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Implementation of Single Hand ECG Acquisition System using Lab VIEW

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A B S T R A C T

In this era, the health state identification using minimal equipment, time and cost demands more advancements in healthcare. One such factor is Electrocardiogram recording and analysis of the signal to depict the health status. ECG signal is widely recorder non-invasively, obeying the standard 3-lead system with electrodes mainly located on Right arm (RA), Left Arm (LA), Right Leg (RL) and Left Leg (LL), which forms the acquisition set-up. This acquisition set-up has pre-gelled electrodes fixed to the patients skin and lead wires running to the processing and display unit. This paper explains our proposed work, as it uses 3 leads fixed to a single arm of the person around the wrist only. Earlier studies has been done, acquiring ECG using active electrodes located on the left upper arm region and ground electrode at elbow/wrist. The work involves the pre-gelled electrodes placed around the wrist at certain distances between each other. The acquired ECG is amplified using Instrumentation Amplifier (IA), sent to NI- LABVIEW DAQ for visualization in LabVIEW software. To eliminate the noises araised due to the closer presence of electrodes, powerline interference, muscle artifacts stronger digital filters are designed using LabView. After filtering, quality of ECG signal acquired from single arm is checked to depict its usability for diagnosis. For comparison, ECG signal from healthy individuals are acquired using standard 3 lead system and the proposed single arm approach. The single-hand approach in ECG acquisition reduces the complexity of the existing acquisition system for a greater extent and provides comfort to patients. The results of comparison were very promising, the values were recorded and found to be in normal range. The proposed ECG acquisition methodology provides us with best ECG signals that can be used for diagnosis. The ECG signals have improved SNR when compared to other existing system.

Keywords: Electrocardiogram, Single arm approach, Pre-gelled electrodes, Data Acquisition Card – DAQ, Filters, Instrumentation amplifier.

1. Introduction

A person's physiological characteristics can provide valuable information about their health. Medical professionals have long monitored patients' biosignals using electronic equipment to help with medical diagnosis. In order to provide everyone with access to high-quality medical treatment, remote patient monitoring is currently required due to variables like the ageing of the global population, the prevalence of chronic diseases, and the resulting rise in healthcare needs. As a result, there is an increasing need for portable and trustworthy medical equipment for home use. Electrocardiography (ECG), the word is derived from Greek “electro” meaning “electricity”, “cardio” referring “ heart” and “graph” meaning “write”, a written record (i.e.) the graph depicting the electrical activity of heart. ECG is one of the most commonly used method in medical system for diagnosing the cardiovascular disease. The P waves, which represent the depolarization of the atria, the QRS complex, which represents the depolarization of the ventricles, and the T wave, which represents the repolarization of the ventricles, are the three primary components of the ECG signal. A healthy person's heart beats between 60 and 100 times per minute on average (bpm). Any deviations from the normal rate points to any one type of heart disease including Arrhythmias, Atrial Fibrillation, Myocardial Infarction, or tissue damage. Heart rate (HR) with typical sinus tachycardia is more than 100 beats per minute (BPM); less than 60 BPM for sinus bradycardia; respiratory sinus arrhythmia; pre-excitation arrhythmia pattern; and WPW syndrome for those caused by autonomic nervous system dysfunction and also AV conduction blocks. Traditional methods for identifying disturbances in the heart's rhythm and calculating heart rate variability include R peak identification in the electrocardiogram (ECG) (HRV). Visually analysing the R peak in a long-term monitoring scenario is particularly difficult because the ECG is a non-stationary signal (Cho et al.2015). Consequently, having a portable, continuous heart rate monitoring device is required (R peak detection). Even though they only record single lead, handheld ECG event recorders are useful for rhythm monitoring because they allow for more flexible interpretation. They utilised the apparatus, tried to determine whether a multi-lead ECG could be recreated using it, and sought to assess diagnostic precision. They rebuilt a nine-lead ECG (leads I, II, and III, V1-6) using a commercially available handheld bipolar ECG event recorder, and the tracings were independently examined by a cardiologist. Over 30 patients were assessed. Atrial fibrillation, atrioventricular block, bundle branch block, and left ventricular hypertrophy were all identified with great accuracy, although ST-segment alterations and extended QTc were less accurate. A single-lead ECG event recorder that is portable can reconstruct a 9-lead ECG and has good diagnosis accuracy for common abnormalities (Nazeri et al. 2019). Wireless ECG sensor detection technique using novel lead system for continuous home care. The techniques or ECG monitoring system were followed by the process it amplifies the signal and filters and remove baseline wandering and common mode noise and provides the sample to the coordinator and the signals were analysed through personal computers by consultant. Here the Manson – likar limb electrodes placement system is considered and the standard system and this system provides a clear result that the new lead placement of electrodes provides compact and convenience of the ECG system when compared to the considered std placement (i.e.) Manson – likar limb method (Wang et al. 2013).

This work describes, the implementation of single hand ECG acquisition system using LabVIEW. The single hand ECG acquisition system uses 3 pre-gelled electrodes applied in three different positions around the wrist to derive the ECG signal of the subject. Many studies shown that ECG signal can be acquired from different position on the left wrist and right wrist, using disposable Ag/AgCl electrodes (García - Niebla et al. 2009). Traditional ECG acquisition system lacks in flexibility and new frameworks has to be validated to make the acquired ECG feasible for diagnosis

2. Related Work

Arrhythmias that are detected early can be treated well, which lowers mortality and disability. Arrhythmias, though, can be transitory in the early stages of disease, lasting only a few seconds, making them challenging to identify. The authors of (Escalona et al. 2017) work is to develop a data driven ECG denoising algorithm based on ensemble empirical mode decomposition (EEMD) methods to extract the far-field heart electrogram signal from noise components recorded in bipolar leads along the left arm. This will allow for continuous non-invasive monitoring of heart rhythm for extended periods of time using a wrist or arm wearable device with advanced biopotential sensors. In a pilot investigation with 34 clinical cases, signal averaging performance was compared to a control denoising method. In comparison to the control SA approach, EEMD was shown to be a dependable, low latency, data-driven denoising strategy that improved the signal-to-noise ratio to a level that was more similar to the SA control method, especially on the upper arm-ECG bipolar leads. In addition, the EEMD's SNR performance was enhanced with the use of an FFT (fast Fourier transform) thresholding technique (EEMD-fft). Another ECG acquisition discussed in (Hannula et al. 2008), involves wrist and the upper arm region of the subject. Amplifier is used to amplify and output the raw ECG from the electrode and sending to Data Acquisition card connected to PC. The pc had integrated real-time analytic software that reads, filters, and analyses the ECG signal using LabVIEW and Matlab. In order to measure and analyse the extremely weak and noisy ECG signal coming from the electrodes, customised amplifier and analysis software solutions were constructed. (Murugappan et al. 2014) LabVIEW is used to build and create a portable, affordable, and clinically viable ECG data acquisition device. A three-lead ECG data acquisition circuit was used to create the ECG signal using an ECG simulator. The resulting signal is preamplified using an instrumentation amplifier (INA118) and filtered using a 0.05 Hz - 113 Hz cutoff frequency.

3. Modules and Methods

The entire work of designing a single hand ECG acquisition is covered under 5 sections as – electrode placement and signal acquisition, signal amplification, display interface, signal filtering, and validation.

3.1 Electrode Placement and Signal Acquisition

An illustration on the functioning of heart is provided by the Electrocardiogram machine (ECG), which records the change in the heart's electrical activity is monitored using electrodes applied to the skin (McFrederick et al. 2017). Recording ECG through pre-gelled Ag/Agcl electrodes is a widely accepted and everywhere used technique, which is highly non-invasive. Though non-invasive, the number of electrodes and lead wires involved in recording ECG introduces noises to the signal. The procedure to record ECG signal involves bio-potential sensors or electrodes to evaluate the variation in electrical conductivity of the heart. The most common and universally accepted electrode placement for ECG recording is Right Arm (RA), Left Arm (LA) and Left Leg (LL), allowing easier pulse detection. Certain types of electrodes are available to meet the need of acquisition like patch electrodes, pre-wired ECG electrodes, and disposable ECG electrodes. This proposed work aims to record ECG from single arm i.e. left arm only. Instead of placing the electrodes in both arms and leg, the electrodes are employed at equal distance between each other, around the wrist region. The pre-gelled electrodes are widely accepted as they can be easily applied over the skin in limb or chest area, but any displacement or change in limb electrode placement has to be recorded and involved during interpretation (Rakin et al.2019). The electrode placement is of interest as any misplacement may lead to artifact introduction into the ECG signal, which may lead to misinterpretations.

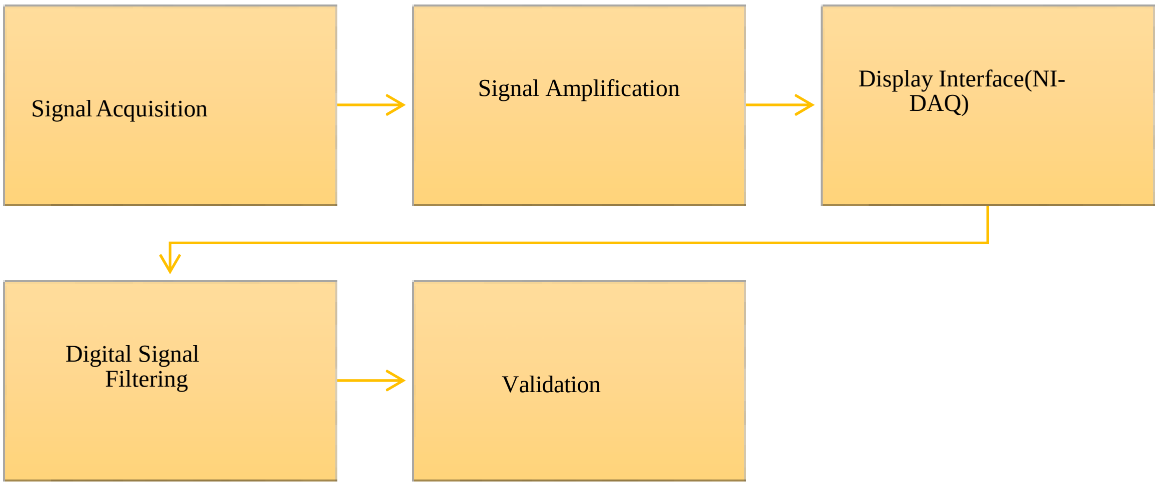

Fig. 1 Modules involved in system design

b) Signal Amplification

The bio-potential ECG sensor acquires the ECG signal and needs to be processed to make sure the signal can be used for diagnosis. The first step in processing the acquired signal is amplification. The biosignal recorded from the skin surface will require amplification to certain level, which is done by setting gain in the amplifier circuit. Usually the amplification is done in the front end, prior to digital processing [7,8]. The amplifier circuit is designed with Instrumentation Amplifier (IA) IC and gain resistors. The implementation of signal amplification is further explained in hardware implementation section.

c) Display Interface

The display unit is very important to visualize the processed or raw signal for interpretation. In general, when an examination is complete, a standard ECG machine prints out the results; there are other devices, though, that display the output signal on a monitor or screen (Buxi et al. 2012). In this work, the amplified ECG signal is displayed in NI- LabVIEW, interfaced through NI- Data Acquisition Card (DAQ). The importance of using LabVIEW workspace is the ECG signal can be saved and reused in future by accessing the read/write measurements.

d) Signal Filtering

The next process performed over a signal is removal of additional noises caused due misplacement of electrodes, motion artifacts, powerline interference, etc. After amplification process, the signal is subjected to different stages of filtering to remove the superimposed noise. [11,12] The digital filters are designed in LabVIEW for effective removal of high frequency noises and powerline interference. The major parameter of filter design is the cut-off frequency, which determines the quality of output signal. The filter design is discussed in software implementation section and the results are discussed in further section.

e) Validation

To demonstrate that the ECG signal obtained using the suggested approach is appropriate for diagnosis; the signal has to be validated against the standard 3- lead ECG. The parameters usually involved in depicting the quality of signal are Signal to Noise Ratio (SNR), power spectrum, etc. The validation performed on the signal is discussed in software implementation.

4. Hardware Implementation

The hardware part of the work involves electrodes to pick up the change in heart's electrical activity and the instrumentation amplifier used for amplification. As discussed a little, the standard three-lead electrode placement to acquire ECG is displayed in fig 2. The ECG signal recorded through this technique is widely applied with machine learning and neural network techniques for various diagnosis. The electrode placement of our work is illustrated in fig 3.   the single hand ECG acquisition from the areas of left wrist.

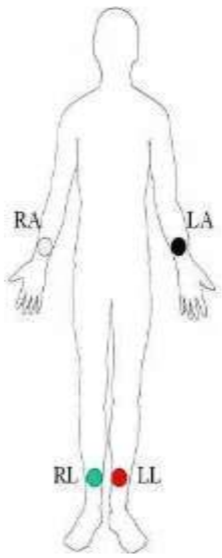

Fig 2. Standard ECG lead positioning

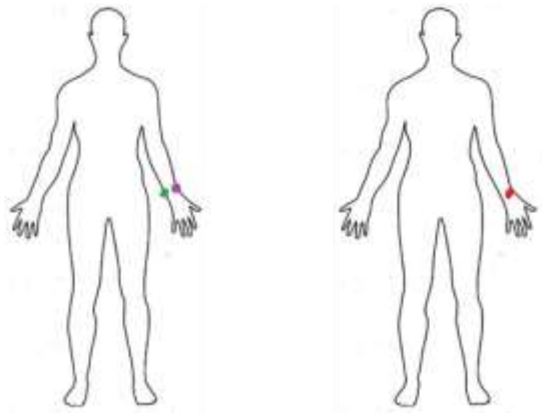

Fig 3. Proposed acquisition system electrode positioning

The electrodes are placed around the wrist region with 2 cm distance between them. The figure 3, illustrates the placement of active – reference electrodes with different color representations; the violet dot represents ground positioning of the electrode, the red and green indicates the positive and negative electrode placement. Electrodes are bio-potential sensors that are used to detect and pick the bio-potential changes beneath the skin, and convert it to electrical signal. The electrical signals are easy to display, process and interpret. One major difficulty in further processing the detected electrical signal is their low voltage. To deal with this challenging low voltage signal instrumentation amplifier is used with fixed gain to amplify the ECG as high voltage signal. The instrumentation amplifier applied in our work is AD620, a high precision amplifier, majorly used in medical applications. The gain is set to amplify the ECG signal to 150 fold with an output voltage level of 1.2V. The advantage of AD620 Instrumentation Amplifier is the variable gain tuning form 1 to 10,000 with no much external components. The gain of amplifier is set using the formula,

To acquire signal, 50 healthy subjects were chosen between the ages of 19-21. ECG signal was recorded from each subject under rest condition. First, ECG was recorded by the standard 3- lead system, locating the electrodes in right arm, left arm and ground. Later, by placing the three electrodes in the same wrist at 2 cm distance each, ECG is recorded. The acquired ECG is amplified to high voltage level using AD620 Instrumentation Amplifier.

4. Software Implementation

The NI-DAQ interface, digital filtering and validation are discussed under software implementation. The amplified high voltage level signal has to be visualized and recorded for further interpretation and usage. The signal is processed and visualized using NI-LabVIEW, when an electrical signal is digitally transformed from analogue using the Data Acquisition Card – NI DAQ. The input ports of the DAQ are connected to the output pins of the instrumentation amplifier. DAQ assistant is all set with parameters on the LabVIEW window with a waveform display component to view the signal. Digital filters are made to reduce noise and distortions from the ECG signal. Wide varieties of filters are available for medical signal processing, amongst which bandpass and notch filters are applied on the signal. The bandpass filter is designed with a cut-off frequency of 0.5 Hz to 100 Hz, to obtain quality, noise free signal. In the same way, notch filter has a cut-off frequency of 50 Hz to remove power line interference caused by acquisition system. The filteration blocks are placed inside the loop of DAQ Assistant. The output of DAQ assistant is fed to bandpass filter and then to notch filter for validation. The software implementation is done for both standard 3-lead recording and the proposed recording set-up.

Fig 4. Electrode placement – standard

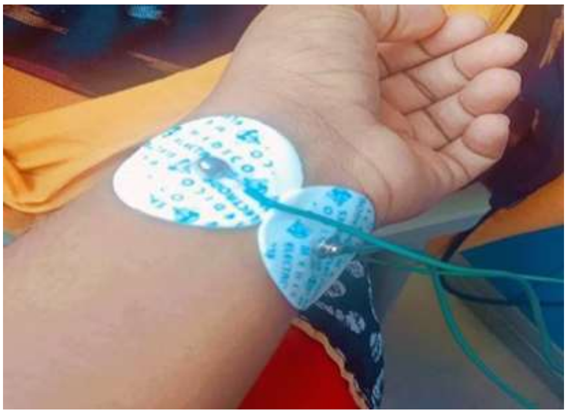

Fig 5. Electrode placement – Proposed

5. Results and Discussion

The final outputs obtained from the design and implementation of single hand ECG acquisition system has been listed one by one in this section. The ECG signal were successfully recorded from 50 healthy individuals, in both the recording set-up.

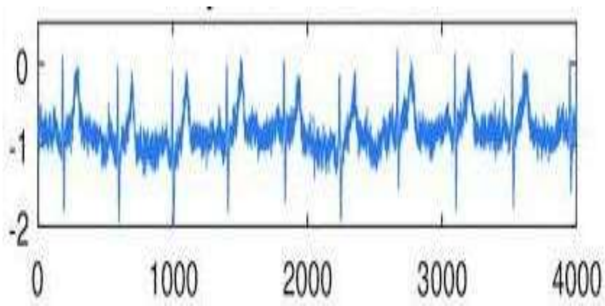

Fig 6. Raw ECG acquired using standard 3-lead system

Initially the subject is connected to the standard three lead setup, ECG is acquired, amplified, filtered and validated in LabVIEW. In the similar way, the signal from same subjects are recorded using proposed single hand approach and the signal is amplified, filtered and validated in LabVIEW, presented as comparison in table 1**,** where the SNR values for 10 subjects are tabulated. The hardware portion has electrodes for acquisition and the instrumentation amplifier for amplifying the low voltage level ECG signal to high level signal. The software portion has the DAQ assistant supported to acquire the digitized signal, digital filters – bandpass and notch to remove noises/artifacts and the waveform display.

The 3 – lead ECG electrodes are positioned on the subject as shown in fig 4. The ECG signal is acquired, processed and displayed in LabVIEW. The proposed electrode placement around the wrist area is shown in figure 5; the next image fig 9 shows the processed ECG signal in LabVIEW. Fig. 8 depicts the sequence diagram of the LabVIEW tools in use.

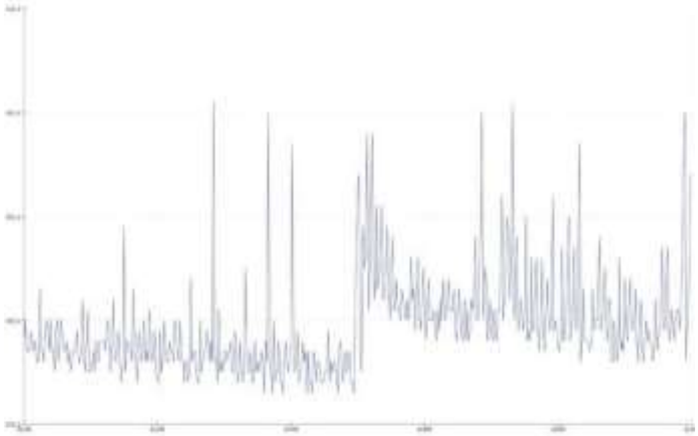

Fig 7. Raw ECG acquired using proposed system

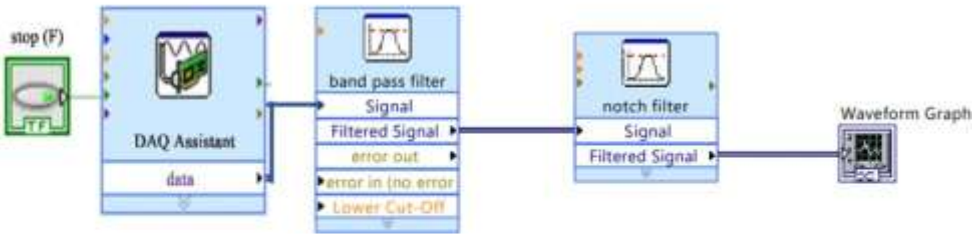

Fig 8. Block diagram designed in LabVIEW

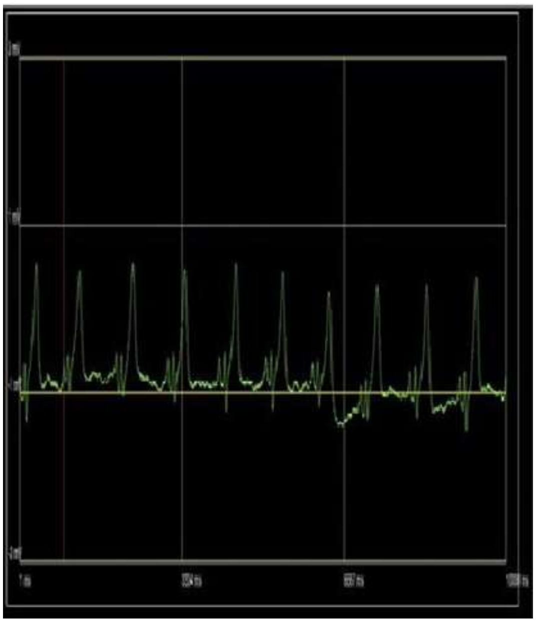

Fig 9. Filtered ECG acquired using proposed system

Subject	SNR of standard system ECG (dB)	SNR of proposed system ECG (dB)
1	10	9.74
2	11.25	12
3	12	10.6
4	15.7	14.23
5	13.39	13.54
6	12	12.02

7	13.05	13
8	10.02	8
9	14.28	14.2
10	10.89	9.22

6. Conclusion

The acquisition of ECG signal by placing three pre-gelled electrodes in the wrist position is done successfully and is validated as aimed. The ECG signal acquisition is done, amplified using Instrumentation amplifier and visualized in LabView after digital filtering. ECG is successfully acquired using the proposed system and standard 3-lead system. The signal is initially amplified using instrumentation amplifier for better visualization. The National Instruments Data Acquisition Card receives the analogue ECG signal that has been amplified (DAQ). The acquired signal has noise superimposed on it, digital filters were designed in NI-LabVIEW to remove power line interference and baseline wander. Signal artifacts are removed by designing a band-pass filter with cut-off range 0.5 – 100 Hz, to remove higher frequency noises and notch filter to eliminate power line interference of 50Hz. The digital filters successfully removed the noises and displayed the ECG waveform. To analyze the ECG signal quality, Signal to Noise Ratio (SNR), is measured to substantiate, acquired ECG has low noise and is similar to the ECG signal acquired through the standard 3-lead positioning system. Finally, the ECG signal acquired through the proposed system has shown good SNR value.

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The results/data/figures in this manuscript have not been published elsewhere, nor are they under consideration (from you or one of your Contributing Authors) by another publisher. I have read the journal policies on author responsibilities and submit this manuscript in accordance with those policies. All of the material is owned by the authors and/or no permissions are required.

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