Research on the Design of Fire Alarm and Pre-treatment Robot System

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Abstract. With the development of society and economy, the application of fire warning robots based on sensors and artificial intelligence technology is a new research field. This paper proposes a design scheme for fire warning and pre-processing robots. The robot is based on visual tracking instead of human Uninterrupted patrol of space sites; comprehensive analysis of environmental data collected by sensors based on fuzzy theory algorithms, and issuing fire warning and alarm signals; analysis of infrared images of electrical equipment based on machine vision to monitor operating conditions; construction of fire site maps based on slam algorithm through laser radar. The fire early warning and pre-processing robot designed in this paper realizes the functions of autonomous inspection, fire early warning, fire detection, fire extinguishing, and obstacle removal. It makes full use of the golden extinguishing time to kill the fire and protect people's lives and property.

1. Introduction
With the development of society, the number of large warehouses, underground spaces and other places are increasing, and their scales are also increasing. The requirements for fire prevention are getting higher and higher, and the demand for reliable and intelligent fire-fighting equipment is becoming more and more urgent. In recent years, the number of fires in these places has been increasing, and the losses caused by fires are also increasing. According to the analysis of experts, the main reasons for the high incidence of fire accidents are improper use of fire by people, negligence of guards, lack of monitoring methods, and ineffective or delayed information processing. Due to the limited personal energy of personnel on duty, negligence cannot be eliminated, there will be errors; personnel inspection methods are also difficult to achieve all-weather monitoring and inspection, and disasters cannot be completely avoided [1]. This makes it has become more and more obvious to equip preventive firefighting robots in large warehouses, shopping malls, and other public spaces to prevent fires, which is the development trend in the next few years.

2. Related research
With the development of economy and technology, robots are becoming more and more popular, robots in various industries are constantly appearing, and the demand for robots in the fire protection industry is becoming more and more urgent. However, for the time being, there is no report on the application of relevant products in actual fire fighting in China. At present, domestic fire treatment methods are mainly...
to set up sensors at fixed points, such as smoke and gas sensors, automatic water spraying detection heads, etc., but these methods can only detect whether there is a fire, and there is basically no monitoring of the environment before the fire, and no early warning can be made.[2]. For disasters that have occurred, only general treatment, such as water spray treatment. It is difficult to achieve targeted prevention and treatment. The research of intelligent preventive and monitoring security systems has just started in China, and related research results have only recently appeared. es with preventive functions are rarely used in the fire-fighting field. In today’s domestic rescue and fire fighting process, robots are not involved in the base wood. Even if there are a few places where fire-fighting robots are used, it is difficult to be effective. Existing fire-fighting robots in service also have many problems in the use process[3].

3. Robot overall scheme design
The robot uses Jetson Nano as the host computer and STM32 as the lower computer. The lower computer controls the sensor system, motor drive system, mechanical arm control system and fire extinguishing control system; the host computer controls the depth camera, lidar, thermal imager, GSM module, and WiFi module. The host computer and the lower computer transmit command information through serial communication[4](Refer to Figure 1).

![Figure 1. Pre-treatment Robot architecture diagram](image)

The program steps performed by the robot after power-on, The robot is divided into automatic inspection mode and manual control mode. After the robot is turned on, it will check the battery level. If the battery is low, the robot will start the automatic charging program to find the charging pile for charging; if the battery is sufficient, the robot will initialize all programs, such as motor driver, robotic arm control program, communication module program, depth camera program, lidar program, and various sensor programs. After the initialization phase, the robot starts the automatic inspection mode. During the inspection process, the robot monitors the navigation track in real time through a depth camera, calculates the deflection angle of the track in the field of view, adjusts the direction of travel, and realizes obstacle avoidance through lidar[5]. During the inspection process, various sensors effectively collect the surrounding environment information and feed it back to the main control for comprehensive analysis and processing through fuzzy theory algorithms. If the analysis result is within the safety threshold, the robot will continue to perform automatic inspection work until it enters the
automatic charging mode when the power is low, and the robot workflow is completed in one cycle. If the analysis result is greater than the warning threshold, the robot sends a fire warning signal to the monitoring background or the bound mobile phone through the GSM module[6]. If the robot detects a flame signal, the robot will send out a fire alarm and enter the manual control mode from the automatic inspection mode. In manual control mode, the robot receives background commands in real time. Firefighters control the robotic arms to transfer dangerous goods or manipulate the fire extinguishing mechanism to extinguish the fire, and complete the pre-treatment work of the fire. At the same time, the laser radar draws a real-time map of the scene, and cooperates with the camera to reflect the fire situation(Refer to Figure 2).

![Flow chart of early warning robot system](image_url)

**Figure 2.** Flow chart of early warning robot system

4. **Algorithm model**

4.1. **Fire diagnosis model based on infrared image**

Fire hazards are directly manifested in abnormal high temperature points and temperature distribution. Therefore, temperature detection is an indispensable aspect of electrical and fire safety detection[7]. The fire early warning robot can use infrared thermal imager to detect and image the surrounding environment to determine whether there is abnormal overheating. This paper studies a fire diagnosis model based on infrared images, carries out temperature testing and infrared detection and diagnosis of the environment to ensure the safety of goods in the scene and the reliable operation of electrical circuits and equipment to prevent fires[8](Refer to Figure 3).
4.2. Fire early warning and alarm model based on fuzzy evidence theory algorithm

Traditional fire detection systems mainly use the information of a single detection signal such as temperature, smoke, and light to determine whether a fire has occurred. This method judges whether there is a fire by setting up a threshold, so that the probability of causing a fire and no fire can only be 1 or 0, and the detection result is one-sided and absolute. To solve this problem, this paper proposes a fuzzy theory method. Extend the original value that can only take 0 or 1 to any value between 0 and 1 to determine the probability of fire. The basic concepts of fuzzy theory are as follows:

Set $U$ as the universe of discourse, a real-valued function of a fuzzy set $A$ on $U$ is: $U \rightarrow [0,1]$, $u \rightarrow u_A(u)$. For $u \in U$, function $u_A$ as $A$ Membership function. The function value $u_A(u)$ is called the membership degree of $A$ to $u$.

The robot chooses the Gaussian function as the fuzzy membership function for fire judgment, as shown in Figure 4–6, the ordinate is the membership value after transformation, and the abscissa is the value, temperature and smoke concentration of the sensor after AD conversion. The curves from left to right indicate no fire, possible and fire. When the smoke concentration, temperature and infrared light intensity all increase, the probability of fire occurrence will also increase.

Figure 4. Flame sensor fuzzy membership function graph
(3) Judgment of the reliability of fire sensors

Through the idea of analytic hierarchy process, the reliability of each sensor is calculated from the fuzzy membership degree. Suppose there are \(p\) sensors and \(q\) fire detection result in a certain fire detection. For result \(k\), the average value of the detection results of each fire detection sensor:

\[
X_k = \frac{1}{p} \sum_{i=1}^{p} X_{ik}
\]

Define a trust function \(d_{mn}\), \(d_{mn}\) represents the ratio of the trust level of the two fire detection sensors \(m\) and \(n\) to the fire detection result \(K\):

\[
d_{mn} = \frac{|X_{nk} - X_{kl}|}{|X_{mk} - X_{kl}|}
\]

Therefore, the discriminant matrix of the trust degree of each sensor for the result \(k\) is as formula (3). From the definition of the formula \(d_{mn}\), it can be seen that the closer the fire detection result of a certain sensor is to the average value, the greater the degree of trust of the sensor relative to the detection results of other sensors, and the larger the elements in the corresponding discrimination matrix.

\[
D^k = \begin{bmatrix}
1 & d_{12} & \cdots & d_{1p} \\
d_{21} & 1 & \cdots & d_{2p} \\
\vdots & \vdots & \ddots & \vdots \\
d_{p1} & d_{p2} & \cdots & 1
\end{bmatrix}
\]

Using the discriminant matrix to find the degree of trust is as follows: first add the discriminant matrix row by row to obtain the trust degree vector:

\[
W_k = \{\omega_1^k, \omega_2^k, \cdots, \omega_r^k, \cdots, \omega_p^k\}
\]
Where $\omega_{r}^{k}$ is:

$$\omega_{r}^{k} = \sum_{n=1}^{p} d_{mn}$$  \hspace{2cm} (5)

Normalize the excessive trust vector $W_{k}$ to get:

$$\overline{\omega}^{k}_{r} = \frac{\omega^{k}_{r}}{\sum_{n=1}^{p} \omega^{k}_{r}}$$  \hspace{2cm} (6)

Obtain the trust vector $W_{k}$, where the element of $\overline{\omega}^{k}_{r}$ represents the trust level of the $r$ sensor to $k$. This process is repeated for each group, and then $\overline{\omega}^{k}_{r}$ is used as the fusion weight of the corresponding membership degree, and the weighted fusion calculation is performed to obtain the degree of support for the fire detection result of the fire sensor measured this time.

5. Conclusion
This paper based on network technology and sensor technology, designs a fire warning and pre-processing robot. The robot uses fuzzy theory algorithms to analyze the probability of no fire, possible fire, and fire, and sends out fire warning and alarm signals; uses infrared image-based fire diagnosis models to identify and diagnose Hidden fire hazards; based on the slam algorithm, a map of the fire scene is constructed through lidar to reflect the real situation of the fire scene; the pre-fire treatment is completed through remote control. The fire warning and pre-treatment robots can not only realize the functions of autonomous inspection and fire warning; they also have the functions of fire detection, fire extinguishing, and obstacle removal. They have certain emergency handling capabilities and make full use of the golden fire extinguishing time. Stifle the fire and protect the safety of people’s lives and property.

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