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A NOVEL FUZZY PCA BASED IMAGE PROCESSING APPROACH ON PCB DEFECT DETECTION

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Abstract
A Printed Circuit board (PCB) is designed to mount and interconnect various electronic components by tracks which are imprinted from copper sheets. During manual inspection of PCB defect there is a more possibility of difficulties in accurate determination of defect presence. This necessitates the automatic inspection of PCB in the aspect of quantitative and qualitative assessment otherwise it results in complete failure of circuit. This paper developed an automatic inspection of PCB board defect by applying enhanced fuzzy logic based PCA approach before the etching process. It detects the presence of defects by producing the result in form of degree of membership of defect (i.e) higher membership value represents higher degree of defect presence.

Keywords – PCB, defect, detection, fuzzy logic, circuit

1. INTRODUCTION
In automatic manufacturing industry the role of machine vision is very important application. The occurrence of defects in PCB during the manufacturing time is quite common. There are two categories of defects namely potential effects and fatal defects. In fatal defect the PCB fails to achieve its design objective and its example are short circuit and open circuit. Potential defects results in compromising performance of PCB during its usage breakout, under etch, missing hole and wrong size are some examples of it [1].

The recognition of these defects at a premature phase in the manufacture progression is advantageous and evades increase of cost due to deferred detection of defects. Hence, it is imperative to work out a consistent system to detect the defects in the PCBs. There are numerous kinds of defects which pestilence printed circuit boards (PCBs). The cause for this is the huge complication and tinniest chips which are mass formed in the millions [2]. All chips enclose thousands of individual systems every one functioning cordially to generate a convinced output. Various defects are rooted by infected materials. An additional defect is where there are physical troubles with the fabric [3]. Voids, fractures, and de-lamination can all come together to lessen or distort PCB performance. In this work fuzzy PCA is used to find whether the PCB is defective or not and if PCB is found to be defective then its degree of defectiveness is calculated using correlation coefficient.

2. RELATED WORK
Heriansyah [4, 5] proposed a technique, which uses referential pixel based approach, where 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, the 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, nose-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. These PCB inspection approaches mainly concentrated on defects detection [6]. However, defects detection did not provide satisfactory information for repairing and quality control work, since the type of detected defects cannot be clearly identified. Based on this incapability of defects detection, defect classification operation is needed in PCB inspection. Therefore, an accurate defect classification procedure is essential especially for an on-line inspection system during PCB production process. Human operators simply inspect visually against prescribed standards. The decisions made by them often involve subjective judgment, in addition to being labour intensive and therefore costly, whereas automatic inspection systems remove the subjective aspects and provide fast, quantitative dimensional assessments. Shih-Chieh Lin et al [7] 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. Khalid et al [8] 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 gray scale format. Although the conversion can be made from gray scale to binary format imperfection still can be occurred. Thus, this algorithm should be improved to handle the gray scale image format. Indera Putera et al [9, 10] 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.

In paper [11] the automatic machine inspection using the different algorithm is discussed mainly subtraction algorithm. In this algorithm we will compare an Ideal image with the Test image in which the defect needs to be detected like missing hole, pin hole, under etch, short-circuit, mouse bite, open-circuit etc.

In study [12] different approaches have been implemented on reference and test PCB images to detect defects on bare PCBs before etching process, since etching usually contributes most destructive defect found on PCBs

From the review of existing approaches it is understood that automated visual inspection is required because of the following criteria:

- They reduce human inspectors of the tiresome jobs concerned.
- Manual inspection is sluggish, expensive, leads to unnecessary scrap rates, and does not guarantee high value.
- Multi-layer boards are not appropriate for human eyes to examine.
- With the assist of an enlarging lens, the typical fault-finding rate of a human being is 90%. at the same time rate drops to 50%. Yet with fault free power and ground layers, the rate does not surpass 70%.
- High sampling inspecting is not applicable.
- Manual inspection is not feasible due to the higher production rates
- Visual inspection is insufficient due to less tolerances capability

3. METHODS

- **Machine Vision**

  Machine vision is the science in which a computer is programmed to process and recognize images and video. It can be implicit as signal processing applied to images and videos. From the images and it sequence it extracts the information thru its artificial intelligence the image data can take numerous forms, such as video sequences, views from multiple cameras, or multi-dimensional data from a medical scanner. There is a necessity for implementing proposed theory and method for construction of machine vision system. It can be implemented for the Automated inspection, Process control, Data base collection and indexing, Modeling of system and environment.
- **Discrete cosine transform**

  Transform coding constitutes an integral component of contemporary image/video processing applications. Transform coding relies on the premise that pixels in an image exhibit a certain level of correlation with their neighboring pixels. A transformation is, therefore, defined to map this spatial (correlated) data into transformed (uncorrelated) coefficients. Clearly, the transformation should utilize the fact that the information content of an individual pixel is relatively small i.e., to a large extent visual contribution of a pixel can be predicted using its neighbours. Some properties of the DCT, which are of particular value to image processing applications.

De correlation: The principle advantage of image transformation is the removal of redundancy between neighbouring pixels. This property helps us to manipulate the uncorrelated transform coefficients as they can be operated upon independently.

4. PRINCIPAL COMPONENT ANALYSIS THEORY

Principal component analysis in signal processing can be described as a transform of a given set of n input vectors (variables) with the same length K formed in the n-dimensional vector x = [x1, x2, ...xn]T into a vector y according to

$$\mathbf{y} = \mathbf{A}\ (\mathbf{x} - \mathbf{m_x}) \quad (1)$$

This point of view enables to form a simple formula (1) but it is necessary to keep in the mind that each row of the vector x consists of K values belonging to one input. The vector mx in Eq. (1) is the vector of mean values of all input variables defined by relation

$$\mathrm{m_x} = E\{\mathrm{x}\} = \frac{1}{K}\sum_{k=1}^{K} \mathrm{x_k} \quad (2)$$

Matrix **A** in Eq. (1) is determined by the covariance matrix **Cx**. Rows in the **A** matrix are formed from the eigenvectors **e** of **Cx** ordered according to corresponding eigen values in descending order. The evaluation of the **Cx** matrix is possible according to relation

$$\mathrm{C_x} = E\{(\mathrm{x}-\mathrm{m_x})(\mathrm{x}-\mathrm{m_x})^{\mathrm{T}}\} = \frac{1}{K}\sum_{k=1}^{K} \mathrm{x_k x_k^T} - \mathrm{m_x m_x^T} \quad (3)$$

As the vector **x** of input variables is *n*-dimensional it is obvious that the size of **Cx** is *n* x *n*. The elements **Cx**(*i*, *i*) lying in its main diagonal are the variances

$$\mathbf{C_x}(i,i) = E\{(\mathrm{x_i} - m_i)^2\} \quad (4)$$

The following are the steps needed to perform a principal component analysis (PCA) on a set of data are:

1. Give the input in matrix form (here DCT matrix)
2. Subtract the mean: For PCA to work properly, we have to subtract the mean from each of the data dimensions. The mean subtracted is the average across each dimension. This produces a data set whose mean is zero.
3. Calculate the covariance matrix
4. Calculate the Eigen values and Eigen vectors of the covariance matrix: Since the covariance matrix is a square matrix, we can calculate the Eigen values and Eigen vectors for this matrix. These are rather important, as they tell us useful information about our data. But, more importantly, they provide us with information about the patterns in data. So, by this process of taking the Eigen vectors of the covariance matrix, we have been able to extract the lines that characterize data.
5. Choosing components and forming a feature vector: Here is where the notion of data compression and reduced dimensionality comes into it. In fact, it turns out that the Eigen vector with the highest Eigen value is the principal component of the data set. It is the most significant relationship between the data dimensions. In general, once Eigen vectors are found from the covariance matrix, the next step is to order them by Eigen value, highest to lowest. This gives the components in order of significance. Now we can ignore the components of lesser significance. We do lose some information, but if the Eigen values are small, we don't lose much information. So the final data set will have lesser dimensions than the original.

5. FUZZY PRINCIPAL COMPONENT ANALYSIS

A fuzzy clustering algorithm with objective function can be formulated as follows: let X=[x1, x2, ...xn] Rs be a finite set of features, where n is the number of objects and p is the number of the original variables, xk j =[x1 j, x2 j, ...,xp j] T and L=(L1, L2, ...Ls) be s clusters, each of which characterizes one of the s clusters composing the cluster substructure of the data set: a partition of X into s fuzzy clusters will be performed by minimizing the objective function as shown in the equation 5

$$J(P,L) = \sum_{i=1}^{S} \sum_{j=1}^{n} ((A_i(x^j))^2\, d^2(x^j, L^i) \quad (5)$$

where P=[A1, A2 ,.........,As] is the fuzzy partition, of the PCB image feature space, Ai(xj) ε [0,1] represents the membership degree of feature point xj to cluster Ai,d(xj,Li) is the distance from a feature point xj to the prototype of cluster Ai. The d(xj,Li) can be calculated as follows

$$d(x^j, L^i) = \| x^j - L^i \| = [\sum_{k=1}^{p} (x_k^{\,j} - L_k^{\,i})^2]^{1/2} \quad (6)$$

If L is given P, we get the fuzzy membership $A_i(x_j)$

$$A_i(x^j) = 1 / \sum_{K=1}^{s} d^2(x^j, L_i)/d^2(x^j, L_k) \quad i=1,2,\ldots.s \quad (7)$$

For a given P, we can obtain L_i

$$L^i = \sum_{J=1}^{n} [A_i(x^j)]^2\, x^j / \sum_{j=1}^{n} [A_i(x^j)]^2 \quad i=1,2,\ldots.\,k \quad (8)$$

Fuzzy covariance matrix C

$$C_{kl} = \sum_{J=1}^{n} [A_i(x^j)]^2\, (x_{jk} - \overline{x_k})(x_{jl} - \overline{x_l}) / \sum_{j=1}^{n} [A_i(x^j)]^2 \quad (9)$$

Define the objective function of FPCA

$$J(A,L;\alpha) = \sum_{J=1}^{n} [A(x^j)]^2\, d^2(x^j, L^i) + \sum_{j=1}^{n} [\bar{A}(x^j)]^2\ \alpha/1-\alpha \quad (10)$$

Where [A,A] is a fuzzy partition. The set A is characterized by its linear centroid. Set A is the complementary fuzzy set. α /1-α is the difference between its hypothetical centroid and the PCB image feature point xj, where α is a real constant from the interval (0,1) .

Centroid for

$$\mathrm{FPCA}\quad v = \sum_{J=1}^{n} [A(x^j)]^2 x^j / \sum_{j=1}^{n} [A(x^j)]^2 \quad (11)$$

where

$$A(x^j) = [\alpha/1-\alpha] / [\alpha/1-\alpha] + d^2(x^j, L) \quad (12)$$

We can transform xj by yj=eT(xj-v) where eigenvectors are e=[e1,e2,.......ek]

5.1.1 ALGORITHM for PCB Defect Detection using Fuzzy Principal Component Analysis

- Give the PCB query image as the input.
- Convert the input from BMP to data file.
- Perform Discrete Cosine Transform on the dataset.
- Extract 3x3 matrix based on subjective analysis.
- Perform fuzzy covariance on the 3x3 matrix.

- Generate characteristic equation from the fuzzy covariance matrix and define objective function of FPCA
- Determine centroid for FPCA
- Solve for maximum Eigen value
- Perform comparison of Eigen values for reference PCB image with testing PCB image using Similarity measure.
- If similarity =1 then result =no defect else result = defect present.

6. EXPERIMENTAL RESULT

Fuzzy system based PCA is used to determine degree of defectiveness present in the PCB. This design consists of 1input and 1 output. The inputs consist of PCA Eigen values while the output is the extent of defectiveness present in the PCB. The variables are used like low, medium and high for input and low, medium and high for output. The outline of our proposed fuzzy expert system can be shown in Figure 1. Mamdani method is used for fuzzification.

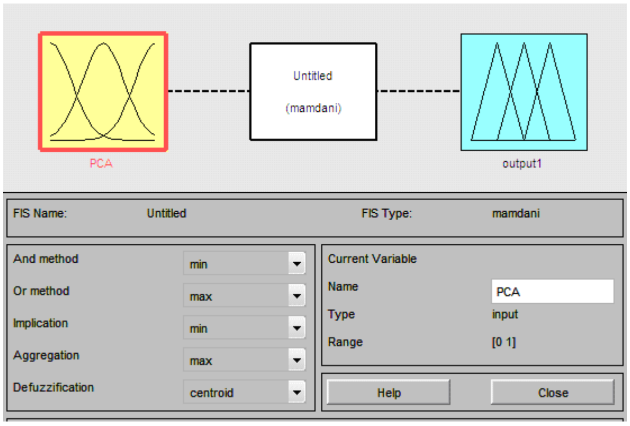
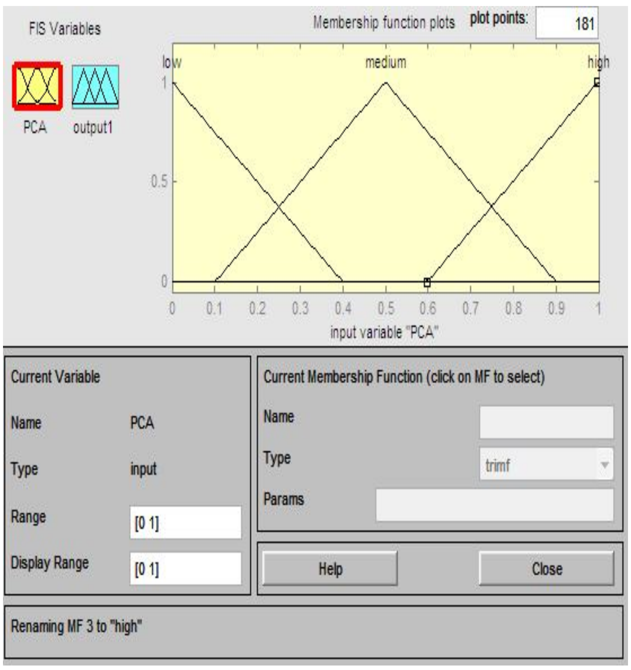


Figure 1 Fuzzy based PCA Expert System



Membership degree and Linguistic Representation of FPCA

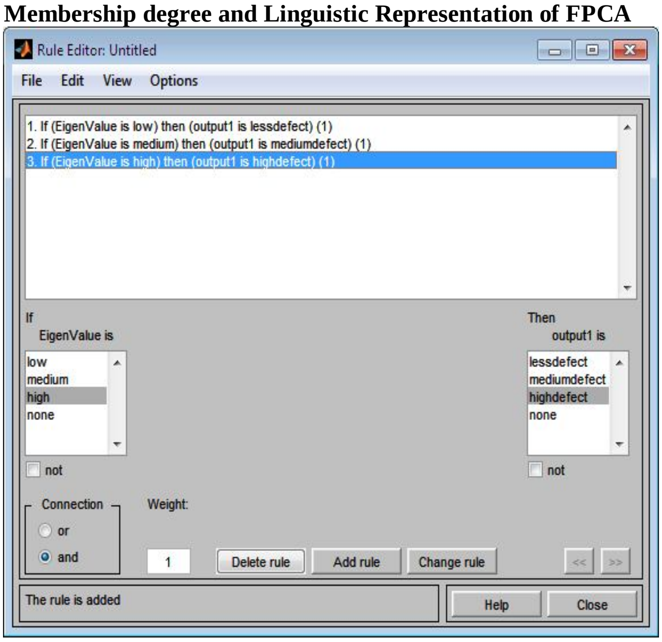


Figure 2 Rule Base of Fuzzy PCA

Rule base is shown in figure 2. Three rules are used in this system. The rules have been developed using if-then method. The rules have been made on the basis of the similarity distance measure

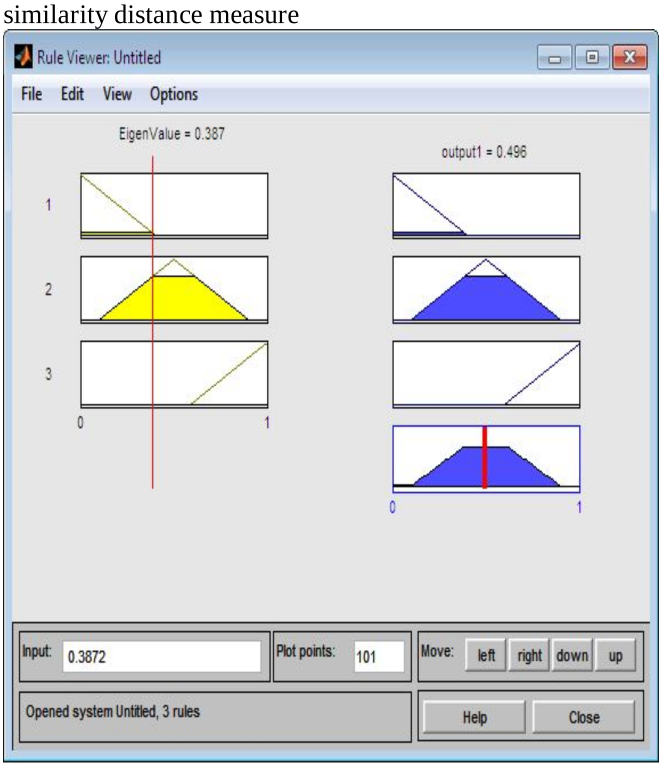


Figure 3 Rule Viewer of Fuzzy PCA

Using these rules, the result risk in term of percentage (%) has been computed. Figure 3 shows the ruler view of the graph obtained between defectiveness of the PCB against Fuzzy PCA Eigen Values. Surface view of the resultant graph is shown in below figure 4.

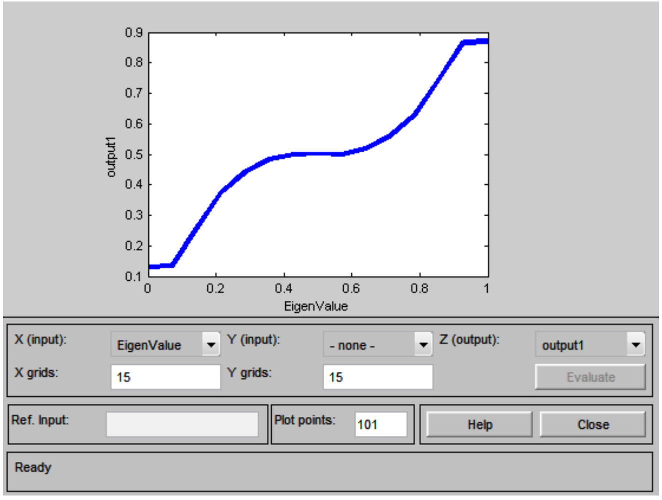


Figure 4 Surface Plot of Eigen value

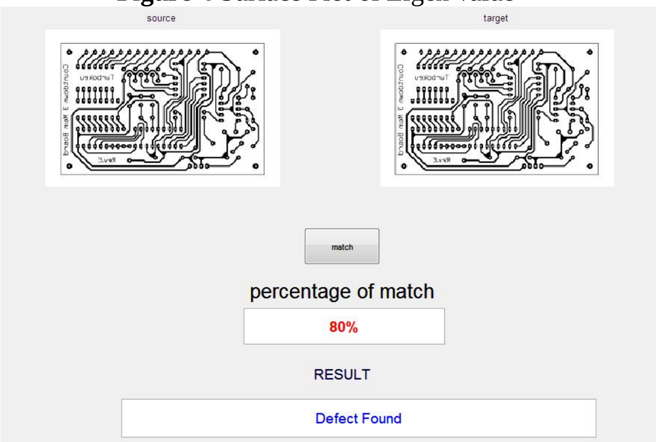
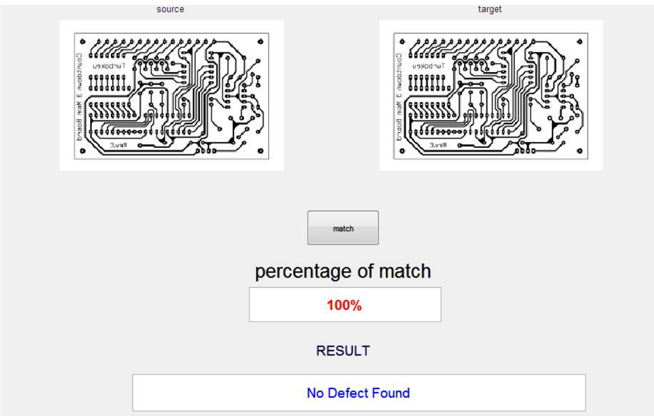


Figure 5.Output of Fuzzy PCA matching with defect found result



Output of Fuzzy PCA matching with no defect found result

The result of the figures(5 & 6) shows the sample input and test images with defect and without defect.

6. CONCLUSION

In this simulated work the PCB is examined and the defects of PCB are determined using Fuzzy PCA. Due to the use of fuzzy objective function the accuracy of the system is very high. By the use of the proposed technique the importance and usage of machine vision in the field of defect detection in PCB bare board is very efficient and effective. This fuzzy inference system provides the result in form of whether the given PCB is defective or not by calculating the degree of defective using Eigen value of the both reference image and test image.

REFERENCES

[1]. M. Moganti, F. Ercal, C. H. Dagli and S. Tsunekawa, “Automatic PCB Inspection Algorithms: A Survey”, Computer Vision and Image Understanding journal, vol.63,1996.

[2]. J. F Canny, “A computational approach to edge detection”, IEEE Transaction on Pattern Analysis and Machine Intelligence, vol. 8, pp 679-698, 1997.

[3]. I. Ibrahim, S.A.R Abu-Bakar, M.M. Mokji et al. “Performance measurement of thresholding algorithms in printed circuit board inspection system”, proceedings of 3rd International Conference on Computational Intelligence, Modeling and Simulation, 2012.

[4]. T. R. Heriansyah, S.A.R AI-Attas, and M.M. Ahmad Zabidi, „Segmentation of PCB Images into Simple Generic Patterns using Mathematical Morphology and Windowing Technique” CoGRAMM Melaka, Malaysia, 2002.

[5]. T. R. Heriansyah, „Segmentation of PCB Images into Simple Generic Patterns using Mathematical Morphology and Windowing Technique” Master□s Thesis, University Technology Malaysia, 2004.

[6]. M. Monganti, F. Ercal, C. H. Dagli and S. Tsunekawa, Automatic PCB inspection algorithm: A survey, Computer Vision and Image Understanding, vol.63, no.2, 1996.

[7]. Shih-Chieh Lin and Chia-Hsin Su “A Visual Inspection System for Surface Mounted Devices on Printed Circuit Board” Department of Power Mechanical Engineering National Tsing Hua University Hsin-Chu Taiwan 300, 2006 IEEE CIS 2006

[8]. N. K. Khalid, Z. Ibrahim, M. S.Z. Abidin (May 2008) An algorithm to group defects on printedcircuit board for automated visual inspection. IJSSST, Vol. 9, No. 2, ISSN: 1473-804x

[9]. S. H. Indera Putera, Syahrul Fahmi Dzafaruddin, Maziah Mohamad, “MATLAB Based Defect Detection and Classification of Printed Circuit Board” Digital Information and Communication Technology and it's Applications (DICTAP), IEEE 2012 Second International Conference. Bangkok.

[10]. S. H. Indera Putera and Z. Ibrahim „Printed Circuit Board Defect Detection Using Mathematical Morphology and MATLAB Image Processing Tools□, ICINT 2010, Shanghai, China, 2010.

[11]. Ashish Singh, Vimal H. Nayak, Automatic Detection of PCB Defects, International Journal for

Innovative Research in Science & Technology, Volume 1, Issue 6 , November 2014

[12]. Suhasini A,Sonal D Kalro, Prathiksha B G , Meghashree B S , Phaneendra H D, PCB defect detection using image subtraction algorithm, International Journal of Computer Science Trends and Technology (IJCST) – Volume 3 Issue 3, May-June 2015

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