Study of PCB micro-drilling geometry detection method based on machine vision

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Abstract. Traditional methods rely on for measuring tools in the machine detection of PCB micro drill have limitations, for example, labor-intensive, poor stability, low efficiency and so on. This paper proposes a detection method for machine vision and image feature extraction, and achieves non-contact, high-precision online/offline automatic measurement of geometry of PCB micro-drilling. The simulation and experimental results show that this method is simple, feasible and able to quickly and accurately measure the PCB micro-drilling. It's up to 1μm and can also be used for dimensional inspection of other small parts. This has great practical value.

Introduction

With tablet computers, smart phones and other electronic devices become increasingly thin, multi-functional, PCB industry trends development of high-end technology products, such as flexible PCB, high density interconnect PCB[1]. The use of micro-drilling is the main way of PCB drilling, thus micro-drilling increase the consumption and become smaller. In the production line, micro-drilling tend to be more automated production. While in the course of processing, if PCB micro-drilling use the wrong size, it will bring the PCB non-drilled hole, larger aperture and other defects, resulting in decreased quality and productivity of PCB board. Due to the amount of micro-drilling becomes more and the size becomes smaller, so it brings a great challenge for dimensional inspection of micro-drilling.

The traditional method of measurement is to rely on measuring a micrometer or caliper. But this method requires manual inspection. It has labor-intensive, large subjective judgment, easy to produce errors of judgment by eye fatigue caused, poor stability and slow. To meet the needs of industry, detection technology based on machine vision was born. It has a non–contact, automated high precision, high speed etc.

In summary, this paper presents a method of dimensional inspection in micro-drilling based on machine vision. Capture images with industrial CCD camera, to process images by image processing techniques, accordingly realizes the micro-drilling size parameters. Compared with traditional measurement methods, this method is stable and viable, high precision and speed.

Analysis of geometric properties in PCB micro-drilling

The materials of micro-drilling are carbide (tungsten steel), which has high hardness, high wear resistance and good stability [2]. Micro-drilling include drill stem and drill body. Blade diameter determines the size of the hole. Blade diameter is the diameter of section round of the drill body. Micro-drilling is often used in the PCB industry and machining of other tiny holes. In order to meet the needs of the PCB industry, the smaller blade diameter, the more difficult to detect and the higher precision. The main geometric parameters of micro-drilling have total length, shank diameter, flute

length, diameter, point angle, etc. [3]. The parameters are illustrated in Figure 1. In this paper, the overall length and diameter of micro-drilling are detected. If the deviation error of micro-drilling is larger diameter, the error of hole is very larger.

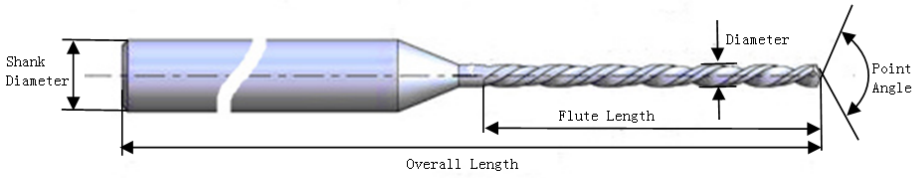


Fig 1 Each parameter diagram of micro drill

The methods and process of visual inspection in micro-drilling

Methods and principles

Size measurement based on machine vision for small parts mainly includes size calibration, image processing and part size calculations. Measurement of part size is characterized by basic geometric parts of detection to complete. After a series of image processing, get the edge image of the part, and then the size of the part is obtained by the geometric features of a part. The general idea of the detection of small parts size is shown in Figure 2.

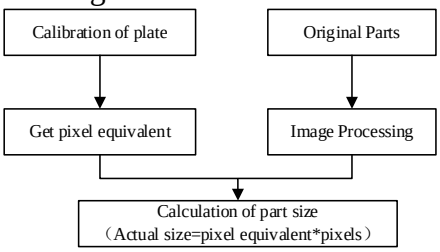


Fig 2 Block diagram of detection algorithm for part size

Detection process

Micro-drilling of PCB NC machine have different shapes and sizes. It is necessary to calculate the geometry of the micro-drilling through effective algorithms. Size measurement consists of two steps: 1 size calibration, get pixel equivalent by black and white chess; 2 calculate the size of micro-drilling, including the overall length and diameter. The calibration process is shown in Figure 3, the calculation process of micro-drilling is shown in Figure 4.

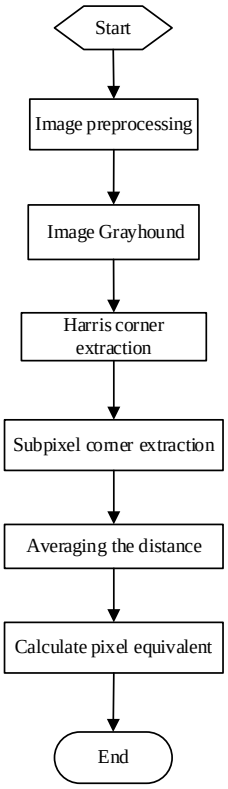
Key Algorithms

Calibration algorithm and simulation of CCD camera

When the calibration plate images processing, corner detection is an important step. There are many methods. After extraction from the edge of the calibration board image, point coordinates can be obtained by striking the boundary corner intersection. But the image of the edge line in the acquisition process may be interrupted or distorted, the corners got will occur errors and low precision. In addition, get corners directly through the calibration plate image, which mainly calculating the gradient and curvature of the image is accomplished [4]. It is reported that the method based on sub-pixel level Harris corner extraction is the best algorithm that can be adapted to a variety of complex situations, relatively stable, the detection accuracy can reach 0.1 pixels. Therefore, in this detection method use a method based on Harris corner extraction sub-pixel level.

After Black and white calibration plate image preprocessing and point extracting based on Harris sub-pixel (see Fig. 5), obtain an average pixel N for each grid. So the actual size of each pixel is equivalent (M = 6mm/N).

PCB micro-drilling size determination algorithm and simulation based on image feature extraction



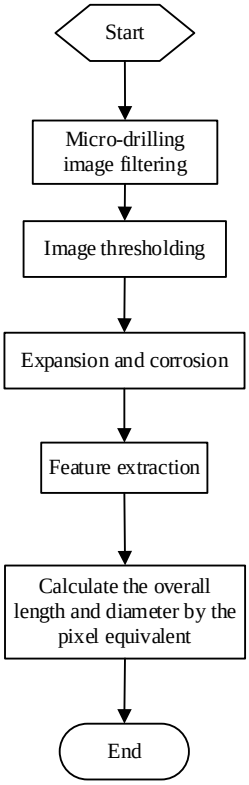


Fig 3 Calibration flowchart **Fig 4 Micro-drilling size calculation flow chart**

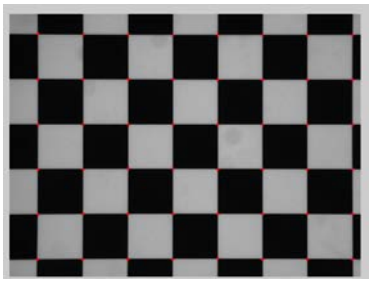


Fig 5 Harris corner detector

1）Image filtering

Due to random noise affects the quality of the image, the original image in the build process is blurred boundary and unclear. Thus it affects the recognition of the detection of the target area. Therefore, methods must be used to improve the quality of the filtered image. Filtering methods commonly used include mean filter and median filter. Mean filter method when removing noise will blur the edges of the image. Accordingly, selecting the method of median filtering and the filter with 3 * 3 templates. Results is shown in Figure 6.

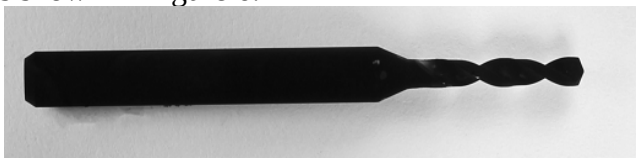


Fig 6 Result of filtering

2）Image segmentation

Image segmentation is an important image processing steps. Briefly, that is for a digital image, the target of interest effectively separated from the background. But threshold segmentation method is more common. The threshold can be used to separate target and background. If the point is greater than or equal to the threshold, it's the background point, otherwise it's the target point [5]. There are many threshold method and the bimodal method is the simplest method, it is suitable for the case of two peaks appear in the histogram of the image. Micro-drilling histogram image is shown in Figure 7.

According to the histogram obtain the threshold value T, if the point in image is greater than or equal to the threshold T, it is set to 0, otherwise 1. The result is as shown in Figure 8.

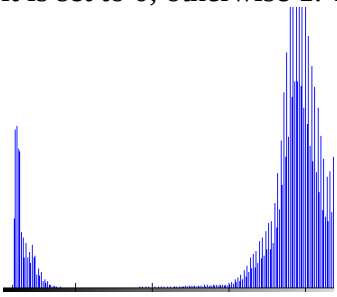


Fig 7 Histogram

Fig 8 Binary image

3）Contour extraction

Edge plays a vital role in the size measurement process. After binary conversion, contour extraction becomes very simple. Edge extraction can achieve the contour extraction. The method is, if the point p (i, j) of image is black, and 8-points in the neighborhood are black, then the point deleted. The reserved pixels are the image edge. Figure 9 is contour extraction result.

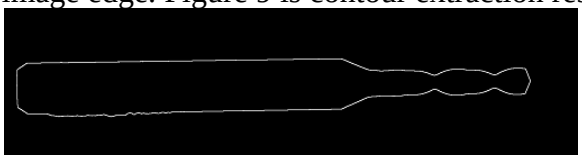


Fig 9 Contour extraction

The results and analysis of experiments

Test system

PCB micro-drilling geometry test system based on Machine Vision is as shown in Fig.10. It includes CCD camera, backlight, PC machines and image acquisition card. CCD camera with NAVITAR Zoom lens supporting, because Zoom 6000 has high magnification, good optical performance and flexibility. Micro-drilling would be placed on the backlight, get the best image by a CCD camera and save. Then analyze through image processing, and finally realize the size measurement of the micro-drilling.

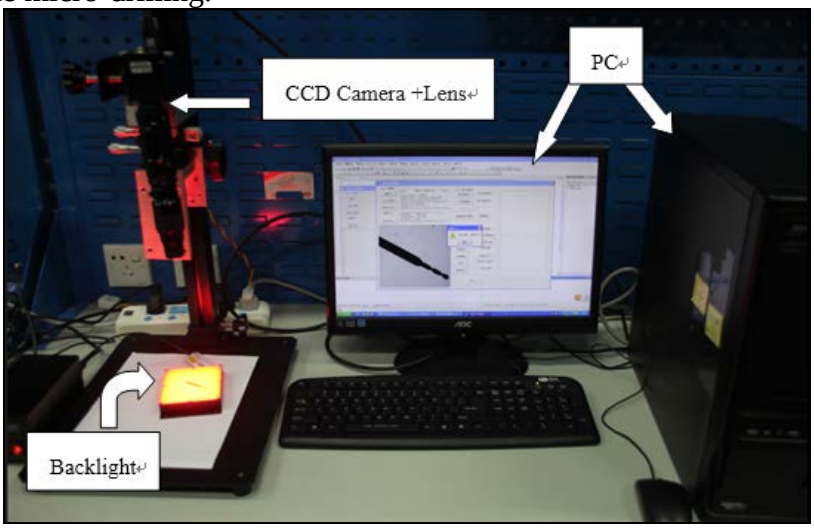


Fig 10 Test system diagram

Test process

First, calibrate for the calibration board, as shown in Fig.11. All together there are 80 corners in the calibration plate image, but the corner points of the image around the corner point do not belong to the calibration plate corner points, so the removed result is shown in Figure 12. The calibration result which selected 16 points is in Table 1.

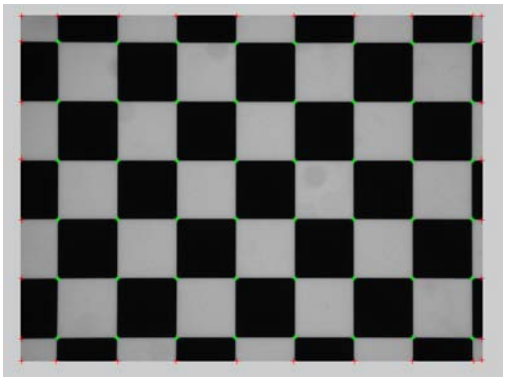


Fig 11 Harris Corner extraction

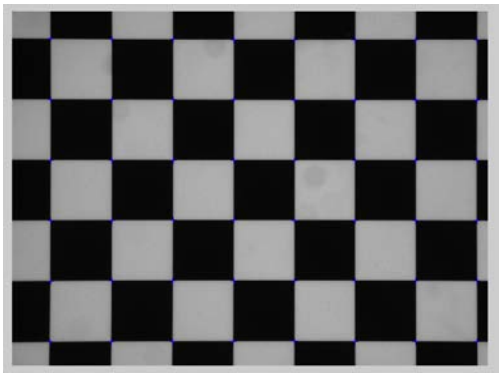


Fig 12 Removal around the corner

Table 1 Corner extraction results Unit：pixel

point number	pixel coordinates	sub-pixel coordinates
1	（717，82）	（717.4339，81.5162）
2	（454，83）	（453.6360，83.4975）
3	（586，83）	（585.4206，82.5714）
4	（60，84）	（60.2301，83.6685）
5	（191，84）	（191.4353，84.0254）
6	（323，84）	（322.5887，83.9015）
7	（717，214）	（716.5738，213.9885）
8	（585，215）	（584.7033，214.9598）
9	（61，216）	（60.9751，215.9246）
10	（192，216）	(191.6447，215.9515)
11	（323，216）	(322.5284，216.0379)
12	(454，216)	(453.5296， 215.5429)
13	(584，346)	(584.3630，346.5086)
14	(716，346)	(715.9804，345.8407)
15	(61，347)	(61.5357，347.3300)
16	(192，347)	(192.2412，347.3725)

Extract sub-pixel coordinates from 48 corner points in the calibration plate image and calculate the average pixel equivalent is 6mm/130.8993pixel = 0.0458mm/pixel.

After obtaining pixel equivalent, process the collected image of micro-drilling, get the micro-drilling contour image. Calculating the micro-drilling of the physical total length L (see Fig. 13) is by finding the minimum bounding rectangle of the target area whose length is the total length of the drill pixel L0. Measuring physical edge micro-drilling diameter D is calculated on the distance between the edges of two corners. The main idea is: along the outline of the micro-drilling image the minimum bounding rectangle lengthwise direction, start scanning each pixel p (i, j) on the left. If the scanning length is less than L/3 and the black pixels occur, the drill blade is on the other side of the rectangle, and then scan in the opposite direction, find corners on the cutting edge. Calculate the distance between angle point and the center line of the minimum bounding rectangle. Remove the corners of relatively small distance. Measure the average pixel value D0 between the two corresponding corners both sides of the center line of the micro-drilling image. Then L = L0 * M, D = D0 * M.

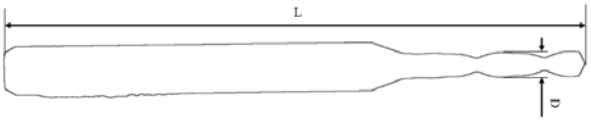


Fig 13 Size diagram of micro drill

Result analysis

By the above method, the study measures 20 micro-drilling samples. Each micro-drilling sample would be tested eight times. A random group measurement results are shown in Table 2.

Table 2 Measurement results Unit：mm

Number	1	2	3	4	5	6	7	8
Overall length	38.2246	38.0073	38.1117	38.1173	38.1657	38.0024	38.1254	38.1489
Diameter	1.6539	1.6551	1.6511	1.6412	1.6477	1.6449	1.6539	1.6594
The average length of overall length	38.1129							
The average length of diameter	1.6509							

The micro-drilling theoretical length is 38 ± 0.20mm and blade diameter is 1.65mm. The average result of micro-drilling blade diameter measured with a micrometer is 1.64309mm. The difference between the two is 0.0009mm. Therefore, the measurement method based on machine vision can reach micron scale, be able to meet the actual demand.

Conclusions

The detection method of micro-drilling geometry based on machine vision is applied to measure the size of the tiny parts. Because vision measurement technology can be meet the high efficiency, high precision measurement requirements, it is widely used in the field of industrial production and testing.

Acknowledgements

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