Research and application of wildfire fire alarm system based on video monitoring technology

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1 Research background

01 research background (1)

A fire is a burning out of control, the harm of fire is self-evident.

01 research background (2)

Wildfires fire alarm system based on video monitoring technology, fire detection sensitivity, not affected by space height, thermal barrier, explosive, toxic to the environment conditions, such as can get richer fire information from video image, such as fire source location and the fire situation and so on, in order to take corresponding rescue fire fighting plan.

In the current framework and background of intelligent fire construction, make full use of the Internet of things technology, artificial intelligence, big data, The regional fire risk assessment model, fire evaluation, emergency rescue plan and combat GIS map information are incorporated into the forest fire safety management platform. Make the monitoring area image visualization, data visualization, information visualization, It shows powerful automatic warning function, whole-domain situation display ability, fire accident traceability ability, efficient intelligent management ability, and improves wildfire fire monitoring ability with low investment, which has important research significance and application value for realizing intelligent forest fire prevention.

01 research background (3)
In order to improve the wildfire fire monitoring in real-time and accuracy, the imaging characteristics of flame and smoke in visible light are studied, design a wildfire fire alarm system based on video monitoring technology. For the forest environment with complex space and diverse disturbance, image adaptive light suppression algorithm is proposed, and based on the four frame differential method and gaussian mixture background model of moving target detection algorithm, According to the static and dynamic characteristics of fire combustion, the color saturation, area growth rate, flicker frequency, circularity and other features of flame and smoke are extracted for multi-feature fusion recognition. When suspected smoke and flame occur, the fire classification alarm based on mean value analysis is adopted to reduce the false alarm rate.

2 Fire recognition

1 An effective adaptive strong light suppression algorithm for fire images is presented

In engineering application, the intensity of ambient illumination will affect the discriminative result of fire image. When the image is disturbed by strong light or even overexposed, it is easy to cause false alarm of fire. Based on the gamma adaptive correction algorithm, the MSRCR(Multi Scale Rtinex with Color Restoration) algorithm is integrated, which can not only adaptively adjust the brightness and contrast of the image, but also recover the Color information of the image when the image is disturbed by strong light or even overexposed. The result is a good visual effect.

![Image recognition results under strong light interference](image)

(a) master map  
(b) the paper algorithm

2 A moving target detection algorithm for wildfire fire is proposed

The smoke and flame of fire are constantly changing processes, and a single detection method can not meet the complex forest environment. In order to accurately detect the
moving target in fire area, a moving target detection method based on improved four-frame difference method and Gaussian mixture model is proposed.

This method will four frame differential method to extract moving target region and extract the gaussian mixture model to prospect area of the logical "or", get a complete movement area, and the area of "on/off" operation, eliminate noise, to fill the hole, to complete the movement state of the target area detection, effectively improve the detection sensitivity cavitation and background of the target.

The algorithm has good robustness, background changes (such as light gradients, floating clouds, swaying leaves, etc.) are adaptable and more suitable for wildfire detection.

The algorithm in this paper extracts renderings of flame and smoke

(a) flame original image   (b) flame target extraction   (c) smoke original image  (D) smoke target extraction

3. The feature recognition algorithm of fire image is studied

(1) Color characteristics of flame images
The color characteristics of the flame are relatively obvious, and the RGB model can be used to segment the flame color. Because the flame is mainly red and yellow, the value of color component is: R>G>B. HSV constraints are added to the decision of RGB color space, as shown in the equation:

\[
\begin{cases}
R \geq G \geq B; \\
R \geq R_T; \\
S \geq (255 - R)S_T/R_T
\end{cases}
\]

Where, \(R_T\) represents the threshold value of R component and \(S_T\) threshold value of saturation S. These two thresholds can be set in the experiment to achieve the best flame identification effect. The pixel of the flame region in the image depends on R component and saturation S.
When this condition in the above equation is met, it is considered as the flame region and displayed as white. Otherwise, it is black.

(2) Irregular edges of smoke images

The irregular edge of smoke image is mainly reflected in the complexity of the shape of smoke in the process of rising. That is, the irregular contour of the smoke area. Compared with pedestrians, trees and other objects, this feature of smoke is very conducive to comparison and discrimination. For this reason, the circular degree is used to describe the complexity of the object shape.

Circular degree is defined as:

\[ L = \frac{4 \pi S}{C^2} \]

Where, \( C \) is the perimeter of the edge of the object, and \( S \) is the area of this region, and the smaller the \( L \) value, the more complex the shape of the image, when the \( L \) is approximately 1, indicating that the shape of the object is similar to the circle.

Experiments show that the degree of circularity indicates the degree of irregularity of the image edge contour. For a large range of connected smoke area, the value of circularity \( L \) is less than 0.1, and we can set the threshold \( T = 0.1 \). The area with circularity \( L < 0.1 \) is regarded as smoke, and the image with circularity \( L > 0.1 \) is regarded as interference.

The roundness comparison between the smoke area and people in the video:
(3) Diffusion characteristics of smoke images

The diffusivity is one of the most prominent dynamic characteristics of early fire smoke. In the image, it is shown that the scope of the foreground area gradually increases. By using this feature, a large number of moving interfering objects and some non-spreading interfering objects, such as pedestrians, swaying leaves, moving vehicles, waterfalls, etc., can be excluded. The area change speed of these interfering objects is relatively slow and will not increase continuously. This paper introduces the concept of area growth rate to describe the diffusion characteristics of smoke.

The area growth rate is expressed as:
\[ f = \frac{\sum_{i=1}^{n} |f_{i+1}(x,y) - f_{i}(x,y)|}{P_i t_n} \]

Where, \( P_i \) represents the total number of pixels in the target extraction area of the video image of frame I in the current video sequence.

In order to reduce the influence of air convection phenomenon on the calculation results and obtain a more accurate area growth rate, this paper adopts the regional area average growth rate, which is defined as follows:

\[ \Delta S_i = \frac{1}{n} \sum_{i=1}^{n} \Delta S_i = \begin{cases} \in \{D1, D2\}, \text{smoke} \\ \text{else} \end{cases} \frac{\partial P_i}{\partial t} = \frac{P_{i+k} - P_i}{k} \]

Where, \( n \) is the number of iteration measurements. The average growth rate of smog area is usually within a certain range. Therefore, the diffusivity threshold \( D1 \) and \( D2 \) are selected to judge whether the average diffusivity is within the range of \( D1 \sim D2 \). The target area whose average diffusivity is outside the threshold range is regarded as the interference area.

(4) Flame flicker characteristics

In the process of fire combustion, under the influence of air flow, the flame shows irregular jitter phenomenon, which is the flicker characteristic of flame. Flicker frequency is one of the most important dynamic characteristics of flame, and the main flicker frequency range of flame is 7-12Hz. The flicker frequency of the flame does not change with the change of the environment. The flicker characteristics of the flame can be used to exclude interfering objects such as car lights and pedestrians, and the flame can be identified and extracted by extracting the flicker frequency of the flame.

The flicker feature of flame is characterized by the changing frequency of pixels on its edge. The calculation formula is expressed as:
Where, \( f \) is the flicker frequency of the flame, \( f_i(x, y) \) and \( f_{i+1}(x, y) \) represent the edge pixels of two consecutive frames of images, and \( t \) represents the time from \( i \) frame to \( n \) frame.

According to Figure (e), the frequency curves of (a) and (b) basically fluctuate in the range of 6-14Hz, and the frequencies of (c) and (d) two interference sources (shaky flashlight and electric lamp) fluctuate in the range of less than 6Hz. The results show that the flame strobe feature can distinguish the flame from other interferences well, and can be used as an important feature to determine whether there is a flame region in the video image.

(5) Attenuation characteristics of smoke on background high-frequency signal (energy spectrum characteristics)

The background image is occluded by the concentration of fire smoke, which is manifested as the high frequency attenuation of smoke. This phenomenon can also be explained by Fourier transform, when the thin smoke is covered by the background, it is equivalent to neutralizing the high-frequency signal on the background signal, so that the component of the background signal tends to the middle and low part, that is, the high-frequency attenuation of the background signal caused by the smoke. In the case of heavy smoke, the gray value of pixels in each area is relatively similar, so there will be no sudden change of pixel value and no attenuation of background signal.

The high-frequency attenuation characteristics of the smoke are shown in the figure.
The attenuation of smoke to the background high-frequency signal is shown by the blur of pixels in the high-frequency signal area on the picture and the darken of the corresponding area on the spectrum map.

4. The fire alarm prediction mechanism is given

Aiming at the false alarms in the practical application of engineering, a wildfire fire alarm rule based on mean value analysis is designed to predict the identification results of the system and give fire alarm grading, which reduces the false alarm rate.

**Fire alarm rule based on mean value analysis**

Considering the random discreteness of environmental disturbance, there is a certain risk of false alarm in the single fire determination result. In order to make the test result more reliable, the identification result $F$ within a test period is taken for mean analysis, and the fire alarm is determined according to whether $F$ is 1.

Assuming that there are $N$ total of fire image alarms within the detection period, the alarm result is $F$, and the alarm threshold is $\alpha$, then:

$$F^* = \begin{cases} 1, & \frac{1}{N} \sum_{i=1}^{N} S_i \geq \alpha \\ 0, & \text{otherwise} \end{cases}$$

Where $S_i$ is the fire identification result of the $i$th, if fire is identified, the value is 1; otherwise, the value is 0. When the proportion of the number of fires in the current period is greater than the threshold $\alpha$ and $F=1$, the fire can be judged as a real event and the fire alarm can be started.

**Classification of fire alarm mechanism**

**Level 1 fire alarm**: At the same time, smoke and flame were identified, and the mean analysis $F=1$;

**Level 2 fire warning**: Only smoke or flame was identified, and the mean analysis $F=1$. 
**Level 3 fire warning:** Although smoke or flame is identified, mean analysis F=0;

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3 System design

1. Design goal — Visualization of forest firefighting

Images data information Management
Visualization visualization Visualization

Powerful automatic early warning function, global situation display ability, fire accident traceability ability, efficient intelligent management ability.
2. **overall architecture**

This system mainly includes video information acquisition, remote communication, image processing and monitoring alarm four parts.

The video collection adopts the barrel type HD camera, which is arranged in the mountaineering pass, the mountaineering path and the rest pavilion. The gimbal type camera is arranged on the mountainside and the top of the mountain to realize the remote fire monitoring.

3. **Software development flow chart**
4. **system interface**

**System Login Page**

![System Login Page](image)

**System Monitoring Interface**

![System Monitoring Interface](image)
System function

1. Video wildfire fire monitoring – provides solutions for forest fire detection
   Fire identification within 3 seconds, automatic alarm within 15 seconds, the first time to control the fire.

2. Intelligent wildfire identification
The system has the function of intelligent wildfire identification, the collection of wildfire fire alarm and hidden danger data, multi-feature fusion of intelligent fire identification algorithm, based on the fire model algorithm library, can quickly identify suspected fire, the location of dangerous situation accurately and through the electronic map screen, trigger the corresponding fire rescue plan.

3, Investigation of suspected wildfire fire — Provide fire warning
For multiple abnormal alarm information within 15 minutes and a radius of 500 meters, the suspected wildfire fire alarm status is automatically determined, the alarm level is actively raised, and the relevant information is submitted to the relevant personnel, so that the whole process data of suspected wildfire hazards can be visible and controllable.
5. Risk assessment system based on big data
   -- to provide decision-making basis for government functional departments

AIT (artificial intelligence technology):
Build all kinds of fire risk analysis model, use big data, neural network and other technologies to optimize the analysis model, according to the results of the model analysis automatically guide the improvement suggestions of fire control work, according to the improvement suggestions to track the improvement effect, continue to optimize the fire safety work, reduce the fire risk.
6、GIS linkage and decision aid

The system has the functions of accurate location of wildfire, electronic map pops up the screen, automatic alarm and linkage alarm video, which can quickly and accurately find the wildfire and locate the location of the fire point.

7、Remote communications

According to the actual situation of the forest, the remote communication can choose 4G/5G communication, microwave communication, or optical fiber communication, etc., and is not easy to be blocked by the complex terrain interference of the forest area.

8、System safe operation and maintenance

Operation and maintenance system for the whole system equipment and application monitoring and management, anti-theft, lightning protection, power supply; To realize the integration of operation and maintenance personnel, and carry out whole-process trace management of operation and maintenance.
9. **User fire alarm APP — provides multi-directional monitoring for mobile terminal users**

User fire alarm APP is against wildfires fire monitoring, and mountain climbing, climbing, lounge and other fire control facilities the running state of real-time monitoring of application software, through the APP can set the case of the emergency contacts, so that in case of the first received a telephone, SMS notification, avoid bigger losses.

10. **Intelligent integrated management platform**

Visual management, support simultaneous access of multiple screens, real-time monitoring of PCS and mobile phones, and wechat alarm push.

The complete intelligent command background takes the high-precision satellite map as the base map, and simultaneously loads the rescue route, water system, monitoring station, observation tower and other spatial data, aiming to provide customers with a comprehensive management platform for fire alarm, fire rescue, risk assessment and so on.
5 System advantage

1. Market comparison of similar products

A: Digital camera + embedded recognition algorithm: the camera must be specified. The single DSP algorithm has limited computing capability and high false positive rate, which is not compatible with the original monitoring system and needs to be rewired.

B: Digital camera + front-end analyzer: additional devices are required for each monitoring channel, and the DSP computing capability of the front-end device is limited and the false positive rate is high.

✓ C: digital or analog common camera: compatible with the old monitoring system, the system is easy to build in engineering applications, the identification algorithm runs on the cloud platform server, powerful OS supports a variety of intelligent algorithms, low false positive rate, fast response.
2. Main indicators

1) fire sensitivity: The response time of video detection system from the detection of flame or smoke to fire alarm signal is no more than 15s.
2) response threshold: Using infrared camera, when the distance is 5m, the focal length of the lens is 4mm, and the viewing field is 0° horizontally and 50° vertically, the response threshold is not greater than 10mm × 10mm.
3) detection distance: According to the HD camera parameters and the atmospheric transparency of the terrain and other conditions, the camera resolution 3840X2160 (4K resolution), 6~100mm variable automatic focusing, the maximum focal length can identify the 2m × 2m burning disk 5 kilometers away.

6. Research Achievements

02 Scientific Achievements

1. Two group standards "T/JIA 0001-2021 Video Fire Detection and Alarm System" and "T/JIA 0002-2021 Video Fire Detection and Alarm System Technical Regulations" have been compiled and issued.

2. The paper "Video fire detection and Alarm System and Its Application" won the second prize of "Excellent Papers in China Installation Industry in 2022" and "Excellent Papers in Jiangsu Installation Industry in 2021".

4. Authorized two invention patents "A fire Identification Device Based on Multi-feature Fusion" and "An Anti-theft Alarm System Based on Video monitoring for Substation Temperature Detection".

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Q&A: