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Android Application for Ambulant ECG Monitoring

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Abstract: The Electrocardiogram (ECG) is an important tool to interpret a wide range of heart conditions. Early warning and patient awareness are critical in preventing permanent heart damage and saving much of the heart muscles. These critical conditions motivated us to propose an application that shows promise for long term ambulant ECG monitoring. The aim of this paper is to develop a prototype android ECG application that works with existing ECG acquisition device. The application will be used for the realization of ECG data signals that are sent from the ECG acquisition device via Bluetooth communication, calculate heart rate and plot it on android mobile phone, and also send this information to the concerned physician through server. We have tested this application in real time by collecting the ECG from the patient in stationary as well as moving conditions. In both situations the application fulfils requirements of the proposed system.

Keywords: Android, Bluetooth, Electrocardiogram, File Transfer Protocol, Heart rate, QRS complex.

I. INTRODUCTION

The design of portable systems for remote monitoring of patients specifically those who are suffering from cardiac diseases are becoming one of the most important fields in telemedicine. A long-term continuous ECG monitoring has been very significant in many situations such as caring for elderly people, especially those with cardiovascular diseases, and for athletes or fitness enthusiasts. Also, in recent years mankind has witnessed a revolution in the smart phone industry and emerging growth in the usage of mobile applications that range from entertainment and educational apps to simple games, health care apps and more[6].

Several groups have developed applications to monitor the ECG in mobile devices, where the samples have been obtained from standard data bases, or they have development the ECG module. Other works have proposed techniques for signal processing via software to reduce noise or classify heart pathologies [9]. Some groups have presented a wearable health monitoring system and its applications for long term monitoring [7, 8].Some has developed application for PDAs and PCs for visualization of ECG [1, 2, 5, and 9]. In this paper we present a low cost, small, low power consumption portable system with wireless transmission for real time ECG acquisition, processing, storing and visualization in a mobile phone. In this work, we describe the implementation of an Android Application that can receive ECG raw signal from acquisition module with wireless transmission capabilities (Bluetooth), process it, extract features and display it for real time ECG visualization in mobile devices. Also we have implemented the Android Application that can send the text file of processed ECG signal data to the remote server with wireless transmission (File Transfer Protocol). So, server can send it to desired person like doctor or physician for medical decisions. In the following section proposed system framework is described. In sections 3 and 4 hardware and implemented software will be explained in detail. Section 5 will introduce the algorithm used for QRS complex detection and heart rate computation. Results and final prototype, together with the conclusions are shown in sections 6 and 7.

II. SYSTEM DESCRIPTION

The layout of the proposed system is as shown in Fig. 1. The system consists of three modules; the patient's ECG acquisition device, trans-reception module, and the control unit in the mobile phone. ECG device is real time continuously attended ambulatory cardiac monitoring system. Ambulatory cardiac monitoring refers to ECG monitoring services provided while the patient is at home or performing daily activities, including sleep. The patient will be wearing a wearable electrode continuously and his ECG will be recorded continuously on real time basis. This data is then sent to the mobile device of the patient, where it is processed, filtered, and plotted in the form of actual ECG waveform. This ECG signal is then sent to the server and server sends this information to the concerned physician along with the patient's basic information, so that the physician can see the ECG of patient directly on his mobile phone. Thus, this system has immediate, 24 hour access to a physician to review transmitted data and make clinical decisions regarding the patient. The physician can assist the patient in case of an emergency.

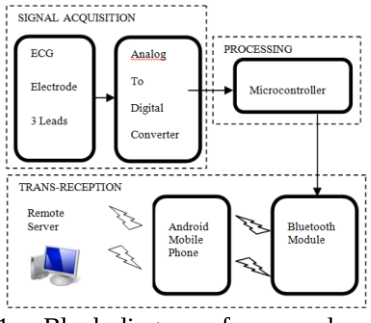

Fig. 1. Block diagram of proposed system

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A. Selected Technology

We have used Bluetooth as transmission protocol for communication between acquisition module and mobile phone as it is the one used by most commercial mobile. In 2003, just two years after the Bluetooth wireless technology was used officially in the world. U.S. Food and Drug Administration (FDA) approved the first Bluetooth used in medical devices. It is the Serial Port Adapter for emergency room equipment, designed for applications such as wireless printing ECG or send medical images in the air [5]. Most recent example is the Bluetooth technology used in blood glucose meters which has been able to capture data using a PDA or laptop. This paper introduces a mobile system in which the heart's electrical activity is transmitted to the mobile via Bluetooth and received, processed, stored and visualized in real time. This type of system is desirable because it can operate without depending on the line of sight with obstacles in between [5].

For sending finally processed ECG signal along with metabolic data of patient to server we have used File Transfer Protocol (FTP). FTP is a standard Internet protocol for transmitting files between devices on the Internet. FTP is an application protocol that uses the Internet's TCP/IP protocols. One of the biggest advantages of FTP is that it is one of the fastest ways to get large files from one machine to another. Most FTP servers requires to log in with a username and password, so it is a secure way of file transfer. FTP allows file transfer back and forth. This type of protocol is required in proposed system for efficient file transfer.
Server then sends the data to intended receiver.

B. Development Environment

Tools and different APIs used for developing mobile app which fulfil projects requirements are provided through the android Software Development Kit (SDK) and Java Development Kit (JDK). To develop Android applications Eclipse development environment has been used. It is freely available for Windows, Mac, and Linux operating systems. The Android Developer Tools (ADT) plug in for Eclipse provides a professional-grade development environment for building Android apps. It is a full Java IDE with advanced features to help build, test, debug, and package Android apps [10]. For the development of application for proposed system mainly Eclipse Kepler was used. The application has been developed using the Java™ Standard Edition with version 7 update 51.

III. HARDWARE DESCRIPTION

The proposed system consists of three lead electrodes for real time continuously attended ambulatory cardiac monitoring. A circuit board was developed for ECG signal processing and wireless data transmission which contains a built in ADC and smart Bluetooth radio. The device is programmed over Bluetooth via simple ASCII commands. Both ASCII and binary data formats are supported [4].

It connects to industry standard sensors to provide wireless, remote signal monitoring and device control in commercial environments. It easily attaches to analog sensor outputs and automatically takes continuous industrial measurements. Data is transferred wirelessly to PC and PDA clients using the Bluetooth Serial Port Profile (SPP). Software applications can control and acquire data as if they were connected to a local serial port [4].

This device uses SPP and should be connected to as a Virtual COM port on PCs, Palms, Pocket PCs, or other clients. Once connected, data will flow in both directions as if the serial port were locally attached. It has a class 1 Bluetooth device with high power transmitter (100 meters) however; actual range may be limited to 100 feet or due to internal antennae or type of client device used to connect to it. Once connected to the device over Bluetooth SPP, it is ready to acquire data. Some special character commands are defined to operate the unit. Each command is a single character. Results are immediate; however any commands given do not survive a power cycle and must be re-issued if the unit is powered down or rebooted remotely [4].

This device uses three electrodes and the acquired signal represents the first Einthoven bipolar lead (Fig. 2). By convention, lead 'I' has the positive electrode on the left arm (LA), and the negative electrode on the right arm (RA), and therefore measures the potential difference between the two arms. In this and the other two limb leads, an electrode on the right leg serves as a reference electrode for recording purposes. An android mobile device which has the wireless communication capability was used to receive the real time ECG data from the acquisition module for displaying the ECG plot on the screen and sending the text file of ECG data to the remote server through the wireless transmission.

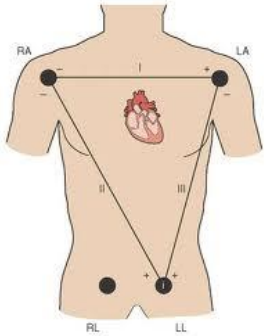

Fig. 2. Einthoven's triangle

IV. APPLICATION DEVELOPED

The software developed can be categorized as high level software for the application in the mobile phone. This application basically is a user interface (UI) which allows us to monitor the patient's ECG in real time. The application can be divided into three modules: the Bluetooth communication, data processing, and FTP.
For Bluetooth communication mobile phone and device switch between master and slave modes as per the requirement. This includes:

- Connecting mobile phone's Bluetooth adapter to the acquisition device's Bluetooth adapter; here mobile phone acts as master and device acts as slave,
- Sending required commands to the device; here mobile phone stay in master mode and device stay in slave mode,

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- Receiving data at mobile phone; here mobile phone switches to slave mode and device switches to master mode.

This application includes following data processing on the received ECG data: Baseline wander removing, QRS complex detection, heart rate computation and plotting ECG.

Then, for communication between mobile phone and server FTP is used, where mobile phone acts as master and server as slave.

V. QRS DETECTION AND HEART RATE COMPUTATION

QRS detection serves as the fundamentals for a wide variety of automated cardiac signal analysis algorithms. Since the shape of QRS complex is time varying, and is subject to physiological variations as well as to corruption due to noise, a reliable QRS detection algorithm is thus essentially demanded in many aspects of applications into the ECG analysis. R-peak is considered as a fixed point identifiable in each cycle for the recognition of almost all ECG parameters, because it has the largest amplitude and sharpest waveform that can be extracted from ECG.

There are large number of recognition algorithms used in ECG-analysers and, in many cases, the principles of operation vary. We have implemented the Pan-Tompkins real time QRS detection algorithm [3]. As shown in Fig. 3 this algorithm uses filtering, differentiation, signal squaring and time averaging to detect the complex. After R peak detection in QRS complexes the heart rate is computed in terms of BPM (beats per minute) from no of R peaks detected per minute.

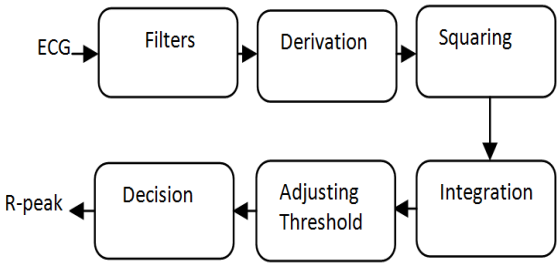

Fig. 3. Pan –Tompkins real time QRS detection algorithm

VI. RESULT

The proposed application for Android mobile phones was developed for a minimum API of 8 (android version 2.2) and mainly tested on android version 4.1.1(API 16)

Fig. 4, 5 and 6 shows the screen shots of user interface for application installed on mobile phone. We tested our system by placing the electrodes to a subject's chest and mobile phone in his hand. The subject was allowed to move freely with the acquisition device and the processing mobile phone kept together within the radio range. Fig. 5 shows the mobile user interface receiving ECG data samples from the acquisition device.

Fig. 6 shows the mobile phone display of a trace of ECG signal for 5.6 seconds that was sampled at 500 Hz. It also shows the QRS complex detected and heart rate calculated. The output ECG signal is clear and of high quality (no visible noise superimposed on the ECG signal).

Fig. 4. User interface in mobile phone

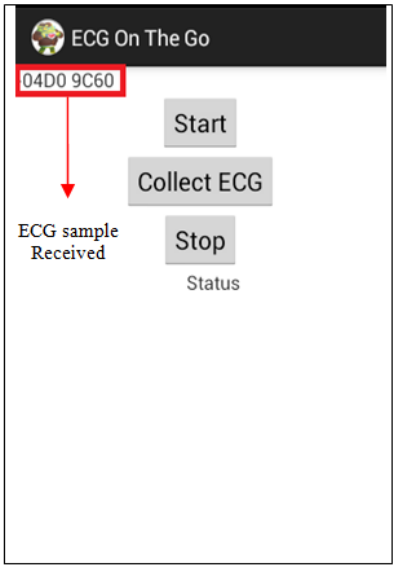

Fig. 5. User interface with data reception

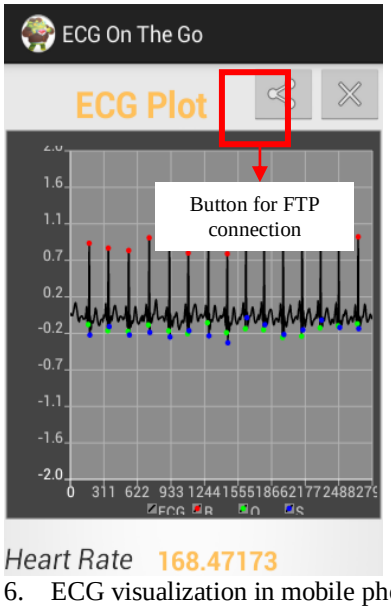

Fig. 6. ECG visualization in mobile phone

VII. CONCLUSION

In this work, an android application was proposed which can continuously receive ECG signals from acquisition device wirelessly, detect QRS complex, compute heart rate and plot the real time ECG signal on mobile phone for displaying. Also, it can send this information to concerned physician via server for medical decision. Experiments show that the proposed system is unobtrusive and can be comfortably used by the user during daily activities.

The paper sets a foundation for future developments that can improve proposed application for wireless health solutions. Some of the features that can be included are detection of irregularities in the rhythms of the heart, monitoring and analysing ECG signals at home and simultaneous automatic alert to the doctor of any emergencies. It is also important to include more options like zooming functionality, which will improve the usability of the app.

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