Detection of Epileptic Seizure using Support Vector Machine Classifier - Extracted Features from EEG Signals

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A thesis submitted to the Department of Computer Science and Engineering
in partial fulfillment of the requirements for the degree of
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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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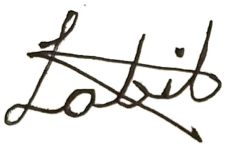

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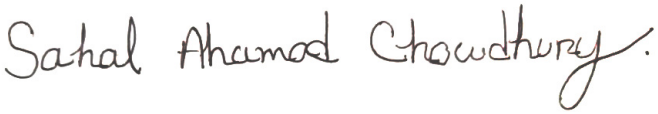

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Abstract

Epilepsy is the most common neurological issue in people after stroke. Around 40 or 50 million individuals on the planet endure epilepsy. Epilepsy is characterized by an irregular seizure in which abnormal electrical activity in the mind causes adjusted recognition or conduct. The most commonly used test for detecting Epilepsy is EEG - which stands for Electroencephalogram. In this thesis, we tried to develop an automated system using machine learning that can detect epileptic seizure. We cropped one hour of pre-seizure and post-seizure signal and extracted features from it. We used Fast Fourier Transformation to make our data easier to process and applied Power Spectrum Density (PSD) to calculate energy from it. Finally we used Support Vector Machine (SVM) to classify among these data to differentiate between seizure and non-seizure. We have managed to achieve 89% accuracy using this method on the 23 cases that we had in our dataset.

Keywords: Seizure; EEG; FFT; SVM; PSD; RBF;

Dedication

Infinite thanks to Allah for making this possible.
We want to dedicate this paper to our beloved parents to whom our debt can never be repaid.

Acknowledgement

Firstly, all praise to the Great Allah for whom our thesis have been completed without any major interruption.
We would like to convey our Sincere thanks to our supervisor, Dr. Mohammad Zavid Parvez, for guiding us through this project, showing us the way to do effective research, and most importantly, for always being there for our support . He shared his knowledge with us in analyzing subject matters also appreciated our approach to synthesizing such themes. His recommendations motivated us to think in new ways, his critiques improved our problem-solving skills, and his encouragement provided us hope and strength when we were lost.

Moreover we want to thank the Department of Computer Science and Engineering for giving us resources and a wonderful working environment which helped us do our research.

Table of Contents

List of Figures

List of Tables

Nomenclature

EEG - Electroencephalography

FFT - Fast Fourier Transform

SVM - Support Vector Machine

RBF - Radial Basis Function

PSD - Power Spectrum Density

ROC - Receiver Operating Characteristic

DFT - Discrete Fourier Transform

EMD - Empirical Mode Decomposition

DCT - Discrete Cosine Transform

DWT - Discrete Wavelet Transform

Chapter 1

Introduction

1.1 Motivation

When the world began to work with technology and medical science, researchers began to work on and study the nervous system to understand our basic biology and body function. So that they can assist when problems arise. Researchers are still looking for ways to prevent diseases. The application of EEG in the human brain's central region. For the prior 80 years, EEG has been used by these kinds of researchers. Previously, working with EEG was very expensive; however, in recent years, it has become extremely cheap and flexible for scientific purposes. In addition, its research has shifted from analog to digital recordings. Now that the cost of hardware and sensors for EEG research has been reduced, it is possible to collaborate on a variety of data-related projects. Because the EEG signal interacts with multiple-sensor research, the next wave of discoveries will be in the fields of psychology and behavioral science. Furthermore, epileptic seizures are a broad topic, and we learned about signal processing, machine learning, neural networks with the help of the Python library, and a little bit about.

1.2 Thesis Overview

An epileptic attack is designated as the duration of symptoms due to abnormal or excessive electrochemical activity within the brain; the impacts of which are uncontrolled activities, shaking, movements in either all or any specific organ with inconsistent levels of consciousness, or simply a mental shifting loss of consciousness [1].In most cases, the continuance of attack isn't sixty seconds which is unimportant but it takes a substantial amount of your time to urge back to a common and consistent phase. Because of this seizure, patients can lose bladder control [1]. Consider the figure below -

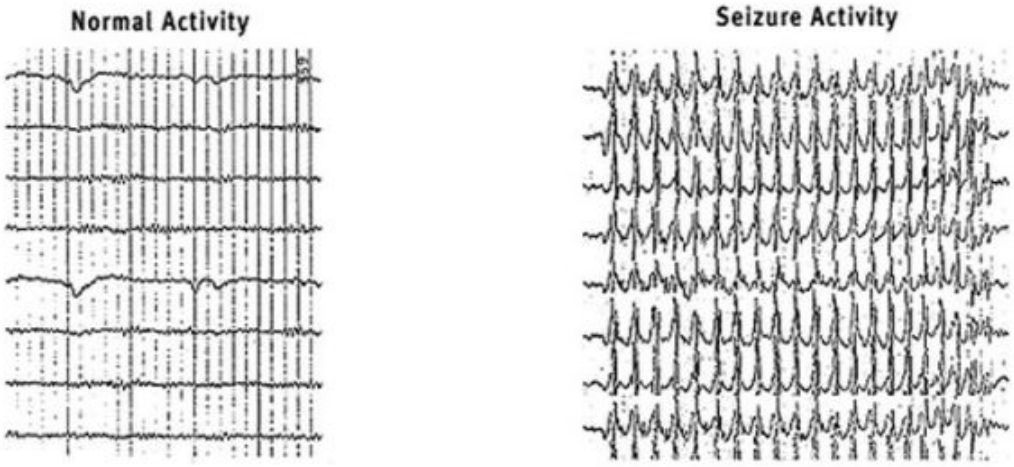

Figure 1.1 : EEG signals of a normal brain and a brain under seizure [43].

There are certainly some behavioral, physical, and physiological activities that provoke an attack. The mainstream reasons are often a touch sleep deprivation. The main sorts of epilepsy are- provoked and unprovoked. The human brain generates electrical signals which can be separated into various frequency bands. In a genuine situation, a man with an epileptic seizure confirms signals unique concerning the typical brain (see Figure 1.1). Within viable signal examination, it can be noticed if the symbols are of the non-seizure or seizure-influenced brain. EEG is an electrophysiological penetrating strategy to preserve the electrical action of the cerebrum. This electrical change alludes to the signs of brain motion. Around 10 percent of individuals have a minimum of one convulsion during a lifetime [1]. Research assumes that stimulated breakdowns occur in about 3.5 per 10,000 people yearly and 4.2 per 10,000 people every year for unprovoked seizures. After one seizure, the probability of experiencing a second is involving around 50-50. Studies also show that about 1 percent of the entire society gets suffering from epilepsy at any provided time and about 4 percent of the population at some point in time [2].

Moreover, almost 80 percent of those with epilepsy are inhabitants of developing countries. On the opposite hand, there are many diseases and factors which may cause epilepsy. Important factors like traumatic brain injuries, central nervous system infections, vessel malady, brain tumors, neurodegenerative diseases, biological process disabilities, perinatal insults, and familial factors are in charge of epilepsy. Many treatment procedures like vagus stimulation and responsive cortical stimulation are usually recommended for epilepsy [3]. Electrical signals of measured amounts are produced by the brain in several sorts of bands namely alpha, gamma, beta, and theta. From various symptoms of brain signals, it is often determined if the person is inside the seizure phase or non-seizure phase. Brain signals are recorded as electroencephalograms(EEG) which is that the movement of the cerebrum measures the voltage fluidity happening due to ionic current flow inside the neuron cells of the brain [4].

The whole process is additionally compared to the BCI(brain-computer interface) system. Although, the neuro-computer combination system features a particular motive and the field of BCI research and development has always focused mainly on neural prosthetic applications that focus on recovering damaged or disabled movement [5].EEG depicts the chronology of the neuron's electrochemical activity over a vast period of your time by electrodes on the scalp. Different activities within the brain are visible in the fluctuation of EEG signals. Thus EEG signals are necessary for predicting the seizure of a patient. Specific patterns of seizure time EEG signals can help to differentiate seizure and normal phases. After considering a particular time frame of EEG signals, feature extractions and classifications are conducted.

1.3 Thesis Orientation

The following parts of the thesis have been created as follows. The 2nd chapter is a review of the literature that highlights relevant work and existing methods based on our proposed approach. Chapter 3 provides an accurate analysis of the background knowledge relevant to our work, as well as the dataset used in this thesis. In Chapter 4, we recommend a strategy for recognizing seizures. The results of the experiments and the related investigations are presented in Chapter 5. Finally, Chapter 6 concludes and evaluates the report.

Chapter 2

Literature Review

Epilepsy is a chronic disorder that causes central nervous system distortion [2]. Because epilepsy has a long-term effect on the brain, this patient may experience recurrent seizure attacks. Repetitive seizures cause disrupted physical symptoms such as hallucination, decreased attention, blinking eyes, sleep deprivation, restlessness, and so on. Epilepsy affects approximately one out of every three people [1]. Electroencephalography (EEG) plays a crucial role in monitoring the brain activity of epileptic patients; however, an expert is needed to research all EEG records to identify epileptic movement [3]. From the study of the electroencephalographic (EEG) recordings, we get the information, valuable insight, and enhanced understanding of the mechanisms that cause epileptic seizures [3]. Poly spike activity identifies epileptic seizures usually [3].In addition, rhythmic waves are used for a wide range of frequencies, and spike-and-wave complexes are used for amplitudes [3]. Considered the time-frequency distribution and extracted several features to detect epilepsy in each section they use a neural network to train the data. The connection between the result and the short-time Fourier transform, which gives $89\% - 100\%$ accuracy [3]. Methods for detecting ictal and interictal states are still evolving, and there are numerous ways to decompose them [4].
In [9], the creators utilized Bolster Vector Machine as a classifier to analyze the preictal and attack states of EEG signals. The creators have used delivered univariate linear choices harming the window estimate of seconds in their equation. Inside the moment step, preprocessing is finished, and at last a decision was arrived on encephalogram signal, following required regularization. Three encephalogram channels are selected by embedding cathodes on the patient's scalp that specializes in seizure, though the 3 electrodes are arranged exterior the condemned surface. The information of the nonheritable encephalogram signals is born-again into fragments of an overlapping window having the strengths of five seconds. Once changing this data to the 5- second fragments, the Butterworth channel [10] was usual to cut back the noise impact. The authors in [9] delivered the essential four related math minutes as options.
To analyze the signals, there are changed methods. Machine learning innovation is one of them. There is such a large sum of approaches to machine learning. Among the first regularly utilized them are SVM(Support vector machine) and ANNs(Artificial neural systems). ANNs have broadly been connected to classify graph and chart signals over the final 20 a long time. a spread of different ANN fundamentally based approaches were concurring to the writing for writhing detection [11]. Neu-

ral organize put along plans are upheld building models of epileptic and normal maps and after that utilizing these models to modify graphs as either epileptic or normal. Models are collected hooked into alternatives extracted from a arrangement enlightening combination. Alternatives unit was chosen with the goal that they capture the contrasts within the epileptic and typical chart.
Thus, a genuine time expectation framework is horrendously precious for the clinicians in appreciation to the patients. The framework is planning to be prepared to anticipate or locate halfway encephalopathy assaults in arrange that preventive measures are taken by the patients or caretakers. Unique procedures are utilized for expectation and position of seizures in writing which joins direct and nonlinear procedures. The fast Fourier rebuild was utilized since the antiquated procedure requires a graphical record time-space flag in recurrence space. FFT could be a non-parametric method for analyzing graphical record range. The non-linear design of graphical record signals, coordinate application of FFT is inappropriate [12]. In any case, for brief sections of At times, graphical record signals are frequently thought about as stationary signals. The riffle repairs up to a few degrees overcome the weaknesses of Fourier rebuild by declining flag into totally distinguishing resolutions and scale levels [13].
For classifications, the least square support vector machine is used; as a result, it demonstrated higher classification accuracy, sensitivity, and specificity with greater consistency across a large number of brain locations [2]. An algorithm for machine learning detects seizure onset by analyzing brain activity and comparing it to various physiological signals [3]. This algorithm detects 93% of 163 test seizures from 23 patients with the help of median detection delay of 3 seconds [2]. Median false detection rate in this algorithm was 2 per 24-hour period [2].For dissecting the presentation of the typical fluctuation-based strategy with nonlinear measurement examination, entropies, calculated relapse, discrete wavelet change, and time-recurrence circulations [2]. This interaction delivered an ideal outcome [2]. To identify epileptic seizures, a crude EEG signal-based convolutional neural network (CNN) was utilized as opposed to separating manual highlights to separate ictal, preictal, and interictal fragments [5]. Correlation time and recurrence signal recurrence area signals inside the Freiburg information base, in the wake of executing the three trials normal correctnesses was 96.7%, 95.4%, and 92.3% were gotten [5]. The ordinary recognition correctnesses inside the CHB-MIT data set[32] were 95.6%, 97.5%, and 93% inside the three tests [5]. At the point when time-area signals from the Freiburg data set were utilized, the average exactnesses were 91.1%, 83.8%, and 85.1% percent inside the three tests. in contrast10 The location exactnesses inside the CHB-MIT data set, on the opposite hand, were just 59.5%, 62.3%, and the three experiments, the regular was 47.9%. Based on these discoveries, every one of the three cases is prepared to do effectively recognizing recurrence area signals [5]. Electroencephalographic (EEG) recognition has been hindered by blocking from explicit terminals, which might be taken out using various procedures like beamforming, proper sheilding etc [8]. Spatial shifting techniques are being grown to supply a more precise diagnosis. Techniques supported Beamforming are used for this reason because of their ability to oblige the passing electrical action from a planned area while lessening the movement to others [8]. Proper shielding is also one of the most popular ways to reduce noise in EEG data. The issue was utilizing waveform assessment, and along these lines,

the sign was separated from the deliberate EEG signal utilizing data about plentifulness and recurrence [7]. On the off chance that the sign began from an epileptogenic focus, it's feasible to remake the predetermined signal. Then it'll feature abnormalities, which can later guide in precise determination [7]. Simulations and results are introduced while exhibiting the presence of a few calculations with simple math [7]. These strategies are applied to true information. It is important to comprehend the situation of the source to remake the sign of revenue [7].DOA assessment techniques, as an alternate, are explored for assessing the situation of the sources. In the fundamental case, there's a drag with the goal of sources once they are very approximate [7]. Electroencephalogram (EEG) is frequently viably characterized by employing a mind PC interface [6].
The comparison of different feature extraction techniques, such as wavelet transform, autonomous component analysis, principal element analysis, autoregressive model, and experimental mode decomposition, focuses essentially on feature extraction techniques [6]. These features are used to distinguish between properties and significant measurements, and they are derived from various patterns [6]. EEG signals can effectively identify brain stimulation, which is why brain-computer interfaces are widely used [6].

Chapter 3

Background Analysis

Epilepsy is a broad topic in medical science, and it can be caused by a variety of factors. Before we get into our detection methods and results, it's important to understand some of the major aspects of this disease. Notably, the studies focused on the brain, epilepsy, and its history, causes, various signals, and classifier methods for detecting signals. All of these studies aided us in developing our methods for achieving the desired results. We will demonstrate the essence of our learning in this section.

3.1 Anatomy of Brain

If we look into our human body, we can see the foremost vital portion which commands the apprehensive structure is the human brain. The brain comprises of a huge mass of nerve tissue that's secured inside the skull. For the neurological organs and direction to the muscles, our brain is the way to get the signals and make choices by sending guidelines to the body. Our brain is in charge of the majority including its cell's work chain, such as with data processing, coordination, as well as direction from our sensory systems [8]. Moreover, the brain can handle each tangible data to the body, controls body weight and breathing, releases hormones. A few capacities for example control our understanding of any particular circumstance, speech, working our limbs, and encapsulates the substance of the intellect and soul.

Our human brain has three important parts which are cerebrum, cerebellum, and brain stem (See Figure 3.1).

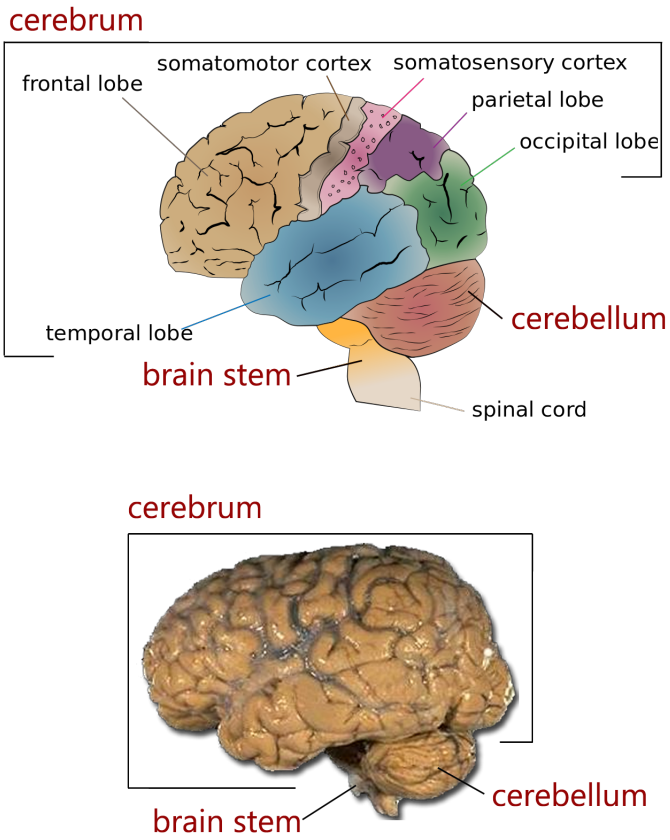

Figure 3.1 : The three major regions of brain [42].

Our brain consists of five senses such as sight, touch, taste, smell, and hearing. Through this five senses our brain can get information. It assembles all messages in such a way that it is important to us that we are able to store data in our memory. The Central Nervous System(CNS) is built up of the brain and the spinal cord. Furthermore, The Peripheral Nervous System (PNS) is built up of nerves that originate from the spinal cord as well as cranial nerves.

3.1.1 Cerebrum cortex

We know the cerebrum is the front portion of the brain which is the biggest portion of the brain The corpus callosum is a bridge that connects the right and left hemispheres of the brain. Here two hemispheres are divided by interhemispheric gap which is additionally known as longitudinal gap [9]. Each side of the equator is isolated into a wide zone known as lobes. Each and every lobe has diverse functionalities. Details of cerebrum is shown in figure 3.2.

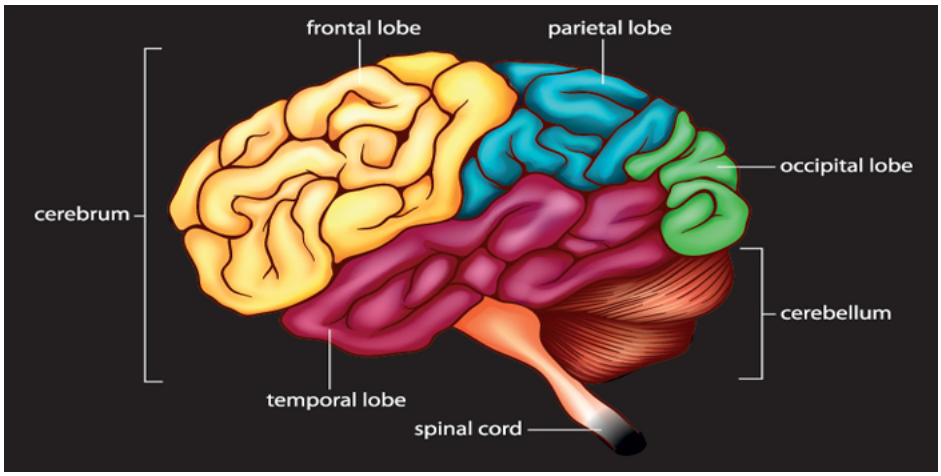

Figure 3.2 : Cerebrum Cortex of Human Brain [40].

Frontal Lobes: Figure 3.3 shows the frontal lobe of a human brain. It is the biggest among all the lobes. Frontal lobe is isolated from the parietal lobe through space which is known as the central sulcus and from the worldly flap through latera sulcus. They are found within the front portion of the brain. These lobes offer assistance the brain to arrange high-level behaviors for example controlling enthusiastic, organizing, logical considering, understanding issues and issues. It moreover arranges body reactions, talking, composing. There's no other portion of the brain where seizures can cause such a wide variety of indications.

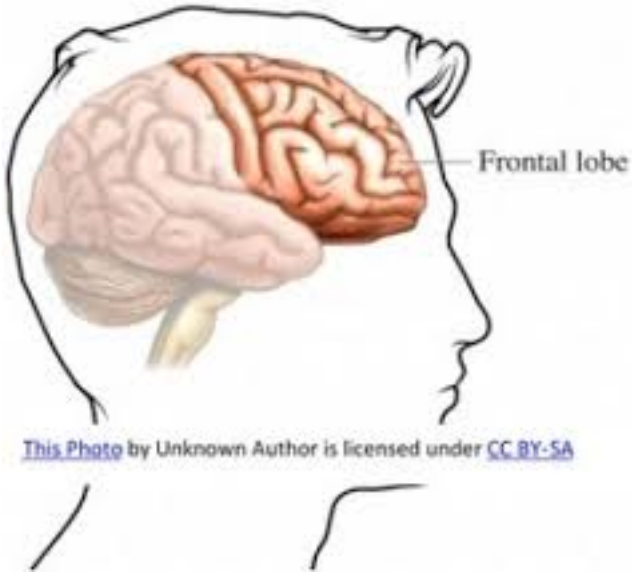

Figure 3.3 : Frontal lobes.

Since the frontal flap is huge and has numerous imperative capacities, frontal lobe seizures may deliver numerous bizarre side effects that can mixed up for other occasions such as a rest disorder, conduct or a psychiatric issue. Frontal lobe seizures regularly happen amid rest and may highlight bike accelerating movements and pelvic pushing. A few individuals shout obscenities or laugh amid frontal lobe seizures [10].

Parietal Lobes: Parietal lobes are within the back of frontal lobes and isolated through the central sulcus. These lobes are in charge of harmonizing tangible data

such as- touch, temperature, weight, pain. Moreover, it can translate words, languages, distinctive signals through eyes, ears, engine, and memory. Fundamentally included in handling "touch," "muscle," and "joint" data from the body and combining it with "vision," "hearing," and "balance" to provide you a wealthy "multimedia" understanding of your 'corporeal' self and the world around it [11].

Temporal Lobes: Brief lobes are at the same level as the ears and found on the side of the head. These lobes synchronize signals from hearing, memory, do arrangements, and offer assistance us to get it a diverse language. It contains the hippocampus which is as well imperative to memorize, learn, and understanding feelings. It is specialized for higher perceptual capacities, such as recognizing faces and other objects and connecting them to fitting "feelings." They do this in near participation with the "amygdala," which lies within the front 'poles' of the worldly lobes. Handle sound-related input from the ears. Have critical phonetic and passionate capacities, and take an interest in high-level vision [12].

Occipital lobes: The essential visual cortex gets visual points of interest from the eyes which are handed-off to a few visual representation regions that can illustrate points of interest from seen objects, remove, profundity, and so on. As the occipital flap is one of the most visual preparing centers within the brain. It is found within the back of the brain. Dependable for "recognition" of visual data. Neurons within the occipital lobes are organized in columns. In located individuals, send visual data to the parietal lobes [12].

3.1.2 Cerebellum

In Latin, the cerebellum is called 'little brain' and it is an important structure of the hindbrain. The cerebrum is the greatest portion of the human brain and it is alluded to in intellectual capacities for illustration memory, consideration, mindfulness, thought, dialect and consciousness. These are the things that basically make all of our recognition of senses and it directs and commands and it tells our muscles to move. The cerebrum processes tangible data and engine data. In people, there are five distributions of the brain where the cerebrum is most gigantic and best-developed among them [13]. It is almost 10% of the whole weight of the brain but it holds all neurons, obscure cells that can exchange data through different electrical signals. The cerebellum is found next to the brainstem and within the back parcel of the cranium. Moreover, it is found howl the sides of the equator of the cerebral cortex. The cerebellum of a human brain is shown in figure 3.4.

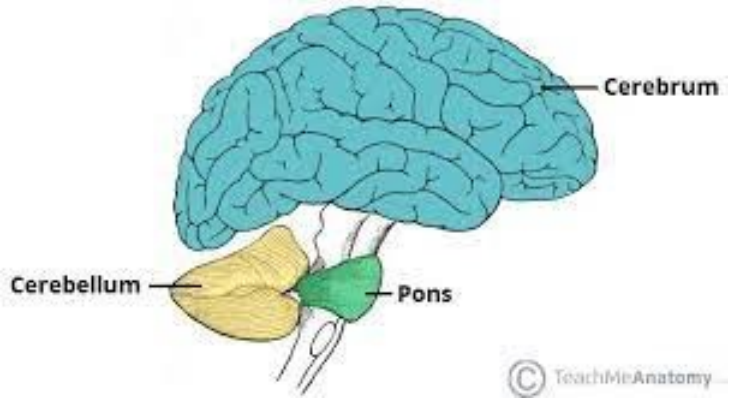

Figure 3.4 : The Cerebellum [41].

Two major parts of the cerebellum are described below.

Cerebellar cortex: In this portion brain contains tissues that are collapsed with most of the cerebellum's neurons. The cerebellar cortex shows up exceptionally diverse from the cerebral cortex in that it comprises of little leaf like laminae called folia The cerebral cortex is split into four sections, each of which corresponds to one of the four lobes of the human brain [14].

Cerebellar nuclei: It is one of the foremost deepest parts of the cerebellum that contains nerve cells. Nerve cells are competent of transmitting all sorts of communication data. The cerebellum has four cerebellar cores inserted within the white matter in its center. From horizontal to average, the four profound cerebellar cores are the dentate, emboliform, globose, and fastigial. Purkinje cells in the cerebellar cortex provide inhibition input, whereas growing optic with ascending optic pathways provide excitation input.In addition, these cores are the origin of the majority of the cerebellum's output filaments. One special case is that filaments from the flocculonodular lobe neural connection specifically on vestibular cores without to begin with passing through the profound cerebellar nuclei [15].

Brainstem: It is the smallest portion of the brain and it connects the brain to the spinal cord. The medulla oblongata, pons, as well as the midbrain make up the brainstem, which is found at the base of the vertebrate brain.The brainstem regulates and controls vital physiological functions such as breathing, pulse rate, and blood pressure.The cranial nerves provide the highest power and obvious transmission to the face and neck [16]. Numerous of the cranial nerve sets come out of the brain stem. For this reason, it is capable for numerous crucial autonomic functions as well as the sensations and developments in our face and head [17]. We can find three parts of brain stem such the midbrain (mesencephalon), the pons (metencephalon), and the medulla oblongata (myelencephalon). It is given in figure 3.5.

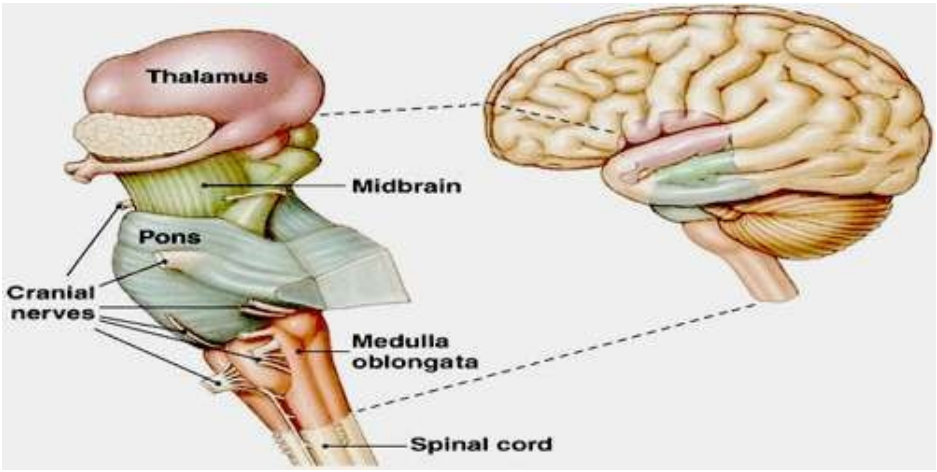

Figure 3.5 Brain stem of the Human brain [42].

Medulla Oblongata: The medulla oblongata which is additionally known as myelencephalon is expressed within the lower half of the brain stem. Its upper portion is associated with the pons. It controls heart rate, weight, breathing because it comprises of the cardiac, respiratory, heaving, vasomotor centers [18].

The Midbrain: Midbrain associated with pons, cerebrum with the forebrain. Here length is found 2cm.Midbrain consists of quadrieminal plate and this plate comprises of predominant and second rate colliculi, cerebral peduncles and this isolated through cerebral and tegmentum. It is also called as mesencephalon and mid brain associates such as- vision, hearing, controlling motors, sleeping cycles, temperature controls.

Pons: From Latin language pons is called "bridge" and it is over the medulla underneath the midbrain and in front of the cerebellum. Pons conducts signals and carries the tangible flag since of the white matter interior it. It is around 2.5 cm in length and comprises of two stalks named cerebellar peduncles. It directs signals from the forebrain to the cerebellum such as- expressions, taste, developments, hearing.

3.1.3 Other Internal structure in the brain

The brain has diverse pathways named white matter tracts that interface the cortex to each portion of the brain. Messages and signals travel to diverse lobs, gyrus, one side another, additionally all other inner structures of the brain.

The Thalamus: The thalamus means in Greek is "inner chamber" is the biggest structure from the embryonic diencephalon. It has midline symmetrical inside the brain, found between the cerebral cortex and midbrain. It is divided into four sections such as- the hypothalamus, epitheliums, ventral thalamus, and the dorsal

thalamus. They are 3cm long, 2,5 cm wide and 2 cm in tall by and large. It acts as an exchange center for both engine and tangible parts of the body and these signals send to the cerebral cortex. It directs things like rest, sharpness, awareness.

The Hypothalamus: The hypothalamus is known in Greek which suggests "under chamber" and its going through the entrance between the nervous system and endocrine framework. The foremost vital work of the hypothalamus is to connect the nervous framework and endocrine framework over the pituitary organ. It insider facts different sorts of neurohormones to discharge hormones from pituitary organs. It can control the autonomic frameworks of the brain and plays an enormous part in control behaviors like thirst, starvation, intake of food and water, rest, and cautious behavior.

The Pituitary Gland: The pituitary organ is called as the "master gland" of hormones and it looks a pea-sized organ. It comprises of three lobes named front, middle, and back It is capable for so numerous forms, faculties the body's needs at that point send those signals to those organs so that they can control their work. It makes a difference the body to advance bone, muscle development, react to push by emitting hormones.

The Pineal Gland: The pineal organ is found within the back of the third ventricle. It is capable for creating melanin that makes a difference balance the inside clock of the body, rest designs, neurotraumatic generation, support of circadian beat. The Limbic framework: In Latin limbus means "edge" it is capable for exercises held since of the hypothalamus and the cerebrum. The limbic framework moreover has the meaning "circle of papas'. It has been accepted as the most center of the limbic framework to think approximately bolstering, overlooking, battling, family, having sex. This framework is isolated into cortical and subcortical components.

The Basal Ganglia: The basal ganglia which are moreover called as basal nuclei are comprises of a gather of subcortical structures that can found within the white matter of the brain. It may be a portion of the extrapyramidal engine framework that works with the pyramidal and limbic framework. It can send messages to thalamus at that point the thalamus handle and alter the signals. It directs developments of eyes, memory, inspiration.

3.2 Electroencephalography signal

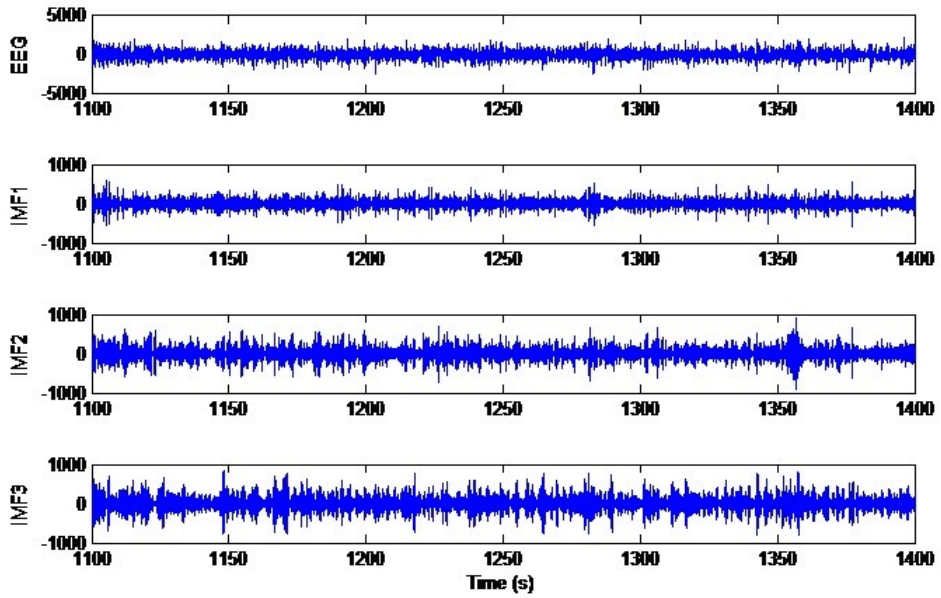

Figure 3.6 : EEG Signals [43].

Figure 3.6 shows an Electroencephalogram(EEG). EEG may be a process of distinguishing voltage change or swaying on brain, which carries the graphical record of electrical action by putting anodes totally different areas on scalp. In this specific setting the most forecast is to pinpoint the brain signals which have variations from the norm and can be recognized as seizure. Our brain shapes how we see our environment, giving the foremost relevant data; our brain captures objects based on that. Human comportment or behavior works based in that put away data. Brain organized with a combination of billions of cells, where half of those are neurons; half of those speed up the deportment of neurons. These neurons are thickly journalist by means of neural connections, which act as portals of inhibitory or excitatory movement [19]. In terms of neurophysiology; neuronal occasion such as swaying or reaction stimulate by tangible invigoration is fundamentally the relative commitment of excitatory and restriction synaptic inputs. An able electrical affectation produced by any synaptic movement is considered as a postsynaptic potential. Emission of a single neuron is troublesome to erase without coordinate contact with it. An electrical field is produced wherever thousands of neurons coincide which is solid sufficient to spread through bones, tissues and skull. Eventually in brain surface this variety can be measured. Considering a resonation of seismic tremor, a single burst could be little to notice in any case, some of diligent beat within the same area at the same time can make a recognizable affect indeed hundreds of kilometers absent.

3.2.1 Brain Waves

Electrical beats within the fundamental cerebrum framework that have monotonous cycles or patterns is called “Brain Waves” [20]. These neural motions dependable

for neural transmission are measured in Hertz [21]. Figure 3.7 shows different kind of brain waves in different states.

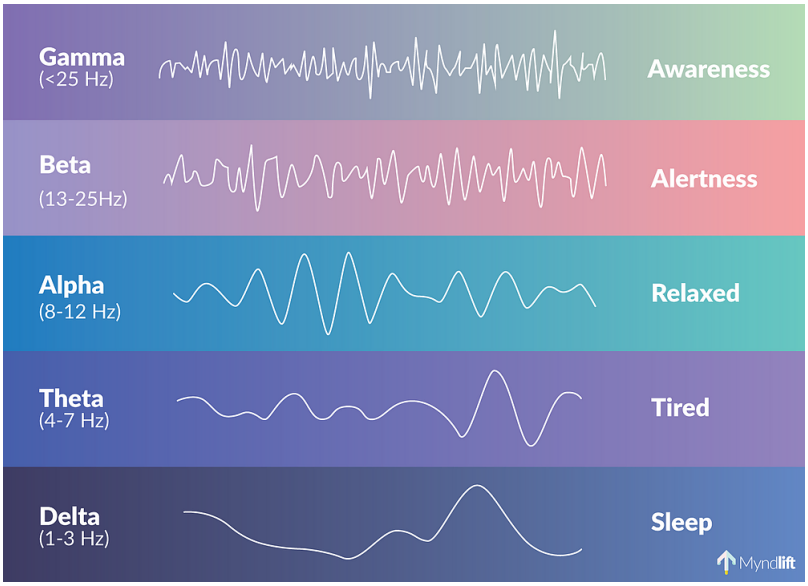

Figure 3.7 : The Brain-Waves of Different Frequency [44].

The brain controls each feeling, behavior, and communicate with other neurons. Brain waves are the result of diverse sorts of synchronized electrical beats and these are identified by setting a sensor on the scalp. These brain waves are isolated into six parts agreeing to their transmission capacities, capacities, ceaseless range of awareness. Brainwaves appear us the refection of the diverse occurrences, diverse areas. Additionally, brain waves alter agreeing to every day sentiments such as- attempted, moderate, tall, short, energized, irate, shock, hyper appear distinctive waves in a distinctive recurrence. EEG signals identify the frequencies of the delta, theta, alpha, beta waves.

Infra-low Waves: Brainwaves Infra moo waves have frequencies that are less than 0.5 Hz. They play major part in brain timing and neural organize work

Delta Waves: Delta Brainwaves Moderate, boisterous brainwaves with a recurrence measurement of 4Hz or below [22]. It is truly normal as the overpowering disposition in modern children up to one year and also during the third and fourth stages of rest. It can happen in two ways: centrally with sub-cortical bruising and dispersal with widespread injuries, metabolic encephalitic hydrocephalus, or major mid-line injuries.

Gamma Waves: Gamma brainwaves are the quickest of the brain waves, with

the most astounding frequency sufficiency and recognition of continuous taking care of information from different parts of the brain. Since the most cloud of the brainwave frequencies, gamma brainwaves transfer info quickly and unpretentiously [23].

Alpha Waves: Alpha contains a frequency some place within the extend of eight to thirteen Hz [24]. It is most commonly present in the rear portions of the head on either side, with more availability on the dominant side. It frequently emerges when shutting the eyes and loosening up, and then disappears upon opening the eyelids or being disturbed by any device [24]. It is a notable beat discovered in regular freed up grown-ups as this wave makes a difference for the most part talking mental coordination, tranquility, preparation, mind and body combination and learning.

Beta Waves: Beta brainwaves thirteen to thirty-eight are little, speedier brainwaves related with a state of mental, mental movement and apparently centered concentration. This is often essentially state of sharpness [25]. Beta waves is by and expansive seen as an ordinary beat and the overpowering patients that are very cautious, tense, or have their eyes open have a higher rhythm.

Theta Waves: We found the frequency as 4 to 8 Hz which is knows as theta and is assigned direct movement [24]. Theta exquisitely ordinary in children age of 1 to 13 years and in rest but thought to be abnormal in attentive seniors. In terms of theta, we consider to be exceedingly daydream, clear symbolism, insight and data past our normal cognizant attentiveness.

3.2.2 The 10-20 System

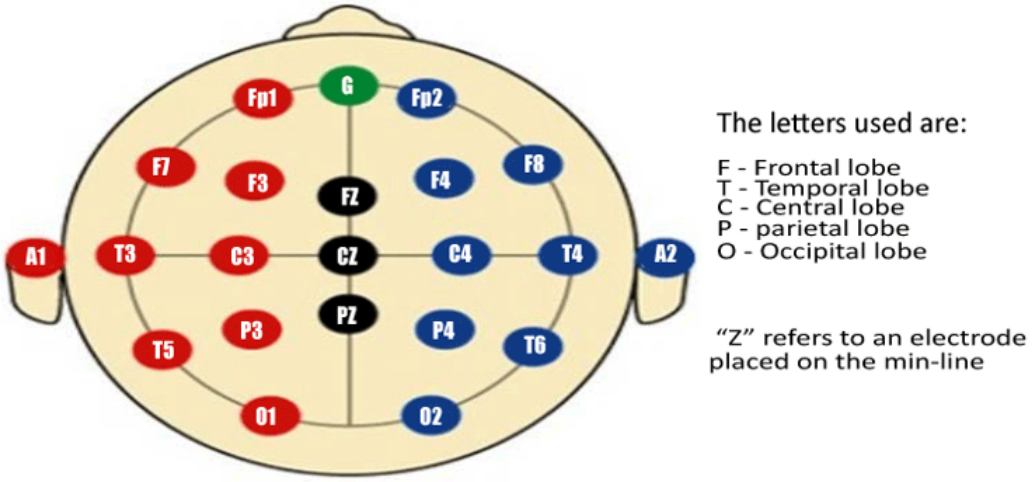

Figure 3.8 : 10-20 Method electrode placing [45].

Figure 3.8 shows the international 10-20 method of electrode placement. To form reliable setups, there are standardized sets of locations for cathodes on the skull. Here, ten-twenty Framework of Terminal Situation may be a strategy utilized to portray the area of brain terminals. Again these brain terminals are utilized to save the electroencephalogram and employing a machine known as (EEG). The EEG could be a database of activity in the brain. Thousands of neurons in the brain worked together to create this data The actual details changes depending on how excited an individual is. When a person is rested, the EEG contains many smooth waves; when a person is excited, the EEG contains many quick waves It is utilized to track brain activity for a multitude of reasons, such as sleep disorders and providing assistance of the brain diagonals like as an epileptic seizure.

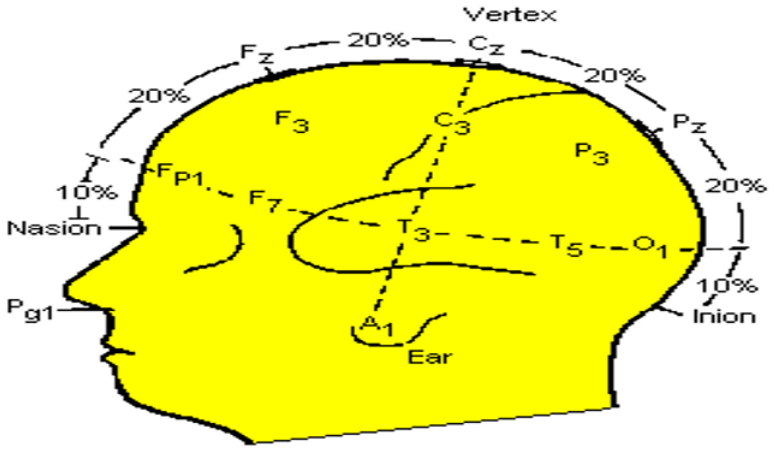

Figure 3.9 : 10 and 20 allude to the 10% or 20% distance [46].

The 10-20 system relies on the link between the position of an electrode and the surrounding area of the frontal lobe. Each spot on this diagram on the left represents a potential electrode site. Also every location does have a sign to recognize the hemisphere as well as a number or any character to recognize the part of the globe Moreover, in this figure we have used character F for Frontal lobe, C for central lobe, P for parietal lobe and T for Temporal lobe. The right hemisphere is represented mostly by digits (2,4,6 and 8) whereas the left is represented by digits (1,3,5 and 7). Again letter Z alludes to a terminal that is put in the middle of the diagram [26].

3.3 Artifacts

Human brain operates continuously and millions of cells exchange biochemical elements among themselves where a small amount of electrical activity is produced during the communication between each neuron. Unfortunately, a single electrical signal generated from one to one neuron communication, cannot be recorded but measurable electric field is created through synchronization of millions of neurons. The electric field is appraised from the scalp passed on through hair, bone and tissue before it is recorded [63]. These recordings of brain activities from different parts of brain are EEG signals. But EEG can be infected by various external

undesirable noise signals, defined as 'Artifacts'. These recorded signals are non-cerebral in origin. Artifacts are any portion of an EEG signal which is not generated from human brain activity and can emulate almost every type of EEG patterns. As a result, significant amount of artifacts lead to wrong interpretation and inappropriate analysis of EEG. Failure to recognize and precisely identify artifacts hampers detection of seizure from EEG signals. So, throughout the recording, a technologist should sharply monitor the patient and the record to ensure notations are made whenever potential artifacts occur. Only technologist can make a positive identification although artifacts are often validated by their characteristic morphology and arrangement. However, we can reduce artifacts by following felicitous signal recording procedures and by designing the system carefully. Artifacts are classified into physiological or non-physiological (technical) artifacts depending upon their source of origin. Physiological artifacts can make an appearance because of different body activities such as movement of the head, body or scalp which influence the electrode scalp interface; or moving body sources like eye, tongue, pharyngeal muscle, heart and sweat glands which generates bioelectrical potentials; or changes in the conductance of tissues (scalp, bone, muscle) and fluids (CSF, blood) between the cerebral cortex and recorded electrodes results in altered volume conduction [46]. Non-physiological artifacts principally appear from two types of sources. Firstly, power sources such as power lines or electrical equipment generate external electrical interface. Secondly, recording electrodes (electrode integrity, positioning and application), pen motors, paper drive, amplifiers, cables or the filters give birth to internal electrical malfunctioning of the recording system.

3.3.1 Physiological artifacts

EEG signals become vague because of physiological artifacts originated from electrical activities from different body parts (except brain) of a subject. There are some physiological artifacts like-

Ocular artifacts: We can electrically model an eye as a magnetic dipole and its movement disfigures the electric field in the area which is known as EOG (Electrooculogram). A movement of the eyes and eyeballs causes a change of potential in the electrodes near the eyes. ERG (Electroretinogram) is a potential difference between retina and cornea of the eye which changes with light, creating artifacts in EEG signals [49]. Voltage adequacy is corresponding to the angle of contemplate. Eye blinks produce high volume of signals that can be numerous times more prominent than the sufficiency of EEG signals of interest.

Muscle Artifacts: Generally show up in the front facing and temporal electrode. Bite/swallow tongue development; gulping, frowning and biting are grouped into muscle artifacts, saw in surface anode in EEG. Shape relies upon the level of muscle compression: powerless compression give a low-amplitude spike train. This

happens less in sleep and cover with beta band (15-30Hz) [64]. It generally show up in the front facing and temporal electrode.

Cardiac artifact: The heart manufactures two kinds of artifacts; electrical artifact shows up as ECG waveform recorded from scalp and structures the QRS complex. A large portion of the heart antique frequencies are close to 1Hz and amplitude is in a few millivolts [49]. The mechanical electrical artifacts which show up as ECG signal close to temporal left location and are most ordinarily found in short neck subjects.

3.3.2 External Artifacts

Surrounding electronic devices, transmission lines are the origin of these artifacts.

Transmission line artifact: Since the transfer speed of EEG signal is 0.5Hz-60Hz and the recurrence of transmission lines is 50Hz or 60Hz [50], the signal effectively blends in with beta band of EEG signal. As a result, it influences all channels or channels with helpless impedance coordinating. This artifact can undoubtedly eliminate by utilizing a notch filter of recurrence range 50 Hz or 60 Hz.

Electrode artifact: Artifacts emerging from electrodes, anode terminal board, input link and selector switches. Most artifacts in this class are recognized by at least one of the accompanying qualities: (1) differ fundamentally from recently recorded action; (2) they don't mix with other recorded movement at the same time or (3) they show up just in channels associated with one electrode. Electrode pop artifact is one of these which show up as forcefully molded transients that interfere with the foundation movement and might be misjudged as tumor [55]. Another one is lead movement artifact and has a more disordered morphology that doesn't look like real EEG movement in any structure and frequently incorporates double phase reversal, that is, phase reversals without the uniformity in polarity that shows a cerebrally created electrical field.

Phone artifact: Cell phone signals are directly responsible for noise in EEG signals. A high recurrence signal shows up as a false signal on the EEG signals. Solution for this artifact isn't to convey a versatile telephone while recording.

Physical movement artifact: Movements of the head and body or of the electrode wires can cause artifacts even if all electrodes make good mechanical and electrical contact. Some movement artifacts can be identified by their rhythmical appearance as, for example, tremor, chewing, sucking, breathing or pulsatile head movement artifacts (cardioballistographic artifact).

Movement artifacts are usually easily recognized during the recording by their association with visible movements and they should be identified by the technologist with notations directly on the recording [56]. Many movement artifacts can be abolished by simply asking the subject to stop moving. In persons who cannot comply (restless or confused patients, infants, patients with movement disorders), a technically adequate recording may not be possible.
Difficulty for the electroencephalographer occurs when the technologist fails to document the occurrence of movements producing artifacts. Unfortunately, asking the technologist to try to recall if specific waveforms were associated with body movements is usually a useless exercise (which nevertheless should be undertaken if only to instruct the technologist in the identification of artifact). In addition to carefully observing the patient and the recording, and making frequent notations regarding movements, the technologist should identify and monitor movements by placing EEG electrodes or other devices (needle electrodes, accelerometers) directly on the path of the body that is moving [56]. In addition, the ECG channel often serves as an effective monitor for detecting gross body movements.

Pulse artifact: Periodic waves of sinusoidal or triangular shape may be picked up by an electrode on or near a scalp artery as the result of pulse waves producing slight change of the electrical contact between electrode and scalp with each dilation and contraction of the artery. This is somewhat more likely to happen with electrodes in the frontal and temporal areas than with electrodes in the central or posterior head regions. Pulse artifact is easily recognized when it appears in a sustained periodic fashion. Unfortunately, it is more often intermittent and somewhat irregular in appearance and maybe difficult to identify. Changing head position, varying blood pressure, and changes in cardiac output throughout each respiratory cycle can all cause the purse artifact morphology to vary from one waveform to the next. Pulse artifact can usually be identified by decreasing the cutoff frequency of the low frequency filter and simultaneously recording the ECG. If it is eliminated by reapplication of the electrode at some distance from the pulsating artery, the new electrode position should precisely indicate on the chart.

Perspiration artifact: Perspiration artifact displayed as low amplitude, expanding waves that commonly have terms more noteworthy than 2 sec; along these lines, they are past the frequency scope of cerebrally created EEG.

3.4 Epileptic seizure:

"Epilepsy" is the condition of intermittent unprovoked seizures. Unnecessary and hyper synchronous discloser of neurons in the brain causes paroxysmal change in neurological capacity which is called a "seizure". The "epileptic seizure" is used to identify a seizure caused by a strange neuronal termination from a non-epileptic cause, such as a psychogenic seizure. Epilepsy has multiple causes, each of which reflects an underlying brain dysfunction [27]. A seizure caused by a redeemable

affront (e.g. fever, hypoglycemia) does not represent epilepsy as it is a fleeting secondary condition and not a permanent condition. "Epilepsy Syndrome" alludes to a collection of clinical features that reliably occur along with comparable seizure types, onset, EEG findings, triggers, hereditary characteristics, characteristic history, prognosis, and response to anti-epileptic drugs (FAE). The International League Against Epilepsy (ILAE) states that a person is considered to have epilepsy if one of the accompanying conditions is met: (1) In both cases, two unjustified or reflex seizures that occur less than 24 hours apart, (2) An reflex or unjustifiable seizure and also a likelihood of further seizures such as an overall risk of not less than 60% and two undeserved seizures within the next 10 years, (3) the diagnosis of epilepsy syndrome [28]. Therefore, depending on the etiology and electrical clinical syndrome, it is possible to be diagnosed after a seizure. The clinical signs and manifestations of epileptic seizures depend on the area of epileptic discharge in the cerebral cortex and the scope and nature of the distribution of epileptic secretions in the brain. The most important factor in seizures is their stereotypes. Epilepsy is viewed as settled for people who have an age-subordinate epilepsy disorder yet are currently past the appropriate age or the individuals who have remained seizure free throughout the previous 10 years with no seizure medications throughout the previous 5 years. As indicated, epilepsy is currently called an illness as opposed to an issue, like other heterogeneous problems such as cancer and coronary illness, which are likewise termed diseases to pass on the earnestness of the condition to lay crowds.

3.4.1 Reasons of epilepsy

Sometimes, it is difficult to pinpoint what triggers epilepsy. Indeed, the reason for epilepsy is obscure in 6 out of each 10 individuals [38]. However, there are a few risk factors that can prompt the improvement of epilepsy, going from age and family ancestry to wounds and contaminations. The most common causes include:

Genetic influence: Certain categories of epilepsy can be inherited , depending on the category of the seizure in the patient or the area of the brain which is affected. All in all, there are genetic effects in these situations. However, experts associate certain types of epilepsy with open genes in many people. Genes are the carriers of epilepsy in genetic inheritance . Specific genes can turn people vulnerable to the natural conditions causing seizures.

Head trauma: People with vehicle accident or any head injury records, have higher tendency of epilepsy.

Brain conditions: One of the major causes of epilepsy amongst adults older than 35 years is stroke. Likewise brain tumors or other kinds of any brain damage can lead to epilepsy.

Infectious diseases: Infectious diseases can be a reason behind epilepsy. For example Meningitis, viral encephalitis, AIDS can trigger epilepsy amongst the patients.

Prenatal injury: Sometimes babies can face brain damage before birth. Such brain damage can be caused by various reasons such as poor diet of mother, her infections , hypoxia, etc. Epilepsy or cerebral palsy is caused by this kind of brain damages.

Development disorders: Sometimes, formation problems such as chemical autism and neurofibromatosis are underlying reasons for epilepsy. Although some extremely common factors can trigger epilepsy, most of them are unknown and varies from person to person. It is a good exercise to keep track of seizure triggers which helps to recognize time of seizure and hence anyone can prepare accordingly. The most common seizure triggers include:
i. Missed medication: People often forget or avoid medication for significant time period which leads to unpredicted seizures. Lack of medication can make seizures more frequent or more intense than usual. In addition, long-term seizures, so-called status epilepticus [47], may occur, and if the seizures persist, there may be a life-threatening medical emergency.
ii. Lack of sleep: Regrettably, sleep and epilepsy form a venomous circle. Epilepsy can disrupt sleep but insufficient sleep can make seizures worse. Hormonal and electrical activity of our brain changes during sleep, which works as seizure trigger. Because of this, some people experience seizures while asleep. Some people with epilepsy develop a disease called sleep apnea [47], which further affects sleep. In addition, some epilepsy drugs can cause side effects such as insomnia.
iii. Stress: Our body's response to a challenge or request is termed as stress. Any event or thought which makes us feel frustrated, angry, or nervous triggers stress. Stress brings seizures in epilepsy patients. Hyperventilate (rapid and deep breathing) is a condition developed while in stress causes abnormal brain activity and seizures.
iv. Alcohol: People affected with seizures cannot have more than 1 to 2 standard drinks (12 ounces of beer with 5% alcohol, 5 ounces of wine with 12% alcohol, 1.5 ounces of distilled spirits with 40% alcohol [48]). Otherwise, seizures are more likely to occur, and seizures may occur when alcohol leaves the body. It is not recommended to be alone after drinking, because seizures may occur within 6-72 hours.
v. Menstruation: During the monthly menstrual cycle, most adult women with epilepsy experience an imbalance of key sex hormones (progesterone and estrogen), which greatly increases the chance of seizures. Although progesterone can actually prevent seizures, estrogen can cause or aggravate seizures.
vi. Fever: Some common diseases like colds and flu, headaches, fever, dehydration or illness-related physical stress can all cause seizures. Medication of these diseases can also trigger seizures.

3.4.2 Different kinds of Seizures

The grouping of seizures helps doctors diagnose epilepsy in patients. According to the type of behavior and brain activity, seizures are divided into two categories: focal (partial) and generalized (local). Some of the seizure types are discussed below.

Focal (partial) seizures: Patients with focal seizures hallucinate as they claim to see, hear or feel things that aren't real. These types of seizures occur in one region or group of cells in a particular side of the brain. Some symptoms of focal seizures may be mistaken for signs of mental illness or other types of neurological diseases. Approximately 60% of people with epilepsy have these seizures. There are two kinds of focal seizures including:

i. Focal onset aware seizures: During a state of awareness and consciousness, if a person counters seizure then it is called focal aware seizure or simple partial seizure.

ii. Focal onset impaired awareness: This type of seizure is also called complex partial seizure which makes a person confused or somehow awareness gets affected.

Generalized seizures: Unlike partial seizures, generalized seizures affect nerve cells on both sides of the brain. The most common symptoms of this attack are muscle cramps, fainting, or fall. Injuries and accidents such as tongue bite and urinary incontinence may occur during generalized seizures (also known as grand-mal seizures). Cognitive deficits are accompanied by general body tension (the so-called "tonic" seizure phase) for 30-60 seconds, and then sudden convulsions ("clonic" phase) for 30-60 seconds, after which the patient enters a deep rest. Six types of generalized seizures [57] include:

i. Absence seizures: Absence seizures are gradual activity that can cause unconscious seizures without having any memory of it. This seizure does not notify about its starting or ending period and can last up to ten seconds [37]. Epilepsy activity occurs throughout the brain resulting unconsciousness with blank stare. Patients with absence seizures experience various symptoms, including loss of muscle control and repetitive movements such as shortness of breath, rhythmic blinking and chewing.

ii. Tonic-Clonic seizures: It is formally known as grand mal seizures and also known as convulsions or convulsive seizures. When most people think of seizures

or epilepsy, they think of these types of seizures. When a person has a tonic-clonic seizure, their arms and legs are first stiffen. It is called tonic stage. Then their limbs and head begin to tremble-this is the clonic stage. As with all seizures, these may be different, especially when people experience the tonic or clonic phase themselves. During a seizure, a person may bite their tongue or mouth, develop urinary incontinence, and even slow or stop breathing (in this case, their breathing should return to normal during the tonic (convulsive) part of the seizure). Patient may feel confused, do not remember what happened, need to sleep for a while, and may have a headache. A complete recovery may take a few minutes to a few hours, depending on the person [44]. This is especially important for people with tonic-clonic seizures. It is important that people around patient know how to provide first aid during a seizure.

iii. Atonic (Drop) seizures: These seizures can cause some or all of a person's body to suddenly become weak. This means that a person's head can fall suddenly, collapse, or even completely collapse to the ground (hence the name drop attack). These types of seizures can be dangerous for their sudden and complete nature .Therefore; children and adults who experience these seizures sometimes wear safety helmets. To make matters worse, these types of seizures usually do not respond to epilepsy treatment. Injured or If she falls for the first time or has an atonic seizure.

iv. Myoclonic seizures: These seizures cause certain parts of the patient's body to tremble; for example, patient's arms or legs may contract suddenly. If a person suddenly twitches his/her feet while sleeping, this is very similar to myoclonic twitches. Jerking feet while sleeping, is a non-epilepsy behavior. People with myoclonic seizures can be considered clumsy. Myoclonic seizures usually do not require first aid, but if this is the first seizure, then doctor's suggestion has to be taken to determine the cause.

v. Tonic seizures: These seizures are very alarming, especially when they occur without clonic seizures. They usually manifest as Lennox-Gastaut disease, or more rarely, multiple sclerosis. Tonic seizures often occur during adolescence, although they can occur at any stage of life.
Facial and truncal muscle spasms, flexion or expansion of the peak and lower-most limits, and impaired cognitive function characterize tonic seizures. There are several types of tonic seizures. Longer seizures are usually accompanied by seizures and may be related to dilated pupils, tachycardia, apnea, cyanosis, salivation, and poor bladder or bowel control. Tonic seizures are often accompanied by confusion after the seizure.

vi. Clonic seizures: Lasting for several minutes, clonic seizures usually affect the neck, face, and arms. These seizures are related to repetitive or rhythmic

sudden muscle movements. Patients of clonic seizures often lose consciousness and remain confused for a while. These seizures can been seen from premature childhood and over time, clonic seizures can develop into generalized tonic-clonic seizures.

3.4.3 Classifications of the Epilepsy

The classification of epilepsy is based on whether it meets the diagnostic criteria for epilepsy. The procedure is performed using a hierarchical group structure, which includes three layers of tissue: seizure type, epilepsy type, and epilepsy syndrome. Images, EEG, and various examinations (if any) are included in the three-level update job. If possible, it should be analyzed at all three levels. The etiology of epilepsy must be considered in the early stages and with each progression of symptoms. It also contains important recommendations for the treatment of patients.

Idiopathic Epilepsy: Idiopathic generalized epilepsies (IGEs) comprise 33% of all epilepsies. They are hereditarily decided and influence in any case typical individuals of all races and genders. IGE manifests as usual absence, myoclonic convulsions, and generalized tonic-clonic seizures, either alone or in a combination of fluctuating and severe. A common seizure is absence status epilepticus (ASE). Most disorders of IGE start in youth or puberty, however some have a grown-up beginning. They are typically deep rooted, albeit a couple is growth-related. To indentify and confirm IGE, the most exquisite test is EEG. Electroencephalogram shows generalized spikes, multiple spikes or spikes/multi spikes, seizures or intervals. Hyperventilation, lack of sleep, and intermittent light stimulation (IPS) often promote these emissions. During hyperventilation, subtle clinical signals can be seen in the video EEG and breath test. EEG may not be common in untreated patients. Suspected cases should be identified by typical EEG, rest and awakening EEG alerts. Subatomic genetic testing has made significant progress in the diagnosis of competing genes and loci; genetic heterogeneity is common [44].

Symptomatic Epilepsy: Partial (or focal) epilepsy (localized, anatomical, or localization-related) is defined as an epileptic seizure that originates from an epileptic focus somewhere in the brain and can be idiopathic, symptomatic, and cryptogenic. Ictal symptoms are determined by location rather than cause. The anatomical origin of some epilepsy is difficult to determine in a specific location or lobe. This is usually the case of epileptic seizures in areas where clinically asymptomatic epilepsy occurs.
Symptomatic (or possibly symptomatic) focal epilepsy is treated as a separate group from Idiopathic focal epilepsy by the new ILAE diagnostic protocol because of the prognosis and treatment of idiopathic focal epilepsy It is significantly different from symptomatic epilepsy. A striking example is medial temporal lobe epilepsy with hippocampal sclerosis, which is one of the most common and typical epilepsy syndromes.

Provoked Epilepsy: A person may have a seizure for any physical reason. This may be a serious clinical illness or injury that started before the seizure, or it may be related to a physical reaction or leakage of a substance or event. Seizures are classified as "provoked". The provocation is caused by the brain that causes the seizure. These seizures are not considered epilepsy. When treating provoked seizures, the reason must be considered. The frequent reasons for provoked seizures include metabolic causes (such as abnormal blood sugar, fever, head or brain injury, stroke or transient ischemic attack (TIA), medication, or abstinence from alcohol), acute illness (such as infection) and reactions to prescription or over-the-counter drugs.

Cryptogenic Epilepsy: Seizures are classified as cryptogenic or symptomatic. Cryptogenic seizures are seizures of unknown etiology that have nothing to do with previous damage to the central nervous system (CNS) that is known to increase the risk of epilepsy. Cryptogenic seizures do not meet the criteria for idiopathic or symptomatic categories. 40% of patients have no identifiable cause of seizures currently. With the development of imaging technology, especially magnetic resonance imaging (MRT), this proportion has dropped rapidly. The term cryptogenic epilepsy is sometimes used interchangeably with idiopathic epilepsy. This situation should be avoided. The term idiopathic epilepsy is dedicated to genetic diseases in which epilepsy is the only manifestation of the disease.

3.4.4 Treatment for epileptic seizures

Treatment can assist a great many people with epilepsy have less seizure, or stop having seizures totally. The objective of treatment in patients with epileptic seizures is to accomplish a seizure free status without unfriendly impacts. This objective is refined in over 60% of patients who require treatment with anticonvulsants. Numerous patients experience antagonistic impacts from these medications, nonetheless, and a few patients have seizures that are hard-headed to clinical treatment. A recent report tracked down that less than 66% of patients with recently analyzed epilepsy are without seizure following 1 year. A more modest examination distributed in 2000 discovered the seizure free rate to be 64%, which is practically indistinguishable from the rate found in the more current investigation [29]. Individuals with seizures experience psychosocial changes after their diagnosis; thusly, social or potentially professional recovery might be required. Numerous doctors disparage the results that an epilepsy analysis may have on patients. For instance, patients with epilepsy may live in dread of encountering the following seizure, and they might be not able to drive or work at statures.

Seizure medication: The medication of seizure is chosen depending on a few factors like how likely the patient will have more seizures, age, sex, and medical conditions of the patient. In most of the cases, a patient of epilepsy can become seizure free by taking one anti-seizure medication. This type of medication is called anti-epileptic drug or AED. Anti-epileptic drugs do not cure epilepsy. They just stop seizures from occurring by changing chemical ratios in the brain

of the patient. This kind of drugs have some side effects. Mild side effects AEDs are dizziness, fatigue, weight gain, thinking problems, lack of coordination, speech problems, etc. There are some side effects that are more serious. Those side effects include suicidal thoughts, depression, inflammation in organs like liver, severe rash, etc. Most common types of AED's are- sodium valproate, carbamazepine, lamotrigine, levetiracetam, topiramate etc.

Ketogenic Diet: Ketogenic diet indicates a diet routine where a person takes low carbohydrate, sufficient protein and high fat. In some cases ketogenic diet has shown good results in reducing the number of seizures among young people. After following this diet for a while, these young people can go back to their regular diet and still remain seizure free. But this diet has side effects like high cholesterol, constipation, kidney stones, weight gain and so on [29].

Vagus nerve stimulation: In this process specialists implant a gadget named vagus nerve stimulator under the chest skin of the patient. Wires of the stimulator are linked with the vagus nerve of the patient's neck. This battery-controlled stimulator transfers electrical energy though the vagus nerve to the brain of the patient. From the outlook this process may not look satisfactory. However, this nerve stimulator can reduce seizures by 20 % - 40% in most cases.
The vast majority actually need to take anti-epileptic medicine, although a few group might have the option to reduce the amount of the prescribed medicines they need to take. Side effects of this vagus nerve stimulation are raspy voice, coughing, difficulty breathing or pain in throat [29].

Epilepsy surgery: When medicine fails to provide sufficient authority over seizures, medical operation can be a a good solution. In an epilepsy surgery, the surgeon eliminates the space within the patient's brain which is responsible for the seizures. This kind of surgery can be done when the test results show that seizures occur in a smaller specific area of the brain and that area does not participate on any vital function of a person like vision, hearing, motor function, speech and so on [29]. However, numerous individuals still may require prescribed medicines to forestall seizures a successful surgery, one might have the option to consume less medication and diminish doses.
In some cases, epilepsy surgery can result into decreasing intellectual capabilities

3.5 Fourier Transform

The Fourier Transform plays a highly signinficant role in the study of mathematics, engineering, physical sciences. One of its significant roles is obtaining solution in the form of equations by analyzing electrical circuits, heat flow and the diffraction of electromagnetic radiation. This fourier transform serves as a unifying concept in the study of physics and engineering, connecting seemingly diverse fields, falling to the core of engineering. FT is somewhat of a highly advanced toolbox for every technical person due to its availabilty present within effective, easy to

use commercial computer programs including Matlabtm , Mapletm, IDLtm, Mathematicatm. In advanced researches and experiments , FT can smooth signals and interpola There are very close similte functions. Fourier transforms made revolutionary changes in topics such as signal processing and digital electronics, since it greatly helps in processing data within those topics. Fourier transforms function of time f(x) into function of frequency, F(s).arities between Fourier series and Fourier transform [46]. From Fourier series we learned how to obtain a sum of sinusoids by rewriting a given periodic function. This concept is also present in the fourier transform where we can implement this on non-periodic functions aswell.

$$F(s) \equiv \int_{-\infty}^{\infty} f(x) e^{-2\pi i s x} dx$$

[Fourier Transform]

$$f(x) \equiv \int_{-\infty}^{\infty} F(s) e^{2\pi i s x} ds$$

[Forward Fourier Transform]

$$e^{i\phi} = \cos\phi + i\sin\phi$$

[Euler's Formula]

Here, x and s are dimensioned where x measures the time t, and so that s, can correspond to inverse time or frequency. (1) is the equation of flourier transform and (2) is usually known as forward transform
(ii) $F(s) \rightleftharpoons f(x)$
The third equation (iii) in the figure, describes complex exponential, which describes that a complex number has both real and imaginary sinusoids parts. Also, ei+1=0 relates five of the foremost important numbers in mathematics [19]. It's easier to govern complex exponentials than trigonometric functions, and that they provide a succinct notation for addressing sinusoids of arbitrary phase, that from the idea of the Fourier transform.

3.6 Machine Learning

Machine learning is one of the most popular and useful branch of computer science. The purpose machine learning is to make the computer capable of learning so that it can make decisions automatically based on its learning. While traditional computing is very much dependent on explicit instructions or programming, machine learning algorithms can improve their performance and can come to a conclusion or decision by interpreting data. To be more specific, machine learning algorithms are trained by using some data and then the algorithms use those training to make decisions or predictions [60]. Developments algorithms and enhancing the ability to make predictions are the core parts of machine learning.

Machine learning is widely used in sectors like data mining, image recognition, language processing etc. where conventional programs are difficult to develop. Because of the improvement and popularity of machine learning algorithms, it has also start to take its place in medical sectors. Since machine learning algorithms can learn and use that learning to make a prediction or decision, identifying brain disease like epileptic seizure can be sector where machine learning perform well. There are various type of machine learning algorithms and each of them performs well in different sectors.

3.6.1 Support Vector Machine

Support Vector Machine (SVM) is a widely used algorithm that works remarkably well for classification. Using SVM with random dataset and other machine learning tools provides a very different dimension to ensemble models. For this reason, SVM is very crucial where high accuracy in prediction is necessary. The objective of SVM is to find a line or plane (hyperplane) that can evidently classify data points.

Hyperplanes and Support Vectors: For the categorization of the data points we can take help of the decision boundaries known as hyperplane. Hyperplane indicates to a decision boundary or plain that helps to categorize data points. The data points which fall under the same side of the hyperplane are considered to be in the same class whereas the data points which fall on the different side of the hyperplane are in different classes [60].

Moreover, the number of features are considered as the hyperplane's dimension. For example the hyperplane is only a single line when there are only 2 input features in it, whereas the hyperplane becomes a bidimensional plane when there are 3 features as input. Hence if the number of features exceed 3, it becomes difficult to comprehend the structure of the hyperplane. Support vectors are the data points which are closer to the hyperplae. The hyperplane's orientation and position also get influenced when the data point support vectors are more close to the hyperplane [25]. We can use those support vector to raise the classifier's margin. If the support vectors get deleted the hyper plane's position will change accordingly. The following figure shows an example of support vectors and hyperplane.

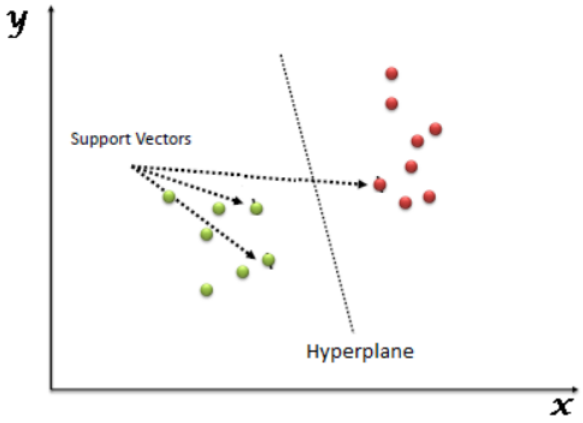

Figure 3.10: Support vectors and hyperplane [61].

We have used the theoretical ideas of SVM to develop our proposed system.

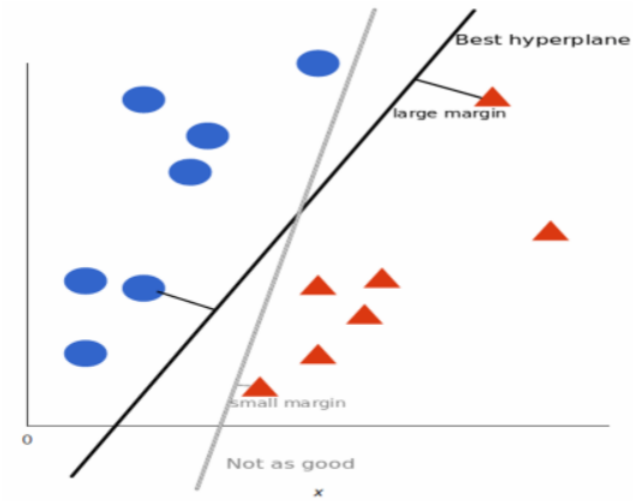

Figure 3.11: SVM for classification [30].

The figure above shows two tags which are red and blue with two features x and y. SVM algorithm tracks down the nearest point of the lines for both of the classes which are support vectors. Margin is the distance between the support vectors and the hyperplane. SVM boosts this margin. The hyperplane with the biggest margin is considered to be an ideal hyperplane or optimal hyperplane. For linear data, a straight line is enough to isolate data points on a plane. For non-linear data, we add a new dimension z. We can calculate z as $z = x^2 + y^2$. The following figure shows an example of a 3D hyperplane.

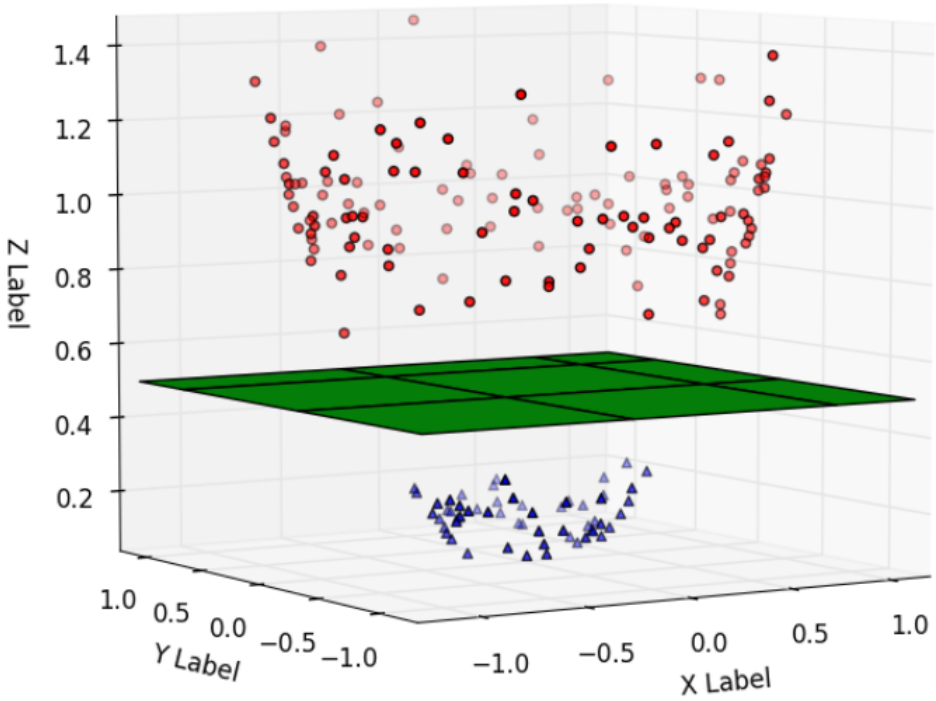

Figure 3.12: 3D hyperplane [62].

Large Margin Intuition: Through the usage of the sigmoid function, the linear function's output is carried and its values get squashed into a range of [0,1] in logistic regression. By considering a threshold value of (0.5), the squashed value gets assigned to Label 0 when it is smaller than the threshold value, otherwise it gets assigned to Label 1. The Linear function's output gets analyzed, then it is identified with one class if the desired result is greater than 1 and it is identified as another class if the result is -1. Therefore this reinforced value range ([-1,1]) is considered as margin and the margin values are changed to 1 and -1 in SVM.

3.7 Dataset

The data that we have used for our research has been collected from Children's Hospital Boston. This dataset contains different EEG recordings that are intractable with seizures [32]. The dataset is available in physionet.org which is managed by the Massachusetts Institute of Technology (MIT). This site contains various medical data which are freely available for research.

The data is grouped into 23 cases and collected from 22 subjects. Among the subjects, 5 patients were male whose age is between 3 and 22 years and the rest 17 are female whose age is between 1.5 and 19 years. Each of the cases has been named as chb01, chb02, chb03 etc. Here, chb01 and chb21 contains EEG data of the same female patient, chb21 was recorded 1.5 years after the recording of

chb01. In the database, the file named SUBJECT-INFO contains the gender and age of each patient. Each case such as chb01, chb02 etc. has 9 to 42 continuous .edf files from a single subject. However, gaps were created because of hardware limitations between consecutively-numbered .edf files, when the signals were not recorded. In most cases, the gaps are not more than 10 seconds. But there are a few exceptions where the gaps are a bit longer. Case chb10 is two hours long and the cases chb04, chb06, chb07, chb09, and chb23 are four hours long. There are some, files in which seizures are recorded are shorter and these happened occasionally. In the database, 256 samples per second with 16-bit resolution all signals were sampled.

The dataset contains 23 EEG signals in total. The International 10-20 system was used for these recordings which is a technique of EEG electrode positions and nomenclature. In the database there are 664 .edf files in RECORDS file and RECORDS-WITH-SEIZURES file contains lists the 129 who suffered from one or more seizures.

After analyzing all this information, we used various methodologies to detect the epileptic seizure. According to our result we decided to use Support Vector Machine (SVM) which seemed to be most suitable for our research and dataset.

Chapter 4

Proposed System

For our research, we have used the CHB-MIT scalp EEG dataset. This dataset has some EEG signals that are non-linear and non-stationary. We know that static means, variances, co-variances change over time. That is why non-stationary signals do not have these. These signals can be in trends, cycles, random walks. To get static means, variances, co-variances, these signals are needed to be turned into stationary signals. A non-linear signal is generated through the system that exploits superposition and scaling properties. Preprocessing is needed to make the signal linear and stationary.

Then, we have cropped the signals where seizure with was detected along with the signals that were recorded one hour before and after the seizure was detected. In the next step, we merged all the cropped signals of each patient. After that, we have added a low and high pass filter. Band filters basically pass signals that have low frequency and high frequency within a particular brand frequency by removing extra noise or changing the input signal.
After band extraction, we used Fourier transformation to convert time to frequency domain and then calculated energy from it. Finally, we used support vector classifier to train the data to calculate accuracy.

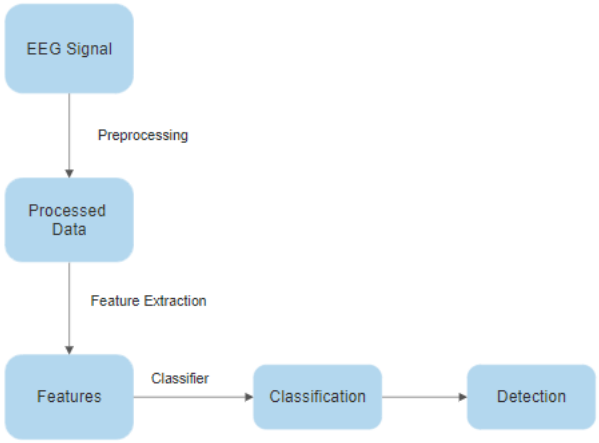

Figure 4.1: Workflow of our proposed method.

4.1 Pre-Processing

The data we have in our dataset are raw EEG data in .edf format. The summary file of each case contains the time when the subject had a seizure. Based on that time, we cropped 1hour of data both prior and subsequent to the seizure attack. But each of the file has one hour of EEG data. So, we had to crop some data from the previous or next file. After cropping pre-seizure and post-seizure data, we merged them. At this stage, the size of the .edf files started to become very large. So, we converted the data to .csv format to make our work easier. In some cases, the duration between two seizures are less than one hour. There were also a few cases where the seizure occurred so early or late in terms of recording data that we could not get one hour of pre-seizure or post-seizure data. We had to ignore ignore these data. Figure 4.2 shows all the parts of a merged file in the preprocessed data

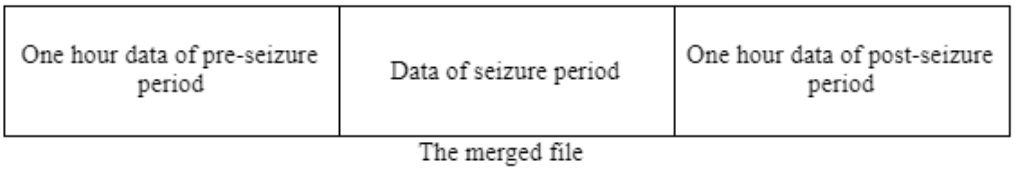

Figure 4.2 : Preprocessed data containing all the parts of a merged file.

4.2 Feature Extraction

The EEG signals that we have in our dataset were recorded on a time domain. After doing some research, we have found out that extracting features in domain frequency or time-domain frequency can lead towards more accurate results. That is why we decided to extract energy features based on Fourier transformation and Power Spectral Density (PSD) for our research. Table 4.1 shows all the features that we have extracted.

Table 4.1: Extracted Features from the data

Frequency Domain Analysis	**Time-Frequency Domain Analysis**
Estimation of spectral power where signals are stationary. (A signal is said to be stationary if its frequency & spectral content are not changing with respect of time).	Localisation of power in time & frequency.
Fast Fourier Transform.	
PSD (Power Spectrum Density)	

Fourier transform is a tool that breaks a waveform into an alternative representation characterized by sines and cosines. Signals from time domain can be changed into frequency domain using Fourier transformation.

$$F(w) = \int_{-\infty}^{\infty} f(t)e^{jwt}dt$$

Purpose of Fourier Transform: Summation of sinusoidal functions like sin(wt) or cos(wt) can create complicated and messy waves between -1 and +1. Each component of a wave can be expressed by only one value which is "w" [34]. Because of this, these waves can be characterized as peaks in frequency space as shown in Figure 4.3.

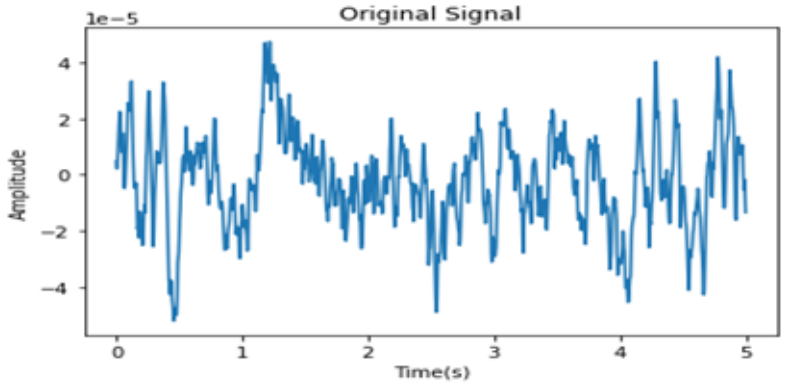

Figure 4.3 : Original Signal.

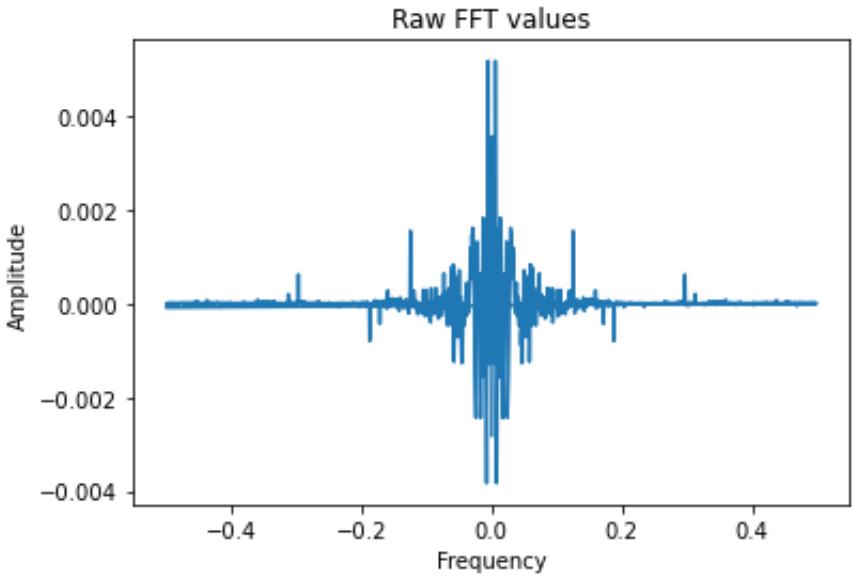

Figure 4.4 : Signal after applying FFT.

The figure 4.4 shows what Fourier transformation actually does. It is now much easier to understand which frequencies are in our waveform after forming the transform. We can now easily understand which frequencies are in our waveform after forming the transform. Now, the simplest option to connect this transformation to the prior procedure and make the entire process apparent is to substitute in Euler's formula.

$$e^{2\pi i\theta} = \cos(2\pi\theta) + \sin(2\pi\theta)$$

This clearly changes or redirect our function in frequency space into:

$$F(k) = \int_{-\infty}^{\infty} f(t)(\cos(-2\pi tk) + i\sin(-2\pi tk))dt$$

And the function in real space becomes:

$$F(t) = \int_{-\infty}^{\infty} f(k)(cos(2\pi tk) + i\sin(2\pi tk)$$

Here sine and cosine are clearly described in formulas which means a point in real space is defined by the integral over all space of the corresponding frequency function multiplied by sinusoidal oscillation.

4.2.1 Discrete Fourier Transform:

$$X(k) = \Sigma_{m=0}^{N-1} X(n)(e)^{-i2\pi nk/N}$$

Defining 'n' as present sample number or to be a set of integers from O→N-1 and contrive them to be a column. We set 'k' to be same thing but in a row. After multiplying them, we get a matrix. This is the centre part of the whole transformation. Unfortunately, this matrix multiplication is a slow process and this makes the whole discrete wavelet transform (DWT) process slow. Because of this, we shifted from DWT to FFT in this part with the help of recursion.

FFT makes a major advance in the field of computer science by simplifying difficult processes. At first glance, this algorithm looks like a usual application of recursion. In principle, it itself is a recursive algorithm but it allows some things that makes it really handy. This algorithm allows an easy bounce back and forth between real space and frequency space and is the core of many physics and engineering supplication. FFT creates a big impact in sectors like super resolution imaging, superfluid vortex position and many more. Cooley-Tukey algorithm is the most common algorithm for FFT.

This algorithm is defined as

$$X(k) = \Sigma_{n=0}^{(\frac{N}{2}-1)} X(2n)(e)^{(-2\pi i(2n)k)/(N/2)} + \Sigma_{n=0}^{(\frac{N}{2}-1)} X(2n)(e)^{(-2\pi i(2n)k)/(N/2))}$$

$$X(k) = E(k) + e^{\frac{-2\pi ik}{N}} O(k)$$

4.2.2 Power Spectrum Density:

PSD is used to find out the strength of the variations as a function of frequency. The unit of PSD is energy per frequency i.e. E/fq. The power spectrum density (PSD) is the most vastly used impertinent decomposition of signals because of the efficiency and elucidation. PSD works on signals that are assumed to be stationary [33]. PSD apprises the energy distribution of EEG (input) signals over a distinct frequency range [29]. This feature identifies the overall frequency context of a specific neural oscillation and then expresses it as a Fourier transformation. A visual representation of the power spectrum waves can be seen in figure 4.5.

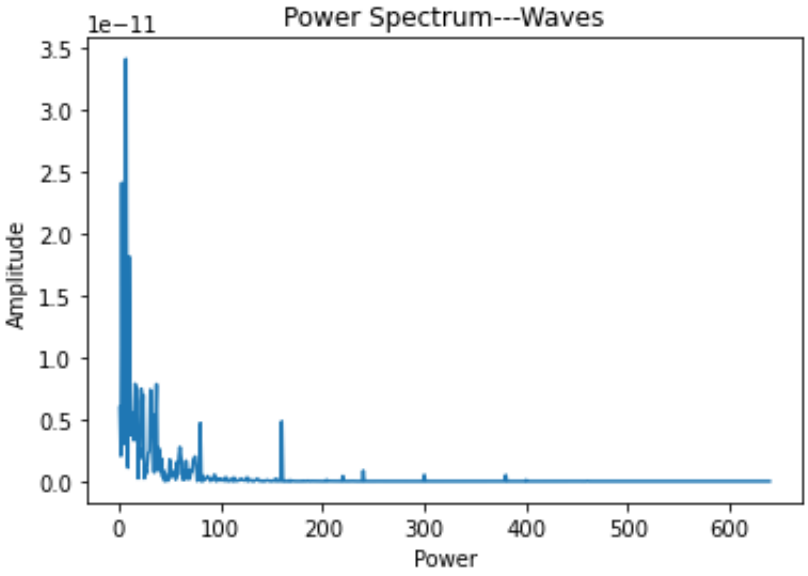

Figure: 4.5 Power Spectrum Waves.

The periodogram method of PSD states that the input EEG that are split into segments are often called as windows. An easy implementation of PSD: first we take the length of the sequence as a sample number, N= length (x) and then the FFT of the signal XDFT = FFT(x).

Now, to obtain energy by using PSD we use the following formula:

$$X(k) = 1/2\pi n|\Sigma_{n=1}^{N} e^{-jwn} X(n)|^2$$

4.3 Classification:

Our main aim is to establish a simple automated system that will scan the EEG signal of human brain waves and tell us whether seizure is preset or not, so in the procedure that we have proposed in this paper for achieving that the approach is to classify the selected modified reports into two possible classes, Class A = EEG signals associated with seizure and class B = EEG signals free of seizure.

Hence, for this classification into class A or B we are implementing a Support Vector Machine learning model as the classifier with the purpose of classifying those classes through the usage of Radial Basis Function (RBF) kernel.
For this thesis analysis, 75% training sets were set up for the learning phase and the other 25% sets were used to find out whether our process worked as intended or not accordingly. Once our testing was done, we our task was to examine the performance and for that purpose we calculated sensitivity, specificity and last but not the least accuracy.

Hence, in our upcoming chapter we will be explaining in detail the examination result.

First let us define the Radial Basis Function as follows -

$$k(x, x_i) = e^{\frac{-|x-x_i|^2}{2\sigma^2}}$$

where the width of the Radial Basis Funcion is being controlled by σ

$$k(x, x_i) = \Pi_{k=1}^{d} \cos[w_0 \frac{x_k - x_i^k}{a}] e^{\frac{-|x_i - x_i^k|}{2a^2}}$$

Where,
d represents dimension
a represents flexible coefficient
$x_i^k = k$-th component of i-th training data

Chapter 5

Result and Discussion

As we have mentioned above that using Fast Fourier Transformation we extracted the features for our procedure, since our aim was to classify the EEG signals as whether thay are seizure-free EEG signals or seizure-associated EEG signals using SVM classifier. Hence, we can finally detect whether seizure is present or not. We took 40 patient data sets and cropped them into 3600s where 1800s was prior to the seizure and 1800s was within the interictal stage of the seizure. After that we transformed time domain to frequency domain using FFT and found out the energy.

Defining the energy as :

$$E_x^{frequency} = \Sigma_{f=0}^{f_{s/2}} |X|f||^2$$

The result we obtained once the training and testing data was done via SVM which was in binary. The statistical values we calculated namely sensitivity, specificity and accuracy evaluates the performance of the binary result and thus were used in this experiment to verify the classification result and determine whether the signals were seizure-free or seizure-associated.
Defining sensitivity as :

$$Sensitivity = \frac{TP}{TP + EN} * 100$$

Defining specificity as :

$$Specificity = \frac{TN}{TN + FP} * 100$$

Defining accuracy as :

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} * 100$$

Where,
TP is referring to events which were true positive
TN is referring to events which were true negative
FP is referring to events which were false positive
FN is referring to events which were false negative

Additionally, we applied other distinct methods for evaluating the comparison of our output shown in tables 5.1 and 5.2.

We conducted the test by comparing the percentages of accuracy, specificity and sensitivity between existing [neuro] methods namely, Empirical Mode Decomposition (EMD), Discrete Cosine Transform (DCT) and the method we proposed, FFT with the linear classification of Support Vector Machine and the Radial Basis Function kernels.

Table 5.1 : The comparisons of accuracy , specificity and sensitivity of other methods with our proposed method with RBF Classifiers

With RBF classifiers	EMD	DCT	Proposed Model
Sensitivity	48.04%	6.35%	61.47%
Specificity	80.40%	89.18%	96.32%
Accuracy	79.05%	78.90%	89.80%

The existing methods like the one Bajaj *et al.*'s feature extraction and classification method (EMD) [30] generates an average sensitivity of 48.04%, specificity of 80.40%, accuracy of 78.97%; Birvinskas *et al.*'s feature extraction and classification method (DCT) [31] generates an average sensitivity of 6.35%, specificity of 89.18%, accuracy of 78.90% with RBF kernel classifiers while our proposed system with RBF kernel classifiers generates a sensitivity of 61.47%, specificity of 96.32% and accuracy of 89.80% on average on CHB-MIT dataset.

Table 5.2 : The comparisons of accuracy , specificity and sensitivity of other methods with our proposed method with Linear Kernel

With Linear Kernel	EMD	DCT	Proposed Model
Sensitivity	56.58%	16.64%	61.68%
Specificity	82.82%	88.37%	88.57%
Accuracy	81.80%	77.35%	85.94%

Besides that, Bajaj *et al.*'s feature extraction and classification method (EMD) [30] showed sensitivity of 56.58%, specificity of 82.82% and accuracy of 81.80% ,Birvinskas *et al.*'s feature extraction and classification method (DCT) [31] generates an average sensitivity of 16.64% , an average specificity of 88.37% and accuracy of 77.35% with the Linear Kernel while our proposed system with the Linear Kernel generates average sensitivity of 61.68%, specificity of 88.57%, and accuracy of 85.94%

Sensitivity plays a bigger role than specificity in the case of seizure detection since the cost of failure detecting the ictal has more weight than non-seizure detection (neuro). Thus in terms of these criteria, the method we propsed outperformed the existing methods (Neuro).

We can use a ROC plot to measeure the performance of the SVM. The ROC plot, also called "a receiver operating characteristic curve", is a graphical plot which displays a binary classifier system's diagnostic capacity as its threshold of discrimination is varied. This plot contains sensitivity against the specificity. To be more specific, it displays the true positive rate (TPR) against the false positive rate (FPR) at random threshold settings. In machine learning ROC also shows the probability of detection. In this chapter we are proposing the successful methods of detecting Epileptic seizures, which exploits EEG signals for time-frequency. The approach proposed exceeds the existing methods in terms of sensitivity, precision and accuracy consideration. Figure 5.1 shows ROC on a testing set.

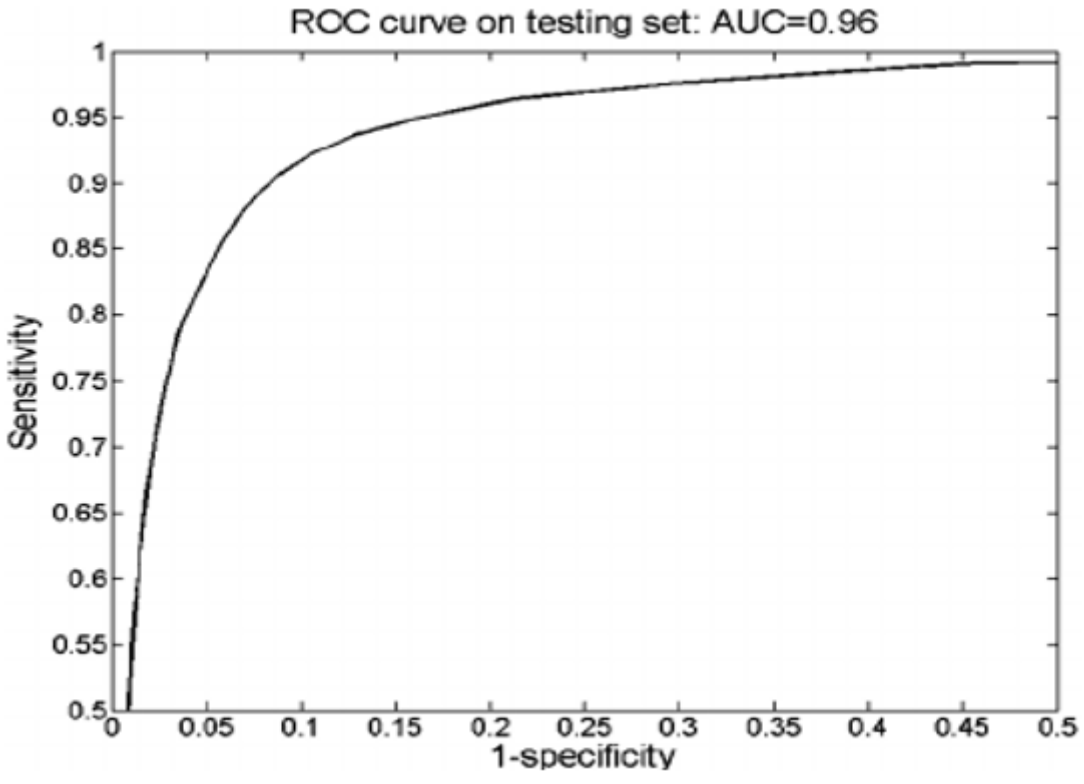

Figure 5.1 : ROC on Testing set.

Chapter 6

Conclusion

To sum up, it is difficult and challenging to detect seizure and non-seizure signals because of instantaneous occurrence between these signals. In our work we have proposed an effective method to detect epileptic seizures. We extracted the features of an EEG signal from the CHB-MIT dataset. Due to different brain locations, patients, types of seizures and hospital environment of the patient, the signals are often inconsistent. This was a major challenge that we had to face in our work.

We extracted features from the EEG signals using FFT and then used SVM to classify between seizure and non-seizure. Our proposed method showed 89% accuracy in the CHB-MIT dataset that we used. For improving accuracy in feature extraction, Empirical Mode Decomposition (EMD) using application of Hilbert-Huang Transform (HHT) can be used to detect time frequency domain. Comparing EMD with SVM can give us knowledge about which feature extraction methods works best with our dataset.

In the near future, we can conduct an analysis of the data by taking help of real time analysis than EEG signal. That can lead us to an improved accuracy of signal with the help of 10-20 system of electrode placement. In the method we proposed, we used one kernel to classify the time-frequency feature. Subsequently if we use more kernels as classifiers, we can get more accurate results.

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