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A Novel Epilepsy Seizure Prediction using AI and IoT

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KEYWORDS

Epilepsy, Wearable Device, Machine Learning

ABSTRACT

Epilepsy is a chronic neurological disorder characterized by sudden occurrence of excessive neuronal discharges which affects most of the people. Epileptic patients are suffering from seizures which cause damage to the neural tissues. It also results in many injuries such as fractures, burns, accident and death. Many methods have been developed for seizure prediction. These methods extract various features from EEG signal and train the classifier to find the seizure appearance. Selecting effective features is very important for seizure detection. The features are obtained using exhaustive spectral and statistical analysis. Signal classification will be done using Artificial Intelligent classifiers. The proposed device is easy to wear and feel comfortable long period of time. A wearable device will be designed which would contain minimum number of electrodes to accurately predict and detect the occurrence of seizure. The signal processing unit will be miniaturized and be made like a pocket device so that it would not affect the social stigma of the patient. This device would be used for chronic epileptic patients where the occurrence of seizure is more frequent. It can predict the occurrence of seizure with accuracy and less number of false positive rate.

1. INTRODUCTION

Epileptic seizures (ES) are a type of neurological condition in which abrupt alterations in electrical impulses cause aberrant brain activity. This abrupt shift in brain activity results in an uncontrollable seizure. ES frequently manifests as uncontrollably fast jerking, light flashing, disorientation, tingling, loss of consciousness, and alterations in taste, hearing, smell, and touch. Psychological conditions such brain tumors, strokes, acute head injuries, brain infections, genetics, drug toxicity, prenatal injuries, sleep disorders, and oxygen deprivation are common among ES patients. According to reports, having epilepsy might negatively impact one's quality of life. Although it can afflict people of any age, it usually first manifests in childhood or in people over 65.

The EEG signals are highly random signals which can be strenuous to analyze and classify normal and abnormal signals. Though seizure signals have different characteristics from the normal signal, an automated system still needs training which involves in maximum number of features from the signal. Usually 21 electrodes are placed in 10-20 arrangement of the scalp to obtain EEG of the brain. If this type of electrodes has to be placed throughout the day for measuring the brain activity, it would be inconvenient and uncomfortable for the patient even when it is in the form of a cap. Numerous wires would reduce mobility of the patient to the maximum. Another type of device which has only four electrodes are also available but the electrode placement cannot be adjusted according the epileptic focus and it might miss out on focal seizures.

A brief overview of proposed methods for identifying seizures in EEG signals is provided in this publication. The research is divided into three categories: machine learning algorithms for epileptic seizure identification, wearable caps for EEG signal measurement, and miniature signal processing units. A fundamental overview of the issue and its causes were covered in Section 1 of the study, which was divided into several sections. A summary of earlier survey publications that address various EEG seizure detection techniques is provided in Section 2. The suggested miniaturized cap for epileptic seizure prediction and the AI-based seizure prediction approach are described in Section 3. The various performance evaluation criteria and future directions are covered in Section 4, and the closing thoughts are covered in Section 5.

2. RELATED WORK

The trailblazer for automatic epileptic seizure detection through EEG signal is Gotman J[1]. In his earliest publication he has proposed automation for the purpose of tracing the EEG only at ictal (EEG recording at the time of occurrence of seizure) state or interictal state(EEG recording between the seizure occurrence). He had initially decomposed the signal into elementary waves and did the analysis with 16 channel EEG signals.

Around the turn of the century there were numerous publications on seizure detections using wavelet transform in EEG signals. One such paper is by Y. U Khan and Gotman J [2]where they had used wavelet transforms on intracerebral EEG signals and detected the seizure discharges. They had done an extensive study of how the frequency ranges fluctuates when compared to the background EEG signal. They have also tried segregating the bursts that occur in the background EEG signal so that it would not be taken as a seizure signal. The false detection was calculated as 0.3 per hour.

The recent trend in seizure detection based on EEG is based artificial intelligence. Lina Wang et al[3] have proposed a nonlinear method where features are extracted from time, time-frequency domains. Constructive features were used to classify them into seizure and normal signals. Classification was done using KNN, SVM, Linear Discriminant Analysis, Naïve Bayes and Logistic Regression. Single channel EEG was taken from the database was used for analysis.

Ahmed I. Sharaf et al [4] have used a tunable Q-wavelet to extract features and has used Firefly feature section algorithm. G Chen et al [5] have applied wavelet transform and decomposed the signal up to sixth level and have chosen certain levels and applied fast Fourier transform to the signals. The features are extracted from the FFT and classified using Nearest neighbor algorithm and claimed to have obtained promising results when applied to the EEG signal available in the data base.

Convolution Neural Network was used by Mengni Zhou et al [6] to classify and seizure and seizure free signals. They have introduced a new method in which the instead of features the signals in time and frequency domain was used as inputs to Convolution Neural Network. It was concluded that frequency domain signal proves to be more beneficial than time domain analysis. Here Pryramidal-1D-CNN is used[7]. The signal is split into sub-bands using fixed size windows that overlap each other and is given to P-1D-CNN and the signal is classified based on the voting system which takes the final decision.KM Tsiouris et al[8] have applied LSTM (long short term memory) networks for seizure prediction and enhance the prediction using CNN.

The work which has directly attempted to predict the occurrence of seizure in a novel method was done by H Chu et al [9]. They have identified an attractor state which occurs in the EEG signals before the occurrence of seizure in most of the cases. The spectral features of the signal at attracter state were identified and they have obtained a sensitivity of 86.67%. Deep learning algorithms have recently used for seizure prediction and detection.

Ye Yuan et al [10]have proposed a multi view deep learning framework in which they have considered time and spectral features of all the EEG signals of a 10 20 electrode placement system. Correlation between each channel has been found. The EEG channels which are important are considered by channel wise competition mechanism and many methods are used for evaluation. Ye yuan et al [11] have also proposed a model ChannelAtt which is an end-to-end multi-view deep learning model. It learns multi-view representation of all the EEG channels as well as their contribution scores that provides a meaningful outcome.

Levin Kuhlmannet al[13] in their extensive review have discussed the upcoming trends of seizure prediction system, available data base and predictor models that could effectively aid in the prediction of seizure.IsabellKiral-Kornek et al[14] has also dealt with the prospects of deep learning in the arena of seizure prediction and detection.

Haneef Z et al[14] have discussed various imaging techniques using, PET, Ictal SPECT and fMRI for localization of seizure as pre-surgical diagnosis. The current trend for seizure prediction is to find novel features which vary closely at the time of seizure or before the occurrence of seizure which could aid in the prediction of data.

3. PROPOSED WORK:

The features are obtained using exhaustive spectral and statistical analysis. Signal classification will be done using Artificial Intelligent classifiers. Since EEG signals exhibits significant variations in amplitude and frequency at the before or at the onset of a seizure, Statistical and spectral analysis for feature extraction will be done to differentiate between normal and seizure signals. The classification of features will be done using Neural network based Artificial Intelligent system. The convulsions which occur during seizure episodes can be detected using Micro Electronic Mechanical System(MEMS) accelerometer.The following fig 1 shows the EEG signal processing.

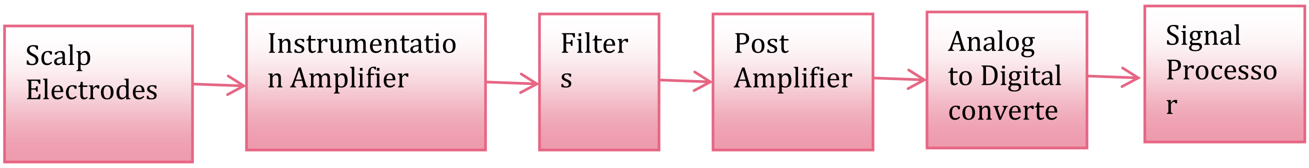

Fig 1 EEG Signal Processing

The spectral and statistical features extracted from the EEG system and MEMS accelerometer system are given to an Artificial Intelligent system for classification which classifies the data stored based on the trained data set available in the data base. The EEG signals observed just before the onset of a seizure is called as Pre-Ictal, and EEG signal observed during the seizure episode is called as Ictal signals and the signals observed after the seizure episode is called as Post-Ictal signals. Fig 3 shows the different stages of ictal.

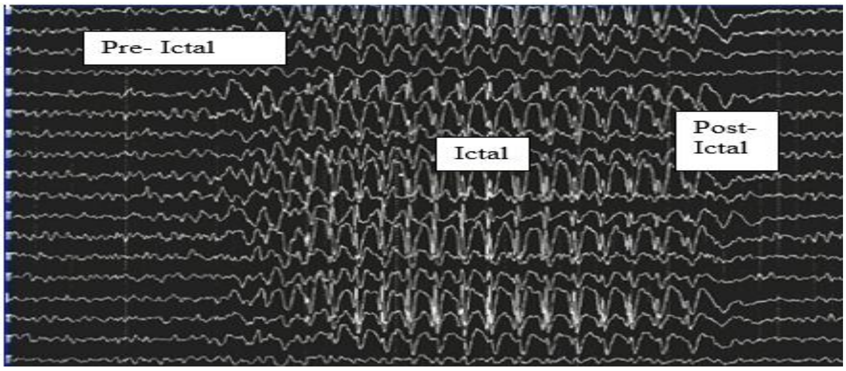

Fig 2. EEG signal of a patient in Pre-Ictal, Ictal and Post-Ictal stages

In some cases there would be some changes in the normal EEG even before the seizure occurs. External manifestation could be head ache, dizziness, tiredness etc. the signals recorded prior to the occurrence of seizure is called Pre-Ictal EEG. Figure (4) shows the periodic pulsation of Pre-Ictal pattern of EEG signal which indicate that a seizure will occur in a short while. If Pre-Ictal pulsations are detected, the occurrence of seizure can be easily predicted and the patient and the care taker can be warned. Fig 3 shows no such changes before the occurrence of seizure and hence the occurrence of seizure is very hard to predict. But seizure can be detected immediately and the patient and the caretaker can be warned at the onset of seizure. The following figures 3 and 4 show the EEg signal with pre ictal pulsation and non pre ictal pulsations.

Figure 3.EEG signals with Pre-Ictal Pulsations

Figure 4. EEG signals with no Pre-Ictal Pulsations

Schema for Data Analysis, Prediction and Detection of Epileptic seizure

The primary target users are patients suffering from epileptic seizures. The secondary users are clinicians who can have this portable device that can be used in their clinics itself. The device will be more cost-effective. The electrodes will be placed on the region of epileptic focus so that the seizure would be detected or predicted more accurately. Huge number of wires will not be present hence the patient will be made more comfortable and electrode placement can be done without much effort.The processor process the signal and find the seizure through algorithm. Extracted EEG values are sent to cloud storage through WiFi module in the signal processing unit.

This device through the supervision of the Clinician can be given to the persons affected by chronic epileptic seizures for acquiring their prolonged EEG data and to provide warning in case there is a pre-ictal pulsation. It can be used for epilepsy patients after the seizure occurrence for monitoring in home or hospital. It can send a warning to the patient's caretaker if any seizure occurs. According to WHO report more than 50 million people are affected worldwide by epilepsy. In India more children are affected by this disorder. More than 1% of the population is affected by Epilepsy in India and a major population dwells in rural areas. Most of the cases go untreated in rural areas. This device can also be used in as a screening device that can be kept in rural health care centres data can be sent to Government Hospitals for further investigations. In this case, many people will get treated at the earliest.

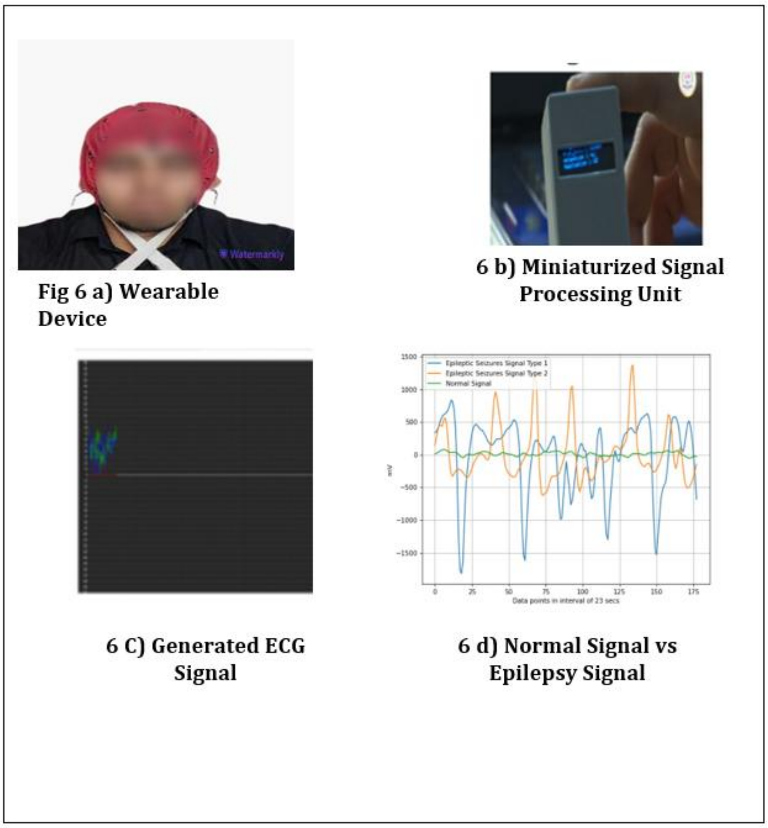

Fig 6 a) Wearable Device

6 b) Miniaturized Signal Processing Unit

6 C) Generated ECG Signal

6 d) Normal Signal vs Epilepsy Signal

Fig 5 Proposed workflow Diagram

The above fig 5 shows the proposed workflow mechanism.The statistical parameters, spectral quantities, of the EEG signal widely vary from the normal pattern for patients with brain disorders. This variation in the patterns can be used for detecting the seizure accurately and can enable the administration of rapid and effective treatment to the seizure patients.

Since EEG signals exhibits significant variations in amplitude and frequency at the before or at the onset of a seizure, Statistical and spectral analysis for feature extraction will be done to differentiate between normal and seizure signals. The classification of features can be done through HBOS algorithm.

4. PERFORMANCE ANALYSIS

The sampling rate is 500Hz. It consists of 32 channels, Segments of 300ms, 500ms in 256Hz is 128 points. The following fig 5 shows the features of dataset

	Fp1	AF3	F3	F7	FC5	FC1	C3	T7	CP5	CP1	...	Cz	C4	T8	CP6	CP2	P4	P8	PO4	O2	Unnamed: 32
0	0.057813	-1.335266	4.640480	0.219573	7.473817	2.314842	1.918097	-9.257533	9.089943	-7.104519	...	-2.241480	1.415335	2.406646	12.864059	4.021099	-2.828598	-2.588735	2.637905	-5.226618	NaN
1	1.367408	10.259654	3.345409	7.897852	-2.446051	-1.655035	-6.301423	-7.290317	-3.546453	-5.705187	...	-2.568397	-5.651418	-0.096730	-4.930759	-1.722504	-6.111309	0.094893	-3.521353	1.887093	NaN
2	-1.783132	4.133553	-0.951680	-1.624803	-1.827309	-2.280364	-2.279225	9.151344	-0.239575	-0.057604	...	-2.132823	-0.521117	8.605298	-4.499946	-3.232839	-4.249645	-3.687167	-7.383004	-4.489537	NaN
3	-3.690217	-0.814000	2.295469	0.901445	8.323679	1.127906	6.356886	11.642082	9.354154	-1.662478	...	-0.506117	-1.154866	-3.940251	7.390881	2.129897	-0.794675	-1.959021	2.774530	-6.323060	NaN
4	2.137114	6.420466	6.122230	10.015321	3.106394	3.183129	3.658535	4.571793	4.917712	-2.325940	...	1.813907	-6.444635	-27.680880	0.641364	1.996658	-0.445779	2.614021	6.161845	3.308816	NaN

5 rows × 33 columns

Fig 5 Features of Dataset

The plots of Fp1 data and AF3 data are plotted in the following figure 6 and 7.

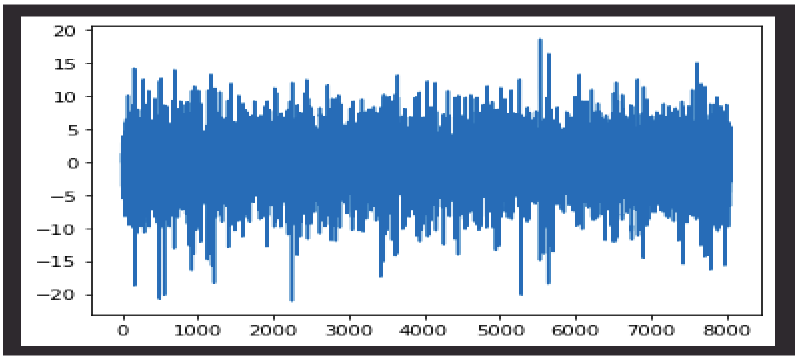

Fig 7 Af3 Data

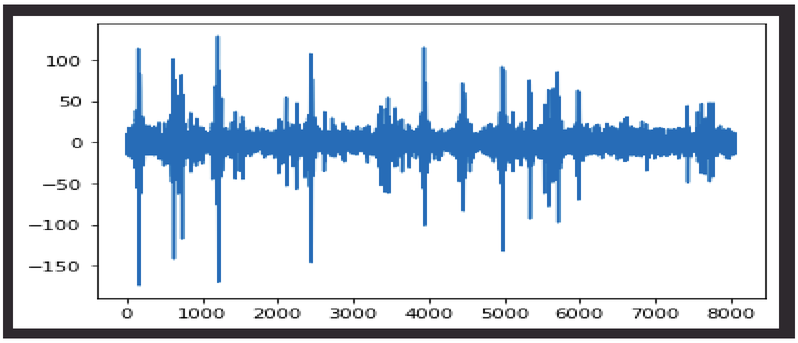

Fig 6 Fp1 Data

Fig 7 AF3 Data

The following graph 8 and 9 show the data points in interval of 23 secs of epileptic seizure signal type1 and type2 patients. Fig 10 shows the precision comparison analysis of

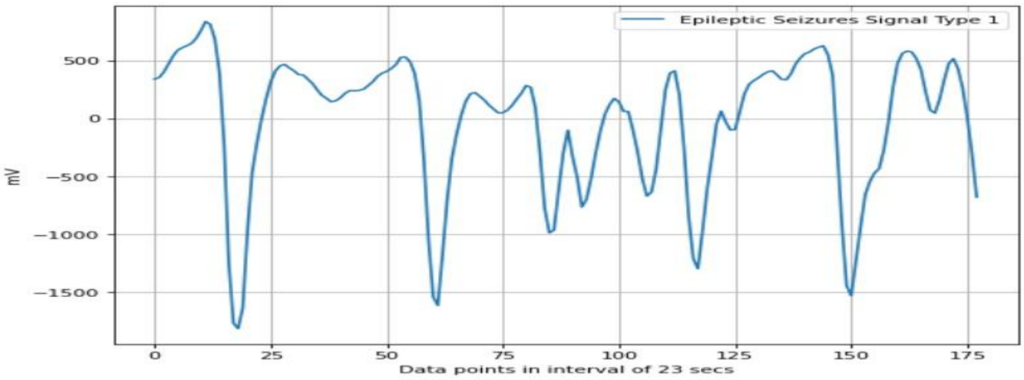

Fig 8 Epileptic Seizure Signal type1

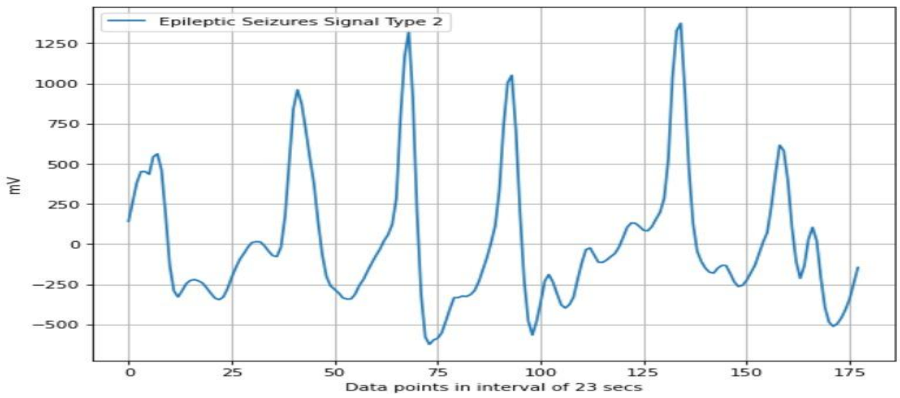

Fig 9 Epileptic Seizure Signal type2

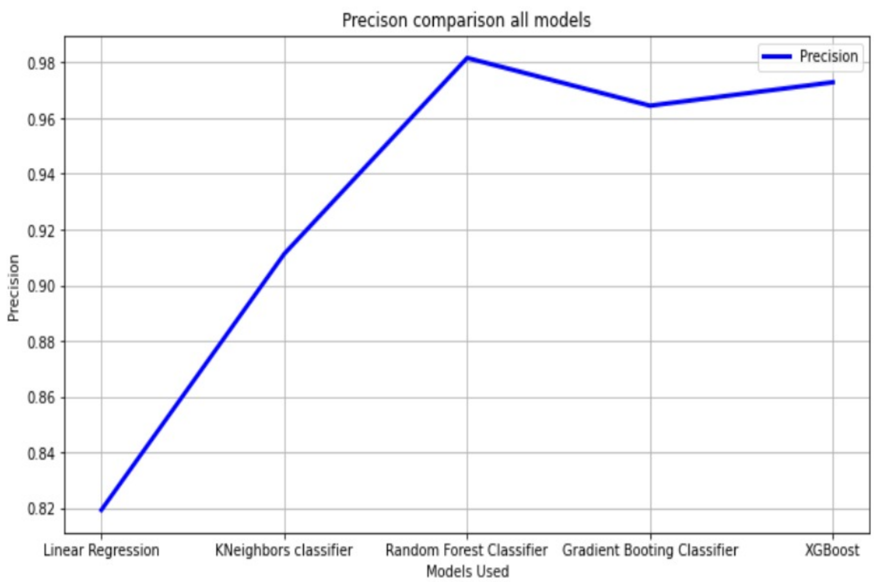

Fig 10 Precision Comparison Analysis

By using the above parameters machine learning algorithms are used to classify the abnormal and normal EEG signals. The algorithms used are Linear Regression, Linear Support Vector Classifier, Random Forest, and XGBoost. The training score for Linear regression performed the best with a training score of 0.991803. The Testing score was best in the XGboost algorithm. The comparative table gives the comparative performance analysis of all the algorithms. The comparative chart is given in below table 1.

Table 1 Comparison between Classifiers

	Classifiers	Train score	Test score	No of Missclassification	% of Missclasification	Training time	Prediction time
0	LR	0.991803	0.886905	5	11.111111	1.247864	0.004817
1	LSVC	0.953514	0.836310	7	15.555556	0.033723	0.000515
2	Random Forest	0.975410	0.889881	5	11.111111	0.031587	0.001699
3	Xgboost	0.975410	0.913690	4	8.888889	0.264133	0.000905

5. CONCLUSION

For the objective of real-time, patient-independent epileptic prediction, a clever, bio-inspired seizure prediction gadget is created and put into use for epileptics. It has a basic front-end circuitry and just 12 EEG electrodes that can be attached to any headband cloth. It keeps track of the epileptic patients' conditions for the doctors' future use, and if a seizure is anticipated, the caregivers are notified right away so that additional intervention measures can be taken. This warning alert aids in preventing hazards to the patient's life. The suggested integrated system makes rapid predictions about the seizure's on-site time. This keeps the patient safe. Additionally, the proposed technology aids physicians in conducting quicker and more accurate patient analyses in hospitals, hence improving treatment process efficiency. In addition to using fewer resources, the developed application is more dependable, usable, and simple to use.

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