Tools For Machine Learning
An overview

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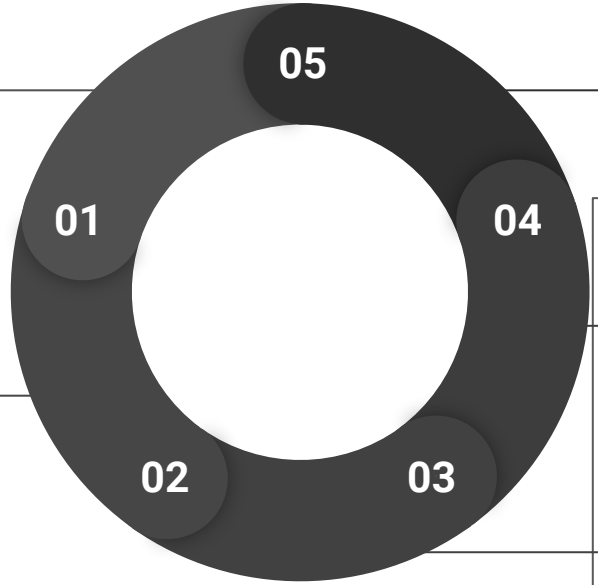
ECE 208/408

Typical Machine Learning System Life Cycle

Problem Definition

Data Collection, Annotation And Preprocessing
Human labor
Web crawler
Annotation tools
Large language models



Document/ Maintain/ Monitoring
Business metrics
Issue tracking
Document creation

Model Deployment Serving
Model compiling
Model serving

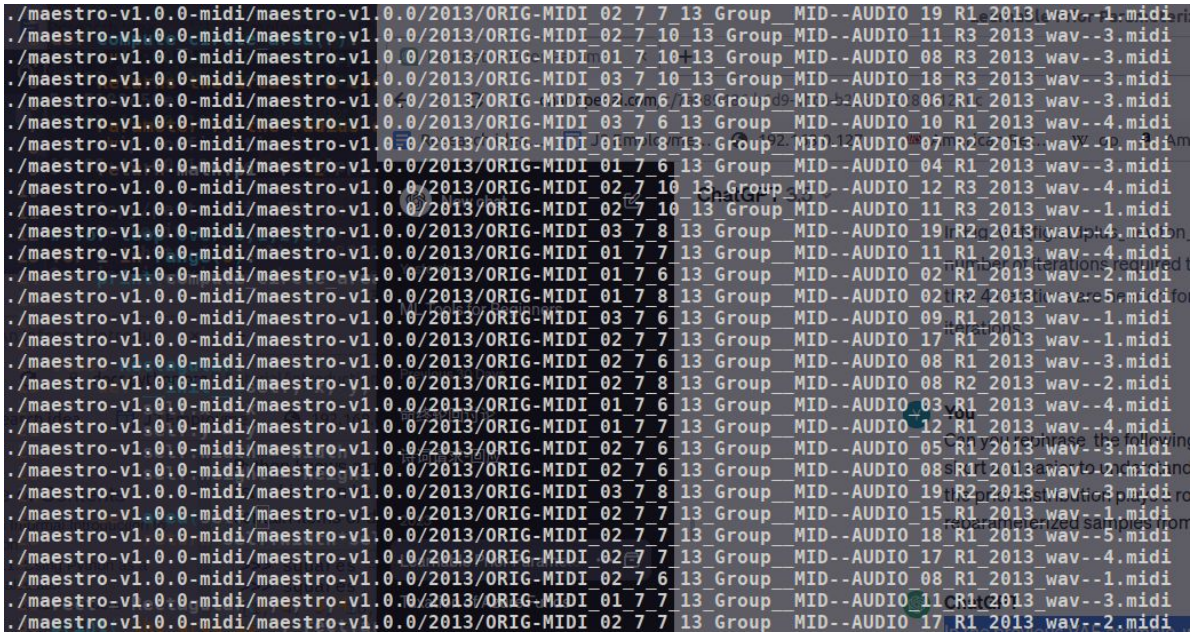
Model Development, Training, and Evaluation
Programming Language
Coding environment
Version control
Logging/Progress monitoring

Today's focus

Using the command line interface

- Instead of using Graphical interface, one often resort to command line interfaces when needed
  - Operating systems provide a set of tools that is more powerful than GUI tools
  - For development, CLI interfaces are easier to be programmed and maintained
- Shell language: POSIX compatible systems (Linux, MacOS, Linux, etc) include their own implementation of shell languages that are similar
- Cheat sheet: https://github.com/RehanSaeed/Bash-Cheat-Sheet
- Basic usage: command argument1 argument2 …..
  - find . -type f
- Pipeline: command1 | command2 | command3…
  - pgrep -f "train.py" | xargs kill

```
find . -type f
```



Find all pids for process matches keyword “train.py” and then kill them all:

pgrep -f "train.py" | xargs kill

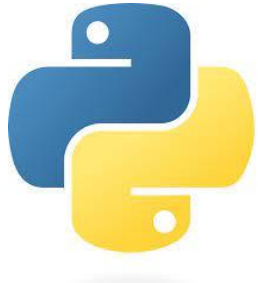
(?) How about

Find . -type f –name ‘*.py’ | xargs rm

(Don’t try if you do not understand)

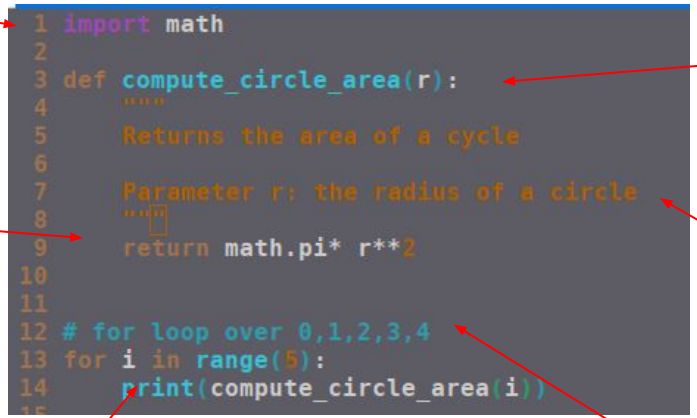
Intro to Python

Python programming language



- The current dominant programming language for machine learning
- Dynamically typed and garbage collected
- Advantage:
  - Usually used as a **glue language** for calling various libraries written in more “low level” language, e.g., C++.
  - Flexible and suitable for fast experimenting
  - Large community base
  - Easy to install and manage packages via the built-in package manager, i.e., PIP
- Disadvantages
  - Slow performance
  - Currently, threads can not be executed on multiple cores in parallel: still more than 5 years to go to remove the global interpreter lock (GIL).
  - Weak and optional typing system makes it prone to bugs easily avoidable by languages like C++.
- The official tutorial: https://docs.python.org/3/tutorial/index.html

Basic Python Code Structure

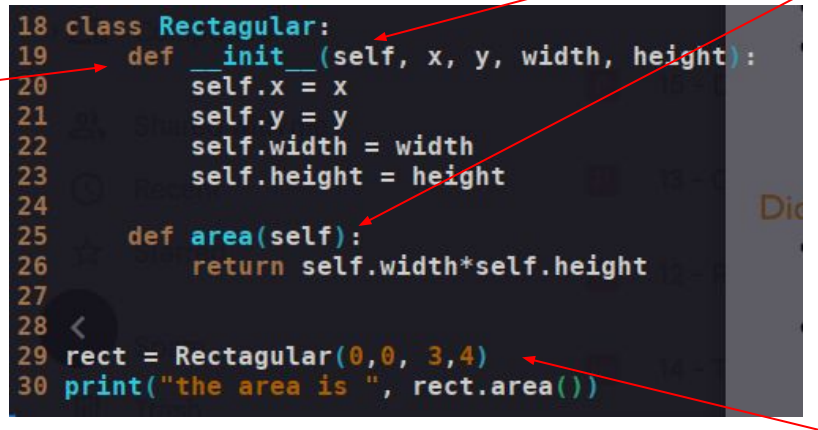



```
1  import math
2
3  def compute_circle_area(r):
4      """
5      Returns the area of a cycle
6
7      Parameter r: the radius of a circle
8      """
9      return math.pi* r**2
10
11
12 # for loop over 0,1,2,3,4
13 for i in range(5):
14     print(compute_circle_area(i))
```

Basic Python Code Structure: Classes

Constructor

Names like "__init__" are special names provided by python.



Reference to the invoking instance of the class

'__init__' called

Python Control flows: if

```
>>> x = int(input("Please enter an integer: "))
Please enter an integer: 42
>>> if x < 0:
...     x = 0
...     print('Negative changed to zero')
... elif x == 0:
...     print('Zero')
... elif x == 1:
...     print('Single')
... else:
...     print('More')
...
More
```

https://docs.python.org/3.10/tutorial/controlflow.html

Python Control flows: for loop

```
>>> # Measure some strings:
... words = ['cat', 'window', 'defenestrate']
>>> for w in words:
...     print(w, len(w))
...
cat 3
window 6
defenestrate 12
```

https://docs.python.org/3.10/tutorial/controlflow.html

Python Control flows: while loop

```
>>> # Fibonacci series:
... # the sum of two elements defines the next
... a, b = 0, 1
>>> while a < 10:
...     print(a)
...     a, b = b, a+b
...
0
1
1
2
3
5
8
```

https://docs.python.org/3.10/tutorial/introduction.html#first-steps-towards-programming

Python: built-in types

- Basic types: bool (True, False), int (0,1,2), float (3.5,4.6), complex (5+4j), string("hi")
- List: l = [1,2,3,4,5]:
  - len(l) # 5
  - l[2]
  - l.append(7)
  - l[:2]+ l[-2:] # [1,2,4,5]
- Set: s = ['apple', 'pear', 'orange']
  - len(s) # 3
  - 'apple' in s # True
  - s.add('grape')
- Dict: d=['apple': 1, 'pear': 2, 'orange': 3]
  - d['pear'] # 2
  - d['grape'] = 7 # ['apple': 1, 'pear': 2, 'orange': 3, 'grape':7]
- Other types: https://docs.python.org/3/library/stdtypes.html

Python: typing hint

Type annotations can be added **to enable static type checker**, (more types are in package *typing*).

```
type Vector = list[float]

def scale(scalar: float, vector: Vector) -> Vector:
    return [scalar * num for num in vector]

# passes type checking; a list of floats qualifies as a Vector.
new_vector = scale(2.0, [1.0, -4.2, 5.4])
```

No error when executed:

```
1 a: list[float] = []
2 a.append("hi")
```

But with a static checker, e.g. mypy:

```
yujia@CCat:~/Programming/Untitled Folder$ mypy  typeExample.py
typeExample.py:2: error: Argument 1 to "append" of "list" has incompatible type "str"; expe
ted "float"  [arg-type]
Found 1 error in 1 file (checked 1 source file)
```

Resources for learning python

- The official tutorial:
  - https://docs.python.org/3/tutorial/index.html
- W3C learning by examples:
  - https://www.w3schools.com/python/
- Coursera python courses
  - https://www.coursera.org/search?query=python&
- The Hitchhiler’s Guide to Python
  - https://docs.python-guide.org/
- Style Guide
  - PEP 8: https://peps.python.org/pep-0008/
  - GOOGLE: https://google.github.io/styleguide/pyguide.html

Development Environment

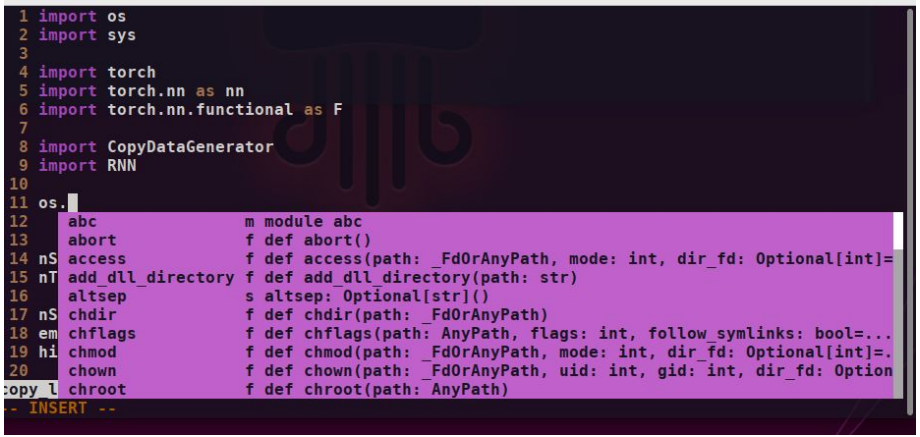
Package manager

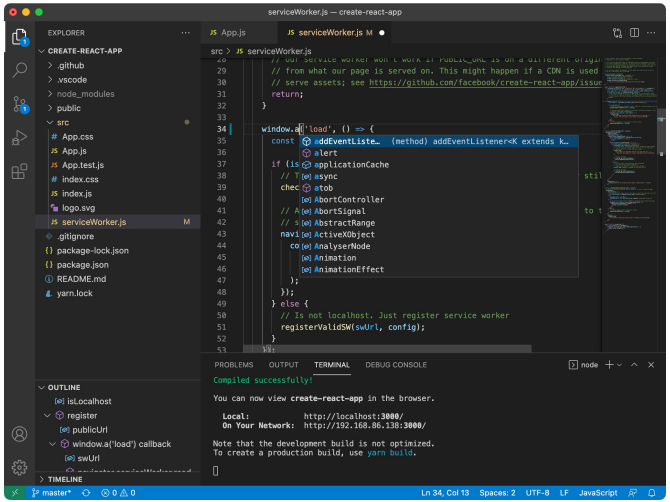
- Linux/OSX package managers
  - Depending on specific linux distributions: APT/DPKG (Debian, Ubuntu, Mint), YUM/RPM(Redhat/Fedora), Pacman(Arch), Zypper(openSUSE), Portage (Gentoo)
  - Homebrew(MacOS)
- PIP
  - Python package management tool
  - Packages can be built into *wheels* and published on https://pypi.org/ and then the package can be directly installed via
    - pip3 install PACKAGENAME
  - See https://packaging.python.org/en/latest/flow/ on how to package and distribute your python project.
- Anaconda
  - A proprietary package management tool that provides an easy-to-use integration of virtual environment and package management.
  - One can create several environment installed with different set of packages under different versions.
  - Not only for python packages
  - Can be used together with PIP in the conda virtual environment
  - Cheatsheet: https://docs.conda.io/projects/conda/en/4.6.0/_downloads/52a95608c49671267e40c689e0bc00ca/conda-cheatsheet.pdf

When you need to install something, first try to install via your package manager.

Development environments

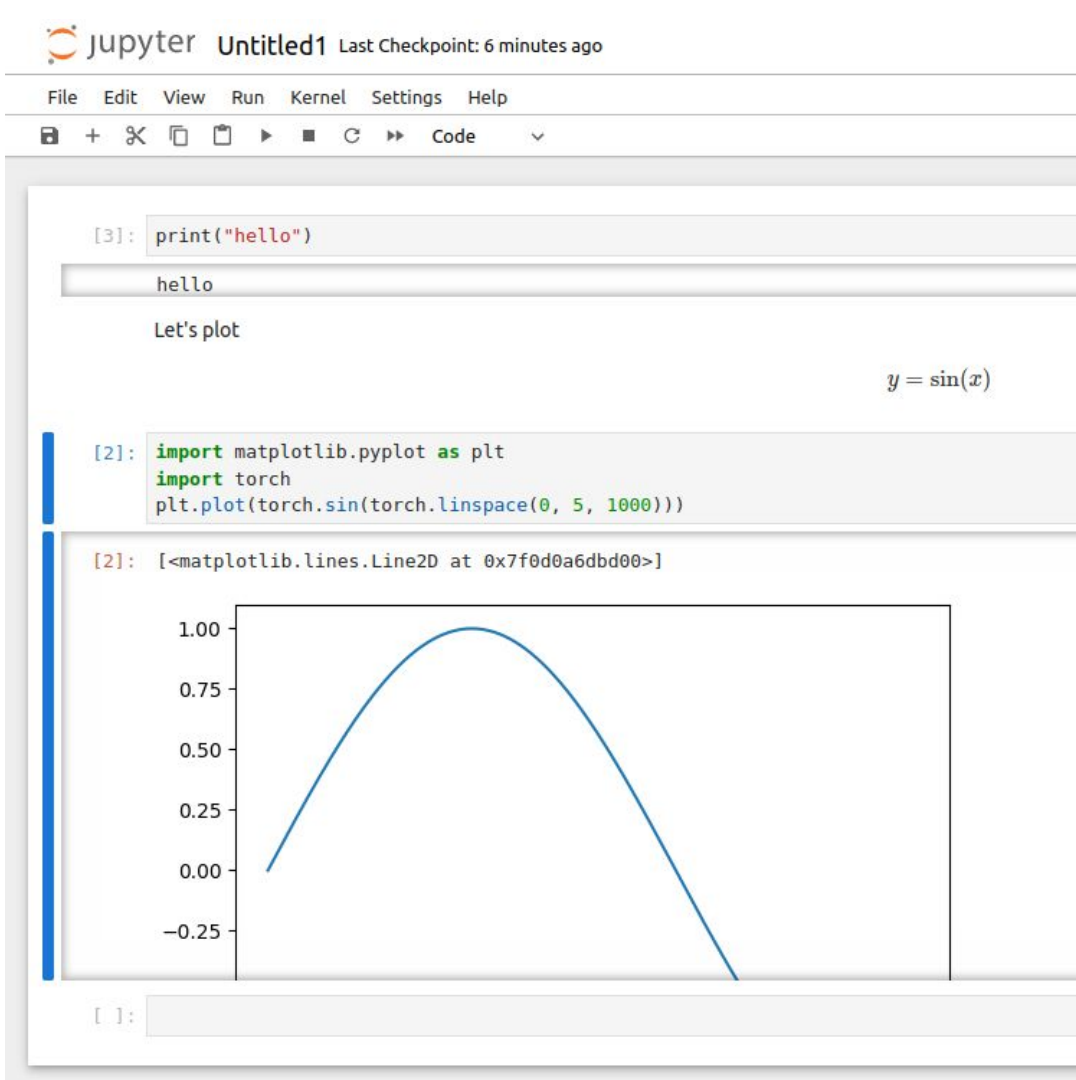
- VIM
  - Simple, fast and reliable
  - Available anywhere for linux based system
  - Powerful plugin system
  - High learning curve
- Visual studio code
  - Powerful plugin system
  - Integrated feature for performing development on a remote machine
  - Integrated version controlling





Jupyter Notebook

- Web based Interactive notebook
- Good for simple experiments and documenting stuffs that require some coding example/ outputs from running.
- Run locally or remote from a server
- Frequently seen in code repos as the format of examples

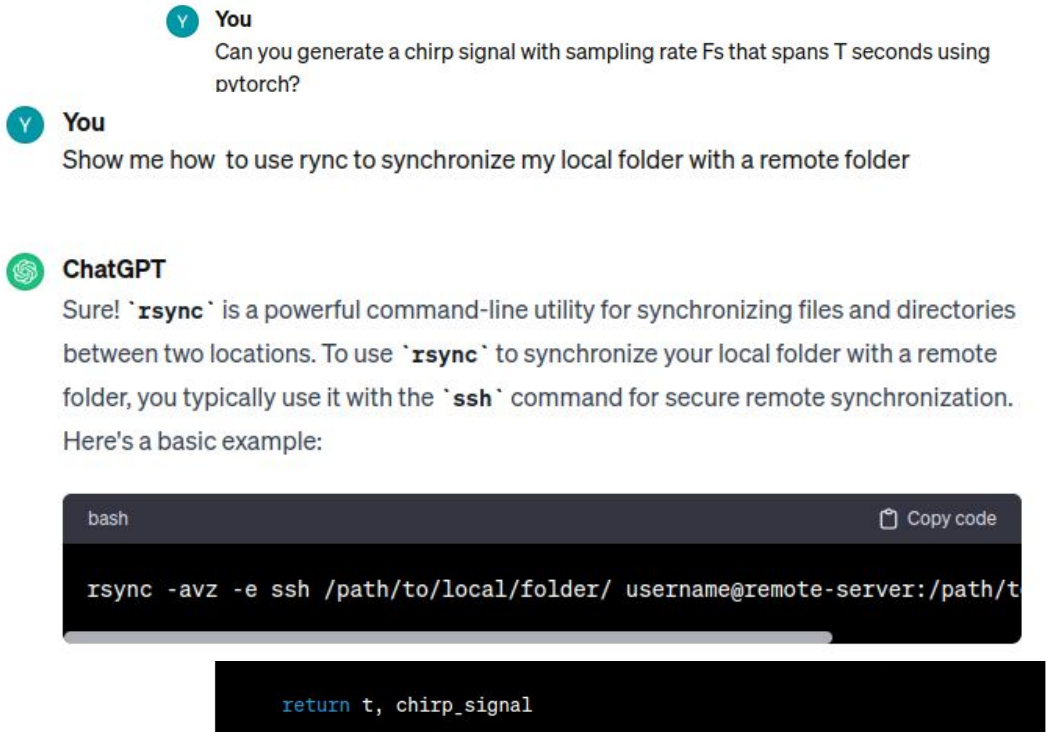


Version Control

- Keep track of changes of your codes
- A necessary for doing real programing
- A lot of options: **Git**/Mercurial/SVN
- Git: the most popular among individuals,
  - Good resource to learn
    - Tutorial videos: https://git-scm.com/videos
    - Visualized learning platform: https://learngitbranching.js.org/
  - Code hosting
    - github, bitbucket, gitlab, etc.

LLM based Tools

- E.g., ChatGPT/Copilot
- Example usage
  - Help with boring tasks
  - Generate Unit tests
  - Help write Commit Messages/ documents/Reports
- Use with caution
  - Fake information
  - Misunderstanding
  - Potential (?) plagiarism



Python Package and Frameworks

Scientific computing libraries

Numpy: numerical computation library

Scipy: scientific computing library built on numpy, which covers python counterparts to Matlab functionalities: integration, optimization, fft, signal processing etc.

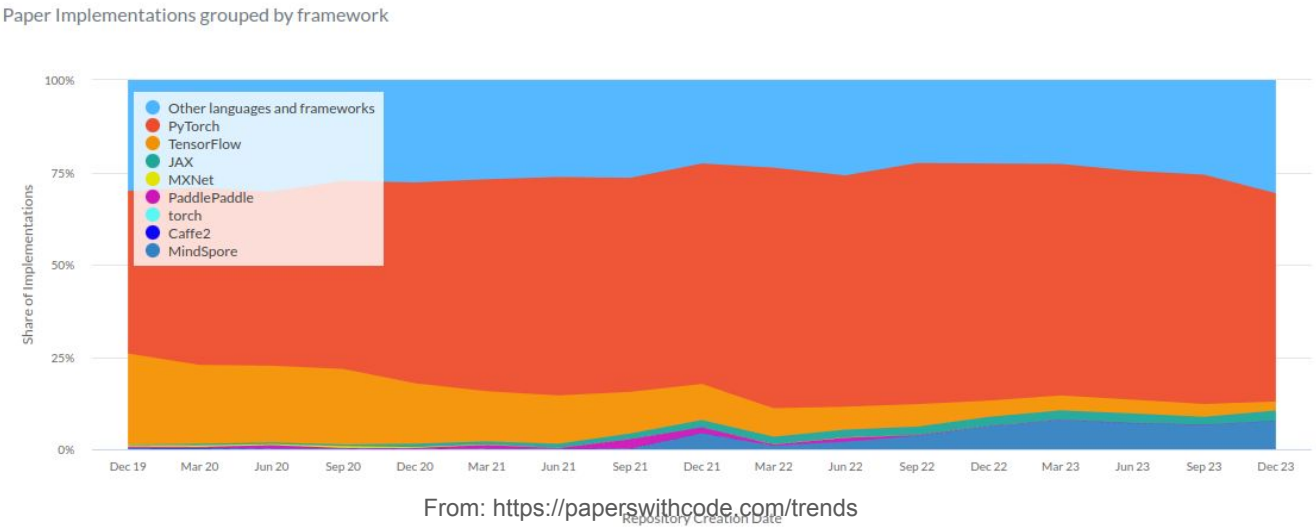
Scikit-learn: A (traditional) Machine learning library which allows you to perform non-deep-learning based regression, classification, etc.

Matplotlib/Seaborn: data visualization

You will get familiar with these tools throughout the progress of programming assignment

Deep learning frameworks

- What they are doing?
  - Numerical Algebra
  - automatic differentiation (aka. backpropagation)
  - Modules for implementing commonly used deep learning practices
- Current dominance in research: **Pytorch**



From: https://paperswithcode.com/trends

Popular Deep learning frameworks

- Pytorch (Meta/ Pytorch Foundation)
  - Dynamic Computational Graph
  - Largest amount of Machine Learning project code repos
  - Just-in-time compiler
  - TorchScript Language for higher performance and generic deployment
- JAX (Google)
  - Similar to Pytorch
  - Created by original authors of the opensource *Autograd* package for numpy, but this time it is sponsored and maintained by Google
  - Most advanced Automatic differentiation features (fast high-order derivatives, automatic vectorization based on function transforms)
  - Have better support on Google's TPU as a Google product
- Tensorflow (Google)
  - One of the early frameworks
  - Static computational graph: declare the whole computational process and then feed in the data
  - Current version supports both static and dynamic computational graph, e.g., GradientTape
  - Have better support on Google's TPU as a Google product
- MindSpore (Huawei)
  - More similar to tensorflow: support both static/dynamic computational graphs
  - Out of box training utilities, Automatic Parallelized Training

PyTorch

TensorFlow

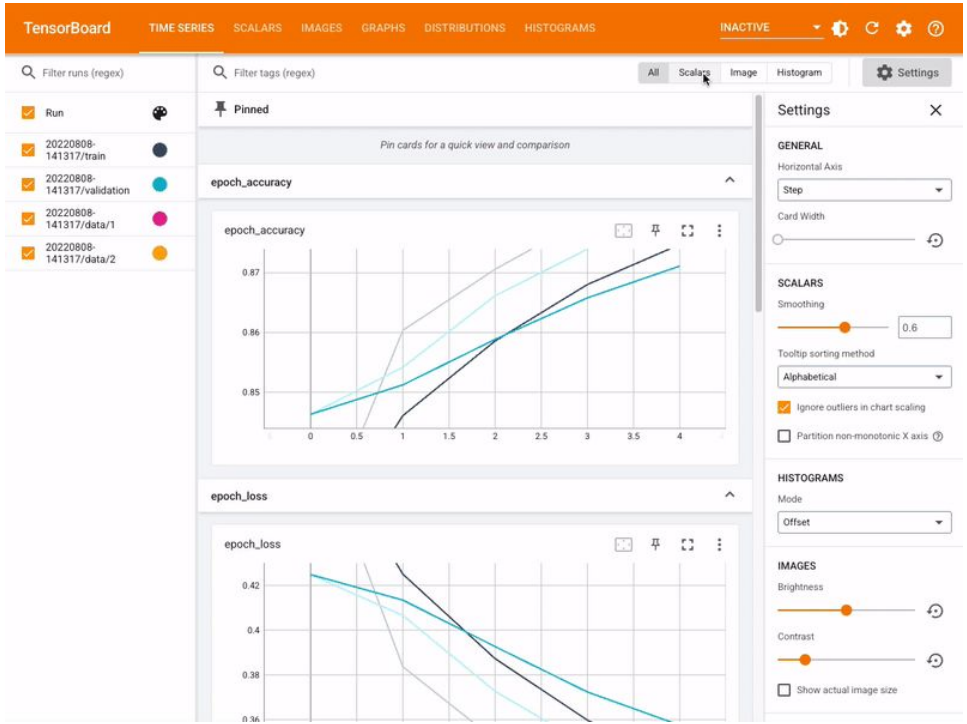
[M]S MindSpore

Higher level training frameworks for DL frameworks

- Deep learning frameworks typically require you to write the actual logics for training, which typically include:
  - data loading, model initialization/restoration, looping over the dataset, backpropagating and updating the model at certain point, parallelization, and logging some metrics during training.
- Instead of writing training logics from scratch, one can use some frameworks that directly provides certain abstractions:
  - **Pytorch Lightning for pytorch**
  - **Keras for tensorflow**

Training Logging

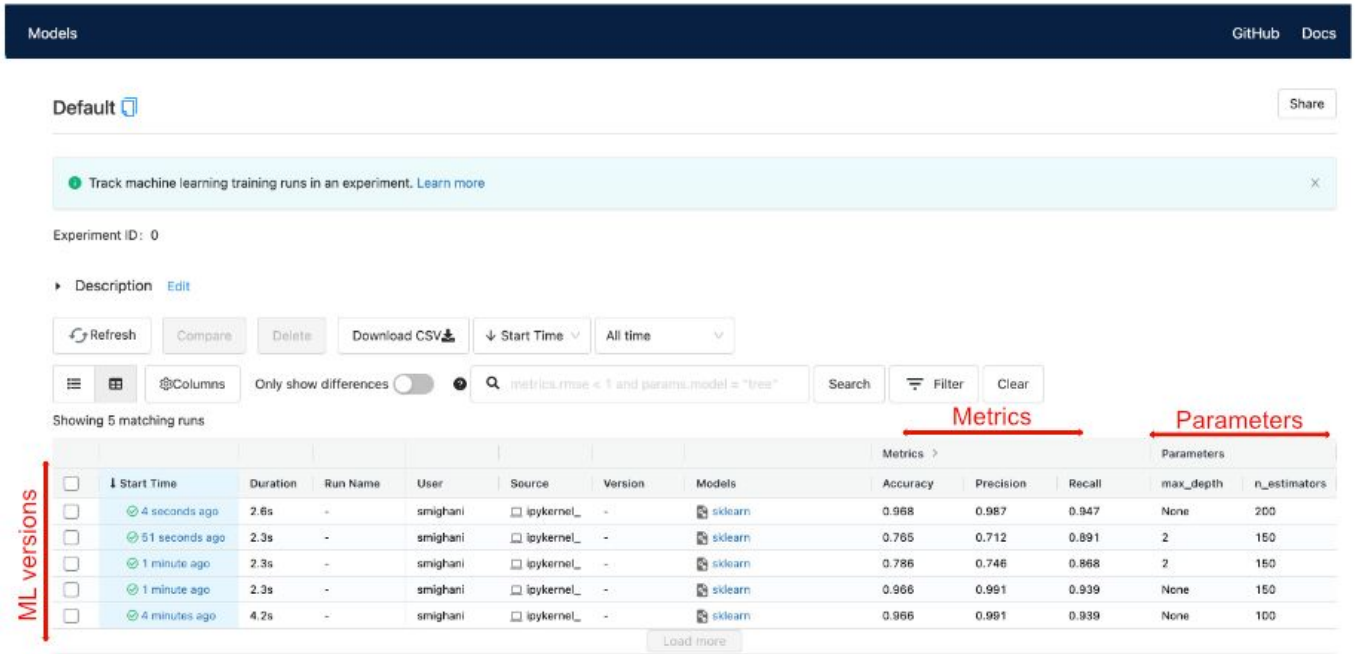
- Keep track of any metrics (loss, accuracy, etc.) during training
- E.g. Tensorboard



https://www.tensorflow.org/tensorboard

Model Versioning

- Keep track of your codes together with trained models
- E.g., MLFlow



https://towardsdatascience.com/mlflow-a-primer-6dfe6be48353

Model Deployment

- Generic Deployment: let your model run on different devices
  - **ONNX**: Open Neural Network Exchange
    - The open standard for representing the machine learning model
    - Can be exported from a variety of Deep learning frameworks
    - Generic tools for deployment, targeting e.g., mobile/DSP board/MicroController

Summary of supported Execution Providers

CPU	GPU	IoT/Edge/Mobile	Other
Default CPU	NVIDIA CUDA	Intel OpenVINO	Rockchip NPU (*preview*)
Intel DNNL	NVIDIA TensorRT	ARM Compute Library (*preview*)	Xilinx Vitis-AI (*preview*)
TVM (*preview*)	DirectML	Android Neural Networks API	Huawei CANN (*preview*)
Intel OpenVINO	AMD MIGraphX	ARM-NN (*preview*)	AZURE (*preview*)
XNNPACK	Intel OpenVINO	CoreML (*preview*)	
	AMD ROCm	TVM (*preview*)	
	TVM (*preview*)	Qualcomm QNN	
		XNNPACK	

Model deployment

- Model Serving: let you create API endpoints for calling your model from remote locations
  - TorchServe
  - TensorFlow serving
  - Huggingface
  - And others

```
curl http://127.0.0.1:8080/predictions/densenet161 -T kitten_small.jpg
```

Which will return the following JSON object


```
[
  {
    "tiger_cat": 0.46933549642562866
  },
  {
    "tabby": 0.4633878469467163
  },
  {
    "Egyptian_cat": 0.06456148624420166
  },
  {
    "lynx": 0.0012828214094042778
  },
  {
    "plastic_bag": 0.00023323034110944718
  }
]
```