ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 11, May 2015

A Review of PCB Defect Detection Using Image Processing

Anoop K. P, Sarath N.S, Sasi Kumar V. V.
Advanced Communication & Signal Processing Laboratory,
Department of Electronics & Communication Engineering, Government College of Engineering Kannur, kerala, India

Abstract----This paper reviews various methods of printed circuit board (PCB) defect detection and classification system using image processing. PCB 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 precise 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. Morphological image segmentation algorithm and simple image processing theories used for detecting defects. 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 computer generated PCBs. Manufactured defect PCB has to be simply thrown away this will save the cost of manufacturing process by reducing the amount of PCB being thrown away.

Index Terms **— Morphological image segmentation, image processing, defect detection and defect classification**.

I. INTRODUCTION

A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be single sided (one copper layer), double sided (two copper layers) or multi-layer (outer and inner layers). Multi-layer PCBs allow for much higher component density. Conductors on different layers are connected with plated through holes called vias. Advanced PCBs may contain components such as capacitors, resistors or active devices embedded in the substrate. An RGB image of PCB is shown in fig 1.

One of the key components in the electronics industries is the production of the PCB. 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. There are two main processes in PCB inspection, defect detection and defect classification. Currently there are many algorithms [1] 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. 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. These systems have advantage over human inspection in which subjectivity, fatigue, slowness and high cost is involved. In recent years, the PCB industries require automation due to many reasons. The most important one is the technological advances in PCBs design and manufacturing. New electronic component fabrication technologies require efficient PCB design and inspection method with compact dimension. The complex and compact design causes difficulties to human inspection [5] process. Another important factor is necessity to reduce the inspection duration. These factors lead to automation in PCB industry. Nowadays automated systems are preferred in manufacturing industry for higher productivity

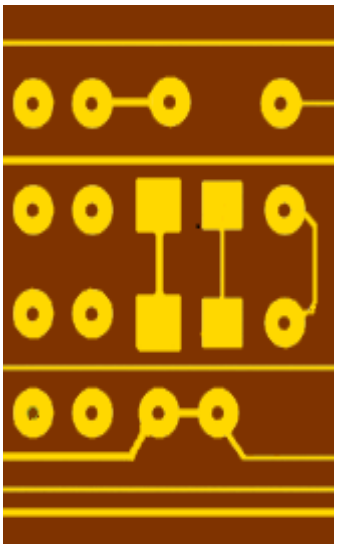


Fig. 1.RGB Image of printed circuit board

In this paper we can use 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. 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. Fig 2 shows a binary image of a single layer bare PCB [2] and Fig 3 shows the same image with defects [2] as listed in Table 1 [4].

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 11, May 2015

Table-1. Defects 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

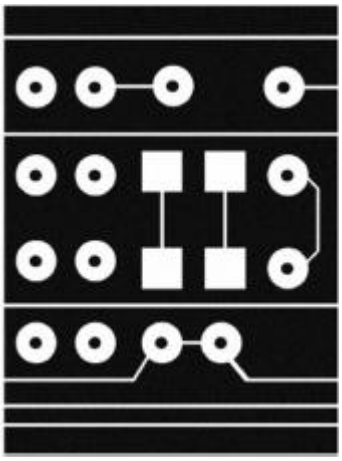


Fig. 2. Binary image of perfect PCB which is given in figure 1

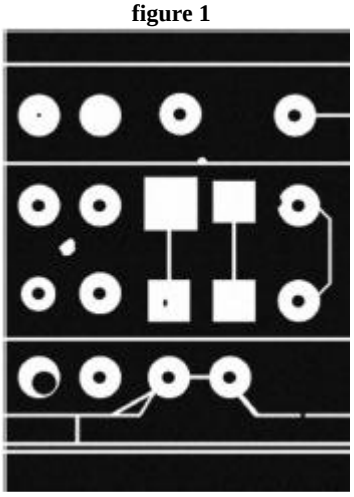


Fig. 3. Binary image of above PCB with certain defects

The rest of the paper is organized as follows. In Section II, we present the current state of the art related to the previous works. In Section III, we discuss the various methods of finding defects on PCB. In Section IV, we propose the work that is intended as the M. Tech project and in Section V, we discuss its applications. Finally Section VI, summarizes this paper with some concluding remarks.

II. CURRENT STATE OF THE ART

Heriansyah, et al. [1], [2] proposed a technique that classify PCB defect using neural network. This algorithm segments the images in to basic primitive patterns. Enclosing the primitive pattern, pattern assignment, pattern normalization and classification where developed using binary morphological image processing and learning vector quantization (LVQ) neural network. The PCB defect could be formed into three group, the defects on the foreground only, the defects on the background only, and the defects on both foreground and background

Wu, et al. [9] has developed a pixel based approach for the performance and comparison. At the time of writing this paper was only algorithm designed for defect classification, Pixel based approach classify seven defects (short, missing hole, pin hole, open, spar, etching problem and mouse-bite). In this approach there are few stages involved those are segmentation, windowing, defect detection, pattern assignment, normalization and classification

Shih-chieh Lin, et al.[6] proposed method has two stages. First stage was screening and the second stage was neural network to classify the defect more accurately. In this 558 training samples were used to train the proposed system first. The first stage shown that pattern matching index is the optimal screen indexing. The second stage the neural network was used to classify the defects and it shown more than three index should be used to effectively identify the defects.

Khalid, et al. [4] Proposed algorithm that can be implemented on the bare PCB to identify and to group PCB defects. However, the major limitation of this algorithm is that the proposed 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. Also, during the computation of defect detection and implementation, this operation brings along the unwanted noise due to misalignment and uneven binarization. Thus, in order to improve the algorithm, unwanted noise should be considered. Since the proposed algorithm at the moment, is only able to separate 14 types of defects into five groups.

S. H Indera Putera, et al. [3], [10] did improvement in Khalid's work by classifying seven groups. This is done by combining image processing algorithm and the segmentation algorithm. Each image is segmented into four patterns and then produced five new images for each pair of segmented reference and test images processed and thus 20 new images produced. Out of which, seven images were beneficial for defect classification. The result of this particular experiment was each group consists of 1 defect and maximum 4 defects and thus improved the work done by Khalid by an increasing number of groups from 5 to 7. This project minimizes the

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 11, May 2015

number of defects for each classified group. The wrong size hole is successfully separated, while missing hole remains as an individual defect. 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 the conductor is absent as a result of errors in the printing or etching process.

Ibrahim, et al. [7] proposed algorithm for defect detection only. The algorithm makes use of wavelet based image difference algorithm. The experimental result of this algorithm shows that the computational got reduced by 82.11 percent for defect detection

III. METHODS OF FINDING DEFECTS

The various methods are used for finding the defects on PCB are follow. Bare PCB is one without any placement of electronic components which is used along with other components to produce electrics goods. In order to reduce cost spending in manufacturing caused by the defected bare PCB, it must be inspected. Moganti et al, [11] proposed three categories of PCB inspection algorithms referential approaches, non-referential approaches, and hybrid approaches.

Referential approaches consist of image comparison and model based technique. 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. Hybrid approaches involve a combination both of the referential and the non-referential approaches.

A. Automated Optical Inspection (AOI)

Automated Optical Inspection (AOI) is an automated visual inspection of PCB where a camera autonomously scans the device under test for both catastrophic failure (missing component) and quality defects (fillet size/shape or component skew). It is commonly used in the manufacturing process due to the fact it is a non-contact test method. It is implemented at many stages through the manufacturing process including bare board inspection, Solder Paste inspection (SPI), pre and post re flow as well as other stages AOI for a bare PCB board inspection may detect these features

1) Line width violations
2) Spacing violation
3) Excess copper
4) Missing pad that is a feature that should be on the board is missing
5) Shorts circuits
6) Cuts
7) Hole breakage, that is a drilled hole (via) is outside of its landing pad

B. Computer Aided System for Defect detection

Computer aided defect detection is an extension of automatic optical inspection systems [7] mentioned in the previous system are used the inspection and assembling processes of PCB. For this purpose, ideal images are usually conforming to both CAD/CAM/CAE software and predefined models by standard databases. The main difficulty of these techniques lies in obtaining precise alignments and uniform lighting conditions on images. By the other hand, the non-referential approach is mainly based on the design rule checking (DRC) method for bare PCBs.

Automatic optical inspection systems detect the same type of surface related defects as manual inspection [4] including bare board inspection, solder bridging, lack of solder, missing components, poor part orientation, lifted leads, tomb stoning, and solder balls. Automatic optical inspection has the following characteristics that contact testing does not have

1) It recognizes potential defects such as out of specs, line Widths, line spacing, voids, pin holes, etc.
2) AOI can inspect art work and provides strict product Control from the onset of production.
3) AOI is a non-contact inspection, thus avoiding mechanical damage

C. Image Subtraction Method

We first compare a PCB standard image with a PCB image, using a simple subtraction algorithm that can highlight the main problem-regions. We have also seen the effect of noise in a PCB image that at what level this method is suitable to detect the faulty image. Our focus is to detect defects on printed circuit boards to see the effect of noise. Nowadays is necessary to improve the quality of PCB. In manufacturing industry there are defects, Misalignment and orientation error so automated inspection is required.

Image subtraction operation is performed in order to get the differences between two images. fig 4 represents the block diagram of image subtraction. The images are the reference image and the inspected image. The method compares both images pixel-by-pixel using XOR logic operator. The resulting image obtained after this operation contains defects.

The subtraction operation will produce either negative or positive image, 1 represents white pixel and 0 represents black pixel in a binary image

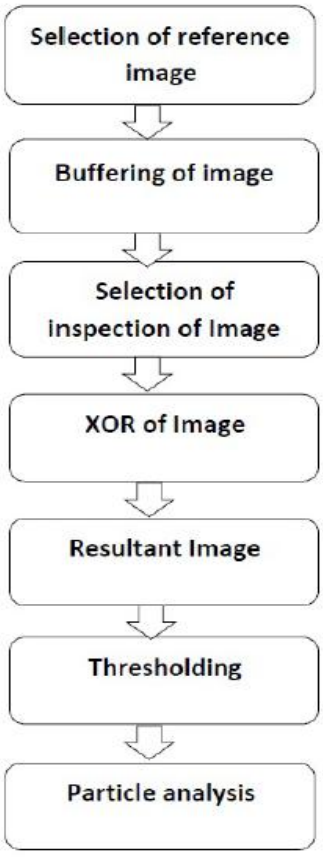
Two rules exists for image subtraction operation

Rule 1: If 1-0 = 1 then it gives positive pixel image

Rule 2: If 0-1 = -1 then it gives negative pixel image

For the image subtraction operation it is required that both images has same size in terms of pixels. The logical XOR operation gives defects in inspected image as compared with reference image

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 11, May 2015



D. Machine Vision

Machine vision (MV) is the technology and methods used to provide image based automatic inspection and analysis. Machine vision is concerned with the theory behind artificial systems that extract information from images and sequence of images. The image data can take many forms, such as video sequences, views from multiple cameras, or multidimensional data from a medical scanner. Machine vision can be implemented for the system involving following processes

1) Automated Inspection process
2) Process control
3) Data base collection and indexing
4) Modeling of system and environment

E. Manual Inspection System

PCB defects are inspected randomly using manual inspection system, which involves human operators. This technique is quite costly since it is highly error prone due to human error. A more sophisticated way of doing the inspection is the use of in house circuit testing (ICT) [9] technique. This technique uses a very expensive machine that checks the conductivity of the PCB using probes. However, the limitation of this technique is it can only detect defects that are based on either shorts or open. Many levels and different image processing techniques can be used.

Human operators simply inspect visually against prescribed standards. The decisions made by them often involve subjective judgment, in addition to being labor intensive and therefore costly, whereas automatic inspection systems remove the subjective aspects and provide fast, quantitative dimensional assessments. Due to the following criteria, the sophistication in automated visual inspection has become a part of the modern manufacturing environment.

IV. PROPOSED M. TECH. PROJECT

In the previous section we discussed various method of defect detection. The proposed M.Tech project is detection of defects on PCB using some of image processing technique. This project aims to propose in detecting and classifying the defects on bare single layer PCBs by introducing a hybrid algorithm. This project proposes a PCB defect detection and classification system using a morphological image segmentation algorithm and image processing theories. This project plans to use template and test images of single layer, bare computer generated PCBs. This project uses mathematical morphology for image segmentation, and image processing algorithm for detection and classification of PCB defects.

V. APPLICATIONS

The quality of PCBs will have a significant effect on the performance of many electronic products. Bare PCB is a PCB without any placement of electronic component, which is used along with other components to produce electric goods. In order to reduce cost spending in manufacturing caused by the defected bare PCB, the bare PCB must be inspected. The technology of computer vision has been highly developed and used in several industry applications. One of these applications is the automatic visual inspection of PCBs. The automatic visual inspection is important because it removes the subjective aspects and provides fast and quantitative assessments. It is responsible for detecting both cosmetic and functional defects and attempts are often made to ensure 100 percent quality assurance for all finished products

VI. CONCLUSION

Various advances took place in PCB manufacturing industry over the last decade. Machine vision may answer the manufacturing industry's need to improve product quality and increase productivity. This study presented a survey of algorithms for visual inspection of PCB. The major limitation of all the existing inspection systems is that all the algorithms need a special hardware platform in order to achieve the desired real-time speeds, which make the systems extremely expensive .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.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 11, May 2015

In PCB inspection system a noise elimination system is designed in such a way that the resultant defects found in this algorithm is more precise. This algorithm is developed to work with binary images only, whereas the output from the camera is in gray scale format. Although the conversion can be made from gray scale to binary format imperfection can be occurred this algorithm should be improved to handle the gray scale image format.

REFERENCES

[1] T. R. Heriansyah, S.A.R AI-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] T. R. Heriansyah, 'Segmentation of PCB Images into Simple Generic Patterns using Mathematical Morphology and Windowing Technique" Master's Thesis, University Technology Malaysia, 2004.

[3] A. S.H Indera Putera, Z.Ibrahim, "Printed Circuit Board Defect Detection Using Mathematical Morphology and MAT LAB Image Processing Tools," Universiti Teknologi MARA, 40450 Shah Alam, Selangor Malaysia, vol. 5, pp. 359–363, 2012.

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

[5] Y. 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.

[6] T. 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.

[7] Z. Ibrahim, S.A.R AI-attas and Z. Aspar, "Analysis of the WaveletBased Image Difference Algorithm for PCB Inspection," proceedings of SICE, Osaka, Japan, 2002.

[8] Prof. Malge P. S, Nadaf R. S.2, "A Survey: Automated Visual PCB Inspection Algorithm," International Journal of Engineering Research and Technology) Vol. 3 Issue 1, January - 2014.

[9] Wen-Yen Wu, Mao-Jiun J.Wang and Chih-Ming Liu,Automated Inspection of Printed Circuit Board Through Machine Vision' Computers in Industry year = 1996, volume = 28.

[10] H. Indera Putera, Syahrul Fahmi Dzafaruddin, :Matlab based defect detection and classification of printed circuit board, digital information and communication technology and its applications (dictap) IEEE 2012 Second International Conference. Bangkok, year = 2012.

[11] M. Moganti, F. Ercal, C. H. Dagli and S. Tsunekawa, Automatic PCB inspection algorithms: A survey Computer Vision and Image Understanding, year = 1996, volume = 26.

AUTHOR BIOGRAPHY

Anoop K. P. received the B-Tech degree in electronics and communication engineering in 2012 from Cochin university of Science and Technology kerala,. Currently doing Mtech degree in signal processing and embedded system at kannur university kerala

Sarath N. S. Received the B-Tech degree in electronics and communication engineering in 2012 from M G university. Currently doing Mtech degree in signal processing and embedded system at kannur university kerala

Sasi kumar V. V. received the B- tech degree in electronics and communication at kerala university**,** and master's degree at college of engineering Trivandrum. Currently working as an associate professor in government college of engineering Kannur.