X-ray Image Recognition Method for Crimping Defects of Strain Clamp Based on OpenCV

Pengwu LI1a* , Ronghai LIU1

Power Science Research Institute of Yunnan Power Grid Co. , Ltd. , Kunming 650217, China
a*2192224044@ncepu.edu.cn

Abstract: The crimp quality of the tension clamp of the line affects the safety of the power grid. At present, the measurement of the quality of the tension clamp has certain limitations. An X-ray image detection method for strain clamp based on image processing technology is proposed. Firstly, the X-ray image of the strain clamp is taken and the image is preprocessed. Secondly, by selecting the defect part image of the typical defect sample, using some statements of OpenCV Python Library in Python to quickly identify and detect other X-ray pictures, and mark the defect part of other pictures. Finally, whether it is a defect is determined according to the cumulative value image of the gray value distribution of the marked defect area. Through the research in this paper, the rapid identification of the X-ray image of the crimping position of the tension clamp can be realized, which has important reference value for the engineering application of the crimping quality inspection of the tension clamp.

1. Introduction

As an important part of the transmission line, the tension clamp is composed of aluminum casing and steel anchor [1]. The aluminum pipe and the steel anchor part are pressed, and formed to combine the wire with the tension resistance clamp, so that it can bear all the tension of the connecting wire and turn on the current. Due to the high safety factor of the line design, accidents will not occur immediately after construction even if there is a quality defect of crimping [2-3]. However, in the case of dancing and long-term breeze vibration after putting into operation, the wire clamp is prone to fracture, thus causing power accidents and endangering social safety.

In practical engineering practice, the front-line workers often use vernier calipers and straight connecting pipes to complete the inspection of the appearance and size of the tension fixture and its connecting line when disassembling it. Before construction, experimental samples are usually made for force analysis according to the requirements of engineering indicators, and manual methods are used to check the crimping quality of tension-resistant wire clips [4]. This manual inspection method requires the construction personnel to have a high level of skills and practice, and it needs to conform to the specification. In addition to the operation space is high above the ground, it not only has potential safety hazards, but also increases the difficulty of operation and is not easy to supervise. Therefore, it is necessary to improve this manual inspection method [5-7].

At present, there are many researches on the quality of tension - resistant wire clamp. Wang Yi Saitama [8] et al. first extracted edge information from X-ray images of tension-resistant line clips, then obtained inflection points by calculating the maximum local curvature on image edge contour, and finally realized automatic detection of tension-resistant line clips' crimping quality by calculating and comparing coordinate differences of each detection position. Li Junhua et al. calculated the depth value
based on the sound pressure curve of finite element simulation and the depth value read by phased array imaging, which to a certain extent solved the problem that the quality of internal crimping of tension-resistant wire clips in traditional transmission lines could not be judged [9]. Based on the basic theory of electromagnetic field, Ouyang Kejian et al. used large-scale universal finite element software to conduct simulation calculation on the anti-electromagnetic interference of the detection device, and combined with the simulation calculation to optimize the design of live detection device, so as to complete the live detection of the quality of the tension line clamp of the transmission line.

All of the above researches can detect the quality of tension clamp, but there are some problems such as high cost and low efficiency. In this paper, the image processing method is used to quickly locate and identify the defects in X-ray images, which has important reference value for the engineering application of the quality inspection of tensioning wire clamp.

2. Preprocessing of tension clip X-ray images

In the process of image shooting, the unpredictability of the environment often leads to the difference of the final image brightness, size, resolution and other information. In order to reduce the influence of unnecessary factors on the algorithm, it is necessary to carry out some image preprocessing work before the implementation of the main process of the algorithm, such as filtering and denoising, image enhancement, etc.

2.1. Filtering and denoising

Noise has a great impact on the acquisition, input, processing and output results of image processing [10]. Therefore, image denoising must be carried out before image processing. At present, the image denoising technology has been developed more mature, there are many effective image denoising methods, this paper uses gaussian filtering.

Gaussian filtering adopts convolution kernel to filter the image through Gaussian function. Suppose the original image is $f(u, v)$, $g(u, v)$ after filtering, and the dimension of The Gaussian kernel matrix $H(u, v)$ is $(2k+1) \times (2k+1)$, then:

$$H(u,v) = \frac{1}{2\pi \sigma^2} \exp \left[ \frac{(u-k-1)^2 + (v-k-1)^2}{2\sigma^2} \right]$$

$$g(u,v) = f(u,v) \times H(u,v)$$

In Equation (1), $\sigma$ represents variance; Equation (2) represents convolution filtering. The effect of gaussian filtering before and after is shown in Figure 1.

![Fig. 1 Effect picture before and after Gaussian filtering](image)

2.2. Image enhancement

After image enhancement processing, the recognition of X-ray image can be enhanced and the difficulty of defect location identification can be reduced. In this paper, the image contrast enhancement algorithm is used to process the acquired tensioning line clip X-ray images.

Image histogram equalization applies image histogram to adjust contrast in the field of image processing. This method is usually used to increase the local contrast of many images, especially when
the contrast of the region to be processed in the image is quite close\[11\]. By this method, the gray value of the target image can be evenly distributed on the histogram. Histogram equalization achieves this function by effectively extending commonly used gray values, thus ensuring that local contrast enhancement is achieved without affecting the overall contrast. The effect before and after mean enhancement of gray histogram is shown in Figure 2.

![Fig. 2 Effect diagram of gray histogram before and after mean enhancement](image)

3. Defect Location
This paper adopts template matching algorithm to locate defects. Template matching algorithm is a technique to find the best matching (similar) part in one image with another template image. After the template image is selected, the matching degree between it and the pixel value of the selected template image is calculated from left to right and top to bottom on the image to be detected. The greater the matching degree, the greater the similarity between the template image and the detection region of the image to be detected. In this paper, three of these algorithms are used to locate the defect location, and the final defect location is obtained by overlapping the three images. In this paper, the implementation image is 1063×664 PNG image, and the development environment is Pycharm. OpenCV and NumPY libraries are required. The selected template image is shown in Figure 3.

![Fig 3 selected template image](image)

There are three methods used and the results are output respectively. The three methods are normalized square variance matching, normalized correlation matching and normalized correlation coefficient matching.

The normalized square variance matching method normalized the correlation matching method, making the algorithm more adaptable to the change of light and gray linear. The smaller the matching value $R(x, y)$ is, the higher the matching degree between the template image and the detected image region is. Therefore, when the matching degree between the template image and the detected image region is the highest, the matching value $R(x, y)$ is 0. Conversely, when the matching degree is lower, the matching value $R(x, y)$ is larger. Matching value $R(x, y)$ function expression is:

$$R(x, y) = \frac{\sum_{x',y'}(T(x',y') - I(x+x',y+y))^2}{\sqrt{\sum_{x',y'}(T(x',y'))^2 \cdot \sum_{x',y'}(I(x+x',y+y))^2}}$$

(3)

The effect diagram of the normalized square error matching method is shown in Figure 4.
The effect diagram of the normalized square error matching method is shown in Figure 4. The normalized correlation matching method normalized the correlation matching method, and used the pixel multiplication operation between template and target image to judge the correlation between the two. Therefore, the larger the result is, the greater the matching degree between template and detected image region is, and the smaller the matching degree between template and detected image region is. Its function expression is:

$$ R_{x,y} = \frac{\sum_{x',y'}[T(x',y') - I(x+x',y+y')]^2}{\sqrt{\sum_{x',y'}[T(x',y')]^2 \cdot \sum_{x',y'}[I(x+x',y+y')]^2}} \quad (4) $$

The effect diagram of normalized correlation matching method is shown in Figure 5.

The normalized correlation coefficient matching method subtracts the average value of the detected image and the template image, and then divides the variance of each image, so that the target image and the template are standardized, which can ensure that the image and the template will not affect the calculation result even if the brightness of the image and the template changes. The calculated correlation coefficient is between -1 and 1. 1 means that the template is exactly the same as the detected image region, -1 means that the brightness of the template is opposite to the detected image region, and 0 means that there is no linear relationship between the template and the detected image. The functional expression of the normalized correlation coefficient matching method is:

$$ R_{x,y} = \frac{\sum_{x',y'}[T(x',y') - I(x+x',y+y')]^2}{\sqrt{\sum_{x',y'}[T(x',y')]^2 \cdot \sum_{x',y'}[I(x+x',y+y')]^2}} \quad (5) $$

The effect diagram of the normalized correlation coefficient matching method is shown in Figure 6.
The images obtained by these three algorithms are superimposed, and the one with the largest number of circled positions can be determined as the defect image. The final position of the crimp defect is shown in Figure 7.

![Image of the final location of the crimping defect]

**FIG. 7 The final location of the crimping defect**

4. Detection of defective parts

The position image of wire crimping defect is taken out separately for defect judgment. Since the gray histogram in image processing reflects the corresponding function between the number of pixels and the occurrence frequency, it can effectively reflect the distribution of gray value in the image, so it can be used to find the jump discontinuities of the change of gray value, so as to automatically calculate whether there are crimping defects at the crimping place. As shown in Figure 8, the whole image is scanned line by line, and the median value is taken and recorded according to the change of gray value.

![Histogram of grayscale image]

**FIG. 8 Histogram of grayscale image**

Initialization window pixels for A pixel, the window along the horizontal line, statistics of gray level distribution of the total value, change for the first time, drop point to point A, continue to move the sliding window, when the first appeared on the jump discontinuity point, record center position as point B, read through the AB two pressure welding wire insertion depth, The gray accumulated value images with defects and without defects are shown in Figure 9 and 10 respectively.

![Defect grayscale cumulative value image]

**FIG. 9 Defect grayscale cumulative value image**
Cumulative gray distribution diagram of defect location image with inadequate crimping. Defect distribution image. Because there is no vacant part during steel anchor crimping, there is no such large cumulative gray difference between AB points. According to the above processing results, according to the function relationship, there is a corresponding relationship between the size in the detected image and the actual size, which is approximately a linear relationship. Therefore, dimension information such as the depth of tension line clamp can be calculated according to the length of the detected image.

Set the threshold value as 150, that is, the difference of Y value between two points AB is 150 gray units. If it is lower than the threshold value, no defect will be judged; otherwise, insufficient crimping defect will be judged. According to the proposed method, X-ray image recognition of tension-resistant wire clip was carried out. Partial detection results are shown in Table 1, and all detection results are shown in Table 2.

**Table 1 Part of the test results**

| Image category | Gray scale accumulation diagram | AB difference | Is it a defect | Judgment situation |
|----------------|---------------------------------|--------------|---------------|-------------------|
| Defect         | ![Defect Image](image)          | 182          | Is            | Correct           |
| Defect         | ![Defect Image](image)          | 211          | Is            | Correct           |
| Defect         | ![Defect Image](image)          | 214          | Is            | Correct           |
| No Defect      | ![No Defect Image](image)       | 123          | No            | Correct           |
| No Defect      | ![No Defect Image](image)       | 143          | No            | Correct           |

**Table 2 Statistics of all test results**

| Image category | No Defect | Defectiveness |
|----------------|-----------|---------------|
| Amount         | 500       | 300           |
| Judged as no defect quantity | 453       | 26            |
| Judged as the number of defects | 47        | 274           |
| Precision rate | 90.6%     | 91.3%         |
5. Conclusion
In this paper, the X-ray images taken by the tension clip are preprocessed. Secondly, by selecting partial images of typical defect samples and using template matching method, other X-ray images can be quickly recognized and detected, and the defect parts of other images can be marked. Finally, the defect can be determined by the image of the gray value distribution of the marked defect area. Through the research of this paper, it can realize the rapid identification of X-ray images of tensioning wire clamp, which has important reference value for the engineering application of tensioning wire clamp quality detection.

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