Prediction of Epilepsy Seizure using Machine Leaning and IOT

[1]BahubaliShiragapur,[2]Tanuja S.Dhope(Shendkar),[3]DinaSimunic,[4]VijayalaxmiJain, [5]Nishikant Surwade

1. Dr D Y Patil School of Engg, Lohegaon, Pune , India
2. JSPM's Rajarshi Shahu College of Engineering,Tathawade,Pune,India
3. FER, University of Zagreb, Croatia
4. Dr. D Y Patil International University Akurdi, Pune, India
5. Dr. D Y Patil School of Engg, Lohegaon, Pune , India

Abstract:

Epileptic seizures are sudden changes in human behavior due to abnormal electrical activity in human brain, which leads to uncontrollable on human body activity. Nowadays various state-of-art techniques are been proposed by various research groups based on Electroencephalogram (EEG) signal, feature extraction followed by classification. In this study extraction of feature is based on advanced signal transform techniques. Further, prediction of medical event (epileptic seizure) is based on statistical methods. The seizure detection is an automated process to detect an event before occurrence. The prediction can be of short prediction or long prediction (several minutes before). This article explores the prediction methodology based on some clinical symptoms such as heart rate changes, cerebral blood flow, blood oxygen and variation in EEG signal, however for our study we have considered EEG signal variation. The signal processing approach predicts the Seizure Occurrence Period (SOP). This medical event is uncertain and may affect to person day to day life. Hence it is really important aspect which needs to be predicted well before the occurrence. This SOP period is considered for generating alarms for clinical decisions. Further this research article will identify the appropriate Artificial Neural Network model (ANN) for developing decision making approach which will be based on feature extraction of EEG signal. Thus, this article is based on design and development of non-invasive method to predict, classify and detect the epilepsy. Moreover the presented article uses wireless technology which will be paired with the external control devices. This article outcome will provide the real time alert system for monitoring epileptic seizure prediction and detection, which will be beneficial to the society.

Index Terms – Epilepsy, ANN, SOP and EEG, Epilepsy, KNN, LPC, PCA, Seizures, IOT.

I. INTRODUCTION

As per World Health Organization (WHO) survey around 60 million people affected by Epilepsy diseases [1]. This is one brain disorder which needs to predict before it occurs to save life threatening situations. Epilepsy seizure is a result of sudden change in Electroencephalogram (EEG) signal reflected as transient high peaks in EEG [2]. The EEG signal is widely used for clinical assessments for measuring brain activity and detection of seizures. Traditionally, visual scanning of a patients EEG data is tedious and time consuming process. Thus there is a need of reliable and automated system to predict, classify and detect the epilepsy, for better treatment. Furthermore, this kind of system can reduce the effects of long term treatment of antiepileptic drugs which are harmful on human neurological system. Thus the there is need of identifying better predictive system will help to doctors to take decisions and reduce clinical observation errors.

Seizure represents a single occurrence event in EEG. However epilepsy is defined as a neurological state characterized by two or more unprovoked seizures. Apart from various types of seizures, most common seizures can be classified as generalized or the form as focal [3]. During the Focal (or partial) seizures , the seizure activity is restricted to a portion of one brain hemisphere. The seizure begins in a part of brain. Focal seizures are of two types; a simple partial seizure is focal seizures with retained awareness. Complex partial seizures or Focal dyscognitive seizures are seizures with loss awareness

The EEG is a biomedical clinical tool used to predict human brain abnormalities. Furthermore, the use of better state-of-art techniques such as 10-20 international system is used to record brain activity [11, 12]. This multichannel time variant signal can be further analyzed by using signal processing tool to extract different signal features. It is possible to detect and predict epilepsy. This study's primary goal is to detect and predict by the use of machine learning approach and process the data by Internet of Things (IoT) devices. Furthermore, this chapter may motivates the research group to solve the societal problems.

We have processed the publically available EEG signal of normal as well as epileptic disorder patient signal using Chebyshev filter, wavelet analysis and extracted the features using wavelet decomposition that captured the frequency of dataset. The seven different techniques like LPC, kurtosis, mean, autocorrelation, skew-ness, spectral energy and feature extraction is done by using PCA. The state of art methods like Artificial Neural Network (ANN) are used to take decision on medical event whether the EEG signal free from epileptic seizure or not.

II. LITERATURE SURV0EY

A set of several unique features can be used for predicting the preictal state of epileptic seizures. Rasekhi et al. in [5] have proposed univariate linear features detection for seizure prediction, 132- dimensional feature space has been used by using six EEG channels and extracted various univariate linear properties. The work suggests the 'Preictal time' begins 10 to 40 minutes ahead the 'Ictal' state with a difference of 10 minutes. 'Preictal' and 'Ictal' states are considered for binary classification test to predict epileptic disorder. They reported that prediction sensitivity is 73.9 %. They used 'Support Vector Machine' (SVM) As a classifier for the classification of EEG signals 'Preictal' and 'Ictal' . Authors suggested use of univariate linear features with fixed window size, with certain regularization decision on EEG signal. They have considered 5-second segmented data for further processing and filtering to reduce noise.

Teixeira et al. in [6] have developed for predicting the epileptic seizure at real time. The medical event prediction is based on machine learning classification methods viz. (SVM), radial basis functions neural networks (RBF) and Multilayer Perceptions Neural Networks (MLP). The authors in [6] have suggested filtering techniques as preprocessing step can be used for removal of artifacts. They suggested SVM classifier can achieve seizure detection sensitivity of 75.8% [8]. The use of wavelet signal processing method for prediction of seizures is suggested in [9]. The wavelet energy and wavelet entropy are considered as features to train neural network. For testing six patient data has been selected from two or three channels. They reported sensitivity is 88 %.

Zandi et al. [10] have also suggested a model for prediction of seizures based on zero crossing by scalp EEG signals. The computation of histogram for all intervals in moving average window for observations at different set of points (Preictal and Interictal). The work suggests an alarm is created at the start or begin of ‘Preictal’ state of seizure to predict seizures. The suggested model provides sensitivity of 88.3% with predicted time of 22.5 minutes.

The authors in [12] suggested that statistical moments, the first four as features are extracted. These features are used to measure the variance, similarity, and symmetry of successive EEG signals samples. As the EEG is non-stationary signal to eliminate noise smoothing of EEG signal for better sensitivity and performance analysis of epilepsy EEG data set signals.

The authors [13] have shown the experimentation for detection of epileptic seizure by using filtering and wavelet transformation techniques. The authors [14] have presented a work on classification of sleep stages operate on wavelet transformation & neural network the detailed and db-4 approximation coefficients and back propagation algorithm are EEG used to train the neural network model for classifying the of sleep signals. The authors [16] have proposed use of lower devices MSP-432 to detect seizure detection. Another research group [17] have discussed on accurate detection of epilepsy with 10 sec prediction time well before the occurrence of medical event.

III. Proposed Approach

The Figure 1 shows the block diagram of the proposed approach.

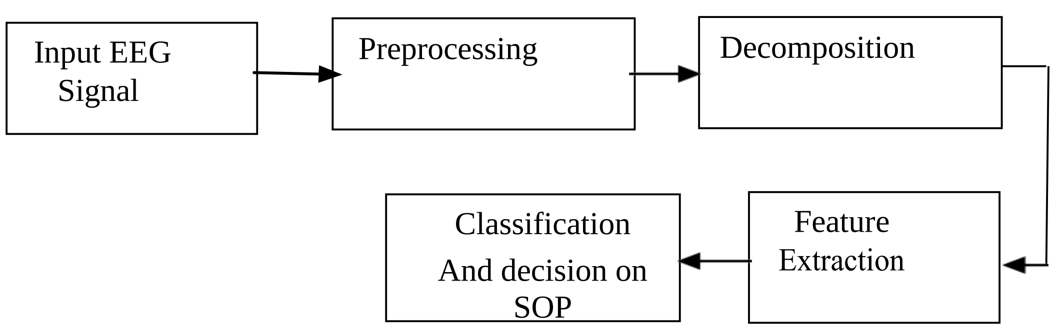


Fig.1. Block diagram of the proposed system

- EEG dataset

Public dataset [15] containing five EEG set are used for experimentation.

The details of dataset are as follows:

- Signal recording segments 100

- Sampling Frequency :1000Hz
- Duration 23.6 seconds of every segments

For experimentation we have used only two sets A,E.

Healthy patients EEG signals are in Set-A, whereas set epileptic patients EEG signal during epilepsy seizures are in Set-E.

A. Pre-Processing

The Chebyshev filtering method is used to remove the artifacts of EEG signal is, it's a non-stationary signal. This will enhance the prediction and detection of epilepsy seizure event.

B. Decomposition

It's a sub-band coding it uses Daubechies wavelet families to decompose the signal for analysis of low frequency band signal. For experimentation db-4 method are used for analysis of EEG data set.

C. Feature Extraction

Various statistical methods are considered such as LPC, kurtoses, Mean, autocorrelation and PCA. These features are considered to train the network for further classification.

a. Linear Predictive Coding (LPC)

The LPC coefficients were computed for non-stationary EEG data set. Thirteen LPC coefficients are considered for simulation. In Linear Prediction present EEG sample are approximated to the linear combination of past samples, i.e.:

$$s(n) = \sum_{K=1}^{P} \propto_k S(n-k) \text{ for some given value of } \rho, S, \propto_k \quad (1)$$

In above equation

$\propto_k, S$: linear prediction coefficients

s(n) : windowed speech sequence.

s(n) is calculated by the product of short time speech frame with either hamming or similar type of window:

$$S(n) = x(n) * w(n) \quad (2)$$

In above windowing sequence is represented by ω(n).

b. Kurtosis

Kurtosis is used to find heavy-tiredness or light-tiredness of data when compared to a normal distribution. The high kurtosis indicates heavy tails and similarly with low kurtosis indicates light tails. For data Y_1, Y_2... Y_N, the kurtosis is given by:

$$Kurtosis = \frac{\sum_{i=1}^{N}(Y_i - Y)^4/N}{S^4} \tag{3}$$

In above equation

- S represents standard deviation
- $\ddot{y}$ represents mean,
- N represents number of data points.

To calculated standard deviation N is used for denominator in kurtosis.

c. Mean

The average of EEG signal is used as another statistical parameter for multi-channel data set signals. This feature helps to differentiate epileptic seizure event. An arithmetic mean is calculated using the following equation:

$$A := \frac{1}{n}\sum_{i=1}^{n} a_i \tag{4}$$

d. Auto-correlation

The self-correlation of signal is an important feature is used to correlate signals based on time difference and average value at origin.

$$R_{XX} = \sum_{i=0}^{\infty} S(n) \tag{5}$$

The correlation coefficient R is used to indicate higher degree of similarity, $[-1, 1]$, with where perfect correlation is given by 1 and perfect anti-correlation is given by -1.

e. PCA

PCA is Principal Components Analysis. For low artifact signal analysis PCA is mostly used compared to LDA and ICA. Furthermore this is used for mapping data to lower dimensional space from high dimensional space.

D. Classification

Classification deals with classifying a new observation, it is based on knowledge gained from training data with known category membership. Various methods, such as Neural networks are like Back-propagation, LVQ, SOM, feed forward , Normalized Correlation, K-Nearest Neighbor (KNN) Hamming Distance, Support Vector Machine (SVM), Weighted Euclidean Distance, etc. are used for classification.

In this chapter, SVM and KNN are used for pattern classification, where the observations are classified based on features.

i. KNN

KNN is a one of the popular classification technique because of its simplicity and robustness. The test observation (feature) is classified by finding a nearest neighbor from calculated from training observations (features)

Various distance metric measurement technique such as Euclidean distance, chebychev, city block, correlation, cosine, Spearman, hamming etc. are used to find the distance between the training and testing vector

A simple Euclidean distance formulae to distance between training and testing vector is given by:

$$d(a,b) = \sqrt{\sum_{i=1}^{n}(a_i - b_i)^2} \tag{6}$$

The testing vector is assigned with a label of class which at smallest distance.

The features are extracted for training and testing set of observations, represent these observations in some different dimension space. The similarity of two different points can be represented by the distance between them in a space

The working of K- nearest neighbor algorithm is as follow [11-13]:

1. Define a positive integer value k, Also calculate the features of new observation.
2. For the new observation, calculate the k closest distances
3. Find the closer classification of this training observation.
4. This helps us to classify the new observation.

If the result is not satisfactory, change the value of k until the reasonable level of correctness is achieved

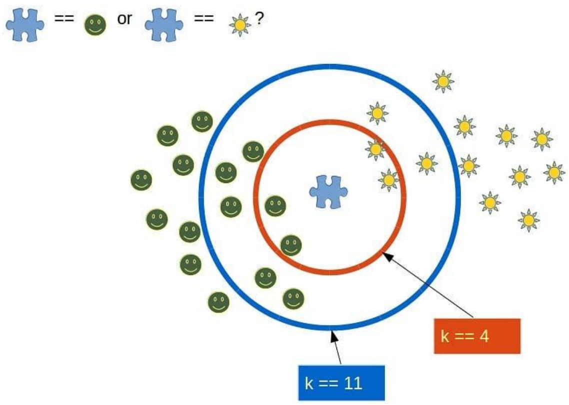


Figure-2. Classification of query image through KNN classifier

In Fig.2, There is two class represented by Blue Squares and Red Triangles. The new testing feature represents by green color is introduced in the feature set. The testing feature classified into the right class using k nearest neighbor by assigning the label of higher majority neighbors.

E. Seizure Prediction:

Fig-3 shows various medical events time lines, it includes no seizure occurrence time interval referred as inter-ictal.

For pre-ictal, the alarm will be set in forthcoming elapsed time denoted by Seizure Prediction Horizon (SPH). The Seizure Occurrence Period (SOP) follows the SPH , The seizure is expected to occur at SOP. After the seizure period, the during post-ictal period ,no seizures are observed. The thumb rule to avoid the harmful situation the cumulative time interval of SPH and SOP should longer than 5 Min. MATLAB simulated results are shown in figure-7.

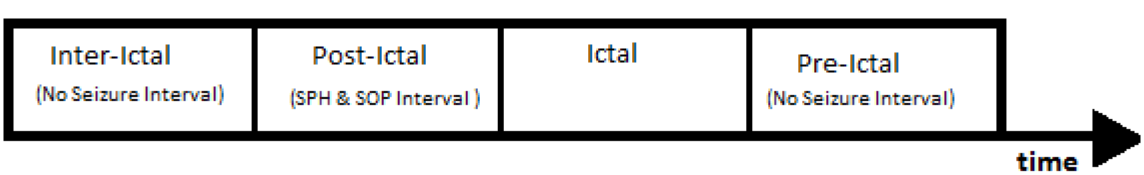


Figure-3 Seizure events time activity

The main objective is to identify and detect SOP at the patient side by wearable devices. Further this data processed remotely by the help of IoT. The block diagram shows complete wireless

Smart Web of Things (SWOT) architecture to monitor epileptic seizure activity at user end with comfortable and portable prototype. The user end observatory device will be connected with clinical side through existing smart phone devices. The figure-4 shows the block diagram of epileptic seizure prediction and detection using signal transform and statistical methods.

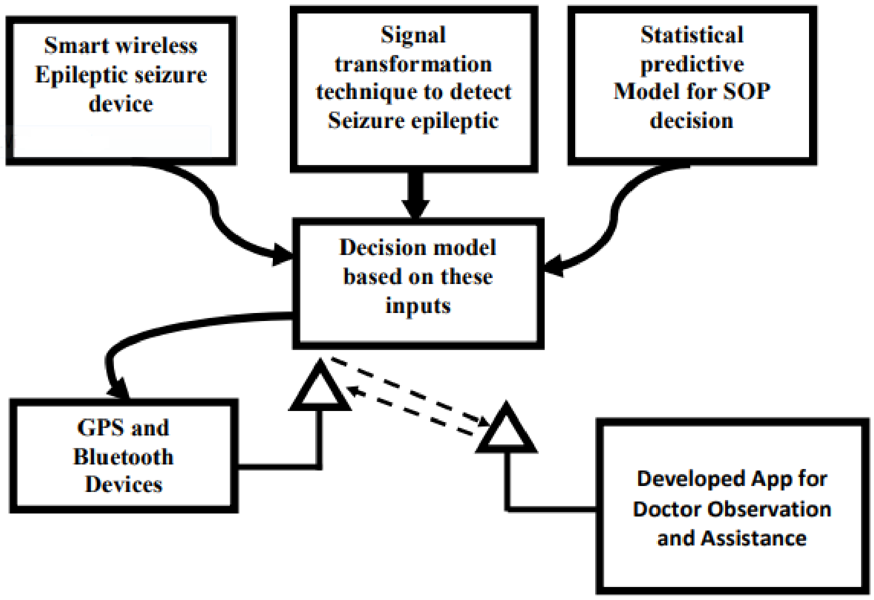


Figure- 4: Web of things (WOT) to predict epileptic seizure

Furthermore such kind of smart medical devices are todays need wherein we can monitor the health status remotely and also location of the patient can be traced. The alarm events can be generated further shared to family members as well as clinical observer for preventive action.

5. Results and discussion:

Simulation Parameter Table-I

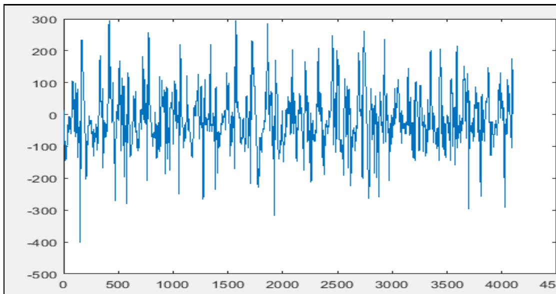
Descriptions	**Parameters**
EEG data set	Set-A & Set-E [15]
Filter	Chebyshev filter
Decomposing technique	Wavelet transform
ANN Classifier	KNN classifier

For the simulation analysis we have used *MATLAB* tool and Table-I parameters are considered. In the proposed work, the EEG signals (Healthy person data set SET-A and Set-

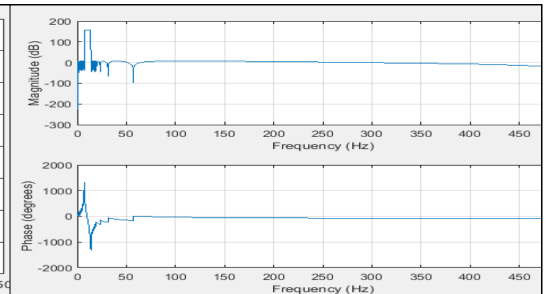
E data for Epileptic seizure person) are pre-processed through Chebyshev filter. The filtered signal is then decomposed by Discrete Wavelet Transform. Different statistical features were extracted to differentiate the normal and epileptic EEG signal as shown in figure-5 and figure-6. The outcomes of the proposed system are described below in a qualitative and quantitative manner.

In the qualitative analysis, the graphical results of the EEG signals are presented.

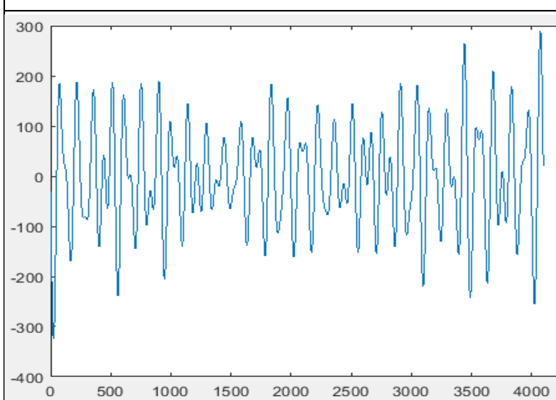
- **Normal EEG**



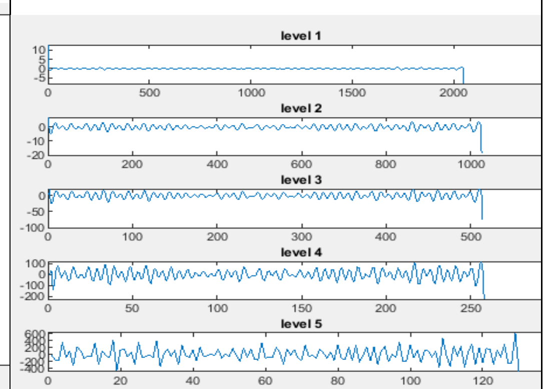
(a)



(b)



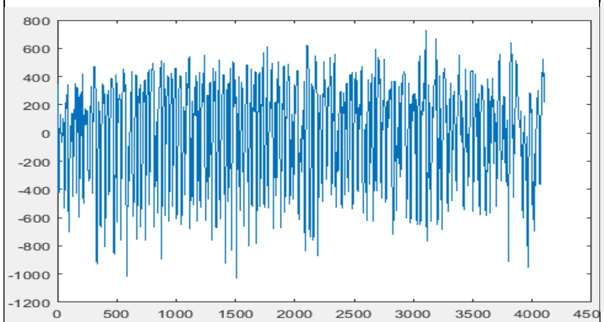
(c)



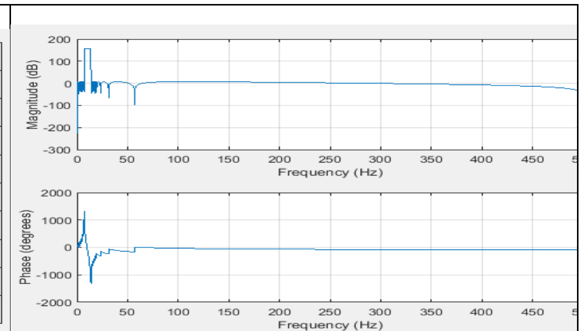
(d)

Figure-5. Qualitative analysis of proposed system on Normal EEG Signal (a) Input Normal EEG signal (b) magnitude and phase plot of the filter (c) filtered signal (d) Wavelet decomposition level 5.

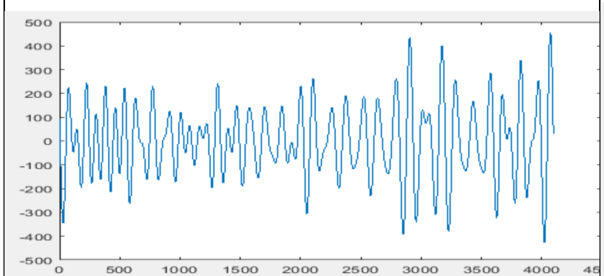
Epileptic EEG



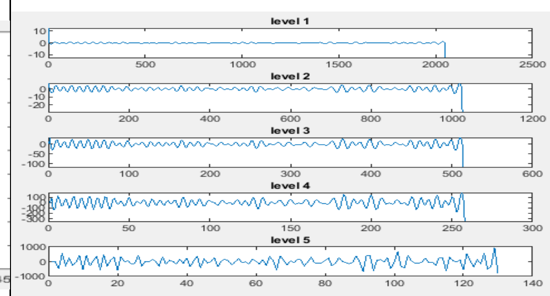
(a)



(b)



(c)



(d)

Figure-6. Qualitative analysis of proposed system on Normal EEG Signal (a) Input Normal EEG signal (b) magnitude and phase plot of the filter (c) filtered signal (d) Wavelet decomposition level-5

Fig-7 shows the seizure timeline activity signal, we need to look for adaptive seizure prediction algorithm (ASPA) for better real time performance.

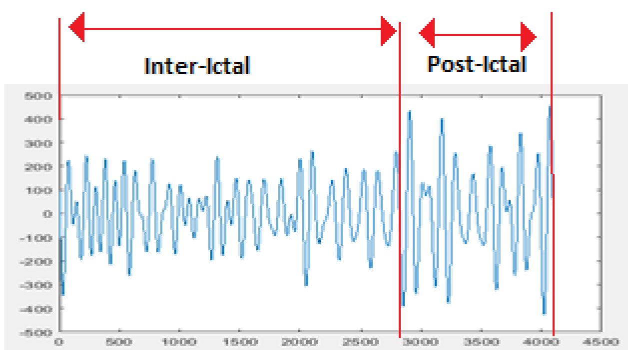


Figure-7: Seizure activity filtered signal

TABLE-II Features of Normal and Epileptic EEG signal

Patient	Features												
	LPC					Kurtosis	Mean	Autocorrelation					PCA
1	1	1.258484	...	-0.0455	-0.0818	624.6202	3.57455	-0.1477	1	...	-0.457	-0.025	0.17166
2	1	1.74397	...	-0.3164	-0.2009	1619.425	3.331812	-0.2513	1	...	-0.164	-0.175	0.20423
3	1	1.367817	...	-0.1833	-0.0946	5079.8	4.538614	-1.9356	1	...	-0.497	0.1293	0.12803
4	1	1.112386	...	0.102362	0.009233	6133.054	2.962493	0.378282	1	...	-0.514	-0.091	0.20748
5	1	1.317612	...	-0.15653	-0.10689	7704.017	2.969006	2.610246	1	...	-0.525	0.1911	0.02850
6	1	1.325386	...	-0.01242	0.009085	2564.211	2.695167	-0.20193	1	...	-0.487	-0.087	0.27810

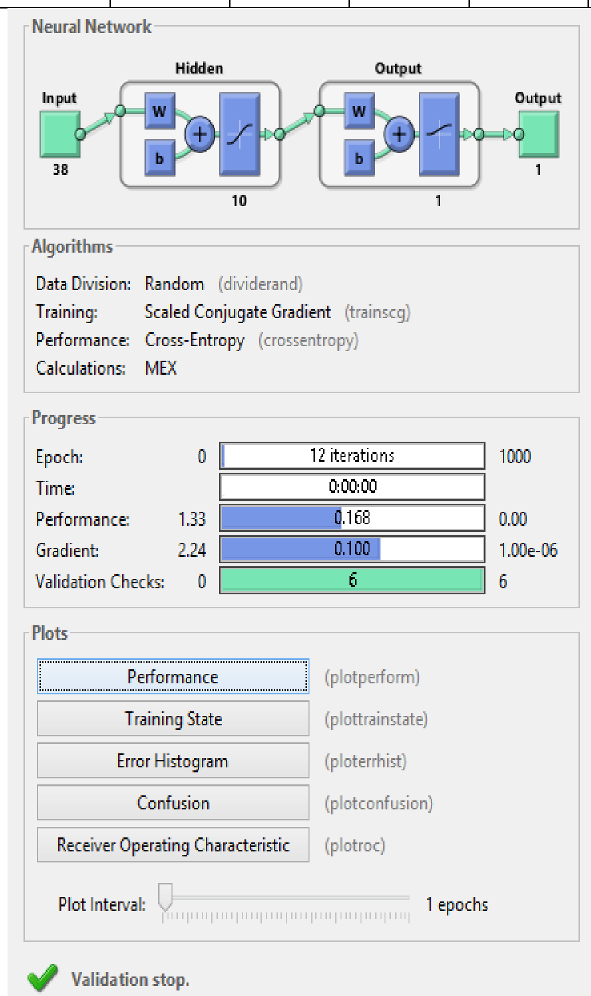


Figure 8: ANN Model

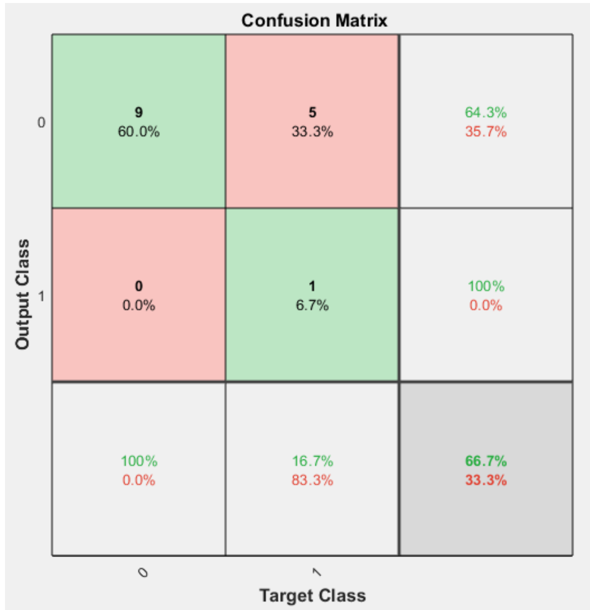


Figure-9. Confusion Matrix

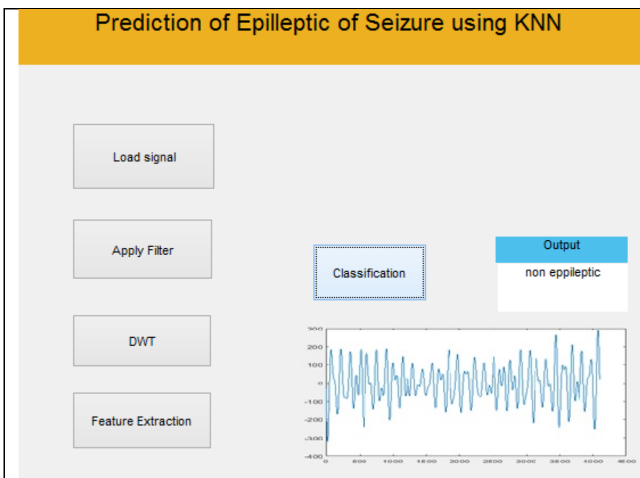


Figure-10. GUI for non-epileptic patient

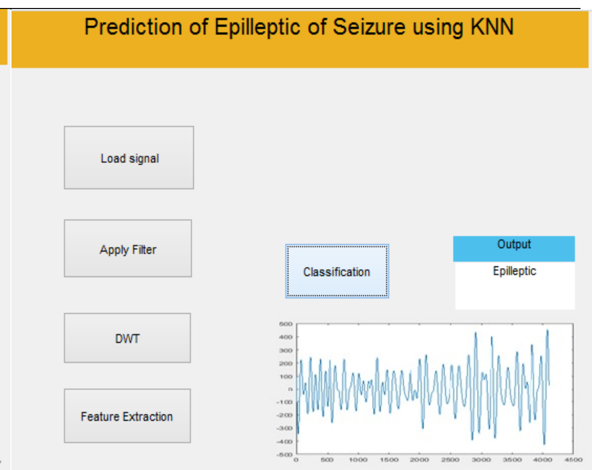


Figure-11. GUI for Epileptic Patient

In TABLE-II, the Extracted features using five different techniques have been tabulated. Patient 1-4 are for normal patient while Patient 4-6 are the epileptic patients. From the above table-II, it is observed that the value of the feature of the epileptic and normal patient differ. These features then applied to the Machine Learning Algorithm (KNN). We have programed and designed the Graphical User Interface (GUI) to display the final output whether the person having epilepsy or not, results are shown in figure-8 to figure-11.

Summary

In this chapter, the system for auto-classification of the normal and epileptic EEG signal has been implemented. EEG signals of the normal and an epileptic patient were collected from online sources. The EEG signals were pre-processed using the Chebyshev filter. From the filtered signal various features are extracted viz. LPC, kurtosis, mean Autocorrelation and PCA. Those features are used as an input in a KNN. The final classification of the EEG signals to the existence of seizures or not is done by KNN. Further filtered signal is used to predict the occurrence seizure event. The application can be scaled up using web of things.

Acknowledgements

We are thankful to Dr. Sanjay Pawar, (Fellowship in Stroke Neurology (FISN), Consultant Stroke Physician), for continuous guidance and more insight on epileptic seizure medical terminologies.

References

[1] https://www.who.int/news-room/fact-sheets/detail/epilepsy

[2] A. T. Tzallas, 1. 2. (2007). Automatic Seizure Detection Based on Time-Frequency Analysis and Artificial Neural Networks. Computational Intelligence and Neuroscience, 13.

[3] E. Jua´rez-Guerra, V. A.-A.-G. (2015). Epilepsy Seizure Detection in EEG Signals Using Wavelet Transforms and Neural Networks. Springer International Publishing Switzerland, 261-269.

[4] Zakareya Lasefr, S. S. (2017). Epilepsy Seizure Detection Using EEG signals. IEEE, 6.

[5] J. Rasekhi, M. R. K. Mollaei, M. Bandarabadi, C. A. Teixeira, and A. Dourado, "Pre-processing effects of 22 linear univariate features on the performance of seizure prediction methods," Journal of Neuroscience Methods, vol. 217, no. 1-2, pp. 9–16, 2013.

[6] C. A. Teixeira, B. Direito, M. Bandarabadi et al., "Epileptic seizure predictors based on computational intelligence techniques: A comparative. study with 278 patients," Computer Methods and Programs in Biomedicine, vol. 114, no. 3, pp. 324– 336, 2014.

[7] C. Brunner, M. Naeem, R. Leeb, B. Graimann, and G. Pfurtscheller, "Spatial filtering and selection of optimized components in four class motor imagery EEG data using

independent components analysis," Pattern Recognition Letters, vol. 28, no. 8, pp. 957–964, 2007.

[8] M. Bandarabadi, C. A. Teixeira, J. Rasekhi, and A. Dourado, "Epileptic seizure prediction using relative spectral power features," Clinical Neurophysiology, vol. 126, no. 2, pp. 237–248, 2015.

[9] K. Gadhoumi, J. Lina, and J. Gorman, "Discriminating preictal and interictal states in patients with temporal lobe epilepsy using wavelet analysis of intracerebral EEG," Clinical Neurophysiology, vol. 123, no. 10, pp. 1906–1916, 2012.

[10] A. S. Zandi, R. Tafreshi, M. Javidan, and G. A. Dumont, "Predicting epileptic seizures in scalp EEG based on a variational Bayesian Gaussian mixture model of zero-crossing intervals," IEEE Transactions on Biomedical Engineering, vol. 60, no. 5, pp. 1401–1413, 2013.

[11] S. J. Roberts, D. Husmeier, I. Rezek, and W. Penny, "Bayesian approaches to Gaussian mixture modeling," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 20, no. 11, pp. 1133–1142, 1998.

[12] Bahubali Shiragapur, Nishikant Surwade, et.al. , "Experimental Study on Detection of Epilepsy", Helix Vol. 9 (3): 5052- 5056, , 2019

[13] Vijaylaxmi Jain, and Bahubali Shiragapur, et.al. "Sleep stages classification using wavelet transform & neural network", Biomedical and Health Informatics (BHI), IEEE-EMBS, BHI 2012 Hong Khong, pp.71-74, 2012.

[14] Song Y. Crowcroft,J., & Zhang, J. (2012). Automatic epileptic seizure detection in EEGs based on optimized sample entropy and extreme learning machine. Journal of neuroscience methods, 210(2), 132-146.

[15] https://physionet.org/content/chbmit/1.0.0/

[16] Farzad Samie ; Sebastian Paul ; and et.al. (2018), "Highly efficient and accurate seizure prediction on constrained IoT devices", IEEE xplorer, ISSN-1558-1101.

[17] Yinda Zhang and et.al.(2018) "Integration of 24 Feature Types to Accurately Detect and Predict Seizures Using Scalp EEG Signals", sensors 2018, 18, 1372; doi:10.3390/s18051372.

[18] Prof. V. V. Shete and et.al, (2011) "Sleep Stage Classification Using Wavelet Transform & Neural Network", Tran-stellar Journal USA, IJECIERD. Vol.2, Issue 2 June 2012 38-45.