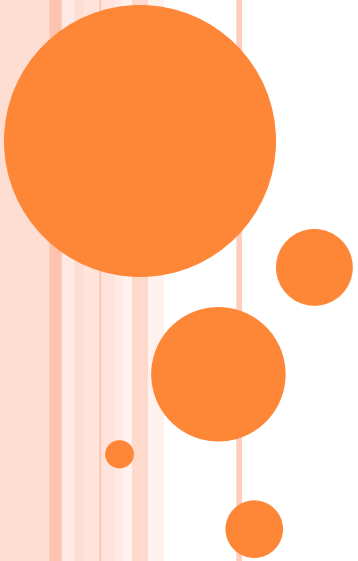
NEURAL NETWORKS

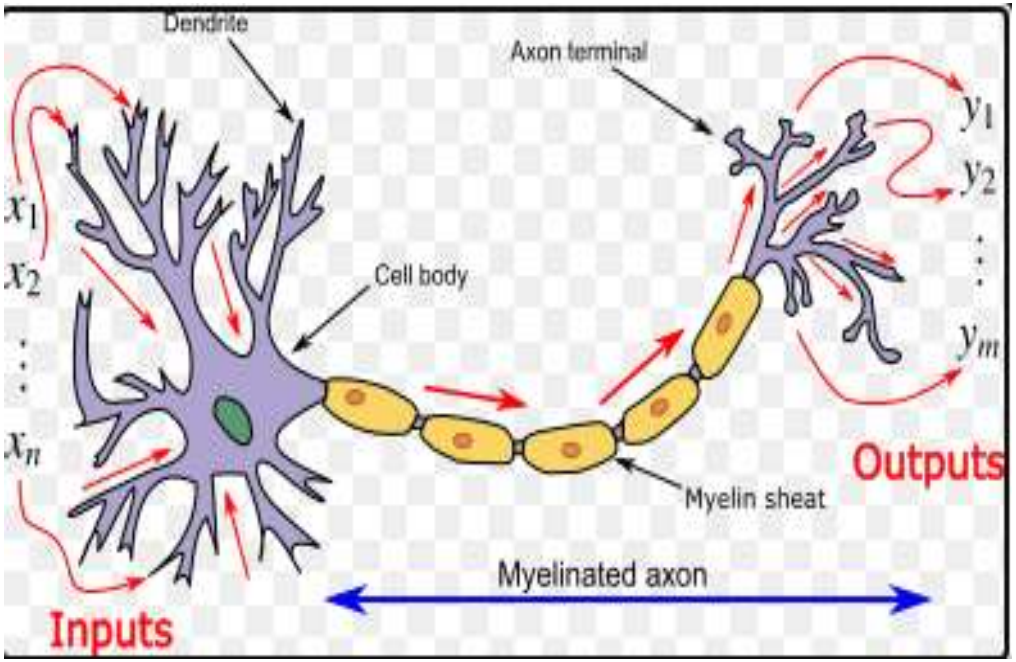


WHAT IS NEURAL NETWORK?

- Artificial Neural Network ANN is an efficient system whose central theme is borrowed from the analogy of biological neural networks.
- In other words, neural network functions in a way similar to the human brain.
- ANN acquires a large collection of units that are interconnected in some pattern to allow communication between the units. These units, also referred to as nodes or neurons, are simple processors which operate in parallel.
- The function of a neural network is to produce an output pattern when presented with an input pattern.

BRAIN – THE ORIGINAL NEURAL NETWORK

- Based on functionality of Brain.
  - Neuron
  - Soma
  - Dendrites
  - Axon
  - Synapse



A biological neuron has four types of components:

1. **Dendrites:** are bunched into highly complex “dendritic trees”. The dendrites receive signals from the other neurons.

   Dendritic trees are connected with the main body of the neuron called soma.

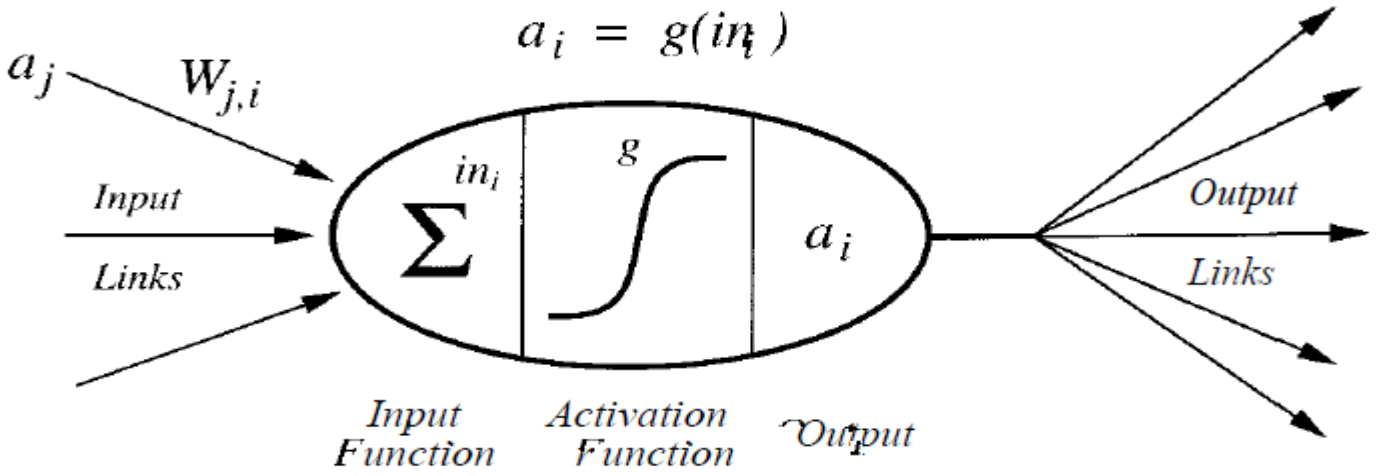
2. **Soma:** The soma sums the incoming signals. When the sufficient input is received, the cell fires.

3. **Axon:** The impulse signal triggered by the cell is transmitted over the axon to the other cells.

4. **Synapse:** The connecting point between a neuron’s axon and other neuron’s dendrite is called synapse. The impulse signals are transmitted across a synaptic gap by means of a chemical process.

NEURAL NETWORKS

- A neural network is
  - composed of a number of nodes, or **units,**
  - **connected by links.**
  - **Each link** has a numeric **weight associated with it.**
- Each unit has
  - a set of input links from other units,
  - a set of output links to other units,
  - a current **activation level, and**
  - **a means of computing the activation level at the next step in time**



- The artificial neuron has a set of ‘n’ **inputs x_i,** each representing the output of another neuron. The inputs are collectively referred to as X.

- Each input is **weighted** before it reaches the main body of the processing elements by the connection strength or the **weight factor**. The amount of information about the input that is required to solve a problem is stored in the form of weights.

- Each signal is multiplied with an associated weight w_1, w_2, w_3, ……..,w_n before it is applied to the **summing block**.

- In addition, the artificial neuron has a bias term w_o, a threshold value ‘ θ ’ that has to be reached or extended for the neuron to produce a signal, a function ‘F’ that acts on the produce signal ‘net’ and an output ‘y’ after the function.

The following relation describes the transfer function of the basic neuron model.

$$y = F(\text{net}) \tag{1.1}$$

where

$$\text{net} = w_0 + x_1 w_1 + x_2 w_2 + x_3 w_3 + \ldots\ldots + x_n w_n \tag{1.2}$$

or

$$\text{net} = w_0 + \sum_{i=0}^{n} x_i w_i \tag{1.3}$$

and the neuron firing condition is:

$$\sum_{i=0}^{n} x_i w_i \geq \theta \text{ [for linear activation function]}, x_0 = 1$$

or

$$F(\text{net}) \geq \theta \text{ [for nonlinear activation function]}$$

CLASSIFICATION OF ARTIFICIAL NEURAL NETWORK

It can be classified on the basis of:

1. Pattern of connection between neurons(architecture of the network)
2. Activation function applied to the neurons.
3. Method of determining weights on the connections(training or learning methods)

ARCHITECTURE OF A NEURAL NETWORK

- The neurons are assumed to be arranged in layers, and the neurons in the same layer behave in the same manner.
- The neurons in one layer can be connected to neurons in another layer.
- The arrangement of neurons into layers and the connection pattern within and between layers is known as architecture.

INPUT LAYER: The neurons in this layer receive the external input signals and perform no computations

OUTPUT LAYER: The neuron in this layer receive signals from neurons either in the input layer or in the hidden layer.

HIDDEN LAYER: The layer of neurons that are connected in between the input layer and the output layer is known as hidden layer.

There are three fundamentally different classes of neural networks. Those are.

1. Single layer feedforward Networks.

2. Multilayer feedforward Networks.

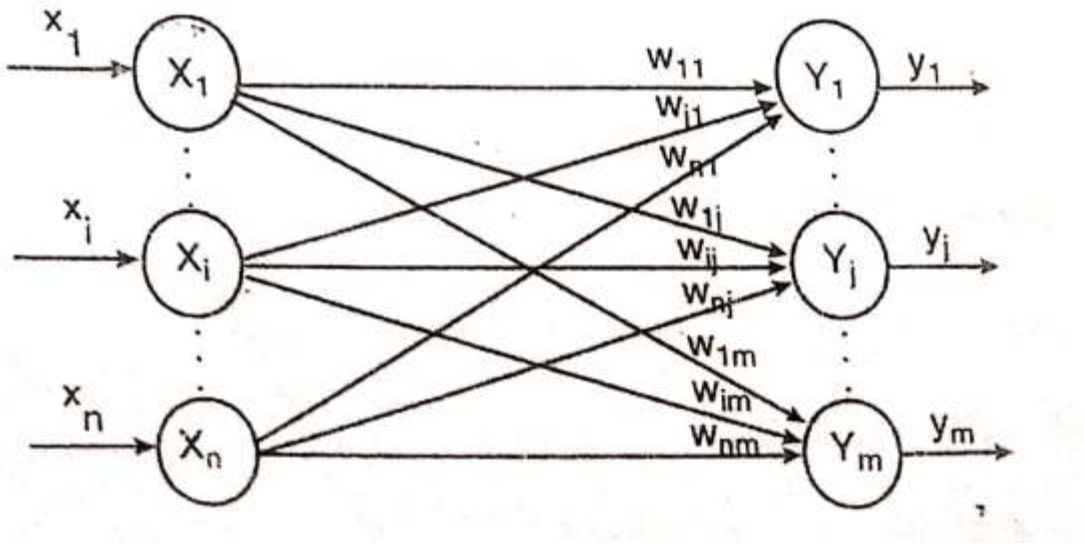
3. Recurrent Networks.

SINGLE LAYER FEED FORWARD NETWORK

A single layer network consists of one layer of connection weights.

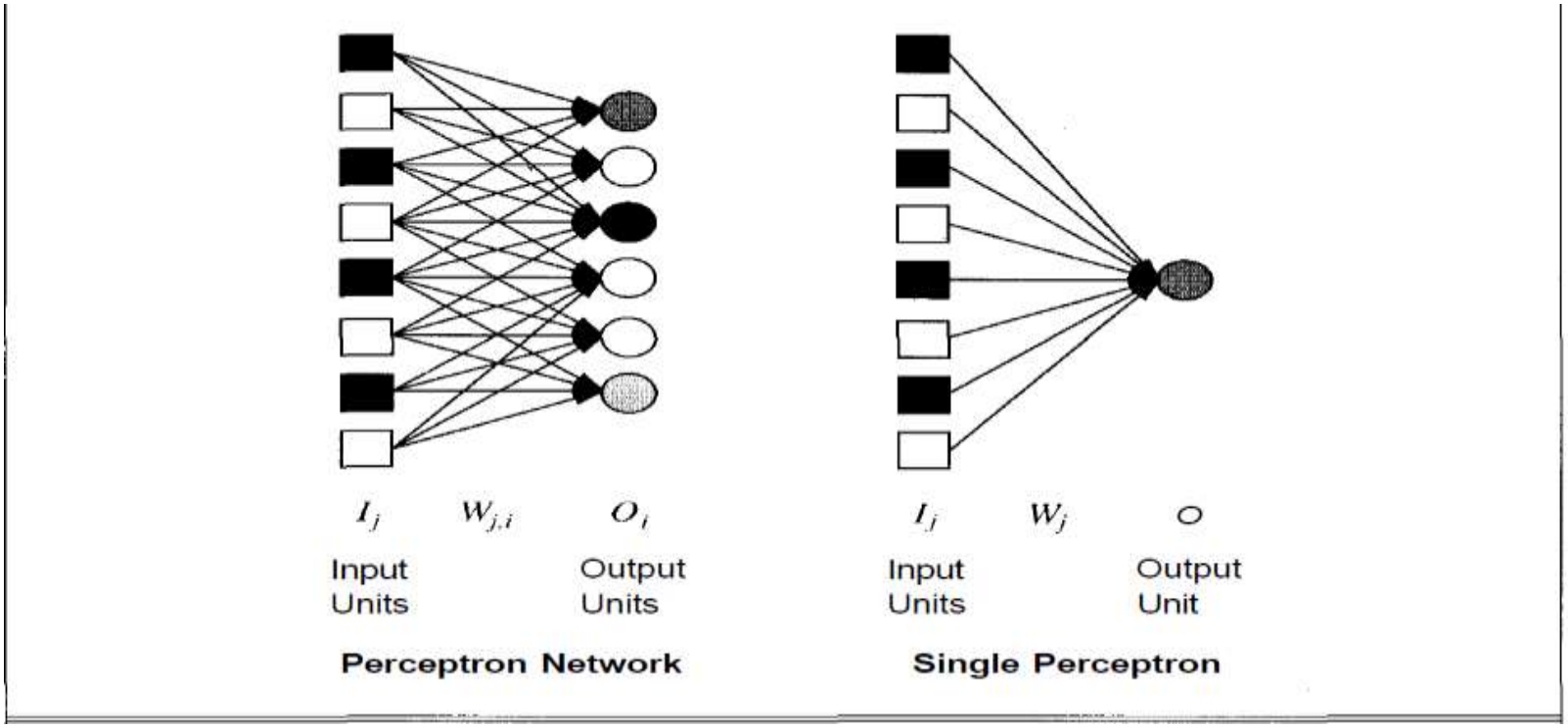
The net consists of a layer of units called input layer, which receive signals from the outside world and a layer of units called output layer from which the response of the net can be obtained.

This type of network can be used for pattern classification problems.



PERCEPTRON

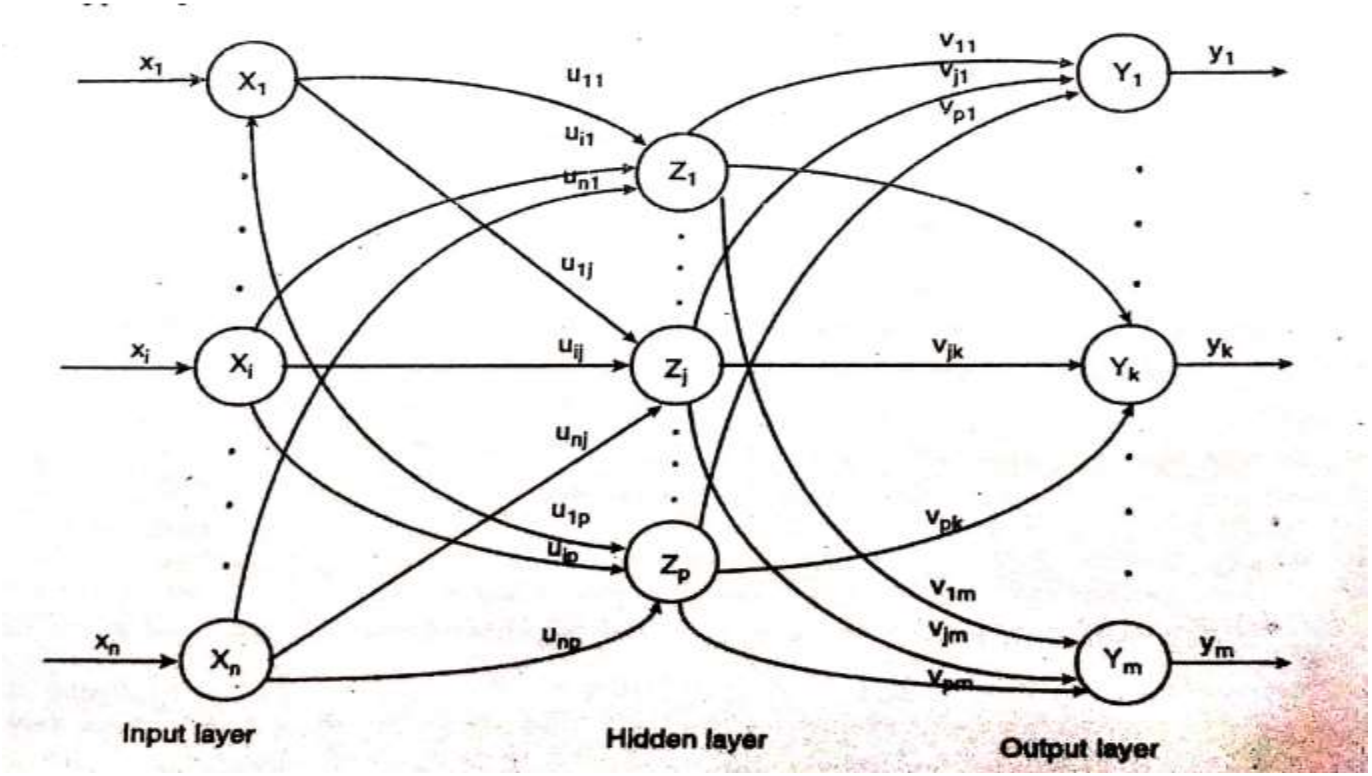
- Perceptron is used as a synonym for a single-layer, feed-forward network



MULTILAYER FEED FORWARD NETWORK

A multilayer network consists of one or more layers of units (called hidden layers) between the input and output layers.

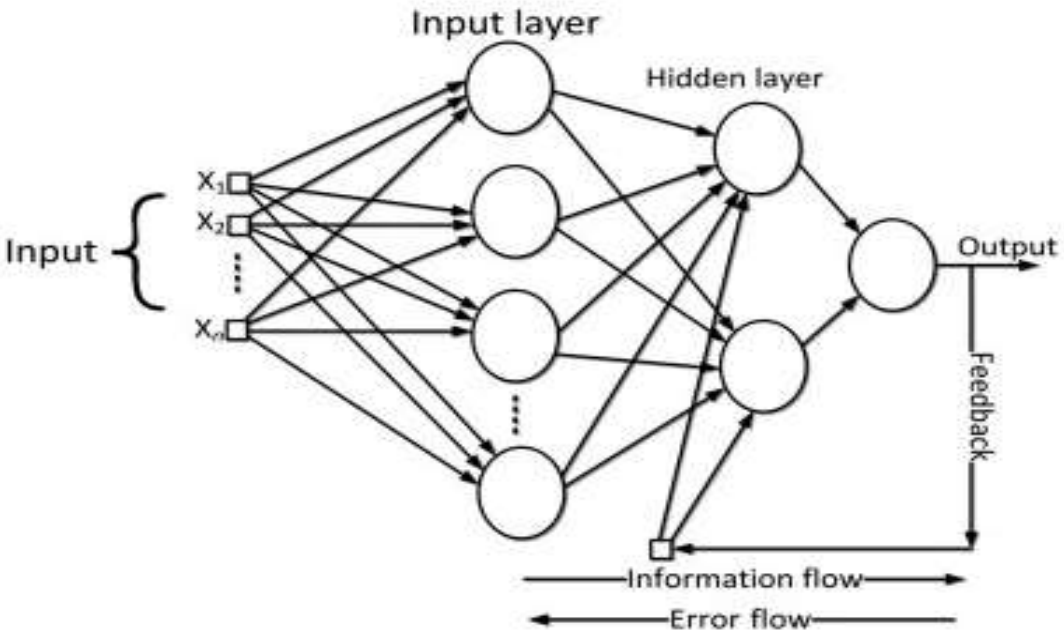
The output of one layer provides the input to the subsequent layer.



Recurrent or Feedback Networks

RNN or feedback neural network is the second kind of ANN model, in which the outputs from neurons are used as feedback to the neurons of the previous layer.

In other words, the current output is considered as an input for the next output.



Activation Function

An activation function is a **function** that is added into an artificial **neural network** in order to help the **network** learn complex patterns in the data.

They basically decide to deactivate neurons or activate them to get the desired output.

When comparing with a **neuron**-based model that is in our brains, the **activation function** is at the end deciding what is to be fired to the next **neurons.**

Types of Activation Functions

1 Binary step

2 Linear

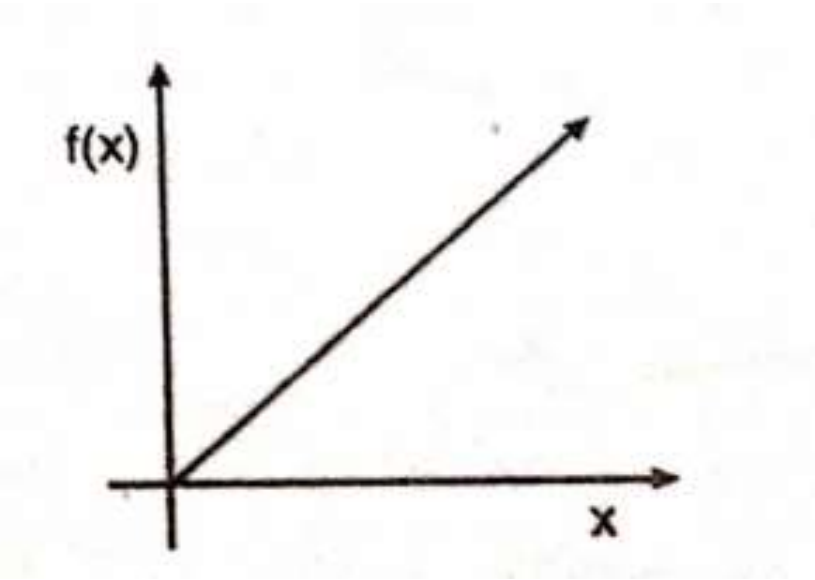
3 Sigmoid

Linear Activation Function

It is a simple straight line activation function where our function is directly proportional to the weighted sum of neurons or input.

Linear activation functions are better in giving a wide range of activations and a line of a positive slope may increase the firing rate as the input rate increases.

f(x)=x for all x.

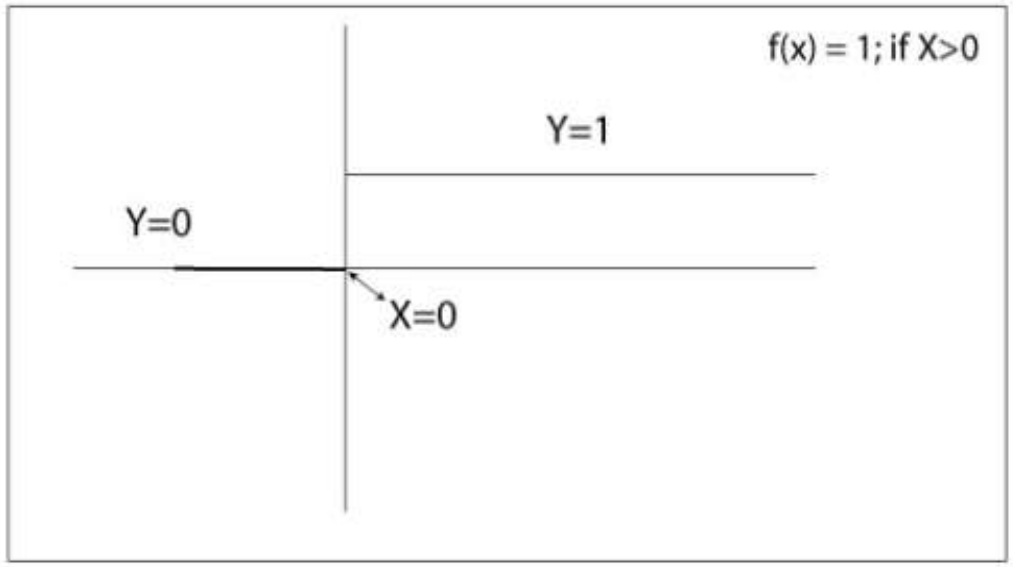


Binary Step Activation Function

This activation function very basic and it comes to mind every time if we try to bound output.

It is basically a threshold base classifier, in this, we decide some threshold value to decide output that neuron should be activated or deactivated.

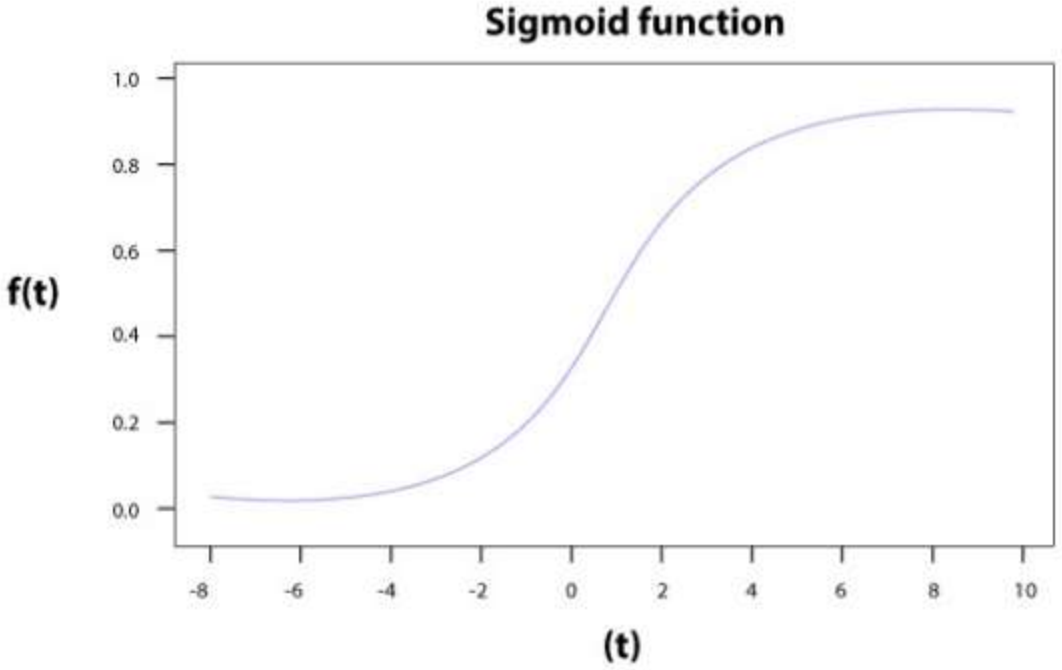
$$f(x) = 1 \text{ if } x > 0 \text{ else } 0 \text{ if } x < 0$$



Sigmoid Activation Function

The sigmoid activation function is used mostly as it does its task with great efficiency, it basically is a probabilistic approach towards decision making and ranges in between **0 to 1,** so when we have to make a decision or to predict an output we use this activation function because of the range is the minimum, therefore, prediction would be more accurate.

$$f(x) = 1/(1+e^{(-x)})$$



ADJUSTMENTS OF WEIGHTS OR LEARNING

Learning, in artificial neural network, is the method of modifying the weights of connections between the neurons of a specified network.

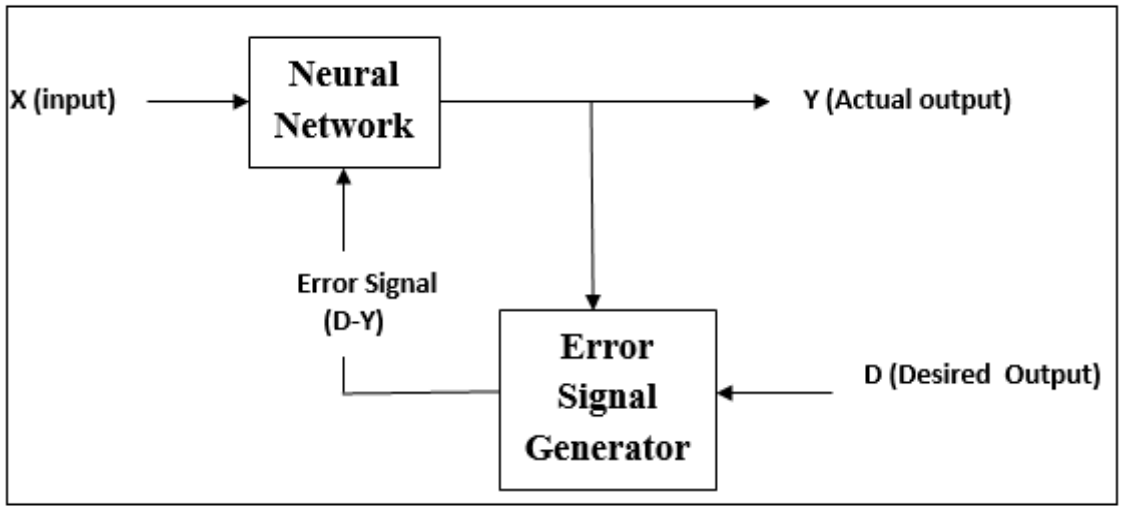
When the actual output response is the same as the desired one, the network has completed the learning phase and network has acquired knowledge.

Learning in ANN can be classified into three categories namely:

1. Supervised learning
2. Unsupervised learning
3. Reinforcement learning.

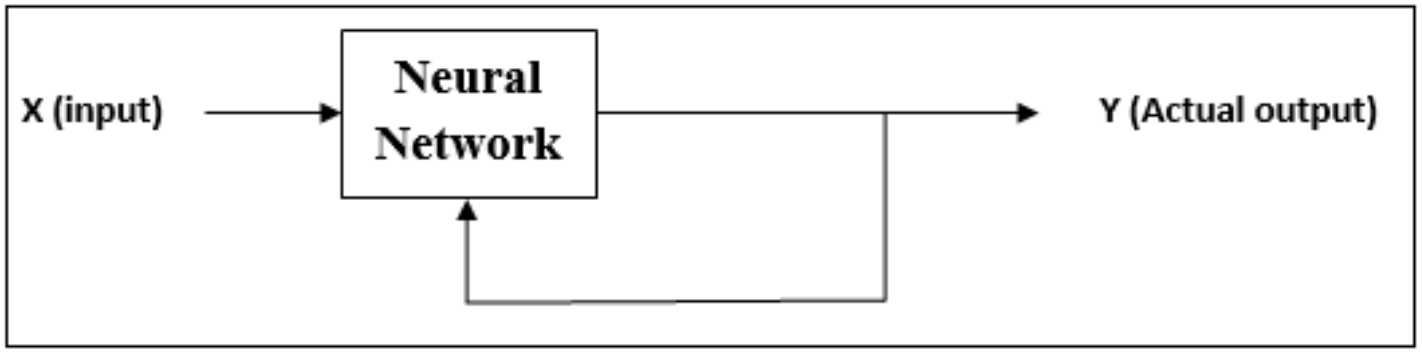
SUPERVISED LEARNING

- Learning is done under the **supervision of a teacher**. This learning process is **dependent.**
- During the training of ANN under supervised learning, the input vector is presented to the network, which will give an output vector.
- This output vector is compared with the desired output vector. An **error signal** is generated, if there is a difference between the actual output and the desired output vector. On the basis of this error signal, the weights are adjusted until the actual output is matched with the desired output.



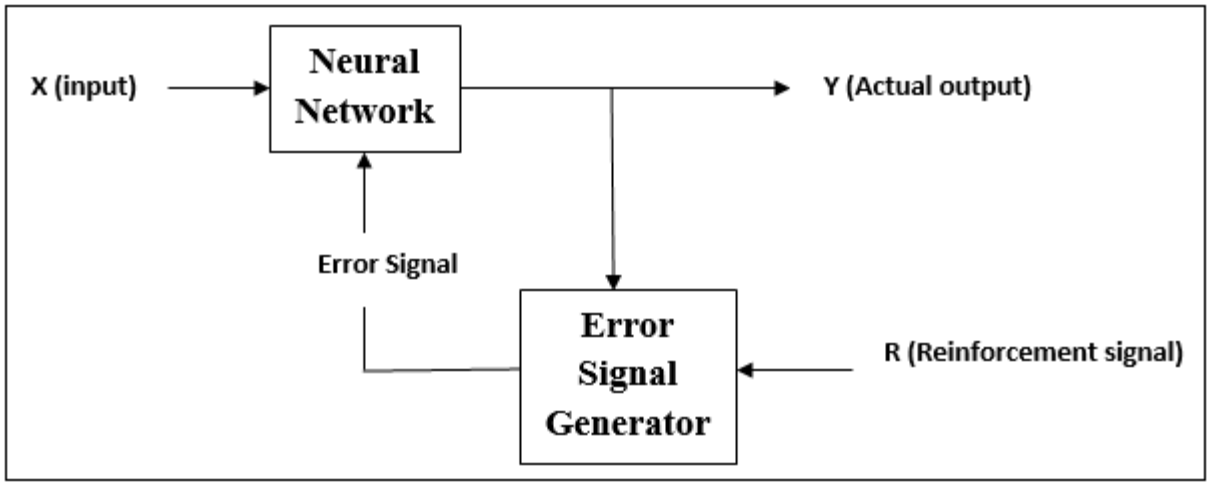
Unsupervised Learning

- Learning is done without the supervision of a teacher. This learning process is independent.
- During the training of ANN under unsupervised learning, the input vectors of similar type are combined to form clusters. When a new input pattern is applied, then the neural network gives an output response indicating the class to which the input pattern belongs.
- There is no feedback from the environment as to what should be the desired output and if it is correct or incorrect.
- In this type of learning, the network itself must discover the patterns and features from the input data, and the relation for the input data over the output.



Reinforcement Learning

- Learning is used to reinforce or strengthen the network over some critic information. This learning process is similar to supervised learning, however we might have very less information.
- During the training of network under reinforcement learning, the network receives some feedback from the environment. This makes it somewhat similar to supervised learning.
- Feedback obtained here is evaluative not instructive, which means there is no teacher as in supervised learning. After receiving the feedback, the network performs adjustments of the weights to get better critic information in future.



APPLICATIONS

1. **Classification:** A neural network can discover the distinguishing features needed to perform a classification task. Classification is the assignment of each object to a specific class, which is important aspect in image classification. Classification tasks includes:

a. Recognition of printed or handwritten characters.

b. Classification of SONAR and RADAR signals.

Using neural nets to recognize the Handwritten digits:

Consider the following sequence of handwritten digits:

Most people effortlessly recognize those digits as **504192.** We humans are stupendously good at making sense of what our eyes show us. But nearly all that work is done unconsciously.

The difficulty of visual pattern recognition becomes apparent if you attempt to write a computer program to recognize digits like those above.

Simple intuitions about how we recognize shapes - "a 9 has a loop at the top, and a vertical stroke in the bottom right" - turn out to be not so simple to express algorithmically.

Neural networks approach the problem in a different way. The idea is to take a large number of handwritten digits, known as **training examples,**

and then develop a system which can learn from those training examples.

In other words, the neural network uses the examples to automatically infer rules for recognizing handwritten digits.

Furthermore, by increasing the number of training examples, the network can learn more about handwriting, and so improve its accuracy.

2. **Signature Verification**: Signatures are one of the most useful ways to authorize and authenticate a person in legal transactions. For this application, the first approach is to extract the feature or rather the geometrical feature set representing the signature. With these feature sets, we have to train the neural networks using an efficient neural network algorithm. This trained neural network will classify the signature as being genuine or forged under the verification stage.