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Research on key technology of oil level safety early warning of substation equipment in conservator based on infrared imaging

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Abstract

with the wide application of infrared imaging technology in electrical equipment, it can achieve better construction of online monitoring system for transformer equipment, and the infrared image processing is a very important part, which is the main link to realize online remote detection. Through infrared image analysis, the oil level of conservator can be determined, so as to provide effective basis for the normal operation of transformer According to. This paper is mainly based on the image projection method to measure the oil level of transformer conservator. The oil level image obtained by infrared imaging technology has a lot of noise, which is not conducive to the measurement of oil level. Therefore, the infrared image needs to be filtered by image filtering technology first, and then the infrared image is used to locate, segment and locate the oil level line by pycharm software, and finally the accurate measurement is made Oil level of transformer conservator.

Keywords

Transformer, conservator, image processing, python, projection method, image filtering.

1. Introduction

Digital image processing comes from two research directions: one is to facilitate people to analyze and improve digital images; the other is to facilitate computer to transmit, display and recognize digital images. The object of this study is digital image processing based on infrared imaging technology. Infrared imaging technology is widely used in power system, which can measure the surface temperature of power equipment in a long distance without contact. The use of infrared imager can detect the oil level of oil conservator of large power transformer, which can facilitate the operation and maintenance personnel to judge the oil level of transformer and provide reference for transformer maintenance It provides an important basis.

At present, a large number of online monitoring methods based on electrical quantity have been proposed for many power equipment. Compared with the electrical quantity monitoring method, the use of non electrical quantity to diagnose electrical equipment fault is more effective in some aspects. Therefore, before the failure of electrical equipment, some electrical quantities of electrical equipment will not change significantly, but some non electrical quantities (such as air pressure, temperature, etc.) will change significantly, so as to facilitate the operation and maintenance personnel to deal with it in time.

In paper [2], an iterative ellipse fitting method is proposed to obtain the position and status of the conservator, that is, the edge points retained in each iteration are used for ellipse fitting, and the points far away from the ellipse point are deleted until the ellipse difference of two successive iterations is within the error range. The result of this method depends on the quality of image processing and the parameter selection of edge detection to a great extent, so the result is greatly affected by the image processing technology and has a certain error.

In [3], the watershed segmentation algorithm based on morphology and the fuzzy clustering segmentation algorithm are selected. In order to detect the oil level of oil conservator effectively

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and accurately, the improved watershed segmentation algorithm is used to segment the infrared image of oil conservator. The improved algorithm takes the multi-scale morphological gradient image as the input image of watershed algorithm. On the premise of focusing on the connectivity between the region and the city, the initial marking image is obtained by using the Otsu method to binary the gradient image, and the final marking image is obtained by removing the pseudo minimum points The minimum points in the labeled image are used as the starting point of watershed segmentation, and the scale gradient image is transformed by watershed to get the final segmentation result.

This paper [16] proposes a method of using the infrared remote sensing and safety early warning system of substation electrical equipment to automatically collect the infrared temperature measurement image of substation electrical equipment, process and segment the image, store the temperature measurement information of each electrical equipment conservator oil level in the database, and carry out safety early warning according to simple rules. However, the paper [16] only uses simple rules, and the research on the method of security early warning based on infrared temperature measurement image information is not deep enough.

Due to the complex and changeable environment and climate conditions of the oil level in the oil conservator of electrical equipment, as well as the diversity of fault and abnormal types and occurrence parts, the research on fault and abnormal diagnosis of electrical equipment based on the information provided by infrared temperature measurement image needs to be carried out in a down-to-earth, in-depth and meticulous manner. At present, the research in this field has only achieved preliminary results There is still a big gap between actual needs.

Oil level is one of the important monitoring parameters of power transformer. It is of great significance to find the oil level too low or too high in time and take corresponding measures to ensure the safe operation of power transformer. When the oil level is too high, it may increase the oil pressure inside the transformer and cause oil spill. When the oil level is too low, the oil level will decrease when the transformer is in low load operation (or the transformer is out of service), or when the weather becomes cold. When the oil level is lower than the transformer cover, the lead or core will be exposed to the air, causing the risk of internal flashover. At the same time, the increase of the contact surface between oil and air will make the insulation performance of insulating oil decrease rapidly. It can be seen that the transformer requires a certain oil level in operation, and it must be checked frequently in operation. When the oil level is too high, try to drain the oil; when the oil level is too low, try to fill the oil to maintain the qualified oil level. The traditional measurement method based on oil level gauge is not only inconvenient for digital acquisition, but also leads to inaccurate measurement due to blockage and other reasons.

2. Basic principle

2.1. Basic principles of image processing calculation

An image can be defined as a two-dimensional function f (x, y), where x and y are spatial coordinates, and the amplitude on any pair of spatial coordinates (x, y) is called the intensity or gray level of the point image. When x, y and amplitude f are finite and discrete values, the image is called digital image. Digital image processing refers to the use of digital computers to process digital images. It is worth mentioning that digital images are composed of limited elements, each element has a specific position and amplitude. These elements are called image elements, picture elements or pixels. Pixel is a word widely used to represent digital image elements. Vision is the most advanced organ of human perception, so there is no doubt that image plays the most important role in human perception.

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However, human perception is limited to the visual band of the electromagnetic spectrum, and imaging machines can cover almost all the electromagnetic spectrum, from gamma rays to radio waves. They can process non-human image sources, including ultrasonic, electron microscope and computer-generated images. Therefore, digital image processing involves a variety of applications.

There is no consensus among the founders on the definition of the scope of image processing or other related fields (for example, image analysis and computer vision). Sometimes the scope of image processing is defined by the feature that the input and output of processing are images. We think that this definition is only artificially defined and restricted. For example, under this definition, even the most common work of calculating the average gray value of an image cannot be regarded as image processing. On the other hand, the highest goal of some fields (such as computer vision) is to simulate human vision with computer, including understanding and reasoning, and taking action according to visual input. This field itself is a branch of artificial intelligence, and its purpose is to imitate human intelligence. The field of artificial intelligence is in the early stage of its development, and its development is much slower than expected. The field of image analysis (also known as image understanding) is between the two disciplines of image processing and computer vision.

There is no clear boundary in the continuum from image processing to computer vision. However, in this continuum, three typical computational processes (i.e., low-level, intermediate, and high-level) can be considered to distinguish the various disciplines. Low level processing involves primary operations, such as image preprocessing to reduce noise, contrast enhancement and image sharpening. Low level processing is characterized by image input and output. Intermediate processing involves segmentation (dividing the image into different regions or objects) and reducing the description of the object to make it more suitable for computer processing and classification (recognition) of different day marks. Intermediate image processing is based on the input image, but the output is the features extracted from these images (such as edge, contour and identification of different objects, etc.). Finally, advanced processing involves the overall understanding of the recognized object in image analysis, and the implementation of vision related recognition functions (at the edge of continuum).

According to the above discussion, we can see that the logical overlapping area of image processing and image analysis is the recognition of specific areas or objects in the image. In this way, we define the digital image processing, including the input and output are image processing, but also includes the extraction of features from the image and recognition of specific objects. A simple example of automatic text analysis is given to illustrate this concept. In the process of automatic text analysis, we first obtain an image containing text, preprocess the image, extract (segment) characters, then describe these characters in a form suitable for computer processing, and finally recognize these characters. All these operations are within the scope of defined digital image processing. Understanding the content of a page may need to consider from the field of image analysis or computer vision according to the complexity of understanding. In this way, the defined concept of digital image processing will be used in the field of special social and economic value.

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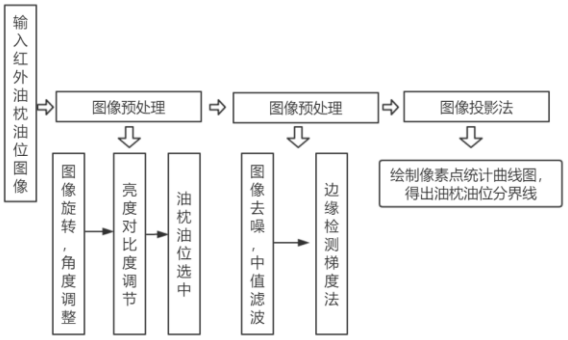
2.2. Oil level line detection process



3. Specific methods for oil level detection of conservator

3.1. Image graying

In RGB model, if r = g = B, the color represents a gray color, and the value of R = g = B is called gray value. Therefore, each pixel of gray image only needs one byte to store gray value (also known as intensity value and brightness value), and the gray range is 0-255.

$$Gray = \sqrt[2.2]{\frac{R^{2.2} + (1.5G)^{2.2} + (0.6B)^{2.2}}{1 + 1.5^{2.2} + 0.6^{2.2}}} \tag{1}$$

Note that the 2.2 power and 2.2 power root, RGB color value can not be simply added directly, but must be converted into physical light power by 2.2 power. Because the relationship between RGB value and power is not a simple linear relationship, but a power function. The exponent of this function is called gamma value, which is generally 2.2. This conversion process is called gamma correction.

Many applications are based on morphological concepts and involve binary images. Although logic operation is very simple in nature, it is a powerful supplementary means to realize image processing algorithm based on morphology. In the following discussion, we focus on logical operations involving binary pixels and images.

The main logic operations used in image processing are and, or and not (complement). The properties of these operations are summarized in Table 1. These operations are perfect in function. They can be combined to form other logic operations.

Table 1: Three basic logic operations

p	q	p与q (p*q)	P或q (p+q)	非(p) ($\bar{p}$)
0	0	0	0	1
0	1	0	1	1
1	0	0	1	0
1	1	1	1	0

3.2. Brightness contrast adjustment

When a picture is too bright or too dark, the whole picture gives people the impression that the characteristics of the picture are not obvious. Images with obvious contrast often have uniform gray distribution, which is usually measured by gray variance (standard deviation). If the standard deviation is large, the general contrast is obvious, and if the standard deviation is

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small, the general contrast is not obvious. The formula of gray histogram transform (cumulative distribution function transform histogram equalization) is as follows:

$$s = T(r) = (L-1)\int_0^r P_r(\omega)d\omega \tag{2}$$

Look at the formula, we assume that the gray level is concentrated in the dark area (bright area), then according to the change of cumulative distribution function, the distribution can be transformed into the entire 0-255 range, and the corresponding histogram gray variance will certainly be larger.

First, the gradient distribution of the original image is counted according to the gradient value, and then the gray value is recalculated according to the above formula according to the rounding, the range of which is the gray value of the gray histogram [0255].

3.3. Median filtering

Median filter is a typical low-pass filter, which is mainly used to suppress impulse noise and protect image edge from being blurred. The filtering method is a non-linear smoothing technology, which sets the gray value of each pixel to the median value of all pixels in a neighborhood window of the point.

Median filtering is a kind of nonlinear signal processing technology which can effectively suppress noise based on sorting statistics theory. The basic principle of median filtering is to replace the value of a point in a digital image or digital sequence with the median value of each point in a neighborhood of the point, so that the surrounding pixel value is close to the real value, so as to eliminate isolated noise points. The method is to use a two-dimensional sliding template of some structure to sort the pixels in the board according to the size of the pixel value, and generate a monotonic up (or down) two-dimensional data sequence.

The output of two-dimensional median filter is as follows:

$$g(x,y) = \text{med}\{f(x-k,y-l),(k,l \in W)\} \tag{3}$$

Where f (x, y) and G (x, y) are the original image and the processed image respectively. W is a two-dimensional template, which is usually 3 * 3, 5 * 5 area. It can also be in different shapes, such as linear, circular, cross, circular, etc.

3.4. Gradient method of edge detection

In image processing, first-order differentiation is realized by gradient method. For a function, the gradient in its coordinates is defined by a two-dimensional column vector:

$$\nabla f = \begin{bmatrix} G_x \\ Gy \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \tag{4}$$

The modulus of this vector is given by the following formula:

$$\nabla f = mag(\nabla f)$$

$$= \left[G_x^2 + G_y^2\right]^{\frac{1}{2}}$$

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$$= \left[(\frac{\partial f}{\partial x})^2 + (\frac{\partial f}{\partial y})^2 \right]^{\frac{1}{2}} \tag{5}$$

Although the components of the gradient vector are linear operators, the modulus of the vector is obviously not linear because of the square sum open operation.

When calculating equation (5) for the whole image, the amount of computation is very large. Therefore, in practical operation, absolute value is often used to replace square and square root operation to approximate the modulus value of gradient:

$$\nabla f \approx |G_x| + |G_y| \tag{6}$$

This formula is simple to calculate and keeps the relative change of gray level, but the isotropic property usually does not exist.

3.5. Morphological open close operation

As we can see, expansion makes the image larger and corrosion makes the image smaller. We use two other important morphological operations: open operation and close operation. The open operation generally makes the contour of the object smooth, breaks the narrow discontinuity and eliminates the thin protrusion. The closed operation also makes the contour smoother, but contrary to the open operation, it usually eliminates narrow discontinuities and long and thin gaps, eliminates small holes, and fills the fractures in the contour.

The structure element B is used to open the set a, expressed as $A \circ B$, which is defined as:

$$A \circ B = (A \ominus B) \oplus B \tag{7}$$

Therefore, using B to open a is to use B to corrode a, and then use B to expand the result.

Similarly, the closed operation of structure element B on set a is expressed as $A \cdot B$, which is defined as follows:

$$A \bullet B = (A \oplus B) \ominus B \tag{8}$$

This formula shows that the closed operation of using structural element B to set a is to use B to expand a, and then use B to corrode the result.

3.6. Statistics of pixels by image projection method

In drawing, the light source is called the projection center, the light is called the projection line, the direction of the light is called the projection direction, the falling plane (such as the ground, wall, etc.) is called the projection plane, the outline of the shadow is called the projection, and the method of using the projection to represent the shape and size of the object is called the projection method. The principle of this projection is to count the number of pixels on the one-dimensional line in X or Y direction under given conditions.

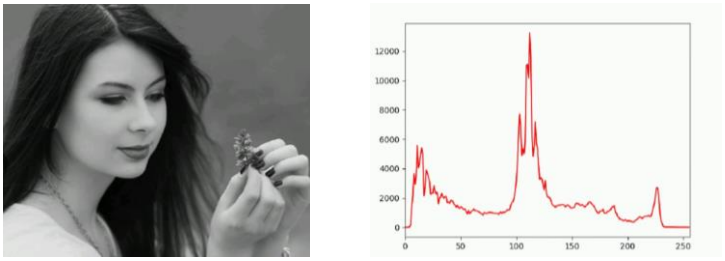

Figure 1: Projection method statistical pixel example map

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3.7. Calculation of oil level line of conservator

Through the image projection method of statistical pixel curve, determine the maximum value of pixel change point, through the pixel comparison is the oil level line.

Firstly, the number of pixels greater than 0 in the i-th row is counted, where I is the number of complete rows. Then, the maximum value is determined by comparing the number of pixels greater than 0 in each row, that is, the position of the oil level line of the conservator, and the specific ordinate is displayed.

4. Concrete example verification

The method described in this paper is verified by processing infrared image of oil level of transformer conservator. Pycharm software is used in the whole image processing process.

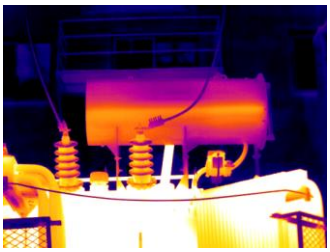

Figure 2: Original infrared image of oil level in conservator

Figure 2 shows the original image of the infrared conservator. Due to the need to count its pixels, but the RGB values in the color image are not equal, which is not convenient for statistics. Therefore, the original image is first grayed to get image 3.

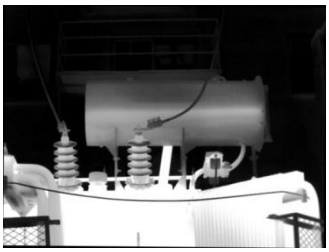

Figure 3: brightness contrast adjustment

When the initial grayscale image brightness is too dark, the whole picture looks like the image features are not obvious, can not highlight the more clear oil level line. After adjusting the brightness contrast of Figure 3, figure 4 with clearer oil level line is obtained.

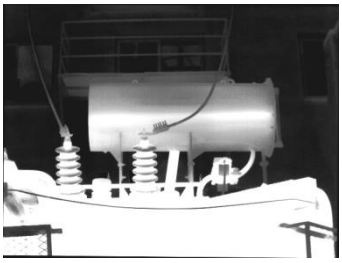

Figure 4: brightness contrast adjustment

Because the image projection needs to count the pixels of the conservator, the conservator needs to be selected before projection.

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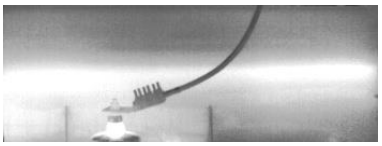

Figure 5: selection of oil conservator

There is a lot of noise interference in the unfiltered oil conservator map, which will affect the pixel statistics. Before the pixel statistics, it is necessary to carry out median filtering on Figure 4, which is mainly used to suppress impulse noise, and at the same time, it can well protect the image edge from being blurred. Figure 5 is obtained after learning to close the mind.

Figure 6: Morphological close operation

In the image projection method, the pixels are projected in the X direction, and the ordinate in Fig. 6 is taken as the abscissa of the pixel statistics table. The pixels in the statistical image 6 are counted, and the pixel statistics Curve Figure 7 is drawn.

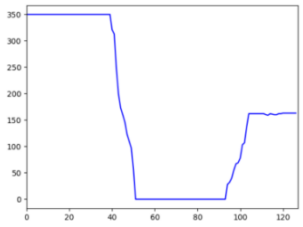

Figure 7: Pixel statistics

Analyze the pixel statistical curve figure 7, get the dividing line of RGB 0 and 255, draw the oil level line figure 8 and Figure 9 of conservator.

Figure 8: Oil level line of conservator

Figure 9: Oil level line of conservator

5. Conclusion

1) The example shows that the method of using infrared conservator image to detect the oil level of transformer is feasible, and can be used as an important way of on-line real-time monitoring the oil level of transformer conservator.

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2) The oil level line of transformer conservator can be effectively measured by pixel statistics of morphological image. The specific operation method is simple, fast and easy to understand compared with the edge fitting method.

3) According to the difference of temperature in the used transformer conservator, the gradient operation is used to get the interface with the largest temperature change rate, and the statistical pixels are used to calculate the oil level line.

4) The final calculated oil level line is 59.84%, which is consistent with the actual measurement.

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