UC Berkeley Extension

Machine Learning With TensorFlow

X433.7 (2 semester units in COMPSCI)

Instructor Alexander I. Iliev, Ph.D.

Course Content Outline

- **Machine Learning With TensorFlow®**
- Introduction, Python - pros and cons
- Python modules, DL packages and scientific blocks
- Working with the shell, IPyton and the editor
- Installing the environment with core packages
- Writing “Hello World”
- Ecosystem, Use Cases, Competition, Users HW1 (5pts)

- **Tensorflow and TensorBoard basics (cont.)**
- TF 1.13+ vs. 2.0+ some differences
- Linear algebra recap
- Data types in Numpy and Tensorflow
- Basic operations in Tensorflow
- Graph models and structures with Tensorboard HW2 (5pts)

- **TensorFlow operations**
- Sessions, graphs, variables, placeholders
- Overloaded operators, Using Aliases
- Eager execution, Data Sets, Tensorboard
- Distributed Strategy HW3 (5pts)

- **TF 2.0 vs. 1.X comparison**
- Upgrading, Migrating 1.x to 2.0
- Control statements, Reductions
- Name scopes

- **TF 1.x vs. 2.0, Machine Learning concepts**
- Machine Learning Models, k-Means, Linear Regression HW4 (5pts)

Course Content Outline

- **Machine Learning**
- Querunners
- Logistic Regression
- Softmax classification
- Splitting Data and Stratification
- Single-Layer and Multi-layer Neural Networks
- Gradient descent and Backpropagation

- **Neural Networks**
- Optimizers
- Object recognition with Convolutional Neural Network (CNN)
- Kernels, Strides, Padding
- Activation Functions: Sigmoid, Tanh, ReLU
- Common layers: Conv2d, Dropout, Pooling Layers
- CNN Overview — Midterm (30pts)

- **Working with images**
- Keras Applications and TensorFlow Hub
- Normalization
- Loading Images
- Image formats and manipulation
- Speech processing — Project proposal due (4pts)

- **CNN Implementation**
- Performance and Model Training — Discussion of student proposals
- Recurrent Neural Network (RNN)
- Long-Short Term Memory (LSTM)
- Word Vector Embedding
- Principal Component Analysis (PCA)
- Digital Audio and Signal Processing

- **CPU/GPU usage + Project Presentations**
- Project Presentation — Final Project (36pts)

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.

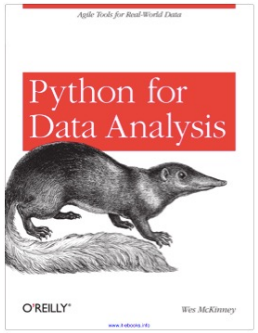
- **Course Grade Weighting**

  1. Class participation: 10% -
  2. Homework: 20% -
  3. Midterm 30% -
  4. Final Project 40% -

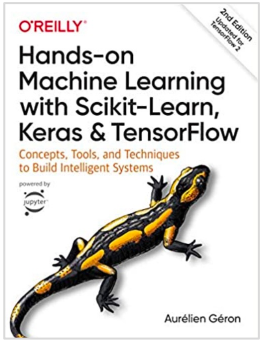
Course Content Outline

- **Optional Reading for the Course**

Title: Python for Data Analysis
ISBN: 9781491957660
Author(s): Wes McKinney
Publisher: O'Reilly Media
Edition Number: 2nd edition
Publication Date: October, 2017

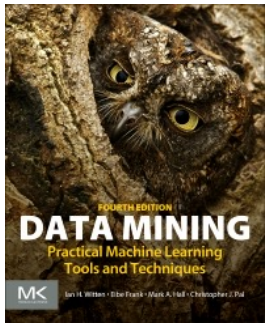


Title: Hands-On Machine Learning with
Scikit-Learn, Keras and TF,
Paperback : 856 pages
ISBN-10 : 1492032646
ISBN-13 : 978-1492032649
Publisher : O'Reilly Media
Edition: 2nd edition
Publication Date: October 15, 2019
kit-Learn, Keras, and TensorFlow

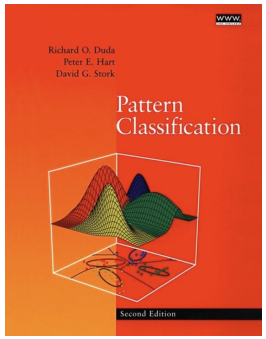


(optional reading)

Title: Data Mining
ISBN: 978-0-12-804291-5
Author(s): Ian H. Witten, Eibe Frank, Mark A. Hall
Publisher: Elsevier
Edition Number: 4th edition
Publication Date: 2016
Free Online copy for 3rd edition (ResearchGate)



Title: Pattern Classification
ISBN: 111858600X, 9781118586006
Author(s): Richard O. Duda
Peter E. Hart, David G. Stork
Publisher: John Wiley & Sons, 2012
Edition: 2nd edition
Publication Date: 2012



Data Mining

Class 1 …

Python, TensorFlow, Versions, Installation, Use Cases and general concepts …

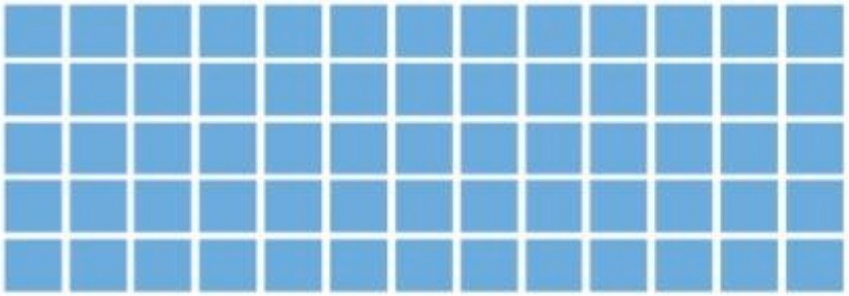
Data

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

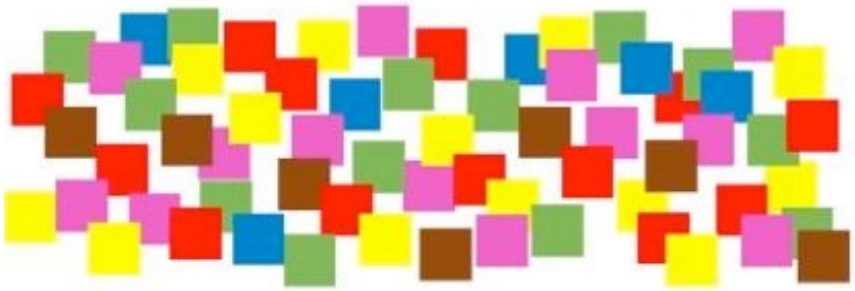
90% of the data in the world today has been created in the last two years alone, at 2.5 quintillion bytes of data a day

report from IBM Marketing Cloud in 2017

Data



Structured Data

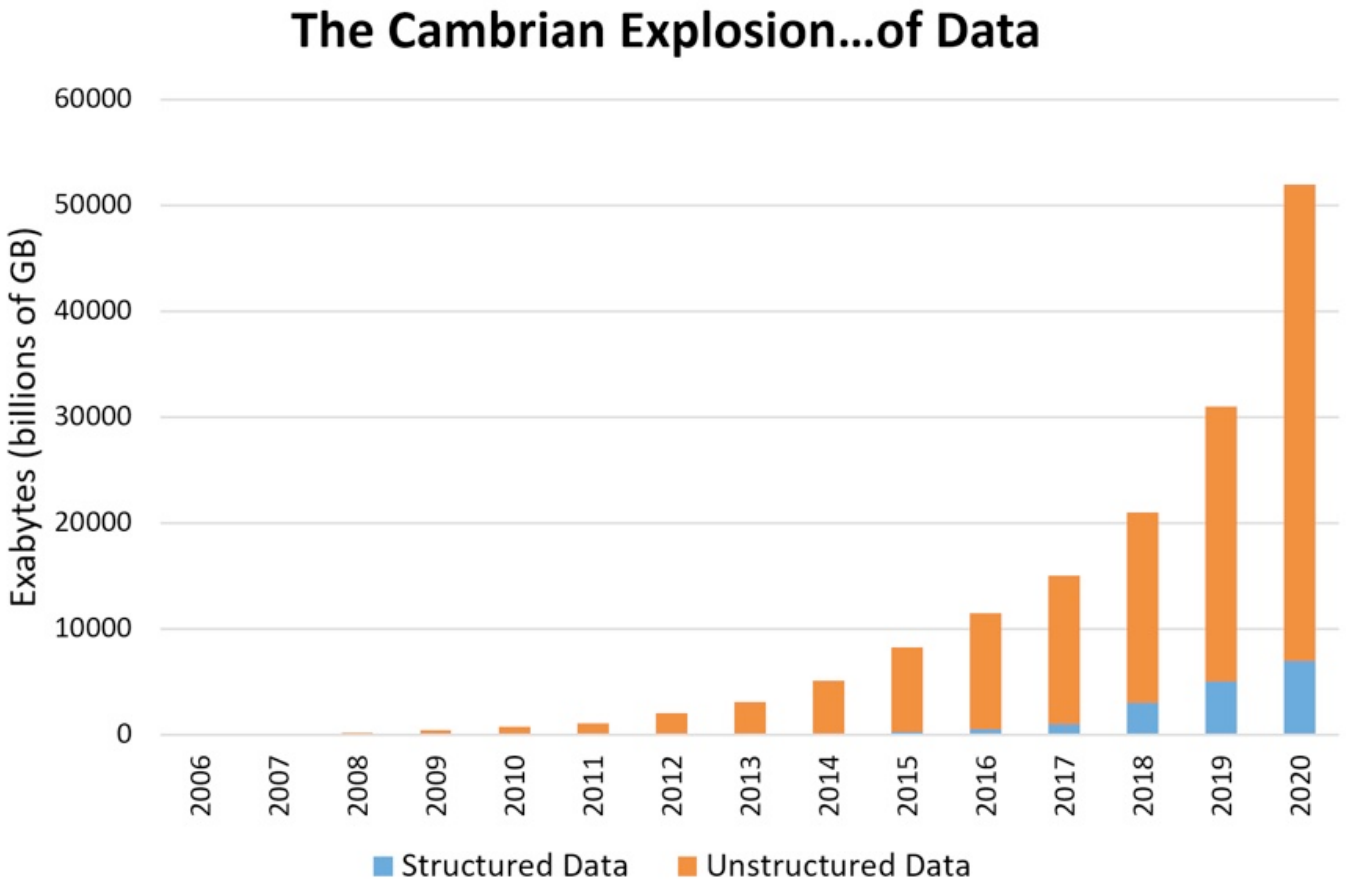


Unstructured Data

Graphical representations illustrate the difference between structured and unstructured data

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

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/

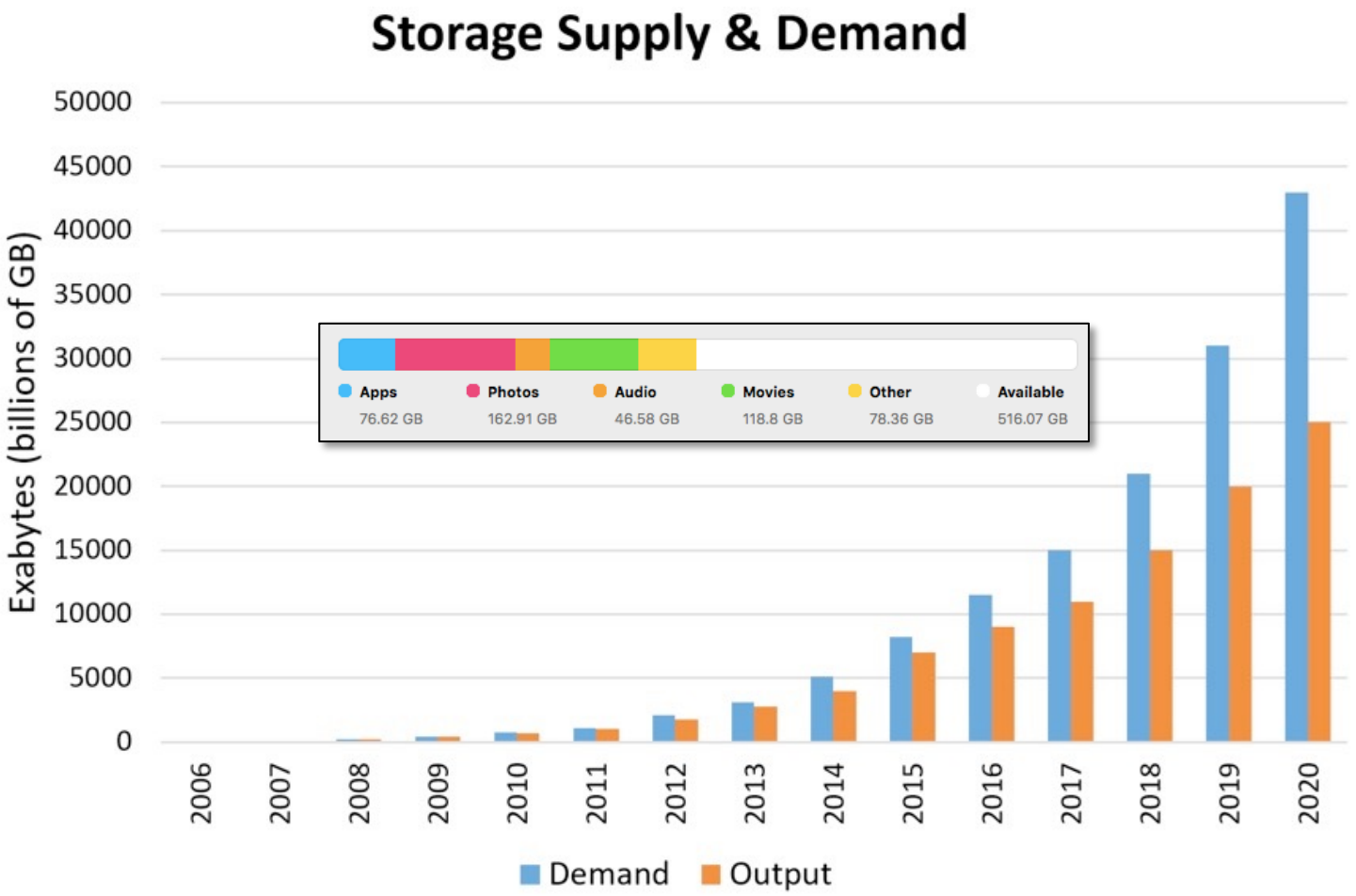
Data

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/

Machine Learning With TensorFlow

- Artificial Intelligence concept
  - It is a concept conceived in the mid 50s with the intention to construct complex machines (computers) that possessed the same characteristics of human intelligence
  - The main idea is to create technologies able to perform specific tasks better than humans can
  - Some of the first intelligent robots emerged in movies such as Star Wars – C-3PO
  - Artificial intelligence (AI) is already part of our everyday lives
  - Some examples of AI involve: image classification, face recognition, voice recognition, speaker recognition, emotion recognition, etc.

Machine Learning With TensorFlow

- Data Mining and Machine Learning concepts
  - In data mining, the data is stored electronically and the search is automated (or semi-automated)
  - It has been estimated that the amount of data stored in the world's databases doubles every 20 months …
  - … Thus the opportunities for data mining increase
  - Data mining is about solving problems by analyzing data already present in databases
  - Data mining finds patterns that can be analyzed to identify distinguishing characteristics

Machine Learning With TensorFlow

- Data Mining and Machine Learning concepts
  - Machine learning came directly from the early AI scientists. The algorithmic approaches over the years included: *decision tree learning*, *logic programming*, *clustering*, *reinforcement learning*, *Bayesian networks*, etc.
  - To "learn" by definition for us humans means to:
    - Obtain knowledge of something and being aware of something
    - Be informed, receive instructions, commit to memory
  - An operational definition for "learn" can be formulated like:
    - Things learn when they change their behavior in a way that makes them perform better in the future. The definition of "better" is given by us and means "performance" rather than "knowledge"

Machine Learning With TensorFlow

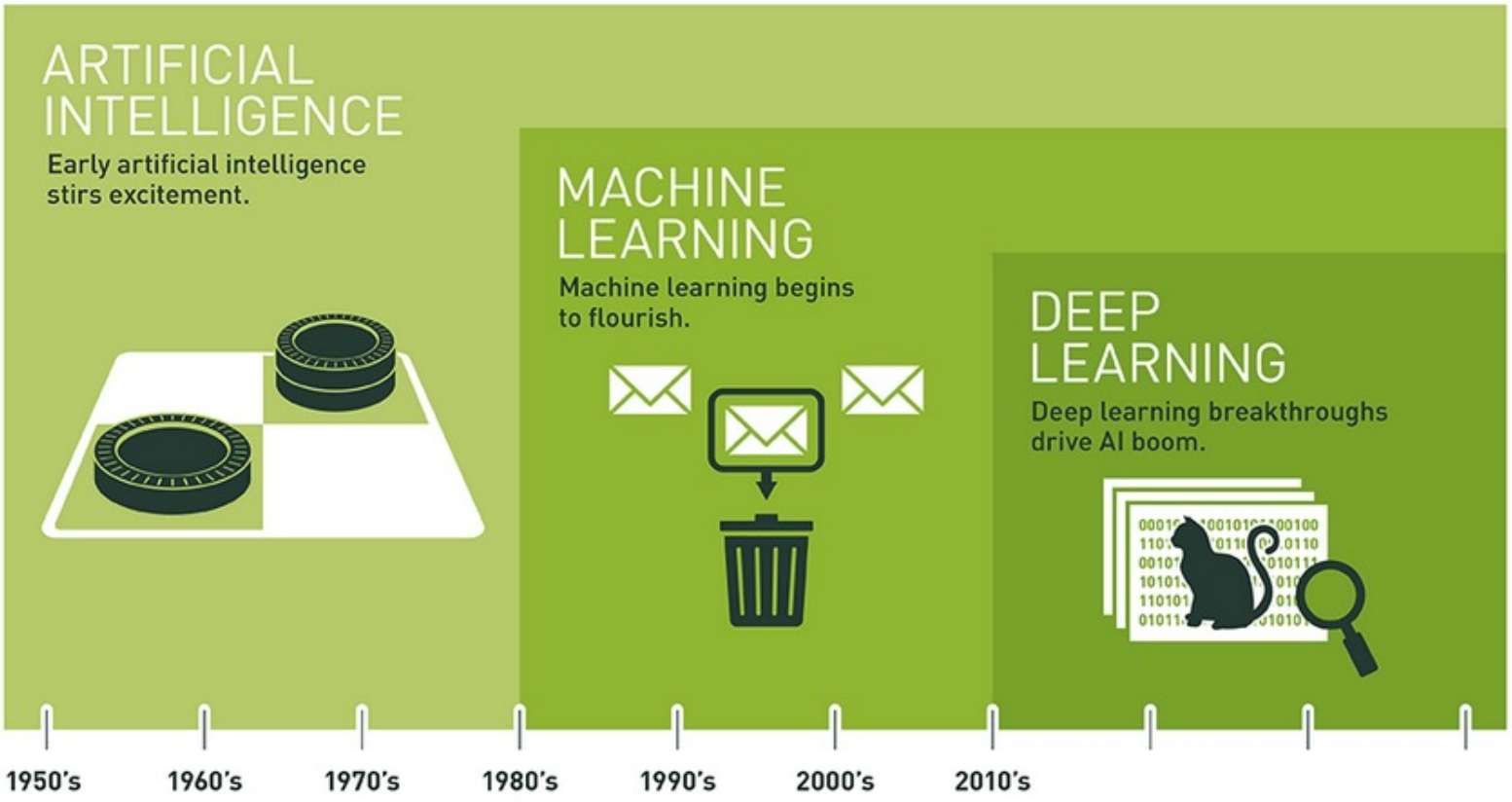
- Data Mining and Machine Learning concepts
  - Machine learning does not entail the conceptual limitations mentioned herein, and disregards any philosophical stance about what learning actually is
  - Machine learning is therefore a practical process connected to Data mining while using algorithms to parse data, learn from it, and then make a prediction
  - Performance:
    - the machine is "trained" using large amounts of data and algorithms that give it the ability to learn;
    - it is then "tested" on a new (usually unknown) set of data

Machine Learning With TensorFlow

- Deep Learning concept
  - Deep Learning is an area in Machine Learning that has been introduced with the objective of moving Machine Learning closer to its goal: Artificial Intelligence
  - Deep Learning has enabled many practical applications of Machine Learning and by extension the overall field of AI
  - Deep Learning breaks down tasks in ways that makes all kinds of machine assists seem possible
  - Areas of implementation are infinite, but some of them are: preventive healthcare, security systems, robotics, cars without drivers, better media recommendations, etc.

Machine Learning With TensorFlow

- Deep Learning concept



source: nvidia.com

Machine Learning With TensorFlow

- Python environment for Deep Learning – 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: NumPy, SciPy, Matplotlib, Theano, Scikit, Tensorflow, etc.
  - Mobile computing for smartphone development by using Kivy for Android and iOS
  - Web-site incorporation by using Django
  - Try it here: https://www.pythonanywhere.com/try-ipython/

Machine Learning With TensorFlow

- Python – pros and cons:

  Pros

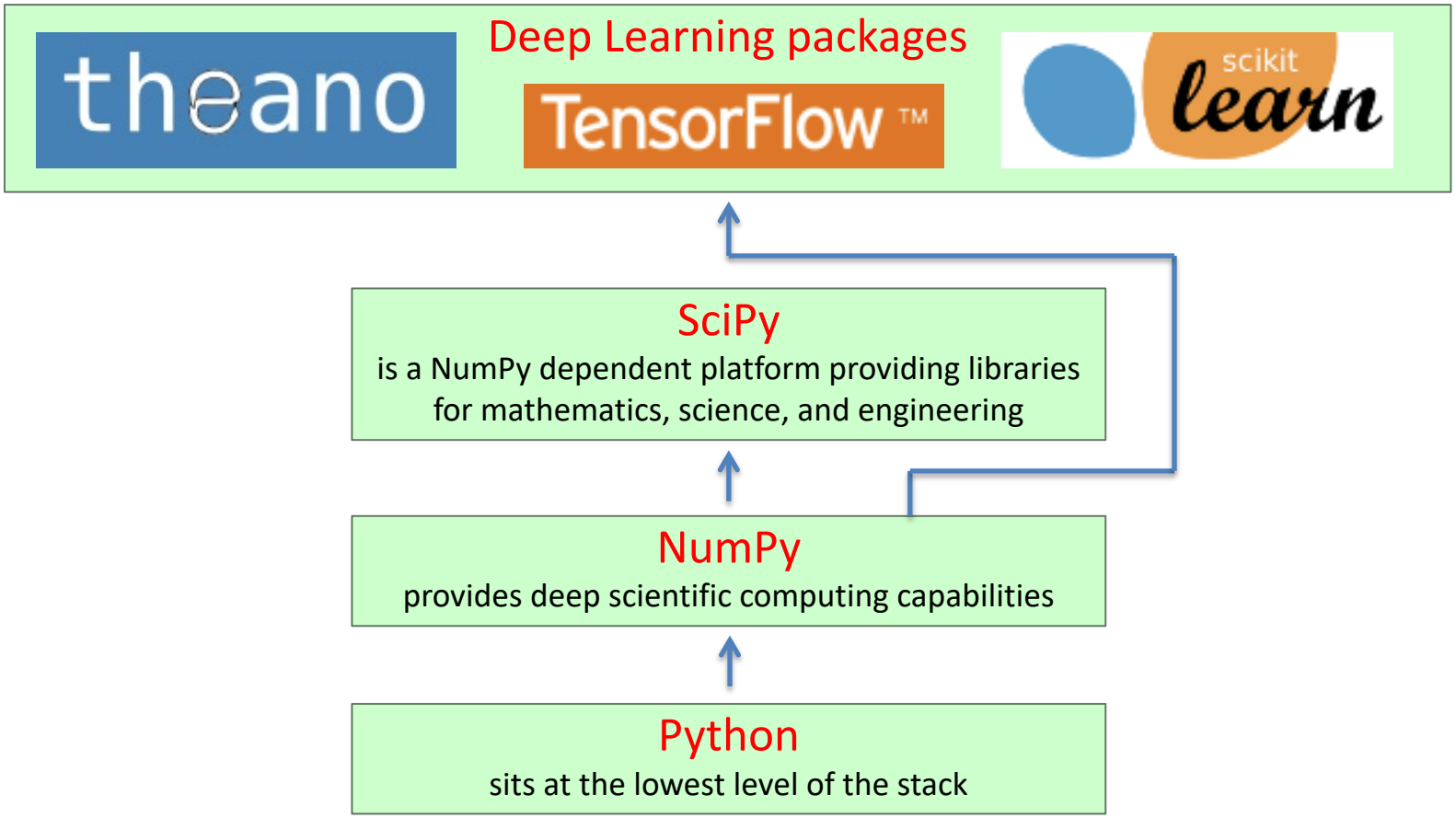
  – High-level object-oriented language that is easy to learn
  – Good readability of the code
  – Quick development time
  – Rich scientific libraries and many others like web server management, serial port access, etc.
  – Easy to share and communicate results
  – Easy to read, manipulate and process 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

Machine Learning With TensorFlow

- Basic stack using NumPy, SciPy and Deep Learning in Python:



Machine Learning With TensorFlow

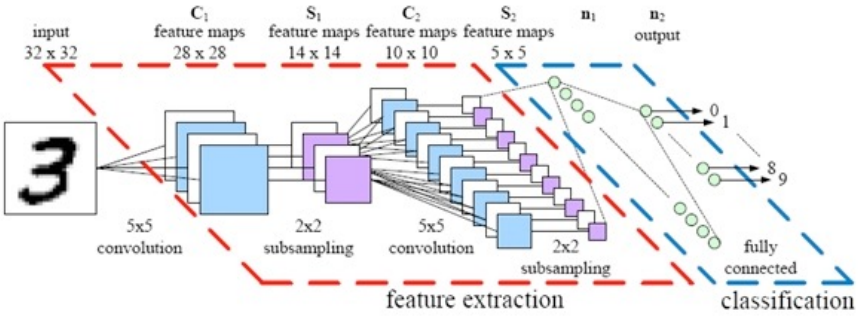
- Python + NumPy + SciPy + ?
  - … is like Matlab + toolboxes + DL processing

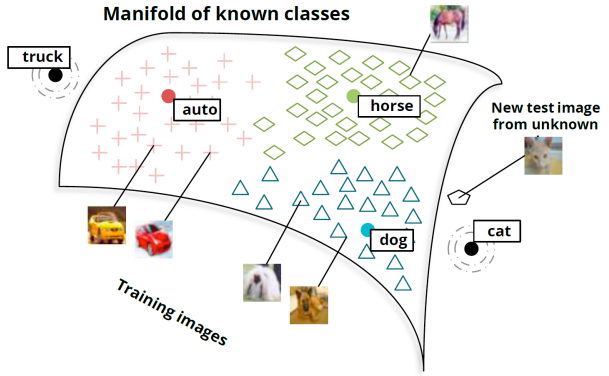
Machine Learning With TensorFlow

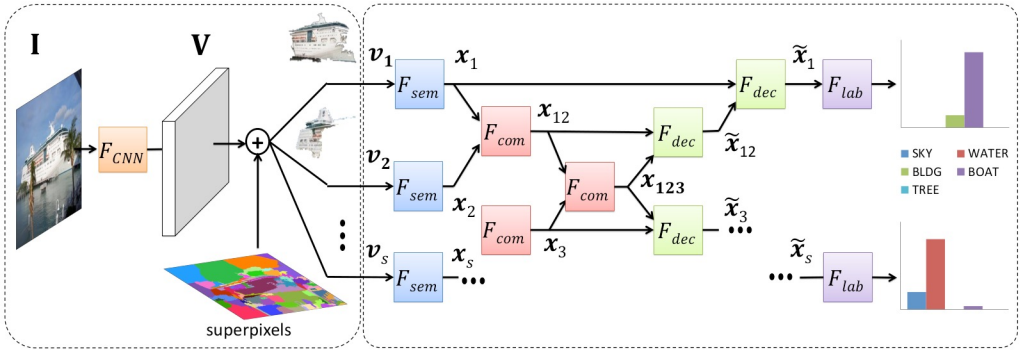
- Python + NumPy + SciPy + Theano + Scikit-Learn + Tensorflow
  - … is like Matlab + toolboxes + DL processing

Machine Learning With TensorFlow

- Python + NumPy + SciPy + Theano + Scikit-Learn + Tensorflow
  - … is like Matlab + toolboxes + DL processing





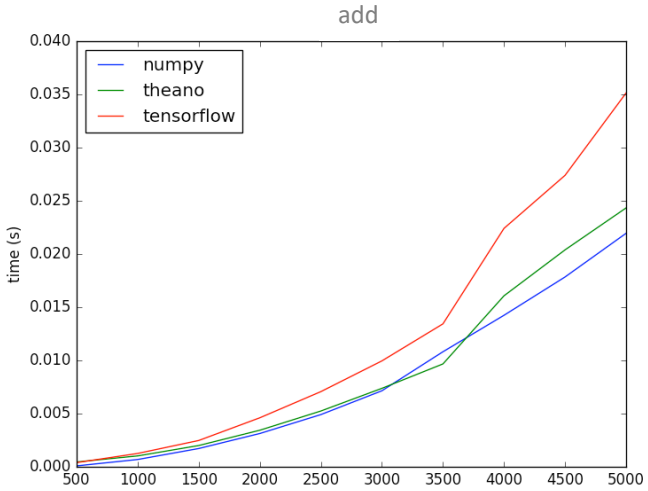


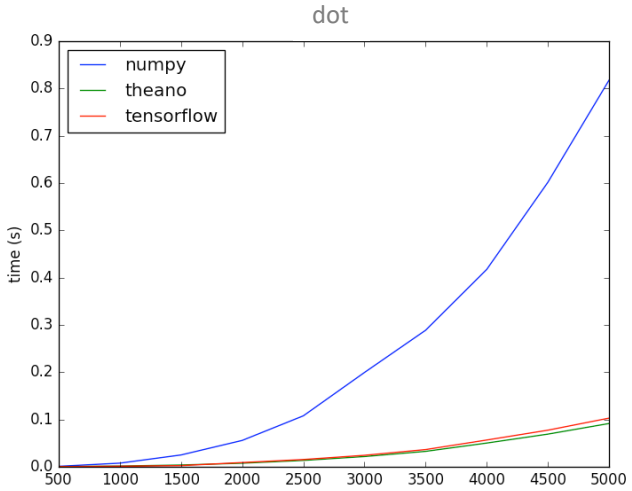
Local Feature Extraction

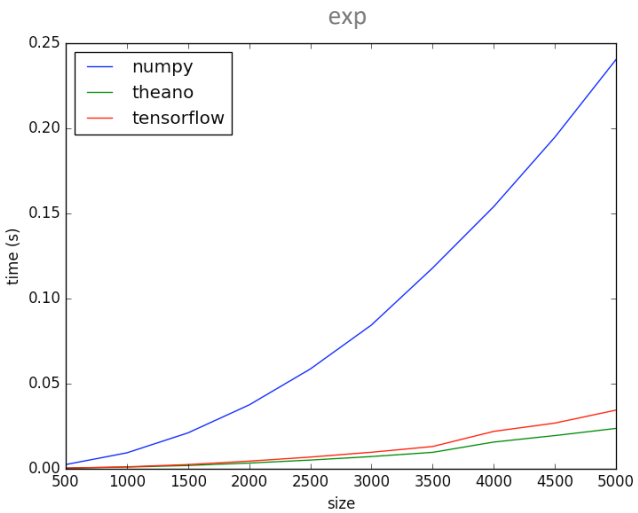
Recursive Context Propagation Network (rCPN)

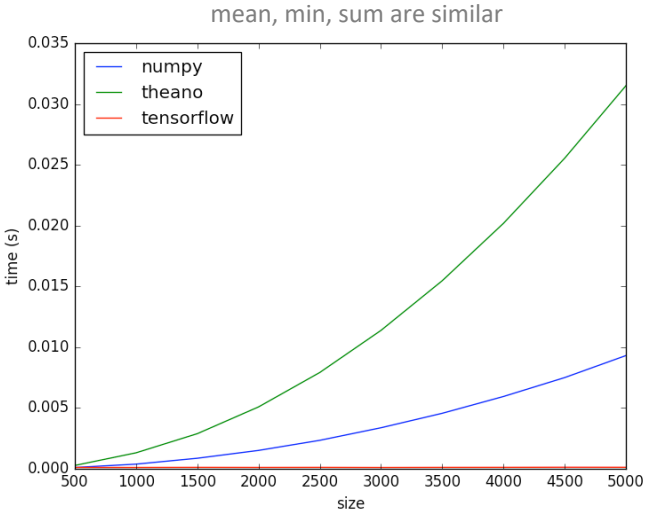
Machine Learning With TensorFlow

- Testing performance for NumPy + Theano + Tensorflow









Machine Learning With TensorFlow

Top Deep Learning Projects

A list of popular github projects related to deep learning (ranked by stars).

Project Name	Stars	Description
TensorFlow	29622	Computation using data flow graphs for scalable machine learning.
Caffe	11799	Caffe: a fast open framework for deep learning. CNN & image processing, written in C++
Theano	4286	Theano is a Python library that allows you to define, optimize, and evaluate mathematical expressions involving multi-dimensional arrays efficiently. It can use GPUs and perform efficient symbolic differentiation.
Leaf	4281	Open Machine Intelligence Framework for Hackers.
Char RNN	3820	Multi-layer Recurrent Neural Networks (LSTM, GRU, RNN) for character-level language models in Torch.
Neural Talk	3694	NeuralTalk is a Python+numpy project for learning Multimodal Recurrent Neural Networks that describe images with sentences.
deeplearning4j	3673	Deep Learning for Java, Scala & Clojure on Hadoop, Spark.
TFLearn	3368	Deep learning library featuring a higher-level API for TensorFlow.
TensorFlow Playground	3352	Play with neural networks!
Scikit Neural Net	849	Deep neural networks without the learning cliff! Classifiers and regressors compatible with scikit-learn.

Source: https://github.com/aymericdamien/TopDeepLearning

Machine Learning With TensorFlow

Top Deep Learning Projects

According to medium.com

View 1+ more

8 Best Deep Learning Frameworks for Data Science enthusiasts

1. TensorFlow. TensorFlow is arguably one of the **best deep learning** frameworks and has been adopted by several giants such as Airbus, Twitter, IBM, and others mainly due to its highly flexible system architecture. ...
2. Caffe. ...
3. Microsoft Cognitive Toolkit/CNTK. ...
4. Torch/PyTorch. ...
5. MXNet. ...
6. Chainer. ...
7. Keras. ...
8. Deeplearning4j.

Apr 5, 2018

Source: https://medium.com/the-mission/8-best-deep-learning-frameworks-for-data-science-enthusiasts-d72714157761

Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow

  - Theano is a Python library that lets you to define, optimize, and evaluate mathematical expressions, especially ones with multi-dimensional arrays (numpy.ndarray)
  - Speed is rivaling C implementations for problems involving large amounts of data
  - It can surpass C on a CPU by many orders of magnitude by taking advantage of GPUs
  - Theano combines aspects of a computer algebra system (CAS) with optimized compiler
  - It can also generate customized C code for many mathematical operations
  - Theano can minimize the amount of compilation/analysis overhead

Source: http://deeplearning.net/software/theano/introduction.html

Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow

  - Theano's compiler applies many optimizations of varying complexity that include, but are not limited to:
    - use of GPU for computations
    - constant folding - evaluating **constant** expressions at compile time (not runtime)
    - merging of similar sub-graphs, to avoid redundant calculation
    - arithmetic simplification (e.g. x*y/x -> y, --x -> x)
    - inserting efficient BLAS operations (e.g. GEMM) in a variety of contexts
    - using memory aliasing to decrease calculations
    - using in place operations wherever it does not interfere with aliasing
    - loop fusion for elementwise sub-expressions
    - improvements to numerical stability (e.g. $\log(1+\exp(x))$ and $\log(\sum_i \exp(x[i]))$)
    - for a complete list, see http://deeplearning.net/software/theano/optimizations.html#optimizations

Source: http://deeplearning.net/software/theano/introduction.html

Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow

  - Theano is a Python library that allows you to define, optimize, and evaluate mathematical expressions involving multi-dimensional arrays efficiently. It features:
  - **tight integration with NumPy** – Use *numpy.ndarray* in Theano-compiled functions
  - **transparent use of a GPU** – Perform data-intensive calculations up to 140x faster than with CPU.(float32 only)
  - **efficient symbolic differentiation** – Theano does your derivatives for function with one or many inputs
  - **speed and stability optimizations** – Get the right answer for log(1+x) even when x is really tiny
  - **dynamic C code generation** – Evaluate expressions faster
  - **extensive unit-testing and self-verification** – Detect and diagnose many types of errors

Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow

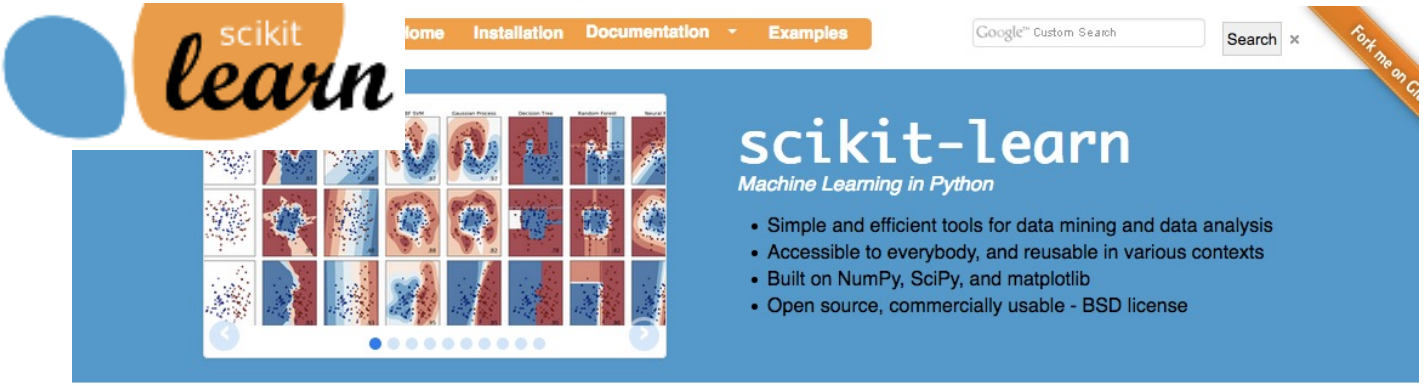
  - Theano and TensorFlow are competing heavily for which one is the best platform
  - Theano outperforms TensorFlow on a single GPU, but TensorFlow outperforms Theano for parallel execution on multiple GPUs
  - Theano has better documentation in general than TensorFlow, although that changes quickly
  - Theano has a native Windows support
  - Both use Numpy arrays
  - TensorFlow is more elegant conceptually cleaner than Theano

Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow
  - **Classification**: Identifying to which category an object belongs to
  - **Regression**: Predicting a continuous-valued attribute associated with an object
  - **Clustering**: Automatic grouping of similar objects into sets
  - **Dimensionality reduction**: Reducing the number of random variables
  - **Model selection**: Comparing, validating and choosing parameters and models
  - **Preprocessing**: Feature extraction and normalization

Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow



Classification

Identifying to which category an object belongs to.

Applications: Spam detection, Image recognition.
Algorithms: SVM, nearest neighbors, random forest, ... — Examples

Regression

Predicting a continuous-valued attribute associated with an object.

Applications: Drug response, Stock prices.
Algorithms: SVR, ridge regression, Lasso, ... — Examples

Clustering

Automatic grouping of similar objects into sets.

Applications: Customer segmentation, Grouping experiment outcomes
Algorithms: k-Means, spectral clustering, mean-shift, ... — Examples

Dimensionality reduction

Reducing the number of random variables to consider.

Applications: Visualization, Increased efficiency
Algorithms: PCA, feature selection, non-negative matrix factorization. — Examples

Model selection

Comparing, validating and choosing parameters and models.

Goal: Improved accuracy via parameter tuning
Modules: grid search, cross validation, metrics. — Examples

Preprocessing

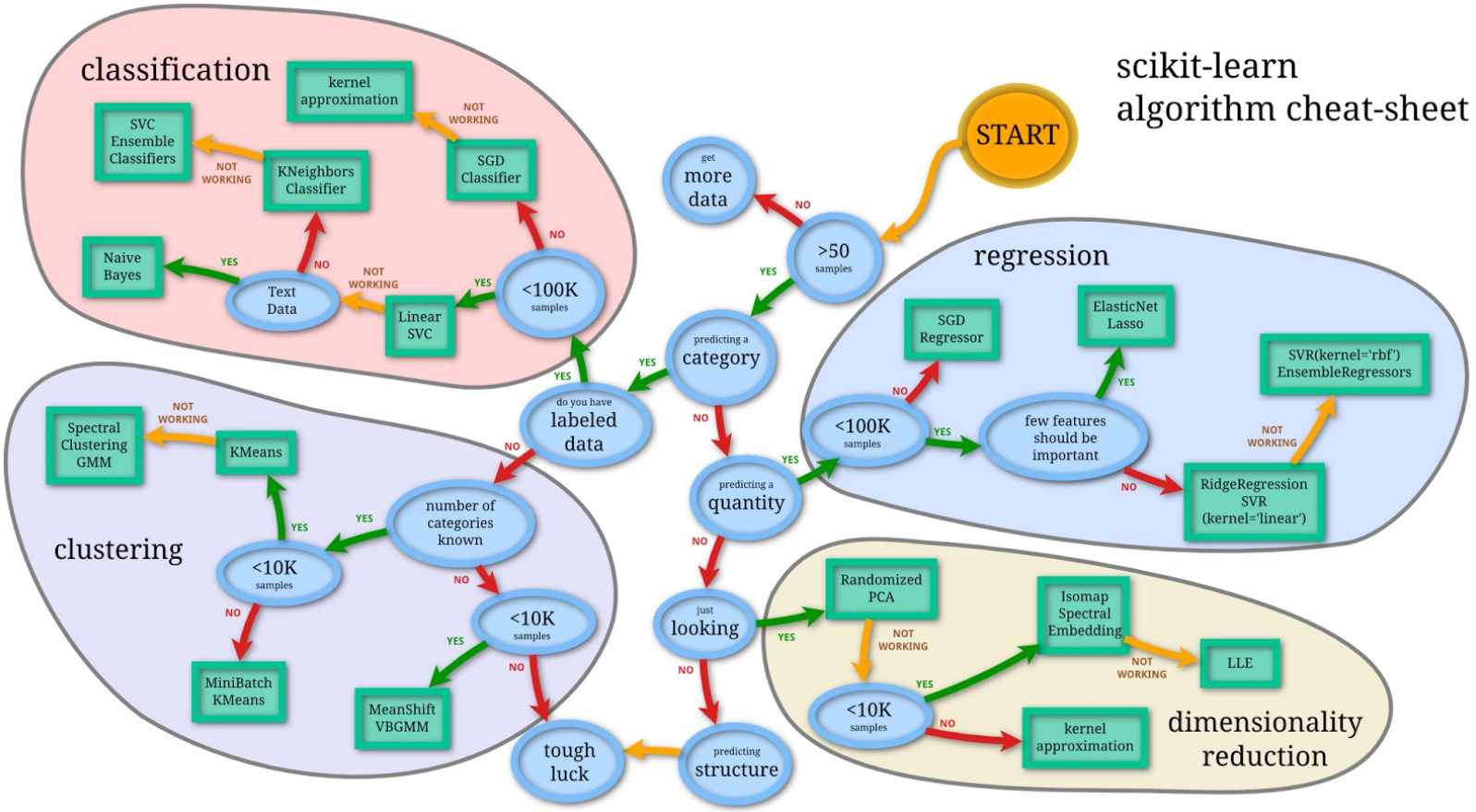
Feature extraction and normalization.

Application: Transforming input data such as text for use with machine learning algorithms.
Modules: preprocessing, feature extraction. — Examples

Source: http://scikit-learn.org/stable/

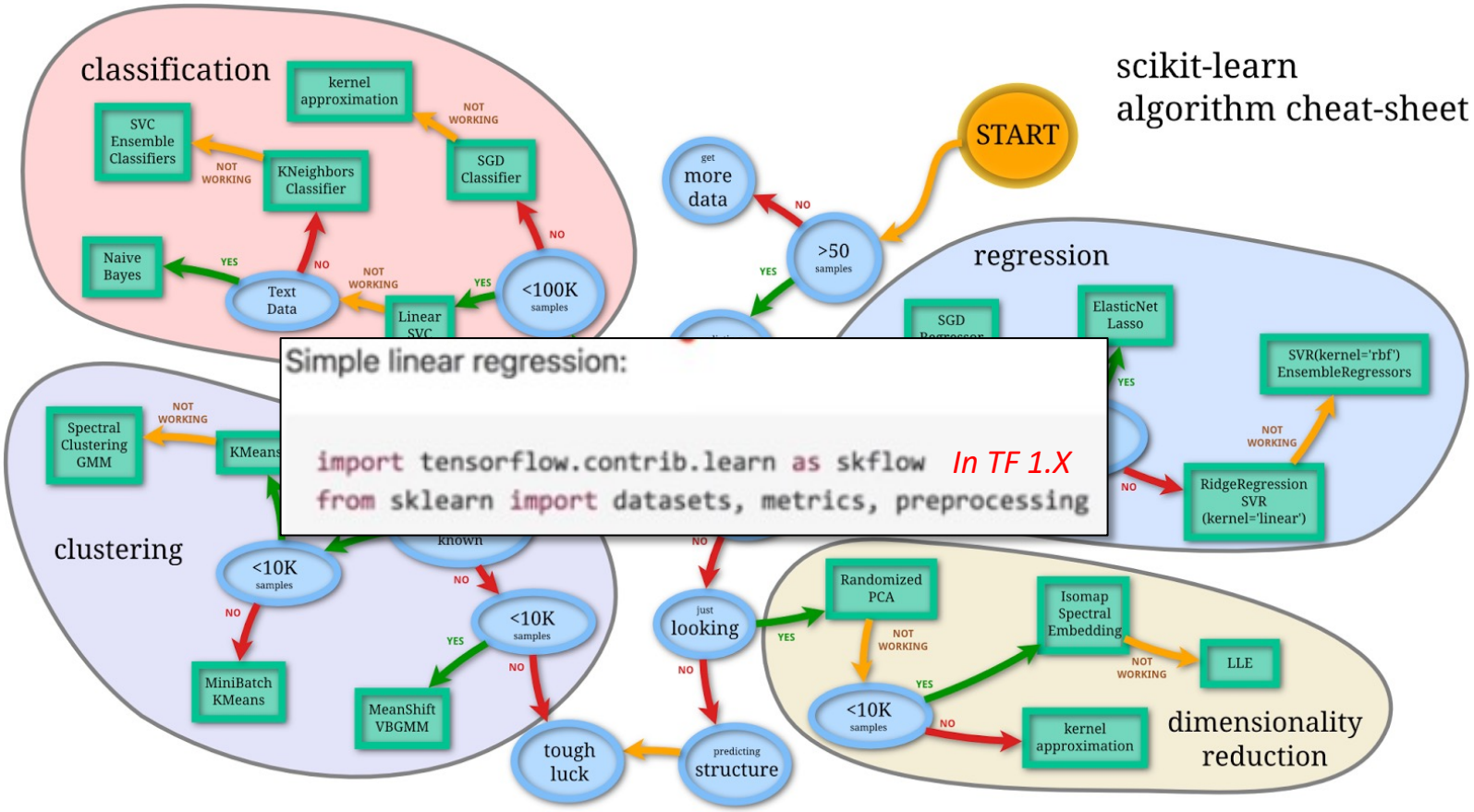
Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow



Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow



UC Berkeley Extension

Tutorial 1

Instructor Alexander I. Iliev, Ph.D.

Installation

- TensorFlow is compatible with 4 operating Systems :

a) Windows OS

b) Mac OS

c) Ubuntu OS

d) Raspbian OS

TensorFlow Case Studies

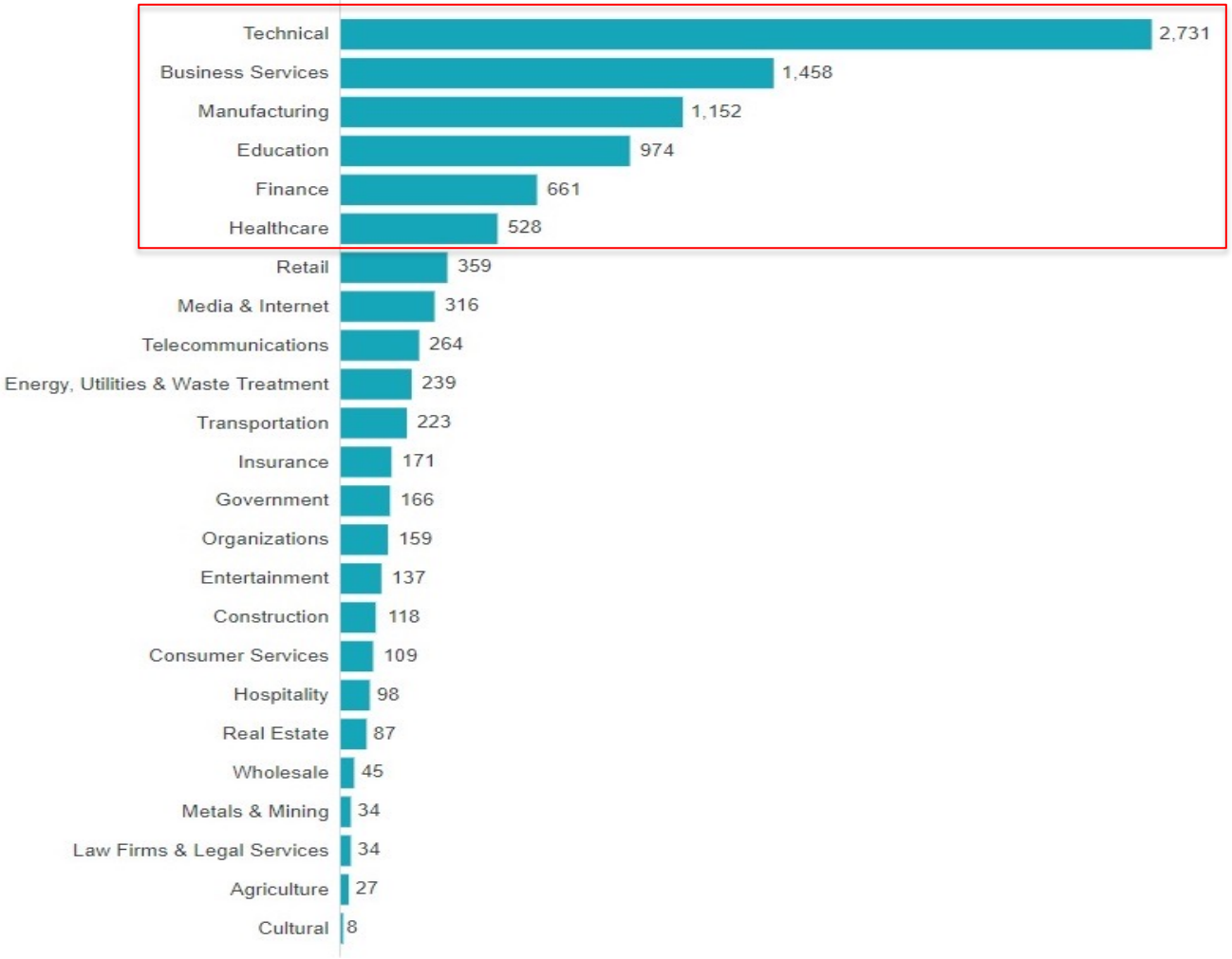
TensorFlow Case Studies

Lets have a quick look at:

- Who started using TensorFlow and Why?
- What are the different companies that are working with TensorFlow?
- How did they get benefited from it?

Companies using TensorFlow

- There are different types of companies that benefited from TensorFlow (creating quite a stir in various fields too)



Few companies that benefitted from using TensorFlow

- TensorFlow being an open package, it became the main paradigm that is being used for many solutions

- Some of the top companies that benefitted from TF are:

    - Airbnb
    - GE HealthCare
    - Airbus
    - Qualcomm

Few companies that benefitted from using TensorFlow

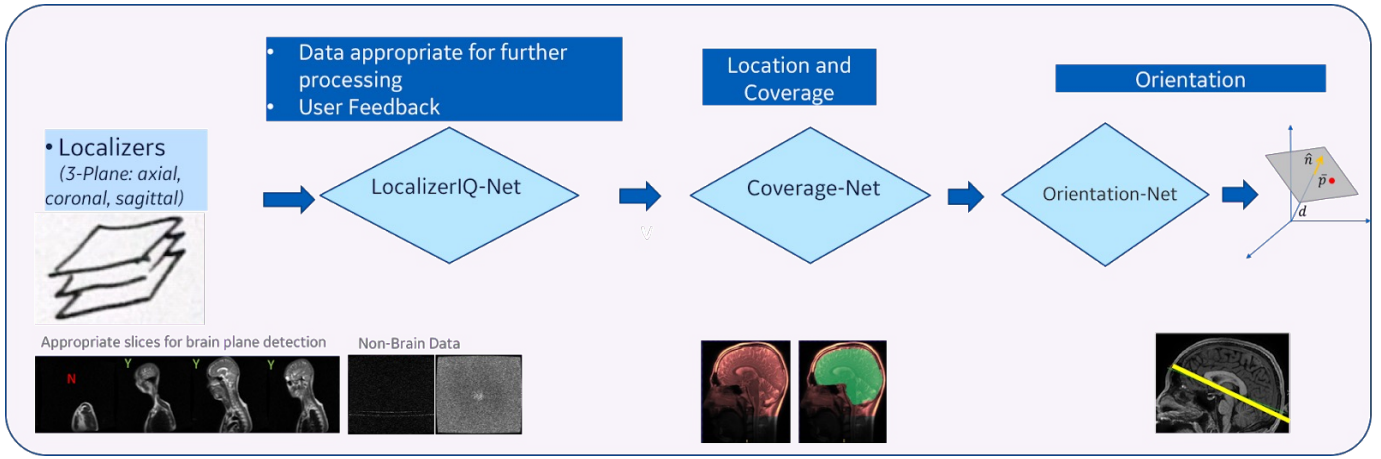
1) 

- Initially the team used to sort the images manually which consumed lots of time and energy
- A smarter way to over come such issues was to shift towards a better technology
- With TensorFlow the efficiency of their business was rapidly growing and this in turn gave the company a smoother experience and better results

Few companies that benefitted from using TensorFlow

2) GE Healthcare

- They used TensorFlow for Intelligent Scanning Using Deep Learning for MRI
- The images now have better clarity for better diagnosis



- This Company is working wonders already in the section of brain. They are looking forward to expand further more to **knee** and **spine** as well.

Few companies that benefitted from using TensorFlow

3) 

- Airbus Defence and Space uses an algorithm to identify satellite images which is sometimes very difficult to determine, even for the human eye, whether an area on a satellite image is cloud or snow

- But it has an error rate of 11%, which has prompted Airbus to test the deep-learning platform TensorFlow

- TensorFlow analyses a large number of images, looks for recurring patterns, and uses this to learn how to identify objects by itself

- In the TensorFlow test phase, the error rate has improved to just 3%

Few companies that benefitted from using TensorFlow

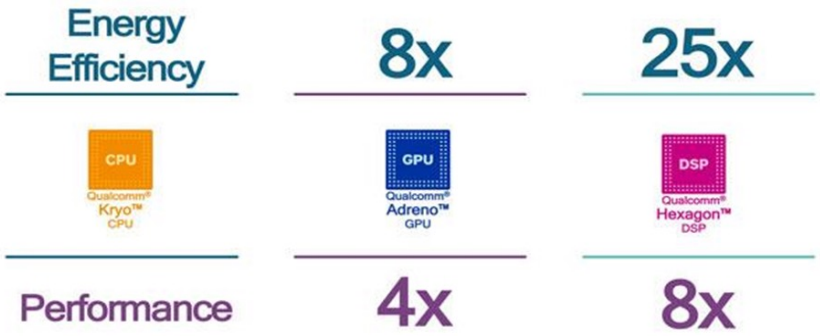
4) Qualcomm

- TensorFlow was designed to run on processing units inside of processors
- Snapdragon processors integrate a CPU, GPU and many technologies including Digital Signal Processor (DSP)
- The companies DSP architecture is designed to process certain audio and video features more quickly and at lower power than a CPU or GPU, which is why it's ideal to exploit its advantages

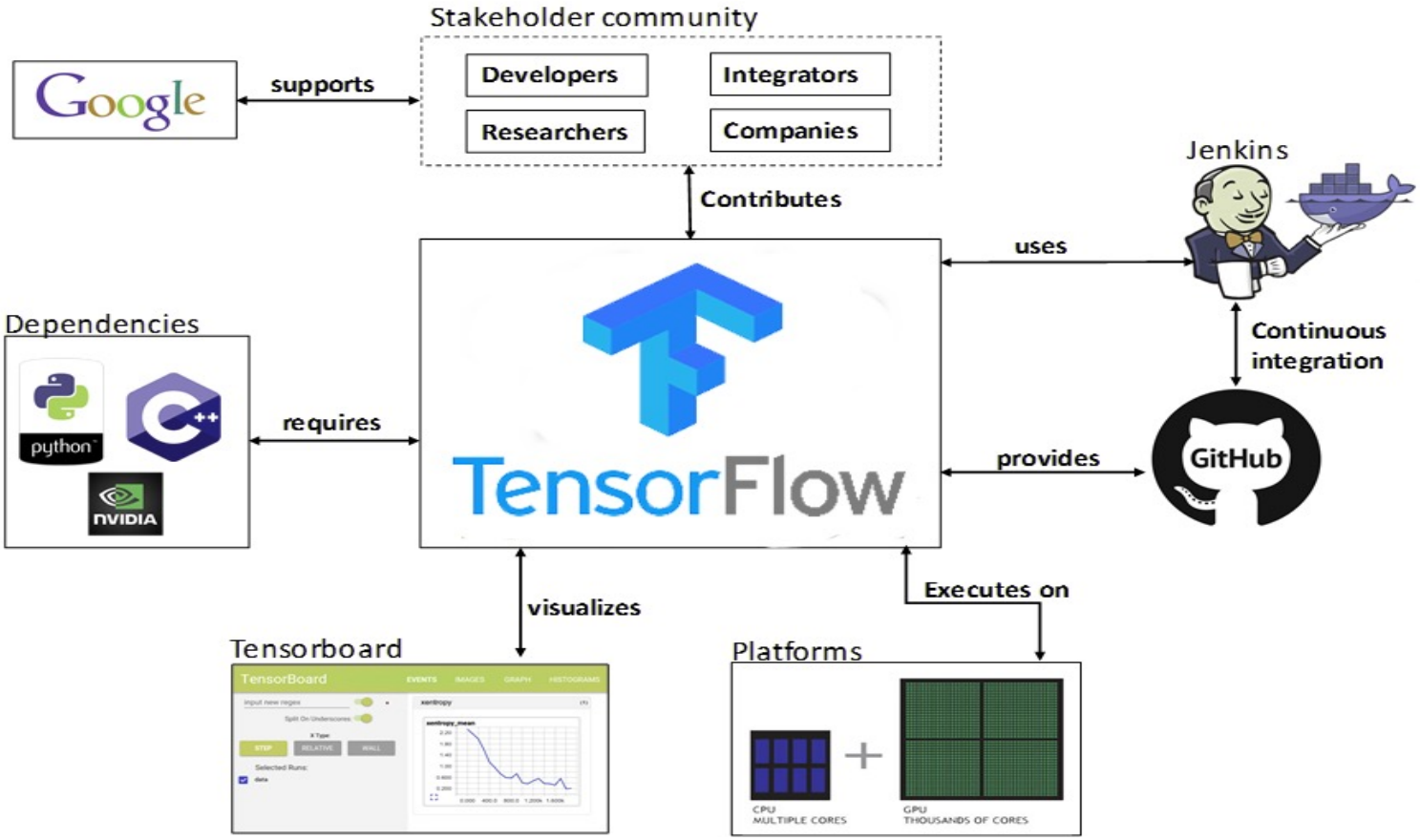
Few companies that benefitted from using TensorFlow

4) Qualcomm

- TensorFlow will run on the DSP so apps can run faster and more efficiently
- Qualcomm Technologies also offers support for TensorFlow on Snapdragon processors via the Qualcomm Snapdragon Neural Processing Engine SDK*
- The chart below illustrates the benefits of apps optimized for the DSP:



TensorFlow Ecosystem



TensorFlow Applications

- Tensorflow runs on a variety of platforms and the installation is Linux-only and more tedious than CPU-only installation.

- The applications go beyond deep learning to support other forms of machine learning:
  - reinforcement learning,
  - any goal-oriented tasks like winning video games or
  - helping a robot navigate an uneven landscape

- allows you to explore: sentiment analysis, google translate, text analysis and best of all image recognition

Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow

  - TensorFlow was originally created by Google as an internal machine learning tool
  - An implementation of it was open-sourced under the Apache 2.0 License in November 2015
  - TensorFlow is an interface for numerical computation as described in the TensorFlow white paper, and Google still maintains its own internal implementation of it
  - Google is constantly pushing internal improvements to the public repository
  - The open-source release contains the same capabilities as Google's internal version

Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow

- TensorFlow™ is an open-source software library for numerical computation using data flow graphs
- TensorFlow was developed by researchers and engineers working on the Google Brain Team within Google's Machine Intelligence research organization for the purposes of conducting machine learning and deep neural networks research
- Nodes in the graph represent mathematical operations, while the graph edges represent the multidimensional data arrays (tensors) communicated between them
- The flexible architecture allows you to deploy computation to one or more CPUs or GPUs in a desktop, server, or mobile device with a single API

Source: https://www.tensorflow.org/

Machine Learning

- Working with Theano, Scikit-Learn and TensorFlow

  - TensorFlow's API is most similar to Theano's
  - TensorFlow does contain a package, "learn" (AKA "Scikit Flow"), that emulates the one-line modeling functionality of Scikit-Learn
  - TensorFlow provides an extensive suite of functions and classes that allow users to define models from scratch mathematically
  - This allows users with the appropriate technical background to create customized, flexible models quickly and intuitively
  - TensorFlow is the best library to use for both Research and Production because it scales across multiple GPUs better than Theano does

Why TensorFlow?

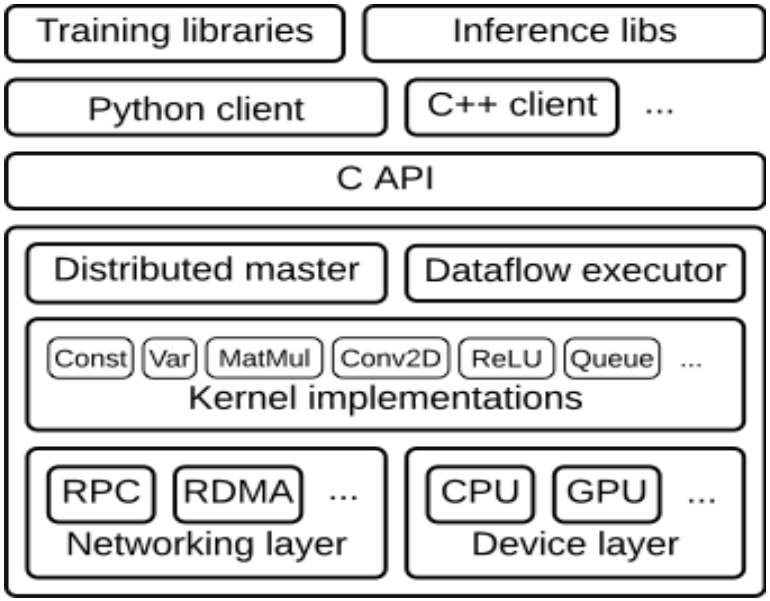
- TensorFlow provides excellent functionalities and services when compared to other popular deep learning frameworks.
- These high-level operations are essential for carrying out complex parallel computations and for building advanced neural network models.
- TensorFlow is a low-level library which provides more flexibility.
- Thus you can define your own functionalities or services for your models

Why TensorFlow?

- Distribute the training time of a neural network model over many servers to reduce the training time.
- TensorFlow's API is a complete package which is easier to use and read, plus provides helpful operators, debugging and monitoring tools, and deployment features.
- TensorFlow can run on multiple CPUs and GPUs.
- TensorFlow is available on 64-bit Linux, macOS, Windows, and mobile computing platforms including Android and iOS.

TensorFlow Architecture

- The TensorFlow runtime is a cross-platform library. The figure below illustrates its general architecture.



Machine Learning With TensorFlow

- Distributions and Dependencies:

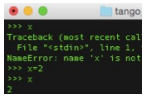
  - Distributions: Python 2.6+, 3.3+
  - Dependencies: Numpy 1.6.1+, Scipy 0.9+

  - Distributions: Python 2.6+, 3.3+
  - Dependencies: Numpy 1.7.1+, Scipy 0.11+

  - Distributions: Python 2.7, 3.4, 3.5, 3.6, 3.7, 3.8
  - Dependencies: Numpy, bazel, six, wheel

Machine Learning With TensorFlow

- 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:

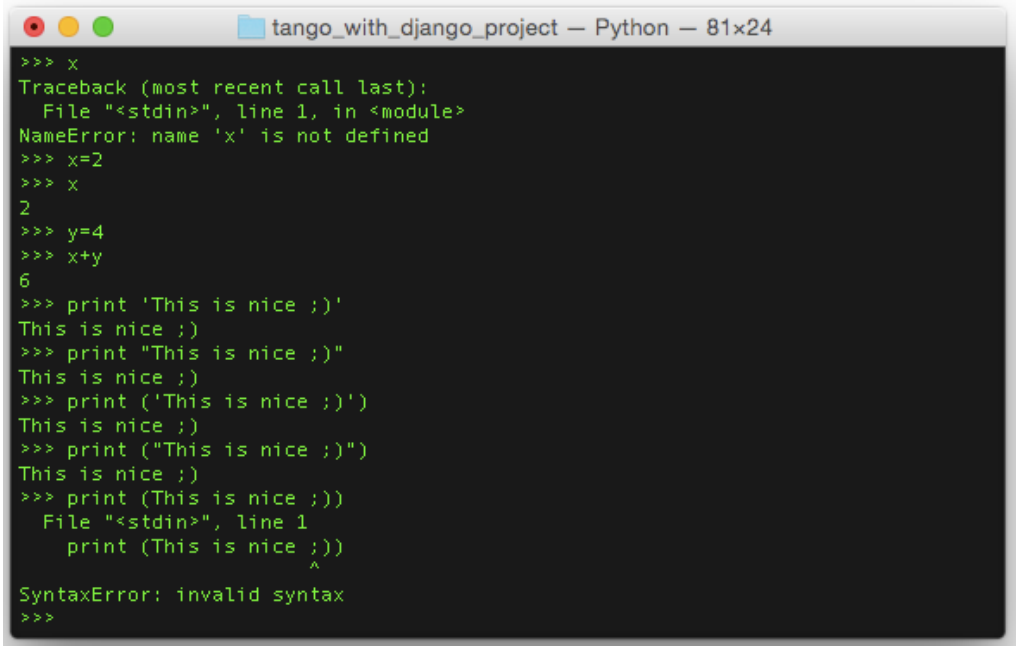
    - Pyzo – a free open-source environment based on Python:
      http://www.pyzo.org/downloads.html

    - Anaconda – Anaconda is the leading open data science platform powered by Python:
      https://www.continuum.io/

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

Machine Learning With TensorFlow

- 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



Machine Learning With TensorFlow

- Working with the shell
  - Creating the Virtualenv environment:
    - to keep our dependencies nice and clean, we're going to be using virtualenv to create a virtual Python environment
    - first, we need to make sure that Virtualenv is installed along with pip, Python's package manager
    - run the following commands (on Mac OS X):

```
$ sudo easy_install pip
$ sudo pip install --upgrade virtualenv
```

    - create a directory to contain this environment:

```
$ sudo mkdir ~/env
```

Machine Learning With TensorFlow

- Working with the shell
  - Creating the Virtualenv environment:
    - now we'll create the environment using either the:
      - virtualenv command in Python 2 or
      - venv module built in Python 3, both located in ~/env/tensorflow

```
# Python 2.7
$ virtualenv --system-site-packages ~/env/tensorflow
# Python 3
$ sudo python3 -m venv --system-site-packages ~/env/tensorflow
```

    - Once it has been created, we can activate the environment using the source command:

```
$ source ~/env/tensorflow/bin/activate
# Notice that your prompt now has a '(tensorflow)' indicator
(tensorflow)$
```

Machine Learning With TensorFlow

- Working with the shell
  - Creating the Virtualenv environment:
    - make sure that the environment is active when we install anything with pip, since that is how Virtualenv keeps track of various dependencies
    - when done, shut it off by using the deactivate command:

```
(tensorflow)$ deactivate
```

    - create a shortcut for activating it by creating alias to your ~/.bashrc file:

```
$ sudo printf '\nalias tensorflow="source ~/env/tensorflow/bin/
activate"' >> ~/.bashrc
```

    - restart your bash:

```
:~ alex$ . ~/.bashrc
```

    - now test it:

```
$ tensorflow
# The prompt should change, as before
(tensorflow)$
```

Machine Learning With TensorFlow

- Working with the shell
  - Installing TensorFlow:
    - make sure that your Virtualenv environment from the previous section is active and run the following command corresponding to your operating system (Mac OS X) and version of Python:

```
# Mac OS X, Python 2.7:
(tensorflow)$ pip install --upgrade https://storage.googlea-
pis.com/tensorflow/mac/tensorflow-0.9.0-py2-none-any.whl

# Mac OS X, Python 3.4+
(tensorflow)$ pip3 install --upgrade https://storage.googlea-
pis.com/tensorflow/mac/tensorflow-0.9.0-py3-none-any.whl
```

use any other version

pip3 install --upgrade https://storage.googleapis.com/tensorflow/mac/cpu/tensorflow-1.15.0-py3-none-any.whl … or … / 2.0 or … / 2.2

Machine Learning With TensorFlow

- Working with the shell
  - Running TensorFlow on iPython:
    - in case you'd like to run TensorFlow in iPython you may have to check where TensorFlow is running from:

```
(tensorflow) Alexandomputer2:~ alex$ which python
/Users/alex/env/tensorflow/bin/python
(tensorflow) Alexandomputer2:~ alex$ which ipython
/usr/local/bin/ipython
```

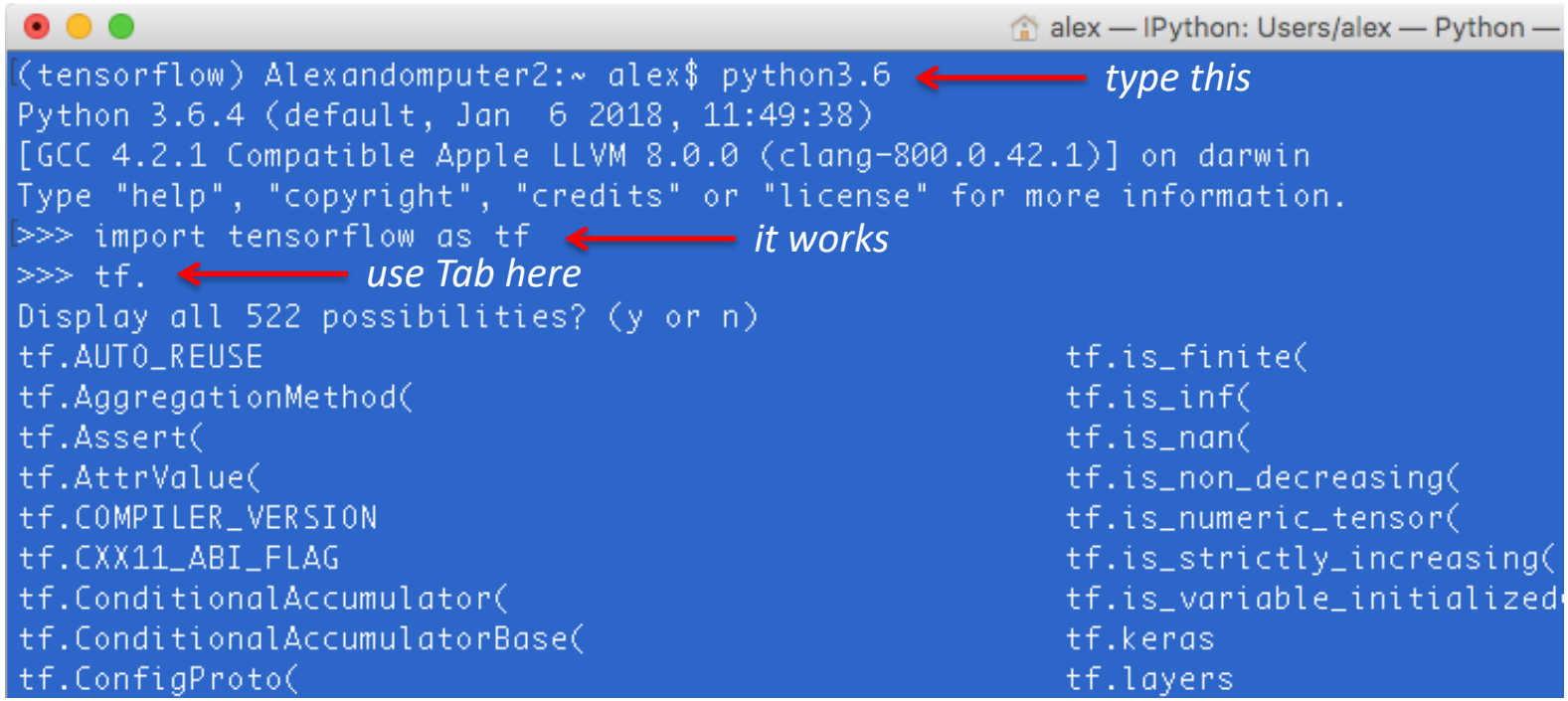
    - Since they run from different locations, iPython may not have the path to run TensorFlow so it is best to reinstall iPython like this in virtualenv:

```
(tensorflow) Alexandomputer2:~ alex$ sudo pip3 install --ignore-installed ipython
```

    - You can also try to change the path

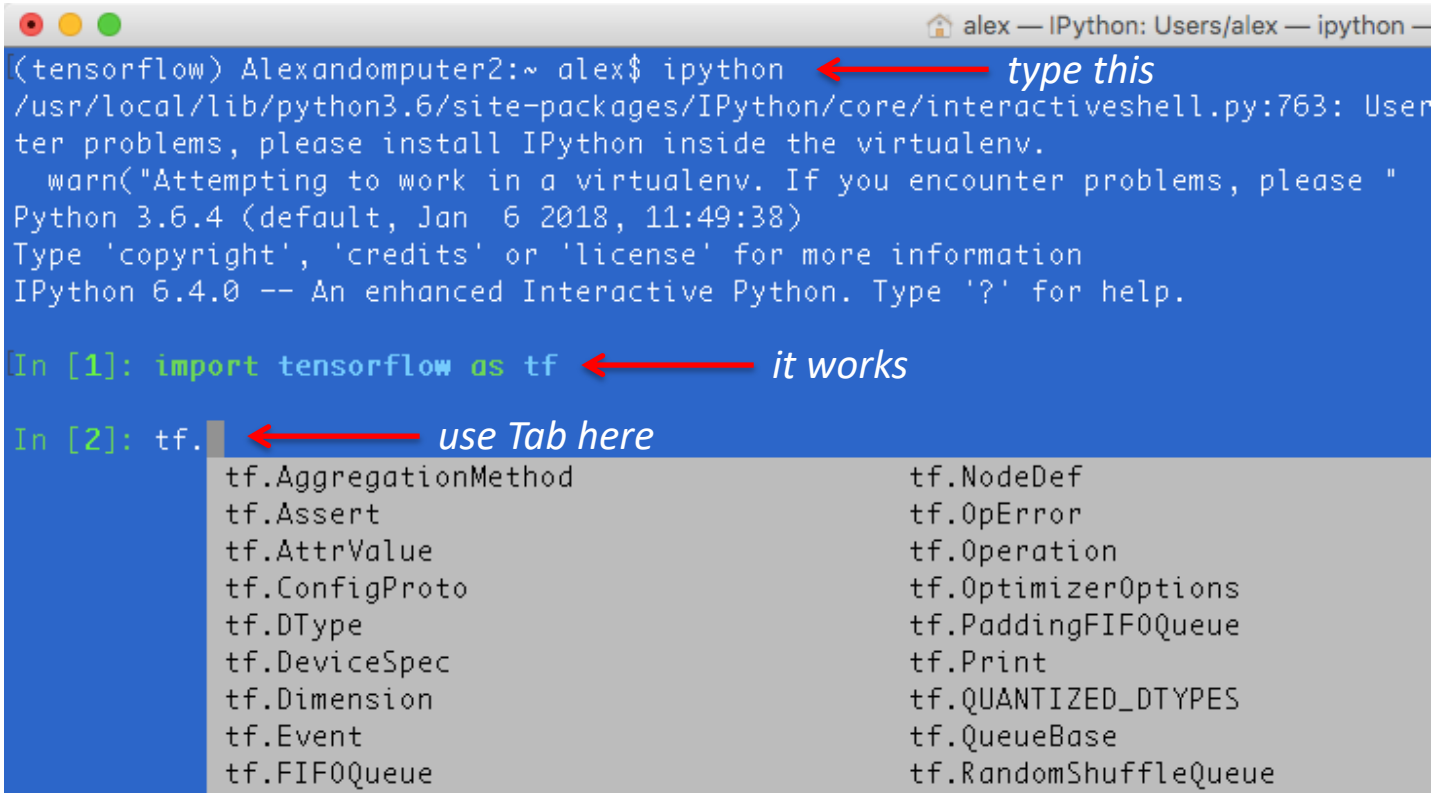
Machine Learning With TensorFlow

- Working with the shell
  - Try TensorFlow on virtualenv and Python3.6:



Machine Learning With TensorFlow

- Working with the shell
  - Try TensorFlow on virtualenv and iPython:



Machine Learning With TensorFlow

- Working with the shell
  - To see the available packages on virtualenv and iPython:

```
In [2]: pip list
```

this will not work, so we use 'help' ...

```
The following command must be run outside of the IPython shell:

    $ pip list
```

  - To check all available modules we type either:

```
In [3]: help('modules')

Please wait a moment while I gather a list of all available modules...
```

we see ... `numpy` ... `matplotlib` ... `tensorflow` ... `tensorboard`

  - Or:

```
In [4]: import
```

this is a tab completion

```
IPython                         alembic
abc                             antigravity
absl                            appnope
aifc                            argparse
```

JUPYTER NOTEBOOK:

- Non-Profit, open-source project.
- Supports Data Science and Scientific Computing across all programming languages
- As all open software, Jupyter is developed by the Jupyter community (GitHub)
- Python language could easily be availed to write a machine learning code on Jupyter since it already comes with a pre-configured data science environment as it runs on the cloud or on our own hardware.

JUPYTER HUB:

- Without asking the users for installation or any other tasks, serves access to users for computational environment and resources.

- Everyone (students, researchers and scientists alike) get their own workspace which can be easily modified by the system administrators.

------Installation------

- Can be installed using CONDA or PiP.

    - conda install -c conda-forge jupyterlab #CONDA
    - pip install jupyterlab #PiP

Machine Learning With TensorFlow

- Working with the shell
  - Installing Jupyter notebook:
    - First, make sure you have installed iPython (on both Python 2 and 3):

```
# Python 2.7
$ sudo python2 -m pip install ipykernel
$ sudo python2 -m ipykernel install
# Python 3
$ sudo python3 -m pip install jupyterhub notebook ipykernel
$ sudo python3 -m ipykernel install
```

    - Then install all dependencies:

```
$ sudo apt-get install build-essential
```

    - use pip to install the Jupyter Notebook (or pip3 for Python 3):

```
# For Python 2.7
$ sudo pip install jupyter
# For Python 3
$ sudo pip3 install jupyter
```

jupyter

Machine Learning With TensorFlow

- Working with the shell
  - Installing Matplotlib and final check:
    - You should be able to see Jupyter in your environment:

```
In [3]: help('modules')

Please wait a moment while I gather a list of all available modules...
```

... jupyter

    - Then install Matplotlib:

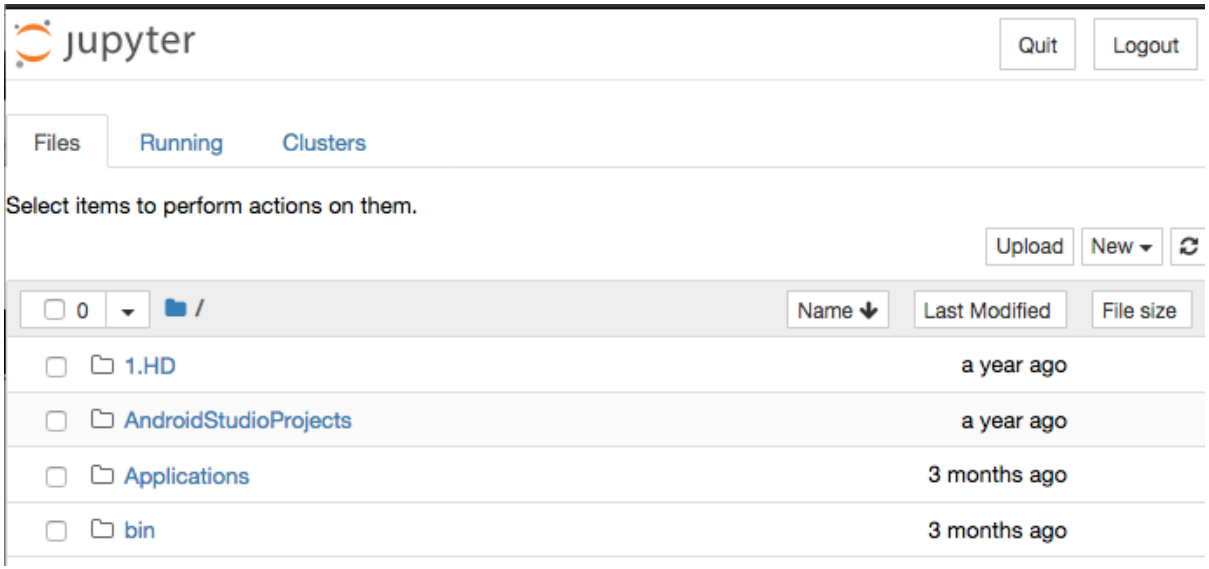
```
# Python 2.7
$ sudo apt-get build-dep python-matplotlib python-tk
# Python 3
$ sudo apt-get build-dep python3-matplotlib python3-tk
```

    - Now check if it works:

```
(tensorflow)$ jupyter notebook
```

Machine Learning With TensorFlow

- Working with the shell
  - Testing your Jupyter environment:
    - You should get a page like this in your browser:



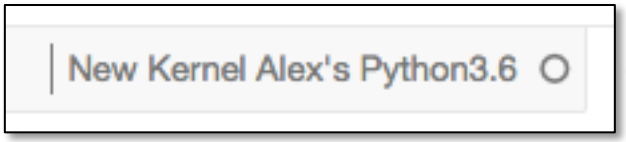
    - With URL: http://localhost:8888/tree

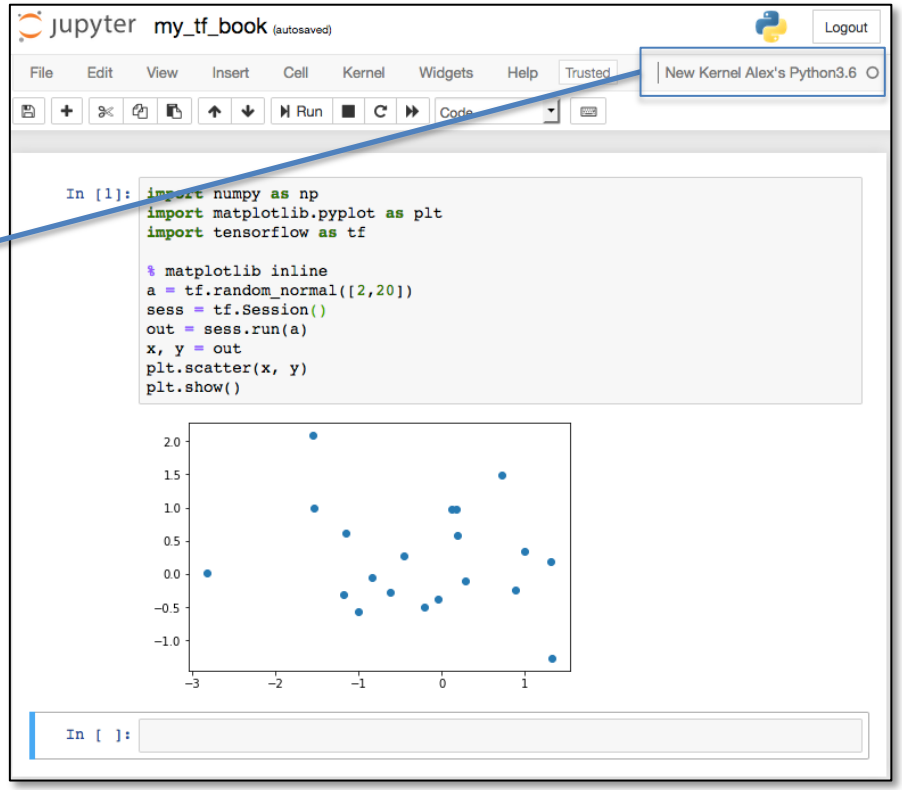
Machine Learning With TensorFlow

- Working with the shell
  - Testing your Jupyter environment:
    - You will be prompted to login:


```
alex$ jupyter notebook --NotebookApp.token=qwerty
```

    - Then run any file you might have:



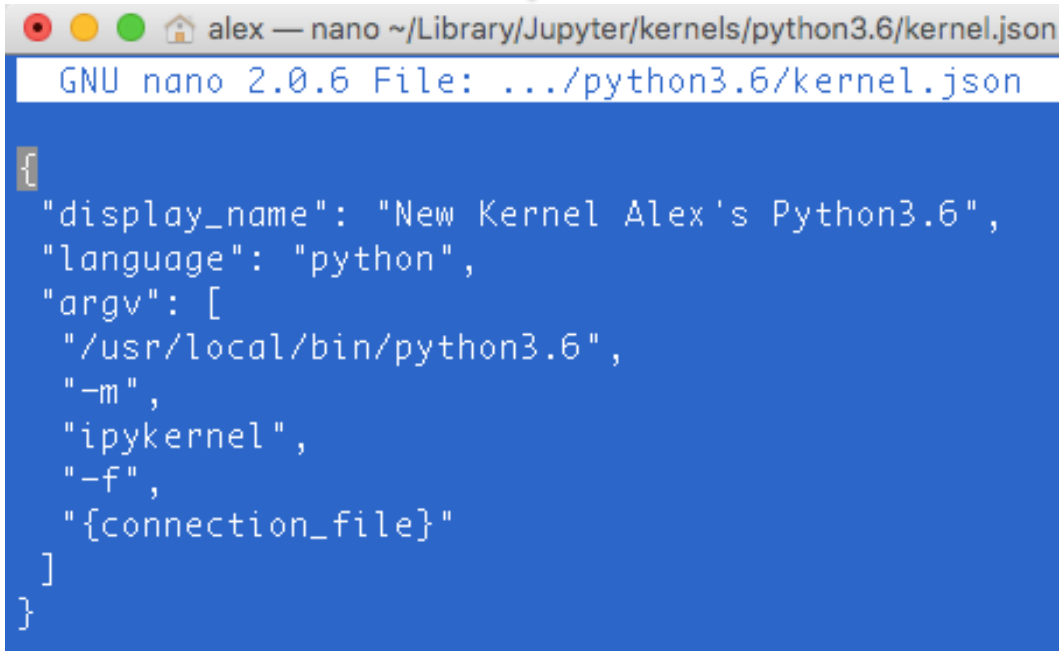


… see next slide

Machine Learning With TensorFlow

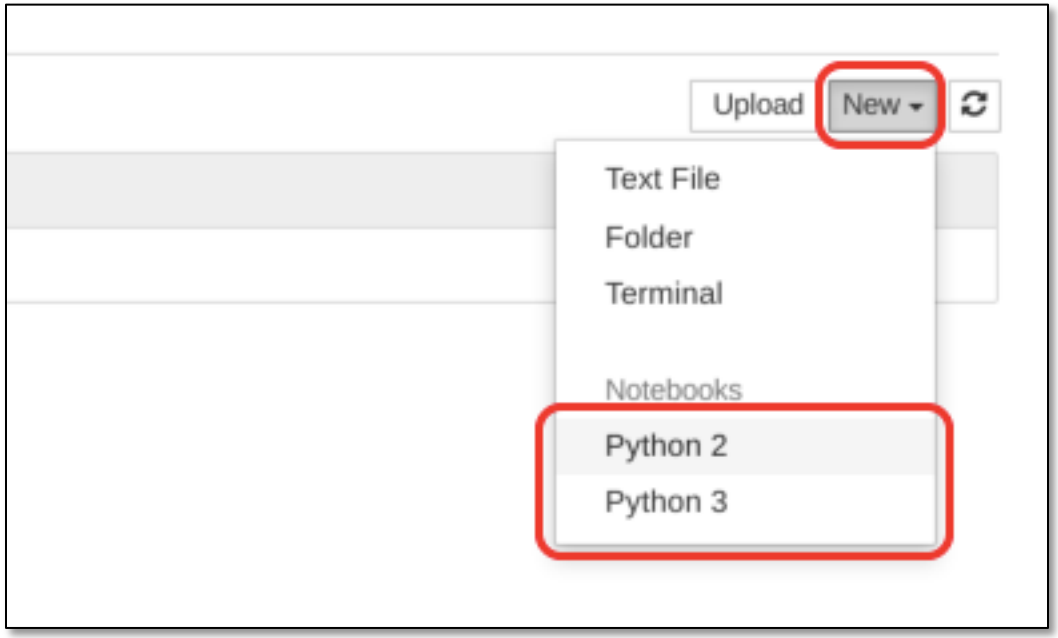
- Working with the shell
  - Testing your Jupyter environment:
    - Here is how to customize your preferred kernel, its source and name:

```
(tensorflow) Alexandomputer2:~ alex$ nano ~/Library/Jupyter/kernels/python3.6/kernel.json
```



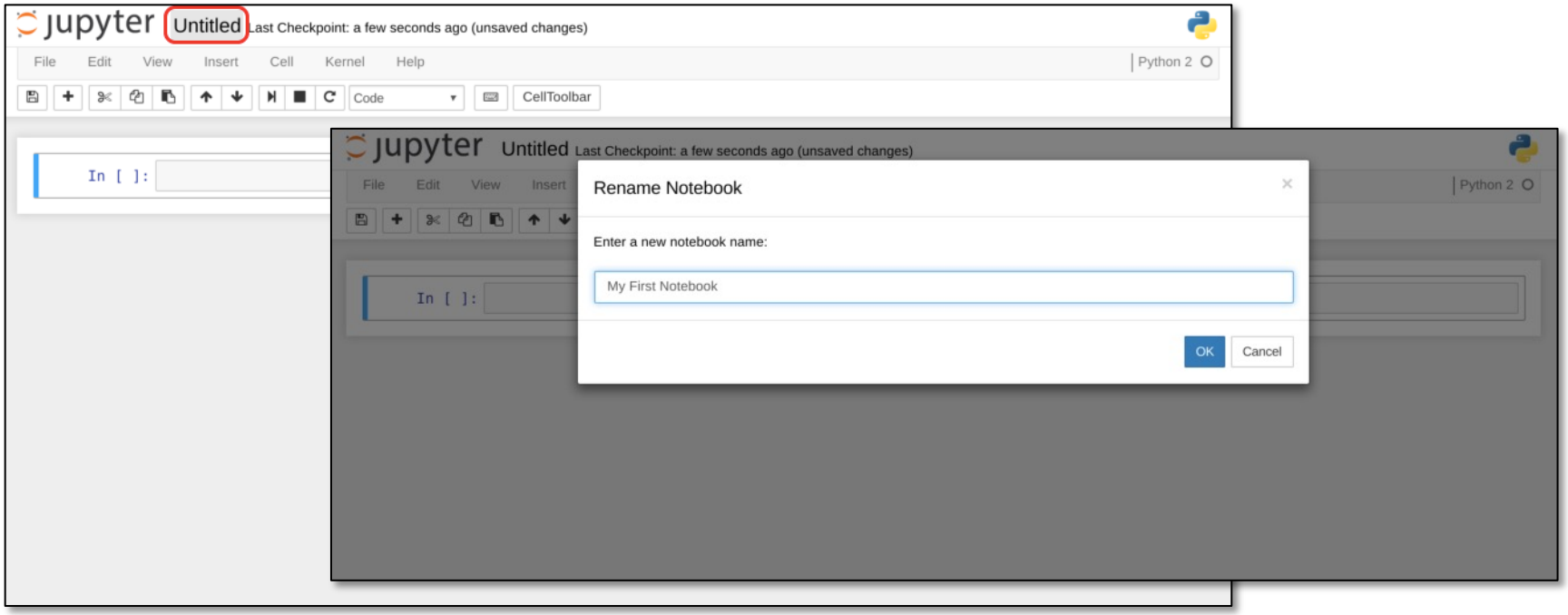
Machine Learning With TensorFlow

- Working with the shell
  - Testing your Jupyter environment:
    - You can start a new file using a different Python version (2 or 3):



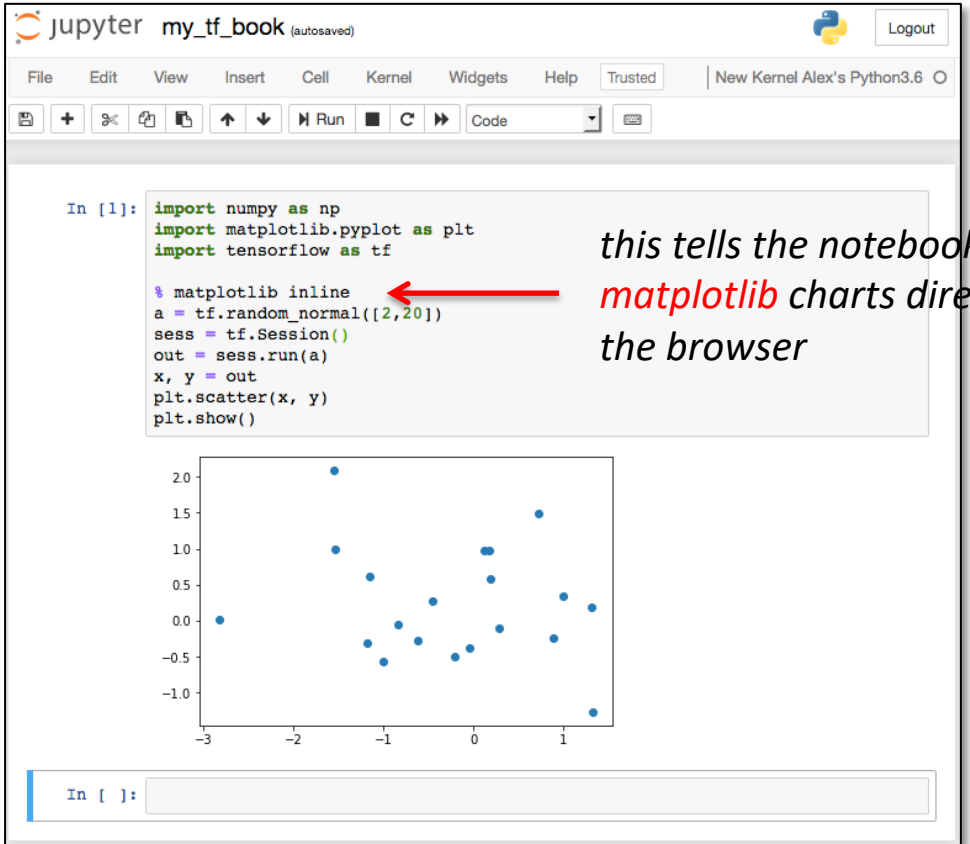
Machine Learning With TensorFlow

- Working with the shell
  - Testing your Jupyter environment:
    - Then you can begin working with it after giving it a name:



Machine Learning With TensorFlow

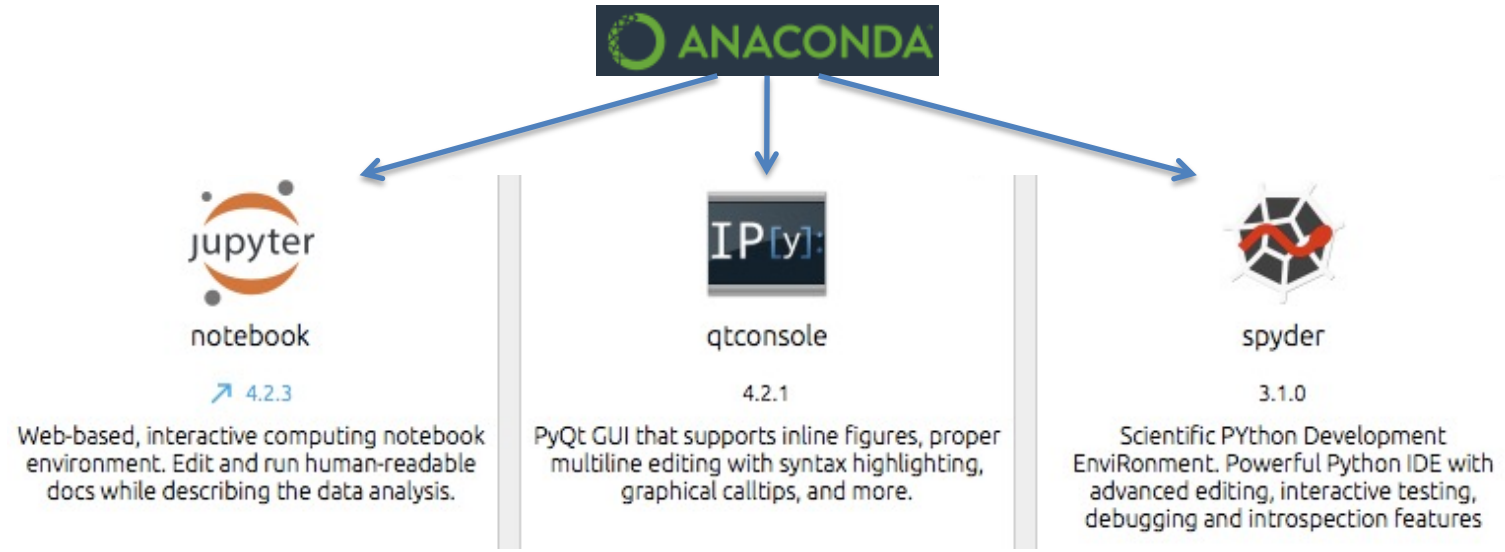
- Working with the shell
  - Testing your Jupyter environment:
    - You can type the code directly in the field or cut and paste it:



this tells the notebook to display matplotlib charts directly inside the browser

Machine Learning With TensorFlow

- Choosing your environment:
  - GUI environments using an interactive editor and debuggers for Python:
    - Anaconda – Anaconda is the leading open data science platform powered by Python: https://www.continuum.io/

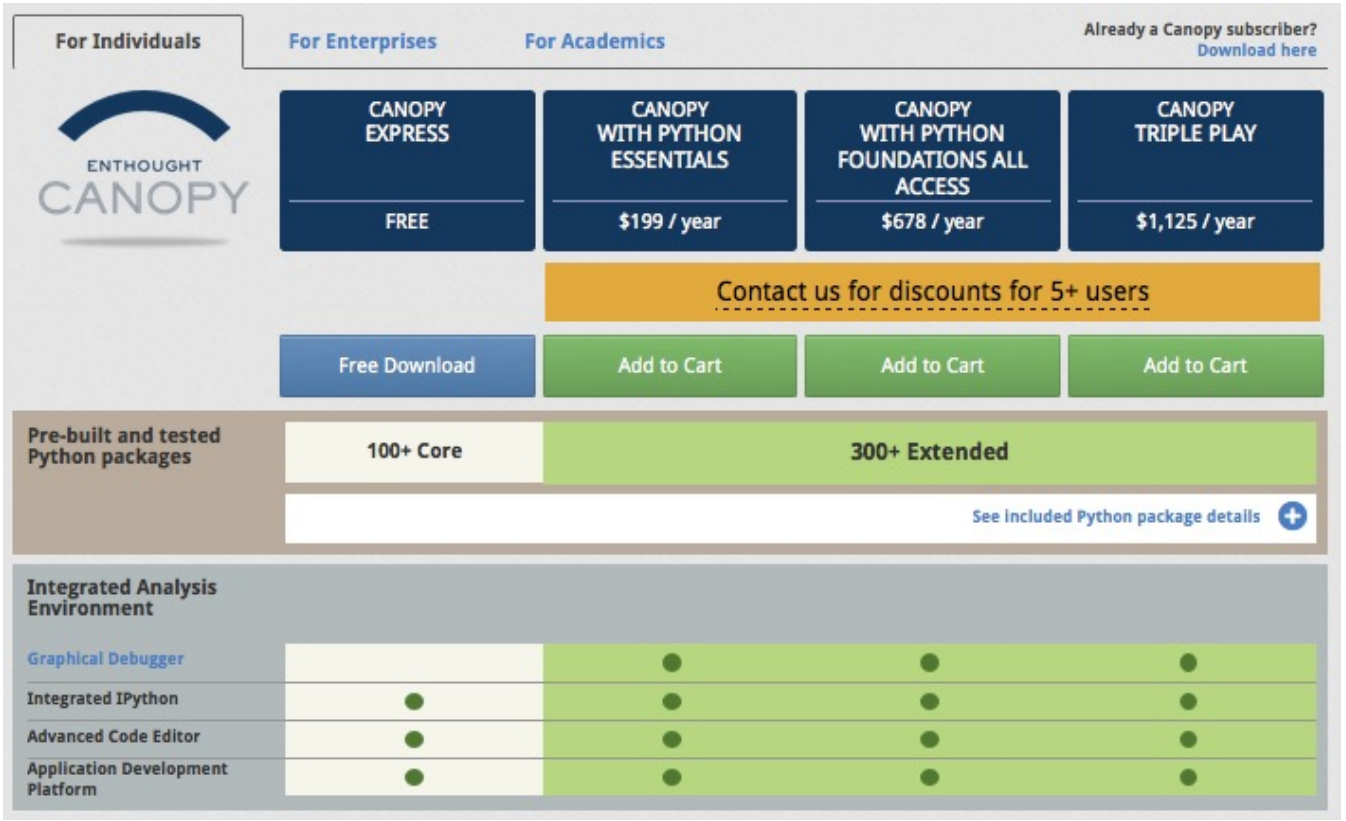


Machine Learning With TensorFlow

- 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



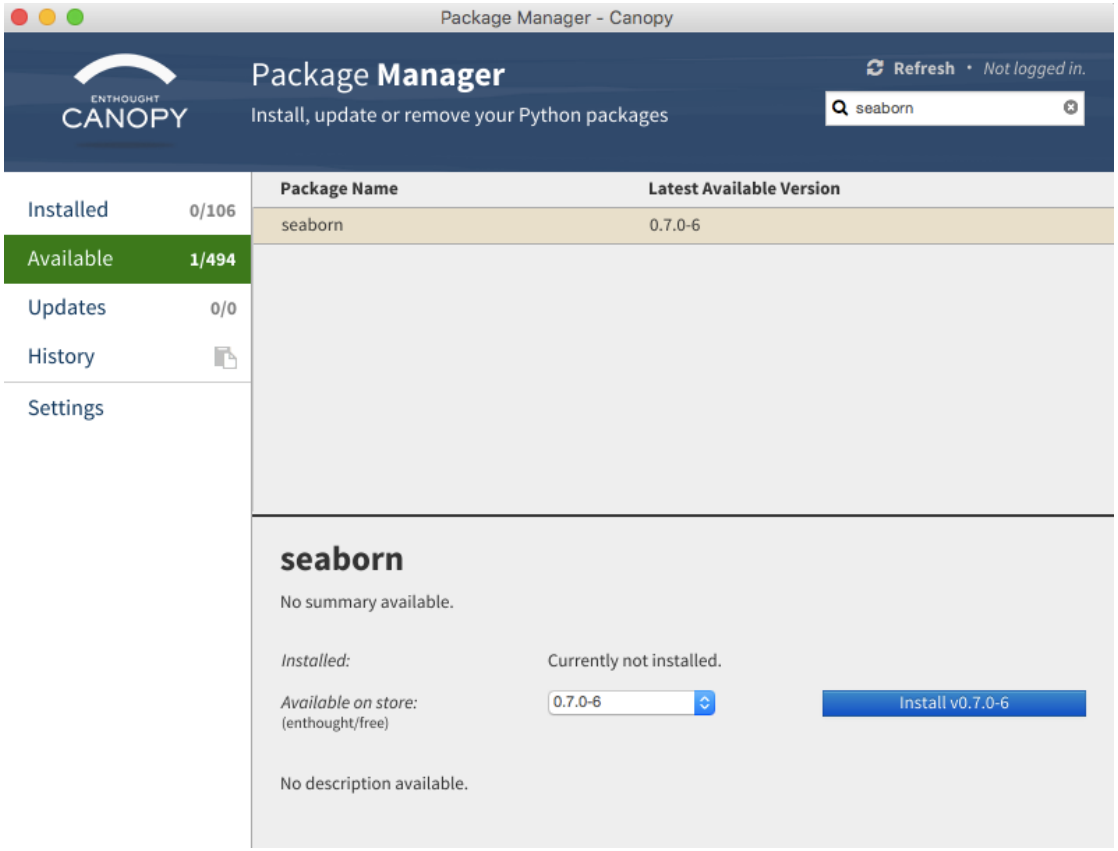
source: https://store.enthought.com/

Machine Learning With TensorFlow

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

Package Manager:

- Packages are installed through Package Manager



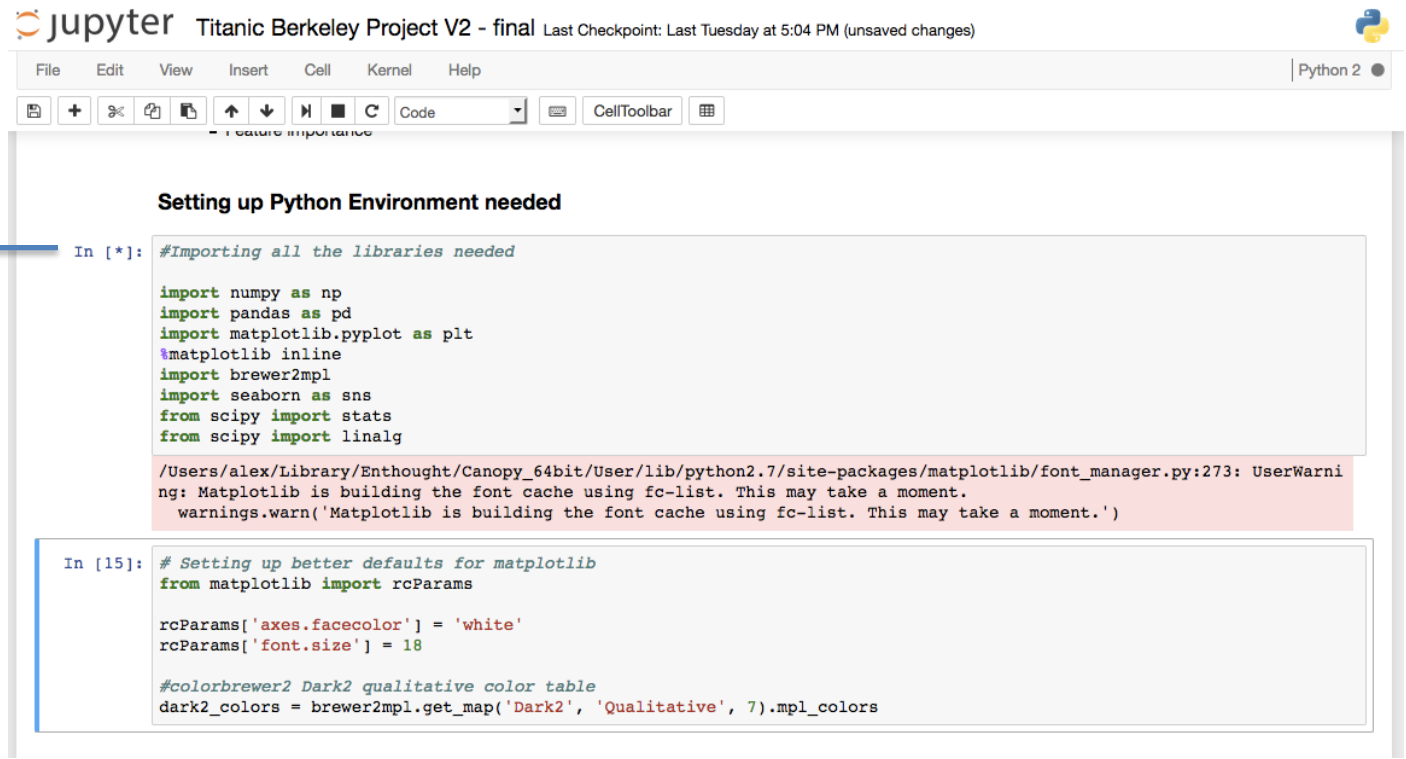
source: https://store.enthought.com/

Machine Learning With TensorFlow

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

Using the browser

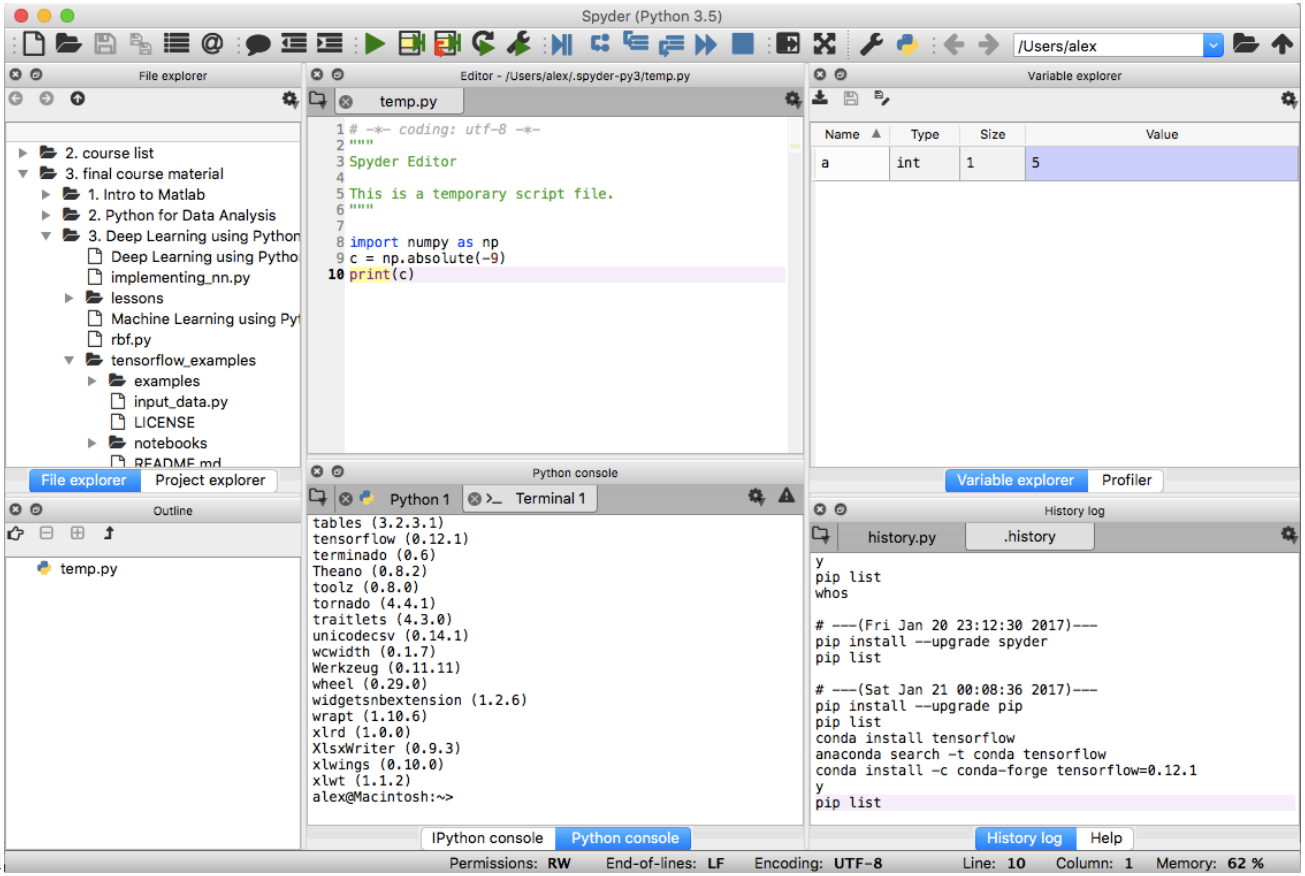
- [*] the line is in a process of executing
- Execute your code sequentially using Shift+Enter



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

Machine Learning With TensorFlow

- Choosing your environment:
  - GUI environments using an interactive editor and debuggers for Python:
    - Spyder – a GUI environment for interactive Python use with shells (terminal- and Qt-based):



GOOGLE COLAB:

- Previously we learnt about installing Jupyter in our hardware, Google Colab gives us access to Jupyter Notebook on our browser
- Runs entirely on the cloud. No need for installation!
- It's easy and efficient for systems which do not have a lot of memory space.
- We can easily write a python code on it and run the shell script via the play button on the left of the code.

Machine Learning With TensorFlow

- Working with Anaconda and Canopy
  - Useful magic commands:

Linux-like:

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

iPython specific:

- edit *file*
- del(parameter)
- reset
- reset -f
- run *file*
- time
- dhist

How to create an alias:

- [35] %alias clc clear

Tips: 1. Using a magic command followed by '?' will give you help for it. Example: 'cd?'

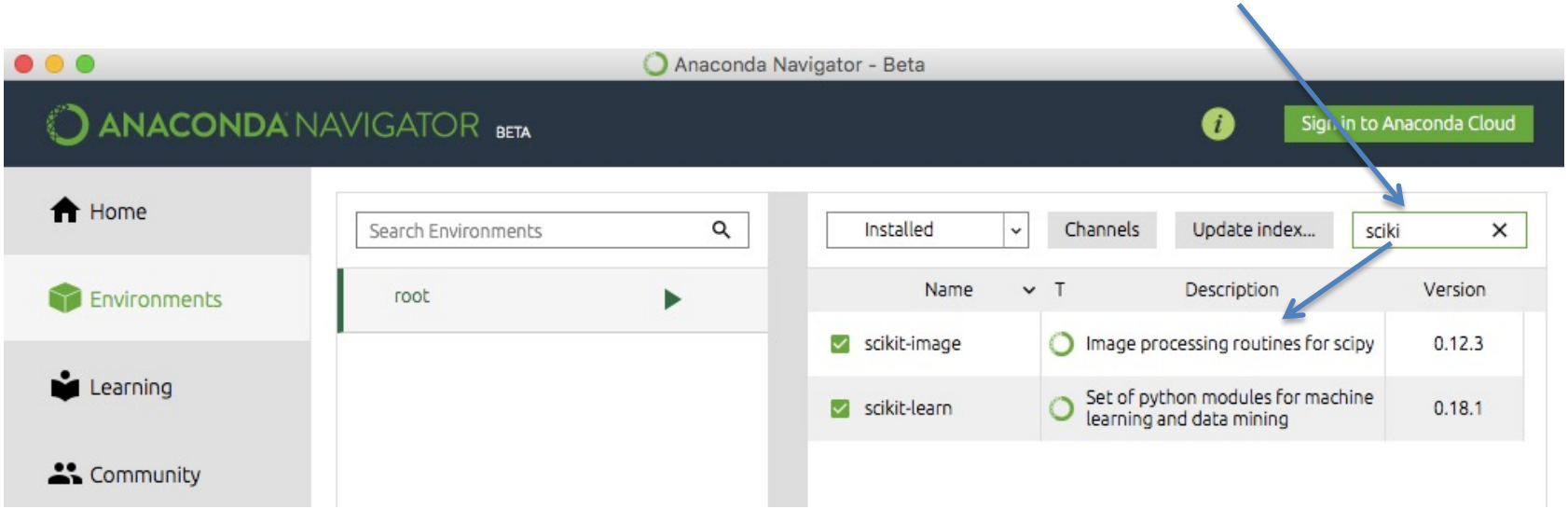
2. Esc will get rid of the help menu

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

Machine Learning

- Working with Anaconda Navigator:

  - Scikit-learn comes installed with Anaconda distribution by default:

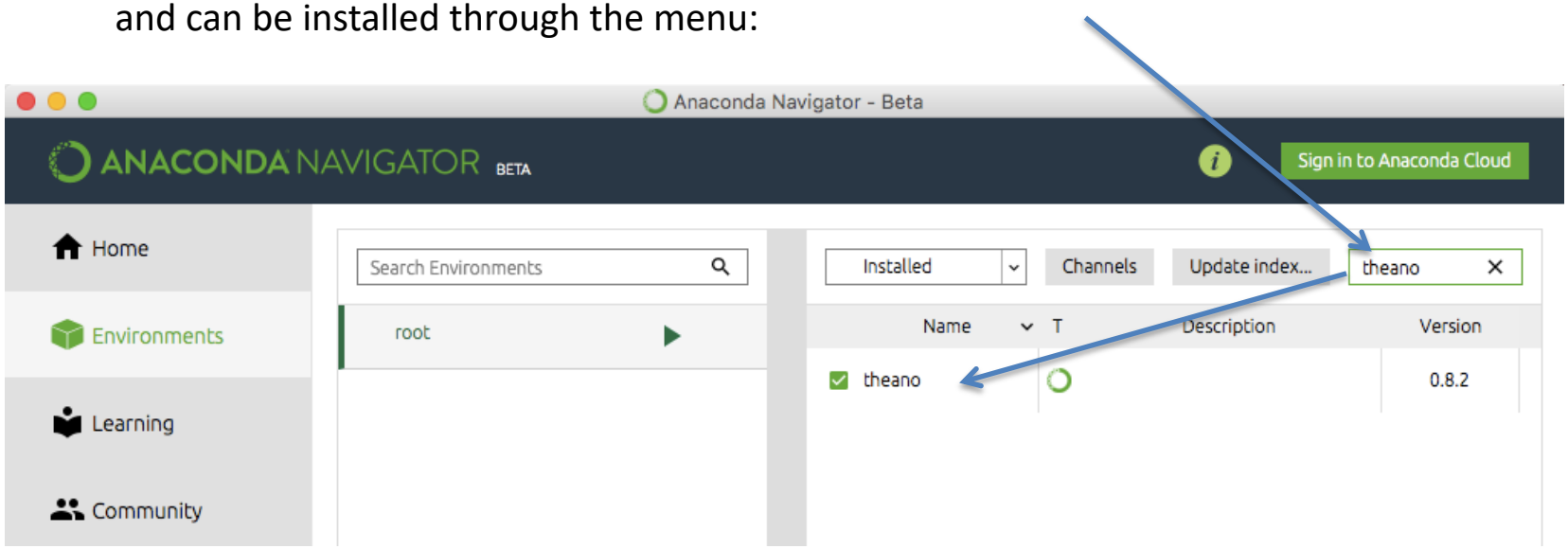


Machine Learning

- Working with Anaconda Navigator:

theano

  - Theano is not installed in Anaconda by default, but is part of the standard repository and can be installed through the menu:

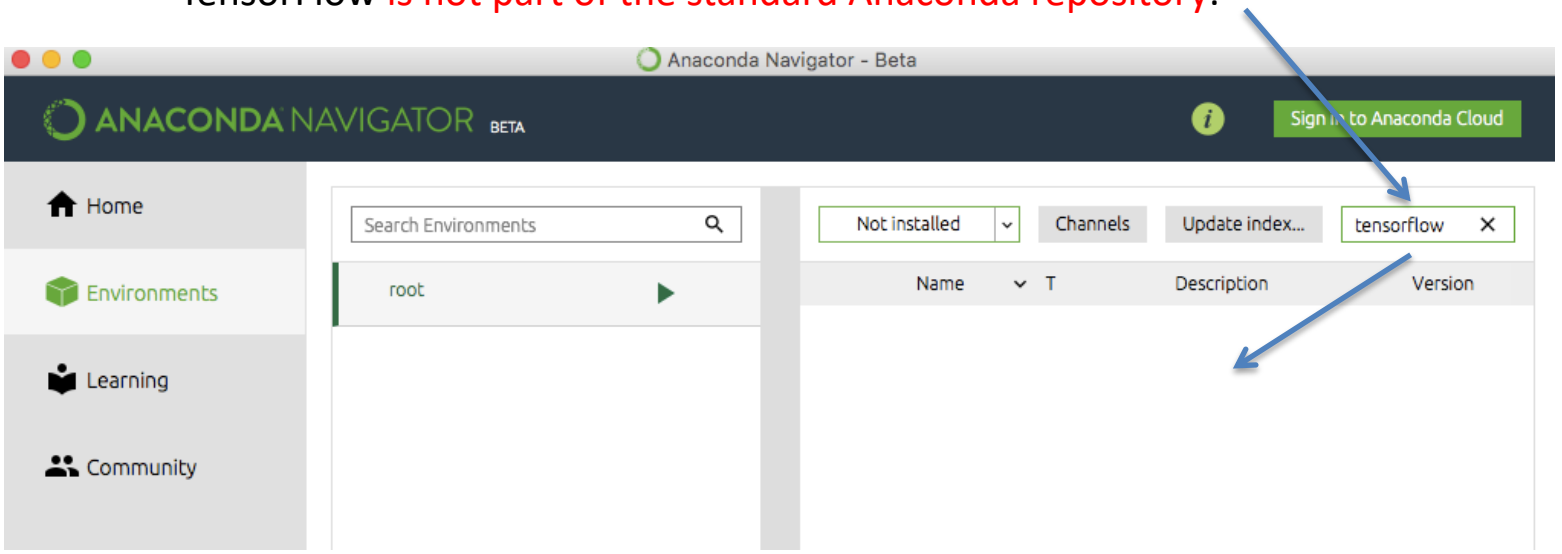


Machine Learning With TensorFlow

- TensorFlow in Anaconda:

TensorFlow™

  - TensorFlow is not part of the standard Anaconda repository:



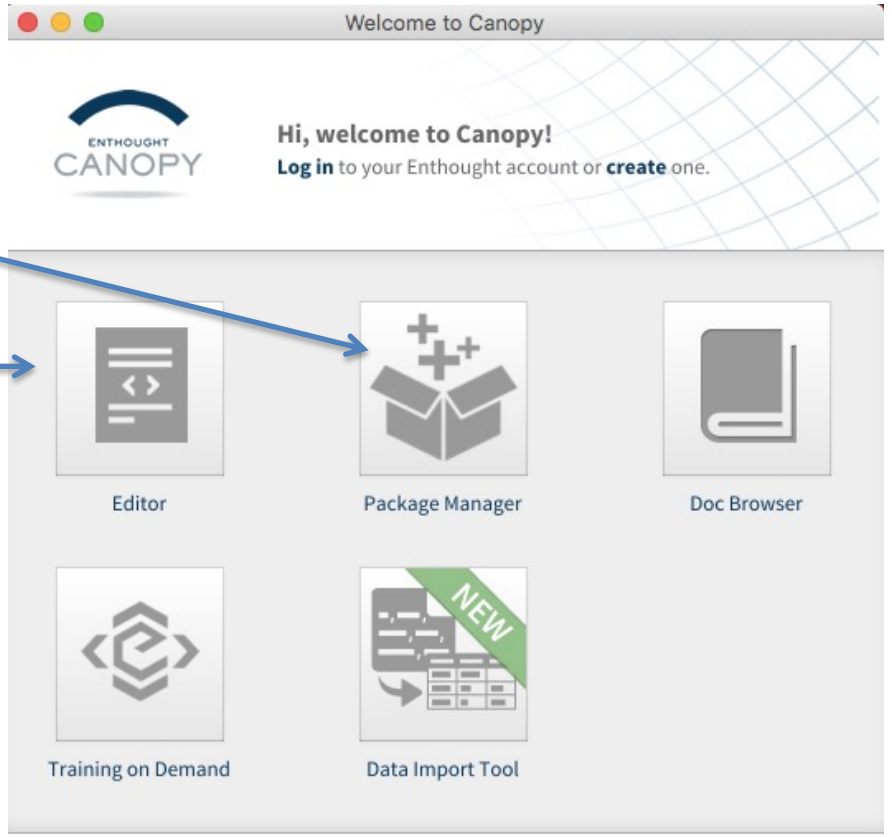
  - So you can install it via Spyder's terminal by typing:
    >>> conda install -c conda-forge tensorflow=1.15.0

Machine Learning With TensorFlow

- TensorFlow in Canopy:

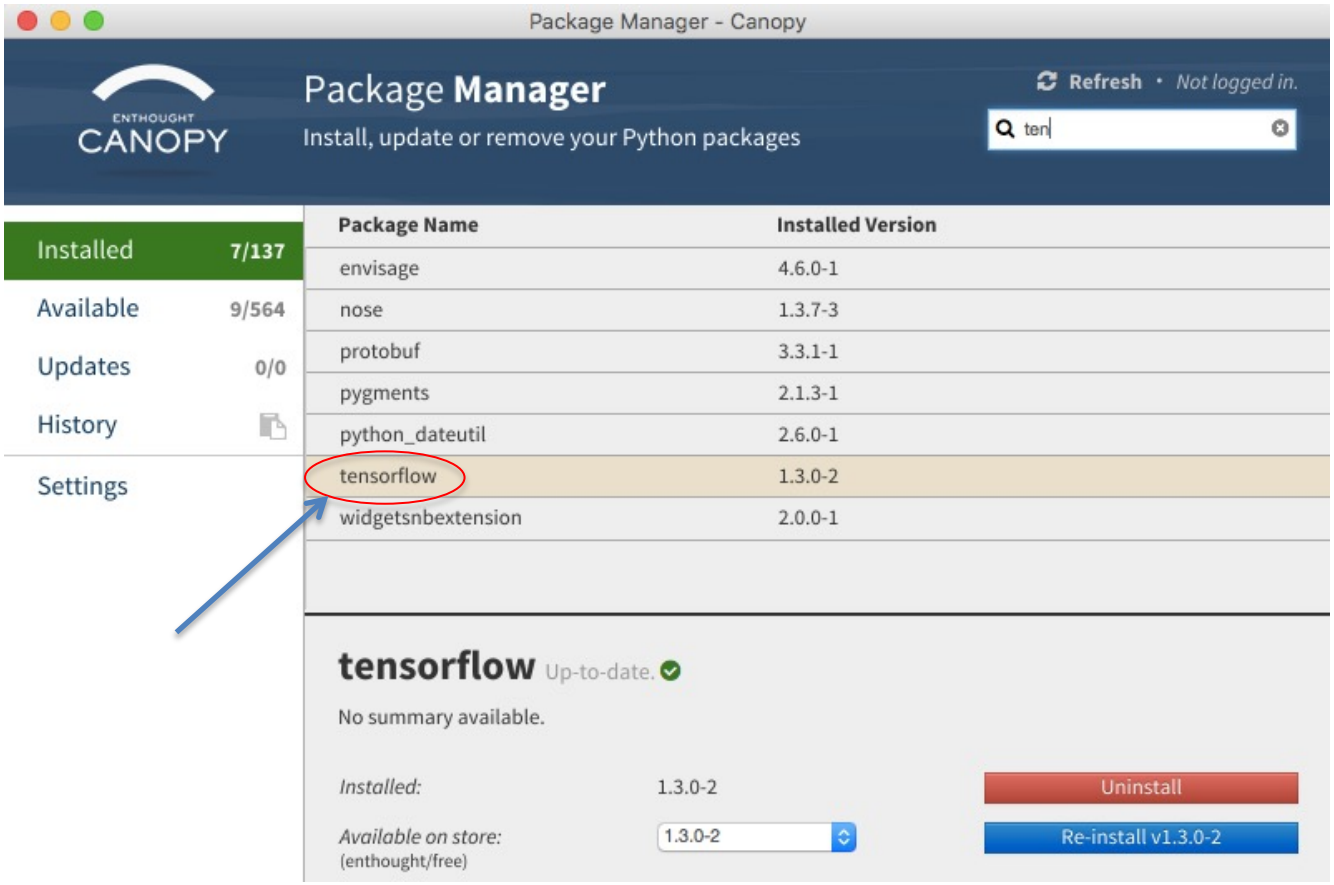
TensorFlow™

1. Install packages from Canopy repository
2. Projects are created here



Machine Learning With TensorFlow

- TensorFlow in Canopy:



Machine Learning With TensorFlow

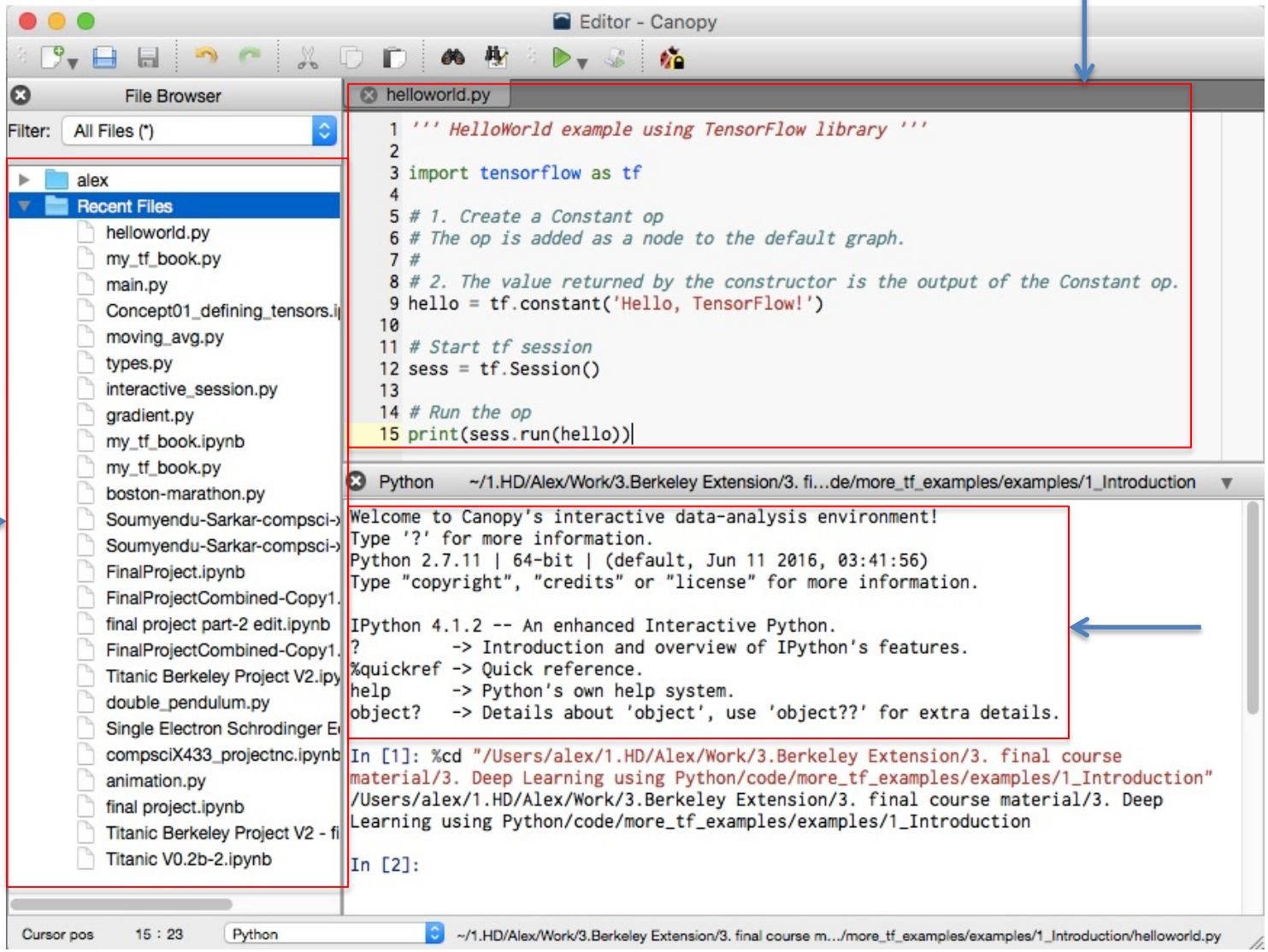
- TensorFlow in Canopy:

TensorFlow™

numpy	1.13.3-1
matplotlib	2.0.0-5
scikit_learn	0.19.1-2
scikits.image	0.13.0-5
scikits.learn	0.8-2
scipy	1.0.0-1

Machine Learning With TensorFlow

- TensorFlow in Canopy:

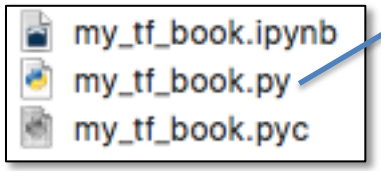


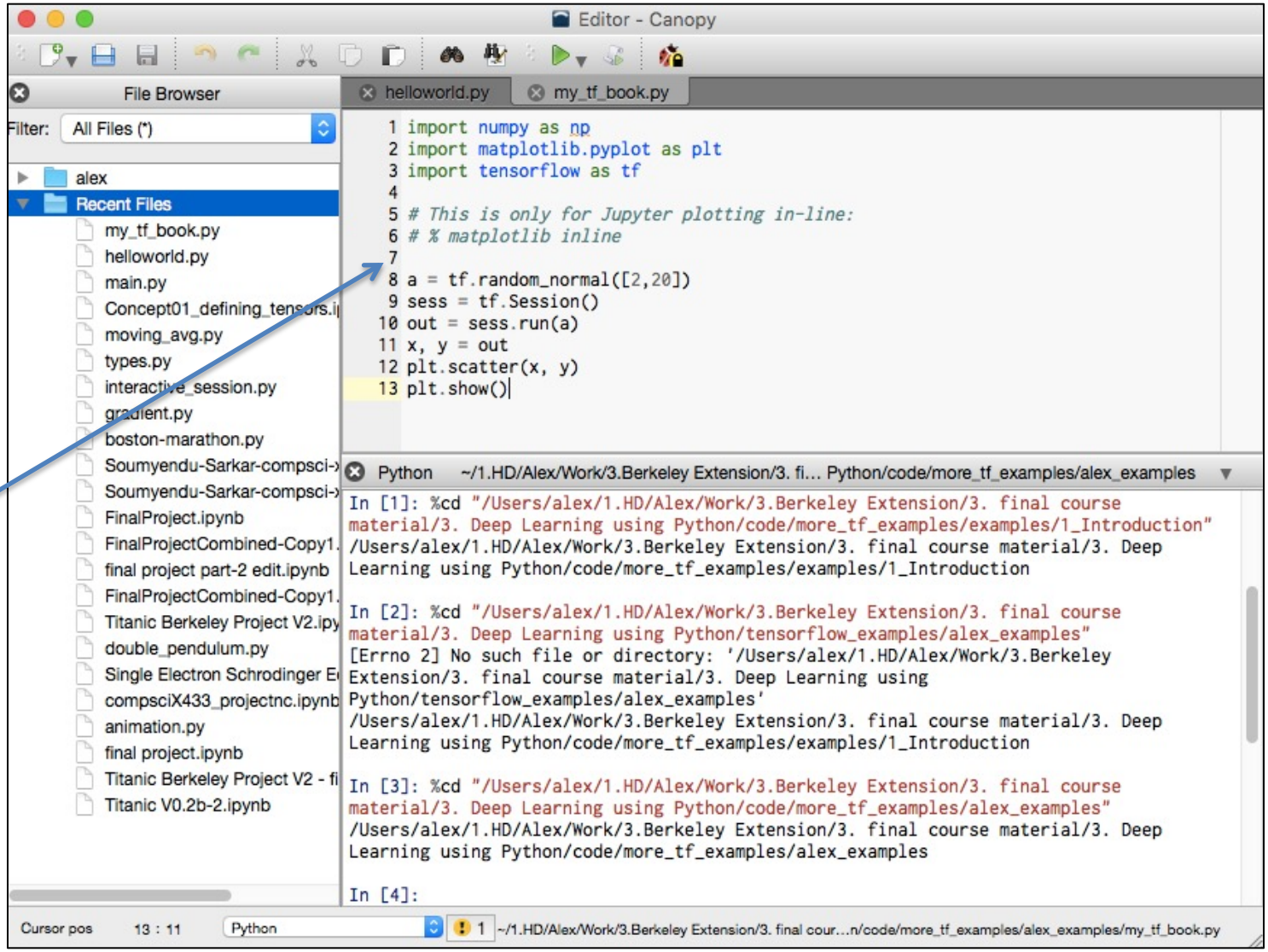
Machine Learning With TensorFlow

- TensorFlow in Canopy:

3 ways to run code:

1. as script file



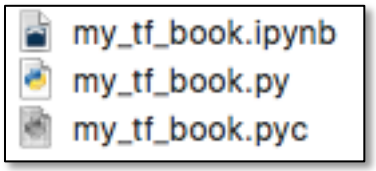


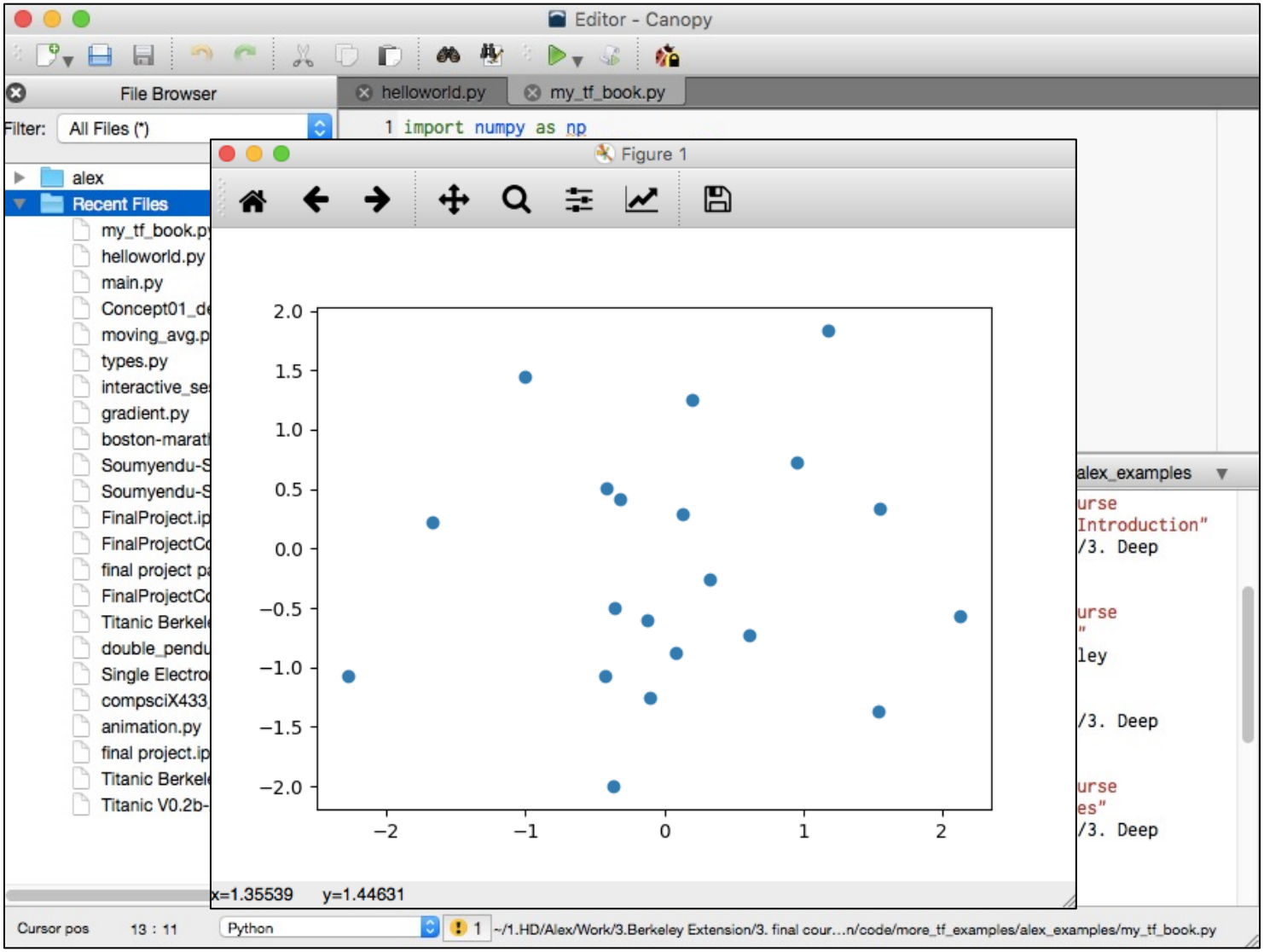
Machine Learning With TensorFlow

- TensorFlow in Canopy:

3 ways to run code:

1. as script file



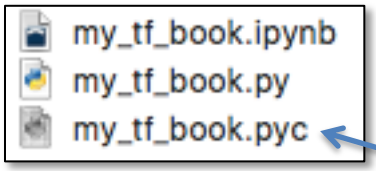


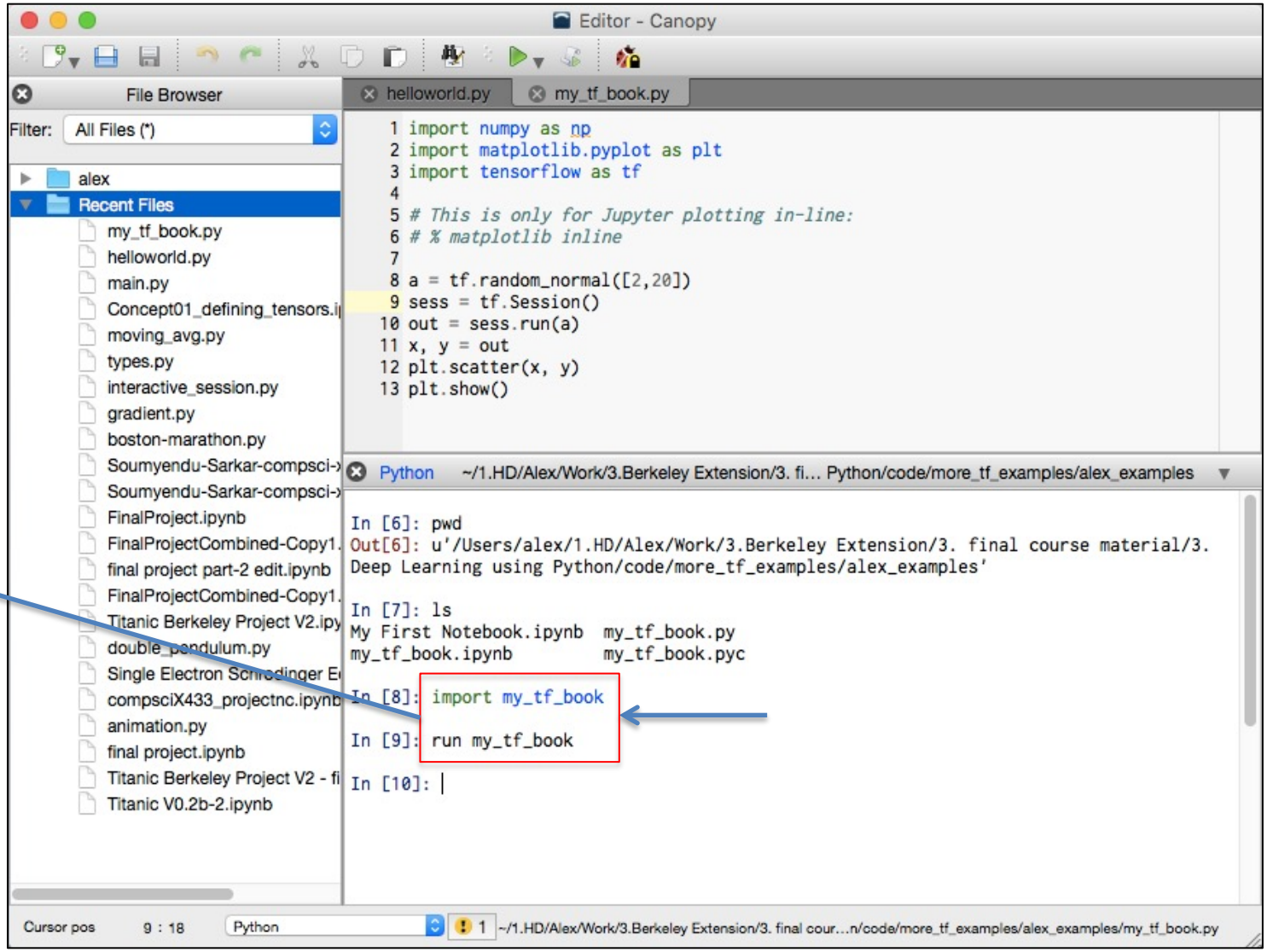
Machine Learning With TensorFlow

- TensorFlow in Canopy:

3 ways to run code:

2. as imported file
(creates compiled version .pyc)



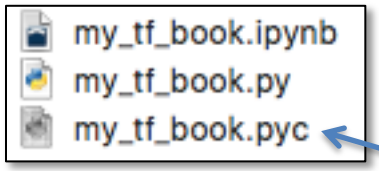


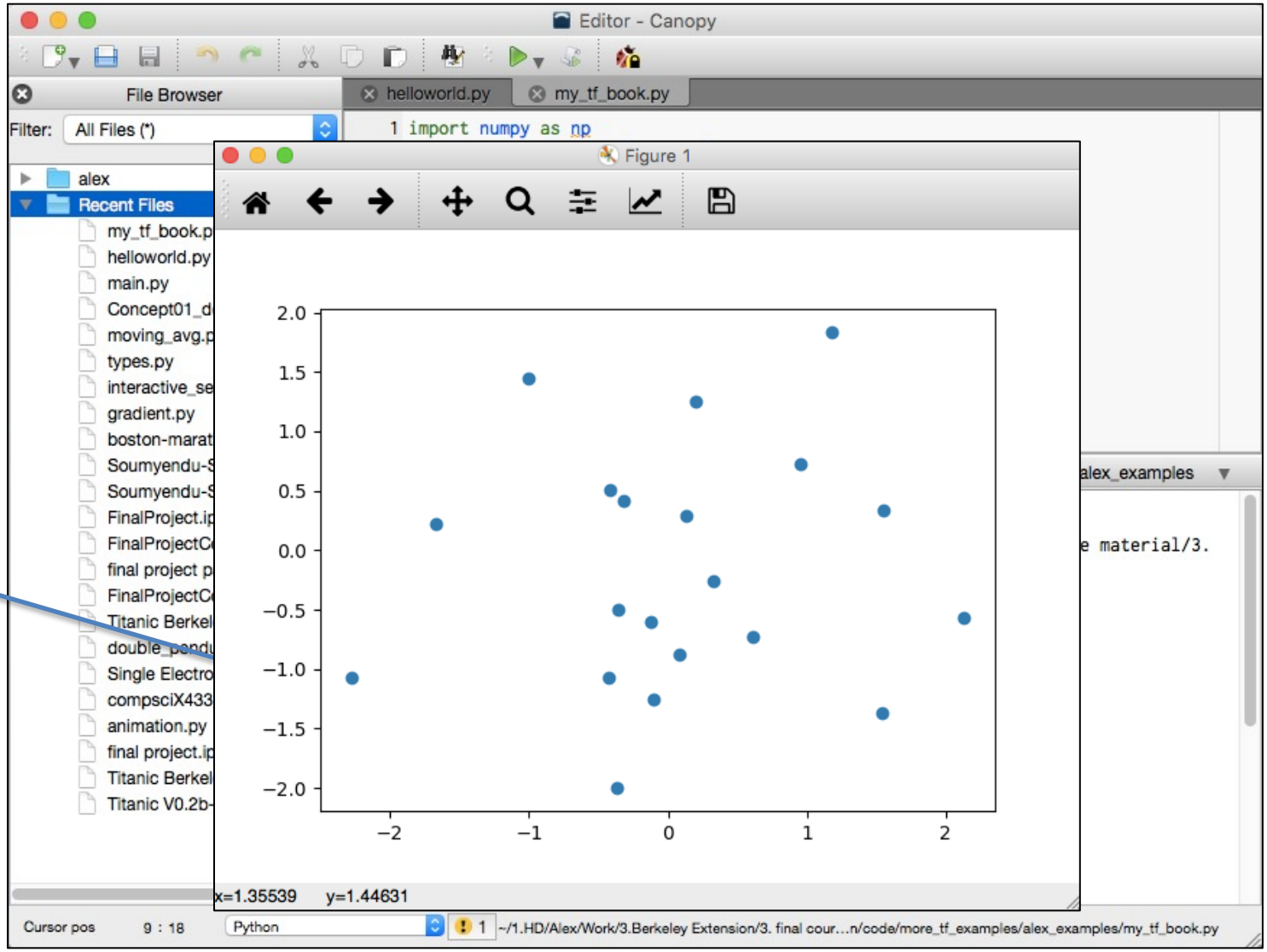
Machine Learning With TensorFlow

- TensorFlow in Canopy:

3 ways to run code:

2. as imported file
(creates compiled version .pyc)



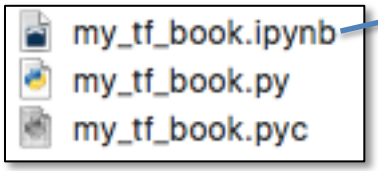


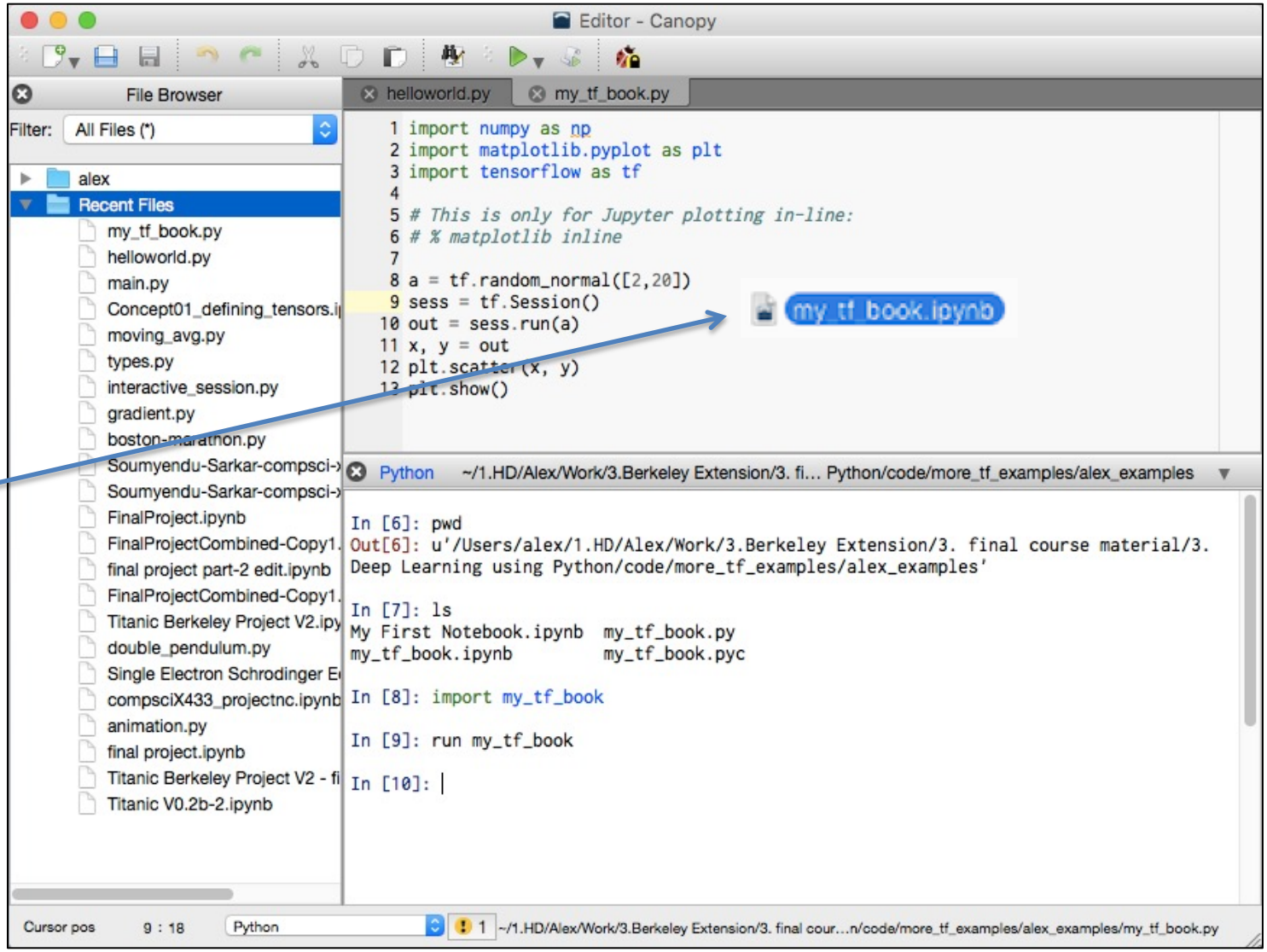
Machine Learning With TensorFlow

- TensorFlow in Canopy:

3 ways to run code:

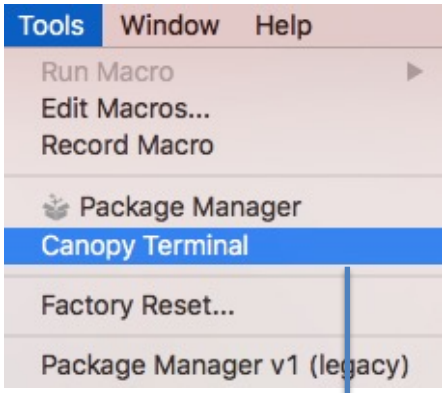
3. in notebook
(it is a .ipynb file)





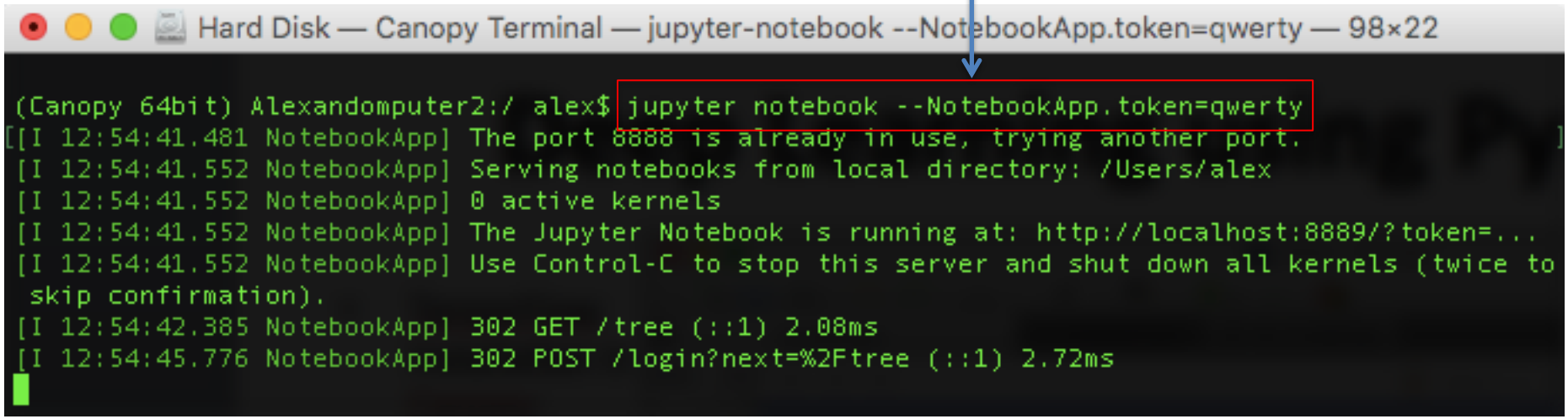
Machine Learning With TensorFlow

- TensorFlow in Canopy:



3 ways to run code:

3. in notebook
(it is a .ipynb file)

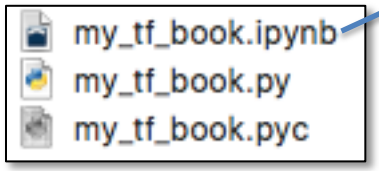


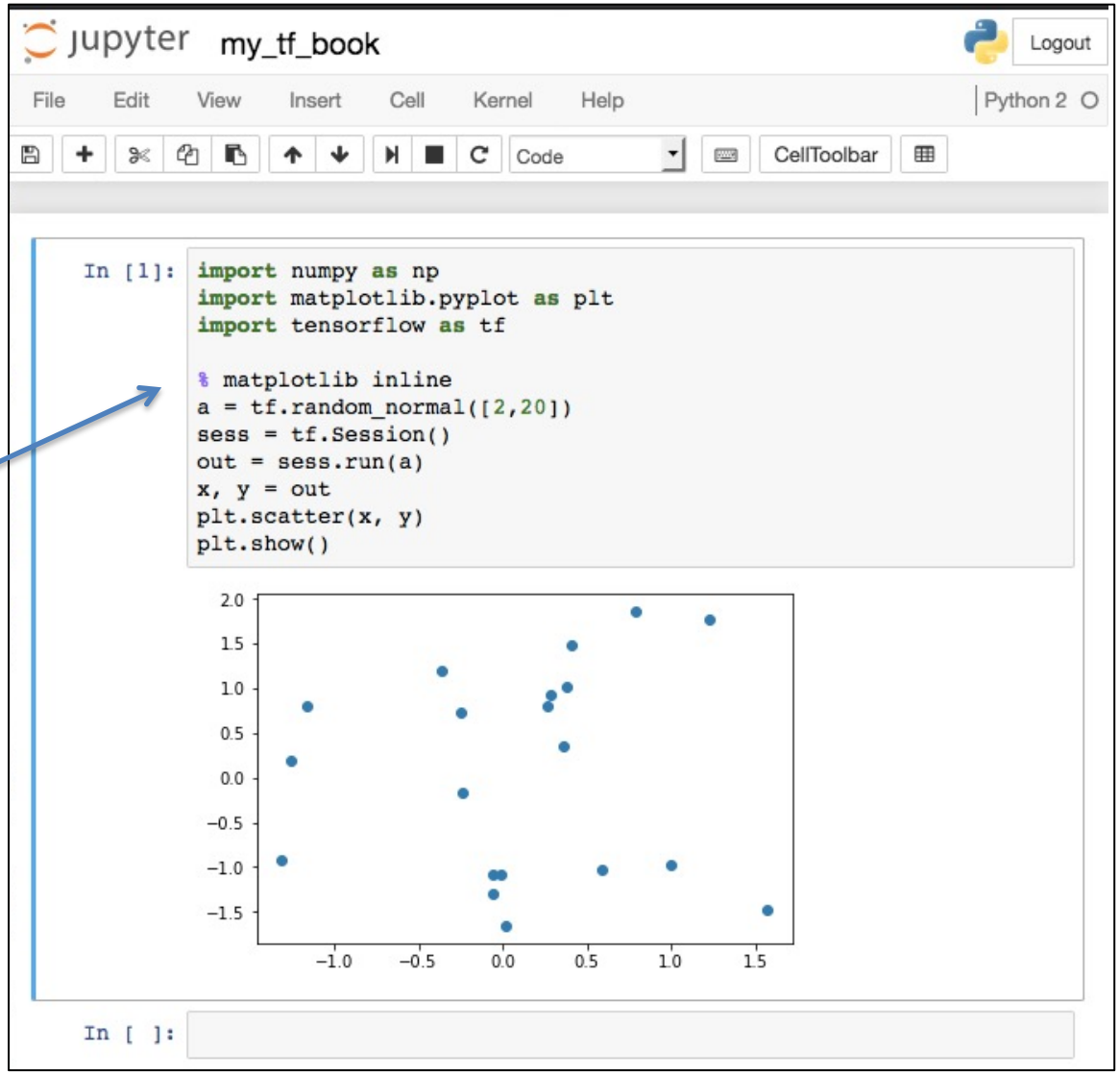
Machine Learning With TensorFlow

- TensorFlow in Canopy:

3 ways to run code:

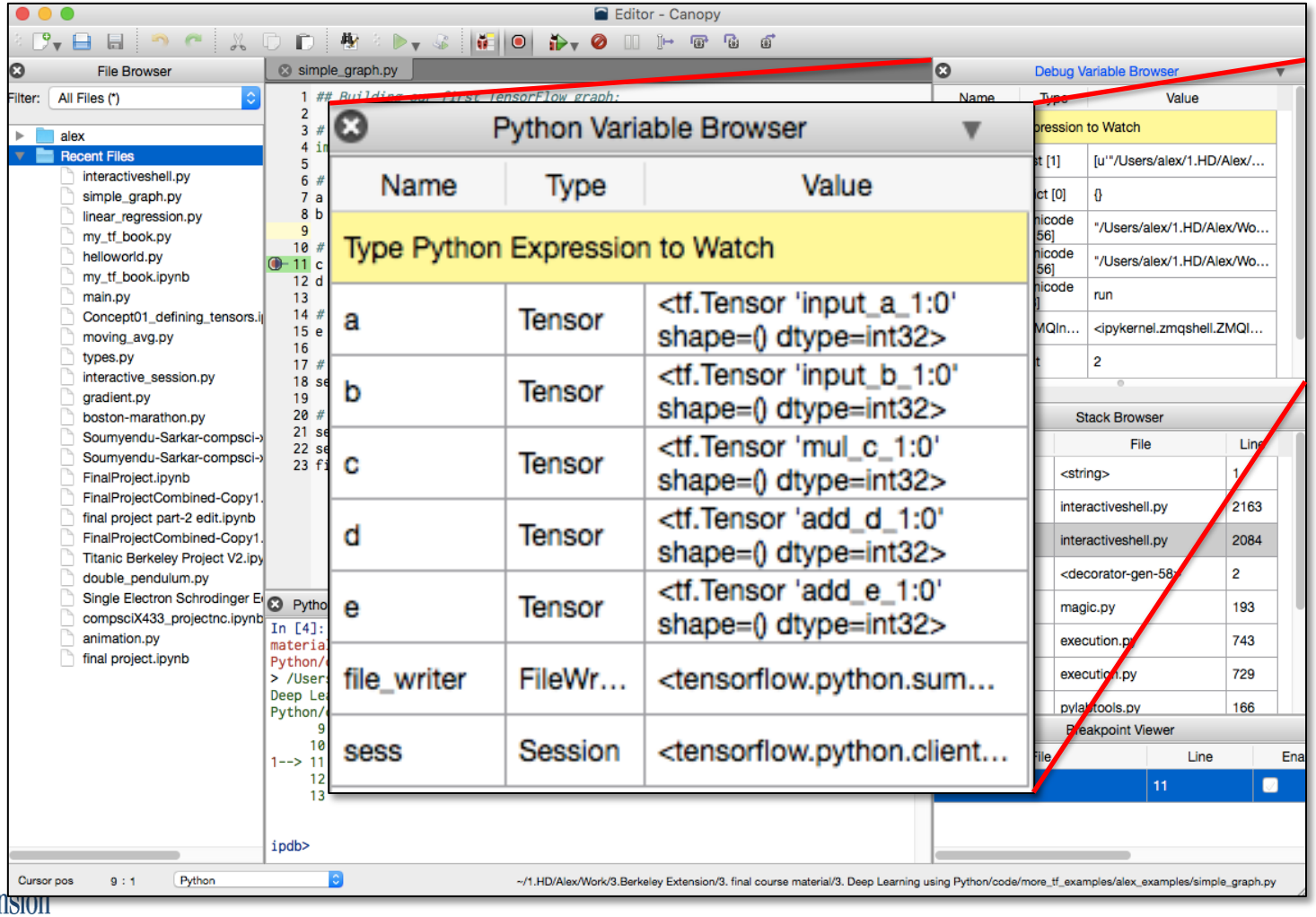
3. in notebook
(it is a .ipynb file)





Canopy debugger

- Running in debug mode:



Machine Learning With TensorFlow

Assignment:

Choose, install and configure your Python-Tensorflow environment

TensorFlow: how it works?

- Nodes and tensors in TensorFlow are Python objects, and TensorFlow applications are themselves Python applications
- The libraries of transformations that are available through TensorFlow are written as high-performance C++ binaries.
- Python just directs traffic between the pieces, and provides high-level programming abstractions to hook them together.
- TensorFlow applications can be run on most any target that's convenient: a local machine, a cluster in the cloud, iOS and Android devices, CPUs or GPUs.
- If you use Google's own cloud, you can run TensorFlow on Google's custom TensorFlow Processing Unit (TPU) silicon for further acceleration.

TensorFlow: how it works?

- TensorFlow 2.0, in beta as of June 2019, revamped the framework in many ways based on user feedback, to make it easier to work with and more performant
- Distributed training is easier to run thanks to a new API
- Support for TensorFlow Lite makes it possible to deploy models on a greater variety of platforms
- However, code written for earlier versions of TensorFlow must be rewritten—sometimes only slightly, sometimes significantly—to take maximum advantage of new TensorFlow 2.0 features.

TensorFlow v/s Competition

- TensorFlow competes with a slew of other machine learning frameworks
- PyTorch, CNTK, and MXNet are three major frameworks that address the same needs

1) PyTorch:

- In addition to being built with Python, and has many other similarities to TensorFlow:
  - Hardware-accelerated components under the hood
  - A highly interactive development model that allows for design-as-you-go work
  - A better choice for fast development of projects that need to be up and running in a short time, but TensorFlow wins on larger projects and more complex workflows

TensorFlow v/s Competition

- TensorFlow competes with a slew of other machine learning frameworks
- PyTorch, CNTK, and MXNet are three major frameworks that address the same needs

2) CNTK :

- The Microsoft Cognitive Toolkit (MCT)
- Uses a graph structure to describe dataflow
- Focuses mostly on creating deep learning neural networks
- Handles many neural network jobs faster
- But CNTK isn't as easy to learn or deploy as TensorFlow

TensorFlow v/s Competition

3) Apache Mxnet :

- Adopted by Amazon as the premier deep learning framework on AWS
- Can scale almost linearly across multiple GPUs and multiple machines.
- It also supports a broad range of language APIs—Python, C++, Scala, R, JavaScript, Julia, Perl, Go—although its native APIs aren't as pleasant to work with as TensorFlow's.

TensorFlow

PROS

GRAPHS :

1

has better computational graph visualizations, which are indigenous when compared to other libraries like Torch and Theano

LIBRARY MANAGEMENT:

2

Backed by Google, TensorFlow has the advantage of the seamless performance, quick updates and frequent new releases with new features

DEBUGGING :

3

lets you execute subparts of a graph which gives it an upper-hand as you can introduce and retrieve discrete data onto an edge

SCALABILITY :

4

The libraries can be deployed on a gamut of hardware machines, starting from cellular devices to computers with complex setups

CONS

1 MISSING SYMBOLIC LOOPS:

TensorFlow does not offer this feature, but there is a workaround using finite unfolding (bucketing).

2 LIMITED SUPPORT FOR WIN:

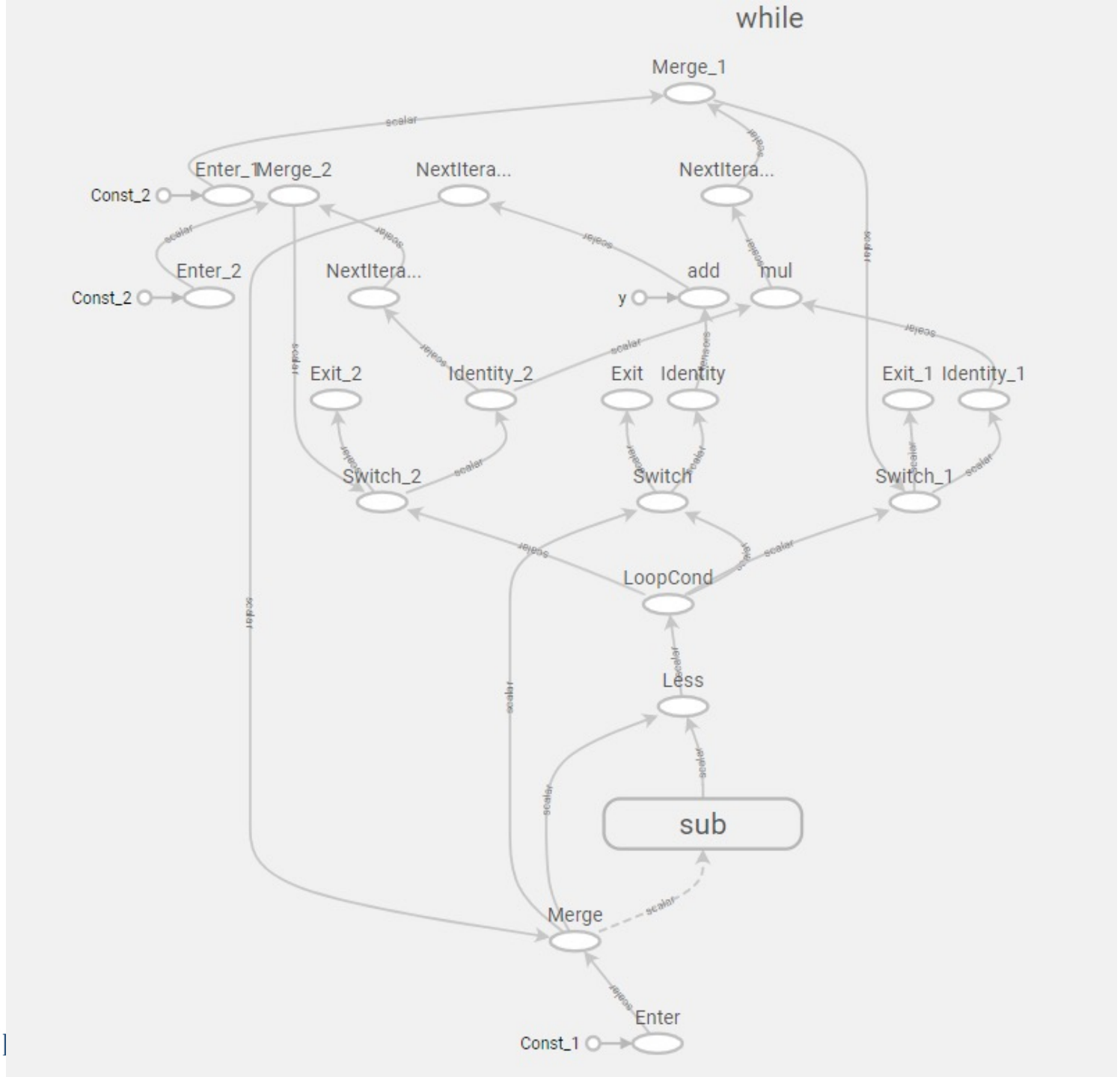
There is still a wide variety of users who are comfortable with a windows environment rather than a Linux in their systems and TensorFlow does not assuage these users.

3 BENCHMARK TESTS :

On small scale TensorFlow lacks behind in both speed and usage when compared to its competitors (not the case for large computations!)

```
import tensorflow as tf

N = tf.constant(100)
i = tf.constant(0)
x = tf.constant(1.5)

def body(i, x, x0):
    return i + 1, x * x0, x0

output = tf.while_loop( lambda i,x,x0: i < N-1, body, [i, x, x] );
# a `Session` encapsulates the environment in which `Operations` are executed, and `Tensors` are evaluated
with tf.Session() as sess:
    writer = tf.summary.FileWriter("while_loop_example")
    writer.add_graph(sess.graph)
    print(sess.run(output))
```


Source: https://stackoverflow.com


while
Merge_1
Enter_1
Merge_2
NextItera...
NextItera...
Const_2
Enter_2
NextItera...
add
mul
Const_2
y
Exit_2
Identity_2
Exit
Identity
Exit_1
Identity_1
Switch_2
Switch
Switch_1
LoopCond
Less
sub
Merge
Enter
Const_1
scalar

Comparison Chart 1/3

	Platform	Cost	Written in language	Algorithms or Features
Scikit Learn	Linux, Mac OS, Windows	Free.	Python, Cython, C, C++	Classification Regression Clustering Preprocessing Model Selection Dimensionality reduction.
PyTorch	Linux, Mac OS, Windows	Free	Python, C++, CUDA	Autograd Module Optim Module nn Module
TensorFlow	Linux, Mac OS, Windows	Free	Python, C++, CUDA	Provides a library for dataflow programming.
Weka	Linux, Mac OS, Windows	Free	Java	Data preparation Classification Regression Clustering Visualization Association rules mining

Comparison Chart 2/3

KNIME	Linux, Mac OS, Windows	Free	Java	Can work with large data volume. Supports text mining & image mining through plugins
Colab	Cloud Service	Free	-	Supports libraries of PyTorch, Keras, TensorFlow, and OpenCV
Apache Mahout	Cross-platform	Free	Java Scala	Preprocessors Regression Clustering Recommenders Distributed Linear Algebra.
Accors.Net	Cross-platform	Free	C#	Classification Regression Distribution Clustering Hypothesis Tests & Kernel Methods Image, Audio & Signal. & Vision
Shogun	Windows Linux UNIX Mac OS	Free	C++	Regression Classification Clustering Support vector machines. Dimensionality reduction

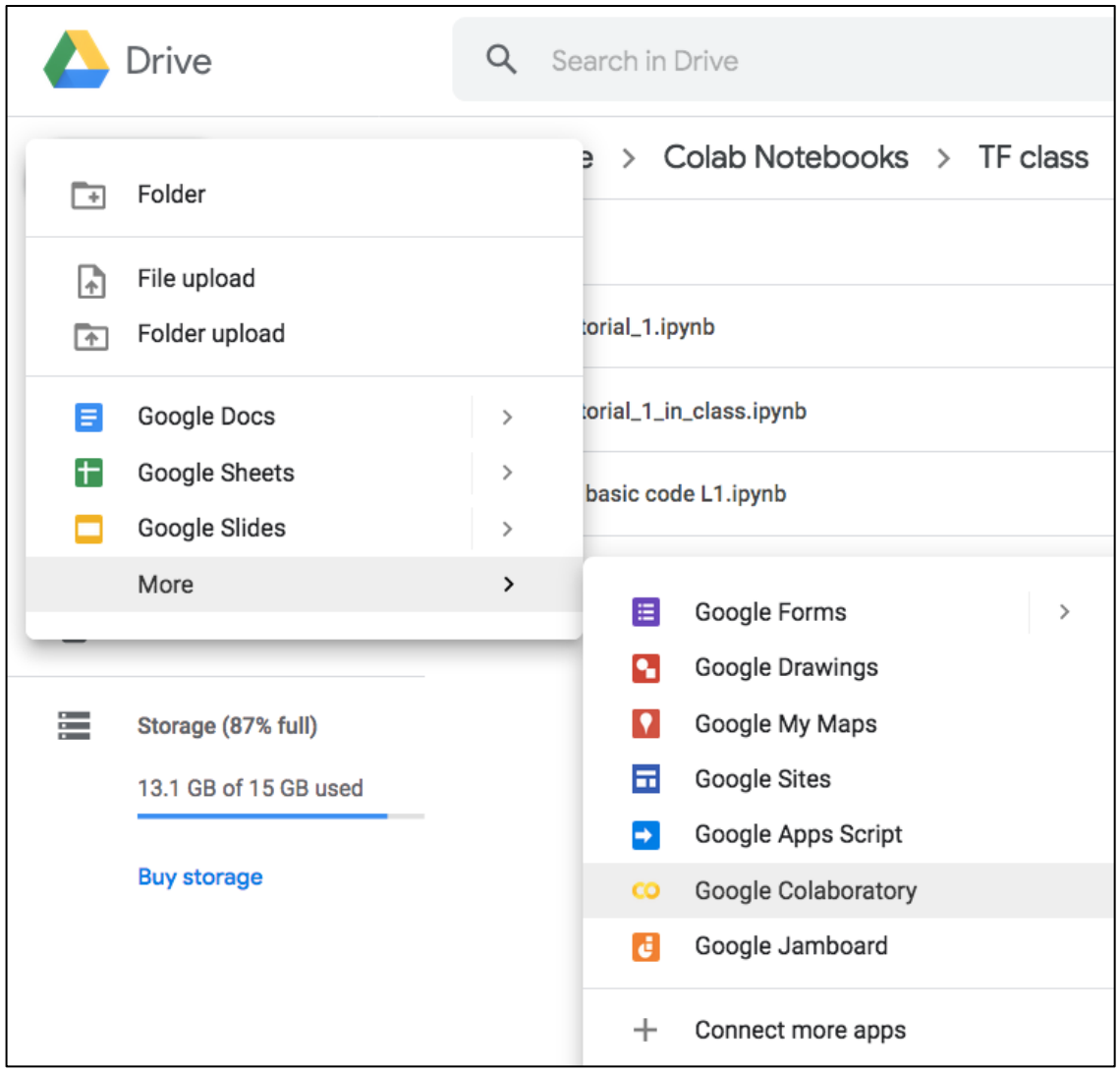
Comparison Chart 3/3

Shogun	Windows Linux UNIX Mac OS	Free	C++	Regression Classification Clustering Support vector machines. Dimensionality reduction Online learning etc.
Keras.io	Cross-platform	Free	Python	API for neural networks
Rapid Miner	Cross-platform	Free plan Small: $2500 per year. Medium: $5000 per year. Large: $10000 per year.	Java	Data loading & Transformation Data preprocessing & visualization.

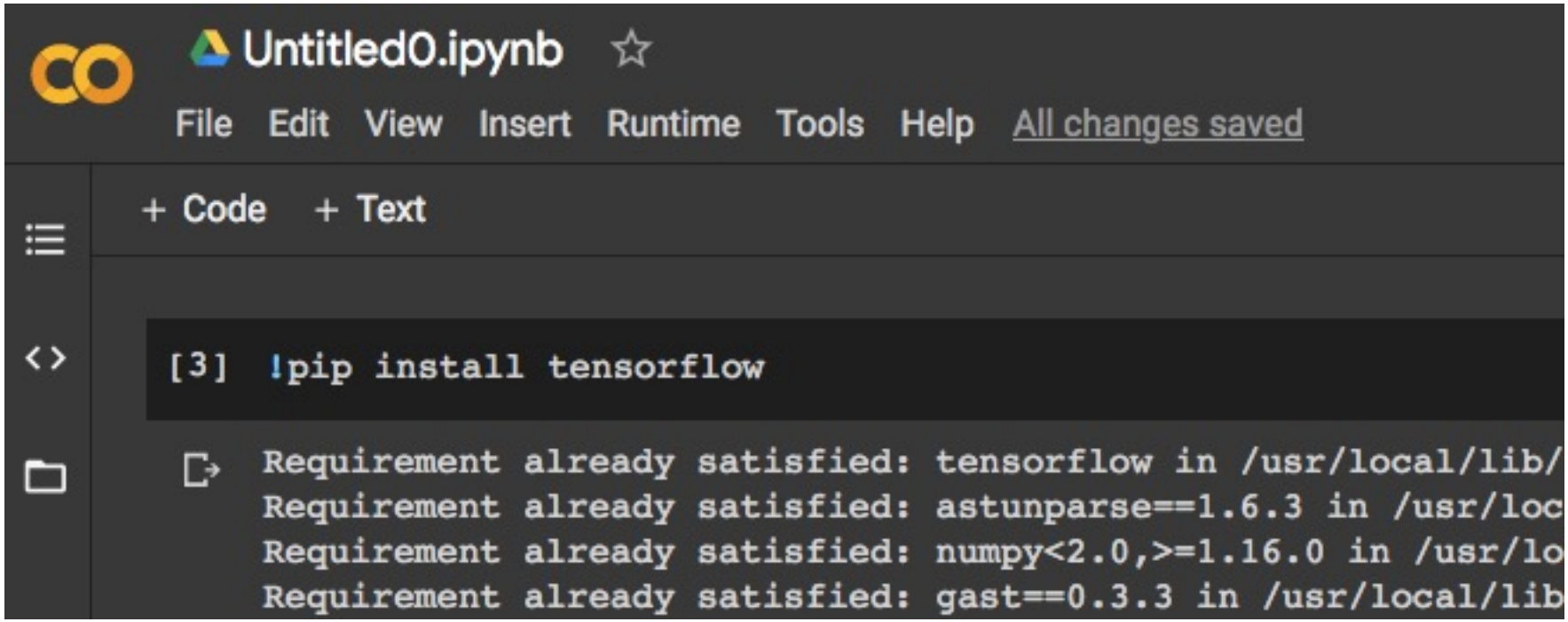
References

- https://www.tensorflow.org/install
- https://www.udemy.com/tutorial/complete-guide-to-tensorflow-for-deep-learning-with-python/installing-tensorflow-environment/
- https://github.com/tensorflow/docs/blob/master/site/en/r1/guide/extend/architecture.md
- https://www.tensorflow.org/guide/effective_tf2
- https://www.tensorflow.org/guide/keras/overview
- https://machinelearningmastery.com/introduction-python-deep-learning-library-tensorflow/
- https://hub.packtpub.com/tensorflow-always-tops-machine-learning-artificial-intelligence-tool-surveys/
- https://medium.com/tensorflow/intelligent-scanning-using-deep-learning-for-mri-36dd620882c4
- https://github.com/aymericdamien/TensorFlow-Examples/blob/master/examples/1_Introduction/basic_operations.py
- https://www.infoworld.com/article/3278008/what-is-tensorflow-the-machine-learning-library-explained.html

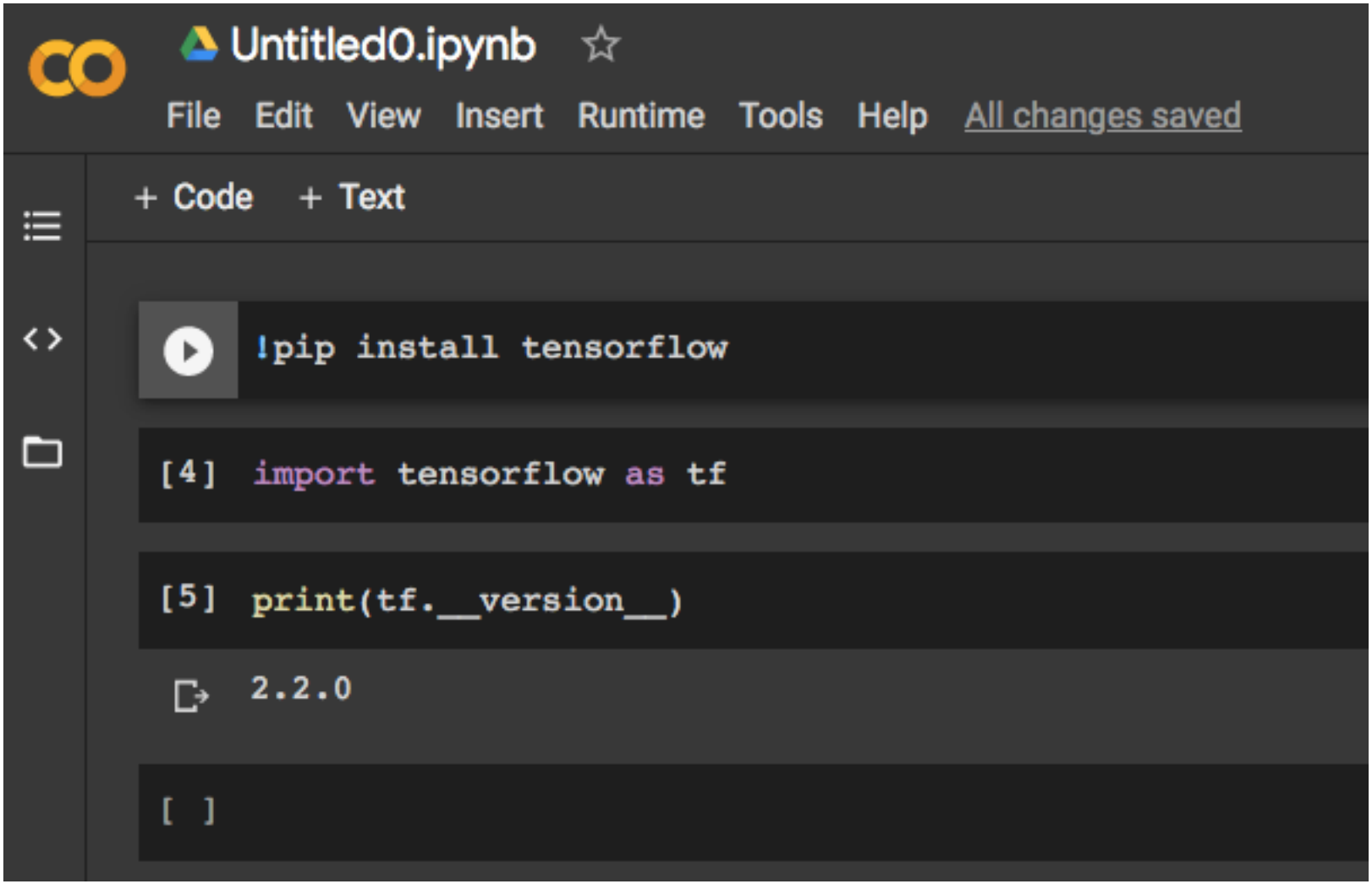
Start with Colab



Start with Colab



Start with Colab



Machine Learning With TensorFlow

- **tf.Session**:

  - Type: type
  - A class for running TensorFlow operations.
  - A `Session` object encapsulates the environment in which `Operation` objects are executed, and `Tensor` objects are evaluated.

For example:

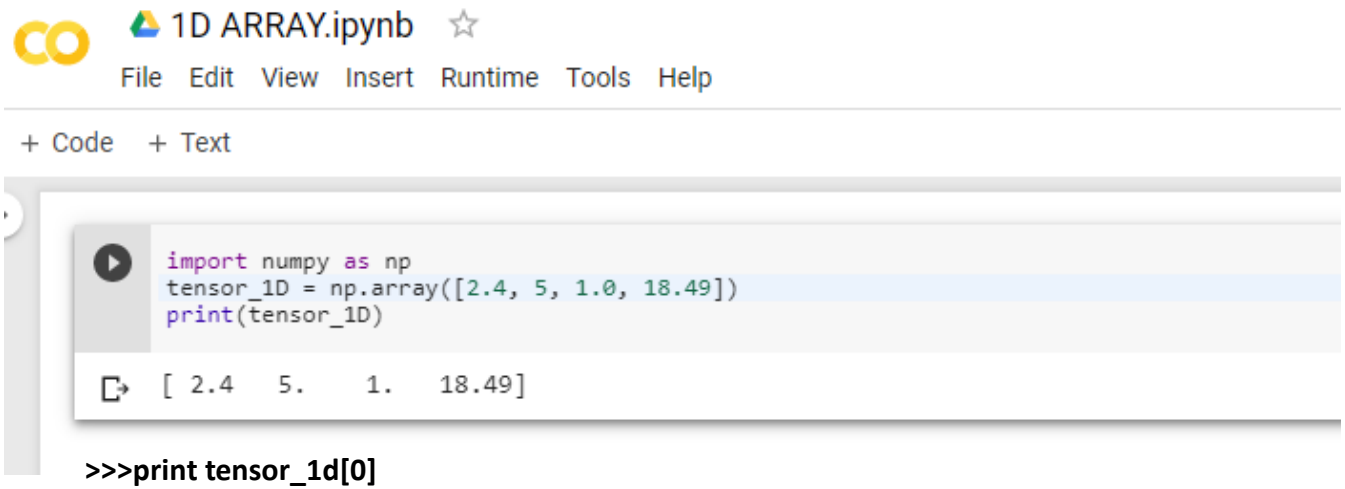
```
# Build a graph.
a = tf.constant(5.0)
b = tf.constant(6.0)
c = a * b
sess = tf.Session()    # Launch the graph in a session.
print(sess.run(c))     # Evaluate the tensor `c`.
```

Basic Code Examples

- **EXAMPLE 1**: CREATING A ONE DIMENSIONAL ARRAY

- One dimensional tensor - normal array structure that has a set of values of the same type

```
>>> import numpy as np
>>> tensor_1D = np.array([2.4, 5, 1.0, 18.49])
>>> print (tensor_1D)
```




```
>>>print tensor_1d[0]
2.4

>>>print tensor_1d[2]
1
```

Basic Code Examples

- **EXAMPLE 2** : CREATING A TWO DIMENSIONAL ARRAY :

- Two dimensional Tensors Sequence of arrays are used for creating “two dimensional tensors”

```
>>>import numpy as np

>>> tensor_2d=np.array([(1,2,3,4),(4,5,6,7),(8,9,10,11),(12,13,14,15)])

>>> print(tensor_2d)
[[ 1 2 3 4]
[ 4 5 6 7]
[ 8 9 10 11]
[12 13 14 15]]
```

Basic Code Examples

- **EXAMPLE 3 :** CREATING MULTIDIMENSIONAL ARRAY

```
import tensorflow as tf

import numpy as np

m1 = np.array([(3,3,3),(3,3,3),(3,3,3)],dtype='int32')

m2 = np.array([(2,2,2),(2,2,2),(2,2,2)],dtype='int32')

print (m1)

print (m2)

m1 = tf.constant(m1)

m2 = tf.constant(m2)

m_product = tf.matmul(m1, m2)

m_sum = tf.add(m1,m2)
```

```
[[3 3 3]
 [3 3 3]
 [3 3 3]]
[[2 2 2]
 [2 2 2]
 [2 2 2]]
```

try it in class …

Basic Code Examples

```
m_3 = np.array([(4,5,6),(3,4,1),(2,0,1)],dtype='float32')

print (m_3)

m_det = tf.matrix_determinant(m_3)

with tf.Session() as sess:

        result1 = sess.run(m_product)

        result2 = sess.run(m_sum)

        result3 = sess.run(m_det)

print (result1)

print (result2)

print (result3)
```

```
In [7]: print (result1)
   ...:
   ...: print (result2)
   ...:
   ...: print (result3)
[[18 18 18]
 [18 18 18]
 [18 18 18]]
[[5 5 5]
 [5 5 5]
 [5 5 5]]
-37.000004
```

try it in class …

Basic Code Examples

matrixmultiplication.ipynb

File Edit View Insert Runtime Tools Help

+ Code + Text

```
import tensorflow as tf
import numpy as np
m1 = np.array([(3,3,3,),(3,3,3),(3,3,3)],dtype='int32')
m2 = np.array([(2,2,2),(2,2,2),(2,2,2)],dtype='int32')
print (m1)
print (m2)
m1 = tf.constant(m1)
m2 = tf.constant(m2)
m_product = tf.matmul(m1, m2)
m_sum = tf.add(m1,m2)
m_3 = np.array([(4,5,6),(3,4,1),(2,0,1)],dtype='float32')
print (m_3)
m_det = tf.matrix_determinant(m_3)
with tf.Session() as sess:
 result1 = sess.run(m_product)
 result2 = sess.run(m_sum)
 result3 = sess.run(m_det)
print (result1)
print (result2)
print (result3)
```

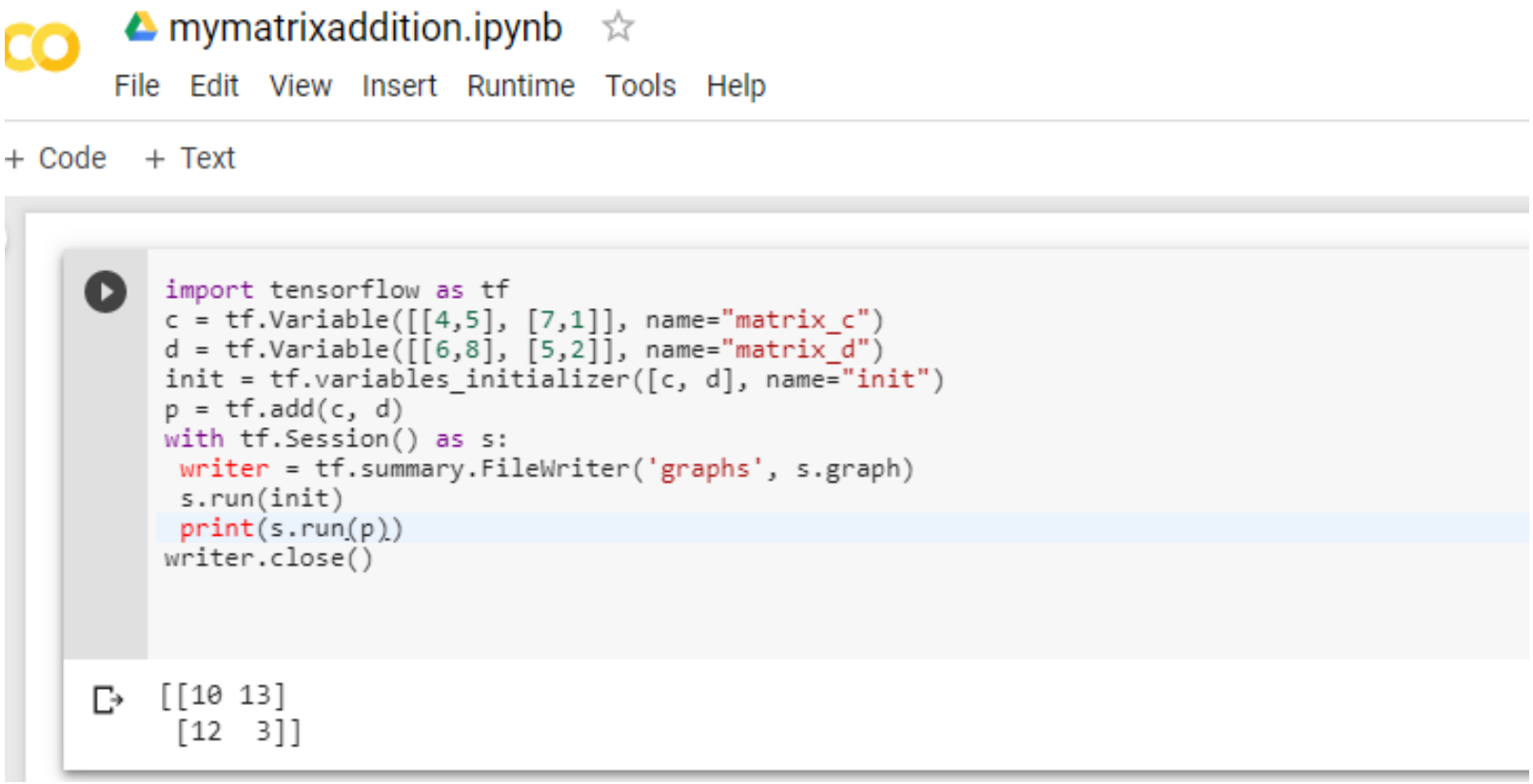
```
[[3 3 3]
 [3 3 3]
 [3 3 3]]
[[2 2 2]
 [2 2 2]
 [2 2 2]]
[[4. 5. 6.]
 [3. 4. 1.]
 [2. 0. 1.]]
[[18 18 18]
 [18 18 18]
 [18 18 18]]
[[5 5 5]
 [5 5 5]
 [5 5 5]]
-37.000004
```

Basic Code Examples

- **EXAMPLE 4 :** MATRIX ADDITION :

```
import tensorflow as tf

c = tf.Variable([[4,5], [7,1]], name="matrix_c")

d = tf.Variable([[6,8], [5,2]], name="matrix_d")

init = tf.variables_initializer([c, d], name="init")

p = tf.add(c, d)

with tf.Session() as s:

        writer = tf.summary.FileWriter('graphs', s.graph)

        s.run(init)

        print(s.run(p))

writer.close()
```

Basic Code Examples



Basic Code Examples

- More examples:

```
1  ## Tensor Types
2  import tensorflow as tf
3  import numpy as np
4
5  # Define a 2x2 matrix in 3 different ways
6  m1 = [[1.0, 2.0], [3.0, 4.0]]                                  # <class 'list'>
7  m2 = np.array([[1.0, 2.0], [3.0, 4.0]], dtype=np.float32) # <class 'np.ndarray'>
8  m3 = tf.constant([[1.0, 2.0], [3.0, 4.0]])                     # <class 'tensorflow'>
9  print(type(m1))
10 print(type(m2))
11 print(type(m3))
12
13 # Create tensor objects out of various types
14 t1 = tf.convert_to_tensor(m1, dtype=tf.float32)          # <class 'tensorflow'>
15 t2 = tf.convert_to_tensor(m2, dtype=tf.float32)          # <class 'tensorflow'>
16 t3 = tf.convert_to_tensor(m3, dtype=tf.float32)          # <class 'tensorflow'>
17 print(type(t1))
18 print(type(t2))
19 print(type(t3))
```

```
Python
In [9]: m3.op.name
Out[9]: 'Const'
```

... try it in class

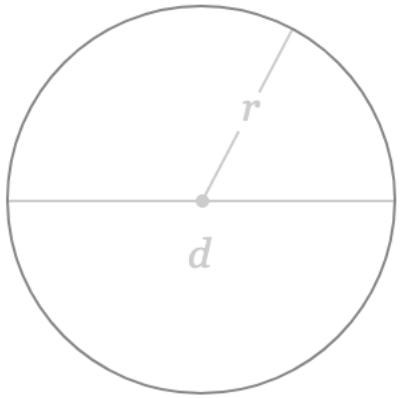
```
Python
In [1]: (executing cell "Tensor Types" (line 2 of "types.py"))
<class 'list'>
<class 'numpy.ndarray'>
<class 'tensorflow.python.framework.ops.Tensor'>
<class 'tensorflow.python.framework.ops.Tensor'>
<class 'tensorflow.python.framework.ops.Tensor'>
<class 'tensorflow.python.framework.ops.Tensor'>
```

Class exercise:

Using TF, find the area of a circle, where:

- You use a constant for *π (3.14 or 22/7)*
- You ask the user for an input of a radius r = using *input*
- Use the formula for an area that is: *A = π * r ^{2}*
- Print your result like this: "Area of circle 78.5"

$$A = \pi r^2$$



Solution: find the area of a circle

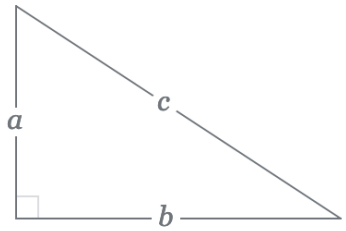
```
import tensorflow as tf

g = tf.Graph()

with g.as_default():
    pi = tf.constant(3.14) #define constant
    radius = tf.constant(5, tf.float32)
    area = tf.multiply((radius ** 2 ), pi)

# launch the graph in a session
with tf.compat.v1.Session(graph = g) as sess:

    print("Area of circle ",sess.run(area))

#OUTPUT ------   Area of circle 78.5
```

Basic operations

HW1:

Find the area of a right triangle with the following parameters:

a	Leg	3
b	Leg	5



Solution

$$A = \frac{a\,b}{2} = \frac{3 \cdot 5}{2} = 7.5$$