Micro pin header defect detection system based on OpenCV

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Abstract: In order to solve the problems of low detection efficiency and large detection error in the process of manual quality inspection, a full-automatic defect detection system is built. The system uses an industrial camera, selects a suitable light source for image acquisition, uses the open source OpenCV visual library for image processing and defect contour recognition, and sets the screening conditions for unqualified products. The system can detect whether the needle arrangement has defects in real time and classify them according to different defect categories. It can greatly improve the detection efficiency of needle arranging production enterprises. Through a large number of experimental tests, the detection success rate can reach 98.67%, which shows that the system is feasible.

1. Introduction

As a kind of connector widely used in PCB circuit boards of electronics, electrical appliances and instruments, the function of row pin is to act as a bridge between blocked or isolated circuits in the circuit and undertake the task of current or signal transmission. This kind of micro electronic components often produce defects due to process and other factors. The manufacturer's conventional detection method is manual detection, but this method has the disadvantages of low efficiency and large error. At present, machine vision technology has been widely used in the quality control and quality assurance inspection system of manufacturing industry\textsuperscript{[1-2]}. This paper combines needle detection with machine vision to build an automatic needle defect detection equipment with faster efficiency and higher precision.

As an effective technology in workpiece detection, machine vision has emerged a large number of cases of defect detection using machine vision at home and abroad. Sun Xiaobang\textsuperscript{[3]} and others have developed a fully automatic detection equipment based on machine vision, which can automatically load and unload materials and automatically screen qualified and defective products, which can meet the detection requirements of end face defects of shock absorber piston rod. After a lot of verification, it shows that the system has the advantages of fast detection speed, high stability and no error detection. Aiming at the problems of low manual detection efficiency and high labor intensity of spring bearing seat, Li Qian \textsuperscript{[4-5]} and others studied the defect types and defect characteristics of spring bearing seat, analyzed and summarized its defect detection process, proposed a defect detection method of spring...
bearing seat based on machine vision, and realized the automation of defect detection. The experimental results show that this method can accurately judge the size of spring bearing seat, welding slag, notch and character, and the detection accuracy can reach 98%. Tu Ke Ling and others automatically recognized the characteristic quality of 400 seeds of pepper varieties through machine vision technology, improved the selection of pepper seeds, and can be used to distinguish high-quality seeds from poor seeds.

This paper takes $2 \times 6p, 2\text{mm}$ spacing needle arrangement as a sample, a set of automatic needle arrangement detection device is built, and the OpenCV open source vision library is used for image processing and contour detection to identify the defects of the workpiece. The research content of this paper has a certain guiding role in improving the production efficiency and automation level of needle arranging enterprises.

2. Image preprocessing

Due to the accuracy of the image acquisition equipment and the influence of dirt and dust on the workpiece surface, in order to better identify the workpiece defects, it is necessary to enhance the characteristics of the target object and suppress the non-target object while enhancing the target object. The general solution is to preprocess the image. This paper uses the open source OpenCV library for image preprocessing, mainly including gray processing, image expansion, median filtering, threshold segmentation, mask and other operations, which provides image materials for the next step of defect detection. The pretreatment steps are shown in Figure 1.

![Image preprocessing process](image)

Figure 1. Image preprocessing process

2.1. Image acquisition and gray processing

The system adopts CCD (mv-em120m / C) industrial camera and bt-2307 double telecentric lens. The voltage of the annular light source is adjusted to 24V, and the distance between the lens and the workpiece is adjusted to 200mm for shooting. Figure 2 (Note: A is a qualified part, B is a part whose spacing meets the strength, C is a part whose spacing does not meet the strength, and D is a part with missing teeth) shows the collected images of workpieces in four different states. Adopt color in OpenCV Library : The bgr2gray function converts a color image into a gray image.

![Workpiece acquisition diagram](image)

Figure 2. Workpiece acquisition diagram

2.2. Image expansion

Because the center point of the detected part in the collected workpiece drawing has a cavity due to the reflection factor, this paper uses the expansion processing to process the original collected image. Image corrosion is to enlarge and coarsen the highlighted area or white part of the image, so that the highlighted area of the result image becomes larger than that of the original image. Through the function cv2.dilate in OpenCV, set the size of convolution kernel to $7 \times 7$ and the number of iterations to 30 to obtain the processing result as shown in Fig. 3.
2.3. Image denoising

In this paper, the nonlinear smoothing technology median filter is used to smooth the image. Median filter is an image processing technology that can effectively suppress noise based on the sorting statistical theory. Median filter replaces the value of a point in a digital image or digital sequence with the median value of each point in a neighborhood of the point, so that the surrounding pixel values are close to the real value, Thus, isolated noise points are eliminated. The gray value of the initial graph at point \((x, y)\) is \(A(x, y)\). Assuming that the gray value of the median filtered image at the same point is \(B(x, y)\), then:

\[
B(x, y) = \text{Median}\{A(x - k, y - 1), k, 1 \in W\}
\]

(1)

Where \(W\) is the selected window size\(^7\).

The convolution kernel parameter in the function \(\text{cv2.medianBlur}\) has been tested for many times, and \(K\) is selected as the parameter in the function. The image after median filtering is shown in Figure 4.

3. Defect detection principle

3.1. Contour extraction

Contour extraction is a key step in defect detection. In this step, \(\text{cv2.findContours}\) function is used to extract, \(\text{RETR_TREE}\) parameter is used to establish a contour of hierarchical tree structure, \(\text{CHAIN_APPROX_NONE}\) is used to store all contour points, and the pixel position difference between adjacent two points is no more than 1. The formula is as follows. Finally, the extracted contour is drawn through \(\text{cv2.drawContours}\) function, The detected contour is filled.

\[
\text{Max}(\text{abs}(x_1 - x_2), \text{abs}(y_2 - y_1)) = 1
\]

(2)

3.2. Number of detected contours

One of the conditions for the defect detection design of the system in this paper is the number of needle teeth. Due to the influence of errors in image processing and image acquisition, the detected contour may be misdetected. Therefore, before the contour quantity detection operation, the contour area is detected through \(\text{cv2.contourArea}\) function. The obtained contour area data are shown in Table 1. According to the detected data, the area screening conditions are set: \(s > 400\). If the conditions are not met, the contour is ignored and the number of contours is not included. Finally, the number of contours \(n\) is obtained.
Table 1. Contour area table

| Serial number | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 |
|---------------|----|----|----|----|----|----|----|----|----|----|----|----|
| Contour area   | 494.5 | 465.0 | 681.5 | 625.5 | 704.5 | 406.0 | 526.0 | 662.5 | 661.0 | 622.0 | 565.5 | 455.5 |

3.3. Image moment

Because the image moment involves distance x and distance y, it is related to two distances and one gray value. The specific definitions are as follows:

The $p+q$ order geometric moment $m_{pq}$ and center distance $\mu_{pq}$ of image $f(x, y)$ are:

$$m_{pq} = \sum_{x=1}^{M} \sum_{y=1}^{N} x^p y^q f(x, y)$$  \hspace{1cm} (3)

$$\mu_{pq} = \sum_{x=1}^{M} \sum_{y=1}^{N} (x - \overline{x})^p (y - \overline{y})^q f(x, y)$$  \hspace{1cm} (4)

Where M and N are the length and width of the image respectively, and $f(x, y)$ corresponds to the gray value of the image at point $(x, y)$.

According to the definition of moment, the gray level of two-dimensional image is represented by $f(x, y)$, and the formula of zero order moment $m_{00}$ is as follows, which represents the sum of image gray levels.

$$m_{00} = \iiint f(x, y) \, dx \, dy$$  \hspace{1cm} (5)

The first moments $m_{10}$ and $m_{01}$ of the image are used to determine the gray center of the image. The formula is as follows:

$$\overline{x} = \frac{m_{10}}{m_{00}}, \quad \overline{y} = \frac{m_{01}}{m_{00}}$$  \hspace{1cm} (6)

The moment values of all contours in the image can be obtained by using the cv2.moments function in OpenCV. The center of gravity coordinates of all contour points can be obtained by setting up the cycle program through formula (3). Finally, the center of gravity coordinates of each contour are drawn in the detection image through the cv2.puttext function. See Table 2 for the center of gravity coordinates of each contour measurement of the qualified work piece.

Table 2. Contour center of gravity coordinates

| number | 0 | 1 | 2 | 3 | 4 | 5 |
|--------|---|---|---|---|---|---|
| coordinates | (445,438) | (554,433) | (666,429) | (775,427) | (886,422) | (995,421) |
| number | 6 | 7 | 8 | 9 | 10 | 11 |
| coordinates | (449,546) | (559,544) | (669,542) | (780,538) | (890,537) | (998,531) |

3.4. Row needle spacing measurement

In this algorithm, the center of gravity coordinates of two adjacent rows of needles are subtracted, and the absolute values are read to obtain the row needle direction and direction spacing respectively, as shown in Table 3 and table 4. From the data in the table, the minimum detected spacing is 108 and the maximum is 115. Considering the errors in the detection process, the spacing screening condition is set as $100 \leq s \leq 120$ as normal parts; $S \geq 150$ or $s \leq 70$ means that the strength requirements are not met, and the output signal is 0; $120 < s < 150$ or $70 < s < 100$ is the correctable range, and the output signal is 1.

Table 3  X-direction spacing of row needles

| number | 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 6-7 | 8-9 | 9-10 | 10-11 |
|--------|-----|-----|-----|-----|-----|-----|-----|------|-------|
| Spacing (s) | 109 | 112 | 109 | 111 | 109 | 110 | 110 | 111 | 110 |

Table 4  X-direction spacing of row needles

| number | 0-6 | 1-7 | 2-8 | 3-9 | 4-10 | 5-11 |
|--------|-----|-----|-----|-----|------|------|
| Spacing (s) | 108 | 111 | 113 | 111 | 115 | 110 |
4. Result analysis
According to the algorithm described in this paper, the workpiece defects can be identified and judged effectively. The identification results are shown in Table 5. A total of 300 samples were tested in this experiment. The sorting results were 244 qualified products, all of which were tested successfully, and the qualified rate was 100%. All 30 missing teeth were tested successfully, and the qualified rate was 100%. There are 16 unqualified tooth pitch parts, of which 2 failed to be tested are correctable parts, and the qualified rate is 87.5%. 10 pieces of tooth pitch can be corrected if they meet the strength requirements, of which 2 pieces fail to pass the test, and the qualified rate is 80.0%. The success rate of comprehensive experiment was 98.67%. Due to the jitter of workpiece during transmission and the accuracy of camera and other acquisition equipment, the recognition accuracy can not reach 100%, but it can still meet the needs of film arranging processing enterprises.

| Workpiece type                          | Should identify | Real recognition | Qualified rate |
|-----------------------------------------|-----------------|-----------------|----------------|
| Qualified products                      | 244             | 244             | 100%           |
| Missing tooth                           | 30              | 30              | 100%           |
| Tooth pitch does not meet strength      | 16              | 14              | 87.5%          |
| Tooth pitch meets strength              | 10              | 8               | 80.0%          |
| total                                   | 300             | 296             | 98.67%         |

5. Conclusion
Based on OpenCV visual library, this paper proposes a set of needle defect detection system based on machine vision technology. After experimental verification, 300 samples are tested. The test results show that the detection success rate can reach 98.67%, indicating that the needle defect detection algorithm and equipment proposed in this paper are feasible and efficient. It has certain reference and application value for improving the detection efficiency of row needle processing enterprises.

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