PCB Defect Detection and Classification Using Image Processing

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Abstract—

Printed circuit boards are by far the most common method of assembling modern electronic circuits. During the manufacturing of PCB many defects are introduced which are harmful to precision circuit performance. A variety of ways has been established to detect the defects found on PCB, but it is also necessary to classify these defects so that the source of these defects can be identified. This study proposes an algorithm to group all 14 defects found on PCB into 5 Groups .the proposed algorithm involves MATLAB image processing operations ,such as image subtraction, image addition, logical XOR, Flood fill, Opening ,erosion.

Keywords— PCB, Defects, Image processing, MATLAB, Opening

I. INTRODUCTION

A bare printed circuit board (PCB) is a PCB that is used before the placement of components and the soldering process [1]. It is used along with other components to produce electronic goods. During the manufacturing of printed circuit boards, widths of insulators and conductors can change because of manufacturing defects such as dust, overetching, underetching, and spurious metals. To reduce manufacturing costs associated with defected bare PCBs, the inspection of bare PCBs is required as the foremost step of the manufacturing process. The objective of printed circuit board (PCB) inspection is to verify that the characteristics of board manufacturing are in conformity with the design specifications.

PCB defects can be categorized into two groups; functional defects and cosmetic defects [5]. Functional defects can seriously affect the performance of the PCB or cause it to fail. Cosmetic defects affect the appearance of the PCB,but can also jeopardize its performance in the long run due to abnormal heat dissipation and distribution of current.Three categories of PCB inspection algorithms have been proposed

1. Referential approaches: - It consists of image comparison and model based techniques.
2. Non-Referential approaches:- Non-referential approaches or design-rule verification methods are based on the verification of the general design rules that is essentially the verification of the widths of conductors and insulators.
3. Hybrid approaches: - Hybrid approaches involve a combination both of the referential and the non-referential approaches.

II. PCB DEFECTS

PCB defects can be categorized into two groups:-

1. Functional defects :- Functional defects can seriously affect the performance of the PCB or cause it to fail.
2. Cosmetic defects:- Cosmetic defects affect the appearance of the PCB, but can also jeopardize its performance in   the long run due to abnormal heat dissipation and distribution of current. There are 14 known types of defects for single layer, bare PCBs as shown in Table I.

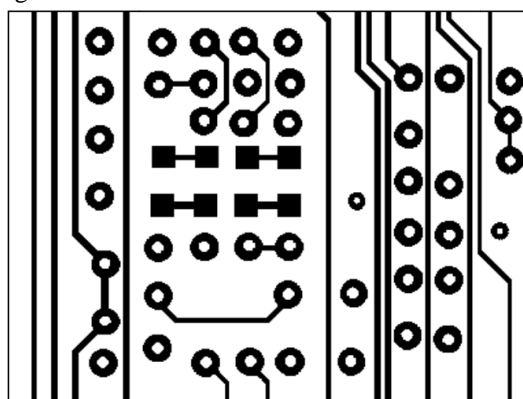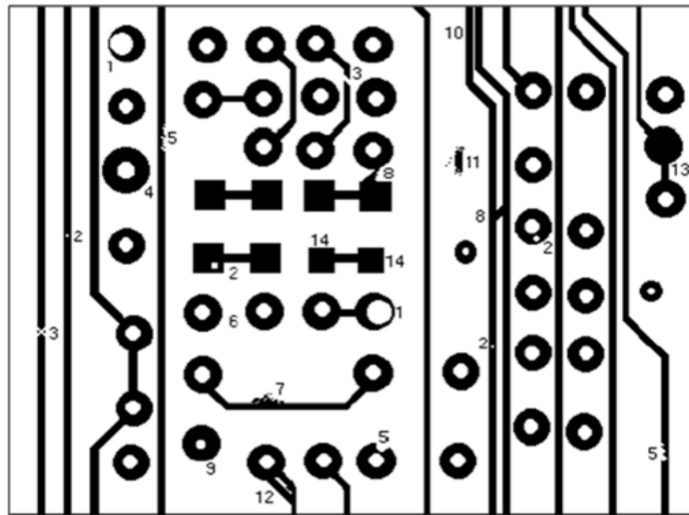Various defects have been shown in figure 1 and 2.

Figure 1: Template image of bare PCB

1.Breakout 2.Pinn hole 3.Open cicuit 4.Underetch 5.Mouse bite 6.Missing conductor 7.Spur 8.Short 9.Wrong size hole 10.Conductor too close 11.Spuriouscooper 12.Excessive short 13.Missing hole 14. Over etch

Fig 2: Defective image of bare PCB

Table 1: Various defects on Bare PCB

S.NO.	DEFECTS
1	OPEN CIRCUIT
2	SHORT
3	CONDUCTOR TOO CLOSE
4	MISSING CONDUCTOR
5	EXCESSIVE SHORT
6	BREAKOUT
7	PIN-HOLE
8	UNDER-ETCH
9	MOUSE-BITE
10	MISSING HOLE
11	OVER-ETCH
12	SPUR
13	WRONG SIZE HOLE
14	SPURIOUS COPPER

III. METHODOLOGIES

A. *Image subtraction operation*
A new image is obtained as a result of the difference between the pixels in the same location of the two input images being subtracted. Image subtraction is widely used for change detection

C=A-B; i.e.Maximum value of A-B and Zero.
(1)

$C(i,j,)=max(A(i,j)-B(i,j),0).$
(2)

B. *Image difference operation*
A new image is obtained as a result of comparison of both images pixel-by-pixel by XOR logic operator.this operation is also called as image comparison operation.

C. *Complement operation*
Complement operator is normally used to change the image from black to white and vice-versa.in complement of Binary image zeros become ones and ones become zeros black and white are reversed.

D. *Flood fill operation*
A hole is a set of background pixels that cannot be reached by filling in the background from the edge of the image.the floodfill operator changes the colour of a region .In grayscale images the holes are filled. Holes are area of dark pixels surrounded by lighter pixels.

E. *Image addition*
Image addition is a method of combining objects in two images.it uses OR logic operator.

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IV.   **THE PROPOSED ALGORITHM**

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The study follows a two-step process to detect and classify the defects. In the first step, defects have been detected and in the second step, the defects have been classified.

Step-I: Detection of defects in PCB image

For detection of defects the template image (It) and the defective image (Id) are compared using image subtraction operation to obtain positive image (Ip) and Negative image (In) as shown below

$$In=It-Id \qquad\qquad (3)$$
$$Ip=Id-It \qquad\qquad (4)$$

The addition of the positive image and the negative image gives all the defects present in the defective image as shown in equation (5).

$$Ia=In+Ip \qquad\qquad (5)$$

Step-II: Classification of defects:

Here the defects have been been classified and grouped into 5 groups as given under:

Group 1: Wrong size hole and missing hole

Group 2: spur,short,conductor tor too close,underetch,spurious copper and excessive short.

Group3: Pinhole and breakout

Group4: overetch,mousebite and opencircuit

Group5: Missing conductor

A. Classification of group1 and group 2 defects:

In this In image has been used along with the complement of template image (Itc). imfill operation (fill all the empty spaces and holes) has been applied on the complement of the template image(Itcf). The In image has been subtracted from the Itcf image to form difference image (Idh). Finally the resultant image Idh has been subtracted from Itcf. The group1 defects i.e. wrong hole size defect and missing hole defect has been presented by the output image (Ig1).Difference of In and Ig1 images gives group 2 defects.

$$Itc=complement (It) \qquad\qquad (6)$$
$$Itcf=flood\ fill (Itc) \qquad\qquad (7)$$
$$Idh=Itcf-In \qquad\qquad (8)$$
$$Ig1=Idh-In \qquad\qquad (9)$$
$$Ig2=In-Ig1 \qquad\qquad (10)$$

B. Classification of Group3 defects:

In this Ip image has been used along with the complement of defective image (Idc). imfill operation (fill all the empty spaces and holes) has been applied on the complement of the defective image(Idcf). The Ip image has been subtracted from the Itcf image to form difference image(Ide). Finally the resultant image Ide has been subtracted from Idcf. The group3 defects i.e.Pinhole defect and breakout defects hve been presented by Ig3.

$$Idc=complement (Id) \qquad\qquad (11)$$
$$Idcf=floodfill(Idc) \qquad\qquad (12)$$
$$Ide=Idcf-ip \qquad\qquad (13)$$
$$Ig3=Idcf-Ide \qquad\qquad (14)$$

C. Classification of Group 4 defects and group 5:

In this the group 3 defects image(Ig3) is subtracted from Ip to obtain result image Ir presenting 4 more defects namely overetch,opencircuit,mousebite and missing conductor .opening of Ir after flood filling it(Irf) is done using disk structuring element of appropriate radius and subtracting it from Irf to separate missing conductor defect from other 3 defects. The group 4 defects have been presented by Ig4.

$$Ir=Ip-Ig3 \qquad\qquad (15)$$
$$Irf=floodfill\ Ir \qquad\qquad (16)$$
$$I1=opening\ of\ (Irf,se);where\ se=\ disk\ structuring\ element \qquad\qquad (17)$$
$$Ig4=Ir-I1 \qquad\qquad (18)$$

Subtracting the group 4 defect image from Ir gives the group 5 defect i.e. missing conductor.

$$Ig5=Ir-Ig4 \qquad\qquad (19)$$

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V.   **EXPERIMENTAL RESULTS**

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The proposed method was tested using no. of defective PCB images .The defective PCB images were generated manually from template PCB images.

Step1: Defect detection

The different defects detected from the test images by using image subtraction method have been shown in Figure3 - Figure.7
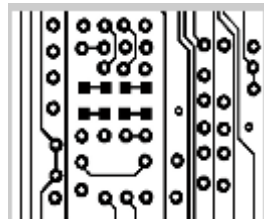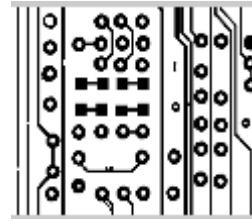
Fig 3:Template image(It)

Fig 4:Defective image(Id)

Fig 5:Negative image(In)

Fig 6:Positive image(Ip)
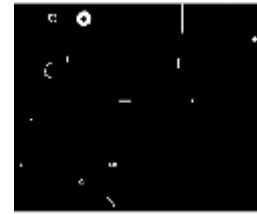

Fig 7: detected defects(Ia)

StepII: Defect classification

After the detection of all defects using image subtraction method, the defects should be classified in different groups. The visual results of various steps in classification have been shown in Figure8 – Figure 12 .From these figures it has been proved that the proposed method is able to classify all the faults in the defect image.

Fig 8: Group 1 defects
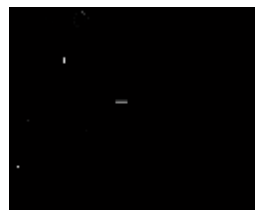

Fig 9: Group 2 defects

Fig 10: Group 3 defects

Fig 11: Group 4 defects

Fig 12:Group 5 defects

VI.   CONCLUSIONS

The detection and classification results of proposed method are promising. Most of the defects like wrong size hole, missing hole, missing conductor, pin hole are successfully detected without any misclassification. The proposed method has some drawbacks like it require the same size of template and defective images. And it requires orientation of test image and base image. Also during computation of defect detection and implementation this operation bring along the unwanted noise due to misalignment. Future work can be done to overcome these drawbacks.

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