# Circuit Board Defect Detection based on Image Processing

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***Abstract*—Because the conventional printed circuit board defect detection is slow, a method base on the edge of image is proposed, this method can quickly locate and detect the detects on the circuit board. The algorithm combines gradient direction characteristics of image edge gray, the different characteristics of different defects in standard image and defect image are used to classify the defects, and then identify the type of defects. Experiments show that this method can detect the short circuit, opening, burr , hole and other defects of the circuit board quickly.**

***Keywords-defect detection; gray gradient; gradient direction; edge detection***

## I. INTRODUCTION

As the printed circuit board (Printed Circuit Board, referred PCB) manufacturing industry developed rapidly, PCB as the basic components of electronic products, has become the essential devices of the computer, mobile phones and other electronic products [1], with the increase of the production complexity and the output of the circuit board, the quality of PCB will not only affect the performance of products, but also affect the security of products. Environment, temperature, equipment, and the incorrect operation will cause the appearance of defects. Due to there are inevitable defects will occur in the process of PCB production, such as short circuit, open circuit, burr, defect, hole and other defects. To ensure the quality and security, PCB board must be detected, the aim is to examine these quality issues timely. At present, there are three methods to detect the detects on printed circuit boards, respectively are reference comparison method, the non-reference comparison method and mixing method [2]. Reference comparison method is that the test image is compared with the standard image; Non-reference comparison method is based on the rules of preset criteria to judge whether there is defective, if it does not match the standards, and thinks that it is defective; The hybrid method is a mixture of the two methods, combines the respective advantages of these two algorithms. This paper mainly uses the reference comparison method, through compares and analysis the test image and the standard image, than judge whether there are defects. So for traditional PCB defect detection method, this paper presents that scanning the edge of image to obtain the gray projection image, analysis the characteristics of different defects in the gray projection, defects can be identified and detected quickly.

## II. SYSTEM STRUCTURE

The overall structure of PCB automatic detection system includes two parts, hardware and software. The hardware part mainly has a light unit, an image acquisition unit, motion control unit and an image processing unit. The purpose of the illumination unit is to generate the suitable lighting, the resulting image has higher contrast and clarity. Motion control unit is used to move the platform and get the PCB image. Image acquisition unit is used to collect the circuit board image. Computer image processing unit is the core of the software, by using appropriate algorithm, the defects of PCB are detected. The structure of the system is shown in Figure 1.

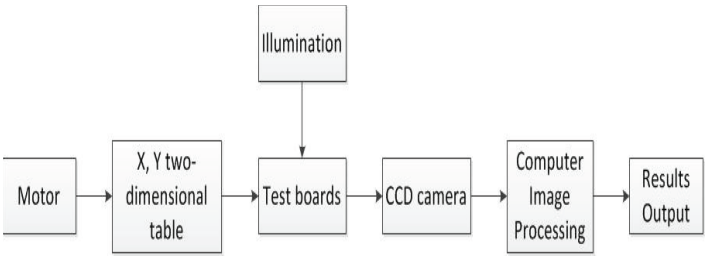



Figure 1 system structure diagram

Working principle of the system: The test circuit board is placed on the motion control console, computer control motor movement, motor driven two dimensional work table movement, make accurate positioning of the PCB board. The CCD camera is transmitted to the test image above, in the appropriate illumination conditions, by the CCD camera and image acquisition equipment accurately collect the test image, the acquired digital image is transmitted to the computer processing module, by defect recognition module in computer, identify the type of the defect and output the result.

## III. SYSTEM SOFTWARE DESIGN

Computer image processing is an important part of PCB detection system, the detection performance of the whole system will be affected directly by it. It includes standard image and test image pre-processing and binarization, the position of the defect is obtained by the contrast of the standard image and the test image, than extract the defect part, with edge detection algorithm to extract the edge of the image, making the gray projection of the edge of image. Finally, identification

of defects, the detection result will be output. The specific detection process is shown in Figure 2.

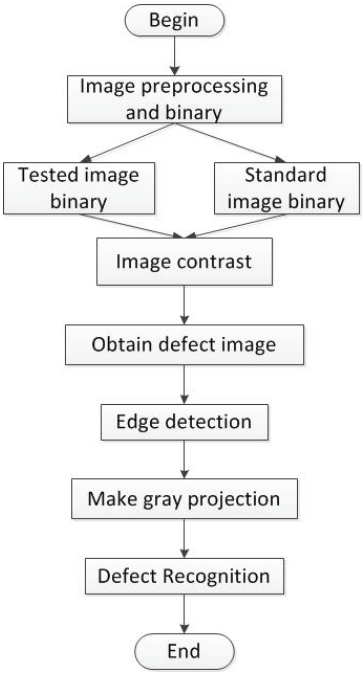



Figure 2 detection flow image

### *A. Image preprocessing and binarization*

In general, in the process of PCB image acquisition and transmission, will be possible to make the decline in the quality or distortion of image, in this case, PCB images are required to be pre processed, the aim is to make the analysis and processing of the image more convenient. The purpose of image pre-processing is to remove the noise and improve the quality of the image. By contrast stretching method to enhance the quality of the image; median filtering method is used to filter out noise in the image. The results of image pre-processing is shown in Figure 3.

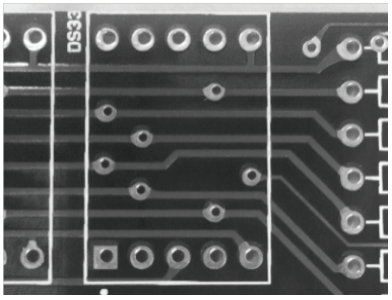


Figure 3 the results of pre-processing

For PCB images, the target we are interested in is the line and the fault part of the image, in order to indentify and analyze these goals, they need to be extracted. Image binarization aim is to separate the line from the PCB board, since the circuit board histogram has significant trough, by using bimodal histogram method [3] to segment the image, can get good recognition results. The results obtained after the image segmentation as shown in Figure 4.

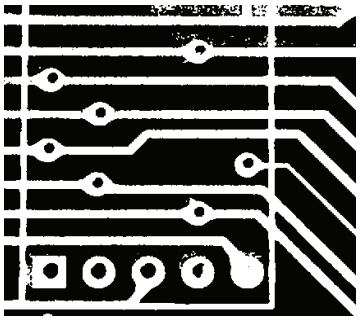


Figure 4 the segmentation results image

### *B. image contrast*

In this paper, we need to detect the detects of the PCB image, and after obtaining binary images of the test PCB image and the standard PCB image, compare the difference between the test binary image of PCB bare board and the standard image to judge whether the PCB bare board has defection, using subtraction method to get the difference between the two images. The standard image and defect images directly do subtraction operation[4], when the standard image is minuend, the defect image is subtrahend, can get defect image of open circuit, voids and defects, as shown in Figure 5 (a). When the defect image is minuend, the standard image is subtrahend, can get defect image of burr and short circuit, as shown in Figure 5 (b).

(a) (b)

Figure 5 defect point image

By contrast images, the difference image is obtained, by a certain order to find defects point from the difference image, and find the defect position of the difference image and recorded it, then defect centers as a benchmark, designate a certain area range, the defect in the test image can be extracted using the optimal rectangular region.

### *C. image edge detection*

Edge detection is the most basic technology in image processing and computer vision. The essence of edge detection is to use some algorithm to extract the boundary between the object and background in the image. In the process of image processing, the edge can greatly reduce the image information being processed, and also retain the shape information of the object in the image. The purpose of edge detection is to identify the point of brightness changed significantly in the digital

image. The commonly used edge detection operator includes Roberts operator, Sobel operator and Canny operator [5], Roberts operator can accurate positioning, but it will lose some information. Canny operator is the most sensitive to all kinds of noise, and can generate false edge. The Sobel operator has a smooth effect on the noise, can provide accurate edge direction information. Sobel operator detects edges from different directions, and uses the gray weighted algorithm of the pixel points to do the edge detection. Classic Sobel edge detection algorithm use two directional template to complete the neighborhood convolution in the image space. The horizontal and vertical templates of the Sobel operator are:

$$S_1 = \begin{matrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{matrix}, \quad S_2 = \begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{matrix}$$

To each of the identified boundary points, the gradient values of gray images of the points are calculated by Sobel operator of $3*3$ size template. The gradient vector of the image $f(x,y)$ in $(x,y)$ points is defined as $\nabla f = \frac{G_x}{G_y} = \frac{\partial f / \partial x}{\partial f / \partial y}$,

Vector $\nabla f$ in $(x,y)$ direction angle is defined as $\alpha(x,y) = \arctan(G_y / G_x)$ ,for sobel operator, the horizontal and vertical gradients of the center $3*3$ window $\begin{matrix} Z_1 & Z_2 & Z_3 \\ Z_4 & Z_5 & Z_6 \\ Z_7 & Z_8 & Z_9 \end{matrix}$ are respectively:

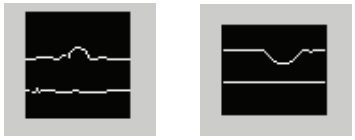
$$G_x = (Z_7 + 2Z_8 + Z_9) - (Z_1 + 2Z_2 + Z_3)$$

$$G_y = (Z_3 + 2Z_6 + Z_9) - (Z_1 + 2Z_4 + Z_7)$$

The gradient vector model can be approximated by absolute value $\nabla f \approx |G_x| + |G_y|$.

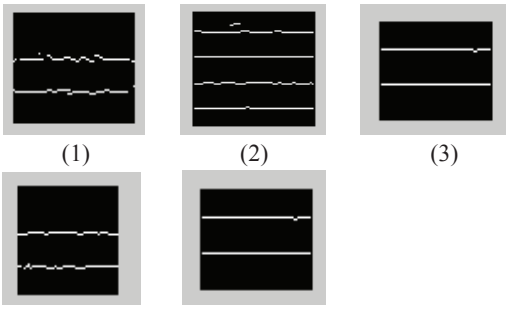
Image edge detection greatly reduces the amount of data, and it can cut out the irrelevant information, and retain the important structural properties of the image. The edges of standard images and defect images are extracted by Sobel algorithm. Figure 6 (1) to (5), respectively indicated the defect edge image of open circuit, short circuit, voids, burrs and defects, and figure 7(1) to (5), respectively indicated the edge image of standard image of the corresponding position of each defect.

(1) (2) (3)



(4) (5)

Figure 6 edge detection image of each defect



(1) (2) (3)

(4) (5)

Figure 7 the edge detection image of the standard image of the corresponding position of each defect

## IV. EXPERIMENTAL ANALYSIS USING

### *A. defect analysis*

By the process of pattern recognition, we can know that if we want to judge each defect, we must know the characteristics of each defect. PCB board line defects mainly include short-circuit, opening, defect, burr and hole etc, through comparative analysis of the defect edge image and the standard edge images, we can know that, the short circuit occurs between two lines, which is connected with the two lines, and is the defect of the wire. The opening, the defect, the void and the burr all occur on one line, but the characteristic is different. The opening refers to a line completely breaking off, the defect is a defect of the line at one end and the line is not broken, the hole is the middle of the line and the line is not broken. These three kinds of defects are in a line. Burr appeared outside the line, it belongs to defect outside the line.

Gray projection method is used to deal with said types of defects, by analyzing the characteristics of the edge in the gray projection results to identify and classify defects. Using the gradient direction of the edge of the circuit to judge the direction of the line in the edge image. If the direction of the line is horizontal, the gray level projection of the edge image is directly used. If the direction of the straight line is tilted, first seek its rotation angle, using the Radon transform to rotate the straight line to the horizontal direction, and then the gray level projection is made. In the following figures, the abscissa represents the line number of horizontal scan the edge of the image, the vertical axis represents the number of white pixels per line. Figure (A) ~ figure (E) respectively are open circuit, short circuit, voids, defects and burrs and its corresponding standard image of gray level projection. Then find the differences between the gray edge projection of each defect image and the gray edge projection of their corresponding standard image, the difference between them as the basis for the classification of defects.

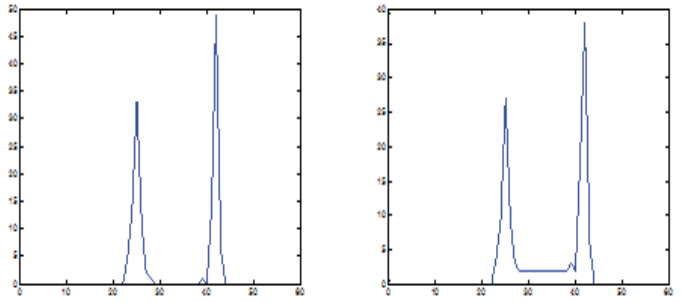


Figure (a) disconnection horizontal projection

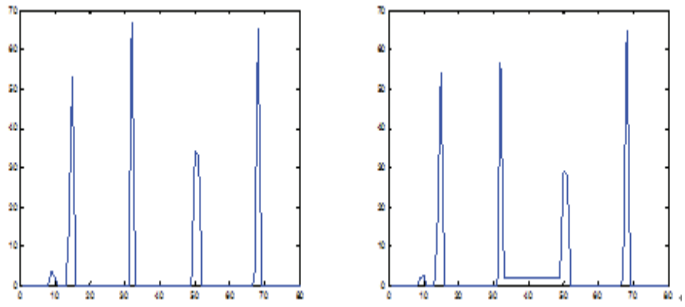


Figure (b) short-circuit horizontal projection

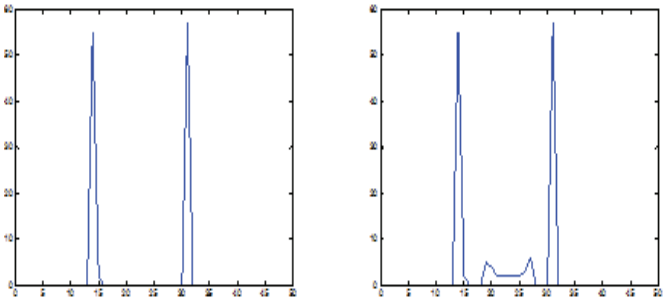


Figure (c) void horizontal projection

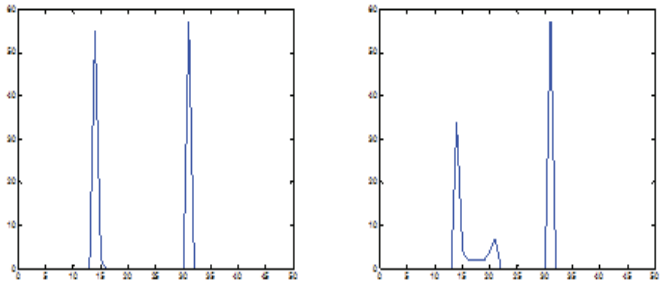


Figure (d) horizontal projection of the defect

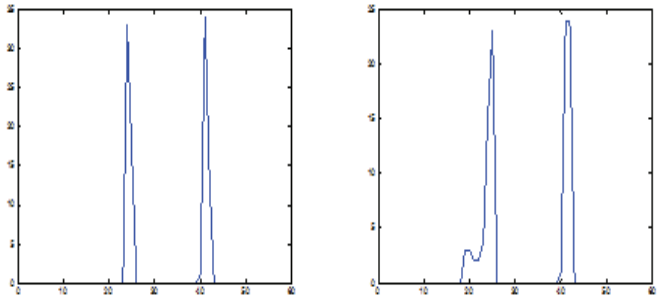


Figure (e) burr horizontal projection

*B. defect classification*

The judgment of defects is based on reference comparison method, the identification is based on the following analysis. First of all, different defects have different characteristics, we must find the different characteristics of each defect in the gray level projection map, and it can be seen that there is a number of value range in the gray projection of the standard image and the gray projection of each defect image is different. The number of value range in the gray level projection of each defect is counted, from each gray projection, if the number of value range is 1, it is open circuit defects; if the number of value range is 2, it is the defect and the burr defect; if the number of value range is 3, it is the empty and the short defect. Then statistics the number of value range in the gray level projection of each standard, and compared with the number of value range in the gray level projection of defect, the number of value range in holes is 1 more than the standard image; the number of value range in short circuit is 1 less than the standard image. Statistics the range of value range of gray projection of each standard image, if the defect is increased in the inner side, it is a defect; if the defect is increased in the outside, it is burr.

According to the defect characteristics in figure(a)~figure(e) and the above analysis, we know the characteristics of all kinds of detects. We use the reference comparison method to detect detects, and set up the test flow chart as shown in figure8.

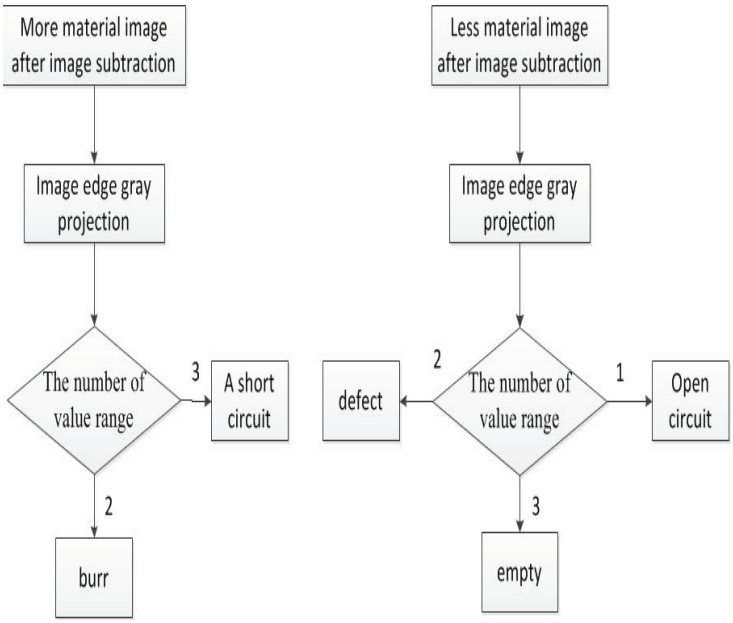



Figure 8 test flow chart

In PCB defect detection, calculating the area of the defect area and the number of connected domain is a commonly method to find defects on PCB. But this method has several drawbacks. For example, if the defect area is too small, the defect can be omitted, and the time consumed by this method is longer, the proposed method can solve the problem. Using this method and the proposed approach do five experiments and calculate its time consuming, the data obtained are shown in Table 1.

TABLE I. PCB DEFECT DETECTION TIME-CONSUMING STATISTICS

| Serial number | Comparison of 2 methods | |
|---|---|---|
| | *Time consuming of Area and connected domain method（s）* | *Time consuming of this method（s）* |
| 1 | 6.18 | 5.32 |
| 2 | 6.02 | 5.13 |
| 3 | 5.75 | 5.03 |
| 4 | 6.45 | 5.33 |
| 5 | 5.98 | 5.13 |

Comparison of experimental data, the method used in this paper is less time-consuming. So the defects on the circuit board can be defected quickly.

## CONCLUSION

Experimental results show that the method can effectively detect the common defects on the circuit board, because only need to extract the edges of the image to analysis and calculation the speed, compared with the traditional detection methods, such as the area of the defect and the method of the connected domain, the time consumed is less. Therefore, using the edge gray gradient of printed circuit board can effectively improve the positioning speed and classification accuracy. The next step is to study how to improve the precision of edge detection, the defects can be accurately detected.

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