Acta Technica 61, No. 4A/2016, 161–168

Key technology simulation of equipment anomaly detection based on image processing

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Abstract. With the deepening of automation of electric network management in our country, more and more substations are equipped with video monitoring system and various alarm systems to realize unattended operation. Therefore, the equipment images collected by the monitoring system are processed, and the equipment anomaly is fast and accurately detected by the monitoring images for early warning of potential hazards, which has an important practical value to the safe operation of the power system. The related algorithms of the image processing are applied to the substation electrical equipment image to analyze and study the characteristics of images when the electrical equipment is abnormal and the related detection techniques and methods. At the same time, a detection method of the power transformer oil leakage is proposed. We first use the difference method on the sample images and monitoring images to get the abnormal region, and the noise of it will be eliminated and it will be segmented. Then the H-S color histogram of the abnormal region corresponding to the sample image and the monitoring image is extracted. The oil leakage condition is detected by observing the change of the gray-brown part of the H-S color histogram. Through experiments, we find that this method can more accurately detect the oil leakage anomalies of the transformer.

Key words. Image processing, equipment anomaly, color histogram.

1. Introduction

The unattended operation of substation has become the trend of power system development, and the electric power departments around the country have basically realized the functions of "four remote" (remoter metering, remote signaling, remote control and remote regulation). However, for the status of fire, the state of the disconnecting link, the oil leakage of the transformer and other equipment anomaly, the monitoring of abnormal conditions is "four remote" cannot be achieved, therefore, remote sensing system will emerge as the times require, it is necessary supplement

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for the unattended substation. Due to the complexity and technical limitations of the equipment anomaly detection process, traditional algorithms are often used to detect the abnormalities of equipment, which often require a lot of manpower and financial costs, and the collected image of the abnormal parts cannot be identified, which cannot ensure the reliability of the results, and then a satisfactory test results cannot be obtained.

Based on image processing, we present an equipment anomaly detection method. The H-S color histogram is extracted by denoising and segmenting the abnormal region of the sample image and the monitoring image. It is found that this method can detect the oil leakage abnormality of the transformer more accurately and realize the effective anomaly detection of the transformer equipment to ensure the accuracy of the detection and meet the actual demand of the equipment anomaly detection automation.

2. Summary

The application of image processing in the monitoring system is also called intelligent video surveillance. It uses image processing, computer vision and pattern recognition, etc., in the case of almost no human intervention, to analyze the image sequence by using the correlation method of the moving target detection in image processing technology to extract the moving target, and then analyzes and predicts to the behavior of the moving target in the images on the basis of following and recognition [1]. Compared with the traditional monitoring system, the main advantage of intelligent video surveillance system is lies in its "intelligence", simply, the intelligent video surveillance system instead of the human eye in a sense. The computer can help to complete a series of tasks through the analysis and judgment of the collected images sequence to greatly reduce the burden on people, and improve the recognition efficiency [2].

With the widely using of video technology and infrared imaging technology in this area, the image processing technology in power system applications become increasingly widespread. For the substation, the main content of video surveillance includes the detection of moving objects, on-site smoke, flames, water, gas and other unusual circumstances. In some research abroad proposed that two matching algorithms are used to identify the casing of the power transformer, and the correlation between the template image and the image to be matched is calculated to determine the matching. In order to improve the speed of matching, two matching strategies are proposed: one is rough, and the other is exact match, but this algorithm has some limitations, the matching image and template image must be the same size and the same direction, and it will fail when the image is zoomed or there is jitter or rotation in the camera acquisition.

With the higher degree of the scale and automation of modern industrial production, the requirements of equipment anomaly detection technology are ever higher. In the production process, the equipment failure will cause unpredictable hazards, thereby affecting production efficiency. Therefore, in-depth exploration of equipment anomaly detection has become a hot research topic in this field [3]. At present, the traditional method of equipment anomaly detection mainly includes optimization method based on machine learning [4]. Because the effectively improvement of the key technology of the equipment anomaly detection system can improve the detection rate of the equipment, reduce the detection time-consuming and avoid the harm caused by the fault to the production. Therefore, it has been paid close attention by relevant experts and scholars, and has very broad development potential [5].

3. Methods

In the unattended substation, power transformers as a common and major equipment, its operating conditions must be monitored timely. When abnormal conditions happen, the corresponding alarm should be given. The accuracy of the method that detect the transformer will have abnormal conditions by detecting the composition of the gas should be improved. When the gas composition changes, it does not necessarily indicate the occurrence of oil spills; and the method of detecting oil droplets in the water method is not applicable to the detection of oil leakage of power transformer. Taking into account the color of the power transformer oil is generally taupe, you can observe the abnormal characteristics of the oil leakage from the perspective of the image, and the abnormal area of the gray level will appear in the surface of the transformer compared with the normal condition, and the color of the abnormal area is taupe, and the shape of the abnormal region is different with the different parts of the oil spill. So the abnormal of the transformer only can be detected by extracting the color characteristics of abnormal areas. Based on this idea, a color histogram-based transformer oil leakage detection method is proposed. Firstly, the abnormal region is detected, and the abnormal region is denoised. Then, the color histogram of the abnormal region of two images is compared. When the taupe part has large changes, the transformer has oil spill.

RGB color space is a cube, and the origin corresponds to black, the vertex farthest away from the origin corresponds to the white. In this model, the gray-scale values from black to white are distributed over the line connecting the origin to the vertices furthest from the origin. The rest of the points in the cube correspond to different colors, and can be represented by vectors from the origin to the point. So each color can be represented by a point in colorized cube in RGB space.

HSV color space is a color space based on human visual characteristics. Parameter H represents color information, that is, the location of the spectral color, the parameter is expressed as an angle, red, green and blue are separated by 1200, the difference of the complementary colors respectively is 1800. Purity S is a proportional value, ranging from 0 to 1, and it represent the ratio between the purity of the selected color and the maximum purity of the color, when $S = 0$, there is only gray. Symbol V represents the bright degree of the colors, ranging from 0 to 1. It is not directly related to light intensity. Unlike the RGB color space, the coordinate system of the HSV color space is a cylindrical coordinate system, but is generally represented by a hexcone. HSV color model is a uniform color space, using a linear scale, and the distance of the color perception is proportion to the Euclidean distance of HSV color model coordinates. The R, G and B values (in the interval

[0,255]) at any point in the RGB space can be converted to the HSV space to obtain the corresponding values of H, S and V, and the conversion formula is as follows:

$$H = \left\{ \begin{array}{l} \arccos\left\{\frac{(R-G)+(R+B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}}\right\} B \leq G \\ 2\pi - \arccos\left\{\frac{(R-G)+(R+B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}}\right\} BG \end{array} \right\}, \tag{1}$$

$$S = \frac{\max(R,G,B) - \min(R,G,B)}{\max(R,G,B)}\,, \tag{2}$$

$$V = \frac{\max(R,G,B)}{255}\,. \tag{3}$$

The global summed histogram is based on the color value as the abscissa and the frequency of the color accumulation as the ordinate. Therefore, the accumulated histogram H of the image is defined as:

$$\overline{H} = \left\{\overline{h}[c_1], \overline{h}[c_k], \ldots, \overline{h}[c_k] \mid 0 \leq \overline{h}[c_{\mathrm{k}}] \leq 1\right\}\,. \tag{4}$$

where $\overline{h}[c_k] = \sum_{c_i \leq c_k} h(c_i)$ represents the cumulative frequency of pixels in c_i to c_k colors, and n denotes the number of quantized colors. In the global cumulative histogram, the adjacent colors are relevant on the frequency.

In the process of converting the RGB color space to the HSV color space, H, S, and V are usually quantized with non-equally spaced, and the hue H, saturation S, and luminance V are divided into eight, three and three, respectively. In the later experiment, we find that the effect of quantization detection is not very good. So, we divide the H space quantization into 16 parts, the saturation S is divided into 4 parts, and the brightness V is divided into 4 parts. Since the hue and color saturation components are closely connected to the way the human perceives the color, only the intuitive color needs to be considered here, the luminance information is temporarily ignored, and only the H component and the S component are taken into account. Since the H component has 16 equal parts, and the S component has 4 equal parts, so the combination of them is 64 kinds. The characteristics of its color is summed up and converted to the RGB model and observed with the naked eye, we can find that the color of the brown part of the color is in the seventh group, but in fact, because the degree of oil spill is different, the color will appear a certain deviation, so the scope of consideration is extended, and the gray-brown of the 7–14 groups is similar, their information are also considered and tested. So the follow-up detection can detect the color histogram information changes of 7–14 groups to determine the oil leakage anomalies of the transformer. Figure 1 is flow chart of the transformer oil leakage detection based on the color histogram.

The specific algorithm is as follows:

1. The sample image and the monitoring image are grayed separately to obtain the difference image.

2. Abnormal areas will be detected and the small particles noise is removed by

morphological open operation.

3. The sample image and the monitoring image will be converted into the HSV space, and the H-S color histogram of each abnormal area detected by (2) will be done.

4. The change of the number of the pixels in the 7–14 groups which belongs to taupe in the HS color histogram is determined. When the difference value of the data of the monitoring image and the sample image will be a certain value (it is 75 in this paper), it can be considered as abnormal oil leakage anomalies in abnormal area.

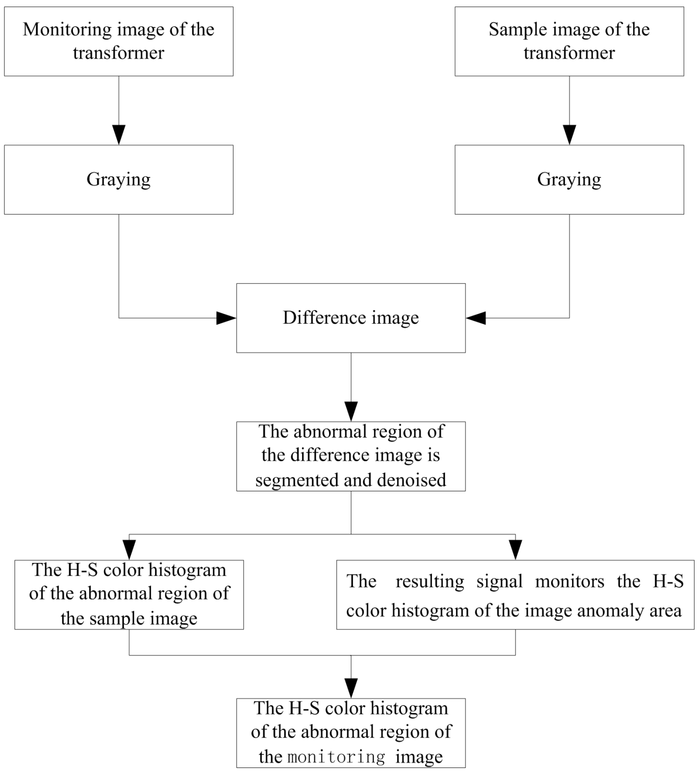

Fig. 1. Transformer oil leakage detection flow chart

4. Results

Three groups of 420×420 pixels of the picture are used to simulate in MATLAB 8.5 environment to verify the effectiveness and correctness of the algorithm, in which the oil pillow part of the transformer occurred abnormal oil leakage in pictures of two

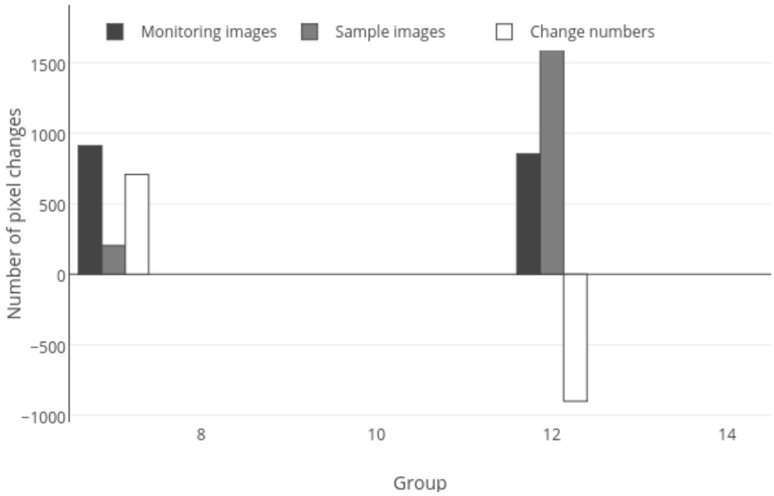

Fig. 2. Number of pixel changes in 7–14 group

groups. The detection results of oil leakage occurred in the transformer oil pillow part are as follows

From Fig. 2, we can see that the pixels of HS color histogram of the 7th and 12th group change greatly. As the specific situation of transformer oil leakage is uncertain, so the group where the taupe of the HS color histogram is located should be expanded. The color of the group 7 in Table 1 is similar to the color of the oil leakage zone. There are negatives in 12th groups, and the reason for this is that the data of the color in the 12th group in the sample image are more, and the color of the 7th group in the monitoring image after the oil leakage covers it.

Table 1. The number of pixels in groups 7 to 14

Group	Monitoring images	Sample images	Change numbers
7	912	204	708
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	853	1754	-901
13	0	0	0
14	0	0	0

5. Discussion

From the above experimental results, we can see that this method can detect the transformer oil leakage anomalies more accurately. From Table 1, we can find that the number of pixel changes have negative in the color group where the brown color is located. This is because the colors before and after the oil spill are likely to be close to each other. A certain group or several groups of pixels will inevitably cause reduction of pixels of other groups. Only the change of the group whose number of pixels is positive is detected here, and the detection result is not affected.

The disadvantage of this method is that when the detection interval is too long, the detection image relative to the rust of the sample image transformer part may fail, and the corresponding alarm is given here when the processing results of the transformer monitoring image of the unattended substation meet the above conditions. The staff needs to do further determine for this anomaly and the extent of the oil leakage.

6. Conclusion

We firstly denoise and segment the sample image and the monitoring image. The original image is transformed from the RGB space to the HSV space based on the visual feature, and then the corresponding HS color histogram of the anomaly area of the sample image and the monitoring image is extracted. The oil leakage abnormality of the transformer is detected by observing the change of the gray-brown part of the HS color histogram. It is found through the experiment that this method can detect the oil leakage abnormality of the transformer more accurately. We proposed a new HS color histogram-based anomaly detection method for oil leakage in power transformers. It is found that this method can detect the abnormal oil leakage of transformer effectively and realize the effective anomaly detection of transformer equipment to ensure the accuracy of detection. At the same time, it meets the actual needs of equipment anomaly detection automation.

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Received November 16, 2016