Research on fire inspection robot based on computer vision

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Abstract. With the rapid development of robots in the world, robots in various application scenarios have come into people's sight, especially various inspection robots appear in people's lives. At present, the application of fire patrol robots is more and more. Now, the fire patrol robots used in the warehouse are all land patrol robots. When they work on the designated route, they have high requirements for the environment. When there is a complex environment with uneven ground, it will have a great impact on the robot. This rail mounted fire inspection robot is running on the track, and the platform can be inspected without dead angle. It has low environmental requirements, high inspection efficiency, real-time alarm, and uses computer vision platform to track, which improves the accuracy of fire source identification. In this design, STM32F4 single chip microcomputer is used as the main control of the whole system, which is completed with a number of servo motors, alarms and other hardware, and computer vision and robot main control data interaction.

1. Introduction
In recent years, robots are used more and more in people's life. For example, in industries, parks and families, it has become an intelligent technology that people rely on in their lives. Robots have been widely used in countries with high level of industry, and their technology is relatively advanced. The first robot in the world was invented in the United States at the end of 1950s. Through a long period of technological development, the United States has become one of the world's robot powers with strong foundation and advanced technology [1]. At present, the market share of industrial robots is very large, which has been widely used in various countries [2,3], such as ABB's automatic assembly robots; service robots, such as iRobot's home robots; medical robots, such as the operating room robot system of intelligent surgical; agricultural robots, such as Eco robot's weeding robots. Among these robots, industrial robots account for the largest proportion. Among them, patrol robots are widely used, such as power line patrol robots, oil pipeline patrol robots, substation intelligent patrol robots, etc.

In today's world, with the continuous progress of science and technology, people use more and more intelligent products in different fields. The large-scale application of intelligent products not only reduces the cost but also greatly improves the efficiency. At present, the fire problem of cargo warehouse is still a serious problem. Because the fire situation of the warehouse is found by the warehouse management personnel, most of the situation when the management personnel find the fire is that the fire has spread rapidly, and it is difficult to control the situation. Based on this situation, many science and technology companies have developed warehouse fire patrol robots. These robots use various sensors for fire patrol according to the predetermined route in the warehouse. Although they play some roles, based
on the complex warehouse ground environment, the efficiency of these ground patrol robots is not high, and the sensors cannot guarantee the normal operation all the time. Detected condition \[4\].

It is imperative to develop a more efficient and accurate inspection robot. A kind of hoisting robot which can inspect the fire in the warehouse can be developed. The robot can inspect the predetermined track above the warehouse, observe whether there is a fire in the warehouse in real time, and carry out real-time alarm and control the warehouse fire extinguishing device to extinguish the fire. This robot can effectively avoid the problems caused by the complex ground environment when it is suspended in the air orbit; moreover, the inspection robot in the suspended orbit has a better field of vision, and can conduct large-scale range scanning at one time. When a fire is found, the alarm in the duty room can ring immediately. At this time, the duty personnel can take rescue actions quickly to achieve the purpose of timely firefighting and reduce the loss caused by the fire.

2. Hardware design of fire patrol robot

2.1. STM32F4 single chip microcomputer

STM32F4 single-chip microcomputer has stronger function and more humanization than the 51 single-chip microcomputer and STM32 F1 series single-chip microcomputer commonly used by students now. STM32F4 series single-chip microcomputer integrates single cycle DSP instruction and floating point unit, which can make the single chip microcomputer have more computing power.

STM32 F4 series includes five mutually compatible digital signal controller (DSC) product lines, which is the perfect combination of MCU real-time control function and DSP signal processing function. The advantages of STM32F4 are advanced architecture, high performance, low voltage, low power consumption, innovative core and peripheral, simple and easy to use, free and low risk. STM32F4 microcontroller is widely used in the project development of college students, because it has a relatively fast start and comprehensive functions for the project development of students.

STM32F4 microcontroller is based on cortex core, which is a series of cortex-m4, which belongs to armv7 architecture. The single-chip microcomputer used in this design is designed by ourselves. The PCB is made by ourselves. The single-chip microcomputer designed by ourselves is designed and manufactured according to the functions used by the robot. Because there are four DC brushless motors controlled by CAN bus in the robot, four can circuits are made on the board Port; because it needs to receive the data transmitted by computer vision and the data interaction between Bluetooth and the main controller of the alarm module, it has made two serial ports; the board needs to connect the receiver of the remote controller, so it has also made one remote control port; and it has made enough I/O ports for sensor and small voltage power supply.

2.2. ICM20602 gyroscope

ICM20602 gyroscope includes 3-axis gyroscope and 3-axis accelerometer. In this design, the user programmable 3-axis accelerometer of this motion sensor is used. This motion sensor is placed on the two axis platform of the robot, and the data returned is used as the speed loop of PID algorithm. The magnetic sensor is equipped with a 1KB FIFO, so that the flow of the serial interface can be reduced, and then the power consumption of the motion sensor can be reduced. The sensor has 16-bit ADC, programmable digital filter, embedded temperature sensor and programmable interrupt. The detailed specification parameters of the accelerometer are shown in the figure below.
2.3. GM6020 PTZ motor
GM6020 PTZ motor is a high performance tributary brushless motor with internal integrated driver. The motor adopts hollow shaft design, with high torque density, high control accuracy, flexible interaction mode and strong protection function. It is suitable for the application scenario of direct drive with low speed and large torque. The schematic diagram of the robot is shown in the figure below.

![Figure 1](image1.png)

**Figure 1.** Accelerometer specifications.

| PARAMETER                          | CONDITIONS          | MIN   | TYP   | MAX   | UNITS | NOTES |
|-----------------------------------|---------------------|-------|-------|-------|-------|-------|
| ACCELEROMETER SENSITIVITY         |                     |       |       |       |       |       |
| Full-Scale Range                  | AF5_SEL=0           | ±2    | g     | ±2    |       |       |
|                                  | AF5_SEL=1           | ±4    | g     | ±2    |       |       |
|                                  | AF5_SEL=2           | ±8    | g     | ±2    |       |       |
|                                  | AF5_SEL=3           | ±16   | g     | ±2    |       |       |
| ADC Word Length                   | Output in two's complement format | 16   | bits  | 2     |       |       |
| Sensitivity Scale Factor          | AF5_SEL=0           | 16,384| LSB/g | ±2    |       |       |
|                                  | AF5_SEL=1           | 8,192 | LSB/g | ±2    |       |       |
|                                  | AF5_SEL=2           | 4,096 | LSB/g | ±2    |       |       |
|                                  | AF5_SEL=3           | 2,048 | LSB/g | ±2    |       |       |
| Sensitivity Scale Factor Initial Tolerance | Component-level | ±1.5  | %     | 1     |       |       |
| Sensitivity Change vs. Temperature| -40°C to +85°C      | ±1.5  | °C    | %     | 1     |       |
| Nonlinearity                      | Best Fit Straight Line | ±0.3  | %     | 1     |       |       |
| Cross-Axis Sensitivity            | ±1                 |       | %     | 1     |       |       |
| ZERO-G OUTPUT                     | Component-level, all axes | ±25  | mg    | 1     |       |       |
|                                  | Board-level, all axes | ±40  | mg    | 1     |       |       |
| Zero-G Level Change vs. Temperature| -40°C to +85°C      | ±0.5  | mg/°C | 1     |       |       |
|                                  | X and Y axes        | ±1    | mg/°C | 1     |       |       |
|                                  | Z axis              | ±1    | mg/°C | 1     |       |       |
| OTHER PARAMETERS                  |                     |       |       |       |       |       |
| Power Spectral Density            | 10 Hz               | 100   | µg/Hz | 1,3   |       |       |
| RNS Noise                         | Bandwidth = 100 Hz  | 1.0   | mg/µs | 1,3   |       |       |
| Low-Pass Filter Response          | Programmable Range  | 5     | Hz    | 2     |       |       |
| Accelerometer Startup Time        | From sleep mode to valid data | 10  | Hz    | 2     |       |       |
| Output Data Rate                  | Low-Noise mode      | 3.91  | Hz    | 2     |       |       |
|                                  | Low Power Mode      | 3.91  | Hz    | 2     |       |       |

2.4. Industrial camera
USB2.0 camera is used in fire inspection robot. This camera is a digital camera. Its working principle is as follows: the real scene is projected on the surface of the image sensor through the optical image generated by lens (lens), then converted into electrical signal, converted into digital image signal after A/
D (analog-to-digital conversion), then sent to the digital signal processing chip (DSP) for processing, and transmitted to the computer through USB interface for processing. USB2.0 camera, as shown in the figure below.

Figure 3. vision recognition camera.

2.5. Main control circuit of robot

In the whole system of warehouse hoisting fire inspection robot, there are three main controllers, which are the main control of computer vision system, the main control of inspection robot and the main control of alarm module. The main control of patrol robot and alarm module have different designs. The main control of the inspection robot is specially set according to the functions required by the robot, and its main control circuit is shown in the figure below.

Figure 4. main control of inspection robot.
The main control circuit includes reset circuit of the board shown in the lower left corner and crystal oscillator circuit shown in the lower right corner. On the chip diagram, it can be seen that the main control has two can bus communication circuits, which can respectively control the DC brushless motor of chassis and pan tilt, and has three serial ports for communication. Two of them are used for data interaction with computer vision and Bluetooth data interaction with the main control of alarm module, and the last one is used for data reception of remote control receiver.

The main control of alarm module is mainly used to connect Bluetooth and control alarm, so only a simple main control circuit board can realize its basic functions according to its functions. Due to the need to connect Bluetooth, a serial port and a small voltage power supply port providing 5V voltage are made; due to the need to connect alarm, the alarm is controlled by relay, a small voltage power supply port of 5V voltage and a signal IO port are needed; due to the need to download program and debug, a program download port is also made. Because the function of the circuit board is simple, one can bus interface and two rows of I/O ports are made to expand the function later. The circuit diagram of this main control is shown in the figure below.

![Circuit Diagram](image-url)

**Figure 5.** main control of alarm module.
3. Computer vision feature extraction

3.1. visual characteristics of moving objects
Target feature extraction is to analyze the pixel information in the image, such as the color, edge and texture distribution of the target image, so as to obtain the distinctive appearance description of the target. This paper mainly focuses on the feature extraction of color, edge and local features.

(1) Color feature: using spectral features to identify the target, which contains a large amount of information, is the most commonly used feature of the target. When the target is rotating, non-rigid deformation and partially occluded in the process of motion, it can still well represent the target image. The expression of color features is different in different color space models (such as RGB, his, HSV, etc.), so the appropriate color space model should be selected in different applications. Color histogram, color moment and color set are the three most commonly used color features. At present, the commonly used recognition algorithms cannot recognize the color of the object directly. As long as the color of the object is involved, the color features should be used.

(2) Edge feature: Although the color feature has better ability to resist the deformation of the target, it lacks the description of the spatial structure of the target and is sensitive to the light. Therefore, in the tracking field of view with frequent light changes, the edge features of the target which are insensitive to the changes of light conditions and have relative stability are often used as visual features for matching. Image edge is a set of pixels which express the step change of the gray level of the surrounding pixels in the image. It exists between the objects, between the front background, or between regions and between primitives. It has two characteristics of direction and amplitude.

(3) Local features: the local features of an image are the feature points extracted from the local area of the image, which express the changes of attributes such as image intensity and color. Generally, they are described by descriptors, which can overcome the adverse effects of light changes, scale expansion and attitude rotation on the target.

3.2. RGB and HSI color space
According to the angle of color perception, color space can be divided into the following three categories:

(1) Mixed color space: composes colors according to the proportion of three basic colors. For example, RGB, CMY (k) and XYZ color spaces.

(2) Nonlinear luminance/chrominance color space: this kind of color space is characterized by using one component to represent non-color perception and two independent components to represent color perception. When black and white images are needed, such a system is very convenient. For example, YUV, etc.

(3) Intensity/saturation/hue color space: using saturation and chroma to describe the perception of color can make the interpretation of color more intuitive, and it is very useful to eliminate the influence of brightness. For example, HSV, HSI, etc.

This paper is mainly used in fire image detection, mainly combined with RGB criterion and HSI criterion, set the appropriate threshold conditions, and detect the corresponding pixel area of the flame.

RGB color model corresponds to a cube in Cartesian coordinate system, and R, G and B represent three coordinate axes respectively. When the corresponding values of R, G and B are all taken as 0, that is, at the coordinate origin, it means black. On the contrary, when the corresponding values of R, G and B are the maximum, it means white. Other points in cube space represent other colors. When the value range of the three components is an integer between 0-255, 16777216 colors can be represented.

HSI color space is based on human visual system, using hue, saturation or chroma and brightness to describe color. HSI color space can be described by a cone space model. The conic model of HSI color space is very complex, but it can show the change of hue, brightness and color saturation clearly. Finally, the extraction effect is shown in the following figure.
Figure 6. recognition results of fire inspection robot based on computer vision.

4. Conclusion
With the development of intelligent robot technology, more and more factory warehouses now use fire patrol robots. The traditional fire patrol robots are all applied on the ground, which have higher requirements on the working environment. When the terrain in the warehouse is complex or the layout of the warehouse is changed due to the accumulation of goods, it will have a great impact on the patrol robots, which is similar to the original patrol routes no match. The inspection robot proposed in this paper does not use the traditional flame sensor, but uses computer vision and industrial camera to scan the environment and lock the fire, which greatly improves the accuracy of fire detection.

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