Design of an Intelligent Housekeeping Robot Based on IOT

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Abstract: This project has developed an IOT based indoor mobile robot, which is used for the housekeeping service and called as “smart housekeeper”. The robot is equipped with the crawler chassis structure and the head lifting machinery. It applies Cortex-M4 as the main controller, and communicates with the outer by WiFi. A smart mobile phone is used as its head. People can operate the robot remotely by another smart mobile phone at any time. It can realize remote video searching, home appliance control, and indoor security. The experiment shows that it works well with all the functions.

Keywords: Housekeeping Robot; WiFi; Home Appliances Control; Video Transmission; Gas detection

I. INTRODUCTION

The traditional housekeeping robot has single function, which is difficult in applying to family daily life\textsuperscript{[1]}. This project has designed an intelligent housekeeping robot which is different from traditional housekeeping robots. It can perform remote real-time communications, home appliances control, indoor security monitoring and environmental monitoring functions. So the robot has the ability to play the “smart housekeeper” role in family life. Key technologies of the robot include the conversion between WiFi signal and infrared signal, image transmission technology, gas detection technology, the Internet of Things technology and so on. The paper will introduce the overall design of the robot, including the design of robot crawler chassis, the design of motion control and home appliances control system, the design of security monitoring and environmental monitoring system. In this study, all systems use the APP which integrates TI's Smartconfig technology, so the robot can easily add network and the mobile phone control the robot to move freely. The robot can also be the platform for subsequent research about Internet of Things robot.

II. DESIGN OF THE INTELLIGENT HOUSEKEEPING ROBOT FUNCTIONS

Robots must be able to safely reach the target position and understand human needs in different environment. The design principle of the robot is that robot uses a simple structure and the plan is easy to be implemented, so the research defines the robot's work environment is indoor environment. The basic working process of the robot is as follows. Firstly, the phone establishes a network to communicate with the robot so that the robot is added to the indoor network. Then, after adding to the network, the phone can be used to control the robot by APP. Operator uses the real-time video function of the app to control the robot to move in home and the indoor environment is shown on the phone screen. Robot's gas sensor can detect the composition of the home gas environment. The robot can learn the infrared remote control keys, so the operator uses APP to order the robot to emit the learning infrared encoding information, achieving the function of controlling indoor appliances.

III. DESIGN OF ROBOT CRAWLER CHASSIS

The robot motion trajectory may have some debris such as newspapers, magazines and toys. These obstacles may hinder the robot stably move to the destination. Compared to the wheel structure, the crawler structure has some characteristics, such as large support area, small ground pressure and rolling resistance, good off-road mobility, etc. In addition, there are track grousers in the crawler support surface,
which make the robot hardly slip. Choosing the crawler structure design helps the robot increase the performance of crossing over obstacles, safely arriving at the designed position.

Robot track structure will suffer the longitudinal resistance when it performs vertical movement on the hard pavement [2]. The resistance is the sliding friction which is from the interaction between the track and the ground. Longitudinal resistance is related with vertical load the track withstand and friction coefficient. Tracked vehicles will take place subsidence phenomenon on the soft ground. According to Baker’s pressure settlement relations [2], track pressure \( p \) and subsidence \( z \) have the relationship

\[
p = \left( \frac{k_c}{b} + k_\phi \right) z^n
\]

\( b \): the short boundary of load surface; \( z \):the amount of soil subsidence; \( k_\phi \):Friction modulus; \( k_c \): adhesion modulus; \( n \): the exponent of soil deformation.

While moving on the loose surfaces, the subsidence phenomenon will occur. It results in longitudinal resistance, which impedes robot motion. Considering evenly distributed vertical pressure of rigid track, the amount of settlement can be calculated from Baker's flat model [2]

\[
z_o = \left( \frac{p}{k_c / b + k_\phi} \right)^{1/n} = \left( \frac{W/b}{k_c / b + k_\phi} \right)^{1/n}
\]

Where:
\( b \): track width and length
\( W \): vertical load
\( n \): subsidence index
\( p \): crawler pressure

Fixed crawler travel mechanism, which has tracks on both sides of the body structure, has good stability. As shown in figure 1, there are two common forms about fixed crawler. One form is that front-wheel or rear-wheel can drive the body to move, which tanks and other military vehicles generally choose. The leading travel agencies can assist the body to complete crossing obstacle movement, and its center height from the ground determines the performance of the crossing obstacle movement. Another crawler form is large engineering machinery generally take [3]. The vehicle track structure doesn’t have a leading wheel, so the crossing obstacle performance and height are inferior to before. However, the body size and quality are usually large in this form, so it is hardly affected by complex terrain.

![Fig.1 Two forms of crawler structure](image1)

Considering the robot’s height, mass, and the home environment requirement about the crossing obstacle performance, the robot uses the displacement change of front wheel to control the track shape to ensure the robot's stability. 3D schematic of the robot’s crawler structure is shown in Fig. 2.

![Fig.2 3D schematic of the robot’s crawler structure](image2)

The robot requires a certain climbing and crossing obstacles ability when it moves on the land. So track structure should be designed to be able to change shape so that robot can meet with different situations. Since the robot has a large mass, the normal vector of torques should be analyzed.

![Fig.3 Robot’s crawler structure vector diagram](image3)

Vector diagram of the robot track structure is shown in Fig.3. The actuator controls lever to make robot chassis
shape deformation. Considering the complexity of zone, the track is designed that actuator changes the angle, pulling the entire track shape to change in order to ensure robot stability. Finally, the robot’s crawler structure model is shown in Fig. 4.

![Fig. 4 Robot’s crawler structure model](image)

### IV. DESIGN OF ROBOT SYSTEM FUNCTIONS

#### A. Design of Motion Control System

Motion control system uses the latest Cortex-M4 processor as the robot’s underlying hardware control core. The system includes sensors, wireless communication, motor feedback, and PID algorithm. With the help of photoelectric sensors, the control system can control the robot precisely. Structure of the entire control model is shown in Fig. 5.

![Fig. 5 Motion control system structure](image)

#### B. Design of Control System for Home Appliances

The home appliances control system of the robot consists of the master platform, wireless router, mobile phone and cloud server. As shown in figure 6, the communication among each part is transfer through the network. All parts constitute the appliances control system. The cellphone makes the main platform add indoor wireless network through the app, setting up the communication among the phone, the main platform, and the wireless router. The three parts connect to the same wireless LAN. The infrared remote control aims at the receiver part of the main platform. Operator presses the button of the control and the corresponding key code is transmitted to cellphone through the main platform. The APP stores the corresponding key value, so that the app’s symbols are corresponded with the infrared remote control buttons and the phone can replace the controller to control home appliances. Cloud server is used to store the infrared encoded information of home appliances control system. Cellphone uses APP to retrieve the information stored in the cloud server and send it back to the master via WiFi. The platform decodes the information and sends it by infrared diodes, achieving the purpose of controlling home appliances.

![Fig. 6 Design of home appliances control system](image)

#### B. Security Monitoring and Environmental Monitoring System

The research designs the robot which can achieve real-time video transmission function. With the help of mobile phone, operator remotely controls the robot to move in the room, achieving security monitoring function. The basic process of implementing video communication is shown in Fig. 7 [4].

![Fig. 7 Process of real-time video transmission](image)
calls Android mobile terminal camera. The collected image frames are encoded, packaged, and sent to the peer device to decode and play. In the part of video coding, system uses H.264 coding technique to encode and transfer the video. Then the encoded video streams are packaged in RTP header, UDP header and IP header. After encapsulation, the packet data transfers through the wireless network to the receiver display side. When the receiver gets the data packets, the system unpacks the packets according to the packet opposite order. After that the system gets out the RTP header and video data, and then the video data is sorted according to the RTP header sequence number and sent to the decoder interface in sequence. Decoder completes decoding of the data, and finally displays the video on the terminal device.

V. EXPERIMENTAL TEST

Based on the above software platform and hardware platform, the intelligent housekeeping robot is shown in Fig.8.

![Fig.8 Photos of the intelligent housekeeping robot](image)

As shown in Fig.9, with the help of APP, mobile phone can control the robot that connects to WiFi to move. The phone is set in the robot head. With the help of remote video data transmission, the robot can reach anywhere in the room. Operator can watch the room real-time situation by the camera of the phone in the robot, achieving the purpose of security monitoring.

![Fig.9 The movement of robot and real-time video transmission](image)

As shown in figure10, the infrared receiving part of the platform captures the infrared signals and stores them in the cloud server. Mobile phone uses APP to retrieve the information stored in the cloud server and send it back to the master via WiFi. The platform decodes the information and sends it by infrared diodes, achieving the purpose of controlling home appliances. This project chooses STM32 experiment board to simulate home appliances. By comparing the infrared remote control key value and mobile phone transmit key value on the display panel, the result shows whether the experiment of home appliances control is successful or not.

![Fig.10 Home appliances control](image)

VI. CONCLUSIONS

The research designs an intelligent housekeeping robot, which has a novel structure, large operating range, easy to be controlled. Operator can control the home appliances and monitor home security and environment by cellphone. The embedded control system based on Cortex-M4 processor uses the WiFi communication in the robot control, which increases the reliability and intelligence of the robot. Experimental testing shows that the housekeeping robot works stably, which lays the foundation of the study of housekeeping robot based on the internet of things.

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