Development of GIS Switch State Judgment System Based on Image Recognition

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Abstract. Aiming at the fast opening and closing speed of the GIS isolation/grounding switch, manual observation is more difficult, so it is difficult to judge the current switch status. This paper proposes an OpenCV-based image identification algorithm to identify the position of the switch movable contact during the opening and closing process of the isolating switch, thereby judging the state of the isolating switch. This system uses Raspberry Pi as the main hardware core, the server drives the CMOS camera through Raspberry Pi 4B, collects image information in the GIS optical observation window, and performs simple processing, and transmits it to the Raspberry Pi 4B based on the UDP protocol as the main core. In the upper computer and adopt the target detection algorithm based on OpenCV to track the current isolation/grounding switch contact position and determine the current opening and closing state.

1. Introduction

GIS equipment is widely used in power systems due to its small footprint and stable performance. Since GIS equipment is a sealed equipment, compared with traditional open equipment, it is not intuitive, and it is impossible to directly observe the contact conditions of the contacts to determine whether the GIS isolation/grounding switch contacts are in place. Failure to close in place will cause equipment accidents, economic losses, and even endanger personal safety. In addition, when an accident occurs in a GIS equipment, it is difficult to deal with, the restoration of power supply is slow, and the cost of accident handling is high, which brings hidden dangers to the use of GIS equipment.

At present, some teams have conducted research on the GIS status determination device. [1-4]. Since the opening and closing of the GIS isolation/grounding switch and the mechanical state when there is a fault are different, the corresponding switch movable contact position is different, so the opening and closing state can be judged by observing the position of the movable contact. Image recognition technology includes three stages: image acquisition, target analysis and tracking, and state judgment. It is based on changes in visual effects brought about by changes in its mechanical state, tracking the movement state of the moving contact to determine the current switch's opening and closing state.

Compared with other methods, the use of image recognition technology to determine the state of the switch's moving contact is more intuitive [4-7]. However, the GIS equipment is a sealed equipment. Compared with the traditional AIS, it is not intuitive. It is not possible to directly observe the contact conditions to determine whether the GIS isolation/grounding switch contacts are in place. Therefore,
this article sets up a video sensor in the GIS optical observation window to collect the movement position of the moving contact inside the GIS in real time and uses the UDP protocol to transmit the collected video information and send it to the client. Image processing technology is used to determine the position of the current switch movable contact, and then determine the current switch state. The structure of the remaining parts of this article is as follows. The second part introduces the structure and methods of the system, the third part describes the experimental structure and results, and the fourth part summarizes the full text and looks forward to the future work.

2. System design and proposed method

2.1. System Design and Moving Target Tracking Algorithm

Raspberry Pi is a palm-sized card computer developed by the British Raspberry Pi Foundation. As a palm-sized card computer, the Raspberry Pi has been widely used in hardware intelligence to create home theatres, wireless routers, FTP servers, face recognition, smart furniture, etc [7-8]. The lightweight and high performance of Raspberry Pi provide a good solution in the application environment of this article.

The purpose of this system is to detect the opening and closing status of the GIS isolation/grounding switch. First, the image data is acquired by the CMOS sensor installed in the optical observation window of the GIS equipment (as shown in Fig 1), and the moving contact of the switch in operation showed in Fig 2. Then the data is transmitted to the terminal for real-time processing through transmission. The overall structure of the system is shown in Fig 3.

Since the GIS isolation/grounding switch has a fast action speed, the operation can be completed in an average of 2-3s. To improve the real-time performance and detection speed, this paper chooses OpenCV as the main core part of the image recognition algorithm. Since the background of the GIS isolation/grounding switch action area is relatively simple (as shown in Fig 2), considering the processing speed of the processor, this paper adopts the inter-frame phase difference method as the target tracking algorithm.

The inter-frame difference method is a method of marking moving objects by performing difference operations on two or three adjacent frames of images in the video. The advantages of the inter-frame difference method are that the algorithm is simple to implement, and the program design...
complexity is low; it is not sensitive to scene changes such as light and can adapt to various dynamic environments with good stability. The disadvantage is that the complete area of the object cannot be extracted, there are "holes" inside the object, and only the boundary can be extracted.

The three-frame difference method is to take the "AND" operation in the two frame difference images of the adjacent three frames of pictures, namely:

\[ D_n(x,y) = \left( F_{n+1}(x,y) - F_n(x,y) \right) \cap \left( F_n(x,y) - F_{n-1}(x,y) \right) \]  

As shown in Fig. 4, where \( F_{n+1} \) is the \((n+1)\)th frame image, \( F_n \) is the \(n\)th frame image, \( F_{n-1} \) is the \((n-1)\)th frame image, \( x \) and \( y \) are the pixel coordinates, \( D \) is the difference image, \( D' \) is the image after OR operation, then through threshold processing, connectivity analysis and discriminate, the current switch movable contact and the opening and closing position.

![Figure 4. Three-frame difference algorithm flowchart.](image)

2.2. Image Processing Algorithm Based on OpenCV

OpenCV is a cross-platform computer vision library based on the BSD license developed by Intel. Firstly, pre-process the obtained image, convert the image into a grey image, and the histogram equalization is performed to obtain a new image with uniform grey distribution, and then median filtering is performed to achieve smoothing of the image.

Grayscale is a method of expressing image brightness, which is calculated by the following formula:

\[ Y = \left[ \frac{R^{1.5} + (1.5G)^{1.5} + (0.6B)^{1.5}}{1 + 1.5^{1.5} + 0.6^{2.2}} \right]^{1/3} \]  

Among them, \( Y \) represents the grey value of the image after grayscale, \( R \) represents the R channel component in the RGB image, \( G \) represents the G channel component in the GRB image, and \( B \) represents the B channel component in the RGB image.

Histogram equalization is to transform the histogram of the original image into a uniform histogram through a transformation function, and then modify the original image according to the uniform histogram to obtain a new image with uniform grey distribution. The equalization operation is defined by the following formula:

\[ Z' = \frac{Z_{\text{max}}}{S} \sum_{i=0}^{S} h(i) \]  

\( Z' \) is the pixel value after equalization, \( S \) is the total number of pixels, \( Z_{\text{max}} \) is the maximum value of the pixel point, and \( h(i) \) represents the cumulative distribution function of the value \( i \).

The median filter adopts a non-linear method, which is very effective in smoothing impulse noise. At the same time, it can protect the sharp edges of the image and select the appropriate point to replace the value of the polluted point. Therefore, the processing effect is good, and it is effective for the image sensor and the transmission channel. The black and white salt and pepper noise produced by decoding processing, etc. performs better. The size of the collected image is 640 × 480, and the 3 × 3 kernel is selected for filtering. The grey value at the centre of the kernel is:

\[ Y(x,y) = \text{median}[Y(x \pm 1, y \pm 1), Y(x, y \pm 1), Y(x \pm 1, y), Y(x, y)] \]  

After the pre-processing, using the three-frame difference method to detect the moving target, determine the state of the current switch movable contact.
2.3. GIS Switch State Judgment Algorithm

Combining OpenCV and the three-frame difference method, the judgment process of the GIS switch state based on the Raspberry Pi platform is shown in the Fig 5.

When preparing for opening and closing operations, the server and client are initialized, ready to transmit and receive data. The client acquires the transmission image, and then pre-processes the image based on OpenCV, then uses the three-frame difference method to track the movement of the switch moving contact, and finally determines the switch state according to the current position and movement direction of the current moving contact.

![Figure 5. GIS switch state judgment process.](image)

3. Experimental result

The experimental platform is shown in Fig. 6. In the early stage, we recorded a GIS isolation/grounding switch action video through a CMOS sensor to verify the performance of the proposed system.

The algorithm is tested on the Raspberry Pi 4B+ platform. The video processing and target recognition speed can reach about 29FPS (as shown in Fig. 7). Although it is found that the outer contour of the identified object is slightly larger than the area of the moving contact, compared to the size of the moving contact itself, the contour error is small and will not interfere with the operation of the system to determine the position of the moving contact.

![Figure 6. Experiment platform.](image)

![Figure 7. Experiment result.](image)
4. Conclusion
This paper proposes an OpenCV-based image recognition algorithm to identify the position of the switch movable contact during the opening and closing of the isolating switch, thereby judging the state of the isolating switch. This system uses Raspberry Pi as the main hardware core, the server drives the CMOS camera through Raspberry Pi 4B, collects image information in the GIS optical observation window, and performs simple processing, and transmits it to the Raspberry Pi 4B as the main core based on UDP protocol. In the host computer, and use the OpenCV-based three-frame difference algorithm to track the current isolation/grounding switch contact position, and achieve a detection speed of about 20FPS, it basically meets the requirements of real-time detection of switch opening and closing status. Later, the image recognition algorithm will be further optimized to reduce the error of the outer contour of the object, to determine the current switch movable contact position more accurately.

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