2-Artificial Neural Networks

Introduction

- Neural networks are parallel computing devices, which is basically an attempt to make a computer model of the brain.
- The main objective is to develop a system to perform various computational tasks faster than the traditional systems.

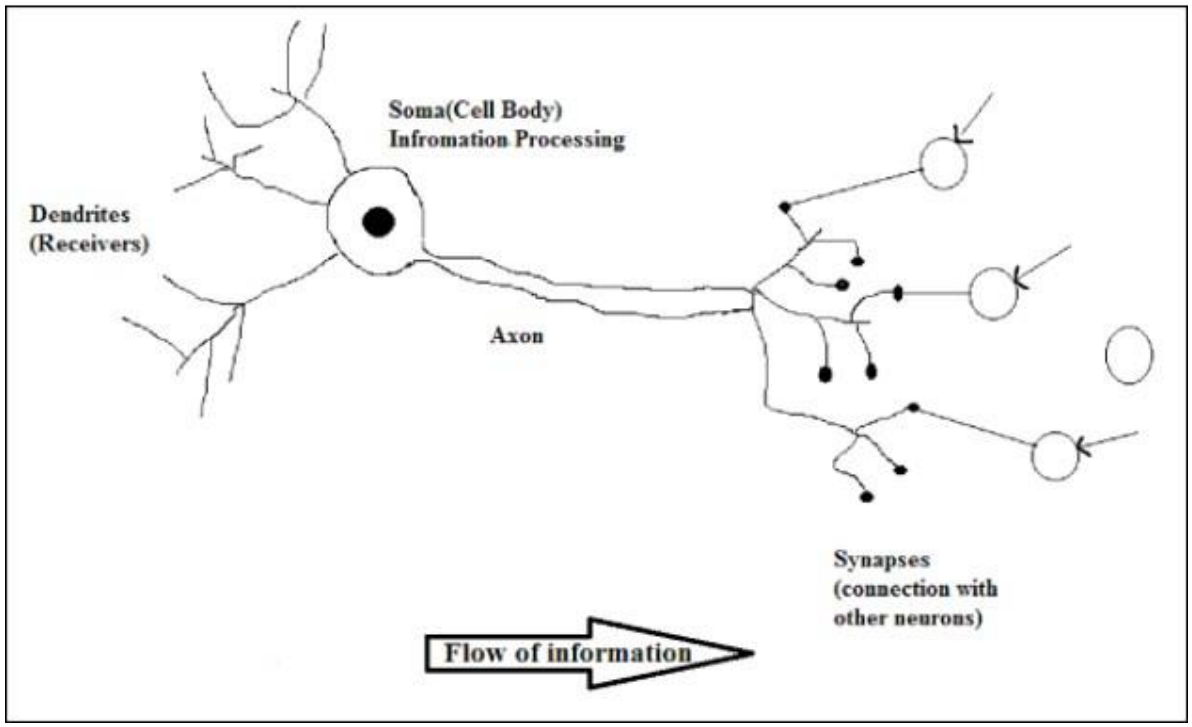
What is Artificial Neural Network?

- Artificial Neural Network (ANN) is an efficient computing system whose central theme is borrowed from the analogy of biological neural networks.
- ANNs are also named as "artificial neural systems," or "parallel distributed processing systems," or "connectionist systems."
- 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.
- Every neuron is connected with other neuron through a connection link.
- Each connection link is associated with a weight that has information about the input signal.
- This is the most useful information for neurons to solve a particular problem because the weight usually excites or inhibits the signal that is being communicated.
- Each neuron has an internal state, which is called an activation signal.
- Output signals, which are produced after combining the input signals and activation rule, may be sent to other units.

Biological Neuron

- A nerve cell (neuron) is a special biological cell that processes information.
- According to an estimation, there are huge number of neurons, approximately 10^{11} with numerous interconnections, approximately 10^{15}

Schematic Diagram



Working of a Biological Neuron

As shown in the above diagram, a typical neuron consists of the following four parts with the help of which we can explain its working −

- Dendrites − They are tree-like branches, responsible for receiving the information from other neurons it is connected to. In other sense, we can say that they are like the ears of neuron.
- Soma − It is the cell body of the neuron and is responsible for processing of information, they have received from dendrites.
- Axon − It is just like a cable through which neurons send the information.
- Synapses − It is the connection between the axon and other neuron dendrites.

ANN versus BNN

- Before taking a look at the differences between Artificial Neural Network (ANN) and Biological Neural Network (BNN), let us take a look at the similarities based on the terminology between these two.

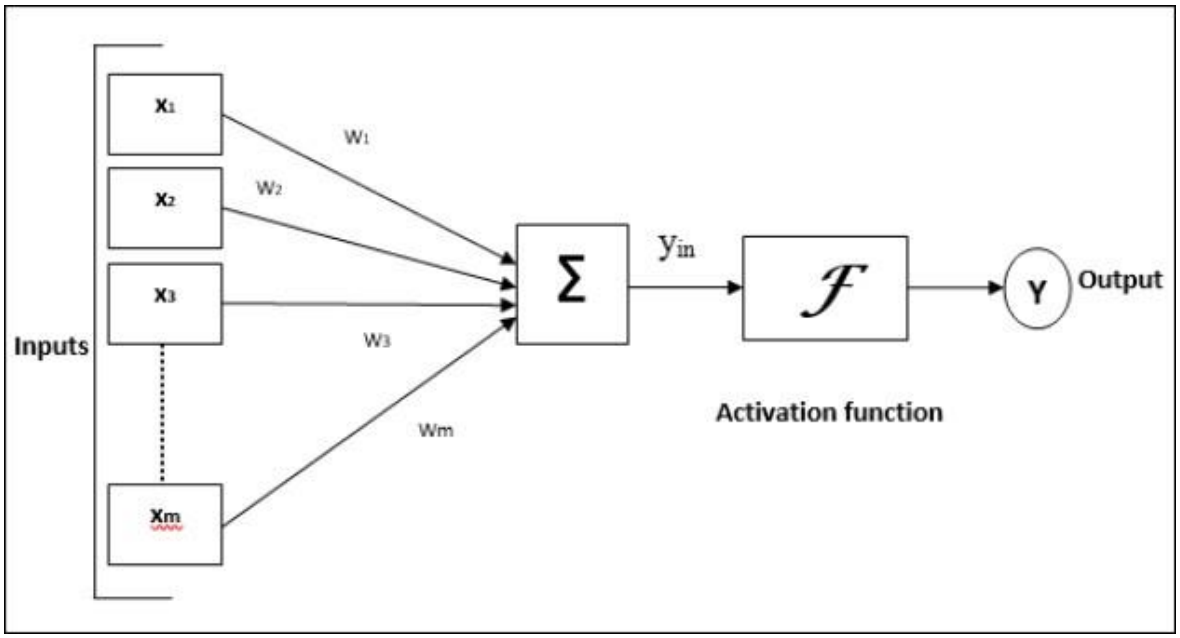
Biological Neural Network (BNN)	Artificial Neural Network (ANN)
Soma	Node
Dendrites	Input
Synapse	Weights or Interconnections
Axon	Output

The following table shows the comparison between ANN and BNN based on some criteria mentioned.

Criteria	BNN	ANN
Processing	Massively parallel, slow but superior than ANN	Massively parallel, fast but inferior than BNN
Size	10^{11} neurons and 10^{15}interconnections	10^2 to 10^4 nodes (mainly depends on the type of application and network designer)
Learning	They can tolerate ambiguity	Very precise, structured and formatted data is required to tolerate ambiguity
Fault tolerance	Performance degrades with even partial damage	It is capable of robust performance, hence has the potential to be fault tolerant
Storage capacity	Stores the information in the synapse	Stores the information in continuous memory locations

Model of Artificial Neural Network

The following diagram represents the general model of ANN followed by its processing.



- An artificial neuron is a mathematical function conceived as a model of biological neurons, a neural network.
- Artificial neurons are elementary units in an artificial neural network.
- The artificial neuron receives one or more inputs and sums them to produce an output.
- Neuron. Neurons are the basic unit of a neural network.
- In nature, neurons have a number of dendrites (inputs), a cell nucleus (processor) and an axon (output). neuron j:
- As you can see they have several inputs, for each input there's a weight (the weight of that specific connection)

i.e., Net input $y_{in}\:=\:\sum_i^m\:x_{i}.w_{i}$

The output can be calculated by applying the activation function over the net input.

$$Y\:=\:F(y_{in}) $$

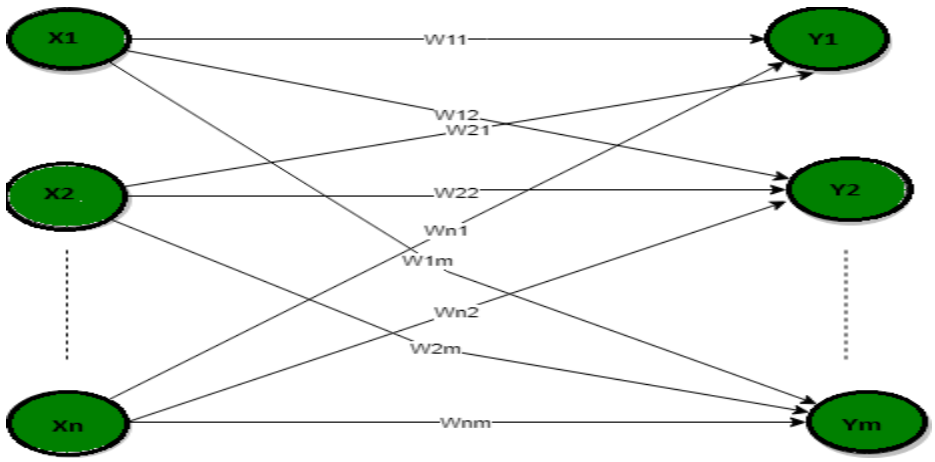
Output = function (net input calculated)

For the above general model of artificial neural network, the net input can be calculated as follows −

$$y_{in}\:=\:x_{1}.w_{1}\:+\:x_{2}.w_{2}\:+\:x_{3}.w_{3}\:\dotso\: x_{m}.w_{m}$$

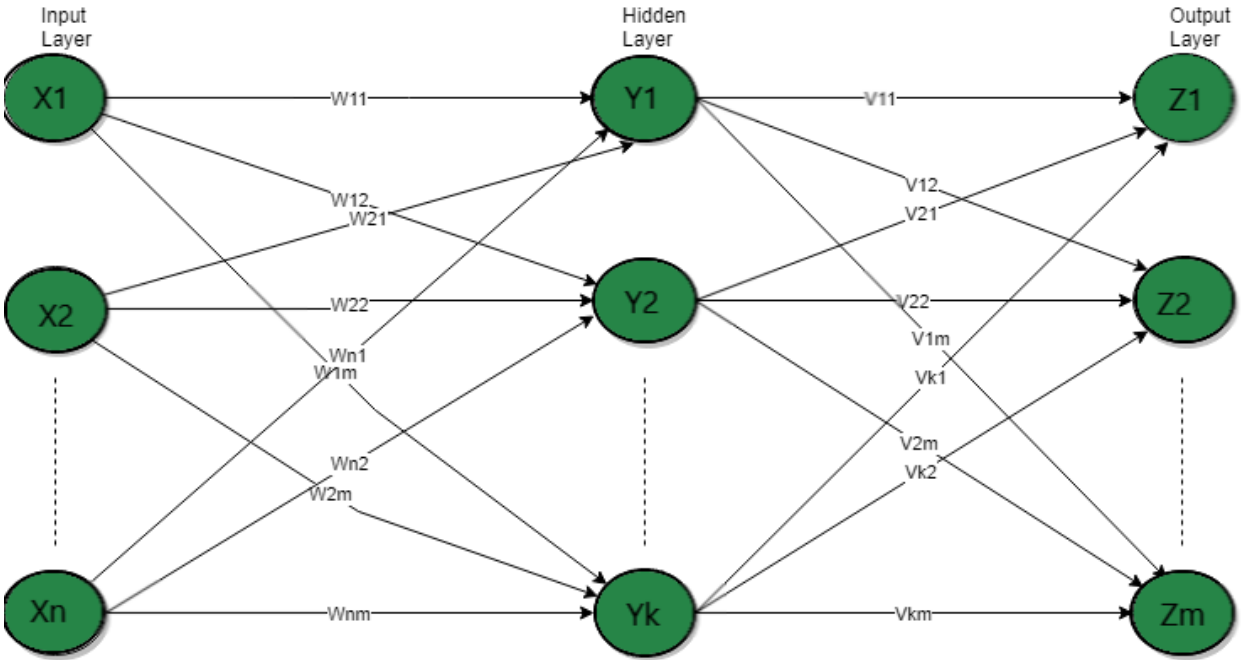
Single-Layer feedforward networks

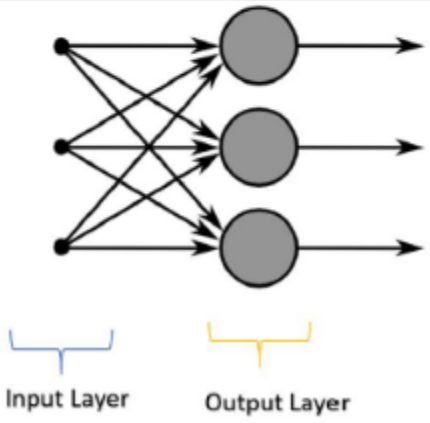
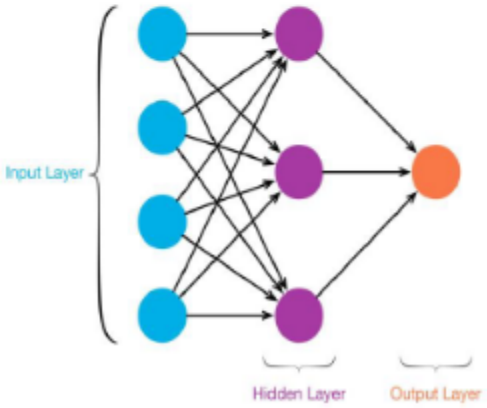
In this type of network, we have only two layers input layer and output layer but input layer does not count because no computation performed in this layer. Output layer is formed when different weights are applied on input nodes and the cumulative effect per node is taken. After this the neurons collectively give the output layer compute the output signals.



Multi-layer feed forward networks

This layer also has hidden layer which is internal to the network and has no direct contact with the external layer. Existence of one or more hidden layers enable the network to be computationally stronger, feed-forward network because information follows through the input function, and the intermediate computations used to define the output Z. There are no feedback connections in which outputs of the model are fed back into itself.

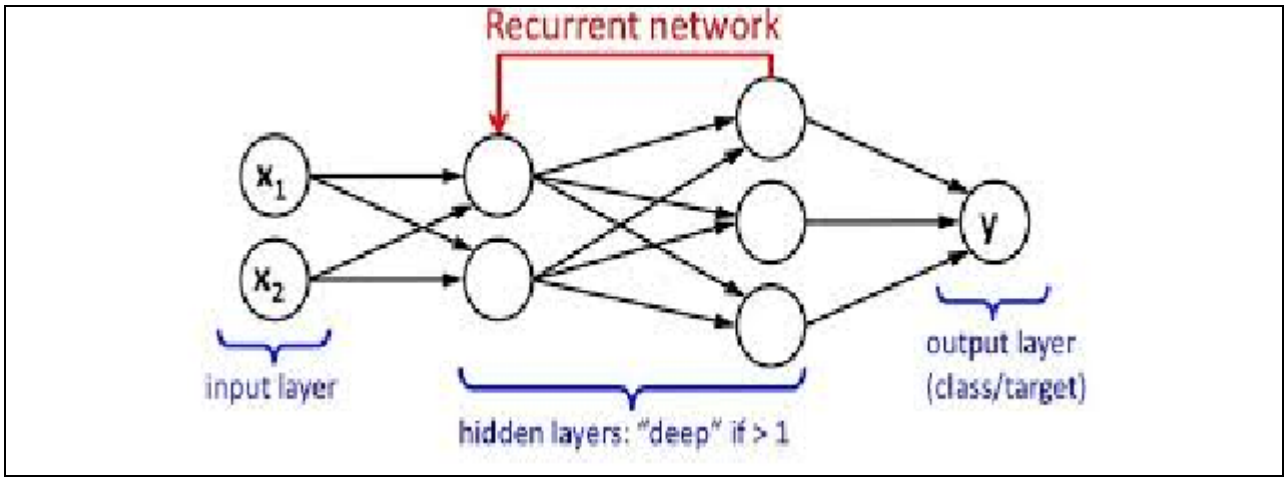


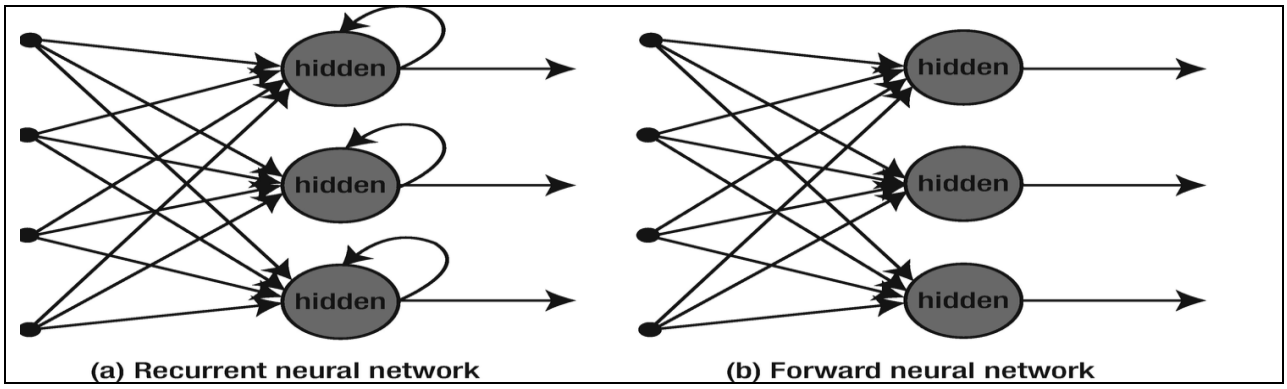
Single Layer Feed-Forward Neural Network	Multi Layer Feed-Forward Neural Network
Layer is formed by taking processing element & combining it with other processing element.	It is formed by interconnection of several layers.
Input & output are linked with each other.	There are multiple layers between input & output layers which are known as hidden layers.
Inputs are connected to the processing nodes with various weights resulting series of output one per node.	Input layers receives input & buffers input signal, output layer generates output.
Zero hidden layers are present.	Zero to several hidden layers are in a network.
Not efficient in certain areas.	More the hidden layers, more the complexity of networks, but efficient output is produced.
	

Recurrent Neural Networks

- Recurrent Neural Network remembers the past and it's decisions are influenced by what it has learnt from the past.
- Note: Basic feed forward networks "remember" things too, but they remember things they learnt during training.

- For example, an image classifier learns what a “1” looks like during training and then uses that knowledge to classify things in production.
- While RNNs learn similarly while training, in addition, they remember things learnt from prior input(s) while generating output(s).





ANN Models - issues

- quality of data and reliability of instrumentation
- separation of data into training and testing sets
- lots of data may be required
- data preprocessing (filtration, synchronization) is vital
- scaling of all data is essential
- Learning can be slow for large networks
- stability of process relationships
- design issues (bias, hidden nodes, algorithm, learning rate)
- separate networks for predictive models
- inclusive networks for classification models