

MATLAB IMPLEMENTATION AND ANALYSIS OF ELECTROCARDIOGRAM (ECG) SIGNALS

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Abstract

In this work, the MATLAB software has been developed to measure electrocardiogram (ECG) signal and to analyze the measured signals. The measurement system consists of three electrodes connected to the ECG sensor (AD8232), data acquisition card (Atmega328 Board) and a laptop-computer. The code for the data acquisition card is tested with the developed MATLAB software. The software includes acquisition of real time ECG data, ECG signal processing and calculating beat rate. The measured signals are recorded in the desired path of the computer. The results are compared with standard data and then show that the system yields equal results compared to the reference measurements for patients at rest. The usability of the system is excellent due to simple three-arm electrode solution. The system can be used for home health care application.

Keywords: ECG, AD8232 ECG Sensor, Arduino Uno, MATLAB Software, Data Acquisition

Introduction

Electrocardiogram (ECG) is a diagnostic tool that measures and records the electrical activity of the heart in detail. Interpretation of these details allows diagnosis of a wide range of heart conditions. An ECG is generated by a nerve impulse stimulus to a heart. The electrical activity of the heart can be recorded at the surface of the body using an electrocardiogram. Therefore the electro-cardio-gram (ECG) is simply a voltmeter that uses up to 12 different leads (electrodes) placed on designated areas of the body. Fig.1 shows the typical ECG measurement system with three electrodes (right arm [RA], left arm [LA] and right leg [RL]) to obtain the source of ECG in this work. Signals are acquired using AD8232 ECG pulse sensor via an Arduino Uno board (ATmega328). MATLAB software is developed and used for data recording and visualization, due to its known capabilities. Since ECG signals are very noisy, usually 50 Hz noise, this developed software is used to test and in order to obtain a good ECG sample of heart.



Figure 1 Typical ECG Measurement System

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Hardware Interface

It is necessary to setup hardware support package for Arduino Uno in MATLAB software. To read the data from the Arduino Uno (Data Acquisition Unit), the support package for MATLAB was first installed from internet. After installing the support package for MATLAB, whether it is installed properly or not was checked by connecting the Arduino Uno (*Data Acquisition Unit*) to a Laptop.

Programming the Data Acquisition Unit

To interface (*communicate*) the DAU (Data Acquisition Unit), the sketch (downloaded program for Arduino Uno) was compiled and up loaded into the DAU. And then tested the DAU with a laptop whether it properly communicates or not.

Hardware Setup

The circuit connection for ECG measurement can be seen in fig. 2. The AD8232 ECG sensor was connected to DAU with their respective pins. To read analog data from the sensor, the output of the sensor was connected to the analog one (A1) pin of DAU.

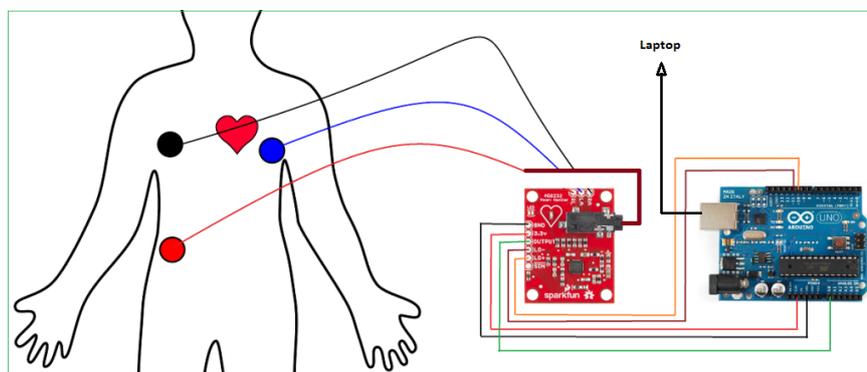


Figure 2 Connections for ECG Measurement System

Software Development

There are three sections in the MATLAB software development for ECG signals. They are real time data acquisition, signal filtering and zero-crossing detection for heart beat rate.

Real Time Data Acquisition

The program flow chart for real time data acquisition algorithm can be seen in fig. 3. In this section, when the program starts it sets the com port of data acquisition hardware (Arduino Uno Board) and the baud rate of serial transmission. Then the program reads sample data from the ECG sensor unit and converts the data into signal voltage. And then the program draws real time graph on the PC screen. After reading 500 sample data, it saves the real time data in the predefined location of the PC/ laptop.

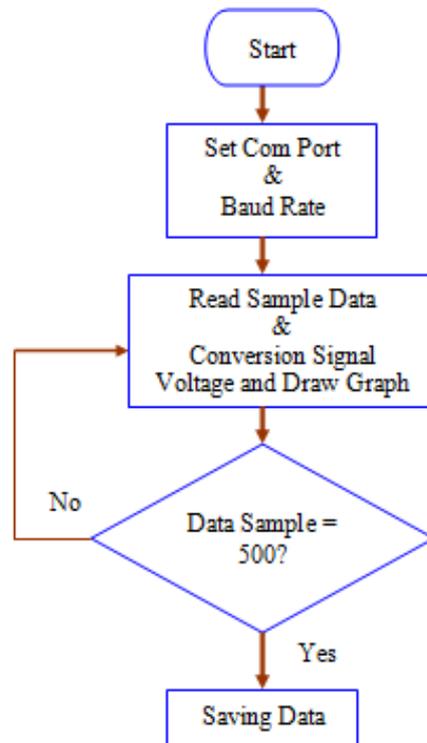


Figure 3 Flow Chart for Real Time Data Acquisition Algorithm

Signal Filtering

Hum noise created by poor power supplies, transformers, or electromagnetic interference sourced by a main power supply is characterized by a frequency of 50 Hz and its harmonics. If this noise interferes with a desired audio or biomedical signal (e.g., in electrocardiography [ECG]), the desired signal could be corrupted. The corrupted signal is useless without signal processing. It is sufficient to eliminate the 50-Hz hum frequency with its second and third harmonics in most practical applications. In this work, the window method FIR (Finite Impulse Response) low-pass filter was used to eliminate above the 25 Hz hum noises. The flow chart for signal filtering algorithm is shown in fig. 4. When the program starts, it sets the filter design as a low-pass filter. And then set the lower and upper cutoff frequencies. After all the settings, the program filters the signal using the '*firwd* and *filter*' functions. Next, it finds the amplitude of the filtered signal and plots the filtered and unfiltered signals.

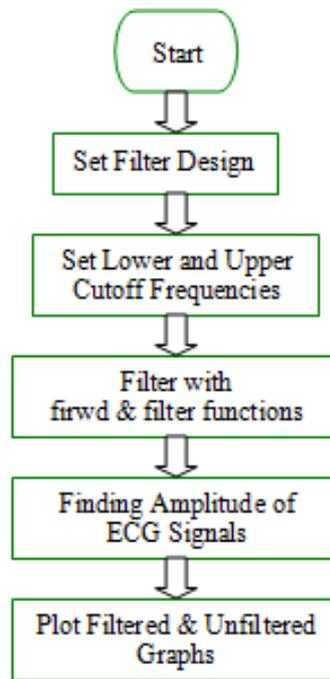


Figure 4 Flow Chart for Signal Filtering Algorithm

Zero-crossing Detection

In this section, the flow chart can be seen in fig. 5. With the processed ECG signal (*filtered signal*), a simple zero-cross algorithm was designed to detect the heart rate. The threshold value of - 0.5 Volt is used and continuously compares each of two consecutive samples with the threshold. If both results are opposite, then a zero crossing is detected and the number of zero crossing is calculated by using the formula. And then, heart rate (beat per minute, BPM) is also calculated and displayed the result on a PC/ Laptop screen.

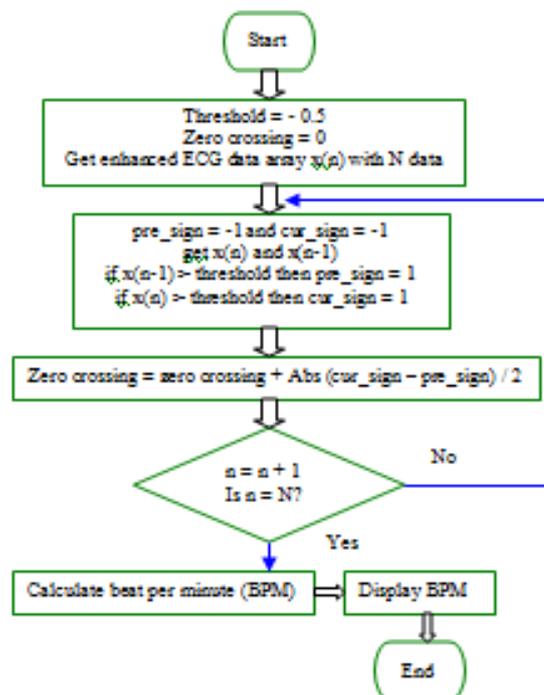


Figure 5 Flow Chart for Zero-crossing Detection Algorithm

Measurement and Analysis of ECG Signals

ECG Signal Acquisition

In this work, ECG signal is acquired from the described ECG system in the above section. Several measurements are made with different three points by using three ECG electrodes from the ECG sensor. Standard ECG electrodes and home made ECG electrodes (local copper electrode and oil) are used to measure ECG signals. These measurements have been successfully tested with the developed MATLAB software. After acquisition of an ECG signal the signal is still contaminated by electromagnetic interference. The patient (a person) should be still and quiet during acquisition so that the electromagnetic interference is reduced to the barest minimum. Filters are used to remove other noises. MATLAB is used for the filter design. A Finite Impulse Response (FIR) digital low-pass filter is designed using Hamming Window. This filter removes the EEG noise and any other frequency above the upper cut off frequency of 25 Hz used here. The sampling frequency is 100 Hz while the order of the filter is ‘9’.

Results and Discussion

Fig. 6 is the first measurement for 50 years old person. The upper graph of the fig.6 is a noisy ECG signal. The lower graph of the fig.6 shows the frequency spectrum of the ECG signal. From this graph, the frequency of the ECG signal is 1.2 Hz and so, beat per minute (BPM) is 72 BPM. The peak between 45 Hz and 50 Hz of the frequency spectrum in the fig.6 shows that it is a noise frequency (about 48 Hz). Fig.7 shows the filtered ECG signal and its frequency spectrum. From this graph, the clean ECG signal can be seen because of low-pass filter. Fig.8 and 9 are the ECG signals and their frequency spectrum for 50 years old person without noise. Fig.10 and 11 are the ECG signals for 8 years old person. The heart beats of these measurements in this work are normal heart conditions and the results are consistent with the standard data. In this work, one real time measurement is made for 5 seconds duration. Therefore, there can be some errors in heart beat calculation. All measured heart beats can be 72, 84, 96 and etc. To reduce these errors, 60 seconds duration can be used for one real time measurement.

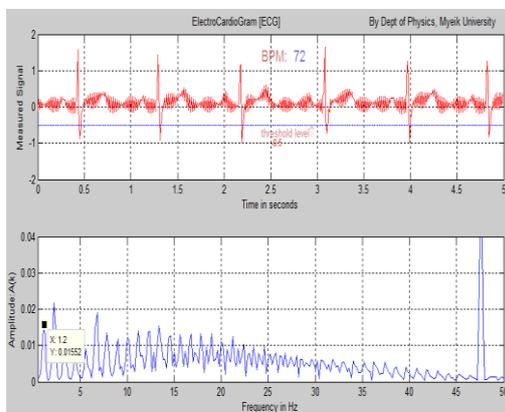


Figure 6 ECG for 50 Years Old without Filter

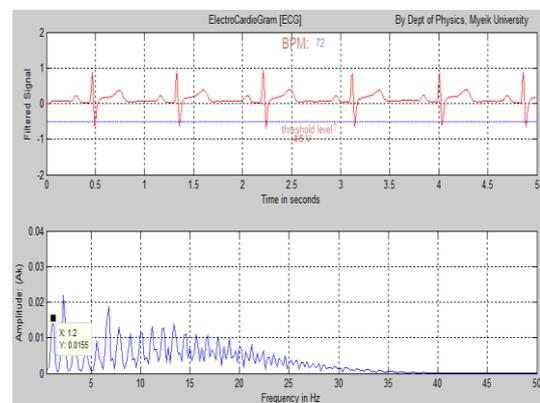


Figure 7 ECG for 50 Years Old with Filter

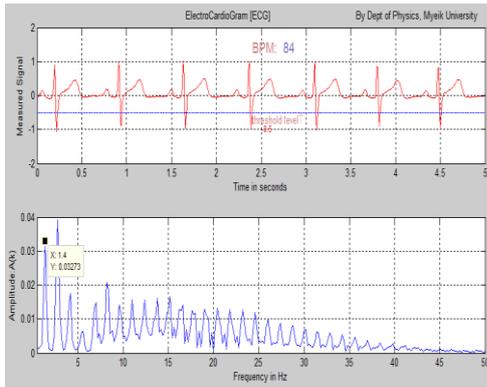


Figure 8 ECG for 50 Years Old without Filter

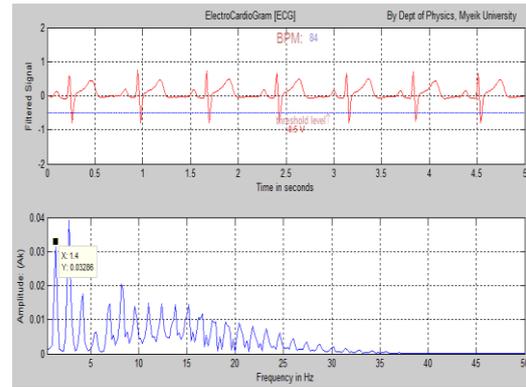


Figure 9 ECG for 50 Years Old with Filter

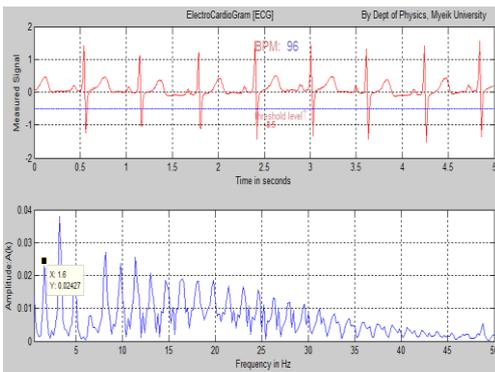


Figure 10 ECG for 8 Years Old without Filter

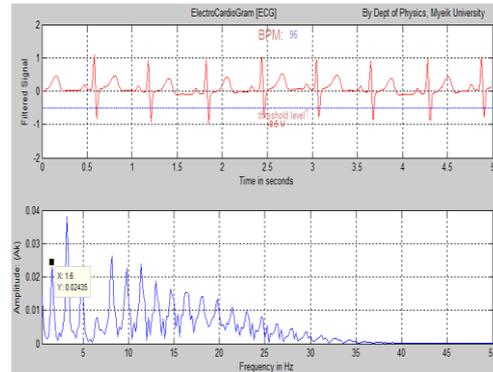


Figure 11 ECG for 8 Years Old with Filter

Conclusion

MATLAB has immense effect on ECG signal processing. It is so useful and handy that everyone can monitor his/her heart condition simply utilizing the power of MATLAB. One of the crucial steps in the ECG analysis is to accurately detect the different waves namely P, Q, R and S depicting the entire cardiac cycle. This proposed work could be continued to further improve the algorithm to detect abnormalities by using calculations of intervals between impulses of two different signals in real time. For processing and design of detection algorithms, MATLAB is used, in which they were implemented as mathematical signal processing operations.

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