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State Recognition of High Voltage Isolation Switch Based on Background Difference and Iterative Search

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Abstract. The automatic recognition of the high voltage isolation switch by remote video monitoring is an effective means to ensure the safety of the personnel and the equipment. The existing methods mainly include two ways: improving monitoring accuracy and adopting target detection technology through equipment transformation. Such a method is often applied to specific scenarios, with limited application scope and high cost. To solve this problem, a high voltage isolation switch state recognition method based on background difference and iterative search is proposed in this paper. The initial position of the switch is detected in real time through the background difference method. When the switch starts to open and close, the target tracking algorithm is used to track the motion trajectory of the switch. The opening and closing state of the switch is determined according to the angle variation of the switch tracking point and the center line. The effectiveness of the method is verified by experiments on different switched video frames of switching states. Compared with the traditional methods, this method is more robust and effective.

1. Introduction

The high-voltage isolating switch is mainly used for closing and breaking of high voltage lines, playing the role of isolation voltage and ensuring the safety of high-voltage electrical appliances ,devices and safety of maintenance staff during maintenance.As shown in Fig.1.

In the maintenance of high voltage line, it is necessary to make sure the switch is in the state of breaking to ensure the safety of high-voltage electrical appliances ,devices and maintenance staff during maintenance. Although the turn rod of the switch arm has the auxiliary switch positioning function, the positioning function will run into greater deviations when the machine starts to wear out. The line maintainer has to go to the switch site and confirm the status of the switch personally due to the demand of remote monitoring methods, which brings in the big waste of human resources and low efficiency in maintenance.

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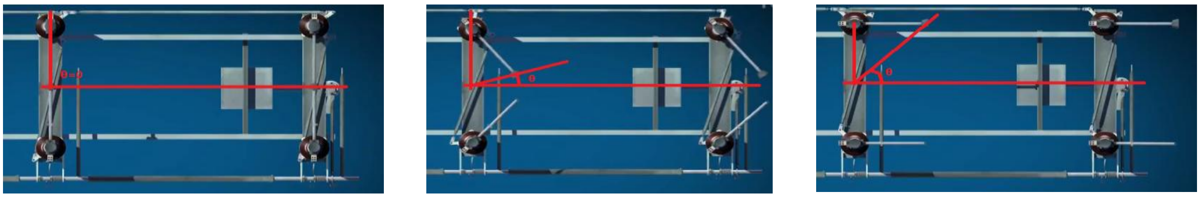

(a)Switch close (b)Switch half open (c)Switch full open

Figure 1. High voltage switch working procedure

2. Previous work

At present, there are several prominent ways to monitor the high voltage power equipment in China.

One is based on target detection technology with Hof forest algorithm [1] and modeling the status information of switch. Such a technology scheme often has large amount of calculations, and it is difficult to capture the switch state in real time, and is compromising to environmental impact. The other is using edge detection algorithm [2] to detect and identify switch state. The drawback is that the image processing ability of low contrast is poor, and the dependence on edge direction is larger. The edge image will be fuzzy. Modal analysis method [3] to realize switch state identification such as the use of others, through the vibration signal, the temperature signal acquisition switch, image and other information to reflect the switch state, this method also has high cost because of involving many devices,difficult to widely apply and need to regularly check to ensure the adjustment the smooth operation of the equipment.

Therefore the existing methods generally have the problems of high cost, low robustness and insufficient application breadth.To solve this problems, this paper proposes a differential and iterative search based on the background of the state recognition method of high voltage isolation switch in substation, using the background subtraction method for fast positioning switch, and then through the iterative search algorithm adaptive tracking trajectory acquisition switch.Then the state of switch position and trajectory determination of isolation switch points. The overall flow of the algorithm is shown in Fig.2.

The algorithm includes two parts: switch detection and trajectory tracking. The switch detection section detects the motion of the switch in real time by the background difference method, and marks the initial position of the switch. Thereafter the initial position of the switch is input to the switch tracking model, then the trajectory of the switch is captured. After the trajectory is used to calculate the angle between the tracking point and the center line, so as to judge the state of the switch.

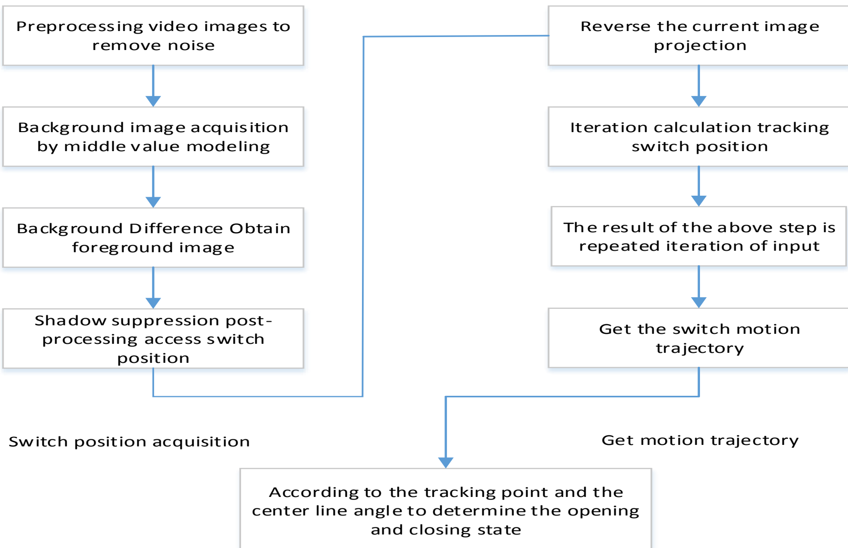

Figure 2. Algorithm flowchart.

3. Method

The method is arranged as follows: the first section introduces the detection algorithm of the switch, the second section introduces the algorithm of switch motion trajectory tracking. Finally, in the third quarter, we enclose the experimental results and analysis.

3.1. switch detection

First, it is necessary to detect the initial position of the switch by using the target detection technique. Belong to the static background motion detection on detection of high-voltage isolation switch, switch the rotarymotion regularly, at present commonly used target detection technology with frame difference method, optical flow method and generalized method of moments[4-7], the background difference method is to detect the initial position of switch. The background difference method is mainly divided into several parts, image preprocessing part,background modelling part, background subtraction part, and post-processing part.

First, the first few frames of the video are obtained, and filtering out the possible noise in the image by the preprocessing method in the acquired images. After that, the processed frames are arranged from small to large according to the gray values of the corresponding pixels in the positions of frames, and then the median value is taken as the gray value of the corresponding pixel points in the background image, which completes the background modeling and determines the background image.

Let the current frame P_t and the background frame F_t respectively,K is the foreground grayscale threshold, subtract the current frame from the background frame, and determine the absolute value. If the absolute value is greater than K, the point is the foreground point , further to get the foreground image.

$$|P_t(x, y) - F_t(x, y)| > K \tag{1}$$

The foreground image is post-processed by the shadow control strategy using the YUV color space to eliminate the shadow problem in the image and obtain the position of the switch.

$$N_{x,y} = \begin{cases} 1, & D(Y) > K_Y \\ 1, & D(U) + D(V) > K_{UV} \\ 0, & \text{others} \end{cases} \tag{2}$$

When the value of $N_{x,y}$ is 1, we can consider the pixel belongs to the foreground. When the value of $N_{x,y}$ is 0, we can regard it as the background area. The difference between the target pixel and the background pixel is defined as D(Y), and the two chrominance differences between the current pixel and the background pixel are defined as D(U) and D(V), respectively. The brightness difference threshold is K_Y, and the threshold of chroma detection is K_{UV}.

We take the following strategy:

1) When the set threshold intensity is less than the brightness difference between pixels, the pixel belongs to the foreground area.

2) Since the difference between the background and the shaded area is very small, we define it as follows: if the color difference is larger than the set threshold, the pixel belongs to the foreground area.

3) The above two cases do not belong to determine the background pixels.

Through such a processing step, the location of the isolator is detected, and the location of the switch is marked with the box. If the overlap area of the box and the first frame of the frame is below a threshold, it is judged that the switch is in motion state and the tracking algorithm is enabled.

3.2. switch track tracking

The object trajectory tracking, the existing methods mainly include similarity measurement and search algorithms of two kinds of algorithm, accuracy and robustness of the tracking algorithm largely depends on the expression of the moving target and the definition of similarity measures, depending on the real-time tracking algorithm in matching search strategy and filtering algorithm [8-10]. In this paper, we track the switch by using searching algorithm. We estimate the position and position of future switches by using searching algorithm, and then determine whether the predicted position is a switch.

Firstly, the target image is converted from RGB color space to HSV color space by using color histogram model, the H component of histogram represents the probability of different H component value in color probability table, and then the each pixel values in the image are replaced by the probability of its color, the probability distribution of grayscale is color.

Then the iterative optimization of the image is used to find the extreme point of probability distribution to locate the target. The specific process can be expressed as:

1) The search window W is determined from the distribution of chromaticity probabilities

2) Get the value of zero matrix

$$N_{00}=\sum_x\sum_y P(x,y)$$

calculate the first moment

$$N_{10}=\sum_x\sum_y xP(x,y)\,,N_{01}=\sum_x\sum_y yP(x,y)$$

Measure the search box center point information

$$X_c=\frac{N_{10}}{N_{00}},Y_c=\frac{N_{01}}{N_{00}}$$

3)Adjust the search box width

width is: $\mathrm{d}=\sqrt{N_{00}/256}$, length is:l=1s

4) When the operation length value of this step is greater than the set value, the above three steps are repeated to reduce the operating distance at which the center of mass coincides with the center of the search window W until less than the set value so far.

The above operations are extended to continuous image sequences.First, it uses the size and center of the search window and the information of the previous frame as the starting value of the search window of the next frame, and then iterates the operation again.Through such an iterative search process, the motion trajectory of the switch is obtained, and the state of the switch is judged according to the motion trajectory of the switch. In actual operation, Considering the camera is fixed right below the switch and located in the middle of the two switch arms, we treat the central line as the reference line, marked by the red line as shown in Figure 1. Through tracking the tracking points in real-time marked at switch arms edge , the angle θ in between switch arms edge and then center line can be determine as shown in Figure 1,then states of the high-voltage isolation switch can be determined through the following rules:

(1) The isolation switch is in open state: $\theta<\theta_0$;

(2) The isolation switch is in close state: $\theta>\theta_1$;

(3) The isolation switch is in the form of open to closing: $\theta_t<\theta_{t+\Delta t}$;

(4) The isolation switch is in the form of close to opening: $\theta_t>\theta_{t+\Delta t}$;

Among them, θ_0 andθ_1 are the thresholds for judging the open and closed states, respectively. θ_t and$\theta_{t+\Delta t}$ are the angle of the tracking point and the switch between the center point and the center line in the video frames of t and t+Δt moments, respectively.

4. Experimental verification and result analysis

4.1. experimental data acquisition

In order to verify the effectiveness of the proposed algorithm, the video of the high voltage isolation switch in several different states is collected, and the data is as follows:

Table 1. Data statistics table.

Video sequence number	Resolution	Number of frames	state
1	1920*1080	412	From close to open
2	1920*1080	560	From open to close
3	1920*1080	1240	Close and then open
4	1920*1080	1225	open and then close

4.2. analysis of experimental results

In order to quantitatively analyze the tracking results, we select two switches as the centerline, take the vertex of one switch as the tracking point, and track the distance between the tracking point and the reference line in real time, as shown in Fig.3. When the angle changes more than 5 angle, it can be considered that the switch begins to open, and when the angle changes more than 40 angle, it is considered that the switch is in a state of thorough opening. Fig.4 shows during the switch operate closing to open and closing, The angle change between the switch tracking point and the reference center line is determined Obviously, it can be seen that the angle appears from the small to the smaller. This process coincides with the switch from closing to open, and then from opening to closing. By comparing the 5 and 40 angles of the two angles, the state and process of the switch can be obtained.

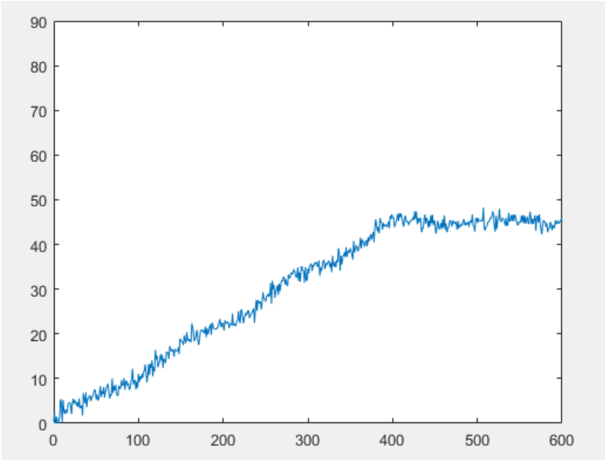

Figure 3. Switch from combined to sub-cases, the tracking point to the center line distance.

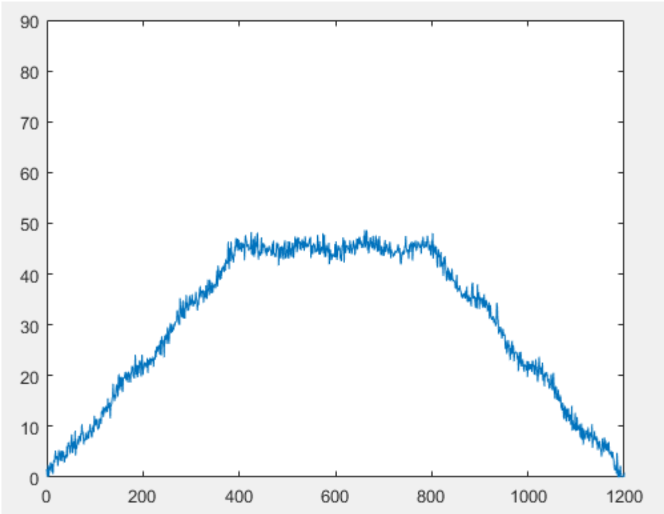

Figure 4. Switch from combined to points, and then to the case, the angle changes between the tracking point and center line.

5. Conclusion

In this paper, we proposed algorithm is based on background difference and iterative search to identify the state recognition of high voltage isolation switches. The algorithm consists of two parts: switch detection and switch track tracking. The switch position is identified by the background difference technique, and the path of the switch is traced by iterative search when the switch is moving. The angle change between the switch tracking point and the reference center line is determined according to the motion trajectory. The experiments show that the method is robust ,effective and with out delay, it can be widely used in various actual situations.

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