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Research Article

Automatic PCB Defects Detection and Classification using Matlab

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Abstract

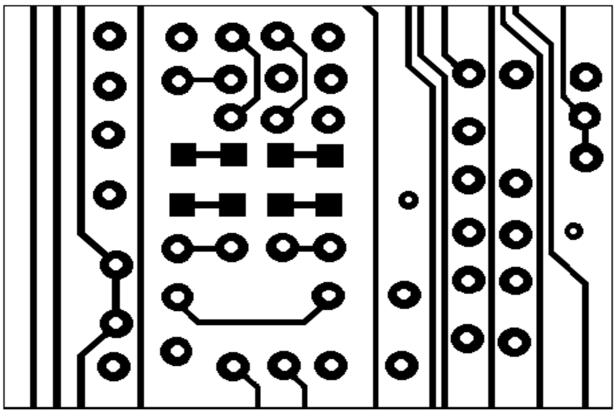
The importance of the Printed Circuit Board inspection process has been magnified by requirements of the modern manufacturing environment. In electronics mass production manufacturing facilities, an attempt is often to achieve 100% quality assurance. In this work Machine Vision PCB Inspection System is applied at the first step of manufacturing. In this system a PCB inspection system is proposed and the inspection algorithm mainly focuses on the defect detection and defect classification of the defects. Defect classification is essential to the identification of the defect sources. The purpose of the system is to provide the automatic defect detection of PCB and relieve the human inspectors from the tedious task of finding the defects in PCB which may lead to electric failure. We first compare a standard PCB inspection image with a PCB image to be inspected. The MATLAB tool is used to detect the defects and to classify the defects. With the solutions designed and implemented in this thesis the algorithm designed in the proposed system is able to detect and classify all the known 14 types of defects successfully with greater accuracy. The algorithm makes use of image subtraction method for defect detection and kNN classification algorithm for the classification of the defects. This thesis will present and analyze the performance of the proposed inspection algorithm. The experiment will measure the accuracy of the system.

Keywords: *PCB- Printed circuit board, PCB Defects detection, Classification*

1. Introduction

Printed circuit board (PCB) fabrication process is a multidisciplinary process, and etching is the most critical part in the PCB manufacturing process. Etching is the process, where the copper board will undergo ‘peeling’ process, where the circuit layout will be preserved while the rest of the copper background will be washed out. In order to minimize scrap caused by the wrongly etched PCB panel, inspection has to be done in early stage.

The traditional way to inspect any defect is visually employing human operators. This process is not time consuming but also highly prone to errors due to humans’ factors. The next trend then is to use machine vision inspection system. However, all of the inspections are done after the etching process where any defective PCB found is no longer useful and is simply thrown away. Since etching process costs 70% of the entire PCB fabrication, it is uneconomical to simply discard the defective PCBs. Hence, this project proposes an automatic visual inspection on the PCB before the etching process so that any defect that could be found on a PCB would be able to be reprocessed. Although many algorithms are available in defect detection, both contact and non-contact methods [M. Moganti et al 1996], none is able to classify these defects. Contact method tests the connectivity of circuits but unable to detect major flaws in cosmetic defects [S. H. Indera Putera et al 2012]. Non-contact uses methods such as ultrasonic and x-ray imaging to detect anomalies in the circuit design, both cosmetic and functional [S. H. Indera Putera et al.2012]. The use of manual labour to visually inspect each PCB is no longer viable since it is prone to human errors, time consuming, requires large overhead costs and results in high wastage [M. Moganti et al. 1996]. Types of defects on single layer bare PCBs are Breakout ,Pin-hole , Open Circuit, Under-etch, Mouse-bite, Missing Conductor, Spur, Short, Wrong Size Hole, Conductor Too Close, Spurious Copper, Excessive Short, Missing Hole, Over-etch[S. H. Indera Putera et al. 2012].



(a)

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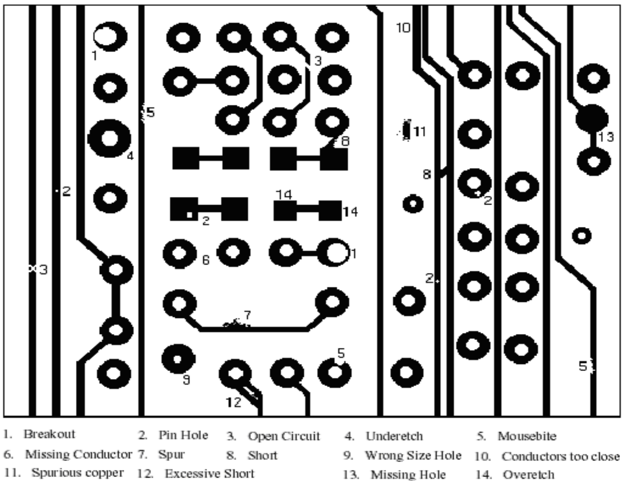

Figure 1: (a) an example of good PCB patterns, (b) An example of defective PCB patterns.

Moganti. Divides the methods for PCB defect detection in to three groups:1) Referential Approach 2) Non-Referential Approach and 3) Hybrid Approach. In this paper the defect identification can be done by using the hybrid method. The Hybrid technique increases the efficiency of the system. These methods have the advantage that they cover a large variety of defects compared to either referential or non-Referential methods alone. The proposed method has the advantage of detecting and classifying all the known 14 defects.

2. Literature Survey

Heriansyah et al. [R Heriansyah 2012] proposed a technique that classifies the defects that could occur on the PCB using neural network. The algorithm segments the image into basic primitive patterns, enclosing the primitive patterns; patterns assignment, patterns normalization, and classification were developed using binary morphological image processing and Learning Vector Quantization (LVQ) neural network. In this approach for training and testing the neural network, 11 Defective patterns have been designed. The designed pattern was in 8 x 8 pixels size, with binary format. The PCB defects could be formed into three groups: the defects on the foreground only, the defects on the background only, and the defects on both foreground and background (the defect is caused by interaction with other object). To classify the defects, LVQ neural network has been selected as the classifier. The designed patterns are trained and tested using this neural network. For the neural network implementation, only two groups of defects will be used for training (i.e. the foreground and the background). For performance comparison, a pixel-based approach developed by Wu et al. was used. At the time of writing this paper, this was the only algorithm designed for defect classification.

The pixel-based approach could classify seven defects (short, missing hole, pinhole, open, mouse-bite, spur, and etching problem). In this approach there are few stages involved: segmentation, windowing (reference image and detected defects), defects detection, pattern assignment, normalization, and classification. For the neural network training part, since this process is done off-line, it does not affect the overall processing time.

Shih-Chieh Lin et al [Shih-Chieh Lin and Chia-Hsin 2006] proposed the method that can be divided into two stages, first stage was screening and the second stage was neural network to classify defect more accurately. 558 training samples were used to train the proposed system first. It was shown that pattern matching index is the optimal screen index in the first stage and in the second stage; it was shown that more than three indexes should be used to effectively identify defects. After this 1949 samples were used to train the system. In first stage, the test confirms that the pattern matching index is the optimal screen index. The false alarm rate is only 12.3% and is much lower than others. At the second stage, the neural network was used to classify defects. When five indexes are used as the inputs to the net work, either the false alarm rate, the missing rate, or the wrong classification is less than 5%.

Khalid et al. [N. K. Khalid 2008] proposed algorithm that can be implemented on 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 greyscale format [6]. Although the conversion can be made from greyscale to binary format imperfection still can be occurred. Thus, this algorithm should be improved to handle the greyscale image format. Also, during the computation of defect detection and implementation, this operation brings along the unwanted noise due to misalignment and uneven binarisation. 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.

These algorithms need two images, namely reference image and test image. In this paper, these algorithms use reference image and test image. At first, both images are subjected to image subtraction operation to produce negative image and positive image. Then, NOT operator and flood-fill operator are applied to template image and the defective image separately. From there, the algorithms continue to produce the results. The results shown will be based on these images.

Five algorithms are developed to detect and classify the defects into five groups. Group 1 will consist of missing hole and wrong size hole. Group 2 will consist of spur, short, spurious copper, excessive short, under-etch negative, and conductor too close negative. Similarly Group 3 includes open circuit, mouse bite, over etch and conductors too close positive. Group 4 includes under etch positive, and Group 5 consists of Pinhole, breakout.

Moganti et al.(1996) Proposed the improved PCB inspection system in which an image registration operation is done 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 précised compare to previous algorithm. Algorithm was effective to the image processing algorithm developed by Khalid by increasing the classification of 14 defects from 5 to 7 groups. Again the limitation of this algorithm is that it can work with binary images only. Although the conversion can be made from greyscale to binary format imperfection still can be occurred.

Indera Putera et al [S. H. Indera Putera et al. 2012] did improvement to 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 defects classification. Result for this particular experiment was, each group consist of 1 defect and maximum 4 defects and thus improved the work done by Khalid by increasing number of group from 5 to 7.

This project minimizes the number of defects for each classified groups. 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 conductor is absent as a result of errors in the printing or etching process. In this section region proposed method used is by measure properties of image regions. Open circuit is maintained in a separate group, while missing conductor is placed in new group. The improved algorithm increased the classification from 7 to 11 groups.

3. Methodology

In the history of the development of inspection system for PCB, the defect detection and the classification are most significant developments.

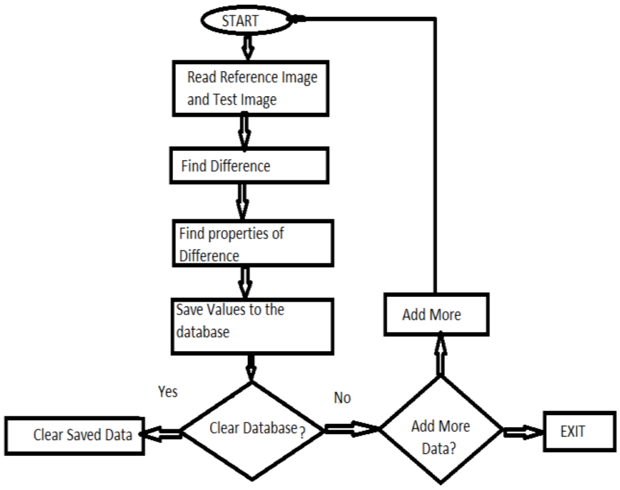

Figure: 2 Flow chart for creating database

The challenge is to classify all the 14 known defects separately. However, image processing algorithms can use many possible methods; one of them is to segment the image using morphological segmentation algorithm and then combining this algorithm with the image processing algorithm developed by Khalid. The new algorithm can be developed to classify all these 14 defects separately. This can be done by comparing stored feature of defect with the feature of defect in test image and define a class of the defect.

The figure 2 depicts the flow chart for creating the database for PCB inspection system. As shown in figure firstly the reference and defective image is selected and the difference is found out. The region properties of this difference is calculated and saved to the database. The region properties such as eccentricity, orientation, major axis length, minor axis length are found out.

Figure 3 depicts the flow chart for evaluating the database. The reference and defected image is selected first and the region properties mentioned above are found out. The classifier will find the maximum match from the database and assign the class to the defect.

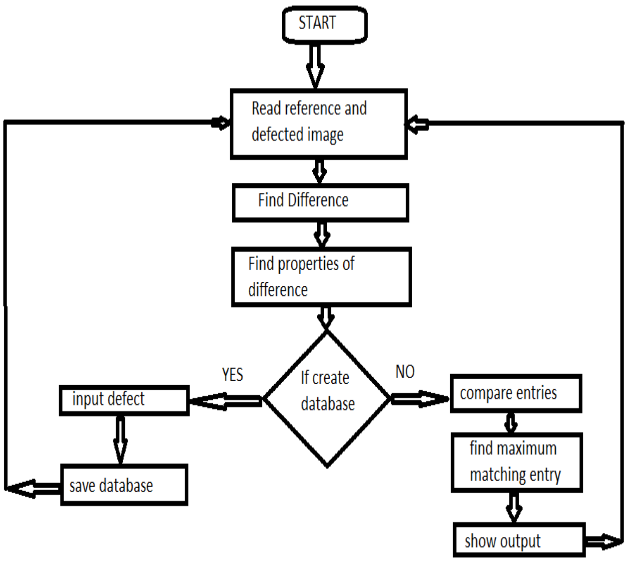

Figure: 3 Flow chart for evaluating data

A. Defect Detection

Image difference operation *:* Image difference is the simplest technique which consists of comparing both reference and test images. Image difference operation is developed in order to get the differences between two images. The image difference can be found out in this project as:

Defect = abs (reference PCB image – Defected PCB Image)

B. Image Feature

The next step is to compute the image features intended to extract. The features chosen had to be discriminative and sufficient in describing the object presented in each image. Therefore Matlab code is developed using the regionprops function from the Image Processing toolbox. This function measures a set of properties of difference of reference image and the test image, like its Eccentricity, Major axis Length, Minor Axis Length, area, and Orientation etc. all

Table 1 Result of Experimentation

Sr. No.	Defects	Detection	Classification	%Accuracy of Classification
1	Breakout	Detected	Classified	75
2	Conductor Too Close	Detected	Classified	75
3	Excessive Short	Detected	Classified	75
4	Missing Conductor	Detected	Classified	80
5	Missing Hole	Detected	Classified	70
6	Mouse-bite	Detected	Classified	75
7	Open Circuit	Detected	Classified	70
8	Over-etch	Detected	Classified	75
9	Pinhole	Detected	Classified	80
10	Short	Detected	Classified	75
11	Spur	Detected	Classified	75
12	Spurious Copper	Detected	Classified	80
13	Under etch	Detected	Classified	75
14	Wrong Size Hole	Detected	Classified	75

the features computed should be normalized, so that they would be weight balanced.

C. Defect Classification

K nearest neighbor (kNN) Classifier: In PCB defects classification using kNN classifier is an off-line operation. The kNN classifier has given the input as the features of difference between reference image and the test (defective) image. The maximum match found in the database will define the class of the defect. The k-Nearest-Neighbours (kNN) is a non-parametric classification method, which is simple but effective in many cases. For a data record t to be classified, its k nearest neighbours are retrieved, and this forms a neighbourhood of t. Maximum matching among the data records in the neighbourhood is usually used to decide the classification for t with or without consideration of distance-based weighting. However, to apply *k*NN we need to choose an appropriate value for *k*, and the success of classification is very much dependent on this value. In a sense, the kNN method is biased by k . There are many ways of choosing the *k* value, but a simple one is to run the algorithm many times with different *k* values and choose the one with the best performance.

4. Results

To measure the accuracy of classification a comparison has been done between the original class of data that detected manually and those that detected using the proposed algorithm. The percentage of correct classification of the detected defect given by the algorithm is presented in Table 4.1. All the defects are detected and classified separately.

Conclusion

This project has investigated in the image processing topic. The intention of the current study was to detect and classify the Bare PCB Defect before etching as the etching costs 70% of the production cost. Moreover, several related topics have been covered in the beginning of this dissertation. The first step is to detect the defect that caused in the PCB image. In order to find the defect the image subtraction operation is used. The second step is to determine the class of that defect. In addition, related works in these techniques have been presented and compared. However, most of the algorithms in the literature review have been implanted to detect the defects where as some of them are to classify the defects using image processing algorithms. From literature all the 14 defects were not classified. Hence, most of the works tend to search in the classification methods.

The kNN classification method considered as one of the most algorithms used to classify the defects based on region properties, since it is easy to implement along with the accuracy it provides. Therefore, different number of defected PCB images has been chosen in order to start the experiment. The result obtained from human observation has been compared with the result obtained from proposed method. In order to measure the performance of this implementation, Accuracy has been calculated. We got maximum Accuracy in classifying all the defects is 80%, and the time required to classify is very less considering all the defects separately. The results show our technique is efficient and runs faster in comparison with other techniques.

Future Scope

PCB defects can be classified into various categories based on the environment and context. Developing proposed PCB inspection system for all the 14 known defects is very difficult as PCB may contain more than one defect and if PCB is loaded. In future, further study on robust technique to differentiate the defects on single PCB image also in the future, we are going to study further defect detection and classification on loaded PCB. Also new techniques based on other classifiers.

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