# Lab 1: Introduction

University of Washington

ECE 596/AMATH 563

Spring 2021

# Outline

- Python Programming Setup
- Python Platforms for DL
- Introduction to Numpy
- Plotting with Matplotlib
- Preparing Data for Machine Learning
- Lab Assignment

# Part 1: Python Programming Setup

# Setting up Python Environment (Anaconda 3)

## What is Anaconda?

Anaconda is a distribution of the Python and R for scientific computing

- Comes with >250 packages automatically installed
- >7500 additional open-source packages available
- Equipped with Jupyter Notebook
- Conda environment manager for easy maintenance of packages

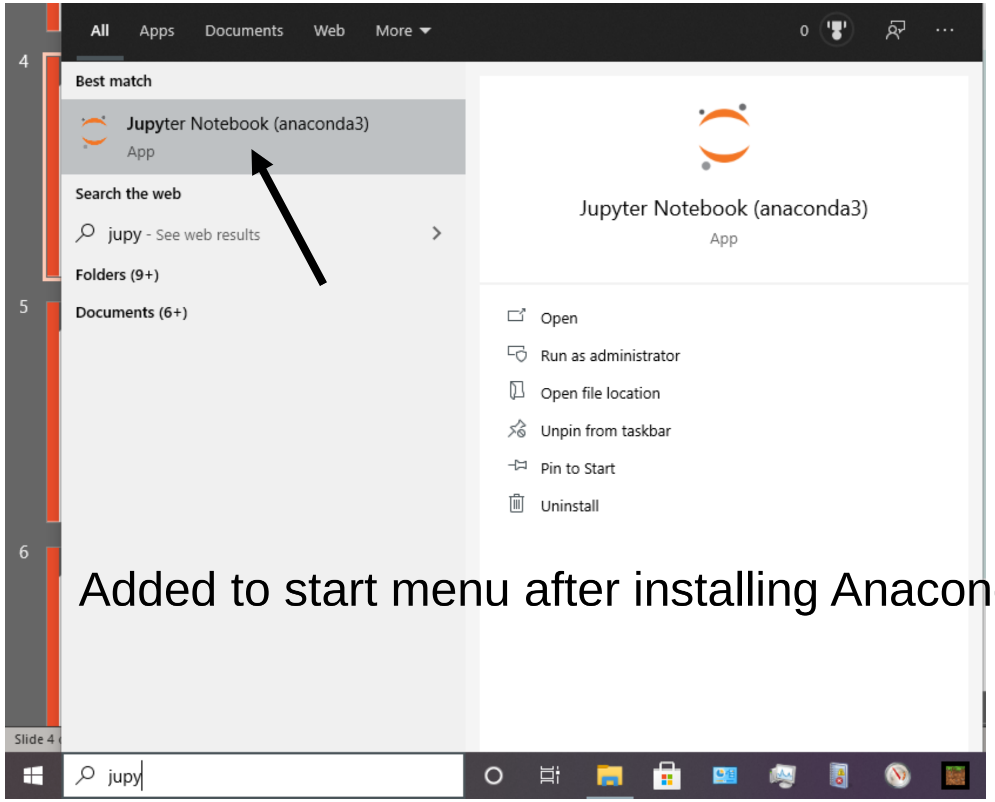
# Setting up Python Environment (Anaconda 3)

## Installing Anaconda 3

https://www.anaconda.com/products/individual

# Starting up Jupyter Notebook (Anaconda3)

## Windows




Added to start menu after installing Anaconda 3

## Mac/Linux

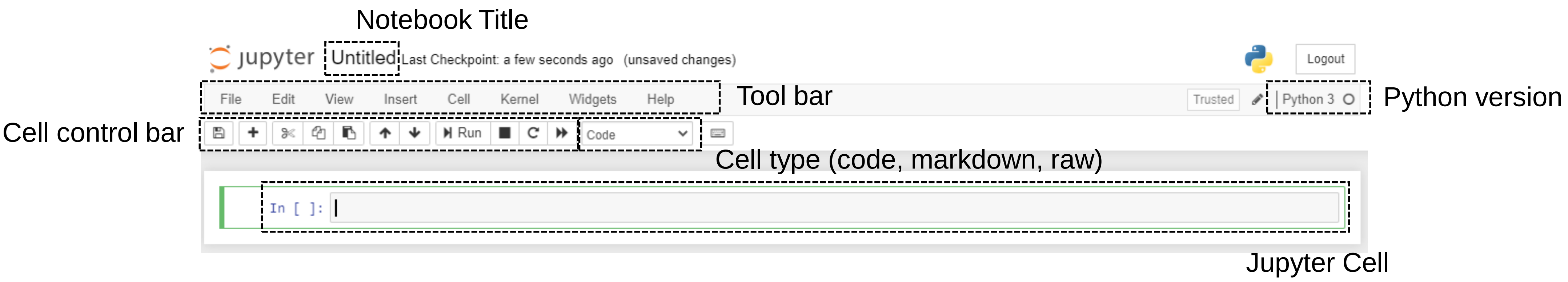
Start terminal

Type “jupyter notebook”

# Starting up Jupyter Notebook (Anaconda3)


Create a new notebook

# Starting up Jupyter Notebook (Anaconda3)




**For more information, visit** https://www.dataquest.io/blog/jupyter-notebook-tutorial/

# Part 2: Python Platforms for DL

# Google Colaboratory

A free Jupyter notebook environment that runs in the cloud

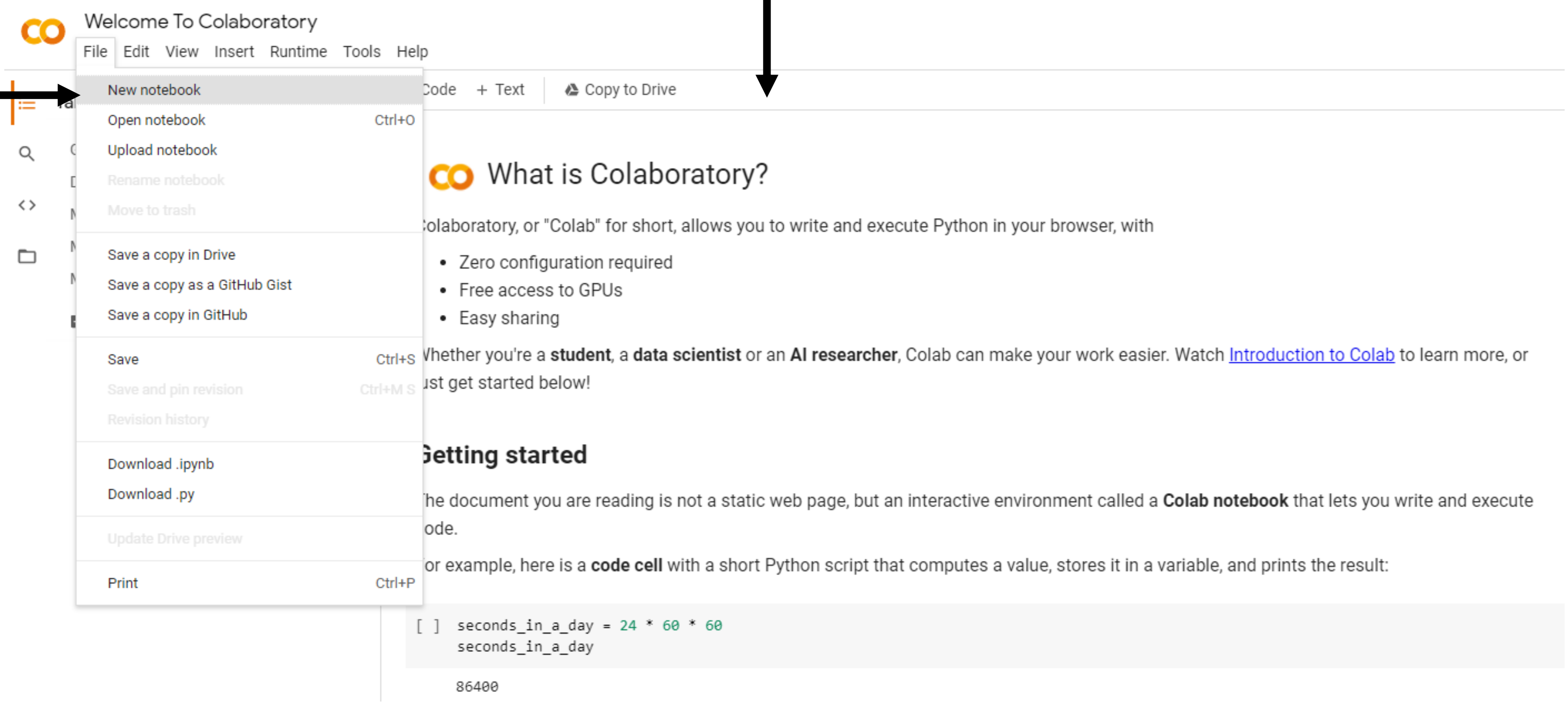
- Saves in Google drive
- Github commit style code sharing with others
- Maximum runtime of 12hrs (Free version)
- Support GPU or TPU for hardware acceleration
- Pre-equipped with latest scientific packages (Numpy, Scipy, etc)

# Google Colaboratory: Getting started

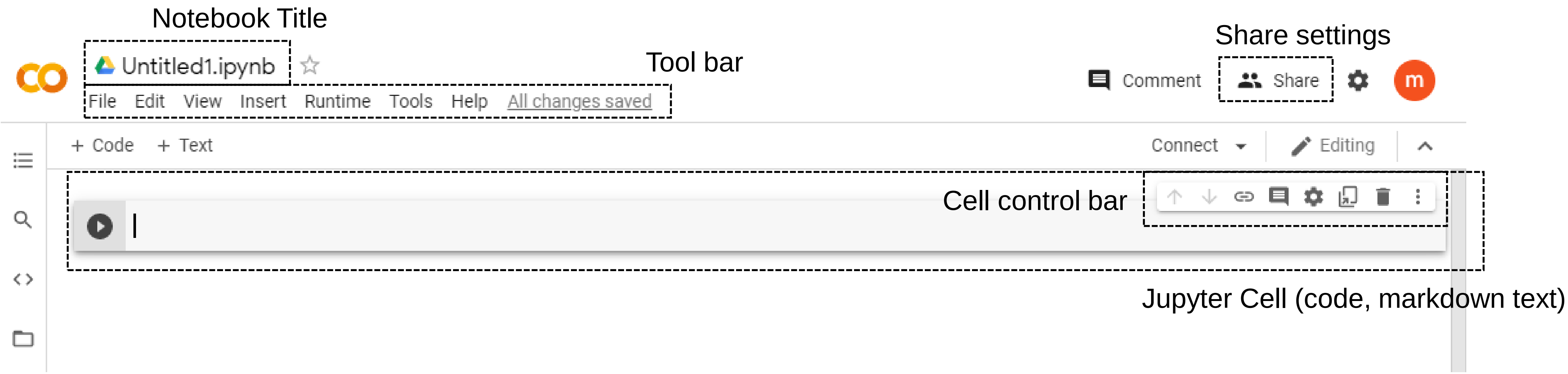
## Tutorial to Colab

https://colab.research.google.com/notebooks/intro.ipynb

Create new Notebook



# Google Colaboratory: Getting started



# Google Cloud

Suite of cloud computing services offered by Google
- Offers AI Platform for deploying DL models
- Support Jupyter Notebook instances
- Provide instances with DL libraries
- Fully customizable hardware spec with state-of-the-art components
- Monthly charge for the service

Setup tutorial by “Towards data science” → https://towardsdatascience.com/get-deep-learning-on-google-cloud-platform-the-easy-way-53f74bab5ee9

# Deep Learning Frameworks

PyTorch

Developed by Facebook

- Lots of modules that are easy to combine
- Easy to edit network
- Lots of pre-trained models
- Seamless integration into Python/Numpy framework

TensorFlow

Developed by Google

- Provides Tensorboard for visualization
- Uses its own session during training
- Great community support
- Tensorflow Lite can run models on mobile devices

mxnet

Developed by Apache

- Supported by Amazon Web Service
- Supports many languages
- Fast and flexible for running DL algorithms
- Features advanced GPU support
- Popular among industrial projects

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mxnet

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**Framework for this class**

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- Supports many languages
- Fast and flexible for running DL algorithms
- Features advanced GPU support
- Popular among industrial projects

# Part 3: Introduction to Numpy

# What is Numpy?

Fundamental package for scientific computing in Python

- Provides multi-dimensional array object
- Provides assortment of mathematical routines for arrays
- Fast array operations through pre-compiled C
- Support vectorization of operations
- Seamlessly integrated with DL frameworks such as PyTorch, TensorFlow

# Constructing Numpy arrays

## From python lists

```
# Defining a numpy array

# 1D array
arr = np.array([1,2,3,4,5])

# 2D array
arr_2d = np.array([[1,2,3,4,5],
                  [6,7,8,9,10],
                  [11,12,13,14,15]])

# 3D array
arr_3d = np.array([[[1,2,3,4,5],
                  [6,7,8,9,10],
                  [11,12,13,14,15]],
                   [[16,17,18,19,20],
                  [21,22,23,24,25],
                  [26,27,28,29,30]]])
```

## From Numpy commands

```
# Define number of each dimension

n1 = 3
n2 = 4
n3 = 5

# Zeros array
zeros_1d = np.zeros(n1)
zeros_2d = np.zeros((n1,n2))
zeros_3d = np.zeros((n1,n2,n3))

# Ones array
ones_1d = np.ones(n1)
ones_2d = np.ones((n1,n2))
ones_3d = np.ones((n1,n2,n3))

# Creating array using np.arange
arr_arange = np.arange(0, 10, 1)      # (start, stop, stepsize)

# Creating an array using np.linspace
arr_linspace = np.linspace(0, 9, 10) # (start, stop, # of bins)
```

## Random arrays

```
# Random array

np.random.seed(10)                 # Fixes the seed number so that random samplings always give same results

rand_arr = np.random.randn(n1, n2) # Random array sampled from standard normal distribution
```

# Basic Matrix Operations in Numpy

Elementwise Addition – np.add()

Elementwise Subtraction – np.subtract()

Elementwise Multiplication – np.multiply()

Elementwise Division – np.divide()

Elementwise Power – np.power()

Dot Product – np.dot()

Transpose – .T operative or np.transpose()

# Useful Numpy functions

**Combining arrays**

Concatenating arrays– np.concetenate()
Stacking arrays – np.stack() (Can add dimensions), np.hstack() (horizontal stack), np.vstack() (vertical stack)

**Finding characteristic values of an array**

Minimum, Maximum, Mean, Sum of array elements – np.min(), np.max(), np.mean(), np.sum()

**Indexing an array**

Indices of minimum and maximum element – np.argmin(), np.argmax()
Sorting the indices from low to high values – np.argsort()
Finding the indices that satisfy conditions – np.where()

# Part 4: Plotting with Matplotlib

# Basic plotting

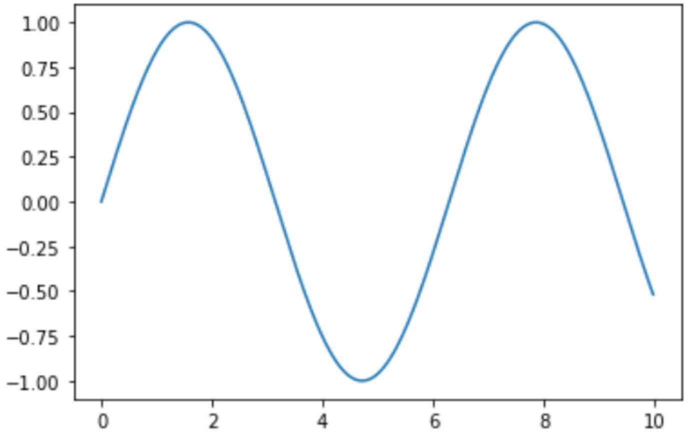
## Import Matplotlib

```
#%matplotlib inline   # If using local notebook runtime, allows you to display the plot inside the jupyter notebook
#%matplotlib notebook # Alternatively, you can use this line instead for interactive plots

import matplotlib.pyplot as plt
```

## Code

```
x = np.arange(0, 10, 1/32) # x axis data
y = np.sin(x)              # y axis data
plt.plot(x, y)             # plot the data
```

## Output

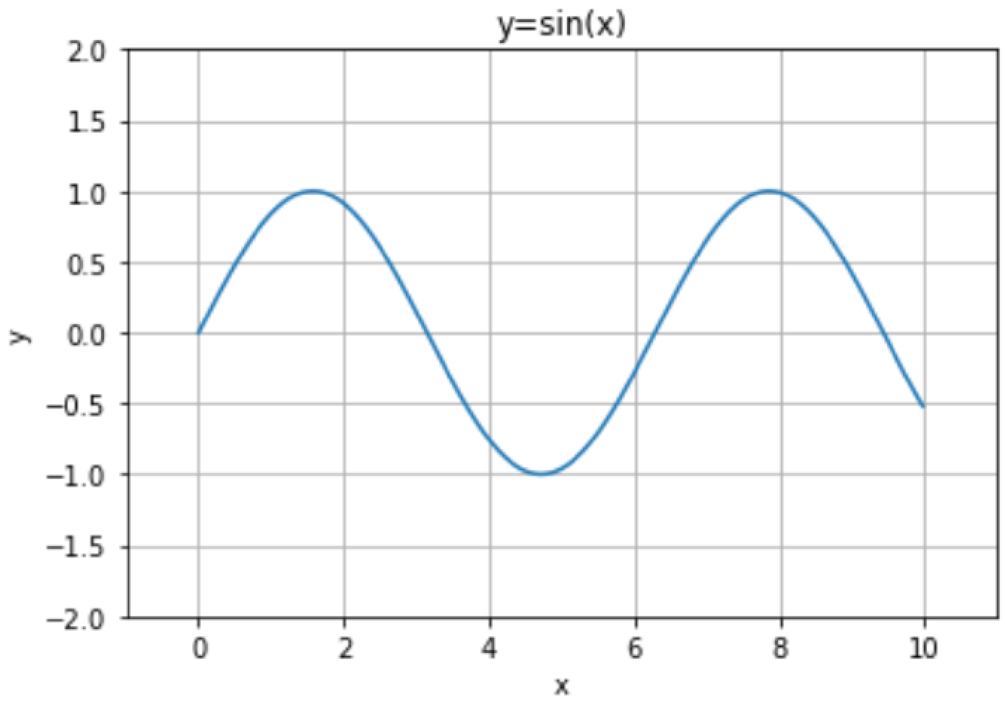


# Labeling your plots

## Code

```
plt.plot(x, y)
plt.title('y=sin(x)')  # set the title
plt.xlabel('x')        # set the x axis label
plt.ylabel('y')        # set the y axis label
plt.xlim(-1, 11)       # set the x axis range
plt.ylim(-2, 2)        # set the y axis range
plt.grid()             # enable the grid
```

## Output

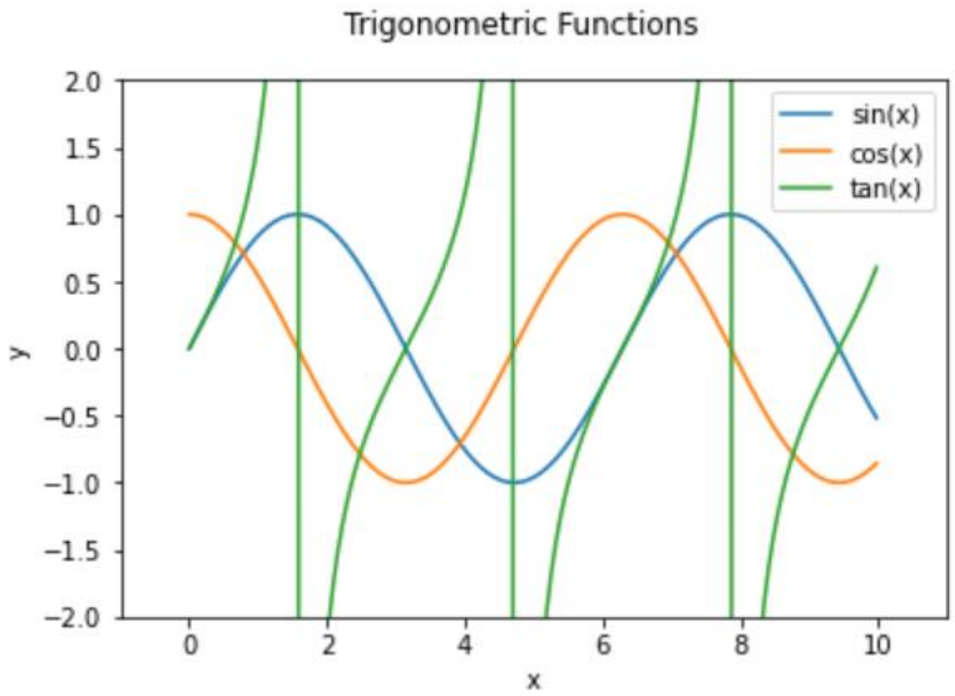


# Multiple plots

## Code

```
# Multiple Plots
# On same figure
x = np.arange(0, 10, 1/32) # x axis data
y1 = np.sin(x)             # y axis data 1
y2 = np.cos(x)             # y axis data 2
y3 = np.tan(x)             # y axis data 3
plt.figure(1)              # create figure 1
plt.plot(x, y1, label='sin(x)')
plt.plot(x, y2, label='cos(x)')
plt.plot(x, y3, label='tan(x)')
plt.xlabel('x')
plt.ylabel('y')
plt.xlim(-1, 11)
plt.ylim(-2, 2)
plt.suptitle('Trigonometric Functions')
plt.legend()
plt.show()
```

## Output

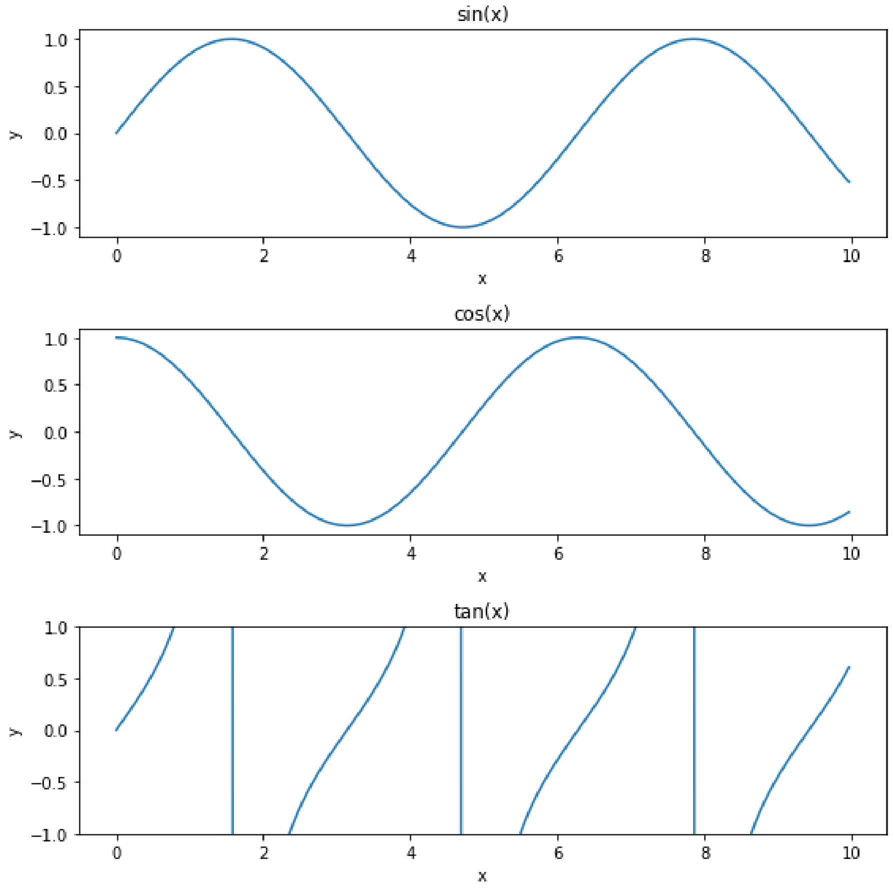


# Creating subplots

## Code

```
# Multiple Subplots
x = np.arange(0, 10, 1/32) # x axis data
y1 = np.sin(x)             # y axis data for subplot 1
y2 = np.cos(x)             # y axis data for subplot 2
y3 = np.tan(x)             # y axis data for subplot 3

fig = plt.figure(2,figsize=(8,8)) # create figure 2

plt.subplot(311)           # (number of rows, number of columns, current plot)
plt.plot(x, y1)
plt.title('sin(x)')
plt.xlabel('x')
plt.ylabel('y')

plt.subplot(312)
plt.plot(x, y2)
plt.title('cos(x)')
plt.xlabel('x')
plt.ylabel('y')

plt.subplot(313)
plt.plot(x, y3)
plt.title('tan(x)')
plt.xlabel('x')
plt.ylabel('y')
plt.ylim(-1, 1)

fig.tight_layout()
```

## Output



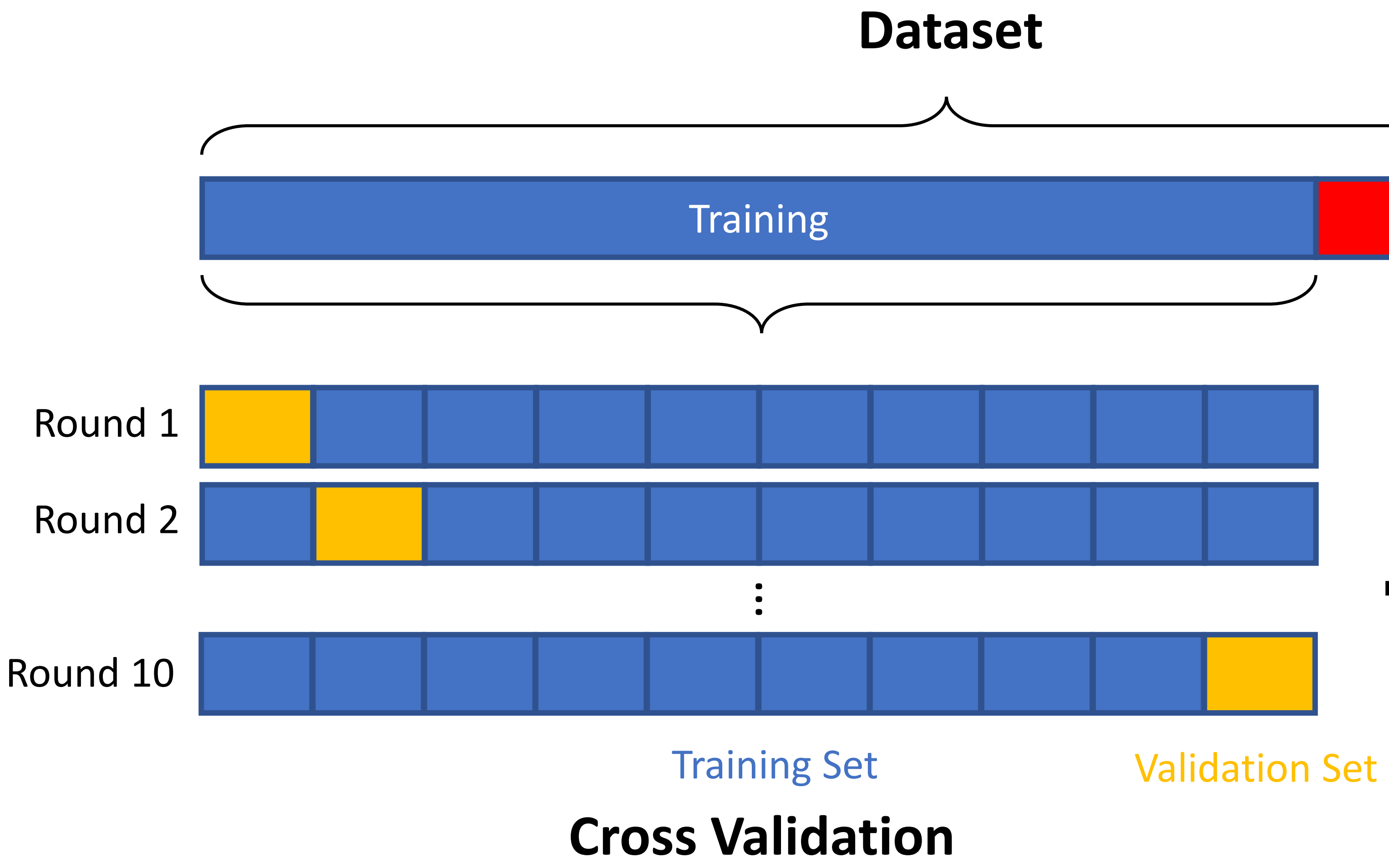
# Part 5: Working with data

# Loading dataset

```
import pandas as pd
import sklearn

# Import necessary modules
from sklearn.linear_model import LogisticRegressionCV

diabetes = pd.read_csv('diabetes.csv') # Read the dataset with pandas
diabetes.head() # Display the head of the data
```

| | Pregnancies | Glucose | BloodPressure | SkinThickness | Insulin | BMI | DiabetesPedigreeFunction | Age | Outcome |
|---|---|---|---|---|---|---|---|---|---|
| **0** | 6 | 148 | 72 | 35 | 0 | 33.6 | 0.627 | 50 | 1 |
| **1** | 1 | 85 | 66 | 29 | 0 | 26.6 | 0.351 | 31 | 0 |
| **2** | 8 | 183 | 64 | 0 | 0 | 23.3 | 0.672 | 32 | 1 |
| **3** | 1 | 89 | 66 | 23 | 94 | 28.1 | 0.167 | 21 | 0 |
| **4** | 0 | 137 | 40 | 35 | 168 | 43.1 | 2.288 | 33 | 1 |

# Dividing dataset into Train, Validation, Test



# Logistic Regression using Scikit-Learn

## Scaling the dataset

```
# Scaling the data

X1 = diabetes.values[:, :-1]                                            # Extract features
Y1 = diabetes.values[:, -1]                                             # Extract labels

# Scale the data z = (x - u) / s

X1_mean = np.mean(X1, axis = 0)                                         # Compute means
X1_std = np.std(X1, axis = 0)                                           # Compute stds
X1_mean_repeated = np.tile(X1_mean, (len(X1), 1))                       # Create repeated array of mean to match X1 dimension
X1_std_repeated = np.tile(X1_std, (len(X1), 1))                         # Create repeated array of std to match X1 dimension
X1_scaled = np.divide(np.subtract(X1, X1_mean_repeated), X1_std_repeated) # Compute z for the array
```

```
# Divide the data into training and testing

test_ratio = 0.3                          # Set the test data ratio
train_size = int(len(X1)*(1-test_ratio))      # Set training data size based on test ratio

X_train = X1_scaled[:train_size]
X_test = X1_scaled[train_size:]
Y_train = Y1[:train_size]
Y_test = Y1[train_size:]
```

**Define Training and Testing sets**

```
# Use cross validation to train
model = LogisticRegressionCV(cv=10).fit(X_train, Y_train)
result = model.score(X_test, Y_test)

print("Accuracy: %.2f%%" % (result*100))
```

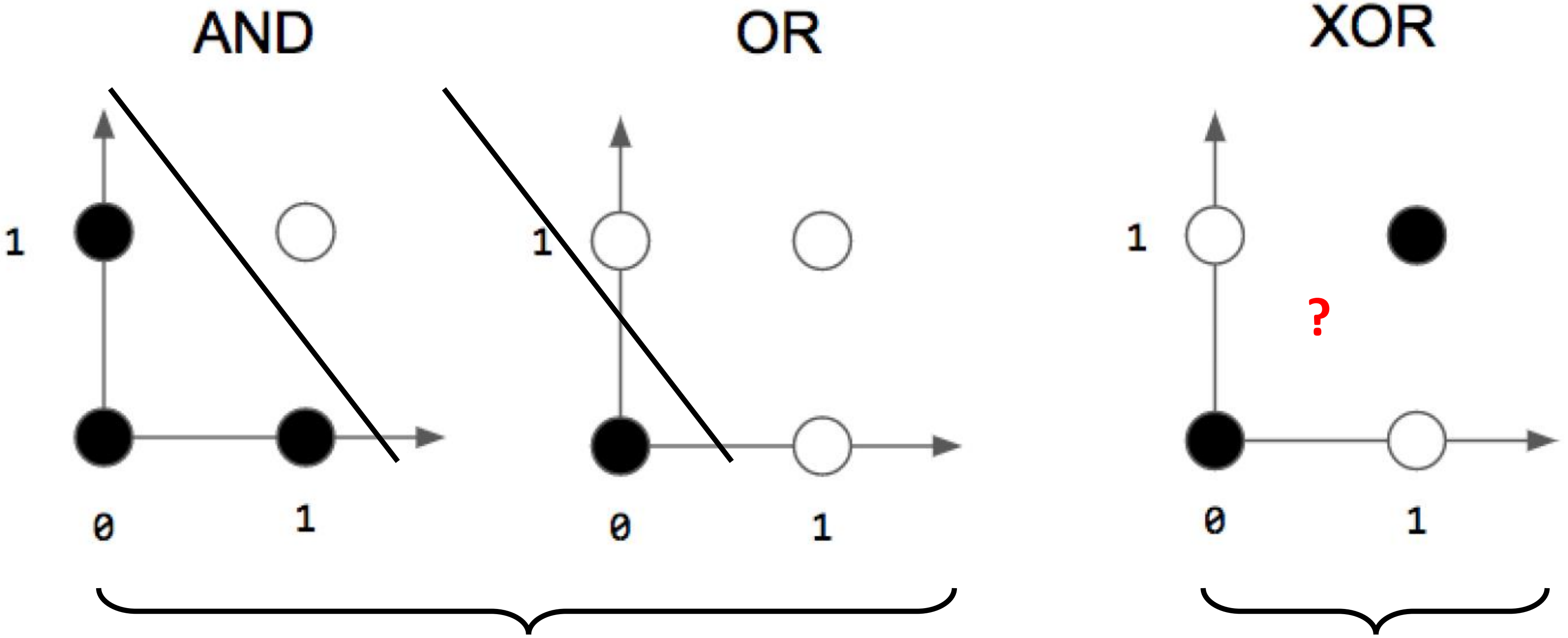
```
Accuracy: 78.79%
```

**Perform Logistic Validation with CV**

# Lab Assignment:

## Implement Neural Network for XOR gate with Numpy

# XOR Problem




**Linearly separable**

**NOT Linearly separable**

# Loading dataset into Numpy array

## Using Pandas

```
# XOR table

# Using Pandas
import pandas as pd

XOR_table = pd.read_csv('XOR_table.csv')
XOR_table
```

| | x1 | x2 | y |
|---|---|---|---|
| **0** | 0 | 0 | 0 |
| **1** | 0 | 1 | 1 |
| **2** | 1 | 0 | 1 |
| **3** | 1 | 1 | 0 |

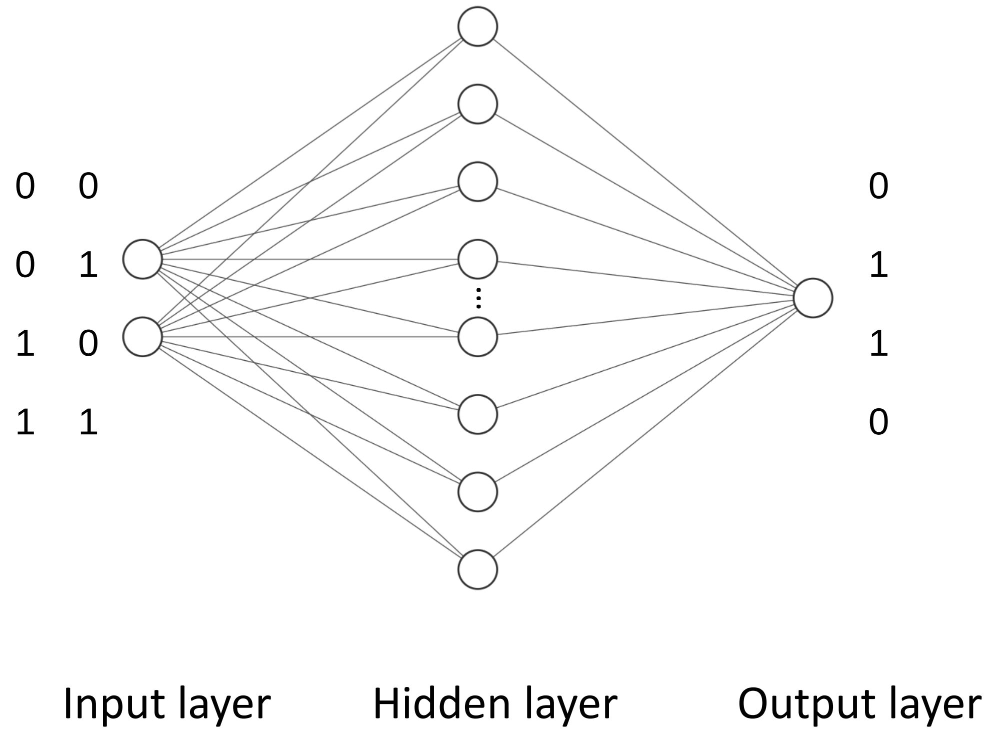
## Converting data into Numpy array

```
XOR_table = XOR_table.values
X = XOR_table[:, :2]
targets = XOR_table[:, -1].reshape(-1,1)

print(X)        # Input data
print(targets) # Output targets
```

```
[[0 0]
 [0 1]
 [1 0]
 [1 1]]
[[0]
 [1]
 [1]
 [0]]
```

# Solving XOR with a neural network

```
# Define dimensions on input, hidden and output layers
input_dim, hidden_dim, output_dim =

# Define learning rate
learning_rate=

# Define a hidden layer
W1=
# Define an output layer
W2=
# Define sigmoid activation function

for i in range(10000):

  # Forward pass: compute predicted y

  # Compute and print loss

  # Backprop to compute gradients of w1 and w2 with respect to L2-norm loss

  # Update weights

  # Save loss to an array
```



# Solving XOR with a neural network (Forward Pass)

Feed Forward Eqns

$z = \sigma(W_1 x + b_1)$

$y = \sigma(W_2 \sigma(W_1 x + b_1) + b_2)$

$y = \sigma(W_2 z + b_2)$

Activation (sigmoid)

$$\sigma(x) = \frac{1}{1 + e^{-x}}$$

L2-Loss Function

$$J = \sum_{i=1}^{N} (y - t)^2$$

$y = predicted\ output$

$t = Target\ output$

# Solving XOR with a neural network (Backward Pass)

Derivative of Activation

$$\frac{d(\sigma(x))}{dx} = \frac{1}{1+e^{-x}} * \left(1 - \frac{1}{1+e^{-x}}\right)$$

$$= \sigma(x)\big(1 - \sigma(x)\big)$$

Gradient of $J$ w.r.t. $W_2$

$$\frac{\partial J}{\partial W_2} = \frac{\partial J}{\partial y}\frac{\partial y}{\partial W_2}$$

$$\frac{\partial J}{\partial y} = 2(y-t)$$

$$\frac{\partial y}{\partial W_2} = \sigma(W_2 z + b_2)(1-\sigma(W_2 z + b_2))z$$

$$\frac{\partial J}{\partial W_2} = 2(y-t)y(1-y)z$$

Gradient of $J$ w.r.t. $W_1$

$$\frac{\partial J}{\partial W_1} = \frac{\partial J}{\partial y}\frac{\partial y}{\partial z}\frac{\partial z}{\partial W_1}$$

$$\frac{\partial J}{\partial y} = 2(y-t)$$

$$\frac{\partial y}{\partial z} = \sigma(W_2 z + b_2)(1-\sigma(W_2 z + b_2))W_2$$

$$\frac{\partial z}{\partial W_1} = \sigma(W_1 x + b_1)(1-\sigma(W_1 z + b_1))x$$

$$\frac{\partial J}{\partial W_1} = 2(y-t)y(1-y)W_2 z(1-z)x$$

Update rule for $W_2$

$$W_2 = W_2 - \alpha\frac{\partial J}{\partial W_2}$$

$$W_2 = W_2 - \alpha 2(y-t)y(1-y)z$$

Update rule for $W_1$

$$W_1 = W_1 - \alpha\frac{\partial J}{\partial W_1}$$

$$W_1 = W_1 - \alpha 2(y-t)y(1-y)W_2 z(1-z)x$$