

Home-based Electrocardiogram Monitoring Device with Google Technology and Bluetooth Wireless Communication

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Abstract. Cardiovascular Disease (CVD) is the global leading silent killer. Regular electrocardiogram (ECG) monitoring in public community serves preventive and diagnostic purposes by detecting life-threatening arrhythmias for early detection of CVDs. There are a lot of commercialized portable heart monitoring devices available in the market, but many of them have some limitations, such as not equipped with Internet-of-Things (IoT) technology, lack of user-friendly interface and data management system. This paper presents a home-based ECG monitoring device which consists of ECG acquisition hardware and Android-based mobile application integrated with Google technology and Bluetooth wireless communication. The ECG acquisition hardware will acquire single lead ECG signal and transmit to the Android-based mobile application via Bluetooth wireless technology to enhance the device mobility and less wiring for user convenience. The acquired ECG data is real-time displayed in mobile application and stored in a phone's local memory for future review, whereas the data management system using Firebase Authentication and Firebase Storage provided by Google technology allows the users and administrators to upload or access the data with the smartphones through online Google Cloud Platform for post-processing. Besides, the mobile application also utilize Global Positioning System (GPS) to detect current user location for immediate medical actions if there are any abnormalities detected. This home-based ECG monitoring device utilizes the embedded system with IoT technology which aims to help the public community enable frequent heart monitoring for early heart disease detection and prevention, as well as promotes applications of telecardiology.

Keywords: Android mobile application, Bluetooth, Cardiovascular Disease (CVD), electrocardiography (ECG), Firebase, Google technology

1 Introduction

Cardiovascular disease (CVD) refers to any disease of heart, vascular disease of the brain, or disease of the blood vessel such as coronary heart disease, strokes, etc. According to World Health Organization (WHO), 31% of global deaths which is about 17.9 million cases are due to CVDs in 2016 [1]. Arrhythmia is a condition where heart rhythm is abnormal and irregular. Depends on the types of arrhythmia, it might be harmless or life-threatening which eventually lead to serious CVDs if the condition prolongs to a certain extend.

There are plenty of commercial electrocardiogram (ECG) monitoring devices which are light-weight, pocket-sized and portable in current medical device market compared to the hospital-grade ECG devices which are bulky. Cardea 20/20 ECGTM is a 12-lead ECG device which uses wireless Bluetooth technology for data transmission and implement Refined Seattle Criteria as software algorithm to detect heart abnormalities [2]. It has high accuracy with 3% of false positives. However, it does not support on-device ECG graph visualization but requires users to execute and view diagnoses through personal computer. In general, some of these devices are cost expensive, does not support ECG signal self-analysis and wireless data transmission, as well as real-time ECG signal display.

There are researchers proposed a low-cost ECG monitoring system for patient using smartphone by using Arduino UNO as the master controller for ECG acquisition and Bluetooth wireless data transmission [3]. However, it is unable to support self-interpretation and data management system. Another Android-based mobile application is proposed in [4] which allows real-time ECG monitoring and automated arrhythmia detection. However, it has limitation that user could neither review nor retrieve raw data because it is lack of data management system for medical services purpose. There is another portable ECG recorder equipped with online cloud system to allow platform user to access their data globally, but it does not support abnormalities detection features [5]. This paper presents a mobile application that integrates with Google technology and Bluetooth wireless communication that targeted for Android smartphobe, to facilitate remote or home-based heart monitoring with the support of IoT technology. The mobile application support few functionalities such as real-time live ECG waveform display, local offline ECG storage, ECG data uploading to the server for post-processing, and location detection to enable prompt medical action in case any heart abnormality is detected.

2 Home-based ECG Monitoring System Design

Fig. 1 shows the overall system design of proposed home-based ECG monitoring device. It consists of an in-house designed ECG acquisition unit, named *myThrob*, to capture a single lead ECG signal and send to a developed mobile application targeted for Android smartphone through Bluetooth wireless communication. The raw ECG data received by the mobile application can be displayed in smartphone in real time, and saved automatically as text files in local phone storage for future review. The build-in ECG signal processing will then analyze the ECG signal for classification of heart rate condition, in terms of normal sinus rhythm, sinus bradycardia and sinus tachycardia, respectively.



Fig. 1. Overall System Design

By using Firebase technology, user can sign up, login and logout using Firebase Authentication. It allows user to upload offline ECG raw data, and medical staff to access the data for further clinical analysis. Administrators also able to control ECG data management system using Firebase Storage by monitoring and control all the activities over the database. The smartphone's GPS service is also utilized to obtain user's location information and share with their caretaker in case there is any emergency. Due to page constraints, this paper will only focus the discussion of mobile app development in terms of Bluetooth connection and offline local storage, arrhythmia detection and real-time ECG graph plotting. For other implementation detail, please refer to [6].

2.1 Bluetooth Connection and Offline Storage

In the mobile app, three buttons are designed and named as "*Bluetooth*", "*Search*" and "*Select Device*", to turn on Bluetooth wireless communication, search for the available nearby Bluetooth devices, and pair with selected device, respectively. If no device is paired successfully, errors regarding the Bluetooth activities will be displayed for users. User is then required to initiate the ECG input streaming by clicking the "*Con-*

nect” button at the main activity page to start receiving raw ECG data from *myThrob* acquisition hardware. They can disconnect the connection anytime the recording is done. All the data received are ASCII characters and stored in a temporary buffer with maximum size of 1024 bytes. Once the user has chosen to disconnect the *myThrob* to terminate input ECG streaming, the saved data in temporary buffer will be converted to string format, and saved as a text file in smartphone’s local storage, with file naming and labelling format as “username_dd/mm/yyyy_hh/mm/ss” to ease data retrieval in future.

2.2 Arrhythmia Detection

A single lead I ECG signal is captured by using an in-house designed ECG acquisition unit, named *myThrob*, with three electrodes attach to user’s left arm, right arm and right leg respectively. *myThrob* consists of OLIMEX SHIELD- EKG-EMG module, Arduino NANO microcontroller board and HC-05 Bluetooth module. The sampling frequency of OLIMEX Shield EKG-EMG Prototype board for ECG signal acquisition were set to 360 Hz.

Among all the ECG values acquired by *myThrob* and received by mobile app through Bluetooth connection, a threshold-based method is implemented for R peak detection. All the input data that exceed a preset threshold value of 500 and their respective pointer will be saved in a temporary array. The former is treated as detected R-peaks, whereas the latter is the time index where R peaks occurs. Based on the detected R peaks, the R-R interval is calculated using equation (1):

$$\text{R-R interval} = (\text{index of B peak} - \text{index of A peak}) * (1/360) \quad (1)$$

By obtaining R-R interval of respective R peaks, we can measure the heart rates in the unit of beat per minute (bpm), as shown in equation (2):

$$\text{Heart Rate} = 60/\text{time interval between two R peaks} \quad (2)$$

Based on the calculated heart rate, the mobile app would able to classify the heart rhythm in terms of normal sinus rhythm, sinus bradycardia and sinus tachycardia according to Table 1.

Table 1. Types of Heart Condition

Condition	Heart Rate Range (bpm)
Normal Sinus Rhythm	60-100
Sinus Bradycardia	<60
Sinus Tachycardia	>100

2.3 Real Time Graph Plotting

This work deploys an open source graph display library, named *MPAndroidChart*, developed by Philipp Jahoda for real time ECG graph plotting in mobile application. When the “*Plot*” button is clicked, all the values from a text file will be read and *addEntry()* function will be executed to plot the ECG waveform in real-time. It will keep running until the input streaming is terminated.

3 Result

For complete system functionality verification, Fluke Patient Simulator is used to simulate the input ECG signal. In order to verify the accuracy of the ECG graph plotting, a Mixed Signals Oscilloscope (MSO) is connected simultaneously to the input pin of *myThrob* and compared with the real-time ECG graph displayed on the mobile app. Both the ECG graphs exhibit similar pattern according to simulated arrhythmia. The mobile application will automatically detect and classify the recorded data, and display the condition and average heart rate. Fig. 2 shows the results of heart rate and arrhythmia detection based on the simulated condition.

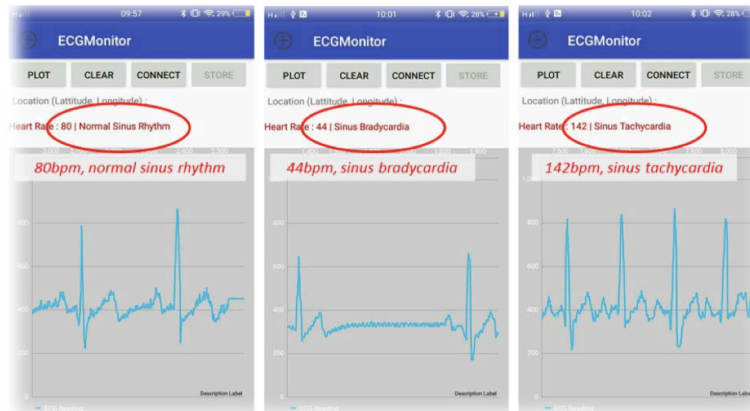


Fig. 2. Heart Rate and Arrhythmia Detection

4 Conclusion

This paper has briefly presented a home-based ECG monitoring device which consists of an ECG acquisition unit and a mobile app by leveraging Internet-of- Things (IoT) technology, mainly on Bluetooth wireless communication and Google services. It supports the functionalities of simple arrhythmia detection, real-time ECG graph display, and data management system. This device could help to improve heart care by connecting patients with doctors regardless of their location to enable prompt medical

consultation in case there is any abnormalities detected. With the implementation of IoT features, this system could also play a role as part of the telecardiology framework. As recommendation of future improvement, this system can be enhanced to support advance life-threatening arrhythmia detection, such as atrial fibrillation as a strong indicator of stroke, with advanced machine learning technique to increase its detection accuracy, at the same time with real-time performance supported.

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