Implementation Of EEG Feature Extractor and Classifier for Seizure Detection On FPGA

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***Abstract*—Seizure is a neurological disorder that affects the brain and changes the activity of the brain. The detection and analysis of seizures is very important. Many different automatic methods are being searched by the experts for detecting the disease. Here we use a Field Programmable Gate Array(FPGA) based classifier to detect seizures in patients. Electroencephalography(EEG) is the best signal that can be used for signal analysis. The EEG signal is filtered using FIR filter to smoothen the signal. Then the features are extracted from the signal using Discrete Wavelet Transform(DWT).The filtered EEG data is processed by a Linear classifier, to detect the seizure in EEG data. The design was developed in Verilog HDL, simulated and implemented on Xilinx FPGA.FIR filter coefficients had been found out by using FDA tool command on MATLAB. It was found that the proposed system was able to classify normal and seizure signals with high accuracy, sensitivity and specificity as compared with previous systems.**

Keywords—Electroencephalogram(EEG);Seizure Detection;Discrete Wavelet Transform(DWT)

I. Introduction

Nowadays in the fast moving world we need everything within a short time and with great accuracy. This is very important in biomedical cases. Seizure is a neurological disorder that affects the brain and changes the activity of the brain. The detection and analysis of seizures is very important. Seizure can affect any person at any age [6]. About 50 million people around the world is suffering from this disease. When seizure occurs, instead of normal flow of electrical energy, there exists a huge energy from brain cells. EEG signal analysis is the most efficient method that can be used for detecting seizure. Most of the abnormalities that occur which are relative to the brain can be found out by analyzing the EEG signal. EEG signals can be recorded from the brain by using electrodes that can be placed on the scalp. In earlier days seizure was detected manually and it is a time consuming process by visually analyzing the EEG signals taken from the brain by experienced neurophysiologists[7].EEG signal consists of sinusoidal signals of distinct frequencies. Thus nonlinear methods are most suitable for analyzing the signal for extracting the maximum information from them [7].

The recorded EEG signal has to undergo a filtering process before analyzing it. The filtering is done in order to smoothen the signal to remove the noise that may be present in the signal.FIR digital filter is most commonly used for the bio medical signal processing because of its simple structure, stationary response and stability[8]. FIR filter always gives a stable and linear phase response. The selection of effective features which clearly represents the characteristics of EEG signal is necessary for seizure detection. The features include amplitude, mean and variance. The features can be extracted using DWT which is a time frequency domain method. This means that it has the ability of representing a signal in both time and frequency domain [9].Linear classifier is used for classifying the data for finding the disease. Linear classifier is efficient and gives a good classification. Linear classifier has good generalization ability, high accuracy and less computational complexity [12].

II. MATERIALS AND METHODS

A. System Design

The major steps included in automatic detection of seizure are filtering, feature extraction and classification as shown in the figure below. Seizure detection can be of two types as either onset detection or event detection. Onset detection as the name suggests detects the starting of the seizure within the shortest time. On the other hand event detection detects whether a seizure has occurred or not with highest accuracy. The proposed system is used for the event detection. The system consists of EEG data which is first filtered in order to smoothen the signal. A 64 order FIR filter is used for processing the signal. The filtered data is then converted to frequency domain using Discrete Wavelet Transform.DWT transforms a signal that exists only in time domain into a signal that exists in both frequency domain and time domain. The features needed for seizure detection are extracted from these signal. The extracted features are classified using Linear classifier. Classifier will classify the data based on how the classifier is learned using some set of normal and affected data before the testing data has given.

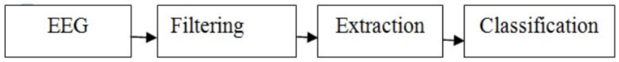

Fig. 1. Block Diagram

B. EEG Database

The database needed for the system was available online by Dr. Ralph Andrzejak of the Epilepsy Centre at the University of Bonn, Germany. The dataset includes data from both seizure patients and normal persons. The sampling rate of the data was 173.61Hz.Each database contains 100 single channel EEG segments. Each data sample consists of 4907 data points. Eight EEG databases are taken as training phase and others are taken as testing phase. "Fig. 2," shows the waveform of EEG database.

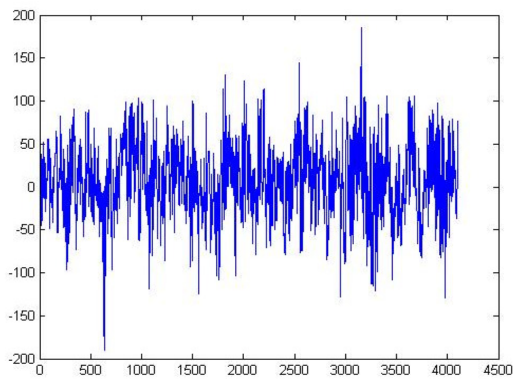

Fig. 2. Normal EEG Signal

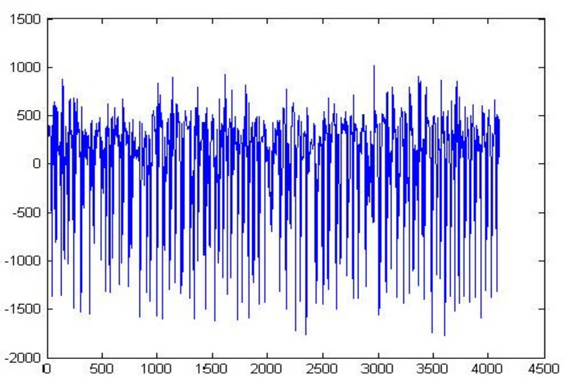

Fig. 3. Seizure EEG Signal

C. Filtering EEG

The signal obtained from the brain through scalp electrodes contains many noises. These signals must be smoothened before analyzing in order to get the accurate result. A low pass FIR filter is used for filtering the EEG signal. Digital filter is widely used for biomedical applications because of its stability and such filters has no feed back.FIR filters gives a linear phase response[8].A 64 order FIR filter is needed for the system. The general equation of the filter is

$$y(n) = \sum_{k=0}^{64} b_k * x_{n-k} \qquad (1)$$

$$y(n) = b_0 * x(n) + b_1 * x(n-1) + \ldots. + b_{64} * x(n-64) \quad (2)$$

where $x(n)$ is input signal, $y(n)$ is output signal

"Fig. 4," shows the FIR Digital Filter which consists of Baugh Wooley Multiplier, Flip flops and Adders.

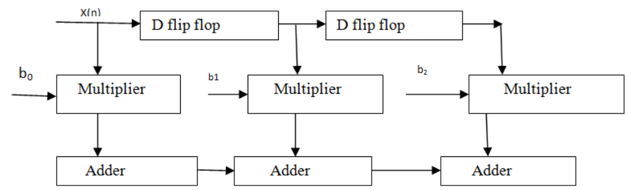

Fig. 4. FIR filter of Order2

FIR filter coefficients are found out using FDA tool command on MATLAB.

D. Discrete Wavelet Transform

Wavelet Transform is a time frequency domain method that converts a signal from time domain into both time and frequency domain. Wavelet transform is actually the extension of Fourier Transform. There are two types of wavelet transform .They are continuous wavelet transform and discrete wavelet transform. In continuous wavelet transform the parameters can be changed continuously[1]. Continuous wavelet transform is defined as follows.

$$CWT(a,b) = \int_{-\infty}^{\infty} x(t) * \Psi^{*}{}_{a,b}(t)dt \qquad (5)$$

where x(t) is the input signal, a and b represents the scaling factor and shifting coefficient. The superscript asterisk represents the complex conjugation.DWT is most commonly used for processing signals like EEG. "Fig. 5," shows the two stage DWT.

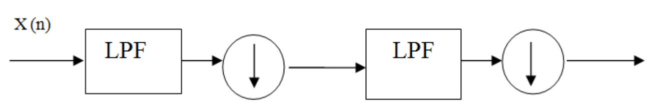

Fig. 5. Discrete Wavelet Transform

It is very useful for seizure detection as it has the capability to capture transient features and converts them into time and frequency domain with accuracy[2].DWT decomposes the signal.DWT can be designed for any stage depending upon the frequency range needed for the signal.DWT structure mainly consists of filters and down samplers. Filters will filter the input signal. Down samplers will down sampled the signal thus keeping only the required frequency range. Two stage consists of two low pass filters and two down samplers.

$$y(n) = \sum_{k=-\infty}^{\infty} x[k]g[n-k] \tag{6}$$

E. Feature Extraction

In feature extraction process certain important features are extracted from the signal. The further processing is done on features. Thus the features extracted must be accurate and must contain the complete information about the signal[4].The main features that are extracted from the signal are given below.

1) Variance:It is the sum of the squaresof the difference between each data sample and the mean of all the data samples.The result is then divided by total number of data samples.It is represented by Var(X).

$$Var(X) = \frac{1}{N}\sum_{i=0}^{N-1}(x_i - x)^2 \tag{3}$$

Where N represents the total number of samples and x_i *represents each sample data.*

2) Mean:It is determined by adding all the samples in the dataset and then dividing that valuewith the total number of samples in the dataset.

$$Mean = \frac{1}{N}\sum_{i=0}^{N-1} x_i \tag{4}$$

Where N represents the total number of samples and the x_i *represents each data sample where 'i' ranges from 0to N-1.*

3) Frequency:It counts the number of values that are greater than a specified value in the given set of data.

F. Linear Classifier

A basic linear classifier is used for classifying the features extracted from the EEG signal to detect the seizure. Classifier works by finding the maximum margin among the features extracted from the signal. Classifier classify the features extracted using DWT to detect the presence of the disease. "Fig. 6," shows the linear classification. In the figure the hyper plane is chosen in such a way that it must have maximum distance from the two set of features. Suppose there are some given data points each belong to one of the two classes, and we have to found out to which class the new data will enter. The best hyper plane is the one that represents the largest separation between the two classes. Here square shows one feature set and triangle shows another feature set. P1 represents the distance of closer feature set from the chosen hyper plane1 and P2 represents the distance of closer feature set from the chosen hyper plane2.The best hyper plane among the hyper plane1 and hyper plane 2 is chosen in such a way that it must have maximum distance from the two feature sets. Here P1,P2 thus considering the hyper plane1 as the best one for seperation.

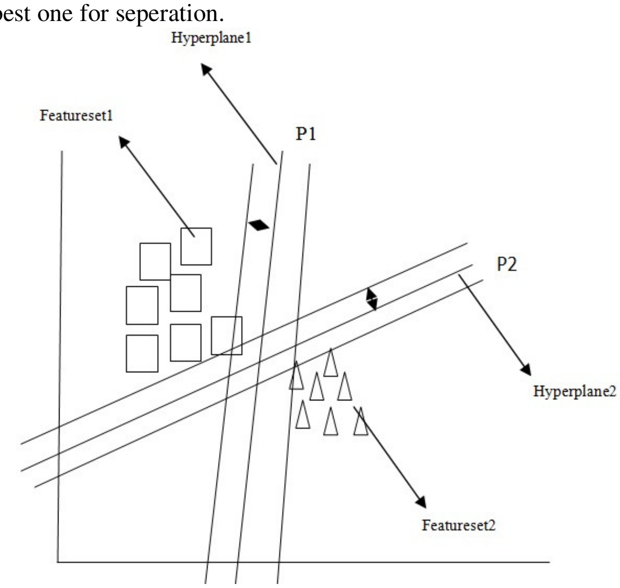

Fig. 6. Linear Classifier

III. RESULTS AND DISCUSSIONS

The system is implemented on FPGA board(Virtex 5).The verilog coding was done on Xilinx ISE 14.2.In this paper eight data samples were taken. The sampling rate of the signal is 173.61Hz.Each database consists of 4097 samples and this is used for evaluation. Since digital filter is used for smoothening the signal the filtered signal has high stability and great accuracy. The use of DWT for feature extraction helps a lot to extract exact features from the given signal without losing any information content from the signal. "Fig. 7,"shows the simulation output of two stage DWT. The features used for training the classifier consists of mean, variance and frequency. "Fig. 8,"shows the detection of disease by checking whether the test data's maximum minimum values are lying on between the range of the training data. In the figure the signal seizure becomes high when the disease is detected otherwise it remains in the low state.

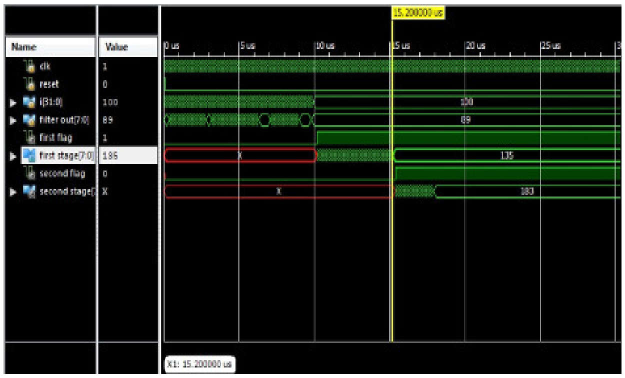

Fig. 7. Discrete Waavelet Transform First Stage

The input signal to DWT has a duration of 10 micro seconds. After the first stage the duration of the signal is 5 micro seconds. The final stage output signal from DWT has a duration of 2.5 micro seconds. Thus the given signal is down sampled.

Fig. 8. Discrete Waavelet Transform Second Stage

Fig. 9. Resultant Waveform

IV. CONCLUSION

In this paper seizure detection in EEG signal is presented.EEG signal is first filtered for removing the noise and for smoothening the signal. After smoothening of the signal features such mean, variance and frequency were extracted from the signal using DWT for each database. Linear classifier is used to classify the signal as normal EEG and seizure EEG signal. The accuracy of the system is computed. The proposed system has high accuracy as compared with the previous systems.

V. FUTURE WORK

Further developments may include the usage of low area architecture which can reduce the area consumed by the filter section and thus can increase the robustness of the system. DCT can be use in the place of DWT for feature extraction.

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