Automated Detection and Severity Analysis of Epilepsy Using Hybrid EEG Classification Techniques

Khushwant Kaur[1,] Meena Jindal[2]
[1,2]Assistant Professor
[1,2]Sri Guru Gobind Singh College, Chandigarh
kkoffwk10@gmail.com, meena.gupta355@gmail.com

ABSTRACT

The early detection and diagnosis of diseases are critical for saving lives, and in the modern era, computer-aided technologies have become indispensable tools for radiologists and physicians. Electroencephalography (EEG) has long been utilized to analyze human behavior and detect brain-related diseases. Epilepsy, a neurological disorder characterized by recurrent seizures, presents significant diagnostic challenges. This paper explores the application of EEG in detecting epilepsy, emphasizing the integration of advanced computational techniques to enhance diagnostic accuracy. The study employs a hybrid classification approach that incorporates Dual-Tree Complex Wavelet Transform (DTCWT) for signal decomposition, followed by feature extraction and classification using Neural Networks and Adaptive Neuro-Fuzzy Inference System (ANFIS). This methodology aims to improve the sensitivity, specificity, and accuracy of epilepsy detection.

Extensive experimentation on EEG datasets from Bern-Barcelona and CHB-MIT databases demonstrates the efficacy of the proposed hybrid system. The results show that incorporating DTCWT significantly outperforms traditional methods, achieving high detection rates and low rejection rates. Neural Networks are utilized for initial classification, while ANFIS assesses the severity of the identified epileptic signals. This approach ensures robust performance even with limited data, making it suitable for practical clinical applications. The study also highlights the importance of integrating various feature extraction techniques and classifiers to effectively capture the complex nature of EEG signals.Overall, this research provides a reliable, efficient, and scalable solution for the diagnosis of epilepsy, contributing significantly to the fields of biomedical engineering and neurology. The integration of advanced computational methods with EEG signal analysis not only enhances diagnostic capabilities but also opens avenues for further research into automated detection systems for other neurological disorders. This work underscores the potential of hybrid models in medical diagnostics, promoting the development of intelligent systems that can assist healthcare professionals in delivering timely and accurate diagnoses, ultimately improving patient outcomes and quality of life. Earlier detection and diagnosis of diseases on time saves human life. In the modern world, computer aided technologies are used by radiologists or physicians to detect diseases in an earlier manner. From the past decades, Electroencephalography (EEG) signals have been used to detect and analyze the behavior of human beings and to detect diseases which are related to the human brain. Epilepsy is a neurological condition characterized by recurrent episodes of sensory disruption, loss of consciousness, or convulsions, all of which belongs to neurological disorder. In this paper, the Epilepsy disease is discussed using statistical statements with the anatomy of the human brain. The applications of EEG signals in various fields are also discussed in this paper.

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Overview of Epilepsy

In excess of 50million individuals all throughout the planet battle with epilepsy, with 5million individuals analyzed every year. In the U.S. there are in excess of 3 million individuals influenced with the sickness, with 180,000 new cases every year (Drazkowski,2007). The seriousness of epileptic seizures can fluctuate from giggling to abrupt unforeseen passing in epilepsy. The assaults can last from seconds to minutes (Fisheretal.2014;Shorvonetal.2011).While there is a lot of obscure information about epileptic seizures, the sub-atomic system includes lopsidedness in the restraint and excitation of neurons prompting hyper synchronization of neuronal action (Paz et al. 2015). Epilepsy is a condition with intermittent seizures, and it can begin any stage inlife. Early diagnosis expands future life expectancy as well as forestalls further harm during physiological turn of events (Gaitatzis et al. 2004). Myelination and synaptic pruning in the prefrontal cortex grow during youth and pre-adulthood (ages 4–21), boosting information processing efficiency and neuronal connections between the prefrontal cortex and other parts of the brain. Additionally, subcortical regions, like the caudate, putamen, thalamus, amygdala, hippocampus, and the cerebellar cortex are created to frame a developing cerebrum (Wierenga et al. 2014). Untreated seizures can lead to sociological and mental stress.

A high proportion of epileptic patients in agricultural nations stay untreated. As indicated by the World Health Organization (WHO), around 3/4th individuals with epilepsy in low-pay nations may not get legitimate treatment (WHO Report 2019) (Kutyniok& Labate, 2012). For example, 9 out of 10 epilepsy patients stay untreated in Africa (De Boer et al. 2008), due to lack of prepared clinical staff. Unfortunately, the interest for nervous system specialists outperforms their stockpile. Because of increasing population, demand for neurology services and neurologists has been on the rise(Dalletal.2013).This issue can be mitigated with computerized online seizure identification. This is particularly valid for long haul electroencephalographic observing. Continuous seizure recognition approaches can be utilized in epilepsy observing units to help neurologists. Outside of medical clinic settings, continuous seizure identification can be utilized to actuate drug conveyance frameworks to illuminate parental figures regarding possibly hazardous circumstances, or for neurostimulation.

Neurological illnesses are issues of the mind, spinal line and nerves all through our body, which emerge because of primary,bio chemical and electrical anomalies. Evaluating these problems require a careful neurological assessment performed by adroit neurologists and neuropsychologists. The World Health Organization, the World Bank, and the Harvard School of Public Health collaborated on the Global Burden of Disease research; there are around 600 known kinds of neurological infections starting from headaches to epilepsy. It is assessed by the World Health Organization that these issues have their impact on more than 1 billion individuals around the world (World Health Organization,2006). This number is required to develop with the ascent in the populace and these illnesses are turning into a genuine danger to general wellbeing. Intercession of these issues incorporates safeguard measures, way of life changes, physiotherapy or other treatment, neuro-recovery, medicine, or activitiesperformedbyneurosurgeons.A portionofthesideeffectsaddingto these issues are loss of sensation, muscle shortcoming, loss of motion, helpless coordination, seizures, activities and changed degrees of cognizance. The various kinds of neurological illnesses are examinedbeneath:

Dementia: This specific problem is because of the decay of scholarly and other psychological abilities that have their own seriousness which go about as an obstruction in their social or word related cooperation. (Abazid et al., 2021) Alzheimer disease is the most well-known sub-organization of Dementia common among individuals old enough gathering 65 and that's just the beginning.

Parkinson's sickness: Parkinson's disease is distinguished by the gradual loss of dopaminergic (mDA) neurons in the substantianigra, a mid brain area of the brain. Degeneration of mDA neurons causes dopamine deficiency in the striatum as well as neuronal denervation, which in certain persons leads to movement-related disorders as well as cognitive difficulties (Lin et al.,2016).

Stroke: A stroke in any case is also calleda Cerebro Vascular Accident(CVA) is a basic condition which brings about quick loss of mind work because of aggravation in the blood supply to the cerebrum (Hamilton et al.,2021).

Brain Tumor: A brain tumour is a mass or growth of abnormal cells in your brain that causes symptoms such as headaches and nausea. There are numerous distinct types of brain tumors. Depending on the type of braintumour, some are noncancerous (benign), while others are cancerous (malignant) (S.Liu et al.,2022).

Epilepsy: It is an ongoing neurological issue of the brain portrayed by paroxysmal generalized changes related with unreasonable release in huge totals of neurons. The pathogenesis of this problem isn't surely known. It isthe second most normal constant non-degenerative neurological illness seen by nervous system specialists. It is assessed that there are around 5.5 million individuals with Epilepsy in India (Rayetal.,2002). As indicated by the epilepsy establishment, the population with epilepsy in the USA is in excess of 2million and around 65 million individualsare burdened around the world (http://www.epilepsyfoundation.org).

Electroencephalogram

The revelation of electroencephalogram (EEG) in 1929 by the German specialist Hans Berger was a verifiable advancement which gave a novel neurologic and mental indicative apparatus at that point, without which the achievement of neurologic and mental conclusion and arranging neurosurgical usable strategies would now be unfathomable (Mesraoua et al.,2019). It was intelligible that mind electrical incitement created the contra sidelong engine reaction; however the possibility that an unconstrained cerebrum electrical flow could be recorded was obscure.

Canton was quick to find the discoveries by recording electrical heartbeats from the uncovered cerebrum of hares. In light of this perception, Berger played out the main EEG electrocardiogram recording during a neurosurgical procedure on a 17-year-old kid. During this period symptomatic apparatuslikelumbarcut,pneumoencephalographyandventriculographywere simply present to distinguish and limit "wiped out locales" in the mind, the disclosure of electroencephalography was an achievement in the progression of neuroscience and of neurologic and neurosurgical experts (Tudor et al., 2005). EEG changed every day neurologic and neurosurgical strategies, and spanned a timetable of around 40 years (1930-1970) until the appearance of PCtomography

What is anElectroencephalogram?

Nerve cells, or neurons, make up around 10 billion of the human brain's cells. Information processing in the brain's network of neurons is enormouslyparallelized.Nervecellsrespondtoinformationbyalteringtheflow of electrical currents across their membranes, which results in the creation of electric and magnetic fields that may be detected on the scalp.' Small electrodes are applied to the scalp in order to measure the electric fields. Electroencephalograms (EEGs) are used to capture the potentials between electrodes(EEG).Electricalactivityisrecordedusing EEG;tinymagneticfields generatedbytheneuronsofthebrainare measuredusing Magnetoencephalography(MEG)(Paetau&Mohamed,2013),whichcameinto subsistencein1970.

Applications ofEEG

Making the computer more empathetic to the user has encouraged in broadening all the functionalities of EEG. EEG is conventionally used to detect Seizures thereby identifying disorders like Epilepsy, Brain Tumor, Stroke, Dementia etc. It deals not only with the physiological level of the brain butalsoanatomyofthebrain.EEGisusedinavarietyofapplications,including Brain-Computer Interface (BCI), Brain Machine Interface (BMI), and Human-Computer Interaction (HCI). People with communication issues can use a computer and electrophysiological signals from their brain to interact with their surroundings via a cerebral or Brain Computer Interface (BCI). BMI provides a cutting-edgesolutionforparalysedorartificiallimbsthatlackcontrol.(Im2018).

Development in areas of Neuroprostheses and BMI has set a gatewayforvictimsoftraumaandstroke whoarehandicappedduetoparalytic attackoramputations.TheBMImakesuseofneuroprostheticsimplantedinthe brain to extract spatial degrees of freedom (e.g. Up/down, left/right) from the number of neurons excited. BMI also allows patients to communicate with a computer through their thoughts (Hamid, 2009; Paetau& Mohamed, 2013). A thought-controlled movement of the wheel chair is made possible to facilitate people who are physicallychallenged.

Devices on par withEEG

Imaging is an important category of demonstrative testing. CT, MRI, fMRI, and PET filters are all examples of specific imaging tests that may be used to evaluate a patient's health. These results let doctors assess whether the patient's brain has any lesions or abnormalities.

X-ray Imaging: In the 1970s, X-rays gave the main direct pictures of ordinary mind life structures. X-rays are a sort of ionizing radiation that are made because of associations among electrons and atoms made to fire at the objective article the cerebrum (Russo, 2017).

Positron Emission Tomography (PET): It estimates outflows from radioactively named synthetics considered tracer that are infused into the circulationsystem,whichbringsabouttheconveyanceofsyntheticsubstances (Santiago,2014).Whenthetracerarrives atthemindthePETgetsthesignals. TheSignalsarechangedoverinto2Dor3D picturesforadditionalassessment by thespecialist.

Single Photon Emission Computed Tomography: SPECT is a tomography methodologythatutilizesradioactivetra cerslikePETandthesignalswhichare recognized are taken care of into the PC to build a few dimensional pictures of dynamic brain locales (Russo,2017).

Computed Tomography (CT): It produces 3-D anatomic pictures of the X-ray thickness of the human body. Uncommon X-ray hardware is utilized to get numerous pictures from various points, and afterward consolidating them to show a cross-segment of body tissues and organs. CT of the cerebrum is a patient-accommodating assessment which is exposed to radiation (Martins etal., 2022).

Magnetic Resonance Imaging (MRI): It permits picturing within the body by utilizingenormousattractiveradiowaves ,andamazingPCs.Theexceptionally itemized pictures of an MRI can assist us with envisioning body tissues in an alternate manner. It is a comparable thing to taking virtual cuts or cuts of the body.ByutilizingongoingadvancesinMa gneticResonance(MR)innovationit is feasible to see both construction and usefulness of the cerebrum. X-ray doesn't utilize any radiation. X-ray represents no dangers except if members have any metal items embedded in their bodies (McDonald,2019).

Functional Magnetic Resonance Imaging (fMRI): It depends on attractive properties of blood to empower researchers to see pictures of blood stream in the mind. In this manner researchers can make "movies" of changes in brain activity as patients perform different assignments or are presented to different improvements (Huettel et al., 2014; Santiago, 2014).

Near Infrared Spectroscopy (NIRS): It is a noninvasive strategy that utilizes aligned frequencies of close to infrared light to enlighten tissue and action underneath the skin (for example inside the cerebrum). These frequencies of light dissipate in the tissue and are consumed distinctively subject to the measure of oxygen connected to hemoglobin. Unabsorbed light returns as an optical signal and is broken down to create a proportion of oxygenated hemoglobin to add up to hemoglobin (Sakurada et al., 2022).

Working of EEG

Electroencephalography is the study of recording and interpreting electrical activity in the brain. In an electroencephalograph, electrical impulses are converted into pen movements by use of electrodes, which are special sensors attached to or just under one's head and connected to an electroencephalograph. The EEG equipment amplifies the data and records theminawavepatternongraphpaperora computerscreen(Taylor&Francis Group, 2018). Electrical activity on an EEG may be used to diagnose a wide range of diseases affecting the brain using these recordings, which display millions of neurons' activity atonce.

Electrode Placement

A silver chloride (AgCl) coating is applied on tiny metal discs, such as stainless steel, tin, gold, or silver, in order to conduct electricity. The input signals to the differential amplifiers are provided from the electrodes which are placed on the scalp after applying a conductive gel. The 10-20 System is an international placement guide for positioning electrodes on the scalp and provides the connection between a brain electrode's placement and the region underneathitcoveringadistancefromnaison(dipbetweennoseandforehead) andinion(thebumpatthebackofthehead abovetheneck)(Sazgar&Young,2019).TheEEGisarecordofbrainactivitywhichisa consequenceofthe activity of thousands of neurons in the brain. The pattern of brain activity dependsonthelevelofaperson'sarousali.e.Fastwavepatternsareobserved using EEG if a person is excited, otherwise slow waves are recorded (Chavakula et al., 2020; Sazgar& Young,2019).

The EEG is used to record brain activities for varied purposes such assleepresearchandalsoindiagnosingdisorderssuchasdementia,epilepsy, tumors, schizophrenia etc. (Schuele & MPH, 2021) Figure 1.2 represents 10-20 placements of electrodes inside view. A letter designates the hemisphere for each site. The letter identifies the lobe. Frontal, Temporal, Central, Parietal & Occipital regions represented as F, T, D, P, Orespectively.

For the purpose of simplified identification an imaginary lobe called central lobe is used by Electroencephalography. The right hemisphere is represented by 2, 4, 6 & 8 whereas the left hemisphere is represented by 1, 3, 5 & 7. The z denotes an electrode placed in the middle line. Electrodes with small numbers are closer to the midline than electrodes with larger numbers. The10 & 20 refers to the 10/20 percentage of inter electrode distance. Another important factor that is to be noted is that the number of electrode usage can also vary. For example, in case of neonates the size of the head being small; the electrode usage is considerably reduced (Chavakula et al., 2020; Rich etal., 2017; Sazgar& Young, 2019).

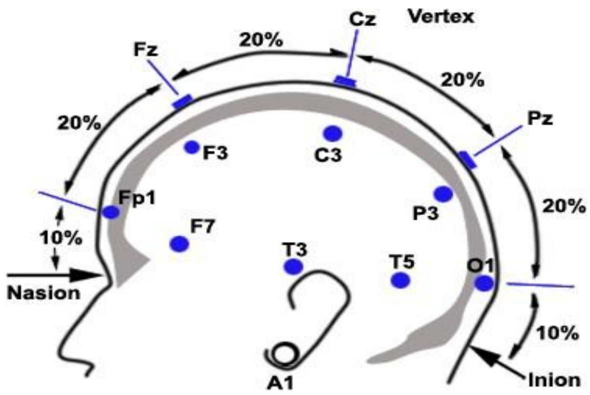

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Figure1.Electrodes placement in side view

Recording EEG using diverseequipment

EEG recording equipment generally is classified into three types and is discussed in the following section.

Conventional Scalp EEG: The electrodes applied to scalp using conductive gel or paste and then lightly abraded to minimize resistance before being recorded non-invasively (Mesraoua et al., 2019). The brain activities are monitored without giving any physical encumbrance to the patient. Figure 1.3 shows the disc electrodes attached to individual wire which are placed on the scalp. The data collected for this study was acquired from this type of conventional scalp EEG.

Electrocorticogram ECoG or intracranial EEG (iEEG): The electrodes are surgicallyimplantedintothebraintomonitorth ebrain'selectricalactivity.Inthis case, the electrodes are directly in touch with the surface of cerebral cortex. ECoG is considered agoldstandard for assessing neuronalactivities in patients with Epilepsy (Mesraouaetal.,2019;Shiman,2018).Neurosu rgerytechniques have been prevalent for many decades, but the risk involved in exposing the brain to infection is alwayspresent.

Figure 2 **EEG cables**

EEG caps: These caps are soft caps and can be used for ambulatory EEG studies and tests on young children who need not strictly adhere to one place. They fit snugly over the head to hold the electrodes in fixed positions, even whenthepatientnodshisheadorengage shimselfinanyphysicalactivity.The EEG caps are designed to be supple so that they could be covered with a hat or scarf for various discreet reasons as desired by the patients. EEG cap designs can also vary for different applications (Li & Teichert,2020).

Some caps are designed to suit for activities like biofeedback studies, where a limited number of electrodes may be adequate and under a different circumstanceitcouldbedesirablethatm orenumberofelectrodesarerequired to observe patients with epilepsy, where an examination of isolated activity of aspecificregionofthebrainisrequired(M azureketal.,2021;Mesraouaetal.,2019; Shiman,2018).

Epileptic Seizure

The human cerebral cortex is made up of the brain and possesses immenseandrichspatio-temporaldynamicsthatareuniquelyfou ndinhumans (Buzsaki,2006).Chemicalandelectricalsi gnalsareusedbymillionsofneurons in the brain for interaction. The Action Potential is a kind of data transmitted by nerve cells. The action potential is also known as a "spike" or "impulse" by neuroscientists, and it is characterised as brief discharges as illustrated in Figure1.4.

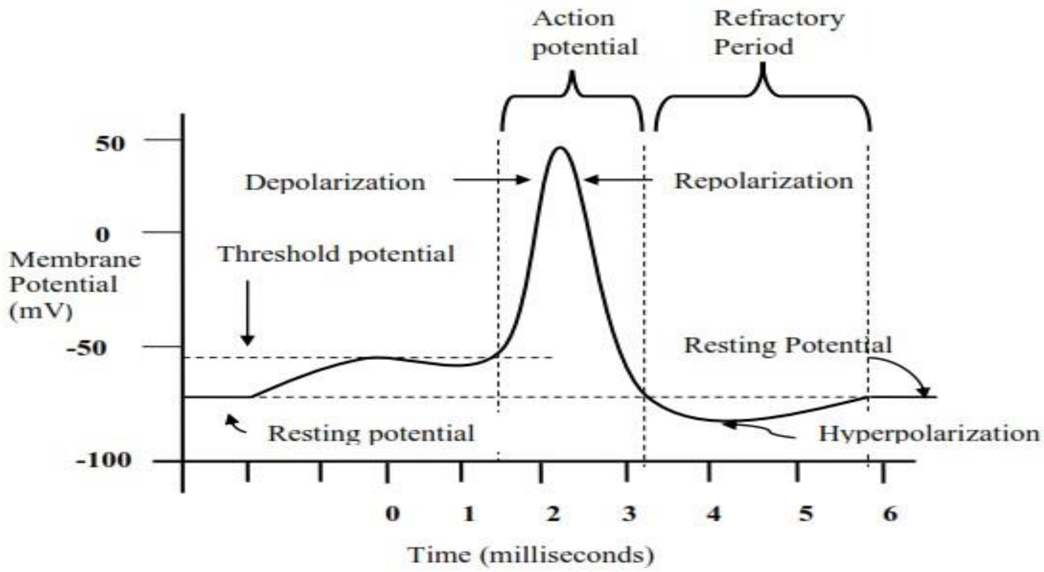

Figure 3 Action Potential produced in aNeuron

A seizure is an abnormal electrical activity and when it happens repeatedly in the brain, it is called epilepsy (Tyagi et al., 2022). This disorder's symptoms and features might be symptomatic or idiopathic. Seizures are divided into two categories: partial and generalised seizures. Generalized seizures occur when a seizure extends to two or more areas of the brain, whereas partial seizures affect just one area of the brain (Satapathy et al., 2019).

Electrical fields are captured by amplifying voltage changes between electrodesonthescalp.Inclinicalpractise ,thescalpEEGisfrequentlyusedto diagnose epilepsy. Silver-chloride electrodes are commonly employed as electrical potential conductors. The conducting paste that coats the skin serves as an interface between the scalp and the electrode, allowing for better connection. It connects the EEG device to the person's electrical potentials.

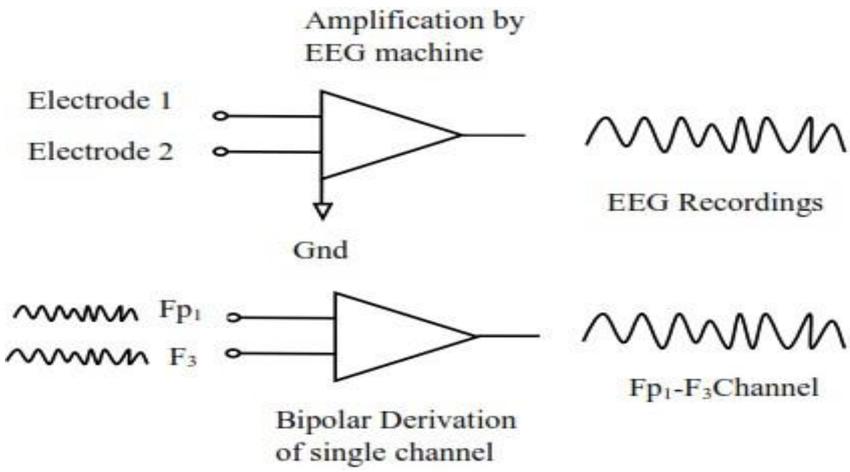

Figure 4 Single amplified output using twoinputs

Montage refers to the set of electrodes that is viewed at a certain point in time. With 21 electrodes and 16 channels, there are 21 or 1.43*10 potential montages. The EEG signal is sent to the amplifier via the montage selector. Filters, voltage dividers, IO connectors, and calibration devices are included in EEG amplifiers. Montages are classed as either referential (monopolar) or bipolar. The difference between the value of the scalp electrode and the value of the reference electrode is recorded by amplifiers using a common reference derivation.AsillustratedinFigure1.5,thebipolar montageconnectsserialpairs of electrodes in straight longitudinal or coronallines.

Morphology of EEGSignals

The recorded electrical activity is described in terms of frequency or wavelength,voltage,waveform,regulation,and otherparticulardescriptorsand measurements. Random, serial, or continual occurrence, Inter-hemispheric coherence (homologous regions) and reactivity (eye opening, mental calculation, sensory stimulus, movement, emotional state) (Valdes-Sosa et al., 2020).

The reaction of EEG components to changes in neurophysiology is anessentialpartoftherecordingofEEGdata.Inordertodistinguishoneaction from another with identical features, a signal pattern is necessary. There are five distinct frequency bands that may be categorized as alpha, beta, theta, delta, and gamma when it comes to the frequency of brain waves. Below is a short summary of the many types of waves (Kodish2021).

- Delta waves have signals that vary from 0.5 to 4 Hz and are symptomatic of brain injury or illness. These large-amplitude waves develop during profound slumber. These waves are not seen in normal, awake people (Kodish,2021).

- Theta waves are brain impulses that have a frequency range of 4 to 7.5 Hz. Theta waves are related to intense meditation and develop in the unconscious mind. This rhythm is present throughout sleepiness and during various phases of sleep (Kodish, 2021; McDaneld,2021).

- Alpha waves occur as a sinusoidal shaped signal with frequency rangeof8to13Hzinadults.Thesesignalsarepredominantinthe adults who are awake but not being engaged in intense mental activity. However, sometimes alpha waves may manifest themselves as sharp waves(Douglas Fields, 2020).
- Fast, low-amplitude waves in the 1426-Hz range are known as beta waves. During mental processes, they are more likely to be foundinthecortex,wheretheyaremorelikelytobefound(Kodish, 2021).

- Frequencies over 30 Hz and up to 45 Hz are associated with a stateofactiveinformationprocessinginthecortex,andareknown as gamma waves. (Kodish, 2021; McDaneld,2021).

Figure 1.6 represents the frequency distribution of the obtained EEG signal in accordance with various bands of frequency content present in the signal. The frequency content present in the signal for one patient clearly indicatesthevaryingfrequencybandspresentintheEEGsignal.Signalsinthe Delta, Theta, Alpha, and Beta bands are represented in the frequency spectrum.Figure1.7showsthequantityofchangesinfrequencydistributionin all samples. It clearly details the amplitude of components of frequency bands present in thesignals

Applications of EEGSignals

InstantaneousEEGreadingsmaybeutilizedtotrackbrainwaveactivity. Many aberrant brain disorders and cognitive deficits may be diagnosed and predicted using EEG data. (Hayes & Stratton, 2017; Siuly et al.,2017).Doctors and skilled neuro scientific researchers could set up and evaluate recordings using electrode caps having 64 channels or more under regulated laboratory circumstances. These high-density electrodes were equallyspreadthroughoutthehumanscalptoas sistresearchersindiscovering the underlying neurological systems involved in behaviors, cognition, or emotional processing, which were previously unknown (Hayes & Stratton, 2017; Siuly et al., 2017; Wirz et al., 2017). Recent advancements in computer hardware and processing technology have made it possible for researchers from all over the world to substantially increase current information about the humanbrain'scomplexityandobtaindeeperinsightsintobrainfunctionsand architecture.

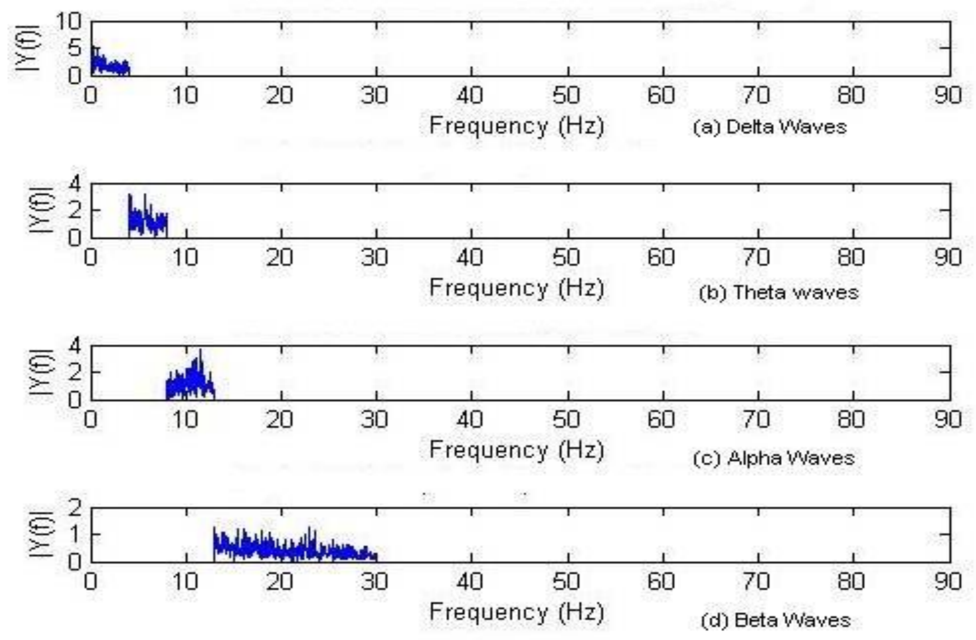

Figure 5 Single–sided amplitude spectrum of different frequency band of asignal

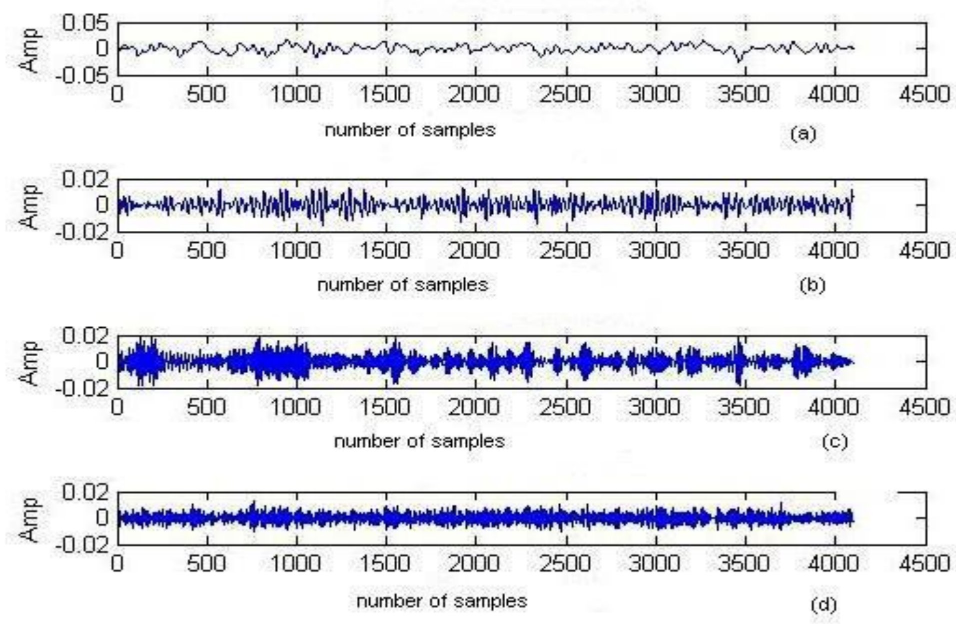

Figure 6 Amplitude content of various frequencies present in anEEG signal

The following are the main applications of the EEG signals which can be utilized for various research areas.

Clinical and Psychiatric Studies

EEG is utilised in clinical and psychiatric settings to assess patients' cognitive states, locate lesion sites and categorize symptoms. Additionally, EEG is often used to assess the effectiveness of medical and psychiatric treatment (e.g., in cognitive-behavioral therapy). Virtual reality therapy is becoming morepopular, and EEG data is being recorded to track the progress ofpatients'brainsovertimeasaresult.Inaddition,EEGsignalsmaybeutilized to diagnose epilepsy illness in certain cases (Hughes & Wilson, 2013; Li &Teichert,2020).

Brain Computer Interfaces (BCI)

BCI are new but rapidly growing area for EEG. When receiving inputs, performing physical motions, or learning and remembering information, it is known which brain regions are engaged. As a result, particularly effective and customised EEG applications for steering devices utilizing brain activity have been developed. This might allow disabled people to control their wheelchairs or move acursor on a computer screen. It could also be implemented in military settings where troops wearanexoskeleton and wearanEEG helmet that allows themtomove,lift,andtransportheavyobjectsmerelybythinkingaboutit.(Türk and Özerdem2019).

Psychology and Neuroscience

The most common use of EEG in psychology research is to look at the brain processes to support attention, learning, and memory. Event-Related Potentials (ERPs) are derived from a constant stream of Brainwave analysis basedonhugetrialrepetition,allowingdefiningneurosciencecausedbystimuli on a highly precise timeframe (tens of milliseconds) (Hayes & Stratton,2017).

CONCLUSION

In conclusion, the research undertaken provides a comprehensive approach to the detection and classification of epilepsy using EEG signals, employing advanced methodologies to enhance diagnostic accuracy and efficiency. The study begins with a detailed overview of epilepsy, its prevalence, and the significant impact it has on individuals and healthcare systems globally. Emphasizing the necessity for early detection and precise diagnosis, this research leverages electroencephalography (EEG) as a pivotal tool in monitoring and diagnosing neurological conditions. The hybrid classification technique proposed integrates Dual-Tree Complex Wavelet Transform (DTCWT) for signal decomposition, followed by feature extraction and classification using Neural Networks and Adaptive Neuro-Fuzzy Inference System (ANFIS). This hybrid approach addresses the limitations of traditional methods by enhancing the sensitivity, specificity, and accuracy of epilepsy detection.The research demonstrates the efficacy of the proposed method through extensive experimentation using EEG datasets from Bern-Barcelona and CHB-MIT databases. Results indicate that the hybrid classification system, particularly when incorporating DTCWT, significantly outperforms traditional techniques, achieving high detection rates and low rejection rates. The use of Neural Networks for initial classification, followed by ANFIS for severity analysis, ensures robust performance even with limited data, making it suitable for practical applications in clinical settings. Furthermore, the study highlights the importance of integrating various feature extraction techniques and classifiers to capture the complex nature of

EEG signals and accurately identify epileptic patterns.Overall, this research contributes to the field of biomedical engineering and neurology by providing a reliable, efficient, and scalable solution for epilepsy diagnosis. The integration of advanced computational methods with EEG signal analysis not only enhances diagnostic capabilities but also opens avenues for further research into automated detection systems for other neurological disorders. This work underscores the potential of hybrid models in medical diagnostics, promoting the development of intelligent systems that can assist healthcare professionals in delivering timely and accurate diagnoses, ultimately improving patient outcomes and quality of life.

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REFERENCES

Abazid, H., Mandall, N., Amoud, H., Saleh, M., & Abdelkader, M. (2021). Deep learning approach for early detection of dementia from brain EEG signals.

Buzsaki, G. (2006). Rhythms of the brain. Oxford University Press.

Chavakula, V., Bhatt, R., Bollo, R. J., Duhaime, A.-C., & Eskandar, E. N. (2020). Mapping brain function with invasive EEG. Neurosurgical Review, 43, 153-161.

De Boer, H. M., Mula, M., & Sander, J. W. (2008). The global burden and stigma of epilepsy. Epilepsy & Behavior, 12(4), 540-546.

Drazkowski, J. F. (2007). Management of epilepsy. Continuum (Minneapolis, Minn.), 13(4), 117-134.

Hayes, M. W., & Stratton, P. B. (2017). Event-related potentials: A methods handbook. Sage Publications.

Kutyniok, G., & Labate, D. (2012). Shearlets: Multiscale analysis for multivariate data. Birkhäuser.

Li, M., & Teichert, T. (2020). Design and implementation of a low-cost portable EEG device for cognitive research. Journal of Neuroscience Methods, 337, 108671.

Mesraoua, B., Deleu, D., Mohammed, U., & Melikyan, G. (2019). EEG and seizure semiology in the diagnosis of epilepsy. Journal of Clinical Neurophysiology, 36(1), 1-7.

Paetau, R., & Mohamed, I. S. (2013). Magnetoencephalography (MEG): The clinical applications. In Handbook of Clinical Neurology (Vol. 116, pp. 167-177). Elsevier.

Satapathy, S. C., Kumar, A., & Sahoo, A. (2019). EEG signal classification using neuro-fuzzy network. Journal of King Saud University-Computer and Information Sciences, 31(1), 52-61.

Schuele, S. U., &Lüders, H. O. (2021). Intractable epilepsy: Management and therapeutic options. Springer.

Shiman, R. A. (2018). Intracranial electroencephalography in epilepsy: current practices, challenges, and future directions. Epilepsy & Behavior, 88, 4-11.