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Mobile Application and Device for Electrocardiograph Monitoring

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Abstract
The traditional methodto do an electrocardiogram (ECG)need to go to hospital, and use 12 leads to record the activity rhythm of the human heart in a short period of time. Combining portable device and mobile application, a portable ECG monitoring system is developed. It use special chip ADS1292R and MSP430 to design a miniaturization ECG acquisition device, obtain the real-time signals continuously, and transmit data to mobile intelligent terminals via Bluetooth, then mobile application analysis and displays the heart rate variability (HRV) parameters. The result shows that the device has the characteristics of miniaturization, low power consumption, real-time,and can accurately calculate the heart rate variability (HRV) parameters. It can monitor ECG for a long time, which is suitable for someone who has no condition to go to the hospital in daily life.

Keywords
ECG:electrocardiograph; HRV: heart rate variability; mobile applications; portable device

I. Introduction

Heart is one of the important organs in human body, which is responsible for converting chemical energy to mechanical energy, and providing the pressure to maintain blood circulation as the function of the "pump". ECG is anequipment to record the curve of the heart potential on the body surface, it changes over time.
HRV is put forward by Hon and Lee in 1965, it reflect the change speed of heart rate. HRV can be used to diagnose Coronary heart disease (CHD), Myocardial infarction (MI), Hypertension and other chronic diseases [1-3]. Time domain HRV parametersincludethe standard deviation of all RR intervals (SDNN), the root mean-square of successive differences of adjacent RR intervals(RMSSD), the pair adjacent RR intervals differing by more than 50 ms(NN50), and the percentage of pairs adjacent RR intervals differing by more than 50 ms (pNN50). Frequency domain HRV parameters include very low /low /high frequency power (VLF/LF/HF) and total power (TP). Nonlinear HRV parameters include relative dispersion and Lipschitz exponent,they play important roles in diagnosing diabetes mellitus, cardiovascular disease, respiratory disease and so on[4-7].
This paper designed a set of mobile applicationand devicefor ECG monitoring. It couldtransmit data to the mobile through Bluetooth 4.0,display and storage HRV parameters on mobile application. It aims at providing a system for people to care for health conveniently in poor medical condition areas

II. Method and System

1. Node Design

The block diagram is shown in figure 1. According to the diagram, sensor node was worn around the heart to detect the signals from 3 dimensions, the special chip ADS1292R play the role of preamplifier, hardware filter, and analog-digital converter. After the signal preprocessed in microcontrollerMSP430F169, it was transmitted to mobile via Bluetooth 4.0. The mobile application could display all kinds of HRV parameters.

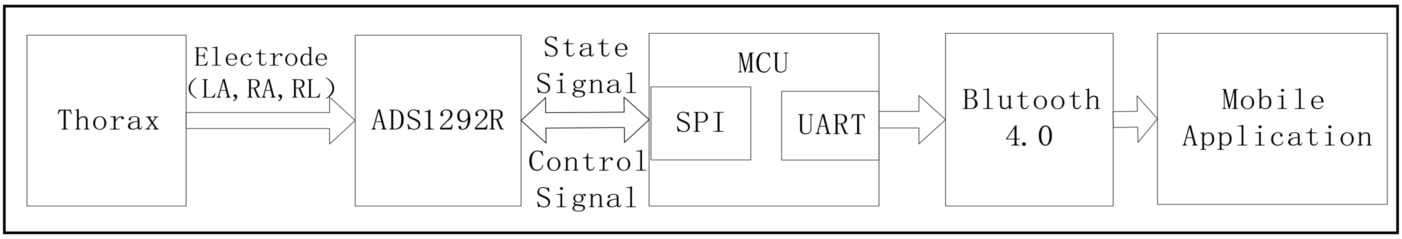

Fig1: The diagram of system structure

2. ECG Pretreatment

The filtering effect of the hardware circuit is not effective on eliminating noise. There still exist 50 Hz power-frequency signal and baseline drift of the low frequency and myo-electrical noise of high frequency in the original ECG [8]. In order to obtain correct HRV parameters, it is necessary to pre-processoriginal ECG signal. The steps include removing noises, amplifying useful signals and eliminating or suppressing undesired signals.
Design a 50 Hz notch filter to filter power frequency; As a result of the ECG frequency concentrated within the 100 Hz, according to the characteristic, it is suitable for designing a 40 order FIR low-pass filter, the cut-off frequency of passband is 40 Hz, sampling rate is 500 Hz., the experiment shows that filter can effectively eliminate the effect of high frequency noise. In addition, we choose the structure of the linear element, and use morphological filter to modify baseline drift, it has the the advantage of speediness, high accuracy. According to figure 2, it shows the original signal, baseline driftsignal, signal of eliminating the high frequency and signal of eliminating baseline drift.

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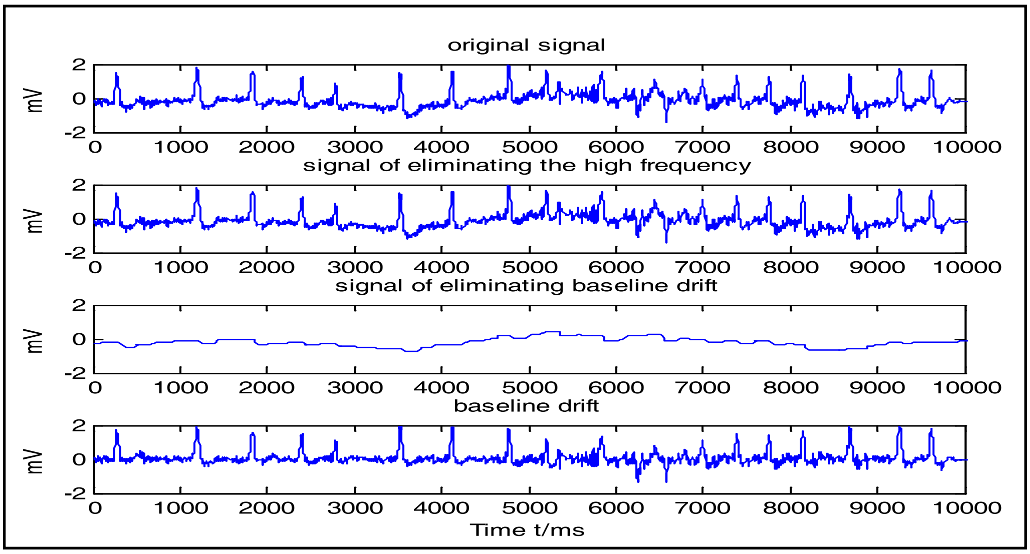

Fig 2: The figure of eliminating the high frequency and baseline drift

3. R Wave Detection

In order to calculate HRV parameters, we must obtain the location of the R wave in ECG, Here,based on analysis of slope, amplitude, and width of the QRS complex, thefollowing method is proposed to detect R wave fiducial points:

(1)Search the Location of the First R Wave

Firstly, remove the former 5s ECG data, because it is instability. When Wf = 500 Hz, calculate the forward differences according the time window of data andfind out the maximum forward difference, then search 100 sampling pointsin front of the position of the maximum forward difference point, the maximum value is the first the location of the R wave.

(2)Search the Location of the Residual R Wave

According to the step (1), we obtained thefirst R wave, regard its latter 100 points as basis point in a circular mode,when Wf= (Wf+RR), calculate the forward differences according the time window of data, then search 100 sampling points in front of the position of the maximum forward difference point, the maximum value is next the location of the R wave.

In the above content, Wf is a dynamic time-window functions, RR is the difference of coordinates between two adjacent R waves. Verified by the experiment, using the dynamic time-window functions canamendthe volatile ECG signal in time. Adoptingthis algorithm to locate the R wave, the accuracy can reach 98%.

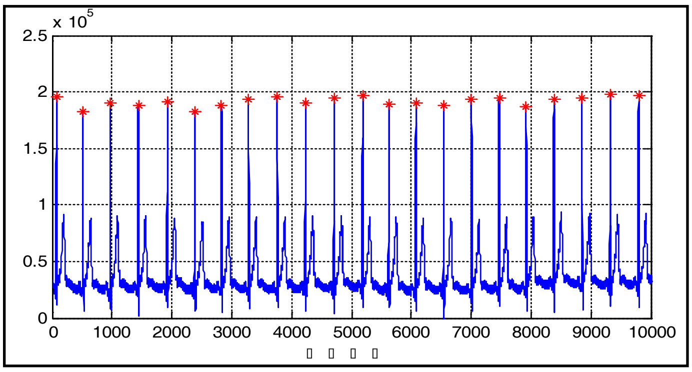

Fig 3:The figure of R wave positioning simulation

4. HRV Parameters

Some of the important time domain HRV parameters based on the definitions are as follows[9]:

SDNN: Standard deviation of all RRintervals.

$$SDNN = \sqrt{\frac{\sum_{i=1}^{N}(RR_i - meanRR)^2}{N}} \quad (1)$$

N is the total number of normal heartbeat; RR_i is theithRR intervals; meanRR is the average value of RR intervals.

NN50: Pair adjacent RR intervals differing by more than 50 ms.

pNN50: Percentage of pairs of adjacent RR intervals differing by more than 50 ms.

$$pNN50 = \frac{NN50}{N} \times 100\% \quad (2)$$

N is the total number of normal heartbeat..

Some of the important frequency domain HRV parameters based on the definitions are as follows,P(k) is the power of the corresponding frequency[10]:

Very low frequency(VLF) :0.003 ~ 0.04Hz

$$VLF = \int_{0.003}^{0.04} P(k)df \quad (3)$$

Low frequency (LF) : 0.04 ~ 0.14Hz

$$LF = \int_{0.04}^{0.14} P(k)df \quad (4)$$

High frequency (HF)

$$TP = \int_{0}^{0.4} P(k)df \quad (5)$$

According to the algorithm of detecting R wave and theformula of calculating HRV, mobile application with Java was achieved in Android intelligent terminal. To verify the consistency of algorithm in MATLAB and mobile application, we randomly selectedthree volunteers to participate in the experiment. To collect 5 minutesECG data andcheckthe location of R wave in same set of data betweenMATLAB and mobile application. Table 1 shows the location statistics of R wave on MATLAB and Android.Table 2 is the frequency domain HRV parameters of three samples.

Table 1 : The location statistics of R wave on MATLAB and Android

sample 1		sample 2		sample 3	
Android	MATLAB	Android	MATLAB	Android	MATLAB
1671	1670	1667	1668	1588	1588
2030	2031	1887	1887	1877	1876
2330	2328	2134	2139	2201	2203
2700	2704	2337	2337	2487	2488
2933	2933	2648	2649	2699	2670
…	…	…	…	…	…

Table 2 : Thefrequency domain HRV parameters of three samples

Sample	TP(ms^2)	VLF(ms^2)	LF(ms^2)	HF(ms^2)	LF/HF
1(woman)	1016.76	432.21	282.06	248.90	1.13
2(man)	1728.57	524.33	491.57	649.27	0.76
3(woman)	1249.34	498.75	384.25	365.93	1.05

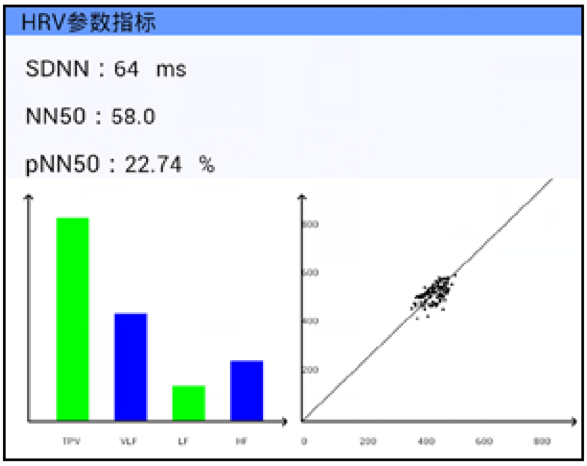

Fig 4: HRV parameter

On two platforms, the location of R wave is nearly uniform, the maximum error of the points are only 5 ms and the average is just 2 ms, RR intervals is generally hundred milliseconds, so the error don't have a significant impact for calculating HRV parameters. Figure 4 is HRV parameters displayed on the intelligent terminal.

III. Results and Discussion

In this work, the system is applied in the wearable field.ECG signal is measured from 3 dimensions,and HRV is analyzed and displayed in the mobile application, it is conform to the requirements of portable devices. In addition, Microcontroller is designed two kinds of running state. when node works in processing state, the power is about 140 mw, and whennode works in standby state, the power is about 110 mw, it conform to the requirement of low power consumption.Experiment shows that the systemis suitable forusing in remote area, where is short of medical facility.

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