Quality Inspection in PCBs and SMDs Using Computer Vision Techniques

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Abstract **- This paper addresses the task of automating the visual inspection of printed circuit board with through hole technique, and surface mount devices (SMD) . We have focused on the following controls of the mounted component using either technology: i) Component twist, ii) Pin defects. A comparison of binarization techniques as well as twist angle estimation methods have been carried out. For inspection of pin defects various morphological image processing techniques have been applied.**

Index terms **- Computer vision, automated visual inspection, printed circuit board inspection.**

I. INTRODUCTION

Both printed circuit boards (PCB) with through hole technique, and surface mount devices (SMD) are the mainstay of the electronics manufacturing technologies. Quality control in these manufacturing technologies is paramount. There exist a sequence of test procedures applied to detect faulty connections, short circuits, missing elements etc. These procedures are based both on i) electrical tests, and ii) visual inspection.

It is argued that visual inspection of PCBs and SMDs is costly and quite time consuming. Furthermore the outcome of the inspection depends on the operators' skill, which degrades over time due to fatigue. It is conjectured that an automatic visual inspection scheme, where computer vision techniques are applied, would alleviate considerably the labor intensive inspection procedure, and hence would eventually contribute to the productivity. In this work we have addressed the following computer vision problems in PCB and SMD inspection: binarization of images for various tasks, inspection of component positions, morphological operations for defect identification.

II. BINARIZATION OF IMAGES

Gray-level images are thresholded for binarization purposes. Various methods of thresholding [1] have been comparatively studied, namely, the Otsu, Kittler and Illingworth, Pun, Kohler and the moment preserving methods. They have been assessed not only with respect to their run times, but also as for their ability in differentiating the pin connections, for bringing into evidence the paths, or for character recognition on the chips. Figure 1 displays the result of the thresholded images using different methods mentioned below. The performance comparison of these thresholding techniques is given in Table 1.

On the other hand multilevel thresholding technique based on the calculation of peaks and valleys from histogram has been used to extract the different structures, such as conductor traces, pads, lands and vias. Figure 2 shows the pads extracted from original image using this technique.

TABLE 1
Performance comparisons of various thresholding methods: execution times, ability to differentiate pins, potential for character recognition, enhancement of the paths.

METHODS	THRESHOLD	EXECUTION TIME	PIN DIFFERENTIATION	CHARACTER RECOGNITION	PATH ANALYSIS
Otsu	94	4 ms	good	bad	good
Kittler&Illingworth	180	19 ms	moderate	bad	bad
Pun	71	4 ms	good	good	moderate
Kapor	128	128 ms	good	bad	bad
Moment preserving	96	2 ms	good	bad	good
Kohler	104	2134 sec.	good	bad	good

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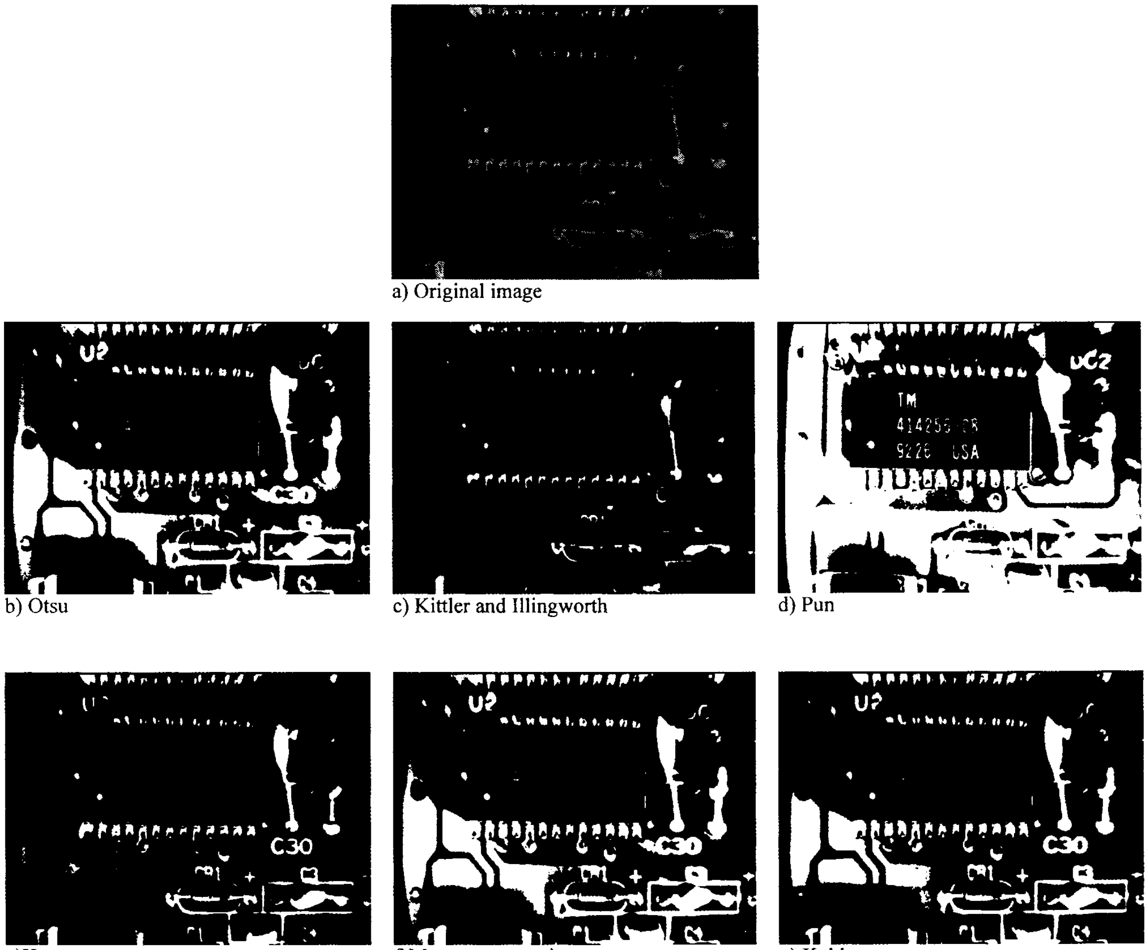


a) Original image
b) Otsu
c) Kittler and Illingworth
d) Pun
e)Kapor
f)Moment preserving
g) Kohler

Figure 1 The results of the thresholding methods.

III. DETERMINATION OF THE TWIST ANGLES

Devices, especially in the SMD technology, can be mounted on the pad with a twist angle. Even though the twist angle may be relatively small, it may still be problematic given the very fine tolerances in this technology. Haralicks' algorithm is used to determine the twist angle (e.g., for IC chips and multilayer ceramic capacitors).

A. Haralicks' Algorithm

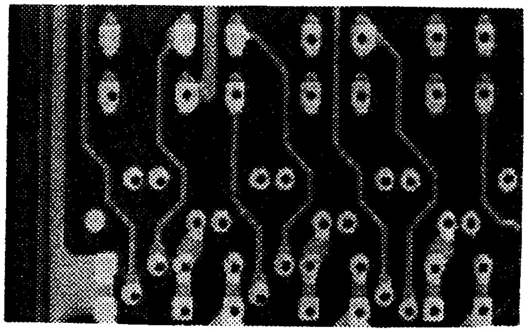
In this method [2], the rectangle representing the component is partitioned into six regions formed by two vertical lines, a known distance g apart, and one horizontal line, as in Figure 2. This partition constitutes the projection index image. But in this partition one must guarantee that the corners of the rectangle are in the extreme sextants of the partition. That is, the corner labeled **a** is in the sextant labeled **A**, the corner labeled **b** is in the sextant labeled **B**, the corner labeled **c** is in the sextant labeled **C**, the corner labeled **d** is in the sextant labeled **D**. Also the height h and width w of the rectangle are assumed to be known.

After these definitions, this projection in this image is placed over the rectangle. Then the twist angle of the rectangle is found using the following formula where θ is the twist angle, h is the known height of the rectangle, g is the grid separation, E and F are the measured areas of the corresponding sextants.

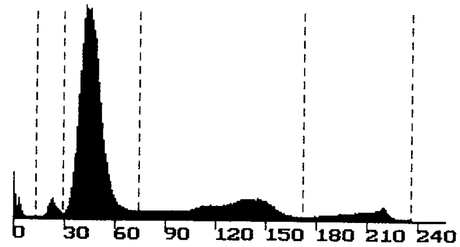
$$\theta = \arccos\left(\frac{h.g}{E+F}\right) \qquad (1)$$

Unfortunately this formula was found to be too inaccurate especially for small angular deviations. It is easy to see this sensitivity, since

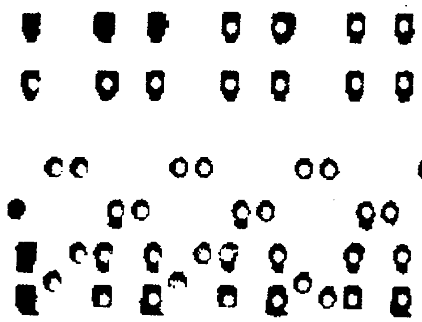
$$\frac{d\theta}{d(E+F)} = \frac{h.g}{(E+F)\sqrt{(E+F)^2-(h.g)^2}} \qquad (2)$$



(a)



(b)



(c)

Figure 2 a) Original image, b) Histogram of the original image, c) The pads after multilevel thresholding

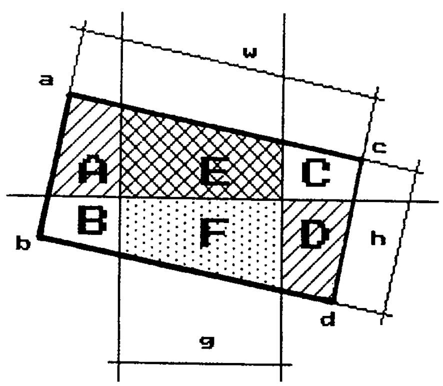
But for small θ's, $E+F \cong h.g$, as can be observed from the geometry of the problem, in Figure 3. Since for small angles, boundary quatization effects affect significantly the statistical performance of the algorithm, this method was not found to be practical for twist angle determination .

B. Extremal Point Technique

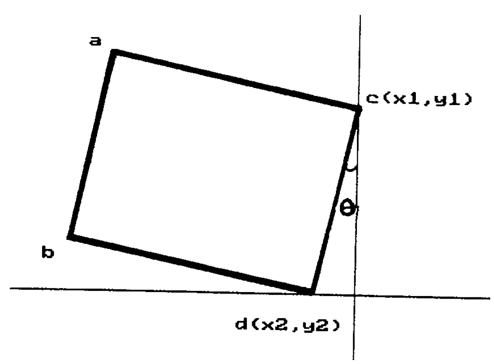
This alternative approach is based on to use the corners of the rectangles which is shown in Figure 3.b. To find the corners, morphological operations are applied and then pairs of corner angle coordinates are used in the following formula to estimate the twist angle.

$$\theta = \arctan\left(\frac{x_1 - x_2}{y_1 - y_2}\right) \qquad (3)$$

In Figure 4.a the estimates of θ found with the two above methods are plotted for different twist angles. The extremal point technique is found to be definitely superior to the Haralicks' algorithm, provided corners are accurately determined

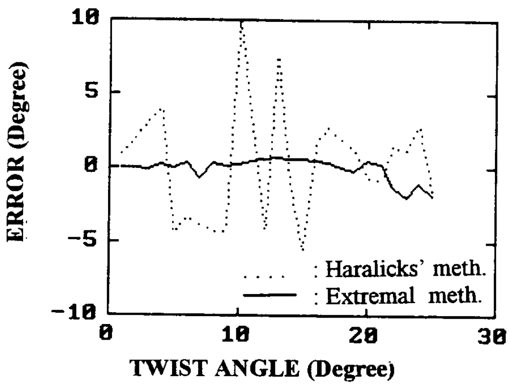


(a)

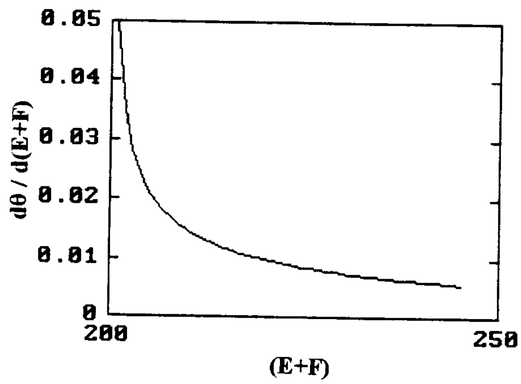


(b)

Figure 3 a) The projection index image in Haralicks' method b) Twist angle estimation using corner



(a)



(b)

Figure 4 a) The estimation errors of θ found with two methods b) The sensitivity analysis of Haralicks' method

IV. MORPHOLOGICAL METHODS

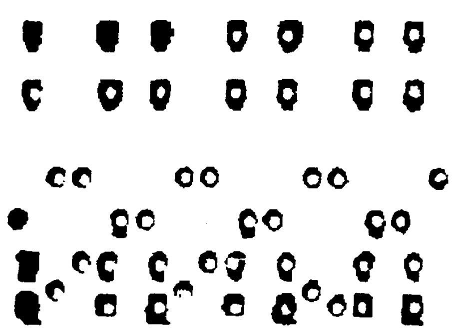
Morphological methods [3] have been applied to the PCB and SMD images for inspection of pins that could be bent or entirely missing, as well as to determine pads without a hole. The following morphological structures and operations as shown in Table 2 have been implemented:

In the example in Figure 3 a 9x9 circular structural element was used for morphological operation. In order to reduce execution time we decomposed 9x9 circle into 3x3 structural elements.

In morphological operations, selection of the structural element and determination of it size are critical. If the minimum radius of pads is n pixels, then radius of structural element must be at least n/2 pixels and at most n-1 pixels. These morphological operations with appropriately sized structuring elements have been shown to successfully detect missing or bent pins of the IC chips, and to extract pads on the board that have not been drilled through. A performance example is illustrated Figure 5 and Figure 6.

TABLE 2

Goal	Structural Element	Operations
Detection of bent pins	5x5 circle	Erosion, Dilation
Detection of missing pins	7x7 circle	Dilation, Erosion
Determination of pads without a hole	9x9 circle	Erosion, Dilation



(a)

(b)

Figure 5. a) Pads of PCB b) Determination undrilled pads via morphological operations

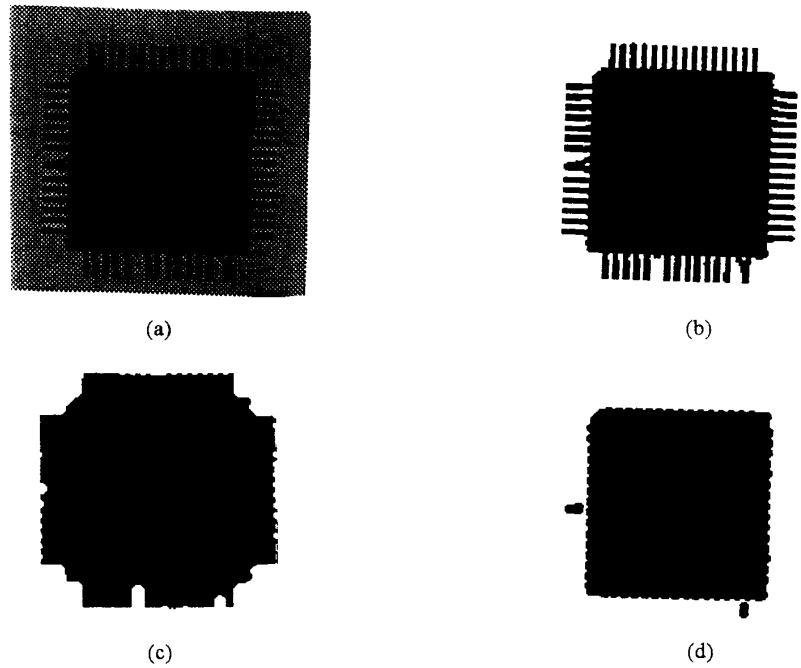


Figure 6. Determination of bent of missing IC pins using morphological operations. a) Original IC image b) Binarized image c)Missing pins determined via closing operation d) Short-circuit pins determined via opening operation

V. CONCLUSIONS

Computer vision algorithms were developed and tested for the quality control of PCB boards. It was shown that thresholding technique used could affect significantly the performance of subsequent algorithms and that Pun and Otsu were proven to be favorable for this specific application. Morphological methods provide robust tools for the detection of defects such as bent or missing pins and undrilled pads.

The hardware platform on which the inspection of boards by computer vision takes place consist of a Pulnix TM 765 CCD camera, Scorpion real time frame grabber (640*480 and 8-bit resolution), camera with adjustable focal length, and 486 DX 50 PCs. These algorithms are planned to be integrated into a full scale, automatic PCB and SMD inspection system.

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