A virtual biosignals analyzer

Bhargav C Goradiya1, Vatsal Shah2, Nisarg Patel3, Yagnik Mehta4, Neel Macwan5
1,2,3,4,5Electronics and Communication, Birla Vishvakarma Mahavidyalaya, Anand, India
e-mail: 1bhargav.goradiya@bvmengineering.ac.in

Abstract. The virtual instrumentation is in great demand now a day due to its flexibility as well as cost-effectiveness. LabVIEW is a great platform in which one can design virtual instruments. This article deals with the design of the virtual biosignal analyzer. This analyzer has been mainly designed for academic purpose. It can be used by industries for understanding the biosignals as well as to find out which filters are best suited for filtering the biosignals. This analyzer consists of the various virtual instrument applications which deal with the analysis of biosignals like ECG, EMG, and EEG. So that the students, professionals as well as industrialists can understand which filter or which analysis is best suited for the particular biosignals, which can help them to design the real-time instrument. The purpose of this article is to provide the virtual toolkit to the professional working in this field so that an accurate real-time instrument can be designed.

1. INTRODUCTION

The LabVIEW stands for Laboratory Virtual Instrumentation Engineering Workbench is a great platform for graphical programming this software is a design by National Instruments. The software is a great tool for Data acquisition, Data analysis, and Automation. LabVIEW is also well known for its Graphical User Interface (GUI). The file extension of this software is.VI. The LabVIEW consists of the 3 panels. Front Panel, Block Panel, and Connector Panel. The Front panel is a user interface that consists of control variables and indicator variables. The control variables are the input which can be varied by a user on the front panel and indicator indicates the output. The block panel is generally the backend where programming is done. The connector panel is used to connect various DAQ hardware so that the virtual instrument can run in real-time. ECG stands for Electrocardiogram. It is the technique that measures heart activity. During the process with each movement of the heart, a pulse is passed through it. This pulse causes the heart muscles to squeeze and pump blood from the heart. A normal ECG indicates the timing of the top and lower chambers of the heart. The movement of the left and right atria develops a wave known as P-wave. While the movement of the right and the left chamber of the heat will make the QRS complex wave. The T-waves are generated during the resting of the ventricle. Fig. 1 [1] shows the standard ECG wave. The application of ECG is used to detect the heart disorder; it provides the breathing rate as well as the bits per minute of the person.
EEG stands for Electroencephalogram. This technique is used to measure the activity of the brain. In this technique, the electrodes are attached to the head scalp. This electrode detects the impulse of the brain cells. The impulses are then amplifying by an amplifier and display on the computer screen. Fig. 2 shows the standard EEG waveform. [2] The EEG waves are classified into 4 categories based on the frequency. Alpha Beta Delta and Theta. Alpha has a frequency of 8-12 Hz. Beta has a frequency of 13-38 Hz. Theta has a frequency of 4-7 Hz. While Delta has a frequency 1-3Hz. The applications of EEG are: To diagnose the Sleep disorder, effect of Anesthesia, identify and diagnose brain death. The figure 2 below shows the EEG wave. This signal is most essential to understand as it is related to our human brain. It is one of the few mobile processes available and offers millisecond-range temporal resolution which is impossible with the Computed Tomography, PET, or MRI.

EMG stands for Electromyography. It is the technique that is used to measure the electrical activity of the skeletal muscles as well as nerve cells. Figure 3 shows the standard EMG wave. [3] In EMG the surface electrodes are attached to the skin to find out the ability of the neuron to send an electrical signal. In other parts, the EMG needle is used which is used to evaluate the signals of the nerve it is attached in the muscle tissue. The application of EMG is: To identify and diagnose the nerve and muscle disorder. The fig. 3 shows the EMG Wave associated with different activities. Moreover, it is also used as a middleware in gesture recognition and Human-Computer interaction.
2. LITERATURE REVIEW

In research article removal of noise in ECG using FIR and IIR filters with various methods by K. S. Kumar, B. Yazdanpanah, and P. R. Kumar [13]. They have compared the filtering results of the ECG and find out that the FIR filters are the most suitable ones compare to the IIR filter. Using the Mean Square error technique. In the article, EEG Classification Using Elliptic Filter and Multilayer Perceptron Based on Gamma Activity Features by author R. Widadi, I. Soesanti, and O. Wabyunggoro [14]. The author has utilized the Elliptical Filtering technique for the EEG and mention their advantages over another filter they have mentioned that the elliptic filter is chosen because it has a lower order for the same tolerance scheme compared to Butterworth, Chebyshev I, and Chebyshev II filters. Also, the elliptic filter has a narrow transition band. So, for EEG, it is a preamble to have the IIR Filters. In the article Gaussian Filtering of EMG Signals for Improved Hand Gesture Classification by author. F. Galyan, Z. M. Abouelenin and V. Kapila [15]. The authors have utilized the Gaussian FIR filter for the filtering of the EMG and they have concluded that it is the best suitable option for EMG filtering. They have proved mathematically. So for EMG analysis, the FIR filters are the best suitable option rather than IIR.

3. COMPONENTS OF BIOMEDICAL TOOLKIT

This analyzer consists of 4 virtual components which acts as design interface and they are:
- ECG Analysis and Filtering
- ECG Types
- EEG Analysis and Filtering
- EMG Analysis and Filtering

3.1. ECG Analysis and Filtering

This virtual component of the analyzer does feature extraction analysis like peak amplitude and peak analysis of the ECG as well as statistical analysis of the ECG. It also performs the filtering of the ECG, the filtering is done by IIR Filter as well as FIR Filter. So that user comes to know which filter is suitable for the ECG filtering. In this design, we have utilized the peak detection mechanism, IIR Filter, FIR Filter from the signal processing toolkit of LabVIEW. Here we have taken recorded ECG having a sampling frequency of 1000 Hz. Here we have fixed the cut off frequencies of the filter that is 0.8 Hz to 2.5 Hz. One can also vary the windows in the FIR filter as well as the Order as well as change the type of IIR filter. From this one can predict that the FIR filters are more suitable for filtering of ECG. Because IIR filters are used for dealing with the low amount of noise but here we have taken the ECG that has a larger amount of the noise so here FIR Rectangular window filter is
more suitable compare to an IIR or FIR filter as shown in the filters below. Fig. 4 and 5 show the result of IIR and FIR filters for ECG. Fig. 6 shows the statistical analysis of ECG. The statistical analysis includes the mean, median, modal, and standard deviation analysis of this signal. This we have to compute using the statistical toolkit of LabVIEW. The Equation of FIR Filter is given by:

\[ h_w(n) = w(n) \ast h(n) \ldots (1.1) \]

Where \( w(n) \) is the window function.

\( h(n) \) is impulse response.

\( h_w(n) \) is the filter coefficient.

3.2. ECG Types

This Virtual component is just for understanding purpose. This instrument displays various abnormal ECG So that one can understand such abnormal ECGs and do analysis on them. The abnormal ECG that we have included in this instrument are Atrial Tachycardia, Ventricular Tachycardia, Junctional Tachycardia, Hyperkalemia, Hypocalcemia, Atrioventricular Block, Hypercalcemia, Hypokalemia. Fig. 7 to 10 shows the front panel of the instrument. We have taken here the MIT-BIH Database and we have simply plotted it. Here we have taken a sampling frequency that is 1000 Hz.
3.3. EEG Analysis and Filtering

This virtual component performs the statistical analysis as well as filtering of the EEG signal. We have utilized here IIR filter as well as FIR filter for analysis. In IIR we have to include the Elliptical as well as Chebyshev filter as there are ripples in EEG signal. So that the user comes to know which filter is suitable for the EEG filtering? Fig. 11 to 14 shows the front panel of the toolkit for EEG. One can also vary the windows in the FIR filter as well as the Order as well as change the type of IIR filter having cutoff frequency 1 to 40Hz. In design we have taken an inbuilt EEG signal so that we can vary it 5 parameters Alpha, Beta, Theta, Delta, Gamma for understanding the purpose and we have taken various IIR Filter and FIR Window Filter Block. From signal processing of LabVIEW. After applying filtering we have found out that due to much more amount of ripples. The elliptical filters are most suitable here. The equation of Elliptical IIR Filter is given by following equation. Moreover, we have
done statistical analysis also which computes basically mean, median, mode, and standard deviation using the statistical toolkit of LabVIEW.

\[ G_n(w) = H(w) = \frac{1}{\sqrt{1 + \varepsilon^2 R_n^2 \left(\frac{w}{w_0}\right)}} \]

Where \( H(w) \) is a transfer function
\( \varepsilon \) is the ripple factor
\( R_n \) is the order of the filter.
\( w_0 \) is the cutoff frequency

Figure 11: IIR Filtering of the EEG

Figure 12: Chebyshev and Elliptical Filtering of the EEG.

Figure 13: FIR Filtering of the EEG.

Figure 14: Statistical Analysis of the EEG.

3.4 EMG Analysis and Filtering

This virtual component does the statistical analysis as well as filtering of the EMG signal we have utilized here IIR filter as well as FIR filter for analysis using signal processing toolkit and statistical toolkit of LabVIEW for statistical analysis. So that the user comes to know which filter is suitable for the EMG filtering. The figure below shows the front panel of the toolkit. One can also vary the windows in the FIR filter as well as the Order as well as change the type of IIR filter. Here cut-off frequency is 1 Hz to 200 Hz. Here user can vary the sample rate of the EMG. Here, We have seen that IIR filters are not suitable since there is no smooth transitions are required and there is the so one can understand that compare to IIR Filter the FIR filter is more suitable. [12] Moreover the amount of
noise is also high. The various window functions associated with FIR are shown in fig.15 and the front panel design is shown in fig.16 to 18.

| Window Type | Peak Sidelobe Amplitude (Relative, dB) | Approximate Width of Main Lobe | Peak Approximation Error, 20\log(\delta) (dB) |
|-------------|---------------------------------------|--------------------------------|-----------------------------------------------|
| Rectangular | -13                                   | $\frac{4\pi}{M+1}$            | -21                                           |
| Bartlett    | -25                                   | $\frac{6\pi}{M}$              | -25                                           |
| Hann        | -31                                   | $\frac{8\pi}{M}$              | -44                                           |
| Hamming     | -41                                   | $\frac{12\pi}{M}$             | -53                                           |
| Blackman    | -57                                   | $\frac{12\pi}{M}$             | -74                                           |

**Figure 15:** Window Functions

**Figure 16:** FIR Filtering of the EMG

**Figure 17:** IIR Filtering of the EMG

**Figure 18:** Statistical Analysis of the EMG
4. COMPARISON OF THE PROPOSED SYSTEM WITH REFERENCE PAPERS AND PARAMETER OF THE SYSTEM

**Table 1: Comparison Table**

| Sr. No | Reference Papers | Virtual Bio-signal Analyzer |
|-------|------------------|-----------------------------|
| 1     | In the article On-line monitoring and Analysis of Bio-electric signals by Anas M.N., A.N. Norali, and WJun the model is designed which does pre-processing, Feature extraction and Peak detection of ECG. They utilize only notch filter.[16] | While in our analyzer we have done IIR and FIR filtering of ECG and we have proved that why FIR filters are more Vulnerable compare to IIR filter as well as we have done real-time histogram generation of the ECG. And feature extraction of ECG also and users can change the orders as well as the type and windows of the FIR filter so that the user can understand more about this bio-signal. |
| 2     | Moreover, the authors have done EEG pre-processing, computes FFT, and PSD of the EEG signal, and also calculates the amplitude of the EEG signals. They have utilized the same filters as they have mentioned in ECG signal pre-processing. | The analyser system i.e., component 3 EEG analysis and filtering in this component we have EEG pre-processing by various filters like IIR Chebyshev, Elliptical, Butterworth, and FIR filters with possible windows rather than FFT we have done the statistical analysis and we have concluded that IIR Elliptical filter is most suitable one and here for more understanding users can vary alpha, beta, delta and theta of EEG waves for better understanding. |
| 3     | Finally, the authors have EMG pre-processing using the same filters, compute short-time Fourier transform and calculate mean and median based on STFT. | The analyser system i.e., component 4 EMG analysis and filtering in this component we have EMG pre-processing by various filters like IIR and FIR filters with possible windows rather than STFT we have done a statistical analysis and we have concluded that the FIR filter is the most suitable one. |
| 4     | This article did not have such component. | The analyzer has also ECG Types component which is used for understanding purposes of abnormal ECG. |
| 5     | This system is designed using LabVIEW biomedical toolkit. | This system is designed using biomedical, signal processing as well as the mathematical toolkit of LabVIEW |

**Table 2: Parameters Table**

| Sr. No | Parameter | ECG | EEG | EMG |
|-------|-----------|-----|-----|-----|
| 1     | IIR Filtering | Not Appropriate for Filtering | Elliptical IIR Filter is most suitable for EEG Filtering | Not Appropriate for Filtering |
| 2     | FIR Filtering | The Window FIR Filters is most suitable for ECG Analysis | The Window FIR Filters is most suitable for EMG Analysis |
5. CONCLUSION AND FUTURE SCOPE

The proposed analyzer is used for academic purposes by academic professionals to explain the students regarding these bio-signals as well as analysis of the bio-signals. The toolkit can also be utilized by the biomedical industry professionals to evaluate these bio-signals as well as also to understand which filters or which analysis is best for a particular bio-signal. To design the real-time biomedical instrument based on it. Moreover, we have compared the proposed system with the Standard papers and we have found that proposed one is a unique approach rather than previous one. So, one can use this system for the above-mentioned purposes. In the future, this toolkit can be utilized as real-time hardware after inaugurating this system with NI ELVIS or any NI DEVICE with a particular sensor that generates the bio-signals. Finally, the proposed analyzer provides a cost-effective solution for academics as well as for industrial purposes. We have designed the entire toolkit using LabVIEW and in future, we will create an application so that it can be used by any user. In the future, one can merge all these applications and provide it as a product to the users incorporated with related fields.

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ACKNOWLEDGMENTS

Authors wishing to acknowledge support of the BVM Engineering College EC department to carry out our work using LabVIEW and necessary resources