

Quick start

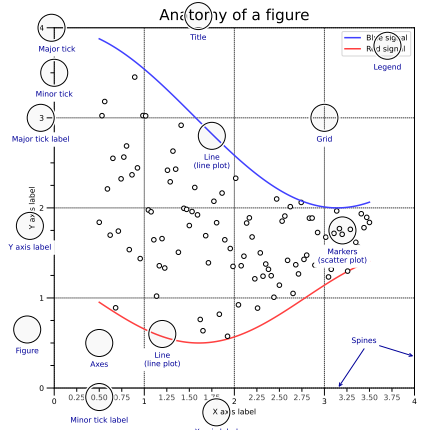
```
import numpy as np
import matplotlib as mpl
import matplotlib.pyplot as plt
```

```
X = np.linspace(0, 2*np.pi, 100)
Y = np.cos(X)
```

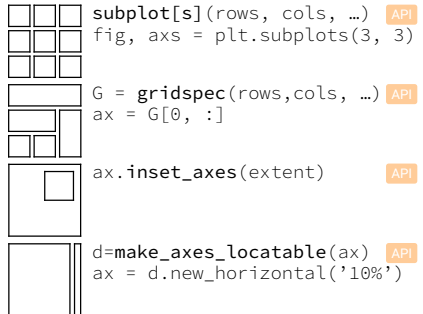
```
fig, ax = plt.subplots()
ax.plot(X, Y, color='green')
```

```
fig.savefig("figure.pdf")
plt.show()
```

Anatomy of a figure



Subplots layout



Getting help

- matplotlib.org
- github.com/matplotlib/matplotlib/issues
- discourse.matplotlib.org
- stackoverflow.com/questions/tagged/matplotlib
- https://gitter.im/matplotlib/matplotlib
- twitter.com/matplotlib
- Matplotlib users mailing list

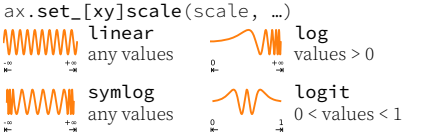
Basic plots



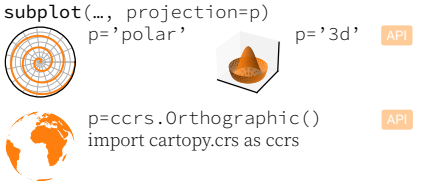
Advanced plots



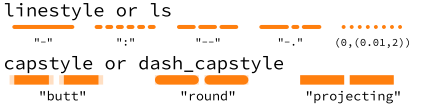
Scales



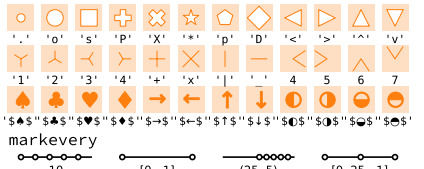
Projections



Lines



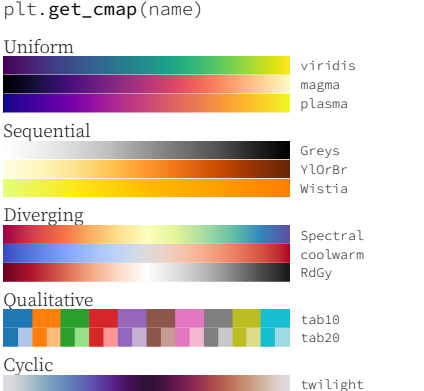
Markers



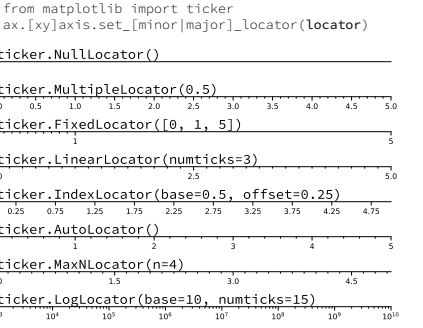
Colors



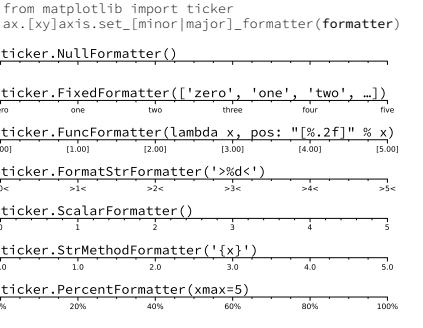
Colormaps



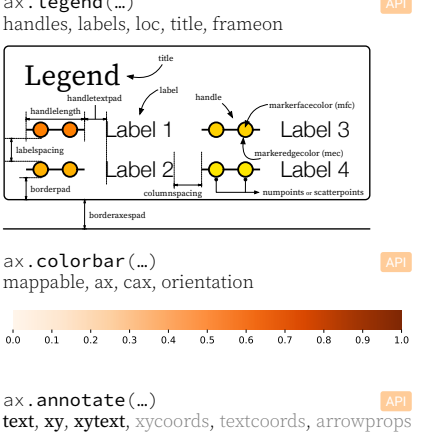
Tick locators



Tick formatters



Ornaments



Event handling

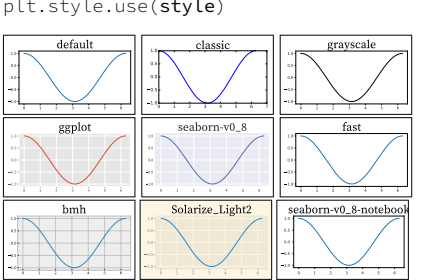
```
fig, ax = plt.subplots()
def on_click(event):
    print(event)
fig.canvas.mpl_connect(
    'button_press_event', on_click)
```

Animation

```
import matplotlib.animation as mpla

T = np.linspace(0, 2*np.pi, 100)
S = np.sin(T)
line, = plt.plot(T, S)
def animate(i):
    line.set_ydata(np.sin(T+i/50))
anim = mpla.FuncAnimation(
    plt.gcf(), animate, interval=5)
plt.show()
```

Styles



Quick reminder

```
ax.grid()
ax.set_xylim(vmin, vmax)
ax.set_xlabel(label)
ax.set_xticks(ticks, [labels])
ax.set_xyticklabels(labels)
ax.set_title(title)
ax.tick_params(width=10, ...)
ax.set_axis_on/off()

fig.suptitle(title)
fig.tight_layout()
plt.gcf(), plt.gca()
mpl.rc('axes', linewidth=1, ...)
[fig|ax].patch.set_alpha(0)
text=r'$\frac{-e^{i\pi}}{2\pi}$'
```

Keyboard shortcuts

- | | |
|---------------------|---------------------|
| ctrl + s Save | ctrl + w Close plot |
| r Reset view | f Fullscreen 0/1 |
| f View forward | b View back |
| p Pan view | o Zoom to rect |
| x X pan/zoom | y Y pan/zoom |
| g Minor grid 0/1 | y Major grid 0/1 |
| l X axis log/linear | L Y axis log/linear |

Ten simple rules

1. Know your audience
2. Identify your message
3. Adapt the figure
4. Captions are not optional
5. Do not trust the defaults
6. Use color effectively
7. Do not mislead the reader
8. Avoid "chartjunk"
9. Message trumps beauty
10. Get the right tool

Matplotlib for beginners

Matplotlib is a library for making 2D plots in Python. It is designed with the philosophy that you should be able to create simple plots with just a few commands:

1 Initialize

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

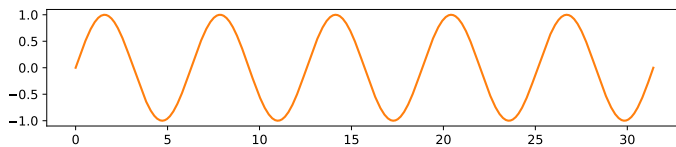
2 Prepare

```
X = np.linspace(0, 10*np.pi, 1000)
Y = np.sin(X)
```

3 Render

```
fig, ax = plt.subplots()
ax.plot(X, Y)
plt.show()
```

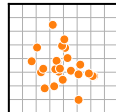
4 Observe



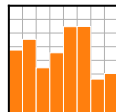
Choose

Matplotlib offers several kind of plots (see Gallery):

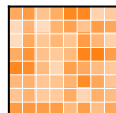
```
X = np.random.uniform(0, 1, 100)
Y = np.random.uniform(0, 1, 100)
ax.scatter(X, Y)
```



```
X = np.arange(10)
Y = np.random.uniform(1, 10, 10)
ax.bar(X, Y)
```



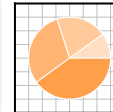
```
Z = np.random.uniform(0, 1, (8, 8))
ax.imshow(Z)
```



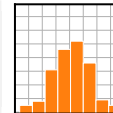
```
Z = np.random.uniform(0, 1, (8, 8))
ax.contourf(Z)
```



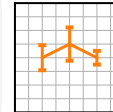
```
Z = np.random.uniform(0, 1, 4)
ax.pie(Z)
```



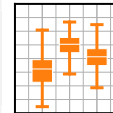
```
Z = np.random.normal(0, 1, 100)
ax.hist(Z)
```



```
X = np.arange(5)
Y = np.random.uniform(0, 1, 5)
ax.errorbar(X, Y, Y/4)
```



```
Z = np.random.normal(0, 1, (100, 3))
ax.boxplot(Z)
```



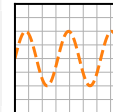
Tweak

You can modify pretty much anything in a plot, including limits, colors, markers, line width and styles, ticks and ticks labels, titles, etc.

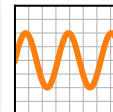
```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, color="black")
```



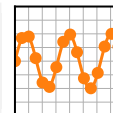
```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, linestyle="--")
```



```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, linewidth=5)
```



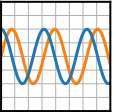
```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, marker="o")
```



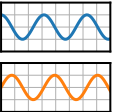
Organize

You can plot several data on the same figure, but you can also split a figure in several subplots (named Axes):

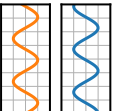
```
X = np.linspace(0, 10, 100)
Y1, Y2 = np.sin(X), np.cos(X)
ax.plot(X, Y1, X, Y2)
```



```
fig, (ax1, ax2) = plt.subplots(2, 1)
ax1.plot(X, Y1, color="C1")
ax2.plot(X, Y2, color="C0")
```

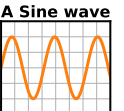


```
fig, (ax1, ax2) = plt.subplots(1, 2)
ax1.plot(Y1, X, color="C1")
ax2.plot(Y2, X, color="C0")
```

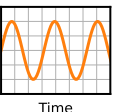


Label (everything)

```
ax.plot(X, Y)
fig.suptitle(None)
ax.set_title("A Sine wave")
```



```
ax.plot(X, Y)
ax.set_ylabel(None)
ax.set_xlabel("Time")
```



Explore

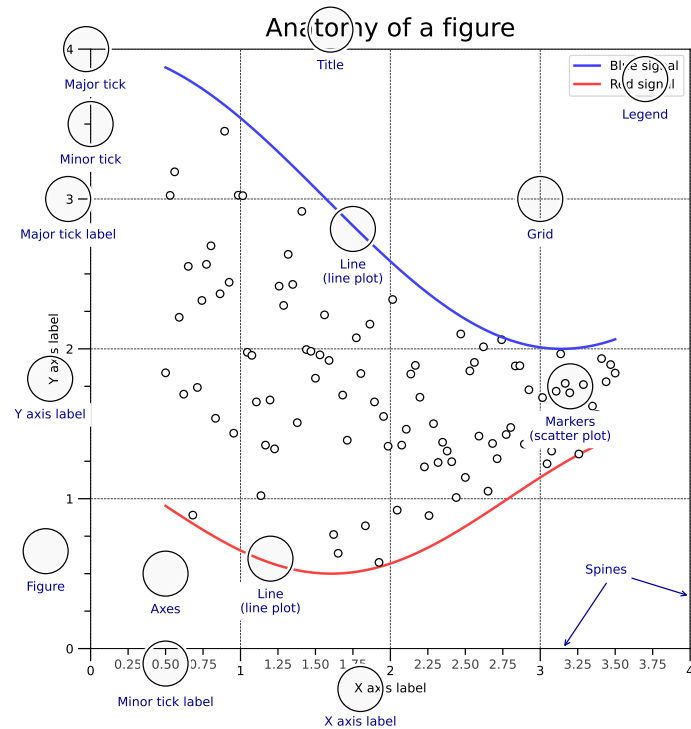
Figures are shown with a graphical user interface that allows to zoom and pan the figure, to navigate between the different views and to show the value under the mouse.

Save (bitmap or vector format)

```
fig.savefig("my-first-figure.png", dpi=300)
fig.savefig("my-first-figure.pdf")
```

Matplotlib for intermediate users

A matplotlib figure is composed of a hierarchy of elements that forms the actual figure. Each element can be modified.

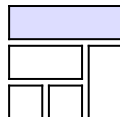


Figure, axes & spines

```
fig, axs = plt.subplots(3, 3)
axs[0, 0].set_facecolor("#ddddff")
axs[2, 2].set_facecolor("#ffffdd")
```



```
gs = fig.add_gridspec(3, 3)
ax = fig.add_subplot(gs[0, :])
ax.set_facecolor("#ddddff")
```

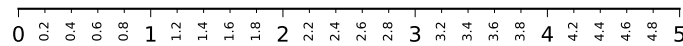


```
fig, ax = plt.subplots()
ax.spines["top"].set_color("None")
ax.spines["right"].set_color("None")
```



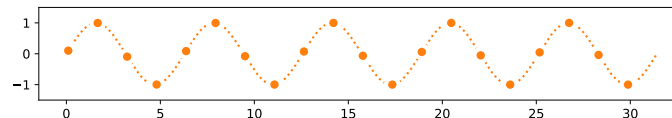
Ticks & labels

```
from mpl.ticker import MultipleLocator as ML
from mpl.ticker import ScalarFormatter as SF
ax.xaxis.set_minor_locator(ML(0.2))
ax.xaxis.set_minor_formatter(SF())
ax.tick_params(axis='x', which='minor', rotation=90)
```



Lines & markers

```
X = np.linspace(0.1, 10*np.pi, 1000)
Y = np.sin(X)
ax.plot(X, Y, "C1o:", markevery=50, mec="1.0")
```



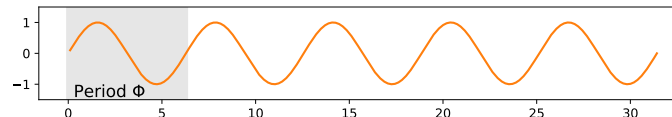
Scales & projections

```
fig, ax = plt.subplots()
ax.set_xscale("log")
ax.plot(X, Y, "C1o-", markevery=50, mec="1.0")
```



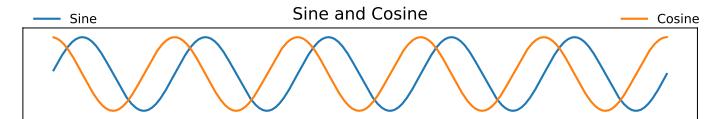
Text & ornaments

```
ax.fill_betweenx([-1, 1], [0], [2*np.pi])
ax.text(0, -1, r"Period $\Phi$")
```



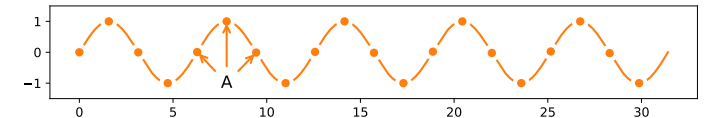
Legend

```
ax.plot(X, np.sin(X), "C0", label="Sine")
ax.plot(X, np.cos(X), "C1", label="Cosine")
ax.legend(bbox_to_anchor=(0, 1, 1, .1), ncol=2,
         mode="expand", loc="lower left")
```



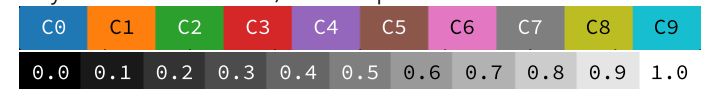
Annotation

```
ax.annotate("A", (X[250], Y[250]), (X[250], -1),
          ha="center", va="center", arrowprops={
            "arrowstyle": "->", "color": "C1"})
```



Colors

Any color can be used, but Matplotlib offers sets of colors:



Size & DPI

Consider a square figure to be included in a two-column A4 paper with 2 cm margins on each side and a column separation of 1 cm. The width of a figure is $(21 - 2 \times 2 - 1)/2 = 8$ cm. One inch being 2.54 cm, figure size should be 3.15×3.15 in.

```
fig = plt.figure(figsize=(3.15, 3.15), dpi=50)
plt.savefig("figure.pdf", dpi=600)
```

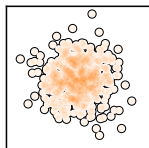
Matplotlib 3.7.4 handout for intermediate users. Copyright (c) 2021 Matplotlib Development Team. Released under a CC-BY 4.0 International License. Supported by NumFOCUS.

Matplotlib tips & tricks

Transparency

Scatter plots can be enhanced by using transparency (alpha) in order to show area with higher density. Multiple scatter plots can be used to delineate a frontier.

```
X = np.random.normal(-1, 1, 500)
Y = np.random.normal(-1, 1, 500)
ax.scatter(X, Y, 50, "0.0", lw=2) # optional
ax.scatter(X, Y, 50, "1.0", lw=0) # optional
ax.scatter(X, Y, 40, "C1", lw=0, alpha=0.1)
```



Rasterization

If your figure has many graphical elements, such as a huge scatter, you can rasterize them to save memory and keep other elements in vector format.

```
X = np.random.normal(-1, 1, 10_000)
Y = np.random.normal(-1, 1, 10_000)
ax.scatter(X, Y, rasterized=True)
fig.savefig("rasterized-figure.pdf", dpi=600)
```

Offline rendering

Use the Agg backend to render a figure directly in an array.

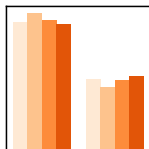
```
from matplotlib.backends.backend_agg import FigureCanvas
canvas = FigureCanvas(Figure())
... # draw some stuff
canvas.draw()
Z = np.array(canvas.renderer.buffer_rgba())
```

Range of continuous colors

You can use colormap to pick from a range of continuous colors.

```
X = np.random.randn(1000, 4)
cmap = plt.get_cmap("Oranges")
colors = cmap([0.2, 0.4, 0.6, 0.8])
```

```
ax.hist(X, 2, histtype='bar', color=colors)
```



Text outline

Use text outline to make text more visible.

```
import matplotlib.patheffects as fx
text = ax.text(0.5, 0.1, "Label")
text.set_path_effects([
    fx.Stroke(linewidth=3, foreground='1.0'),
    fx.Normal([])])
```



Multiline plot

You can plot several lines at once using *None* as separator.

```
X,Y = [], []
for x in np.linspace(0, 10*np.pi, 100):
    X.extend([x, x, None]), Y.extend([0, sin(x), None])
ax.plot(X, Y, "black")
```



Dotted lines

To have rounded dotted lines, use a custom linestyle and modify dash_capstyle.

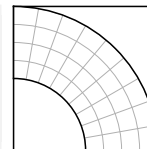
```
ax.plot([0, 1], [0, 0], "C1",
        linestyle=(0, (0.01, 1)), dash_capstyle="round")
ax.plot([0, 1], [1, 1], "C1",
        linestyle=(0, (0.01, 2)), dash_capstyle="round")
```



Combining axes

You can use overlaid axes with different projections.

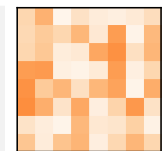
```
ax1 = fig.add_axes([0, 0, 1, 1],
                    label="cartesian")
ax2 = fig.add_axes([0, 0, 1, 1],
                    label="polar",
                    projection="polar")
```



Colorbar adjustment

You can adjust a colorbar's size when adding it.

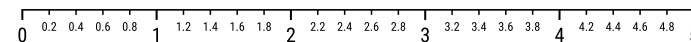
```
im = ax.imshow(Z)
cb = plt.colorbar(im,
                  fraction=0.046, pad=0.04)
cb.set_ticks([])
```



Taking advantage of typography

You can use a condensed font such as Roboto Condensed to save space on tick labels.

```
for tick in ax.get_xticklabels(which='both'):
    tick.set_fontname("Roboto Condensed")
```



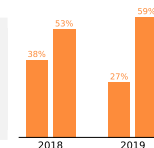
Getting rid of margins

Once your figure is finished, you can call `tight_layout()` to remove white margins. If there are remaining margins, you can use the `pdfcrop` utility (comes with TeX live).

Hatching

You can achieve a nice visual effect with thick hatch patterns.

```
cmap = plt.get_cmap("Oranges")
plt.rcParams['hatch.color'] = cmap(0.2)
plt.rcParams['hatch.linewidth'] = 8
ax.bar(X, Y, color=cmap(0.6), hatch="/")
```



Read the documentation

Matplotlib comes with an extensive documentation explaining the details of each command and is generally accompanied by examples. Together with the huge online gallery, this documentation is a gold-mine.

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