UC Berkeley Extension

Python for Data Analysis and Scientific Computing

X433.3 (2 semester units in COMPSCI)

Instructor Alexander I. Iliev, Ph.D.

Course Content Outline

- **Methods of Instruction**

  Lectures and in-class discussions will be the main tools of instruction. Homework problems will help students absorb the material and get to practice in their free time. Since this is a more specialized course that naturally delves into specific topics a midterm exam will be held to assess the performance of the students midway through the course.

- **Credit Requirements**

  Students must complete all homework assignments and pass all exams. They also must receive a passing grade on the final exam to receive a passing grade in the course.

- **Course Grade Weighting**

  1. In-class participation: 10%
  2. Homework: 20% - Wednesdays - use the weekend to prepare
  3. Midterm 30% - Monday - use the weekend to prepare
  4. Final Project 40% - Wednesday

- **Optional Reading for the Course**

  Title: Python for Data Analysis

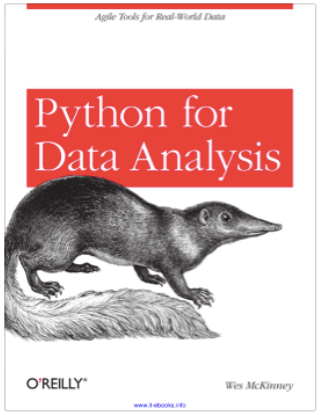
  ISBN-10: 1449319793 and ISBN-13: 978-1449319793

  Author(s): Wes McKinney

  Publisher: O'Reilly Media

  Edition Number: 1 edition

  Publication Date: November 1, 2012



Course Content Outline

- **Python for Data Analysis and Scientific Computing®**
- Python - pros and cons
- Installing the environment with core packages
- Python modules, packages and scientific blocks
- Working with the shell, IPyton and the editor HW1

- **Basic language specifics 1/2**
- Basic arithmetic operations, assignment operators, data types, containers
- Iterative programming (if/elif/else)
- Conditional expressions
- Recursion programming (for/continue/while/break)
- Functions: definition, return values, local vs. global variables

- **Basic language specifics 2/2**
- Functions (cont.): objects, methods, passing by value and reference
- Scripts, modules, packages
- I/O interaction with files
- Standard library
- Exceptions

- **NumPy 1/3**
- Why NumPy?
- Data type objects
- NumPy arrays
- Indexing and slicing of arrays

- **Matplotlib**
- What is Matplotlib?
- Basic plotting
- Tools: title, labels, legend, axis, points, subplots, etc.
- Advanced plotting: scatter, pie, bar, 3D plots, etc.

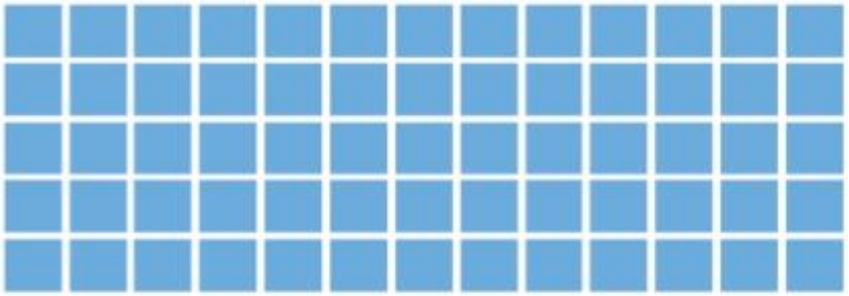
Data

- The world's digital content and media is growing rapidly at a never stopping rate

90% of the data in the world today has been created in the last two years alone, at 2.5 quintillion bytes of data a day

report from IBM Marketing Cloud in 2017

Data



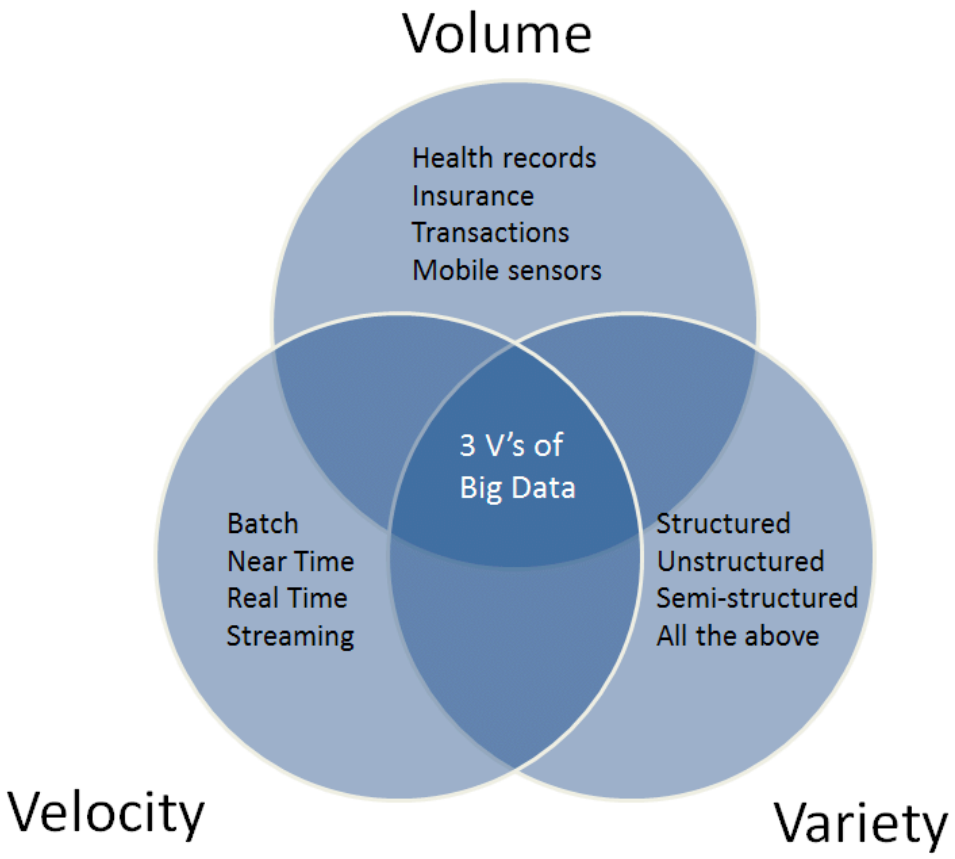
Structured Data

Unstructured Data

Graphical representations illustrate the difference between structured and unstructured data

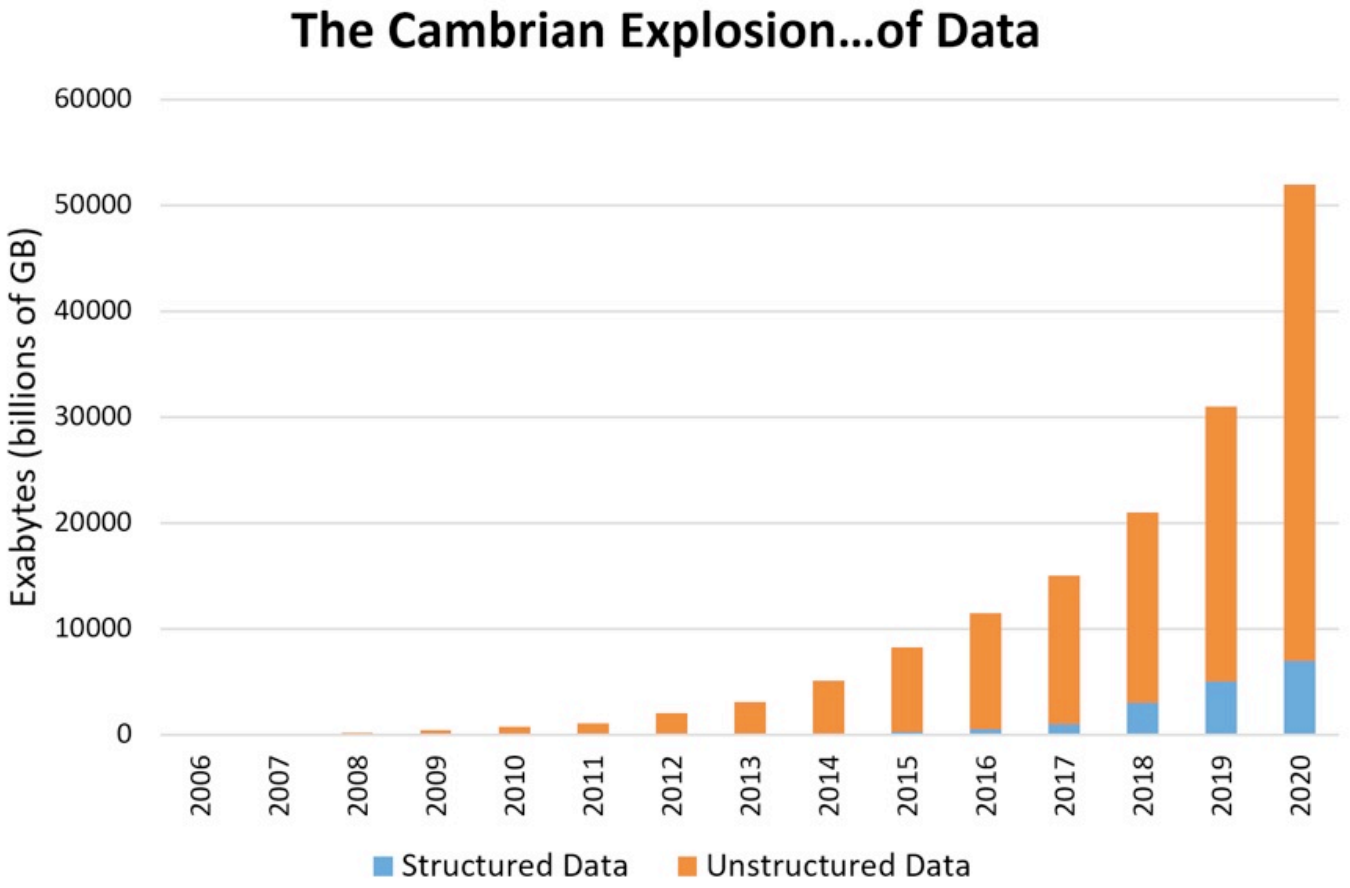
Source: https://www.eetimes.com/ and Sherpa Software

Big Data



Variability, Veracity, and Value

Data



Source: https://www.eetimes.com/

Data

Multiplying Factor	SI Prefix	Scientific Notation	Name
1 000 000 000 000 000 000 000 000	Yotta (Y)	10^{24}	1 septillion
1 000 000 000 000 000 000 000	Zetta (Z)	10^{21}	1 sextillion
1 000 000 000 000 000 000	Exa (E)	10^{18}	1 quintillion
1 000 000 000 000 000	Peta (P)	10^{15}	1 quadrillion
1 000 000 000 000	Tera (T)	10^{12}	1 trillion
1 000 000 000	Giga (G)	10^{9}	1 billion
1 000 000	Mega (M)	10^{6}	1 million
1 000	kilo (k)	10^{3}	1 thousand
0 001	milli (m)	10^{-3}	1 thousandth
0 000 001	micro (u)	10^{-6}	1 millionth
0 000 000 001	nano (n)	10^{-9}	1 billionth
0 000 000 000 001	pico (p)	10^{-12}	1 trillionth
0 000 000 000 000 001	femto (f)	10^{-15}	1 quadrillionth
0 000 000 000 000 000 001	atto (a)	10^{-18}	1 quintillionth
0 000 000 000 000 000 000 001	zepto (z)	10^{-21}	1 sextillionth
0 000 000 000 000 000 000 000 001	yocto (y)	10^{-24}	1 septillionth

Metric prefixes defined at the 19th General Conference on Weights and Measures in 1991

Source: https://www.eetimes.com/

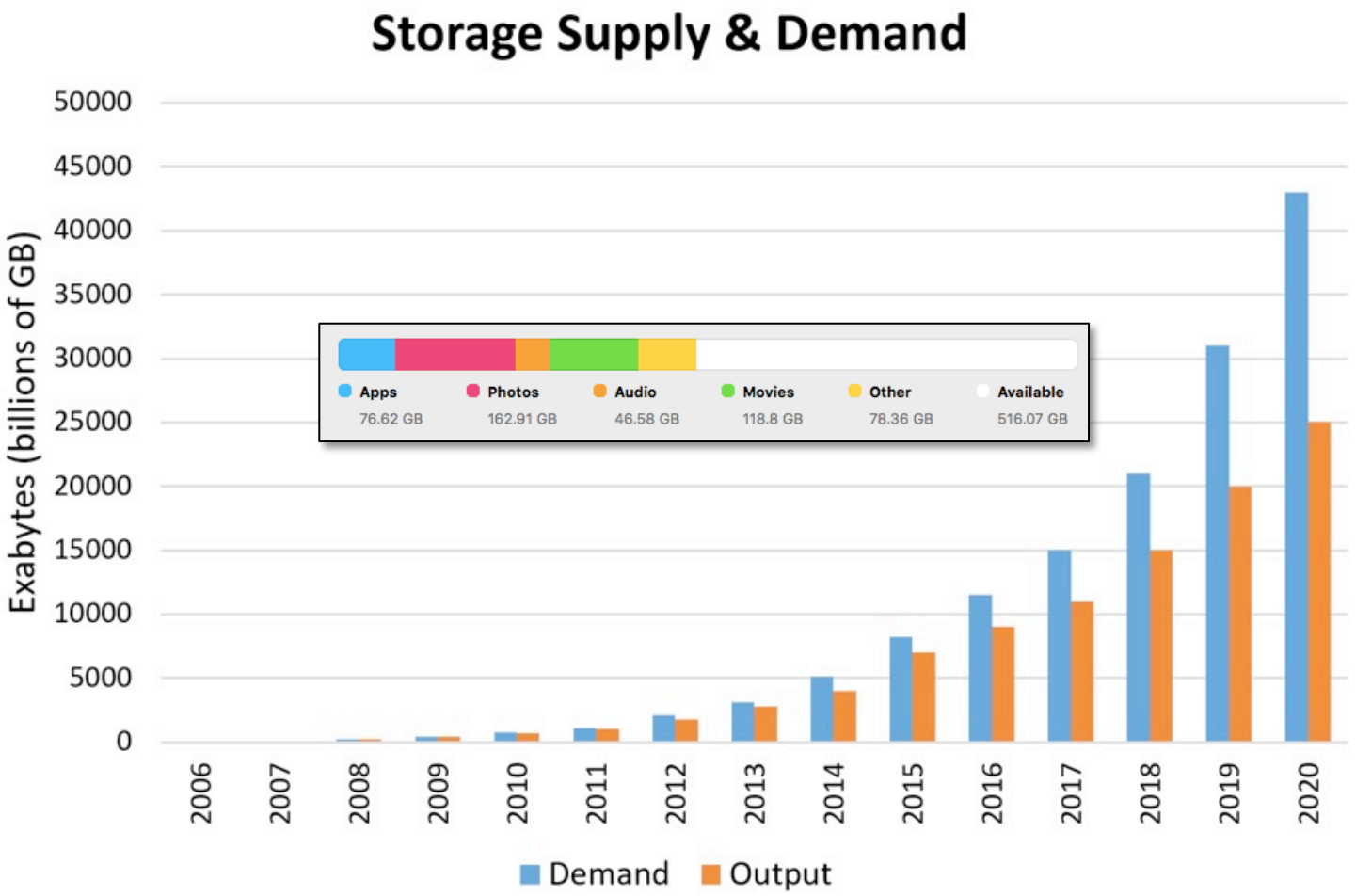
Data

Multiplying Factor	SI Prefix	Scientific Notation	Name
1 208 925 819 614 629 174 706 176	Yottabytes	2^{80}	1 septillion
1 180 591 620 717 411 303 424	Zettabytes	2^{70}	1 sextillion
1 152 921 504 606 846 976	Exabytes	2^{60}	1 quintillion
1 125 899 906 842 624	Petabytes	2^{50}	1 quadrillion
1 099 511 627 776	Terabytes	2^{40}	1 trillion
1 073 741 824	Gigabytes	2^{30}	1 billion
1 048 576	Megabytes	2^{20}	1 million
1 024	kilobytes	2^{10}	1 thousand

Examples of prefixes used to measure digital data with a binary system

Source: https://www.eetimes.com/

Data

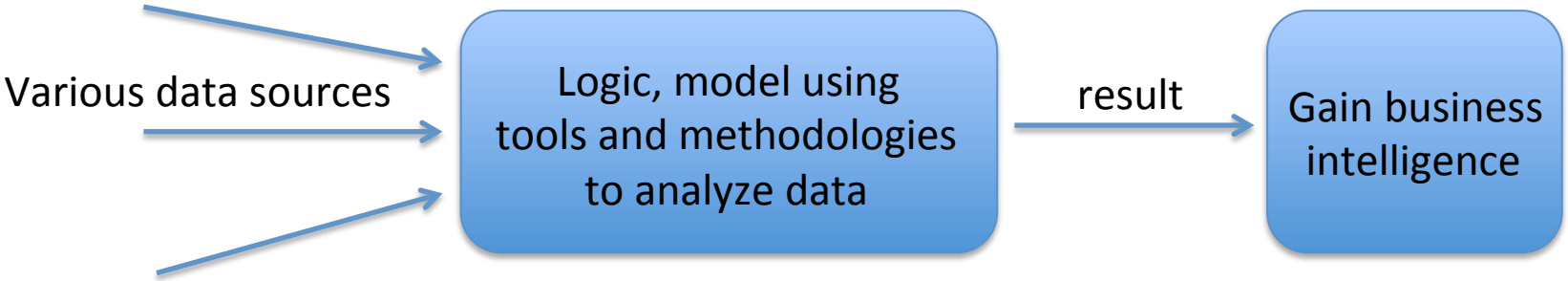


Storage supply and demand growth over two decades

Source: https://www.eetimes.com/

Why using Data Analytics?

- To solve complex scientific or business tasks
- Using complex data from various sources
- Using tools and methods to extract meaningful scientific or business insights



Data Analytics vs Data Analysis

- Data analytics is a broader field, which includes data analysis as part of its core
- Data analytics defines the methodology used behind the analysis
- Methodology means to comprehend the cognitive processes that are used in order to understand any given problem and explore data in logical fashion
- Data analytics also includes:
  - data collection, creation and extraction;
  - transformation using specific tool sets and techniques;
  - different methods for analysis;
  - communication of results.

The Problem

The Problem

- Example: Facebook 
  - Over 2 billion active users worldwide generate enormous amounts of user data
  - Every 60 seconds there are:
    - 136,000 photos are uploaded
    - 510,000 comments are posted
    - 283,000 status updates are made
  - lots of unstructured data (audio, photos, videos)

Data Analysis

- What is it?

Data analysis, is a process of inspecting, cleansing, transforming, and modeling data with the goal of discovering useful information, suggesting conclusions, and supporting decision-making.

source: Wikipedia

Data Analysis

- How does it work?
  - First user data is collected
  - Then user behavior is studied
  - Data is packaged for advertisers
  - Enhance useful functionality (ex. shopping) and gather even more data from users (habits, preferences, etc.)

Why using Data Analytics?

- Data can be very noisy and hard to use

Types of Data Analytics

- Descriptive data analytics studies data based on previous samples
  (what happened?)
- Diagnostic data analytics studies the reasons and isolates the problem
  (why it happened?)
- Predictive data analytics predicts the possible future outcome using statistical modeling
  (what might happen?)
- Prescriptive data analytics makes logical decisions to suggest best course of action
  (what to do?)

Planning your strategy

- Problem analysis to mitigate risks
- Create your action plan
- Effort estimation
- Visualize and organize the results
- Creating business logic
- Report the results to leadership using analysis for:
  - various approach
  - different cost
  - benefits for each case

More about the data…

- Is the data available?
- How do we access it?
- How big is the data?
- What type(s) of data is it?

- How good is the source of data?
- What is the scope (local vs global)?
- How frequently is collected?
- … more

More about the data…

- Plan ahead how to work with the data:
  - Collect it
  - Store it (is possible)
  - Study the dataset
  - Prepare and clean it
  - Analyze it
  - Organize and visualize it
  - Make conclusions about the data
  - Analyze small pieces more often than wait and process the entire dataset. It just might be too late!

More about the data…

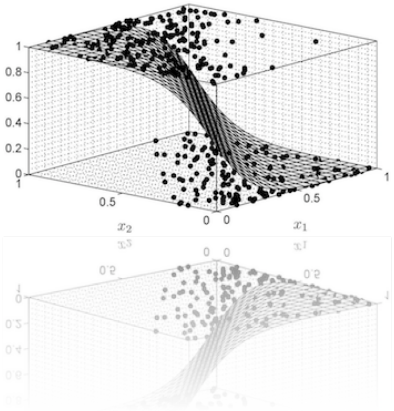
- Create and keep data dictionary containing:
  - databases
  - tables
  - fields
  - keys
  - schemas
  - data types
  - scope (local vs. global)
  - how it was loaded (using web services or ingested)
  - frequency (how often was the data collected?)

Case study

- Example 1:

data source

statistical modeling



tailored offering

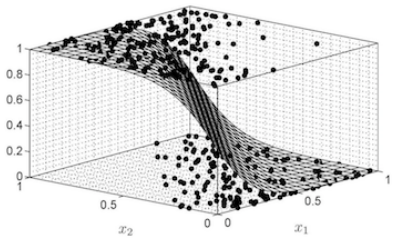
Case study

- Example 2:

Netflix

user preferences

data analysis



Result: 3,000,000 new subscribers,
who paid back the show cost !!!

The Excel power user

- Using Microsoft Excel spreadsheets containing data for analysis

Pros

- Most business will use this method because it is easy
- It is affordable
- It is versatile as can be applied quickly

Cons

- It provides a very limited toolset for analyzing and visualizing data
- Not for large and complex datasets

Python for Data Analysis and Scientific Computing

- Python implementation started in 1989 by Guido Van Rossum
- Python intended to be the successor of the ABC language
- Python 2.0 released in late 2000
- Python 3.0 released in late 2008 and was mostly incompatible with its predecessor
- EOL for Python 2.7 was initially set at 2015, but postponed to 2020
- Google announced to work on a transcompiler for Python 2.7 – Jan.2017

Python for Data Analysis and Scientific Computing

- Python comparison to Java:
  - Dynamic vs static typing
  - Braces vs indentation
  - Speed and portability
  - Interpreted vs compiled

Python for Data Analysis and Scientific Computing

- Python with NumPy and SciPy – why using it?
  - Because you can develop proof-of-concept solutions fairly easily and free
  - Open-source software that is widely spread
  - Fast development time
  - Many scientific libraries
  - Mobile computing for smartphone development by using Kivy for Android and iOS
  - Web-site incorporation by using Django

Python for Data Analysis and Scientific Computing

- Python – pros and cons:

  Pros

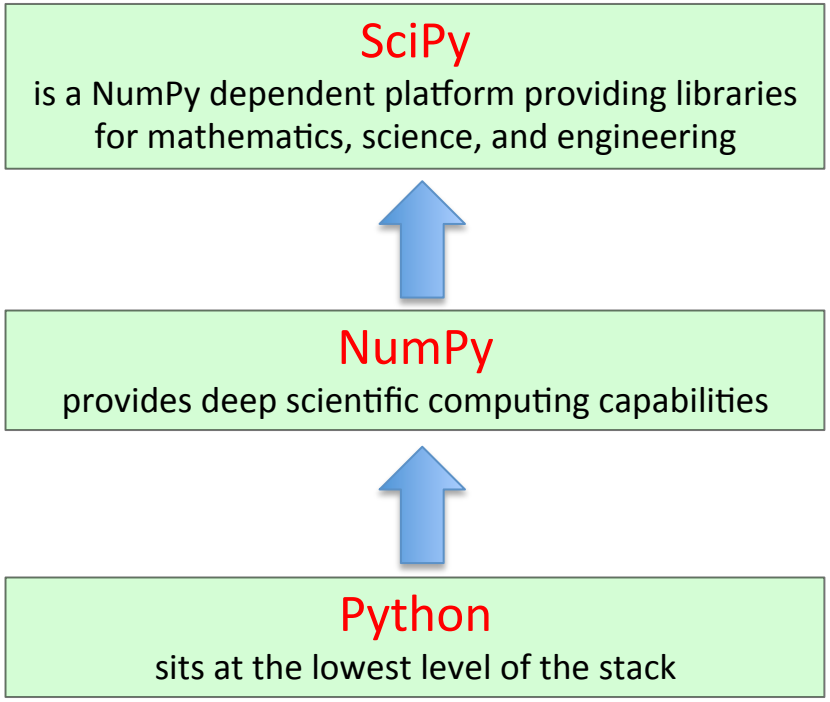
  - High-level object-oriented language that is easy to learn
  - Good readability of the code
  - Quick development time
  - Rich scientific libraries and many others like web server management, serial port access, etc.
  - Easy to share and communicate results
  - Easy to read, manipulate and process data
  - A single environment for many tasks. No need to learn another language
  - Free and open-source software that is widely spread

  Cons

  - Speed of execution since it is higher level language
  - Mobile computing for smartphone development (unless you use Kivy: Linux, Windows, OS X, Android and iOS)
  - It is not included in Web browsers, because it is hard to secure
  - Design flows because it is dynamically typed language and some errors show at runtime such as syntactic errors (mistyping variable names)
  - Python can be both interpreted (.py) and compiled (.pyc)
  - Documentation isn't at the level of PHP or Java
  - Not all algorithms found in other specialized platforms or toolboxes (Matlab) are available

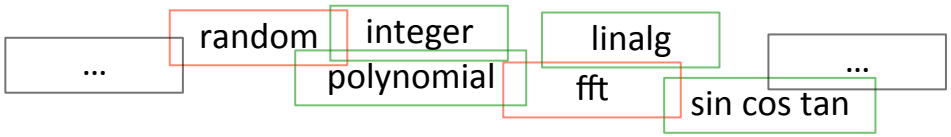
Python for Data Analysis and Scientific Computing

- Basic stack using NumPy and SciPy for Python:



Python for Data Analysis and Scientific Computing

- Python + NumPy
  - … is like Matlab
  - NumPy provides the code for any fundamental data structure:



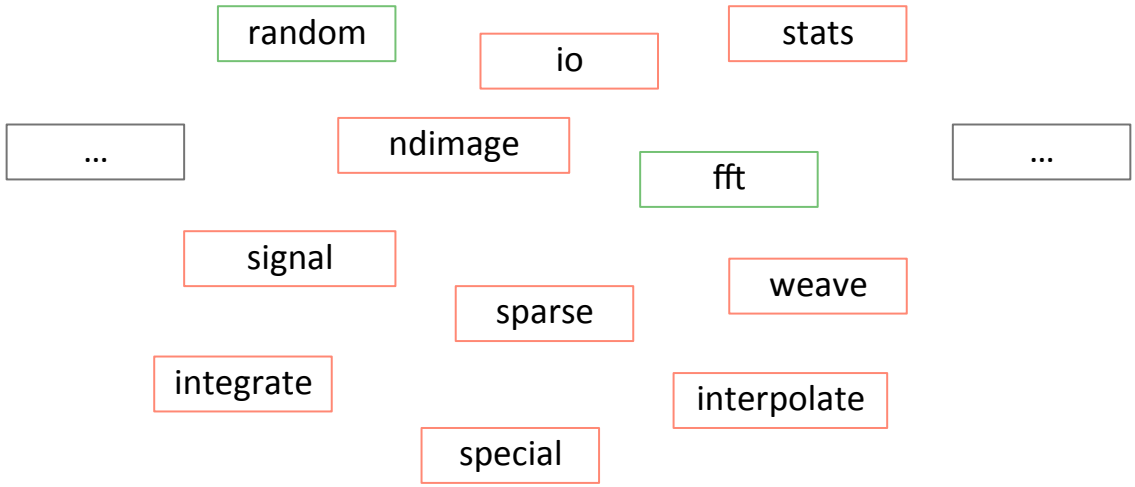
  - There two basic data structures in NumPy:

NDArray
- is an N-dimensional array type
- describes a collection of "items" of the same type
- the items are indexed using N integers

UFunc
- provides fast operations on arrays
- operates element-by-element on arrays
- example are: *sin, cos, tan, +, -, etc.*

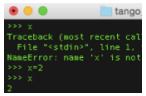
Python for Data Analysis and Scientific Computing

- Python + NumPy + SciPy
  - … is like Matlab + toolboxes
  - SciPy provides many specialized packages, which makes it very competitive and powerful platform



Python for Data Analysis and Scientific Computing

- Choosing your environment:
  - Using the shell (primarily for Linux and OSX users):



    - Obtaining Python with core packages:
      https://www.python.org/downloads/
    - Obtaining the NumPy & SciPy libraries:
      http://www.scipy.org/scipylib/download.html
  - GUI environments using an interactive editor and debuggers for Python:

IP[y]:

    - IPython – a GUI environment for interactive Python use with shells (terminal- and Qt-based):
      http://www.ipython.org/

    - Python(x,y) – free scientific and engineering environment for numerical computations, data analysis and data visualization:

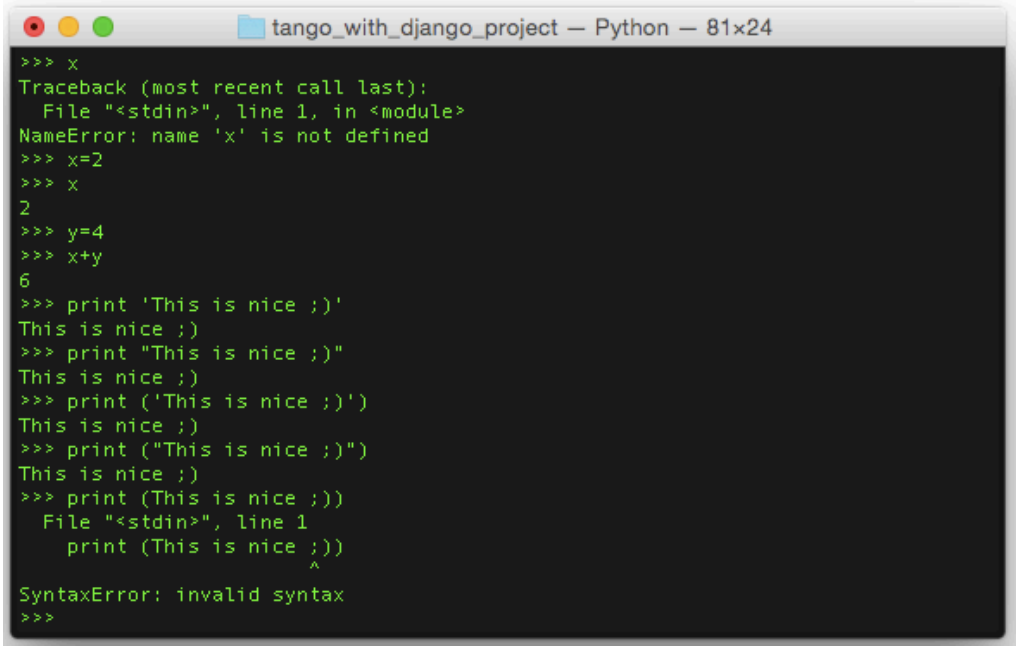
    - Canopy – Python based environment providing core scientific analytic and scientific Python packages, for scientific development and visualization:
      https://store.enthought.com/

    - IEP – Interactive Editor for Python, is an interactive cross-platform Python IDE that is simple and efficient. IEP consists of an **editor**, a **shell**, and a set of **tools** to help the developer
      http://www.iep-project.org/

    - Pyzo – a free open-source environment based on Python:
      http://www.pyzo.org/downloads.html
    - … other

Python for Data Analysis and Scientific Computing

- Working with the shell
  - The shell:
    - present on OSX, Unix and Linux systems
    - provides a quick and easy to use plain text environment for swift execution of simple commands
    - it is flexible and lightweight
    - it has a Unix/Linux look and feel and is not used only for Python and it's packages and modules



Python for Data Analysis and Scientific Computing

- Using the shell (linux and OSX users):
  - Using 'pip': a tool for installing Python packages from the Python Package Index
    - In your terminal type:

      $ sudo easy_install pip

      $ sudo pip install --upgrade pip
    - Then you can install python and some packages:

      $ pip install python

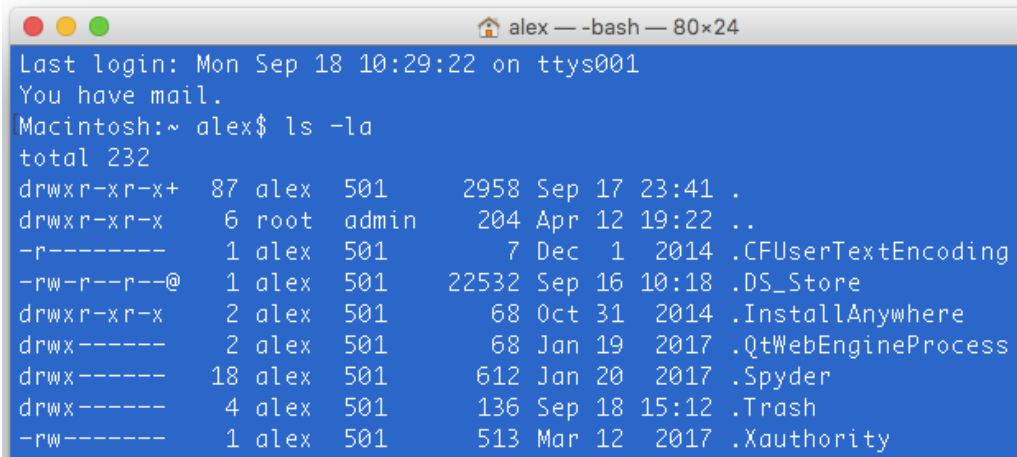
      $ pip install numpy

      $ pip install scipy

      $ pip install matplotlib

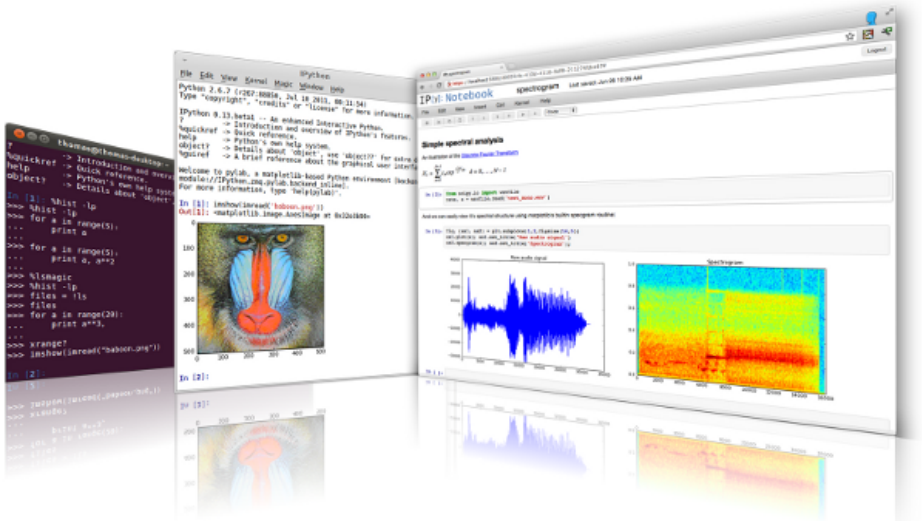
      $ pip install django

** a side note on permissions and ownership:*



Python for Data Analysis and Scientific Computing

- Working with IPyton
  - IPython
    - Is a GUI environment for interactive Python use with shells (terminal- and Qt-based) and these key features:
      - Interpreters that can be embedded into users' custom projects
      - It has a build-in web-based interactive notebook environment with complete set of shell features and support for embedded figures, animations and multimedia
      - Use of GUI toolkits and support for interactive data visualization
      - A high-performance library for parallel computing portable to multicore systems, clusters and cloud computing



Python for Data Analysis and Scientific Computing

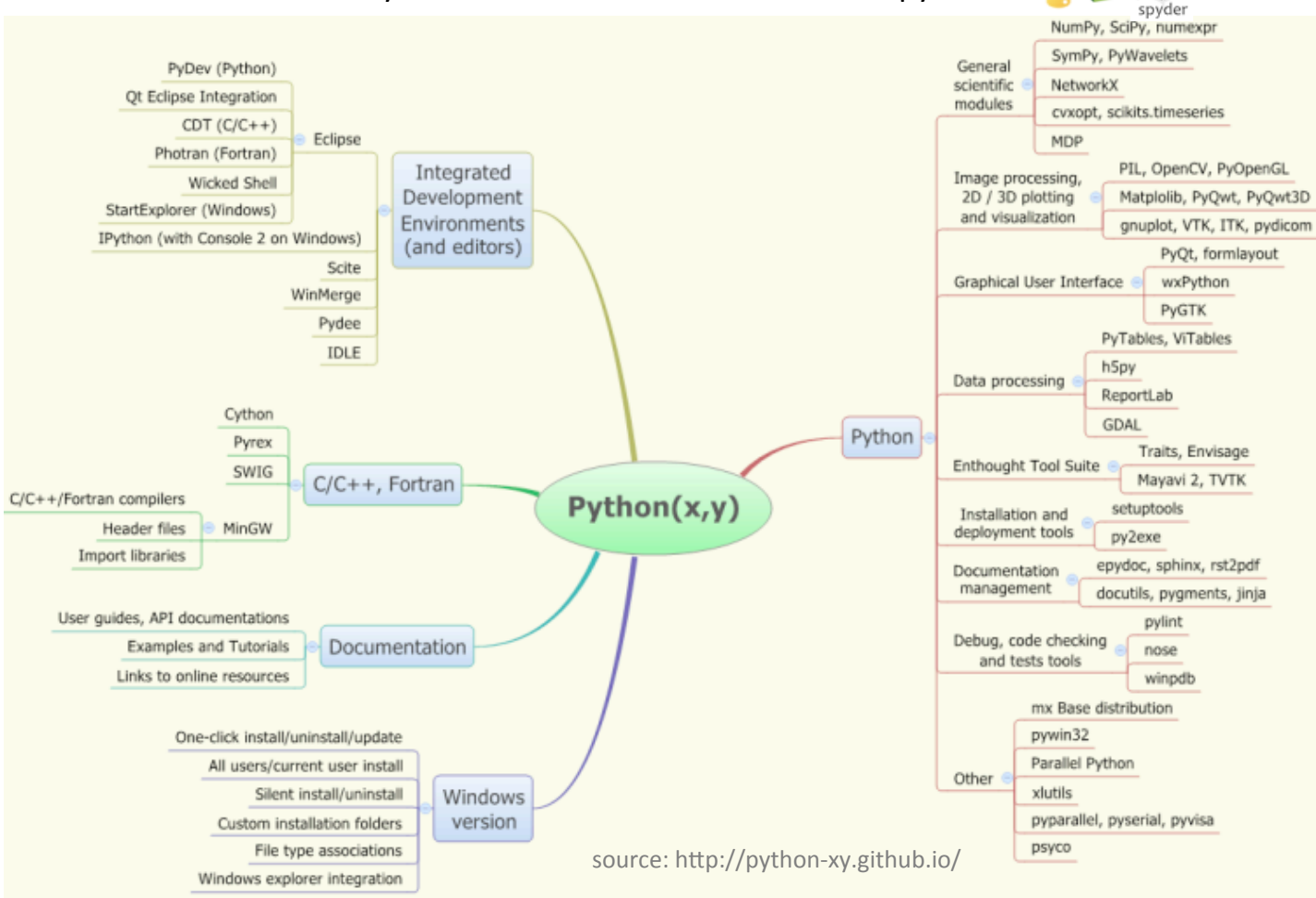
- Working with IPyton and the editor
  - IPython and the editor
    - History, persistent across sessions
    - Caching of output results during a session
    - Extensible tab completion, with support by default for completion of python variables and keywords, filenames and function keywords
    - Comprehensive system of 'magic' commands for controlling the environment and performing many tasks related either to IPython or the operating system
    - A rich configuration system with easy switching between different setup
    - System shell access with user-extensible alias setup
    - Session logging and reloading
    - Code is easy to embed and use in other Python programs and GUIs
    - Embedded debugger

Python for Data Analysis and Scientific Computing

- Working with alternative environments:
  - Python(x,y) – a free scientific-oriented Python Distribution based on Qt and Spyder –

It offers:

- object-oriented prog.
- MATLAB-like syntax
- parallel computing
- 2D & 3D plotting
- any level coding



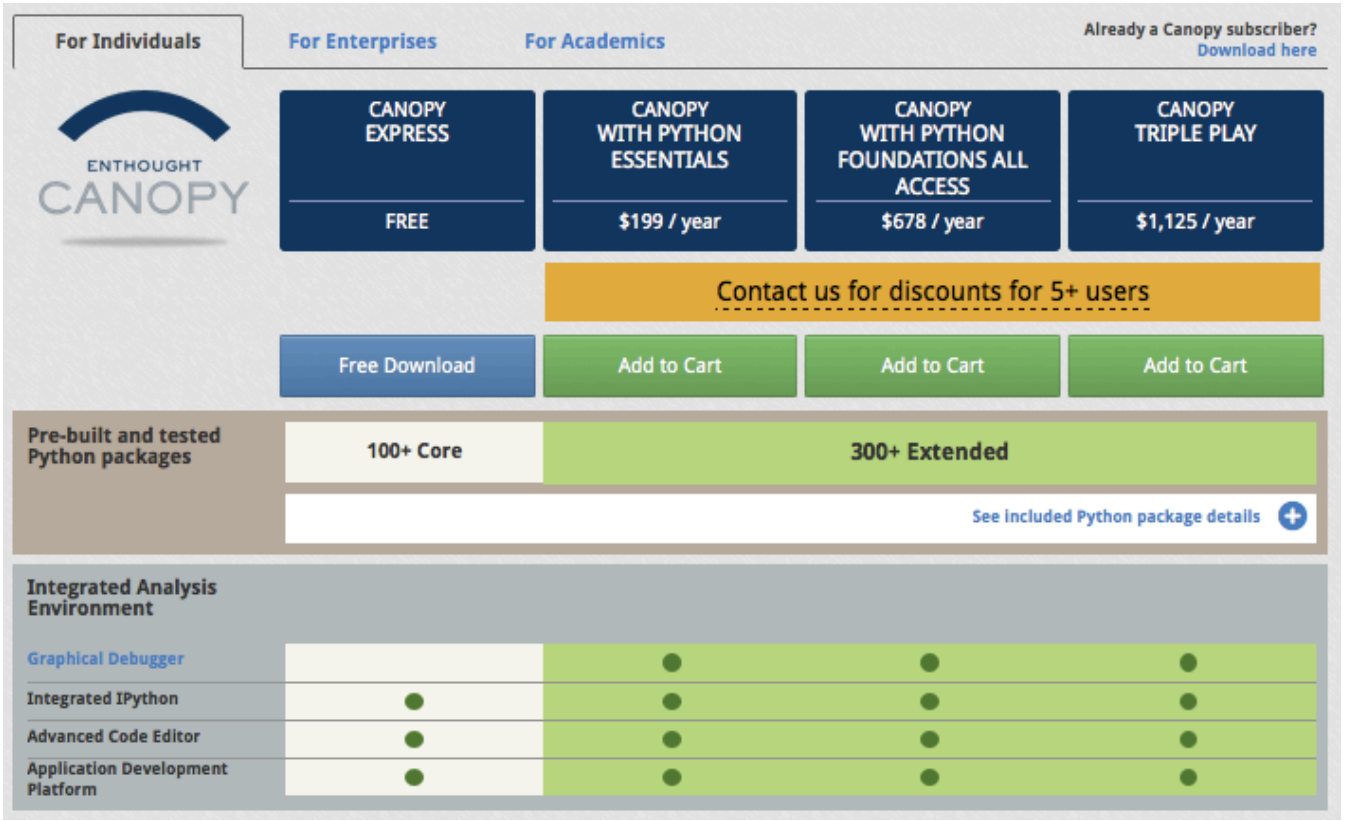
source: http://python-xy.github.io/

Python for Data Analysis and Scientific Computing

- Working with alternative environments:
  - Canopy – scientific and analytic Python package distribution. has a free version, but limited

It offers:

- object-oriented prog.
- MATLAB-like syntax
- many packages
- graphical debugger is NOT free



Python for Data Analysis and Scientific Computing

- Working with alternative environments:
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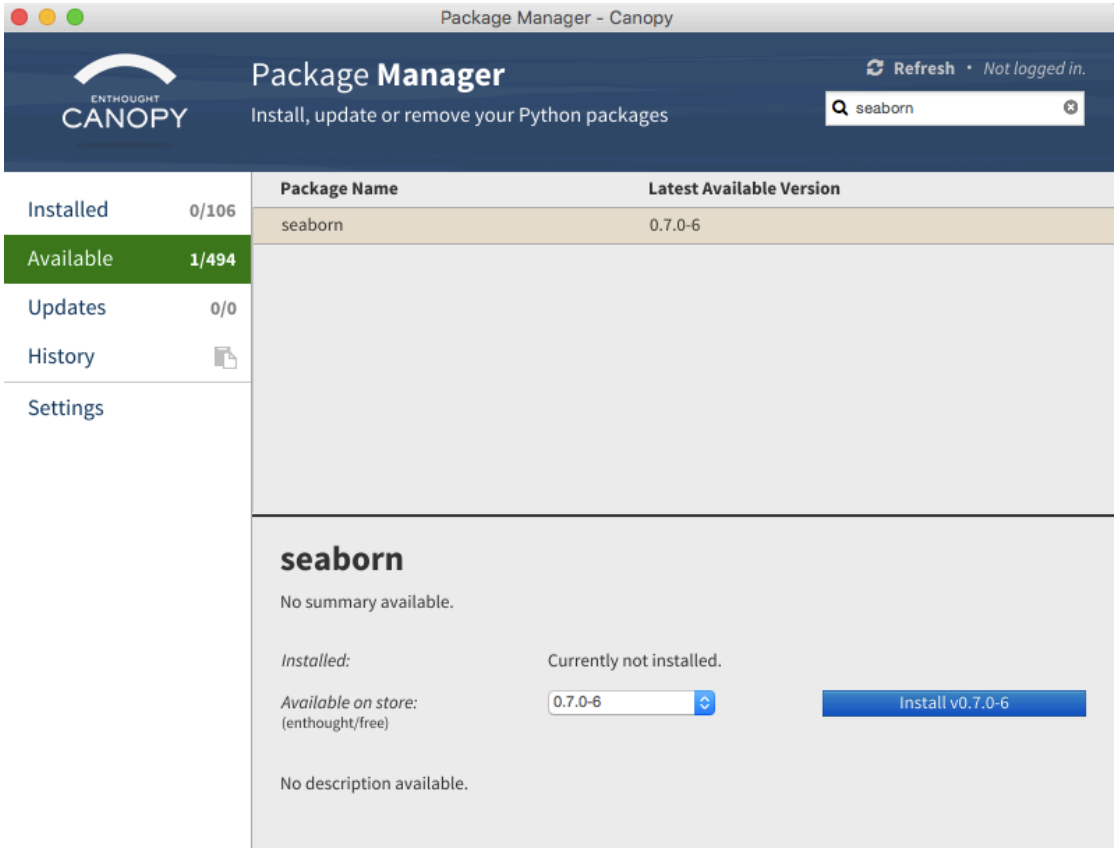
Package Manager:

- Packages are installed through Package Manager

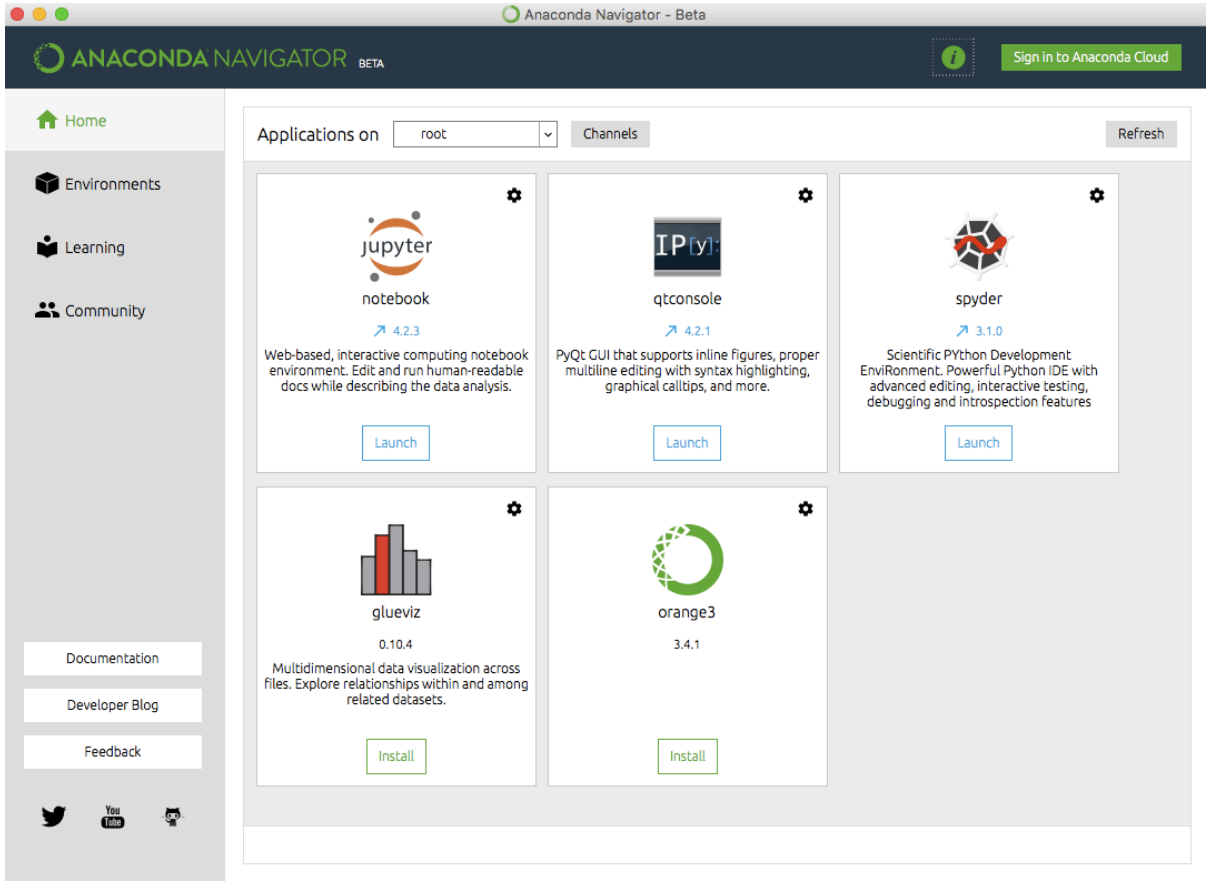


Python for Data Analysis and Scientific Computing

- Working with alternative environments:
  - Anaconda Navigator

Available are:

- Jupyter Notebook
- IP[y] qtconsole
- Spyder
- glueviz



Python for Data Analysis and Scientific Computing

- Working with alternative environments:
  - Anaconda Navigator

Available are:

- Jupyter Notebook
- IP[y] qtconsole
- Spyder
- glueviz

- **Jupyter**: is also available in Canopy: it is a web-based interactive computing notebook environment. Easy to read and describe the data analysis

- **IP[y] qtconsole**: is a PyQt based GUI working with various figures and plots among other editing features

- **Spyder**: is for scientific python development with interactive testing env and debugging features. It can be installed independently in some platforms such as Linux

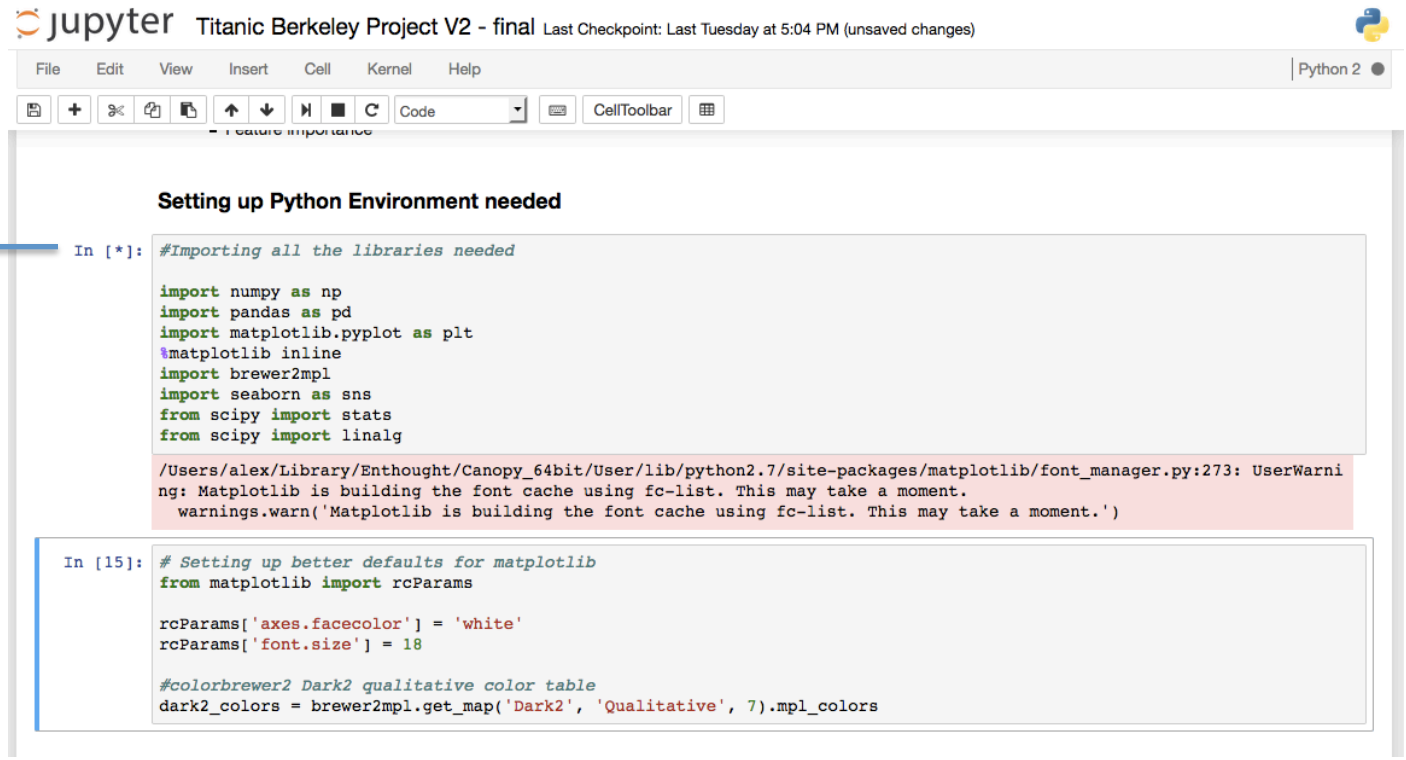
- **glueviz**: n-dimensional data visualization using multiple files. View the relationships among multiple datasets

Python for Data Analysis and Scientific Computing

- Working with alternative environments:
  - Canopy – scientific and analytic Python package distribution. has a free version, but limited

Using the browser

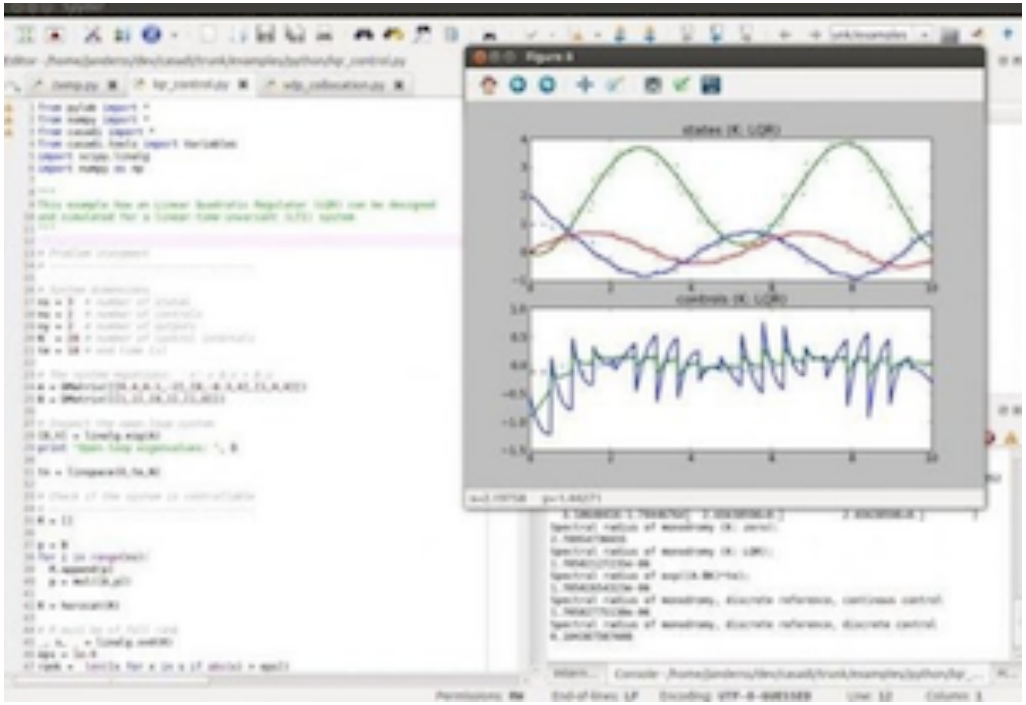
- [*] the line is in a process of executing
- Execute your code sequentially using Shift+Enter



source: https://store.enthought.com/

Python for Data Analysis and Scientific Computing

- Working with alternative environments:
  - Spider …
    - ***Spider*** is a free Open-source

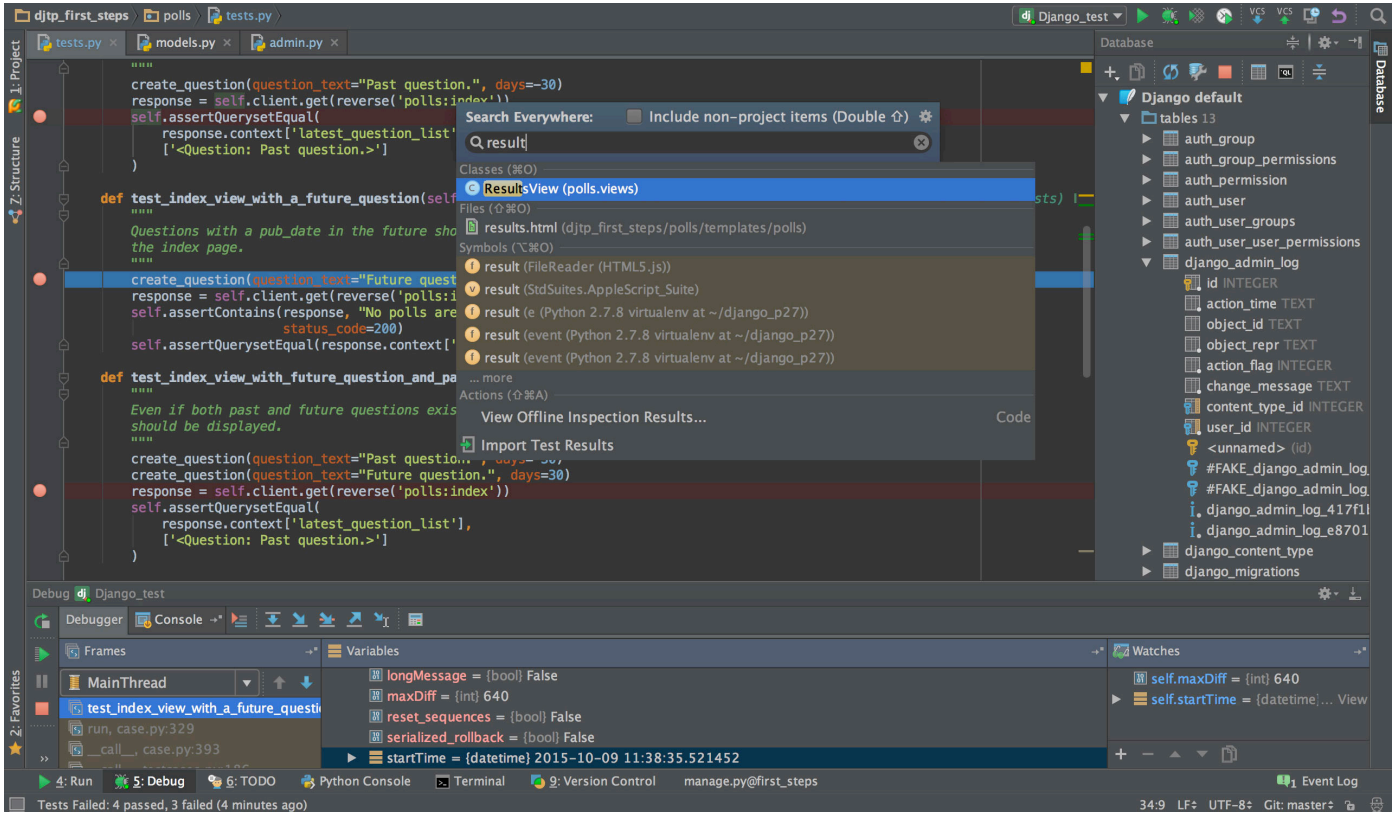


Python for Data Analysis and Scientific Computing

- Working with alternative environments:
  - Pycharm – scientific and analytic Python package distribution. has a free version, but limited

It offers:

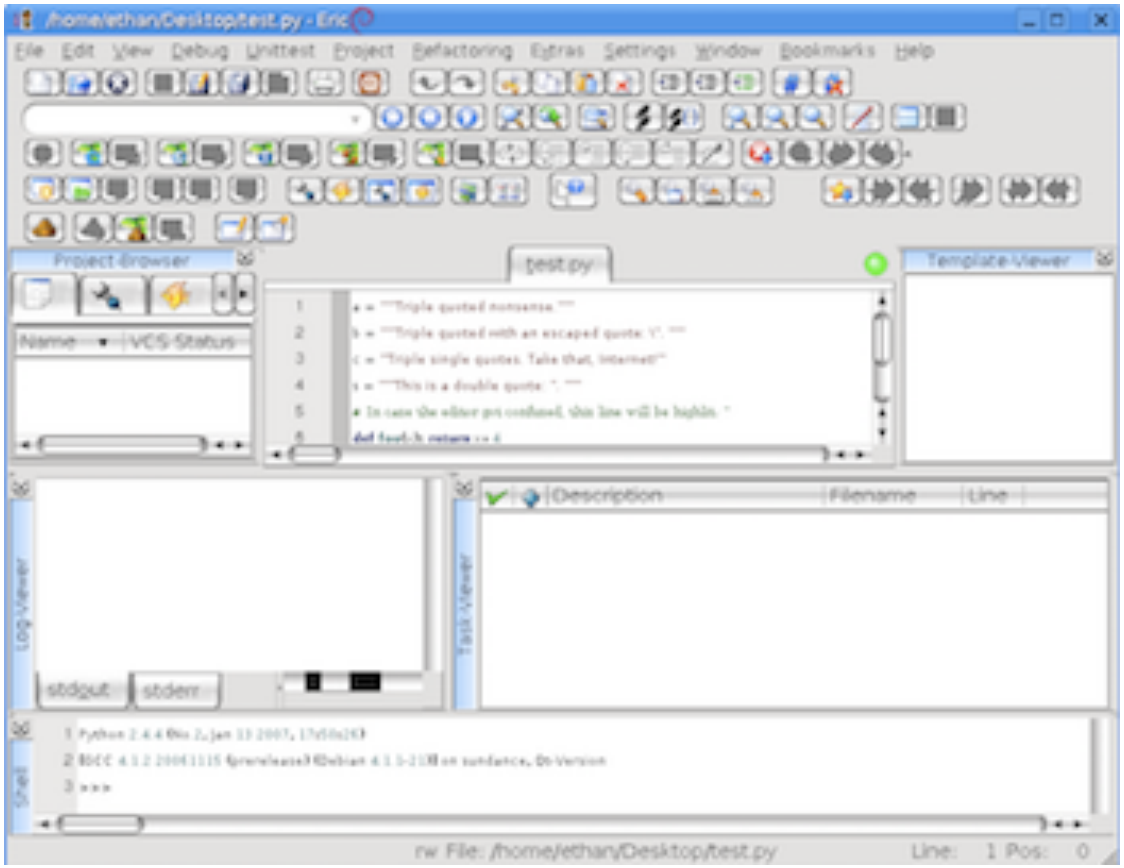
- object-oriented prog.
- save time by auto completing the routines
- on-the-fly error checking
- focus on bigger picture
- many features
- many packages



source: https://www.jetbrains.com/pycharm/

Python for Data Analysis and Scientific Computing

- Working with alternative environments:
  - Eric …
    - ***Eric*** is a free Open-source



Python for Data Analysis and Scientific Computing

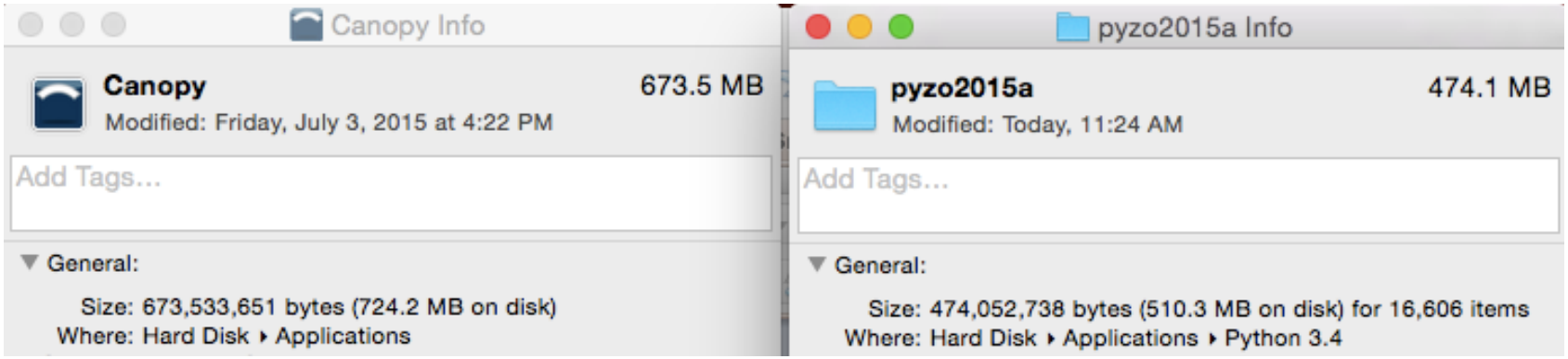
- Working with alternative environments:
  - Pyzo … what?

PYZO: PYTHON TO THE PEOPLE

    - ***Pyzo*** is a free Open-source BSD-licensed
    - It is an easy to use GUI computing environment based on Python 3
    - It is built to make Python's potential for scientific and engineering computing to be easily accessible
    - Pizo is combined with IEP to make a powerful easy to use comprehensive environment for scientific computing and visualization
    - Pyzo is a comprehensive development environment pre-built with:
      - many scientific packages including NumPy, SciPy and Matplotlib
      - uses IEP as the front-end IDE
      - IPython and a notebook
    - Complete packages for Pyzo are given here: http://www.pyzo.org/packages.html

Python for Data Analysis and Scientific Computing

- Working with alternative environments:
  - Pyzo takes less space than Canopy (without Canopy debugger installed)



Python for Data Analysis and Scientific Computing

- Python packages for data analysis:

  - **NumPy**: provides fast precompiled functions for numerical routines, large n-dimensional arrays, and matrices, as well as high-level mathematical functions to operate on these arrays

  - **SciPy**: provides scientific, technical, and deep analytical computing functionality and contains modules for statistics, optimization, linear algebra, integration, interpolation, and plenty more

  - **Matplotlib**: is a plotting library used by NumPy that provides the ability to embed plots into applications using GUI toolkits like wxPython, Qt, or GTK+

  - **Pandas**: offers data structures and manipulation and analysis of numerical tables

Python for Data Analysis and Scientific Computing

- Python packages for data analysis:

  - **Scikit-learn**: contains various algorithms for classification, regression and clustering such as: naive Bayes, SVM, logistic regression, random forests, gradient boosting, k-means and DBSCAN. It is designed to use the scientific libraries NumPy and SciPy

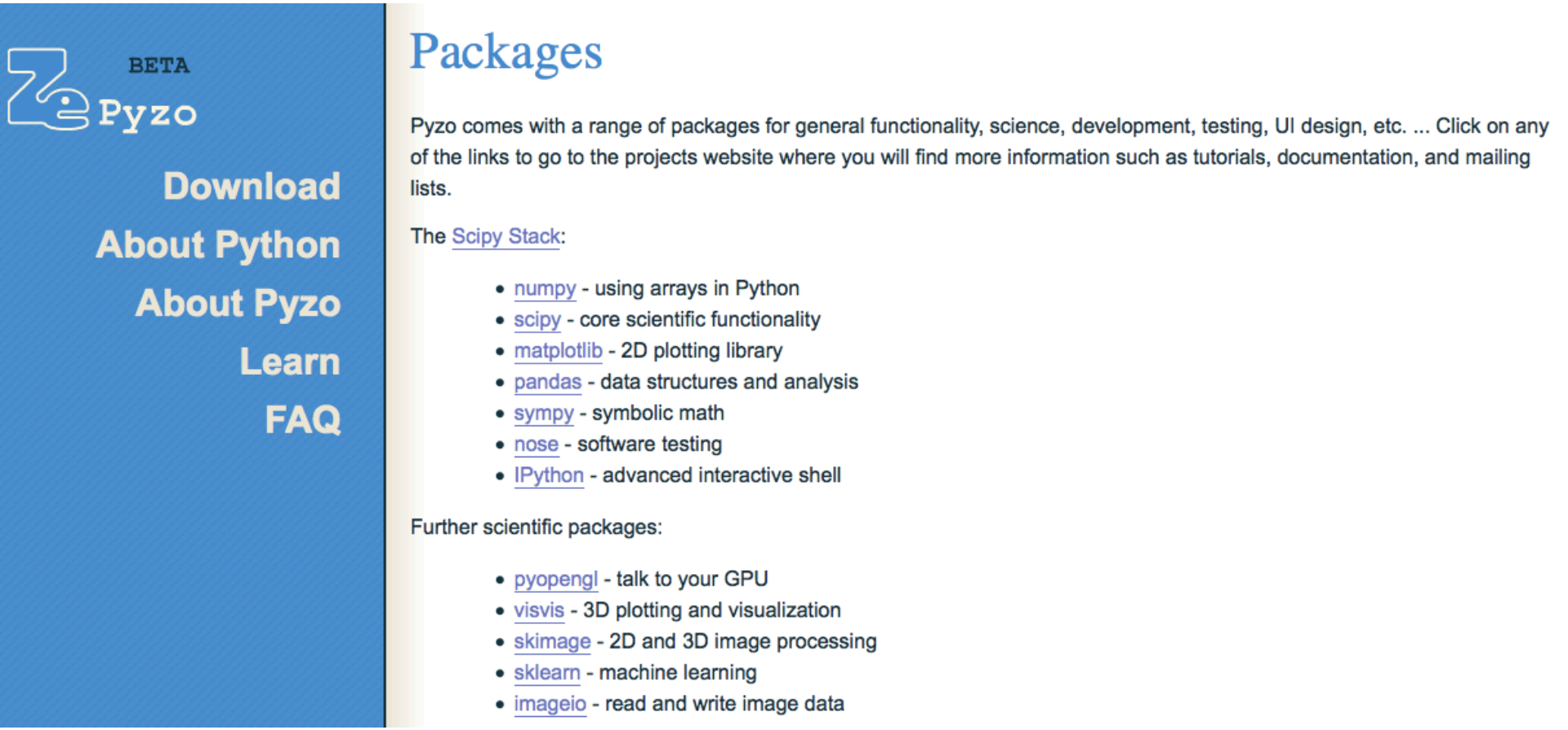
  - **Theano**: with Theano you can define, evaluate, and optimize mathematical expressions applied to n-dimensional arrays

  - **Statsmodels**: provides statistical models, statistical tests, plotting functions, and descriptive statistics, while working with different types of data

  - **Other**: Mlpy, NLTK, Keras, PyBrain, Hebel, nolearn, Orange

Python for Data Analysis and Scientific Computing

- Working with Pyzo



source: http://www.pyzo.org/packages.html#packages

Python for Data Analysis and Scientific Computing

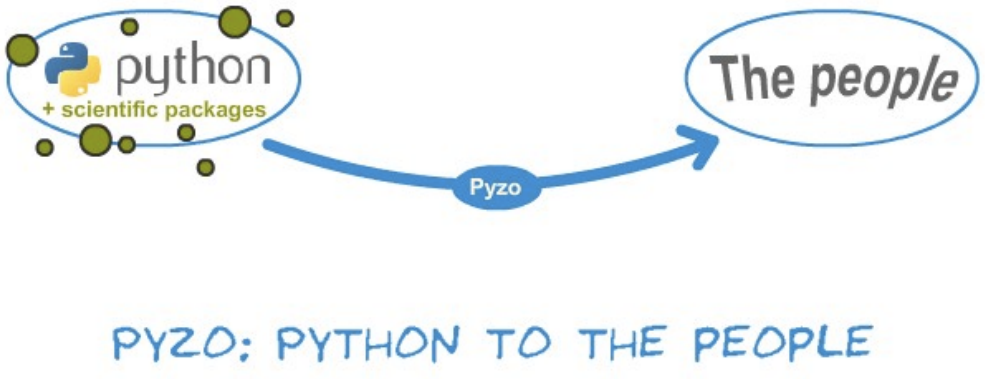
- Working with Pyzo
  - Useful magic commands:

Linux-like:

- pwd
- ls
- mkdir
- rmdir
- whos
- dir()
- cd
- history

Python IEP/Pyzo specific:

- edit *file*
- del(parameter)
- reset
- reset -f
- run *file*
- time
- colors (nocolor,linux,lightbg)
- dhist



Tip: Using a magic command followed by '?' will give you help for it. Example: 'cd?'

magic comprehensive list: http://ipython.org/ipython-doc/3/interactive/magics.html

Python for Data Analysis and Scientific Computing

- How to check your packages? .. (In your interactive editor - I use Pyzo)

```
In [3]: import pip
In [4]: pip
Out[4]: <module 'pip' from '/Applications/Python 3.4/pyzo2015a/lib/python3.4/site-packages/pip/__init__.py'>
In [5]: pip list
Out[5]:
You are using pip version 6.0.8, however version 7.0.1 is available.
…. snip snip snip …
Django 1.8.1
…. snip snip snip …
matplotlib 1.4.2
…. snip snip snip …
numpy 1.9.1
…. snip snip snip …
scipy 0.15.1          ->          one can use: "scipy.__version__" to check the package version (scipy in this case)
```

or

```
In [5]: pip.get_installed_distributions()
Out[5]:
…. snip snip snip …
Django 1.8.1 (/Applications/Python 3.4/pyzo2015a/lib/python3.4/site-packages),
…. snip snip snip …
matplotlib 1.4.2 (/Applications/Python 3.4/pyzo2015a/lib/python3.4/site-packages),
…. snip snip snip …
numpy 1.9.1 (/Applications/Python 3.4/pyzo2015a/lib/python3.4/site-packages),
…. snip snip snip …
scipy 0.15.1 (/Applications/Python 3.4/pyzo2015a/lib/python3.4/site-packages),
```

- Using:

```
In [6]: help()
```

Python for Data Analysis and Scientific Computing

- Python modules, packages and scientific blocks
  - A module is a Python file with .py extension containing definitions and statements
  - Modules implement a set of functions and can be *imported* into other modules using the *import* command:

Example:

Lets create our first Python program called – *lecture1.py*:

```
# Let's make a simple addition until certain criteria is not met
def add(a):       # the criteria to be met is a
        x, y = 2, 4
                while x < a:
                print(x,y),
                x = x + y
```

Possible usage:

```
# importing a module called 'lecture1'
import lecture1          -> must be in the same working folder
lecture1.add(24)
```

Tips:

1. *to check what's loaded in memory simply look at the workspace*
2. *if you enter an infinite loop hit 'ctrl-c' to break the loop and stop the execution*
3. *try debugging your program using breakpoints*

Python for Data Analysis and Scientific Computing

- Python modules, packages and scientific packages
  - A *module* in Python is a source file that can expose classes, functions and global variables
  - A *package* in Python is a directory of one or several Python modules (source .py files)

Example:

```
# 1. this is how we import a package:
import math
        Usage:
        math.acos(0.3454453)

# 2. this is how we import a module from a package:
import acos from math … ( or: from math import acos)
        Usage:
        acos(0.3454453)
```

Tips:

1. *Observe what's loaded in workspace in the two cases above*
2. *you can delete a particular item from workspace by using **'del(item)'***
3. *to clear the workspace use **'reset'***
4. *The built-in function **'dir()'** is used to find what's currently defined and shown in workspace*

Python for Data Analysis and Scientific Computing

- Python modules, packages and scientific blocks
  - **'sys'**: includes information about the modules available to us. It includes built-in and imported modules
  - **Imported modules:** usually Python programs are a combination of several modules imported with a main application

    They can be seen in the following way:

```
import sys, textwrap
names = sorted(sys.modules.keys())
name_text = ' || '.join(names)
print(textwrap.fill(name_text))
```

  - **Built-in modules:** the interpreter can be built and compiled with some C modules, that do not appear in the imported modules list since they were included in the package

    They can be seen in the following way:

```
import sys
for module_name in sys.builtin_module_names:
    print(module_name)
```

  - **The search path:** the search path for modules is managed as a list saved in **sys.path.** The default path list consist of the script directory used to start the application and the current working directory

```
sys.path
```

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Magic commands in **IPython**:

List of important **Magic** commands in **IPython**:

%automagic	magic [-brief,]
ls	lsmagic
pwd	ed, edit
cd	load
mv	run
dir	time
mkdir	writefile
rm, rmdir	env
who, whos	system
alias, unalias	config
hist, history	save
dhist	logoff logon logstart logstate logstop

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HW assignment 1:

Make sure you have chosen, installed and configured your Python-NumPy-SciPy environment