MATLAB Based Defect Detection and Classification of Printed Circuit Board

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***Abstract-* A variety of ways has been established to detect defects found on printed circuit boards (PCB). In previous studies, defects are categories into seven groups with a minimum of one defect and up to a maximum of 4 defects in each group. Using Matlab image processing tools this research separates two of the existing groups containing two defects each into four new groups containing one defect each by processing synthetic images of bare through-hole single layer PCBs.**

Keyword: Image Processing, Printed Circuit Board, Defect Classification.

I. Introduction

Visual inspection is one of highest cost in printed circuit boards (PCB) manufacturing. Although many algorithms are available in defect detection, both contact and non-contact methods [6], none is able to classify these defects. Contact method tests the connectivity of circuits but unable to detect major flaws in cosmetic defects [7]. Non-contact uses methods such as ultrasonic and x-ray imaging to detect anomalies in the circuit design, both cosmetic and functional [8-11]. The use of manual labour to visually inspect each PCB is no longer viable since it is prone to human errors, time consuming, requires large overhead costs and results in high wastage. Thus an automation inspection system is highly desirable. 'MATLAB Based Defect Detection And Classification of Printed Circuit Board' seeks to improve the classification of defects by an algorithm developed by Indera Putera [1]. From seven groups, it is observed that several groups contain more than one defect each. This project separates the defects in larger groups into smaller groups. This increases the efficiency of the inspection system in classifying defects. Since certain PCB pattern are produced in different processes, classification of defects can help in determining the root causes of error and reduce production cost in the long run. Focus is given to separate groups of defects in the hole segment, thick line segment and thin line segment.

II. Methodology

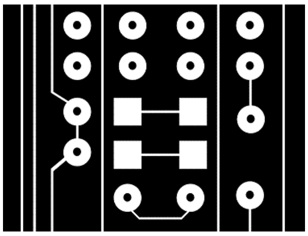
Printed circuit defects are mainly missing or extra elements on the board. PCB defects can be categorized into two groups; functional defects and cosmetic defects [5]. Functional defects can be fatal to the circuit operations while cosmetic defects affect the appearance of the circuit board but may affect the performance of the circuit in long term. The PCB manufacturing process is based on chemical and mechanical actions that may damage the intended design. Frequently, various PCB defects such as break out, pin-hole, open-circuit, under-etch and mouse-bite occurred during production. Types of defects on single layer bare PCBs are shown in Table I.

TABLE I. DEFECTS ON SINGLE LAYER BARE PCB

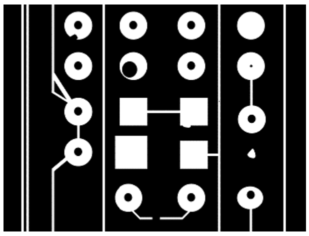
No.	Defect
1	Breakout
2	Pin-hole
3	Open Circuit
4	Under-etch
5	Mouse-bite
6	Missing Conductor
7	Spur
8	Short
9	Wrong Size Hole
10	Conductor Too Close
11	Spurious Copper
12	Excessive Short
13	Missing Hole
14	Over-etch

Computer generated printed circuit board images absent from any defects, known as Template Images are designed as control images to compare with the circuit that contains defects, knows as Test Images as shown in Figure 1. Any anomalies between Template and Test Image are declared as defects. Indera Putera [1] classified these defects into seven groups.

Based on reviews of previous works, Heriansyah [2] develop a PCB image segmentation algorithm to separate PCB images into four main segments which are square segment, hole segment, thin line segment and thick line segment using mathematical morphology and windowing technique. Morphological process involves techniques such as dilation, erosion, opening and closing which helps in partitioning the images and associates certain types of defects with certain patterns. Refer to Figure 2 for an example of PCB image segmentation.

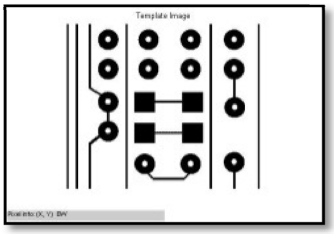


Template image

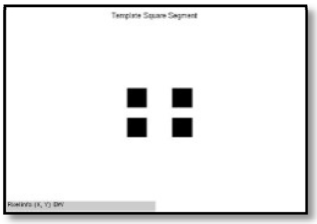


Test Image

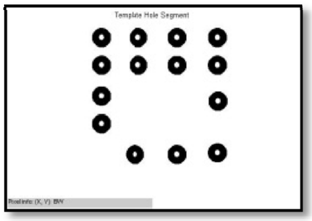
Figure 1: Template and Test image



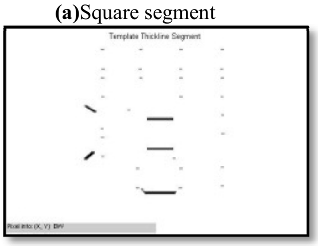
Template image



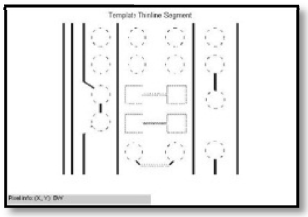
(a) Square segment



(b)Hole segment



(c)Thick-line



(d)Thin-line

Figure 2: Image Segmentation

Then Khalid [3] produced an image processing algorithm using Matlab by subtracting the images and performing logical operations such as X-OR, IMFILL and NOT. X-OR is used for image subtraction. Positive image is the result of subtracting the test image from the template image and the negative image is the result of subtracting the template image from the test image as in Figure 3 and 4. The IMFILL operation fills out the pad holes and pin holes while NOT operation inverts the binary value of template and test images as in Figure 5 and 6. Grey-scale images with values ranging from 0 to 255 are converted to two level binary images with a value of either 0 or 1. Khalid's work managed to classify 14 defects into five groups.

Recently Indera Putera and Ibrahim [1] performed an improvement to Khalid's work by classifying 14 defects into seven groups. This is done by combining the segmentation [2] algorithm with the image processing algorithm [3]. The image processing algorithm produces five new images for each pair of segmented template and test images processed. When it is combined with the segmentation algorithm, where each image is segmented into four patterns, 20 new images are produce. Out of this, seven images are beneficial for classification of defects as in Table II. For this particular exercise each group consist of minimum 1 defect and maximum 4 defect and consequently improve the image processing done by Khalid [3] by increasing the number of group from 5 to 7.

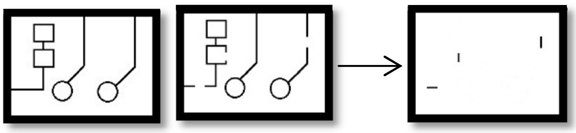


Figure 3: Positive Image from X-OR Operation

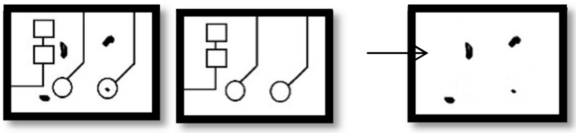


Figure 4: Negative Image from X-OR Operation

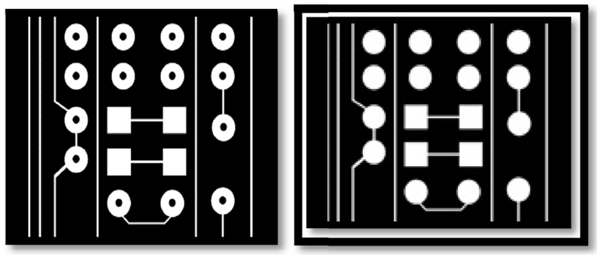


Figure 5: IMFILL Operation

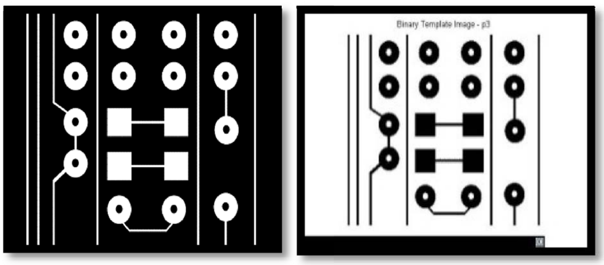


Figure 6: NOT Operation

TABLE II. CLASSIFIED GROUP OF DEFECTS

No.	Image	Classified Defects
1	G13	Under etch
2	G21	Wrong size hole Missing hole
3	G22	Over etch, mouse bite
4	G25	Breakout, pinhole
5	G33	Short, Excessive short, Spurious copper, Spur
6	G42	Missing conductor, Open circuit
7	G43	Conductor too close

In order to increase the number of groups and reduce the number of defects in each group, image property measurement method is used to measure image regions. In this study, group G21 from the hole segment is separated into individual groups each containing one defect namely over etch and mouse-bite. The same technique is applied to G42 from the thin line segment where the two new groups created contains only one defect namely missing conductor and open circuit. The procedure is extended to group G32 from the thick line segment which contains the same type of defect as in G42. The output images are increased from 20 to 23.

A. *Hole Segment Improvement*

To separate the defects in G21 which are missing hole and wrong size hole in the hole segment, regionprops method are used to measure the area of objects. Wrong size hole is succesfuly removed from G21 and placed into a new group; G28 as in Table III. Figure 7 shows how measurement is used to differentiate wrong size hole and missing hole.

B. *Thick-line and Thin-line improvement*

Region-prop is a method of determining the area of each object in an image. Missing conductor covers a larger area than open circuit. So, with the difference in area, groups G32 and G42 from the thick line and thin line segments are successfully broken into two new groups each containing one defect in each group. Figure 8 shows the step on determining the area range by using region props method. Improvement on the thick line and thin line segments where missing onductor is removed from group G32 and G42 and placed in its own group; G38 for thick line segment and G48 for thin line segment which can be observe in Tables IV and V respectively.

TABLE III. HOLE IMPROVEMENT

No.	Group	Classified Defects
1	**21**	Missing hole
2	**22**	Over etch mouse bite
3	**23**	Updated negative
4	**24**	Updated positive
5	**25**	Breakout, pinhole
6	**28**	Wrong size hole

TABLE IV. THICK-LINE IMPROVEMENT

No.	Group	Classified Defects
1	**31**	MH1
2	**32**	Open circuit
3	**33**	Spur, Short, Spurious copper, Excessive short
4	**34**	Under etch
5	**35**	Breakout, pinhole
6	**38**	Missing conductor

TABLE V. THIN-LINE IMPROVEMENT

No.	Group	Classified Defects
1	**41**	MH1
2	**42**	Open circuit
3	**43**	Conductor too close
4	**44**	Under-etch positive
5	**45**	Breakout, pinhole
6	**48**	Missing conductor

Figure 7: Area Range in Hole Classification Segment

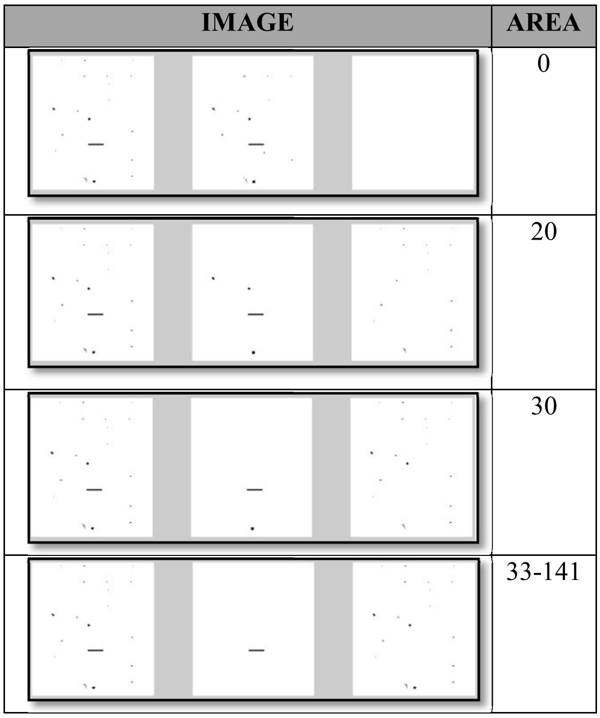
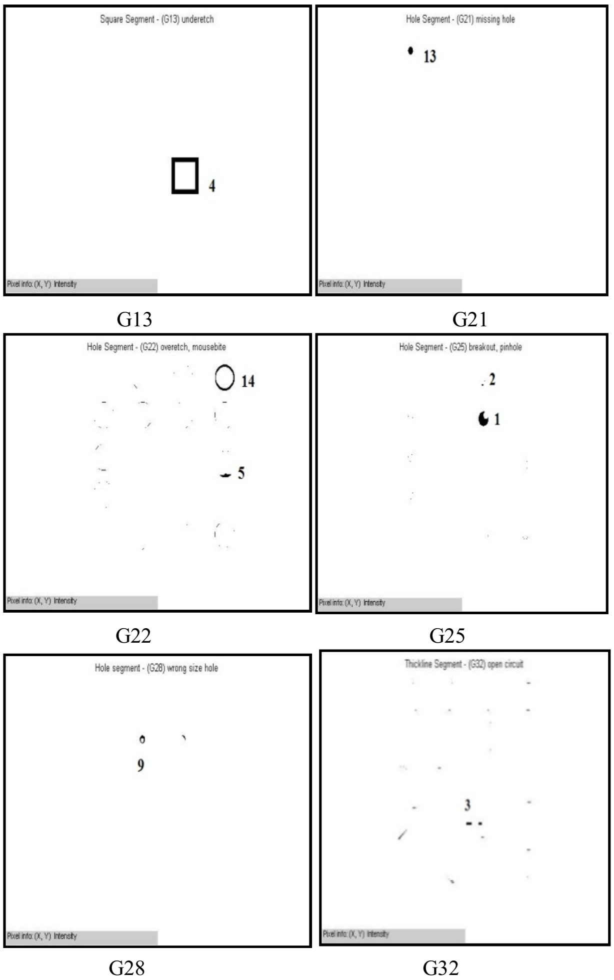


Figure 8: Area Range in thick-line and thin-line Segment.

VII. RESULT AND DISCUSSION

This project minimizes the number of defects for each classified groups. Wrong size hole is successfully separated from G21 and placed in G28 while missing hole remains as an individual defect in G21. Both G32 and G42 contain missing conductor and open circuit defects. Both these defects have the same characteristic which is the absence of copper which acts as connectors or conductors between pads. The only significant difference between missing conductor and open circuit is that in missing conductor the entire conductor that connects to the circuit is lost, while in open circuit, only a small portion of conductor is absent as a result of errors in the printing or etching process. In this section region props method used is by measure properties of image regions. Programs code has been developed to isolate defects in this G42 group. Open circuit is maintained in group G42 while missing conductor is placed in new group named as G48. The same is applied to G32. The improved algorithm increased the classification from 7 to 11 groups as in Table VI. A sample of results for a test image consisting of random defects is shown in Figure 9.



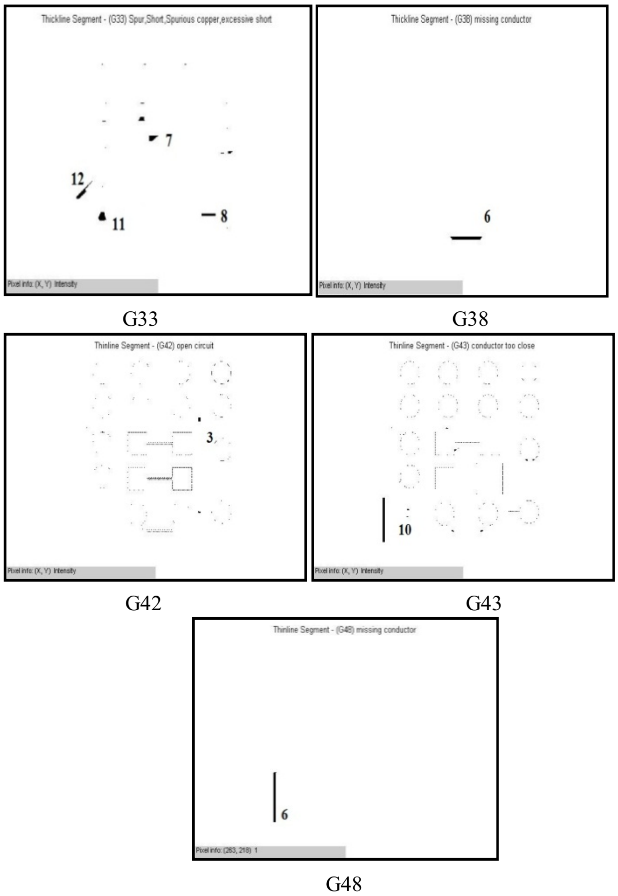


Figure 9: Sample Result of Image Defect Detection and Classification

TABLE VI. CLASSIFIED DEFECT GROUPS

No	Image	Defect Classified
1	G13	Under etch
2	G21	Missing Hole
3	G22	Over etch, Mouse bite
4	G25	Breakout, pinhole
5	G28	Wrong size hole
6	G32	open circuit (Thick line)
7	G33	Short, Excessive Short, Spurious Copper, Spur
8	G38	Missing Conductor (Thick line)
9	G42	Thin Line, Open Circuit
10	G43	Conductor too Close
11	G48	Missing Conductor (Thin line)

VII. CONCLUSION

It can be concluded that this project have been implemented successfully since number of groups is increased from 7 into 11 However, there are groups which still contains more than one defect such G22, G25 and G33 because the image came from the same negative image. Subtraction of images is not possible since defects in the same group have similar characteristics. Future improvement for the algorithm should overcome this limitation. Integration with an image capturing system such as camera is also essential for actual performance verification of defect detection and classification of PCBs.

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