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Automatic Detection Method of Circuit Boards Defect Based on Partition Enhanced Matching

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Abstract: Automatic detection of circuit boards defect based on the image processing techniques, is affected by the too large size of the circuit boards image and unclear characteristic factors and its detection speed and detection accuracy always needs to be improved. To this end, an automatic detection method of circuit boards defect based on partition enhanced matching was proposed in this study. First, the image of standard board and pending board was divided into some sub-blocks. Second, a piecewise linear transformation method was used in enhancing the characteristics of the image of each sub-block. Finally, gray scale statistical matching method was used to determine whether the sub-lock image is defective. Experimental results show that this detection method can obtain a fast speed and a good accuracy.

Key words: Circuit boards defect, image segmentation, image enhancement, image matching

INTRODUCTION

Quality testing of circuit boards is a very important work which directly related to whether the electrical equipment assembly and commissioning work could effectively complete (Tae-Hyoung and Hwa-Jung, 2005). This detection work can be divided into two directions. One is specifically targeted at the detection of the bare board (on which only printing the transmission lines and no electrical component), another is targeted at the detection of the complete board (on which a variety of electrical component has been configured). This article focuses on the first type of circuit board.

In the printing process about circuit boards, a bare board may include a variety of defects, such as short circuit, open circuit, bumps, dents, etc. (Tee and Pascual, 2007). For detecting these defects, the main mean is artificial visual observation. This approach is not only inefficiency, but the undetected rate significantly increased with increase of the labor intensity of testing personnel (Putera *et al*., 2012).

In recent years, the research to improve defect detection efficiency and automation of circuit board had constantly appeared, vision inspection and pattern recognition technology based on the image processing had commonly been applied (Jiang *et al*., 2012; Da Silva *et al*., 2010). From the current level of research, two problems have constrained the development of visual detection technology of the circuit boards defect. First, image noise will be introduced in the process of capturing the circuit board image. How to highlight circuit morphological characteristics becomes very critical (Qingxiang *et al*., 2010; Putera and Ibrahim, 2010; Benedek, 2011). Second, the image of the circuit boards is relatively large and the time consumed to perform image processing and pattern recognition algorithms is relatively long that will affect the real time performance of automatic detection (Gebus *et al*., 2009; Jingchao, 2000; Shuchun *et al*., 2011; Yu *et al*., 2011).

To this end, we build an automatic detection method of circuit boards defect based on partition enhanced matching, under the premise of accurately pinpoint of circuit boards defect and upgrade the speed of automatic query.

ANALYSIS OF THE IMAGE FEATURE OF CIRCUIT BOARDS DEFECT

In the printed circuit board, due to malfunction of mechanical welding torch, walk errors, solder adhesions, PCB board inherent defects and other issues, a variety of printing defects will come into beings. Among them, the most common defects include short circuit, open circuit, sunken, hump, pinholes, etc., displayed in the form of image feature, as shown in Fig. 1.

In these defects, sunken, hump and pinholes characteristics will cause the instability on the circuit partial connection and the open circuit characteristics, short circuit characteristics will directly lead the entire circuit system not work properly. Therefore, the detection of defects of the printed circuit board is the essential work to ensure whether it meet the processing requirements.

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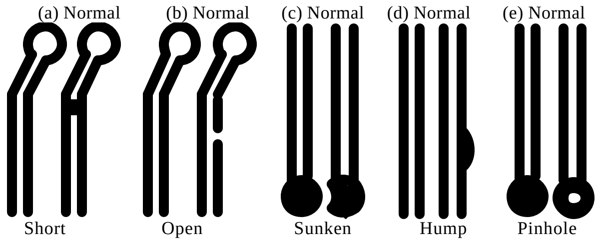

Fig. 1(a-e): Image feature of defect of circuit board. (a) Short defect, (b) Open defect, (c) Sunken defect, (d) Hump defect and (e) Pinhole defect. If there are some defects, the circuit board is often difficult to work normally

DEFECT DETECTION METHOD BASED ON PARTITION ENHANCED MATCHING

When conducting defect detection of large quantities of printed circuit boards, artificial method becomes powerless. In order to improve accuracy and speed of the defect detection, automatic detection method is generally used based on image processing. A common detection idea is that use the standard board without any defects as detection benchmark and compare printed circuit image between pending board and standard board by using the comparison method based on the image gray statistics. If statistical difference is not bigger than the threshold, the pending board will be confirmed no defect. On the contrary, the pending board will be considered defective. In practical applications, this method is restricted by two conditions. First, the image capturing process will be subject to a variety of factors, resulting in that the characteristic information is not obvious. Second, the image of the printed circuit board is generally relatively large. When gray feature statistical comparison is carried out, real-time of automatic detection is poor.

To this end, we have designed a defect detection method based on partition enhanced matching. First, carry out same segmentation for images of standard board and board to be detected. Second, conduct feature enhancement for each sub-block image. Third, implement the gray scale statistics matching in the corresponding sub-blocks image between standard board and pending board. Finally, judge whether there is some defects on pending board image according to threshold and mark them if the pending board had been confirmed defective. The advantage of this method is that, after block processing, the execution time of a variety of image processing algorithms on sub-block image is very low, thus ensuring high-speed execution of the entire inspection process. In addition, more accurate result will be obtained about defect detection by using the enhanced matching method.

Block processing of the original image: For the image of the standard board and each image of the board to be detected, block processing should be carried out firstly. According to different size, original image will be divided different number. A 256*256 pixel image can be divided into 16 sub-blocks and mathematical description is shown in formula (1):

$$B=\begin{bmatrix} B_{11} & B_{12} & B_{13} & B_{14} \\ B_{21} & B_{22} & B_{23} & B_{24} \\ B_{31} & B_{32} & B_{33} & B_{34} \\ B_{41} & B_{42} & B_{43} & B_{44} \end{bmatrix} \tag{1}$$

where, B represents the original image and B_{ij} represents the sub-block image.

After this processing, the subsequent defect detection work transformed into the matching problem of sub-block image between printed circuit board to be detected and standard board.

Image enhancement based on the piecewise linear transformation: Affected by the camera photo luminosity, ambient lighting conditions, electromagnetic noise interference, some problem will appear during the process of shooting circuit board image. For example, features are not clear and contrast between effective area and background is not strong. To this end, image enhancement technology should be used in strengthening the features. For general image of circuit board, the gray histogram has three obvious intervals, background area, bonding wire area, solder joints area. In this case, piecewise linear transformation can be used in enhancement for circuit board image.

Let f(x, j) and f'(x, j), respectively describe the pixel of original image and transformed image. To original image, relationship between several major gradation interval point is shown as $0<\alpha<\beta<T_f$. To transformed image, relationship between several major gradation interval point is shown as $0<\alpha<\beta<T_f$. The transform model is just like formula (2):

$$f'(i,j)=\begin{cases}\dfrac{\alpha'}{\alpha}f(i,j) & 0\le f(i,j)<\alpha\\ \dfrac{\beta'-\alpha'}{\beta-\alpha}[f(i,j)-\alpha]+\alpha' & \alpha\le f(i,j)<\beta\\ \dfrac{T_f-\beta'}{T_f-\beta}[f(i,j)-\beta]+\beta' & \beta\le f(i,j)<T_f\end{cases}\tag{2}$$

For different circuit board images and different sub-blocks, interval points should be set according to the distribution of their original histogram. Thus, enhancement result will be more effect.

Image matching based on the gray scale statistical characteristics: After block processing and feature enhancement, pending board defect can be judged by comparing sub-block of standard board image and sub-block of pending board image. Here, image matching technology was used with gray scale statistical characteristics to carry out the comparison between the image of the corresponding sub-blocks. Mathematical formula is as follows:

$$\text{Sim}=\frac{\sum_{s=-c_y}^{w_y-c_y}\sum_{t=-c_x}^{w_x-c_x}[I_Q(x+t,y+s)-M_Q(x,y)]^2}{\sum_{s=-c_y}^{w_y-c_y}\sum_{t=-c_x}^{w_x-c_x}[I_S(x+t,y+s)-M_S(x,y)]^2}\tag{3}$$

where, Sim represents a similarity comparison, the subscript S, Q represents the sub-blocks of the standard broad image and sub-blocks of pending board image, w_x and w_y is the height and width of every sub-block image, (c_x, c_y) represents the center point coordinates of the image of the sub-block, (x, y) represents the arbitrary pixel of image of the sub-blocks. M(x, y) is calculated as Eq. 4:

$$M(x,y)=\frac{1}{w_y*w_x}\sum_{i=-c_y}^{w_y-c_y}\sum_{i=-c_x}^{w_x-c_x}I(i,j)\tag{4}$$

By comparing Sim with the prefined threshold, the detection conclusion will be obtained whether the pending board has defects.

EXPERIMENTS AND EXPERIMENTAL ANALYSIS

In order to verify the effectiveness of the proposed method, we carried out the actual detection experiments. The images of standard board and pending board and their sub-blocks are shown as Fig. 2.

In Fig. 2, the size of original image is 150*144 pixels. According to this size, it is divided into six sub-blocks with the size of 50*72.

Where the left is the image of the standard board and the right is the image of pending board to be detected. Thereafter, piecewise linear transformation was used in enhancement of very sub-block and gray scale statistical matching was performed to detect defects on pending board. Detection result is shown in Fig. 3.

In Fig. 3, the top of the figure is the original sub-block after image segmentation and the bottom is enhanced sub-block through the piecewise linear transformation. As an example with first sub-block of the standard board image, gray-scale of several images ranges in 0-10, 10-50,50-150 before strengthen. After strengthen, gray-scale range in 0-30, 30-80, 80-200. By image enhancement, features brightness becomes evident in the image. After matching similarity just like Eq. 3, defective sub-block was identified as numeral "1", "2", "3", "4". Sub-block with label "1" has sunken defect. Sub-block with label "2" has short defect. Sub-block with label "3" has hump defect. Sub-block with label "4" has open defect. Experimental results show that not only defect had been detected but also defect region had been obtained by using the detection method proposed in this study. At the same time, detection time is only 19.7 msec for 150*144 size image.

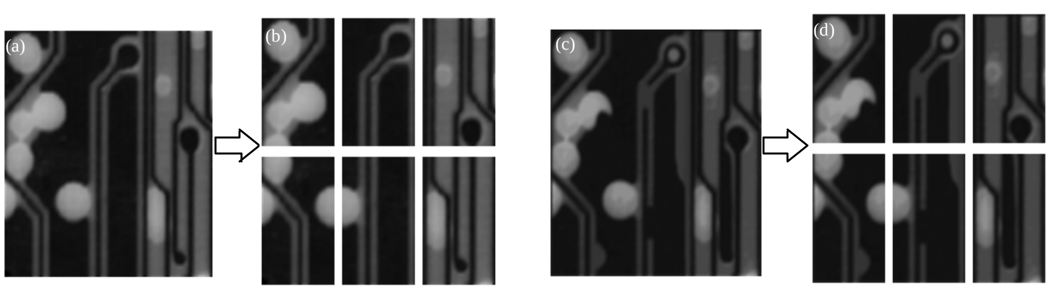

Fig. 2(a-d): Results of image segmentation. (a) Standard circuit, (b) Six subimages of standard circuit, (c) Deffect circuit board and (d) Six sub images of defect circuit board. Based on the work of this step, defect detection will be carried out by comparing sub-image of corresponding position between standard circuit board and defect circuit board

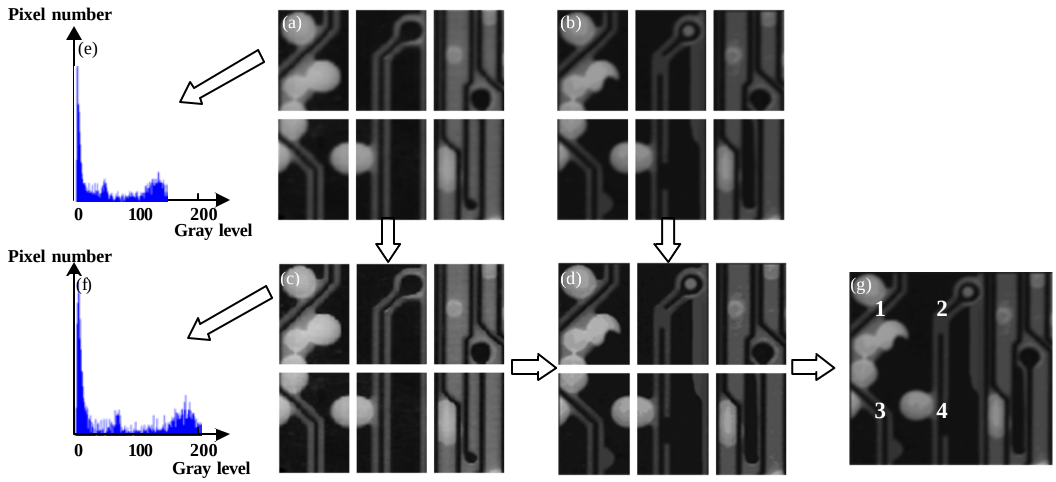

Fig. 3(a-g): Experimental results, (a, b) Original standard image and defect image of circuit board the top, (c, d) Enhanced standard image and defect image, (e, f) Two histogram of first-block of original standard image and enhanced image and (g) Detection result image is shown at right

DISCUSSION

Compared with current methods, the proposed method has some advantages as followings:

- From the view of theory, the existing methods use some high-complexity algorithms, such as wavelet packet decomposition (Qingxiang *et al*., 2010), path planning method (Tae-Hyoung and Hwa-Jung, 2005), biological characteristics classification (Jiang *et al*., 2012). In this study, we only use common image processing operation to achieve the same detection effect
- From the view of operation, the existing methods often use other means to assist detection, such as marked points (Benedek, 2011), biological characteristics (Jiang *et al*., 2012), X-ray (Tee and Pascual, 2007). In this study, our method only use common image processing method without using any other auxiliary means
- As the time of detect circuit board defect, the proposed method also roughly locate the defect region. Besides, the speed of our method is fast

CONCLUSION

For solve the problem of automatic detection of circuit boards defect, an automatic detection method based on partition enhanced matching had been proposed in this study. In this method, original image was segmented into some sub-block image first which create the conditions for the reduction of time-consuming. Then, piecewise linear transformation technology was used in strengthening image characteristics, and image matching technology based on gray statistics was using retrieve the similarity between sub-block image of standard board and sub-block image of pending board. Experimental results show the advantages of this detection method in terms of accuracy and real-time.

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