ARTIFICIAL
NEURAL
NETWORK
3.1 INTRODUCTION

As computers advanced into their infancy in the 1950s, it became possible to begin to model the rudiments of the theories concerning human thought. Nathaniel Rochester from the IBM research laboratories led the first effort to simulate a neural network; that first attempt failed but later attempts were successful. It was during the time that traditional computing began to flower and as it did the emphasis in computing left the neural research in the background.

Today, neural network implementations are occurring everywhere, as nature itself are the proofs that this kind of thing works. In future, the very key to the whole technology would lie in hardware development. Currently most neural network development is simply proving that the principle works.

The research in developing neural networks is due to processing limitations, which take weeks to learn. To take these prototypes out of the lab and put them into use requires specialized chips. IC manufacturers are working on three types of neuron chips - digital, analog, and optical. Some companies are working on creating a silicon compiler to generate a neural network called Application Specific Integrated Circuit (ASIC). These ASIC and neuron-like digital chips appear to be the wave of the near future. Ultimately, optical chips look very promising.
3.2 TRADITIONAL COMPUTING AND NEURAL NETWORKS

Neural networks offer a different way to analyse data and to recognize patterns within that data, than traditional computing methods. However, it is not solutions for all computing problems. Traditional computing methods work well for problems that can be well characterized [9].

Table 3.1: comparison of characteristics of traditional computer and neural network

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Traditional computing</th>
<th>Neural Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing style</td>
<td>Sequential via rules concepts calculations</td>
<td>Parallel via images pictures controls.</td>
</tr>
<tr>
<td>functions</td>
<td></td>
<td></td>
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<tr>
<td>Learning Method</td>
<td>By rules accounting word processing,</td>
<td>By Example Sensor processing, Speech</td>
</tr>
<tr>
<td>Applications</td>
<td>And inventory, Digital communication.</td>
<td>Recognition, Pattern recognition, Text</td>
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<tr>
<td></td>
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<td>recognition.</td>
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</table>

All artificial neural networks are based on the concept of neurons connections and transfer functions. There is a similarity between the different neural networks organized in categories of applications. These functions are given bellow:

- Prediction
- Classification
- Data association
- Data conceptualization
- Data filtering
### Table 3.2: Type of network and its use

<table>
<thead>
<tr>
<th>Network Type</th>
<th>Use of Network</th>
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<tbody>
<tr>
<td>Prediction</td>
<td>Use input values to predict some output.</td>
</tr>
<tr>
<td>Classification</td>
<td>Use input values to determine the classification.</td>
</tr>
<tr>
<td>Data Association</td>
<td>Classifies and recognizes data that contains errors.</td>
</tr>
<tr>
<td>Data Conceptualization</td>
<td>Analyze the inputs so that grouping relationships can be inferred.</td>
</tr>
<tr>
<td>Data Filtering</td>
<td>Smooth the input signal.</td>
</tr>
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### 3.3 PHYSIOLOGY OF NEURONS IN BRAIN

Electroencephalogram (EEG) in the present form does not assist very much diagnostically or prognostically in determining the extent of depression. To overcome difficulties in analysis of EEG, ANN has been used in automated staging of sleep at which EEG signals conveys more information.

The primary interest is to explore and reproduce human information processing tasks. ANN is used to detect K-Complexes in EEG, also used for comparing patterns to match observed values with the ideal value. EEG signals are classified into different bands according to frequency of a signal. ANN also gives superior results than all parametric and non-parametric methods for identification of EEG power spectra.

The exact working of human brain is still a challenge to the researchers. The most basic element of human brain is a specific type of cell, which unlike the rest of the body doesn’t appear to regenerate. Because this type of cell is only part of body that is not slowly replaced, it’s assumed that these cells provide us abilities to remember, think, and
apply previous experiences to our every action. These cells, all 100 billion of them are known as neurons. Each of these neurons can connect up to 200000 other neurons, although 1000 to 10000 is typical. The neurons receive inputs from other sources, combine them in some other way and perform generally a nonlinear operation on the result and then output the final result.

As shown in the Fig.3.1 the basic structure of the neuron has four prominent parts. Soma is the central part of neuron. Dendrites are the hair like extensions of soma, which act like input channels.

Fig. 3.1 Basic structure of neuron

These input channels receive their inputs from other neurons. The junctions between two neurons are called as Synapse. The soma processes the value and outputs it using axons. The biological neurons are structurally more complex. The differential concentration of ions between the cell’s interior and exterior points to the cell membrane are the critical element governing ionic distribution. The resistance across the surface of a neuron is approximately 400 Ω/sq.cm. Resistance of neuron changes during the passage of impulse. The capacitance of the network is
calculated to be of the order of $6\mu$F/sq.cm. The delay for processing in one neuron is about 4msec. The cell membrane is polarized and potential difference between its inner and outer wall is 60 to 80 mV. This difference in the potentials arises due to the difference in the potassium ions ratio in between the inner and outer section of the neurons [10].

3.3.1 Inspiration From Nature

Since a long time human beings are continuously perceiving the nature for new ideas. Right from discovery of airplanes up to the modern robots, human kinds have copied the nature. Subsequently this strategy has led the scientists in computer field to develop the algorithms from behavior of some objects in nature. Researchers working on ANN were inspired by human neurons. The prominent attempts to model these neurons led to the development of the architecture of neural networks.

3.3.2 The Biological Neuron

The current models of neural networks are inspired mathematical models that use a large number of simple, homogenous but highly interconnected processing elements and weighted connection creates a neural network called as artificial neural network.

Each component of processing elements corresponds to a component of as follows:

- Neurons : Processing elements
- Dendrites : Inputs
- Synapses : Weights
- Summer : Summation function
- Threshold : Threshold function
- Axon : Net output
The most basic element of the human brain is a specific type of cell, which provides us abilities to remember, think and apply previous experiences to our every action. These cells are known as neurons; each of these neurons can connect with up to 2 lakh other neurons. The power of the brain comes from the numbers of these basic components and the multiple connections between them.

The brain cells unlike the normal cells are not replaced throughout the lifespan. This creates highly interconnected structures in brain cells, which impart them learning capability. The neurons are more complicated than those used in artificial neural networks. The main goal of Artificial
Neural Networks is not to model the brain but search the capabilities of the nature and apply them for solving the problems of everyday life.

Brain like properties of neural network are identified as given below:

- The individual units are simple processing units.
- Learning involves modification of strength of interconnection according to locally available information.
- The units are highly interconnected giving a highly parallel architecture.

3.3.2 Artificial Neuron

The basic unit of neural networks is the artificial neurons, simulates the four basic functions of natural neurons. Artificial neurons are much simpler than the biological neuron; fig.3.4 shows the basics of an artificial neuron.

Inputs to the network are represented by the mathematical symbol, \( x(n) \). Each of these inputs are multiplied by a connection weight, these weights are represented by \( w(n) \). In the simplest case, these products are simply summed, fed through a transfer function to generate a result at the output.
Weighting factors: A neuron usually receives many simultaneous inputs. Each input has its own relative weight, which gives the impact on the processing element’s summation function. These weights perform the same function as the varying synaptic strengths of biological neurons. Weights are adaptive coefficients within the network that determine the intensity of input signal as registered by the artificial neuron. They are a measure of input connections strength. These strengths can be modified in response to various training sets and according to a network’s specific topology or through its learning rules.

Summation function: The first step in a processing element's operation is to compute the weighted sum of all the inputs. Mathematically the inputs and corresponding weights are vectors that are represented by \((x_1, x_2, \ldots, x_n)\) and \((w_1, w_2, \ldots, w_n)\) respectively. The total input signal is inner product of these two vectors. This simplistic summation is found by multiplying each component of \(I\) vector by
corresponding component of w vector and then adding up all the products.

Geometrically the inner product of two vectors can be considered a measure of their similarity. If the vectors point in same direction then the product is maximum and if in opposite direction then inner product is minimum. Some summation functions have additional processes applied to result before it is passed to transfer function this process is called activation function.

**Transfer Function:** The result of summation function, almost always the weighted sum is transformed to a working output through algorithmic process known as transfer function. In the transfer function the summation total can be compared with some threshold to determine the neural output. If the sum is greater than the threshold value, the processing element generates a signal. If the sum is less than the threshold, no signal or some inhibitory signal is generated.

The threshold or transfer function is generally non-linear. Linear functions are limited because the output is simply proportional to input. In other type of transfer function, the threshold or ramping function could mirror the input within a given range and still act as hard limiter outside that range. It is a linear function that has been clipped to maximum and minimum values, making it non-linear.

Sigmoid or S-shaped curve is common for curve to be called sigmoid when it ranges from 0 to 1, hyperbolic tangent when range is –1 to 1. The exciting feature is for these curves both the function and its derivative are continuous.

**Scaling and limiting:** after processing elements, transfer function result can pass through additional process, which scale and limit. This scaling simply multiplies a scale factor times the transfer value and then
adds an offset. Limiting ensures that scaled result does not cross upper or lower bound.

**Output Function:** Each processing element is allowed one output signal, which it may output to hundreds of other neurons. Some network topologies however modify the transfer result to incorporate competition among neighboring processing elements. First competition determines which artificial neuron is active or provides an output. Second competition determines which processing element will participate in learning or adaptation process.

**Error Function And Back Propagated Value:** In most learning networks the difference between current output and desired output is calculated. This raw error is then transformed by error function to match particular network architecture. The most basic architectures use this error directly, but some modify error to fit their specific purposes. The artificial neurons error is typically propagated into the learning function of another processing element. This error term is sometimes called the current error. This current error is typically propagated backwards to a previous layer.

**Learning Functions:** The purpose of learning function is to modify variable connection weights on the inputs of each processing elements according to some neural based algorithm.

### 3.4 ARTIFICIAL NEURAL NETWORKS

An Artificial neural network is a powerful data modeling that is able to capture and represent complex input or output relationships. The motivation for the development of neural network technology stemmed from the desire to develop an artificial system that could perform intelligent tasks similar to those performed by the human brain.
A neural network acquires knowledge through learning, stored within inter-neuron connection strengths known as synaptic weights. The true power of neural networks lies in their ability to represent both linear and non-linear relationships and to learn these relationships directly from the data being modeled. Traditional linear models are simply inadequate, when it comes to modeling data that contains non-linear characteristics. The most common neural network model is the multilayer perceptron neural network, known as a supervised network because it requires a desired output in order to learn. The goal of this type of network is to create a model that correctly maps the input to the output using historical data so that the model can then be used to produce the output when the desired output is unknown [11].

Fig.3.5 Structure of ANN

3.5 THRESHOLD LOGIC UNIT (TLU)

An artificial Neural Network consists of small units called as threshold logic units (TLU). Various inputs are given to neuron in parallel. A variable weight value is associated with each input in TLU. Each input is multiplied by its weight and finally all are added, this is
called as weighted sum. This value is given to a special function, which finally calculates the output value; these functions are called as transfer functions. There are many transfer functions, which are used according to applications. These are simple, linear and sigmoid-transfer functions. Perhaps there are much more differences between TLU and natural neurons.

- TLU fire only once when it crosses threshold. The natural neurons may fire a series of pulses when they are stimulated.
- TLU are updated synchronously after some regular interval. Natural neurons are updated asynchronously.

### 3.6 ALGORITHMS FOR TRAINING ANN

Train of algorithm, which can be stored, the classical problems and these rules are well established that they are perfect for all times. The algorithm described here depends on the principle of minimal disturbance to reduce the output error with minimal disturbance. Unless this principle is practiced, it is difficult to simultaneously store the required pattern responses.

As adaptive algorithms evolved, two kinds of on-line rules have come to stay, the error correction rules and the gradient rules. The weights of the network are altered to correct the error in the output response to the present input pattern presentation by gradient descent with the objective of reducing mean square, averaged overall training procedures.
3.7 DESIGN STEPS FOR ARTIFICIAL NEURAL NETWORK

ANN is a field that tries to replicate brain-like computing. A network can have many layers of neurons where the output of one layer becomes input to the next layer of neurons and a network can have more than one output signal; thus output layer can have more than one neuron.

A network of neurons is made to perform a certain task by designing and training an appropriate network through the process of learning or memorization.

The design of network involves steps to determine:

- Number of layers to use
- Number of neurons to use in each layer
- Connectivity pattern between the layers and neurons,
- Node function to use at each neuron, and
- Mode of operation of network, feedback vs. feed forward.

The training of network involves determining connection weights \([w_{ij}]\) and threshold values \([\theta_i]\) from set of training data. Training of network is accomplished by adjusting weights \([w_{ij}]\) by means of local learning law. A local learning law means changing the connection weights by an amount \([\Delta w_{ij}]\) after observing each training data. A learning law is based on general idea that a network is supposed to perform a certain task and weights to be set such that the error in the performance of that task is minimized.

Therefore, under the connectionist theory of learning the connection weight \(w_{ij}(t)\) after observing \(t^{th}\) training data is given by:

\[ w_{ij}(t) = w_{ij}(t-1) + \Delta w_{ij}(t) \]

where \(\Delta w_{ij}(t)\) is weight adjustment after \(t^{th}\) sample and is determined by local learning law.
The Back propagation law is as follows;

$$\Delta w_{ij}(t) = -\eta(\delta E / \delta w_{ij}(t)) + \alpha\Delta w_{ij}(t-1).$$

Here $\eta$ is learning rate i.e. step size for weight update at step $t$ and $\alpha$ is momentum gain. $E$ is mean square error of whole network based on some desired outputs, in supervised mode of learning. Back propagation is steepest descent algorithm and $-\delta E / \delta w_{ij}(t)$ is steepest descent direction i.e. negative of gradient.

### 3.8 ARCHITECTURE OF NEURAL NETWORK

#### 3.8.1 Feed-Forward Networks

Feed-forward ANN allows signals to travel one way only; from input to output. There is no feedback the output of any layer does not affect that same layer. Feed-forward ANN tends to be straightforward networks that associate inputs with outputs. They are extensively used in pattern recognition. This type of organization is also referred to as bottom-up or top-down.

#### 3.8.2 Feedback Networks

Feedback networks can have signals flow in both directions by introducing loops in the network. Feedback networks are very powerful and can get extremely complicated. Feedback networks are dynamic; their state is changing continuously until they reach an equilibrium point. They remain at the equilibrium point until the input changes and a new equilibrium needs to be found. Feedback architectures are also referred to as interactive or recurrent, although the latter term is often used to denote feedback connections in single-layer organizations.
3.8.3 Methods of Learning

The network can be subject to supervised or unsupervised learning. The learning is called supervised if external criteria are used and matched by the network output. In supervised learning, the inputs are applied to network along with the expected response. The unsupervised approach is also termed as self-organising.

The brain basically learns from experience. Neural networks are sometimes called machine-learning algorithms because changing of its connection weights causes the network to learn the solution to a problem. The strength of connection between the neurons is stored as a weight value for the specific connection. The system learns new knowledge by adjusting these connection weights. The learning ability of a neural network is determined by its architecture and algorithmic method chosen for training.

3.9 BACK-PROPAGATION MODEL

Back propagation model is used to learn the nonlinear functions; learning takes place by back propagating the derivative of the error to all hidden layers. Errors in output determine measures of hidden layer and output layer, which are used as basis for adjustment of weights between the hidden and input layer.

Adjusting two sets of weights between two pairs of layers and recalculating the outputs is an iterative process and is carried out until the error falls below a tolerant level. The model may use log sigmoid, tan sigmoid or linear function.
3.10 TRAINING AN ARTIFICIAL NEURAL NETWORK

Once a network has been structured for a particular application, that network is ready to be trained. To start this process the initial weights are chosen randomly. Then the training or learning begins.

There are two approaches to training

- Supervised
- Unsupervised.

Supervised training involves a mechanism of performing the network with the desired output either by manually grading the network performance or by providing the desired output with the inputs. Unsupervised training is where the network has to make sense of the inputs without outside help. Unsupervised training is used to perform some initial characterization on inputs.

In supervised training both inputs and the outputs are provided. The network then processes the inputs and compares its resulting outputs against the desired outputs. Errors are then propagated back through the system causing the system to adjust the weights, which control the network. This process occurs as the weights are continuously changes. The set of data, which enables the training, is called the training set. During the training of the network the same set of data is processed many times as the connection weights are ever refined.

The other type of training is called unsupervised training. In unsupervised training, the network is provided with inputs but not with desired outputs. The system itself must then decide what features it will use to group the input data.
3.11 ANN IN BIOMEDICAL APPLICATIONS

Artificial Neural Networks (ANN) is currently a research area in medicine has extensive application to biomedical systems in future. At the moment, the research is mostly on modeling parts of the human body and recognizing diseases from various scans. Neural networks learn by example so the details of how to recognize the disease are not needed. The sets of EEG data acts as training sets of all the various types of the disease are needed to recognize the disease.

Neural Networks are used experimentally to model the human cardiovascular system. Building a model of the cardiovascular system of an individual and comparing it with the real time physiological measurements taken from the patient can achieve diagnosis.

Another reason that justifies the use of ANN technology is the ability of ANN to provide sensor fusion, which is the combining of values from several different sensors. Sensor fusion enables the ANN to learn complex relationships among the individual sensor values, which would otherwise be lost if the values were individually analyzed. In medical modeling and diagnosis, this implies that even though each sensor is sensitive only to a specific physiological variable, ANN are capable of detecting complex medical conditions by fusing the data from the individual biomedical sensors.

Artificial Neural Networks are extensively used for physiological signal analysis. The complex and irregular nature of physiological signals makes them too complex to be analyzed by conventional methods. The learning ability of neural networks can be easily employed to analyze the signals like EEG, EMG and ECG. The data compression of these signals has also proved very successful using this technology.
The application of artificial neural networks (ANN) to EEG analysis may yield improvements in classification accuracy, particularly in case of single trial analysis. Statistical models require a priori determination of exact features of the signal significant, whereas analysis by ANN demands only a reasonable choice of network architecture. Generalized ANN also has the potential to perform better than linear methods such as discriminant analysis because of their capacity to implement nonlinear boundaries in the problem space.

The research work is continued with review of literature published in various national or international journals and conferences to study the latest developments in the field of EEG. The concentration is given on research related to physiological signal analysis and diagnosis in EEG. Literature review is carried out in chapter 4.