International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Defect Detection in Printed Board Circuit using Image Processing

N. Munisankar, S. Nagarajan, B. Narendra Kumar Rao

Abstract*: *A printed circuit board without connecting with any components called as a bare PCB. Consider a PCB as a basic part which has been settled with more electronic units. In order to display the manufacturing process, the drawbacks have been taken by PCB individually. The reflection of this separation process impacts the performance of the circuits. Also, we have examined about classification methodologies as well as referential based PCB detection. From the input images, the needed and related information has been pulled out using image processing methodologies by the referential based PCB detection. Comparing with the un-defected PCB images, this was used to find out the defects. To meet the goal of the PCB defect detection, several feature extraction and pre-processing methods are derived in this article. The PCB defects have been classified by those features using the machine learning algorithms. Moreover, several types of machine learning algorithms are derived in this article. This paper helps the researchers for achieving a better solution for image processing and machine learning-based printed circuit board the defect classification.

Index Terms*: *Image processing, printed circuit board, machine learning, defect classification, feature extraction.

I. INTRODUCTION

The basic structural unit of several contemporary electronic products are known as PCB (Printed Circuit Board). And, it was classified into 2 types. a) Bare PCB b) Assembled PCB The components are routed with the PCB board was called as printed circuit assembly (PCA) or printed circuit board assembly (PCBA). More Benefits of existing using PCB such as during assembly process and wiring, it reduced the likelihood of errors. Productivity of automation industrial gets increased. The appearance of more new methodologies were introduced due to increased productivity. Saved the considerable space. More complex and accurate. Although, inspecting a bare PCB is a main thing during the real PCB production process. Because of this inspection, they can find and categorize the defective circuit board earlier and left it for further proceedings. This removal helped to prevent greater loses as well as saved the cost. Also traditional detection methods contain the following. i) Electrical testing ii) X-ray methods iii) Visual Inspection.

Revised Manuscript Received on December 30, 2019.
***** Correspondence Author
N. Munisankar*, Department of Computer Science and Engineering, Annamalai University, Chidambaram, India.
Dr. S. Nagarajan, Department of Computer Science and Engineering, Government college of engineering, Trichy, India.
B. Narendra Kumar Rao, Department of Computer Science and Engineering, Sree Vidyanekethan Engineering college, Autonomous, Tirupati, India.

AOI is an automated inspection technology based on machine vision [1]. This modern automated inspection technology gets introduced which was named as, an automatic optical inspection (AOI). Due to the benefits of its high-tech and non-contact, it was generally used in PCB inspection industry [2]. The detection system was composed in the below terms as follows: a) An image processing device b) An image acquisition device c) A motion control device d) Camera. The major benefits of AOI are (i) Avoiding the limitation of weakness in artificial check. ii) Improving detection efficiency [3]. The main component of AOI was so expensive and it was very complex for several PCB manufacturers to accept [4]. So a cheaper automatic PCB inspection system [5] has to be developed as necessary.

The alternative to find defect of PCB is vison-based detection methodology which is categorized into three types [6] as follows: The first one is reference comparison in which the defect area is identified based on the comparison process with the aid of template image. The advantage of reference comparison based defect detection is i) Easy to understand and ii) Intuitive. The major drawback of reference comparison based defect detection is in the photographing process, it was sensitive to the light environment. the scone one is high alignment accuracy required. The second one is non-reference comparison where the defects are discovered based on the design rules, this comparison method was used to check whether the traces and layout of the circuit board to be tested are reasonable. The major demerit of the non-reference comparison methodology easy to lose large defects and distortion characteristics. The third one is considering the advantages of reference based method and non-reference based method. However, the implementation of this hybrid comparison is very hard when compared with the other two methodologies and it requires large amount of computational complexity. No other way to provide more exact information for the further step such as repair, if the founded defect cannot be identified and categorized. So they need to analyse more about the defect classification in the defect detection process [3].

II. OVERVIEW OF PCB DEFECT DETECTION

While PCB manufacturing process going on, two types of defects was happened.

I. **Functional Defects** - It affected the PCB's performance.
II. **Cosmetic Defects** – It affected the PCB's appearance [7].

PCB inspection algorithms are classified into three types.

They are:

1. **Referential based inspection methods** – Contains model-based techniques as well as image comparison.
2. **Non-Referential based inspection** – This was also known as design-rule verification methods which were based upon the verification of the general design rules. Also, it was mandatory to verify widths of insulators and conductors.
3. **Hybrid inspection methods**: It was a combination of both non-referential methods and referential.

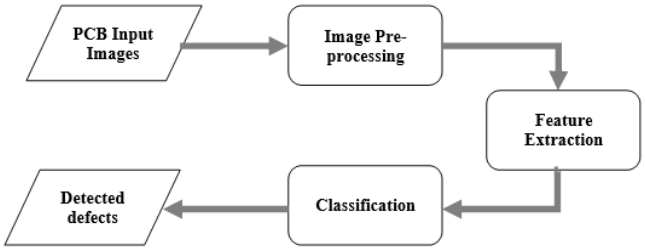
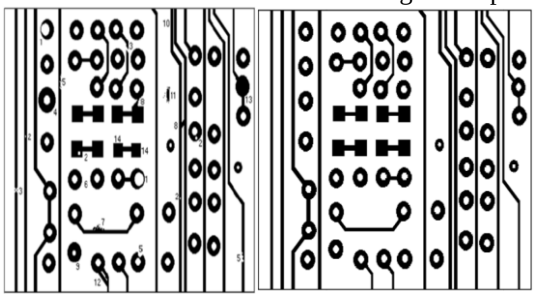


Fig. 1. Block diagram of the PCB defect classification

In this paper, we focused on the image comparison based referential inspection methods where the features of non-defected PCB images are collected which will be compared with the defected images and classify the defects according to the various defect factors. Before the feature extraction process, the input images are subjected to pre-processing phase to remove the unnecessary noise and enhance the quality of the image. The pre-processing phase enhances the result of the feature extraction process. The resultant information of feature extraction process is progressed by the classification algorithm. The overall block diagram of the PCB defect classification algorithm presented in figure 1.The fig. 1 represents the overall block diagram of the image processing-based PCB defect detection methodology. Initially, the PCB input data are collected from the database where each image is subjected to the pre-processing phase where the noises in the images are removed and enhance the quality of the PCB input image. Once the quality of the images is enhanced, then the useful appropriate information is extracted from that images by utilizing the appropriate feature extraction methodologies which are given to classification algorithm to categorize the defects by compared with the non-defected PCB images.



(a) (b)

Fig. 2. a) Non-defected printed circuit board b) Defected printed circuit board

TABLE I. VARIOUS DEFECTS OF BARE PCB

S. No	Defects
1	Open Circuit
2	Short
3	Conductor Too Loose
4	Missing Conductor
5	Excessive Short
6	Breakout
7	Pin-Hole
8	Under-Etch
9	Mouse-Bite
10	Missing Hole
11	Over-Etch
12	Spur
13	Wrong Size Hole
14	Spurious Copper

A. Input Image Collection

The PCB DSLR dataset is one of the widely utilized dataset for PCB analysis based on computer vision. The PCB DSLR composed with 748 images captured using professional DSLR camera under various constraints. The images in the PCB DSLR dataset composed with information about bounding box and segmentation of Integrated chips [8]. Another, widely used dataset is synthesized PCB dataset which is constructed by Weibo Huang, Peng Wei [9]. The synthesized PCB dataset used for detecting, classification and registration task and the dataset composed with 1386 images along with six types of defects. The Deep PCB dataset constructed by Sanli Tang et al. [10] which composed with 1500 PCB image pairs among them 1000 image pairs are utilized for training purpose remaining 500 can be utilized for testing. The pair of images represents the defect free image and tested defected image. The sample image of non-defected printed circuit board and the defected printed circuit board is presented in Fig. 2 (a) and 3 (b) respectively. The list of possible defects is tabulated in table 1.

1) Major defects of PCBA

Based on the industry statistics, 74% of the defects are identified due to three major PCB assembly defects such as components shift, solder bridging and open solder joints. The brief description of each defects are given below.

a) Open Solder Joints

When there are no joints available among the lead, pad, and other components of PCB, the open solder joints defects are occurred. Another major reason for the open solder joint is, the solder is not existing on the component but the solder available only on the PCB pad.

b) Solder Bridging

Solder bridging is also considered as shorts, which occurs when the soldering is not done properly which is very difficult to find. The undetected solder bridging leads severe damage to entire circuit such as blow up or burn up of a component and PCB trace.

c) Component Shift

The mis-sorted of an item to its target named as the term of component shift. This has been happened when reflowing since the components ability to float on the molten solder. Also, the components contain more pads like BGA components.

Because of the surface tension of the molten solder, those BGA components are rearranged themselves. Therefore, several times the components are settled in the same place in order to confirm that they are settled in the accurate place which means it was in the center of the pad or the land areas.

B. Pre-processing

Applying procedures to both input and output intensity images [11] are called in a significant name as Pre-processing. Transformation of raw image data into a clean image data was named as Image pre-processing. Raw image data consists the following. a) Noise b) Missing/incomplete/inconsistent/false values [12]. Merits of Pre-processing such as a) Improved the image date to decrease the reluctant falsifications. b) Enhanced some image characteristics vital for additional processing [13]. c) Beneficial impacts on the excellence of feature extraction and the outcomes of image analysis. [14]

Although, images are fetched and predicted from the satellites. When taking an image from the digital camera, there was a shortage in brightness as well as contrast due to the boundaries of illumination constraints and imaging subsystems. The image enhancement process solved the problem of various types of noise such as a) Edge enhancement, b) Noise filtering, c) Contrast, d) Sharpening, e) Magnifying, f) Pseudo-colouring. Merits of Image Enhancement such as 1) This concept used in image analysis, animate display and feature extraction. 2) Increase the inherent information content in the data by itself. 3) More importance has been given to the certain image characteristics. 4) This algorithm was application dependent as well as Interactive. 5) Here, few of the methodologies as histogram modification [15], contrast stretching and noise filtering.

C. Feature Extraction

In the field of image processing, feature extraction is the significant process which is utilized to extracting the useful information from the input image. The widely applied feature extraction methodologies are briefly described in this section.

Edges

Edge points represents the boundary among the image regions and the edge depicts that shape of the object which includes many junctions. In image processing field, the edges are identified based on the set of point with the strong gradient magnitude. Most of the edge detection algorithms utilizes the chain gradient points together to discover the edges in the image. The variations in the edge detection methodologies varies with respect to the set of constraints on the various properties of the edge such as smoothness, shape and gradient value. The edges are considered as single-dimension structure in local.

1) Corners/interest points

Corners are local two-dimensional structure which is also known as interest point which is also considered as point-based feature of the image. The corner detection algorithm applied after the edge detection algorithm. Based on the analysis of edges, the corner detection algorithm discovers the rapid changes in the direction. The selected points are frequently known as interest points.

2) Blobs/regions of interest points

Blobs also known as region of interest points which deliver the additional information about the structure of the region with respect to regions of the image. The blob descriptor also utilizes the interest point features to differentiate the regions of the image. When the corner detection is applied on the shrinking image, the corner detector discovers the sharp edges in the shrunk image which may smooth in the original image. This process makes the more difficult to identify the variations among the blob detector and corner detector. The consideration of optimal notation of scaling of corner makes identify the difference among the blob detector and corner detector. However, the optimal notation of scaling varies with respect to various kind of structure of the image. The DoH and LoG blob detectors also considered as corner detectors.

3) Ridges

A ridge descriptor utilized to identify the ridges of the scaled object in the image. The ridge point is considered as single-dimensional curve which indicates the symmetry axis and local ridge attribute width along with ridge point. When compared with the edge feature, corner and blob features, extraction of ridges features using algorithmically is very difficult from the grey-level images. However, the ridge descriptors are widely applied in the field of medical images to discover the blood vessels and used in aerial images to extracting road extraction. The high-level ridge features can be extracted only after the extraction of the low-level ridge features. Extraction of low-level features can be done directly from the original image. The extraction of ridge feature doesn't require domain specific knowledge and extracted feature composed the required information about the image [16].

D. Classification

Once the features extracted from the input image which will be compared with the original image to discover the variations of the input image. To categorize the variations classification algorithm are required. The brief description of the machine learning classifiers is presented below.

1) Machine learning algorithm

Machine learning is a backbone of artificial intelligence which provides the automatic learning capability to the system based on the experience which helps to enhance the performance of artificial intelligence system. Rather than explicitly writing programming, the machine learning methodologies are focusing on development of programs which has capability of generating useful information from the raw data and use them for learning based on various methodologies such as supervised learning, unsupervised learning, semi-supervised and reinforced learning.

a) Supervised machine learning algorithms

It utilizes the labelled example of data which is also considered as training data for learning purpose. During the learning process, the supervised learning methodology make analysis on the training dataset for generating functions to predict the output values.

The predicted output values are verified with the original output values during the training process. Based on the verification process, the functions are updated to produce relevant output. Once the training process completed, the trained model has the capability of produce the relevant result for the new data. The quality of the output in the supervised learning depends on the training data and training process.

b) Unsupervised machine learning algorithms

It doesn't require labelled training data meanwhile the unsupervised machine learning algorithm doesn't produce exact output like supervised training algorithm. The unsupervised learning algorithms utilized to describe the hidden structure of the unlabelled data. The unsupervised learning methodology analyses the unlabelled data and infer the function to discover and describe the unknown structure of unlabelled data.

c) Semi-supervised machine learning algorithms

It utilizes large volume of unlabelled data and small volume of labelled data leads to enhance the performance of the learning capability. When the collected labelled training date needs relevant and skilled resources to train, the semi-supervised learning methodology is utilized. Generally, the collected unlabelled data doesn't need more relevant and skilled resources.

d) Reinforcement machine learning algorithms

It is another kind of learning methodology where this learning methodology determines the rewards and generates relevant actions by communicating with its environment. The reinforcement learning composed with three major characteristics such as delayed reward, error search and trial. Based on the reward feedback methodology, the reinforcement learning methodology allows the software agent or machine to discover the best set of action for the environment which leads to maximize the performance.

In order to analysis the massive amount of data, the machine learning algorithms were utilized and it provides more accurate outcomes and delivers faster result. However, the machine learning algorithm requires more time and data resources during the training process.

III. LITERATURE WORKS

Numerous methods are suggested by the researchers on PCB defect classification. In this section, brief valuations of a few essential contributions to the existing works of literature are presented.

Author	Method	Advantage	Data	Limitation	Performance measure
Weibo Huang, Peng Wei [9]	Convolutional Neural Network	Gradientdiffusion occurs is solved by designing a dense connection structure	synthesized dataset	Works only in the lesser size of the dataset and consuming more time	Defectdetection is error rate, classification precision rate, average precision rate
Zhisheng Lu et al. [17]	Non-referencecomparison framework of PCB defects detection(PCBDD)	Robustness to changes in grayscalecaused by changes in lighting and less computation complexity	PCBSET	The SVM classifier is only suitable for linearly separable cases. Failed to identify the location of the defect	Defect classification accuracy, Computation time
M.H. Annaby et al. [18]	Improved Normalized Cross-Correlation	The original information is essentially preserved by 1D descriptors. Applied NCC to 1D vector, which speeds up the computations.	PCB image dataset	The static threshold value for discovering the correlation map and the methodology is very sensitive to noise	Accuracy rate, True negative alarm, False positive alarm, Computation time
Sanli Tang et al. [10]	Deep model-based defect detectors	Group Pyramid Pooling (GPP) based feature integration method to achieve better accuracy	DeepPCB	GPP Requires computational time for inference	Precision Recall F-mean
EunHye Yuk [19]	Non reference learning methodology with Random Forest classification	Flexible PCB inspection without limitations regarding the specific type of fault.	synthesized dataset	Only deal with the minimum number of faults	False-negative rate, True negative rate

Ji-Deok Song et al. [20]	Genetic algorithm-based feature extraction and SVM based classification	Improved classification result	Synthesized SMT defect dataset	Limited defects are used concerning to register and capacitor	Classification accuracy
Nian Cai et al. [21]	Deep learning-based surface-mount technology (SMT) solder joints inspection	CascadedConvolutional neural network	Synthesized SMT solder joint samples	Only solder joint defects are detected	Precision Recall F-measure

IV. THE OBJECTIVE OF THE RESEARCH

To overcome the above-mentioned issues in section 3. The researchers follow a few major objectives in the detection of defects in the PCB using image processing and machine learning methodologies.

- Develop a new pre-processing method to enhance the quality of PCB input image which removes the noise and enhances the quality of input image which leads improve the quality of the feature extraction process.
- The development of appropriate feature extraction helps to identify all types of PCB defects and extracts useful information from the input image.
- Develop an optimal classifier for effectively classify the PCB defects.

V. CONCLUSION

Printed circuit board (PCB) inspection is an essential part of the PCB production process. Traditional PCB bare board defect detection methods have their defects. However, the PCB bare board defect detection method based on automatic optic inspection is feasible and effective, and it is having more and more applications in industry. Based on the idea of the reference comparison method, this study aims at studying the classification of defects based on the image processing and machine learning methodologies where we have described various image processing methodologies such as pre-processing and feature extraction methods. Moreover, we have presented various types of machine learning methodologies for the classification process. This paper helps the researchers for achieving a better solution for image processing and machine learning-based printed circuit board the defect classification.

REFERENCES

1. W.C. Wang, S.L. Chen, L.B. Chen, W.J. Chang, "A machine vision-based automatic optical inspection system for measuring drilling quality of printed circuit boards," IEEE Access, vol.5, pp. 10817-10833, 2017.
2. E.N. Malamas, E.G.M. Petrakis, M. Zervakis, L. Petit, and J.D. Legat, "A survey on industrial vision systems, applications, and tools," Image and vision computing, vol. 21, no. 2, pp. 171-188, 2003.
3. P. Wei, C. Liu, M. Liu, Y. Gao, and H. Liu, "CNN-based reference comparison method for classifying bare PCB defects," The Journal of Engineering, vol. 2018, no. 16, pp. 1528-1533, 2018.
4. F. Guo and Shu-an Guan, "Research of the machine vision-based PCB defect inspection system," In International Conference on Intelligence Science and Information Engineering, pp. 472-475, 2011.
5. D.B. Anitha, and M. Rao, "A survey on defect detection in bare PCB and assembled PCB using image processing techniques," In International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), pp. 39-43, 2017.
6. M. Moganti, F. Ercal, C.H. Dagli, S. Tsunekawa, "Automatic PCB inspectionalgorithms: a survey," Computer vision and image understanding, vol. 63, no. 2, pp.287-313, 1996.
7. S. Ray, and J. Mukherjee, "A hybrid approach for detection and classification of the defects on a printed circuit board," International Journal of Computer Applications, vol. 121, no. 12, pp.42-48, 2015.
8. C. Pramerdorfer, and M. Kampel, "A dataset for computer-vision-based PCB analysis," In 14th IAPR International Conference on Machine Vision Applications (MVA), pp. 378-381, 2015.
9. W. Huang, and P. Wei, "A PCB Dataset for Defects Detection and Classification," arXiv preprint arXiv:1901.08204, 2019.
10. S. Tang, F. He, X. Huang, and J. Yang, "Online PCB Defect Detector On A New PCB Defect Dataset," arXiv preprint arXiv:1902.06197, 2019.
11. S. Robertson, H. Azizpour, K. Smith, and J. Hartman, "Digital image analysis in breast pathology—from image processing techniques to artificial intelligence," Translational Research, vol. 194, pp. 19-35, 2018.
12. M. Poostchi, K. Silamut, R.J. Maude, S. Jaeger, and G. Thoma, "Image analysis and machine learning for detecting malaria," Translational Research, vol. 194, pp. 36-55, 2018.
13. S. Hore, S. Chakroborty, A.S. Ashour, N. Dey, A.S. Ashour, D. Sifaki-Pistolla, T. Bhattacharya, and S.R. Chaudhuri, "Finding contours of hippocampus brain cell using microscopic image analysis," Journal of Advanced Microscopy Research, vol. 10, no. 2, pp. 93-103, 2015.
14. N. Dey, "Uneven illumination correction of digital images: A survey of the state-of-the-art," Optik, vol. 183, pp. 483-495, 2019.
15. M.I. Razzak, S. Naz, and A. Zaib, "Deep learning for medical image processing: Overview, challenges and the future," In Classification in BioApps, Cham, pp. 323-350, 2018.
16. S. Balan and L.E. Sunny, "Survey on Feature Extraction Techniques in ImageProcessing", International Journal for Research in Applied Science & Engineering Technology, Vol. 6, No. 3, pp. 217-222, 2018.
17. Z. Lu, Zhisheng, Q. He, X. Xiang, and H. Liu, "Defect detection of PCB based on Bayes feature fusion," The Journal of Engineering 2018, no. 16, pp. 1741-1745, 2018.
18. M.H. Annaby, Y.M. Fouda, and M.A. Rushdi, "Improved Normalized Cross-Correlation for Defect Detection in Printed-Circuit Boards," IEEE Transactions on Semiconductor Manufacturing, vol. 32, no. 2, pp. 199-211, 2019.
19. K. Kamalpreet, K. Beant, "PCB Defect Detection and Classification Using Image Processing", International Journal ofEmerging Research in Management &Technology, Vol. 3, No. 8, pp. 42-46, 2014.
20. J.D. Song, Y.G. Kim, and T.H. Park, "SMT defect classification by feature extraction region optimization and machine learning," The International Journal of Advanced Manufacturing Technology, vol. 101, no. 5-8, pp. 1303-1313, 2019.
21. N. Cai, G. Cen, J. Wu, F. Li, H. Wang, and X. Chen, "SMT solder joint inspection via a novel cascaded convolutional neural network," IEEE Transactions on Components, Packaging, and Manufacturing Technology, vol. 8, no. 4, pp. 670-677, 2018.

AUTHORS PROFILE

Mr. N. Munisankar, Pursuing the Ph.D at Annamalai University in the Department of Computer Science and Engineering in the area of Image processing and Machine learning .he had his Bachelor degree and Master's degree from Sri Venkatesa Perumal College of Engineering and Technology, Autonomous affiliated to JNTUA, Anantapuramu. He is currently working as an Assistant Professor in the Department of Computer Science and Engineering, SVPCET [Autonomous]

Dr. S. Nagarajan is currently working as an Assistant Professor in the Department of Computer Science and Engineering, Government College of Engineering-Srirangam, Trichy. Previously he worked as an Assistant Professor in the Department of Computer Science and Engineering, Faculty of Engineering & Technology, Annamalai University since 2002. He received his B.E. Degree in Electronics & Communication Engineering from Bharathidasan University in the year 1994 and M.B.A. (Personnel Management) from Madurai Kamaraj University. He completed both his M.E. degree and Ph.D. in Computer Science & Engineering from Annamalai University. He has 21 years of teaching service to his credit. He has published many research papers in International journals and conferences. His research interests include Computer Vision, Artificial Intelligence, Image Processing and Pattern Recognition. He is a member in CSI, IAENG, CSTA, and UACEE.

Dr. B. Narendra Kumar Rao, is currently the Head of the Department of Computer Science and Engineering at sree vidyanekethan engineering college, Tirupati. He completed Ph.D from JNTUH, Hyderabad with specialization in CSE. He Pursued his M.Tech in CS from JNTUA, Anantapuramu. He has Nineteen years of teaching experience in the domain of computer science. He also has an industrial experience up to five years in the cutting edge technologies.

He has 16 international publications and 20 conference presentations to his credit. His current research includes embedded systems, Machine learning and Software Engineering.