Diagnosis of Epilepsy in Patients Based on the Classification of EEG Signals Using Fast Fourier Transform

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Abstract. The brain signals of human or animal is recorded from many sensors placed on the scalp, called EEG signals. Based on this signal, many brain diseases which occur in human and animal is simply found and prevented. A popular brain disease is epileptic seizure. Nowadays, many scientists use the different methods to recognize abnormal activities of the brain functionality, thence diagnosis of epilepsy is easier. In this paper, we propose a way to detect seizure in human. Fast Fourier transform is used to convert the EEGs signals into the simpler form, remove some noises and get better features.

Keywords: EEG · Fast fourier transform · Neural network · Epilepsy · Seizure

1 Introduction

Electroencephalography (EEG) is developed as the method to support the diagnosis and treatment of the abnormal symptoms in human. EEG is sampled from many electrode placed in the scalps to record of electrical activity along the scalp. An EEG signals is a measurement of currents that flow during synaptic excitation of the dendrites of many pyramidal neurons in the cerebral cortex [1]. EEG signals is always used to diagnose many brain disorders. Commonly, the signals of the brain of a diseased man and a healthy man are different, it is discriminated based on the difference of the brain waves, especially the frequency ranges. These frequency bands from low to high frequencies respectively are called alpha, theta, beta, delta and gamma [1].

EEG signals is usually applied into the healthy fields to detect the diseases concerned brain, especially epileptic seizures. Developing the human EEG signals is important application in the field of epilepsy. The detection of epileptic seizures using different techniques has been successful, particularly for the detection of adult seizures. Epilepsy is a disorder of the normal brain function, making some differences in activities of brain. It is many seizures occur frequently, repeated spontaneous, unpredictable and uncontrollable. According to statistics, epileptic seizures affects about 1% of the population [2]

Nowadays, the scientists are constantly trying to find more effective methods to control this diseases based on the human EEGs. EEG remains the most useful way for

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the study of epilepsy [1]. In order for a responsive neurostimulation device to successfully stop seizures, a seizure must be detected and electrical stimulation applied as early as possible. The method proposed in this paper will be used for detecting seizures in human and to reduce the diseased ability in human.

Fourier transform is a linear operator, it is useful for analyzing nonstationary signals by expressing frequency as a rate of change in phase, so that the frequency can vary with time domain [3]. The benefits of the signal processing is clearly confirmed. It can also be applied in many different types with special effects, especially in scientific fields, not only in a subject. With the increasing development, its methods and application ability attracted a lot of engineers, physicists and mathematicians researched into [4].

After using fast Fourier transform (FFT) to remove phase information and taking frequency domain, Neural Network is applied to classify the seizure data and non-seizure data. Naïve Bayes and Logistic Regression are also investigated for comparison.

2 Proposed Method

2.1 Fast Fourier Transform

Fourier transform was named the French mathematician, Joseph Fourier, is an integral transforms used to develop a function based on the basic sine function [5]. Fourier transform has many scientific applications, such as in physics, arithmetic, signal processing, probability, statistics, oceanography, geometry and many other areas. In signal processing and related industries, the Fourier transform is often thought as the switching signal into component amplitude and frequency. The widespread application of FT derived from the useful properties of this transformation. It usually uses for non-periodic signals. Typically, Fourier transform is attached to the continuous Fourier transform and also called Continuous-time Fourier transform (CTFT).

Given a signal $x(t)$, the Fourier transform $X(\omega)$ of $x(t)$ is defined to be the frequency function

$$X(\omega) = \int_{-\infty}^{\infty} x(t)\, e^{-j\omega t} dt, \qquad -\infty < \omega < \infty \tag{1}$$

where ω is the continuous frequency variable.

In mathematics, the Discrete Fourier transform (DFT) is used in Fourier analysis for the discrete-time systems, it is also called Discrete time Fourier transform (DTFT). The input of this method is a finite sequence of real numbers or complex numbers, it is a good ideal for handling information on the computer. In particular, this method is widely used in signal processing to analyze the frequencies contained in a signal, to discard the phase information in this signal and to do as convolution operations. Fast Fourier transform (FFT) is an efficient algorithm to compute the DFT.

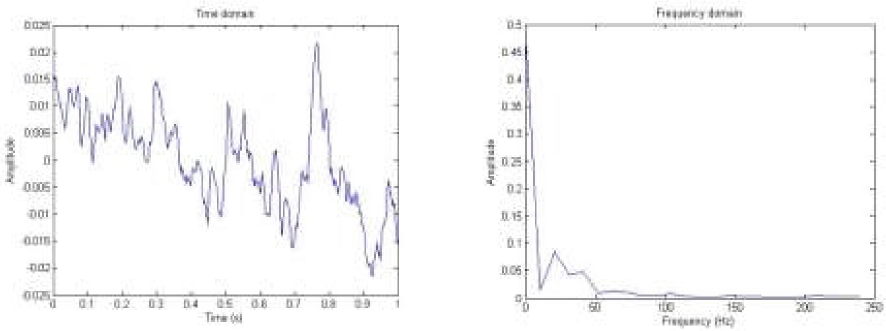

Fig. 1. The time domain and frequency domain of a seizure EEG segment using FFT

$$X(\Omega) = \sum_{n=-\infty}^{\infty} x[n]\, e^{-jn\Omega} \quad (2)$$

Ω in this case is called D-T frequency of the signals.

Based on the foundation of DFT, FFT is proposed as a good algorithm to analyze the signal data. There are many FFT methods. In this paper, we use the FFT function in Matlab function. Figure 1 shows the plot of the first second of the seizure data and its graph in frequency domain after applying FFT to convert.

2.2 Classification : Neural Network (NN)

Neural Network (NN), or Artificial neural network (ANN), was proposed to try to simulate intelligence activities of human. Since its inception, the neuron network has rapidly developed in many fields of identification, classification, noise reduction, predictions…[5];

ANN are regeneration of the functions of the human nervous system with a multitude of neural associated with each other through network. Like as human brains, ANN are learned by experiences, save these experience and use it in appropriated situations.

NN is the organization of computing units and the types of connections permitted. It consists of three components: Input layer, Hidden layer and Output layer. In particular, the hidden layer consists of neurons, receiving the input data from the previous neuron layers and convert the input data to the next layer based on computing the values of the network parameters (weights) [6][7]. A Neural network model can have a lot of hidden layers.

Each output element of the ANN is computed as follows:

$$o = f\left(\left(\sum_{i=1}^{N} x_i w_i\right) - t\right) \quad [3]$$

This models computes the weight sum of its input based on the weight w_i , compares with threshold t and passes the results to a non-linear function f.

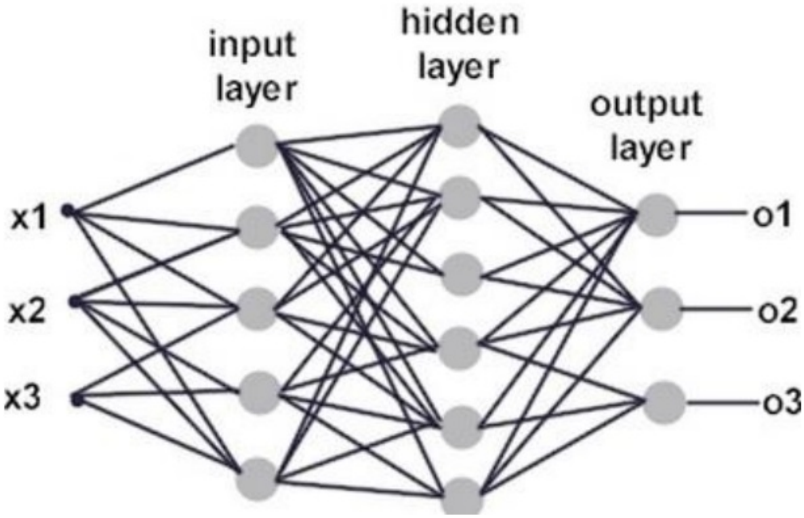

Fig. 2. An example of the multilayer network

3 Experimental Results and Discussion

3.1 Data Acquisition

The dataset is recorded from eight American patients with temporal and extra-temporal lobe epilepsy undergoing evaluation for epilepsy surgery. The EEG recordings are from depth electrodes implanted along anterior-posterior axis of hippocampus, and from subdural electrode grids in various locations. Data sampling rates vary from 500 Hz to 5,000 Hz. The number of channels used for each patients is also not same.

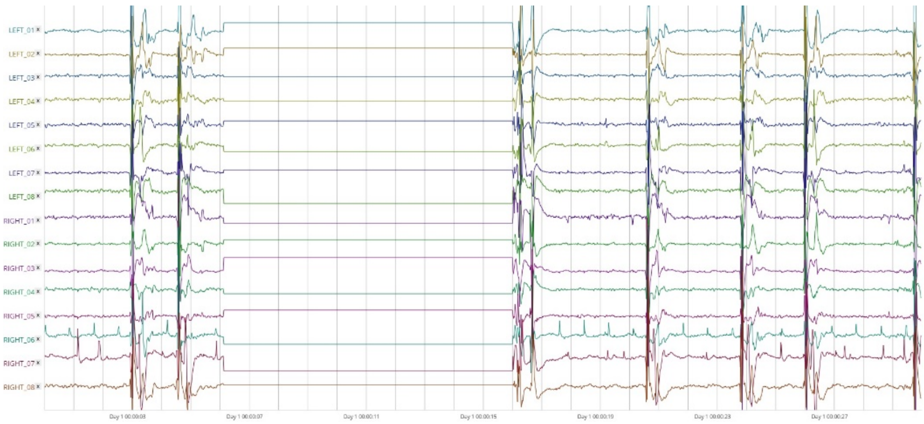

Fig. 3. An example of the original data

The data is separated into many segments based on the recorded time. Each segment corresponds with data signal part sampled in one second. The data signals used in this paper are arranged sequentially, the seizure segments are first arranged, followed by the non-seizure segments. Figure 3 presents the data signal of a subject sampled at 500Hz with 16 channels in the first 30 seconds. It is plotted by the International Epilepsy Electrophysiology Portal's tool [17].

Tables 1 and 2 respectively show the number of channels of eight patients and the quantity of seizure and non-seizure segments in each patient. The number of non-seizure segments is always more than the seizure segment.

Table 1. The number of electrodes placed in the scalp of each patient and the data's sampling rates

	Channels
Patient 1	68
Patient 2	16
Patient 3	55
Patient 4	72
Patient 5	64
Patient 6	30
Patient 7	36
Patient 8	16

Table 2. The number of electrodes placed in the scalp of each patient and the data's sampling rates

	Seizure segments	Non-seizure segments
Patient 1	70	104
Patient 2	151	2990
Patient 3	327	714
Patient 4	20	190
Patient 5	135	2610
Patient 6	225	2772
Patient 7	282	3239
Patient 8	180	1710

This dataset is gotten freely at the International Epilepsy Electrophysiology portal [17] and was developed by the University of Pennsylvania and the Mayo Clinic.

3.2 Experiment

For data preprocessing, Fast Fourier transform is applied to each segment, taking frequency magnitudes in the range 1-47Hz and removing noise information.

Actually, the signal of this data is a discrete variable type. Therefore, applying FFT into this dataset is necessary and judicious. Fast Fourier transform is applied to each segment of whole data in turn. Normalizing them after converting is quite necessary.

In data mining, selecting good features or reducing the number of feature is also a problem to solve. The good features will give better results and they must be fitting to a classifier. To get the features for classification, the original data must be transformed from data space into another space, the feature space. The simplest way to find the features of this dataset is to calculate its eigenvalues. The eigenvalues is computed from the covariance matrix which received from the normalized matrix. We used these eigenvalues as the new features to become the inputs of Neural Network model. We also present the work process in figure 4.

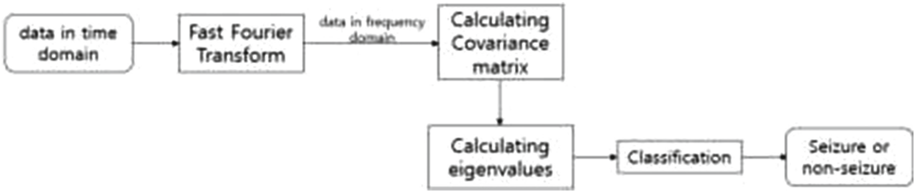

Fig. 4. The flowchart of our process

After classification, the accuracy is calculated by following formula [19]:

$$ACC = \frac{\#PredictedLabels == \#TestLabels}{\#Total}$$

In this paper, we got a haft of seizure segments and about 75 percent of non-seizure segments to train while the others are to use as a test part. Afterward, we used Neural Network for classification. We also used Naïve Bayes and Logistic Regression for comparison. The results are presented in table 3 for three classification methods. The best way to detect seizure is to use Neural Network to classify, the average accuracy in this case is more than 88 percent. Some of subjects get the high accuracies, while the others get very low accuracies. As the first subject, it always receives bad results because its signal is not clear, retains many noise. Furthermore, the number of recorded samples is also less, not enough to classify exactly.

Table 3. The accuracy after classifying seizure and non-seizure segments of 8 patients

Subjects	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Neural Network (%)	78.79	98.02	80.03	91.73	82.46	95.03	88.76	89.8
Naïve Bayes (%)	74.37	97.7	83.37	88.79	76.78	91.61	91.01	87.16
Logistic Regression (%)	69.03	97.3	83.38	90.46	77.87	92.49	91.99	89.47

4 Conclusion

Using Fast Fourier Transform, the signal will be converted from time domain into another domain, frequency domain. In this domain, the data signal become simpler to analyze and handle. EEG signals usually contain many noise because of the recorded condition, recorded environment, including the patients. Thus, application of FFT to remove some noises gets better results. The detection seizure or non-seizure of a patient or a canine become easier.

Furthermore, the combination FFT and NN makes the classification process more advantageously. The seizure diagnose sometimes incorrect or in accurate because of several issues such as the complexity of the input data, the value of options as deviation, error threshold, the number of neurons per layer not selected correctly

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