International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161
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Research Article

Printed Circuit Board Defect Detection using Wavelet Transform

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Accepted 16 July 2014, Available online 01 Aug 2014, **Vol.4, No.4 (Aug 2014)**

Abstract

Electronic manufacturing industry, the printed circuit board manufacturing is basic requirement. One of the backbones in electronic manufacturing industry is the printed circuit board (PCB) manufacturing. Due to the human limited resources and speed requirements, manual inspection is ineffective to inspect every printed circuit board. Image difference operation is frequently used in automated printed circuit board (PCB) inspection system as well as in many other image processing applications. This inspection of PCB consists of mainly missing or wrongly placed components in the PCB. If there is any missing electronic component then it is not so damaging the PCB. But if any of the component that can be placed only in one way and has been soldered in other way around, then the same will be damaged and there are chances that other components may also get damaged. To avoid this, a PCB inspection is in demand that may take care of the missing or wrongly placed electronic components. Hence, this paper presents an efficient algorithm for an automated visual PCB inspection system that detects and locates any defect found on PCBs. The PCB inspection system is then improved by incorporating a geometrical image registration, minimum thresholding technique and median filtering in order to solve alignment and uneven illumination problem. Finally, defect classification operation is employed in order to identify the source for six types of defects namely, missing hole, pin hole, under etch, short-circuit, mouse bite, and open-circuit. The goal of this technique is to enhance the image difference operation in term of computation time using wavelet transform techniques like a dB1, dB2, dB3 and dB4 wavelets.

Keywords: *PCB defects; Wavelet Decomposition; Thresholding; Image Difference operation*

1. Introduction

Bare printed circuit board (PCB) is a PCB without any placement of electronic components (Hong et al., 1998) which is used along with other components to produce electrics goods. In order to reduce cost spending in manufacturing caused by the defected bare PCB, the bare PCB must be inspected. Current practice in printed circuit board (PCB) manufacturing requires an etching process, which is irreversible. The printing process, which is done before the etching process, caused most of the destructive defects found on the PCB. Once the PCB laminate is etched, the defects, if any exist would cause the PCB laminate to become useless. Due to human limited resources and speed requirements, manual inspection is ineffective for inspecting every PCB laminate. Therefore, manufacturers require an automated system to detect the defects online, which may occur during the printing process (W.wen *et al, 1996*), (F.moganti *et al,1996)*, (C.Torrence *et al,1998)*. As the technology advances, the PCB pattern has become denser and more complicated so as to facilitate smaller end products. Thus, manual inspection may not applicable anymore. Meanwhile, the rapid development in computer technology such as higher speed processors, larger memory capacities, and with lower costs have resulted in better and cheaper equipment for automation mechanism in the inspection process. Hence, there exists a possibility of introducing and implementing an automated PCB inspection system to remove the subjective aspects of manual inspection and at the same time to provide a real-time assessment of the PCB panel.

2. Defects

There are verity of defects is found in electronic circuit some are of functional defects and some are of visual defects. Functional defects can seriously cause damage to the PCB, meaning that the PCB does not function as needed. Visual defects do not affect the functionality of the PCB in short term. But in long period, the PCB will not perform well since the improper shape of the PCB circuit pattern could contribute to potential defects (Zuwairie Ibrahima *et al, 2005).*

Here, fig 1 shows good PCB pattern and fig 2 shows PCB image with defects. For example, this defects are of breakout, short, pin hole, wrong size hole, open circuit, conductor too close, under etch, spurious copper, mouse bite, excessive short, missing conductor, missing hole, spur, and over etch. Here an important fact is that since the proposed algorithm is mainly based on reference comparison method, i.e. reference image is compared with test image therefore some defects, which related to design rule of PCB would not be detected.

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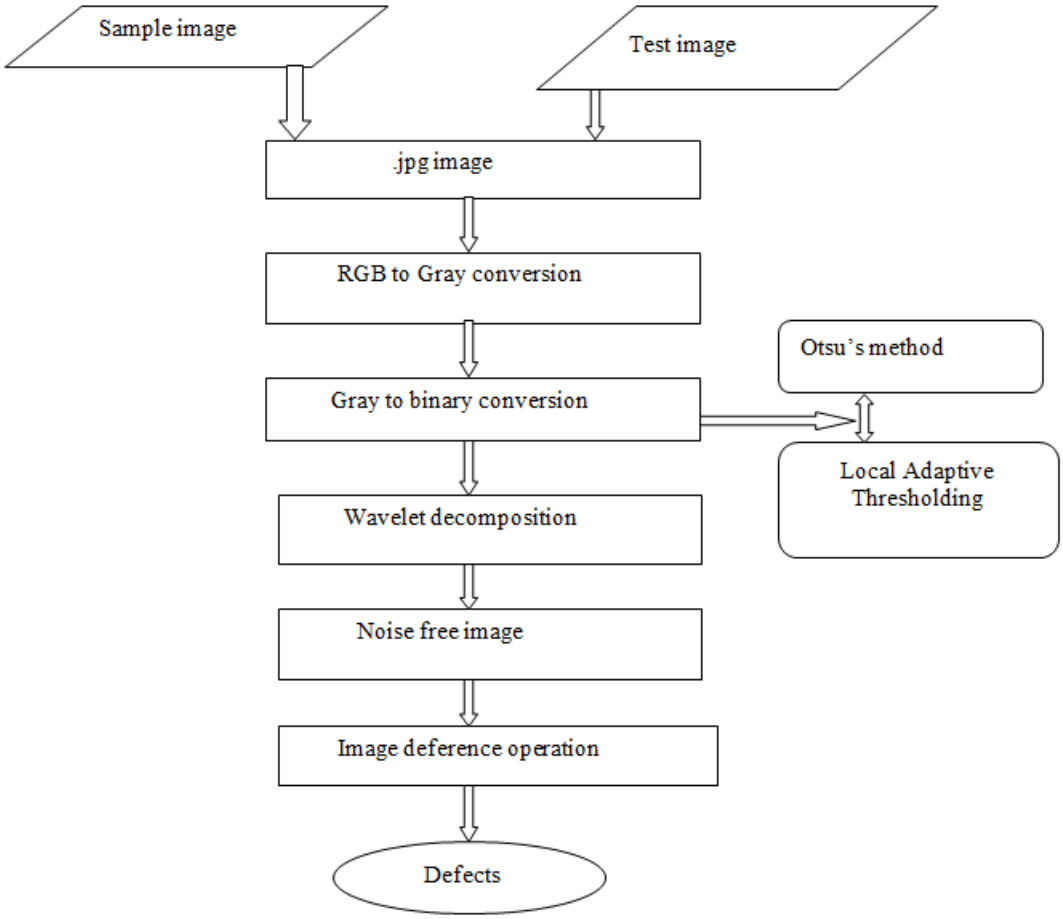


Fig. 3 System Block Diagram

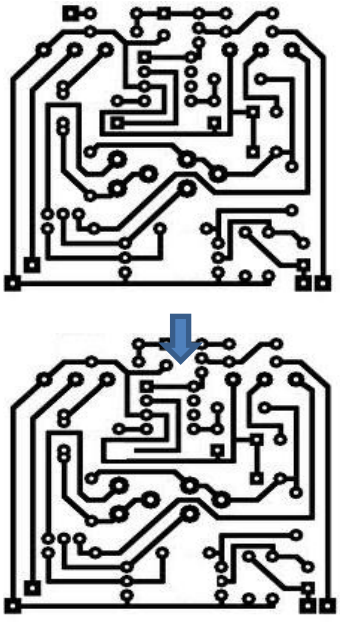


Fig 1 An Example of Good PCB Pattern

3. System block diagram

Fig 3. Shows system block diagram for PCB defect detection. In this system configuration sample image is compared with test image (image with defects). These both images should be converted into .jpg image and from RGB to Gray due to the fact that digital system algorithm can be applied only to gray scale image. Low frequency components are filtered by using wavelet decomposition. Thresolding with using otsu's method is being used for noise free image. And at last using image comparition operation on approximation coefficient will result in resultant defect image.

4. Pre-processing technique

Pre-processing is very essential step in this technique of image processing field. Pre-processing technique is basic and important step towards the success of PCB defect detection. In some cases, the original data or image is of poor quality due to blurred image. Pre-processing phase is concern with reduction of noise in the input image.

1. RGB to Gray Conversion

Here, it is required to covert RGB image into Gray image for further converting into binary image. If image is not in a gray form then it is important to converts image into gray form. In gray scale conversion the image will be comprised as black at weakest intensity and white at strongest intensity and there will be many shades in between. It replace every pixel of image after calculation of gray conversion into new required gray scale pixel value. If gray level is done at 8 bit then it will give 256

shades. Here, gray scale image is having value from 0 to 255 pixel value.

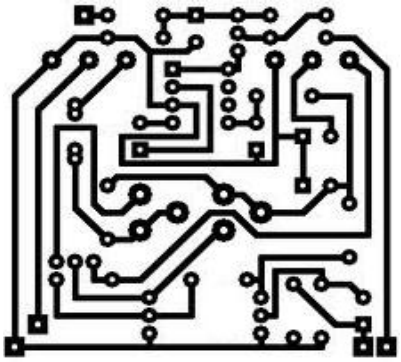


Fig. 4 Image after Gray conversion

2. Smoothing and Noise Removal

Images do have some stray pixels and some unwanted marks. By using Median filter noise can be filtered from the image. Smoothing operation in gray image is used for noise reduction and filtering is used for noise removal. Median filter viz nonlinear filter is more popular because it has excellent noise removal capabilities.

Order Statistics Filter

Order statistics filter are non linear filter whose response is based on the ranking of the pixel and then replacing the value of centre pixel with the value known by ranking result. In Median Filter viz the best example of non linear filter, replaces value of the median of the gray levels in the neighbourhood of that pixel. Median filter are popular because they provide excellent noise removal capabilities with less blurring of the pixel.

12	13	13
14	18	20
20	17	15

Fig. 5 Pixel Values before using Median Filter

12	13	13
14	18	20
20	17	15

Fig. 6 Pixel Values after using Median Filter

3. Gray to Binary Conversion

Binarization is process which converts gray image into binary image. Here threshold value is found using Otsu's method. It consists of computation histogram and probability of each intensity level of image. Desired threshold value is correspondence to the between class variance. The histogram of gray scale values of a document image typically consists of two picks: A high pick corresponding to the white background and a smaller peak corresponding to the foreground. Hence, threshold gray scale value can be determined by an optimal value in the valley between the two picks.

4. Wavelet Decomposition

Wavelet is a zero mean function and satisfies the so-called admissibility condition The computation of the wavelet transform on a two dimensional signal, an image, is applied as a successive convolution by a filter entry of row/column followed by a column/row arrangement as depicted in Fig. 3 Thus, for a two-dimensional wavelet transform, after the first level wavelet transform operation, the input image can be divided into 4 parts: approximation, horizontal, vertical, and diagonal details where the size of each part is reduced by a factor of two compared to the original input image as shown in Fig. 4.The approximation image is a compressed and coarser part of the original input image. Meanwhile, the horizontal, vertical, and diagonal details contain the horizontal, vertical, and diagonal components of the input image respectively. When a second level wavelet transform is applied, the approximation part of the first level will be further decomposed into four components as shown in Fig. 5. For a higher level, iteration is repeated in the same way until the desired level is reached.

Approximation	Horizontal Detail
Vertical Detail	Diagonal Detail

Fig. 7 First Level Wavelet Transform

<table>
<tr><td>LL</td><td>LH</td><td rowspan="2">Horizontal Detail</td></tr>
<tr><td>HL</td><td>HH</td></tr>
<tr><td colspan="2">Vertical Detail</td><td>Diagonal Detail</td></tr>
</table>

Fig. 8 Second Level Wavelet Transform

5. Image Difference operation

By using image comparison algorithm defect of the PCB can be determined. Here comparison is of sample image and test image approximation coefficient is done. If both image have same coefficient then resultant coefficient will take it as back ground(i.e. one) and if both are not same then it will take resultant coefficient as foreground(i.e. zero). Thus, error can be determined as a resultant image.

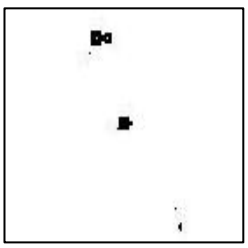


Fig. 9 Resultant Image of Two Different Images

6. Expected outcome

Figure 10 depicts the PCB inspection system developed in this research for detecting and classifying defects on PCB which includes some major stages. The stages are:

Stage 1: Defective image is registered according to the template image. Both this images are stored at proper

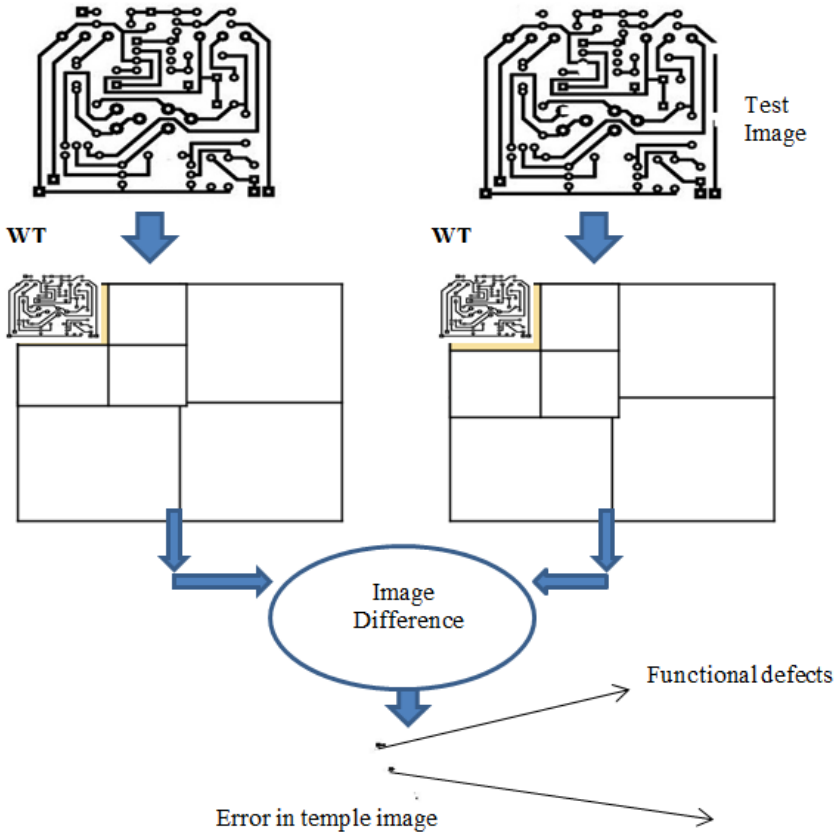
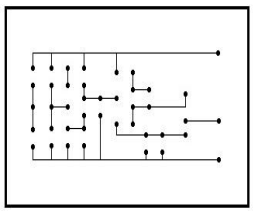
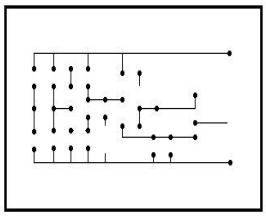
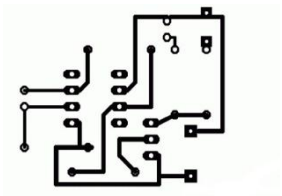
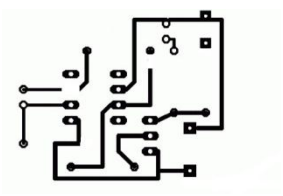
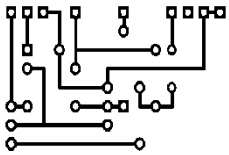
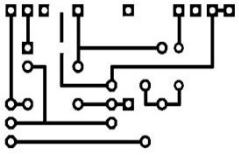
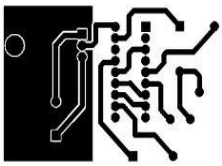
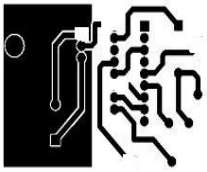
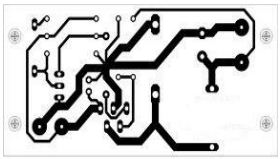
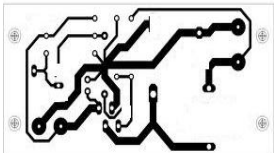
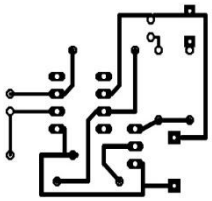
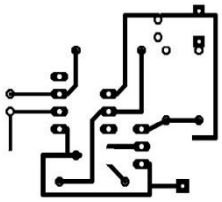
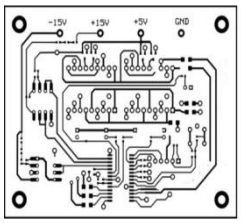
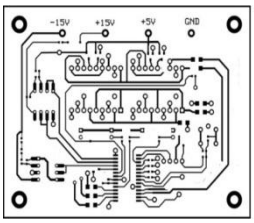
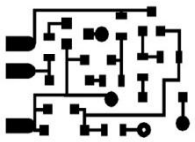
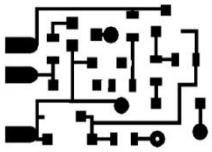
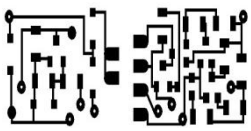
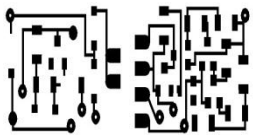
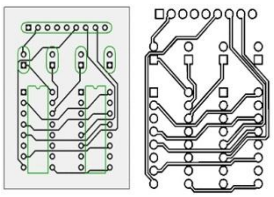
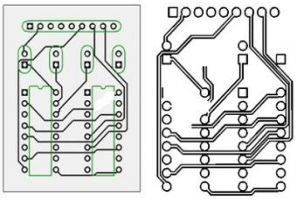


Fig. 10 Expected Outcomes of Wavelet Transform

Table 1 PCB Fault Detection using dB4 Wavelets

Sr. No.	Sample Image	Test Image	No. of defects are in test image	No. of defects are found in error image	Efficiency (dB4 Wavelet)
1			4	3	75%
2			4	4	100%
3			4	4	100%
4			6	5	83.33%

5			6	5	83.33%
6			5	5	100%
7			6	6	100%
8			4	4	100%
9			6	5	83.33%
10			6	6	100%

place in computer. Image is selected and this image now be utilized throughout the program for all processing.

Stage 2: pre-processing is an essential step in any image processing task. If image is colored then it has to be converted into Gray.

Stage 3: A thresholding algorithm is performed to each image. Minimum thresholding algorithm has been used to positive and negative images. This process is used to remove noise and it will also convert gray image to binary image.

Stage 4: The template of size 3x3 of median filter is employed to remove small noise in the both images.

Stage 5: The proposed defect classification algorithms are used to classify all defects occurred in both images. The types of defects that occur in images are short-circuit, missing hole, and under etch positive, open-circuit, pin hole, mouse bite and under etch negative.

The proposed algorithm is developed to detect and classify six different printing defects, namely, missing hole, pinhole, under etch, short-circuit, open-circuit, and mouse bite, using a combination of a few image processing operations such as image difference operation. Even though a similar algorithm has been previously proposed (W. Y. Wu et al, 1996), the applicability of the defect classification algorithm has been demonstrated solely based on computer-generated images. Hence, the difficulties of solving the alignment and uneven illumination issues have been ignored, and apparently, this is a limitation of these previous papers work. In this study, a software-based image deference operation using Wavelet Decomposition is taken into account, and the defect classification algorithm is implemented based on real PCB images. Also, the best thresholding algorithm aided with filtering algorithm has been investigated, and thus all unwanted noise interfered can be eliminated, ensuring that just real defects will be inspected.

5. Results

From above table 1 we can say that result using dB4 wavelets shows approximately 100% efficiency than dB1, dB2 and dB3 wavelets.

Conclusion

In recent years, the pattern width and space become smaller and smaller to increase the integration rate of electrical components per unit area of PCB. This means the size of defect is also minute and actually may be less than 30 micron. These defects are not easily detected by the human eyes and would take too much inspection time. For this reason, automatic visual inspection system is needed. As a conclusion, among the variety algorithms, this project emphasizes the image difference operation to get better improvement by introducing wavelet transform (dB4) into image difference operation. This operation can be done on real time PCB image as sample image and test (bare template) image. The proposed algorithm is tested on more than 50 images and got 100% defect detection accuracy.

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