Review of automatic fire water monitor system

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Abstract—The fire protection technology of large space building based on fire water monitor is a research hotspot in the field of fire protection technology. Aiming at the related contents and existing problems of the current fire water monitor research, this paper introduces the working principle and characteristics of the automatic fire water monitor system, and summarizes the research on the fire detection and positioning of the automatic fire water monitor system, the jet trajectory of the fire water monitor and the fire water monitor control system. This paper summarizes the research methods and shortcomings of fire detection positioning, fire water monitor jet trajectory and fire water monitor control system, and puts forward suggestions and prospects.

1. Introduction
With the rapid development of China's economy, there are more and more tall buildings, and the fire safety of large space buildings has also become a difficult point. In case of fire, the temperature and concentration of flue gas will be greatly reduced, however, the traditional automatic fire sprinkler system with smoke and temperature sensing has some disadvantages, such as poor timeliness, poor pertinence, low efficiency and complex pipeline of fire extinguishing system \cite{1}. It is difficult to achieve the expected alarm and fire extinguishing effect, so the automatic fire water monitor system is even more important. Many scholars of domestic and foreign have carried out in-depth research on fire water monitor, but there are still many problems need to be solved. Therefore, on the basis of previous scholars' research, this paper discusses the research status and limitations of fire water monitors, and prospects for future development.

2. Automatic fire water monitor system
2.1. Automatic fire water monitor
The automatic fire water monitor is a kind of fire extinguishing equipment which can automatically detect and locate the fire source and use water as the medium to extinguish the fire in a long distance. Automatic fire water monitor mainly includes fire detection positioning module and fire water supply module. The fire detection positioning module detects the fire through the fire detector, realizes the fire location and completes the fire alarm. The fire water supply module can adjust the elevation angle and horizontal angle of the fire water monitor to complete the fire extinguishing. It has the characteristics of large range, high degree of automation and fast fire extinguishing speed.
2.2. Working principle of automatic fire water monitor system

The automatic fire water monitor detects whether there is a fire within its range through the fire detection positioning module. When the fire detection positioning module detects the fire signal, it will send out the fire alarm signal and locate the fire source. After the fire source location is completed, the fire source location information is transmitted to the fire water supply module. According to the fire location information, the fire water supply module adjusts the horizontal angle and elevation angle of the fire water monitor through the motor drive, so that the nozzle of the fire water monitor is aligned with the fire source, then the solenoid valve is opened to spray water source for fire extinguishing. When the fire is extinguished, the water spray will be stopped and the surrounding area will be automatically detected repeatedly. If there are still fire source, it will automatically turn on again to extinguish the fire. After confirming that there is no fire source, it will enter the standby monitoring state, as shown in Fig. 1.

3. Fire detection positioning module

The fire detection and positioning module mainly includes fire detection and alarm, fire positioning. At present, the research of fire detection and positioning is mainly based on computer vision. It mainly uses the visual characteristics of fire in the image, including the color characteristics, dynamic characteristics and static characteristics of the fire to detect the fire. Firstly, all kinds of interference objects in the image captured by the camera are eliminated as much as possible, and then the fire target is identified more accurately by using the color characteristics, static characteristics and dynamic characteristics of the fire. On the basis of identifying the fire, the fire location is realized by binocular positioning and other methods.

3.1. Fire detection

Fire detection is based on the chemical and physical changes such as smoke, fire light, temperature, etc. when the fire occurs, it is captured by electronic devices, so as to realize early fire detection. With the development of computer technology, there are more and more methods to detect fireworks using image and video analysis technology. Video fire detection technology has a wider space coverage, and the fire detection accuracy is higher. The general process of video fire detection is divided into five parts: image acquisition, image preprocessing, image segmentation, flame feature extraction and flame detection and recognition, as shown in Fig. 2.

In the fire detection algorithm research, D.S. Yang [2] proposed HSI color model to describe flame color, and morphological method to process binary image. A method of foreground accumulation image was proposed. Static distractors were eliminated through the recognition of dynamic part, and then the flame position was located by the centroid of static part. Wong [3] used the Otsu method and Rayleigh distribution analysis method to segment the image, used the optimal threshold to enhance the extraction of fire image, and used the nearest neighbor algorithm to distinguish the non-flame area and the flame area. Z.H. Li [4] proposed a flame recognition algorithm based on dynamic fuzzy logic by fusing the dynamic characteristics of the flame, the static characteristics of the flame and the color characteristics of the flame, which improved the sensitivity and accuracy of the flame recognition algorithm. L. Lin [5]
uses the RGB color model of the image to preliminarily segment the flame, further eliminates the interference by using the brightness value of the center of the flame gradually decreasing to the surrounding, and uses the contour moment to detect the flame similarity, so as to judge the change trend of the flame, so as to ensure the rationality of the static detection results.

The above fire detection based on computer vision has obvious advantages compared with the traditional temperature and smoke sensor fire detector. It can monitor the environment in real time, and can monitor the fire scene remotely; it can locate the fire, and provide the location information of the fire to guide fire water monitors to extinguish fires; it can effectively detect the fire in large space with the advantages of long detection distance and wide detection range. However, it also has its own shortcomings. It is easy to be interfered by strong light, moving objects and available fire in the environment, resulting in wrong recognition. And in the early stage of the fire, there is only smoke or temperature change, and there is no open fire. The image taken by the camera can not detect the characteristic information of the flame, which causes the fire detection not timely.

3.2. Fire positioning
Fire positioning is to use one or more cameras to image the fire source in the same scene at different positions, and recover the location information of the fire source by using the obtained parallax. Typical binocular stereo vision fire location includes image acquisition, camera calibration, feature extraction, stereo matching and fire source location. Typical flow chart of binocular stereo fire positioning, as shown in Fig. 3.

![Flow chart of binocular stereo fire positioning](image)

On the research of fire positioning, L.K.Qin [6] used SURF algorithm to extract feature points of the image, combined ratio method and correlation function method to match the image, which made the calculation speed faster. The camera was self calibrated by using intersecting binocular camera calibration technology, and the mapping relationship between the two-dimensional image and the three-dimensional space was obtained, and the three-dimensional coordinate information of the fire source was obtained to guide the fire water monitor to put out fire. J.N.Ouyang [7] uses surf algorithm and RANSAC algorithm to improve the matching accuracy. The algorithm reduces the running time and the false matching rate of feature points, and has good real-time performance and robustness. W. Chen [8] uses the matching method based on pixel gray level to realize stereo matching of heterogeneous images. In view of the big difference of gray information of different images in template matching, disparity matching is realized by using gray information and spatial relationship of pixels. X.M.Li [9] designed the calibration device of binocular vision system by analyzing the characteristics of visible fire flame and infrared image, and designed the workflow of image calibration in binocular vision fire detection system based on OpenCV. L.L.Wang [10] used Zhang Youzheng's calibration method to accurately calibrate the camera, proposed an image matching algorithm based on SIFT feature descriptor, and selected appropriate proportional threshold, used Euclidean distance for SIFT feature vector matching, and used RANSAC algorithm to further eliminate the wrong matching points, so as to realize the calibration of heterogeneous binocular vision system.

4. Fire water supply module
The fire water supply part is mainly composed of fire water monitor body, motor drive module and controller. Combined with mechanical design, mechanical transmission control technology, computer vision technology, image transmission technology and image matching technology, the fire water supply module locates the fire source according to the fire detection positioning module, and controls the motor...
to drive the fire water monitor body to rotate through the controller to spray water to the fire source, accurately locate and effectively extinguish the fire.

4.1. Jet trajectory of fire water monitor

The jet trajectory of fire water monitors is one of the key research contents of fire monitors. In order to accurately spray the water flow to the ignition point after knowing the location information of the fire source, it is necessary to master the movement track of the water flow in the space after the spray of the nozzle, that is, the jet trajectory, so as to realize the accurate impact of the water jet on the fire source and achieve the purpose of extinguishing the fire. The prediction accuracy of jet trajectory and falling water point of fire water monitor is directly related to the effect of fire fighting. It plays an vital role in the fire monitor system. Therefore, many scholars have carried out research in this field.

1) Research on the jet trajectory of fire water monitor based on mathematical model. Y.L.Min [11] proposed a new air resistance, and applied theoretical calculation model to study the range of fire water monitor and its influencing factors. J.Sun [12] studied the jet structure and stability of the fire water monitor based on the crushing theory and through theoretical analysis and experimental results. HATTON [13] gave an empirical model of water jet according to the influence of air resistance, and compared the experimental data with simulation simulation to give the water jet trajectory curve. Q.J.Xiang and L.Xue [14] proposed a jet trajectory prediction method with only one undetermined coefficient. Through experiments, the jet trajectory of fire water monitors was measured, and a undetermined coefficient with the smallest error was found to obtain a suitable value for the undetermined coefficient. Z.Q.Liu [15] proposed a correction scheme for pitch angle compensation based on engineering test. Through the experiment, the database of jet trajectory parameters was established to make the falling point hit the fire source accurately, thereby improving the accuracy of water jetting and the efficiency of fire extinguishing.

The research on jet trajectory of fire water monitor based on mathematical model is based on Newton's second law. The water droplets or a segment of jet micro cluster in water jet are taken into consideration. Combined with the effect of air resistance and gravity, the water jet motion model is established to predict the jet trajectory. However, the research of jet trajectory based on mathematical model is to simplify the jet process with physics, and regard the jet trajectory as a simple parabola model, which only considers the influence of air resistance and gravity, and does not consider the influence of wind speed and internal flow field of fire water monitor. In view of the influence factors of different models, different flow rates and different environments, there is no general mathematical model. It is necessary to determine the parameters in the jet calculation formula through a large number of water jet test data.

2) Research on jet trajectory of fire water monitor based on computer vision. J.Chen [16] first obtained the jet trajectory area through background subtraction method and Otsu threshold segmentation algorithm, then extracts jet trajectory based on template matching and one-way search, and used curve fitting method to fit the jet trajectory to extract the complete jet trajectory. J.Yang and M.Zhao [17] combined the vector search method and the particle swarm optimization iterative search algorithm to identify the jet trajectory, and iteratively solved the optimal jet trajectory and falling water point, which solved the problem that the camera shaking or background change caused the fire water monitor jet trajectory identification and positioning accuracy reduction. D.Y.Wang and M.Yao [18] used the infrared image of the infrared thermal imager to analyze the frequency domain, and analyzed the gray image, marked the points meeting the required characteristics, according to the characteristics of the jet trajectory, connected into a curve, and obtained the jet trajectory curve. D.F.Yuan [19] used the dark primary color prior theory and the background subtraction method based on the Gaussian mixture model to obtain the motion region, and obtains the target point of the jet trajectory through matching and unidirectional search, which was obtained by the least square method and naive Bayes classifier training. Where the jet falls.

The research on the jet trajectory of fire water monitor based on computer vision is to use the video and image information collected by the camera for computer processing. The image processing
technology and tracking technology are used to identify the jet trajectory and the falling water point. According to the location information of the fire source, the falling water point is guided to move to the fire point. However, due to the complex background environment, more interference, and the lack of recognition accuracy of the algorithm, the accuracy of fire water monitor jet trajectory identification based on computer vision is low. The jet trajectory prediction of fire water monitor based on computer vision needs computer image processing compared with the prediction based on mathematical model, which takes a long time and has poor real-time performance in the fire extinguishing process. In the dark environment, the video and image taken by ordinary visible light camera are too dark, which makes it difficult to identify the jet trajectory.

4.2. Fire water monitor control system
The control system is an important part of the automatic fire water monitor. The fire water monitor control system is mainly composed of microprocessor, power supply module, communication module, motor drive module, position and speed acquisition module, controller, etc. The control system generally needs to meet the requirements of functional control and control accuracy in terms of control requirements. H.W.Qin [20] used the anti-collision protocol, 433MHz radio frequency communication technology and master-slave security authentication protocol to realize the data transmission of the control system, which effectively solved the problem of environmental restrictions on the bus transmission field. H.B.Hu [21] selected the TMS320F28335 processing chip as the main control chip, designed the minimum system, motor drive module, wireless module and power module, and proposed a control strategy based on linear auto-disturbance rejection, and designed a linear active disturbance rejection controller, which has better control performance compared with the traditional PD controller. G.Zhang [22] uses the encoder to detect the position angle of the pitch and horizontal mechanism in real time through the preset pitch step angle library and horizontal swing angle library, and then controls the rotation direction and angle of the pitch and horizontal motor.

The research of fire water monitor control system is mainly the design of system hardware and software and the research of control strategy. The ultimate goal is to control the fire water monitor to extinguish the fire effectively. The control system needs to automatically control the movement of fire water monitors and adjust the fire water monitors by controlling motors, so as to realize the accurate hitting of the fire source by the water jet of the fire water monitor. However, most of the existing automatic fire water monitor are open-loop control, the accurate positioning of fire water monitor is difficult to control, the accuracy of control needs to be improved; the degree of automation of fire water monitor is not high, and requires human assistance.

5. Summary and Prospect
1) In the large space environment, there are many uncertain factors. The recognition rate and accuracy of fire detection based on visible light camera is still low. We can use the binocular vision fire detection and positioning based on the fusion of visible light and infrared video to fuse the visible light and infrared video, realize the information complementary between the visible image and the infrared image, and obtain a more accurate understanding and interpretation of the scene. Improve the accuracy of fire identification and reduce the situation of missing and false detection.

2) The wind direction and wind speed of the fire environment have a certain impact on the jet trajectory, and the initial velocity of the water flow, the working pressure of the fire water monitor, and the water flow of the fire water monitor also have an impact on the jet trajectory. In the study, the influence of wind on the jet trajectory should be considered. By analyzing the movement law of the wind field and the influence law on the jet trajectory of the fire water monitor, a more accurate shooting can be established, and combined with the structure design of the fire water monitor and the motion characteristics of the internal flow field, the jet trajectory of the fire water monitor is studied to reduce the range error and improve the prediction accuracy of the water flow point.

3) In the research of fire water monitor control system, the closed-loop intelligent control technology can be used to improve the control accuracy and further improve the efficiency of fire fighting; optimize
the software and hardware of the system to reduce the adjustment time and increase the adjustment accuracy; design the reasonable control strategy. When there are multiple fire sources, the priority can be judged according to the fire source situation to carry out more effective fire-fighting. The fire water monitor system should be developed towards intelligence, from a simple angle of adjustment, towards network, remote and unmanned development.

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