A radio frequency based positioning and alarm device for rural nursing homes for the elderly

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Abstract: In order to solve the problem of poor management in rural nursing homes in China, this paper studies the positioning equipment's precise range, reliability, anti-interference ability and scope of application using the wireless sensing theory, GPS positioning technology, RFID technology, sensor technology and GSM wireless communication technology. Based on this, a kind of practical wireless intelligent positioning equipment is developed for the remote monitoring and real-time positioning in the daily life of the nursing home to facilitate finding the elderly in great need of emergency services and improve equipment efficiency. It can monitor the elderly's heart rate in real time and call for help in time in case of heart rate abnormalities to reduce the waiting time for rescue. It has accurate positioning both indoors and outdoors, easy to carry with low cost. And it can meet the needs of future elderly nursing services, not only facilitating the nursing staff's management, but also protecting the safety of the elderly.

Keywords: rural nursing homes, wireless Sensor, heart rate monitoring, remote monitoring

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1 Introduction

Population aging is an inevitable phenomenon in the process of population development. According to the United Nations Population Organization, it indicates to be an aging society in a country or region if the proportion of the population over 60 years of age (including 60 years old) reaches 10% of the total population, or the proportion of the elderly population over 65 years (including 65 years old) accounts for 7% of the total population (Bao, 2010; United Nations). China has entered into the aging society early in the year of 1999 (Kou, 2012). According to the results of the sixth census, the total population of China is 1.37 billion, of which the population of people aged 60 and above is 178 million, accounting for 13.26% and 2.93% higher than the fifth census. The population aged 65 and above is 1.2 billion, accounting for 8.9% and 1.9% higher compared to the fifth census. At the same time, the degree of rural population aging in China has reached 15.4%, 2.14% higher than the national average of 13.26%, and higher than the urban aging level (Creedy and Guest, 2008; Wang, 2012; Office of the National Committee on ageing).

On the one hand, the development of urban population aging in China has shown a trend of being empty nest. In 2007, China's empty nest elderly family accounted for 25% of the total elderly family with the number of 23.4 million. It is estimated that by 2030, the proportion of our country's empty nest elderly family may reach 90%, when our elderly families will be completely 'empty nest' (Li, 2007). On the other hand, the policy of reform and opening up has provided large-scale rural migration opportunities to the rural labor force, which leads to the growing of the rural "left-behind population" (Yin and Huang, 2011). The relocation of the labor force of the township has made the rural areas faced with enormous pension pressure and severe challenges since it has the

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level of aging far more than the city's (Yu, 2012; Liu, 2013).

The urban and rural differences in economic fundamentals and system of organization result in the different development of urban and rural pension situation. At present, the old-age service agencies and facilities are relatively sound in some large cities, while there are many problems and difficulties in operation and management in rural areas, due to many reasons such as system construction, economic level, historical legacy and etc., in which the most serious is the security risks (Cuddihy et al., 2003).

In recent years, many universities and research institutions have carried out various human-centered research work aiming at improving the quality of the elderly life with the support of the government and society in the western developed countries, especially in the United States and Japan. Compared with the western developed countries, the majority of the current domestic research for the elderly still remains in a passive level featuring as medical care and the overall technology level lags behind, because of our research in intelligent monitoring technology started relatively late and lacked enough investment (Pan, 2013; Wang and Liu, 2012).

Considering the aging trend and poor management of nursing home in China, this paper designs a kind of wireless intelligent positioning device with the functions of indoor and outdoor positioning, heart rate real-time monitoring, one-button call and autonomous alarm, etc., through the research of intelligent monitoring at home and abroad. It has combined the RFID technology, GPS positioning technology, sensor technology and communication and network technology to conduct remote monitoring and real-time positioning for the daily life of the elderly in the nursing home. It is in line with the needs of future nursing services and has a broad market prospect since it can not only facilitate the management of nursing homes, but also protect the safety of the elderly.

2 Principle

2.1 Overall hardware module

2.1.1 Microprocessor module

Microprocessor is the core of the system hardware. Considering the performance, price and other parameters, the IAP15W4K48S4LQFP48 chip was adopted with its schematic diagram shown in Figure 1. It works at 28 MHz with the program space of 48 KB and SRAM space of 4 KB, and it is featured as low power consumption, high cost effective, high performance, multi-I/O port, being easy to use, small size and being easy to extend and so on. It is very suitable for the development of handheld and mobile terminal equipment.

With the combination of industrial computer and mobile terminal, it has fulfilled real-time and accurate supervision of the elderly personal safety through real-time positioning indoor and outdoor, intelligent rounds, special room overtime alarm and heart rate information monitoring.

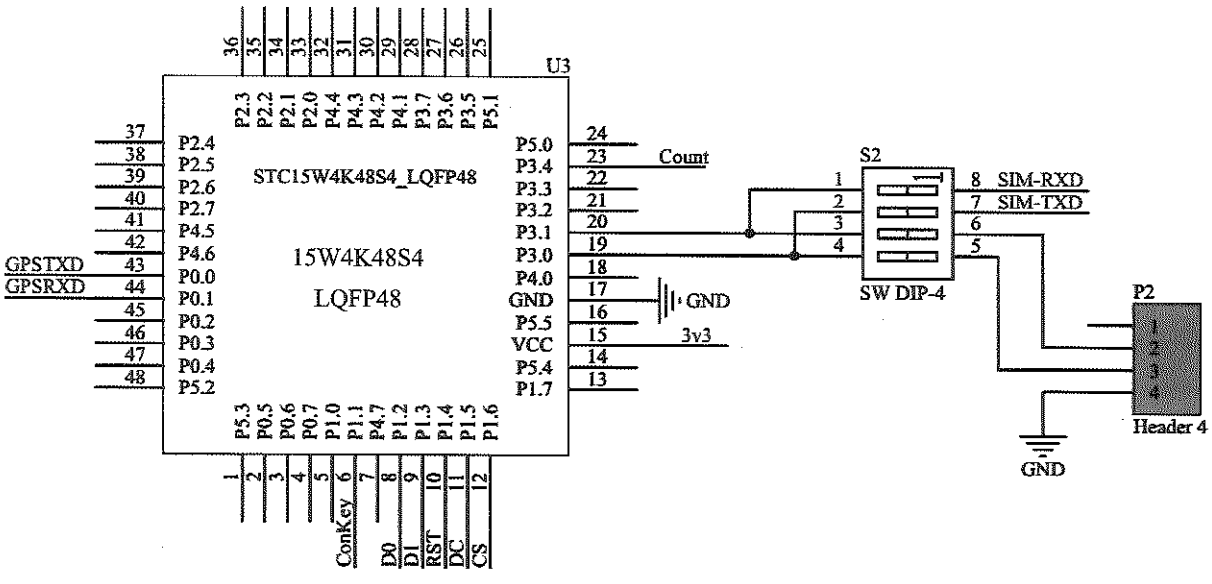

Figure 1 Schematic diagram of the microprocessor

2.1.2 Radio Frequency Identification Module

It uses the MFRC522 in the system, the schematic diagram shown in Figure 2. It is a kind of chip applied in 13.56 MHz non-contact communication of highly integrated level, the internal transmitter part of which can drive the reader antenna and ISO 14443A/MIFARE card to communicate with the answering machine, with no other circuit needed. The receiver section provides a robust and efficient demodulation and decoding circuit for handling ISO14443A-compatible transponder signals. The digital section handles with the ISO14443A frames and error detection (parity & CRC). In addition, it also supports the fast CRYPTO1 encryption algorithm to validate the MIFARE family of products. The MFRC522 supports MIFARE-family higher speed non-contact communication, two-way data transfer rate up to 424 kbit/s. It is also possible to select one of modes such as SPI, I2C or serial UART (similar to RS232) according to different user requirements, which is helpful to reduce the connection, the PCB board size and cost (Wang et al., 2014; Zhu et al., 2012; Guo et al., 2011).

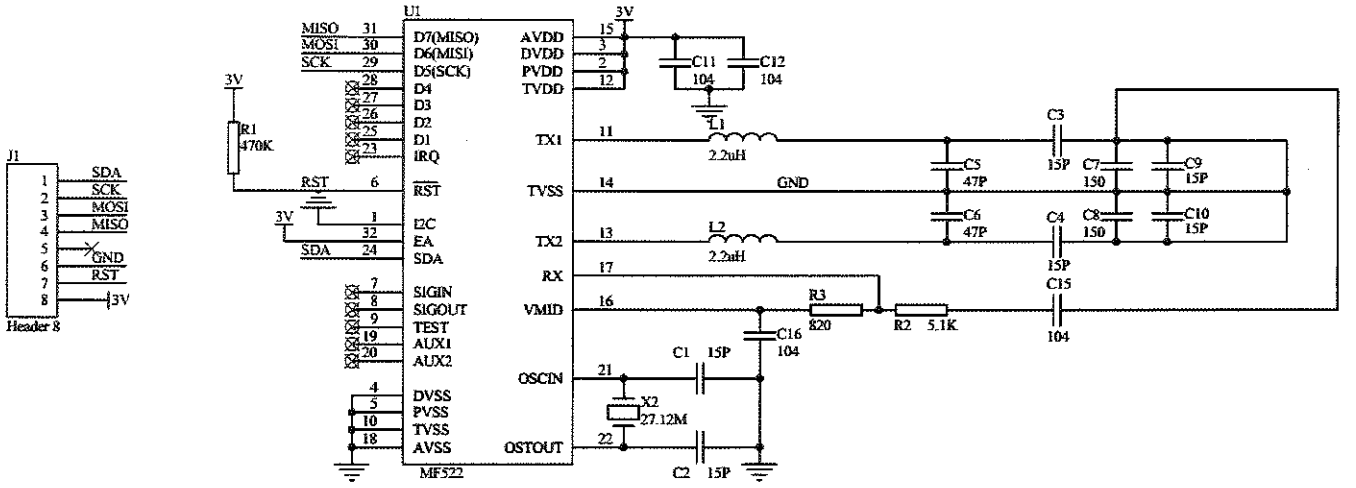

Figure 2 The schematic diagram of MFRC522

The electrical part of the radio frequency card within the mobile terminal consists of only one antenna and an ASIC. The antenna is only a few sets of winding coil, very suitable for packaging. The ASIC consists of a high-speed (106KB baud rate) RF interface, a control unit and an 8 Kbit EEPROM.

The reader has a set of fixed frequency of electromagnetic waves to the mobile terminal. The mobile terminal has an LC series resonant circuit whose frequency is the same as that of the reader. Under the excitation of the electromagnetic wave, the LC resonant circuit resonates so that there generates charge in the capacitor. The other end of the capacitor is connected to a one-way conduction electronic pump, which transfers the charge within the capacitor to another capacitor for storage. When the accumulated charge reaches 2 V, the capacitor can be used as power supply to provide operating voltage for other circuits, which helps to send out the data in the card or access to the reader data.

One can be identified as the only user by the radio frequency identification module since each RF card has unique information.

2.1.3 GPS positioning module

The system uses U-BLOX NEO-M8N-0-01, a high-precision GPS positioning module, its schematic diagram shown in Figure 3. The U-BLOX M8 can simultaneously acquire and track different GNSS (Global Navigation Satellite) systems, that is, parallelly receive GPS (QZSS) and GLONASS or BeiDou, or both receive GLONASS and BeiDou. This platform is specifically suited for high-performance applications that require the highest availability and accuracy even in the environment where GPS signals are poor (especially in the urban canyons). As the optimal positioning of the GPS/SBAS operation can be achieved in the clear sky conditions, the M8 platform is also equipped with a built-in intelligent automatic switching function. It can be automatically switch to a single GNSS operating mode according to the visibility and reliability of the GNSS satellites (Zhou et al., 2012).

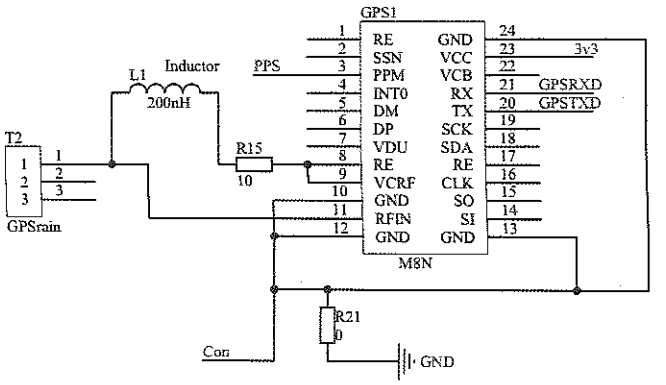

Figure 3 Schematic diagram of positioning module

U-BLOX M8 also offers long offline A-GNSS (GPS and GLONASS) function. With the U-BLOX's AssistNOW A-GNSS service, the offline support data can be valid for up to 35 days.

It is a comprehensive consideration of power and efficiency to select this chip, because it has a high rate of regeneration and supports both of the Beidou and GPS signals with low power consumption, fast positioning speed, high positioning accuracy.

2.1.4 GSM communication module

The system uses SIMcom's SIM800c module, the schematic diagram is shown in Figure 4. The module can support four bands of GSM/GPRS, namely, GSM850, EGSM900, DCS1800 and PCS1900MHz. The reason of selection of this chip is that it has low power consumption, high compatibility, small size and so on so as to meet the requirements of power consumption and communication. Meanwhile, it also meets the requirements of the wearable equipment. The positioning information and the heart rate module data are sent out to the industrial computer directly via SMS through the GPRS network. After receiving, the computer processes the information and data by the microprocessor module to timely determine the location coordinates and supervise the heart rate information in order to ensure the elderly personal safety (Chen et al., 2015; Sheng et al., 2012).

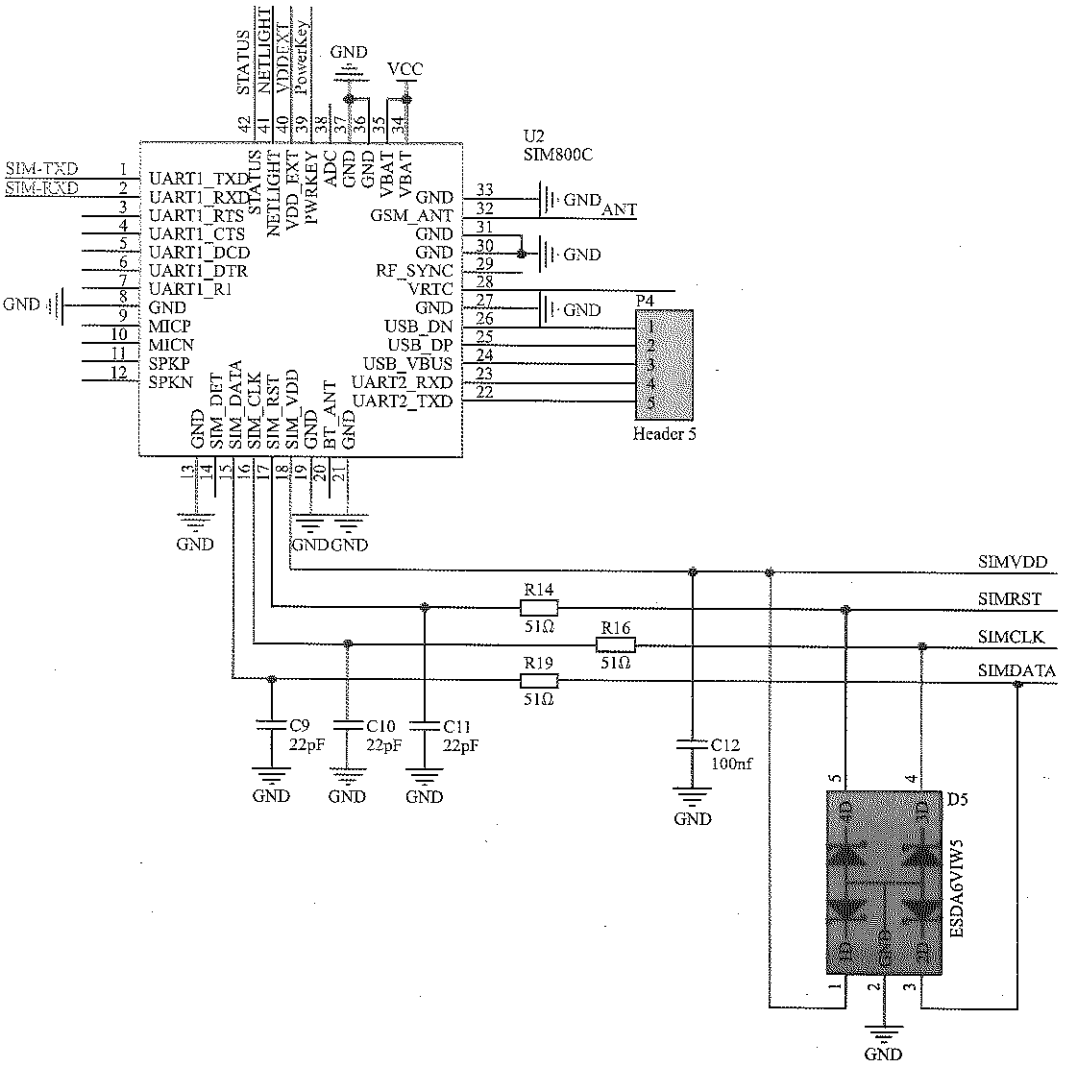

Figure 4 Schematic diagram of communication module

2.1.5 Heart rate sensor

The photoelectric heart rate sensor, son1303, can be placed in various parts of the human body to test human heart rate and pulse. The use of reflective photoelectric sensor, combined with the son3130 op amp, ensures a more flexible measurement, the scope of application including wearable electronic products and pulse measuring instruments of new test methods. The sensor integrates a high-tech nano-coating environment to filter unwanted light sources and reduce misjudgment from interferences of other sources. The SON1303 uses green light of 570 nm luminous wavelength, with higher reflectivity and sensitivity compared with the infrared light. And meanwhile, it improves the S/N ratio with higher accuracy.

The 3D simulation diagram of the mobile terminal and heart rate sensor circuit board are shown in Figures 5 and 6. The heart rate sensor is mounted on the back of the mobile terminal.

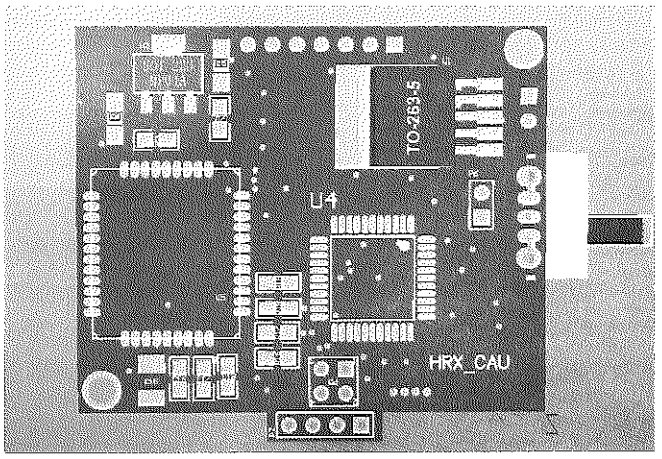

Figure 5 Circuit board of the mobile terminal (back)

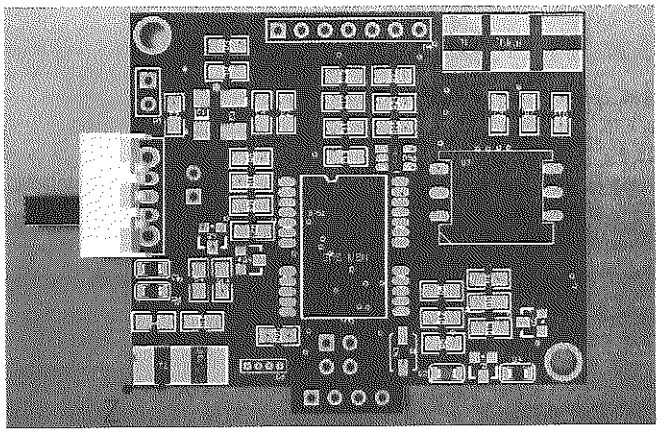

Figure 6 Circuit board of the mobile terminal (front)

2.2 Workflow

The system workflow chart is divided into three parts: the mobile terminal to collect data (Figure 7), the wireless network with two-way transmission of data, and the industrial control computer's analysis and processing data (Figure 8). The RFID detection model is shown in Figure 9 and the system communication model is shown in Figure 10.

After the mobile terminal system is powered on, the modules are initialized, and the GSM module initiates the connection to the server. After the connection is successful, the information is sent to the microprocessor through the serial port. The GPS module initiates communication to the satellite, and sends the relevant information to the microprocessor through the serial port. The heart rate sensor sends the user's heart rate data back to the microprocessor in real time. The microprocessor waits for instructions and instantly sends AT command to the GSM module if it finds there are heart rate monitoring data abnormalities or the elderly takes the initiative to press the call button in the process. Then the GSM communicates with the industrial control computer or calls the emergency contact in the form of text messages or telephone through the wireless network as well as promptly notifies the relevant medical staff. The GPS module sends the positioning information to the microprocessor in real time, which will detect if the positioning data is abnormal, so as to determine whether the elderly have security risks (Home telemedicine monitoring and consulting intelligent systems, 2001; Maybank and Tan, 2000; Naylor and Attwood, 2003). If it finds the elderly's location information is abnormal, the microprocessor immediately sends the AT command to the GSM module, which will inform the relevant medical staff by SMS and telephone, thus to ensure the health and environmental safety of the elderly.

After the industrial computer system is powered on, the modules are initialized. The GSM module initiates the connection to the server. After the connection is successful, the information is sent to the microprocessor through the serial port and displayed on the LCD screen. The RFID radio module starts and waits for the user to enter the recognition area. When the user enters the recognition area, the RFID radio module identifies the user information, informs the microprocessor through the

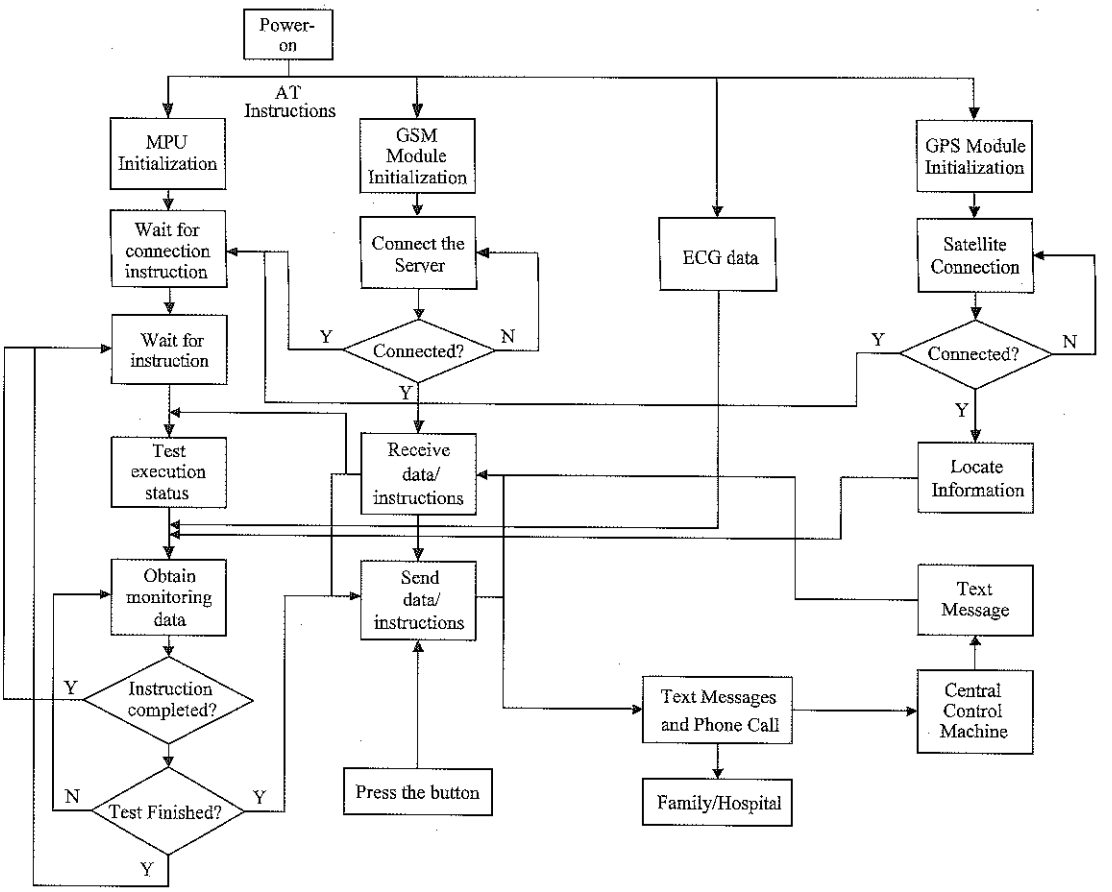

Figure 7 Working flow chart of the mobile terminal

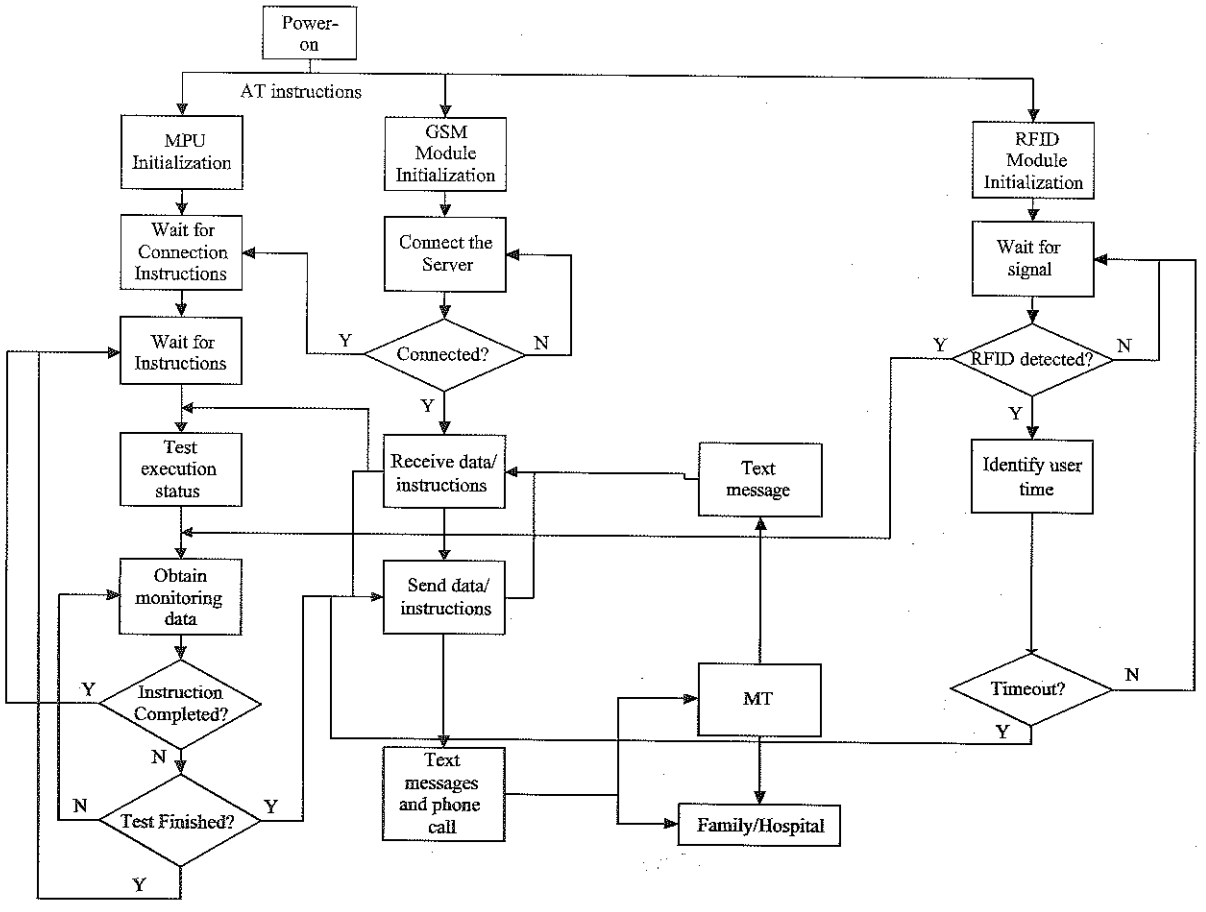

Figure 8 Working flow chart of the industrial control computer

serial port to record information and data such as time. The industrial computers have different time sets according to their locations. Taking the bathroom for example, the elderly toilet time should not be more than half an hour, so the timing in the computer at the toilet door is set at 30 minutes. It begins from the elderly entering into the bathroom, and if he/she does not leave the bathroom within 30 minutes, the computer will send an AT commands to the GSM module through the serial port in the form of SMS and telephone calls to inform the relevant health care workers, so as to ensure timely and effective protection of the elderly's personal safety.

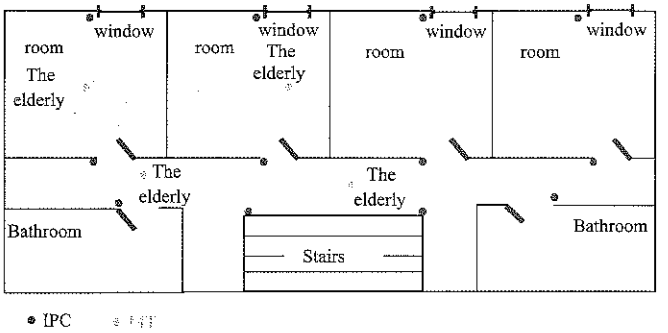

Figure 9 Diagrammatic sketch of the RFID monitoring

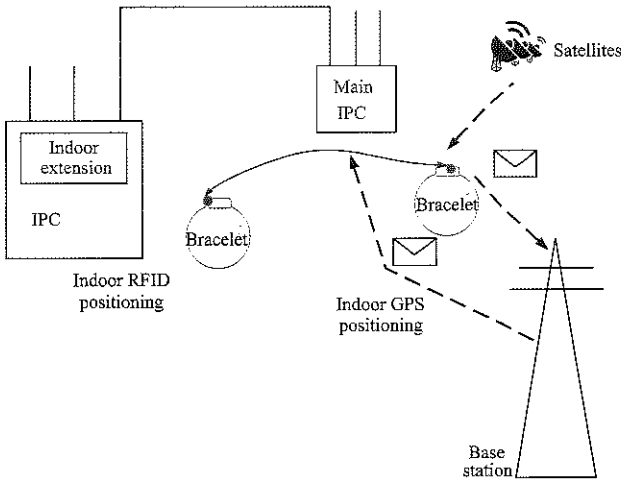

Figure 10 Diagrammatic sketch of the system communication

3 Test and Analysis

3.1 Test results

After the completion of the laboratory test, the performances of the mobile terminals and industrial computers were verified in Quyang County, Taiyuan, Shanxi Province. The computers were installed both at the living room door side and the bathroom door side, and the mobile terminal was put on for field testing and verification.

The GPS data are shown in Table 1.

Table 1 The latitude and longitude of GPS positioning data

Times	1	2	3	4
Latitude (N)	38°26′57918″	38°26′57911″	38°26′57902″	38°26′57874″
Longitude (E)	112°43′02524″	112°43′02470″	112°43′02424″	112°43′02354″
Times	5	6	7	8
Latitude (N)	38°26′57837″	38°26′57814″	38°26′57764″	38°26′57732″
Longitude (E)	112°43′02266″	112°43′02205″	112°43′02106″	112°43′02034″
Times	9	10	11	12
Latitude (N)	38°26′57708″	38°26′57700″	38°26′57806″	38°26′57821″
Longitude (E)	112°43′01979″	112°43′01941″	112°43′01932	112°43′01948″
Times	13	14	15	
Latitude (N)	38°26′57833″	38°26′57837″	38°26′57840″	
Longitude (E)	112°43′01963″	112°43′01966″	112°43′01962″	

According to the GPS test results of the latitude and longitude of the original data, a scatter plot is shown in Figure 11.

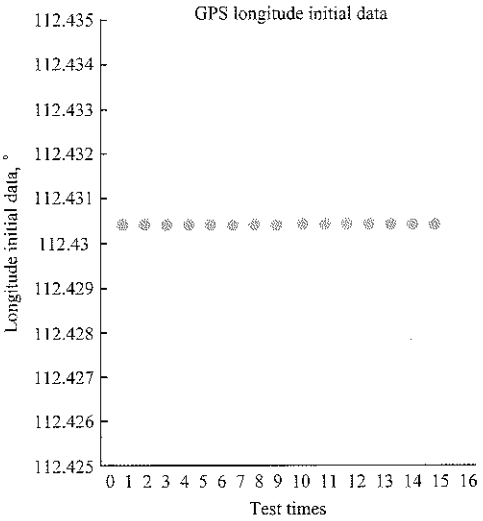

Figure 11 Scatter plots of the original data of GPS longitude

The functions including the indoor RFID near field communication, real-time heart rate monitoring and its accuracy, as well as the intelligent alarm have been validated. The field test is illustrated in Figures 12 to 18.

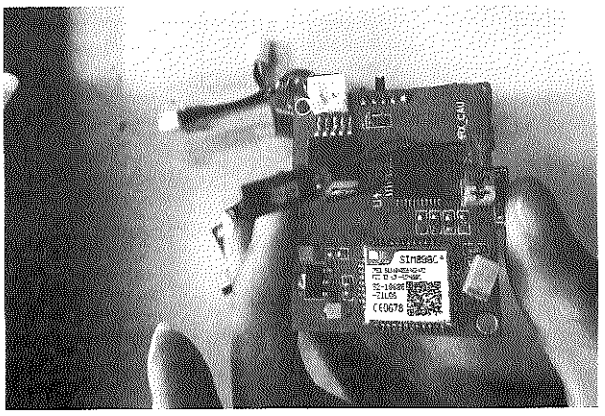

Figure 12 The mobile terminal (back)

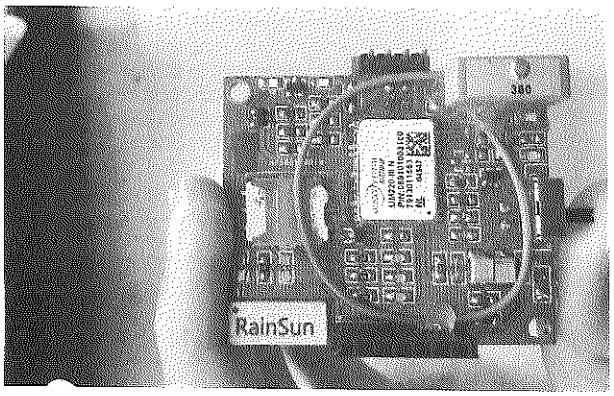

Figure 13 Mobile terminal (front without liquid crystal display)

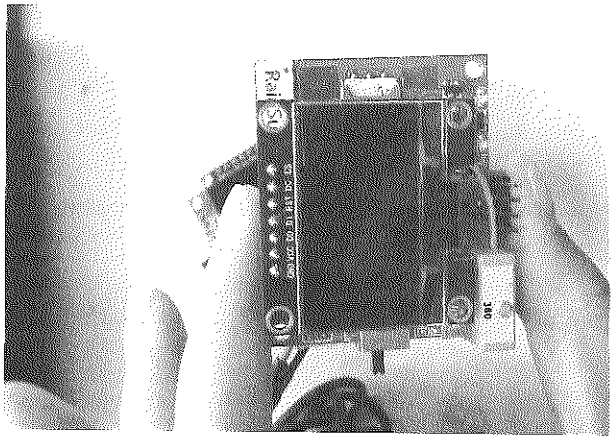

Figure 14 Mobile terminal (front with liquid crystal display)

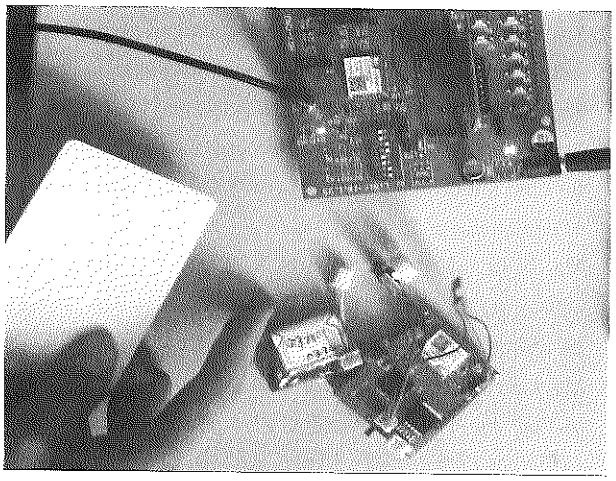

Figure 15 Industrial control computer and mobile terminal

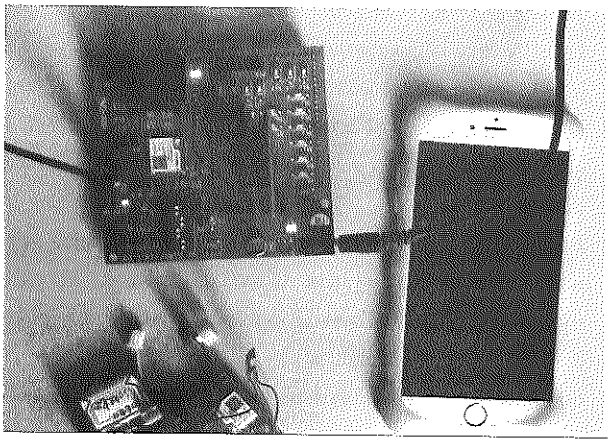

Figure 16 Indoor test of RFID and message sending

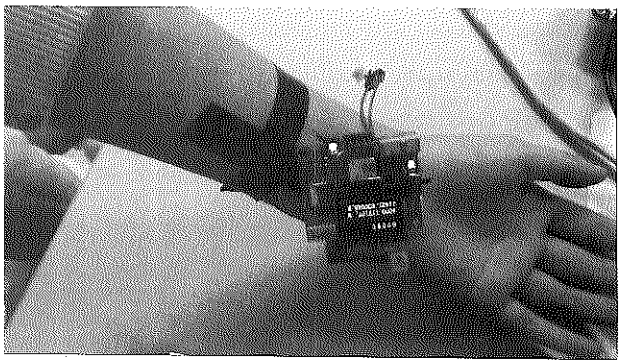

Figure 17 Real time monitoring of heart rate

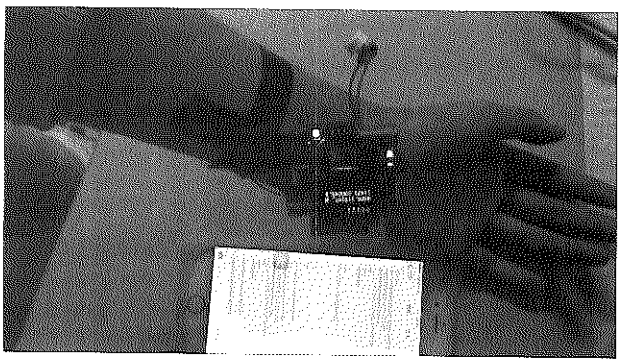

Figure 18 Alarm test for abnormal heart rate

3.2 Performance analysis

3.2.1 Functional testing

The heart rate detection sensor works properly. The RFID radio frequency identification works normally and in a reliable status. The GSM accesses to message and dials normally. The GPS outdoor positioning data have slightly offset. The microprocessor has a quick instruction and analysis of data.

3.2.2 Performance testing

The heart rate sensor can detect the correct and effective heart rate data in the arm, ear and face. When the abnormal heart rate is detected, the mobile terminal immediately sends out the alarm message. The RFID effectively identifies the card number corresponding to the specific user and completes the indoor auxiliary positioning.

3.2.3 Performance analysis

- Both the design of the GSM module antenna and the block of indoor environment on the signal will affect the time of the module connected to the network.
- The design of the power circuit, the capacity of the battery pack and the working mode of each module will affect the working hours of the battery pack, to a certain extent, leading to the long-term work inconvenience.
- The design of the circuit board, antenna design, the

indoor and outdoor environmental interference and the signal strength of the satellite and communication base station, will have impact on the communication network and GPS positioning accuracy.

4 Conclusions

The following conclusions have been achieved through the laboratory pre-test and the actual test in rural areas.

Compared with domestic and foreign research results, the common chips and techniques selected in this paper can to a large extent reduce the cost of production, so that it will not constitute a lot of economic pressure for the rural nursing homes. The device has quick and accurate response, being easy to install, and can be used off the PC.

The device is repairable and rechargeable, equipped with the most common Micro USB charging port. It is small size, light weight, easy for the elderly to carry and use, hardly affecting the daily activities of the elderly.

It can be found from the actual test that the device does have the functions of indoor and outdoor positioning, real-time heart rate monitoring, one call for help and emergency alarm. The GPS positioning data is accurate with low cost, and the heart rate monitoring in real time is effective, so there will be a good promotion prospect in the future.

Acknowledgments

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