Matplotlib

A tutorial

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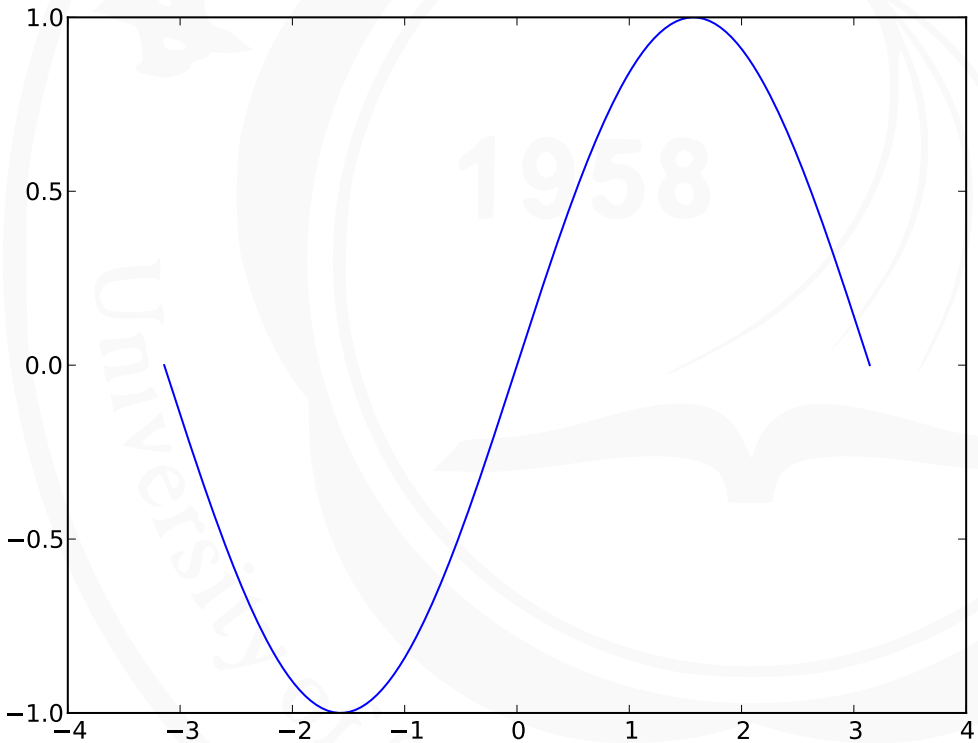
Curve plot

Let's plot a curve

```
import math
import matplotlib.pyplot as plt


# Generate a sinusoid
nbSamples = 256
xRange = (-math.pi, math.pi)

x, y = [], []
for n in xrange(nbSamples):
  k = (n + 0.5) / nbSamples
  x.append(xRange[0] + (xRange[1] - xRange[0]) * k)
  y.append(math.sin(x[-1]))

# Plot the sinusoid
plt.plot(x, y)
plt.show()
```

Curve plot

This will show you something like this



numpy

matplotlib can work with *numpy* arrays

```
import math
import numpy
import matplotlib.pyplot as plt


# Generate a sinusoid
nbSamples = 256
xRange = (-math.pi, math.pi)

x, y = numpy.zeros(nbSamples), numpy.zeros(nbSamples)
for n in xrange(nbSamples):
  k = (n + 0.5) / nbSamples
  x[n] = xRange[0] + (xRange[1] - xRange[0]) * k
  y[n] = math.sin(x[n])

# Plot the sinusoid
plt.plot(x, y)
plt.show()
```

numpy provides a lot of function and is efficient

numpy

- *zeros* build arrays filled of 0
- *linspace* build arrays filled with an arithmetic sequence

```
import math
import numpy
import matplotlib.pyplot as plt


# Generate a sinusoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.zeros(nbSamples)
for n in xrange(nbSamples):
  y[n] = math.sin(x[n])

# Plot the sinusoid
plt.plot(x, y)
plt.show()
```

numpy

numpy functions can work on entire arrays

```
import math
import numpy
import matplotlib.pyplot as plt


# Generate a sinusoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.sin(x)

# Plot the sinusoid
plt.plot(x, y)
plt.show()
```

PDF output

Exporting to a PDF file is just one change

```
import math
import numpy
import matplotlib.pyplot as plt


# Generate a sinusoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.sin(x)

# Plot the sinusoid
plt.plot(x, y)
plt.savefig('sin-plot.pdf', transparent=True)
```

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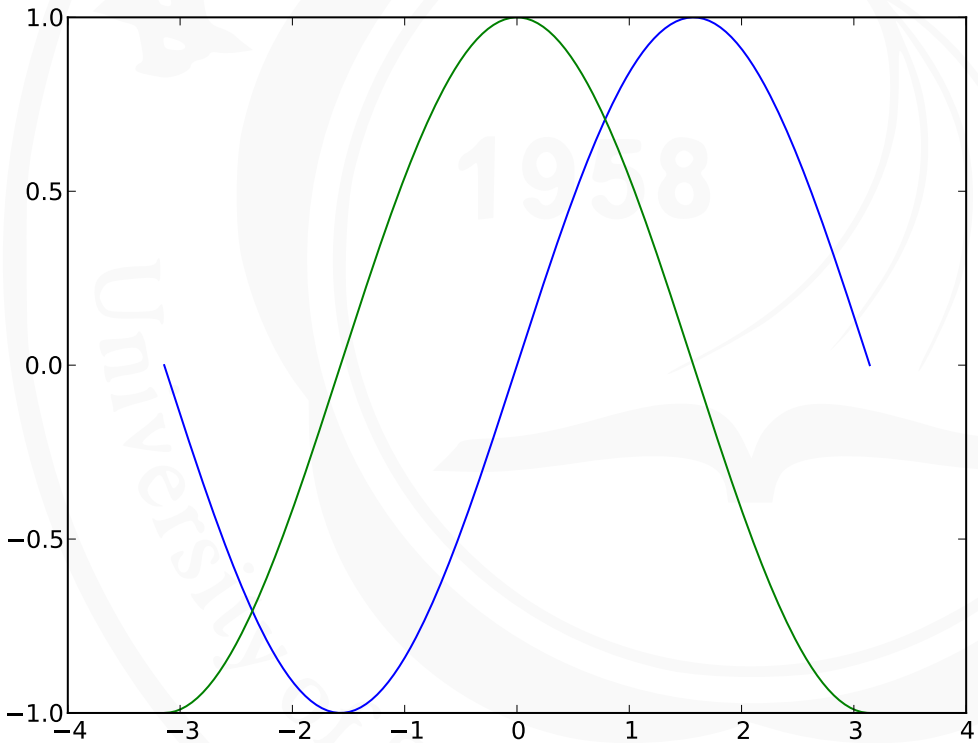
Multiple curves

It's often convenient to show several curves in one figure

```
import math
import numpy
import matplotlib.pyplot as plt


# Generate a sinusoid and a cosinoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.sin(x)
z = numpy.cos(x)

# Plot the curves
plt.plot(x, y)
plt.plot(x, z)
plt.show()
```

Multiple curves

It's often convenient to show several curves in one figure



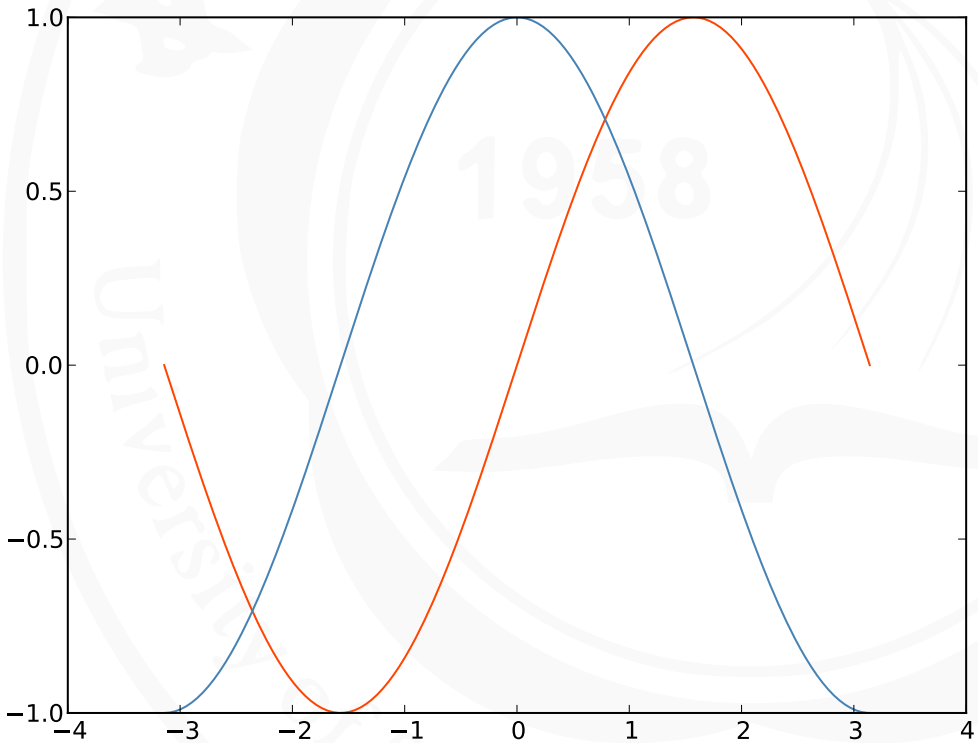
Custom colors

Changing colors can help to make nice documents

```
import math
import numpy
import matplotlib.pyplot as plt


# Generate a sinusoid and a cosinoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.sin(x)
z = numpy.cos(x)

# Plot the curves
plt.plot(x, y, c='#FF4500')
plt.plot(x, z, c='#4682B4')
plt.show()
```

Custom colors

Changing colors can help to make nice documents



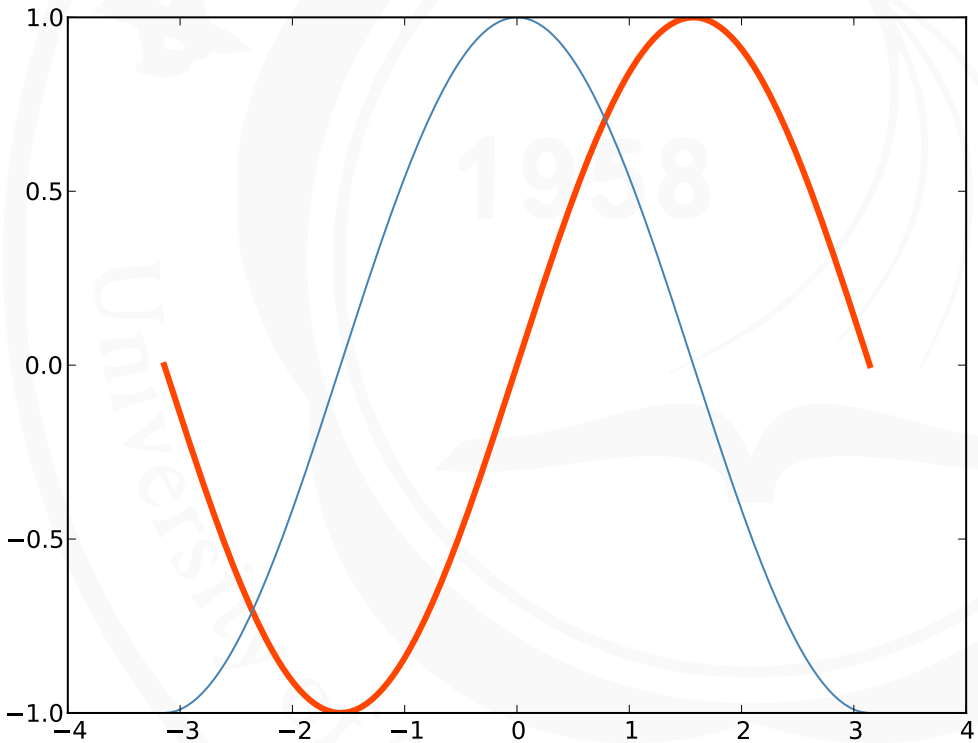
Line thickness

Line thickness can be changed as well

```
import math
import numpy
import matplotlib.pyplot as plt


# Generate a sinusoid and a cosinoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.sin(x)
z = numpy.cos(x)

# Plot the curves
plt.plot(x, y, linewidth=3, c='#FF4500')
plt.plot(x, z, c='#4682B4')
plt.show()
```

Line thickness

Line thickness can be changed as well



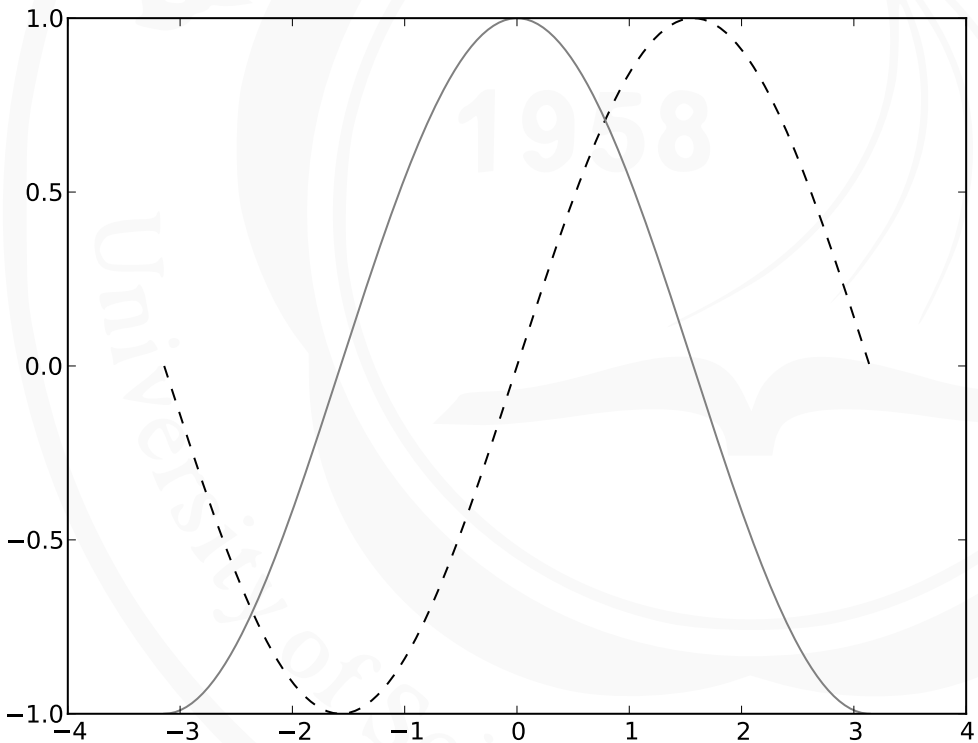
Line patterns

For printed document, colors can be replaced by line patterns

```
import math
import numpy
import matplotlib.pyplot as plt

# Linestyles can be '-', '--', '-.', ':'

# Generate a sinusoid and a cosinoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.sin(x)
z = numpy.cos(x)

# Plot the curves
plt.plot(x, y, linestyle='--', c='#000000')
plt.plot(x, z, c='#808080')
plt.show()
```

Line patterns

For printed document, colors can be replaced by line patterns



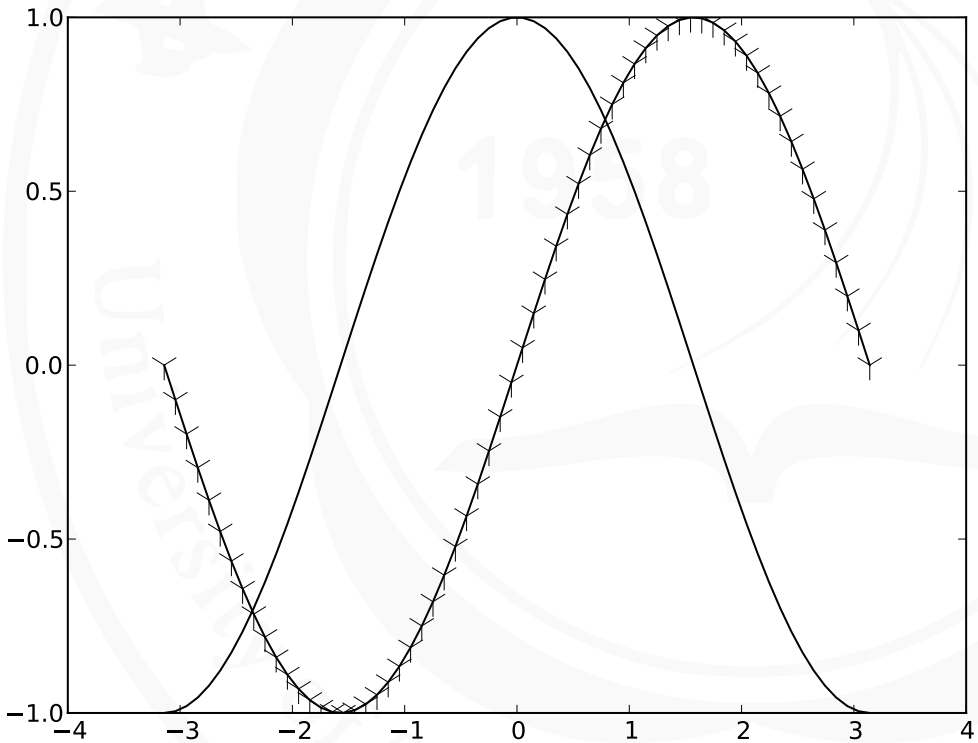
Markers

It sometime relevant to show the data points

```
import math
import numpy
import matplotlib.pyplot as plt

# Markers can be '.', ',', 'o', '1' and more

# Generate a sinusoid and a cosinoid
x = numpy.linspace(-math.pi, math.pi, num=64)
y = numpy.sin(x)
z = numpy.cos(x)

# Plot the curves
plt.plot(x, y, marker='1', markersize=15, c='#000000')
plt.plot(x, z, c='#000000')
plt.show()
```

Markers

It sometime relevant to show the data points



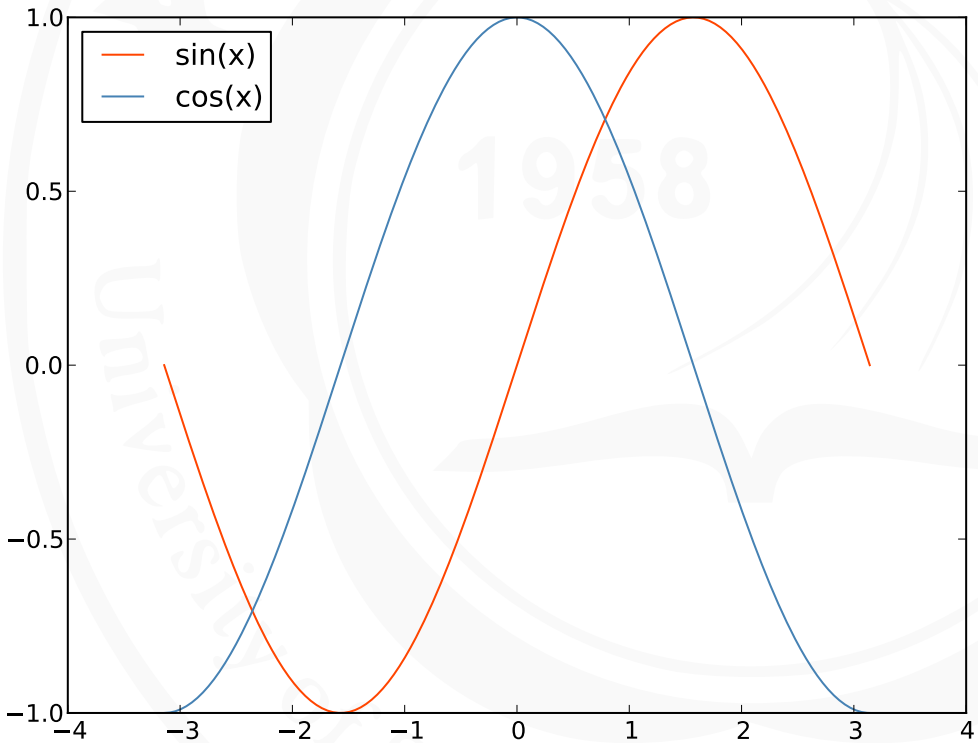
Legend

A legend can help to make self–explanatory figures

```
import math
import numpy
import matplotlib.pyplot as plt

# legend location can be 'best', 'center', 'left', 'right', etc.

# Generate a sinusoid and a cosinoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.sin(x)
z = numpy.cos(x)

# Plot the curves
plt.plot(x, y, c='#FF4500', label='sin(x)')
plt.plot(x, z, c='#4682B4', label='cos(x)')
plt.legend(loc='best')
plt.show()
```

Legend

A legend can help to make self–explanatory figures



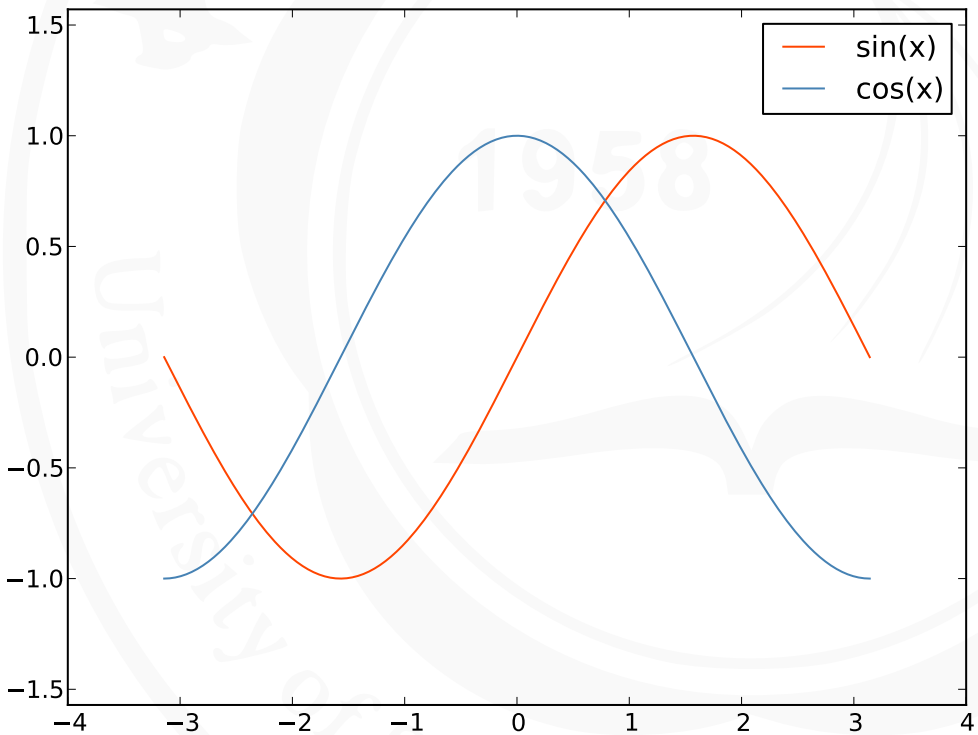
Custom axis scale

Changing the axis scale can improve readability

```
import math
import numpy
import matplotlib.pyplot as plt

# legend location can be 'best', 'center', 'left', 'right', etc.

# Generate a sinusoid and a cosinoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.sin(x)
z = numpy.cos(x)

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111)

axis.set_ylim(-0.5 * math.pi, 0.5 * math.pi)

# Plot the curves
plt.plot(x, y, c='#FF4500', label='sin(x)')
plt.plot(x, z, c='#4682B4', label='cos(x)')
plt.legend(loc='best')
plt.show()
```

Custom axis scale

Changing the axis scale can improve readability



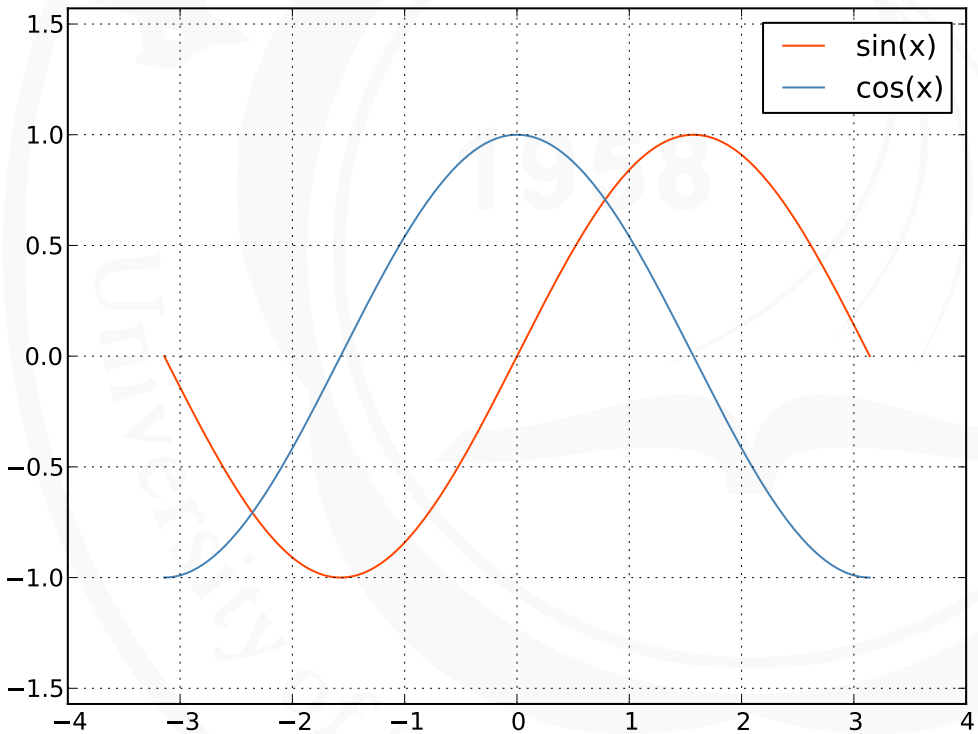
Grid

Same goes for a grid, can be helpful

```
import math
import numpy
import matplotlib.pyplot as plt

# legend location can be 'best', 'center', 'left', 'right', etc.

# Generate a sinusoid and a cosinoid
x = numpy.linspace(-math.pi, math.pi, num=256)
y = numpy.sin(x)
z = numpy.cos(x)

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111)

axis.set_ylim(-0.5 * math.pi, 0.5 * math.pi)
axis.grid(True)

# Plot the curves
plt.plot(x, y, c='#FF4500', label='sin(x)')
plt.plot(x, z, c='#4682B4', label='cos(x)')
plt.legend(loc='best')
plt.show()
```

Grid

Same goes for a grid, can be helpful



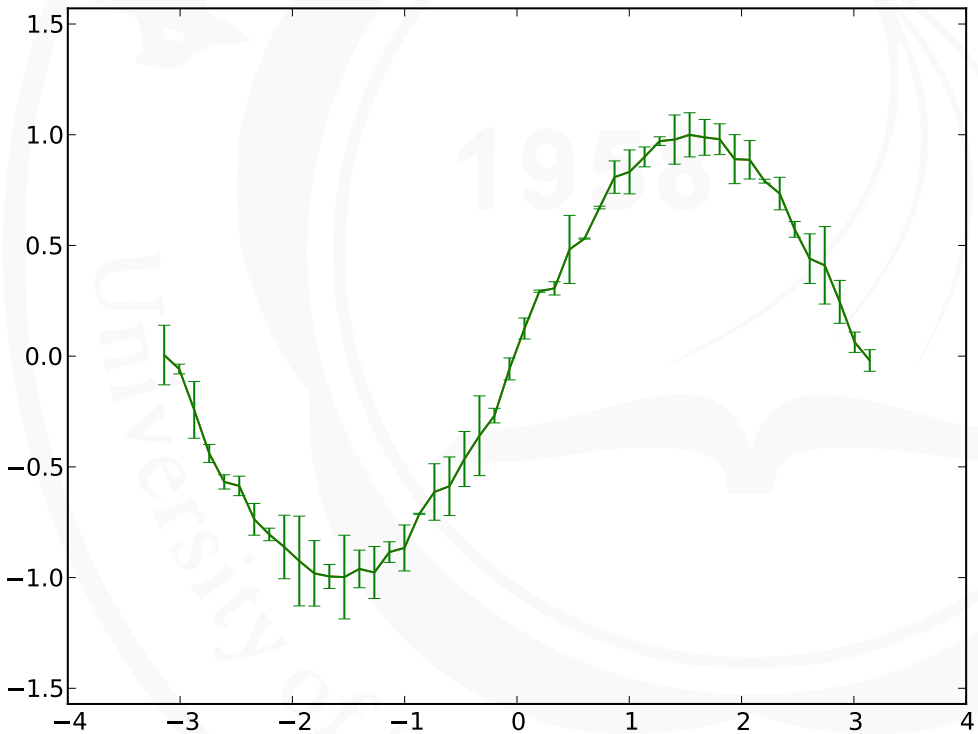
Error bars

Your data might come with a known measure error

```
import math
import numpy
import numpy.random
import matplotlib.pyplot as plt

# Generate a noisy sinusoid
x = numpy.linspace(-math.pi, math.pi, num=48)
y = numpy.sin(x + 0.05 * numpy.random.standard_normal(len(x)))
yerror = 0.1 * numpy.random.standard_normal(len(x))

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111)

axis.set_ylim(-0.5 * math.pi, 0.5 * math.pi)

# Plot the curves
plt.plot(x, y, c='#FF4500')
plt.errorbar(x, y, yerr=yerror)
plt.show()
```

Error bars

Your data might come with a known measure error



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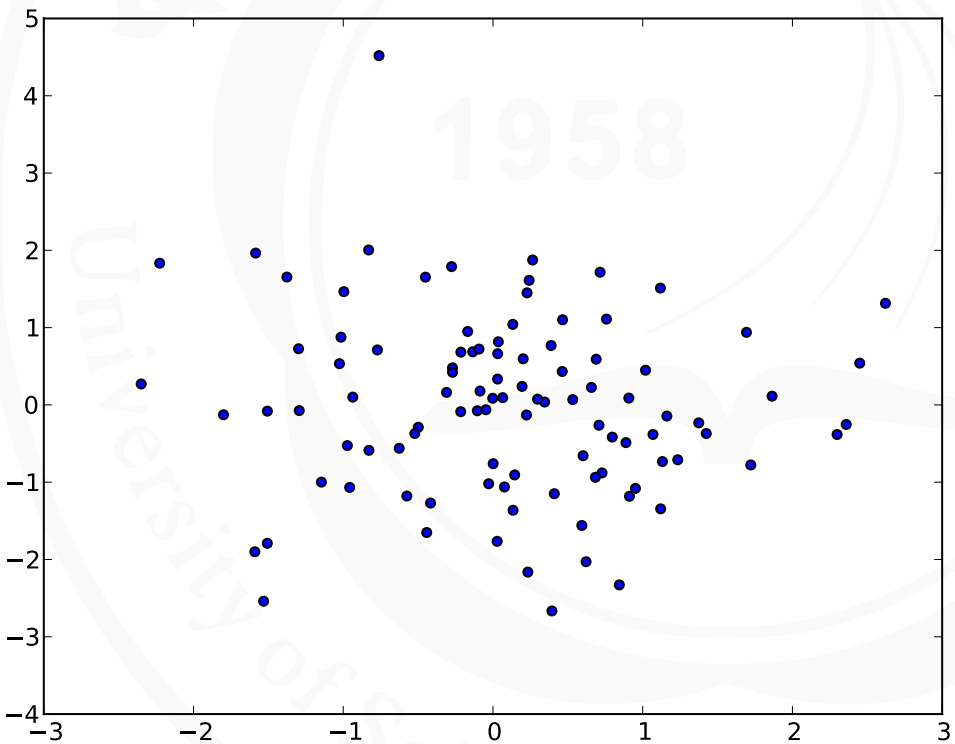
Scatter plot

A scatter plot just shows one point for each dataset entry

```
import numpy
import numpy.random
import matplotlib.pyplot as plt

# Generate a 2d normal distribution
nbPoints = 100
x = numpy.random.standard_normal(nbPoints)
y = numpy.random.standard_normal(nbPoints)

# Plot the points
plt.scatter(x, y)
plt.show()
```

Scatter plot

A scatter plot just shows one point for each dataset entry



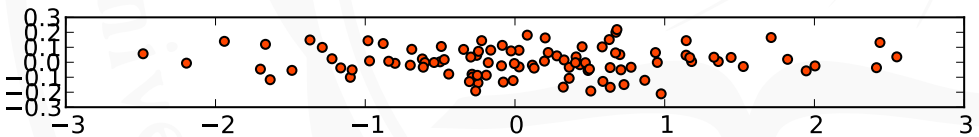
Aspect ratio

If can be very important to have the same scale on both axis

```
import numpy
import numpy.random
import matplotlib.pyplot as plt

# Generate a 2d normal distribution
nbPoints = 100
x = numpy.random.standard_normal(nbPoints)
y = 0.1 * numpy.random.standard_normal(nbPoints)

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111, aspect='equal')

# Plot the points
plt.scatter(x, y, c='#FF4500')
plt.show()
```

Aspect ratio

If can be very important to have the same scale on both axis



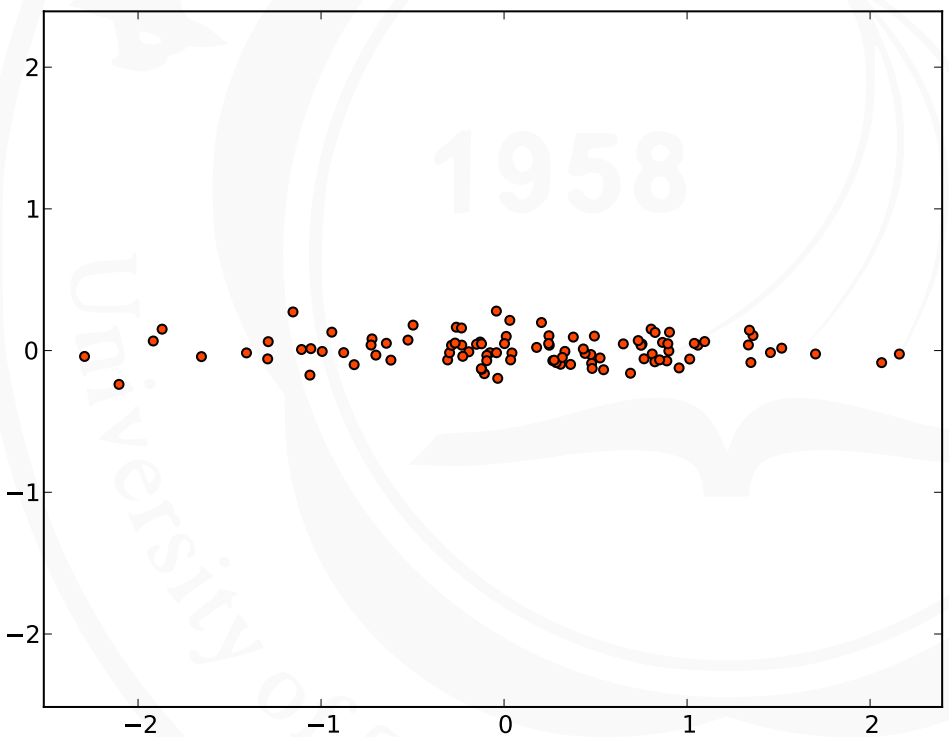
Aspect ratio

Alternative way to keep the same scale on both axis

```
import numpy
import numpy.random
import matplotlib.pyplot as plt

# Generate a 2d normal distribution
nbPoints = 100
x = numpy.random.standard_normal(nbPoints)
y = 0.1 * numpy.random.standard_normal(nbPoints)

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111)

cmin, cmax = min(min(x), min(y)), max(max(x), max(y))
cmin -= 0.05 * (cmax - cmin)
cmax += 0.05 * (cmax - cmin)

axis.set_xlim(cmin, cmax)
axis.set_ylim(cmin, cmax)

# Plot the points
plt.scatter(x, y, c='#FF4500')
plt.show()
```

Aspect ratio

Alternative way to keep the same scale on both axis



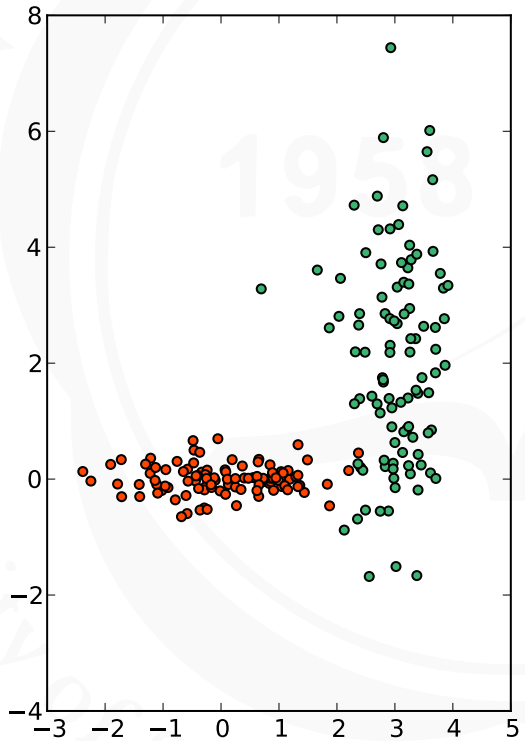
Multiple scatter plots

As for curve, you can show 2 datasets on one figure

```
import numpy
import numpy.random
import matplotlib.pyplot as plt

colors = ('#FF4500', '#3CB371', '#4682B4', '#DB7093', '#FFD700')

# Generate a 2d normal distribution
nbPoints = 100

x, y = [], []

x += [numpy.random.standard_normal(nbPoints)]
y += [0.25 * numpy.random.standard_normal(nbPoints)]

x += [0.5 * numpy.random.standard_normal(nbPoints) + 3.0]
y += [2 * numpy.random.standard_normal(nbPoints) + 2.0]

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111, aspect='equal')

# Plot the points
for i in xrange(len(x)):
  plt.scatter(x[i], y[i], c=colors[i % len(colors)])

plt.show()
```

Multiple scatter plots

As for curve, you can show 2 datasets on one figure



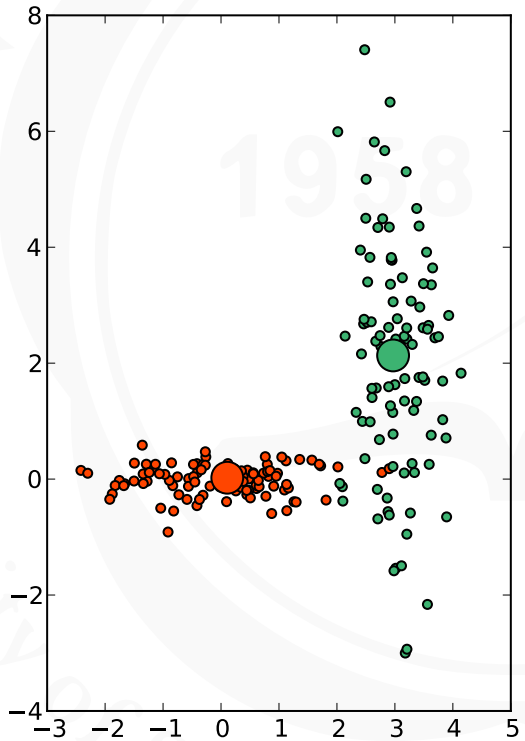
Showing centers

It can help to see the centers or the median points

```
import numpy
import numpy.random
import matplotlib.pyplot as plt

colors = ('#FF4500', '#3CB371', '#4682B4', '#DB7093', '#FFD700')

# Generate a 2d normal distribution
nbPoints = 100

x, y = [], []

x += [numpy.random.standard_normal(nbPoints)]
y += [0.25 * numpy.random.standard_normal(nbPoints)]

x += [0.5 * numpy.random.standard_normal(nbPoints) + 3.0]
y += [2 * numpy.random.standard_normal(nbPoints) + 2.0]

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111, aspect='equal')

# Plot the points
for i in xrange(len(x)):
  col = colors[i % len(colors)]
  plt.scatter(x[i], y[i], c=col)
  plt.scatter([numpy.median(x[i])], [numpy.median(y[i])], c=col, s=250)

plt.show()
```

Showing centers

It can help to see the centers or the median points



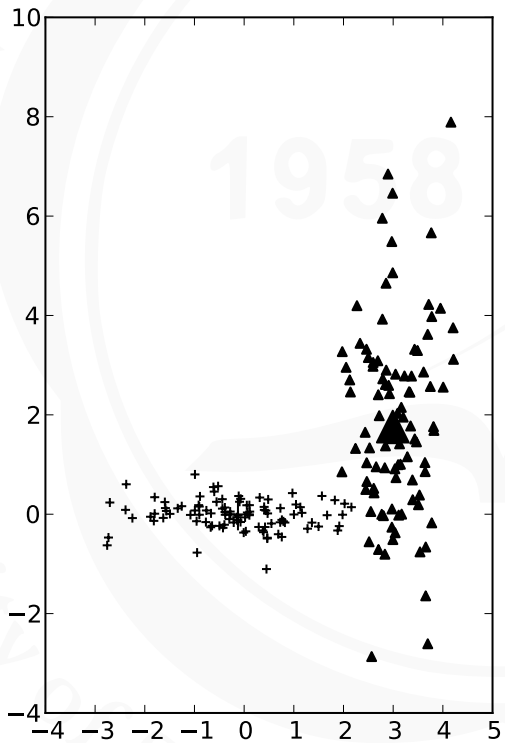
Marker styles

You can use different markers styles

```
import numpy
import numpy.random
import matplotlib.pyplot as plt

markers = ('+', '^', '.')

# Generate a 2d normal distribution
nbPoints = 100

x, y = [], []

x += [numpy.random.standard_normal(nbPoints)]
y += [0.25 * numpy.random.standard_normal(nbPoints)]

x += [0.5 * numpy.random.standard_normal(nbPoints) + 3.0]
y += [2 * numpy.random.standard_normal(nbPoints) + 2.0]

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111, aspect='equal')

# Plot the points
for i in xrange(len(x)):
  m = markers[i % len(markers)]
   plt.scatter(x[i], y[i], marker=m, c='#000000')
   plt.scatter([numpy.median(x[i])], [numpy.median(y[i])], marker=m, s=250, c='#000000

plt.show()
```

Marker styles

You can use different markers styles



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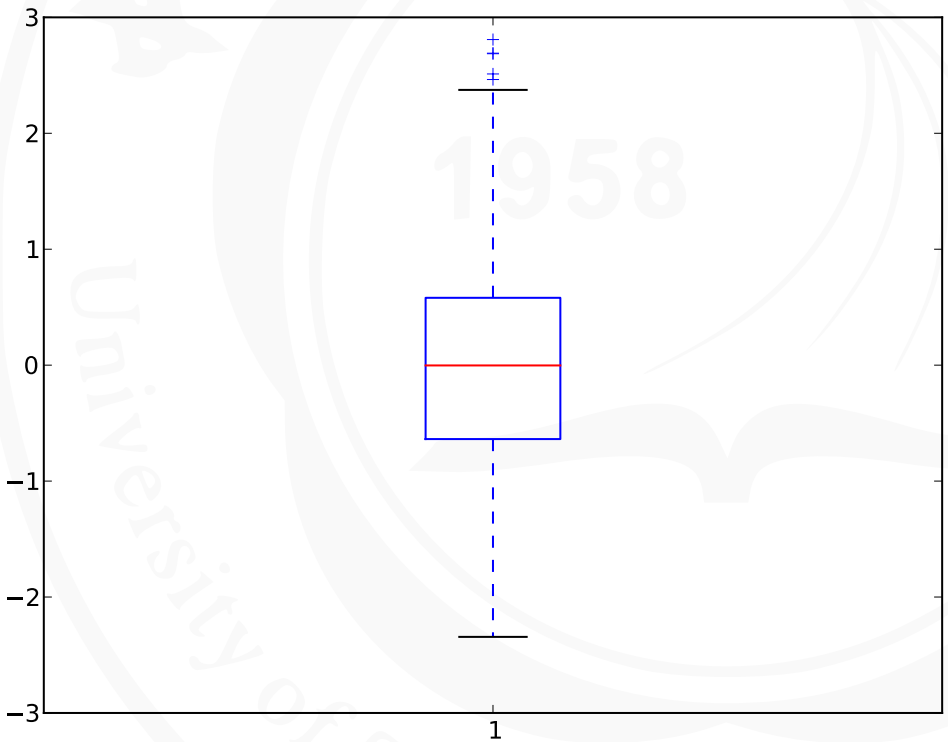
Boxplots

Let's do a simple boxplot

```
import numpy
import numpy.random
import matplotlib.pyplot as plt


# Generate normal distribution data
x = numpy.random.standard_normal(256)

# Show a boxplot of the data
plt.boxplot(x)
plt.show()
```

Boxplots

Let's do a simple boxplot



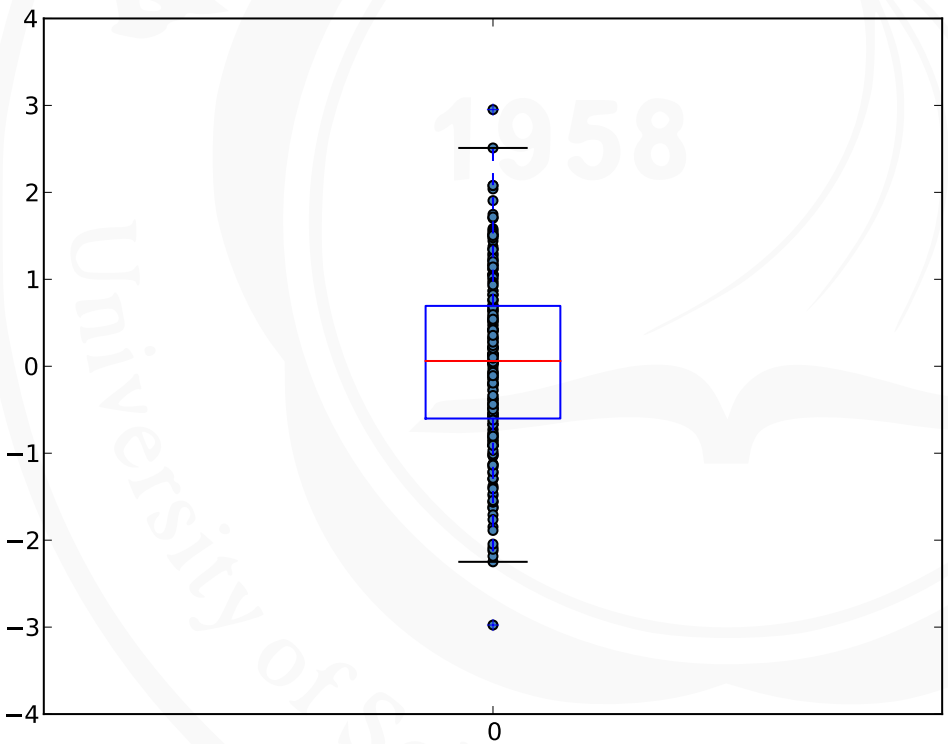
Boxplots

You might want to show the original data in the same time

```
import numpy
import numpy.random
import matplotlib.pyplot as plt


# Generate normal distribution data
x = numpy.random.standard_normal(256)

# Show a boxplot of the data
plt.scatter([0] * len(x), x, c='#4682B4')
plt.boxplot(x, positions=[0])
plt.show()
```

Boxplots

You might want to show the original data in the same time



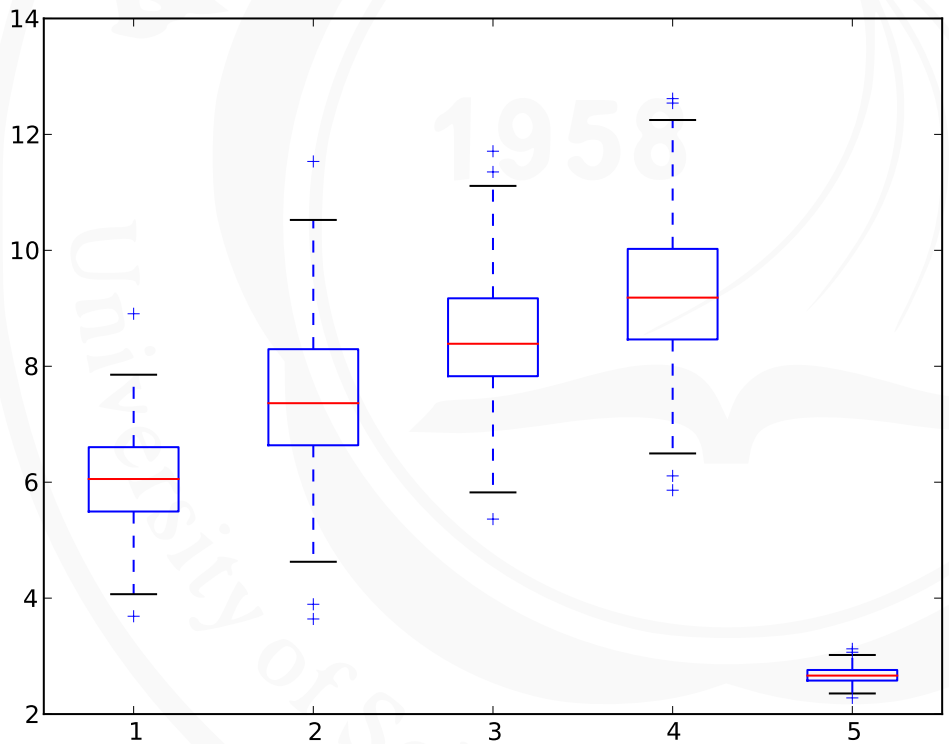
Multiple boxplots

Boxplots are often used to show side by side various distributions

```
import numpy
import numpy.random
import matplotlib.pyplot as plt


# Generate normal distribution data
data = []
for i in xrange(5):
  mu = 10 * numpy.random.random_sample()
  sigma = 2 * numpy.random.random_sample() + 0.1
  data.append(numpy.random.normal(mu, sigma, 256))

# Show a boxplot of the data
plt.boxplot(data)
plt.show()
```

Multiple boxplots

Boxplots are often used to show side by side various distributions



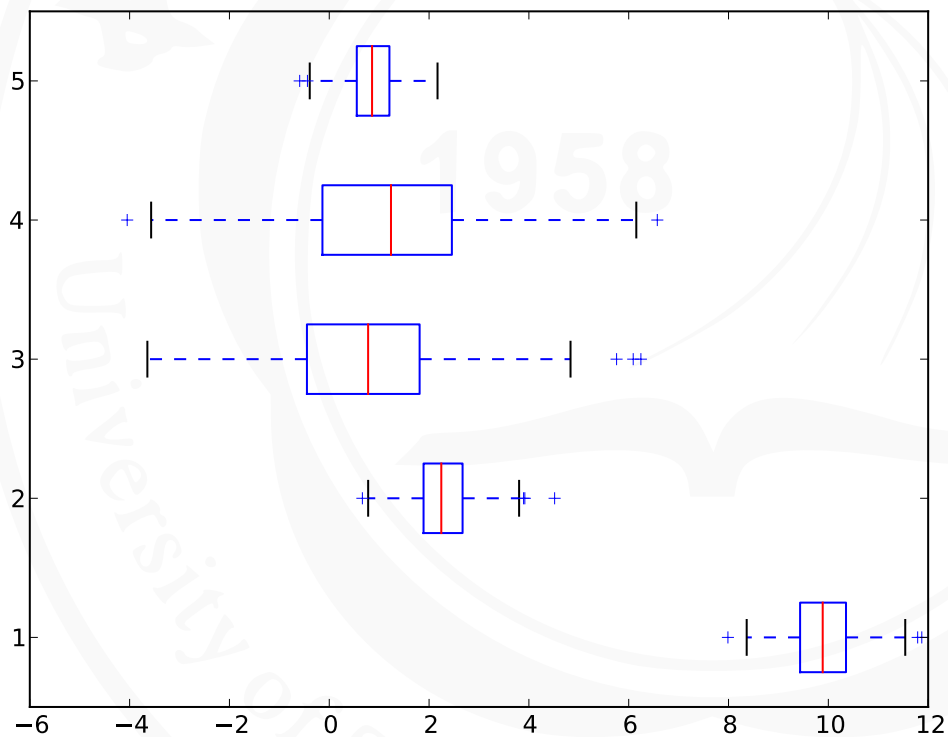
Orientation

Changing the orientation is easily done

```
import numpy
import numpy.random
import matplotlib.pyplot as plt



# Generate normal distribution data
data = []
for i in xrange(5):
  mu = 10 * numpy.random.random_sample()
  sigma = 2 * numpy.random.random_sample() + 0.1
  data.append(numpy.random.normal(mu, sigma, 256))

# Show a boxplot of the data
plt.boxplot(data, vert=0)
plt.show()
```

Orientation

Changing the orientation is easily done



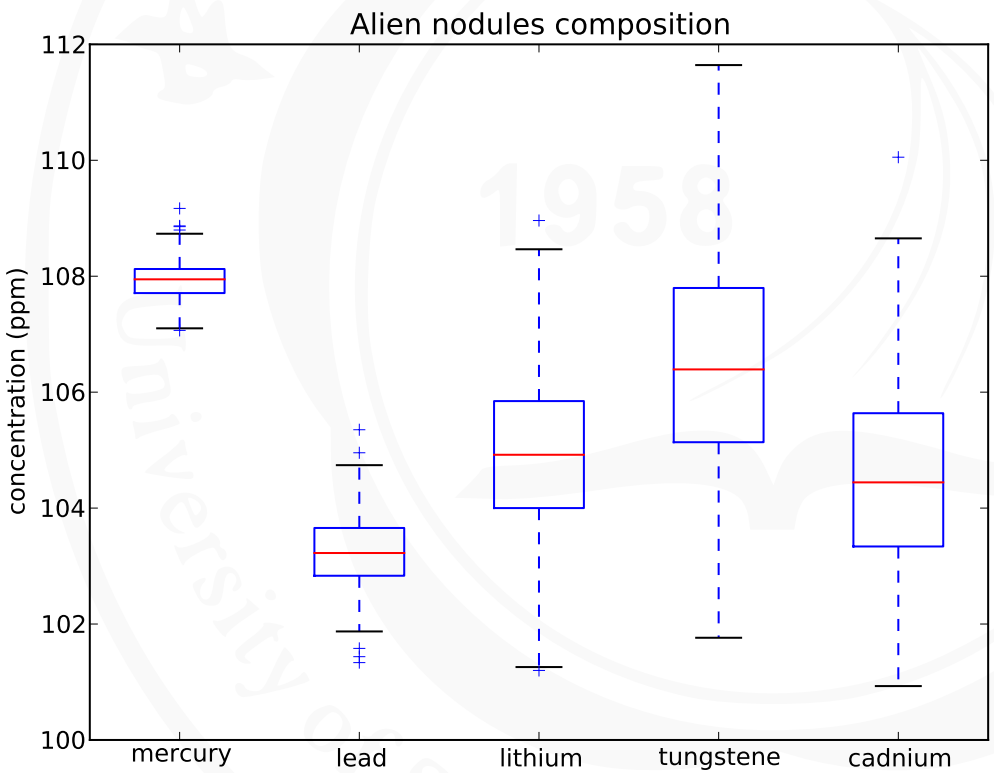
Legend

Good graphics have a proper legend

```
import numpy
import numpy.random
import matplotlib.pyplot as plt



# Generate normal distribution data
labels = ['mercury', 'lead', 'lithium', 'tungstene', 'cadnium']
data = []
for i in xrange(len(labels)):
  mu = 10 * numpy.random.random_sample() + 100
  sigma = 2 * numpy.random.random_sample() + 0.1
  data.append(numpy.random.normal(mu, sigma, 256))

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111)

axis.set_title('Alien nodules composition')
xtickNames = plt.setp(axis, xticklabels = labels)
axis.set_ylabel('concentration (ppm)')

# Show a boxplot of the data
plt.boxplot(data)
plt.show()
```

Legend

Good graphics have a proper legend



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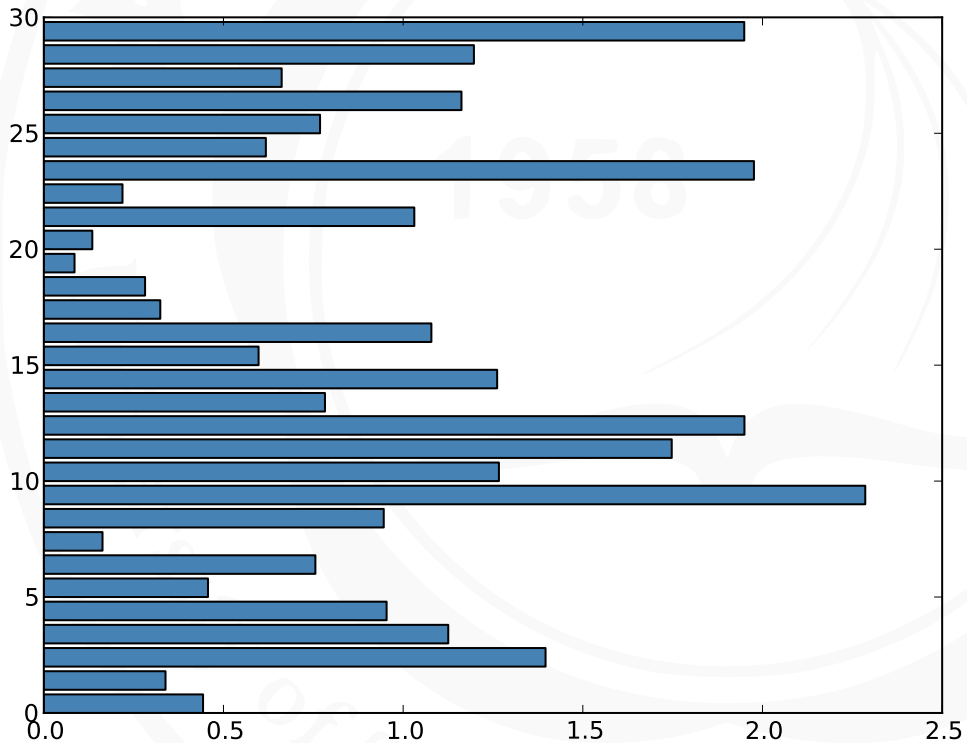
Histograms

Histogram are convenient to sum-up results

```
import numpy
import numpy.random
import matplotlib.pyplot as plt


# Some data
data = numpy.abs(numpy.random.standard_normal(30))

# Show an histogram
plt.barh(range(len(data)), data, color='#4682B4')
plt.show()
```

Histograms

Histogram are convenient to sum-up results



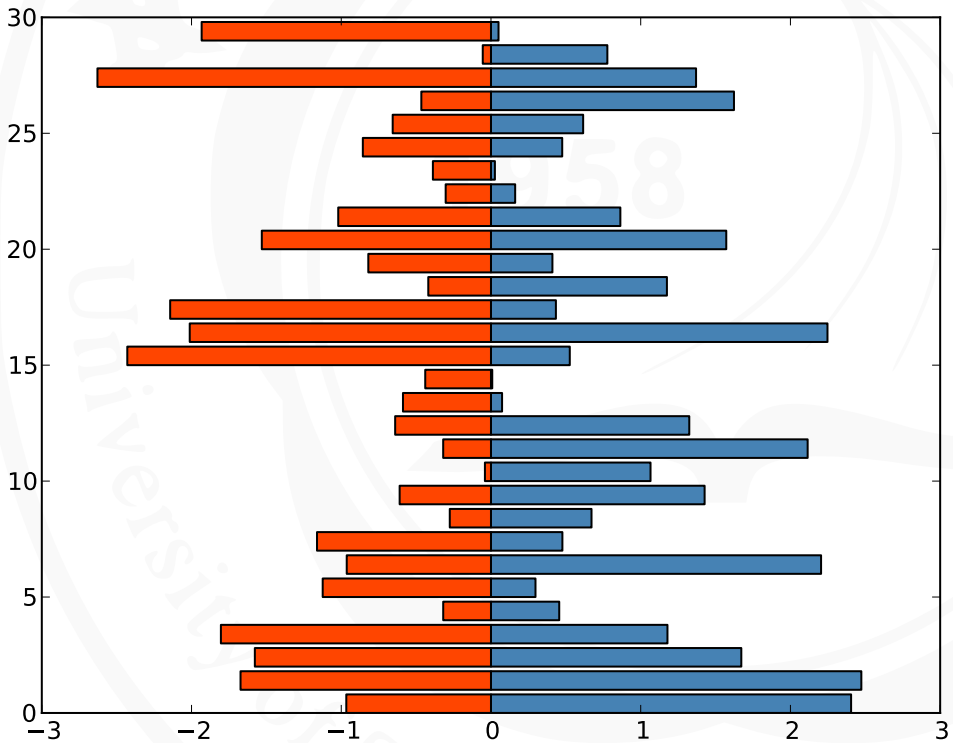
Histograms

A variant to show 2 quantities per item on 1 figure

```
import numpy
import numpy.random
import matplotlib.pyplot as plt



# Some data
data = [[], []]
for i in xrange(len(data)):
  data[i] = numpy.abs(numpy.random.standard_normal(30))

# Show an histogram
labels = range(len(data[0]))

plt.barh(labels, data[0], color='#4682B4')
plt.barh(labels, -1 * data[1], color='#FF4500')
plt.show()
```

Histograms

A variant to show 2 quantities per item on 1 figure



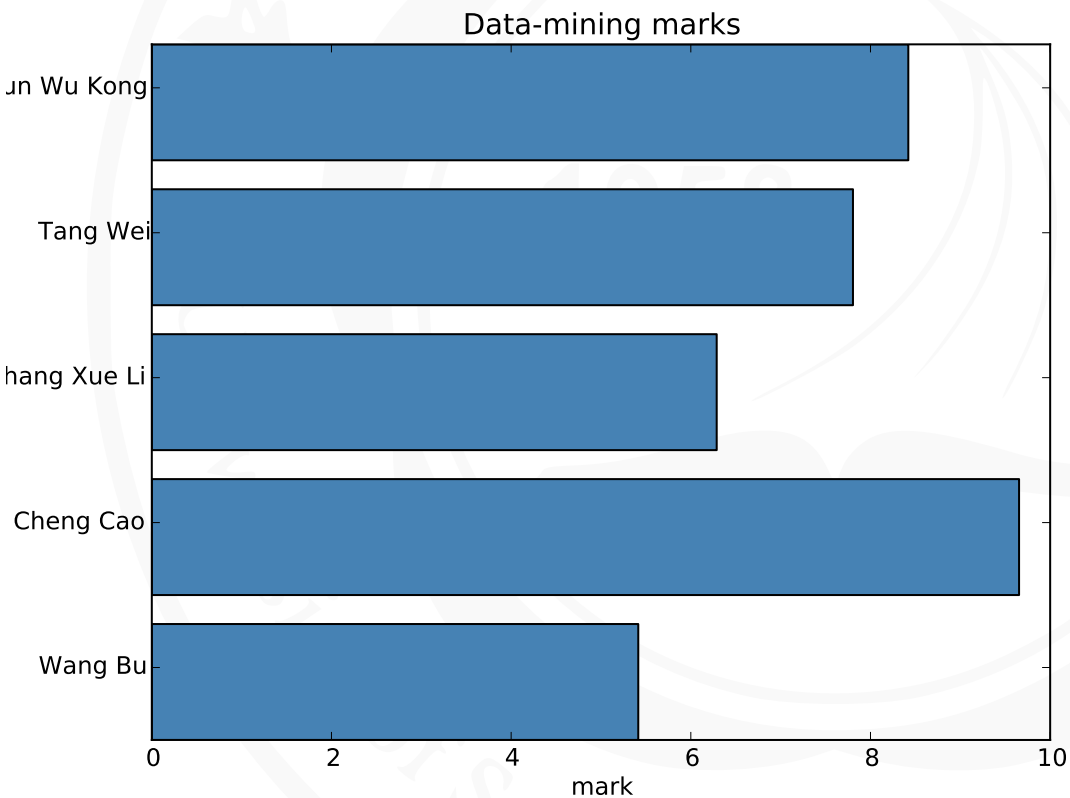
Labels

Very often, we need to name items on an histogram

```
import numpy
import numpy.random
import matplotlib.pyplot as plt


# Some data
names = ['Wang Bu', 'Cheng Cao', 'Zhang Xue Li', 'Tang Wei', 'Sun Wu Kong']
marks = 7 * numpy.random.random_sample(len(names)) + 3

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111)

axis.set_xlim(0, 10)

plt.yticks(numpy.arange(len(marks))+0.5, names)

axis.set_title('Data-mining marks')
axis.set_xlabel('mark')

# Show an histogram
plt.barh(range(len(marks)), marks, color='#4682B4')
plt.show()
```

Labels

Very often, we need to name items on an histogram



Error bars

Error bars, to indicate the accuracy of values

```
import numpy
import numpy.random
import matplotlib.pyplot as plt


# Some data
names = ['6809', '6502', '8086', 'Z80', 'RCA1802']
speed = 70 * numpy.random.random_sample(len(names)) + 30
error = 9 * numpy.random.random_sample(len(names)) + 1

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111)

plt.yticks(numpy.arange(len(names))+0.5, names)

axis.set_title('8 bits CPU benchmark - string test')
axis.set_xlabel('score')

# Show an histogram
plt.barh(range(len(names)), speed, xerr=error, color='#4682B4')
plt.show()
```

Error bars

Error bars, to indicate the accuracy of values

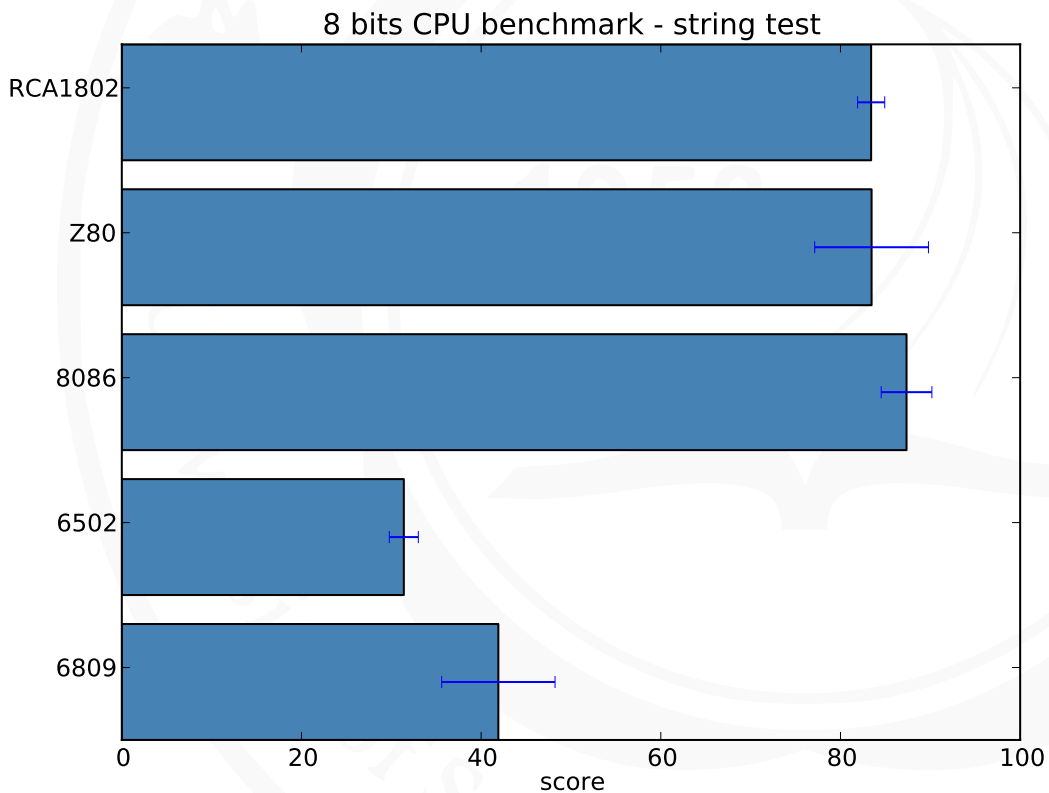


Table of Contents

Old Faithful

Let's display some real data: *Old Faithful* geyser

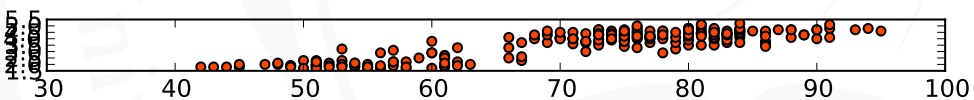
Old Faithful

This way works, but good example of half-done job

```
import numpy
import matplotlib.pyplot as plt

# Read the data
data = numpy.loadtxt('./datasets/geyser.dat')

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111, aspect='equal')

# Plot the points
plt.scatter(data[:,0], data[:,1], c='#FF4500')
plt.show()
```

Old Faithful

This way works, but good example of half-done job



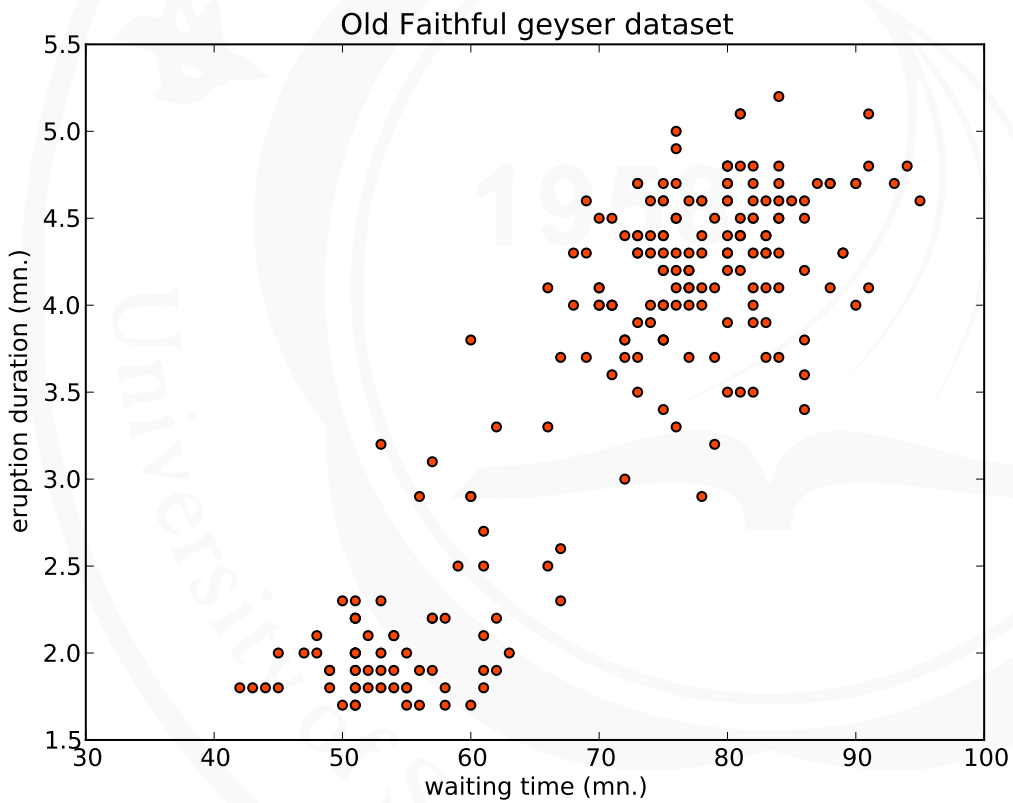
Old Faithful

Let's make a more readable figure

```
import numpy
import matplotlib.pyplot as plt

# Read the data
data = numpy.loadtxt('./datasets/geyser.dat')

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111)

axis.set_title('Old Faithful geyser dataset')
axis.set_xlabel('waiting time (mn.)')
axis.set_ylabel('eruption duration (mn.)')

# Plot the points
plt.scatter(data[:,0], data[:,1], c='#FF4500')
plt.show()
```

Old Faithful

Let's make a more readable figure



Mercury & fishes

Let's display more complex data: fishes and mercury poisoning

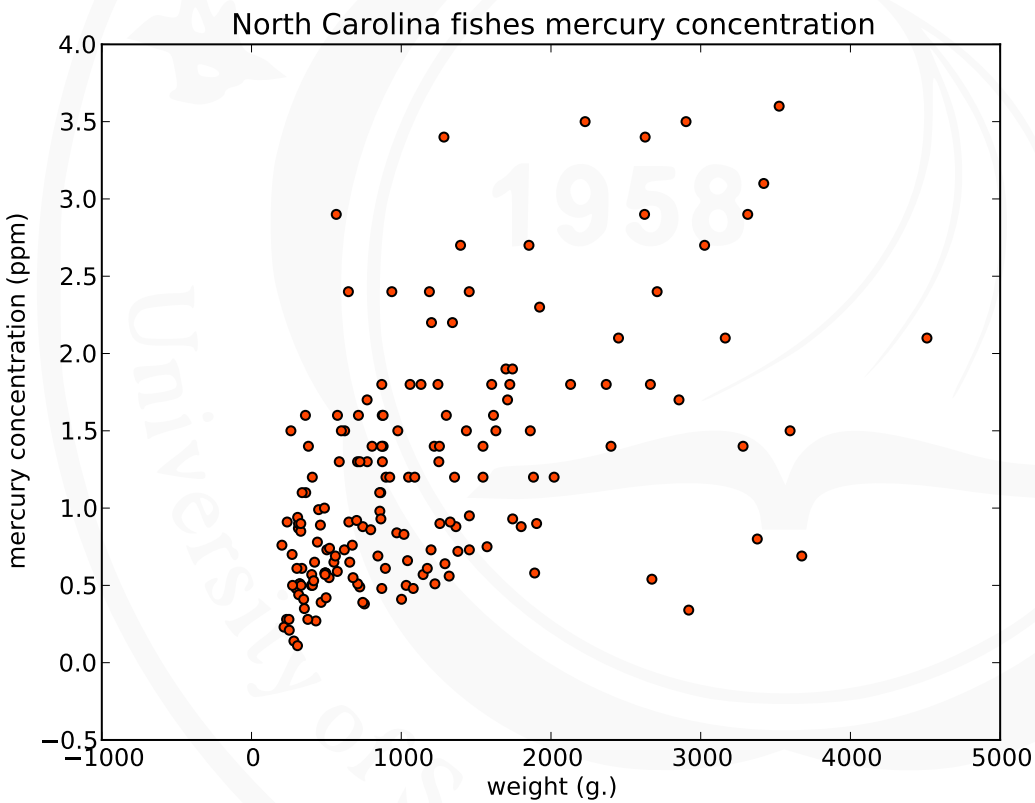
Mercury & fishes

A first try

```
import numpy
import matplotlib.pyplot as plt



# Read the data
data = numpy.loadtxt('./datasets/fish.dat')

# Axis setup
fig = plt.figure()
axis = fig.add_subplot(111)

axis.set_title('North Carolina fishes mercury concentration')
axis.set_xlabel('weight (g.)')
axis.set_ylabel('mercury concentration (ppm)')

# Plot the points
plt.scatter(data[:,3], data[:,4], c='#FF4500')
plt.show()
```

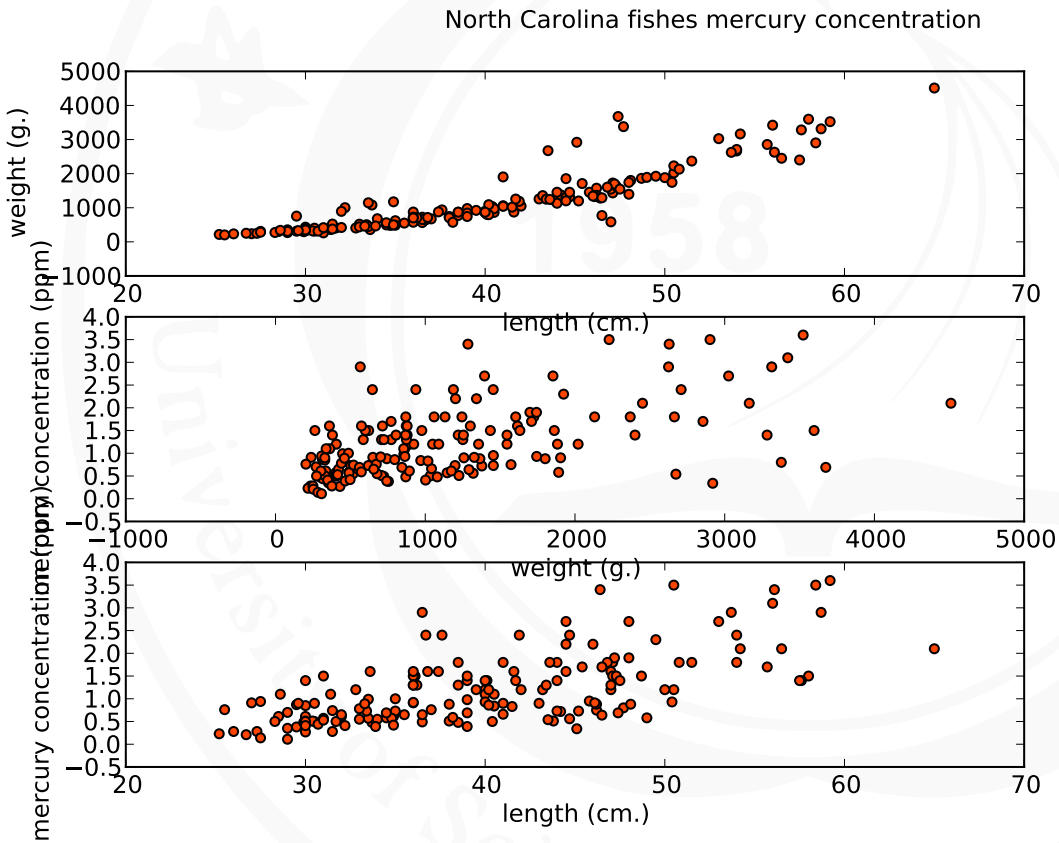
Mercury & fishes

A first try



Mercury & fishes

Show more information with *subplots*



Mercury & fishes

Data from one river with its own color