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Automatic Optical Inspection For Mechanical Defect Identification

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Abstract — **Printed circuit boards are by far the most common method of assembling modern electronic circuits. During the manufacturing of PCB many defects are introduced which are harmful to precision circuit performance. A variety of ways has been established to detect the defects found on PCB, but it is also necessary to classify these defects so that the source of these defects can be identified. In this paper, we represent an approach to the automated inspection of printed circuit boards. A model based on the coordinates and connectivity analysis of the circles is formed using some new approaches to edge linking, and fusion of some edge based and region based algorithms. The filters are used as an edge based algorithms. The edge linking algorithm extracts out the connectivity information for the circles using a new approach depending on making the decisions on fixation points. The use of this new model and the novel techniques for region finding and edge following has proved to be efficient and time saving.**

Key Words —**Edge detection, filters, image processing, PCB defects**

I. INTRODUCTION

Now a day's its necessary to improve the quality of PCB. In manufacturing industry there are defects, misalignment and orientation error so automated inspection is required. The defects can be analyzed by machine vision using algorithms developed for it. So machine vision provides a measurement technique for regularity and accuracy in the Inspection process. These systems have advantage over human inspection in which subjectivity, fatigue, slowness and high cost is involved. In recent years, the PCB industries require automation due to many reasons. The most important one is the technological advances in PCB's design and manufacturing. New electronic component fabrication technologies require efficient PCB design and inspection method with compact dimension. The complex and compact design causes difficulties to human inspection process. Another important factor is necessity to reduce the inspection duration. These factors lead to automation in PCB industries. Nowadays automated systems are preferred in manufacturing industries for higher productivity.

II. PROPOSED METHOD

A. BARE PCB DEFECTS

There are some defects commonly found on PCB. Conductor breaking and short-circuit are characterized as fatal defects. Pinhole, breakout, Over etch, and under etch are characterized as potential defects. Fatal defects are those in which the PCB does not attend the objective they are designed for, and potential defects are those compromising the PCB during their utilization. During etching process, the anomalies occurring on bare PCB could be largely classified in two categories: the one is excess of Copper and the other one is missing copper. The incomplete etching process leaves unwanted conductive materials and forms defects like short, extra hole, protrusion, island, and small space. The excessive etching makes open, pin hole, nick (mouse bite), and thin pattern. In addition to the defects mentioned above, some other defects may exist on bare PCB, for example, missing holes (due to tool break), scratch (due to handling mistake) and cracks.

B. TECHNOLOGY DESCRIPTION

An arithmetic or logic operation between images is a pixel-by-pixel transformation. It produces an image in which each pixel derives its value from the value of pixels with the same coordinates in other images. Single Thresholding: A gray scale image is turned into a binary image by first choosing a gray level T in the original image, and then turning every pixel black or white according to whether its gray value is greater than or less than T.

• A pixel becomes white if its gray level is > T
• A pixel becomes black if its gray level is <= T

Double Thresholding: Here we choose two values T1 and T2 and apply a thresholding operation as:

• A pixel becomes white if it's gray level between T1 and T2
•A pixel becomes black if its gray level is otherwise.

SPATIAL FILTERING:

•A "mask" is moved a (rectangle or usually with sides of odd length or other shape) over the given Image.
• A new image whose pixels have gray values are calculated from the gray values under the mask.
• The combination of mask and function is called filter.
• Linear function of all the gray values in the mask, then the filter is called a linear filter.
• Spatial filtering requires 3 steps:

1. The mask should be positioned over current pixel,
2. Form all products of filter elements with the corresponding elements of the neighborhood.
3. Add up all the products.

• This must be repeated for every pixel in the image (filter, image, shape).

C. EDGE DETECTION

Edges are abrupt changes in the intensity of pixels, discontinuity in image brightness or contrast. They usually occur on the

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boundary of two regions. Edge detection is a process of identifying edges in an image to be used as a fundamental asset in image analysis. It reduces unnecessary information in the image while preserving the structure of the image. It extracts important features like corners, lines and curves. Edge detection is extensively used in image segmentation when we want to divide the image into areas corresponding to different objects. If we need to extract different object from an image, we need Edge Detection. Typically, there are three steps to perform edge detection: Noise reduction, Edge enhancement and Edge localization.

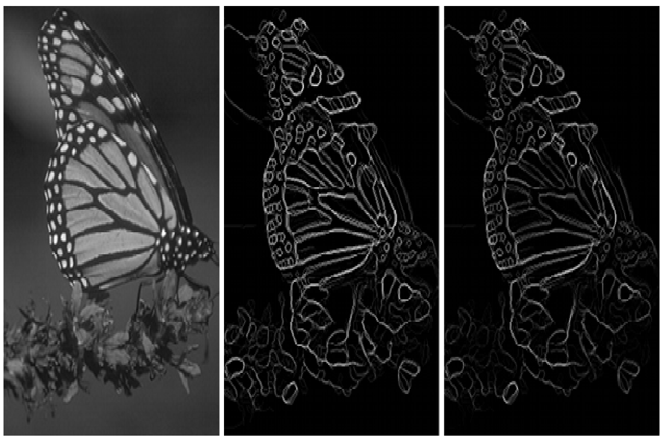

Fig.2.1: Edge detection

D. FILTERS

Most images are affected to some extent by noise that is unexplained variation in data: disturbances in image intensity which are either un-interpretable or not of interest. Image analysis is often simplified if this noise can be filtered out. In an analogous way filters are used in chemistry to free liquids from suspended impurities by passing them through a layer of sand or charcoal. Engineers working in signal processing have extended the meaning of the term filter to include operations which accentuate features of interest in data. Employing this broader definition, image filters may be used to emphasize edges — that is, boundaries between objects or parts of objects in images. Filters provide an aid to visual interpretation of images, and can also be used as a precursor to further digital processing, such as segmentation.

1. Sobel operator

A way to avoid having the gradient calculated about an interpolated point between the pixels which is used 3 x 3 neighborhoods for the gradient calculations. On The arrangement of pixels are about the pixel [i, j] shown in the Table below. The Sobel operator is the magnitude of the gradient computed by:

$$M\sqrt{s_x^2 + s_y^2}$$

Where the partial derivatives are computed by:

$$s_x = (a_2 + ca_3 + a_4) - (a_0 + ca_1 + a_6)$$
$$s_y = (a_0 + ca_1 + a_2) - (a_6 + ca_5 + a_4)$$

With the constant c = 2.

Like the other gradient operators, S_x and S_y can be implemented using convolution masks:

Table: Masks used by Sobel Operator

S_x=

-1	0	1
-2	0	2
1	0	1

S_y=

1	2	1
0	0	0
-1	-2	-1

Note that this operator is placed on emphasizing pixels that are closer to the center of the mask. The Sobel operator is one of the most commonly used edge detectors.

2. Canny operator

Canny edge detector approximates the operator that optimizes the product of signal-to-noise ratio and localization. It is generally the first derivative of a Gaussian. For example, in our case study shown the shark type is identified in Fig (a) and (b).

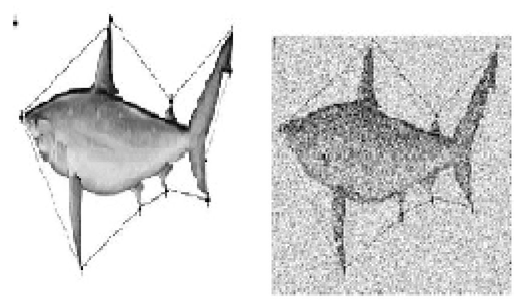

Fig.2.2 *(a):* Shark image Canny

Fig.2.2 *(b):* Edges using a Detector

The Smoothing is computed as I[i,j] to denote the image. G[i,j, •] has to be a Gaussian smoothing filter where • is the spread of the Gaussian and controls the degree of smoothing. The result of convolution of *I*[i,j] with G[i,j, •] gives an array of smoothed data as: S[i, j] • G[i, j, •]* I[i, j].

3. Log operator

This method combines Gaussian filtering with the Laplacian for edge detection. The edge points of an image can be detected by finding the zero crossing of the 2nd derivative of the image intensity. The main advantage of Marr-Hildreth (LoG) is tested and established among the wider area around the pixels. Thus

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finding the correct places of edges seems to be very easy, which also the outermost advantage in Marr-Hildreth Edge Detection. The Laplacian of Gaussian (LoG) operator uses the Laplacian filter for Marr's edge detection. The disadvantage is that it reduces the accuracy in finding out the orientation of edges and malfunctioning at the corners, curves, where the gray level intensity function variations. L(x, y)⊗G(x, y)⊗ f (x, y).

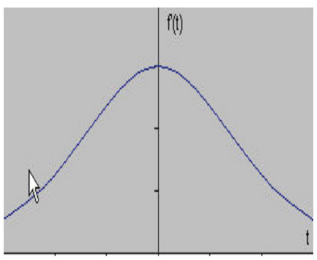

Fig.2.3 (a):1st derivative

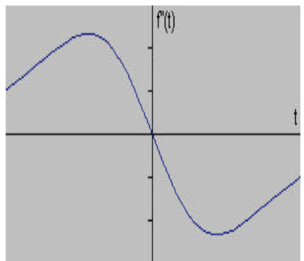

Fig.2.3 (b):2nd derivative

4. Robert operator

The Roberts cross operator provide a simple approximation to the gradient magnitude:

$$G[f[i,j]] = |f[i,j] - f[i+1,j+1]| + |f[i+1,j] - f[i,j+1]|$$

Using convolution masks, this becomes:

$$G[f[i,j]] = |G_x| + |G_y|$$

Where Gx and Gy are calculated using the following masks:

Table - Masks used by Roberts Operator

G_x=

1	0
0	-1

G_y=

0	-1
1	0

As with the previous 2 x 2 gradient operator, the differences are computed at the interpolated point [i + 1/2, j + 1/2]. The Roberts operator is an approximation to the continuous gradient at the interpolated point and not at the point [i, j] as it might be expected.

5. Prewitt operator

The Prewitt operator uses the same equations as the Sobel operator, where constant c = 1.

Table - Masks used by Prewitt gradient Operator

S_x=

-1	0	1
-1	0	1
-1	0	1

S_y=

1	1	1
0	0	0
-1	-1	-1

Therefore, note that, unlike the Sobel operator, this operator does not place any emphasis on pixels that are closer to the center of the masks.

6. Zero crossing operator

The advantages of the zero crossing operators are detecting edges and their orientations. In this zero cross operator detection of edges and their orientations is said to be simple due to the approximation of the gradient magnitude is simple. The second advantage is the fixed characteristics in all directions. The disadvantage is sensitivity to the noise. In detecting the edges and their orientations are increased in the noise to the image this will eventually degrade the magnitude of the edges. The second disadvantage is that, the operation gets diffracted by some of the existing edges in the noisy image.

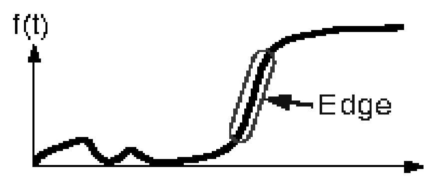

Fig.2.4 (a): First derivative

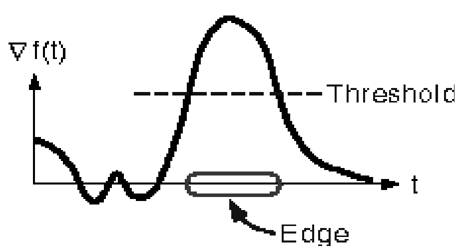

Fig.2.4 (b): Second derivative

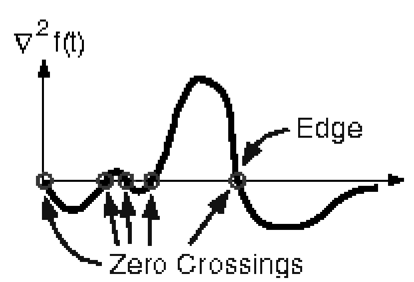

Fig.2.4(c): Identification of Zero Crossing

III. METHODOLOGY

The white light source is fixed under the glass slab. The PCB is placed on the glass slab and light emerges through the holes present on the PCB. The master image of the golden card is initially captured using high resolution camera and stored in the system. The manufactured PCB's image is captured and the same is compared with the master image. During the comparison process the pattern matching is done in order to detect the defects. The classification of the defects includes either an addition of hole or absence of hole and segment or line shifting. During the course of defect detection white light emerges through the extra hole if present or there is blockage of light if the predicted hole is missing.

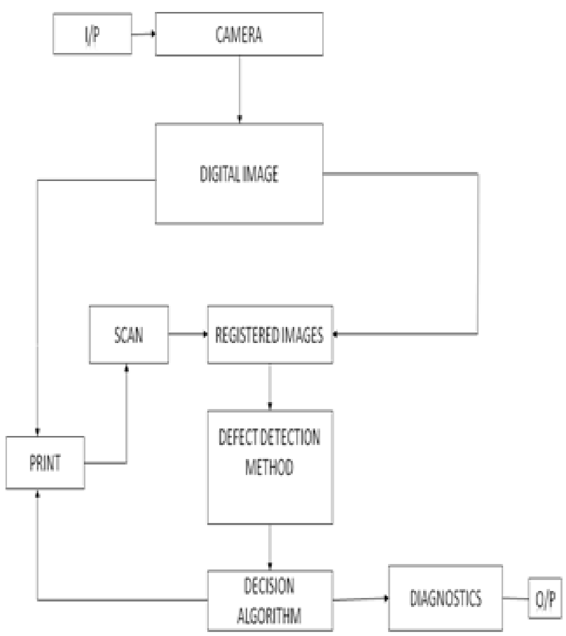

Fig.3.1: Block Diagram

a. Algorithm

STEP 1: Start
STEP 2: The master PCB image is read.
STEP 3: The color image with RGB component is converted to gray scale.
STEP 4:The image is complimented to get non negative values.
STEP 5: The image is resized in order to compress the image
STEP 6:The value of image is converted to floating point variable in order to save it in huge values.
STEP 7:Any one of the filtering techniques is applied for edge detection and to remove noise. The types of filters used are Sobel, Canny, Log, Prewitt, Roberts and zero cross.
STEP 8: Step no: 1 to 8 is repeated to the test image.
STEP 9: Master image and test image are compared.
STEP10:If any defect found then the string "images are dislike" is been displayed.
STEP 11:If defects are not found then the string "images are alike" is been displayed.
STEP 12:Stop.

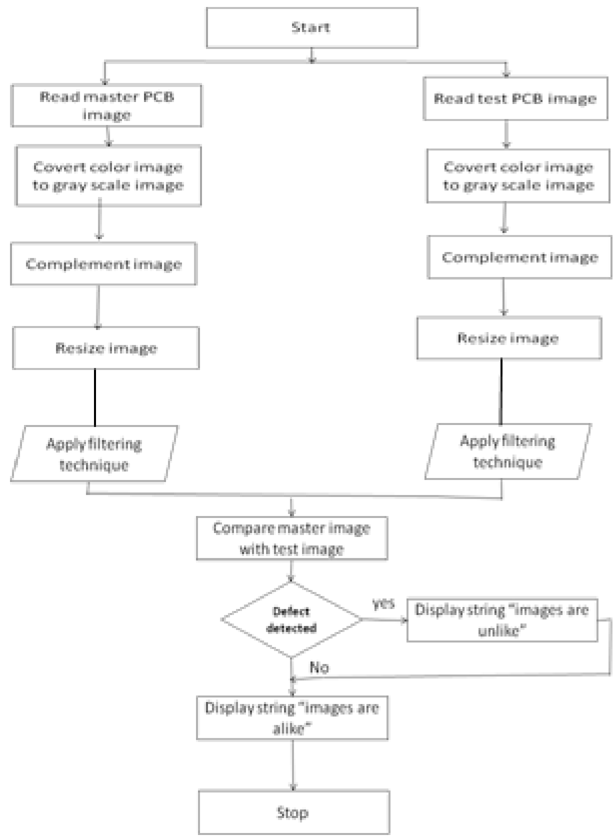

Fig.3.2: Flow Chart

There are many ways to perform the edge detection. However, it may be grouped into two categories, that are gradient and Laplacian. The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image. The Laplacian method searches for the zero crossings in the second derivative of the image to find edges. This first Fig (a) shows the edges of an image detected using the gradient method (Roberts, Prewitt, Sobel) and the Laplacian method (Marrs-Hildreth). It can compare the feature extraction using the Sobel edge detection with the feature extraction using the Laplacian. It seems that although it is better for some features (i.e. the fins), it still suffers from mis-mapping some of the lines. A morph is constructed using individual selected points which will work better. It also should be noted that this method suffers the same drawbacks as the previous method, due to large contrast between images and the inability to handle the large translations of features. Laplacian Edge Detection- It wishes to build a morphing algorithm which operates on features extracted from target images automatically. It can be a good beginning to find the edges in the target images. Here, we have accomplished this by implementing a Laplacian Edge Detector.

IV. Results And Discussion

Based on the algorithms shown above, these algorithms need two images, namely template image and defective image. In this paper, these algorithms use template image and defective image. At first, both images are subjected to image subtraction operation to produce an resultant image. Various filters are used on the images to map them on edge based. Based on the image size different filters shows the error rate and finds the defect In this we have done testing for three different defective PCBs & then by increasing the noise level for each image seen that how much this method is capable to detect a faulty PCB & then based on graphic user interface (GUI) PSNR ratio is calculated for different filters. From there, the algorithms continue to produce the results. The results shown will be based on these images.

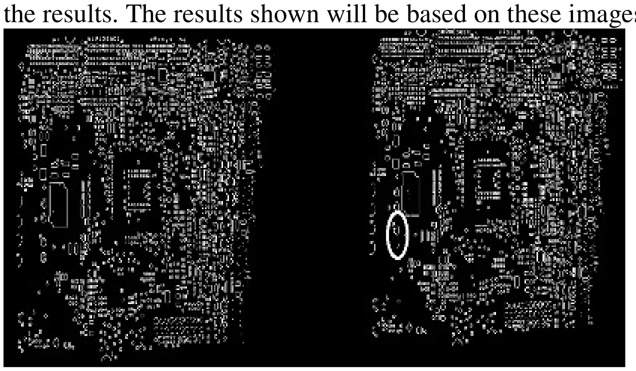

Fig.4.1: Sobel filter

The above Fig 4.1 shows the output of the Sobel filter and encircled area shows the defected area.

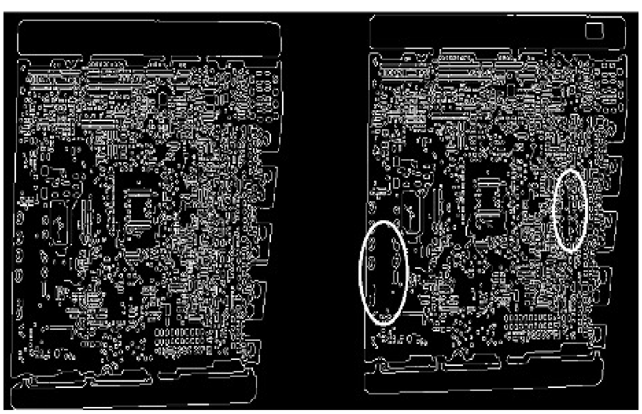

Fig.4.2: Canny filter

The above Fig 4.2 shows the output of the canny filter and encircled area shows the defected area.

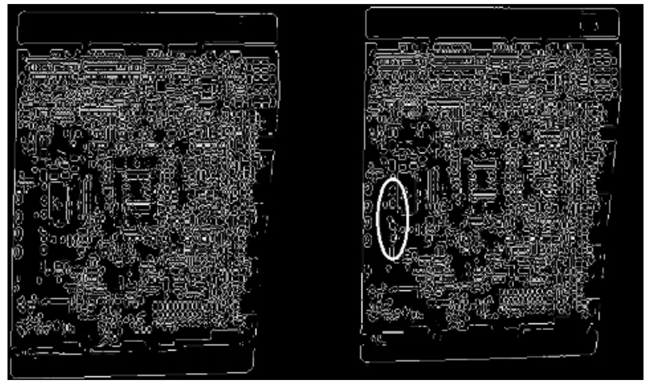

Fig.4.3: LoG filter

The above Fig 4.3 shows the output of the LoG filter and encircled area shows the defected area.

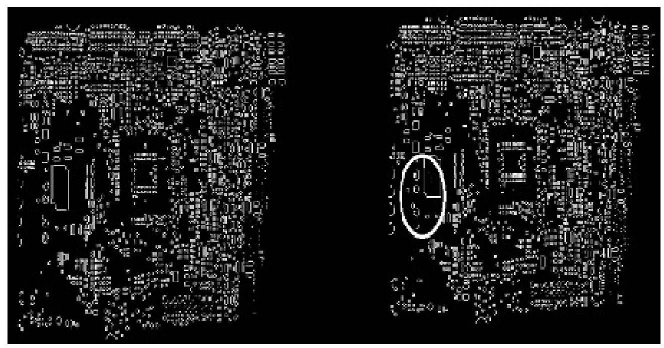

Fig.4.4: Prewitt filter

The above Fig 4.4 shows the output of the Prewitt filter and encircled area shows the defected area.

Fig.4.5: Robert filter

The above Fig 4.5 shows the output of the Robert filter and encircled area shows the defected area.

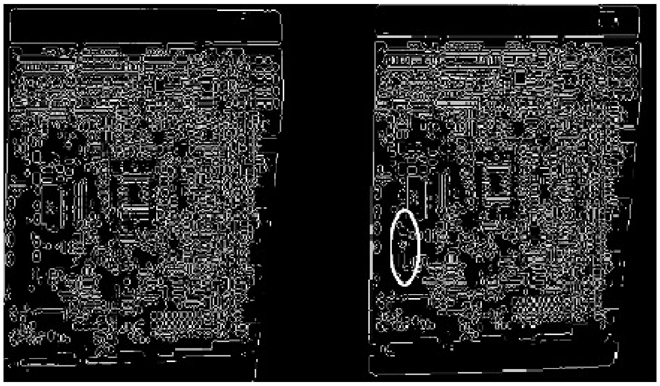

Fig.4.6: Zero crossing filter

The above Fig 4.6 shows the output of the Zero crossing filter and encircled area shows the defected area.

If there is defect a string will be displayed "images are dislike" else "images are alike" in case if there are no defects in MATLAB window.

V. CONCLUSION

PCB quality testing is very important from the point of view of sales and ultimately success of the product. Our simulated work in this research gave rise to lots of useful insights. Especially, it is very clear now that using machine vision many of the defects on the PCB can be detected with good accuracy. Also we concluded that effect of noise can also be one of the major factors in detecting defects. The effect of noise is been reduced using edge detection techniques, where also the image is enhanced. The source of such noise could be noise in the CCD's signal itself or it could be some noise between CCD and original object. We see that our simulation works very well for different types of images and not just for a single type of image. With power of tools such as MATLAB, we were able to capture useful information, and process the same to detect the defects. We have developed our model on a real time system. On this system, we used a camera with a simple illumination set-up, which led to many problems due to non-uniform illumination. Illumination is actually the most important factor that diminishes the performance of our design. When good illumination conditions are satisfied, our design is robust.

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