Deduction of Artificial Intelligence Calculation Theory in Electrical Engineering Automation

Bin Meng a, *, Xinyang Ji b, Gaoshan Hu c
Shenyang Urban Construction University, Shenyang, 110167, China

a, *Corresponding author e-mail: mengbin@syucu.edu.cn, b jixinyang@syucu.edu.cn, c hugaoshan@syucu.edu.cn

Abstract. In order to overcome the shortcomings of manual on-site confirmation of switch position status in smart substations, realize automatic identification of circuit breaker and isolating switch positions, and improve the remote monitoring capability of switchgear in substations, the paper designs and studies a set of remote substations based on bilateral filtering dissipation algorithm Switch equipment state image recognition system. The system takes SIFT, image gravy method, binary method, Hough transform and other theoretical algorithms as the core, and uses high-speed DSP chip as the platform to divide and combine the switch images collected by the CCD camera. Status identification, and then upload the monitoring picture to the remote monitoring room via Ethernet. Invested in experimental research and found that the identification system is accurate and fast to distinguish the switch status, which can greatly improve the safety and efficiency of switchgear monitoring, and has a high promotion value.

Key words. Electrical engineering, automation, isolation switch equipment, remote monitoring, bilateral filtering algorithm, image grayscale.

1. Introduction
In the substation, if the operating state of the electrical equipment or the operating mode of the power system changes, a series of switching operations on the electrical equipment are required. Switch the electrical equipment from one state to another state by operating the isolating switch, circuit breaker, and hooking up and disconnecting the grounding wire, or change the operation mode of the system. In the traditional substation, in order to prevent the switch from malfunctioning or inadequate, it is necessary for the operator to stand next to the switch and perform a visual inspection; once a problem with the switch is found, use the walkie-talkie or quickly run to the operation the room notified the operator and immediately implemented a series of emergency measures to prevent the danger from expanding [1]. In order to ensure the smooth progress of the switching operation, it is also necessary for the operator to visually observe the switch to ensure that the switch action is in place before taking the next step. In this way, the labour consumption is relatively large, and there are also potential safety hazards.

Based on this, this paper proposes an image recognition algorithm that uses image processing and pattern recognition technology to realize the automatic recognition function of the position and state of
the substation circuit breaker and isolating switch [2]. This method can replace the operator to realize the identification and verification of the position status of the equipment during the switching operation, and realize the standard modelling of the identification information based on the IEC61850 standard and the seamless communication connection with the monitoring background switching operation module, which greatly reduces the labour intensity of the operating personnel, shortens the operating time, and eliminates the influence of subjective factors of the on-site personnel, and truly realizes the "one-button" sequence control of the substation switching operation, which is unattended for the substation and automatic operation management. The model provides technical premises.

2. Isolation switch imaging model and its characteristics
In computer vision and graphics, the basic model describing switch imaging is:

\[ L(x, y) = L_0(x, y)e^{-\beta(x,y)} + A(1 - e^{-\beta(x,y)}) \]  \hspace{1cm} (1)

In the formula, \( L(x, y) \) is the observed switch image, that is, the input image; \( L_0(x, y) \) is the light intensity of the scene, which is the restored image, also known as the scene albedo; \( \beta \) is the atmospheric scattering coefficient, \( d(x,y) \) is the scene depth, and \( e^{-\beta(x,y)} \) is the transmittance distribution; \( L \) is the atmosphere. The intensity of light radiation is generally assumed to be a global constant. From equation (1), it can be seen that the imaging model of the isolation switch is composed of \( L_0(x, y)e^{-\beta(x,y)} \) and \( A(1 - e^{-\beta(x,y)}) \). The first term represents direct attenuation. Due to the scattering of medium particles in the atmosphere, the reflected light of some objects is lost due to scattering, and the unshattered part directly reaches the intensity of the imaging sensor; the second term is the ambient light model, reflecting the global atmospheric light intensity. Scattering causes the color of the scene to shift. Rewrite the other party's program (1) to obtain another equivalent form:

\[ L(x, y) = L_0(x, y)(1 - \frac{V(x,y)}{A}) + V(x, y) \]  \hspace{1cm} (2)

In the formula, \( V(x,y) \) is used to denote the natural environment of the switch, that is, \( V(x,y) = A(1 - e^{-\beta(x,y)}) \). Therefore, \( L_0(x, y) \) can be obtained only by estimating \( V(x,y) \) and \( A \), and an image without fog under ideal conditions can be obtained.

3. Switch image restoration algorithm

3.1. The physical constraints of switching on and off the natural environment
Objects in nature have the characteristics of reflection and absorption of light, and the colour of the image of an object is formed by reflecting light of some frequencies in white light and absorbing light of specific frequencies [3]. Under atmospheric transformation, the colour of an object is generated due to the reflection and absorption characteristics of the three colour components of light. For a colour-rich object or a single grey-white object, at least one of the colour components has a low reflection coefficient and an intensity value. Therefore, for the switch image \( L(x, y) \), the switch natural environment \( V(x,y) \) should meet the constraints of physical characteristics:

\[ 0 \leq V(x,y) \leq W(x,y) \]  \hspace{1cm} (3)

In the formula, \( W(x,y) = \min_{c \in \{R,G,B\}} L(x,y) \), for colour images, \( W \) represents the minimum of the three colour channels in \( L \), and for grayscale images, there is \( D \). This is basically consistent with the viewpoint of the literature [3], that is, the value of each pixel of the switch natural environment should be between 0 and the minimum channel value of the original image.
3.2. Switching the generation of the natural environment

Bilateral filtering is a non-linear smoothing filtering method that preserves edges. Its weight is given by the product of the smoothing function of spatial domain $S$ and value domain $R$. The weight value of each pixel in the filter window and the distance of the pixel from the centre of the window and the grayscale level difference between the two is related. In this paper, the bilateral filter whose spatial domain and amplitude domain are both Gaussian functions is expressed as follows:

$$BF(I)_{x,y} = \sum_{q \in S} G_{\sigma_s}(p-q) G_{\sigma_r}(|I_p - I_q|)$$

(4)

In the formula, $G_{\sigma_s}$ and $G_{\sigma_r}$ are the kernel functions with $\sigma_s$, $\sigma_r$ as the parameter in the spatial domain and the amplitude domain, respectively. $S$ represents the neighbourhood with $p$ as the centre point, and $I_p$ and $I_q$ represent the grey values corresponding to the pixel points $p$ and $q$. It can be seen from the filtering method considerations both the similarity relationship of amplitude and the neighboring relationship in space. For pixels with small amplitude difference and close to the centre point pixel, the weight given by bilateral filtering is greater; while for the amplitude difference Larger pixels with similar distances are given smaller weights [4]. Therefore, the bilateral filter can effectively maintain the edge information of the image, thereby suppressing the halo phenomenon induced at the edge due to the jump of the depth of field in the restored image.

In this paper, we also use the local smoothing characteristics of bilateral filtering to pre-process $W(x,y)$ to filter out texture details while retaining the edge characteristics in the image, so as to obtain an initial estimate of the natural environment of the switch:

$$W_{BF}(x,y) = BF(W(x,y))$$

(5)

Since switching the natural environment is only related to the atmospheric light value and $A$ the depth of the scene $d$, and the atmospheric light value is assumed to be a global constant, the value of switching the natural environment is larger in the distant view with higher fog density, on the contrary, the value of switching the natural environment is larger at the close view with lower fog density. $W(x,y)$ smaller value means that the distant view area is more scattered by the global atmospheric light and the contrast is lower than that of the close view area [5]. In this paper, the local mean $E(x,y)$ and the local standard deviation $D(x,y)$ of $A$ are accurately estimated by the mean filter to further distinguish the near and distant regions, as follows:

$$E(x,y) = AF(W(x,y),s)$$

(6)

$$D(x,y) = \sqrt{AF((W(x,y) - E(x,y))^2,s)}$$

(7)

In the formula, $AF(\bullet,s)$ represents the local mean filter, and the rectangular window of $s \times s$ is selected for mobile search processing. Estimating the standard deviation by performing local mean calculation on $W(x,y)$ can ensure the reliability and robustness of the estimation, which is more accurate than the methods in literature and literature. Since there is less fog in the texture area with better contrast, the fog density estimate in this part should be reduced, that is, the initial estimate of the switch natural environment minus the local standard deviation of $W(x,y)$:

$$V'(x,y) = W_{BF}(x,y) - D(x,y)$$

(8)

When a brightly coloured target appears in the close-range area and the details are rich, the above method is used to weaken the denoising processing of the area, which can effectively avoid the phenomenon of colour oversaturation in the restoration result. Finally, consider the physical constraint $0 \leq V(x,y) \leq W(x,y)$ to obtain the final estimate of the natural environment of the switch:

$$V(x,y) = \max(\min(pV'(x,y),W(x,y)),0)$$

(9)
In the formula, $p \in (0,1)$ is the denoising adjustment parameter, which aims to keep a small part of the fog in the distant view and make the denoised image more natural.

In order to increase the calculation speed, we use the approximate method of fast bilateral filtering to accelerate. The algorithm represents the bilateral filter as a linear convolution in a three-dimensional space, performs Gaussian low-pass filtering in the down-sampled high-dimensional space, and uses three-dimensional linear interpolation. As shown in Figure 1.

![Figure 1. Isolating switch image under bilateral filtering](image)

### 3.3. Image restoration

Another key factor in solving the imaging equation of the isolation switch is the estimation of the atmospheric light $A$ value, which can also be understood as the estimation of the pixel value at the densest point of the fog. Literature selects the first 0.1% bright pixel value of the dark channel image, which corresponds to the largest pixel in the switch image as atmospheric light. However, this method only takes a single maximum value and is not robust, because the degraded image may be accompanied by noise impact [6]. From the analysis in the previous section, the switch natural environment $V$ approximately reflects the fog concentration distribution, so this article estimates $A$ according to the histogram statistics on the basis of the literature. Assuming that the total number of pixels is $N$ and the histogram is $V_{hist}$, calculate the histogram to accumulate $\sum_{i=0}^{255} V_{hist}$. At $\sum_{i=0}^{999} V_{hist} > 99\% \times N$ that time, look for the area of the pixel with the gravy value of $j$ in $V$, and the corresponding area in the switch image can be identified as a dense fog area. Then calculate the average value of the three color channels in the dense fog area, and use the largest average value as the estimate of atmospheric light $A$. This method is simple and effective, and has stronger robustness than the method using the "highest brightness pixel" in the dense fog area in the literature.

Using the estimated switch natural environment $V$ and global atmospheric light $A$, the radiation intensity of the scene under ideal conditions can be directly recovered according to equation (2):

$$L_0(x, y) = \frac{A(L(x, y) - V(x, y))}{A - V(x, y)}$$  \hspace{1cm} (10)
4. Simulation experiment research

4.1. Tracking the dynamic trajectory of switch operation
In the actual measurement, four videos of the isolating switch under different states and the corresponding isolating switch state were collected, as shown in Table 1.

| Video sequence number | Resolution / px | Number of frames | status |
|-----------------------|-----------------|-----------------|--------|
| 1                     | 1920×1080       | 452             | From combined to divided state |
| 2                     | 1920×1080       | 584             | From divided to combined state |
| 3                     | 1920×1080       | 1369            | Divide before close state       |
| 4                     | 1920×1080       | 1482            | Close first and then divide state |

4.2. Recognition of switch status
In the actual measurement, the centre line of the two blades is selected as the reference baseline, and the centre of the blade is used as the reference tracking point. When tracking the position of the knife, the distance between the reference tracking point and the reference baseline (the number of pixels that differ) is calculated in real time. When the distance gradually increases, it means that the switch is in the process of closing to opening; otherwise, when the distance gradually decreases, then it means that the switch is in the process of opening to closing [7]. The change curve of the distance between the reference tracking point and the reference baseline (number of pixels) during the process of disconnecting the isolating switch is shown in Figure 2. By comparing with the set closed reference baseline 8 and open reference baseline 30 threshold, when the distance exceeds 8 each pixel can be considered as the switch starts to open. When it exceeds 30 pixels, the switch can be considered as fully open. In practical applications, these two parameters can be adjusted according to the actual situation.

Figure 2. The change curve of the distance between the reference tracking point and the reference baseline (number of pixels) in the process of disconnecting the isolating switch from closing to opening
When using the two methods to identify the status of the isolating switch, the gravy projection method is sometimes limited by the shooting angle. The reason is that the middle fault of the closed rod occurs when the closed image is recognized, so that the system misrecognizes, and sometimes suffers the reason is limited to the shooting angle. After the isolation switch is disconnected, the left and right contacts are relatively close, and three gravy value peaks cannot appear during gravy-scale projection to prove the disconnection of the isolation switch, leading to system misunderstandings. These misunderstandings or Rejection can be greatly avoided when the angle method is used. When using the angle method, sometimes the illumination is not ideal, and there is a fault in the middle of the closed rod [8]. After applying the Hough transform, the system can also recognize that the two straight lines have the same slope and form a straight line, which will not affect the judgment of the final result, even if it is the shooting angle is inconsistent with the original one, and it has little effect on the use of the final angle method. This is the reason why the angle method can achieve 100% recognition in this experiment. The experimental results fully show that the angle method is very helpful to the remote operation of smart substations in engineering, and the reliability is relatively high.

5. Conclusion
An automatic image recognition method based on the isolation switch is given. Using the sparse representation of the filter algorithm to represent the knife tracking model, the tracking accuracy is improved, and a scheme for identifying the state of the knife and the movement of the knife is given. The actual measurement results show that the method in this paper has the advantages of high accuracy and good robustness for switch state recognition, and has a wide range of practical engineering application value.

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