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Research Article

A Design of Multifunctional Smart Window with Large Angle Opening and Closing

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ABSTRACT

With the vigorous advancement of intelligent manufacturing, smart home has gradually entered people's daily life. At present, smart window always have the problem of low intelligence and a few functions. And almost all kinds of traditional windows have the problem of inconvenient cleaning outside. The paper proposed a new mechanical structure design of the window, so that the window can be turned by nearly 160 degrees, which is convenient for cleaning the both sides of the window. In terms of intelligent systems, a variety of sensors combined with Internet modules are used to realize the remote intelligent control (turning with the wind, and automatically closing windows when there is no one at home when bad weather). Window adds a child mode, which is based on machine vision. In this mode, when the window detects that there is a child nearby, the window will be automatically closed to effectively avoid the accident of children falling from the building caused by climbing the window.

1. Introduction

With the development of science and technology and the improvement of people's living standards, the smart window industry has developed rapidly around the world. Thanks to the development of the construction industry, China's smart window market has grown steadily year by year, occupying an important market position. It can be seen that smart windows are the industry and the future development trend.

On this basis, the team first conducted research on existing window products. Fig. 1 shows the mainstream traditional windows currently on the market. It is not difficult to see that traditional windows mainly have the following disadvantages:

Inconvenient cleaning: limited by its structural design, it is difficult for users to clean the glass from outside of the window, which will affect the light transmission and aesthetics of the window for a long time.

Manual control: Traditional windows still require manual opening or closing.

There are potential safety hazards: Children may fall from buildings because the windows do not have protective equipment. The window structure is simple and easy to be damaged, which leads to the problem of burglary and brings economic losses to users.

Fig.1. Traditional window structure

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In the research on smart windows, it is found that the defects of existing smart windows are mainly manifested in the following aspects:

Low degree of intelligence: all kinds of intelligent windows have single functions. For example, smart dimming glass windows study the light transmission of glass; smart security windows are developed in terms of automatic alarms.

Inconvenient installation: Fig. 2 shows the control principle of a mainstream smart window product on the market. By adding a slider to the window or the wall next to the window, a controller is installed on the slider, and the controller is connected to the window. Through the controller's movement on the slider controls the opening and closing of the window. This puts higher demands on the strength of the window frame and the space reserved for window installation. But this has not changed the inconvenience caused by the traditional window structure, and the disadvantage of inconvenient cleaning still exists.

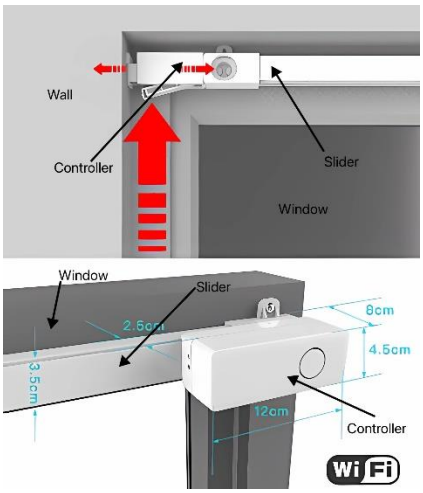

Fig.2. Traditional smart windows

Aiming at the problems of existing traditional windows and smart windows, the team designed a new smart window. First of all, a new design is made on the mechanical structure of the window, so that the window can be turned 160°, which solves the problem of cleaning the outside. At the same time, the structure is integrated with the window frame for easy installation.

At the same time, adding a variety of sensors enables the window to adapt to more usage scenarios. The child identification and alarm module is also added to improve safety.

2. Control System Design

The control system is composed of core controller, sensor, display, motor and Bluetooth module.

2.1. *Hardware Design of Control System*

The control system is composed of Arduino UNO and ESP8266, which is used to process the data and control commands received by the sensor and Bluetooth. Sensors include compass module, temperature and humidity sensor, air dust sensor, rain sensor, harmful gas sensor, and combustible gas sensor [1], which are responsible for sensing changes in the surrounding environment. For example, the harmful gas sensor will automatically open the window when harmful gas is detected.

A 1.3-inch OLED screen is used to display the data collected by the sensors installed on the window. Stepper motors and stepper motor drivers are used to control the mechanical structure movement of the window. The main elements of the window are shown in Fig. 3.

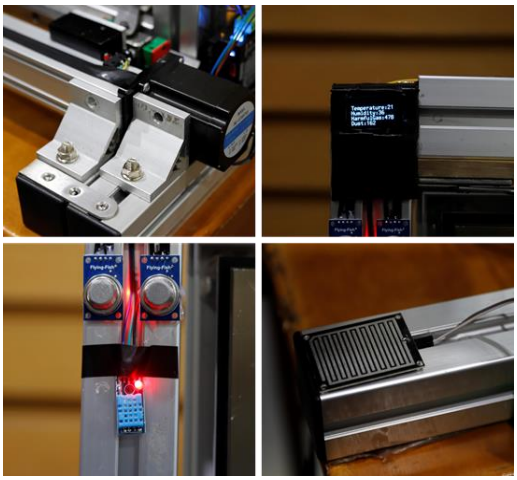

Fig.3. The main elements of the window

2.2. *Hardware connection of Control System*

The core controller receives and analyzes the data sent by the sensors connected to it through the Arduino UNO. With the processed data, the core controller can drive the stepper motor to control the movement of the window's mechanical structure, thereby changing the state of the window.

The 1.3-inch OLED screen is connected to the controller via the I2C bus. The frequency of screen drawing and refreshing is controlled by the Arduino UNO timer, refreshing once every certain time, so that the controller can process the received information or instructions in time [2].

The Bluetooth module on the smart window is connected with the controller through the USART bus to realize the wireless transceiver function in close range.

The connection mode of each sensor and the one-chip computer is shown in Fig.4.

Fig.4. Nearly 160° flipped windows

A stepping motor is connected between the controller and the mechanical structure of the smart window, and the stepping motor is controlled by sending a pulse signal to the motor driver to open or close the window.

The Bluetooth module mounted on the smart window is connected to the controller through the USART bus to realize the short-distance wireless transceiver function. The circuit connection diagram of the control system is shown in Fig.5.

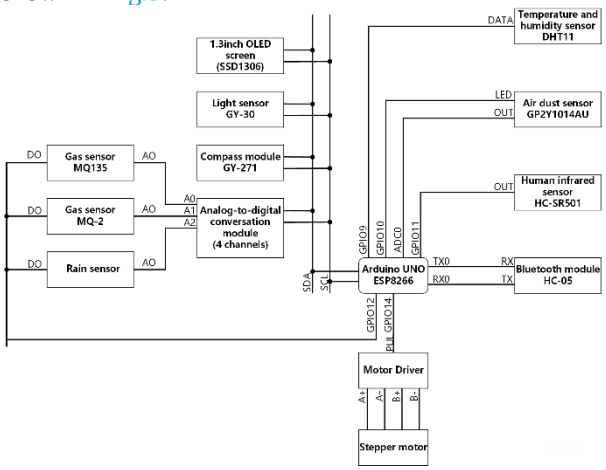

Fig.5. Control system connection diagram

3. Mechanical Structure Design

Smart design of the mechanical structure is the key to the large-angle opening and closing of the smart window. The structure is designed by adding the connecting rod (the motor drives the lead screw and makes the slider move in the horizontal direction through the movement of the lead screw, and the window is rotated by the connecting rod during the movement of the slide), only one motor can realize the window flip nearly 160 degrees. The connecting rod structure and the window mechanical structure are shown in Fig. 6 and 7 respectively.

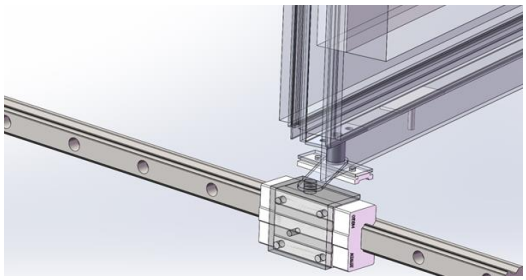

Fig.6. Connection rod structure

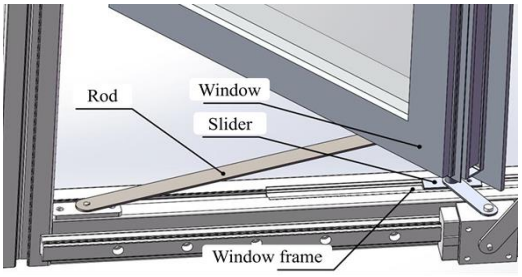

Fig.7. Mechanical structure drawing

Fig.8 shows the three typical open states of the window, namely 30°, 90° and 160°. Compared with the existing windows, it can effectively solve the problem of difficult cleaning from outside. Clean the outside of the window is shown in Fig.9.

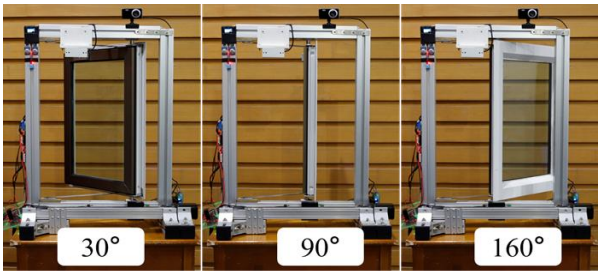

Fig.8. Mechanical structure drawing

Fig.9. Clean the outside of the window

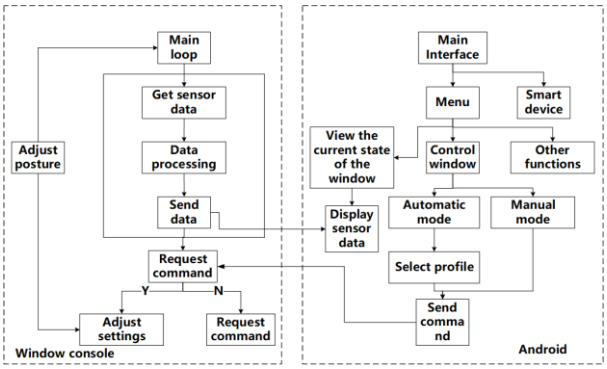

Fig.11. Process of App control

4. App Design

The team developed a mobile App for smart windows, and the App interface is shown in Fig. 10. It is connected to the control system through Bluetooth on the mobile phone, so that the user can control the window through the App. The main functions of the App include querying, displaying environmental data information, searching for nearby windows that can be paired, and controlling windows. The process of App controlling windows is shown in Fig. 11.

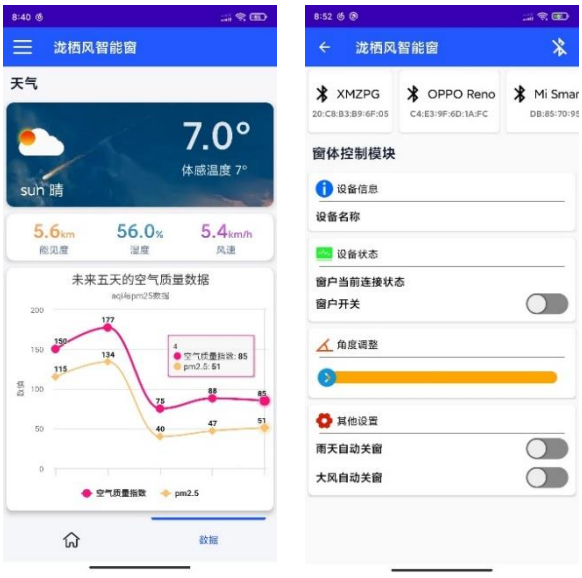

Fig.10. App interface

5. Algorithm Design

5.1. *Control algorithm design*

In a general program cycle, the controller obtains external information by polling and displays it on the display. However, due to the presence of rain outside the window, indoor toxic gas, combustible gas and other emergencies, higher priority countermeasures are required. Therefore, various sensors can send interrupt signals to the controller through digital output pins, which ensures priority deal with emergencies. The work flow chart is shown in Fig.12, which can realize the following functions:

- When the weather is bad and there is no one in the house, the windows will be closed automatically [3].
- Automatically open windows when the indoor air is bad or contains harmful gas.
- Adjust the opening and closing angle by itself according to the external wind direction.
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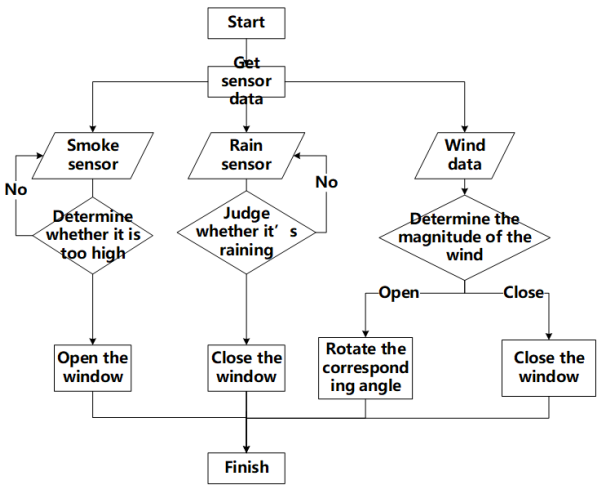

Fig.12. Work flow chart

5.2. *The algorithm of detecting and protecting child*

When a person is within the shooting range of the camera, the camera will automatically find and detect the user's face image.

A fixed-length feature vector is extracted from the convolution feature map, and then the feature vector is input into two fully connected layer networks. The age and gender classification is training from face features. In order to effectively prevent the occurrence of falling down caused by children climbing windows, when the camera detects that the child is close to the window, the window will automatically be closed. The result of child face detection and recognition is shown in Fig. 13.

Fig.13. Children's face recognition results

In the training stage, the system recognized 136 of the 150 samples of children's photos, with an accuracy of 90.6%. And in the testing stage, 150 of the 186 samples of children's photos is recognized, with an accuracy of 80.6%. Anyway, the recognition rate should be improved.

6. Conclusion

Aiming at the shortcomings of traditional window in intelligence and mechanical structure, this paper proposes a new multi-scene smart window with wide-angle opening and closing mechanical structure. The structure is based on the original traditional casement window design, and a linkage mechanism is added, which enables the window to be turned over by nearly 160 degrees, effectively solving the problem of difficult cleaning of the outer side of the window.

At the same time, the window can adjust the opening and closing angle according to the wind direction to ensure the maximum air intake. When the camera detects that there is a child's activity near the window, it will sound an alarm and automatically close the window to prevent accidents caused by children climbing the window. In summary, this wide-angle opening and closing multifunctional smart window will have broad market prospects.

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He majored in Machinery and electronics engineering in College of Mechanical Engineering, Tianjin University of Science and Technology. He studied mechanical control engineering and other related knowledge, and achieved certain results in related professional competitions.

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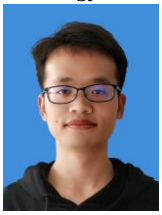

He majored in automation in College of Electronic Information and Automation, Tianjin University of Science and Technology. He learned SCM and data crawler and other related knowledge, and achieved certain results in relevant professional competitions.

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