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DISCRETE WAVELET TRANSFORM, IMAGE SCRAMBLING, ARNOLD TRANSFORM

VEENA GAONKAR, H. G. VIRANI

Dept of Electronics and Telecommunication, Goa College of Engineering, Farmagudi, Goa, India.

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Corresponding Author

Ms. Veena Gaonkar

Abstract

A variety of ways has been established to detect defects on printed circuit boards (PCBs), but it is also crucial to classify these defects in order to analyze and identify the root causes of the defects. This paper proposes a PCB defect detection system by incorporating proper image registration and noise elimination procedure to solve the alignment and uneven illumination problem. Resultant output of defect detection stage is further used for classification process. Classification system is improved by combining image segmentation algorithm [1] and 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 which helps to increase the number of groups and reduce the number of defects in each group.

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.

It is important to note that the previously proposed algorithms did not take into account the image registration problem [4] as a result; the image still could be interfered by unwanted noise due to slightly misalignment and uneven binarization. Hence, it is difficult to reduce or diminish the noise in the output image. Based on this deficiency of defect detection, the results obtained in defect classification stage will be also inaccurate. Hence defect classification algorithm is improved by incorporating proper image Registration and noise elimination technique to solve the alignment and uneven illumination problem.

Currently there are many algorithms developed for PCB defect detection, using contact or non contact methods. 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 [3].

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.

DEFECTS

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 I.

TABLE I: Defect 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

III. THE IMPROVED PCB INSPECTION SYSTEM

Figure 1 depicts the PCB inspection system developed in this research for detecting and classifying defects on PCB which includes four major stages. The stages are:

Stage 1:Image registration process-- The image registration process is an important stage in inspecting real PCB images. Image registration can be broadly

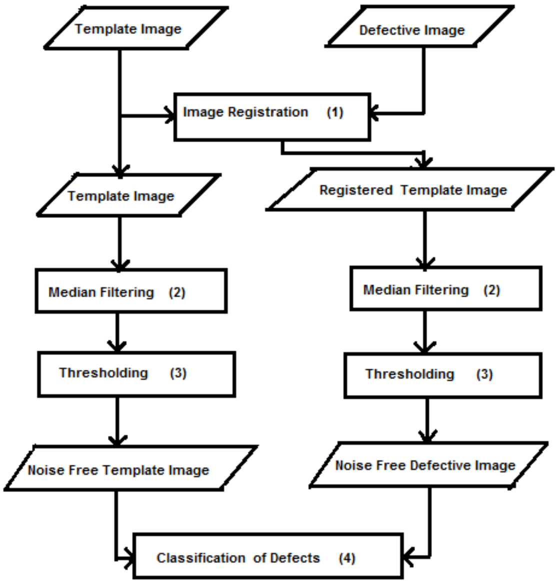


Fig 1. Flow chart of the improved PCB inspection system defined as the process of finding a transformation that aligns one image to another. In this research, geometric transformation is used to find a transformation that aligns a template image and a defective image.

Stage 2: Median filtering-- In acquisition processing of images, due to input conversion apparatuses and influences of ambient environment, obtained digital images will contain many kinds of noises, which interfere with the useful information in post-processing and result in information loss or misidentification. We choose median filtering to improve image quality, and median filtering can efficiently inhibit noises in images and protect the boundaries of images.

Stage 3: Thresholding-- The output of the thresholding operation is a binary image whose one state will indicate the foreground objects and whose complementary state will correspond to the background. To separate the foreground and background in an image, the correct threshold value must be found. Several different methods for choosing a threshold exist; users can manually choose a threshold value, or a thresholding algorithm can compute a value automatically, which is known as automatic thresholding .

Stage 4: The classification of defects— Noise free template and defective images are fed into the image segmentation algorithm to separate PCB images into four main segments which are square segment, hole segment, thick line segment and thin line segment using mathematical morphology as shown in figure 2.

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 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. Image processing algorithm developed by Khalid [2], to classify the 14 defects into five groups. Those groups with the respective defects are as follows:

Group1: missing hole, wrong size hole.

Group2: spur, short, spurious copper, excessive short, conductor too close

Group3: open circuit, mouse bite, overetch, conductor missing.

Group4: under etch.

Group5: pinhole and breakout.

By combining morphological image segmentation and image processing algorithms it is possible to classify the defects into more number of groups and also reduce the number of defects in each group.

SIMULATION RESULTS

Two images are needed for the inspection, the Template image and the Defective image as shown in figure 3 and Figure 4 respectively. The result of the previous PCB inspection system has indicated that without a proper imageregistration operation, the PCB inspection system is likely to totally fail. Hence, theimproved PCB inspection systemincorporating with a reliable imageregistration operation. The result of image registration is shown in Figure 5. Two gray-scale images are needed for this operation, template image and a defectiveimage as shown in Figures 3 and 5. However, the images may still feature interference by unwanted noise due toslight misalignment and uneven binarization. To effectively eliminate the noise, median filtering and thresholding technique is used. Khalid's classification

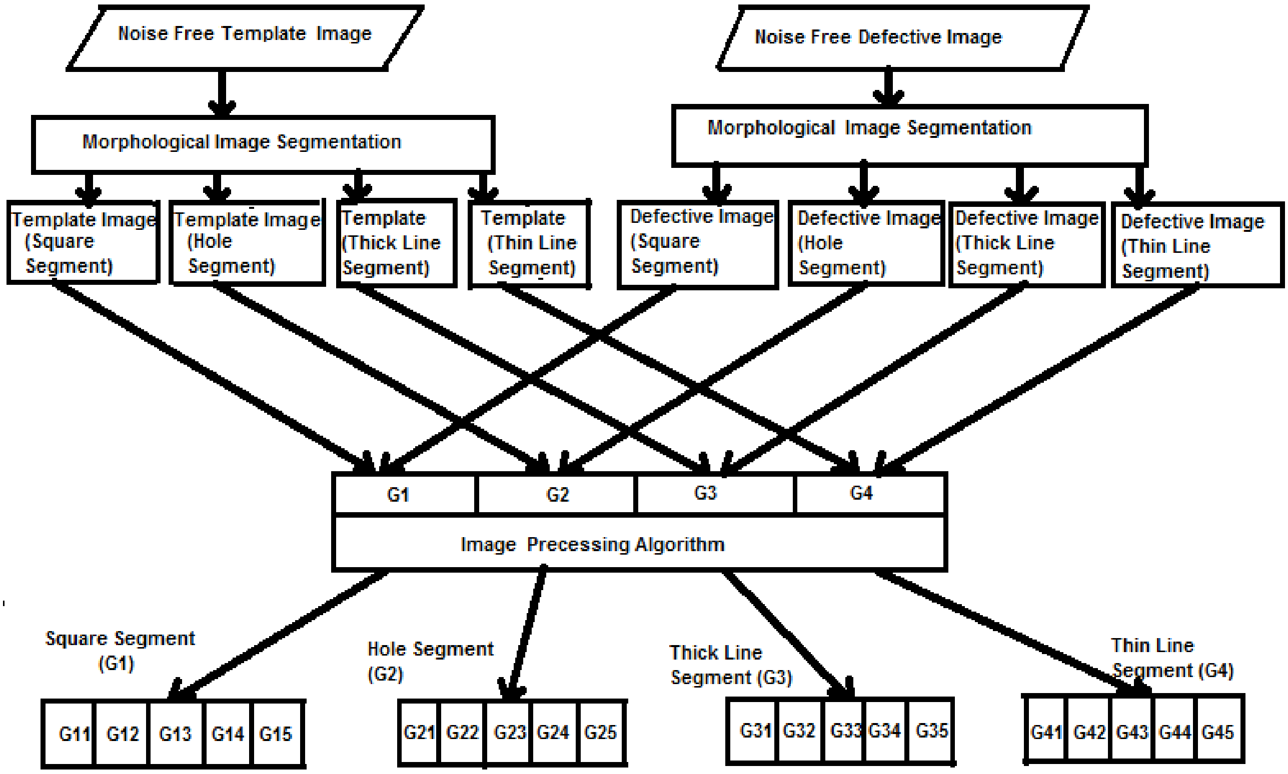
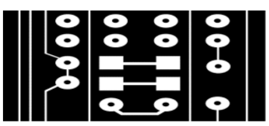
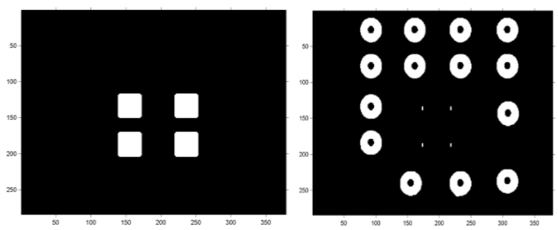


Fig 2. Algorithm for PCB defect classification





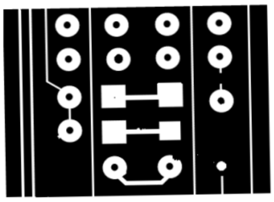


Fig 4. Defective bare PCB image

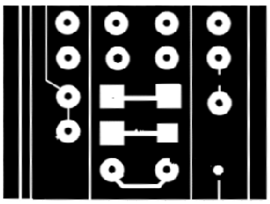


Fig 5.Registered defective image

can be further improved by combining the image segmentation algorithm developed by Heriansyah[1] and image processing algorithm developed by Khalid[2].Both the images [figure 3 and figure 5]are segmented into 4 segments each; square segment, hole-segment, thick line segment and thin-line segment. The image processing algorithm is able to generate 4x5 images (20 images) which will improve the overall defect classifi- cation ability of the system by increasing the number of groups from 5 to7 as listed in Table III. A sample of result for a defective image consisting of random defects is shown in figure 8.

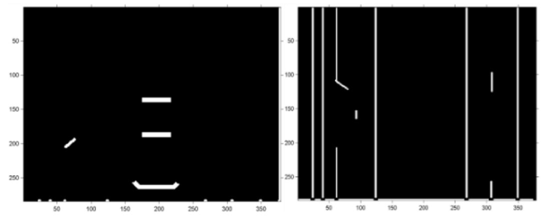


Fig 6. Morphological segmentation for Template Image

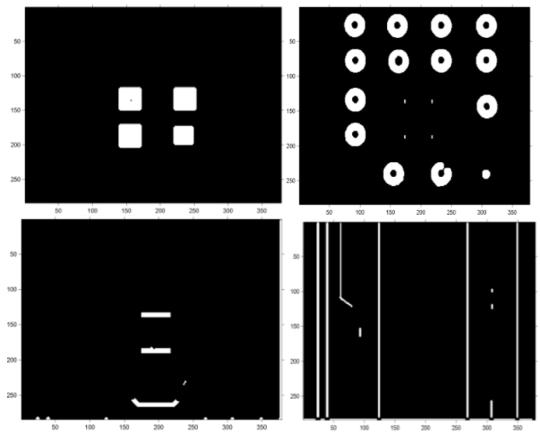


Fig 7:Morphological Segmentation for defective Image

TABLE III.Classified Group of Defects

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

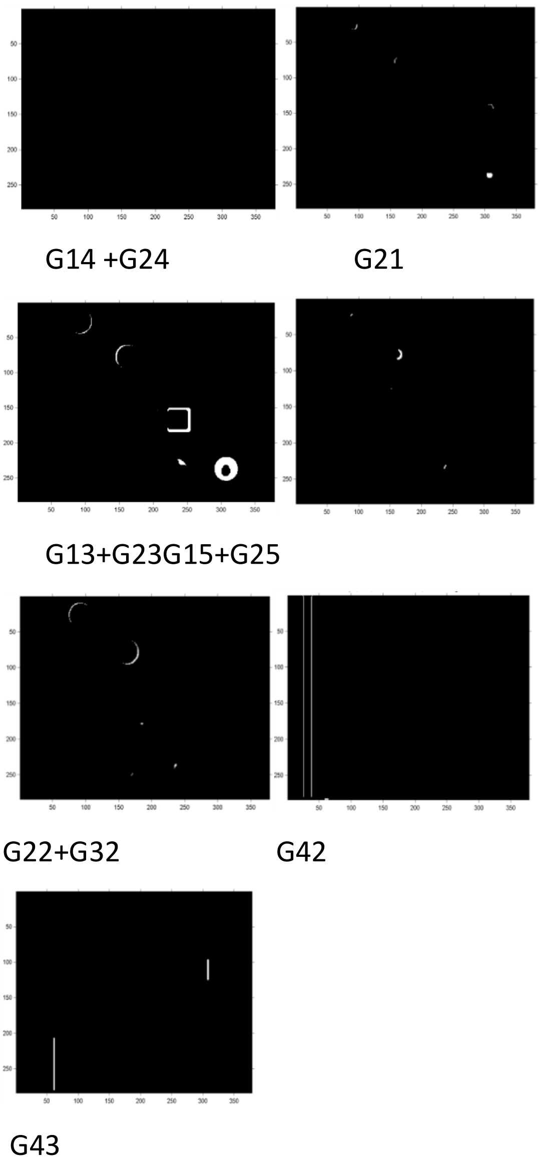


Fig 8.Sample Result of Defect Image

CONCLUSION

The improved PCB inspection system incorporated with an image registration operation to solve the alignment problem. A noise elimination procedure is designed in such a way that the resultant defects found in this algorithm is more precised compare to previous algorithm. Algorithm is also successfully able to improve the image processing algorithm developed by Khalid[2] by increasing the classification of 14 defects from 5 to 7 groups.

However, the major limitation of this algorithm is developed to work with binary images only, whereas the output from the cameras is in grayscale format. Although the conversion can be made from grayscale to binary format imperfection still can be occurred. Thus, this algorithm should be improved to handle the grayscale image format. Future improvement for the algorithm should include the ability to detect and classify all 14 defects individually.

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