ACES: AI TechLab in Jupyter Notebooks

Accelerating AI/ML Workflows on a Composable Cyberinfrastructure

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02/10/2026

High Performance
Research Computing
DIVISION OF RESEARCH

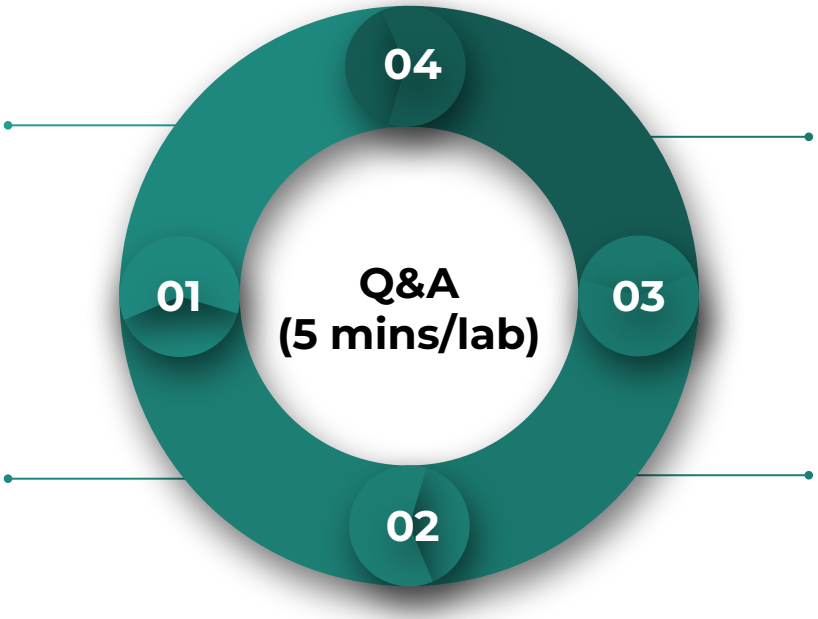
Outline

Lab I. JupyterLab (30 mins)

We will build and activate a ModuLair virtual environment and run JupyterLab on HPRC ACES portal.

Lab II. Data Exploration (30 mins)

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



Lab IV. Deep Learning (30 minutes)

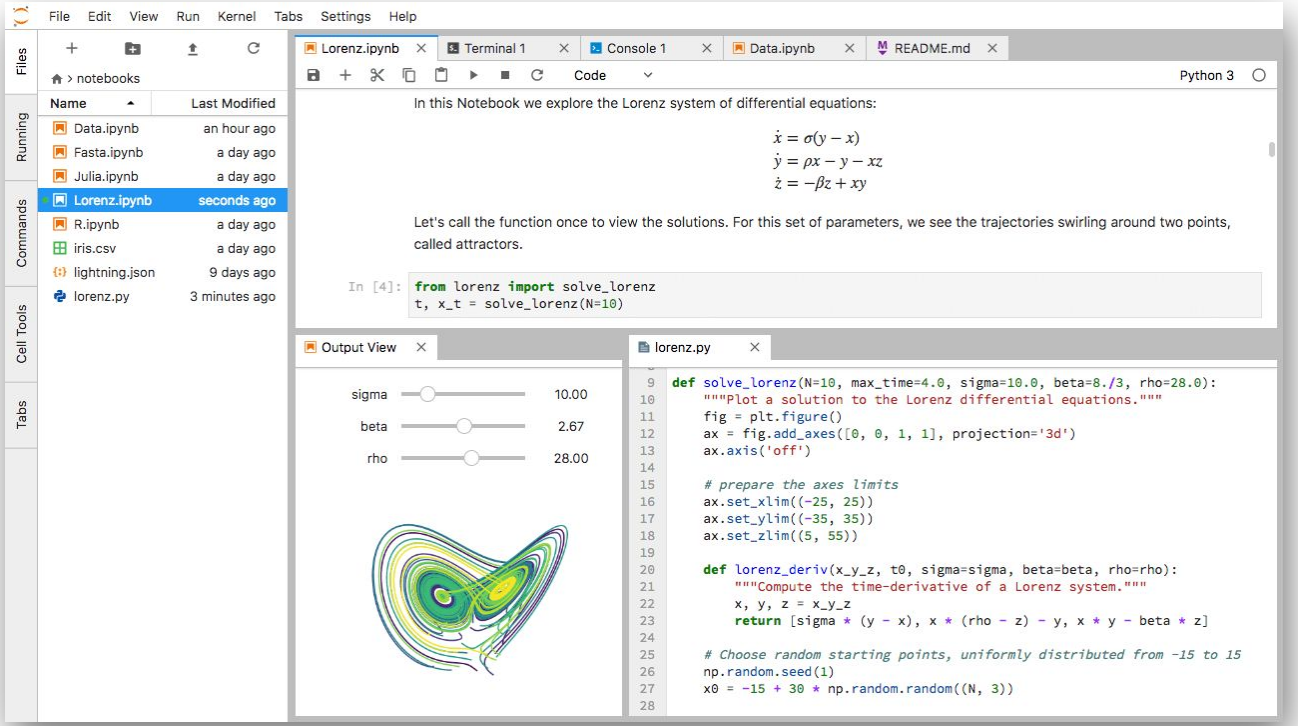
We will learn how to use PyTorch to build and train a simple image classification model with deep neural network (DNN).

Lab III Machine Learning (30 minutes)

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

Figure 1. Structure of the AI TechLab.

Lab I. JupyterLab



L1 - Resources

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

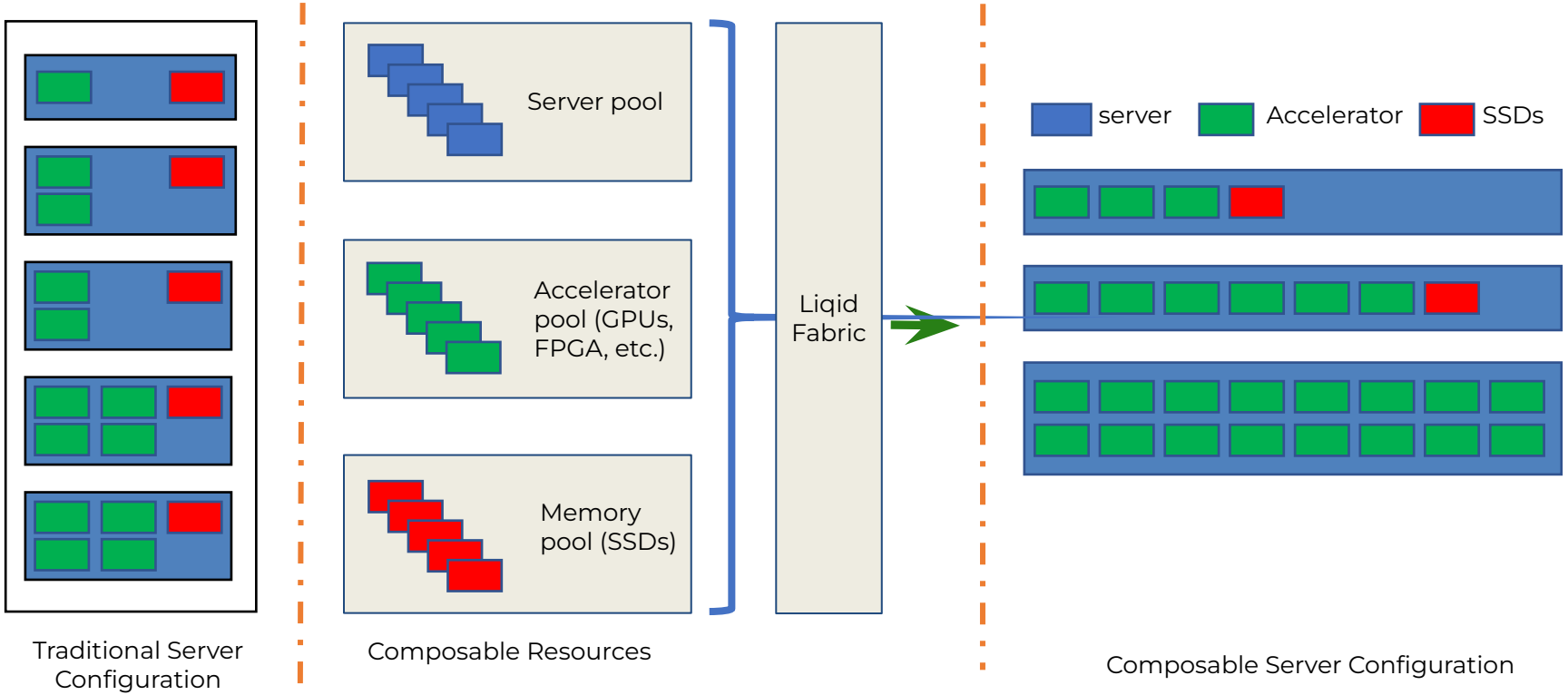
NSF ACES

Accelerating Computing for Emerging Sciences

Our Mission:

- Develop an NSF ACSS CI testbed
- Offer an accelerator testbed for numerical simulations and AI/ML workloads
- Provide consulting, technical guidance, and training to researchers
- Collaborate on computational and data-enabled research.

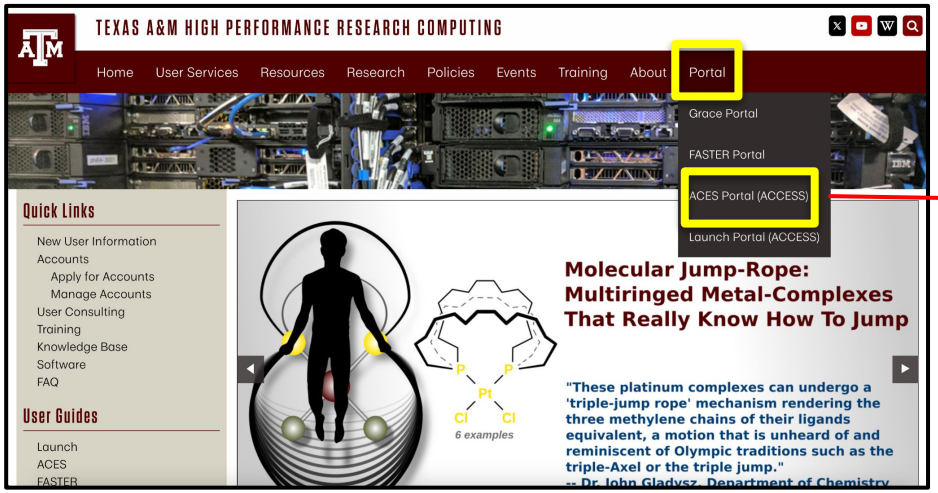
Design: Composability at the Hardware Level

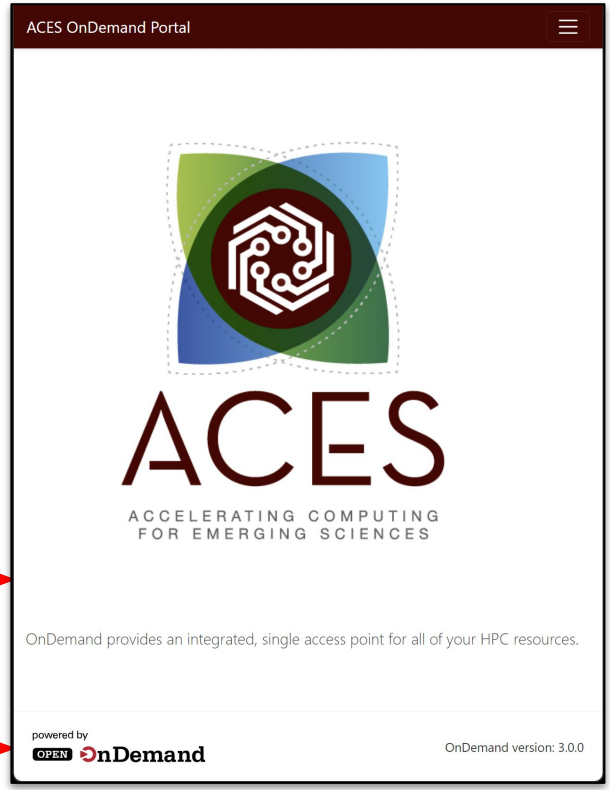


ACES Accelerators

Component	Quantity	Description
Graphcore IPU: Colossus GC200 Bow	 16 16	Each IPU group hosted with a CPU server as a POD16 on a 100 GbE RoCE fabric
NVIDIA GPUs: H100 A30	 30 4	 For HPC, DL Training, AI Inference For AI Inference and Mainstream Compute
BittWare IA-840F FPGA	3	Accelerator with Agilex AGF027 FPGA and 64 GB of DDR4
NextSilicon Coprocessor	2	Reconfigurable accelerator with an optimizer continuously evaluating application behavior.
NEC Vector Engine	8	Vector computing card (8 cores and HBM2 memory)
Intel Optane SSD	48	18 TB of SSDs addressable as memory w/ MemVerge Memory Machine.
Intel PVC GPUs	120	Intel GPUs for HPC, DL Training, AI Inference

ACES Portal

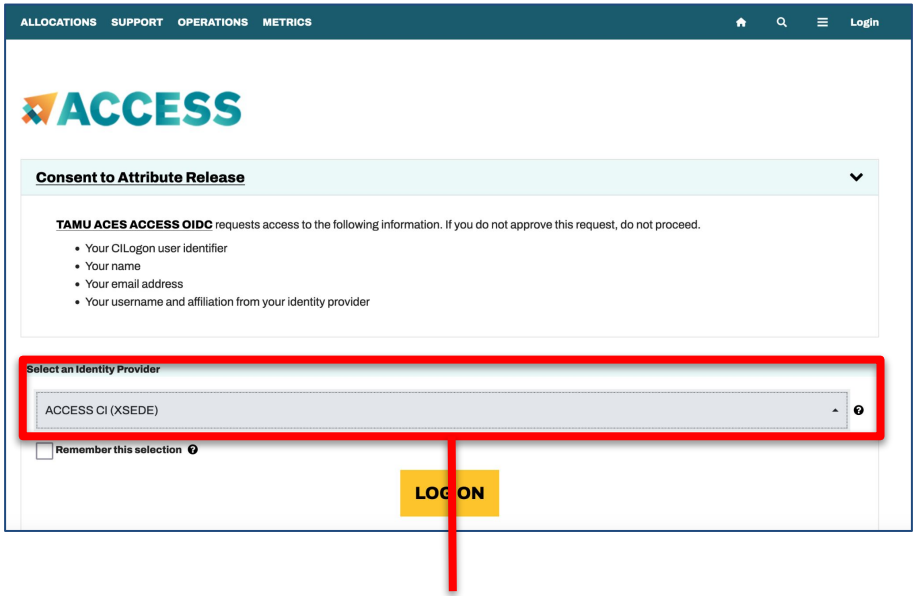




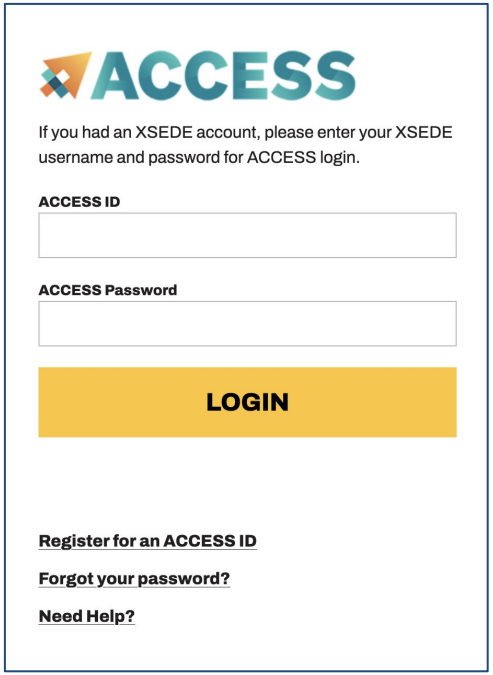
ACES Portal portal-aces.hprc.tamu.edu
is the web-based user interface for the ACES cluster.

Open OnDemand (OOD) is an advanced web-based graphical interface framework for HPC users.

Accessing ACES via the Portal (ACCESS)



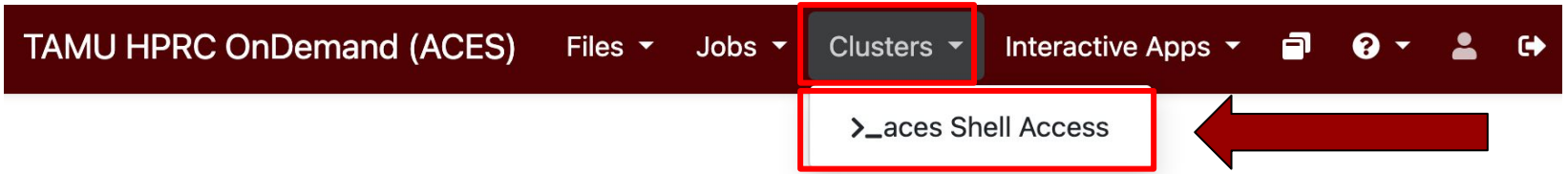
Select the Identity Provider appropriate for your account.



Log in using your ACCESS or institutional credentials.

Get a Shell on ACES

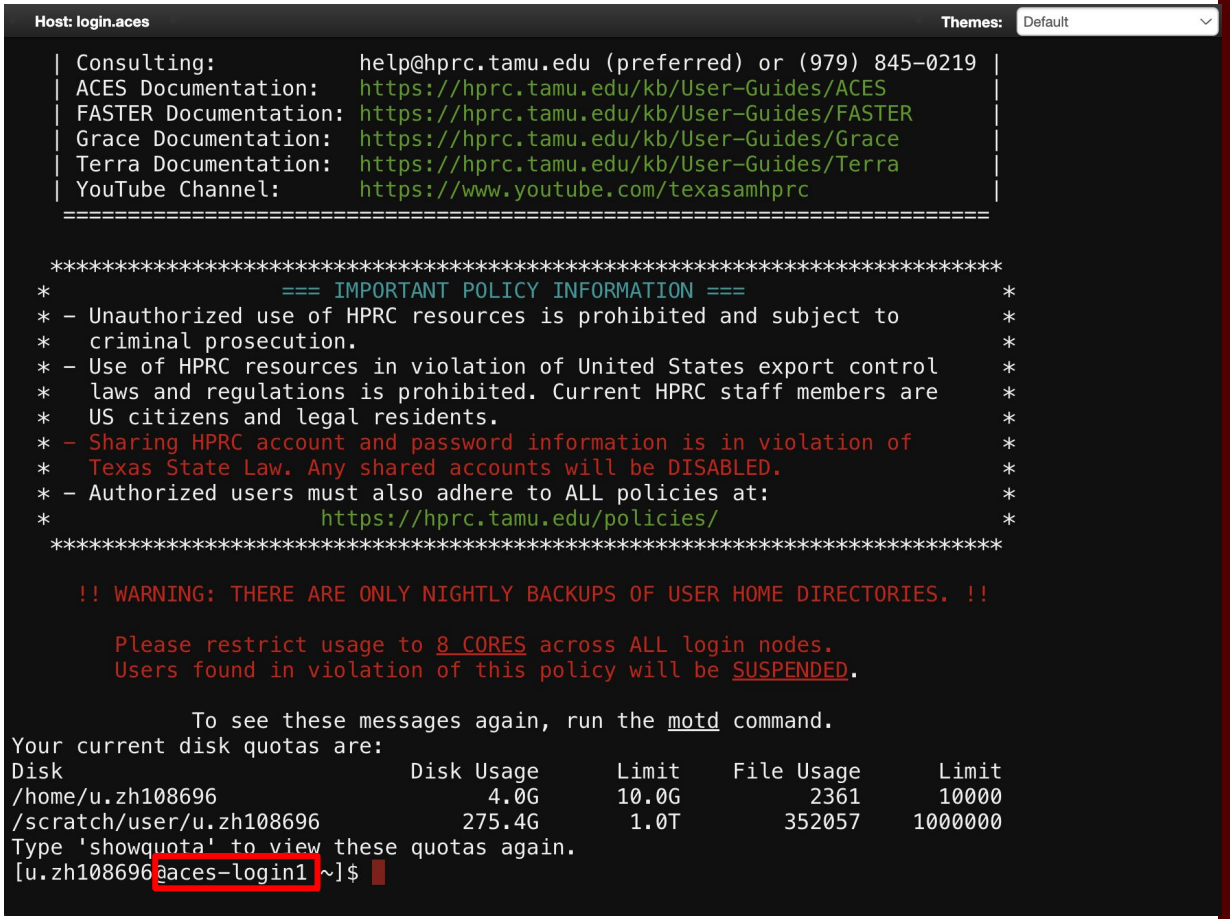
Click on “Clusters” menu → _aces Shell Access



Success!

Welcome to the ACES login node.

Check which login node you are on.



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
  ```

(Option 1) Environment Setup: ModuLair

- The ModuLair Framework is designed to streamline the management of Python environments on HPC clusters.

  Core Functionalities:

  - ➢ Creating Environments (`create_venv`)
  - ➢ Activating Environments (`activate_venv`)
  - ➢ Listing Environments (`list_envs`)
  - ➢ Deleting Environments (`delete_venv`)

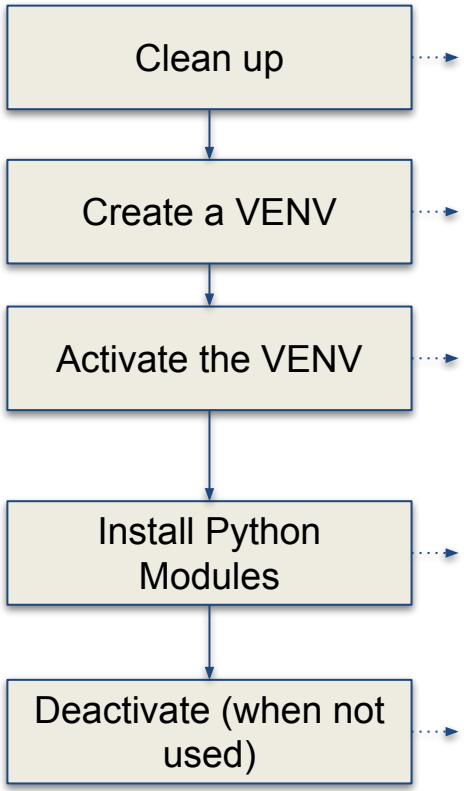
hprc.tamu.edu/kb/Software/ModuLair

Advantages of ModuLair

- ModuLair builds virtual environments in $SCRATCH (at $SCRATCH/virtual_envs) instead of using $HOME to avoid filling your home directory space quickly.

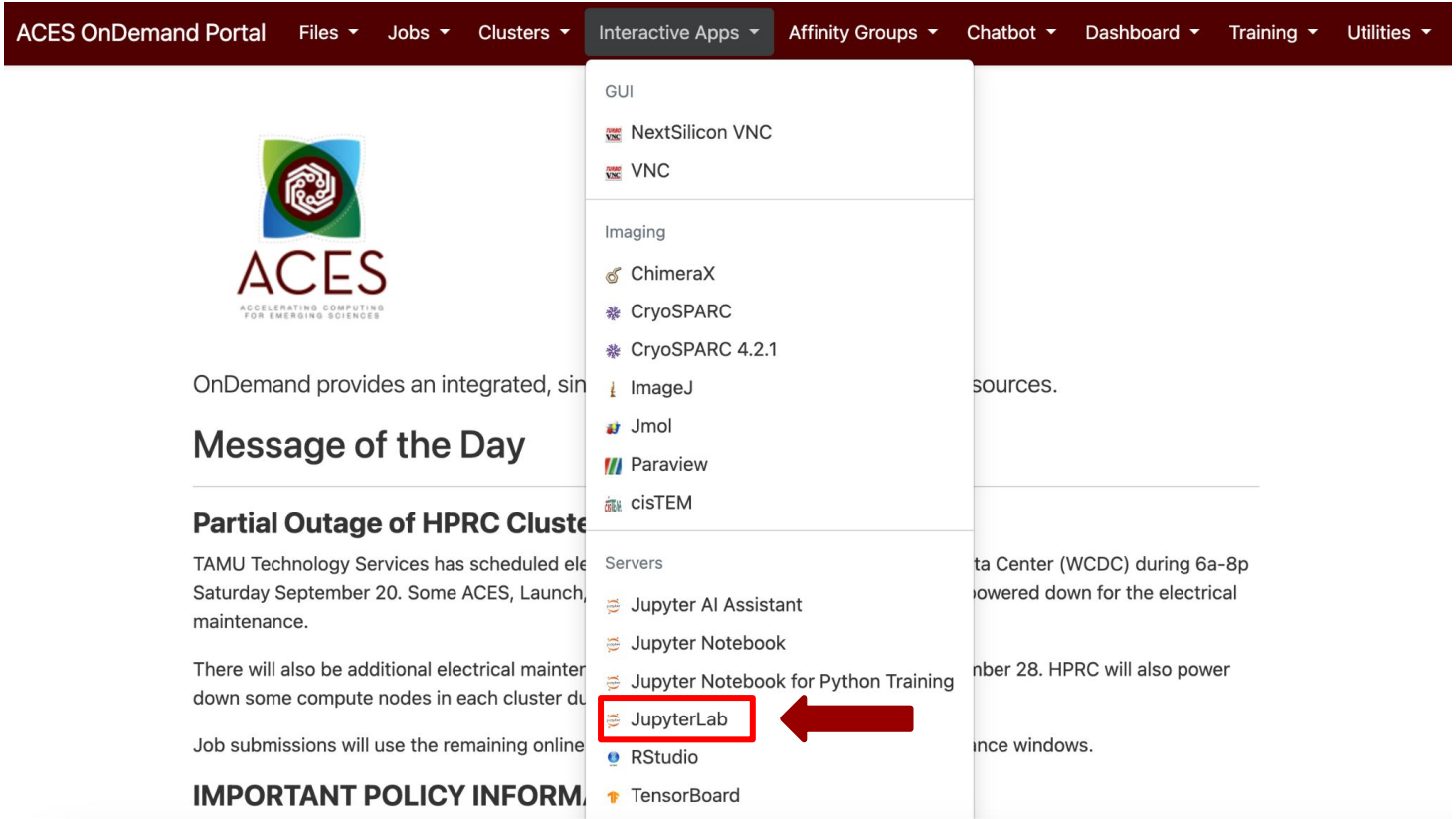
- ModuLair automatically records the toolchain and Python modules used to create each environment, so you don’t need to keep track of them yourself.

ModuLair

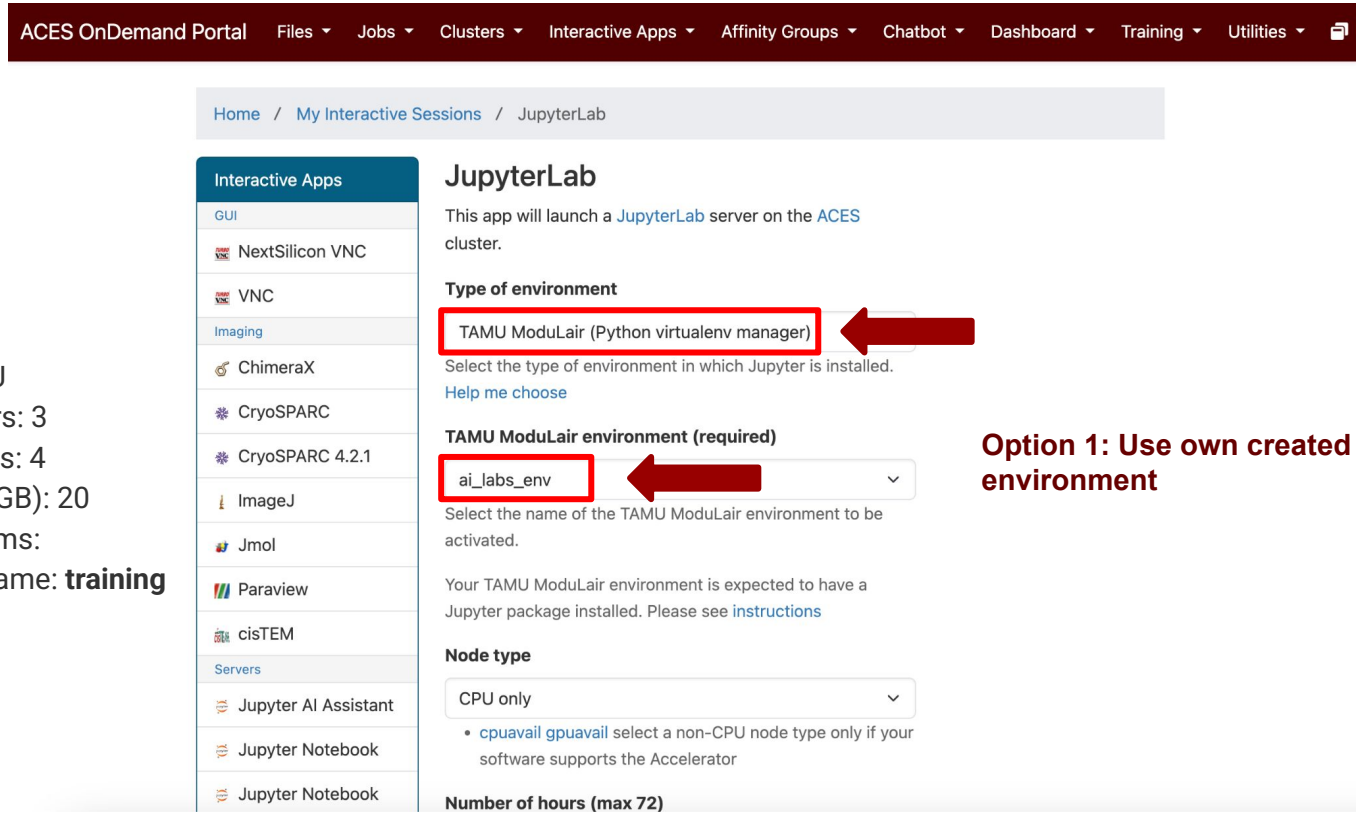



```
# clean up
cd $SCRATCH
module purge

# create a ModuLair virtual environment
create_venv ai_labs_env -d "Environment for \
AI TechLab" -t "GCCcore/12.2.0 Python/3.10.8"

# activate the virtual environment
source activate_venv ai_labs_env

# install required packages
pip3 install jupyter
pip3 install pandas matplotlib
pip3 install scikit-learn
pip3 install torch torchvision \
  --index-url https://download.pytorch.org/whl/cu126
pip3 install transformers

# deactivate the virtual environment
# deactivate
```

Go to JupyterLab Page



JupyterLab Page

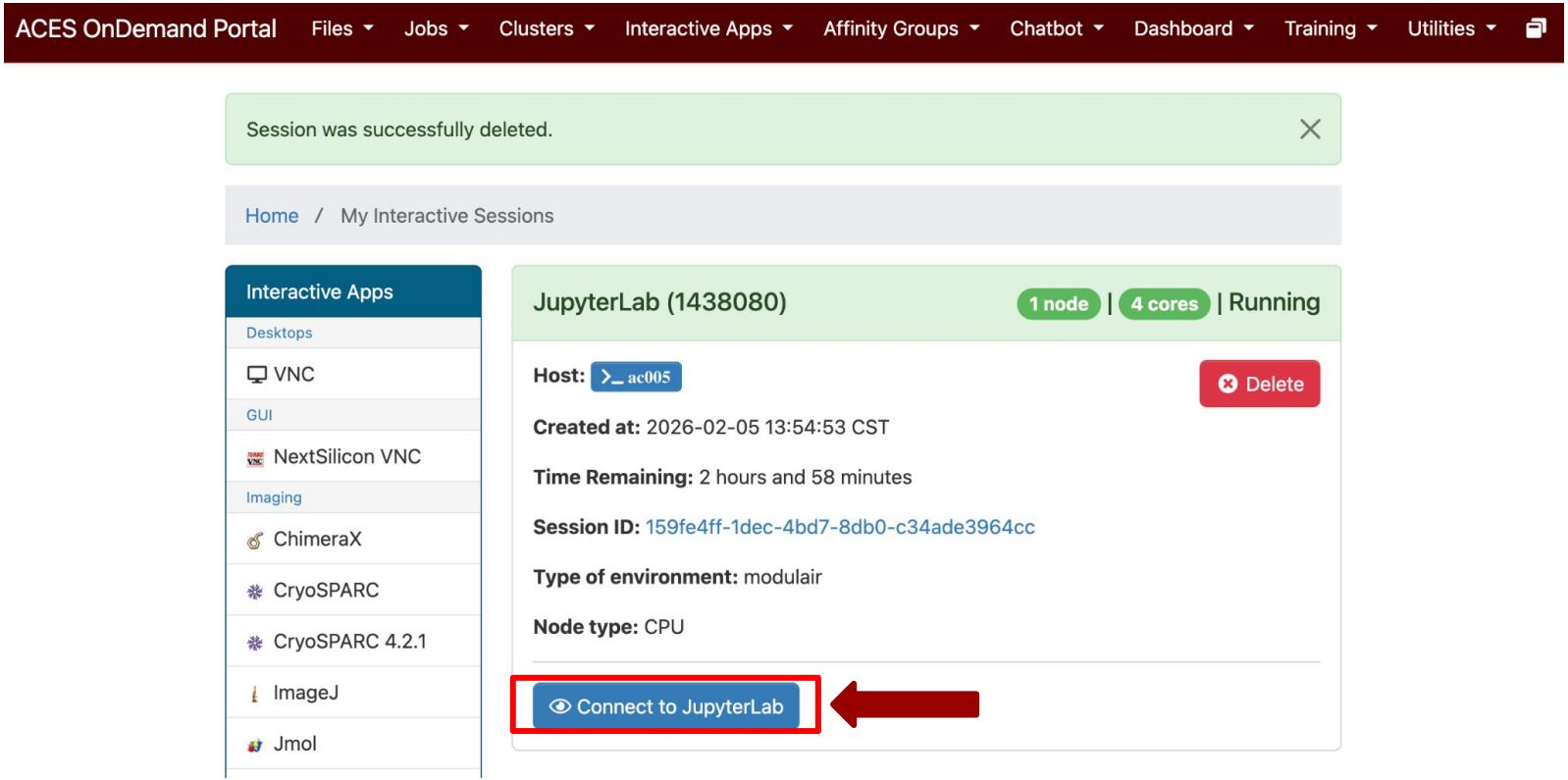


Other fields:

- Node Type: CPU
- Number of hours: 3
- Number of cores: 4
- Total memory (GB): 20
- Advanced Params:
  Reservation Name: **training**

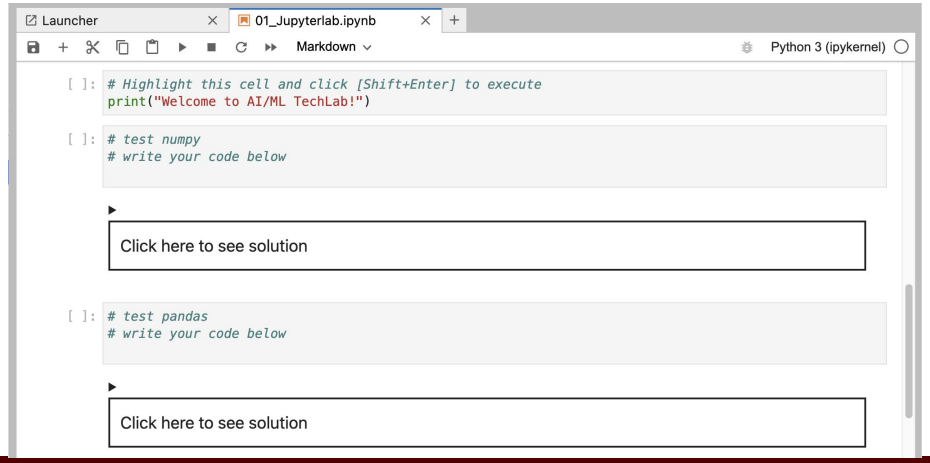
Option 1: Use own created ModuLair environment

Connect to JupyterLab



Review and Exercise

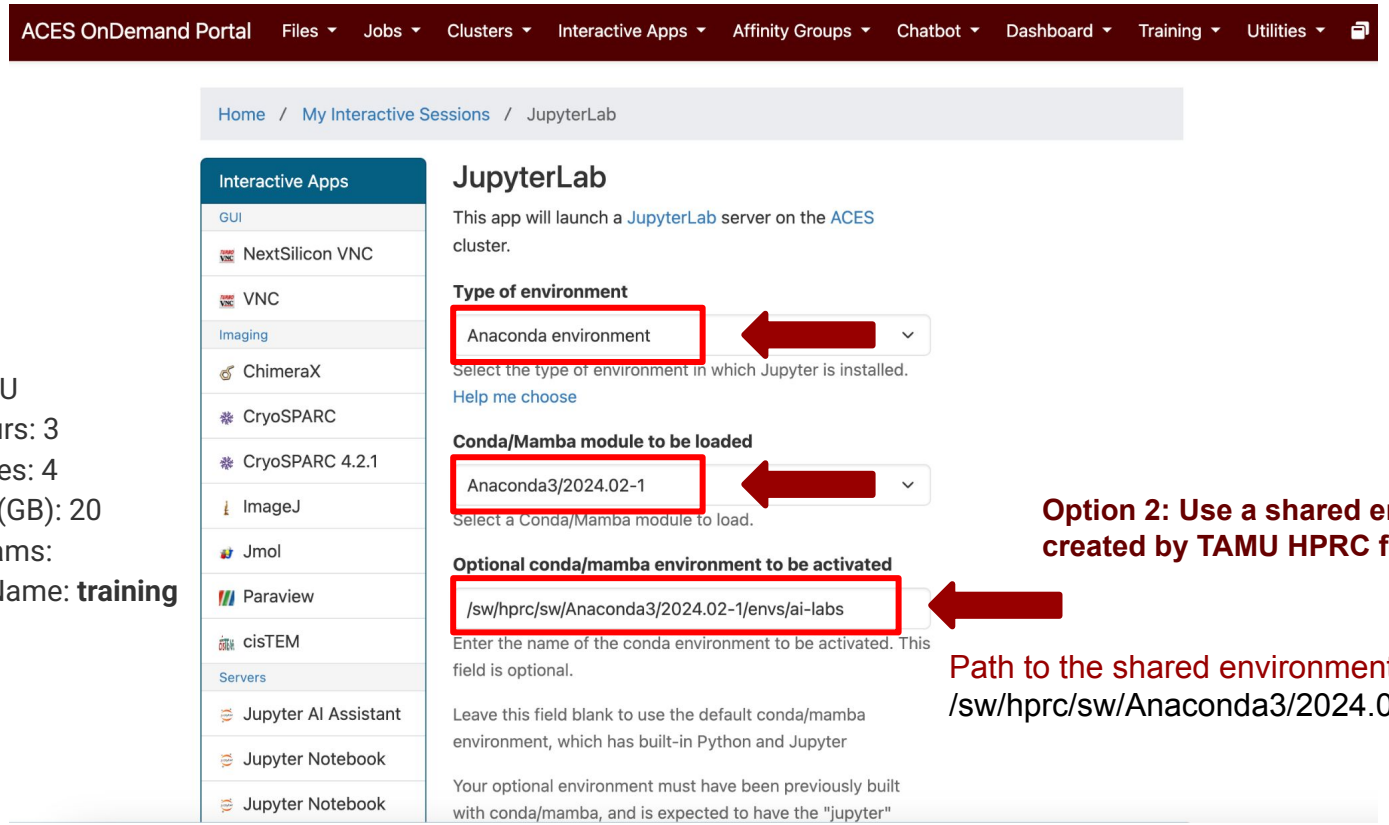
- Log into ACES through ACES Portal (ACCESS)
- Copy the training materials to your $SCRATCH directory
- Launch JupyterLab app
- In the notebook named *01_Jupyterlab.ipynb*, follow the instructions to import the required modules to make sure they have been loaded properly.



(Option 2) Shared Anaconda Env.

Other fields:

- Node Type: CPU
- Number of hours: 3
- Number of cores: 4
- Total memory (GB): 20
- Advanced Params:
  Reservation Name: **training**



Option 2: Use a shared environment created by TAMU HPRC for this course

Path to the shared environment:
/sw/hprc/sw/Anaconda3/2024.02-1/envs/ai-labs

Lab II. Data Exploration

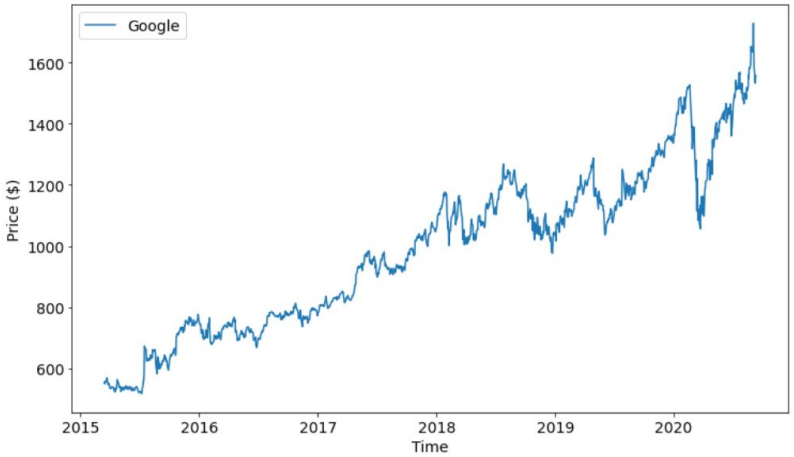
Data Structures

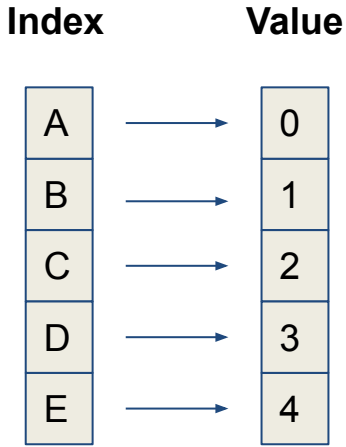
Pandas has two data structures that are descriptive and optimized for data with different dimensions.

- **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

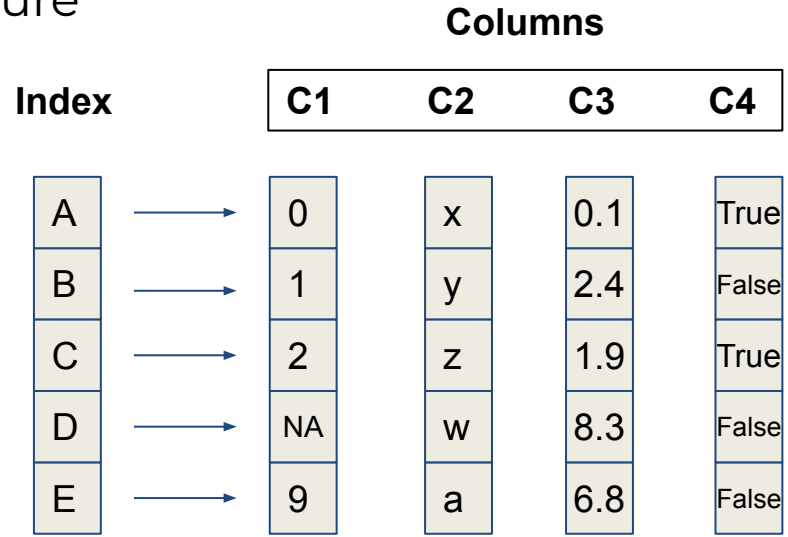




DataFrame in pandas

- 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



Pandas Learning Objectives

After this lesson, you will know how to:

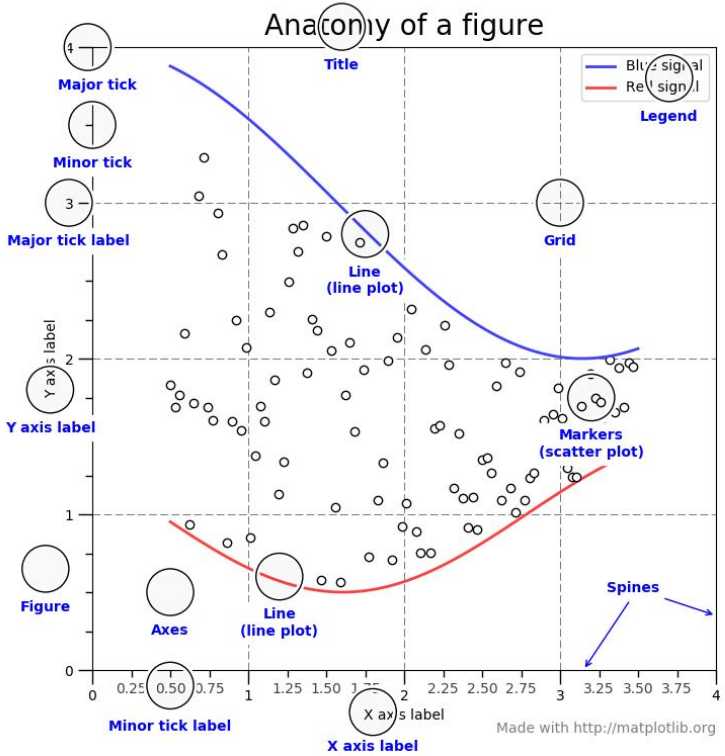
- Create a DataFrame
- Retrieve a Row or Column
- Drop Entries
- Index, Select, and Filter data
- Sort data
- Input and Output

JupyterLab Exercises

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)

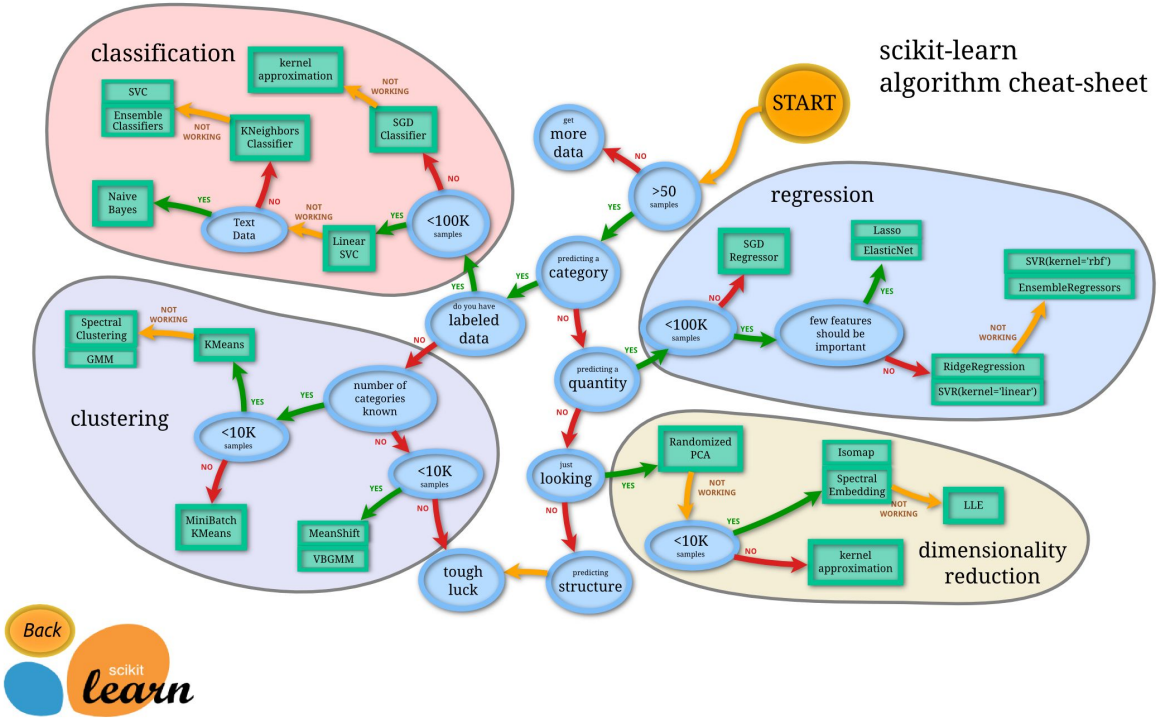
Matplotlib Learning Objectives

After this lesson, you will know how to create:

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

JupyterLab Exercises

Lab III. Machine Learning

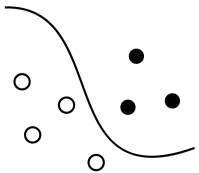


Main Features of scikit-learn

Classification

Identifying category of an object

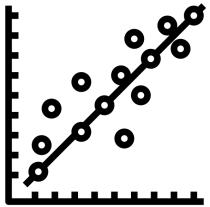
Applications: Spam detection, image recognition.
Algorithms: SVM, nearest neighbors, random forest, and more...



Regression

Predicting a attribute for an object

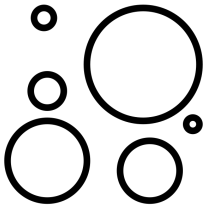
Applications: Drug response, Stock prices.
Algorithms: SVR, nearest neighbors, random forest, and more...



Clustering

Grouping similar objects into sets

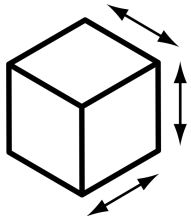
Applications: Customer segmentation, Grouping experiment outcomes
Algorithms: k-Means, spectral clustering, mean-shift, and more...



Dimension Reduction

Reducing the number of dimensions

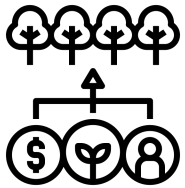
Applications: Visualization, Increased efficiency **Algorithms:** k-Means, feature selection, non-negative matrix factorization, and more...



Model Selection

Selecting models with parameter search

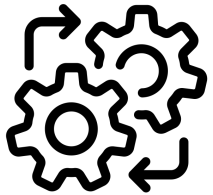
Applications: Improved accuracy via parameter tuning **Algorithms:** grid search, cross validation, metrics, and more...



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...



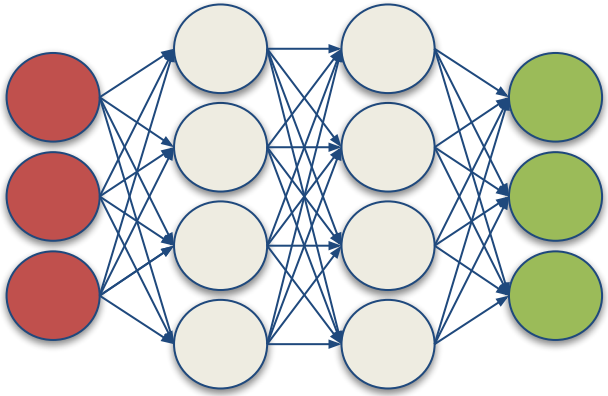
JupyterLab Exercises

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/

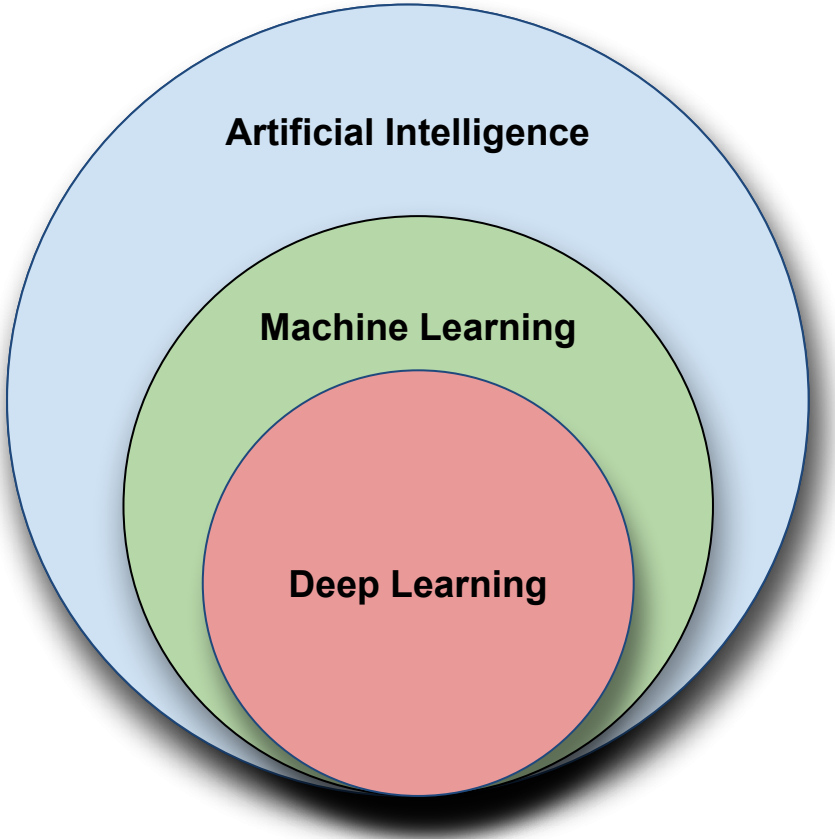
Visualization of CNN
by Adam Harley
https://adamharley.com/nn_vis/cnn/3d.html



TensorFlow PyTorch

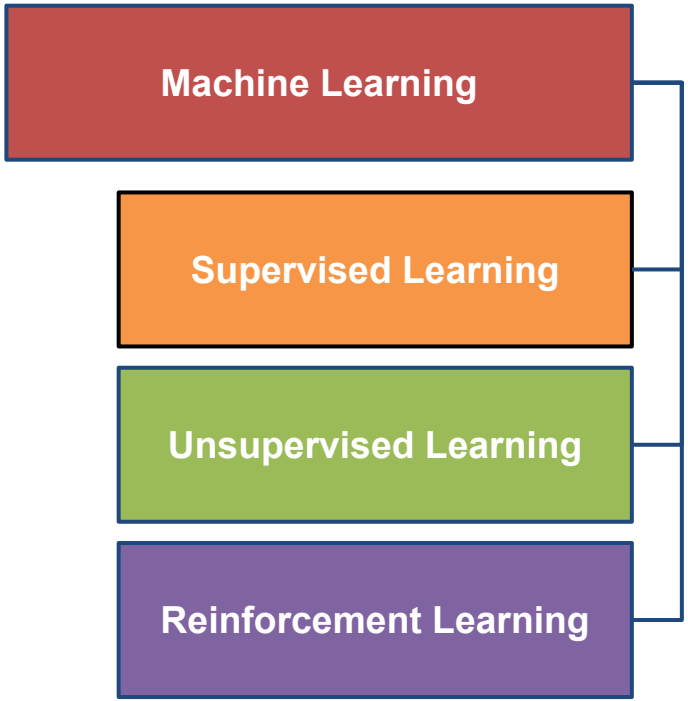
Introduction to AI/ML/DL

- **AI (Artificial Intelligence)**: Machines simulating human intelligence
- **ML (Machine Learning)**: A method to enable AI through data learning
- **DL (Deep Learning)**: A type of ML using layered neural networks

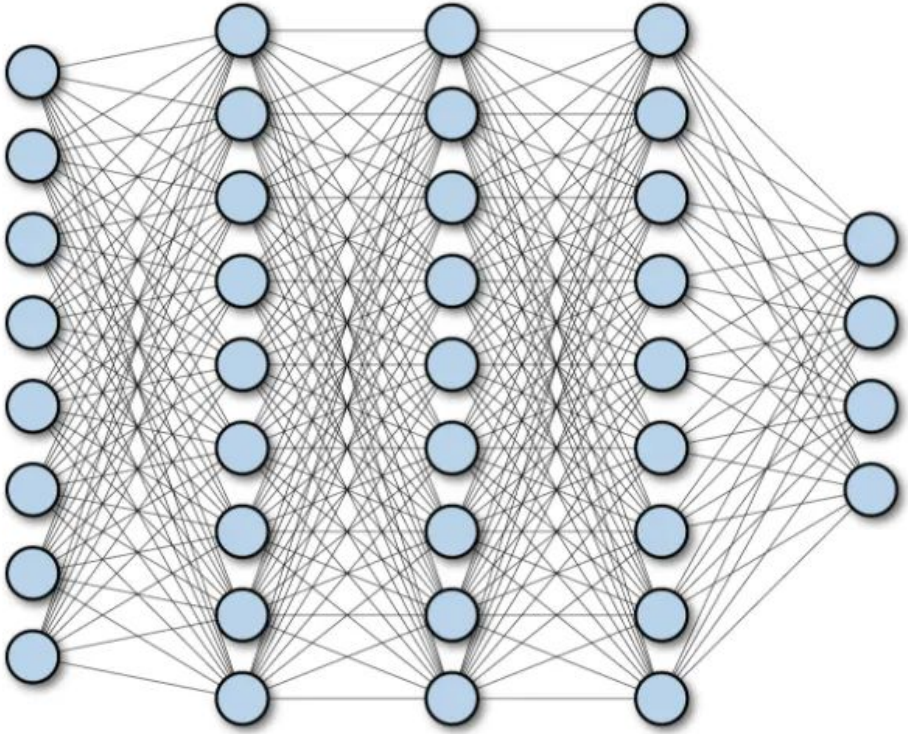


Types of ML Algorithms

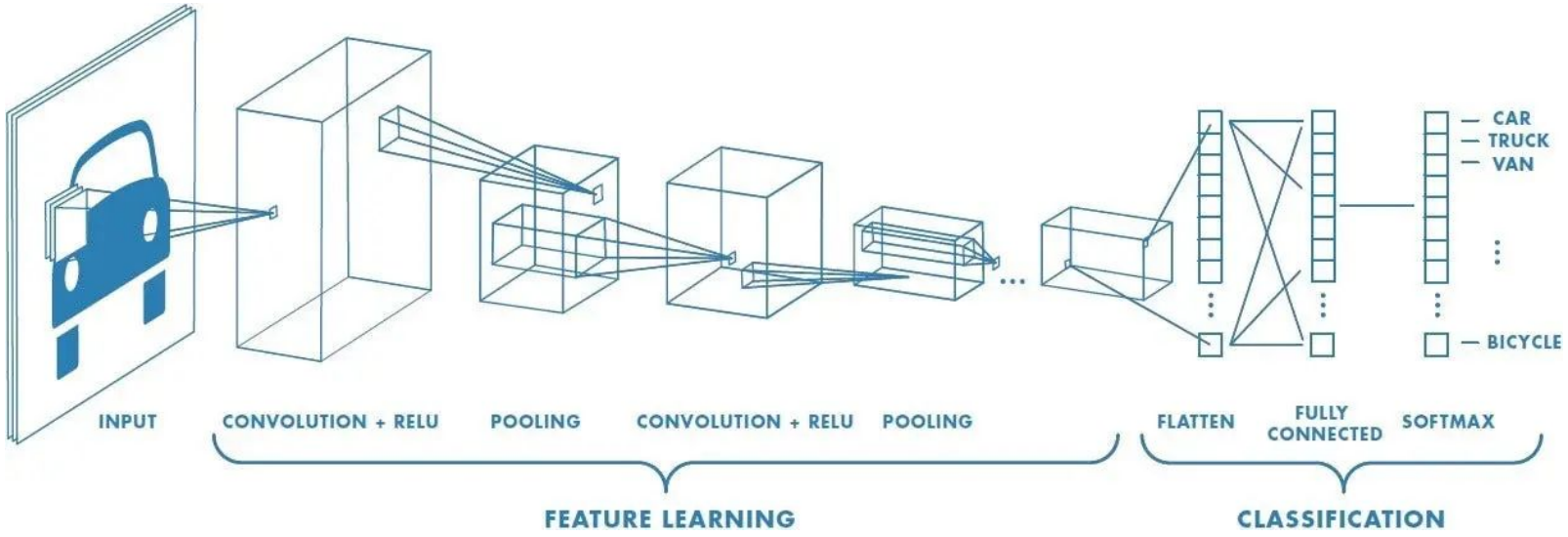
- **Supervised Learning**
  - trained with labeled data; including regression and classification problems
- **Unsupervised Learning**
  - trained with unlabeled data; clustering and association rule learning problems.
- **Reinforcement Learning**
  - no training data; stochastic Markov decision process;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



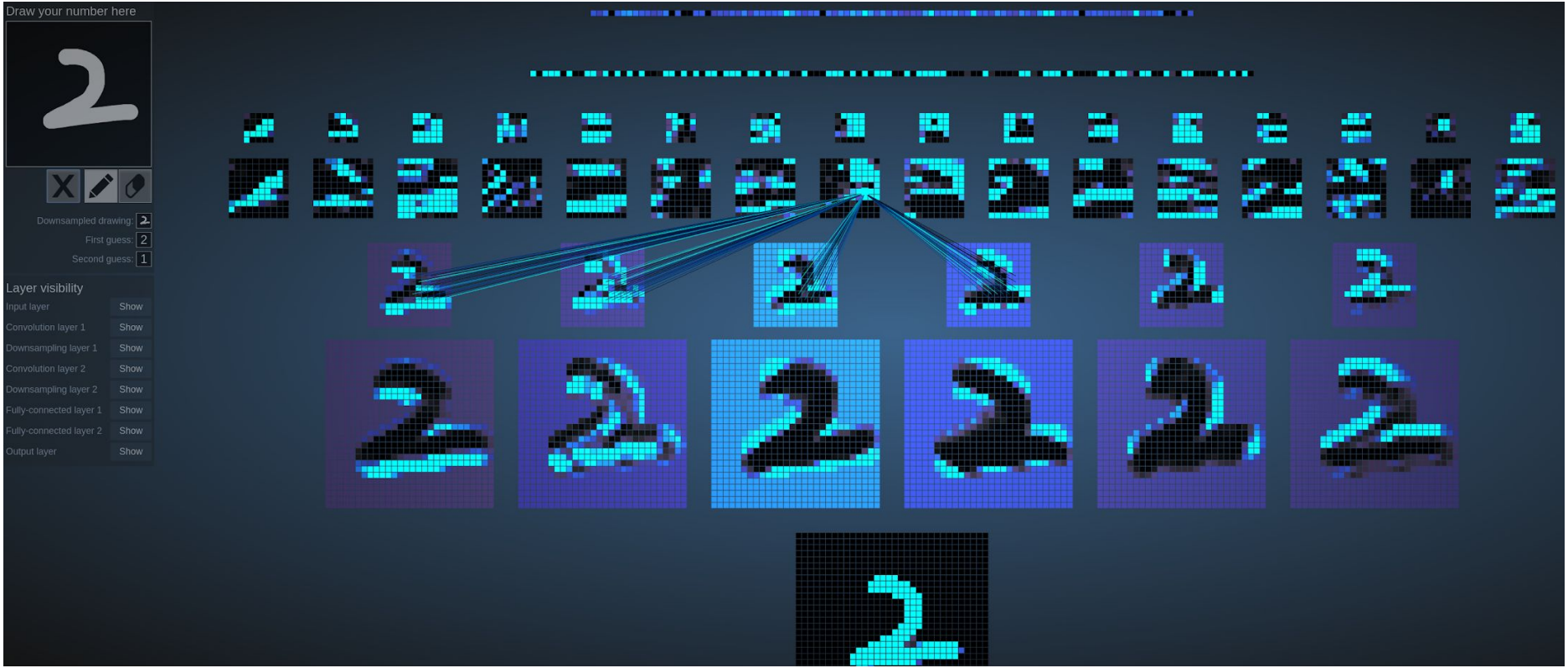
Fully Connected Neural Network



Convolutional Neural Network (CNN)



MNIST - Convolutional Neural Network Visualization

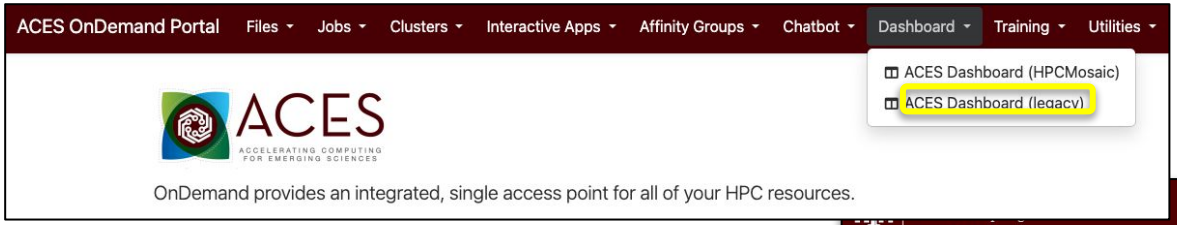


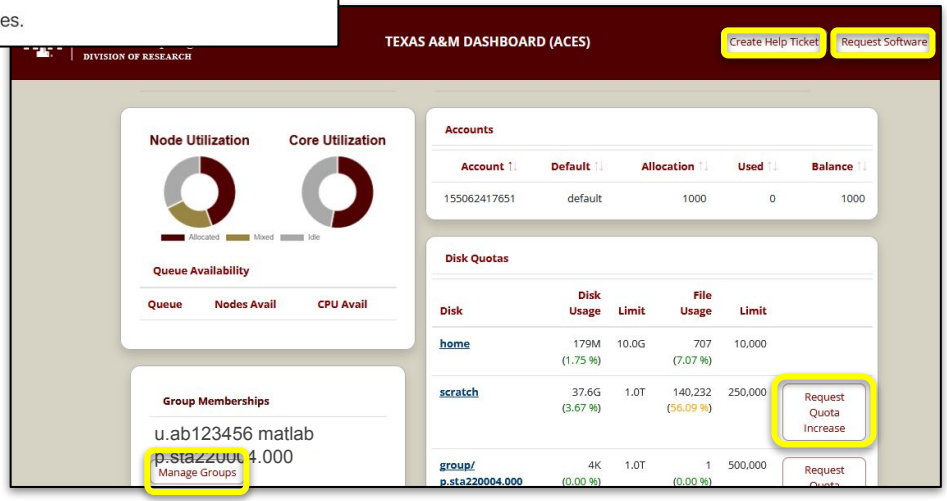
(Image Credit: https://adamharley.com/nn_vis/cnn/3d.html)

Need Help?

First check the FAQ: https://hprc.tamu.edu/kb/FAQ/Accounts

- ACES user Guide: https://hprc.tamu.edu/kb/User-Guides/ACES
- Email your questions to help@hprc.tamu.edu





Need Help?

Help us help you -- tell us:

- Which cluster
- Username
- Job id(s) if any
- Location of your jobfile, input/output files
- Application used if any
- Module(s) loaded if any
- Error messages
- Steps you have taken, so we can reproduce the problem

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https://u.tamu.edu/hprc_shortcourse_survey

Help us help you. Please include details in your request for support, such as, Cluster (ACES, FASTER, Grace, Launch), NetID (UserID), Job information (JobID(s), Location of your jobfile, input/output files, Application, Module(s) loaded, Error messages, etc), and Steps you have taken, so we can reproduce the problem.