International Journal of Electrical and Computer Engineering (IJECE)
Vol. 14, No. 5, October 2024, pp. 6047~6056
ISSN: 2088-8708, DOI: 10.11591/ijece.v14i5.pp6047-6056

Cloud based prediction of epileptic seizures using real-time electroencephalograms analysis

Gousia Thahniyath[1], Chelluboina Subbarayudu Gangaiah Yadav[2], Rajagopalan Senkamalavalli[3], Shanmugam Sathiya Priya[4], Stalin Aghalya[5], Kuppireddy Narsimha Reddy[6], Subbiah Murugan[7]
[1]Department of Computer Science and Engineering, Dayananda Sagar University, Bangalore, India
[2]Department of Electronics and Communication Engineering, Chaitanya Bharathi Institute of Technology, Andhra Pradesh, India
[3]Department of Computer Science and Engineering, Kammavari Sangham Institute of Technology, Bangalore, India
[4]Department of Electronics and Communication Engineering, Panimalar Engineering College, Chennai, India
[5]Department of Electronics and Communication Engineering, St. Joseph's College of Engineering, Chennai, India
[6]Department of Electronics and Communication Engineering, Vardhaman College of Engineering, Hyderabad, India
[7]Department of Biomedical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India

Article Info

Article history:

Received Jan 22, 2024
Revised Jul 5, 2024
Accepted Jul 9, 2024

Keywords:

Cloud computing
Electroencephalograms analysis
Epileptic seizure prediction
Intelligent healthcare systems
Signal processing

ABSTRACT

This study aims to improve the accuracy of epileptic seizure prediction using cloud-based, real-time electroencephalogram analysis. The goal is to build a strong framework that can quickly process electroencephalogram (EEG) data, extract relevant features, and use advanced machine learning algorithms to predict seizures with high accuracy and low latency by taking advantage of cloud platforms' computing power and scalability. The main objective is to provide patients and their caregivers with timely notifications so that they may control epilepsy episodes proactively. The goal of this project is to improve the lives of people with epilepsy by reducing the impact of seizures and improving treatment results via real-time analysis of EEG data. Cloud computing also allows the suggested seizure prediction system to be more accessible and scalable, meaning more people worldwide could benefit from it. This section discusses the results from five separate datasets of patients with epileptic seizures who underwent EEG analysis with the following details as frontopolar (FP1, FP2), frontal (F3, F4), frontotemporal (F7, F8), central (C3, C4), temporal (T3, T4), parieto-temporal (T5, T6), parietal (P3, P4), occipital (O1, O2), time (HH:MM:SS).

Corresponding Author:

Gousia Thahniyath
Department of Computer Science and Engineering, Dayananda Sagar University
Innovation Campus, Kudlu Gate, Hosur Main Road, Bangalore, Karnataka, India
Email: gousia-cse@dsu.edu.in

1. INTRODUCTION

This research aims to provide a new method for forecasting epileptic seizures by analyzing electroencephalogram (EEG) data in real-time on the cloud. The unpredictability of epilepsy, a neurological illness marked by repeated convulsions, causes substantial hardship for those afflicted. Timely intervention and better patient outcomes may be achieved with early seizure prediction. An EEG prediction model that can identify preictal (period immediately before a seizure occurs) rhythms is our goal, and we want to achieve this by using recent developments in cloud computing and machine learning. Our mission is to develop a real-time EEG data analysis tool that may help people with epilepsy, their loved ones, and medical professionals better prepare for and respond to seizure episodes.

Our study's main contribution is integrating cloud-based infrastructure with advanced machine learning algorithms designed for EEG analysis. We aim to address the drawbacks of conventional seizure prediction methods, such as their reliance on offline processing and lack of real-time capabilities, by using cloud platforms' scalability and computing capacity. In addition, our method is designed to tackle the issue of tailored seizure prediction models that consider that each person's EEG patterns and seizure dynamics are unique. We are adding elements like patient-specific data and adaptive learning methods to make our prediction engine more accurate and reliable. By showing that cloud-based predictive analytics for neurological illnesses is feasible and useful, our study has therapeutic implications and adds to healthcare informatics. One of our long-term goals is to improve the accessibility and usefulness of seizure prediction tools by integrating them into current healthcare infrastructure and making them available remotely using cloud computing. This will benefit patients all over the globe.

Our effort aims to provide a cloud-based platform for real-time EEG analysis to improve current methods for predicting epileptic seizures. Our goal is to improve the lives of people with epilepsy by developing a scalable and effective solution for early seizure detection using cloud computing and machine learning methods. The rest of the paper is organized as real-time EEG analysis for epileptic seizures is summarized in section 2. Section 3 shows the outcomes of applying the EEG analysis parameters to five patents with varying timings. The last section, section 4, presents the conclusion.

Cutting-edge technology has improved neurological disease therapy. Millions worldwide suffer from epilepsy, a neurological illness that causes seizures. Epileptic episodes must be predicted early and accurately for effective treatment and quality of life. Conventional EEG analysis methods have limited real-time processing and predicting accuracy [1]. Due to rapid advances in cloud computing, image processing, and signal processing, epileptic seizure prediction has changed. Cloud computing for real-time EEG monitoring improves seizure prediction in epilepsy patients by using cutting-edge image and signal processing. This research uses cloud-based technology to improve epilepsy care by predicting more accurately and quickly [2].

The ability to elastically access data and processing power has made cloud computing a basic technology. Its medical usage has enabled substantial advancement. Medical professionals may securely save huge EEG data on the cloud for worldwide data interchange and cooperation [3]. Cloud-based systems may build complex continuous EEG analysis algorithms due to their high processing capabilities. Cloud resources are scalable so the system can handle a rising mountain of data for real-time monitoring and analysis. This study combines cloud computing infrastructures to swiftly interpret EEG data for epileptic seizure analysis and prediction [4]. Cloud computing and powerful imaging and signal processing may help predict epileptic seizures. Image processing may reveal brain activity anomalies that precede seizures in EEG images [5]. Contemporary wavelet transforms and neural network methods examine EEG data in the frequency domain to detect minute seizure signals. This project will combine many methodologies into a predictive model that can recognize complex patterns and outliers to enhance seizure predictions. Cloud computing infrastructure for fast analysis and real-time prediction improves epilepsy management efficiency [6]. This research examines how cloud computing, image processing, and signal processing may anticipate epileptic seizures. A reliable prediction model that can greatly enhance epilepsy patients' access to personalized therapy is the main aim. This study aims to create and deploy a cloud-based platform that processes massive EEG datasets using cutting-edge image and signal processing algorithms to identify early epileptic episodes [7].

The convergence of cutting-edge technology has transformed healthcare by solving innovative new issues. Unpredictability makes epilepsy one of numerous health disorders difficult. Due to the necessity for timely action, epileptic seizure prediction uses cloud computing, image processing, and signal processing [8]. Cloud computing, a technical marvel that has smashed borders, underpins this new concept. Cloud computing has altered healthcare with its scalable, on-demand infrastructure and information exchange capabilities. The cloud can securely store huge EEG data for epilepsy management. The cloud's flexibility meets processing demands, enabling complex real-time EEG analysis methods [9]. Innovative image and signal processing approaches have been created alongside the cloud's capabilities. Researchers have understood complex EEG spatial patterns using advanced image processing. EEG recordings may be analyzed using Fourier analysis and machine learning techniques to identify temporal and spectral changes that may suggest a seizure. Using these strategies enhances prediction model resilience and accuracy [10].

This novel approach to expanding healthcare technology usage is an essential addition to the area. The study methodology's emphasis on predictive algorithms and an appealing user interface ensures accessibility and user-friendliness for healthcare professionals and patients [11]. Epilepsy's numerous brain abnormalities have long been difficult to treat. Deciphering seizure patterns requires unique methodologies due to its unpredictability. EEG real-time brain activity analysis is a huge step toward accurately predicting and treating seizures [12]. Healthcare is booming, and cloud computing is key. Because it can bypass physical constraints, it has endless storage and processing power, offering new medical research options. The cloud can immediately handle enormous EEG data for epilepsy research as a virtual neural network [13]. Only contemporary image and signal processing approaches may reveal crucial insights into EEG data. Image processing techniques meticulously analyze EEG images to reveal undetectable patterns. Advanced temporal and frequency domain signal processing may detect seizure precursors [14]. It is easier to deal with details and assets creating a more cohesive ecosystem [15]. Increased connectivity and productivity in the cloud are both benefits of interoperability. It expands our knowledge of epilepsy and foreshadows a humane medical technology. Cloud computing, image processing, and signal processing enable us to understand seizures at a basic level rather than merely predict them. The results of this investigation are significant for creating personalized epilepsy treatment programs [16]. The data is stored, analyzed, and shown using ThingSpeak, a cloud-based IoT platform. It has a simple interface which can be utilized to observe water levels, observe data from the past, and expand discovering which can be applied to handle water resources better [17].

Epileptic seizures, which cause sudden, abnormal brain electrical activity, present several problems to neurology. Despite advances, doctors aim to predict these seizures. Cloud computing, image processing, and signal processing may help solve complex brain signals in the digital age [18]. Scalable and available cloud technologies are the digital canvas for this innovative undertaking. Cloud computing acts as a "virtual neural network." in epilepsy research processing, having massive amounts of information in real-time. The cloud's collaborative capabilities allow researchers to examine undiscovered EEG data, encouraging a global information-sharing network [19]. Accurate seizure prediction requires imaging and signal processing. Inspired by neural networks, image processing methods decipher complicated spatial patterns in EEG images to capture details the human eye misses. Signal processing systems must cross the frequency spectrum to understand EEG temporal details. Combining these strategies is like a jigsaw puzzle with connected pieces [20]. It signals a new era in neurological care, where data-driven insights will redefine patient experience. This research imagines a future where epilepsy patients may use technologically advanced social networks for comfort and support [21].

Epileptic seizures test the brain's delicate neuronal dance mysteriously. Despite medical advances, epileptic seizure prediction remains difficult. Cloud computing, image processing, and signal processing illuminate brainwaves in the digital age [22]. Cloud computing is an example of human creativity in the digital cosmos, providing an almost endless canvas for computational research. Cloud systems drive neuroscience breakthroughs because of their scalability and computational power. In epilepsy research, the cloud becomes a brain nexus where powerful algorithms can immediately analyze massive data. Cloud-based tools speed up research and enable scientists to study EEG data [23] deeply. A detailed understanding of brain signals is needed to anticipate epilepsy accurately. Inspired by the brain's neural networks, image processing techniques examine EEG images pixel by pixel to identify tiny changes. Signal processing methods concurrently explore the time and frequency domains to understand brainwave dynamics [24]. This work illuminates a game-changing potential for neurological therapy beyond fundamental science. When physicians can predict seizures in real-time, epileptic patients may feel more in control and confident. Combining cloud computing, image processing, and signal processing ushers in patient-centered, compassionate healthcare [25]. Their unpredictability challenges medical expertise, sparking a quest for new treatments. Combining cloud computing, image, and signal processing transforms epileptic brainwave understanding [26]. Cloud computing has revolutionized neural data analysis. Cloud services may become neural networks with extraordinary processing power in this enormous cyberspace. Cloud computing gives researchers access to undiscovered EEG data. Its scalability allows systematic analysis of epileptic brain activity, leading to unexpected results [27]. The scope is to expand an IoT system that assists sustainability and energy efficiency by providing real-time observation and insights into power utilization [28]. The benefits of incorporating the Internet of Things and Geographic Information Systems in agriculture, with a particular accent on the possibility of transforming soil observing and nutrient management to raise crop output while minimizing negative environmental effects [29].

2. METHOD

The notation depicts a conventional 10-20 EEG electrode placement method. This brain activity mapping technique is utilized clinically. Odd-numbered electrodes are placed on the left side of the scalp, and even-numbered electrodes on the right. Epilepsy diagnosis and treatment typically include EEG monitoring. Certain brain electrical activity patterns may signal epilepsy or assist in diagnosing it on the EEG.

2.1. Different types of EEG

2.1.1. Routine EEG

This is the standard EEG recording typically done in a clinical setting. It involves placing electrodes on the scalp to record electrical activity from the brain, usually 20-30 minutes. Routine EEG can capture interictal epileptiform discharges, which are abnormal electrical patterns between seizures, and help in diagnosing epilepsy. Pros: Routine EEG is non-invasive, relatively inexpensive, and readily available. It helps in diagnosing epilepsy by detecting interictal epileptiform discharges. It can also provide information about background brain activity and assist in monitoring the effects of medication. Cons: Routine EEG has limitations in capturing epileptic events, as it only records for a short duration and may miss transient abnormalities. It may not always correlate with clinical symptoms, leading to false-negative or false-positive results. Interpretation of routine EEG requires expertise, and subtle abnormalities can be overlooked. Figure 1 shows the hybrid machine learning-swarm intelligence epileptic seizure detection model. Human brain EEG data are preprocessed and used for stationary wavelet transformation. EEG waves are divided into many subbands. The mean absolute value, standard deviation, skewness, kurtosis, root mean square (RMS) power, the ratio of neighboring sub-bands mean absolute values, and other Hjorth parameters have been retrieved as features for each coefficient in each sub-band. The deep neural network (DNN) model is trained using optimum features picked using the binary dragonfly method from each sub-brands retrieved features. After training, the model classified EEG signals as seizure or normal.

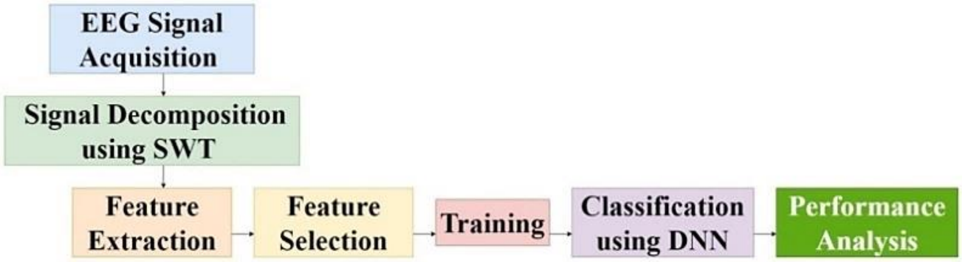

Figure 1. System flow diagram for epileptic seizure detection

2.1.2. Long-term video EEG monitoring

LTM involves continuous EEG recording combined with simultaneous video monitoring over an extended period, ranging from several hours to days or weeks. This type of EEG is crucial for capturing seizure events and correlating them with EEG findings. It provides valuable information for determining seizure type, localization, frequency, and response to treatment. Pros: LTM allows continuous recording of EEG activity and video monitoring, enabling the correlation of clinical events with EEG findings. It provides comprehensive data on seizure frequency, duration, and semiology, aiding diagnosis and treatment planning. LTM can capture both ictal and interictal epileptiform discharges, enhancing diagnostic yield. Cons: LTM is resource-intensive, requiring specialized equipment and personnel for prolonged monitoring. Patient compliance and tolerance for long-term monitoring may pose challenges. Interpretation of LTM recordings can be time-consuming and may require expert review. EEG signals are recorded to identify epileptic seizures. Pre-processing includes sampling, filtering, and artifact removal. After pre-processing, the signal is feature extracted for categorization. Final categorization uses machine-learning approaches to identify epilepsy. Figure 2 depicts the procedure.

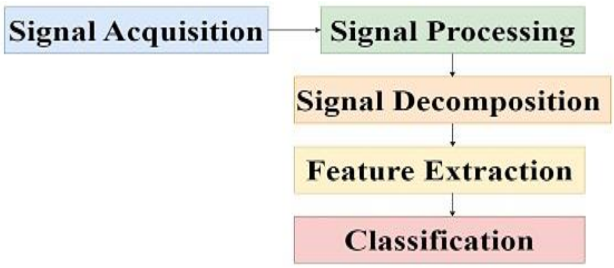

Figure 2. Detecting epilepsy seizures

2.1.3. Ambulatory EEG

Ambulatory EEG involves recording EEG activity while the patient engages in normal daily activities outside the hospital setting. The electrodes are usually attached to the scalp with a portable recording device worn by the patient. Ambulatory EEG can provide insights into seizure patterns that may not be captured during routine EEG and can also help assess the efficacy of medications and identify triggers for seizures. Pros: Ambulatory EEG allows recording brain activity over an extended period in the patient's natural environment, increasing the likelihood of capturing seizure events that may not occur during a routine EEG. It provides valuable insights into daily patterns of seizure activity and can help identify triggers or associations with specific activities. Ambulatory EEG is less restrictive than inpatient monitoring, promoting patient comfort and compliance. Cons: Ambulatory EEG recordings may be susceptible to motion artifacts and environmental interference, affecting data quality. Interpretation of ambulatory EEG requires expertise to differentiate epileptic activity from artifacts accurately. The duration of ambulatory EEG monitoring is limited, and longer monitoring periods may be necessary to capture infrequent or nocturnal seizures. Figure 3 shows that generalized epileptic seizures may be absent (petit mal), tonic-clonic (grand mal), atonic, myoclonic, clonic, and tonic.

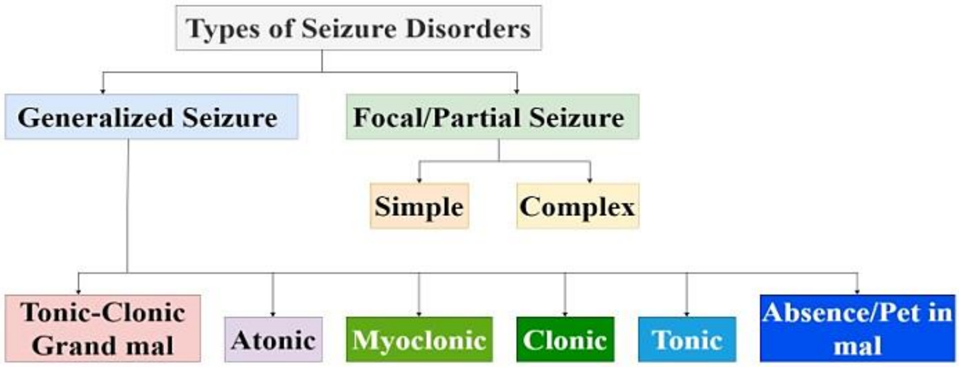

Figure 3. Types and subtypes of seizures

2.1.4. Intraoperative EEG: Intraoperative

EEG is recorded during neurosurgical procedures for epilepsy, such as epilepsy surgery or implantation of devices like vagus nerve stimulators or deep brain stimulators. It helps guide the surgical procedure and ensure that critical brain regions are not disturbed during surgery. Pros: Intraoperative EEG provides real-time monitoring of brain activity during neurosurgical procedures for epilepsy, allowing neurosurgeons to localize epileptogenic zones accurately and avoid damage to critical brain regions. It helps guide surgical resection boundaries and assess the efficacy of interventions such as cortical stimulation. Intraoperative EEG can provide immediate feedback on the effects of surgical manipulations, facilitating intraoperative decision-making. Cons: Intraoperative EEG requires specialized equipment and expertise to perform and interpret in the operating room setting. Surgical procedures and anesthetics can affect EEG signals, complicating interpretation and reducing signal quality. Intraoperative EEG may not always correlate with preoperative findings or postoperative outcomes.

3. RESULTS AND DISCUSSION

3.1. Quantitative EEG (qEEG)

Quantitative EEG involves the analysis of EEG data using advanced computational techniques to extract quantitative measures of brain activity. It provides additional information about brain function and can help localize epileptogenic zones and predict treatment outcomes. Pros: qEEG involves advanced computational EEG data analysis, providing objective measures of brain activity and connectivity. It enables quantitative assessment of epileptiform abnormalities, network dynamics, and spatial localization of epileptogenic zones. qEEG can facilitate early detection of epileptic activity and prediction of treatment outcomes. Cons: qEEG requires specialized software and expertise to accurately perform data analysis and interpretation. The clinical utility of qEEG metrics may vary depending on patient characteristics, electrode placement, and analysis techniques. Standardizing qEEG protocols and validation of quantitative measures are ongoing challenges. The abbreviation typically represents Frontopolar (FP1, FP2), Frontal (F3, F4), Frontotemporal (F7, F8), Central (C3, C4), Temporal (T3, T4), Parieto-temporal (T5, T6), Parietal (P3, P4), Occipital (O1, O2), Time (HH:MM:SS). Figure 4 shows the 5 patients' EEG analysis readings. EEG-based patient statuses are depicted in Tables 1 to 5, each shows the EEG samples of the first to fifth patients, respectively.

The notation depicts a conventional 10-20 EEG electrode placement method. This brain activity mapping technique is utilized clinically. Odd-numbered electrodes are placed on the left side of the scalp, and even-numbered electrodes are on the right. Epilepsy diagnosis and treatment typically include EEG monitoring. Certain brain electrical activity patterns may signal epilepsy or assist in diagnosing it on the EEG. EEG detects aberrant brain electrical activity, including spikes, sharp waves, and rhythmic patterns, which diagnose epileptic seizures. EEG monitoring over time helps physicians discover atypical seizure patterns, locate the brain's seizure cause, and customize treatment techniques. EEG helps confirm epilepsy, identify seizure types, guide drug management, and assess therapy efficacy.

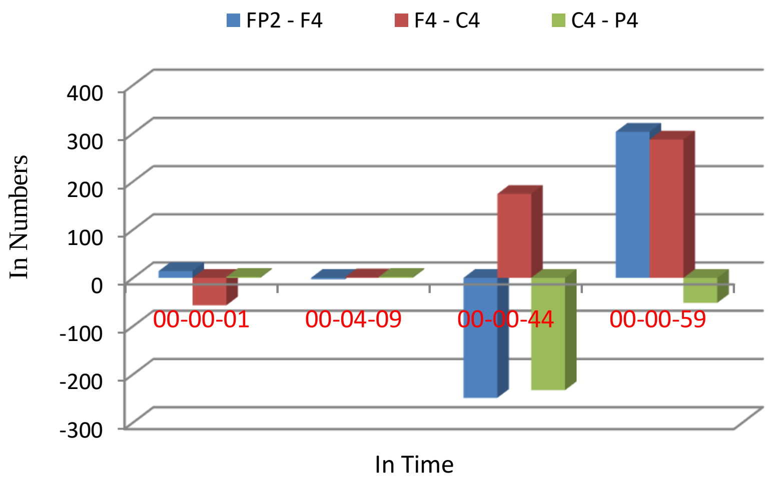

Figure 4. Patient's status

Table 1. The first patient's EEG samples

Time (in hh-mm-ss)	FP2 - F4	F4 - C4	C4 - P4	P4 - O2	FP2 - F8	F8 - T4	T4 - T6	T6 - O2	FP1 - F3	F3 - C3	C3 - P3	P3 - O1	FP1 - F7	F7 - T3	T3 - T5	T5 - O1
00-00-01	14	-57	2	1	38	-46	-83	52	-33	-28	-39	64	-65	-30	54	5
00-00-02	19	-48	0	14	43	-41	-89	71	-44	-26	-25	62	-81	-24	69	2
00-00-03	22	-35	-4	24	43	-38	-72	73	-54	-34	-14	72	-72	-33	68	8
00-00-04	58	-20	-4	44	76	-31	-56	88	-32	-25	-6	85	-38	-34	78	17
00-00-05	40	-26	-19	56	60	-47	-60	96	-57	-29	-17	93	-72	-37	84	16

Table 2. The second patient's EEG samples

Time (in hh-mm-ss)	FP2 - F4	F4 - C4	C4 - P4	P4 - O2	FP2 - F8	F8 - T4	T4 - T6	T6 - O2	FP1 - F3	F3 - C3	C3 - P3	P3 - O1	FP1 - F7	F7 - T3	T3 - T5	T5 - O1
00-04-05	11	-9	-1	6	6	-2	0	3	0	-1	5	2	-5	5	2	3
00-04-06	2	-3	-4	-3	2	-4	-10	5	13	-2	-6	1	9	-8	7	-1
00-04-07	0	0	-2	-5	3	-4	12	-18	-13	2	1	-6	-4	-6	-6	0
00-04-08	4	-9	-5	6	0	-10	-1	7	-3	0	-2	2	-4	-4	-3	7
00-04-09	-3	1	2	-2	-1	0	-3	1	-8	5	-1	-8	-5	-3	-3	0

Table 3. The third patient's EEG samples

Time (in hh-mm-ss)	FP2 - F4	F4 - C4	C4 - P4	P4 - O2	FP2 - F8	F8 - T4	T4 - T6	T6 - O2	FP1 - F3	F3 - C3	C3 - P3	P3 - O1	FP1 - F7	F7 - T3	T3 - T5	T5 - O1
00-02-01	130	-64	-82	175	121	14	-58	82	41	119	-110	21	15	-176	131	100
00-02-02	122	117	-249	227	122	-64	75	84	55	-27	31	-74	-81	113	-33	-14
00-02-03	161	-9	-113	82	59	100	-137	99	-25	98	-124	41	-178	214	-161	115
00-02-04	-7	9	86	-50	147	-50	-66	7	-91	57	-45	-19	-192	96	50	-52
00-02-05	-34	26	-143	66	-113	-95	300	-177	-37	161	19	-19	68	59	-75	71

Table 4. The fourth patient's EEG samples

Time (in hh-mm-ss)	FP2 - F4	F4 - C4	C4 - P4	P4 - O2	FP2 - F8	F8 - T4	T4 - T6	T6 - O2	FP1 - F3	F3 - C3	C3 - P3	P3 - O1	FP1 - F7	F7 - T3	T3 - T5	T5 - O1
00-00-41	-18	-150	323	-2	-211	260	-130	239	305	-440	157	-20	22	-92	-111	136
00-00-42	152	103	-172	148	86	64	-41	122	178	307	-153	-165	2579	-2387	32	-56
00-00-43	-94	182	-174	112	-93	-34	75	79	374	-93	-71	-155	140	182	-49	-218
00-00-44	-249	174	-233	377	-118	109	-83	162	99	729	-967	561	50	31	78	263

Table 5. The fifth patient's EEG samples

Time (in hh-mm-ss)	FP2 - F4	F4 - C4	C4 - P4	P4 - O2	FP2 - F8	F8 - T4	T4 - T6	T6 - O2	FP1 - F3	F3 - C3	C3 - P3	P3 - O1	FP1 - F7	F7 - T3	T3 - T5	T5 - O1
00-00-56	-325	-14	39	-399	-154	-1047	913	-411	458	360	4537	-5020	188	400	-810	557
00-00-57	193	-7	-438	394	-60	-54	-39	295	-282	72	437	-122	284	-457	107	172
00-00-58	250	-86	-7	-201	345	-431	-7	49	-490	194	400	154	112	21	-6	132
00-00-59	303	287	-52	-233	486	-320	182	-43	-215	271	-633	316	66	145	-517	45
00-01-00	-137	-218	-442	690	-492	315	-68	138	270	126	-510	229	-273	272	288	-172

3.2. Source localization EEG

This technique involves using advanced imaging methods to localize the source of epileptic activity within the brain. It helps identify the seizure onset zone and plan targeted interventions such as surgery or focused neurostimulation. Pros: Source localization EEG involves advanced imaging techniques to localize the origin of epileptic activity within the brain, providing precise anatomical localization and functional mapping of epileptogenic zones. It helps guide surgical planning, optimize electrode placement, and predict surgical outcomes. Source localization EEG can enhance the accuracy and efficacy of epilepsy surgery, minimizing the risk of neurological deficits. Cons: Source localization EEG requires sophisticated neuroimaging software and expertise to accurately perform image processing, source reconstruction, and interpretation. Its clinical utility may be limited by image resolution, signal-to-noise ratio, and variability in source localization algorithms. EEG helps confirm epilepsy, identify seizure types, guide drug management, and assess therapy efficacy.

3.3. Sleep EEG

Sleep EEG is performed to evaluate brain activity during sleep, as seizures often occur during sleep or are influenced by sleep patterns. It helps assess the impact of sleep on seizure activity and identify specific patterns associated with sleep-related seizures. Pros: Sleep EEG provides valuable information about brain activity during different stages of sleep, as seizures often occur or are influenced by sleep patterns. It helps in characterizing sleep-related epileptic syndromes and identifying specific abnormalities associated with nocturnal seizures. Sleep EEG can enhance diagnostic yield by capturing seizure events that coincide with sleep. Cons: Sleep EEG requires specialized equipment and expertise to perform and interpret accurately. Patient preparation for sleep EEG may be time-consuming, and compliance with sleep deprivation protocols can be challenging. Sleep EEG recordings may be susceptible to artifacts related to sleep movements or environmental factors.

4. CONCLUSION

Prospects and obstacles abound for using cloud-based real-time EEG analysis in seizure prediction. Several obstacles still need to be overcome, but technological progress holds some encouraging possibilities for better seizure prediction accuracy and more rapid therapies. Securely storing and processing sensitive patient data on cloud servers is the biggest obstacle since it requires strong encryption and adherence to strict privacy standards. Seizure prediction systems' real-time nature may be compromised by worries about latency and network connection brought about by dependence on cloud infrastructure. Also, various people and kinds of seizures produce EEG data that are complicated and variable, which might restrict the accuracy of the prediction models. The deployment of such systems might have a substantial effect, improving the quality of life for epilepsy patients via tailored treatment methods and lowering the frequency and severity of seizures, notwithstanding these limitations. This section discusses the results from five separate datasets of patients with epileptic seizures who underwent EEG analysis with the following details as Frontopolar (FP1, FP2), Frontal (F3, F4), Frontotemporal (F7, F8), Central (C3, C4), Temporal (T3, T4), Parieto-temporal (T5, T6), Parietal (P3, P4), Occipital (O1, O2), Time (HH:MM:SS).

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BIOGRAPHIES OF AUTHORS

Gousia Thahniyath is an assistant professor at the Department of Computer Science and Engineering, Dayananda Sagar University, Bangalore. Gousia Thahniyath has completed her Ph.D. from Visveswaraya Technological University. Her area of research is related to wireless sensor networks. She has completed her M.E. in computer science and engineering from Bangalore University and her B.E. in computer science and engineering from Gulbarga University. She has 16 years of teaching experience and has one year of industrial experience. She has published papers in 7 international journals and has presented papers at international and national conferences. She can be contacted at email: gousia-cse@dsu.edu.in.

Chelluboina Subbarayudu Gangaiah Yadav is currently working as an associate professor of ECE at Chaitanya Bharathi Institute of Technology, Proddatur. He has 12 years of experience in teaching. He did an M.Tech. in specialization VLSI system design and a further Ph.D. in the same discipline. His broad field of research was VLSI and Embedded Systems. His areas of interest include VLSI embedded systems and IoT. He has published research papers in both international and national journals of repute. He has published patents and also published a book. He also serves as the NAAC and NBA Coordinator. He is a member of technical societies like IETE, ISTE, ISRD, and IAENG. He has organized workshops and webinars at a national level. He has served as a reviewer for Scopus-indexed journals. He can be contacted at gangaiahh.ece@cbit.edu.in.

Rajagopalan Senkamalavalli is currently working as a Professor, Department of Information Science and Engineering, AMC Engineering College, Bangalore, Karnataka, India. She has 15 Years of teaching experience in computer science engineering subjects. She has published a book on artificial intelligence and expert systems. She has attended 20 seminars and presented many papers at national and international conferences. She has published many papers in national and international journals. She is a recipient of the President Award in Girls Guide. She can be contacted at id-dr.rsenkamalavalli@ksit.edu.in.

Shanmugam Sathiya Priya is currently working as a professor in the Department of ECE at Panimalar Institute of Technology Chennai. She obtained her Ph.D. from Sathyabama University, her master's degree with honors in communication systems from Thiagarajar College of Engineering, Madurai, and her bachelor's degree in electronics and communication engineering from Mohamed Sathak Engineering College, Kilakarai, affiliated with Madurai Kamaraj University, Madurai. She has published 25 papers in international and national journals and 32 papers in national conferences. Her areas of interest include wireless communication, UWB communication, and channel estimation. She has more than 23 years of teaching experience. She has attended 15 short-term courses, attended 30 seminars, workshops, and FDPs, and organized seminars and workshops related to her area of research. She is one of the authors of the books *Transmission Lines and Waveguides* and *Integrated Circuits Applications Tunable Diode and Photonics*. She is a life member in ISTE. She can be contacted at sathiyapriya.anbunathan@gmail.com.

Stalin Aghalya is presently working as an associate professor in the ECE Department, at St. Joseph's College of Engineering, Chennai. She has pursued her full-time Ph.D. from Anna University, India. She received her M.E. (Optical communication) in 2002 from CEG, Anna University, Chennai, and her B.E. (Electronics and communication engineering) in 1991 from TPGIT, Vellore. Her research interests are wireless networks, mobile networks, and digital image processing. She has more than 23 years of teaching experience. She can be contacted at aghalya70@gmail.com.

Kuppireddy Narsimha Reddy received the Ph.D. Degree in ECE from KLEF, AP in 2023, and the M.Tech. degree in VLSI design from the Viganan University, AP, India, in 2011, and the B.Tech. degree in electronics and communication engineering from JNTUH University, Hyderabad, India, in 2009. His research interests include signal processing, image processing, and VLSI design. He has published 13 research papers in various international journals and conferences. Presently he is working as an assistant professor in the Department of ECE, Vardhaman College of Engineering, Hyderabad, Telangana. He can be contacted at simha.vce@vardhaman.org.

Subbiah Murugan is an adjunct professor at Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India. He published his research articles in many international and national conferences and journals. His research areas include network security and machine learning. He can be contacted at smuresjur@gmail.com.