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Real-Time Arrhythmia Detection Using NI LabVIEW and Sending Notification via SIM800L GSM Module

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ABSTRACT

It is well-known that in case of cardiovascular diseases an early diagnosis is one of the vital role to prevent the deaths. Although there are many devices and applications to diagnose the diseases, most of them are either too expensive or an expert is required to use it.

The aim of the current study is measuring the Electrocardiogram (ECG) signals from the human-body in real-time, processing these signals simultaneously via LabVIEW and by calculating heart rate of a patient using Teager Energy method, detecting tachycardia and bradycardia arrhythmias. Therefore, using an Arduino UNO and SIM800L GSM module, the information of a patient regarding abnormality of his/her heart beats could be sent to a his/her relative or a doctor. With this new low cost and simple application, an arrythmia could be immediately detected and one can intervene the patient on time.

Keywords: Electrocardiogram (ECG), Arrhythmia, Arduino UNO, SIM800L

1 Introduction

Cardiovascular diseases (CVD) continue to be the biggest cause of deaths worldwide. In 2008, more than 17 million people died from CVDs. More than 3 million of these deaths occurred before the age of 60 and unfortunately they were largely preventable. People with cardiovascular diseases or under high cardiovascular risk need early diagnose and appropriate medications [1]. The increase in the number of people with heart disease caused an increase in the measurement electrocardiogram (ECG) records in hospitals. It is well-known that ECG is a record of the heart's electrical activity over time, produced by an electrocardiograph. The electrical impulses in the heart are originated from the sinoatrial node and pass through the heart muscle, where it provides electrical initiation of systole or contraction of the heart [2].

ECG signals can be measured on electrodes that are selectively placed on a patient's skin. Electrodes on different sides of the heart measure the activity of different parts of the heart muscle. Knowing these details is very important in diagnosing a wide variety of heart diseases that threaten human life. The modern control system has built using the latest technologies in the field of communication to collect vital signs of the heart and send it over long distances [3]. In Fig. 1, a typical ECG signal sample is displayed [4].

An ECG sample described by five peaks and valleys identified with P, Q, R, S and T letters is presented in figure 1. ECG signal analysis is based on accurate and reliable detection of these peaks. QRS complex detection is one of the major task in ECG analysis. When the QRS complex is defined and correctly

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detailed, the heart rate can be calculated. Besides, other analyses such as ST segment analyses can also be performed.

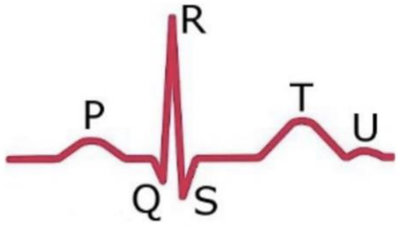

Figure 1: A typical ECG signal sample

The heart provides blood circulation within the body by regularly making contraction and relaxation movements. In cases where these contraction and relaxation periods show irregularity, non-rhythmic contraction and relaxation begin to be involved in movements. Such irregular behaviour of the heart is called arrhythmia. Under normal conditions the heart beats 60 to 100 times per minute for healthy adults. This heart activity may vary depending on the psychological and physical conditions of a person. When the normal activity is changed, rhythm irregularities, in other words, arrhythmias appear [5]. Detection of an arrhythmia on time and its transmission to relatives of a person and healthcare professionals are very important for saving human life. Tachycardia is one of these arrhythmias and when a heart rate is over 100 beats per minute (bpm) it is called tachycardia. Another type of arrhythmia is bradycardia which refers a heart rate slower than normal rate.

There are many studies in literature that investigate the arrhythmia detection methods [6-8]. Rege et al., proposed a simple, single lead, and real-time ECG device designed on LabVIEW intended for the detection tachycardia [9]. Their results showed that their developed algorithm was able to detect possible tachycardia. However, their study was limited only for monitoring the arrhythmias. Das et al., offered arduino - based online heart rate detection and possible arrhythmias rely on heart rates [10]. Although their algorithm was good enough to calculate hear rate accurately, presenting the results was limited with monitoring as well.

This current study is based on detecting tachycardia and bradycardia arrhythmias using an ECG module AD8232 via LabVIEW and with the help of Arduino UNO and SIM800L GSM module, sending an information about the patient's health situation to relative or doctor of a patient.

2 Research Methodology

In this study, an AD8232 ECG sensor, an Analog to Digital Converter (NI myDAQ), an Arduino Uno and an SIM800L GSM module were used. The complete block diagram of the study is presented in Fig. 2.

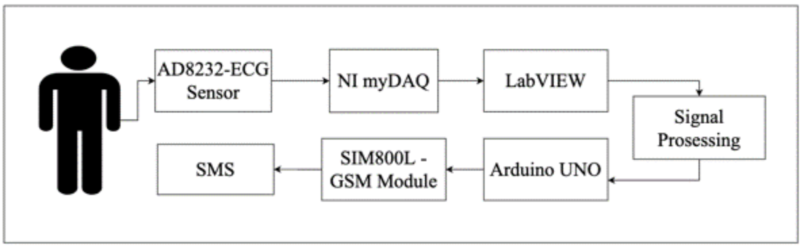

Figure 2: The block diagram of the complete study

Firstly, ECG electrodes were placed on the patient's skin to measure the signals. With the help of Einthoven triangle electrodes' locations were placed, which refers to the right and left arms and the left leg. The ECG records were measured using AD8232 module which is an integrated signal conditioning circuit for bio-potential measurement applications.

As a second step of the study, NI myDAQ card was used to convert received analog ECG signals to the computer environment. NI myDAQ provides analog input and output (AIO), digital input and output

(DIO), power supplies, audio and digital multimeter (DMM) functions in a USB device. It allows users to record and process the signals in real-time. The user can also monitor, process and analyze the raw signals simultaneously with NI LabVIEW on the computer [11].

In order to monitor acquired raw signals from ECG module via myDAQ card, LabVIEW DAQ assistant tool in the program was used.

The receive mode was selected as the continuous mode in the configuration settings. In addition, the sampling rate was set at 1kHz and 3kHz for the sample signal to be read. The signal processing starts with filtering. Signal filtering is one of the major tasks in signal processing. After receiving the raw biological signals using electrodes, they need to be processed to make the signal clearer and detectable. Since this study focused on ECGs, firstly the signal bandwidth was adjusted. To do this, firstly a bandpass filter was implemented. Then, a band stop filter was applied on the signals. The bandpass filter is a combination of low pass and high pass filter. Basically, the desired signal weakens the lower and higher frequencies than the frequency range. 0.01 Hz and 120 Hz were selected as the low and high cut-off frequencies, respectively [12]. The Filter type used here is called the Butterworth filter, which makes the frequency response of the signal smoother [13]. The Butterworth filter order was set to 7. Another filter that was used in this study is band stop filter. The band stop filter is also a series combination of low and high pass filter. This type of filter removes noise within a certain range. Here it was used to eliminate 50 Hz power line interference. In the band stop function of the LabVIEW, the cut- off frequencies were selected as 49 Hz and 51 Hz as low and high cut-off values. Therefore the 50 Hz power line noise was subtracted from the signal [14].

In order to compute the heart rate from the ECG signals, Teager Energy (TE) method was used. This method mainly shows the frequency and momentary changes of the signal amplitude, which is very sensitive to subtle changes. The use of TE can also minimize the effects of P and T waves on QRS complex detection [15]. Since the heart rate was intended to be calculated using the Teager Energy formula, firstly, the time period between two R waves were obtained. The Bio signal Rate Extractor tool from the LabVIEW Biomedical Toolkit was used for this purpose.

High and low threshold values were determined according to the amplitude of the signal obtained to determine the peaks. The value found by Teager Energy formula is divided by 60. Therefore, the heart rate per minute could be calculated. The calculation part is given in Fig. 3.

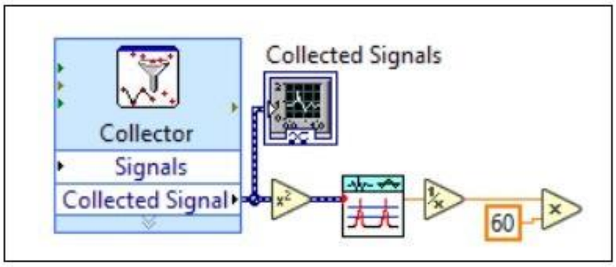

Figure 3: The heart rate calculation part of the complete algorithm

After calculation the heart rate, the GSM module was implemented to the algorithm in order to send the information to the relatives of a patient or a doctor. The SIM800L GSM module used in the LabVIEW can be controlled manually with the help of AT commands. VISA Serial operator, which is one of the serial communication tools, has been used for the GSM module that can be controlled in LabVIEW environment. Any messages can be sent using the AT + CMGS command via this module. The algorithm for communication is displayed in Fig. 4.

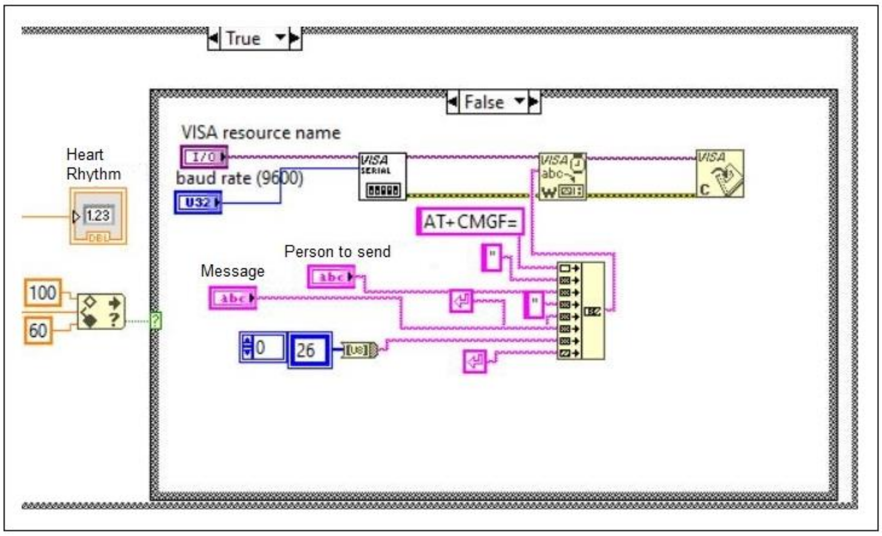

Figure 4: The communication part of the complete algorithm.

Arduino Uno R3 microcontroller was used to connect LabVIEW with the GSM module. With a simple Arduino code, testing of a system was completed. The limit values of the heart arrhythmia were chosen 60 bpm and 100 bpm. Values not in this range are perceived as heart arrhythmias and stimulated via messages.

3 Results and Discussion

In this study, the received signals were firstly determined by the filters, and then the peak points were determined by the Teager Energy technique and the heart rate per minute was calculated. The calculated value was compared with a calibrated pulse meter. In order to receive an SMS out of the program, a subject was asked to run for a while. When his heart rate was up to 100 bpm, the algorithm was complied. Then, the information was given to the phone number entered in the microprocessor code. Therefore, the abnormality could be received via SMS successfully. The representation output of the algorithm is presented in Fig. 5.

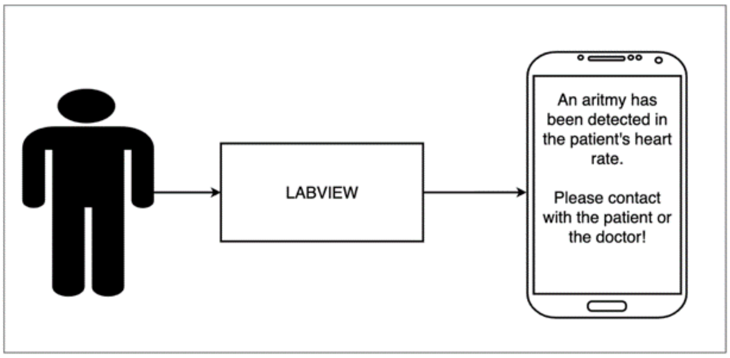

Figure 5: The representation output of the complete algorithm.

The preliminary results showed that a relative or a doctor do not have to be present near to the patient all the time. Besides, the parameters inside the algorithm can be easily modified to an individual's heart waveform. Therefore, the user may the opportunity to decide whether the abnormality is considered as arrhythmia or not. Even though this ECG monitoring and arrhythmia detection system does not replace a standard ECG devices, the usage of this low-cost and user-friendly system may contribute towards prevent deaths due to delayed intervention. In fact, if this system can be made as portable and may be wirelessly, then the signals would be transmitted to a remote device having the arrhythmia detection and could be monitored continuously.

4 Conclusions

The current study was based on measuring ECG signals from a person's body and acquiring these signals using NI LabVIEW. With the help of biomedical signal processing toolkit, the signal was filtered and the heart rate was computed using by Teager Energy method in real time. If the arrhythmia was detected either tachycardia or bradycardia, the program sent a SMS via SIM800L GSM module to a relative of a patient or a doctor. Therefore, this low cost application provided the user early detection of arrhythmias and getting immediate help from outside.

Future studies should include more options of arrhythmias. Consequently, different diagnostic information would be detected from his/her ECGs.

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