Unit-3 Artificial Neural Network

1.1 What is Biological Neurons and Synapses

- The human brain is defined as an information processing system. It is also known as biological neural network.
- Human bearing biological neural network is also known as neurons system and the fundamental unit of this system is known as neuron or nerve cell. Hence, a neuron is defined as the structural or fundamental unit of neural network or nervous system.
- The human brain contains about 10 billion nerve cell or neurons on average; each neuron is connected to other neurons through about 10^{15}connections.

1.2 Schematic Diagram of Biological Neuron

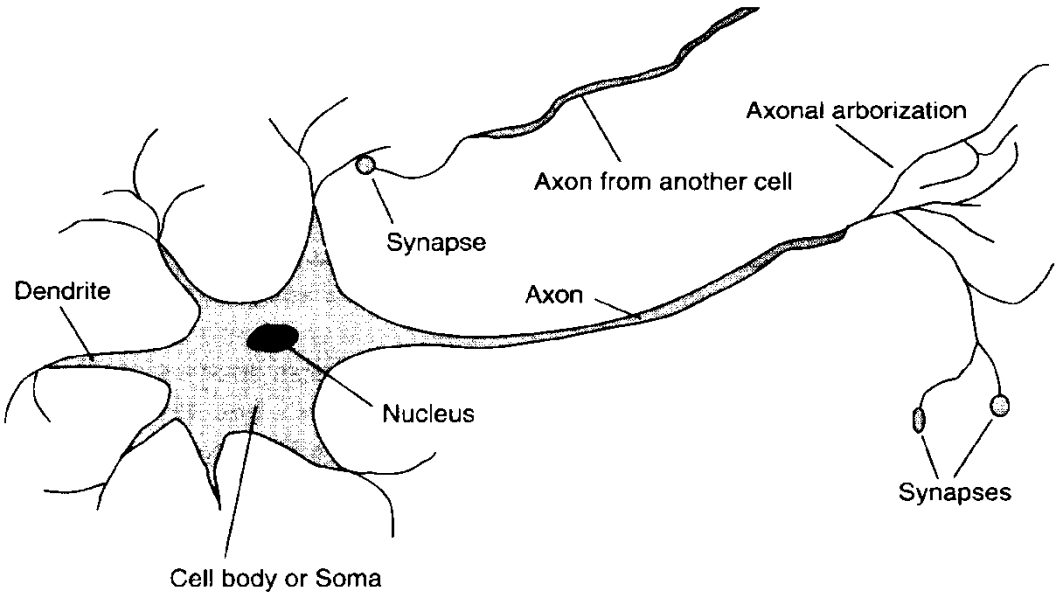

Figure 1.1 schematic diagram of biological neuron

1.3 Different Part of Biological Neuron

- Biological neuron or nerve cell consists of following parts-
  1) Cell body (Soma)
  2) Axon
  3) Synapses
  4) Dendrites

Cell Body:

- A neuron consists of cell body also called as Soma, where the all neurons are located, where is center part of the cell body.
- The shape of cell body is irregular and all the processing of neurons takes place inside the cell body.
- It regulates the received signals and given to other cell body.
- It also manages the energy economy of neurons. The size of a typical cell body of a neuron is range from 10 to 80 micrometer.

Axon:-

- It is single long
- It has multiple branches into strands and sub strands connecting to many other neurons at the junction, called as synaptic junction (synapses or synaptic points).
- The main purpose of axon is the transmission of generated neural activity (response on signal) to the other neurons called a motor neuron. The size of axon is odd odder of micrometer.

Synapse:-

- These are the connecting parts at which neurons are meeting together from where the signals are transmitted from one neuron to other through dendrites.

Dendrites:-

- There is the tree like formation associated with cell body. It senses as a receptor for signals from other neurons.
- There is basically short processor which terminates mostly near the cell body.

1.4 Basic Working Principle of Biological Neurons

- Although there exists several different types of neurons but all types of neurons on the same basic principle.
- Human neurons system is very complex structure because of vast number of neurons and their interconnection.
- The total number of neurons in a normal human brain is estimated to be in the vicinity of 10^{11}which are interconnected through 10^{15}connections. They are distributed in layers.
- Initially, the dendrites receive signal from other neurons at connecting points (synaptic points) or synapses.

- It is a complex chemical process in which specific transmitter substances are related from sending side to the junction.
- The effect is to raises or lowers the electrical potential inside the body of the receiving cell.

1.5 Characteristics of Biological Neurons:

- There are some features of biological neural network that makes it superior even to the most sophisticated artificial intelligence computer system for some task not for all. Some of them are as following-
  1) Robustness and fault tolerance
  2) Flexibility
  3) Ability to deal with a variety of data situations
  4) Collective competition

1. Robustness and fault tolerance

- The decay of nerve cell does not seem to affect the performance significantly.

2. Flexibility

- The network automatically adjusts itself to a newer environment using any preprogrammed instructions.

3. Ability to deal with a variety of data situations

- The network can deal with a variety of data such that it can deal with the information i.e. fuzzy, probabilistic and contradictory.

4. Collective competition

- The network performs routinely many operations and also a given task in a distributed manner.

2. Characteristics of Artificial Neural Network

2.1 Introduction of artificial neural Network

- A set of processing units when assembled in a closely interconnected network, offers surprisingly a rich structure and exhibit some feature of the biological neural network. Such a structure is known as artificial neural network.
- ANN's are biological inspired symbolic networks or system i.e. they composed of the elements that performs in a manner nearly similar to the functioning of biological neurons.

- In general, an ANN's is a machine or neuron that is designed to model in the way, in which the brain performs a particular task or function of interest, the network is usually implemented by using electronic components or it is simulated in a software on a digital computer.
- To achieve a good performance of an ANN employs a massive interconnection of simple computing cells called as neurons or processing units.

2.2 Formal definition of ANN

- A formal definition of ANN given by Haykins such as:
  "An artificial neural network is a massively (especially) parallel distributed processor made up of simple processing units, which has a natural tendency for storing experimental knowledge and making it available for use".
- It resemble the brain in two respects
  1. Knowledge is acquired by the network from its environment through learning process.
  2. Interconnection strength, known as synaptic weights, is used to store the acquired knowledge.

General Model of a Processing Unit

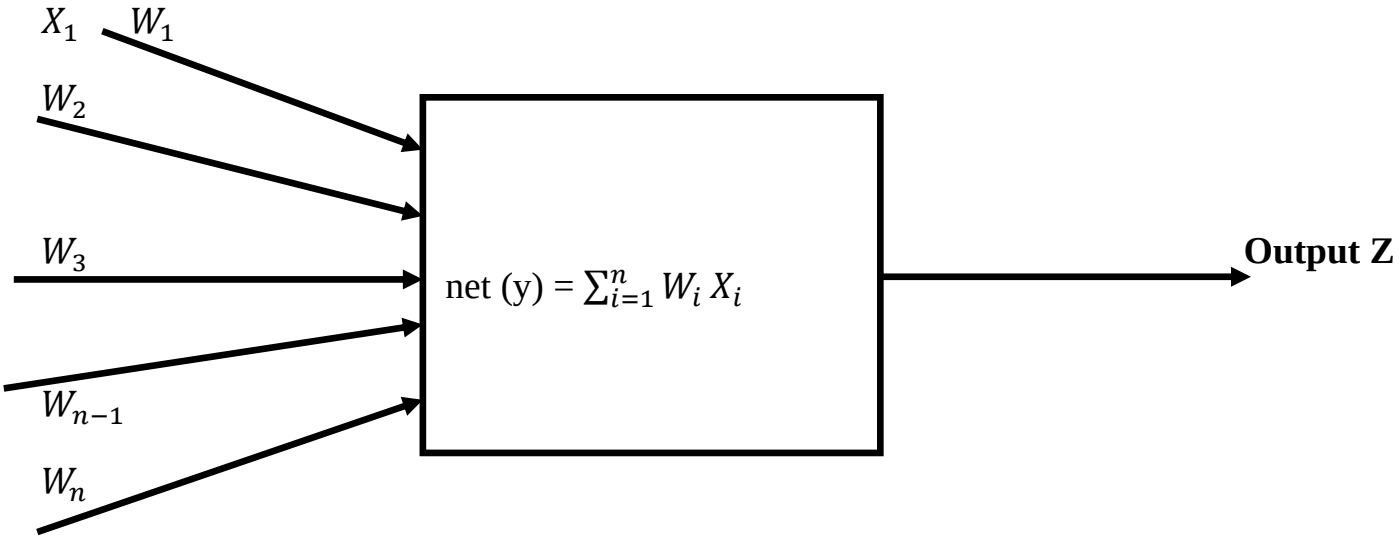

Figure: General Model of a Processing Unit without activation function

General Model of a Processing Unit with activation function

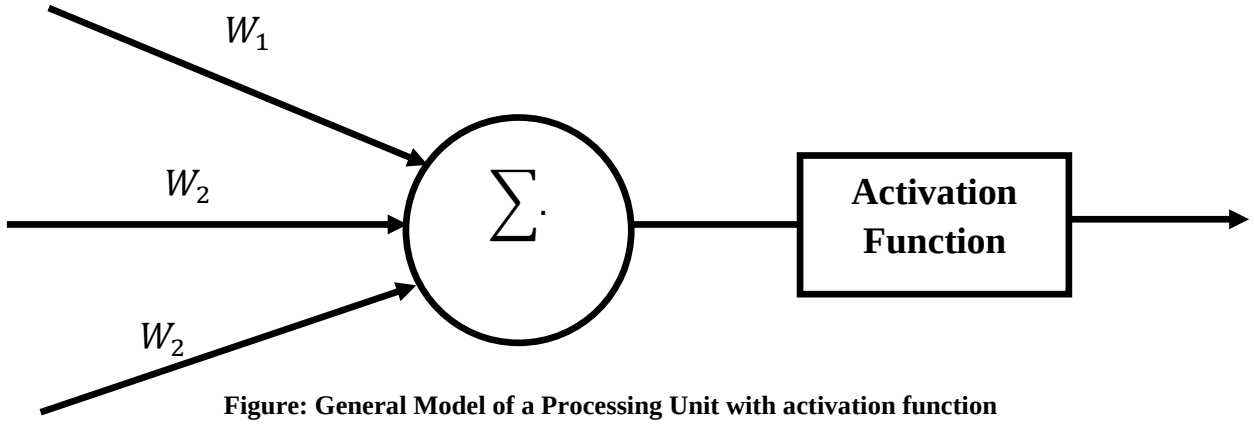

Figure: General Model of a Processing Unit with activation function

- In above figure, x_1, x_2, x_3….x_n are the input and W_1, W_2, W_3 ... ... W_n are the corresponding weight of the inputs.
- The weighted sum $x_1W_1 + x_2W_2 + \cdots .. + x_nW_n$ is known as 'net' or 'activation' value.
- The output part produces the signal from the received activation value depending upon the activation function.

2.3 Characteristics of ANN

1) They are extremely powerful computational devices.
2) Massive parallelism makes them very efficient because this property makes it potentially fast for the computation of certain task.
3) They can learn from experience and generalized from training data.
4) They can have a quality toward fault tolerance.
5) They can deal with the situation where a normal synaptic system having a lot of difficulties.

2.4 Terminology of ANN

There are some important terms related to the ANN, these terms are collectively known as terminology of ANN. The terminology of ANN is as follows-

a) Processing Unit
b) Interconnection
c) Operation
d) Update

Processing Unit:-

- An artificial neural network can be considered as highly simplified model of the complex structure of biological neural network.
- An ANN consists of number of interconnected units called as processing units. The general model of a processing unit consists of a summing part followed by an output.
- The summing part receives *N* number of input values. Each value is weighted by a weight value and then summing part determines a weighted sum. The sine of weight for each input determines whether the input is excitatory (positive weight) or inhibitory (negative weight).
- This weighted sum is known as net or activation value which is then faded to the output path.
- The output part produces a signal from the activation value. The input could be continuous or discrete data values, and likewise the output also could be continuous or discrete.

Interconnection:-

- In an ANN, several processing units are interconnected to some topology to accomplish a pattern recognition task.
- Therefore, the input to a processing unit may come from the output of some other processing units and/or from external source.
- Similarly the output of each of the processing units may be given to several processing units including it.
- The amount of output of one unit received by another unit depends on the strength of connection between the units, and it is reflected in the weight value associated with the connected link.

Operation:-

- In operation, each unit of ANN (processing units) receives input from other interconnected units and/or from an external source.
- A weighted sum (net or activation value) is computed at a given instant of time and then this net or activation value determines the actual output function or path.

Update:-

- In implementation, there are several options available for both activation and synaptic dynamic but in practical life, for biological neural network, the activation dynamic including the update is much more complex as compared to the ANN.
- The model of ANN along with the governing equation of activation and synaptic design according to pattern recognition task to be handled or under consideration.
- The adjustment of weights in ANN is known as learning which is very most aspect without learning of ANN is useless.

Characteristics of ANN

1. They are extremely powerful computational devices.
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3. They can learn from experience and generalized from training data.
4. They can deal with the situation where a normal symbolic system having a lot of difficulties.
5. They have a quality toward fault tolerance.
6. They have inbuilt capability to adapt the synaptic weights to change (learning) in the surrounding environment.

Types of Activation Function:

- A single artificial neuron

$$\mathbf{y = X_0W_0 + X_1W_1 + X_2W_2 + \cdots + X_mW_m = \sum_{j=0}^{m} X_jW_j}$$

The weighted sum is called the net output.

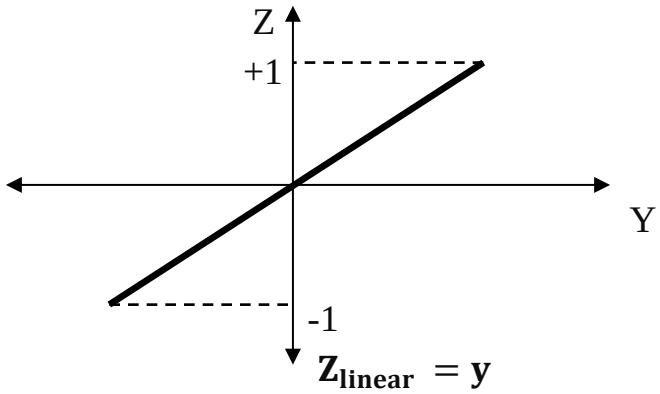
- The neuron output is-

$$z = f(y)$$

- f is called the activation function, also called transfer function, sqrurshily function.
- ***Definition:-*** an activation function defines the output of a neuron or processing unit in term of induced local field or activation potential v of the neuron or processing unit. It is denoted by a symbol $\Psi(v)$. An activation function is used for limiting the amplitude of the output of a processing unit.

- An activation function $\Psi(v)$ is applied to weighted sum or net value of the activation function is the neuron output.
- An activation function should be continuous, differentiable and bounded.
- An activation function can be linear as well non-linear. The non-linear activation functions are usually used in multi-layer neuron networks. The different types of activation functions are as follows-
    1. ***Linear function***
    2. ***Step or threshold function***
    3. ***Sign function***
    4. ***Sigmoid function***

1. Linear function:

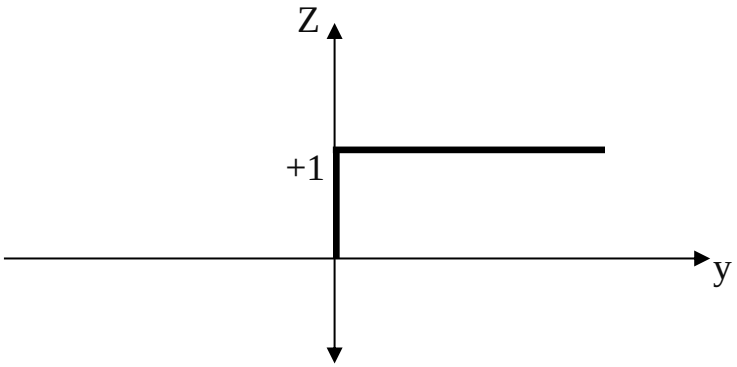


The simplest f is the linear function i.e.

Output-

Z = y

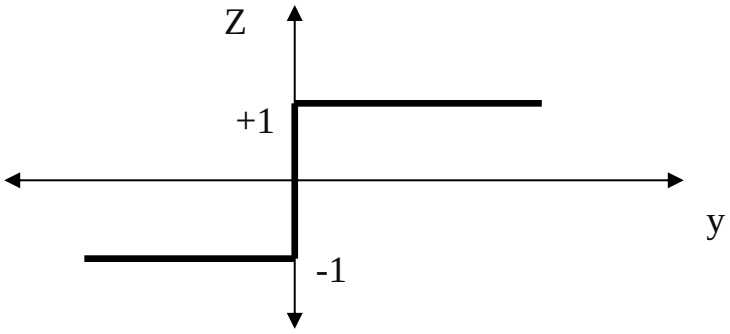
2. Step or threshold function



Here,

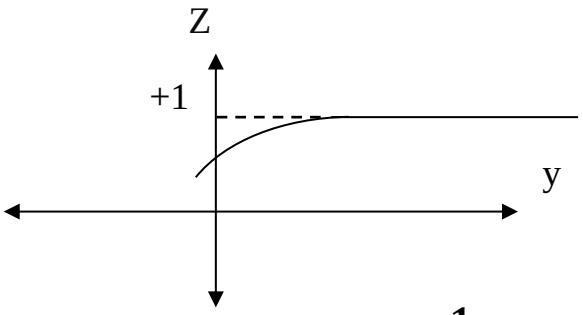
$$\mathbf{Z_{step}} = \begin{cases} \mathbf{1}\ ; \mathbf{if\ y} \geq \mathbf{0} \\ \mathbf{0}\ ; \mathbf{if\ y} < 0 \end{cases}$$

3. **Sign function**



$$\mathbf{Z_{sign}} = \begin{cases} +\mathbf{1}\,;\mathbf{if\ y} \geq \mathbf{0} \\ -\mathbf{1}\,;\mathbf{if\ y} < 0 \end{cases}$$

4. Sigmoid function



$$\mathbf{Z_{Sigmoid}} = \frac{\mathbf{1}}{\mathbf{1} + \mathbf{e^{-y}}}$$

Sigmoid function is the most commonly used function because it's continuous and differentiable everywhere.

Example of Computing a Neuron output:

- A neuron output z given the following-

x_1	x_2	W_1	W_2	x_5
0.5	**0.15**	**0.02**	**0.7**	**0.9**

The activation function is sigmoid; the inputs are x_1 and x_2; the weights are w_1 and w_2; the bias is 1.0 and the bias weight is W_0.

The output before activation function is-

$y = 0.5 * 0.02 + 0.15 * 0.7 + 0.9 * 1.0 = 1.015$

The neuron output after the activation function-

$$\mathbf{Z_{Sigmoid}} = \frac{\mathbf{1}}{\mathbf{1 + e^{-y}}}$$

$$\mathbf{Z_{Sigmoid}} = \frac{\mathbf{1}}{\mathbf{1 + e^{-1.015}}} = \mathbf{0.734}$$

If the function is linear then z=y=1.015