

Visual Recognition and Localization of Printed Circuit Board

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Abstract. Precise positioning is one of the key steps in defect detection for printed circuit boards. This paper proposes a method to evaluate the roundness of printed circuit board image by least squares method and determine the position of the target circle by area sorting and screening method to realize the accurate extraction of the positioning parameters of the circular reference point (positioning circle). The CCD camera is used to capture images of the printed circuit board, and the median filtering is used for image preprocessing. The printed circuit board is separated from the image background by the gray projection segmentation technique, and the object in the image smaller than the positioning circle area is hidden. After comparing the circularity of the graphic in the printed circuit board image, two positioning circles are found according to the size of the graphic area to determine the coordinates of the center of the circle. The experimental results show that the positioning circle detection result of this method is accurate and requires less time than the traditional Hough transform detection circle.

Keyword. Machine vision; Positioning circle detection; Gray projection; Circularity

1. Introduction

Printed circuit boards (PCBs) are core components of modern electronic products. The detection of PCB is an important part of modern electronic product testing. As the density, complexity, and number of components on the PCB continue to increase, the labor intensity and difficulty of manual inspection are greatly increased. Due to the low detection efficiency and unstable quality, traditional PCB defect detection technologies such as manual visual inspection cannot meet the requirements of modern electronic product production[1]. Therefore, image processing is used to implement the component mounting detection system on the PCB, and when the PCB is tested, the PCB is first accurately positioned. Accurate positioning of the reference points (Mark points) on the PCB is a key step in achieving subsequent PCB inspection[2]. The common Mark point shapes are round, diamond, triangle, cross and so on. This paper focuses on the circular Mark points.

Commonly used circular Mark points detection methods mainly include Hough transform, edge detection and template matching. Documents [3-4] use Hough transform to detect the center of the PCB positioning circle. The Hough transform has high detection reliability and can still achieve ideal characteristics in the state of noise, deformation, and even partial loss. However, the calculation of such methods is large and the detection speed is slow, which is difficult to meet the requirements for the generation of PCB defect detection reference points[5].



This paper discusses the location problem of the reference point (positioning circle) in the defect detection of the embedded minimum system PCB. The image acquisition device collects the PCB image and preprocesses it. In this paper, a circularity detection method is firstly applied, and then the positioning algorithm of the reference point is determined according to the size of the circular area in the detection object. Finally, the algorithm is compared with the commonly used Hough transform circle detection algorithm.

2. System design

2.1. Embedded minimum system PCB

This paper studies the location of the positioning circle in the defect detection of embedded minimum system PCB. The architecture of the embedded minimum system PCB is simplified. PCB are small in size, simple in wiring and non-crossing, with fewer guide holes, but the function is powerful and widely used. Nowadays, many electronic products are developed and tested by using the embedded minimum system core board, which is one of the commonly used tools in the field of automation control and embedded system. At the same time, it is also a tool for learning and practicing in major universities. In the industry, there is a large demand for embedded minimum system PCB testing. The two positioning circles on the PCB are respectively distributed in the upper left corner and the lower right corner, as shown in the annotation in Figure 1.

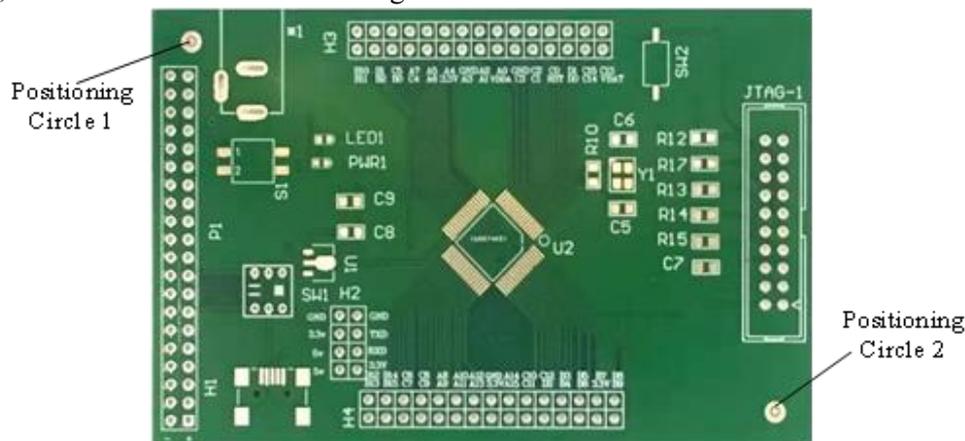


Figure 1. Embedded minimum system PCB.

2.2. System component of machine vision

A complete PCB image acquisition system consists of a CCD camera, a circular lens and a ring-shaped RGB light source. The hardware part of the system image acquisition is shown in Figure 2. The upper computer image processing system is composed of a computer and image processing software.

The PCB is placed on the platform, and the platform is moved up and down by the rotation of the screw rod to realize image acquisition. The center of the CCD camera, the circular lens, and the ring-shaped RGB light source should be as vertical as possible on the PCB to be tested, so that the collected image is free of distortion[6].

2.3. Experimental procedure

The positioning circle detection process of embedded minimum system PCB is shown in Figure 3.

3. Image location

Before locating the positioning circle in the image, the image needs to be processed. The main purpose of image preprocessing is to remove the useless information in the image, and reduce the complexity of the image, and highlight the basic features of the PCB holes, lines, pads, etc. It is convenient for

computer analysis and processing. The preprocessing flowchart for the PCB image is shown in Figure 4.

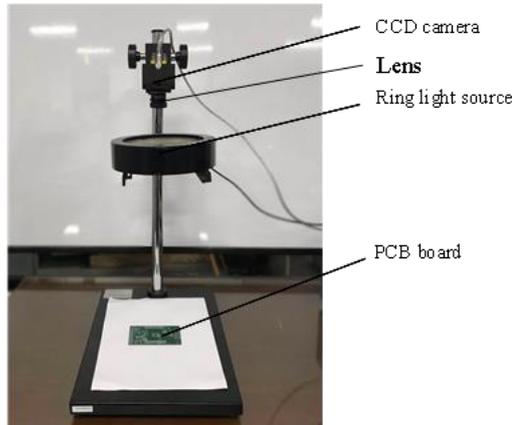


Figure 2. Image acquisition system.

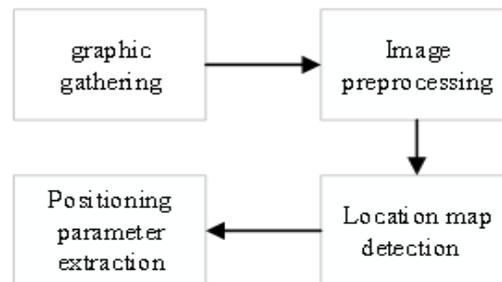


Figure 3. Positioning circle detection process.

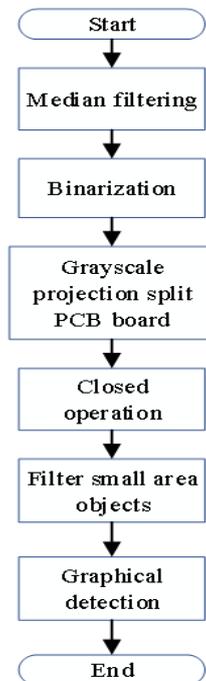


Figure 4. Image preprocessing process

3.1. Median Filtering

The acquired image usually contains noise. The so-called image noise refers to the random interference signal received by the image during the ingestion or transmission. In order to better identify the positioning circle, it is necessary to remove the noise of the image. Median filtering is a classic method of smoothing noise, which is very effective in eliminating salt and pepper noise. It can be used to protect image edge information and is used in research to preserve solder joint contour images [7].

Median filtering is a kind of statistical sorting filtering. Its idea is to sort all pixels in a certain field from small to large, compare the size of pixel values, take out the median of them as the value of the central pixel of this field, and eliminate the isolated noise points. (such as salt and pepper noise). Calculate the pixel value at (x, y) :

$$g(x, y) = \text{median}\{f(s, t)\} \quad (1)$$

Among them, $g(x, y), f(s, t)$ are the original image and the processed image. The field usually uses 3×3 or 5×5 areas. The images collected in this experiment are subjected to median filtering processing using the domain 5×5 area to protect the edges of the image and smooth the impulse noise.

3.2. Morphological closure

The morphological closed operation indicates expansion before corrosion. Expansion expands the components of an image, and corrosion shrinks the components of an image. The effect of the expansion is to expand the edges of the target image so that adjacent pixel points are aggregated by larger boundary pixels. The closing operation smoothers a portion of the contour, bridging the narrower discontinuities and the elongated gullies, eliminating small holes and filling the breaks in the contour [8]. The closed operation of set A by structuring element B is expressed as $A \cdot B$, which is defined as follows;

$$A \cdot B = (A \oplus B) \ominus B \quad (2)$$

The hole on the PCB becomes smaller after being expanded, and the ring becomes larger. The effect of corrosion is to remove some pixels with low correlation between the boundary of the object. In the PCB image processing, the closing operation can appropriately eliminate the disturbed line edge spots. The contour of the binary image of the PCB after the closed operation is more distinctive, so as to facilitate the subsequent positioning circle recognition.

3.3. Gray projection

The gray projection algorithm is a motion estimation algorithm that estimates the motion of an image based on the image gray curve. Its principle is to project the corresponding direction of the image, that is, take a line in the direction, counting the number of black points of the pixels on the image perpendicular to the straight line (axis), and summing up the sum as the value of the position of the axis; The image projection is to map the image to such a feature, and based on this feature, the cutting position (coordinate) of the image is determined, and the original image is cut with this coordinate to obtain the target image [9]. In this paper, the gray projection algorithm is used to perform horizontal projection and vertical projection on the PCB image, and the PCB and the back image are separated from the image to complete the extraction of the feature points in the PCB.

3.4. Positioning circle detection

In this paper, the circularity of the PCB image is detected. According to the circularity, the possible positioning circle is judged, and the circular area is sorted and screened to determine the coordinates of the positioning circle center. In this paper, the least squares method is used to evaluate the circularity [10].

For a circle at any position in a plane rectangular coordinate system, its general equation is

$$x^2 + y^2 + Dx + Ey + F = 0 \quad (3)$$

Where D, E, and F are three parameters, and $D^2 + E^2 - 4F > 0$.

By calculating the sum of the squares of the distances from the points on the edge of the circle to the ideal circle, the three parameters (D, E, F) of the circle are determined, and the objective function is obtained.

$$G(D, E, F) = \sum_{i=1}^N [(X_i^2 + Y_i^2 + DX_i + EY_i + F)]^2 \quad (4)$$

$G(D, E, F)$ seeks partial derivatives for D, E, and F, so that the partial derivative is equal to 0, that is

$$\frac{\partial G(D, E, F)}{\partial D} = \sum_{i=1}^N 2(X_i^2 + Y_i^2 + DX_i + EY_i + F)X_i = 0 \quad (5)$$

$$\frac{\partial G(D, E, F)}{\partial E} = \sum_{i=1}^N 2(X_i^2 + Y_i^2 + DX_i + EY_i + F)Y_i = 0 \quad (6)$$

$$\frac{\partial G(D, E, F)}{\partial F} = \sum_{i=1}^N 2(X_i^2 + Y_i^2 + DX_i + EY_i + F) = 0 \quad (7)$$

Among them, N is the number of edge points; it is the coordinate of the point data of the circle edge under the coordinate system. The simultaneous equations (3), (4), and (5) solve the parameters D, E,

and F of the circular equation. According to the parameters of the obtained circle, the center (X_c, Y_c) of the circle is obtained by the following formula.

$$X_c = \frac{D}{-2}, Y_c = \frac{E}{-2} \quad (8)$$

Therefore, the PCB image is preprocessed first, and the possible positioning circle is determined according to the circularity size, and the circle area is sorted and screened, thereby determining the positioning circle, extracting the center point parameter, and realizing the rapid positioning of the positioning circle.

4. Experimental result

The positioning circle detection experiment of PCB board image is performed in the MATLAB environment of Windows system. The PCB board image is captured by the camera as shown in Figure 5. The image in the red box is the image captured by the camera.

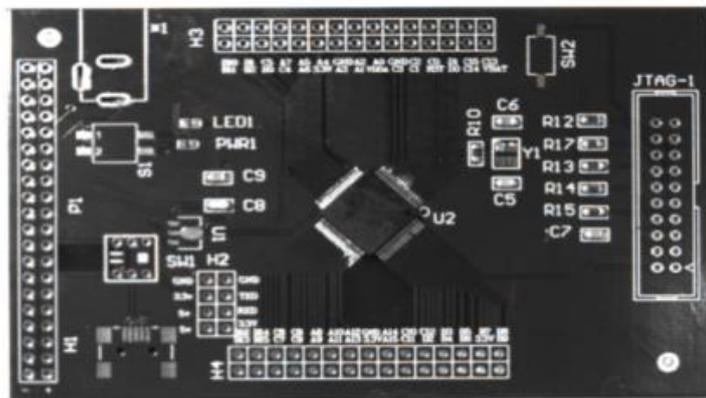


Figure 5. Original drawing of PCB board

Then the median filtering is performed on the original image, and converted into binary image, grayscale projection, morphological closure operation. The experimental processing results are as follows

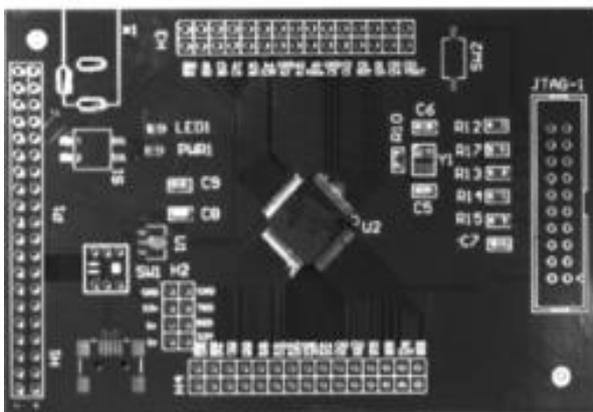


Figure 6. Median filtering.

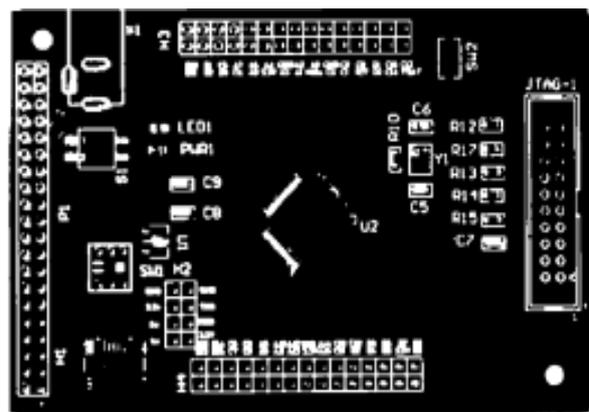


Figure 7. Binarized image.

By using the gray projection method, the PCB on the picture is separated from the background, according to the grayscale image (Figure 8), and a picture of only the PCB board image is obtained as shown in Figure 9.

The image after the morphological closure operation has a sharp outline as shown in Figure 10. In order to reflect the experimental effect, after the morphological closed operation, a small area object smaller than the positioning circle area is screened and filtered (Figure 11). This includes some of the

pads, holes, and traces, but the detection of the positioning circle and the subsequent detection of the PCB image cannot affect and interfere, because these small-area objects are recoverable.

The circularity detection is now performed on the PCB image. If the detected result is closer to 1, the image is rounded as shown in Figure 12.

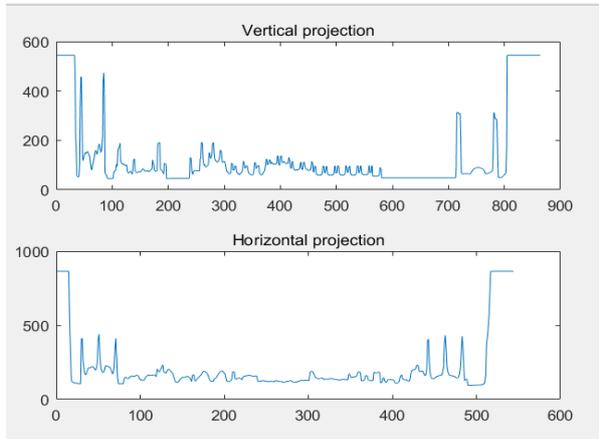


Figure 8. Grayscale.

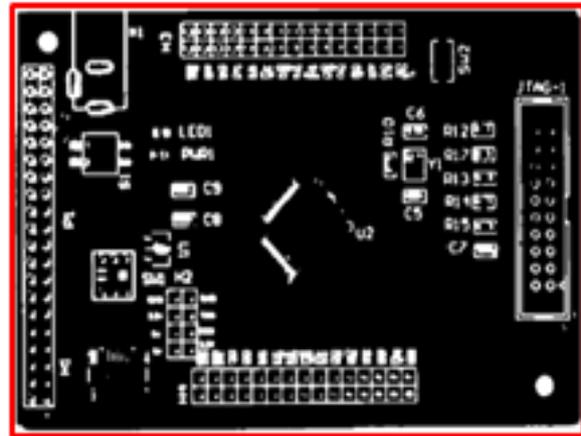


Figure 9. Divided PCB image.

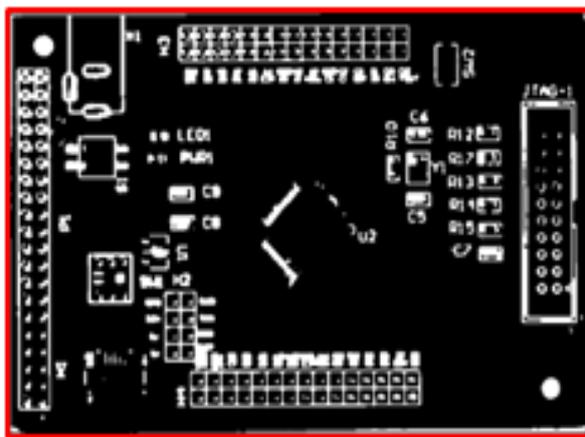


Figure 10. Closed operation.

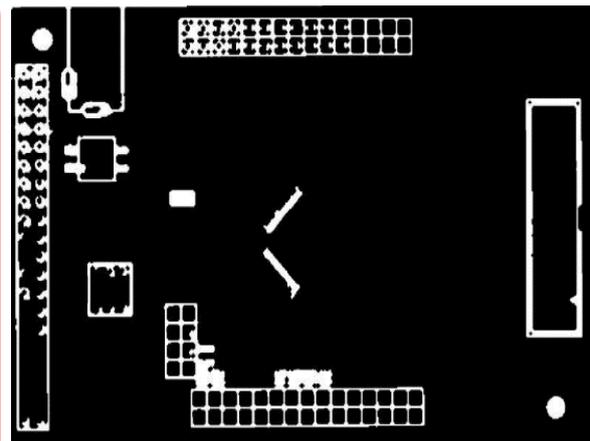


Figure 11. Filter small area object.

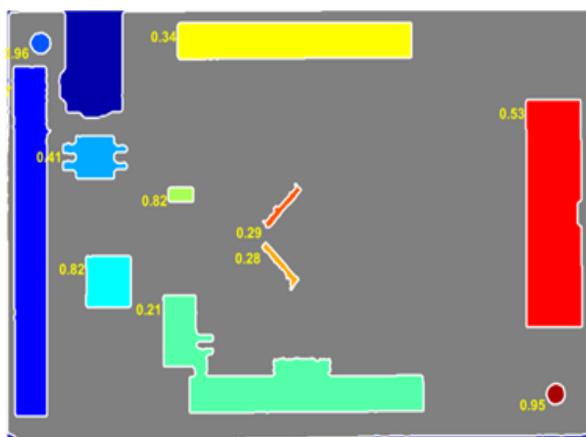


Figure 12. Positioning circle detection.

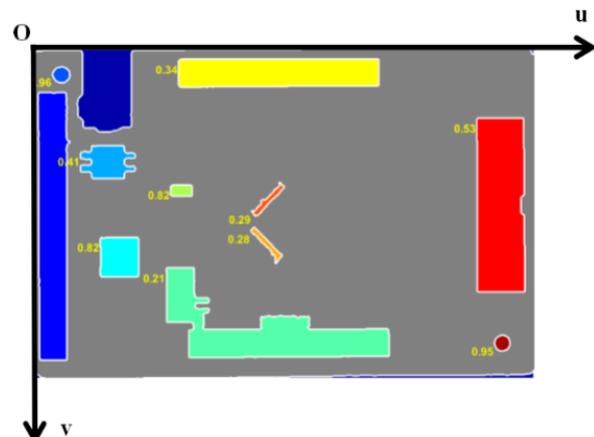


Figure 13. Image coordinate system.

According to the circularity of the detected object, the circle is selected out, and the positioning circle is determined by sorting the area of the circular image to obtain the center of the positioning circle. It can be seen from Figure12 that the circularity of the two positioning circles is 0.96 and 0.95, respectively, and the circularity of the other figures does not exceed 0.90. If there is an object exceeding the circularity of 0.90, the positioning circle is screened by comparing the area of the graphic. The positioning circles are screened and the coordinate parameters of the center of the circle are determined.

In order to intuitively experience the effect of the method, the experimental results obtained by the method are compared with the traditional Hough transform detection circle, as shown in Table 1 and Table 2. Wherein, the obtained center coordinate parameter is obtained in the image coordinate system. The image coordinate system establishes a direct coordinate system u-v in pixels based on the upper left corner of the image (Figure 13). The abscissa u and the ordinate v of the pixel respectively correspond to the number of columns in the image array and the number of rows in which they are located.

Table 1. The experimental results obtained by this method

Serial number	Center coordinates	operation hours
1	(46, 40)	0.018879
2	(721, 449)	

Table 2. The experimental results of hough transform

Serial number	Center coordinates	operation hours
1	(45, 39)	11.4498
2	(723, 448)	

From the analysis of Table 1 and Table 2, it can be seen that both methods can be used for the detection of the positioning circle, and the obtained center coordinates are almost the same. However, Hough transform needs longer time to detect the location circle, and the time required by this method is much less than that required by Hough transform detection, and the method is simple to operate and less computational complexity. Through comparison, the accuracy and rapidity of the method are reflected.

5. Conclusion

This paper discussed the location problem of the positioning circle in the defect detection of embedded minimum system PCB. The image acquisition device collected the PCB image and preprocessed it. A circularity detection method was proposed, and the positioning algorithm for determining the positioning circle was determined according to the circular area of the detection object. The simulation experiments show that compared with the traditional Hough transform detection circle, the positioning circle parameters extracted by this method are accurate, and require less time and less computation, which is beneficial to the efficiency of PCB defect detection in industry.

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