2010 2nd International Conference on Education Technology and Computer (ICETC)

Printed Circuit Board Defect Detection Using Mathematical Morphology and MATLAB Image Processing Tools

S.H Indera Putera, Z.Ibrahim
Faculty of Electrical Engineering
Universiti Teknologi MARA, 40450 Shah Alam, Selangor
Malaysia
Email: (zura_putra@yahoo.com, zuwairiefke@gmail.com)

***Abstract*— various concentrated work on detection of defects on printed circuit boards (PCBs) have been done, but it is also crucial to classify these defects in order to analyze and identify the root causes of the defects. This project is aimed in detecting and classifying the defects on bare single layer PCBs by introducing a hybrid algorithm by combining the research done by Heriansyah et al [1] and Khalid [2]. This project proposes a PCB defect detection and classification system using a morphological image segmentation algorithm [1] and simple the image processing theories [2]. Based on initial studies, some PCB defects can only exist in certain groups. Thus, it is obvious that the image processing algorithm could be improved by applying a segmentation exercise. This project uses template and test images of single layer, bare, grayscale computer generated PCBs. The research improves Khalid [2] work by increasing the number of defect categories from 5 to 7, with each category classifying a minimum of 1 to a maximum 4 different types of defects and a total of 13 out of 14 defects were classified.**

Keywords- Morphological Segmentation; Image Processing

I. INTRODUCTION

Visual inspection is generally the largest cost of PCB manufacturing. It is responsible for detecting both cosmetic and functional defects and attempts are often made to ensure 100% quality assurance for all finished products. There are two main processes in PCB inspection: *defect detection* and *defect classification.* 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 [4]. 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 [5 - 8]. Although these techniques are successful in detecting defects, none is able to classify the defects.

This project utilizes a non contact reference based, image processing approach for defect detection and classification. A template of a defect free PCB image and a defected test PCB image are segmented and compared with each other using image subtraction and other procedures. Discrepancies between the images are considered defects and are classified based on similarities and area of occurrences.

This paper is organized as follows. Section 2 defines the review of previous works and research methodology chosen for this project. Section 3 and section 4 describes the details of mathematical morphology for image segmentation and image processing algorithm for detection and classification of PCB defects. Section 5 contains the experimental results for defect detection and classification while the discussion and conclusion is described in section 6.

II. LITERATURE REVIEW AND RESEARCH METHODOLOGY

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. There are 14 known types of defects for single layer, bare PCBs as shown in Table I. Figure 1 shows a grayscale image of a single layer, bare PCB and Figure 2 shows the same image but with defects as listed in Table 1.

Table 1 Defect on Single Layer Bare PCB

No	Defect Name
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

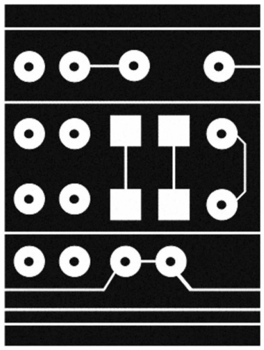


Fig. 1 Template Greyscale PCB Image

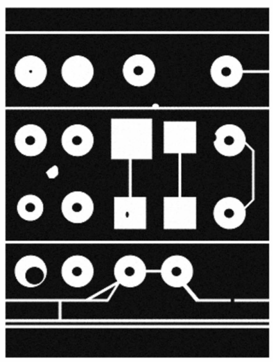


Fig. 2 Test Greyscale PCB Image

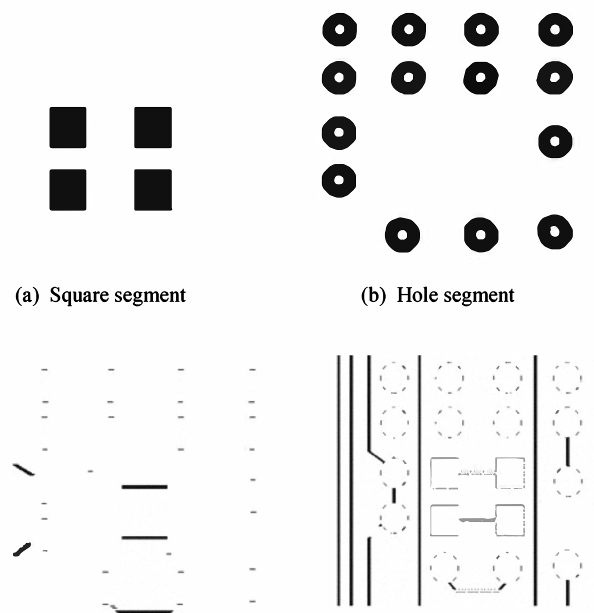
Based on reviews of previous works, Heriansyah et al [1] developed a PCB image segmentation algorithm by clustering primitive patterns of a PCB image into four main segments using mathematical morphology and windowing technique. Later Heriansyah [9] classifies 12 out of the 14 known PCB defects by combining the image segmentation with artificial neural network (ANN). Recently, Khalid [2] produced an image processing algorithm using MATLAB by subtracting the images and performing X-OR operation. The 14 defects are then grouped into 5 categories. This project combines two previous works. First, the complex PCB images are divided into four different segments of well-defined generic patterns [1], and later fed into the image processing algorithm [2] where defects are detected and classified.

III. Mathematical Morphology for Image Segmentation

Referring to Heriansyah et al [1], images are segmented into primitive patterns using morphological techniques such as dilation, erosion, opening, and closing. The windowing technique is used to enclose the segmented pattern in a compact window with an assigned coordinate which helps in partitioning the inspection tasks among multiple processors for faster on-line processing, and associates certain types of defects with certain basic pattern, thus making inspection easier.

This research does an adaptation of the mathematical morphology for image segmentation by Heriansyah et al [1] in preparing the images for defect detection and classification. MATLAB is used for this purpose.

A template image is a grayscale image of a perfect PCB pattern without any defects or deformation which is used as reference as in Figure 1. A test image is a grayscale image of a defective PCB as in Figure 2 which is synthetically generated to contain all 14 defects as listed in Table 1. Both the images are segmented into 4 segments each; *square-segment, hole-segment, thick-line segment* and *thin-line segment* as in Figure 3 and Figure 4. The square segment contains the image of square pads, the hole-segment contains the image of hole pads, the thick-line segment contains the image of thick conductors and the thin-line segment contains the images of thin conductors. 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. By breaking the image into clusters, some of the defects associated with certain segments can easily be identified and classified.



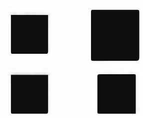
(a) Square segment

(b) Hole segment

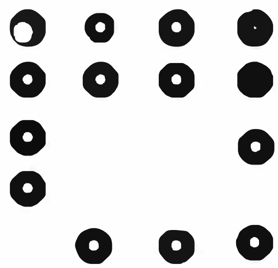
(c) Thick-line segment

(d)) Thin-line segment

Fig. 3 Morphological Segmentation for Template Image

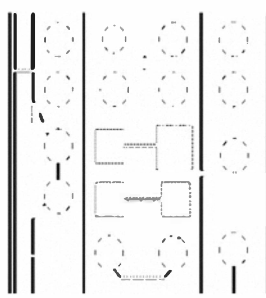


(a) Square segment



(b) Hole segment

(c) Thick-line segment



(d)) Thin-line segment

Fig. 4 Morphological Segmentation for Test Image

IV. IMAGE PROCESSING FOR PCB DEFECT DETECTION AND CLASSIFICATION

Once the template and test images are segmented, threshold values for the greyscale images are determined to convert the images into binary. Greyscale images with levels of between 0 and 255 are converted into binary images with only two levels; 0s and 1s. This is to simplify further processes. This project will not consider uneven binary conversions that can cause unwanted noise. It is observed that unwanted noise occurs occasionally in the thin-line and thick-line segments as in Figure 4.

The binary images are fed into the image processing algorithm developed by Khalid [2], using MATLAB image processing tools. The algorithm uses operations such as NOT, X-OR and IMFILL. NOT operation inverts the binary values of template and test images for each segment. An example of the inverting process is shown in Figure 5. 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 shown in Figure 7 and Figure 8. The notations for NOT and X-OR are:

NOT: $output = \overline{bit1}$

X-OR: $output = bit1 \oplus bit2$

The IMFILL operation fills out all the pad holes and pin holes on the images as in Figure 6 while the X-OR operation subtracts one image from the other. The subtraction process produces two types of images; positive image and negative image

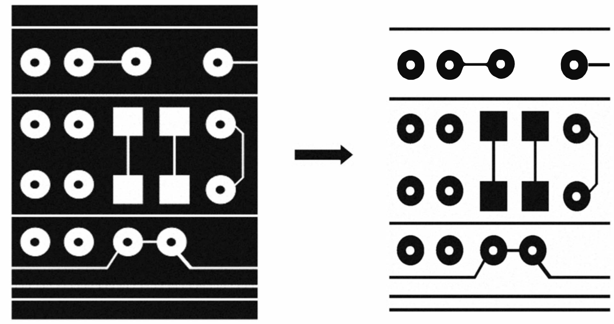


Fig. 5 NOT Operation

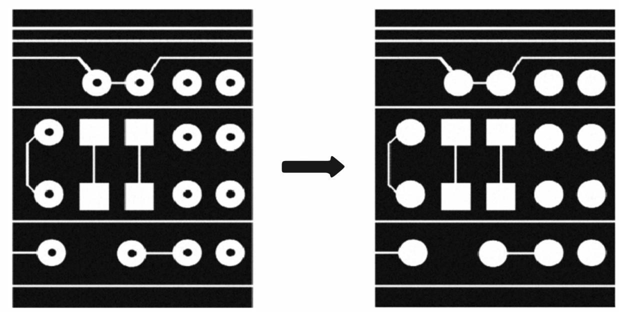


Fig. 6. IMFILL Operation

The image processing algorithm produces 5 new images for each pair of segmented template and test images processed. Since the morphological segmentation algorithm is able to produce 4 images for both template and test image, thus, the image processing algorithm is able to generate 4x5 images (20 images) which will improve the overall defect detection and classification ability of the system. The overall algorithm of the project is shown in Figure 9.

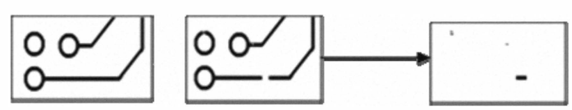


Fig. 7 Positive image from X-OR Operation

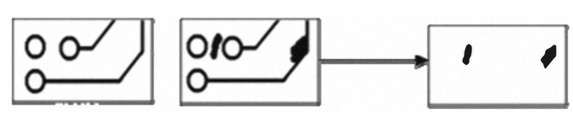


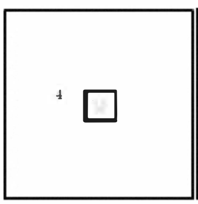
Fig. 8 Negative image from X-OR Operation

V. RESULTS

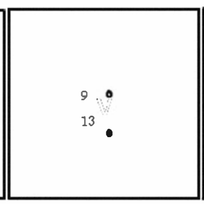
Based on exercises conducted for several test and template images, an example of result obtained is shown in Figure 10. From the 20 images generated by the image processing algorithm, 7 images were identified as beneficial. The images are named G13, G21, G22, G25, G33, G42 and G43 as is Figure 10. G13 is generated from the square segment, G21, G22 and G23 from the hole segment, G33 from the thick-line segment and G42 and G43 from the thin-line segment. The defects classified by these groups are listed in Table 2. For this particular exercise, each group is able to classify a minimum of 1 defect to a maximum of 4 defects, and is able to improve the image processing algorithm by Khalid [2] by increasing the classification groups from 5 to 7.

Table 2 Classified Defect Groups

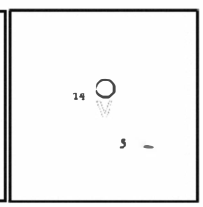
No	Image	Defect Classified
1	G13	Under etch
2	G21	Wrong size hole Missing hole
3	G22	Over etch Mouse bite
4	G25	Breakout
5	G33	Short Excessive short Spurious copper Spur
6	G42	Missing conductor Open circuit
7	G43	Conductor too close



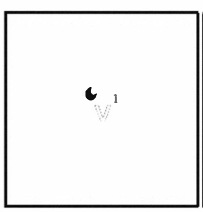
(a) G13



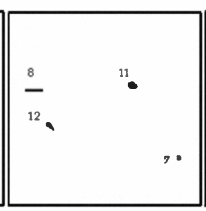
(b) G21



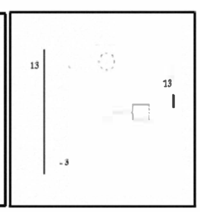
(c) G22



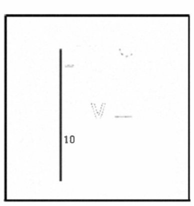
(d) G25



(e) G33



(f) G42



(g) G43

Fig. 10(a-g) Classified Defect Images

VI. Conclusion and Discussion

From the sample experiment, the hybrid algorithm successfully detects and classifies 13 defects into 7 groups. (G13, G21, G22, G25, G33, G42, G43). The limitation of this algorithm is that some groups are unable to address each defect individually. Unwanted images were also generated by noise during grayscale to binary conversion. Furthermore, *pin-hole* defect was ignored due to elimination of the defect by the morphological image segmentation procedure. Future improvement for the algorithm should include the ability to detect and classify all 14 defects individually. Integration with an image capturing system such as camera, frame grabber and personal computer is also essential for actual performance verification of defect detection and classification of PCBs.

References

[1] R. Heriansyah, S.A.R Al-Attas, and M.M. Ahmad Zabidi, 'Segmentation of PCB Images into Simple Generic Patterns using Mathematical Morphology and Windowing Technique', CoGRAMM Melaka, Malaysia 2002

[2] N.K. Khalid. 'An Image Processing Approach Towards Classification of Defects on Printed Circuit Board', *Projek Sarjana Muda, Universiti Teknologi Malaysia, 2007* .

[3] M. Moganti, F. Ercal, C.H. Dagli, and S. Shunekawa, 'Automatic PCB Inspection Agorithm: A Survey', 1996, 63. No. 2.

[4] T. Taniguchi, D. Kacprzak, S. Yamada, M. Iwahara, and T. Miyogashi, 'Defect Detection on Printed Circuit Board by using Eddy-Current Technique and Image Processing', IOI Press, 2000

[5] Wen-Yen Wu, Mao-Jiun J.Wang and Chih-Ming Liu, 'Automated Inspection of Printed Circuit Board Through Machine Vision', *Computers in Industry,* 28 (1996) pp.103-111.

[6] Z. Ibrahim, S.A.R Al-attas and Z. Aspar, 'Analysis of the Wavelet-Based Image Difference Algorithm for PCB Inspection', in proceedings of SICE, Osaka, Japan, 2002

[7] Z. Ibrahim, S.A.R Al-attas, Z. Aspar and M.M. Mokji 'Performance Evaluation of Wavelet-based PCB Defect Detection and Localization Algorithm', in proceedings of ICIT, 2002, Bangkok, Thailand

[8] Z.Ibrahim, S.A.R Al-attas and Z. Aspar, 'Coarse Resolution Defect Localization Algorith for an Automated Visual PCB Inspection', Jurnal Teknologi, 37(D) Dis. 2002: 79–92

[9] R. Heriansyah. 'Classification of Defect on Bare PCB using Neural Network Technique', *Masters Thesis, Universiti Teknologi Malaysia.* 2004.

[10] D.M. Tsai and B.T. Lin, 'Defect Detection of Gold-Plated Surfaces on PCBs Using Entropy', Int J. Adv Manuf Technol (2002) 20:420–428

[11] K. Chomsuwan, S. Yamada and M. Iwahara,' Improvement on Defect Detection Performance of PCB Inspection Based on ECT Technique With Multi-SV-GMR Sensor', IEEE Transaction on Magnetics vol. 43, no. 6, June 2007

[12] F. Wang, X. Li and G. Xu, 'The PCB Defect Inspection System Design Based on Lab Windows/CVI', International Conference on Industrial Mechatronics and Automation, ICIMA, 2009.

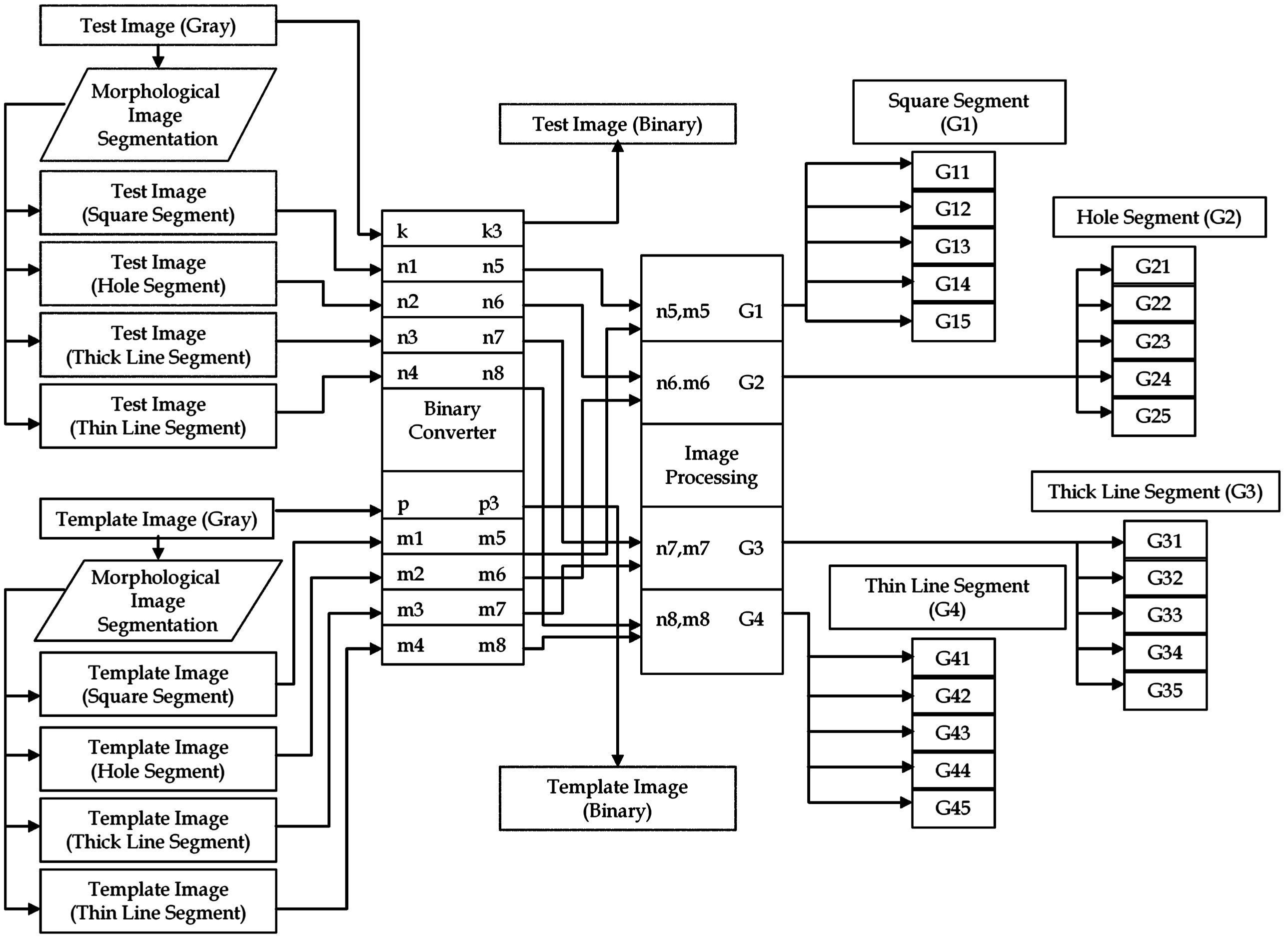


Fig. 9. Algorithm for PCB Defect Detection Using Mathematical Morphology and MATLAB Image Processing Tools