ECG Signal Analysis

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ABSTRACT
Electrocardiogram (ECG or EKG) is basically a diagnostic tool that measures and records the electrical signal by comparing the activity of heart. Electrocardiogram has significant importance since it reveals important information about various disorders .The purpose of this work is to extract R-wave and find heart rate using LabVIEW. In this work an algorithm has been developed for the detection of R-wave, which is based on array subset and array min and max method using LabVIEW. LabVIEW (laboratory virtual instrument engineering workbench) is a graphical programming language that uses icons instead of lines of text to create programs. The work is executed in four stages. Firstly data acquisition, secondly it denoises the signal to remove the noise from the ECG signal, thirdly it detects the R-wave and lastly analysis is done by calculating heart rate. LabVIEW and the related toolkit i.e., Advanced signal processing toolkit is used to build the graphical programme .ECG data are acquired from the subjects which includes 5000 samples recorded at a sampling frequency of 1000Hz.

Keywords
ECG Signal, LabVIEW, Wavelet Denoise, WA detrend, Array Min & Max, Array Subset.

1. INTRODUCTION
The ECG records the electrical activity of the heart. Each heart beat is displayed as a series of electrical waves characterized by peaks and valleys. The ECG signal has frequency range of 0.05-100Hz and its dynamic range is 1-10mv.The ECG signal is characterized by five peaks and valleys. These are labeled by the letters P, Q, R, S, and T. The performance of ECG analyzing system depends mainly on the detection of the QRS complex and T and P waves. The P-wave represents the activation of the upper chamber of the heart, the atria, while the QRS complex and T-wave represent the excitation of the ventricals on the lower chamber of the heart. Isoelectric line is basically the baseline voltage of ECG and it is measured as the portion of the tracing following the T-wave and preceding the next P-wave. In the normal state of the heart, the R-R interval is in the range of 0.12 to 0.2 seconds. The QRS interval is from 0.04 to 0.12 seconds.

The Q-T interval is less than 0.42 seconds and the normal rate of the heart is from 60 to 100 beats per minute. So, from the recorded shape of the ECG, one can determine whether the heart activity is normal or abnormal.

Electrocardiogram (ECG) consists of graphical recording of electrical activity of the heart over time. It is the most recognized biological signal, and with non-invasive method, it is commonly used for diagnosis of some diseases and abnormalities. Each portion of the ECG waveform carries information that is relevant to the clinician in arriving at a proper diagnosis.

The electrocardiogragh signal taken from a patient generally gets corrupted by external noises, hence it necessiciates the need of a proper noise free ECG signal. A signal acquisition system consists of several stages including signal acquisition through hardware and software instrumentation, filtering and processing for the extraction of information.

A ECG waveform is shown in figure 1.1. It is a combination of P-wave, T-wave, and a QRS complex. The complete waveform is called an electrocardiogram with labels P, Q, R, S and T indicating its distinctive features.

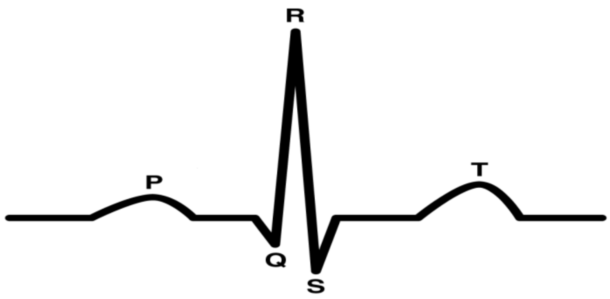


Fig.1.1 ECG Signal

ECG signal consists of a recurrent wave sequence of P-wave, QRS-complex and T-wave associated with each beat. Isoelectric line is basically the baseline voltage of ECG and it is measured as the portion of the tracing following the T-wave and preceding the next P-wave [9].

Laboratory Virtual Instruments Engineering Workbench (LabVIEW) software is used as the integrating, platform for acquiring, processing and transmitting the physiological data as it is an excellent graphical programming environment to develop sophisticated measurement, test and control systems. LabVIEW is a program development application much like C or BASIC. However LabVIEW is different from those applications in one more important respect. Other of code, while LabVIEW uses a graphical programming language, G, to create programs in block diagram form, system with extensive libraries of functions and subroutines for any programming task. LabVIEW also includes execution to see how data passes through the program and single step through the program to make debugging and program development easier.

Table 1.1: Normal Values of ECG

Parameter	Normal Value
Heart Rate	60-100 bpm
P Wave	Amplitude: 0.25±0.05mV

	Interval: 110±20ms
QRS Complex	Amplitude: 1.60±0.5mV Interval: 100ms±20ms
R Wave	Amplitude: 1.60±0.5mV
Q Wave	Amplitude: 0.25 times the R Wave
T Wave	Amplitude: -0.5mV Interval: 160ms
PQ or PR Interval	Interval 120 – 200 ms

2. BRIEF DESCRIPTION AND METHODOLOGY

The proposed work has been done by the following way;

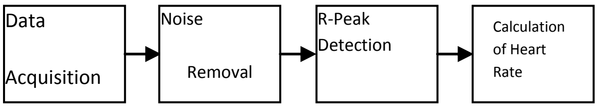


Fig.2.1: System Block Diagram

2.1 Data Acquisition

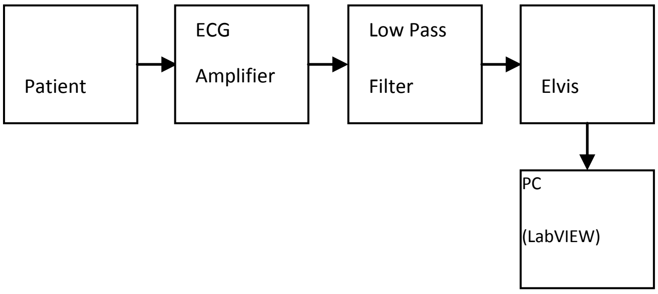


Fig.2.2: Block Diagram of Data Acquisition

Lead II configuration is used here to acquire the ECG signal.

In the Lead II configuration, the positive electrode is on the left leg and the negative electrode is on the right arm.

2.2 ECG Recording

Electrodes are placed over the surface of the skin with the help of electrodes the signal is acquired. The ECG amplifier detects the electrical signal generated by the heart. The signal from the ECG amplifier is passed to the low pass filter. Since the ECG signal gets corrupted by different types of artifacts and interference, to avoid such noises low pass filter is used. Output of the filter is passed to the ELVIS board. The output is recorded on a PC for the purpose of display and enabling for further signal processing.

2.3 Algorithm used to remove noise

2.3.1 Removal of Baseline Wandering

Baseline wandering usually comes from respiration at frequency wandering between 0.15Hz and 0.3Hz.Wavelet transform can also be used to remove the baseline wandering by eliminating the trend of the ECG signal. The wavelet transform based approach is better because it introduces no latency and less distortion than the digital filter based approach. The LabVIEW ASPT (Advanced signal processing toolkit) provides the WA Detrend virtual instrument which removes the low frequency trend of the signal.

$$\text{Trend level} = \left[\frac{\log_2 2t}{\log_2 N}\right]$$

Where t is the sampling duration and N is the number of sampling points.

The data used here has a sampling frequency of 1000Hz and 5000 sampling points in total, therefore the trend level is 0.35 according to the equation. Trend level specifies the number of levels of the wavelet decomposition, which is approximately,

Number of decomposition level

= (1-trend level)*log2(N)

The WA detrend virtual instrument has an option to specify the wavelet type used for the discrete wavelet analysis. The one selected here is symlet 3 (sym 3) [10].

2.3.2 Removal of Wideband Noise

After removing baseline wander 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 one cannot remove them by using traditional digital filters. To remove the wideband noises. The Wavelet Denoise Express Virtual instrument is used here.

The Express Virtual instrument decomposes the ECG signal into several sub bands. The Virtual instruments offer an option to select either discrete wavelet transform or undecimated wavelet transform to denoise the signal. The transform type used here is discrete wavelet transform (DWT) to denoise the ECG signal [10].

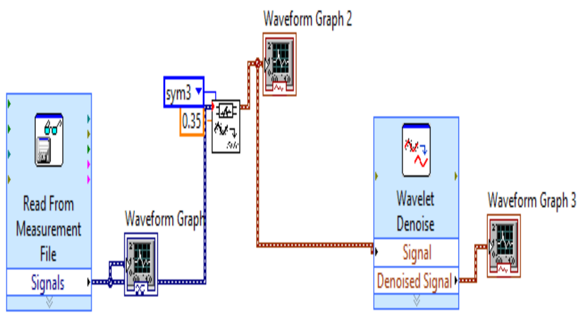
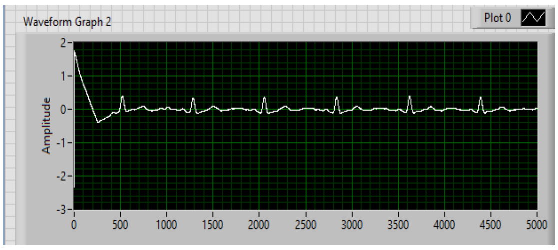


Fig.3.1: VI diagram to remove baseline wander and wideband noise

(a)



(b)

(c)

Fig.3.2: (a) Original signal, (b) Base line wander removed signal (c) Denoised signal

2.4 Heart Rate Determination

Heart rate is determined by the number of heart beats per unit of time expressed as beats/minute (BTM).

Heart rate or heart pulse , is the speed of the heartbeat measured by the number of poundings of the heart per unit time- typically beats per minute (bpm).The heart rate can vary according to the body's physical needs, including the need to absorb oxygen and execute carbon dioxide.

The heart rate is calculated as follows,

$$HR = \frac{60000}{RR - Interval}$$

2.5 Array Min and Max

Array min & max returns the maximum and minimum values found in array, along with the indexes for each value.

The array min & max compares each data type according to the rules for array comparison. If a numeric array has one dimension the max index and min index outputs are scalar integers .If a numeric array has more than one direction, these outputs are 1D arrays that contain the indexes of the maximum and minimum values. If the input array is empty, max index and min index are -1.

Here our aim is to find the R-peak. Therefore max value max index is used for the purpose. Max value give the R-peak amplitude and max index gives the location of R-peak.

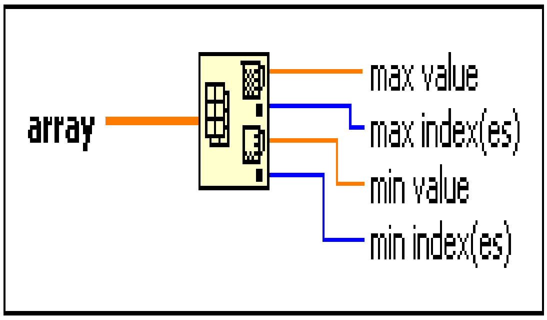


Fig.3.3: Array Min Max

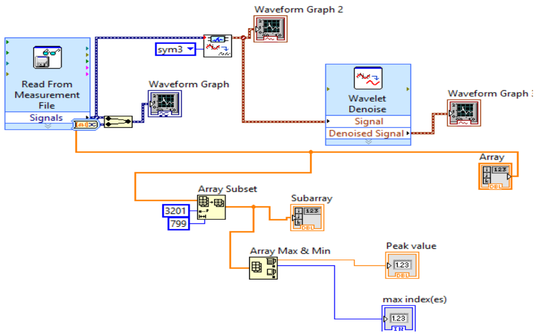


Fig.3.4: VI diagram to find R-peak

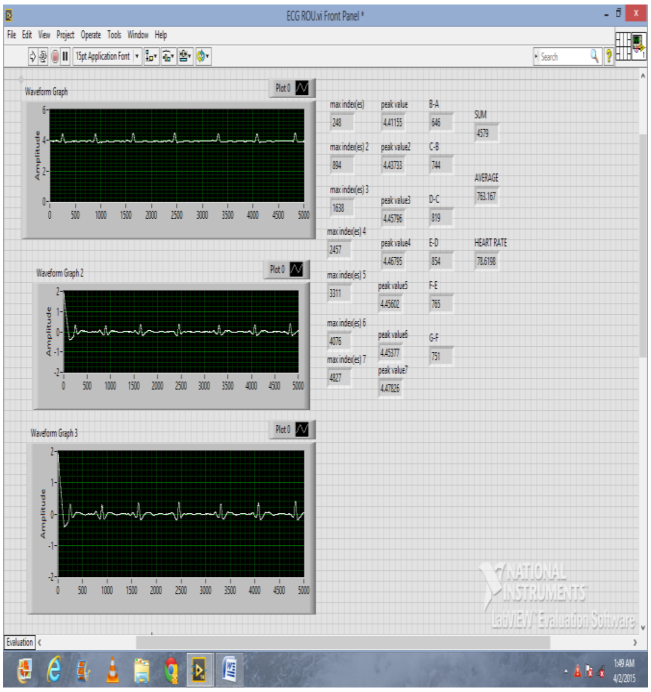


Fig.3.5: Front panel of VI Diagram used in Proposed System

3. RESULTS & DISCUSSION

3.1 Result:

The ECG signal has been acquired from the subject/patient by placing the clamp electrodes over the surface of the skin and it has been displayed on the screen (PC).ECG signal analysis has been done using LabVIEW software and the input signal is collected from the read from measurement file.

The VI is designed to remove noise, R-peak detection, calculate the heart rate and it is found that all the heart rate lie in normal region in 60 to 100 bpm.

Table 3.1 (a) R-Peak Detection

	Amplitude (mV)	Location
Subject 1:	4.54627	215
	4.51307	858
	4.46827	2130
	4.44796	2736
	4.46859	3904
Subject 2:	4.41155	248
	4.43733	894
	4.45796	1638
	4.46795	2457
	4.45602	3311
Subject 3:	4.39962	201
	4.37158	917
	4.34322	1774
	4.32549	2552
	4.38254	3313
Subject 4:	4.3898	520
	4.3777	1283
	4.39156	2054
	4.40349	2834
	4.35837	3623
Subject 5:	4.39898	520
	4.3777	1283
	4.39156	2054
	4.40349	2834
	4.35837	3623

Table 3.2 Heart rate of Normal Subject

SUBJECT	R-R INTERVAL	HEART RATE (60000/R-R INTERVAL)
SUBJECT 1	731.75	81.99
SUBJECT 2	775.75	77.34
SUBJECT 3	778	77.12
SUBJECT 4	765.75	78.35
SUBJECT 5	787.25	76.21

3.2 Discussion

Table 3.1 shows the value of R-peak amplitude and R-peak location by using array subset and array min & max, R-peak amplitude and its location are found for 5 subjects.

Table 3.2 shows the values of RR-Interval and Heart Rate.

4. CONCLUSION

By using LabVIEW WA detrend VI and Wavelet Denoise Express VI of Advanced signal processing tool kit the baseline wandering and wideband noise in ECG signal acquired from the subjects has been successfully removed. The extraction of R-wave, heart rate calculation has been done.Future development can be made as follows:

- Real time operation for recognizing the cardiac disorders can also be done.
- To design better feature extraction methodology which can improve the classification result of cardiac disorders in ECG signal.

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