

Experimental Study on Detection of Epilepsy

^{*1}Prof. Bahubali Shiragapur,²Prof. Nishikant Surwade,³Aishwarya Nair,⁴Shefali Singh, ⁵Priya Choudhary

^{1,2} Professor, Department of E&TC Engineering, Dr. D Y Patil School of Engineering, Lohegaon, Pune(MH)

^{3,4,5} Student, Department of E&TC Engineering, Dr. D Y Patil School of Engineering, Lohegaon, Pune(MH)

Email: bahu2001@gmail.com, nishikant.surwade@dypic.in, aishwaryabnair95@gmail.com,
singhshefali856@gmail.com, choudharypriya2795@gmail.com

Received: 09th January 2019, Accepted: 13th February 2019, Published: 30th June 2019

Abstract

Epilepsy is a neurological disease which can be referred as a disorder of the central nervous system, considered by the loss of consciousness and seizures. Epileptic patients are subjected to epileptic seizures that cause abnormal excessive brain activity. This condition affects approximately 5% of the world's population. Ideally, it is possible to detect and predict epilepsy. For detection, we can consider computer electroencephalograph, smart watches etc., whereas for prediction we can use machine learning artificial intelligence, phase correlation. Our objective is to survey different approaches to Epileptic seizure detection. In our work, we have pre-processed the EEG signal of both normal and Epileptic signal by using a Chebyshev filter. Later, we have used Wavelet analysis to decompose the filtered signal into five sub-levels. However, we have considered only the lower sub-level for further processing. The features are extracted using wavelet decomposition for further analysis.

Keywords

Epileptic Seizure, Seizures, Electroencephalogram(EEG), Chebyshev, Wavelet Transform (WT).

Introduction

Epilepsy is a neurological disorder causing abnormal excessive brain activity. This condition affects approximately 5% of the world's population. It is the fourth most common neurological disorder and it affects people of all ages. According to the World Health Organization (WHO), it estimates that epilepsy affects 50 million people worldwide [1]. The seizure is called as a single episode whereas multiple episodes of seizure are called epilepsy, which is a disorder. Epilepsy often follows many medical disorders such as traumas, and drug or alcohol intoxication [1]. They are also associated with brain tumours, abscesses, congenital malformation, stroke; which is mainly of two types: One is the Ischemic i.e. obstruction of blood vessels and the other one is Haemorrhage i.e. rupture of blood vessels. Epilepsy begins before 20 years of age in more than 75% of patients. Epilepsy is not synonymous with mental retardation or illness; it is not associated with an intellectual level. The cause for epilepsy in most of the cases is unknown (clinical expert's opinion).

Epilepsy that occurs because of other issues may be preventable. Seizures can be controlled with 20 types of medication, depending on the type of seizures. Inexpensive options are often available. It is not necessary that all cases of epilepsy are lifelong, in some cases it can be cured, if proper medication is being taken [2]. Out of the four lobes of the brain i.e. Frontal, Temporal, Occipital, and Parietal lobes, if the disorder is in Frontal, Occipital, Parietal then the person can be treated with the help of proper medications. But, if it is affected on temporal lobe then the person must undergo surgery because it is the most common indication for surgery. Before that, the person shouldn't have any other diseases such as high blood pressure, diabetes etc., before undergoing surgery. Seizures beginning at the frontal lobe area of the brain are usually shorter than those that start at temporal lobe area [2].

Out of many types of seizures, mainly there are two types of seizures: Focal and Generalized seizures. The focal seizure is also called a Partial seizure. Focal is further classified as Simple partial seizure, Complex partial seizure, and Partial seizures that secondarily generalize [3]. A simple partial seizure is localized to one side of the brain and it may spread to other areas. In this, consciousness is not lost. In Complex partial seizure, it lasts for about few minutes. A partial seizure may spread to other areas of the brain. A generalized seizure is also called as Grand mal seizure. This usually happens due to hereditary. They are of six types: Tonic-clonic seizures, Clonic seizures, Tonic seizure, Myoclonic seizures, Absence seizures, Atonic seizures. In tonic-clonic seizure the body stiffens, jerks, shakes and may also lose consciousness. It lasts for around 1 to 3 minutes. The clonic seizure is the seizure in which muscles have spasms, which may often make our face, neck, and arm-muscles jerk rhythmically. They may last for about several minutes. A tonic seizure lasts less than 20 seconds and often happens during sleep. In this, the muscles in our arms, legs, or trunk tense up. The myoclonic seizure usually appears as a sudden brief jerk or twitches in arms and legs. Absence seizures are called Petit mal seizure. In this, seizure that involves brief, sudden lapses in attention and staring blankly into space, the episodes last less than 15 seconds.

Electroencephalogram (EEG), Magnetic Response Imaging (MRI), Positron-Emission Tomography (PET), etc. are the existence of numerous technologies for diagnosing epileptic seizure [3]. EEG is the method of recording

the brain waves by placing the surface electrodes on the scalp using the electrode conductive gel. If seizure takes place at the time of taking EEG, then it shows a sharp spike wave for the prediction purpose [4]. MRI shows the brain structure and its abnormality. Abnormality like scars, tumor, infection and the brain mask formation are seen on MRI. In PET, it is used to observe the metabolic process in the body to diagnose the disease.

There are two possible versions in terms of detecting and predicting epilepsy [4]. First one is the Basic version and the second is the extended version. Basic versions are Neurologists, Nurses, Paediatrician, Healthcare workers whereas the extended version is the Researchers, Scholars, Epileptologists, and Neurophysiologists [4]. Ideally, it is possible to detect and predict epilepsy. For the detection of an epileptic seizure, it will take around 30-60 minutes per patient. The person with clinical history, it may take around four hours or maybe 24 hours depending on the event. According to the researcher's point of view, it is possible to detect and predict the seizure. Brain interface with the computer, smartwatch etc. can be used for detection of Epilepsy. For prediction purpose, various approaches can be used such as machine learning, phase correlation, through which we can predict the Epilepsy. Thus, we can take precaution for proper medication well before the occurrence of event.

This paper is organized as follows: Section I describes the methods and procedures of pre-processing and wavelet decomposition. Section II refers to EEG dataset, pre-processing, decomposition and feature extraction. Algorithm is presented in section III. Section IV shows result along with the discussion.

Materials and Methods

The objective is to determine whether the given signal is epileptic seizure or non-seizure. The chart works in a different number of stages. For pre-processing, we have used a publicly available dataset from the University of Bonn, Germany This dataset is classified as healthy patients (eyes opened, and eyes closed), seizure-free patients and epileptic patients. This collection of the dataset is identified as O, Z, F, N, and S. Set O contains EEG signals of healthy patients with eyes opened; set Z contains healthy patients but with eyes closed. Set F and N, it contains EEG signals recording of seizure-free patients. And lastly, Set S contains EEG signals from Epileptic patients. However, in our work, we have used Set F and Set S. For processing the signal, we applied the Chebyshev filter to the IIR filter to eliminate any artifacts from the EEG signal and to get maximum spectral efficiency [4]. Further, decomposing the signal, Wavelet analysis is used [5][6]. From various wavelet transform, we have considered Daubechies Wavelet. For feature extraction, we have applied a Wavelet Transform. Figure-1 shows the conceptual block diagram of epileptic seizure detection.



Figure 1: Block Diagram

EEG Dataset

For the detection of Epilepsy, we have used publicly available EEG dataset from the University of Bonn, Germany. The dataset is classified as healthy patients (eyes opened, and eyes closed), seizure-free patients and epileptic patients. These collections of the dataset are identified as Z, N, O, F, and S. Each of the EEG dataset contains 100 segments with duration of 23.6 seconds. The sampling frequency is 173.6Hz with each segment containing 4,096 samples. Set Z contains EEG signals of healthy patients with eyes opened; set N contains healthy patients but with eyes closed. Set F and O, it contains EEG signals recording of seizure-free patients. And lastly, Set S contains EEG signals from Epileptic patients. However, in our work, we have used Set O and Set S. These two settings will be used as an input in our proposed method. Figure-2 shows Normal input signal and Figure-3 shows Epileptic input signal.

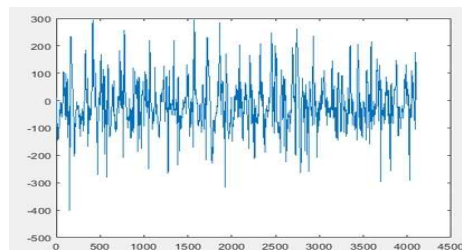


Figure 2: Normal Signal

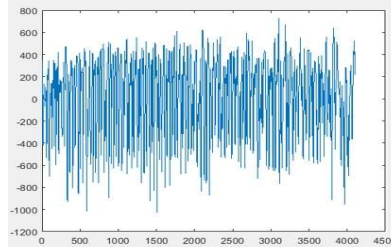


Figure 3: Epileptic Signal

Pre-processing

For pre-processing technique, we have used a Chebyshev filter. Chebyshev Higher Order Filter is applied to the EEG signal so that higher frequency components can be removed. This Chebyshev filter is passed to Infinite Impulse Response filter (IIR), to get the maximum spectral efficiency. This spectral efficiency is directly proportional to the order of the filter along with the stopband and passband coefficients [7]. IIR filters are infinite, recursive, unstable, it doesn't consider the linear characteristics. Here we have proposed 7th order Chebyshev bandpass filter, to reduce the frequency spectral noise. To have the stability in the signal, we have converted 7th order Chebyshev bandpass to 2nd order Chebyshev bandpass. Figure-4 and Figure-5 shows the filtered response of normal and epileptic signal.

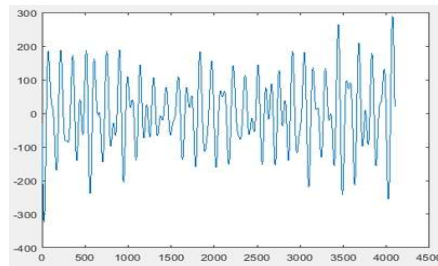


Figure 4: Filtered Normal Signal

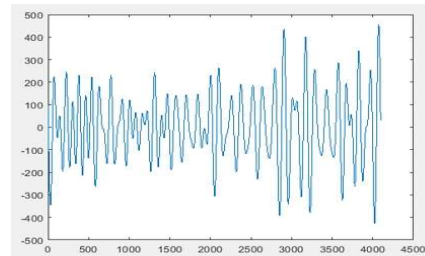


Figure 5: Filtered Epileptic Signal

Decomposition

To denoise and compress the signal, we have considered Discrete Wavelet Transform(DWT). With DWT we can analyze progressively narrow sub-bands at different resolution [8][9]. From various wavelet transform, we have used Daubechies Wavelet Transform (db2) to get the highest number A of vanishing moments. The names of the Daubechies family wavelets are written dbN, where N is the order, and db the "surname" of the wavelet [9]. We have decomposed the approximation sub-band at multiple levels wavelets, for fine-scale analysis. Out of the five sub-bands, we have considered the lowest frequency sub-band as it consists of less noise as compared to the highest frequency sub-band which comprises with noise. This decomposition is further used for feature extraction using lower frequency sub-band. Figure-6 and Figure-7. shows that various stages of decomposed signal of both normal and epileptic patients.

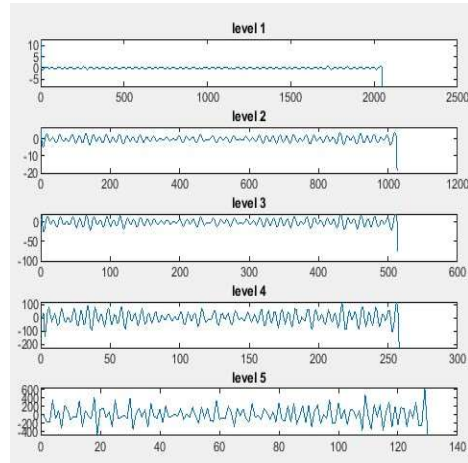


Figure 6: Wavelet Decomposition of Normal Signal

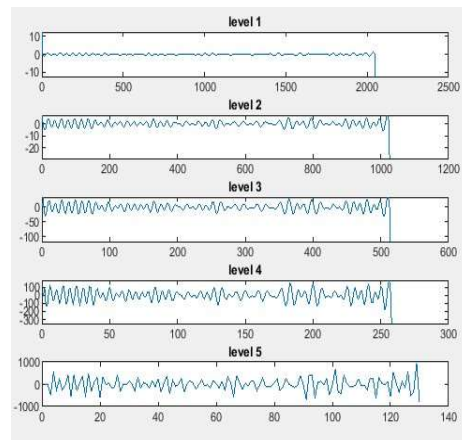


Figure 7: Wavelet Decomposition of Epileptic Signal

Feature Extraction

Discrete Wavelet Transform (DWT) is applied for feature extraction in terms of wavelet coefficient vector. The feature extraction used are mean, auto-correlation, linear predictive coding(LPC), Kurtosis, Skewness and Spectral energy. The calculated values for Normal and Epileptic are shown in the Table 1 and Table 2 (in section

Algorithm:

1. Import the time varying EEG data set
2. Select only EEG signal and discard all other parameters
3. Display the original EEG signal
4. Design the Chebyshev filter to reduce the frequency spectral noise
5. Apply the filter to the original signal
6. Decompose the original filtered signal to five sub-band levels using wavelet transform
7. Select the lower band frequency for further processing
8. Now apply the bandpass filter to separate the difference band like level 1, level 2, level 3, level 4, level 5.
9. The wavelet of the 5th band is considered as a feature extraction.
10. Repeat step 1 to step 9 for each EEG sample.
11. Store all the features of each EEG sample in excel sheet with prospective lobes.
12. Train and test the features using training model
13. Evaluate the performance.

Results and Discussion

Table -1 represents feature extraction of normal patients and Table-2 represents feature extraction of epileptic person. These features are further used for training Artificial Neural Network (ANN), analysis of this will be covered in Part-II article.

Patients	LPC	Kurtosis	Mean	Auto-correlation	Skewness	Spectral energy
1.	0.2156	16.3004	0.3320	0.0273	0.2806	0.0106
2.	0.6157	8.3738	-0.0479	0.0281	0.0235	0.0065
3.	0.1330	14.3954	-0.4230	0.0291	-0.1797	0.0165

Table 1: Feature Extraction of Normal Patients

Patients	LPC	Kurtosis	Mean	Auto-correlation	Skewness	Spectral energy
1.	0.1325	3.6524	3.6987	0.0283	0.3566	0.6101
2.	0.2759	5.1468	0.2790	0.0237	-0.0788	1.0180
3.	0.1007	15.3282	-5.6170	0.0347	-1.9868	0.4718

Table 2: Feature Extraction of Epileptic Patients

Conclusion

In this paper we have studied and expressed the cause of epileptic seizure with the help of clinical experts. For experimentation analysis we have extracted the features using DWT followed by Chebyshev filter type-I. The various statistical features are extracted using Wavelet transform, are useful to train ANN for classification. Furthermore, Classification and detection of Epileptic Seizure will be covered in part-II article. We request reader to please refer part-II article for clear understanding of detection and prediction using ANN.

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.

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