Study of Artificial Neural Network

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Introduction:-

An Artificial Neural Network (ANN) is a mathematical model that tries to simulate the structure and functionalities of biological neural networks. Basic building block of every artificial neural network is artificial neuron, that is, a simple mathematical model (function). Such a model has three simple sets of rules: multiplication, summation and activation. At the entrance of artificial neuron the inputs are weighted what means that every input value is multiplied with individual weight. In the middle section of artificial neuron is sum function that sums all weighted inputs and bias. At the exit of artificial neuron the sum of previously weighted inputs and bias is passing trough activation function that is also called transfer function. Although the working principles and simple set of rules of artificial neuron looks like nothing special the full potential and calculation power of these models come to life when we start to interconnect them into artificial neural networks (Figure 1) These artificial neural networks use simple fact that complexity can grown out of merely few basic and simple rules.

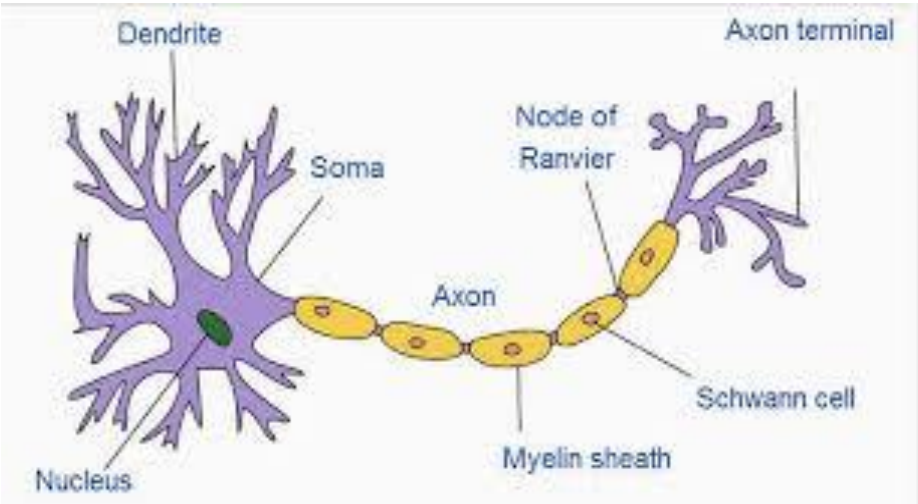

Figure 1 Flow of information in human brain.

In order to fully harvest the benefits of mathematical complexity that can be achieved through interconnection of individual artificial neurons and not just making system complex and unmanageable [4]. We usually do not interconnect these artificial neurons randomly.

Artificial Neuron

Artificial neuron is a basic building block of every artificial neural network. Its design and functionalities are derived from observation of a biological neuron that is basic building block of biological neural networks (systems) which includes the brain, spinal cord and peripheral ganglia. Similarities in design and functionalities can be seen in Fig. 3. whereas the left side of a figure represents a biological neuron with its soma, dendrites and axon and where the right side of a figure represents an artificial neuron with its inputs, weights, transfer function, bias and outputs [3].

Biological Neural Network:

Biological neuron or a nerves cell system consists of synapses, dendrites, the cell body (hillock) and the axon. The main building blocks are discussed as below:-

- Synapse the elementary signal processing device.
  (i) A synapse is a biological device, which convert a pre-synaptic electrical signal into a chemical signal and then back into post-synaptic electrical signal.
  (ii) The input pulse train has its amplitude modified by parameter srored in the synapse.
- The post synaptic signals are aggregated and transferred along the dendrites to the nerve cell body.
- The cell body generate the output neuronal signal, a spike which is transferred along the axon to the synaptic terminal of other neurons.

- The frequency off firing of neuron is proportional to the total synaptic activities and is control by synaptic parameters (weight).
- The pyramidal cell can receive 104 synaptic input and it can fan out the output signal to thousands of targets cell- a connectivity difficult to achieve in the ANNs.

Generally the function of the main element can give us-

1. **Dendrites-** receive signals from other neurons. The dendrites tree is in the form of very fine bush of thin filters around the neural cell body.
2. **Soma-** Soma or cell body, Sums all the incoming signals.
3. **Axon-** When a particular amount of input is received, then the cell fires. It transmits signals through axon to other cells.

Basically, a biological neuron receives input from other sources, combine them in some way, perform a generally non-linear operation on the result and then output the final results. The figure 2 shows the relationship of these parts.

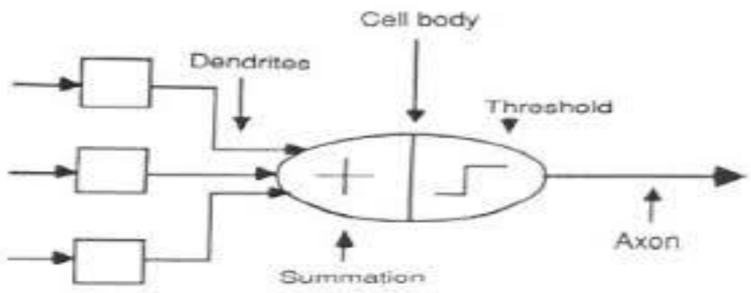

Figure 2 Biological neuron design

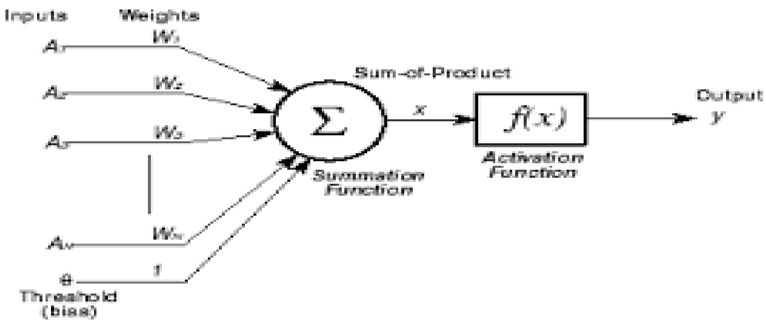

Figure 3 Artificial neuron design

In case of biological neuron information comes into the neuron via dendrite, soma processes the information and passes it on via axon. In case of artificial neuron the information comes into the body of an artificial neuron via inputs that are weighted (each input can be individually multiplied with a weight). The body of an artificial neuron then sums the weighted inputs, bias and "processes" the sum with a transfer function. At the end an artificial neuron passes the processed information via output(s). Benefit of artificial neuron model simplicity can be seen in its mathematical description below:

$$y(k) = f\left(\sum_{i=0}^{m} w_i(k).x_i(k) + b\right) \tag{1}$$

(1) Where $x_i(k)$ is input value in discrete time k where i goes from 0 to m.

(2) $w_i(k)$ is weight value in discrete time k goes from 0 to m,

(3) b is bias,

(4) f is a transfer function,

(5) $y_i(k)$ is a output value in discrete time k.

As seen from a model of an artificial neuron and its equation (1) the major unknown variable of our model is its transfer function. Transfer function defines the properties of artificial neuron and can be any mathematical function. We choose it on the basis of problem that artificial neuron (artificial neural network) needs to solve and in most cases we choose it from the set of functions: Step function, Linear function and Non-linear (Sigmoid) function defined in this chapter.

Artificial Neural Network:

When combining two or more artificial neurons we are getting an artificial neural network. If single artificial neuron has almost no usefulness in solving real-life problems the artificial neural networks have it. In fact artificial neural networks are capable of solving complex real-life problems by processing information in their basic building blocks (artificial neurons) in a non-linear, distributed, parallel and local way. The way that individual artificial neurons are interconnected is called topology, architecture or graph of an artificial neural network. The fact that interconnection can be done in numerous ways results in numerous possible topologies that are divided into two basic classes. Figure 3 (below) shows these two topologies; the left side of the figure represent simple feed- forward topology (acyclic graph) where information flows from inputs to outputs in only one direction and the right side of the figure represent simple recurrent topology (semi- cyclic graph) where some of the information flows not only in one direction from input to output but also in opposite direction. While observing Figure 3, we need to mention that for easier handling and mathematical describing of an artificial neural network we group individual neurons in layers. On Figure 3 we can see input, hidden and output layer.

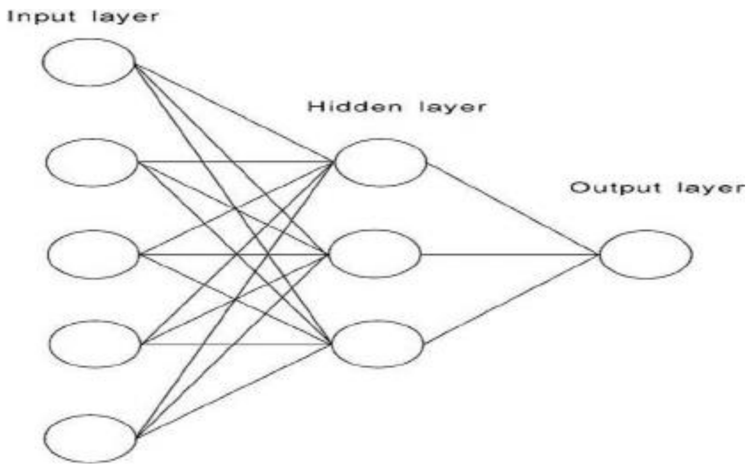

Figure 3 a simple neural network with 5 input, 1 output and one hidden layers

Usage of Artificial Neural Networks:

One of the greatest advantages of artificial neural networks is their capability to learn from their environment. Learning from the environment comes useful in applications where complexity of the environment (data or task) make implementations of other type of solutions impractical. As such artificial neural networks can be used for variety of tasks like classification, function approximation, data processing, filtering, clustering, compression, robotics, regulations, decision making, etc. Choosing the right artificial neural network topology depends on the type of the application and data representation of a given problem. When choosing and using artificial neural networks we need to be familiar with theory of artificial neural network models and learning algorithms [3]. Complexity of the chosen model is crucial; using to simple model for specific task usually results in poor or wrong results and over complex model for a specific task can lead to problems in the process of learning. Complex model and simple task results in memorizing and not learning. There are many learning algorithms with numerous tradeoffs between them and almost all are suitable for any type of artificial neural network model. Choosing the right learning algorithm for a given task takes a lot of experiences and experimentation on given problem and data set. When artificial neural network model and learning algorithm is properly selected we get robust tool for solving given problem.

Type of function used in ANN:

(1). **Hard limiting or threshold function: -** It is defined as

$$f(v) = \begin{cases} 1 & if \quad v \geq 0 \\ 0 & if \quad v < 0 \end{cases} \tag{2}$$

and so the relative output of a neuron n using this function is denoted by

$$f(v)=\begin{cases}1 & if \quad v_k \geq 0 \\ 0 & if \quad v_k < 0\end{cases} \tag{3}$$

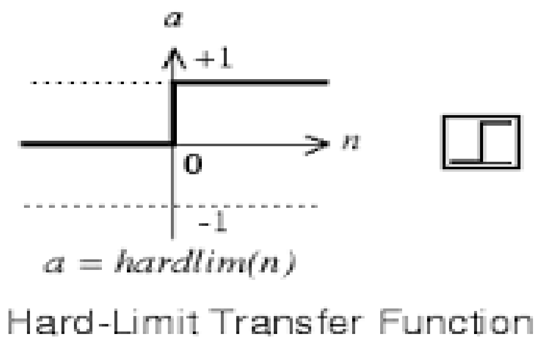

Figure 4 Hard limit or threshold function

Thus here the model takes the values as 1 if local field of that neuron non-negative and 0 otherwise.

(2). **Piecewise linear function:-** This function is defined as

$$f(v)=\begin{cases}1 & if \ v \geq 1/2 \\ v & if \ -1/2 < v < 1/2 \\ 0 & if \quad v \leq -1/2\end{cases}$$

This function is an approximation to a non linear amplifier and reduces it to threshold function if linear function has infinite amplification.

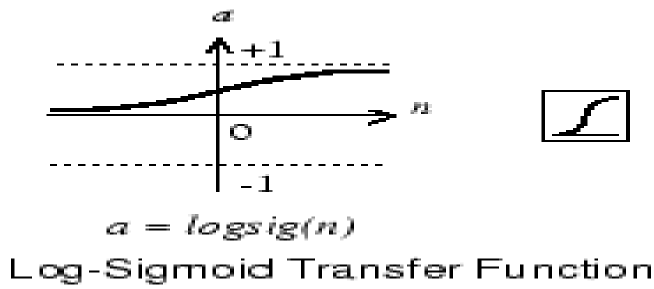

Figure 5 piecewise linear function

(3). Sault limiting or sigmoid functions:

It is the mostly used transferred function because it is differentiable. The typically used sigmoid functions are

$$f(v)=\frac{2}{1+e^{-\lambda}}-1 \quad \text{and} \quad f(v)=\frac{1}{1+e^{-\lambda}}$$

These function are also known as soft limiting activation function and is used for bipolar continuous (having both negative and positive response of neuron) and unipolar continuous activation function (having only negative response). The response is known graphically for a bipolar continuous function.

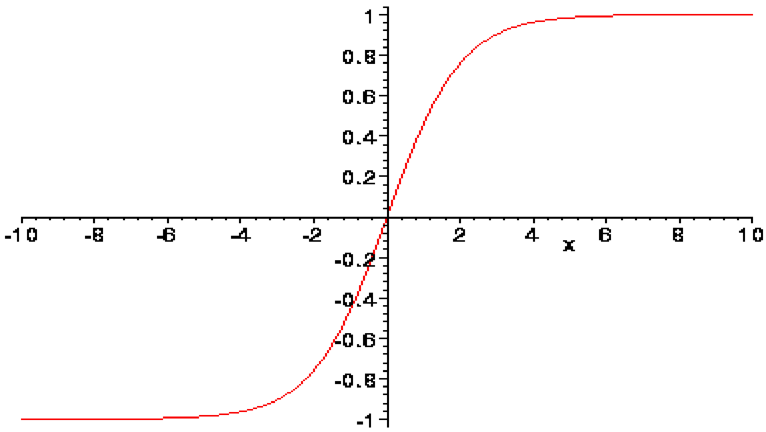

Figure 6 Sault limiting function

Type of Models

In this method, the output layers of neurons are connected to the input layers of neurons in the forward direction. These are also known as acyclic networks. These network are single or multi layered with any no. of nodes and neurons. A network having m inputs and n neurons [4], the input matrix is

$$x=[x_1, x_2, ..., x_n] \quad \text{and} \quad y=[y_1, y_2, ..., y_n] \tag{3}$$

The w_{pq} is the weight connected between q th input and p th neuron and implies the the activation values will be

$$u_p = \sum_{q=1}^{m} w_{pq}.x_q \tag{4}$$

The transformation of n neuron is given by the output signals as

$$u_p = f(w'_p.x) \tag{5}$$

And weight vector is,

$$w_p = [w_{p_1}, w_{p_2}, ..., w_{p_m}]' \text{ for } p=1,2,.........., n \tag{6}$$

The mapping of the input space x into output space is given by

$$S=[w_x]. \tag{7}$$

For the entire network with n layers the weight matrix is W .

The diagonal matrix S having the entire diagonal element as the m values of activation values in matrix u is

$$S = \begin{bmatrix} f(0) & 0 & - & - & 0 \\ 0 & f(0) & - & - & - \\ - & - & - & - & - \\ - & - & - & - & - \\ 0 & 0 & 0 & - & f(0) \end{bmatrix} \quad (8)$$

Where patterns are input and output signals and there is synaptic connection known by weight.

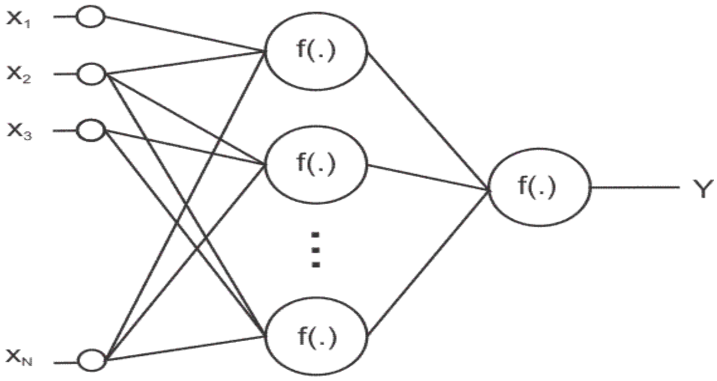

Figure 7 inter connection in Feedback network

Feed Back Network:

In feedback network input connect to the output by neurons. This network allows us to control one output by the help of other output. This network is suitable if at time't' the present output at time $(t+\Delta t)$,where W is weight matrix [2], by using (8) and all the calculations done in [1] we have

$$y(t+\Delta t) = S[Wy(t)] \quad (9)$$

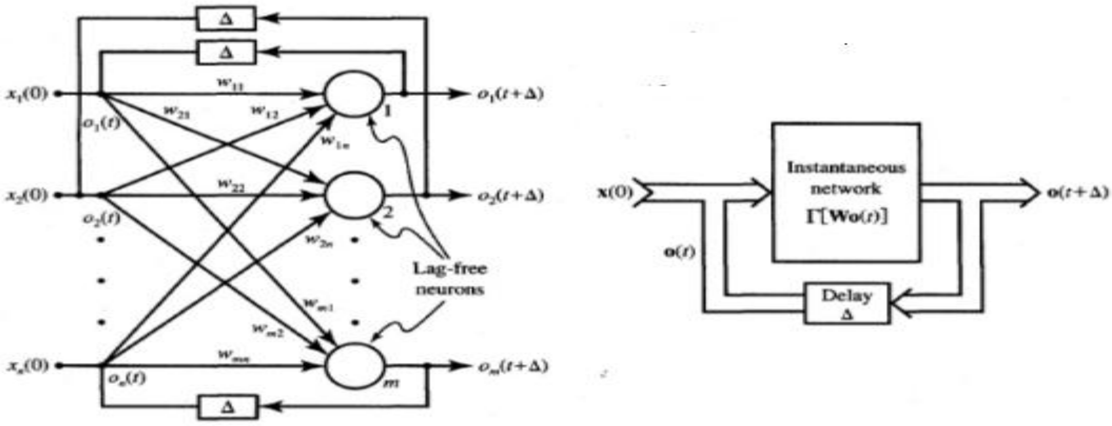

Figure 8 Feedback network and Block Diagram

This network required to initialize only $y(0) = x(0)$, after that input is taken off and system is left to itself in this feedback configuration and no input is required , after that to make the network for all $t > 0$. The feedback network is of two type continuous timed and discrete timed.

In discrete timed networks

$$y^{k+1} = S[W_{y^k}] \\ = S[WS[....S(W_x(0))....]] \tag{10}$$

Is recurrence relation for the output at an instant k+1. This is also known as automation. The delayed are converted with continuous timed networks.

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