Module 02

Matplotlib Overview

Data Science Developer

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Introduction

- Matplotlib is the "grandfather" library of data visualization with Python. It was created by John Hunter.
- He created it to try to replicate MatLab's (another programming language) plotting capabilities in Python.
- So if you happen to be familiar with matlab, matplotlib will feel natural to you.
- It is an excellent 2D and 3D graphics library for generating scientific figures.

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Some of the major Pros of Matplotlib

- Generally easy to get started for simple plots
- Support for custom labels and texts
- Great control of every element in a figure
- High-quality output in many formats
- Very customizable in general

Installation

You'll need to install matplotlib first with either:

- conda install matplotlib
- or pip install matplotlib

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Importing

```
In [1]: import matplotlib.pyplot as plt
```

You'll also need to use this line to see plots in the notebook:

```
In [2]: %matplotlib inline
```

That line is only for jupyter notebooks, if you are using another editor, you'll use: **plt.show()** at the end of all your plotting commands to have the figure pop up in another window.

Example

using 2 numpy arrays

```
In [3]: import numpy as np
        x = np.linspace(0, 5, 11)
        y = x ** 2

In [4]: x

Out[4]: array([0. , 0.5, 1. , 1.5, 2. , 2.5, 3. , 3.5, 4. , 4.5, 5. ])

In [5]: y

Out[5]: array([ 0.  ,  0.25,  1.  ,  2.25,  4.  ,  6.25,  9.  , 12.25, 16.  ,
               20.25, 25.  ])
```

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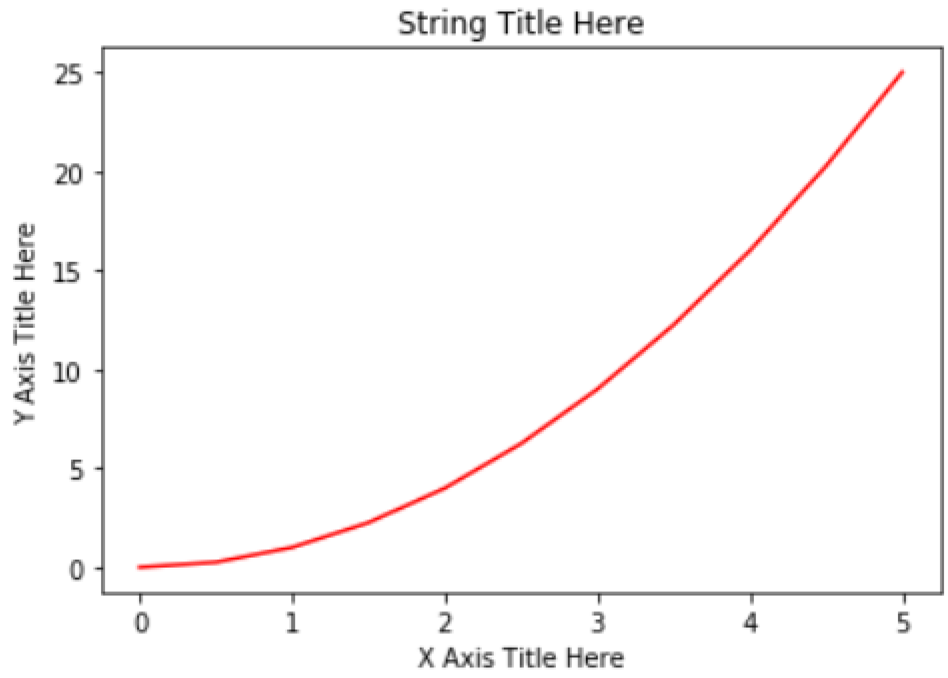
Basic Matplotlib Commands

In [6]:
```
plt.plot(x, y, 'r') # 'r' is the color red
plt.xlabel('X Axis Title Here')
plt.ylabel('Y Axis Title Here')
plt.title('String Title Here')
plt.show()
```



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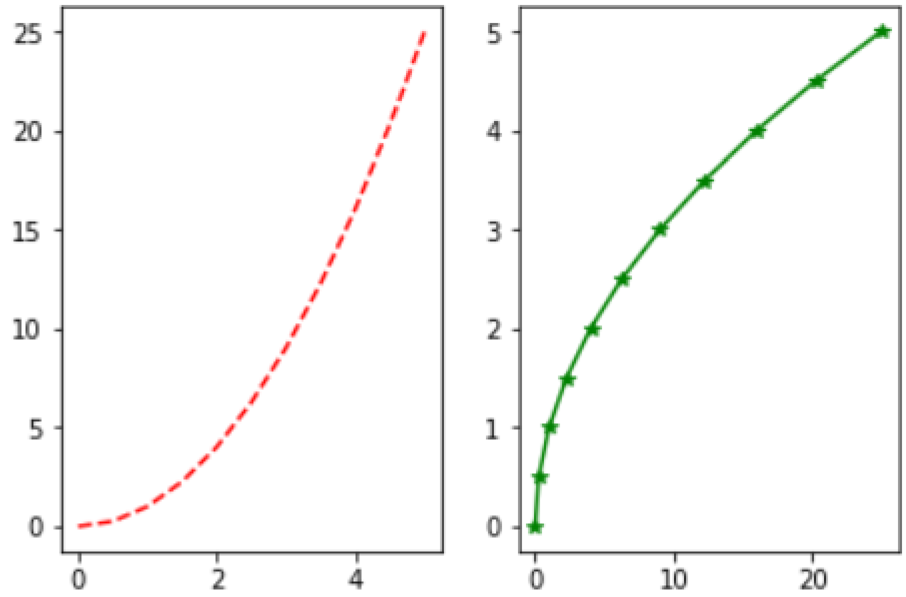
Creating Multiplots on Same Canvas

```
In [7]: # plt.subplot(nrows, ncols, plot_number)
        plt.subplot(1,2,1)
        plt.plot(x, y, 'r--') # More on color options later
        plt.subplot(1,2,2)
        plt.plot(y, x, 'g*-');
```



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Matplotlib Object Oriented Method

Now that we've seen the basics, let's break it all down with a more formal introduction of Matplotlib's Object Oriented API.

This means we will instantiate figure objects and then call methods or attributes from that object.

Introduction to the OOM

The main idea in using the more formal Object Oriented method is to create figure objects and then just call methods or attributes off of that object.

This approach is nicer when dealing with a canvas that has multiple plots on it.

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Introduction to the OOM

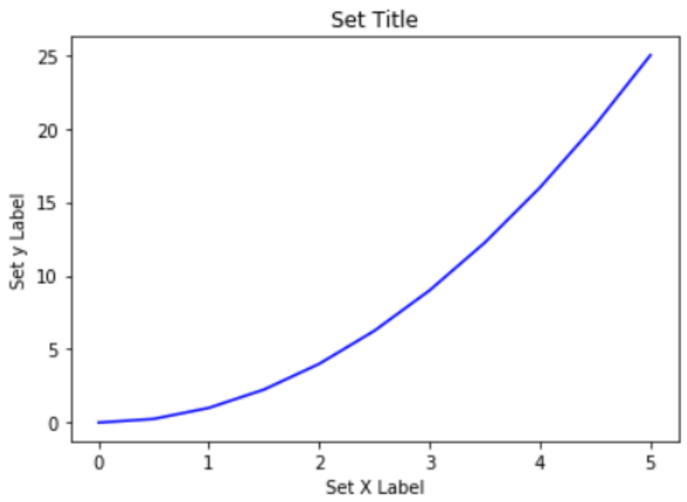
To begin we create a figure instance. Then we can add axes to that figure:

In [8]:
```
# Create Figure (empty canvas)
fig = plt.figure()

# Add set of axes to figure
axes = fig.add_axes([0.1, 0.1, 0.8, 0.8]) # left, bottom, width, height (range 0 to 1)

# Plot on that set of axes
axes.plot(x, y, 'b')
axes.set_xlabel('Set X Label') # Notice the use of set_ to begin methods
axes.set_ylabel('Set y Label')
axes.set_title('Set Title')
```

Out[8]:
```
Text(0.5,1,'Set Title')
```



Introduction to the OOM

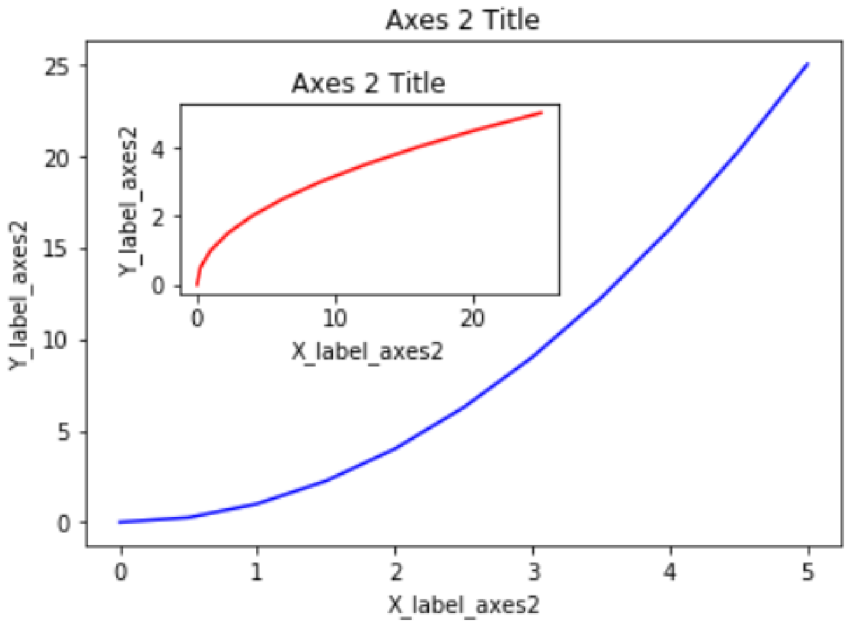
Code is a little more complicated, but the advantage is that we now have full control of where the plot axes are placed, and we can easily add more than one axis to the figure:

```
# Creates blank canvas
fig = plt.figure()

axes1 = fig.add_axes([0.1, 0.1, 0.8, 0.8]) # main axes
axes2 = fig.add_axes([0.2, 0.5, 0.4, 0.3]) # inset axes

# Larger Figure Axes 1
axes1.plot(x, y, 'b')
axes1.set_xlabel('X_label_axes2')
axes1.set_ylabel('Y_label_axes2')
axes1.set_title('Axes 2 Title')

# Insert Figure Axes 2
axes2.plot(y, x, 'r')
axes2.set_xlabel('X_label_axes2')
axes2.set_ylabel('Y_label_axes2')
axes2.set_title('Axes 2 Title');
```



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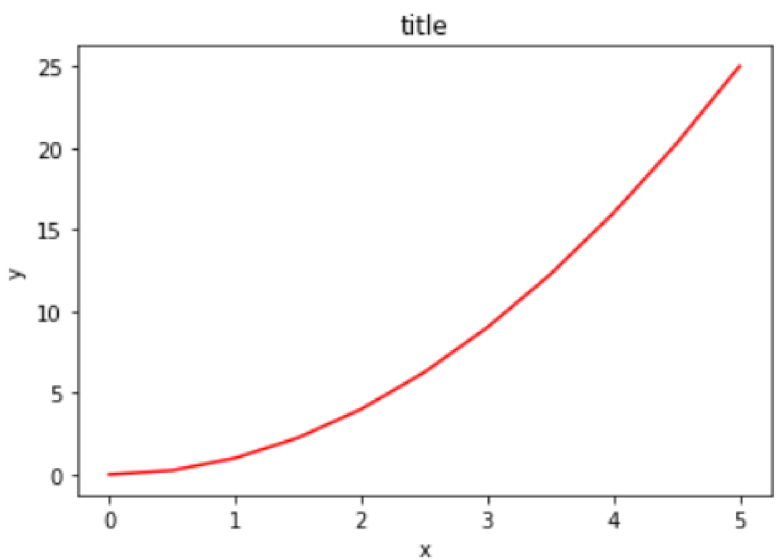
subplots()

The plt.subplots() object will act as a more automatic axis manager.
Basic use cases:

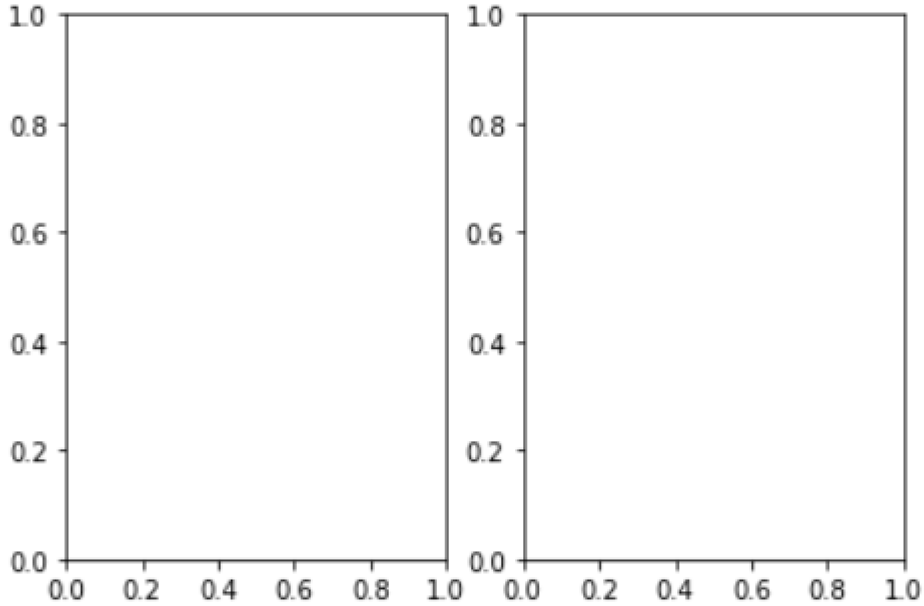
```
# Use similar to plt.figure() except use tuple unpacking to grab fig and axes
fig, axes = plt.subplots()

# Now use the axes object to add stuff to plot
axes.plot(x, y, 'r')
axes.set_xlabel('x')
axes.set_ylabel('y')
axes.set_title('title');
```



subplots()

Then you can specify the number of rows and columns when creating the subplots() object:

```python
# Empty canvas of 1 by 2 subplots
fig, axes = plt.subplots(nrows=1, ncols=2)
```

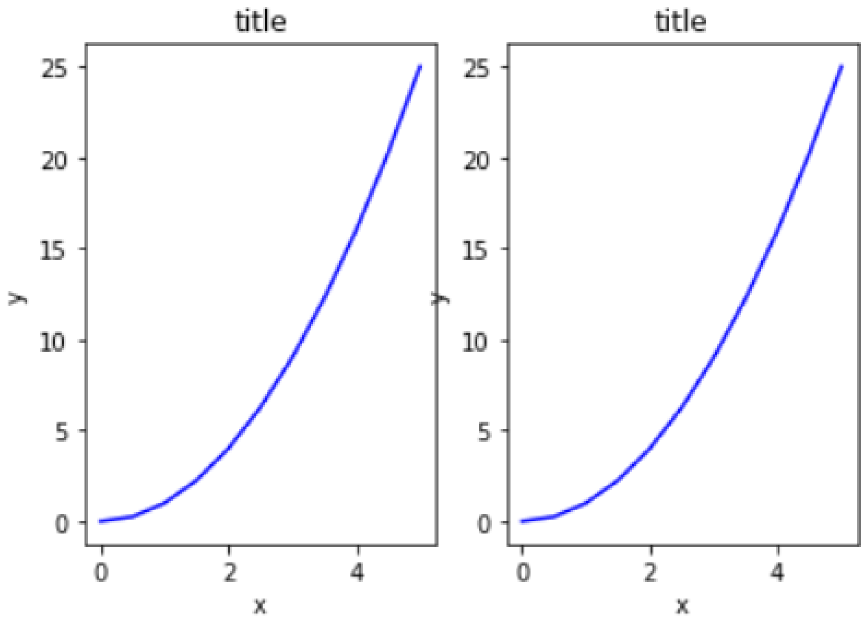


```python
# Axes is an array of axes to plot on
axes
```

```
array([<matplotlib.axes._subplots.AxesSubplot object at 0x0000024709792E80>,
       <matplotlib.axes._subplots.AxesSubplot object at 0x00000247097C0320>],
      dtype=object)
```

We can iterate through this array:

```python
for ax in axes:
    ax.plot(x, y, 'b')
    ax.set_xlabel('x')
    ax.set_ylabel('y')
    ax.set_title('title')

# Display the figure object
fig
```



A common issue with matplolib is overlapping subplots or figures.
We can use **fig.tight_layout()** or **plt.tight_layout()** method, which automatically adjusts the positions of the axes on the figure canvas so that there is no overlapping content:

```
fig, axes = plt.subplots(nrows=1, ncols=2)

for ax in axes:
    ax.plot(x, y, 'g')
    ax.set_xlabel('x')
    ax.set_ylabel('y')
    ax.set_title('title')

fig
plt.tight_layout()
```

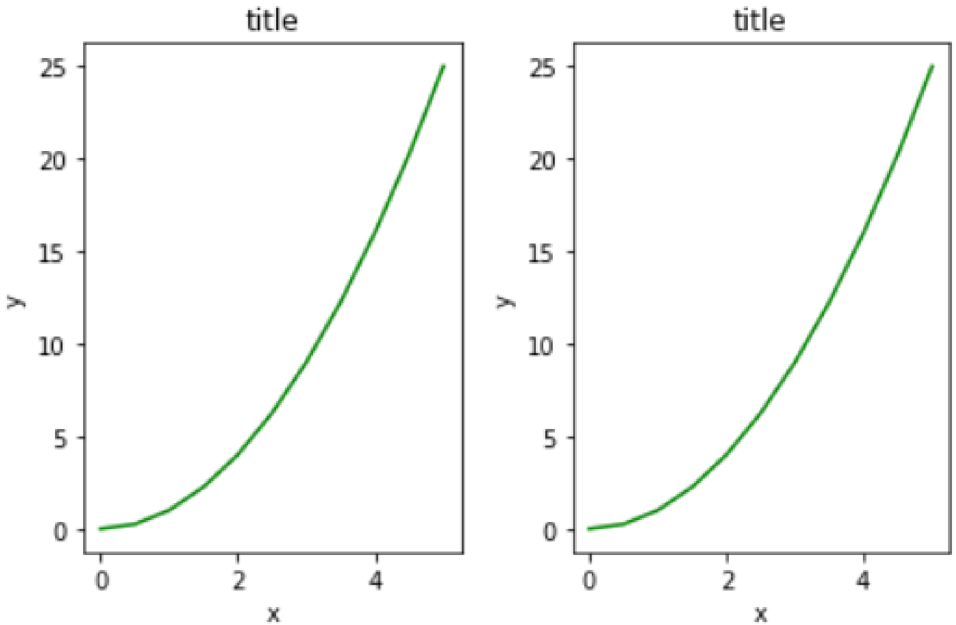


Figure size, aspect ratio and DPI

Matplotlib allows the aspect ratio, DPI and figure size to be specified when the Figure object is created. You can use the figsize and dpi keyword arguments.

- figsize is a tuple of the width and height of the figure in inches
- dpi is the dots-per-inch (pixel per inch).

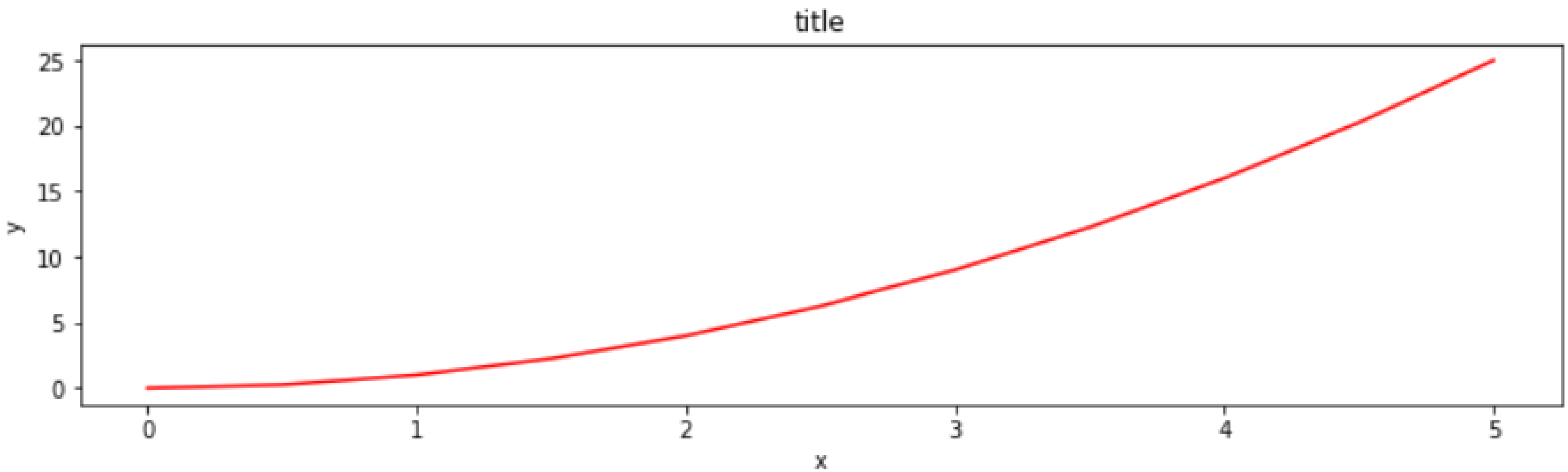
For example:

```
fig = plt.figure(figsize=(8,4), dpi=100)
```

```
<Figure size 800x400 with 0 Axes>
```

The same arguments can also be passed to layout managers, such as the subplots function:

```
fig, axes = plt.subplots(figsize=(12,3))

axes.plot(x, y, 'r')
axes.set_xlabel('x')
axes.set_ylabel('y')
axes.set_title('title');
```



Saving Figures

Matplotlib can generate high-quality output in a number formats, including PNG, JPG, EPS, SVG, PGF and PDF.

To save a figure to a file we can use the savefig method in the Figure class:

```
fig.savefig("filename.png")
```

Here we can also optionally specify the DPI and choose between different output formats:

```
fig.savefig("filename.png", dpi=200)
```

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Legends, labels and titles

Now that we have covered the basics of how to create a figure canvas and add axes instances to the canvas, let's look at how decorate a figure with titles, axis labels, and legends.

Figure titles

A title can be added to each axis instance in a figure. To set the title, use the set_title method in the axes instance:

```
ax.set_title("title");
```

Axis labels

Similarly, with the methods set_xlabel and set_ylabel, we can set the labels of the X and Y axes:

```
ax.set_xlabel("x")
ax.set_ylabel("y");
```

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Legends

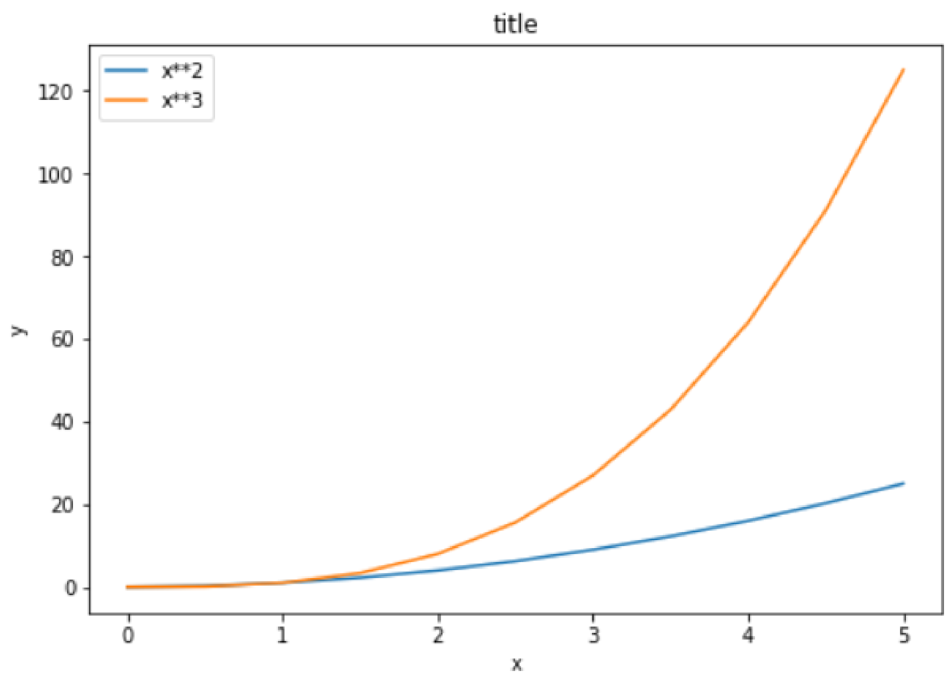
You can use the label="label text" keyword argument when plots or other objects are added to the figure, and then using the legend method without arguments to add the legend to the figure:

```
fig = plt.figure()

ax = fig.add_axes([0,0,1,1])

ax.plot(x, x**2, label="x**2")
ax.plot(x, x**3, label="x**3")
ax.set_title("title")
ax.set_xlabel("x")
ax.set_ylabel("y")
ax.legend()
```

```
<matplotlib.legend.Legend at 0x247095fb198>
```



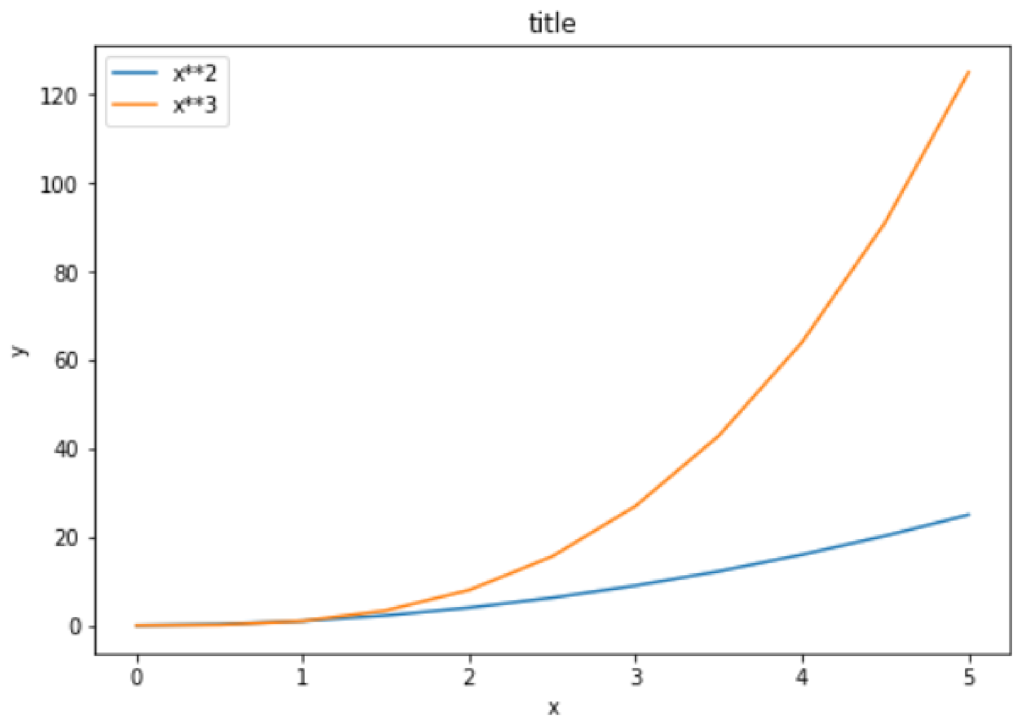
The legend function takes an optional keyword argument **loc** that can be used to specify where in the figure the legend is to be drawn. The allowed values of **loc** are numerical codes for the various places the legend can be drawn. Some of the most common **loc** values are:

```
# Lots of options....

ax.legend(loc=1) # upper right corner
ax.legend(loc=2) # upper left corner
ax.legend(loc=3) # lower left corner
ax.legend(loc=4) # lower right corner

# .. many more options are available

# Most common to choose
ax.legend(loc=0) # let matplotlib decide the optimal location
fig
```



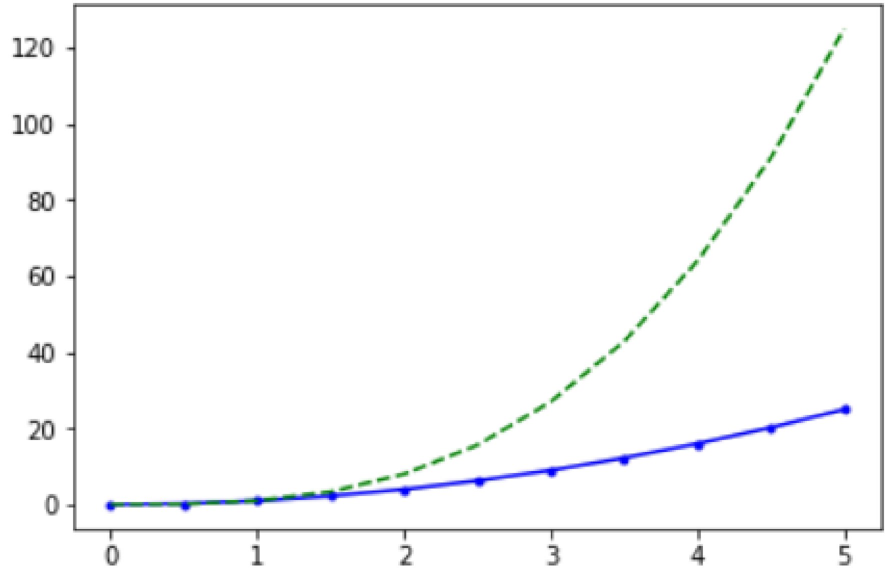
Setting colors, linewidths, linetypes

Colors with MatLab like syntax

With matplotlib, we can define the colors of lines and other graphical elements in a number of ways. First of all, we can use the MATLAB-like syntax where 'b' means blue, 'g' means green, etc. The MATLAB API for selecting line styles are also supported: where, for example, 'b.-' means a blue line with dots:

```
# MATLAB style line color and style
fig, ax = plt.subplots()
ax.plot(x, x**2, 'b.-') # blue line with dots
ax.plot(x, x**3, 'g--') # green dashed line
```

```
[<matplotlib.lines.Line2D at 0x247087177b8>]
```



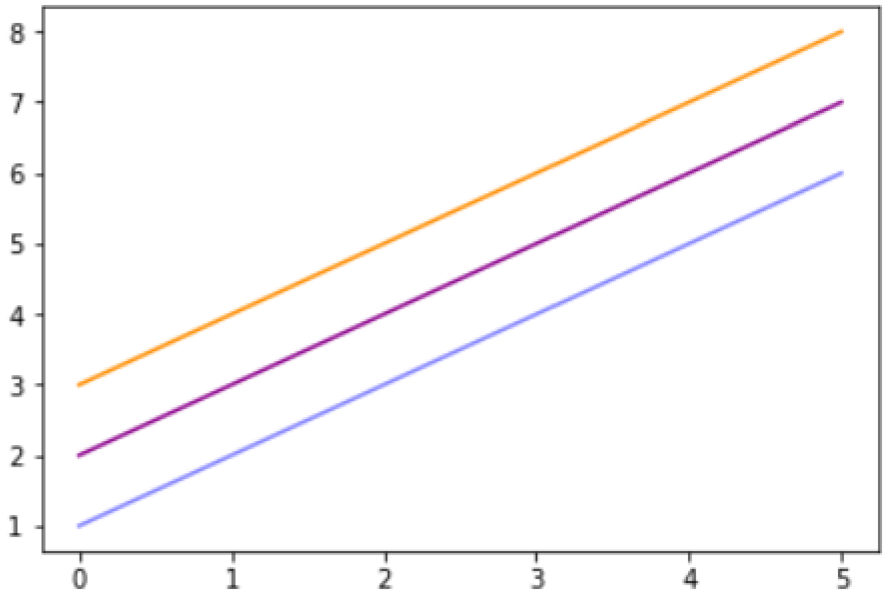
Colors with the color= parameter

We can also define colors by their names or RGB hex codes and optionally provide an alpha value using the color and alpha keyword arguments. Alpha indicates opacity.

```
fig, ax = plt.subplots()

ax.plot(x, x+1, color="blue", alpha=0.5) # half-transparant
ax.plot(x, x+2, color="#8B008B")        # RGB hex code
ax.plot(x, x+3, color="#FF8C00")        # RGB hex code
```

```
[<matplotlib.lines.Line2D at 0x24709528898>]
```



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Line and marker styles

To change the line width, we can use the linewidth or lw keyword argument. The line style can be selected using the linestyle or ls keyword arguments:

```
fig, ax = plt.subplots(figsize=(12,6))

ax.plot(x, x+1, color="red", linewidth=0.25)
ax.plot(x, x+2, color="red", linewidth=0.50)
ax.plot(x, x+3, color="red", linewidth=1.00)
ax.plot(x, x+4, color="red", linewidth=2.00)

# possible linestype options '-', '–', '-.', ':', 'steps'
ax.plot(x, x+5, color="green", lw=3, linestyle='-')
ax.plot(x, x+6, color="green", lw=3, ls='-.')
ax.plot(x, x+7, color="green", lw=3, ls=':')

# custom dash
line, = ax.plot(x, x+8, color="black", lw=1.50)
line.set_dashes([5, 10, 15, 10]) # format: line length, space length, ...

# possible marker symbols: marker = '+', 'o', '*', 's', ',', '.', '1', '2', '3', '4', ...
ax.plot(x, x+ 9, color="blue", lw=3, ls='-', marker='+')
ax.plot(x, x+10, color="blue", lw=3, ls='--', marker='o')
ax.plot(x, x+11, color="blue", lw=3, ls='-', marker='s')
ax.plot(x, x+12, color="blue", lw=3, ls='--', marker='1')

# marker size and color
ax.plot(x, x+13, color="purple", lw=1, ls='-', marker='o', markersize=2)
ax.plot(x, x+14, color="purple", lw=1, ls='-', marker='o', markersize=4)
ax.plot(x, x+15, color="purple", lw=1, ls='-', marker='o', markersize=8, markerfacecolor="red")
ax.plot(x, x+16, color="purple", lw=1, ls='-', marker='s', markersize=8,
        markerfacecolor="yellow", markeredgewidth=3, markeredgecolor="green");
```

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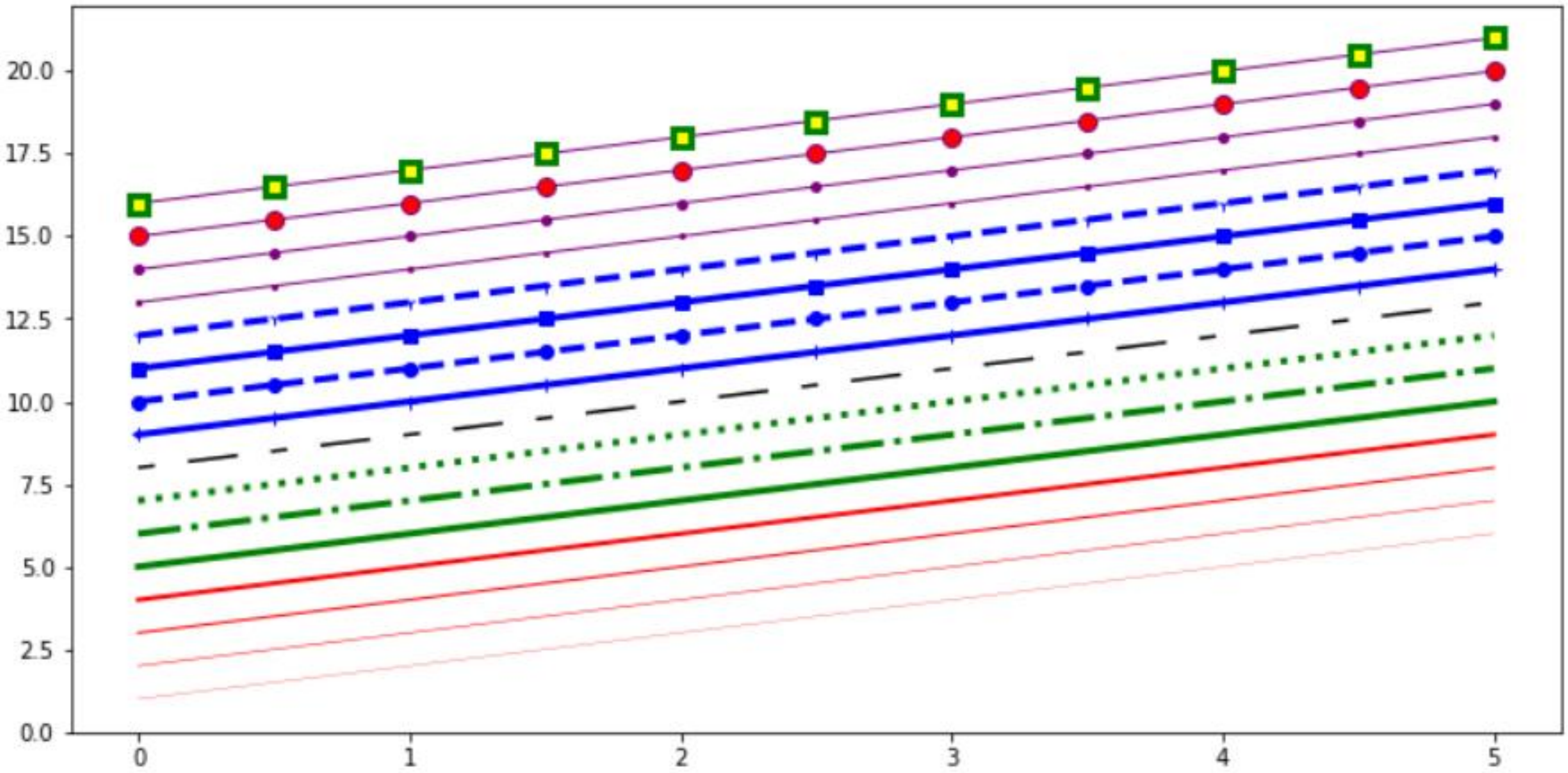

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Plot Range

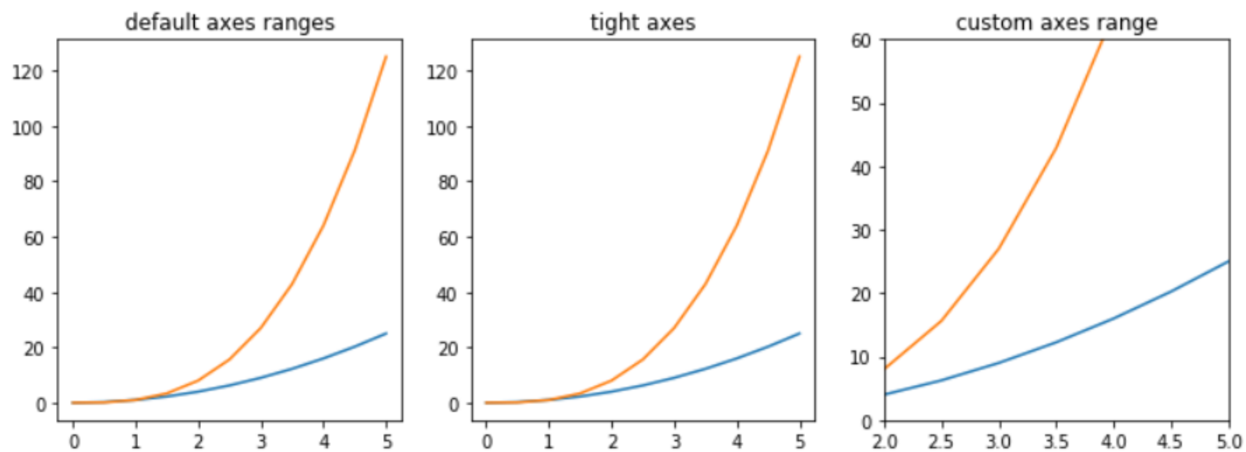
We can configure the ranges of the axes using the set_ylim and set_xlim methods in the axis object, or axis('tight') for automatically getting "tightly fitted" axes ranges:

```
fig, axes = plt.subplots(1, 3, figsize=(12, 4))

axes[0].plot(x, x**2, x, x**3)
axes[0].set_title("default axes ranges")

axes[1].plot(x, x**2, x, x**3)
axes[1].axis('tight')
axes[1].set_title("tight axes")

axes[2].plot(x, x**2, x, x**3)
axes[2].set_ylim([0, 60])
axes[2].set_xlim([2, 5])
axes[2].set_title("custom axes range");
```

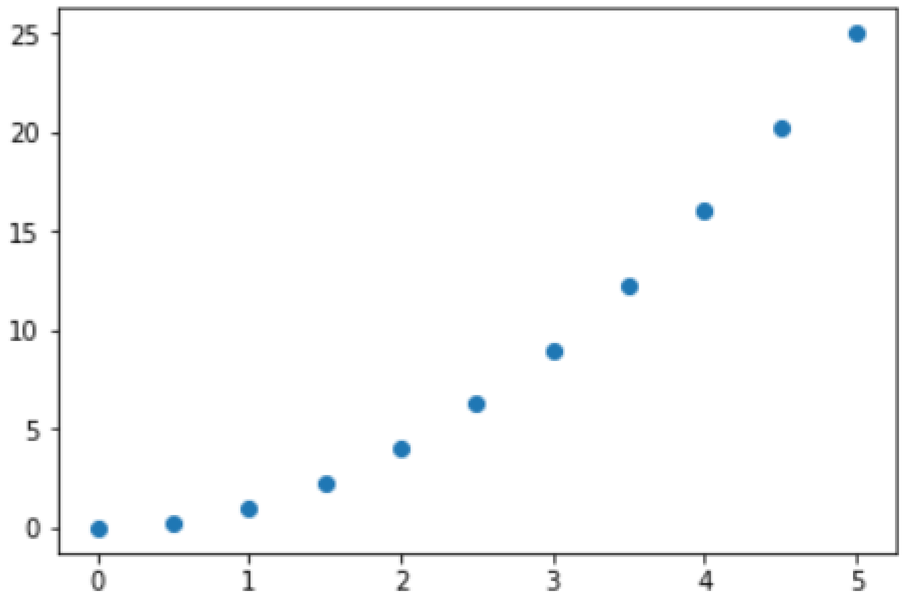


Special Plot Types

There are many specialized plots we can create, such as barplots, histograms, scatter plots, and much more. Most of these type of plots we will actually create using seaborn, a statistical plotting library for Python. But here are a few examples of these type of plots:

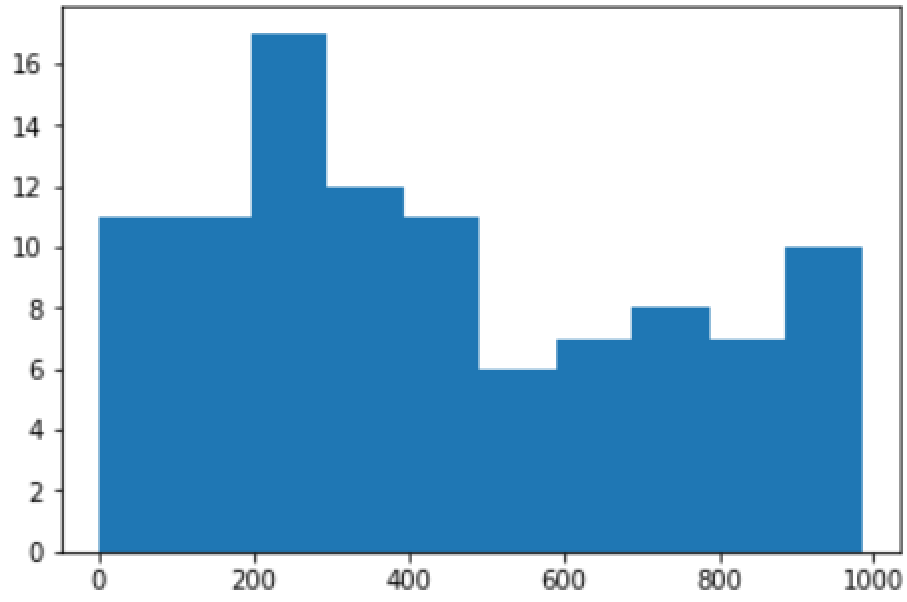
```
plt.scatter(x,y)
```

```
<matplotlib.collections.PathCollection at 0x24709a13860>
```



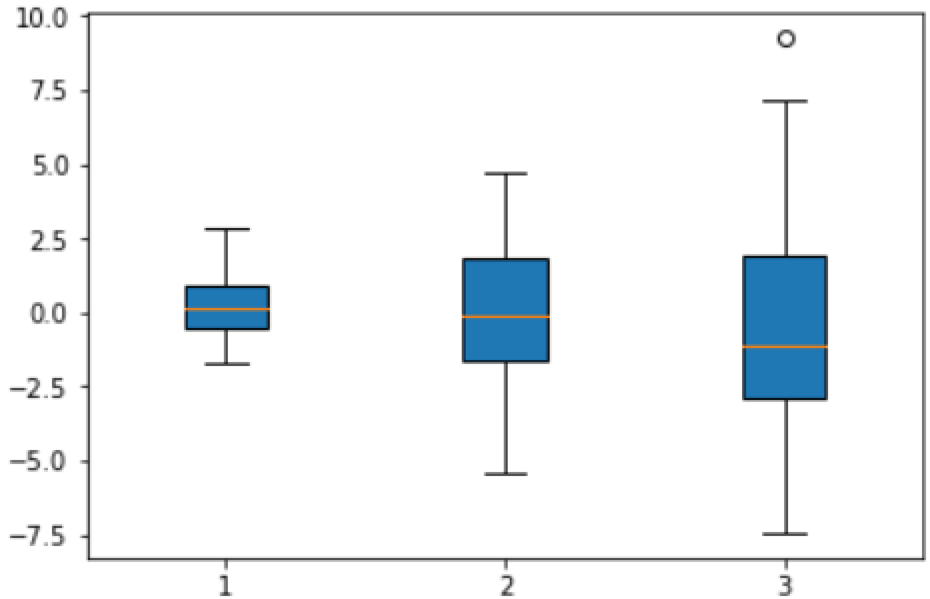
```python
from random import sample
data = sample(range(1, 1000), 100)
plt.hist(data)
```

```
(array([11., 11., 17., 12., 11.,  6.,  7.,  8.,  7., 10.]),
 array([  1. ,  99.3, 197.6, 295.9, 394.2, 492.5, 590.8, 689.1, 787.4,
        885.7, 984. ]),
 <a list of 10 Patch objects>)
```



```
data = [np.random.normal(0, std, 100) for std in range(1, 4)]

# rectangular box plot
plt.boxplot(data,vert=True,patch_artist=True);
```



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