

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
```

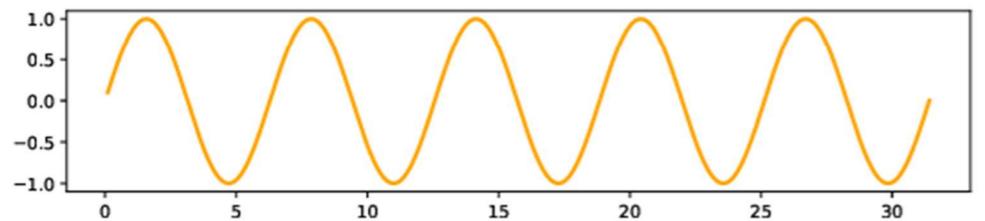
2 Prepare

```
X = np.linspace(0, 4*np.pi, 1000)  
Y = np.sin(X)
```

3 Render

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

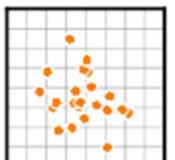
4 Observe



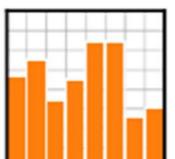
Choose

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)
```



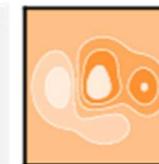
```
X = np.arange(10)  
Y = np.random.uniform(1, 10, 10)  
ax.bar(X, Y)
```



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



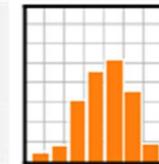
```
Z = np.random.uniform(0, 1, (8,8))  
ax.contourf(Z)
```



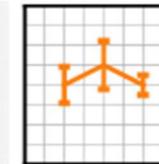
```
Z = np.random.uniform(0, 1, 4)  
ax.pie(Z)
```



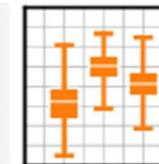
```
Z = np.random.normal(0, 1, 100)  
ax.hist(Z)
```



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



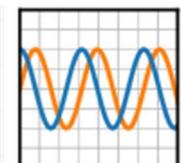
```
Z = np.random.normal(0, 1, (100,3))  
ax.boxplot(Z)
```



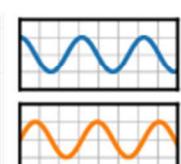
Organize

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

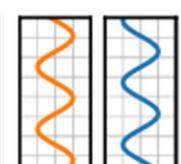
```
X = np.linspace(0, 10, 100)  
Y1, Y2 = np.sin(X), np.cos(X)  
ax.plot(X, Y1, X, Y2)
```



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

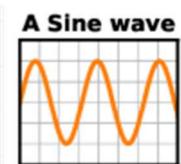


```
fig, (ax1, ax2) = plt.subplots((1,2))  
ax1.plot(Y1, X, color="C1")  
ax2.plot(Y2, X, color="C0")
```

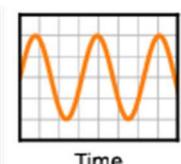


Label (everything)

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



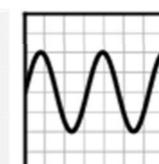
```
ax.plot(X, Y)  
ax.set_ylabel(None)  
ax.set_xlabel("Time")
```



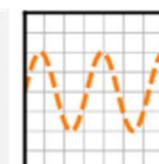
Tweak

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

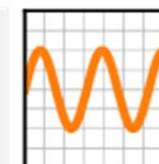
```
X = np.linspace(0, 10, 100)  
Y = np.sin(X)  
ax.plot(X, Y, color="black")
```



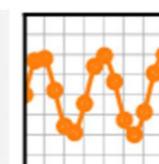
```
X = np.linspace(0, 10, 100)  
Y = np.sin(X)  
ax.plot(X, Y, linestyle="--")
```



```
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")
```



Explore

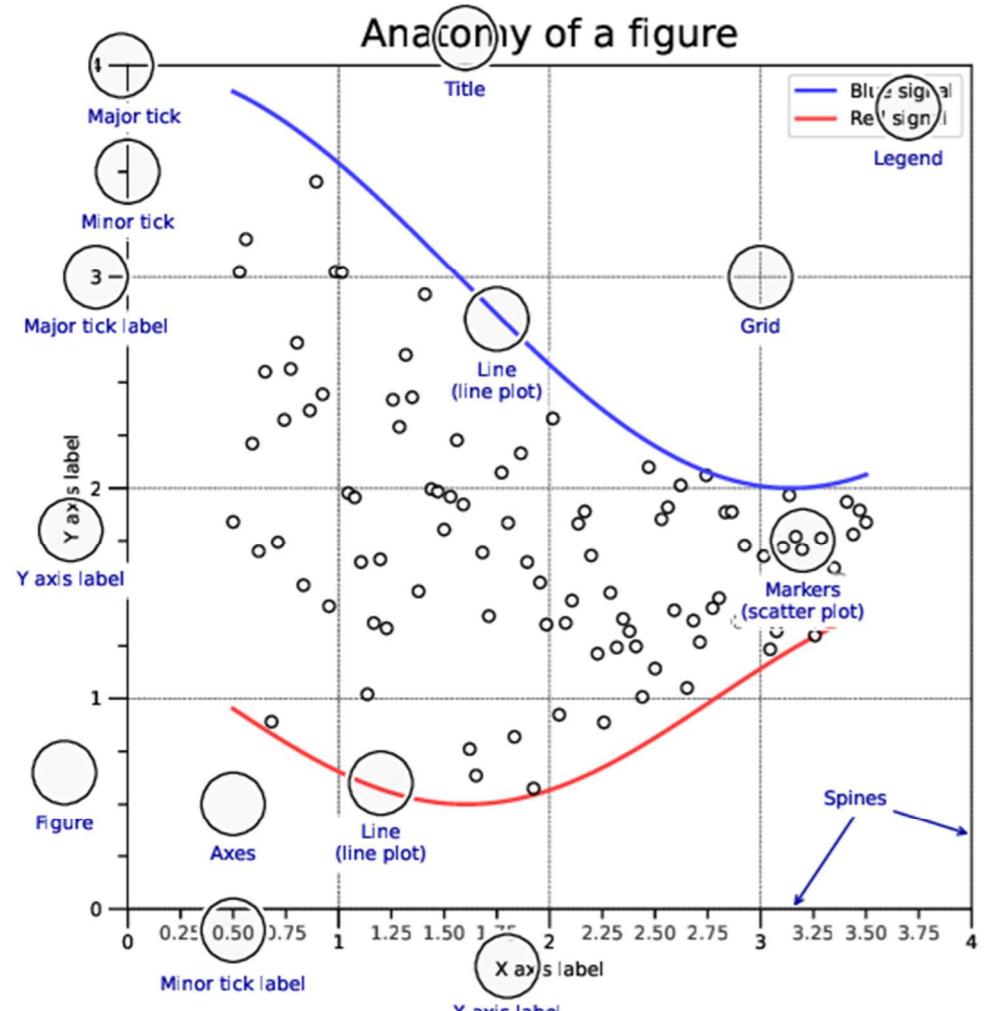
Figures are shown with a graphical user interface that allows to zoom and pan the figure, to navigate between the different views and to show the value under the mouse.

Save (bitmap or vector format)

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

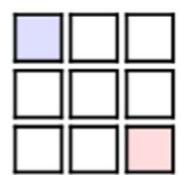
Matplotlib for intermediate users

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

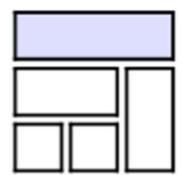


Figure, axes & spines

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



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

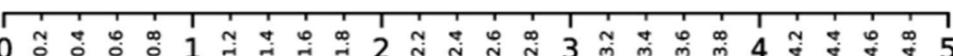


```
fig, ax = plt.subplots()
ax.spines["top"].set_color("None")
ax.spines["right"].set_color("None")
```



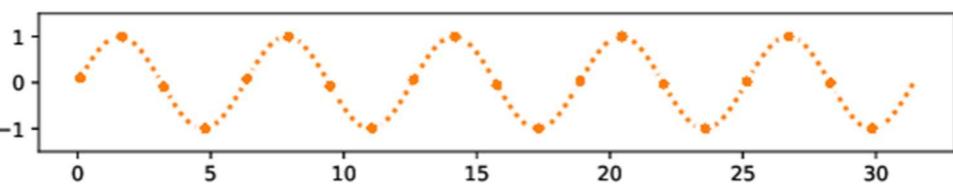
Ticks & labels

```
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)
```



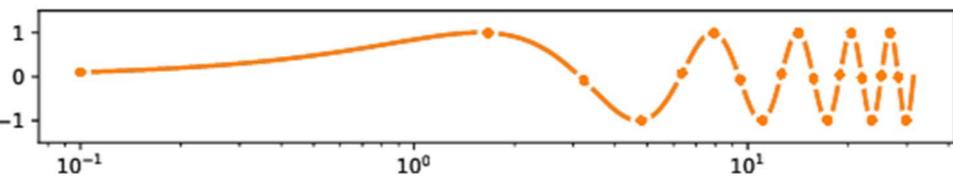
Lines & markers

```
X = np.linspace(0.1, 10*np.pi, 1000)
Y = np.sin(X)
ax.plot(X, Y, "C1o:", markevery=25, mec="1.0")
```



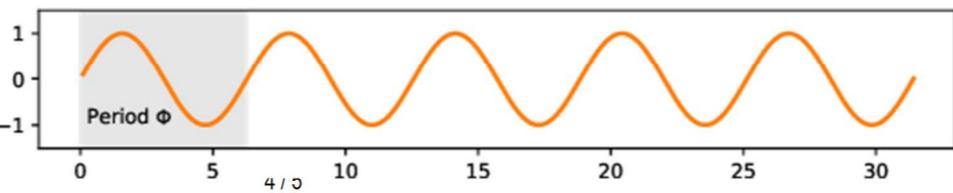
Scales & projections

```
fig, ax = plt.subplots()
ax.set_xscale("log")
ax.plot(X, Y, "C1o-", markevery=25, mec="1.0")
```



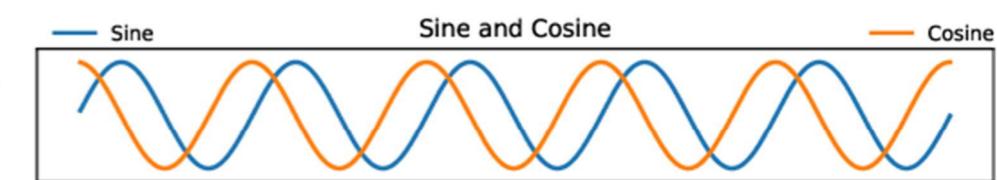
Text & ornaments

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



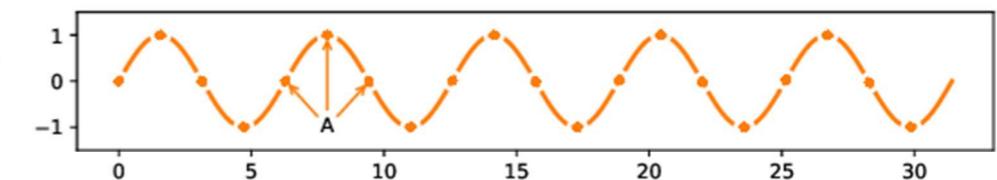
Legend

```
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:

C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9

1.0

Size & DPI

Consider a square figure to be included in a two-columns A4 paper with 2cm margins on each side and a column separation of 1cm. The width of a figure is $(21 - 2*2 - 1)/2 = 8\text{cm}$. One inch being 2.54cm, 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)
```

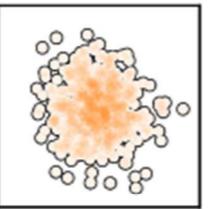
Matplotlib 3.5.0 handout for intermediate users. Copyright (c) 2021 Matplotlib Development Team. Released under a CC-BY 4.0 International License. Supported by NumFOCUS.

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

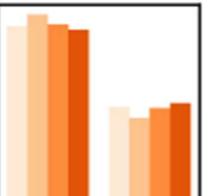
Use the Agg backend to render a figure directly in an array.

```
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.path_effects 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")
```

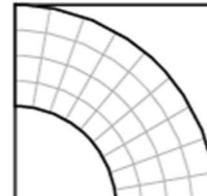


Combining axes

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")
```

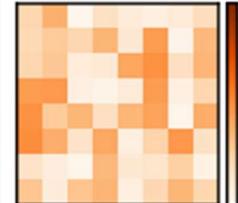
5/5



Colorbar adjustment

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

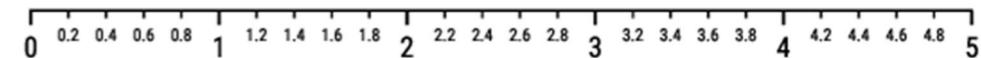
```
im = ax.imshow(Z)
cb = plt.colorbar(im,
                  fraction=0.046, pad=0.04)
cb.set_ticks([])
```



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")
```



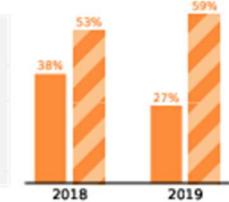
Getting rid of margins

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.