Research on Fire Image Detection Algorithm of Electrical Substation

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Abstract. In order to quickly identify the fire hazards and formulate the corresponding measures inside the transformer substation. A fire detection algorithm of transformer substation based on block marking is studied. On the basis of the transformer substation monitoring platform, the image of primary equipment in the transformer substation is collected through the video monitoring software. According to the flame characteristics, the affected parts are identified and located by block marking. The fire detection algorithm is realized by using OpenCV. Through the fire identification software, the operation of the equipment can be monitored inside the substation in real time, and the fire hazards can be detected in time. The experimental results show that: through the image preprocessing and block marking, comparing the characteristics of the flame, the monitoring and alarm analysis of the primary equipment area in the transformer substation can be realized, and the rapid response to the fire can be realized accurately.

Keywords. Block marking; feature analysis; fire detection.

1. Introduction
The development of human civilization is promoted by fire. But fire has also brought endless troubles to people’s production and life in modern society, among which electrical problem accounts for one third of all kinds of fire. The prevention of electrical accidents is the key factor to curb fire. The fundamental means to prevent electrical fire is to enrich the monitoring and analysis technology and find out the fire hazards in time, and implement the corresponding countermeasures quickly. In this paper, the video monitoring to primary equipment in electrical power substation is studied, and the fire recognition algorithm is developed to check the equipment area and find the abnormal situation as soon as possible by video acquisition function in electrical power substation [1-2].

2. System Design
Based on the domestic electrical power Linux system, this paper studies a fire recognition algorithm [3] through Qt development platform and opencv visual function library, which takes monitoring equipment in electrical power substation as hardware platform, captures video stream to the monitoring host by outdoor cameras, and achieves the analysis of the scene area through the fire recognition algorithm [4-5].

The fire recognition algorithm realizes the recognition and location with the block mark[6-10], which reduces the calculation through image preprocessing, improves the Velocity of detection and reduces false alarms by feature matching.
3. Algorithm Design

Fire recognition algorithm is designed on substation video monitoring platform [11-13]. Firstly, the collected image should be preprocessed. Secondly, the fire location is achieved by block marking. Finally the fire feature is used to distinguish the location [14-15].

3.1. Graying

The image collected by the video monitoring system is colorful, so the calculation is large, which affects the real-time performance of fire recognition. It is necessary to gray the image first.

The collected image uses three vectors of R, G, B of which the range of value is 0-255 to express color information. So each pixel can express 2553 kinds of color information. The resolution of a single image is 640 * 480. So it is necessary to simplify the image to improve the real-time.

Firstly, the mean value of the three vectors is calculated. Secondly, the mean value is taken as the only vector of the image. So the RGB color information is converted into YUV, where U and V represent the color information and Y represents the brightness information. The unique vector information is assigned to Y, U and V are ignored, and only the brightness information of the collected image is retained. The vector relationship between Y and RGB is (1).

\[
Y = 0.3R + 0.59G + 0.11B
\]  

(1)

The collected image becomes gray image after conversion, which reduces the calculation of real-time analysis and provides conditions for subsequent binary processing. Figure 1 shows the conversion effect of gray image of fire.

![Figure 1. Grayscale flame image.](image)

3.2. Binarization

In case of fire, the brightness of the flame is higher than that of other objects in the image. According to this characteristic, the flame can be separated from the background. In order to identify the flame area, we need to set a brightness threshold \( T_0 \) for Y. The part higher than \( T_0 \) is identified as the flame area, and the brightness value of all pixels in this area is set to 255. The other part lower than \( T_0 \) is identified as the background area, and the brightness value of all pixels in this area is set to 0. Then the gray image is converted into black and white image, which further reduces the calculation of image processing.

3.3. Optimal Threshold Selection

In order to prevent the misjudgement of fire, we need to set the threshold \( T_0 \) according to the brightness characteristics of the flame. After large of experiments, we set \( T_0 \) to 100. When the gray value of the image exceeds 75, we can judge that there is a suspected fire happened.

In order to accurately separate the flame and background information, we need to calculate a more appropriate threshold according to the gray value distribution of the collected image. According to the initial threshold 100, we divide the image into two parts, and then calculate the average value \( L_1 \) and \( H_1 \) for the gray value of the two parts respectively, where a new threshold \( T_1 \) is calculated on the average value of the two parts. According to the new threshold \( T_1 \), we divide the image into two new parts. Repeat the above steps and obtain \( T_n \) repeatedly for N times. According to \( T_n \), we divide the image into two parts of flame and background accurately. This is the process of using the iterative mean method to select the optimal threshold. The formula (2) is as follows.
With the number of iterations increases, when $|T_n - T_{n-1}|$ is small enough, $T_n$ is infinitely close to the optimal threshold. In consideration of the real-time performance of the system, after large of experiments, the number of iterations is set to 3. If the final iteration result $T_3 \leq 100$, it is judged that there is no fire in the area. The collected pictures should be excluded, on which the next picture will be judged. If the final result $T_3 \geq 110$, it is judged that there may be a fire in the area, and the image is binarized and segmented.

The optimal threshold binarization segmentation effect is shown in figure 2.

![Figure 2. Schematic diagram of flame binary segmentation effect.](image)

### 3.4. First Block Marking

According to the binary image information, we count and mark each connected white area in the image, which is the first block marking. By marking, the area of each white area can be calculated.

First of all, take (1, 1) of the pixel array as the starting point to scan the collected image from left to right and from top to bottom, as shown in figure 3.

![Figure 3. Scanning principle of the first lump mark.](image)

Scanning right from (1, 1) to (1, 14).

Two white continuous areas (1, 2) to (1, 6) and (1, 10) to (1, 13) were found and marked with block 1 and block 2 respectively.

After scanning the first line, jump to (2, 1) and start scanning the second line.

In line 2, two white continuous areas (2, 6) to (2, 7) and (2, 9) to (2, 10) are found. Since (2, 6) to (2, 7) are connected with (1, 2) to (1, 6), this area is still marked as block 1. (2, 9) to (2, 10) are connected with (1, 10) to (1, 13), so this area is still marked as block 2.

After scanning the second line, jump to (3, 1) and start scanning the third line.

Two white continuous areas (3, 2) to (3, 4) and (3, 7) to (3, 8) are found in line 3. Since (3, 2) to (3, 4) are not connected with any of the above areas, the area is marked as block 3. (3, 7) to (3, 8) and (2, 6) to (2, 7), (2, 9) to (2, 10) are connected together. At this time, the area is marked as the party with smaller serial number, and an equivalent combination is established between block 2 and block 1.

Finally, the equivalent combination is combined into a block, and marked as the smallest number in the set. The statistics and analysis of the marked blocks in the collected image are obtained by reordering.
3.5. Block Screening
In order to improve the accuracy of fire identification and prevent the misjudgement caused by light and other interference factors, we delete the smaller blocks. In the process of the first block marking, the number of pixels of each block is recorded at the same time. Through a large number of experiments, we set an area threshold of 100, and those below this threshold are deleted as interference information. Figure 4 is the flame area after screening.

![Figure 4. Flame area after screening.](image)

3.6. Block Filling
The purpose of block filling is to fill the bubbles in the target area, so as to better analyze and distinguish the shape characteristics of the target area.

Create a set of 5 * 5 pixels to scan the image, and the gray value of the pixels of the scanning volume is 255.

The scanning mode is similar to that of the first block marking, starting from the first line to the fifth line, with every five columns as one step. After completion, the scanning starts from the sixth line to the tenth line, and so on.

In the process of scanning, the gray values of the scanning volume and the scanned area are calculated with AND. If the calculation results are 0 completely or 1 completely, the next area is scanned. If both 1 and 0 are included in the calculation result, all the pixel values of the scanned area are set to 255 to fill and expand the bubbles in the target area.

In order to corrode the expanded area, the second scanning is needed, and then the second scan is needed. If the calculation results are 0 completely or 1 completely, the next area will be scanned. If the calculation results contain both 1 and 0, the pixel values of the scanned area are all set to 0 to achieve the corrosion of the expansion part of the target area.

The effect of block filling is shown in figure 5.

![Figure 5. Effect picture of block filling.](image)

3.7. Second Block Marking
In the second scanning, contour tracking method is used to the target area, which can quickly obtain the shape characteristics of the area. The principle of contour tracking method is shown in figure 6.
The scanning mode is the same as the first block marking. When the target area is reached, the scanning is interrupted and the contour tracking mode is turned on. The tracking direction depends on the method of gray value comparison of neighborhood pixels. The principle is shown in figure 7.

After the scanning pointer P reaches the target area, when the first pixel is marked with A, the contour tracking mode is turned on, and the forward direction is determined by the gray level of the adjacent 8 pixels. The discrimination process is as follows.

Start from the pixel on the right side of the marked point and number it clockwise from 0 to 7. Starting from point 0, the discrimination is carried out in the order of 0 → 1 → 2 → 3 → 4 → 5 → 6 → 7 → 0. When the gray level jumps from 0 to 255 and the 255 pixel is not marked, the 255 pixel is the next direction of pointer P, when the discrimination process of the neighborhood pixel is stopped.

The pointer P advances to the next pixel, marks a, and repeats the previous process until two marked points appear in the discrimination process, indicating that the pointer has returned to the starting point and completed the contour tracking.

After the contour tracking is completed, the scanning process is restarted. When A pixel is encountered, the scanning continues, and all the scanned pixels are marked with A until another A pixel is encountered, when the marking ends. The marking process is shown in figure 8.
Figure 8. Schematic diagram of scanning mark.

The red mark is the contour mark, the white mark is the scanning mark, and other blocks in the image are marked according to B, C, etc. Finally, the geometric center and area of each target block are obtained through the second marking, and the appropriate block is selected for fire location. The effect is shown in figure 9.

Figure 9. Fire location.

4. Algorithm Implementation

In order to improve the rapidity and accuracy of fire recognition, we carry out feature extraction compared with flame template on the basis of block marking, and conduct a large number of feature recognition training through Opencv, so that the system has the ability of recognizing fire.

4.1. Feature Extraction

Firstly, the image of alcohol lamp is collected as the experimental object, and after locking the flame area by using the block mark, the system extracts the features of the area, and the extraction results are shown in figure 10.

Figure 10. Schematic diagram of flame feature extraction.

4.2. Color Discrimination

According to the color characteristics of the flame, we select the flame color template for comparison training, and the color card of the color template is shown in figure 11.
The corresponding RGB values of the template color card are shown in Table 1.

| Color code | R  | G  | B  |
|------------|----|----|----|
| 001        | 72 | 36 | 17 |
| 002        | 115| 61 | 5  |
| 003        | 175| 93 | 9  |
| 004        | 205| 106| 7  |
| 005        | 173| 88 | 7  |
| 006        | 132| 72 | 13 |
| 007        | 190| 103| 2  |
| 008        | 236| 137| 8  |
| 009        | 249| 145| 9  |
| 010        | 247| 137| 3  |
| 011        | 255| 178| 18 |
| 012        | 203| 112| 10 |
| 013        | 222| 136| 10 |
| 014        | 255| 164| 7  |
| 015        | 255| 177| 6  |
| 016        | 250| 184| 5  |
| 017        | 239| 152| 12 |
| 018        | 199| 115| 14 |
| 019        | 244| 177| 31 |
| 020        | 255| 221| 150|
| 021        | 251| 229| 197|
| 022        | 252| 235| 238|
| 023        | 253| 235| 216|
| 024        | 251| 188| 81 |
| 025        | 242| 210| 119|
| 026        | 255| 246| 220|
| 027        | 244| 246| 245|
| 028        | 245| 246| 243|
| 029        | 249| 244| 246|
| 030        | 248| 204| 124|

Firstly, the system divides the extracted feature region into several equal area small regions, and each small region calculates a mean value of color. Secondly, each mean value is compared with the template value one by one to analyze the color matching error, matching success rate and fire recognition rate. Thirdly, a large number of experimental images are trained by OpenCV library. Finally, when the color matching error is ±5% and the matching success rate is more than 70%, the fire recognition success rate can reach 99.3%. The training process is shown in Figure 12.
4.3. Fire Identification and Detection

According to the block recognition algorithm and flame feature training, through a large number of experiments, the application of fire image detection algorithm is realized. Figures 13-15 are the recognition results of the fire image, and the fire area is marked by the green box.

![Flame color training process.](image)

**Figure 12.** Flame color training process.

![Fire detection effect.](image)

**Figure 13.** Fire detection effect.

![Fire detection effect.](image)

**Figure 14.** Fire detection effect.

![Fire detection effect.](image)

**Figure 15.** Fire detection effect.

After the simulation and analysis of fire algorithm, we develop fire recognition system based on QT platform, and complete the fire recognition algorithm with OpenCV visual library.

5. Conclusion

This paper introduces the practical application of fire detection in electrical production. Based on the substation monitoring system, the QT platform detection software under Linux architecture is developed, and the OpenCV visual library is equipped to complete the calculation and analysis process of fire intelligent alarm based on the block mark and flame feature comparison.

Experiments show that the fire detection method based on computer vision technology can effectively judge any scene logically, and has wide applicability and strong recognition ability.
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