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RESEARCH ARTICLE

Multi-Parameter Cardiac Remote Monitoring System based on Android

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ABSTRACT

A novel multi-parameter cardiac remote monitoring system based on Android is presented and demonstrated for overall health surveillance of Electrocardiograph (ECG), heart sound and pulse compared to the shortcomings of the monitoring through single ECG. This system is composed of a multi-channel physiological parameter acquisition unit, an Android terminal and a cloud server. Several key technologies such as integration of multi-parameter acquisition, Bluetooth Low Energy (BLE) data communication, Android terminal waveform drawing and data management, and cloud-based data storage are researched. Experimental results show that the aforementioned three physiological parameters can be gathered simultaneously at the rate of 1 KHz and the BLE communication, waveform drawing and data management in mobile terminal can be achieved. The system we presented has the merits of high Signal-to-Noise Ratio, comprehensive heart monitoring data and convenience for using and carrying, which provides an important reference for telemedicine and mobile health, and lays a good foundation for the integration of multi-parameter cardiac care.

Keywords: Cardiac monitoring, ECG, Heart sound, Pulse, Android.

1. INTRODUCTION

Heart disease is a common cause of sickness and death. Among the death toll in the world, about 1/3 die of such diseases. With the age structure of population aging, the proportion of cardiovascular disease is also increasing [1]. Owing to the hospital care conditions, economic conditions of patients and personal time constraints, the monitoring of cardiovascular disease population coverage is inadequate. Patients, who are in critical condition, can't be rescued in a timely manner. The popularity of smart phone makes mobile medication the focus of attention. Mobile health care can reduce medical costs while achieving the purpose of rational allocation of medical resources.

ECG is the most intuitive, widely used heart examination technique, but it is only used for heart organic diseases. [2] A number of heart diseases is often manifested in the way of heart murmur, so that heart sound can be used to screen early heart diseases [3]. Alternatively, we can assess the cardiac reserve capacity by heart sound analysis, which can effectively avoid the occurrence of cardiovascular accidents caused by cardiac reserve capacity decline. Besides, medicine has confirmed that the shape, intensity, speed, and rhythm of pulse signals mostly reflect the physical and pathological characters of heart-blood system in human bodies. The pulse can be detected as a valid assessment of the degree of cardiovascular health, and human blood pressure can also be estimated through the pulse characteristics. [4, 5] combined ECG with heart sound and pulse to monitor the heart, which makes up for ECG monitoring deficiencies and not only can improve the reliability of heart disease diagnosis, but also

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can achieve early diagnosis and screening of heart diseases. By combining the data of ECG, heart sound and pulse signal we can realize a more comprehensive analysis of heart health, and reduce the incidence of heart disease and mortality.

[6] Combining the advantages of mobile medication, we aim at the deficiency of the ECG signal detection and the solution of multi-parameter cardiac remote monitoring system based on Android is presented. We have completed the design of cardiac parameter acquisition terminal and realized the collection of ECG, heart sound, pulse signal and wireless data transmission. The software development based on Android system has been designed. In addition to it, the BLE communication, waveform drawing and data management have been achieved.

2. GENERAL STRUCTURE OF THE SYSTEM

As shown in figure 1, multi-parameter cardiac remote monitoring system based on Android, consists of physiological parameters acquisition unit, the Android terminal and the cloud server.

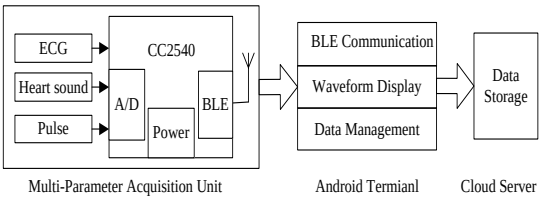

Figure 1.General structure figure of system

Multiple-parameter acquisition unit is used to collect ECG, heart sound and pulse signal simultaneously. As a result of integrated design, there is no need to use an external sensor, and the collection is more convenient. The acquisition unit sends the data through the BLE to the Andorid terminal, which increases the battery life and increases the standby time of the signal acquisition unit [7, 8].

Android terminal implements data reception, waveform display and data management. It uses SurfaceView method to draw, so as to avoid blocking thread. Android terminal can send data to the cloud server for storage and further processing through the network. The doctor can refer to data in the cloud server to analysis and diagnose and then send results to the user.

3. MULTI-PARAMETER ACQUISITION UNIT

3.1. Integrated structure

Multiple-parameters acquisition unit consists of the acquisition module, bluetooth CC2540 minimum system and power supply module. It mainly completes the acquisition, processing and transmission of three parameters that consists of ECG, heart sound and pulse signal. Acquisition module includes ECG electrode, heart sound sensor and pulse sensor. It collects three kinds of physiological signals simultaneously. For example, it uses metal dry electrode to measure the two thumbs to get I-lead ECG [9]. The heart sound signal is collected in the chest by using a piezoelectric diaphragm heart sound sensor, and the pulse signal was obtained by measuring the finger with a photoelectric volume pulse sensor. We used Bluetooth CC2540 as the main controller, to achieve the above three kinds of signal's acquisition and digitization, and then send the signal data to the Android terminal via the Bluetooth protocol stack. The ECG module uses the BMD101 system-on-chip, which has advanced analog front-end circuitry, flexible digital signal processing, extremely low system noise and controllable gain. The acquisition unit adopts the integrated structure design and it's appearance is shown in figure 2.

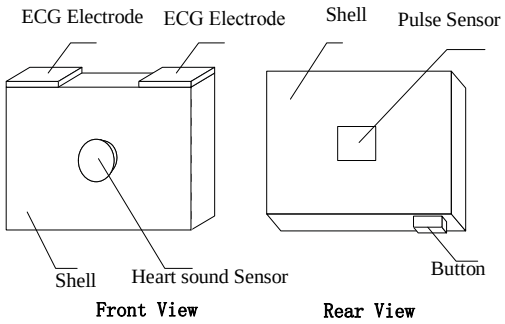

Figure 2.Integrated structure figure of acquisition unit

3.2. BLE protocol stack operating mechanism

The CC2540 is a system-on-chip suitable for low-power applications. It is used to control the physiological signal acquisition of acquisition module, and send the ECG, heart sound, and pulse signal to Android terminal. Its main characteristic is low power consumption, in ultra-low power mode. Figure 3 shows the workflow of the BLE protocol stack running

on the Bluetooth CC2540. First, start the system initialization, task initialization, and then run the operating system, to determine the task. If there is a executing task, continue implementing the task. If no, start the loop of task. In the periodic tasks of the protocol stack, the acquisition and analog-to-digital conversion of the heart sound signal and the pulse signal are respectively performed, and the digitized ECG signal is received through the serial port, and then the signal is assigned to the characteristic value of the Bluetooth protocol stack. Finally it is sent to Android terminal.

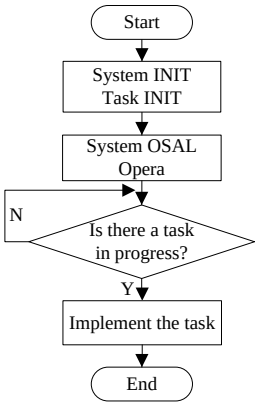

Figure 3.BLE protocol stack workflow

4. ANDRIOD TERMINAL APPLICATION

Android terminal application is developed under the Android6.0 platform. It includes the terminal User Interface (UI) design and application function design. Terminal application is mainly applied to achieve the reception of ECG, heart sound and pulse, waveform display, data storage and other functions.

4.1. UI design

UI is used to interact in an user friendly way. The material design is choosed to provide a consistent UI for different terminal equipment. In the UI design, according to the demand analysis, UI is made up of Login, BLE communication (COM), waveform playback and data management (MGT). Navigation (NAV) Drawer is used in the UI navigation. The main function modules are all on the sidebar and the waveform display UI uses Fragment with ViewPager functions to achieve, which can make UI more flexible and improve the user experience and programming efficiency. Terminal UI flow chart is shown in figure 4.

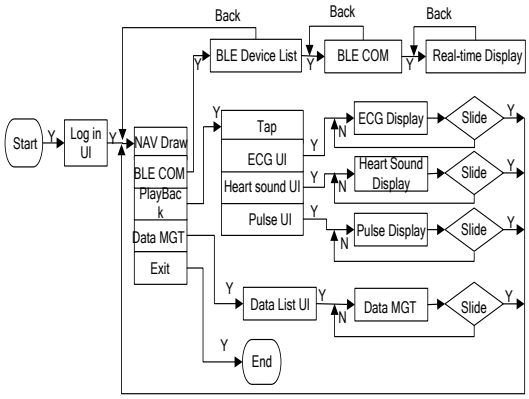

Figure 4.Terminal UI flow chart

4.2. BLE communication and data storage

BLE communication is mainly used to complete the connection between terminal bluetooth and multiple parameter acquisition unit, and data storage primarily complete the three stored physiological signals. The terminal program uses the BluetoothManager.getAdapter () method to get the native Bluetooth adapter and then confirm whether the current Bluetooth is turned on, if not open, prompt the user to open Bluetooth, when Bluetooth is turned on, call the BluetoothAdapter.startLeScan () method to scan the BLE devices in the valid range, and then use the BluetoothDevice.connectGatt () method to connect to the Generic Attribute Profile (GATT) server, while returning a BluetoothGatt instance. This instance can be used for GATT client operation, BluetoothGatt read BLE equipment services and characteristics.

The terminal sets the notification for each characteristic individually via the setCharacteristicNotification () method. After the terminal is connected with the acquisition unit, set the notification to the BLE characteristic so that the terminal program can listen to the BLE characteristic. If the value of the BLE characteristic variable changes, it immediately triggers the callback function onCharacterChanged () in the service. This change is sent out by broadcast, and the main program will receive and obtain BLE data from the broadcast, then verify its validity, next open up a new thread to store the valid data to the terminal SD card. By setting notification to the characteristic to read the value of the BLE characteristic variable, the advantage is that once BLE characteristic variable values change, it will immediately trigger the callback function of the terminal.

The way of reading BLE variable values can effectively avoid the loss of data and ensure the integrity of the data. BLE communication and data storage flow chart is shown in figure 5.

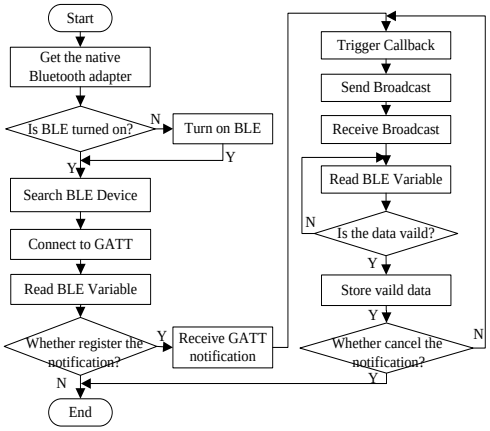

Figure 5.BLE communication and data storage flow chart

4.3. ECG, heart sound, pulse waveform display

Waveform display mainly display ECG, heart sound and pulse waveform, which divides into two parts including real-time waveform display and waveform playback. In real-time waveform display, the terminal connects with the acquisition unit via BLE and register notification to receive the data, then convert it to data format, finally send valid data to the drawing thread for waveform drawing. In waveform playback, the terminal application reads data from the local, converts the data format, and then sends the data to the waveform playback thread. In the terminal program, the real-time waveform display thread controls the data reception by registrating notification or cancelling notification, and the data receiving, the data processing and the waveform drawing are placed in the sub-thread in order to avoid blocking the main thread. After connecting the terminal and acquisition unit, the terminal program will open a new thread for data receiving and data processing and then will open up a new drawing thread to draw. The communication between data thread and drawing thread relays on Android's Handler asynchronous message mechanism. Waveform playback thread is similar to the real-time waveform display.

Select SurfaceView that supports double buffering and multi-threaded technique to draw the waveform, which can avoid blocking main thread. SurfaceView is usually used in conjunction with SurfaceHolder, which calls SurfaceHeader's getHolder () method to get the SurfaceHolder. SurfaceHolder provides a way to get a Canvas object. First lock the canvas through the lockCanvas () method to get the current canvas object, then draw the received data as a waveform, finally unlock the canvas with unlockCanvasAndPost () [10]. Waveform real-time display flow chart is shown in figure 6 and waveform playback as shown in figure 7.

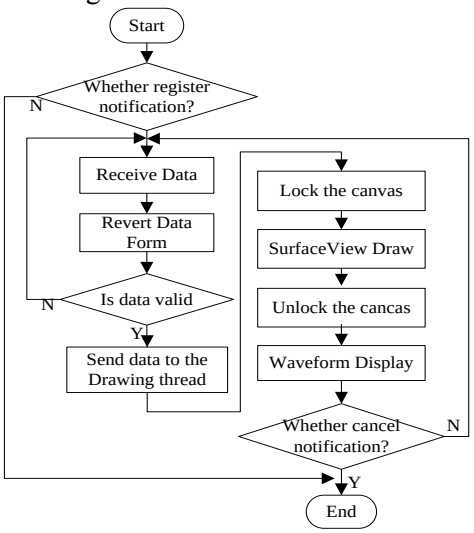

Figure 6.Waveform real-time display flow chart

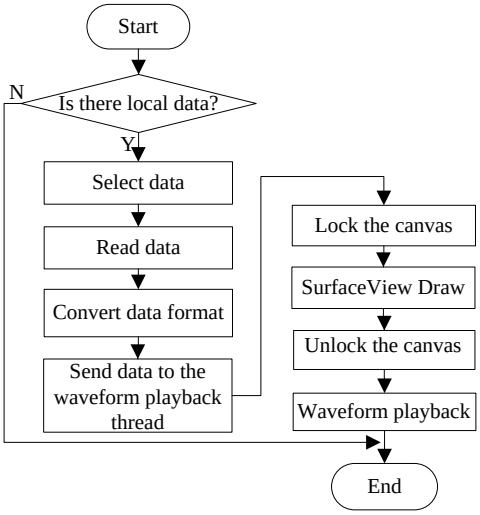

Figure 7.Waveform playback flow chart

4.4. Data management

The ECG, heart sound and pulse data management, include query, delete, upload to the cloud and other operations. First of all, specify the directory of data files to display in the form of a list through the file.listFiles () method, then set AlertDialog for each entry in the list. When clicking the entry, user can choose to delete data or upload data to the cloud. AlertDialog's setPositiveButton is set to upload data to the cloud. The NegativedButton

of the SecretAlertDialogset is set to delete the native data, and the data is deleted from the local machine by calling file.delete () to free the memory.

5. EXPERIMENTAL RESULT

The system completed the design of the multi-physiological parameter acquisition unit, and it can collect ECG, heart sound and pulse signal simultaneously without external sensors. In the absence of data omissions, the acquisition rate of multi-parameter acquisition unit can reach 1KHz, and the signal to noise ratio is high. The original data waveforms are shown in figure 8, figure 9, figure 10 and the system has completed the terminal UI and function programming, the terminal program runs on LG G4 terminal and the system is Android6.0. The ECG waveform is shown in figure 11, the heart sound waveform is shown in figure 12 and the pulse waveform is shown in figure 13. According to the display of the waveform, one can see that the signals waveform that display on the terminal are same with the original waveforms. The key features of ECG, heart sound and pulse are obvious, which can meet the needs of doctors reference diagnosis. Besides the communication between terminal and cloud server, users can upload and download data under the relevant network.

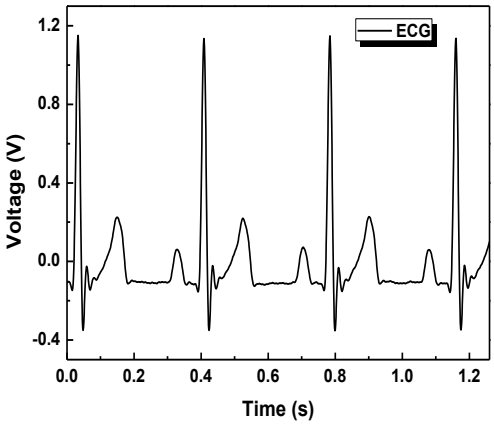

Figure 8.Original ECG waveform

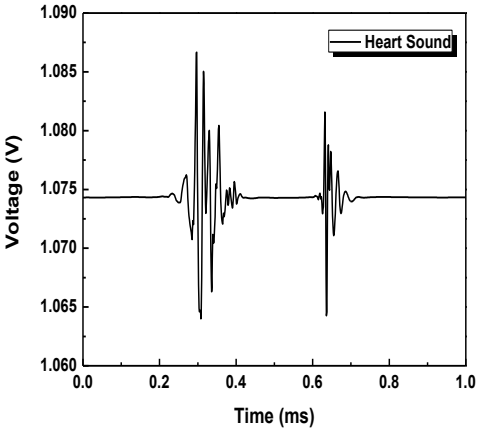

Figure 9.Original heart sound waveform

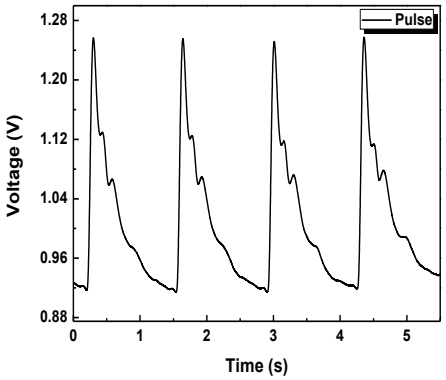

Figure 10.Original pulse waveform

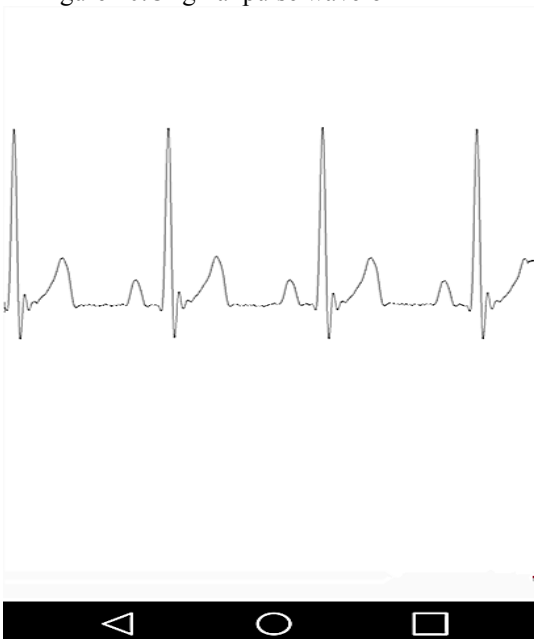

Figure 11.ECG waveform

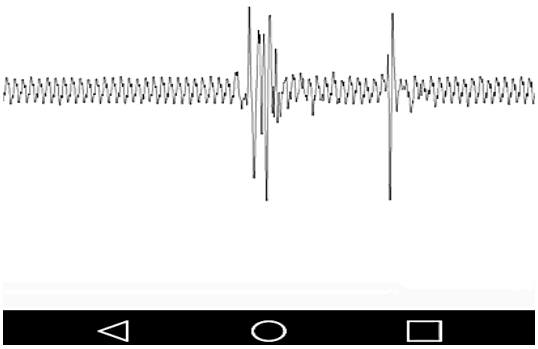

Figure 12.Heart sound waveform

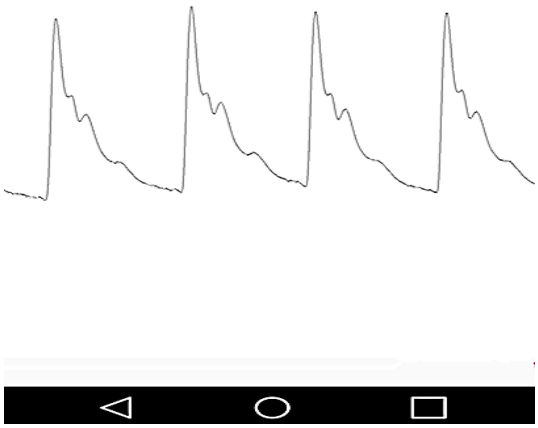

Figure 13.Pulse waveform

6. CONCLUSION

The system that is based on the Android platform has realized the monitoring of ECG, heart sound and pulse signal. The acquisition speed is 1KHz and so it's easy for the professional to process the data. After processing the data the professional can get the key features of the parameters, which can achieve the remote monitoring of the heart by the cloud. The multi-parameter cardiac remote monitoring system can impove the reliability of diagnosis of heart, cardiovascular diseases and can reduce the condition of medical treatment. In the future, the patient can easily get guide from the professional by collecting datas and sending to the cloud [11]. The research results can promote the formation of telemedicine system that has the concept of mobile health, and has important social benefits and good application prospects.

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