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Design of Scenic Area Trash Can Detection System Based on Internet of Things Technology

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Abstract

With the rapid advancement and widespread adoption of Internet of Things (IoT) technology, there emerges a critical need for intelligent waste management solutions in scenic spots. This paper proposes a design scheme of trash can detection system for scenic area based on Internet of Things (IoT) technology, addressing the problems existing in current scenic area trash cans. Through real-time data transmission, the proposed system enables real-time monitoring of trash overflow, tilt angles, and fire incidents, thereby enhancing scenic area management efficiency and service quality.

Keywords

IoT, Scenic Area Trash Can, Real-time Detection System.

1. Introduction

With the accelerated development of Internet of Things (IoT) technologies and their deep integration into urban infrastructure, intelligent waste management systems have demonstrated significant application value in smart city construction. Existing research has primarily focused on urban waste classification systems [1]. However, a research gap remains regarding intelligent management solutions for trash cans in specialized scenarios, particularly in tourist attractions characterized by complex terrain features and strict environmental protection requirements [2].

Current manual inspection methods in scenic areas face three prominent challenges: Firstly, traditional fixed periodic inspection pattern leads to operational inefficiency. Secondly, delayed detection of abnormal conditions, such as trash can tilting or catching fire, bring security risks. Thirdly, the distribution of trash cans in large scenic spots is scattered. Some research use 5G or WiFi communication methods, but the former has a high maintenance cost, and the latter cannot solve the problem of long-distance communication in scenic spots.

To address these limitations, this study proposes a IoT-based detection system integrating multi-sensor and low-power wide-area network (LPWAN) technologies [3]. Main research includes: (1) Combined with ultrasonic ranging and pressure sensor, the system can detect the overflow state of the trash can in real time; (2) The system can detect the abnormal state of tilting and catching fire in real time; (3) The wireless communication solution based on LoRa can effectively overcome the signal attenuation problem in mountainous terrain.

2. Overall System Design

In order to solve the problems of full overflow of trash cans and the need for manual fixed periodic inspection and maintenance, the overall functions of the designed trash can detection system include three functions: overflow state detection, abnormal state detection and communication system. The overall scheme design is shown in Fig. 1.

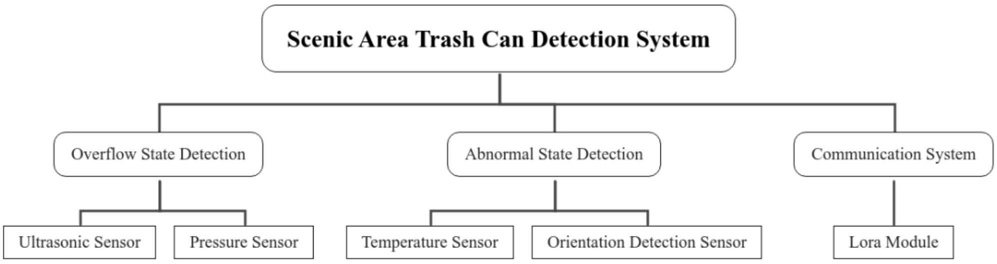

Fig. 1 Overall design of scenic area trash can detection system

The overflow state detection function is mainly composed of ultrasonic sensor and pressure sensor. The ultrasonic sensor emits ultrasonic waves into the inside of the trash can, and the ultrasonic wave is reflected after encountering the trash, and the sensor receives the echo. The real-time distance from the sensor to the trash surface, is calculated by measuring the time difference between the emission and reception of the sound wave. The pressure sensor is installed at the bottom of the trash can to detect the weight of the trash in real time. The microprocessor integrates the real-time data of the ultrasonic sensor and the pressure sensor, calculates the space occupation of the trash can in real time.

Abnormal state detection mainly includes temperature sensor and orientation detection sensor. The temperature sensor can detect the temperature state inside the trash can in real time to avoid the spontaneous combustion of trash caused by high ambient temperature or improperly discarded cigarette butts. The orientation detection sensor can detect the tilting state of the trash can caused by high winds or human factors.

The communication system is mainly composed of LoRa communication module, which is used for updating the detection results of overflow state and abnormal state to the system in real time. It’s a lower-power method to realize the long-distance wireless communication of the scenic spot.

3. System Hardware Design

3.1. Overflow State Detection

The hardware of overflow state detection function is mainly composed of the main control chip, ultrasonic sensor and pressure sensor. The main control chip adopts STM32F103, which has rich peripheral resources and is cost-effective, meeting the needs of the system. The ultrasonic sensor HC-SR04 [4] is a widely used low-cost ranging module, which is installed on the upper inside of the trash can. After sending a high-level pulse of at least 10 us to the ultrasonic sensor Trig pin, the sensor will automatically send out eight 40 kHz ultrasonic waves. When the ultrasonic wave is reflected back from the trash surface, a high-level pulse will be generated in the Echo pin. The width of the pulse is proportional to the distance. The hardware circuit of the ultrasonic sensor HC-SR04 is shown in Fig. 2.

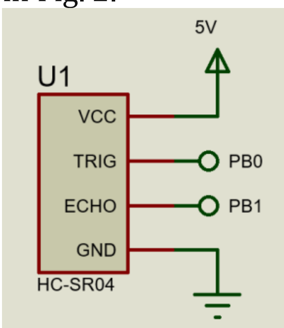

Fig. 2 The hardware circuit of the ultrasonic sensor HC-SR04

The pressure sensor HX711 [5] is a high-precision 24-bit A/D converter chip that integrates peripheral circuits, including a regulated power supply and an on-chip clock oscillator. It has the advantages of high integration, low cost, fast response, and strong anti-interference ability. A stable power supply is provided to the full-bridge circuit composed of four pressure resistors through E + and E-, and no additional power supply circuit is required. Channel A connects the differential signal of the bridge sensor, and the programmable gain of channel A is 128 or 64. The sensor can communicate with the main control chip via serial port protocol through the PD_SCK and DOUT pins. The hardware circuit of the pressure sensor HX711 is shown in Fig. 3.

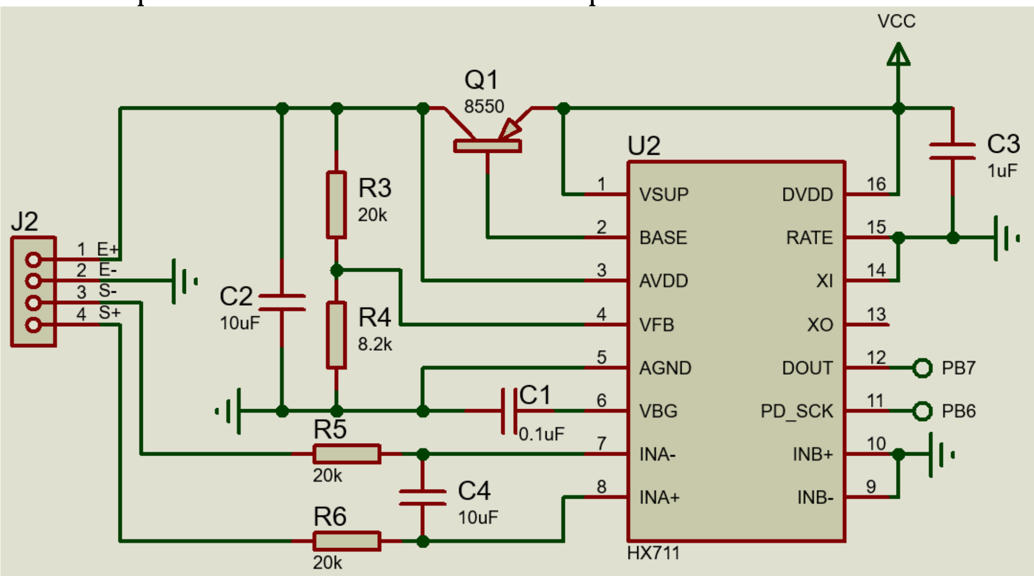

Fig 3 The hardware circuit of the pressure sensor HX711

3.2. Abnormal State Detection

The hardware of abnormal state detection is mainly composed of temperature sensor DS18B20 and orientation detection sensor MPU6050.

Temperature sensor DS18B20 [6] is a digital temperature sensor with small size, wide voltage power supply and simple interface with microprocessor, which is suitable for digital temperature measurement in narrow space of trash can. The working power supply of the sensor is directly connected to the power supply of the microprocessor. No other peripheral components are needed in use. The main control chip only needs to communicate with DS18B20 through the single wire protocol. The hardware connection is simple and the circuit cost is greatly reduced. The hardware circuit of the temperature sensor DS18B20 is shown in Fig. 4.

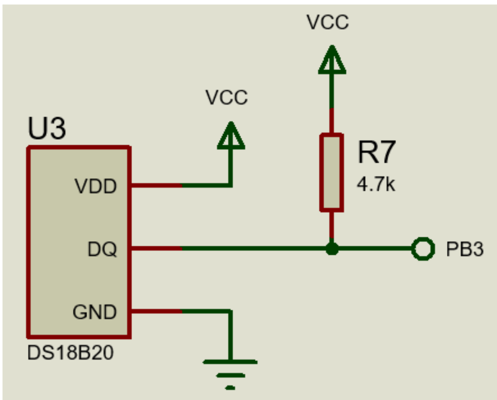

Fig. 4 The hardware circuit of the temperature sensor DS18B20

The orientation detection sensor MPU6050 [7] is a chip that can simultaneously detect three-axis acceleration and three-axis gyroscopes. The main control chip can obtain sensor data directly through the IIC interface. After filtering the original data, combining the multi-sensor data and calculating the tilting angle, the main control chip can get the tilting state of the trash can. The hardware circuit of the orientation detection sensor MPU6050 is shown in Fig. 5.

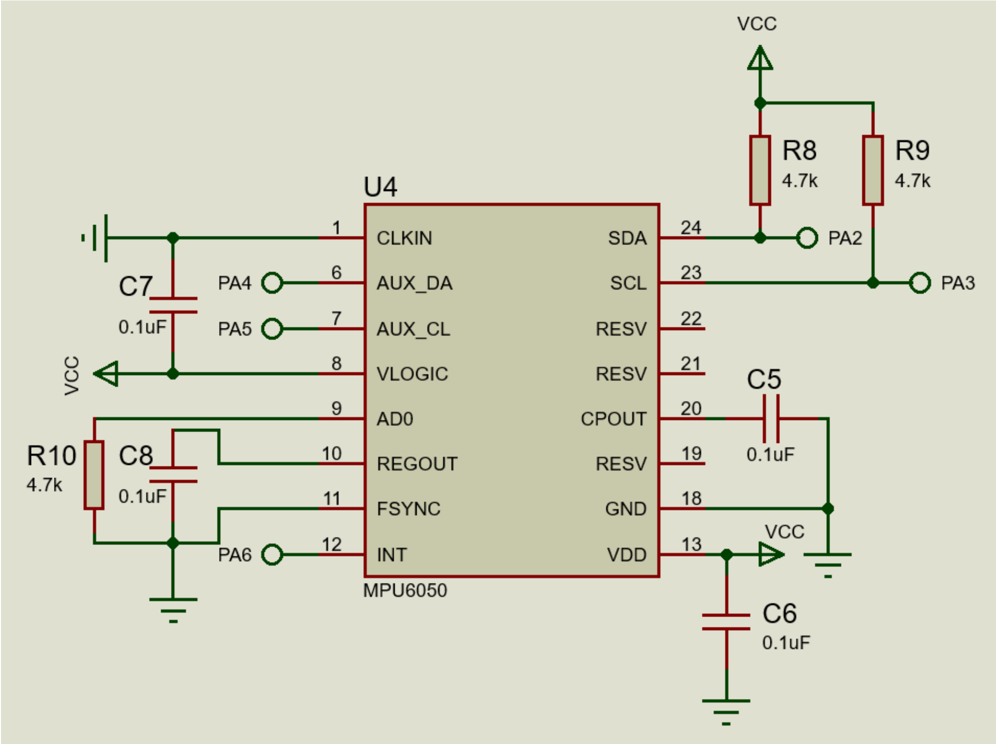

Fig. 5 The hardware circuit of the orientation detection sensor MPU6050

3.3. Communication System

LoRa, as a representative technology of low-power wide-area network, is a wireless communication technology specifically for IoT applications. It has the advantages of long transmission distance, low power consumption and strong anti-interference performance, and is suitable for scenic spot trash can detection system. The system adopts E32-TTL-100 module, and the core chip is SX1278 chip. After data communication via UART serial port, the results of overflow state detection and abnormal state detection can be uploaded to the LoRa gateway in real time. The hardware circuit of LoRa module is shown in Fig. 6.

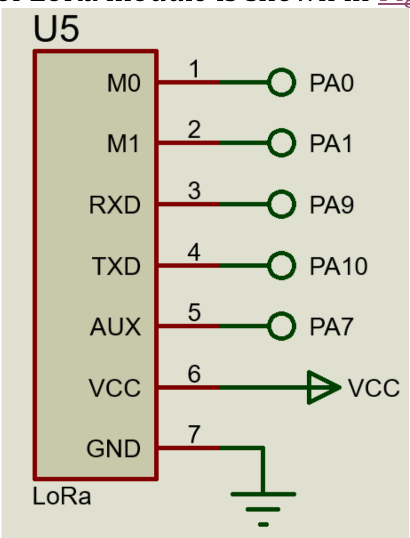

Fig. 6 The hardware circuit of LoRa module

4. System Software Design

In the Keil5 development environment, the main program is programmed in C language. The main control chip main program first initializes the configuration of system clock, GPIO pin, timer, UART serial port, IIC interface, etc., and then enters the main loop. Then the main loop periodically executes ultrasonic ranging program, trash weight detection program, temperature detection program, orientation detection program, and communication program.

4.1. Ultrasonic Ranging Program Design

The ultrasonic ranging program firstly outputs a high-level pulse of 20 us to the Trig pin, and waits for the high-level pulse output by the Echo pin. If the high-level voltage is detected in the Echo pin, it starts the timer to capture the time of the high-level pulse, and the ultrasonic wave round-trip time t can be obtained. The distance s can be determined using the formula $s = t \times v / 2$, where t represents the ultrasonic wave round-trip time and v is the speed of sound (340 m/s). The result s is the distance from the top of the trash can to the trash, when the measured distance s is less than 5cm, the trash can are regarding as in a full overflow state. The flow chart of the ultrasonic ranging program is shown in Fig. 7.

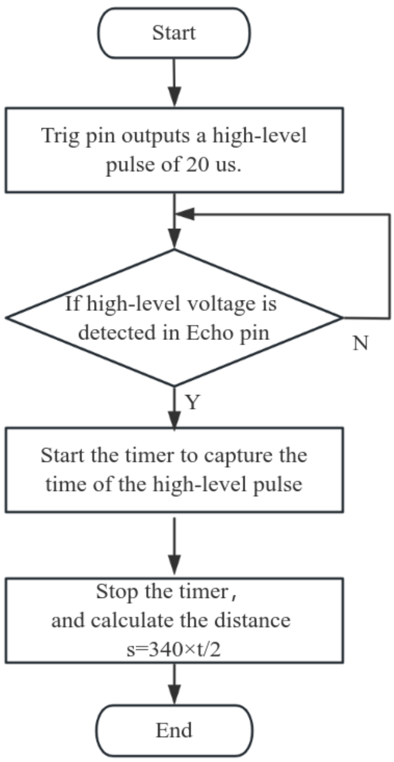

Fig. 7 The flow chart of ultrasonic ranging program

4.2. Trash Weight Detection Program Design

The trash weight detection program mainly processes the data of the pressure sensor. Firstly, the main control chip outputs 25 clock pulse signals to the PD_SCK pin of the pressure sensor in turn. At the rising edge of the first clock pulse, the highest bit (MSB) of the output 24-bit data is read from the DOUT pin. Until the 24th clock pulse is completed, and the 24-bit output data is read bit by bit from the highest bit to the lowest bit. The 25th clock pulse is used to select the channel and channel gain of the next A/D conversion. The selected input channel is A channel and the selected gain is 128. According to the filtered sampling value, the trash weight can be calculated. The flow chart of the trash weight detection program is shown in Fig. 8.

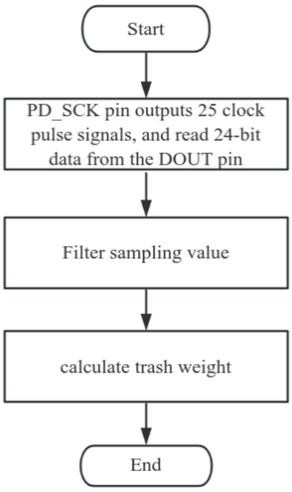

Fig. 8 The flow chart of trash weight detection program

4.3. Temperature Detection Program Design

The main control chip uses a single bus for half-duplex communication with the temperature sensor DS18B20. Firstly, the main control chip generates a reset pulse on the bus, which needs to output a low level holding time of at least 480 us. Then the main control chip releases the bus and waits for DS18B20 to generate a low-level response pulse. At this time, the pull-up resistance of the hardware circuit will raise the bus level. After receiving the response pulse, the main control chip outputs 2us low-level pulse on the bus to enter the read operation, and then sets the pin mode to input mode to read 1bit bus temperature data. After a delay of 50 us, the main control chip repeats the read operation until 2 bytes are read. Through the temperature calculation rules of DS18B20, the current temperature of the trash can is calculated. When the collected temperature is greater than 50 °C, it indicates that the cigarette butts may be put into the trash can. It will trigger the system to upload the alarm event of catching fire. The flow chart of the temperature detection program is shown in Fig. 9.

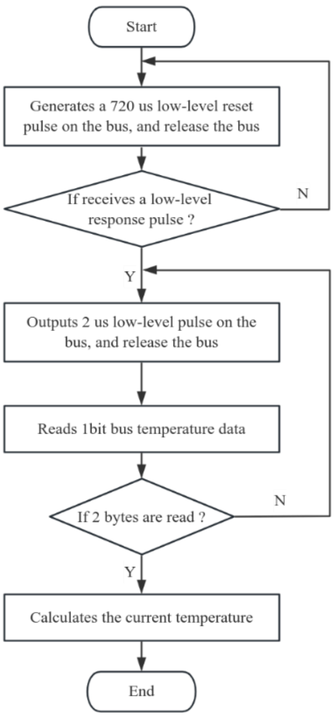

Fig. 9 The flow chart of temperature detection program

4.4. Orientation Detection Program Design

The main control chip uses I2C to communicate with the orientation detection sensor MPU6050. After obtaining the original data of accelerometer and gyroscope through serial communication, the data filtering is carried out by Kalman filter algorithm [8]. Then the accelerometer and gyroscope data are combined by the complementary filtering algorithm to calculate the Euler angle. The tilting state of the system can be judged by the pitch angle or roll angle. The flow chart of the design of the orientation detection program is shown in Fig. 10.

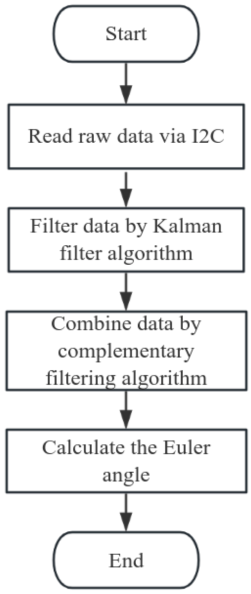

Fig. 10 The flow chart of orientation detection program

4.5. LoRa Communication Program Design

The main control chip communicates with the LoRa module through the UART serial port. In order to reduce power consumption [9], all sensor data of the trash can detection system will be sorted into a certain format data packet and sent to the gateway periodically. However, when the system detects an alarm event, it can immediately trigger a communication event and send the data to the gateway to improve the response speed. The flow chart of the LoRa communication program is shown in Fig. 11.

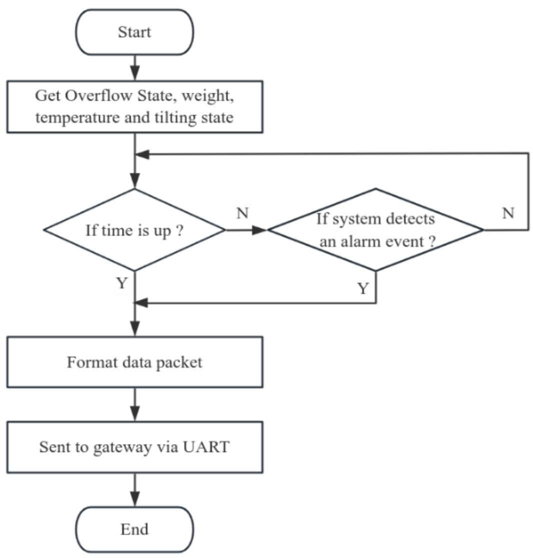

Fig. 11 The flow chart of the LoRa communication program

5. Conclusion

In order to solve the problems of manual inspection of trash cans in scenic spots, this paper designs a trash can detection system based on IoT technology. The system can intelligently detect the overflow state, tilting state and fire incidents through sensors. The detection results are uploaded to the gateway in real time through LoRa long-distance wireless communication. The detection system helps scenic spot manage the status of trash cans more conveniently and contributes to the sustainable development of scenic areas.

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