Artificial Neural Network

Dr. P. K. Chaurasia

Associate Professor,

Department of Computer Science and Information Technology

MGCUB, Motihari, Bihar

Biological Inspirations

- Humans perform complex tasks like vision, motor control, or language understanding very well.
- One way to build intelligent machines is to try to intimate the human brains.

Human Brain

- The human brain is highly complex , non-linear and parallel computer, composed of some 10^{11} neurons that are densely connected.
- A neuron is much slower (10^{-3} sec) compared to a silicon logic gate (10^{-9} sec), however the major interconnections between neurons makeup for the comparable slow rate.
- Individual neurons operate in a few milliseconds. Calculations do not involve more than about 100 serial steps and the information sent from one neuron to another is very small.
- Some of the neural structure of the brain is present at birth, while other parts are developed through learning, especially in early stages of life, to adapt to the environment

Biological Neuron

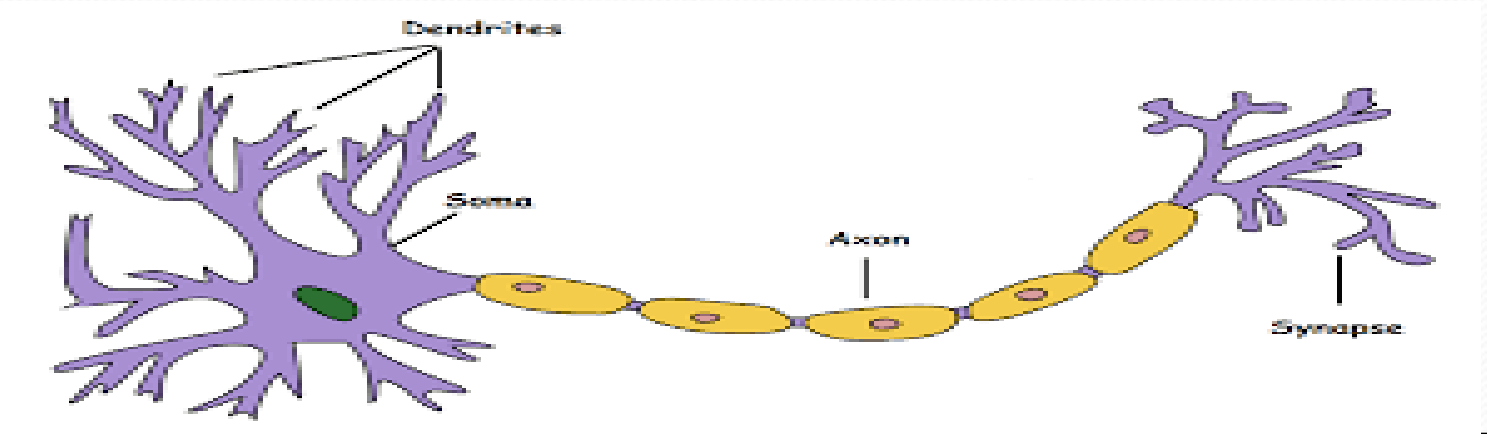
A biological neuron may have as many as 10,000 different inputs, and may send its output (the presence or absence of a short-duration spike) to many other neurons. Neurons are wired up in a 3-dimensional pattern.

Dendrites: Nerve fibres carrying electrical signals to the cell.

Cell Body: Computes a non-linear function of its inputs .

Axon: Single long fiber that carries the electrical signal from the cell body to other neurons.

Synapse: The point of contact between the axon of one cell and the dendrite of another, regulating a chemical connection whose strength affects the input to the cell.



Neural Network

- 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.
- These tasks include pattern recognition and classification, approximation, optimization, and data clustering.

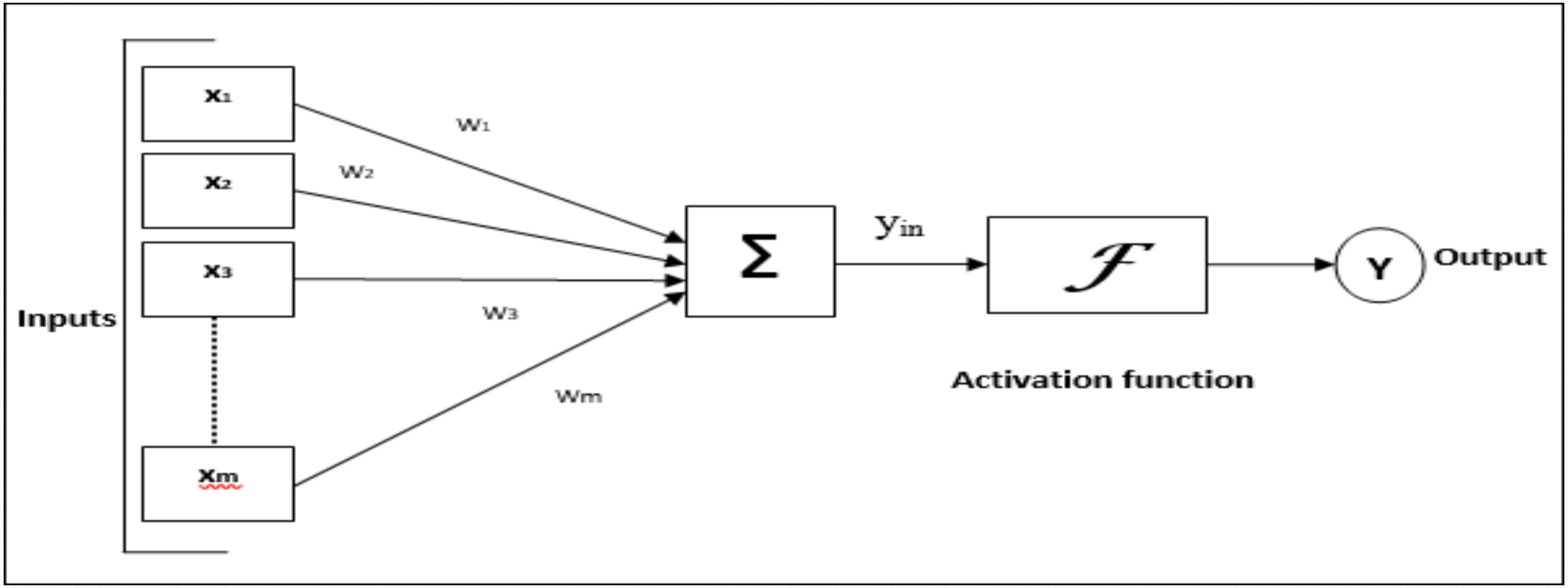
What is Artificial Neural Network?

- Computational model inspired by the human brain:
- Massive parallel, distributed system, made up of simple processing units(neurons).
- Synaptic connection strengths among neurons are used to store the acquired knowledge.
- Knowledge is acquired by the network from its environment through a learning process.

Properties of Artificial Neural Network

- **Learning from Experience:**
  - Labeled or unlabeled
- **Adaptivity:**
  - Changing the connection strengths to learn things.
- **Non-linearity:**
  - The non-linear activation functions are essential.
- **Fault tolerance:**
  - If one of the neurons or connections is damaged, the whole network still works quite well.

Model of ANN



- The net input can be calculated as:

$$Y_{in} = X_1.W_1 + X_2.W_2 + X_3.W_3 \ldots\ldots\ldots X_m.W_m$$

$$\text{Net Input } Y_{in} = \Sigma X_i.\ W_i$$

- The output can be calculated as:

$$Y = F(yin)$$

Processing of ANN

- ANN depends upon the following three building blocks −
  - Network Topology
  - Adjustments of Weights or Learning
  - Activation functions

Network Topology

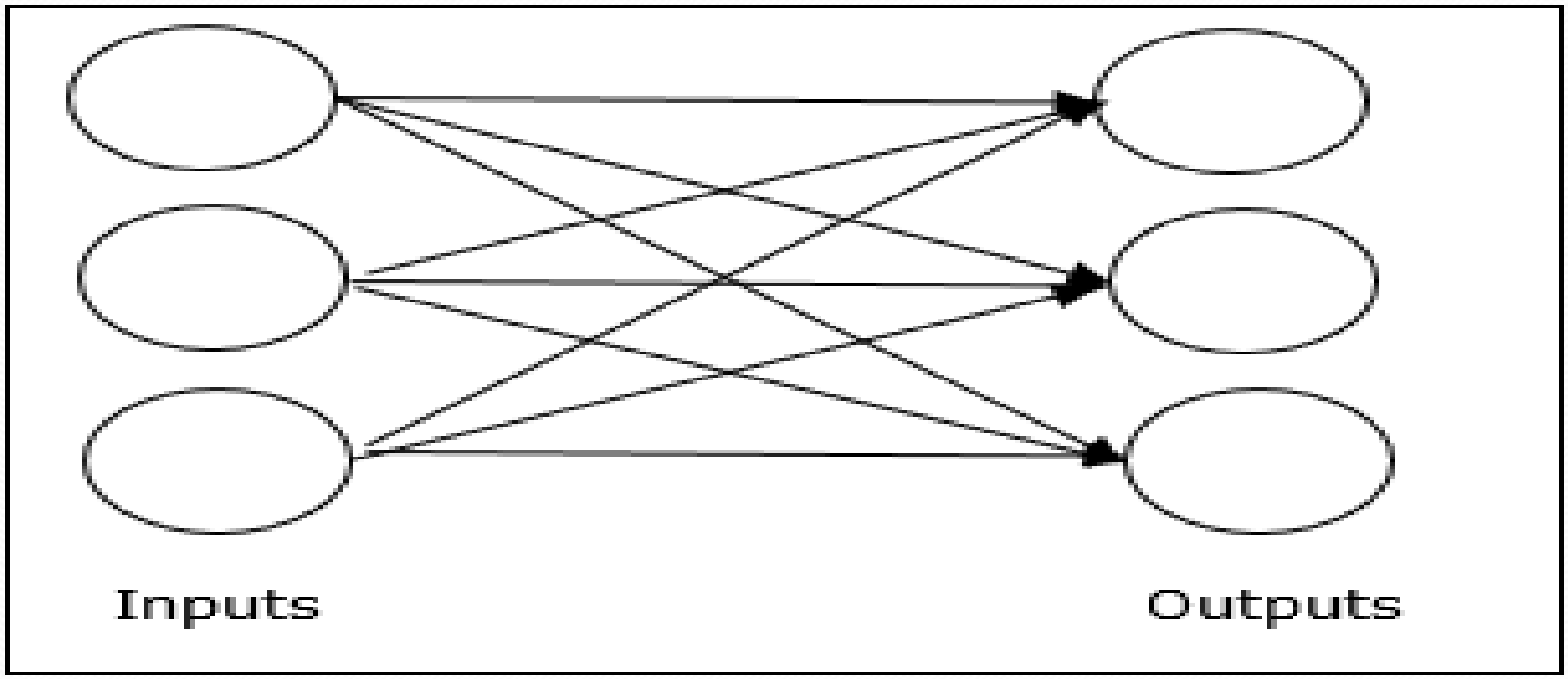
- It is the arrangement of a network along with its nodes and connecting lines. According to the topology, ANN can be classified as the following kinds −
  - Single Layer Network
  - Multi Layer Network

Single Layer Network

- All the nodes in a layer are connected with the nodes of the previous layers.
- The connection has different weights upon them.
- There is no feedback loop means the signal can only flow in one direction, from input to output.

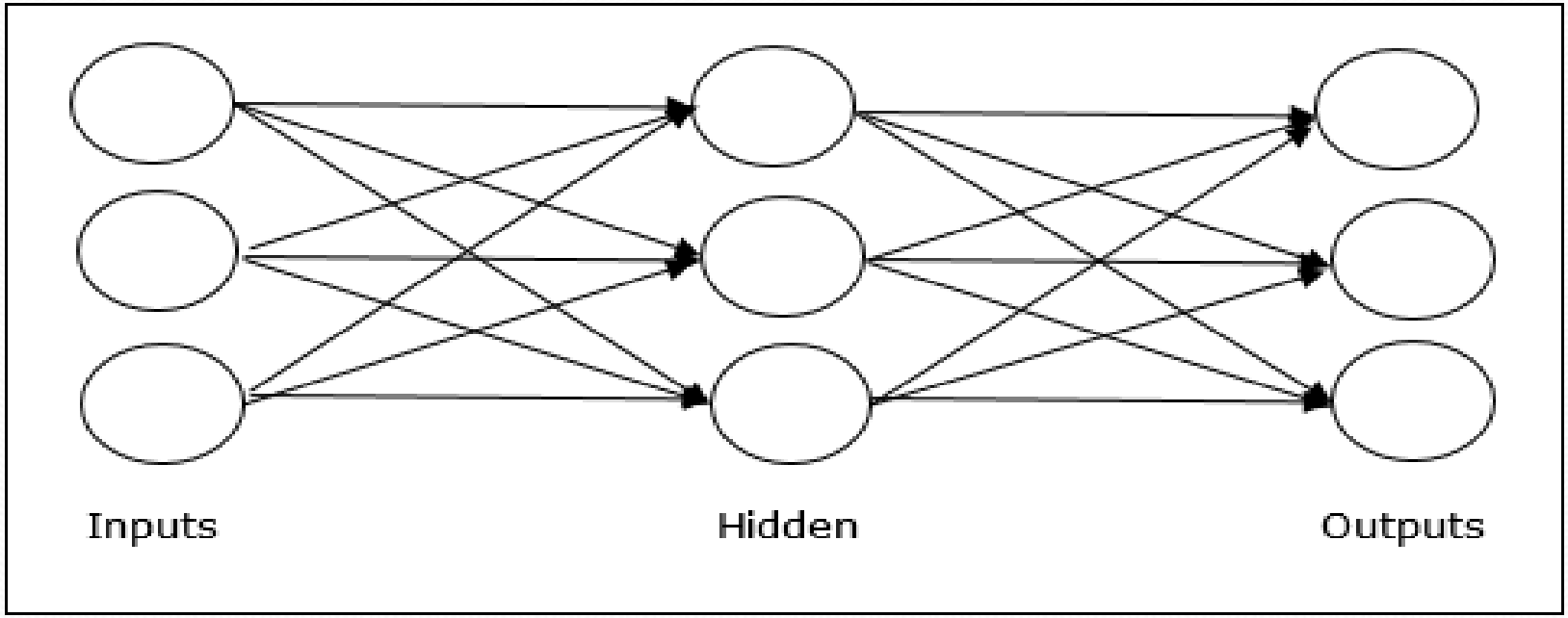
Single Layer Network

- The concept of ANN having only one weighted layer. In other words, we can say the input layer is fully connected to the output layer.



Multi Layer Network

- The concept of ANN having more than one weighted layer. As this network has one or more layers between the input and the output layer, it is called hidden layers.



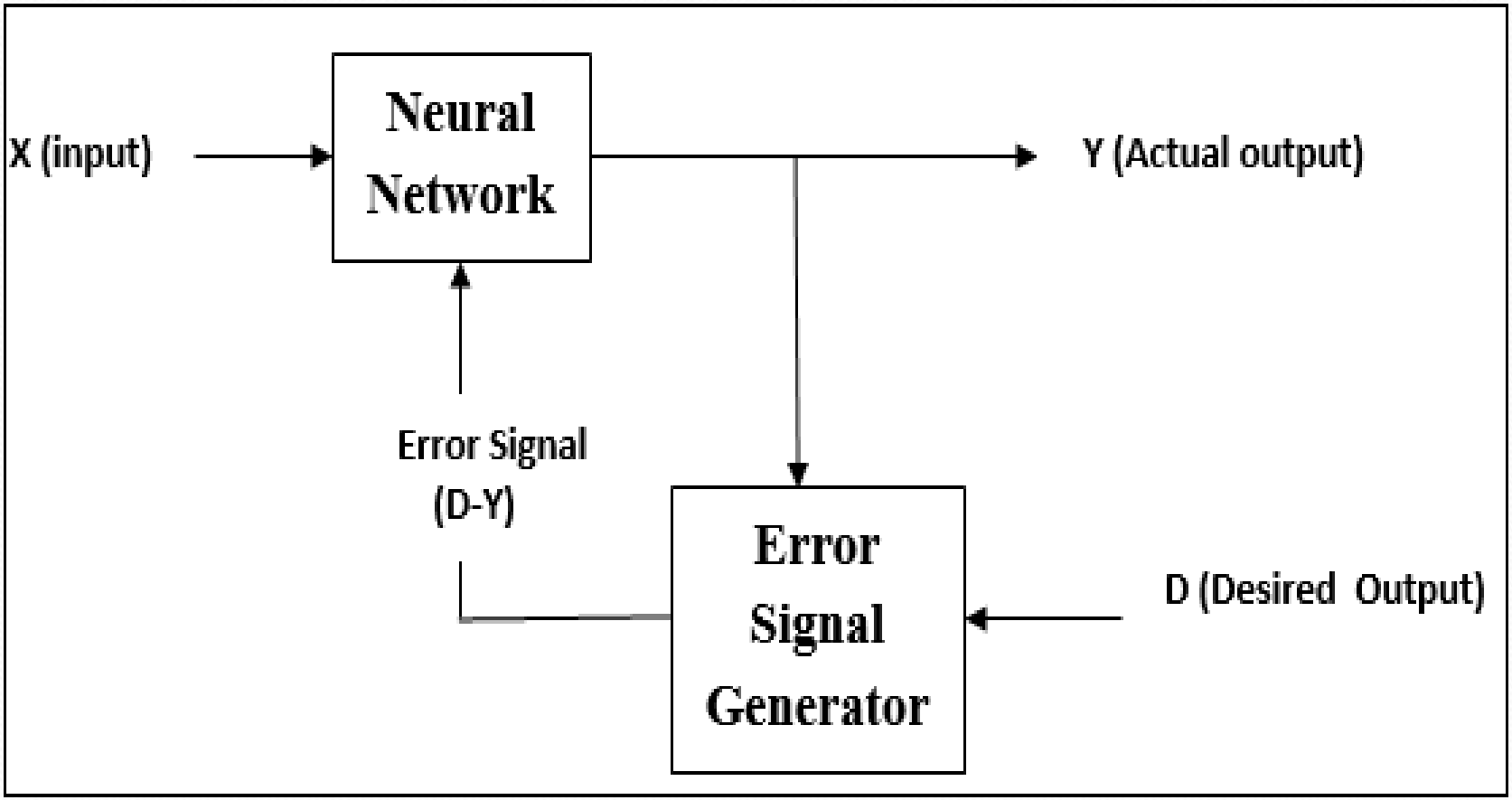
Adjustments of Weights or Learning

- It is the method of modifying the weights of connections between the neurons of a specified network.
- Learning in ANN can be classified into three categories:
  - Supervised learning
  - Unsupervised learning

Supervised Learning

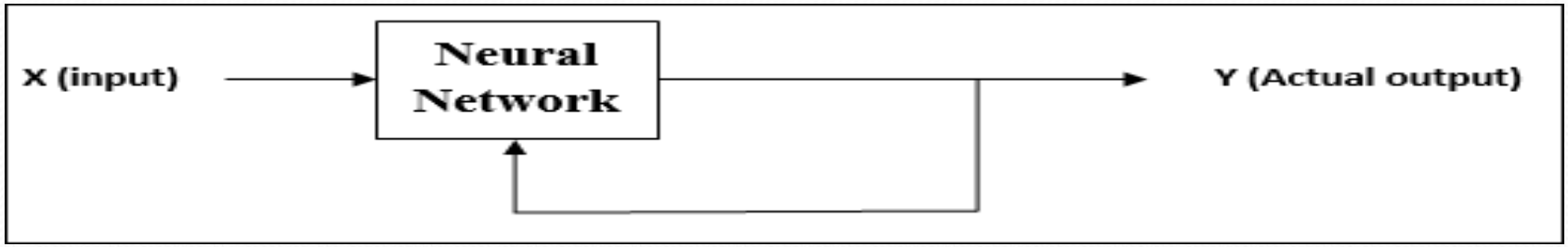
- This type of learning is done under the supervision of a teacher. This learning process is dependent.
- The training of ANN under supervised learning, the input vector is presented to the network, which will give an output vector.
- This output vector is compared with the desired output vector.
- An 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.

Supervised Learning



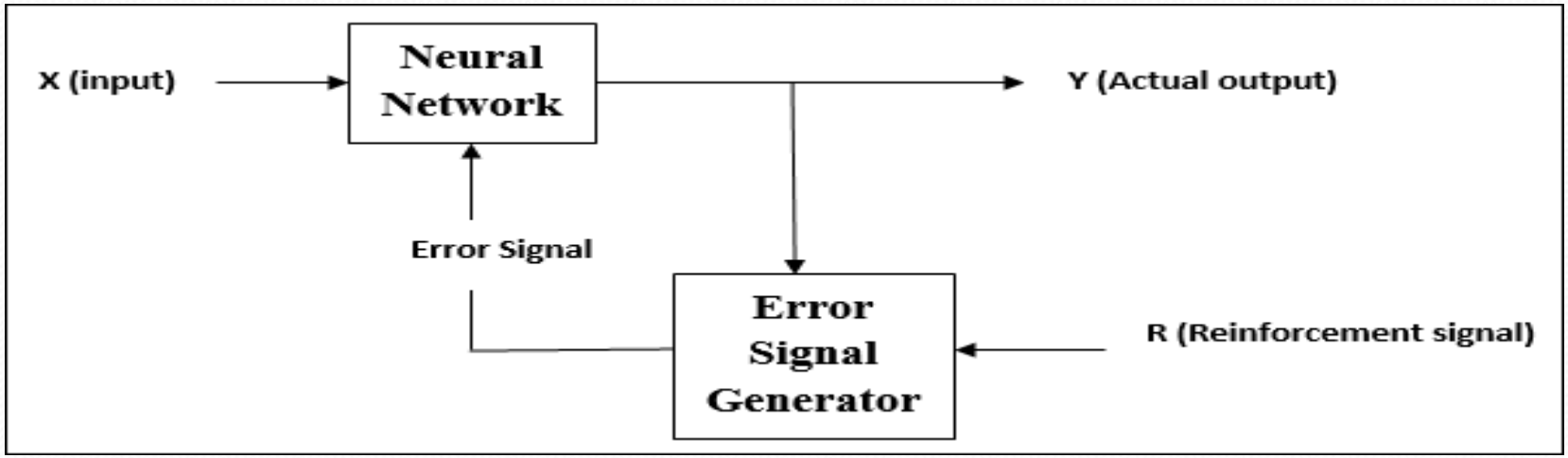
Unsupervised Learning

- This type of learning is done without the supervision of a teacher. This learning process is independent.
- 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.
- 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

- This type of 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.
- It is similar to supervised learning.
- 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.



Activation Functions

- It is the extra force or effort applied over the input to obtain an exact output. In ANN, we can also apply activation functions over the input to get the exact output.
- Following are some of the activation functions:
  - Linear activation function
  - Sigmoid activation function

Types of Activation Function

Linear Activation Function:

- It is also called the identity function as it performs no input editing. It can be defined as:

$$F(x) = X$$

Sigmoid Activation Function:

It is of two types:

- Binary Sigmoidal Function
- Bioplar Sigmoidal Function

Binary Sigmoidal Function

- This activation function performs input editing between 0 and 1.
- It is positive in nature. It is always bounded, which means its output cannot be less than 0 and more than 1.
- It is also strictly increasing in nature, which means more the input higher would be the output.
- It can be defined as:

$$F(x) = sigm(x) = \frac{1}{1 + exp(-x)}$$

Bipolar Sigmoidal Function

- This activation function performs input editing between -1 and 1.
- It can be positive or negative in nature.
- It is always bounded, which means its output cannot be less than -1 and more than 1.
- It is also strictly increasing in nature like sigmoid function.
- It can be defined as:

$$F(x) = sigm(x) = \frac{2}{1 + exp(-x)} - 1 = \frac{1 - exp(x)}{1 - exp(x)}$$

Review Questions

- What is Neural Network?
- What is ANN? What are the properties of ANN? Explain.
- What is the difference between NN and ANN? Explain.
- What are the topology of ANN?
- What is activation function? What are the different types of activation function?

References

- List of books referred:
  - Neural Networks: A Comprehensive Foundation, S. Haykin .
  - Pattern Recognition with Neural Networks, C. Bishop
  - Neural Network Design, Hagan, Demuth and Beale.
- List of websites referred:
  - http://people.sabanciuniv.edu/berrin/cs512/lectures/7-nn1-intro.ppt.pdf
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Thank you!