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Method for Identifying, Locating and Diagnosing the Status of Indicator Lights in Panel and Cabinet Based on Multi-Feature

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Abstract: ***In order to solve the problem that the traditional substation is not connected with the integrated automation system, which leads to the problem of false detection and missing detection of equipment fault, this paper proposes a method for identifying and locating and diagnosing the status of indicator lights in panel and cabinet based on multi-feature. Firstly, the color histogram algorithm was used to extract the color features of red, yellow and green indicator lights when they were on or off; Secondly, based on the color image threshold segmentation algorithm in the video stream, the real-time contour of a single or multiple fault device indicator area was obtained, and the centroid coordinate position of the area was calculated to realize the fault device indicator location and fault type judgment; Finally, the video stream analysis and statistics were used to obtain the time sequence characteristics of indicator light on and off. The video images of red, yellow and green indicator lights flashing at 0.5Hz, 2Hz and 0.5-2hz frequency are simulated. The detection results show that the detection accuracy is higher than 85% except for the low recognition rate (81.8%) of continuous change of indicator light flashing frequency. This method can accurately identify and locate the indicator light of the faulty equipment in the intelligent patrol panel of the main control room of the substation, and judge the type and emergency degree of the faulty equipment, so as to provide auxiliary technical support for the dispatching automation system of the traditional substation.***

Keywords: Threshold Segmentation, Regional Characteristics, Time Series Characteristics, Video Image

1. Introduction

Many domestic substations have achieved operation and maintenance automation. However, a small number of substations still have some deficiencies in the degree of automation due to the difficulty and high cost of automation transformation project [1]. Therefore, in these substations, the monitoring and dispatching personnel can only remotely monitor the on-site situation of the substation, and when the on-site fault occurs, the maintenance personnel can only judge and analyze the fault type of the equipment by retrieving the on-site video data [2], and the monitoring effect is easily affected by many factors such as the psychological quality and business level of the staff of each department, resulting in inaccurate monitoring information Arrange to solve the problems such as untimely failure and wrong judgment of maintenance personnel, resulting in false detection and missed detection, which will lead to personnel risk and damage to the equipment. In recent years, computer vision and image processing technology have been gradually applied to substation monitoring, which can conduct real-time monitoring on the intelligent patrol panel of the panel and cabinet in the main control room of the substation with insufficient digitization, identify and locate the indicator light of the faulty equipment, judge the emergency degree of the equipment fault on this basis, and give a real-time warning to the suspicious state, Compared with the digital transformation of the substation, this method costs much less. To some extent, it can assist the staff to complete the monitoring and patrol inspection of the equipment status [3], which can not only protect the existing investment, but also improve the automation technology level of the substation, and provide a reliable guarantee for the safe operation of the equipment.

For the research on dynamic recognition in video images, literature [4]-[5] proposes an algorithm for flame recognition based on video image processing technology, which can directly detect the flame size and accurately evaluate the training results. Tang Lin et al. [6] set the threshold in HSV color space through video analysis and image recognition processing technology. When the pixel is within the threshold range, it is determined that there is light of current color in this area. Finally, by traversing each video image, similarity matching between images is carried out to determine whether there is color change of indicator light. For the indicator area calibrated by Huang Zhanhua et al. [7], in YUV (Y represents brightness, u and V represent chromaticity) mode, the value of U-V = R-G represents the red and green information of the indicator, and the frame difference method is used to count the brightness difference between frames to judge the flashing state. For the study of indicator recognition, literature [8] sets a threshold in RGB space to extract the color of red and green areas as the final target area. For the study of regional features, the image threshold segmentation in reference [9] is carried out in HSV color space, and the candidate areas are geometrically filtered to obtain the candidate areas of traffic lights. In reference [10], traffic lights are modeled separately in HSV space to obtain the segmentation threshold of each channel, and then the segmented image is filtered through shape features to obtain the candidate area of indicator light. YeHu Shen et al. [11] used the mean and variance of H and s channels to segment the image in HSV space, and then used the regional characteristics to judge the circular region to identify the traffic signal. Document [12] image segmentation in RGB color space, which performs Hough circle transformation on the edge detected image to detect circular signal lamps, but this method, is only limited to circular signal lamps arranged in the horizontal direction. Chen Wei et al. [13] carried out threshold segmentation on the sphere based on the color image, and the effect of this method will be better when recognizing objects of specific color.

According to the characteristics of the indicator lights in the panel cabinet of the main control room of the substation and the operation and maintenance requirements, it can be found that locating and identifying the status of multiple equipment status indicator lights of the same or different colors in the intelligent patrol panel and obtaining the on-off timing characteristics of the indicator lights are the key to realize the intelligent alarm. Therefore, this paper proposes to use the three characteristics of color, area and on-off sequence to locate and diagnose the status of the intelligent alarm patrol indicator in the main control room, and the effectiveness of this method is proved by experimental simulation. The research results can provide technical support for the dispatching automation system of traditional substation, and better assist the coordinated operation of monitoring, duty dispatching, maintenance and other departments.

2. Overall Scheme of Indicator Recognition, Location and State Diagnosis

Firstly, a large number of single indicator images are collected, and their color features are extracted based on color histogram algorithm; Secondly, based on the threshold segmentation algorithm, the region contour of the alarm indicator is obtained and its region features are extracted; Finally, the flashing frequency of the indicator is determined by obtaining the on-off timing characteristics of the indicator. The overall scheme is shown in Figure 1.

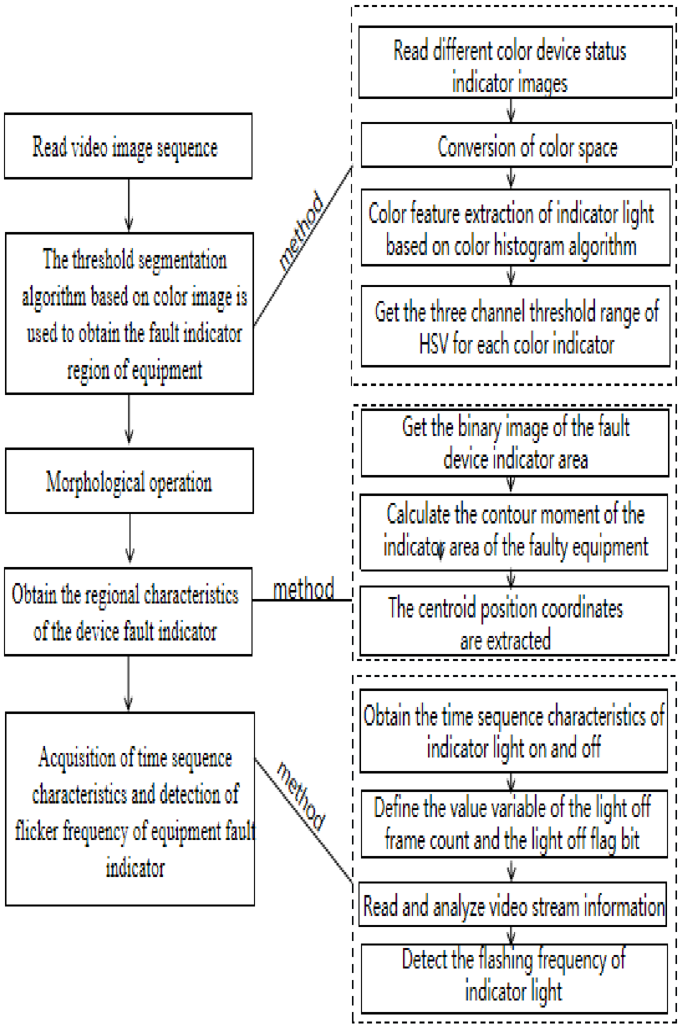
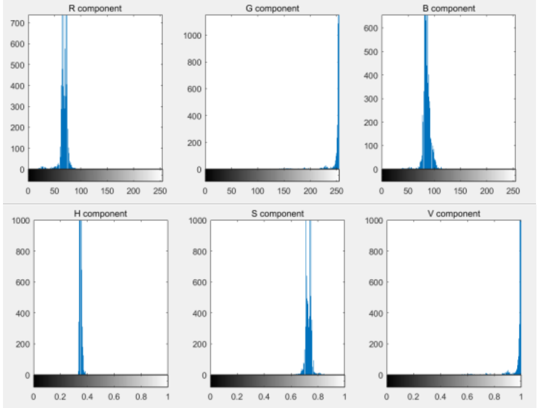
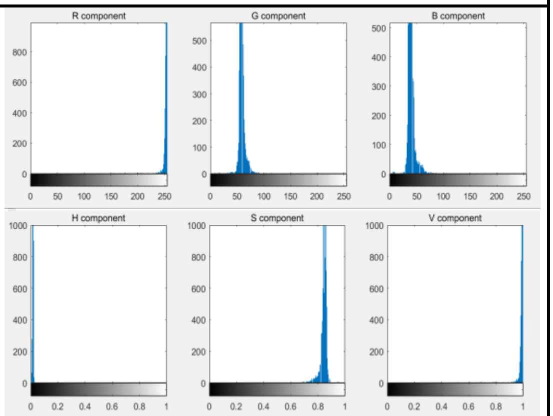
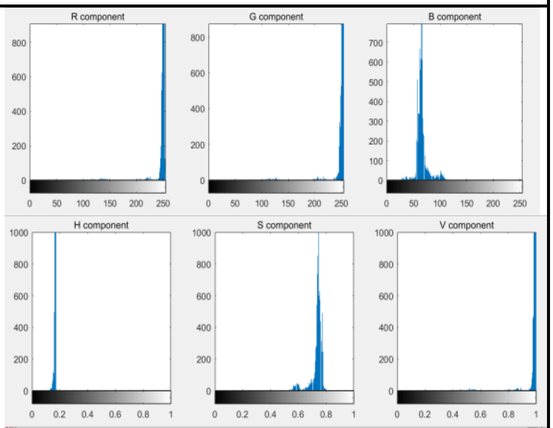


Figure 1: Overall scheme of indicator recognition, location and status diagnosis based on multi-feature

3. Color Feature Extraction of Indicator Light Based on Color Histogram Algorithm

The fault equipment indicator light is a luminous body. Clear color images can be collected through the camera. It is necessary to select an appropriate color space to segment the color image and quickly and accurately segment the fault equipment indicator light area. At the same time, it also needs to ensure that the amount of calculation is small and meet the requirements of real-time. In this paper, the scene of extracting color features is a single device status indicator image without considering its distribution in space, and the color histogram is to count the number of pixels in different intervals from a mathematical point of view, so as to describe the color of the image without considering the spatial position of each color. The most commonly used color spaces are RGB color space and HSV color space. For the selection of color space, the following experiments are carried out for common red, yellow and green indicators, as shown in Table 1.

Table 1: Histogram distribution of indicator lights in different color spaces

Color	Histogram distribution of each component
Green R:75 G:255 B:95 H:0.385 S:0.798 V: 1	
Red R:255 G:55 B:48 H:0.015 S:0.813 V:1	
Yellow R:255 G:255 B:60 H:0.185 S:0.785 V:1	

It can be seen from table 1 that the color determination of various color indicators in RGB color space is jointly affected by the three channels R, G and B, while in HSV color space, H channel can basically determine a certain color, while the influence of S and V channels on color judgment is not obvious. For example, in RGB color space, green (R: 75, G: 255, B: 95) and yellow (R: 255, G: 255, B: 60); In HSV color space, green (H: 0.385, s: 0.798, V: 1) and yellow (H: 0.185, S: 0.785, V: 1). It can be seen that the setting of threshold in HSV color space is simpler and the amount of calculation is less. This paper needs to judge the color and on-off state of equipment indicator light. On this basis, combined with s-channel saturation and V-channel brightness, the on-off state of indicator light can be better judged. Therefore, this paper adopts HSV space which is closer to people's subjective understanding of color.

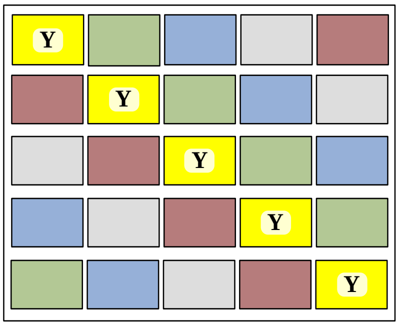
4. Extraction of Indicator Light Region Based on Threshold Segmentation Algorithm

4.1 Threshold Segmentation of Color Image

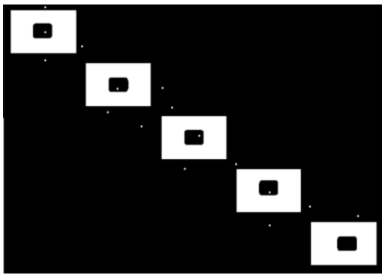
Image segmentation is a process of dividing an image into several regions with specific properties and extracting the region of interest from it [14]. The threshold segmentation algorithm is characterized by simple implementation and high computational efficiency [15]. In the process of image processing, color images can provide more feature information than gray images. In this paper, according to histogram segmentation algorithm of gray image [16], in HSV color space, the H, S and V components are processed with multiple thresholds respectively. The threshold range is set to white (255), and the rest belongs to the background area set to black (0), so as to realize the image segmentation. The split strategy is:

（1）

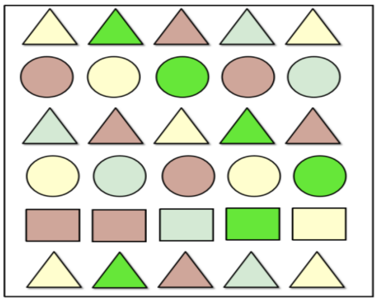
Where, the double thresholds H1 and H2 set on the H component, the double thresholds S1 and S2 set on the S component and the double thresholds V1 and V2 set on the V component. Thus, the binary processing of color image is realized, and the binary image of equipment fault indicator is obtained. This paper simulates yellow and green equipment fault indicators with different shapes, and proves that this method is not affected by shape factors, as shown in Figure 2. However, sometimes the detected results are not closed and there is sporadic noise, so this paper will use morphological operation to close the edge and delete the noise.



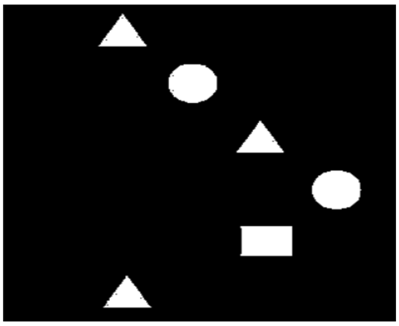
(a) Original image



(b) Binary image based on yellow segmentation



(c) Original image



(d) Binary image based on green segmentation

Figure 2: Binary image of color image segmentation

4.2 Morphological Operation

Morphological operation in image processing is based on shape processing operation [17], among which the most basic operation is corrosion and expansion [18]-[19]. The open operation is the process of etching the image first and then expanding, which is used to eliminate the boundary of small objects or smooth large objects; The closed operation is the process of expanding the image first and then corroding, which is used to eliminate the small black hole in the image. In this paper, the noise effect of the indicator light area of the fault equipment is eliminated by using on operation and expansion. The effect diagram is shown in Figure 3. Compared with Figure 2(b), it is clear that the hole phenomenon in the middle of the equipment fault indicator area is eliminated.

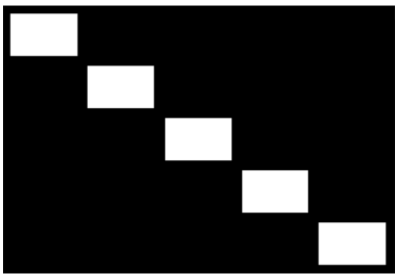


Figure 3: Effect diagram of expansion and opening operation

4.3 Extract the Area Feature of the Indicator Light

In the intelligent alarm patrol panel of the panel cabinet in the main control room of the substation, each indicator represents the operation status and fault type of different equipment, as shown in Figure 2(a). Therefore, these indicators need to be distinguished and positioned, otherwise false detection will occur. For the binary image obtained above after threshold segmentation and morphological operation, the shape invariant moment method is used to extract the regional characteristics of the fault equipment indicator light, so as to determine the equipment fault type in the intelligent patrol panel of the screen and cabinet.

Generally, the fault equipment indicator area detected is not a point, so the center point of the area is used to locate. The centroid of a figure of the same shape with constant mass per unit area is the center point of the area. Because the quality distribution of binary image is uniform, and its centroid and centroid coincide, this paper uses centroid to represent a region. Mark the position of the device (x_i, y_j)(i=0, 1,.., n-1;j=0, 1,.., m-1) as the coordinate of the detected area of the device.

(2)

4.3.1 Area of Indicator Light for Faulty Equipment

In order to obtain the centroid of the indicator light region of the faulty equipment, we must first obtain the area of the region. For a binary bounded function f(x, y), its moment of (j+k) is

(3)

Since j and k can take all nonnegative integer values, they form an infinite set of moments, and M_{jk} is unique to the function f(x, y). The parameter j+k is called the order of the moment. In particular, the zero order moment can be used to represent the area of the object, that is, the area of the indicator light area of the faulty equipment can be expressed as

(4)

4.3.2 Centroid Coordinates of the Fault Equipment Indicator Area

When j=1，k=0, M_{10} is the sum of the X coordinates of all points in the indicator light area of the detected faulty equipment for the binary image, and M_{01} is the sum of the Y coordinates of all points in the area, so

(5)

It is the centroid coordinate of the fault equipment indicator area in the binary image obtained after detecting the equipment fault indicator.

Take the centroid of the equipment fault indicator area as the center to construct the central moment, then the calculation of the moment is always the centroid of the point in the target area relative to the target area. Take the picture with a resolution of 600 * 425 as an example, the position of the origin is in the upper left corner of the image. In the coordinate system, x increases from left to right and Y increases from top to bottom, as shown in Figure 4. The position of the centroid of each rectangular region on the diagonal is independent of other regions.

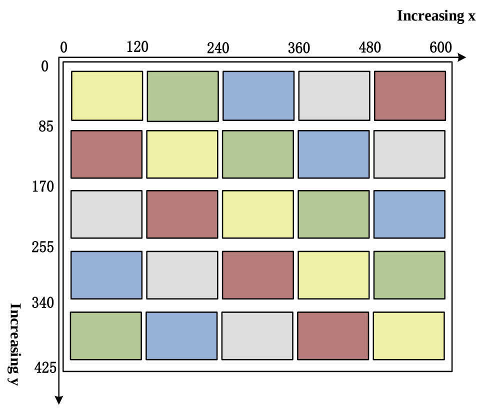


Figure4: Coordinate system

Therefore, after obtaining the binary image of the fault equipment indicator area based on the threshold segmentation algorithm, the fault equipment indicator can be located by obtaining its contour, calculating the spatial moment, and then calculating the centroid position coordinates of the area. However, in addition to a single indicator alarm, two or more indicators may alarm at the same time, including the same color and different color indicators. This method can distinguish the equipment status indicators in the intelligent patrol panel and further determine the equipment fault type.

5. Acquisition of Timing Characteristics of Indicator Light On and Off

The equipment status indicator will have three states: on, off and flashing. The flashing frequency of the indicator is commonly used to indicate the severity and urgency of equipment failure. The different flashing frequencies of the indicator usually represent the emergency degree of equipment failure, and the 0.5Hz flashing frequency indicates that the monitoring dispatcher is prompted that the equipment is abnormal; 2Hz flashing frequency means that the equipment fault is a serious fault and must be handled at the first time. This paper analyzes and counts the on-off timing characteristics of the indicator light by reading the video stream in real time frame by frame, which can be used as the basis for judging the emergency degree of equipment failure, and detects the flashing frequency of the indicator light in the video image. The specific process is shown in Figure 5.

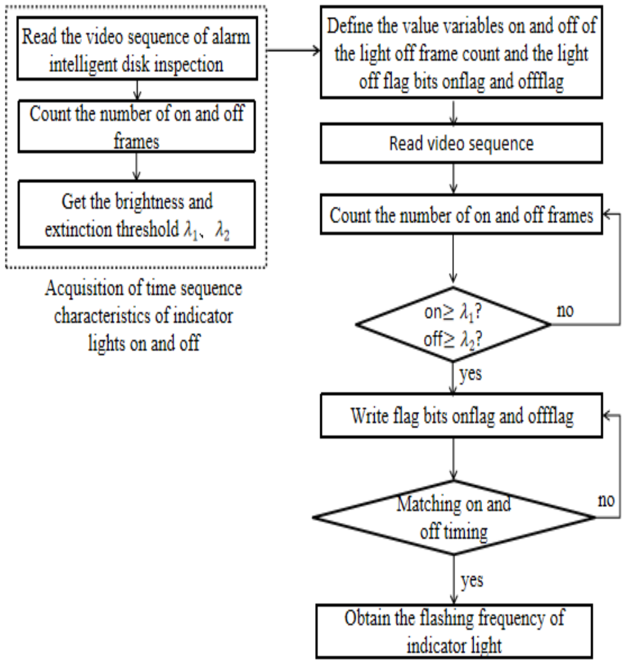
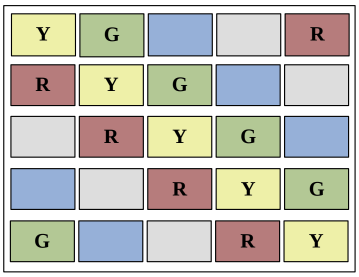


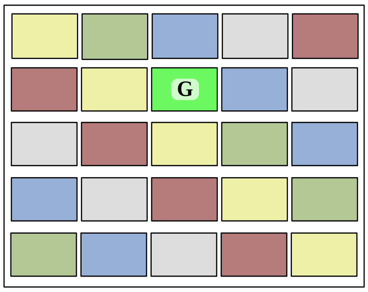
Figure 5: Flow chart of indicator flashing frequency detection

6. Experiment and Result Analysis

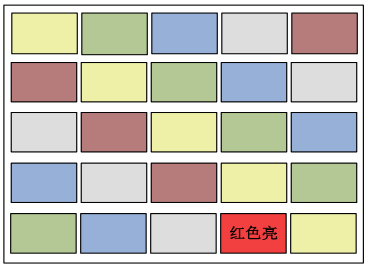
For the monitoring of the intelligent patrol panel of the panel cabinet in the main control room of the substation, a simulation experiment platform is built in this paper, which includes five colors of equipment indicator lights, which can be controlled by the switch to turn on and off the red, yellow and green indicator lights, as shown in Figure 6.



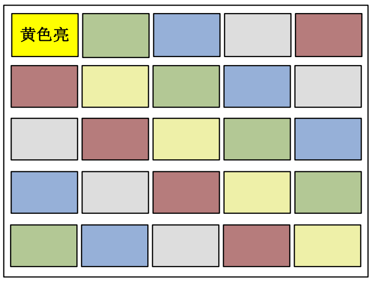
(a) Analog intelligent alarm patrol platform



(b) The green indicator light is on



(c) The red indicator light is on



(d) The yellow indicator light is on

Figure 6: Analog intelligent alarm patrol platform

6.1 Extraction of Color Features of Equipment Indicator Lights

The fault equipment indicator image obtained by the camera is a dynamic change process, and factors such as ambient light will affect the obtained indicator color image. Therefore, it is necessary to fully consider and collect the image of a single device indicator in various cases to obtain the accurate threshold range of each color indicator.

In this paper, 185 three color indicator images are collected, and the distribution threshold range of red, yellow and green indicator lights in the on and off state in the three-dimensional HSV color space is obtained experimentally, as shown in Figure 7.

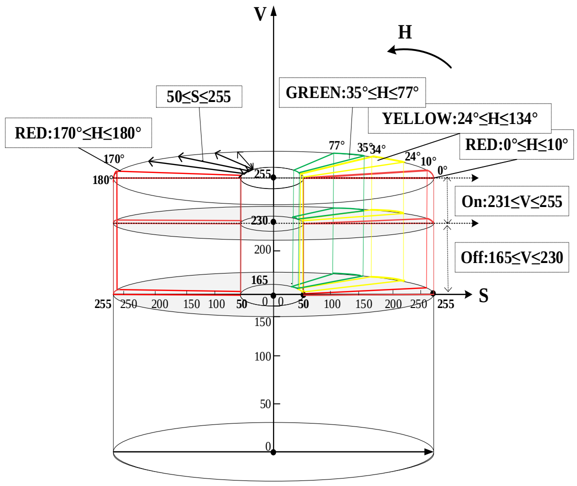


Figure 7: Status distribution of indicator lights in HSV color space

It can be seen from Figure 7 that the ranges of H, S and V values are [0, 180), [0, 255), [0, 255), in which the H component can distinguish three colors of red, yellow and green, and the V component can distinguish the on-off state of the indicator lamp. The specific color and on-off state threshold range are shown in Table 2.

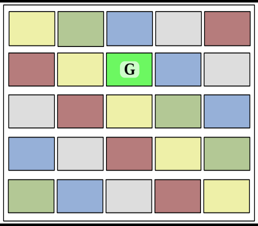
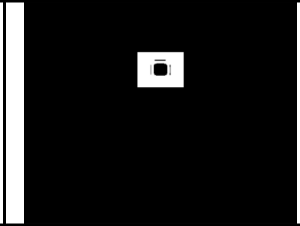
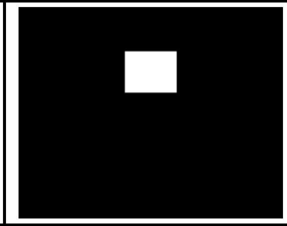
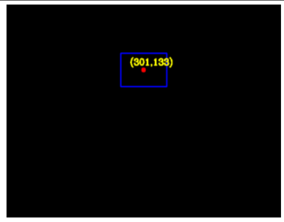
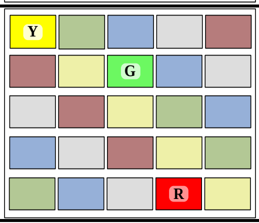
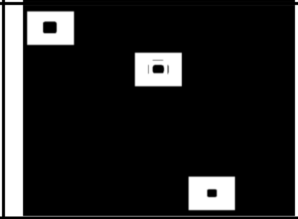
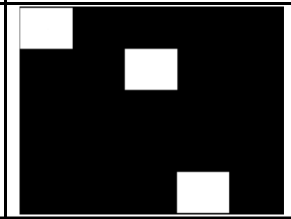
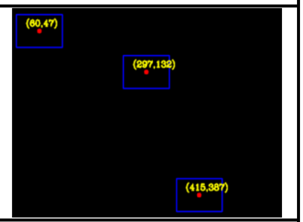
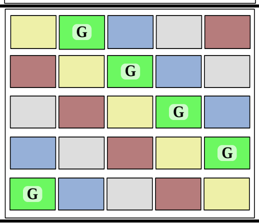
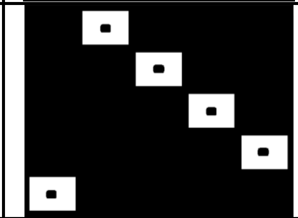
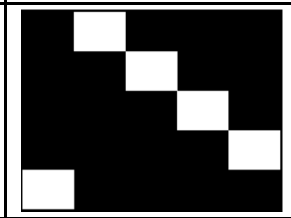
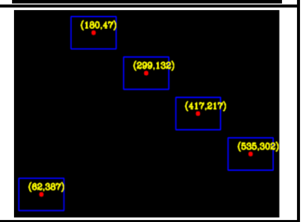
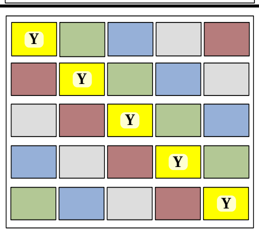
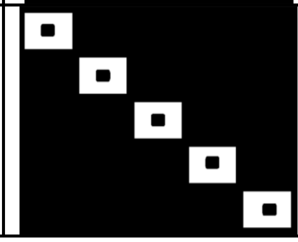
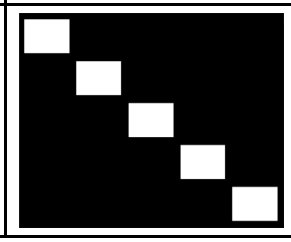
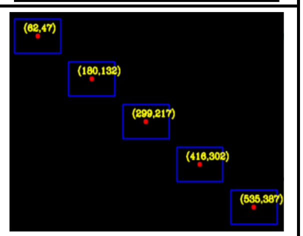
Table 2: On and off threshold of each color indicator

H/S/V	Yellow	Green	Red
H	$24 \le H \le 34$	$35 \le H \le 77$	$0 \le H \le 10$ $170 \le H \le 180$
S	$50 \le S \le 255$	$50 \le S \le 255$	$50 \le S \le 255$
V	$165 \le V_{off} \le 230$ $231 \le V_{on} \le 255$	$165 \le V_{off} \le 230$ $231 \le V_{on} \le 255$	$165 \le V_{off} \le 230$ $231 \le V_{on} \le 255$

6.2 Extraction of Regional Features of Equipment Indicator Lights

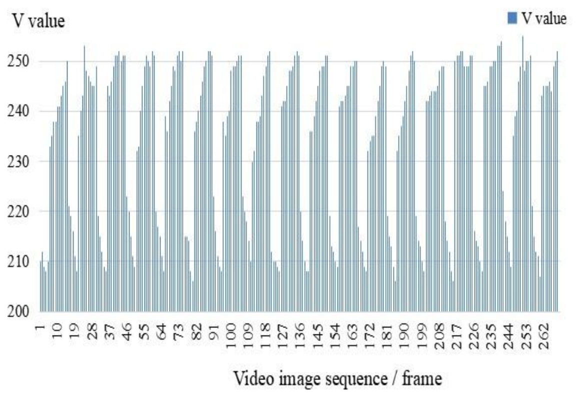
In this paper, several possible indicator lights on and off are tested, including the identification of single and multiple indicator lights on at the same time; For the lighting status of multiple indicators, including the same color and different color indicators lighting at the same time. The method in this paper is used to extract the regional features, and finally each indicator can be distinguished by the position coordinates of the centroid. The position of the centroid coordinates of each indicator area can represent an equipment fault type, and finally identify and locate the equipment fault type. The experimental results are shown in Table 3.

Table 3: Results of indicator recognition under various conditions

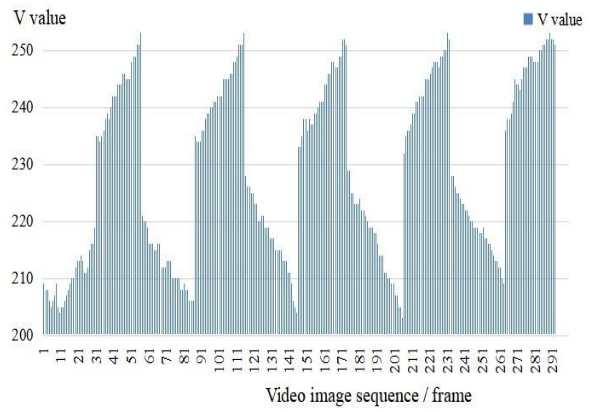
State	Original Image	Image after Threshold Segmentation	Image after Morphological Operation	Centroid Coordinates of Target Area
Single Indicator Light				
Different Color Indicator Light				
Discontinuous Position and Same Colored Indicator Light				
Continuity Location and Identical Colored Indicator Light				

6.3 Acquisition of Timing Characteristics of Equipment Indicator Light On and Off

According to the method of extracting the on-off timing characteristics of the equipment indicator, this paper simulates the equipment indicator flashing at the frequency of 2Hz and 0.5Hz in the video with the frame rate of 30fps, and obtains the on-off timing characteristics of the indicator through experiments. The experimental results are shown in Figure 8.



(a) 2Hz flashing indicator



(b) 0.5Hz flashing indicator

Figure 8: Time sequence characteristics of indicator light on and off

According to Figure 8(a), the on-off timing characteristics of the indicator flashing at the frequency of 2Hz can be obtained. The indicator is continuously off for about 5 frames and continuously on for about 10 frames, which is a flicker visible to the human eye. According to Figure 8(b), the on-off timing characteristics of the indicator flashing at the frequency of 0.5Hz can be obtained. The indicator is continuously off for about 30 frames and continuously on for about 30 frames, which is a flicker visible to the human eye, According to this feature, the threshold and for detecting the flashing frequency of the indicator light in the video image are set.

In this paper, through the experiment on the video of red, yellow and green indicator lights changing three flashing frequencies at 0.5Hz, 2Hz and 0.5-2hz, it is set according to the obtained threshold. When the threshold is reached, the flag bit is written and the on-off timing is matched to determine the flashing frequency of the indicator light. The final experimental results are shown in Table 4, For the detection of 0.5Hz and 2Hz fixed frequency flashing indicator lights, the detection accuracy is higher than 85%. For the detection of 0.5-2hz frequency changing indicator lights, errors will occur due to the uncertainty of the frequency at the transformation time, so the accuracy is slightly lower. Experiments show that this method can realize the detection of fault equipment indicator lights flashing at different frequencies in video images. However, due to the simulation of flashing indicator lights at different frequencies and the collection of videos under various conditions, color errors will be generated due to the influence of environmental factors, which will affect the detection results of flashing frequency.

Table 4: Test results of video set collected in this paper

Sample frequency / Hz (/ sheet)	Number of test results / sheet RED YELLOW GREEN	Detection accuracy /%
0.5(45)	12 14 13	86.7
2(50)	14 18 14	92.0
0.5-2(55)	12 16 17	81.8

7. Conclusion

In view of the problems that the traditional substation does not realize the automation system, there will be potential personal safety hazards due to the untimely dispatching work, and the safe operation of the equipment cannot be guaranteed, this paper extracts the color features, regional features and on-off timing features of the equipment indicators based on the multi feature identification, positioning and state diagnosis method of the panel and cabinet indicators. The main conclusions are as follows.

1) A large number of single indicator images are collected and color features are extracted to obtain the threshold range of green, red and yellow indicators and the two conditions of on and off are divided, which effectively reduces the interference of environment and other factors.

2) Aiming at the situation that multiple indicator lights with the same or different colors alarm at the same time, the regional characteristics of the indicator lights are extracted to distinguish and locate multiple equipment indicator lights, so as to realize the identification of equipment fault types.

3) For the detection of dynamic flashing indicator light, this paper proposes a method to obtain the timing characteristics of indicator light on and off. Through experiments, the flashing indicators of fault equipment with different frequencies are detected in video images, which prove the feasibility of detecting the flashing frequency of indicator light. This method is used as the basis to judge the emergency degree of equipment fault.

The method in this paper not only provides a reference for the identification and positioning of the indicator light in the main control room, but also provides a technical scheme for diagnosing the emergency degree of equipment fault through the flashing frequency of the indicator light, which has a certain practical application value.

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