IJCSE International Journal of Computer Sciences and Engineering Open Access
Survey Paper Vol.-7, Issue-6, June 2019 E-ISSN: 2347-2693

A Survey on Various Approaches of Automatic Optical Inspection for PCB Defect Detection

[1]Mukesh Kumar, [2]Manjesh Kumar

[1]Department of Electronics and Communication Engineering
[1]Sant Longowal Institute of Engineering and Technology, Longowal, Punjab
[2]Suncity Enterprises, Jaipur

Corresponding Author: mukeshrai131985@gmail.com

DOI: https://doi.org/10.26438/ijcse/v7i6.837841 | Available online at: www.ijcseonline.org

Accepted: 14/Jun/2019, Published: 30/Jun/2019

***Abstract*—** The Printed circuit board (PCB) is one of the crucial components of the electronics industry. An automated visual inspection system is required to provide a fast and quantitative assessment of PCB, since manual defect detection system is not efficient and time-consuming. Machine vision technology is an alternative to manual inspections and measurements with the help of high-resolution digital camera and image processing. This paper presents the various possible defects in PCB that can affect the working of electronic gadgets. Major defects are classified mainly under Fatal and Potential that can be detected mainly by any of the three approaches as Referential, Non-referential, and, Hybrid to find out defects present in PCB. After a comparative study of these methods, we have tried to find out the significantly fast and accurate method.

***Keywords*—** PCB, Automated Visual inspection, Machine Vision, Image processing, Referential, Non-referential, Hybrid approach

I. INTRODUCTION

The PCB quality plays a pivotal role in the performance of electronic gadgets. A PCB mechanically supports and electronically connects electronic components. The circuit formed by PCB is less expensive and quicker than other wiring methods because mounting and wiring of various components are done with single component. The PCB may have various defects during its manufacturing due to misalignment and orientation. So, for detecting the defects in PCB there are many methods used like manual inspection, electrical performance testing, and automatic optical inspection (AOI) . Manual inspection is expansive, not much efficient, and taking more time. Therefore, an automated visual inspection system is required to provide fast and quantitative assessment of PCB. Machine vision is a combination of computer hardware and software working together with camera and source of light for capturing an image. It is being used in different industry to automate the production and increase the quality of the product.

The paper is organized as follows-The related work is arranged in section II. Section III shows the defect classification in PCB. The various defect detection approach of AOI is discussed in Section IV. Section V discusses the conclusion followed by the different references.

II. RELATED WORKS

There are various research works have been taken place in the field automated inspection of PCB. A brief recollection of the contributions by eminent researchers is summarized here:

Mukesh Kumar et al. [1] have developed an algorithm to generate standard database for bare PCB defect detection. The algorithm starts with PCB image acquisition, succeeded by colour plane extraction, look up table transformation, thresholding, filtering, advance morphology and finally particle analysis are done to generate standard data. The generated database can be used for referential method of PCB defect detection. Total time taken to execute the proposed algorithm is 14 ms meaning that per second it can execute 71 PCB.

Mukesh Kumar et al. [2] proposed an algorithm for pre-processing PCB image to enhance it using National instrument Assistant Vision software. This method effectively sharpens edge tracks to enhance the PCB image. Performance meter shows that time taken for enhancement is 10 ms or 99.43 parts per second.

Ang Teohong et al. [3] worked on the pattern and colour image analysis techniques with Matrix Imaging Library. The system is tested with PCB boards from factory production line. and achieved PCB board flux defects sorting accuracy at 86.0% based on proposed pattern matching technique combined with red colour filter band histogram.

Yang Hanlin et al. [4] proposed defect detection of printed circuit boad based on partition enhanced matching. Starting with acquisition of standard board and pending board image, and divide it into sub-blocks. In next step, to enance the caracteristics of each block's image, a piecewise linear transformation method is used. Lastly grey scale statistical matching method is used to judge whether the sub-block image is defective or not. Experimental result shows that this defect detection is achieved at high speed with better accuracy.

T. J. Mateo Sanguino et al. [5] proposed modification of the subtraction method based on reference images and combined with a particle classification algorithm based on two measures of light intensity. The system allows classification of twelve types of defects through statistical techniques. The methods have been analytically compared and their performances have been studied.

Ziyin Li et al. [6] proposed an algorithm with image processing, artificial intelligence, & motion control. The image denoising, image enhancement & image segmentation algorithm are also used. This design is helpful in detecting short circuit & open circuit defects with wire gaps, voids, scratch defects etc also. This design is a non-contact PCB defects detection. The maximum resolution of this design is 15 µm and rate of success of defect detection success is more than 95 %.

Fenglin Guo et al. [7] starting with the introduction of the whole system structure with principle of vision detection, also discussed the concern core technologies used in PCB defect inspection. At last implemented one set of test system with the core technologies mentioned. To enhance the image double sigmoid transformation technique is used and defect detection is done using template matching. The PCB can be effectively inspected, located and recognized with 5 PCBs per minute with this method.

Shu-an Guan et al. [8] used double Sigmoid transformation method for the enhancement of the acquired image. This transformation method effectively sharpens edges to enhance PCB image.

Zuwairie Ibrahim et al. [9] proposed a technique to abolish or diminish the noise as much as possible during the process of defect detection. For defect detection in PCB, Image subtraction method is used. The result showed a considerable improvement during the real-time inspection of PCB.

Syamsiah Mashohor et al. [10] presented an integrated system with a number of image processing algorithm entrenched within a Genetic algorithm-based support to offer an alteration and superior quality analysis with fewer intricacy. The proposed framework allowed concerto of tasks such as edge detection and thresholding to enhance defect detection precision with less execution time.

Ji-joong Hong et al. [12] used the reference comparison method for PCB inspection. The proposed algorithm makes the system cheaper, realistic and proficient to recognize the real time system.

M. Moganti et al. [13] divided the defect detection algorithms mainly in reference comparison (reference-based) method, design-rule checking (non-referential) method and hybrid method, which involved an amalgamation of reference comparison and design-rule methods.

Timothy S. Newman et al. [14] presented survey on taxonomy of inspection system based on their sensory input. It discussed the benefits and feasibility of automated visual inspection. The methodology of various inspection systems was discussed and highlighted the commonly used techniques. It believes that the PC-based solutions will become more feasible.

III. DEFECT CLASSIFICATION

PCB defects are mainly classified into two categories: Fatal defects are those in which the PCB does not attend the objective, they are designed for. Potential defects are those compromising PCB during utilization.

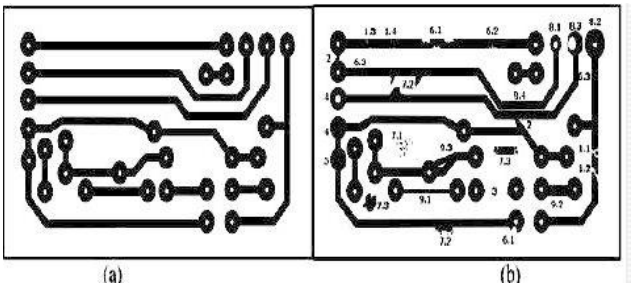

Fig.1 PCB without error (a) and PCB with error (b) [16]

Table 1 Various defects classification in bare PCB

FATAL	1. Breaks	1.1 Fracture
		1.2 Cut
		1.3 Scratches
		1.4 Cracks
	2. Shorts/Bridges	
	3. Missing conductor	
	4. Incorrect hole dimension	
	5. Missing hole	
POTENTIA	6. Partial open	6.1 Mouse bits
		6.2 Nicks
		6.3 Pin holes
	7. Excessive spurious	7.1 Specks
		7.2 Spurs/Protrusions
		7.3 Smears
	8. Pad violation	8.1 Under etching
		8.2 Over etching
		8.3 Breakout
	9. Variations between the printed lines	9.1 Small thickness wiring
		9.2 Large conductors

Fig.1 shows the two PCB one is without any error (a) and other having various errors (b) to analyse it. The various major defects that can occur in PCB are classified in Table 1.

IV. DEFECT DETECTION APPROACH

The AOI method is popularly known as non-touch detection method. The system detects and recognizes the defects present in PCB non- destructively, swiftly, and precisely. The main AOI equipment manufacturing industries are Teradyne in U.S., opt Rotech in Israel, Diagnosis in Britain, and MVT in Ireland etc. The Classification of Automatic optical inspection system is shown in Fig.2 It is broadly classified into Reference inspection, Non–referential inspection, and Hybrid approach.

1. Referential inspection method

The referential inspection methods are used for execution of a real point-to-point comparison, where the reference data is taken from a source of good image and stored into database. This image is used to detect defects like missing tracks, missing termination, opens, and shorts.

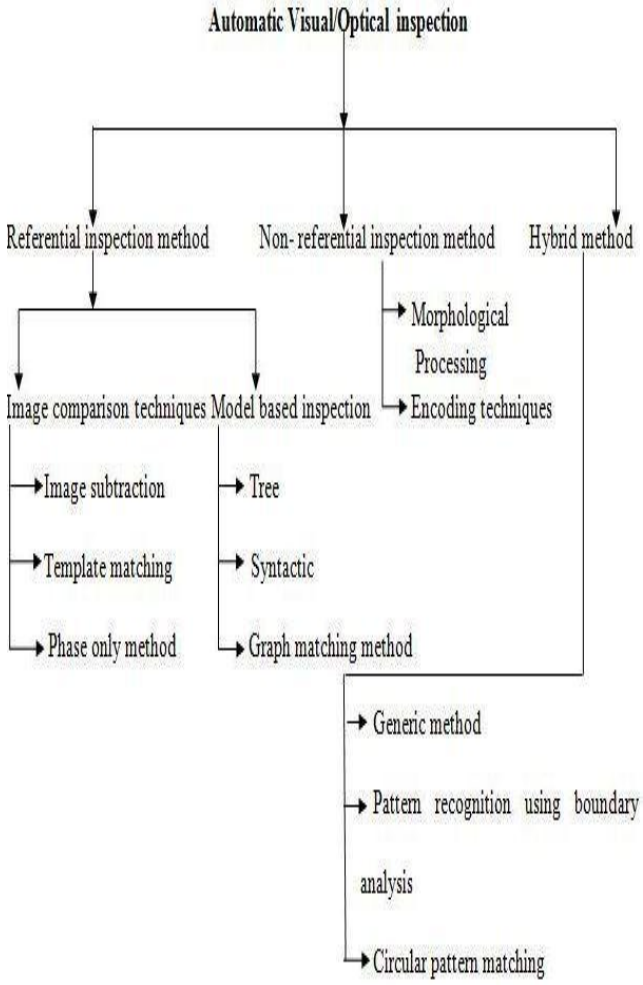

Fig.2 Shows classification of defect detection algorithm

A. Image comparison method

❖ Image subtraction

It is the simplest and most direct approach to find out the defects associated with PCB. In this method both the standard image and the image to be detected is acquired and the logical XOR operation is performed on them, which can be seen in Fig.3

- The overall defects can be verified in the geometry of the PCB.
- Registration, colour variation, reflectivity variation and lighting sensitivity are some issues regarding this method.

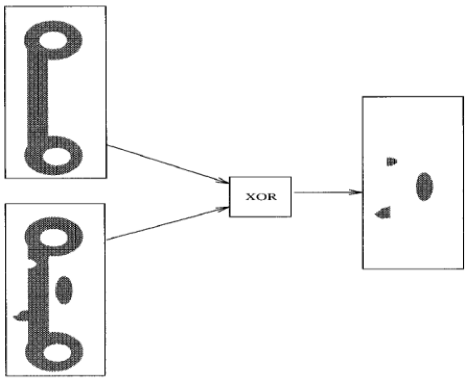

Fig.3 Image subtraction operation

- Template matching
  The modified form of image processing is template matching m. In this the extracted features from the image to be inspected is compared with the stored standard database. Using this method, the sensitivity of the input data and space for storage data is reduced however it enhances the robustness of the system. Limitation of this system is that it becomes more expensive because of enormous number of templates used.
- Phase only method
  Phase only method is based on phase only imaging and it is an alternate method to the slandered template matching. In phase only image all the information is stored in the phase because it is an image with unit power spectral density. This method uses Fourier transformation on the image, next normalization on the transformed image, to spread over entire grayscale range and finally inverse-Fourier transformation applies on normalized image to reduce a map of significant image difference. The disadvantage is that it takes large amount of inspection time in comparison to simple template matching method.

B. Model base inspection methods

The inspection using model-based methods are dependent on matching the pattern with the set of predefined models. The performance of this method is strongly affected by the selection of the model.

- Syntactic approach
  A PCB image is modelled as a finite set of alphabets/symbols. The method involves tracing the boundary points and analysing the shape to produce syntactic description of the shape using the primitive shapes that best describes the PCB patterns.

- Graph matching methods
  This method depends on the structural, topological, and geometrical properties of the image. This method compares the standard graph of PCB which to be inspected with the reference PCB image. The topological information incorporates a weighted graph composed of several nodes, edges, connections, and their locations.

2. Non-reference inspection method

Non–reference methods do not require any reference pattern to work with that, the idea is based on design specific standards. These methods are also called as design rule verification or generic property methods. This is time consuming process and hence the response time of the system decreases, when the design rule verification directly applied on the image. So first a method used to transform the image into a form to reduce the verification time.

A. Morphological processing

This uses an expansion-contraction process without any predefined model of perfect pattern. Ye and Danielson presented an algorithm for verification of minimum conductor & insulator trace width.

B. Encoding techniques

This encoding technique used boundary analysis and run length encoding. Boundary analysis techniques work on the representation of the boundaries in a traceable form, followed by a rule verification procedure. West et al implemented a free- man chain coding techniques to detect faults

3. Hybrid inspection method

The hybrid inspection method increases the efficiency of the system with the help of both referential and design rule methods exploiting the strengths and overcoming the weakness of each of the two methods. It covers a large variety of defects comparing to referential or design rule techniques alone. PCB which do not violate the design rules are detected by referential approach. Fig.4 shown below states the performance of these methods based on the size of features. The design rule process detects all the defects within small and medium sized features where as referential method is equally sensitive upto the largest feature. This method is 100 % error sensitive , irrespective of feature sizes on printed circuit board (PCB).

- Generic method

This method is combination of both the referential and design rule techniques but it does not compare a reference image and the image to be tested, pixel-by-pixel. It eliminates the need of storage requirement, generation, registration, and the comparision of a reference with the test image. This method compares a small list of predicted feature types and location with a list of predicted feature. This method has a major improvement on the non-referential technology.

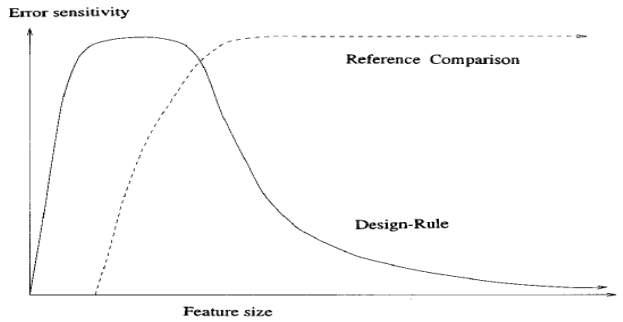

Fig.4 Showing performance of reference and design rule method [13]

- Pattern detection using boundary analysis

This inspection system uses a hybrid flaw detection techniques based on pattern detection and boundary analysis techniques. This method locates the region that could flaw and conduction measurement done onlyon that regions, resulting in increase of the speed of pattern matching.

- Circular pattern matching

Yu et al proposed and implemented a hardware technique based on radial encoding for high speed inspection of artwork and bare boards. Encoding is done by template comparator while verification of th ecode is done by done by defect detection logic to judge the codes are contradicting.

- Radial matching algorithm

This method uses a learning sample pattern from a standard PCB and converting these pattern into the characteristic features known as radial codes.

- Shape comparision method

In the Ai-1029 system Nikon employed a pattern comparison method based on automatic learning procedures. First, the input is taken, and system breaks it into small segments after that store the segments as reference file. Next, the system repeats the same process with the input image to be tested. If the new image which is to be tested, is matched with the reference file, then no defect otherwise the image referred as defective.

V. CONCLUSIONS

Among the various inspection system used for defect detection in PCB, the Automatic Optical Inspection is most emerging and widely accepted techniques. The contribution of previously published research articles is discussed. The different defect that may persist in PCB is mentioned followed by automatic optical inspection for PCB defect detection. After facing several complexities, problems, and challenges the design for Automatic defect detection in PCB using Machine vision has been developed.

REFERENCES

[1] M. Kumar, N. Kumar, M. Kumar, Ajay Kumar Vishwakarma, "A Novel Approach of Standard Data Base Generation for Defect Detection in Bare PCB", in the IEEEinternational conference on ICCCA, 2015, pp. 11-15, 2015.

[2] M. Kumar, M. Kumar, G. Kumar, "PCB Image Enhancement using Machine Vision for Effective Defect Detection", international Journal of Advanced Engineering Research and Science (IJAERS) Vol-1, Issue-3, pp.50-53, Aug- 2014.

[3] A. eohong, Z.B. Ibrahim, S. Ramli, "Computer machine vision inspection on Printed Circuit Board flux defects", American Journal of Engineering and Applied Sciences, Science Publication, Vol-6, Issue-3, pp.263-273, 2013.

[4] Y. hanlin, W. jun., "Automatic detection method of Circuit Boards defect based on partition enhanced matching", Information Technology Journal, Vol-11, pp.2256-2260, 2013.

[5] T.J. Mateo Sanguino and M.S. Rodriguez, "Computer-Aided System for Defect Inspection in the PCB Manufacturing Process", In the 16th IEEE International Conference on Intelligent Engineering Systems, pp. 151-156. 2012.

[6] Z. Li, Q. Yang, "System design for PCB defects detecion based on AOI technology", In IEEE, International Congress on Image and Signal Processing, Vol-4, pp.1988-1992, 2011.

[7] F. Guo, S. Guan," Research of the Machine Vision Based PCB Defect Inspection System", In IEEE International Conference on Intelligence Science and Information Engineering, pp. 472-475, 2011.

[8] S. Guan, F. Guo, "A New Image Enhancement Algorithm for PCB Defect Detection", In IEEE International Conference on Intelligence Science and Information Engineering, pp.454-456 2011.

[9] Z. Ibrahim, N.K. Khalid, I. Ibrahim, M.S. Zainal Abidin, M.M. Mokji, S. A. Rahman Syed Abu Bakar," A noise elimination procedure for Printed Circuit Board inspection system" In the 2nd IEEE Asia International Conference on Modelling & Simulation, pp. 332-33, 2008.

[10] S. Mashohor, J.R. Evans, A.T. Erdogan "Automatic Hybrid Genetic Algorithm Based Printed Circuit Board Inspection" In the IEEE NASA/ESA Conference on Adaptive Hardware and Systems, pp. 390-400, 2006.

[11] Z. Ibrahim , S.A.R Al-Attas, O. Ono, and M.M. Mokji, "A noise elimination procedure for Wavelet-Based Printed Circuit Board inspection system", Asian Control Conference, pp. 875-880, 2004

[12] J.J. Hong, K.J. Park, K.G. Kim "Parallel Processing Machine Vision System for Bare PCB Inspection", In IECON'98, Proceedings of the 24th Annual Conference of the IEEE Industrial Electronics Society, Vol. 3, pp. 1346-1350, 1998.

[13] M. Moganti., F. Ercal, S. Tsunekaw,"Automatic PCB inspection algorithms: A Survey", Computer vision and image understanding, Vol.63, pp. 287–313, 1996.

[14] T.S. Newman, A.K. Jain,"A Survey of Automated Visual inspection", Computer vision and image understanding, Vol. 61, pp. 231-262,1995.

[15] Y. Hara., N. Akiyana, and K. Kaasaki , "Automatic inspection system for Printed Circuit Boards", IEEE Transactions on pattern analysis and Machine intelligence, Vol. 6, pp. 623-630, 1983.

[16] F.R. Leta, F.F. Feliciano, F.P. Martins "Computer vision system for Printed Circuit Board inspection", ABCM Symposium Series in Mechatronics, Volume 3, pp. 623-632, 2008.

Authors Profile

Mukesh kumar received the B.Tech. degree from West bengal university, kolkata and M.Tech. degree from Sant Longowal Institue of Engineering and Technology, Longowal (Punjab) in 2011 and 2014 respectively. He is currently pursuing Ph.D. degree in the Department of Electronic and Communication, Sant Longowal Institue of Engineering and Technology, Longowal (Punjab). His current research interests include Image processing, low power VLSI design, and Radiation hardened memory design. He is reviewer of SCI and other peer reviewed journals and has 1 year of teaching as well as 4 years of Research experience.

Manesh kumar received the B.E. and M.E. degree from Rajasthan Technical University, Rajasthan in 2010 and 2013 respectively. He is currently serve as the Project Manager in Suncity Enterprises. His current research interests include Image processing, Power system. He is author of 3 books and has more than 6 year of teaching and industrial experience.

