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Epileptic Seizures Detection Using Machine Learning: A Review

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***Abstract* - These episodes may be attributed to abnormal chemical alterations in the brain or anomalies in the cerebral region. These illnesses are classified as chronic and increase the likelihood of death due to their abrupt onset and absence of preceding symptoms. Seizures can be identified by analyzing the brain signals produced by neuronal cells. Traditionally, electroencephalogram (EEG) recordings a multi-channel depiction of brain neuronal activity is used for brain signal monitoring. This paper examines important advancements made in the analysis of EEG waveforms to create predictive algorithms for epilepsy.**

Keywords: Machine learning, electroencephalogram (EEG), Epileptic seizures, Support Vector Machine, SVM.

I. Introduction

Epilepsy, a neurological disorder originating from ancient Greece, was initially documented in ancient Babylonian texts approximately 3000 years ago. This disease has a pervasive impact on various animal species, including rats, cats, and others. Epilepsy can result from genetic abnormalities or disruptions in brain electrical activity, which can be induced by low blood sugar or oxygen deprivation during birth [1]. It is defined by recurring and unpredictable seizures of different intensities, resulting in loss of consciousness and widespread body shaking. These seizures manifest abruptly and present substantial dangers, especially during activities that could be perilous for people with epilepsy [2]. Epilepsy affects approximately 50 million people worldwide, regardless of age or gender. About 70% of those affected can manage their condition with antiepileptic drugs, while the remaining 30% require surgical intervention [3]. Stroke, brain tumors, and birth defects are among the potential causes of epilepsy, and electroencephalography (EEG) is commonly used to record the brain's electrical activity [4]. These waves are analyzed and diagnosed by specialized and experienced doctors, but this diagnosis and analysis require a long time, making the task tedious and uncertain in results [5]. Therefore, researchers have turned to wave analysis and assistance in disease diagnosis using computers and machine learning programs [6][7]. This research aims to review recent studies focusing on the classification and prediction of neurological seizures in recent years. It aims to support future researchers in this field by identifying the best methods and algorithms that have been developed in recent research.

This paper is prepared as follows: Section 2: Type of elliptic seizure; Section 3: Dataset; Section 4: Electroencephalogram (EEG); Section 5: Feature selection; Section 6: Machine learning.

II. Type of Elliptic Seizure

Clinicians classify epileptic seizures into two primary categories, generalized seizures, and partial seizures, based on their analysis of electroencephalography (EEG) [8].

Focal seizures, also known as partial seizures, exclusively impact one hemisphere of the brain rather than the entire organ. Simple-Partial Seizures and Complex-Partial Seizures are two distinct subcategories of partial seizures that can be further distinguished. During a simple partial seizure, the patient remains conscious but exhibits anomalous behavior and interacts with their surroundings in an atypical manner.

In a complex-partial seizure, the patient is confused and exhibits involuntary movements such as mumbling and chewing; this type is also known as a 'focal impaired awareness seizure'. Generalized seizures are also divided into two types: Generalized Convulsive Seizure and Generalized non-convulsive Seizure [9][8].

III. Dataset

A team of researchers utilized a dataset obtained from the University of Bonn in Germany. The dataset has five distinct groups (A, B, C, D, and E), with each group consisting of 100 individual signals. Each signal was recorded for 23.6 seconds and had a frequency of 173.6 Hz. The samples were taken under different conditions, with the EEG recorded at times when the patient's eyes were open and at other times when the patient's eyes were closed. EEG samples were obtained from non-epileptic persons and epilepsy patients, some during seizures and others before and after surgical

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procedures. The official website of the German University of Bonn provides access to surgical data [10][11][12][13].

Another database proposed by the University of California, Irvine (UCI) was also used, which contains data for 4097 patients, with each patient having 500 readings, with each reading lasting 23.5 seconds at a frequency of 178 Hz per second. Each reading is taken by 23 electrodes and produces five types of brain activity. This database can be accessed through Kaggle [14][15][16]. This study uses intracranial electroencephalography (iEEG) data to accurately read brain electrical signals without noise or attenuation in the signal reaching the electrode, unlike EEG. Data from the University of Helsinki was used, which gives a sensitivity to waves of up to 77%. It is noted that the data used in this case was very small compared to databases used for other research to test models in realtime. A variety of machine learning models have been used and achieved a prediction accuracy of about 90%[17].

IV. Electroencephalogram (EEG)

Electroencephalography (EEG) is a technique employed to detect and quantify the electrical signals in the brain and ascertain their precise origins. Electrodes, which are sensors, are positioned on the scalp to amplify the signals produced by neurons in the brain. The electrical signals demonstrate nonlinearity and are vulnerable to interference from other waves, hence introducing intricacy to the study of the waves. This poses a basic obstacle encountered by ehtEEG technology [13]. EEG, or electroencephalography, is a method used to measure the flow of ionic current between nerve tissues in the brain. It also determines the voltage changes caused by electrodes placed on the patient's scalp [18].

The electrodes are placed in varying quantities on the patient's scalp, and the ECG produced from the reading becomes more precise as the number of electrodes, also referred to as electrodes, increases [19]. This study utilized AutoML technology in conjunction with the Neural Architecture Search (NAS) algorithm to develop models for automated analysis of EEG data and enhance epilepsy identification. The utilized models showed enhancements in design correctness, F1-score, and Cohen's Kappa coefficient by 7.68%, 7.82%, and 9.60%, respectively.

Furthermore, it played a role in diminishing the duration needed to construct the neural network utilized for examining and extracting characteristics associated with the EEG chart [20]. Figure 1 depicts a patient undergoing an electroencephalogram (EEG) procedure [21].

Figure 1: shows a patient undergoing an EEG procedure

V. Feature Selection

The research findings from multiple studies demonstrate a high level of precision in the analysis and prediction of epilepsy at an early stage utilizing wavelet and FFT techniques. More precisely, the utilization of Discrete Wavelet Transform (DWT) in conjunction with machine learning classifiers such as Random Forest (RF) and Multilayer Perceptron (MLP) resulted in accuracies of around 97.96% [22] . In another study, wavelet threshold denoising and Gradient Boosting Decision Tree (GBDT) were used to predict epilepsy seizures. The study achieved an average accuracy ranging from 91.76% to 92.50% [22]. In addition, a technique that employed a Discrete Wavelet Transform (DWT) for extracting features and a Support Vector Machine (SVM) for classification produced an average prediction accuracy of 96.38% [23]. These data collectively show that wavelet-based approaches are useful in precisely evaluating and predicting epilepsy at an early stage.

VI. Machine Learning

The effectiveness of using machine learning algorithms to predict the accuracy of epilepsy wave classification varies depending on the methodology used. Numerous degrees of precision have been documented in several studies. An example of this can be observed in the Random Forest classifier, which exhibited a significant level of accuracy (96%) in predicting survival based on EEG data [24]. However, a thorough analysis of ensemble machine learning algorithms has demonstrated that the C4.5 classifier exhibits outstanding performance in accurately predicting epileptic episodes based on EEG inputs [25]. A study utilized a restricted dataset and employed sophisticated deep learning and machine learning algorithms to precisely forecast epileptic seizures with a sensitivity rate of 77% and an accuracy rate of

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90% [17]. XGBoost attained a classification accuracy of up to 96% in distinguishing seizures across various levels fo [26].

The study employed artificial neural networks (ANNs) to detect and classify epileptic events. In addition, the study implemented an unbalanced learning technique to improve the accuracy of evaluating naimbalanced data [27]. This research study uses machine learning techniques to precisely diagnose epileptic episodes. The method utilizes waveform alterations to extract distinctive characteristics from EEG signals in the time-frequency domain. The results of wave transforms are utilized as inputs for many machine learning algorithms like Principal Component Analysis (PCA), Logistic Regression (LR), Support Vector Machine (SVM), Support Vector Classifier (SVC), K-Nearest Neighbors (KNN), and Naive Bayes. The findings demonstrated that the KNN and Naive Bayes classifications achieved the maximum level of accuracy in discriminating between attributes, with a respective accuracy rate of 98.30% and 95.86% [28].

VII. Conclusion

In this research, many studies and research were reviewed that dealt with methods of detecting epileptic seizures using different methods for reading electrical brain information, such as EEG and IEEG. The most prominent studies on techniques used to detect and analyze features in EEG were highlighted, which include techniques such as DWT, FFT, and PCA. Studies related to the most prominent algorithms used in the processes of detecting and classifying epileptic waves using machine learning, such as SVM, XGBoost, C4.5, SVC, RF, KNN, and ANN, were also reviewed. There is no text provided. Research articles were used that documented the databases utilized, as well as research that evaluated the rates of accuracy and sensitivity. According to the research, the wavelet method was shown to be the most efficient approach for extracting features, and the SVM algorithm was identified as the most suitable machine learning algorithm, as evidenced by multiple works cited in this study. The results emphasize the necessity for additional research on the classification of patients' cognitive awareness levels using EEG data analysis. The objective of this study is to precisely categorize individuals' state of consciousness and offer vital insights to medical practitioners or families about their condition, particularly during episodes of unconsciousness or reduced awareness.

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