Computational Environments and Toolchains

Topic 02 — Scientific Computing using Python

Lecture 01 — Mathplotlib

Kieran Murphy and David Power

Department of Science,
Waterford IT.
(kmurphy@wit.ie,dpower@wit.ie)

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Outline

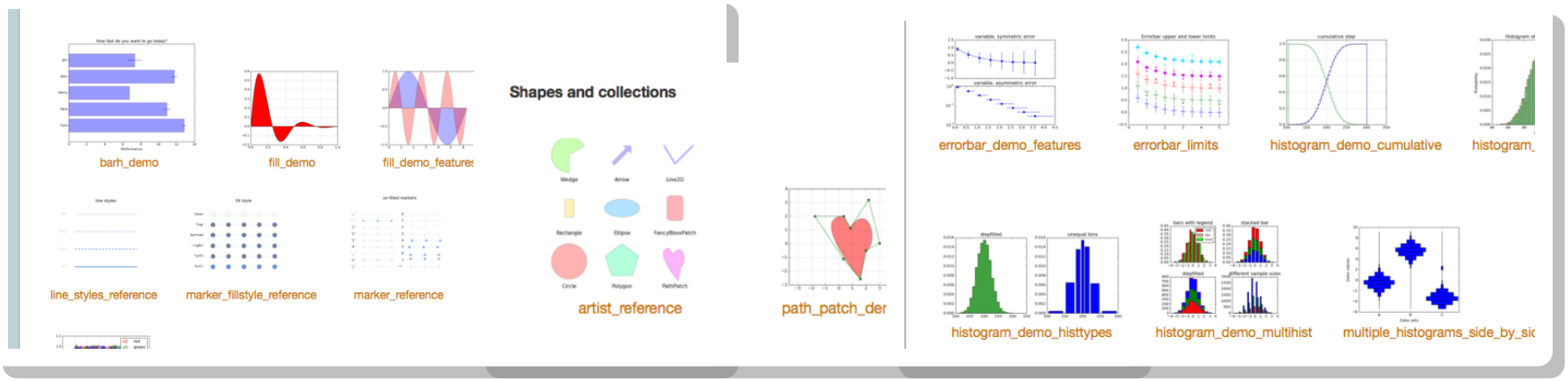
- matplotlib (2D and 3D plotting library)
- numpy (high performance matrix library)
- scipy (scientific computation library)

Outline

A 20 Second Into to Mathplotlib

- Matplotlib is the standard plotting library for scientific python
- Design objectives
  - Plots should look great – publication quality.
  - Supports formats suitable for inclusion with TEX documents.
  - Embeddable in a graphical user interface for application development.
  - Code should be easy enough to understand and extendable.
- Mostly it is for 2D data (including surface plots of $f(x, y)$, etc.)
- Active development with lots of new features
- Best way to figure out how to do something: look at the gallery

  `http://matplotlib.org/gallery.html`



Importing Matplotlib

- There are several interfaces to matplotlib that provide varying amounts of access to its underlying functionality

  `http://matplotlib.org/faq/usage_faq.html`

  - matplotlib is the entire package.
  - pyplot is a module within matplotlib that provides easy access to the core plotting routines.
  - pylab combines pyplot and numpy into a single namespace to give a MatLab like interface
    - This is recommended for interactive work but I tend to just import both pylab and numpy separately.
- A number of toolkits extend the functionality
  - basemap and cartopy: mapping (e.g. projecting onto a globe, geographical boundaries)
  - mplot3d: basic 3-d plotting.
  - AxesGrid: high-level methods for arranging multiple plots together in a figure

Mathplotlib Backends

matplotlib can output to a number of different devices—the backends provide this functionality:

- Interactive backends (allow for plotting to the screen, and updates (animations) with each command (if desired)):
  - pygtk, wxpython, tkinter , qt, macosx
- Hardcopy backends (saving to external image files):
  - PNG, SVG, PDF, PS

To select a backend:

backend.py

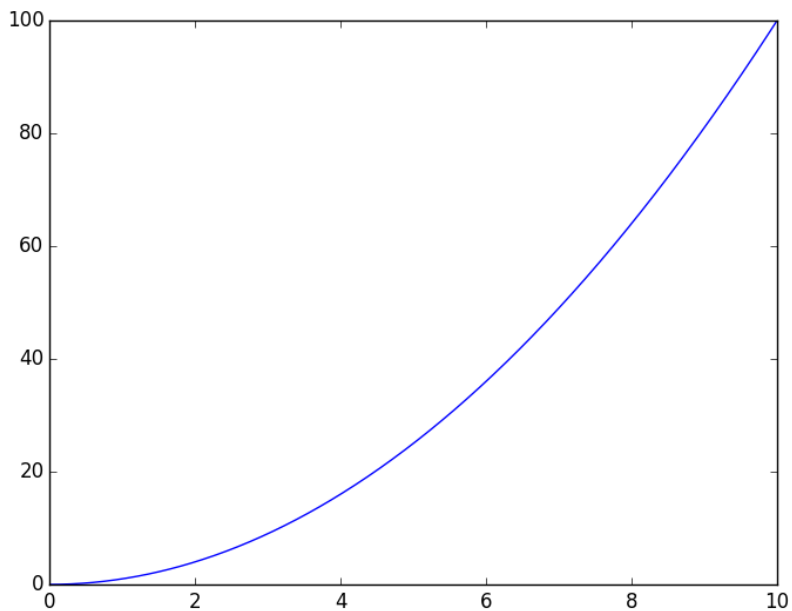
```
1 import matplotlib
2 matplotlib.use("PS")
3 import matplotlib.pyplot as plt
```

In iPython, use the %matplotlib inline to get images embedded in the notebooks.

Line Plot (Basic)

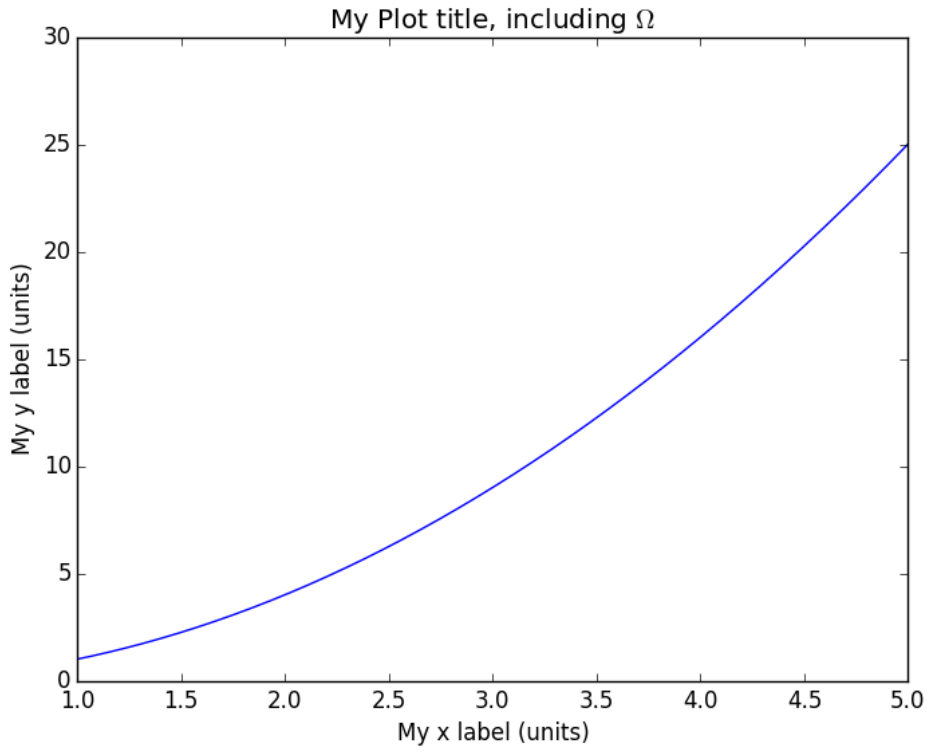
line_plot .py

```
5  import numpy as np
6  import matplotlib.pyplot as plt
7
8  x = np.linspace(0, 10, 1000)     # evenly spaced points
9  y = np.power(x, 2)               # element-wise squaring
10
11 plt.plot(x, y)
12
13 plt.savefig("line_plot.png")
```

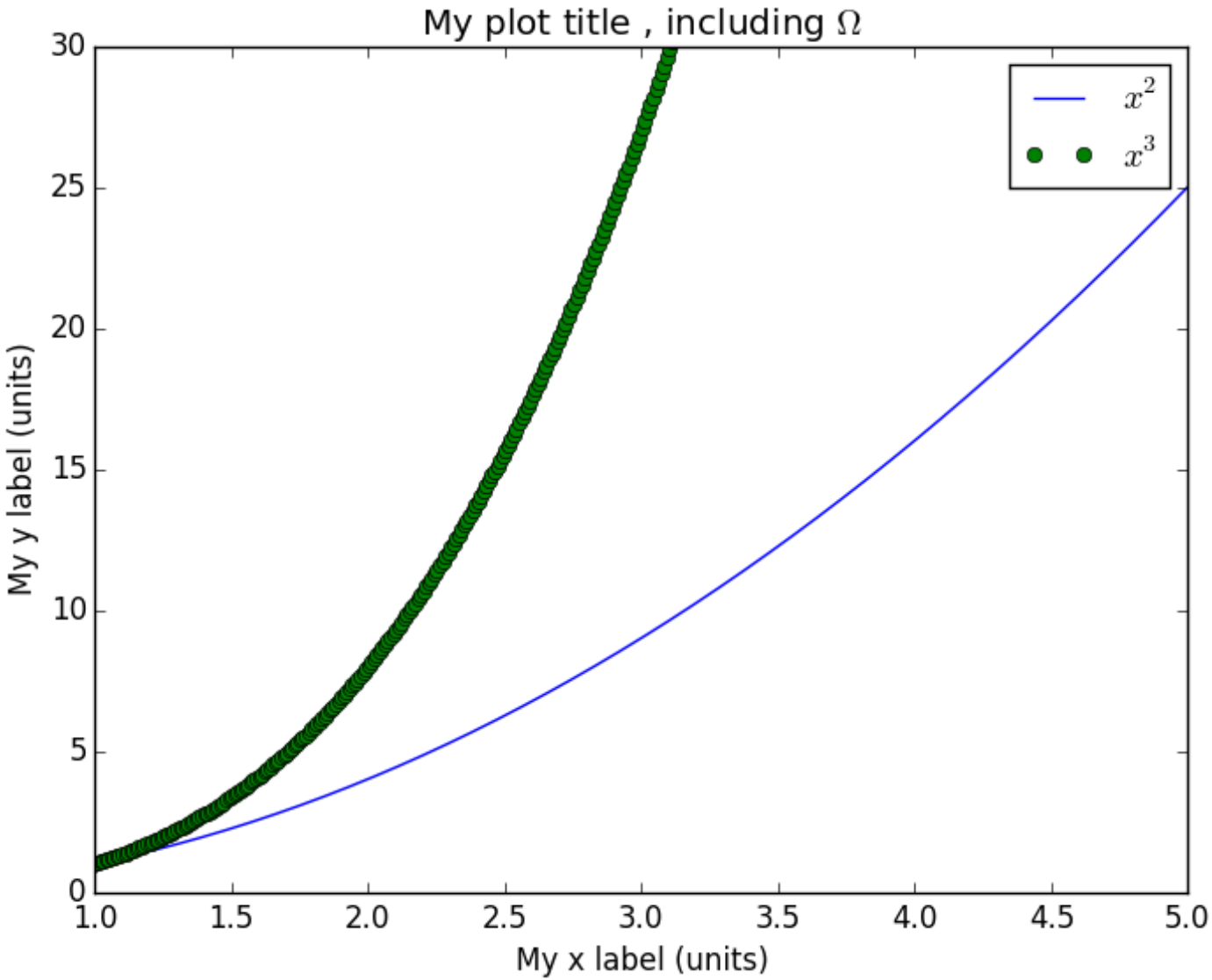


Line Plot (Proper)

```
5  import numpy as np
6  import matplotlib.pyplot as pl
7
8  x = np.linspace(0, 10, 1000)
9  y = np.power(x, 2)
10
11 plt.plot(x, y)
12 plt.xlim((1, 5))
13 plt.ylim((0, 30))
14 plt.xlabel("My x label (units)")
15 plt.ylabel("My y label (units)")
16 plt.title("My Plot title, including $\Omega$")
17
18 plt.savefig("line_plot_proper.png", bbox_inches="tight")
```



Line Plot (Fancy)

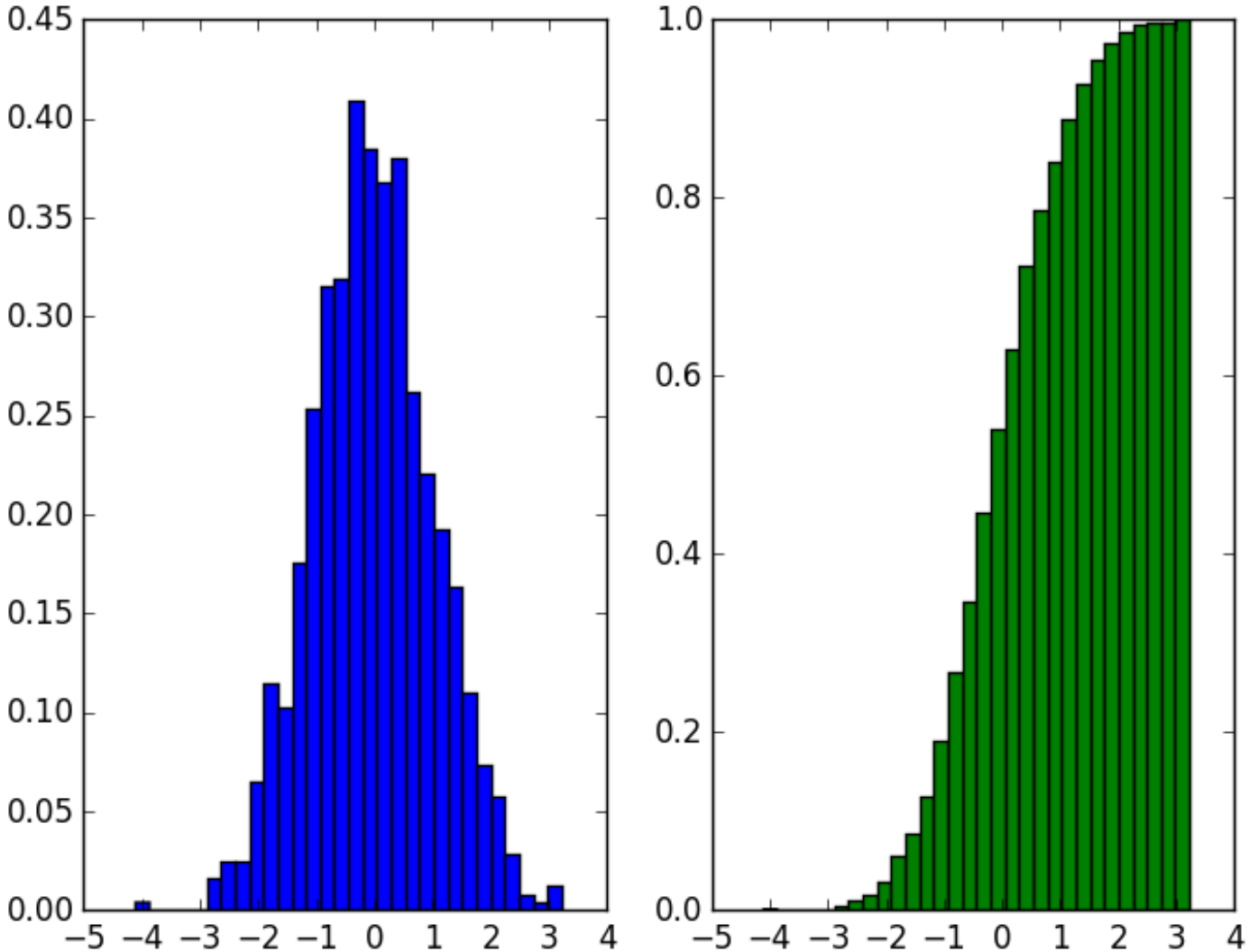


Line Plot (Fancy) — Code

line_plot_fancy .py

```
5  import numpy as np
6  import matplotlib.pyplot as plt
7
8  x = np.linspace(0, 10, 1000)
9  y1 = np.power(x, 2)
10 y2 = np.power(x, 3)
11
12 plt.plot(x, y1, "b-", x, y2, "go")          # look at me !
13 plt.xlim((1, 5))
14 plt.ylim((0, 30))
15 plt.xlabel("My␣x␣label␣(units)")
16 plt.ylabel("My␣y␣label␣(units)")
17 plt.title("My␣plot␣title␣,␣including␣$\Omega$")
18 plt.legend(("$x^2$", "$x^3$"))               # and me !
19
20 plt.savefig("line_plot_fancy.png", bbox_inches="tight")
```

Histogram

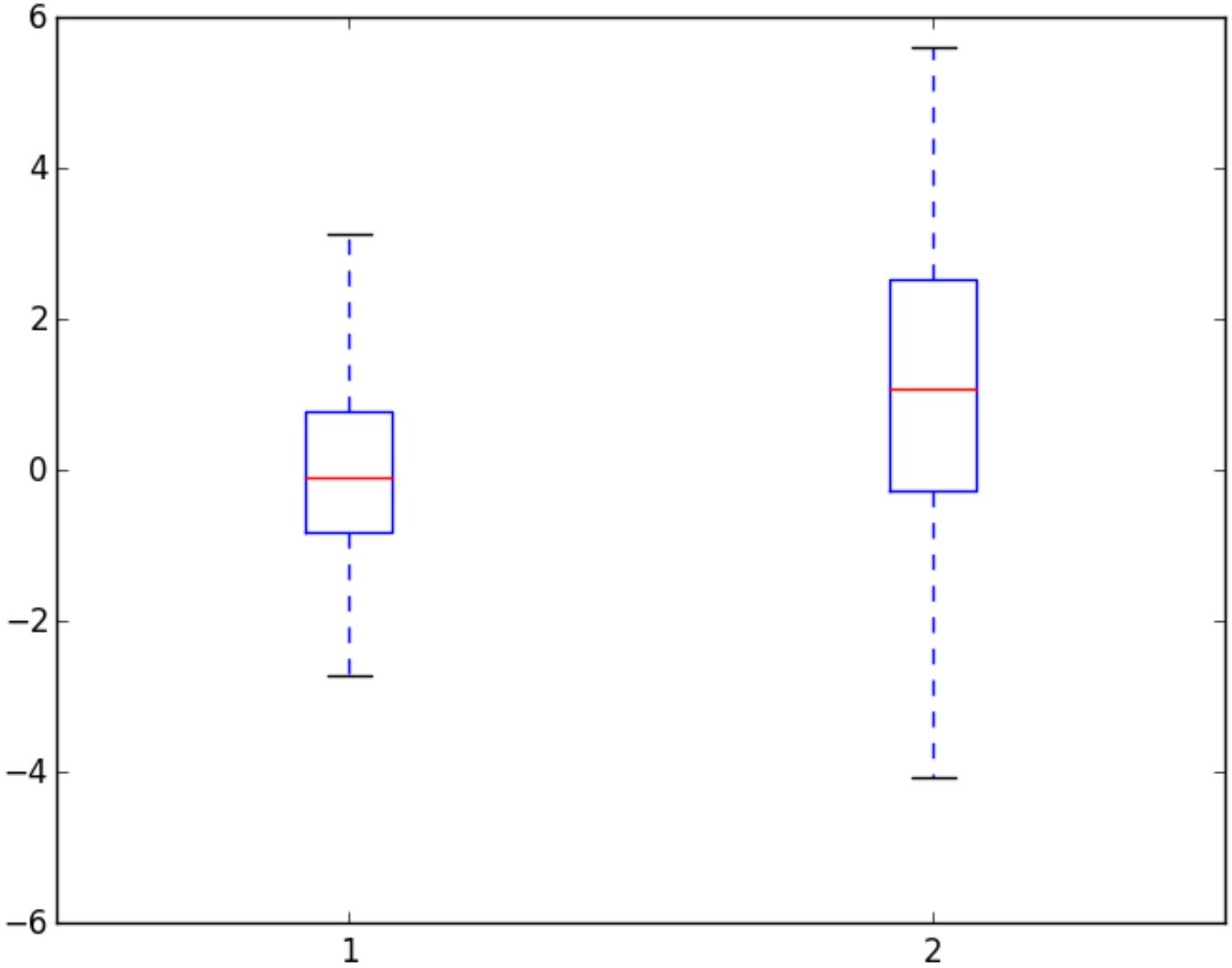

0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−5 −4 −3 −2 −1 0 1 2 3 4
1.0
0.8
0.6
0.4
0.2
0.0
−5 −4 −3 −2 −1 0 1 2 3 4

Histogram — Code

histogram.py

```
5  import numpy as np
6  import matplotlib.pyplot as plt
7
8  data = np.random.randn(1000)
9
10 # histogram (pdf)
11 plt.subplot(1, 2, 1)
12 plt.hist(data, bins=30, normed=True, facecolor="b")
13
14 # empirical cdf
15 plt.subplot(1, 2, 2)
16 plt.hist(data, bins=30, normed=True, color="g", cumulative=True)
17
18 plt.savefig("histogram.png", bbox_inches="tight")
```

Box Plot



Box Plot — Code

box_plot.py

```
5  import numpy as np
6  import matplotlib.pyplot as plt
7
8  samp1 = np.random.normal(loc=0., scale=1., size=100)
9  samp2 = np.random.normal(loc=1., scale=2., size=100)
10 plt.boxplot((samp1, samp2))
11
12 plt.savefig("box_plot.png", bbox_inches="tight")
```

In descriptive statistics, a box plot is a convenient way of graphically depicting groups of numerical data through their quartiles — min, first quartile, median (second quartile), third quartile, and max.
https://en.wikipedia.org/wiki/Box_plot

Image Plot

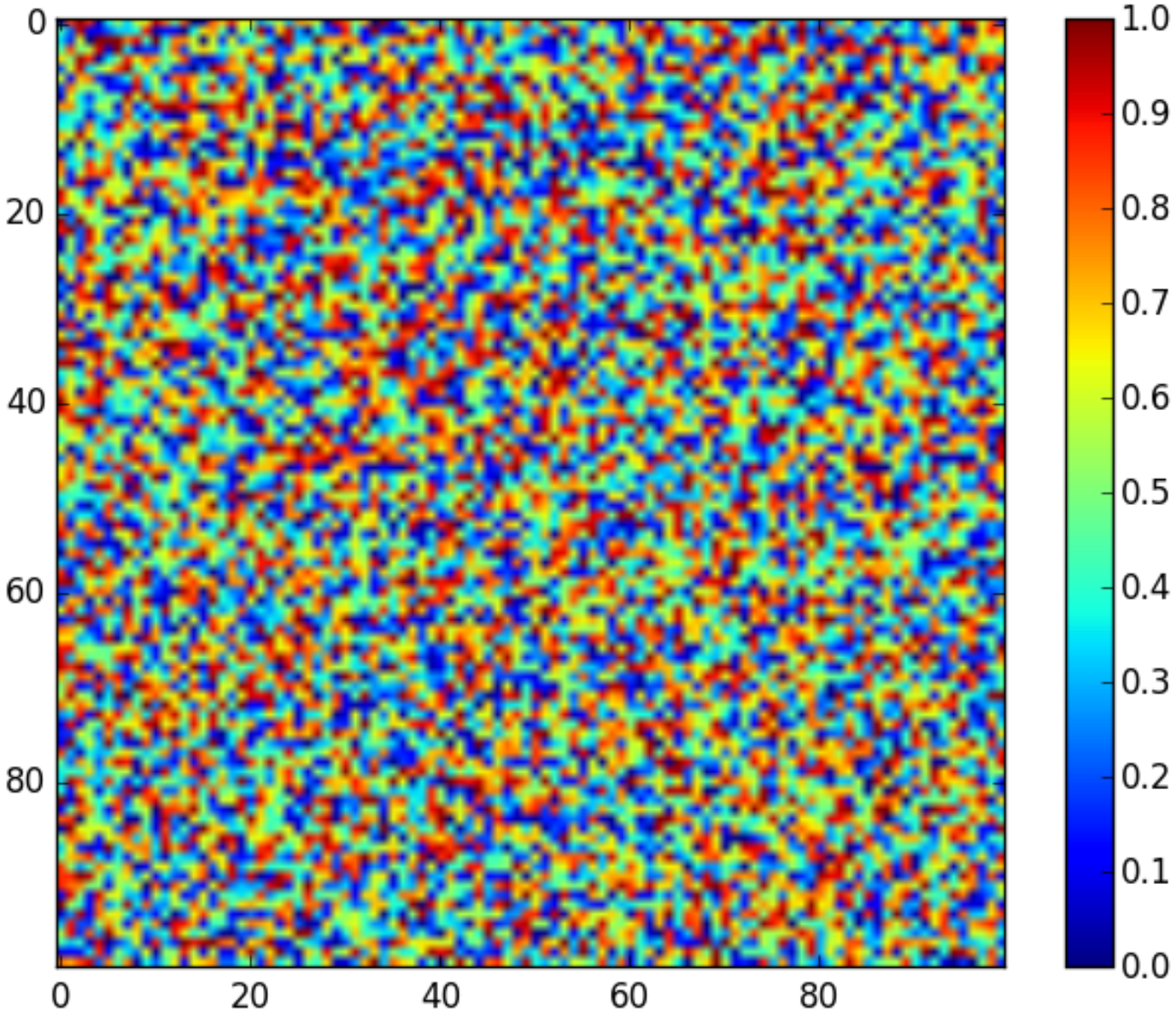
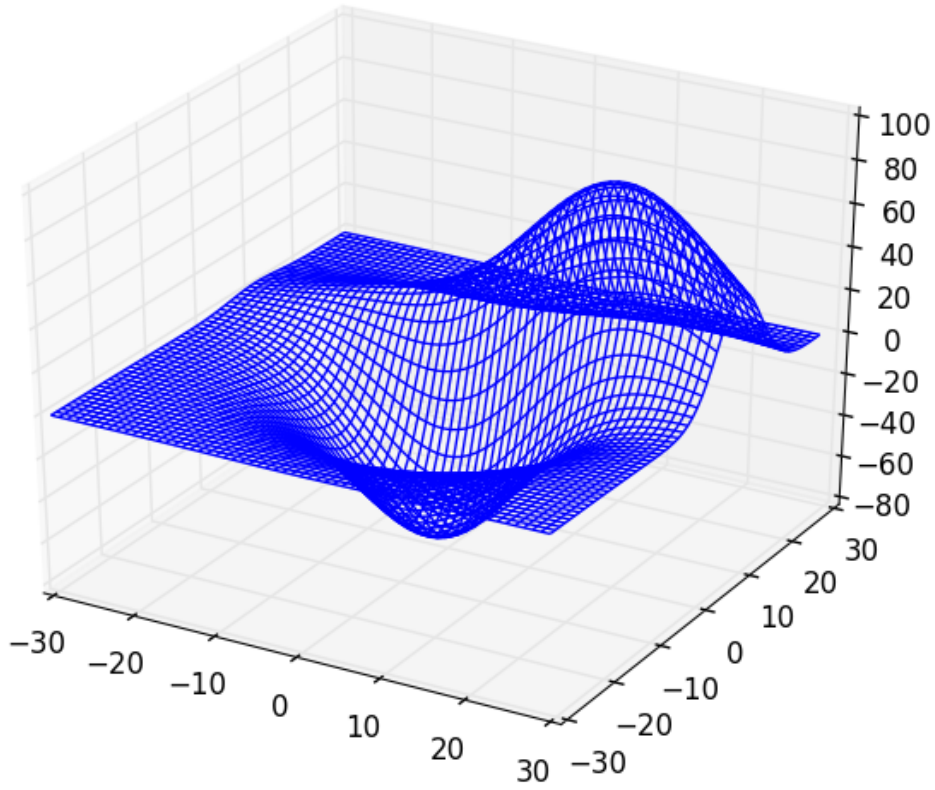


Image Plot — Code

image_plot.py

```
5  import numpy as np
6  import matplotlib.pyplot as plt
7
8  A = np.random.random((100, 100))
9  plt.imshow(A)                    # Display an image on the axes
10 plt.hot()                        # set colormap to hot
11 plt.colorbar()                   # Add a colorbar to a plot
12
13 plt.savefig("image_plot.png", bbox_inches="tight")
```

Wire Plot




```
5  from mpl_toolkits.mplot3d import axes3d
6  import matplotlib.pyplot as plt
7
8  ax = plt.subplot(111, projection="3d")
9
10 X, Y, Z = axes3d.get_test_data(0.1)
11 ax.plot_wireframe(X, Y, Z)
12
13 plt.savefig("wire_plot.png", bbox_inches="tight")
```