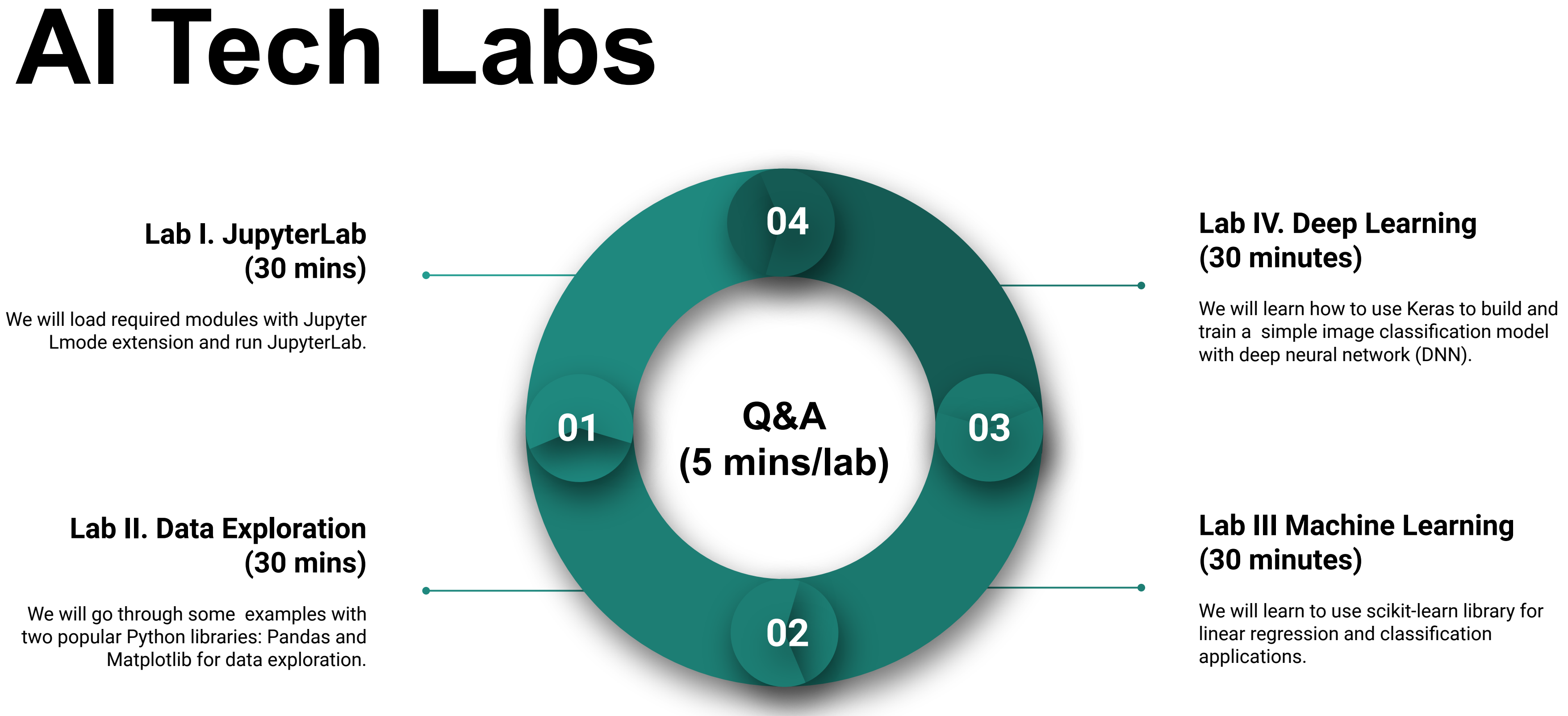
Technology Lab: Using AI Frameworks in Jupyter Notebook

Zhenhua He

11/29/2022

ACES
ACCELERATING COMPUTING FOR EMERGING SCIENCES

High Performance Research Computing
DIVISION OF RESEARCH



AI Tech Labs

Lab I. JupyterLab (30 mins)

We will load required modules with Jupyter Lmode extension and run JupyterLab.

Lab II. Data Exploration (30 mins)

We will go through some examples with two popular Python libraries: Pandas and Matplotlib for data exploration.

Lab III Machine Learning (30 minutes)

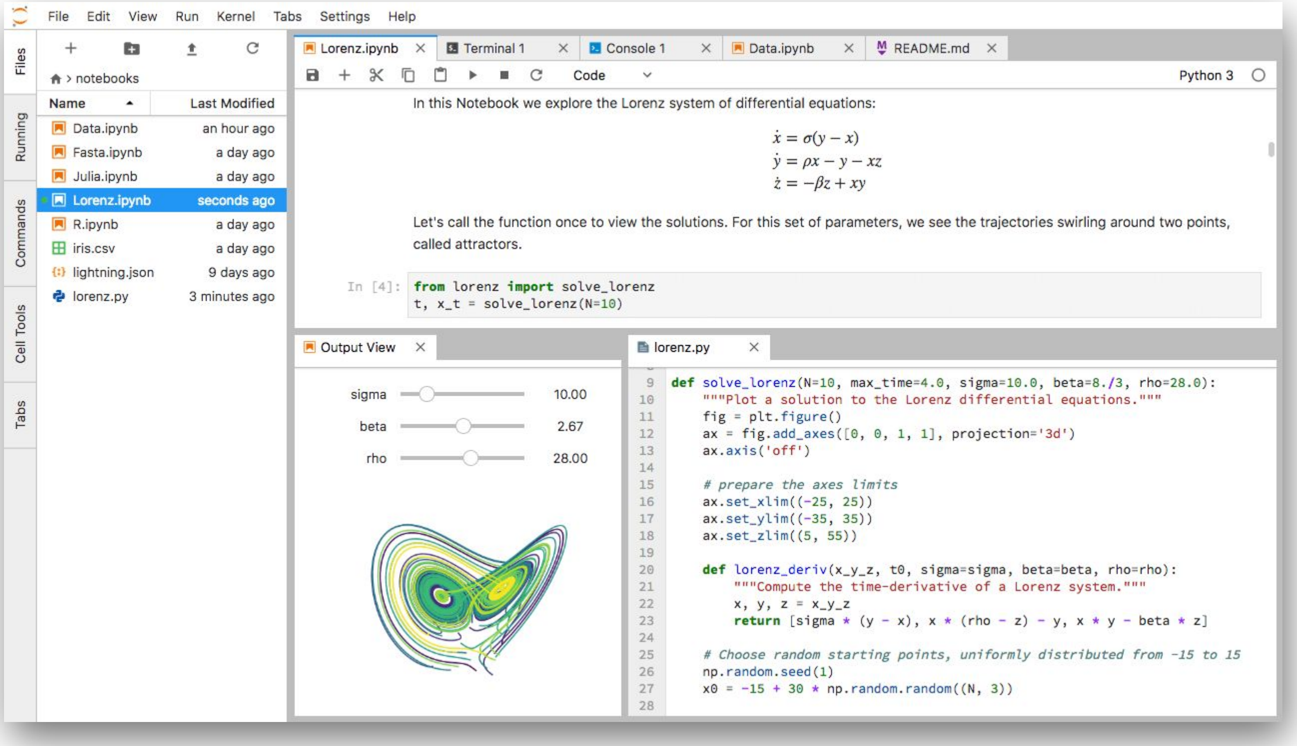
We will learn to use scikit-learn library for linear regression and classification applications.

Lab IV. Deep Learning (30 minutes)

We will learn how to use Keras to build and train a simple image classification model with deep neural network (DNN).

Figure 1. Structure of the Technology Lab.

Lab I. JupyterLab



Name	Last Modified
Data.ipynb	an hour ago
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Lorenz.ipynb	seconds ago
R.ipynb	a day ago
iris.csv	a day ago
lightning.json	9 days ago
lorenz.py	3 minutes ago

In this Notebook we explore the Lorenz system of differential equations:

$$\dot{x} = \sigma(y - x)$$
$$\dot{y} = \rho x - y - xz$$
$$\dot{z} = -\beta z + xy$$

Let's call the function once to view the solutions. For this set of parameters, we see the trajectories swirling around two points, called attractors.

```
In [4]: from lorenz import solve_lorenz
        t, x_t = solve_lorenz(N=10)
```

sigma	10.00
beta	2.67
rho	28.00

```
def solve_lorenz(N=10, max_time=4.0, sigma=10.0, beta=8./3, rho=28.0):
    """Plot a solution to the Lorenz differential equations."""
    fig = plt.figure()
    ax = fig.add_axes([0, 0, 1, 1], projection='3d')
    ax.axis('off')

    # prepare the axes limits
    ax.set_xlim((-25, 25))
    ax.set_ylim((-35, 35))
    ax.set_zlim((5, 55))

    def lorenz_deriv(x_y_z, t0, sigma=sigma, beta=beta, rho=rho):
        """Compute the time-derivative of a Lorenz system."""
        x, y, z = x_y_z
        return [sigma * (y - x), x * (rho - z) - y, x * y - beta * z]

    # Choose random starting points, uniformly distributed from -15 to 15
    np.random.seed(1)
    x0 = -15 + 30 * np.random.random((N, 3))

```

L1 - Resources

- Texas A&M High Performance Research Computing (HPRC)
- FASTER Quick Start Guide
- ACES Phase I Guide
- ACCESS Documentation
- FASTER Portal
- HPRC YouTube Channel
- help@hprc.tamu.edu

Getting Started with FASTER and ACES

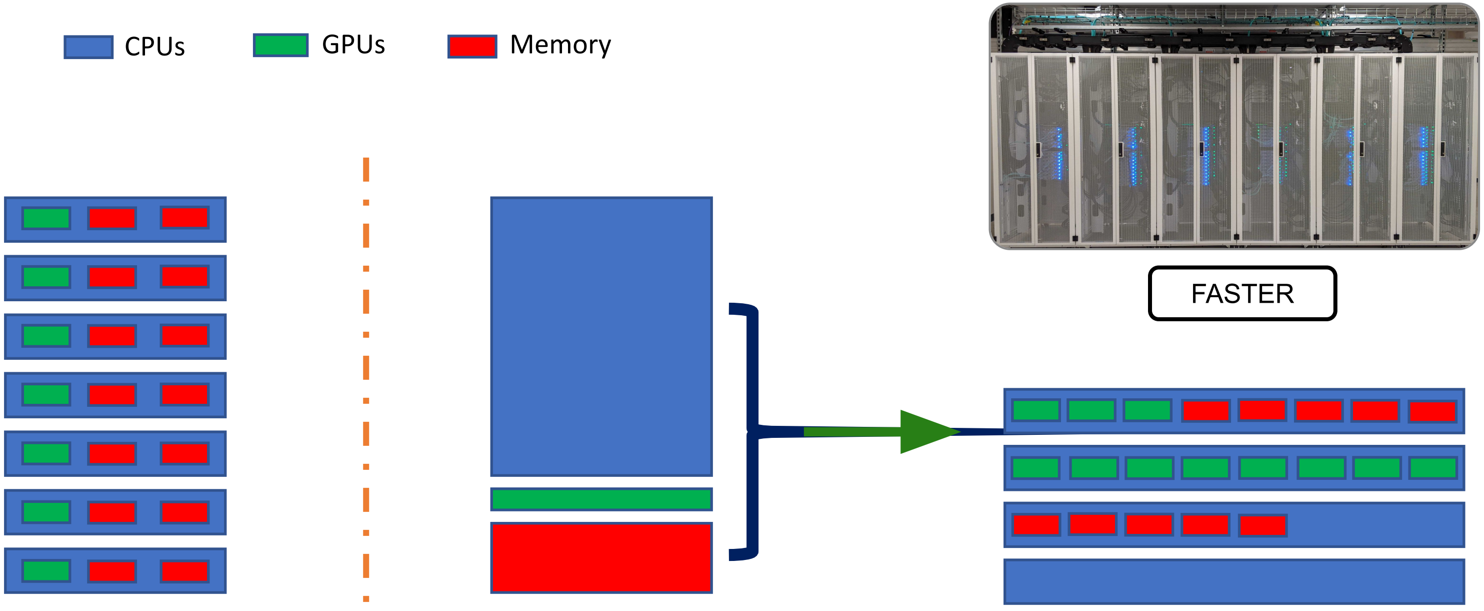
FASTER Cluster

hprc.tamu.edu/wiki/FASTER:Intro

Node Type	Quantity
64-core login nodes	4 (3 for TAMU, 1 for ACCESS)
64-core compute nodes (256GB RAM each)	180 (11,520 cores)
Composable GPUs	200 T4 16GB 40 A100 40GB 10 A10 24GB 4 A30 24GB 8 A40 48GB
Interconnect	Mellanox HDR100 InfiniBand (MPI and storage) Liqid PCIe Gen4 (GPU composability)
Global Disk	5PB DDN Lustre appliances

FASTER (Fostering Accelerated Sciences Transformation Education and Research) is a 180-node Intel cluster from Dell featuring the Intel Ice Lake processor.

Composability at the Hardware Level



Typical HPC layout

Disaggregated Resource Pool

Composed layout

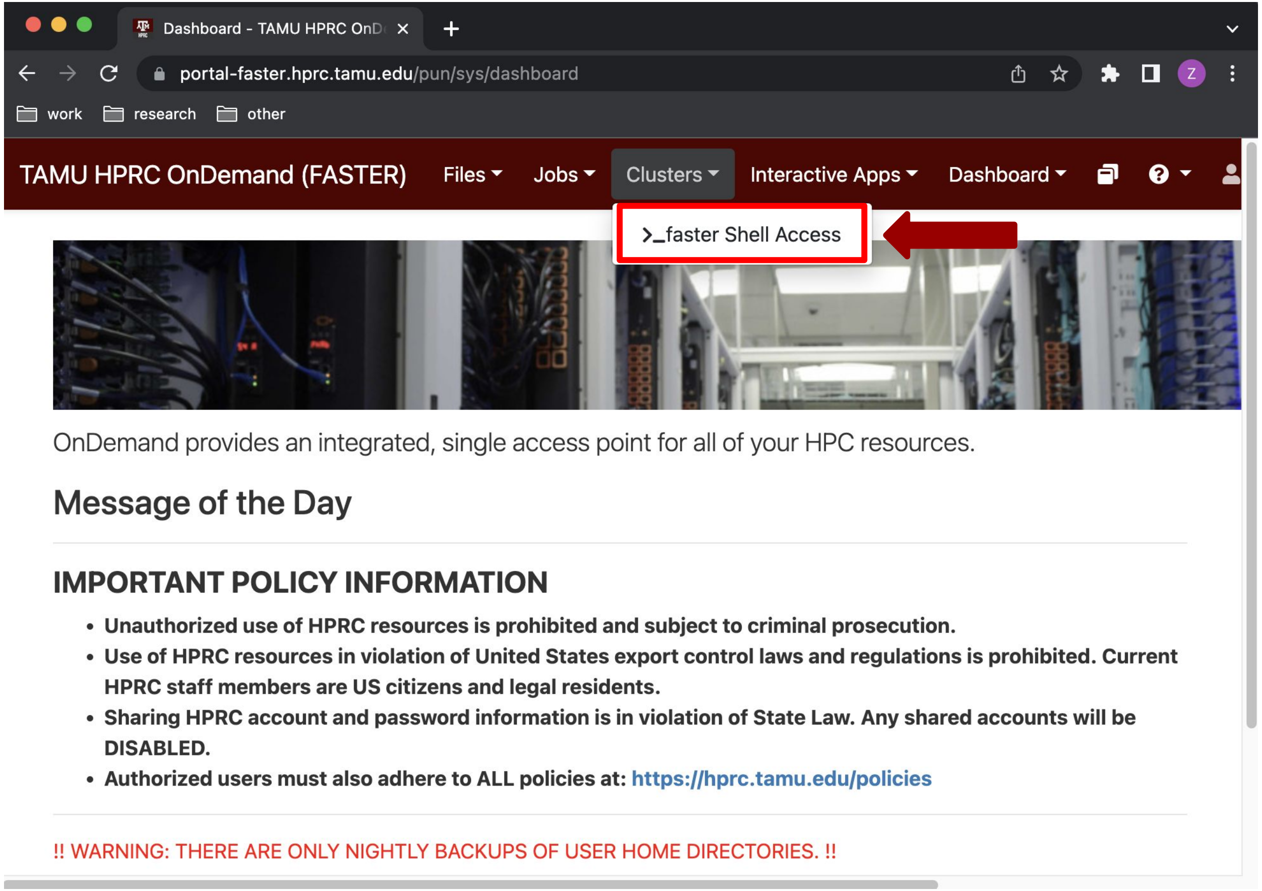
hprc.tamu.edu/resources

ACES - Accelerating Computing for Emerging Sciences (Phase I)

Component	Quantity	Description
Graphcore IPU	16	16 Colossus GC200 IPUs and dual AMD Rome CPU server on a 100 GbE RoCE fabric
Intel FPGA PAC D5005	2	FPGA SOC with Intel Stratix 10 SX FPGAs, 64 bit quad-core Arm Cortex-A53 processors, and 32GB DDR4
Intel Optane SSDs	8	3 TB of Intel Optane SSDs addressable as memory using MemVerge Memory Machine.

ACES Phase I components are available through FASTER

Shell Access - I



Dashboard - TAMU HPRC OnD
portal-faster.hprc.tamu.edu/pun/sys/dashboard
work
research
other
TAMU HPRC OnDemand (FASTER)
Files
Jobs
Clusters
Interactive Apps
Dashboard
>_faster Shell Access

OnDemand provides an integrated, single access point for all of your HPC resources.

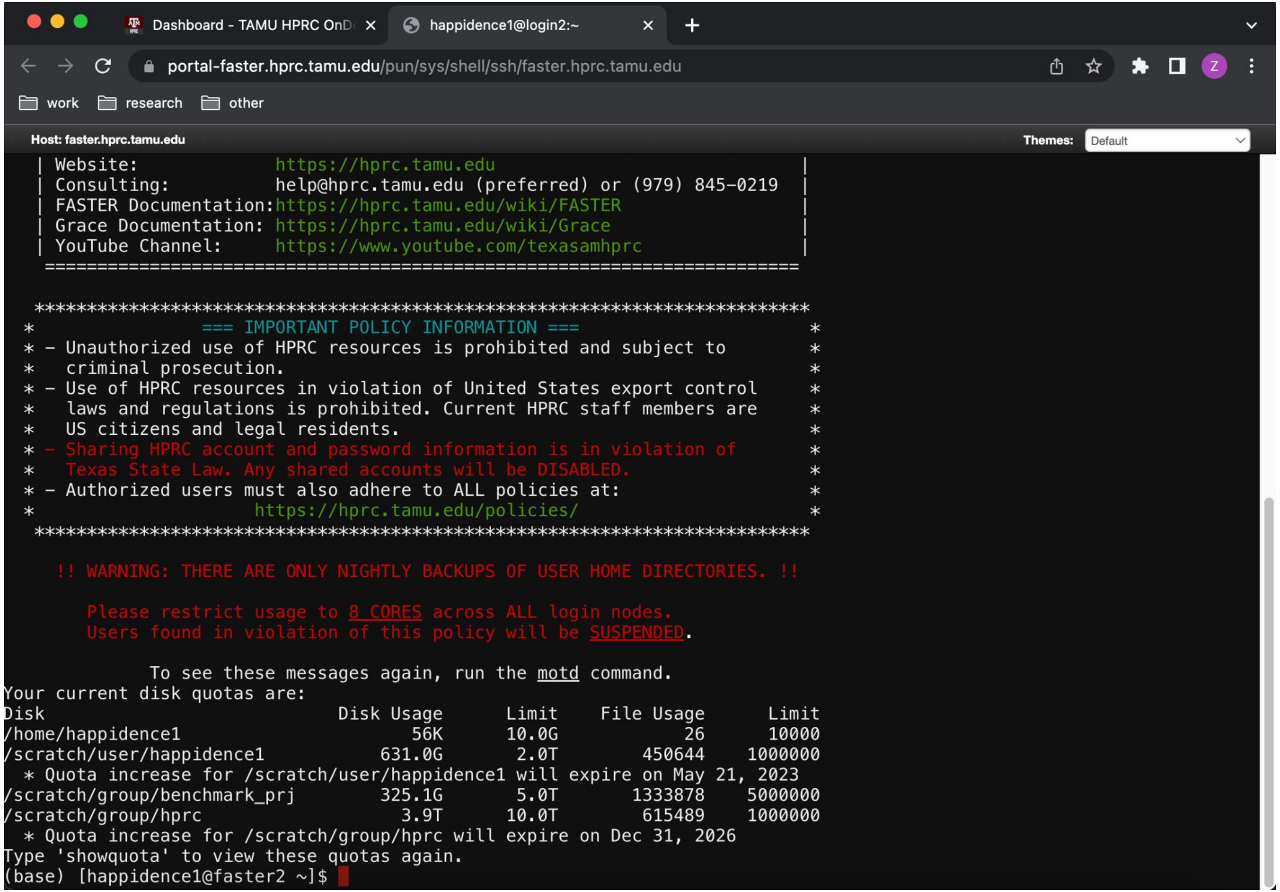
Message of the Day

IMPORTANT POLICY INFORMATION

- **Unauthorized use of HPRC resources is prohibited and subject to criminal prosecution.**
- **Use of HPRC resources in violation of United States export control laws and regulations is prohibited. Current HPRC staff members are US citizens and legal residents.**
- **Sharing HPRC account and password information is in violation of State Law. Any shared accounts will be DISABLED.**
- **Authorized users must also adhere to ALL policies at: https://hprc.tamu.edu/policies**

!! WARNING: THERE ARE ONLY NIGHTLY BACKUPS OF USER HOME DIRECTORIES. !!

Shell Access - II


Dashboard - TAMU HPRC OnD
happidence1@login2:~
portal-faster.hprc.tamu.edu/pun/sys/shell/ssh/faster.hprc.tamu.edu
work
research
other

Host: faster.hprc.tamu.edu

Themes: Default

```
 | Website:             https://hprc.tamu.edu                                |
 | Consulting:          help@hprc.tamu.edu (preferred) or (979) 845-0219     |
 | FASTER Documentation:https://hprc.tamu.edu/wiki/FASTER                    |
 | Grace Documentation: https://hprc.tamu.edu/wiki/Grace                     |
 | YouTube Channel:     https://www.youtube.com/texasamhprc                  |
  ========================================================================

 **************************************************************************
*               === IMPORTANT POLICY INFORMATION ===                        *
* - Unauthorized use of HPRC resources is prohibited and subject to         *
*   criminal prosecution.                                                   *
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*   US citizens and legal residents.                                        *
* - Sharing HPRC account and password information is in violation of       *
*   Texas State Law. Any shared accounts will be DISABLED.                  *
* - Authorized users must also adhere to ALL policies at:                   *
*                     https://hprc.tamu.edu/policies/                       *
 **************************************************************************

   !! WARNING: THERE ARE ONLY NIGHTLY BACKUPS OF USER HOME DIRECTORIES. !!

      Please restrict usage to 8 CORES across ALL login nodes.
      Users found in violation of this policy will be SUSPENDED.

             To see these messages again, run the motd command.
Your current disk quotas are:
Disk                            Disk Usage      Limit    File Usage      Limit
/home/happidence1                      56K      10.0G            26      10000
/scratch/user/happidence1           631.0G       2.0T        450644    1000000
  * Quota increase for /scratch/user/happidence1 will expire on May 21, 2023
/scratch/group/benchmark_prj        325.1G       5.0T       1333878    5000000
/scratch/group/hprc                   3.9T      10.0T        615489    1000000
  * Quota increase for /scratch/group/hprc will expire on Dec 31, 2026
Type 'showquota' to view these quotas again.
(base) [happidence1@faster2 ~]$ 
```

Commands to copy the materials

- Navigate to your personal scratch directory

  ```
  $ cd $SCRATCH
  ```

- Files for this course are located at

  ```
  /scratch/training/ai_tech_labs
  ```

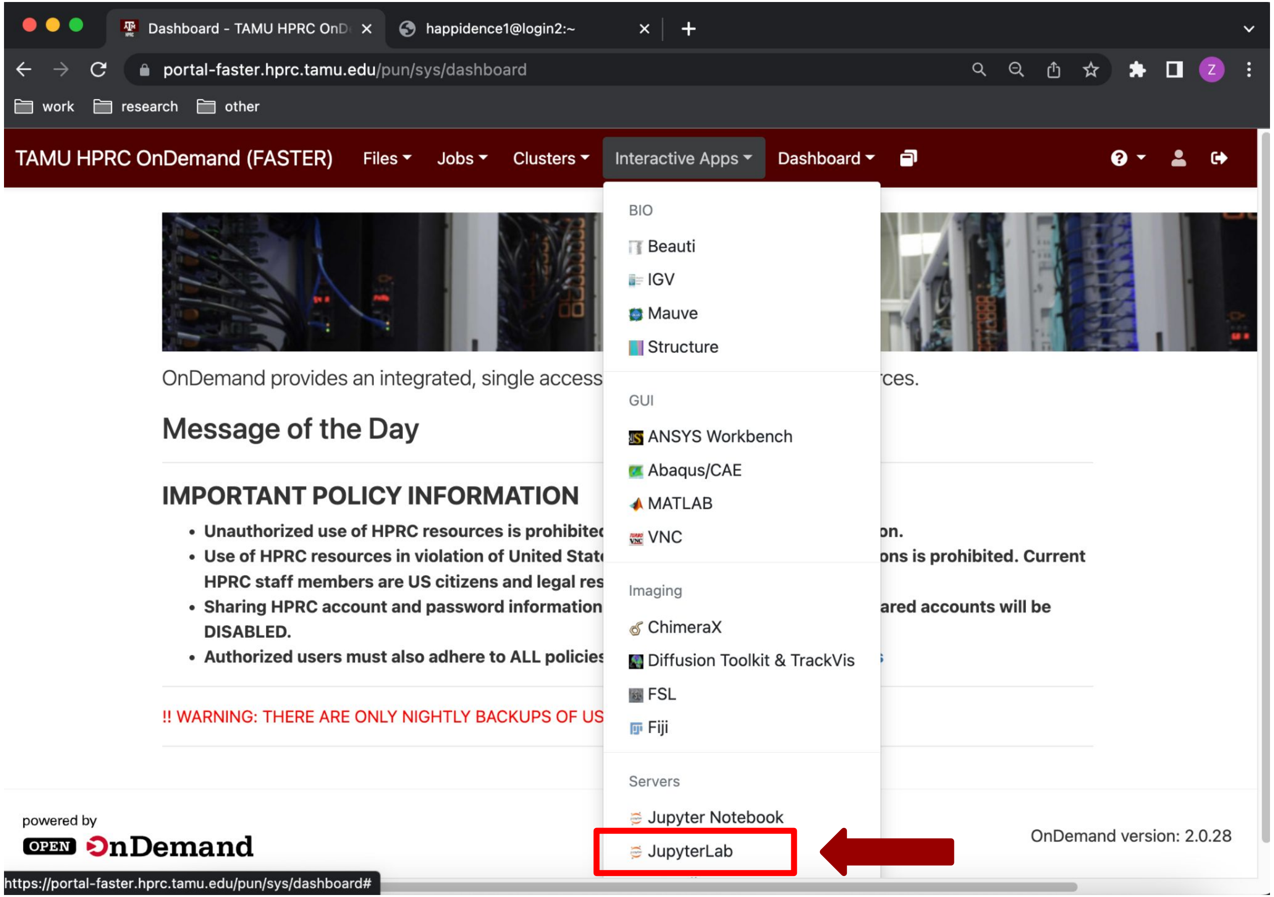
  Make a copy in your personal scratch directory

  ```
  $ cp -r /scratch/training/ai_tech_labs $SCRATCH
  ```

- Enter this directory (your local copy)

  ```
  $ cd ai_tech_labs
  ```

Go to JupyterLab Page



OnDemand provides an integrated, single access ces.

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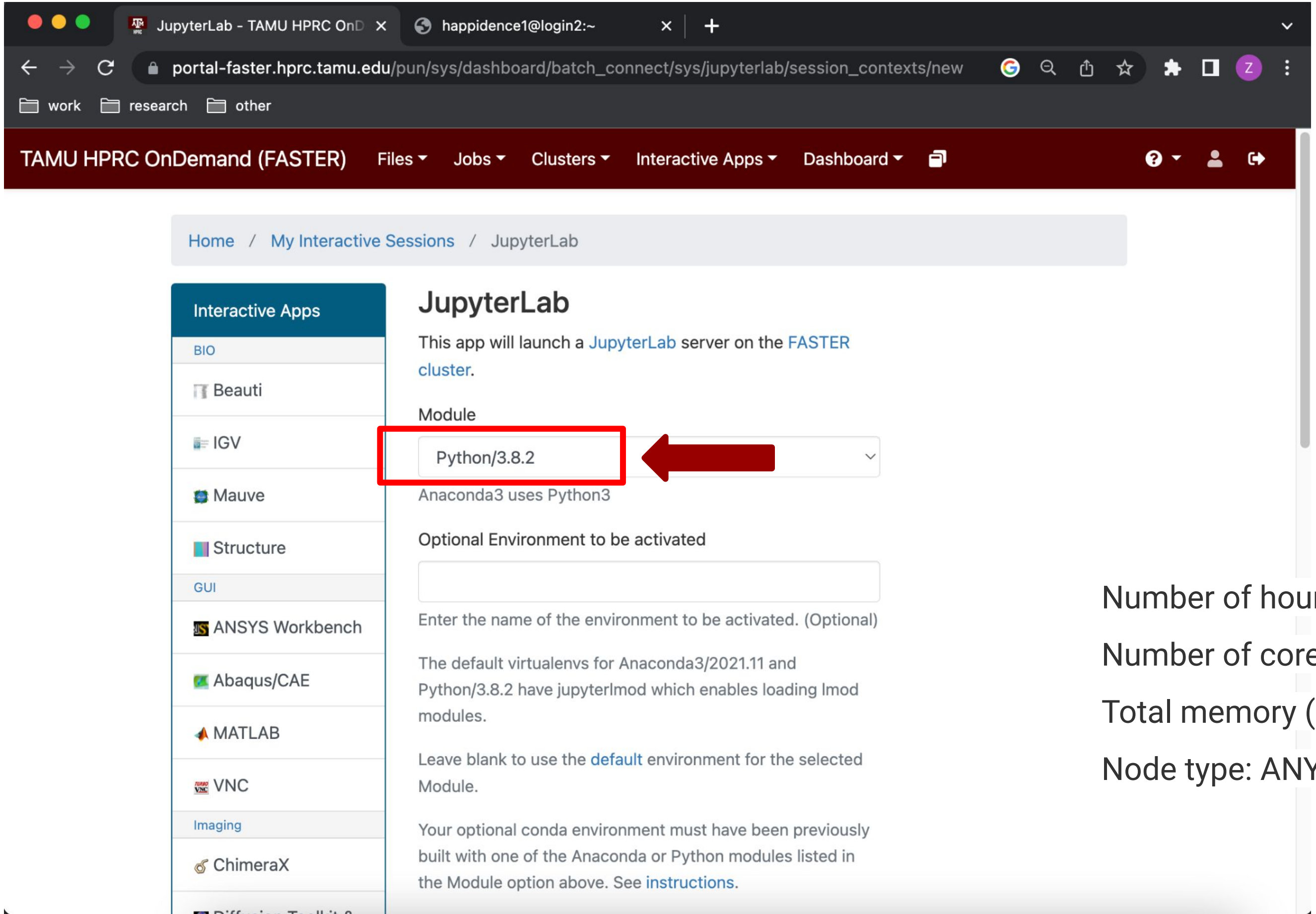
!! WARNING: THERE ARE ONLY NIGHTLY BACKUPS OF US

JupyterLab Page



JupyterLab - TAMU HPRC OnD
happidence1@login2:~
portal-faster.hprc.tamu.edu/pun/sys/dashboard/batch_connect/sys/jupyterlab/session_contexts/new
work
research
other
TAMU HPRC OnDemand (FASTER)
Files
Jobs
Clusters
Interactive Apps
Dashboard
Home / My Interactive Sessions / JupyterLab
Interactive Apps
BIO
Beauti
IGV
Mauve
Structure
GUI
ANSYS Workbench
Abaqus/CAE
MATLAB
VNC
Imaging
ChimeraX

JupyterLab

This app will launch a JupyterLab server on the FASTER cluster.

Module: Python/3.8.2

Anaconda3 uses Python3

Optional Environment to be activated

Enter the name of the environment to be activated. (Optional)

The default virtualenvs for Anaconda3/2021.11 and Python/3.8.2 have jupyterlmod which enables loading lmod modules.

Leave blank to use the default environment for the selected Module.

Your optional conda environment must have been previously built with one of the Anaconda or Python modules listed in the Module option above. See instructions.

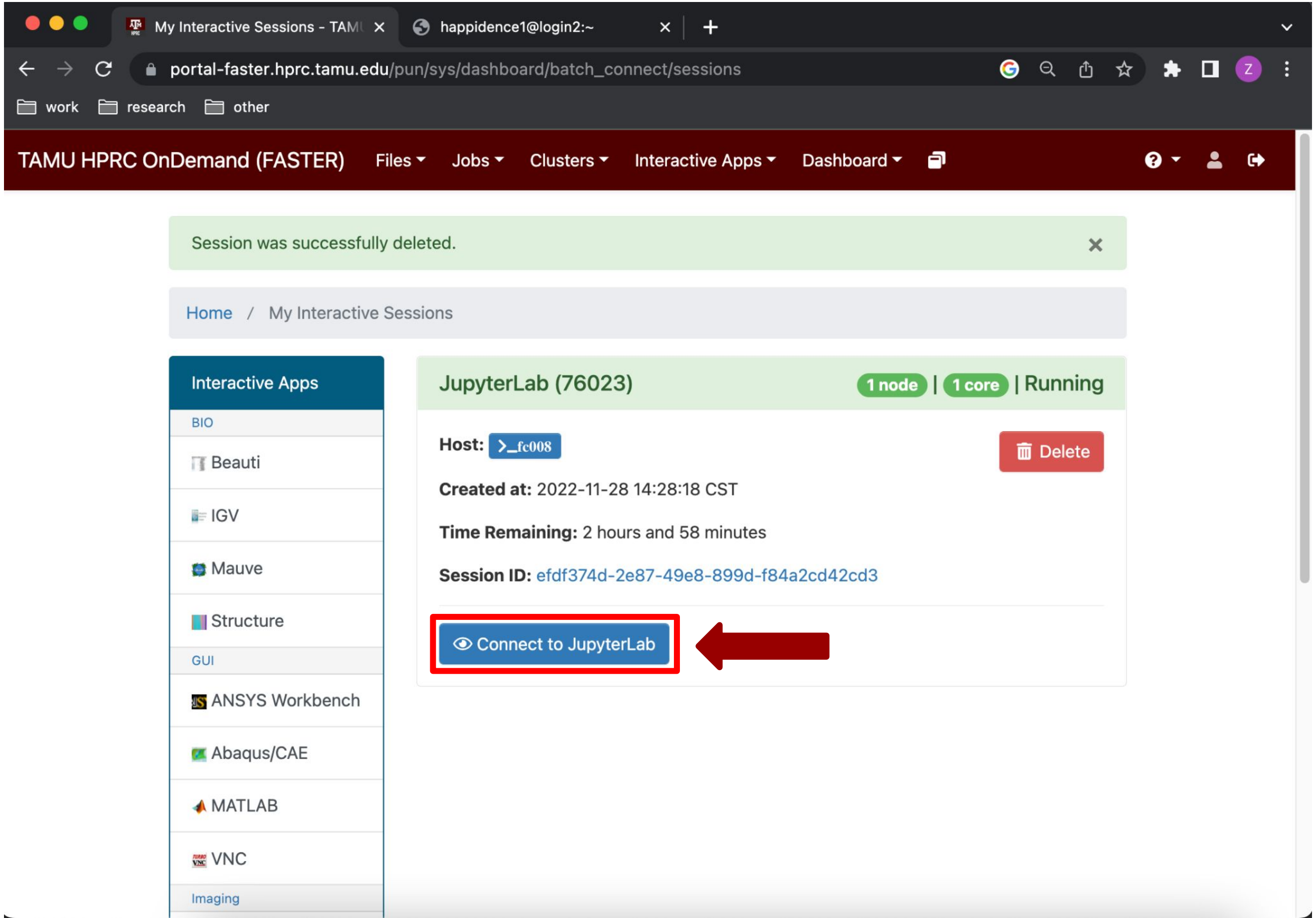
Number of hours: 3

Number of cores: 1

Total memory (GB): 2

Node type: ANY

Connect to JupyterLab



My Interactive Sessions - TAMU
happidence1@login2:~
portal-faster.hprc.tamu.edu/pun/sys/dashboard/batch_connect/sessions
work
research
other
TAMU HPRC OnDemand (FASTER)
Files
Jobs
Clusters
Interactive Apps
Dashboard

Session was successfully deleted.

Home / My Interactive Sessions

JupyterLab (76023) 1 node | 1 core | Running

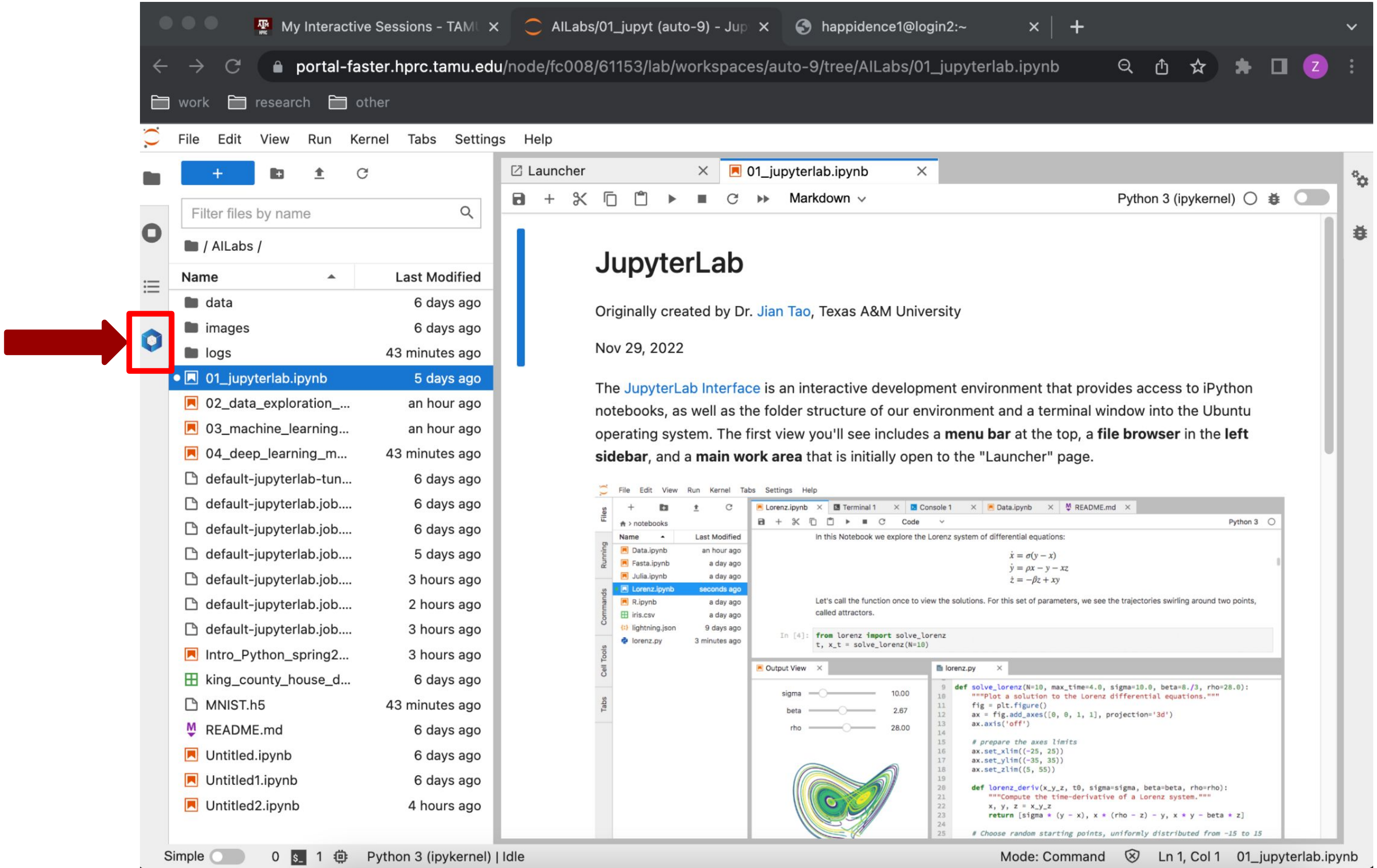
Host: >_fc008

Created at: 2022-11-28 14:28:18 CST

Time Remaining: 2 hours and 58 minutes

Session ID: efdf374d-2e87-49e8-899d-f84a2cd42cd3

JupyterLab Lmod Extension



Name	Last Modified
data	6 days ago
images	6 days ago
logs	43 minutes ago
01_jupyterlab.ipynb	5 days ago
02_data_exploration_...	an hour ago
03_machine_learning...	an hour ago
04_deep_learning_m...	43 minutes ago
default-jupyterlab-tun...	6 days ago
default-jupyterlab.job....	6 days ago
default-jupyterlab.job....	6 days ago
default-jupyterlab.job....	5 days ago
default-jupyterlab.job....	3 hours ago
default-jupyterlab.job....	2 hours ago
default-jupyterlab.job....	3 hours ago
Intro_Python_spring2...	3 hours ago
king_county_house_d...	6 days ago
MNIST.h5	43 minutes ago
README.md	6 days ago
Untitled.ipynb	6 days ago
Untitled1.ipynb	6 days ago
Untitled2.ipynb	4 hours ago

JupyterLab

Originally created by Dr. Jian Tao, Texas A&M University

Nov 29, 2022

The JupyterLab Interface is an interactive development environment that provides access to iPython notebooks, as well as the folder structure of our environment and a terminal window into the Ubuntu operating system. The first view you'll see includes a **menu bar** at the top, a **file browser** in the **left sidebar**, and a **main work area** that is initially open to the "Launcher" page.

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R.ipynb	a day ago
iris.csv	a day ago
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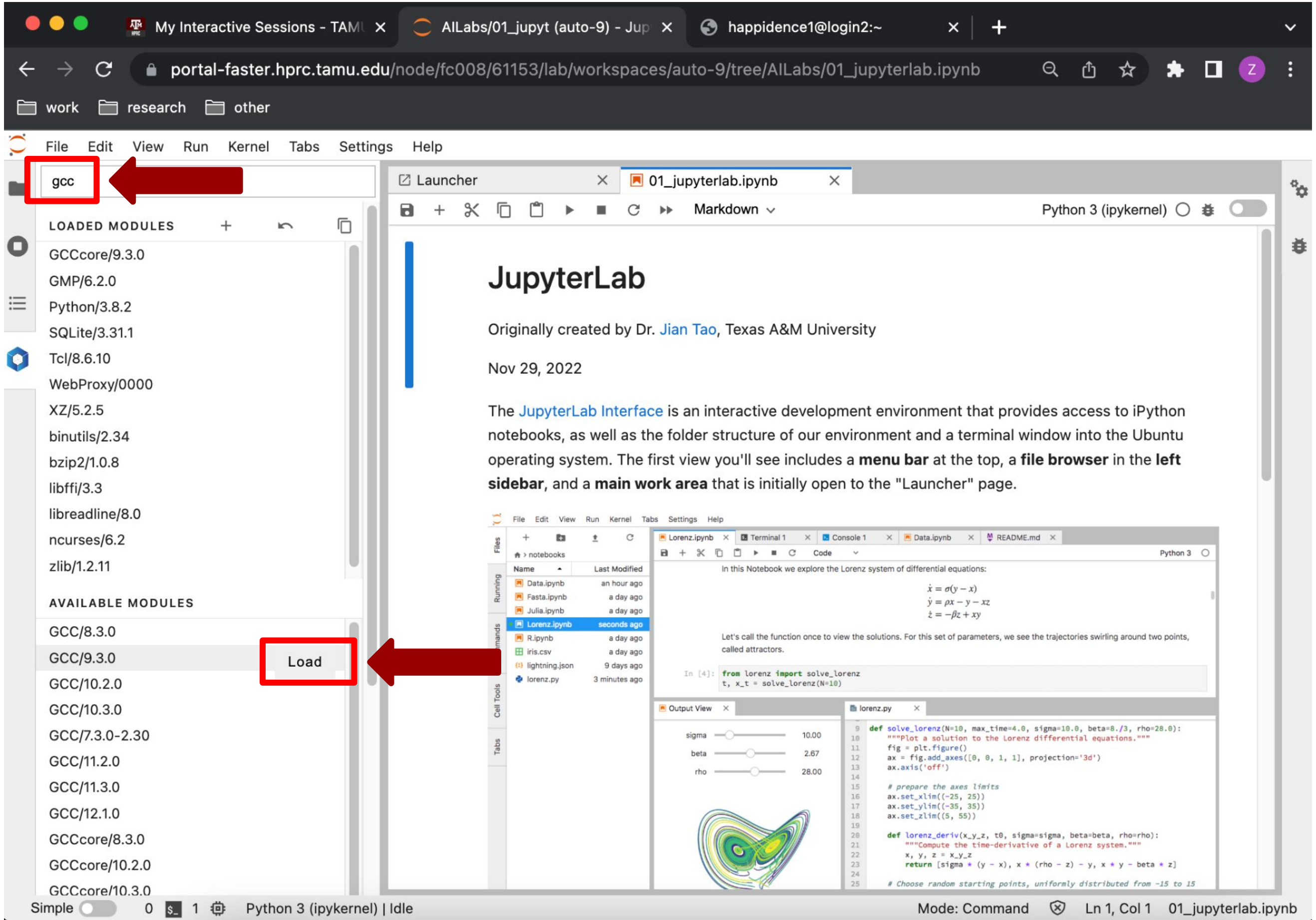
JupyterLab Lmod Extension



My Interactive Sessions - TAMU
AILabs/01_jupyt (auto-9) - Jup
happidence1@login2:~
portal-faster.hprc.tamu.edu/node/fc008/61153/lab/workspaces/auto-9/tree/AILabs/01_jupyterlab.ipynb
work
research
other
File
Edit
View
Run
Kernel
Tabs
Settings
Help
Launcher
01_jupyterlab.ipynb
Markdown
Python 3 (ipykernel)
Load
Simple
Mode: Command

gcc

LOADED MODULES

- GCCcore/9.3.0
- GMP/6.2.0
- Python/3.8.2
- SQLite/3.31.1
- Tcl/8.6.10
- WebProxy/0000
- XZ/5.2.5
- binutils/2.34
- bzip2/1.0.8
- libffi/3.3
- libreadline/8.0
- ncurses/6.2
- zlib/1.2.11

AVAILABLE MODULES

- GCC/8.3.0
- GCC/9.3.0
- GCC/10.2.0
- GCC/10.3.0
- GCC/7.3.0-2.30
- GCC/11.2.0
- GCC/11.3.0
- GCC/12.1.0
- GCCcore/8.3.0
- GCCcore/10.2.0
- GCCcore/10.3.0

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        return [sigma * (y - x), x * (rho - z) - y, x * y - beta * z]

    # Choose random starting points, uniformly distributed from -15 to 15
```

Python 3 (ipykernel) | Idle

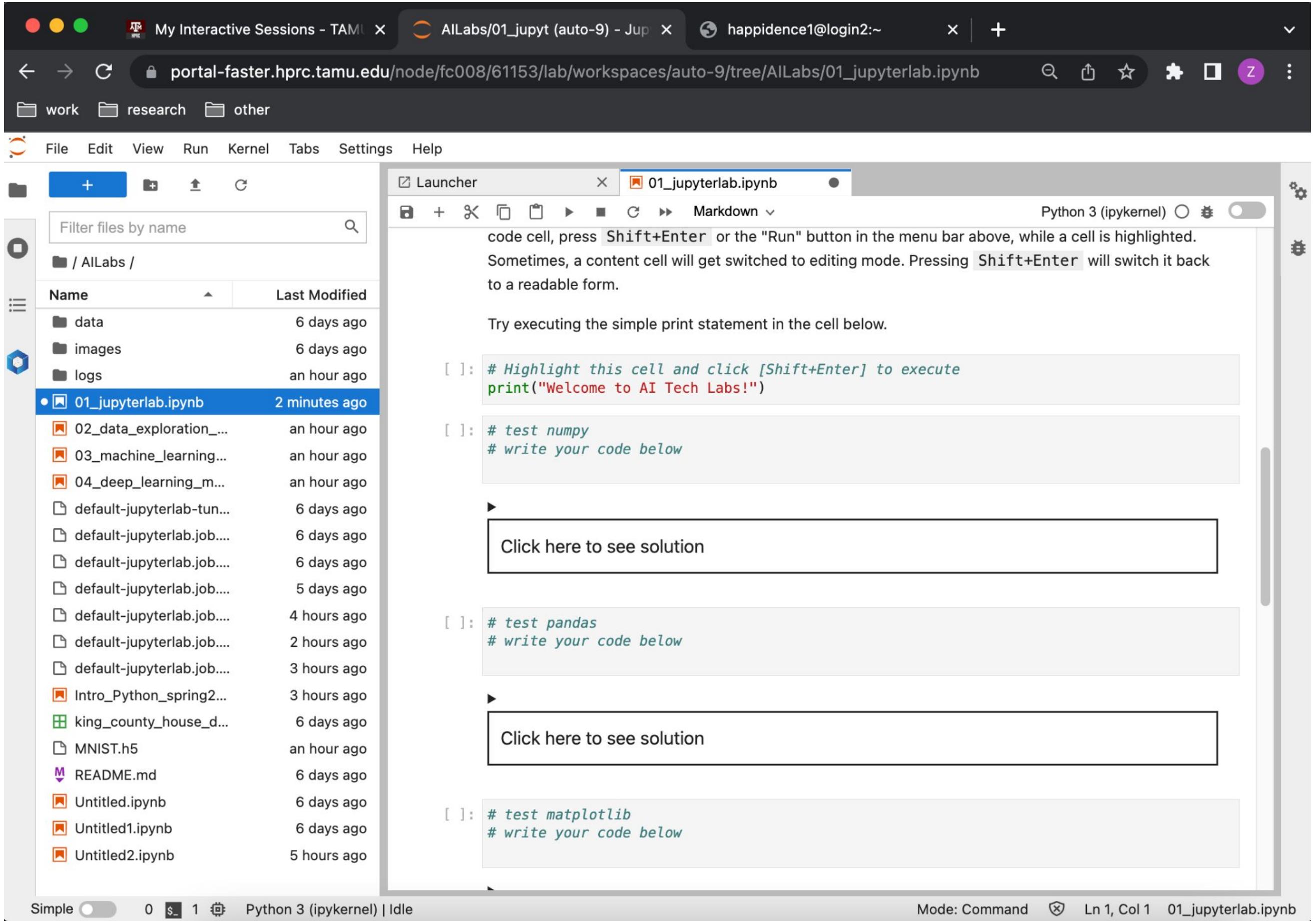
Ln 1, Col 1 01_jupyterlab.ipynb

Exercise: Load Required Modules

- GCC/9.3.0
- OpenMPI/4.0.3
- scikit-learn/0.23.1-Python-3.8.2
- TensorFlow/2.3.1-Python-3.8.2

Note: numpy and matplotlib have already been in the Scipy-bundle/2020.03-Python-3.8.2 module.

Test loaded modules



Name	Last Modified
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logs	an hour ago
01_jupyterlab.ipynb	2 minutes ago
02_data_exploration_...	an hour ago
03_machine_learning...	an hour ago
04_deep_learning_m...	an hour ago
default-jupyterlab-tun...	6 days ago
default-jupyterlab.job....	6 days ago
default-jupyterlab.job....	6 days ago
default-jupyterlab.job....	5 days ago
default-jupyterlab.job....	4 hours ago
default-jupyterlab.job....	2 hours ago
default-jupyterlab.job....	3 hours ago
Intro_Python_spring2...	3 hours ago
king_county_house_d...	6 days ago
MNIST.h5	an hour ago
README.md	6 days ago
Untitled.ipynb	6 days ago
Untitled1.ipynb	6 days ago
Untitled2.ipynb	5 hours ago

code cell, press `Shift+Enter` or the "Run" button in the menu bar above, while a cell is highlighted. Sometimes, a content cell will get switched to editing mode. Pressing `Shift+Enter` will switch it back to a readable form.

Try executing the simple print statement in the cell below.

```
[ ]: # Highlight this cell and click [Shift+Enter] to execute
     print("Welcome to AI Tech Labs!")
```

```
[ ]: # test numpy
     # write your code below
```

▶ Click here to see solution

```
[ ]: # test pandas
     # write your code below
```

▶ Click here to see solution

```
[ ]: # test matplotlib
     # write your code below
```

Lab II. Data Exploration

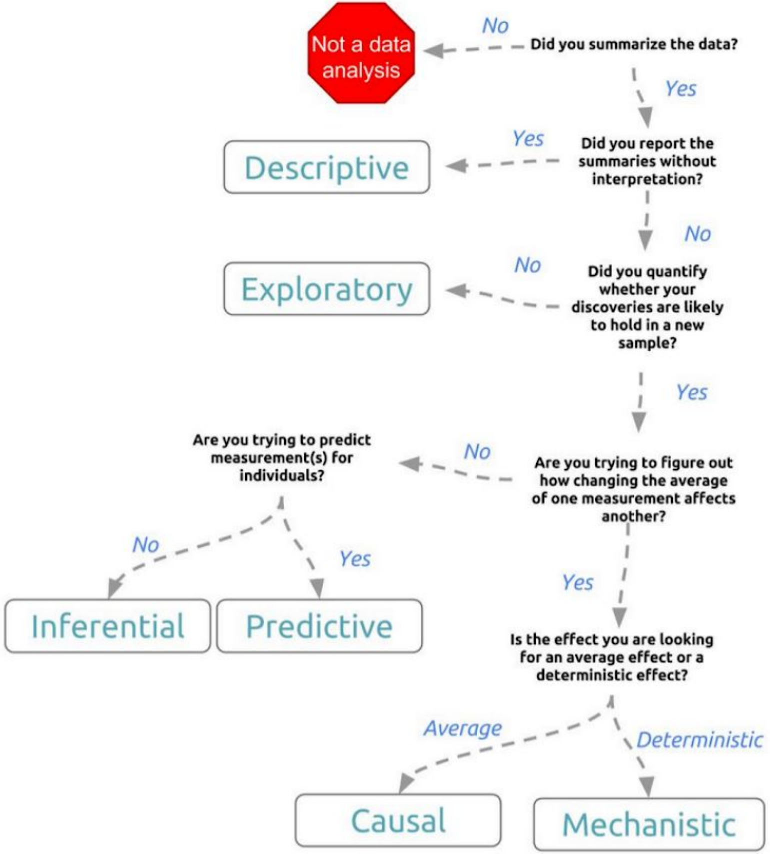
matplotlib

pandas

$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$

Types of Data Science Problems

- **Descriptive** (summaries, e.g., census)
- **Exploratory** (search for unknowns, e.g., four-planet solar system)
- **Inferential** (find correlations, e.g., many social studies)
- **Predictive** (make predictions, e.g., Face ID, Echo, Siri)
- **Causal** (explore causation, e.g., smoking versus lung cancer)
- **Mechanistic** (determine governing principles, e.g., experimental science)


Did you summarize the data?
No
Not a data analysis
Yes
Did you report the summaries without interpretation?
Yes
Descriptive
No
Did you quantify whether your discoveries are likely to hold in a new sample?
No
Exploratory
Yes
Are you trying to figure out how changing the average of one measurement affects another?
No
Are you trying to predict measurement(s) for individuals?
No
Inferential
Yes
Predictive
Yes
Is the effect you are looking for an average effect or a deterministic effect?
Average
Causal
Deterministic
Mechanistic

Credit: Jeff Leek - The Elements of Data Analytic Style

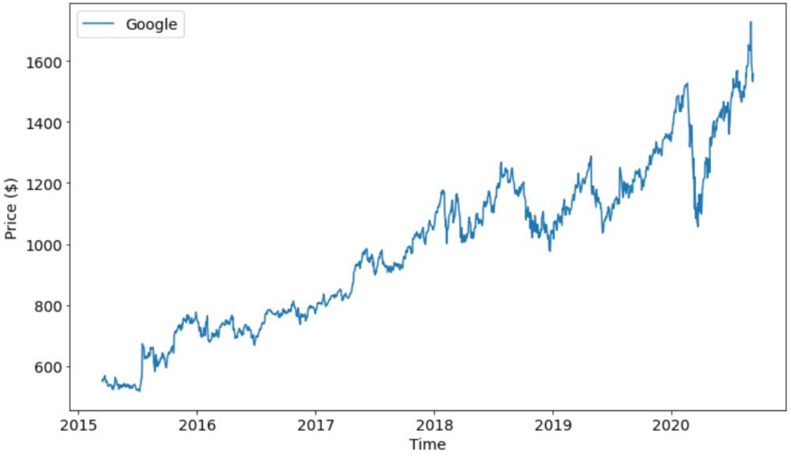
Data Structures

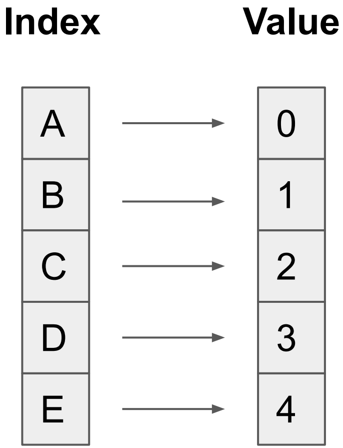
Pandas has two data structures that are descriptive and optimized for data with different dimensions.

- **Series:** 1D labeled array
- **DataFrame:** General 2D labeled, size-mutable tabular structure with potentially heterogeneously-typed columns

Series in pandas

- One-dimensional labeled array
- Capable of holding any data type (integers, strings, floating point numbers, etc.)
- Example: time-series stock price data

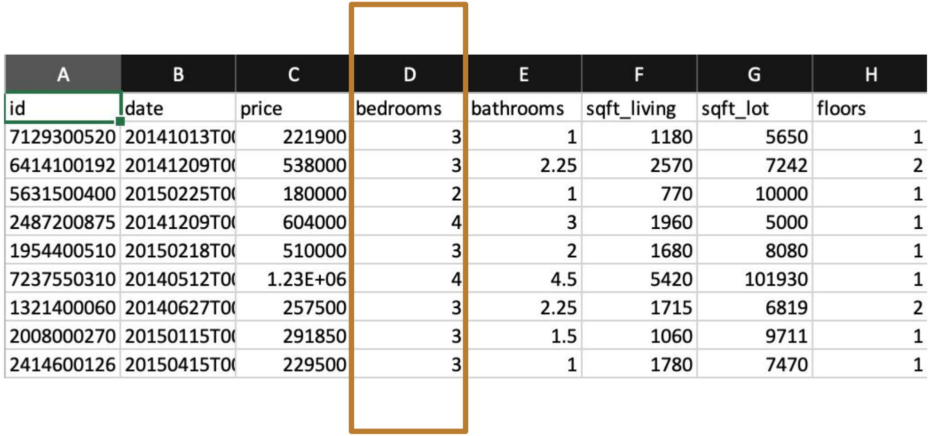




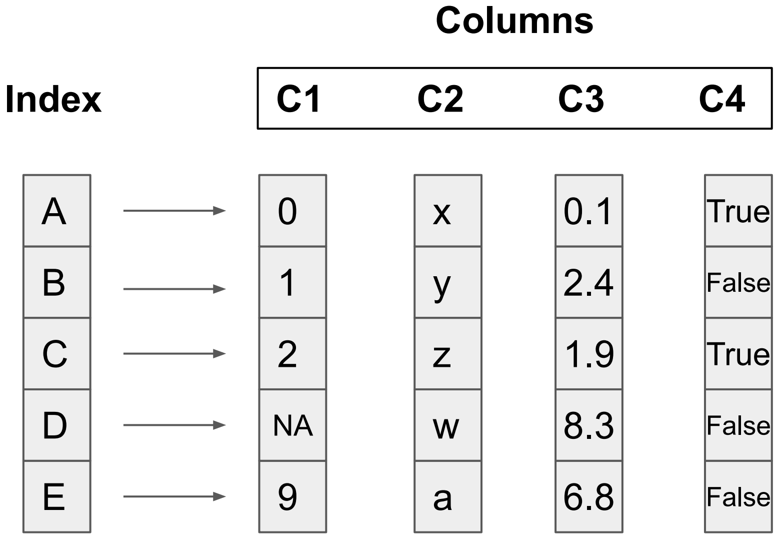
Index	Value
A	0
B	1
C	2
D	3
E	4

DataFrame in pandas

- Primary Pandas data structure
- A dict-like container for Series objects
- Two-dimensional size-mutable
- Heterogeneous tabular data structure



A	B	C	D	E	F	G	H
id	date	price	bedrooms	bathrooms	sqft_living	sqft_lot	floors
7129300520	20141013T0	221900	3	1	1180	5650	1
6414100192	20141209T0	538000	3	2.25	2570	7242	2
5631500400	20150225T0	180000	2	1	770	10000	1
2487200875	20141209T0	604000	4	3	1960	5000	1
1954400510	20150218T0	510000	3	2	1680	8080	1
7237550310	20140512T0	1.23E+06	4	4.5	5420	101930	1
1321400060	20140627T0	257500	3	2.25	1715	6819	2
2008000270	20150115T0	291850	3	1.5	1060	9711	1
2414600126	20150415T0	229500	3	1	1780	7470	1



Columns

Index	C1	C2	C3	C4
A	0	x	0.1	True
B	1	y	2.4	False
C	2	z	1.9	True
D	NA	w	8.3	False
E	9	a	6.8	False

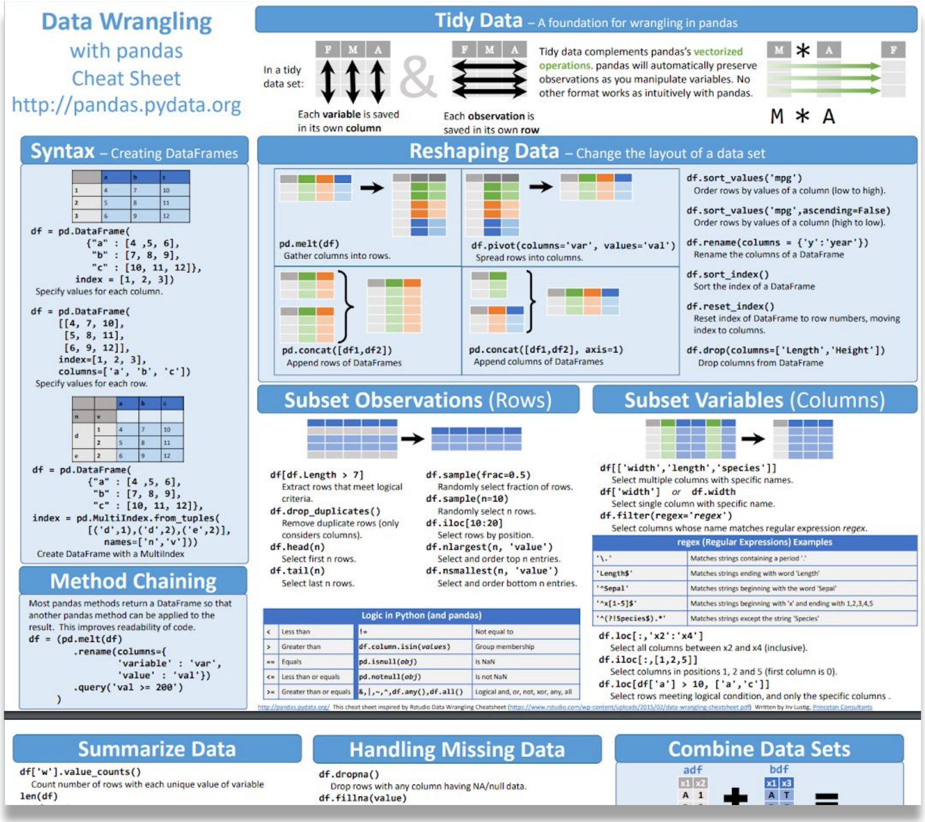
Pandas Learning Objectives

After this lesson, you will know how to:

- Create a DataFrame
- Drop Entries
- Index, Select, and Filter data
- Sort data
- Input and Output

☞ **JupyterLab Exercises**

Pandas Cheat Sheet



Data Wrangling with pandas Cheat Sheet http://pandas.pydata.org

Syntax – Creating DataFrames

	a	b	c
1	4	7	10
2	5	8	11
3	6	9	12

```
df = pd.DataFrame(
          {"a" : [4 ,5, 6],
           "b" : [7, 8, 9],
           "c" : [10, 11, 12]},
        index = [1, 2, 3])
```

Specify values for each column.

```
df = pd.DataFrame(
     [[4, 7, 10],
      [5, 8, 11],
      [6, 9, 12]],
     index=[1, 2, 3],
     columns=['a', 'b', 'c'])
```

Specify values for each row.

		a	b	c
n	v			
d	1	4	7	10
	2	5	8	11
e	2	6	9	12

```
df = pd.DataFrame(
          {"a" : [4 ,5, 6],
           "b" : [7, 8, 9],
           "c" : [10, 11, 12]},
index = pd.MultiIndex.from_tuples(
          [('d',1),('d',2),('e',2)],
             names=['n','v']))
```

Create DataFrame with a MultiIndex

Method Chaining

Most pandas methods return a DataFrame so that another pandas method can be applied to the result. This improves readability of code.

```
df = (pd.melt(df)
        .rename(columns={
                'variable' : 'var',
                'value' : 'val'})
        .query('val >= 200')
     )
```

Tidy Data – A foundation for wrangling in pandas

In a tidy data set:

Each **variable** is saved in its own **column**

Each **observation** is saved in its own **row**

Tidy data complements pandas's vectorized operations. pandas will automatically preserve observations as you manipulate variables. No other format works as intuitively with pandas.

Reshaping Data – Change the layout of a data set

`pd.melt(df)`
Gather columns into rows.

`df.pivot(columns='var', values='val')`
Spread rows into columns.

`pd.concat([df1,df2])`
Append rows of DataFrames

`pd.concat([df1,df2], axis=1)`
Append columns of DataFrames

`df.sort_values('mpg')`
Order rows by values of a column (low to high).

`df.sort_values('mpg',ascending=False)`
Order rows by values of a column (high to low).

`df.rename(columns = {'y':'year'})`
Rename the columns of a DataFrame

`df.sort_index()`
Sort the index of a DataFrame

`df.reset_index()`
Reset index of DataFrame to row numbers, moving index to columns.

`df.drop(columns=['Length','Height'])`
Drop columns from DataFrame

Subset Observations (Rows)

`df[df.Length > 7]`
Extract rows that meet logical criteria.

`df.drop_duplicates()`
Remove duplicate rows (only considers columns).

`df.head(n)`
Select first n rows.

`df.tail(n)`
Select last n rows.

`df.sample(frac=0.5)`
Randomly select fraction of rows.

`df.sample(n=10)`
Randomly select n rows.

`df.iloc[10:20]`
Select rows by position.

`df.nlargest(n, 'value')`
Select and order top n entries.

`df.nsmallest(n, 'value')`
Select and order bottom n entries.

Logic in Python (and pandas)			
<	Less than	!=	Not equal to
>	Greater than	df.column.isin(*values*)	Group membership
==	Equals	pd.isnull(*obj*)	Is NaN
<=	Less than or equals	pd.notnull(*obj*)	Is not NaN
>=	Greater than or equals	&,|,~,^,df.any(),df.all()	Logical and, or, not, xor, any, all

Subset Variables (Columns)

`df[['width','length','species']]`
Select multiple columns with specific names.

`df['width']` *or* `df.width`
Select single column with specific name.

`df.filter(regex='regex')`
Select columns whose name matches regular expression *regex*.

regex (Regular Expressions) Examples	
'\.'	Matches strings containing a period '.'
'Length$'	Matches strings ending with word 'Length'
'^Sepal'	Matches strings beginning with the word 'Sepal'
'^x[1-5]$'	Matches strings beginning with 'x' and ending with 1,2,3,4,5
'^(?!Species$).*'	Matches strings except the string 'Species'

`df.loc[:,'x2':'x4']`
Select all columns between x2 and x4 (inclusive).

`df.iloc[:,[1,2,5]]`
Select columns in positions 1, 2 and 5 (first column is 0).

`df.loc[df['a'] > 10, ['a','c']]`
Select rows meeting logical condition, and only the specific columns .

http://pandas.pydata.org/ This cheat sheet inspired by Rstudio Data Wrangling Cheatsheet (https://www.rstudio.com/wp-content/uploads/2015/02/data-wrangling-cheatsheet.pdf) Written by Irv Lustig, Princeton Consultants

Summarize Data

`df['w'].value_counts()`
Count number of rows with each unique value of variable

`len(df)`

Handling Missing Data

`df.dropna()`
Drop rows with any column having NA/null data.

`df.fillna(value)`

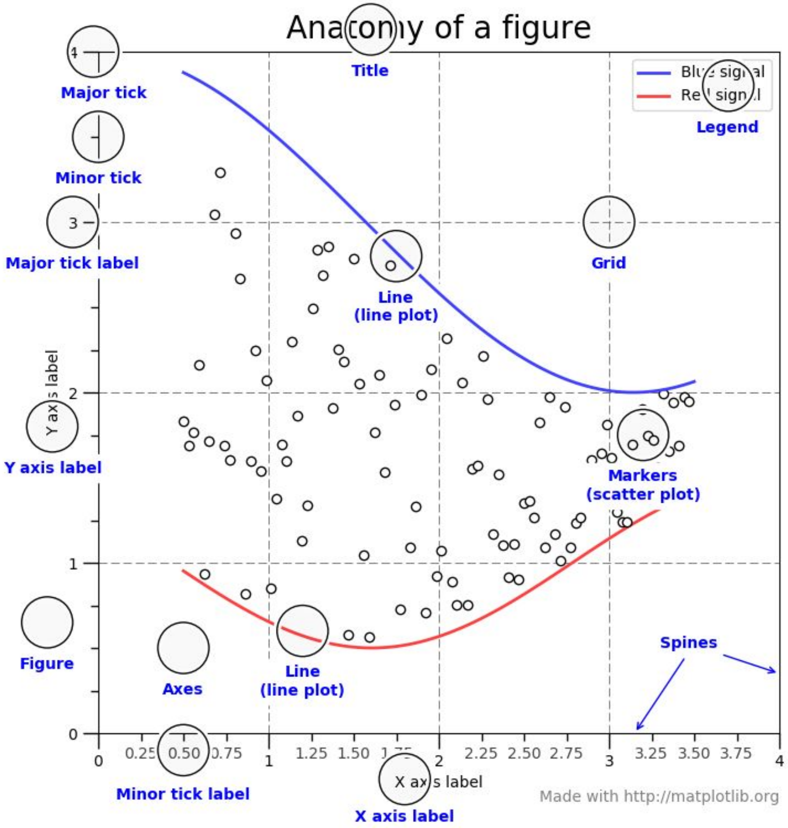
Combine Data Sets

https://pandas.pydata.org/Pandas_Cheat_Sheet.pdf

Key Plotting Concepts in Matplotlib

- **Matplotlib: Figure**
  Figure is the object that keeps the whole image output. Adjustable parameters include:
  1. Image size (set_size_inches())
  2. Whether to use tight_layout (set_tight_layout())

- **Matplotlib: Axes**
  Axes object represents the pair of axis that contain a single plot (x-axis and y-axis). The Axes object also has more adjustable parameters:
  1. The plot frame (set_frame_on() or set_frame_off())
  2. X-axis and Y-axis limits (set_xlim() and set_ylim())
  3. X-axis and Y-axis Labels (set_xlabel() and set_ylabel())
  4. The plot title (set_title())



(Credit: matplotlib.org)

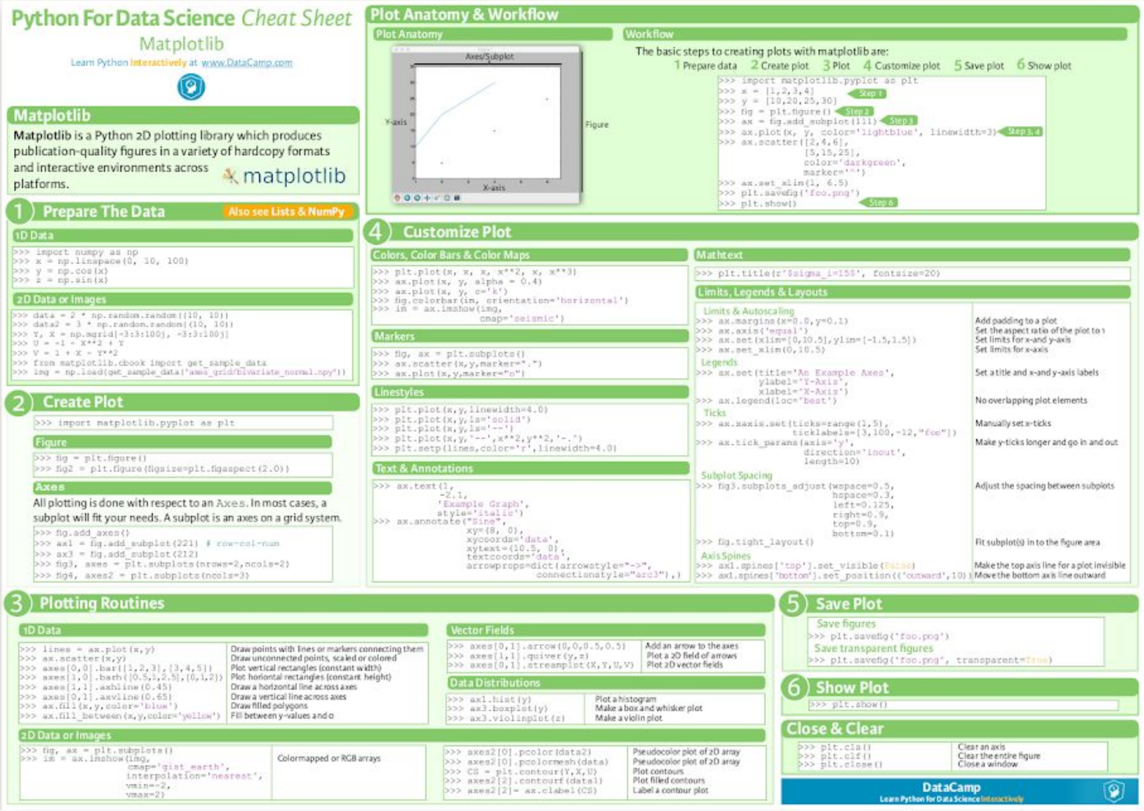
Matplotlib Learning Objectives

After this lesson, you will know how to:

- Scatter plot and Line plot
- Subplots
- Color map
- Contour figures
- 3D figures
  - Surface plots
  - Wire-frame plot
  - Contour plots with projections

☞ **JupyterLab Exercises**

Matplotlib Cheat Sheet



Python For Data Science *Cheat Sheet*

Matplotlib

Learn Python Interactively at www.DataCamp.com

Matplotlib

Matplotlib is a Python 2D plotting library which produces publication-quality figures in a variety of hardcopy formats and interactive environments across platforms.

matplotlib

1 Prepare The Data

Also see Lists & NumPy

1D Data

```
>>> import numpy as np
>>> x = np.linspace(0, 10, 100)
>>> y = np.cos(x)
>>> z = np.sin(x)
```

2D Data or Images

```
>>> data = 2 * np.random.random((10, 10))
>>> data2 = 3 * np.random.random((10, 10))
>>> Y, X = np.mgrid[-3:3:100j, -3:3:100j]
>>> U = -1 - X**2 + Y
>>> V = 1 + X - Y**2
>>> from matplotlib.cbook import get_sample_data
>>> img = np.load(get_sample_data('axes_grid/bivariate_normal.npy'))
```

2 Create Plot

```
>>> import matplotlib.pyplot as plt
```

Figure

```
>>> fig = plt.figure()
>>> fig2 = plt.figure(figsize=plt.figaspect(2.0))
```

Axes

All plotting is done with respect to an `Axes`. In most cases, a subplot will fit your needs. A subplot is an axes on a grid system.

```
>>> fig.add_axes()
>>> ax1 = fig.add_subplot(221) # row-col-num
>>> ax3 = fig.add_subplot(212)
>>> fig3, axes = plt.subplots(nrows=2,ncols=2)
>>> fig4, axes2 = plt.subplots(ncols=3)
```

Plot Anatomy & Workflow

Plot Anatomy

Workflow

The basic steps to creating plots with matplotlib are:

1 Prepare data 2 Create plot 3 Plot 4 Customize plot 5 Save plot 6 Show plot

```
>>> import matplotlib.pyplot as plt
>>> x = [1,2,3,4]                 Step 1
>>> y = [10,20,25,30]
>>> fig = plt.figure()            Step 2
>>> ax = fig.add_subplot(111)     Step 3
>>> ax.plot(x, y, color='lightblue', linewidth=3)   Step 3, 4
>>> ax.scatter([2,4,6],
               [5,15,25],
               color='darkgreen',
               marker='^')
>>> ax.set_xlim(1, 6.5)
>>> plt.savefig('foo.png')
>>> plt.show()                    Step 6
```

4 Customize Plot

Colors, Color Bars & Color Maps

```
>>> plt.plot(x, x, x, x**2, x, x**3)
>>> ax.plot(x, y, alpha = 0.4)
>>> ax.plot(x, y, c='k')
>>> fig.colorbar(im, orientation='horizontal')
>>> im = ax.imshow(img,
                   cmap='seismic')
```

Markers

```
>>> fig, ax = plt.subplots()
>>> ax.scatter(x,y,marker=".")
>>> ax.plot(x,y,marker="o")
```

Linestyles

```
>>> plt.plot(x,y,linewidth=4.0)
>>> plt.plot(x,y,ls='solid')
>>> plt.plot(x,y,ls='--')
>>> plt.plot(x,y,'--',x**2,y**2,'-.')
>>> plt.setp(lines,color='r',linewidth=4.0)
```

Text & Annotations

```
>>> ax.text(1,
            -2.1,
            'Example Graph',
            style='italic')
>>> ax.annotate("Sine",
                xy=(8, 0),
                xycoords='data',
                xytext=(10.5, 0),
                textcoords='data',
                arrowprops=dict(arrowstyle="->",
                                connectionstyle="arc3"),)
```

Mathtext

```
>>> plt.title(r'$sigma_i=15$', fontsize=20)
```

Limits, Legends & Layouts

Limits & Autoscaling

`>>> ax.margins(x=0.0,y=0.1)`	Add padding to a plot
`>>> ax.axis('equal')`	Set the aspect ratio of the plot to 1
`>>> ax.set(xlim=[0,10.5],ylim=[-1.5,1.5])`	Set limits for x-and y-axis
`>>> ax.set_xlim(0,10.5)`	Set limits for x-axis

Legends

`>>> ax.set(title='An Example Axes',`
`ylabel='Y-Axis',`
`xlabel='X-Axis')`
	Set a title and x-and y-axis labels

`>>> ax.legend(loc='best')`	No overlapping plot elements

Ticks

`>>> ax.xaxis.set(ticks=range(1,5),`
`ticklabels=[3,100,-12,"foo"])`
	Manually set x-ticks

`>>> ax.tick_params(axis='y',`
`direction='inout',`
`length=10)`
	Make y-ticks longer and go in and out

Subplot Spacing

`>>> fig3.subplots_adjust(wspace=0.5,`
`hspace=0.3,`
`left=0.125,`
`right=0.9,`
`top=0.9,`
`bottom=0.1)`
	Adjust the spacing between subplots

`>>> fig.tight_layout()`	Fit subplot(s) in to the figure area

Axis Spines

`>>> ax1.spines['top'].set_visible(False)`	Make the top axis line for a plot invisible
`>>> ax1.spines['bottom'].set_position(('outward',10))`	Move the bottom axis line outward

3 Plotting Routines

1D Data

`>>> lines = ax.plot(x,y)`	Draw points with lines or markers connecting them
`>>> ax.scatter(x,y)`	Draw unconnected points, scaled or colored
`>>> axes[0,0].bar([1,2,3],[3,4,5])`	Plot vertical rectangles (constant width)
`>>> axes[1,0].barh([0.5,1,2.5],[0,1,2])`	Plot horiontal rectangles (constant height)
`>>> axes[1,1].axhline(0.45)`	Draw a horizontal line across axes
`>>> axes[0,1].axvline(0.65)`	Draw a vertical line across axes
`>>> ax.fill(x,y,color='blue')`	Draw filled polygons
`>>> ax.fill_between(x,y,color='yellow')`	Fill between y-values and 0

Vector Fields

`>>> axes[0,1].arrow(0,0,0.5,0.5)`	Add an arrow to the axes
`>>> axes[1,1].quiver(y,z)`	Plot a 2D field of arrows
`>>> axes[0,1].streamplot(X,Y,U,V)`	Plot 2D vector fields

Data Distributions

`>>> ax1.hist(y)`	Plot a histogram
`>>> ax3.boxplot(y)`	Make a box and whisker plot
`>>> ax3.violinplot(z)`	Make a violin plot

2D Data or Images

`>>> fig, ax = plt.subplots()`
`>>> im = ax.imshow(img,`
`cmap='gist_earth',`
`interpolation='nearest',`
`vmin=-2,`
`vmax=2)`
	Colormapped or RGB arrays

`>>> axes2[0].pcolor(data2)`	Pseudocolor plot of 2D array
`>>> axes2[0].pcolormesh(data)`	Pseudocolor plot of 2D array
`>>> CS = plt.contour(Y,X,U)`	Plot contours
`>>> axes2[2].contourf(data1)`	Plot filled contours
`>>> axes2[2]= ax.clabel(CS)`	Label a contour plot

5 Save Plot

Save figures

```
>>> plt.savefig('foo.png')
```

Save transparent figures

```
>>> plt.savefig('foo.png', transparent=True)
```

6 Show Plot

```
>>> plt.show()
```

Close & Clear

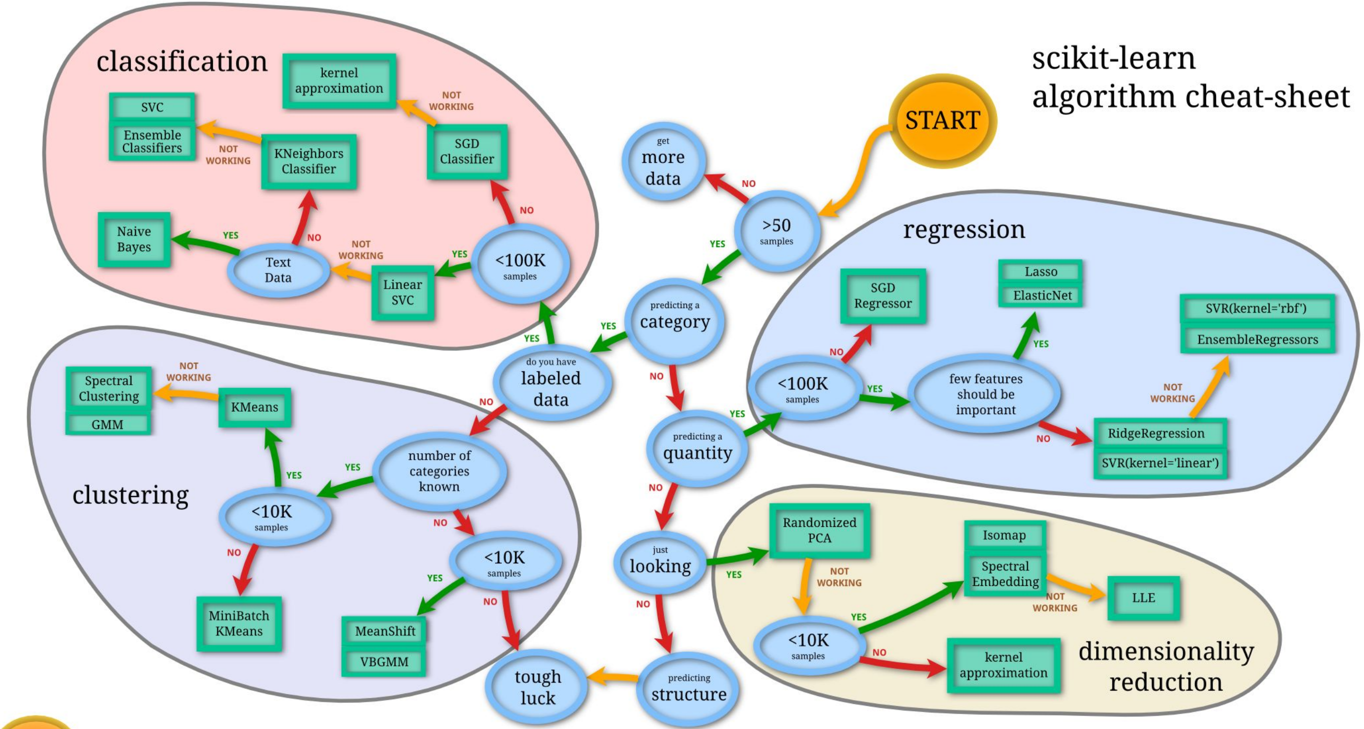
`>>> plt.cla()`	Clear an axis
`>>> plt.clf()`	Clear the entire figure
`>>> plt.close()`	Close a window

DataCamp

Learn Python for Data Science Interactively

https://s3.amazonaws.com/assets.datacamp.com/blog_assets/Python_Matplotlib_Cheat_Sheet.pdf

Lab III. Machine Learning



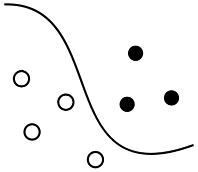
Back

Main Features of scikit-learn

Classification

Identifying category of an object

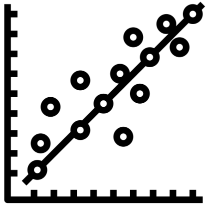
Applications: Spam detection, image recognition. **Algorithms**: SVM, nearest neighbors, random forest, and more...



Regression

Predicting a attribute for an object

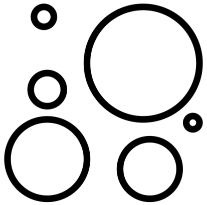
Applications: Drug response, Stock prices. **Algorithms**: SVR, nearest neighbors, random forest, and more...



Clustering

Grouping similar objects into sets

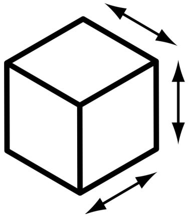
Applications: Customer segmentation, Grouping experiment outcomes **Algorithms:** k-Means, spectral clustering, mean-shift, and more...



Dimension Reduction

Reducing the number of dimensions

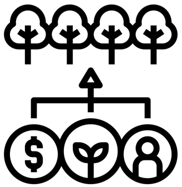
Applications: Visualization, Increased efficiency **Algorithms:** k-Means, feature selection, non-negative matrix factorization, and more...



Model Selection

Selecting models with parameter search

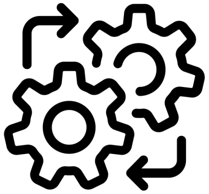
Applications: Improved accuracy via parameter tuning **Algorithms:** grid search, cross validation, metrics, and more...



Preprocessing

Preprocessing data to prepare for modeling

Applications: Transforming input data such as text for use with machine learning algorithms. **Algorithms:** preprocessing, feature extraction, and more...



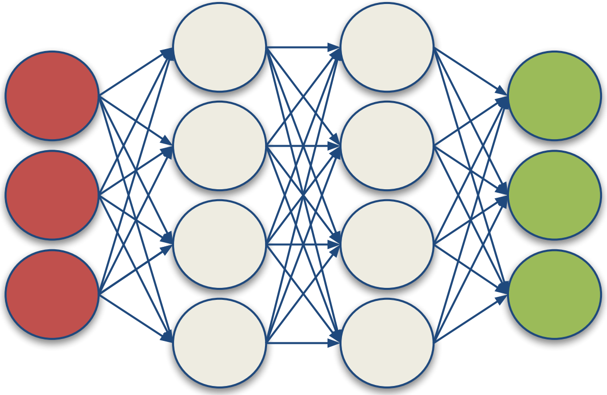
Credit: icons are from The Noun Project under Creative Commons Licenses

Lab IV. Deep Learning

Deep Learning
by Ian Goodfellow, Yoshua Bengio, and Aaron Courville
http://www.deeplearningbook.org/

Animation of Neutron Networks
by Grant Sanderson
https://www.3blue1brown.com/

Visualization of CNN
by Adam Harley
https://www.cs.ryerson.ca/~aharley/vis/conv/

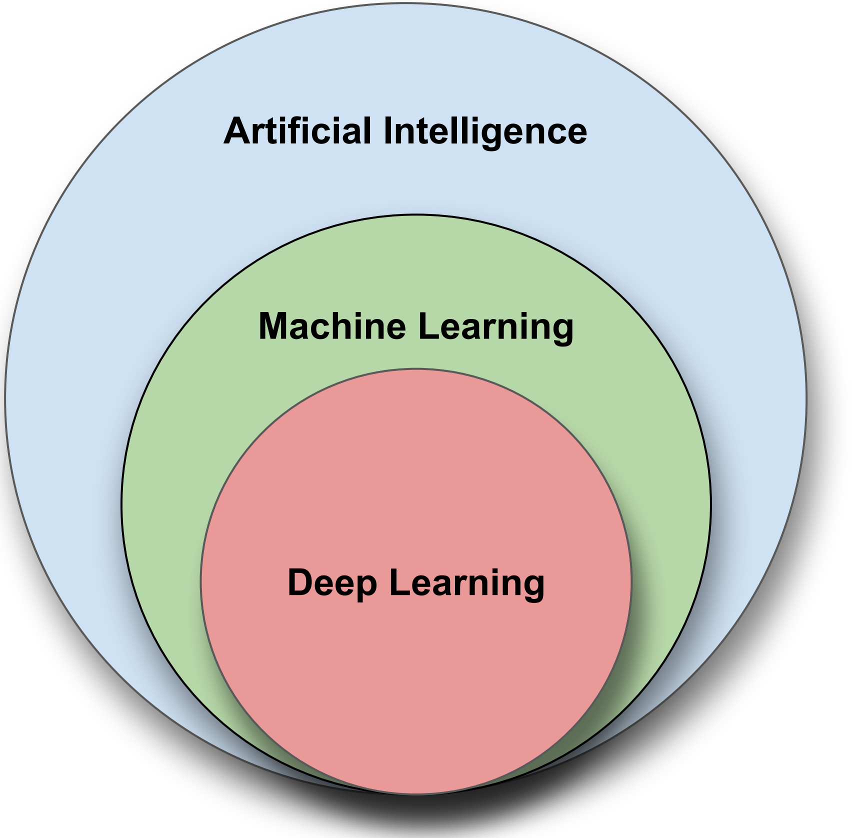


TensorFlow 2.0

Keras

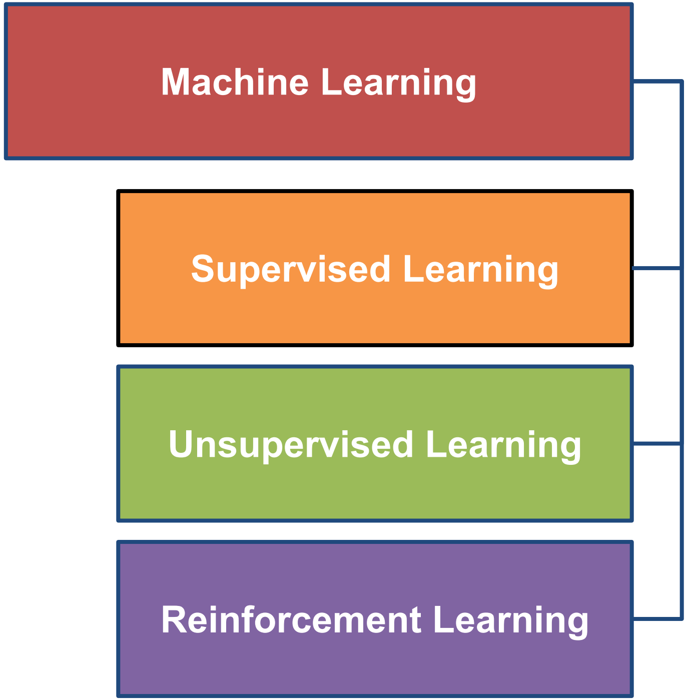
Relationship of AI, ML, and DL

- **Artificial Intelligence (AI)** is anything about man-made intelligence exhibited by machines.
- **Machine Learning (ML)** is an approach to achieve **AI**.
- **Deep Learning (DL)** is one technique to implement **ML**.



Types of ML Algorithms

- **Supervised Learning**
  - trained with labeled data; including regression and classification problems
- **Unsupervised Learning**
  - trained with unlabeled data; clustering and association rule learning problems.
- **Reinforcement Learning**
  - no training data; stochastic Markov decision process; robotics and self-driving cars.

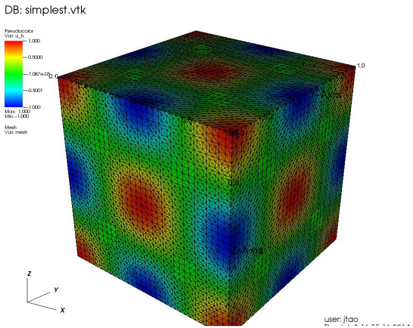

Machine Learning

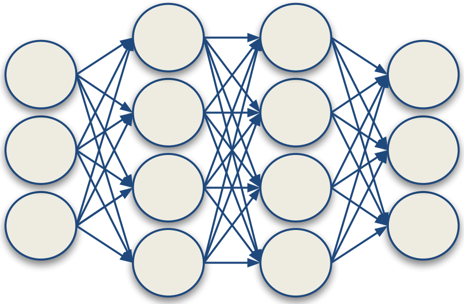
Supervised Learning

Unsupervised Learning

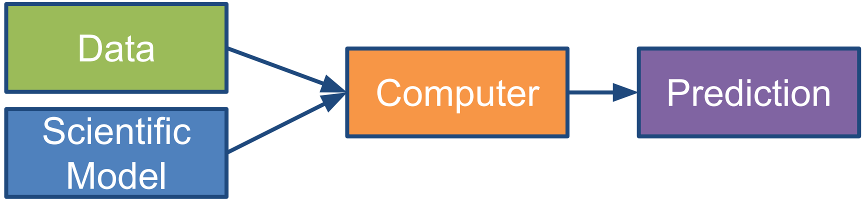
Reinforcement Learning

Machine Learning

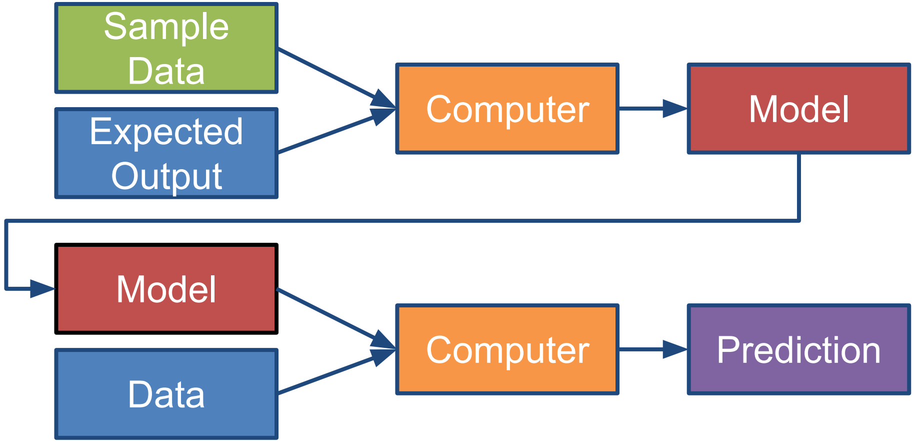




Traditional Modeling



Machine Learning (Supervised Learning)



Inputs and Outputs

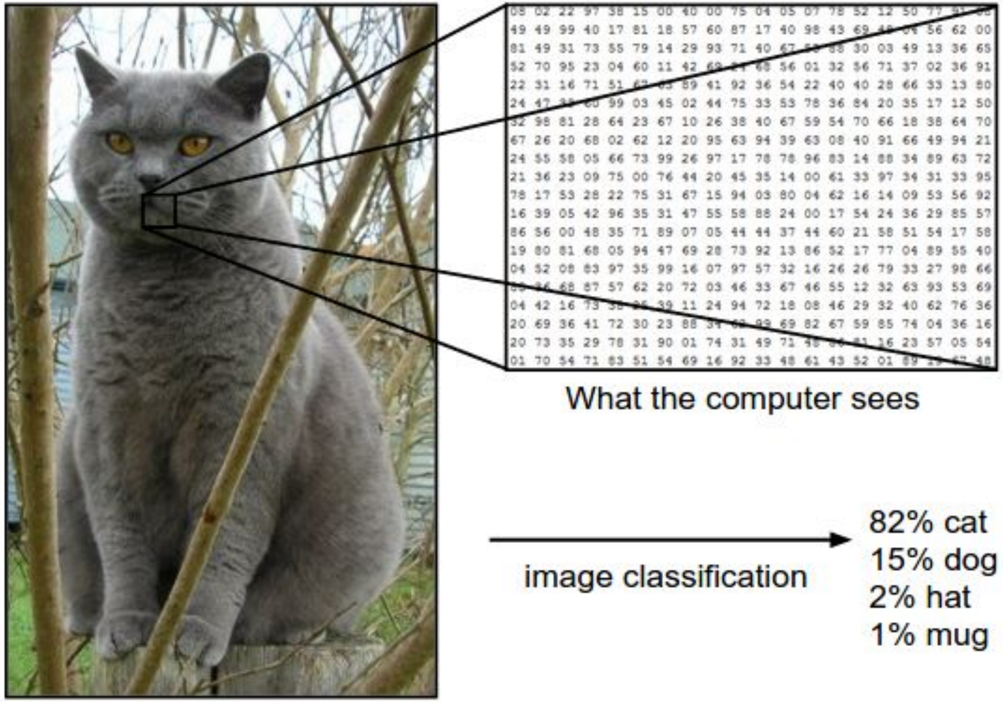
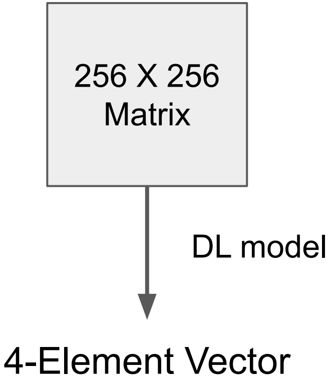
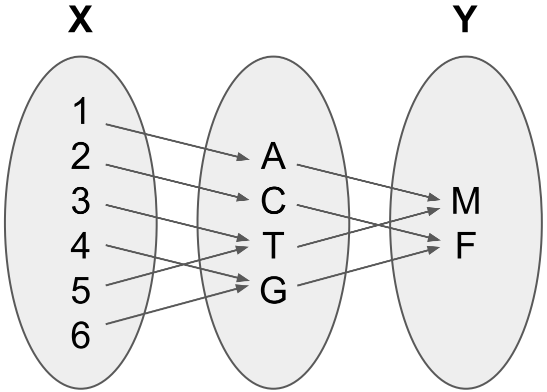


Image from the Stanford CS231 Course


256 X 256 Matrix

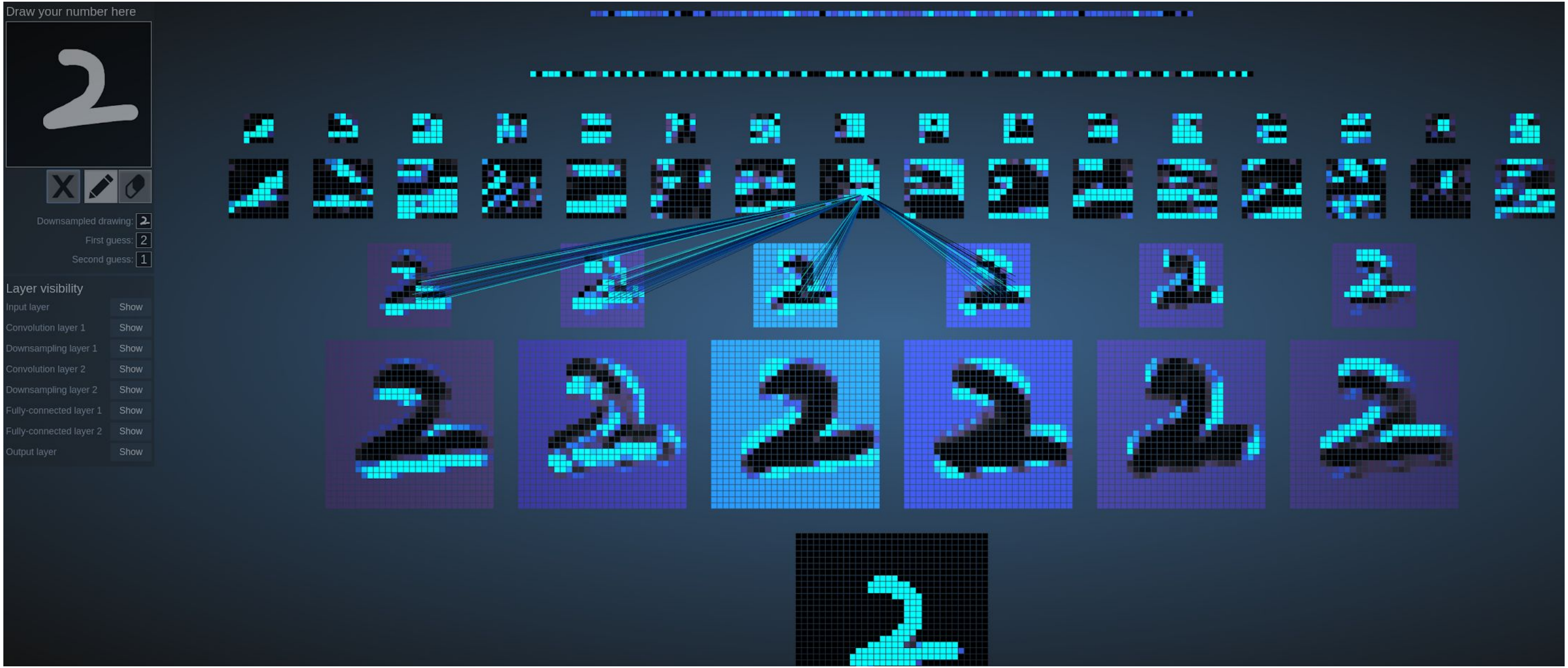
DL model

4-Element Vector



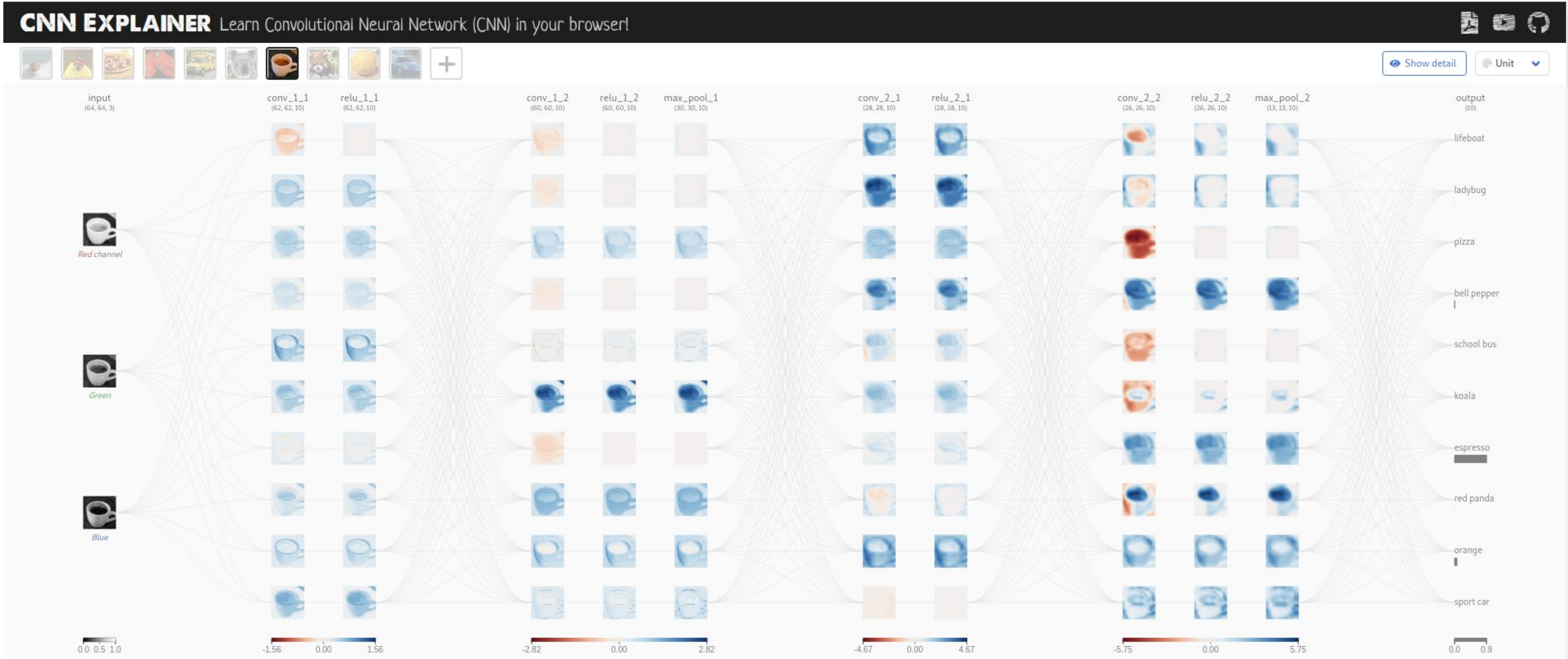
With deep learning, we are searching for a **surjective** (or **onto**) function **f** from a set **X** to a set **Y**.

MNIST - CNN Visualization



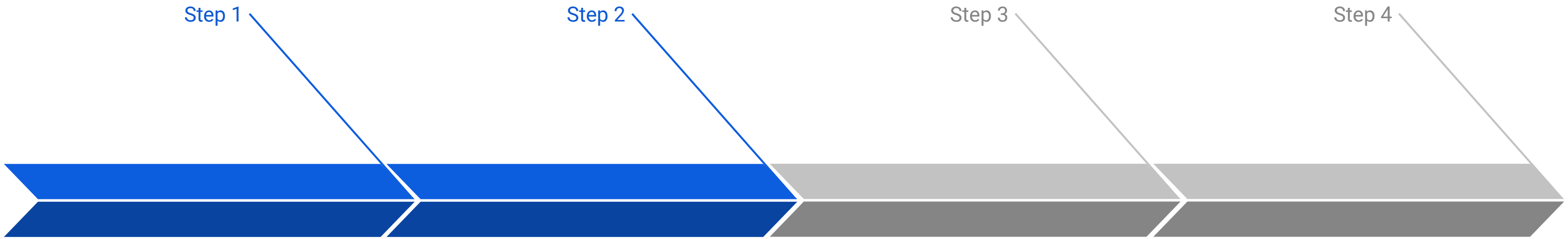
(Image Credit: http://scs.ryerson.ca/~aharley/vis/)

CNN Explainer



(Image Credit: https://poloclub.github.io/cnn-explainer/)

Machine Learning Workflow with Keras



Prepare Train Data

The preprocessed data set needs to be shuffled and splitted into training and testing data.

Define Model

A model could be defined with Keras Sequential model for a linear stack of layers or Keras functional API for complex network.

Training Configuration

The configuration of the training process requires the specification of an optimizer, a loss function, and a list of metrics.

Train Model

The training begins by calling the fit function. The number of epochs and batch size need to be set. The measurement metrics need to be evaluated.