The Design and Implementation of the Smart Trash Can based on the Internet of Things

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Abstract. Choosing MSP430F149 as the main control chip and using the human body sensor module, infrared ranging module, motor, ultrasonic module, GSM module as peripheral components, the Smart trash can proposed in this paper can realize automatic garbage classification and garbage overflow detection. The human body infrared sensor module senses the approach of the human body in real time, triggers the Single-Chip Microcomputer to work, and opens the lid of the trash can; The entry of garbage is monitored in real time, responding to the Single-Chip Microcomputer driving the LDC1000 metal sensor for metal detection; The purpose of garbage classification could be achieved through the forward and reverse rotation of the motor; After the motor returns to its original position, the ultrasonic module installed in the middle of the trash can is used to detect whether the garbage is overflowed. The GSM module determines whether to send a message according to the ultrasonic detection. The test of the device shows that the control effect is good and the expected design goal is achieved.

1. Introduction

Trash can is common and essential items in everyday life. The effective use of trash can in daily life plays an important role in improving the quality of life, the quality of the environment, and the image of the city. With the widespread application of the Internet of Things technology, people are paying more attention to environmental protection issues while enjoying the convenience of life brought by technology.[1] Protecting the environment and improving resource utilization are the policy that China has been implementing all the time. Garbage is an unused mineral deposit with huge resource potential. The implementation of garbage classification is related to the living environment of masses of people and meaningful for the conservation of resources, and is also an important reflection of the level of social civilization.[2] The breakdown of the source of the garbage is the basis and key of the classification. The garbage classification can reduce the waste, thereby reducing the financial and labor resources for transporting waste, simplifying the harmless treatment at the end, benefiting to the waste management, and optimizing the waste treatment system.

In recent years, people has a lot of ideas about smart trash can, and have also made some explorations on waste recognition technology. Smart trash can is a new type of smart products, basing on automatic control technology and Internet of Things technology. It uses microcomputer control chip, new sensor detection device and mechanical transmission device to transform and develop traditional trash can.[3] We designed an automatic waste sorting and overflow detection device.
2. The Hardware Design for System

Based on the design requirements of the smart trash can, the ultra-low-power MSP430F149 chip was selected as the MCU of the single-chip microcomputer, the stable performance LDC1000 was used as the metal detection module. The stepper motor was used as garbage classification. The ultrasonic module detects whether the garbage is overflowed or not, and GSM module would send a message. In addition, LCD1602 is selected as the display screen for debugging. The overall block diagram of the system hardware is shown in the Figure 1.

![Figure 1. Overall system block diagram.](image)

The 16-bit ultra-low-power Single-Chip Microcomputer MSP430 uses two unique clock designs, the basic clock system and the phase-locked loop clock system. These two clocks generate the clocks required by the CPU and various functional modules. Users can command these clocks to be turned on or off through code to achieve low power control. LDC1000 metal sensor has the advantages of low power consumption, package simplification and low cost. Users only need to connect a PCB coil or a homemade metal coil to achieve non-contact inductance detection.[4] The LDC1000 coil metal sensor uses the eddy current principle to conveniently implement functions such as angle detection, displacement detection, and motion detection. The LDC1000 is connected to the MCU using a four-wire SPI method of attachment. The MCU realizes the control of the metal sensor LDC1000 and reading of data through the SPI interface connection. During the SPI communication process, the sensor plays the role of a slave machine.

28BYJ-48 open-loop controlled stepper motor can quickly transform the electric pulse signal into angular displacement signal. Under the condition of proper voltage, the rotation speed and stop position of the motor are merely determined by pulse signal frequencies and pulses output by the I/O port. When the driver of the stepper motor receives the pulse signal output from the I/O port, it drives the stepper motor to automatically rotate a specific angle. The user can control the number of pulses through the code, thus controlling the angular displacement so that it could achieve accurate positioning. What’s more, users can also control the speed and acceleration of the motor by controlling pulse frequencies and totally governs the speed.[5] HC-SR04P ultrasonic ranging module works between 3.3-3.5v. When the power supply voltage is 5v, the detection distance would be 2-450cm. When the voltage is 3.3v, the detection distance could be 2-400cm. The detection angle could be less than 15 degrees, and 90 degrees is the best detection angle. It uses an industrial-grade MCU whose working temperature is -20-80℃.

GSM (Global System for Mobile Communications) is nowadays one of the major cellular network systems in the world. After years of development and optimization of the GSM network, the technology is now very mature, the signal is stable, and the communication distance is basically not affected by the surrounding environment. It is a very good solution to realize the electronic alarm, ultra-remote remote control of industrial equipment and transmission of information by using the short message function of GSM mobile phone.

The SIM900A module basically sends AT commands through the serial port to achieve control, and uses the UART serial port to communicate with the microcontroller to achieve short message transmission. Controller MCU is connected to SIM900a through TX, RXD, GN, and 5-18V DC power
is connected to SIM900a through VCC and GND. LCD1602 liquid crystal is a module for displaying test data. During the debugging phase, it is necessary to display the RP value of metal detection, the distance of obstacles detected by infrared ranging sensors, and the distance of ultrasonic detection, and perform corresponding debugging. During the finished product test phase, LCD1602 can be used to display prompt information, two lines of data and 16 characters each.

3. The Software Design for System

Using IAR software as the compiler and C language as the programming language, the software of device is written and downloaded to the MSP430F149 microcontroller to run. The program starts from the main function, judges in turn whether there is garbage entering, and whether the garbage entering is metal, etc., then the stepper motor could make a corresponding response, and finally the program detects whether the garbage overflows and triggers the GSM module to send an alarm message.

The workflow of LDC1000 metal sensor: The microcontroller reads the address of the corresponding register of the LDC1000 metal sensor through the SPI interface, and then accesses the data in the register through the address. Users can directly call the LDC process to get the corresponding data. The workflow of ultrasonic module: The ultrasonic module uses rising and falling edges to trigger timer B, records the time of the rising and falling edges, and then calculates the distance from the module to the object based on the time difference and parameters. The single-chip microcomputer captures the rising/falling edges of timer B, calculates the time difference, and then processes the data. Finally, the result would be displayed on the LCD screen.

The workflow of GSM module: SIM900aGSM module supports RS232 serial port and TTL serial port. This design uses TTL serial port for debugging, uses UART serial port (P3.4, P3.5 port) to receive and send data. Then the GSM would send information through AT command and designated receiving number control module. The workflow of Stepper Motor Module: The operation of the motor is controlled by a program of single-chip microcomputer. If the ultrasonic module detects that garbage is dumped and the metal sensor detects that the garbage is metal, the program will control the single-chip microcomputer to drive the stepper motor for an 90 degrees forward rotation, thus putting the garbage into the right trash can. If the garbage is non-metal, the stepper motor would rotate 90 degrees in the opposite direction, thus putting the non-metal trash into the left trash can.

4. System debug

First individually debug each module such as ultrasonic module, LDC1000 module, stepper motor, GSM module, etc. After each module can work normally and achieve the expected results, then the programs of each module are combined, debugged, and burned to the single-chip microcomputer for testing. After the crystal oscillator is configured, XT2 is used as the clock required for the single-chip microcomputer to run, and then initialize the various modules. Each module enters the running state. The programming of the loop body needs to directly or indirectly call the functions of each module and make some logical judgments, and finally achieve the corresponding design requirements.

The physical diagram of the device is shown in the Figure 2. According to the design requirements, when the human body approaches, the human infrared sensing module enters the working state, triggers the single-chip microcomputer to run, and controls the motor to open the lid of the trash can. The infrared ranging sensor detects whether there is garbage dumping, and the LDC1000 metal sensor detects whether it is metal. The motor performs garbage classification. When metal garbage is detected, the motor rotates 90 degrees forward and then returns to the original position by 90 degrees. When non-metal garbage is detected, it rotates 90 degrees reverse and then returns to the original position by 90 degrees. The ultrasonic module detects whether the garbage is overflowed after the motor returns to its original position, and notifies GSM to send a short message.
5. Conclusion
Adoption of MSP430F149 single-chip microcomputer technology and cooperation with corresponding peripheral equipment to realize the detection of metal waste, non-metal waste and metal waste classification in the public environment. Infrared human body sensor module is used to open and close the lid of the trash can, and GSM is used to detected whether the garbage is overflowed and sends a message to the staff for processing. The realization of this design has certain practical significance, but there are still many shortcomings in the design, such as low efficiency and low resolution. Due to the theoretical deviation of each module used, it is easily affected by the external environment and voltage. A certain offset will occur in actual work, making the test results unstable. On the other hand, the program design is not perfect, and it cannot achieve high execution efficiency and reasonable performance. These are the vulnerabilities that exist in the design and need to be optimized, and they need to be improved step by step during experimental testing.

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