Detection of Pre-Epileptic Seizure by Using Wavelet Packet Decomposition and Artifical Neural Networks

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Abstract

Epilepy is one of the best known disease in the world and it affects the life of patiens in a negative way. There are a lot of studies which include EEG signals are in progress to remove these problems. Accurate and reliable EEG signals give important information about the situation of the brain and its electrical activity so they are vital for epileptic seizure detection. In this study healthy and interictal EEG signals are used to detect pre-epileptic seizure. The proposed study includes three stages. Firstly, in the preprocess stage EEG signals are normalized and then wavelet packet decomposition method is used to each signal to obtain key features. At the final stage artifical neural networks are applied to classify these key features. In our study we had 99% classification rate for 100 healthy and 100 interictal EEG signals.

1. Introduction

Epilepsy is a chronical disease which occurs in the brain and affects about 50 million people all around the world at any age [1]. During the epileptic seizure normal brain activities become more erratic, cause abnormal behavior and emotions which creates physical and psychological consequences negatively and impresses the life of patients in an unexpected way. Patients are suffer in their daily life because of the nature of epilepsy, its timing and its intensity.

Epilepsy can be treated with different methods and techniques like medication and surgical operation. Medication is more affordable and straigthforward method that is generally chosen by low and middle income countries. Approximately 70% epilepsy patient can be successfully treated with medication technique [2]. Surgical operation is applied while drug treatmant doesn't work. Yet, nearly 25% of epilepsy patiens can not respond any treatment [3]. Thus, to create a suitable method for treatment has a great importance and EEG is the major part of that method.

Electroencephalogram (EEG) is the crucial for the neurological problems and consists of many information about the brain function and its electrical activity which is collected by electrodes. Generally EEG is considered as a noninterventionist technique and normally, brain signals are collected by electrodes from brainpan, however in some cases EEG is an interventionist and brain activity is monitored through inside the brain. Both techniques have advantages and disadvantages yet they both give valuable information about the activity of brain. EEG is popular since its information is useful for many cases such as diagnoss, estimation, recognition of epilepsy. Interpretation of these brain signals with traditional techniques is more complex and time consuming so analyzing these signals with a computer is a necessary. Many statistical and entropy methods are used for diagnose and estimate epileptic seizures in nowadays.

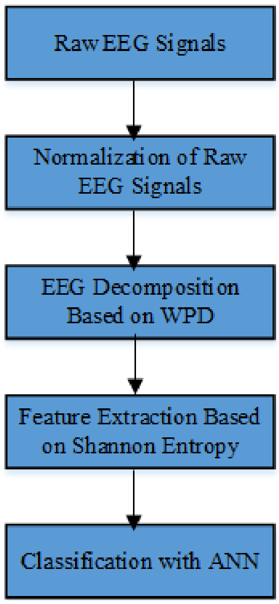

Fig. 1. The activity diagram of the process.

2. Related Work

Authors in [4] developed a mobile application to detect epileptic seizures. In their study firstly they created different algorithms to remove and resample the artifacts. In the feature extraction process they used different kind of methods and separated them into four categories. After feature extraction they chose the key features by using selection algorithms and compared them to their performance and classification rate. The propesed method was used for 500 EEG signals and they integrated theri work into an android mobile application to test live EEG signals.

Authors in [5] proposed a hybrid method to detect the epilepsy by classifying the normal and epileptic EEG signals. They decomposed the EEG signals with Multi-Wavelet Transform decomposition method to five levels. After the decomposition process Approximate Entropy was used to create feature space and it was used as an input for ANN classifier. At the end of their study they noticed that classification rate for normal and epileptic EEG signals with proposed method was about 90%.

Authors in [6] compared their methods performance in order to detect epileptic seizures. In their work they used three different datasets. In the first group they used healthy and epileptic EEG signals. In the second totally four datasets (normal with eyes open-closed, interictal and epileptic) were considered. In the final group, all of datasets were examined. Before they measured the performance of proposed method, authors applied Discrete Wavelet Transform (DWT) to each signal with four level decomposition. Key features were obtained by using line length method and in the final process Multi-layer perceptron neural network (MLPNN) was applied as a classifier. All datasets performance was determined three different parameters such as sensitivity, specificity and classification accuracy.

Authors in [7] created a review study about methods used for detection of epileptic seizures. In their study they considered statistical and entropy methods, wavelet methods for feature extraction. After that they also mentioned the classification techniques with different EEG datasets and their classification accuracy.

Authors in [8] presented an approach to detect epilepsy using EEG signals and rulebased classifiers. They used four different classifiers (random forest, decision tree, support vector machine based random forest (SVM-RF) and support vector machine based decision tree). They performed experiments to test the performance of each classifier through three different datasets. While first group consists of healthy and epileptic EEG signals, second group includes healthy, epileptic and free intertcal EEG signals. The last group consist of all five datasets. After they used all classifier they found that random forest had the best performance.

Authors in [9] proposed a method to detect and classify the epilepsy based on EEG signals. For the feature extraction part they used five level wavelet decomposition to minimize the amount of information. After decomposition statistical method and Bag of Words (BoW) were appllied to each band to create feature space.

Authors in [10] presented a reliable method to detect epilepsy by using dual-tree complex wavelet transform (DT-CWT) technique. After decomposition they performed nonlinear feature techniques to each decomposed subbands. Features were collected by using non-linear techniques like Hurst exponent, Permutation Entropy and Fractal Dimension and used as an input for four different classifiers (SVM, KNN, DT, RF). Finally they compared each classifier performance in order to their accuracy to determine which classifier is the best.

Authors in [11] classified the epilepsy by using ictal and non-ictal EEG signals. To do so first they used multivariate emprical mode decomposition to decompose EEG singals. Then they used time and frequency domains to get features and classified them with ANN. Classification accuracy was found 87,2%.

Authors in [12] proposed a new method to classify the EEG signals. During the study they applied three level Tunable-Q Wavalet Transform (TQWT) method to degrade the signals. In the second phase of the study, Kraskov Entropy was used to every subband in order to compose feature space. Then they applied LS-SVM classifier and compared the classfication accuracy with other methods. Study shows that classification accuracy with proposed approch was 97,75%.

3. Methodology

3.1 Dataset

In this study publicly available EEG dataset is used which otained from [13]. Dataset includes five subsets and each subset specified as Z, O, N, F and S. Subset of Z and O have been taken from surface EEG recordings and represents the healthy ones with eyes open and eyes closed respectively. N and F subsets includes seizure-free intervals which was recorded from hippocampal and epileptic zone of the brain. The last subset S contains epileptic signals called ictal signals. While subset Z and O have been recorded extracranially, subset N, F and S have been recorded intracranially. Every subset includes 100 single-channel EEG recordings of 23,6 s. Sampling frequency of EEG signals was measured as 173,6 Hz and includes 4097 samples. Figure 2 shows typical EEG signals for each subset (Z, O, N, F, S). In this paper F and S subsets are used to analyze, classify and detect epileptic seizure.

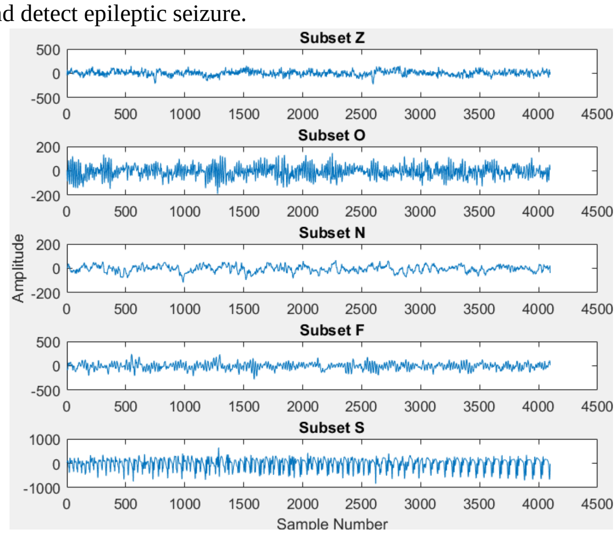

Fig 2. Typical EEG signals for each subset.

3.2 Wavelet Packet Decomposition (WPD)

The Wavelet Packet Dransform (WPD) is the method to analyze non-stationary EEG signals for time-frequency domain and provides multi-resolution information about the data. It can be said that WPD is the extended version of Discrete Wavelet Transform (DWT) method [14]. It decompose the signals further including approximation and detailed coefficients than DWT thus, WPT holds better frequency resolution and it gives better information in high level frequency parts of the signal. Original signal is decomposed to its coefficients by passing low (L) and high (H) pass filter until the desired wavelet or level is achieved. The full decomposition of two level WPD process is shown in Figure 3.

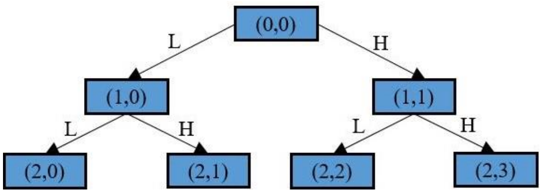

Fig 3. WPD for level 2.

The Wavelet Packet Decomposition is defined as a funcitons [15]:

$$\Psi_{y,z}^{x}(s) = 2^{-y/2}\Psi^{x}(2^{-y}s - z) \quad (1)$$

In the equaiton x represents the inversion paramater and x = 1,2,3, ….., y^n and n represents the level of decomposition of the signal. y can be defined as the expansion paramater while z is the shifting parameter.

Equation 2 and 3 shows the prosses of wavelet Ψ^x;

$$\Psi^{2x} = \frac{1}{\sqrt{2}}\sum_{-\infty}^{\infty} t(z)\Psi^{x}(\frac{h}{2} - z) \quad (2)$$

$$\Psi^{2x+1} = \frac{1}{\sqrt{2}}\sum_{-\infty}^{\infty} d(z)\Psi^{x}(\frac{h}{2} - z) \quad (3)$$

In the functions t(z) and d(z) represents the filters which are discrete and fourbase-model mirror filters respectively.

During the decomposition, wavelet coefficients can be obtained by the following equation;

$$c_{y,z}^{x} = \int_{-\infty}^{\infty} p(t)\Psi_{y,z}^{x}(t)dt \quad (4)$$

While $c_{y,z}^{x}$ represents the coefficients, p(t) can be defined as a signal.

3.3 Shannon Entropy (ShEN)

Entropy is used to calculate inconsistencies in time series at any frequency. High value entorpy is achieved when the data has smooth and broad probability on the other had, if data has narrow and peaked probability it means that entrop values is low Shannon Entropy was formed in 1948 by Claude Shannon to measure the uncertainty. It is used to compute probabilities by estimating regularity of EEG time series in signal processing. ShEN is computed as the following formula;

$$ShEN = \sum_{f} d_f \log(1/d_f) \quad (5)$$

$\sum d_f$ represents the summation of power levels of every frequency and d_f represents the normalization of power.

3.4 Classification by Applying Artificial Neural Networks

After the key features obtained, interictal and healthy EEG signals are classified by using Artifical Neural Network (ANN). ANN firstly used approximately 50 years ago in order to utilize devices based on simulation of human brain [11].An Artifical Neural Network can be defined as a system which can learn by itself based on human brain and its process. Like human brain ANN has neurons that work together by sharing information. ANNs are very popular in signal processing, biomedical areas, pattern recognition, data analysis and detection process. [6]. ANNs are generally used for classification, optimization, feature extraction and they can perform operations with missing information. ANN consists of many neurons that have five basic components (input, output, weights, summation function, activation function and output). Inputs replaced from synapses come from the outside world and represent the information neurons have. Weights show the value of the information and its effect on the neuron. While summation function calculates the certain information, activation function creates the exact output of the neuron. Figure 4 shows the typical ANN model.

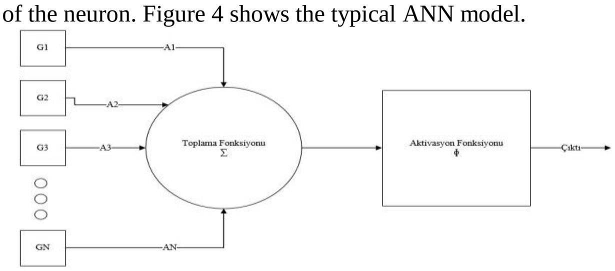

Fig 4. ANN model [16].

4. Results and Discussion

In our proposed method, normalized EEG signals are decomposed by using WPD to level 4. Figure 5 and 6 shows the decomposed healthy and interictal EEG signal respectively. Then Shannon Entropy (ShanEn) is calculated for each decomposed signal and key features are obtained for each subsignal. In the last stage of the method we classify the signals by using 4-cross validation. We divide 200 EEG signals homogeneously (100 healthy and 100 interictal) into four datasets as shown in Table 1. Each dataset consist of 50 signals which are healthy and interictal equally. During the classification process, initally, first 3 (D1, D2 and D3) datasets are trained and the D4 are used for testing. Then D2, D3 and D4 are used as a trainer and D1 is applied to test the network. This process lasts until each dataset is used to test the system. Figure 7 and Figure 8 shows classfiy results for each dataset. The average classifcation accuracy is found 99%. The prophosed method gives more accurate classification rather than WD (Wavelet Decomposition) with LogEn Entropy which was 97,5% [17].

Table 1. Datasets for signals

Dataset 1 (D1) (25 healthy + 25 interictal)	Dataset 2 (D2) (25 healthy + 25 interictal)
Dataset 3 (D3) (25 healthy + 25 interictal)	Dataset 4 (D4) (25 healthy + 25 interictal)

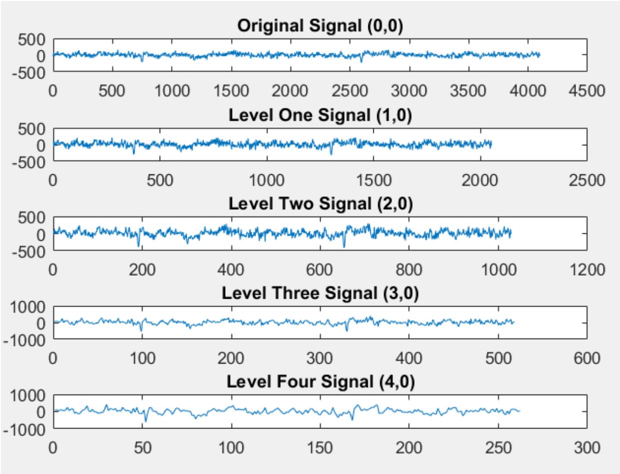

Fig 5. Decomposed healthy signals with level 4.

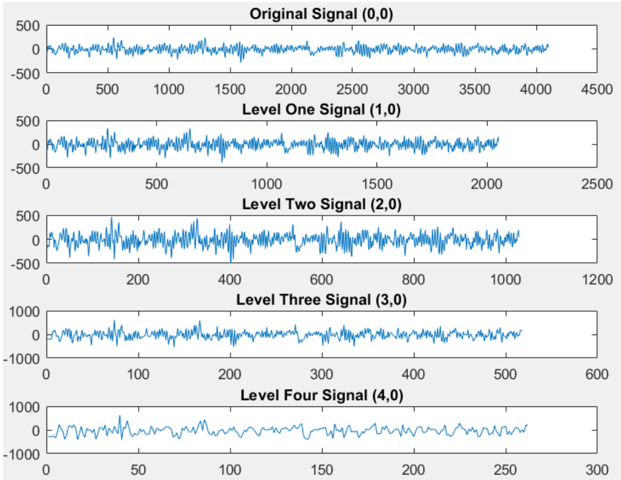

Fig 6. Decomposed interictal signals with level 4.

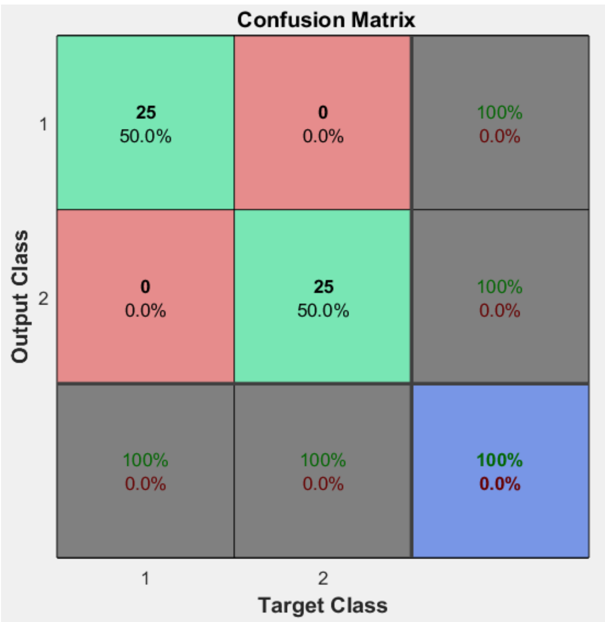

Fig 7. Confusion matrix results for testing D1, D2 and D3.

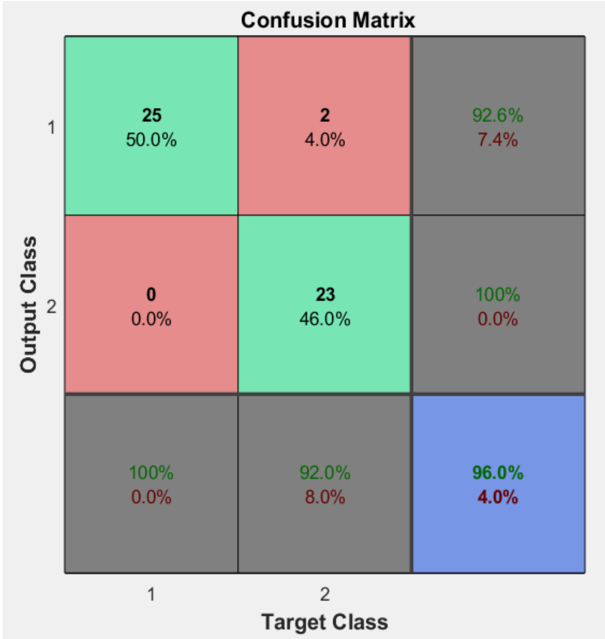

Fig 8. Confusion matrix results for testing D4.

4. Conclusion

In this paper we proposed a WPD based classification method to detect pre-epileptic seizure by using healthy and interictal EEG signals. Features are extracted by applying ShanEn and ANN is used to classify key features. The result of our method is found 99% classsification accuracy.

5. References

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