Electrocardiogram monitoring system based on Android smartphone and microcontroller unit

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Abstract. Disease of the heart is one of the death main cause in the world. Special attention to prevent more deaths from the heart disease is needed; one of them is early diagnose for heart disease with electrocardiogram (ECG). ECG represent electrical activity of the heart. The heart’s electrical activity can be recorded using some electrodes that is placed on certain body’s surface. ECG records can be used to determine abnormalities of the heart. We design a ECG monitoring system based on android smartphone and microcontroller unit. The ECG signal is obtained directly from patient using AD8232 module. Then, ECG signal is processed in microcontroller unit. Furthermore, the ECG signal is sent to Android smartphone and displayed in this device. We analyse the abnormalities of the heart using the heart rate from ECG signal. Heart rate is obtained from RR-interval in the ECG which represent the time interval between two detected R peak. We use modified Pan-Tompkins algorithm to detect the peak of R wave. The device that we design give good performance to detect and analyse abnormalities of the heart using heart rate.

1. Introduction
In 2013, cardiovascular disease (CVD) was the common cause of death in the world [1], accounting for estimated 17.8 million (16.5-18.1 million, 95% uncertainty interval) of 54 million total death, or 31.5% (30.3%-32.9%, 95% uncertainty interval) of all global deaths [2]. Special attention to prevent more death from the heart disease is needed, one of them is early diagnose for heart disease with electrocardiogram (ECG) [3]. ECG represent electrical activity of the heart. The heart’s electrical activity can be recorded using some electrodes that is placed on certain body’s surface. ECG records can be used to determine abnormalities of the heart [4–6] Venu et.al use ECG to diagnose hyperkalemia by using of traditional and novel parameters [7].

In conventional healthcare system, ECG is monitored in fixed place like hospitals so the patient has to come to the hospital to diagnose some heart disease. In order to make easy the monitoring of patient’s physiological information such as electrocardiogram, a mobile healthcare system is needed. The development of body sensor network technology makes possibilities to monitor patient’s psychological parameters [8].

Some development of ECG monitoring system has been conducted. Li et.al develop a heart disease monitoring system for pervasive healthcare service based on Internet of Things [9]. Lou et.al develops a health monitoring system that works wirelessly based on smartphone [8]. In this paper, we present a ECG monitoring system based on android smartphone and microcontroller unit. The ECG signal is
obtained directly from patient using an electrocardiogram module. Then, ECG signal is processed in microcontroller unit. Furthermore, the ECG signal is sent to Android smartphone and displayed in this device. We analyze the abnormalities of the heart using the heart rate from ECG signal.

2. Numerical Methods
This present a ECG monitoring system based on android smartphone and microcontroller unit. This section consist of how the data is collected and how the heart rate is obtained from electrocardiogram.

2.1. Data collection
We recruit 4 patients in this study and record 8 ECG signals. The ECG signal for each patient is recorded which is 5 minutes in duration. The average age of the participant is 22 years old and their participation is compensated. During the ECG recording, the patient is asked to relax and take a normal breath.

2.2. ECG monitoring design
ECG monitoring is designed to monitor and record ECG signal form the patient. The monitoring system consist of AD8232 module, microcontroller Arduino UNO, HC-05 Bluetooth module, and a smartphone with Android operating system. Figure 1 shows block diagram of the ECG monitoring system. Module AD8232 is an integrated signal conditioning block for biopotential measurement such as ECG. It eliminates the motion artifacts and electrode half-cell potential using two-pole highpass filter. This filter is coupled with the instrumentation architecture of the amplifier tightly. So, the filter allows large gain and highpass filtering in a single stage. This design allows for analog-to-digital converter (ADC) or a microcontroller with ultralow power to acquire the output signal easily. It has 1100 times signal amplification so the ECG signal can be recorded [10]. Arduino UNO is a microcontroller board with Atmega328 microprocessor built-in. It has 6 analog inputs,14 digital input/output pins (6 pins can be used as pulse wide modulation (PWM) output), an In-Circuit Serial Programming (ICSP) header, a 16 MHz quartz crystal, a USB connection [11]. HC-05 Bluetooth module designed for transparent wireless serial connection setup. It is fully qualified Bluetooth V2.0 + Enhanced Data Rate 3Mbps modulation with complete 2.4GHz radio baseband and transceiver [12].

![Figure 1. Diagram block system of ECG monitoring system](image)

2.3. Heart rate determination
Heart rate is determined by calculate the number of R-peak that occur in one minute [3]. So, an R-peak detection is required to determine the heart rate. We use R-peak determination based on R-peak detection that is developed by Chen *et.al* [13]. Figure 2 shows block diagram of R-peak detection. This method consists of band pass filtering and decision making.
To compute HR in real-time, equation (1) is used,

\[
HR = \frac{60,000}{RR-interval(ms)}
\]

where \(HR\) is heart rate and \(RR-interval\) is the time intervals between successive heart beats are measured in the electrocardiogram from one R-peak to the next R-peak [14].
3. Results and Discussion

ECG monitoring is developed and designed to record and monitoring ECG signal from the patient. AD8232 ECG module is used for recording, filtering, and amplifying the ECG signal that is obtained from patient. This ECG module is a single lead ECG module and consists of three electrodes which is placed in the patient body surface to record the ECG signal. The ECG signal that is obtained from the patient is processed in Arduino UNO for R-peak detection and heart rate calculation. The processed ECG signal is sent to Android device using Bluetooth HC-05 module through wireless communication based on TTL serial data. Android Smartphone is used for displaying and saving the ECG signal into text file. Figure 3 shows the user interface (UI) of Android smartphone during the ECG monitoring.

![Figure 3. Android smartphone user interface during ECG signal monitoring](image-url)

From the heart rate, with predict the abnormality of the heart with Equation (2), the Android will give warning if it detects abnormal heart beat.

\[
\begin{align*}
    \text{if } HR > 100 \lor HR < 60 \rightarrow \text{abnormal} \\
    \text{if } HR < 100 \lor HR > 60 \rightarrow \text{normal}
\end{align*}
\] (2)

2.4. Performance of R-peak detection

The performance of the R-peak detection for heart rate measurement is measured with three parameters as follow,

\[
\begin{align*}
    Accuracy &= 1 - \frac{FP+FN}{Total\Beat} \times 100\% \\
    Sensitivity &= \frac{TP}{TP+FN} \times 100\% \\
    Positive\Predictive &= \frac{TP}{TP+FP} \times 100\%
\end{align*}
\] (3)

where TP is true positive, FP is false positive, FN is false negative.
Table 1. Accuracy, Sensitivity, Positive Predictive

| Patient | Accuracy | Sensitivity | Positive Predictive |
|---------|----------|-------------|---------------------|
| 001-1   | 75.77    | 78.87       | 96.22               |
| 001-2   | 88.05    | 91.51       | 96.36               |
| 002-1   | 81.38    | 81.38       | 100.00              |
| 002-2   | 87.12    | 87.95       | 99.07               |
| 003-1   | 89.22    | 89.43       | 99.76               |
| 003-2   | 89.15    | 89.15       | 100.00              |
| 004-1   | 92.83    | 92.83       | 100.00              |
| 004-2   | 89.25    | 90.19       | 98.97               |
| Total   | 86.40    | 87.38       | 98.89               |

The performance of the R-peak detection for heart rate measurement is measured with three parameters, they are accuracy, sensitivity, and positive predictive. Table 1 shows the performance of R-peak detection. The total accuracy, sensitivity, and positive predictive of the R-peak detection are 86.40%, 87.38%, and 98.89%, respectively.

4. Conclusion

We design an ECG monitoring system based on android smartphone and microcontroller unit. The ECG signal is obtained directly from patient using AD8232 module. Then, ECG signal is processed in microcontroller unit. Furthermore, the ECG signal is sent to Android smartphone and displayed in this device. We analyze the abnormalities of the heart using the heart rate from ECG signal. Heart rate is obtained from RR-interval in the ECG which represent the time interval between two detected R peak. The device that we design give good performance to detect and analyze abnormalities of the heart using heart rate. the performance of R-peak detection is evaluated with three parameters, they are accuracy, sensitivity, and positive predictive. The accuracy, sensitivity, and positive predictive of the R-peak detection are 86.40%, 87.38%, and 98.89%, respectively.

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