Research on Fire Fighting Scheme of Indoor Fire Fighting Robot Based on Multi-sensor

Tian Junwei
School of Mechanical and Electrical Engineering
Xi'an University of Technology
Xi'an, China
E-mail: junweitian@163.com

Li Jintao
Northwest Industrial Group
Xi'an, China
E-mail:DDrm326@163.com

Ding Ruimin
School of Mechanical and Electrical Engineering
Xi'an University of Technology
Xi'an, China
E-mail: DDrm326@163.com

Zhang Yanling
School of Mechanical and Electrical Engineering
Xi'an University of Technology
Xi'an, China
E-mail: zylyanlin@sohu.com

***Abstract*—How to find the fire source point is the key technical point of the indoor fire-fighting robot in the operation process. The proposed low-cost comprehensive detection fire source solution using multi-sensor and surveillance camera photo recognition can successfully solve the problem that the fire-fighting robot can accurately search for the fire point indoors. The problem is that the fire-fighting device equipped by the robot can perform fire-fighting operation and issue an alarm after the fire source is discovered, and the loss of personnel property is minimized.**

Keywords-Multi-sensor; Fire-fighting Robot; Fusion Detection; Fire Extinguishing Device

I. INTRODUCTION

Fire incidents can cause loss of life, property damage and permanent disability to affected victims, as well as long-term psychological and traumatic[1]. The source of urban fires is usually indoor fires, so it is especially important to prevent fires from the source[2]. With the advancement of sensing technology, information and communication technology, the progress of fire sensing technology has been considerable in recent years[3]. At the same time, the fire fighting and rescue work in the first time after the fire has become a new idea for the development of fire fighting robots, using mobile The robot performs this task in areas prone to fire, which can help avoid unfortunate accidents or death[4]. How to quickly search and locate the fire source point and make timely and effective treatment is the problem faced by the fire-fighting robot in the development process. At present, there are several solutions in the problem of determining the fire source point: using drone shooting combined with computer vision system to search for fire Source point and provide fire situation[5]-[6]; Document 7 uses computer vision to realize fire detection video analysis research, and proposes a convolutional neural network (CNN) for identifying fires in video[7]; In the literature 2, multi-sensor based fire extinguishing robots use DTMF and Bluetooth remote control and GSM and GPS technology to operate in multiple modes, using three different flame sensors, temperature sensors and smoke sensor sensors to ensure correct detection of fire[2] The volcano robot that can enter the fire source environment and self-navigate through the fire and send information about the fire behavior is a robot image processing system and communication architecture based on GSM technology and microcontroller[8]. References 9 and 10 refer to multi-sensor based fire source detection, in which Zigbee and data acquisition systems (DAQ) can be integrated to drive circuits for communication under these dangerous

conditions[9]-[10]; image processing is used to detect Fire [11] has emerged in recent years; documents 12-14 propose the use of multi-sensors to solve the problem of fire source detection and positioning[12]-[14]; Literature 15-17 proposes how to optimize the design of fire-fighting robots[15]-[17]. In addition, the air hose type robot[18] for fire water jets mentioned in the fire extinguishing measures document 18 is used for fire extinguishing; the use of a fan blown flame source[19] is proposed in the literature 19.

At present, fire-fighting robots[20] use computer vision applications or graphics processing methods in fire source search, which are generally costly and complex, and are often used in large-scale factories for fire hazard prevention and alarm, and the functions are mostly fire source detection. Fire-fighting measures after the system detects the fire are not provided. The proposed low-cost comprehensive detection fire source solution for multi-sensor and surveillance camera photo recognition can effectively solve the problem that the fire-fighting robot searches for the fire point indoors. The fire-fighting device equipped by the robot can also implement the fire-fighting operation after obtaining the fire source point. In larger cases, an alarm is required to notify the rescuer to minimize the loss.

II. Overall plan

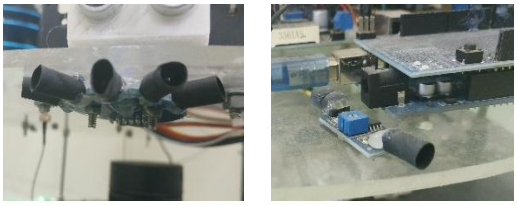
How to detect the indoor fire source point is an important step in the multi-sensor fire-fighting robot. The multi-sensor-based indoor fire-fighting robot uses a variety of sensors combined with the camera to monitor the position of the fire source point in real time. When the fire-fighting robot detects it. Immediately after the indoor fire source location, an alarm indication can be made and the fire suppression procedure can be initiated.

A. Sensor selection

1) Fires can be accompanied by harmful fumes that can spread indoors. With a detection range of 60 m^2, a smoke sensor with a concentration of 300-10000 ppm (combustible gas) can detect smoke in the room. The sensor is mainly used in the fire fighting robot during the cruise process. When the smoke sensor detects the suspected smoke area, the robot will actively move to this area to confirm the further fire source point.

2) Temperature sensor The temperature around the position where the fire source point appears in the room is inevitably raised, and the temperature sensor is mounted on the robot. The temperature range is from -55 ℃ to +125 ℃, and the sensitivity is high, meeting the indoor temperature measurement requirements. The robot can sense the indoor temperature during the cruise process. If an abnormal high temperature condition is detected in a certain area, the system will issue a warning, and cooperate with the smoke sensor and the flame sensor to determine whether there is a danger and determine the location of the fire source.

3) Flame detection sensor The indoor fire prevention robot is equipped with a flame sensor detection module. As shown in Fig. 1, the flame sensor is sensitive to the flame spectrum and has high sensitivity, and can detect a flame or a light source having a wavelength in the range of 760 nm to 1100 nm. To prevent the flame sensor from identifying an error, the system needs to match the image recognition of the camera to identify whether it is a fire source, eliminate the source interference and determine the fire level. When the robot determines the fire source area and is close to the fire source point, after the flame sensor detects the position of the fire source, the system sends a command to the robot actuator, and the robot alarms and starts the fire extinguishing process.



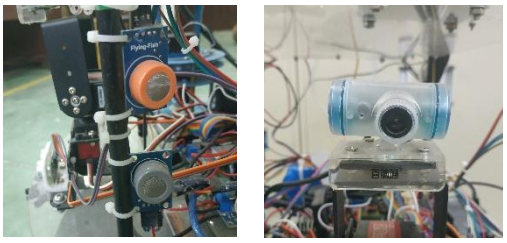
(a)Five-way flame detection module (b) Single-channel flame sensor module

Figure 1. Flame sensor

B. Sensor Layout Sensor + Camera

In order to ensure accurate identification of the fire source point, a variety of sensors and cameras are needed to detect and identify the fire source. The flame sensor is mainly used to determine the distance between the fire source and the robot. The flame sensor uses five-way flame

detection. Module and single-channel flame sensor module, the five-way flame detection module is installed in front of the robot, its detection range is greater than 120°, the test distance of the light source of the lighter is 80cm, the greater the fire, the farther the measurement distance, the left and right sides of the robot and the positive A single flame sensor is installed at the rear, and the single-channel flame sensor has a detection angle of about 60°. The robot can monitor the indoor situation in an indoor cruise process. The smoke sensor and camera layout of the robot are shown in Figure 2 below.



(a)Smoke sensor module (b) Camera

Figure 2. Smoke sensor and camera layout

In view of the detection principle of the flame sensor, in order to prevent the flame sensor from misdetection the light source as a fire source, it is necessary to cooperate with the surveillance camera to take a suspected fire source image to further confirm whether it is a fire source, and the image information collected by the camera can determine the size of the fire. The multi-sensor fire source point detection is mainly based on the flame detection sensor, supplemented by the temperature sensor and the smoke sensor. At the same time, combined with the comprehensive detection method of the camera, it ensures the accurate identification of the fire position and position of the fire source, and provides the implementation of the next fire extinguishing operation. in accordance with.

III. FIRE-FIGHTING DEVICE

The indoor fire-fighting robot is equipped with the function of detecting the indoor fire alarm and taking emergency treatment. When the sensor identification system recognizes the fire source and issues an alarm, the fire-fighting program should be started immediately. The fire extinguishing device has the following three design schemes: Solution 1: The robot itself carries a fire extinguisher. When encountering a fire, use a mechanical arm to pull the fire extinguisher pull ring and the fire extinguisher to spray, but the robot carrying the fire extinguisher will cause the weight of the robot body to increase. The occupied robot space is large; Solution 2: The robot body is equipped with a fan. When the fire is encountered, the fan is turned on to extinguish the fire. Increasing fan fire extinguishing can only be applied in the real life when the fire source is a small fire source such as a candle. In the case of a large fire source, it may be counterproductive; Option 3: It is the water fire extinguishing method adopted by most firefighting robots. A water spray device is installed on the robot, and the water spray is used to rapidly lower the ambient temperature for fire extinguishing purposes. The fire extinguishing device equipped with the robot selects the third scheme. The water pipe and the high-power nozzle can be installed on the robot, and the water tank can be provided. In the case of danger, the nozzle of the spraying device (shown in Fig.3) can refine the water. After the large amount of water mist is sprayed in an umbrella shape, the ambient temperature is rapidly reduced (Fig. 4 is the structure diagram of the spray device), and the toxic and harmful smoke can be dissipated and the direction of the flue gas flow can be changed. The water tank is designed with an automatic water filling device (as shown in the Fig.5), can be used as a water source after the water storage in the tank is consumed. Fire extinguishing has certain limitations, so the fire robot for a larger fire will start the alarm program (Fig.6 is the robot's fire extinguishing system) to avoid loss of personnel property.

A. *Nozzle flow calculation*

The volume of the water storage tank is 3.5 L, the length of the water pipe is 600 mm, and the flow rate of the nozzle is calculated:

$$Q=K\sqrt{10P} \tag{1}$$

In the middle:
Q – nozzle flow
K –Flow Coefficient
P – Nozzle pressure, MPa

Where the nozzle diameter It is 1.1mm, the flow coefficient is 55, the spray diameter is 2m, and the pressure at the nozzle is 0.15 MPa. The flow rate of the nozzle during fire extinguishing is about 1.1 L/min, so the water tank of the fire extinguishing device is fully loaded once for 3 minutes, when the water volume is insufficient. An automatic watering device can be used to carry out the water tank.

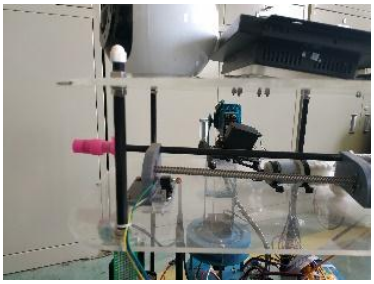
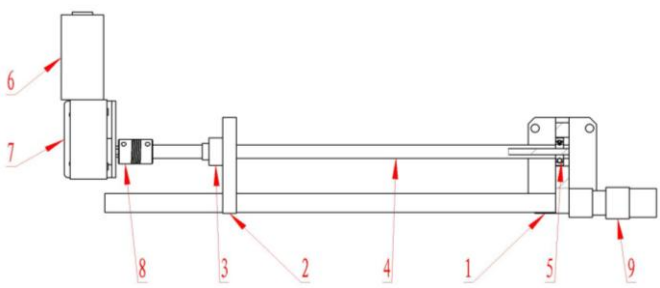


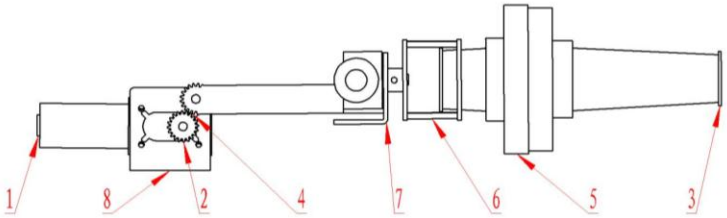
Figure 3. Fire extinguishing device



1.Fixing bracket 2. Moving bracket 3. Nut 4. Leading screw (right-handed) 10X300 5. Bearing

6. Geared motor 7. Motor bracket 8. Coupling 9. Nozzle

Figure 4. Spraying device



1.Geared motor 2. Motor gear 3. Irrigation joint 4. Sector tooth 5. Water gun head interface

6. Rotating bracket 7. Motor bracket 1 8. Motor bracket 2

Figure 5. Automatic watering device

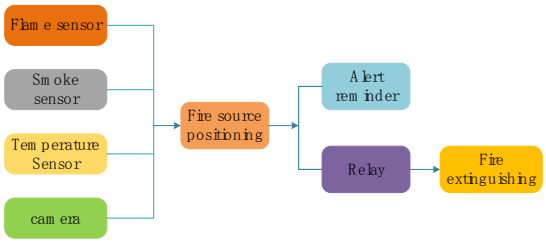


Figure 6. Fire Robot Fire Extinguishing System

IV. EXPERIMENT AND RESULT ANALYSIS

The fire extinguishing scheme of multi-sensor fusion detection fire source for fire protection robot is experimentally verified. The following conclusions can be drawn by using candle to simulate indoor fire source: (1) After setting the distance between the robot and the fire source point, it can be found Fire source point and take the initiative to start the fire extinguishing program; (2) After the fire source point is found, the fire source can be fixed at a fixed point, and the water mist is continuously sprayed until the fire extinguishing source is extinguished (Fig. 7 is the robot fire source detection and processing experiment). Table 1 below shows experimental data of robot fire detection reaction time:

TABLE I. FIRE SOURCE TEST EXPERIMENTAL DATA

Determine The Fire Source Reaction Time				
0.8m	1.3m	1.8m	3m	5m
2sfound fire source	2sfound fire source	5sfound fire source	20sfound fire source	Need to search

Figure 7. Robot fire source detection processing experiment

It can be concluded from the above experimental data that the fire-fighting robot can identify the nearby fire source point more quickly when a fire occurs indoors, and the fire source can be autonomously extinguished under the controllable fire source.

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