An Automated Fault Detection System for PCB Design Using Digital Image Processing

Mr. Akash R. Kasturkar[1] Dr. S. D. Lokhande[2]
[1]M.E Student [2]Principal
[1]Department of Electronic & Tele-Communication Engineering
[1,2]SCOE, Pune, India

Abstract— In Electronics industries in order to communicate design information for the manufacturing of various types of PCBs Gerber format file is used. Since the manufacturing of PCBs is costly process so any defect during manufacturing must be avoided, especially with the high complexity level or many of today's boards. A PCBs Defect detection and classification system uses machine vision which is used to find difficulties occurred in manual inspection. It eliminates subjective aspects and gives fast, quantitative and dimensional quality. It is also very crucial to classify the defects in order to examine and identify root causes of the defects. Defects present in PCBs are as short or open circuit, under-etch, mouse-bite and missing hole. This project proposes a PCB defect detection and classification based on imaging morphological algorithm for segmentation and simple image processing theories. Some PCBs defects exists only in certain groups. Hence, it is obvious that to improve image processing algorithm for applying a segmentation exercise. The referential approach has been implemented on defected PCBs images and template in order to detect number of defects present on bare PCB just before the etching process, because etching generally contributes most damages found on PCBs. So, PCB inspection system is then improved by using a geometrical image registration, minimum Thresholding and median filtering in order to solve alignment and uneven illumination problem.

Key words: Automated Visual System, Image Registration, Image Subtraction, Image Thresholding

I. INTRODUCTION

Printed Circuit Board (PCB) without any placement of electronic components is called as Bare PCB. In PCB design PCB inspection or PCB quality check is one of the important stage. In order to reduce cost spending in manufacturing caused by the defected bare PCB film, the bare PCB film must be inspected before PCB manufacturing. For mass production of PCBs PCB inspection is must, especially with high level of complexity of boards [1] [2]. Fabrication of PCB is one of the costly process in designing of any electronic device. Hence detection of possible design faults which may be because of improper functionality of photo plotter which is used for PCB film printing is very useful task. In manufacturing process of PCB three steps are involved, where the PCB inspection is necessary to detect defects. First step is printing film for bare PCB design, second step is the components mounting over the PCB surface and third is the soldering of components. In this paper Machine Vision System for PCB inspection is applied at the first step of manufacturing, i.e., the making of bare PCB. After designing a PCB layout using PCB layout designing tool next step is printing film of design from Gerber file generated. For manufacturing of various types of printed circuit board in electronics industry Gerber format file is used. This Gerber file is input for photo plotter from which PCB film is designed. Photo plotter is electro-mechanical machine which reads data from Gerber file and converts it into pixel image and then writes this on film. Anything wrong with Gerber file during communication or photo plotter leads to faulty design of film which further leads to defected PCB design. This Two images are input for the system. One image is computer generated image from Gerber viewer tool using Gerber file. This image is referred as reference image. Second is scanned image of PCB film designed form photo plotter machine using same Gerber file. Two images are taken from two completely different source which may have different PSF (Point Spread Function) value, different pixel values and different sizes. These two images are processed using image processing techniques. While scanning PCB film there may be some rotation or translation in image. So comparing these two images directly is not possible.

II. LITERATURE SURVEY

In early days of PCB manufacture or manufacturing of any other electronic component inspection had been done manually. But this method had limitation. Also fault detection was not very accurate, mostly in case of complex circuits so some faults were not spotted and passed to the next stage of production without detection and results into faulty design. This was the only way for inspection before automation. Automated optical inspection is the preferred method of PCB inspection. An automated visual printed circuit board (PCB) inspection is used to reduce problems occurred in manual inspection. In research works mentioned in [1] referential approach is used on computer generated reference image and defective PCB images to locate defects on bare PCBs before etching process, since etching causes many destructive defects found on PCBs. To improve results and alignment problem image registration techniques, minimum thresholding and median filtering techniques are used and subtraction must be used to detect defect on PCBs. However subtraction directly contributes unwanted noise due to misalignment and uneven binary illumination and thus which results into decrease in accuracy of the defect detection. For proper alignment of both images image registration technique is used. Inspection system explained in [3] is for missing components or wrongly placed components in PCB. Missing of electronic component will not damage PCB but if any component is wrongly placed then there may chances of damage of component or damage of components presents next to wrongly placed component. To avoid this automated visual inspection system is used for

wrongly placed components on PCB explained in [3]. The system is divided into two parts where firstly system is trained for standard PCB and then in second part inspection process for PCB under test for wrongly placed component is done by comparing it with standard PCB. The image of the PCB is first grabbed using CCD camera and stored in grayscale shades in bit-mapped format (BMP format). The noise present in terms of scattered pixels is removed and components are distinguished with respect to their location and size. As explained in [4] where machine vision PCB inspection is applied at the first stage of PCB manufacturing i.e. making of bare PCB. Here also standard PCB image is compared with PCB image to be inspected by applying subtraction algorithm on both images to identify defected region. Further they are classified such as over etching (opens), under etching (shorts), holes. Reference image is XORed with inspected image which is subtraction process. For the image subtraction operation it is required that both images has same size in terms of pixels. Orientation of inspected image must be same as reference image. Defect detection and classification and localization method explained in [2] uses mathematical morphology and image processing tools. Besides the need to detect the defects, it is also necessary to classify and locate these defects so that the source and location of these defects can be identified. This project combines two previous works. First, the images of complex PCBs are divided into different segments of four well-defined generic patterns [1], and then fed into the image processing algorithm [2] where defects are detected and classified.

III. METHODOLOGY

The Gerber Format files which are generated by using various software used for PCB Design has to be printed on the copper plate but because of photo-plotter there will be mismatch between the reference image and scanned image so in order to reduce this image registration algorithm is used. Image registration algorithm involves the following techniques.

A. Point Spread Function and Image blurring

Image rendered from computer is binary image which is generated using Gerber viewer tool and another image is scanned from PCB film which has grayscale pixel values. Comparing these two images will lead to undesired results in scanned image there is spreading of pixel values to surrounding pixels due to some PSF value of scanner. In scanned image pixel information at a point spreads to surrounding points. The function which describes this spreading is called PSF (Point Spread Function). So before going for operation on images those images must bring to the same level of comparison. For this blurring rendered image so that PSF value for both images will match to some extent. Here PSF value will not match exactly but close to actual one, which will helps in improving comparison result and fault detection. In blur image colors from various objects are spread over an area around the objects in that image. Light form each point in the scene spread over multiple points in the image. This spreading is described by point spread function. As blurring is just spreading of information from each points into surrounding points, in image domain this is accomplished by convolution function.

Convolution involves sliding of window over an image, and setting each point of the image to the centre of window. Then taking sum of point-wise multiplication of the values of window and values of points in the image bounded by window. To blur image window used is Gaussian blur kernel. Following equation gives convolution of image I with Gaussian blur kernel.

$$B(x,y) = \sum_{i=-\infty}^{\infty} \sum_{j=-\infty}^{\infty} I(i,j) . K(x-i,-j) \qquad (1)$$

In above equation B is blur Image. I is original image. i & j are vertical and horizontal offsets. For blurring we are using Gaussian bur kernel. Equation for Gaussian kernel is,

$$K(x,y) = \frac{1}{2\pi\sigma^2} \times e^{\frac{-x^2+y^2}{2\sigma^2}} \qquad (2)$$

K(x, y) value calculated by Gaussian kernel formula. σ is the standard deviation for Gaussian function and (x, y) relate to pixel coordinates within an image with vertical offset and horizontal offset respectively. Amount of blurring depends on the size of kernel and variance σ^2 of Gaussian function. Larger the size of kernel will give ore amount of blur.

B. Image Thresholding

In computer vision, image segmentation is the process of partitioning a digital image into multiple segments (sets of pixels, also known as super-pixels). The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image (edge detection). Each of the pixels in a region are similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic(s). The Image segmentation is the division of an image into regions or categories, which correspond to different objects or parts of objects. Every pixel in an image is allocated to one of a number of these categories. A good segmentation is typically one in which: pixels in the same category have similar greyscale of multivariate values and form a connected region, or neighbouring pixels which are in different categories have dissimilar values. Segmentation is often the critical step in image analysis: the point at which we move from considering each pixel as a unit of observation to working with objects (or parts of objects) in the image, composed of many pixels. If segmentation is done well then all other stages in image analysis are made simpler. Edge detection is a well-developed field on its own within image processing. Region boundaries and edges are closely related, since there is often a sharp adjustment in intensity at the region boundaries. Edge detection techniques have therefore been used as the base of another segmentation technique. The edges identified by edge detection are often disconnected. To segment an object from an image however, one needs closed region boundaries.

C. Morphological Operation

Morphology is a technique of image processing based on shape and form of objects. Morphological methods apply a structuring element to an input image, creating an output image at the same size. By choosing the size and shape of the Neighbour, you can construct a morphological operation that is sensitive to specific shapes in the Input image. The morphological operations can first be defined on greyscale images where the Source image is planar (single-channel). The definition can then be expanded to full-colour Images. Morphological operations such as erosion, dilation, opening, and closing. Often combinations of these operations are used to perform morphological image analysis. There are many Useful operators defined in mathematical morphology. They are dilation, erosion, opening and Closing. Morphological operations apply structuring elements to an input image, creating an Output image of the same size. Morphological enhancement morphological operations are used to perform different operation to increase the contrast and detect the background characterized by poor contrast**.**

D. Template Matching

For this three fiducials are marked on PCB layout which will appear on both images. Normalized cross-correlation template matching algorithm is applied on both images to find fiducials locations. Before explaining about normalized cross-correlation we have to know something about cross-correlation. Cross-correlation algorithm is measure of similarity of two signals. It evaluates degree of matching between two identical signals [5]. Using cross correlation has some advantages. Computation of cross-correlation is simple. For faster matching it can be used with Fourier Transform. Translations and scaling of signals does not affect cross-correlation. Normalized cross-correlation is mostly used to measure degree of similarity or dissimilarity between two images. Also sensitivity to linear changes in amplitude of illumination is very low for normalized cross correlation [6]. Computation time increases for matching of template increases as the window size of template gets bigger.

IV. RESULT AND DISCUSSION

As In Electronic Industry to communicate design information for manufacturing of various types of printed circuits Gerber file format is used. Hence in order to get the Gerber file as input we have to use various software for designing PCB. For this system of fault detection we have developed one GUI (Guide User Interface) as shown in figure 1 which will give the result of either the inspected PCB is correct or defected one.
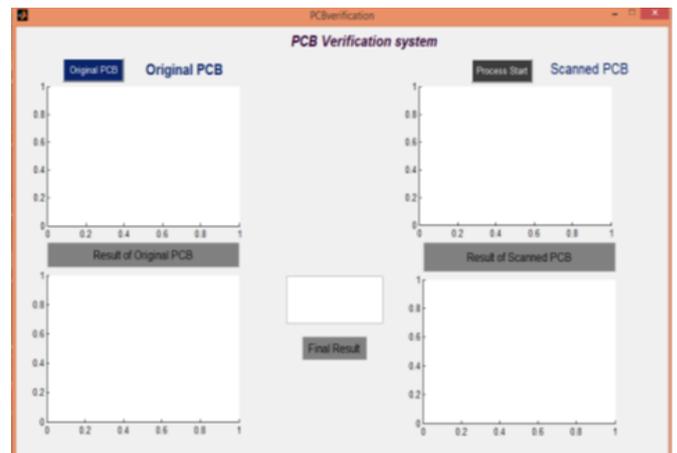

Fig. 1: Simulator for System

All images which are using for inspection purpose must have same dpi value. image generated using Eagle PCB layout tool on computer. Image is generated by printing the layout by using scanner. four fiducials can be seen at the four corners of image. image as shown in figure 2 is used as the reference image for our task which is captured by using camera which is interfaced with our MATLAB/PC. we have to read our reference image by clicking the push button as original PCB.
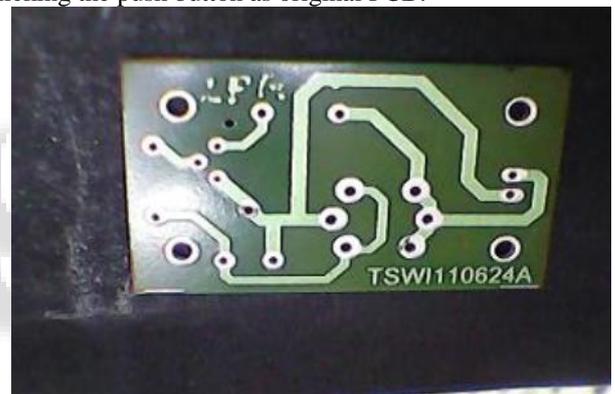

Fig. 2: Reference PCB Image

After reading of the reference image we have to start process by clicking start process button on developed software. As the process gets started camera which is interfaced with matlab captures the image of scanned image which is present on the conveyor belt. After getting both reference image and scanned image the Gaussian blur algorithm is applied in order to have proper subtraction method because it is not possible to compare the two images directly so we have to apply blur algorithm with some window size and also with some variance value. After application of Gaussian blur algorithm thresholding is applied on both reference and scanned image. Then edge detection technique or the boundary tracking algorithm is used in order to track boundaries of the holes or tracks. After tracking of the holes or tracks in images we have to apply the morphological operations such as dilation which is suitable for our method in order to get clear view of the holes or tracks. After application of the morphological operation the result will become as shown in figure 3.
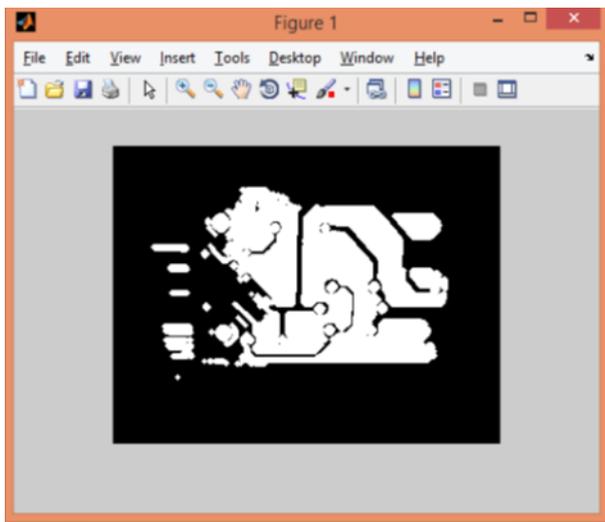
Fig. 3: Result of Reference PCB Image

By using morphological operation the number of connected objects in the given image is calculated. so after application of operation we can get the number of connected objects in reference and scanned image. After the comparison of these two images the final result will be displayed on GUI as shown in figure 4. As the message displayed on GUI the further process is carried out by interfaced hardware whether the inspected PCB is to be send for fabrication process or not. If PCB is correct then it is used for fabrication purpose and if not then it must be corrected first and then used for further fabrication purpose.
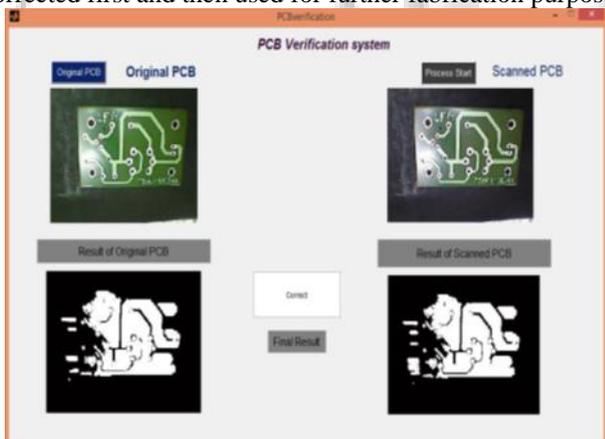

Fig. 4: Final Result Displayed on GUI

V. CONCLUSION

PCB inspection is very important part of PCB manufacturing process. Automated PCB fault detection technique is preferred over manual inspection since manual inspection not applicable for the complex circuits and also yields a poor results. Here we have described a method for detection of possible faults because of defected PCB film i.e. faults due to defected film is detected before actual fabrication of PCB. In this work reference image and scanned image are going to be compared with each other by using various image processing tools as discussed above. This simulation works correctly for different types of PCBs. Computer generated image and scanned image must have same dpi value and there must be three fiducials marks for both images. In further work automatic feature detection techniques can be implemented for image registration. Work explained in this report with some addition can be useful for

inspection of PCB after manufacturing to detect defect such as over etching, under etching. It can also be extended for detection of missing components or wrong placement of components on PCB.

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