ICIC Express Letters
Volume **6**, Number **3**, March **2012**

ICIC International ©2012 ISSN 1881-803X
pp. 717–722

AN IMAGE REGISTRATION TECHNIQUE TO ENHANCE PCB INSPECTION ALGORITHMS WITH REAL IMAGES

Ismail Ibrahim[1], Syed Abdul Rahman Syed Abu Bakar[1], Musa Mohd Mokji[1]
Kamal Khalil[1], Zulkifli Md. Yusof[1], Jameel Abdulla Ahmed Mukred[1]
Mohd Saberi Mohamad[2] and Zuwairie Ibrahim[1]

[1]Faculty of Electrical Engineering
[2]Faculty of Computer Science and Information Systems
University Teknologi Malaysia
81310, Skudai, Johor, Malaysia
ismail_xyz@yahoo.com; { syed; musa; kamal; zmdyusof; jameel; zuwairie }@fke.utm.my
saberi@utm.my

Received June 2011; accepted September 2011

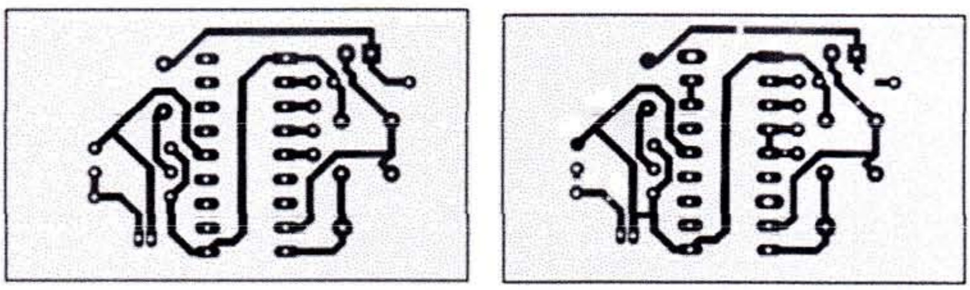
Abstract. *It is well known that real PCB image inspection based on referential approaches faces misalignment problems in detecting defects between a template image and a defective image. Hence, a reliable image registration technique is needed to align these two images perfectly. Hence, a registration technique which incorporates affine transformation and bi-cubic interpolation has been proposed. Experimental results have shown that this registration technique is suitable to be employed to obtain well-aligned defective images before detection algorithm takes place in PCB inspection.*
Keywords: Printed circuit boards, Image registration, Affine transformation, Bi-cubic interpolation, Defect detection

1. **Introduction.** A bare printed circuit board (PCB) is a PCB that is used before the placement of components and soldering process [1]. It is used along with other components to produce electronic goods. To reduce manufacturing cost associated with defected bare PCBs, the inspection of bare PCBs is required as the foremost step of the manufacturing process. Moganti et al. [2] proposed three categories of PCB inspection algorithms: referential approaches, non-referential approaches and hybrid approaches. Referential inspection is performed by making a comparison between the template PCB image and tested PCB images. Non-referential approaches or design-rule verification method are based on the verification of the general design rules that essentially verify the widths of conductors and insulators. Hybrid approaches involve a combination both of referential and non-referential approaches. This approach has the advantages of referential and non-referential approaches, but at the expense of being more complex.

In this paper, PCB inspection based on referential approaches is used as it can be easily employed in hardware, and consequently high processing rates are possible to achieve [2-4]. Another advantage of these approaches is that large defects such as missing conductor wires can be detected [4]. However, this approach has several drawbacks such as large data storage is needed [4-6], an accurate registration technique is required [2-7], sensitive to illumination and sensor conditions [2,3,5-7], and lack of flexibility [5]. To obtain a well-aligned defective image without applying the existing mechanical registration fixture [8], an image registration that incorporates a geometric transformation and image resampling is proposed in this paper. At the end, several different printing defects occuring on real PCB images, namely, missing hole, pin hole, underetch positive, underetch negative, short-circuit, open-circuit, and mousebite can be detected perfectly.

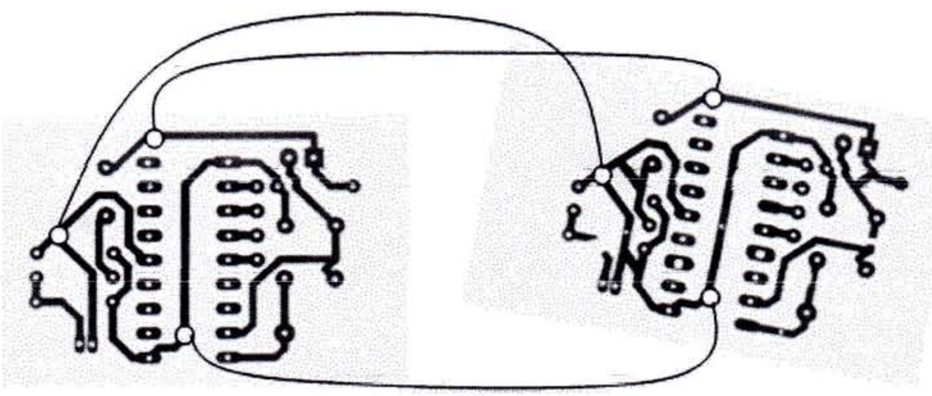
2. **Defect on Bare Printed Circuit Board.** In PCB fabrication, there are several processes that must be followed: artwork master, photo tool production, exposure and development of inner layers, etching of inner layers, laminating and drilling, plating through holes, exposure and development of outer layers, plating tin-lead and etch, and machine and solder mask [2]. The printing processes of artwork master, photo tool production, and exposure and development of inner layers, which are performed before the etching process, constitute the source of two groups of defects. The first group of defects includes short and open-circuit. These defects fall into the fatal defects category. Meanwhile, other defects such as pinhole, underetch positive, underetch negative and missing hole fall into the potential defects category. It should be noted that fatal defects are those in which the PCB does not address the objective for which they were designed, while potential defects are those that compromise the PCB during the utilization. Figure 1(a) and Figure 1(b) show a PCB template and a PCB defective image, respectively. Though each defect shown in Figure 2 is a representative example of certain kind of defect, the shape and size of the defects may vary from one instance to another.

3. **Image Registration.** The goal of image registration is to find the best transformation that aligns one image to another [9]. More precisely, it is used to find a correspondence function, or mapping that takes each spatial coordinate from the template image and returns a coordinate for the defective image. The transformation consists of a two stage process: the geometric transformation and the image resampling [9]. Geometric transformations define the relationship between points in two images.



(a) (b)

FIGURE 1. (a) A template bare PCB image; (b) a defective bare PCB image



(a) (b)

FIGURE 2. (a) Template image; (b) defective image (rotated by some degrees)

With this transformation, a correspondence between pixels in a defective image with the pixels in a template image is established. As presented in Figure 2(a), the template image is assumed not to be rotated. At the other hand, the defective image has been rotated by some degrees, as shown in Figure 2(b). By establishing correspondence between each pixel in the template image with the each pixel in the defective image, the defective image can be registered. If the size of the template and defective image are 100 × 100 pixels, so, there are 10000 correspondence points that must been aligned between these two images. As an example, three points have been chosen to visualize the correspondence between these two images, as exposed in Figure 2(a) and Figure 2(b).

The geometric transformation method used for this study is based on an affine transform. The affine transform is a linear coordinate transformation that can be expressed by vector addition and matrix multiplication, as presented in the following equation.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix} \tag{1}$$

An affine transform has six degrees of freedom. Two of the degrees, t_x and t_y belong to translation. The remaining four degrees, which are a_{11}, a_{12}, a_{21} and a_{22} are used to calculate scaling and shearing between two images. In this study, a globally affine and smooth transformation model added with intensity variations which were established by Periaswamy and Farid [10], is used by including two new parameters; a_{31} for contrast and a_{32} for brightness. The previous affine transform equation can be modified as following.

$$a_{31}f(x,y,t) + a_{32} = f(a_{11}x + a_{12}y + t_x, a_{21}x + a_{22}y + t_y, t-1) \tag{2}$$

where $f(x,y,t)$ and $f(\hat{x},\hat{y},t-1)$ represent template and defective images, respectively.

In image resampling, interpolation is required as the transformed grid points of the input image generally no longer coincide with the grid points of the output image and vice versa. At first, the planar transformation is assumed has been accomplished and new point co-ordinates (x', y') have been obtained. The position of the point does not generally fit the discrete raster of the output image, and the collection of transformed points gives the samples of the output image with non-integer coordinates. Values on the integer grid are needed, and each pixel value in the output image raster can be obtained by interpolating of some neighboring non-integer samples [11]. An interpolation method influences image quality. The three most common interpolation methods are nearest neighbor, linear, and bi-cubic. This paper uses bi-cubic interpolation because this interpolation method does not suffer from the step-like boundary problem of nearest-neighborhood interpolation and copes with linear interpolation blurring as well. Bi-cubic interpolation preserves fine details in the image very well.

4. **Flow Process of the PCB Inspection Algorithm.** Flow process of the PCB inspection algorithm is depicted as in Figure 3. Firstly, the image registration operation proposed is executed in order to acquire a good registered defective image. Secondly, image subtraction operation is utilized to the template and registered defective images to yield real defects on positive image and negative image. Denote that these two images are in gray-level and the type of defects occur on the images can be checked in [12] for details. Thresholding and a proper filtering operation are then employed to eliminate all remaining noise in these two images.

5. **Experimental Results and Discussion.** Several experiments were performed to validate the performance of the image registration used. The results of the PCB inspection algorithm with and without image registration operation are compared and presented in Figures 4 and 5, respectively. Both systems have been executed using real PCB images as shown in Figure 1. However, the subtracted image could still be interfered by unwanted noise occurred at line boundary. Thus, threshold operation is executed for both images

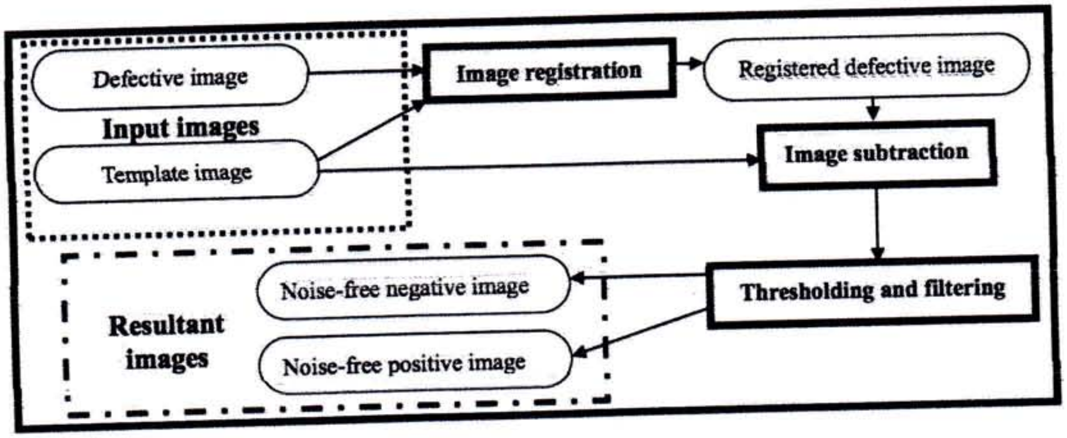
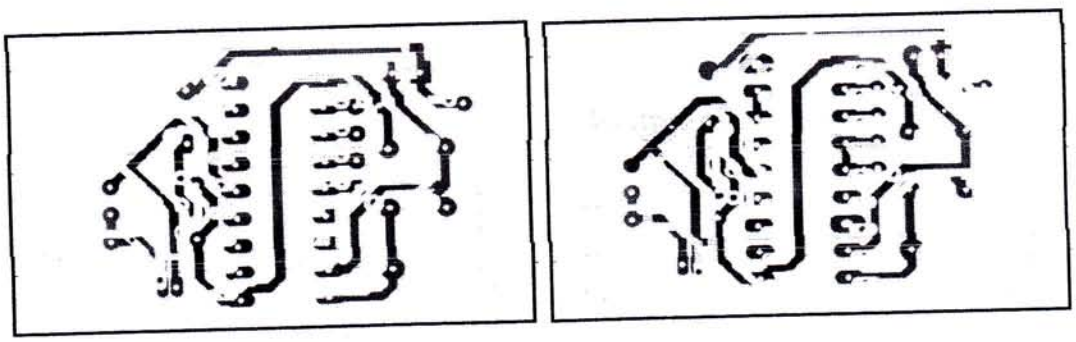
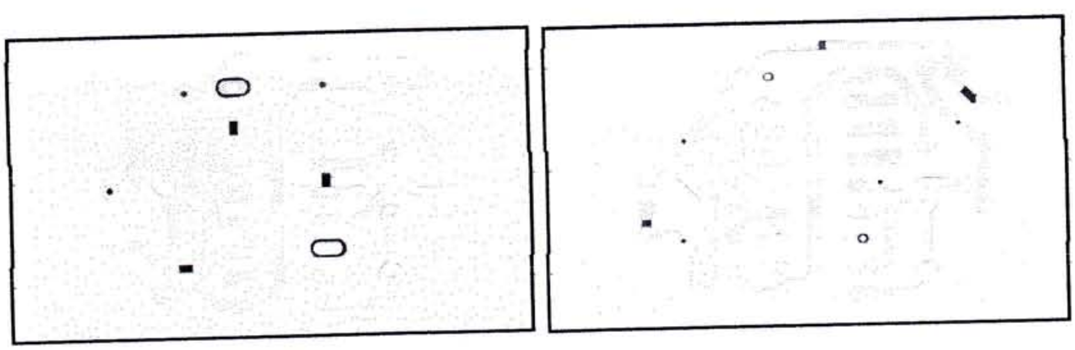


FIGURE 3. Flow process of the inspection algorithm



(a) (b)

FIGURE 4. Non-registered images: (a) positive image; (b) negative image

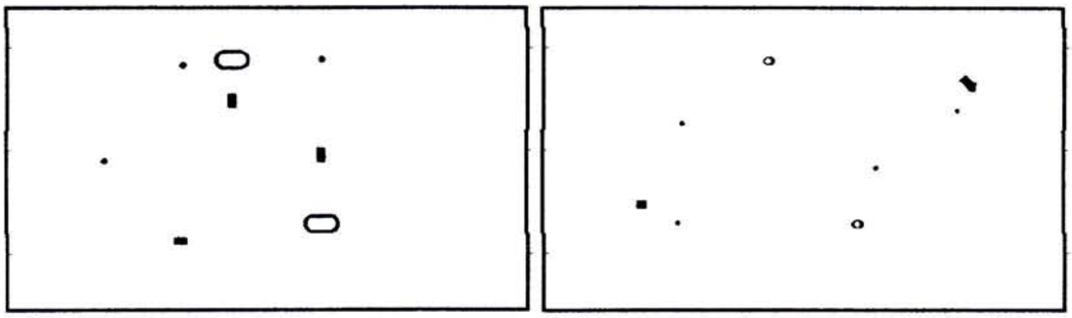


(a) (b)

FIGURE 5. Registered images: (a) positive image; (b) negative image

to remove the noise that exists together with actual defects. Threshold operation is also used to convert the both images to be binary images.

For implementation, the threshold values, t, for the positive image and negative image, are 165 and 157, respectively. For these two images, minimum thresholding has been used. As a result, the thresholded positive and negative images are produced. Median filtering is then executed to both thresholded images. This operation is useful to remove any small noise that still occurred in an image. Noise free pixels should remain unchanged during the filtering process [13]. This operation produces noise-free positive and negative images as depicted in Figure 6. The results imply that without a good image registration, these kinds of images are impossible to be obtained.



(a) (b)

FIGURE 6. Noise free registered images: (a) positive image; (b) negative image

6. Conclusions. This paper presents an image registration technique that could provide a well-aligned defective image to enhance a PCB inspection algorithm with real images. The registration technique has been proven to be an alternative way to inspect defects on real PCB images and it is able to give a good result as well as mechanical registration system.

Acknowledgment. This work is financially supported by Universiti Teknologi Malaysia (UTM) and Ministry of Higher Education Malaysia (MOHE) through the UTM GUP Research Funds (Vote Q.J130000.7123.01J35 and Q.J130000.7107.01H29).

REFERENCES

[1] J. Hong, K. Park and K. Kim, Parallel processing machine vision system for bare PCB inspection, *Proc. of the 24th Annual Conference of the IEEE*, pp.1346-1350, 1998.

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

[3] M. Moganti and F. Ercal, Automatic PCB inspection systems, *IEEE Potentials*, vol.14, no.3, pp.6-10, 1995.

[4] C. R. Charette, S. Park, R. Williams, B. Benhabi and K. C. Smith, Development and integration of a micro-computer based image analysis system for automatic PCB inspection, *Proc. of International Conference on Computer Integrated Manufacturing*, pp.129-135, 1988.

[5] R. T. Chin, Automated visual inspection algorithms, *Computer Vision: Theory and Applications*, 1992.

[6] R. T. Chin and C. A. Harlow, Automated visual inspection: A survey, *IEEE Trans. on Pattern Analysis and Machine Intelligence*, vol.4, no.6, pp.557-553, 1982.

[7] W.-Y. Wu, M.-J. Wang and C.-M. Liu, Automated inspection of printed circuit boards through machine vision, *Computers in Industry*, vol.28, no.2, pp.103-111, 1996.

[8] L. Brown, A survey of image registration techniques, *ACM Computing Surveys*, vol.24, no.4, pp.325-376, 1992.

[9] W. Wu, M. Wang and C. Liu, Automated inspection of printed circuit boards through machine vision, *Computers in Industry*, vol.28, no.2, pp.103-111, 1996.

[10] S. Periaswamy and H. Farid, Medical image registration with partial data, *Medical Image Analysis Journal*, vol.10, no.3, pp.452-464, 2006.

[11] J. G. Moik, *Digital Processing of Remotely Sensed Images*, 1980.

[12] I. Ibrahim, Z. Ibrahim, K. Khalil, M. M. Mokji and S. A. R. S. Abu-Bakar, An algorithm for classification of five types of defects on bare printed circuit board, *International Journal of Computer Sciences and Engineering Systems*, vol.5, no.3, 2011.

[13] A. Hussain, M. A. Jaffar and A. M. Mirza, Random-valued impulse noise removal using fuzzy logic, *International Journal of Innovative Computing, Information and Control*, vol.6, no.10, pp.4273-4288, 2010.