Middle Scale Tiny Components Online Detection Based on Machine Vision

Q.M. LIU [1,2a], X. LI [1,b], X. Wu [1,c] and L. ZHANG [1,d]

[1]College of Mechanical Engineering in Hangzhou Dianzi University, Hangzhou, Zhejiang, China

[2]College of Information Engineering in Hangzhou Dianzi University, Hangzhou, Zhejiang, China

[a]qml@hdu.edu.cn, [b]1083133837@qq.com, [c]327791153@qq.com, [d]215821772@qq.com

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Abstract. For middle scale components online detection, a chip online detection method was proposed based on machine vision, the hardware platform was built, the software system was developed, and a new sub-pixel localization algorithm for line and arc was put forward. Through image preprocessing, edge detection and the deletion of small area objects, the target area of chip image was obtained. Through sub-pixel location, the detection precision and accuracy can be improved. Comparing the detection parameters and parameter indexes, the functions of eliminating the unqualified product and determining the positive and negative polarity, center position and rotation angle of qualified product are well implemented. The detection time is less than 1s, achieving real time detection requirements.

Introduction

With the increasing of miniature components and devices in recent years, the demands for the detection of these parts are increasing at the same time. Because micro machine's geometry size distributes between 10 microns and 10 mm [1], micro machine belong to middle scale components[2]. As the detecting theory of middle scale tiny component is not yet mature, it needs further research. The research object in this article is a square chip, which still need to be detected by eye in small and medium enterprises.

The chip's positive and negative terminals are both squares, negative area is bigger than the positive's. The chip surface is plated in tin, which has high reflective. The high light area in the image gathered by COMS sensor is the target area.

Machine vision detection system

The chip on-line detection equipment bench is shown in Fig. 1.

Vision detection system consists of light source, chip rolled plate, lens, 130w CMOS camera, image acquisition card and computer, etc. As there needs to make enough space in the workbench to satisfy the movement of the manipulator, there are only 3 strip sources. In order to not disturb the manipulator's movement, select the lens of WWL08-250 with working distance 250mm.

Image processing

Image processing is the important basis and prerequisite of vision detection [3]. Image processing quality affects precision, accuracy and real-time. It includes image preprocessing, edge detection, deleting small area objects and sub-pixel location. Fig. 2 are the chip images after pretreatment.

Fig. 1 detection bench

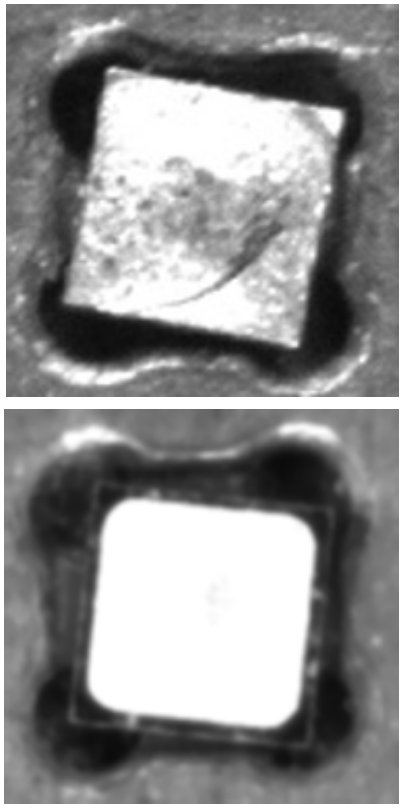


Fig. 2 a Negative chip
b Positive chip

Image preprocessing includes image de-noising and lens distortion correction[4-5]. Lens distortion is the distortion caused by optical lens distortion perspective. Compared with macro-vision system, as there are more lens in micro-vision system, distortion is serious. Remove salt and pepper noise by median filtering and correct image by lens distortion correction. The images are in Fig. 3.

Canny edge detection has the advantage of single pixel edge, accurate positioning and continuous edge, especially for weak edges. The edge profiles are shown in Fig. 4.

In Fig. 4, in addition to the middle closed contour lines, the rest of the contour edge lines are disturbing edges, which need to be removed. Calculate pixel number of each contour, namely the contour area, set the threshold value, delete areas less than the threshold. For some disturbing edges connected to the chip edge, fill outline and detect them. Chip profiles are shown in Fig. 5.

A new sub-pixel localization

Edge contours in middle scale components are usually line, circle and arc. A new sub-pixel localization method algorithm was proposed in this paper for these contours.

Sub-pixel localization algorithm for line contour:

1) Carry out hough linear transform for edges, determine points on the line through the distance from point to line, get the normal direction of the edge points.

2) Take points every 0.5 pixel in height along normal direction, a total of 10 points.

3) Calculate the gray value of the 10 interpolation points.

4) Calculate interpolation points' differences of forward and backward in normal direction, take relative difference results as the weight of the relative position, get the ideal positions of edge points as sub-pixel points.

5) Fit line by the sub-pixel points.

When the edge is circle or arc, the detection method is similar to the above. The differences are that normal is the attachment of edge points and center point, and fitting curve is circle.

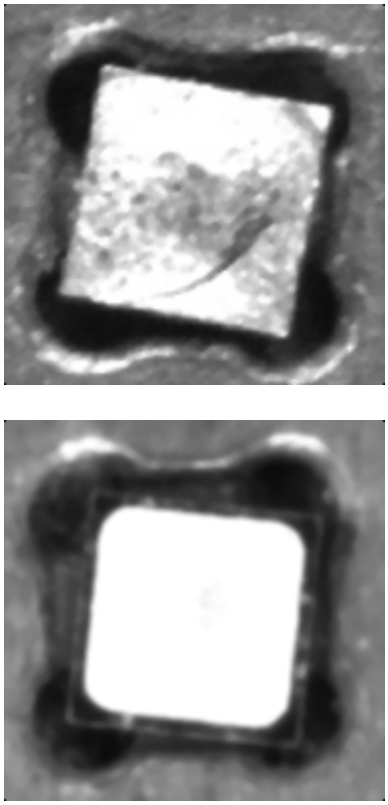


Fig. 3 a Negative chip
b Positive chip

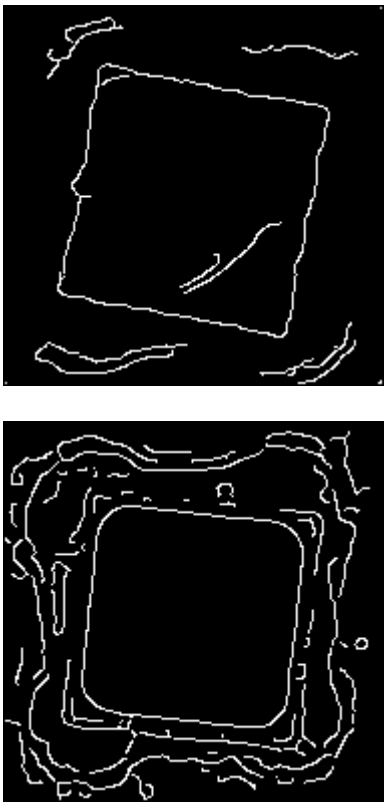


Fig. 4 a Negative chip
b Positive chip

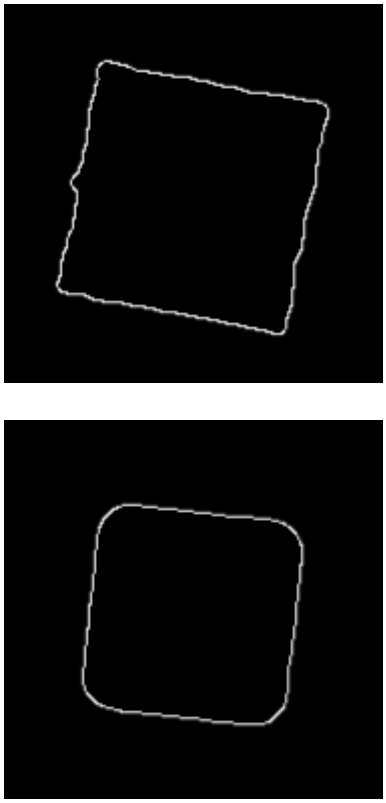


Fig. 5 a Negative chip
b Positive chip

The red lines are edge normal. As shown in figure 6a, the interpolation point is(y, x), surrounding pixels are (y_1, x_1),(y_1, x_2),(y_1, x_1),(y_2, x_2). To avoid the presence of noise on the surrounding pixels to interfere the interpolation results, surrounding pixels' gray values were replaced by neighborhood means. Calculate the angles of the interpolation point and surrounding pixels, θ_1 θ_2. θ is the angle of normal and horizontal direction.

The intersections of normal (y_1,x_2) and around rectangle are p_1(y_{p1},x_1) and p_1(y_{p2},x_2). The distance of p_1 to the left up point in the rectangle is $d_{p1,1} = y_{p1} - y_1$, the distance of p_1 to the left down point in the rectangle is $d_{p1,3} = 1 - d_{p1,1}$. The gray value of p_1 is:

$$g(p1) = d_{p1,3} g(y_1, x_1) + d_{p1,1} g(y_3, x_1) \quad (1)$$

Similarly, the gray value of p_2 is:

$$g(p2) = d_{p2,3} g(y_1, x_2) + (1 - d_{p2,3}) g(y_3, x_2) \quad (2)$$

From them, $d_{p2,3}$ is the distance of p_2 to the right down point in the rectangle.
The gray value of interpolate point (y, x) is:

$$g(y,x) = \frac{|0.5 - y_{p1}|}{|0.5 - y_{p1}| + |0.5 - y_{p2}|} g(p2) + \frac{|0.5 - y_{p2}|}{|0.5 - y_{p1}| + |0.5 - y_{p2}|} g(p1) \quad (3)$$

The calculation methods of the rest five kinds in figure 6,7 are the same of figure 6a.

As an image can be seen as discrete function, the edge first derivative can be got by first order difference along normal direction. The difference is divided into forward difference and backward difference.

The forward difference is:

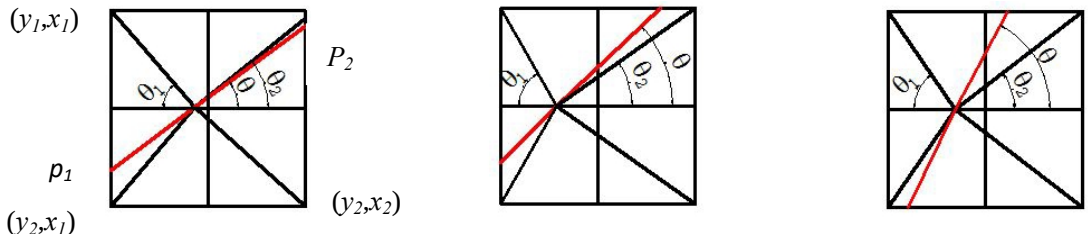
$$\Delta d_i = g_{i+1} - g_i \tag{4}$$

The backward difference is:

$$\nabla d_i = g_i - g_{i-1} \tag{5}$$

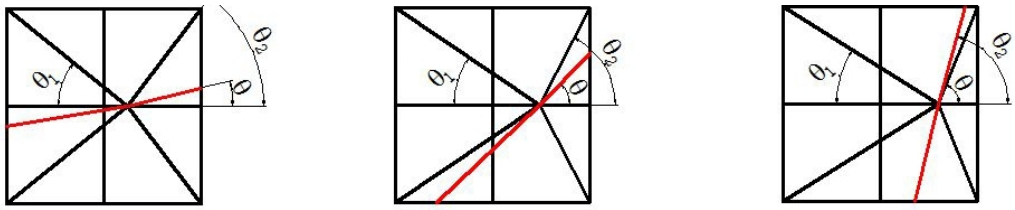
The edge position got by the forward difference is ahead of the actual edge position and the position got by the backward difference lags behind the actual position. The relationship of ideal edge point a0, edge position a1 got by the forward difference and edge position a2 got by the backward difference is shown in equation6:

$$a_0 \approx (a_1 + a_2)/2 \tag{6}$$



a $|q| < q_2$ b $q_2 < |q| < q_1$ c $|q| > q_1$

Fig. 6 when $\theta_1 > \theta_2$, the positions of interpolation points and the surrounding pixels



a $|q| < q_1$ b $q_1 < |q| < q_2$ c $|q| > q_2$

Fig. 7 when $\theta_1 < \theta_2$, the positions of interpolation points and the surrounding pixels

The chips' edge profiles were got by this sub-pixel localization algorithm shown in figure 8.

Size calibration and parameter calculation

The parameters got by image processing are measured in pixel, while the location of manipulator are measured in mm. It needs unit conversion. This article uses calibration with 1mm width to calibrate size. Calculate the numbers of pixels of 1mm in the calibration, and get the size of a pixel.

Chip parameters include area, rectangularity, side length ratio, center position and rotation angle. Fill up contours in figure 5, get their areas and minimum circumscribed rectangle areas, calculate rectangularities. Calculate side lengths and edge ratios, get center positions and rotation angles of chips in figure 8. Test results are shown in table 1.

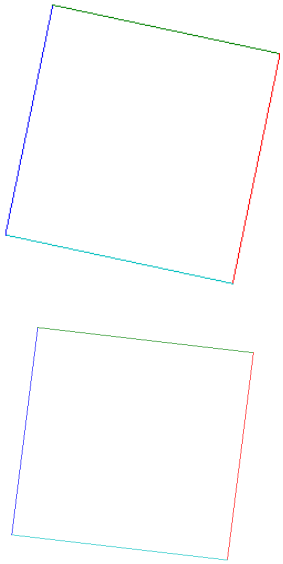


Fig. 8 a Negative chip
b Positive chip

Table 1 parameters

Parameter	Positive chip	Negative chip
The distance of chip center to groove center/[um]	(21.87,-0.44)	(18.11,2.14)
Rotation angle/rad	-6.9	-11.86
Chip area/[pix]	10963	14253
Rectangularity	0.964	0.955
Side length/[pix]	103.10*102.92	111.96*111.16
Side length ratio	1.002	1.007

Conclusion

In this paper, a hardware platform was built, a software system was developed, a new sub-pixel localization algorithm was proposed for chips in middle scale. It can get the parameters of chips, including area, rectangularity, side length ratio, center position and rotation angle and so on.

Comparing the parameters and parameter indexes, make sure the polarity of a chip and whether it is qualified. The testing time is less than 1s, meeting the requirements of on-line detection.

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