Researches on a Wall-Climbing Robot Based on Electromagnetic Adsorption

Kai Huang [1], Xiangdong Li [1], Ye Sun [2 b], Yong Chen [2 a], Miao Hao [2] and Yihui Zhang [1]
[1] *Special Equipment Safety Supervision Inspection Institute of Jiangsu Province, Nanjing 210036, China*
[2] *Nanjing Forestry University, Nanjing 210037, China*

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Abstract: The technical bottleneck of the wall-climbing robots based on magnetic adsorption is that the magnetic force is not only the adsorption force but also the moving resistance force. The bigger the adsorption force is, the bigger the moving resistance force is. In order to solve this problem, a unique wall-climbing robot based on electromagnetic adsorption is proposed. Electromagnets fixed in the synchronous belts get into or out of work in turn to realize the unity of adsorption and mobility. An embedded Linux system is constructed to transport videos from the robot to the handheld terminal in real time. A MCS-51 based controller is designed to perform robot control. A prototype robot is manufactured and tested. Experiments show the video delay is less 0.45s and the remote-control distance is beyond 80m.

1 INTRODUCTION

Wall-climbing robots have wide applications in industry and other fields. According to serving environment and working media, the adsorption modes for wall-climbing robots are classified into negative pressure adsorption[1-2], bionic dry adhesive adsorption[3-4], magnetic adsorption and etc. Negative pressure adsorption is not limited by working media, but it will suffer from air leakage if the surface is very rough. Bionic dry adhesive adsorption is suitable for all kind of surfaces, and magnetic adsorption only works for magnetic-conductor. Magnetic adsorption includes electromagnetic adsorption, permanent magnetic adsorption and their combinations. As to magnetic adsorption, many researches are focused on permanent magnetic adsorption[5-8]. A few of researches are based on electromagnetic adsorption[9]. Extensive researches have been carried on wall-climbing robots for many years, but there is few prototype wall-climbing robot which is suitable for actual uses until now. One of the technical bottlenecks is the unity of adsorption and mobility.

2 OVERALL DESIGN

In this paper, a unique structure is proposed to solve the above problems. As shown in Figure 1, the unique wall-climbing robot is composed of a main frame, two synchronous belts with embedded electromagnets, two conductive troughs, four synchronous belt wheels, two step motors and its controllers, and etc. The conductive plate provides electric power for the electromagnet. 16 electromagnets are fixed in a synchronous belt equispacedly. The U-shaped conductive trough is arranged inside the synchronous belt. When the synchronous belt wheels are driven to rotate, the electromagnets will be brought into and out of contact with the conductive trough one by one. That is, only these electromagnets which contact with the conductive trough can generate magnetic force. In this way, when the wall-climbing robot moves forward, the electromagnets will get into or out of work in turn. As to our prototype, 6 electromagnets always stick to the wall surface at the same time to support the whole robot. According to this scheme, the magnetic force is only the adsorption force instead of the resistance force.

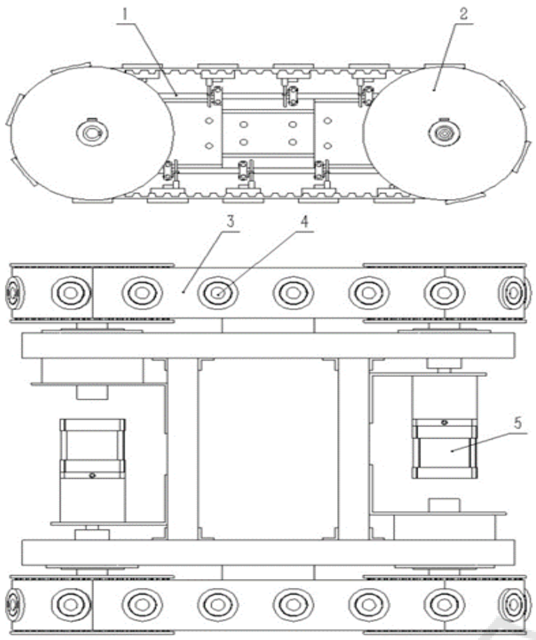

Figure 1: The plane assembly drawing of wall-climbing robot

1-Conductive plate, 2-Timing belt pulley,3-Timing belt, 4-Electromagnet, 5-Stepper motor

In addition, the main frame is made of aluminium alloy in order to reduce the weight. The robot outline is 335mm*295mm, and the wheel is 106mm in diameter. A camera on the robot is employed to capture videos and the operator can watch the pictures displayed on the screen of a handheld terminal.

In this paper, comprehensive consideration of different forms of controls, the control system of the wall-climbing robot uses two distributed control systems which are hand-hold terminal control and vehicle on-board controller. Figure 2 shows the overall block diagram of derusting wall-climbing robot.

The main function of the wall-climbing robot's hand-hold terminal is to send the control signal to the vehicle-mounted controller by wireless transmission so as to realize the remote-controlled movement of the wall-climbing robot.

The on-board controller is the execution layer of the wall-climbing robot control system. It has two main functions: one is to control the climbing robot's forward, backward and steering on the wall, and the other is to communicate with the handheld terminal by wireless communication. The microcontroller board of vehicle controller will immediately execute the appropriate procedures to control the stepper motor after receiving the command signal, and then it can control the movement of the wall-climbing robot.

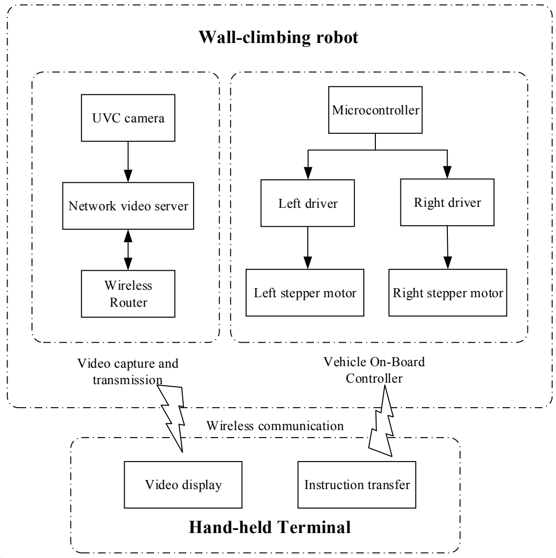

Figure 2: Block diagram of control system of derusting wall-climbing robot

3 DESIGN OF THE CONTROL SYSTEM

3.1 Hardware Design

The handheld terminal is based on a MCS-51controller to realize remote-control and image wireless transmission. The circuit of the vehicle control system is composed of STC12C5A60S2 microcontroller, stepper motor drive circuit, wireless receiving circuit, power conversion circuit and serial port download circuit. The wireless receiving circuit is responsible for constantly receiving the control instructions issued by the handheld terminal. After receiving the control signal, it is resolved by the single chip microcomputer as the output of the pulse command to the stepper motor driver.

3.2 Software Design

One can operate the robot movement through the interface of the handheld terminal. The software of the vehicle controller includes wireless transmission and stepper motor driving. The wireless reception subroutine is for receiving control instructions issued by handheld terminal. Figure 3 shows the flow chart of receiving and sending subroutines.

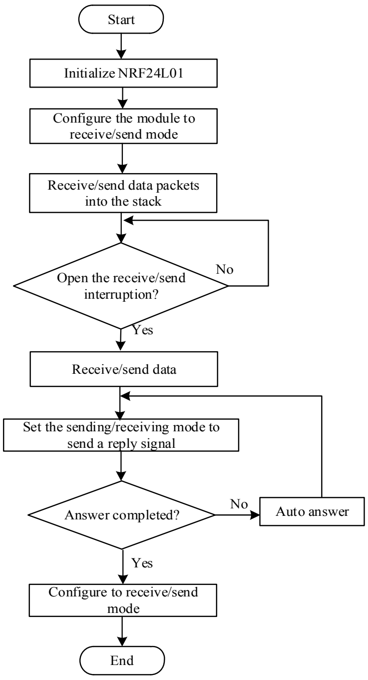

Figure 3: Subroutine for Wireless receiver/ transmission

4 WIRELESS IMAGE TRANSMISSION

Images captured by a camera on the robot are displayed on a screen mounted on the handheld terminal. The hardware needed for wireless video transmission is composed of an embedded development board, a router and a camera. The software development processes are shown in Figure 4 and Figure 5.

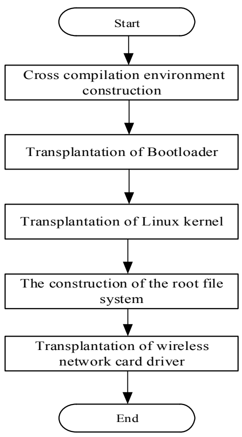

Figure 4: The steps of building the software development environment of Linux system

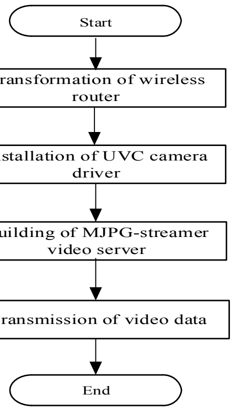

Figure 5: Building of video image acquisition end

5 RESULTS AND CONCLUSION

A prototype robot was designed and manufactured, as show in Figure 6. Experiment results on video transmission are shown in Table 1. The max video delay is about 0.45s. Since the robot moves slowly in routine inspection, the delay is acceptable in our application.

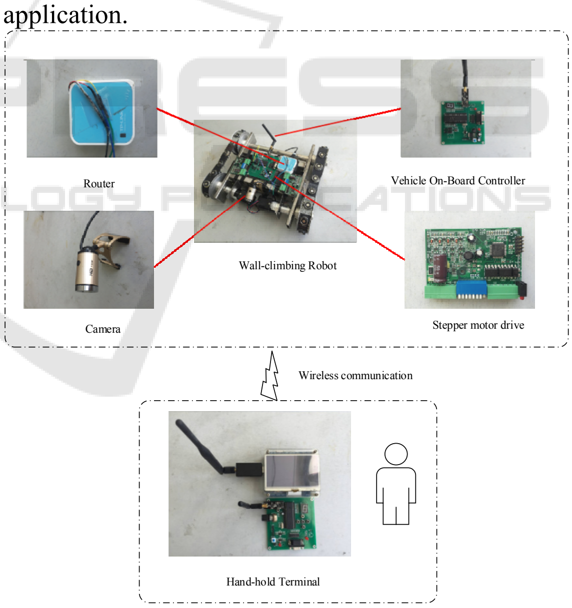

Figure 6: Composition diagram of experimental system

Table 1: Main directory of root file system(unit:second)

Actual stopwatch timer	LCD display	Delay
03:29.26	03:29.06	0.20
03:39.37	03:38.93	0.44
03:40.58	03:40.13	0.45
03:42.37	03:41.95	0.42
03:44.04	03:43.75	0.29

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APPENDIX

Hong Xiaowei,the student of Nanjing Forestry University, is the co-author of this article.