Clearing the confusion once and for all: fig, ax = plt.subplots()

Learn about figure and axes objects in Matplotlib

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Introduction

> By reading this article, you will learn the two core objects in Maptlolib plots: figure and axes. You will finally understand the difference between simple plotting (`plt.plot`) and creating subplots with `plt.subplots()`.

When you begin your journey into Data Science, you are introduced to Matplotlib as your first library for Data Visualization. Most tutorials for beginners play a cruel trick on students by introducing them first to the 'beginner-friendly' `pyplot > plt` interface. As these poor students venture into the real world, they will find out the dudes on StackOverflow and most other people use a more flexible object-oriented way. They will get confused and most probably move on to Seaborn and Plotly. Or even worse, to the no-code interface of Tableau, like I almost did. (Because of this confusion, I specifically remember myself going through Quora and StackOverflow threads wondering if people were using Tableau over Matplotlib)

This article will introduce you to figure and axes objects in Matplotlib and their advantages over other methods.

Overview

> *The sample data and the notebook of the article are available in this GitHub repo.*

Setup

```python
# Loading necessary libraries
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

# Plotting pretty figures and avoid blurry images
%config InlineBackend.figure_format = 'retina'
# No need to include %matplotlib inline magic command. These things come built-in now.

# Ignore warnings
import warnings
warnings.filterwarnings('ignore')

# Enable multiple cell outputs
from IPython.core.interactiveshell import InteractiveShell
InteractiveShell.ast_node_interactivity = 'all'
```

setup.py hosted with ♡ by GitHub view raw

```
# Load some sample data
medals = pd.read_csv('data/medals_by_country_2016.csv', index_col=[0])
climate_change = pd.read_csv('data/climate_change.csv', parse_dates=['date'])
```

0202.py hosted with ♡ by GitHub view raw

```
# Basic exploration
medals.info()
climate_change.info()

_____________________
<class 'pandas.core.frame.DataFrame'>
Index: 10 entries, United States to Japan
Data columns (total 3 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   Bronze  10 non-null     int64
 1   Gold    10 non-null     int64
 2   Silver  10 non-null     int64
dtypes: int64(3)
memory usage: 320.0+ bytes
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 706 entries, 0 to 705
Data columns (total 3 columns):
 #   Column         Non-Null Count  Dtype
---  ------         --------------  -----
 0   date           706 non-null    datetime64[ns]
 1   co2            699 non-null    float64
 2   relative_temp  706 non-null    float64
dtypes: datetime64[ns](1), float64(2)
memory usage: 16.7 KB
_____________________

medals.head()
```

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	Bronze	Gold	Silver
United States	67	137	52
Germany	67	47	43
Great Britain	26	64	55
Russia	35	50	28
China	35	44	30

```
>>> climate_change.head()
```

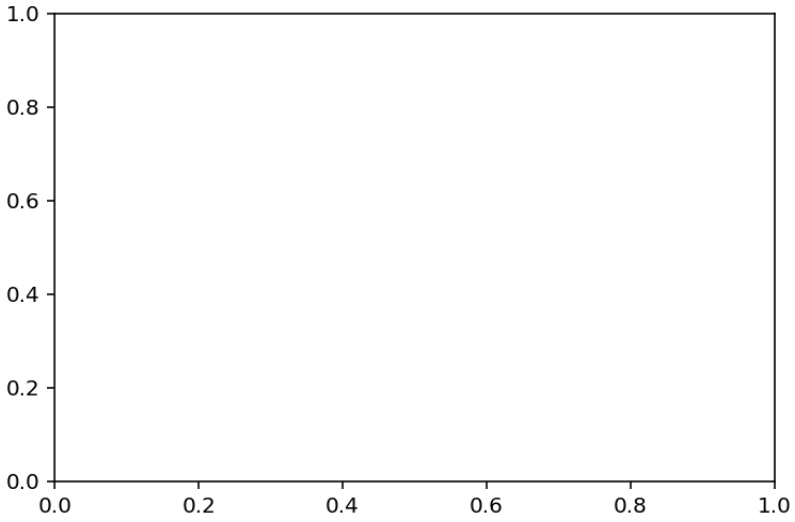
	date	co2	relative_temp
0	1958-03-06	315.71	0.10
1	1958-04-06	317.45	0.01
2	1958-05-06	317.50	0.08
3	1958-06-06	NaN	-0.05
4	1958-07-06	315.86	0.06

plt.subplots(), preliminary understanding

It all starts with calling `.subplots()` command:

```
>>> plt.subplots()

(<Figure size 432x288 with 1 Axes>, <AxesSubplot:>)
```



If you pay attention, apart from the blank plot, the function also returned a tuple of two values:

[OUT]: (<Figure size 432x288 with 1 Axes>, <AxesSubplot:>)

Every time we call `subplots()` function, it will return these types of tuples always with two values. In Python, there is a technique called tuple unpacking. Let me show you a simple example:

```
# Create an arbitrary tuple
numbers = (10, 11, 12)
# Assign each of its values to a single variable
ten, eleven, twelve = numbers
```

0204.py hosted with ♡ by GitHub view raw

If we print the values of the above three:

```
>>> print(ten)
10
>>> print(eleven)
11
>>> print(twelve)
12
```

Great, we unpacked a tuple of size 3 into three different variables. So, now you will understand this code better:

```
# Two variables because function returns tuple of size 2
fig, ax = plt.subplots()
```

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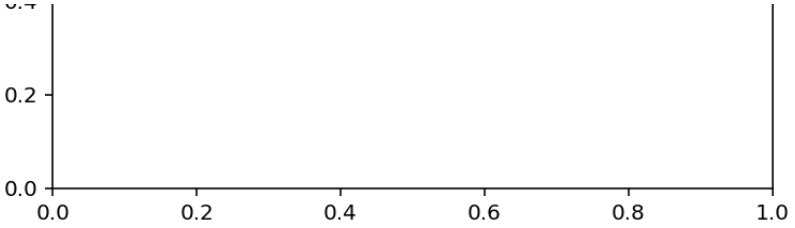


> *We created two variables, `fig` and `ax`. Remember, these are arbitrary names but a standard and we are one of the good guys, so we will follow the convention.*

These two variables now hold the two core objects used for all types of plotting operations. First object `fig`, short for `figure`, imagine it as the frame of your plot. You can resize, reshape the frame but you cannot draw on it. On a single notebook or a script, you can have multiple figures. Each figure can have multiple subplots. Here, subplot is synonymous with axes. The second object, `ax`, short for axes, is the canvas you draw on. Or rephrasing, it is the blank sheet you can plot and hold your data. An axes object can only belong to one figure.

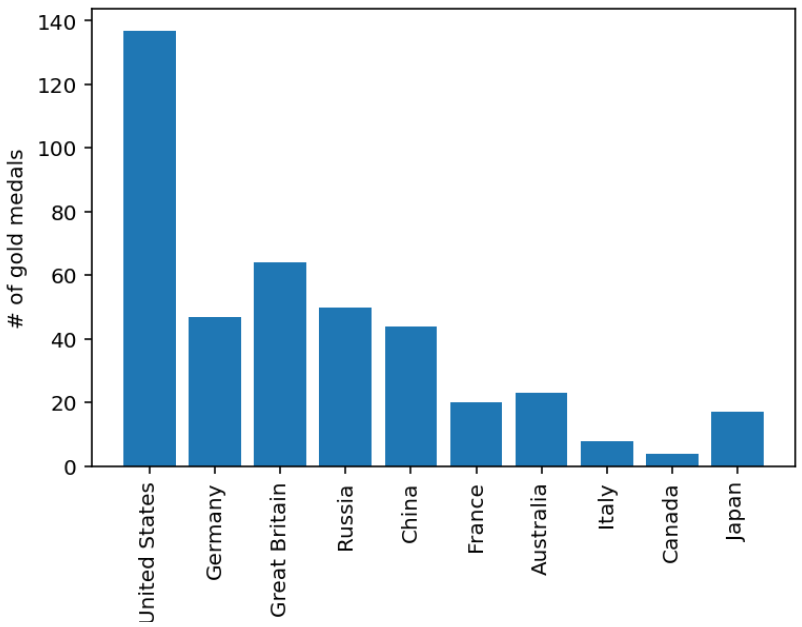
Axes methods vs. pyplot, understanding further

At the beginning of the post, I said that `pyplot` was a more beginner-friendly method to interact with Matplotlib. It is true that compared to axes methods, `pyplot` offers a quicker and more concise method of plotting. It will have less local variables and syntax. But why most people prefer the object-oriented way?

Let's see the concise way of `pyplot`:

```
1  plt.bar(medals.index, medals['Gold'])
2  plt.xticks(rotation=90)
3  plt.ylabel('# of gold medals');
```

0206.py hosted with ♡ by GitHub view raw



Well, this was easy. It only took us three lines. Now let's what happens if we try to plot (completely unrelated) the climate change data next to it:

```
plt.bar(medals.index, medals['Gold'])
plt.xticks(rotation=90)
plt.ylabel('# of gold medals')
plt.plot(climate_change['date'], climate_change['co2']);
_______________
TypeError: tzinfo argument must be
None or of a tzinfo subclass, not type 'UnitData'
```

0207.py hosted with ♡ by GitHub view raw

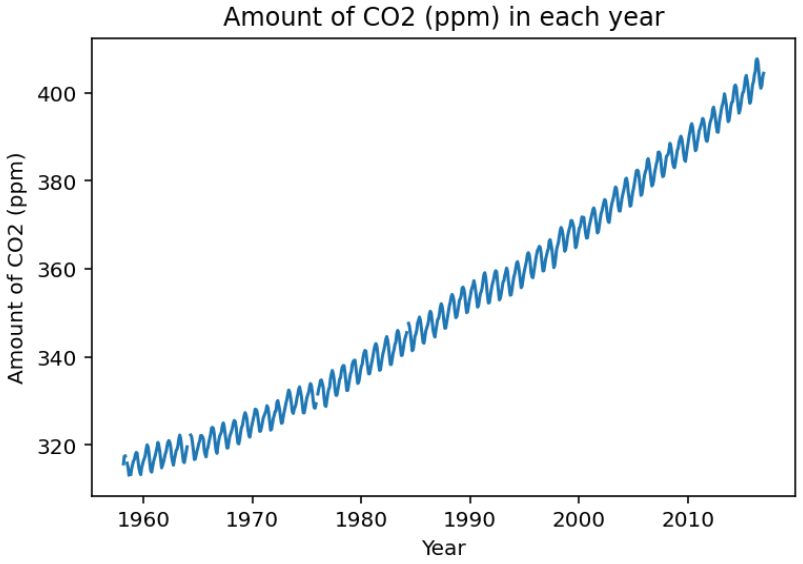
In this case, we get a `TypeError`. `pyplot`, on its own, cannot create new axes or a new figure and intelligently plot the new data. As we get to more complex plotting like this one, we are going to need a more flexible approach.

Mpl has this concept called `current figure`. By default, `pyplot` itself creates a `current figure` axes and plots on it. If for example, we want to focus on that `current figure` and plot extra data on it, as we tried in the last example, `pyplot` moves the `current figure` to a new one immediately after a new plotting command is given.

To avoid this, let's see the approach where we are in full control of each figure and axes:

```
fig, ax = plt.subplots()
ax.plot(climate_change['date'], climate_change['co2'])
ax.set(title='Amount of CO2 (ppm) in each year', xlabel='Year',
       ylabel='Amount of CO2 (ppm)');
```

0208.py hosted with ♡ by GitHub view raw



We specifically point out that we are working on this `fig` object. It means that any plotting command we write will be applied to the axes (`ax`) object that belongs to `fig`. Unless, we define a new figure with `plt.subplots()` command, the current `figure` will be the variable `fig`. This way is very

nice since now we can create as many axes or subplots in a single figure and work with them.

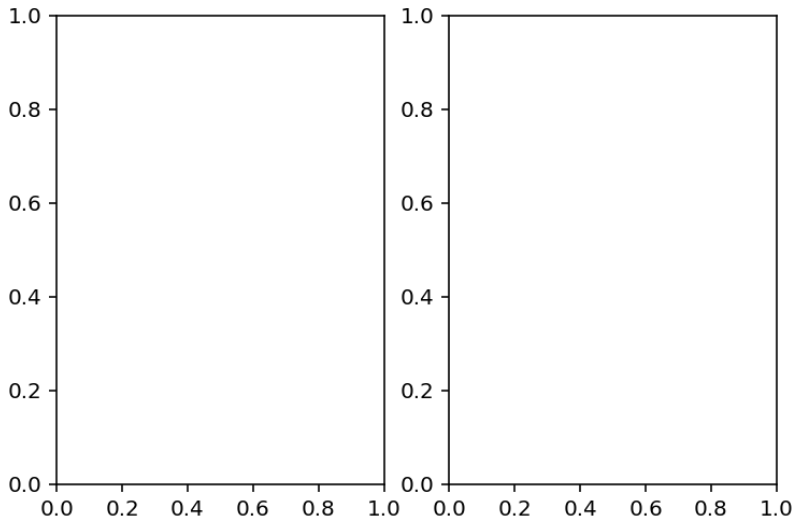
> *From now on, I will be using subplot and axes terms interchangeably as they are synonyms.*

plt.subplots() grid system

We saw an example of creating one subplot. Let's see how can create more in a single figure:

```
fig, ax = plt.subplots(nrows=1, ncols=2)
print(ax)
print(type(ax))

____________________
[<AxesSubplot:> <AxesSubplot:>]
<class 'numpy.ndarray'>
```

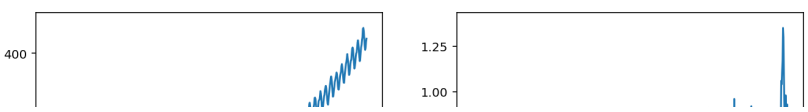
0209.py hosted with ♡ by GitHub view raw

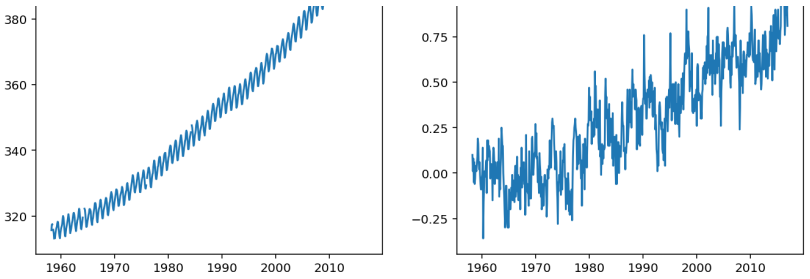


Among other parameters, `.subplots()` have two parameters to specify the grid size. `nrows` and `ncols` are used to point out the number of rows and columns we need respectively. If you paid attention, now our second variable contains not one but two axes. And it is now given as a `numpy.ndarray`. So, we have to unpack or index this array to use our plotting commands:

```
# Unpacking method
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 5))
fig.tight_layout(pad=3)
ax1.plot(climate_change['date'], climate_change['co2'])
ax2.plot(climate_change['date'], climate_change['relative_temp'])

plt.show();
```

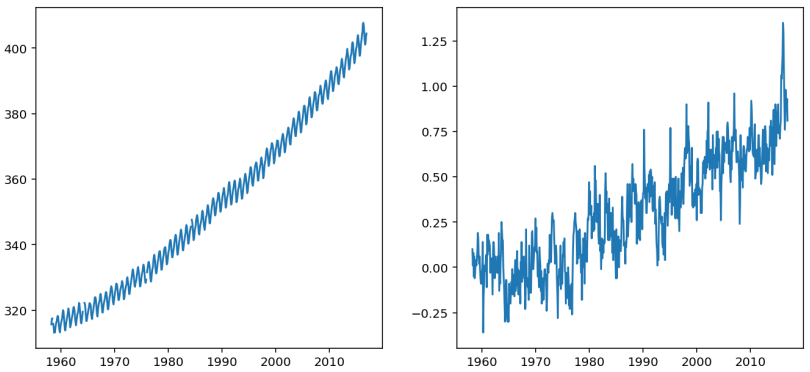
0210.py hosted with ♡ by GitHub view raw






```
# Indexing method
fig, ax = plt.subplots(1, 2, figsize=(10, 5))
fig.tight_layout(pad=3)
ax[0].plot(climate_change['date'], climate_change['co2'])
ax[1].plot(climate_change['date'], climate_change['relative_temp'])

plt.show();
```

0211.py hosted with ♡ by GitHub view raw

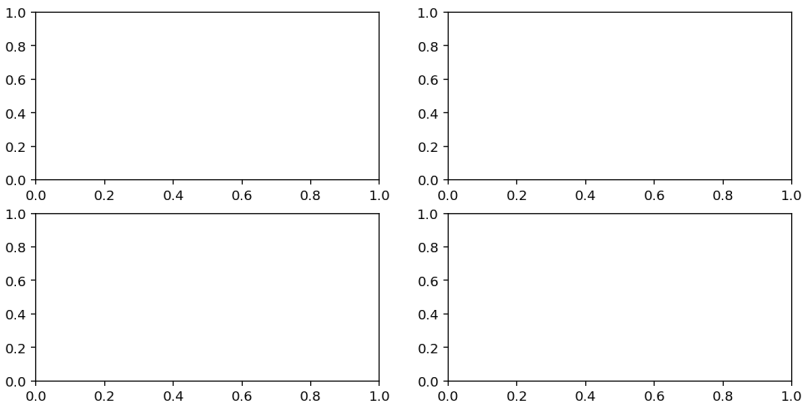


> ***Pro Tip**: Notice the `fig.tight_layout()` function with `padding` set to 3. It will give the subplots a little breathing room.*

The two methods are completely similar and up to you to choose one. Let's see one more example but slightly more difficult:

```
# Unpacking method
fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(2, 2, figsize=(10, 5))
# .....
```

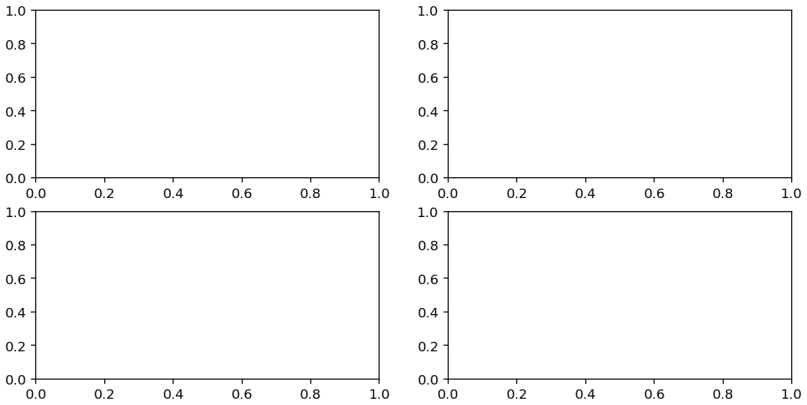
0212.py hosted with ♡ by GitHub view raw




```
# Indexing method
fig, ax = plt.subplots(2, 2, figsize=(10, 5))
# ax[0, 0].plot(___)
# ax[1, 1].plot(___)
```

```
ax.shape

_____
(2, 2)
```

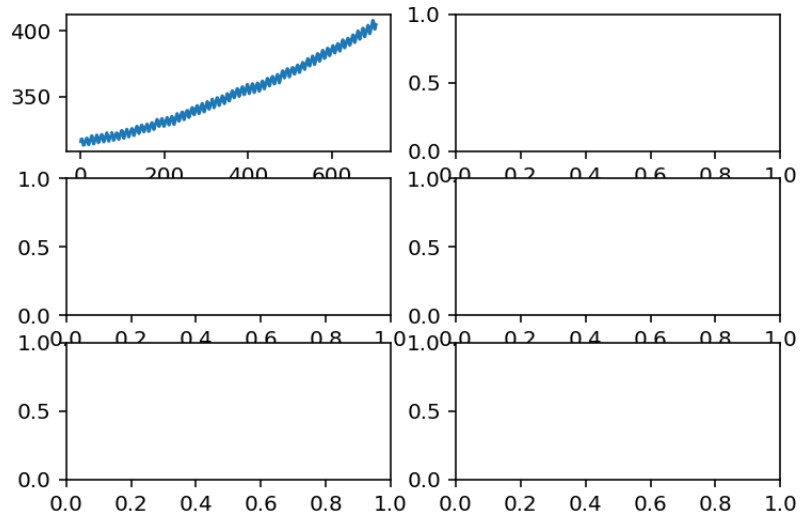
0213.py hosted with ♡ by GitHub view raw



> ***Pro Tip**: Set the `figsize=(width, height)` argument properly. It will make your plots more distinct.*

```
# Additional method if you don't want to use double indexes
fig, ax = plt.subplots(3, 2)
ax.flat[0].plot(climate_change['co2']);
```

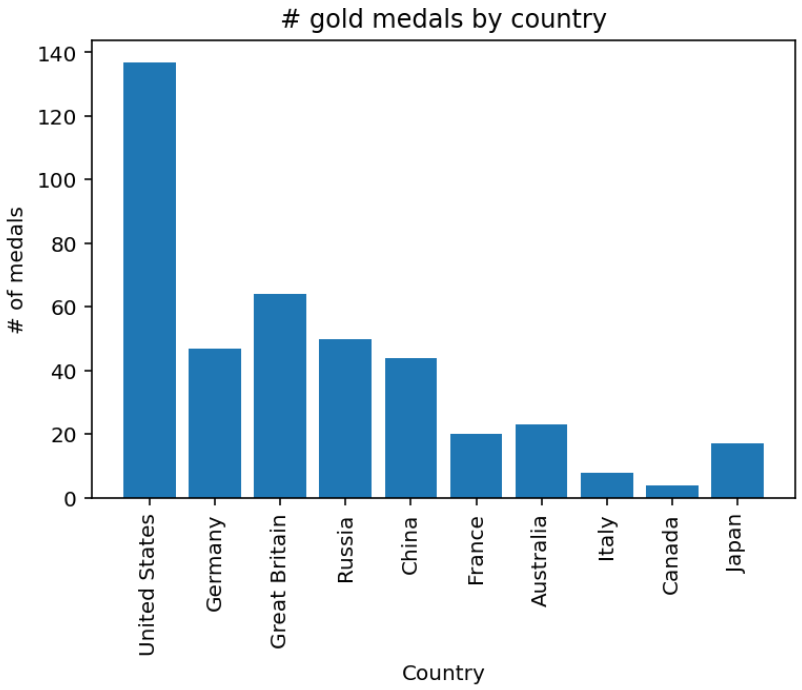
0214.py hosted with ♡ by GitHub view raw



This article is not about plotting in particular, but to give you intuition for figure and axes objects. However, let me briefly walk you through some of the other common methods for the axes object:

```
# Setting title, labels, etc.
fig, ax = plt.subplots()
ax.bar(medals.index, medals['Gold'])
ax.set(title='# gold medals by country', ylabel='# of medals', xlabel='Country')
ax.set_xticklabels(medals.index, rotation=90)

plt.show();
```

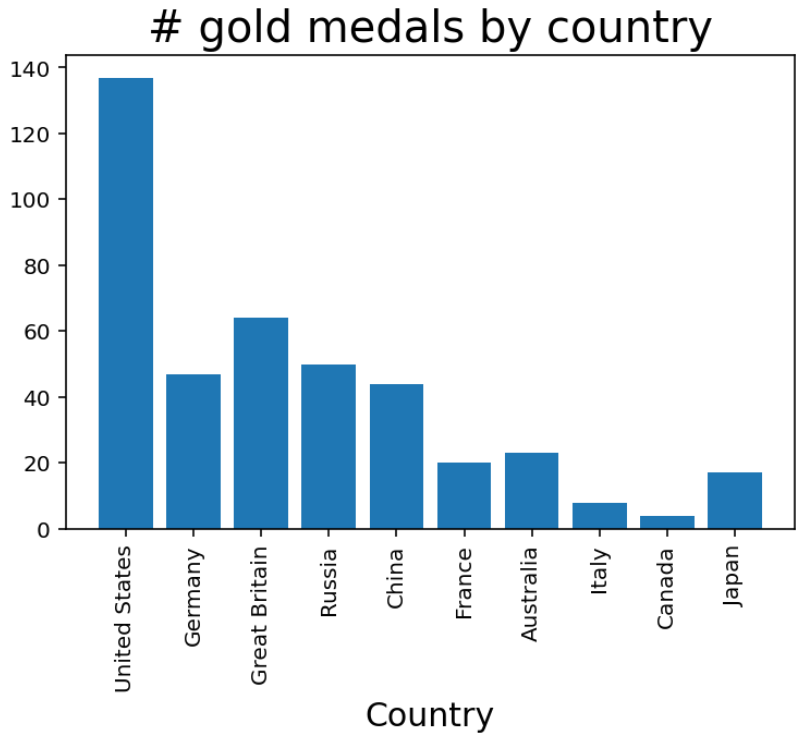
0215.py hosted with ♡ by GitHub view raw



All the methods that are available in `pyplot` API has an equivalent through `ax.set_`. If you use a general, `ax.set()` method, you will avoid repetition when you have multiple subplots. However, if you need to specify additional parameters to specific parts of your plot, use `ax.set_`:

```
1  fig, ax = plt.subplots()
2  ax.bar(medals.index, medals['Gold'])
3  ax.set_xticklabels(medals.index, rotation=90)
4  ax.set_xlabel('Country', fontsize=15)
5  ax.set_title("# gold medals by country", fontsize=20)
6  plt.show();
```

0216.py hosted with ♡ by GitHub view raw

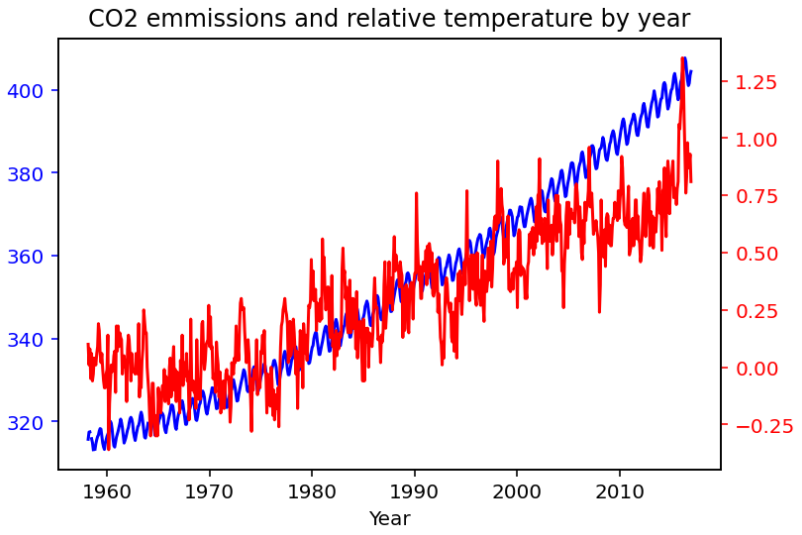


Doubling axis

Sometimes, we want to have a single subplot to have more than one `XAxis` or `YAxis`. While it is not possible with plain `pyplot` interface, it is very easy with top-level `figure` object-oriented API. Let's say we want to plot the `relative_temp` and `co2` columns of `climate_change` in a single plot. We want them to share an `XAxis` since the data is for the same time period:

```
# Create a figure and an axis
fig, ax = plt.subplots()
# Plot CO2 emissions with a blue line
ax.plot(climate_change['date'], climate_change['co2'], color='blue')

# Specify that we will be using a twin x axis
ax2 = ax.twinx()

ax2.plot(climate_change['date'], climate_change['relative_temp'], color='red')

# Change the color of ticks
ax.tick_params('y', colors='blue')     # 'y' because we want to change the y axis
ax2.tick_params('y', colors='red')

ax.set(title='CO2 emmissions and relative temperature by year',
       xlabel='Year') # Does not matter which one you pick, ax or ax2
plt.show();
```

0218.py hosted with ♡ by GitHub view raw



We wanted to have a common `XAxis`, which was `date` column, so we created another axis using `ax.twinx()`. If in some cases you want a common `YAxis`, the equivalent function is `ax.twiny()`.

Sharing a commong axis between subplots

Let's say we wanted to compare the CO2 emissions of the eighties with nineties. Ideally, we would want to plot the eighties on one side and nineties to the other. So, let's subset our data for these two time periods:

```
# Set the date column as index for easy subsetting
climate_change.set_index('date', inplace=True)

# Subset data for two time periods
eighties = climate_change['1980-01-01': '1989-12-31']
```

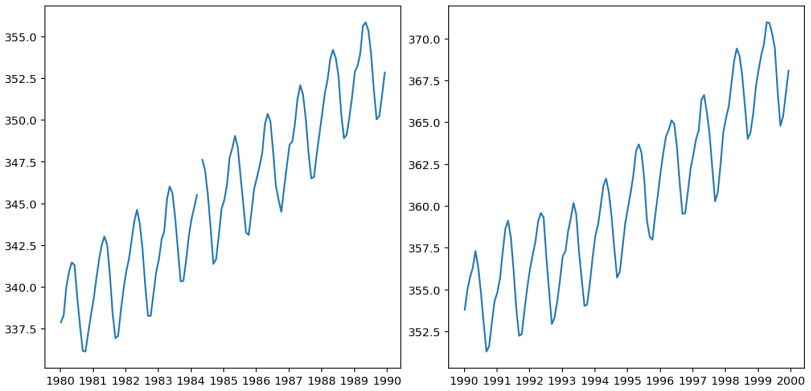
```
6   nineties = climate_change['1990-01-01': '1999-12-31']
```

0219.py hosted with ♡ by GitHub view raw

> ***Pro Tip**: Set the date column as an index for a dataframe if you are working with time-series data. Use `.set_index()` method or use `index_col` parameter in `pd.read_csv()` function. It will make subsetting for time periods much easier.*

```
1   # Create axes and  a figure
2   fig, ax = plt.subplots(1, 2, figsize=(10, 5))
3   fig.tight_layout()
4   # Plot eighties
5   ax[0].plot(eighties.index, eighties['co2'])
6   # Plot nineties
7   ax[1].plot(nineties.index, nineties['co2'])
8
9   plt.show();
```

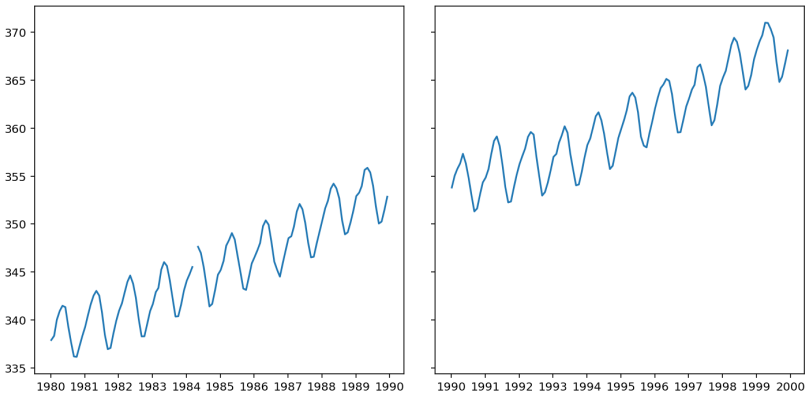
0220.py hosted with ♡ by GitHub view raw



Great, we have the two plots side by side, but if we look closer, our plots are misleading. It looks like there was not much difference in CO2 emmissions throughout two time periods. The reason for this is that the two plots have different `YAxis` ranges. Let's set it right for better insight:

```
1   # Create axes and  a figure
2   fig, ax = plt.subplots(1, 2, figsize=(10, 5), sharey=True)
3   fig.tight_layout()
4   # Plot eighties
5   ax[0].plot(eighties.index, eighties['co2'])
6   # Plot nineties
7   ax[1].plot(nineties.index, nineties['co2'])
8
9   plt.show();
```

0223.py hosted with ♡ by GitHub view raw



Now, it is clear that CO2 emissions continued increasing through time (it is much higher that this right now). We use `sharey=True` to specify that we want the same `YAxis` for all the subplots.

Working with figure object

I think you noticed that once you create a figure object using `.subplots()` command or other methods, pretty much everything happens with axes objects. One common method of `figure` object is `savefig()` method. So, let's get exploring. We will get back to our double-axed plot of CO2. Let's save it to local memory:

```
# Create a figure and an axis
fig, ax = plt.subplots()
# Plot CO2 emissions with a blue line
ax.plot(climate_change.index, climate_change['co2'], color='blue')

# Specify that we will be using a twin x axis
ax2 = ax.twinx()

ax2.plot(climate_change.index, climate_change['relative_temp'], color='red')

# Change the color of ticks
ax.tick_params('y', colors='blue')     # 'y' because we want to change the y axis
ax2.tick_params('y', colors='red')

ax.set(title='CO2 emmissions and relative temperature by year',
       xlabel='Year') # Does not matter which one you pick, ax or ax2
fig.savefig('co2_relative_temp.png');
```

0224.py hosted with ♡ by GitHub view raw

We passed a filename as a string to save. This saves an image with that name in the root directory. Possible image formats to use:

1. `.png` - if you want your figures to be of high quality and do not care about disk space, use `png`. This format allows for lossless compression.
2. `.jpg` - lossy compression. `jpg` images will have less size than `png`s and have lower quality. This format is recommended if you want to upload the images later to a website or any other similar ways.
3. `.svg` - supports animations and image editing. Use this format if you want to modify the figures using editing software like Adobe Illustrator.

Other parameters of `.savefig()` allows for controlling the quality of your figures:

```
# Stands for dots per inch, 300 is very high quality
fig.savefig('sample.png', dpi=300)
# Control image quality with percentage
fig.savefig('sample.jpg', quality=50)
```

0225.py hosted with ♡ by GitHub view raw

Conclusion