Matplotlib Tutorial: 2. Object-oriented Plotting

In the previous section of the tutorial we covered Matlab-style plotting with the `pylab` interface. Here we will cover a slightly more complicated interface offered by matplotlib, which will be much more powerful in the long-run. This object-oriented approach is the recommended API in most data visualization scenarios.

As part of this discussion, we will discuss generating multi-panel plots using the `subplot` and `subplots` commands

As before, we'll start by entering the matplotlib inline mode & doing some future imports:

In [1]:
```
%matplotlib inline
from __future__ import print_function, division
```

Behind the scenes: Figure and Axes

When we called `pylab.plot` previously, there were a few things happening in the background:

- matplotlib created a `Figure` instance, which is an object describing the plot window and its properties, and containing lists of all its elements
- matplotlib created an `Axes` element within the figure. An axes can be thought of as a plotting window, where data can be arranged by `x` and `y` coordinates.

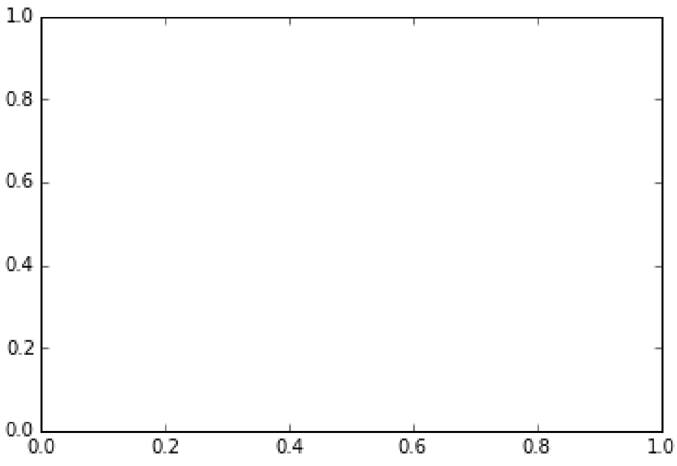
We're going to repeat some of the previous examples now, except we will specify these `Figure` and `Axes` instances explicitly:

First we need to import the `pyplot` interface. The conventional way to do this is as follows:

In [2]:
```
import matplotlib.pyplot as plt
```

Now we will create our figure and axes:

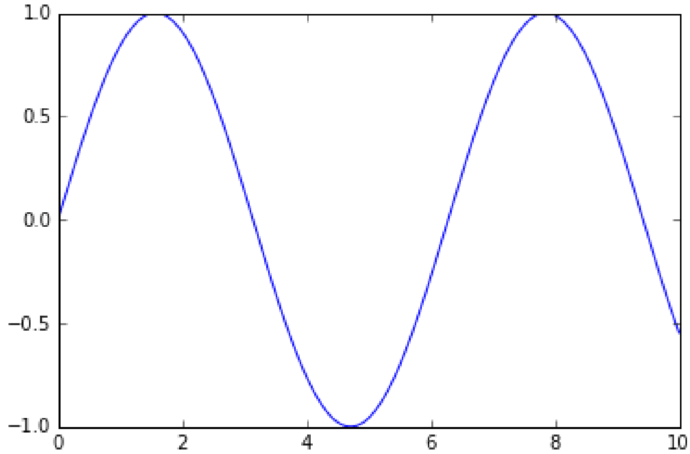
In [3]:
```
fig = plt.figure()  # a new figure window
ax = fig.add_subplot(1, 1, 1)  # specify (nrows, ncols, axnum)
```



As we can see, this creates a blank axes. Now we can call `plot` as we did before, except now we use the `plot` method of `ax`:

In [4]:
```python
import numpy as np
x = np.linspace(0, 10, 1000)
y = np.sin(x)

ax.plot(x, y)
fig  # this is required to re-display the figure
```

Out[4]:

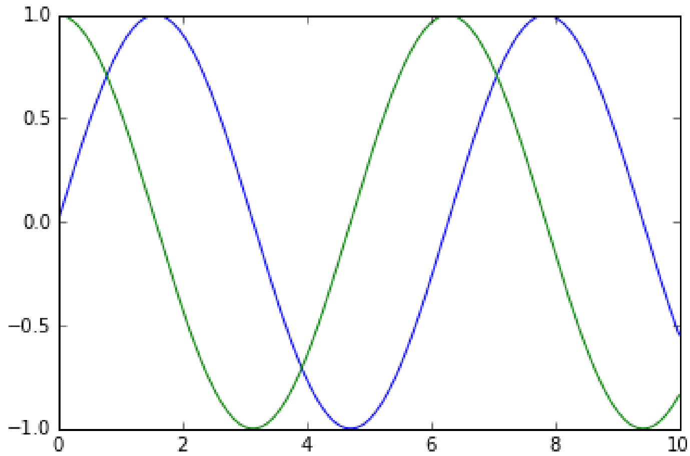


We can already see one advantage to the new interface: the figure remains open between IPython commands! There are ways to make this happen using the `pylab` interface we saw previously, but they're much less clean.

Let's see this explicitly by now over-plotting a cosine:

In [5]:
```python
y2 = np.cos(x)
ax.plot(x, y2)

fig
```

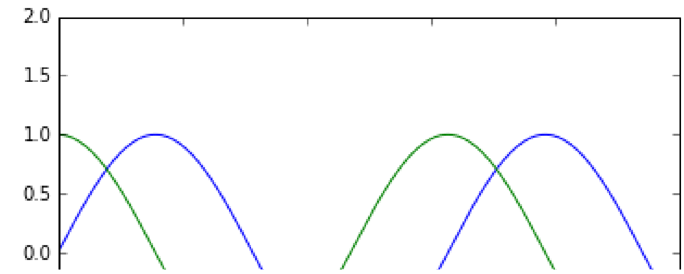
Out[5]:

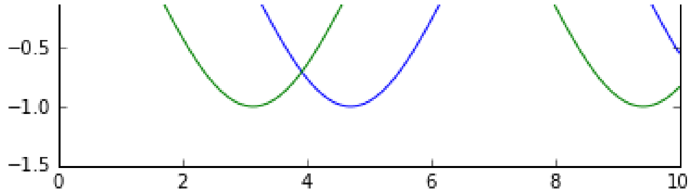


We can set the axes limits using `ax.set_xlim` rather than `pylab.xlim`:

In [6]:
```python
ax.set_ylim(-1.5, 2.0)
fig
```

Out[6]:

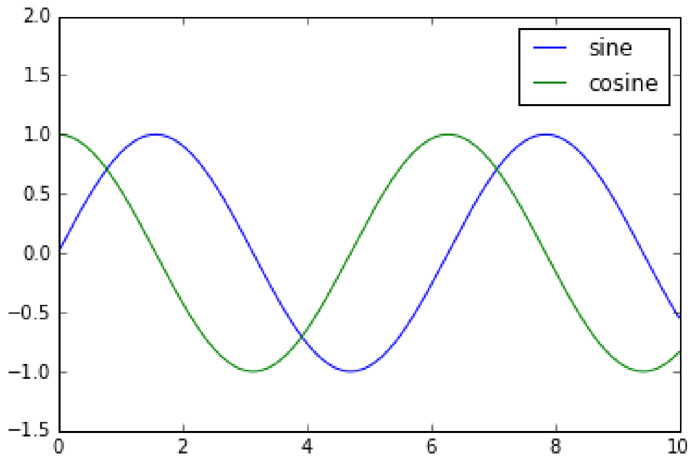




And, as before, we can add a legend:

In [7]:
```
ax.legend(['sine', 'cosine'])
fig
```

Out[7]:

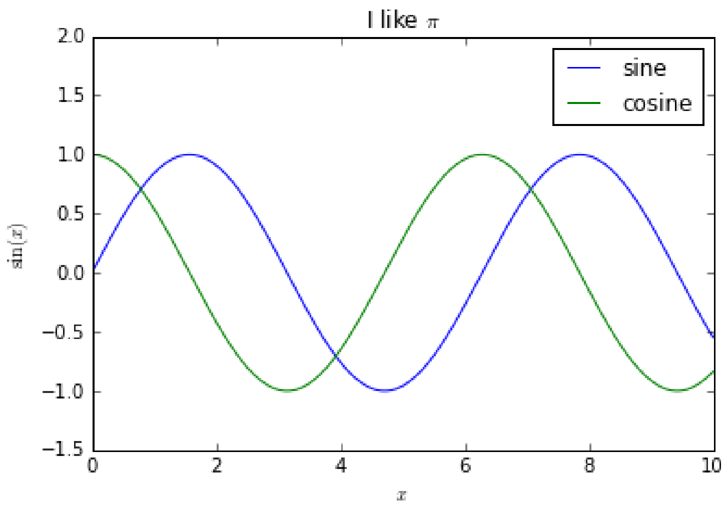


Note that in this case, we didn't label the lines when we first drew them, but instead called `legend()` with a list of labels.

We can similarly annotate the plot using the `set_*` methods

In [8]:
```
ax.set_xlabel("$x$")
ax.set_ylabel("$\sin(x)$")
ax.set_title("I like $\pi$")

fig
```

Out[8]:



Multi-panel Figures: Subplots

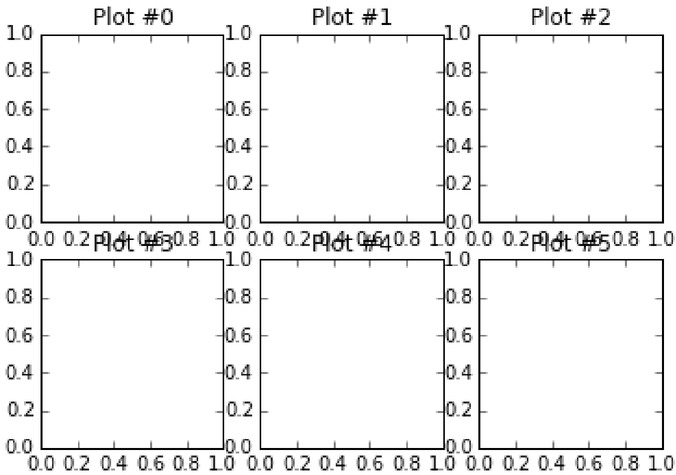
Above we snuck over a new command: `fig.add_subplot`. This command allows us to create a grid of plot panels that can show any sort of plot. The interface is

```
fig.add_subplot(rows, cols, num)
```

In this case the `rows` tells how many rows are in the grid, the `cols` tells how many columns are in the grid, and the `num` tells the number of the subplot to create: counting from left to right, top to bottom and indexed starting at 1. (The 1-based counting is an unfortunate hold-over from the command's matlab roots).

For example:

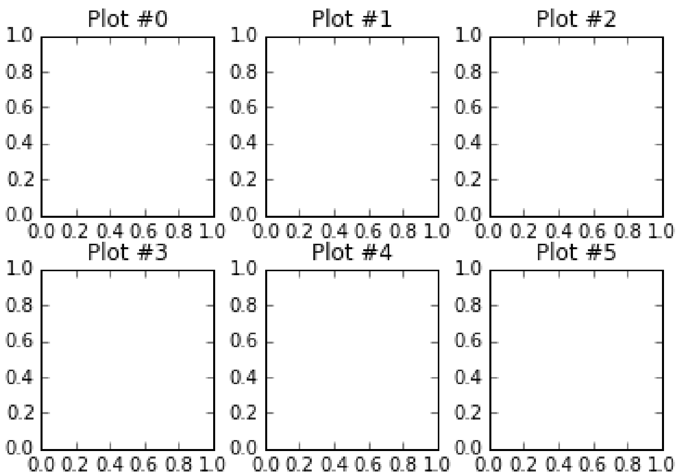
In [9]:
```
fig = plt.figure()
for i in range(6):
    ax = fig.add_subplot(2, 3, i + 1)
    ax.set_title("Plot #%i" % i)
```



We immediately see a problem: our labels are overlapping. There are a few ways to deal with this, but one is to use the `subplots_adjust` command. We'll adjust the width between each plot (`wspace`), and the height between each plot (`hspace`) as a fraction of the size of each plot:

In [10]:
```
fig.subplots_adjust(wspace=0.3, hspace=0.3)
fig
```

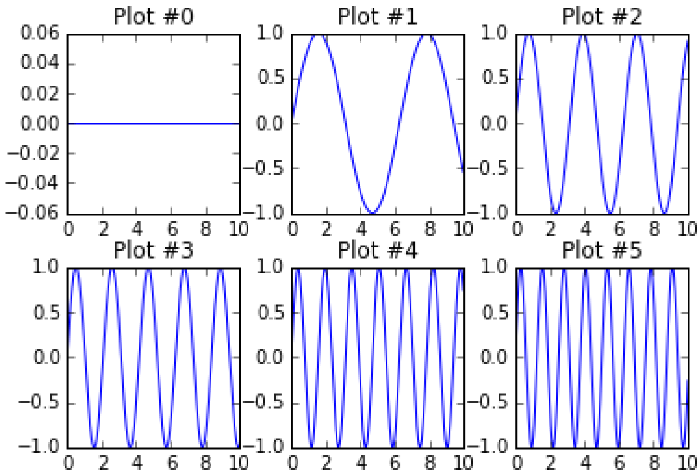
Out[10]:



We can now plot anything we desire in the plots. For example:

In [11]:
```
x = np.linspace(0, 10, 1000)
for i in range(6):
    fig.axes[i].plot(x, np.sin(i * x))

fig
```

Out[11]:

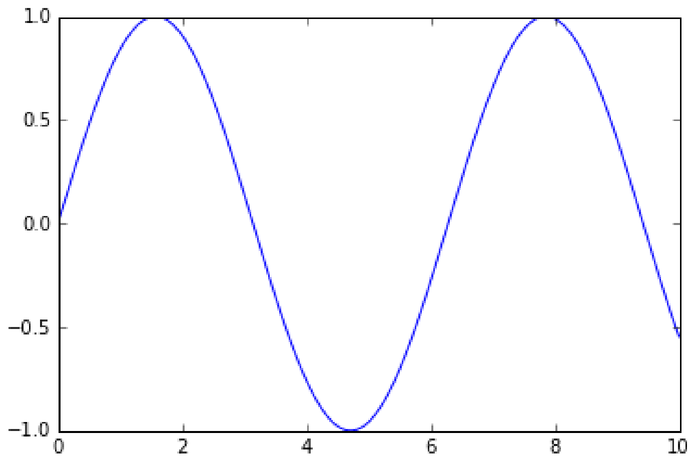


Easy Pythonic Subplotting: plt.subplots()

Matplotlib 1.0 (June 2010) added an even nicer subplot interface, `plt.subplots`. It automates the creation of the figure and subplots.

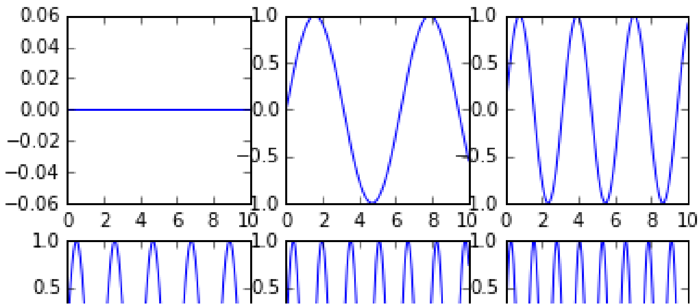
First we'll create just a single figure and axes:

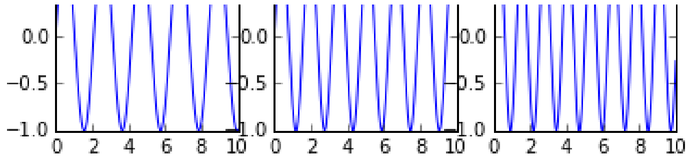
In [12]:
```
# create just a single figure and axes
fig, ax = plt.subplots()

ax.plot(x, np.sin(x));
```



We can also create multiple subplots and plot the same data as above:

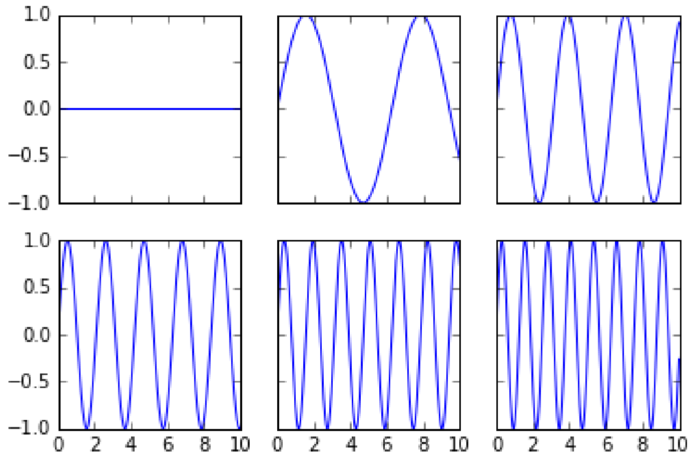
In [13]:
```
fig, ax = plt.subplots(2, 3)  # 2x3 grid

for i in range(2):
    for j in range(3):
        ax[i, j].plot(x, np.sin((3 * i + j) * x))
```





In this case, we know that all the plots have the same `x` range and the same `y` range, and it would be nice if we could take away all the unnecessary labels. This can be done by specifying `sharex` or `sharey`:

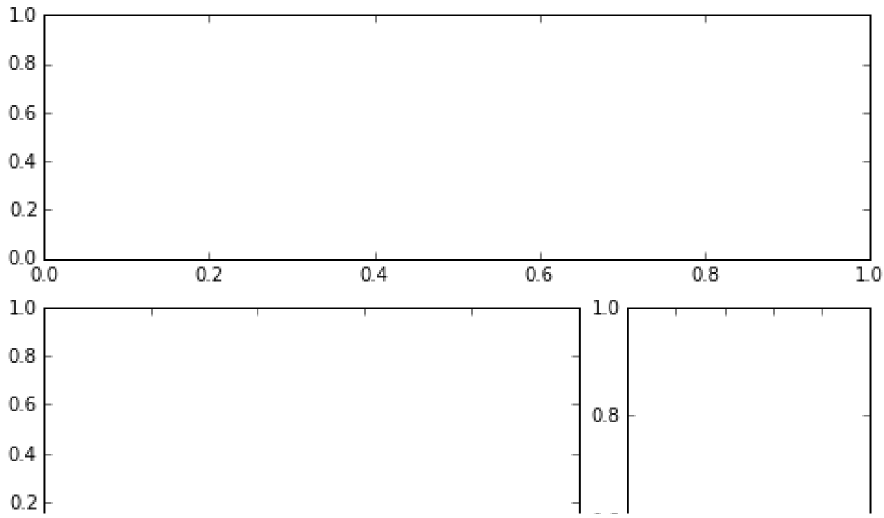
In [14]:
```
fig, ax = plt.subplots(2, 3, sharex=True, sharey=True)  # 2x3 grid

for i in range(2):
    for j in range(3):
        ax[i, j].plot(x, np.sin((3 * i + j) * x))
```

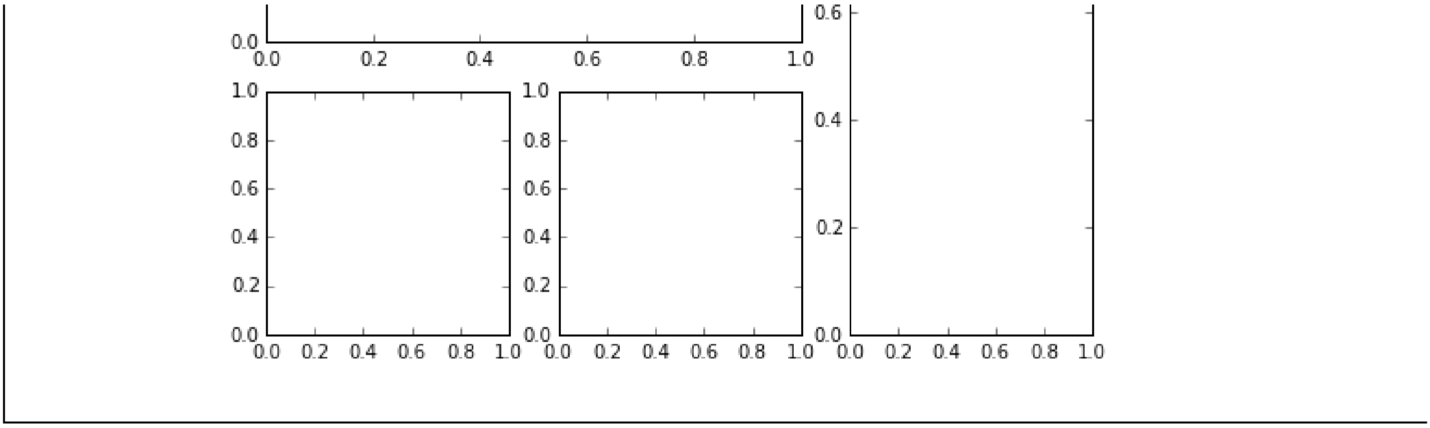


More Complicated Gridding: GridSpec

Sometimes more complicated gridding and subplotting is desired. Matplotlib 1.0 also added the `gridspec` module, which offers a lot of flexibility in creating multiple axes. For example:

In [15]:
```
fig = plt.figure(figsize=(8, 8))
gs = plt.GridSpec(3, 3)
ax1 = fig.add_subplot(gs[0, :])
ax2 = fig.add_subplot(gs[1, :2])
ax3 = fig.add_subplot(gs[1:, 2])
ax4 = fig.add_subplot(gs[2, 0])
ax5 = fig.add_subplot(gs[2, 1])
```




0.0
0.0 0.2 0.4 0.6 0.8 1.0
1.0 0.8 0.6 0.4 0.2 0.0
0.0 0.2 0.4 0.6 0.8 1.0
1.0 0.8 0.6 0.4 0.2 0.0
0.0 0.2 0.4 0.6 0.8 1.0
0.6 0.4 0.2 0.0
0.0 0.2 0.4 0.6 0.8 1.0