Smart Inspection Guard - Inspection Robot for Unattended Plants

Liangyu Wang *, Yanhong Yu, Yizhun Peng

College of Electronic Information and Automation, Tianjin University of Science and Technology, 300457, China

*E-mail: *2697909953@qq.com*

Abstract

This document describes an intelligent inspection robot, based on Arduino and Raspberry Pi, with autonomous navigation and video surveillance. The robot uses infrared sensors for tracing, RFID for localization, and uploads the captured video to the server. The innovative integration of wireless charging technology realizes the unattended function, as well as the self-designed camera clamping mechanism. Key technologies cover differential control, wireless charging, data communication and server design. Tests show that the robot can improve inspection efficiency and quality, save labor costs, and comply with the trend of intelligent manufacturing.

Keywords: Intelligent Inspection Robot, Autonomous Navigation, RFID, Infrared Tracing, Wireless Charging

1. Introduction

With the rapid development of the times, the level of automation is also increasing, the application of robots is becoming more and more widespread, industrial, educational, medical and service robots are also specifically applied in various industries, replacing numerous positions, but also for people to bring great convenience, and some of the work of repetitive, boring traditional positions will also be replaced by robots. [1]

For large-scale unattended plant, the traditional inspection method is not enough to meet the demand, in order to reduce the work intensity of laborers, the use of robots instead of people to complete those repetitive and boring work, improve the quality of equipment inspection. This paper designs an intelligent inspection robot for unattended machine rooms, relay stations and other locations, which has the functions of autonomous patrol, network video monitoring and so on.

The rest of this article is organized as follows. The second section introduces the overall design of intelligent inspection robot. The third section introduces the hardware design of intelligent inspection robot. The fourth section describes its software design.The fifth part summarizes the main content of this paper.

2. The Overall Design

2.1. Overall structural design

The inspection robot system has four components: an Arduino-based control system for movement and data, a Raspberry Pi-based logic system for tasks like path planning and image capture, a server for data storage, and a client for accessing data. It operates in a distributed manner with a control center, data transmission, and a robot terminal layer equipped with sensors. The robot can inspect autonomously, avoid obstacles, and send alerts when needed.

2.2. Hardware structure of the robot

The robot's chassis is designed with two active wheels and two universal driven wheels for agile turns. The active wheels are powered by motors controlled by an Arduino2560, which takes commands from a Raspberry Pi. A 4S battery with explosion-proof and power detection features supplies power, regulated to ensure reliable operation of the electronics. The robot also has a wireless charging receiver and eight infrared sensors for navigation. It includes temperature and humidity sensors and a height-adjustable camera bracket with three cameras and LED lights, all connected with 3D-printed parts.The appearance and physical drawing of the inspection robot is shown in Fig.1.

Fig.1 Exterior and physical view of the inspection robot

2.3. The working process

This design inspection robot uses Raspberry Pi as the logic processor, its functional modules are: image acquisition (Open CV), path planning, motion control, maintenance and support module, each module communicates with each other through the MQTT protocol, and the motion control module communicates with the underlying motion controller Arduino through I2C to send control commands.

The robot operates via an Arduino that executes commands from a Raspberry Pi and uses infrared sensors for path tracing, ensuring it follows a predetermined route. An RFID reader under the chassis prompts the robot to stop for image capture, which are then uploaded to a server for client access. [2]It runs on a 4S battery with a voltage regulator to power the Arduino and Raspberry Pi, and it can wirelessly recharge at designated charging points when the battery is low.

3. Hardware Design of Robot

3.1. Design of the navigation system

The navigation algorithm for inspection robots is designed for swift and stable movement along a guide line, utilizing infrared sensors to determine the robot's position and orientation. This design employs the TCRT5000 reflective infrared sensor for the trajectory module, which includes a high-power infrared transmitter and a high-sensitivity receiver. [4]When the transmitted infrared signal is reflected back to the receiver, the resistance in the receiver changes, leading to a voltage change in the circuit. This change is then processed by an ADC converter module to yield output results. The resistance change, and thus the voltage signal, depends on the intensity of the infrared signal received, which is influenced by the color of the reflective surface and the distance from the receiver to the emitting surface .Infrared sensor shown in Fig.2.

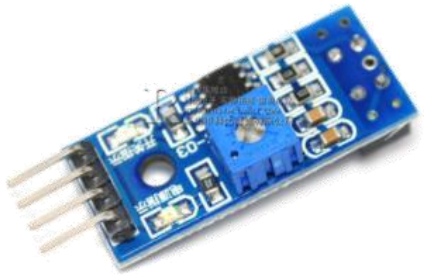

Fig.2 Infrared sensor

3.2. Fixed-point image acquisition

(1)Fixed-point identification:

RFID technology enables the inspection robot to identify its position and capture images by detecting positioning cards along its route through radio frequency communication. The RFID system, which includes tags, readers, and a communication network, works by having the reader send out a signal that the tags receive and respond to, allowing the reader to decode the tag's information and send it to a computer for processing and control actions.

(2)Image acquisition:

The inspection robot is equipped with a high-definition camera that activates and captures images at designated locations during its tasks. The captured image data is then analyzed and processed, with the final results sent to a server for storage. This system allows for early detection of equipment failures, enabling timely maintenance and preventing major safety incidents. When the environment is poorly lit, a fill light module consisting of six LEDs is used to ensure clear image capture, and this module can be configured to be normally open or closed based on the robot's working conditions.[3]

3.3. Automatic obstacle avoidance system design

For distant objects, the robot uses visual recognition and ranging. Up close or when passing obstacles, cameras might miss the full view, so photoelectric sensors on the robot's corners are used for obstacle avoidance. If the robot strays off course, it retreats, turns 30 degrees, and repeats until it finds the navigation line again, ensuring it doesn't damage any equipment.

3.4. Underlying motion controller

The Arduino2560 is an open-source electronics platform consisting of hardware (Arduino boards) and software (Arduino IDE). It's based on a simple I/O interface and uses a Java/C-like language similar to Processing/Wiring.[5]Arduino can interact with the environment via sensors and control devices like lights and motors. The board's microcontroller is programmed using the Arduino language, compiled into binary, and uploaded to the controller. Projects can involve just Arduino or combine it with other software on a PC for communication. The hardware architecture is shown in Fig.3.

Fig.3 Arduino2560

4. The Software Design

4.1. Design of the tracing algorithm

A tracing algorithm based on eight infrared sensors was designed to enable the robot to recognize and follow the black line for navigation.The feedback values from the infrared sensors determine the robot's motion states, including stopping, traveling straight, small adjustments and large adjustments.Through the coding approach, the robot is able to perform six different types of motion to suit different tracing needs.

4.2. Software design of navigation and localization module

RFID technology is utilized for localization, and the card reader reads the RF card information to enable the robot to achieve precise positioning on the inspection route.Communication between the reader and the Raspberry Pi ensures that the robot is able to stop at a specific location for image acquisition.The RFID system consists of tags, readers and a communication network to ensure accurate data transmission and processing.

4.3. Path planning algorithm design

Python language is applied on Raspberry Pi to automatically generate maps and navigate according to the path planning algorithm.The patrol mode of the robot is categorized into fully automatic patrol and point-to-point patrol to adapt to different inspection needs.Through the recursive function and path table, the robot is able to record and optimize the path to achieve efficient patrol.

4.4. Image acquisition module software design

The robot is equipped with three cameras for collecting panoramic images of the equipment and uploading the data to the server via wireless network.The image acquisition module is triggered when the RFID card is read by the RFID reader, which ensures image acquisition at a specific location.The captured image data is packaged and uploaded along with the power and location information of the robot for remote monitoring and analysis.

5. Conclusion

There is a growing demand for safety and environmental monitoring in many warehouses, logistics and production lines in China. Although inspection robots have been used in the power industry, they have not yet been popularized in the field of ground inspection. With the development of science and technology, the shortcomings of manual inspection are gradually being compensated by intelligent inspection robots, which are of great significance in terms of social and economic benefits. This paper introduces an intelligent inspection robot, which integrates infrared, photoelectric, temperature and humidity sensors and cameras, and is able to record the site conditions. The robot is based on Raspberry Pi and Arduino, runs logic processing and motion control programs, and uploads video information to the client via wireless network. We also designed a low-battery automatic return wireless charging function, and verified the robot's detection accuracy and functional reliability through lab tests. This robot is able to monitor the status of items, environmental parameters and power level in real time, and automatically plan the path and avoid obstacles to ensure the safety and efficiency of inspection.

References

1. Xing S-Y, Jiang W. Research on communication quality of substation inspection robot. Internet of Things Technology, 2018.
2. Meng Xiangzhong, Wang Baolei. Research and design of RFID-based wireless charging system for substation inspection robot. Industrial Instrumentation and Automation Device, 2017
3. Ma Yiming. Application of intelligent inspection robot in unattended substation . North China Electric Power University, 2017.
4. Zhang Qiang, Hu Lifu, Li Peng. Design of intelligent substation inspection robot based on WIFI. China Science and Technology Information, 2016
5. WU Gongping, YANG Zhiyong, Wangwei, et al. Autonomous charging and docking control method for inspection robot. Journal of Harbin Institute of Technology, 2016

Authors Introduction

Liangyu Wang

Liangyu Wang is currently pursuing his undergraduate degree at the School of Electronic Information and Automation, Tianjin University of Science and Technology.

Yanhong Yu

Yanhong Yu is currently pursuing her undergraduate degree at the School of Electronic Information and Automation, Tianjin University of Science and Technology.

Yizhun Peng

He is an associate professor at the School of Electronic Information and Automation, Tianjin University of Science and Technology, with research interests in neural network control.