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A Survey on Epilepsy Seizure Detection Using Machine Learning Technique

[1]N. Saranya and [2]D. Karthika Renuka
[1]Park College of Engineering and Technology, Coimbatore, Tamil Nadu, India.
[2] PSG College of Technology, Coimbatore, Tamil Nadu, India.

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Abstract: Epilepsy, One of the most prevalent neurological disorder. Its a chronic condition is characterized by voluntary, unpredictable, and recurrent seizures that affects millions of individuals worldwide. A brief alteration in normal brain function that affects the health of patients occurs in this chronic condition. Detection of epileptic seizures before the start of the onset is beneficial. Recent studies have suggested approaches to machine learning that automatically execute those diagnostic tasks by integrating statistics and computer science. Machine learning, an application of AI (Artificial Intelligence) technology, allows a machine to learn something new automatically and thereby improve its output through meaningful data. For the prediction of epileptic seizures from electroencephalogram (EEG) signals, machine learning techniques and computational methods are used. There is a vast amount of medical data available today about the disease, its symptoms, causes of illness and its effects. But this data is not analyzed properly to predict or to study a disease. The objective of this paper is to provide detailed versions of machine learning predictive models for predicting epilepsy seizure detection and describing several types of predictive models and their applications in the field of healthcare. So that seizures can be predicted earlier before it occurs, it will be useful for epilepsy patients to improve their safety and quality of their life.

Keywords - Predictive analytics; Prediction models; Machine learning; Classifications.

1. Introduction

Epilepsy it makes difficulty for patients to live a normal life because it is difficult to predict when seizures will occur. In this regard, if seizures could be predicted a reasonable period of time before their occurrence, epilepsy patients could take precautions against them and improve their safety and quality of life. While first lines of treatment consist of long-term medications-based therapy, more than one third of patients are refractory. A huge amount of medical data is available today regarding the disease, their symptoms, reasons for illness, and their effects on health. But this data is not analyzed properly to predict or to study a disease. The aim of this paper is to give a detailed version of predictive models and describing various types of predictive models, Applications of machine learning are significantly seen on health and biological data sets for better outcomes [1,5]. Researchers/scientists on different areas, specifically, data mining and machine learning, are actively involved in proposing solutions for better seizure detection. Machine learning has been significantly applied to discover sensible and meaningful patterns from different domain datasets [8]. It plays a significant and potential role in solving the problems of various disciplines like healthcare [5]. Applications of machine learning can also be seen on brain datasets for seizure detection, epilepsy lateralization, differentiating seizure sates, and localization [4,6]. This has been done by various machine learning classifiers such as ANN, SVM, decision tree, decision forest, and random forest.

1.1 Epileptic Seizures States

Early prediction of epileptic seizures ensures enough time before it occurs it is extremely useful because the attack can be avoided by the drug. In addition, seizures can be predicted by detecting the beginning of the preictal state. Epileptic seizures have four different states:

1. **Preictal State** : A state that appears before the seizure begins.
2. **Ictal State** : That begins with the onset of the seizure and ends with an attack.
3. **Postictal State** : A state that starts after ictal state

4.**Interictal State** : That starts after the postical state of 1st seizure and ends before the start of preictal state of consecutive seizure.

Therefore, the purpose of our investigation is to detect the appearance of preictal state for epileptic seizures. Machine learning models are used to predict epileptic seizures. These machine learning models include EEG signal acquisition, signal preprocessing, features extraction from the signals, and finally classification [4] between different seizure states in Fig 1.

1.2 Steps To Develop Predictive Model

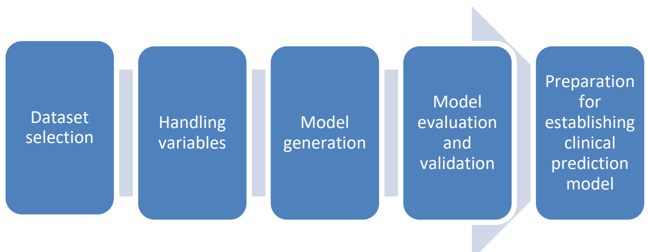

Fig 1: Develop Predictive Model

Clinical Model

The aim of prediction modeling is to develop an accurate and useful clinical prediction model with multiple variables using comprehensive datasets. The clinical prediction model is very valuable as it can be applied to a various scenario like screening, prediction, medical decision making and education in health. In the medical field, the prognosis is considered as a fundamental component. The process of developing clinical prediction model is explained with five steps:

Dataset Selection

The dataset is one of the most important components of the clinical prediction model. Researchers should use different types of datasets, depending on the purpose of the prediction model. For example, a model for screening high-risk individuals with undiagnosed condition/disease can be developed using cross-sectional cohort data. Accordingly, longitudinal or prospective cohort datasets should be used for prediction models for future events.

Handling Variables

datasets contain more variables than can reasonably be used in a prediction model, evaluation and selection of the most predictive and sensible predictors should be done. Additionally, variables which are highly correlated with others may be excluded because they contribute little unique information.

Model Generation

Although there are no consensus guidelines for choosing variables and determining structures to develop the final prediction model, various strategies with statistical tools are available. Regression analyses, including linear, logistic, and Cox models are widely used depending on the model and its intended purpose.

Model Evaluation and Validation

After model generation, researchers should evaluate the predictive power of their proposed model using an independent dataset, where truly external dataset is preferred whenever available.

There are several standard performance measures that capture different aspects: two key components are calibration and discrimination. Calibration can be assessed by plotting the observed proportions of events against the predicted probabilities for groups defined by ranges of individual predicted risk . Discrimination is the ability to distinguish events versus non-events.

1.3 Prediction System Model for Predicting Epilepsy Disease

Feature Extraction

Feature Extraction starts from an initial set of measured data and builds derived values (features) intended to be informative and non-redundant, facilitating the subsequent learning and generalization steps, and in some cases leading to better human interpretations.

Feature extraction is related to dimensionality reduction. The selected features are expected to contain the relevant information from the input data, so that the desired task can be performed by using this reduced representation instead of the complete initial data. In feature extraction, for the purpose noise removal various filters are used in proposed models.

Classifications

Classification is a process of categorizing a given set of data into classes; It can be performed on both structured or unstructured data. The process starts with predicting the class of given data points. The classes are often referred to as target, label or categories.

The classification predictive modeling is the task of approximating the mapping function from input variables to discrete output variables. The main goal is to identify which class/category the new data will fall into. We have to extract some temporal features from ictal and non-ictal state and performed a comparison for suitable selection of a classifier.

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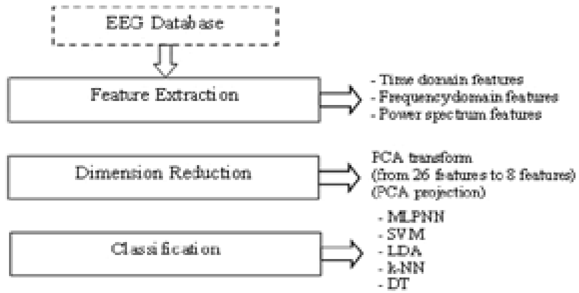

Fig 2: The system proposed for seizure prediction.

2. Literature review

Deferent Prediction Models Used For Seizure Detection

2.1 K-Nearest Neighbors

This algorithm is simple to implement, robust to noisy training data and effective if training data is large. The method employs a feature extractor coupled with K-Nearest Neighbor (KNN) classifier. The KNN classifier is employed for automatic classification of the EEG Signals into two categories viz. healthy subjects and epileptic subjects. The KNN classifier is developed with a training feature vector and then tested with a testing feature vector for binary classification of the EEG signals. the proposed method has been developed using 5 sets of EEG signals from a publicly available EEG time series database. The average accuracy of our proposed scheme is as high as 91.33%[9].

2.2 Decision Tree

decision forest algorithms could be more effective for other knowledge discovery tasks besides seizure detection. This study will help the researchers with their data science backgrounds to identify which statistical and machine learning classifiers are more relevant for further improvement to the existing methods for seizure detection. The classifiers such as SVM, ANN, and KNN are considered as prominent ones due to their remarkable performances in different domains decision forest (ensemble of decision trees)—is most effective. This is because it can produce multiple sensible, explanatory logic rules with high accuracy of prediction. random forest classifier was applied for the seizure detection model. The obtained average classification accuracy by this approach was 98.75%[1].Even though these classifiers contribute well to brain datasets, some of the relevant works on seizure detection using these classifiers are reported here. the problem is that the classifier trains the dataset twice, one for SVM-GA and another for SVM-PSO. This could be a time-consuming

2.3 Random Forest

The random forest classification algorithm has a high degree of parallelization, which improves operational efficiency. This is advantages for training on large quantities of EEG data. The classification of the features is performed using a random forest classifier. Depending on the training datasets and the optimization preferences, the performance of the algorithm were: 93.84%[12] However, it does generate a large number of hyper-parameters during the training process, and it may be difficult to determine the optimal parameters. Reduction in over-fitting and random forest classifier is more accurate than decision trees in most cases.

2.4 Logistic Regression

Logistic regression is a machine learning algorithm for classification. In this algorithm, the probabilities describing the possible outcomes of a single trial are modeled using a logistic function. Logistic regression is designed for this purpose (classification), and is most useful for understanding the influence of several independent variables on a single outcome variable. but Works only when the predicted variable is binary, assumes all predictors are independent of each other and assumes data is free of missing values.

2.5 Naive Bayes

This algorithm requires a small amount of training data to estimate the necessary parameters. Naive Bayes classifiers are extremely fast compared to more sophisticated methods. Naive Bayes classifiers work well in many real-world situations such as document classification and spam filtering. Naive Bayes based system is helpful for diagnosis of epilepsy disease. Naive Bayes offers highest accuracy of 95% in 2012. The results show that this system can do good prediction with minimum error and also this technique is important to diagnose diabetes disease. But in 2015, accuracy offered by Naive Bayes is low. It is particularly useful when the number of samples is very large. It supports different loss functions and penalties for classification.

3.6 Support Vector Machine (SVM)

Support vector machine is a representation of the training data as points in space separated into categories by a clear gap that is as wide as possible. SVM performs better for prediction of epileptic seizures in terms of sensitivity. Effective in high dimensional spaces and uses a subset of training points in the decision function so it is also memory efficient This system brings forth the achievement of sensitivity, specificity and classification accuracy which are 90, 90 and 94%, respectively with simple preprocessing.SVM offers highest accuracy of 94%[13].

In many application areas, SVM shows good performance result. Attribute or features used are correctly responded by SVM. It is a binary classifier. For the classification of multi-class, it can use pair wise classification. Support Vector Machines (**SVM**) has been employed to provide potential solutions for prediction models very effectively and a state-of-the-art machine learning algorithm.

3.7 Artificial Neural Network (ANN)

Developed an EEG seizure detector based on an artificial neural network.EEG signal data are transferred to FPGA-based ANN emulator core. The Core is trained on data which are patient's data and healthy person's data. After training, test data is loaded to ANN Emulator Core to detect any epileptic seizure of person's EEG signal. For analyzing brain's electrical activity, the designed ANN output layer makes a decision whether the person has epilepsy or not.The main advantage is to improve speed and accuracy for epileptic seizure detection. The accuracy of the model using ANN shows 93%.

3.8 Recurrent Neural Network (RNN)

In RNN, in which a network's output state depends on an arbitrary number of previous inputs. However, RNN has not been widely used in applications due to the lack of an efficient and universal training method. Other attempts have been made to overcome these limitations by using a special type of RNN as Elman network (EN) to detect epileptic seizures. An EN has the additional set called "context layer". The hidden layer is connected to these context units are incorporated recurrent EN and RBFNN to detect epileptic seizures with the wavelet entropy features. The result showed 94.5% accuracy for detecting epileptic seizures.

Table1. Comparison of ML Methods

S.No	Title	Author	Prediction Model	Disease	Tool	Dataset	Accuracy
1	A Review of Epileptic Seizure Detection using Machine Learning Classifiers	Mohammed Khubeb,2020	SVM, ANN, and KNN	Seizure Detection	Weka	CHB-MIT Bonn Bern-Barcelona-EEG Dataset	98.3%
2	Artificial Intelligence in Healthcare: Review And Prediction Case Studies	Guoguang Rong ,2019	Spectrum-Weighted Adaptive Directed Transfer Function (Swadtf)	Heart Disease	Not Mentioned	Not Mentioned	Sensitivity Of 84.82%
3	Epileptic Seizure Prediction Based On Permutation Entropy	Yanli Yang,2018	Support Vector Machine, Permutation Entropy,	Epileptic Seizure	Not Mentioned	Freiburg EEG Dataset	94%
4	Chaos Feature Study In Fractional Fourier domain For Preictal Prediction Of Epileptic Seizure	Keling Feia,2017	SVM	Epileptic Seizure	Weka	-	91.50%
5	EpilepticSeizures Prediction using Machine Learning Methods	Syed Muhammad Usman,2017	Support Vector Machines, Emd	Epileptic Seizures Prediction	-	CHB-MIT Dataset.	92.23%
6	Towards Improved Design And Evaluation Of Epileptic Seizure Predictors	Iryna Korshunova, 2017	Support Vector Machines, Lda	Epileptic Seizure	Weka	Kaggle Seizure Prediction Challenge Dataset	90%
7	Predicting Epileptic Seizures From Scalp Eeg Based On Attractor State Analysis	Hyunho Chua ,2017	Svm,Early Warning Indicator	Epileptic Seizures	-	CHB-MIT Dataset	86.67%

8	Epileptic Seizure Prediction Using A New Similarity Index For Chaotic Signals	Hamid Niknazar Ali, Motie Nasrabadi ,2017	Statistical Behavior Of Local Extrema (Sble)	Epileptic Seizure	-	Freiburg EEG Database	96.3
9	Detection Of Epilepsy Using Hilbert Transform And Knn Based Classifier	Raj Vipani,2017	K-Nearest Neighbours	Epilepsy Detection		EEG Database	91.33%.
10	Automatic Epileptic Seizure Prediction Based On Scalp Eeg and ECG Signals	Keider Hoyos ,2016	Linear-Bayes And K-Nearest Neighbors Classifier	Epileptic Seizure	Weka	Neurocentro Database	94%.
11	Cloud-Based Deep Learning of Big-EEG Data For Epileptic Seizure Prediction	Mohammad, Parsa Hosseini, 2016	Cloud-Based Brain - Computer Interface(BCI)	Epileptic Seizure	-	Manual	94%
12	Epileptic Seizure Prediction Using Statistical Behavior of Local Extreme and Fuzzy Logic System	Hamid Niknazar, 2015	Fuzzy Logic, LOO Technique	Epileptic Seizure	Not Mentioned	Freiburg EEG Dataset	80.45%
13	Early Seizure Detection Algorithm Based On Intracranial Eeg And Random Forest Classification	Cristian Donos,2015	Random Forest Classifier	Seizure Detection	-	CHB-MIT Dataset	93.84%
14	Early Prediction Of Medication Refractorine In Children With Idiopathic Epilepsy Based On Scalp EEG Analysis	Lung-Chang, 2014	SVM	Epilepsy Detection	Weka	-	94.2%
15	Early Seizure Detection Using Naïve Bays Classifiers	2012	Naive Bayes	Seizure Detection	-	-	93%

3. Discussion

Epilepsy is a dynamic disease, characterized by numerous types of seizures, syndromes, and presentations. This has led to a wide array of ictal and interictal EEG records to analyze. To understand these signals, investigators have begun employing various signal processing techniques, including both univariate and multivariate tools. Even with these tools, the richness of the data sets has meant that these techniques have had limited success in predicting seizures. These limitations may in part stem from our lack of understanding of the mechanism leading to seizures. In many cases, the initial success of a particular measure has been difficult to replicate because the first set of trials was the victim of overtraining. Thus far, no measure has been able to reliably and repeatedly predict seizures with a high level of specificity and sensitivity. Although the lines between seizure prediction, early detection, and detection can sometimes blur. For early prediction of epilepsy seizure detection , several machine-learning algorithms perform very well. From existing literature, it is observed that SVM and multi model approach((ANN,SVM & KNN) are both algorithms offer the better accuracy as compare to other algorithms.

4. Conclusion

In this paper a detail description of predictive modeling is presented, A researcher who is willing to do research in developing clinical prediction model would be benefited by this paper. There is a wide range of scope for the development of clinical prediction models especially for epilepsy seizure detection, as this is a disease in developing countries like India. The various techniques discussed in this article need to be continually studied, refined, and combined. They should be tested on standard data sets for their results to be accurately compared. After full development, techniques should be tested on out-of-sample data sets to determine their effect and it will help epilepsy patients could take precautions against them and improve their safety and quality of life.

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