SciPy

Data Analytics in Python

The SciPy Stack

SciPy is a Python-based ecosystem of libraries and tools for scientific computing and data analytics

- iPython
- Jupyter notebooks
- Numpy
- Pandas
- Matplotlib

iPython is the primary way of interacting with the SciPy stack – whether through the shell or a Jupyter notebook – so we'll learn iPython first

iPython

Two modes:

- Interactive shell
  - Replacement for `python` REPL
- Jupyter notebook
  - Interactive web-based documents mixing text, executable code, graphics

Before we proceed, make sure your computer is ready (OS shell):

```
$ conda update conda
$ conda update python ipython jupyter numpy pandas matplotlib
```

iPython Shell History

```
In [1]: ['Sage', 'Thyme', 'Oragano', 'Posh']
Out[1]: ['Sage', 'Thyme', 'Oragano', 'Posh']

In [2]: type(In[1])
Out[2]: str

In [3]: type(Out[1])
Out[3]: list

In [4]: spices = Out[1]

In [5]: spices
Out[5]: ['Sage', 'Thyme', 'Oragano', 'Posh']

In [6]: spices is Out[1]
Out[6]: True
```

In is a list, Out is a dict.

iPython Help

Single ? gives abbeviated version of python's `help`

```
In [7]: def add(a, b):
   ...:     """Return the result of + operation on a and b"""
   ...:     return a + b
   ...:
In [8]: add?
Signature: add(a, b)
Docstring: Return the result of + operation on a and b
File:      ~/cs2316/<ipython-input-7-af5293282e78>
Type:      function
```

Double ?? gives source code, if available.

```
In [9]: add??
Signature: add(a, b)
Source:
def add(a, b):
    """Return the result of + operation on a and b"""
    return a + b
File:      ~/cs2316/<ipython-input-7-af5293282e78>
Type:      function
```

iPython Magic Commands

Special commands provided by iPython, prepended by %.

- Run a Python script from within iPython:

```
In [35]: %run people.py
[<Stan, 2008-08-13, 150cm, 45kg>,
 <Kyle, 2008-02-25, 160cm, 50kg>,
 <Cartman, 2008-05-26, 140cm, 100kg>,
 <Kenny, 2009-07-30, 130cm, 40kg>]
```

- Get help with a magic command with ?

```
In [2]: %cd?
Docstring:
Change the current working directory.

This command automatically maintains an internal list of directories
you visit during your IPython session, in the variable _dh. The
command %dhist shows this history nicely formatted. You can also
do 'cd -<tab>' to see directory history conveniently.

Usage:

  cd 'dir': changes to directory 'dir'.
(additional output elided)
```

Get a list of all magic commands with `%lsmagic`

iPython Shell Commands

Run shell commands by prepending with a !

```
In [27]: !ls *.py
fun.py     grades.py  maths.py   people.py  pp.py

In [28]: pyscripts = !ls *.py

In [29]: pyscripts
Out[29]: ['fun.py', 'grades.py', 'maths.py', 'people.py', 'pp.py']
```

iPython provides magic commands for most common shell commands.

iPython Direcotry Bookmarking

Great timesaving feature: bookmark directories

```
In [3]: %pwd
Out[3]: '/home/chris/vcs/github.com/cs2316/cs2316.github.io/code'

In [4]: %cd
/home/chris

In [5]: %bookmark cs2316code ~chris/vcs/github.com/cs2316/cs2316.github.io/code

In [6]: cd cs2316code
(bookmark:cs2316code) -> ~chris/vcs/github.com/cs2316/cs2316.github.io/code
/home/chris/vcs/github.com/cs2316/cs2316.github.io/code
```

iPython Automagic commands

With `automagic` turned on, some shell commands can be run as if they were built into iPython:

```
In [22]: pwd
Out[22]: '/Users/chris/cs2316'

In [23]: ls *.py
fun.py    grades.py maths.py  people.py pp.py
```

- Toggle automagic on and off with `%automagic`.
- These commands work with automagic:
  - `%cd`, `%cat`, `%cp`, `%env`, `%ls`, `%man`, `%mkdir`, `%more`, `%mv`, `%pwd`, `%rm`, and `%rmdir`

Timing Code in iPython

```
In [23]: import numpy as np

In [24]: pylist = list(range(1, 100000))

In [25]: nparray = np.arange(1, 1000000)

In [35]: %timeit _ = [x * 2 for x in pylist]
100 loops, best of 3: 7.89 ms per loop

In [37]: %timeit _ = nparray.copy() * 2
100 loops, best of 3: 3.76 ms per loop
```

Notice that I copied the Numpy array before applying the * 2 operation to make the comparison to the Python list comprehension fair. You'll learn why when we discuss Numpy in the next lecture.

Profiling a Script

```
In [7]: %run -p -l 10 -s cumulative funcalc.py
         2673375 function calls (1147466 primitive calls) in 1.691 seconds

   Ordered by: cumulative time
   List reduced from 56 to 10 due to restriction <10>

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
      2/1    0.000    0.000    1.691    1.691 {built-in method builtins.exec}
        1    0.000    0.000    1.691    1.691 <string>:1(<module>)
        1    0.000    0.000    1.691    1.691 interactiveshell.py:2431(safe_execfile)
        1    0.000    0.000    1.691    1.691 py3compat.py:182(execfile)
        1    0.000    0.000    1.690    1.690 funcalc.py:1(<module>)
        1    0.000    0.000    1.689    1.689 funcalc.py:46(main)
        1    0.039    0.039    1.689    1.689 funcalc.py:34(profile)
510961/10000   0.510    0.000    0.603    0.000 funcalc.py:14(sub)
510961/10000   0.514    0.000    0.598    0.000 funcalc.py:6(add)
510961/10000   0.340    0.000    0.340    0.000 funcalc.py:22(mult)
```

- `-p` means profile
- `-l 10` means show only 10 lines
- `-s cumulative` means sort by cumulative time

Profiling a Function

%prun profiles a function. Uses same options as % run -p.

```
In [10]: %prun -l 10 -s cumulative funcalc.profile()
         2673429 function calls (1148052 primitive calls) in 1.726 seconds

   Ordered by: cumulative time
   List reduced from 15 to 10 due to restriction <10>

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
        1    0.000    0.000    1.726    1.726 {built-in method builtins.exec}
        1    0.000    0.000    1.726    1.726 <string>:1(<module>)
        1    0.042    0.042    1.726    1.726 funcalc.py:34(profile)
511231/10000   0.537    0.000    0.620    0.000 funcalc.py:6(add)
511231/10000   0.523    0.000    0.615    0.000 funcalc.py:14(sub)
511231/10000   0.336    0.000    0.336    0.000 funcalc.py:22(mult)
    20000    0.019    0.000    0.097    0.000 random.py:223(randint)
   501231    0.092    0.000    0.092    0.000 funcalc.py:15(dec)
   501231    0.082    0.000    0.082    0.000 funcalc.py:7(inc)
    20000    0.036    0.000    0.078    0.000 random.py:179(randrange)
```

Interactive Debugging in iPython

Enter a debug session with `%debug` . . .

A Taste of Data Analytics in iPython Shell

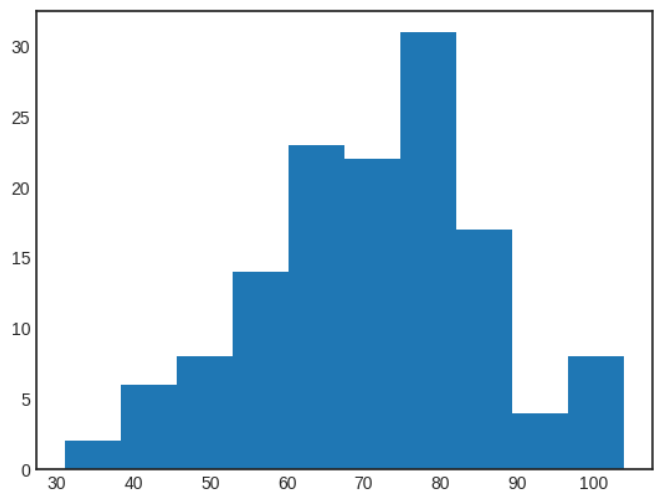
```
In [1]: cd analytics/
/home/chris/vcs/github.com/cs2316/cs2316.github.io/code/analytics

In [3]: exam1grades = np.loadtxt('exam1grades.txt')

In [4]: import matplotlib.pyplot as plt

In [5]: %matplotlib qt5

In [6]: plt.hist(exam1grades)
Out[6]:
(array([ 2.,  6.,  8., 14., 23., 22., 31., 17.,  4.,  8.]),
 array([ 31. ,  38.3,  45.6,  52.9,  60.2,  67.5,  74.8,  82.1,
         89.4,  96.7, 104. ]),
 <a list of 10 Patch objects>)
```



Jupyter Notebooks

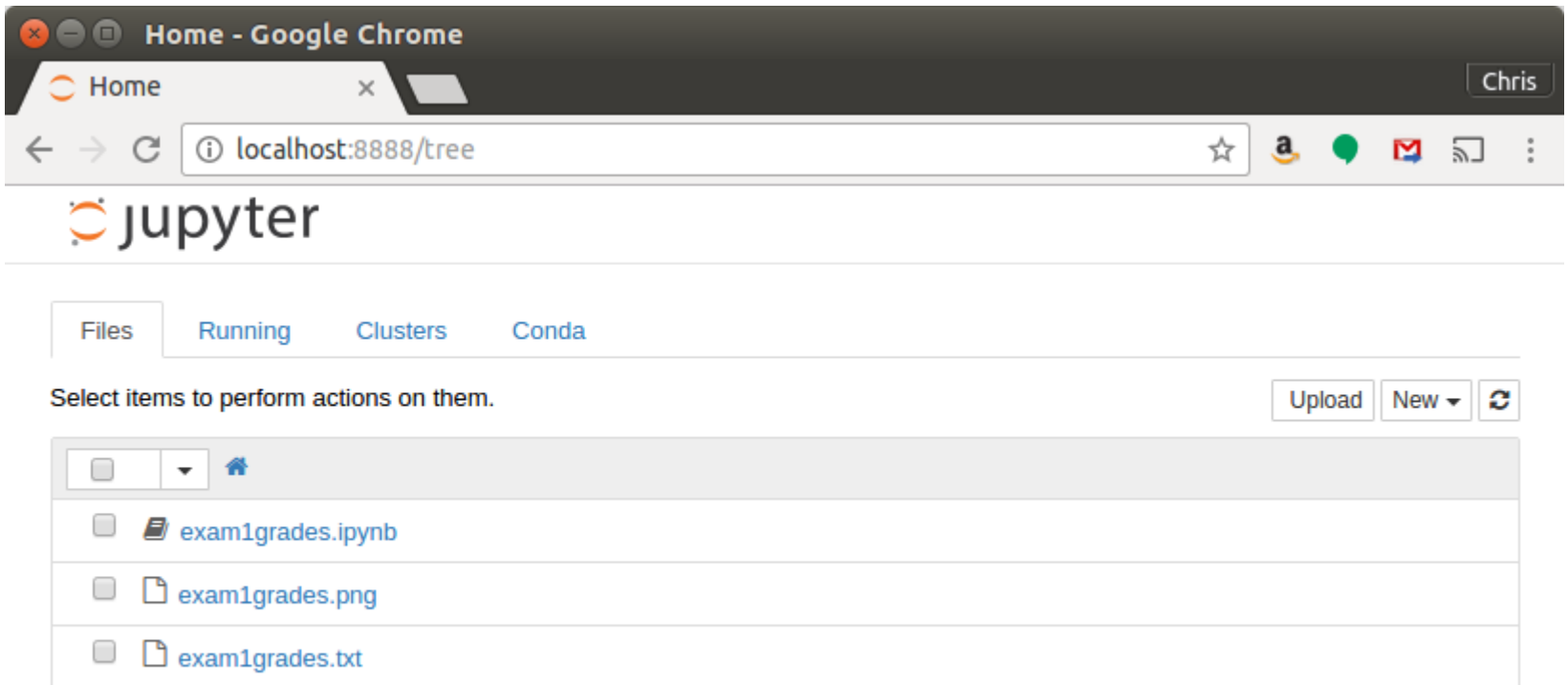
Go to the directory that holds your notebooks, or the class web site repo's `code/analytics` directory for this example and enter `jupter notebook`.

```
[chris@bolshoi ~/vcs/github.com/cs2316/cs2316.github.io/code/analytics]
$ jupyter notebook
[I 15:06:15.705 NotebookApp] Serving notebooks from local directory:
     /home/chris/vcs/github.com/cs2316/cs2316.github.io/code/analytics
[I 15:06:15.705 NotebookApp] 0 active kernels
[I 15:06:15.705 NotebookApp] The Jupyter Notebook is running at:
     http://localhost:8888/
[I 15:06:15.705 NotebookApp] Use Control-C to stop this server and shut down all
     kernels (twice to skip confirmation).
Created new window in existing browser session.
```

Now a Jupter Notebook server is running and you're ready to use iPython from the Jupyter Notebook web interface.

Jupyter Web Interface

After running `jupyter notebook` from your OS command shell, open a browser and navigate to `localhost:8888`. You'll see a screen that looks like this:



Notice the listing of files in the directory in which you started the Jupyter notebook server.

A Taste of Data Analytics in Jupyter Notebook

Select the `exam1grades.ipynb` file and you'll get this: