An Early Detection Technique for the detection of Epilepsy using EEG signals

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In the name of Allah most beneficent most merciful

“My success, my inspiration, my guidance, my accomplishment, my reconciliation in my reform work, my welfare, my adjustment, my adaptation, my prosperity can come only and only through Allah, and none else”

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AUGUST 2019

Declaration

I certify that this research work titled "An Early Detection technique for the diagnosis of Epilepsy through using EEG signals'' is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources is properly acknowledged / referred.

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"This is by the Grace of my Lord to test me whether I am grateful or ungrateful! And whoever is grateful, truly, his gratitude is for (the good of) his own self, and whoever is ungrateful, (he is ungrateful only for the loss of his own self). Certainly! My Lord is Rich (Free of all wants), Bountiful" [An-Naml: 40]

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Dedication

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Abstract

The advent of the EEG signals and their applications in medical filed have opened many new avenues for the mankind to excel in. Today Electroencephalogram or EEG is one of the frontline tool for diagnosis of brain related issues. EEG plays the pivotal role in making the whole neurological disorder mapping more easy and time efficient. Through the state of the art diagnosis techniques thanks to advancement in pattern recognition and artificial intelligence systems are being modeled which can detect any kind of neurological disorders and can make appropriate changes into them as well.

EEG signals demonstrate the electrical movement of brain and consist of useful data for the different states of brain to get and study the detailed information about the brain. The identification of various categories of EEG signals is normally performed by the experts from the field of visual inspection. To complete that process manually it may cause human based errors and cause a lot of time and also considered as time taking process and also not much reliable. Visually inspecting the EEG signals for the purpose of detecting the epileptic seizures varies according to the expertise of human experts. That's why, an automatically detection of epileptic seizures is essential in the real environment.

Our proposed methodology is evaluated with different parameters and testing accuracy of 94 % is reported for a publicly available dataset.to maintain the state of the art technique is applied on one other dataset and in that Total training accuracy of 98.74% is obtained through that and testing accuracy which is obtained is 95.22%

Keywords: Electroencephalogram (EEG), discrete wavelet transforms, Signal Classification, Neural Network, IPSO, epilepsy, seizure, CAD methods.

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CHAPTER 1

Introduction

EEG signals are electrical signals generated in brain as a response of the neuron collision phenomenon. Electroencephalography (EEG) is considered one of the greatest clinically and technically exploited signals recorded from the brains of humans. Therefore, its dimensions play an important role in the studies of brain. In particular, the investigation of EEG signals has been known as the greater method to the extracting problem of knowledge of the brain.

Brain research has been highlighted as an area of national interest in recent years. This research has the potential to impact many important areas, from the detection, treatment, and increased understanding of diseases such as Alzheimer's and epilepsy, to the neural control of devices to aid the handicapped, to a greater understanding of how the human brain functions on a basic level.

The classification of brain signals recorded by imaging devices using machine learning approaches is a very powerful tool in many of these areas of research. For example, machine learning techniques show promise in the early detection of Alzheimer’s or giving warning before an epileptic seizure. These techniques are already being used in devices such as the P300 speller (Guan et al., 2004) to provide a communication device for the severely handicapped.

In addition, neuroscience problems present a unique set of challenges that require innovation in machine learning. The data obtained from brain activity monitoring devices are noisy, have high dimensionality, and are costly to collect, which limits the number of data samples that can be collected. The combination of these factors leads to exceedingly complex data, which are difficult to analyze or classify, even using the most sophisticated and modern techniques.

This thesis presents novel results in the broad area of brain signal classification. First, it provides a comparative evaluation of standard machine learning and data preprocessing techniques in brain signal classification. Second, the use of deep learning techniques for brain signal classification is explored in detail. While these techniques are state of the art in many other applications of machine learning, there are relatively few published results of their use in brain signal classification.

The huge number of neurons in brain collides with each other and generates electrical signals of very small energy which are measured and recorded in the form of EEG signals. The famous method for recording EEG signals is 10-20 electrode placement scheme in which several small electrodes are placed on human scalp. These electrodes are connected to computer at the other end through wires which record the brain activity signals. Careful analysis of EEG signals help in identification of several brain related disorders. Among many brain related diseases, epilepsy is one of the chronic brain disorders. According to epilepsy foundation it is the fourth most common neurological disease which affect individual of all ages. Major symptom of epilepsy is seizure but it doesn't mean that if a person has seizer then he must be affected by epilepsy. So, classification of seizure into epileptic seizure and other seizure is a bit difficult for human eyes. In order to address this problem, it is required to develop such a system which takes in EEG signals, analyze and process these signals and differentiate between normal and epileptic seizure.

The very first task in the examination and processing of EEG signals is to extract useful features from the EEG signals, which is done by random feature selection technique of EEG signal and then sequential feature selection which will be proved beneficial in features classification problem. After that Neural Networks are trained for features classification purpose. Neural Networks are widely used in many areas for making appropriate decisions. The basic idea behind NN is that there are different layers of the networks which are interconnected through links and each layer has specific number of processing units which are called neurons. The neural network is provided with some inputs and weight parameters (through which neurons of different layers are connected), the processing is done in the neurons at different layers and finally at the output layer the decision is taken appropriately. Different types of activation functions are used in the neurons for processing at different layers for different purposes. Most famous are RBF, LBP, Wavelet transform functions, Gabor wavelet etc. we will be using logistic function as the basis function in our neural network reason being that it is well suited for binary classification and here in this problem we have only two classes i.e. normal seizure and epileptic seizure.

Learning is inevitable step in any machine learning (classification/ regression) algorithm through which the classifier is trained well optimized in order to minimize the classification error and maximize the accuracy. There are numerous optimization techniques and algorithms (e.g. Gradient Descent, Back propagation, Particle Swarm Optimization, Bee Swarm Optimization, Ant colony optimization etc.) in the literature which can be used for optimization, so one can ask that which one is to be used? The point is, there is always a tradeoff between algorithm complexity and accuracy. In this work, rather than using back propagation for network parameters optimization and learning of the NN, we have used Swarm optimization (SO) algorithm for training of our NN to classify EEG signals for identification of normal and epileptic seizure.

1.1 Motivation

On a very first time that technique were attempted in the year of 1875 by one of the British neurophysiologist who was named as Richard Caton, who started research on brain cells and recorded the electric activities of brain tissues of different animals. Later after other scientists started following his research. However, the research was later started in 1920s, that the real-world and analytical calculated values of electroencephalography was predictable through humans by placing scalp electrodes. Brain research has been highlighted as an area of national interest in recent years. This research has the potential to impact many important areas, from the detection, treatment, and amplified understanding of different diseases like epilepsy and Alzheimer's, to the neural control of devices to aid the handicapped, to a greater understanding of how the human brain functions on a basic level.

The classification of brain signals recorded by imaging devices using machine learning approaches is a very powerful tool in many of these areas of research. For example, machine learning techniques show promise in the early detection of Alzheimer’s or giving warning before an epileptic seizure[1]. These techniques are already being used in devices such as the P300 speller (Guan et al) to provide a communication device for the severely handicapped.

Neural networks are really powerful just like nonlinear signal processors. Artificial neural network itself cannot be considered as any algorithm, this is not an algorithm but that can be considered as a framework being used for many other machine learning algorithms for processing complex data types.

In medical diagnosis, most of the signals generated are responses to activity of muscles and are time domain signals with amplitude/ peaks which are analyzed by the domain experts (medical doctors) to identify disorders on the basis of deviations in signals amplitude and variations in time[2]. It is a matter of fact that more information can be carried out from the signals if these are transformed to other domains and are then analyzed.

Physician may be on very first prescribing only a single medicine starting from a low dose and may increase the dose gradually until the seizures got controlled. But these anti-seizures medicines may also have some side effects on human body as well[3]. These side effects can include

- Dizziness
- Skin rash or allergy
- Speech problems
- Weight gain
- Fatigue
- Nausea
- Memory problems

These medicines can also leads toward some severe side effects as well but these are rare as well

- Depression
- Severe kind of skin allergy
- Suicidal thoughts

To avoid all of these severities it is better to diagnose the epilepsy in the very start so that the chances of any loss can also be reduced. For that purpose EEG signals are proved really beneficial for diagnoses of seizures. There are many techniques already available for feature extraction and diagnosis of the disease, but here a novel approach is being proposed for the feature extraction and diagnosis of epilepsy by training neural networks.

1.2 Application

The classification of brain signals is a growing area of research, with emerging applications in both applied and theoretical neuroscience. These applications can generally be divided into a few main areas including device control, brain state detection, medical diagnosis, and basic research.

1.3 Objective and Contribution

Different kinds of efforts are being made for introducing different kinds of methodologies and practices for the purpose of detection of epileptic seizures and classification of features being used. Few efforts are also being made for proposing different techniques to increase the accuracy of detection of seizures[4]. These cases are related to neurological disorder and medical records are so sensitive in nature any small error can lead toward a big misguidance.

In this thesis, our main focus is to propose a novel methodology for the purpose of detection and classification of epileptic seizures just to achieve accuracy. Because if accurate results are not obtained properly then the medication related to epilepsy might be started and the patient is not actually having epilepsy that can lead to any big problem for that person life. So, accuracy of results matters a lot to diagnose the actual disease.

Our proposed methodology consists of five different kinds of steps, visualization of dataset, reading dataset through python code and plotting graphs of them, then data processing and feature selection through Simple Random Sampling and Sequential Feature Selection then training neural networks and then finally classifying the features through Artificial Neural Networks and checking the accuracy of results. Later accuracy, specificity and time domain will be checked. For that technique python will used for the coding purpose on pycharm as a front end and ANACONDA as a backend.

1.4 Research Challenges

Brain imaging data presents numerous stimulating problems to machine learning, all of which are current topics of open research[5]:

1.4.1 Brain signals are noisy

The information is polluted by a variety of factors including muscle movement, measurement error, brain activity that is not of interest, and electromagnetic interference from the environment.

1.4.2 Brain signals have high dimensionality

There are frequently hundreds of channels, sampled at up to 1000 Hz. The raw data frequently presents up to hundreds of thousands of features per trial. The data are a time series and have spatial interactions, potentially requiring investigation of temporal and frequency components in conjunction with spatial analyses.

1.4.3 Data collection is expensive and time consuming

It is difficult to collect sufficient data for many of the most powerful machine learning techniques. Generally thousands or tens of thousands of samples per class are desired in modern deep learning applications, but it is often impractical to produce more than a few hundred samples per subject in brain imaging tasks, particularly if they need to be derived for clinical or medical studies. The goal of this thesis is to investigate techniques for addressing these challenges.

1.5 Outline

In chapter 2 we are going to discuss the research work or techniques already done related to that topic. Detection of features, classification of features detection of epileptic seizures through different kinds of techniques will be discussed in that chapter. In chapter 3 the proposed methodology will be discussed in depth. Techniques and methods being used to get the accuracy of results will be discussed in that section. In chapter 4 the obtained results will be discussed in detail which will be achieved through different datasets. In chapter 5 conclusions of work and future work of that technique will be discussed in detail.

1.6 Summary

The purpose of this thesis is to improve techniques that are able to categorize various types of Electroencephalography (EEG) signals in order to diagnose and treat neurological diseases. In this chapter importance of diagnosis of epilepsy at time is described briefly. That is also described if the disease is not properly and accurately diagnosed it can lead toward a major issues, because in medical minor errors cannot be accepted. Many techniques which are already proposed to help in the diagnosis of epileptic seizures are also described. Different kind of methodologies s is also proposed to extract the features and classify the features according to their type.

CHAPTER 2

Literature Review

That chapter is divided into five important sections. In the first section the detail of epilepsy will be given. In the second section epileptic seizures their causes and kinds will be discussed. In the third section medication and physician consultancy will be discussed. In the fourth section Electroencephalogram signals and their importance will be discussed. In the fifth section diagnosis techniques and methods will be discussed

2.1 Epilepsy

Epilepsy is known as a disorder activates of brain or can also be called as neurological disorder. Epilepsy is a disorder of nervous system where brain activities of the human become abnormal and human shows an unusual behavior. Having a single seizure doesn't means the person is suffering from epilepsy .Two or more than that seizures occurring in one day time period is considered as an epileptic seizure. According to World Health Organization (WHO) estimation approximately 50-60 million [6-7] from the overall world population is afflicted from that disease and approximately 1% population is having the neurological disorder [8-9] and having the prevalence order of almost 0.6-0.8% from the total population of the world. From this population,a two-thirds average of patients can get a sufficient control on seizures from medication of anticonvulsive and the other of 8-10% of patients disease cannot be controlled through the medication so, the only way to get rid of the seizures is surgery. For the remaining of 25% patient,not any reliable treatment is currently available. Therapy can only be perfectly done if that is diagnosed too early and proper treatment is started on time. Sometimes in the severecondition, it leads to the death of the patient. The total prevalence of that disease in developed countries has been noticed from approximately 4-10 cases from the 1000 people, while the countries which are being developed has been counted as 14-57 people from the 1000 of people.

Anyone from any age group can suffer from epilepsy. That can affect both gender group male or female or from any background. Seizure can occur at any age due to any reason, these reasons can vary widely. Some patients with that disease just simply become blank for few seconds during the seizure occur, while some people jerk their legs and arms repeatedly during the seizure. The types of abnormalities vary from patient to patient. Every patient suffers from different kind of situation during the seizure.

2.1.1 Epileptic seizures

One of the chronic and sudden disorders of brain activities are known as seizures. Epileptic seizures show the clinical signs for the redundant and hypersynchronous movement of neurons in the brain. Disturbance in movement, or bladder function or losing the control on bowel or loss of consciousness or other cognitive function disorder can be caused by these seizures. During the activity of seizure the patients loses their normal situation and behaves in an abnormal way and do awkward activities just because of not being in their senses[10]. During the seizure activity patient is not aware about what he/she is doing at that moment.

Normally seizures are observed almost 2, 3 minutes before the pre-seizure periods. Epileptic seizures affect the human brain and the daily lives of patients are hugely disturbed. Unfortunately, the detecting of epilepsy is difficult in a sense of support of patient in detecting the seizure because at that time patient is not in a situation that he/she can press any alarm or cannot receive any warning to detect that seizure is going to occur[11].The patient loses his consciousness so that’s why it badly affects patients routine and quality of life and also affects the family members of the patients as well. Because these kind of patients can never be kept alone that any time seizure can occur and patients can lose their consciousness.

If the seizures are going uncontrolled then the patient himself and the family members of patient will start experiencing major limitations and problems. Social and the educational activities of the person will be affected because of sudden seizures. These kinds of limitations will badly affect the patient’s quality of life and the family life as well. However long and uncontrolled seizures can create permanent damage of brain cells[12].

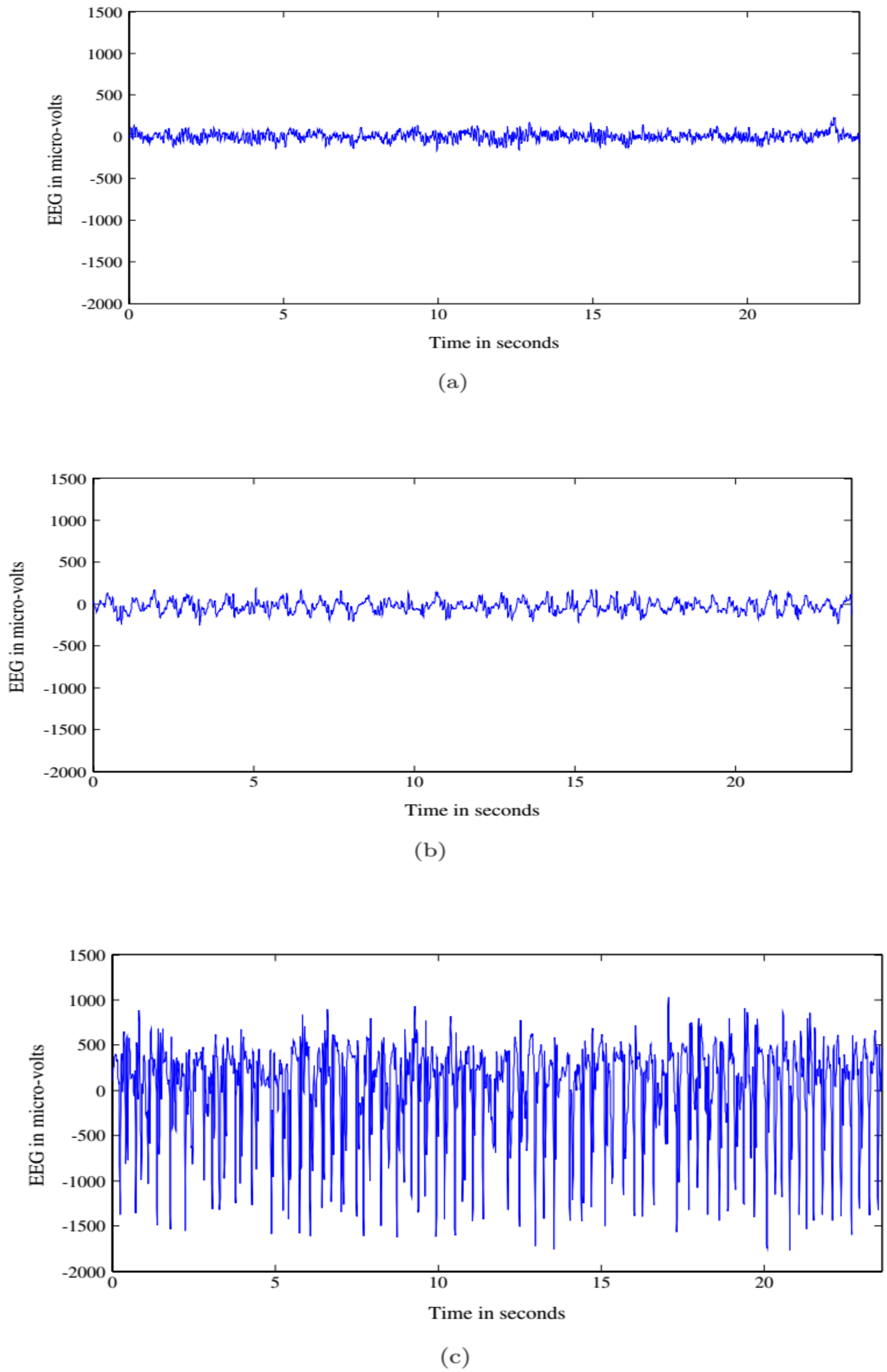

Figure 2. 1: Representation of Epileptic EEG Signals [19] algorithm based on one dimensional EEG signals and two dimensional formed images analysis where a) normal signal , b) inter-ictal phase, c) ictal phase

The best strategy to avoid seizures of epilepsy to detect these perfectly at onset and a proper therapy can be started. Before starting any kind of medication to the patient the most important s know about the disease from which the patient is suffering from. Where the seizures treatment is so important but more than that it is important to diagnose the disease accurately however that is most significant to know about the patient that either he has epilepsy or not and then it is also most important to know the severity level of the disorder before starting any kind of treatment[13]. Therefore detecting and remedial of epilepsy is mandatory. If that is properly diagnosed then it can help the patient to improve the quality of life.

Classification between normal EEG signals and Epileptic EEG signals can be easily done frequency range of both cases is totally different from each other. Now a days the strength of handling of epilepsy is pharmacological. Anti-epileptic seizures medicines are taken on the daily basis to avoid seizures and to achieve a steady-state meditation in the patient's blood. Particular meditation is preferred to get maximum effective seizure control with the minimum amount of side effects. However, nearly 33% [14] of patients having epileptic seizures have seizures control through medical therapy.

EEG waveforms are generally classified according to their frequency, amplitude, and shape, as well as the sites on the scalp at which they are recorded. The most familiar classification uses EEG waveform frequency (eg, alpha, beta, theta, and delta) Kinds of Seizure

Different kinds of seizures are available which effects differently on human brain. Every seizure type has its own symptoms and effects[15].

- Focal Seizures
- Generalized seizures

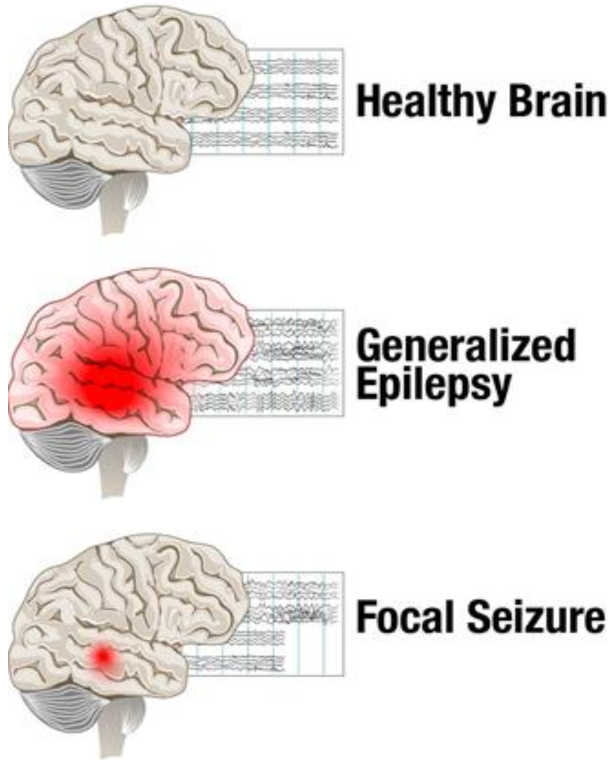

Figure 2.2: a)Healthy brain b) focal seizures c) generalized seizure [72]

2.1.1.1 Focal Seizures

- Focal Seizures “without loss of consciousness
- Focal Seizures “with impaired awareness”

2.1.1.2 Generalized seizures

- Absence Seizures
- Atonic Seizures
- Tonic Seizures
- Clonic Seizures
- Myoclonic Seizures
- Tonic-clonic Seizures

Focal seizures

When abnormalities occur in just one area of brain and disturb only a limited area of brain during the seizure activity. In this the patient remains alert and can interact with others.

i. Focal seizures without loss of consciousness

In this the patients remains in their consciousness. Change in the emotions, feelings and few other things happen. The worst condition in that is jerking of body parts like legs and arms.

ii. Focal Seizures with impaired awareness

This kind of Seizures causes unconsciousness. The patients suffering from these kinds of seizures cannot behave normally during the period of seizure. That covers only a specific area of brain and creates disorder in that region. The patient unintentionally starts rubbing his hands, start walking in circle and repeat these movements.

Generalized seizures

Which occur in whole area of brain, that occur when both sides of brain misfire and as a result seizure occur and patient losses his consciousness

i. Absence seizures

Also known as petit mal seizures most of the time occurs in early age group like children's. As a result the patients get blank and start staring into space for few time periods. Most of the time that don't cause any long lasting issues.

ii. Tonic seizures

That can be the severe type of seizures; these seizures can attack on muscles of body and affects the patients badly. In this scenario the patient starts shivering, jerking and twitching his body parts. Patient losses his consciousness completely and fell down on the ground. Sometimes, patient losses his control on bladder or bowls as well.

iii. Atonic seizures

In this kind of seizure attack the patient losses his muscle tone partially or completely and the patient fell down on the ground. This kind of seizure occurs when the patient is already having any other kind of seizure activity as well. These are more common in children then adults. The duration of this seizure activity is normally less than the 15 seconds. Atonic seizure is also known as drop seizure or a kinetic seizure.

iv. Clonic seizures

These seizures are linked with continuous jerking of muscle movement which can cause the felling down of patient and loss of consciousness on temporary basis. These seizures are less common and normally occur in early ages.

v. Myoclonic seizures

These seizures can occur with atonic seizure. In these seizures patients jerks their whole body of any of the body part. Sometimes these seizures are not as strong that a clear movement can be noticed.

vi. Tonic-Clonic Seizures

Grand mal Seizures are now being known with the name of Tonic-clonic seizures. When the seizure occur the body starts shaking and stiffening and patient losses his consciousness and sometimes control on bladder as well. In this scenario some patients start biting their tongue during the seizure.

2.1.2 Causes of Epilepsy

That is a neurological disorder which can be caused due to any reason and can be detected at any stage of life. In half of the circumstances the cause cannot be found clearly. In the remaining cases the cause of the seizure can be from the followings

i. Genetic Influence
ii. Head trauma
iii. Brain Conditions
iv. Infectious Diseases
v. Prenatal Injury
vi. Development Disorder
vii. High Fever
viii. Tumor in Brain

Genetic Influence

Sometimes that disease runs in families. If someone is having epileptic seizures and there is a past history of that in the family then it means that comes through genetics and might be the reason of the seizures is that.

Head trauma

The seizures started occurring after any accident or any kind of brain injury can be known as head trauma cause.

Brain Condition

Abnormalities in brain like strokes can also cause the seizures. Strokes normally occur after 35 years.

Infectious Diseases

The seizures can also be caused by infection diseases such as AIDS, Meningitis. There are strong chances of occurring of seizures during these diseases. So, during these kind of diseases patient should be kept under high observation.

Prenatal Injury

Before the birth of child, babies are too sensitive so if they do not get proper nutrition and oxygen or if their mother is suffering from any infection that can affect the brain of child. After birthday maybe that child suffers from epilepsy.

Development Disorder

Epilepsy can also be linked with growing illnesses, like autism and neurofibromatosis.

High Fever

When someone is suffering from an uncontrolled fever then patients may suffers from fits that can result really bad outcomes like epileptic seizures.

2.1.3 Complications during epilepsy

Loss of consciousness can create many complications for patients. During the seizure activity, patient loses his self-defense power[16]. Seizure can cause dangerous outputs for patient and surrounded people. Patient can face different kind of complications like

i. Falling
ii. Accidents
iii. Drowning
iv. Emotional Health Issues

Falling

During the seizure activity patient does not remain in his consciousness so be fell down and as a result his body can get injured.

Accidents

If the patient is driving and suddenly seizure occurs as a result patient will immediately loses his awareness that can cause a severe accident

Drowning

If the patient is suffering from epileptic seizures he is all times in a fear that anytime seizure can occur if the person is taking bath and seizure occur he will suddenly fell down.

Emotional Health Issues

Patient suffering from that disease will be different in nature then the normal people. He has fear of occurring seizure at any time. The person more likely has psychological problems just like depression and anxiety. That can be due to medians or his previous attack of seizure.

2.1.4 When to consult with doctor

The patient should not ignore if he/she is suffering from these situations

- When the seizure occur more than two times a day and lasts more then 5-6 minutes
- After occurring first seizure second seizure is pursued directly
- In high fever there are strong chances of occurring of seizure

- When arms and legs suddenly started twitching
- Coming of saliva foam from mouth during seizure
- When the patient lost his/her sensations

2.2 Electroencephalogram signals

Electroencephalogram (EEG) shows the temporal and contiguous brain information. For this purpose electrical voltages are used for the purpose of diagnosis of epilepsy in the patients. EEG signals are examined thoroughly in epilepsy to find out the abnormalities present in the human brain. In this way of detection of abnormalities, tinny electrodes are applied over the human surface of scalp[17]. However, Nowadays a technique for diagnosis of a seizure is also considering interviewing of patients and EEG signals recordings inspection by the highly professional medical team in hospitals but according to research, this approach cannot be considered reliable because patients may show their self as normal human being when the seizure does not occur. Before starting any medication instantly classification between healthy and epileptic patients is most important for this purpose (EEG) signals are used for the differentiation between the patients and normal persons[18].

Through EEG signals the patient's data recordings can be easily taken by inserting electrodes above the patient scalp, which record the electrical activity of the human brain on which electrodes were placed. Amplitude and frequencies of the EEG signals can fluctuate from 10-100 micro volts and 1-100 Hz respectively[19]. If the obtained recordings are change from normal brain waves recordings. The changes are very common in normal pattern of human brain waves as well, although the person is not having any seizure activity at that time. The electrodes are placed in that format on the head of the patient as shown in fig 2.1. During that time brain signals are recorded and then other processes are done for the diagnosis of epilepsy.

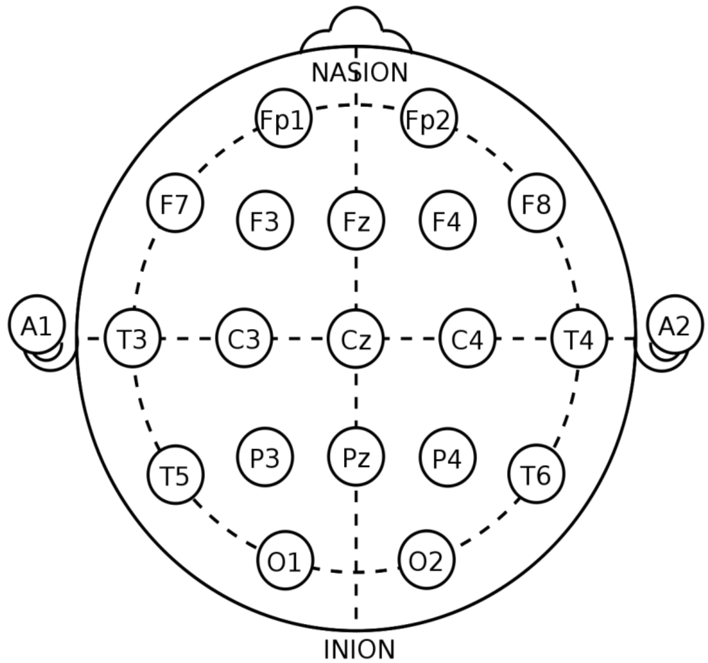

Figure 2.3: The format of the EEG recording [73]

Physician can monitor the person on video during conducting the EEG recordings while the person is awake or sleeping, to record the seizures which a person experiences. Recording of these EEG signals can help the physician to determine the severity of seizures. These obtained recordings might be mono polar or bipolar. The recordings of Mono Polar of the electrode potential at the level of active electrodes are measured by using few reference points like earlobe, ground etc, which can be placed anywhere in the body. Bipolar recordings are just a difference in voltage between the two active electrodes. During that time brain signals are recorded and then other processes are done for the diagnosis of epilepsy. Between two of these mono polar technique is more popular and also used more than bipolar[20]. The signals which are extracted from electrodes are known as raw EEG signals.

Raw EEG signals may hold some non-cerebral signals which are known as artifacts .Actually these are the pollutions within the signals. EEG signals are populated by many types of signals which can by blinking of eye, movement related disturbance, movement of muscles of face, effort of scalp muscles. And sometimes the signals ECG, EOG, EMG, and the EEG get mixed with each other and overlap with one another[21]. These kinds of interrupts are known as biomedical artifacts. These kinds of contaminations are most difficult to remove because all of these resembles with real EEG signals. The Electroencephalography (EEG) reflects the electrical activity produced by human brain. The electrical activity of human brain which is recorded by

EEG is one of major tool to check whether brain is properly functioning or there exist some neurological disorder like brain tumor, head injury, stroke, epilepsy, dementia, sleep disorder and as well as to monitor anesthesia depth given during operations. So, EEG is readily available evidence to check brain function with time. The electrical activity of brain is also suggested for the treatment of abnormalities, learning problems, change in behavior also called as Autism, gaze concentration, delay in speaking etc.

Another kind of pollution is environmental pollution which occurred due to noise, pulse or de-stabilizations of electrodes in the environment[22]. These are known as environment artifacts. Removal of such types of artifacts is too essential from clinical perspective to get the accurate results of the patient. Improvement in technology is decreasing the occurring ratio of these artifacts. While taking the EEG measurement, the cerebral cortex recording is most important measurement because this portion of brain is mostly responsible for intellectual tasks. This portion has great influence on EEG measurements because of its position. All types of movement and processing of complex visual information, language comprehension and problem solving tasks are done by cerebral cortex. The anatomy of human brain is shown in figure 2.1, all activities of major portion of brain is highlighted with their functions.

Thus, many processes are performed on raw EEG signals to make these signals readable. Different kind of advance level techniques are performed on those EEG signals to get the filtered signals clean from artifacts[23]. And after getting these outputs neural networks are applied on those signals to classify them.

Brain of a normal human being produces the electric current of some microvolt's. The voltage of the human brain fluctuates with the time, which is because of the ionic current which runs from brain to neurons. The activities of the brain are observed around 20-40 minutes time period. As a result, EEG signals are generated. The electric potential is received by a particular neuron, which is too lesser to detect that. That's why EEG signals decide the outline of the synchronous actions related to huge amount of the neurons already existing in the human mind. Such kinds of neurons are having the related spatial alignment to grow results. Most important the human mind computer interface has the most estimated edges technique in among the human minds and the machines available.

Hans Berger for the first time recorded EEG signals. He observed different behavior of brain potential produced in the form of waves. These rhythmic changes in brain waves vary with the state of mind. A number of electrodes are temporarily glued on human skull at different locations for the recording of EEG signals. An individual electrode in return is connected to amplifier and EEG recording machine. Finally, the result of recording is electrical signals in form of waves displayed on to the computer screen. According to need multiple electrodes can be placed on human skull for EEG recording. These electrodes are in range of 1 to 256 and are placed in analogous and is called multichannel EEG recording, where one channel is made by pair of electrodes placed parallel. Every channel yields a signal during an EEG recording.

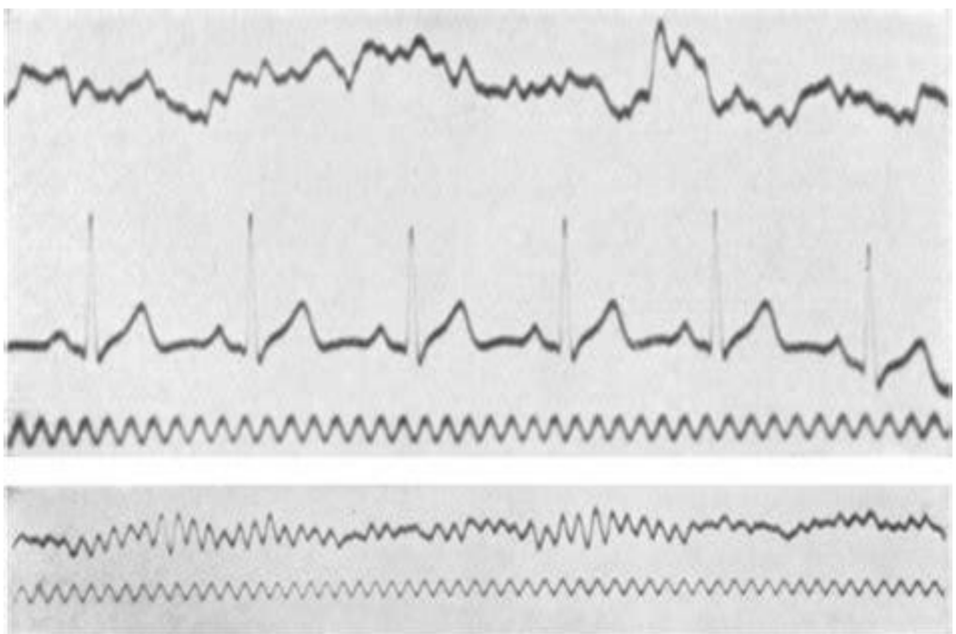

Figure 2.4: First EEG signal Hans Berger (Berger, 1929).

2.2.1 Brain waves

EEG signals have four main kinds of waves which are known as brainwaves which are delta, theta, alpha, and the last one is beta waves. Our brainwaves changes according to mood swing like what we are thinking what we are eating what we are feeling etc. when the slower brainwaves are dominant on our brain system at that time we feel tried or lazy[24]. And when the higher brainwaves are dominant we feel hyper-alert and awful.

Table 2.1 Describing the brain waves and their range

EEG Band	Frequency Range	Location
Delta	0.4 Hz	Frontal Lobe
Theta	4.7 Hz	Midline Temp
Alpha	8.13 HZ	Frontal Occipital
Beta	13.36 HZ	Frontal Central
Gamma	30.100 Hz	Parietial Lobe

Delta Brainwaves(0.5-3 HZ)

These brainwaves are sluggish and low in frequency rate with extremelypowerful just as a drum beat these is originated in a deepest meditation and in the dreamless sleep.

Theta Brainwaves 3-8 HZ

These brainwaves mostly happen in sleep but these are also powerful in deep consideration. In theta we are in a dream or in any imaginary world beyond our normal conscious awareness.

Alpha Brainwaves 8-12 HZ

Alpha brainwaves represent the current status of human brain means flowing thoughts in mind. Alpha waves represent the overall mental coordination, alertness and calmness available in the human body.

Beta Brainwaves 12-38 HZ

Beta waves are considered as fast waves and active during decision making steps judgmental task problem solving related activities. These are sub divided in three more categories which are following

- Lo-Beta (Beta1, range: 12-15Hz)
  Known as fast idle
- Beta (Beta2, range: 15-22Hz)
  Dynamically supposing out anything
- Hi-Beta (Beta3, range: 22-38Hz)
  Excitement or high anxiety condition

The existence of these kinds of waves supports in the identification of different kind of diseases like epilepsy, insomnia, anxiety problems, hyper-vigilance or others problems linked with our emotional and neurological conditions[25].

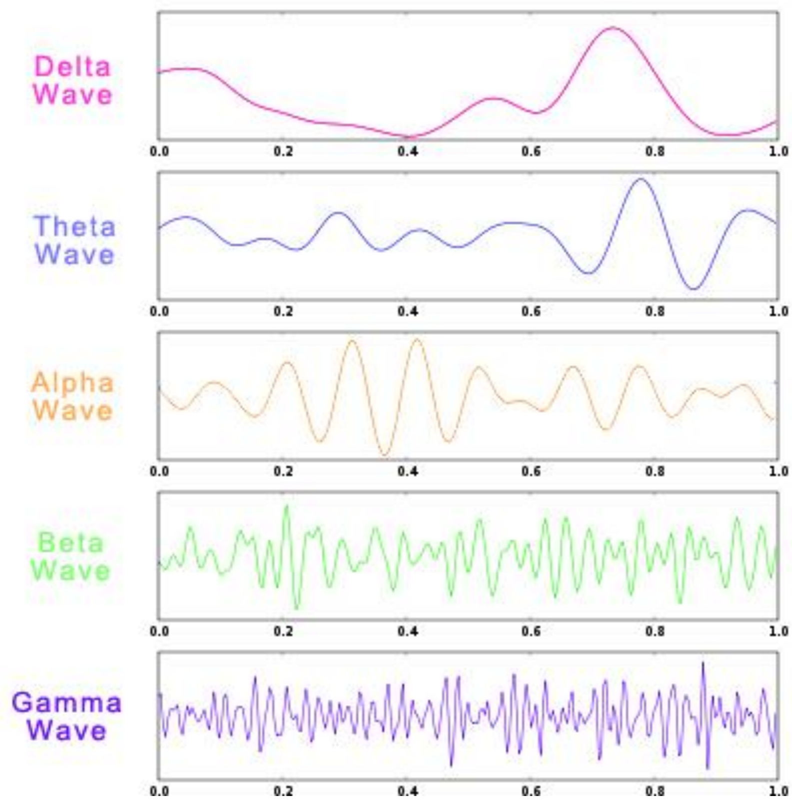

Figure 2.5: Frequency range of brain waves source [72]

2.2.2 EEG signals Rhythm

Frequency is the key element to study abnormalities in a given EEG pattern and find the reasons for behavior which is displayed by individuals with cognitive impairment. The electrical activity of human EEG is demonstrated as aperiodic random oscillations with irregular bursts of fluctuations which are normally characterized in definite bands[26]. Table 2.1 demonstrates these EEG bands.

2.3 Seizures

Seizures are indicators of a brain disorder. Seizures occur because of abrupt, irregular electrical movement in the brain. The frequency range of seizure activity is from 0.5 till 29 Hz, [27]always less than 40 HZ. The person living with the disease of epilepsy knows a seizure can occur at any time, and he spend his whole day with a fear of seizure and the family of the patient also suffers from same condition.

2.3.1 Detection of Seizure before Time

Figure 2.6: Smart monitor to detect seizure

The family of the patient with epilepsy can never leave them alone because of that. To give special kind of favor to these kinds of people Anoo Nathan introduces a smart watch to known as smart monitor which detects the seizure before time and generates an alert message to the caregiver of that person. These kinds of devices can help the patient and their families as well. The Smart Watch procedure is that it connects with Android phones through its pp; the use of that smart monitor must have that phone nearby so it can send the alert notification through generating text message on the phone screen. That alert contains the epileptic person’s GPS recordings as well. According to Anoo Nathan iPhone-compatible version will also be introduced later[29].

For the people whose seizures are not being stopped by using medicines, the Smart Watch can help these kinds of people to avoid any serious output by the result of seizure. The wristwatch is constantly registering the motions of that person, and the algorithms of that watch crunch the data to notice the patterns of movement before occurring of seizure. Because that responds every movement, that wrist watch can help people who experience from jerky epileptic seizures, except those who suffer from "absence seizures" when patients gets blank and start staring into space for few time periods. Most of the time that don't cause any long lasting issues.

Anoo Nathan the founder of that smart watch says that the Smart watch device is not approved yet by FDA ("Food and Drug Administration")[30]. Currently he has not any authorized confirmation for "diagnosis of seizures," but that smart watch can "detect abnormal motions." .Her Company is gathering outputs from ongoing clinical trials. Moreover she says my first preference is to get that approval from FDA.

Anoo Nathan says she firstly make-believe that parents who are using the Smart Watch and that app to keep an eye on their children how much satisfied they are. 60 percent of smart watch users are presently wearing the watch are below the21 age group. Moreover, she says she is totally satisfied that her product can help adults, children and parents too. She told about her one of the customer who is in his 40s and was not able to move anywhere without his parents' and even he was not allowed to leave his home for going his friend's apartment. "This product provides him with a degree of autonomy and independence he never had before," says Nathan.

To make the Smart Watch she also collects that person seizure data so the person and the physicians both can review that data to note down the expected time, duration etc. Providing the obtained record help her to design an accurate device. While, that device has proved a great support and help in the mobile health market. According to research that concept of watch is growing very fast and proved beneficial for patient himself and his family as well.

2.3.2 Related Work

Electroencephalography which means the recording the human brain signals also known as electrical field of "encephalos" (actually a Greek language word used for the term of brain;

which he mean by “what is inside the head”), in the very first time that were revealed in the year of1875 by one of the British neurophysiologist who was named as Richard Caton, who started research on brain cells and recorded the electric activities of brain tissues of different animals like rabbits and monkeys. Then the other scientists started following his research. However, the research was later started in 1920s, [31] that the real-world and analytical calculated values of electroencephalography was predictable through humans by placing scalp electrodes.

For accurately detection of the epileptic seizures in epilepsy, Signals of the electroencephalogram are considered beneficial for handling of abnormalities of neurological states and brain physiological state for broad range of applications in the community of biomedical. EEG signals demonstrate the electrical movement of brain and consist of useful data for the different states of brain to get and study the detailed information about the brain. The identification of various categories of EEG signals is normally performed by the experts from the field of visual inspection. To complete that process manually it may cause human based errors and cause a lot of time and also considered as time taking process and also not much reliable. Visually inspecting the EEG signals for the purpose of detecting the epileptic seizures varies according to the expertise of human experts. That’s why, an automatically detection of epileptic seizures is essential in the real environment of clinic of the neurological disorders[32].

For the purpose of classification of seizures key factor is extraction of features. For this purpose different methods are introduced till today and many researchers have done research on that key issue. Which is to easily extract the features from the datasets of patients and normal people and then comparison can be easily done in between the normal and epileptic patient’s data values. There are many extraction techniques for features are currently available which are frequency-domain, time-domain, and time-frequency domain[33]. By using these techniques researchers of that domain are currently trying to extract the patterns available in a hidden matter in the signals EEG data.

Pattern recognition is a technique used for the purpose of detection of epileptic seizures; in this technique hidden pattern from EEG are extracted using signals of EEG data. Many researchers from that field have also tried analysis of Multi-Fractional type data relying on the Generalized Fractal Dimensions and the discrete wavelength transform (DWT) based techniques for the purpose of the classification of EEG signals for the Epileptic datasets[34]. Discrete wavelet transform is basically an estimation technique used for expressing the general functions as an infinite set of wavelets. The main theme behind that idea of discrete wavelet analysis is comprised of expressing a normal signal as the linearly combined functions of a specific group of functions (WT) which are gained by shifting and expanding the only single function called as a mother wavelet. Breakdown of signals leads toward a group of coefficients which are known as wavelet coefficients. However the signal can be reassembled as a linear grouping of the wavelet functions which are calculated by the wavelet coefficients. For obtaining the exact rebuilding of the signal, the numbers which are calculated for that purpose must be satisfactory by all conditions. The important feature in this technique is localization of the time-frequency feature. The wavelet transform can be expressed as a low pass filter which satisfies all the standards of current scenario.

For this purpose different kind of classifiers like Support Vector Machine, ANN Artificial Neural Networks, k-nearest neighbors (K-NN) logistic regression, quadratic analysis, surrogate data analysis, Markov modeling, mixture of expert model, naïve bays, Gaussian mixture model[35], learning vector quantization are different techniques used to classify the epileptic seizures and abnormalities of brain through EEG signals. All of these pattern recognition approaches main focus is to improve the accuracy of classification with combining different techniques for extraction of feature and classification used for the purpose of detection of the epileptic seizures. Therefore accuracy depends on the feature extraction technique and the classifier selected for that purpose.

One of the researchers named Gajic et al. [36] has extracted various kinds of features using frequency, time, and time-frequency domain and non-linear analysis were also used for the extraction of different feature. As a result the features which were extracted using that method were obtained against those sub-bands and these features were having well-structured representative characteristics. The dimensions of the features were reduced by the researchers by the using scatter matrices. By that method 98.7% accuracy were obtained. Gajic et al[37] used a wavelet transform method for extracting key features. For reducing the dimensionality of feature they used scatter metrics. As an input those features were used like as a required quadratic classifier. Database having the record of the EEG data was divided into two classes which are the class of healthy people and the class of elliptic people during the normal state and the patients of epilepsy in the state of having a seizure. In this 99% of accuracy was obtained.

Siuly and Li [38] proposed a component analysis method for key feature extraction for classification purpose of multi class EEG signals which were actually obtained from data of EEG signals using the technique of optimum allocation-based principle. Four different kinds of classifiers named LS-SVM, naïve Bays, linear discriminate analysis and the last one was k-nearest neighbor algorithm (KNN) were used for that purpose [39]e. The purpose was to get the best classifier. Four different types of output coding ways were used for multi-class LS-SVM; used as the codes of output for the purpose of error correcting, and the codes with minimum output, and One Versus One (1vs1) and one versus all. And by using classifier in LS-SVM_1vs1 in the method 100% accuracy were obtained.

Through the empirical mode decomposition technique the process of feature extraction was also carried out. The all feature which were extracted through that technique were moved toward two different kinds of classifiers which are classification and the regression tree and a classifier named C4.5 were used. Martis et al [40] proposed the method of C4.5 classifier and the good experimental results were obtained through that technique. Accuracy, Specificity and Sensitivity of 95.33%, 97% and 98% were respectively achieved.

Usage of higher order spectra with the involvement of raw EEG recordings for the purpose of features extraction was proposed by the Chua et al [41] in this technique Support Vector Machine and the Gaussian Mixture Model classifier were considered by him for the purpose of detecting the epileptic EEG signals. 93.11, 92.56 were the average accuracies achieved for the HOS based GMM and Support vector machine classifiers respectively, trying that for different types of EEG classes of like normal, Pre-seizure and the last is epileptic EEGs.

Meanwhile Guo et all [42] used a generic algorithm for extracting different kind of features from data of EEG signals automatically for enhancement of performance of classifier as well as for the purpose to minimize the features dimensionality. In this work two groups of datasets were used by them. First one category was having two different classes of physically fit people, abnormal people with having epilepsy and the second category was having three different classes of distinct categories which were physically fit people, inter-ictal and ictal ones. For the classification purpose of two different group’s k nearest neighbor classifier was used. The accuracies achieved from genetic algorithm and without genetic algorithm were 99.2% and 88.6% consecutively. While for the second group the obtained accuracies were 67.2% and 93.5% without Genetic Algorithm and with Genetic algorithm respectively.

Through discrete wavelength, EEG signals were decomposed which basically were noticed from the healthy people and the patients of epilepsy. Ocak[43] extracted approximate entropy from approximation and the detailed coefficients. Through that methodology 96% accuracy were achieved.

A special type of Artificial Neural Network (ANN) classifier was recommended by Srinivasan et al, for identification of epileptic EEG signals [44]. That method achieved the maximum of 100% accuracy. He also introduced a particular kind of persistent Neural Network named Elman network [45]. Features extracted from time domain and from the frequency domain were used as an input in proposed classifier. Through that network technique 99.6% of accuracy was yielded from that single input feature.

A flow of wavelet-ApEn for the choice of features was proposed by Shen et al[46]. In this technique fisher score were used for adaptive feature selection, and Support Vector Machine was used for features classification for the detection of seizures in epilepsy. That method was applied on different kinds of EEG recordings of epilepsy like data available on open sources and also on clinically available EEG data. Through that technique overall accuracy of classification obtained was 99.97% and 98.73% respectively.

Siuly et al [47] proposed a method for sampling of data which is known as Sampling Technique is centered on LS-SVM. On a first step ST were used by them for extracting features from the two different groups of normal people with their open eyes and then the patients suffering from the disease of epilepsy during the occurring of epileptic seizure. They applied the Least Square – Support Vector Machine (LS-SVM) for extracting features. By that method the total obtained accuracy of classification for both of the testing datasets and the datasets of training were 80.05 and 80.31% respectively.

One of the researchers named Gajic et al. has extracted various kinds of features using frequency, time, and time-frequency domain and non-linear analysis were also used for the extraction of different feature. As a result the features which were extracted using that method were obtained against those sub-bands and these features were having well-structured representative characteristics. The dimensions of the features were reduced by the researchers by the using scatter matrices As an input those features were used like as a required quadratic classifier. Database having the record of the EEG data was divided into two classes which are the class of healthy people and the class of elliptic people during the normal state and the patients of epilepsy in the state of having a seizure. In this 99% of accuracy was obtained. Table 2.2 summarizes the related work on EEG signal classification.

Table 2.2 Related work Summary of the different researches

No.	Feature extraction Technique	Classifier
1	Hilbert transform	CART classifier
2	Random Sampling	Random Forest Classifier
3	Discrete Wavelet transform	SVM classifier
4	Wavelet packets	Neural Network
5	N/A	Softmax classifier

CHAPTER 3

Proposed Methodology

"Research methodology is the systematic, theoretical analysis of the procedures applied to a field of study. Methodology involves procedures of describing, explaining and predicting phenomena so as to solve a problem; it is the 'how'; the process, or techniques of conducting research."(Kothari, 2004)

3.1 Problem statement

Simply stated, the problem explored in this thesis is An Early Detection technique for the diagnosis of Epilepsy through using EEG signals. While the classification of EEG signals can be useful in many areas, and diagnosis of epilepsy is from one of them. These kinds of diseases can be detected by using EEG signals and analyzing them.

EEG signals contain an unlimited deal of the information related to the function of the brain. While the process of classification and evaluations of these signals are inadequate. Moreover not any definite criterion is evaluated by the researchers and experts, visual analysis of EEG signals is inadequate. Since routine medical diagnosis desires the analysis of EEG signals, for that purpose some automation and computer techniques have been utilized that. The problem of EEG classification in these types of experiments has a number of challenges that must be considered, including:

- There is high variability between subjects and within subjects,
- There is limited availability of data, and
- The data is composed of multiple channels of time series information

This thesis will address these challenges by exploring several variations of architecture selection, model search, regularization, and training paradigms within a deep learning context, with the aim of harnessing the expressive power of deep learning while avoiding over fitting.

3.2 High Variability

The highly variable nature of EEG data leads to difficulty in classification. Samples in the same class may be very different in nature from one another. There are multiple sources of variability both within subjects and between subjects. Sources of within subject variability are briefly summarized below:

3.2.1 Level of Attention

If the subject is not focused on the task, the patterns of activity produced by their brain will be quite different. This not only impacts data quality, but also reduces the amount of data that can be collected.

3.2.2 Multiple Sessions

Many experiments call for the subject to attend multiple sessions of data collection. The subject can be more or less focused, and may be in a different mood, both of which affect the data. Another common source of variability is the physical placement of the EEG electrodes. It can be very difficult to insure they are in the exact same location. Thus, channels may be collecting data from a slightly different source from one trial to the next.

3.2.3 Muscle movements

A constant issue in EEG data analysis is that the electrical activity created from muscle movement has a far higher magnitude than that produced by brain activity. This is particularly noticeable and problematic when the subject blinks. There are methods to reduce the impact of certain types of movements, including eye blinks, such as using independent component analysis to regress out the artifact. However, these methods are imperfect.

3.2.4 Machine noise

There is a certain amount of uncertainty inherent from the machine itself. Slow drifts in the data are common and are caused by either slight movements of the electrode or sweat interfering with the sensor. Movement in wires connecting the electrodes can cause similar issues. These issues can often be mitigated through the use of band pass filters, however. Sources of between subject variability are briefly described below:

3.2.5 Differing physiologies

Differences in skull shape can lead to electrodes monitoring different relative portions of the brain. Thus, the brain activity collected by an electrode on one subject may be from a slightly different region than the activity collected by the same sensor on a different subject.

3.2.6 Differing cognitive patterns

There are individual variations in how information is processed, and thus, the same stimulus may illicit differing responses in different subjects.

3.2.7 Differing behavior

Some subjects will be more focused on the task than others. Some will perform better than others on the experimental task. Differing behavior is associated with differences in brain activity patterns.

3.3 Methodology

Here in this chapter, we have discussed our proposed methodology which is used for feature extraction and diagnosis of epileptic seizures. Wavelet transform has been developed as an important tool for the purpose of extraction of features of no stationary signals. Wavelet transform has a better resolution and it has higher performance for the detection of epileptic seizure as compared to other different techniques. Step by step proposed methodology is discussed in depth.

We have proposed a method for the classification of seizures activities occur in human brain for that purpose it was important to extract useful features of brain by considering different patient's dataset. Classification of EEG signals for identification of epileptic seizure is a step wise process which includes transformation of the EEG signals into some other domain, features extraction, feeding in these features to neural network at input layer, NN training using SO and classification at the output layer. Our Proposed methodology is divided into five different steps which are listed

- Visualization of dataset with raw EEG signals
- Discreet wavelet for noise removal

- Data processing/ feature extraction
- Training neural networks with swam optimization
- Classification

All of these steps are performed on dataset of different patients to classify in between normal activity of brain and epileptic seizure activity. For that purpose data of different people is observed that will contain normal people data as well so that classification between normal brain area and epileptic area can easily classified.

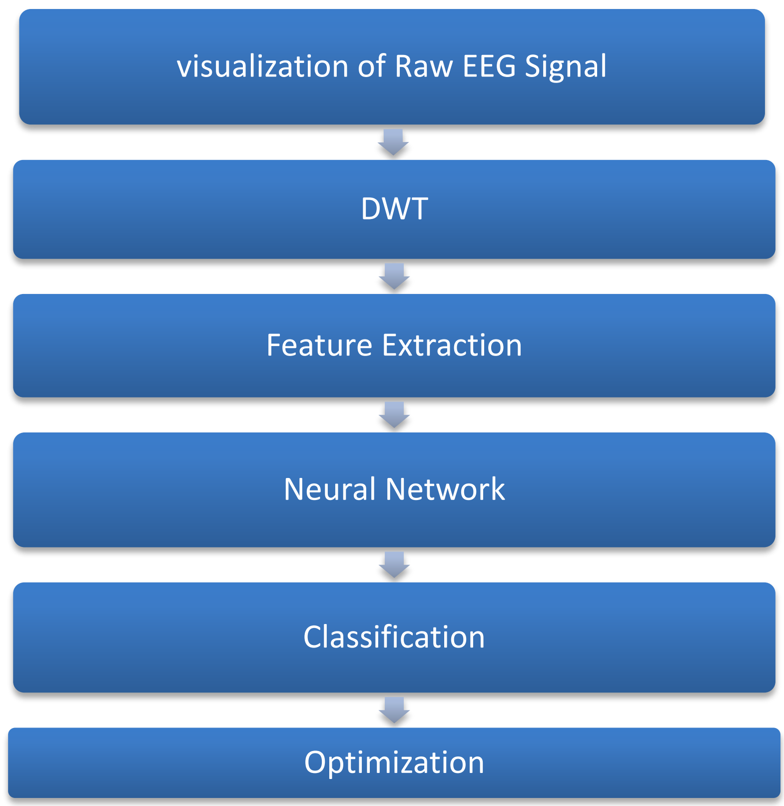

Figure 3 1: Proposed Systems Flow Diagram for Classification of EEG Signals

Steps which are involved in feature extraction and features classification are explained in detailed steps. Software's and programming languages used for the implementation of that methodology are also discussed in detail. Data of patients is too important to get good results.

By considering all these techniques we develop a new method for extracting features of different kinds through various datasets. After extraction of features classification of EEG signals will be done to classify the type of seizure. The process of selection of features is the most important and technical part which effects the working of whole model so, if the features are properly extracted the complete pipeline will work in a very effective manner. The technique of feature extraction is useful in terms that it minimizes the cost of computation and also increases the overall performance of the classifier being used in the technique. For this purpose we are using the combination of Simple Random Sampling and Sequential Feature Selection to get the best results. Main focus is to introduce a technique which has higher level of results accuracy and lower level of complexity in understanding to achieve the best results. Just because that is a neurological issue so any kind of misguidance and error cannot be acceptable.

Through EEG signals the patient's data recordings can be easily taken by inserting electrodes above the patient scalp, which record the electrical activity of the human brain on which electrodes were placed. Amplitude and frequencies of the EEG signals can fluctuate from 10-100 micro volts and 1-100 Hz respectively [49]. If the obtained recordings are change from normal brain waves recordings. The changes are very common in normal pattern of human brain waves as well, although the person is not having any seizure activity at that time.

3.4 Dataset 1 description

For the purpose of visualization we have used python. It has seen that Python become most popular language of data sciences in the year of 2018. Then a UCI dataset is used for that purpose. The dataset is based on five different kinds of people information. Trained dataset of UCI is used for that purpose, because good results can only be generated through good data. So the record of the patients available must be clear and not ambiguous.

Two different types of languages are used to get the better accuracy and to train the dataset in a well-mannered way. For that Python and MATLAB are used. In particular, the distribution which was used was the Anaconda scientific distribution of Python 3.6. NumPy library was used for the vast majority of numerical computations. Machine learning algorithms are used in that. The first step which was taken was visualization of dataset through that a normal human being can notice the abnormality in the brain waves signals. For that NumPy and pandas are used in python. Sequential model is created in NN. Sklearn is used for the scaling of data and for data preprocessing. Data has too much unarranged values data is arranged in a way that it can easily set and choose values from dataset. Normally in other different kind of models we first need to set Seed value but neural network has not that function of to save output. Pandas are used to read, change, manipulate and update the data. For the purpose of indexing Location function is used here. X is considered an input variable and y is considered a target variable. There were 5 different categories in the dataset which were

1. eyes open, means when they were recording the EEG signal of the brain the patient had their eyes-open
2. eyes closed, means when they were recording the EEG signal the patient had their eyes-closed
3. Yes they identify where the region of the tumor was in the brain and recording the EEG activity from the healthy baron area
4. They recorder the EEG from the area where the tumor was located
5. Recording of seizure activity

For prediction binary digits are used that's why 1 is assigned to affected variables and to all others 0 is assigned.

1	**0**
Epilepsy	**Normal**

0.2-20% value range is set where the value will lie it will be assigned into that class. Scaling of values is done

Keras is used to build sequential model there are different kinds of model available like back propagation, forward propagation etc but we have used sequential model because on different positive points.

3.5 Visualization of EEG signals

Data visualization is from one of the core abilities in the field of data science. Moreover, In order to start building useful and informative models, we first of all need to understand the underlying dataset and then work can be started on that. In this thesis, we will cover building effective data visualizations in Python for understanding of dataset. We will cover the pandas plotting tools in depth. Data visualization is the restraint of trying to understand the available data by placing it in the form of visual context so that trends, correlations and patterns that might not otherwise be detected can be exposed.

For understanding big data visualization can be considered as a good approach. Visualization of data is another practice of visual art which grabs our intension toward it and our eyes keeps on that message [50]. When a human eye sees that chart at that time human mind identifies the abnormality, outlier present in that chart. Data visualization tells the highlighting points of the whole story through different charts. A good visualization tells the story by removing the all kinds of noise present in that data and highlight the all kinds of important information from whole data. The library which is available in python “Pandas” is useful for the purpose of Visualization that is easy to use in the interface that is built on Matplotlib. After performing the step of visualization dataset becomes clearer and no ambiguity remains and then the methodology can be applied on the dataset to get the desired results.

In python we have used Pandas which is an open source tool for data structures and for the analysis of data. We have started by importing pandas and then aliasing it as a pd so that it can give us a shorthand term to use during our analysis. Pandas allow us to import files through different formats but the most common and trustworthy is CSV. To get the graphs of that dataset UCI dataset is imported and step by step details of all these five categories is checked which is clearly showing the abnormality in the graph.

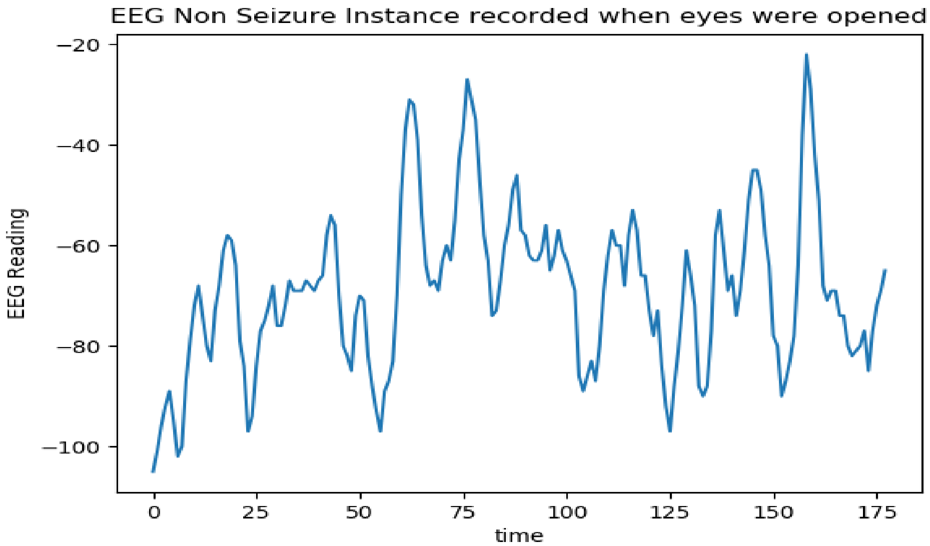

Figure 3.2: EEG Non seizure instance recorded when eyes were open

The graph showing the EEG Non Seizure Instance recorded when the eyes of the person were opened. The EEG recordings are done according to the time. On the x-axis the time is set according to the goal and on the y-axis EEG recordings are set. Any kind of abnormality is not seen in that condition. Mean no seizure is detected during that time span.

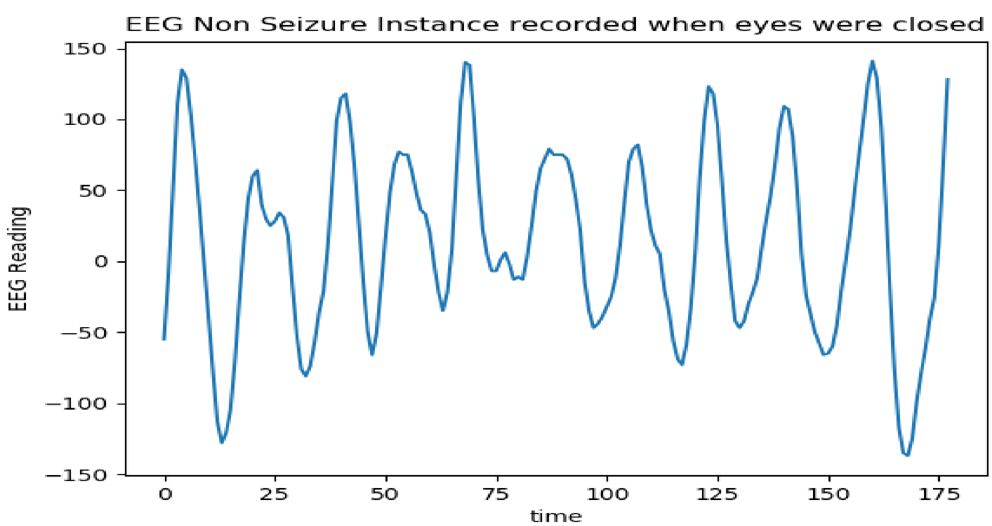

Figure 3.2: EEG Non seizure instance recorded when eyes were closed

The graph showing the EEG Non Seizure Instance recorded when the eyes of the person were closed. The EEG recordings are done according to the time. On the x-axis the time is set according to the goal and on the y-axis EEG recordings are set. Any kind of abnormality is not seen in that condition. Mean no seizure is detected during that time span. But EEG recordings are varying according to every new condition of brain waves.

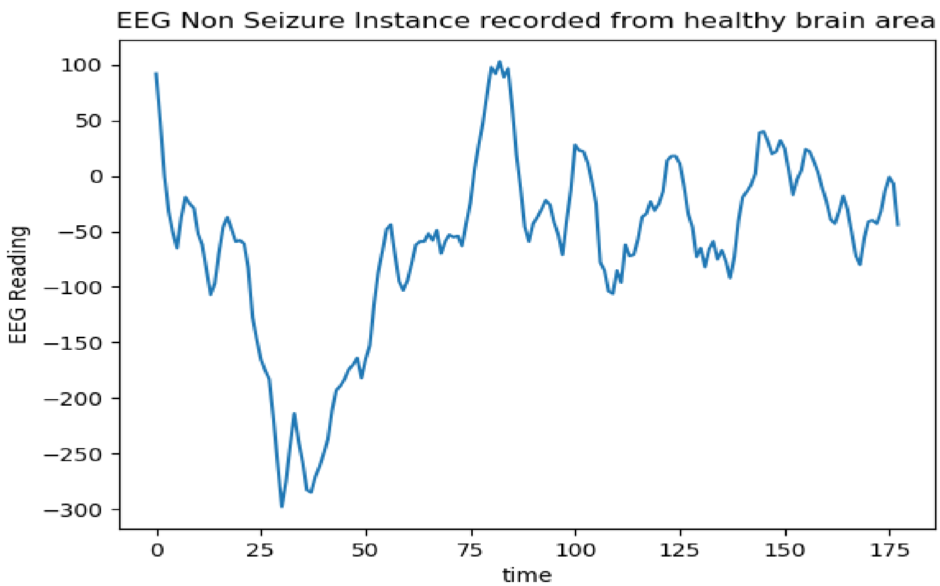

Figure 3.3: EEG Non seizure instance recorded from healthy brain area

The graph showing the EEG Non Seizure Instance recorded from the healthy brain area. The EEG recordings are done according to the time. On the x-axis the time is set according to the goal and on the y-axis EEG recordings are set. Any kind of abnormality is not seen in that condition. Mean no seizure is detected during that time span. But EEG recordings are varying according to every new condition of brain waves. Healthy brain shows different recordings in every turn.

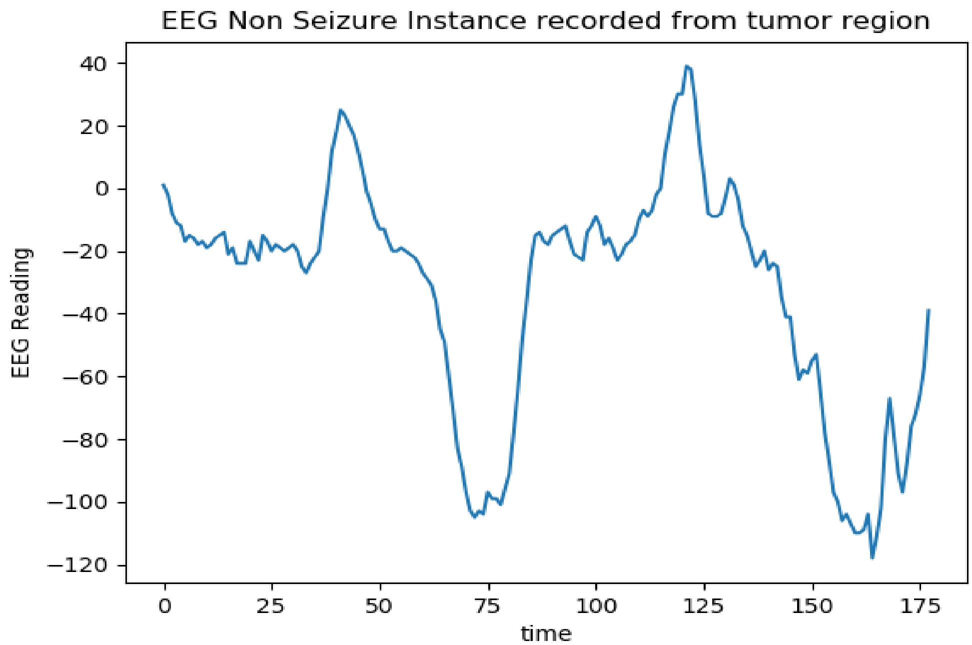

Figure 3.4: EEG Non seizure instance recorded from tumor region

The graph showing the EEG Non Seizure Instance recorded from the tumor region of the brain. The EEG recordings are done according to the time. On the x-axis the time is set according to the goal and on the y-axis EEG recordings are set. Any kind of abnormality is not seen in that condition. Mean no seizure is detected during that time span. But EEG recordings are varying according to every new condition of brain waves. Brain waves of a normal human brain and an ill brain are totally different and that can be observed manually by anyone as figure 4.5 is showing a pause in the wave.

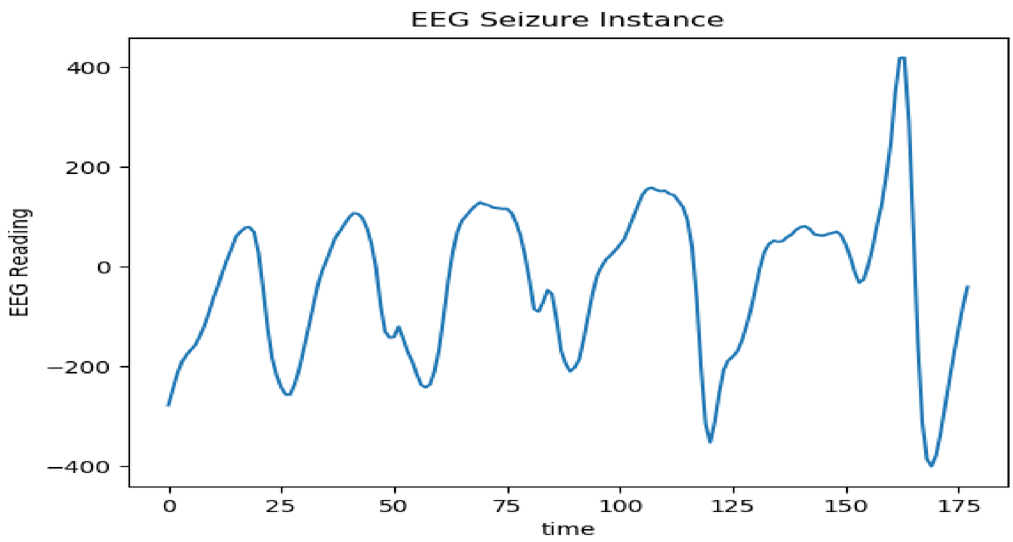

Figure 3.5: EEG seizure instance

The graph is showing the EEG Non Seizure Instance. The EEG recordings are done according to the time. That is a graph with epileptic seizure. On the x-axis the time is set according to the goal and on the y-axis EEG recordings are set. Any kind of abnormality is not seen in that condition. Mean no seizure is detected during that time span. But EEG recordings are varying according to every new condition of brain waves. These brain waves are changing in every coming second and these brain waves are really slow in speed then the other ones.

3.6 Discrete Wavelet Transform

The wavelet transform (WT) is one of those kinds of technique which is based upon the multi resolution analysis the main task of that is it decomposes the signals into different frequency bands. Noise which is present in the dataset is also removed by using DWT. Discrete wavelet transform is applied on the EEG signals to remove the noise from those signals. This WT characteristic is useful in analyzing the epileptic seizure signal because the EEG signals contain low-frequency information with long time periods and high-frequency information with short time periods [38]. The WT could be continuous wavelet transform (CWT)/discrete wavelet transforms (DWT). The drawback of CWT is the high redundancy. However, with DWT, it is easier to decompose the signal into different levels using group of filters.

In medical diagnosis, most of the signals generated are responses to activity of muscles and are time domain signals with amplitude/ peaks which are analyzed by the domain experts (medical doctors) to identify disorders on the basis of deviations in signals amplitude and variations in time. It is a matter of fact that more information can be carried out from the signals if these are transformed to other domains and are then analyzed. E.g. frequency domain analysis of such signals gives more insight into the signal as compared to time domain analysis but the problem with Frequency domain is that these types of signals (i.e. EEG and ECG signals) have very rapid sharp changes and transient components which cannot be well studied in frequency domain.

3.7 Neural networks

Artificial neural networks are computing systems made up of large number of simple, highly interconnected processing elements (called nodes or artificial neurons) that abstractly emulate the structure and operation of the biological nervous system. Learning in ANNs is accomplished through special training algorithms developed based on learning rules presumed to mimic the learning mechanisms of biological systems. There are many different types and architectures of neural net-works varying fundamentally in the way they learn. In this paper, feed forward back propagation neural network considered

The architecture of BPN may contain two or more layers. A simple two-layer ANN consists only of an input layer containing the input variables to the problem, and output layer containing the solution of the problem. This type of network is a satisfactory approximate or for linear problems. However, for approximating nonlinear systems, additional intermediate (hidden) processing layers are employed to handle the problem's nonlinearity and complexity. The determination of appropriate number of hidden layers is one of the most critical tasks in neural network design. Unlike the input and output layers, one starts with no prior knowledge as to the number of hidden layers. A network with too few hidden nodes would be incapable of differentiating between complex patterns leading to only a linear estimate of the actual trend. ANNs' success depends on both the quality and quantity of the data.

Neural Networks (NN) are generally being used in machine learning and various other fields of engineering's and computer science areas for solving the decision making problems and these are also proved to give promising results with reliable accuracy. Numerous architectures are discussed in the literature with different activation functions in the neuron at different layers. Here, we have a neural network of 3 layers which can be input layer, hidden or middle layer and the last output layer with results. The total number of neurons in input layer can vary according to data. Here, we have a neural network of 3 different layers which are named as input, hidden (weight) and the last is output layers. The overall number of neurons present in the input layer is 20, as there are 20 features extracted from each EEG signal, in the hidden layer we have 40 neurons and only a single neuron is present in the last layer which is output layer while the problem is binary classification of EEG signal into epileptic and normal seizure.

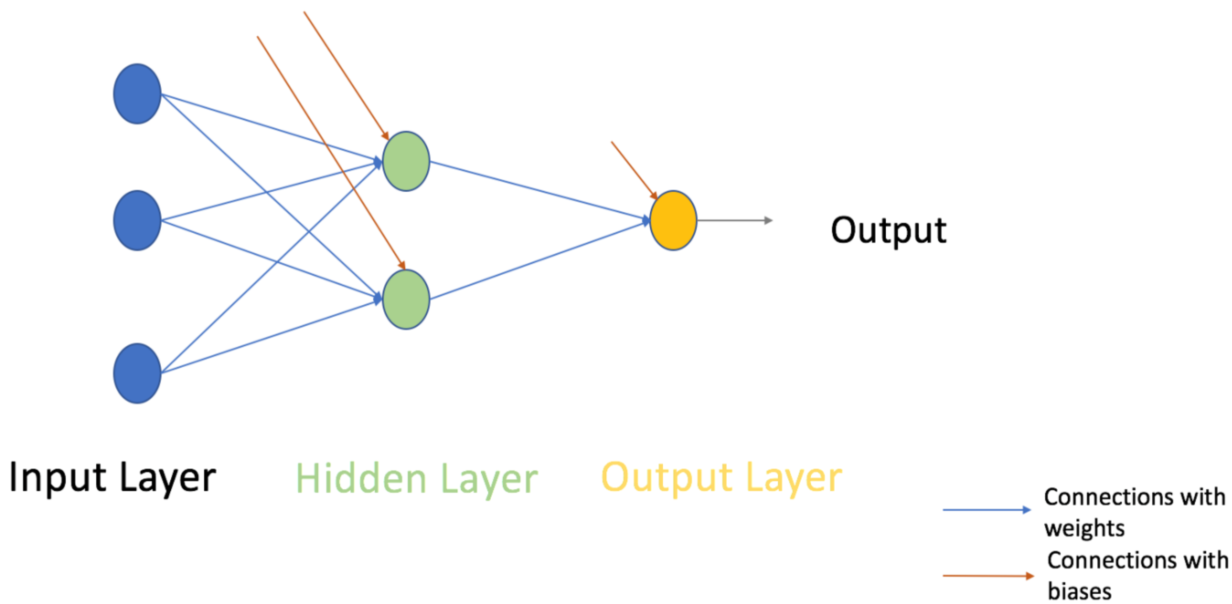

Figure 3 6: General Architecture of 3 layered Neural Network [72]

3.8 Classification

Epileptic seizures are manifestations of epilepsy. Careful analyses of the electroencephalograph (EEG) records can provide valuable insight and improved understanding of the mechanisms causing epileptic disorders. The detection of epileptiform discharges in the EEG is an important component in the diagnosis of epilepsy. As EEG signals are non-stationary, the conventional method of frequency analysis is not highly successful in diagnostic classification.

EEG signals involve a great deal of information about the function of the brain. But classification and evaluation of these signals are limited. Since there is no definite criterion evaluated by the experts, visual analysis of EEG signals in time domain may be insufficient. Routine clinical diagnosis needs to analysis of EEG signals. Therefore, some automation and computer techniques have been used for this aim. Since the early days of automatic EEG processing, representations based on a Discrete wavelet Transform have been most commonly applied. This approach is based on earlier observations that the EEG spectrum contains some characteristic waveforms that fall primarily within four frequency bands—delta (<4 Hz), theta (4–8 Hz), alpha (8–13 Hz) and beta (13–30 Hz). Such methods have proved beneficial for various EEG characterizations, but fast Fourier transform (FFT), suffer from large noise

3.9 Optimization

RMS props, Adagrad, SGD and swam optimizer's are used for the purpose of optimization and to get accuracy and as a result Adagrad provides maximum of testing and training accuracy.

- Adam gives maximum of accuracy where training accuracy is 98.74% and testing accuracy is 95.22%.
- Testing and training accuracy graphs are shown in figures. Iterations are changed from 0 till 140.

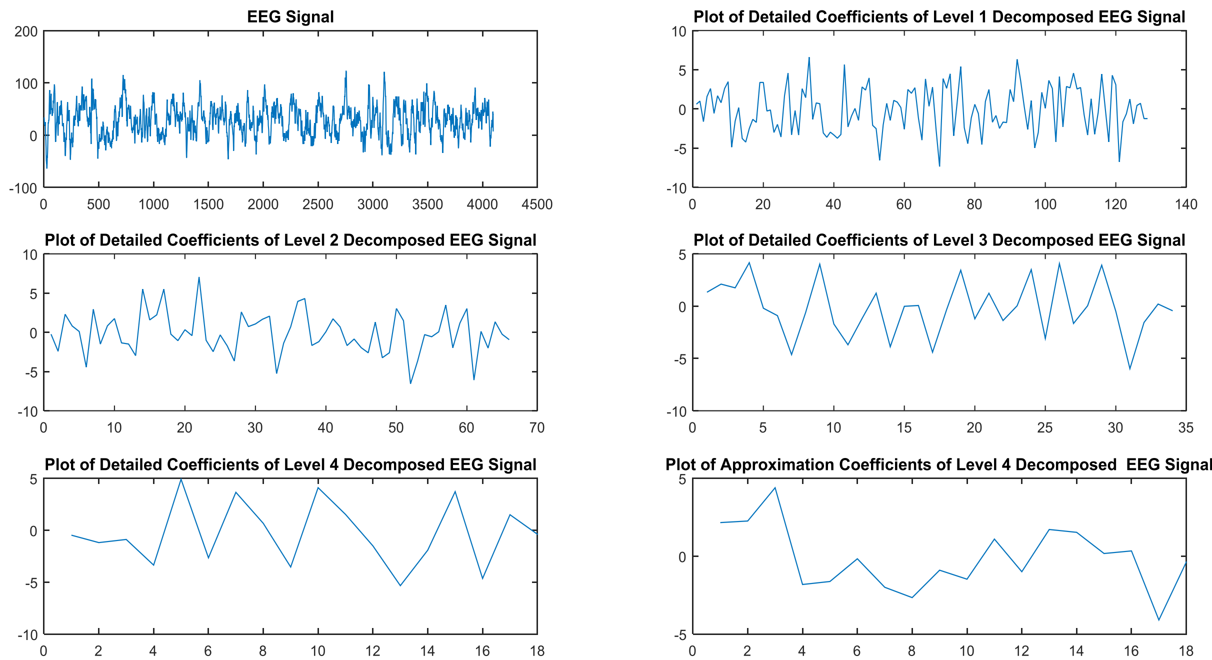

Figure 3.7: Representing the decomposition of EEG Signal into Sub Bands

In this work, we have EEG signals in the form of text files which are of length 4097. We have applied DWT with Daubechies basis function and window size is 256, which decompose the input signal into four different detailed coefficients which are uniquely named by (d1, d2, d3, d4) moreover four different kinds of approximation coefficients are also used which are also uniquely named by (a1, a2, a3, a4). These first three coefficients of approximation i.e. a1, a2, a3 are discarded for the sake of simplicity while keeping a4. So, at the end we have total of 5 coefficients i.e. d1, d2, d3, d4 and a4 from which we have extracted four statistical features as follow:

- Maximum numbers of wavelet coefficients are present within every sub band.
- Standard Deviation is taken which is related to wavelet coefficients in every sub band.
- Lowest numbers of different wavelet coefficients are found within the all sub band.
- The average mean value relating with every wavelet coefficients is obtained from every sub band.

So, we have total of 20 numbers of features, which are extracted from the each EEG signal. These features will further serve as an input for the neural network at input layer.

Table 1.1 Description of parameters with their values

Symbols used	Description	Considered value/size
ƛ0	Initial inertia weight	0.8
ƛ1	Final inertia weight for linear selection	0.5
C1	Local search coefficient	0.9
C2	Global search coefficient	0.9
P	Population size	25,50,80,100
g1	Number of generation’s for linear increment	50
g2	Number of generation’s for non-linear increment	50

Chapter 4

Experimental Results

We have 500 samples of EEG signals in our data set for the detection of epileptic seizures. We have labeled the EEG signals data with 1 and 2 which shows whether the EEG signal belongs to normal or epileptic seizure class respectively. Out of total 500 EEG signals samples, 450 are used as training samples for the learning/ training of our classifier while rest of the 50 samples are used as testing.

4.1 Model Accuracy

Table 4.1 Comparison in Accuracy for varying number of iterations with fixed

Number of Iterations	Training Accuracy	Testing Accuracy
50	94.25 %	91.23 %
100	98.15 %	97.07 %
200	99.83 %	98.15 %
500	99.83 %	98.36 %
1000	99.90 %	98.86 %

As per table 4.1 the overall accuracy of our model has been device at 98.86% which is more than satisfactory given the rate of the seizure detection and the time proximity that has been provided to the model of 23.3 sec the model designed can bring in more valuable processes to the whole new dimensions precise and timely decision making. The neural network was trained on different epochs and the best rate at which the accuracy had come was 500, but to further our results and making sure that the model is more accurate we also tested the model over 1000 epochs and the overall results have shown that the overall accuracy at 500 t0 1000 epochs had been the same therefore it is safe to say that the lesser epochs will make computation lesser and will provide more cheaper hardware implementation which will require lesser memory and power at the same time as well.

4.2 Comparison with Literature

In the following table 4.2 the main theme is to compare the metrics of our proposed model with the other research work that have been done prior to us. It is worth mentioning some of the notable works especially the work of R. Hussein [10] who has been able to achieve an overall accuracy of 100% what is more intriguing is the fact that the paper in which the accuracy was provided did not accounted for the over fitting of the test data and how to avoid it in the first place, secondly the same work did not mentioned how the model worked on different benchmark datasets as well. Other researchers have also been able to make some impacts like [11] and [12] but their accuracy level is far lesser than our model as well, it is also important to know that all these research works have been done in the last 4 or 5 years

Table 4.2 Comparison of results with different research works

Author	Technique	Testing Accuracy
R.J Martiz [11]	Wavelet Transform and CART	82.23 %
Christian Donos [15]	Random Sampling	91.13 %
Han and Karypis [12]	WP and Decision Tree	93 %
R. Hussien [10]	Softmax	100 %
Our proposed Model	DWT & ANN	98.86 %

4.3. Overall Model accuracy and Loss

The classifier is evaluated with different number of iterations and different numbers of particles in the SO learning algorithm and hence resulted in different training and testing accuracy which is depicted in the figures below. The overall accuracy and the loss function are basically the functions of the neural network.

4.3.1 The Loss Function

The loss function is the metric of the neural network that how well it has been able to train itself from the given training data. The overall accuracy of the loss function defines the nature of the neural network for us. The lesser the loss value means that the network has been trained more accurately and higher the loss function depicts that the accuracy of the model loss function is less, thus rendering the network more prone to errors and less precise than it should have been

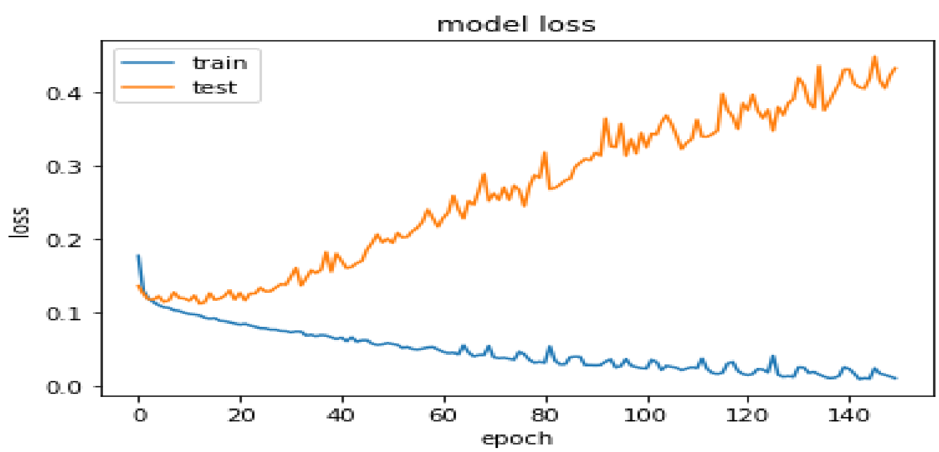

Figure 4.1: Testing and training graph

4.3.2 Accuracy of the Model

The accuracy of the model is defined by how well it has been able to test that testing data after it has been trained, it loss imperative that the loss function plays an important role in the accuracy of the model, therefore as we earlier discussed when the model loss function is less than we will be able to detect the testing data more accurately. Here in figure 4.2 we have shown the model accuracy of 1000 epochs and the overall accuracy of the model is 98.86%

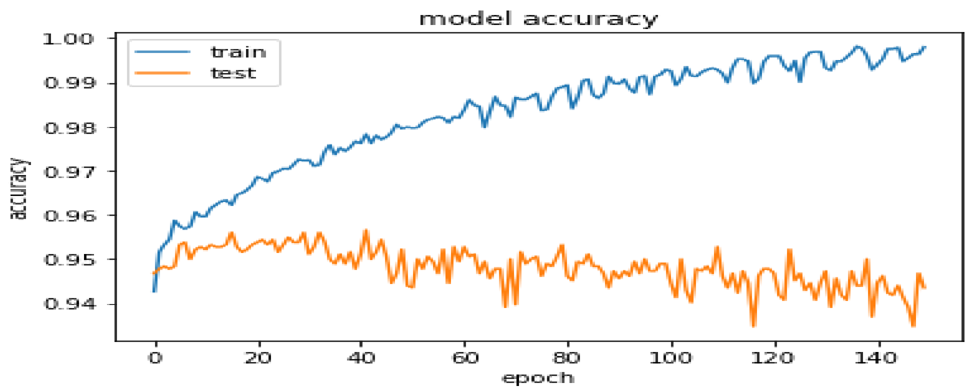

Figure 4. 2: Model Accuracy of Testing and Training

4.4 Confusion Matrix

The confusion matrix that I have designed is for the 1000 epochs, as it is stated the confusion matrix depicts the rate at which the neural network detects the true and false values. When a model has higher rate at which it is able to detect and decide the true positive values then such model is given the factor of more precise. It is also important that the model does not allow any true value to be false therefore constant iterations and learning and updating the loss function through these learning curves will be able to

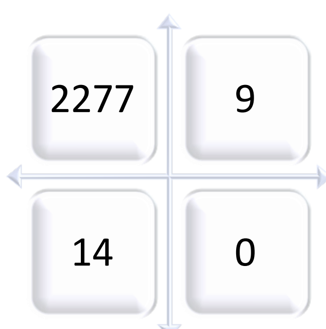

Figure 4.3 Confusion matrixes at 1000 epochs

CHAPTER 5

Conclusion and Future Work

5.1 Conclusion

Diagnosing epilepsy is a difficult task requiring observation of the patient, an EEG, and gathering of additional clinical information. An artificial neural network that classifies subjects as having or not having an epileptic seizure provides a valuable diagnostic decision support tool for neurologists treating potential epilepsy, since differing etiologies of seizures result in different treatments. In this work, classification of EEG signals was examined. The features are extracted using wavelet transform technique.

The combinational use of discrete wavelet for noise removal feature extraction for the EEG classification is still in its early stages. Swam optimization has really helped to get the desired accuracy; it is difficult to find architectures and training paradigms that result in improvements over traditional methods. However, as research continues into the use of neural networks for classification of EEG signals, best practices will become well known. The results of our experiments show a strong case for the extraction of required features and then training them through artificial neural network for the purpose of classification.

We have done EEG signals classification for the identification of epileptic and normal seizure. The classifier is evaluated with 500 EEG signals dataset and the accuracies are given in table 1 with changing numbers of the iterations. That is worth mentioning by growing number of iterations in SO algorithm, the training accuracy get improve but the testing accuracy is not consistent with varying number of iterations.

To maintain the state of the art the technique is implemented on two different kinds of datasets of epileptic patients, both of these datasets are benchmark dataset. Through using that technique required features are appropriately extracted and then neural network is built perfectly according to that feature which helps features to check their accuracy.

5.2 Future work

Further research is needed to find more elaborated memory architectures and its appropriate training algorithms. Neural networks as classifiers have here a high potential because they can compute in real time with a high numbers of features. This characteristic enables the development and construction of transportable devices, improving substantially the quality of life of epileptic patients intractable by medication and that must learn to live with seizures. There are two main avenues for the extension of this research: application will be performed on more datasets, and other techniques will be applied for the purpose of feature extraction and optimization.

5.2.1 Feature Extraction Technique

There are wide varieties of techniques which can be utilized effectively for the extraction of features for the diagnosis of epileptic seizures. One of them is random sampling and then using Support vector machine. We have performed feature extraction through using discrete wavelength transform this technique gives us quite better results from visualization perspective. In the future random sampling technique will be used for that purpose with SVM [69] and it is hereby expected that this technique will also give us best results.

In our proposed methodology, we have used the idea of neural network with sigmoid activation functions in each neuron at each layer of the network and the network is trained with Swarm Optimization (SO) algorithm. Instead of using sigmoid function as activation function in neuron, wavelet transform can be used for the sake of maximum information processing in the EEG signals. Moreover, instead of using ordinary Swarm Optimization for training, Bee Swarm or Ant colony optimization can also be used to enhance the classification accuracy.

5.2.2 Latest Neural Network

More detailed and advanced Neural Networks are being introduced which gives more accuracy that can be used to get the better accuracy, as it is a medical field and a sensitive study so any kind of negligence is not acceptable in any case. And maximum accuracy proves beneficial to detect the patient brain state and to tell either patient is having epilepsy or does have any other disease so that further patient can be treated according to that.

5.2.3 Classification technique

Support vector machine (SVM) is a linear classifier and one of the exciting algorithms in machine learning and used by most of the BCI. It was first introduced by Vapnik and was determined by principal of statistical learning theory and structural risk minimization. SVM searches a line that creates a clear gap among the dataset and split it into designated category. The line which splits the data is called hyper plane, [70] it capitalizes the distance between the hyper plane and the points that are nearer from each class that is called as support vectors. The motivation for this method is to reduce the complexity of the learned model and improving performance. Due to this, SVM provides good generalization [71].

5.2.4 More Datasets

Currently, these techniques were only applied on two datasets. In order to show generalizability, it is desirable to replicate this research on further datasets with different properties. The dataset in this thesis involved the classification of epileptic seizure. While this is a fairly common task in EEG classification, there are several other common tasks that should also be explored. Due to the ease of classification and potential upside in this task, it is a valuable extension. Finally, extending this work to datasets of any sort of disordered patient having brain issue can be observed and cause can be checked. It has been difficult to classify using traditional techniques is important in establishing the benefit of these techniques. The dataset explored in this thesis was collected through UCI.

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Completion Certificate

It is certified that the contents of thesis document titled "An Early Detection Technique for the detection of Epilepsy using EEG signals" submitted by Mr. Syed M Hassan Abbaswith Registration No. 00000118929 have been found satisfactory for the requirement of degree.

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