A Novel Miniature Circuit Breaker Surface Detecting System Based on Machine Vision Technology

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Abstract

A efficient non-contact miniature circuit breaker surface detecting system was presented based on the principle of the machine imaging technology. This visual detection system is aimed at the automatic detection of the installation direction of the test button (T-button) of miniature circuit breaker. By analyzing the characteristics of the T-button and the detection requirements, the appropriate camera, light mode and lens were determined, and then the proper images were obtained for further processing. To solve the belt seriously jitter, this paper studies the RGB color image space of miniature circuit breaker and component labeling algorithm, and then introduces an algorithm of location of T-button. Finally, character template matching was utilized to detect the installation direction of the T-button. This system can greatly optimizing the efficiency, and is very suitable for the rapid detection of a large number of miniature circuit breaker. The test results show that the accuracy of detection by this method can reach over 99% and the false detection rate is lower than 1%, which meets the practical production requirement.

Keywords

Miniature circuit breaker; machine vision; control; T-button.

1. Introduction

Machine vision technology was proposed in the 1960s and 1970s[1]. However, due to the limitations of algorithm theory and computer hardware at that time, machine vision . With the development of science and technology, by the beginning of this century, machine vision technology has been gradually applied to the actual production and life. technology still remained in the laboratory research stage[2]. At present, machine vision technology is mainly applied in the following scenes, such as fingerprint, face recognition, virtual reality, auto self-driving, and so on[3].

Due to the introduction of automated production lines, miniature circuit breakers usually use robot arms instead of human hands, thus achieving rapid installation. A T-button is installed on each circuit breaker, and the square T-button can be installed in four directions, which means the probability of correct installation is only 1/4. In order to ensure the correct rate of installation, some enterprises add a worker to check whether the test button is installed incorrectly after the completion of circuit breaker assembly, which undoubtedly increases the labor cost. This paper presents A novel miniature circuit breaker surface detecting system based on machine vision technology, this technology is mainly used in the manufacturing process of miniature circuit breaker, such as image matching and recognition algorithm[4], visual system reliability, visual interaction and so on.

2. The Design of the Detection System

This circuit breaker detection system contains the following modules: image acquisition unit, central processing unit, data transmission unit, display module and action execution unit, as shown in figure 1. The image data acquisition module is used to collect the image data of the miniature circuit breaker under test. The data acquisition unit includes strip light source, camera and bracket.The camera output is connected to the CPU. The camera is used to collect image information and transmit it to the central processing unit for signal processing. In order to improve the detection efficiency, we use the method of placing four circuit breakers side by side at a time to carry out rapid detection and improve the work efficiency. The bracket pendulum is fixed near the miniature circuit breaker under test for fixing the camera. As the detection target is composed of four circuit breakers with a large width, two strip light sources are selected. The strip light source is placed at the bottom of the support to provide a stable light source for the miniature circuit breaker under test.

The central processing unit (CPU) contains a computer, which is used to process the collected image data, extract the key information, and start the matching and recognition algorithm of printing quality inspection, namely, to compare the captured image with the standard image, determine whether it is qualified, and control the action execution module to execute the action mechanism; The CPU also counts the quality test results of the miniature circuit breaker, which is connected to HDBaseT and data transmission module through HDMI.

The data sending module is connected with the display module through the wireless network. The data transmission and reception module can adopt 3G/4G data transmission terminal, and the data transmission and reception module is used for reliable data conversion and transmission of the statistical results of the quality detection of miniature circuit breakers.

The display module is used to display the statistical results of the image recognition process and the quality detection of the miniature circuit breaker. The action execution module includes photoelectric sensor, PLC controller, blocking device, conveyor belt and motor. Two photoelectric sensors are placed on both sides of the initial end of the conveyor belt to sense the arrival of the circuit breaker under test, so that the object under test can be placed under the strip light source and camera lens accurately. The PLC controller receives the photoelectric signal, drives the blocking device to work to block the miniature circuit breaker, and sends the message to the central controller. The PLC controller is controlled by the central processor and uniformly executes the action mechanism, such as releasing the blocking device and eliminating unqualified products according to the test results. The blocking device can be realized by a strip baffle, which is controlled by a PLC controller. When the PLC detects the photoelectric signal, the blocking device acts to block the control belt and is controlled by the motor. The conveyor belt is used to transport the miniature circuit breaker under test. The motor can select the common three-phase 380V electromagnetic braking motor to control the action of the conveyor belt.

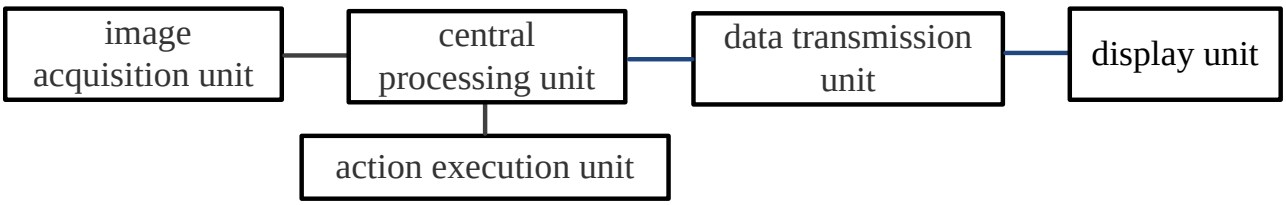


Fig1 the detective machine vision system

The system structure is shown in figure 2.This detection system works as follows： The photoelectric sensor senses the arrival of the miniature circuit breaker, the controller receives the photoelectric signal, drives the blocking device to work to block the miniature circuit breaker, and sends messages to the computer. The computer receives the signal of the controller and begins to process the collected image at this moment. After the processing is completed, the computer sends out the processing result

to the controller. Then the controller releases the block and drives the action of the actuator according to the result to eliminate the unqualified products.

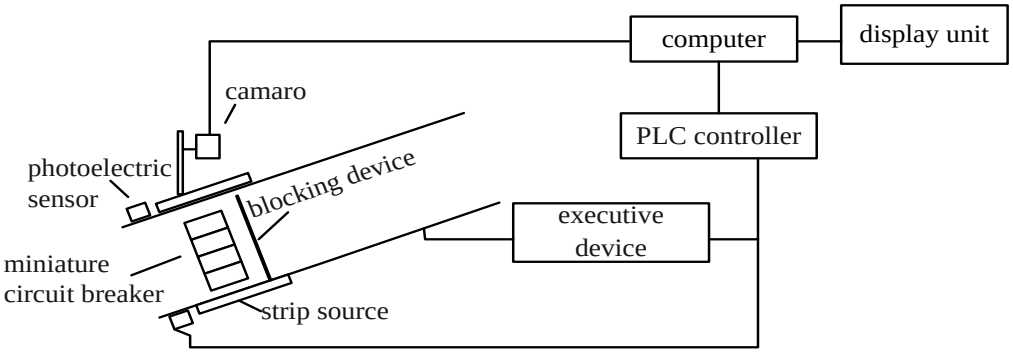


Fig 2 the structure of the miniature circuit breaker detective system

3. The Design of Image Processing Algorithm

3.1 The Block Diagram of algorithm

The block diagram of the algorithm is shown in figure 3. And the whole process of the algorithm can be roughly described as follows.

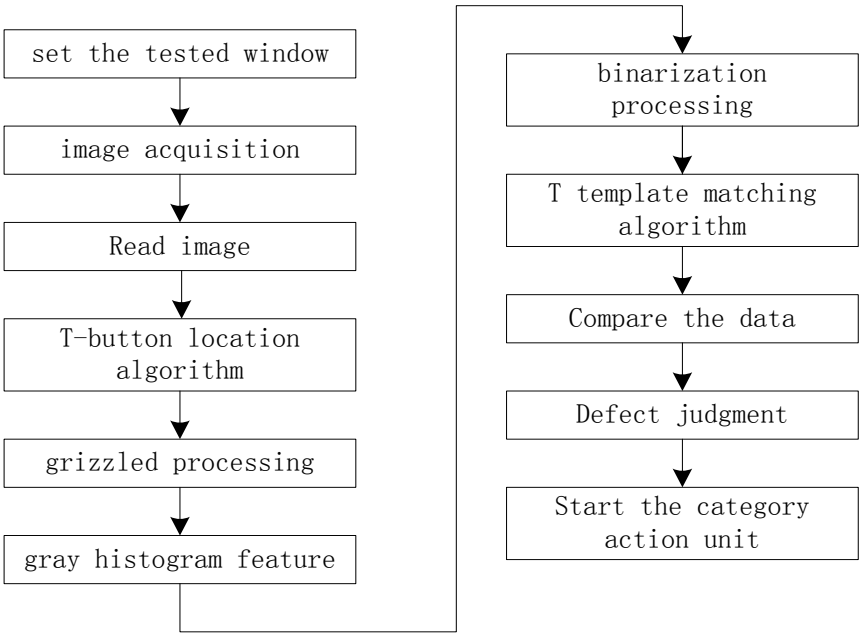


Fig 3 Block Diagram of algorithm

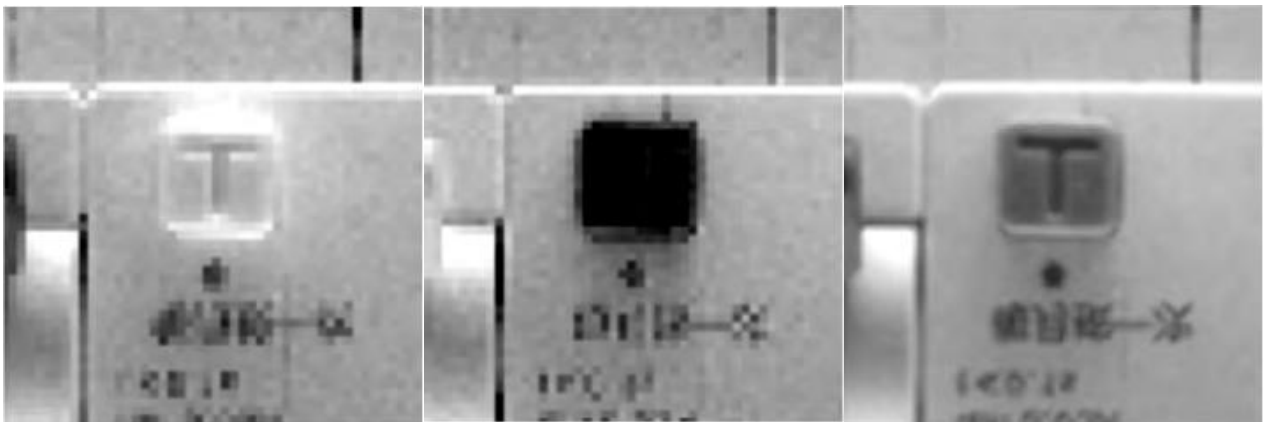
3.2 The Description of Algorithm

T-button location algorithm

Set the tested window . The main purpose of the system is to detect whether the installation orientation of the T button is correct, so the key step is to collect clear images under test. Because the mechanical vibration on the pipeline causes the products on the conveyor belt to shake constantly, it is impossible to obtain the test button image by presetting the position of the tested image. Therefore, this paper presets a large acquisition rectangle window on each circuit breaker image[5]. The window includes

the T button, and the size of the window ensures that the T button is not biased out of the window coursed by the vibration of the device. After the experiment, the size of the intercepted image is set as 96*96 pixels.

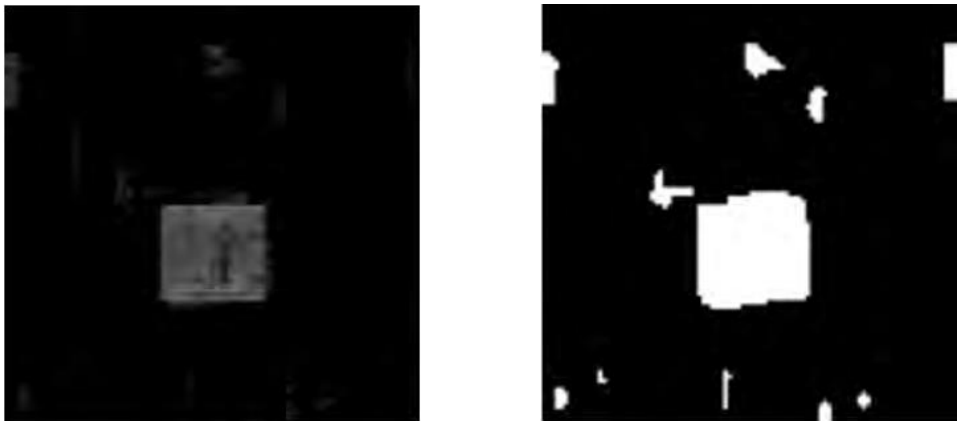
RGB image preprocessing. A pixel of an RGB color space image is composed of three components, R, G and B, of which R, G and B are gray level descriptions of red, green and blue respectively. According to the color theory, various colors can be obtained through the change of the three color channels of RGB and the superposition of each other. When a region in the image appears red, its red component must be larger than the other two components. Then, if the red channel image is subtracted from the blue and green channel image, the red region image can be extracted. The test button of the miniature circuit breaker used in this test is orange, the same color does not exist in other areas of the product. The image of the T button area was separated according to the three channels of RGB. The RGB channels of region image is shown in figure 4.



(a) R channel image (b) G channel image (c) B channel image

Fig 4 RGB channels of region image

It can be seen from the images of each channel that the pixel value of the red channel of the test button was significantly higher than that of the green channel and the blue channel, while the pixel value of the three channels of the background area was similar. In this paper, the difference operation is performed in the RGB color image space, and the difference image is obtained by subtracting the green channel and the blue channel from the red channel image. Then the difference image is denoised, and the mean binarization algorithm is used to segment the difference image. The images of difference operation and binarization algorithm are shown in figure 5.



(a) image after difference operation (b) image after binarization algorithm

Fig 5 images of difference operation and binarization algorithm

Connected domain labeling algorithm. The connected domain marker is based on binary image (foreground pixel gray value is 1, background pixel gray value is 0). According to some connectivity rules of pixels in the image, pixels of the same connected domain are represented by the same label, so as to distinguish the connected region. In fig 5(b), the difference image is segmented by binarization to form a number of connected areas. The area where the test button is located is the

largest. In this study, binary images were scanned twice and the results were marked. The test button can be located from the region of interest image by finding the region with the largest number of tags in the tag result.

binarization algorithm research of T button image

In order to detect the character T, the image of the test button must be segmented. Before image segmentation, the original image needs to be grayscale. Histogram equalization algorithm is adopted to improve the image contrast and gray range. After the equalization, the image is obviously clearer and the contour of the character T is more obvious. In this study, a binarization algorithm based on normalization was used to segment the test buttons[6].The calculation process is shown as follows

$$dst(i,j) = \frac{(src(i,j) - \min(src)) * (b' - a')}{\max(src) - \min(src) + a'} \tag{1}$$

Where, dst ——target image, src ——source image; i ——row; j ——column; $\min(src)$ ——The minimum pixel value of an image ; $\max(src)$——The maximum pixel value of an image; $a' = MIN(a,b)$; $b' = MAX(a,b)$;a, b means the range to normalize, the value ranges from 0 to1;In this study, when the threshold value is 0.5, the background shadow effect of character T is better. The Image segmentation results of characters T in different directions are shown in figure 6

Fig 6 Image segmentation results of characters T in different directions

As can be seen from the figure, the character T presents a relatively clear state, but there are still partial shadows on both sides, but corrosion can be used for filtering later.

3.2.1 Judgement part

This section will match the final processed T character with the target template T character and draw a conclusion. The essence of template matching is to search for a target in a large image[7].Due to the small size of the positioning image, the traditional xor algorithm can be used, and the established test button template can be used to traverse the image to be detected. The xor calculation is small and easy to implement, which can meet the real-time requirements of the system and realize the fast detection of the test button.

4. Analysis of experimental results

To verify the quality of system , 100 miniature circuit breakers of were tested on site, 80 of which were installed correctly and 20 were installed incorrectly.A total of 5 tests were conducted, and the test results are shown in table 1.

Table 1 Test result of miniature circuit breakers

Test No.	correct number of circuit breakers	error number of circuit breakers	accuracy (%)	misjudgment rate(%)
1	79	20	99	1
2	80	20	100	0
3	79	19	98	2
4	80	19	99	1
5	79	20	99	1
Average value	70.4	19.6	99	1

As can be seen from the experimental results in table 1, after five tests, the detection accuracy of the visual detection system for the test button of the miniature circuit breaker is as high as 99%, and the misjudgment rate is only 1%.

5. Conclusion

To sum up, this study builds a miniature circuit breaker surface detecting system based on Machine Vision Technology. The system structure is simple and easy to implement. The experiment and practical application show that the system can detect the installation direction of the test button, the system is reliable and with high accuracy, this provide an important reference for future research.

Acknowledgments

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