Design of Intelligent Pension Online Monitoring System Under the Environment of Internet of Things

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Abstract: With the improvement of the degree of aging, the traditional pension model can no longer meet the growing needs of the elderly. Therefore, it is necessary to use the intelligent means of information technology to improve the level of pension services. This paper will integrate multi-sensor fusion technology, NB-IoT communication technology and cloud platform technology to develop and design a smart pension online monitoring system to realize real-time collection of human health and motion status information and realize monitoring platform management. In this system, STM32 microcontroller will be used as the main control module, and MAX30102, ADXL345 and DS18B20 sensors will be used to collect the heart rate, blood oxygen, displacement and body temperature of the human body in real time. On the one hand, the communication part is completed by the BC20 Internet of Things module. The data transmission between the terminal detection device and the cloud platform, on the other hand, the HC-42 Bluetooth module is used to complete the data communication with the mobile phone. The test results show that the system can collect and process data accurately in real time and maintain good communication with the cloud platform and mobile phone. The designed system has strong pertinence, easy operation, high reliability and broad development prospects.

Keywords: Smart Pension, Internet of Things, NB-IoT Communication Technology, Ali Cloud Platform

1 Introduction

At present, the problem of old-age care is increasingly concerned and valued by people. The old-age care model has also changed from traditional family old-age care to social old-age care. The traditional old-age care model will slowly withdraw from the historical stage[1]. China's pension service level is in the middle reaches, but there are still many problems, such as the lack of unified supervision and reasonable layout of pension service institutions, the low level of home care services, and the unbalanced development of community and institutional pensions[2]. Therefore, building a smart pension service system to provide a safe, comfortable and convenient living environment for the elderly is an inevitable choice to solve the pension problem in China.

At present, the Internet of Things technology has been widely used in various fields, especially in the medical and health industry, such as wearable devices, intelligent medical care, remote monitoring and nursing[3]. With the advent of the 5G era, the further development of the Internet of Things technology will provide new opportunities for smart old-age care.

At home and abroad, the construction of intelligent pension online monitoring system based on Internet of things technology is actively carried out, focusing on the integration of the overall acquisition system[4]. At the same time, it is committed to visualizing the collected data so that users and relevant medical staff can understand the health of the elderly; in addition, the data cloud processing method is optimized to facilitate the collection and analysis of regional human health information, so as to better provide strong support for the health protection of the elderly[5].

The development of intelligent nursing industry in foreign countries is relatively mature, especially in countries that have entered a serious aging, such as the United States, Britain, Japan and so on. In these countries, pension services are gradually becoming intelligent and modern. The following will focus on the architecture and development of the United States and the United Kingdom in the field of smart old-age care services.

The intelligent nursing industry in the United States adopts a market-oriented business model and introduces market competition. Large high-tech companies, such as Apple, Philips and Comet Labs, actively develop intelligent pension products, and upgrade and transform products according to the various needs of the elderly[6]. In the field of intelligent old-age care, science and technology enterprises have made significant progress, and have successfully developed smart home and elderly life auxiliary equipment, which has laid a solid technical foundation for the realization of intelligent old-age care. Continuous Care Retirement Community (CCRC) is a community care model that serves the needs of the elderly. It provides a wide range of services, such as elderly care, health management and home care, aiming to provide a full range of care for the elderly[7]. CCRC uses information technology to realize real-time monitoring of the health status of the elderly through an intelligent information platform, and connects to a remote health management platform to realize data sharing between medical institutions and communities. On this basis, the elderly can be dynamically managed.

In recent years, the British government has been committed to building a smart elderly care service system to provide more convenient, professional, efficient and intelligent medical care services for the elderly, so as to improve the quality of elderly care services. In order to achieve this goal, the government has taken measures to encourage pension institutions and enterprises to innovate the existing pension service model, implement the intelligent pension service system, and create a better living environment and conditions for the elderly[8]. In 2011, the University of Hertford born the smart home system-'Inter Home'. The system can detect the vital signs of the elderly and realize remote monitoring of medical staff and family members by wearing wristband devices and using wireless network connections. With the popularity of the community home care model, the United Kingdom has introduced the concept of combining medical care with nursing care in the community, and created a comprehensive intelligent platform called "Internet + pension" and "Internet + medical care." These platforms use information technology such as the Internet and remote monitoring to meet the three different needs of the elderly for independent living, assisted living and professional care. These measures aim to provide convenient, professional, efficient and intelligent medical care services for the elderly[9].

Through research, it is found that more and more people abroad use remote monitoring to monitor the elderly, but they cannot better adapt to the changing needs of the elderly. The use of space is isolated and not universal[10].

At present, many enterprises and researchers in China provide intelligent services such as medical care and life services for the elderly by means of the Internet, the Internet of Things, big data and other technical means.

In order to better meet the nursing needs of the elderly, Liu Sihua et al. carried out research on the application of intelligent wearable devices for elderly care in 2020. The study found that the use of smart wearable devices can more accurately and more effectively collect the work data of nursing staff, so as to

better understand their work. This is of great significance to improve the quality of nursing service for the elderly. Most importantly, the study shows that wearable devices can be used to optimize the home care service model, and the recognition accuracy of nursing behavior is high. This will provide more comfortable home care services for the elderly, and more intelligent and efficient working methods for nursing staff. In summary, the research on intelligent wearable devices for elderly care is of great significance. It will provide better nursing services for the elderly and provide more scientific and standardized working environment and methods for nursing staff[11].

In 2021, Huang Huanhuan et al. proposed a design scheme of smart pension platform based on hybrid perception model, and developed a smart pension platform based on this model. This platform relies on a hybrid perception model, through sensors, smart devices and other technologies, to complete the monitoring and service of the health data of the elderly. For example, through professional algorithm model monitoring, monitoring the heart rate, blood oxygen saturation, blood pressure and other key indicators of the elderly, timely remind the elderly to carry out corresponding medical care. Through experiments, Huang Huanhuan and others proved the effectiveness of the intelligent pension platform. The platform can not only improve the quality of life of the elderly, but also provide them with better medical care and life services. This is a very meaningful research result, which is of great significance to alleviate the plight of the elderly at home and promote the health and happiness of the elderly[12].

In summary, the research direction of domestic pension services is mainly about the function, form, equipment products and facilities space location of the pension environment, and has carried out in-depth discussion and detailed exploration, emphasizing the design focus of the nursing home space suitable for the elderly. However, the elderly in traditional old-age care institutions are faced with many inconveniences. Whether it is from various furniture products to the use of equipment, or from the living environment to the activity place, combined with many aspects to consider, traditional old-age care institutions can not provide a more comfortable old-age care space for the elderly. In view of the above problems, it is particularly important to design a more intelligent management system scheme for traditional pension institutions, so as to realize the interconnection and interoperability of equipment products, family facilities and guardian information[13].

This paper designs an online monitoring system for intelligent elderly care based on the Internet of things, which can monitor the changes of heart rate, blood oxygen data, body temperature and spatial displacement of the subjects in real time. At the same time, it intelligently stores and manages user data information on the PC side, so that managers can view user-related information at any time. Mainly to achieve the following functions:

(1) Realizing the collection of heart rate and blood oxygen data of the elderly;

(2) The realization of the elderly body temperature measurement;

(3) Realize the monitoring of the displacement change of the subject;

(4) View, store and manage data on the cloud platform;

(5) Real-time display of detection data on the mobile phone.

2 System Overall Scheme Design

2.1 System Overall Scheme Analysis

The design of the intelligent pension online monitoring system in the Internet of Things environment takes the microcontroller as the control core, and uses the heart rate blood oxygen sensor and the attitude sensor as the measurement components. The collected data is uploaded to the cloud platform through the NB-IoT module, and the control commands transmitted from the cloud are accepted at the same time. The function of intelligent pension online monitoring is realized, and the requirements of the whole system are completed[14]. The overall architecture diagram of the design of the intelligent pension online monitoring system in the Internet of Things environment is shown in Fig.1:

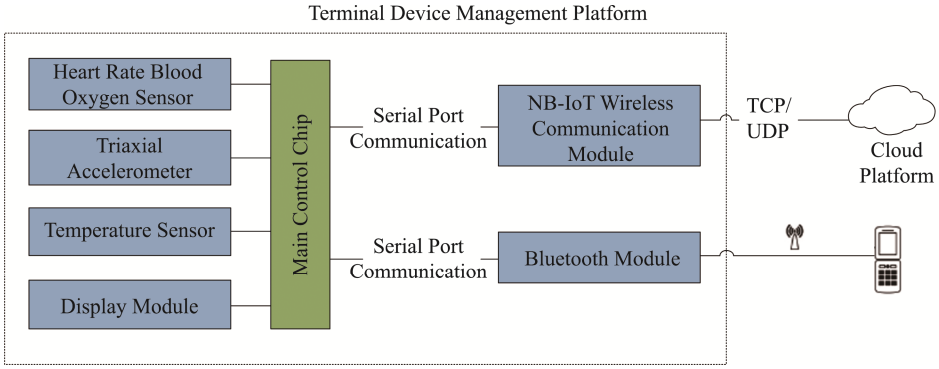

Fig.1 Overall Architecture of the System

2.2 System Function Analysis

(1) System Scheme Implementation

The design of the intelligent elderly care online monitoring system based on the Internet of Things environment is based on the cooperation of STM32 microcontroller, MAX30102 heart rate blood oxygen sensor, ADXL345 triaxial accelerometer and DS18B20 temperature sensor module. The data is transmitted to the cloud platform through the NB-IoT module and the HC-42 Bluetooth module is transmitted to the mobile phone, and the upper layer instructions are monitored at the same time. The overall scheme is shown in Fig.2.

(2) Acquisition End

The collecting terminal is mainly composed of MAX30102 heart rate blood oxygen sensor, ADXL345 acceleration sensor, DS18B20 temperature sensor module and related circuits. It is responsible for the high-frequency acquisition of heart rate blood oxygen, three-axis acceleration and body temperature, and transmits the collected analog signal to the control terminal through the IIC bus for subsequent data processing. The main functions are as follows: 1) to realize the detection of the heart rate and blood oxygen signal of the subject to be tested; 2) to realize the acceleration value (unit m/s^2) on the x, y, z axis of the high frequency acquisition; 3) to realize the temperature detection of the subject to be tested.

The collected signal is transmitted to the main control chip by AD conversion to wait for processing.

(3) The Controlling End

The STM32F103C8T6 single-chip microcomputer is used as the control terminal, which is responsible for receiving the data collected by the terminal hardware, and further outputs the results to the liquid crystal display screen through data processing.

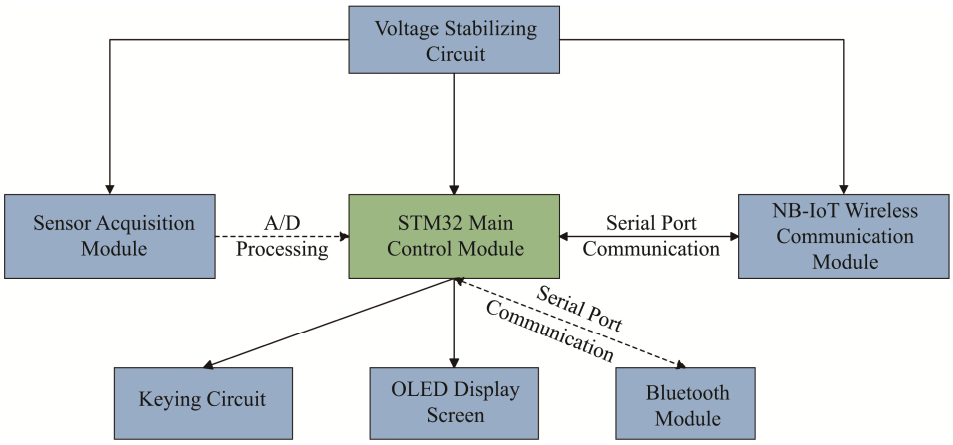

Fig.2 System Hardware Connection Schematic Diagram

Monitor the upper cloud commands and perform related actions.

(4) Server

The server is mainly composed of Ali cloud platform, which is responsible for managing terminal equipment, data transmission and management.

Through the Bluetooth module, the collected data is transmitted to the mobile phone.

3 System Hardware Design

3.1 Master Module

STM32F103C8T6 single chip microcomputer is selected as the control system of this intelligent pension online monitoring system. STM32F103 is a 32-bit microcontroller with high performance and suitable for embedded applications. The series of single-chip microcomputers have multiple DMA channels. In the Internet of Things environment, the intelligent pension online monitoring system has higher requirements for data processing and analysis speed and overall stability of the system.

As the core control module of the whole system, the function of the single-chip microcomputer is mainly responsible for collecting terminal sensor data and communicating with the NB-IoT module. The chip supports multiple interfaces and supports multi-channel advanced control timers. It can be used to drive ADCs with excellent performance and very low power consumption[15].

3.2 Power Module

In the system design, we need to supply power to the whole system, we choose to use USB output power supply. In the design of power supply circuit, we should first consider the power supply voltage required by each module, and then design the corresponding circuit. The power supply in the hardware circuit is: STM32 control module (operating voltage 3.3V), sensor acquisition module (operating voltage 3.3V~5V), NB-IoT module (operating voltage 2.2V~3.62V), HC-42 (operating voltage 1.8V~3.6V). The whole system should give priority to meet the microprocessor 3.3V optimal voltage. In order to meet the system requirements, it is necessary to design a reliable and stable voltage stabilizing circuit, which converts 5V voltage into 3.3V voltage as the power supply voltage of the system[16]. The wiring diagram is shown in Fig.3.

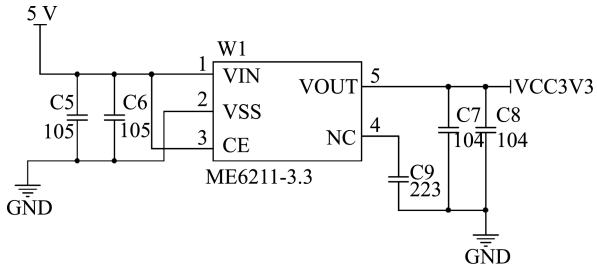

Fig.3 Wiring Schematic Diagram of Voltage Stabilizing Circuit

3.3 Heart Rate Blood Oxygen Acquisition Module

This design needs to detect the heart rate and blood oxygen level of the elderly in real time. We use the MAX30102 heart rate and blood oxygen sensor with high precision and low price to complete the data collection of the heart rate and blood oxygen of the subject.

The sensor integrates infrared light-emitting diodes, photodiodes and signal processing circuits, supports multiple working modes, and provides continuous non-invasive heart rate monitoring. And MAX30102 adds a low-noise electronic circuit with ambient light suppression inside, thereby increasing the sampling rate and reducing power consumption. Therefore, the use of MAX30102 can better ensure the stable endurance of the system for a long time, and achieve more accurate and reliable heart rate and oxygen saturation monitoring[17].

The chip is divided into two parts: analog signal acquisition circuit and digital processing circuit. The analog signal acquisition circuit is responsible for photoelectric signal conversion and solves the problem of signal attenuation. The digital processing circuit filters the data, reads and writes into the internal register, and sends the data to the main control module for further processing. Considering the speed, accuracy and stability of data transmission, digital signal processing usually requires the use of high-speed ADC conversion circuit for analog-to-digital signal conversion. The circuit schematic is shown in Fig.4.

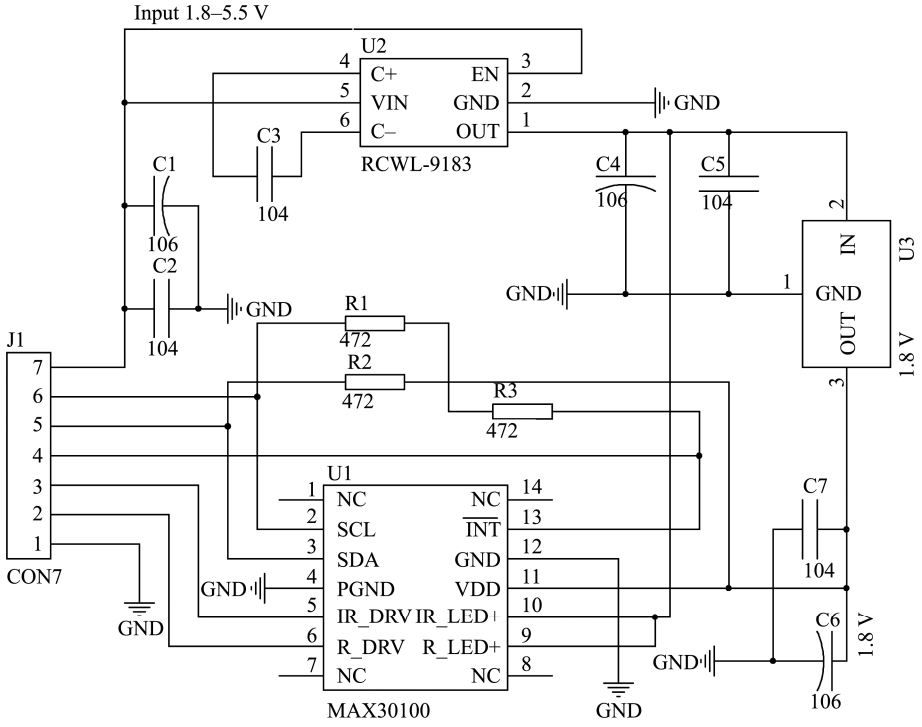

Fig.4 MAX30102 Circuit Schematic Diagram

3.4 Displacement Detection Module

This design requires real-time detection of the spatial displacement of the elderly in order to detect abnormalities in time. In order to realize this function, the system adopts ADXL345 three-axis accelerometer, which is a three-axis accelerometer. It can measure the acceleration in x, y and z directions, and directly output digital signal, which has the characteristics of fast response. The sensor integrates IIC and SPI interfaces to facilitate communication with the main control module without AD conversion.

In the detection, the system selects 'acceleration' as the main parameter. Human motion includes three components: forward ('rolling'), vertical ('yaw') and lateral ('pitch'). In order to accurately detect the movement of the elderly, it is necessary to detect the acceleration on the three axes of X, Y and Z in real time. In this way, the number of steps and displacement distance can be accurately recorded, so as to provide better care and protection for the elderly. The circuit schematic is shown in Fig.5.

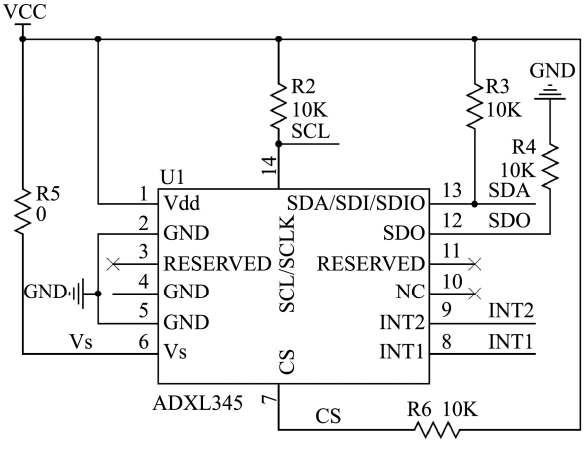

Fig.5 ADXL345 Circuit Schematic Diagram

3.5 Temperature Detection Module

In order to detect the temperature of the subject and find out the abnormal situation in time, the DS18B20 temperature sensor is used in this design. The sensor has powerful functions and can measure the temperature in the range of −55°C to +125°C. The circuit is simple and easy to expand. Only one interface

pin is needed to realize information communication, which is convenient for program development and debugging. And its price is more affordable.

3.6 Display Module

From the point of view of the acquisition and display of the whole system, we select the OLED liquid crystal display as the display module. This module is suitable for systems with high display requirements and high display frequency. Using self-luminous OLED display technology, no backlight, power saving and high contrast, it can show good display effect in different scenes; in addition, OLED has a fast reaction speed and can achieve smoother image display.

The collected human heart rate, blood oxygen and displacement information are displayed on the OLED liquid crystal display through the SPI communication protocol. The single chip computer transmits the data to the display screen through the serial port. When there is a current flowing through the organic light-emitting diode screen, the diode in the screen will emit bright light, and the processed data signal will be synchronized to the OLED display and converted into a visual signal displayed on the screen. This facilitates the observation of data signals[18].

3.7 Bluetooth Module

HC-42 Bluetooth module is selected. HC-42 Bluetooth communication module is a device with excellent performance and high power efficiency, which can provide Bluetooth communication function of 5.0 protocol. It has the characteristics of low energy consumption, stable work, high efficiency and wide applicability. By using the HC-42 module, we can achieve fast, stable and efficient Bluetooth communication and improve the stability of the entire system.

3.8 Internet of Things Communication Module

There are a large number of users to be monitored in scenarios such as community pension, so we choose the BC20 module with simple networking and massive capacity as the Internet of Things communication module of the intelligent pension online detection system. The module supports GNS positioning, high performance, low power consumption, and fully built-in interfaces and protocol lines. It can be used in the NB-IoT environment and is widely used in smart agriculture, smart pension and other fields. Based on the existing cellular network, the capacity of single network access node can reach 200,000.

4 Software Design

The system software design mainly includes the following seven parts: main control program design, heart rate blood oxygen acquisition program design, displacement acquisition program design, temperature acquisition program design, Bluetooth communication program design, NB-IoT module program design and cloud platform development.

(1) Main Control Program Design

The main control program mainly realizes system initialization, heart rate, blood oxygen, body temperature and displacement data detection, data upload server and monitoring upper instructions[19]. The main control program flow chart is shown in Fig.6:

(2) Heart Rate Blood Oxygen Acquisition Program Design

The system collects the user's heart rate blood oxygen data by the MAX30102 sensor. In the actual detection process, the LED lamp and the infrared light are measured in turn, and the reflected light after contact with the skin is accepted by the photosensitive triode. After A/D conversion and amplification, it is stored in FIFO, and the collected signal data is obtained by IIC when accessing. The program design process is shown in Fig.7.

(3) Displacement Acquisition Program Design

In this system, the acquisition of displacement information for users is completed by the ADXL345 three-axis acceleration sensor. Firstly, the initialization self-test is carried out, and then the X, Y and Z axis data are collected through automatic detection. Finally, through data processing, the number of walking steps is calculated and the data is output. As shown in Fig.8, the ADXL345 sensor data acquisition process.

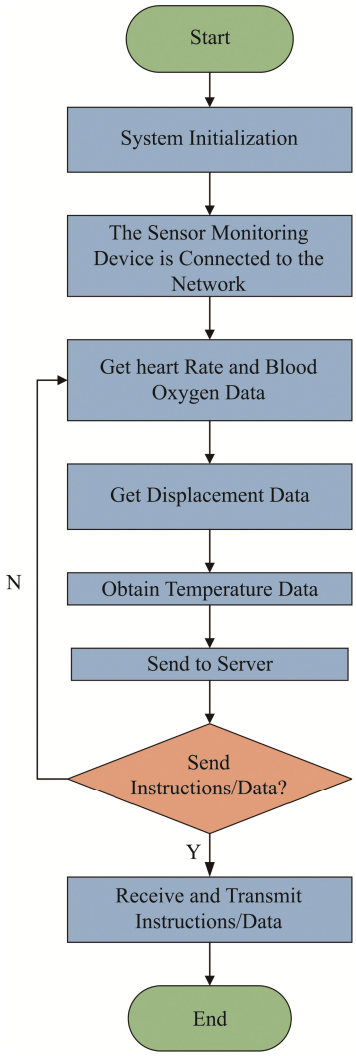

Fig.6 Main Program Control Flow Chart

(4) Temperature Acquisition Program Design

In this system, the collection of the user's body temperature data is completed by the DS18B20 sensor. Before use, the sensor needs to be initialized. Then, in a specific period of time, the collected body temperature data is stored in DS18B20 by writing data. Finally, the stored data is read from DS18B20 during the period of reading data. Fig.9 is the flow chart of DS18B20 sensor data acquisition.

(5) Bluetooth Communication Program Design

There are two ways for Bluetooth module to realize data communication. One is to use the serial communication of STM32 microcontroller to transmit the detected information directly to the Bluetooth module, and then communicate with the mobile phone through Bluetooth. The other is the communication with the mobile phone, which needs to be set through the AT command and enter the serial port transmission mode. As shown in Fig.10, the HC-42 Bluetooth module communication process.

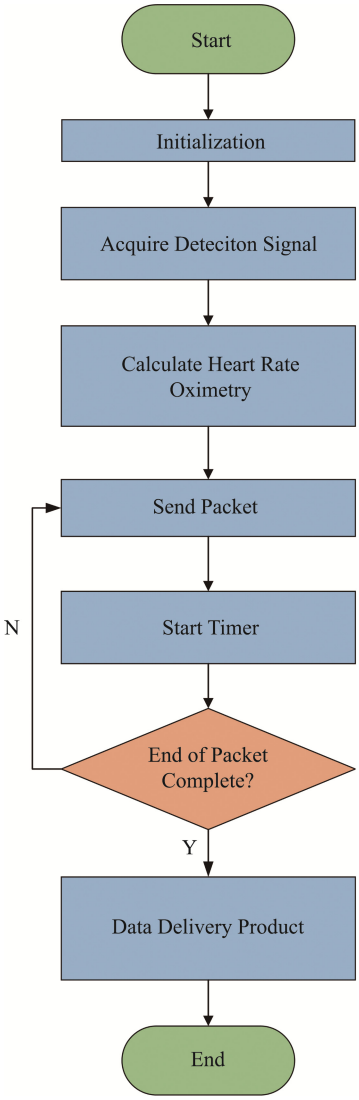

Fig.7 Flow Chart of Heart Rate Blood Oxygen Acquisition

(6) NB-IoT Module Program Design

NB-IoT module communication can be divided into two parts. The lower communication is through the USART serial port, the NB-IoT module and the STM32. Firstly, STM32 processes the collected data and sends

it to the data buffer, and then sends the data bit by bit to the NB-IoT module. If STM32 receives data, the process is the opposite; the upper communication is the communication between the NB-IoT module and the cloud platform. There are many matching communication protocols, such as MQTT, TCP/UDP, LWM2M. According to the design, the TCP/UDP protocol is selected to realize the communication with the cloud platform and carry out data transmission[20]. As shown in Fig.11, it is the NB-IoT wireless communication data transmission process.

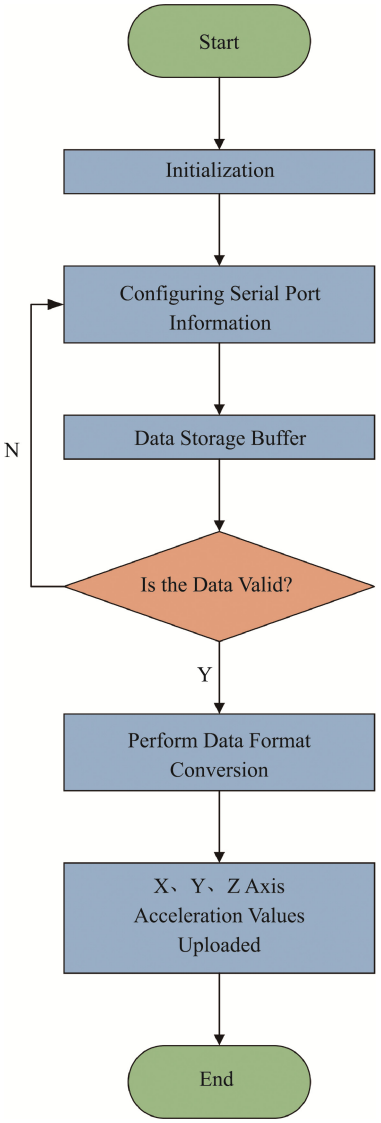

Fig.8 Flow Chart of Displacement Acquisition Program

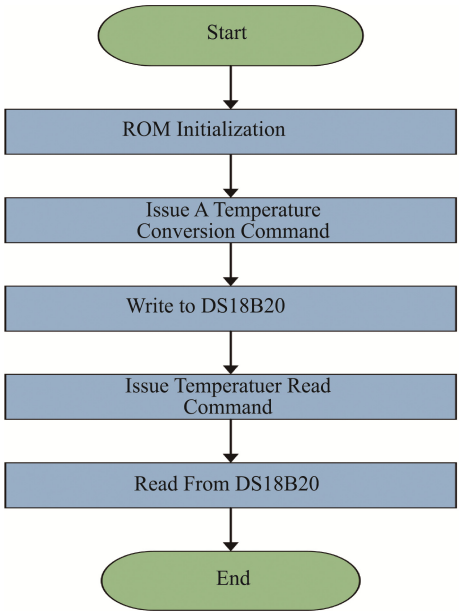

Fig.9 Flow Chart of Temperature Acquisition Program

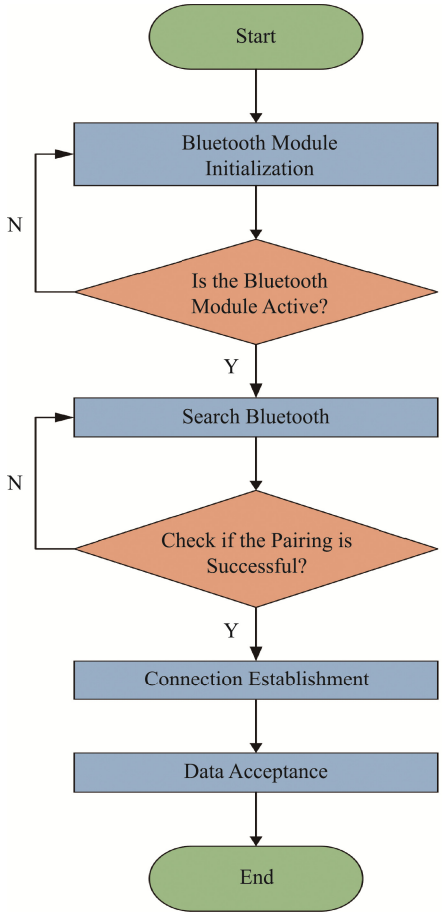

Fig.10 Flow Chart of Bluetooth Communication Program

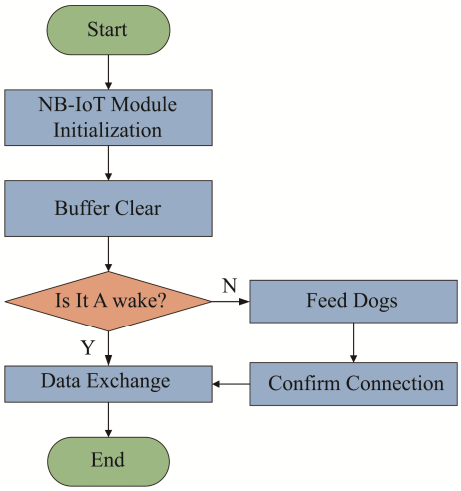

Fig.11 Flow Chart of NB-IoT Communication Module Program

(7) Cloud Platform Development

The main function of the cloud platform is to realize the storage and processing of user data, and to analyze and mine user data[21]. In this design, Alibaba Cloud platform is selected to provide a comprehensive Internet of Things solution for smart elderly care and smart hardware devices, which can realize the development, deployment and management services of the product[22]. As shown in Fig.12, it is the process of Alibaba cloud platform equipment entering the network.

After the cloud platform registration is completed, the relevant configuration of the server is performed by managing the security group, such as port and attribution network group, etc.[23]

5 Experimental Verification

This design collects the data of blood oxygen, heart rate and displacement of the elderly through the human body sensor, the NB-IoT module transmits data to the ECS cloud server on the Alibaba Cloud platform. In order to verify the feasibility of this system, this article tests the automatic acquisition module, Bluetooth communication module and cloud platform communication module respectively.

5.1 Automatic Acquisition Module Test

The experimenter placed the finger near the sensor, and MAX30102, ADXL345 and DS18B20 can normally collect the information of human heart rate, blood oxygen, body temperature and spatial displacement.

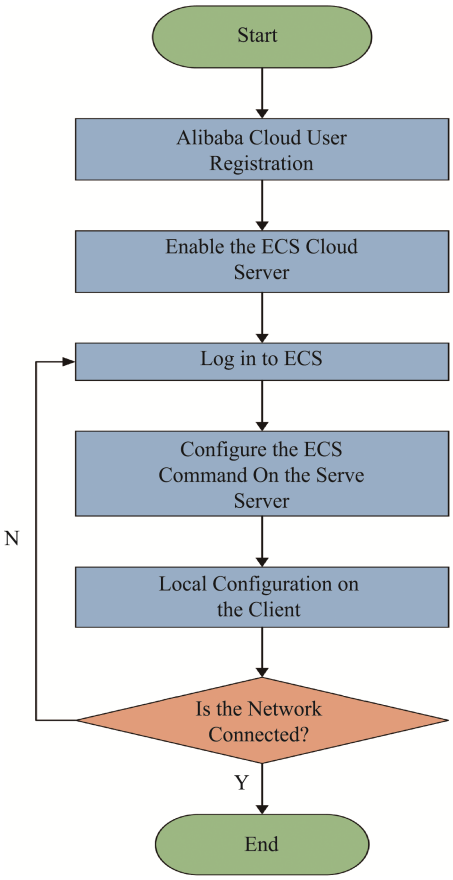

Fig.12 Ali Cloud Platform Equipment Networking

5.2 Bluetooth Communication Module Test

Through the Bluetooth debugger, the HC-42 Bluetooth module can communicate with the mobile phone normally, and realize the real-time transmission of data, which is consistent with the data on the OLED display.

5.3 Cloud Platform Communication Module Test

After completing the ECS server setting, enter the virtual machine, call the network debugging tool, and observe that the data is successfully received and the data is displayed correctly.

5.4 Experimental Result

The experiment was carried out at room temperature of 25℃. The body temperature (finger temperature), heart rate and blood oxygen saturation of the experimenters were measured ten times to obtain the mean value, and the measured mean value was compared with the actual mean value. The results are shown in Table 1. It can be seen from the table that the temperature (finger temperature), heart rate and blood oxygen saturation values measured by the system are more accurate.

Table 1 Ratio of the Measured Average to the Actual Average

Measurement Content	Measured Average	Actual Average	Differentials
Body Temperature (℃)	27.6	30	2.4
Heart Rate	88	80	8
Oxyhemoglobin Saturation (%)	91	98	7

6 Conclusion

In order to provide an efficient management mode for guardians and a safer, more comfortable and more convenient living environment for the elderly in services such as home-based care for the elderly, community-based care for the elderly and nursing homes, this paper designs an intelligent online monitoring system for the elderly based on the Internet of Things environment. The system realizes the automation of intelligent monitoring, automatically collects the user's heart rate, blood oxygen, body temperature and spatial displacement data, transmits them to the cloud server, realizes the real-time and visualization of data monitoring, effectively improves the shortcomings of the traditional pension model, and greatly improves the work efficiency of managers.

NB-IoT technology is a new Internet of Things technology. Due to its low power consumption and wide coverage, it can realize long-term low power consumption operation of sensors and meet the requirements of low delay and high reliability of sensors. Therefore, this system can realize the long-term stable operation of the equipment with the help of NB-IoT technology, which greatly reduces the cost of equipment management.

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