Cloud-assisted Tracking Medical Mobile Robot for Indoor Elderly

Huiru Cao[1], Runjie Chen[1], Yucheng Gu[1], Huiyi Xu[1]

1Nanfang College of Sun Yat-Sen University, Guangzhou 510970

xiaocao0924@163.com, 18122733972@163.com, 18819460393@163.com, coyeehui@163.com

***Abstract*—Recently, research related to medical robots received considerable attention due to an increase in aging population. However, most of the existing approaches for designing medical robots have drawbacks in terms of lacking mobility, real-time monitoring of health conditions and emotional response. In this paper, we present a design for a cloud-assisted medical robot with mobility, which can remotely monitor and collect the parameters of human body. Moreover, the robot can upload this information to cloud and distribute it to a smart terminal in real-time. We construct the control and communication systems based on the main controller STM32 and WIFI, respectively. Further, user-friendly APPs are designed and a prototype of the mobile robot is built. Our proposed design approach can ensure the safety of elderly, reduce the burden of taking care of the elderly, and deal with emergency situations.**

Keywords—Cloud-assisted; Medical Mobile Robot; Remote Monitoring; User Terminal.

I. Introduction

When the elderly get sick in any family, the reason for sickness needs to be identified and treated at once. With the implementation of China's family planning policy, typical family structure has changed. The scale of family structure becomes miniaturization [1]. The 4-2-1 family structure, which has broken the 3 or 4 generations live-in family structure, becomes the main family structure. Nowadays, as the younger generation moves out in pursuit of freedom or for improving the quality of life, the elderly generation is left to live alone or together with other elderly people [2-3].

When the elderly people get sick suddenly, and if nobody is around them in emergency situations, their situation may become worse and may lead to their death. It is important to reduce the number of deaths due to such situations [4]. The remote health monitoring system will take action when the elderly people get sick and it reduces the possibility of death due to illness.

At present, research people are concentrating on the traditional approaches without paying too much attention to how to cure patients in quick time or provide with human body monitoring service [5]. The Wi-Fi module used in intelligent Internet of things can be combined with a WSN (Wireless Sensor Network, WSN) to send and receive data over a short distance. A smart phone application, for example, an android application can interact with the WSN over a short distance [6], but it has a limited range. With the advancement of cloud technology, we can overcome the shortcomings of accessing data remotely using a wireless connection. But there is still a lack of data collection from the human body and data visualization on the android application.

Our system uses a cloud server, a WSN and vanguard technology. Any networked android application can access the data stored by using Wi-Fi on the cloud server, and use it for data visualization. The application generates a warning if it finds any anomalies in the accessed data. Our system increases the monitoring flexibility and reliability, minimizes the loss of life, and improves the safety of elderly.

The structure of the paper is as follows: Section 2 presents the framework of cloud-assisted mobile robot. Section 3 gives the design of the mobile robot. Platform implementation is presented in Section 4. Finally, Section5 concludes the paper.

II. Framework of Cloud-assisted Mobile Robot

Recently, due to the development of technology and the need of assignment, the IoT (Internet of Things, IoT) is becoming popular. With the development of WSN, the speed and stability to transfer data are better than before. The IoT technology facilitates a remotely controlled intelligent machine. When the machine tries to solve a complicated problem, it needs high computational capability. However airborne equipment items do not have ability to deal with the problem as ordinary processors do not meet the computational demands. The cloud technology can solve the limited computational capability problem. The machine transmits the data to the cloud server. Through the server, analyzes the data and takes an action. This is the most effective way to solve the remote health monitoring problem. Cloud technology is a way that combines software and hardware through internet and virtual technology to provide users with a service.

Our system consists of four parts: a robot, IoT, a cloud server, and a user terminal. The robot device contains STM32, tracking drives based on STM32, and a parameter collection module. The IoT is an open platform based on Internet of things technology and industrial characteristics. Fig 1 shows the system structure. The IoT is applicable to all kinds of internet protocols and supports various sensors, smart hardware to quickly access data service. The IoT also provides support for abundant API and application templates for various industries and intelligent hardware development, and thereby cutting down the budget of development and planning. The IoT can support various features such as device connection, protocol adaptation, data storage, data security, and analysis. User terminals are used to access data of users and make data visualization. The working principle is that the robot sends a signal in a time interval to the object to have a physical examination and collect the parameters. Next, the mobile robot connects the indoor router through the Wi-Fi module to upload the collected data. The robot then interacts with a public cloud to store the data. After the cloud server receives the data, it classifies and stores the data in a memory block which is pre-allocated. The cloud server waits for a request from an application. The application sends a command to the server using the TCP protocol. After receiving the command, the server sends the data to the application. When the application receives the parameters, it shows them using data visualization, and it decides if any of the parameters exceed some specified values.

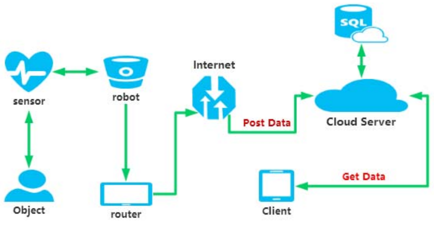

Fig 1. Indoor elderly monitoring system structure.

System function: Monitoring abnormal parameters is using an android application; tracking the target is using a vehicle-mounted ultrasonic module; examination is using a vehicle-mounted data collection module; storing data is using a cloud server, which is to protecting the data.

III. MOBILE ROBOT DESIGN

2.1 Main controller for Mobile Robot

In the mobile medical robot, an STM32F103 controller and an ESP8266 Wi-Fi module are used for processing and transmitting the parameters in the vehicle-mounted system, respectively. The STM32F103 enhanced controller series has an inner ARM (Acorn RISC Machine, ARM) core. This Cortex-M3 is the most advanced embedded ARM processor providing a low-cost platform by reducing the number of pins and power consumption. The processor has an excellent computing performance and an advanced interrupt responding system. The Cortex-M3 is a 32bit RISC processor which provides extra coded efficiency and achieves a good kernel performance in 8 or 16bit storage computer system. The working frequency of the processor is 72 MHz and comprises high-speed storage (128k flash and 20k SRAM). The processor is able to meet the MCU demand. The controller has abundant enhanced I/O ports and peripherals connected to two APB buses. The MCU has two 12bit ADCs, three general purpose16bit timers and a PWM timer. The controller also consists of normal and advanced communication interfaces such as two I^2Cs and SPIs, three USARTs, an USB and a CAN. The controller meets demand of the system and exchanges data with ESP8266 through the serial peripheral interface.

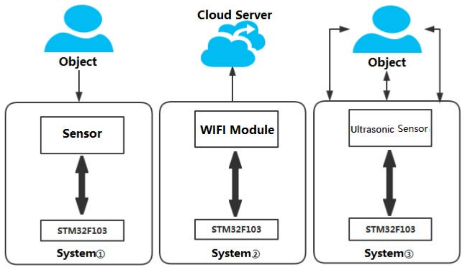

Fig. 2 Robot hardware system.

As shown in Fig 2, our system uses an ESP8266 WIFI module for data transmission. The ESP8266 is a chip designed by Le Xin Company for IoT. The chip has an internal integration CPU, which is a 32bit processor that can be used as Wi-Fi protocol processor or an application processor. The chip supports 80MHz and 160MHz frequency. A programmer can write an application program and upload it onto the chip. The processor can run the program written by the programmer. We can choose the output capacity frequency and protocol through USART port. Through the interrupt request, the STM32F103 controller sends the data after receiving all of the data. We can set the frequency, the transmission address, and the rate of transmission and the length of data packets in the application. The ESP8266 uses advanced power management techniques and minimizes the power consumption in the logic system as in Fig 3. The ESP8266 module can switch between the sleeping mode and the working mode. In the sleeping mode, the current consumption is less than 12uA. In working mode, the power consumption is less than 1.0mW (DTIM=3) or 0.5mW (DTIM=10). This feature improves the battery life and enables the robot to send the data instantaneously. The module also has quick and easy-to-use embedded ports and a safe and stable Wi-Fi wireless link. The ESP8266 module uses the TCP/IP for data transmission.

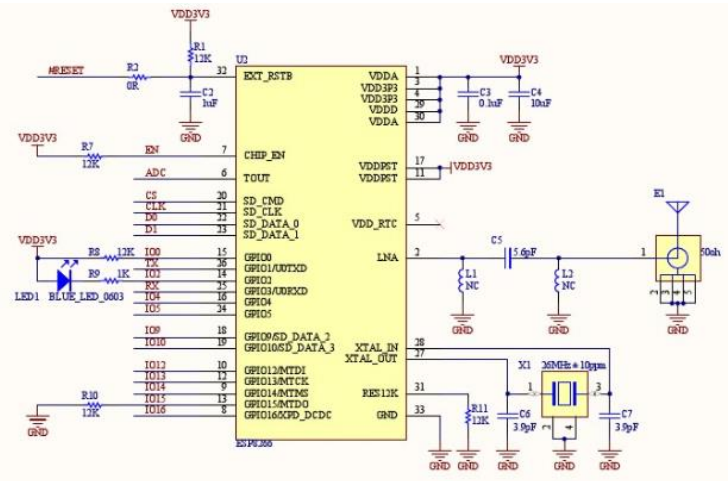

Fig 3. ESP8266 WIFI module circuit diagram.

2.2 System Software Design

A Tracking algorithm based on ultrasonic modules

There are three ultrasonic modules placed in the special mechanical structure on the front side of the robot. The tracking function is realized by measuring the distance with the three modules. Adjusting angle is the best way to improve the precision, and we modify the code and adjust the angle several times. The ultrasonic module comprises a stable and precise HC-SR04 unit, which has a shorter fade zone. The module is used in the robot for obstacle avoidance, object distance measurement, liquid level measurement, public safety, and parking measurement.

The working principle trigger of IO pin measures distance and gives at less 10us high-level signal. The module sends an 840Khz square wave and checks if there is a receive signal. If there is a receive signal, the ECHO of IO pin sends a high-level signal. The high-level signal time is the ultrasonic signal from sent to receive. The distance is computed using the formula

Distance = （high-level signal time * (340M/S））/2

A controlling pin sends a high-level output signal of duration less than 10us. The receiving pin waits for the high-level output. It means that the counting will turn on if there is an output. When the pin changes to low-level output, the data can be read. This is the time for measurement, and we can calculate the distance.

The algorithm principle is that the vehicle-mounted main controller uses the distance difference between the three modules to judge the object location. According to the measured difference, electric machinery takes an action. The machinery ensures that the robot and the object are keeping a right distance. We denote the three modules as follows. The left, middle and right modules are denoted using S1, S2 and S3, respectively. They are used to measure distance. The tracking algorithm is summarized in Table 1.

Table 1 The pseudo code of the tracking algorithm

```
TRACKING   ALGORITHM
FOLLOW (S1, S2, S3)
Define  Limit1  Number1 ,Limit2  Number2
Return=POSTURE-JUDGMENT(S1, S2, S3)
If (Return ==L)
    MOTO-L-MOVE ()
Else If  (Return ==R)
        MOTO-R-MOVE ()
Else If  (Return ==M)
        If (S2≤Limit1)
            MOTO-Both-BACK ()
        Else If (Limit1≤S2≤Limit2)
            MOTO-Both-STOP ()
        Else If (S2≥Limit2)
            MOTO-Both-MOVE ()
```

B The main controller-STM32F103 program design

The timer 2 calculates the measurement time. The timer 4 calculates the time used for recording the heart rate. The timer 1 calculates the time interval between physical examinations. When the main controller is turned on, it begins monitoring and tracking using temperature and humidity data acquisition module, and the ultrasonic module. The timer 1 starts counting. When the time of timer 1 exceeds the limit, the controller runs the main program. After generating the buzzer sound, contact type temperature detection module and contact type heart-rate detection module will turn-on and start a physical examination. The examination takes about 10s. After the examination, the buzzer rings. The temperature and humidity data acquisition module and the ultrasonic module will continue working. The device will send the measured parameters to the cloud server through Wi-Fi.

C Communication between the client and the cloud server

The cloud server accepts various commands for communication during interaction with an application. The application sends a GET command to the server using the TCP protocol. The TCP protocol is a connection-oriented and reliable communication protocol based on byte stream. The TCP protocol is defined by RFC 793 of IETF. The TCP uses a three-way handshake procedure to establish a connection, as shown in Fig 4. The transmitter sends the SYN request for connection, and waits for the receiver response. The receiver sends a SYN-ACK and the transmitter will send an ACK confirmation after receiving the SYN-ACK from the receiver. This three-way handshake process protects the application from establishing a wrong connection. The flow control protocol for TCP is an adjustable window protocol.

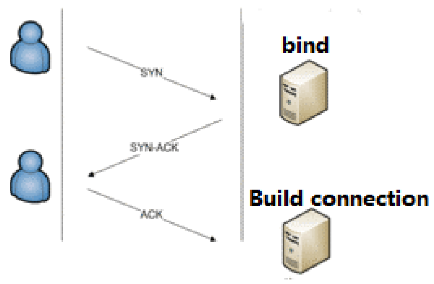

Fig 4. TCP three-way handshake procedure.

D Client application interface design

The application includes a main interface, a sub-interface of data visualization image and a warning interface. The application interface is implemented using the JAVA programming language based on Linux for Android. We apply object-oriented programming methods to encapsulate the abstract objects into classes. The buttons in the main interface provide a link into its sub-interface. The sub-interface is shown in the form of a line chart in Fig 5. When any of the measured parameters exceed a predefined threshold, the interface will generate a warning and activate an alarm.

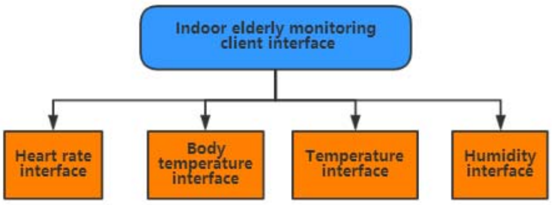

Fig 5. Indoor elderly monitoring system interface function module

IV. PLATFORM IMPLEMENTATION

As shown in Fig 6, we built the platform on a tracked vehicle. The ultrasonic, heartbeat, temperature and other sensors are placed on the robot through communication ports. Furthermore, for increasing the communication ability, a Wi-Fi module is mounted on the vehicle through the SPI (Serial Peripheral Interface, SPI) port. An MCU is used for processing different tasks, such as sensing, data storage, and information upload or download.

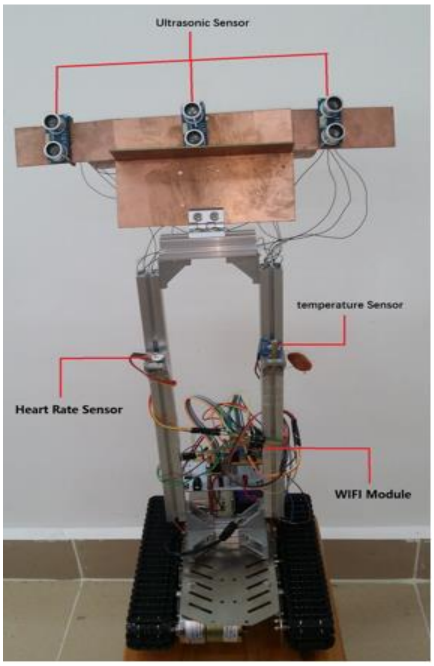

Fig. 6 Protoype of the mobile robot.

The function of data visualization has been implemented in the application by using the JAVA programming language based on Linux for Android. After establishing the initial main and sub-interfaces, we can enter the sub-interface by clicking the button in the main interface, as shown in Fig 7. Through the TCP protocol, the received parameters are displayed in the sub-interface.

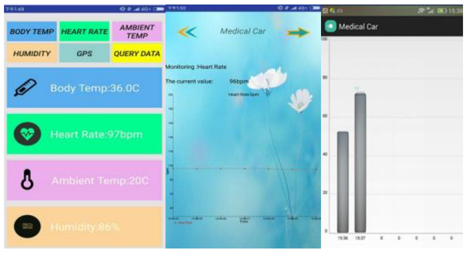

Fig 7. The main and sub-interface of the program for human body parameterization.

V. CONCLUSIONS

The developing country is gradually becoming an aging society in the 21st century. The health of elderly, especially the health of solitary elderly is becoming a top priority. The pace of life is increasing continuously and everyone works in cooperation with a due division of labor. Because of these factors, the youth go out for work. Therefore, the elderly and the children will live alone at home.

With the development of health monitoring, the prospect of intelligent family monitoring system and armamentarium is cheerful. Our proposed system can remotely monitor and collect the human body parameters. It is the key method to solve this problem. The remote monitoring system is the most efficient way to avoid the death and loss of the property in emergency situations. It has a great future. In future, we will try to use the intelligent recognition technology based on computer vision. This new module can be used to replace the ultrasonic module in the proposed design, and it can improve the precision of the tracking function.

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