Learning Tensorflow for Developing Machine Learning Models

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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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- Code and slide avialable at: https://github.com/thesukantadey/TF_ADBU

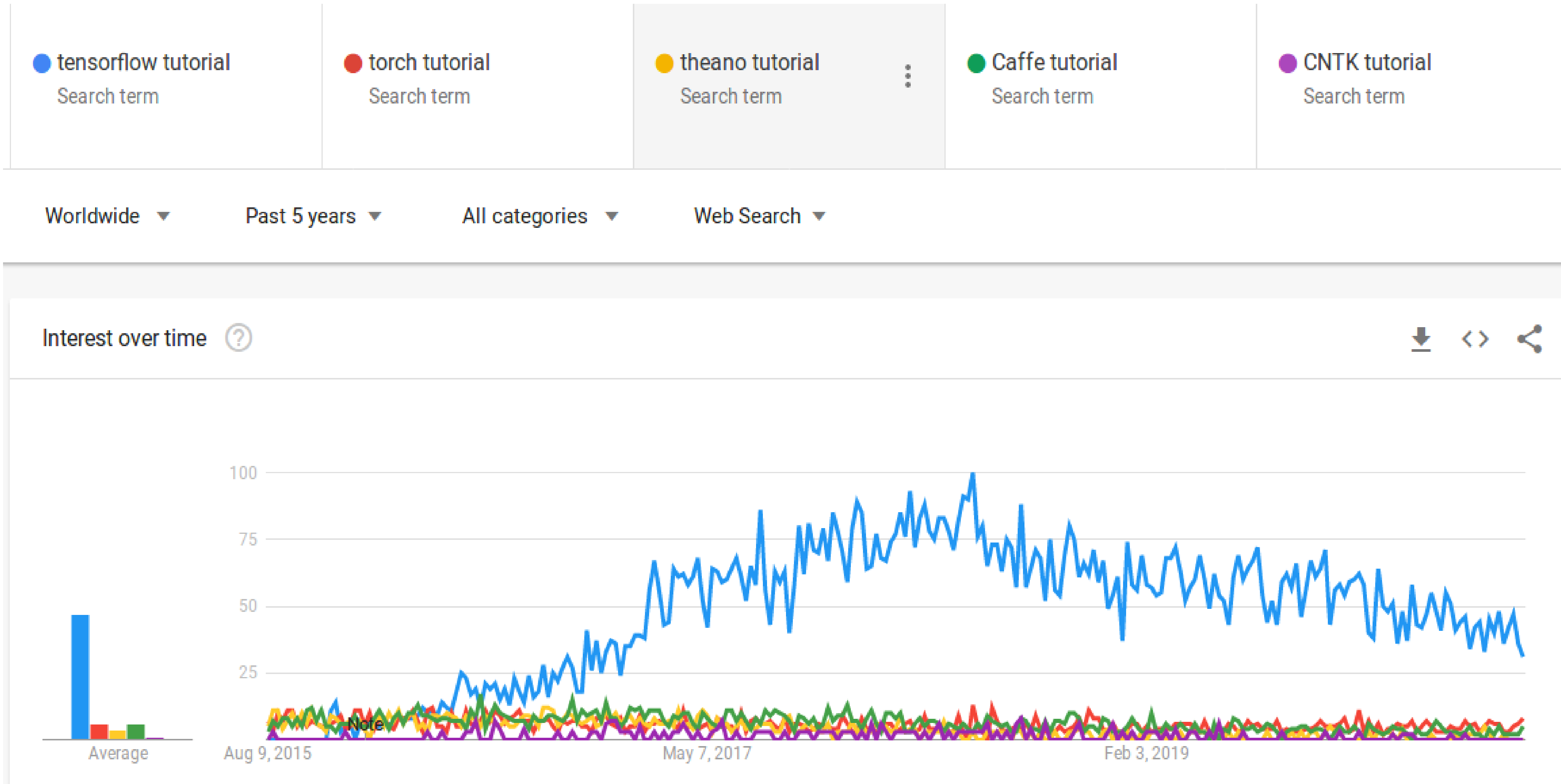
Overview

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

What’s TensorFlow™?

- 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™?



What’s TensorFlow™?

- 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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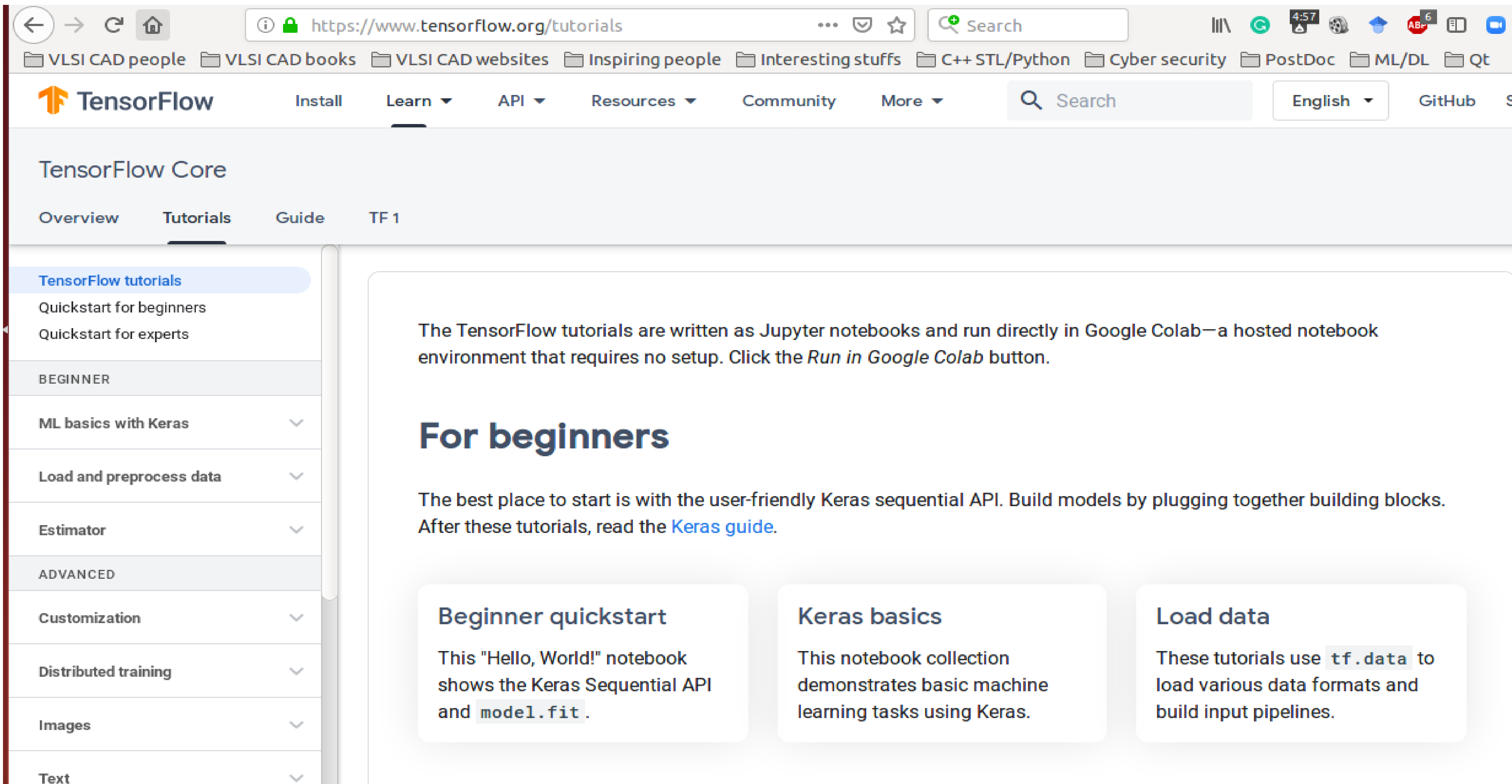
TensorFlow online tutorials

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

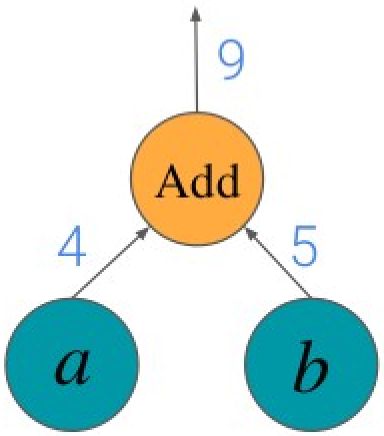


Basic Code Structure

- 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

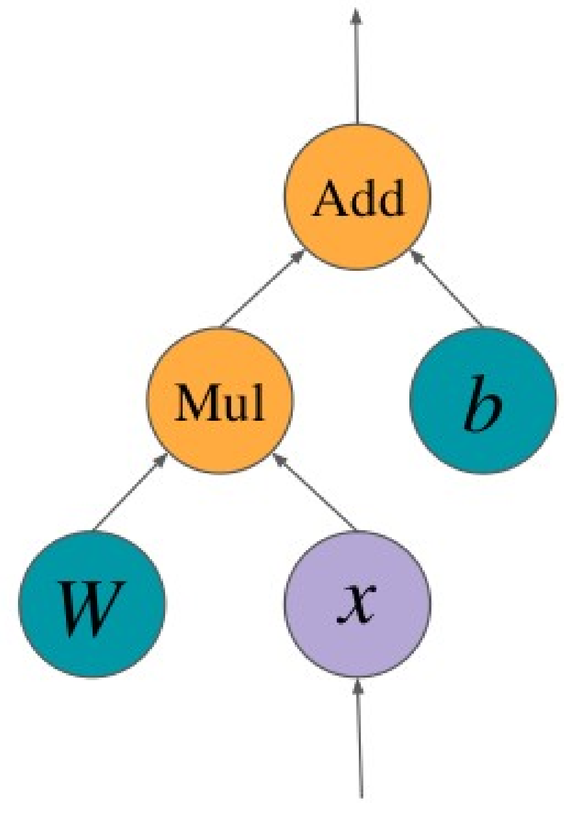
- Constants are fixed value tensors - not trainable
- Variables are tensors initialized in a session – trainable
- Placeholders are tensors of values that are unknown during the graph construction, but passed as input during a session
- Ops are functions on tensors

Basic Code Structure - Graphs

$$\hat{y} = Wx + b$$

variable variable

ops placeholder



Basic Code Structure - Sessions

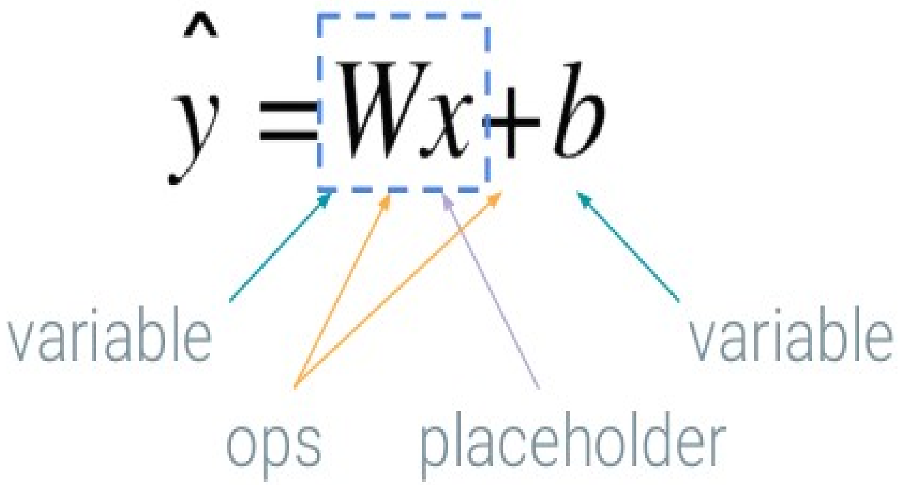
- Session is the runtime environment of a graph, where operations are executed, and tensors are evaluated

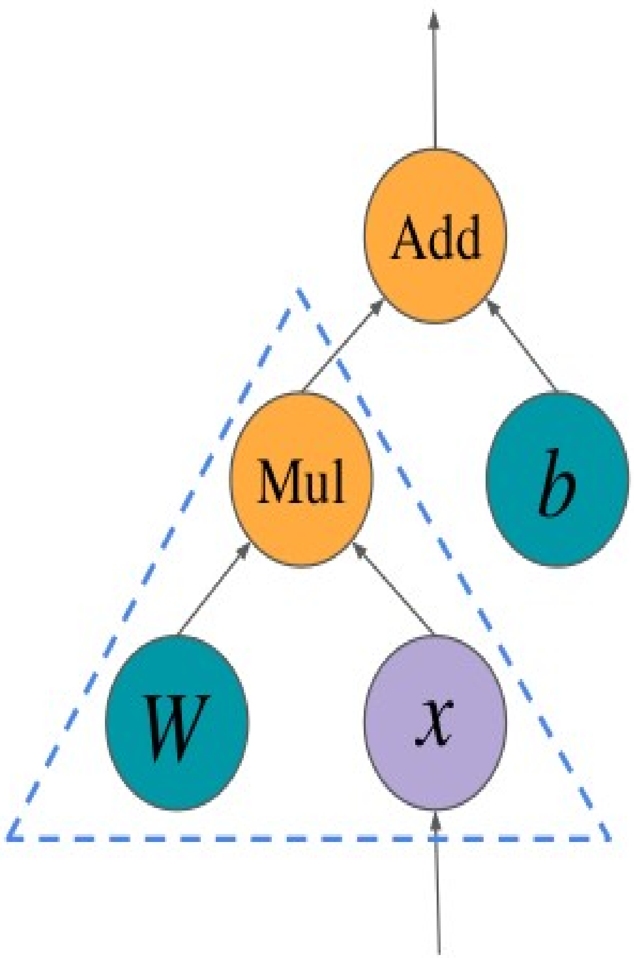
```
>>> import tensorflow as tf
>>> a = tf.constant(4)
>>> b = tf.constant(5)
>>> add_op = tf.add(a, b)
>>> print(add_op)
Tensor("Add:0", shape=(), dtype=int32)
```

```
>>> 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.

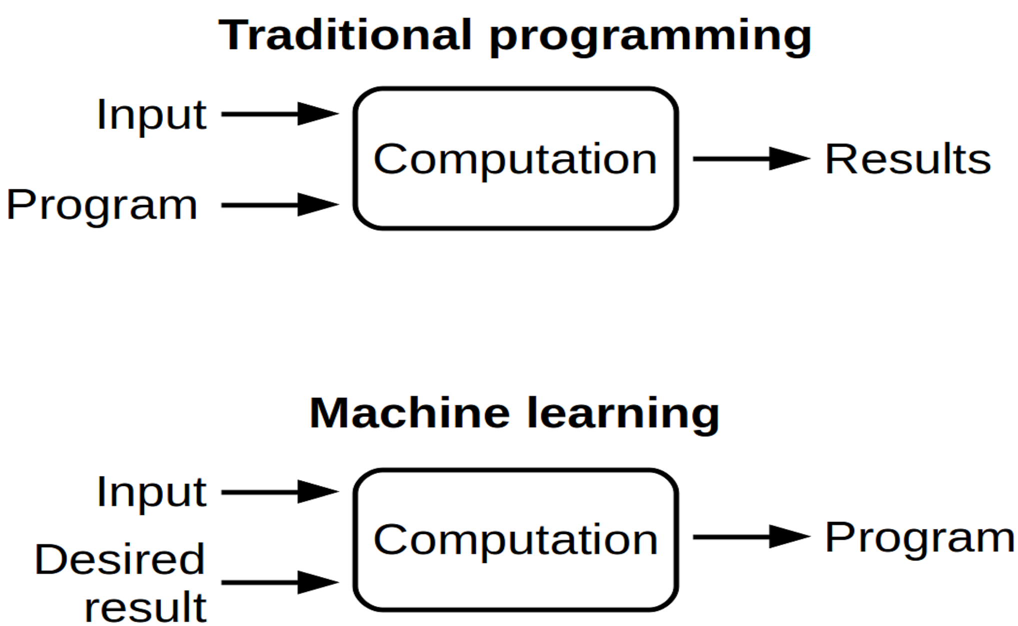


Figure: Difference between Traditional programming and Machine Learning

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.

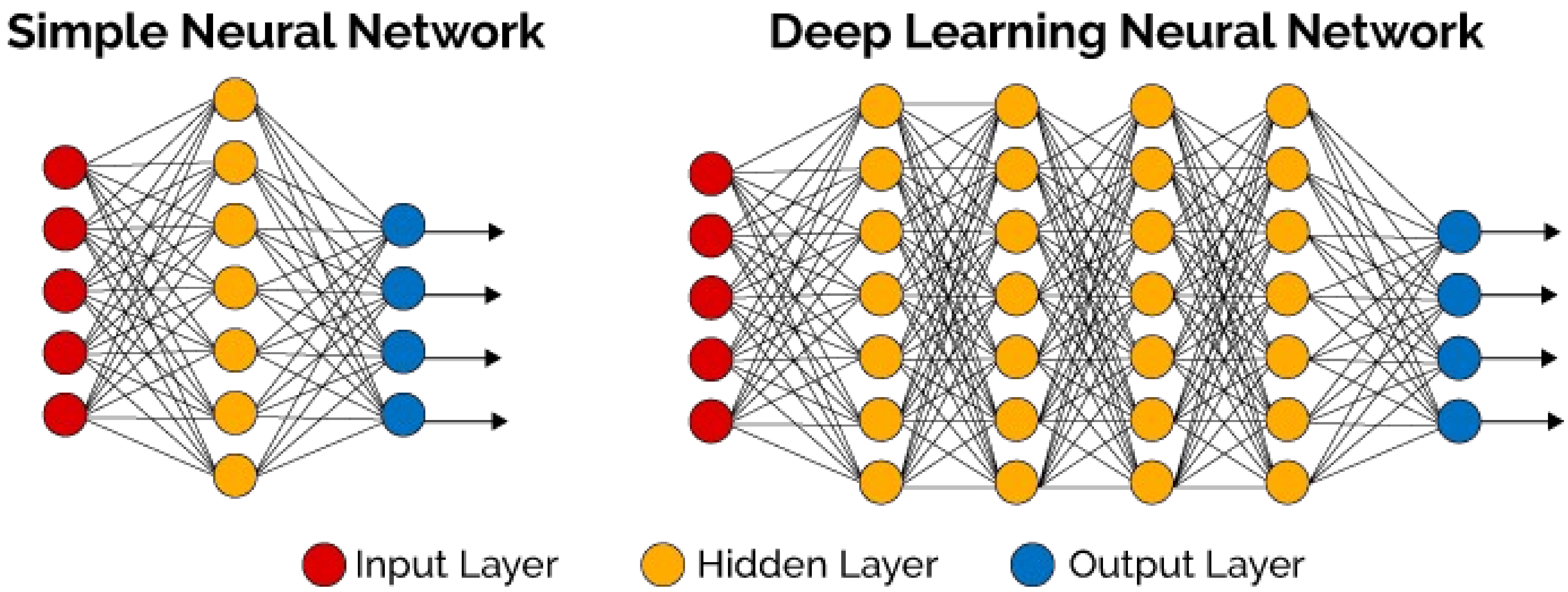
Classification

- 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

```
import tensorflow as tf
```

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

Constructing Neural Networks in TF

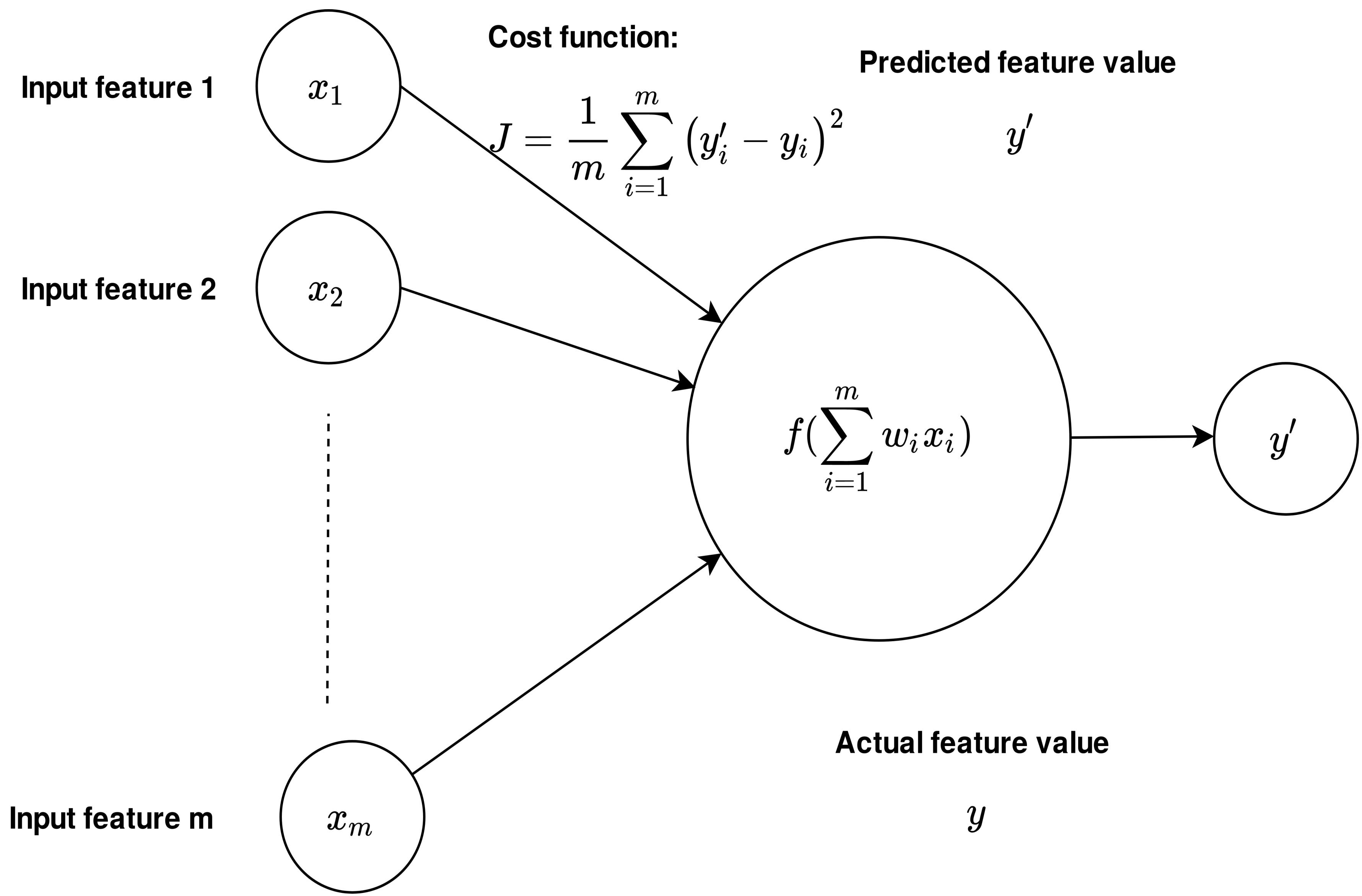
```
input_layer = Input(shape=(X.shape[1],))
dense_layer_1 = Dense(15, activation='relu')(input_layer)
dense_layer_2 = Dense(10, activation='relu')(dense_layer_1)
output = Dense(y.shape[1], activation='softmax')(dense_layer_2)

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?



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