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Bare PCB Defect Detection and Sorting Using Image Processing Techniques

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Abstract— The importance of the Printed Circuit Board inspection process has been magnified by requirements of the modern manufacturing environment where delivery of 100% defect free PCBs is the expectation. To meet such expectations, identifying various defects and their types becomes the first step. In this PCB inspection system the inspection algorithm mainly focuses on the defect detection using the natural images. Many practical issues like tilt of the images, bad light conditions, height at which images are taken etc. are to be considered to ensure good quality of the image which can then be used for defect detection. In this paper results of an attempt made at defect detection considering various factors using the image processing techniques with MATLAB is presented.

Keywords: PCB, Defect detection, MATLAB, Image Processing.

I. INTRODUCTION

Printed circuit board is a platform which mechanically supports and electrically connects electronic components on a composite sandwich of conductive and non-conductive layers with a well-defined and designed circuitry. The conductive layer is generally copper although aluminum, nickel, chrome and other metals are used, the non-conductive layer is generally a composite of epoxy and glass fibers. Printed circuit board (PCB) fabrication is a multidisciplinary process, and etching is the most critical part in the PCB manufacturing process. The main objective of Etching process is to remove the exposed unwanted copper other than the required circuit pattern. In order to minimize scrap caused by the wrongly etched PCB panel, inspection has to be done in early stage 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 not economical to simply discard the defective PCBs [1]. In this paper a method to identify the defects using PCB images and associated practical issues are addressed. We have used Matlab tools and some of the major types of single layer PCB defects such as Pattern Cut, Pin hole, Pattern Short, Nick etc.,are addressed effectively so that the PCB would be reprocessed as necessary.

II. LITERATURE REVIEW

Moganti et al proposed an 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 précise compared to previous algorithm [1]. The limitation of this algorithm is that it can work with binary images only. InderaPutera et al did improvement to Khalid's work by classifying PCB images into 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 thus 20 new images were produced [2]. Out of which, seven images were beneficial for defects classification. Heriansyah et al. proposed a technique that classifies the defects of 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 with a 8 x 8 pixels size. The PCB defects could be formed into three groups, the defects on the foreground, the defects on the background 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 were used for training (i.e. the foreground and the background). For performance comparison, a pixel-based approach developed by Wu et al. was used. The pixel-based approach could classify seven defects (short, missing hole, pinhole, open, mouse-bite, spur, and etching problem). This approach consists of few stages such as segmentation, windowing (reference image and detected defects), defects detection, pattern assignment, normalization, and classification [3].

Shih-Chieh Lin et al proposed the method that can be divided into two stages, first stage was screening and the second stage was neural network to classify defects more accurately by using 558 training samples. 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 14.3% and is much lower than others. At the second stage, the neural network was used to classify defects [4]. Khalid et al. proposed algorithm that can be implemented on bare PCB to identify and to group the defects. However, the major limitation of this algorithm is that it can work with binary images only, whereas the output from the cameras is in grayscale format [5]. Although the conversion can be made from grayscale to binary format imperfections will occur. These algorithms need two images, namely 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 to produce the results which are 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 [6].

Oguz et al proposed a new method based on an improved Canny edge detection algorithm and the traditional Canny operator has high edge detection capability [7]. This method can have better detection and better processing speed, that has laid a favorable foundation for UAV visual navigation. Ouslim et al says that a vision processing needs effective feature detectors to estimate the structure and properties of objects in an image. The best known is Canny edge detection that combine a Gaussian low pass filter for noise reduction and non-maximal suppression and hysteresis threshold for edge localization. A problem of this approach is that the threshold values are being fixed to gradient maxima which is not an optimal choice. Thus, Canny uses two thresholds values namely T_{low} and T_{high} to reduce the number of false positive of pixels that represent significant contours in the image. Therefore, a method that computes the threshold values from the foreground and background image pixels are used [8]. According to Ercal et al, an image is divided into several blocks using multiple resolution levels. After that, a sampling approach is used on global and local regions to get the optimal thresholds by selecting the highest of the class variance values [9].

III. METHODOLOGY

In any manufacturing facility achieving 100% yield is the final objective and for that purpose quality is checked at every stage or process to ensure defect free products. In essence detecting defects at each stage is the main focus and in this PCB process, inspection, manually or automated way, needs to happen at each stage. According to Khalid the methods of PCB defect detection is generally classified into two groups, that is image subtraction and feature extraction [5].

A. Image Subtraction

Image subtraction is the simplest approach of PCB inspection. The PCB to be inspected is compared with the reference image and the subtracted image shows defects. Normally used operation is XOR and the method has an advantage that it allows for verification of overall defects in the geometry of the board, but the disadvantage is that it suffers from the practical problems such as reflectivity variation, lightning sensitivity, image registration, and colour variation. Simply stated: Defect = abs (reference PCB image – Defected PCB Image).

B. Feature Extraction

In pattern recognition and image processing, feature extraction is a special form of dimensionality reduction. When the input data to an algorithm is too large to be processed and is suspected to be redundant then the input data will be transformed into a reduced representation set of features. Transforming the input data into the set of features is called feature extraction. If the features extracted are carefully chosen it is expected that the relevant information from the input data is extracted in order to perform the desired task.

IV. PROPOSED METHOD

We use MATLAB as a tool to perform various tasks of defect detection in PCB. MATLAB is a name that stands for matrix laboratory which is a high-performance language for technical computing. It integrates computation, visualization, and programming in an environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

The goal of the implementation phase is to translate the system design into code in a given programming language that can be executed by the computer and performs the computation specified by the design. Therefore in this proposed method we work with natural PCB images, that is the distance from where the image is taken varies all the time so the above two methods does not handle the distance issue and at the time of testing it does not match with the reference image. This problem is handled here by dividing the image into smaller sub images i.e. extracting the portion of the blue shaded area of the PCB images. These division is done even for the reference image and both these are compared to detect the defect. Since we are handling the real image we concentrated our study on

i. Angle of tilt of PCB
ii. Vertical distance at which the images are captured
iii. Images at with bad illumination conditions

As shown in Fig.1 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.

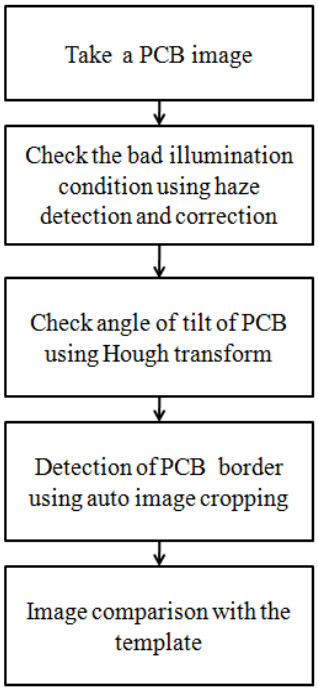
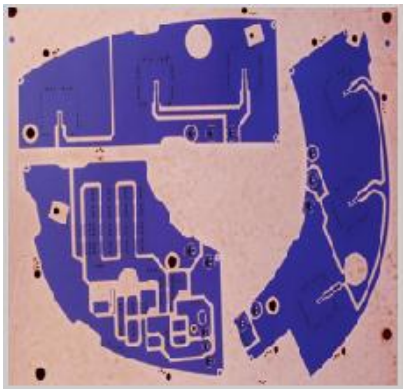


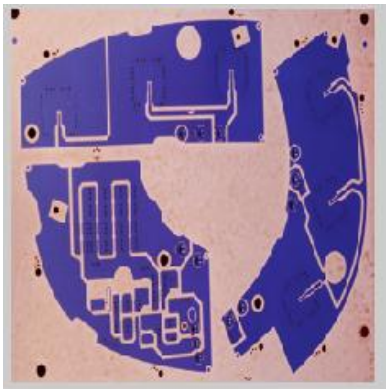
Fig. 1: Flow chart for creating the database

V. RESULT

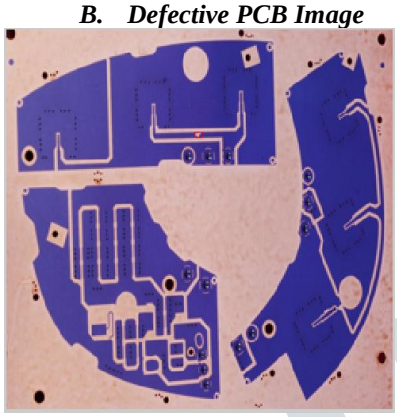
The identification of defects in natural PCB images is processed and the defect is identified with respect to the reference image using MATLAB tools. The Fig.2 below shows the bare PCB defect detection and sorting using image processing techniques. Thus the MATLAB features a family of add-on application-specific solutions called toolboxes. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems and many others



A. Reference PCB Image



B. Defective PCB Image



C. Pinhole Defect Identification

Fig. 2: Bare PCB Defect detection and Sorting using Image Processing Techniques

VI. CONCLUSION

Thus the identification of bare PCB defects of natural images are sorted using image processing techniques and many practical issues like tilt of the images, bad light conditions, height at which the images are taken etc, are considered in order to ensure the good quality of the image.

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