PCB Defect Inspection System using Mathematical Morphology and MATLAB Image Processing Tools

Veena Gaonkar[1]

[1]Assistant Professor

[1]Department of Electronics and Telecommunication

[1] Don Bosco College of Engineering Goa University, India

Abstract— *Up to the present, there has been a lot of work and research concentrated on PCB defect detection. PCB defect detection is necessary for verification of the characteristics of PCB to make sure it is in conformity with the design specifications. However, besides the need to detect the defects, it is also crucial to classify these defects so that the source of these defects can be identified. Unfortunately, this area has been neglected and not been given enough attention. The area of focus in this thesis is to classify the defects on bare single layer PCB's by using the research done by Heriansyah [1] and Khalid [2] to classify defects using morphological image segmentation algorithm and simple image processing theories. This output was further processed by using object classification algorithm based on the vicinity tracks surrounding the defect taken into consideration and region properties which helps to measure image regions of defects. As a result of this strategy, it was possible to successfully classify all defects into individual 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 errors and reduce production cost in the long run.*

Keywords— Printed circuit Board, Morphological image processing, Defect classification, Image segmentation

I. INTRODUCTION

Visual inspection is one of the highest cost in printed circuit boards (PCB) manufacturing. 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.

Currently there are many algorithms developed for PCB defect detection using contact or non-contact methods [3]. Contact method tests the connectivity of the circuit but is unable to detect major flaws in cosmetic defects such as mouse-bite or spurious copper and is very setup-sensitive. Any misalignment can cause the test to fail completely. Non-contact methods can be from a wide range of selection from x-ray imaging, ultrasonic imaging, thermal imaging and optical inspection using image processing. Although these techniques are successful in detecting defects, none is able to classify the defects.

The defect classification system introduced by Indera Putera [4] could classify 14 commonly known PCB defects into seven groups by using morphological image segmentation algorithms and Matlab image processing algorithms. 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.

This paper is organized as follows. Section 2 defines the review of previous works. Section 3 describes the improvement done in the previous classification system to classify PCB defects into more individual groups. Section 4 contains the simulation results for defect classification while the conclusion is described in section 5.

II. LITERATURE REVIEW

PCB defects can be categorized into two groups: functional defects and cosmetic defects. 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. There are 14 known types of defects for single layer, bare PCBs as shown in Table 1.

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

Table 1: Defect on Single Layer Bare PCB

Based on reviews of previous works, Heriansyah [1] 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 morphological tools such as dilation, erosion, opening and closing which helps in partitioning the images and associates certain types of defects with certain patterns. Then Khalid [2] produced an image processing algorithm using Matlab by subtracting the images and performing logical operations such as image subtraction, image addition, logical X-OR, IMFILL and

NOT. Khalid's work managed to classify 14 defects into five groups as shown in Table 2.

No.	Image	Classified Defects
1	G1	Missing hole, Wrong size hole
2	G2	Spur, Short, Conductor too close, Spurious copper, Excessive short
3	G3	Open circuit, Mouse bite, Overetch, conductor missing
4	G4	Underetch
5	G5	Pinhole,Breakout

Table 2: Classification of defects into 5 groups

Recently Indera Putera and Ibrahim [4] performed an improvement to Khalid's work by classifying 14 defects into seven groups. This is done by combining the segmentation [1] algorithm with the image processing algorithm [2].The image processing algorithm as shown in fig 1 produces five new images for each pair of segmented template and test images processed, as a result 20 new images are produced.

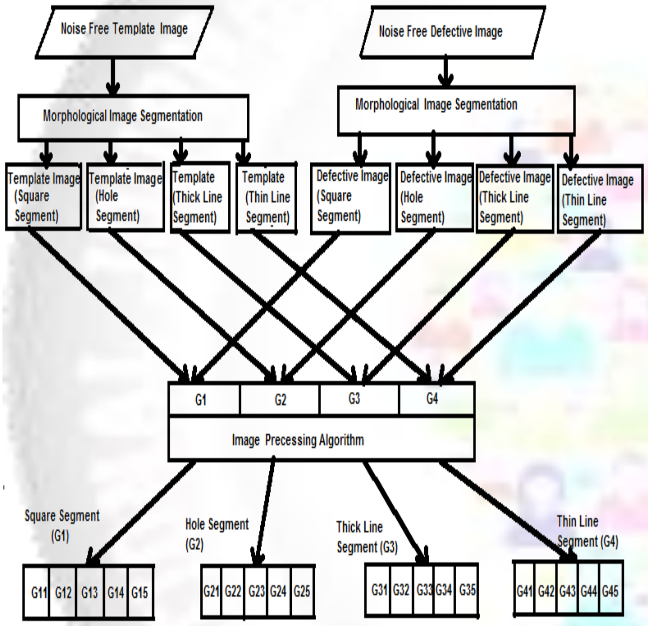


Fig. 1: Algorithm for PCB defect classification

Some defects only occur on particular segments of test image such as wrong size hole, breakout and missing hole for hole segment or missing conductor and open circuit for thin-line segment. Other defects might exist in multiple segments. Mouse-bite and under-etch might exist in both hole and square segments. This improved classification of defects from five to seven groups.

No.	Image	Classified Defects
1	G14+G24	Underetch
2	G21	Wrong size hole, Missing hole
3	G13+G23	Mouse bite, Overetch
4	G15+G25	Breakout, pinholes
5	G22+G32	Spur, Short, Spurious copper, Excessive short
6	G42	Conductor too close
7	G43	Conductor Missing, Open Circuit

Table 3: Classification of defects into 7 groups

III. An improved classification algorithm

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.

To separate the defects in G21 which is missing hole and wrong size hole in the hole segment ,region props method are used to measure the area of the objects. Wrong size hole was successfully removed from G21 and placed into new group G26 as in table 4.Missing conductor covers a larger area than open circuit. So, with the difference in area, group G43 from the thin line segment are successfully broken into two new groups each containing one defect in each group. Similarly Breakout and pinholes was separated into two groups by using region props method.

No.	Image	Classified Defects
1	G14+G24	Underetch
2	G21	Missing hole
3	G13+G23	Mouse bite, Overetch
4	G15+G25	Breakout
5	G26	Wrong size hole
6	G27	Pinholes
7	G22+G32	Spur, Short, Spurious copper, Excessive short
8	G42	Conductor too close
9	G43	Conductor Missing
10	G46	Open Circuit

Table 4: Classification of defects into 10 groups

A method based on boundary lines is used to detect the vicinity of the object. The process consist of tracing four outer lines around the particle in clockwise direction (left, top, right and bottom) .Based on the object tracks as listed in the table 5,the defects were classified still further. In this work, short and excessive short defect will be treated as the same as short defect. Hence, there will be 13 defects that will be classified as listed in Table 6.

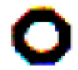
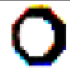
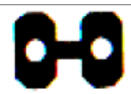
Defect	**Track vicinity**	**Original Pad**	**Defective particle**
Mousebite	1		
Overetch	Greater than 2		
Spurious Copper	0		
Spur	1		
Short / Extra short	2		

Table 5: Categorization of Defects based on vicinity Tracks

No.	Image	Classified Defects
1	G14+G24	Underetch
2	G21	Missing hole
3	G13+G23	Overetch
4	G15+G25	Breakout
5	G26	Wrong size hole
6	G27	Pinholes

7	G28	Mouse bite
8	G22+G32	Spur
9	G36	Short, Excessive short
10	G37	Spurious copper
11	G42	Conductor too close
12	G43	Conductor Missing
13	G46	Open Circuit

Table 6: Classification of defect into 13 groups

IV. Simulation Results

Two images are needed for the inspection, the reference image and the defective image as shown in Fig. 2 and Fig. 3 respectively.

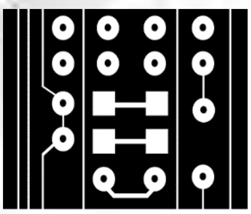


Fig. 2: A Template PCB image

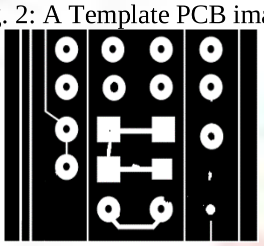


Fig. 3: A defective PCB image

Both the images [fig2 and fig3]are segmented into 4 segments each; square segment, hole-segment, thick-line segment and thin-line segment.

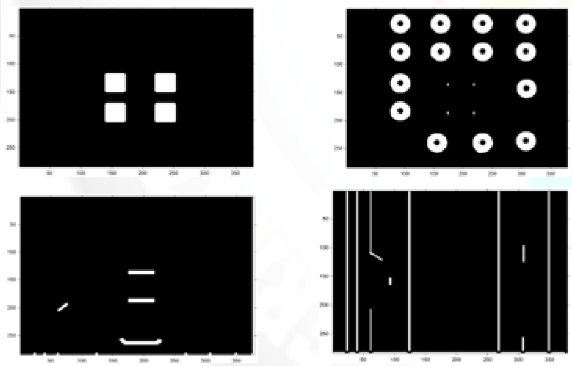


Fig 4: Morphological segmentation for Template Image

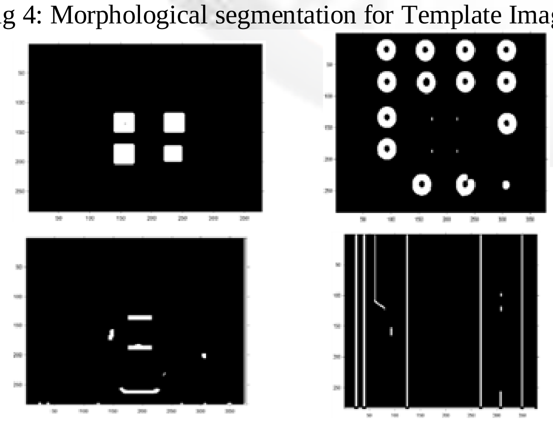
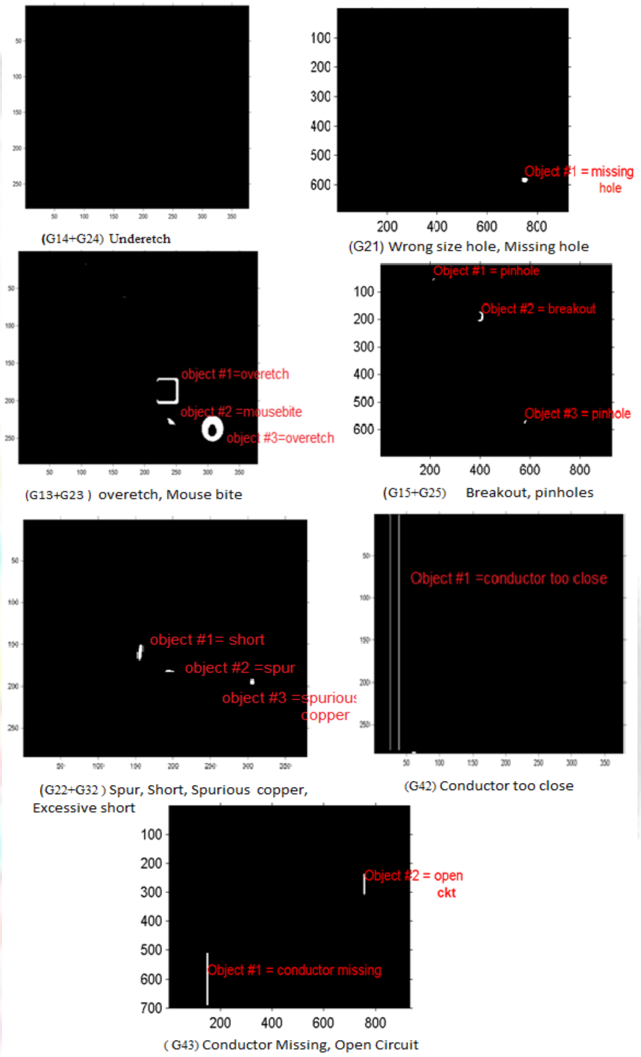


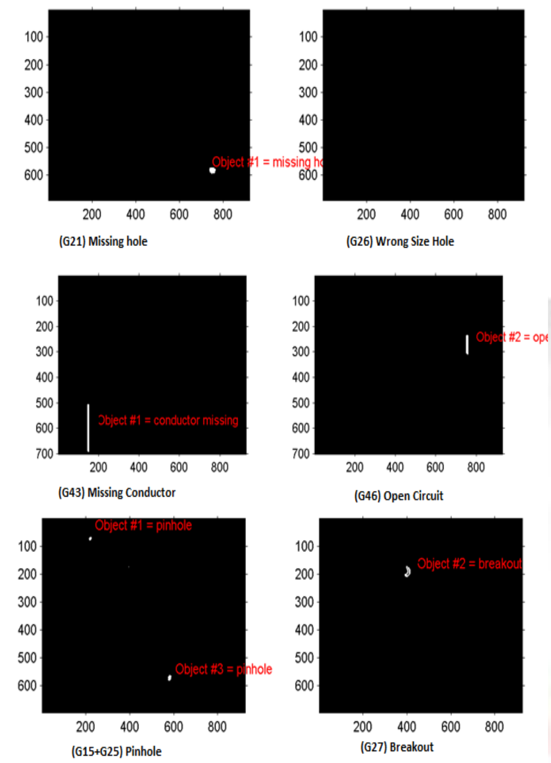
Fig. 5: Morphological Segmentation for Test Image

Since the morphological segmentation algorithm is able to produce 4 images for both template and test image, thus the image processing algorithm produces 5 new images for each pair of segmented template and test images processed.

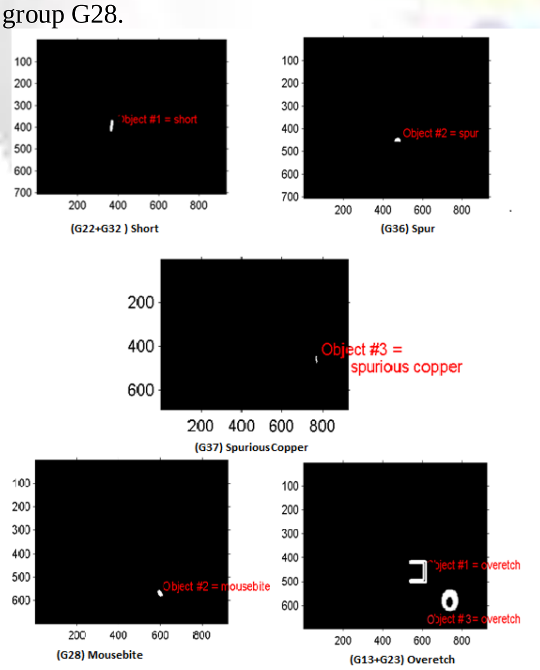
The image processing algorithm is able to generate 4x5 images (20 images) which will improve the image processing done by Khalid by increasing the number of groups from 5 to7 as shown in images below.



To separate the defects in G21 which are missing whole and wrong size hole in the hole segment, regionprops method are used to measure the area of objects. Wrong size hole is successfully removed from G21 and placed into new group G26.Group G43 which is missing conductor and open circuit was also isolated into 2 groups by maintaining missing conductor in the same group and open circuit is placed into new group G46.Pinhole and breakout from G15+G25 was also separated into 2 groups by placing pinholes into new group G27.



Finally for the defects short, spur spurious copper, mousebite and overetch by tracing the four outer lines (left, top, right, and bottom) around the defects on the test image it was possible to find the number of vicinity tracks the defect is connected to. Based on this information group G22+G32 consisting of spur, short, spurious copper was isolated into 3 new groups. Also overetch and mousebite from group G13+G23 was separated by maintaining overetch in the same group and mousebite was placed into new group G28.



V. Conclusion

From the simulation result, the hybrid algorithm successfully classifies all defects individually by considering short and excessive short as 1 group. However, the major limitation of this algorithm is developed to work with binary images only, whereas the output from the cameras is in gray scale format. Although the conversion can be made from gray scale to binary format imperfection still can be occurred. Thus, this algorithm should be improved to handle the gray scale image format. Furthermore, defects such as pinholes were ignored due to elimination of the defect by the morphological image segmentation procedure.

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