Bradycardia Detection using ECG Signal Processing and MATLAB

Ledisi G. Kabari, Ugochukwu C. Onwuka

Abstract—**Electrocardiogram is the record of electrical activity of heart. ECG is a test to detect and study normal rhythmic activity of the heart. Signal processing are very often used methods in a biomedical engineering research. This paper presents Bradycardia detection by utilization of digital signal filtering on electrocardiogram (ECG) using MATLAB. MATLAB was used to analyze and process ECG dataset gotten from Physionet online database with focus on R-R peaks to calculate the heartbeat, by applying high pass filtering and squaring the signal. The results obtained using MATLAB for ECG analysis and detection of arrhythmia is very fast and useful.**

***Index Terms*—Bradycardia; Biomedical Engineering; Heartbeat; MATLAB; Signal Processing.**

I. Introduction

Bradycardia is a condition where an individual has a resting heart rate of less than 60 beats per minute (BPM) in adults. Bradycardia typically does not cause symptoms until the rate drops below 50 BPM. When symptomatic, it may cause fatigue, weakness, dizziness, sweating, and at very low rates, fainting. During sleep, a slow heartbeat with rates around 40–50 BPM is common, and is considered normal. Highly trained athletes may also have athletic heart condition, a very slow resting heart rate that occurs as a result of sport adaptation and helps prevent tachycardia(Heart rate > 100) during training.

Electrocardiogram is the record of electrical activity of heart. ECG is a test to detect and study normal rhythmic activity of the heart for instance heart attacks, irregular heartbeat [1]-[3]. The amplitude and time span of the ECG wave carry helpful knowledge regarding the nature of disease troubling the heart.

The Electrocardiogram abbreviated as ECG or EKG is a medical diagnostic device that quantifies and records electrical activities of the heart generated by nerve impulse stimulus. Current diffused around the surface of the body builds a voltage drop, which is a couple of microvolts (μV) to millivolts (mV) with an impulse variation; Thus, ECG is purely a voltmeter that uses up to 12 different electrodes placed on specified areas of the body. This very usually small amplitude of impulse requires amplification to about a thousand times.

Electrocardiogram plays a fundamental role in diagnosing numerous diseases related to cardiac activities. It aids medical doctors to provide necessary information about status of disease condition and abnormalities of a patient's heart by studying and analyzing electrocardiogram signals generated by the heart. ECG signal consists of components like segments, intervals, and waves are studied and evaluated based on the size, and duration time [4].

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II. ECG Analysis and Parameters

A regular electrocardiogram tracing of a normal heartbeat (or cardiac cycle) consists of a P wave, a QRS complex and a T wave. A small U wave is normally visible in 50 to 75% of ECGs. These waves and QRS complex are shown in Fig. 1.

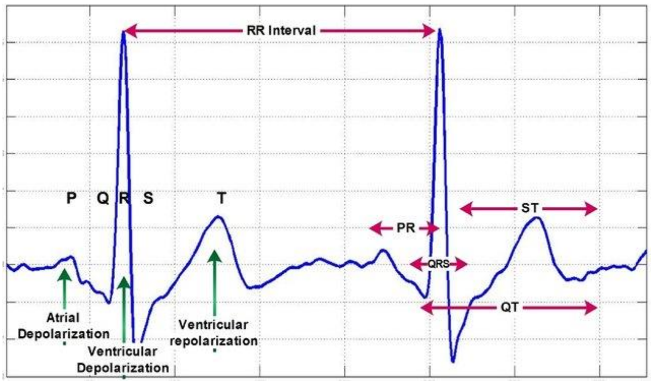

Fig. 1. Standard ECG nonlinear waveform showing R-R interval [5]

The parameters used for the analysis of the QRS complex are QRS duration, R-R interval and heart rate of the signals.

QRS duration: The duration of QRS complex of ECG is found by dividing the number of samples between the QRS complex and the sampling frequency of the signal; By knowing this duration, we can know whether the signal is abnormal or normal. As per the standards, the standard QRS duration of a normal ECG signal will range from 0.06 to 0.10 seconds [4].

*R-R interval***:** R-peak is the longest amplitude peak in ECG signal. The R-R interval is calculated by dividing number of samples between two R peaks and sampling frequency of the signal. It plays a vital role in finding abnormalities of a signal [6].

Heart rate: Heart rate can be measured by using the formulae shown in Equation (1).

$$\text{Heart Rate} = \frac{60}{R{-}R\ (interval\ in\ seconds)} \quad (1)$$

A healthy person's average rate of heart beat is 72 beats per minute. For a normal person, it will be in between 70–80 beats per minute. In a normal sinus rhythm, bradycardia means a resting heart rate of below 60 bpm and tachycardia will have a heart rate above 90 bpm [7].

Heart Beat Abnormalities: Bradycardia is detected when heart rate is less than 60bpm (<60bpm) while Tachycardia is detected when heart rate is greater than 100bpm (>100bpm). This is shown in Table I.

TABLE I: HEART BEAT ABNORMALITIES

Heart abnormality	symptoms
Bardycardia	Heart rate is less than 60bpm (<60bpm)
Tachycardia	Heart rate is greater than 100bpm (>100bpm)

III. MATERIALS AND METHOD

The experiment was performed with MATLAB (matrix laboratory) 2015, MATLAB integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include: Application development, including Graphical User Interface building.

The test dataset signal for the demonstration was taken from Physionet arrhythmia MIT-BIH database named 200m.mat [8]. The data is characterized with occasional bursts of high-frequency and severe noise and artifact in the lower channel. With sample frequency 360Hz, val has 1 row (signal) and 3600 columns (samples/signal).

Duration: 0:10
Sampling frequency: 360 Hz Sampling interval: 0.002777777778 sec

Row	Signal	Gain	Base	Units
1	V1	200	0	mV

MATLAB code was written to give a Plot of the ECG (200m) data showing the non-linear structure of the heart ECG signal. A pre-filtering was applied to remove background noise from the plotted ECG signal using high pass filtering. Then Squaring the EGC signal to remove the negatives and make the R-R peaks very visible or prominent

IV. RESULTS AND DISCUSSION

Plot of the ECG (200m) data showing the non-linear structure of the heart ECG signal gives the plot in Fig. 2. Applying pre-filtering to remove background noise from the plotted ECG signal using high pass filtering gives the plot in Fig. 3. Squaring the EGC signal to remove the negatives and make the R-R peaks very visible or prominent gives the plot in Fig. 4. An overview of the entire signal processing is as shown in Fig. 5.

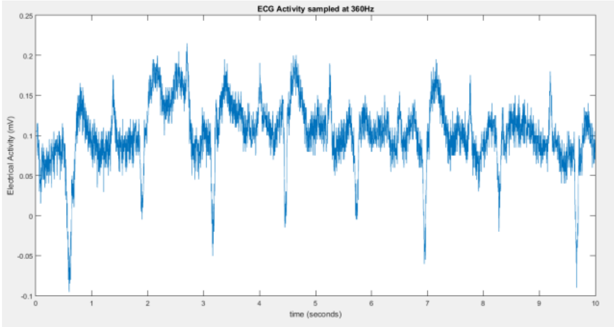

Fig. 2. ECG data demonstration (time in seconds calculated using the sampling frequency)

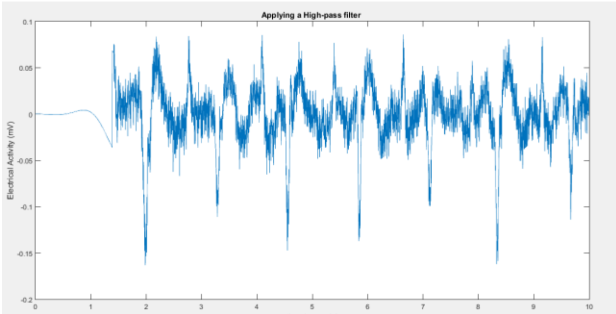

Fig. 3. Filtered ECG data

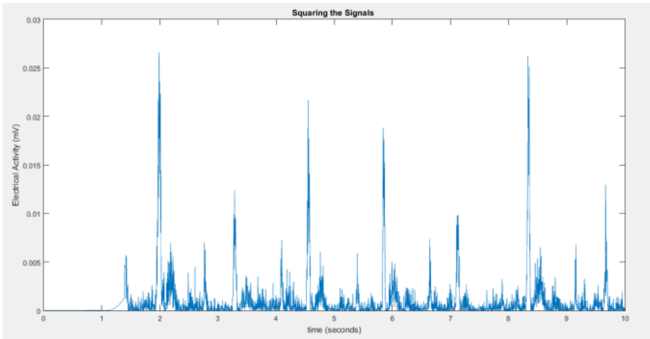

Fig. 4. Squared ECG Signals (to remove negatives)

An overview of the entire signal processing is as shown in Fig. 5.

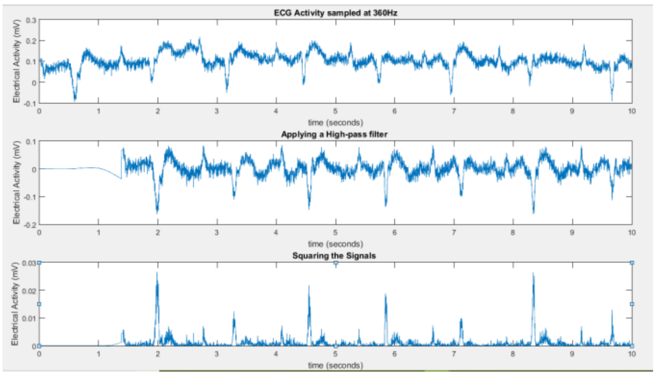

Fig. 5. ECG signal overview

Determining the heartbeat rate

To calculate the heart beat rate in bpm, we will employ equation 1 and Fig. 4 above showing the R-R peaks taking the threshold at 0.01mV.

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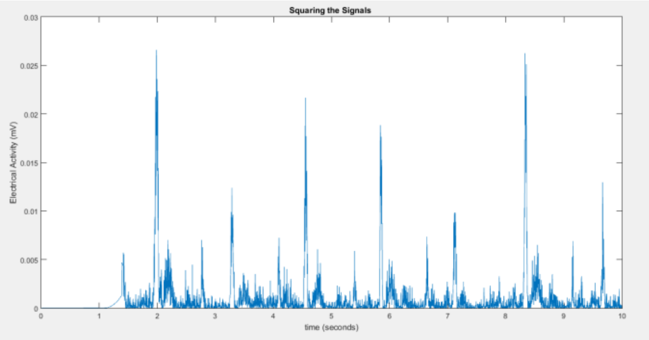
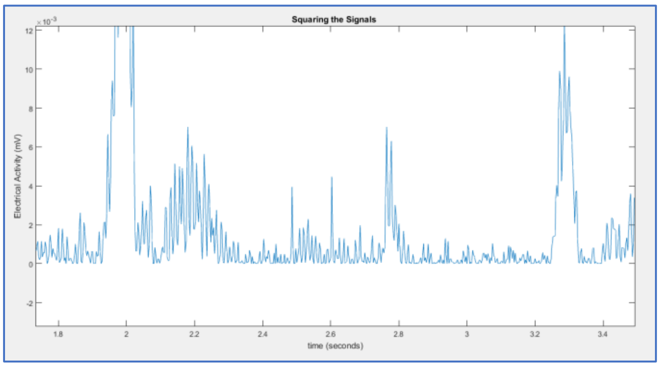


Fig. 6. Squared signal indicating the R-R peaks

Zooming in to get the time between the two R – R intervals gives Fig. 7.



3.3 – 2=1.3

Fig. 7. R-R peak interval

From (1):

$$\text{Heart Rate} = \frac{60}{R\!-\!R\ (interval\ in\ seconds)}$$

Thus, the heart rate = $\frac{60}{3.3-2}$ = 46.15bpm

From Table I, the heart rate is less than 60 bpm, therefore the patient is suffering from Bradycardia.

V. Conclusion

ECG is an effective device for accurate diagnosis of different heart diseases, with the help of MATLAB rich tools for signal analysis and processing, it has made ECG data easier to analyze and visualize quickly.

The results obtained using MATLAB for ECG analysis and detection of bradycardia is very fast and useful, as the ECG can be easily read, saved in a file and the filtering, derivation, squaring to make it more visible.

Appendix

MATLAB Source code

```
load ('200m.mat');       % this loads the signal to
val matrix
ESignal = (val-0)/200;  %where 0 is the base and
200 is the gain
Fs=360;                   %where Fs is the sampling
frequency provided in the data set
t = (0:length(ESignal)-1)/Fs; % time is 1/f,
therefore the time is length sample / Fs
plot(t,ESignal);
xlabel('time (seconds)');
ylabel('Electrical Activity (mV)');
title('ECG Activity sampled at 360Hz');

% applying high pass filter
h=fir1(1000,1/360*2,'high');
ESignal_Filter = filter(h,1,ESignal);
plot(t,ESignal_Filter);
xlabel('time (seconds)');
ylabel('Electrical Activity (mV)');
title('Applying a High-pass filter ');

%squaring the signal
desq=(ESignal_Filter.^2);
plot(t,desq);

xlabel('time (seconds)');
ylabel('Electrical Activity (mV)');
title('Squaring the Signals ');
```

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