Learning Tensorflow for Developing Machine Learning Models

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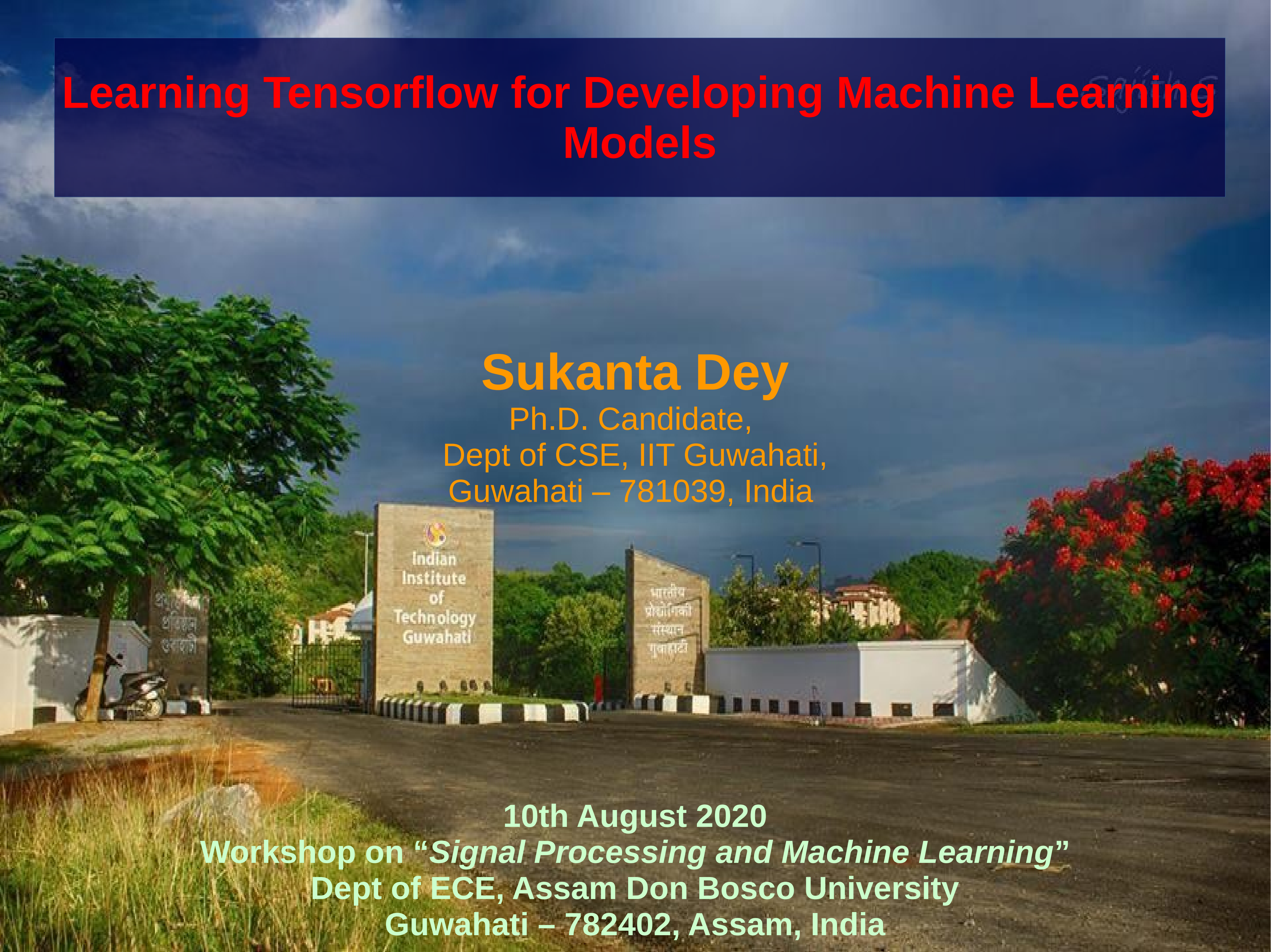
10th August 2020
Workshop on "*Signal Processing and Machine Learning*"
Dept of ECE, Assam Don Bosco University
Guwahati – 782402, Assam, India



About Me

- BE in ETC, AEC (2014)
- M.Tech-PhD in CSE, IIT Guwahati (2014 to Present)
- Research Interest: Machine Learning, VLSI CAD, Hardware Security.
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- Website: https://thesukantadey.github.io/

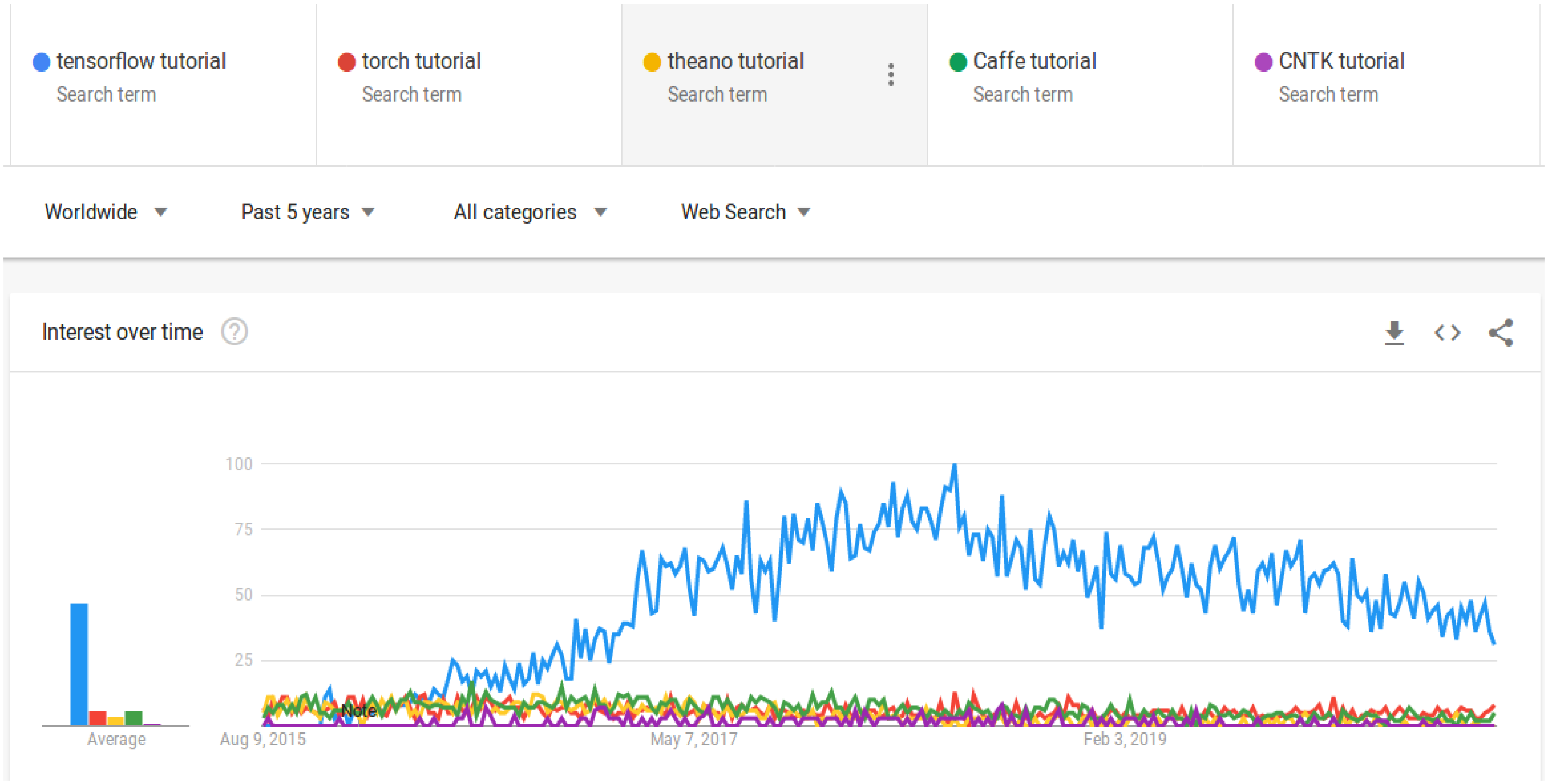
Overview

- Introduction to TensorFlow
- A basic ML classifier
- Hands-on Codes on Google Colab
- Summary

What’s TensorFlow^{TM}?

- Open source software library for numerical computation using data flow graphs
- Originally developed by Google Brain Team to conduct machine learning and deep neural networks research
- General enough to be applicable in a wide variety of other domains as well

Why TensorFlow^{TM}?



● tensorflow tutorial
Search term

● torch tutorial
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● theano tutorial
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● Caffe tutorial
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● CNTK tutorial
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Worldwide ▾ Past 5 years ▾ All categories ▾ Web Search ▾

Interest over time

What’s TensorFlow^{TM}?

- Python API
- Portability: deploy computation to one or more CPUs or GPUs in a desktop,
- server, or mobile device with a single API
- Flexibility: from Raspberry Pi, Android, Windows, iOS, Linux to server farms
- Visualization (TensorBoard is da bomb)
- Checkpoints (for managing experiments)
- Auto-differentiation autodiff (no more taking derivatives by hand. Yay)
- Large community (> 10,000 commits and > 3000 TF-related repos in 1 year)
- Awesome projects already using TensorFlow

Companies using Tensorflow

- Google
- OpenAI
- DeepMind
- Snapchat
- Uber
- Airbus
- eBay
- Dropbox
- A bunch of startups

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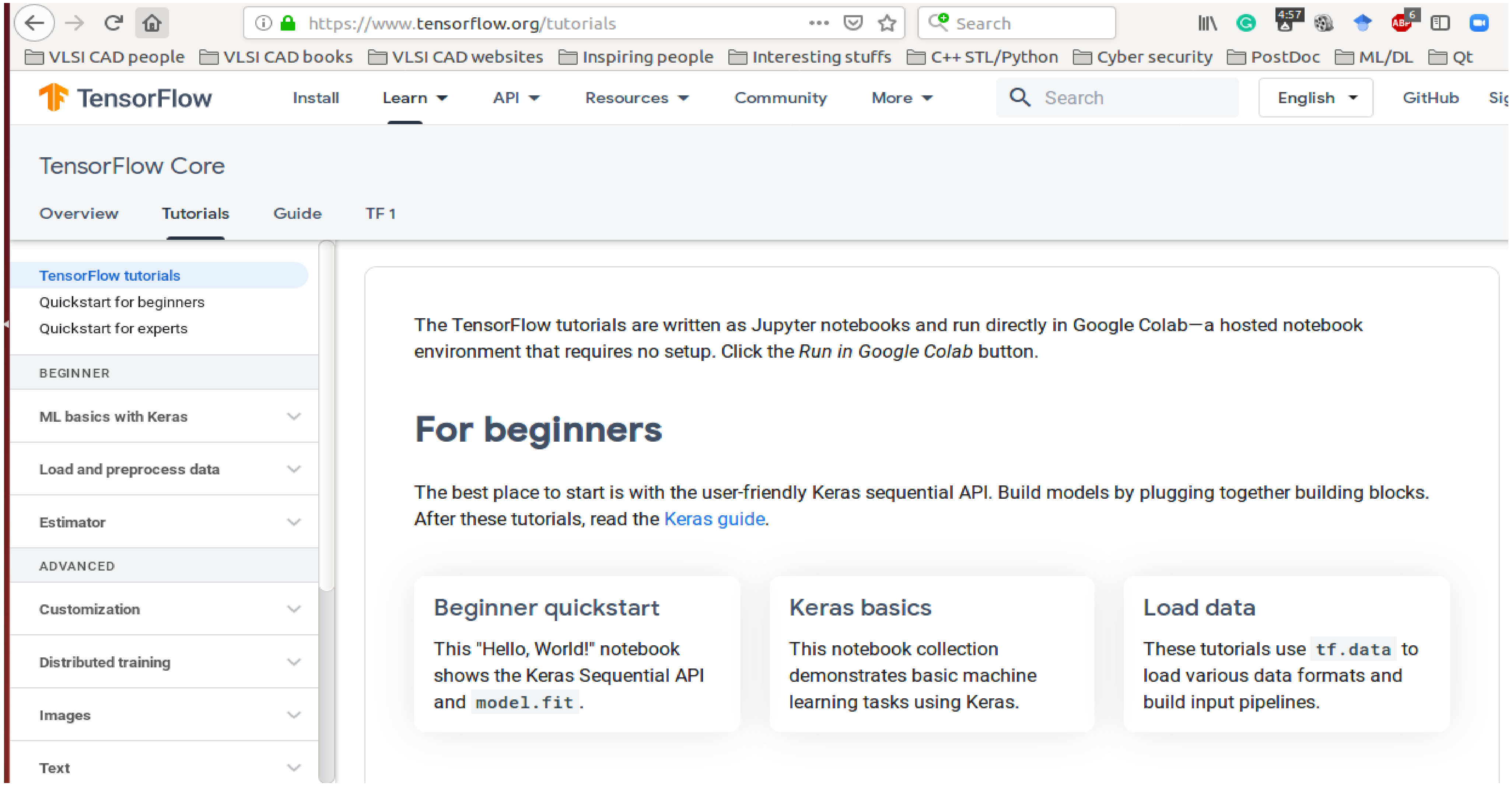
TensorFlow online tutorials

- https://www.tensorflow.org/tutorials/


https://www.tensorflow.org/tutorials

VLSI CAD people | VLSI CAD books | VLSI CAD websites | Inspiring people | Interesting stuffs | C++ STL/Python | Cyber security | PostDoc | ML/DL | Qt

TensorFlow | Install | Learn | API | Resources | Community | More | Search | English | GitHub

TensorFlow Core

Overview | Tutorials | Guide | TF 1

TensorFlow tutorials
Quickstart for beginners
Quickstart for experts
BEGINNER
ML basics with Keras
Load and preprocess data
Estimator
ADVANCED
Customization
Distributed training
Images
Text

The TensorFlow tutorials are written as Jupyter notebooks and run directly in Google Colab—a hosted notebook environment that requires no setup. Click the *Run in Google Colab* button.

For beginners

The best place to start is with the user-friendly Keras sequential API. Build models by plugging together building blocks. After these tutorials, read the Keras guide.

Beginner quickstart

This "Hello, World!" notebook shows the Keras Sequential API and `model.fit`.

Keras basics

This notebook collection demonstrates basic machine learning tasks using Keras.

Load data

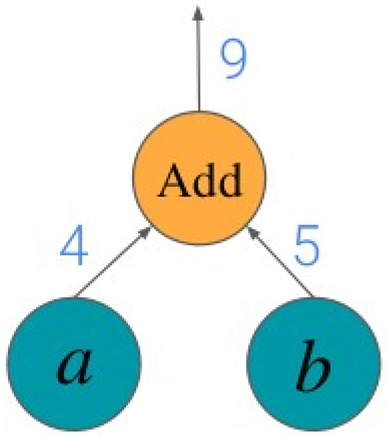
These tutorials use `tf.data` to load various data formats and build input pipelines.

Basic Code Structure

- View functions as computational graphs
- First build a computational graph, and then use a session to execute operations in the graph
- This is the basic approach, there is also a dynamic approach implemented in the recently introduced eager mode

Basic Code Structure

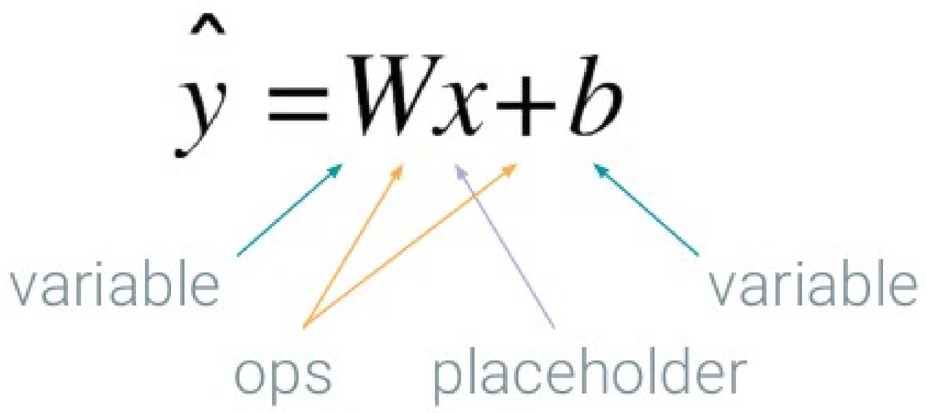
- Nodes are operators (ops), variables, and constants
- Edges are tensors
  - 0-d is a scalar
  - 1-d is a vector
  - 2-d is a matrix
- TensorFlow = Tensor + Flow = Data + Flow

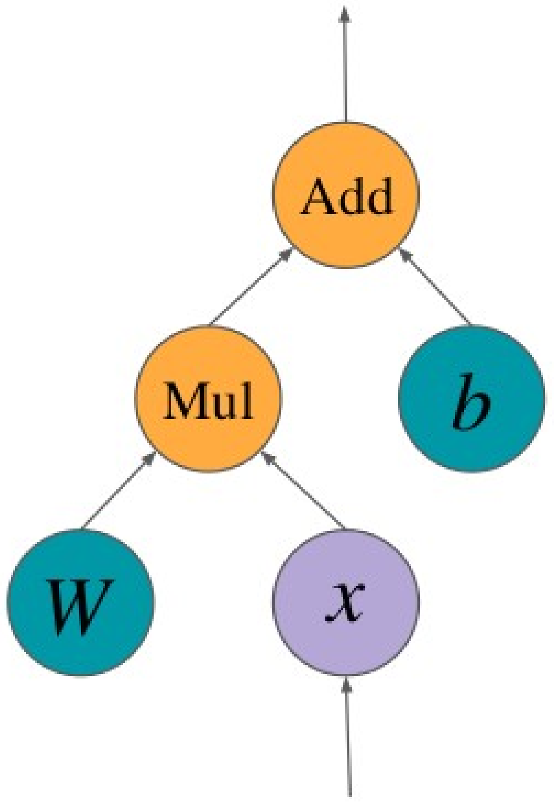


Basic Code Structure

- Constants are fixed value tensors - not trainable
- Variables are tensors initialized in a session – trainable
- Placeholders are tensors of values that are unknown during the graph construction, but passed as input during a session
- Ops are functions on tensors

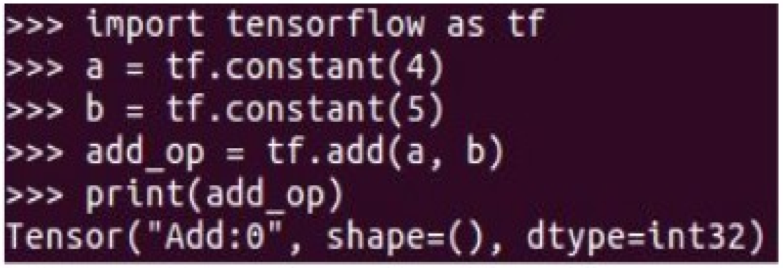
Basic Code Structure - Graphs



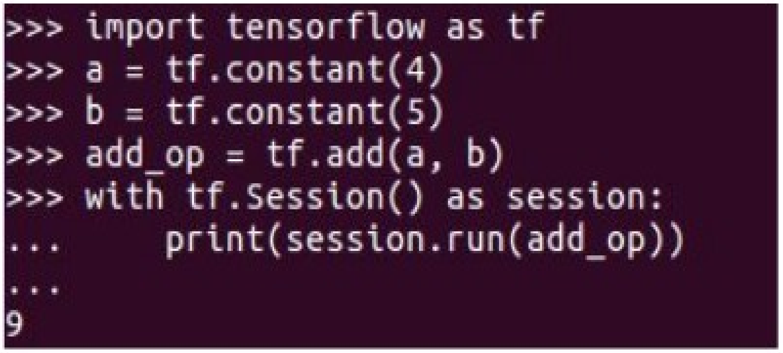


Basic Code Structure - Sessions

- Session is the runtime environment of a graph, where operations are executed, and tensors are evaluated



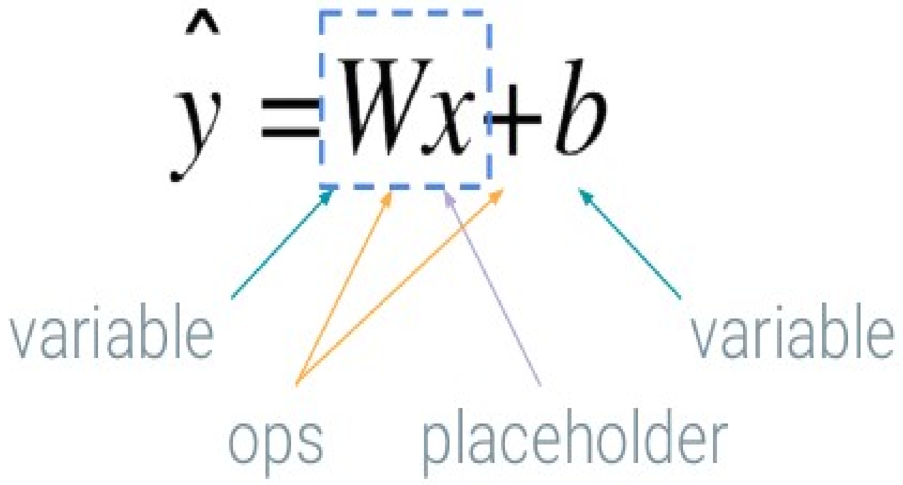
```
>>> import tensorflow as tf
>>> a = tf.constant(4)
>>> b = tf.constant(5)
>>> add_op = tf.add(a, b)
>>> print(add_op)
Tensor("Add:0", shape=(), dtype=int32)
```

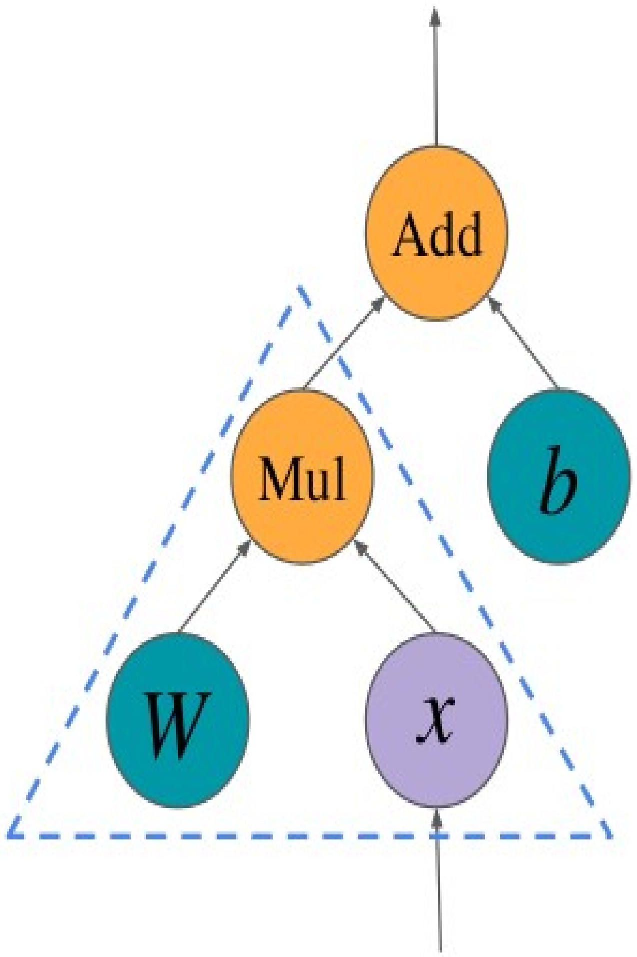


```
>>> import tensorflow as tf
>>> a = tf.constant(4)
>>> b = tf.constant(5)
>>> add_op = tf.add(a, b)
>>> with tf.Session() as session:
...     print(session.run(add_op))
...
9
```

- `a.eval()` is equivalent to `session.run(a)`, but in general, "eval" is limited to executions of a single op and ops that returns a value
- Upon op execution, only the subgraph required for calculating its value is evaluated

Basic Code Structure - Sessions





TensorFlow 1.x vs TensorFlow 2.x

- Only Static Computation graph.
- Heavyweight build-then-run was overkill for simple applications
- Low level API
- tf.Session for hard separation from Python

- Both dynamic and static supported
- Eager execution
- High level API Keras Integrated
- No sessions, just functions. tf.function decorator for advanced uses

Machine Learning

- **Machine Learning:** Inlelligence demonstrated by machines using its previous experiences.
- Supervised Learning: Labelled data.
- Unsupervised Learning: Unlabelled data.

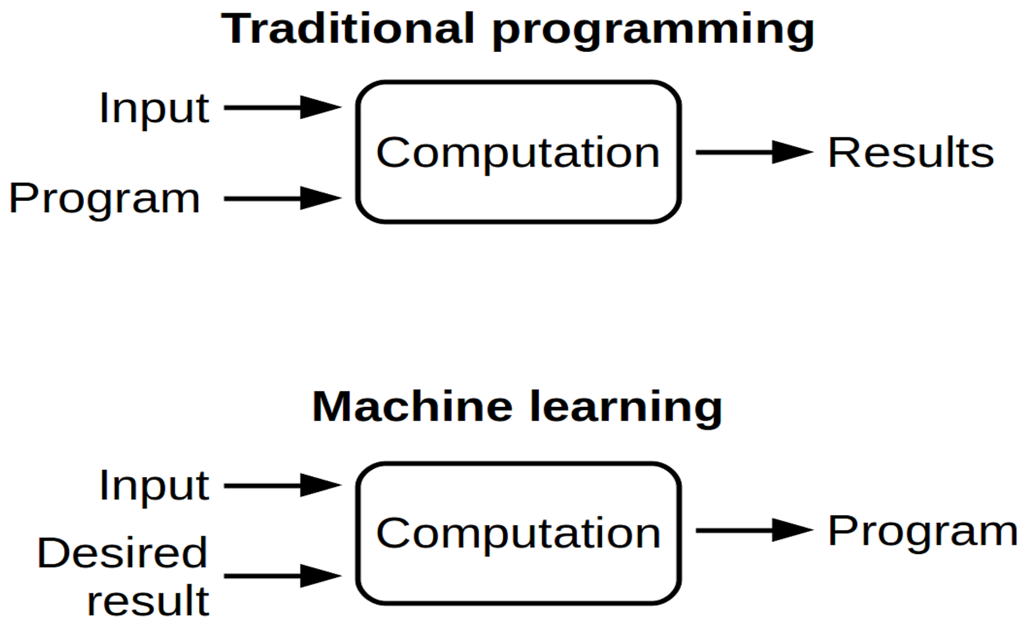


Figure: Difference between Traditional programming and Machine Learning

Supervised Learning

- All data are labeled.
- For a set of input features there is output feature.
- Types of Supervised Learning tasks:
- Regression (Linear Regression demo)
- Classification (Logistic Regression demo)

Linear Regression

- In regression, the output variable is a continous variable.
- Multiple input features or variables.
- One output feature or variable.
- For eg: Housing Price Prediction Problem.
- Input feature: House area, location, number of rooms etc.
- Output feature: Price of house.

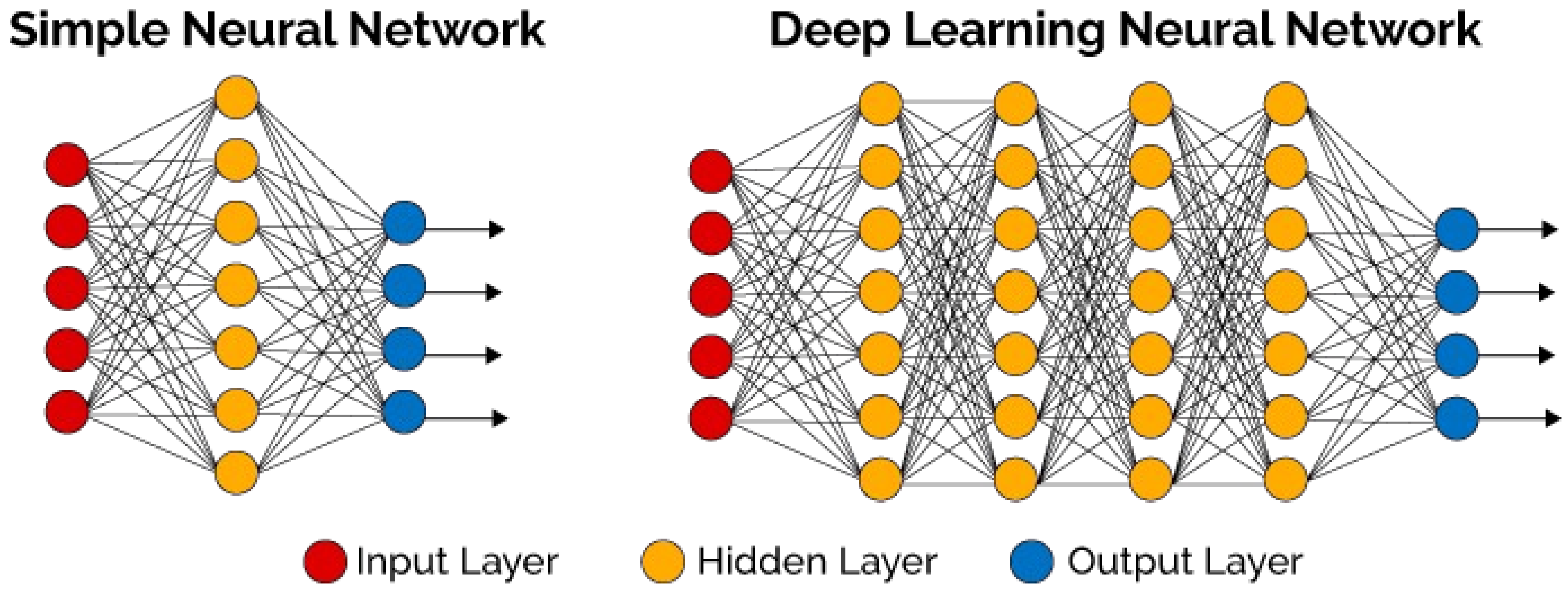
Classification

- In logistic regression, the output variable is discrete “Yes” or “No”.
- In multi-class regression, there can be multiple classes of output.

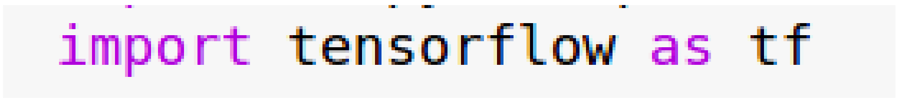
Traditional Machine Learning Models

- SVM
- Decision Trees
- Random Forest
- Gaussian Process Regression
- For these models you can use sci-kit learn package
- Tensorflow is famous for creating deep learning models

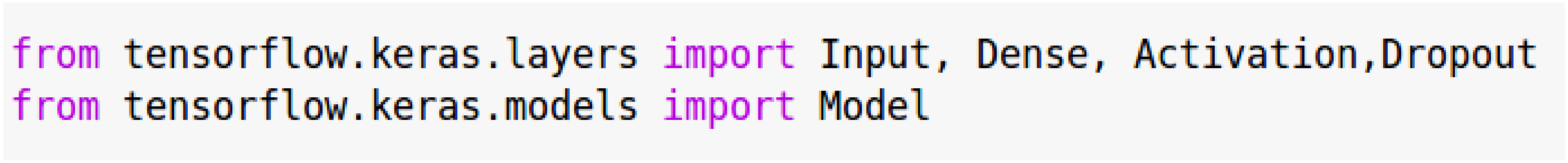
Neural Networks



Constructing Neural Networks in TF

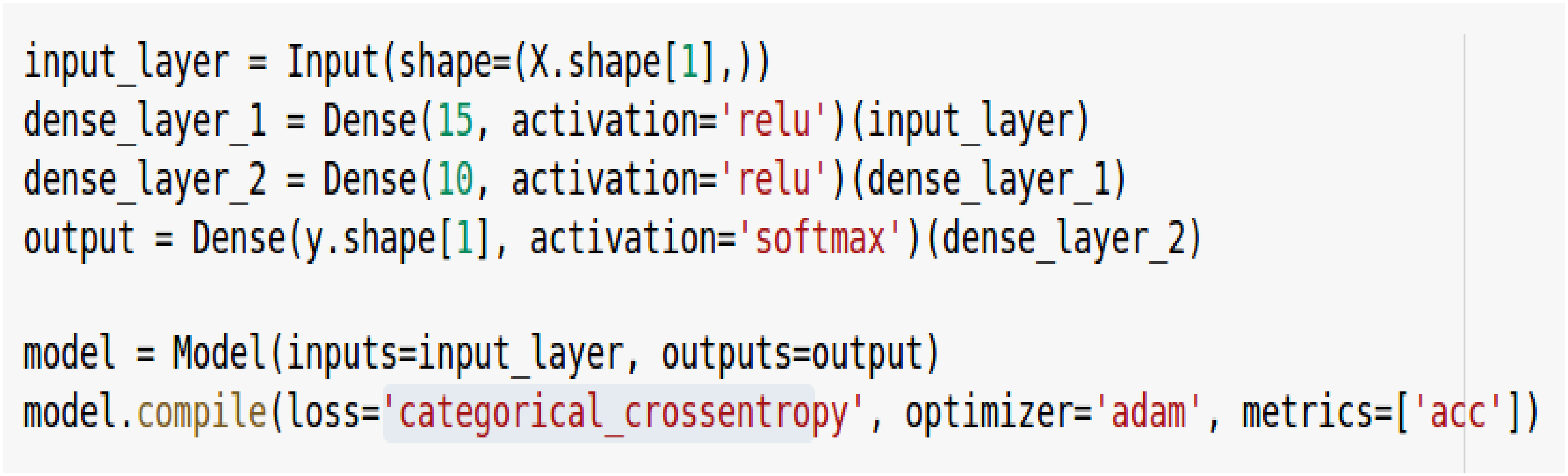


```python
import tensorflow as tf
```



```python
from tensorflow.keras.layers import Input, Dense, Activation,Dropout
from tensorflow.keras.models import Model
```

Constructing Neural Networks in TF



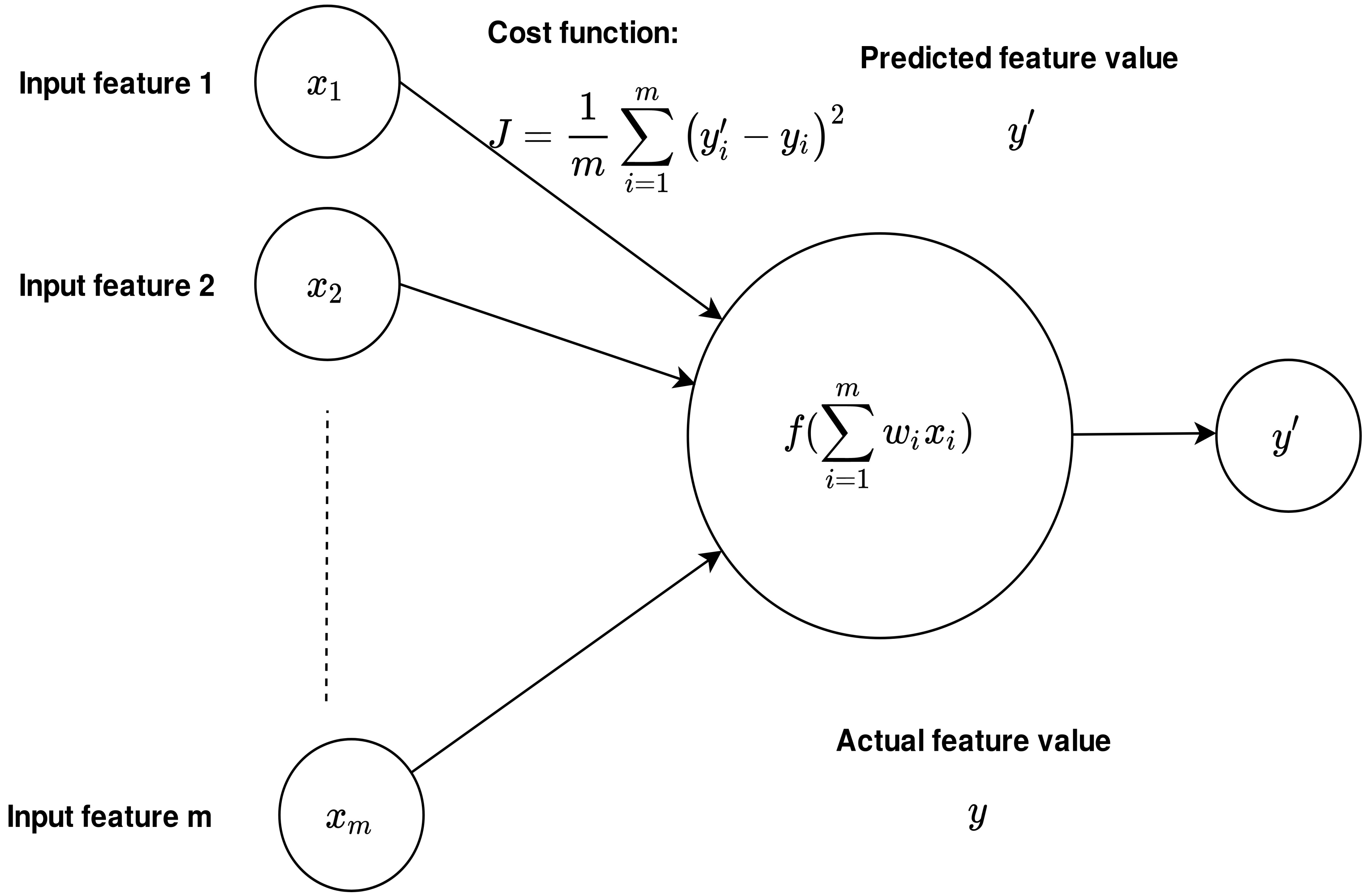
```
input_layer = Input(shape=(X.shape[1],))
dense_layer_1 = Dense(15, activation='relu')(input_layer)
dense_layer_2 = Dense(10, activation='relu')(dense_layer_1)
output = Dense(y.shape[1], activation='softmax')(dense_layer_2)

model = Model(inputs=input_layer, outputs=output)
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['acc'])
```

Layers

- Dense
- Conv1D
- Conv2D
- AveragePooling1D

https://www.tensorflow.org/api_docs/python/tf/keras/layers

How Deep Neural Networks Work?



Cost function:

$$J = \frac{1}{m}\sum_{i=1}^{m}\left(y'_i - y_i\right)^2$$

Predicted feature value

y'

Actual feature value

y

How Deep Neural Networks Work?

Forward propagation:

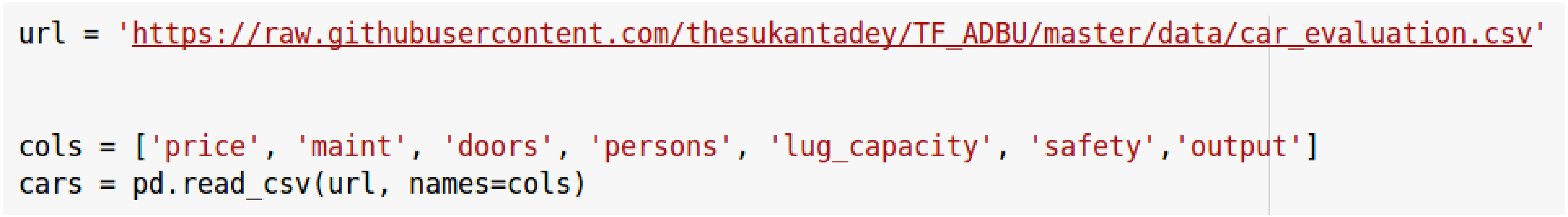
- Loss function is calculated
- Activation added non-linearity.

Backward propagation:

- Loss is minimized.
- Weight updated.

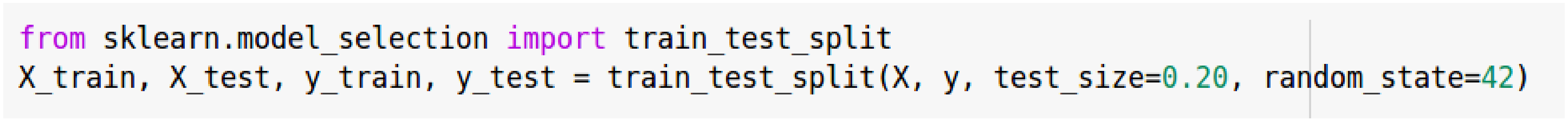
Dataset

Reading Dataset:



```
url = 'https://raw.githubusercontent.com/thesukantadey/TF_ADBU/master/data/car_evaluation.csv'


cols = ['price', 'maint', 'doors', 'persons', 'lug_capacity', 'safety','output']
cars = pd.read_csv(url, names=cols)
```

Spliting Training and Test dataset:

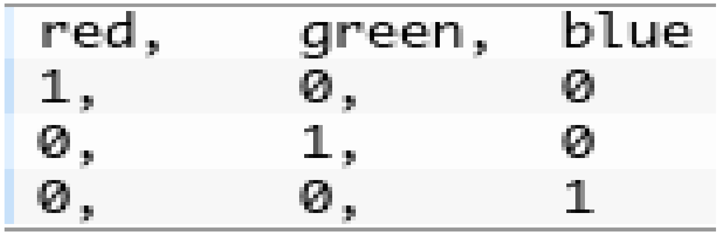


```
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.20, random_state=42)
```

Encoding, Scaling, Normalization

Encoding:

- Integer Encoding
- One-hot encoding



red,	green,	blue
1,	0,	0
0,	1,	0
0,	0,	1

Scaling/Normalization:

- Standard Scaler
- MixMax Scaler

https://towardsdatascience.com/scale-standardize-or-normalize-with-scikit-learn-6ccc7d176a02

Activation Functions

- The activation function is a mathematical “gate” in between the input feeding the current neuron and its output going to the next layer.
- It can be as simple as a step function that turns the neuron output on and off, depending on a rule or threshold.
- Or it can be a transformation that maps the input signals into output signals that are needed for the neural network to function.

https://www.tensorflow.org/api_docs/python/tf/keras/activations

Activation Functions

- Rectified Linear Unit (ReLU)
- Sigmoid
- tanh
- Softmax (used in last layer)
- Exponential
- Leaky ReLU

https://www.tensorflow.org/api_docs/python/tf/keras/activations

ReLU Activation

- Computationally efficient—allows the network to converge very quickly.
- Non-linear—although it looks like a linear function, ReLU has a derivative function and allows for backpropagation.

https://www.tensorflow.org/api_docs/python/tf/keras/activations

Softmax Activation

- Softmax assigns decimal probabilities to each class in a multi-class problem.
- Softmax is implemented through a neural network layer just before the output layer.
- The Softmax layer must have the same number of nodes as the output layer.

https://www.tensorflow.org/api_docs/python/tf/keras/activations

Loss Function

- Mean-square Error
- Categorical Cross Entropy
- Binary Cross Entropy
- Hinge
- Huber
- Mean Absolute Error

https://www.tensorflow.org/api_docs/python/tf/keras/losses

Mean-square Error Loss Function

- Mean Square Error (MSE) is the most commonly used regression loss function.

$$MSE = \frac{\sum_{i=1}^{n} (y_i - y_i^p)^2}{n}$$

https://www.tensorflow.org/api_docs/python/tf/keras/losses

Categorical Cross Entropy Loss Function

- Cross-entropy loss, or log loss, measures the performance of a classification model whose output is a probability value between 0 and 1.
- Cross-entropy loss increases as the predicted probability diverges from the actual label.

https://www.tensorflow.org/api_docs/python/tf/keras/losses

Optimizer

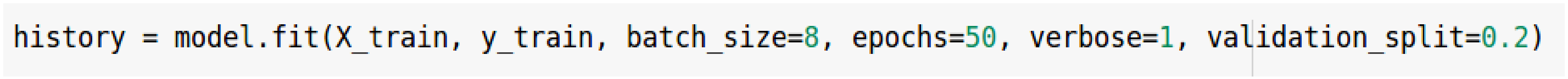
- Gradient Descent
- Stochastic Gradient Descent
- Mini-Batch Gradient Descent
- Momentum
- Adagrad
- AdaDelta
- Adam

Adam is the best optimizers. If one wants to train the neural network in less time and more efficiently than Adam is the optimizer.

https://towardsdatascience.com/optimizers-for-training-neural-network-59450d71caf6

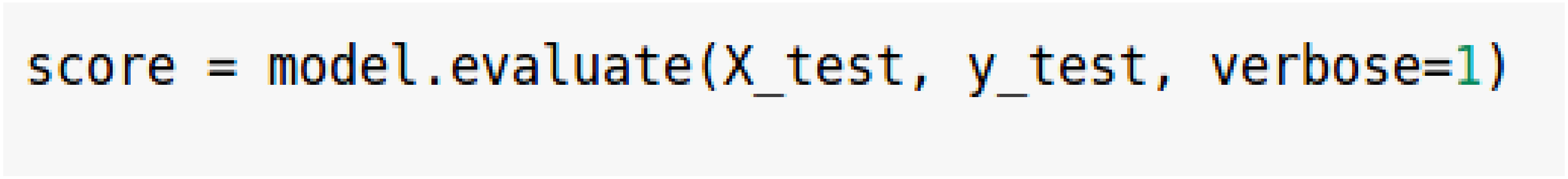
Training & Testing & Accuracy

Training:



```
history = model.fit(X_train, y_train, batch_size=8, epochs=50, verbose=1, validation_split=0.2)
```

Testing:



```
score = model.evaluate(X_test, y_test, verbose=1)
```

https://www.tensorflow.org/guide/keras/train_and_evaluate?hl=sl

Epochs, Batch and Iterations

- Epochs: One Epoch is when an ENTIRE dataset is passed forward and backward through the neural network only ONCE.
- Batch size: Total number of training examples present in a single batch.
- Iterations: It is the number of batches needed to complete one epoch.
- Let’s say we have 2000 training examples that we are going to use.
- We can divide the dataset of 2000 examples into batches of 500 then it will take 4 iterations to complete 1 epoch.

Hands-on Codes on Google Colab

- Go to: https://colab.research.google.com/
- New Notebook.
- This will create .ipynb file on your browser.
- This is a python interpreter similar to Jupyter notebook.
- This can be saved in your Google drive.
- You can choose Python 2 or 3.
- You can also use Google GPU or TPU.

Thank You