Design of Wireless Motion Sensor Node

Ziyou Zhang¹, Yibo Wang¹, Kunyu Miao¹, Xinyuan Ying¹

¹Zhejiang University of Technology, Hangzhou, Zhejiang, 310012, China

*Corresponding author's e-mail: 201806061027@zjut.edu.cn

Abstract. The wireless transmission node designed in this report receives the data generated by the ECG detection module, temperature measurement module, and exercise statistics module by using the STM32 single-chip microcomputer system. STM32 sends the results after digital signal processing and algorithm calculations to the mobile terminal, realizing the dynamic display of electrocardiogram, body temperature, exercise volume and monitoring of arrhythmia. We separately debug the function and stability of each module and finally integrate it into a system. Experimental tests show that the system can display various data more accurately and achieve corresponding functions.

1. Scheme design

1.1 Top-level design

The wireless motion sensor node system scheme in this article is shown in Figure 1, which is composed of an ECG detection system, a body temperature measurement system, an exercise statistics system, a single-chip computer system, a transmission system and a terminal. The ECG detection system uses the front-end chip ADS1292, the body temperature measurement system uses the LMT70 chip, the exercise statistics system uses the MPU-6050 chip, the STM32F407 microcontroller system is the control core, the ESP8266 module is the transmission system, and the Android mobile phone is the terminal. The ECG detection system, body temperature measurement system, and exercise statistics system transfer the tester's real-time data to the single-chip microcomputer through the transmission system, and then pass the transmission system to the mobile terminal and display it in real time after being processed by the single-chip microcomputer.

Figure 1. Top-level design diagram

1.2 System structure

Figure 2 shows the wireless motion sensor system diagram, which is mainly divided into three parts:

Figure 2. System structure diagram
signal acquisition, processing, and transmission. The STM32 processing module processes and analyzes the data obtained by the ECG acquisition circuit, the LMT70 body temperature acquisition circuit, and the exercise volume statistics circuit, and then packages and delivers it to the ESP8266 wireless transmission circuit at equal intervals. The mobile terminal receives the data and displays it after connecting to the server.

1.3. Scheme demonstration
This system is mainly composed of functional modules such as ECG detection module, body temperature measurement module, exercise statistics module, and wireless transmission module. The following will analyze and select some implementation schemes of functional modules.

(1) Scheme selection of exercise volume statistics
Solution 1: Use the Mpu6000 chip to calculate the number of steps through acceleration changes in three directions.
Solution 2: Use the Mpu6050 chip and add the analysis of human body inclination and posture on the basis of acceleration transformation, which can better correspond to the measured value and the actual number of steps.

Considering the requirements for the accuracy of the number of steps, option two is selected.

(2) Scheme selection of wireless transmission
Solution 1: Using Bluetooth transmission, Bluetooth low power consumption is also suitable for short-distance communication, as long as the pairing connection can send and receive data.
Solution 2: WIFI module is used for transmission based on TCP server, and the mobile phone is connected to the server through AP mode to send and receive data.

Because the development of the Bluetooth system is more complicated, and the pairing process requires two-way confirmation between the sender and the receiver, and the WIFI solution only requires the receiver to connect to the server, so the second option is chosen.

2. Theoretical analysis and calculation

2.1. ECG signal processing and heart rate calculation
The analog front end of ECG acquisition obtains 24-bit ECG data after ADC conversion, and transmits it to MCU through SPI communication to obtain the original ECG signal [1]. We derive and plot the original signal and find that there is obvious high-frequency interference. Then we analyzed it by FFT and found that the interference is mainly concentrated on the 50Hz frequency. Therefore, we need to design a low-pass filter. We set the upper limit frequency of the passband to 25Hz, and the effect after simulation by Matlab is shown in Figure 3.

The heart rate calculation can be calculated by dividing the time by the period, and the mark point can be found by peak detection.

Suppose that the number of marked points found is N, the length of the array passed from the first to the Nth is X, and the sampling frequency is Fs. Then the heart rate H can be calculated according to the formula

\[ H = \frac{60Fs(N-1)}{X} \]

At the same time, if the heart rate change is greater than the 20% threshold in a short time, an arrhythmia alarm will be issued.

2.2. Temperature calculation
LMT70 reflects the change of temperature through the change of the voltage value of its two pins. Through its technical documentation, we found that there are two ways to convert voltage into temperature, one is the second (third) order derivative formula method, and the other is the first derivative look-up table method. Since the precision is required to be in the integer range, the derivative
look-up table method is selected. The voltage acquisition uses 12-bit AD within the single-chip microcomputer, and its resolution accuracy can reach 1mV. The collected voltage values are linearly interpolated to find the corresponding parameters. The 1°C voltage difference of the look-up table method is controlled at about 20mV, so the accuracy is good.

2.3. Steps and distance realization algorithm analysis
Due to the accuracy problem of the MPU6050 sensor, there is a certain drift error, so the measurement algorithm based on Kalman filter attitude calculation is used to reduce the error and drift caused by noise and improve the accuracy of attitude parameter estimation.

![Matlab simulation effect](image1)
![Before and after Kalman filtering](image2)

After obtaining the three sets of data of roll angular velocity, yaw angular velocity and pitch angular velocity, the three angular velocity data are converted into yaw angle, pitch angle and roll angle by integral calculation. Here we use the commonly used quaternion method for posture calculation, which has a small amount of calculation and high precision. [3] If the posture parameter reaches the trigger threshold of the step number condition, a step is counted.

3. Circuit and programming

3.1. ECG part

3.1.1. ECG acquisition circuit module
According to the ADS1292 chip manual, some circuit diagrams have been obtained, so we mainly need to design the peripheral circuit. The part of the network label F in the figure is a filter circuit, which uses the impedance detection method. The 32KHz (or 64KHz) high frequency square wave is input to the human body, and then the impedance change between the two electrodes can be calculated after the circuit is filtered. Add C4 tantalum capacitors and C3 ceramic capacitors in parallel to eliminate high-frequency interference and low-frequency interference. C11-C15 and high resistance R5 and R6 form the common mode amplification of the signal, increasing the signal-to-noise ratio. Since the digital signal is collected, sharing the analog ground and digital ground does not affect the data. The designed ECG module circuit is shown in Figure 5.
3.1.2. ECG measurement and heart rate measurement algorithm
There is high frequency interference in the collected ECG signal, so use a low-pass filter to eliminate it. The filter equation can be obtained by processing the Matlab filter design parameters:

\[ y[n] = (1 \times x[n - 3]) + (3 \times x[n - 2]) + (3 \times x[n - 1]) + (1 \times x[n - 0]) \]
\[ + (0.2780599176 \times y[n - 3]) + (-1.1828932620 \times y[n - 2]) \]
\[ + (1.7600418803 \times y[n - 1]) \]

According to the equation, the corresponding filter code can be written.

Heart rate measurement is mainly to search for marked points (ECG spikes). By finding multiple consecutive marked points, the heart rate can be calculated by dividing the number of points by time. Since the ECG signal is connected to the human body, there is a baseline drift. For the problem of ECG baseline drift, we can perform signal preprocessing through moving average filtering [4], interpolation fitting method, cubic spline interpolation method [5], etc. But for heart rate, the method used in this article does not need to deal with baseline drift. The heart rate measurement mark point cannot be a fixed level, so we introduce the maximum slope point, that is, the point with the largest level change between two consecutive points. Since the points with large changes in the ECG signal are on the spike, the spike duration is much less than the heartbeat cycle, so even if the found point is not at the same position between the two cycles, it will not cause too much error.

The arrhythmia can only be monitored by monitoring the ECG cycle. If the change of two adjacent ECG cycles is greater than 20%, the arrhythmia alarm will be triggered.

3.2. Movement part

3.2.1. Steps measurement module
This module uses the MPU-6050 module, and its schematic diagram is as follows, where Q2 is a 5V to 3.3V circuit to power the chip.

3.2.2. Steps measurement algorithm
MPU-6050 provides a three-dimensional acceleration sensor and a three-dimensional inclination sensor. When a person is walking, the acceleration and inclination will change rhythmically. The number of steps can be calculated by processing the changes. Every time you walk, the acceleration will change from the positive direction to the negative direction. We use this as the main parameter to design the algorithm, and perform Kalman filtering and smoothing on the acceleration data. At the same time, the number of inclination angles is used as the second trigger threshold, which plays a double-confirmation effect on the step counting algorithm, which can reduce many misjudgments.
3.3. Android host computer design
We use Android Studio IDE to implement the interface and functions of the host computer. Its communication module uses Socket programming, and it is agreed with the client node (Single-chip multi-signal acquisition system) to use the JASON standard protocol for transmission. We use the Android open source Jason package library for analysis and programming, and convert the byte packets passed over into temperature, heart rate, step count, and waveform data. The waveform data is drawn according to the MP Android library, and a storage space is opened to manage the received data [5].

3.4. Wireless motion sensor node program flow
The execution flow chart of the wireless motion sensor node originally designed is shown in Figure 9. The system uses the STM32F407 microcontroller as the control core. ADS1292, LMT70, and MPU6050 modules provide raw data input. ESP8266 is used as a transmission module. The single-chip microcomputer receives raw data and uses internal data processing algorithms to output information such as heart rate, temperature, and steps. The ESP8266 module sends data through the TCP protocol and receives it by the mobile APP terminal. The information is displayed and the human-computer interaction is completed.
4. Conclusion

In order to meet the needs of personal daily exercise monitoring, the wireless motion transmission sensor node designed in this paper uses the STM32 single-chip microcomputer system to process the data generated by each sensor module and send it to the mobile terminal through the WIFI module for real-time monitoring, detection and management of users sports data. Once arrhythmia occurs, and the body temperature is too high or too low, it will promptly remind other life threats, so as to realize the function of vital signs monitoring. The experiment proves that the system measurement is relatively accurate. If this device is optimized, it can be transformed into a daily exercise ECG monitoring product.

References

[1] Lin Shida, Zhu Jijun. (2017) Wearable ECG monitoring system based on fabric electrodes[J]. Journal of Transducer Technology, Vol. 30(6): 944-949.
[2] Chen Gang, Wang Wei. (2016) Di Peng. Dynamic positioning optimization based on Kalman filter[J]. Ship Electronic Engineering, Vol. 36(5):60-62, 117.
[3] Zhang Jianyong, Zhao Zhongyi, Cui Yongzhi. (2020), Research on attitude measurement of unmanned vehicles based on extended Kalman filter[J]. Journal of Liaoning University of Technology (Natural Science Edition), 40(4):216-218.
[4] Momot A. (2009) Methods of weighted averaging of ECG signals using Bayesian inference and criterion function minimization[J]. Biomedical Signal Processing & Control, 4(2):162-169.
[5] Liu Yanli, Zhao Weisong, Li Haikun, et al. (2011) Research on the elimination of pulse wave signal baseline drift based on morphological filtering [J]. Journal of Hefei University of Technology: Natural Science Edition, 34(4):525-528.