Human Brain VS Computer

Motivation

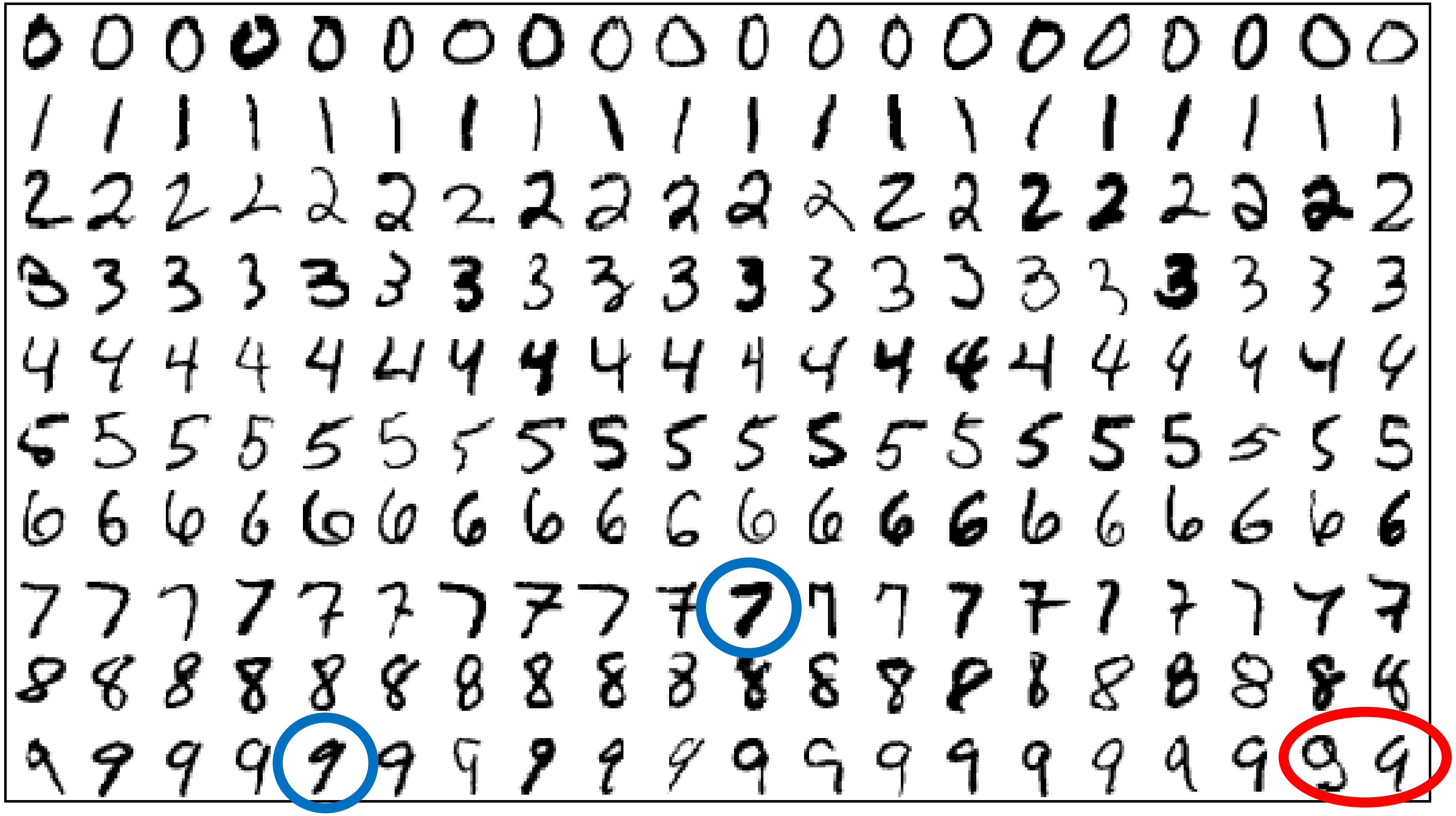
Human mind - Good at image recognition, pattern recognition etc

Computer - Good at arithmetic calculations

$$2574304 \times e^{354} \div \tan 5.1\pi$$

Handwriting recognition

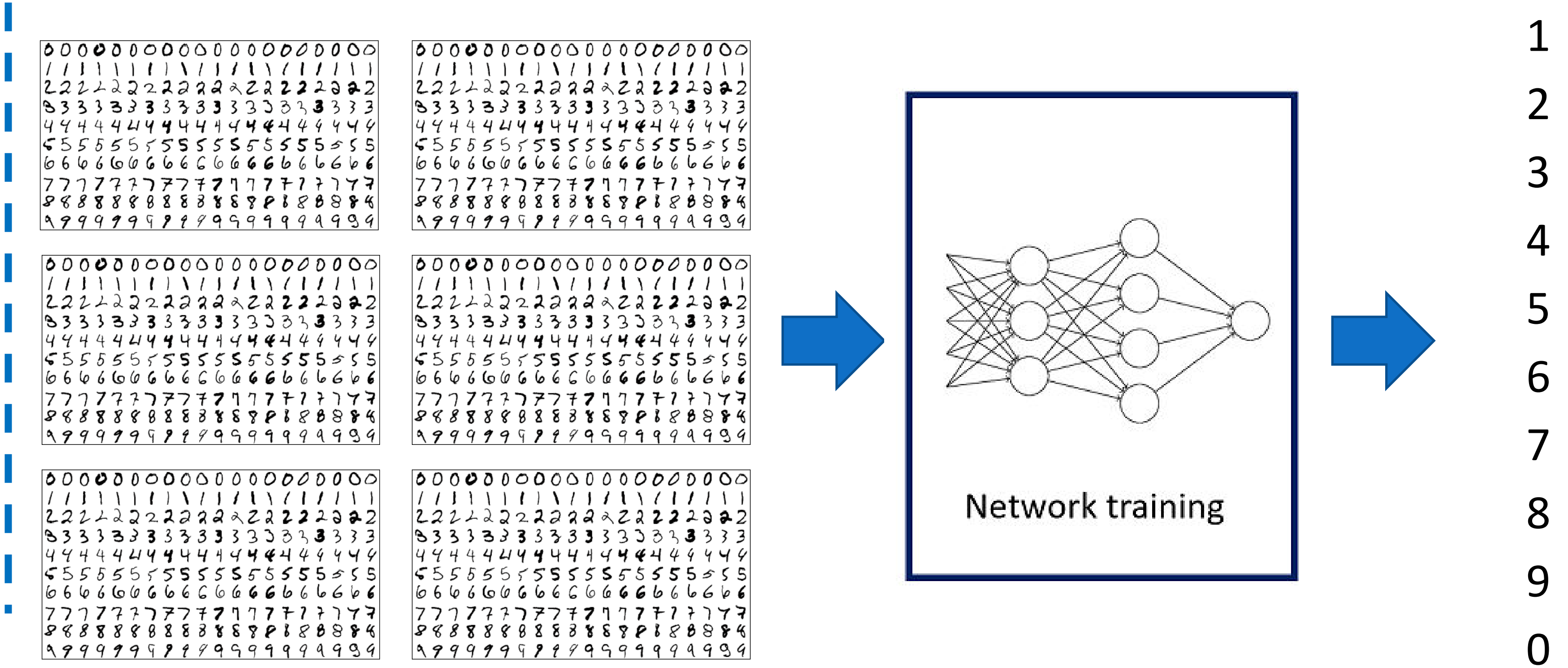
Making precise rules is difficult



Neural Networks

Pattern recognition

Neural Networks creates own complex pattern recognition rules



Network training

1
2
3
4
5
6
7
8
9
0

Training data

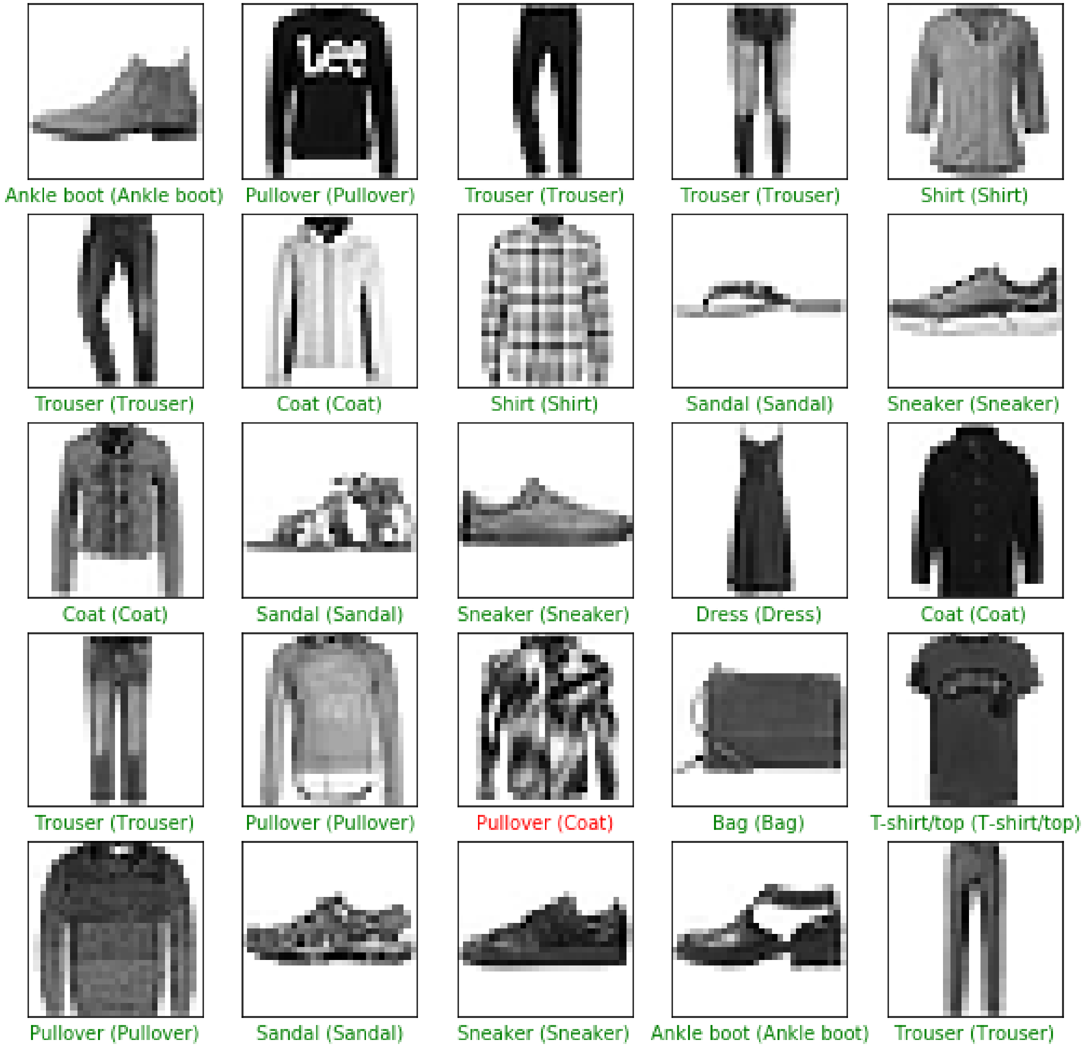
Future Prediction

Dataset

Fashion MNIST

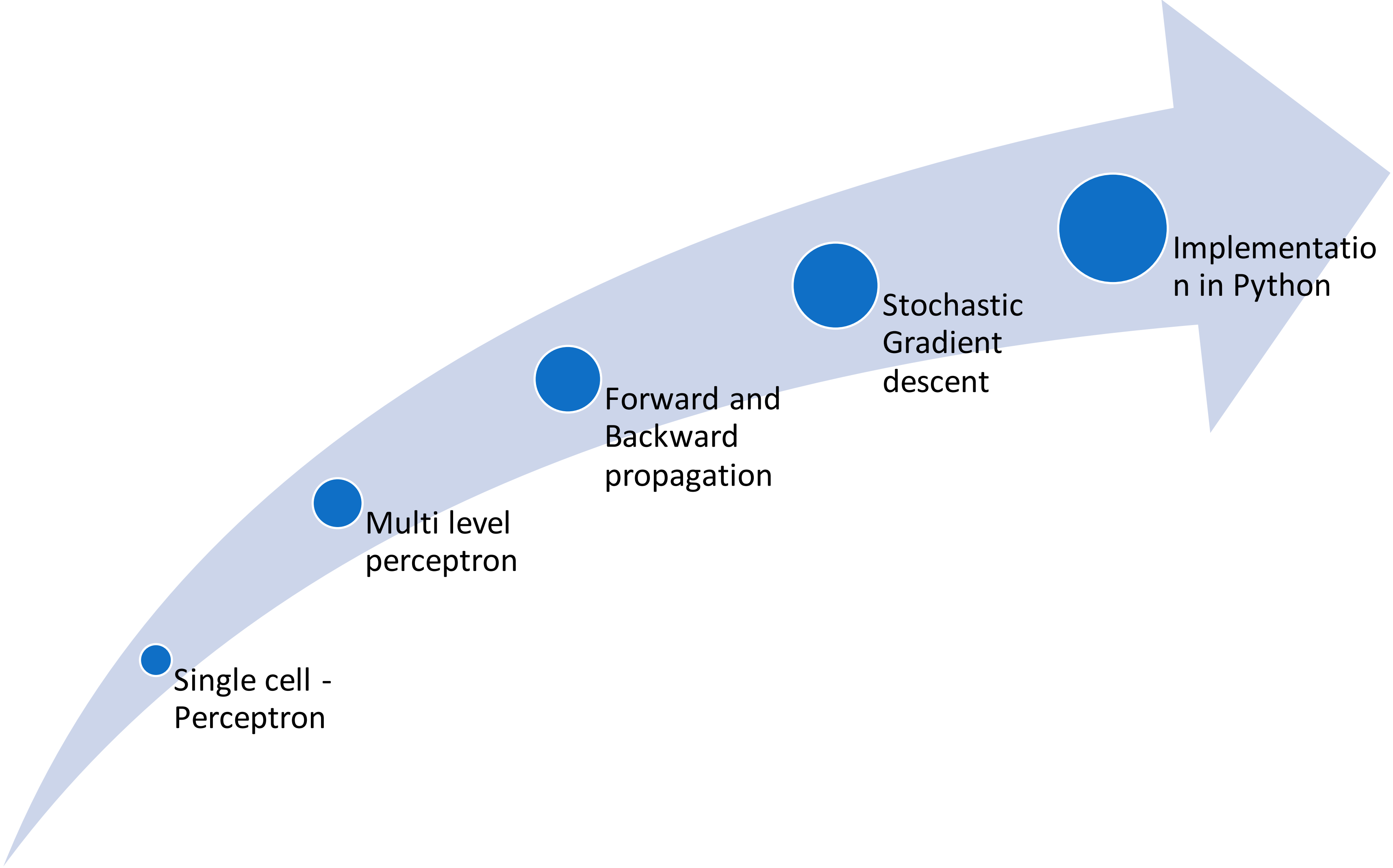
We will classify images

into 10 fashion items



Course Flow

Course Flow



Single cell - Perceptron

Multi level perceptron

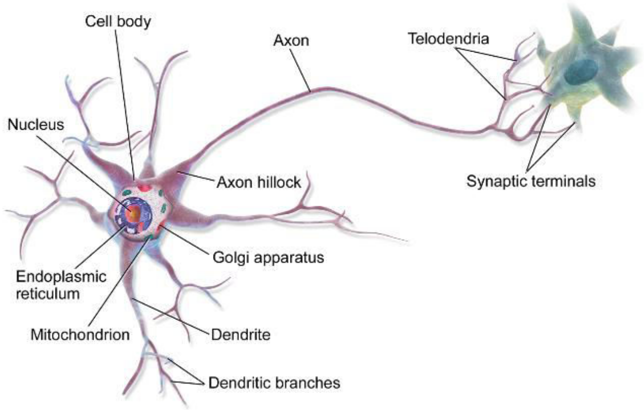
Forward and Backward propagation

Stochastic Gradient descent

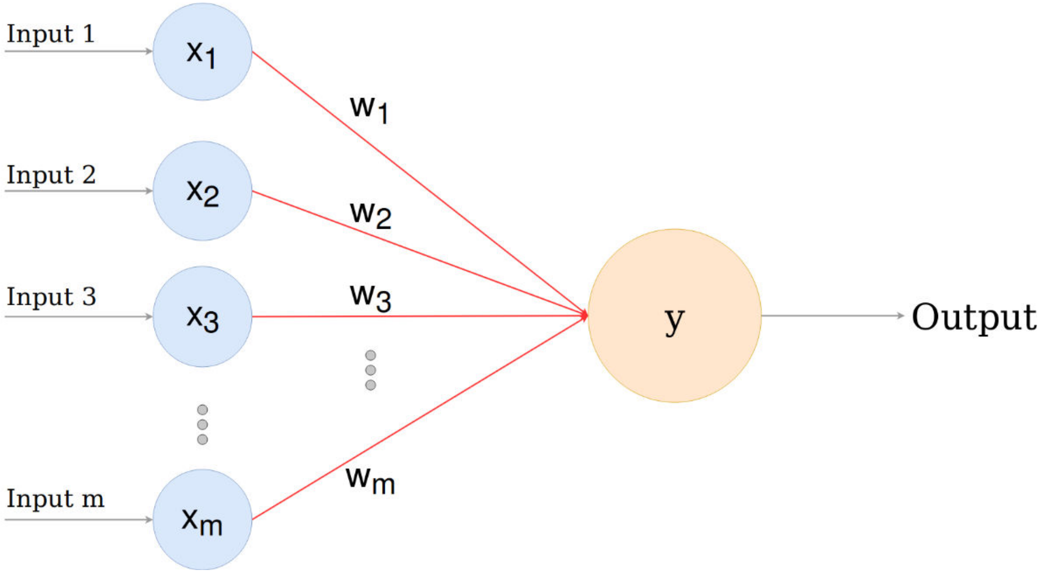
Implementation in Python

Perceptron

Artificial Neuron



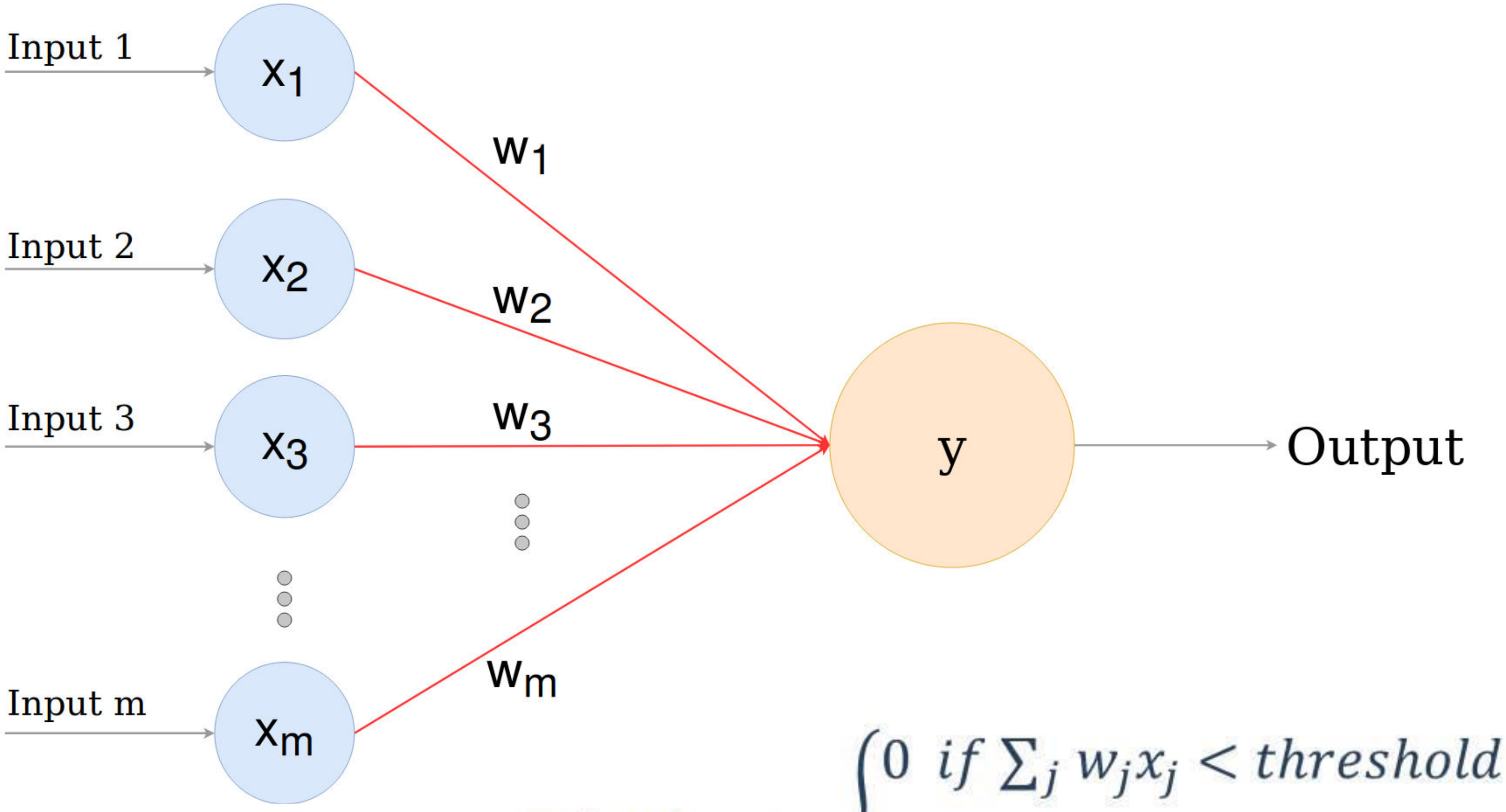
Biological Neuron



Artificial Neuron

Perceptron

Artificial Neuron



$$output = \begin{cases} 0 \ if \sum_j w_j x_j < threshold \\ 1 \ if \sum_j w_j x_j > threshold \end{cases}$$

Example

Purchasing a Shirt

Color

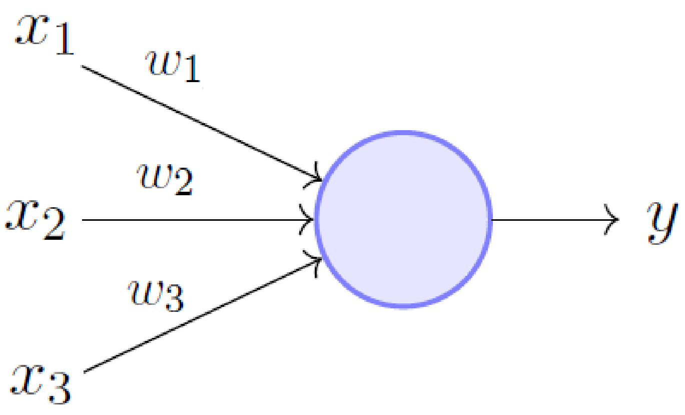
- Blue or Not

Sleeves

- Full or half

Fabric

- Cotton or not



You will buy the shirt or not

Example

Purchasing a Shirt

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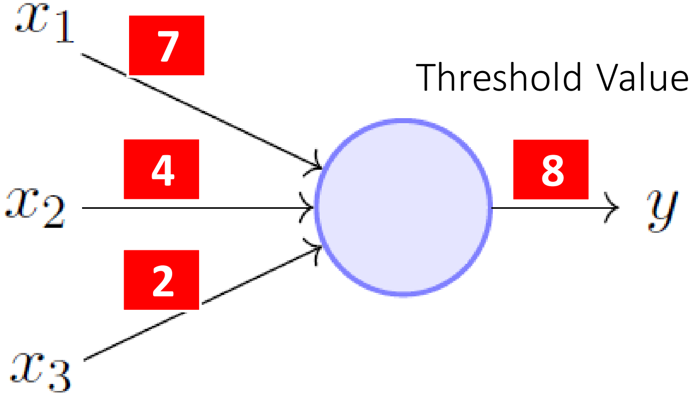

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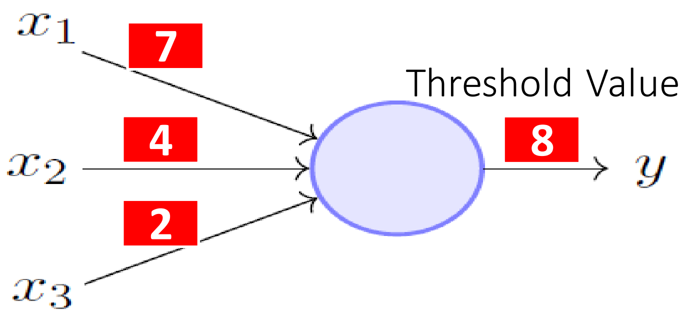


You will buy the shirt or not

Color	Sleeves	Fabric	Calculated Sum	Threshold	Buy / Not Buy
Blue	Half	Non Cotton	7*1 + 4*0 + 2*0 = 7	8	Not buy
Blue	Full	Non Cotton	11	8	Buy
Not Blue	Full	Cotton	6	8	Not Buy

Example

Purchasing a Shirt

Color

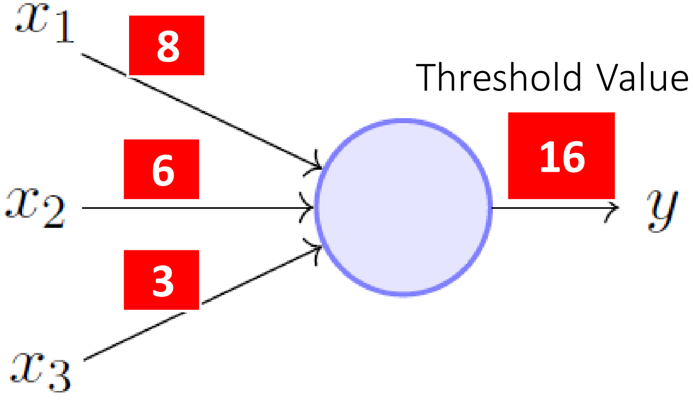
- Blue or Not

Sleeves

- Full or half

Fabric

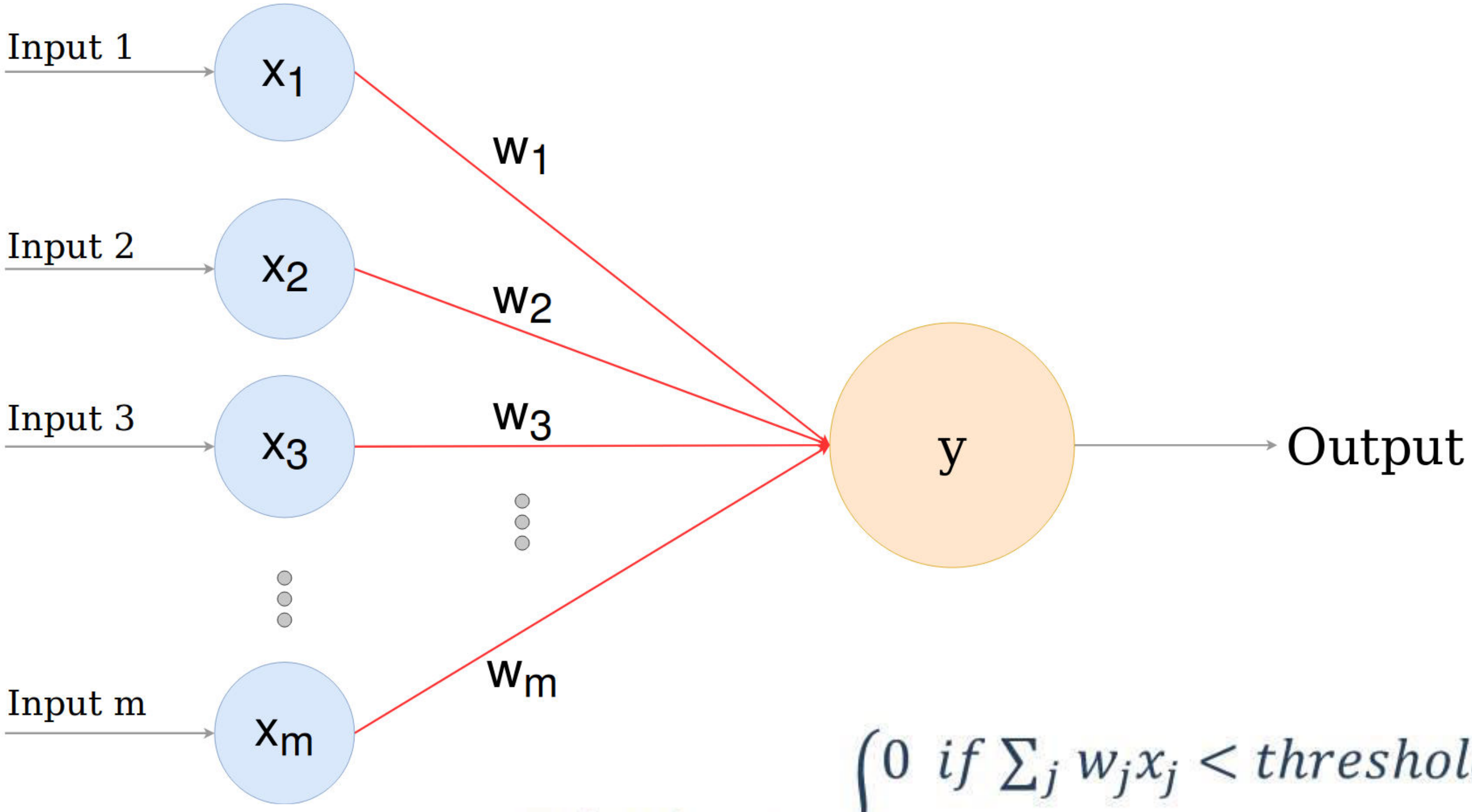
- Cotton or not



You will buy the shirt or not

Perceptron

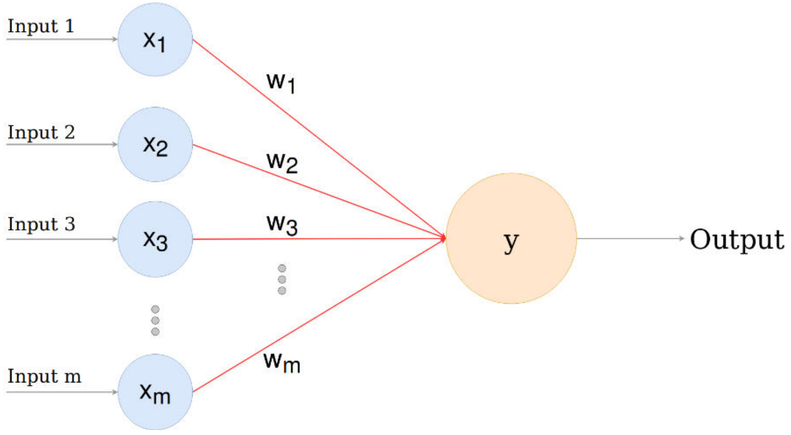
Removing Binary Restriction



$$output = \begin{cases} 0 \ \ if \sum_j w_j x_j < threshold \\ 1 \ \ if \sum_j w_j x_j > threshold \end{cases}$$

Perceptron

Standard Equation



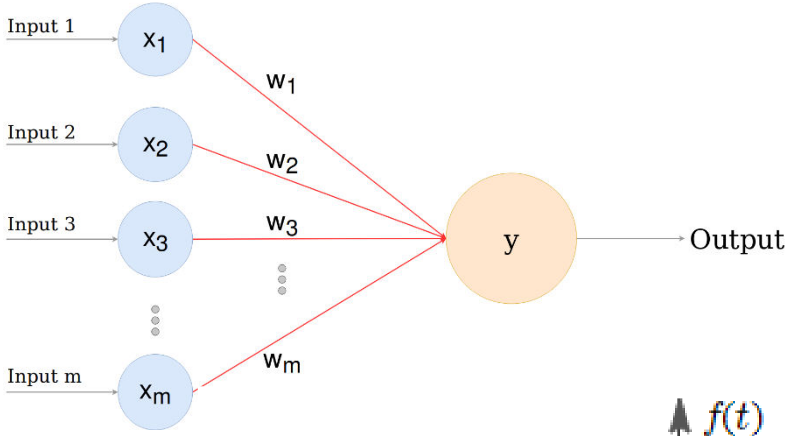
$$output \;=\; \begin{cases} 0 \;\; if \sum_j w_j x_j < threshold \\ 1 \;\; if \sum_j w_j x_j > threshold \end{cases}$$

$$Output \;=\; \begin{cases} 0, & \sum_j w_j\, x_j + b \;< 0 \\ 1, & \sum_j w_j\, x_j + b \geq 0 \end{cases}$$

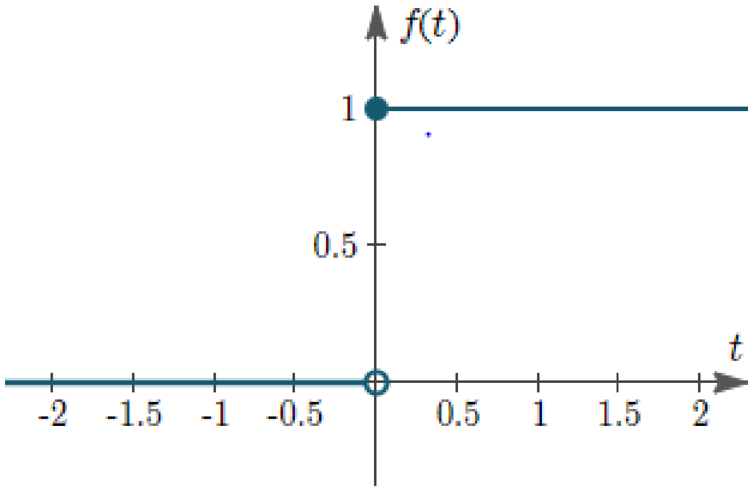
b is called Bias

Perceptron

Graphical Representation



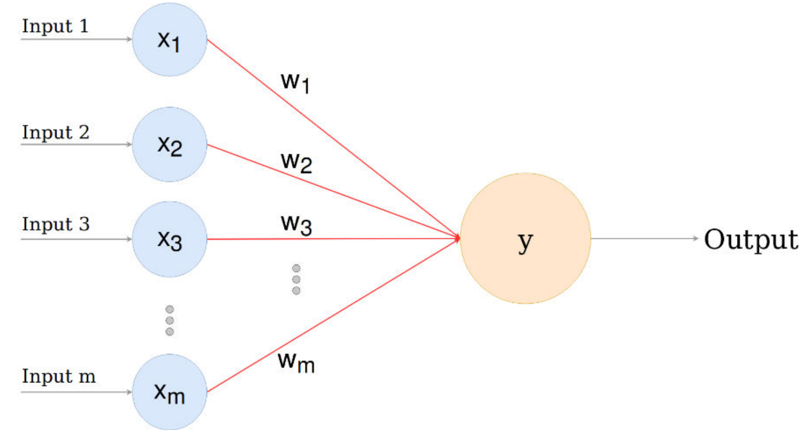
$$Output = \begin{cases} 0, & \sum_j w_j x_j + b < 0 \\ 1, & \sum_j w_j x_j + b \geq 0 \end{cases}$$



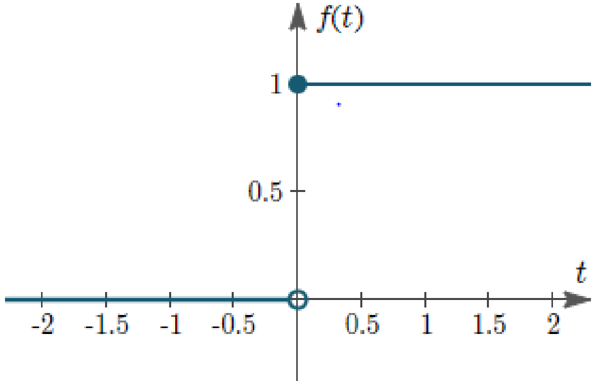
Step Activation function

Perceptron

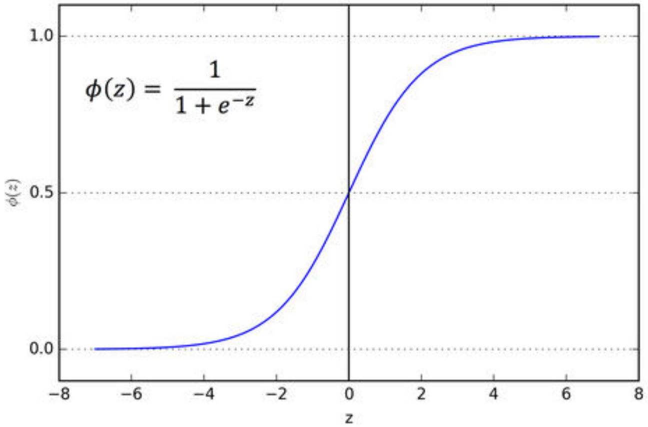
Sigmoid Activation



$$Output = \begin{cases} 0, & \sum_j w_j x_j + b < 0 \\ 1, & \sum_j w_j x_j + b \geq 0 \end{cases}$$



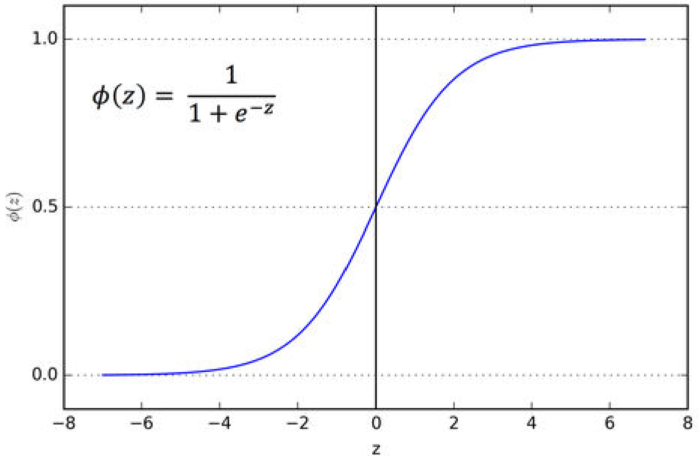
Step Activation function



Sigmoid Activation function

Perceptron

Sigmoid Activation



Sigmoid Activation function

- Sigmoid is better because it is less sensitive to individual observation
- Artificial neuron with sigmoid activation is called sigmoid or logistic neuron

$$\sigma(z) \equiv \frac{1}{1+e^{-z}}.$$

$$Output = \frac{1}{1+\exp(-\sum_j w_j x_j - b)}.$$

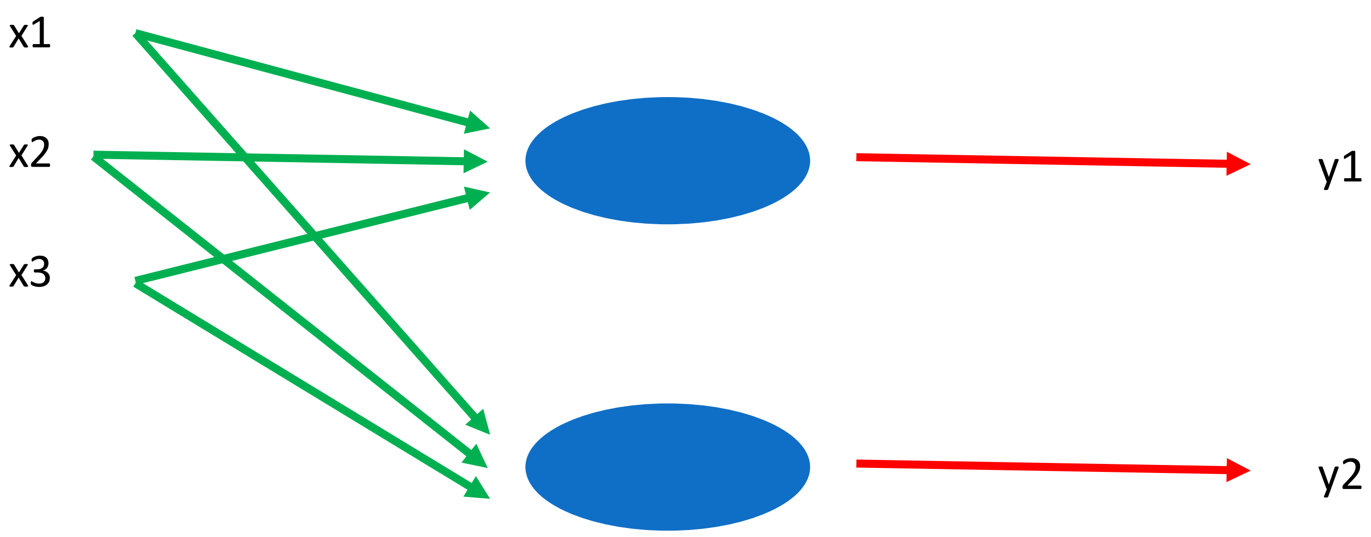
Making Networks

Two types of Stacking

- Parallel
- Sequential

Making Networks

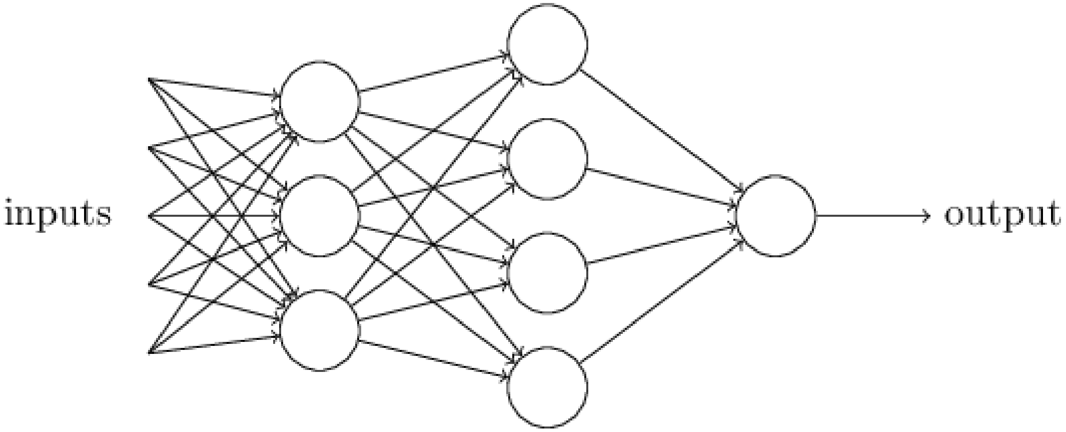
Parallel Stacking



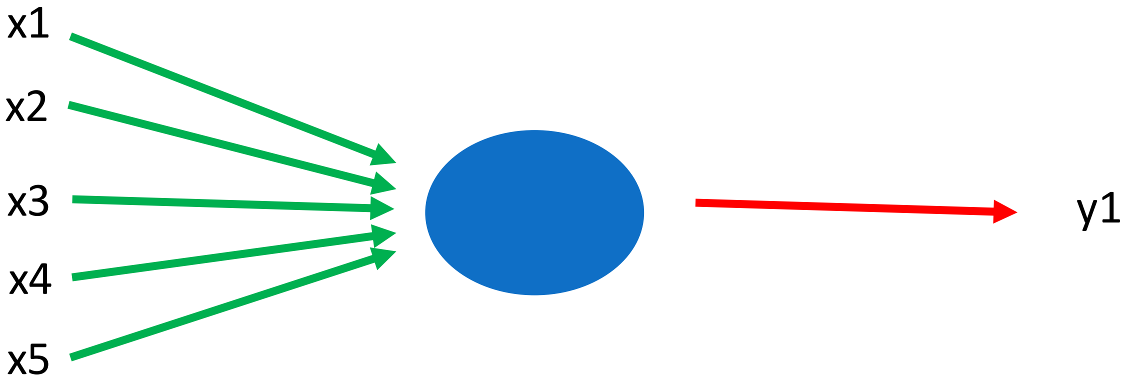
With parallel stacking we can get multiple outputs with the same input

Making Networks

Sequential Stacking

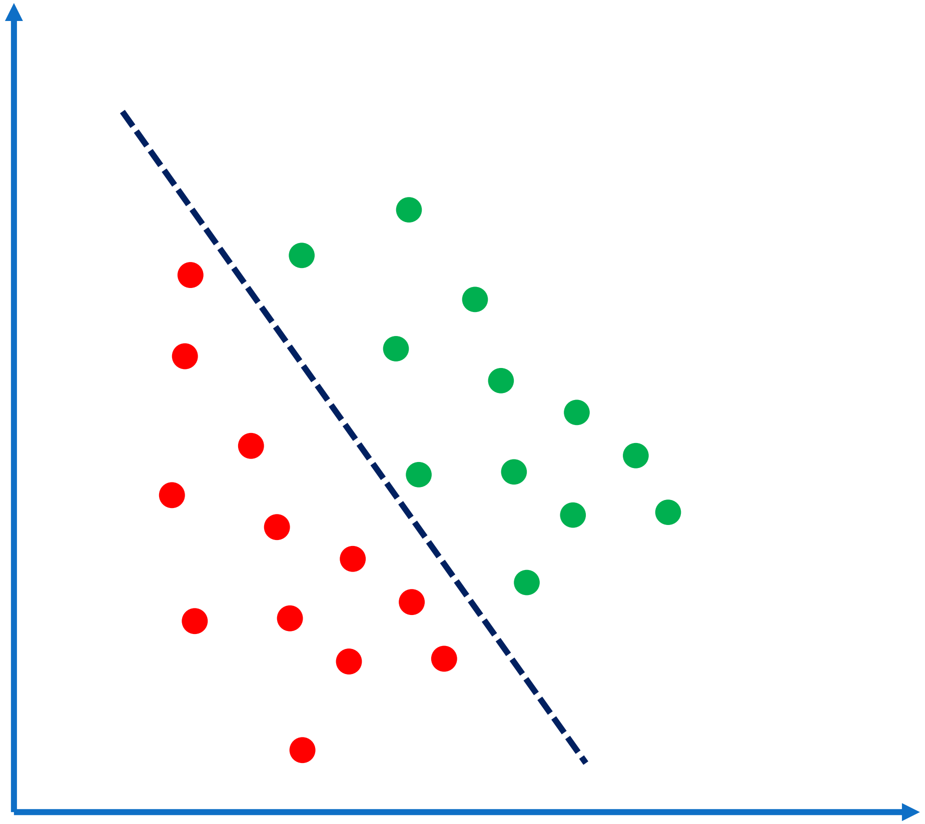


Why not use a single neuron



Making Networks

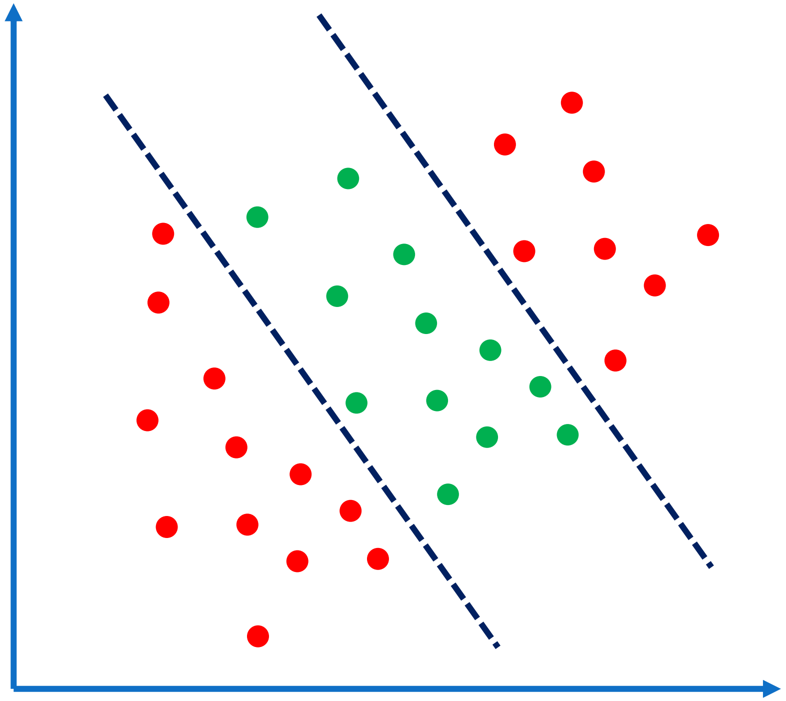
Sequential
Stacking

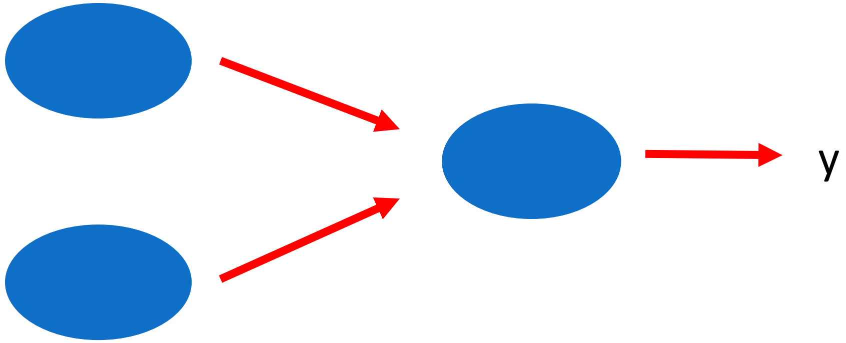


Single neuron can handle such linear classification problem

Making Networks

Sequential Stacking

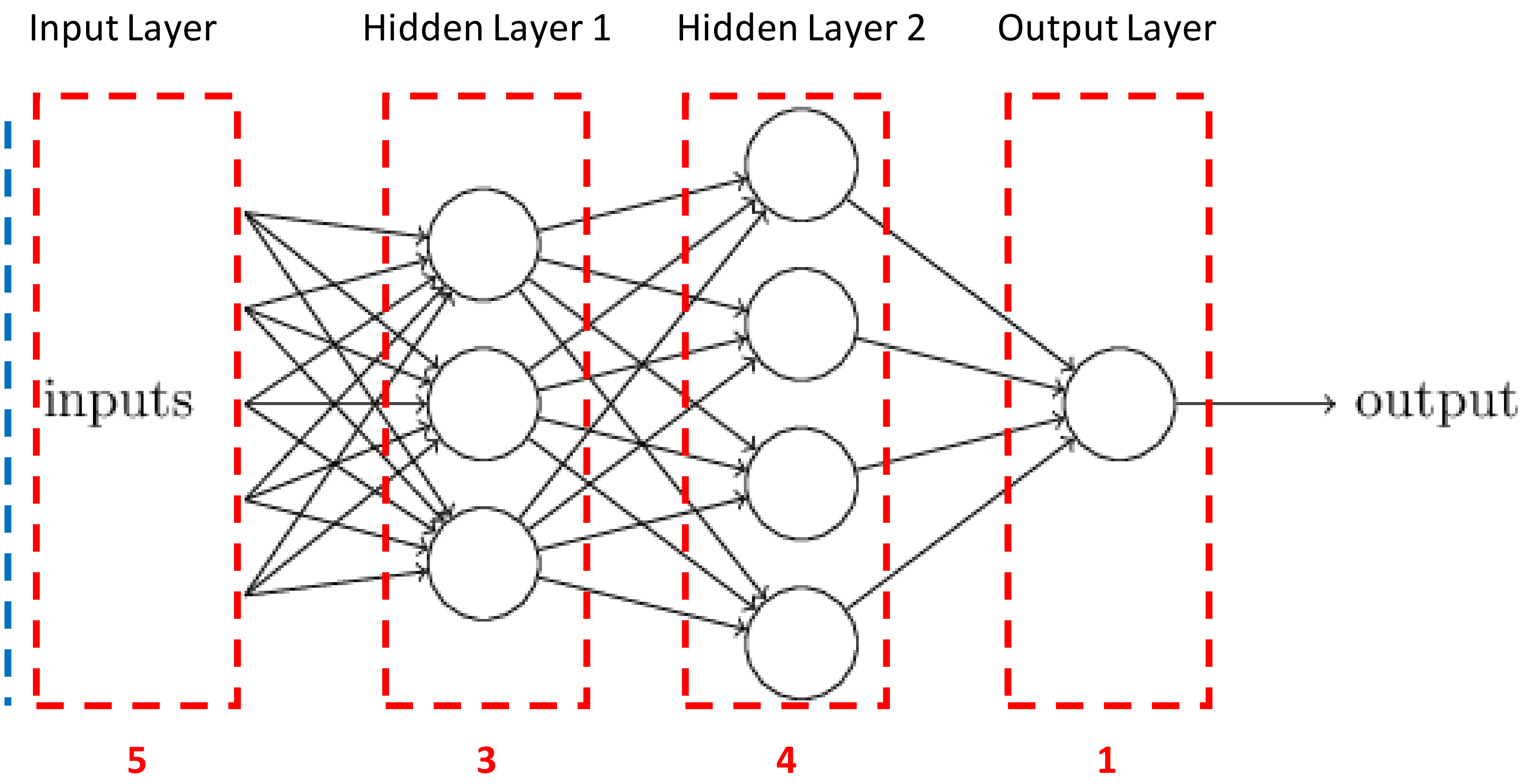




Each neuron can focus on the particular features of the object instead of the final outcome

Making Networks

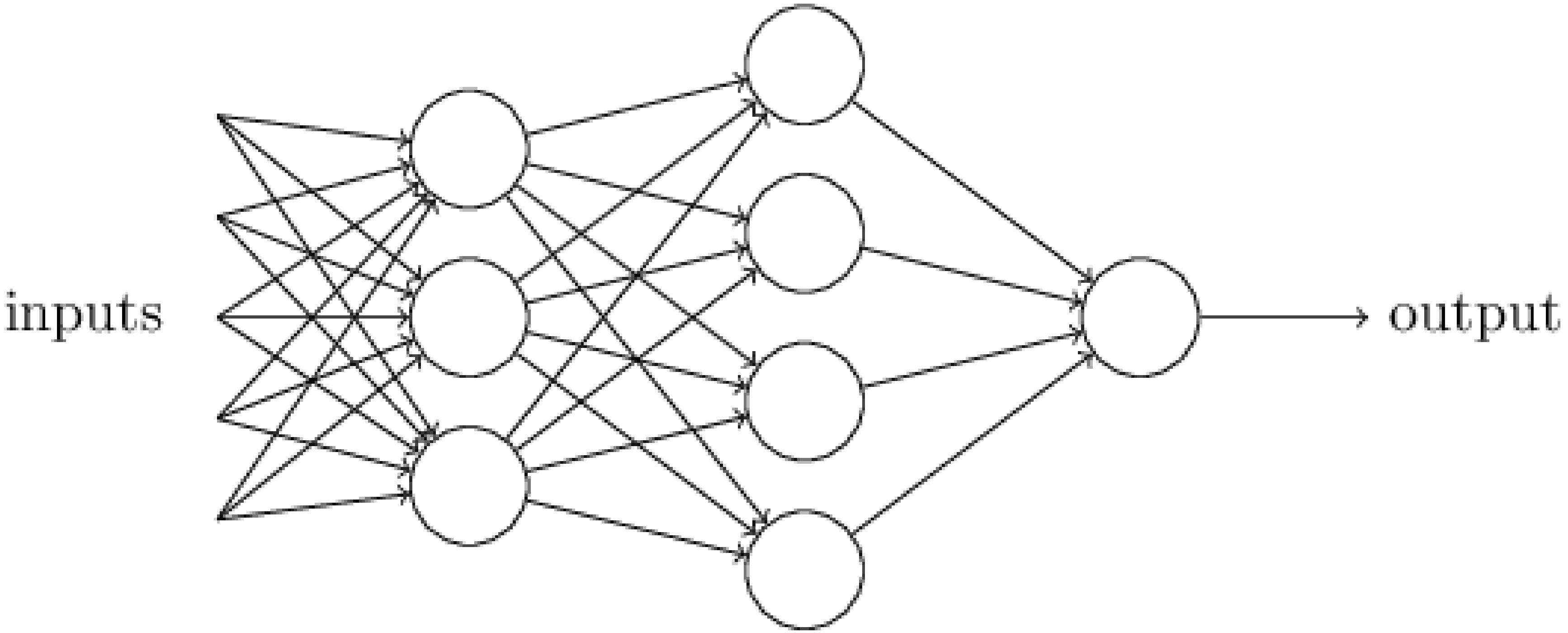
Nomenclature



5-3-4-1 Network

Making Networks

Nomenclature



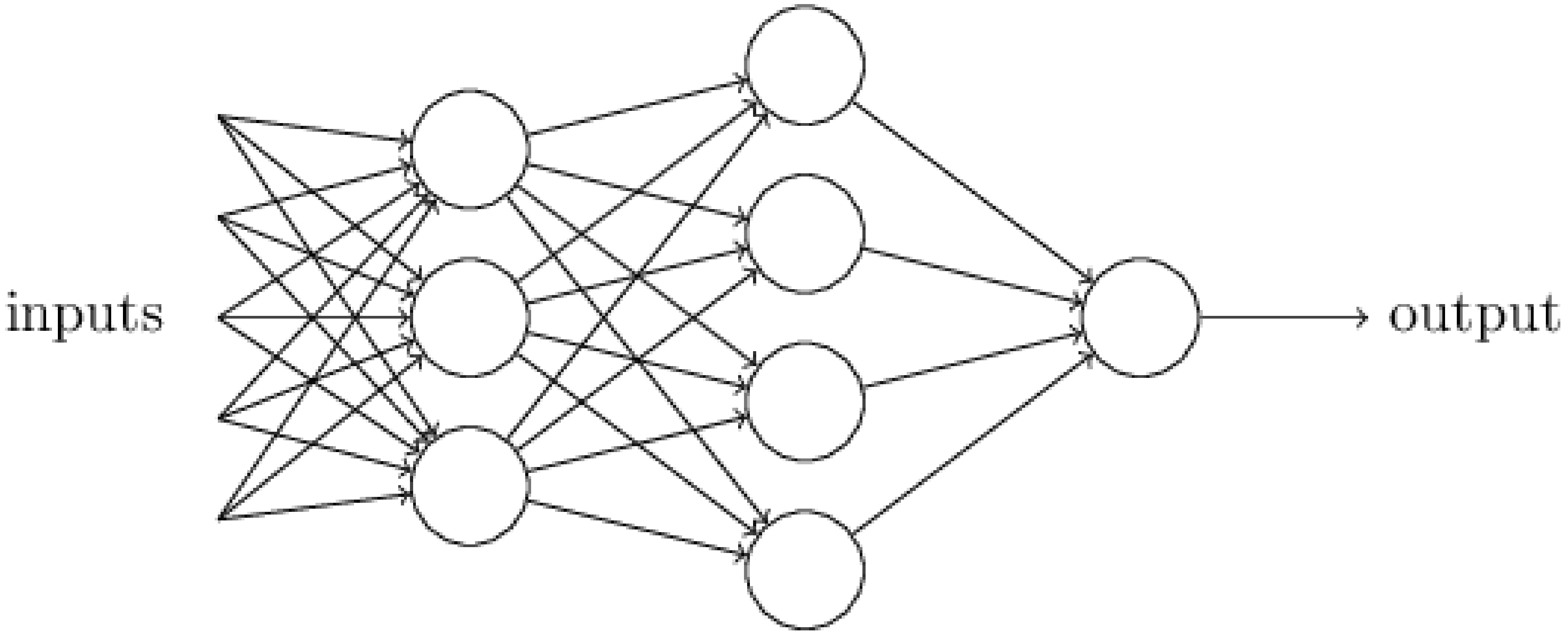
Feed Forward Network – One directional processing

Fully connected network – Output from a neuron goes to all neurons of next layer

Deep Learning

Such artificial neural networks primarily constitutes deep learning

Deep Learning



More number of layers => Deeper network => More complex relationships

Neural Network

How it works

Covered till Now

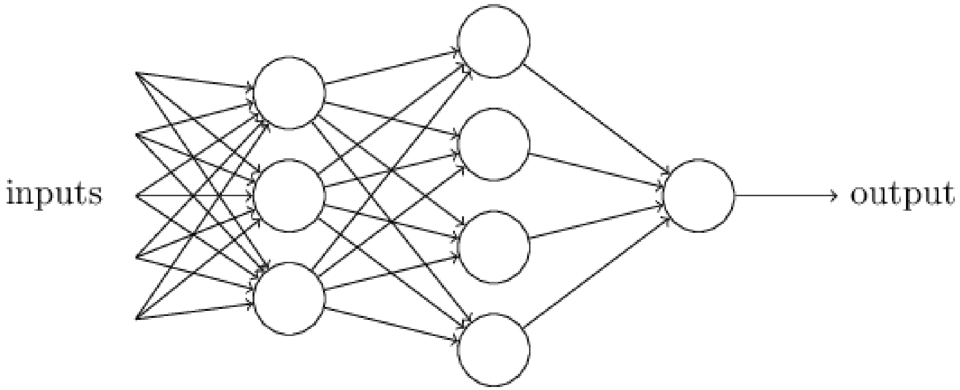
- What is a neural network

Now we are going to learn

- How does a neural network works

Problem Statement

Quick Recap



$$\sigma(z) \equiv \frac{1}{1+e^{-z}}.$$

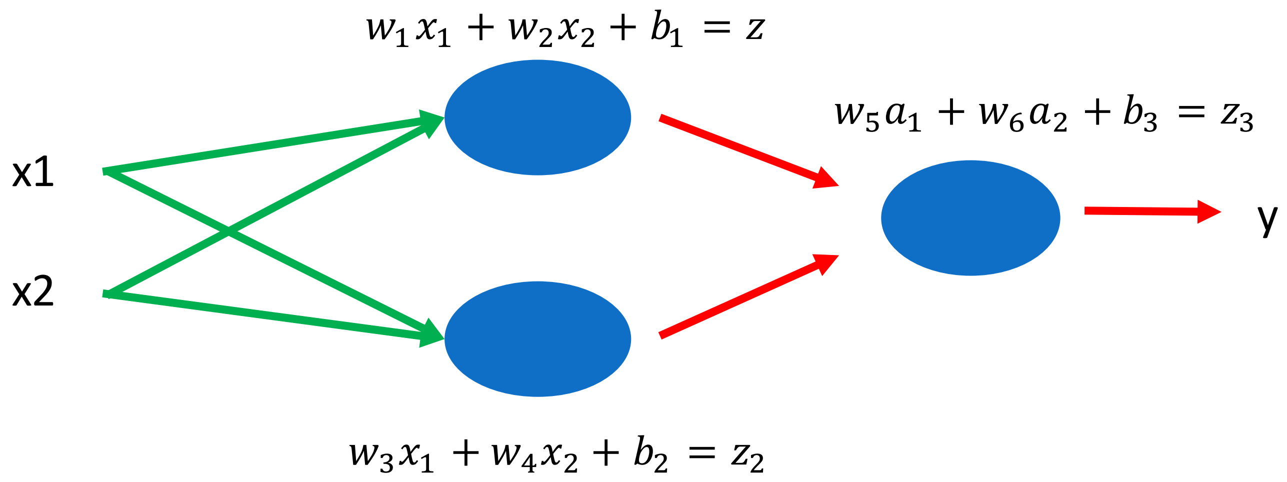
$$Output = \frac{1}{1+\exp(-\sum_j w_j x_j - b)}.$$

Problem Statement

- Establish the values of weights and biases so that predicted output is as close to actual output as possible

Problem Statement

Example



$$w_1 x_1 + w_2 x_2 + b_1 = z$$

$$w_5 a_1 + w_6 a_2 + b_3 = z_3$$

$$w_3 x_1 + w_4 x_2 + b_2 = z_2$$

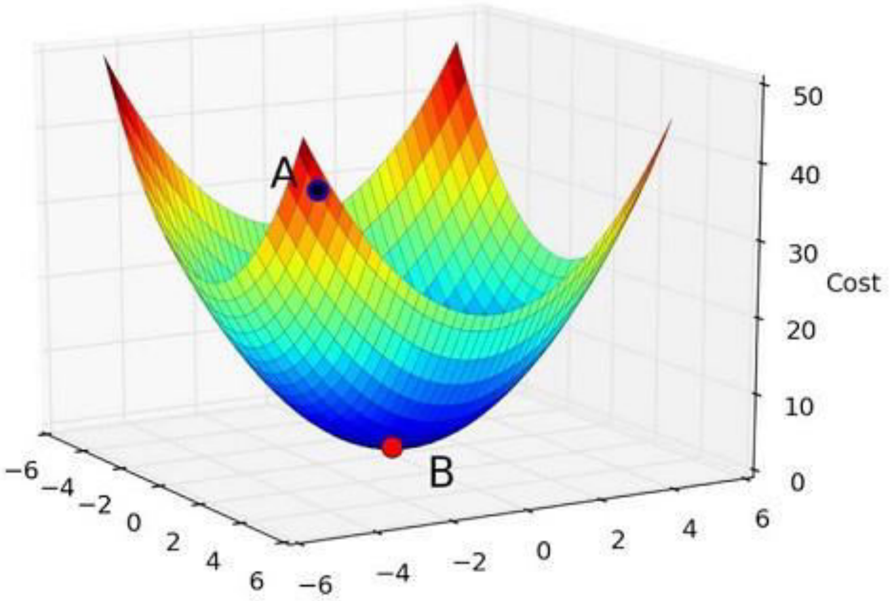
Variables to be established in this neural network

- Weights - W1, W2.........W6
- Biases - B1, B2, B3

Total - 9 variables

Neural Network

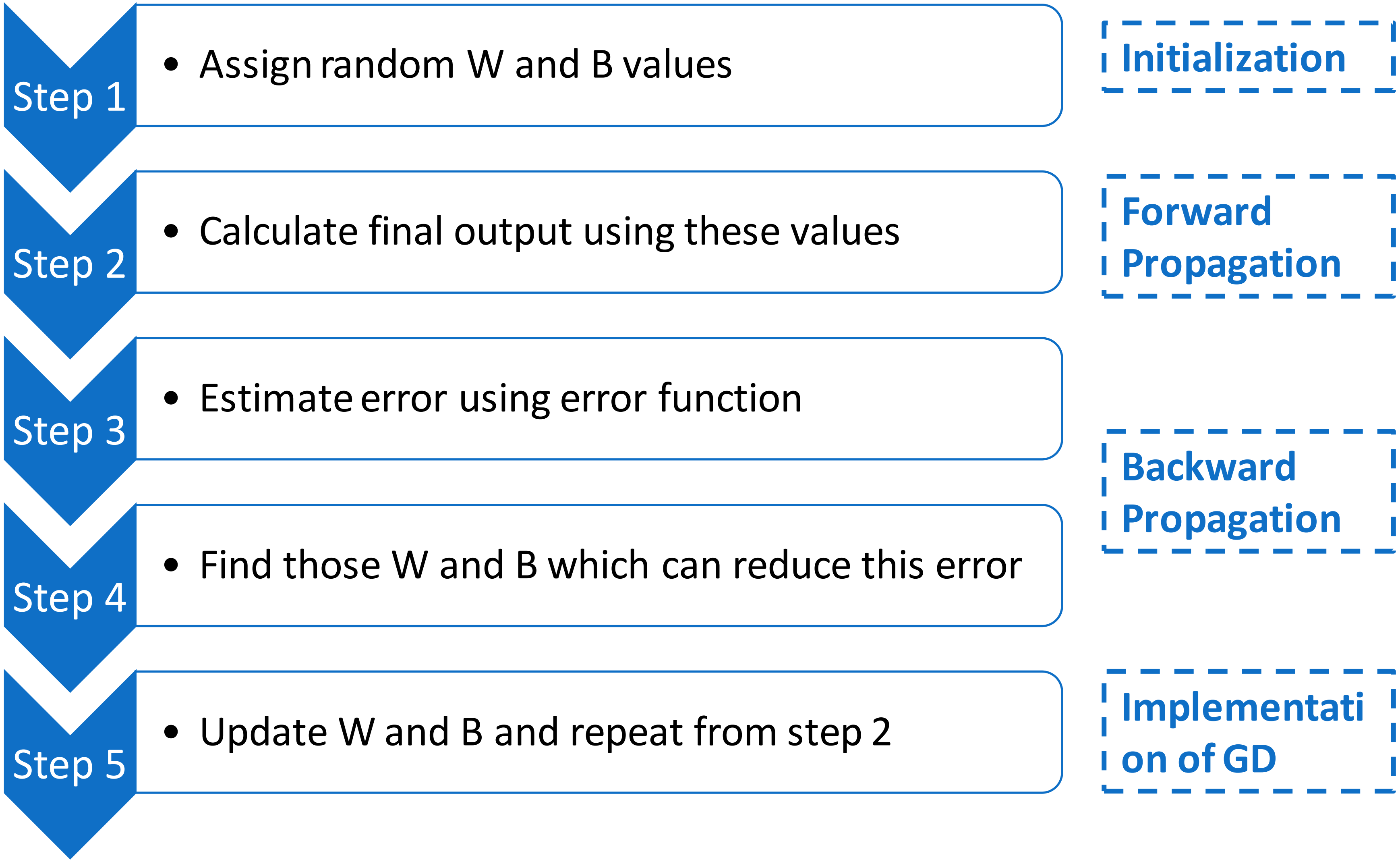
Gradient Descent



- GD is an optimization technique to find minimum of a function
- Better than other technique such as OLS when we have large number of features and complex relationships

Gradient Descent

Process



Step 1
- Assign random W and B values

Initialization

Step 2
- Calculate final output using these values

Forward Propagation

Step 3
- Estimate error using error function

Step 4
- Find those W and B which can reduce this error

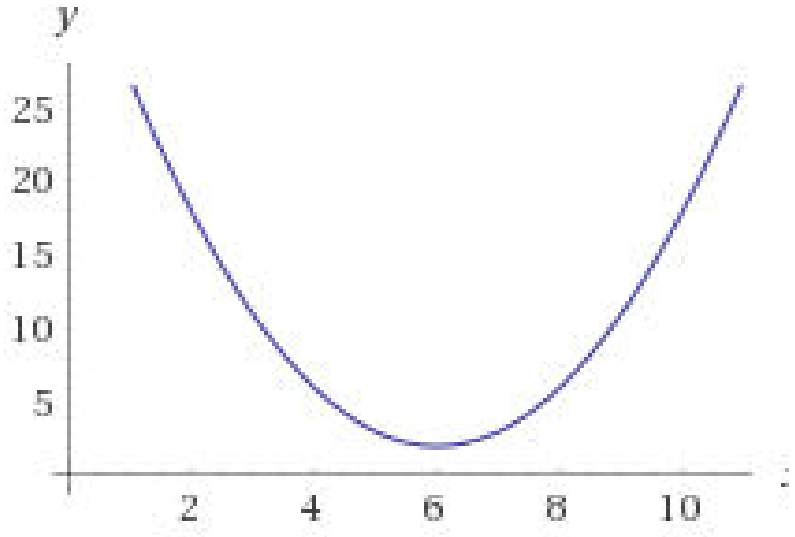
Backward Propagation

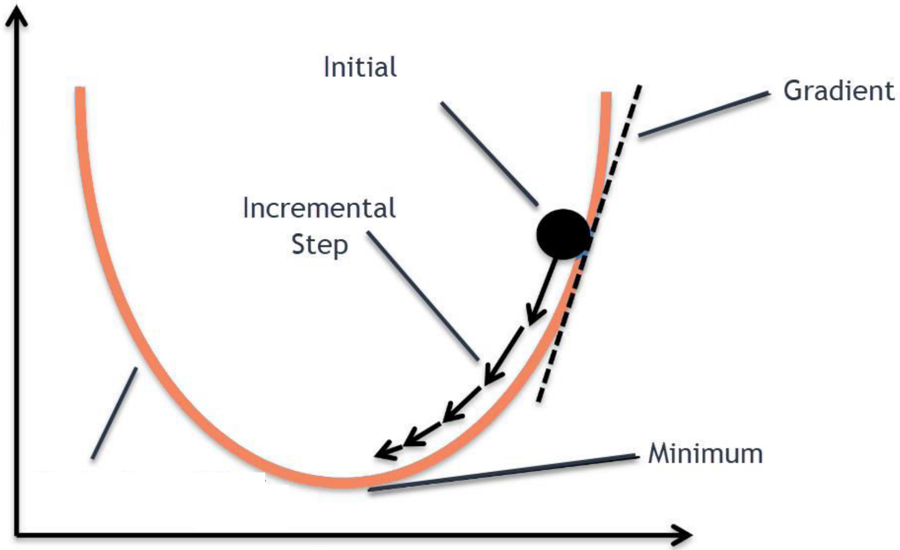
Step 5
- Update W and B and repeat from step 2

Implementation of GD

Neural Network

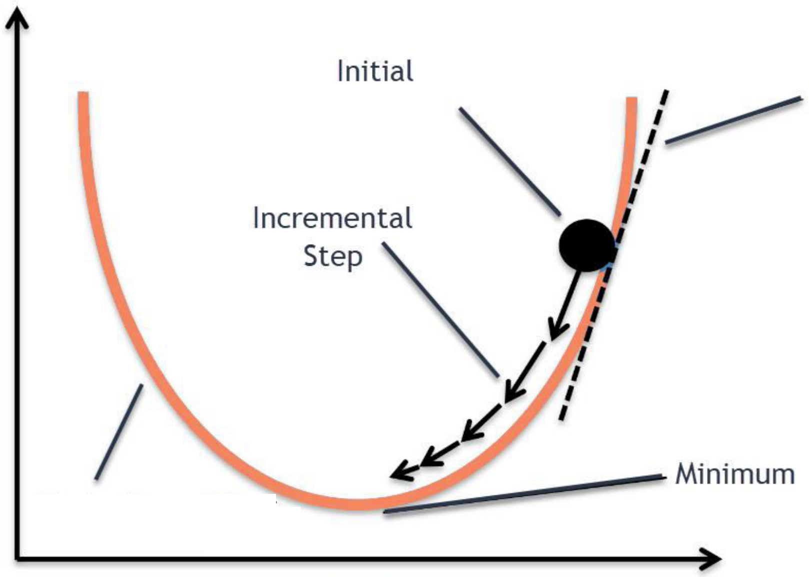
Gradient Descent





Neural Network

Gradient Descent



1. Start at a random point
2. Find out the instantaneous slope at that point
3. Slightly move in the direction of steepest slope
4. Reiterate

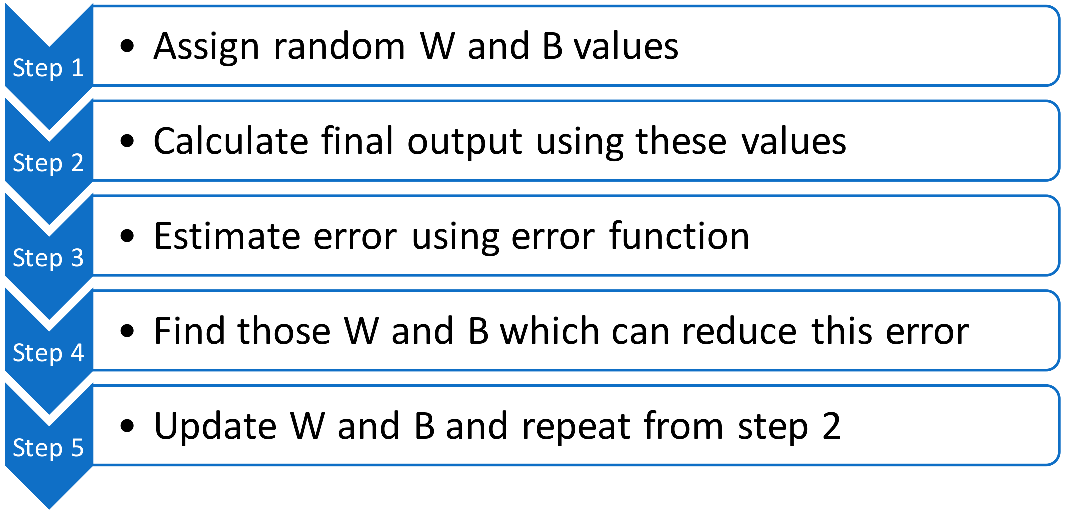
Gradient

Descent

Gradient Descent

Gradient Descent

Error Function



Step 1
- Assign random W and B values

Step 2
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Step 3
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Step 5
- Update W and B and repeat from step 2

Error Function

Assume predicted output = 0.3 , actual output = 0

Distance =0 - 0.3 = -0.3

Error Function $_1$ = |-0.3|= 0.3

Error Function $_2$ = (-0.3)^2= 0.09

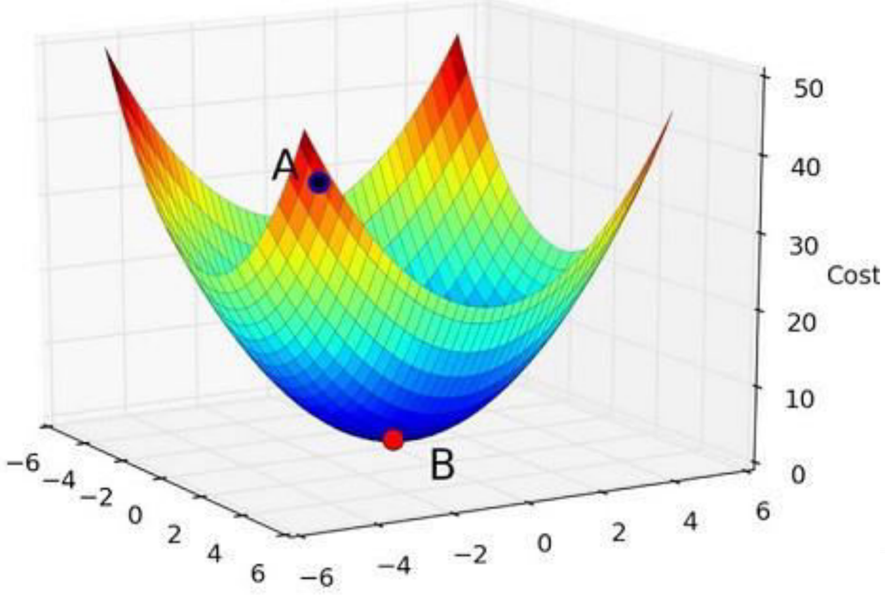
Square function works well with regression but not with classification

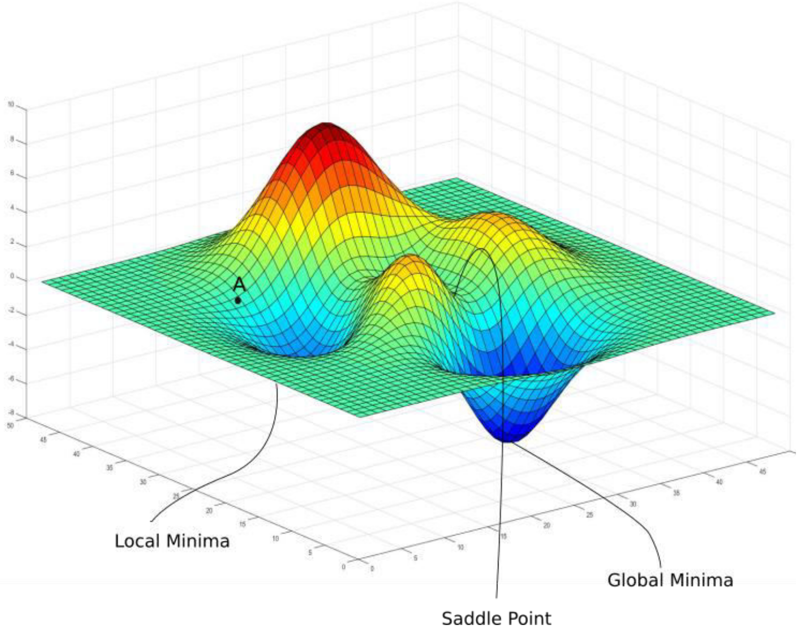
Gradient Descent

Error Function

Cross Entropy Error Function

$$= \quad -y\log(y') - (1-y)\log(1-y')$$





Gradient Descent

Error Function

Cross Entropy Error Function

$$= \quad -y\log(y') - (1-y)\log(1-y')$$

Assume actual output = y = 1 ,

Error = - [1(log(y’)) + (1-1)(log(1-y’))]

Error = - [log(y’)]

To minimize error, we have to minimize –log(y’)

i.e. maximize log(y’)

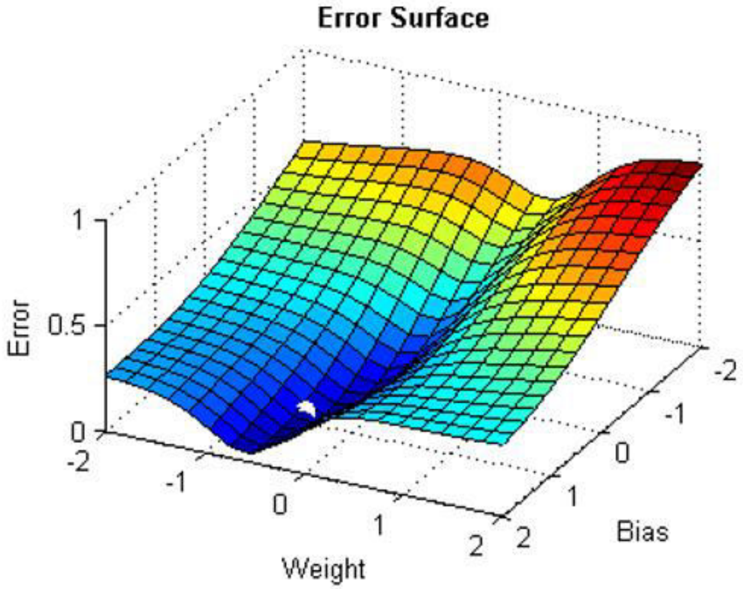
$\Rightarrow$ Maximize y’

Since y’ lies between 0 and 1, y’ should be as close to 1 as possible

Gradient Descent

Back Propagation

- Step 1 • Assign random W and B values
- Step 2 • Calculate final output using these values
- Step 3 • Estimate error using error function
- Step 4 • Find those W and B which can reduce this error
- Step 5 • Update W and B and repeat from step 2



$$w = w - \alpha \Delta w$$

$$b = b - \alpha \Delta b$$

α is learning rate, Δw *and* Δb are unit steps

Alpha determines number of steps we take in downward direction

Gradient Descent

Back Propagation

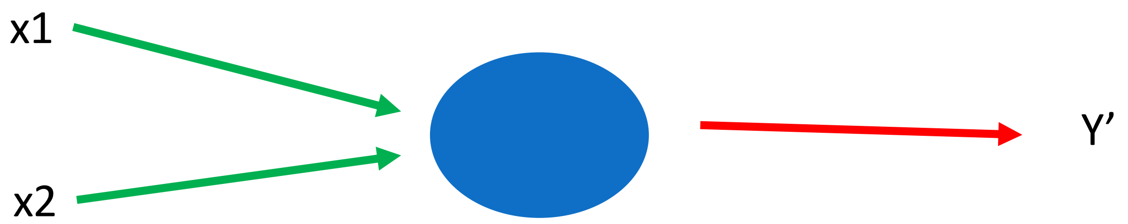
$$w = w - \alpha \Delta w$$

$$b = b - \alpha \Delta b$$

To find $\Delta w \; and \; \Delta b$

We do back propagation

Example



$$w_1 x_1 + w_2 x_2 + b_1 = z$$

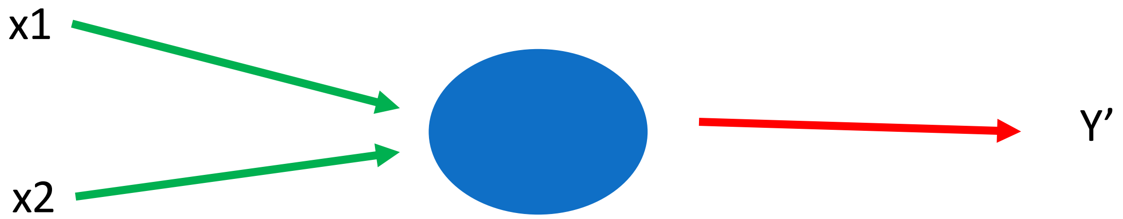
$$\sigma(z) \equiv \frac{1}{1 + e^{-z}}.$$

Error Function

$$= \quad -y \log(y') - (1 - y) \log(1 - y')$$

Gradient Descent

Back Propagation



$$w_1 x_1 + w_2 x_2 + b_1 = z$$

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

Error Function

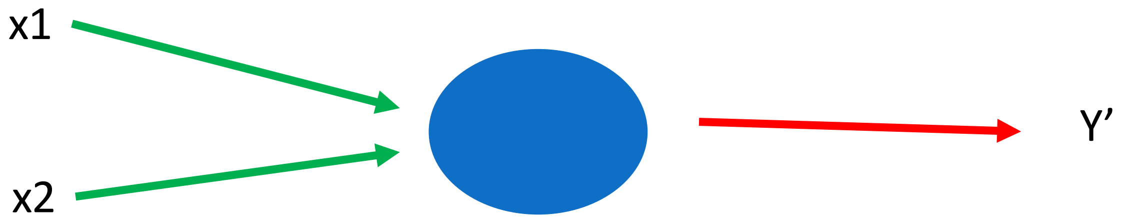
$$= \quad -y\log(y') - (1-y)\log(1-y')$$

$Step\ 1$ – Initialization

W1	W2	B
2	3	-4

Gradient Descent

Back Propagation



$$w_1x_1 + w_2x_2 + b_1 = z$$

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

Error Function

$$= \quad -y\log(y') - (1-y)\log(1-y')$$

$Step$ 2 – Forward propagation

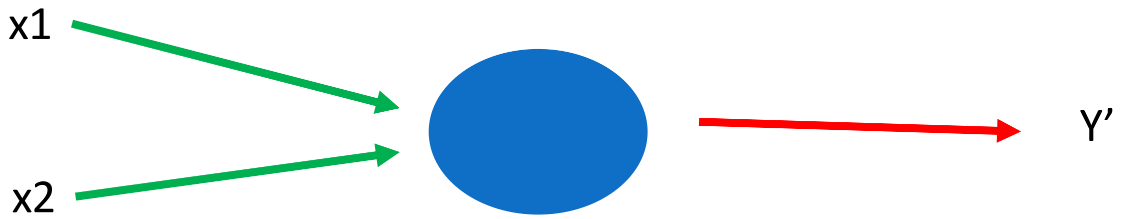
x1	x2	y
10	-4	1

$$z = 2 \times 10 + 3 \times -4 + (-4) = 4$$

Applying activation function $\sigma(z) = 0.982$

Gradient Descent

Back Propagation



$w_1 x_1 + w_2 x_2 + b_1 = z$

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

Error Function

$$= \quad -y\log(y') - (1-y)\log(1-y')$$

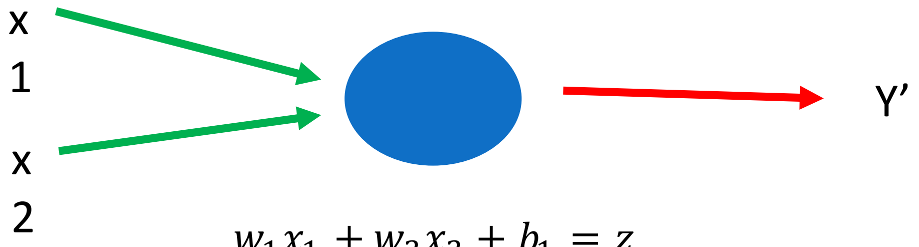
$Step$ 3 – Error calculation $= \quad -y\log(y') - (1-y)\log(1-y')$

Y’	y
0.982	1

$E = 0.0079$

Gradient Descent

Back Propagation



$$w_1x_1 + w_2x_2 + b_1 = z$$

$$\sigma(z) \equiv \frac{1}{1+e^{-z}}.$$

Error Function

$$= \quad -y\log(y') - (1-y)\log(1-y')$$

$Step\ 4$ – Back Propagation

$$\frac{\partial E}{\partial y'} = \text{slope of error wrt y}' = \frac{\partial(-1 \times \log(y')\ )}{\partial y'} = -\frac{1}{y'}$$

$$\frac{\partial y'}{\partial z} = \text{slope of activation function wrt z} = \frac{e^{-z}}{(1+e^{-z})^2}$$

$$\frac{\partial z}{\partial w_1} = x_1 = 10 \qquad \frac{\partial z}{\partial w_2} = x_2 = -4 \qquad \frac{\partial z}{\partial b} = 1$$

Gradient Descent

Back Propagation

$Step\ 4$ – Back Propagation

$$\frac{\partial E}{\partial y'} = \text{slope of error wrt y}' = \frac{\partial(-1 \times \log(y')\ )}{\partial y'} = -\frac{1}{y'}$$

$$\frac{\partial y'}{\partial z} = \text{slope of activation function wrt z} = \frac{e^{-z}}{(1+e^{-z})^2}$$

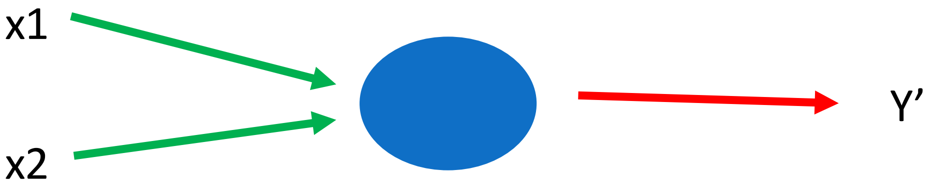
$$\frac{\partial z}{\partial w_1} = x_1 = 10 \qquad \frac{\partial z}{\partial w_2} = x_2 = -4 \qquad \frac{\partial z}{\partial b} = 1$$

$To\ get \frac{\partial E}{\partial w_1}\ i.e. \Delta w_1$ we apply chain rule $\frac{\partial E}{\partial w_1} = \frac{\partial E}{\partial y\prime} \times \frac{\partial y\prime}{\partial z} \times \frac{\partial z}{\partial w_1} = -0.186$

$Similarly \frac{\partial E}{\partial w_2} = 0.0746 \qquad \frac{\partial E}{\partial b} = -0.0186$

Gradient Descent

Back Propagation



$$w_1x_1 + w_2x_2 + b_1 = z$$

$$\sigma(z) \equiv \frac{1}{1+e^{-z}}.$$

Error Function

$$= \quad -y\log(y') - (1-y)\log(1-y')$$

$Step$ 5 – Updating w and b

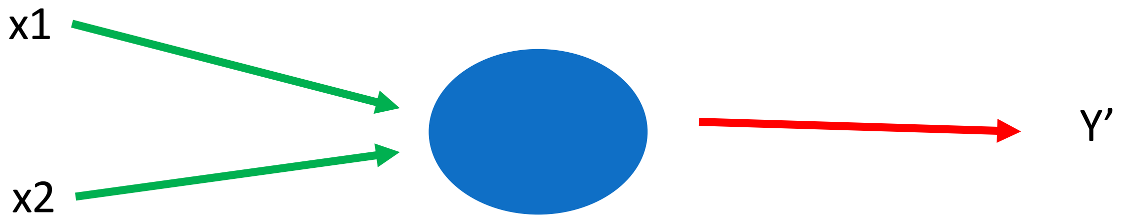
$$w1 = w1 - \alpha\Delta w1 = 2 - 5 \times -0.186 = 2.93$$

$$w2 = w2 - \alpha\Delta w2 = 3 - 5 \times 0.0746 = 2.627$$

$$b = b - \alpha\Delta b = -4 - 5 \times -0.0186 = -3.907$$

Gradient Descent

Back Propagation



$$w_1x_1 + w_2x_2 + b_1 = z$$

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

Error Function

$$= -y\log(y') - (1-y)\log(1-y')$$

$Repeat\ Step\ 2\ -$

x1	x2	y
10	-4	1

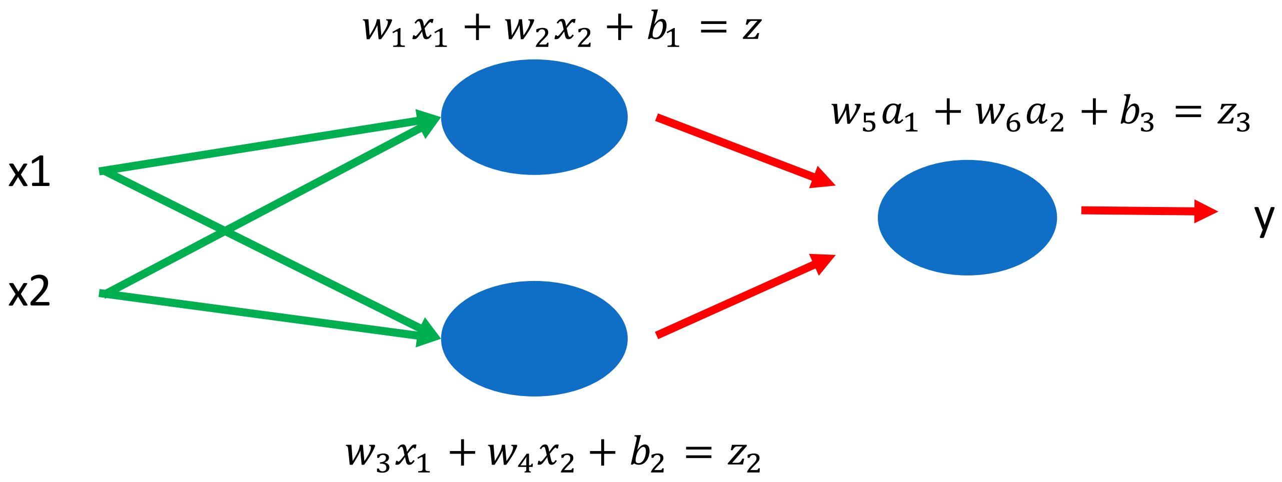
$$z = 2.9 \times 10 + 2.6 \times -4 + (-3.9) = 14.7$$

Applying activation function $\sigma(z) = 0.999$

Neural Network

Activation Function

Q – Why do we use activation functions



$w_1 x_1 + w_2 x_2 + b_1 = z$
$w_5 a_1 + w_6 a_2 + b_3 = z_3$
x1
x2
y
$w_3 x_1 + w_4 x_2 + b_2 = z_2$

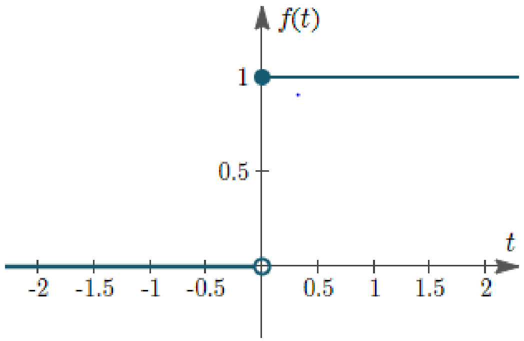
Ans

- To put special boundary conditions on the output
- To introduce non linearity and find complex patterns

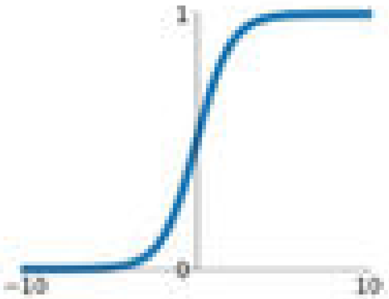
Neural Network

Activation Function

Q – What are the different types of activation functions

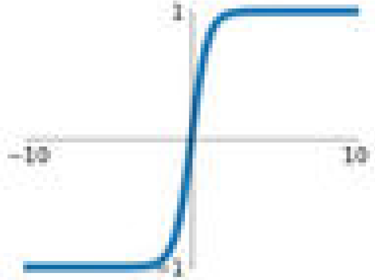


Step



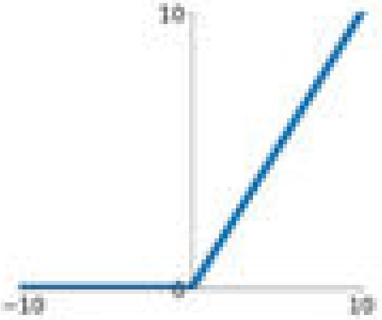
Sigmoid

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



tanh

$\tanh(x)$



ReLU

$\max(0, x)$

Neural Network

Activation Function

Q – What are the different types of activation functions

Function	Upper Boundary	Lower Boundary	Class /Reg	Layer
Step	1	0	Classification	Mostly Output
Sigmoid	1	0	Classification	Hidden & Output
Hyperbolic Tangent (TanH)	1	-1	Classification	Hidden & Output
Rectified Linear Unit (ReLU)	0	infinity	Regression/ classification	Hidden

Neural Network

Activation Function

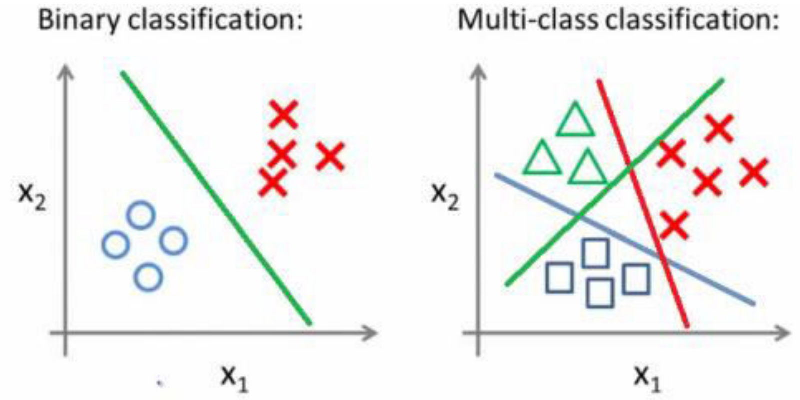
Q – Can Hidden layers and output layers have different activation functions?

Ans - Yes

Neural Network

Activation Function

Q – What is multi class classification? Is there any specific activation function for this?



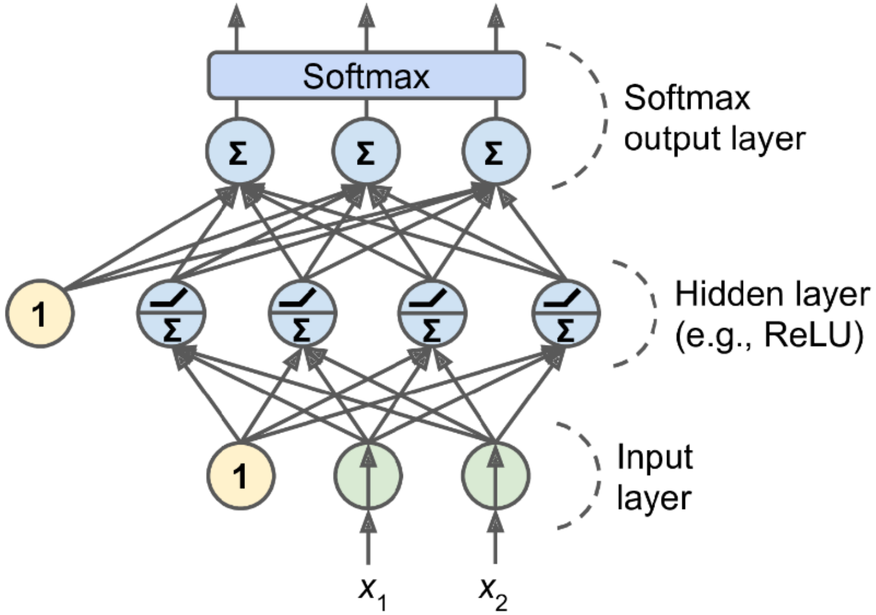
Ans

- Two classes like ‘Yes’ or ‘No’ => Binary Classification
- More than 2 classes like ‘shirts’, ‘trousers’ or ‘socks’ => Multiclass classification
- For multiclass, we use softmax activation

Neural Network

Activation Function

Q – What is multi class classification? Is there any specific activation function for this?



Ans

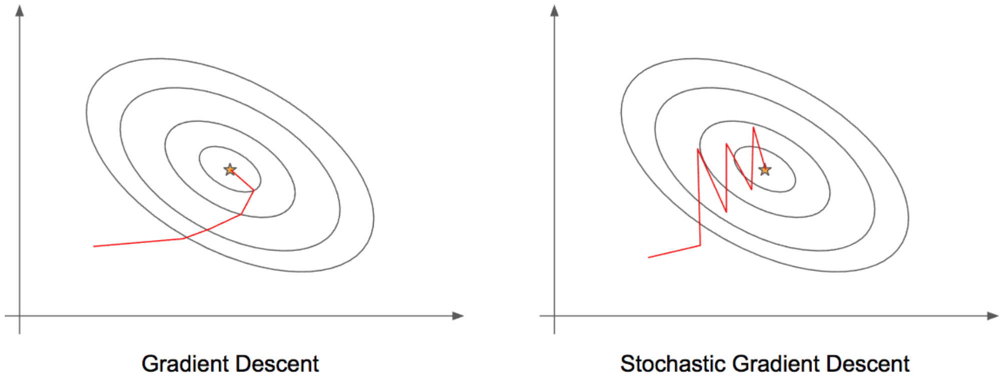
- For each class we keep one output neuron with sigmoid activation
- All the outputs go into softmax layer where each output is divided by the total sum to bring the total probability to one

Neural Network

Gradient descent

Q – What is the difference between Gradient descent and stochastic gradient descent

- Stochastic gradient descent => Single training record, forward and backward propagation
- Gradient descent => Full training set, forward and backward propagation
- Mini Batch Gradient descent => small batch of training set, forward and backward propagation



Neural Network

Epoch

Q – What is an Epoch

- Epoch is one cycle through the full training data
- It is different from iteration
- Example – Suppose we have 1000 training records, if we are doing SGD i.e. one record is input at a time, then 1000 iterations within one epoch
- If we enter 1000 records 2 time => Epoch is 2

Neural Network

Classification Hyperparameters

Hyperparameter	Typical value
# input neurons	One per input feature
# hidden layers	Depends on the problem, but typically 1 to 5
Hidden activation	ReLU

Hyperparameter	Binary classification	Multilabel binary classification	Multiclass classification
# output neurons	1	1 per label	1 per class
Output layer activation	Logistic	Logistic	Softmax
Loss function	Cross entropy	Cross entropy	Cross entropy

Neural Network

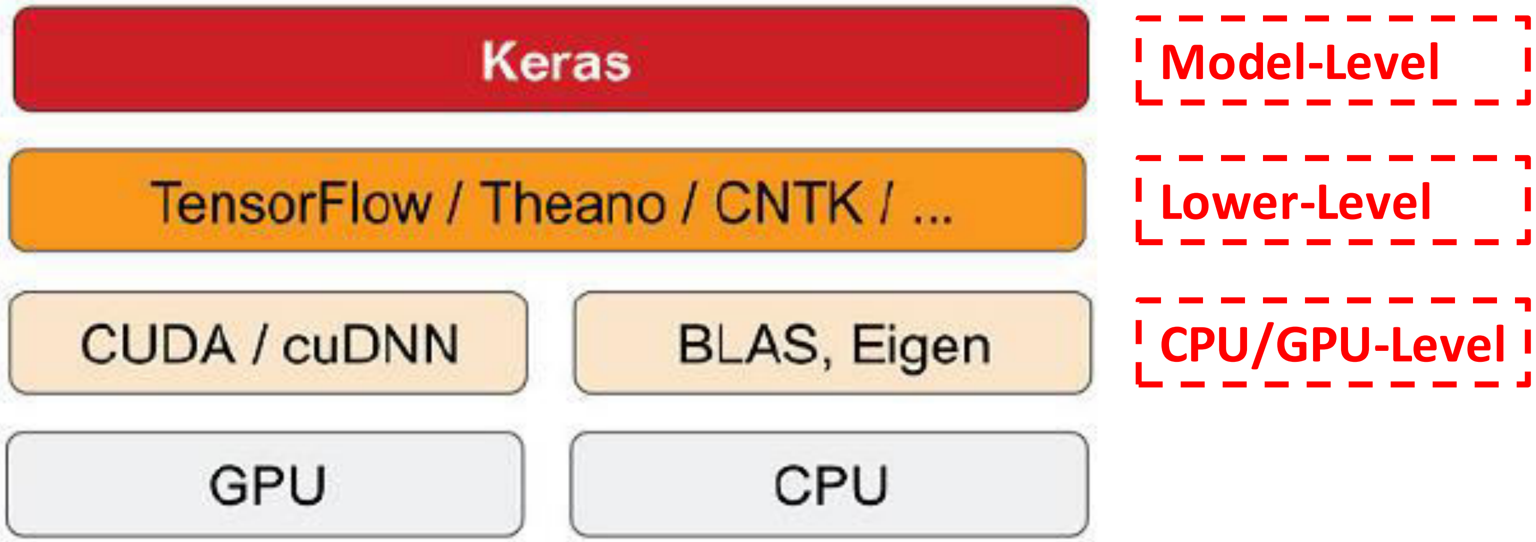
Regression Hyperparameters

Hyperparameter	Typical value
# input neurons	One per input feature
# hidden layers	Depends on the problem, but typically 1 to 5
# neurons per hidden layer	Depends on the problem, but typically 10 to 100
# output neurons	1 per prediction dimension
Hidden activation	ReLU
Output activation	None
Loss function	MSE

Neural Network

Keras & Tensorflow

Keras is a model-level library, providing high-level building blocks for developing deep-learning models



Keras

TensorFlow / Theano / CNTK / ...

CUDA / cuDNN

BLAS, Eigen

GPU

CPU

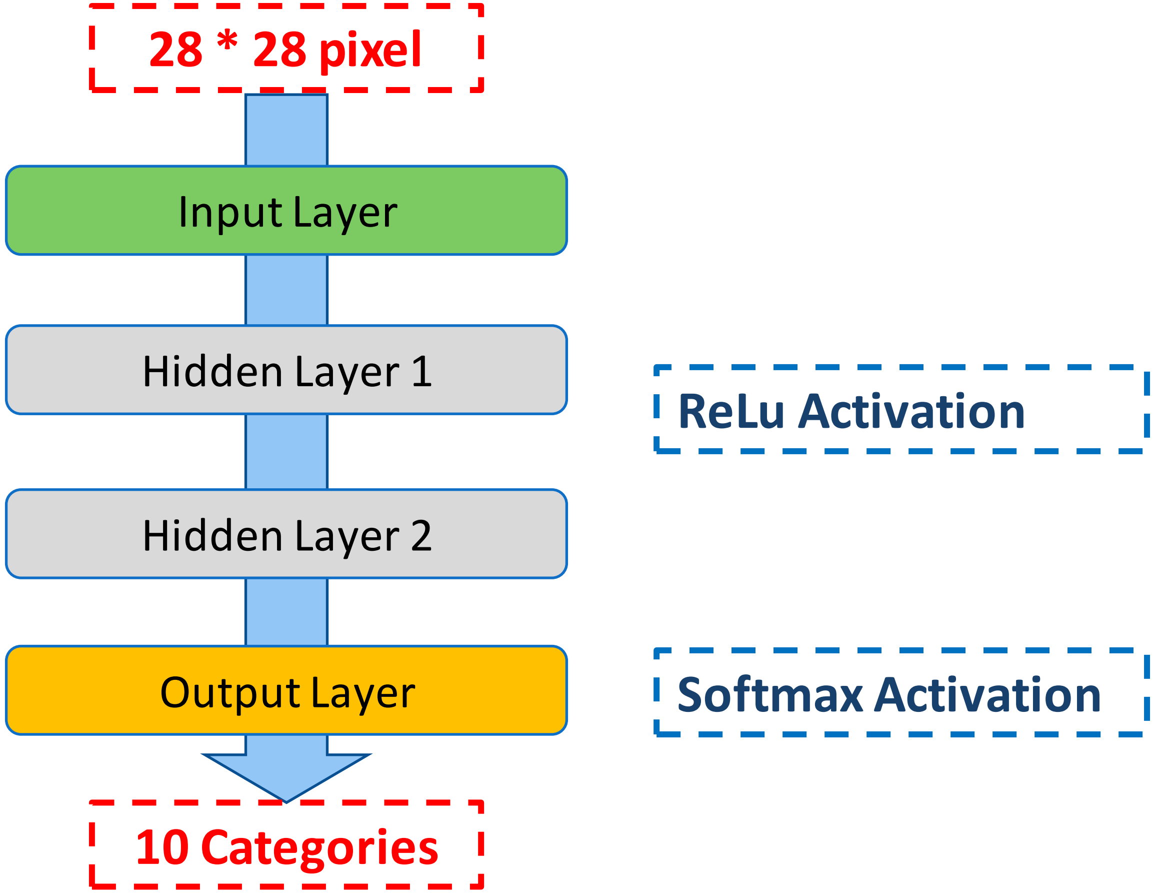
Model-Level

Lower-Level

CPU/GPU-Level

Neural Network

Keras & Tensorflow



28 * 28 pixel

Input Layer

Hidden Layer 1

Hidden Layer 2

Output Layer

10 Categories

ReLu Activation

Softmax Activation