Detection and Classification of Printed Circuit Board Defects Using Image Subtraction Method

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Abstract- The method for detection and classification of defects in Printed circuit boards using image subtraction has been presented in this paper. Image subtraction method is one of the simplest methods for the inspection of the PCB defects. The defects like missing hole, over and under etching, wrong hole size defects, missing conductor and break lines have been detected and classified in this paper.

Keywords- Image subtraction, detection, PCBs, classification, XOR operation, NOT operation.

I. INTRODUCTION

Different methods have been developed for the computer based inspection of the PCBs. These methods can be classified as referential and non-referential. In referential method, test image has to be compared with the base image, which is considered to be 'perfect image'. Examples of referential methods are dimension verification and expansion/contraction [1], image subtraction method [2], template matching [3].

Non-referential methods are based on generic design rules for the printed circuit boards [1]. In the non-referential method, there is no need of standard image. Defects in PCBs can be divided into two main parts: fatal and potential. Fatal defects are those in which the PCB does not fulfill the objective they are designed for, and potential defects are those compromising the PCB during their utilization [3], [4].

A new method based on referential technique has been proposed in this paper for detection and classification of defects. For each defect a separate handcrafted algorithm has been developed.

II. IMAGE SUBTRACTION METHOD

Image subtraction is a kind of pixel subtraction process, where by the numeric value of one pixel or the complete image is subtracted from the image. The image subtraction operator takes two images as input and third image as output, whose pixel values are simply those of the first image minus the corresponding pixel values from the second image. Authors had earlier implemented the image subtraction method to obtain the differences between the two images [2]. The method had compared both the images pixel-by-pixel using XOR logic operator. The resulting image had shown only the defects.

The subtraction of two images was performed as:

$$g(i,j) = f_1(i,j) - f_2(i,j) \quad \ldots\ldots\ldots\ldots \quad (1)$$

where g is the output image
f_1 is the reference input image
f_2 is the inspected input image

TABLE I. TRUTH TABLE FOR XOR LOGIC OPERATION

Bit 1	Bit2	Output
0	0	0
0	1	1
1	0	1
1	1	0

In Table I, it has been shown that if the bit1 (pixel value) of base image is not equal to pixel value of test image (bit 2) then there is a defect.

Image subtraction method can be implemented on assembled PCBs [5], solder pasted PCBs [6]. Solder joint inspection based on neural network combined with genetic algorithm had aslo been proposed [7] In subtraction based methods following are the basic steps: i) image acquisition has been done to acquire the digital image ii) image processing has been done to suppress the noise and other distortions from the image to be processed iii) image alignment has been done to align the true image and the test image. iv) image subtraction has been used to obtain the difference between the true and the test image.

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For the classification of the defects the resultant difference image has been used [8]. Above explained method can be combined with wavelets with reduced pixel value of image to detect the defects [9], [10].

III. DEFECT CLASSIFICATION USING MODIFIED IMAGE SUBTRACTION METHOD

The method which follows a two step process to detect and classify the defects has been proposed. In the first step, defects have been detected and in the second step, the defects have been classified. For classification of different defects, separate handcrafted algorithm has been developed.

Step – I: Detection of defects in PCB image

For the detection of defects, the test image (I_T) is compared with the base image (I_B) using image subtraction method. Two output images are obtained (positive image (I_P) and negative image (I_N) as shown in the following equations:

$$I_P = I_B - I_T \quad (2)$$
$$I_N = I_T - I_B \quad (3)$$

The addition of the positive image and the negative image gives all the detects present in the test image. The defects are stored in an intermediate image named detection image (I_D). The whole process of detection has been shown in Fig.1.

$$I_D = I_P + I_N \quad (4)$$

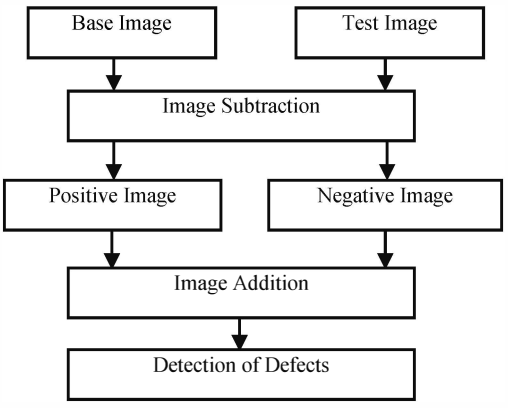

Fig.1 Flowchart for Detection of defects in test image

Step- II: Classification of Defects

The various algorithms have been developed for classification of different defects presented as under:

A. Classification of wrong hole size defects

For the classification of wrong hole size the process has been graphically shown in Fig. 2.

In this I_P and I_N images has been used along with the complement of test image (I_{CT}). Flood fill operation (fill all the empty spaces and holes) has been applied on the complement of the test image (I_{CTF}). The I_N image has been subtracted from the I_{CTF} image presented difference image (I_{DCF}). Finally the result of I_{DCF} has been subtracted from I_{CTF} . The wrong hole size defects has been presented by the output image(I_{WHD}).

$$I_{DCF} = I_{CTF} - I_N \quad (5)$$
$$I_{WHD} = I_{CTF} - I_{DCF} \quad (6)$$

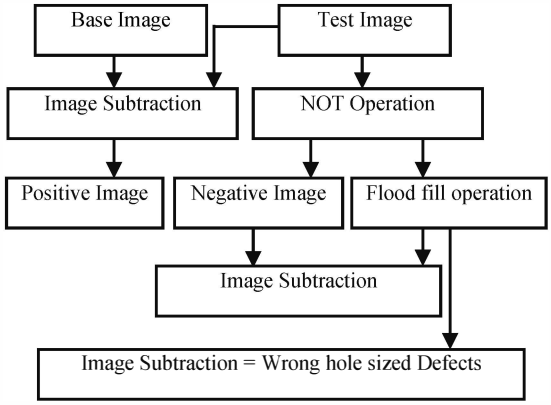

Fig.2 Flow chart for the classification of wrong hole size defects

B. Classification of etching defects

For the classification of etching defects the process has been graphically shown in Fig.3.

In this I_P and I_N image has been used along with the complement of base image (I_{CB}). Flood fill operation has been applied on the complement of the base image (I_{CBF}).

The I_{CBF} image has been subtracted from I_P image to present the output image(I_{ED}) as etching defects.

$$I_{ED} = I_P - I_{CBF} \quad (7)$$

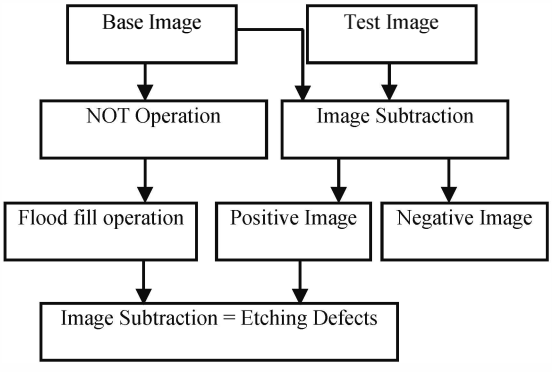

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Fig.3 Flowchart for the classification of etching defect

C. Classification of missing hole defects

For the classification of missing hole defects the process has been graphically shown in Fig. 4.
In this I_P and I_N image has been used along with the complement of base image (I_{CB}). Flood fill operation has been applied on the complement of the base image (I_{CBF}). The I_{CBF} image has been subtracted from I_P image to present the output image(I_{ED}) as etching defects.

Finally I_{ED} has been subtracted from I_P. The missing hole defects have been presented by the resultant image(I_{MHD}).

$$I_{ED} = I_P - I_{CBF} \quad (8)$$
$$I_{MHD} = I_P - I_{ED} \quad (9)$$

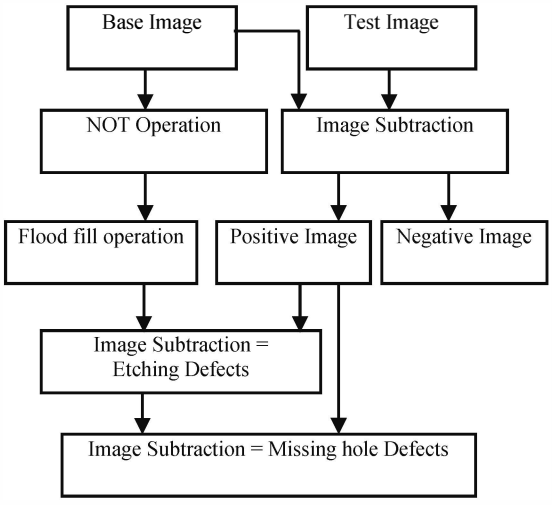

Fig.4 Flowchart for the classification of missing hole defects

D. Classification of missing conductors & break lines

The remaining defects can be classified by the addition of all the defects classified (results of Fig. 2,3,4) and then subtracted from all the possible defects (result of Fig.1).

IV. RESULTS

The proposed method was tested using a number of faulty PCB images. The faulty PCBs were manually generated from fault free PCB images. The results on one of the test images in terms of detection and classification has been visually shown in the Fig.5 (a-e).

A. Detection of defects

Fig. 5(a) shows base image which has been considered as the reference image for all the test image. Fig.5 (b) shows the faulty test image with defects like missing hole, over and under etching, wrong hole size defects, missing conductor and break lines.

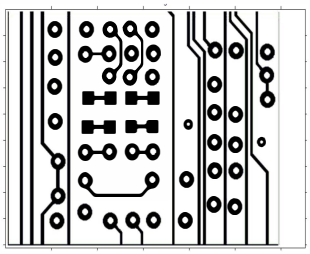

Fig. 5(a) Base image

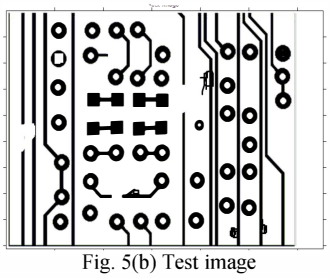

Fig. 5(b) Test image

Positive image computed by the subtraction of test image from the base image has been shown in Fig. 5 (c) and negative image computed by the subtraction of base image from the test image has been shown in Fig. 5(d). Addition of positive and negative image that leads to detection of all possible defects in test image has been shown in Fig. 5(e).

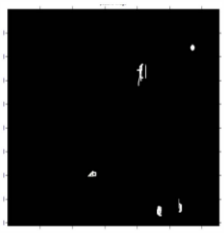

Fig. 5 (c) Positive image

Fig. 5(d) Negative image

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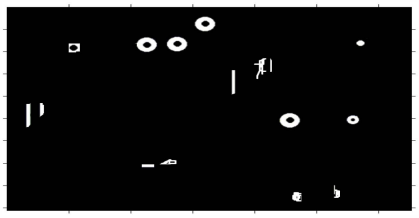

Fig. 5(e) Detection of all possible defects in test image

B. Classification of defects

After the detection of all defects, the defects should be classified in different groups. In this paper, the different defects like etching defects, missing hole defects, wrong hole size, missing conductors and break lines has been classified. The visual results of various steps in classification have been shown in Fig.5 (f-m). From these figures it has been proved that the proposed method is able to classify all the faults in the given image.

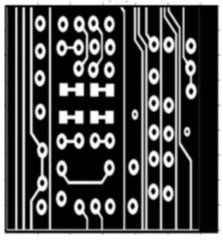

Fig. 5(f) NOT operation on base image

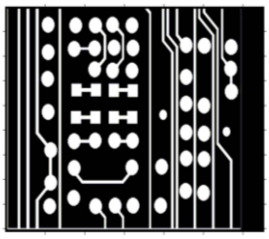

Fig.5(g) Flood filled operation on base image

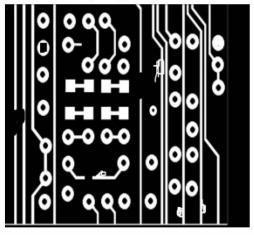

Fig. 5(h) NOT operation on test image

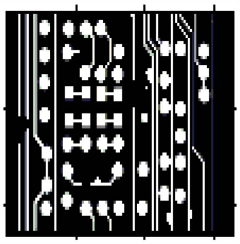

Fig. 5(i) Flood filled operation on test image

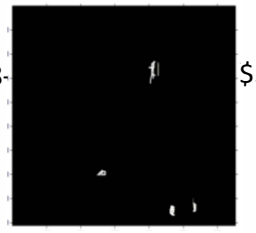

Fig. 5(j) Etching defects

Fig.5 (k) Missing hole defects

Fig.5 (l) Wrong hole size defect

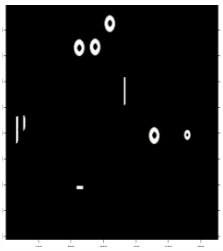

Fig. 5 (m) Missing conductors & break lines

V. CONCLUSION & FUTURE WORK

It is concluded from the results that defects can be detected and classified easily with the help of image subtraction method. But image subtraction has some drawbacks like it require the same size of base and test images. And it requires orientation of test image and base image. Our proposed method also has these inherent drawbacks. Future work can be done to overcome this drawback.

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