A Health Shirt with ECG Real-time Display on Android Platform

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Abstract

A health shirt which can measure ECG continuously has been designed. ECG signal is sampled by AD8232 and transmitted to the Android platform through Bluetooth. After analyzing the signal, the result has been displayed on the screen. The fabric electrodes measuring the ECG are mild to the skin and can be reused for many times. Designing in the aim of low power consumption, the ECG acquisition module can work continuously as long as 30 hours. Using the highly integrated hardware, the module weighs less than 20 grams, which is suitable to be sewed on the shirt. The heart rate, heart rate variation and some other physiological parameters can be calculated. The users can have a better understanding of their health. Finally, we have done several experiments under difference situations. The results have achieved the expected effect.

Keyword: health shirt; Android platform; low power consumption; real-time display; physiological parameters.

I. Introduction

Nowadays, with the increasing number of the people who suffer from cardiovascular diseases, there is a trend that people begin to pay more attention to their health condition. This situation has made the new invention of medical machines to be smaller and smarter[1].

Everyday ECG monitoring is essential for the people who suffer from cardiovascular diseases. Even for the person without any heart diseases, the message contained in ECG can still provide a plenty of information on their health situation. According to the research by Naschitz, relative short QT intervals are features of the chronic fatigue syndrome related dysautonomia[2]. So it is helpful and necessary for ordinaries to monitor their ECG regularly to have a better understanding of their health.

Unfortunately the current products cannot fully satisfy the needs. The electrocardiographs used in hospital are too large and expensive for the public to afford. The holters, which is much smaller, can measure ECG signal continuously for 24 hours in hospital. But they still hold a shortage of the abundant wires. The electrodes of holters can lead to the discomfort feeling in users. Otherwise, the electrodes used in most ECG monitors are made of AgCl and Ag which can stimulate the skin and cause allergy when attached for a long time. The electrodes can also be dropped down by dehydration, which is detrimental for measuring.

In order to overcome the shortage of the clumsy monitoring system, many efforts have been taken. LifeShirt system, which is created by VivoMetrics company, is a noninvasive, continuous ambulatory monitoring system that can collect physiological signal during daily time[3]. The users can wear this shirt and monitor their physiological signals conveniently. But LifeShirt still utilizes traditional Ag/AgCl electrodes which are often criticized for their discomfort and irritation.

Under this background, we have designed a Health shirt to measure users' ECG signal which is comfortable to wear and mild to the skin.

II. Realization

The Health shirt contains several dry electrodes and a small ECG monitoring module. We can detect the user's ECG in real time just by wearing this shirt. The ECG waves will be displayed on the screen of the smartphone.

This system consists of three parts: the shirt embedded with dry electrodes, an ECG acquisition module and a smartphone based on Android platform. The overall framework of the system is depicted in the figure 1.

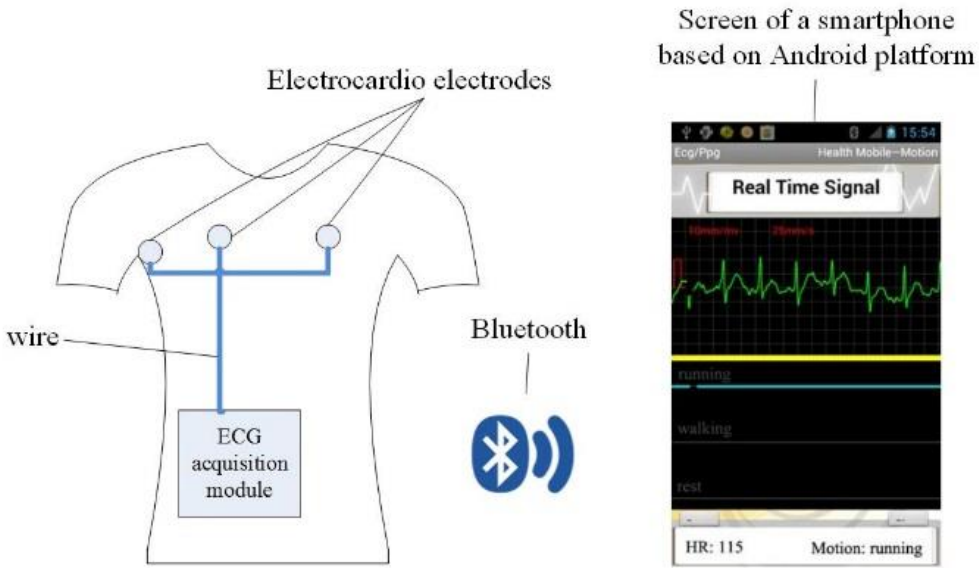

Fig. 1. The framework of the system

A. Wearable design

In order to measure the ECG signal on the breast, we weaved three dry electrodes into a belt which is used to tie. Two electrodes lie between the center line of the breast. Another electrode that lies near right arm is applied for driven-right-leg, which is used to reduce interferences. The placement of the electrodes is similar to the lead I in the ECG measurement.

The dry electrodes are carefully designed to increase the magnitude of the ECG signal and reduce the impedance between the skin and the electrodes. They are also called fabric electrodes and made of conductive fabric, sponge filing layer and a supporting belt (Fig.2).

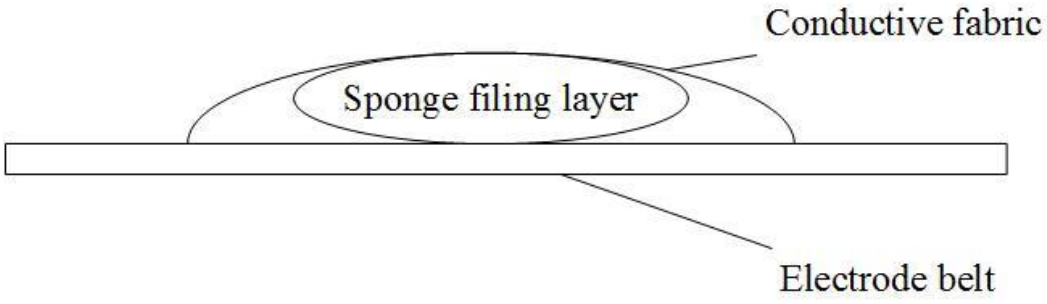

Fig. 2.The components of the fabric electrodes

The conductive fabric on the sponge is used to detect and transmit the signal to the ECG acquisition module. The sponge filing layer beyond the Electrode belt is applied to increase the tightness and comfort of the electrodes. The sponge filing layer is covered by the conductive fabric and sewed on the electrode belt. And the belt is applied to adjust the tightness between the electrodes and the skin.

With the purpose of making the belt wearable, we have sewed it to the clothes inside. This method has made the electrodes not only fixed in the clothes, but also attached to the skin tightly (Fig.3).

Fig. 3.Picture of the shirt inside

B. ECG acquisition module

To make a device which can measure ECG signal and transmit it to the smartphone in real time, we have designed a hardware system to accomplish our purpose (Fig.4).

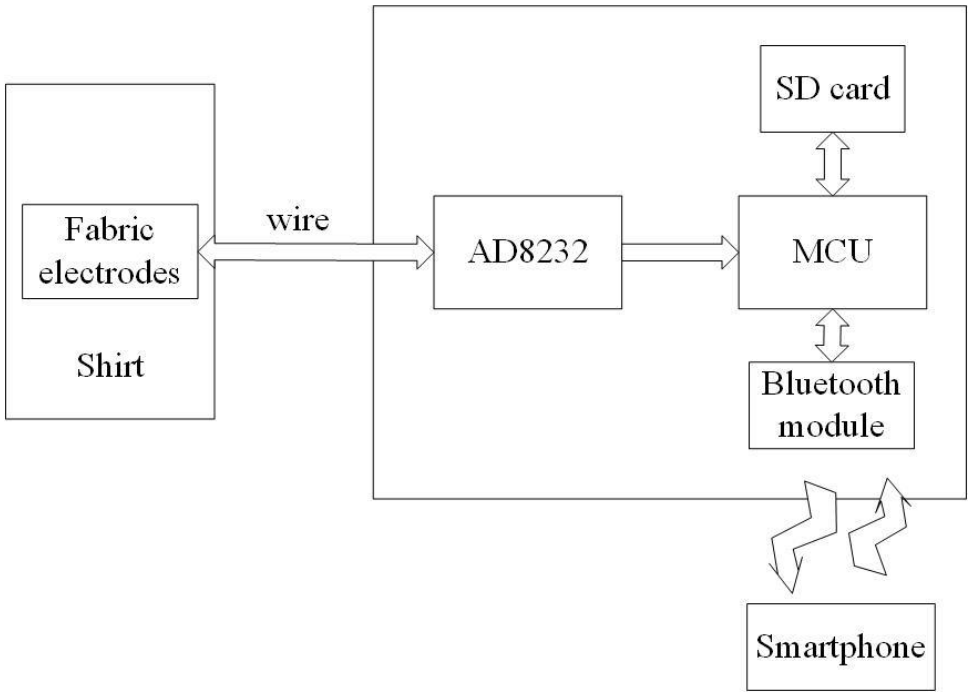

Fig. 4. Block diagram of the hardware system

The sampling frequency of the device is 150Hz. And we have adopted several methods to minimize the size and power consumption.

The signal collected from the fabric electrodes is transmitted to AD8232, which is an integrated signal conditioning block for ECG and other biopotential measurement applications. It is designed to extract, amplify, and filter weak ECG signals in the presence of noisy conditions[4]. The micro controller unit (MCU) equipped in the module is STM32L151. It uses an ultra-low-power Cortex-M3 core and a flexible CPU clock[5]. In the case of Bluetooth module, CC2540 is adopted in the system. It is produced by Texas Instruments Company and famous for its cost-effective, low-power and true system-on-chip in the areas of Bluetooth low energy applications[6].

Using the above modules, we have designed and completed the ECG acquisition module on a PCB board (Fig.5). The board holds a length of 45.1mm and a width of 41.92mm, which is small enough to be kept on a shirt.

Fig. 5.The PCB board of the ECG acquisition modules

At the same time, in order to realize the purpose for long-term monitoring, we optimize the energy system according to the character of the lithium battery. Otherwise, we hibernate the MCU most of the time by distributing the task of storage data to direct memory access (DMA), which is quite efficient and energy-saving. Finally, we accomplish the goal that the module can work as long as 30 hours continuously with the weight of only 20 grams.

C. Software implementation

In order to display the ECG signals, we design an Android application on the smartphone. In the application, the ECG signal is displayed on the screen in real-time. The heart rate is also calculated and showed below (Fig.6).

The application is developed on the Android system, which is a world-widely used and open-source platform. By programming in Java, we design an interface which acts as an interaction between the smartphone and the ECG module.

Fig. 6. The display of ECG signal in the smartphone

By connecting the smartphone and the module through Bluetooth, the ECG signal and the hate rate of the user are displayed on the screen.

III. EEG Signal Processing

Considering the large amount of the noise and interference in the ECG signal, we have come up several methods to filter the signal and locate the QRS waves to estimate the heart rate and some other physiological parameters.

A. ECG filtering algorithms

The ECG signal is interfered by the power frequency and some other high frequency noise. The smoothing filter and low pass filters are used to reduce the impact of those effects. On the other hand, baseline drift also exits in the ECG signal. To filter out the drift and get a stable signal, high pass filters are applied in the processing.

We firstly use 5-point smoothing filter to remove the high frequency noise in the ECG signal roughly. Then a high pass filter has been applied to suppress the baseline drift. A comb filter is then used to filter out the power frequency interference. The time delay caused by the filters has be calculated and subtracted in the final ECG signal (Fig.7).

The all ECG signal processing algorithms are implemented in MATLAB, which is skilled at data analysis, matrix manipulation and etc.

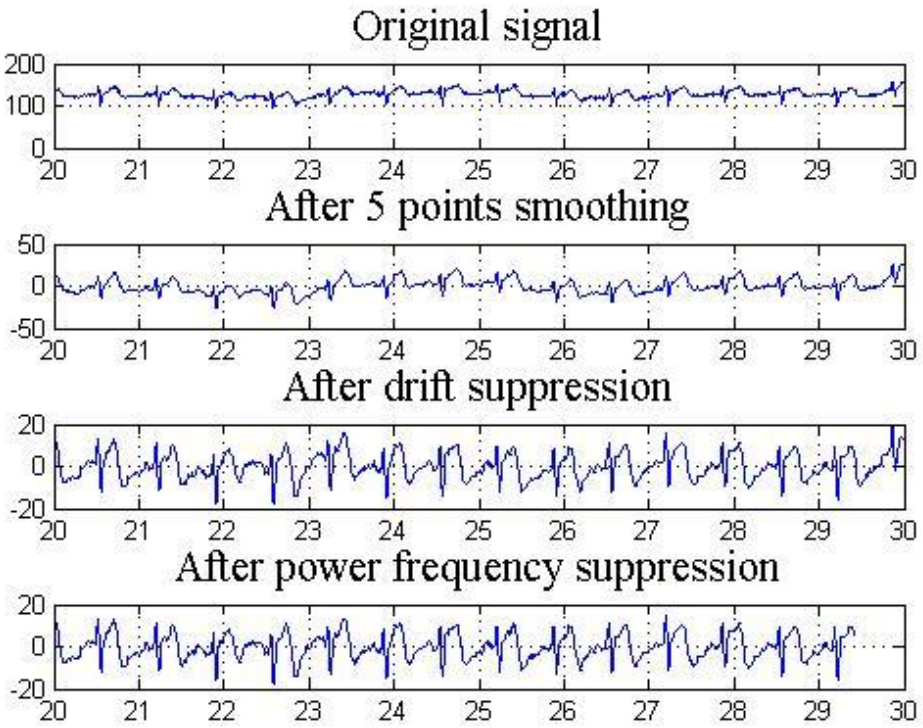

Fig. 7. The ECG filtering

B. Feature selection algorithms

The locations of QRS waves play a significant role in the analysis of the ECG signal. Many meaningful physiological parameters can be calculated on the basis of the QRS waves such as heart rate and heart rate variation (HRV). Many efforts have been put to locate QRS waves efficiently. After comparing many kinds of methods in the research, we use morphology filtering to position the peaks of QRS waves.

Morphology filter can eliminate high frequency noise and keep the geometry information of the signal at the same time [7]. After the transmutation applied by morphology filter, R peaks are easy to locate by a threshold detection algorithm (Fig.8).

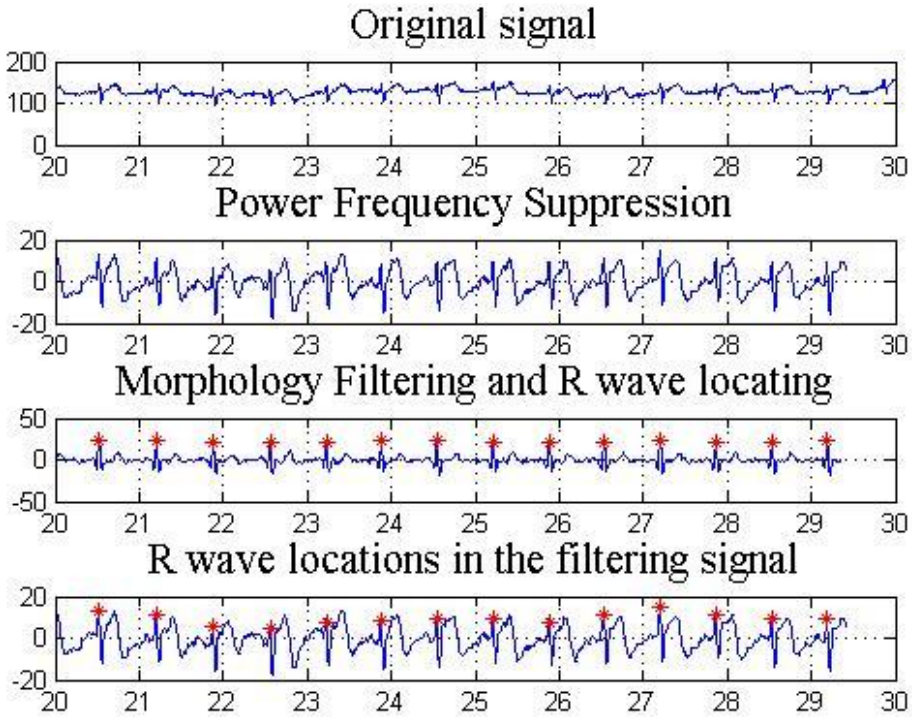

Fig. 8. Morphology filtering

From the experiment results, we can find that the QRS waves are detected effectively in the signal and the heart rate can easily be calculated after locating the peaks of QRS waves.

IV. Conclusions

By wearing the health shirt and connecting the smartphone with the ECG acquisition module, the user's ECG is displayed on the screen (Fig.9). The heart rate is also calculated and showed below the ECG signal at the same time.

The health shirt can be applied into multiple areas. It is comfortable to wear and monitor the user's ECG signal no matter what position the user holds (Fig.9).

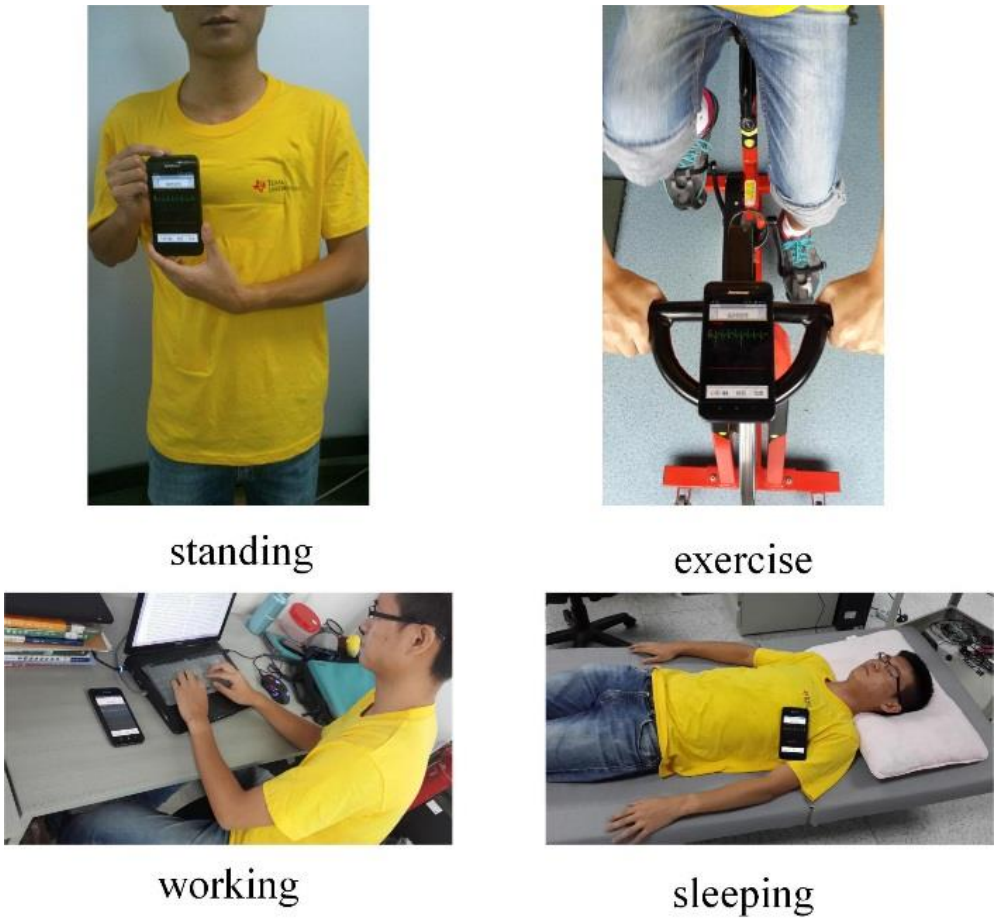

Fig. 9. The health shirt under different conditions

So just wearing the health shirt, we can monitor our ECG signal under different conditions. The data of heart rate in exercise can be used to judge the consumption of the sports and the user's ability to suffer. By monitoring the ECG signal in sleep, it can provide a sufficient and detail information about our sleeping quality. By analyzing the ECG data in the work, we can have a better understanding of our health. So it is very useful and convenient for us to detect the disorder of heart rate and avoid the overload.

In conclusion, the health shirt can be very useful to the person whose ECG need monitoring regularly. And it can also provide significant information about the user's health condition under different situations. By wearing the health shirt, the users can monitor their heart rate timely and effectively.

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