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The Design of the Intelligent Medicine Box for the Elderly

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Abstract: With the increase in the number of elderly people in the world, the problem of population aging has gradually become prominent. People are paying more and more attention to the elderly, and medical supplies for the elderly have also attracted great attention. At present, various intelligent medical boxes have appeared in the domestic and foreign markets. These medicine boxes mainly include functions such as setting time, reminding to take medicine regularly, and SMS notification service. This project designed an intelligent medicine box, which is based on 80C51 single-chip microcomputer, loaded with infrared on-beam sensor, three-axis acceleration sensor, short message module, and Bluetooth module. The main functions of the system include intelligent detection module, timing reminder function, short message notification module and anti-fall detection module. On the one hand, the intelligent system can monitor and remind the elderly to take medications in time. On the other hand, it can also monitor the personal safety of the elderly alone at home. This is different from the current intelligent medical box on the market and is also the highlight of the system.

Keywords: Intelligent Monitoring, Signal Transmission, Intelligent Reminder, Intelligent Control

1. Introduction

Since the 1970s, whether in developed or developing countries [1], population aging has become a universal concern worldwide. At the same time, with the advancement of science and technology, the improvement of medical standards, the life expectancy of the world's population continues to increase, and the aging problem is the most prominent problem among the population problems. At present, the world's most aging countries include Japan, Italy, Germany, etc., which are as high as 25%, and the elderly population over 65 in my country accounts for 7% of the total population. According to this standard, our country has entered an aging society [15].

The level of China's medical technology continues to advance rapidly. The living conditions of ordinary people continue to be improved. People's life expectancy is increasing day by day. China's aging process is accelerating. The cluster of elderly people suffering from chronic diseases is also inevitably increasing.

In some rural areas of China, due to the underdeveloped economy, many young people go out to work to earn money, making the elderly become empty nesters. At present, medicine chests with intelligent reminders for the elderly are not only expensive, but also relatively cumbersome to operate. There are some difficulties for the elderly with lower education level [8].

In foreign countries, the research on nursing care of the elderly mainly relies on intelligent nursing robots. Represented by the American nursing robot, the robot 'Helpmate' is a fully autonomous mobile robot. The robot system is equipped with various types of smart sensors, that has obstacle avoidance and autonomous navigation functions. This robot can reach the designated destination through the man-machine interface operation, and complete the tasks of delivering medicines, food, medical records, etc. smoothly and safely. At the same time, the 'Helpmate' robot will can open the door autonomously and can also take the elevator alone. At present, 80 hospitals around the world are using it [2]. However, 'Helpmate' robot is very expensive, ordinary household users cannot afford it, and it is difficult for the general public to benefit.

At present, China is in a stage of rapid development. With the advancement of medical technology and the improvement of living conditions, people's life span has also been extended, and Chinese people aging process is accelerating. It is predicted that by 2025, Chinese population of elderly people who is aged 60 and above will reach 308 million, the proportion of the elderly population in Chinese total population will reach 21.1%. At the same time, the number of elderly people suffering from chronic diseases will inevitably increase, and the compliance of elderly people with chronic diseases in my country is relatively low. Only 40% of patients can consciously take medicine on time. Elderly people with chronic diseases are generally older, who have memory decline and do not remember when to take medicine. When the elderly with chronic diseases are discharged from the hospital, their children's younger generations will also be less concerned about the elderly, and they often forget to supervise the elderly because of their work [9].

2. Previous Work

The paper "Of Pill Boxes and Piano Benches:" Home-made" Methods for Managing Medication" (Leysia Palen & Stinne Lookalike, University of Aarhus) propose that elders organize and remember to take their medication-methods that leverage a kind of distributed cognition. They show how mobile health care workers participate in the development and execution of these systems [3].

The paper "Design of smart reminder pill box based on APP" (Liu Xiaoying, Dalian University of Science and Technology), which introduce the design of a family medicine box based on single chip microcomputer. The system uses an infrared sensor to detect whether the current medical box is opened. The system can set the time, and use the voice broadcast to remind to take the medicine on time. When the intelligent system detects that the elder has not taken the medicine over time, the system calls the short message module to send notification information [4].

"Monitoring system for the safe medication of elderly and chronically ill patients based on "Internet+"" (Wu Zheng, Chongqing University of Posts and Telecommunications). The paper constructs a set of safe medication monitoring system to realize the monitoring system for the safe medication of elderly and chronically ill patients in hospital and at home. This system realize the whole-process medication safety supervision of "hospital-home", and conduct necessary data collection and analysis for professionals in medical institutions carry out health evaluation, disease prediction, health guidance, etc [5].

In summary, the intelligent medical box is already a certain degree of intelligence, which can use sensors for real-time detection to see if the elderly have taken the medication on time, Pay attention to the convenience and emotion of medical box packaging design. Our project specifically designed a fully autonomous intelligent medical box based on the characteristics of the Chinese elderly. Which can set system clock for taking medicine, which is using intelligent infrared sensors to check if the tablets are taken away on time, while the system will send message to the guardian of the elderly. In addition, one of the most important functions of the system is the anti-fall detection function, which is using three-axis sensor ADXL345 to detect whether the elder's body has tilted or fell, If an elderly person is detected to fall, the system will notify community staff or medical staff as soon as possible. Provide effective first aid at the first time, reduce the occurrence of human tragedies.

3. Our System Solution

3.1. System Function Description

This system uses STC89C52 single-chip microcomputer as the main controller, and the system is loaded with infrared sensors, acceleration sensors and buzzers. Bluetooth communication etc. The team built a low-cost, easy-to-operate smart reminder medicine box, which is convenient for the empty-nest or lonely elderly to complete the operation alone, without the need for children to conduct complicated teaching to the elderly. If the elderly do not take the medicine on time, the system will promptly inform their children with GSM modules.

The main functions of the system include intelligent medication reminder function. On the one hand, the infrared through-beam sensor detects whether the medicine is taken out of the tablet within the set time range. On the other hand, when the tablet is not taken within the set time range, the elderly will be deemed to have forgotten to take the tablet. At this time, the system will notify the elder's children or guardians as soon as possible:

1. Automatic medication reminder function: The system uses infrared through-beam sensors to detect whether the medicine is taken, and the medicine bottle is specially designed according to the system function. If the medicine is not taken within the specified time, the buzzer will sound to remind the elderly to take the medicine.
2. System SMS notification: When the elder presses the number buttons on the infrared remote control, the system can actively send text messages to the corresponding contact. The message reminds that the elder wants to talk to the corresponding contact person, and then the contact person takes the initiative to call the elder [6].
3. Manual reminder to take medicine function: When the system starts the buzzer for a period of time, the elderly still have not completed the medication task autonomously. Then the single-chip intelligent system will actively send text messages to the guardian's mobile phone, and the guardian will remind the elderly to take the medicine by phone.
4. Add and delete contacts: The system can modify the phone number of the contact through the infrared remote control, which is displayed by the LCD.

5. Elderly anti-fall detection function: When the system uses the acceleration sensor to detect that the elderly has fallen, the system will control the SIM900A module through the Bluetooth module connection, and send a text message to the guardian's mobile phone, promptly notify and actively start rescue at the first time.

3.2. System Hardware Platform

This system uses STC89C52 micro-controller as MCU, which is a high-performance, low-power 8-bit CMOS (Complementary Metal-Oxide-Semiconductor) micro-controller, with 8K bytes of program storage space, 512 bytes of data storage space, and 4K bytes of internal storage space EEPROM (Electrically Erasable Programmable read only memory) storage space, support serial download. The system works under the voltage of 5.5V-3.8V. There are 3 (16-bit) timers/timers and 4 external interrupts available for use, and there are 39 general-purpose I/O ports for external expansion of the chip.

The system uses SIM900A module to realize short message communication. The SIM900A module is a high-performance industrial-grade GSM/GPRS (Global System for Mobile Communications/General packet radio service) module. It can provide functions such as voice calls, short messages, GPRS data transmission, text broadcasting and base station positioning [6].

The system uses the three-axis accelerometer ADXL345 smart sensor to realize the function of the anti-drop detection module. It can measure the state of the chip, including the direction and magnitude of the acceleration. It can be used to judge the movement state of the chip or the change of the tilt angle.

The medication reminder function of the intelligent medicine box [10] is mainly completed by infrared through-beam sensors. The smart medicine box detects whether the medicine is taken away in real time. The main detection method used by the system is whether the infrared sensor is blocked or not. If the infrared radiation is blocked, it means that the medicine exists, and the elderly have not taken the tablets to take the medicine. Then the system activates the hardware buzzer to remind the elderly to take the medicine and take the medicine on time.

The hardware structure block diagram of the system is shown as in Figure 1.

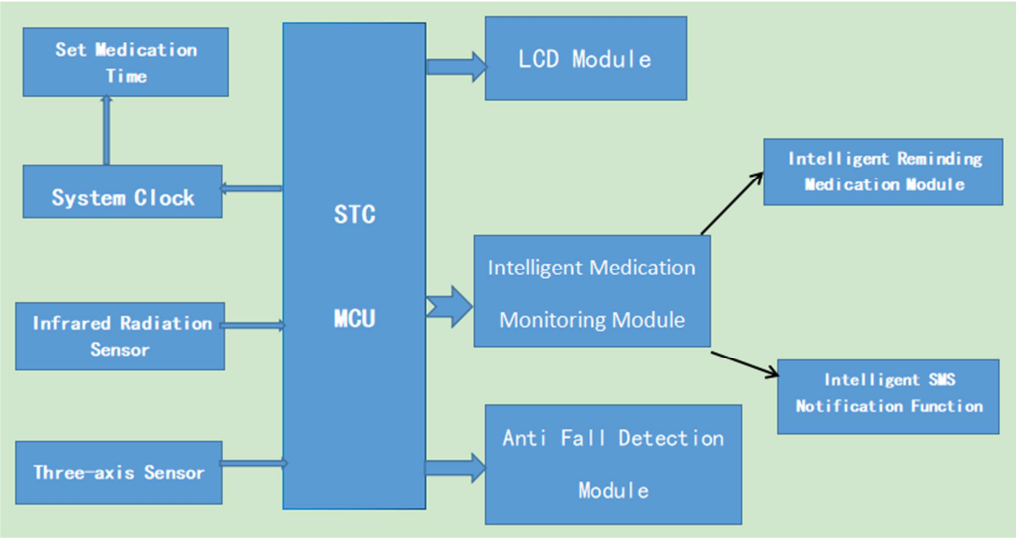

Figure 1. *The system structure block diagram.*

3.3. System Software Design

3.3.1. Integrated Development Platform

The development of this project uses Keil uVision5 software integrated development platform. The designer uses the C language to write the system function modules. The basic code at the bottom of the system uses assembly language to complete the design. Keil is a professional single-chip development tool designed by ARM. It provides development programs including C compiler, macro assembly, linker, library management, simulation debugger, etc., which is convenient for the development and debugging of single-chip-based system functions.

3.3.2. System Function Module Design

(1) Design of intelligent reminder module

This smart medicine box is designed to serve the elderly who are older and have a low level of education. According to the loading of the intelligent infrared through-beam sensor, the system detects whether the tablets in the medicine box have been taken out within the setting time. If the tablet is taken away, it is deemed that the elderly have completed the action of taking the medicine autonomously; If the tablet is not taken away within the specified time, it will be deemed that the elderly have forgotten to take the medicine, the system will start the buzzer for real-time reminder function.

The infrared through-beam sensor uses 74HC14D chip, its working voltage is 3.3V~5V, it can be directly driven by the single-chip microcomputer, and its output mode is pulse signal. When the sensor detects an object in the middle, it outputs a high level, and when there is no object, it outputs a low level. It can be directly connected to the MCU pin to observe the

value to judge whether there is an object [11, 12].

The working principle of the buzzer is mainly determined by the frequency and duty cycle of the input signal. We can control the timbre or tone of the buzzer by changing the frequency of the input signal. If you want to adjust the size of the sound, you can adjust it by changing the duty cycle of the input signal. According to the above two principles, the operation of buzzer ringing reminder can be realized.

SIM900A SMS communication module uses serial communication, and uses AT commands to control the module. AT instruction set is sent from terminal equipment (TE) or data terminal equipment (DTE) to terminal adapter (TA) or data circuit terminal equipment (DCE). Through TA, TE sends AT commands to control the functions of the mobile station (MS) and interact with GSM network services. Users can control calls, short messages, data services, faxes etc. Through AT commands.

There are two indicators D5 and D6 on the SIM900A module. According to the status of the indicator, system can reflect the status of the module [14]. The specific corresponding situation is shown in Table 1:

Table 1. *GSM module working status and indicators.*

D5	D6	Module status
Long bright	On one second, off one second	Searching the web
Long bright	On one second, off three seconds	Web completed, working
Long bright, then off one second	On one second, off one second	voltage cannot meet the requirements
Extinguish	On one second, off three seconds	Incoming call reminder
Turns off and then lights up	On one second, off three seconds	Received a text message

The key source code of the module is as follows:

```
if( (((TIME[2]/16)*10)+(TIME[2]%16)) == EatTime[0])
    //AM 8:00
    if((((TIME[1]/16)*10)+(TIME[1]%16))>=EatTime[1]&
&(((TIME[1]/16)*10)+(TIME[1]%16)) < EatTime[2])
    //AM 8:00-8:05
    {
        if(SD1 == 0)    //don't take pills
        {
            beep = ~beep;  //buzzer is working
            delay(6);
        }
        else
            MLN_flag=2;
    }
    else        //AM 8:05-8:59
        if(SD1 == 0)    //don't take pills yet by buzzer
        {
            SendMessageOfOutTimeOrFallDwoan(0);
    //send the message to guardian
    MLN_flag=2;
        }
```

The above just lists the code implementation of a single infrared through-beam sensor. In the code, the Eat-time[] array saves the time threshold for the elderly to take medicine overtime. The value can be changed by infrared remote control, the default is 8:00 to 8:05 in the morning, 12:00 to 12:05 in the noon, and 7:0 to 7:05 in the evening.

(2) Design of anti-fall detection module

With the Chinese aging process accelerates, more and more old people have become empty-nest old people or old people who lost themselves alone. Without the children's protection and company, there is a lack of emotional care for the elderly. AS the elderly grow older, their health is getting worse and worse, and they may be accompanied by a variety of chronic diseases. Due to the lack of the company of their children, there have also been many cases of sudden deaths of elderly people living alone. The family members did not discover and carry out effective rescue operations in the first time. In order to prevent this tragedy from happening again, the system has specially designed a real-time intelligent detection function to detect whether the elderly fell accidentally.

The system design a small MCU as a slave, the master and slave MCU are respectively equipped with HC-05 Bluetooth [7] to realize the communication. ADXL345 three-axis accelerometer was installed on the slave machine, which is used to detect the current acceleration value of the system. Put the device on the feet of the elderly. When an elderly person living alone is at home, if an accidental fall occurs, the value of the acceleration sensor will be changed. When the system receives a change in the value of the acceleration sensor, it means that an accident may happen to the elderly living alone. At the same time, the system will generate early warning signals as soon as possible, and notify community staff to check and actively carry out rescue work [13].

The system uses the ADXL345 three-axis accelerometer. The ALT ADDRESS pin is grounded, The address of the device I^2C is 0x53 (then the R/W bit), which is converted to 0xA6 for writing and 0xA7 for reading. ADXL345 three-axis sensor uses binary complement data format. After the user reads the acceleration data from the data register, the data must be reconstructed. DATAX0 is the low byte register of X axis acceleration, DATAX1 is the high byte register. The same data format is used for the Y-axis and Z-axis. In the 13-bit mode, the upper 4 bits are the sign bits.

The intelligent control system judges whether the elder falls down by the change of the acceleration sensor value. When the elder falls down, an external force is applied to the sensor, causing its acceleration to change. The system can judge whether the elder falls dow, according to the acceleration value. The three-axis sensor records the acceleration in three directions. The system generates the final decision control data value according to certain algorithm fusion processing [16]. The specific formula is as follows:

$$a = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

The specific core key codes of this module are as follows:

```
Multiple_Read_ADXL345();   //Read data continuously and store it in BUF
display_x(); //Process the x-axis acceleration and add its square to and_data
display_y(); //Process the y-axis acceleration and add its square to and_data
display_z(); //Process the z-axis acceleration and add its square to and_data
and_data = sqrt(and_data);//Square root operation
conversion(and_data);//Process the value, take out the value of each digit
if( qian > 2 )
{
   Uart1Send(2);
}
and_data = 0;
```

(3) Design of display module

The system uses LCD1602 liquid crystal module to realize auxiliary display function. The LCD1602 module needs to operate according to the steps in its timing diagram. The module has two working modes, one is to write instructions, the other is to write data and display characters. The two methods of operation are:

Write instructions: first put the RS pin low, then set the RW pin low. Send the instruction to be written to the data bus D0~D7. Sending a high pulse to the E pin, the command will be written.

Write data and display characters: Set the RS pin high set the RW pin low. Send the data to be written to the data line bus D0~D7. Give a high pulse to the E pin, and the data will be written.

The system needs to initialize the LCD1602 module before proceeding with other operations. The system uses the command write function for initial settings, and uses the data write function to display data. LcdWriteCom() is a single-byte command writing function, which can realize the writing of commands to complete initialization. LcdWriteData() is a single-byte data write function, which can display the data on the LCD screen. For the writing of multiple data, it is only necessary to perform a loop judgment on the LcdWriteData () function to realize the writing of multiple data.

```
void LcdWriteCom(uchar com)       //Write command
{
   LCD1602_E = 0;       //Enable and clear
   LCD1602_RS = 0;      //Select write command
   LCD1602_RW = 0;      //Select write command
   LCD1602_DATAPINS = com;
   Lcd1602_Delay1ms(1);

   LCD1602_E = 1;       //Write timing
   Lcd1602_Delay1ms(5);
   LCD1602_E = 0;
   LCD1602_DATAPINS = com << 4; //Send low four bits
   Lcd1602_Delay1ms(1);
   LCD1602_E = 1;       //Write timing
   Lcd1602_Delay1ms(5);
   LCD1602_E = 0;
}

void LcdWriteData(uchar dat)                  //write data
{
   LCD1602_E = 0;       //Enable and clear
   LCD1602_RS = 1;      //Select write command
   LCD1602_RW = 0;      //Select write command

   LCD1602_DATAPINS = dat;
   Lcd1602_Delay1ms(1);
   LCD1602_E = 1;       //Write timing
   Lcd1602_Delay1ms(5);
   LCD1602_E = 0;
   LCD1602_DATAPINS = dat << 4; //Write lower 4
   Lcd1602_Delay1ms(1);
   LCD1602_E = 1;       //Write Sequece
   Lcd1602_Delay1ms(5);
   LCD1602_E = 0;
}
```

4. System Function Analysis and Test

4.1. Intelligence Reminder Module Test

The system sets the default time thresholds which are 8:00~8:05, 12:00~12:05, 19:00~19:05. During this period of time, if the infrared through-beam sensor detects that the medicine in the middle has not been taken away, it will sound through the buzzer to remind the elderly to take medicine and eat. If the medicine is not taken within the specified time, the system will stop the sound and send a text message to the guardian's mobile phone to inform the elderly.

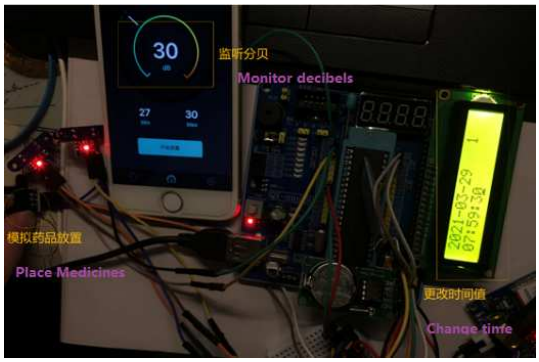

Figure 2. *Buzzer reminder function test.*

The experimental test scenario is described as follows: when the system completes related pr-operations, using your fingers to simulate a tablet. Do not remove the fingers located between the infrared through-beam sensors. It is time to eight o'clock, We need to observe whether the buzzer sounds to remind, and confirm it by the decibel value. After the system function unit test [18], we did hear the buzzer sound. At the

same time, the project used special equipment to measure the high and low value of the sound, as shown in the picture, 72 decibels. The result is shown in Figure 3. The functional test has achieved the expected effect.

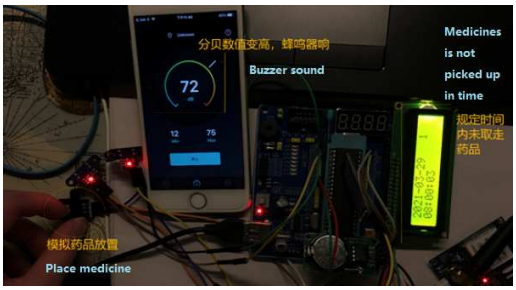

Figure 3. *Medication reminder test.*

System function module test 2-timeout SMS [19] reminder function. The system uses fingers to simulate the placement of medicines, keeping the position of the fingers still. When the time reaches 8:05, please observe whether LCD1602 displays 'Message Out'? As shown in the figure below, the test results met the expected requirements. When the system time reaches 8:05 and the tablets are not taken away, the intelligent system autonomously sends relevant notification information to the guardian of the elderly. When the guardian receives a message, on the one hand, he can call the elder to instruct him to take medicine on time; on the other hand, he can give emotional care regularly and know how the elder is physically.

Figure 4. *Timeout reminder test.*

Figure 5. *Notify guardian SMS test.*

4.2. Anti-fall Detection Test

When the three-axis acceleration sensor is stationary, the total acceleration experienced is about 1g (gravitational acceleration). When the three-axis acceleration sensor is subjected to external force, the total acceleration received will be changed, and the system sets 2g as the critical value. If the acceleration of the three-axis acceleration sensor exceeds 2g, the slave MCU will send information to the master MCU through the Bluetooth serial port, and control the GSM module to send SMS to remind the guardian.

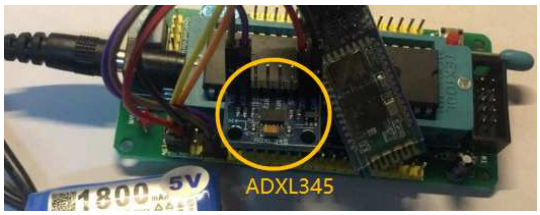

Figure 6. *The position of the ADXL345 sensor.*

By shaking the three-axis acceleration sensor, it simulates the external force that the old man acts on the sensor when he falls. The acceleration of the three-axis acceleration sensor is 1g when it is stationary, and its instantaneous acceleration exceeds 2g due to shaking. The LCD liquid crystal display will display 'Message Fall Down', as shown in Figure 7.

Figure 7. *SMS send successfully.*

The guardian receives the text message and reads the message, determines whether the elder has an accident, and calls back to confirm the situation in time. The result is shown in Figure 8. After the system test, the guardian [20] can successfully receive the short message, the message content is timely and correct, and the ideal test result is achieved.

Figure 8. *SMS received successfully.*

5. Conclusion

In order to benefit more ordinary people, we have already independently designed an intelligent medicine box mainly for the elderly. The system hardware is based on STC89C52 single-chip microcomputer, using interrupt, serial communication, infrared communication, I^2C communication technology, loading and combining short message communication module, infrared sensor and other sensor modules, which can realize the functions of intelligent reminder for the elderly taking medicine, SMS communication, and fall detection of the elderly. This system serves the forgetful elderly who need long-term medication due to chronic diseases and guardians who need to go out to work every day.

This system is based on STC single-chip microcomputer, loaded with infrared on-beam sensor and three-axis acceleration sensor. The system can intelligently monitor and collect data in real time. The system integrates the collected data with necessary data to generate intelligent decision-making control data, so as to realize the function of intelligent reminder and notification of the system. The intelligent control system firstly solves the problem that most elderly people cannot take medication on time; secondly, it can notify family members as soon as the elderly are in danger to avoid recurring human tragedies.

According to the detailed investigation [14] and demand analysis in the early stage of the system. The design of system tries its best to reduce the system power consumption and cost, simplify the tedious operation of the system, achieve economic benefits, and the operation is simple and convenient. The system has a good market application prospect and promotion value.

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Biography

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