ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2016

Defect Detection on Printed Circuit Board using Local Binary Pattern

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ABSTRACT: The significance of the Printed Circuit Board inspection process has been increased as well as very much precised by requirements of the modern manufacturing environment. In electronics mass production manufacturing facilities, an attempt is often to achieve 100% quality assurance but is it not achievable to produce 100% defect free PCB's on large scale. So inspection process is required to nullify the defected production. In this research paper, we propose a relatively easy method to detect defect on Printed Circuit Board based on image processing which is very much acceptable in comparison to the present state of art techniques developed till date. Proposed method is based on LBP (Local Binary Pattern) and its extension version RI-LBP (Rotation Invariant- Local Binary Pattern). There is a two level hierarchy starting from finding abnormal designing, defect detection like wrong holes, defects while etching, broken lines etc. on bare PCB, the system will decide whether the PCB is accepted or rejected. On 2nd level hierarchy, defects based on placement of various components are detected using the template image of the PCB's. Limitation of current method to determine defect on an aligned PCB image is overcome by proposed method. Results are produced on both bare and component placed PCB's. Our main focus is to find defects on PCB's.

KEYWORDS: PCB defects, Defect localization, Texture classification, Local binary pattern, Rotation invariant

I. INTRODUCTION

Printed Circuit Board (PCB) inspection is one of the vital processes in the manufacturing process of electronics goods as there are uncertainties like tolerances, perfect position and sometimes orientation errors. The objective of printed circuit board (PCB) inspection is to authenticate that the characteristics of board manufacturing are in consistency with the design specifications. The inspection system can inspect the printed circuit boards on many levels. These levels are inspection of bare PCB, inspection after component placement and inspection of soldering side as finalized product is produced. With the increase in requirement, PCBs contains detailed and complex patterns which are not sufficiently and effectively inspected by manual visual systems as they are tiring and subjective to errors. As PCBs normally contain multifaceted and comprehensive patterns, inspection through visual and manually is so tiring and very subjective to errors. Furthermore, manual inspection is time-consuming, costly, and can leads to extreme scrap rates [10]. Besides, it also does not assure high quality results. Printed circuit boards are manufactured at different a level that's why the defect detection system is to be designed so as to detect defect on all stages whether it is a Bare PCB or a component placed PCB. PCB without any electronic components (as shown in figure below) is called as Bare PCB and which is used along with other components so as to derive different electric goods. In order to reduce cost spending in manufacturing caused by the defected bare PCB, the bare PCB must be investigated before components are placed and soldered on it.

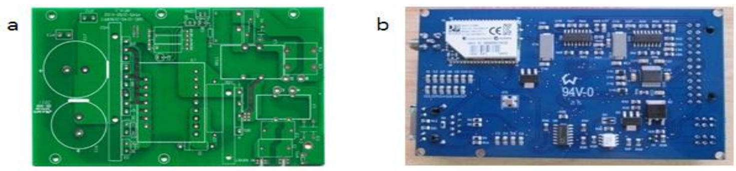

Figure1- (a) Bare PCB; (b) Component placed PCB

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PCB defects can be recognizing as of two types: Functional defects and cosmetic defects [4]. A functional defect also affects the performance of the PCB. Cosmetic defects affect the appearance of the PCB, but can also make vulnerable its performance in the long run due to heat dissipation and distribution of current to all components placed on PCB. it is crucial to detect these two types of defects in the inspection phase. There are many printing defects and anomalies that will be looked at like breakout, short, pin hole, wrong size hole, open circuit, conductor missing, under etch, copper spur, mouse bite, excessive short, missing conductor, missing hole, spur and over etch.

Usually, after the defect detection mechanism the defect classification will take place. Presently, here has been a lot of work focused on the detection of defects on the PCB. Moganti [1] categorize PCB inspection techniques. Main classification of defect detection techniques is based on how defect is detected is shown in table below:

Table 1 – Classification of Defect detection techniques.

S. No.	Approach	Further Classification
1)	Referential approach	i. Model based inspection ii. Image comparison
2)	Non-Referential approach	i. Morphological processing ii. Encoding techniques
3)	Hybrid approach	Combination of both referential and non referential approach.

Besides the need to detect the defects and classify, it is also essential to locate these defects so that the source and location of these defects can be identified. The main aim of defect localization is to determining the position of defects on PCB reflected during the testing of test image in comparison with the template image.

II. Related work

In [1] author provides broad classification of PCB inspection into three levels. These all three are based on automation and classified as referential approach, non- referential approach and hybrid approach. Furthermore these three approaches are further classified.
In [10] author gives comparative study of different algorithms developed and propose an approach based on hybrid approach combining both morphological image segmentation and other simple operations like noise removal, wavelet transformation and subtraction method.
In [7] author proposes an approach that classifies the defects occurred on PCB using Neural network. The approach segments the image into primitive patterns, patterns normalization and classification were developed using morphological image processing and local vector quantization neural network.
In [5] author designed an algorithm which is implemented on bare PCB to identify and to group PCB defects. Major drawback of this algorithm is that it is suitable to work on binary images only, whereas the output from the cameras is in gray scale format. The gray scale to binary conversion can be made still some imperfection can be occurred.
In [6] author developed an image processing approach using non-contact reference method for defect detection and classification. There are many restriction like unwanted images were also generated by noise during gray-scale to binary conversion and Pin-hole defect was ignored.
In [2] author designed a multi resolution approach for gray-scale and rotation invariant texture image classification using local binary patterns and discrimination of section and sample distributions. The method is based on identifying that certain local binary patterns are having fundamental properties of local image texture and the occurrence their histogram is established as to be a very powerful texture feature.
Using few operations in a very small neighbourhood and a lookup table, the advantage of computational simplicity is achieved using the proposed operator by the author.The spatial configuration of local image texture is characterize by the operator and the performance can be further enhanced by mixing them with rotation invariant variance measures that characterize the contrast of local image texture of the image.
In [8] author compares for efficiency of performance of three texture based feature extraction methods for face recognition. The investigation is done on different facial expression database using Grey Level Co-occurrence Matrix

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(GLCM), Local Binary Pattern (LBP) and Elliptical Local Binary Template (ELBT). The study shows how Local Binary Pattern is found to be a better face recognition method among the tested methods. Experimental results also show that accuracy improves when classification is done based on segmenting face region .

In [3] author designed a novel and efficient facial image representation system based on local binary pattern (LBP) texture features. The face image is separated into several blocks from which the LBP feature extraction and concatenated into an enhanced feature vector that has to be used as descriptor of face. Using different challenges, the performance of the proposed method is assessed in the face recognition.

In [9] author reviewed a survey on LBP methodology including several more recent variations.Considering facial recognition as an application of the LBP approach, LBP-based facial image analysis is broadly reviewed and its effectiveness is shown in a number of applications, expanding in particular for facial image analysis tasks like face detection, face recognition, demographic classification, etc.

III.INTRODUCTION TO LOCAL BINARY PATTERN

The basic local binary pattern operator, firstly introduce by Ojala [2], based on the hypothesis that texture has locally two complementary aspects, a pattern and its strength. The LBP was proposed to describe the local textural patterns as a two-level task. The inventive version of the technique operator works in a 3 × 3 pixel block of an image. The very first step of function starts the working with the neighbourhood of eight pixels and considering center pixel as threshold. An LBP code for the neighbourhood of center pixel is produced by multiplying the threshold values with binary weights given to the corresponding pixels, and adding up the result. As the neighbourhood consists of 8 pixels, a total of 256 different labels can be obtained depending on the comparative gray values of the center and the pixels in the local neighbourhood .In its simplest form the LBP operator takes the pixel and generates a binary 1 if the value of neighbour of the centre pixel has larger value than the centre pixel.

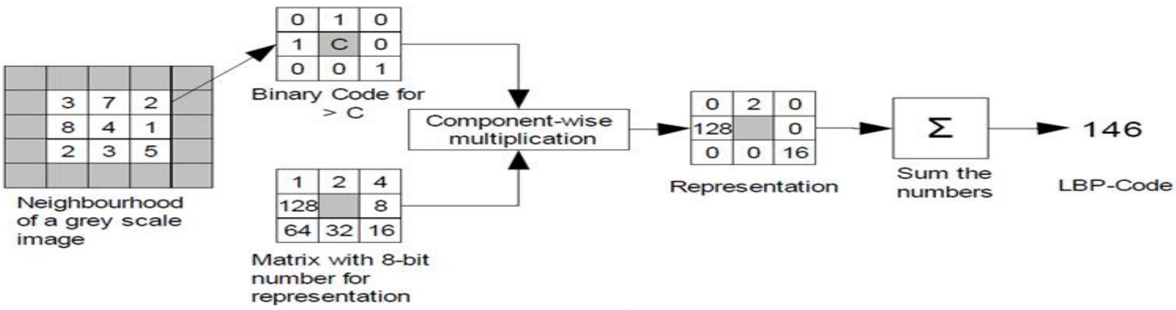

Figure 2- Example for calculation of Local Binary Pattern code

The operator generates a binary 0 if the neighbour is less than the centre. The eight neighbours of the centre can then be represented with an 8-bit number such as an unsigned 8-bit integer, making it a very compact description. Fig.4 shows an example of an LBP operator. As sampling of neighbourhood during LBP codes is done using circular path, which makes calculations invariant to the rotation of the image. If an image is received at any rotation, it means that the gray scale values g_p moves along the perimeter of the circular neighbourhood of the selected neighbour at g_c.The neighbourhood selected is indexed in counter-clockwise direction initializing in the positive x-axis direction, the image rotation obviously results in different LBP value. The all zeros pixels (black) or all ones pixels (white) are unaffected at all angles of rotation that's why it is not applied

To eliminate the rotation effect, each and every LBP code is rotated back to a reference position which provides all rotated sets of a binary code similar to reference position code.

This alteration can be done using the equation as follows:

$$LBP^{ri}_{P,R} = \min\{ROR(LBP_{P,R}, i) \mid i = 0, 1 .... P-1\} \qquad .... (1)$$

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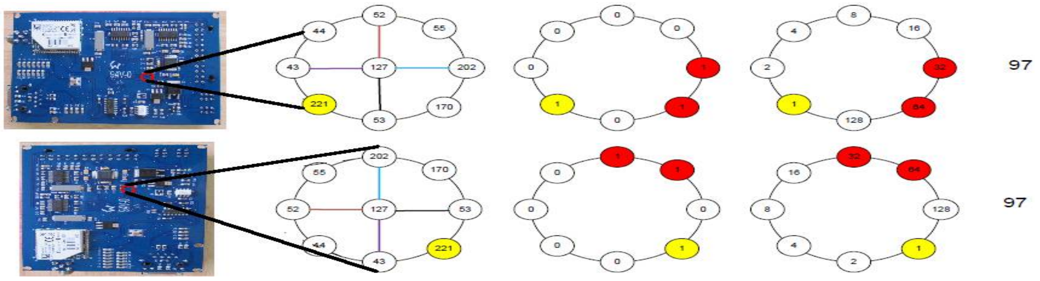

Figure 3- Effect of rotation invariant LBP on image rotation

IV. PROBLEM FORMULATION

The basic automated defect detection system starts with morphological operations performed on PCBs like erosion, dilation, opening, closing, boundary extraction etc. Only detection of defects on tracks of bare PCB can be done using morphological operations and it is very much successful but same method cannot produce efficient results once components are placed on PCB.

Another best approach after basic morphological processes is image subtraction method which is using XOR logic for comparison purposes. Under this process comparison of pixel by pixel value of the standard image to a test image is done in order to detect the defects. This algorithm runs fast and gives better results. In case of bare PCB's, only two level of pixel values has to be compare, one for tracks and other for background region. Above said method took lot of time to analyse a PCB which is having components placed on it. As pixel values are increased and that are also having so different values to compare, that's why lot of time is utilized for processing only even though it gives a true output. Considering processing time as key industry parameters it is very much necessary to give spotlight on the system achievements in terms of processing time. Size of the image to be processed is also another factor which affects the cost of the system. Bare PCB's are of less size as compared to component placed PCB's as different components are of different color and size which changes the pixel values drastically of that particular place where they are placed. Taking into consideration that image size is a key factor to be improved, an extension to the previous system to reduce the size of the image is done using the Haar wavelet transform. Once the size is reduced using Haar wavelet transform [10], same above said operation of subtraction can be used. As Haar wavelet transform is a compression technique, the loss due to compression whether small but important informatory portion of the PCB gets neglected and considered as missing portion while comparing it with template image, which may not be a defect in reality.

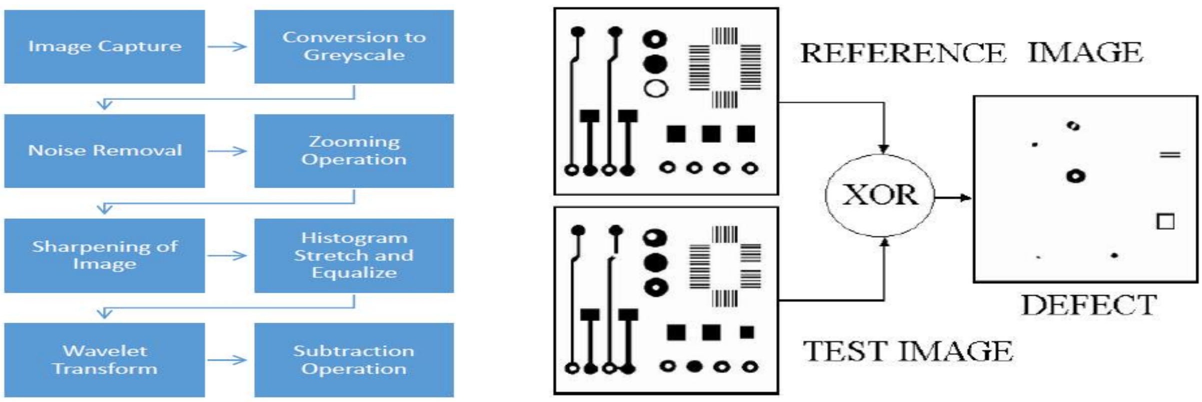

Figure 4- Block diagram of Present State of Art Techniques

V. OBJECTIVE & PROPOSED SYSTEM

The main focus of this paper is to become the familiar with defects types that are occurred on PCB and the various methods which are widely used for detection of defects. This paper also includes various techniques based on Local Binary Pattern and an approach based on LBP for texture classification for defining the different types of defects.

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The objective of the proposed project includes:

1. To design a real time application for defect detection in PCB at different level of manufacturing.
2. To enhance the local feature extraction and localize the defect using LBP.
3. To show the defects on different screen by localizing the defected region using projections graphs.
4. Time comparison graphs are drawn on the basis of time consumed by proposed work in comparison with present state of art techniques.
5. To optimize LBP using rotation-invariance, enable overcoming the perception of both human error and conveyor belt vibrations causing small angle variations while acquisition of test image.

To rise above from the shortcomings of all previous algorithms, an improved and quicker process is proposed which provides quantitative as well as qualitative results. The proposed system follows the following steps:-

Step 1 The very first step is to read the template image of the non-defective PCB and the test image of the PCB to be tested.
Step 2 Selection of symmetric neighborhood set for both the images.
Step 3 Convert the RGB image into HSV domain.
Step 4 Calculate and store the threshold values for each neighborhood set covering the whole image using Local binary pattern technique.
Step 5 Compare both template and test images of PCBs using Local Binary Pattern to find out the defects.

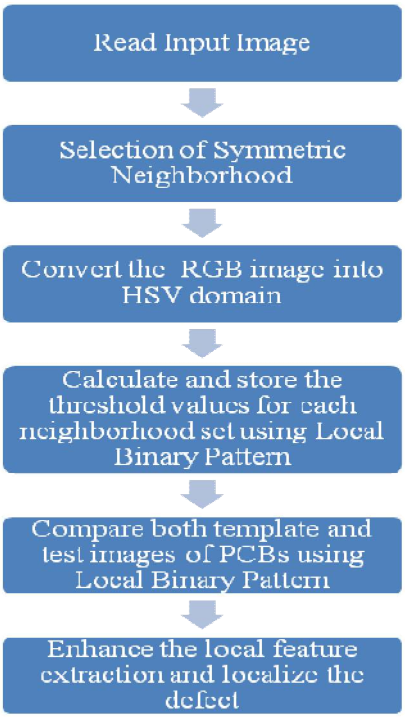

Figure 5- Block diagram for the proposed work

VI. SIMULATION RESULTS

The simulation studies involve results generated focused on thoroughly testing the realization of the PCB's defects and its localization on the basis of Local Binary Patterns. The results showed that the algorithm can accurately detect and locate the defects corresponding to a template scanned image of PCB. The results further confirmed starts from a user friendly GUI (Graphical User Interface) which is providing a Select Original button to pick a template image and Select Test button pick a Test image and preview for the both images on the same GUI.

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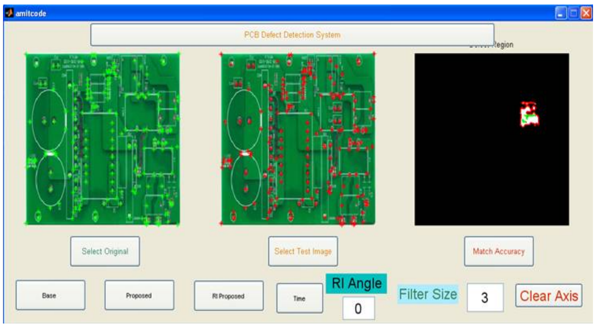

Figure 6- Result of proposed system on bare PCB

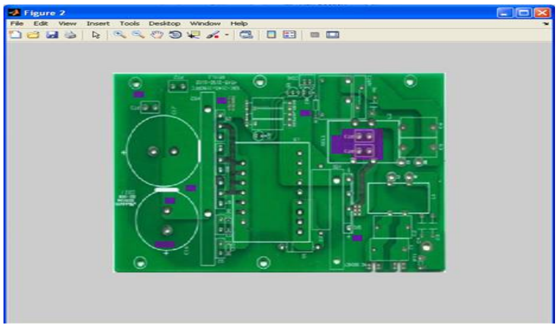

Figure 7- Defected region obtained by proposed system

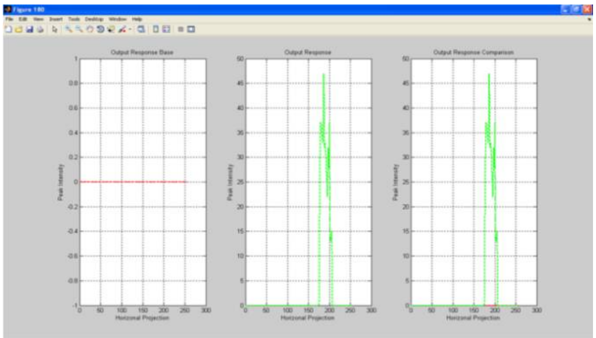

Figure 8- Comparison graphs for horizontal projection

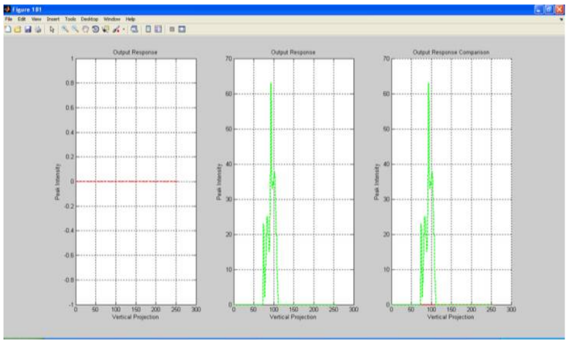

Figure 9- Comparison graphs for vertical projection

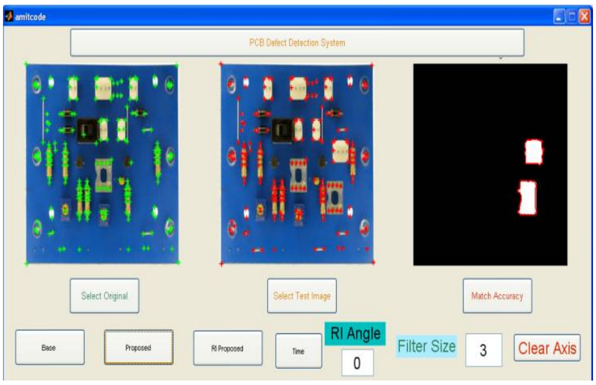

Figure 10- Result of proposed system on component placed PCB

Figure 11- Defected region obtained by proposed system

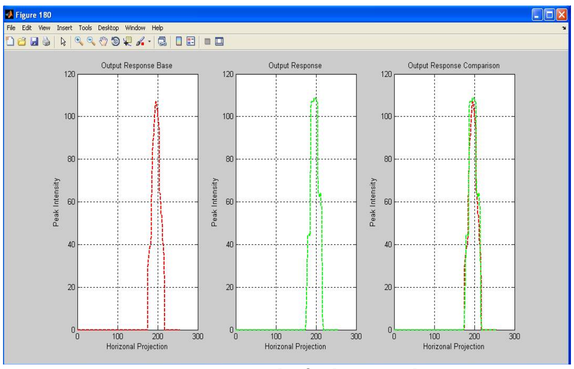

Figure 12-Comparison graphs for horizontal projection

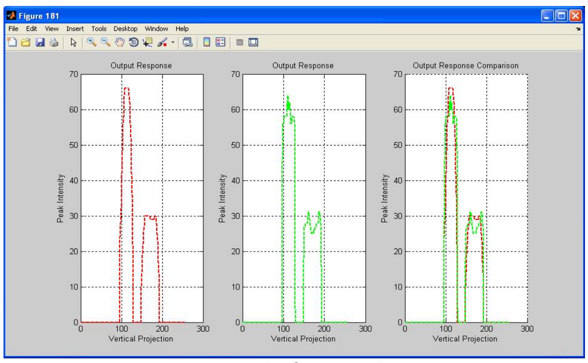

Figure13- Comparison graphs for vertical projection

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The above figures (i.e. figure 8, 9, 12, 13) represent the projections of intensities of the defected region on both vertical and horizontal levels. First axes represent the intensity projection of base method followed by proposed method on second axes and comparison of both base and proposed intensity projections on third axes. Main problem associated with PCB defect classification is the task of identifying a defects at different surface orientations. Therefore we consider rotation invariant texture features for both bare and components based PCB's. As we are taking the consideration that alignment took place due to vibrations in PCB while travelling on conveyor belts and these alignments could be of very minute angles that's why we test the proposed RI-LBP system from the range of -25 degree to +25 degree from reference axis (i.e. Zero Degree). To check whether rotation invariance local binary patterns on PCB defect detection works efficiently and accurately, we rotate the test image at different angles (-25°, -20°, -15°, -10°, -5°, 0°, +5°, +10°, +15°, +20°, +25°).

Figure 14- Result of test image rotated at -25°

The following figures consists of template image and results of RI-Proposed test image at various testing angles.

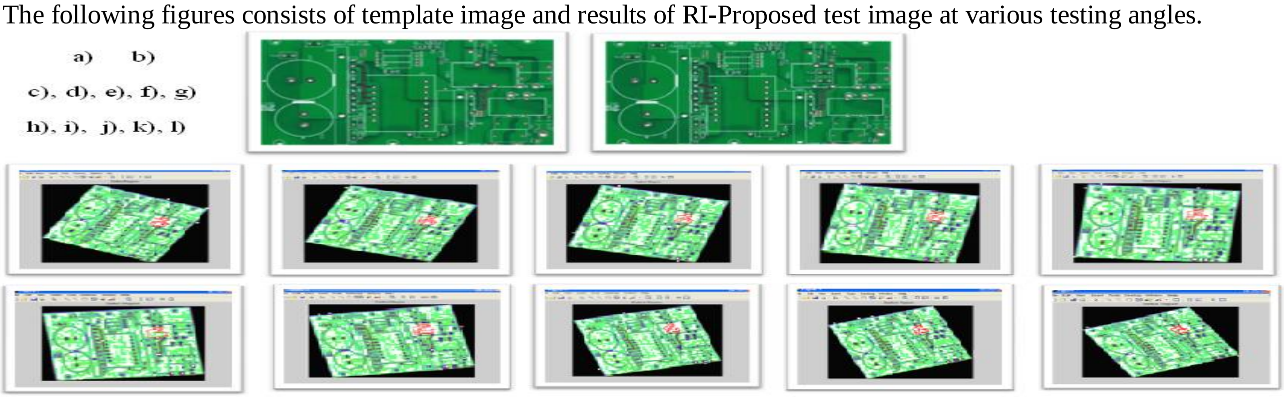
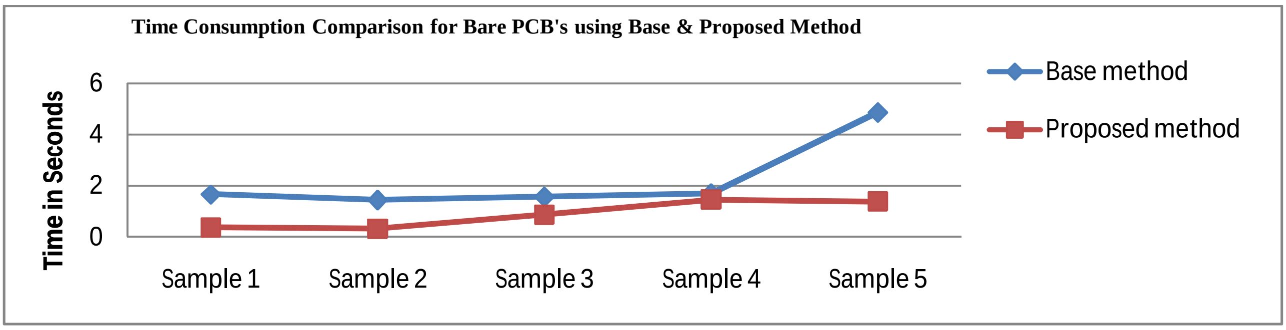


Figure 15- Defected region obtained in HSV Domain by RI-Proposed system on bare PCB rotated at various angles: (a)Template image, (b) Test image, (c) -25°, (d) -20°, (e) -15°, (f) -10°, (g) -5°, (h) +5°, (i) +10°, (j)+15°, (k) +20° & (l) +25°.

The following graphs represent the variations in time consumption by different samples and results shows that proposed method is widely ahead as compare to base method in quantitative analysis and can be applicable for real time processing.



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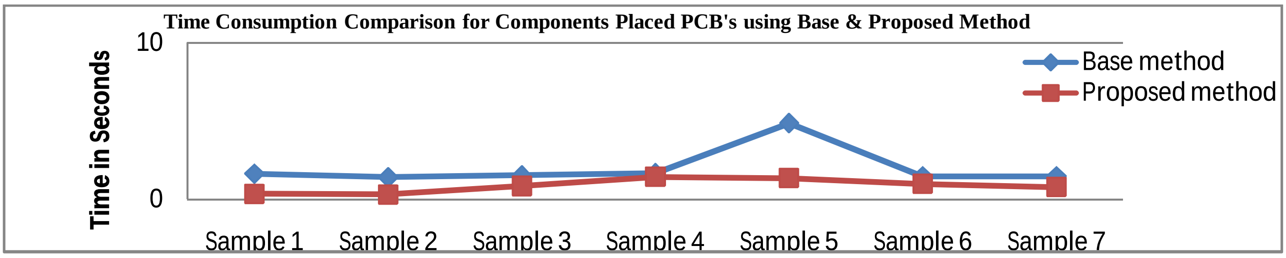

VII. CONCLUSION AND FUTURE WORK

The work is successfully implemented on both types of PCB's either bare or components placed by comparing images of PCB to detect and to locate the defects on PCB. By comparing, the research work with the existing work, it is observed that this presented work is giving better result than the existing works, because this work produces the output without degrading or compressing of the quality of the image. Due to its fast processing in computations, proposed algorithm can be applied as real time application with conveyor belts as online testing algorithm. The extension of proposed system i.e. RI-LBP produces the results for the alignment of the test image in comparison of template image which is the most important factor we achieve during this research. Time comparison charts represent that the proposed system is very much applicable during the manufacturing time. One direction for future expansion of the software will be building it with more specific criterion regarding selection of filter size as in accordance with input test image size as it is easier and having quick response with a fixed filter size for particular size of test image which is manually selected under the proposed system. Moreover, using extensions of Local Binary Patterns like Local Ternary Pattern and other modifications results can be further enhanced.

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BIOGRAPHY

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