A Noise Elimination Procedure for Printed Circuit Board Inspection System

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Abstract

Image difference operation is frequently used in automated printed circuit board (PCB) inspection system as well as in many other image processing applications. During the implementation, this operation brings along the unwanted noise due to misalignment and uneven binarization. Thus, this paper proposes a method to eliminate, if possible, or to reduce as much as possible such noise during the computation of defect detection. This paper used a template PCB image and the tested PCB image as the input. Image subtraction operation will be applied between the images. The results of applying the proposed method showed a significant improvement during the real-time inspection of printed circuit boards.

1. Introduction

There exist numerous numbers of algorithms, techniques, and approaches reported in the area of automated visual PCB inspection to date. As stated by Moganti et al. [1], these can be divided into three main categories: referential approaches, rule-based approaches, and hybrid approaches.

Referential approaches, consists of image comparison and model-based techniques. Image comparison technique simply compares the tested PCB image against the reference PCB image using simple XOR logic operator [2].

Model-based technique, on the other hand, matches the tested PCB image by using a predefined model [3].

Rule-based approaches test the design rule of the PCB traces to determine whether each PCB trace fall within the required dimensions or not. Mathematical morphological operation is frequently used where dilation and erosion are basic operation [4]. Lastly, hybrid approaches combines the referential approaches and design-rule approaches to make use the advantages and overcome the shortcomings of each approach.

In the PCB inspection, an image difference operation is employed as part of the algorithm. During the real-time implementation, this operation normally contributes unwanted noise due to misalignment and uneven binarization and thus, the accuracy of the defect detection could be degraded. Hence, it is critically important to design a noise elimination procedure in order to eliminate, if possible, or rather to reduce as much as possible the noise cause by image difference operation.

In this paper, a noise elimination procedure is proposed based on the manipulation of *positive* and *negative* image. It is discovered that if the image difference operation is performed as an image subtraction operation, the noise interference in the output image is actually the combination of noise in the positive and negative images. Note that after the image subtraction, three types of data are produced: *positive*, *negative*, and *zero* values of data. Only the two-dimensional data, images of *positive* and *negative* value contain the undesired noise, if any, and the *zero* one did not affect the output of the algorithm.

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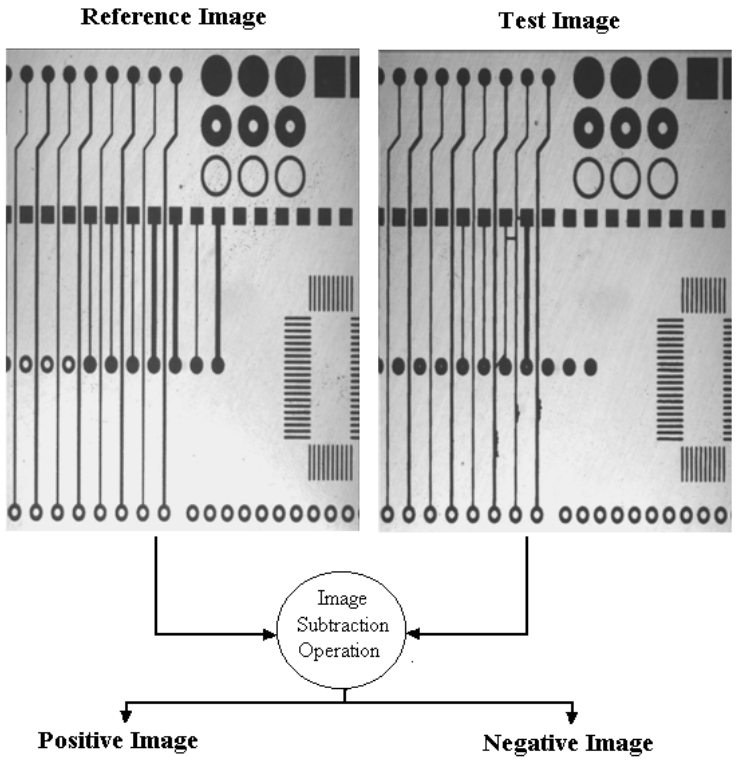

Figure 1. Defect detection procedures

Due to this argument, one possible way to reduce the noise is by separating the image difference output into the positive and negative image by using image subtraction and then, the noise reduction is applied to the positive and negative images to remove unwanted noise occurs in the images. Next, the noise free positive and negative images are combined together to produce the output of the inspection. Before the image difference operation is utilized, it is also important to bring the tested and reference image as close as possible during alignment. The proposed approach has been employed previously for a PCB inspection system based on wavelet-transform [5-6].

2. Image subtraction operation

As mentioned previously, during the real-time implementation, the image difference operation that is employed in the PCB inspection algorithm is replaced by image subtraction operation. Consider three images named as *Img1*, *Img2*, and *Img3* of size M x N where M is the length and N is the height of the image respectively.

The parameter x, denotes the column of the image, from 1 to M, and parameter y, denotes the row of the image, from 1 to N where both x and y are integers. Every pixel in the *Img1*, *Img2*, and *Img3* are denoted by *Img1[x,y]*, *Img2[x,y]*, and *Img3[x,y]* respectively. *Img1* and *Img2* are the input to the image subtraction operation, whereas the *Img3* is created as a place to store the output values. Initially, x and y are set to 1. Therefore;

```
for every x (1,M)
{
        for every y (1,N)
        {
        Img3[x,y] = Img1[x,y] – Img2[x,y];
        }
}
```

3. Implementation of noise elimination procedure and discussion

Two images are needed for the inspection, the reference image and the tested image as shown in Figure 1. These images, in gray scale, are captured from the reference and inspected PCB laminate by a high-resolution monochrome CCD camera. Using the captured images, image subtraction operation is applied for both of the images.

The PCB alignment can be done automatically by utilizing a mechanical device as well. But the subtracted image could still be interfered by unwanted noise due to slightly misalignment and uneven binarization. Hence, it is difficult to reduce or diminish the noise in the output image. In order to make the noise elimination effective, the subtracted image is divided to a positive and negative image as shown in Figure 2 and Figure 3. Thus, it is possible to detect all the defects by applying image subtraction operation between the reference image and tested image.

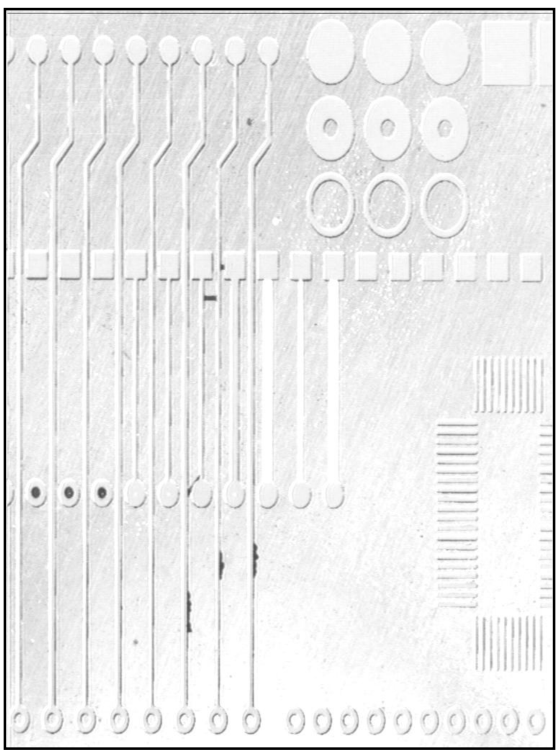

Figure 2. Positive image

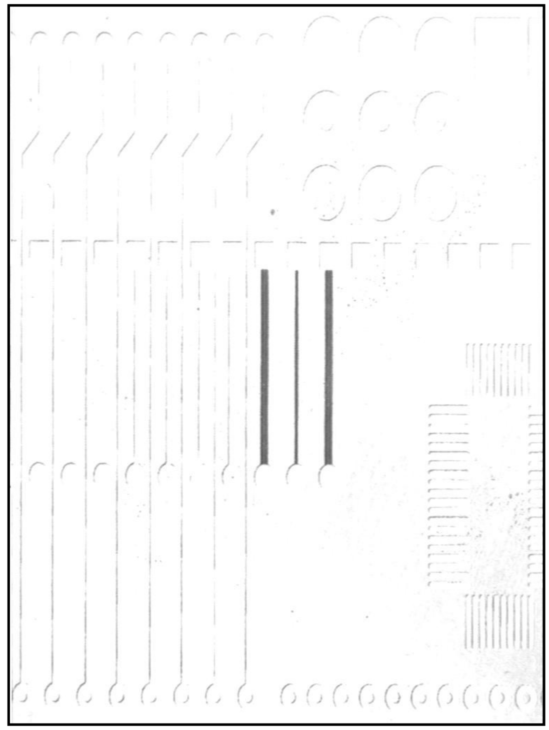

Figure 3. Negative image

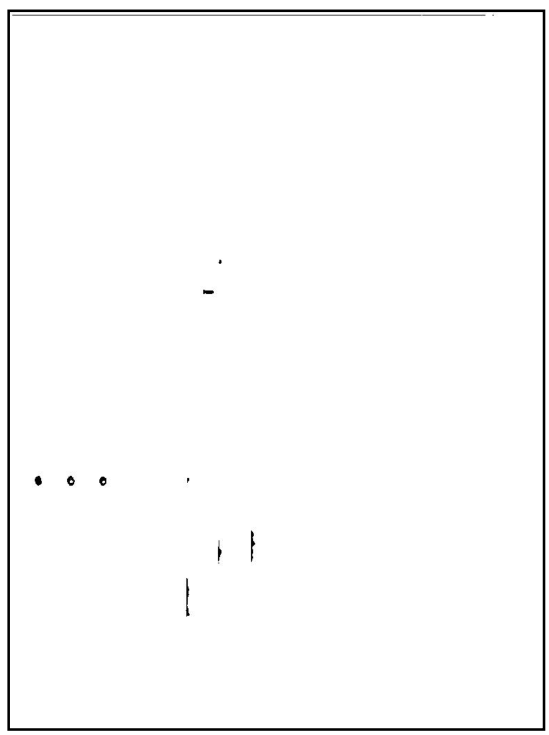

Figure 4. Noise free positive image

Figure 2 and Figure 3 are then used for noise elimination procedure. Threshold operation is instigated for both images to clearly differentiate the elements between reference and tested PCB image and to convert an intensity images into a binary images. For implementation, the best threshold values, τ, for the positive and negative images, are 115 and 158, respectively. Figure 4 and Figure 5 show the positive and negative image in binary after the noise elimination process respectively.

The next step is to combine the noise free positive and negative images by simply applying the XOR logic operator. The output is the final result of the inspection process. The output of the inspection system is illustrated in Figure 6. The overall flow of the noise elimination procedure is illustrated in Figure 7.

The proposed noise elimination procedure is implemented on a Pentium III 800MHz microcomputer facilitated with a PCVISION Plus frame grabber.

The images are captured by a high resolution 1k x 1k pixels UNIQ monochrome CCD camera. MVTools machine vision library is used for programming. The inspection system also consists of a lighting devices and several camera lens for a good quality captured images. The results come out from the processing part is displayed via a monitor to the users.

4. Conclusions

In practice, the point-to-point image difference operation employed in automated PCB visual inspection suffers from the unwanted noise due to misalignment and uneven binarization during the implementation. Hence, a noise elimination procedure is designed and developed in such a way that the positive and negative images are acquired from image subtraction operation and the noise elimination is applied to the positive and negative images, separately.

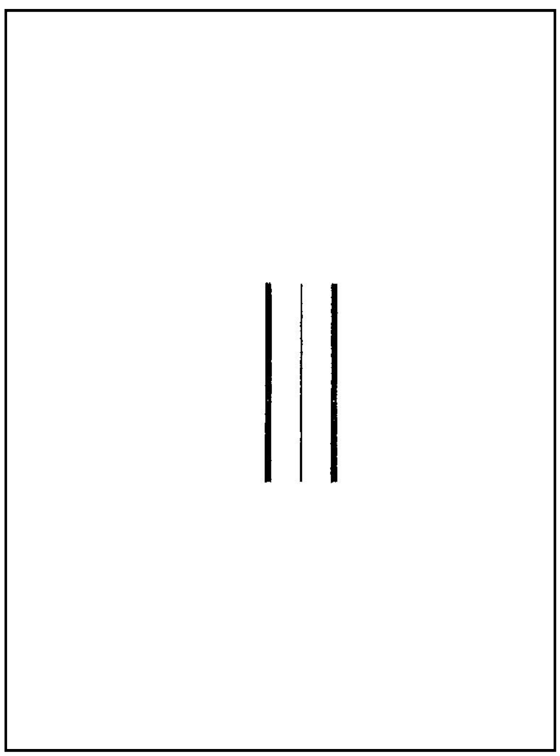

Figure 5. Noise free negative image

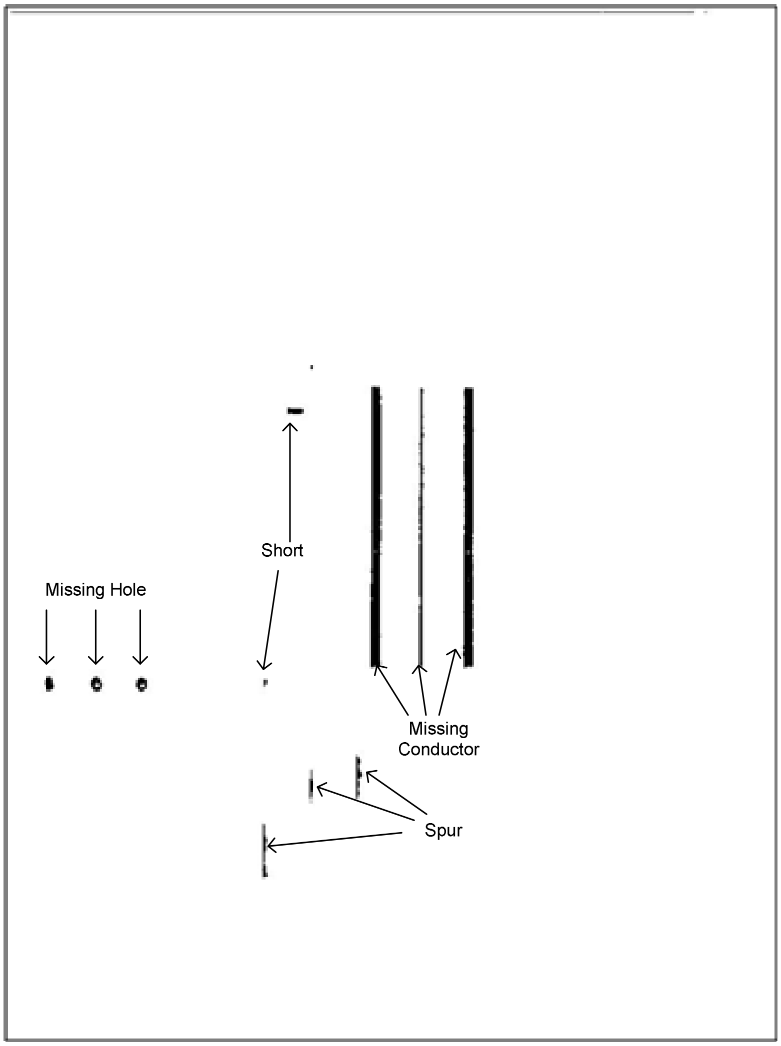

Figure 6. Defect detected

In this study, the best threshold values, τ, for the positive and negative images, are 115 and 158, respectively. An automated approach to obtain these values is being investigated at present.

The resultant images are combined to produce the output of the inspection system. It is expected that the proposed method is well suited for small and medium scale PCB manufacturers where the sophisticated alignment facilities is hard to purchase.

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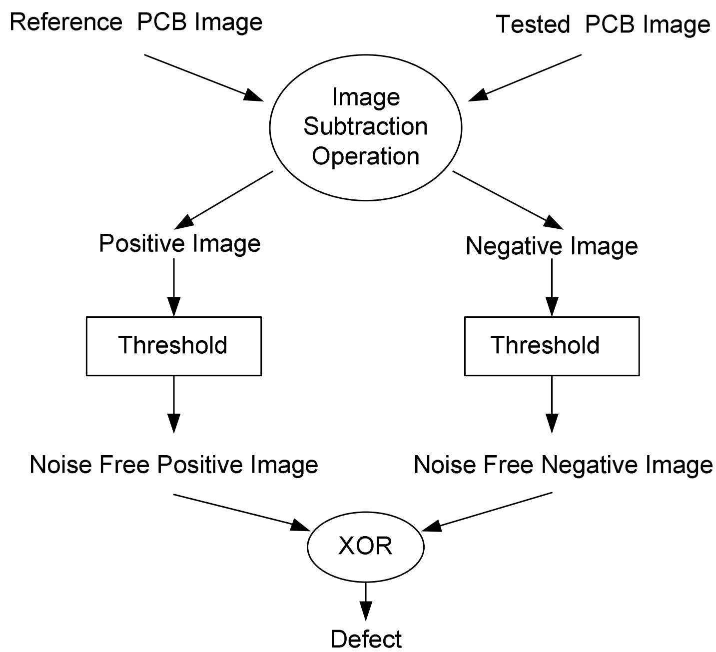

Figure 7. Noise elimination procedures

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