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A REVIEW ON EPILEPSY SEIZURE DETECTION TECHNIQUES

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Abstract- The abnormal activities of the human brain are recorded by the Electroencephalogram (EEG) signal. The EEG signal has a wide range of applications in the healthcare field. During the diagnosis of any disease, theEEG signal plays an important role. In this work, we discussed the epilepsy seizure detection methods from the EEG signal dataset. Various machine learning approaches are used to detect epileptic seizures from the recorded EEG signal dataset. The three main steps followed for the epilepsy seizure detection data availability, pre-processing, and features learning and classification. The epilepsy seizure EEG signal shows the interrupted EEG signal means brain disorder functionality is demonstrated via the EEG signal. The seizure detection is performed for medical treatment. The pre-processing and features extraction step affected the seizure detection process execution time and prediction accuracy. State of the art methods use the Bonn university EEG dataset and CHB-MIT dataset for the classification of epileptic signal from recorded EEG signal. The machine learning classifiers provided improvement in the classification accuracy and effectively utilized. Some deep learning methods like CNN are also used, which provided better classification accuracy than the machine learning approach. After studies various machine and deep learning approaches, we get an idea to design a Bayesian Optimization-based Long Short Term Memory (LSTM) model for epilepsy seizure detection.

Keywords: Epilepsy Seizure, EEG Signal, Bonn-University dataset, Machine, and Deep learning approaches, etc.

I. INTRODUCTION

The Electroencephalogram (EEG) has a wide range of applications in the medical field. The human brain abnormalities can be diagnosis by the EEG signal monitoring. Various neurological issues are diagnosis by the EEG signal. In the Brain-Computer Interface (BCI), the EEG plays a vital role in recognizingthe abnormal condition of the brain. The EEG signal contains a considerable amount of information that can be used by the BCI to classify the anomalous signal from a standard EEG signal. The brain sickness estimation and a better understanding of BCI applications are supported by the EEG signal [1].

The epilepsy signal detection from an EEG signal dataset is a popular topic of research in the modern era. Epilepsy is a brain disease of human or animal which required continues time monitoring. Various methods are used to classify the epilepsy signal from the recorded EEG signal in state of the art. The EEG signal classification includes the semi-supervised, unsupervised, and supervised. The epilepsy seizure produced due to the multiple brain electrical signal generates at the same time, which causes changes in human behavior, memory loss, and loss of breadth.Epilepsy is produced in the brain cortex portion, which causes abnormality and instability in the brain. The typical neuron environment of the mind is disturbed due to epilepsy and causes strange sensations, behavior, and loss of consciousness. The electrochemical impulses are created by the neuron, which produced some human emotions and action. The unbalance of neuron electrochemical signal generates abnormal condition in the brain and cause epilepsy. EEG is an important platform to monitor and diagnosis the seizure condition of the patient. The main focus of the EEG signal is an elliptic seizure. The electrical signal of EEG represents the brain activity produced by the neurons. A rapid change in the recorded EEG signal shows the presence of elliptic seizures. The abnormality condition is occurring in the recorded EEG signal at the time elliptic movement [2]. The EEG signal provides clinical data which contains normal, as well as seizure,continuously occur condition. The recorded EEG signal can be classified for the elliptic seizure condition and monitor patient health.

In this paper, we discussed the various deep learning and machine learning approaches to epileptic seizure detection from the recorded EEG signal dataset. The commonly used database is Bonn University EEG [2-8, 10-15, 17, 18, 20-23, 25, and 26] and CHB-MIT EEG datasets [2, 18, 24, and 27] tested with the machine and deep learning approaches. The Bern Bacelona [3, 4, and 8] EEG dataset is also tested in various methods of seizure detection. The detailed of previously used schemes for the epilepsy seizure detection is provided in section II.

II. LITERATURE REVIEW

State of the art various techniques are proposed for the epilepsy signal classification from the available EEG datasets. The three main steps of EEG signal classifications are dataset selection, feature extraction, and classification. Based on these three sections, we divided the related work with different used methods. The freely available datasets are generally used for the EEG signal classification task. Various datasets are tested with deep learning and transform-based approaches of classification. We categorized the studied methods in two sections, one for the machine learning approaches and others for the deep learning approaches. The used dataset for the epilepsy seizure detection isBonn university EEG[2-8, 10-15, 17, 18, 20-23, 25, and 26], Bern Bacelona [3, 4 and 8], Temple University Hospital EEG SeizureCorpus (TUSZ) [1], Children Hospital Boston (CHB)-MIT [2, 18, 24 and 27], Continues EEG signal data construction [9] were tested through the different features extractions methods and classifiers for the epileptic seizure prediction. The Bonn University Dataset was considered by most of the researchers due to its availability and stability. The CHB-MIT dataset also used by various authors to validate the real-time based methods of epilepsy classifications. The raw dataset cannot be used directly as the input of the classifiers. The pre-processing of raw data by using some filters which avoid the noise and unwanted signals is mandatory for the EEG signal classification task. After the preprocessing of raw data, features are extracted with the help of various methods.

1.1 MACHINE LEARNING APPROACHES

The EEG signal is contained the time domain and frequency domain features. Some statistics features are also extracted from the freely available datasets. Discrete Wavelet Transform (DWT) [6, 7, 12, 17, 21, 22, 25], Independent Component Analysis (ICA) and MFCC [1], Multi-Objective Evolutionary Algorithm (MOEA) [2], Spatial Pattern (CSP) [3], semantic features extraction using BILMF Variational Mode Decomposition (VMD) [4], time domain features extraction like energy and wavelet based [10, 11], Fast Wavelet Transform (FWT) [12], EMD [10]and Ellipse area calculation [10], 1-Dimensional Ternary Patterns (1D-TP) [13], Dual Tree Complex Wavelet Transform (DTCWT) [14], Principle Component Analysis (PCA) [15], 6 Bandpass filter, FFT and cross correlation [19], Wavelet Packet Decomposition (WPD) and Kernel Principle Component Analysis (KPCA) [20], Local Neighbor Descriptive Pattern (LNDP) and Histogram features [23], Time Domain Features Calculation [24], Short Time Fourier Transform (STFT) [26] and Power Spectrum Density (PSD) [27] are proposed by the many researcher to improved the accuracy of the classifiers. In most of the studies, the transform-based features extraction methods are considered, which provided effective outcomes in terms of classification of an epileptic seizure.

The classification task is the major phase of the EEG data classification. The performance of the proposed method is tested based on the classifiers. The previous used classifiers are Support Vector Machine (SVM) [1, 2, 3, 15, 19, 21, 22, 26, 27], Cosine Signal Measurement (CSM-SVM) [10], Universum Twin Support Vector Machine (RUTWSVM) [11], Universum Support Vector Machine (USVM) [11], Least Square SVM [14, 24], Random Forest (RF) [4, 13, 14], Artificial Bee Colony Algorithm (ABC) tune Radial Basis Function Neural Network (RBFNN) [17], Modified Particle Swarm Optimization (MPSO)-RBFNN [25], RBFNN [26], Artificial Neural Network (ANN) [7, 23], Multi-Layer Perceptron Neural Network (MLPNN) [12, 22], and K-nearest neighbor provided efficient and economical classification of epileptic seizure. The summarized of studied machine learning approaches are listed in table 1 with their accuracy and advantages.

Table 1 Machine learning approaches for Epilepsy Seizure classification

Reference	Year	Dataset	Features Extraction Methods	Classifiers	Accuracy	Advantages
Maryati et al.[1]	2019	TUSZ	ICA, Hjorth Descriptor and MFCC	SVM	91.4%	Provided different accuracy in terms of different section of SVM kernel
Nandi et al.[2]	2019	CHB-MIT	MOEA	Bayesian Optimization tuned SVM	97.5%	SVM provided better accuracy
Shoka et al.[3]	2019	Bonn University EEG, Bern Bacelona EEG	CSP	SVM	98%	Survey of deep learning methods of EEG signal classification
Rao et al.[4]	2018	Bonn University EEG, Bern Bacelona EEG	BILMF VMD	RF	78% for Bern dataset and 94.1 for Bonn dataset	Accuracy improved from 4 to 10%
Ozer et al.[7]	2019	Bonn University EEG	DWT	ANN	99.5%	Execution response is quick
Torse et al.[10]	2019	Bonn University EEG	EMD and Ellipse are calculation	CSM-SVM	96.4%	Can be used for out of samples data
Tanveer et al. [11]	2019	Bonn University EEG	Wavelet	USVM and UTSVM	99%	Tested on lots of real world dataset
Ahuja et al.[12]	2018	Bonn University EEG	DWT	LM-MLPNN	99.4%	Less execution time
Kaya et al. [13]	2018	Bonn University EEG	1D-TP	RF	99.5%	Less execution time
Desai et al.[14]	2018	Bonn University EEG	DCTWT	RF and Least Square SVM	99.87%	Less MSE
Banka et al.[15]	2018	Bonn University EEG	PCA	SVM	99%	Both normal and seizure prediction
Bhasker et al.[16]	2018	-------	--------	Various	survey	Survey
Satapathy et al.[17]	2017	Bonn University EEG	DWT	ABC tuned RBFNN	82%	ABC enhanced the performance of RBFNN
Shiao et al.[19]	2017	Dog-L4	6 Bandpass filter, FFT and cross correlation	SVM	----	Provided clinical medical performances
Wu et al.[20]	2017	Bonn University EEG	WPD and KPCA	TSK fuzzy logic model	95%	Less computational cost

Arif et al.[21]	2017	Bonn University EEG	DWT	SVM and GRLVQ	98.66% for GRLVQ	Less testing time
Jagadev et al.[22]	2017	Bonn University EEG	DWT with PCA	MLPNN and SVM	99.5%	Less execution time
Jaiswal et al.[23]	2017	Bonn University EEG	LNDP and Histogram	ANN	99.8%	Tested on large data
Das et al.[24]	2017	CHB-MIT	Time domain	LSVM, EBT and WKNN	74% for LSVM, 89% for WKNN and 91% for EBT	EBT provided higher classification accuracy
Dehuri et al.[25]	2017	Bonn University EEG	DWT	IPSO tuned RBFNN	99%	Minimum testing time
Ahmadi et al.[26]	2017	Bonn University EEG	STFT	SVM and RBFNN	97.85%	Lower computational cost
Fong et al.[27]	2017	CHB-MIT	EMD and PSD	KNN and SVM	92.3%	Minimum prediction time

1.2 DEEP LEARNING APPROACHES

The Deep learning schemes also havea wide range of applications in the field of epileptic seizure detection from the EEG signal dataset. Some researchers use the deep learning methods like Convolutional Neural Network (CNN) [5, 8, 9], Recurrent Neural Network (RNN) [6], and Multi-Class CNN [18] are proposed for the epileptic seizure classification. The deep learning algorithms do not require the feature extraction method separately. Both the task features extraction and classification are performed in a designed network. A CNN model is designed to learn the EEG signal features and classification tasks. The CNN model performed two task features extraction and classification. The two datasets contain the two classes of EEG signal one is standard EEG signal class, and the other shows the seizure EEG signal. The input data signal is pre-processed by the wavelet transform and a spectrum signal achieved. The spectrum signal is provided to the CNN model, which extracts the features and classifies the non-seizure and seizure EEG signal. The proposed CNN model provided better accuracy range from 99% to 99.5% for the non-seizure and seizure EEG signal classification [5, 8, and 9]. A Recurrent Neural Network (RNN), for the classification of the EEG signal dataset. The Bonn University EEG dataset is used for the classification of epilepsy seizure signal. The input EEG signal is preprocessed by the Wavelet Transform method (DWT) and extract the 20 eigenvalues features. The extracted features are inserted into the proposed RNN model, which classified the epileptic seizure EEG signal. The proposed RNN model is compared with the other classification model like Logistic Regression (LR), Support Vector Machine (SVM), K-Nearest Neighbor (KNN), Random Forest (RF) and Decision Tree (DT). The proposed RNN model provided 99% epileptic signal classification accuracy than the other testing methods [6]. A multiclass CNN model for the classification of EEG signals from the Bonn university dataset. The time domain and frequency domain handcraft features are extracted from the input signal. The CHB-MIT dataset is also tested with the multiclass CNN classifier. The proposed algorithm provided higher accuracy for the Bonn and CHB-MIT dataset. The accuracy for the Bonn dataset is 97.64% and 97.52% for the CHB-MIT dataset. The execution time is also reduced by the multiclass CNN model [18]. Table 2 provided a summary of deep learning approaches studied.

Table 2 Studied Deep Learning Approaches

Reference	Year	Dataset	Features Extraction Methods	Classifiers	Accuracy	Advantages
Liu et al.[5]	2019	Bonn University EEG	---------	CNN	90%	Single channel EEG signal classified
Lim et al.[6]	2019	Bonn University EEG	DWT	RNN	99%	Better than the RF and DT classifiers
Martin et al.[8]	2019	Bern Bacelona EEG and Epileptic Seizure Recognition	CNN	CNN	99% and 99.5%	Comparative study provided
Chaari et al.[9]	2019	Continues EEG signal data construction	CNN	CNN	99.48%	Completely classification
Ramkrishanan et al.[18]	2019		CNN	Multiclass CNN	97.64% for Bonn and 97.52% for CHB-MIT	Less execution time

III. ANALYSIS

Various State-of-the-art methods of epilepsy seizure classification is analyzed in this work. We divided the studied approaches into two categories one is machine learning approaches, and the other is deep learning approaches. Among the machine learning approaches, the SVM provided a better solution in terms of accurate classification of the epilepsy EEG signal. Anepilepsy seizure detection by using three features extraction methods Mel Frequency Cepstral Coefficients (MFCC), Hjorth Descriptor, and Independent Component Analysis (ICA) and SVM classifier. An EEG dataset of Temple University Hospital Seizure Corpus (TUSZ) is used to detect the epilepsy seizure. The three types of seizure Generalized Non-Specific Seizure (GNSZ), Focal Non-Specific Seizure (FNSZ), and Tonic-Clonic Seizure (TCSZ) are classified with the Support Vector Machine (SVM). A standard EEG signal is also added to the TUSZ dataset and four types of categories classified. Among the three features extraction method, the combination of MFCC and Hjorth Descriptor provided better accuracy, sensitivity, and specificity. The obtained value of three evaluation parameters accuracy, sensitivity, and specificity are 91.4%, 90.25%, and 97.83%. The optimal results are evaluated with the Hybrid features extraction method (MFCC-Hjorth Descriptor) and SVM classifier [1]. The features like time domain, spectral domain, wavelet domain, connectivity, and entropy are extracted from the CHB-MIT dataset. A Multi-Objective Evolutionary algorithm (MOEA) is used to select the extracted features. The chosen features insert as the input to machine learning classifier SVM. Further, the hyperparameters of the SVM classifier is tuned by the Bayesian Optimization. The proposed Bayesian Optimization optimized SVM classifier accuracy is higher than the Linear Discriminant Analysis (LDA) and Quadratic Linear Discriminant Analysis (QLDA) methods. The accuracy achieved by BO-SVM is 97.5% for the CHB-MIT data classification task [2]. The two datasets of EEG signal Bonn University and Bern Bacelona are tested with the BLIMFs features extractor with the Random Forest (RF) classifier. The input data is decomposed through the variation mode decomposition (VMD) than the BLIMFs applied for the feature extraction. The extracted features are used to the RF classifier, which provided better accuracy than the KNN and SVM classifier. The RF classifier provided 78% for the Bern dataset and 94.1 for the Bonn dataset, which shows an improvement from 4 to 10%. The combination of DWT and SVM provided better outcomes for the machine learning approaches.

The CNN and RNN models produced better classification results than the machine learning approaches. We select the modified version of the RNN model known as Long Short Term Memory (LSTM) for the classification of epileptic seizure signal. The Bonn university EEG and CHB-MIT dataset will be tested by the Bayesian Optimization tuned LSTM model. The evaluated results are compared with the previously used schemes like SVM or CNN.

IV. CONCLUSION

This paper represents the survey on various machine learning, and deep learning approaches are used for the classification of epilepsy seizure signal detection. In the medical field, both methods have a wide range ofapplications.The machine learning algorithms required additional features extraction algorithms, but deep learning algorithms performed both task feature extraction and features classification. The machine learning classifiers provided improvement in the classification accuracy and effectively utilized. Some deep learning methods like CNN is also used, which provided better classification accuracy than the machine learning approach. After studies various machine and deep learning approaches, we get an idea to design a Bayesian Optimization-based Long Short Term Memory (LSTM) model for epilepsy seizure detection. The deep learning algorithms provided higher classification accuracy with a lower computational cost. The execution time is also less for the deep learning algorithms epilepsy seizure prediction. Table 1 and Table 2 show the most used schemes for epilepsy seizure detection. Among the studied projects, the time and wavelet domain feature provided better classification accuracy than the other approaches.

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