Rotman

INTRO TO DATA VISUALIZATION

Part II Intro to Matplotlib – Concepts and Basic Plots

August 28, 2025 Prepared by Jay Cao / **MDAL**

Website: https://rmdal.github.io/mma-dv-2025/

Rotman School of Management
UNIVERSITY OF TORONTO

Python Visualization Package Landscape (1)

- Matplotlib & derivatives
  - Pandas.DataFrame.plot (simple plots directly from pandas dataframes)
  - Seaborn (high-level interface; good-looking and modern default graphics)
  - Plotnine (an implementation of *the grammar of graphics*; R ggplot2-like syntax)
    - Funded by Posit (formerly RStudio)
  - Cartopy, geoplot, geopandas's plot() (geospatial visualization)
  - Many more, a full list
- plotly, plotly express, & plotly dash
  - Modern-looking, interactive web-based charts; support dashboard;
  - Built on plotly.js, a javascript plotting library.

Python Visualization Package Landscape (2)

- HoloViz
  - A set of high-level tools
    - e.g., hvPlot (interactive plot), Panel (dashboard), GeoViews (geospatial plot), etc.
  - Built on Bokeh (yet another Python plotting tool), Matplotlib, Plotly
- Lets-plot
  - yet another implementation of the grammar of graphics (i.e., R ggplot2-like syntax)
  - by JetBrains, the PyCharm IDE developer
- Vega-Altair
  - a declarative visualization library based on the Vega-Lite grammar
  - Declarative (say what you want) vs imperative (say how to get what you want by step-by-step instructions)
- Many more…

Why Matplotlib

- General purpose
  - Flexible/low-level enough to plot almost anything you want

- Highly customizable plots
  - You could consider using seaborn for quick and good-looking default plots if not much customization is needed

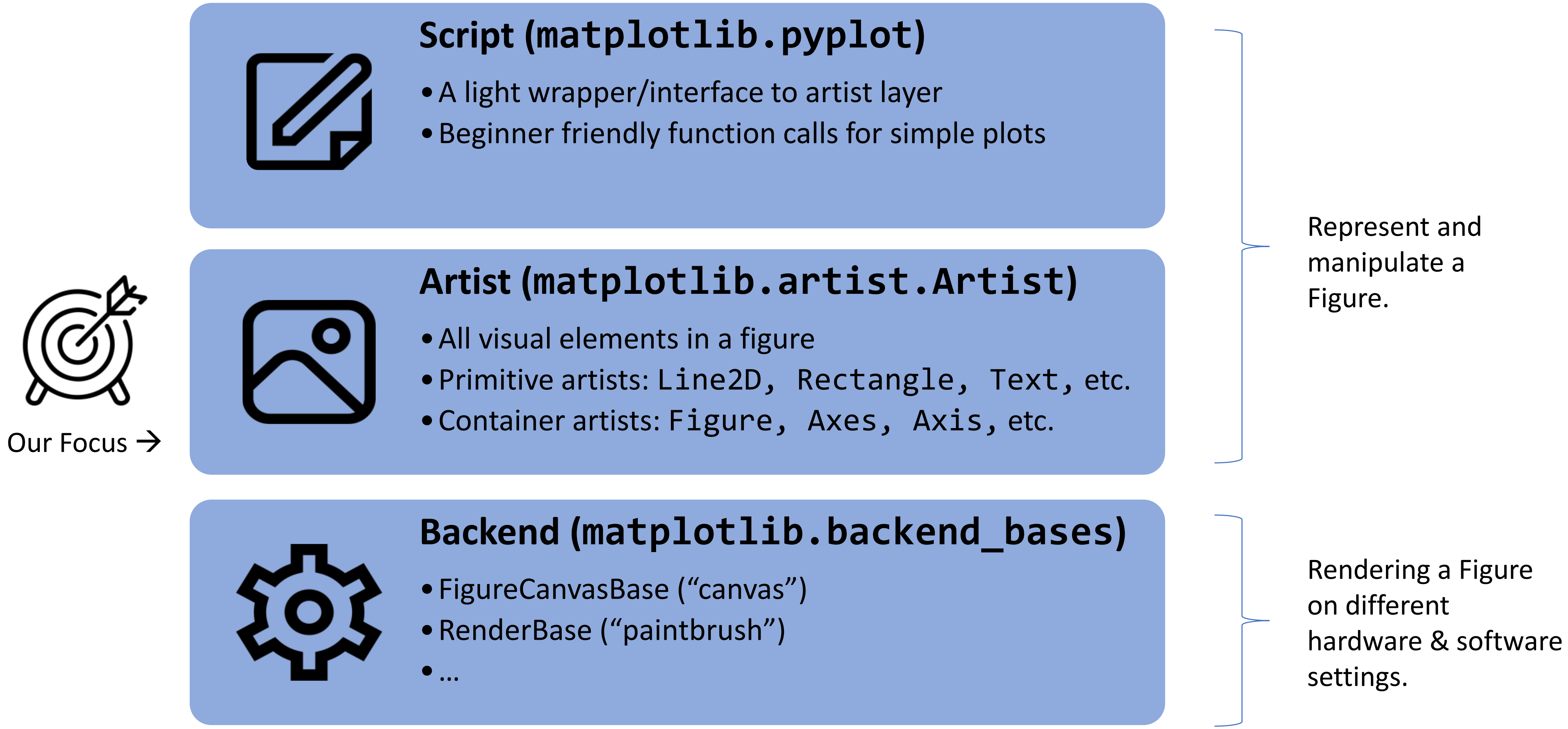
- Integrate well with other packages (because its many derivatives)
  - E.g., pandas, geopandas, etc.

- Good documentation and community support

Our Plan to Learn Matplotlib

- Understand the principles/fundamentals
  - Matplotlib library basic architecture
  - Anatomy of a figure & object hierarchy
  - Two coding styles/approaches
- Work through two main notebooks
  - Basic plots
  - From default to publication-ready – how to refine/customize a plot
- Won’t take you through syntax for each type of plots

Matplotlib Software Architecture



Script (`matplotlib.pyplot`)

- A light wrapper/interface to artist layer
- Beginner friendly function calls for simple plots

Artist (`matplotlib.artist.Artist`)

- All visual elements in a figure
- Primitive artists: `Line2D, Rectangle, Text,` etc.
- Container artists: `Figure, Axes, Axis,` etc.

Backend (`matplotlib.backend_bases`)

- FigureCanvasBase (“canvas”)
- RenderBase (“paintbrush”)
- …

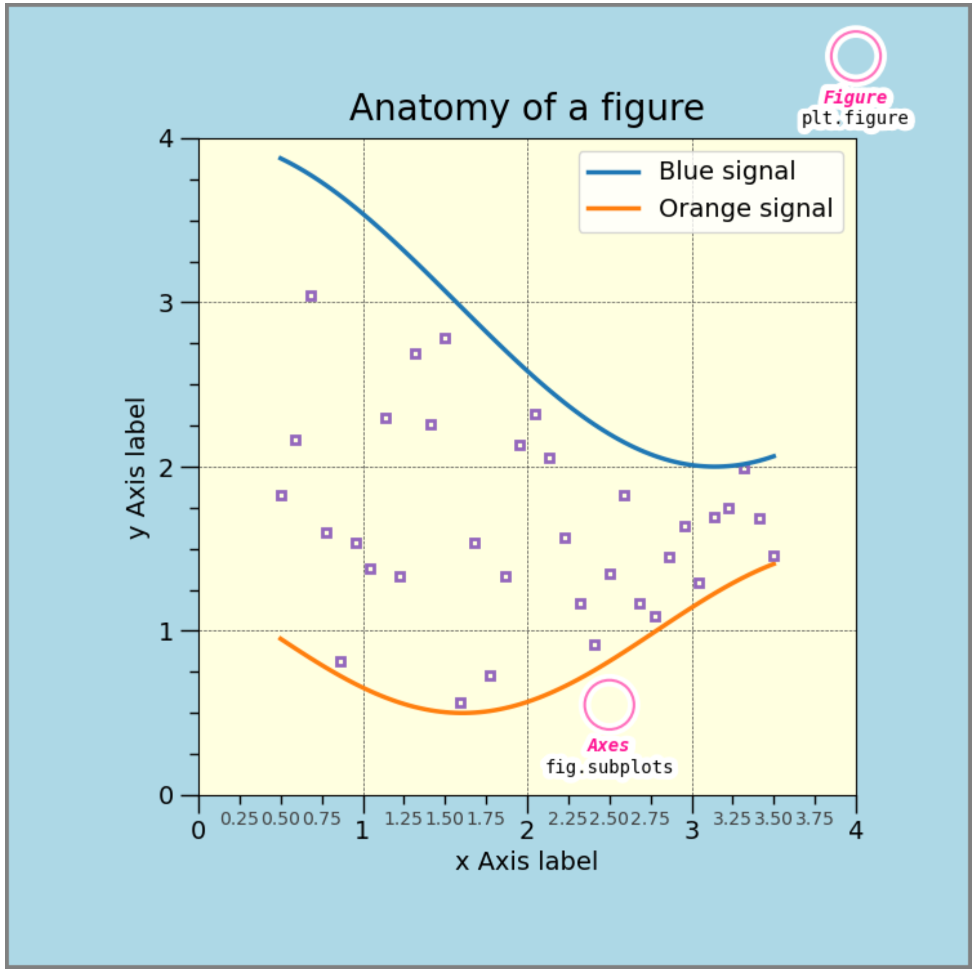
Our Focus →

Represent and manipulate a Figure.

Rendering a Figure on different hardware & software settings.

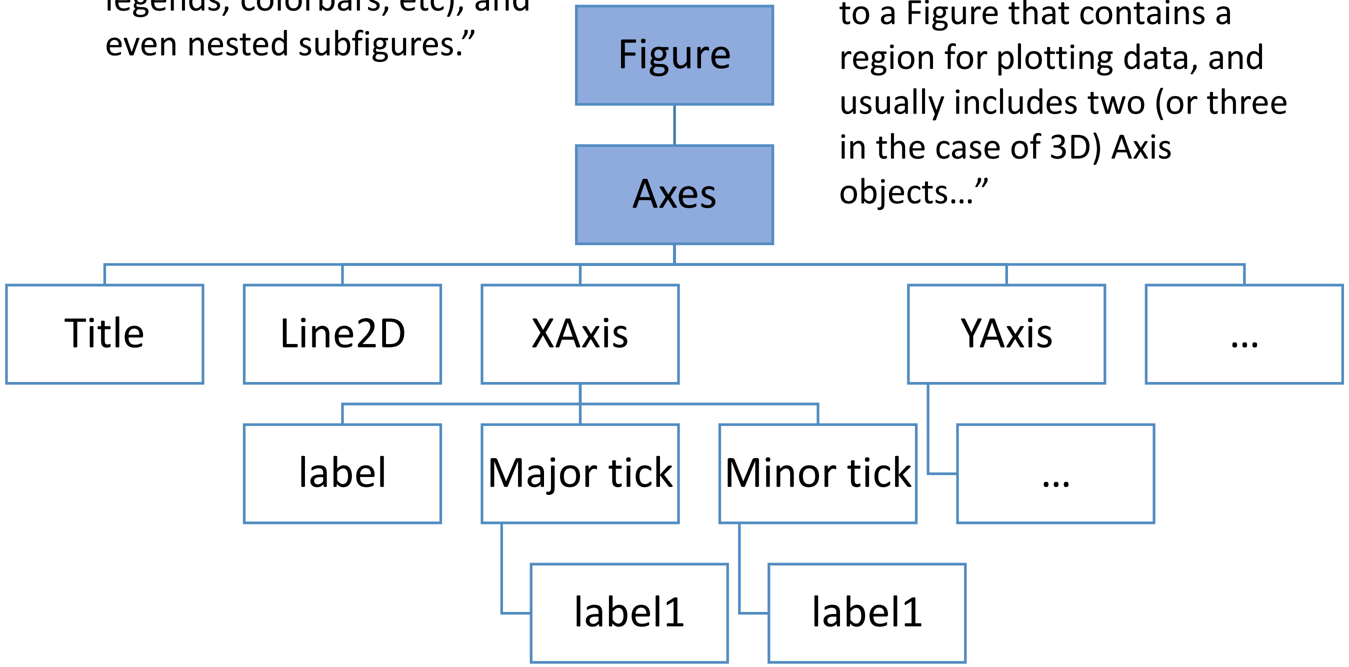
Icons from www.flaticon.com (the archery icon by Mayor Icons)

Anatomy of a Figure & Object Hierarchy (1)



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

“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…”

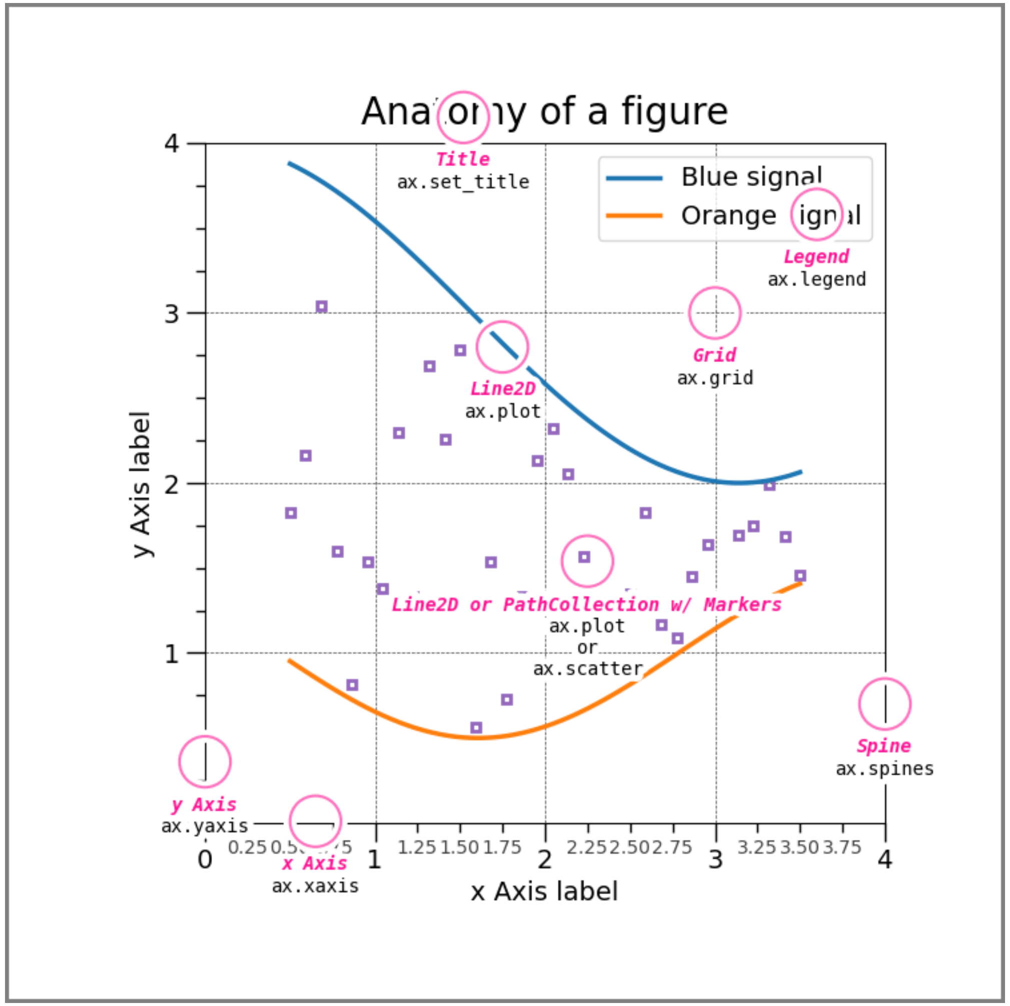


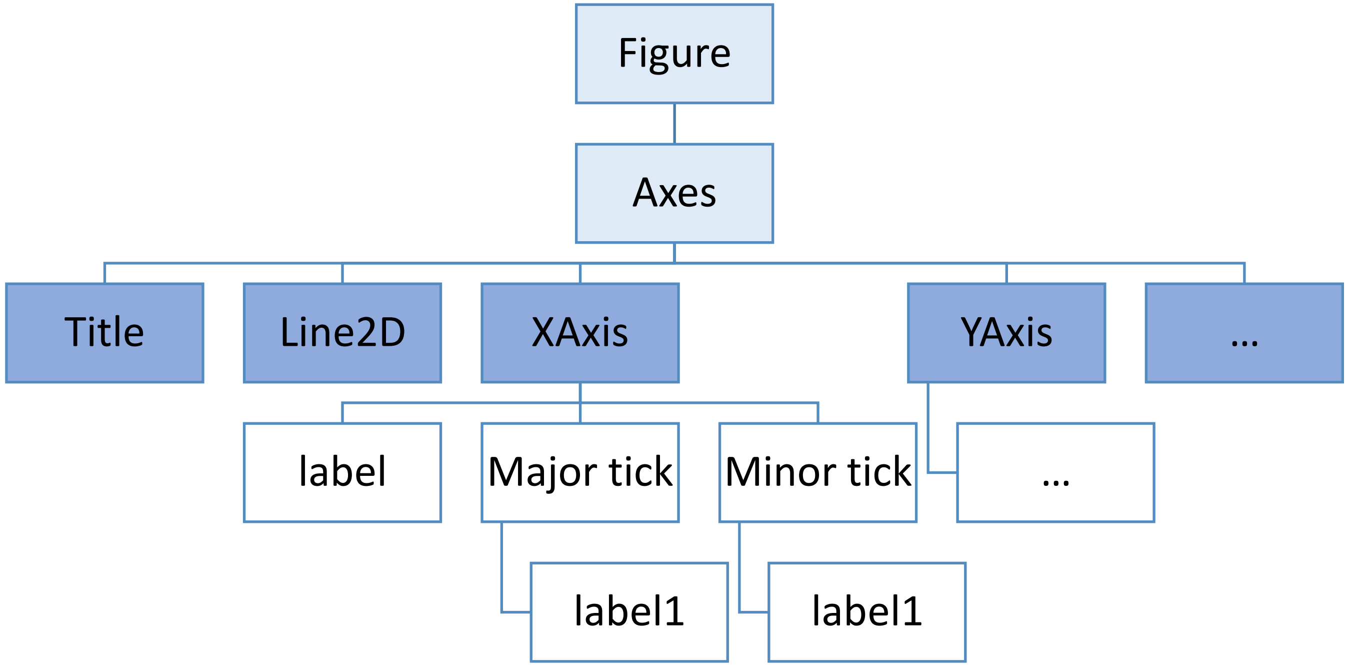
- Figure
  - Axes
    - Title
    - Line2D
    - XAxis
      - label
      - Major tick
        - label1
      - Minor tick
        - label1
    - YAxis
      - …
    - …

Note: Only a subset of the objects are shown in this diagram.

Ref. https://matplotlib.org/stable/users/explain/quick_start.html#parts-of-a-figure

Anatomy of a Figure & Object Hierarchy (2)





Figure

Axes

Title, Line2D, XAxis, YAxis, ...

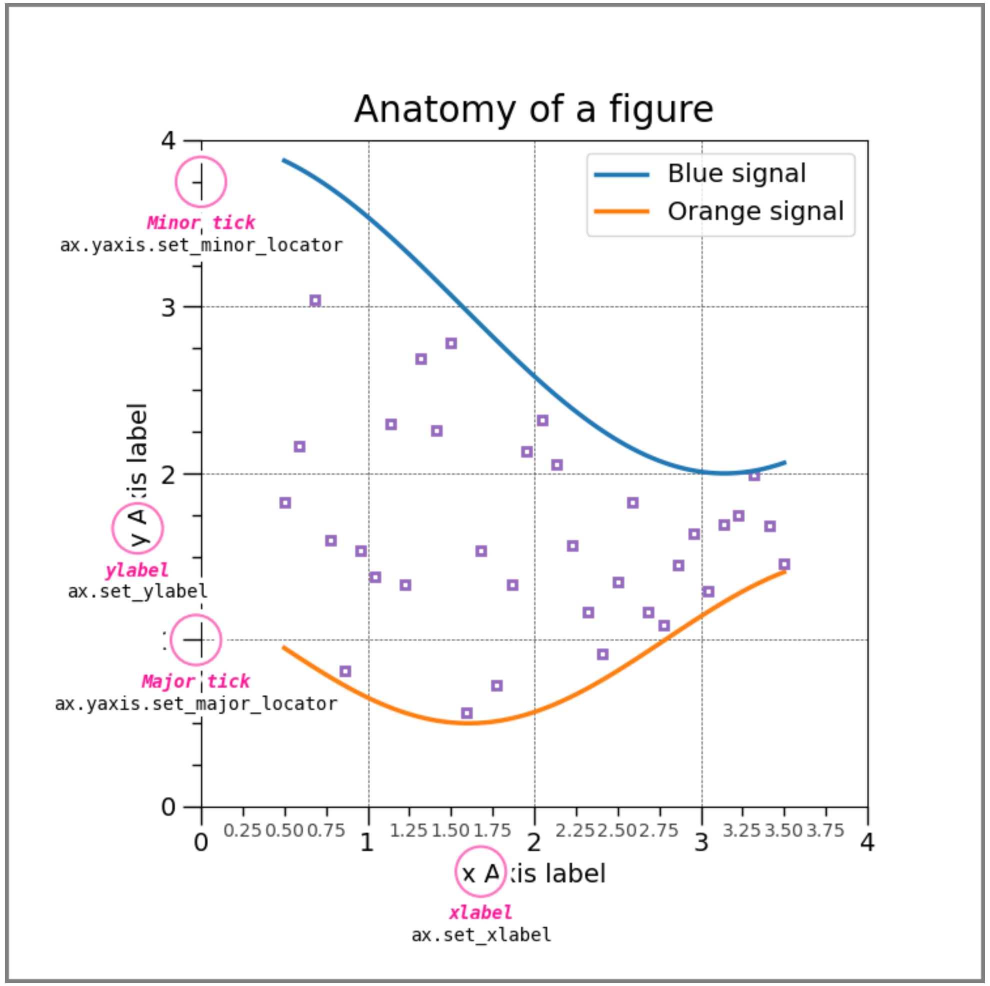
label, Major tick, Minor tick, ...

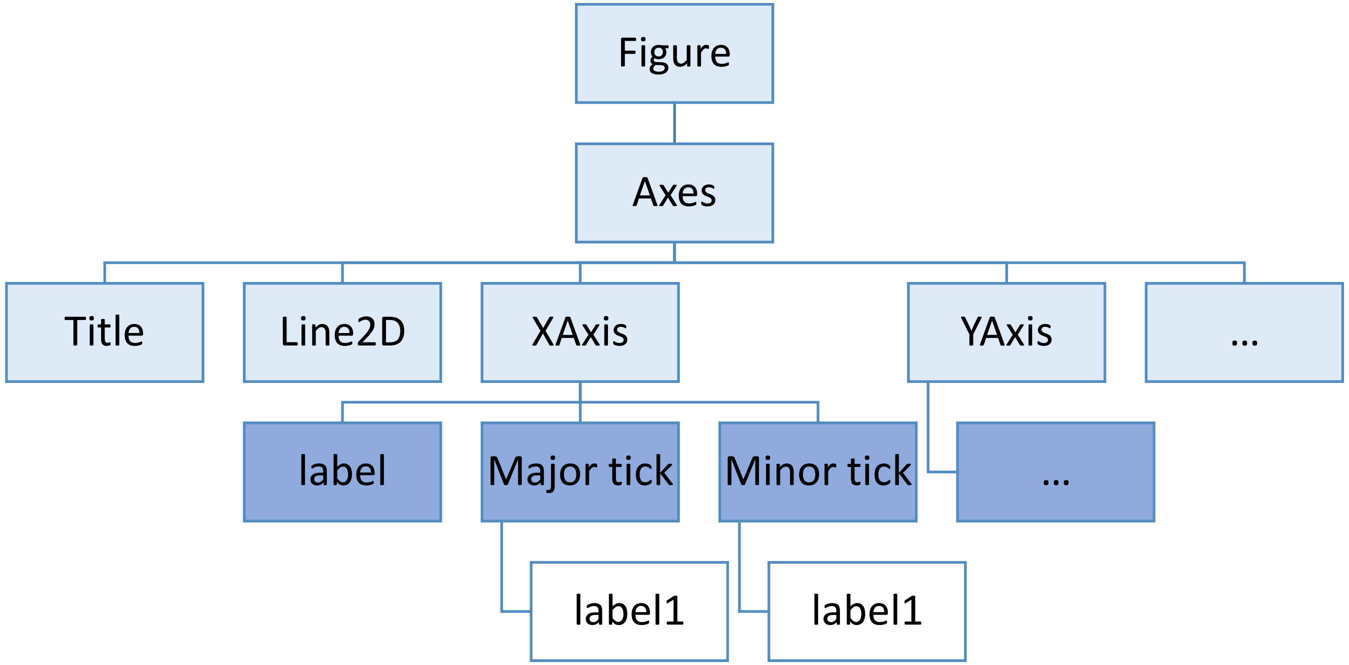
label1, label1

Note: Only a subset of the objects are shown in this diagram.

Ref. https://matplotlib.org/stable/users/explain/quick_start.html#parts-of-a-figure

Anatomy of a Figure & Object Hierarchy (3)



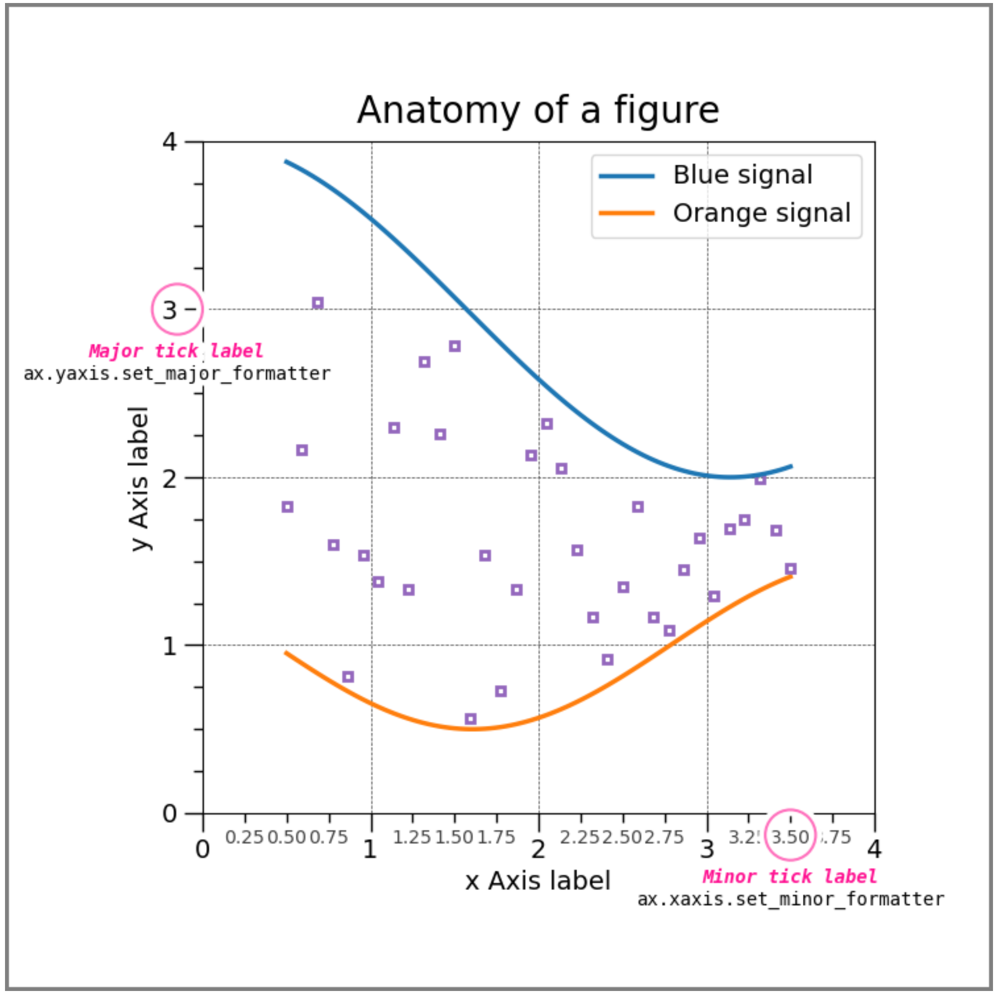


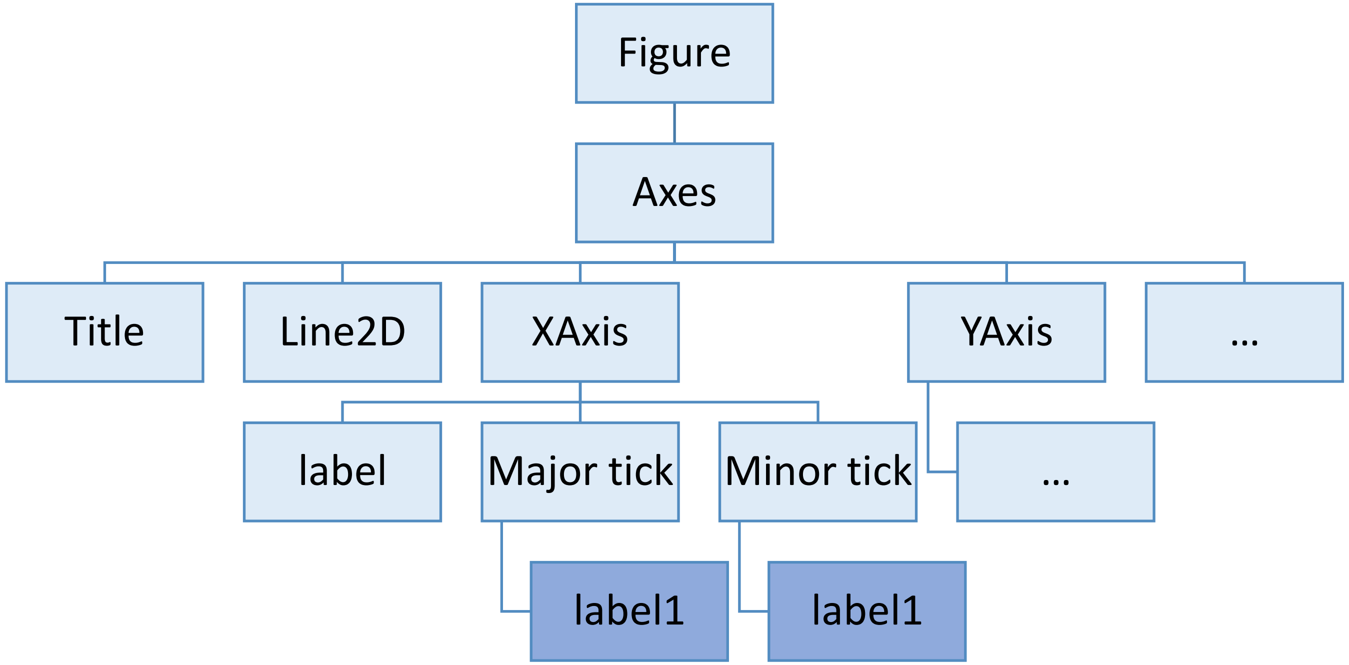
- Figure
  - Axes
    - Title
    - Line2D
    - XAxis
      - label
      - Major tick
        - label1
      - Minor tick
        - label1
    - YAxis
      - …
    - …

Note: Only a subset of the objects are shown in this diagram.

Ref. https://matplotlib.org/stable/users/explain/quick_start.html#parts-of-a-figure

Anatomy of a Figure & Object Hierarchy (4)





Figure

Axes

Title

Line2D

XAxis

YAxis

...

label

Major tick

Minor tick

...

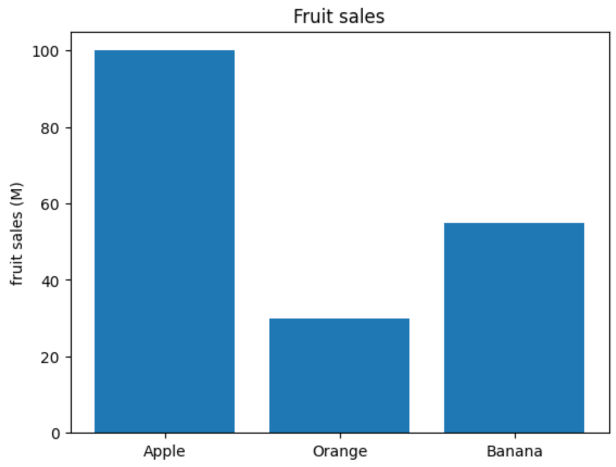
label1

label1

Note: Only a subset of the objects are shown in this diagram.

Ref. https://matplotlib.org/stable/users/explain/quick_start.html#parts-of-a-figure

Two Coding Styles/Approaches



```
import pandas as pd
import matplotlib.pyplot as plt

# create a simple dataset for plotting
df = pd.DataFrame(data = {
   'fruits': ['Apple', 'Orange', 'Banana'],
   'sales': [100, 30, 55],
})

# Approach 1 (script layer; implicit; stateful;)

# call plt.bar() function from matplotlib.pyplot
# implicitly create figure and axes
plt.bar(x=df["fruits"], height=df["sales"])


# call pyplot level functions to set title and ylabel
# implicitly refer to the current axes’ title and ylabel
plt.title("Fruit sales")
plt.ylabel("fruit sales (M)")

# show the plot
plt.show()
```

```
import pandas as pd
import matplotlib.pyplot as plt

# create a simple dataset for plotting
df = pd.DataFrame(data = {
   'fruits': ['Apple', 'Orange', 'Banana'],
   'sales': [100, 30, 55],
})

# Approach 2 (artist layer; explicit; stateless; OOP;)

# create a figure and an axes (subplot)
fig, ax = plt.subplots()

# explicitly call the bar method of the axes just created
ax.bar(x=df["fruits"], height=df["sales"])

# explicitly call the set_xyz() methods of the axes instance
ax.set_title("Fruit sales")
ax.set_ylabel("fruit sales (M)")

# show the plot
plt.show()
```

Ref. https://matplotlib.org/stable/users/explain/quick_start.html#coding-styles

The Artist Layer Approach - Preferred

- Why?

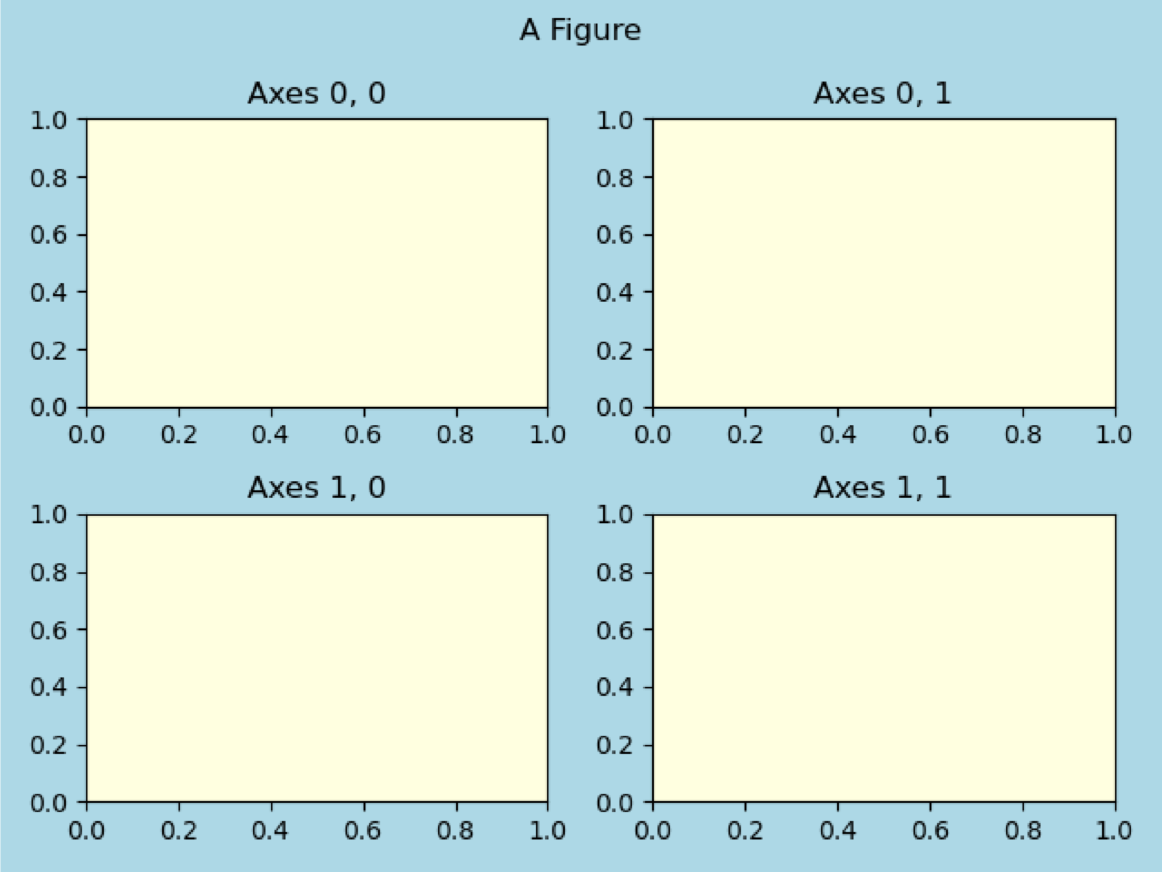
- Figure and Subplots/Axes
  - Create a figure with 2x2 grid of Axes: **`fig, ax = plt.subplots(2, 2)`**
  - Set figure-level properties/objects: **`fig.set_facecolor(), fig.suptitle()`**

- Manipulate objects below an Axes (using method calls)
  - 1-layer below, e.g., **`ax.plot(), ax.set_title(), ax.set_facecolor()`**
  - 2-layer below, e.g., **`ax.set_ylabel(), ax.yaxis.set_major_locator()`**
  - 3-layer below, e.g., **`ax.yaxis.set_major_formatter()`**

Ref. 1) https://matplotlib.org/stable/api/axes_api.html; 2) https://matplotlib.org/stable/api/axis_api.html

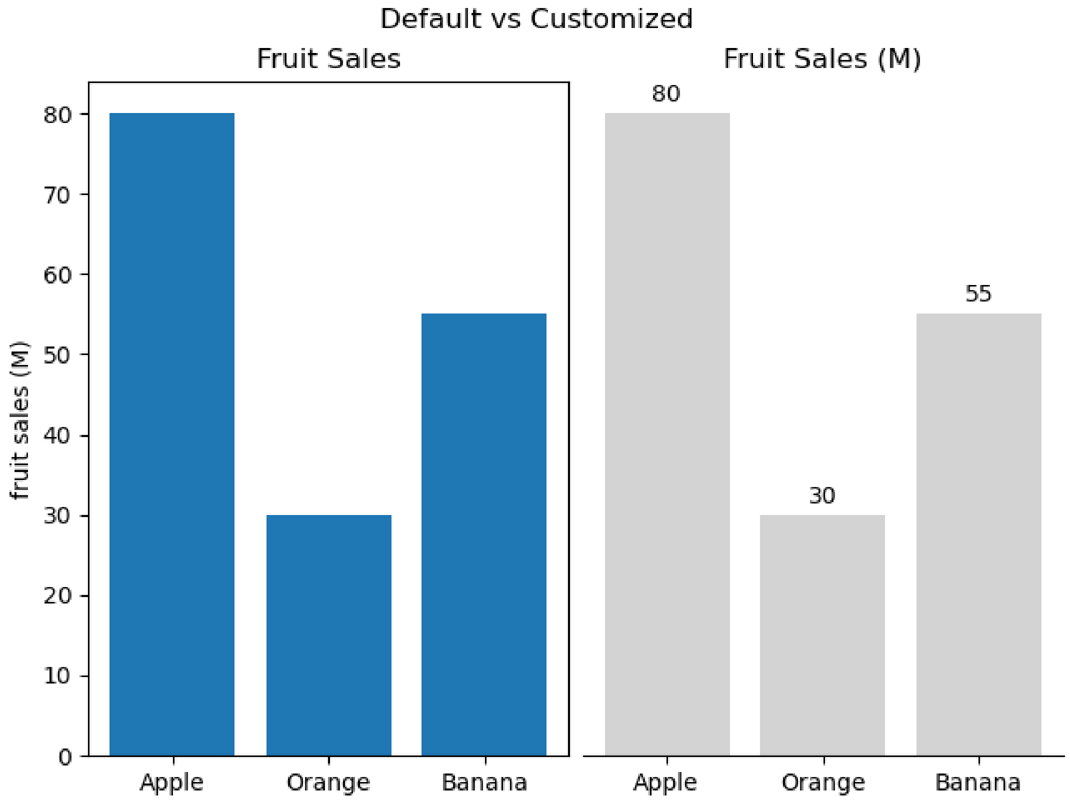
The Artist Layer Approach – Subplots

```python
import matplotlib.pyplot as plt

# create a figure with 2x2 grid of subplots
fig, axes = plt.subplots(nrows=2, ncols=2)

# set the title of the figure
fig.set_facecolor('lightblue')
fig.suptitle('A Figure')

# set the title of each subplot
for row in range(2):
   for col in range(2):
      axes[row, col].set_title(f'Axes {row}, {col}')
      axes[row, col].set_facecolor('lightyellow')

# set layout and display the plot
plt.tight_layout()
plt.show()
```



The Artist Layer Approach – An Example

```python
import matplotlib.pyplot as plt

# create a simple dataset for plotting
df = pd.DataFrame(data = {
   'fruits': ['Apple', 'Orange', 'Banana'],
   'sales': [80, 30, 55],
})

# Approach 2 gives cleaner code when having more
# than one subplot
fig, axes = plt.subplots(nrows=1, ncols=2,
                         layout="constrained")

axes[0].bar(x=df["fruits"], height=df["sales"])
axes[0].set_ylabel("fruit sales (M)")
axes[0].set_title("Fruit Sales")

rects = axes[1].bar(x=df["fruits"], height=df["sales"],
                    color="lightgray")
axes[1].bar_label(rects, padding=3)
axes[1].spines[["top", "right", "left"]].set_visible(False)
axes[1].yaxis.set_visible(False)
axes[1].set_title("Fruit Sales (M)")

fig.suptitle("Default vs Customized")

plt.show()
```



Hands-on: Basic Concepts

- Architecture
- Object hierarchy
- Two coding styles/approaches

Hands-on: Basic Plots

- The gapminder dataset
- Matplotlib or Seaborn
- A few basic plots
  - Bar plot and grouped bar plot
  - Line plot
  - Histogram
  - Scatter plot
- Bubble plot (a taste of customizing a default plot)