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STUDY AND ANALYSIS OF ECG SIGNAL USING LABVIEW AND MULTISIM

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Abstract: This paper deals with study and analysis of ECG Signal processing by using LABVIEW and MULTISIM tools. Study of ECG signal includes ECG signal generation, preprocessing and feature extraction in ECG signals. Using simulation and virtual Instrumentation together in the design environment, allows us to work on real-time ECG signals with great accuracy and convenience. Mathematical capabilities of SPICE to accurately model complex circuits and devices, together with measurement capabilities of Virtual Instrumentation such as data collection, automation, testing etc., opens up many engineering circuit and system design possibilities.

Keywords: ECG signal processing, LABVIEW, MULTISIM, Real-time signal

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1. INTRODUCTION

In the growing world of Biomedical engineering, the need to be able to quickly design circuitry which interfaces to a human signal is a common design problem. For example, a wavelet filter for QRS detection for example can be designed in a circuit simulation package, however the signals which will interface to that particular circuit will be simple simulation stimuli (such as a sine wave, square wave etc...). To truly test a biomedical wavelet filter, we need to be able to interface the design to a real signal. LabVIEW with its signal processing capabilities provides a robust and efficient environment for resolving ECG signal processing problems. This paper analyses how to use LabVIEW's powerful tools in generating, denoising, analyzing, and extracting ECG signals easily and conveniently.

Injection of real-time test signal into circuit simulation using Virtual Instrument and comparing the results of simulation data, with test bench data and automatically optimizing the design for accuracy is possible with LABVIEW and MULTISIM integration.
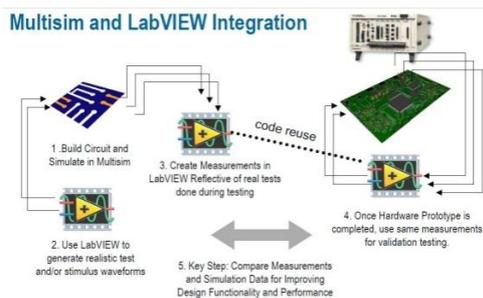

Figure 1. LABVIEW and MULTISIM Co-simulation

Electrocardiography (ECG) is the electrical signature of the heart and thus one of the important indicators of our pathological condition. It is a useful screening tool for a variety of cardiac abnormalities such as Tachycardia, Bradycardia, bundle block and ventricular fibrillation. In general, the frequency range of an ECG signal varies between 0.05–100 Hz with the dynamic range between 1–10 mV. The ECG signal is characterized by five peaks and valleys labeled by the letters P, Q, R, S, T. The QRS complex is the most prominent wave form within the electrocardiographic (ECG) signal, with normal duration from 0.06 s to 0.1 s.
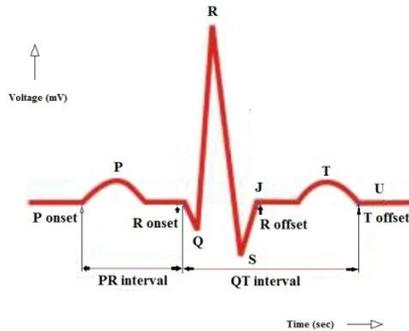
Figure 2. A Typical one-cycle ECG tracing

The objective to analyze accurately an ECG signal is especially important, where the feature extraction of the ECG signals is to locate the interested characteristic points that can be used to detect possible cardiovascular abnormalities. The fast and precise detection of QRS complexes is very important in ECG signal analysis, for it is the precondition of the correlative parameters calculation and diagnosis.

ECG signal processing can be roughly divided into two stages by functionality: preprocessing and feature extraction. The preprocessing stage removes or suppresses noise from the raw ECG signal and the feature extraction stage extracts diagnostic information from the ECG signal [1].
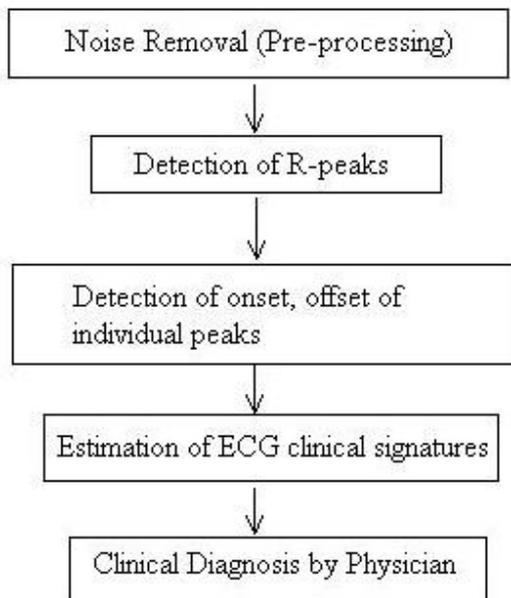
Figure 3. General steps for ECG Signal Analysis

I. ECG SIGNAL GENERATION

The LABVIEW Biomedical Toolkit has the facility for generating ECG signals from external files that can be downloaded from MIT-BIH Arrhythmia Database. Read Biosignal VI in the Biomedical Toolkit can be used for this purpose.

## II. ECG SIGNAL PROCESSING

A. Preprocessing

Preprocessing ECG signals helps to remove contaminants from the ECG signals. ECG contaminants are classified into the following categories:

- power line interference

- electrode pop or contact noise

- patient–electrode motion artifacts

- electromyographic (EMG) noise

- baseline wandering

Among these noises, the power line interference and the baseline wandering are the most significant and can strongly affect ECG signal analysis. The power line interference is narrow-band noise centered at 60 Hz (or 50 Hz) with a bandwidth of less than 1Hz. Usually the ECG signal acquisition hardware can remove the power line interference. However the baseline wandering and other wideband noises are not easy to be suppressed by hardware equipments. Instead, the software scheme is more powerful and feasible for offline ECG signal processing. The following methods can be used to remove baseline wandering and the other wideband noise [2].

a. Removing Baseline Wandering

The wavelet transform is an effective way to remove signals within specific sub-bands. The LabVIEW ASPT provides the WA Detrend VI which can remove the low frequency trend of a signal. Figure 4 shows an example of removing baseline wandering by using the WA Detrend VI.
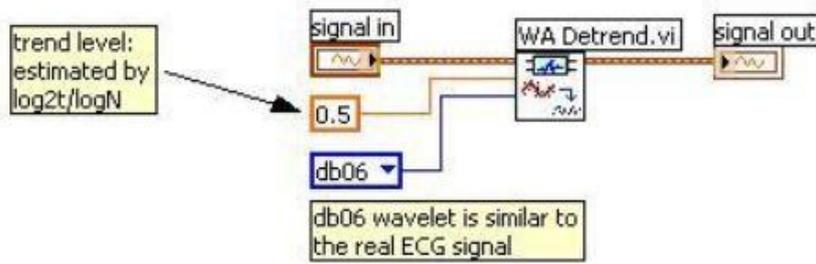
Figure 4: Using the WA Detrend VI to remove baseline wandering

This example uses the Daubechies6 (db06) wavelet because this wavelet is similar to the real ECG signal. In the ECG signal used, sampling duration is of 60 seconds, and 12000 sampling points in total, therefore the trend level is 0.5 according to the following equation:

$$trend\ level = \left\lceil \frac{\log_2 2t}{\log_2 N} \right\rceil$$

where *t* is the sampling duration and *N* is the number of sampling points.
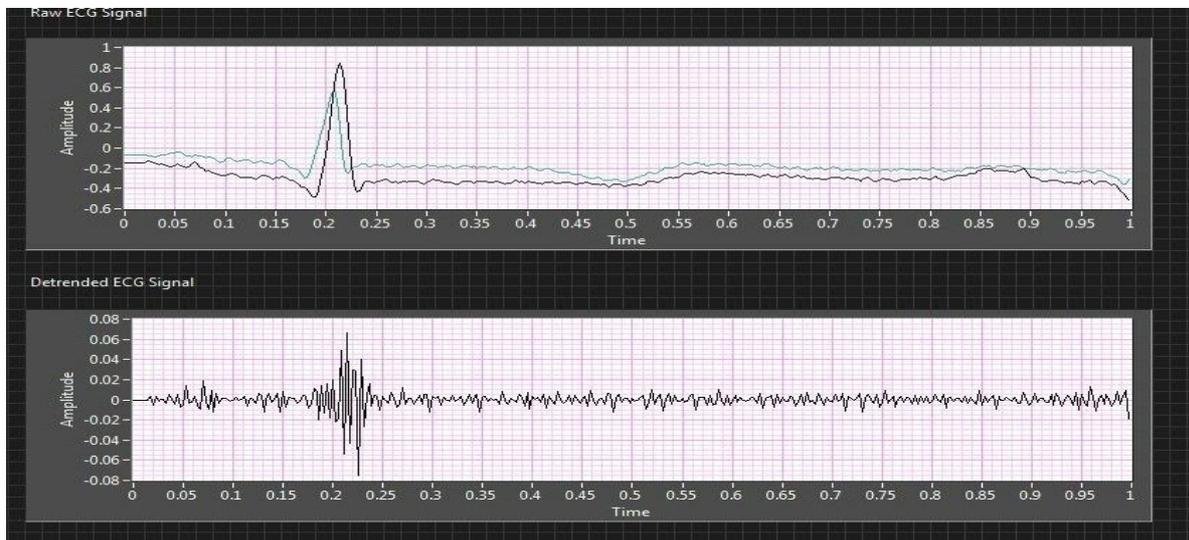
Figure 5. ECG Signal before and after removing baseline wandering

b. Removing Wideband Noise

After baseline wandering is removed, the resulting ECG signal is more stationary and explicit than the original signal. However, some other types of noise might still affect feature extraction of the ECG signal. The noise may be complex stochastic processes within a wideband, so it cannot remove them by using traditional digital filters.

To remove the wideband noises, the Wavelet Denoise Express VI can be used. This LabVIEW based higher-level Express VI first decomposes the ECG signal into several sub-bands by applying the wavelet transform, and then modifies each wavelet coefficient by applying a threshold or shrinkage function, and finally reconstructs the denoised signal. The figure 6 shows an example of applying the undecimated wavelet transform (UWT) to the ECG signal.
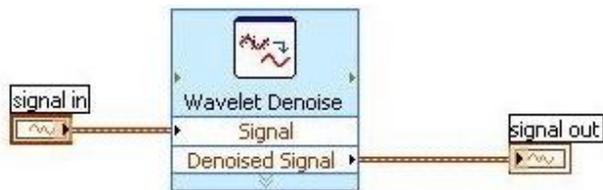
Figure 6. Removing wideband noise by applying UWT

The UWT has a better balance between smoothness and accuracy than the discrete wavelet transform (DWT). By comparing the denoised ECG signal with the non-denoised ECG signal, as shown in Figure 7, it can be found that the wideband noises are strongly suppressed while almost all the details of the ECG signal are kept invariant.
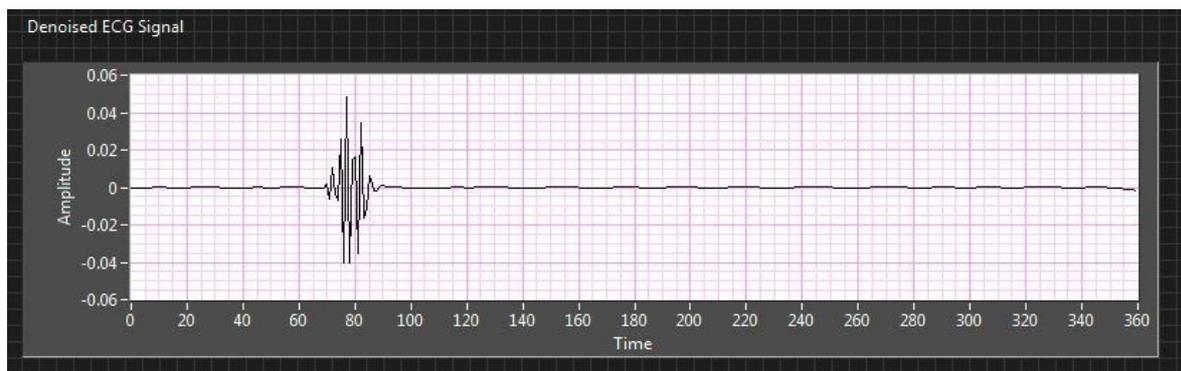

Figure 7. ECG Signal after UWT denoising
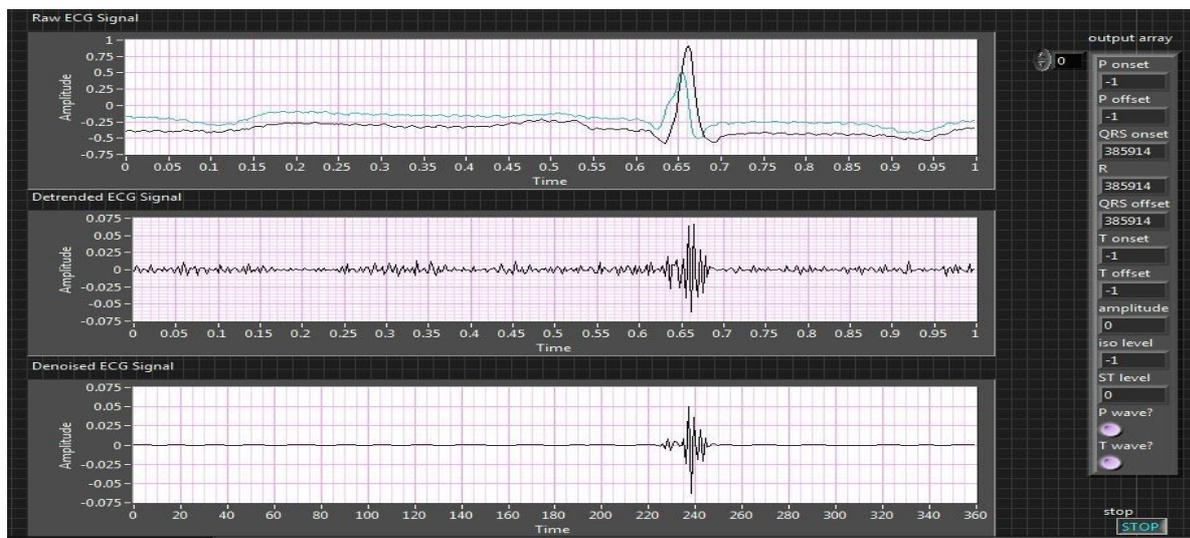
B. Feature Extraction

For the purpose of diagnosis, often we need to extract various features from the preprocessed ECG data, including QRS intervals, QRS amplitudes, PR intervals, QT intervals, etc. These features provide information about the heart rate, the conduction velocity, the condition of tissues within the heart as well as various abnormalities. It supplies evidence for the diagnoses of cardiac diseases [3].

For this reason, it has drawn considerable attention in the ECG signal processing field. This section mainly discusses how to perform ECG feature extraction. LabVIEW Biomedical Toolkit provides an ECG Feature Extractor VI for users to extract ECG features conveniently. We can select whether to detect QRS only or to detect all supported ECG features, including R position, R amplitude, iso level, QRS onset, QRS offset, P onset, P offset, T onset and T offset [4].
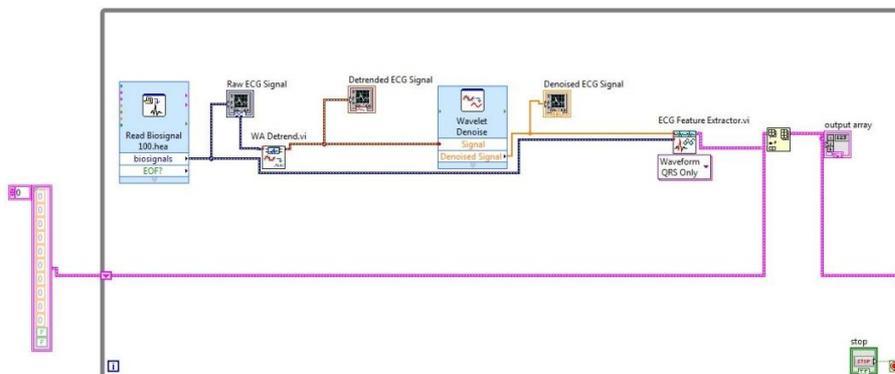
Figure 8. Implementation of QRS Detection

The ECG Feature Extractor firstly detects all beats (R waves) in the signal, and then extracts other features for every beat. For normal ECG signals, R waves can be easily detected. While abnormal morphology makes the detection difficult for ECG from patients with some specific heart diseases. Thus sometimes it is needed to perform some signal enhancement (preprocessing) before feature extraction.

Figure 9. Original ECG, ECG after Detrending, Denoising and QRS parameters detection

The preprocessed ECG signal is used to detect position of R waves. After that, all other features will be extracted using original signal, because the signal enhancement may change these features.

Once all the peaks are detected, these are taken as there ferences and an optimum window width is selected and the waves are scanned on both the sides of the peaks to get the zero crossing points for obtaining onsets and offsets. If the signal is not crossing zero line, then the minimum values in that window are considered as onsets and offsets. The peak values detected using LabVIEW are carried to the mathscript node as inputs and zero crossing points or minimum values(onsets and offsets) are taken as outputs from the mathscript node.

III.CONCLUSION

By using the LABVIEW WA De trend virtual instrument and Wavelet Denoise express VI, baseline wandering and all the irrelevant noise has been successfully removed from raw ECG signal. No universally acceptable solution has been found yet for ECG feature extraction due to variety of algorithms, huge diversity of the waveform, the noise and artifacts accompanying the ECG signals. The advantage of LABVIEW graphical programming language is that, it provides a robust and efficient environment and tool for generating very fast, less complex and useful algorithms.

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