Design of monitoring system for intelligent windows based on cloud platform

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Abstract. With the development of Internet of Things technology, the intelligent window is entering people's lives. There are many intelligent window products in the market, but most of them are costly or functions-limited with insufficient consideration of intelligence and humanization. Therefore, an intelligent window monitoring system based on Alibaba Cloud is introduced in this paper. This product can be automatically controlled according to environmental changes or manually controlled using the APP/infrared remote control. The indoor situation is displayed on the mobile phone and OLED screen in real-time, so that people can always grasp the situation and make correct judgment and operation in time. The product has a wide scope of applications. It is suitable for most families, rich in functions, more humanized, and has certain practicality.

1. Introduction
Lives of modern families in our country are becoming intelligent. The continuous introduction of policies related to the Internet of Things has provided valid support for the smart home industry, which makes it a rising industry in the application of the Internet of Things in one fell swoop. At the same time, the progress of key technologies and the improvement of the industrial system have also laid an important foundation for the development of the smart home industry. Therefore, the smart home industry enjoys promising development prospects.

At present, the windows of most buildings are still manually controlled, however, this traditional method is increasingly unable to meet the daily needs of modern people[1]. People in modern society are occupied with work since they leave early and return late. People sometimes forget to close the window or open it for ventilation, which leads to an awkward situation, they cannot close the window in time when encountering bad weather no matter how fast they go back. When there is a leak of combustible gas in the home, it will cause unnecessary loss or even horrible damage if the window is not opened in time for ventilation. Therefore, designing an intelligent window which can monitor indoor situations in real-time and control the open and close of windows remotely is an urgent problem.

The technical solutions adopted by the intelligent windows control system can be divided into two categories: one is the use of wired networking technology, including CAN (Controller Area Network) bus, PLC, RS232/485, etc.; the other is the use of wireless networking technology, including WLAN, ZigBee, GPRS, Bluetooth, DNLA, etc. In references [2-4], the CAN bus is well presented in intelligent window, smart home, and smart car window, ensuring reliable communication between various parts of the system. According to references [5-7], ZigBee has realized the flexible networking
and wireless remote control of the system in the intelligent window and smart home. Wired networking technology has high reliability, good anti-interference performance, large throughput, and is suitable for long-distance communication. However, its wiring is cumbersome, with costly installation and maintenance, and there’s room for improvement for scalability. Although wireless networking technology is not as functional as wired networking technology in terms of reliability, anti-interference and throughput, it has good scalability, low installation and maintenance costs, which is suitable for smart home[7]. Therefore, Wi-Fi control mode is used in the paper, which belongs to wireless networking technology.

Research on intelligent windows continues, but most of them have simple functions, such as realize the opening and closing of the window only by sensors[8]. There are also intelligent window products that can realize infrared alarm[9], SIM SMS control[10], etc. However, as mobile phones become more powerful, fewer people use traditional SMS. Therefore, an intelligent window monitoring system based on Alibaba Cloud is discussed in the paper.

2. Hardware structure

STM32F103ZET6 is used as the main control chip of the system in the paper. The system displays the information collected by the temperature sensor, combustible gas sensor and rain sensor on the OLED display screen in real-time, and also uploads the data to Alibaba Cloud through the Wi-Fi module. The sensor information can be used to instruct the motor drive module to open and close the window. Besides, the control form of infrared remote control has been added, which can switch the control mode of the system with one click to meet the needs of more people. Figure 1 shows the overall system block diagram. The use and principle of each hardware part will be explained in detail below.

| ULN2003 motor drive module | DS18B20 temperature sensor module |
|---------------------------|----------------------------------|
| 0.96inch OLED display     | MQ-2 combustible gas sensor module|
| infrared remote control receiver | rain sensor module |
|                           | ESP8266 Wi-Fi module             |

**Figure 1. System block diagram.**

2.1. Motor drive

Considering that the action of opening and closing the window needs to be slow and accurate, we select the stepper motor because its features are slow speed and easy control of the rotation angle compared to the DC motor. The stepper motor 28BYJ-48 is selected in the system. To expand, the stepper motor has the following characteristics:

- The accuracy of the stepper motor is 3%-5% of the step angle, and it is not accumulated.
- Stepper motor has the characteristics of instant start and rapid stop
- The stepper motor needs to add a drive signal to run at a certain angle, otherwise, it will stop.

Based on the third feature, we select ULN2003 drive module, it is to provide the drive signal for the stepper motor, so as to realize the window opening and closing at a fixed angle and a stable speed. The ULN2003 drive module can provide a faster current rise and fall speeds, making the current waveform close to a rectangle. Meanwhile, it also holds high power and efficiency, which drives the stepper motor to rotate well.
2.2. OLED display
The 0.96inch OLED display screen of Zhongjingyuan Electronics is chosen in the paper. OLED is considered to be the next-generation flat panel display emerging application technology, because it enjoys the advantages of self-illumination, no backlight, high contrast, thin thickness, wide viewing angle, fast response, wide temperature range, simple structure and process, etc. The OLED display chosen is a white version with SPI interface, whose display effect is white text on a black background and resolution is 128*64.

2.3. Wi-Fi module
The Wi-Fi module selected in the paper is ESP8266 module produced by Ai-Thinker. ESP8266 is an ultra-low power UART-Wi-Fi transparent transmission module, with the industry's most competitive package size and ultra-low energy consumption technology, which is designed for mobile devices and IoT applications.

ESP8266 supports three working modes:
- STA: ESP8266 is connected to the Internet through a router, and the mobile phone or computer can remotely control the device through the Internet;
- AP: ESP8266 is used as a hotspot to directly communicate with a mobile phone or computer for wireless LAN control;
- STA+AP: Coexistence mode of the two modes[11].

Since the sensor information will be uploaded to the cloud, we select the STA mode. In other words, Wi-Fi module is used to connect to the router, so as to realize remote monitoring and control.

3. Software design
In order to embody practicality and humanity, two modes are used for control in the system, namely automatic mode and controllable mode. The overall idea of the design is shown in figure 2.

After the system is powered on, it defaults to automatic mode (it can also be designed into controllable mode, which can be achieved by rewriting the program). The opening and closing of the window in automatic mode only depends on real-time data measured by the temperature sensor, the combustible gas sensor and the rain sensor. Thus, the system can intelligently determine whether to open or close the window based on environmental circumstance to achieve the goal of ensuring indoor safety and ventilation. When pressing the switch mode button which is on the infrared remote control, the system then switches to controllable mode. In controllable mode, the system is only controlled by infrared remote control and APP. The sensor information obtained through real-time detection is not only used for automatic control mode, but also used for OLED screen display and upload to Alibaba Cloud. The APP can display the indoor situation on the mobile phone in real-time by subscribing to the sensor information stored in Alibaba Cloud.

![Figure 2. Software design block diagram.](image)

The following are software design from three aspects: control mode, Alibaba Cloud implementation and APP design.
3.1. Control mode

3.1.1. Automatic mode. The software flow of automatic mode is shown in figure 3. After the system selects automatic mode, the main controller compares three sets of sensing information with three preset thresholds Vol1, Vol2, and Vol3. When the detection value Vol_{MQ-2} of the combustible gas sensor MQ-2 module is greater than Vol1, the system drives the motor to open the window; When the detecting value Vol_{rain} of rain sensor is greater than Vol2, the system drives the motor to close the window; When the detection value Vol_{temp} of the temperature sensor DS18B20 module is greater than Vol3, the system drives the motor to open the window. The priority of the three sensors decreases in order. For example, when the judgment of the combustible gas sensor takes effect, the control of the latter two will be invalid.

![Software flow chart in automatic mode](image)

Figure 3. Software flow chart in automatic mode.

As can be seen from the flow chart, if the control mode is not switched, the judgment is made continuously. If one of the conditions is met, it will cause the window to be constantly opened or closed, which is very likely to make damage. Therefore, a switch flag is set. When the window is open, the switch flag will be set to 1, and the window closing operation is allowed, the window opening operation is invalid. Similarly, when the window is closed, the switch flag is cleared to 0, only the window opening operation is allowed but not the window closing operation.

3.1.2. Controllable mode. The change of the detection information of sensors in controllable mode will not drive the window. At this time, it can only be controlled by the infrared remote control and APP. This part mainly describes the software control of the infrared remote control. The infrared
remote control module includes an infrared remote control and an infrared receiver, and the infrared receiver can receive a 38KHz modulated remote control signal. After the infrared remote control is initialized, two global variables are defined in the external interrupt function, which are the acceptance flag and the acceptance code. When a button is pressed on the infrared remote control, the acceptance flag will be set to 1 to tell the system that a button has been pressed. At the same time, the value corresponding to the button is stored in the acceptance code. The three buttons in the infrared remote control are used in the design, which are respectively used for mode switching, window opening and window closing.

3.2. Alibaba Cloud implementation

The process of connecting the devices to Alibaba Cloud can be shown in figure 4. The first step is to create Products and Devices on Alibaba Cloud's developer platform. The system will automatically generate device triplets, namely ProductKey, DeviceName and DeviceSecret. Only when the triplets in the program precisely match, can the hardware device communicate with Alibaba Cloud.

![Figure 4. The process of accessing Alibaba Cloud.](image)

![Figure 5. APP interface.](image)

After the devices are successfully activated, TSL (Thing Specification Language) needs to be configured in the cloud first. In the Internet of Things platform, defining the TSLs is to specify product functions. The TSL describes what it is, what can be done and what services can be provided. Six TSLs are set, namely “mode switching”, “window status”, “window operation”, “temperature”, “rainfall level” and “combustible gas concentration”. The attributes of “mode switching” and “window status” are set to “read-write”, and the others are set to “read-only”.

After the TSLs have been defined, the device information can be uploaded to the cloud through programming. Wi-Fi module selects STA mode so that it connects to wireless connection. After
configuring the CONNECT message, SUBSCRIBE message and PUBLISH message in the file mqtt.c, the sensor information transmitted to the main controller can be uploaded to Alibaba Cloud for updating in real-time. Indoor conditions and environmental information can be remotely monitored by subscribing to related topics using an APP on the mobile phone.

3.3. APP design
Following the hardware uploads various amounts of information to Alibaba Cloud through the MQTT protocol, it saves different information according to topics. In order to better achieve humanization and remote monitoring, APP is added and essential to the design. MQTT protocol is also used for the communication between APP and Alibaba Cloud. The APP needs to send a CONNECT message to Alibaba Cloud first. A SUBSCRIBE message can be sent to subscribe to different topics and display them on phone if the connection is smooth. Similarly, APP can also access to the hardware by sending PUBLISH message to the cloud.

The interface design of the APP is shown in figure 5. Android Studio is used for APP editing in the design. As can be seen from figure 5, the user name and password need to be entered first for MQTT protocol connection when using the APP. After the connection is successful, the status of the window is opened or closed will be seeable. Then, a user can try to operate the system, such as opening and closing the window, switching between the controllable mode and the automatic mode. Meanwhile, a user will be able to grasp the information remotely of indoor temperature, combustible gas concentration, whether it rains outdoor and the degree of rainfall via his/her mobile phone anytime, anywhere.

4. Testing and analyzing
After the product and devices are built on the Alibaba Cloud, the devices will be inactive. The device situation is shown in figure 6. The newly created two devices, “application” and “hardware,” respectively represent the APP side and the hardware side. It can be seen from figure 6 that the two devices belong to the same product called “Intelligent_window,” but both devices are in an inactive state.

![Figure 6. Inactive devices.](image)

When both the hardware and the APP are programmed to connect to Alibaba Cloud through the MQTT protocol, the status of the two devices changes, as shown in figure 7. It can be seen from figure 7 that both devices are activated and shown online, the last online time is also displayed at the rightmost column.

![Figure 7. Activated devices.](image)

The functional test of the system is carried out below. After the entire system is on, it is in automatic mode by default. The drive of window in automatic mode depends only on the current environmental conditions. When the “MODE SWITCH” button on the APP is pressed, the system switches to
controllable mode. In this mode, the APP or the infrared remote control can be used to open and close the window.

As can be seen from figure 8, OLED can be used to display indoor environment conditions in real-time, including temperature, combustible gas concentration, and the degree of rainfall, which is convenient for users to manage the condition at home while detection values are also sent to the APP through Alibaba Cloud. Windows become smart home appliance, and users can monitor and control them remotely.

![OLED display](image)

**Figure 8.** OLED display.

### 5. Conclusion

An intelligent window monitoring system that integrates intelligence and humanization is introduced and discussed in the paper. The system is rich in functions, including automatic control using multiple sensors, controllable control using an infrared remote control and mobile phone, and it also displays indoor information on OLED. Furthermore, every piece of information in the system can be uploaded to Alibaba Cloud via Wi-Fi. The design embraces the characteristics of wide application range and simple operation, so it is high in practicality and user-popular.

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