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Design of Control System of Cleaning Machine for Exterior Wall of High-rises based on STM32

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Abstract

According to the characteristics of good cleaning effect, wide application range and good safety performance required by the external wall cleaning machine, this paper puts forward a suspended external wall cleaning machine based on STM32 control, and designs the control system based on the structure. On the one hand, a control system based on stm32f407 is designed by using Altium designer software, and PI controller is used to control the motor to realize the cleaning function and obstacle avoidance function. On the other hand, through the simulation experiment of PI controller with Simulink software, it is verified that the designed high-rises external wall cleaning machine has fast response speed and good robustness.

Keywords

External Wall High-rises Building Cleaning Machine; STM32, PI Control Regulator; Simulation Experiment.

1. Introduction

With the development of urban construction, more and more high-rises are built in the urban area. The wall cleaning of high-rises buildings has become an important part of city appearance [1]. The wall material of high-rises is complex, some concave and convex parts are unevenly distributed, and the convex wall edge between floors also makes the existing cleaning tools difficult to solve. However, it is dangerous to employ workers to stand in the platform and clean the wall [2]. Therefore, a new type of cleaning machine for exterior wall of high-rises is needed to solve the cleaning problem of inclined or uneven wall.

In this paper, a cleaning machine controlled by STM32 for external wall of high-rises is proposed, and the control system is designed based on this structure. The designed system has the characteristics of fast response and good robustness.

2. General Design

As is shown in Figure 1, the cleaning machine for external wall of high building includes winch, traction rope, guide rope, counterweight, main part and other structures. The winch provides power for the main part, and the main part moves up and down along the guide rope through the traction rope. The main part includes brush motor, ultrasonic sensor, quad-rotor, gear, rotating motor, spring and pressure sensor.

Among them, 1-winch, 2-traction rope, 3-guide rope, 4-main part and 5-counterweight. When the cleaning machine works normally on the wall, two ultrasonic sensors are used to determine the distance from the wall and the inclination angle of the wall [3]. The cleaning direction of the cup-brush motor can be changed by rotating motor to drive the movement of gear, so as to realize the cleaning of the inclined wall. And a pressure sensor is set [4], when cleaning the inclined wall, if the cup-brush and the wall do not fit well, the data read by the pressure sensor will not reach the set range.

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The controller sends the command to the quadrotor to increase the power until the set range is met, which can improve the cleaning effect. On the contrary, the control system sends the command to reduce the power to ensure that the cup-brush is protected.

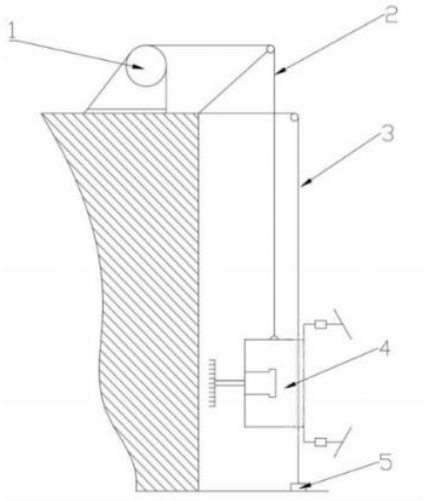

Figure 1. Structure diagram of cleaning machine for external wall

Based on the above structure, a control system including pressure sensor, ultrasonic sensor, solenoid valve, motor drive module is designed by using STM32 series microcontroller. STM32 series microcontroller is an embedded microcontroller designed by Stmicroelectronics. It has the characteristics of high performance, low cost, low power consumption, and can be cut. It is widely used in the field of embedded development [5].

3. Control system design

3.1 System hardware

The control system of the cleaning machine for external wall of high-rises designed in this paper, as is shown in Figure 2, includes six parts: main controller, pressure sensor, ultrasonic sensor, solenoid valve, motor drive, switching mode power supply.

According to the number of pins, performance requirements, cost performance and other factors, the main controller chip is STM32F407ZGT6, and the core of the chip is ARM - Cortex-M3[6]. The working frequency is 168 MHZ, with 144 GPIO and 14 timers, supporting SPI, IIC, USART, USB, CAN, IIS, SDIO, Ethernet and other communication modes, which can meet the requirements of the control system of cleaning machine for external wall of high-rises.

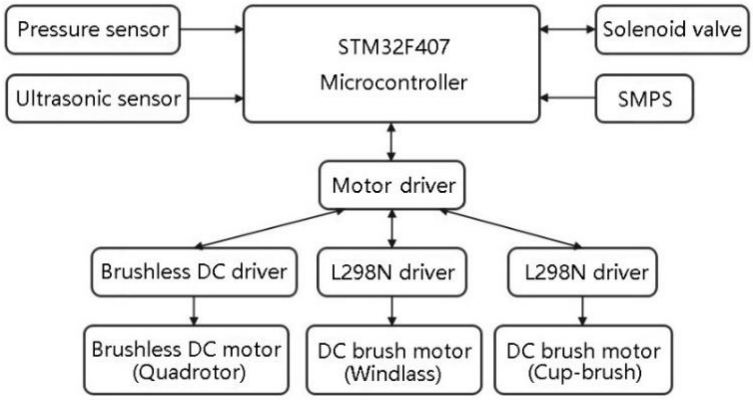

Figure 2. Structure diagram of control

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The specific hardware selection is shown in Table 1.

Table 1. System hardware selection

Numble	Model
Main controller	STM32F407VGT6
Pressure sensor	HX711
Ultrasonic sensor	US-015
Quadrotor motor	Brushless DC motor
Brush motor	DC brush motor
Brush motor driver	L298N
Hoist motor	DC brush motor
Hoist motor driver	L298N
Solenoid valve	DC12V
Switching mode power supply	S-60-12

3.2 System hardware

3.2.1 Control algorithm

PID control algorithm, with the characteristics of wide application and good robustness, is the most mature and widely used control algorithm in continuous system [7]. It has good robustness, simple principle and easy implementation. The expression of conventional PID control algorithm is as follows.

$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt} \quad (1)$$

Among it, K_p is the proportional coefficient, K_i is the integral coefficient and K_d is the differential coefficient.

In order to shorten the control time and improve the response speed of the system, the incremental PID control algorithm is adopted [8]. The expression of incremental PID control algorithm is as follows.

$$\Delta u(k) = K_p[e(k) - e(k-1)] + K_i e(k) + K_d[e(k) - 2e(k-1) + e(k-2)] \quad (2)$$

The block diagram of the quadrotor motor control system based on incremental PID control algorithm is shown in Figure 3.

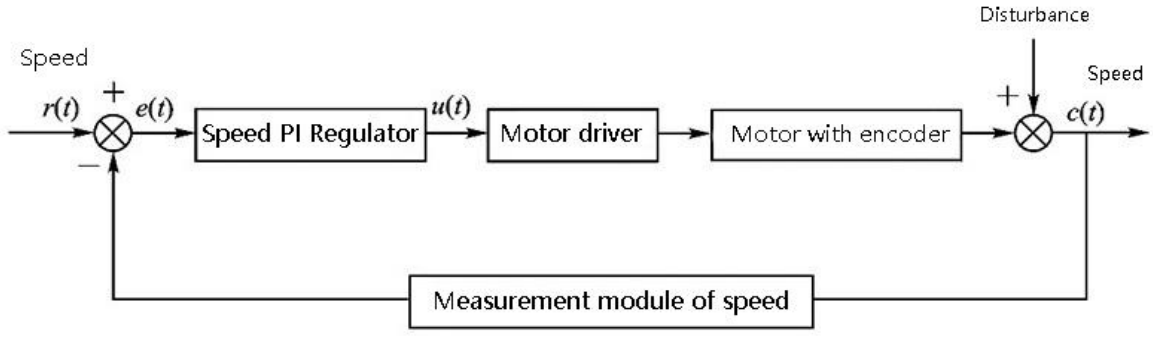

Figure 3. Block diagram of speed PI control system

Through the measurement module of speed in the encoder, the speed data of the quadrotor motor in the cleaning machine is collected and transmitted to the STM32 microcontroller. The controller receives the speed data, compares the actual speed of the motor with the set standard speed, and sends a signal to the encoder to control the acceleration and deceleration of the quadrotor motor, and then the function of obstacle-avoiding was realized.

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3.2.2 Simulation result

The initial conditions are set as follows: rope length is 25m, obstacle height is 5cm, $K_p = 20$,$K_i = 30$, $K_d = 0$. The result shows that the speed PI system can make the cleaning machine quickly recover to a fixed obstacle height of 5 cm in 4s under external interference, with fast response and good robustness. The simulation result is shown in Figure 4.

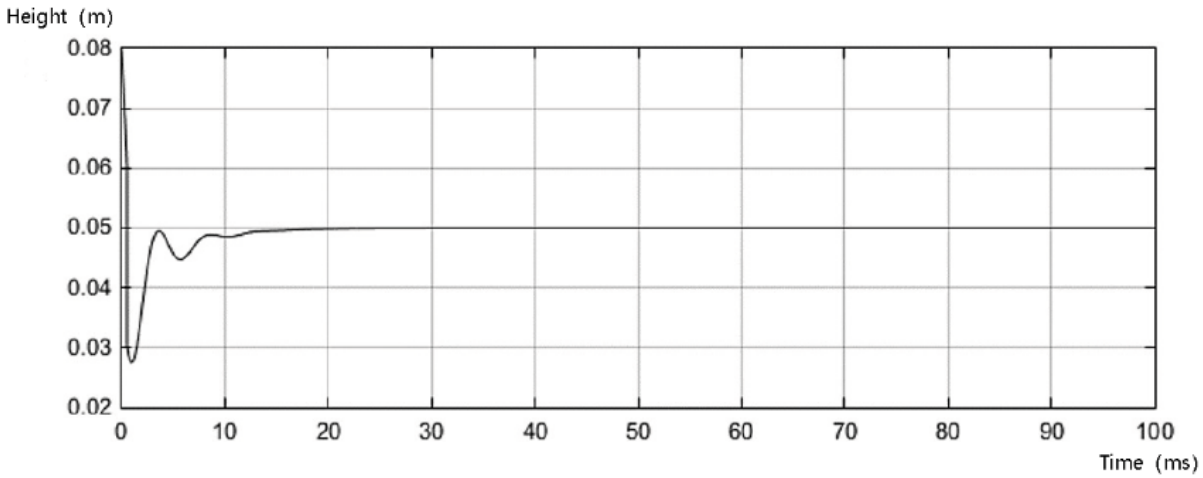

Figure 4. Simulation results of speed PI system

4. Conclusion

This paper presents a control system of cleaning machine for external wall of high-rise based on STM32. The system includes six parts: main controller, pressure sensor, ultrasonic sensor, solenoid valve, motor driver and switching mode power supply. PI controller is used to realize the function of obstacle-avoiding, so that the cleaning machine can complete the cleaning of uneven wall. The simulation result shows that the control system design is reasonable.

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