COMPARATIVE ANALYSIS ON BRAIN DISORDER DETECTION USING EEG

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Abstract- Electroencephalography (EEG) educate about the condition of the brain i.e. about the electrical activity of the brain. The electrical parameter measured as voltage at diverse points of brain act as EEG basis. These signals are generally varying with time and not stationary in nature. These signals can be studied using numerous signal processing procedures. In this paper, few numerical approaches to examine EEG signals are discussed. The EEG is a medicinal modality that plays vital roles in identifying, displaying and recording electrical activity in the brain. This paper reviews various analysis method of EEG signal for brain diseases like Epilepsy, Brain Injuries, behavioral disorders, sleep disorders, Alzheimer 's disease and schizophrenia. Event-related potential (ERP), Short Time Fourier Transform (STFT) and Fast Fourier Transform (FFT) are some of the techniques used for analyzing EEG.

Keywords- Electroencephalography, Epilepsy, sleep disorders, Brain Injuries, Alzheimer's disease, schizophrenia.

1. INTRODUCTION

Human brain is an important part of human which controls whole human body parts. It is group of neurons that selects human behavior. Brain contains lots of neurons which play a vital role for governing performance of human regarding motor stimulus. Such neurons are used for sending information from brain to various parts of body. Individual behavior is possibly pictured in motorized and sensual statuses such as moving of eyes, shivering lips, memory, responsiveness, finger clasping etc. Such conditions are associated with particular frequency of EEG that aids to recognize well-designed behavior of complex brain structure. [1]

The Electroencephalogram can be considered as an important mean that is used to study human brain activity and neurological disorder The EEG is coarsely described as electrical impulses mean of activities occurring at various places on the scalp. Further precisely, EEG is said to be accumulation of out of cell current movements of an enormous group of neurons. EEG records are attained by employing electrodes of great conductivity and having impedance less than 5000 Ω in diverse areas of the head.

EEG has also been accepted for several other clinical symptoms. For example, EEG displays the anesthesia depth during surgical process. If sensitivity is high, it shows abrupt changes in neural operational, it has revealed fairly supportive in this setting in observing for probable technical hitches such as infarction or ischemia.

Electric potentials events can be noted between active electrodes pairs or with reference to an assumed passive electrode referred as reference. These trials are principally done on the head surface also known as scalp EEG or by use of distinct electrodes inserted in the brain when a surgical operation is done. It is known as intracranial EEG. In surface EEG recordings, 10 20 electrode system is used for placing of electrodes. It comprises total 19 electrodes (or sometimes number varies) distributed uniformly over the head, normally earlobes are used as reference. It is a noninvasive, handy and relatively inexpensive technique.

As per medical doctors and radiologists observation, right side of brain is responsible for left side of body and left side of brain controls right side of body. A noteworthy characteristic of EEG includes nondestructive, pain less, with no side effect and precise interpretations for some brain diseases such as epilepsy, memory loss, Alzheimer and autism.

Epilepsy has been most public neurological disorders which is part of most of researches on EEG analysis.. About one-third of the whole diseases in emerging countries results from brain disorders such as epilepsy, schizophrenia and brain injuries. A sudden change from the typical pattern of EEG is often related with these disorders.

EEG signals are easy to misread hence highly trained neurologist is essential to investigate EEG signals However, well-timed diagnosis and treatment of brain disorders is possible and can make a difference. This situation urgently calls for development of a precise algorithm, which can be used for EEG-based recognition of brain disorder and neural function monitoring with insignificant human intervention[2-36].

2. BRAIN

It is most significant functional organ which controls and coordinates other muscles and nerves in human body. It is divided into two hemispheres known as right hemisphere and left hemisphere. Each hemisphere can be further separated into four lobes such as Frontal,

Temporal, Parietal and Occipital lobes.

Frontal lobe is biggest lobe which is located behind the forehead. The left frontal lobe is responsible for speech and linguistic. It is concerned with planning, organization, problem solving, memory, impulse control, decision making, selective attention and governing behavior and emotions. Damage to Frontal lobe will results in emotion disparity, language and memory related disorders. Fig. 1 shows Human Brain.

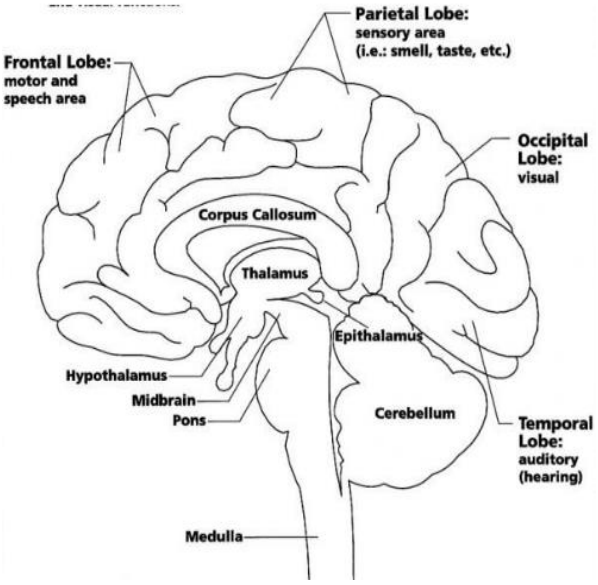

Fig. 1 Human Brain

Temporal lobe is found behind the ear under parietal and behind frontal lobe. This is responsible for sound and speech in numerous aspects of memory. It may create hearing, linguistic and sensory problems during damage.

Occipital lobe is placed at the lower back of head which relates sensitivity and process visual information. It creates pictorial and perception defects after getting damage on this part.

Behind the frontal lobe, parietal lobe is located which assimilates sensory information from different parts of body. It may create the recognizing inability problem and locating parts of the body.

From medical past, it is well recognized that specific action/ activity / states are controlled by specific part of the brain.

Table 1 represents functional characteristics of different brain parts. Activity wen tongue is moved is known as Hypoglossal. Optic, Accumulator, Abducent and Trigeminal are related with vision and eyes. Glossopharyngeal monitors the taste and swallowing activity. Heart beats are monitored by Vagus.

Table 1 Functions of different parts of brain

Sr. No.	Name	Function
1	Hypoglossal	Tongue movement
2	Accessory	Voluntary neck muscle, moves head
3	Vagus	Involuntary Muscles, Heart rate
4	Glossopharyngeal	Taste, Swallow
5	Vestibulocochlear	Hearing , Balance
6	Facial	Face movement, Salivate
7	Abducent	Moves Eyes
8	Trigeminal	Face Sensation
9	Trochlear	Eye movement
10	Oculomotor	Eye, Pupil movement
11	Optic	Sight
12	Olfactory	Smell

3. EEG SIGNAL

Electrophysiological nurturing method of recording electrical movement of brain is known to be EEG. It is categorized as noninvasive, in which the electrodes located are not inserted in the scalp. In some cases, invasive electrodes are taken into account, for ex in electrocorticography. These are named intracranial EEG. EEG represents voltage variations that are result of ionic current present in brain neurons. [1] Medically, EEG comprises the brain's spontaneous electrical activity recordings that are considered over a time period. This is recorded from plentiful scalp electrodes. [1] Analytical applications commonly emphasis either on the EEG spectral content or event-related potentials. Fig. 2 shows Normal EEG Signal.

It is pathologically proven that EEG signals are alienated based on value of frequency range into numerous smaller bands. Delta is having range of 1 to 4.1 Hz; theta is having frequency of 4.1 to 8 Hz, Alpha is having frequency of 8.5 to13.1 Hz, Beta is having frequency of 13.2 to 30.5 Hz and Gamma is having frequency of 30.2 to 80.2 Hz. Consequently, quite a lot of researchers randomly focus on these different sub bands.

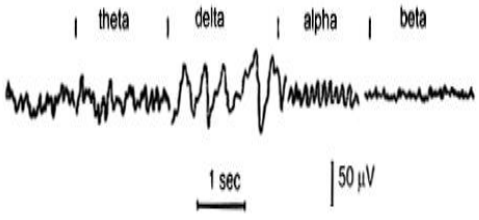

Fig. 2 Normal EEG Signal

3.1. Delta: frequency is approximately of 4.1 Hz or less.

It has maximum amplitude and it is slowest in nature. In infants it is rhythm that is leading up to 1 year. Delta waves are related to various brain tasks including deep sleep condition. In adults, it is frequently most protruding. Deep sleep states represent presence of prominent delta waves in recording. Fig. 3 shows Delta Wave.

Fig. 3 Delta Wave

3.2. Theta: it has frequency varying from 4.1 to 8 Hz. It is said to be categorized as relaxed action also known as slow variant. In children's up to 13 years, theta waves seem normal during sleep but it seems abnormal in adults in awake state, it seems abnormal. Focal subcortical lesions can be considered as theta waves. Duration between waking and awake state, theta frequency varies more. Fig. 4 shows Theta Wave.

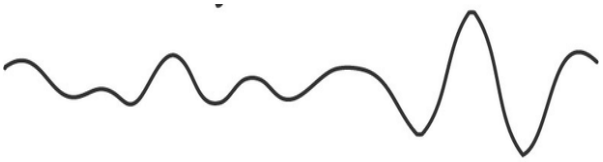

Fig. 4 Theta Wave

3.3.Alpha: frequency ranges between 8.5 and 13.1 Hz. It is typically observed along each subsequent regions. It shows higher amplitude on the prevailing side. When eyes are closed and in relaxing state Alpha waves appear. When eyes are opened, they disappear. They also disappear in warning situations like thought process, calculations. It is mostly observed in relaxed adults. It is normally existent in life post 13 year. Fig. 5 shows Alpha Wave.

Fig. 5 Alpha Wave

3.4. Beta: It is considered as fast occurrence wave. Frequency ranges from 14 Hz and more. It represents proportioned distribution and is most apparent on front side. Hypnotic drugs like benzodiazepines are used for highlighting beta rhythm. It shows absenteeism or reduction in impaired cortical areas. It can be in general treated like common regularity. It is the prevailing pulse in Patients having their eyes open presents beta wave. Alertness or anxiousness is also responsible for beta waves. Fig. 6 shows Beta Wave.

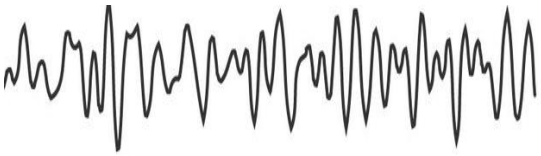

Fig. 6 Beta Wave

3.5. Gamma: Its frequency ranges between approximately 30–100 Hz. Gamma rhythms represents togetherness of diverse neuron populations into a single linkage for performing a definite cognitive or motor function. Fig. 7 shows Gamma Wave.

Fig. 7 Gamma Wave

3.1 Variables used in the classification of EEG activity

Age is factor that changes EEG appearance. The prenatal and neonatal EEG differs in many parameters from EEG of an adult. Two common EEG patterns are observed in Fetuses. In first pattern, brain waves with low frequencies along with spikes are observed which are known as Discontinuous. In another pattern, brain waves with short intervals of lager amplitudes are seen along with sharp spikes which are known as Trace alternant. Adult age EEG contains has faster frequency alternations than EEG in childhood.

The state of person is also responsible in changing EEG pattern. In polysomnography, EEG also considered along with Electromyogram and Electrooculography to investigate stages of sleep. During Stage I sleep which is result of drowsiness can be observed using EEG with increasing theta frequencies. Santamaria and Chiappa discussed various drowsiness patterns. During Stage II, spindles of sleep are observed.

These spindles are rhythms in range of 12–14 Hz range also known as sigma band. Stage II activities are characterized by 3–6 Hz range. Presence of slow wave sleep contains delta frequencies which represents Stage III and IV. The Awake EEG and EEG related to rapid eye movement are similar.

Frequency

Frequency is related to different categories like rhythmic, arrhythmic, dysrhythmic.

Voltage

Voltage values are based on techniques used for recording. It includes terms like suppression or depression.

Morphology

Depend on frequencies used to form wave, there are different morphologies such as monomorphic, polymorphic, sinusoidal, and transient. Wave patterns can be described as being:
Monomorphic: Single frequency
Polymorphic: multiple frequencies
Sinusoidal: Similar to sine waves
Transient: An isolated wave or pattern spike or sharp waves

Synchrony

Synchrony is defined from rhythm appearance or patterns over different areas of head, either on the same side i.e. unilateral or both sides i. e. bilateral.

Periodicity

Periodicity is categorized in lateralized, generalized or focal.

3.2 Recording of EEG

In process of cranial EEG recording, the record is attained using conductors located on the head with a pulse transmitting gel. Before this, scalp area is processed through abrasion which decreases impedance caused by dead skin cells.

Electrode placement points are acknowledged using the 10-20 electrode system as shown in fig 8. A number and a letter are used for labeling each location. For frontal lobe F and for temporal lobe T is used. Right side of the head is denoted by even numbers and odd values mean the left side of skull. Some letters used are Fp denotes Frontal pole, C signifies central, P defines Parietal, O symbolize occipital and T denotes temporal. 10 20 system is based on percentage of distance I n 10-20 range. Z is used for marking which means zero.

No of electrodes used are based on situation or patient age. In general 19 electrodes along with ground and reference electrodes are used. For neonates these electrode numbers can be less. For special clinical application as per requirement, number of electrodes can be increased. High-density arrays are available with composition of 256 electrodes that are evenly spread out along scalp.

One differential amplifier is used per electrode. Each differential amplifier has a common system reference electrode.

EEG channels specific representation is known as montage.

Sequential montage

Each channel characterizes the alteration between two neighboring conductors.

Referential montage

Every single path characterizes unlikeness amongst definite conductor and nominated as referential conductor.

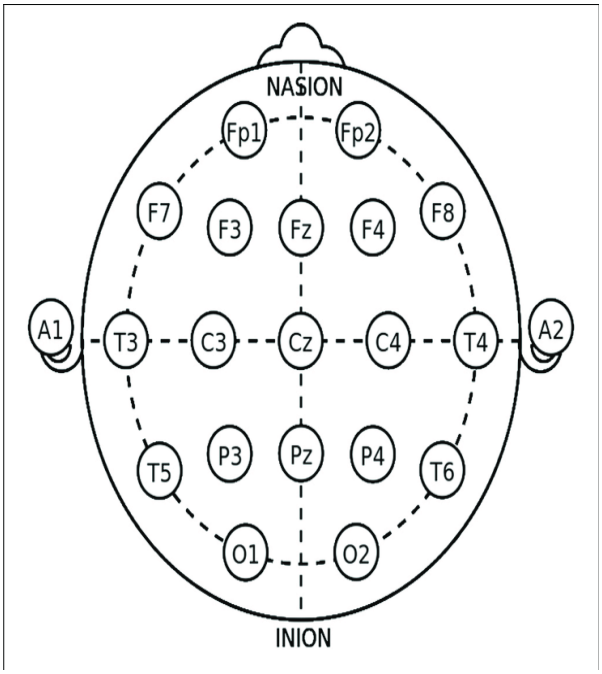

Fig. 8 The 10/20 Electrode Placement

Average reference montage

It compromises summing total amplifiers values followed by averaging. Attained average works as communal reference for every path.

Laplacian montage

Every path signifies alteration among an conductor and a prejudiced averaging of the adjacent conductors.

4. EEG ANALYSIS

The raw EEG signals are adulterated by artifacts caused by different sources. As these artifacts may misjudge the brain activity and misdiagnosis of brain disorder, it's significant to remove these artifacts first. Researchers have established many techniques for artifact removal, including regression-based methods, component based methods and adaptive filtering methods and also use of notch filter. Processing steps are shown in fig. 9.

In reading EEGs, one should identify artifacts which vague the EEG and may complicate the understanding of physician. Artifacts are unwanted signals recorded by EEG electrodes but that are not produced by brain. Some artifact may mimic true epileptic irregularities. In identifying artifact from EEG waves, Attentiveness of distribution for right EEG abnormality is vital. Patient give rise to physiologic unwanted signals and surrounding are responsible for non-physiologic artifacts. Some of examples are hiccups, EKG, EMG, movement of eyes, pacemaker, sway artifact, loose electrodes, electric interference and bed movements.

The first important task to remove artifacts is to first identify them. Two types : Physiological and non-physiological

Physiological Unwanted Signals

- Eye movement
- Movement of muscles
- Heart Rhythm
- Perspiration
- Breathing

Non-physiological Unwanted Signals

- Loose Electrode
- Cable displacement
- Wrong reference point
- EMI
- Body instability

After the elimination of the artifacts, the noteworthy features of the EEG signals are extracted & selected. Feature extracting is important process for finding certain characteristics of EEG signals.

In recent years, diverse methods are discussed and implemented for processing brain waves. It compromises frequency domain, time domain and combined domain. The extracting features and selecting them using various processes are significant to recognize definite goods that can effectively be implied in categorizing EEG waves . There are numerous approaches used in feature extraction including either frequency or time or combined domain analysis. The structures such as minimum, maximum, mean, standard deviation and energy are frequently used in time-domain analysis. In frequency-domain analysis, Fourier transform is used to convert signal in frequency domain. In some cases if it is inadequate to offer signal features for ordering using just frequency statistics, tf analysis is used for enlightening classification accuracy.

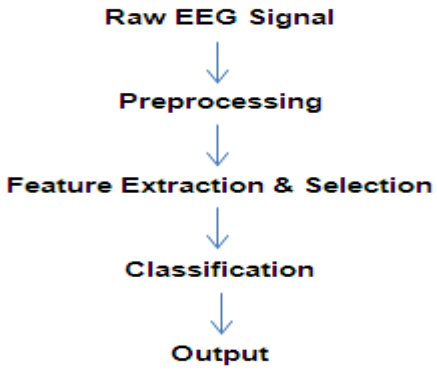

Fig. 9 EEG Signal Processing

The EEG spectral analysis depends on sub-bands frequencies. Researchers have principally used wavelet transform (WT) and time-frequency distributions (TFD) to analyze the EEG spectral forms.

5 BRAIN ABNORMALITIES

EEG is important tool for diagnostic tests for brain disorder. For regular clinical EEG record persists half an hour excluding grounding time. Electrodes placed on scalp are used to distinguish different electric activities in brain. EEG defines variations in brain rhythms that are advantageous in detecting brain conditions. An EEG can be used for analysis of the following disorders:

- Presence of Tumor in brain
- Damage to brain cells due to injury
- Brain malfunctioning (encephalopathy)
- Brain Infection (encephalitis)
- Strokes
- Sleep ailments

It can also:

- discriminate normal cells from epileptic cells, including fainting, cortical movement disorders and migraine
- Diagnose brain dead condition
- predict in dragging patients
- find the dosage of anti-epileptic medications
- Display anesthesia depth
- To observe and control strokes

5.1 Epilepsy

Epilepsy is a nervous ailment that is caused due to firing (excess voltage) of brain neural activities. Such

existence of epileptic seizure is unpredictable. Brain activity can be measured using numerous methods, both noninvasive and invasive. [2] EEG is the primary investigative tool for detecting epilepsy. EEG gives worthy resolution in space as well as time as matched to former techniques. Seizures take place regardless of the conditions. Epileptic Patients experience from unexpected and unanticipated seizures. During this patients are not able to secure themselves and are vulnerable to unconsciousness, demise or harm due to collapsing and traffic accidents. Till today, epilepsy is largely cured with medicines and operation; its incurable, and anticonvulsants medicines are not entirely in effect for some epilepsy cases. Epilepsy can be categorized into two types: EEG is one of the diagnostic methods to detect abnormalities of the brains electrical activity. Presence of epilepsy can be detected from EEG signals by computing the spikes. Epilepsy has three states: ictal, preictal and post ictal. Ongoing seizure period is termed ictal. Pre seizure period is termed pre ictal state. After seizure the period of EEG is termed post ictal.

5.2 Traumatic Brain Injury

The TBI is a significant reason of assimilated epilepsies. It is acknowledged as a significant origin of demise and incapacities after mishap. The obtainability of device which provides timely finding of brain abnormalities might significantly develop superiority of abnormal patients living and also avoid demises.

4.3 Alzheimer's Disease

The AD is an enlightened illness comprising cerebral deficiency, behavior ailments and memorial loss. It is the utmost communal reason of dementia, having 70% of cases. Few years before, more than fifty million persons were suffering from some kind of dementia. This number may get tripled in next decade. AD is well-thought-out a greatly troublesome condition for affected persons and their relatives and caretakers. It is the main reason of need and incapacity for adult people. This disease is principally expensive for the humanity. This disease can be characterized in 4 prominent stages. Mild Cognitive Impairment (MCI), accumulative cerebral deficits and increasing necessity, terminating in the patient's whole necessity on caretakers and whole behavior deteriorating.

5.4 Schizophrenia

The Schizophrenia is a biological brain disease, which affects roughly one in 100 people at some time during their lives. Schizophrenia is an intellectual ailment, which is described by a widespread range of disorders while carrying out several tasks or while resting. These disorders should be described autonomously of the precise assignment, in initial states, i.e., formerly carrying out the task or at rest. Schizophrenia is related with disorders in the lobes and areas of the brain, which are accountable for information processing, temporary memory and executive functions. The analysis of schizophrenic spectrum disorders and other psychotic disorders is thought-provoking. The scientific community is regularly working to assimilate the latest clinical and scientific advances in the field of psychiatry into investigative and statistical manuals. Promising and capable young youth or early adulthood people are often overwhelmed by Schizophrenia and transforming them individuals who require a extraordinary degree of care and support throughout their lives. Schizophrenia interrupts the brains ability to recognize and interpret reality to think and to feel. Schizophrenia is not related to split personality or multiple personality or bipolar disorder. Schizophrenia has long bemused psychiatrists and terrified the layperson, seeming to appear without warning to confound developing minds poised on the threshold of adult life. Schizophrenia is fundamentally the condition when a person starts having complications in interpreting reality. They confuse their supposed thoughts with the authentic happenings. A person with schizophrenia will show an abrupt but substantial change in his or her behavior as well as indicators like delusions, hallucinations, abnormal speech, extremely erratic behavior, an absenteeism of emotional responsiveness, in appropriate emotional reactions, disadvantaged speech and a potentially hazardous loss of the desire or ability to care for himself or herself.

6. DISCUSSIONS

All of these conditions have one common characteristics of EEG signal which is irregularity in waveform.

In seizure detection method, the objective is to grow both the sensitivity and the specificity of the seizure detection algorithm as well as to diminish the detection delay. The suggested procedure has been verified over tremendous minutes of brain signals commencing dual dissimilar data, the CHB-MIT dataset, and the KU Leuven dataset, which gave 0.871 and 0.881 sensitivity separately and 0.99 specificity[5].

Prabhapreet Kaur designed a system that uses wavelet sub band coding technique and altered training sets of rule that trains neural network classifier for brain waves. The system was tested and equated with SVM. The proposal attained accuracy of 99.97%. [14]

Bruno Albert, Jingjing Zhang aimed a handy choice support system called EmerEEG, which can detect

TBI with the help of discriminant analysis on structures mined from data copies as a result of programmed artifacts elimination. The planned procedure diagnosed TBI on foundation of method generated from medically categorized EEG archives. These algorithms obtained accuracy of 79.1% in eliminating artifacts, and accuracy of 87.85 % in TBI identification[6].

Oleksii Shandra1 & Alexander R. Winemiller used both gender mice in their model of closed-head TBI. In this diffused injury is induced and then tested the postulate that astrocytes reply exclusively to turgid injury. Artifacts are automatically removed using preprocessing algorithm. It avoids wastage of time for manual scrutiny and elimination of data segments. Supervised machine learning is used for classifying statistics. The scheme is later fed by valuation of probable brain damage[2].

Easwara moorting and Uthayakumar emphasized on the novel method which is useful to specify the state of illness of epileptic patient from EEG recording. Analysis is grounded on wavelet decomposition through DWT. With this analysis they tested the patient state. [27]

Evrim Acar, Canan Aykut-Bingol proposed an procedure which practices combination of tf features showing normal and abnormal waves which distinguishes multi-channel EEG signals[32].

A novel technique is offered for general, online, and concurrent automatic recognition of multimorphologic ictal-patterns in persons brain waves with their verification about uninterrupted, monotonous medical brain activity recordings of fifty six subjects having period of almost forty three hours and supplementary thousand minutes of normal brain signals which calculates incorrect alarm amounts. Analysis of ninety one attacks (thirty seven focal, fifty four secondary) represented 6 utmost public structures like beta, alpha, delta along with theta). Seizure morphology shows a essential part in growing the recognition system performance. Furthermore, besides permitting a reliable, timely and precise finding with average precise recognition rate of 96.2% for early time of ictal patterns of brain signals, this method simplifies automatic early detection[33].

Yuedong Song considered Sample Entropy to investigate in the form of extracted characteristics method for classifying 3 unalike categories of EEG signals and observing epileptic seizures. In epileptic seizure SampEn value decreases unexpectedly and this circumstance is utilized in the proposed algorithm. BPNN and ELM has been tested in this research. It accomplishes 95.67 % classification accuracy with faster speed[36].

Yuedong Song, Pietro described a organized assessment of recent methods for detecting seizures. This assessment proposed a dependable, convenient epilepsy recognition method. PCA and Gas has been used to several linear and nonlinear techniques. PCA used for feature reduction proved more efficient than applying GAs. [28]

Thasneem Fathima, Yusuf U Khan suggested a method in which EEG signals are classified into abnormal and normal classes. Statistical scatterings features were studied and extracted for each of EEG frame. After features extraction like variance and other charactyeristicsproved best set of features. Classification accuracy of 96% is obtained. [24]

7. RESULTS

Normal and EEG signals are analyzed and results obtained are shown below. As per analysis shown in figure 10 power of Beta band is increased in case of epileptic patients. So such analysis is beneficial for differentiating normal and abnormal occurrence of brain signals.

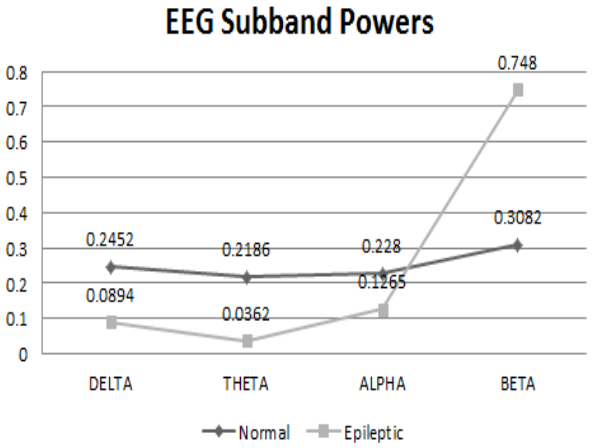

Fig. 10 EEG subband powers

Fig 11 shows standard deviation calculated for each subband of Normal and epileptic EEG. Considering sub bands of different frequency values for normal and abnormal signals, their standard deviation is calculated.

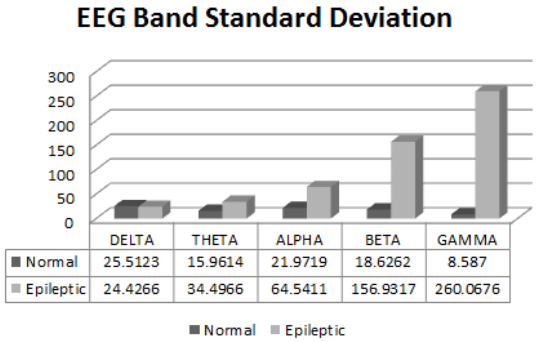

Fig. 11 EEG subband standard deviation

Fig. 12 represents relative power distribution among various sabbands of Normal and epileptic EEG. When relative power values are calculated, it can be observed that relative power is having greater value in beta bands in case of epileptic EEG.

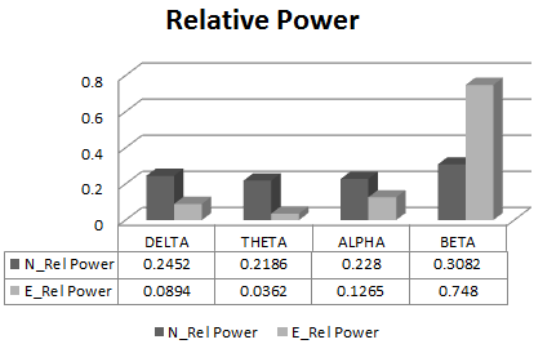

Fig. 12 EEG subband relative powers

8. CONCLUSIONS

The brain signal analysis is considered the investigating technique of early detection of disorder and recovery. The methodologies of the analyzing diseases also differ according to the diseases. Some of the technique to analyses EEG waveform is using time-frequency pre-processing while others use focal wave to detect the active side in the EEG signal. More research and development needs to be done to improve the usage of the EEG. It can be concluded that EEG plays its role as a detection tool to detect the disease in the early stage, rehabilitation, classification or as an assistive tool for the patient according to the needs of the diseases.

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