'Neural Network' a Supervised Machine Learning Algorithm

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***Abstract*- As a machine learning algorithm, neural network has been widely used in various research projects to solve various critical problems. The concept of neural networks is inspired from the human brain. The paper will explain the actual concept of Neural Networks such that a non-skilled person can understand basic concept and also make use of this algorithm to solve various tedious and complex problems. The paper demonstrates the designing and implementation of fully design Neural Network along with the codes. It gives various architectures of ANN also the advantages, disadvantages & applications.**

***Keywords* - biological neuron, artificial neuron, artificial neural network, feed forward network, advantages, disadvantages and applications.**

I. INTRODUCTION

Neural network is a kind of Machine Learning algorithm. It is a model to predict the output based upon a given set of data.
There are two types of machine learning models.

- Supervised and
- Unsupervised

In former model, there are set of training examples with associated correct answers. The algorithm learns to predict the correct answers from this training set. Whereas, in the later model, the algorithm can find trends in the given data, without looking for the specific answers.
An example of supervised learning is, learning to predict whether the given model is spam if million mails are given with the tag of spam or no-spam. Example of unsupervised learning is clustering or grouping of similar type of data or anomaly detection.

- Neural network is supervised learning algorithm; it learns the process to produce the desired output.
- It learns from the unknown inputs and outputs, adopts to it and tries to predicts the future output without any errors.
- The initial given inputs and outputs are called training data. After learning from the known inputs and outputs, it can produce outputs without any errors in unknown environments.[8]

II. STRUCTURE OF NEURAL NETWORK

An Artificial Neural Network is a system based on the operation of biological neural network, in other words, it is an emulation of biological neural system.

Biological Neural Network

Human brain is extremely complicated and lots of very smart researchers are still struggling to find out how the brain really works. Neuron is the smallest cell of our brain, which makes us think and do smart work.

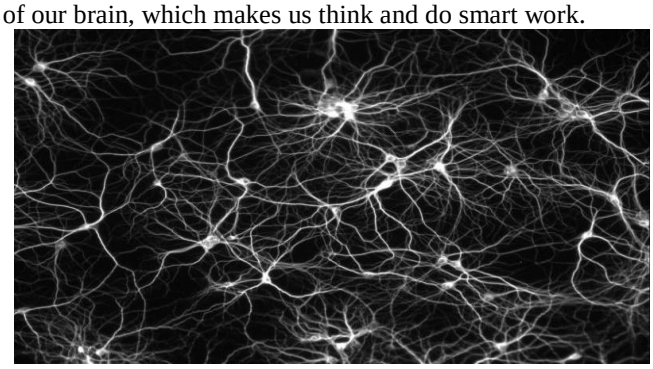

Fig.1. Neural Network in Human Body[3]

It is special biological cell that process information from one neuron to another neuron with the help of some electrical and chemical changes. A biological neural network is web of these interconnected neurons which are millions and millions in number and it makes the human brain best example of parallel processing. In a network of biological neuron such as brain, neuron are individual cells which receives input from other neurons or from a sensing cell and then send an outpour to other cells that are connected to it.

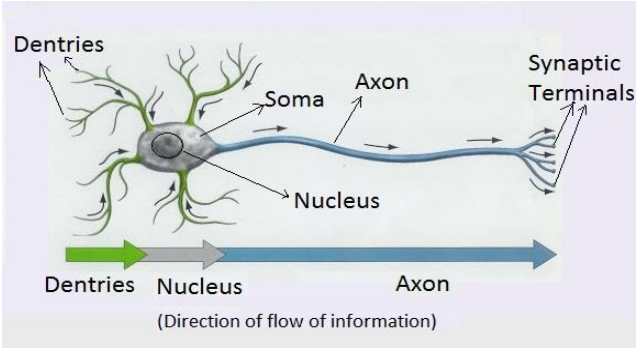

Fig.2. Human Neurons

A human Neuron is composed of a cell body or soma and two types of out reaching tree like branches: the axon and the dendrites. The cell body has a nucleus that contains information about hereditary traits and plasma that holds the molecular equipments or producing material needed by the neurons. The whole process of receiving and sending signals is done in particular manner. The whole process of information transfer is also represented in fig.2 along with the direction of signal flow. The basic components of a biological neuron are:-

Dendrites - Dendrites are hair like extensions of a neuron, and each dendrite can bring some input to the neuron (from neurons in the previous layer). These inputs are given to the soma. A neuron receives signals from other neuron through dendrites.

Soma - Soma is responsible for processing these inputs, and the output is provided to other neurons through the axon and synapses.

Axon - The axon is responsible for carrying the output of soma to other neurons, through the synapses. The Neuron send signals as spikes of electrical activity through a long thin stand known as an axon and an axon splits this signals through synapse and send it to the other neurons.

Synapses - Synapses of one neuron is connected to the dendrites of neurons in the next layer. The connections between neurons are possible because of synapses and dendrites.

Structure of Artificial Neuron

An artificial neural network consists of several layers and each layer has a number of artificial neurons in it. Artificial Neuron is much simpler then the biological neuron. It consists of various inputs, much like the biological neuron. Instead of Soma and Axon in biological neuron, artificial neuron use a summation unit and a transfer function unit. The output of one neuron in one layer is connected as input to multiple or all neurons in the next layer. Input is fed to the neurons in input layer, and output is obtained from the neurons in the last layer. For an artificial neuron, there is a weight value associated with each input.

A neuron is an information-processing unit which is fundamental to the operation of the neural. The three basic elements of the neural models are:

1. Synaptic Weights
2. Linear Combiner
3. Activation function

The brief study of these elements is given below:

1) **Synaptic Weights**: A set of synapse which is characterized by the strength or weight of its own. It is also known as connecting links. An adder for summing the inputs signals, weighted by the respective synapse of the neuron. The operation is called **linear combiner**. An **activation function** for limiting the amplitude of output of the neuron. Sometimes it is also called squashing functions .
2) **Linear Combiner -** All the inputs are fed to the neuron; in addition to these input values each link in neural network has an associated weight parameter "wi". The summation unit of neuron initially finds the net-value. For this, the product of each input value and corresponding connection weight is calculated. i.e, input value x(i) of each input to the neuron is multiplied with the associated connection weight w(i). These products are summed and fed to the transfer function.

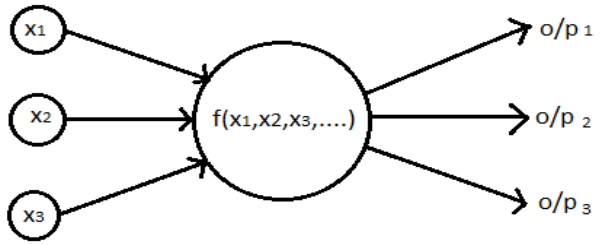

Fig.3 Single Neuron with inputs x1, x2, x3 etc. and Transfer Function f(x1,x2,x3,…).

For calculating the value of first hidden unit, each input is associated with a weight.

Activation function for first hidden unit *h1* is as:

$$h1 = f(w1,1.\ i1,\ w2,1\ .\ i2,\ w3,1\ .\ i3\ ,\ w4,1\ .\ i4)$$

wi,j is scaling factor for the i^{th} *input going to* j^{th} *hidden input.[8]*

A neuron also has a bias value, which affects the net value. A bias of a neuron is set to a random value, when the network is initialized.

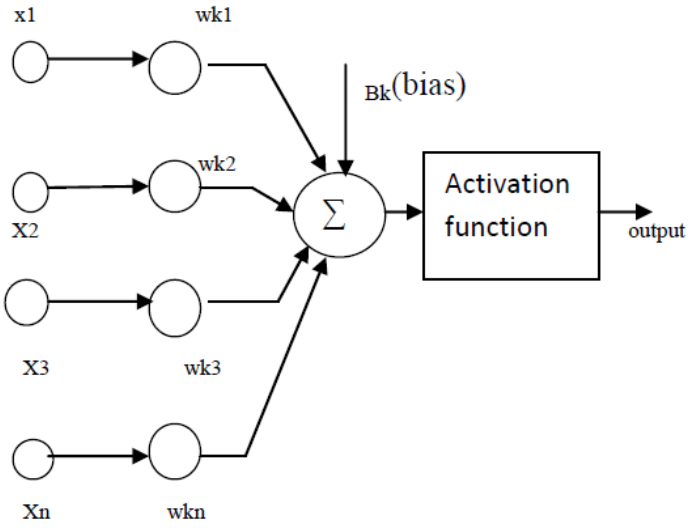

Fig.4 Nonlinear model of a neuron, [1]

i.e, if **x** is the input signal, and **w** is the associated Synaptic weight, then pseudo code for net value calculation is as follows.

```
netValue=0
  for i=0 to neuron.input.count-1
  netValue=netValue + x(i) * w(i)
next
  netValue=netValue + Bias
```

Code 1: The pseudo code for net value calculation

3) Transfer Functions

Transfer Functions are basically the activation function. Its a simple function that uses the net value to generate an output. This output is then propagated to the neurons of the next layer. There are four forms of Activation Functions that can be used. Threshold, Piecewise Linear, Sigmoid and Gaussian all are different from each other. Activation functions with their demonstration are as shown in figure below.

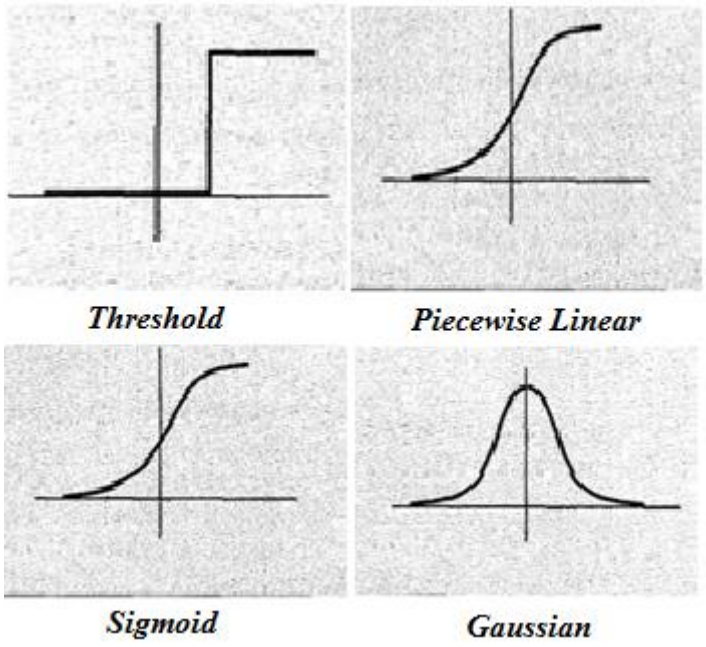

Fig.5 Activation functions [3]

The choice of activation function is very important when designing a neural network. One most common function is the **Heaviside function**.

If the sum of inputs is greater than some Threshold T, output is ONE otherwise the output is ZERO.

$$U_T(x_1,x_2,\ldots) = \begin{cases} 1, & \text{if } x_i \quad T \\ 0, & \text{Otherwise} \end{cases}$$

This corresponds to biological theory that behaves like a real neuron cell either fires do or don't signal.[8]

```
if (netValue<0.5)
        output = 0
else
        output = 1
```

Code 2: The pseudo code for Heaviside function

One problem with this transfer function is this is a non-differentiable function. we can not use it with gradient descent method*. (*gradient descent method is used to find out the weights in ANN)

Therefore another common logistic function is **Sigmoid Transfer Function**. A sigmoid transfer function will take a net value as input and produce an output between 0 and 1 as shown.

$$F(x_1,x_2,\ldots) = \begin{cases} 1 \\ \hline 1 + e^{-x_1 - x_2 - \ldots\ldots\ldots\ldots} \end{cases}$$

```
output = 1 / (1 + exp( -netValue))
```

Code 3: The pseudo code for Sigmoid Transfer Function

The logistic function is very similar to step function and is differentiable, there fire the neural network make use of logistic function.

Network Architecture

A single neuron in neural network is connected to multiple neurons usually to all the neurons in the next layer and also, the neuron in one layer can accept inputs from all neurons in the previous layer.

The manner, in which the neuron of a neural network is structured, is linked with the learning algorithm to train the network. So learning algorithm is used in the design of neural network as a structure. Learning algorithms are used to train neural network. In general there are different classes of network architectures:

1. Single Layer FeedForward Networks
2. Multilayer FeedForward Networks
3. Recurrent Networks

1. Single Layer FeedForward Networks:

Fig.6 shows the single layer feedforward network**.** In a layered network the neurons are organized in the forms of layers. Here we have input layer as a source nodes that corresponds to that gives output but vice versa is not true. It is also called acyclic or FeedForward type. Here no hidden layer is present. It is called single layer feedforward networks because it has number of input layer but only one output layer. We do not count the source node in this type of architecture because no computation is performed in this type of architecture.

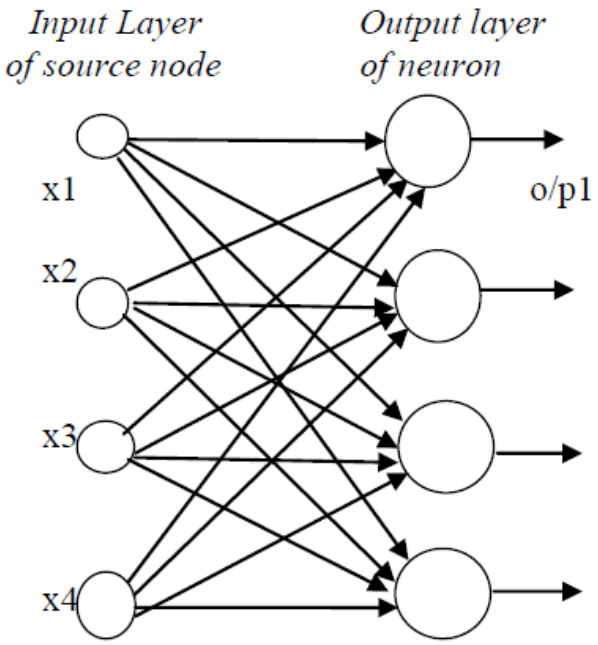

Fig.6 FeedForward or a cyclic network with a single layer of neuron[1]

2. Multilayer Feedforward Networks:

In the second layer of feedforward networks one or more hidden layers are present, whose computation nodes are corresponding called hidden neurons and hidden units. Higher order statistics can be obtained by adding or more hidden layers. Here source nodes are called input layer, signals are applied to the computation node in the second layer.

3. Recurrent Networks:

It is different from feedforward network in that manner that it has least one feedback loop. It may consist of a single layer of neurons with each neuron feeding, its output signal back to the inputs of all other neurons. Feedback loop has the great impact on learning and its performance. It involve the use of unit delay elements which results in nonlinear dynamic behavior. Here connection of units form directed cycles.

This creates an internal state of the network which allows it to run dynamic temporal behavior. RNNs can use their internal memory to process arbitrary sequences of inputs. So this network is different from feed forward method. This makes them applicable to tasks such as unsegmented connected handwriting recognition, where they have achieved the best known results.

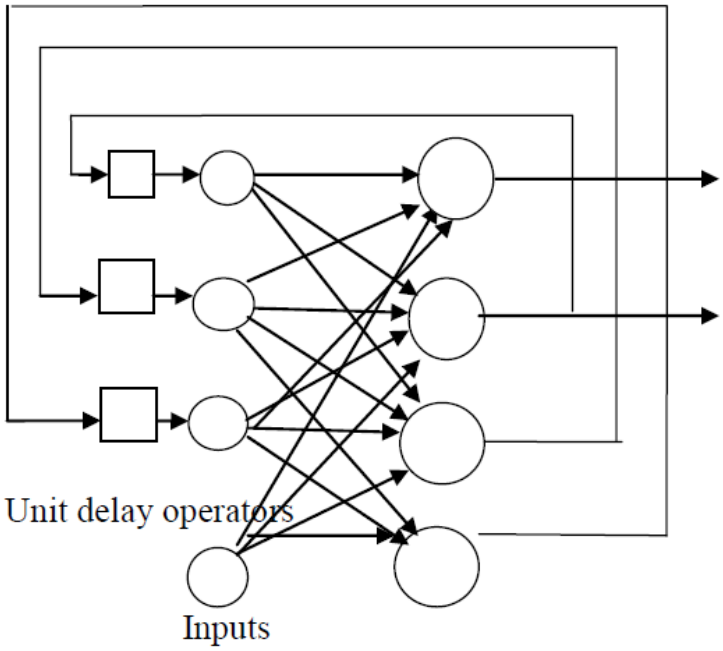

Fig. 7 Recurrent network with hidden layer[1]

Prediction and Learning

To use the neural network we need to teach the neural network in order to choose the weight parameter. Prediction of result using neural network is simple but the difficult part is teaching the neuron the right value of weight. Learning is a process by which free

parameters of a neural network are adapted through a process of stimulation by the environment through which it is embedded. There are different types of algorithms are used in different learning types. Different types of learning are:

1. **Error-Correction Learning:** It is a learning in which synaptic weights are correct according to the error of the neuron output. Here the output generated is compared with target output and desired response.
   Error= Desired response-Actual output

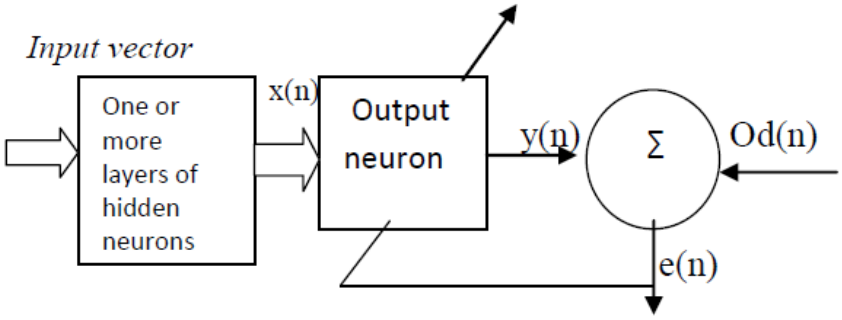

Fig.8 Block Diagram of neural network with error correction[2]

2. **Memory Based Learning:** In this type of learning all the past experiences are stored in large memory of correctly classified input-output examples (x_i,d_i) where xi denotes an input vector and di denotes the corresponding desired response.
3. **Hebbian Learning:** It is one of the oldest and famous learning. Hebb's Law states that if neuron *i* is near enough to excite neuron *j* and repeatedly participates in its activation, the synaptic connection between these two neurons is strengthened and neuron *j* becomes more sensitive to stimuli from neuron *i*.
4. **Competitive Learning:** In competitive learning, neurons compete among themselves to be activated. In this type of learning only single neuron is active at a time only.
5. **Learning with a Teacher:** It is also referred as supervised learning. We think that a teacher has knowledge of the environment which is representing by a input-output set.
   Vector describe state Of environment

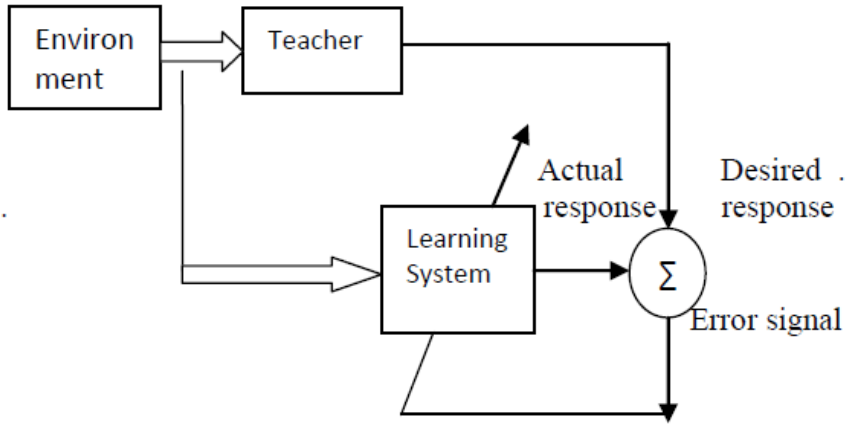

Fig.8. Block diagram of Learning with teacher

6. **Learning without a Teacher:** It is also known as an unsupervised learning. Here all the process is done without the supervision of any teacher. Means there is no teacher to oversee the process.
7. **Adaptive Learning:** This type of learning has an ability to adapt their synaptic weights to changes in the surrounding environment and retrained environment with minor changes in the operating environmental conditions.

III. BENEFITS OF NEURAL NETWORKS

Following are the benefits of neural networks:

Generalization: It refers to the neural network produce reasonable outputs for inputs not countered during training**.**

Input-Output Mapping: Learning with a teacher called supervisor learning involves modifications of the synaptic weights by applying training samples. Each sample consists of unique input signal and correspondence to desire response.

Adaptively: Neural network has an ability to adapt their synaptic weights to changes in the surrounding environment and retrained environment with minor changes in the operating environmental conditions.

Evidence Response: In pattern classification, neural network does not design only give information about the pattern to select but also about the confidence in the decision made.

Parallel Processing: Neural Network provides excessive parallel processing which helps to provide complex problems fast. Computing is done with self learning in a parallel and distributed manner.[3]

Fault Tolerance: A neural network, implemented in hardware form, has the potential to be inherently fault tolerant and capable of robust computation. Its performance degrades under some operating conditions.

VLSI Implement ability: Massive nature of neural network makes it massively fast for complex computations. The same feature is well suited for implementation using VLSI implementations.

IV. ADVANTAGES OF NEURAL NETWORK

There are many advantages of neural network which are given below:

- Neural network performs linear tasks.
- During the failure of any element, it continues works without any problem in its parallel nature.
- A neural network learns it does not need to reprogram.
- It can be implemented in any application.
- It can be implemented without any problem.

V. DISADVANTAGES OF NEURAL NETWORK

There are some disadvantages of neural networks which are discussed as following:

- Neural networks needs training to operating.
- Its architecture is different from architecture of microprocessor therefore it needs to be emulated.
- For large neural networks, it requires high processing time.

VI. APPLICATIONS OF NEURAL NETWORKS

ANN have been successfully applied for solving highly non-linear problems in pattern recognition, prediction, system identification and control due to their nonlinear parallel processing, their adaptability, fault tolerance and generalization characteristics.[5] Some applications of neural networks are:

- **Character & Pattern Recognition**: Neural network is used to recognize handwritten characters. The basic idea of character recognition in Palm Pilot becomes very popular in these days.[6]
- **Image Compression:** In image processing, neural networks process and receive vast amount of information at once and make them useful.
- **Speech Recognition**: It is also used in speech recognition to identify the words and person who is saying that words.
- **Power Management in WSN:** Neural Network Algorithm are used to process the structure of a wireless sensor network and produce some information which can be used to improve the performance of WSN's power management applications. [7]
- **Stock Market Predication:** The day-to-day business of the stock market is extremely complicated. Many factors weigh in whether a given stock will go up or down on any given day. Since neural networks can examine a lot of information quickly and sort it all out, they can be used to predict stock prices.
- **Autonomous land Vehicle:** Artificial neural networks are capable of performing the reactive aspects of autonomous driving, such as staying on the road and avoiding obstacles. The system is able to stay on the road and also able to follow a route to a predetermined destination, turning appropriately at intersections and stopping when it has reached its goal. [8]

VII. CONCLUSION & FUTURE WORK

Artificial Neural Network is designed by studying human brain. The neurons on human brain communicate to each other to make a decision. In technical field neural networks are often referred to as Artificial Neural Network (ANN). It is one of the fastest growing fields in artificial intelligence and it has great future. It is being widely used in many complex applications to solve various issues like power management, medical treatments, parallel processing etc. further researches are going on in the field of artificial neural networks to enhance its applications.

VIII. REFERENCES

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