Arrhythmia Detection Based on ECG Signal Using Android Mobile for Athlete and Patient

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Abstract— **the heart is a vital organ that needs to be monitored periodically by everyone, including athletes and heart patients. Heart condition of an athlete requires special attention to keep his/her stamina and performance, however monitoring the heart signal during athlete activity is challenge to be solved. In this research, we developed a mini wearable ECG device and real time arrhythmia detection based android mobile application. ECG signals acquired live by the ECG's analog front end and sent through a Bluetooth module to Android mobile devices. On Android application processed data analysis based Pan Tompkins algorithms to detect complex QRS ECG signal and heart beats. From the number of heart rate can be detected abnormalities. Upon completing the system, we tested the system using signals generated by Fluke PS400 and real data. There are three categories of abnormalities under study: brachycardia, tachycardia, and sinus arrhythmia. Normal heart signal is also included in the test. These experiments indicated accuracy of 98.4% for generated signals and 99.6% for real signal. The application itself need 2.09 MB of memory and can run under all smartphone running Android.**

Keywords—ECG, arrhythmia, android, Pan Tompkins

I. INTRODUCTION

Arrhythmia is a medical condition that covers a wide range of cardiac pathology [1]. Arrhythmia means heart rhythm irregularity. The condition of heart rhythm may be too fast (tachycardia), too slow (brachycardia) or irregular. Arrhythmia causes the heart does not pump enough blood to the body, which can cause damage to the brain, heart and other vital organs. Medical experts can detect arrhythmia using ECG devices.

Heart health is one of the important parameters of an athlete. This condition requires continuous monitoring while athlete performing the exercise. From this observation can be determined the condition of heart. Mini wearable ECG device that has been made in previous research [2] can be used for ECG signal acquisition, especially athletes. Previous result however does not include signal processing applications for analysis of the signals. Signal processing and analysis in smartphone can be very useful to support the mobility of monitoring system. Nowadays, the smart phone has a high-speed processor to support digital signal processing in real time. Then smart phone devices have been widely used for biomedical signal processing and analysis of ECG [3], [4], [5].

Some researchers have started the hearth monitoring system using smartphone. Stefan Gradl for example, implemented a real-time ECG monitoring and arrhythmia detection using Android-based mobile devices [6]. Gradl used Shimmer module to retrieve the ECG signal and sent data to the smart phone through Bluetooth. Signal processing applications using Pan Tompkins algorithm and feature extraction to detect arrhythmia. In that research, Gradl, however, did not implement the ECG signal acquisition device.

Many algorithms and methods can be implemented to detect arrhythmia with the goal of using a memory resource as small as possible but still have good performance. However, it remains necessary justification of medical experts to diagnose.

In this project, focus on the realization of the small dimension and mobile ECG's hardware[12], then use Pan Tompkins algorithm to determine the QRS complex ECG, a real time arrhythmia detection on Andorid mobile and data validation. Contribution of this research is develop a mobile ECG device with easy connectivity to Android devices, research possibilities for Internet of Things (IoT) application and low cost ECG as alternative medical devices in developing countries.

The contents of this paper are organized as follows: Section II presents description of the ECG, Arrhythmia, Pan Tompkins Algorithm and Android fundamentals. At Section III is brief description of the system design and implementation. Test result and discussion are described in Section IV. Section V concludes this paper.

II. THEORY

Electrocardiograph

Electrocardiograph is a bio-potential signal generated by the heart muscle. Electrocardiograph signal can be used to analyze the health condition of the heart [7]. These conditions can be seen from the form, orientation and rhythm of ECG's signal [8]. The normal form of the ECG signal can be seen in Figure 1.

The ECG signal is taken using bipolar Einthoven's triangle technique. This technique takes 3 leads of ECG signal (Lead I, II, and III). In this research, we use Lead II to take ECG signal. The Electrode configuration of Lead II can be seen in Figure 2.

Arrhythmia

Arrhythmias are heart rhythm disorder, a condition in which the heart is beating too fast (tachycardia), too slow (brachycardia) or irregularly. Arrhythmias caused by the heart's electrical conduction system disorders. ECG signal which represents the arrhythmia can be seen in Figure 3.

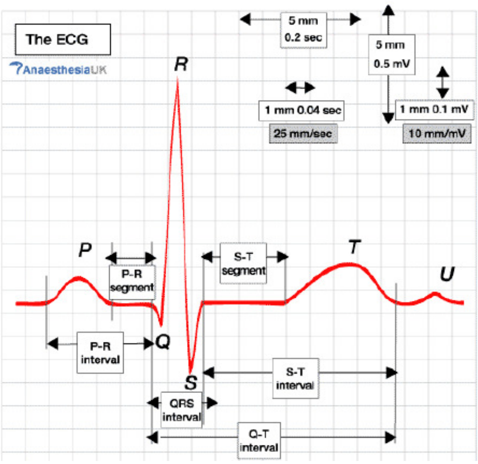


Figure 1. Normal ECG's Form [9]

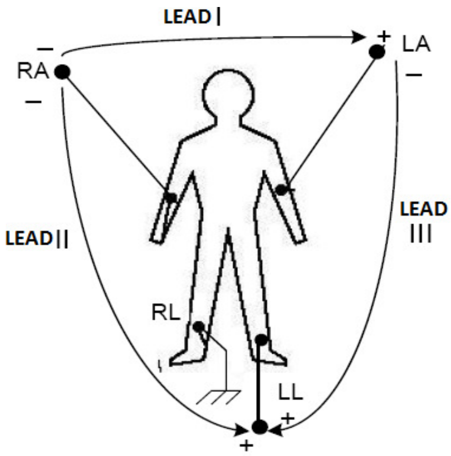


Figure 2. Einthoven Triangle [10]

Arrhythmia can be a serious problem if not treated immediately. Some types of arrhythmia can cause harm and even death for example ventricular tachycardia. An athlete requires continuous monitoring of heart conditions to maintain a healthy heart. If detected abnormalities such as arrhythmia, it can get immediate medical care.

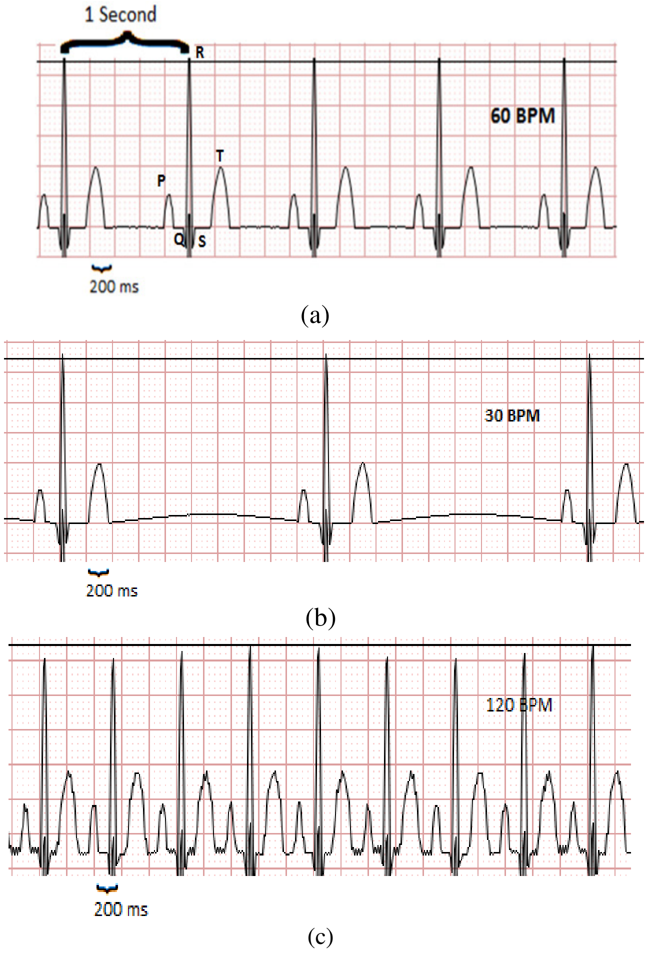


Figure 3. (a) Normal ECG's (b) brachycardia (c) tachycardia

Pan Tompkins

Pan-Tompkins is an algorithm developed by Pan and Willis J. Jiapu Tompkins that can be used to detect the QRS wave of the ECG in real time. Analysis of the QRS peak is the most important thing in this study. So the success of this project is determined on the accuracy of QRS complex detection. There are several methods for detecting QRS ECG but based on previous studies [6], this algorithm has a good performance in detecting the QRS and easily applied to mobile applications. So that this algorithm we use on this project. In general, the Pan Tompkins algorithm is show in Figure 4.

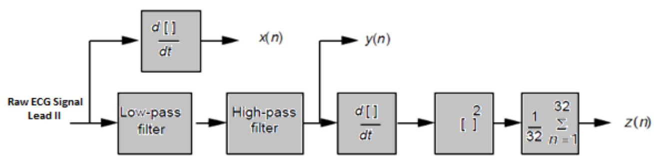


Figure 4. Pan Tompkins Algorithm Scheme [11]

Android

Android is a Linux-based operating system that is widely used on a smart phone. Android is an open source application so that users can create and develop applications in accordance with their wishes.

Android has complete tools/libraries for making the application easier. In this research, there are 3 main components: access the Bluetooth communication to receive data of ECG, digital signal processing to apply the algorithm, and the Graphical User Interface.

III. SYSTEM DESIGN

Hardware implementation is not discussed in this section, has been described in the previous publication [12]. This section focuses on creating Android applications programs.

Application for this system is developed using the Eclipse IDE with java language. Eclipse is chosen because it is open source and has built-in plug in or library to facilitate for making digital signal processing applications on mobile Android device.

There are three main parts to build applications in this project include: data communication using Bluetooth, a digital signal processing for the realization of the Pan Tompkins algorithm, and design the GUI to display the measurement parameters.

Data Connection

Raw digital ECG signal is sent via Bluetooth Bee module from ECG device to the smart phone. The digital data is sent serially by the microcontroller to the Bluetooth Bee module at 9600 bps data rate. By Bluetooth Bee, the data is sent using a Bluetooth protocol to communicate with the smart phone. Bluetooth Bee acts as a slave and smart phone as a master.

The android application can access the Bluetooth communication peripheral. The Bluetooth application is already available on the Eclipse library. The script to access Bluetooth is given in the following statement:

```
mBluetoothAdapter =
BluetoothAdapter.getDefaultAdapter();
mRfcommClient = new
BluetoothRfcommClient(this,mHandler);
checkBluetooth();
```

Pan Tompkins Implementation

Pan Tompkins algorithm consists of band pass filter (HPF and LPF), derivatives, square, integral, threshold and decision. The sampling frequency of this ECG system is 200 Hz. Each part of this process is described mathematically using input-out relation. Detail descriptions of each sub-system are as follows ([13]):

- *Low Pass Filter*
  LPF is used to reduce the noise from the power source and the interference T wave [11]. Equation of LPF can be written as :

$$y(n) = 2y(n-1) - y(n-2) + x(n) - 2x(n-6) + x(n-12) \quad (1)$$

- *High Pass Filter*
  HPF is used to reduce noise that produced by the body and baseline wander. Equation of HPF as follows:

$$y(n) = y(n-1) + x(n-16) - x(n-17) - 1/32\,[x(n) - x(n-32)] \quad (2)$$

- *Differentiation*
  After filtered, ECG Signal is differentiated to obtain the optimal QRS complex. Equation of Differential module *as follows*:

$$y(n) = 1/8\,[2x(n) + x(n-1) - x(n-3) - 2x(n-4)] \quad (3)$$

- *Squaring*
  Signal is squared so that all components of the signal have a positive value. Equation of squaring *as follows*:

$$y(n) = x^2(n) \quad (4)$$

- *Sliding Window Integration*
  The function of this Sub-system is to obtain the envelope of QRS complex. Equation of sliding window integration *as follows*:

$$y(n) = 1/32\,[x(n-32) + x(n-31) + \ldots + x(n)] \quad (5)$$

- *Decision*
  This module is performed to determine whether the results of the integration are QRS complex or not. There is a threshold that can be adjusted to optimize detection.

GUI Design

GUI that was implemented consists of two parts: The first part to display the numeric data and text of heart rate, time between QRS/beats and signal classification. The second part is to perform the live capture of ECG signal, result of digital signal processing and heart rate in graph form. GUI design is shown in Figure 5.

IV. RESULTS

Since the ECG's hardware and the Android application is completed, further testing the system performance. The focus of the testing, performed on the application program includes data plot on the graph, the performance of Pan Tompkins module, ECG signal classification and memory resources. The following sections are detailed explanation of the test.

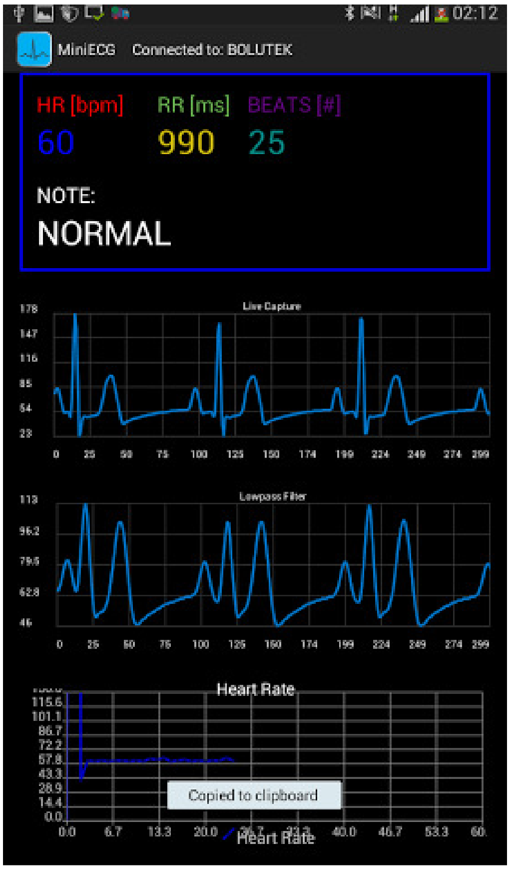
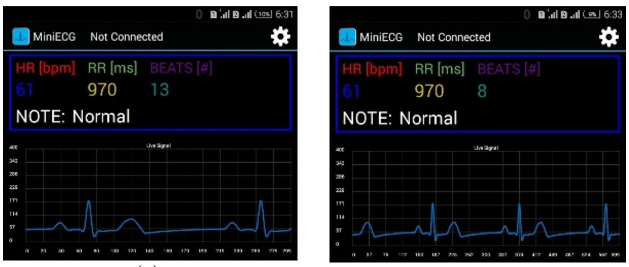


Figure 5. GUI’s Screen shoot

Data Plot

In application, digital data of ECG signal represented in graphical form. There are 200 data samples per second are plotted in real time. In application programs, number of buffers can be adjusted to change the amount of data that can be displayed on the screen. ECG signals on application program can be seen in Figure 6.

From Figure 6, it can be concluded that the application has been successfully representing data in graphical form. The greater the number of buffers, then the amount of data that can be displayed on the screen becomes more. (note: for the same acquisition conditions).

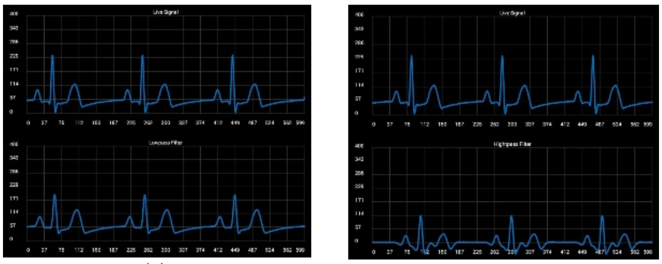


(a) (b)

Figure 6.(a) Plot ECG with buffer size of 200 (b)Buffer size of 600

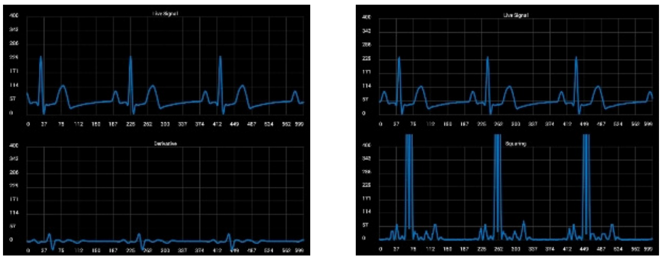
Pan Tompkins module performance

This module is key success in arrhythmia detection applications. Pan Tompkins algorithm performance testing is done by looking at the output of each block. Numeric value of output in each sub-system is not described in this section, but the success of the Pan Tompkins module can be seen from graph of output in each sub-systems. Graphics output are shown in Figure 7, 8, and 9.



(a) (b)

Figure 7. (a) LPF Output (b) HPF Output



(a) (b)

Figure 8. (a) Differentiation Output (b) Square Output

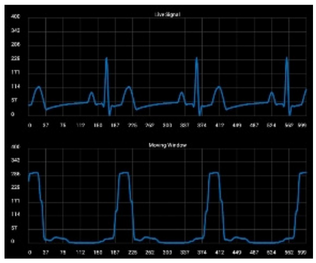


Figure 9. Sliding Window Integration Output

Figure 8 (a) is the output of differentiation. In this figure, P and T waves have been attenuated. QRS complex appears even more clearly. Furthermore, the output signal differentiation is squared, so all the components of signal are have positive value. Finally, the sliding window integration has good performance to get envelope of squared signal.

The system was also tested for calculating the heart rate per minute. For this test, the ECG signal is generated using Fluke PS400 ECG signal generator/simulator. In this simulator, the number of heart rate can be adjusted. For testing, the amounts of HR that used are 30, 60, 120 and 180 Beat per minute and performed 5 times for each HR. The test results can be seen in Table 1.

Table 1. QRS Detection (Signal generated by simulator)

No	QRS/minutte	QRS Detected	%True
1	30 (Normal)	30	100
		30	100
		30	100
		30	100
		30	100
2	60 (Normal)	60	100
		60	100
		60	100
		60	100
		60	100
3	82 (Sinyal PVC)	76	92,7
		75	91,5
		75	91,5
		76	92,7
		76	92,7
3	120	120	100
		120	100
		120	100
		120	100
		120	100
4	180	180	100
		180	100
		180	100
		180	100
		180	100

Testing was also done by taking the ECG signal from a person's body directly. Measurement result can be seen in Table 2.

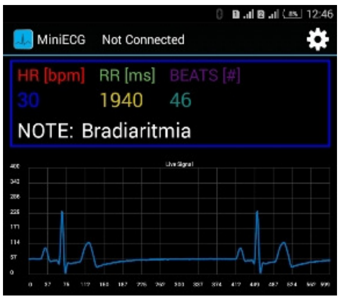
Table 2. QRS Detection (Signal from the body)

No	Patient ID	HR/minute	HR Detected	%True
1	A	85	85	100
2	B	88	87	99
3	C	65	65	100
4	D	83	82	98,8
5	E	74	74	100

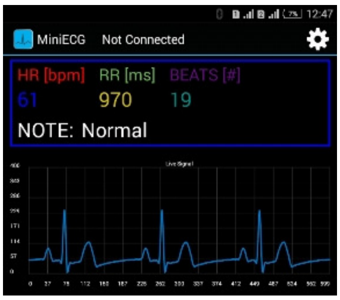
From Table 2, it can be concluded that the Pan Tompkins algorithm that implemented on the application is successfully detect QRS well. Test results using simulator, the system can detect 98.4% QRS complex and 99.6% for signal which taken from the body directly.

ECG Signal Classification

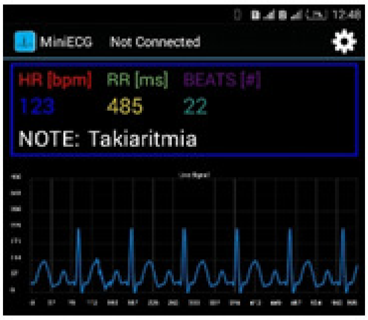
Applications can detect brachycardia (heart rate < 60), tachycardia (heart rate > 100) and unstable heart rate. The test results can be seen in Figure 10.



(a)



(b)



(c)

Figure 10. Classification of ECG (a) Brachycardia (b) Normal (c) Tachycardia

Memory Resource

The usage of memory is important in application design. Good application should use minimum memory resource but still maintain good performance and speed to process the data. After installation on android smart phone, this application requires 2.09 MB of memory resource while the application running. With small memory requirement that described before, this system can be applied to all the smart phones based on Android operating system.

V. CONCLUSION

In this research, a mobile ECG monitor based on Bluetooth and Android had successfully realized and implemented. The system can also detect abnormalities heart beat that is arrhythmia. Applications can detect the QRS complex of ECG signal, with success rate 98.4% for the signal which generated by Fluke PS400 simulator and 99.6% for ECG signals taken from the body. The program can classify the ECG signal is normal, brachycardia, tachycardia or sinus arrhythmia. Total memory usage to run the application is 2.09 MB. This application can be applied to all Android-based smart phones. Further research, required the signal processing application based on the form of ECG's signal to determine more specific cardiac abnormalities.

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