Econometric Society Workshop on Scientific Computing with Python and Julia

John Stachurski

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Agenda

1. **09:00am – 10:15am** Overview & Introduction to Python
2. **10:15am – 10:45am** Coffee break
3. **10:45am – 12:00pm** Introduction to Julia

Personnel

NYU:

- Felipe Alvez
- Chase Coleman
- Pierre Mabille
- Matthew McKay
- John Stachurski

FRBNY:

- Erica Moszkowski
- Pearl Li

Aims

1. An overview and comparisons
2. Help with installation
3. Lower fixed costs to getting started

Sponsors

See

- http://quantecon.org/
- http://www.numfocus.org/

Resources

- http://quantecon.org/econometric_society_workshop.html
- entry point at bottom of http://quantecon.org

Python Set Up

Anaconda

- Python + the main scientific libraries
- Free from `http://continuum.io/downloads`
- Choose the Python 3.5 version
- Make it your default Python distribution

Explore:

- Read the docs at `https://docs.continuum.io/anaconda`
- Try starting anaconda-navigator (in a terminal or search apps)

Overview

- What's Python?
- What's Julia?
- Pros and cons
- Which to choose?

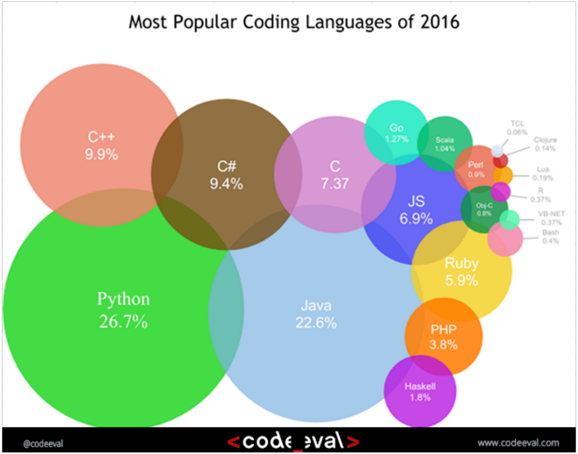
What's Python?

Modern, high level, open source, general purpose programming language

Used extensively by

- Tech firms (YouTube, Dropbox, Reddit, etc., etc.)
- Hedge funds and finance industry
- Scientists (academia, NASA, CERN, etc.)
- etc., etc.

Very popular in "data science" / machine learning


Most Popular Coding Languages of 2016
C++
9.9%
C#
9.4%
C
7.37
Go
1.27%
Scala
1.04%
Perl
0.9%
TCL
0.06%
Clojure
0.14%
Lua
0.19%
R
0.37%
Obj-C
0.8%
VB-NET
0.37%
Bash
0.4%
JS
6.9%
Ruby
5.9%
Python
26.7%
Java
22.6%
PHP
3.8%
Haskell
1.8%
@codeeval
www.codeeval.com

Strengths

- Modern design
- Clean syntax, readability
- Great libraries
- Friendly community
- High productivity

What's Julia?

Modern, high level, open source, scientific programming language

Strengths:

- Nice design
- High productivity...
- and high performance!

Julia vs Python

Who will benefit more from Julia?

- Focused on scientific programming
- Write your own algorithms
- Need optimization / high performance

Negatives

- Some instability
- Some libraries still under development

Who will benefit more from Python?

- Care about stability and high productivity
- Diverse coding needs
- Use a lot of data / empirics

Negatives:

- Optimization is a bit more work than Julia

Python/Julia vs C/Fortran

But isn't C/Fortran faster?

Not really...

And what matters is productivity

Python and Julia help us maximize productivity, so

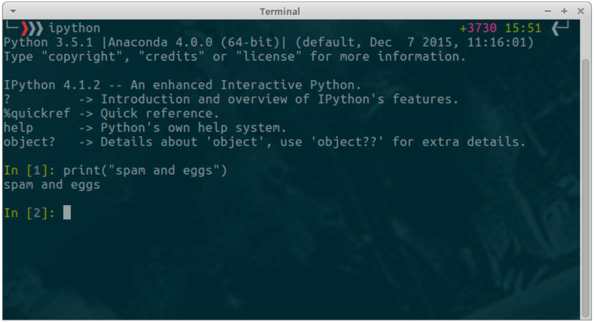
- Write your programs in Python or Julia
- Optimize your hot loops

Interacting with Python

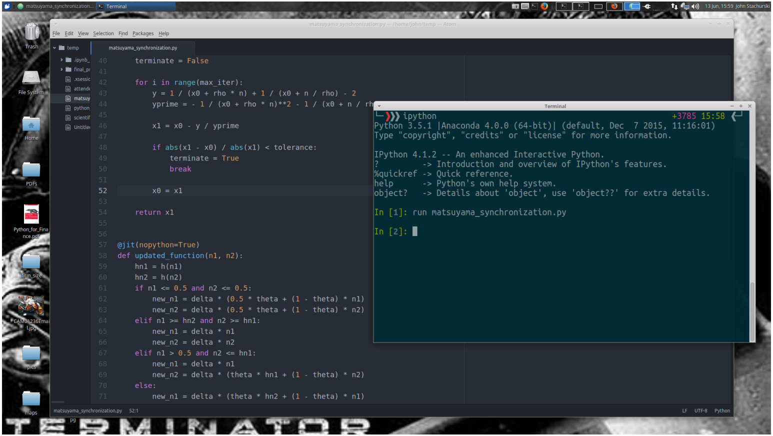
Options

- The IPython REPL
- IDEs like Spyder
- Text editor (e.g., Atom or Sublime) plus the REPL
- Jupyter notebooks

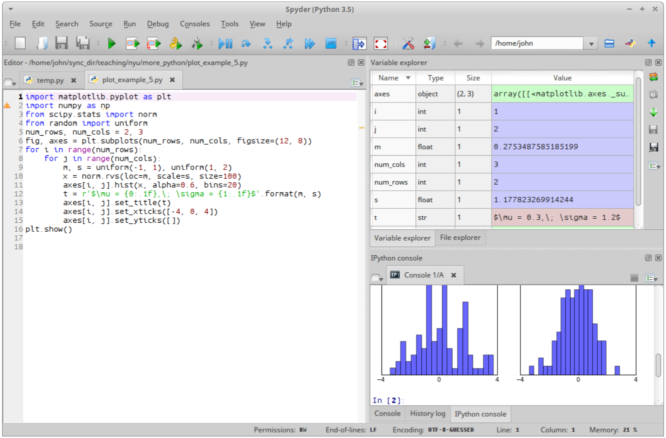
IPython REPL (Read Eval Print Loop)



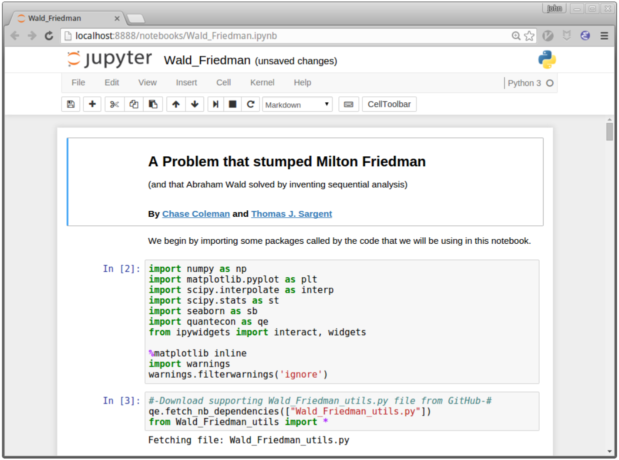
Atom text editor + IPython REPL



Spyder


Spyder (Python 3.5)
File Edit Search Source Run Debug Consoles Tools View Help
/home/john
Editor - /home/john/sync_dir/teaching/nyu/more_python/plot_example_5.py
temp.py
plot_example_5.py
import matplotlib.pyplot as plt
import numpy as np
from scipy.stats import norm
from random import uniform
num_rows, num_cols = 2, 3
fig, axes = plt.subplots(num_rows, num_cols, figsize=(12, 8))
for i in range(num_rows):
for j in range(num_cols):
m, s = uniform(-1, 1), uniform(1, 2)
x = norm.rvs(loc=m, scale=s, size=100)
axes[i, j].hist(x, alpha=0.6, bins=20)
t = r'$\mu = {0:.1f},\; \sigma = {1:.1f}$'.format(m, s)
axes[i, j].set_title(t)
axes[i, j].set_xticks([-4, 0, 4])
axes[i, j].set_yticks([])
plt.show()
Variable explorer
Name Type Size Value
axes object (2, 3) array([[<matplotlib.axes._su…
i int 1 1
j int 1 2
m float 1 0.2753487585185199
num_cols int 1 3
num_rows int 1 2
s float 1 1.177823269914244
t str 1 $\mu = 0.3,\; \sigma = 1.2$
Variable explorer File explorer
IPython console
Console 1/A
−4 0 4
−4 0 4
In [2]:
Console History log IPython console
Permissions: RW End-of-lines: LF Encoding: UTF-8-GUESSED Line: 1 Column: 1 Memory: 21 %

Jupyter notebooks



Jupyter Notebooks

Let's focus on Jupyter notebooks

- A browser based front end to Python, Julia, R, etc.
- Allows for rich text, graphics, etc.
- Easy to run remotely on servers / in cloud

References and examples:

- Ref: `http://quant-econ.net/py/getting_started.html`
- Examples: `http://notebooks.quantecon.org/`

An Easy Python Program

Next step: write and pick apart small Python program

Aim: To simulate and plot

$$\epsilon_0, \epsilon_1, \ldots, \epsilon_T \quad \text{where} \quad \{\epsilon_t\} \stackrel{\text{IID}}{\sim} N(0,1)$$

Notes

1. Like all first programs, to some extent contrived
2. We focus as much as possible on pure Python

First pass

```
import matplotlib.pyplot as plt
from random import normalvariate

ts_length = 100
epsilon_values = []
for i in range(ts_length):
    e = normalvariate(0, 1)
    epsilon_values.append(e)
plt.plot(epsilon_values, 'b-')
plt.show()
```

- http://quant-econ.net/py/python_by_example.html

Import Statements

Importing a module causes Python to

- run the code in those files
- set up a matching **namespace** to store variables

```
In [1]: import random

In [2]: random.normalvariate(0, 1)
Out[2]: 0.18415513098683509

In [3]: random.uniform(0, 1)
Out[3]: 0.11883707116624409
```

You can also just import the names directly:

```
In [4]: from random import normalvariate, uniform

In [5]: normalvariate(0, 1)
Out[5]: -0.724874290965l001

In [6]: uniform(0, 4)
Out[6]: 0.2469625165818922
```

Lists

Statement epsilon_values = [] creates an empty list

Lists: a Python data structure used to group objects

```
In [7]: x = [10, 'foo']

In [8]: type(x)
Out[8]: list
```

Note that different types of objects can be combined in a single list

Adding a value to a list:

```
In [10]: x
Out[10]: [10, 'foo']

In [11]: x.append(0.5)

In [12]: x
Out[12]: [10, 'foo', 0.5]
```

Here append() is an example of a **list method**

- a function “attached to” an object

Another example of a list method:

```
In [13]: x
Out[13]: [10, 'foo', 0.5]

In [14]: x.pop()
Out[14]: 0.5

In [15]: x
Out[15]: [10, 'foo']
```

Each data type has its own methods

```
In [1]: s = 'foobar'

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

In [3]: s.capitalize()
Out[3]: 'Foobar'

In [4]: s.upper()
Out[4]: 'FOOBAR'
```

To see all string methods, type `s.` and hit “Tab”

Loops

Consider again these lines from test_program_1.py

```
6 for i in range(ts_length):
7     e = normalvariate(0, 1)
8     epsilon_values.append(e)
9 plt.plot(epsilon_values, 'b-')
```

Lines 7–8 are the **code block** of the for loop

Reduced indentation signals end of code block

Exercise

Simulate and plot the correlated time series

$$x_{t+1} = \alpha \, x_t + \epsilon_{t+1} \quad \text{where} \quad x_0 = 0 \quad \text{and} \quad t = 0, \ldots, T$$

Here $\{\epsilon_t\} \overset{\text{IID}}{\sim} N(0,1)$

In your solution, restrict your import statements to

```
import matplotlib.pyplot as plt
from random import normalvariate
```

Set $T = 200$ and $\alpha = 0.9$

Solution

```
import matplotlib.pyplot as plt
from random import normalvariate

alpha = 0.9
ts_length = 200
current_x = 0

x_values = []
for i in range(ts_length):
    x_values.append(current_x)
    current_x = alpha * current_x + normalvariate(0, 1)
plt.plot(x_values, 'b-')
plt.show()
```