right=0.85)
ax = fig.add_subplot(axes_class=AxesZero)

# make right and top axis invisible
ax.axis["right"].set_visible(False)
ax.axis["top"].set_visible(False)

# make xzero axis (horizontal axis line through y=0) visible.
ax.axis["xzero"].set_visible(True)
ax.axis["xzero"].label.set_text("Axis Zero")

ax.set_ylim(-2, 4)
ax.set_xlabel("Label X")
ax.set_ylabel("Label Y")
```

(continues on next page)

(continued from previous page)

```
# Or:
# ax.axis["bottom"].label.set_text("Label X")
# ax.axis["left"].label.set_text("Label Y")

# make new (right-side) yaxis, but with some offset
ax.axis["right2"] = ax.new_fixed_axis(loc="right", offset=(20, 0))
ax.axis["right2"].label.set_text("Label Y2")

ax.plot([-2, 3, 2])
plt.show()
```

Simple Axisline3




```
import matplotlib.pyplot as plt

from mpl_toolkits.axisartist.axislines import Axes

fig = plt.figure(figsize=(3, 3))

ax = fig.add_subplot(axes_class=Axes)

ax.axis["right"].set_visible(False)
ax.axis["top"].set_visible(False)

plt.show()
```

6.24.17 Animation

Basic animated line plot

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation

fig, ax = plt.subplots()

x = np.arange(0, 2*np.pi, 0.01)
line, = ax.plot(x, np.sin(x))


def animate(i):
    line.set_ydata(np.sin(x + i / 50))  # update the data.
    return line,


ani = animation.FuncAnimation(
    fig, animate, interval=20, blit=True, save_count=50)

# To save the animation, use e.g.
#
# ani.save("movie.mp4")
#
# or
#
# writer = animation.FFMpegWriter(
#     fps=15, metadata=dict(artist='Me'), bitrate=1800)
# ani.save("movie.mp4", writer=writer)

plt.show()
```

Tags: component: animation level: beginner

Total running time of the script: (0 minutes 9.034 seconds)

Decay

This example showcases:

- using a generator to drive an animation,
- changing axes limits during an animation.

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import itertools

import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation


def data_gen():
    for cnt in itertools.count():
        t = cnt / 10
        yield t, np.sin(2*np.pi*t) * np.exp(-t/10.)


def init():
    ax.set_ylim(-1.1, 1.1)
    ax.set_xlim(0, 1)
    del xdata[:]
    del ydata[:]
    line.set_data(xdata, ydata)
    return line,

fig, ax = plt.subplots()
line, = ax.plot([], [], lw=2)
ax.grid()
xdata, ydata = [], []


def run(data):
    # update the data
    t, y = data
    xdata.append(t)
    ydata.append(y)
    xmin, xmax = ax.get_xlim()

    if t >= xmax:
        ax.set_xlim(xmin, 2*xmax)
        ax.figure.canvas.draw()
    line.set_data(xdata, ydata)

    return line,

# Only save last 100 frames, but run forever
ani = animation.FuncAnimation(fig, run, data_gen, interval=100,␣
 ↪init_func=init,
                              save_count=100)
```

(continues on next page)

(continued from previous page)

```
plt.show()
```

Total running time of the script: (0 minutes 22.048 seconds)

Animated histogram

Use histogram's *BarContainer* to draw a bunch of rectangles for an animated histogram.

```
import functools

import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation

# Setting up a random number generator with a fixed state for␣
 ↪reproducibility.
rng = np.random.default_rng(seed=19680801)
# Fixing bin edges.
HIST_BINS = np.linspace(-4, 4, 100)

# Histogram our data with numpy.
data = rng.standard_normal(1000)
n, _ = np.histogram(data, HIST_BINS)
```

To animate the histogram, we need an `animate` function, which generates a random set of numbers and updates the heights of rectangles. The `animate` function updates the *Rectangle* patches on an instance of *BarContainer*.

```
def animate(frame_number, bar_container):
    # Simulate new data coming in.
    data = rng.standard_normal(1000)
    n, _ = np.histogram(data, HIST_BINS)
    for count, rect in zip(n, bar_container.patches):
        rect.set_height(count)

    return bar_container.patches
```

Using *hist()* allows us to get an instance of *BarContainer*, which is a collection of *Rectangle* instances. Since *FuncAnimation* will only pass the frame number parameter to the animation function, we use `functools.partial` to fix the `bar_container` parameter.

```
# Output generated via `matplotlib.animation.Animation.to_jshtml`.

fig, ax = plt.subplots()
_, _, bar_container = ax.hist(data, HIST_BINS, lw=1,
                              ec="yellow", fc="green", alpha=0.5)
```

(continues on next page)

(continued from previous page)

```
ax.set_ylim(top=55)  # set safe limit to ensure that all data is␣
↪visible.

anim = functools.partial(animate, bar_container=bar_container)
ani = animation.FuncAnimation(fig, anim, 50, repeat=False, blit=True)
plt.show()
```

Tags: plot-type: histogram component: animation

Total running time of the script: (0 minutes 10.630 seconds)

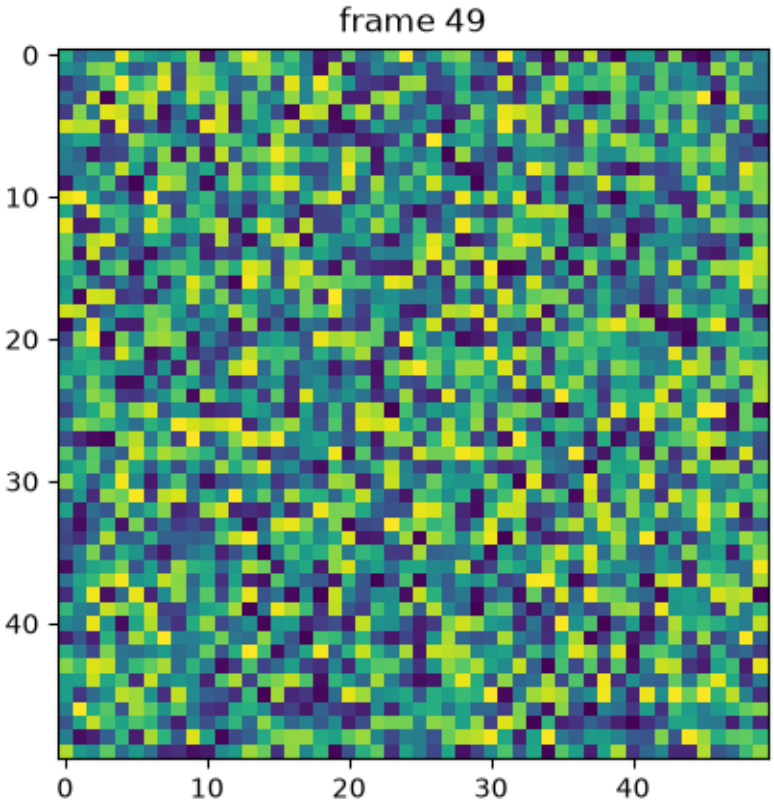
pyplot animation

Generating an animation by calling *pause* between plotting commands.

The method shown here is only suitable for simple, low-performance use. For more demanding applications, look at the *animation* module and the examples that use it.

Note that calling time.sleep instead of *pause* would *not* work.

Output generated via *matplotlib.animation.Animation.to_jshtml*.



```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)
data = np.random.random((50, 50, 50))

fig, ax = plt.subplots()

for i, img in enumerate(data):
    ax.clear()
    ax.imshow(img)
    ax.set_title(f"frame {i}")
    # Note that using time.sleep does *not* work here!
    plt.pause(0.1)
```

Total running time of the script: (0 minutes 8.970 seconds)

The Bayes update

This animation displays the posterior estimate updates as it is refitted when new data arrives. The vertical line represents the theoretical value to which the plotted distribution should converge.

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import math

import matplotlib.pyplot as plt
import numpy as np

from matplotlib.animation import FuncAnimation


def beta_pdf(x, a, b):
    return (x**(a-1) * (1-x)**(b-1) * math.gamma(a + b)
            / (math.gamma(a) * math.gamma(b)))


class UpdateDist:
    def __init__(self, ax, prob=0.5):
        self.success = 0
        self.prob = prob
        self.line, = ax.plot([], [], 'k-')
        self.x = np.linspace(0, 1, 200)
        self.ax = ax

        # Set up plot parameters
        self.ax.set_xlim(0, 1)
```

(continues on next page)

(continued from previous page)

```
        self.ax.set_ylim(0, 10)
        self.ax.grid(True)

        # This vertical line represents the theoretical value, to
        # which the plotted distribution should converge.
        self.ax.axvline(prob, linestyle='--', color='black')

    def start(self):
        # Used for the *init_func* parameter of FuncAnimation; this is␣
 ↪called when
        # initializing the animation, and also after resizing the␣
 ↪figure.
        return self.line,

    def __call__(self, i):
        # This way the plot can continuously run and we just keep
        # watching new realizations of the process
        if i == 0:
            self.success = 0
            self.line.set_data([], [])
            return self.line,

        # Choose success based on exceed a threshold with a uniform␣
 ↪pick
        if np.random.rand() < self.prob:
            self.success += 1
        y = beta_pdf(self.x, self.success + 1, (i - self.success) + 1)
        self.line.set_data(self.x, y)
        return self.line,

# Fixing random state for reproducibility
np.random.seed(19680801)


fig, ax = plt.subplots()
ud = UpdateDist(ax, prob=0.7)
anim = FuncAnimation(fig, ud, init_func=ud.start, frames=100,␣
 ↪interval=100, blit=True)
plt.show()
```

Tags: component: animation plot-type: line

Total running time of the script: (0 minutes 14.242 seconds)

The double pendulum problem

This animation illustrates the double pendulum problem.

Double pendulum formula translated from the C code at http://www.physics.usyd.edu.au/~wheat/dpend_html/solve_dpend.c

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import matplotlib.pyplot as plt
import numpy as np
from numpy import cos, sin

import matplotlib.animation as animation

G = 9.8  # acceleration due to gravity, in m/s^2
L1 = 1.0  # length of pendulum 1 in m
L2 = 1.0  # length of pendulum 2 in m
L = L1 + L2  # maximal length of the combined pendulum
M1 = 1.0  # mass of pendulum 1 in kg
M2 = 1.0  # mass of pendulum 2 in kg
t_stop = 2.5  # how many seconds to simulate
history_len = 500  # how many trajectory points to display


def derivs(t, state):
    dydx = np.zeros_like(state)

    dydx[0] = state[1]

    delta = state[2] - state[0]
    den1 = (M1+M2) * L1 - M2 * L1 * cos(delta) * cos(delta)
    dydx[1] = ((M2 * L1 * state[1] * state[1] * sin(delta) * cos(delta)
                + M2 * G * sin(state[2]) * cos(delta)
                + M2 * L2 * state[3] * state[3] * sin(delta)
                - (M1+M2) * G * sin(state[0]))
               / den1)

    dydx[2] = state[3]

    den2 = (L2/L1) * den1
    dydx[3] = ((- M2 * L2 * state[3] * state[3] * sin(delta) *␣
 ↪cos(delta)
                + (M1+M2) * G * sin(state[0]) * cos(delta)
                - (M1+M2) * L1 * state[1] * state[1] * sin(delta)
                - (M1+M2) * G * sin(state[2]))
               / den2)
```

(continues on next page)

(continued from previous page)

```
    return dydx

# create a time array from 0..t_stop sampled at 0.01 second steps
dt = 0.01
t = np.arange(0, t_stop, dt)

# th1 and th2 are the initial angles (degrees)
# w10 and w20 are the initial angular velocities (degrees per second)
th1 = 120.0
w1 = 0.0
th2 = -10.0
w2 = 0.0

# initial state
state = np.radians([th1, w1, th2, w2])

# integrate the ODE using Euler's method
y = np.empty((len(t), 4))
y[0] = state
for i in range(1, len(t)):
    y[i] = y[i - 1] + derivs(t[i - 1], y[i - 1]) * dt

# A more accurate estimate could be obtained e.g. using scipy:
#
#   y = scipy.integrate.solve_ivp(derivs, t[[0, -1]], state,␣
 ↪t_eval=t).y.T

x1 = L1*sin(y[:, 0])
y1 = -L1*cos(y[:, 0])

x2 = L2*sin(y[:, 2]) + x1
y2 = -L2*cos(y[:, 2]) + y1

fig = plt.figure(figsize=(5, 4))
ax = fig.add_subplot(autoscale_on=False, xlim=(-L, L), ylim=(-L, 1.))
ax.set_aspect('equal')
ax.grid()

line, = ax.plot([], [], 'o-', lw=2)
trace, = ax.plot([], [], '.-', lw=1, ms=2)
time_template = 'time = %.1fs'
time_text = ax.text(0.05, 0.9, '', transform=ax.transAxes)


def animate(i):
    thisx = [0, x1[i], x2[i]]
```

(continues on next page)

(continued from previous page)

```
    thisy = [0, y1[i], y2[i]]

    history_x = x2[:i]
    history_y = y2[:i]

    line.set_data(thisx, thisy)
    trace.set_data(history_x, history_y)
    time_text.set_text(time_template % (i*dt))
    return line, trace, time_text


ani = animation.FuncAnimation(
    fig, animate, len(y), interval=dt*1000, blit=True)
plt.show()
```

Total running time of the script: (0 minutes 51.327 seconds)

Animated image using a precomputed list of images

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation

fig, ax = plt.subplots()


def f(x, y):
    return np.sin(x) + np.cos(y)

x = np.linspace(0, 2 * np.pi, 120)
y = np.linspace(0, 2 * np.pi, 100).reshape(-1, 1)

# ims is a list of lists, each row is a list of artists to draw in the
# current frame; here we are just animating one artist, the image, in
# each frame
ims = []
for i in range(60):
    x += np.pi / 15
    y += np.pi / 30
    im = ax.imshow(f(x, y), animated=True)
    if i == 0:
        ax.imshow(f(x, y))  # show an initial one first
    ims.append([im])
```

(continues on next page)

(continued from previous page)

```
ani = animation.ArtistAnimation(fig, ims, interval=50, blit=True,
                                repeat_delay=1000)

# To save the animation, use e.g.
#
# ani.save("movie.mp4")
#
# or
#
# writer = animation.FFMpegWriter(
#     fps=15, metadata=dict(artist='Me'), bitrate=1800)
# ani.save("movie.mp4", writer=writer)

plt.show()
```

Tags: component: animation

Total running time of the script: (0 minutes 10.440 seconds)

Frame grabbing

Use a MovieWriter directly to grab individual frames and write them to a file. This avoids any event loop integration, and thus works even with the Agg backend. This is not recommended for use in an interactive setting.

```
import numpy as np

import matplotlib

matplotlib.use("Agg")
import matplotlib.pyplot as plt

from matplotlib.animation import FFMpegWriter

# Fixing random state for reproducibility
np.random.seed(19680801)


metadata = dict(title='Movie Test', artist='Matplotlib',
                comment='Movie support!')
writer = FFMpegWriter(fps=15, metadata=metadata)

fig = plt.figure()
l, = plt.plot([], [], 'k-o')

plt.xlim(-5, 5)
```

(continues on next page)

(continued from previous page)

```
plt.ylim(-5, 5)

x0, y0 = 0, 0

with writer.saving(fig, "writer_test.mp4", 100):
    for i in range(100):
        x0 += 0.1 * np.random.randn()
        y0 += 0.1 * np.random.randn()
        l.set_data([x0], [y0])
        writer.grab_frame()
```

Multiple Axes animation

This example showcases:

- how animation across multiple subplots works,
- using a figure artist in the animation.

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation
from matplotlib.patches import ConnectionPatch

fig, (axl, axr) = plt.subplots(
    ncols=2,
    sharey=True,
    figsize=(6, 2),
    gridspec_kw=dict(width_ratios=[1, 3], wspace=0),
)
axl.set_aspect(1)
axr.set_box_aspect(1 / 3)
axr.yaxis.set_visible(False)
axr.xaxis.set_ticks([0, np.pi, 2 * np.pi], ["0", r"$\pi$", r"$2\pi$"])

# draw circle with initial point in left Axes
x = np.linspace(0, 2 * np.pi, 50)
axl.plot(np.cos(x), np.sin(x), "k", lw=0.3)
point, = axl.plot(0, 0, "o")

# draw full curve to set view limits in right Axes
sine, = axr.plot(x, np.sin(x))

# draw connecting line between both graphs
```

(continues on next page)

(continued from previous page)

```
con = ConnectionPatch(
    (1, 0),
    (0, 0),
    "data",
    "data",
    axesA=axl,
    axesB=axr,
    color="C0",
    ls="dotted",
)
fig.add_artist(con)


def animate(i):
    x = np.linspace(0, i, int(i * 25 / np.pi))
    sine.set_data(x, np.sin(x))
    x, y = np.cos(i), np.sin(i)
    point.set_data([x], [y])
    con.xy1 = x, y
    con.xy2 = i, y
    return point, sine, con


ani = animation.FuncAnimation(
    fig,
    animate,
    interval=50,
    blit=False,  # blitting can't be used with Figure artists
    frames=x,
    repeat_delay=100,
)

plt.show()
```

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches.ConnectionPatch*
- *matplotlib.animation.FuncAnimation*

Tags: component: axes component: animation

Total running time of the script: (0 minutes 6.881 seconds)

Pause and resume an animation

This example showcases:

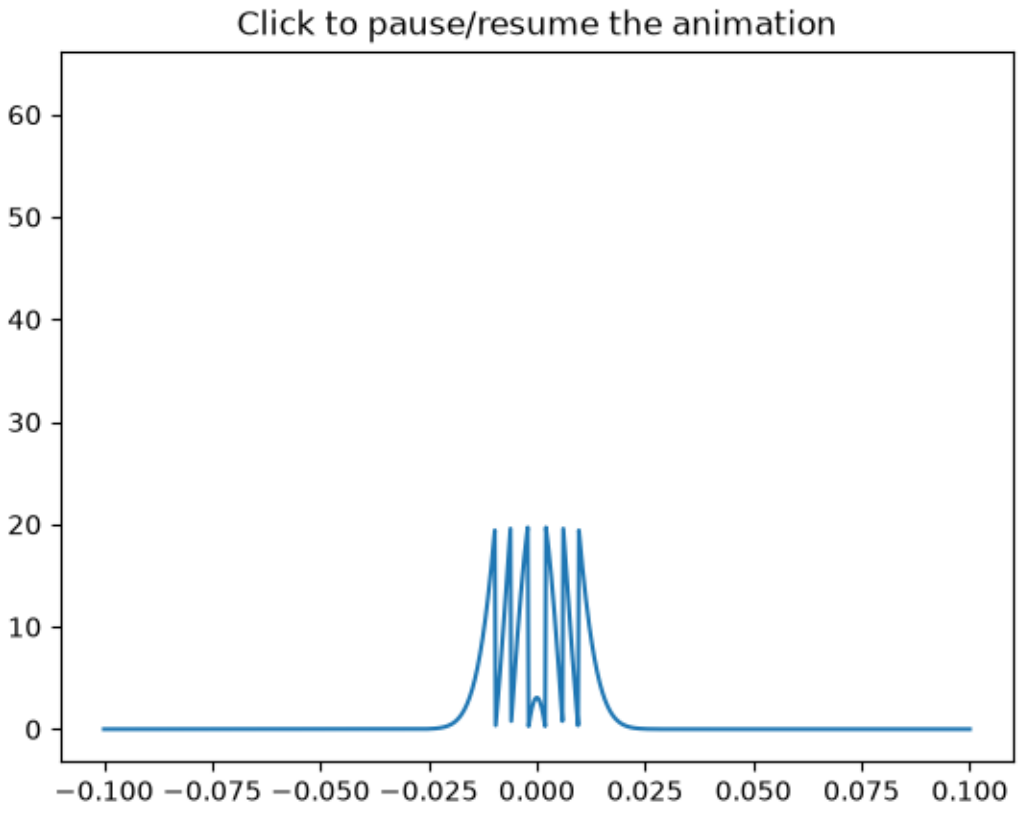
- using the Animation.pause() method to pause an animation.
- using the Animation.resume() method to resume an animation.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.

Output generated via *matplotlib.animation.Animation.to_jshtml*.




```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation


class PauseAnimation:
    def __init__(self):
        fig, ax = plt.subplots()
        ax.set_title('Click to pause/resume the animation')
        x = np.linspace(-0.1, 0.1, 1000)

        # Start with a normal distribution
        self.n0 = (1.0 / ((4 * np.pi * 2e-4 * 0.1) ** 0.5)
                   * np.exp(-x ** 2 / (4 * 2e-4 * 0.1)))
        self.p, = ax.plot(x, self.n0)

        self.animation = animation.FuncAnimation(
            fig, self.update, frames=200, interval=50, blit=True)
        self.paused = False
```

(continues on next page)

(continued from previous page)

```
        fig.canvas.mpl_connect('button_press_event', self.toggle_pause)

    def toggle_pause(self, *args, **kwargs):
        if self.paused:
            self.animation.resume()
        else:
            self.animation.pause()
        self.paused = not self.paused

    def update(self, i):
        self.n0 += i / 100 % 5
        self.p.set_ydata(self.n0 % 20)
        return (self.p,)


pa = PauseAnimation()
plt.show()
```

Rain simulation

Simulates rain drops on a surface by animating the scale and opacity of 50 scatter points.

Author: Nicolas P. Rougier

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.animation import FuncAnimation

# Fixing random state for reproducibility
np.random.seed(19680801)


# Create new Figure and an Axes which fills it.
fig = plt.figure(figsize=(7, 7))
ax = fig.add_axes((0, 0, 1, 1), frameon=False)
ax.set_xlim(0, 1), ax.set_xticks([])
ax.set_ylim(0, 1), ax.set_yticks([])

# Create rain data
n_drops = 50
rain_drops = np.zeros(n_drops, dtype=[('position', float, (2,)),
                                      ('size',     float),
                                      ('growth',   float),
```

(continues on next page)

(continued from previous page)

```
                                     ('color',    float, (4,))])

# Initialize the raindrops in random positions and with
# random growth rates.
rain_drops['position'] = np.random.uniform(0, 1, (n_drops, 2))
rain_drops['growth'] = np.random.uniform(50, 200, n_drops)

# Construct the scatter which we will update during animation
# as the raindrops develop.
scat = ax.scatter(rain_drops['position'][:, 0], rain_drops['position
↪'][:, 1],
                  s=rain_drops['size'], lw=0.5, edgecolors=rain_drops[
↪'color'],
                  facecolors='none')


def update(frame_number):
    # Get an index which we can use to re-spawn the oldest raindrop.
    current_index = frame_number % n_drops

    # Make all colors more transparent as time progresses.
    rain_drops['color'][:, 3] -= 1.0/len(rain_drops)
    rain_drops['color'][:, 3] = np.clip(rain_drops['color'][:, 3], 0,␣
↪1)

    # Make all circles bigger.
    rain_drops['size'] += rain_drops['growth']

    # Pick a new position for oldest rain drop, resetting its size,
    # color and growth factor.
    rain_drops['position'][current_index] = np.random.uniform(0, 1, 2)
    rain_drops['size'][current_index] = 5
    rain_drops['color'][current_index] = (0, 0, 0, 1)
    rain_drops['growth'][current_index] = np.random.uniform(50, 200)

    # Update the scatter collection, with the new colors, sizes and␣
↪positions.
    scat.set_edgecolors(rain_drops['color'])
    scat.set_sizes(rain_drops['size'])
    scat.set_offsets(rain_drops['position'])
    return [scat]


# Construct the animation, using the update function as the animation␣
↪director.
animation = FuncAnimation(fig, update, interval=10, save_count=100,␣
```

(continues on next page)

(continued from previous page)

```
    blit=True)
plt.show()
```

Tags: component: animation plot-type: scatter purpose: fun

Total running time of the script: (0 minutes 3.240 seconds)

Animated 3D random walk

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation

# Fixing random state for reproducibility
np.random.seed(19680801)


def random_walk(num_steps, max_step=0.05):
    """Return a 3D random walk as (num_steps, 3) array."""
    start_pos = np.random.random(3)
    steps = np.random.uniform(-max_step, max_step, size=(num_steps, 3))
    walk = start_pos + np.cumsum(steps, axis=0)
    return walk


def update_lines(num, walks, lines):
    for line, walk in zip(lines, walks):
        line.set_data_3d(walk[:num, :].T)
    return lines


# Data: 40 random walks as (num_steps, 3) arrays
num_steps = 30
walks = [random_walk(num_steps) for index in range(40)]

# Attaching 3D axis to the figure
fig = plt.figure()
ax = fig.add_subplot(projection="3d")

# Create lines initially without data
lines = [ax.plot([], [], [])[0] for _ in walks]

# Setting the Axes properties
ax.set(xlim3d=(0, 1), xlabel='X')
```

(continues on next page)

(continued from previous page)

```
ax.set(ylim3d=(0, 1), ylabel='Y')
ax.set(zlim3d=(0, 1), zlabel='Z')

# Creating the Animation object
ani = animation.FuncAnimation(
    fig, update_lines, num_steps, fargs=(walks, lines), interval=100)

plt.show()
```

Tags: component: animation plot-type: 3D

Total running time of the script: (0 minutes 10.988 seconds)

Animated scatter saved as GIF

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation

fig, ax = plt.subplots()
ax.set_xlim(0, 10)

scat = ax.scatter(1, 0)
x = np.linspace(0, 10)


def animate(i):
    scat.set_offsets((x[i], 0))
    return (scat,)


ani = animation.FuncAnimation(fig, animate, repeat=True, frames=len(x)␣
 ↪- 1, interval=50)

# To save the animation using Pillow as a gif
# writer = animation.PillowWriter(fps=15,
#                                 metadata=dict(artist='Me'),
#                                 bitrate=1800)
# ani.save('scatter.gif', writer=writer)

plt.show()
```

Tags: component: animation plot-type: scatter purpose: reference level: intermediate

Total running time of the script: (0 minutes 8.604 seconds)

Oscilloscope

Emulates an oscilloscope.

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation
from matplotlib.lines import Line2D


class Scope:
    def __init__(self, ax, maxt=2, dt=0.02):
        self.ax = ax
        self.dt = dt
        self.maxt = maxt
        self.tdata = [0]
        self.ydata = [0]
        self.line = Line2D(self.tdata, self.ydata)
        self.ax.add_line(self.line)
        self.ax.set_ylim(-.1, 1.1)
        self.ax.set_xlim(0, self.maxt)

    def update(self, y):
        lastt = self.tdata[-1]
        if lastt >= self.tdata[0] + self.maxt:  # reset the arrays
            self.tdata = [self.tdata[-1]]
            self.ydata = [self.ydata[-1]]
            self.ax.set_xlim(self.tdata[0], self.tdata[0] + self.maxt)
            self.ax.figure.canvas.draw()

        # This slightly more complex calculation avoids floating-point␣
↪issues
        # from just repeatedly adding `self.dt` to the previous value.
        t = self.tdata[0] + len(self.tdata) * self.dt

        self.tdata.append(t)
        self.ydata.append(y)
        self.line.set_data(self.tdata, self.ydata)
        return self.line,


def emitter(p=0.1):
    """Return a random value in [0, 1) with probability p, else 0."""
    while True:
        v = np.random.rand()
```

(continues on next page)

(continued from previous page)

```
        if v > p:
            yield 0.
        else:
            yield np.random.rand()


# Fixing random state for reproducibility
np.random.seed(19680801 // 10)


fig, ax = plt.subplots()
scope = Scope(ax)

# pass a generator in "emitter" to produce data for the update func
ani = animation.FuncAnimation(fig, scope.update, emitter, interval=50,
                              blit=True, save_count=100)

plt.show()

# ..tags:: animation, plot-type: line
```

Total running time of the script: (0 minutes 19.463 seconds)

Matplotlib unchained

Comparative path demonstration of frequency from a fake signal of a pulsar (mostly known because of the cover for Joy Division's Unknown Pleasures).

Author: Nicolas P. Rougier

Output generated via *matplotlib.animation.Animation.to_jshtml*.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.animation as animation

# Fixing random state for reproducibility
np.random.seed(19680801)


# Create new Figure with black background
fig = plt.figure(figsize=(8, 8), facecolor='black')

# Add a subplot with no frame
ax = plt.subplot(frameon=False)
```

(continues on next page)

(continued from previous page)

```
# Generate random data
data = np.random.uniform(0, 1, (64, 75))
X = np.linspace(-1, 1, data.shape[-1])
G = 1.5 * np.exp(-4 * X ** 2)

# Generate line plots
lines = []
for i in range(len(data)):
    # Small reduction of the X extents to get a cheap perspective␣
 ↪effect
    xscale = 1 - i / 200.
    # Same for linewidth (thicker strokes on bottom)
    lw = 1.5 - i / 100.0
    line, = ax.plot(xscale * X, i + G * data[i], color="w", lw=lw)
    lines.append(line)

# Set y limit (or first line is cropped because of thickness)
ax.set_ylim(-1, 70)

# No ticks
ax.set_xticks([])
ax.set_yticks([])

# 2 part titles to get different font weights
ax.text(0.5, 1.0, "MATPLOTLIB ", transform=ax.transAxes,
        ha="right", va="bottom", color="w",
        family="sans-serif", fontweight="light", fontsize=16)
ax.text(0.5, 1.0, "UNCHAINED", transform=ax.transAxes,
        ha="left", va="bottom", color="w",
        family="sans-serif", fontweight="bold", fontsize=16)


def update(*args):
    # Shift all data to the right
    data[:, 1:] = data[:, :-1]

    # Fill-in new values
    data[:, 0] = np.random.uniform(0, 1, len(data))

    # Update data
    for i in range(len(data)):
        lines[i].set_ydata(i + G * data[i])

    # Return modified artists
    return lines
```

(continues on next page)

(continued from previous page)

```
# Construct the animation, using the update function as the animation␣
 ↪director.
anim = animation.FuncAnimation(fig, update, interval=10,␣
 ↪save_count=100)
plt.show()
```

Tags: component: animation plot-type: line purpose: fun

Total running time of the script: (0 minutes 9.580 seconds)

6.24.18 Widgets

Examples of how to write primitive, but GUI agnostic, widgets in matplotlib

Annotated cursor

Display a data cursor including a text box, which shows the plot point close to the mouse pointer.

The new cursor inherits from `Cursor` and demonstrates the creation of new widgets and their event callbacks.

See also the *cross hair cursor*, which implements a cursor tracking the plotted data, but without using inheritance and without displaying the currently tracked coordinates.

Note

The figure related to this example does not show the cursor, because that figure is automatically created in a build queue, where the first mouse movement, which triggers the cursor creation, is missing.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.backend_bases import MouseEvent
from matplotlib.widgets import Cursor


class AnnotatedCursor(Cursor):
    """
    A crosshair cursor like `~matplotlib.widgets.Cursor` with a text␣
 ↪showing \
    the current coordinates.

    For the cursor to remain responsive you must keep a reference to␣
 ↪it.
    The data of the axis specified as *dataaxis* must be in ascending
    order. Otherwise, the `numpy.searchsorted` call might fail and the␣
 ↪text
```

(continues on next page)

(continued from previous page)

```
   disappears. You can satisfy the requirement by sorting the data␣
↪you plot.
   Usually the data is already sorted (if it was created e.g. using
   `numpy.linspace`), but e.g. scatter plots might cause this problem.
   The cursor sticks to the plotted line.

   Parameters
   ----------
   line : `matplotlib.lines.Line2D`
       The plot line from which the data coordinates are displayed.

   numberformat : `python format string <https://docs.python.org/3/\
   library/string.html#formatstrings>`_, optional, default: "
↪{0:.4g};{1:.4g}"
       The displayed text is created by calling *format()* on this␣
↪string
       with the two coordinates.

   offset : (float, float) default: (5, 5)
       The offset in display (pixel) coordinates of the text position
       relative to the cross-hair.

   dataaxis : {"x", "y"}, optional, default: "x"
       If "x" is specified, the vertical cursor line sticks to the␣
↪mouse
       pointer. The horizontal cursor line sticks to *line*
       at that x value. The text shows the data coordinates of *line*
       at the pointed x value. If you specify "y", it works in the␣
↪opposite
       manner. But: For the "y" value, where the mouse points to,␣
↪there might
       be multiple matching x values, if the plotted function is not␣
↪biunique.
       Cursor and text coordinate will always refer to only one x␣
↪value.
       So if you use the parameter value "y", ensure that your␣
↪function is
       biunique.

   Other Parameters
   ----------------
   textprops : `matplotlib.text` properties as dictionary
       Specifies the appearance of the rendered text object.

   **cursorargs : `matplotlib.widgets.Cursor` properties
       Arguments passed to the internal `~matplotlib.widgets.Cursor`␣
```

(continues on next page)

(continued from previous page)

```
↪instance.
        The `matplotlib.axes.Axes` argument is mandatory! The parameter
        *useblit* can be set to *True* in order to achieve faster␣
↪rendering.

    """

    def __init__(self, line, numberformat="{0:.4g};{1:.4g}", offset=(5,
↪ 5),
                 dataaxis='x', textprops=None, **cursorargs):
        if textprops is None:
            textprops = {}
        # The line object, for which the coordinates are displayed
        self.line = line
        # The format string, on which .format() is called for creating␣
↪the text
        self.numberformat = numberformat
        # Text position offset
        self.offset = np.array(offset)
        # The axis in which the cursor position is looked up
        self.dataaxis = dataaxis

        # First call baseclass constructor.
        # Draws cursor and remembers background for blitting.
        # Saves ax as class attribute.
        super().__init__(**cursorargs)

        # Default value for position of text.
        self.set_position(self.line.get_xdata()[0], self.line.
↪get_ydata()[0])
        # Create invisible animated text
        self.text = self.ax.text(
            self.ax.get_xbound()[0],
            self.ax.get_ybound()[0],
            "0, 0",
            animated=bool(self.useblit),
            visible=False, **textprops)
        # The position at which the cursor was last drawn
        self.lastdrawnplotpoint = None

    def onmove(self, event):
        """
        Overridden draw callback for cursor. Called when moving the␣
↪mouse.
        """
```

(continues on next page)

(continued from previous page)

```
        # Leave method under the same conditions as in overridden␣
↪method
        if self.ignore(event):
            self.lastdrawnplotpoint = None
            return
        if not self.canvas.widgetlock.available(self):
            self.lastdrawnplotpoint = None
            return

        # If the mouse left drawable area, we now make the text␣
↪invisible.
        # Baseclass will redraw complete canvas after, which makes␣
↪both text
        # and cursor disappear.
        if event.inaxes != self.ax:
            self.lastdrawnplotpoint = None
            self.text.set_visible(False)
            super().onmove(event)
            return

        # Get the coordinates, which should be displayed as text,
        # if the event coordinates are valid.
        plotpoint = None
        if event.xdata is not None and event.ydata is not None:
            # Get plot point related to current x position.
            # These coordinates are displayed in text.
            plotpoint = self.set_position(event.xdata, event.ydata)
            # Modify event, such that the cursor is displayed on the
            # plotted line, not at the mouse pointer,
            # if the returned plot point is valid
            if plotpoint is not None:
                event.xdata = plotpoint[0]
                event.ydata = plotpoint[1]

        # If the plotpoint is given, compare to last drawn plotpoint␣
↪and
        # return if they are the same.
        # Skip even the call of the base class, because this would␣
↪restore the
        # background, draw the cursor lines and would leave us the job␣
↪to
        # re-draw the text.
        if plotpoint is not None and plotpoint == self.
↪lastdrawnplotpoint:
            return
```

(continues on next page)

(continued from previous page)

```
        # Baseclass redraws canvas and cursor. Due to blitting,
        # the added text is removed in this call, because the
        # background is redrawn.
        super().onmove(event)

        # Check if the display of text is still necessary.
        # If not, just return.
        # This behaviour is also cloned from the base class.
        if not self.get_active() or not self.visible:
            return

        # Draw the widget, if event coordinates are valid.
        if plotpoint is not None:
            # Update position and displayed text.
            # Position: Where the event occurred.
            # Text: Determined by set_position() method earlier
            # Position is transformed to pixel coordinates,
            # an offset is added there and this is transformed back.
            temp = [event.xdata, event.ydata]
            temp = self.ax.transData.transform(temp)
            temp = temp + self.offset
            temp = self.ax.transData.inverted().transform(temp)
            self.text.set_position(temp)
            self.text.set_text(self.numberformat.format(*plotpoint))
            self.text.set_visible(self.visible)

            # Tell base class, that we have drawn something.
            # Baseclass needs to know, that it needs to restore a clean
            # background, if the cursor leaves our figure context.
            self.needclear = True

            # Remember the recently drawn cursor position, so events␣
↪for the
            # same position (mouse moves slightly between two plot␣
↪points)
            # can be skipped
            self.lastdrawnplotpoint = plotpoint
        # otherwise, make text invisible
        else:
            self.text.set_visible(False)

        # Draw changes. Cannot use _update method of baseclass,
        # because it would first restore the background, which
        # is done already and is not necessary.
        if self.useblit:
            self.ax.draw_artist(self.text)
```

(continues on next page)

(continued from previous page)

```
            self.canvas.blit(self.ax.bbox)
        else:
            # If blitting is deactivated, the overridden _update call␣
↪made
            # by the base class immediately returned.
            # We still have to draw the changes.
            self.canvas.draw_idle()

    def set_position(self, xpos, ypos):
        """
        Finds the coordinates, which have to be shown in text.

        The behaviour depends on the *dataaxis* attribute. Function␣
↪looks
        up the matching plot coordinate for the given mouse position.

        Parameters
        ----------
        xpos : float
            The current x position of the cursor in data coordinates.
            Important if *dataaxis* is set to 'x'.
        ypos : float
            The current y position of the cursor in data coordinates.
            Important if *dataaxis* is set to 'y'.

        Returns
        -------
        ret : {2D array-like, None}
            The coordinates which should be displayed.
            *None* is the fallback value.
        """

        # Get plot line data
        xdata = self.line.get_xdata()
        ydata = self.line.get_ydata()

        # The dataaxis attribute decides, in which axis we look up␣
↪which cursor
        # coordinate.
        if self.dataaxis == 'x':
            pos = xpos
            data = xdata
            lim = self.ax.get_xlim()
        elif self.dataaxis == 'y':
            pos = ypos
            data = ydata
```

(continues on next page)

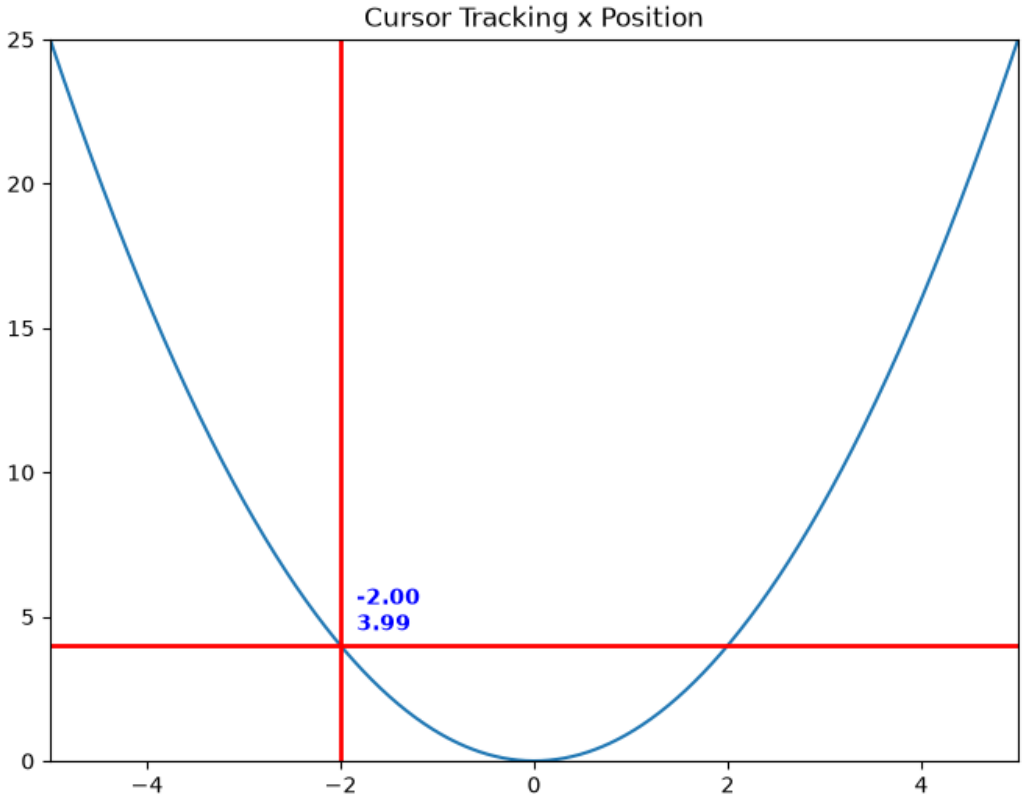
(continued from previous page)

```
            lim = self.ax.get_ylim()
        else:
            raise ValueError(f"The data axis specifier {self.dataaxis}␣
↪should "
                             f"be 'x' or 'y'")

        # If position is valid and in valid plot data range.
        if pos is not None and lim[0] <= pos <= lim[-1]:
            # Find closest x value in sorted x vector.
            # This requires the plotted data to be sorted.
            index = np.searchsorted(data, pos)
            # Return none, if this index is out of range.
            if index < 0 or index >= len(data):
                return None
            # Return plot point as tuple.
            return (xdata[index], ydata[index])

        # Return none if there is no good related point for this x␣
↪position.
        return None

    def clear(self, event):
        """
        Overridden clear callback for cursor, called before drawing␣
↪the figure.
        """

        # The base class saves the clean background for blitting.
        # Text and cursor are invisible,
        # until the first mouse move event occurs.
        super().clear(event)
        if self.ignore(event):
            return
        self.text.set_visible(False)

    def _update(self):
        """
        Overridden method for either blitting or drawing the widget␣
↪canvas.

        Passes call to base class if blitting is activated, only.
        In other cases, one draw_idle call is enough, which is placed
        explicitly in this class (see *onmove()*).
        In that case, `~matplotlib.widgets.Cursor` is not supposed to␣
↪draw
        something using this method.
```

(continues on next page)

(continued from previous page)

```
        """

        if self.useblit:
            super()._update()


fig, ax = plt.subplots(figsize=(8, 6))
ax.set_title("Cursor Tracking x Position")

x = np.linspace(-5, 5, 1000)
y = x**2

line, = ax.plot(x, y)
ax.set_xlim(-5, 5)
ax.set_ylim(0, 25)

# A minimum call
# Set useblit=True on most backends for enhanced performance
# and pass the ax parameter to the Cursor base class.
# cursor = AnnotatedCursor(line=lin[0], ax=ax, useblit=True)

# A more advanced call. Properties for text and lines are passed.
# Watch the passed color names and the color of cursor line and text, ␣
 ↪to
# relate the passed options to graphical elements.
# The dataaxis parameter is still the default.
cursor = AnnotatedCursor(
    line=line,
    numberformat="{0:.2f}\n{1:.2f}",
    dataaxis='x', offset=[10, 10],
    textprops={'color': 'blue', 'fontweight': 'bold'},
    ax=ax,
    useblit=True,
    color='red',
    linewidth=2)

# Simulate a mouse move to (-2, 10), needed for online docs
t = ax.transData
MouseEvent(
    "motion_notify_event", ax.figure.canvas, *t.transform((-2, 10))
)._process()

plt.show()
```



Trouble with non-biunique functions

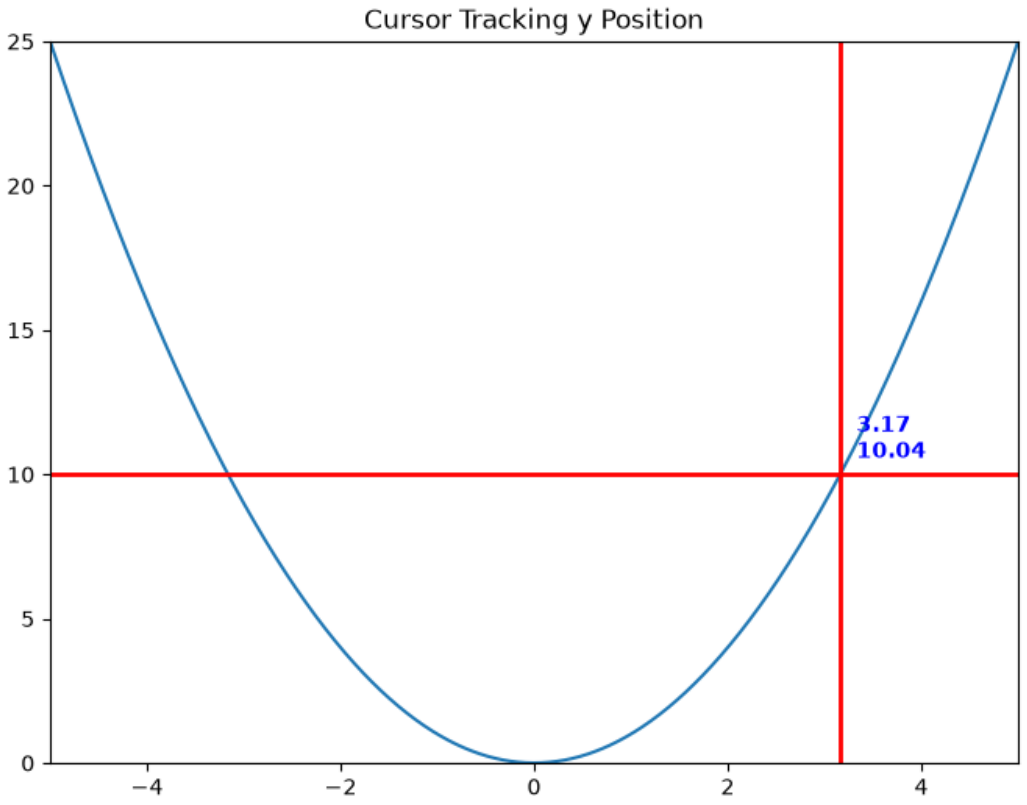
A call demonstrating problems with the *dataaxis=y* parameter. The text now looks up the matching x value for the current cursor y position instead of vice versa. Hover your cursor to y=4. There are two x values producing this y value: -2 and 2. The function is only unique, but not biunique. Only one value is shown in the text.

```
fig, ax = plt.subplots(figsize=(8, 6))
ax.set_title("Cursor Tracking y Position")

line, = ax.plot(x, y)
ax.set_xlim(-5, 5)
ax.set_ylim(0, 25)

cursor = AnnotatedCursor(
    line=line,
    numberformat="{0:.2f}\n{1:.2f}",
    dataaxis='y', offset=[10, 10],
    textprops={'color': 'blue', 'fontweight': 'bold'},
    ax=ax,
```

(continues on next page)

(continued from previous page)

```
    useblit=True,
    color='red', linewidth=2)

# Simulate a mouse move to (-2, 10), needed for online docs
t = ax.transData
MouseEvent(
    "motion_notify_event", ax.figure.canvas, *t.transform((-2, 10))
)._process()

plt.show()
```



Buttons

Constructing a simple button GUI to modify a sine wave.

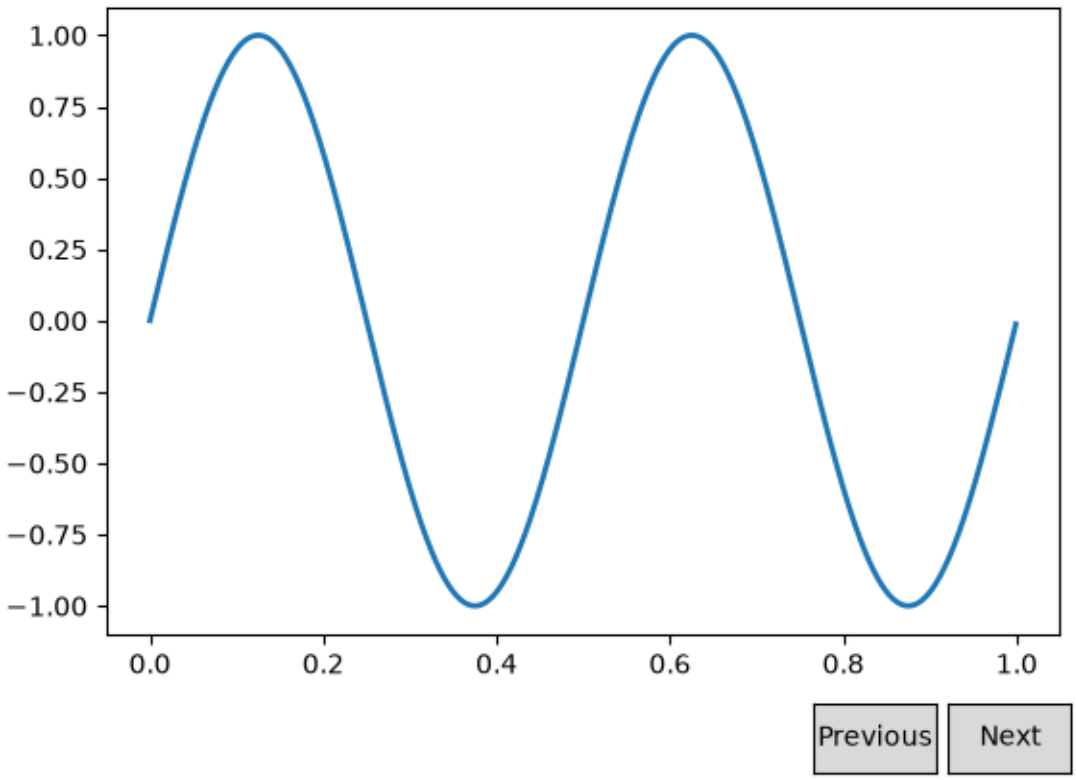
The `next` and `previous` button widget helps visualize the wave with new frequencies.

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
from matplotlib.widgets import Button

freqs = np.arange(2, 20, 3)

fig, ax = plt.subplots()
fig.subplots_adjust(bottom=0.2)
t = np.arange(0.0, 1.0, 0.001)
s = np.sin(2*np.pi*freqs[0]*t)
l, = ax.plot(t, s, lw=2)


class Index:
    ind = 0

    def next(self, event):
        self.ind += 1
        i = self.ind % len(freqs)
        ydata = np.sin(2*np.pi*freqs[i]*t)
        l.set_ydata(ydata)
        plt.draw()

    def prev(self, event):
        self.ind -= 1
        i = self.ind % len(freqs)
        ydata = np.sin(2*np.pi*freqs[i]*t)
        l.set_ydata(ydata)
        plt.draw()

callback = Index()
axprev = fig.add_axes((0.7, 0.05, 0.1, 0.075))
axnext = fig.add_axes((0.81, 0.05, 0.1, 0.075))
bnext = Button(axnext, 'Next')
bnext.on_clicked(callback.next)
bprev = Button(axprev, 'Previous')
bprev.on_clicked(callback.prev)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.Button*

Check buttons

Turning visual elements on and off with check buttons.

This program shows the use of *CheckButtons* which is similar to check boxes. There are 3 different sine waves shown, and we can choose which waves are displayed with the check buttons.

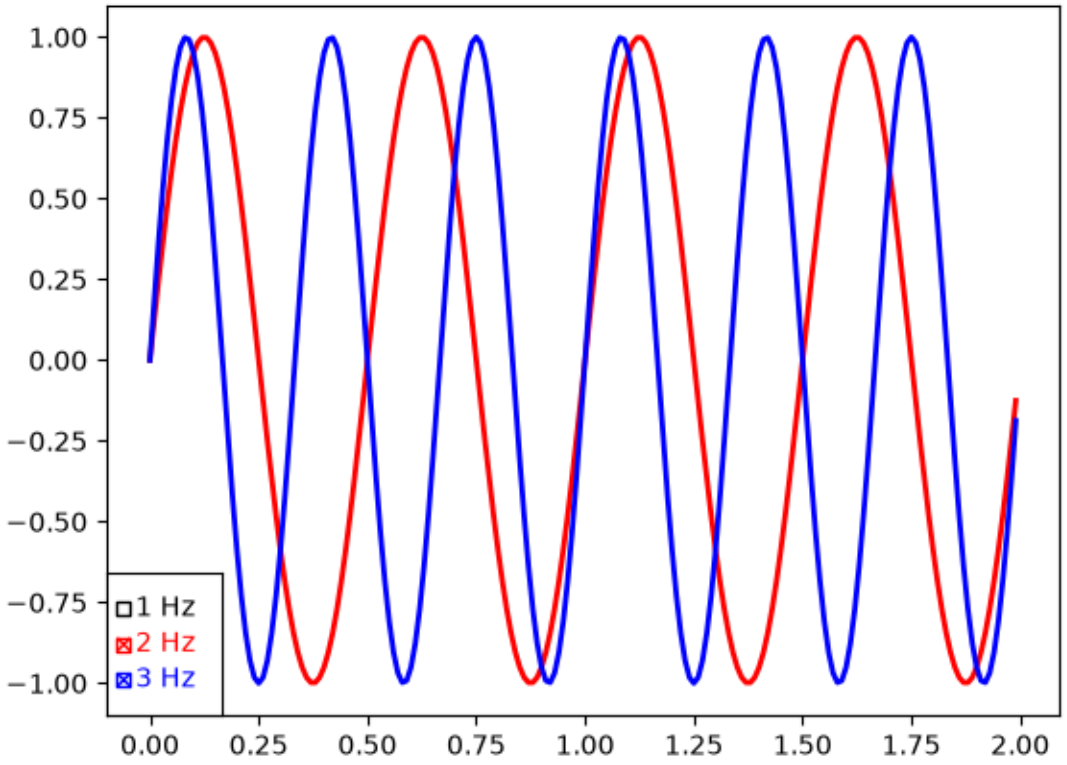
Check buttons may be styled using the *check_props*, *frame_props*, and *label_props* parameters. The parameters each take a dictionary with keys of artist property names and values of lists of settings with length matching the number of buttons.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import CheckButtons
```

(continues on next page)

(continued from previous page)

```
t = np.arange(0.0, 2.0, 0.01)
s0 = np.sin(2*np.pi*t)
s1 = np.sin(4*np.pi*t)
s2 = np.sin(6*np.pi*t)

fig, ax = plt.subplots()
l0, = ax.plot(t, s0, visible=False, lw=2, color='black', label='1 Hz')
l1, = ax.plot(t, s1, lw=2, color='red', label='2 Hz')
l2, = ax.plot(t, s2, lw=2, color='blue', label='3 Hz')

lines_by_label = {l.get_label(): l for l in [l0, l1, l2]}
line_colors = [l.get_color() for l in lines_by_label.values()]

# Make checkbuttons with all plotted lines with correct visibility
rax = ax.inset_axes([0.0, 0.0, 0.12, 0.2])
check = CheckButtons(
    ax=rax,
    labels=lines_by_label.keys(),
    actives=[l.get_visible() for l in lines_by_label.values()],
    label_props={'color': line_colors},
    frame_props={'edgecolor': line_colors},
    check_props={'facecolor': line_colors},
)


def callback(label):
    ln = lines_by_label[label]
    ln.set_visible(not ln.get_visible())
    ln.figure.canvas.draw_idle()

check.on_clicked(callback)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.CheckButtons*

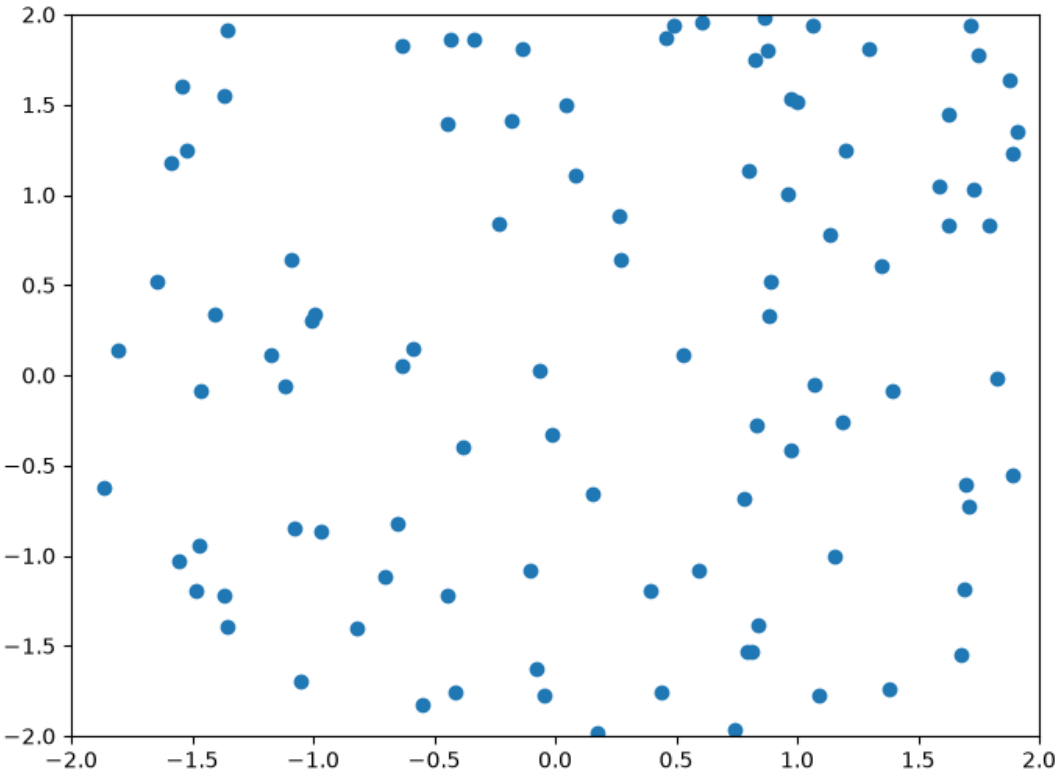
Cursor

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import Cursor

# Fixing random state for reproducibility
np.random.seed(19680801)

fig, ax = plt.subplots(figsize=(8, 6))

x, y = 4*(np.random.rand(2, 100) - .5)
```

(continues on next page)

(continued from previous page)

```
ax.plot(x, y, 'o')
ax.set_xlim(-2, 2)
ax.set_ylim(-2, 2)

# Set useblit=True on most backends for enhanced performance.
cursor = Cursor(ax, useblit=True, color='red', linewidth=2)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.Cursor*

Lasso Selector

Interactively selecting data points with the lasso tool.

This examples plots a scatter plot. You can then select a few points by drawing a lasso loop around the points on the graph. To draw, just click on the graph, hold, and drag it around the points you need to select.

```
import numpy as np

from matplotlib.path import Path
from matplotlib.widgets import LassoSelector


class SelectFromCollection:
    """
    Select indices from a matplotlib collection using `LassoSelector`.

    Selected indices are saved in the `ind` attribute. This tool fades␣
↪out the
    points that are not part of the selection (i.e., reduces their␣
↪alpha
    values). If your collection has alpha < 1, this tool will␣
↪permanently
    alter the alpha values.

    Note that this tool selects collection objects based on their␣
↪*origins*
    (i.e., `offsets`).

    Parameters
    ----------
    ax : `~matplotlib.axes.Axes`
        Axes to interact with.
    collection : `matplotlib.collections.Collection` subclass
        Collection you want to select from.
    alpha_other : 0 <= float <= 1
        To highlight a selection, this tool sets all selected points␣
↪to an
        alpha value of 1 and non-selected points to *alpha_other*.
    """
```

(continues on next page)

(continued from previous page)

```
    def __init__(self, ax, collection, alpha_other=0.3):
        self.canvas = ax.figure.canvas
        self.collection = collection
        self.alpha_other = alpha_other

        self.xys = collection.get_offsets()
        self.Npts = len(self.xys)

        # Ensure that we have separate colors for each object
        self.fc = collection.get_facecolors()
        if len(self.fc) == 0:
            raise ValueError('Collection must have a facecolor')
        elif len(self.fc) == 1:
            self.fc = np.tile(self.fc, (self.Npts, 1))

        self.lasso = LassoSelector(ax, onselect=self.onselect)
        self.ind = []

    def onselect(self, verts):
        path = Path(verts)
        self.ind = np.nonzero(path.contains_points(self.xys))[0]
        self.fc[:, -1] = self.alpha_other
        self.fc[self.ind, -1] = 1
        self.collection.set_facecolors(self.fc)
        self.canvas.draw_idle()

    def disconnect(self):
        self.lasso.disconnect_events()
        self.fc[:, -1] = 1
        self.collection.set_facecolors(self.fc)
        self.canvas.draw_idle()


if __name__ == '__main__':
    import matplotlib.pyplot as plt

    # Fixing random state for reproducibility
    np.random.seed(19680801)

    data = np.random.rand(100, 2)

    subplot_kw = dict(xlim=(0, 1), ylim=(0, 1), autoscale_on=False)
    fig, ax = plt.subplots(subplot_kw=subplot_kw)

    pts = ax.scatter(data[:, 0], data[:, 1], s=80)
    selector = SelectFromCollection(ax, pts)
```

(continues on next page)

(continued from previous page)

```
    def accept(event):
        if event.key == "enter":
            print("Selected points:")
            print(selector.xys[selector.ind])
            selector.disconnect()
            ax.set_title("")
            fig.canvas.draw()

    fig.canvas.mpl_connect("key_press_event", accept)
    ax.set_title("Press enter to accept selected points.")

    plt.show()
```

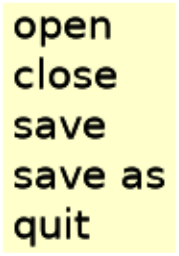
References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.LassoSelector*
- *matplotlib.path.Path*

Menu

Using texts to construct a simple menu.




```
from dataclasses import dataclass

import matplotlib.pyplot as plt

import matplotlib.artist as artist
import matplotlib.patches as patches
from matplotlib.typing import ColorType


@dataclass
class ItemProperties:
    fontsize: float = 14
    labelcolor: ColorType = 'black'
    bgcolor: ColorType = 'yellow'
    alpha: float = 1.0


class MenuItem(artist.Artist):
    padx = 0.05  # inches
    pady = 0.05
```

(continues on next page)

(continued from previous page)

```
    def __init__(self, fig, labelstr, props=None, hoverprops=None,
                 on_select=None):
        super().__init__()

        self.set_figure(fig)
        self.labelstr = labelstr

        self.props = props if props is not None else ItemProperties()
        self.hoverprops = (
            hoverprops if hoverprops is not None else ItemProperties())
        if self.props.fontsize != self.hoverprops.fontsize:
            raise NotImplementedError(
                'support for different font sizes not implemented')

        self.on_select = on_select

        # specify coordinates in inches.
        self.label = fig.text(0, 0, labelstr, transform=fig.
↪dpi_scale_trans,
                              size=props.fontsize)
        self.text_bbox = self.label.get_window_extent(
            fig.canvas.get_renderer())
        self.text_bbox = fig.dpi_scale_trans.inverted().
↪transform_bbox(self.text_bbox)

        self.rect = patches.Rectangle(
            (0, 0), 1, 1, transform=fig.dpi_scale_trans
        )  # Will be updated later.

        self.set_hover_props(False)

        fig.canvas.mpl_connect('button_release_event', self.
↪check_select)

    def check_select(self, event):
        over, _ = self.rect.contains(event)
        if not over:
            return
        if self.on_select is not None:
            self.on_select(self)

    def set_extent(self, x, y, w, h, depth):
        self.rect.set(x=x, y=y, width=w, height=h)
        self.label.set(position=(x + self.padx, y + depth + self.pady /
↪ 2))
```

(continues on next page)

(continued from previous page)

```
        self.hover = False

    def draw(self, renderer):
        self.rect.draw(renderer)
        self.label.draw(renderer)

    def set_hover_props(self, b):
        props = self.hoverprops if b else self.props
        self.label.set(color=props.labelcolor)
        self.rect.set(facecolor=props.bgcolor, alpha=props.alpha)

    def set_hover(self, event):
        """
        Update the hover status of event and return whether it was␣
↪changed.
        """
        b, _ = self.rect.contains(event)
        changed = (b != self.hover)
        if changed:
            self.set_hover_props(b)
        self.hover = b
        return changed


class Menu:
    def __init__(self, fig, menuitems):
        self.figure = fig

        self.menuitems = menuitems

        maxw = max(item.text_bbox.width for item in menuitems)
        maxh = max(item.text_bbox.height for item in menuitems)
        depth = max(-item.text_bbox.y0 for item in menuitems)

        x0 = 1
        y0 = 4

        width = maxw + 2 * MenuItem.padx
        height = maxh + MenuItem.pady

        for item in menuitems:
            left = x0
            bottom = y0 - maxh - MenuItem.pady

            item.set_extent(left, bottom, width, height, depth)
```

(continues on next page)

(continued from previous page)

```
            fig.artists.append(item)
            y0 -= maxh + MenuItem.pady

        fig.canvas.mpl_connect('motion_notify_event', self.on_move)

    def on_move(self, event):
        if any(item.set_hover(event) for item in self.menuitems):
            self.figure.canvas.draw()


fig = plt.figure()
fig.subplots_adjust(left=0.3)
props = ItemProperties(labelcolor='black', bgcolor='yellow',
                       fontsize=15, alpha=0.2)
hoverprops = ItemProperties(labelcolor='white', bgcolor='blue',
                            fontsize=15, alpha=0.2)

menuitems = []
for label in ('open', 'close', 'save', 'save as', 'quit'):
    def on_select(item):
        print(f'you selected {item.labelstr}')
    item = MenuItem(fig, label, props=props, hoverprops=hoverprops,
                    on_select=on_select)
    menuitems.append(item)

menu = Menu(fig, menuitems)
plt.show()
```

Mouse Cursor

This example sets an alternative cursor on a figure canvas.

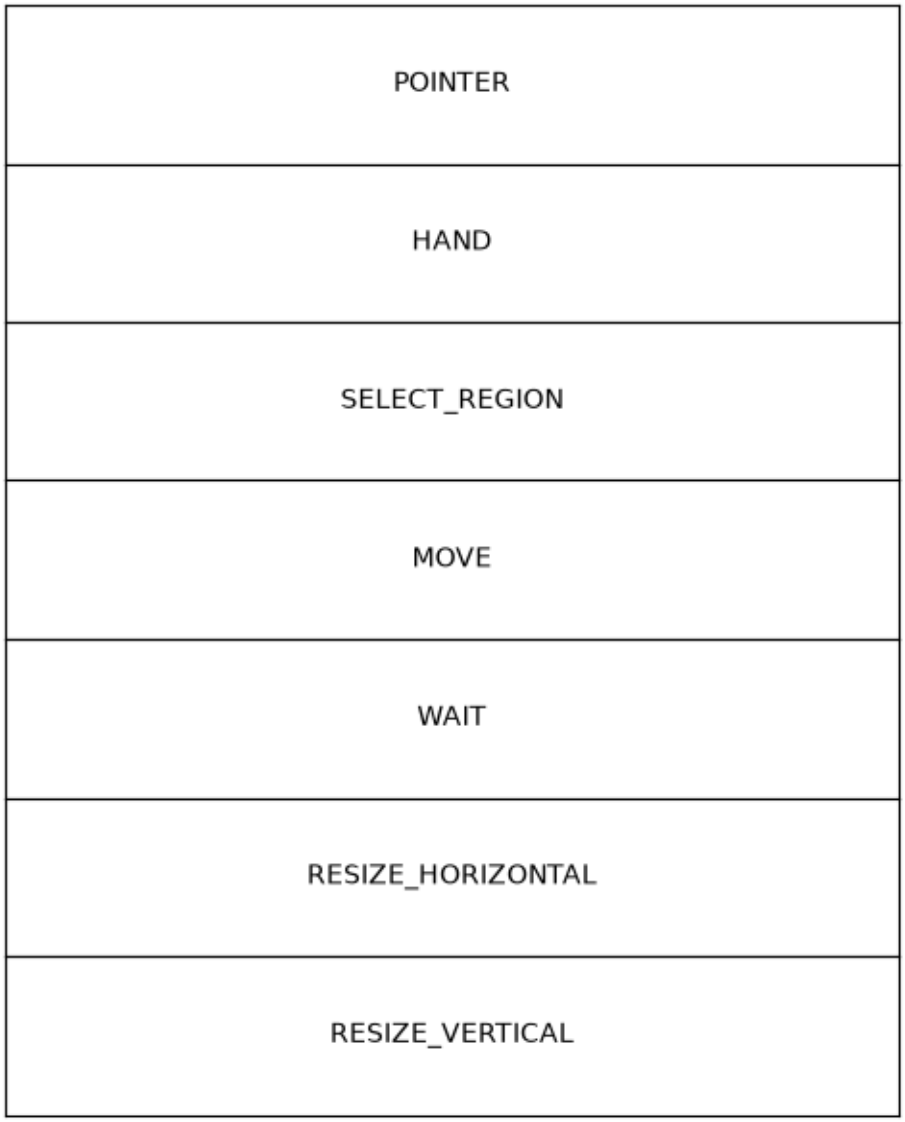
Note, this is an interactive example, and must be run to see the effect.

```
import matplotlib.pyplot as plt

from matplotlib.backend_tools import Cursors

fig, axs = plt.subplots(len(Cursors), figsize=(6, len(Cursors) + 0.5),
                        gridspec_kw={'hspace': 0})
fig.suptitle('Hover over an Axes to see alternate Cursors')

for cursor, ax in zip(Cursors, axs):
    ax.cursor_to_use = cursor
    ax.text(0.5, 0.5, cursor.name,
            horizontalalignment='center', verticalalignment='center')
```

(continues on next page)

(continued from previous page)

```
    ax.set(xticks=[], yticks=[])


def hover(event):
    if fig.canvas.widgetlock.locked():
        # Don't do anything if the zoom/pan tools have been enabled.
        return

    fig.canvas.set_cursor(
        event.inaxes.cursor_to_use if event.inaxes else Cursors.
 ↪POINTER)


fig.canvas.mpl_connect('motion_notify_event', hover)

plt.show()
```


Hover over an Axes to see alternate Cursors
POINTER
HAND
SELECT_REGION
MOVE
WAIT
RESIZE_HORIZONTAL
RESIZE_VERTICAL

References

The use of the following functions, methods, classes and modules is shown in this example:

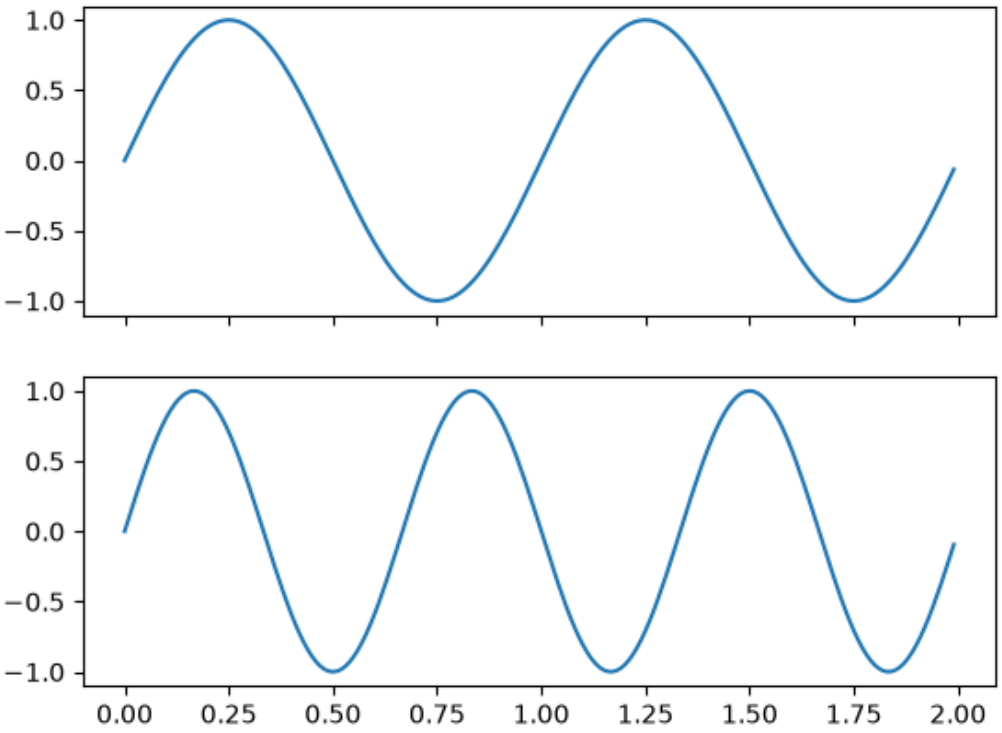
- *matplotlib.backend_bases.FigureCanvasBase.set_cursor*

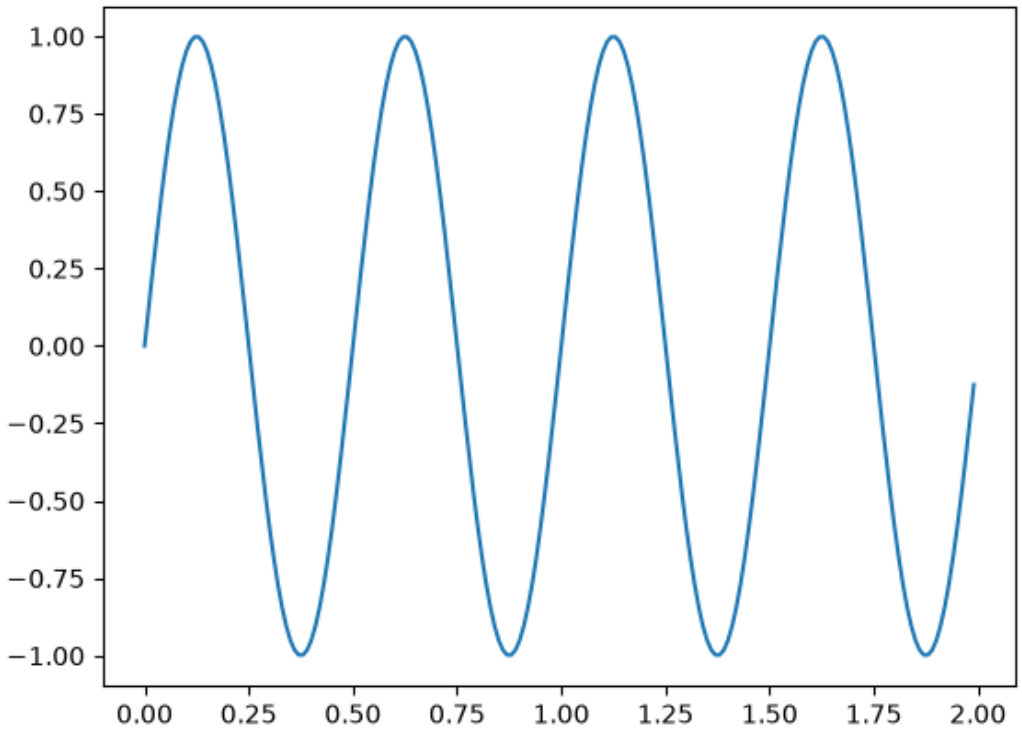
Multicursor

Showing a cursor on multiple plots simultaneously.

This example generates three Axes split over two different figures. On hovering the cursor over data in one subplot, the values of that datapoint are shown in all Axes.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import MultiCursor

t = np.arange(0.0, 2.0, 0.01)
s1 = np.sin(2*np.pi*t)
s2 = np.sin(3*np.pi*t)
s3 = np.sin(4*np.pi*t)

fig, (ax1, ax2) = plt.subplots(2, sharex=True)
ax1.plot(t, s1)
ax2.plot(t, s2)
fig, ax3 = plt.subplots()
ax3.plot(t, s3)

multi = MultiCursor((ax1, ax2, ax3), color='r', lw=1)
plt.show()
```


1.0
0.5
0.0
−0.5
−1.0
1.0
0.5
0.0
−0.5
−1.0
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00



-

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.MultiCursor*

Select indices from a collection using polygon selector

Shows how one can select indices of a polygon interactively.

```
import numpy as np

from matplotlib.path import Path
from matplotlib.widgets import PolygonSelector


class SelectFromCollection:
    """
    Select indices from a matplotlib collection using␣
↪`PolygonSelector`.
```

(continues on next page)

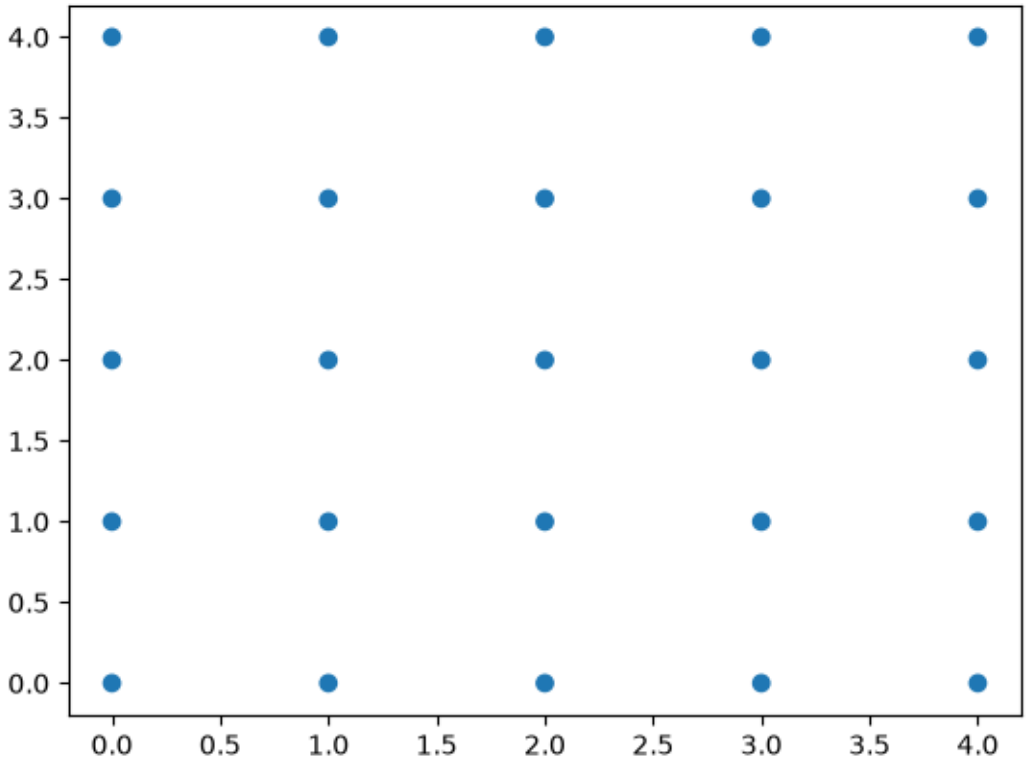
(continued from previous page)

```
    Selected indices are saved in the `ind` attribute. This tool fades␣
↪out the
    points that are not part of the selection (i.e., reduces their␣
↪alpha
    values). If your collection has alpha < 1, this tool will␣
↪permanently
    alter the alpha values.

    Note that this tool selects collection objects based on their␣
↪*origins*
    (i.e., `offsets`).

    Parameters
    ----------
    ax : `~matplotlib.axes.Axes`
        Axes to interact with.
    collection : `matplotlib.collections.Collection` subclass
        Collection you want to select from.
    alpha_other : 0 <= float <= 1
        To highlight a selection, this tool sets all selected points␣
↪to an
        alpha value of 1 and non-selected points to *alpha_other*.
    """

    def __init__(self, ax, collection, alpha_other=0.3):
        self.canvas = ax.figure.canvas
        self.collection = collection
        self.alpha_other = alpha_other

        self.xys = collection.get_offsets()
        self.Npts = len(self.xys)

        # Ensure that we have separate colors for each object
        self.fc = collection.get_facecolors()
        if len(self.fc) == 0:
            raise ValueError('Collection must have a facecolor')
        elif len(self.fc) == 1:
            self.fc = np.tile(self.fc, (self.Npts, 1))

        self.poly = PolygonSelector(ax, self.onselect,␣
↪draw_bounding_box=True)
        self.ind = []

    def onselect(self, verts):
        path = Path(verts)
        self.ind = np.nonzero(path.contains_points(self.xys))[0]
```

(continues on next page)

(continued from previous page)

```
        self.fc[:, -1] = self.alpha_other
        self.fc[self.ind, -1] = 1
        self.collection.set_facecolors(self.fc)
        self.canvas.draw_idle()

    def disconnect(self):
        self.poly.disconnect_events()
        self.fc[:, -1] = 1
        self.collection.set_facecolors(self.fc)
        self.canvas.draw_idle()


if __name__ == '__main__':
    import matplotlib.pyplot as plt

    fig, ax = plt.subplots()
    grid_size = 5
    grid_x = np.tile(np.arange(grid_size), grid_size)
    grid_y = np.repeat(np.arange(grid_size), grid_size)
    pts = ax.scatter(grid_x, grid_y)

    selector = SelectFromCollection(ax, pts)

    print("Select points in the figure by enclosing them within a␣
↪polygon.")
    print("Press the 'esc' key to start a new polygon.")
    print("Try holding the 'shift' key to move all of the vertices.")
    print("Try holding the 'ctrl' key to move a single vertex.")

    plt.show()

    selector.disconnect()

    # After figure is closed print the coordinates of the selected␣
↪points
    print('\nSelected points:')
    print(selector.xys[selector.ind])
```




```
Select points in the figure by enclosing them within a polygon.
Press the 'esc' key to start a new polygon.
Try holding the 'shift' key to move all of the vertices.
Try holding the 'ctrl' key to move a single vertex.

Selected points:
[]
```

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.PolygonSelector*
- *matplotlib.path.Path*

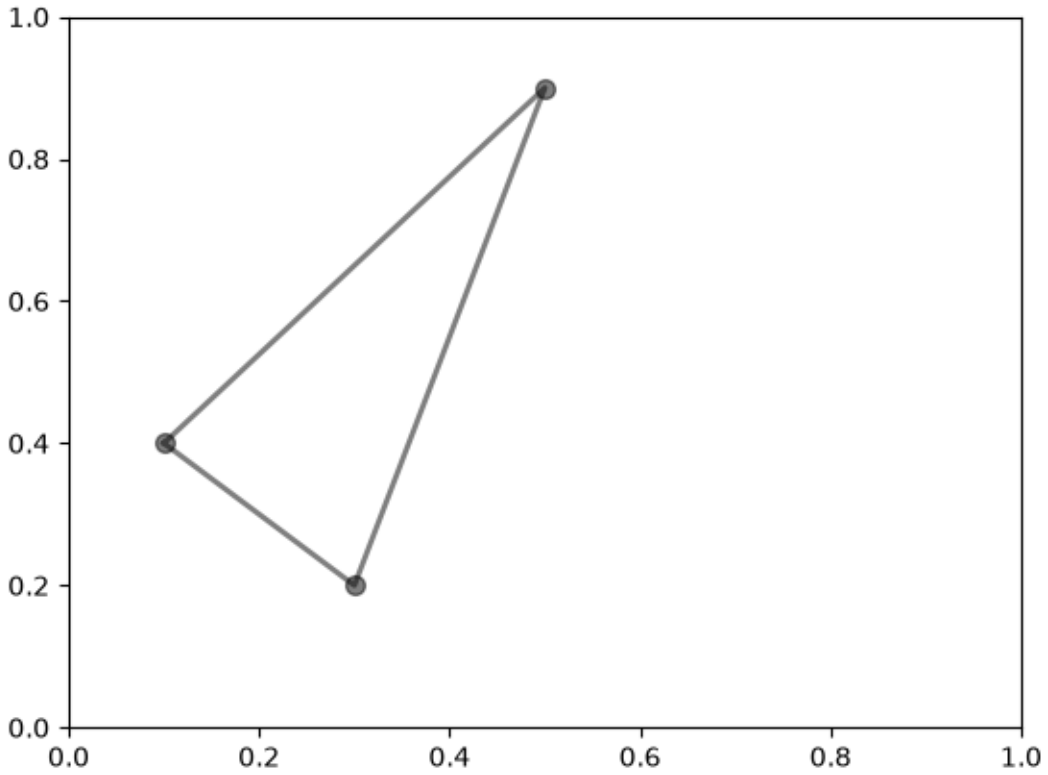
Polygon Selector

Shows how to create a polygon programmatically or interactively

```
import matplotlib.pyplot as plt

from matplotlib.widgets import PolygonSelector
```

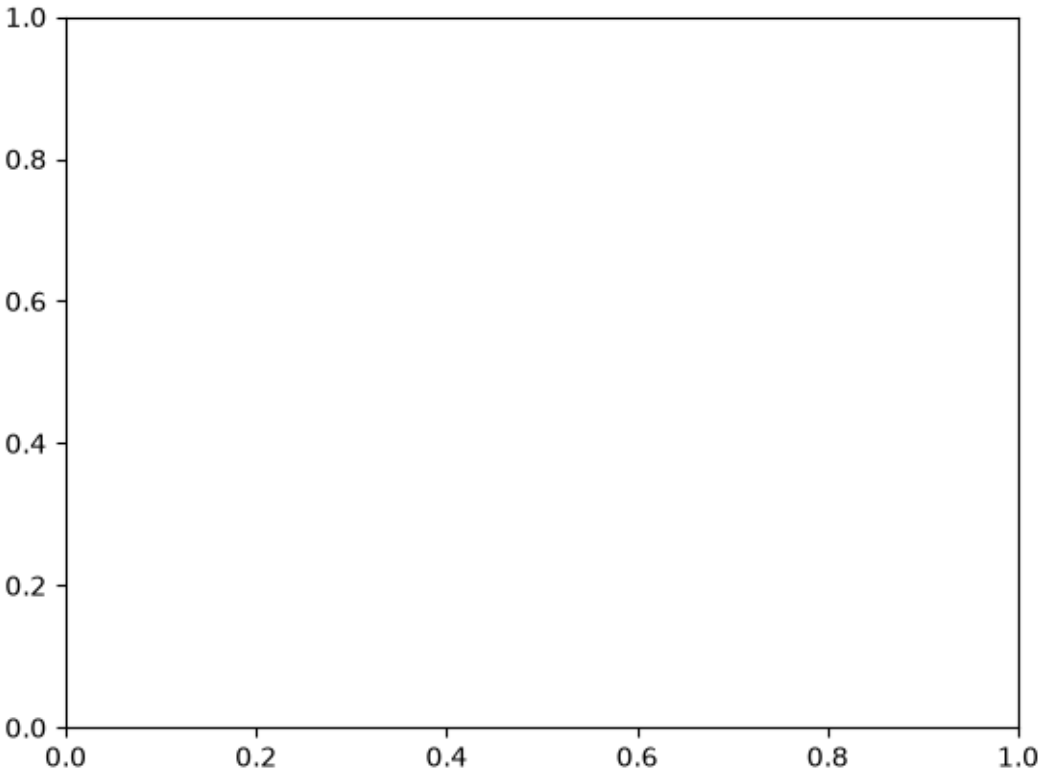
To create the polygon programmatically

```
fig, ax = plt.subplots()
fig.show()

selector = PolygonSelector(ax, lambda *args: None)

# Add three vertices
selector.verts = [(0.1, 0.4), (0.5, 0.9), (0.3, 0.2)]
```



To create the polygon interactively

```
fig2, ax2 = plt.subplots()
fig2.show()

selector2 = PolygonSelector(ax2, lambda *args: None)

print("Click on the figure to create a polygon.")
print("Press the 'esc' key to start a new polygon.")
print("Try holding the 'shift' key to move all of the vertices.")
print("Try holding the 'ctrl' key to move a single vertex.")
```




```
Click on the figure to create a polygon.
Press the 'esc' key to start a new polygon.
Try holding the 'shift' key to move all of the vertices.
Try holding the 'ctrl' key to move a single vertex.
```

Tags: component: axes styling: position plot-type: line level: intermediate domain: cartography domain: geometry domain: statistics

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.PolygonSelector*

Radio Buttons

Using radio buttons to choose properties of your plot.

Radio buttons let you choose between multiple options in a visualization. In this case, the buttons let the user choose one of the three different sine waves to be shown in the plot.

Radio buttons may be styled using the *label_props* and *radio_props* parameters, which each take a dictionary

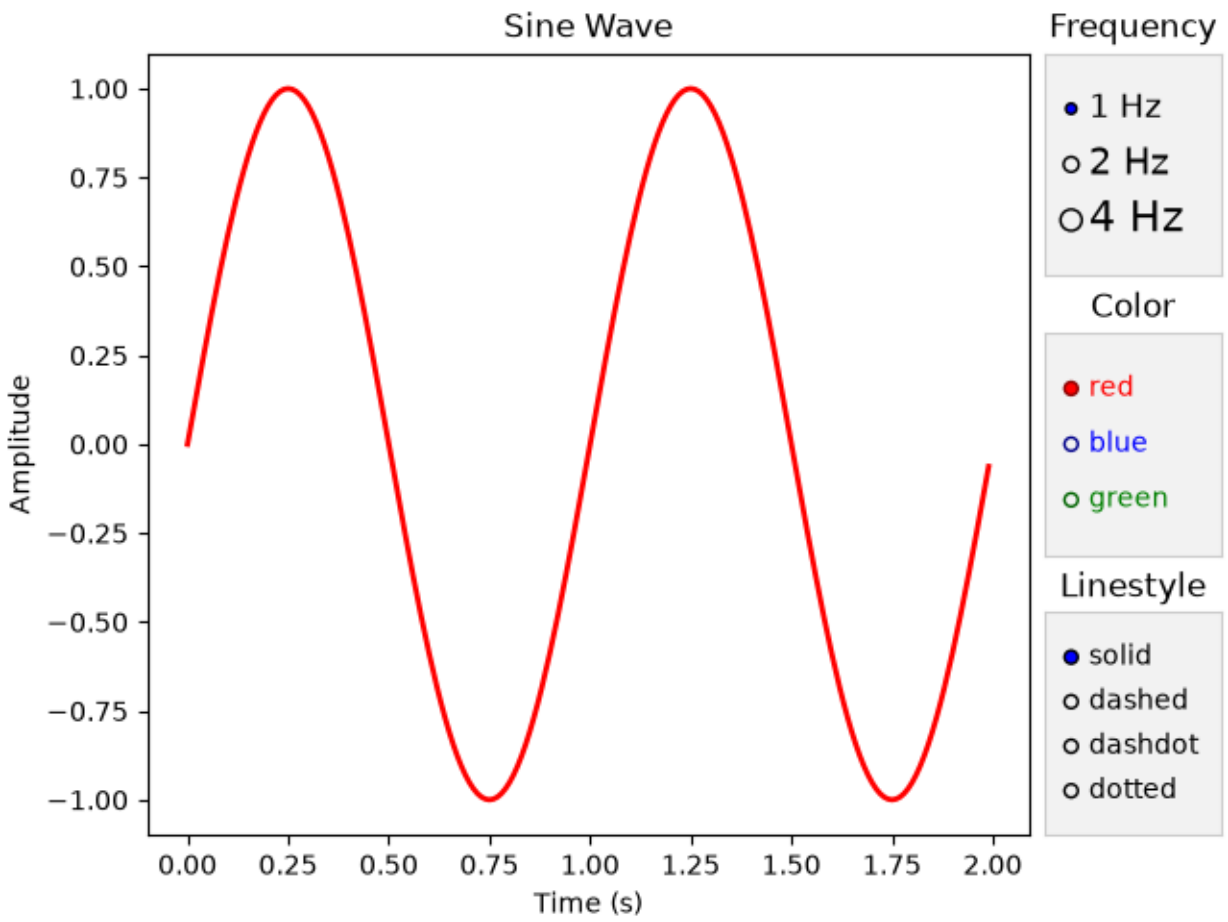
with keys of artist property names and values of lists of settings with length matching the number of buttons.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import RadioButtons

FREQUENCIES = {'1 Hz': 1, '2 Hz': 2, '4 Hz': 4}

t = np.arange(0.0, 2.0, 0.01)


def f(t, freq):
    return np.sin(2 * np.pi * freq * t)

fig, axd = plt.subplot_mosaic(
    [
        ['main', 'freq'],
        ['main', 'color'],
        ['main', 'linestyle'],
    ],
    width_ratios=[5, 1],
    layout='constrained',
)
(line,) = axd['main'].plot(t, f(t, freq=1), lw=2, color='red')
axd['main'].set(xlabel="Time (s)", ylabel="Amplitude", title="Sine Wave
 ↪")

background_color = '0.95'
edge_color = '0.8'

axd['freq'].set_facecolor(background_color)
axd['freq'].spines[:].set_color(edge_color)
axd['freq'].set_title('Frequency')
radio = RadioButtons(axd['freq'], labels=list(FREQUENCIES.keys()),
                     label_props={'fontsize': [12, 14, 16]},
                     radio_props={'s': [16, 32, 64]})


def update_frequency(label):
    ydata = f(t, freq=FREQUENCIES[label])
    line.set_ydata(ydata)
    fig.canvas.draw()
radio.on_clicked(update_frequency)


axd['color'].set_facecolor(background_color)
```

(continues on next page)

(continued from previous page)

```
axd['color'].spines[:].set_color(edge_color)
axd['color'].set_title('Color')
radio2 = RadioButtons(
    axd['color'], ('red', 'blue', 'green'),
    label_props={'color': ['red', 'blue', 'green']},
    radio_props={
        'facecolor': ['red', 'blue', 'green'],
        'edgecolor': ['darkred', 'darkblue', 'darkgreen'],
    })


def update_color(label):
    line.set_color(label)
    fig.canvas.draw()
radio2.on_clicked(update_color)


axd['linestyle'].set_facecolor(background_color)
axd['linestyle'].spines[:].set_color(edge_color)
axd['linestyle'].set_title('Linestyle')
radio3 = RadioButtons(axd['linestyle'], ('solid', 'dashed', 'dashdot',
 ↪'dotted'))


def update_linestyle(label):
    line.set_linestyle(label)
    fig.canvas.draw()
radio3.on_clicked(update_linestyle)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.RadioButtons*

Radio Buttons Grid

Using radio buttons in a 2D grid layout.

Radio buttons can be arranged in a 2D grid by passing a `(rows, cols)` tuple to the *layout* parameter. This is useful when you have multiple related options that are best displayed in a grid format rather than a vertical list.

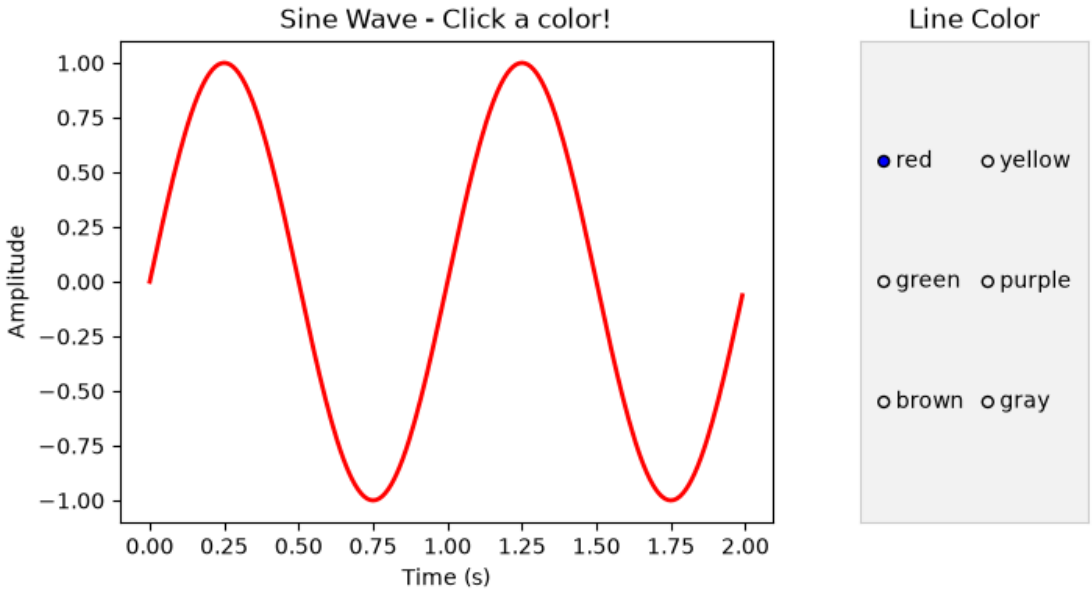
In this example, we create a color picker using a 2D grid of radio buttons to select the line color of a plot.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import RadioButtons

```

(continues on next page)

(continued from previous page)

```
# Generate sample data
t = np.arange(0.0, 2.0, 0.01)
s = np.sin(2 * np.pi * t)

fig, (ax, ax_buttons) = plt.subplots(
    1,
    2,
    figsize=(8, 4),
    width_ratios=[4, 1.4],
)

# Create initial plot
(line,) = ax.plot(t, s, lw=2, color="red")
ax.set(xlabel="Time (s)", ylabel="Amplitude", title="Sine Wave - Click␣
 ↪a color!")

# Configure the radio buttons axes
ax_buttons.set_facecolor("0.95")
ax_buttons.spines[:].set_color("0.8")
ax_buttons.set_title("Line Color")
# Create a 2D grid of color options (3 rows x 2 columns)
colors = ["red", "yellow", "green", "purple", "brown", "gray"]
radio = RadioButtons(ax_buttons, colors, layout=(3, 2))


def update_color(label):
    """Update the line color based on selected button."""
    line.set_color(label)
    fig.canvas.draw()
radio.on_clicked(update_color)


plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.RadioButtons*

Tags: styling: color styling: conditional plot-type: line level: intermediate purpose: showcase

Image scaling using a RangeSlider

Using the RangeSlider widget to control the thresholding of an image.

The RangeSlider widget can be used similarly to the *widgets.Slider* widget. The major difference is that RangeSlider's `val` attribute is a tuple of floats `(lower val, upper val)` rather than a single float.

See *Slider* for an example of using a `Slider` to control a single float.

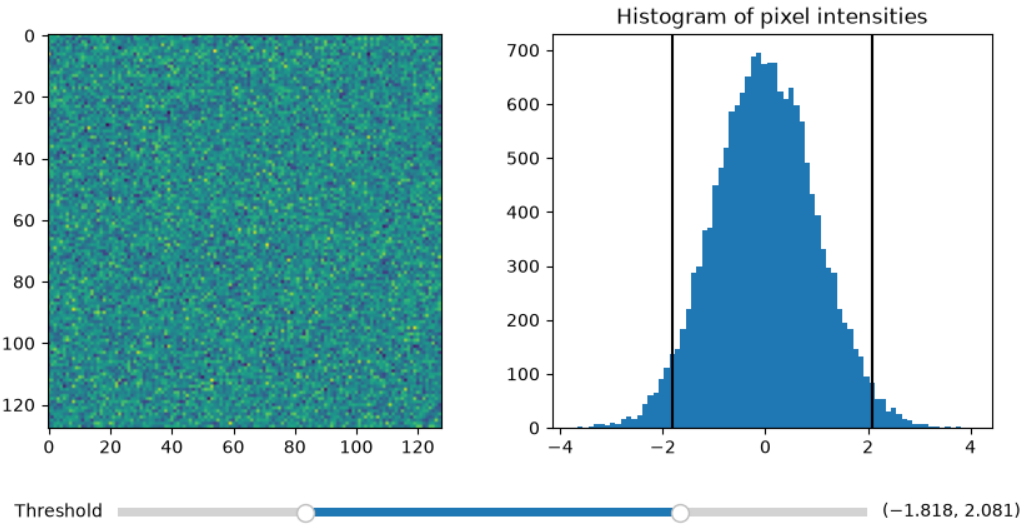
See *Snap sliders to discrete values* for an example of having the `Slider` snap to discrete values.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import RangeSlider

# generate a fake image
np.random.seed(19680801)
N = 128
img = np.random.randn(N, N)
```

(continues on next page)

(continued from previous page)

```
fig, axs = plt.subplots(1, 2, figsize=(10, 5))
fig.subplots_adjust(bottom=0.25)

im = axs[0].imshow(img)
axs[1].hist(img.flatten(), bins='auto')
axs[1].set_title('Histogram of pixel intensities')

# Create the RangeSlider
slider_ax = fig.add_axes((0.20, 0.1, 0.60, 0.03))
slider = RangeSlider(slider_ax, "Threshold", img.min(), img.max())

# Create the Vertical lines on the histogram
lower_limit_line = axs[1].axvline(slider.val[0], color='k')
upper_limit_line = axs[1].axvline(slider.val[1], color='k')


def update(val):
    # The val passed to a callback by the RangeSlider will
    # be a tuple of (min, max)

    # Update the image's colormap
    im.norm.vmin = val[0]
    im.norm.vmax = val[1]

    # Update the position of the vertical lines
    lower_limit_line.set_xdata([val[0], val[0]])
    upper_limit_line.set_xdata([val[1], val[1]])

    # Redraw the figure to ensure it updates
    fig.canvas.draw_idle()


slider.on_changed(update)
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.RangeSlider*

Rectangle and ellipse selectors

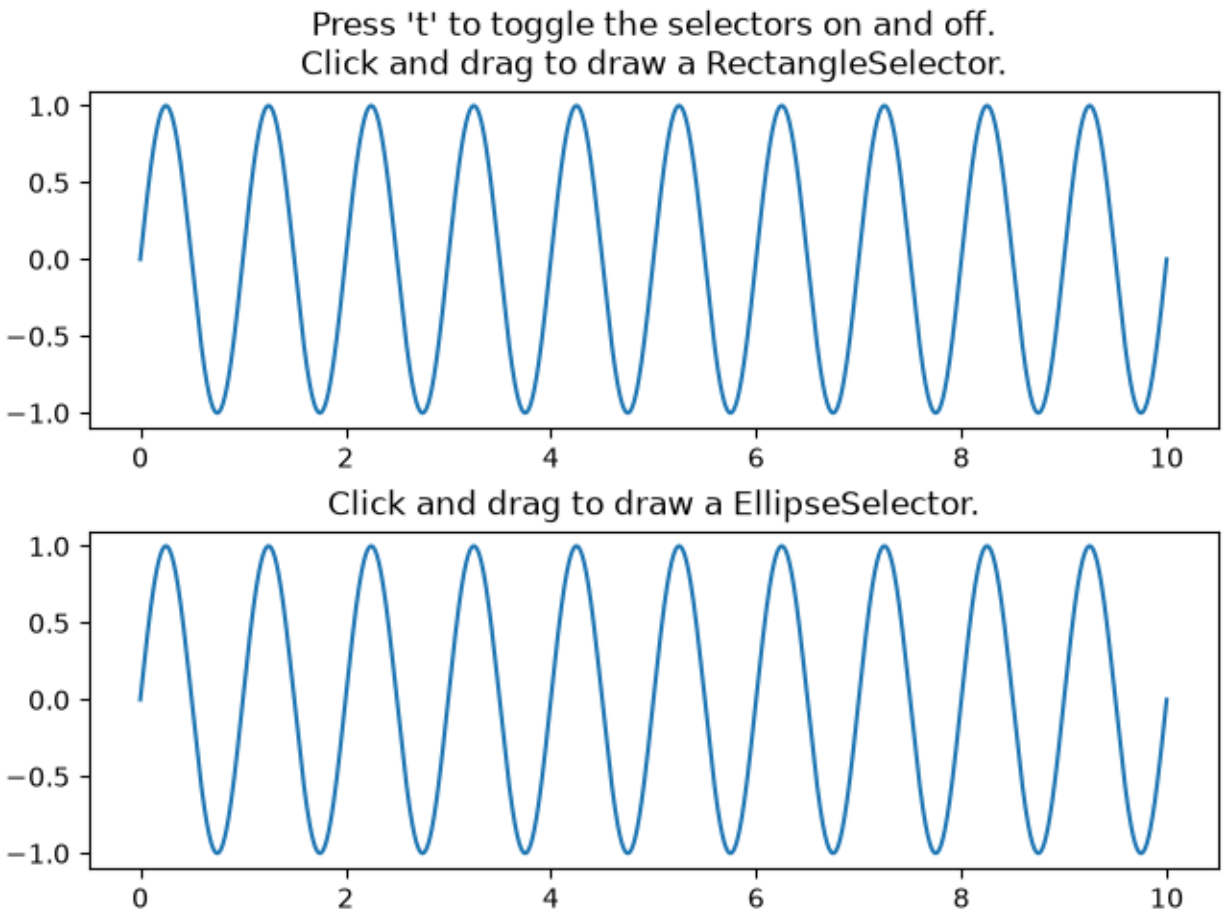
Click somewhere, move the mouse, and release the mouse button. *RectangleSelector* and *EllipseSelector* draw a rectangle or an ellipse from the initial click position to the current mouse position (within the same axes) until the button is released. A connected callback receives the click- and release-events.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import EllipseSelector, RectangleSelector


def select_callback(eclick, erelease):
    """
    Callback for line selection.

    *eclick* and *erelease* are the press and release events.
    """
    x1, y1 = eclick.xdata, eclick.ydata
    x2, y2 = erelease.xdata, erelease.ydata
    print(f"({x1:3.2f}, {y1:3.2f}) --> ({x2:3.2f}, {y2:3.2f})")
```

(continues on next page)

(continued from previous page)

```
    print(f"The buttons you used were: {eclick.button} {erelease.
 ↪button}")


def toggle_selector(event):
    print('Key pressed.')
    if event.key == 't':
        for selector in selectors:
            name = type(selector).__name__
            if selector.active:
                print(f'{name} deactivated.')
                selector.set_active(False)
            else:
                print(f'{name} activated.')
                selector.set_active(True)


fig = plt.figure(layout='constrained')
axs = fig.subplots(2)

N = 100000  # If N is large one can see improvement by using blitting.
x = np.linspace(0, 10, N)

selectors = []
for ax, selector_class in zip(axs, [RectangleSelector,␣
 ↪EllipseSelector]):
    ax.plot(x, np.sin(2*np.pi*x))  # plot something
    ax.set_title(f"Click and drag to draw a {selector_class.__name__}.
 ↪")
    selectors.append(selector_class(
        ax, select_callback,
        useblit=True,
        button=[1, 3],  # disable middle button
        minspanx=5, minspany=5,
        spancoords='pixels',
        interactive=True))
    fig.canvas.mpl_connect('key_press_event', toggle_selector)
axs[0].set_title("Press 't' to toggle the selectors on and off.\n"
                 + axs[0].get_title())
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.RectangleSelector*
- *matplotlib.widgets.EllipseSelector*

Slider

In this example, sliders are used to control the frequency and amplitude of a sine wave.

See *Snap sliders to discrete values* for an example of having the `Slider` snap to discrete values.

See *Image scaling using a RangeSlider* for an example of using a `RangeSlider` to define a range of values.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import Button, Slider
```

(continues on next page)

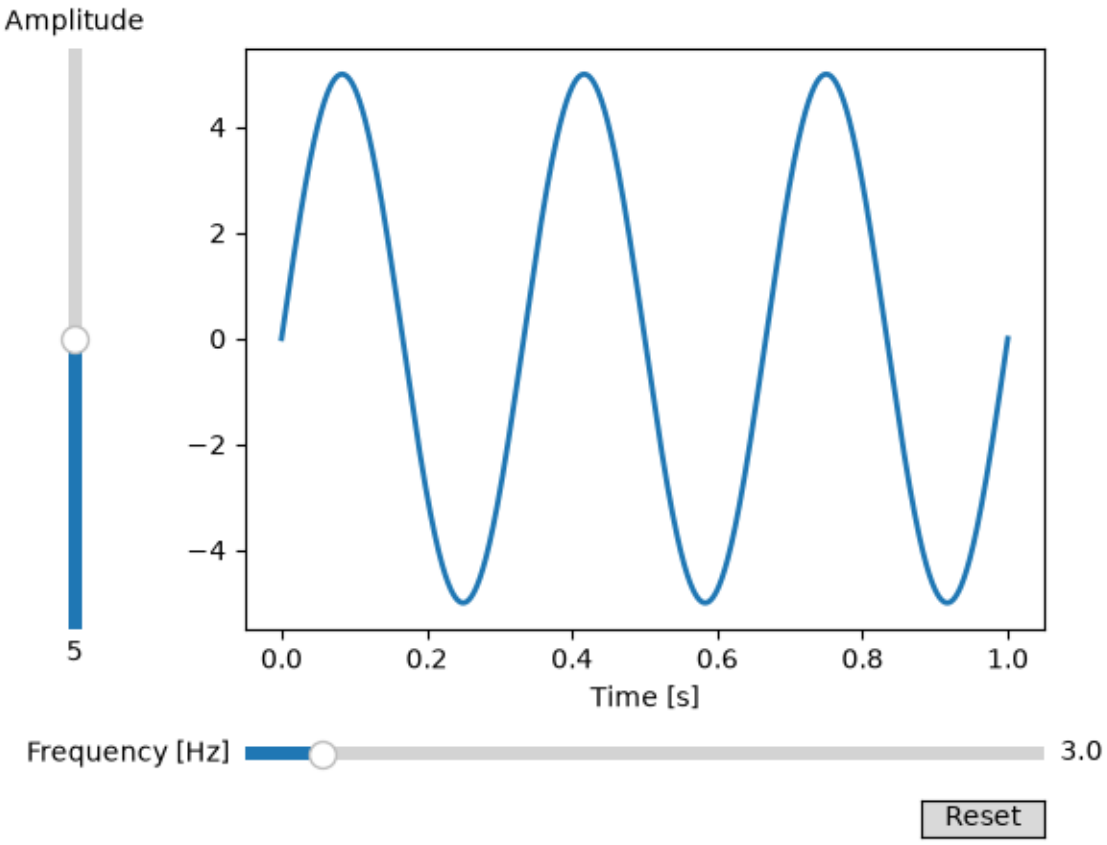
(continued from previous page)

```
# The parametrized function to be plotted
def f(t, amplitude, frequency):
    return amplitude * np.sin(2 * np.pi * frequency * t)

t = np.linspace(0, 1, 1000)

# Define initial parameters
init_amplitude = 5
init_frequency = 3

# Create the figure and the line that we will manipulate
fig, ax = plt.subplots()
line, = ax.plot(t, f(t, init_amplitude, init_frequency), lw=2)
ax.set_xlabel('Time [s]')

# adjust the main plot to make room for the sliders
fig.subplots_adjust(left=0.25, bottom=0.25)

# Make a horizontal slider to control the frequency.
axfreq = fig.add_axes((0.25, 0.1, 0.65, 0.03))
freq_slider = Slider(
    ax=axfreq,
    label='Frequency [Hz]',
    valmin=0.1,
    valmax=30,
    valinit=init_frequency,
)

# Make a vertically oriented slider to control the amplitude
axamp = fig.add_axes((0.1, 0.25, 0.0225, 0.63))
amp_slider = Slider(
    ax=axamp,
    label="Amplitude",
    valmin=0,
    valmax=10,
    valinit=init_amplitude,
    orientation="vertical"
)


# The function to be called anytime a slider's value changes
def update(val):
    line.set_ydata(f(t, amp_slider.val, freq_slider.val))
    fig.canvas.draw_idle()
```

(continues on next page)

(continued from previous page)

```
# register the update function with each slider
freq_slider.on_changed(update)
amp_slider.on_changed(update)

# Create a `matplotlib.widgets.Button` to reset the sliders to initial␣
 ↪values.
resetax = fig.add_axes((0.8, 0.025, 0.1, 0.04))
button = Button(resetax, 'Reset', hovercolor='0.975')


def reset(event):
    freq_slider.reset()
    amp_slider.reset()
button.on_clicked(reset)

plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.Button*
- *matplotlib.widgets.Slider*

Snap sliders to discrete values

You can snap slider values to discrete values using the `valstep` argument.

In this example the Freq slider is constrained to be multiples of pi, and the Amp slider uses an array as the `valstep` argument to more densely sample the first part of its range.

See *Slider* for an example of using a `Slider` to control a single float.

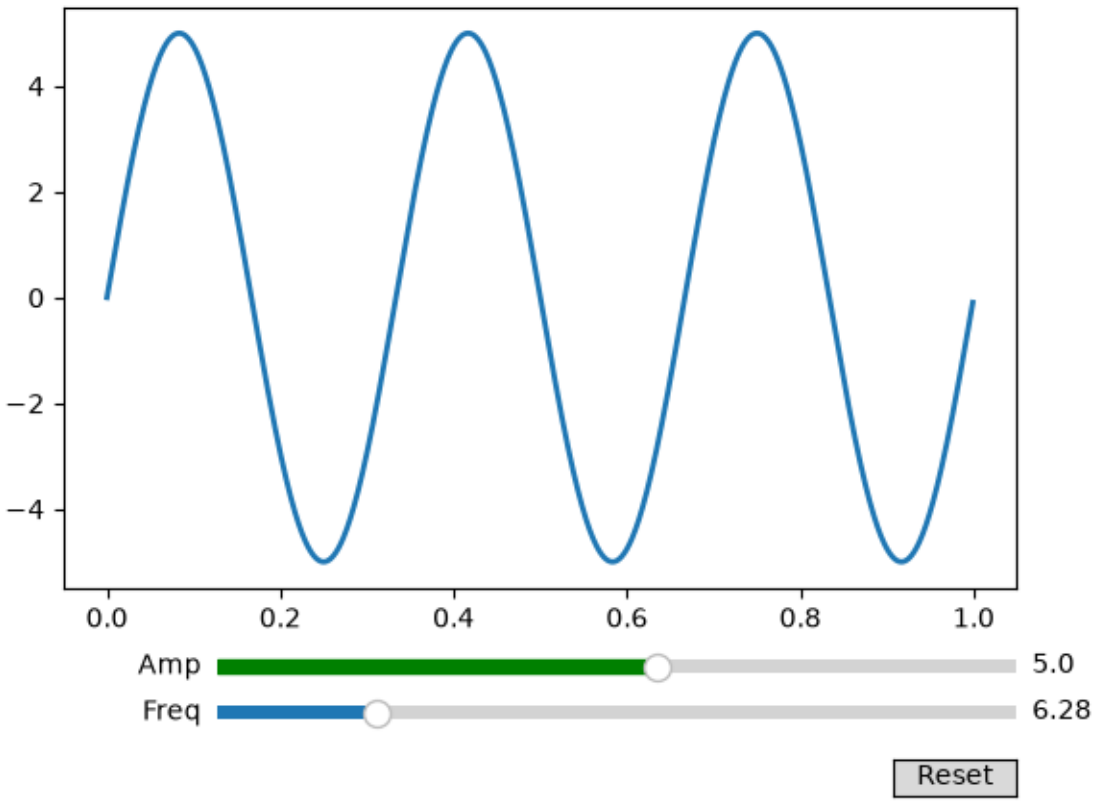
See *Image scaling using a RangeSlider* for an example of using a `RangeSlider` to define a range of values.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import Button, Slider

t = np.arange(0.0, 1.0, 0.001)
a0 = 5
f0 = 3
s = a0 * np.sin(2 * np.pi * f0 * t)

fig, ax = plt.subplots()
fig.subplots_adjust(bottom=0.25)
l, = ax.plot(t, s, lw=2)

ax_freq = fig.add_axes((0.25, 0.1, 0.65, 0.03))
ax_amp = fig.add_axes((0.25, 0.15, 0.65, 0.03))

# define the values to use for snapping
allowed_amplitudes = np.concatenate([np.linspace(.1, 5, 100), [6, 7, 8,
 ↪ 9]])

# create the sliders
samp = Slider(
    ax_amp, "Amp", 0.1, 9.0,
    valinit=a0, valstep=allowed_amplitudes,
    color="green"
)

sfreq = Slider(
    ax_freq, "Freq", 0, 10*np.pi,
```

(continues on next page)

(continued from previous page)

```
    valinit=2*np.pi, valstep=np.pi,
    initcolor='none'  # Remove the line marking the valinit position.
)


def update(val):
    amp = samp.val
    freq = sfreq.val
    l.set_ydata(amp*np.sin(2*np.pi*freq*t))
    fig.canvas.draw_idle()


sfreq.on_changed(update)
samp.on_changed(update)

ax_reset = fig.add_axes((0.8, 0.025, 0.1, 0.04))
button = Button(ax_reset, 'Reset', hovercolor='0.975')


def reset(event):
    sfreq.reset()
    samp.reset()
button.on_clicked(reset)


plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.Slider*
- *matplotlib.widgets.Button*

Span Selector

The *SpanSelector* is a mouse widget that enables selecting a range on an axis.

Here, an x-range can be selected on the upper axis; a detailed view of the selected range is then plotted on the lower axis.

Note

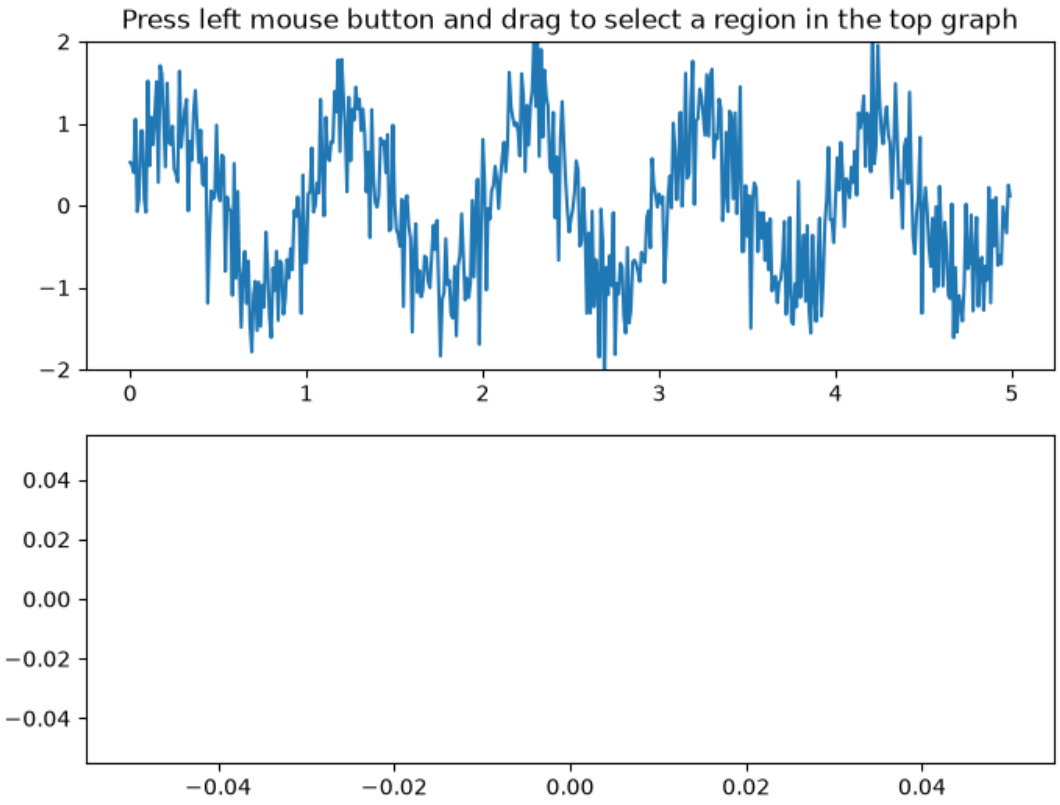
If the SpanSelector object is garbage collected you will lose the interactivity. You must keep a hard reference to it to prevent this.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import SpanSelector

# Fixing random state for reproducibility
np.random.seed(19680801)

fig, (ax1, ax2) = plt.subplots(2, figsize=(8, 6))

x = np.arange(0.0, 5.0, 0.01)
y = np.sin(2 * np.pi * x) + 0.5 * np.random.randn(len(x))

ax1.plot(x, y)
ax1.set_ylim(-2, 2)
ax1.set_title('Press left mouse button and drag '
              'to select a region in the top graph')

line2, = ax2.plot([], [])


def onselect(xmin, xmax):
    indmin, indmax = np.searchsorted(x, (xmin, xmax))
    indmax = min(len(x) - 1, indmax)

    region_x = x[indmin:indmax]
    region_y = y[indmin:indmax]

    if len(region_x) >= 2:
        line2.set_data(region_x, region_y)
        ax2.set_xlim(region_x[0], region_x[-1])
        ax2.set_ylim(region_y.min(), region_y.max())
        fig.canvas.draw_idle()


span = SpanSelector(
    ax1,
    onselect,
    "horizontal",
    useblit=True,
    props=dict(alpha=0.5, facecolor="tab:blue"),
```

(continues on next page)

(continued from previous page)

```
    interactive=True,
    drag_from_anywhere=True
)
# Set useblit=True on most backends for enhanced performance.


plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.SpanSelector*

Textbox

The Textbox widget lets users interactively provide text input, including formulas. In this example, the plot is updated using the *on_submit* method. This method triggers the execution of the *submit* function when the user presses enter in the textbox or leaves the textbox.

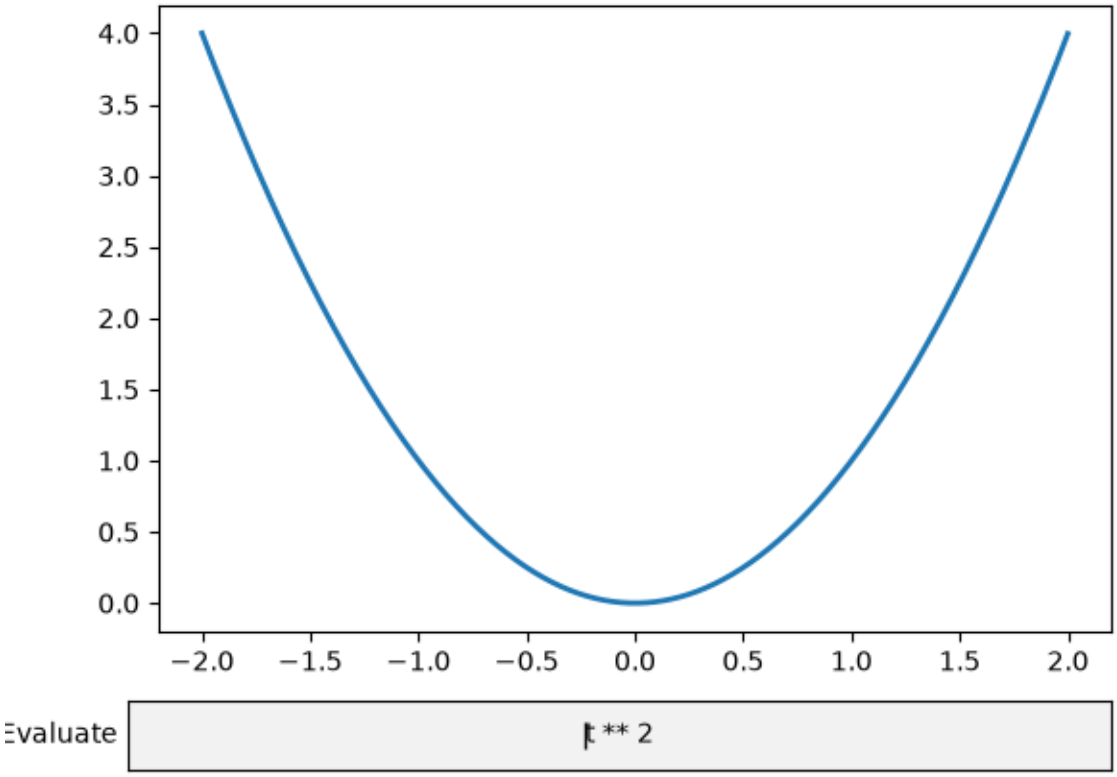
Note: The *matplotlib.widgets.TextBox* widget is different from the following static elements: *Annotations* and *Placing text boxes*.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.widgets import TextBox

fig, ax = plt.subplots()
fig.subplots_adjust(bottom=0.2)

t = np.arange(-2.0, 2.0, 0.001)
l, = ax.plot(t, np.zeros_like(t), lw=2)


def submit(expression):
    """
    Update the plotted function to the new math *expression*.

    *expression* is a string using "t" as its independent variable,␣
 ↪e.g.
    "t ** 3".
    """
    ydata = eval(expression, {'np': np}, {'t': t})
    l.set_ydata(ydata)
    ax.relim()
    ax.autoscale_view()
    plt.draw()


axbox = fig.add_axes((0.1, 0.05, 0.8, 0.075))
text_box = TextBox(axbox, "Evaluate", textalignment="center")
text_box.on_submit(submit)
text_box.set_val("t ** 2")  # Trigger `submit` with the initial string.
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.widgets.TextBox*

6.24.19 Event handling

Matplotlib supports *event handling* with a GUI neutral event model, so you can connect to Matplotlib events without knowledge of what user interface Matplotlib will ultimately be plugged in to. This has two advantages: the code you write will be more portable, and Matplotlib events are aware of things like data coordinate space and which axes the event occurs in so you don't have to mess with low level transformation details to go from canvas space to data space. Object picking examples are also included.

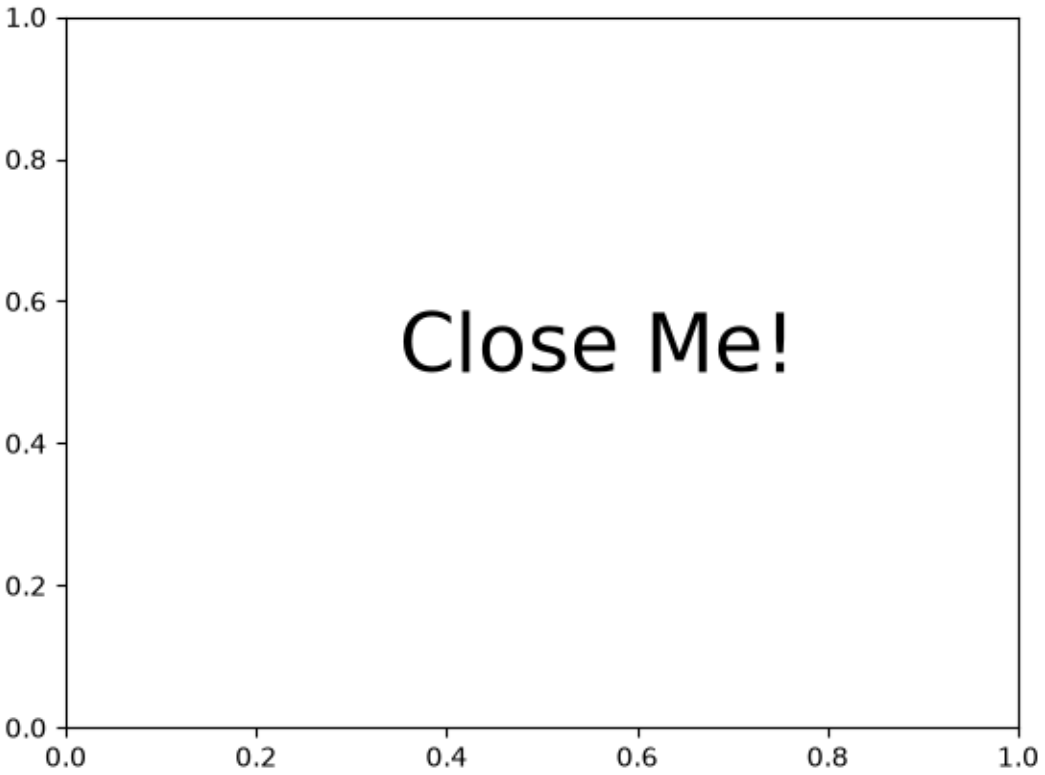
Close event

Example to show connecting events that occur when the figure closes.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import matplotlib.pyplot as plt


def on_close(event):
    print('Closed Figure!')

fig = plt.figure()
fig.canvas.mpl_connect('close_event', on_close)

plt.text(0.35, 0.5, 'Close Me!', dict(size=30))
plt.show()
```

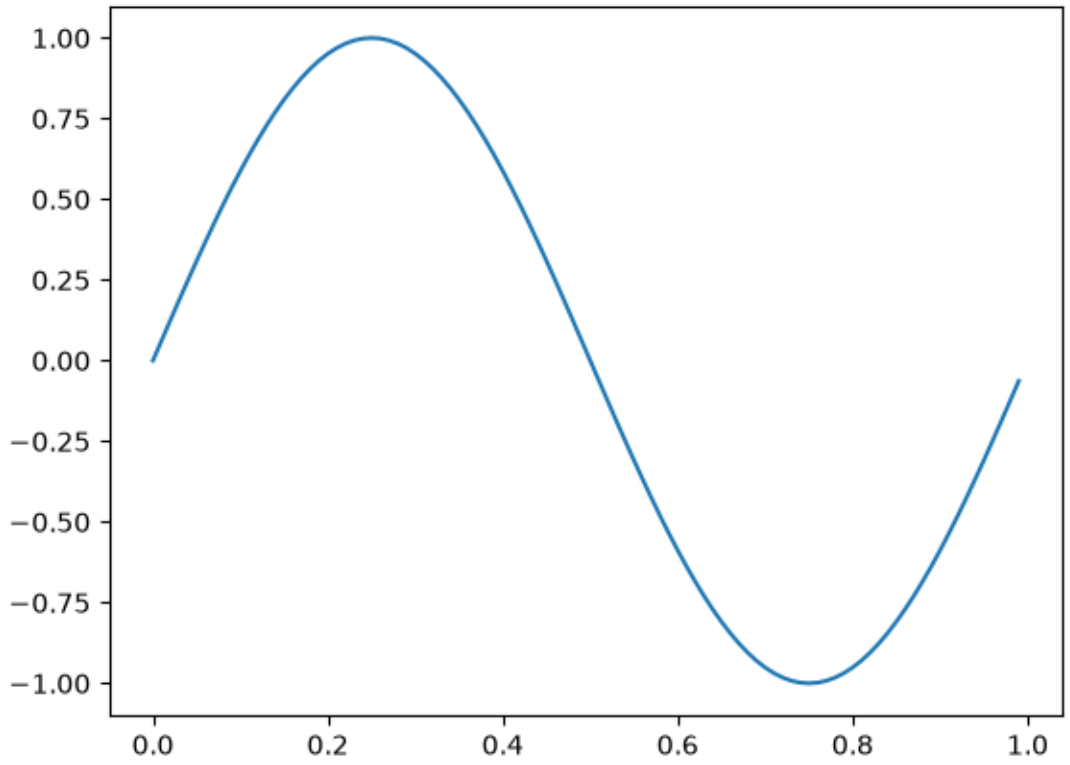
Mouse move and click events

An example of how to interact with the plotting canvas by connecting to move and click events.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.backend_bases import MouseButton

t = np.arange(0.0, 1.0, 0.01)
s = np.sin(2 * np.pi * t)
fig, ax = plt.subplots()
ax.plot(t, s)


def on_move(event):
    if event.inaxes:
        print(f'data coords {event.xdata} {event.ydata},',
              f'pixel coords {event.x} {event.y}')
```

(continues on next page)

(continued from previous page)

```
def on_click(event):
    if event.button is MouseButton.LEFT:
        print('disconnecting callback')
        plt.disconnect(binding_id)


binding_id = plt.connect('motion_notify_event', on_move)
plt.connect('button_press_event', on_click)

plt.show()
```

Cross-hair cursor

This example adds a cross-hair as a data cursor. The cross-hair is implemented as regular line objects that are updated on mouse move.

We show three implementations:

1) A simple cursor implementation that redraws the figure on every mouse move. This is a bit slow, and you may notice some lag of the cross-hair movement.
2) A cursor that uses blitting for speedup of the rendering.
3) A cursor that snaps to data points.

Faster cursoring is possible using native GUI drawing, as in *Add a cursor in WX*.

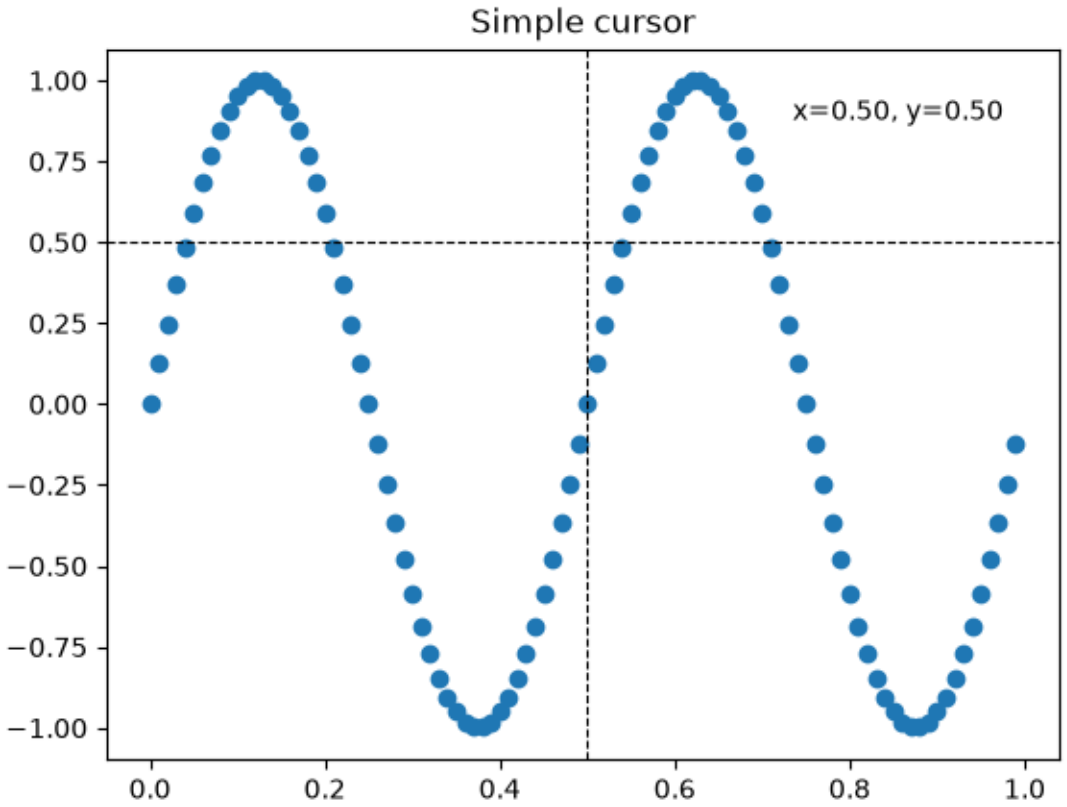
The mpldatacursor and mplcursors third-party packages can be used to achieve a similar effect.

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.backend_bases import MouseEvent


class Cursor:
    """
    A cross hair cursor.
    """
    def __init__(self, ax):
        self.ax = ax
        self.horizontal_line = ax.axhline(color='k', lw=0.8, ls='--')
        self.vertical_line = ax.axvline(color='k', lw=0.8, ls='--')
        # text location in axes coordinates
        self.text = ax.text(0.72, 0.9, '', transform=ax.transAxes)

    def set_cross_hair_visible(self, visible):
        need_redraw = self.horizontal_line.get_visible() != visible
```

(continues on next page)

(continued from previous page)

```
        self.horizontal_line.set_visible(visible)
        self.vertical_line.set_visible(visible)
        self.text.set_visible(visible)
        return need_redraw

    def on_mouse_move(self, event):
        if not event.inaxes:
            need_redraw = self.set_cross_hair_visible(False)
            if need_redraw:
                self.ax.figure.canvas.draw()
        else:
            self.set_cross_hair_visible(True)
            x, y = event.xdata, event.ydata
            # update the line positions
            self.horizontal_line.set_ydata([y])
            self.vertical_line.set_xdata([x])
            self.text.set_text(f'x={x:1.2f}, y={y:1.2f}')
            self.ax.figure.canvas.draw()


x = np.arange(0, 1, 0.01)
y = np.sin(2 * 2 * np.pi * x)

fig, ax = plt.subplots()
ax.set_title('Simple cursor')
ax.plot(x, y, 'o')
cursor = Cursor(ax)
fig.canvas.mpl_connect('motion_notify_event', cursor.on_mouse_move)

# Simulate a mouse move to (0.5, 0.5), needed for online docs
t = ax.transData
MouseEvent(
    "motion_notify_event", ax.figure.canvas, *t.transform((0.5, 0.5))
)._process()
```



Faster redrawing using blitting

This technique stores the rendered plot as a background image. Only the changed artists (cross-hair lines and text) are rendered anew. They are combined with the background using blitting.

This technique is significantly faster. It requires a bit more setup because the background has to be stored without the cross-hair lines (see `create_new_background()`). Additionally, a new background has to be created whenever the figure changes. This is achieved by connecting to the `'draw_event'`.

```
class BlittedCursor:
    """
    A cross-hair cursor using blitting for faster redraw.
    """
    def __init__(self, ax):
        self.ax = ax
        self.background = None
        self.horizontal_line = ax.axhline(color='k', lw=0.8, ls='--')
        self.vertical_line = ax.axvline(color='k', lw=0.8, ls='--')
        # text location in axes coordinates
        self.text = ax.text(0.72, 0.9, '', transform=ax.transAxes)
        self._creating_background = False
```

(continues on next page)

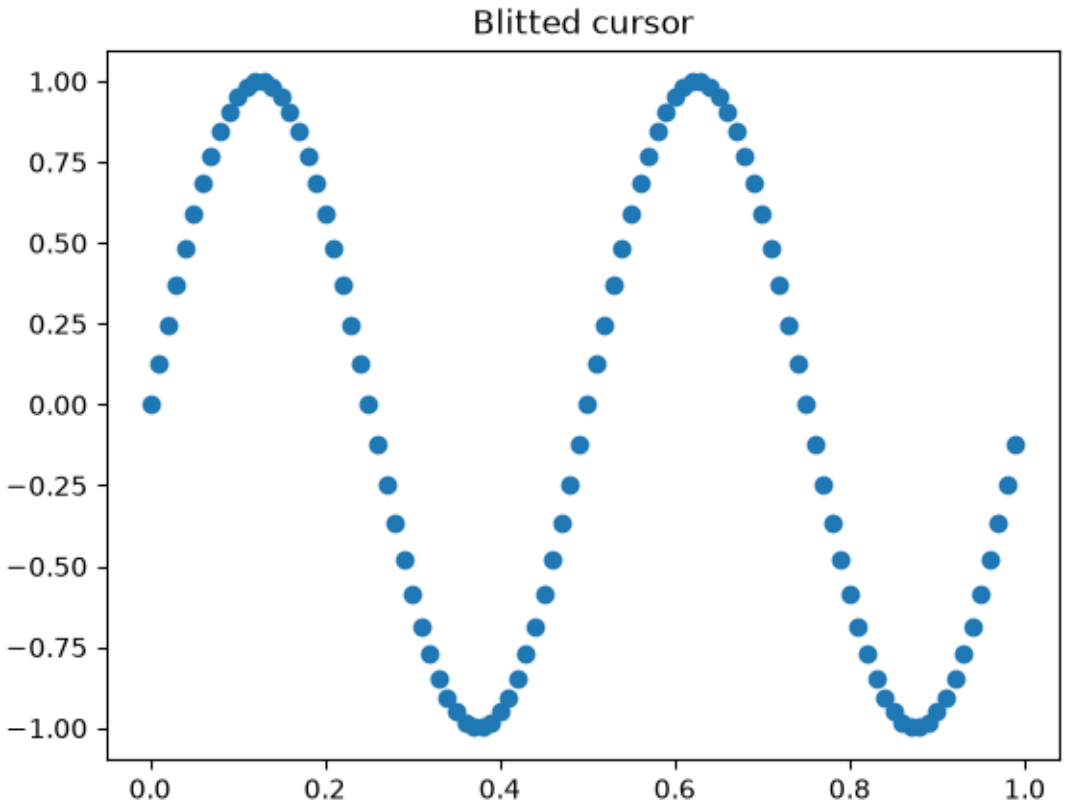
(continued from previous page)

```
        ax.figure.canvas.mpl_connect('draw_event', self.on_draw)

    def on_draw(self, event):
        self.create_new_background()

    def set_cross_hair_visible(self, visible):
        need_redraw = self.horizontal_line.get_visible() != visible
        self.horizontal_line.set_visible(visible)
        self.vertical_line.set_visible(visible)
        self.text.set_visible(visible)
        return need_redraw

    def create_new_background(self):
        if self._creating_background:
            # discard calls triggered from within this function
            return
        self._creating_background = True
        self.set_cross_hair_visible(False)
        self.ax.figure.canvas.draw()
        self.background = self.ax.figure.canvas.copy_from_bbox(self.ax.
↪bbox)
        self.set_cross_hair_visible(True)
        self._creating_background = False

    def on_mouse_move(self, event):
        if self.background is None:
            self.create_new_background()
        if not event.inaxes:
            need_redraw = self.set_cross_hair_visible(False)
            if need_redraw:
                self.ax.figure.canvas.restore_region(self.background)
                self.ax.figure.canvas.blit(self.ax.bbox)
        else:
            self.set_cross_hair_visible(True)
            # update the line positions
            x, y = event.xdata, event.ydata
            self.horizontal_line.set_ydata([y])
            self.vertical_line.set_xdata([x])
            self.text.set_text(f'x={x:1.2f}, y={y:1.2f}')

            self.ax.figure.canvas.restore_region(self.background)
            self.ax.draw_artist(self.horizontal_line)
            self.ax.draw_artist(self.vertical_line)
            self.ax.draw_artist(self.text)
            self.ax.figure.canvas.blit(self.ax.bbox)
```

(continues on next page)

(continued from previous page)

```
x = np.arange(0, 1, 0.01)
y = np.sin(2 * 2 * np.pi * x)

fig, ax = plt.subplots()
ax.set_title('Blitted cursor')
ax.plot(x, y, 'o')
blitted_cursor = BlittedCursor(ax)
fig.canvas.mpl_connect('motion_notify_event', blitted_cursor.
 ↪on_mouse_move)

# Simulate a mouse move to (0.5, 0.5), needed for online docs
t = ax.transData
MouseEvent(
    "motion_notify_event", ax.figure.canvas, *t.transform((0.5, 0.5))
)._process()
```



Snapping to data points

The following cursor snaps its position to the data points of a *Line2D* object.

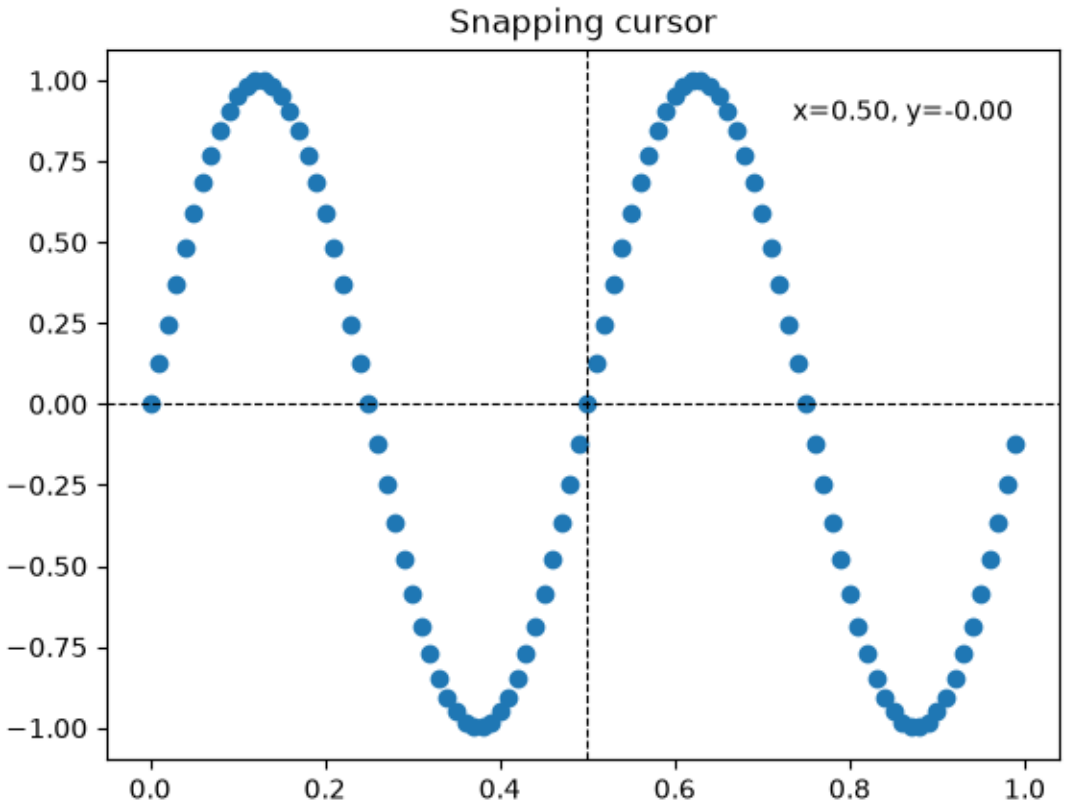
To save unnecessary redraws, the index of the last indicated data point is saved in `self._last_index`. A redraw is only triggered when the mouse moves far enough so that another data point must be selected. This reduces the lag due to many redraws. Of course, blitting could still be added on top for additional speedup.

```
class SnappingCursor:
    """
    A cross-hair cursor that snaps to the data point of a line, which␣
 ↪is
    closest to the *x* position of the cursor.

    For simplicity, this assumes that *x* values of the data are␣
 ↪sorted.
    """
    def __init__(self, ax, line):
        self.ax = ax
        self.horizontal_line = ax.axhline(color='k', lw=0.8, ls='--')
        self.vertical_line = ax.axvline(color='k', lw=0.8, ls='--')
        self.x, self.y = line.get_data()
        self._last_index = None
        # text location in axes coords
        self.text = ax.text(0.72, 0.9, '', transform=ax.transAxes)

    def set_cross_hair_visible(self, visible):
        need_redraw = self.horizontal_line.get_visible() != visible
        self.horizontal_line.set_visible(visible)
        self.vertical_line.set_visible(visible)
        self.text.set_visible(visible)
        return need_redraw

    def on_mouse_move(self, event):
        if not event.inaxes:
            self._last_index = None
            need_redraw = self.set_cross_hair_visible(False)
            if need_redraw:
                self.ax.figure.canvas.draw()
        else:
            self.set_cross_hair_visible(True)
            x, y = event.xdata, event.ydata
            index = min(np.searchsorted(self.x, x), len(self.x) - 1)
            if index == self._last_index:
                return  # still on the same data point. Nothing to do.
            self._last_index = index
            x = self.x[index]
            y = self.y[index]
```

(continues on next page)

(continued from previous page)

```
            # update the line positions
            self.horizontal_line.set_ydata([y])
            self.vertical_line.set_xdata([x])
            self.text.set_text(f'x={x:1.2f}, y={y:1.2f}')
            self.ax.figure.canvas.draw()


x = np.arange(0, 1, 0.01)
y = np.sin(2 * 2 * np.pi * x)

fig, ax = plt.subplots()
ax.set_title('Snapping cursor')
line, = ax.plot(x, y, 'o')
snap_cursor = SnappingCursor(ax, line)
fig.canvas.mpl_connect('motion_notify_event', snap_cursor.
 ↪on_mouse_move)

# Simulate a mouse move to (0.5, 0.5), needed for online docs
t = ax.transData
MouseEvent(
    "motion_notify_event", ax.figure.canvas, *t.transform((0.5, 0.5))
)._process()

plt.show()
```



Data browser

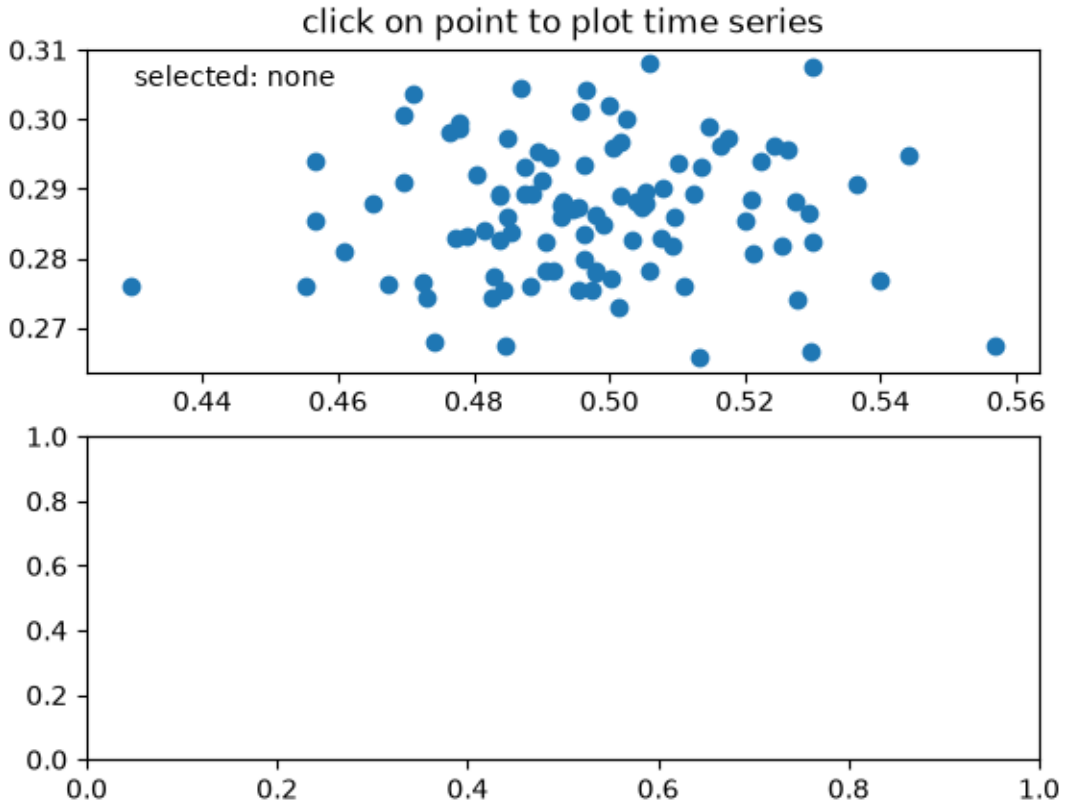
Connecting data between multiple canvases.

This example covers how to interact data with multiple canvases. This lets you select and highlight a point on one axis, and generating the data of that point on the other axis.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import numpy as np


class PointBrowser:
    """
    Click on a point to select and highlight it -- the data that
    generated the point will be shown in the lower Axes.  Use the 'n'
    and 'p' keys to browse through the next and previous points
    """

    def __init__(self):
        self.lastind = 0
```

(continues on next page)

(continued from previous page)

```
        self.text = ax.text(0.05, 0.95, 'selected: none',
                            transform=ax.transAxes, va='top')
        self.selected, = ax.plot([xs[0]], [ys[0]], 'o', ms=12,␣
↪alpha=0.4,
                                 color='yellow', visible=False)

    def on_press(self, event):
        if self.lastind is None:
            return
        if event.key not in ('n', 'p'):
            return
        if event.key == 'n':
            inc = 1
        else:
            inc = -1

        self.lastind += inc
        self.lastind = np.clip(self.lastind, 0, len(xs) - 1)
        self.update()

    def on_pick(self, event):

        if event.artist != line:
            return True

        N = len(event.ind)
        if not N:
            return True

        # the click locations
        x = event.mouseevent.xdata
        y = event.mouseevent.ydata

        distances = np.hypot(x - xs[event.ind], y - ys[event.ind])
        indmin = distances.argmin()
        dataind = event.ind[indmin]

        self.lastind = dataind
        self.update()

    def update(self):
        if self.lastind is None:
            return

        dataind = self.lastind
```

(continues on next page)

(continued from previous page)

```
        ax2.clear()
        ax2.plot(X[dataind])

        ax2.text(0.05, 0.9, f'mu={xs[dataind]:1.3f}\nsigma=
↪{ys[dataind]:1.3f}',
                 transform=ax2.transAxes, va='top')
        ax2.set_ylim(-0.5, 1.5)
        self.selected.set_visible(True)
        self.selected.set_data([xs[dataind]], [ys[dataind]])

        self.text.set_text('selected: %d' % dataind)
        fig.canvas.draw()


if __name__ == '__main__':
    import matplotlib.pyplot as plt

    # Fixing random state for reproducibility
    np.random.seed(19680801)

    X = np.random.rand(100, 200)
    xs = np.mean(X, axis=1)
    ys = np.std(X, axis=1)

    fig, (ax, ax2) = plt.subplots(2, 1)
    ax.set_title('click on point to plot time series')
    line, = ax.plot(xs, ys, 'o', picker=True, pickradius=5)

    browser = PointBrowser()

    fig.canvas.mpl_connect('pick_event', browser.on_pick)
    fig.canvas.mpl_connect('key_press_event', browser.on_press)

    plt.show()
```

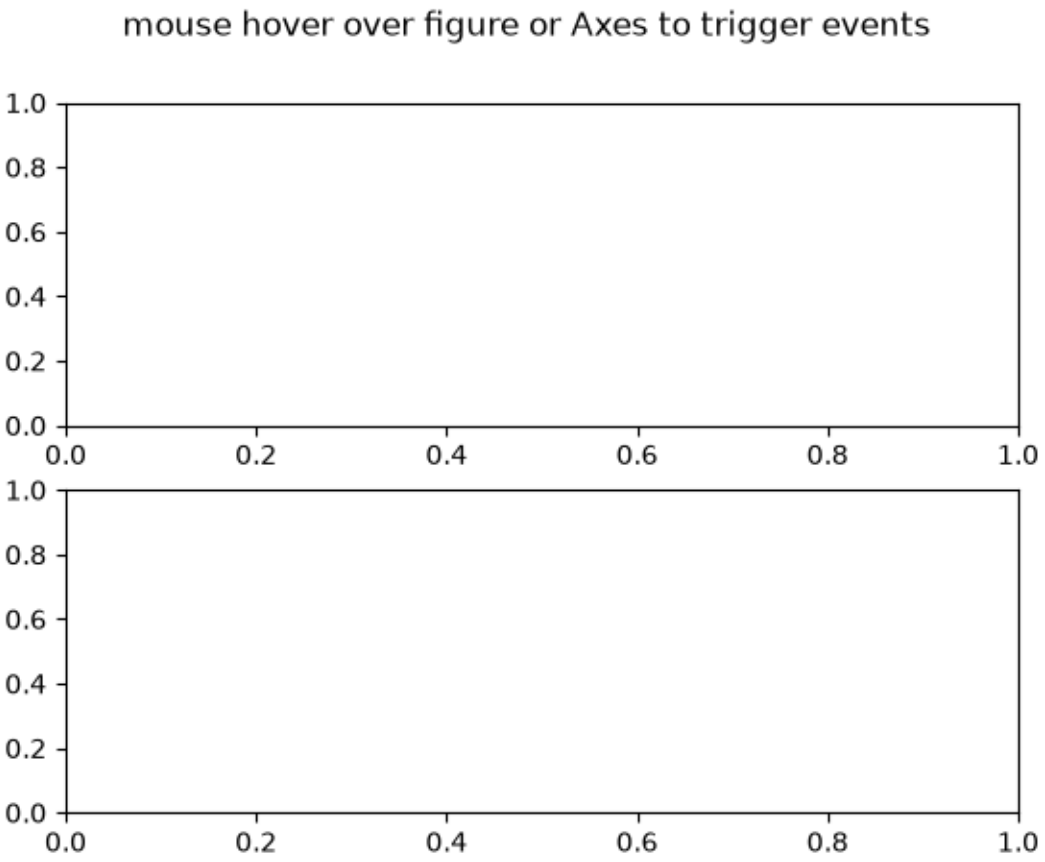
Figure/Axes enter and leave events

Illustrate the figure and Axes enter and leave events by changing the frame colors on enter and leave.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import matplotlib.pyplot as plt


def on_enter_axes(event):
    print('enter_axes', event.inaxes)
    event.inaxes.patch.set_facecolor('yellow')
    event.canvas.draw()


def on_leave_axes(event):
    print('leave_axes', event.inaxes)
    event.inaxes.patch.set_facecolor('white')
    event.canvas.draw()


def on_enter_figure(event):
```

(continues on next page)

(continued from previous page)

```
    print('enter_figure', event.canvas.figure)
    event.canvas.figure.patch.set_facecolor('red')
    event.canvas.draw()


def on_leave_figure(event):
    print('leave_figure', event.canvas.figure)
    event.canvas.figure.patch.set_facecolor('grey')
    event.canvas.draw()


fig, axs = plt.subplots(2, 1)
fig.suptitle('mouse hover over figure or Axes to trigger events')

fig.canvas.mpl_connect('figure_enter_event', on_enter_figure)
fig.canvas.mpl_connect('figure_leave_event', on_leave_figure)
fig.canvas.mpl_connect('axes_enter_event', on_enter_axes)
fig.canvas.mpl_connect('axes_leave_event', on_leave_axes)

plt.show()
```

Interactive functions

This provides examples of uses of interactive functions, such as ginput, waitforbuttonpress and manual clabel placement.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.

```
import time

import matplotlib.pyplot as plt
import numpy as np


def tellme(s):
    print(s)
    plt.title(s, fontsize=16)
    plt.draw()
```

Define a triangle by clicking three points

```
plt.figure()
plt.xlim(0, 1)
plt.ylim(0, 1)

tellme('You will define a triangle, click to begin')

plt.waitforbuttonpress()

while True:
    pts = []
    while len(pts) < 3:
        tellme('Select 3 corners with mouse')
        pts = np.asarray(plt.ginput(3, timeout=-1))
        if len(pts) < 3:
            tellme('Too few points, starting over')
            time.sleep(1)  # Wait a second

    ph = plt.fill(pts[:, 0], pts[:, 1], 'r', lw=2)

    tellme('Happy? Key click for yes, mouse click for no')

    if plt.waitforbuttonpress():
        break

    # Get rid of fill
    for p in ph:
        p.remove()
```

Now contour according to distance from triangle corners - just an example

```
# Define a nice function of distance from individual pts
def f(x, y, pts):
    z = np.zeros_like(x)
    for p in pts:
        z = z + 1/(np.sqrt((x - p[0])**2 + (y - p[1])**2))
    return 1/z


X, Y = np.meshgrid(np.linspace(-1, 1, 51), np.linspace(-1, 1, 51))
Z = f(X, Y, pts)

CS = plt.contour(X, Y, Z, 20)

tellme('Use mouse to select contour label locations, middle button to␣
 ↪finish')
CL = plt.clabel(CS, manual=True)
```

Now do a zoom

```
tellme('Now do a nested zoom, click to begin')
plt.waitforbuttonpress()

while True:
    tellme('Select two corners of zoom, middle mouse button to finish')
    pts = plt.ginput(2, timeout=-1)
    if len(pts) < 2:
        break
    (x0, y0), (x1, y1) = pts
    xmin, xmax = sorted([x0, x1])
    ymin, ymax = sorted([y0, y1])
    plt.xlim(xmin, xmax)
    plt.ylim(ymin, ymax)

tellme('All Done!')
plt.show()
```

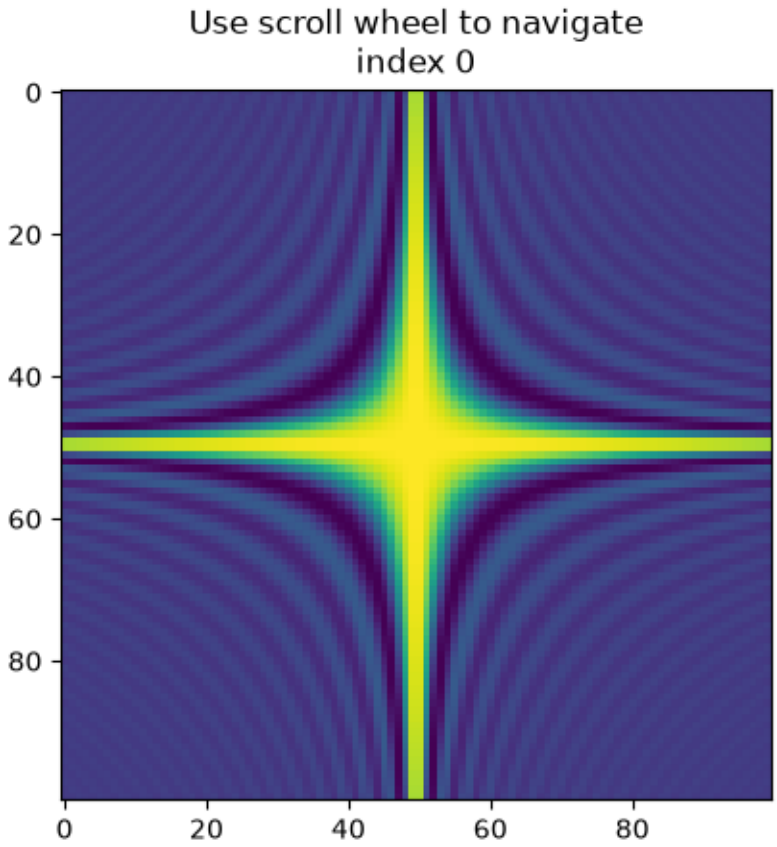
Scroll event

In this example a scroll wheel event is used to scroll through 2D slices of 3D data.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import matplotlib.pyplot as plt
import numpy as np


class IndexTracker:
    def __init__(self, ax, X):
        self.index = 0
        self.X = X
        self.ax = ax
        self.im = ax.imshow(self.X[:, :, self.index])
        self.update()

    def on_scroll(self, event):
        print(event.button, event.step)
        increment = 1 if event.button == 'up' else -1
        max_index = self.X.shape[-1] - 1
        self.index = np.clip(self.index + increment, 0, max_index)
        self.update()

    def update(self):
```

(continues on next page)

(continued from previous page)

```
        self.im.set_data(self.X[:, :, self.index])
        self.ax.set_title(
            f'Use scroll wheel to navigate\nindex {self.index}')
        self.im.axes.figure.canvas.draw()


x, y, z = np.ogrid[-10:10:100j, -10:10:100j, 1:10:20j]
X = np.sin(x * y * z) / (x * y * z)

fig, ax = plt.subplots()
# create an IndexTracker and make sure it lives during the whole
# lifetime of the figure by assigning it to a variable
tracker = IndexTracker(ax, X)

fig.canvas.mpl_connect('scroll_event', tracker.on_scroll)
plt.show()
```

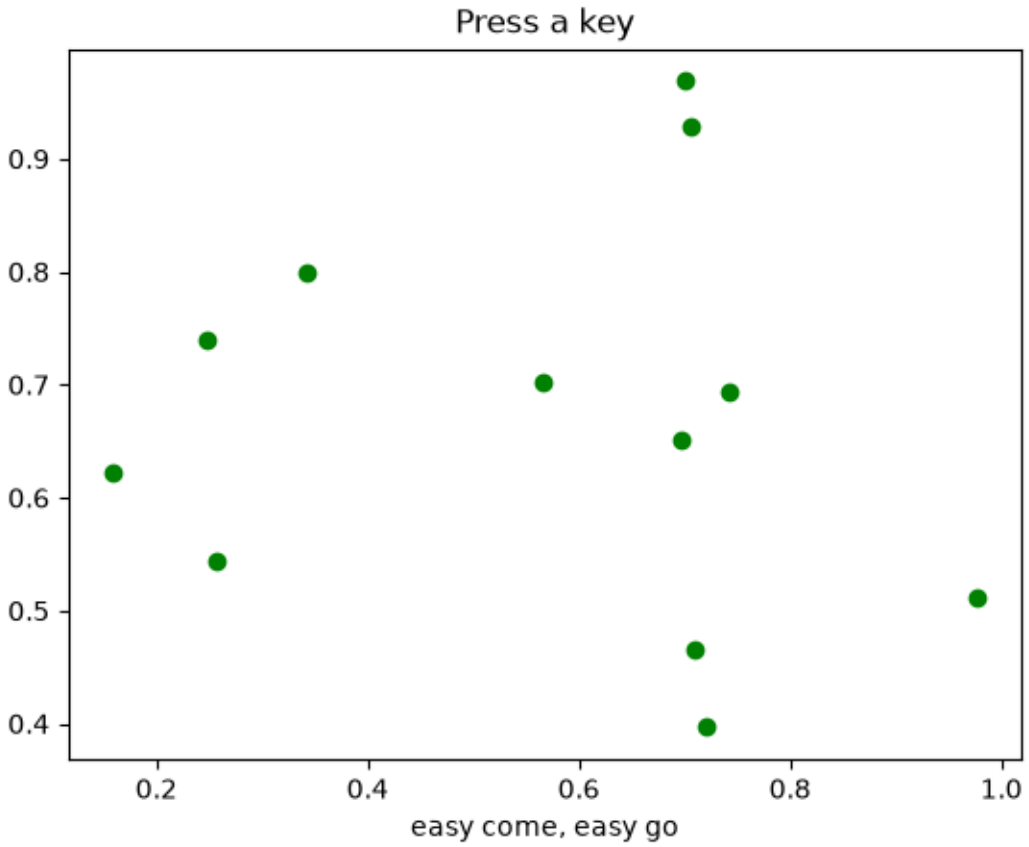
Keypress event

Show how to connect to keypress events.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import sys

import matplotlib.pyplot as plt
import numpy as np


def on_press(event):
    print('press', event.key)
    sys.stdout.flush()
    if event.key == 'x':
        visible = xl.get_visible()
        xl.set_visible(not visible)
        fig.canvas.draw()


# Fixing random state for reproducibility
np.random.seed(19680801)

fig, ax = plt.subplots()
```

(continues on next page)

(continued from previous page)

```
fig.canvas.mpl_connect('key_press_event', on_press)

ax.plot(np.random.rand(12), np.random.rand(12), 'go')
xl = ax.set_xlabel('easy come, easy go')
ax.set_title('Press a key')
plt.show()
```

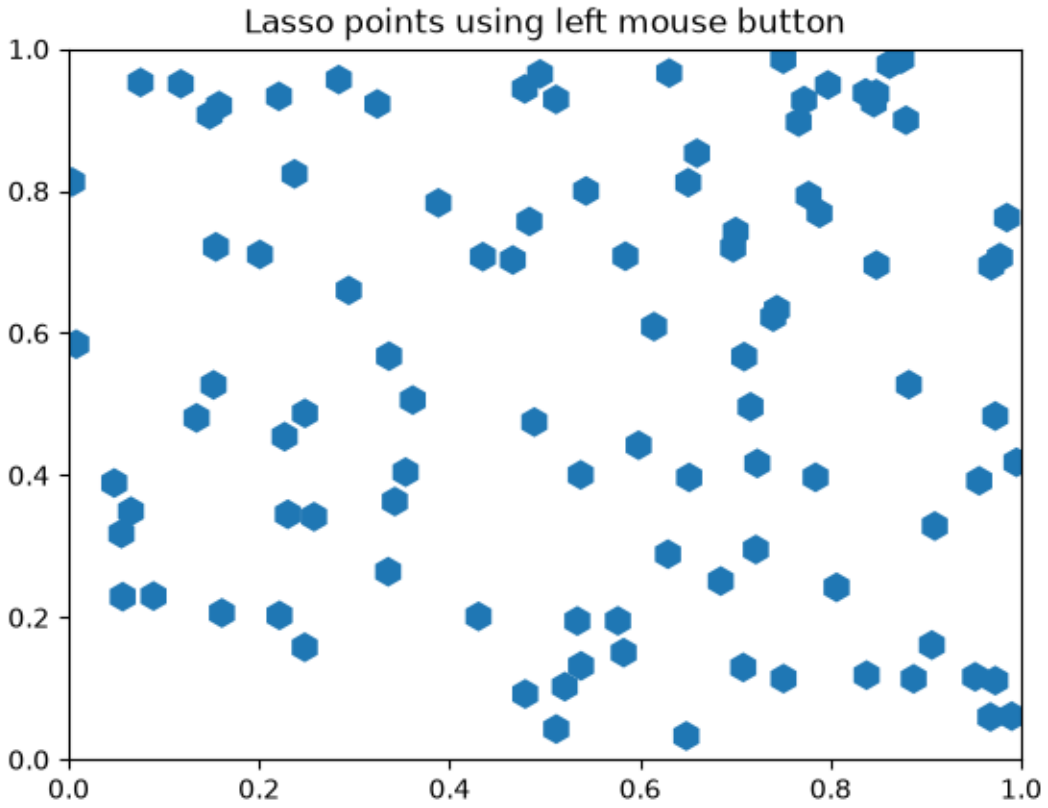
Lasso Demo

Use a lasso to select a set of points and get the indices of the selected points. A callback is used to change the color of the selected points.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.



```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib import colors as mcolors
from matplotlib import path
from matplotlib.collections import RegularPolyCollection
from matplotlib.widgets import Lasso


class LassoManager:
    def __init__(self, ax, data):
        # The information of whether a point has been selected or not␣
↪is stored in the
        # collection's array (0 = out, 1 = in), which then gets␣
↪colormapped to blue
        # (out) and red (in).
        self.collection = RegularPolyCollection(
            6, sizes=(100,), offset_transform=ax.transData,
            offsets=data, array=np.zeros(len(data)),
            clim=(0, 1), cmap=mcolors.ListedColormap(["tab:blue",
↪"tab:red"]))
        ax.add_collection(self.collection)
        canvas = ax.figure.canvas
        canvas.mpl_connect('button_press_event', self.on_press)
        canvas.mpl_connect('button_release_event', self.on_release)

    def callback(self, verts):
        data = self.collection.get_offsets()
        self.collection.set_array(path.Path(verts).
↪contains_points(data))
        canvas = self.collection.figure.canvas
        canvas.draw_idle()
        del self.lasso

    def on_press(self, event):
        canvas = self.collection.figure.canvas
        if event.inaxes is not self.collection.axes or canvas.
↪widgetlock.locked():
            return
        self.lasso = Lasso(event.inaxes, (event.xdata, event.ydata),␣
↪self.callback)
        canvas.widgetlock(self.lasso)  # acquire a lock on the widget␣
↪drawing

    def on_release(self, event):
        canvas = self.collection.figure.canvas
```

(continues on next page)

(continued from previous page)

```
        if hasattr(self, 'lasso') and canvas.widgetlock.isowner(self.
 ↪lasso):
            canvas.widgetlock.release(self.lasso)


if __name__ == '__main__':
    np.random.seed(19680801)
    ax = plt.figure().add_subplot(
        xlim=(0, 1), ylim=(0, 1), title='Lasso points using left mouse␣
 ↪button')
    manager = LassoManager(ax, np.random.rand(100, 2))
    plt.show()
```

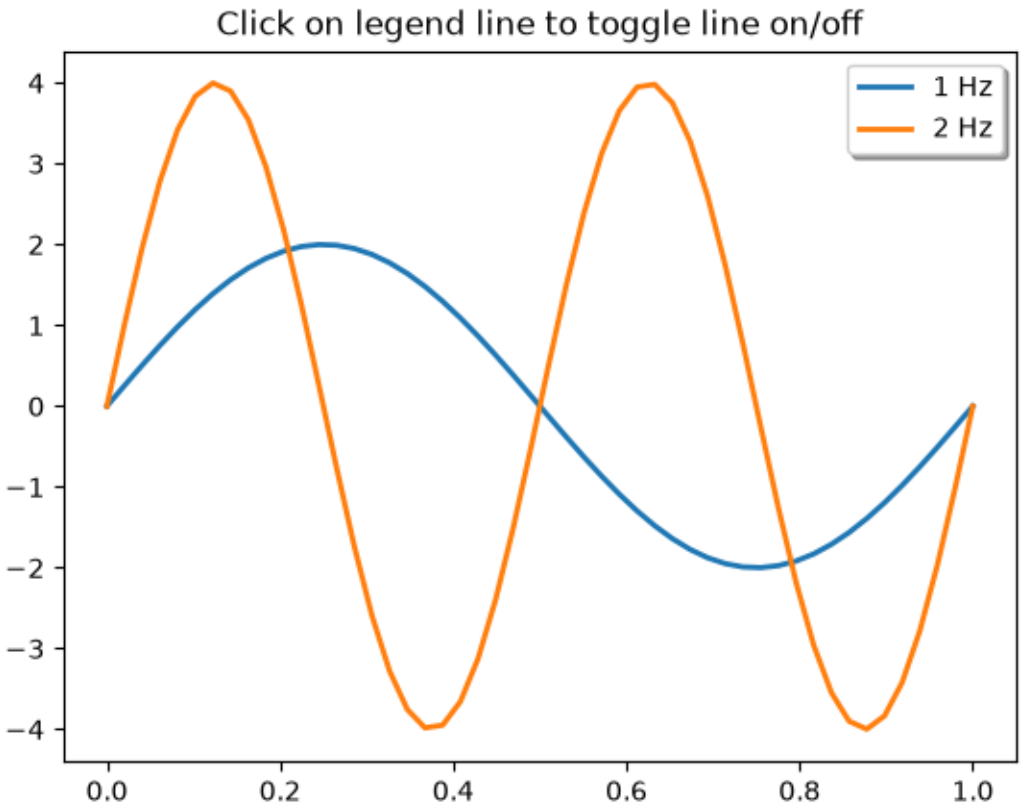
Legend picking

Enable picking on the legend to toggle the original line on and off

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import matplotlib.pyplot as plt
import numpy as np

t = np.linspace(0, 1)
y1 = 2 * np.sin(2 * np.pi * t)
y2 = 4 * np.sin(2 * np.pi * 2 * t)

fig, ax = plt.subplots()
ax.set_title('Click on legend line to toggle line on/off')
(line1, ) = ax.plot(t, y1, lw=2, label='1 Hz')
(line2, ) = ax.plot(t, y2, lw=2, label='2 Hz')
leg = ax.legend(fancybox=True, shadow=True)

lines = [line1, line2]
map_legend_to_ax = {}  # Will map legend lines to original lines.

pickradius = 5  # Points (Pt). How close the click needs to be to␣
 ↪trigger an event.

for legend_line, ax_line in zip(leg.get_lines(), lines):
```

(continues on next page)

(continued from previous page)

```
    legend_line.set_picker(pickradius)  # Enable picking on the legend␣
 ↪line.
    map_legend_to_ax[legend_line] = ax_line


def on_pick(event):
    # On the pick event, find the original line corresponding to the␣
 ↪legend
    # proxy line, and toggle its visibility.
    legend_line = event.artist

    # Do nothing if the source of the event is not a legend line.
    if legend_line not in map_legend_to_ax:
        return

    ax_line = map_legend_to_ax[legend_line]
    visible = not ax_line.get_visible()
    ax_line.set_visible(visible)
    # Change the alpha on the line in the legend, so we can see what␣
 ↪lines
    # have been toggled.
    legend_line.set_alpha(1.0 if visible else 0.2)
    fig.canvas.draw()


fig.canvas.mpl_connect('pick_event', on_pick)

# Works even if the legend is draggable. This is independent from␣
 ↪picking legend lines.
leg.set_draggable(True)

plt.show()
```

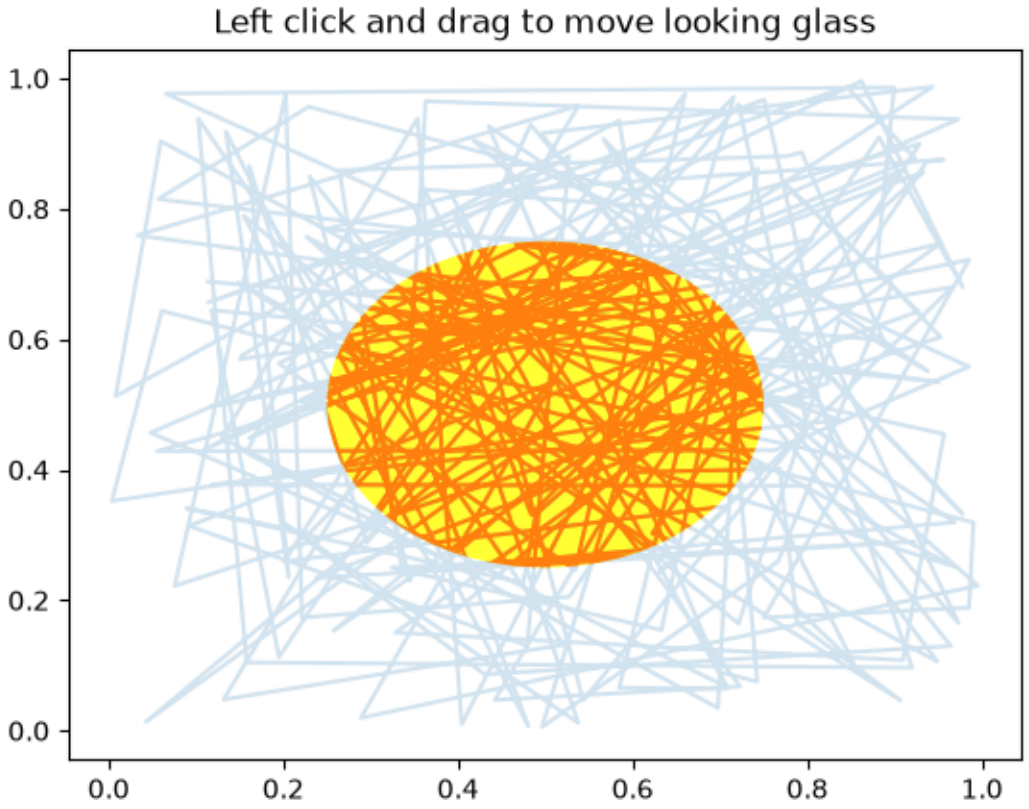
Looking glass

Example using mouse events to simulate a looking glass for inspecting data.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.patches as patches

# Fixing random state for reproducibility
np.random.seed(19680801)

x, y = np.random.rand(2, 200)

fig, ax = plt.subplots()
circ = patches.Circle((0.5, 0.5), 0.25, alpha=0.8, fc='yellow')
```

(continues on next page)

(continued from previous page)

```
ax.add_patch(circ)


ax.plot(x, y, alpha=0.2)
line, = ax.plot(x, y, alpha=1.0, clip_path=circ)
ax.set_title("Left click and drag to move looking glass")


class EventHandler:
    def __init__(self):
        fig.canvas.mpl_connect('button_press_event', self.on_press)
        fig.canvas.mpl_connect('button_release_event', self.on_release)
        fig.canvas.mpl_connect('motion_notify_event', self.on_move)
        self.x0, self.y0 = circ.center
        self.pressevent = None

    def on_press(self, event):
        if event.inaxes != ax:
            return

        if not circ.contains(event)[0]:
            return

        self.pressevent = event

    def on_release(self, event):
        self.pressevent = None
        self.x0, self.y0 = circ.center

    def on_move(self, event):
        if self.pressevent is None or event.inaxes != self.pressevent.
 ↪inaxes:
            return

        dx = event.xdata - self.pressevent.xdata
        dy = event.ydata - self.pressevent.ydata
        circ.center = self.x0 + dx, self.y0 + dy
        line.set_clip_path(circ)
        fig.canvas.draw()

handler = EventHandler()
plt.show()
```

Path editor

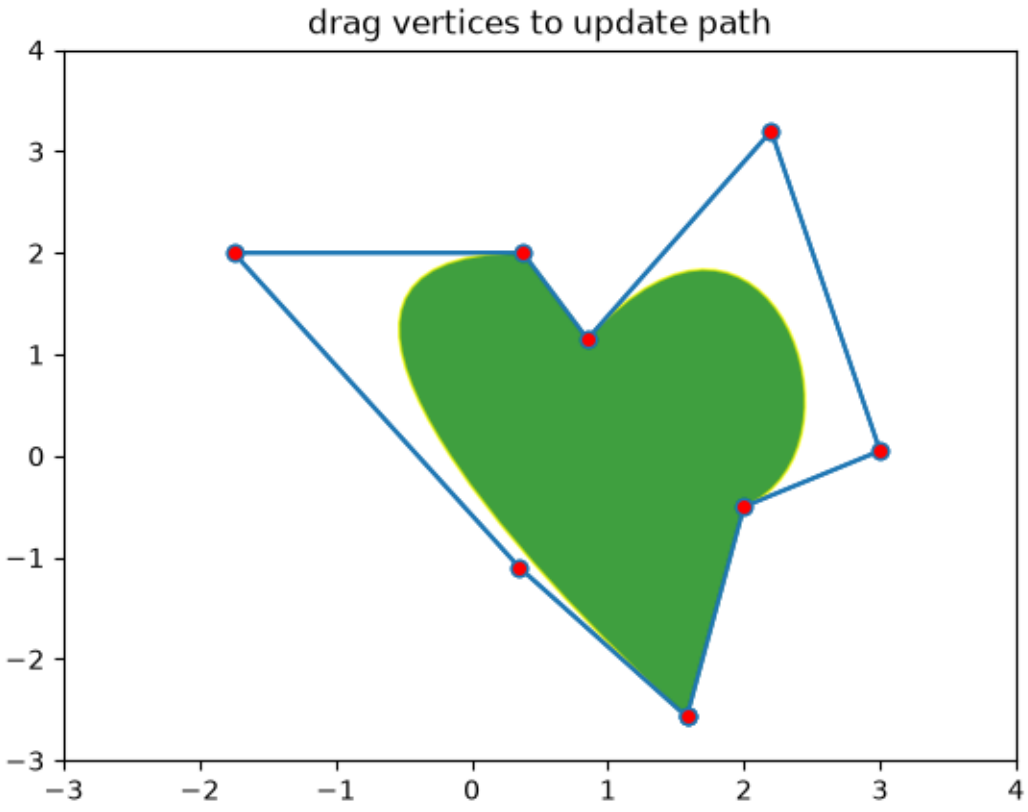
Sharing events across GUIs.

This example demonstrates a cross-GUI application using Matplotlib event handling to interact with and modify objects on the canvas.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.backend_bases import MouseButton
from matplotlib.patches import PathPatch
from matplotlib.path import Path
```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots()

pathdata = [
    (Path.MOVETO, (1.58, -2.57)),
    (Path.CURVE4, (0.35, -1.1)),
    (Path.CURVE4, (-1.75, 2.0)),
    (Path.CURVE4, (0.375, 2.0)),
    (Path.LINETO, (0.85, 1.15)),
    (Path.CURVE4, (2.2, 3.2)),
    (Path.CURVE4, (3, 0.05)),
    (Path.CURVE4, (2.0, -0.5)),
    (Path.CLOSEPOLY, (1.58, -2.57)),
]

codes, verts = zip(*pathdata)
path = Path(verts, codes)
patch = PathPatch(
    path, facecolor='green', edgecolor='yellow', alpha=0.5)
ax.add_patch(patch)


class PathInteractor:
    """
    A path editor.

    Press 't' to toggle vertex markers on and off.  When vertex␣
 ↪markers are on,
    they can be dragged with the mouse.
    """

    showverts = True
    epsilon = 5  # max pixel distance to count as a vertex hit

    def __init__(self, pathpatch):

        self.ax = pathpatch.axes
        canvas = self.ax.figure.canvas
        self.pathpatch = pathpatch
        self.pathpatch.set_animated(True)

        x, y = zip(*self.pathpatch.get_path().vertices)

        self.line, = ax.plot(
            x, y, marker='o', markerfacecolor='r', animated=True)
```

(continues on next page)

(continued from previous page)

```
        self._ind = None  # the active vertex

        canvas.mpl_connect('draw_event', self.on_draw)
        canvas.mpl_connect('button_press_event', self.on_button_press)
        canvas.mpl_connect('key_press_event', self.on_key_press)
        canvas.mpl_connect('button_release_event', self.
↪on_button_release)
        canvas.mpl_connect('motion_notify_event', self.on_mouse_move)
        self.canvas = canvas

    def get_ind_under_point(self, event):
        """
        Return the index of the point closest to the event position or␣
↪*None*
        if no point is within ``self.epsilon`` to the event position.
        """
        xy = self.pathpatch.get_path().vertices
        xyt = self.pathpatch.get_transform().transform(xy)  # to␣
↪display coords
        xt, yt = xyt[:, 0], xyt[:, 1]
        d = np.sqrt((xt - event.x)**2 + (yt - event.y)**2)
        ind = d.argmin()
        return ind if d[ind] < self.epsilon else None

    def on_draw(self, event):
        """Callback for draws."""
        self.background = self.canvas.copy_from_bbox(self.ax.bbox)
        self.ax.draw_artist(self.pathpatch)
        self.ax.draw_artist(self.line)

    def on_button_press(self, event):
        """Callback for mouse button presses."""
        if (event.inaxes is None
                or event.button != MouseButton.LEFT
                or not self.showverts):
            return
        self._ind = self.get_ind_under_point(event)

    def on_button_release(self, event):
        """Callback for mouse button releases."""
        if (event.button != MouseButton.LEFT
                or not self.showverts):
            return
        self._ind = None

    def on_key_press(self, event):
```

(continues on next page)

(continued from previous page)

```
        """Callback for key presses."""
        if not event.inaxes:
            return
        if event.key == 't':
            self.showverts = not self.showverts
            self.line.set_visible(self.showverts)
            if not self.showverts:
                self._ind = None
        self.canvas.draw()

    def on_mouse_move(self, event):
        """Callback for mouse movements."""
        if (self._ind is None
                or event.inaxes is None
                or event.button != MouseButton.LEFT
                or not self.showverts):
            return

        vertices = self.pathpatch.get_path().vertices

        vertices[self._ind] = event.xdata, event.ydata
        self.line.set_data(zip(*vertices))

        self.canvas.restore_region(self.background)
        self.ax.draw_artist(self.pathpatch)
        self.ax.draw_artist(self.line)
        self.canvas.blit(self.ax.bbox)


interactor = PathInteractor(patch)
ax.set_title('drag vertices to update path')
ax.set_xlim(-3, 4)
ax.set_ylim(-3, 4)

plt.show()
```

Pick event demo

You can enable picking by setting the "picker" property of an artist (for example, a Matplotlib Line2D, Text, Patch, Polygon, AxesImage, etc.)

There are a variety of meanings of the picker property:

- *None* - picking is disabled for this artist (default)
- bool - if *True* then picking will be enabled and the artist will fire a pick event if the mouse event is over the artist.

Setting `pickradius` will add an epsilon tolerance in points and the artist will fire off an event if its data is within epsilon of the mouse event. For some artists like lines and patch collections, the artist may provide additional data to the pick event that is generated, for example, the indices of the data within epsilon of the pick event

- function - if picker is callable, it is a user supplied function which determines whether the artist is hit by the mouse event.

```
hit, props = picker(artist, mouseevent)
```

to determine the hit test. If the mouse event is over the artist, return hit=True and props is a dictionary of properties you want added to the PickEvent attributes.

After you have enabled an artist for picking by setting the "picker" property, you need to connect to the figure canvas pick_event to get pick callbacks on mouse press events. For example,

```
def pick_handler(event):
    mouseevent = event.mouseevent
    artist = event.artist
    # now do something with this...
```

The pick event (matplotlib.backend_bases.PickEvent) which is passed to your callback is always fired with two attributes:

mouseevent

the mouse event that generate the pick event.

The mouse event in turn has attributes like x and y (the coordinates in display space, such as pixels from left, bottom) and xdata, ydata (the coords in data space). Additionally, you can get information about which buttons were pressed, which keys were pressed, which Axes the mouse is over, etc. See matplotlib.backend_bases.MouseEvent for details.

artist

the matplotlib.artist that generated the pick event.

Additionally, certain artists like Line2D and PatchCollection may attach additional metadata like the indices into the data that meet the picker criteria (for example, all the points in the line that are within the specified epsilon tolerance)

The examples below illustrate each of these methods.

Note

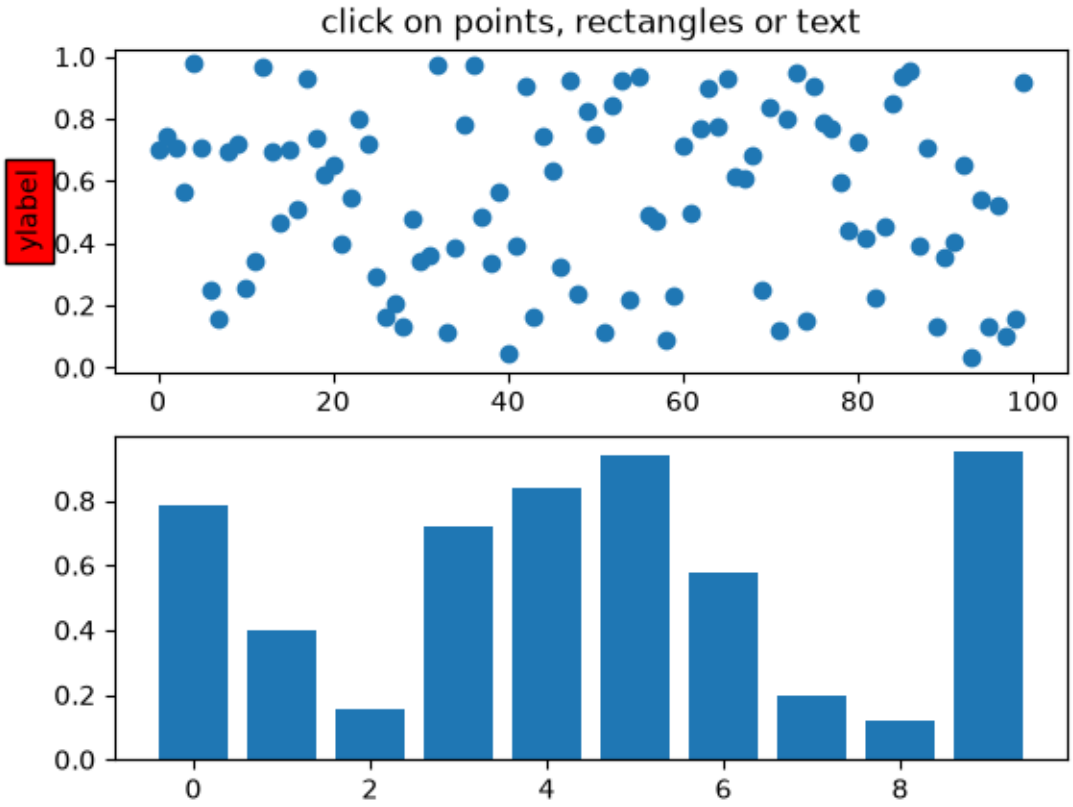
These examples exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.

```
import matplotlib.pyplot as plt
import numpy as np
from numpy.random import rand

from matplotlib.image import AxesImage
from matplotlib.lines import Line2D
from matplotlib.patches import Rectangle
from matplotlib.text import Text

# Fixing random state for reproducibility
np.random.seed(19680801)
```

Simple picking, lines, rectangles and text

```
fig, (ax1, ax2) = plt.subplots(2, 1)
ax1.set_title('click on points, rectangles or text', picker=True)
ax1.set_ylabel('ylabel', picker=True, bbox=dict(facecolor='red'))
line, = ax1.plot(rand(100), 'o', picker=True, pickradius=5)

# Pick the rectangle.
ax2.bar(range(10), rand(10), picker=True)
for label in ax2.get_xticklabels():  # Make the xtick labels pickable.
    label.set_picker(True)


def onpick1(event):
    if isinstance(event.artist, Line2D):
        thisline = event.artist
        xdata = thisline.get_xdata()
        ydata = thisline.get_ydata()
        ind = event.ind
        print('onpick1 line:', np.column_stack([xdata[ind],␣
 ↪ydata[ind]]))
    elif isinstance(event.artist, Rectangle):
        patch = event.artist
        print('onpick1 patch:', patch.get_path())
    elif isinstance(event.artist, Text):
        text = event.artist
        print('onpick1 text:', text.get_text())


fig.canvas.mpl_connect('pick_event', onpick1)
```



Picking with a custom hit test function

You can define custom pickers by setting picker to a callable function. The function has the signature:

```
hit, props = func(artist, mouseevent)
```

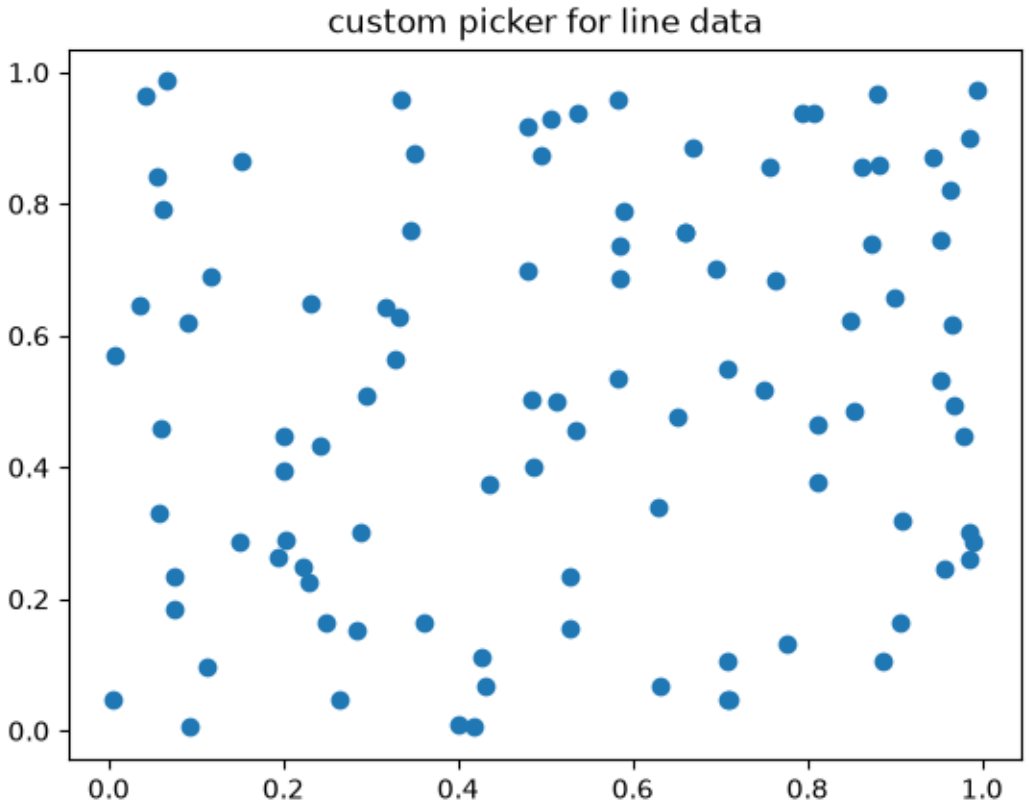
to determine the hit test. If the mouse event is over the artist, return `hit=True` and `props` is a dictionary of properties you want added to the *`PickEvent`* attributes.

```
def line_picker(line, mouseevent):
    """
    Find the points within a certain distance from the mouseclick in
    data coords and attach some extra attributes, pickx and picky
    which are the data points that were picked.
    """
    if mouseevent.xdata is None:
        return False, dict()
    xdata = line.get_xdata()
    ydata = line.get_ydata()
    maxd = 0.05
    d = np.sqrt(
```

(continues on next page)

(continued from previous page)

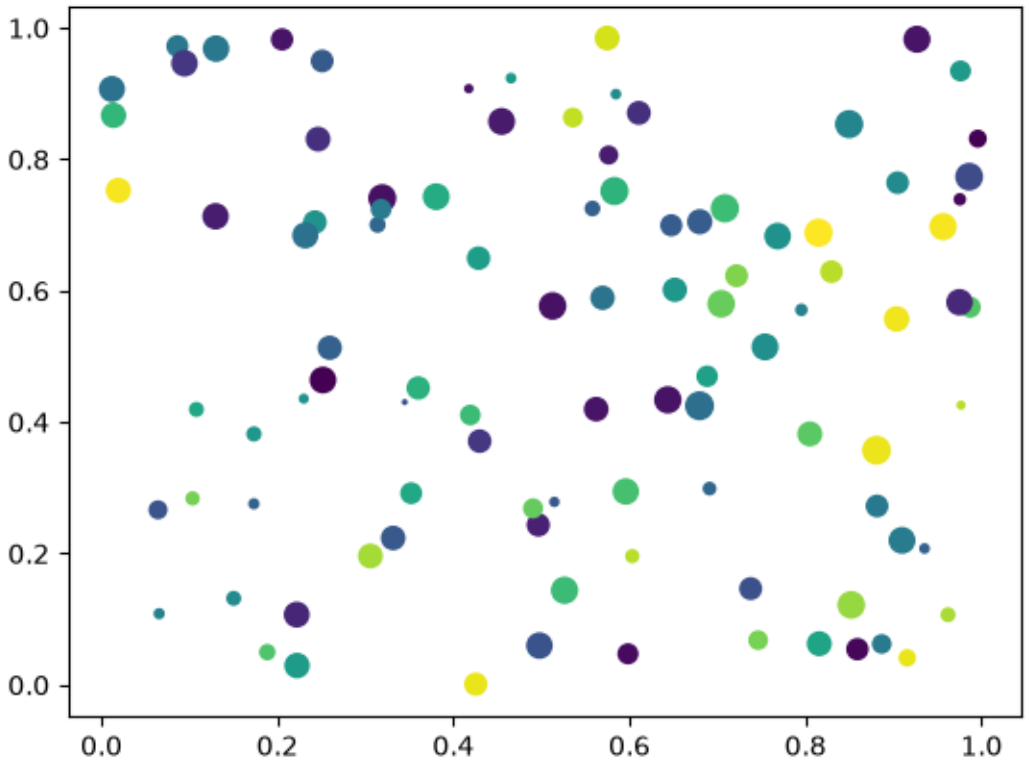
```
        (xdata - mouseevent.xdata)**2 + (ydata - mouseevent.ydata)**2)

    ind, = np.nonzero(d <= maxd)
    if len(ind):
        pickx = xdata[ind]
        picky = ydata[ind]
        props = dict(ind=ind, pickx=pickx, picky=picky)
        return True, props
    else:
        return False, dict()


def onpick2(event):
    print('onpick2 line:', event.pickx, event.picky)


fig, ax = plt.subplots()
ax.set_title('custom picker for line data')
line, = ax.plot(rand(100), rand(100), 'o', picker=line_picker)
fig.canvas.mpl_connect('pick_event', onpick2)
```



Picking on a scatter plot

A scatter plot is backed by a *PathCollection*.

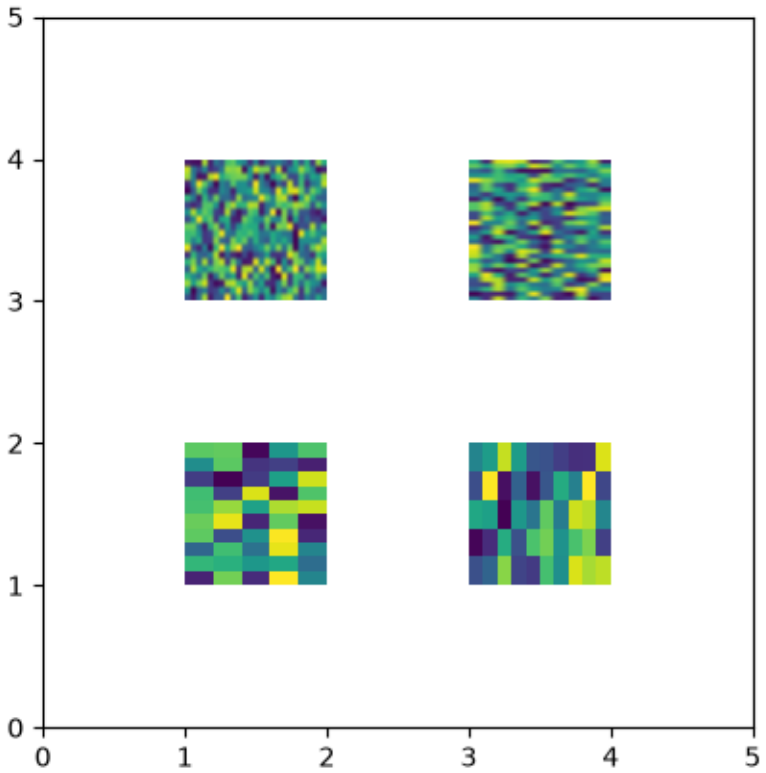
```
x, y, c, s = rand(4, 100)


def onpick3(event):
    ind = event.ind
    print('onpick3 scatter:', ind, x[ind], y[ind])


fig, ax = plt.subplots()
ax.scatter(x, y, 100*s, c, picker=True)
fig.canvas.mpl_connect('pick_event', onpick3)
```



Picking images

Images plotted using *Axes.imshow* are *AxesImage* objects.

```
fig, ax = plt.subplots()
ax.imshow(rand(10, 5), extent=(1, 2, 1, 2), picker=True)
ax.imshow(rand(5, 10), extent=(3, 4, 1, 2), picker=True)
ax.imshow(rand(20, 25), extent=(1, 2, 3, 4), picker=True)
ax.imshow(rand(30, 12), extent=(3, 4, 3, 4), picker=True)
ax.set(xlim=(0, 5), ylim=(0, 5))


def onpick4(event):
    artist = event.artist
    if isinstance(artist, AxesImage):
        im = artist
        A = im.get_array()
        print('onpick4 image', A.shape)


fig.canvas.mpl_connect('pick_event', onpick4)

plt.show()
```



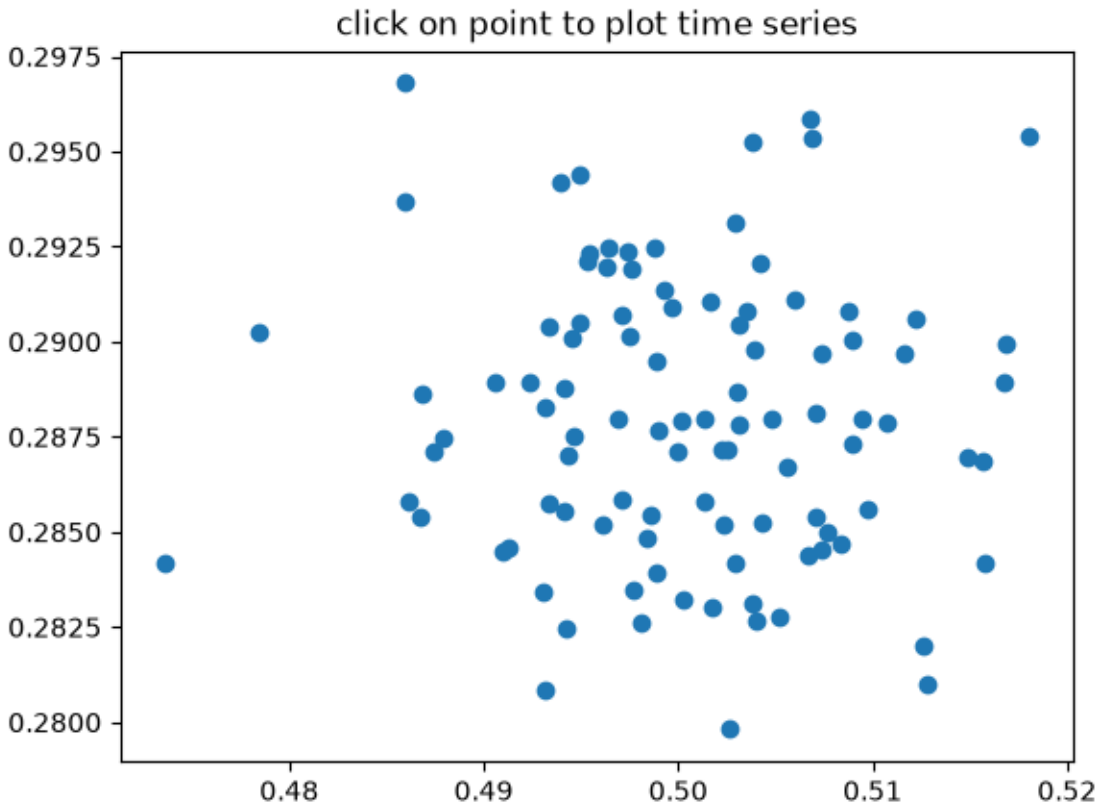
Pick event demo 2

Compute the mean (mu) and standard deviation (sigma) of 100 data sets and plot mu vs. sigma. When you click on one of the (mu, sigma) points, plot the raw data from the dataset that generated this point.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)

X = np.random.rand(100, 1000)
xs = np.mean(X, axis=1)
```

(continues on next page)

(continued from previous page)

```
ys = np.std(X, axis=1)

fig, ax = plt.subplots()
ax.set_title('click on point to plot time series')
line, = ax.plot(xs, ys, 'o', picker=True, pickradius=5)


def onpick(event):

    if event.artist != line:
        return

    N = len(event.ind)
    if not N:
        return

    figi, axs = plt.subplots(N, squeeze=False)
    for ax, dataind in zip(axs.flat, event.ind):
        ax.plot(X[dataind])
        ax.text(.05, .9, f'mu={xs[dataind]:1.3f}\nsigma=
↪{ys[dataind]:1.3f}',
                transform=ax.transAxes, va='top')
        ax.set_ylim(-0.5, 1.5)
    figi.show()


fig.canvas.mpl_connect('pick_event', onpick)

plt.show()
```

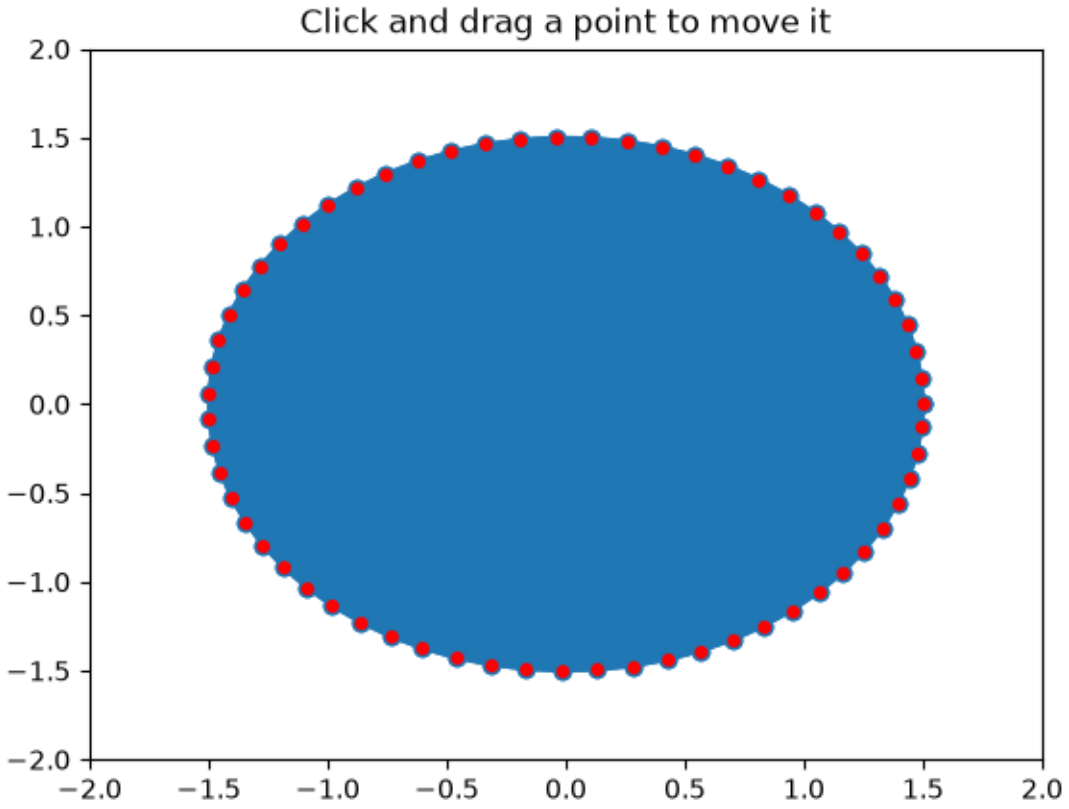
Polygon editor

This is an example to show how to build cross-GUI applications using Matplotlib event handling to interact with objects on the canvas.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import numpy as np

from matplotlib.artist import Artist
from matplotlib.lines import Line2D


def dist_point_to_segment(p, s0, s1):
    """
    Get the distance from the point *p* to the segment (*s0*, *s1*),␣
 ↪where
    *p*, *s0*, *s1* are ``[x, y]`` arrays.
    """
```

(continues on next page)

(continued from previous page)

```
    s01 = s1 - s0
    s0p = p - s0
    if (s01 == 0).all():
        return np.hypot(*s0p)
    # Project onto segment, without going past segment ends.
    p1 = s0 + np.clip((s0p @ s01) / (s01 @ s01), 0, 1) * s01
    return np.hypot(*(p - p1))


class PolygonInteractor:
    """
    A polygon editor.

    Key-bindings

      't' toggle vertex markers on and off.  When vertex markers are␣
 ↪on,
          you can move them, delete them

      'd' delete the vertex under point

      'i' insert a vertex at point.  You must be within epsilon of the
          line connecting two existing vertices

    """

    showverts = True
    epsilon = 5  # max pixel distance to count as a vertex hit

    def __init__(self, ax, poly):
        if poly.figure is None:
            raise RuntimeError('You must first add the polygon to a␣
 ↪figure '
                               'or canvas before defining the␣
 ↪interactor')
        self.ax = ax
        canvas = poly.figure.canvas
        self.poly = poly

        x, y = zip(*self.poly.xy)
        self.line = Line2D(x, y,
                           marker='o', markerfacecolor='r',
                           animated=True)
        self.ax.add_line(self.line)

        self.cid = self.poly.add_callback(self.poly_changed)
```

(continues on next page)

(continued from previous page)

```
        self._ind = None  # the active vert

        canvas.mpl_connect('draw_event', self.on_draw)
        canvas.mpl_connect('button_press_event', self.on_button_press)
        canvas.mpl_connect('key_press_event', self.on_key_press)
        canvas.mpl_connect('button_release_event', self.
↪on_button_release)
        canvas.mpl_connect('motion_notify_event', self.on_mouse_move)
        self.canvas = canvas

    def on_draw(self, event):
        self.background = self.canvas.copy_from_bbox(self.ax.bbox)
        self.ax.draw_artist(self.poly)
        self.ax.draw_artist(self.line)
        # do not need to blit here, this will fire before the screen is
        # updated

    def poly_changed(self, poly):
        """This method is called whenever the pathpatch object is␣
↪called."""
        # only copy the artist props to the line (except visibility)
        vis = self.line.get_visible()
        Artist.update_from(self.line, poly)
        self.line.set_visible(vis)  # don't use the poly visibility␣
↪state

    def get_ind_under_point(self, event):
        """
        Return the index of the point closest to the event position or␣
↪*None*
        if no point is within ``self.epsilon`` to the event position.
        """
        # display coords
        xy = np.asarray(self.poly.xy)
        xyt = self.poly.get_transform().transform(xy)
        xt, yt = xyt[:, 0], xyt[:, 1]
        d = np.hypot(xt - event.x, yt - event.y)
        indseq, = np.nonzero(d == d.min())
        ind = indseq[0]

        if d[ind] >= self.epsilon:
            ind = None

        return ind

    def on_button_press(self, event):
```

(continues on next page)

(continued from previous page)

```
        """Callback for mouse button presses."""
        if not self.showverts:
            return
        if event.inaxes is None:
            return
        if event.button != 1:
            return
        self._ind = self.get_ind_under_point(event)

    def on_button_release(self, event):
        """Callback for mouse button releases."""
        if not self.showverts:
            return
        if event.button != 1:
            return
        self._ind = None

    def on_key_press(self, event):
        """Callback for key presses."""
        if not event.inaxes:
            return
        if event.key == 't':
            self.showverts = not self.showverts
            self.line.set_visible(self.showverts)
            if not self.showverts:
                self._ind = None
        elif event.key == 'd':
            ind = self.get_ind_under_point(event)
            if ind is not None:
                self.poly.xy = np.delete(self.poly.xy,
                                         ind, axis=0)
                self.line.set_data(zip(*self.poly.xy))
        elif event.key == 'i':
            xys = self.poly.get_transform().transform(self.poly.xy)
            p = event.x, event.y  # display coords
            for i in range(len(xys) - 1):
                s0 = xys[i]
                s1 = xys[i + 1]
                d = dist_point_to_segment(p, s0, s1)
                if d <= self.epsilon:
                    self.poly.xy = np.insert(
                        self.poly.xy, i+1,
                        [event.xdata, event.ydata],
                        axis=0)
                    self.line.set_data(zip(*self.poly.xy))
                    break
```

(continues on next page)

(continued from previous page)

```
        if self.line.stale:
            self.canvas.draw_idle()

    def on_mouse_move(self, event):
        """Callback for mouse movements."""
        if not self.showverts:
            return
        if self._ind is None:
            return
        if event.inaxes is None:
            return
        if event.button != 1:
            return
        x, y = event.xdata, event.ydata

        self.poly.xy[self._ind] = x, y
        if self._ind == 0:
            self.poly.xy[-1] = x, y
        elif self._ind == len(self.poly.xy) - 1:
            self.poly.xy[0] = x, y
        self.line.set_data(zip(*self.poly.xy))

        self.canvas.restore_region(self.background)
        self.ax.draw_artist(self.poly)
        self.ax.draw_artist(self.line)
        self.canvas.blit(self.ax.bbox)


if __name__ == '__main__':
    import matplotlib.pyplot as plt

    from matplotlib.patches import Polygon

    theta = np.arange(0, 2*np.pi, 0.1)
    r = 1.5

    xs = r * np.cos(theta)
    ys = r * np.sin(theta)

    poly = Polygon(np.column_stack([xs, ys]), animated=True)

    fig, ax = plt.subplots()
    ax.add_patch(poly)
    p = PolygonInteractor(ax, poly)

    ax.set_title('Click and drag a point to move it')
```

(continues on next page)

(continued from previous page)

```
    ax.set_xlim(-2, 2)
    ax.set_ylim(-2, 2)
    plt.show()
```

Pong

A Matplotlib based game of Pong illustrating one way to write interactive animations that are easily ported to multiple backends.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.

```
import time

import matplotlib.pyplot as plt
import numpy as np
from numpy.random import randint, randn

from matplotlib.font_manager import FontProperties

instructions = """
Player A:       Player B:
  'e'      up     'i'
  'd'     down    'k'

press 't' -- close these instructions
             (animation will be much faster)
press 'a' -- add a puck
press 'A' -- remove a puck
press '1' -- slow down all pucks
press '2' -- speed up all pucks
press '3' -- slow down distractors
press '4' -- speed up distractors
press ' ' -- reset the first puck
press 'n' -- toggle distractors on/off
press 'g' -- toggle the game on/off

  """
```

(continues on next page)

(continued from previous page)

```
class Pad:
    def __init__(self, disp, x, y, type='l'):
        self.disp = disp
        self.x = x
        self.y = y
        self.w = .3
        self.score = 0
        self.xoffset = 0.3
        self.yoffset = 0.1
        if type == 'r':
            self.xoffset *= -1.0

        if type == 'l' or type == 'r':
            self.signx = -1.0
            self.signy = 1.0
        else:
            self.signx = 1.0
            self.signy = -1.0

    def contains(self, loc):
        return self.disp.get_bbox().contains(loc.x, loc.y)


class Puck:
    def __init__(self, disp, pad, field):
        self.vmax = .2
        self.disp = disp
        self.field = field
        self._reset(pad)

    def _reset(self, pad):
        self.x = pad.x + pad.xoffset
        if pad.y < 0:
            self.y = pad.y + pad.yoffset
        else:
            self.y = pad.y - pad.yoffset
        self.vx = pad.x - self.x
        self.vy = pad.y + pad.w/2 - self.y
        self._speedlimit()
        self._slower()
        self._slower()

    def update(self, pads):
        self.x += self.vx
        self.y += self.vy
        for pad in pads:
```

(continues on next page)

(continued from previous page)

```
            if pad.contains(self):
                self.vx *= 1.2 * pad.signx
                self.vy *= 1.2 * pad.signy
        fudge = .001
        # probably cleaner with something like...
        if self.x < fudge:
            pads[1].score += 1
            self._reset(pads[0])
            return True
        if self.x > 7 - fudge:
            pads[0].score += 1
            self._reset(pads[1])
            return True
        if self.y < -1 + fudge or self.y > 1 - fudge:
            self.vy *= -1.0
            # add some randomness, just to make it interesting
            self.vy -= (randn()/300.0 + 1/300.0) * np.sign(self.vy)
        self._speedlimit()
        return False

    def _slower(self):
        self.vx /= 5.0
        self.vy /= 5.0

    def _faster(self):
        self.vx *= 5.0
        self.vy *= 5.0

    def _speedlimit(self):
        if self.vx > self.vmax:
            self.vx = self.vmax
        if self.vx < -self.vmax:
            self.vx = -self.vmax

        if self.vy > self.vmax:
            self.vy = self.vmax
        if self.vy < -self.vmax:
            self.vy = -self.vmax


class Game:
    def __init__(self, ax):
        # create the initial line
        self.ax = ax
        ax.xaxis.set_visible(False)
        ax.set_xlim(0, 7)
```

(continues on next page)

(continued from previous page)

```
        ax.yaxis.set_visible(False)
        ax.set_ylim(-1, 1)
        pad_a_x = 0
        pad_b_x = .50
        pad_a_y = pad_b_y = .30
        pad_b_x += 6.3

        # pads
        pA, = self.ax.barh(pad_a_y, .2,
                           height=.3, color='k', alpha=.5, edgecolor='b
↪',
                           lw=2, label="Player B",
                           animated=True)
        pB, = self.ax.barh(pad_b_y, .2,
                           height=.3, left=pad_b_x, color='k', alpha=.
↪5,
                           edgecolor='r', lw=2, label="Player A",
                           animated=True)

        # distractors
        self.x = np.arange(0, 2.22*np.pi, 0.01)
        self.line, = self.ax.plot(self.x, np.sin(self.x), "r",
                                  animated=True, lw=4)
        self.line2, = self.ax.plot(self.x, np.cos(self.x), "g",
                                   animated=True, lw=4)
        self.line3, = self.ax.plot(self.x, np.cos(self.x), "g",
                                   animated=True, lw=4)
        self.line4, = self.ax.plot(self.x, np.cos(self.x), "r",
                                   animated=True, lw=4)

        # center line
        self.centerline, = self.ax.plot([3.5, 3.5], [1, -1], 'k',
                                        alpha=.5, animated=True, lw=8)

        # puck (s)
        self.puckdisp = self.ax.scatter([1], [1], label='_nolegend_',
                                        s=200, c='g',
                                        alpha=.9, animated=True)

        self.canvas = self.ax.figure.canvas
        self.background = None
        self.cnt = 0
        self.distract = True
        self.res = 100.0
        self.on = False
        self.inst = True    # show instructions from the beginning
```

(continues on next page)

(continued from previous page)

```
        self.pads = [Pad(pA, pad_a_x, pad_a_y),
                     Pad(pB, pad_b_x, pad_b_y, 'r')]
        self.pucks = []
        self.i = self.ax.annotate(instructions, (.5, 0.5),
                                  name='monospace',
                                  verticalalignment='center',
                                  horizontalalignment='center',
                                  multialignment='left',
                                  xycoords='axes fraction',
                                  animated=False)
        self.canvas.mpl_connect('key_press_event', self.on_key_press)

    def draw(self):
        draw_artist = self.ax.draw_artist
        if self.background is None:
            self.background = self.canvas.copy_from_bbox(self.ax.bbox)

        # restore the clean slate background
        self.canvas.restore_region(self.background)

        # show the distractors
        if self.distract:
            self.line.set_ydata(np.sin(self.x + self.cnt/self.res))
            self.line2.set_ydata(np.cos(self.x - self.cnt/self.res))
            self.line3.set_ydata(np.tan(self.x + self.cnt/self.res))
            self.line4.set_ydata(np.tan(self.x - self.cnt/self.res))
            draw_artist(self.line)
            draw_artist(self.line2)
            draw_artist(self.line3)
            draw_artist(self.line4)

        # pucks and pads
        if self.on:
            self.ax.draw_artist(self.centerline)
            for pad in self.pads:
                pad.disp.set_y(pad.y)
                pad.disp.set_x(pad.x)
                self.ax.draw_artist(pad.disp)

            for puck in self.pucks:
                if puck.update(self.pads):
                    # we only get here if someone scored
                    self.pads[0].disp.set_label(f"   {self.pads[0].
↪score}")
                    self.pads[1].disp.set_label(f"   {self.pads[1].
↪score}")
```

(continues on next page)

(continued from previous page)

```
                    self.ax.legend(loc='center', framealpha=.2,
                                   facecolor='0.5',
                                   prop=FontProperties(size='xx-large',
                                                       weight='bold'))

                    self.background = None
                    self.ax.figure.canvas.draw_idle()
                    return
                puck.disp.set_offsets([[puck.x, puck.y]])
                self.ax.draw_artist(puck.disp)

        # just redraw the Axes rectangle
        self.canvas.blit(self.ax.bbox)
        self.canvas.flush_events()
        if self.cnt == 50000:
            # just so we don't get carried away
            print("...and you've been playing for too long!!!")
            plt.close()

        self.cnt += 1

    def on_key_press(self, event):
        if event.key == '3':
            self.res *= 5.0
        if event.key == '4':
            self.res /= 5.0

        if event.key == 'e':
            self.pads[0].y += .1
            if self.pads[0].y > 1 - .3:
                self.pads[0].y = 1 - .3
        if event.key == 'd':
            self.pads[0].y -= .1
            if self.pads[0].y < -1:
                self.pads[0].y = -1

        if event.key == 'i':
            self.pads[1].y += .1
            if self.pads[1].y > 1 - .3:
                self.pads[1].y = 1 - .3
        if event.key == 'k':
            self.pads[1].y -= .1
            if self.pads[1].y < -1:
                self.pads[1].y = -1

        if event.key == 'a':
```

(continues on next page)

(continued from previous page)

```
            self.pucks.append(Puck(self.puckdisp,
                                   self.pads[randint(2)],
                                   self.ax.bbox))
        if event.key == 'A' and len(self.pucks):
            self.pucks.pop()
        if event.key == ' ' and len(self.pucks):
            self.pucks[0]._reset(self.pads[randint(2)])
        if event.key == '1':
            for p in self.pucks:
                p._slower()
        if event.key == '2':
            for p in self.pucks:
                p._faster()

        if event.key == 'n':
            self.distract = not self.distract

        if event.key == 'g':
            self.on = not self.on
        if event.key == 't':
            self.inst = not self.inst
            self.i.set_visible(not self.i.get_visible())
            self.background = None
            self.canvas.draw_idle()
        if event.key == 'q':
            plt.close()


fig, ax = plt.subplots()
canvas = ax.figure.canvas
animation = Game(ax)

# disable the default key bindings
if fig.canvas.manager.key_press_handler_id is not None:
    canvas.mpl_disconnect(fig.canvas.manager.key_press_handler_id)


# reset the blitting background on redraw
def on_redraw(event):
    animation.background = None


# bootstrap after the first draw
def start_anim(event):
    canvas.mpl_disconnect(start_anim.cid)
```

(continues on next page)

(continued from previous page)

```
    start_anim.timer.add_callback(animation.draw)
    start_anim.timer.start()
    canvas.mpl_connect('draw_event', on_redraw)


start_anim.cid = canvas.mpl_connect('draw_event', start_anim)
start_anim.timer = animation.canvas.new_timer(interval=1)

tstart = time.time()

plt.show()
print('FPS: %f' % (animation.cnt/(time.time() - tstart)))

#
```

Tags: interactivity: event-handling purpose: fun

Resampling Data

Downsampling lowers the sample rate or sample size of a signal. In this tutorial, the signal is downsampled when the plot is adjusted through dragging and zooming.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.

```
import matplotlib.pyplot as plt
import numpy as np


# A class that will downsample the data and recompute when zoomed.
class DataDisplayDownsampler:
    def __init__(self, xdata, y1data, y2data):
        self.origY1Data = y1data
        self.origY2Data = y2data
        self.origXData = xdata
        self.max_points = 50
        self.delta = xdata[-1] - xdata[0]

    def plot(self, ax):
        x, y1, y2 = self._downsample(self.origXData.min(), self.
```

(continues on next page)

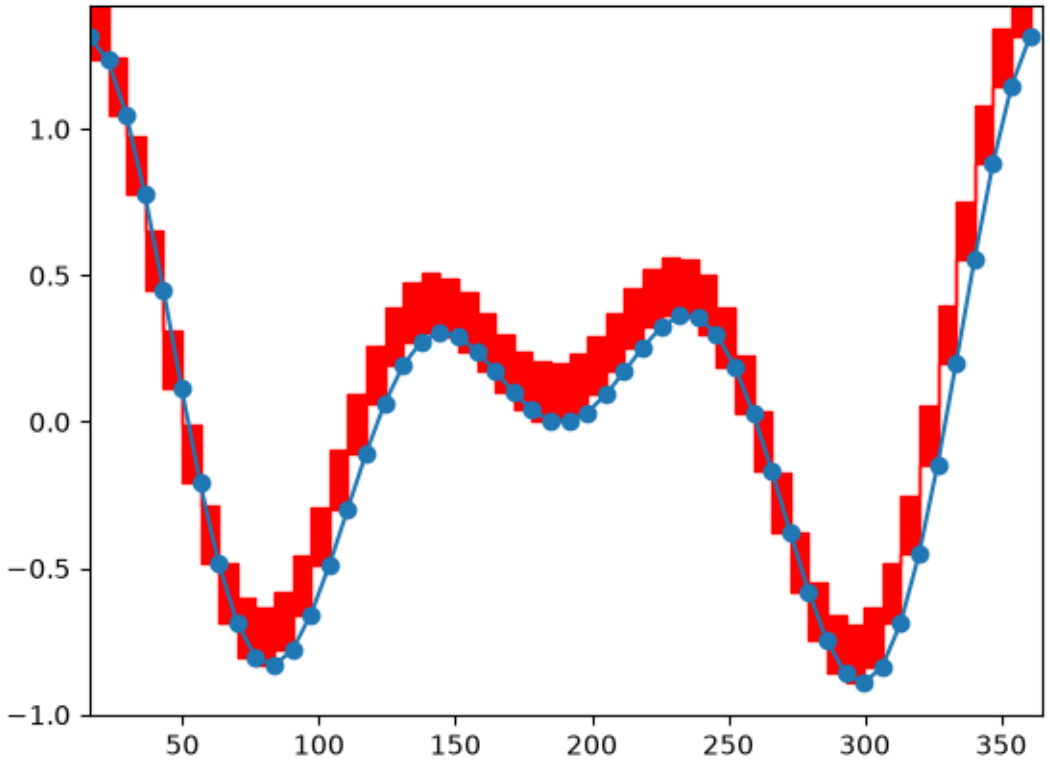
(continued from previous page)

```
↪origXData.max())
        (self.line,) = ax.plot(x, y1, 'o-')
        self.poly_collection = ax.fill_between(x, y1, y2, step="pre",␣
↪color="r")

    def _downsample(self, xstart, xend):
        # get the points in the view range
        mask = (self.origXData > xstart) & (self.origXData < xend)
        # dilate the mask by one to catch the points just outside
        # of the view range to not truncate the line
        mask = np.convolve([1, 1, 1], mask, mode='same').astype(bool)
        # sort out how many points to drop
        ratio = max(np.sum(mask) // self.max_points, 1)

        # mask data
        xdata = self.origXData[mask]
        y1data = self.origY1Data[mask]
        y2data = self.origY2Data[mask]

        # downsample data
        xdata = xdata[::ratio]
        y1data = y1data[::ratio]
        y2data = y2data[::ratio]

        print(f"using {len(y1data)} of {np.sum(mask)} visible points")

        return xdata, y1data, y2data

    def update(self, ax):
        # Update the artists
        lims = ax.viewLim
        if abs(lims.width - self.delta) > 1e-8:
            self.delta = lims.width
            xstart, xend = lims.intervalx
            x, y1, y2 = self._downsample(xstart, xend)
            self.line.set_data(x, y1)
            self.poly_collection.set_data(x, y1, y2, step="pre")
            ax.figure.canvas.draw_idle()


# Create a signal
xdata = np.linspace(16, 365, (365-16)*4)
y1data = np.sin(2*np.pi*xdata/153) + np.cos(2*np.pi*xdata/127)
y2data = y1data + .2

d = DataDisplayDownsampler(xdata, y1data, y2data)
```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots()

# Hook up the line
d.plot(ax)
ax.set_autoscale_on(False)  # Otherwise, infinite loop

# Connect for changing the view limits
ax.callbacks.connect('xlim_changed', d.update)
ax.set_xlim(16, 365)
plt.show()
```




```
using 52 of 1396 visible points
```

Tags: interactivity: zoom interactivity: event-handling

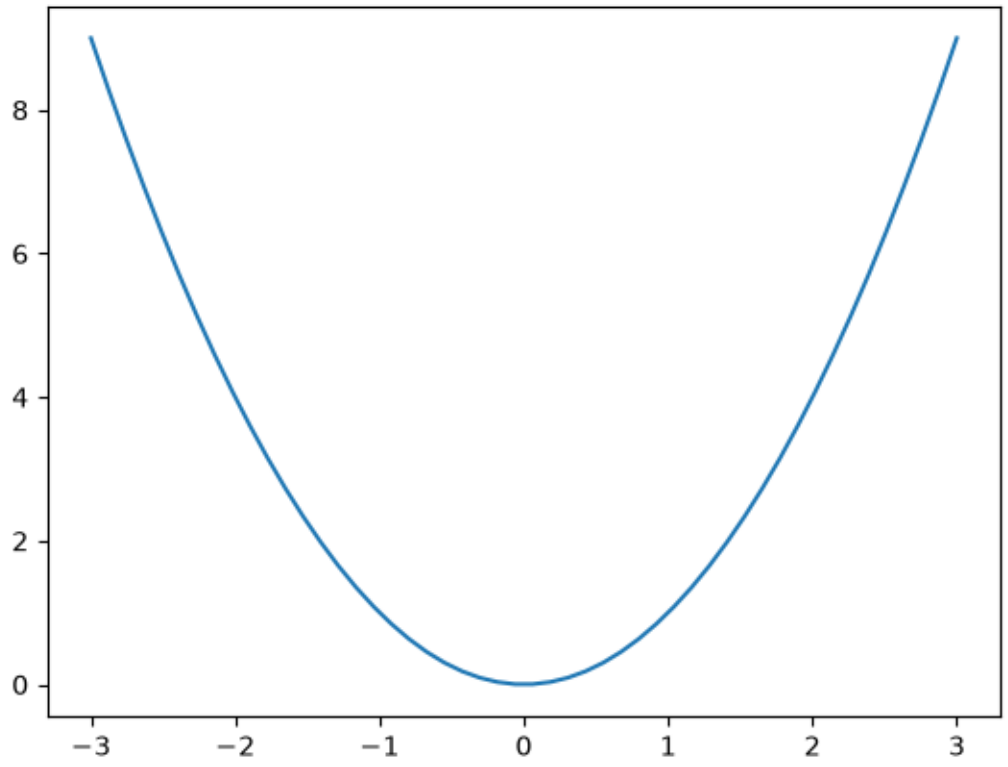
Timers

Simple example of using general timer objects. This is used to update the time placed in the title of the figure.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
from datetime import datetime

import matplotlib.pyplot as plt
import numpy as np


def update_title(axes):
    axes.set_title(datetime.now())
    axes.figure.canvas.draw()
```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots()

x = np.linspace(-3, 3)
ax.plot(x, x ** 2)

# Create a new timer object. Set the interval to 100 milliseconds
# (1000 is default) and tell the timer what function should be called.
timer = fig.canvas.new_timer(interval=100)
timer.add_callback(update_title, ax)
timer.start()

# Or could start the timer on first figure draw:
# def start_timer(event):
#     timer.start()
#     fig.canvas.mpl_disconnect(drawid)
# drawid = fig.canvas.mpl_connect('draw_event', start_timer)

plt.show()
```

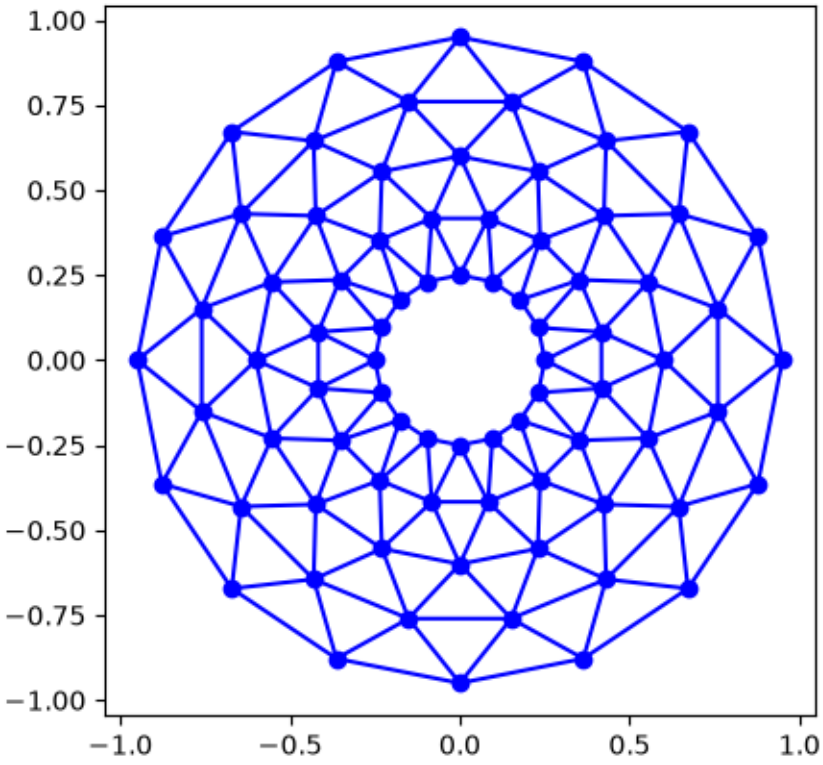
Trifinder Event Demo

Example showing the use of a TriFinder object. As the mouse is moved over the triangulation, the triangle under the cursor is highlighted and the index of the triangle is displayed in the plot title.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Polygon
from matplotlib.tri import Triangulation


def update_polygon(tri):
    if tri == -1:
        points = [0, 0, 0]
    else:
        points = triang.triangles[tri]
```

(continues on next page)

(continued from previous page)

```
    xs = triang.x[points]
    ys = triang.y[points]
    polygon.set_xy(np.column_stack([xs, ys]))


def on_mouse_move(event):
    if event.inaxes is None:
        tri = -1
    else:
        tri = trifinder(event.xdata, event.ydata)
    update_polygon(tri)
    ax.set_title(f'In triangle {tri}')
    event.canvas.draw()


# Create a Triangulation.
n_angles = 16
n_radii = 5
min_radius = 0.25
radii = np.linspace(min_radius, 0.95, n_radii)
angles = np.linspace(0, 2 * np.pi, n_angles, endpoint=False)
angles = np.repeat(angles[..., np.newaxis], n_radii, axis=1)
angles[:, 1::2] += np.pi / n_angles
x = (radii*np.cos(angles)).flatten()
y = (radii*np.sin(angles)).flatten()
triang = Triangulation(x, y)
triang.set_mask(np.hypot(x[triang.triangles].mean(axis=1),
                         y[triang.triangles].mean(axis=1))
                < min_radius)

# Use the triangulation's default TriFinder object.
trifinder = triang.get_trifinder()

# Setup plot and callbacks.
fig, ax = plt.subplots(subplot_kw={'aspect': 'equal'})
ax.triplot(triang, 'bo-')
polygon = Polygon([[0, 0], [0, 0]], facecolor='y')  # dummy data for␣
 ↪(xs, ys)
update_polygon(-1)
ax.add_patch(polygon)
fig.canvas.mpl_connect('motion_notify_event', on_mouse_move)
plt.show()
```

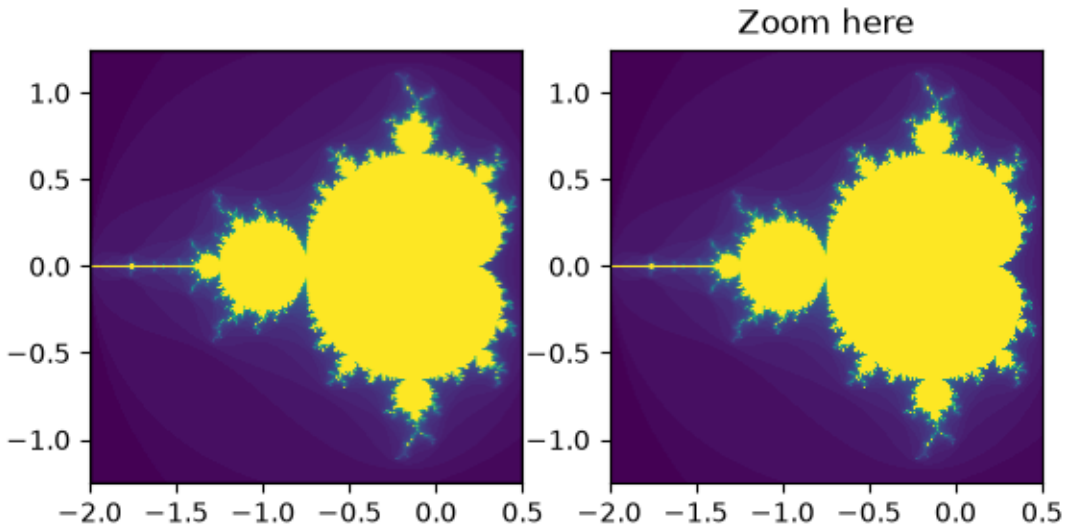
Viewlims

Creates two identical panels. Zooming in on the right panel will show a rectangle in the first panel, denoting the zoomed region.

Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.




```
import functools

import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Rectangle
```

(continues on next page)

(continued from previous page)

```
# A class that will regenerate a fractal set as we zoom in, so that you
# can actually see the increasing detail.  A box in the left panel␣
 ↪will show
# the area to which we are zoomed.
class MandelbrotDisplay:
    def __init__(self, h=500, w=500, niter=50, radius=2., power=2):
        self.height = h
        self.width = w
        self.niter = niter
        self.radius = radius
        self.power = power

    def compute_image(self, xlim, ylim):
        self.x = np.linspace(*xlim, self.width)
        self.y = np.linspace(*ylim, self.height).reshape(-1, 1)
        c = self.x + 1.0j * self.y
        threshold_time = np.zeros((self.height, self.width))
        z = np.zeros(threshold_time.shape, dtype=complex)
        mask = np.ones(threshold_time.shape, dtype=bool)
        for i in range(self.niter):
            z[mask] = z[mask]**self.power + c[mask]
            mask = (np.abs(z) < self.radius)
            threshold_time += mask
        return threshold_time

    def ax_update(self, ax):
        ax.set_autoscale_on(False)  # Otherwise, infinite loop
        # Get the number of points from the number of pixels in the␣
 ↪window
        self.width, self.height = ax.patch.get_window_extent().size.
 ↪round().astype(int)
        # Update the image object with our new data and extent
        ax.images[-1].set(data=self.compute_image(ax.get_xlim(), ax.
 ↪get_ylim()),
                          extent=(*ax.get_xlim(), *ax.get_ylim()))
        ax.figure.canvas.draw_idle()


md = MandelbrotDisplay()

fig1, (ax_full, ax_zoom) = plt.subplots(1, 2)
ax_zoom.imshow([[0]], origin="lower")  # Empty initial image.
ax_zoom.set_title("Zoom here")

rect = Rectangle(
    [0, 0], 0, 0, facecolor="none", edgecolor="black", linewidth=1.0)
```

(continues on next page)

(continued from previous page)

```
ax_full.add_patch(rect)


def update_rect(rect, ax):  # Let the rectangle track the bounds of␣
 ↪the zoom axes.
    xlo, xhi = ax.get_xlim()
    ylo, yhi = ax.get_ylim()
    rect.set_bounds((xlo, ylo, xhi - xlo, yhi - ylo))
    ax.figure.canvas.draw_idle()


# Connect for changing the view limits.
ax_zoom.callbacks.connect("xlim_changed", functools.
 ↪partial(update_rect, rect))
ax_zoom.callbacks.connect("ylim_changed", functools.
 ↪partial(update_rect, rect))

ax_zoom.callbacks.connect("xlim_changed", md.ax_update)
ax_zoom.callbacks.connect("ylim_changed", md.ax_update)

# Initialize: trigger image computation by setting view limits; set␣
 ↪colormap limits;
# copy image to full view.
ax_zoom.set(xlim=(-2, .5), ylim=(-1.25, 1.25))
im = ax_zoom.images[0]
ax_zoom.images[0].set(clim=(im.get_array().min(), im.get_array().
 ↪max()))
ax_full.imshow(im.get_array(), extent=im.get_extent(), origin="lower")

plt.show()
```

Zoom modifies other Axes

This example shows how to connect events in one window, for example, a mouse press, to another figure window.

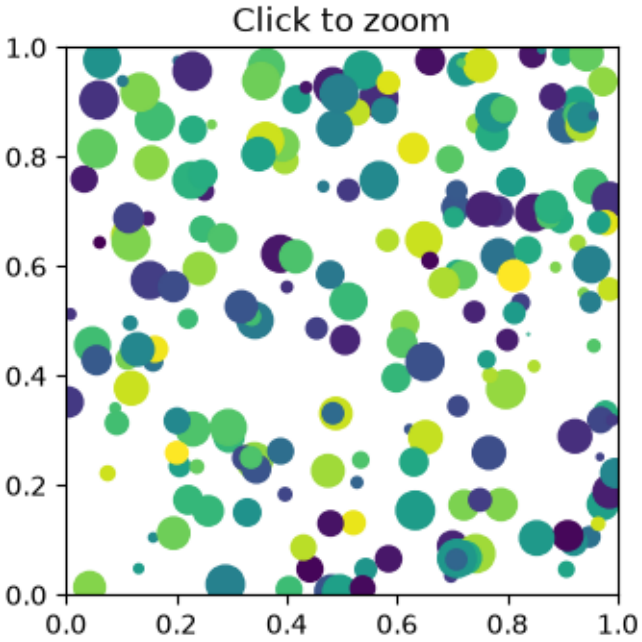
If you click on a point in the first window, the z and y limits of the second will be adjusted so that the center of the zoom in the second window will be the (x, y) coordinates of the clicked point.

Note the diameter of the circles in the scatter are defined in points**2, so their size is independent of the zoom.

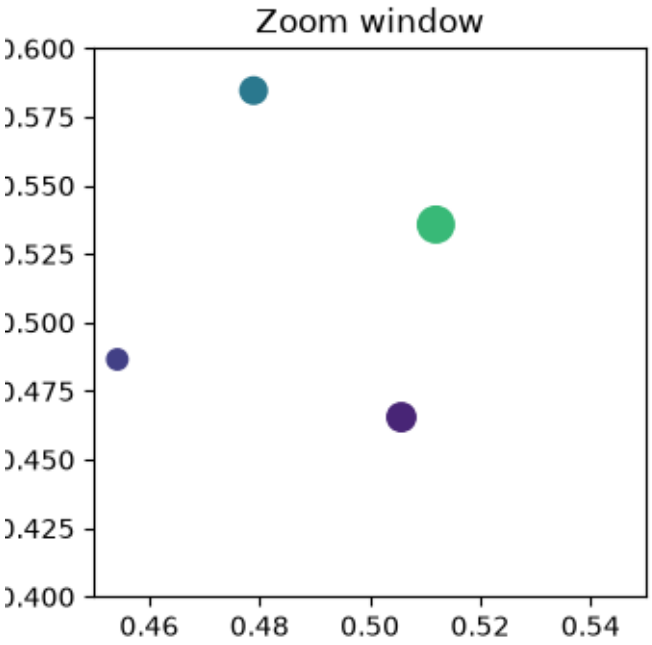
Note

This example exercises the interactive capabilities of Matplotlib, and this will not appear in the static documentation. Please run this code on your machine to see the interactivity.

You can copy and paste individual parts, or download the entire example using the link at the bottom of the page.



-



-

```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
# Fixing random state for reproducibility
np.random.seed(19680801)

figsrc, axsrc = plt.subplots(figsize=(3.7, 3.7))
figzoom, axzoom = plt.subplots(figsize=(3.7, 3.7))
axsrc.set(xlim=(0, 1), ylim=(0, 1), autoscale_on=False,
          title='Click to zoom')
axzoom.set(xlim=(0.45, 0.55), ylim=(0.4, 0.6), autoscale_on=False,
           title='Zoom window')

x, y, s, c = np.random.rand(4, 200)
s *= 200

axsrc.scatter(x, y, s, c)
axzoom.scatter(x, y, s, c)


def on_press(event):
    if event.button != 1:
        return
    x, y = event.xdata, event.ydata
    axzoom.set_xlim(x - 0.1, x + 0.1)
    axzoom.set_ylim(y - 0.1, y + 0.1)
    figzoom.canvas.draw()

figsrc.canvas.mpl_connect('button_press_event', on_press)
plt.show()
```

6.24.20 Embedding Matplotlib in graphical user interfaces

You can embed Matplotlib directly into a user interface application by following the embedding_in_SOMEGUI.py examples here. Currently Matplotlib supports PyQt/PySide, PyGObject, Tkinter, and wxPython.

When embedding Matplotlib in a GUI, you must use the Matplotlib API directly rather than the pylab/pyplot procedural interface, so take a look at the examples/api directory for some example code working with the API.

CanvasAgg demo

This example shows how to use the agg backend directly to create images, which may be of use to web application developers who want full control over their code without using the pyplot interface to manage figures, figure closing etc.

Note

It is not necessary to avoid using the pyplot interface in order to create figures without a graphical front-end - simply setting the backend to "Agg" would be sufficient.

In this example, we show how to save the contents of the agg canvas to a file, and how to extract them to a numpy array, which can in turn be passed off to Pillow. The latter functionality allows e.g. to use Matplotlib inside a cgi-script *without* needing to write a figure to disk, and to write images in any format supported by Pillow.

```
from PIL import Image

import numpy as np

from matplotlib.backends.backend_agg import FigureCanvasAgg
from matplotlib.figure import Figure

fig = Figure(figsize=(5, 4), dpi=100)

# Do some plotting.
ax = fig.add_subplot()
ax.plot([1, 2, 3])

# Option 1: Save the figure to a file; can also be a file-like object␣
 ↪(BytesIO,
# etc.).
fig.savefig("test.png")

# Option 2 (low-level approach to directly save to a numpy array):␣
 ↪Manually
# attach a canvas to the figure (pyplot or savefig would automatically␣
 ↪do
# it), by instantiating the canvas with the figure as argument; then␣
 ↪draw the
# figure, retrieve a memoryview on the renderer buffer, and convert it␣
 ↪to a
# numpy array.
canvas = FigureCanvasAgg(fig)
canvas.draw()
rgba = np.asarray(canvas.buffer_rgba())
# ... and pass it to PIL.
im = Image.fromarray(rgba)
# This image can then be saved to any format supported by Pillow, e.g.:
im.save("test.bmp")

# Uncomment this line to display the image using ImageMagick's␣
```

(continues on next page)

(continued from previous page)

```
 ↪`display` tool.
# im.show()
```

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.backends.backend_agg.FigureCanvasAgg*
- *matplotlib.figure.Figure*
- *matplotlib.figure.Figure.add_subplot*
- *matplotlib.figure.Figure.savefig* / *matplotlib.pyplot.savefig*
- *matplotlib.axes.Axes.plot* / *matplotlib.pyplot.plot*

Embed in GTK3 with a navigation toolbar

Demonstrate NavigationToolbar with GTK3 accessed via pygobject.

```
import gi

gi.require_version('Gtk', '3.0')
from gi.repository import Gtk

import numpy as np

from matplotlib.backends.backend_gtk3 import NavigationToolbar2GTK3 as␣
 ↪NavigationToolbar
from matplotlib.backends.backend_gtk3agg import FigureCanvasGTK3Agg as␣
 ↪FigureCanvas
from matplotlib.figure import Figure

win = Gtk.Window()
win.connect("delete-event", Gtk.main_quit)
win.set_default_size(400, 300)
win.set_title("Embedded in GTK3")

fig = Figure(figsize=(5, 4), dpi=100)
ax = fig.add_subplot(1, 1, 1)
t = np.arange(0.0, 3.0, 0.01)
s = np.sin(2*np.pi*t)
ax.plot(t, s)

vbox = Gtk.VBox()
win.add(vbox)
```

(continues on next page)

(continued from previous page)

```
# Add canvas to vbox
canvas = FigureCanvas(fig)  # a Gtk.DrawingArea
vbox.pack_start(canvas, True, True, 0)

# Create toolbar
toolbar = NavigationToolbar(canvas)
vbox.pack_start(toolbar, False, False, 0)

win.show_all()
Gtk.main()
```

Embed in GTK3

Demonstrate adding a FigureCanvasGTK3Agg widget to a Gtk.ScrolledWindow using GTK3 accessed via pygobject.

```
import gi

gi.require_version('Gtk', '3.0')
from gi.repository import Gtk

import numpy as np

from matplotlib.backends.backend_gtk3agg import FigureCanvasGTK3Agg as␣
 ↪FigureCanvas
from matplotlib.figure import Figure

win = Gtk.Window()
win.connect("delete-event", Gtk.main_quit)
win.set_default_size(400, 300)
win.set_title("Embedded in GTK3")

fig = Figure(figsize=(5, 4), dpi=100)
ax = fig.add_subplot()
t = np.arange(0.0, 3.0, 0.01)
s = np.sin(2*np.pi*t)
ax.plot(t, s)

sw = Gtk.ScrolledWindow()
win.add(sw)
# A scrolled window border goes outside the scrollbars and viewport
sw.set_border_width(10)

canvas = FigureCanvas(fig)  # a Gtk.DrawingArea
canvas.set_size_request(800, 600)
```

(continues on next page)

(continued from previous page)

```
sw.add(canvas)

win.show_all()
Gtk.main()
```

Embed in GTK4 with a navigation toolbar

Demonstrate NavigationToolbar with GTK4 accessed via pygobject.

```
import gi

gi.require_version('Gtk', '4.0')
from gi.repository import Gtk

import numpy as np

from matplotlib.backends.backend_gtk4 import NavigationToolbar2GTK4 as␣
 ↪NavigationToolbar
from matplotlib.backends.backend_gtk4agg import FigureCanvasGTK4Agg as␣
 ↪FigureCanvas
from matplotlib.figure import Figure


def on_activate(app):
    win = Gtk.ApplicationWindow(application=app)
    win.set_default_size(400, 300)
    win.set_title("Embedded in GTK4")

    fig = Figure(figsize=(5, 4), dpi=100)
    ax = fig.add_subplot(1, 1, 1)
    t = np.arange(0.0, 3.0, 0.01)
    s = np.sin(2*np.pi*t)
    ax.plot(t, s)

    vbox = Gtk.Box(orientation=Gtk.Orientation.VERTICAL)
    win.set_child(vbox)

    # Add canvas to vbox
    canvas = FigureCanvas(fig)  # a Gtk.DrawingArea
    canvas.set_hexpand(True)
    canvas.set_vexpand(True)
    vbox.append(canvas)

    # Create toolbar
    toolbar = NavigationToolbar(canvas)
    vbox.append(toolbar)
```

(continues on next page)

(continued from previous page)

```
    win.present()


app = Gtk.Application(application_id=
 ↪'org.matplotlib.examples.EmbeddingInGTK4PanZoom')
app.connect('activate', on_activate)
app.run(None)
```

Embed in GTK4

Demonstrate adding a FigureCanvasGTK4Agg widget to a Gtk.ScrolledWindow using GTK4 accessed via pygobject.

```
import gi

gi.require_version('Gtk', '4.0')
from gi.repository import Gtk

import numpy as np

from matplotlib.backends.backend_gtk4agg import FigureCanvasGTK4Agg as␣
 ↪FigureCanvas
from matplotlib.figure import Figure


def on_activate(app):
    win = Gtk.ApplicationWindow(application=app)
    win.set_default_size(400, 300)
    win.set_title("Embedded in GTK4")

    fig = Figure(figsize=(5, 4), dpi=100)
    ax = fig.add_subplot()
    t = np.arange(0.0, 3.0, 0.01)
    s = np.sin(2*np.pi*t)
    ax.plot(t, s)

    # A scrolled margin goes outside the scrollbars and viewport.
    sw = Gtk.ScrolledWindow(margin_top=10, margin_bottom=10,
                            margin_start=10, margin_end=10)
    win.set_child(sw)

    canvas = FigureCanvas(fig)  # a Gtk.DrawingArea
    canvas.set_size_request(800, 600)
    sw.set_child(canvas)
```

(continues on next page)

(continued from previous page)

```
    win.present()


app = Gtk.Application(application_id=
 ↪'org.matplotlib.examples.EmbeddingInGTK4')
app.connect('activate', on_activate)
app.run(None)
```

Embed in Qt

Simple Qt application embedding Matplotlib canvases. This program will work equally well using any Qt binding (PyQt6, PySide6, PyQt5, PySide2). The binding can be selected by setting the *QT_API* environment variable to the binding name, or by first importing it.

```
import sys
import time

import numpy as np

from matplotlib.backends.backend_qtagg import FigureCanvas
from matplotlib.backends.backend_qtagg import NavigationToolbar2QT as␣
 ↪NavigationToolbar
from matplotlib.backends.qt_compat import QtWidgets
from matplotlib.figure import Figure


class ApplicationWindow(QtWidgets.QMainWindow):
    def __init__(self):
        super().__init__()
        self._main = QtWidgets.QWidget()
        self.setCentralWidget(self._main)
        layout = QtWidgets.QVBoxLayout(self._main)

        static_canvas = FigureCanvas(Figure(figsize=(5, 3)))
        # Ideally one would use self.addToolBar here, but it is␣
 ↪slightly
        # incompatible between PyQt6 and other bindings, so we just␣
 ↪add the
        # toolbar as a plain widget instead.
        layout.addWidget(NavigationToolbar(static_canvas, self))
        layout.addWidget(static_canvas)

        dynamic_canvas = FigureCanvas(Figure(figsize=(5, 3)))
        layout.addWidget(dynamic_canvas)
        layout.addWidget(NavigationToolbar(dynamic_canvas, self))
```

(continues on next page)

(continued from previous page)

```
        self._static_ax = static_canvas.figure.subplots()
        t = np.linspace(0, 10, 501)
        self._static_ax.plot(t, np.tan(t), ".")

        self._dynamic_ax = dynamic_canvas.figure.subplots()
        # Set up a Line2D.
        self.xdata = np.linspace(0, 10, 101)
        self._update_ydata()
        self._line, = self._dynamic_ax.plot(self.xdata, self.ydata)
        # The below two timers must be attributes of self, so that the␣
↪garbage
        # collector won't clean them after we finish with __init__...

        # The data retrieval may be fast as possible (Using QRunnable␣
↪could be
        # even faster).
        self.data_timer = dynamic_canvas.new_timer(1)
        self.data_timer.add_callback(self._update_ydata)
        self.data_timer.start()
        # Drawing at 50Hz should be fast enough for the GUI to feel␣
↪smooth, and
        # not too fast for the GUI to be overloaded with events that␣
↪need to be
        # processed while the GUI element is changed.
        self.drawing_timer = dynamic_canvas.new_timer(20)
        self.drawing_timer.add_callback(self._update_canvas)
        self.drawing_timer.start()

    def _update_ydata(self):
        # Shift the sinusoid as a function of time.
        self.ydata = np.sin(self.xdata + time.time())

    def _update_canvas(self):
        self._line.set_data(self.xdata, self.ydata)
        # It should be safe to use the synchronous draw() method for␣
↪most drawing
        # frequencies, but it is safer to use draw_idle().
        self._line.figure.canvas.draw_idle()


if __name__ == "__main__":
    # Check whether there is already a running QApplication (e.g., if␣
↪running
    # from an IDE).
    qapp = QtWidgets.QApplication.instance()
    if not qapp:
```

(continues on next page)

(continued from previous page)

```
        qapp = QtWidgets.QApplication(sys.argv)

    app = ApplicationWindow()
    app.show()
    app.activateWindow()
    app.raise_()
    qapp.exec()
```

Embed in Tk

```
import tkinter

import numpy as np

# Implement the default Matplotlib key bindings.
from matplotlib.backend_bases import key_press_handler
from matplotlib.backends.backend_tkagg import FigureCanvasTkAgg,␣
 ↪NavigationToolbar2Tk
from matplotlib.figure import Figure

root = tkinter.Tk()
root.wm_title("Embedded in Tk")

fig = Figure(figsize=(5, 4), dpi=100)
t = np.arange(0, 3, .01)
ax = fig.add_subplot()
line, = ax.plot(t, 2 * np.sin(2 * np.pi * t))
ax.set_xlabel("time [s]")
ax.set_ylabel("f(t)")

canvas = FigureCanvasTkAgg(fig, master=root)  # A tk.DrawingArea.
canvas.draw()

# pack_toolbar=False will make it easier to use a layout manager later␣
 ↪on.
toolbar = NavigationToolbar2Tk(canvas, root, pack_toolbar=False)
toolbar.update()

canvas.mpl_connect(
    "key_press_event", lambda event: print(f"you pressed {event.key}"))
canvas.mpl_connect("key_press_event", key_press_handler)

button_quit = tkinter.Button(master=root, text="Quit", command=root.
 ↪destroy)
```

(continues on next page)

(continued from previous page)

```
def update_frequency(new_val):
    # retrieve frequency
    f = float(new_val)

    # update data
    y = 2 * np.sin(2 * np.pi * f * t)
    line.set_data(t, y)

    # required to update canvas and attached toolbar!
    canvas.draw()


slider_update = tkinter.Scale(root, from_=1, to=5, orient=tkinter.
 ↪HORIZONTAL,
                              command=update_frequency, label=
 ↪"Frequency [Hz]")

# Packing order is important. Widgets are processed sequentially and␣
 ↪if there
# is no space left, because the window is too small, they are not␣
 ↪displayed.
# The canvas is rather flexible in its size, so we pack it last which␣
 ↪makes
# sure the UI controls are displayed as long as possible.
button_quit.pack(side=tkinter.BOTTOM)
slider_update.pack(side=tkinter.BOTTOM)
toolbar.pack(side=tkinter.BOTTOM, fill=tkinter.X)
canvas.get_tk_widget().pack(side=tkinter.TOP, fill=tkinter.BOTH,␣
 ↪expand=True)

tkinter.mainloop()
```

Embed in wx #2

An example of how to use wxagg in an application with the new toolbar - comment out the add_toolbar line for no toolbar.

```
import wx
import wx.lib.mixins.inspection as WIT

import numpy as np

from matplotlib.backends.backend_wxagg import FigureCanvasWxAgg as␣
 ↪FigureCanvas
from matplotlib.backends.backend_wxagg import \
```

(continues on next page)

(continued from previous page)

```
    NavigationToolbar2WxAgg as NavigationToolbar
from matplotlib.figure import Figure


class CanvasFrame(wx.Frame):
    def __init__(self):
        super().__init__(None, -1, 'CanvasFrame', size=(550, 350))

        self.figure = Figure()
        self.axes = self.figure.add_subplot()
        t = np.arange(0.0, 3.0, 0.01)
        s = np.sin(2 * np.pi * t)

        self.axes.plot(t, s)
        self.canvas = FigureCanvas(self, -1, self.figure)

        self.sizer = wx.BoxSizer(wx.VERTICAL)
        self.sizer.Add(self.canvas, 1, wx.LEFT | wx.TOP | wx.EXPAND)
        self.SetSizer(self.sizer)
        self.Fit()

        self.add_toolbar()  # comment this out for no toolbar

    def add_toolbar(self):
        self.toolbar = NavigationToolbar(self.canvas)
        self.toolbar.Realize()
        # By adding toolbar in sizer, we are able to put it at the␣
 ↪bottom
        # of the frame - so appearance is closer to GTK version.
        self.sizer.Add(self.toolbar, 0, wx.LEFT | wx.EXPAND)
        # update the axes menu on the toolbar
        self.toolbar.update()


# Alternatively you could use:
# class App(wx.App):
class App(WIT.InspectableApp):
    def OnInit(self):
        """Create the main window and insert the custom frame."""
        self.Init()
        frame = CanvasFrame()
        frame.Show(True)

        return True
```

(continues on next page)

(continued from previous page)

```
if __name__ == "__main__":
    app = App()
    app.MainLoop()
```

Embed in wx #3

Copyright (C) 2003-2004 Andrew Straw, Jeremy O'Donoghue and others

License: This work is licensed under the PSF. A copy should be included with this source code, and is also available at https://docs.python.org/3/license.html

This is yet another example of using matplotlib with wx. Hopefully this is pretty full-featured:

- both matplotlib toolbar and WX buttons manipulate plot
- full wxApp framework, including widget interaction
- XRC (XML wxWidgets resource) file to create GUI (made with XRCed)

This was derived from embedding_in_wx and dynamic_image_wxagg.

Thanks to matplotlib and wx teams for creating such great software!

```
import wx
import wx.xrc as xrc

import numpy as np

from matplotlib.backends.backend_wxagg import FigureCanvasWxAgg as␣
 ↪FigureCanvas
from matplotlib.backends.backend_wxagg import \
    NavigationToolbar2WxAgg as NavigationToolbar
import matplotlib.cbook as cbook
from matplotlib.figure import Figure

ERR_TOL = 1e-5  # floating point slop for peak-detection


class PlotPanel(wx.Panel):
    def __init__(self, parent):
        super().__init__(parent, -1)

        self.fig = Figure((5, 4), 75)
        self.canvas = FigureCanvas(self, -1, self.fig)
        self.toolbar = NavigationToolbar(self.canvas)  # matplotlib␣
 ↪toolbar
        self.toolbar.Realize()

        # Now put all into a sizer
```

(continues on next page)

(continued from previous page)

```
        sizer = wx.BoxSizer(wx.VERTICAL)
        # This way of adding to sizer allows resizing
        sizer.Add(self.canvas, 1, wx.LEFT | wx.TOP | wx.GROW)
        # Best to allow the toolbar to resize!
        sizer.Add(self.toolbar, 0, wx.GROW)
        self.SetSizer(sizer)
        self.Fit()

    def init_plot_data(self):
        ax = self.fig.add_subplot()

        x = np.arange(120.0) * 2 * np.pi / 60.0
        y = np.arange(100.0) * 2 * np.pi / 50.0
        self.x, self.y = np.meshgrid(x, y)
        z = np.sin(self.x) + np.cos(self.y)
        self.im = ax.imshow(z, cmap="RdBu", origin='lower')

        zmax = np.max(z) - ERR_TOL
        ymax_i, xmax_i = np.nonzero(z >= zmax)
        if self.im.origin == 'upper':
            ymax_i = z.shape[0] - ymax_i
        self.lines = ax.plot(xmax_i, ymax_i, 'ko')

        self.toolbar.update()  # Not sure why this is needed - ADS

    def GetToolBar(self):
        # You will need to override GetToolBar if you are using an
        # unmanaged toolbar in your frame
        return self.toolbar

    def OnWhiz(self, event):
        self.x += np.pi / 15
        self.y += np.pi / 20
        z = np.sin(self.x) + np.cos(self.y)
        self.im.set_array(z)

        zmax = np.max(z) - ERR_TOL
        ymax_i, xmax_i = np.nonzero(z >= zmax)
        if self.im.origin == 'upper':
            ymax_i = z.shape[0] - ymax_i
        self.lines[0].set_data(xmax_i, ymax_i)

        self.canvas.draw()


class MyApp(wx.App):
```

(continues on next page)

(continued from previous page)

```
    def OnInit(self):
        xrcfile = cbook.get_sample_data('embedding_in_wx3.xrc',
                                        asfileobj=False)
        print('loading', xrcfile)

        self.res = xrc.XmlResource(xrcfile)

        # main frame and panel ---------

        self.frame = self.res.LoadFrame(None, "MainFrame")
        self.panel = xrc.XRCCTRL(self.frame, "MainPanel")

        # matplotlib panel -------------

        # container for matplotlib panel (I like to make a container
        # panel for our panel so I know where it'll go when in XRCed.)
        plot_container = xrc.XRCCTRL(self.frame, "plot_container_panel
↪")
        sizer = wx.BoxSizer(wx.VERTICAL)

        # matplotlib panel itself
        self.plotpanel = PlotPanel(plot_container)
        self.plotpanel.init_plot_data()

        # wx boilerplate
        sizer.Add(self.plotpanel, 1, wx.EXPAND)
        plot_container.SetSizer(sizer)

        # whiz button ------------------
        whiz_button = xrc.XRCCTRL(self.frame, "whiz_button")
        whiz_button.Bind(wx.EVT_BUTTON, self.plotpanel.OnWhiz)

        # bang button ------------------
        bang_button = xrc.XRCCTRL(self.frame, "bang_button")
        bang_button.Bind(wx.EVT_BUTTON, self.OnBang)

        # final setup ------------------
        self.frame.Show()

        self.SetTopWindow(self.frame)

        return True

    def OnBang(self, event):
        bang_count = xrc.XRCCTRL(self.frame, "bang_count")
        bangs = bang_count.GetValue()
```

(continues on next page)

(continued from previous page)

```
        bangs = int(bangs) + 1
        bang_count.SetValue(str(bangs))


if __name__ == '__main__':
    app = MyApp()
    app.MainLoop()
```

Embed in wx #4

An example of how to use wxagg in a wx application with a custom toolbar.

```
import wx

import numpy as np

from matplotlib.backends.backend_wxagg import FigureCanvasWxAgg as␣
 ↪FigureCanvas
from matplotlib.backends.backend_wxagg import \
    NavigationToolbar2WxAgg as NavigationToolbar
from matplotlib.figure import Figure


class MyNavigationToolbar(NavigationToolbar):
    """Extend the default wx toolbar with your own event handlers."""

    def __init__(self, canvas):
        super().__init__(canvas)
        # We use a stock wx bitmap, but you could also use your own␣
 ↪image file.
        bmp = wx.ArtProvider.GetBitmap(wx.ART_CROSS_MARK, wx.
 ↪ART_TOOLBAR)
        tool = self.AddTool(wx.ID_ANY, 'Click me', bmp,
                            'Activate custom control')
        self.Bind(wx.EVT_TOOL, self._on_custom, id=tool.GetId())

    def _on_custom(self, event):
        # add some text to the Axes in a random location in axes␣
 ↪coords with a
        # random color
        ax = self.canvas.figure.axes[0]
        x, y = np.random.rand(2)  # generate a random location
        rgb = np.random.rand(3)  # generate a random color
        ax.text(x, y, 'You clicked me', transform=ax.transAxes,␣
 ↪color=rgb)
        self.canvas.draw()
```

(continues on next page)

(continued from previous page)

```
        event.Skip()


class CanvasFrame(wx.Frame):
    def __init__(self):
        super().__init__(None, -1, 'CanvasFrame', size=(550, 350))

        self.figure = Figure(figsize=(5, 4), dpi=100)
        self.axes = self.figure.add_subplot()
        t = np.arange(0.0, 3.0, 0.01)
        s = np.sin(2 * np.pi * t)

        self.axes.plot(t, s)

        self.canvas = FigureCanvas(self, -1, self.figure)

        self.sizer = wx.BoxSizer(wx.VERTICAL)
        self.sizer.Add(self.canvas, 1, wx.TOP | wx.LEFT | wx.EXPAND)

        self.toolbar = MyNavigationToolbar(self.canvas)
        self.toolbar.Realize()
        # By adding toolbar in sizer, we are able to put it at the␣
 ↪bottom
        # of the frame - so appearance is closer to GTK version.
        self.sizer.Add(self.toolbar, 0, wx.LEFT | wx.EXPAND)

        # update the axes menu on the toolbar
        self.toolbar.update()
        self.SetSizer(self.sizer)
        self.Fit()


class App(wx.App):
    def OnInit(self):
        """Create the main window and insert the custom frame."""
        frame = CanvasFrame()
        frame.Show(True)
        return True


if __name__ == "__main__":
    app = App()
    app.MainLoop()
```

Embed in wx #5

Tip

As a development and debugging aid, you can replace `wx.App` by `wx.lib.mixins.inspection.InspectableApp`. This adds the capability to start the Widget Inspection Tool via `Ctrl-Alt-I`.

```
import wx
import wx.lib.agw.aui as aui

from matplotlib.backends.backend_wxagg import FigureCanvasWxAgg as␣
 ↪FigureCanvas
from matplotlib.backends.backend_wxagg import \
    NavigationToolbar2WxAgg as NavigationToolbar
from matplotlib.figure import Figure


class Plot(wx.Panel):
    def __init__(self, parent, id=-1, dpi=None, **kwargs):
        super().__init__(parent, id=id, **kwargs)
        self.figure = Figure(dpi=dpi, figsize=(2, 2))
        self.canvas = FigureCanvas(self, -1, self.figure)
        self.toolbar = NavigationToolbar(self.canvas)
        self.toolbar.Realize()

        sizer = wx.BoxSizer(wx.VERTICAL)
        sizer.Add(self.canvas, 1, wx.EXPAND)
        sizer.Add(self.toolbar, 0, wx.LEFT | wx.EXPAND)
        self.SetSizer(sizer)


class PlotNotebook(wx.Panel):
    def __init__(self, parent, id=-1):
        super().__init__(parent, id=id)
        self.nb = aui.AuiNotebook(self)
        sizer = wx.BoxSizer()
        sizer.Add(self.nb, 1, wx.EXPAND)
        self.SetSizer(sizer)

    def add(self, name="plot"):
        page = Plot(self.nb)
        self.nb.AddPage(page, name)
        return page.figure


def demo():
```

(continues on next page)

(continued from previous page)

```
    app = wx.App()
    frame = wx.Frame(None, -1, 'Plotter')
    plotter = PlotNotebook(frame)
    axes1 = plotter.add('figure 1').add_subplot()
    axes1.plot([1, 2, 3], [2, 1, 4])
    axes2 = plotter.add('figure 2').add_subplot()
    axes2.plot([1, 2, 3, 4, 5], [2, 1, 4, 2, 3])
    frame.Show()
    app.MainLoop()

if __name__ == "__main__":
    demo()
```

Embedding WebAgg

This example demonstrates how to embed Matplotlib WebAgg interactive plotting in your own web application and framework. It is not necessary to do all this if you merely want to display a plot in a browser or use Matplotlib's built-in Tornado-based server "on the side".

The framework being used must support web sockets.

```
import argparse
import io
import json
import mimetypes
from pathlib import Path
import signal
import socket

try:
    import tornado
except ImportError as err:
    raise RuntimeError("This example requires tornado.") from err
import tornado.httpserver
import tornado.ioloop
import tornado.web
import tornado.websocket

import numpy as np

import matplotlib as mpl
from matplotlib.backends.backend_webagg import (FigureManagerWebAgg,
                                                ␣
 ↪new_figure_manager_given_figure)
from matplotlib.figure import Figure
```

(continues on next page)

(continued from previous page)

```
def create_figure():
    """
    Creates a simple example figure.
    """
    fig = Figure()
    ax = fig.add_subplot()
    t = np.arange(0.0, 3.0, 0.01)
    s = np.sin(2 * np.pi * t)
    ax.plot(t, s)
    return fig


# The following is the content of the web page.  You would normally
# generate this using some sort of template facility in your web
# framework, but here we just use Python string formatting.
html_content = """<!DOCTYPE html>
<html lang="en">
  <head>
    <!-- TODO: There should be a way to include all of the required
 ↪javascript
               and CSS so matplotlib can add to the set in the future
 ↪if it
               needs to. -->
    <link rel="stylesheet" href="_static/css/page.css" type="text/css">
    <link rel="stylesheet" href="_static/css/boilerplate.css" type=
 ↪"text/css">
    <link rel="stylesheet" href="_static/css/fbm.css" type="text/css">
    <link rel="stylesheet" href="_static/css/mpl.css" type="text/css">
    <script src="mpl.js"></script>

    <script>
      /* This is a callback that is called when the user saves
         (downloads) a file.  Its purpose is really to map from a
         figure and file format to a url in the application. */
      function ondownload(figure, format) {
        window.open('download.' + format, '_blank');
      };

      function ready(fn) {
        if (document.readyState != "loading") {
          fn();
        } else {
          document.addEventListener("DOMContentLoaded", fn);
        }
      }
```

(continues on next page)

(continued from previous page)

```
      ready(
        function() {
          /* It is up to the application to provide a websocket that the figure
             will use to communicate to the server.  This websocket object can
             also be a "fake" websocket that underneath multiplexes messages
             from multiple figures, if necessary. */
          var websocket_type = mpl.get_websocket_type();
          var websocket = new websocket_type("%(ws_uri)sws");

          // mpl.figure creates a new figure on the webpage.
          var fig = new mpl.figure(
              // A unique numeric identifier for the figure
              %(fig_id)s,
              // A websocket object (or something that behaves like one)
              websocket,
              // A function called when a file type is selected for download
              ondownload,
              // The HTML element in which to place the figure
              document.getElementById("figure"));
        }
      );
    </script>

    <title>matplotlib</title>
  </head>

  <body>
    <div id="figure">
    </div>
  </body>
</html>
"""


class MyApplication(tornado.web.Application):
    class MainPage(tornado.web.RequestHandler):
        """
        Serves the main HTML page.
        """
```

(continues on next page)

(continued from previous page)

```
        def get(self):
            manager = self.application.manager
            ws_uri = f"ws://{self.request.host}/"
            content = html_content % {
                "ws_uri": ws_uri, "fig_id": manager.num}
            self.write(content)

    class MplJs(tornado.web.RequestHandler):
        """
        Serves the generated matplotlib javascript file.  The content
        is dynamically generated based on which toolbar functions the
        user has defined.  Call `FigureManagerWebAgg` to get its
        content.
        """

        def get(self):
            self.set_header('Content-Type', 'application/javascript')
            js_content = FigureManagerWebAgg.get_javascript()

            self.write(js_content)

    class Download(tornado.web.RequestHandler):
        """
        Handles downloading of the figure in various file formats.
        """

        def get(self, fmt):
            manager = self.application.manager
            self.set_header(
                'Content-Type', mimetypes.types_map.get(fmt, 'binary'))
            buff = io.BytesIO()
            manager.canvas.figure.savefig(buff, format=fmt)
            self.write(buff.getvalue())

    class WebSocket(tornado.websocket.WebSocketHandler):
        """
        A websocket for interactive communication between the plot in
        the browser and the server.

        In addition to the methods required by tornado, it is required␣
↪to
        have two callback methods:

            - ``send_json(json_content)`` is called by matplotlib when
              it needs to send json to the browser.  `json_content` is
              a JSON tree (Python dictionary), and it is the␣
```

(continues on next page)

(continued from previous page)

```
↪responsibility
            of this implementation to encode it as a string to send␣
↪over
            the socket.

        - ``send_binary(blob)`` is called to send binary image data
            to the browser.
    """
    supports_binary = True

    def open(self):
        # Register the websocket with the FigureManager.
        manager = self.application.manager
        manager.add_web_socket(self)
        if hasattr(self, 'set_nodelay'):
            self.set_nodelay(True)

    def on_close(self):
        # When the socket is closed, deregister the websocket with
        # the FigureManager.
        manager = self.application.manager
        manager.remove_web_socket(self)

    def on_message(self, message):
        # The 'supports_binary' message is relevant to the
        # websocket itself.  The other messages get passed along
        # to matplotlib as-is.

        # Every message has a "type" and a "figure_id".
        message = json.loads(message)
        if message['type'] == 'supports_binary':
            self.supports_binary = message['value']
        else:
            manager = self.application.manager
            manager.handle_json(message)

    def send_json(self, content):
        self.write_message(json.dumps(content))

    def send_binary(self, blob):
        if self.supports_binary:
            self.write_message(blob, binary=True)
        else:
            data_uri = ("" +
                        blob.encode('base64').replace('\n', ''))
            self.write_message(data_uri)
```

(continues on next page)

(continued from previous page)

```
    def __init__(self, figure):
        self.figure = figure
        self.manager = new_figure_manager_given_figure(id(figure),␣
↪figure)

        super().__init__([
            # Static files for the CSS and JS
            (r'/_static/(.*)',
             tornado.web.StaticFileHandler,
             {'path': FigureManagerWebAgg.get_static_file_path()}),

            # Static images for the toolbar
            (r'/_images/(.*)',
             tornado.web.StaticFileHandler,
             {'path': Path(mpl.get_data_path(), 'images')}),

            # The page that contains all of the pieces
            ('/', self.MainPage),

            ('/mpl.js', self.MplJs),

            # Sends images and events to the browser, and receives
            # events from the browser
            ('/ws', self.WebSocket),

            # Handles the downloading (i.e., saving) of static images
            (r'/download.([a-z0-9.]+)', self.Download),
        ])


if __name__ == "__main__":
    parser = argparse.ArgumentParser()
    parser.add_argument('-p', '--port', type=int, default=8080,
                        help='Port to listen on (0 for a random port).
↪')
    args = parser.parse_args()

    figure = create_figure()
    application = MyApplication(figure)

    http_server = tornado.httpserver.HTTPServer(application)
    sockets = tornado.netutil.bind_sockets(args.port, '')
    http_server.add_sockets(sockets)

    for s in sockets:
```

(continues on next page)

(continued from previous page)

```
        addr, port = s.getsockname()[:2]
        if s.family is socket.AF_INET6:
            addr = f'[{addr}]'
        print(f"Listening on http://{addr}:{port}/")
    print("Press Ctrl+C to quit")

    ioloop = tornado.ioloop.IOLoop.instance()

    def shutdown():
        ioloop.stop()
        print("Server stopped")

    old_handler = signal.signal(
        signal.SIGINT,
        lambda sig, frame: ioloop.add_callback_from_signal(shutdown))

    try:
        ioloop.start()
    finally:
        signal.signal(signal.SIGINT, old_handler)
```

Fourier Demo WX

```
import wx

import numpy as np

from matplotlib.backends.backend_wxagg import FigureCanvasWxAgg as␣
 ↪FigureCanvas
from matplotlib.figure import Figure


class Knob:
    """
    Knob - simple class with a "setKnob" method.
    A Knob instance is attached to a Param instance, e.g.,␣
 ↪param.attach(knob)
    Base class is for documentation purposes.
    """

    def setKnob(self, value):
        pass


class Param:
```

(continues on next page)

(continued from previous page)

```
    """
    The idea of the "Param" class is that some parameter in the GUI␣
↪may have
    several knobs that both control it and reflect the parameter's␣
↪state, e.g.
    a slider, text, and dragging can all change the value of the␣
↪frequency in
    the waveform of this example.
    The class allows a cleaner way to update/"feedback" to the other␣
↪knobs when
    one is being changed.  Also, this class handles min/max␣
↪constraints for all
    the knobs.
    Idea - knob list - in "set" method, knob object is passed as well
      - the other knobs in the knob list have a "set" method which gets
        called for the others.
    """

    def __init__(self, initialValue=None, minimum=0., maximum=1.):
        self.minimum = minimum
        self.maximum = maximum
        if initialValue != self.constrain(initialValue):
            raise ValueError('illegal initial value')
        self.value = initialValue
        self.knobs = []

    def attach(self, knob):
        self.knobs += [knob]

    def set(self, value, knob=None):
        self.value = value
        self.value = self.constrain(value)
        for feedbackKnob in self.knobs:
            if feedbackKnob != knob:
                feedbackKnob.setKnob(self.value)
        return self.value

    def constrain(self, value):
        if value <= self.minimum:
            value = self.minimum
        if value >= self.maximum:
            value = self.maximum
        return value


class SliderGroup(Knob):
```

(continues on next page)

(continued from previous page)

```
    def __init__(self, parent, label, param):
        self.sliderLabel = wx.StaticText(parent, label=label)
        self.sliderText = wx.TextCtrl(parent, -1, style=wx.
↪TE_PROCESS_ENTER)
        self.slider = wx.Slider(parent, -1)
        # self.slider.SetMax(param.maximum*1000)
        self.slider.SetRange(0, int(param.maximum * 1000))
        self.setKnob(param.value)

        sizer = wx.BoxSizer(wx.HORIZONTAL)
        sizer.Add(self.sliderLabel, 0,
                  wx.EXPAND | wx.ALL,
                  border=2)
        sizer.Add(self.sliderText, 0,
                  wx.EXPAND | wx.ALL,
                  border=2)
        sizer.Add(self.slider, 1, wx.EXPAND)
        self.sizer = sizer

        self.slider.Bind(wx.EVT_SLIDER, self.sliderHandler)
        self.sliderText.Bind(wx.EVT_TEXT_ENTER, self.sliderTextHandler)

        self.param = param
        self.param.attach(self)

    def sliderHandler(self, event):
        value = event.GetInt() / 1000.
        self.param.set(value)

    def sliderTextHandler(self, event):
        value = float(self.sliderText.GetValue())
        self.param.set(value)

    def setKnob(self, value):
        self.sliderText.SetValue(f'{value:g}')
        self.slider.SetValue(int(value * 1000))


class FourierDemoFrame(wx.Frame):
    def __init__(self, *args, **kwargs):
        super().__init__(*args, **kwargs)
        panel = wx.Panel(self)

        # create the GUI elements
        self.createCanvas(panel)
        self.createSliders(panel)
```

(continues on next page)

(continued from previous page)

```
        # place them in a sizer for the Layout
        sizer = wx.BoxSizer(wx.VERTICAL)
        sizer.Add(self.canvas, 1, wx.EXPAND)
        sizer.Add(self.frequencySliderGroup.sizer, 0,
                  wx.EXPAND | wx.ALL, border=5)
        sizer.Add(self.amplitudeSliderGroup.sizer, 0,
                  wx.EXPAND | wx.ALL, border=5)
        panel.SetSizer(sizer)

    def createCanvas(self, parent):
        self.lines = []
        self.figure = Figure()
        self.canvas = FigureCanvas(parent, -1, self.figure)
        self.canvas.callbacks.connect('button_press_event', self.
↪mouseDown)
        self.canvas.callbacks.connect('motion_notify_event', self.
↪mouseMotion)
        self.canvas.callbacks.connect('button_release_event', self.
↪mouseUp)
        self.state = ''
        self.mouseInfo = (None, None, None, None)
        self.f0 = Param(2., minimum=0., maximum=6.)
        self.A = Param(1., minimum=0.01, maximum=2.)
        self.createPlots()

        # Not sure I like having two params attached to the same Knob,
        # but that is what we have here... it works but feels kludgy -
        # although maybe it's not too bad since the knob changes both␣
↪params
        # at the same time (both f0 and A are affected during a drag)
        self.f0.attach(self)
        self.A.attach(self)

    def createSliders(self, panel):
        self.frequencySliderGroup = SliderGroup(
            panel,
            label='Frequency f0:',
            param=self.f0)
        self.amplitudeSliderGroup = SliderGroup(panel, label='␣
↪Amplitude a:',
                                                param=self.A)

    def mouseDown(self, event):
        if self.lines[0].contains(event)[0]:
            self.state = 'frequency'
```

(continues on next page)

(continued from previous page)

```
        elif self.lines[1].contains(event)[0]:
            self.state = 'time'
        else:
            self.state = ''
        self.mouseInfo = (event.xdata, event.ydata,
                          max(self.f0.value, .1),
                          self.A.value)

    def mouseMotion(self, event):
        if self.state == '':
            return
        x, y = event.xdata, event.ydata
        if x is None:  # outside the Axes
            return
        x0, y0, f0Init, AInit = self.mouseInfo
        self.A.set(AInit + (AInit * (y - y0) / y0), self)
        if self.state == 'frequency':
            self.f0.set(f0Init + (f0Init * (x - x0) / x0))
        elif self.state == 'time':
            if (x - x0) / x0 != -1.:
                self.f0.set(1. / (1. / f0Init + (1. / f0Init * (x - x0) / x0)))

    def mouseUp(self, event):
        self.state = ''

    def createPlots(self):
        # This method creates the subplots, waveforms and labels.
        # Later, when the waveforms or sliders are dragged, only the
        # waveform data will be updated (not here, but below in setKnob).
        self.subplot1, self.subplot2 = self.figure.subplots(2)
        x1, y1, x2, y2 = self.compute(self.f0.value, self.A.value)
        color = (1., 0., 0.)
        self.lines += self.subplot1.plot(x1, y1, color=color, linewidth=2)
        self.lines += self.subplot2.plot(x2, y2, color=color, linewidth=2)
        # Set some plot attributes
        self.subplot1.set_title(
            "Click and drag waveforms to change frequency and amplitude",
            fontsize=12)
        self.subplot1.set_ylabel("Frequency Domain Waveform X(f)", fontsize=8)
        self.subplot1.set_xlabel("frequency f", fontsize=8)
```

(continues on next page)

(continued from previous page)

```
        self.subplot2.set_ylabel("Time Domain Waveform x(t)",␣
↪fontsize=8)
        self.subplot2.set_xlabel("time t", fontsize=8)
        self.subplot1.set_xlim(-6, 6)
        self.subplot1.set_ylim(0, 1)
        self.subplot2.set_xlim(-2, 2)
        self.subplot2.set_ylim(-2, 2)
        self.subplot1.text(0.05, .95,
                           r'$X(f) = \mathcal{F}\{x(t)\}$',
                           verticalalignment='top',
                           transform=self.subplot1.transAxes)
        self.subplot2.text(0.05, .95,
                           r'$x(t) = a \cdot \cos(2\pi f_0 t) e^{-\pi␣
↪t^2}$',
                           verticalalignment='top',
                           transform=self.subplot2.transAxes)

    def compute(self, f0, A):
        f = np.arange(-6., 6., 0.02)
        t = np.arange(-2., 2., 0.01)
        x = A * np.cos(2 * np.pi * f0 * t) * np.exp(-np.pi * t ** 2)
        X = A / 2 * \
            (np.exp(-np.pi * (f - f0) ** 2) + np.exp(-np.pi * (f + f0)␣
↪** 2))
        return f, X, t, x

    def setKnob(self, value):
        # Note, we ignore value arg here and just go by state of the␣
↪params
        x1, y1, x2, y2 = self.compute(self.f0.value, self.A.value)
        # update the data of the two waveforms
        self.lines[0].set(xdata=x1, ydata=y1)
        self.lines[1].set(xdata=x2, ydata=y2)
        # make the canvas draw its contents again with the new data
        self.canvas.draw()


class App(wx.App):
    def OnInit(self):
        self.frame1 = FourierDemoFrame(parent=None, title="Fourier Demo
↪",
                                       size=(640, 480))
        self.frame1.Show()
        return True
```

(continues on next page)

(continued from previous page)

```
if __name__ == "__main__":
    app = App()
    app.MainLoop()
```

GTK3 spreadsheet

Example of embedding Matplotlib in an application and interacting with a treeview to store data. Double-click on an entry to update plot data.

```
import gi

gi.require_version('Gtk', '3.0')
gi.require_version('Gdk', '3.0')
from gi.repository import Gdk, Gtk

from numpy.random import random

from matplotlib.backends.backend_gtk3agg import FigureCanvas  # or␣
 ↪gtk3cairo.
from matplotlib.figure import Figure


class DataManager(Gtk.Window):
    num_rows, num_cols = 20, 10

    data = random((num_rows, num_cols))

    def __init__(self):
        super().__init__()
        self.set_default_size(600, 600)
        self.connect('destroy', lambda win: Gtk.main_quit())

        self.set_title('GtkListStore demo')
        self.set_border_width(8)

        vbox = Gtk.VBox(homogeneous=False, spacing=8)
        self.add(vbox)

        label = Gtk.Label(label='Double click a row to plot the data')

        vbox.pack_start(label, False, False, 0)

        sw = Gtk.ScrolledWindow()
        sw.set_shadow_type(Gtk.ShadowType.ETCHED_IN)
        sw.set_policy(Gtk.PolicyType.NEVER, Gtk.PolicyType.AUTOMATIC)
        vbox.pack_start(sw, True, True, 0)
```

(continues on next page)

(continued from previous page)

```
        model = self.create_model()

        self.treeview = Gtk.TreeView(model=model)

        # Matplotlib stuff
        fig = Figure(figsize=(6, 4))

        self.canvas = FigureCanvas(fig)  # a Gtk.DrawingArea
        vbox.pack_start(self.canvas, True, True, 0)
        ax = fig.add_subplot()
        self.line, = ax.plot(self.data[0, :], 'go')  # plot the first␣
↪row

        self.treeview.connect('row-activated', self.plot_row)
        sw.add(self.treeview)

        self.add_columns()

        self.add_events(Gdk.EventMask.BUTTON_PRESS_MASK |
                        Gdk.EventMask.KEY_PRESS_MASK |
                        Gdk.EventMask.KEY_RELEASE_MASK)

    def plot_row(self, treeview, path, view_column):
        ind, = path  # get the index into data
        points = self.data[ind, :]
        self.line.set_ydata(points)
        self.canvas.draw()

    def add_columns(self):
        for i in range(self.num_cols):
            column = Gtk.TreeViewColumn(str(i), Gtk.
↪CellRendererText(), text=i)
            self.treeview.append_column(column)

    def create_model(self):
        types = [float] * self.num_cols
        store = Gtk.ListStore(*types)
        for row in self.data:
            store.append(tuple(row))
        return store


manager = DataManager()
manager.show_all()
Gtk.main()
```

GTK4 spreadsheet

Example of embedding Matplotlib in an application and interacting with a treeview to store data. Double-click on an entry to update plot data.

```
import gi

gi.require_version('Gtk', '4.0')
gi.require_version('Gdk', '4.0')
from gi.repository import Gtk

from numpy.random import random

from matplotlib.backends.backend_gtk4agg import FigureCanvas  # or␣
↪gtk4cairo.
from matplotlib.figure import Figure


class DataManager(Gtk.ApplicationWindow):
    num_rows, num_cols = 20, 10

    data = random((num_rows, num_cols))

    def __init__(self, *args, **kwargs):
        super().__init__(*args, **kwargs)
        self.set_default_size(600, 600)

        self.set_title('GtkListStore demo')

        vbox = Gtk.Box(orientation=Gtk.Orientation.VERTICAL,␣
↪homogeneous=False,
                       spacing=8)
        self.set_child(vbox)

        label = Gtk.Label(label='Double click a row to plot the data')
        vbox.append(label)

        sw = Gtk.ScrolledWindow()
        sw.set_has_frame(True)
        sw.set_policy(Gtk.PolicyType.NEVER, Gtk.PolicyType.AUTOMATIC)
        sw.set_hexpand(True)
        sw.set_vexpand(True)
        vbox.append(sw)

        model = self.create_model()
        self.treeview = Gtk.TreeView(model=model)
        self.treeview.connect('row-activated', self.plot_row)
```

(continues on next page)

(continued from previous page)

```
        sw.set_child(self.treeview)

        # Matplotlib stuff
        fig = Figure(figsize=(6, 4), layout='constrained')

        self.canvas = FigureCanvas(fig)  # a Gtk.DrawingArea
        self.canvas.set_hexpand(True)
        self.canvas.set_vexpand(True)
        vbox.append(self.canvas)
        ax = fig.add_subplot()
        self.line, = ax.plot(self.data[0, :], 'go')  # plot the first␣
↪row

        self.add_columns()

    def plot_row(self, treeview, path, view_column):
        ind, = path  # get the index into data
        points = self.data[ind, :]
        self.line.set_ydata(points)
        self.canvas.draw()

    def add_columns(self):
        for i in range(self.num_cols):
            column = Gtk.TreeViewColumn(str(i), Gtk.
↪CellRendererText(), text=i)
            self.treeview.append_column(column)

    def create_model(self):
        types = [float] * self.num_cols
        store = Gtk.ListStore(*types)
        for row in self.data:
            # Gtk.ListStore.append is broken in PyGObject, so insert␣
↪manually.
            it = store.insert(-1)
            store.set(it, {i: val for i, val in enumerate(row)})
        return store


def on_activate(app):
    manager = DataManager(application=app)
    manager.show()


app = Gtk.Application(application_id=
↪'org.matplotlib.examples.GTK4Spreadsheet')
app.connect('activate', on_activate)
```

(continues on next page)

(continued from previous page)

```
app.run()
```

Display mathtext in WX

Demonstrates how to convert (math)text to a wx.Bitmap for display in various controls on wxPython.

```
from io import BytesIO

import wx

import numpy as np

from matplotlib.backends.backend_wx import NavigationToolbar2Wx
from matplotlib.backends.backend_wxagg import FigureCanvasWxAgg as␣
 ↪FigureCanvas
from matplotlib.figure import Figure

IS_WIN = 'wxMSW' in wx.PlatformInfo


def mathtext_to_wxbitmap(s):
    # We draw the text at position (0, 0) but then rely on
    # ``facecolor="none"`` and ``bbox_inches="tight", pad_inches=0``␣
 ↪to get a
    # transparent mask that is then loaded into a wx.Bitmap.
    fig = Figure(facecolor="none")
    text_color = (
        np.array(wx.SystemSettings.GetColour(wx.
 ↪SYS_COLOUR_WINDOWTEXT)) / 255)
    fig.text(0, 0, s, fontsize=10, color=text_color)
    buf = BytesIO()
    fig.savefig(buf, format="png", dpi=150, bbox_inches="tight",␣
 ↪pad_inches=0)
    s = buf.getvalue()
    return wx.Bitmap.NewFromPNGData(s, len(s))


functions = [
    (r'$\sin(2 \pi x)$', lambda x: np.sin(2*np.pi*x)),
    (r'$\frac{4}{3}\pi x^3$', lambda x: (4/3)*np.pi*x**3),
    (r'$\cos(2 \pi x)$', lambda x: np.cos(2*np.pi*x)),
    (r'$\log(x)$', lambda x: np.log(x))
]


class CanvasFrame(wx.Frame):
```

(continues on next page)

(continued from previous page)

```
    def __init__(self, parent, title):
        super().__init__(parent, -1, title, size=(550, 350))

        self.figure = Figure()
        self.axes = self.figure.add_subplot()

        self.canvas = FigureCanvas(self, -1, self.figure)

        self.change_plot(0)

        self.sizer = wx.BoxSizer(wx.VERTICAL)
        self.add_buttonbar()
        self.sizer.Add(self.canvas, 1, wx.LEFT | wx.TOP | wx.GROW)
        self.add_toolbar()  # comment this out for no toolbar

        menuBar = wx.MenuBar()

        # File Menu
        menu = wx.Menu()
        m_exit = menu.Append(
            wx.ID_EXIT, "E&xit\tAlt-X", "Exit this simple sample")
        menuBar.Append(menu, "&File")
        self.Bind(wx.EVT_MENU, self.OnClose, m_exit)

        if IS_WIN:
            # Equation Menu
            menu = wx.Menu()
            for i, (mt, func) in enumerate(functions):
                bm = mathtext_to_wxbitmap(mt)
                item = wx.MenuItem(menu, 1000 + i, " ")
                item.SetBitmap(bm)
                menu.Append(item)
                self.Bind(wx.EVT_MENU, self.OnChangePlot, item)
            menuBar.Append(menu, "&Functions")

        self.SetMenuBar(menuBar)

        self.SetSizer(self.sizer)
        self.Fit()

    def add_buttonbar(self):
        self.button_bar = wx.Panel(self)
        self.button_bar_sizer = wx.BoxSizer(wx.HORIZONTAL)
        self.sizer.Add(self.button_bar, 0, wx.LEFT | wx.TOP | wx.GROW)

        for i, (mt, func) in enumerate(functions):
```

(continues on next page)

(continued from previous page)

```
            bm = mathtext_to_wxbitmap(mt)
            button = wx.BitmapButton(self.button_bar, 1000 + i, bm)
            self.button_bar_sizer.Add(button, 1, wx.GROW)
            self.Bind(wx.EVT_BUTTON, self.OnChangePlot, button)

        self.button_bar.SetSizer(self.button_bar_sizer)

    def add_toolbar(self):
        """Copied verbatim from embedding_wx2.py"""
        self.toolbar = NavigationToolbar2Wx(self.canvas)
        self.toolbar.Realize()
        # By adding toolbar in sizer, we are able to put it at the␣
↪bottom
        # of the frame - so appearance is closer to GTK version.
        self.sizer.Add(self.toolbar, 0, wx.LEFT | wx.EXPAND)
        # update the axes menu on the toolbar
        self.toolbar.update()

    def OnChangePlot(self, event):
        self.change_plot(event.GetId() - 1000)

    def change_plot(self, plot_number):
        t = np.arange(1.0, 3.0, 0.01)
        s = functions[plot_number][1](t)
        self.axes.clear()
        self.axes.plot(t, s)
        self.canvas.draw()

    def OnClose(self, event):
        self.Destroy()


class MyApp(wx.App):
    def OnInit(self):
        frame = CanvasFrame(None, "wxPython mathtext demo app")
        self.SetTopWindow(frame)
        frame.Show(True)
        return True


if __name__ == "__main__":
    app = MyApp()
    app.MainLoop()
```

Matplotlib with Glade 3

```
from pathlib import Path

import gi

gi.require_version('Gtk', '3.0')
from gi.repository import Gtk

import numpy as np

from matplotlib.backends.backend_gtk3agg import FigureCanvasGTK3Agg as␣
↪FigureCanvas
from matplotlib.figure import Figure


class Window1Signals:
    def on_window1_destroy(self, widget):
        Gtk.main_quit()


def main():
    builder = Gtk.Builder()
    builder.add_objects_from_file(
        str(Path(__file__).parent / "mpl_with_glade3.glade"),
        ("window1", ""))
    builder.connect_signals(Window1Signals())
    window = builder.get_object("window1")
    sw = builder.get_object("scrolledwindow1")

    # Start of Matplotlib specific code
    figure = Figure(figsize=(8, 6), dpi=71)
    axis = figure.add_subplot()
    t = np.arange(0.0, 3.0, 0.01)
    s = np.sin(2*np.pi*t)
    axis.plot(t, s)

    axis.set_xlabel('time [s]')
    axis.set_ylabel('voltage [V]')

    canvas = FigureCanvas(figure)  # a Gtk.DrawingArea
    canvas.set_size_request(800, 600)
    sw.add(canvas)
    # End of Matplotlib specific code

    window.show_all()
    Gtk.main()
```

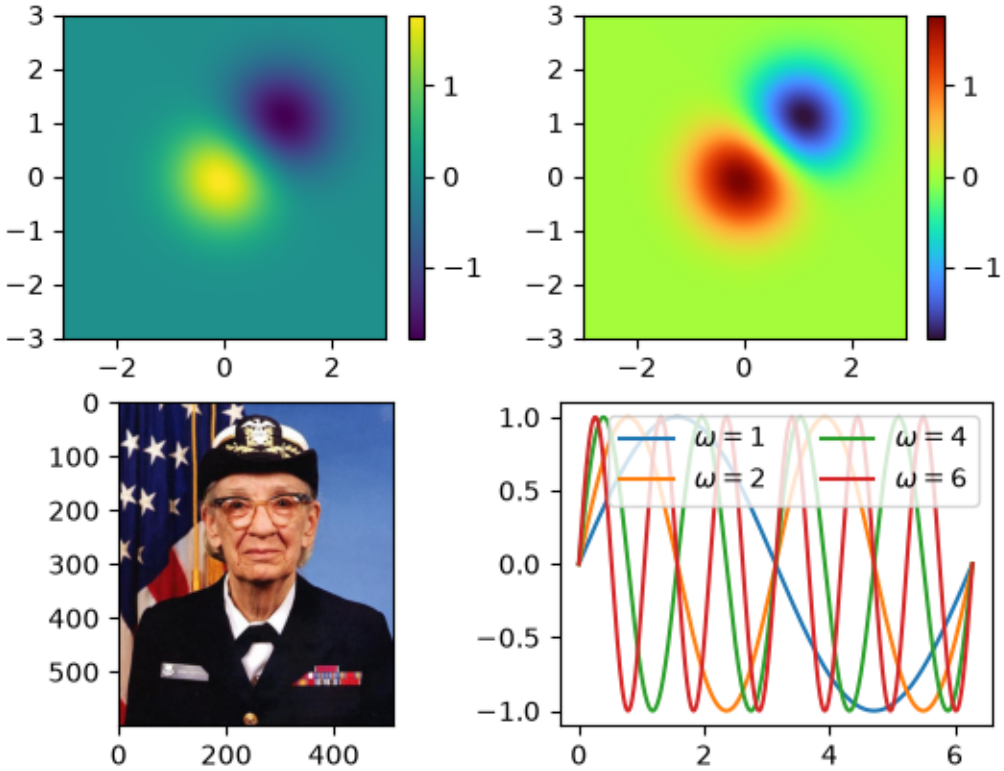
(continues on next page)

(continued from previous page)

```
if __name__ == "__main__":
    main()
```

mplcvd -- an example of figure hook

To use this hook, ensure that this module is in your `PYTHONPATH`, and set `rcParams["figure.hooks"] = ["mplcvd:setup"]`. This hook depends on the `colorspacious` third-party module.




```
import functools
from pathlib import Path

from PIL import Image
import colorspacious

import numpy as np

_BUTTON_NAME = "Filter"
_BUTTON_HELP = "Simulate color vision deficiencies"
```

(continues on next page)

(continued from previous page)

```
_MENU_ENTRIES = {
    "None": None,
    "Greyscale": "greyscale",
    "Deuteranopia": "deuteranomaly",
    "Protanopia": "protanomaly",
    "Tritanopia": "tritanomaly",
}


def _get_color_filter(name):
    """
    Given a color filter name, create a color filter function.

    Parameters
    ----------
    name : str
        The color filter name, one of the following:

        - ``"none"``: ...
        - ``"greyscale"``: Convert the input to luminosity.
        - ``"deuteranopia"``: Simulate the most common form of␣
↪red-green
          colorblindness.
        - ``"protanopia"``: Simulate a rarer form of red-green␣
↪colorblindness.
        - ``"tritanopia"``: Simulate the rare form of blue-yellow
          colorblindness.

        Color conversions use `colorspacious`_.

    Returns
    -------
    callable
        A color filter function that has the form:

        def filter(input: np.ndarray[M, N, D])-> np.ndarray[M, N, D]

        where (M, N) are the image dimensions, and D is the color␣
↪depth (3 for
        RGB, 4 for RGBA). Alpha is passed through unchanged and␣
↪otherwise
        ignored.
    """
    if name not in _MENU_ENTRIES:
        raise ValueError(f"Unsupported filter name: {name!r}")
    name = _MENU_ENTRIES[name]
```

(continues on next page)

(continued from previous page)

```
    if name is None:
        return None

    elif name == "greyscale":
        rgb_to_jch = colorspacious.cspace_converter("sRGB1", "JCh")
        jch_to_rgb = colorspacious.cspace_converter("JCh", "sRGB1")

        def convert(im):
            greyscale_JCh = rgb_to_jch(im)
            greyscale_JCh[..., 1] = 0
            im = jch_to_rgb(greyscale_JCh)
            return im

    else:
        cvd_space = {"name": "sRGB1+CVD", "cvd_type": name, "severity
": 100}
        convert = colorspacious.cspace_converter(cvd_space, "sRGB1")

    def filter_func(im, dpi):
        alpha = None
        if im.shape[-1] == 4:
            im, alpha = im[..., :3], im[..., 3]
        im = convert(im)
        if alpha is not None:
            im = np.dstack((im, alpha))
        return np.clip(im, 0, 1), 0, 0

    return filter_func


def _set_menu_entry(tb, name):
    tb.canvas.figure.set_agg_filter(_get_color_filter(name))
    tb.canvas.draw_idle()


def setup(figure):
    tb = figure.canvas.toolbar
    if tb is None:
        return
    for cls in type(tb).__mro__:
        pkg = cls.__module__.split(".")[0]
        if pkg != "matplotlib":
            break
    if pkg == "gi":
        _setup_gtk(tb)
```

(continues on next page)

(continued from previous page)

```
    elif pkg in ("PyQt5", "PySide2", "PyQt6", "PySide6"):
        _setup_qt(tb)
    elif pkg == "tkinter":
        _setup_tk(tb)
    elif pkg == "wx":
        _setup_wx(tb)
    else:
        raise NotImplementedError("The current backend is not supported
↪")


def _setup_gtk(tb):
    from gi.repository import Gio, GLib, Gtk

    for idx in range(tb.get_n_items()):
        children = tb.get_nth_item(idx).get_children()
        if children and isinstance(children[0], Gtk.Label):
            break

    toolitem = Gtk.SeparatorToolItem()
    tb.insert(toolitem, idx)

    image = Gtk.Image.new_from_gicon(
        Gio.Icon.new_for_string(
            str(Path(__file__).parent / "images/eye-symbolic.svg")),
        Gtk.IconSize.LARGE_TOOLBAR)

    # The type of menu is progressively downgraded depending on GTK␣
↪version.
    if Gtk.check_version(3, 6, 0) is None:

        group = Gio.SimpleActionGroup.new()
        action = Gio.SimpleAction.new_stateful("cvdsim",
                                               GLib.VariantType("s"),
                                               GLib.Variant("s", "none
↪"))
        group.add_action(action)

        @functools.partial(action.connect, "activate")
        def set_filter(action, parameter):
            _set_menu_entry(tb, parameter.get_string())
            action.set_state(parameter)

        menu = Gio.Menu()
        for name in _MENU_ENTRIES:
            menu.append(name, f"local.cvdsim::{name}")
```

(continues on next page)

(continued from previous page)

```
        button = Gtk.MenuButton.new()
        button.remove(button.get_children()[0])
        button.add(image)
        button.insert_action_group("local", group)
        button.set_menu_model(menu)
        button.get_style_context().add_class("flat")

        item = Gtk.ToolItem()
        item.add(button)
        tb.insert(item, idx + 1)

    else:

        menu = Gtk.Menu()
        group = []
        for name in _MENU_ENTRIES:
            item = Gtk.RadioMenuItem.new_with_label(group, name)
            item.set_active(name == "None")
            item.connect(
                "activate", lambda item: _set_menu_entry(tb, item.
 ↪get_label()))
            group.append(item)
            menu.append(item)
        menu.show_all()

        tbutton = Gtk.MenuToolButton.new(image, _BUTTON_NAME)
        tbutton.set_menu(menu)
        tb.insert(tbutton, idx + 1)

    tb.show_all()


def _setup_qt(tb):
    from matplotlib.backends.qt_compat import QtGui, QtWidgets

    menu = QtWidgets.QMenu()
    try:
        QActionGroup = QtGui.QActionGroup  # Qt6
    except AttributeError:
        QActionGroup = QtWidgets.QActionGroup  # Qt5
    group = QActionGroup(menu)
    group.triggered.connect(lambda action: _set_menu_entry(tb, action.
 ↪text()))

    for name in _MENU_ENTRIES:
```

(continues on next page)

(continued from previous page)

```
        action = menu.addAction(name)
        action.setCheckable(True)
        action.setActionGroup(group)
        action.setChecked(name == "None")

    actions = tb.actions()
    before = next(
        (action for action in actions
         if isinstance(tb.widgetForAction(action), QtWidgets.QLabel)),␣
↪None)

    tb.insertSeparator(before)
    button = QtWidgets.QToolButton()
    # FIXME: _icon needs public API.
    button.setIcon(tb._icon(str(Path(__file__).parent / "images/eye.png
↪")))
    button.setText(_BUTTON_NAME)
    button.setToolTip(_BUTTON_HELP)
    button.setPopupMode(QtWidgets.QToolButton.ToolButtonPopupMode.
↪InstantPopup)
    button.setMenu(menu)
    tb.insertWidget(before, button)


def _setup_tk(tb):
    import tkinter as tk

    tb._Spacer()  # FIXME: _Spacer needs public API.

    button = tk.Menubutton(master=tb, relief="raised")
    button._image_file = str(Path(__file__).parent / "images/eye.png")
    # FIXME: _set_image_for_button needs public API (perhaps like _
↪icon).
    tb._set_image_for_button(button)
    button.pack(side=tk.LEFT)

    menu = tk.Menu(master=button, tearoff=False)
    for name in _MENU_ENTRIES:
        menu.add("radiobutton", label=name,
                 command=lambda _name=name: _set_menu_entry(tb, _name))
    menu.invoke(0)
    button.config(menu=menu)


def _setup_wx(tb):
    import wx
```

(continues on next page)

(continued from previous page)

```
    idx = next(idx for idx in range(tb.ToolsCount)
               if tb.GetToolByPos(idx).IsStretchableSpace())
    tb.InsertSeparator(idx)
    tool = tb.InsertTool(
        idx + 1, -1, _BUTTON_NAME,
        # FIXME: _icon needs public API.
        tb._icon(str(Path(__file__).parent / "images/eye.png")),
        # FIXME: ITEM_DROPDOWN is not supported on macOS.
        kind=wx.ITEM_DROPDOWN, shortHelp=_BUTTON_HELP)

    menu = wx.Menu()
    for name in _MENU_ENTRIES:
        item = menu.AppendRadioItem(-1, name)
        menu.Bind(
            wx.EVT_MENU,
            lambda event, _name=name: _set_menu_entry(tb, _name),
            id=item.Id,
        )
    tb.SetDropdownMenu(tool.Id, menu)


if __name__ == '__main__':
    import matplotlib.pyplot as plt

    from matplotlib import cbook

    plt.rcParams['figure.hooks'].append('mplcvd:setup')

    fig, axd = plt.subplot_mosaic(
        [
            ['viridis', 'turbo'],
            ['photo', 'lines']
        ]
    )

    delta = 0.025
    x = y = np.arange(-3.0, 3.0, delta)
    X, Y = np.meshgrid(x, y)
    Z1 = np.exp(-X**2 - Y**2)
    Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
    Z = (Z1 - Z2) * 2

    imv = axd['viridis'].imshow(
        Z, interpolation='bilinear',
        origin='lower', extent=[-3, 3, -3, 3],
```

(continues on next page)

(continued from previous page)

```
        vmax=abs(Z).max(), vmin=-abs(Z).max()
    )
    fig.colorbar(imv)
    imt = axd['turbo'].imshow(
        Z, interpolation='bilinear', cmap='turbo',
        origin='lower', extent=[-3, 3, -3, 3],
        vmax=abs(Z).max(), vmin=-abs(Z).max()
    )
    fig.colorbar(imt)

    # A sample image
    photo = Image.open(cbook.get_sample_data("grace_hopper.jpg"))
    axd['photo'].imshow(photo)

    th = np.linspace(0, 2*np.pi, 1024)
    for j in [1, 2, 4, 6]:
        axd['lines'].plot(th, np.sin(th * j), label=f'$\\omega={j}$')
    axd['lines'].legend(ncols=2, loc='upper right')
    plt.show()
```

pyplot with GTK3

An example of how to use pyplot to manage your figure windows, but modify the GUI by accessing the underlying GTK widgets.

```
import matplotlib

matplotlib.use('GTK3Agg')  # or 'GTK3Cairo'
import gi

import matplotlib.pyplot as plt

gi.require_version('Gtk', '3.0')
from gi.repository import Gtk

fig, ax = plt.subplots()
ax.plot([1, 2, 3], 'ro-', label='easy as 1 2 3')
ax.plot([1, 4, 9], 'gs--', label='easy as 1 2 3 squared')
ax.legend()

manager = fig.canvas.manager
# you can access the window or vbox attributes this way
toolbar = manager.toolbar
vbox = manager.vbox

# now let's add a button to the toolbar
```

(continues on next page)

(continued from previous page)

```
button = Gtk.Button(label='Click me')
button.show()
button.connect('clicked', lambda button: print('hi mom'))

toolitem = Gtk.ToolItem()
toolitem.show()
toolitem.set_tooltip_text('Click me for fun and profit')
toolitem.add(button)

pos = 8  # where to insert this in the toolbar
toolbar.insert(toolitem, pos)

# now let's add a widget to the vbox
label = Gtk.Label()
label.set_markup('Drag mouse over axes for position')
label.show()
vbox.pack_start(label, False, False, 0)
vbox.reorder_child(toolbar, -1)


def update(event):
    if event.xdata is None:
        label.set_markup('Drag mouse over axes for position')
    else:
        label.set_markup(
            f'<span color="#ef0000">x,y=({event.xdata}, {event.ydata}
 ↪)</span>')


fig.canvas.mpl_connect('motion_notify_event', update)

plt.show()
```

pyplot with GTK4

An example of how to use pyplot to manage your figure windows, but modify the GUI by accessing the underlying GTK widgets.

```
import matplotlib

matplotlib.use('GTK4Agg')  # or 'GTK4Cairo'
import gi

import matplotlib.pyplot as plt

gi.require_version('Gtk', '4.0')
```

(continues on next page)

(continued from previous page)

```
from gi.repository import Gtk

fig, ax = plt.subplots()
ax.plot([1, 2, 3], 'ro-', label='easy as 1 2 3')
ax.plot([1, 4, 9], 'gs--', label='easy as 1 2 3 squared')
ax.legend()

manager = fig.canvas.manager
# you can access the window or vbox attributes this way
toolbar = manager.toolbar
vbox = manager.vbox

# now let's add a button to the toolbar
button = Gtk.Button(label='Click me')
button.connect('clicked', lambda button: print('hi mom'))
button.set_tooltip_text('Click me for fun and profit')
toolbar.append(button)

# now let's add a widget to the vbox
label = Gtk.Label()
label.set_markup('Drag mouse over axes for position')
vbox.insert_child_after(label, fig.canvas)


def update(event):
    if event.xdata is None:
        label.set_markup('Drag mouse over axes for position')
    else:
        label.set_markup(
            f'<span color="#ef0000">x,y=({event.xdata}, {event.ydata}
 ↪)</span>')


fig.canvas.mpl_connect('motion_notify_event', update)

plt.show()
```

SVG Histogram

Demonstrate how to create an interactive histogram, in which bars are hidden or shown by clicking on legend markers.

The interactivity is encoded in ecmascript (javascript) and inserted in the SVG code in a post-processing step. To render the image, open it in a web browser. SVG is supported in most web browsers used by Linux and macOS users. Windows IE9 supports SVG, but earlier versions do not.

Notes

The matplotlib backend lets us assign ids to each object. This is the mechanism used here to relate matplotlib objects created in python and the corresponding SVG constructs that are parsed in the second step. While flexible, ids are cumbersome to use for large collection of objects. Two mechanisms could be used to simplify things:

- systematic grouping of objects into SVG <g> tags,
- assigning classes to each SVG object according to its origin.

For example, instead of modifying the properties of each individual bar, the bars from the *hist* function could either be grouped in a PatchCollection, or be assigned a class="hist_##" attribute.

CSS could also be used more extensively to replace repetitive markup throughout the generated SVG.

Author: david.huard@gmail.com

```
from io import BytesIO
import json
import xml.etree.ElementTree as ET

import matplotlib.pyplot as plt
import numpy as np

plt.rcParams['svg.fonttype'] = 'none'

# Apparently, this `register_namespace` method is necessary to avoid␣
 ↪garbling
# the XML namespace with ns0.
ET.register_namespace("", "http://www.w3.org/2000/svg")

# Fixing random state for reproducibility
np.random.seed(19680801)

# --- Create histogram, legend and title ---
plt.figure()
r = np.random.randn(100)
r1 = r + 1
labels = ['Rabbits', 'Frogs']
H = plt.hist([r, r1], label=labels)
containers = H[-1]
leg = plt.legend(frameon=False)
plt.title("From a web browser, click on the legend\n"
          "marker to toggle the corresponding histogram.")


# --- Add ids to the svg objects we'll modify

hist_patches = {}
```

(continues on next page)

(continued from previous page)

```
for ic, c in enumerate(containers):
    hist_patches[f'hist_{ic}'] = []
    for il, element in enumerate(c):
        element.set_gid(f'hist_{ic}_patch_{il}')
        hist_patches[f'hist_{ic}'].append(f'hist_{ic}_patch_{il}')

# Set ids for the legend patches
for i, t in enumerate(leg.get_patches()):
    t.set_gid(f'leg_patch_{i}')

# Set ids for the text patches
for i, t in enumerate(leg.get_texts()):
    t.set_gid(f'leg_text_{i}')

# Save SVG in a fake file object.
f = BytesIO()
plt.savefig(f, format="svg")

# Create XML tree from the SVG file.
tree, xmlid = ET.XMLID(f.getvalue())


# --- Add interactivity ---

# Add attributes to the patch objects.
for i, t in enumerate(leg.get_patches()):
    el = xmlid[f'leg_patch_{i}']
    el.set('cursor', 'pointer')
    el.set('onclick', "toggle_hist(this)")

# Add attributes to the text objects.
for i, t in enumerate(leg.get_texts()):
    el = xmlid[f'leg_text_{i}']
    el.set('cursor', 'pointer')
    el.set('onclick', "toggle_hist(this)")

# Create script defining the function `toggle_hist`.
# We create a global variable `container` that stores the patches id
# belonging to each histogram. Then a function "toggle_element" sets␣
 ↪the
# visibility attribute of all patches of each histogram and the opacity
# of the marker itself.

script = """
<script type="text/ecmascript">
<![CDATA[
```

(continues on next page)

(continued from previous page)

```
var container = %s

function toggle(oid, attribute, values) {
    /* Toggle the style attribute of an object between two values.

    Parameters
    ----------
    oid : str
      Object identifier.
    attribute : str
      Name of style attribute.
    values : [on state, off state]
      The two values that are switched between.
    */
    var obj = document.getElementById(oid);
    var a = obj.style[attribute];

    a = (a == values[0] || a == "") ? values[1] : values[0];
    obj.style[attribute] = a;
    }

function toggle_hist(obj) {

    var num = obj.id.slice(-1);

    toggle('leg_patch_' + num, 'opacity', [1, 0.3]);
    toggle('leg_text_' + num, 'opacity', [1, 0.5]);

    var names = container['hist_'+num]

    for (var i=0; i < names.length; i++) {
        toggle(names[i], 'opacity', [1, 0])
    };
    }
]]>
</script>
""" % json.dumps(hist_patches)

# Add a transition effect
css = tree.find('.//{http://www.w3.org/2000/svg}style')
css.text = css.text + "g {-webkit-transition:opacity 0.4s ease-out;" +␣
 ↪\
    "-moz-transition:opacity 0.4s ease-out;}"

# Insert the script and save to file.
tree.insert(0, ET.XML(script))
```

(continues on next page)

(continued from previous page)

```
ET.ElementTree(tree).write("svg_histogram.svg")
```

SVG Tooltip

This example shows how to create a tooltip that will show up when hovering over a matplotlib patch.

Although it is possible to create the tooltip from CSS or javascript, here we create it in matplotlib and simply toggle its visibility on when hovering over the patch. This approach provides total control over the tooltip placement and appearance, at the expense of more code up front.

The alternative approach would be to put the tooltip content in `title` attributes of SVG objects. Then, using an existing js/CSS library, it would be relatively straightforward to create the tooltip in the browser. The content would be dictated by the `title` attribute, and the appearance by the CSS.

author

David Huard

```
from io import BytesIO
import xml.etree.ElementTree as ET

import matplotlib.pyplot as plt

ET.register_namespace("", "http://www.w3.org/2000/svg")

fig, ax = plt.subplots()

# Create patches to which tooltips will be assigned.
rect1 = plt.Rectangle((10, -20), 10, 5, fc='blue')
rect2 = plt.Rectangle((-20, 15), 10, 5, fc='green')

shapes = [rect1, rect2]
labels = ['This is a blue rectangle.', 'This is a green rectangle']

for i, (item, label) in enumerate(zip(shapes, labels)):
    patch = ax.add_patch(item)
    annotate = ax.annotate(labels[i], xy=item.get_xy(), xytext=(0, 0),
                           textcoords='offset points', color='w', ha=
 ↪'center',
                           fontsize=8, bbox=dict(boxstyle='round,␣
 ↪pad=.5',
                                                 fc=(.1, .1, .1, .92),
                                                 ec=(1., 1., 1.), lw=1,
                                                 zorder=1))

    ax.add_patch(patch)
    patch.set_gid(f'mypatch_{i:03d}')
```

(continues on next page)

(continued from previous page)

```
    annotate.set_gid(f'mytooltip_{i:03d}')

# Save the figure in a fake file object
ax.set_xlim(-30, 30)
ax.set_ylim(-30, 30)
ax.set_aspect('equal')

f = BytesIO()
plt.savefig(f, format="svg")

# --- Add interactivity ---

# Create XML tree from the SVG file.
tree, xmlid = ET.XMLID(f.getvalue())
tree.set('onload', 'init(event)')

for i in shapes:
    # Get the index of the shape
    index = shapes.index(i)
    # Hide the tooltips
    tooltip = xmlid[f'mytooltip_{index:03d}']
    tooltip.set('visibility', 'hidden')
    # Assign onmouseover and onmouseout callbacks to patches.
    mypatch = xmlid[f'mypatch_{index:03d}']
    mypatch.set('onmouseover', "ShowTooltip(this)")
    mypatch.set('onmouseout', "HideTooltip(this)")

# This is the script defining the ShowTooltip and HideTooltip␣
 ↪functions.
script = """
    <script type="text/ecmascript">
    <![CDATA[

    function init(event) {
        if ( window.svgDocument == null ) {
            svgDocument = event.target.ownerDocument;
            }
        }

    function ShowTooltip(obj) {
        var cur = obj.id.split("_")[1];
        var tip = svgDocument.getElementById('mytooltip_' + cur);
        tip.setAttribute('visibility', "visible")
        }

    function HideTooltip(obj) {
```

(continues on next page)

(continued from previous page)

```
        var cur = obj.id.split("_")[1];
        var tip = svgDocument.getElementById('mytooltip_' + cur);
        tip.setAttribute('visibility', "hidden")
        }

    ]]>
    </script>
    """

# Insert the script at the top of the file and save it.
tree.insert(0, ET.XML(script))
ET.ElementTree(tree).write('svg_tooltip.svg')
```

Tool Manager

This example demonstrates how to

- modify the Toolbar
- create tools
- add tools
- remove tools

using *matplotlib.backend_managers.ToolManager*.

```
import matplotlib.pyplot as plt

from matplotlib.backend_tools import ToolBase, ToolToggleBase

plt.rcParams['toolbar'] = 'toolmanager'


class ListTools(ToolBase):
    """List all the tools controlled by the `ToolManager`."""
    default_keymap = 'm'  # keyboard shortcut
    description = 'List Tools'

    def trigger(self, *args, **kwargs):
        print('_' * 80)
        fmt_tool = "{:12} {:45} {}".format
        print(fmt_tool('Name (id)', 'Tool description', 'Keymap'))
        print('-' * 80)
        tools = self.toolmanager.tools
        for name in sorted(tools):
            if not tools[name].description:
                continue
```

(continues on next page)

(continued from previous page)

```
            keys = ', '.join(sorted(self.toolmanager.
 ↪get_tool_keymap(name)))
            print(fmt_tool(name, tools[name].description, keys))
        print('_' * 80)
        fmt_active_toggle = "{!s:12} {!s:45}".format
        print("Active Toggle tools")
        print(fmt_active_toggle("Group", "Active"))
        print('-' * 80)
        for group, active in self.toolmanager.active_toggle.items():
            print(fmt_active_toggle(group, active))


class GroupHideTool(ToolToggleBase):
    """Show lines with a given gid."""
    default_keymap = 'S'
    description = 'Show by gid'
    default_toggled = True

    def __init__(self, *args, gid, **kwargs):
        self.gid = gid
        super().__init__(*args, **kwargs)

    def enable(self, *args):
        self.set_lines_visibility(True)

    def disable(self, *args):
        self.set_lines_visibility(False)

    def set_lines_visibility(self, state):
        for ax in self.figure.get_axes():
            for line in ax.get_lines():
                if line.get_gid() == self.gid:
                    line.set_visible(state)
        self.figure.canvas.draw()


fig = plt.figure()
plt.plot([1, 2, 3], gid='mygroup')
plt.plot([2, 3, 4], gid='unknown')
plt.plot([3, 2, 1], gid='mygroup')

# Add the custom tools that we created
fig.canvas.manager.toolmanager.add_tool('List', ListTools)
fig.canvas.manager.toolmanager.add_tool('Show', GroupHideTool, gid=
 ↪'mygroup')
```

(continues on next page)

(continued from previous page)

```
# Add an existing tool to new group `foo`.
# It can be added as many times as we want
fig.canvas.manager.toolbar.add_tool('zoom', 'foo')

# Remove the forward button
fig.canvas.manager.toolmanager.remove_tool('forward')

# To add a custom tool to the toolbar at specific location inside
# the navigation group
fig.canvas.manager.toolbar.add_tool('Show', 'navigation', 1)

plt.show()
```

Embed in a web application server (Flask)

When using Matplotlib in a web server it is strongly recommended to not use pyplot (pyplot maintains references to the opened figures to make *show* work, but this will cause memory leaks unless the figures are properly closed).

Since Matplotlib 3.1, one can directly create figures using the *Figure* constructor and save them to in-memory buffers. In older versions, it was necessary to explicitly instantiate an Agg canvas (see e.g. *CanvasAgg demo*).

The following example uses Flask, but other frameworks work similarly:

```
import base64
from io import BytesIO

from flask import Flask

from matplotlib.figure import Figure

app = Flask(__name__)


@app.route("/")
def hello():
    # Generate the figure **without using pyplot**.
    fig = Figure()
    ax = fig.subplots()
    ax.plot([1, 2])
    # Save it to a temporary buffer.
    buf = BytesIO()
    fig.savefig(buf, format="png")
    # Embed the result in the html output.
    data = base64.b64encode(buf.getbuffer()).decode("ascii")
    return f"<img src='{data}'/>"
```

Since the above code is a Flask application, it should be run using the flask command-line tool: run

```
flask --app web_application_server_sgskip run
```

from the directory containing this script.

Clickable images for HTML

Andrew Dalke of Dalke Scientific has written a nice article on how to make html click maps with Matplotlib agg PNGs. We would also like to add this functionality to SVG. If you are interested in contributing to these efforts that would be great.

Add a cursor in WX

Example to draw a cursor and report the data coords in wx.

```
import wx

import numpy as np

from matplotlib.backends.backend_wx import NavigationToolbar2Wx
from matplotlib.backends.backend_wxagg import FigureCanvasWxAgg as␣
 ↪FigureCanvas
from matplotlib.figure import Figure


class CanvasFrame(wx.Frame):
    def __init__(self, ):
        super().__init__(None, -1, 'CanvasFrame', size=(550, 350))

        self.figure = Figure()
        self.axes = self.figure.add_subplot()
        t = np.arange(0.0, 3.0, 0.01)
        s = np.sin(2*np.pi*t)

        self.axes.plot(t, s)
        self.axes.set_xlabel('t')
        self.axes.set_ylabel('sin(t)')
        self.figure_canvas = FigureCanvas(self, -1, self.figure)

        # Note that event is a MplEvent
        self.figure_canvas.mpl_connect(
            'motion_notify_event', self.UpdateStatusBar)
        self.figure_canvas.Bind(wx.EVT_ENTER_WINDOW, self.ChangeCursor)

        self.sizer = wx.BoxSizer(wx.VERTICAL)
        self.sizer.Add(self.figure_canvas, 1, wx.LEFT | wx.TOP | wx.
 ↪GROW)
```

(continues on next page)

(continued from previous page)

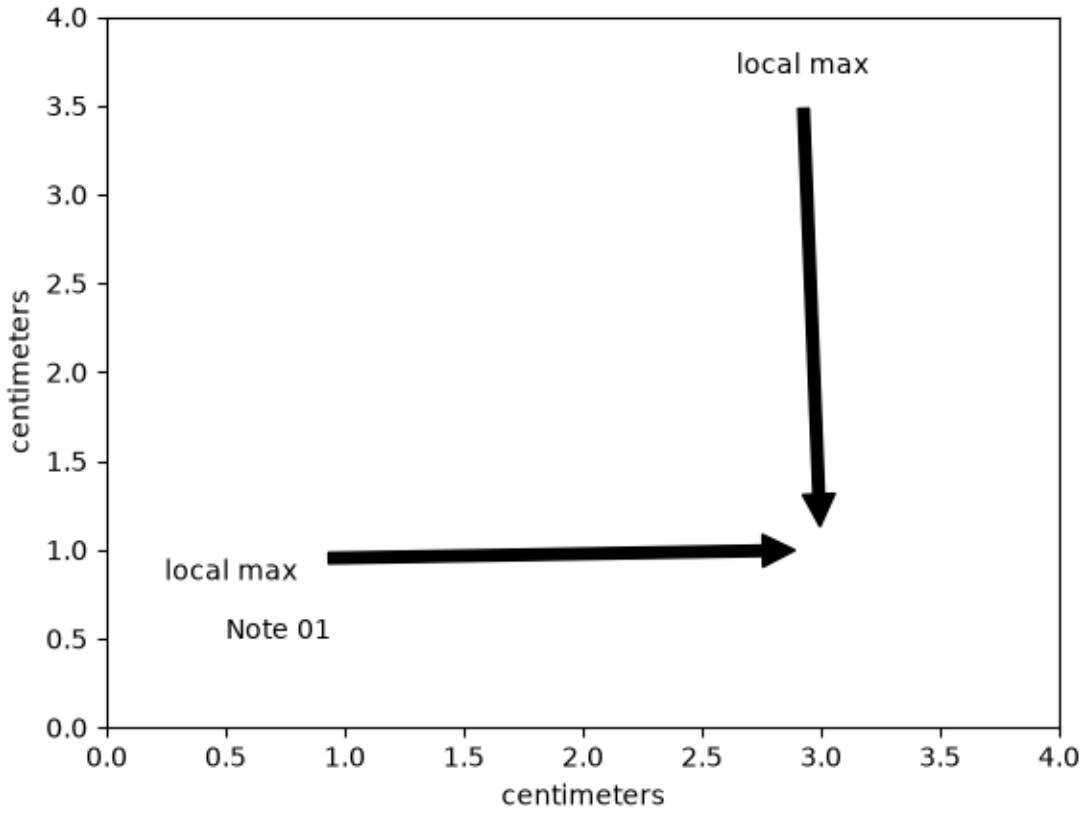
```
        self.SetSizer(self.sizer)
        self.Fit()

        self.statusBar = wx.StatusBar(self, -1)
        self.SetStatusBar(self.statusBar)

        self.toolbar = NavigationToolbar2Wx(self.figure_canvas)
        self.sizer.Add(self.toolbar, 0, wx.LEFT | wx.EXPAND)
        self.toolbar.Show()

    def ChangeCursor(self, event):
        self.figure_canvas.SetCursor(wx.Cursor(wx.CURSOR_BULLSEYE))

    def UpdateStatusBar(self, event):
        if event.inaxes:
            self.statusBar.SetStatusText(f"x={event.xdata}  y={event.
 ↪ydata}")


class App(wx.App):
    def OnInit(self):
        """Create the main window and insert the custom frame."""
        frame = CanvasFrame()
        self.SetTopWindow(frame)
        frame.Show(True)
        return True


if __name__ == '__main__':
    app = App()
    app.MainLoop()
```

6.24.21 Units

These examples cover the many representations of units in Matplotlib.

Annotation with units

The example illustrates how to create text and arrow annotations using a centimeter-scale plot.




```
from basic_units import cm

import matplotlib.pyplot as plt

fig, ax = plt.subplots()

ax.annotate("Note 01", [0.5*cm, 0.5*cm])

# xy and text both unitized
ax.annotate('local max', xy=(3*cm, 1*cm), xycoords='data',
            xytext=(0.8*cm, 0.95*cm), textcoords='data',
            arrowprops=dict(facecolor='black', shrink=0.05),
            horizontalalignment='right', verticalalignment='top')

# mixing units w/ nonunits
ax.annotate('local max', xy=(3*cm, 1*cm), xycoords='data',
            xytext=(0.8, 0.95), textcoords='axes fraction',
            arrowprops=dict(facecolor='black', shrink=0.05),
            horizontalalignment='right', verticalalignment='top')
```

(continues on next page)

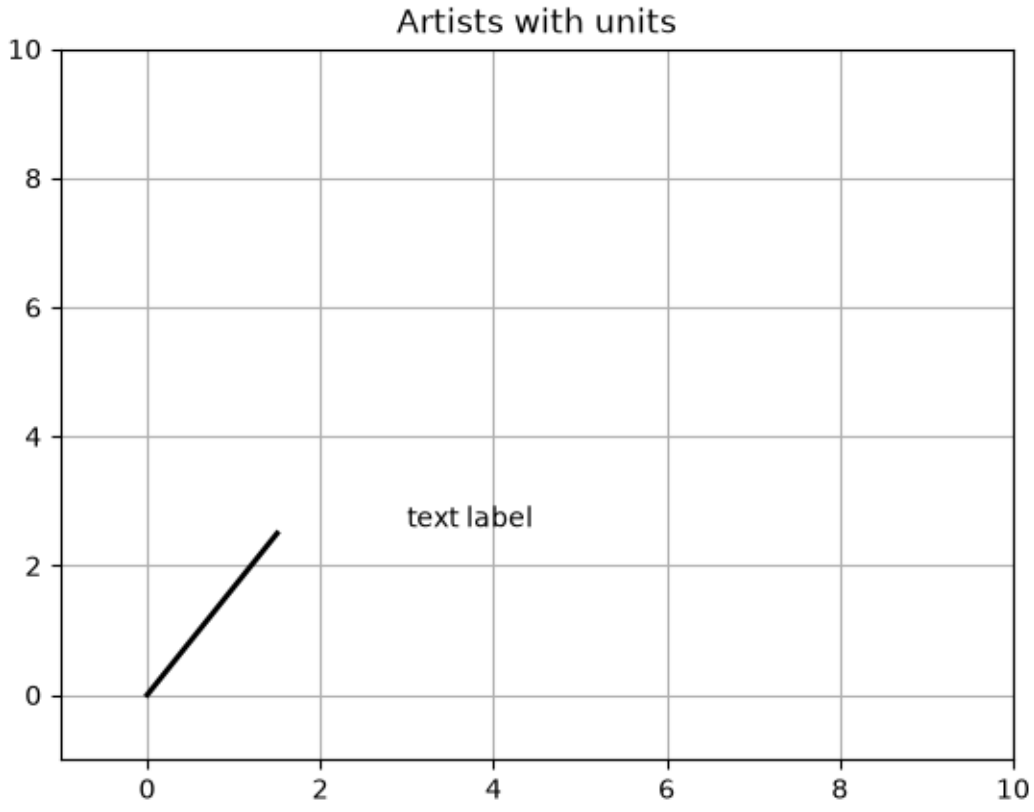
(continued from previous page)

```
ax.set_xlim(0*cm, 4*cm)
ax.set_ylim(0*cm, 4*cm)
plt.show()
```

Artist tests

Test unit support with each of the Matplotlib primitive artist types.

The axis handles unit conversions and the artists keep a pointer to their axis parent. You must initialize the artists with the axis instance if you want to use them with unit data, or else they will not know how to convert the units to scalars.




```
import random

from basic_units import cm, inch

import matplotlib.pyplot as plt
import numpy as np
```

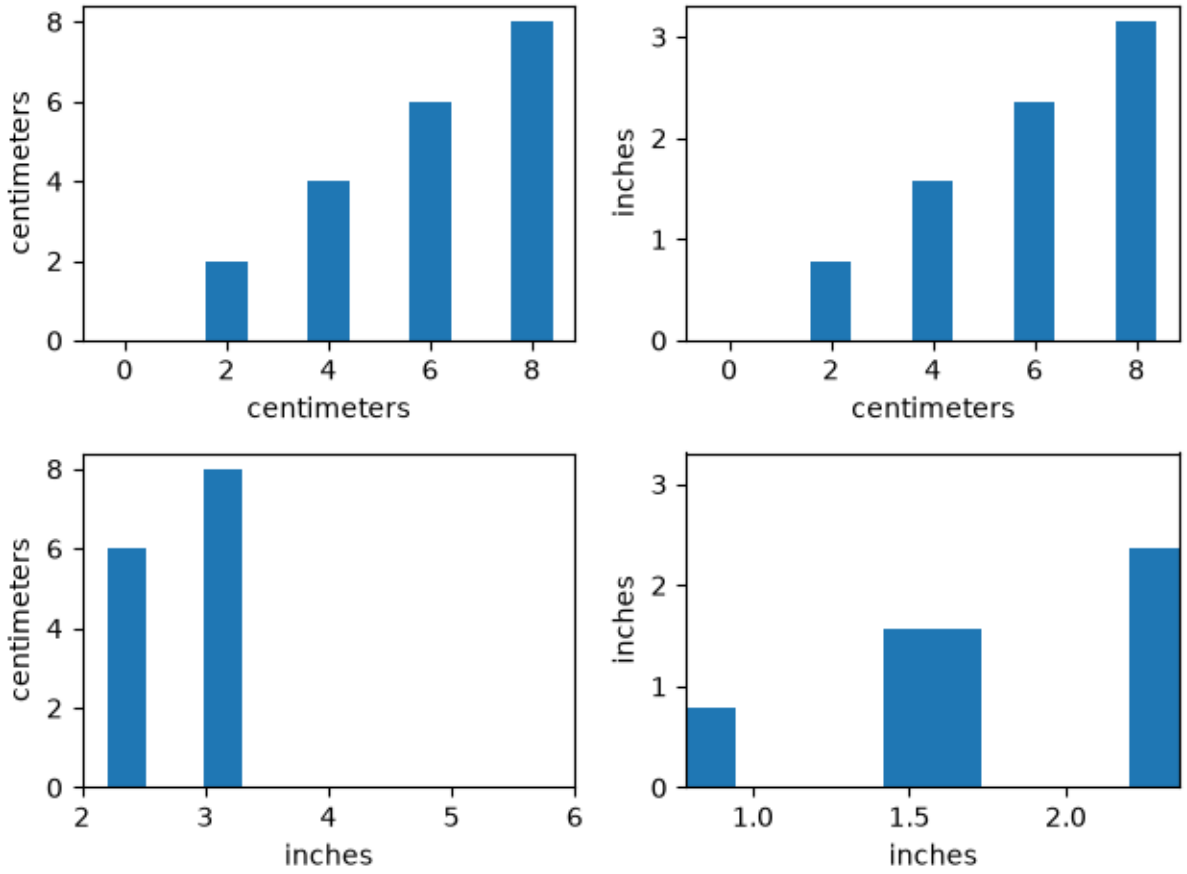
(continues on next page)

(continued from previous page)

```
import matplotlib.collections as collections
import matplotlib.lines as lines
import matplotlib.patches as patches
import matplotlib.text as text

fig, ax = plt.subplots()
ax.xaxis.set_units(cm)
ax.yaxis.set_units(cm)

# Fixing random state for reproducibility
np.random.seed(19680801)

if 0:
    # test a line collection
    # Not supported at present.
    verts = []
    for i in range(10):
        # a random line segment in inches
        verts.append(zip(*inch*10*np.random.rand(2, random.randint(2,␣
 ↪15))))
    lc = collections.LineCollection(verts, axes=ax)
    ax.add_collection(lc)

# test a plain-ol-line
line = lines.Line2D([0*cm, 1.5*cm], [0*cm, 2.5*cm],
                    lw=2, color='black', axes=ax)
ax.add_line(line)

if 0:
    # test a patch
    # Not supported at present.
    rect = patches.Rectangle((1*cm, 1*cm), width=5*cm, height=2*cm,
                             alpha=0.2, axes=ax)
    ax.add_patch(rect)


t = text.Text(3*cm, 2.5*cm, 'text label', ha='left', va='bottom',␣
 ↪axes=ax)
ax.add_artist(t)

ax.set_xlim(-1*cm, 10*cm)
ax.set_ylim(-1*cm, 10*cm)
# ax.xaxis.set_units(inch)
ax.grid(True)
ax.set_title("Artists with units")
plt.show()
```

Bar demo with units

A plot using a variety of centimetre and inch conversions. This example shows how default unit introspection works (ax1), how various keywords can be used to set the x and y units to override the defaults (ax2, ax3, ax4) and how one can set the xlimits using scalars (ax3, current units assumed) or units (conversions applied to get the numbers to current units).




```
from basic_units import cm, inch

import matplotlib.pyplot as plt
import numpy as np

cms = cm * np.arange(0, 10, 2)
bottom = 0 * cm
width = 0.8 * cm

fig, axs = plt.subplots(2, 2)

axs[0, 0].bar(cms, cms, bottom=bottom)

axs[0, 1].bar(cms, cms, bottom=bottom, width=width, xunits=cm,␣
```

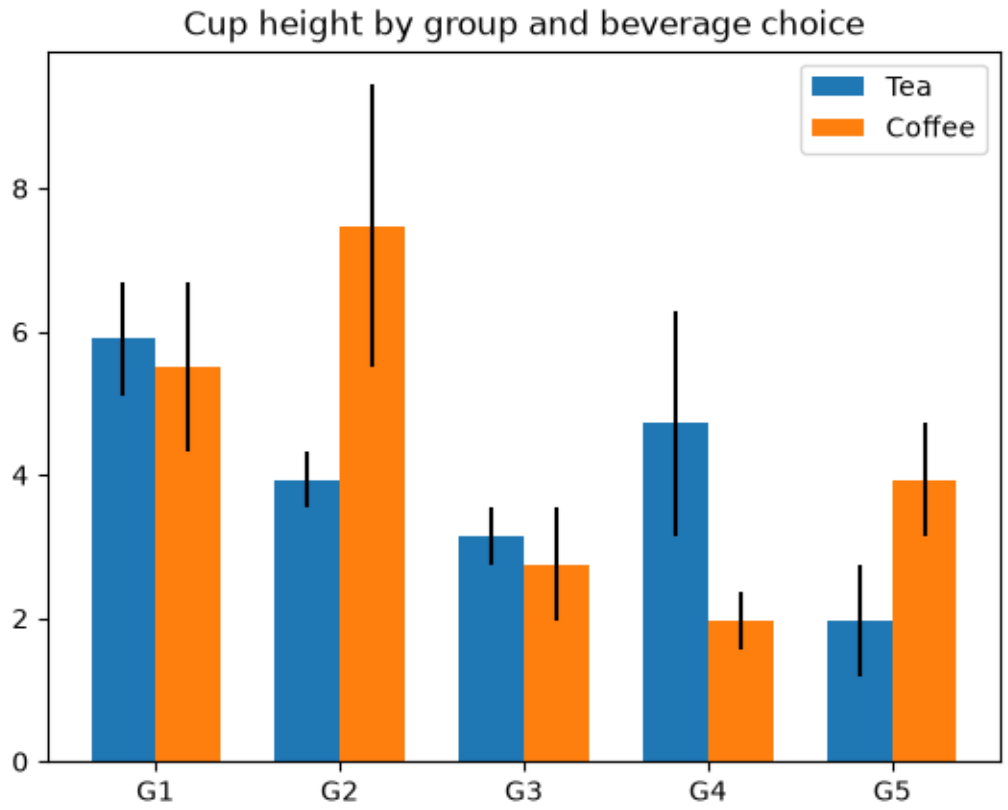
(continues on next page)

(continued from previous page)

```
 ↪yunits=inch)

axs[1, 0].bar(cms, cms, bottom=bottom, width=width, xunits=inch,␣
 ↪yunits=cm)
axs[1, 0].set_xlim(2, 6)  # scalars are interpreted in current units

axs[1, 1].bar(cms, cms, bottom=bottom, width=width, xunits=inch,␣
 ↪yunits=inch)
axs[1, 1].set_xlim(2 * cm, 6 * cm)  # cm are converted to inches

fig.tight_layout()
plt.show()
```

Group barchart with units

This is the same example as *the barchart* in centimeters.




```
from basic_units import cm, inch
```

(continues on next page)

(continued from previous page)

```
import matplotlib.pyplot as plt
import numpy as np

N = 5
tea_means = [15*cm, 10*cm, 8*cm, 12*cm, 5*cm]
tea_std = [2*cm, 1*cm, 1*cm, 4*cm, 2*cm]

fig, ax = plt.subplots()
ax.yaxis.set_units(inch)

ind = np.arange(N)    # the x locations for the groups
width = 0.35          # the width of the bars
ax.bar(ind, tea_means, width, bottom=0*cm, yerr=tea_std, label='Tea')

coffee_means = (14*cm, 19*cm, 7*cm, 5*cm, 10*cm)
coffee_std = (3*cm, 5*cm, 2*cm, 1*cm, 2*cm)
ax.bar(ind + width, coffee_means, width, bottom=0*cm, yerr=coffee_std,
       label='Coffee')

ax.set_title('Cup height by group and beverage choice')
ax.set_xticks(ind + width / 2, labels=['G1', 'G2', 'G3', 'G4', 'G5'])

ax.legend()
ax.autoscale_view()

plt.show()
```

Basic units

This file implements a units library that supports registering arbitrary units, conversions between units, and math with unitized data. This library also implements a Matplotlib unit converter and registers its units with Matplotlib. This library is used in the examples to demonstrate Matplotlib's unit support. It is only maintained for the purposes of building documentation and should never be used outside of the Matplotlib documentation.

```
import itertools
import math

from packaging.version import parse as parse_version

import numpy as np

import matplotlib.ticker as ticker
import matplotlib.units as units
```

(continues on next page)

(continued from previous page)

```
class ProxyDelegate:
    def __init__(self, fn_name, proxy_type):
        self.proxy_type = proxy_type
        self.fn_name = fn_name

    def __get__(self, obj, objtype=None):
        return self.proxy_type(self.fn_name, obj)


class TaggedValueMeta(type):
    def __init__(self, name, bases, dict):
        for fn_name in self._proxies:
            if not hasattr(self, fn_name):
                setattr(self, fn_name,
                        ProxyDelegate(fn_name, self._proxies[fn_name]))


class PassThroughProxy:
    def __init__(self, fn_name, obj):
        self.fn_name = fn_name
        self.target = obj.proxy_target

    def __call__(self, *args):
        fn = getattr(self.target, self.fn_name)
        ret = fn(*args)
        return ret


class ConvertArgsProxy(PassThroughProxy):
    def __init__(self, fn_name, obj):
        super().__init__(fn_name, obj)
        self.unit = obj.unit

    def __call__(self, *args):
        converted_args = []
        for a in args:
            try:
                converted_args.append(a.convert_to(self.unit))
            except AttributeError:
                converted_args.append(TaggedValue(a, self.unit))
        converted_args = tuple([c.get_value() for c in converted_args])
        return super().__call__(*converted_args)


class ConvertReturnProxy(PassThroughProxy):
    def __init__(self, fn_name, obj):
```

(continues on next page)

(continued from previous page)

```
        super().__init__(fn_name, obj)
        self.unit = obj.unit

    def __call__(self, *args):
        ret = super().__call__(*args)
        return (NotImplemented if ret is NotImplemented
                else TaggedValue(ret, self.unit))


class ConvertAllProxy(PassThroughProxy):
    def __init__(self, fn_name, obj):
        super().__init__(fn_name, obj)
        self.unit = obj.unit

    def __call__(self, *args):
        converted_args = []
        arg_units = [self.unit]
        for a in args:
            if hasattr(a, 'get_unit') and not hasattr(a, 'convert_to'):
                # If this argument has a unit type but no conversion␣
↪ability,
                # this operation is prohibited.
                return NotImplemented

            if hasattr(a, 'convert_to'):
                try:
                    a = a.convert_to(self.unit)
                except Exception:
                    pass
                arg_units.append(a.get_unit())
                converted_args.append(a.get_value())
            else:
                converted_args.append(a)
                if hasattr(a, 'get_unit'):
                    arg_units.append(a.get_unit())
                else:
                    arg_units.append(None)
        converted_args = tuple(converted_args)
        ret = super().__call__(*converted_args)
        if ret is NotImplemented:
            return NotImplemented
        ret_unit = unit_resolver(self.fn_name, arg_units)
        if ret_unit is NotImplemented:
            return NotImplemented
        return TaggedValue(ret, ret_unit)
```

(continues on next page)

(continued from previous page)

```
class TaggedValue(metaclass=TaggedValueMeta):

    _proxies = {'__add__': ConvertAllProxy,
                '__sub__': ConvertAllProxy,
                '__mul__': ConvertAllProxy,
                '__rmul__': ConvertAllProxy,
                '__cmp__': ConvertAllProxy,
                '__lt__': ConvertAllProxy,
                '__gt__': ConvertAllProxy,
                '__len__': PassThroughProxy}

    def __new__(cls, value, unit):
        # generate a new subclass for value
        value_class = type(value)
        try:
            subcls = type(f'TaggedValue_of_{value_class.__name__}',
                          (cls, value_class), {})
            return object.__new__(subcls)
        except TypeError:
            return object.__new__(cls)

    def __init__(self, value, unit):
        self.value = value
        self.unit = unit
        self.proxy_target = self.value

    def __copy__(self):
        return TaggedValue(self.value, self.unit)

    def __getattribute__(self, name):
        if name.startswith('__'):
            return object.__getattribute__(self, name)
        variable = object.__getattribute__(self, 'value')
        if hasattr(variable, name) and name not in self.__class__.__
↪dict__:
            return getattr(variable, name)
        return object.__getattribute__(self, name)

    def __array__(self, dtype=object, copy=False):
        return np.asarray(self.value, dtype)

    def __array_wrap__(self, array, context=None, return_scalar=False):
        return TaggedValue(array, self.unit)

    def __repr__(self):
```

(continues on next page)

(continued from previous page)

```
        return f'TaggedValue({self.value!r}, {self.unit!r})'

    def __str__(self):
        return f"{self.value} in {self.unit}"

    def __len__(self):
        return len(self.value)

    if parse_version(np.__version__) >= parse_version('1.20'):
        def __getitem__(self, key):
            return TaggedValue(self.value[key], self.unit)

    def __iter__(self):
        # Return a generator expression rather than use `yield`, so␣
↪that
        # TypeError is raised by iter(self) if appropriate when␣
↪checking for
        # iterability.
        return (TaggedValue(inner, self.unit) for inner in self.value)

    def get_compressed_copy(self, mask):
        new_value = np.ma.masked_array(self.value, mask=mask).
↪compressed()
        return TaggedValue(new_value, self.unit)

    def convert_to(self, unit):
        if unit == self.unit or not unit:
            return self
        try:
            new_value = self.unit.convert_value_to(self.value, unit)
        except AttributeError:
            new_value = self
        return TaggedValue(new_value, unit)

    def get_value(self):
        return self.value

    def get_unit(self):
        return self.unit


class BasicUnit:
    # numpy scalars convert eager and np.float64(2) * BasicUnit('cm')
    # would thus return a numpy scalar. To avoid this, we increase the
    # priority of the BasicUnit.
    __array_priority__ = np.float64(0).__array_priority__ + 1
```

(continues on next page)

(continued from previous page)

```
    def __init__(self, name, fullname=None):
        self.name = name
        if fullname is None:
            fullname = name
        self.fullname = fullname
        self.conversions = dict()

    def __repr__(self):
        return f'BasicUnit({self.name})'

    def __str__(self):
        return self.fullname

    def __call__(self, value):
        return TaggedValue(value, self)

    def __mul__(self, rhs):
        value = rhs
        unit = self
        if hasattr(rhs, 'get_unit'):
            value = rhs.get_value()
            unit = rhs.get_unit()
            unit = unit_resolver('__mul__', (self, unit))
        if unit is NotImplemented:
            return NotImplemented
        return TaggedValue(value, unit)

    def __rmul__(self, lhs):
        return self*lhs

    def __array_wrap__(self, array, context=None, return_scalar=False):
        return TaggedValue(array, self)

    def __array__(self, t=None, context=None, copy=False):
        ret = np.array(1)
        if t is not None:
            return ret.astype(t)
        else:
            return ret

    def add_conversion_factor(self, unit, factor):
        def convert(x):
            return x*factor
        self.conversions[unit] = convert
```

(continues on next page)

(continued from previous page)

```
    def add_conversion_fn(self, unit, fn):
        self.conversions[unit] = fn

    def get_conversion_fn(self, unit):
        return self.conversions[unit]

    def convert_value_to(self, value, unit):
        conversion_fn = self.conversions[unit]
        ret = conversion_fn(value)
        return ret

    def get_unit(self):
        return self


class UnitResolver:
    def addition_rule(self, units):
        for unit_1, unit_2 in itertools.pairwise(units):
            if unit_1 != unit_2:
                return NotImplemented
        return units[0]

    def multiplication_rule(self, units):
        non_null = [u for u in units if u]
        if len(non_null) > 1:
            return NotImplemented
        return non_null[0]

    op_dict = {
        '__mul__': multiplication_rule,
        '__rmul__': multiplication_rule,
        '__add__': addition_rule,
        '__radd__': addition_rule,
        '__sub__': addition_rule,
        '__rsub__': addition_rule}

    def __call__(self, operation, units):
        if operation not in self.op_dict:
            return NotImplemented

        return self.op_dict[operation](self, units)


unit_resolver = UnitResolver()

cm = BasicUnit('cm', 'centimeters')
```

(continues on next page)

(continued from previous page)

```
inch = BasicUnit('inch', 'inches')
inch.add_conversion_factor(cm, 2.54)
cm.add_conversion_factor(inch, 1/2.54)

radians = BasicUnit('rad', 'radians')
degrees = BasicUnit('deg', 'degrees')
radians.add_conversion_factor(degrees, 180.0/np.pi)
degrees.add_conversion_factor(radians, np.pi/180.0)

secs = BasicUnit('s', 'seconds')
hertz = BasicUnit('Hz', 'Hertz')
minutes = BasicUnit('min', 'minutes')

secs.add_conversion_fn(hertz, lambda x: 1./x)
secs.add_conversion_factor(minutes, 1/60.0)


# radians formatting
def rad_fn(x, pos=None):
    if x >= 0:
        n = int((x / np.pi) * 2.0 + 0.25)
    else:
        n = int((x / np.pi) * 2.0 - 0.25)

    if n == 0:
        return '0'
    elif n == 1:
        return r'$\pi/2$'
    elif n == 2:
        return r'$\pi$'
    elif n == -1:
        return r'$-\pi/2$'
    elif n == -2:
        return r'$-\pi$'
    elif n % 2 == 0:
        return fr'${n//2}\pi$'
    else:
        return fr'${n}\pi/2$'


class BasicUnitConverter(units.ConversionInterface):
    @staticmethod
    def axisinfo(unit, axis):
        """Return AxisInfo instance for x and unit."""

        if unit == radians:
```

(continues on next page)

(continued from previous page)

```
            return units.AxisInfo(
                majloc=ticker.MultipleLocator(base=np.pi/2),
                majfmt=ticker.FuncFormatter(rad_fn),
                label=unit.fullname,
            )
        elif unit == degrees:
            return units.AxisInfo(
                majloc=ticker.AutoLocator(),
                majfmt=ticker.FormatStrFormatter(r'$%i^\circ$'),
                label=unit.fullname,
            )
        elif unit is not None:
            if hasattr(unit, 'fullname'):
                return units.AxisInfo(label=unit.fullname)
            elif hasattr(unit, 'unit'):
                return units.AxisInfo(label=unit.unit.fullname)
        return None

    @staticmethod
    def convert(val, unit, axis):
        if np.iterable(val):
            if isinstance(val, np.ma.MaskedArray):
                val = val.astype(float).filled(np.nan)
            out = np.empty(len(val))
            for i, thisval in enumerate(val):
                if np.ma.is_masked(thisval):
                    out[i] = np.nan
                else:
                    try:
                        out[i] = thisval.convert_to(unit).get_value()
                    except AttributeError:
                        out[i] = thisval
            return out
        if np.ma.is_masked(val):
            return np.nan
        else:
            return val.convert_to(unit).get_value()

    @staticmethod
    def default_units(x, axis):
        """Return the default unit for x or None."""
        if np.iterable(x):
            for thisx in x:
                return thisx.unit
        return x.unit
```

(continues on next page)

(continued from previous page)

```
def cos(x):
    if np.iterable(x):
        return [math.cos(val.convert_to(radians).get_value()) for val␣
 ↪in x]
    else:
        return math.cos(x.convert_to(radians).get_value())


units.registry[BasicUnit] = units.registry[TaggedValue] =␣
 ↪BasicUnitConverter()
```

Ellipse with units

Compare the ellipse generated with arcs versus a polygonal approximation.

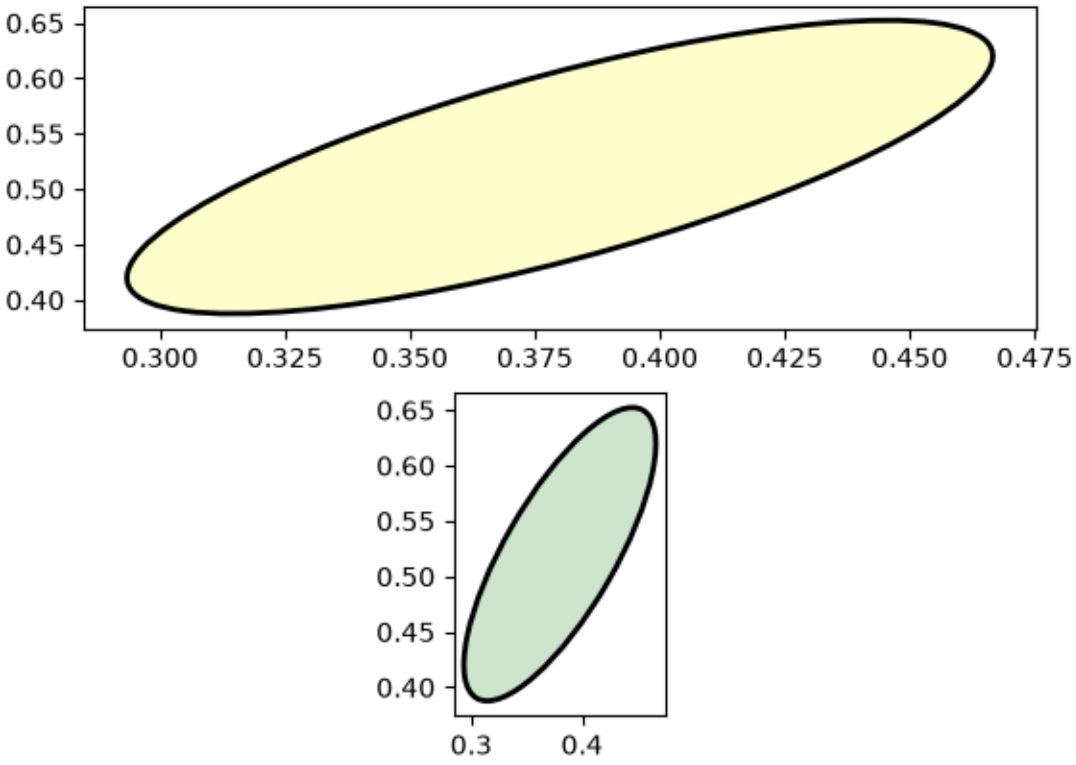
```
from basic_units import cm

import matplotlib.pyplot as plt
import numpy as np

from matplotlib import patches

xcenter, ycenter = 0.38*cm, 0.52*cm
width, height = 1e-1*cm, 3e-1*cm
angle = -30

theta = np.deg2rad(np.arange(0.0, 360.0, 1.0))
x = 0.5 * width * np.cos(theta)
y = 0.5 * height * np.sin(theta)

rtheta = np.radians(angle)
R = np.array([
    [np.cos(rtheta), -np.sin(rtheta)],
    [np.sin(rtheta),  np.cos(rtheta)],
    ])


x, y = np.dot(R, [x, y])
x += xcenter
y += ycenter
```

```
fig = plt.figure()
ax = fig.add_subplot(211, aspect='auto')
ax.fill(x, y, alpha=0.2, facecolor='yellow',
```

(continues on next page)

(continued from previous page)

```
        edgecolor='yellow', linewidth=1, zorder=1)

e1 = patches.Ellipse((xcenter, ycenter), width, height,
                     angle=angle, linewidth=2, fill=False, zorder=2)

ax.add_patch(e1)

ax = fig.add_subplot(212, aspect='equal')
ax.fill(x, y, alpha=0.2, facecolor='green', edgecolor='green',␣
↪zorder=1)
e2 = patches.Ellipse((xcenter, ycenter), width, height,
                     angle=angle, linewidth=2, fill=False, zorder=2)


ax.add_patch(e2)
fig.savefig('ellipse_compare')
```

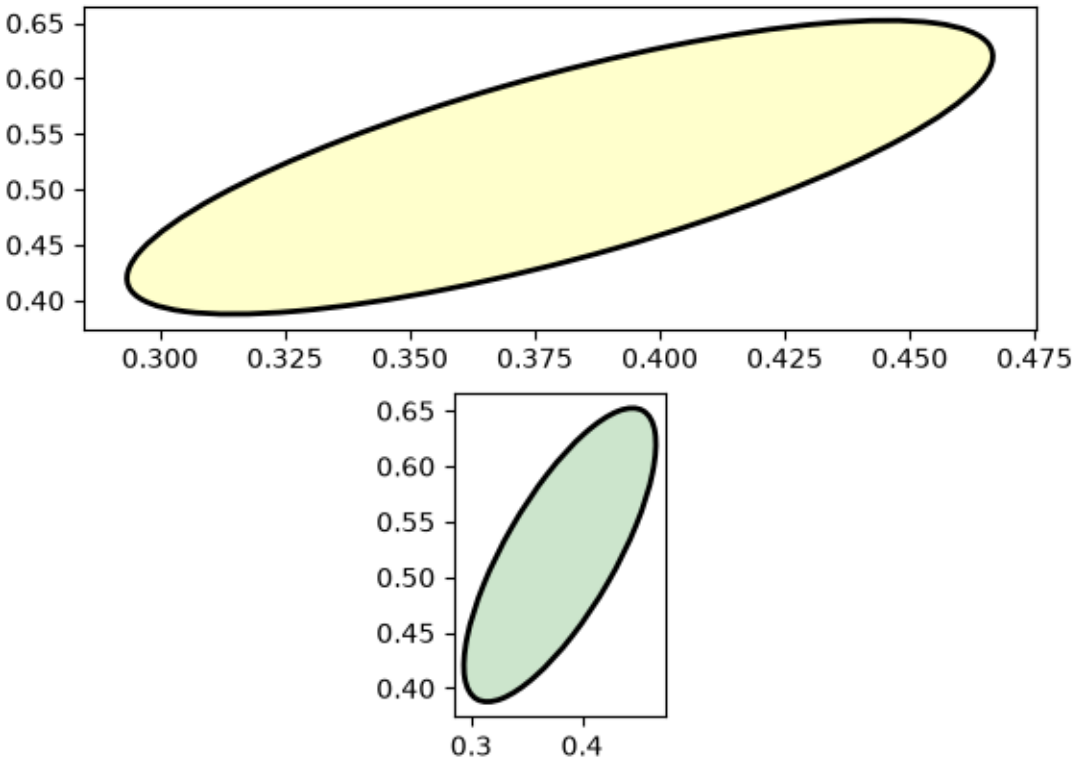



```
fig = plt.figure()
ax = fig.add_subplot(211, aspect='auto')
```

(continues on next page)

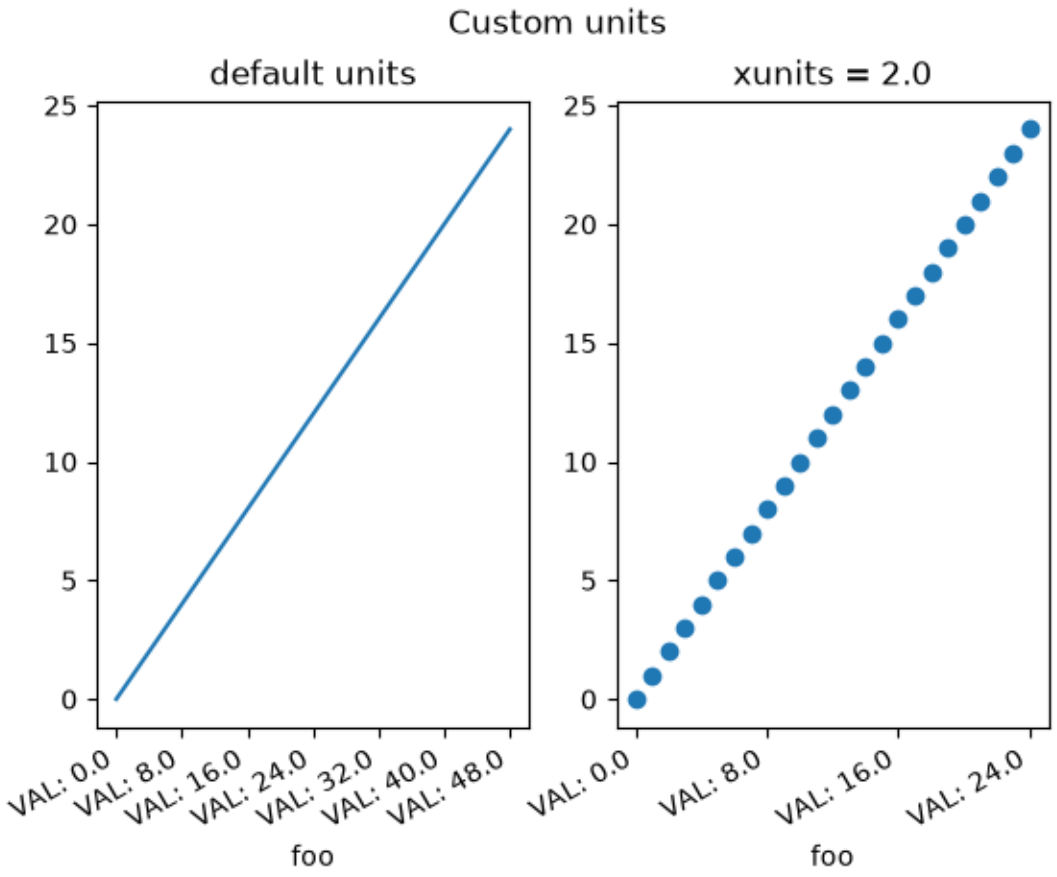
(continued from previous page)

```
ax.fill(x, y, alpha=0.2, facecolor='yellow',
        edgecolor='yellow', linewidth=1, zorder=1)

e1 = patches.Arc((xcenter, ycenter), width, height,
                 angle=angle, linewidth=2, fill=False, zorder=2)

ax.add_patch(e1)

ax = fig.add_subplot(212, aspect='equal')
ax.fill(x, y, alpha=0.2, facecolor='green', edgecolor='green',␣
↪zorder=1)
e2 = patches.Arc((xcenter, ycenter), width, height,
                 angle=angle, linewidth=2, fill=False, zorder=2)


ax.add_patch(e2)
fig.savefig('arc_compare')

plt.show()
```



Evans test

A mockup "Foo" units class which supports conversion and different tick formatting depending on the "unit". Here the "unit" is just a scalar conversion factor, but this example shows that Matplotlib is entirely agnostic to what kind of units client packages use.




```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.ticker as ticker
import matplotlib.units as units


class Foo:
    def __init__(self, val, unit=1.0):
        self.unit = unit
        self._val = val * unit

    def value(self, unit):
        if unit is None:
            unit = self.unit
```

(continues on next page)

(continued from previous page)

```
        return self._val / unit


class FooConverter(units.ConversionInterface):
    @staticmethod
    def axisinfo(unit, axis):
        """Return the Foo AxisInfo."""
        if unit == 1.0 or unit == 2.0:
            return units.AxisInfo(
                majloc=ticker.IndexLocator(8, 0),
                majfmt=ticker.FormatStrFormatter("VAL: %s"),
                label='foo',
                )

        else:
            return None

    @staticmethod
    def convert(obj, unit, axis):
        """
        Convert *obj* using *unit*.

        If *obj* is a sequence, return the converted sequence.
        """
        if np.iterable(obj):
            return [o.value(unit) for o in obj]
        else:
            return obj.value(unit)

    @staticmethod
    def default_units(x, axis):
        """Return the default unit for *x* or None."""
        if np.iterable(x):
            for thisx in x:
                return thisx.unit
        else:
            return x.unit


units.registry[Foo] = FooConverter()

# create some Foos
x = [Foo(val, 1.0) for val in range(0, 50, 2)]
# and some arbitrary y data
y = [i for i in range(len(x))]
```

(continues on next page)

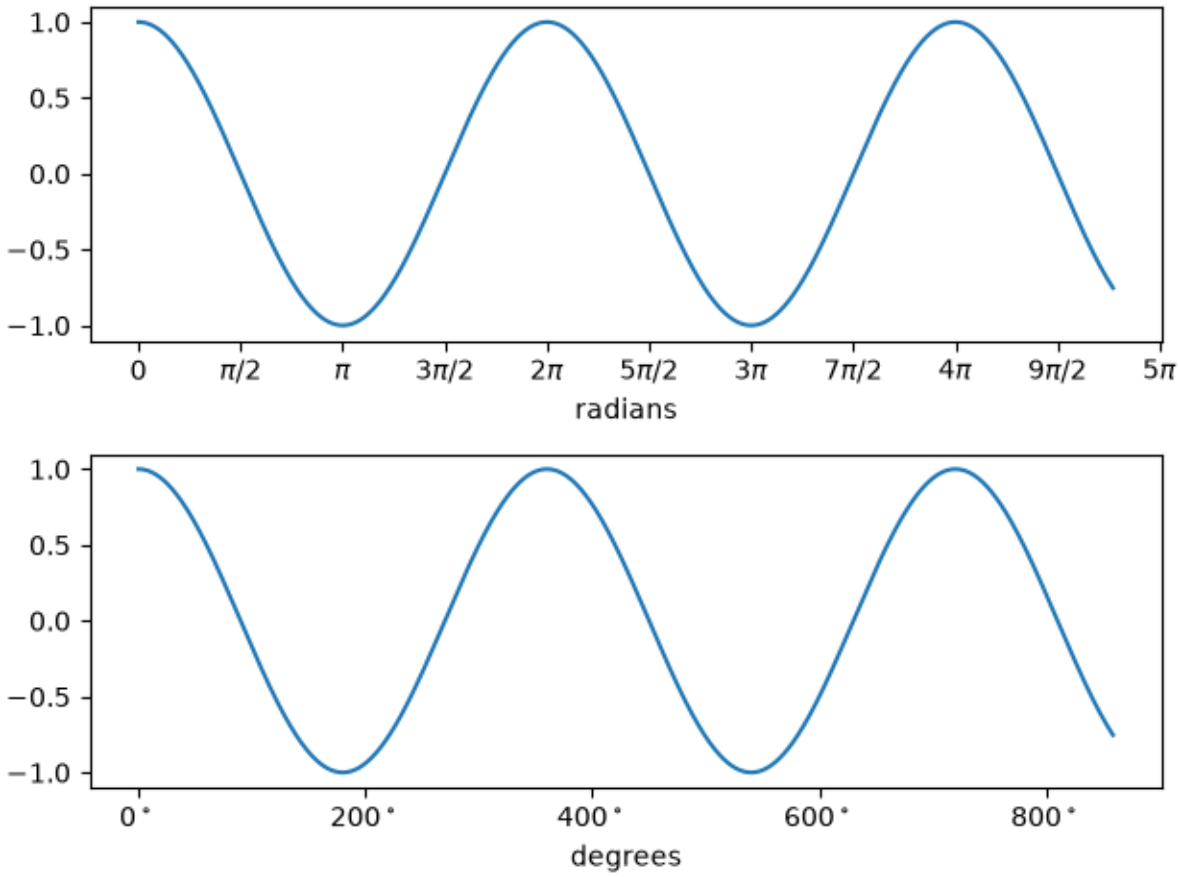
(continued from previous page)

```
fig, (ax1, ax2) = plt.subplots(1, 2)
fig.suptitle("Custom units")
fig.subplots_adjust(bottom=0.2)

# plot specifying units
ax2.plot(x, y, 'o', xunits=2.0)
ax2.set_title("xunits = 2.0")
ax2.tick_params(axis='x', rotation=30, rotation_mode='xtick')

# plot without specifying units; will use the None branch for axisinfo
ax1.plot(x, y)  # uses default units
ax1.set_title('default units')
ax1.tick_params(axis='x', rotation=30, rotation_mode='xtick')

plt.show()
```

Radian ticks

Plot with radians from the basic_units mockup example package.

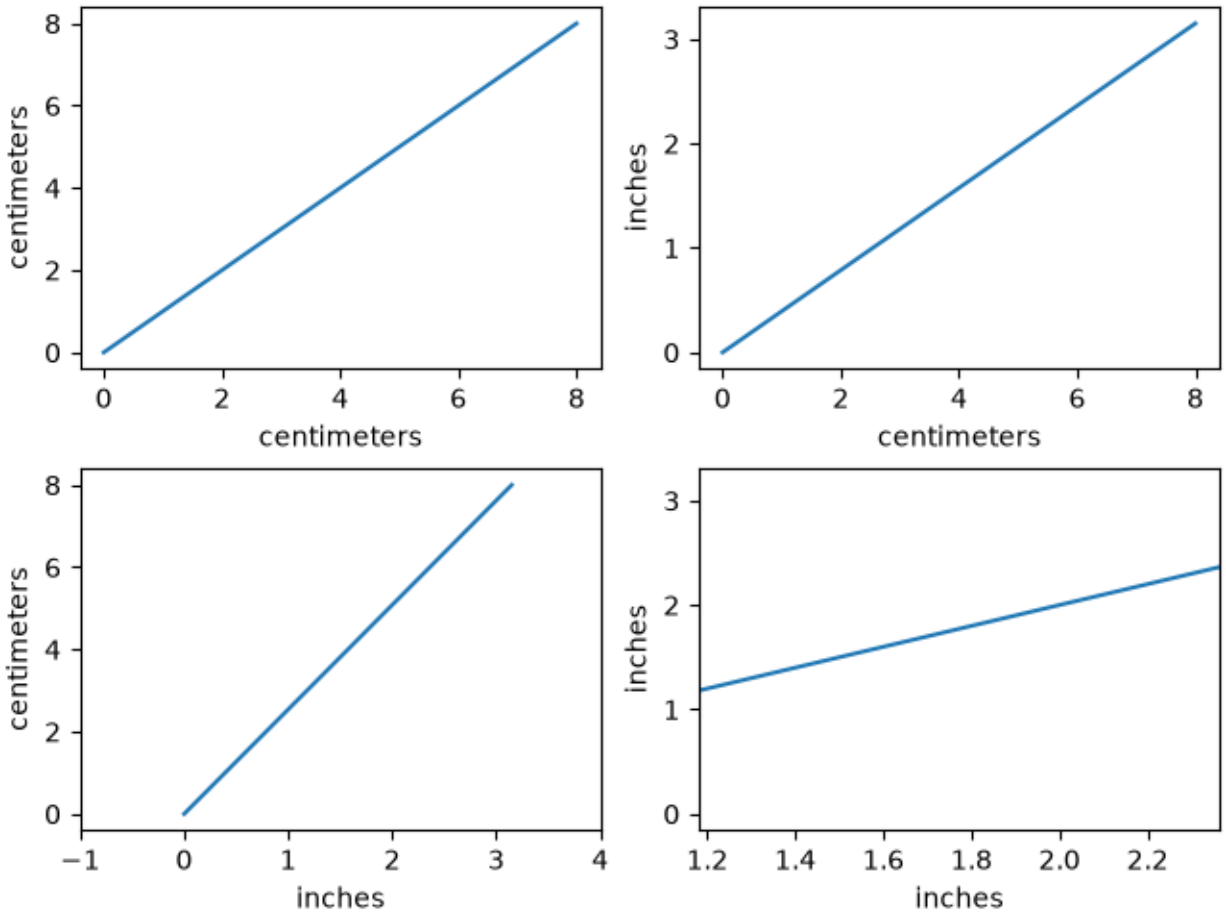
This example shows how the unit class can determine the tick locating, formatting and axis labeling.




```
from basic_units import cos, degrees, radians

import matplotlib.pyplot as plt
import numpy as np

x = [val*radians for val in np.arange(0, 15, 0.01)]

fig, axs = plt.subplots(2)

axs[0].plot(x, cos(x), xunits=radians)
axs[1].plot(x, cos(x), xunits=degrees)

fig.tight_layout()
plt.show()
```

Inches and centimeters

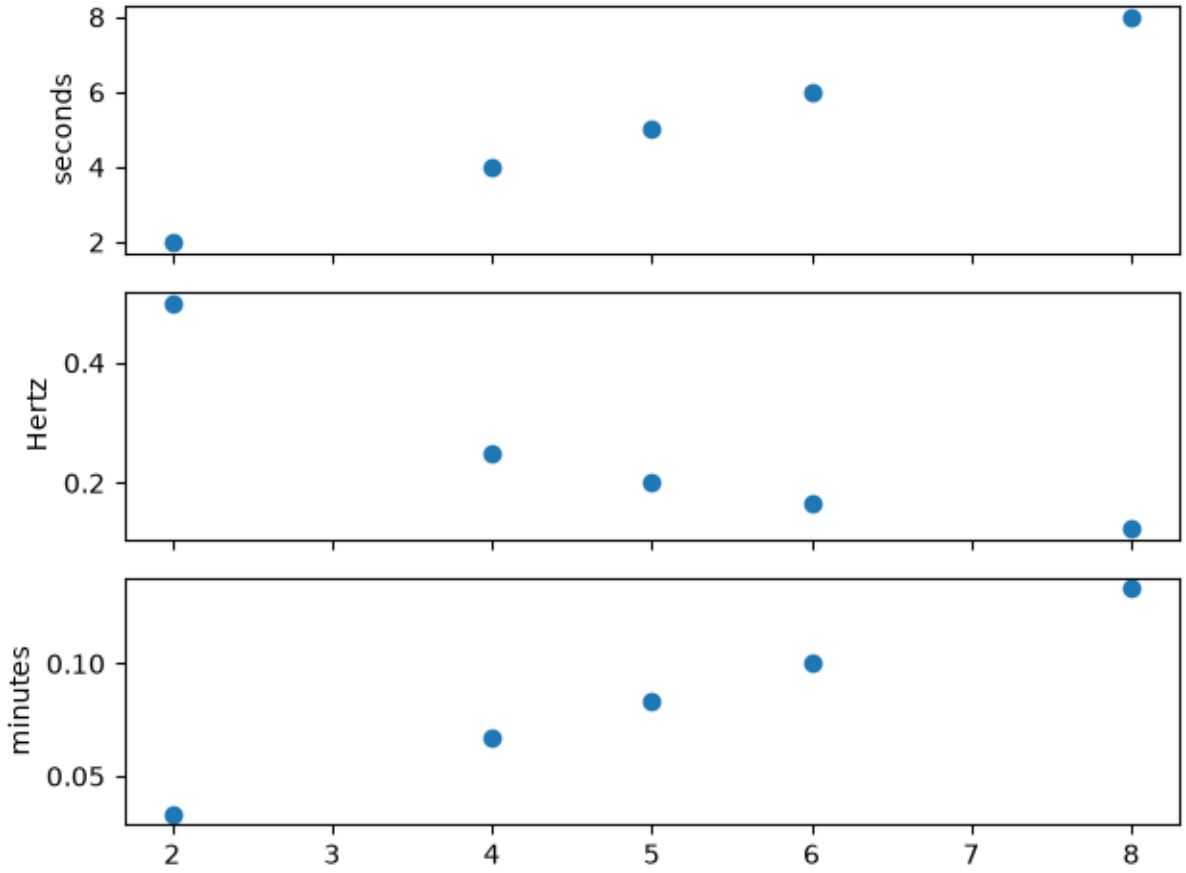
The example illustrates the ability to override default x and y units (ax1) to inches and centimeters using the *xunits* and *yunits* parameters for the `plot` function. Note that conversions are applied to get numbers to correct units.




```
from basic_units import cm, inch

import matplotlib.pyplot as plt
import numpy as np

cms = cm * np.arange(0, 10, 2)

fig, axs = plt.subplots(2, 2, layout='constrained')

axs[0, 0].plot(cms, cms)

axs[0, 1].plot(cms, cms, xunits=cm, yunits=inch)

axs[1, 0].plot(cms, cms, xunits=inch, yunits=cm)
axs[1, 0].set_xlim(-1, 4)  # scalars are interpreted in current units

axs[1, 1].plot(cms, cms, xunits=inch, yunits=inch)
axs[1, 1].set_xlim(3*cm, 6*cm)  # cm are converted to inches

plt.show()
```

Unit handling

The example below shows support for unit conversions over masked arrays.




```
from basic_units import hertz, minutes, secs

import matplotlib.pyplot as plt
import numpy as np

# create masked array
data = (1, 2, 3, 4, 5, 6, 7, 8)
mask = (1, 0, 1, 0, 0, 0, 1, 0)
xsecs = secs * np.ma.MaskedArray(data, mask, float)

fig, (ax1, ax2, ax3) = plt.subplots(nrows=3, sharex=True)

ax1.scatter(xsecs, xsecs)
ax1.yaxis.set_units(secs)
ax2.scatter(xsecs, xsecs, yunits=hertz)
ax3.scatter(xsecs, xsecs, yunits=minutes)
```

(continues on next page)

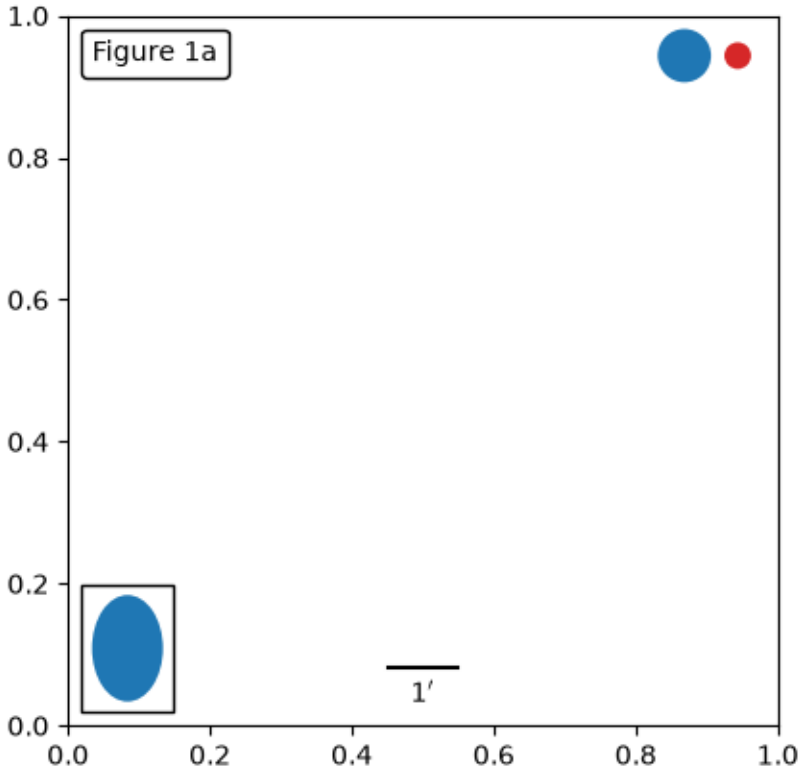
(continued from previous page)

```
fig.tight_layout()
plt.show()
```

6.24.22 Miscellaneous

Anchored Artists

This example illustrates the use of the anchored objects without the helper classes found in *mpl_toolkits.axes_grid1*. This version of the figure is similar to the one found in *Simple Anchored Artists*, but it is implemented using only the matplotlib namespace, without the help of additional toolkits.




```
from matplotlib import pyplot as plt
from matplotlib.lines import Line2D
from matplotlib.offsetbox import (AnchoredOffsetbox, AuxTransformBox,␣
 ↪DrawingArea,
                                  TextArea, VPacker)
from matplotlib.patches import Circle, Ellipse


def draw_text(ax):
```

(continues on next page)

(continued from previous page)

```
    """Draw a text-box anchored to the upper-left corner of the␣
↪figure."""
    box = AnchoredOffsetbox(child=TextArea("Figure 1a"),
                            loc="upper left", frameon=True)
    box.patch.set_boxstyle("round,pad=0.,rounding_size=0.2")
    ax.add_artist(box)


def draw_circles(ax):
    """Draw circles in axes coordinates."""
    area = DrawingArea(width=40, height=20)
    area.add_artist(Circle((10, 10), 10, fc="tab:blue"))
    area.add_artist(Circle((30, 10), 5, fc="tab:red"))
    box = AnchoredOffsetbox(
        child=area, loc="upper right", pad=0, frameon=False)
    ax.add_artist(box)


def draw_ellipse(ax):
    """Draw an ellipse of width=0.1, height=0.15 in data␣
↪coordinates."""
    aux_tr_box = AuxTransformBox(ax.transData)
    aux_tr_box.add_artist(Ellipse((0, 0), width=0.1, height=0.15))
    box = AnchoredOffsetbox(child=aux_tr_box, loc="lower left",␣
↪frameon=True)
    ax.add_artist(box)


def draw_sizebar(ax):
    """
    Draw a horizontal bar with length of 0.1 in data coordinates,
    with a fixed label center-aligned underneath.
    """
    size = 0.1
    text = r"1$^{\prime}$"
    sizebar = AuxTransformBox(ax.transData)
    sizebar.add_artist(Line2D([0, size], [0, 0], color="black"))
    text = TextArea(text)
    packer = VPacker(
        children=[sizebar, text], align="center", sep=5)  # separation␣
↪in points.
    ax.add_artist(AnchoredOffsetbox(
        child=packer, loc="lower center", frameon=False,
        pad=0.1, borderpad=0.5))  # paddings relative to the legend␣
↪fontsize.
```

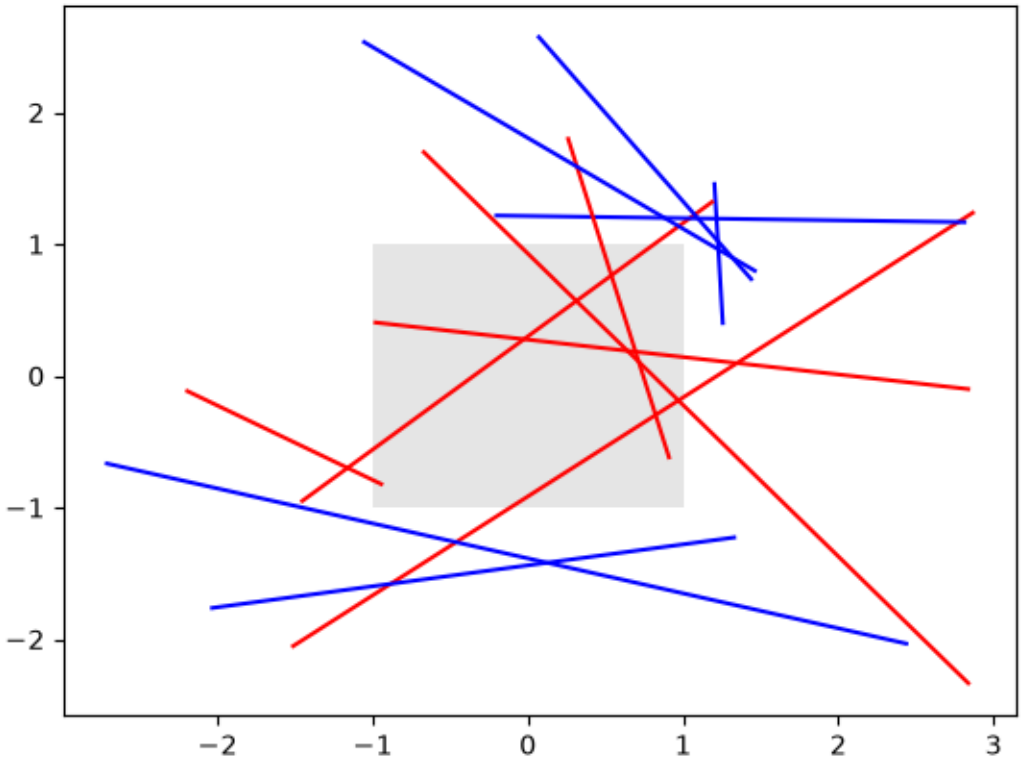
(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots()
ax.set_aspect(1)

draw_text(ax)
draw_circles(ax)
draw_ellipse(ax)
draw_sizebar(ax)

plt.show()
```

Identify whether artists intersect

The lines intersecting the rectangle are colored in red, while the others are left as blue lines. This example showcases the *intersects_bbox* function.




```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
from matplotlib.path import Path
from matplotlib.transforms import Bbox

# Fixing random state for reproducibility
np.random.seed(19680801)


left, bottom, width, height = (-1, -1, 2, 2)
rect = plt.Rectangle((left, bottom), width, height,
                     facecolor="black", alpha=0.1)

fig, ax = plt.subplots()
ax.add_patch(rect)

bbox = Bbox.from_bounds(left, bottom, width, height)

for i in range(12):
    vertices = (np.random.random((2, 2)) - 0.5) * 6.0
    path = Path(vertices)
    if path.intersects_bbox(bbox):
        color = 'r'
    else:
        color = 'b'
    ax.plot(vertices[:, 0], vertices[:, 1], color=color)

plt.show()
```

Manual Contour

Example of displaying your own contour lines and polygons using ContourSet.

```
import matplotlib.pyplot as plt

from matplotlib.contour import ContourSet
from matplotlib.path import Path
```

Contour lines for each level are a list/tuple of polygons.

```
lines0 = [[[0, 0], [0, 4]]]
lines1 = [[[2, 0], [1, 2], [1, 3]]]
lines2 = [[[3, 0], [3, 2]], [[3, 3], [3, 4]]]  # Note two lines.
```

Filled contours between two levels are also a list/tuple of polygons. Points can be ordered clockwise or anticlockwise.

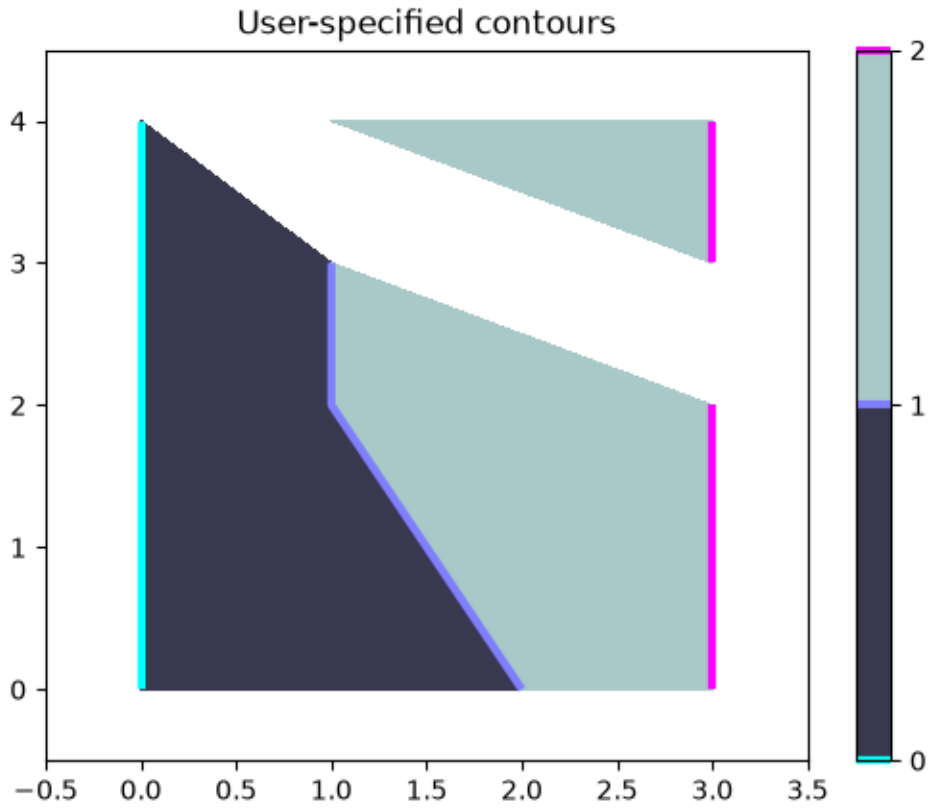
```
filled01 = [[[0, 0], [0, 4], [1, 3], [1, 2], [2, 0]]]
```

(continues on next page)

(continued from previous page)

```
filled12 = [[[2, 0], [3, 0], [3, 2], [1, 3], [1, 2]],  # Note two␣
↪polygons.
            [[1, 4], [3, 4], [3, 3]]]
```

```
fig, ax = plt.subplots()

# Filled contours using filled=True.
cs = ContourSet(ax, [0, 1, 2], [filled01, filled12], filled=True, cmap=
↪"bone")
cbar = fig.colorbar(cs)

# Contour lines (non-filled).
lines = ContourSet(
    ax, [0, 1, 2], [lines0, lines1, lines2], cmap="cool", linewidths=3)
cbar.add_lines(lines)

ax.set(xlim=(-0.5, 3.5), ylim=(-0.5, 4.5),
       title='User-specified contours')
```



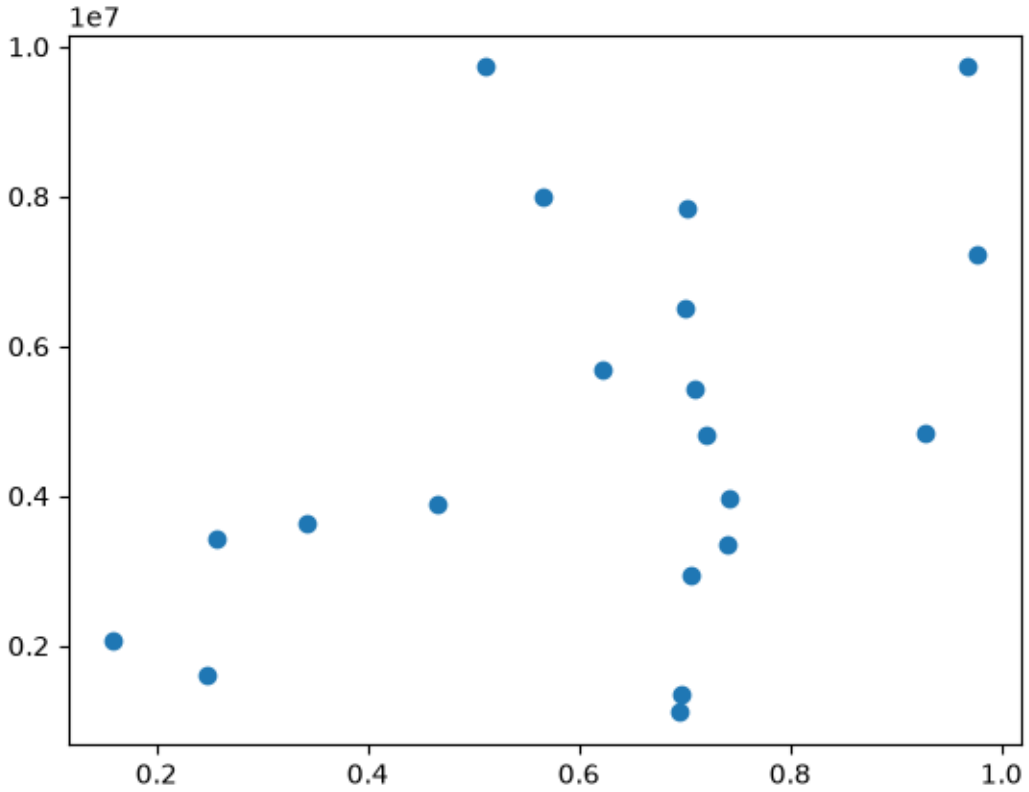
Multiple filled contour lines can be specified in a single list of polygon vertices along with a list of vertex

kinds (code types) as described in the Path class. This is particularly useful for polygons with holes.

```
fig, ax = plt.subplots()
filled01 = [[[0, 0], [3, 0], [3, 3], [0, 3], [1, 1], [1, 2], [2, 2],␣
 ↪[2, 1]]]
M = Path.MOVETO
L = Path.LINETO
kinds01 = [[M, L, L, L, M, L, L, L]]
cs = ContourSet(ax, [0, 1], [filled01], [kinds01], filled=True)
cbar = fig.colorbar(cs)

ax.set(xlim=(-0.5, 3.5), ylim=(-0.5, 3.5),
       title='User specified filled contours with holes')

plt.show()
```

Coords Report

Override the default reporting of coords as the mouse moves over the Axes in an interactive backend.




```
import matplotlib.pyplot as plt
import numpy as np


def millions(x):
    return '$%1.1fM' % (x * 1e-6)


# Fixing random state for reproducibility
np.random.seed(19680801)

x = np.random.rand(20)
y = 1e7 * np.random.rand(20)

fig, ax = plt.subplots()
ax.fmt_ydata = millions
plt.plot(x, y, 'o')
```

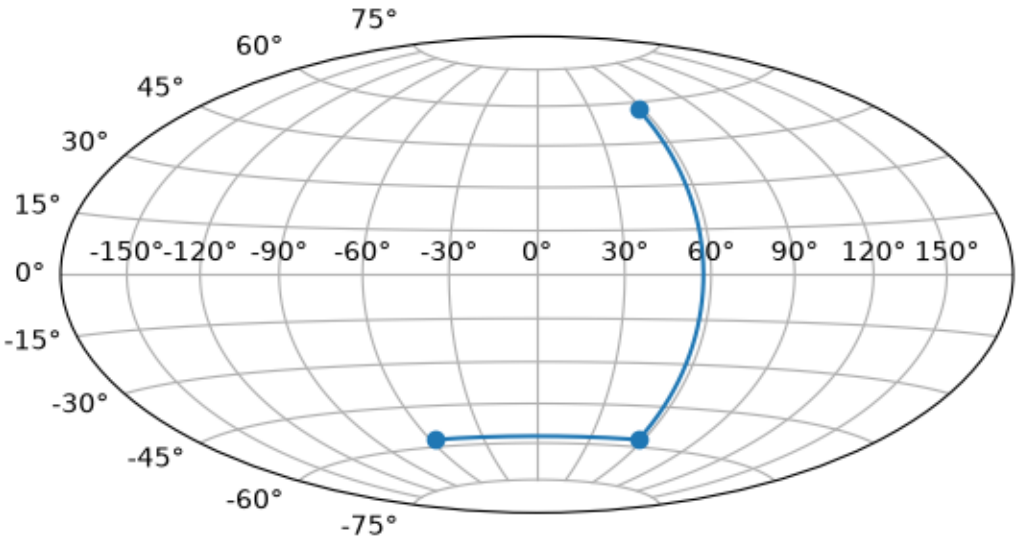
(continues on next page)

(continued from previous page)

```
plt.show()
```

Custom projection

Showcase Hammer projection by alleviating many features of Matplotlib.




```
import numpy as np

import matplotlib
from matplotlib.axes import Axes
import matplotlib.axis as maxis
from matplotlib.patches import Circle
from matplotlib.path import Path
from matplotlib.projections import register_projection
import matplotlib.spines as mspines
from matplotlib.ticker import FixedLocator, Formatter, NullLocator
from matplotlib.transforms import Affine2D, BboxTransformTo, Transform
```

(continues on next page)

(continued from previous page)

```
rcParams = matplotlib.rcParams

# This example projection class is rather long, but it is designed to
# illustrate many features, not all of which will be used every time.
# It is also common to factor out a lot of these methods into common
# code used by a number of projections with similar characteristics
# (see geo.py).


class GeoAxes(Axes):
    """
    An abstract base class for geographic projections
    """
    class ThetaFormatter(Formatter):
        """
        Used to format the theta tick labels.  Converts the native
        unit of radians into degrees and adds a degree symbol.
        """
        def __init__(self, round_to=1.0):
            self._round_to = round_to

        def __call__(self, x, pos=None):
            degrees = round(np.rad2deg(x) / self._round_to) * self._
 ↪round_to
            return f"{degrees:0.0f}\N{DEGREE SIGN}"

    RESOLUTION = 75

    def _init_axis(self):
        self.xaxis = maxis.XAxis(self)
        self.yaxis = maxis.YAxis(self)
        # Do not register xaxis or yaxis with spines -- as done in
        # Axes._init_axis() -- until GeoAxes.xaxis.clear() works.
        # self.spines['geo'].register_axis(self.yaxis)

    def clear(self):
        # docstring inherited
        super().clear()

        self.set_longitude_grid(30)
        self.set_latitude_grid(15)
        self.set_longitude_grid_ends(75)
        self.xaxis.set_minor_locator(NullLocator())
        self.yaxis.set_minor_locator(NullLocator())
        self.xaxis.set_ticks_position('none')
        self.yaxis.set_ticks_position('none')
```

(continues on next page)

(continued from previous page)

```
        self.yaxis.set_tick_params(label1On=True)
        # Why do we need to turn on yaxis tick labels, but
        # xaxis tick labels are already on?

        self.grid(rcParams['axes.grid'])

        Axes.set_xlim(self, -np.pi, np.pi)
        Axes.set_ylim(self, -np.pi / 2.0, np.pi / 2.0)

    def _set_lim_and_transforms(self):
        # A (possibly non-linear) projection on the (already scaled)␣
↪data

        # There are three important coordinate spaces going on here:
        #
        # 1. Data space: The space of the data itself
        #
        # 2. Axes space: The unit rectangle (0, 0) to (1, 1)
        #    covering the entire plot area.
        #
        # 3. Display space: The coordinates of the resulting image,
        #    often in pixels or dpi/inch.

        # This function makes heavy use of the Transform classes in
        # ``lib/matplotlib/transforms.py.`` For more information, see
        # the inline documentation there.

        # The goal of the first two transformations is to get from the
        # data space (in this case longitude and latitude) to Axes
        # space.  It is separated into a non-affine and affine part so
        # that the non-affine part does not have to be recomputed when
        # a simple affine change to the figure has been made (such as
        # resizing the window or changing the dpi).

        # 1) The core transformation from data space into
        # rectilinear space defined in the HammerTransform class.
        self.transProjection = self._get_core_transform(self.
↪RESOLUTION)

        # 2) The above has an output range that is not in the unit
        # rectangle, so scale and translate it so it fits correctly
        # within the Axes.  The peculiar calculations of xscale and
        # yscale are specific to an Aitoff-Hammer projection, so don't
        # worry about them too much.
        self.transAffine = self._get_affine_transform()
```

(continues on next page)

(continued from previous page)

```
        # 3) This is the transformation from Axes space to display
        # space.
        self.transAxes = BboxTransformTo(self.bbox)

        # Now put these 3 transforms together -- from data all the way
        # to display coordinates.  Using the '+' operator, these
        # transforms will be applied "in order".  The transforms are
        # automatically simplified, if possible, by the underlying
        # transformation framework.
        self.transData = \
            self.transProjection + \
            self.transAffine + \
            self.transAxes

        # The main data transformation is set up.  Now deal with
        # gridlines and tick labels.

        # Longitude gridlines and ticklabels.  The input to these
        # transforms are in display space in x and Axes space in y.
        # Therefore, the input values will be in range (-xmin, 0),
        # (xmax, 1).  The goal of these transforms is to go from that
        # space to display space.  The tick labels will be offset 4
        # pixels from the equator.
        self._xaxis_pretransform = \
            Affine2D() \
            .scale(1.0, self._longitude_cap * 2.0) \
            .translate(0.0, -self._longitude_cap)
        self._xaxis_transform = \
            self._xaxis_pretransform + \
            self.transData
        self._xaxis_text1_transform = \
            Affine2D().scale(1.0, 0.0) + \
            self.transData + \
            Affine2D().translate(0.0, 4.0)
        self._xaxis_text2_transform = \
            Affine2D().scale(1.0, 0.0) + \
            self.transData + \
            Affine2D().translate(0.0, -4.0)

        # Now set up the transforms for the latitude ticks.  The input␣
↪to
        # these transforms are in Axes space in x and display space in
        # y.  Therefore, the input values will be in range (0, -ymin),
        # (1, ymax).  The goal of these transforms is to go from that
        # space to display space.  The tick labels will be offset 4
        # pixels from the edge of the Axes ellipse.
```

(continues on next page)

(continued from previous page)

```
        yaxis_stretch = Affine2D().scale(np.pi*2, 1).translate(-np.pi,␣
↪0)
        yaxis_space = Affine2D().scale(1.0, 1.1)
        self._yaxis_transform = \
            yaxis_stretch + \
            self.transData
        yaxis_text_base = \
            yaxis_stretch + \
            self.transProjection + \
            (yaxis_space +
             self.transAffine +
             self.transAxes)
        self._yaxis_text1_transform = \
            yaxis_text_base + \
            Affine2D().translate(-8.0, 0.0)
        self._yaxis_text2_transform = \
            yaxis_text_base + \
            Affine2D().translate(8.0, 0.0)

    def _get_affine_transform(self):
        transform = self._get_core_transform(1)
        xscale, _ = transform.transform((np.pi, 0))
        _, yscale = transform.transform((0, np.pi/2))
        return Affine2D() \
            .scale(0.5 / xscale, 0.5 / yscale) \
            .translate(0.5, 0.5)

    def get_xaxis_transform(self, which='grid'):
        """
        Override this method to provide a transformation for the
        x-axis tick labels.

        Returns a tuple of the form (transform, valign, halign)
        """
        if which not in ['tick1', 'tick2', 'grid']:
            raise ValueError(
                "'which' must be one of 'tick1', 'tick2', or 'grid'")
        return self._xaxis_transform

    def get_xaxis_text1_transform(self, pad):
        return self._xaxis_text1_transform, 'bottom', 'center'

    def get_xaxis_text2_transform(self, pad):
        """
        Override this method to provide a transformation for the
        secondary x-axis tick labels.
```

(continues on next page)

(continued from previous page)

```
        Returns a tuple of the form (transform, valign, halign)
        """
        return self._xaxis_text2_transform, 'top', 'center'

    def get_yaxis_transform(self, which='grid'):
        """
        Override this method to provide a transformation for the
        y-axis grid and ticks.
        """
        if which not in ['tick1', 'tick2', 'grid']:
            raise ValueError(
                "'which' must be one of 'tick1', 'tick2', or 'grid'")
        return self._yaxis_transform

    def get_yaxis_text1_transform(self, pad):
        """
        Override this method to provide a transformation for the
        y-axis tick labels.

        Returns a tuple of the form (transform, valign, halign)
        """
        return self._yaxis_text1_transform, 'center', 'right'

    def get_yaxis_text2_transform(self, pad):
        """
        Override this method to provide a transformation for the
        secondary y-axis tick labels.

        Returns a tuple of the form (transform, valign, halign)
        """
        return self._yaxis_text2_transform, 'center', 'left'

    def _gen_axes_patch(self):
        """
        Override this method to define the shape that is used for the
        background of the plot.  It should be a subclass of Patch.

        In this case, it is a Circle (that may be warped by the Axes
        transform into an ellipse).  Any data and gridlines will be
        clipped to this shape.
        """
        return Circle((0.5, 0.5), 0.5)

    def _gen_axes_spines(self):
        return {'geo': mspines.Spine.circular_spine(self, (0.5, 0.5),␣
```

(continues on next page)

(continued from previous page)

```
↪0.5)}

    def set_yscale(self, *args, **kwargs):
        if args[0] != 'linear':
            raise NotImplementedError

    # Prevent the user from applying scales to one or both of the
    # axes.  In this particular case, scaling the axes wouldn't make
    # sense, so we don't allow it.
    set_xscale = set_yscale

    # Prevent the user from changing the axes limits.  In our case, we
    # want to display the whole sphere all the time, so we override
    # set_xlim and set_ylim to ignore any input.  This also applies to
    # interactive panning and zooming in the GUI interfaces.
    def set_xlim(self, *args, **kwargs):
        raise TypeError("Changing axes limits of a geographic␣
↪projection is "
                        "not supported.  Please consider using Cartopy.
↪")

    set_ylim = set_xlim

    def format_coord(self, lon, lat):
        """
        Override this method to change how the values are displayed in
        the status bar.

        In this case, we want them to be displayed in degrees N/S/E/W.
        """
        lon, lat = np.rad2deg([lon, lat])
        ns = 'N' if lat >= 0.0 else 'S'
        ew = 'E' if lon >= 0.0 else 'W'
        return ('%f\N{DEGREE SIGN}%s, %f\N{DEGREE SIGN}%s'
                % (abs(lat), ns, abs(lon), ew))

    def set_longitude_grid(self, degrees):
        """
        Set the number of degrees between each longitude grid.

        This is an example method that is specific to this projection
        class -- it provides a more convenient interface to set the
        ticking than set_xticks would.
        """
        # Skip -180 and 180, which are the fixed limits.
        grid = np.arange(-180 + degrees, 180, degrees)
```

(continues on next page)

(continued from previous page)

```
        self.xaxis.set_major_locator(FixedLocator(np.deg2rad(grid)))
        self.xaxis.set_major_formatter(self.ThetaFormatter(degrees))

    def set_latitude_grid(self, degrees):
        """
        Set the number of degrees between each longitude grid.

        This is an example method that is specific to this projection
        class -- it provides a more convenient interface than
        set_yticks would.
        """
        # Skip -90 and 90, which are the fixed limits.
        grid = np.arange(-90 + degrees, 90, degrees)
        self.yaxis.set_major_locator(FixedLocator(np.deg2rad(grid)))
        self.yaxis.set_major_formatter(self.ThetaFormatter(degrees))

    def set_longitude_grid_ends(self, degrees):
        """
        Set the latitude(s) at which to stop drawing the longitude␣
↪grids.

        Often, in geographic projections, you wouldn't want to draw
        longitude gridlines near the poles.  This allows the user to
        specify the degree at which to stop drawing longitude grids.

        This is an example method that is specific to this projection
        class -- it provides an interface to something that has no
        analogy in the base Axes class.
        """
        self._longitude_cap = np.deg2rad(degrees)
        self._xaxis_pretransform \
            .clear() \
            .scale(1.0, self._longitude_cap * 2.0) \
            .translate(0.0, -self._longitude_cap)

    def get_data_ratio(self):
        """
        Return the aspect ratio of the data itself.

        This method should be overridden by any Axes that have a
        fixed data ratio.
        """
        return 1.0

    # Interactive panning and zooming is not supported with this␣
↪projection,
```

(continues on next page)

(continued from previous page)

```
    # so we override all of the following methods to disable it.
    def can_zoom(self):
        """
        Return whether this Axes supports the zoom box button␣
↪functionality.

        This Axes object does not support interactive zoom box.
        """
        return False

    def can_pan(self):
        """
        Return whether this Axes supports the pan/zoom button␣
↪functionality.

        This Axes object does not support interactive pan/zoom.
        """
        return False

    def start_pan(self, x, y, button):
        pass

    def end_pan(self):
        pass

    def drag_pan(self, button, key, x, y):
        pass


class HammerAxes(GeoAxes):
    """
    A custom class for the Aitoff-Hammer projection, an equal-area map
    projection.

    https://en.wikipedia.org/wiki/Hammer_projection
    """

    # The projection must specify a name.  This will be used by the
    # user to select the projection,
    # i.e. ``subplot(projection='custom_hammer')``.
    name = 'custom_hammer'

    class HammerTransform(Transform):
        """The base Hammer transform."""
        input_dims = output_dims = 2
```

(continues on next page)

(continued from previous page)

```
        def __init__(self, resolution):
            """
            Create a new Hammer transform.  Resolution is the number␣
↪of steps
            to interpolate between each input line segment to␣
↪approximate its
            path in curved Hammer space.
            """
            Transform.__init__(self)
            self._resolution = resolution

        def transform_non_affine(self, ll):
            longitude, latitude = ll.T

            # Pre-compute some values
            half_long = longitude / 2
            cos_latitude = np.cos(latitude)
            sqrt2 = np.sqrt(2)

            alpha = np.sqrt(1 + cos_latitude * np.cos(half_long))
            x = (2 * sqrt2) * (cos_latitude * np.sin(half_long)) /␣
↪alpha
            y = (sqrt2 * np.sin(latitude)) / alpha
            return np.column_stack([x, y])

        def transform_path_non_affine(self, path):
            # vertices = path.vertices
            ipath = path.interpolated(self._resolution)
            return Path(self.transform(ipath.vertices), ipath.codes)

        def inverted(self):
            return HammerAxes.InvertedHammerTransform(self._resolution)

    class InvertedHammerTransform(Transform):
        input_dims = output_dims = 2

        def __init__(self, resolution):
            Transform.__init__(self)
            self._resolution = resolution

        def transform_non_affine(self, xy):
            x, y = xy.T
            z = np.sqrt(1 - (x / 4) ** 2 - (y / 2) ** 2)
            longitude = 2 * np.arctan((z * x) / (2 * (2 * z ** 2 - 1)))
            latitude = np.arcsin(y*z)
            return np.column_stack([longitude, latitude])
```

(continues on next page)

(continued from previous page)

```
        def inverted(self):
            return HammerAxes.HammerTransform(self._resolution)

    def __init__(self, *args, **kwargs):
        self._longitude_cap = np.pi / 2.0
        super().__init__(*args, **kwargs)
        self.set_aspect(0.5, adjustable='box', anchor='C')
        self.clear()

    def _get_core_transform(self, resolution):
        return self.HammerTransform(resolution)


# Now register the projection with Matplotlib so the user can select␣
 ↪it.
register_projection(HammerAxes)


if __name__ == '__main__':
    import matplotlib.pyplot as plt

    # Now make a simple example using the custom projection.
    fig, ax = plt.subplots(subplot_kw={'projection': 'custom_hammer'})
    ax.plot([-1, 1, 1], [-1, -1, 1], "o-")
    ax.grid()

    plt.show()
```

Customize Rc

I'm not trying to make a good-looking figure here, but just to show some examples of customizing *rcParams* on the fly.

If you like to work interactively, and need to create different sets of defaults for figures (e.g., one set of defaults for publication, one set for interactive exploration), you may want to define some functions in a custom module that set the defaults, e.g.,:

```
def set_pub():
    rcParams.update({
        "font.weight": "bold",   # bold fonts
        "tick.labelsize": 15,    # large tick labels
        "lines.linewidth": 1,    # thick lines
        "lines.color": "k",      # black lines
        "grid.color": "0.5",     # gray gridlines
        "grid.linestyle": "-",   # solid gridlines
```

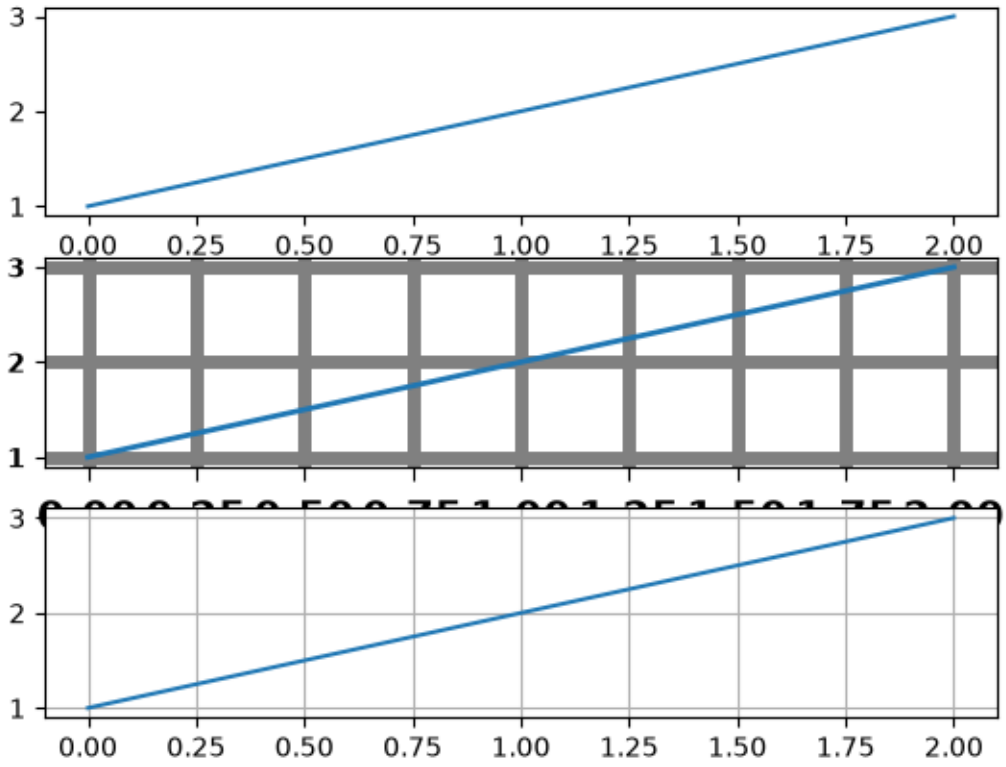
(continues on next page)

(continued from previous page)

```
        "grid.linewidth": 0.5,   # thin gridlines
        "savefig.dpi": 300,      # higher resolution output.
    })
```

Then as you are working interactively, you just need to do:

```
>>> set_pub()
>>> plot([1, 2, 3])
>>> savefig('myfig')
>>> rcdefaults()  # restore the defaults
```




```
import matplotlib.pyplot as plt

plt.subplot(311)
plt.plot([1, 2, 3])

# the axes attributes need to be set before the call to subplot
plt.rcParams.update({
    "font.weight": "bold",
    "xtick.major.size": 5,
```

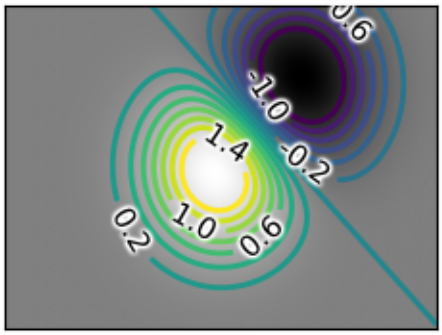
(continues on next page)

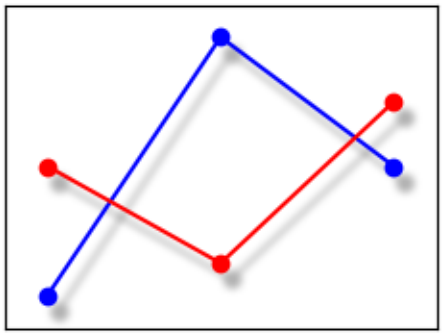
(continued from previous page)

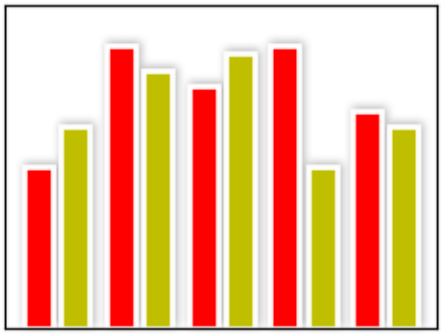
```
    "xtick.major.pad": 7,
    "xtick.labelsize": 15,
    "grid.color": "0.5",
    "grid.linestyle": "-",
    "grid.linewidth": 5,
    "lines.linewidth": 2,
    "lines.color": "g",
})
plt.subplot(312)
plt.plot([1, 2, 3])
plt.grid(True)

plt.rcdefaults()
plt.subplot(313)
plt.plot([1, 2, 3])
plt.grid(True)
plt.show()
```

AGG filter

Most pixel-based backends in Matplotlib use Anti-Grain Geometry (AGG) for rendering. You can modify the rendering of Artists by applying a filter via *Artist.set_agg_filter*.







```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.artist import Artist
from matplotlib.colors import LightSource
import matplotlib.transforms as mtransforms


def smooth1d(x, window_len):
    # copied from␣
 ↪https://scipy-cookbook.readthedocs.io/items/SignalSmooth.html
    s = np.r_[2*x[0] - x[window_len:1:-1], x, 2*x[-1] - x[-1:-
 ↪window_len:-1]]
    w = np.hanning(window_len)
    y = np.convolve(w/w.sum(), s, mode='same')
    return y[window_len-1:-window_len+1]


def smooth2d(A, sigma=3):
    window_len = max(int(sigma), 3) * 2 + 1
```

(continues on next page)

(continued from previous page)

```
    A = np.apply_along_axis(smooth1d, 0, A, window_len)
    A = np.apply_along_axis(smooth1d, 1, A, window_len)
    return A


class BaseFilter:

    def get_pad(self, dpi):
        return 0

    def process_image(self, padded_src, dpi):
        raise NotImplementedError("Should be overridden by subclasses")

    def __call__(self, im, dpi):
        pad = self.get_pad(dpi)
        padded_src = np.pad(im, [(pad, pad), (pad, pad), (0, 0)],
 ↪"constant")
        tgt_image = self.process_image(padded_src, dpi)
        return tgt_image, -pad, -pad


class OffsetFilter(BaseFilter):

    def __init__(self, offsets=(0, 0)):
        self.offsets = offsets

    def get_pad(self, dpi):
        return int(max(self.offsets) / 72 * dpi)

    def process_image(self, padded_src, dpi):
        ox, oy = self.offsets
        a1 = np.roll(padded_src, int(ox / 72 * dpi), axis=1)
        a2 = np.roll(a1, -int(oy / 72 * dpi), axis=0)
        return a2


class GaussianFilter(BaseFilter):
    """Simple Gaussian filter."""

    def __init__(self, sigma, alpha=0.5, color=(0, 0, 0)):
        self.sigma = sigma
        self.alpha = alpha
        self.color = color

    def get_pad(self, dpi):
        return int(self.sigma*3 / 72 * dpi)
```

(continues on next page)

(continued from previous page)

```
    def process_image(self, padded_src, dpi):
        tgt_image = np.empty_like(padded_src)
        tgt_image[:, :, :3] = self.color
        tgt_image[:, :, 3] = smooth2d(padded_src[:, :, 3] * self.alpha,
                                      self.sigma / 72 * dpi)
        return tgt_image


class DropShadowFilter(BaseFilter):

    def __init__(self, sigma, alpha=0.3, color=(0, 0, 0), offsets=(0,␣
 ↪0)):
        self.gauss_filter = GaussianFilter(sigma, alpha, color)
        self.offset_filter = OffsetFilter(offsets)

    def get_pad(self, dpi):
        return max(self.gauss_filter.get_pad(dpi),
                   self.offset_filter.get_pad(dpi))

    def process_image(self, padded_src, dpi):
        t1 = self.gauss_filter.process_image(padded_src, dpi)
        t2 = self.offset_filter.process_image(t1, dpi)
        return t2


class LightFilter(BaseFilter):
    """Apply LightSource filter"""

    def __init__(self, sigma, fraction=1):
        """
        Parameters
        ----------
        sigma : float
            sigma for gaussian filter
        fraction: number, default: 1
            Increases or decreases the contrast of the hillshade.
            See `matplotlib.colors.LightSource`

        """
        self.gauss_filter = GaussianFilter(sigma, alpha=1)
        self.light_source = LightSource()
        self.fraction = fraction

    def get_pad(self, dpi):
        return self.gauss_filter.get_pad(dpi)
```

(continues on next page)

(continued from previous page)

```
    def process_image(self, padded_src, dpi):
        t1 = self.gauss_filter.process_image(padded_src, dpi)
        elevation = t1[:, :, 3]
        rgb = padded_src[:, :, :3]
        alpha = padded_src[:, :, 3:]
        rgb2 = self.light_source.shade_rgb(rgb, elevation,
                                           fraction=self.fraction,
                                           blend_mode="overlay")
        return np.concatenate([rgb2, alpha], -1)


class GrowFilter(BaseFilter):
    """Enlarge the area."""

    def __init__(self, pixels, color=(1, 1, 1)):
        self.pixels = pixels
        self.color = color

    def __call__(self, im, dpi):
        alpha = np.pad(im[..., 3], self.pixels, "constant")
        alpha2 = np.clip(smooth2d(alpha, self.pixels / 72 * dpi) * 5,␣
↪0, 1)
        new_im = np.empty((*alpha2.shape, 4))
        new_im[:, :, :3] = self.color
        new_im[:, :, 3] = alpha2
        offsetx, offsety = -self.pixels, -self.pixels
        return new_im, offsetx, offsety


class FilteredArtistList(Artist):
    """A simple container to filter multiple artists at once."""

    def __init__(self, artist_list, filter):
        super().__init__()
        self._artist_list = artist_list
        self._filter = filter

    def draw(self, renderer):
        renderer.start_rasterizing()
        renderer.start_filter()
        for a in self._artist_list:
            a.draw(renderer)
        renderer.stop_filter(self._filter)
        renderer.stop_rasterizing()
```

(continues on next page)

(continued from previous page)

```
def filtered_text(ax):
    # mostly copied from contour_demo.py

    # prepare image
    delta = 0.025
    x = np.arange(-3.0, 3.0, delta)
    y = np.arange(-2.0, 2.0, delta)
    X, Y = np.meshgrid(x, y)
    Z1 = np.exp(-X**2 - Y**2)
    Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
    Z = (Z1 - Z2) * 2

    # draw
    ax.imshow(Z, interpolation='bilinear', origin='lower',
              cmap="gray", extent=(-3, 3, -2, 2), aspect='auto')
    levels = np.arange(-1.2, 1.6, 0.2)
    CS = ax.contour(Z, levels,
                    origin='lower',
                    linewidths=2,
                    extent=(-3, 3, -2, 2))

    # contour label
    cl = ax.clabel(CS, levels[1::2],  # label every second level
                   fmt='%1.1f',
                   fontsize=11)

    # change clabel color to black
    from matplotlib.patheffects import Normal
    for t in cl:
        t.set_color("k")
        # to force TextPath (i.e., same font in all backends)
        t.set_path_effects([Normal()])

    # Add white glows to improve visibility of labels.
    white_glows = FilteredArtistList(cl, GrowFilter(3))
    ax.add_artist(white_glows)
    white_glows.set_zorder(cl[0].get_zorder() - 0.1)

    ax.xaxis.set_visible(False)
    ax.yaxis.set_visible(False)


def drop_shadow_line(ax):
    # copied from examples/misc/svg_filter_line.py
```

(continues on next page)

(continued from previous page)

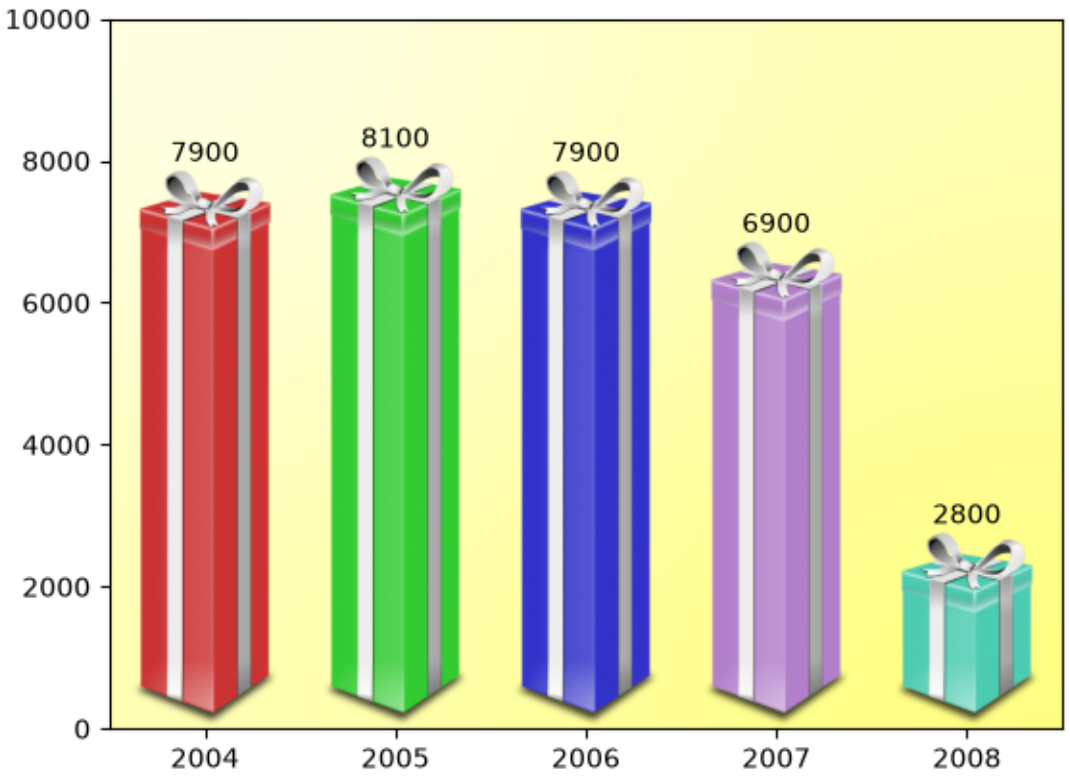
```
    # draw lines
    l1, = ax.plot([0.1, 0.5, 0.9], [0.1, 0.9, 0.5], "bo-")
    l2, = ax.plot([0.1, 0.5, 0.9], [0.5, 0.2, 0.7], "ro-")

    gauss = DropShadowFilter(4)

    for l in [l1, l2]:

        # draw shadows with same lines with slight offset.
        xx = l.get_xdata()
        yy = l.get_ydata()
        shadow, = ax.plot(xx, yy)
        shadow.update_from(l)

        # offset transform
        transform = mtransforms.offset_copy(l.get_transform(), ax.
↪figure,
                                            x=4.0, y=-6.0, units=
↪'points')
        shadow.set_transform(transform)

        # adjust zorder of the shadow lines so that it is drawn below␣
↪the
        # original lines
        shadow.set_zorder(l.get_zorder() - 0.5)
        shadow.set_agg_filter(gauss)
        shadow.set_rasterized(True)  # to support mixed-mode renderers

    ax.set_xlim(0., 1.)
    ax.set_ylim(0., 1.)

    ax.xaxis.set_visible(False)
    ax.yaxis.set_visible(False)


def drop_shadow_patches(ax):
    # Copied from barchart_demo.py
    N = 5
    group1_means = [20, 35, 30, 35, 27]

    ind = np.arange(N)  # the x locations for the groups
    width = 0.35  # the width of the bars

    rects1 = ax.bar(ind, group1_means, width, color='r', ec="w", lw=2)

    group2_means = [25, 32, 34, 20, 25]
```

(continues on next page)

(continued from previous page)

```
    rects2 = ax.bar(ind + width + 0.1, group2_means, width,
                    color='y', ec="w", lw=2)

    drop = DropShadowFilter(5, offsets=(1, 1))
    shadow = FilteredArtistList(rects1 + rects2, drop)
    ax.add_artist(shadow)
    shadow.set_zorder(rects1[0].get_zorder() - 0.1)

    ax.set_ylim(0, 40)

    ax.xaxis.set_visible(False)
    ax.yaxis.set_visible(False)


def light_filter_pie(ax):
    fracs = [15, 30, 45, 10]
    explode = (0.1, 0.2, 0.1, 0.1)
    pie = ax.pie(fracs, explode=explode)

    light_filter = LightFilter(9)
    for p in pie.wedges:
        p.set_agg_filter(light_filter)
        p.set_rasterized(True)  # to support mixed-mode renderers
        p.set(ec="none",
              lw=2)

    gauss = DropShadowFilter(9, offsets=(3, -4), alpha=0.7)
    shadow = FilteredArtistList(pie.wedges, gauss)
    ax.add_artist(shadow)
    shadow.set_zorder(pie.wedges[0].get_zorder() - 0.1)


if __name__ == "__main__":

    fix, axs = plt.subplots(2, 2)

    filtered_text(axs[0, 0])
    drop_shadow_line(axs[0, 1])
    drop_shadow_patches(axs[1, 0])
    light_filter_pie(axs[1, 1])
    axs[1, 1].set_frame_on(True)

    plt.show()
```

Ribbon box




```
from PIL import Image

import matplotlib.pyplot as plt
import numpy as np

from matplotlib import cbook
from matplotlib import colors as mcolors
from matplotlib.image import AxesImage
from matplotlib.transforms import Bbox, BboxTransformTo,␣
↪TransformedBbox


class RibbonBox:

    # Image.open reads this image as 8-bit; divide by 255 to convert␣
↪to 0-1.
    original_image = np.asarray(Image.open(
        cbook.get_sample_data("Minduka_Present_Blue_Pack.png"))) / 255
    cut_location = 70
```

(continues on next page)

(continued from previous page)

```
    b_and_h = original_image[:, :, 2:3]
    color = original_image[:, :, 2:3] - original_image[:, :, 0:1]
    alpha = original_image[:, :, 3:4]
    nx = original_image.shape[1]

    def __init__(self, color):
        rgb = mcolors.to_rgb(color)
        self.im = np.dstack(
            [self.b_and_h - self.color * (1 - np.array(rgb)), self.
 ↪alpha])

    def get_stretched_image(self, stretch_factor):
        stretch_factor = max(stretch_factor, 1)
        ny, nx, nch = self.im.shape
        ny2 = int(ny*stretch_factor)
        return np.vstack(
            [self.im[:self.cut_location],
             np.broadcast_to(
                 self.im[self.cut_location], (ny2 - ny, nx, nch)),
             self.im[self.cut_location:]])


class RibbonBoxImage(AxesImage):
    zorder = 1

    def __init__(self, ax, bbox, color, *, extent=(0, 1, 0, 1),␣
 ↪**kwargs):
        super().__init__(ax, extent=extent, **kwargs)
        self._bbox = bbox
        self._ribbonbox = RibbonBox(color)
        self.set_transform(BboxTransformTo(bbox))

    def draw(self, renderer):
        stretch_factor = self._bbox.height / self._bbox.width

        ny = int(stretch_factor*self._ribbonbox.nx)
        if self.get_array() is None or self.get_array().shape[0] != ny:
            arr = self._ribbonbox.get_stretched_image(stretch_factor)
            self.set_array(arr)

        super().draw(renderer)


def main():
    fig, ax = plt.subplots()
```

(continues on next page)

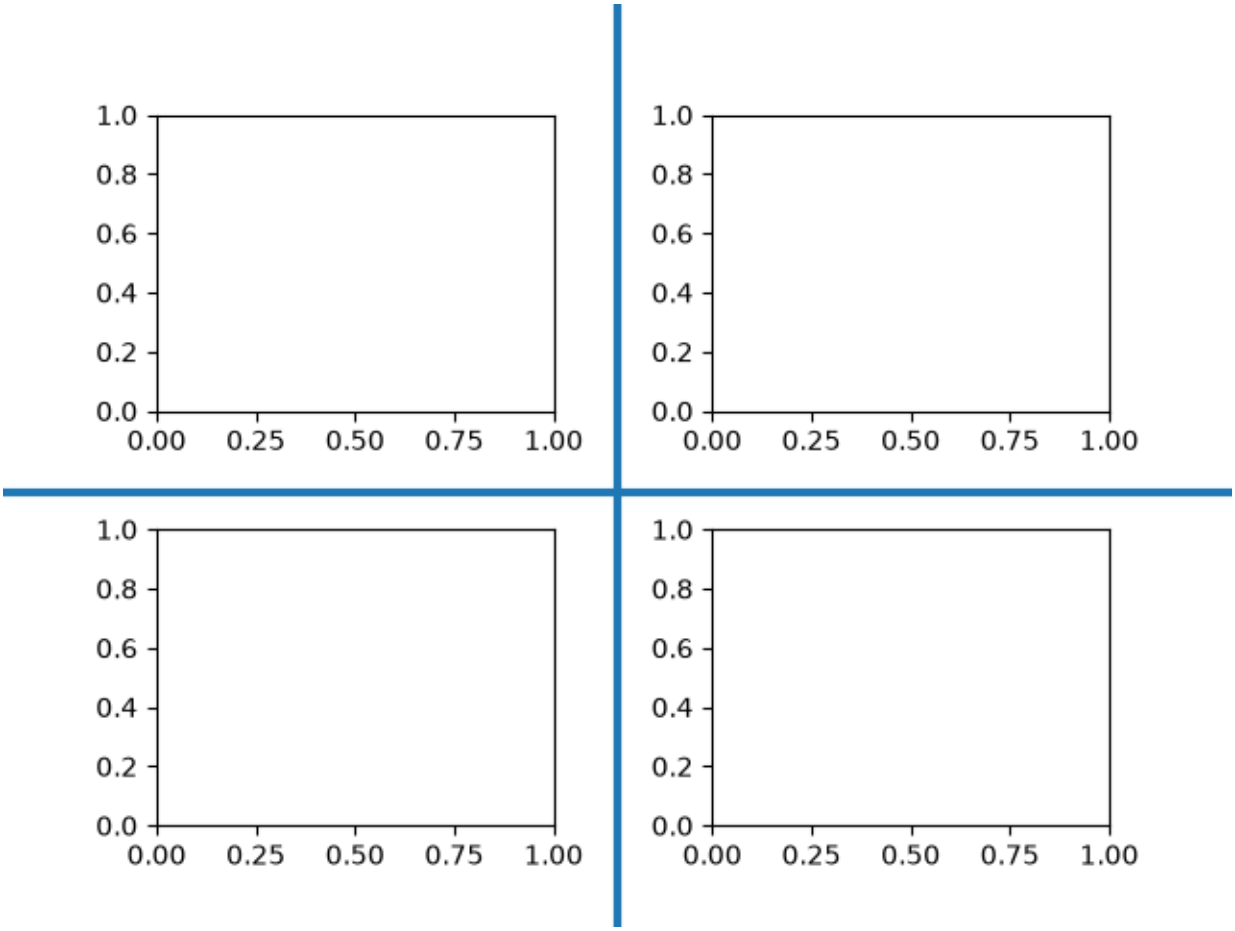
(continued from previous page)

```
    years = np.arange(2004, 2009)
    heights = [7900, 8100, 7900, 6900, 2800]
    box_colors = [
        (0.8, 0.2, 0.2),
        (0.2, 0.8, 0.2),
        (0.2, 0.2, 0.8),
        (0.7, 0.5, 0.8),
        (0.3, 0.8, 0.7),
    ]

    for year, h, bc in zip(years, heights, box_colors):
        bbox0 = Bbox.from_extents(year - 0.4, 0., year + 0.4, h)
        bbox = TransformedBbox(bbox0, ax.transData)
        ax.add_artist(RibbonBoxImage(ax, bbox, bc, interpolation=
 ↪"bicubic"))
        ax.annotate(str(h), (year, h), va="bottom", ha="center")

    ax.set_xlim(years[0] - 0.5, years[-1] + 0.5)
    ax.set_ylim(0, 10000)

    background_gradient = np.zeros((2, 2, 4))
    background_gradient[:, :, :3] = [1, 1, 0]
    background_gradient[:, :, 3] = [[0.1, 0.3], [0.3, 0.5]]  # alpha␣
 ↪channel
    ax.imshow(background_gradient, interpolation="bicubic", zorder=0.1,
              extent=(0, 1, 0, 1), transform=ax.transAxes)

    plt.show()


main()
```

Add lines directly to a figure

You can add artists such as a *Line2D* directly to a figure. This is typically useful for visual structuring.

```
import matplotlib.pyplot as plt

import matplotlib.lines as lines

fig, axs = plt.subplots(2, 2, gridspec_kw={'hspace': 0.4, 'wspace':␣
 ↪0.4})
fig.add_artist(lines.Line2D([0, 1], [0.47, 0.47], linewidth=3))
fig.add_artist(lines.Line2D([0.5, 0.5], [1, 0], linewidth=3))
plt.show()
```

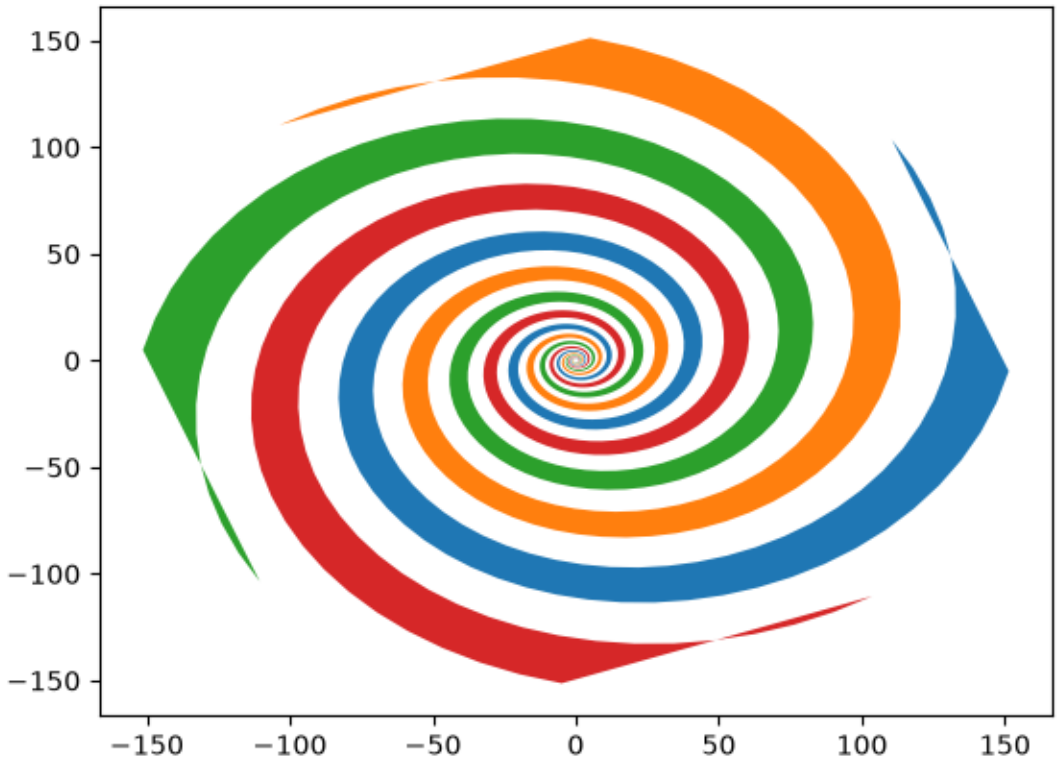


References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.pyplot.figure*
- *matplotlib.lines*
- *matplotlib.lines.Line2D*

Fill spiral




```
import matplotlib.pyplot as plt
import numpy as np

theta = np.arange(0, 8*np.pi, 0.1)
a = 1
b = .2

for dt in np.arange(0, 2*np.pi, np.pi/2.0):

    x = a*np.cos(theta + dt)*np.exp(b*theta)
    y = a*np.sin(theta + dt)*np.exp(b*theta)

    dt = dt + np.pi/4.0

    x2 = a*np.cos(theta + dt)*np.exp(b*theta)
    y2 = a*np.sin(theta + dt)*np.exp(b*theta)

    xf = np.concatenate((x, x2[::-1]))
    yf = np.concatenate((y, y2[::-1]))
```

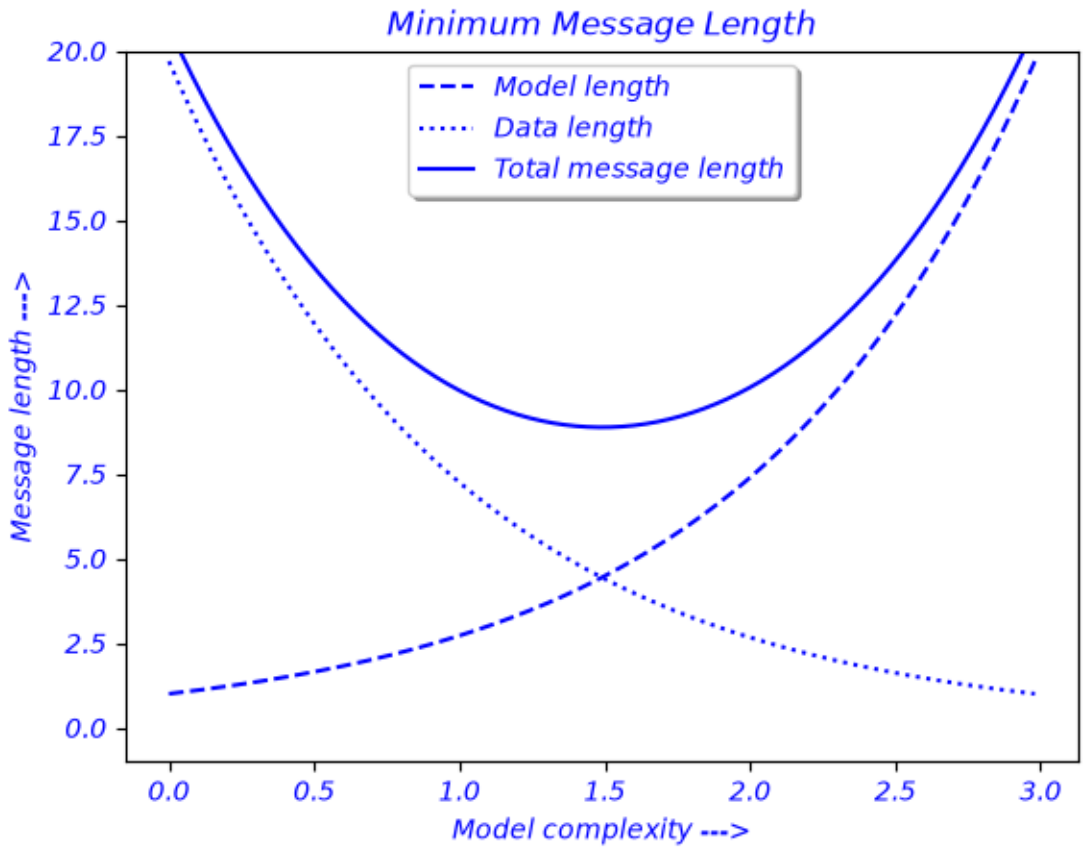
(continues on next page)

(continued from previous page)

```
    p1 = plt.fill(xf, yf)

plt.show()
```

Findobj Demo

Recursively find all objects that match some criteria




```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.text as text

a = np.arange(0, 3, .02)
b = np.arange(0, 3, .02)
c = np.exp(a)
d = c[::-1]
```

(continues on next page)

(continued from previous page)

```
fig, ax = plt.subplots()
plt.plot(a, c, 'k--', a, d, 'k:', a, c + d, 'k')
plt.legend(('Model length', 'Data length', 'Total message length'),
           loc='upper center', shadow=True)
plt.ylim([-1, 20])
plt.grid(False)
plt.xlabel('Model complexity --->')
plt.ylabel('Message length --->')
plt.title('Minimum Message Length')


# match on arbitrary function
def myfunc(x):
    return hasattr(x, 'set_color') and not hasattr(x, 'set_facecolor')


for o in fig.findobj(myfunc):
    o.set_color('blue')

# match on class instances
for o in fig.findobj(text.Text):
    o.set_fontstyle('italic')


plt.show()
```

Font indexing

This example shows how the font tables relate to one another.

```
(16, 0, 1384, 1493)
36 57 65 86
AV 0
AV 0
AV -131
AT -159
```

```
import os

import matplotlib
from matplotlib.ft2font import FT2Font, Kerning
```

(continues on next page)

(continued from previous page)

```
font = FT2Font(
    os.path.join(matplotlib.get_data_path(), 'fonts/ttf/DejaVuSans.ttf
 ↪'))
font.set_charmap(0)

codes = font.get_charmap().items()

# make a charname to charcode and glyphind dictionary
coded = {}
glyphd = {}
for ccode, glyphind in codes:
    name = font.get_glyph_name(glyphind)
    coded[name] = ccode
    glyphd[name] = glyphind
    # print(glyphind, ccode, hex(int(ccode)), name)

code = coded['A']
glyph = font.load_char(code)
print(glyph.bbox)
print(glyphd['A'], glyphd['V'], coded['A'], coded['V'])
print('AV', font.get_kerning(glyphd['A'], glyphd['V'], Kerning.
 ↪DEFAULT))
print('AV', font.get_kerning(glyphd['A'], glyphd['V'], Kerning.
 ↪UNFITTED))
print('AV', font.get_kerning(glyphd['A'], glyphd['V'], Kerning.
 ↪UNSCALED))
print('AT', font.get_kerning(glyphd['A'], glyphd['T'], Kerning.
 ↪UNSCALED))
```

Font properties

This example lists the attributes of an *FT2Font* object, which describe global font properties. For individual character metrics, use the *Glyph* object, as returned by *load_char*.

```
Num instances:   0
Num faces:       1
Num glyphs:      5343
Family name:     DejaVu Sans
Style name:      Oblique
PS name:         DejaVuSans-Oblique
Num fixed:       0
Bbox:                (-2080, -717, 3398, 2187)
EM:                  2048
Ascender:            1901
Descender:           -483
```

(continues on next page)

(continued from previous page)

```
Height:              2384
Max adv width:       3461
Max adv height:      2384
Underline pos:       -175
Underline thickness: 90
Italic:           True
Bold:             False
Scalable:         True
Fixed Sizes:      False
Fixed Width:      False
Sfnt:             True
Horizontal:       True
Vertical:         False
Kerning:          True
Fast Glyphs:      False
Multiple Masters: False
Glyph Names:      True
External Stream:  True
Hinter:           True
Cid Keyed:        False
Tricky:           False
Color:            False
Variation:        False
Svg:              False
Sbix:             False
Sbix Overlay:     False
```

```
import os

import matplotlib
import matplotlib.ft2font as ft

font = ft.FT2Font(
    # Use a font shipped with Matplotlib.
    os.path.join(matplotlib.get_data_path(),
                 'fonts/ttf/DejaVuSans-Oblique.ttf'))

print('Num instances:  ', font.num_named_instances)  # number of named␣
 ↪instances in file
print('Num faces:      ', font.num_faces)            # number of faces␣
 ↪in file
```

(continues on next page)

(continued from previous page)

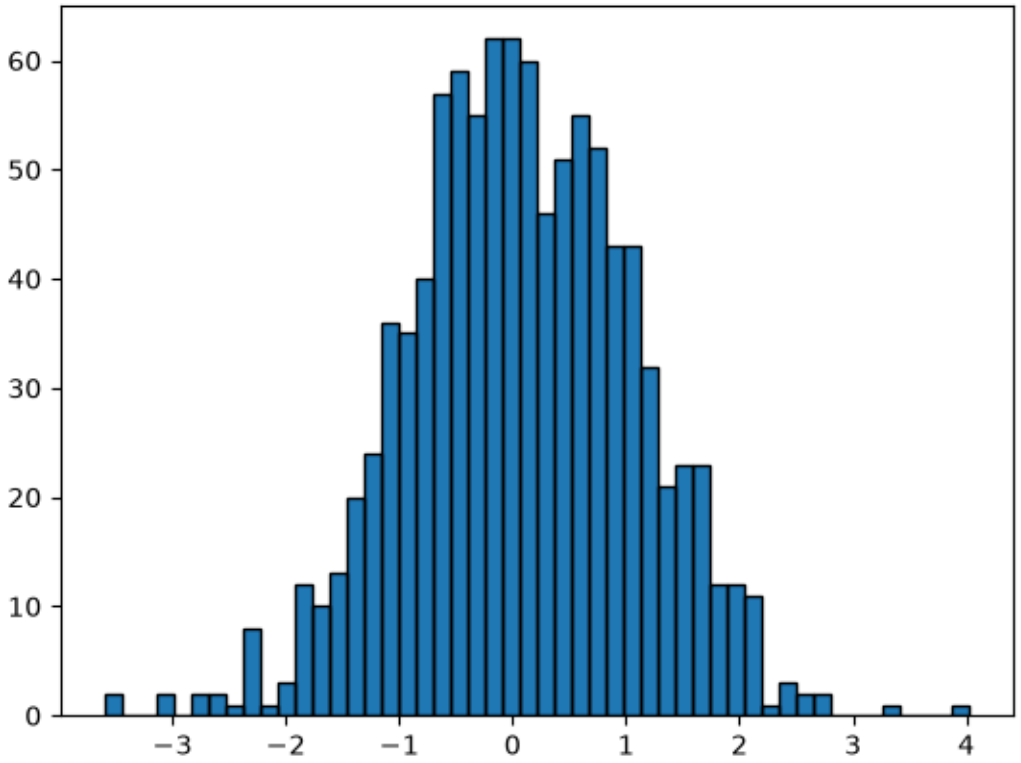
```
print('Num glyphs:     ', font.num_glyphs)           # number of␣
 ↪glyphs in the face
print('Family name:    ', font.family_name)          # face family name
print('Style name:     ', font.style_name)           # face style name
print('PS name:        ', font.postscript_name)      # the postscript␣
 ↪name
print('Num fixed:      ', font.num_fixed_sizes)      # number of␣
 ↪embedded bitmaps

# the following are only available if face.scalable
if font.scalable:
    # the face global bounding box (xmin, ymin, xmax, ymax)
    print('Bbox:               ', font.bbox)
    # number of font units covered by the EM
    print('EM:                 ', font.units_per_EM)
    # the ascender in 26.6 units
    print('Ascender:           ', font.ascender)
    # the descender in 26.6 units
    print('Descender:          ', font.descender)
    # the height in 26.6 units
    print('Height:             ', font.height)
    # maximum horizontal cursor advance
    print('Max adv width:      ', font.max_advance_width)
    # same for vertical layout
    print('Max adv height:     ', font.max_advance_height)
    # vertical position of the underline bar
    print('Underline pos:      ', font.underline_position)
    # vertical thickness of the underline
    print('Underline thickness:', font.underline_thickness)

for flag in ft.StyleFlags:
    name = flag.name.replace('_', ' ').title() + ':'
    print(f"{name:17}", flag in font.style_flags)

for flag in ft.FaceFlags:
    name = flag.name.replace('_', ' ').title() + ':'
    print(f"{name:17}", flag in font.face_flags)
```

Building histograms using Rectangles and PolyCollections

Using a path patch to draw rectangles.

The technique of using lots of *Rectangle* instances, or the faster method of using *PolyCollection*, were implemented before we had proper paths with moveto, lineto, closepoly, etc. in Matplotlib. Now that we have them, we can draw collections of regularly shaped objects with homogeneous properties more efficiently with a PathCollection. This example makes a histogram -- it's more work to set up the vertex arrays at the outset, but it should be much faster for large numbers of objects.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.patches as patches
import matplotlib.path as path

np.random.seed(19680801)  # Fixing random state for reproducibility

# histogram our data with numpy
data = np.random.randn(1000)
n, bins = np.histogram(data, 50)

# get the corners of the rectangles for the histogram
left = bins[:-1]
right = bins[1:]
bottom = np.zeros(len(left))
top = bottom + n

# we need a (numrects x numsides x 2) numpy array for the path helper
# function to build a compound path
XY = np.array([[left, left, right, right], [bottom, top, top,␣
 ↪bottom]]).T

# get the Path object
barpath = path.Path.make_compound_path_from_polys(XY)

# make a patch out of it, don't add a margin at y=0
patch = patches.PathPatch(barpath)
patch.sticky_edges.y[:] = [0]

fig, ax = plt.subplots()
ax.add_patch(patch)
ax.autoscale_view()
plt.show()
```



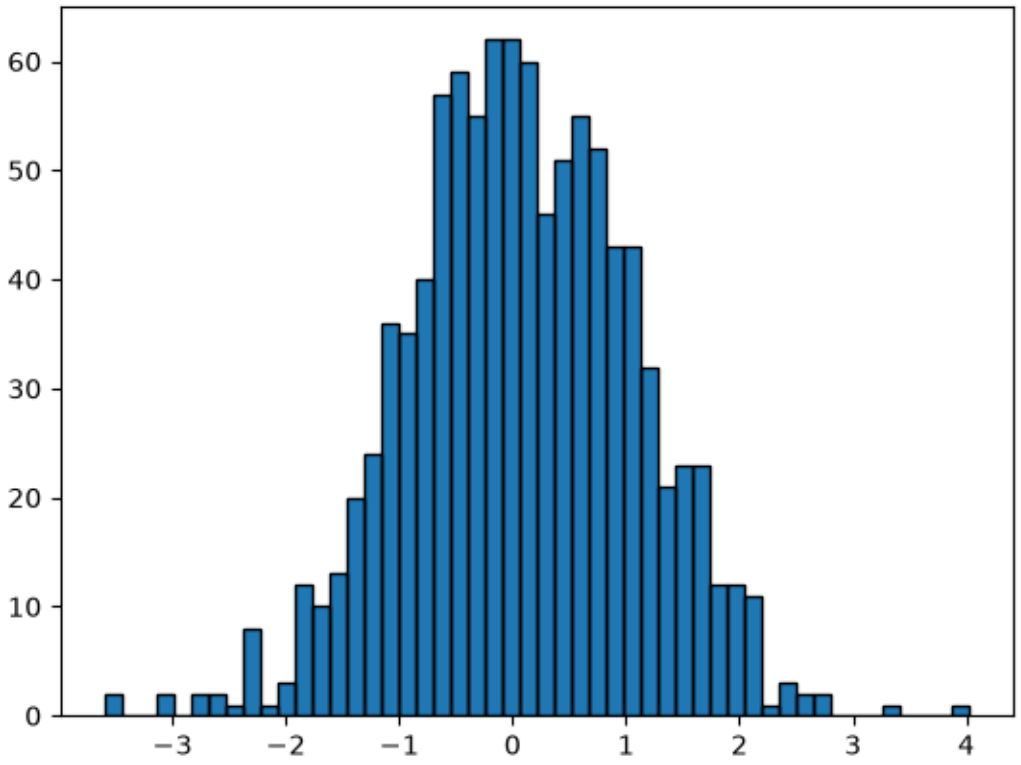
Instead of creating a three-dimensional array and using *make_compound_path_from_polys*, we could as well create the compound path directly using vertices and codes as shown below

```
nrects = len(left)
nverts = nrects*(1+3+1)
verts = np.zeros((nverts, 2))
codes = np.ones(nverts, int) * path.Path.LINETO
codes[0::5] = path.Path.MOVETO
codes[4::5] = path.Path.CLOSEPOLY
verts[0::5, 0] = left
verts[0::5, 1] = bottom
verts[1::5, 0] = left
verts[1::5, 1] = top
verts[2::5, 0] = right
verts[2::5, 1] = top
verts[3::5, 0] = right
verts[3::5, 1] = bottom

barpath = path.Path(verts, codes)

# make a patch out of it, don't add a margin at y=0
```

(continues on next page)

(continued from previous page)

```
patch = patches.PathPatch(barpath)
patch.sticky_edges.y[:] = [0]

fig, ax = plt.subplots()
ax.add_patch(patch)
ax.autoscale_view()
plt.show()
```



References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.patches*
- *matplotlib.patches.PathPatch*
- *matplotlib.path*
- *matplotlib.path.Path*
- *matplotlib.path.Path.make_compound_path_from_polys*

- *matplotlib.axes.Axes.add_patch*
- *matplotlib.collections.PathCollection*

This example shows an alternative to

- *matplotlib.collections.PolyCollection*
- *matplotlib.axes.Axes.hist*

Hyperlinks

This example demonstrates how to set a hyperlinks on various kinds of elements.

This currently only works with the SVG backend.

```
import matplotlib.pyplot as plt
import numpy as np
```

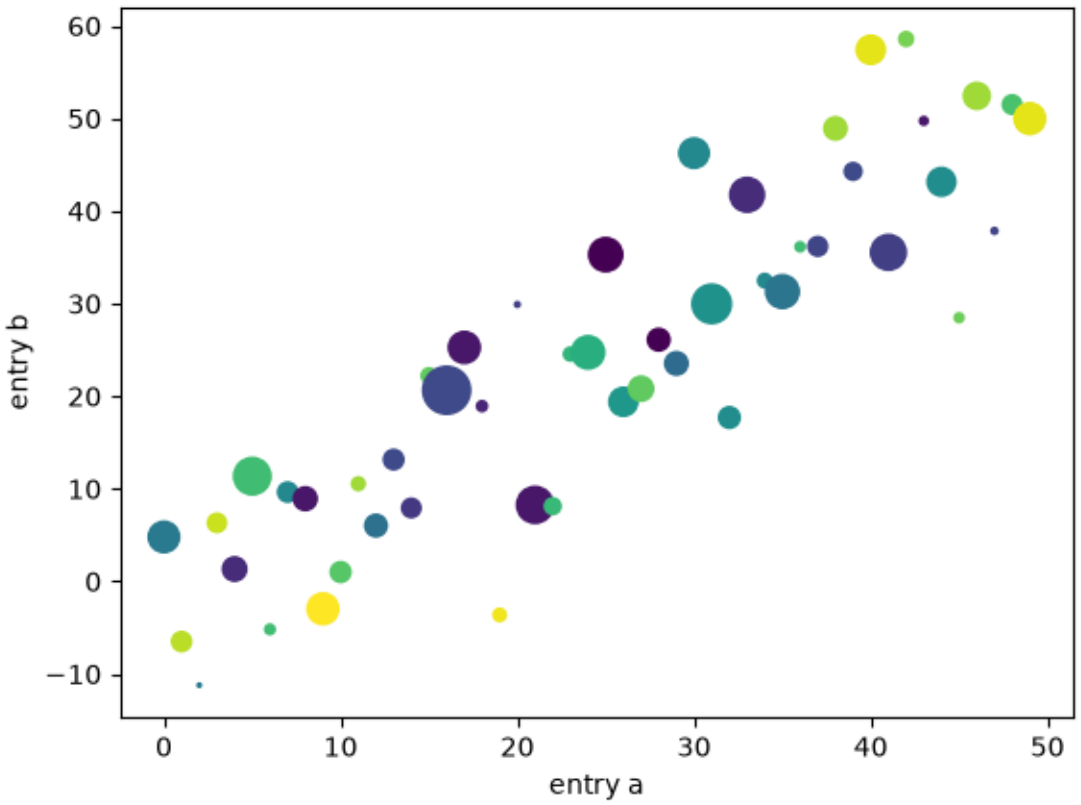
```
fig = plt.figure()
s = plt.scatter([1, 2, 3], [4, 5, 6])
s.set_urls(['https://www.bbc.com/news', 'https://www.google.com/',␣
 ↪None])
fig.savefig('scatter.svg')
```

```
fig = plt.figure()
delta = 0.025
x = y = np.arange(-3.0, 3.0, delta)
X, Y = np.meshgrid(x, y)
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2

im = plt.imshow(Z, interpolation='bilinear', cmap="gray",
                origin='lower', extent=(-3, 3, -3, 3))

im.set_url('https://www.google.com/')
fig.savefig('image.svg')
```

Plotting with keywords

Some data structures, like dict, structured numpy array or `pandas.DataFrame` provide access to labelled data via string index access `data[key]`.

For these data types, Matplotlib supports passing the whole datastructure via the `data` keyword argument, and using the string names as plot function parameters, where you'd normally pass in your data.




```
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)

data = {'a': np.arange(50),
        'c': np.random.randint(0, 50, 50),
        'd': np.random.randn(50)}
data['b'] = data['a'] + 10 * np.random.randn(50)
data['d'] = np.abs(data['d']) * 100

fig, ax = plt.subplots()
ax.scatter('a', 'b', c='c', s='d', data=data)
ax.set(xlabel='entry a', ylabel='entry b')
plt.show()
```

Matplotlib logo

This example generates the current matplotlib logo.

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.cm as cm
import matplotlib.font_manager
from matplotlib.patches import PathPatch, Rectangle
from matplotlib.text import TextPath
import matplotlib.transforms as mtrans

MPL_BLUE = '#11557c'


def get_font_properties():
    # The original font is Calibri, if that is not installed, we fall␣
 ↪back
    # to Carlito, which is metrically equivalent.
    if 'calibri' in matplotlib.font_manager.findfont('Calibri:bold').
 ↪lower():
        return matplotlib.font_manager.FontProperties(family='Calibri',
                                                      weight='bold')
    # Our website documentation uses Carlito because Calibri is␣
 ↪proprietary.
    if 'carlito' in matplotlib.font_manager.findfont('Carlito:bold').
 ↪lower():
        print('Original font not found. Falling back to Carlito. '
              'The logo text will not be in the correct font.')
        return matplotlib.font_manager.FontProperties(family='Carlito',
                                                      weight='bold')
    print('Original font not found. '
          'The logo text will not be in the correct font.')
    return None


def create_icon_axes(fig, ax_position, lw_bars, lw_grid, lw_border,␣
 ↪rgrid):
    """
    Create a polar Axes containing the matplotlib radar plot.

    Parameters
    ----------
    fig : matplotlib.figure.Figure
        The figure to draw into.
    ax_position : (float, float, float, float)
```

(continues on next page)

(continued from previous page)

```
        The position of the created Axes in figure coordinates as
        (x, y, width, height).
    lw_bars : float
        The linewidth of the bars.
    lw_grid : float
        The linewidth of the grid.
    lw_border : float
        The linewidth of the Axes border.
    rgrid : array-like
        Positions of the radial grid.

    Returns
    -------
    ax : matplotlib.axes.Axes
        The created Axes.
    """
    with plt.rc_context({'axes.edgecolor': MPL_BLUE,
                         'axes.linewidth': lw_border}):
        ax = fig.add_axes(ax_position, projection='polar')
        ax.set_axisbelow(True)

        N = 7
        arc = 2. * np.pi
        theta = np.arange(0.0, arc, arc / N)
        radii = np.array([2, 6, 8, 7, 4, 5, 8])
        width = np.pi / 4 * np.array([0.4, 0.4, 0.6, 0.8, 0.2, 0.5,␣
↪0.3])
        bars = ax.bar(theta, radii, width=width, bottom=0.0, align=
↪'edge',
                      edgecolor='0.3', lw=lw_bars)
        for r, bar in zip(radii, bars):
            color = *cm.jet(r / 10.)[:3], 0.6  # color from jet with␣
↪alpha=0.6
            bar.set_facecolor(color)

        ax.tick_params(labelbottom=False, labeltop=False,
                       labelleft=False, labelright=False)

        ax.grid(lw=lw_grid, color='0.9')
        ax.set_rmax(9)
        ax.set_yticks(rgrid)

        # the actual visible background - extends a bit beyond the axis
        ax.add_patch(Rectangle((0, 0), arc, 9.58,
                               facecolor='white', zorder=0,
                               clip_on=False, in_layout=False))
```

(continues on next page)

(continued from previous page)

```
        return ax


def create_text_axes(fig, height_px):
    """Create an Axes in *fig* that contains 'matplotlib' as Text."""
    ax = fig.add_axes((0, 0, 1, 1))
    ax.set_aspect("equal")
    ax.set_axis_off()

    path = TextPath((0, 0), "matplotlib", size=height_px * 0.8,
                    prop=get_font_properties())

    angle = 4.25  # degrees
    trans = mtrans.Affine2D().skew_deg(angle, 0)

    patch = PathPatch(path, transform=trans + ax.transData,␣
 ↪color=MPL_BLUE,
                      lw=0)
    ax.add_patch(patch)
    ax.autoscale()


def make_logo(height_px, lw_bars, lw_grid, lw_border, rgrid,␣
 ↪with_text=False):
    """
    Create a full figure with the Matplotlib logo.

    Parameters
    ----------
    height_px : int
        Height of the figure in pixel.
    lw_bars : float
        The linewidth of the bar border.
    lw_grid : float
        The linewidth of the grid.
    lw_border : float
        The linewidth of icon border.
    rgrid : sequence of float
        The radial grid positions.
    with_text : bool
        Whether to draw only the icon or to include 'matplotlib' as␣
 ↪text.
    """
    dpi = 100
    height = height_px / dpi
    figsize = (5 * height, height) if with_text else (height, height)
```

(continues on next page)

(continued from previous page)

```
    fig = plt.figure(figsize=figsize, dpi=dpi)
    fig.patch.set_alpha(0)

    if with_text:
        create_text_axes(fig, height_px)
    ax_pos = (0.535, 0.12, .17, 0.75) if with_text else (0.03, 0.03, .
↪94, .94)
    ax = create_icon_axes(fig, ax_pos, lw_bars, lw_grid, lw_border,␣
↪rgrid)

    return fig, ax
```

A large logo:

```
make_logo(height_px=110, lw_bars=0.7, lw_grid=0.5, lw_border=1,
          rgrid=[1, 3, 5, 7])
```

A small 32px logo:

```
make_logo(height_px=32, lw_bars=0.3, lw_grid=0.3, lw_border=0.3,␣
↪rgrid=[5])
```

A large logo including text, as used on the matplotlib website.

```
make_logo(height_px=110, lw_bars=0.7, lw_grid=0.5, lw_border=1,
          rgrid=[1, 3, 5, 7], with_text=True)
plt.show()
```

```
findfont: Font family ['Calibri'] not found. Falling back to DejaVu␣
↪Sans.
```

(continues on next page)

(continued from previous page)

```
Original font not found. Falling back to Carlito. The logo text will␣
 ↪not be in the correct font.
```

Multipage PDF

This is a demo of creating a pdf file with several pages, as well as adding metadata and annotations to pdf files.

```
import datetime

import matplotlib.pyplot as plt
import numpy as np

from matplotlib.backends.backend_pdf import PdfPages


# Create the PdfPages object to which we will save the pages:
# The with statement makes sure that the PdfPages object is closed␣
 ↪properly at
# the end of the block, even if an Exception occurs.
with PdfPages('multipage_pdf.pdf') as pdf:
    plt.figure(figsize=(3, 3))
    plt.plot(range(7), [3, 1, 4, 1, 5, 9, 2], 'r-o')
    plt.title('Page One')
    pdf.savefig()  # saves the current figure into a pdf page
    plt.close()

    # if LaTeX is not installed or error caught, change to `False`
    plt.rcParams['text.usetex'] = True
    plt.figure(figsize=(8, 6))
    x = np.arange(0, 5, 0.1)
    plt.plot(x, np.sin(x), 'b-')
    plt.title('Page Two')
    pdf.attach_note("plot of sin(x)")  # attach metadata (as pdf note)␣
 ↪to page
    pdf.savefig()
    plt.close()

    plt.rcParams['text.usetex'] = False
    fig = plt.figure(figsize=(4, 5))
    plt.plot(x, x ** 2, 'ko')
    plt.title('Page Three')
    pdf.savefig(fig)  # or you can pass a Figure object to pdf.savefig
    plt.close()

    # We can also set the file's metadata via the PdfPages object:
```

(continues on next page)

(continued from previous page)

```
    d = pdf.infodict()
    d['Title'] = 'Multipage PDF Example'
    d['Author'] = 'Jouni K. Sepp\xe4nen'
    d['Subject'] = 'How to create a multipage pdf file and set its␣
 ↪metadata'
    d['Keywords'] = 'PdfPages multipage keywords author title subject'
    d['CreationDate'] = datetime.datetime(2009, 11, 13)
    d['ModDate'] = datetime.datetime.today()
```

Multiprocessing

Demo of using multiprocessing for generating data in one process and plotting in another.

Written by Robert Cimrman

```
import multiprocessing as mp
import time

import matplotlib.pyplot as plt
import numpy as np

# Fixing random state for reproducibility
np.random.seed(19680801)
```

Processing Class

This class plots data it receives from a pipe.

```
class ProcessPlotter:
    def __init__(self):
        self.x = []
        self.y = []

    def terminate(self):
        plt.close('all')

    def call_back(self):
        while self.pipe.poll():
            command = self.pipe.recv()
            if command is None:
                self.terminate()
                return False
            else:
                self.x.append(command[0])
                self.y.append(command[1])
                self.ax.plot(self.x, self.y, 'ro')
```

(continues on next page)

(continued from previous page)

```
        self.fig.canvas.draw()
        return True

    def __call__(self, pipe):
        print('starting plotter...')

        self.pipe = pipe
        self.fig, self.ax = plt.subplots()
        timer = self.fig.canvas.new_timer(interval=1000)
        timer.add_callback(self.call_back)
        timer.start()

        print('...done')
        plt.show()
```

Plotting class

This class uses multiprocessing to spawn a process to run code from the class above. When initialized, it creates a pipe and an instance of `ProcessPlotter` which will be run in a separate process.

When run from the command line, the parent process sends data to the spawned process which is then plotted via the callback function specified in `ProcessPlotter:__call__`.

```
class NBPlot:
    def __init__(self):
        self.plot_pipe, plotter_pipe = mp.Pipe()
        self.plotter = ProcessPlotter()
        self.plot_process = mp.Process(
            target=self.plotter, args=(plotter_pipe,), daemon=True)
        self.plot_process.start()

    def plot(self, finished=False):
        send = self.plot_pipe.send
        if finished:
            send(None)
        else:
            data = np.random.random(2)
            send(data)


def main():
    pl = NBPlot()
    for _ in range(10):
        pl.plot()
        time.sleep(0.5)
    pl.plot(finished=True)
```

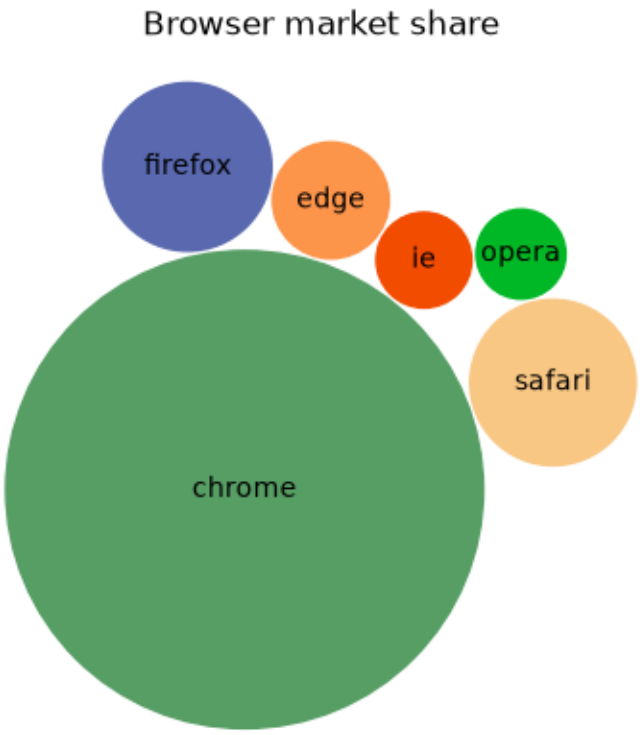
(continues on next page)

(continued from previous page)

```
if __name__ == '__main__':
    if plt.get_backend() == "MacOSX":
        mp.set_start_method("forkserver")
    main()
```

Packed-bubble chart

Create a packed-bubble chart to represent scalar data. The presented algorithm tries to move all bubbles as close to the center of mass as possible while avoiding some collisions by moving around colliding objects. In this example we plot the market share of different desktop browsers. (source: https://gs.statcounter.com/browser-market-share/desktop/worldwidev)




```
import matplotlib.pyplot as plt
import numpy as np

browser_market_share = {
    'browsers': ['firefox', 'chrome', 'safari', 'edge', 'ie', 'opera'],
```

(continues on next page)

(continued from previous page)

```
    'market_share': [8.61, 69.55, 8.36, 4.12, 2.76, 2.43],
    'color': ['#5A69AF', '#579E65', '#F9C784', '#FC944A', '#F24C00', '
↪#00B825']
}


class BubbleChart:
    def __init__(self, area, bubble_spacing=0):
        """
        Setup for bubble collapse.

        Parameters
        ----------
        area : array-like
            Area of the bubbles.
        bubble_spacing : float, default: 0
            Minimal spacing between bubbles after collapsing.

        Notes
        -----
        If "area" is sorted, the results might look weird.
        """
        area = np.asarray(area)
        r = np.sqrt(area / np.pi)

        self.bubble_spacing = bubble_spacing
        self.bubbles = np.ones((len(area), 4))
        self.bubbles[:, 2] = r
        self.bubbles[:, 3] = area
        self.maxstep = 2 * self.bubbles[:, 2].max() + self.
↪bubble_spacing
        self.step_dist = self.maxstep / 2

        # calculate initial grid layout for bubbles
        length = np.ceil(np.sqrt(len(self.bubbles)))
        grid = np.arange(length) * self.maxstep
        gx, gy = np.meshgrid(grid, grid)
        self.bubbles[:, 0] = gx.flatten()[:len(self.bubbles)]
        self.bubbles[:, 1] = gy.flatten()[:len(self.bubbles)]

        self.com = self.center_of_mass()

    def center_of_mass(self):
        return np.average(
            self.bubbles[:, :2], axis=0, weights=self.bubbles[:, 3]
        )
```

(continues on next page)

(continued from previous page)

```
    def center_distance(self, bubble, bubbles):
        return np.hypot(bubble[0] - bubbles[:, 0],
                        bubble[1] - bubbles[:, 1])

    def outline_distance(self, bubble, bubbles):
        center_distance = self.center_distance(bubble, bubbles)
        return center_distance - bubble[2] - \
            bubbles[:, 2] - self.bubble_spacing

    def check_collisions(self, bubble, bubbles):
        distance = self.outline_distance(bubble, bubbles)
        return len(distance[distance < 0])

    def collides_with(self, bubble, bubbles):
        distance = self.outline_distance(bubble, bubbles)
        return np.argmin(distance, keepdims=True)

    def collapse(self, n_iterations=50):
        """
        Move bubbles to the center of mass.

        Parameters
        ----------
        n_iterations : int, default: 50
            Number of moves to perform.
        """
        for _i in range(n_iterations):
            moves = 0
            for i in range(len(self.bubbles)):
                rest_bub = np.delete(self.bubbles, i, 0)
                # try to move directly towards the center of mass
                # direction vector from bubble to the center of mass
                dir_vec = self.com - self.bubbles[i, :2]

                # shorten direction vector to have length of 1
                dir_vec = dir_vec / np.sqrt(dir_vec.dot(dir_vec))

                # calculate new bubble position
                new_point = self.bubbles[i, :2] + dir_vec * self.
↪step_dist
                new_bubble = np.append(new_point, self.bubbles[i, 2:4])

                # check whether new bubble collides with other bubbles
                if not self.check_collisions(new_bubble, rest_bub):
                    self.bubbles[i, :] = new_bubble
```

(continues on next page)

(continued from previous page)

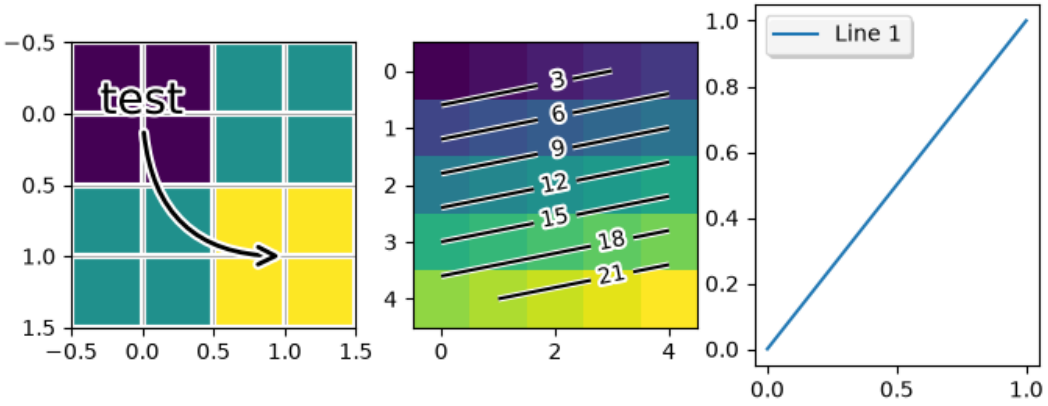
```
                    self.com = self.center_of_mass()
                    moves += 1
                else:
                    # try to move around a bubble that you collide with
                    # find colliding bubble
                    for colliding in self.collides_with(new_bubble,␣
↪rest_bub):
                        # calculate direction vector
                        dir_vec = rest_bub[colliding, :2] - self.
↪bubbles[i, :2]
                        dir_vec = dir_vec / np.sqrt(dir_vec.
↪dot(dir_vec))
                        # calculate orthogonal vector
                        orth = np.array([dir_vec[1], -dir_vec[0]])
                        # test which direction to go
                        new_point1 = (self.bubbles[i, :2] + orth *
                                      self.step_dist)
                        new_point2 = (self.bubbles[i, :2] - orth *
                                      self.step_dist)
                        dist1 = self.center_distance(
                            self.com, np.array([new_point1]))
                        dist2 = self.center_distance(
                            self.com, np.array([new_point2]))
                        new_point = new_point1 if dist1 < dist2 else␣
↪new_point2
                        new_bubble = np.append(new_point, self.
↪bubbles[i, 2:4])
                        if not self.check_collisions(new_bubble,␣
↪rest_bub):
                            self.bubbles[i, :] = new_bubble
                            self.com = self.center_of_mass()

            if moves / len(self.bubbles) < 0.1:
                self.step_dist = self.step_dist / 2

    def plot(self, ax, labels, colors):
        """
        Draw the bubble plot.

        Parameters
        ----------
        ax : matplotlib.axes.Axes
        labels : list
            Labels of the bubbles.
        colors : list
            Colors of the bubbles.
```

(continues on next page)

(continued from previous page)

```
        """
        for i in range(len(self.bubbles)):
            circ = plt.Circle(
                self.bubbles[i, :2], self.bubbles[i, 2],␣
 ↪color=colors[i])
            ax.add_patch(circ)
            ax.text(*self.bubbles[i, :2], labels[i],
                    horizontalalignment='center', verticalalignment=
 ↪'center')


bubble_chart = BubbleChart(area=browser_market_share['market_share'],
                           bubble_spacing=0.1)

bubble_chart.collapse()

fig, ax = plt.subplots(subplot_kw=dict(aspect="equal"))
bubble_chart.plot(
    ax, browser_market_share['browsers'], browser_market_share['color
 ↪'])
ax.axis("off")
ax.relim()
ax.autoscale_view()
ax.set_title('Browser market share')

plt.show()
```

Patheffect Demo




```
import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
from matplotlib import patheffects

fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(8, 3))
ax1.imshow([[1, 2], [2, 3]])
txt = ax1.annotate("test", (1., 1.), (0., 0),
                   arrowprops=dict(arrowstyle="->",
                                   connectionstyle="angle3", lw=2),
                   size=20, ha="center",
                   path_effects=[patheffects.withStroke(linewidth=3,
                                                        foreground="w
 ↪")])
txt.arrow_patch.set_path_effects([
    patheffects.Stroke(linewidth=5, foreground="w"),
    patheffects.Normal()])

pe = [patheffects.withStroke(linewidth=3,
                             foreground="w")]
ax1.grid(True, linestyle="-", path_effects=pe)

arr = np.arange(25).reshape((5, 5))
ax2.imshow(arr)
cntr = ax2.contour(arr, colors="k")

cntr.set(path_effects=[patheffects.withStroke(linewidth=3, foreground=
 ↪"w")])

clbls = ax2.clabel(cntr, fmt="%2.0f", use_clabeltext=True)
plt.setp(clbls, path_effects=[
    patheffects.withStroke(linewidth=3, foreground="w")])

# shadow as a path effect
p1, = ax3.plot([0, 1], [0, 1])
leg = ax3.legend([p1], ["Line 1"], fancybox=True, loc='upper left')
leg.legendPatch.set_path_effects([patheffects.withSimplePatchShadow()])

plt.show()
```

Print image to stdout

print png to standard out

usage: python print_stdout.py > somefile.png

```
import sys
```

(continues on next page)

(continued from previous page)

```
import matplotlib

matplotlib.use('Agg')
import matplotlib.pyplot as plt

plt.plot([1, 2, 3])
plt.savefig(sys.stdout.buffer)
```

Rasterization for vector graphics

Rasterization converts vector graphics into a raster image (pixels). It can speed up rendering and produce smaller files for large data sets, but comes at the cost of a fixed resolution.

Whether rasterization should be used can be specified per artist. This can be useful to reduce the file size of large artists, while maintaining the advantages of vector graphics for other artists such as the Axes and text. For instance a complicated *pcolormesh* or *contourf* can be made significantly simpler by rasterizing. Setting rasterization only affects vector backends such as PDF, SVG, or PS.

Rasterization is disabled by default. There are two ways to enable it, which can also be combined:

- Set *set_rasterized* on individual artists, or use the keyword argument *rasterized* when creating the artist.
- Set *Axes.set_rasterization_zorder* to rasterize all artists with a zorder less than the given value.

The storage size and the resolution of the rasterized artist is determined by its physical size and the value of the dpi parameter passed to *savefig*.

Note

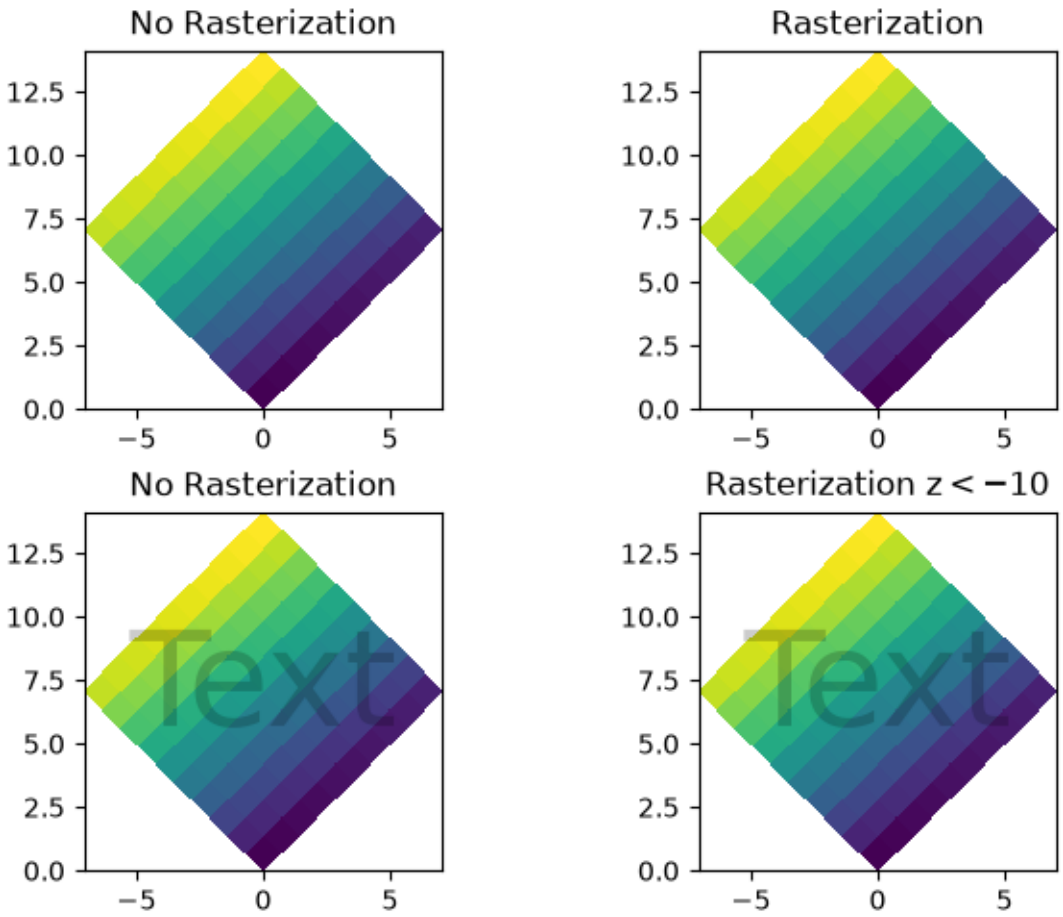
The image of this example shown in the HTML documentation is not a vector graphic. Therefore, it cannot illustrate the rasterization effect. Please run this example locally and check the generated graphics files.

```
import matplotlib.pyplot as plt
import numpy as np

d = np.arange(100).reshape(10, 10)  # the values to be color-mapped
x, y = np.meshgrid(np.arange(11), np.arange(11))

theta = 0.25*np.pi
xx = x*np.cos(theta) - y*np.sin(theta)  # rotate x by -theta
yy = x*np.sin(theta) + y*np.cos(theta)  # rotate y by -theta

fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(2, 2, layout="constrained
 ↪")
```

(continues on next page)

(continued from previous page)

```
# pcolormesh without rasterization
ax1.set_aspect(1)
ax1.pcolormesh(xx, yy, d)
ax1.set_title("No Rasterization")

# pcolormesh with rasterization; enabled by keyword argument
ax2.set_aspect(1)
ax2.set_title("Rasterization")
ax2.pcolormesh(xx, yy, d, rasterized=True)

# pcolormesh with an overlaid text without rasterization
ax3.set_aspect(1)
ax3.pcolormesh(xx, yy, d)
ax3.text(0.5, 0.5, "Text", alpha=0.2,
         va="center", ha="center", size=50, transform=ax3.transAxes)
ax3.set_title("No Rasterization")

# pcolormesh with an overlaid text without rasterization; enabled by␣
 ↪zorder.
# Setting the rasterization zorder threshold to 0 and a negative␣
 ↪zorder on the
# pcolormesh rasterizes it. All artists have a non-negative zorder by␣
 ↪default,
# so they (e.g. the text here) are not affected.
ax4.set_aspect(1)
m = ax4.pcolormesh(xx, yy, d, zorder=-10)
ax4.text(0.5, 0.5, "Text", alpha=0.2,
         va="center", ha="center", size=50, transform=ax4.transAxes)
ax4.set_rasterization_zorder(0)
ax4.set_title("Rasterization z$<-10$")

# Save files in pdf and eps format
plt.savefig("test_rasterization.pdf", dpi=150)
plt.savefig("test_rasterization.eps", dpi=150)

if not plt.rcParams["text.usetex"]:
    plt.savefig("test_rasterization.svg", dpi=150)
    # svg backend currently ignores the dpi
```




```
The PostScript backend does not support transparency; partially␣
↪transparent artists will be rendered opaque.
```

References

The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.artist.Artist.set_rasterized*
- *matplotlib.axes.Axes.set_rasterization_zorder*
- *matplotlib.axes.Axes.pcolormesh* / *matplotlib.pyplot.pcolormesh*

Total running time of the script: (0 minutes 2.337 seconds)

Set and get properties

The pyplot interface allows you to use `setp` and `getp` to set and get object properties respectively, as well as to do introspection on the object.

Setting with `setp`

To set the linestyle of a line to be dashed, you use `setp`:

```
>>> line, = plt.plot([1, 2, 3])
>>> plt.setp(line, linestyle='--')
```

If you want to know the valid types of arguments, you can provide the name of the property you want to set without a value:

```
>>> plt.setp(line, 'linestyle')
    linestyle: {'-', '--', '-.', ':', '', (offset, on-off-seq), ...}
```

If you want to see all the properties that can be set, and their possible values, you can do:

```
>>> plt.setp(line)
```

`setp` operates on a single instance or a list of instances. If you are in query mode introspecting the possible values, only the first instance in the sequence is used. When actually setting values, all the instances will be set. For example, suppose you have a list of two lines, the following will make both lines thicker and red:

```
>>> x = np.arange(0, 1, 0.01)
>>> y1 = np.sin(2*np.pi*x)
>>> y2 = np.sin(4*np.pi*x)
>>> lines = plt.plot(x, y1, x, y2)
>>> plt.setp(lines, linewidth=2, color='r')
```

Getting with `getp`

`getp` returns the value of a given attribute. You can use it to query the value of a single attribute:

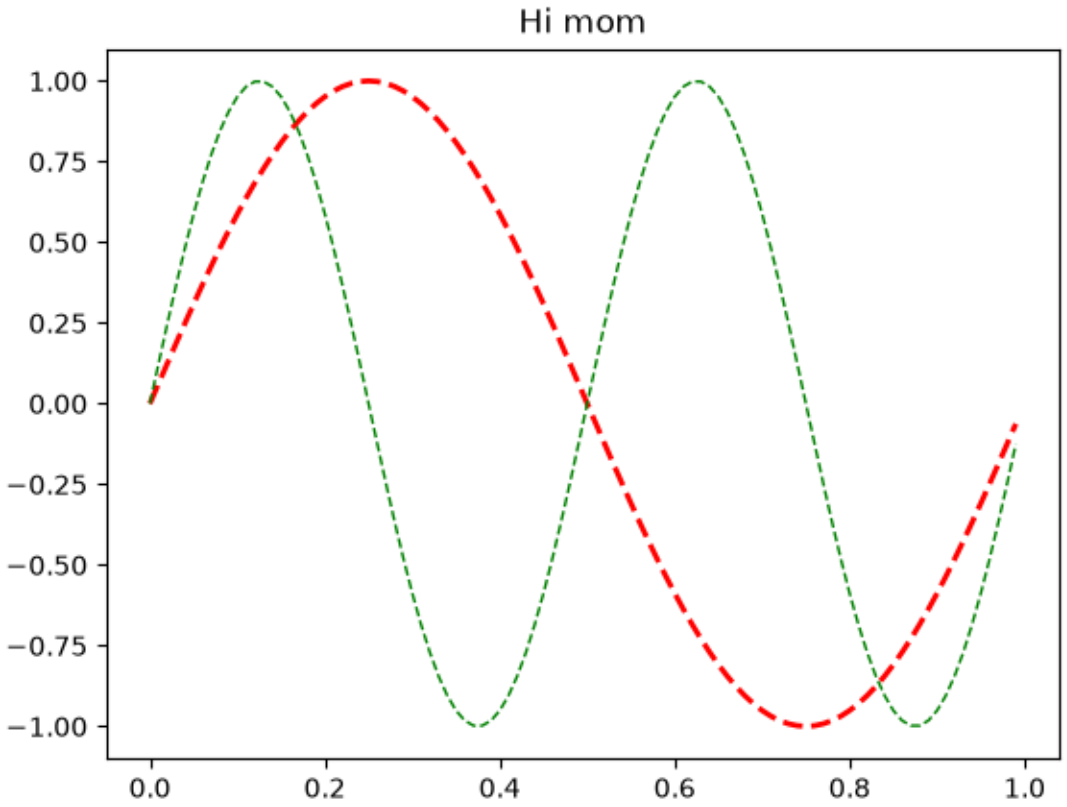
```
>>> plt.getp(line, 'linewidth')
    0.5
```

or all the attribute/value pairs:

```
>>> plt.getp(line)
    aa = True
    alpha = 1.0
    antialiased = True
    c = b
    clip_on = True
    color = b
    ... long listing skipped ...
```

Aliases

To reduce keystrokes in interactive mode, a number of properties have short aliases, e.g., 'lw' for 'linewidth' and 'mec' for 'markeredgecolor'. When calling set or get in introspection mode, these properties will be listed as 'fullname' or 'aliasname'.



```
Line setters
  agg_filter: a filter function, which takes a (m, n, 3) float array␣
 ↪and a dpi value, and returns a (m, n, 3) array and two offsets from␣
 ↪the bottom left corner of the image
  alpha: float or None
  animated: bool
  antialiased or aa: bool
  clip_box: `~matplotlib.transforms.BboxBase` or None
  clip_on: bool
  clip_path: Patch or (Path, Transform) or None
  color or c: :mpltype:`color`
  dash_capstyle: `.CapStyle` or {'butt', 'projecting', 'round'}
  dash_joinstyle: `.JoinStyle` or {'miter', 'round', 'bevel'}
  dashes: sequence of floats (on/off ink in points) or (None, None)
  data: (2, N) array or two 1D arrays
  drawstyle or ds: {'default', 'steps', 'steps-pre', 'steps-mid',
 ↪'steps-post'}, default: 'default'
  figure: `~matplotlib.figure.Figure` or `~matplotlib.figure.SubFigure`
  fillstyle: {'full', 'left', 'right', 'bottom', 'top', 'none'}
  gapcolor: :mpltype:`color` or None
  gid: str
  in_layout: bool
  label: object
  linestyle or ls: {'-', '--', '-.', ':', '', ...} or (offset,␣
 ↪on-off-seq)
  linewidth or lw: float
  marker: marker style string, `~.path.Path` or `~.markers.MarkerStyle`
  markeredgecolor or mec: :mpltype:`color`
  markeredgewidth or mew: float
  markerfacecolor or mfc: :mpltype:`color`
  markerfacecoloralt or mfcalt: :mpltype:`color`
  markersize or ms: float
  markevery: None or int or (int, int) or slice or list[int] or float␣
 ↪or (float, float) or list[bool]
  mouseover: bool
  path_effects: list of `.AbstractPathEffect`
  picker: float or callable[[Artist, Event], tuple[bool, dict]]
  pickradius: float
  rasterized: bool
  sketch_params: (scale: float, length: float, randomness: float)
  snap: bool or None
  solid_capstyle: `.CapStyle` or {'butt', 'projecting', 'round'}
  solid_joinstyle: `.JoinStyle` or {'miter', 'round', 'bevel'}
  transform: `~matplotlib.transforms.Transform`
  url: str
  visible: bool
```

(continues on next page)

(continued from previous page)

```
  xdata: 1D array
  ydata: 1D array
  zorder: float
Line getters
    agg_filter = None
    alpha = None
    animated = False
    antialiased or aa = True
    bbox = Bbox(x0=0.0, y0=-1.0, x1=0.99, y1=1.0)
    children = []
    clip_box = TransformedBbox(     Bbox(x0=0.0, y0=0.0, x1=1.0, ...
    clip_on = True
    clip_path = None
    color or c = r
    dash_capstyle = butt
    dash_joinstyle = round
    data = (array([0.  , 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, ...
    drawstyle or ds = default
    figure = Figure(640x480)
    fillstyle = full
    gapcolor = None
    gid = None
    in_layout = True
    label = _child0
    linestyle or ls = --
    linewidth or lw = 2.0
    marker = None
    markeredgecolor or mec = r
    markeredgewidth or mew = 1.0
    markerfacecolor or mfc = r
    markerfacecoloralt or mfcalt = none
    markersize or ms = 6.0
    markevery = None
    mouseover = False
    path = Path(array([[ 0.00000000e+00,  0.00000000e+00],   ...
    path_effects = []
    picker = None
    pickradius = 5
    rasterized = False
    sketch_params = None
    snap = None
    solid_capstyle = projecting
    solid_joinstyle = round
    tightbbox = Bbox(x0=80.0, y0=52.8, x1=571.04, y1=422.4)
    transform = CompositeGenericTransform(     TransformWrapper(  ...
    transformed_clip_path_and_affine = (None, None)
```

(continues on next page)

(continued from previous page)

```
    url = None
    visible = True
    window_extent = Bbox(x0=80.0, y0=-316.79999999999995, x1=571.04,␣
 ↪y...
    xdata = [0.   0.01 0.02 0.03 0.04 0.05]...
    xydata = [[0.         0.        ]  [0.01       0.06279052] ...
    ydata = [0.         0.06279052 0.12533323 0.18738131 0.248...
    zorder = 2
Rectangle setters
  agg_filter: a filter function, which takes a (m, n, 3) float array␣
 ↪and a dpi value, and returns a (m, n, 3) array and two offsets from␣
 ↪the bottom left corner of the image
  alpha: float or None
  angle: unknown
  animated: bool
  antialiased or aa: bool or None
  bounds: (left, bottom, width, height)
  capstyle: `.CapStyle` or {'butt', 'projecting', 'round'}
  clip_box: `~matplotlib.transforms.BboxBase` or None
  clip_on: bool
  clip_path: Patch or (Path, Transform) or None
  color: :mpltype:`color`
  edgecolor or ec: :mpltype:`color` or None
  edgegapcolor: :mpltype:`color` or None
  facecolor or fc: :mpltype:`color` or None
  figure: `~matplotlib.figure.Figure` or `~matplotlib.figure.SubFigure`
  fill: bool
  gid: str
  hatch: {'/', '\\', '|', '-', '+', 'x', 'o', 'O', '.', '*'}
  hatch_linewidth: unknown
  hatchcolor: :mpltype:`color` or 'edge' or None
  height: unknown
  in_layout: bool
  joinstyle: `.JoinStyle` or {'miter', 'round', 'bevel'}
  label: object
  linestyle or ls: {'-', '--', '-.', ':', '', ...} or (offset,␣
 ↪on-off-seq)
  linewidth or lw: float or None
  mouseover: bool
  path_effects: list of `.AbstractPathEffect`
  picker: None or bool or float or callable
  rasterized: bool
  sketch_params: (scale: float, length: float, randomness: float)
  snap: bool or None
  transform: `~matplotlib.transforms.Transform`
  url: str
```

(continues on next page)

(continued from previous page)

```
  visible: bool
  width: unknown
  x: unknown
  xy: (float, float)
  y: unknown
  zorder: float
Rectangle getters
    agg_filter = None
    alpha = None
    angle = 0.0
    animated = False
    antialiased or aa = True
    bbox = Bbox(x0=0.0, y0=0.0, x1=1.0, y1=1.0)
    capstyle = butt
    center = [0.5 0.5]
    children = []
    clip_box = None
    clip_on = True
    clip_path = None
    corners = [[0. 0.]  [1. 0.]  [1. 1.]  [0. 1.]]
    data_transform = BboxTransformTo(     TransformedBbox(        ␣
 ↪Bbox...
    edgecolor or ec = (0.0, 0.0, 0.0, 0.0)
    edgegapcolor = None
    extents = Bbox(x0=80.0, y0=52.8, x1=576.0, y1=422.4)
    facecolor or fc = (1.0, 1.0, 1.0, 1.0)
    figure = Figure(640x480)
    fill = True
    gid = None
    hatch = None
    hatch_linewidth = 1.0
    hatchcolor = (0.0, 0.0, 0.0, 1.0)
    height = 1.0
    in_layout = True
    joinstyle = miter
    label =
    linestyle or ls = solid
    linewidth or lw = 0.0
    mouseover = False
    patch_transform = CompositeGenericTransform(     BboxTransformTo( ␣
 ↪ ...
    path = Path(array([[0., 0.],        [1., 0.],        [1.,...
    path_effects = []
    picker = None
    rasterized = False
    sketch_params = None
```

(continues on next page)

(continued from previous page)

```
    snap = None
    tightbbox = Bbox(x0=80.0, y0=52.8, x1=576.0, y1=422.4)
    transform = CompositeGenericTransform(     CompositeGenericTra...
    transformed_clip_path_and_affine = (None, None)
    url = None
    verts = [[ 80.   52.8]  [576.   52.8]  [576.  422.4]  [ 80...
    visible = True
    width = 1.0
    window_extent = Bbox(x0=80.0, y0=52.8, x1=576.0, y1=422.4)
    x = 0.0
    xy = (0.0, 0.0)
    y = 0.0
    zorder = 1
Text setters
  agg_filter: a filter function, which takes a (m, n, 3) float array␣
 ↪and a dpi value, and returns a (m, n, 3) array and two offsets from␣
 ↪the bottom left corner of the image
  alpha: float or None
  animated: bool
  antialiased: bool
  backgroundcolor: :mpltype:`color`
  bbox: dict with properties for `.FancyBboxPatch` or None
  clip_box: `~matplotlib.transforms.BboxBase` or None
  clip_on: bool
  clip_path: Patch or (Path, Transform) or None
  color or c: :mpltype:`color`
  figure: `~matplotlib.figure.Figure` or `~matplotlib.figure.SubFigure`
  fontfamily or family or fontname: {FONTNAME, 'serif', 'sans-serif',
 ↪'cursive', 'fantasy', 'monospace'}
  fontfeatures: list of str, or tuple of str, or None
  fontproperties or font or font_properties: `.
 ↪font_manager.FontProperties` or `str` or `pathlib.Path`
  fontsize or size: float or {'xx-small', 'x-small', 'small', 'medium',
 ↪ 'large', 'x-large', 'xx-large'}
  fontstretch or stretch: {a numeric value in range 0-1000,
 ↪'ultra-condensed', 'extra-condensed', 'condensed', 'semi-condensed',
 ↪'normal', 'semi-expanded', 'expanded', 'extra-expanded',
 ↪'ultra-expanded'}
  fontstyle or style: {'normal', 'italic', 'oblique'}
  fontvariant or variant: {'normal', 'small-caps'}
  fontweight or weight: {a numeric value in range 0-1000, 'ultralight',
 ↪ 'light', 'normal', 'regular', 'book', 'medium', 'roman', 'semibold',
 ↪ 'demibold', 'demi', 'bold', 'heavy', 'extra bold', 'black'}
  gid: str
  horizontalalignment or ha: {'left', 'center', 'right'}
  in_layout: bool
```

(continues on next page)

(continued from previous page)

```
  label: object
  language: str or None
  linespacing: 'normal' or float, default: 'normal'
  math_fontfamily: str
  mouseover: bool
  multialignment or ma: {'left', 'right', 'center'}
  parse_math: bool
  path_effects: list of `.AbstractPathEffect`
  picker: None or bool or float or callable
  position: (float, float)
  rasterized: bool
  rotation: float or {'vertical', 'horizontal'}
  rotation_mode: {None, 'default', 'anchor', 'xtick', 'ytick'}
  sketch_params: (scale: float, length: float, randomness: float)
  snap: bool or None
  text: object
  transform: `~matplotlib.transforms.Transform`
  transform_rotates_text: bool
  url: str
  usetex: bool, default: :rc:`text.usetex`
  verticalalignment or va: {'baseline', 'bottom', 'center',
↪'center_baseline', 'top'}
  visible: bool
  wrap: bool
  x: float
  y: float
  zorder: float
Text getters
    agg_filter = None
    alpha = None
    animated = False
    antialiased = True
    bbox_patch = None
    children = []
    clip_box = None
    clip_on = True
    clip_path = None
    color or c = black
    figure = Figure(640x480)
    fontfamily or family or fontname = ['sans-serif']
    fontfeatures = None
    fontname or name = DejaVu Sans
    fontproperties or font or font_properties =␣
↪sans\-serif:style=normal:variant=normal:weight=nor...
    fontsize or size = 12.0
    fontstyle or style = normal
```

(continues on next page)

(continued from previous page)

```
    fontvariant or variant = normal
    fontweight or weight = normal
    gid = None
    horizontalalignment or ha = center
    in_layout = True
    label =
    language = None
    linespacing = normal
    math_fontfamily = dejavusans
    mouseover = False
    parse_math = True
    path_effects = []
    picker = None
    position = (0.5, 1.0)
    rasterized = False
    rotation = 0.0
    rotation_mode = default
    sketch_params = None
    snap = None
    stretch = normal
    text = Hi mom
    tightbbox = Bbox(x0=294.5, y0=426.7294270833333, x1=361.5, y1=...
    transform = CompositeGenericTransform(     BboxTransformTo(   ...
    transform_rotates_text = False
    transformed_clip_path_and_affine = (None, None)
    unitless_position = (0.5, 1.0)
    url = None
    usetex = False
    verticalalignment or va = baseline
    visible = True
    window_extent = Bbox(x0=294.5, y0=426.7294270833333, x1=361.5,␣
↪y1=...
    wrap = False
    zorder = 3
```

```
import matplotlib.pyplot as plt
import numpy as np

x = np.arange(0, 1.0, 0.01)
y1 = np.sin(2*np.pi*x)
y2 = np.sin(4*np.pi*x)
```

(continues on next page)

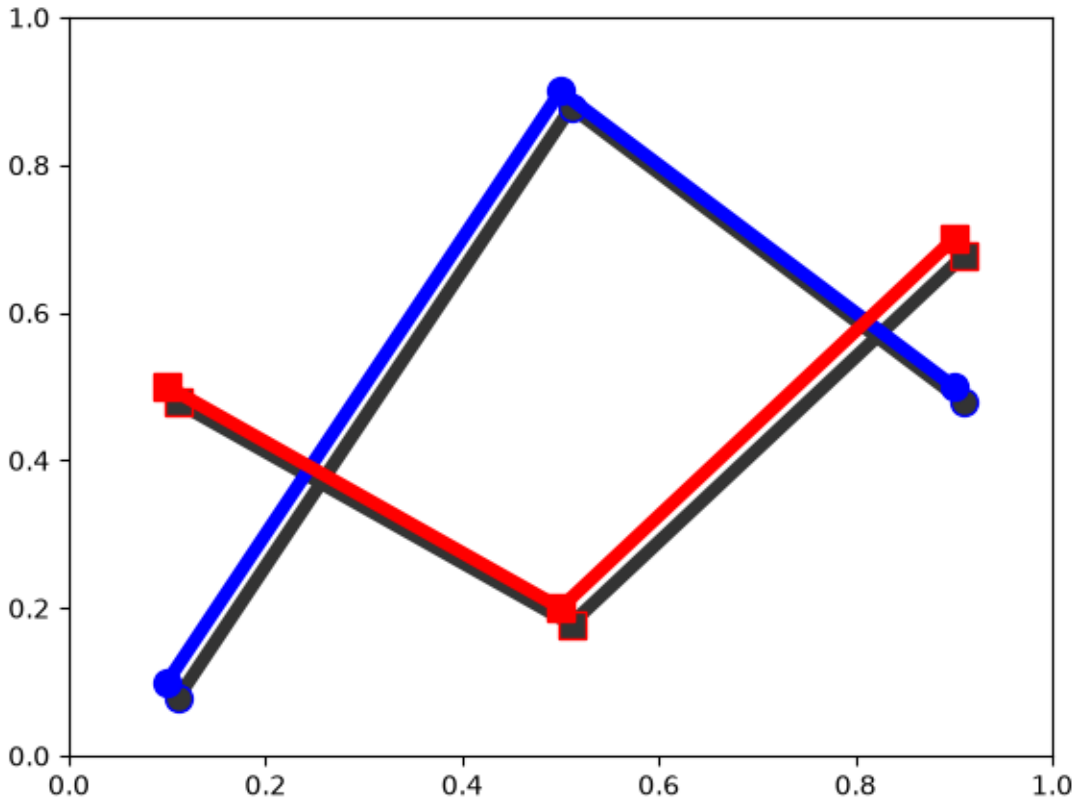
(continued from previous page)

```
lines = plt.plot(x, y1, x, y2)
l1, l2 = lines
plt.setp(lines, linestyle='--')       # set both to dashed
plt.setp(l1, linewidth=2, color='r')  # line1 is thick and red
plt.setp(l2, linewidth=1, color='g')  # line2 is thinner and green


print('Line setters')
plt.setp(l1)
print('Line getters')
plt.getp(l1)

print('Rectangle setters')
plt.setp(plt.gca().patch)
print('Rectangle getters')
plt.getp(plt.gca().patch)

t = plt.title('Hi mom')
print('Text setters')
plt.setp(t)
print('Text getters')
plt.getp(t)

plt.show()
```

Apply SVG filter to a line

Demonstrate SVG filtering effects which might be used with Matplotlib.

Note that the filtering effects are only effective if your SVG renderer support it.




```
Saving 'svg_filter_line.svg'
```

```
import io
import xml.etree.ElementTree as ET

import matplotlib.pyplot as plt

import matplotlib.transforms as mtransforms

fig1 = plt.figure()
ax = fig1.add_axes((0.1, 0.1, 0.8, 0.8))

# draw lines
l1, = ax.plot([0.1, 0.5, 0.9], [0.1, 0.9, 0.5], "bo-",
              mec="b", lw=5, ms=10, label="Line 1")
l2, = ax.plot([0.1, 0.5, 0.9], [0.5, 0.2, 0.7], "rs-",
```

(continues on next page)

(continued from previous page)

```
              mec="r", lw=5, ms=10, label="Line 2")


for l in [l1, l2]:

    # draw shadows with same lines with slight offset and gray colors.

    xx = l.get_xdata()
    yy = l.get_ydata()
    shadow, = ax.plot(xx, yy)
    shadow.update_from(l)

    # adjust color
    shadow.set_color("0.2")
    # adjust zorder of the shadow lines so that it is drawn below the
    # original lines
    shadow.set_zorder(l.get_zorder() - 0.5)

    # offset transform
    transform = mtransforms.offset_copy(l.get_transform(), fig1,
                                        x=4.0, y=-6.0, units='points')
    shadow.set_transform(transform)

    # set the id for a later use
    shadow.set_gid(l.get_label() + "_shadow")


ax.set_xlim(0., 1.)
ax.set_ylim(0., 1.)

# save the figure as a bytes string in the svg format.
f = io.BytesIO()
plt.savefig(f, format="svg")


# filter definition for a gaussian blur
filter_def = """
  <defs xmlns='http://www.w3.org/2000/svg'
        xmlns:xlink='http://www.w3.org/1999/xlink'>
    <filter id='dropshadow' height='1.2' width='1.2'>
      <feGaussianBlur result='blur' stdDeviation='3'/>
    </filter>
  </defs>
"""
```

(continues on next page)

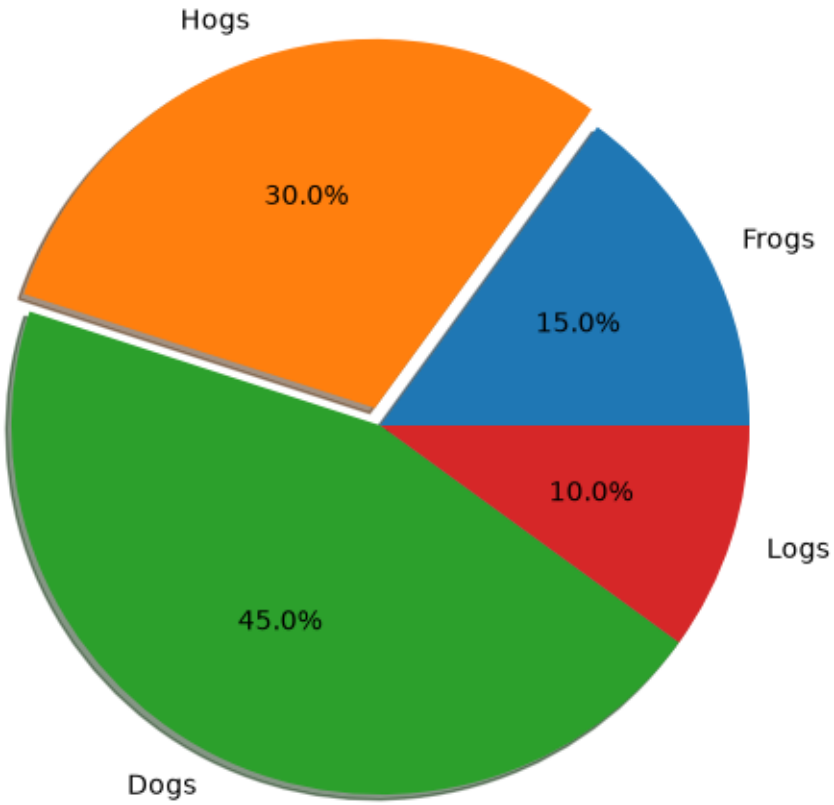
(continued from previous page)

```
# read in the saved svg
tree, xmlid = ET.XMLID(f.getvalue())

# insert the filter definition in the svg dom tree.
tree.insert(0, ET.XML(filter_def))

for l in [l1, l2]:
    # pick up the svg element with given id
    shadow = xmlid[l.get_label() + "_shadow"]
    # apply shadow filter
    shadow.set("filter", 'url(#dropshadow)')

fn = "svg_filter_line.svg"
print(f"Saving '{fn}'")
ET.ElementTree(tree).write(fn)
```

SVG filter pie

Demonstrate SVG filtering effects which might be used with Matplotlib. The pie chart drawing code is borrowed from pie_demo.py

Note that the filtering effects are only effective if your SVG renderer support it.




```
Saving 'svg_filter_pie.svg'
```

```
import io
import xml.etree.ElementTree as ET

import matplotlib.pyplot as plt

from matplotlib.patches import Shadow

```

(continues on next page)

(continued from previous page)

```
# make a square figure and Axes
fig = plt.figure(figsize=(6, 6))
ax = fig.add_axes((0.1, 0.1, 0.8, 0.8))

labels = 'Frogs', 'Hogs', 'Dogs', 'Logs'
fracs = [15, 30, 45, 10]

explode = (0, 0.05, 0, 0)

# We want to draw the shadow for each pie, but we will not use "shadow"
# option as it doesn't save the references to the shadow patches.
pie = ax.pie(fracs, explode=explode, labels=labels, autopct='%1.1f%%')

for w in pie.wedges:
    # set the id with the label.
    w.set_gid(w.get_label())

    # we don't want to draw the edge of the pie
    w.set_edgecolor("none")

for w in pie.wedges:
    # create shadow patch
    s = Shadow(w, -0.01, -0.01)
    s.set_gid(w.get_gid() + "_shadow")
    s.set_zorder(w.get_zorder() - 0.1)
    ax.add_patch(s)


# save
f = io.BytesIO()
plt.savefig(f, format="svg")


# Filter definition for shadow using a gaussian blur and lighting␣
 ↪effect.
# The lighting filter is copied from␣
 ↪http://www.w3.org/TR/SVG/filters.html

# I tested it with Inkscape and Firefox3. "Gaussian blur" is supported
# in both, but the lighting effect only in Inkscape. Also note
# that, Inkscape's exporting also may not support it.

filter_def = """
  <defs xmlns='http://www.w3.org/2000/svg'
        xmlns:xlink='http://www.w3.org/1999/xlink'>
    <filter id='dropshadow' height='1.2' width='1.2'>
```

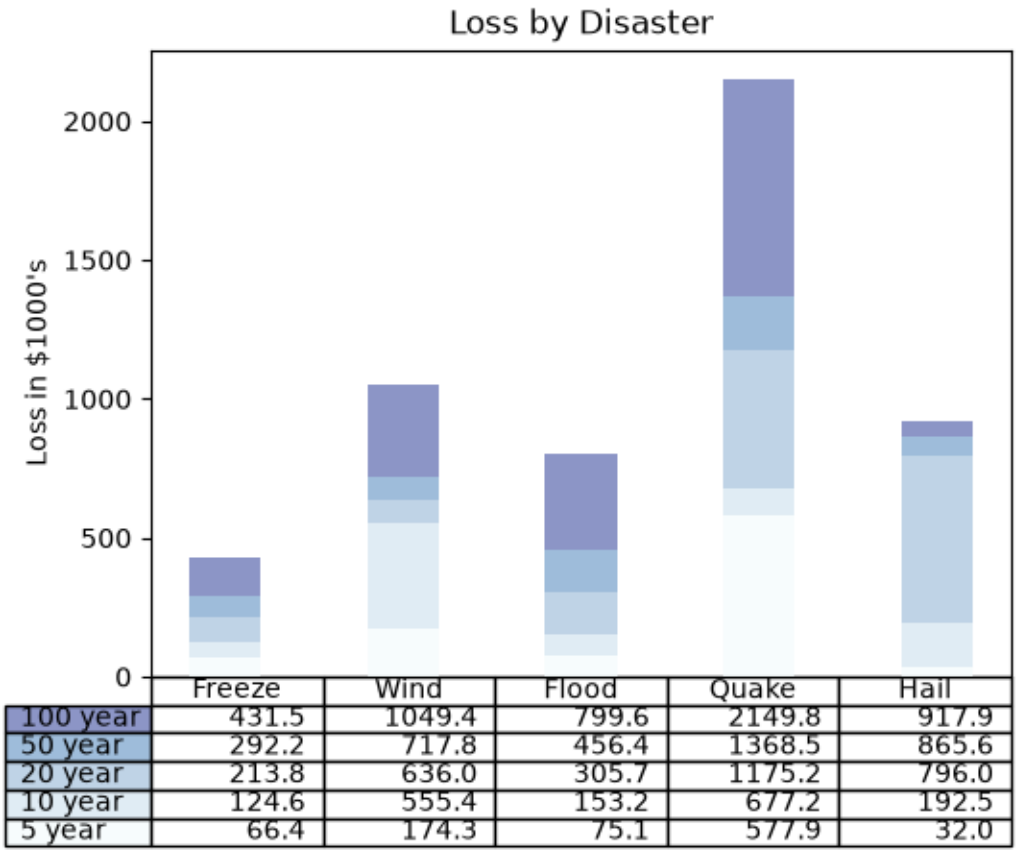
(continues on next page)

(continued from previous page)

```
      <feGaussianBlur result='blur' stdDeviation='2'/>
    </filter>

    <filter id='MyFilter' filterUnits='objectBoundingBox'
            x='0' y='0' width='1' height='1'>
      <feGaussianBlur in='SourceAlpha' stdDeviation='4%' result='blur'/
 ↪>
      <feOffset in='blur' dx='4%' dy='4%' result='offsetBlur'/>
      <feSpecularLighting in='blur' surfaceScale='5' specularConstant=
 ↪'.75'
           specularExponent='20' lighting-color='#bbbbbb' result=
 ↪'specOut'>
        <fePointLight x='-5000%' y='-10000%' z='20000%'/>
      </feSpecularLighting>
      <feComposite in='specOut' in2='SourceAlpha'
                   operator='in' result='specOut'/>
      <feComposite in='SourceGraphic' in2='specOut' operator=
 ↪'arithmetic'
    k1='0' k2='1' k3='1' k4='0'/>
    </filter>
  </defs>
"""


tree, xmlid = ET.XMLID(f.getvalue())

# insert the filter definition in the svg dom tree.
tree.insert(0, ET.XML(filter_def))

for i, pie_name in enumerate(labels):
    pie = xmlid[pie_name]
    pie.set("filter", 'url(#MyFilter)')

    shadow = xmlid[pie_name + "_shadow"]
    shadow.set("filter", 'url(#dropshadow)')

fn = "svg_filter_pie.svg"
print(f"Saving '{fn}'")
ET.ElementTree(tree).write(fn)
```

Table Demo

Demo of table function to display a table within a plot.




```
import matplotlib.pyplot as plt
import numpy as np

data = [[ 66386, 174296,  75131, 577908,  32015],
        [ 58230, 381139,  78045,  99308, 160454],
        [ 89135,  80552, 152558, 497981, 603535],
        [ 78415,  81858, 150656, 193263,  69638],
        [139361, 331509, 343164, 781380,  52269]]

columns = ('Freeze', 'Wind', 'Flood', 'Quake', 'Hail')
rows = ['%d year' % x for x in (100, 50, 20, 10, 5)]

values = np.arange(0, 2500, 500)
value_increment = 1000

# Get some pastel shades for the colors
colors = plt.colormaps["BuPu"](np.linspace(0, 0.5, len(rows)))
```

(continues on next page)

(continued from previous page)

```
n_rows = len(data)

index = np.arange(len(columns)) + 0.3
bar_width = 0.4

# Initialize the vertical-offset for the stacked bar chart.
y_offset = np.zeros(len(columns))

# Plot bars and create text labels for the table
cell_text = []
for row in range(n_rows):
    plt.bar(index, data[row], bar_width, bottom=y_offset,␣
 ↪color=colors[row])
    y_offset = y_offset + data[row]
    cell_text.append(['%1.1f' % (x / 1000.0) for x in y_offset])
# Reverse colors and text labels to display the last value at the top.
colors = colors[::-1]
cell_text.reverse()

# Add a table at the bottom of the Axes
the_table = plt.table(cellText=cell_text,
                      rowLabels=rows,
                      rowColours=colors,
                      colLabels=columns,
                      loc='bottom')

# Adjust layout to make room for the table:
plt.subplots_adjust(left=0.2, bottom=0.2)

plt.ylabel(f"Loss in ${value_increment}'s")
plt.yticks(values * value_increment, ['%d' % val for val in values])
plt.xticks([])
plt.title('Loss by Disaster')

plt.show()
```

TickedStroke patheffect

Matplotlib's *patheffects* can be used to alter the way paths are drawn at a low enough level that they can affect almost anything.

The *patheffects guide* details the use of patheffects.

The *TickedStroke* patheffect illustrated here draws a path with a ticked style. The spacing, length, and angle of ticks can be controlled.

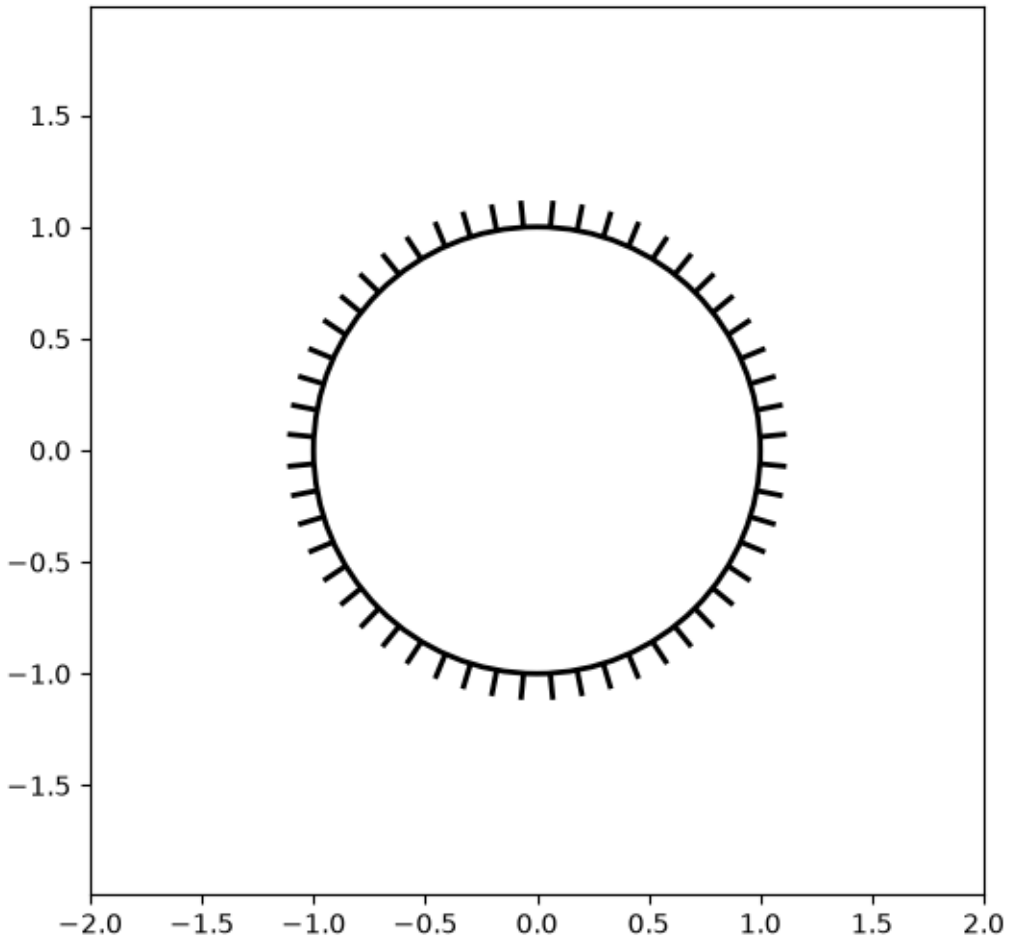
See also the *Lines with a ticked patheffect* example.

See also the *Contouring the solution space of optimizations* example.

```
import matplotlib.pyplot as plt
import numpy as np
```

Applying TickedStroke to paths

```
import matplotlib.patches as patches
from matplotlib.path import Path
import matplotlib.patheffects as patheffects

fig, ax = plt.subplots(figsize=(6, 6))
path = Path.unit_circle()
patch = patches.PathPatch(path, facecolor='none', lw=2, path_effects=[
    patheffects.withTickedStroke(angle=-90, spacing=10, length=1)])

ax.add_patch(patch)
ax.axis('equal')
ax.set_xlim(-2, 2)
ax.set_ylim(-2, 2)

plt.show()
```



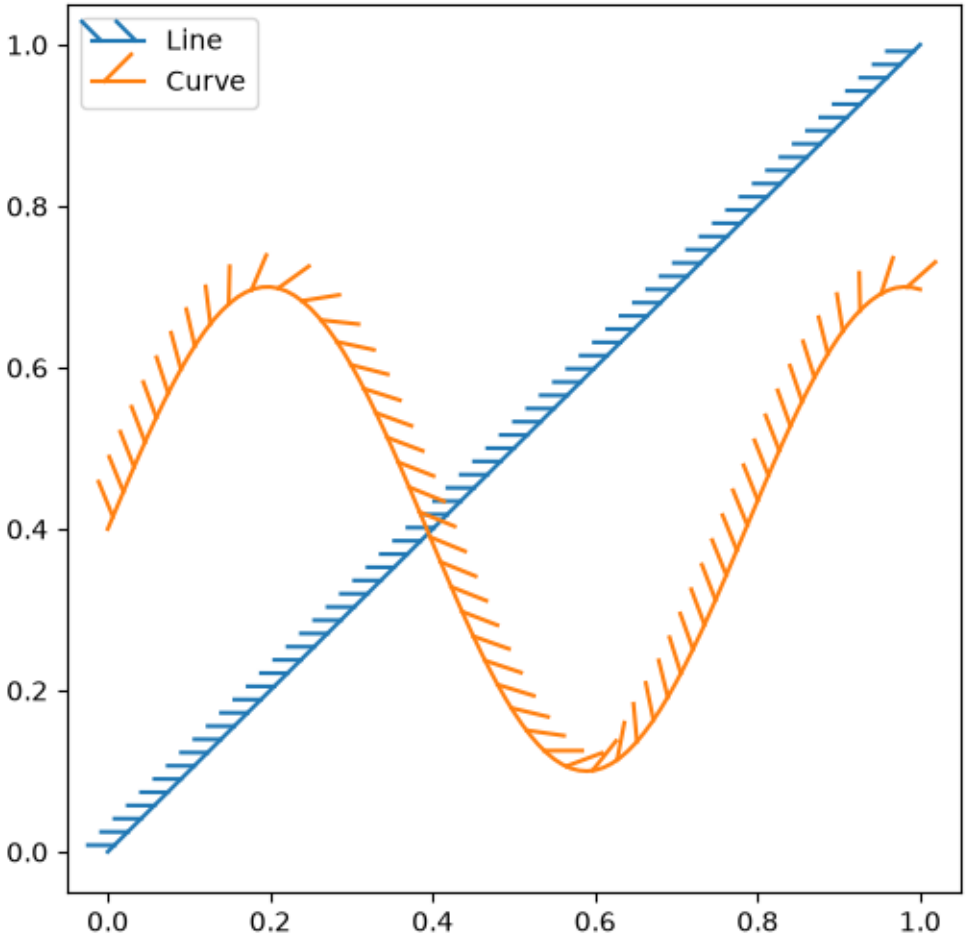
Applying TickedStroke to lines

```
fig, ax = plt.subplots(figsize=(6, 6))
ax.plot([0, 1], [0, 1], label="Line",
        path_effects=[patheffects.withTickedStroke(spacing=7,␣
 ↪angle=135)])

nx = 101
x = np.linspace(0.0, 1.0, nx)
y = 0.3*np.sin(x*8) + 0.4
ax.plot(x, y, label="Curve", path_effects=[patheffects.
 ↪withTickedStroke()])

ax.legend()
```

(continues on next page)

(continued from previous page)

```
plt.show()
```



Applying TickedStroke to contour plots

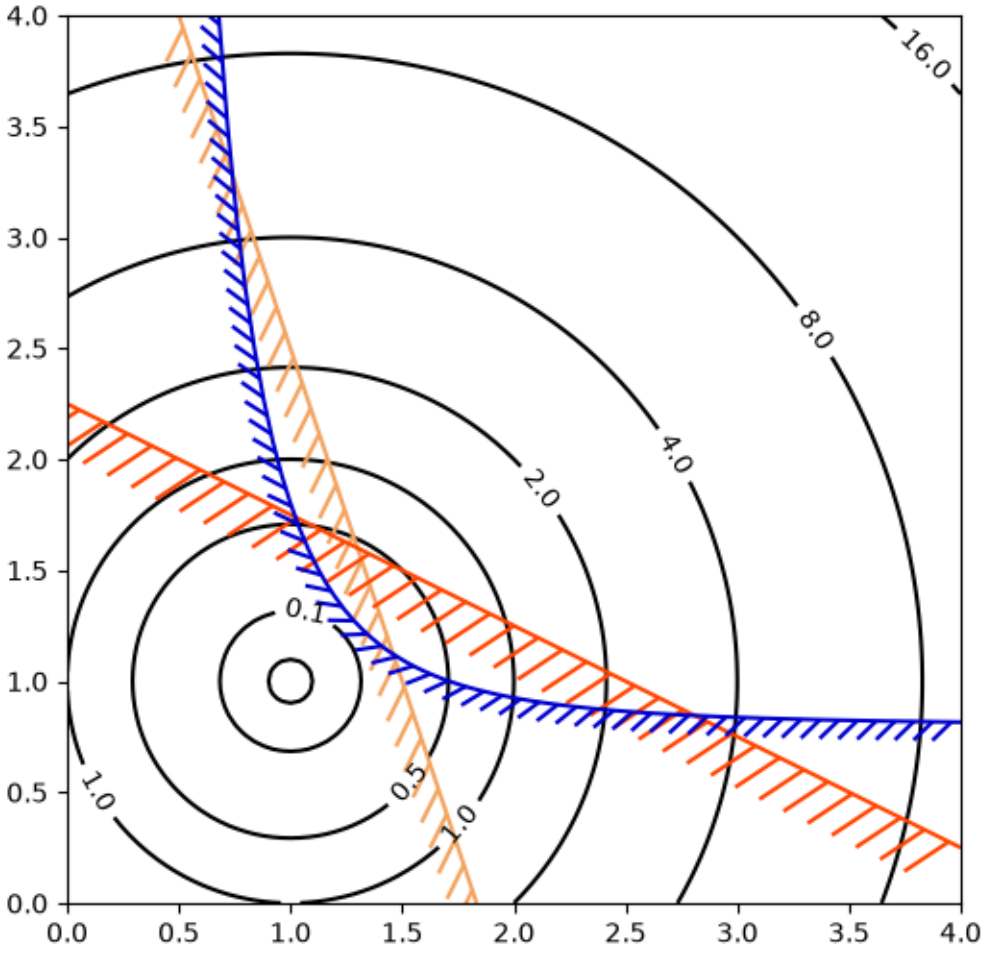
Contour plot with objective and constraints. Curves generated by contour to represent a typical constraint in an optimization problem should be plotted with angles between zero and 180 degrees.

```
fig, ax = plt.subplots(figsize=(6, 6))

nx = 101
ny = 105
```

(continues on next page)

(continued from previous page)

```
# Set up survey vectors
xvec = np.linspace(0.001, 4.0, nx)
yvec = np.linspace(0.001, 4.0, ny)

# Set up survey matrices.  Design disk loading and gear ratio.
x1, x2 = np.meshgrid(xvec, yvec)

# Evaluate some stuff to plot
obj = x1**2 + x2**2 - 2*x1 - 2*x2 + 2
g1 = -(3*x1 + x2 - 5.5)
g2 = -(x1 + 2*x2 - 4.5)
g3 = 0.8 + x1**-3 - x2

cntr = ax.contour(x1, x2, obj, [0.01, 0.1, 0.5, 1, 2, 4, 8, 16],
                  colors='black')
ax.clabel(cntr, fmt="%2.1f", use_clabeltext=True)

cg1 = ax.contour(x1, x2, g1, [0], colors='sandybrown')
cg1.set(path_effects=[patheffects.withTickedStroke(angle=135)])

cg2 = ax.contour(x1, x2, g2, [0], colors='orangered')
cg2.set(path_effects=[patheffects.withTickedStroke(angle=60,␣
 ↪length=2)])

cg3 = ax.contour(x1, x2, g3, [0], colors='mediumblue')
cg3.set(path_effects=[patheffects.withTickedStroke(spacing=7)])

ax.set_xlim(0, 4)
ax.set_ylim(0, 4)

plt.show()
```



Direction/side of the ticks

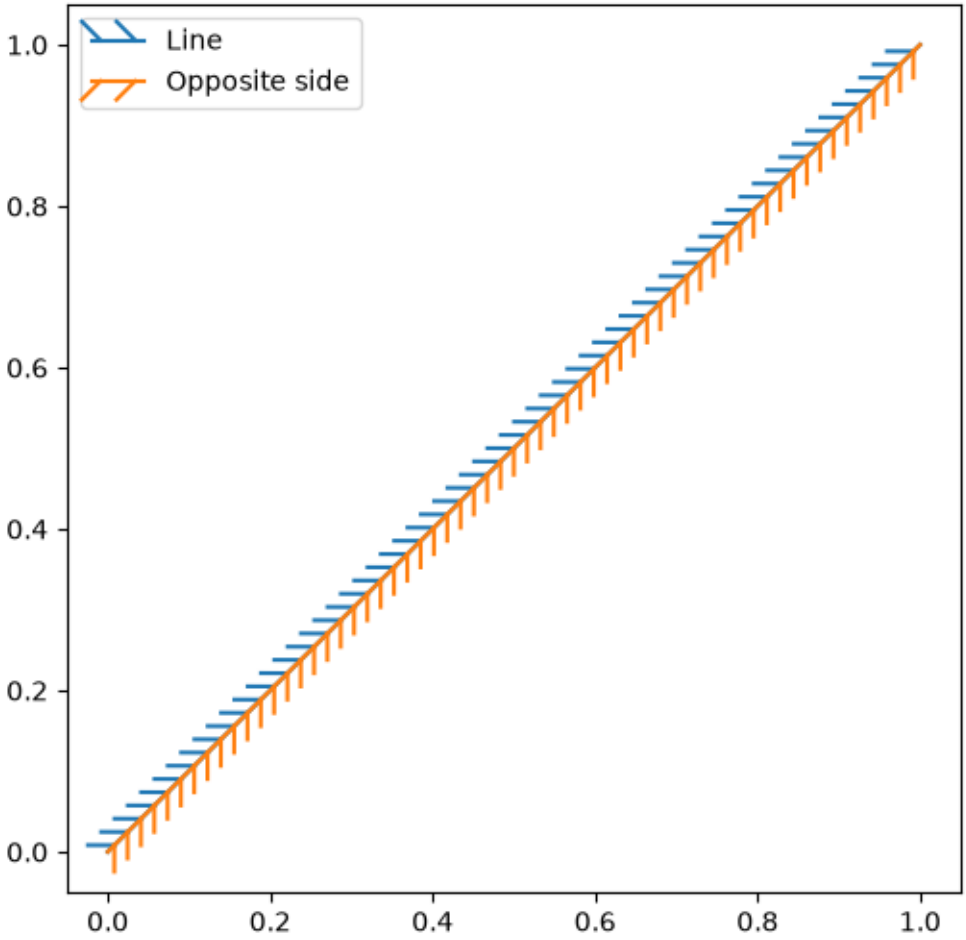
To change which side of the line the ticks are drawn, change the sign of the angle.

```
fig, ax = plt.subplots(figsize=(6, 6))
line_x = line_y = [0, 1]
ax.plot(line_x, line_y, label="Line",
        path_effects=[patheffects.withTickedStroke(spacing=7,␣
 ↪angle=135)])

ax.plot(line_x, line_y, label="Opposite side",
        path_effects=[patheffects.withTickedStroke(spacing=7, angle=-
 ↪135)])
```

(continues on next page)

(continued from previous page)

```
ax.legend()
plt.show()
```

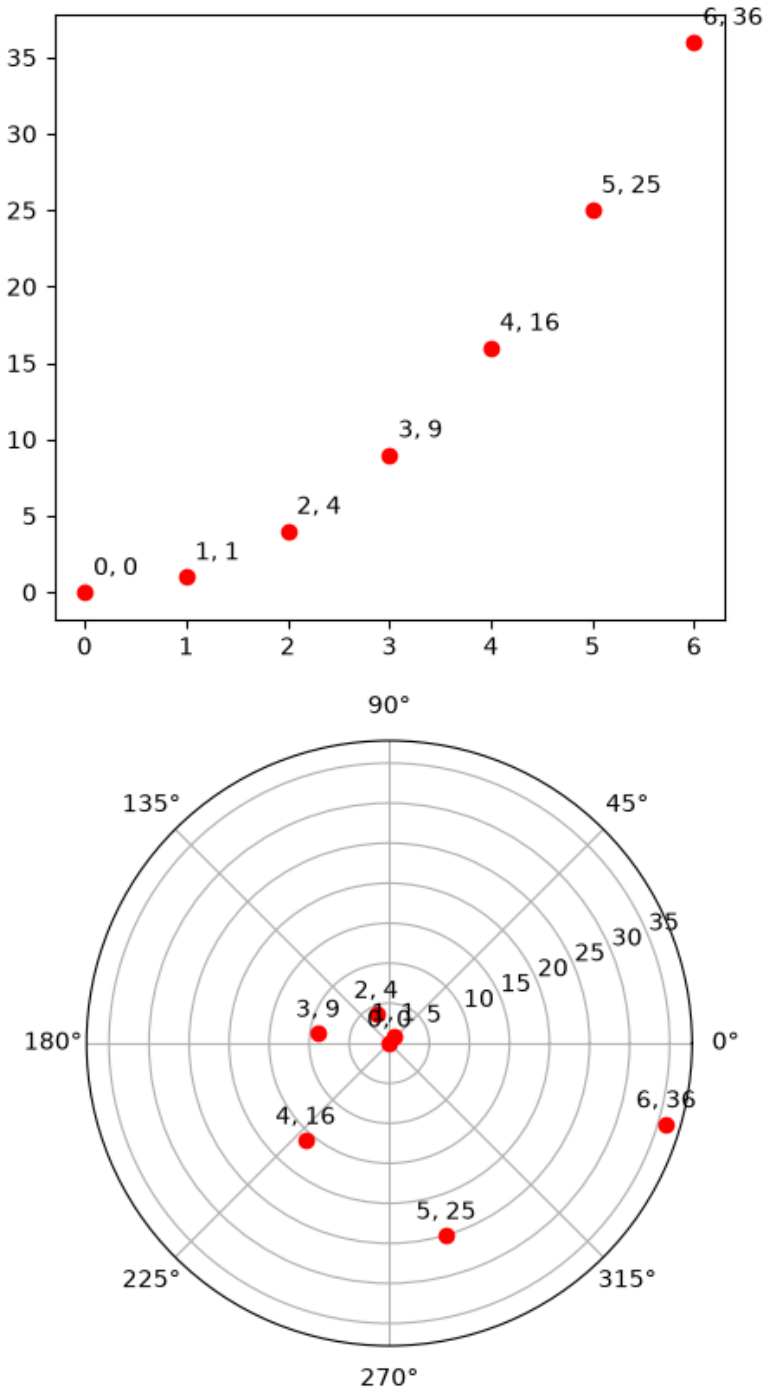


Total running time of the script: (0 minutes 1.237 seconds)

transforms.offset_copy

This illustrates the use of *transforms.offset_copy* to make a transform that positions a drawing element such as a text string at a specified offset in screen coordinates (dots or inches) relative to a location given in any coordinates.

Every Artist (Text, Line2D, etc.) has a transform that can be set when the Artist is created, such as by the corresponding pyplot function. By default, this is usually the Axes.transData transform, going from data units to screen pixels. We can use the *offset_copy* function to make a modified copy of this transform, where the modification consists of an offset.


6, 36
5, 25
4, 16
3, 9
2, 4
1, 1
0, 0
0
5
10
15
20
25
30
35
0
1
2
3
4
5
6
90°
135°
45°
180°
0°
225°
315°
270°

```
import matplotlib.pyplot as plt
import numpy as np

import matplotlib.transforms as mtransforms

xs = np.arange(7)
ys = xs**2

fig = plt.figure(figsize=(5, 10))
ax = plt.subplot(2, 1, 1)

# If we want the same offset for each text instance,
# we only need to make one transform.  To get the
# transform argument to offset_copy, we need to make the Axes
# first; the subplot function above is one way to do this.
trans_offset = mtransforms.offset_copy(ax.transData, fig=fig,
                                       x=0.05, y=0.10, units='inches')

for x, y in zip(xs, ys):
    plt.plot(x, y, 'ro')
    plt.text(x, y, '%d, %d' % (int(x), int(y)), transform=trans_offset)


# offset_copy works for polar plots also.
ax = plt.subplot(2, 1, 2, projection='polar')

trans_offset = mtransforms.offset_copy(ax.transData, fig=fig,
                                       y=6, units='dots')

for x, y in zip(xs, ys):
    plt.polar(x, y, 'ro')
    plt.text(x, y, '%d, %d' % (int(x), int(y)),
             transform=trans_offset,
             horizontalalignment='center',
             verticalalignment='bottom')

plt.show()
```

Zorder Demo

The drawing order of artists is determined by their `zorder` attribute, which is a floating point number. Artists with higher `zorder` are drawn on top. You can change the order for individual artists by setting their `zorder`. The default value depends on the type of the Artist:

Artist	Z-order
Images (*AxesImage*, *FigureImage*, *BboxImage*)	0
Patch, *PatchCollection*	1
Line2D, *LineCollection* (including minor ticks, grid lines)	2
Major ticks	2.01
Text (including Axes labels and titles)	3
Legend	5

Any call to a plotting method can set a value for the zorder of that particular item explicitly.

Note

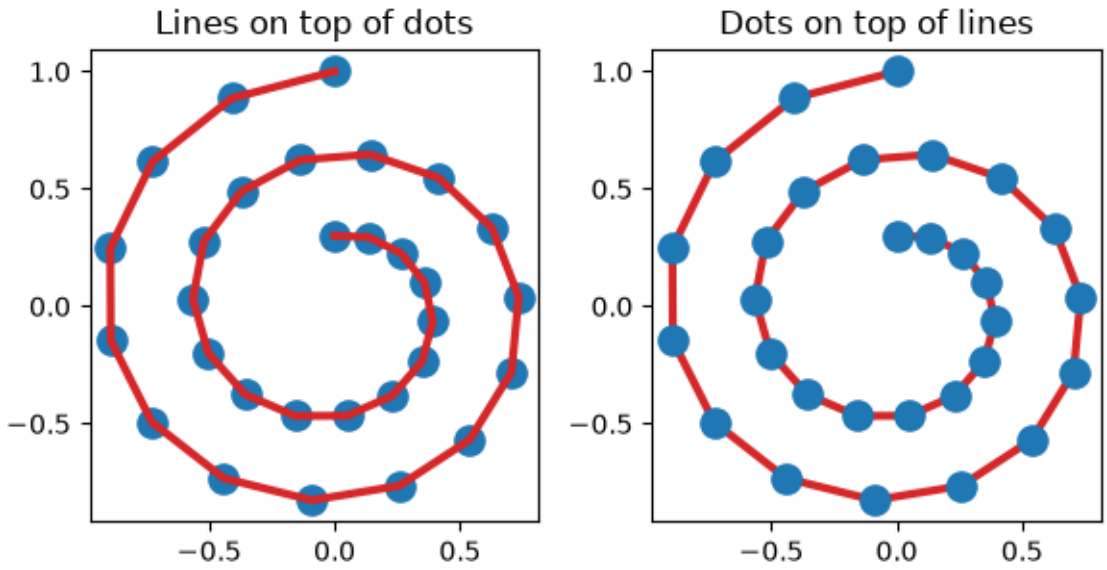
set_axisbelow and *rcParams["axes.axisbelow"]* (default: `'line'`) are convenient helpers for setting the zorder of ticks and grid lines.

Drawing is done per *Axes* at a time. If you have overlapping Axes, all elements of the second Axes are drawn on top of the first Axes, irrespective of their relative zorder.

```
import matplotlib.pyplot as plt
import numpy as np

r = np.linspace(0.3, 1, 30)
theta = np.linspace(0, 4*np.pi, 30)
x = r * np.sin(theta)
y = r * np.cos(theta)
```

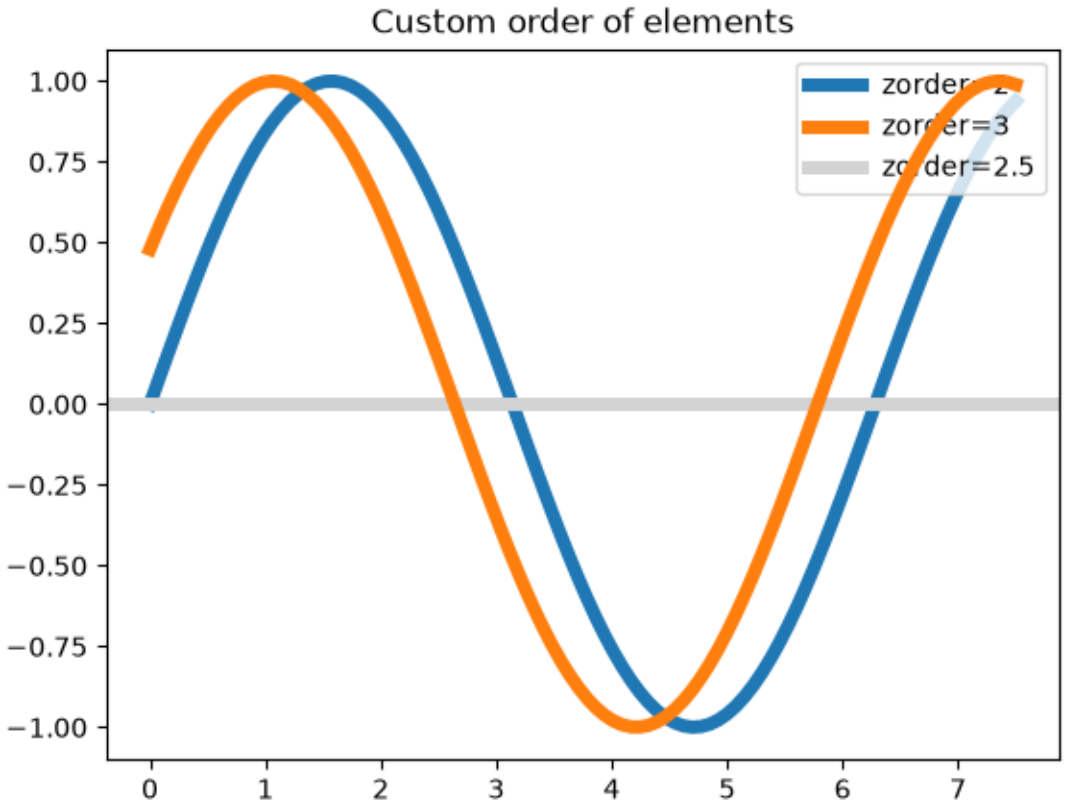
The following example contains a *Line2D* created by *plot()* and the dots (a *PatchCollection*) created by *scatter()*. Hence, by default the dots are below the line (first subplot). In the second subplot, the `zorder` is set explicitly to move the dots on top of the line.

```
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(6, 3.2))

ax1.plot(x, y, 'C3', lw=3)
ax1.scatter(x, y, s=120)
ax1.set_title('Lines on top of dots')

ax2.plot(x, y, 'C3', lw=3)
ax2.scatter(x, y, s=120, zorder=2.5)  # move dots on top of line
ax2.set_title('Dots on top of lines')

plt.tight_layout()
```



Many functions that create a visible object accepts a `zorder` parameter. Alternatively, you can call `set_zorder()` on the created object later.

```
x = np.linspace(0, 7.5, 100)
plt.rcParams['lines.linewidth'] = 5
plt.figure()
plt.plot(x, np.sin(x), label='zorder=2', zorder=2)  # bottom
plt.plot(x, np.sin(x+0.5), label='zorder=3',  zorder=3)
plt.axhline(0, label='zorder=2.5', color='lightgrey', zorder=2.5)
plt.title('Custom order of elements')
l = plt.legend(loc='upper right')
l.set_zorder(2.5)  # legend between blue and orange line
plt.show()
```



6.24.23 Showcase

Anatomy of a figure

This figure shows the name of several matplotlib elements composing a figure

```
import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Circle
from matplotlib.patheffects import withStroke
from matplotlib.ticker import AutoMinorLocator, MultipleLocator

royal_blue = [0, 20/256, 82/256]


# make the figure

np.random.seed(19680801)

X = np.linspace(0.5, 3.5, 100)
```

(continues on next page)

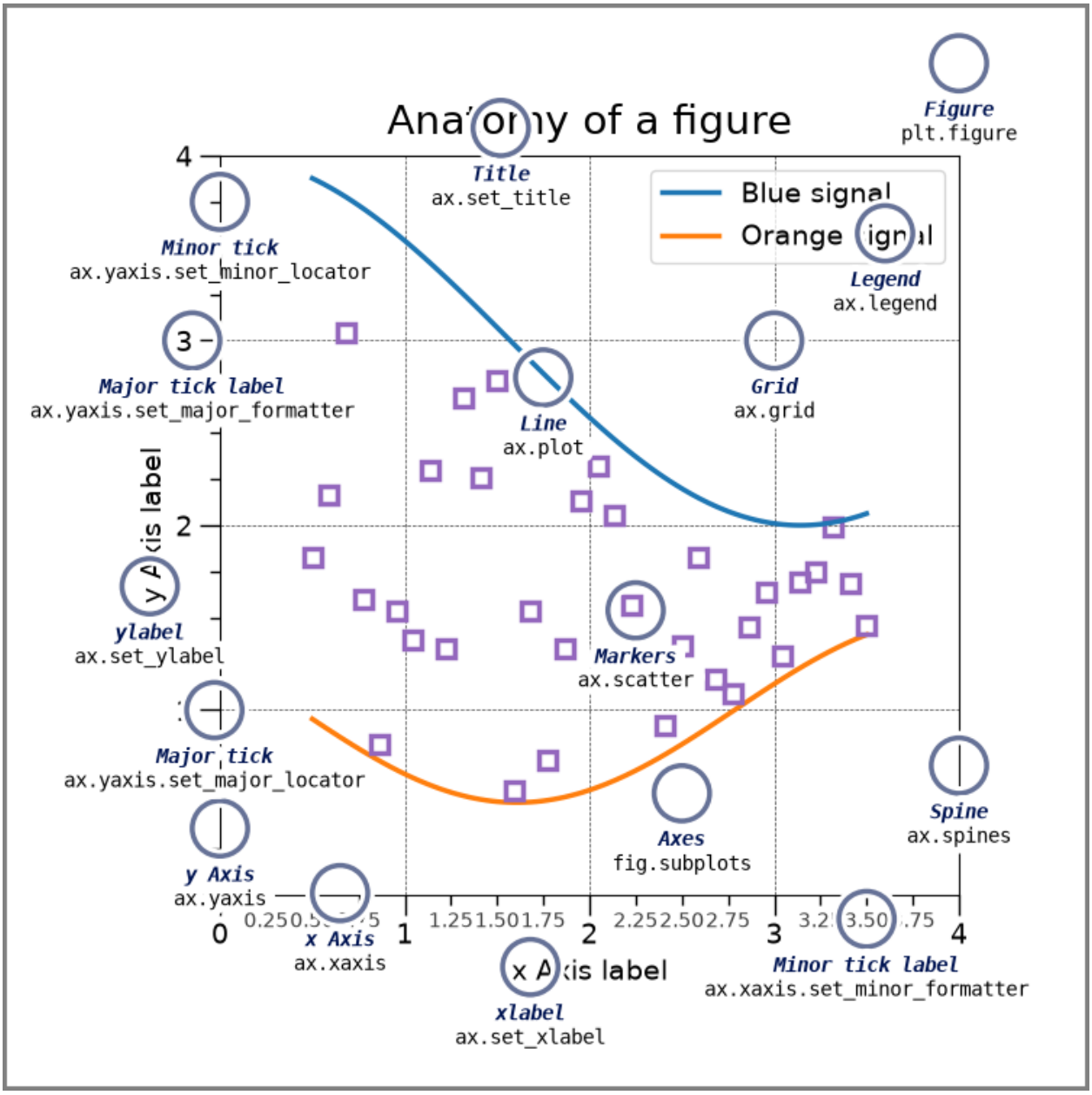
(continued from previous page)

```
Y1 = 3+np.cos(X)
Y2 = 1+np.cos(1+X/0.75)/2
Y3 = np.random.uniform(Y1, Y2, len(X))

fig = plt.figure(figsize=(7.5, 7.5))
ax = fig.add_axes((0.2, 0.17, 0.68, 0.7), aspect=1)

ax.xaxis.set_major_locator(MultipleLocator(1.000))
ax.xaxis.set_minor_locator(AutoMinorLocator(4))
ax.yaxis.set_major_locator(MultipleLocator(1.000))
ax.yaxis.set_minor_locator(AutoMinorLocator(4))
ax.xaxis.set_minor_formatter("{x:.2f}")

ax.set_xlim(0, 4)
ax.set_ylim(0, 4)

ax.tick_params(which='major', width=1.0, length=10, labelsize=14)
ax.tick_params(which='minor', width=1.0, length=5, labelsize=10,
               labelcolor='0.25')

ax.grid(linestyle="--", linewidth=0.5, color='.25', zorder=-10)

ax.plot(X, Y1, c='C0', lw=2.5, label="Blue signal", zorder=10)
ax.plot(X, Y2, c='C1', lw=2.5, label="Orange signal")
ax.plot(X[::3], Y3[::3], linewidth=0, markersize=9,
        marker='s', markerfacecolor='none', markeredgecolor='C4',
        markeredgewidth=2.5)

ax.set_title("Anatomy of a figure", fontsize=20, verticalalignment=
 ↪'bottom')
ax.set_xlabel("x Axis label", fontsize=14)
ax.set_ylabel("y Axis label", fontsize=14)
ax.legend(loc="upper right", fontsize=14)


# Annotate the figure

def annotate(x, y, text, code):
    # Circle marker
    c = Circle((x, y), radius=0.15, clip_on=False, zorder=10,␣
 ↪linewidth=2.5,
               edgecolor=royal_blue + [0.6], facecolor='none',
               path_effects=[withStroke(linewidth=7, foreground='white
 ↪')])
    ax.add_artist(c)
```

(continues on next page)

(continued from previous page)

```
    # use path_effects as a background for the texts
    # draw the path_effects and the colored text separately so that the
    # path_effects cannot clip other texts
    for path_effects in [[withStroke(linewidth=7, foreground='white
 ↪')], []]:
        color = 'white' if path_effects else royal_blue
        ax.text(x, y-0.2, text, zorder=100,
                ha='center', va='top', weight='bold', color=color,
                style='italic', fontfamily='monospace',
                path_effects=path_effects)

        color = 'white' if path_effects else 'black'
        ax.text(x, y-0.33, code, zorder=100,
                ha='center', va='top', weight='normal', color=color,
                fontfamily='monospace', fontsize='medium',
                path_effects=path_effects)


annotate(3.5, -0.13, "Minor tick label", "ax.xaxis.set_minor_formatter
 ↪")
annotate(-0.03, 1.0, "Major tick", "ax.yaxis.set_major_locator")
annotate(0.00, 3.75, "Minor tick", "ax.yaxis.set_minor_locator")
annotate(-0.15, 3.00, "Major tick label", "ax.yaxis.set_major_formatter
 ↪")
annotate(1.68, -0.39, "xlabel", "ax.set_xlabel")
annotate(-0.38, 1.67, "ylabel", "ax.set_ylabel")
annotate(1.52, 4.15, "Title", "ax.set_title")
annotate(1.75, 2.80, "Line", "ax.plot")
annotate(2.25, 1.54, "Markers", "ax.scatter")
annotate(3.00, 3.00, "Grid", "ax.grid")
annotate(3.60, 3.58, "Legend", "ax.legend")
annotate(2.5, 0.55, "Axes", "fig.subplots")
annotate(4, 4.5, "Figure", "plt.figure")
annotate(0.65, 0.01, "x Axis", "ax.xaxis")
annotate(0, 0.36, "y Axis", "ax.yaxis")
annotate(4.0, 0.7, "Spine", "ax.spines")

# frame around figure
fig.patch.set(linewidth=4, edgecolor='0.5')
plt.show()
```



References

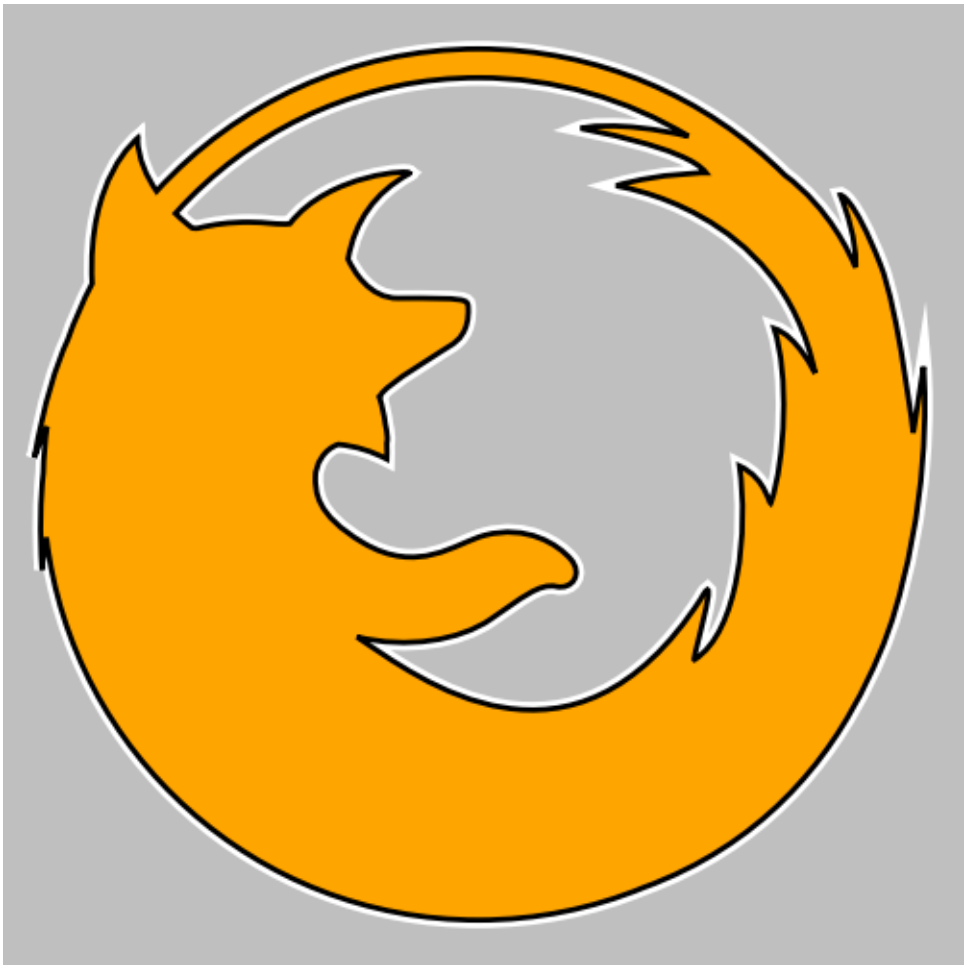
The use of the following functions, methods, classes and modules is shown in this example:

- *matplotlib.pyplot.figure*
- *matplotlib.axes.Axes.text*
- *matplotlib.axis.Axis.set_minor_formatter*
- *matplotlib.axis.Axis.set_major_locator*
- *matplotlib.axis.Axis.set_minor_locator*

- *matplotlib.patches.Circle*
- *matplotlib.patheffects.withStroke*
- *matplotlib.ticker.FuncFormatter*

Firefox

This example shows how to create the Firefox logo with path and patches.



```
import re

import matplotlib.pyplot as plt
import numpy as np

import matplotlib.patches as patches
from matplotlib.path import Path

# From: https://dmitrybaranovskiy.github.io/raphael/icons/#firefox
firefox =
```

(continues on next page)