

Wavelet analysis of EEG using LABVIEW

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Abstract: The Electroencephalogram (EEG) is a biological signal that represents the electrical activity of the brain and is the main resource of information for studying neurological disorders. Corruption of EEG signal is caused by occurrence of various artifacts like line interference, electroculogram, electrocardiogram and muscle activity [3]. These artifacts resources increase the difficulty in analyzing the EEG signal and obtaining clinical information. So it is necessary to design a procedure to decrease such artifacts in EEG. The blanking of the EEG signal due to blinking of the patient's eye is the problem encountered in the removal of artifact[14]. So elimination of ocular artifact called Electroculogram (EOG) from Electroencephalogram (EEG) signal using wavelet method on Laboratory Virtual Instrumentation Engineering Workbench (Lab VIEW) platform is the fundamental basis of the system. An algorithm using wavelet analysis is implemented to eliminate eye blink artifact without loss of important part of original EEG signal [1,8,11].

Keywords: Ocular artifact, Haar wavelet, EEG, Discrete Wavelet Transform, EOG.

1.INTRODUCTION

Normal EEG signals are usually registered from electrodes placed on scalp and often very small in amplitude of order 20 μ V. The electroencephalogram (EEG) contains useful diagnostic information on variety of neurological disorders. It is a non-invasive method used to measure the electrical activity of human brain. The EEG like all biomedical signal contamination or artifacts (signals of other than brain activity) which reduce its usefulness [1]. Blinking or moving eyes called the electroculogram (EOG). The EOG spreads across the scalp to contaminate the EEG, when it is referred to as an ocular artifact (OA). For example, In figure [1] the effects of blinks (NREM) and eye movements on an EEG and an EOG are illustrated. The upper two plots show the effect of two brief eye movements. The change in amplitude that is caused by the movement is more prominent in the right plot because the EOG is recorded closer to the eyes. The lower two plots illustrate the effect of blink[14].

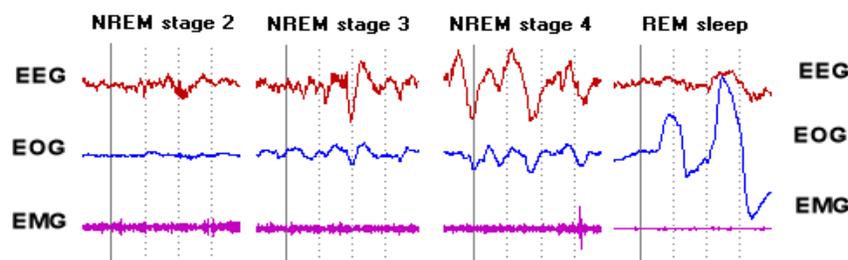


Fig 1 . Iliustration of the eye movements and comparision bewteen EEG , EOG and EMG .

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a development environment based on graphical programming. It uses terminology, icons and ideas familiar to technician, scientists, and engineers and relies on graphical symbols rather than textual language to describe programming actions. It is graphical programming that uses icons instead of lines of text to create applications. In contrast to text based programming language, where instructions determine program execution, LabVIEW dataflow programming, where data determine execution. Complex Filter using LabVIEW graphical programming were designed having four frequencies ranges from 0.5 to 3 Hz, 4 to 7 Hz, 8 to 13 Hz and 13 to 30 Hz [13]. for separating out EEG wave forms into Delta, Theta, Alpha and Beta waveforms. Visual output is a waveform of graph as well as chart graph [2].

The wavelet analysis of EEG method mainly involves three stages. They are:

- 1) EEG simulation
- 2) Extraction of brain waves from EEG
- 3) Removal of artifacts from EEG

2. SIMULATION OF EEG

This community example briefly looks at how to simulate EEG data in LabVIEW using the Biomedical Toolkit add-on. The VI is included at the end of this document and makes use of both the Simulate EEG express VI and the EEG FFT Spectrum VI of the Biomedical Toolkit [4]. This example is the first in a series of example programs that make use of the toolkit to acquire biosignals in the real world. Simulating signals is a good way to check the behavior of your program before acquiring real world data. It is also a good measure of what sort of amplitudes and frequencies to expect when performing the acquisition with your own hardware. The NI LabVIEW Biomedical Toolkit can be used for both educational and research related purposes and includes functions for Biosignal Acquisition, Biosignal Measurements, File I/O and Medical Image Processing. With the Biomedical Toolkit, you can take EEG, ECG and EMG measurements easily and effectively and display their waveforms in LabVIEW [7].

2.1 Coding in labview

The following image shows the coding used to display a simulated EEG waveform and perform an FFT on the data so that we can view it in the frequency domain [4]. Typical EEG frequencies range from 0-30 Hz, with expected amplitudes of 10 μV –

100

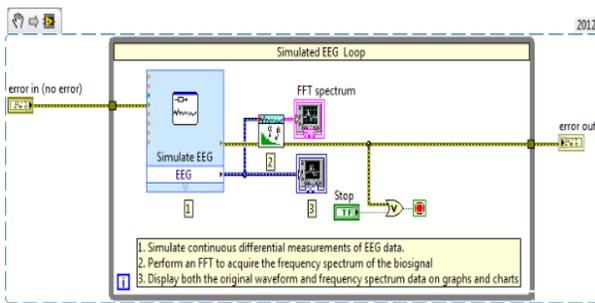


Fig 2. The express simulate VI.

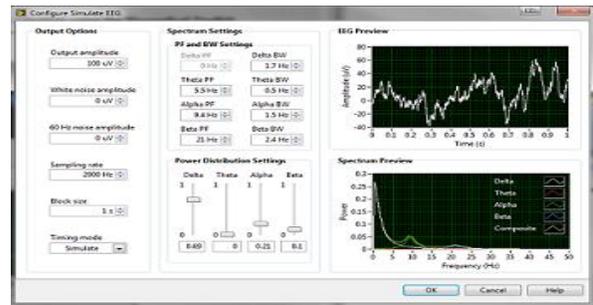


Fig 3. Wavelet Analysis

Configuring the Simulate EEG express VI involves setting the the expected amplitude levels and simulated sample rate. You can also set the frequency composition of the EEG data and preview the data before it is generated [5]. EEG data is actually a superposition of many bio signals, each with varying frequencies. The expected observed frequencies when taking EEG measurements is determined by the electrodes placement on the scalp [6]. One of the added advantages to using the Simulate EEG express VI is generating simulated 60 Hz noise, which is a major design consideration when working with EEG data. Take a look at the following Configure Simulate EEG dialogue box to familiarize yourselves with the express VI set-up.

3. EXTRACTION OF EEG FROM BRAIN WAVES

LABVIEW is a graphical programming event. Programs in IDE are called Virtual Instruments(VI), consists of Block Diagram (BD) and Front Panel (FP). BD provides graphical code environment development whereas a FP allows the user to interact with a VI. It provides an efficient and easy –to-use environment for code development especially w LABVIEW is a graphical programming environment [15]. It provides an efficient and easy –to-use environment for code development especially when the user needs to interact the program and visualize the result. Unlike text based programming languages like C which follow a control flow execution model, the environment of programming follows a dataflow execution model. After an extensive and exceedingly informative session [5], it comes to understand that Scalp EEG picked up from sensors placed on the forehead is in actuality a summation of brainwaves of different frequencies and artifacts such muscle activity, eye blinks, pulse signals and line noise[8]. Extracting useful artifacts from raw EEG signal and transforming it into a useful control output is done by processing it in LabVIEW. The FP provides for a useful tool for providing Neurofeedback to the user. The input raw EEG as mentioned above also includes the EOG [9], which basically can be termed as wavelets with larger amplitudes due to muscle related movements in the ocular region. Since the acquisition is done in real time, thresholding the amplitudes pertaining to the eye blinks and counting the time intervals between consecutive eye blinks has worked efficiently in counting two and three consecutive eye blinks and also eliminating the effect of normal eye blinks [13]. The following part of the block

diagram describes the analysis of raw data, thresholding, and outputting the number of blinks on visual feedback which is further utilized in controlling the device [5].

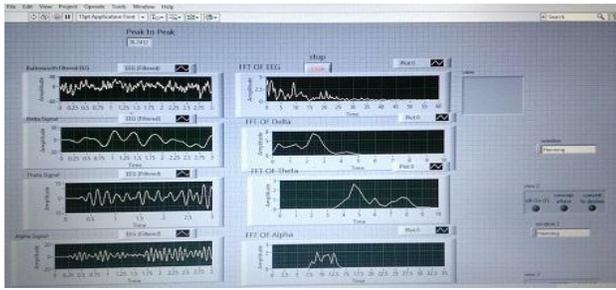


Fig 4. Wave intensity extraction.

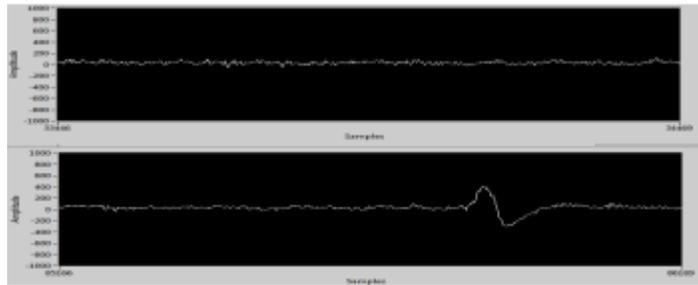


Fig 4. Blink occurring in the second waveform chart.

Blinking causes a spike in the EEG of appreciable magnitude as compared to base signal without the blink artifact. This enables us to detect eye blinks by thresholding the EEG signal. Also, the time difference between consecutive eye blinks can also be found out with simple programming instructions involving timed looping statements and shift registers to send data between loops in LabVIEW. A clear momentary spike can be seen in fig. 4 where a blink occurred as opposed to a clear EEG waveform with no physical movements occurring [11]. When a single blink of magnitude more than that set by a certain threshold occurs, a counter starts counting the number of milliseconds before another blink occurs. If the blinks occur within a certain time limit, it is counted as a double blink. In a similar manner, triple blinks are also detected. Experimentally, it has been found that voluntary blinking produces a deflection of magnitude 400 micro volts and above, thus this is used as a threshold for blink detection [10]. As mentioned above, raw EEG data is essentially a summation of various brain wave oscillations and artifacts[14]. Some oscillations of notable importance are as follows:

1. Alpha waves: Frequency ranging from 3- 13 Hz and corresponds to meditation levels in the brain activity.
2. Beta waves: Frequencies ranging from 12 – 30 Hz and these beta states are the states corresponding to normal waking consciousness.
3. Theta waves: 4 Hz- 7 Hz.
4. Delta waves: Frequencies less than 3 Hz.

The beta wave in particular can be attributed to the “concentration” part of the brain activity and this is what is being used to control the output magnitude. The beta wave magnitude is deduced by first building a waveform 450 samples long by inserting samples sent by the BCI point-by point into an array and then using an elliptic bandpass filter and the power spectrums are respectively calculated after using FFT on the input signal [4] as shown in fig.3.4. Similarly meditation which corresponds to alpha wave intensity can also be deduced [6].

4.REMOVAL OF ARTIFACTS FROM EEG

To eliminate artifacts is prevent them from occurring in the first place. Of course prohibiting subjects from blinking or moving their eyes is uncomfortable for the patient, and nearly impossible to achieve [6]. To have a person in such a controlled or constrained state could affect the EEG output and even introduce new artifacts. Fixation of the eye is inadequate because it does not eliminate involuntary eye movement and cannot be used when performing a task requiring eye movement [12-13]. The effectiveness of this method is highly questionable, especially in children and patients suffering from neurological pathology. The least elegant method of removal is to have trained technicians manually detect and remove epochs of corrupted data based on artifact characteristics such as amplitude, signal variance, frequency content, or slope that exceed a certain threshold [3]. This extremely arduous and very subjective task leads to a significant amount of data loss, especially when there is a limited amount of data or a high frequency of blinking [12]. The other techniques involved in ocular artifact removal are Linear Filtering, Regression analysis and Wavelet analysis. As we processed wavelet analysis method for artifact removal, let us discuss in detail about wavelet analysis [15].

4.1 Wavelet Analysis for detecting patterns in EEG

The application of wavelet-based analysis to neuronal waveforms such as EEG has been demonstrated to offer advantages in signal detection, component separation, and computational speed over traditional time and frequency techniques. A wavelet representation improves time resolution as the length of the neuronal event decreases, allowing improved resolution in the

detection of the time of its occurrence[1-2]. The use of wavelet packets introduces precise control of frequency selectivity which results in accurate component detection even if they overlap in time and frequency [17]. Because “wavelets sweep through a signal at different scales” to identify a pattern similar to itself, matching the wavelet shape to the artifact desired, specifically targets the artifact for detection and feature extraction[13]. Thus a pattern recognition scheme is possible that can be used for artifact detection in EEG that is not sensitive to physiological variations [11].

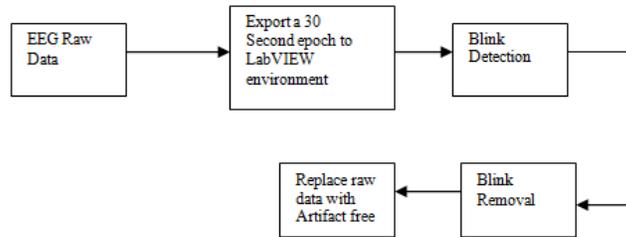


Fig 5. Flow chart

The EEG are contaminated by EOG signal. The EOG signal is a non-cortical activity. The eye and brain activities have physiologically separate sources, so the EEG is a superposition of the true EEG and some portion of the EOG signal [13]. It can be represented as

$$EEG (rec)=EEG(true)+k.EOG \quad \dots\dots(1)$$

Where,

EEG (rec) - contaminated EEG,

EEG (true) - EEG due to the cortical activity (i.e.,Brain activity)

k.EOG - Propogated ocular artifact from eye

The Algorithm involves the following steps:

- i) Apply Discrete Wavelet Transform to the contaminated EEG with Haar wavelet as the basis function to detect the OA Zone[16].
- ii) Apply Wavelet Transform with Coif 3 as the basis function to the contaminated EEG with OA zones identified for removing Ocular Artifacts then reconstructed the EEG signal[17].

5. RESULTS

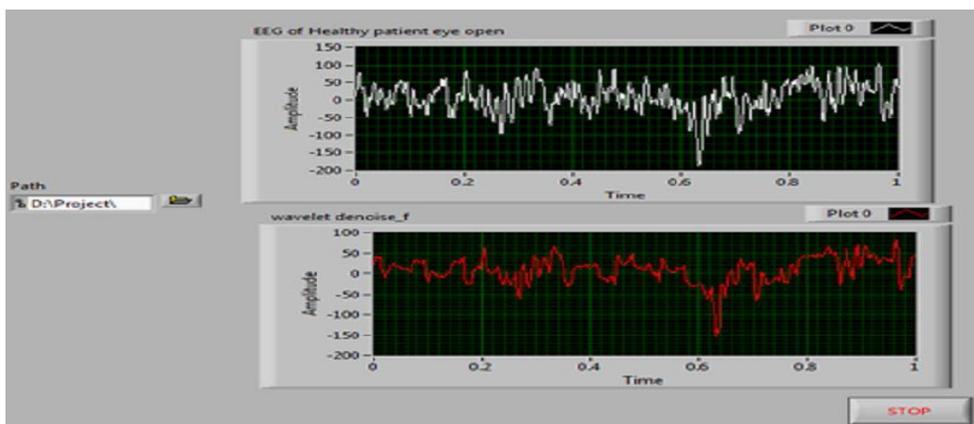


Fig 6. Front panel of EEG healthy patient eye open

Above figure shows front panel of EEG healthy patient eye open , EEG in upper waveform graph and lower waveform graph represent removal of artifact from EEG data. EEG data in upper waveform graph does not immediately convey useful information. Applying discrete wavelet transform to EEG signal is able to extract the useful information from

the noise and present it in a form, more comprehensible than the original data. The below figure.7 show block diagram of EEG healthy patient eye open [13].

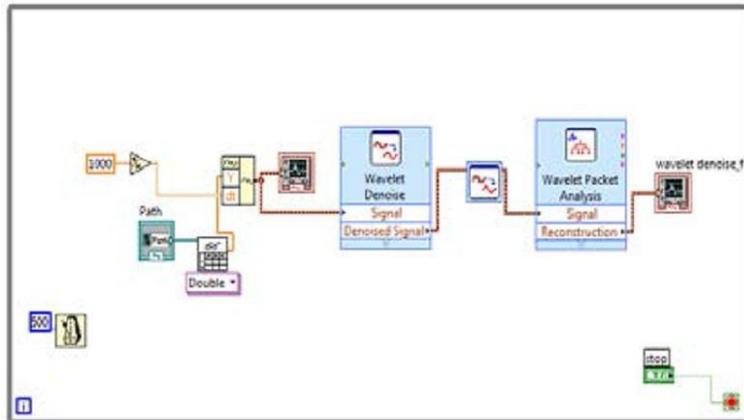


Fig 7. Block diagram of EEG healthy patient eye open

Haar wavelet is used to decompose the EEG signal to detect the exact moment when the state of the eye changes. Decomposition of the EEG with the Haar wavelet results in a step function with a falling edge for a change in the state of the eyes from open to close and a step function with a rising edge for a change in state of the eyes from close to open [9][15]. Here the EOG contaminated EEG is decomposed upto 6 levels using Haar wavelet [1] is shown in below figure.

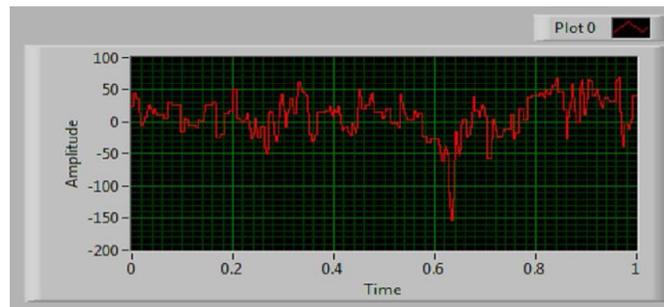


Fig 8. Haar wavelet

5. CONCLUSION

The use of wavelet analysis was successfully used in the detection and removal of eye movement and eye blink at artifact in EEG.

6.ACKNOWLEDGEMENT

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