Design of Airport Wireless Bird Repellent Monitoring System

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Abstract. At present, the status detection of the bird driving equipment in the airport is completed by manual periodic inspection. This method can't grasp the status of the bird repelling equipment in real time and cost human resources. In view of this situation, a remote monitoring system based on STM32 is proposed. The system uses the embedded STM32 as the control and data processing core to collect the signals of the temperature sensor, pressure sensor, power supply voltage and sound sensor of the bird-repelling equipment. It is uploaded to the host computer through ZigBee technology to analyze the working conditions of the bird-repelling equipment and the situation of the gas gun. Through the test of the design system, the results show that the detection accuracy of the system can meet the actual need, the correct rate of detecting sound signal is 100%. In the environment of two concrete buildings, the wireless transmission distance is within 800m, and the error rate is 0.

1. Introduction

Bird collision is an important factor threatening aviation safety. Today, with the rapid development of the aviation industry, the scope of human activities is expanding, and the places where birds inhabit are gradually reduced. Therefore, the environment suitable for birds in the airport attracts a large number of birds to stay near the airport for a long time, which is a huge hidden danger for the take-off and landing process of the aircraft. The first bird collision took place in the United States in 1912, and people realized the impact of bird collision on the aviation industry [1]. According to the statistics of bird collision by civil aviation administration, the direct economic losses caused by bird collision were up to several billion dollars every year [2].

At present, the main method of repelling birds is that the airport staff rushed to the location of the bird's situation, using sound threat, visual interference and other means to drive birds. In order to ensure the normal operation of the bird driving equipment, the staff should regularly check the status of the bird driving equipment. In view of the current situation of airport bird repelling, combined with modern electronic technology and wireless technology, a remote monitoring system based on STM32 is developed to realize real-time monitoring of the working conditions of bird repelling equipment, and it is of great significance to improve the efficiency of bird-removing and lower cost.

2. Introduction to the overall scheme of the system

The overall design of the system is divided into two modules, namely upper machine module and lower machine module, as shown in Figure 1. The upper computer module consists of computer (PC) and a ZigBee central node. The lower computer module consists of sensor module, signal conditioning module, A/D module, STM32, ZigBee terminal node and gas gun driving module. The four quantities
measured by the sensor module are: the power supply voltage, the ambient temperature of the bird-repelling equipment, the pressure of the gas gun, and the sound of the gas gun. The host computer sends a command to collect the output of each sensor of the lower computer, the lower computer starts A/D to sample and convert the temperature, voltage and pressure, and sends the converted digital signal to the upper computer through the ZigBee module, and displays it in real time on the upper computer. When judging that the bird-repelling equipment is normal, the host computer sends a command to drive the gas gun, and at the same time collects the sound signal from the gas gun. The collected sound signal is subjected to windowed FFT processing in STM32 to obtain the maximum spectral value, and the maximum value is uploaded to the ZigBee node of the upper computer through the ZigBee module of the lower computer. After further processing, it is displayed on the host computer to judge whether the gas gun launch is successful.

![Figure 1. The overall scheme of the system.](image1)

![Figure 2. Temperature acquisition circuit.](image2)

3. System hardware design

In the lower computer, the hardware design mainly refers to the connection between the control chip STM32 and the peripheral circuit. The model of STM32 used in the system is STM32F303VCT6, It has its own A/D sampling chip. The hardware design of the lower computer includes the processing of the output signal of the sensor and the connection with the pin of STM32F303VCT6, and the connection between the wireless transceiver module SZ05-ADV-TTL and the pin of STM32F303VCT6. The upper computer hardware design is mainly the interface between the wireless transceiver module SZ02-RS232-2KM and the upper computer. Due to space limitation, this paper mainly introduces temperature sensor module, sound sensor module, wireless transceiver module and circuit of main control chip.

3.1. Temperature acquisition module

The temperature acquisition module is used to monitor the temperature of the bird repellent equipment to ensure the normal operation of the equipment.

The temperature sensor used in the system is TC1047AVNB. The voltage range of the device is 2.5v to 5.5v, the measuring temperature range is -40°C to +125°C, and the output voltage range is 100mV(-40°C), 500mV(0°C), 750mV(+25°C) and 1.75v (+125°C) [3]. TC1047AVNB has three ports, the power supply positive, power ground, and signal output. Figure 2 is the circuit for signal processing and sampling of the temperature sensor. The amplifier MCP6022-I/SN forms a voltage follower for buffer and isolate of the signal. After voltage division, one 0.1μF capacitor is connected in parallel for filtering, and the IN_T terminal is connected to the A/D sampling channel of the STM32 processor.

3.2. Sound acquisition module

The sound sensor SPU410HR5H converts the sound of the gas gun into a voltage signal, and is amplified by a signal amplifying circuit, A/D conversion. The digital signal is stored in STM32's RAM. The sampling frequency of the sound signal is 40KHz. When sampling 2048 points, it is subjected to windowed FFT processing to obtain the maximum spectral value.
Figure 3 shows the peripheral circuit of the sound sensor. The sound sensor SPU410HR5H has a frequency range of 100Hz ~ 10kHz and outputs a millivolt signal. MCP6021 is used as an amplifier to amplify the signal. After amplification and filtering, the IN_M end of the circuit is connected to the A/D acquisition channel of STM32 processor (the 26th pin of STM32).

![Figure 3. Temperature acquisition circuit.](image)

### 3.3. Peripheral circuit design of wireless module

Figure 4 shows the transceiver module SZ05-ADV-TTL, which is connected to the lower computer STM32. The pin functions of SZ05-ADV-TTL are shown in Table 1. The transceiver module connected with the upper computer is SZ02-RS232-2KM, and the data interface of SZ02-RS232-2KM is RS232. It is connected to the computer via a USB to serial cable.

ZigBee is a wireless network communication technology standard with dynamic routing characteristics. The communication frequency band is 2.4GHz, it makes the wireless module have the characteristics of flexible networking and strong anti-interference ability [4,5]. The maximum communication distance of this module can reach 2KM in the case of no obstacles. The distance of wireless communication required by this system is between 1.5KM and 2KM, and the module meets the requirements.

![Figure 4. SZ05-ADV-TTL device pin.](image)

#### Table 1. SZ05-ADV-TTL pin function.

| Pin number | Identification | Function         | Remarks          |
|------------|----------------|-----------------|------------------|
| 14         | CFG            | Configuration   | Active low       |
| 20         | GND            | Power ground    |                  |
| 21         | VCC            | Power supply    | 5V               |
| 22         | RX1            | TTL level       | Connected to the lower machine TX |
| 23         | TX1            | TTL level       | Connect to the lower machine RX |
| 28         | RST            | Reset           | Low level active |

### 3.4. STM32F303VCT6 pin assignment

The main control chip STM32F303VCT6 has up to 100 pins. PB3, PB4 and PE6 are respectively connected to the data receiving pin, the data transmitting pin and the CFG configuration pin of the wireless module SZ05-ADV-TTL. PA3 is connected to the sound signal output terminal IN_M. PB0, PC0 and PC1 are respectively connected to the external voltage output port IN_V, temperature signal output port IN_T and pressure signal output port IN_P. The output level of PC9 drives the operation of the bird-driving module circuit. PF0 and PF1 are used as pins of external crystal oscillator circuit to generate 8MHz clock source. The device's power supply voltage is 3.3V.

### 4. System software design

The system software mainly includes the lower computer signal acquisition software, serial port setting software, ZigBee node configuration, and sound signal processing software. The software development environment is Keil's ARM development tool MDK.
4.1. Lower computer main program design

The lower computer software mainly completes the functions of temperature signal, pressure signal, sound signal and power voltage signal acquisition, bidirectional transmission of data and FFT operation of sound signal. Figure 5 is a flow chart of the main program of the lower computer. Initialization includes the ADC operating mode, sampling frequency setting, FFT conversion point setting of the sound signal, and initialization of ZigBee.

![Figure 5. STM32 main program flow chart.](image1)

The master chip STM32F303VCT6 of the lower computer has four internal ADCs, and each ADC has 19 channels. The ADCs of different channels can work in three different modes, which are single, continuous and discontinuous working modes. In this system, the ADC that collects temperature, voltage, and pressure is set to the loop mode, and the ADC that collects the sound signal is set to a single working mode.

The sampling frequency of the ADC is implemented using the timer TIM of the STM32. Channel 4 of ADC1 converts the sound signal, the trigger source selects the advanced timer TIM1; ADC2 channel 6 and channel 7 convert the pressure and temperature, respectively, the trigger source is the basic timer TIM6; ADC3 channel 2 converts the voltage, the trigger source is the basic timer TIM7. If the frequency of the time base is 72 MHz, the temperature, voltage, and pressure sampling frequency is 100 Hz, and the sound signal sampling frequency is 40 kHz. Sampling frequency calculation formula:

\[
\text{Sampling frequency} = \frac{\text{Time base formula}}{(TIM\_Prescaler+1)\times(TIM\_Period+1)}.
\]

STM32 automatically stores the conversion data into the 16-bit data register ADC_DR after A/D conversion. The FFT points of the sound signal are controlled by a direct memory access (DMA) method, that is, a Buff is defined to receive the data transmitted by the DMA and then perform the FFT operation. The size of the Buff is set by us. The maximum number of data transfers of the DMA can reach 65535. When the DMA completes the FFT points required for transmission, an interrupt is generated to process the data.

4.2. Lower computer serial communication mode configuration

STM32 and SZ05-ADV-TTL communication adopt USART serial communication mode. This mode works in two-way communication, using data transmission (TX) and data receiving (RX) pins. The serial port configuration steps are: ① Enable GPIO clock and USART clock for RX and TX pins; ② Initialize the GPIO, and configure the RX to the floating input mode, and set the TX to the push-pull output mode; ③ Configuring USART parameters; ④ Configure the interrupt controller (NVIC) and enable the USART interrupt; ⑤ Enable USART.
4.3. ZigBee node configuration

The system uses two ZigBee nodes, which are the central node and the terminal node. The terminal node communicates with the lower computer STM32 via USART2, and the central node and the host computer PC are connected through the RS323 to USB interface.

1. Terminal node configuration

The configuration of the terminal node is implemented by using software in the STM32. The process is as follows:

(1) Pull down the CFG pin of the module SZ05-ADV-TTL for 3 seconds to make the module configuration state.
(2) Send local module read parameter command: 23 A0. The output frame format of the module parameters is A2+14 bytes of valid data.
(3) Send the parameter setting command, that is, 23 FE + 14 bytes to configure the data.
(4) Send the restart module command 23 23 to complete the configuration.

2. Central node configuration

First connect the PC to the SZ02-RS232-2KM module via USB to serial cable.

(1) Check the port number of the computer in the properties of the computer, and then set the parameters through the serial debugging assistant. Select the correct COM port detected by the computer, set the baud rate to 38400.
(2) Press and hold the configuration button for 3 seconds, and the device enters the configuration state. After entering the configuration state, the ALM, NET, and RUN lights on the module will flash simultaneously.
(3) Enter the system prompt security code "SHUNCOM".
(4) After entering the security code, the system automatically displays the configuration parameters. After the configuration is complete, enter "D" to restart the device and exit the configuration.

5. Test and analysis of the system

System testing mainly includes testing of wireless transmission distances and testing the reliability of temperature, sound, pressure and supply voltage acquisition and processing. Figure 6 shows the main interface of the airport bird monitoring system in the upper computer. In the figure, 001# and 002# respectively represent different devices in different positions. In the test, 001# equipment is used, that is, using gas gun to drive away birds.

5.1. Temperature and voltage reliability test

The temperature value for the normal operation of the bird-repelling equipment is set between -20 °C and 60 °C. If this temperature range is exceeded, the equipment is considered to be faulty. In the test of the reliability of the temperature sensor, the system test data is compared with the value of the industrial mercury thermometer. The test time is 12:00 pm on June 12, 2018, and the room temperature is tested every two hours. The data is recorded every two hour, for a total of 10 numbers, and partial experimental data is shown in Table 2.

The normal power supply voltage of the lower computer is between 10V and 12.5V. In the experiment, the voltage value displayed by the PC is compared with the measured value of the multimeter, and the maximum error value is 0.2V.

Table 2. Temperature experiment data comparison.

| Numble | Data         | Time  | Temperature display(°C) | Display system(°C) | Deviation |
|--------|--------------|-------|-------------------------|--------------------|-----------|
| 1      | 2018.6.12    | 17:00 | 35.3                    | 36.1               | 0.8       |
| 2      | 2018.6.12    | 21:00 | 31.4                    | 31.9               | 0.5       |
| 3      | 2018.6.13    | 1:00  | 28.7                    | 29.1               | 0.4       |
| 4      | 2018.6.13    | 5:00  | 27.9                    | 28.1               | 0.2       |
| 5      | 2018.6.13    | 9:00  | 33.6                    | 34                 | 0.4       |
5.2. Sound signal acquisition and processing reliability test

The sound signal acquisition, processing and transmission reliability were tested. Figure. 8 shows the upper computer display value when there is a sound signal. In the same environment, multiple tests were performed, and the recorded partial data are shown in Table 3.

**Table 3.** Sound experiment data comparison.

| Numble | No sound measurement | Sound measurement | Difference |
|--------|----------------------|-------------------|------------|
| 1      | 12695                | 41562             | 28867      |
| 2      | 10473                | 45782             | 35309      |
| 3      | 11954                | 39655             | 27701      |
| 4      | 12539                | 42336             | 29797      |
| 5      | 11735                | 45388             | 33653      |

5.3. Sound signal acquisition and processing reliability test

In the experiment, the wireless transmission distance of the power supply voltage test value of the lower computer was tested. There are buildings in the experiment. Table 4 is the recorded data.

**Table 4.** Wireless distance test.

| Numble | Wireless distance(m) | Obstacle situation | Multimeter measurement(V) | System measurement(V) |
|--------|----------------------|--------------------|---------------------------|-----------------------|
| 1      | 60                   | No obstacles       | 12                        | 11.9                  |
| 2      | 300                  | A building         | 12                        | 11.8                  |
| 3      | 600                  | Two building       | 12                        | 11.8                  |
| 4      | 800                  | Two building       | 12                        | 11.8                  |
| 5      | 1000                 | Three building     | 12                        | 0                     |

From the test results, due to the presence of obstacles, when the distance reaches 1000 meters, the upper computer and the lower computer can’t communicate normally.

6. Conclusion

Designed a set of airport wireless bird monitoring system, completed the analog acquisition and data processing of the lower computer, completed the setting of the ZigBee module of the lower computer and the upper computer, and completed the command transmission of the upper computer and the display of the data. The experimental results show that the temperature and voltage measurement accuracy of the bird-repelling equipment can meet the actual requirements, the system can correctly judge whether there is a sound signal or no sound signal. If there are two buildings, the error rate of wireless transmission distance of the system is 0 within 800m.

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