Intelligent Recognition and Visual Measurement System Based on Workpiece Primitives to be Measured

Senwei Li[1], Tianxiang Zhai[1], Shukai Yin[2], Xiaolong Huang[3], Xue Mei[1*]

[1] *Nanjing Tech University, No. 30 Puzhu South Road Jiangbei new area, Nanjing, 211816, China*
[2]*University of California, Los Angeles, 405 Hilgard Avenue, Los Angeles, CA 90095-1405, the United States of America*
[3] *Nanjing Dashu Intelligent Technology Co. Ltd, No. 9 Qiande Road Jiangning National High Tech Park, Nanjing,211122, China*

Abstract

With the improvement of industrial manufacturing level, there are many kinds of workpieces and complex parameters. Traditional measurement methods are inefficient in the face of new products or different customer needs. It is urgent to develop a general and efficient measurement system. Based on primitive extraction technology of the workpiece to be measured, the intelligent recognition and vision system can automatically identify the type of workpiece and measure and calculate the relevant parameters. The core of this system is image processing and automatic recognition. On the premise of ensuring high precision and high stability, it has stronger universality and higher intelligence.

Keywords

Primitive extraction; workpiece; image processing; automatic recognition

1. Introduction

With the development of intelligent technology, the automation level and status of industrial manufacturing are becoming higher and higher. Accordingly, higher requirements are put forward for the inspection specifications of industrial products. In the actual inspection process of workpiece, because the types of workpieces to be tested and the types of parameters to be measured are different, the manual inspection is time-consuming and laborious, and the non-contact measurement method based on machine vision emerged as the times require [1-5].

However, the degree of system automation is low; The non-contact measurement method can not only be applied to the measurement of traditional mechanical workpiece, but also widely used in geography, agriculture, medicine and other aspects [6-10].

The system uses the non-contact measurement method based on primitive extraction and identification [11] to improve the detection efficiency and universality. Taking the workpiece primitive (line, curve, circle, ellipse, rectangle, arc, etc.) to be measured as the detection unit, the intelligent recognition of workpiece and automatic measurement of parameters can be realized; This system is convenient for adding different types of workpieces, and can realize the measurement of various sizes and irregular workpieces.

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EMAIL: 1184193332@qq.com (Senwei Li); 1301596214@qq.com (Tianxiang Zhai); shukaiyin1122@g.ucla.edu (Shukai Yin); 1245623687@qq.com (Xiaolong Huang); seraph_mx@163.com (Xue Mei)
ORCID: 0000-0002-4220-2984 (Senwei Li); 0000-0003-2521-0605 (Tianxiang Zhai); 0000-0002-3279-7435 (Shukai Yin); 0000-0002-9694-5564 (Xiaolong Huang); 0000-0002-4751-0644 (Xue Mei)

2. Intelligent identification and measurement of workpiece

The intelligent recognition and visual measurement system is based on the primitive of the workpiece to be tested. According to the type and number of primitives and the surface area of the workpiece to be measured, the intelligent recognition of the workpiece to be measured is realized.

2.1. Image acquisition and preprocessing

The example of the image acquired by the system for the measured workpiece is shown in Figure 1. The hardware of the system is mainly composed of optical platform, linear motor, servo motor, laser scanner and industrial computer. The intelligent recognition and visual measurement system is based on machine vision. The principle of workpiece size measurement is relatively complex. The system is mainly composed of four functional modules: image acquisition, image data processing, result display and data communication. In order to make the whole system operate coordinately and have accurate, fast and stable measurement ability, it is necessary for all modules to work together efficiently. Among them, the image acquisition module and the image data processing module play a vital role in the whole visual measurement system.

Figure 1: Example of image acquisition

Affected by electromagnetic interference, environmental dust, workpiece surface polishing and other factors, it is easy to cause noise points in the acquired image.

The principle of circular primitive is to solve the value of (a, b, c) in circular equation (1) so that the value of $E(a, b, c)$ in equation (2) can be minimized. Assume that the coordinate equation of the circular primitive is: $(x - A)^2 + (y - B)^2 = R^2$;Let $a = -2A, b = -2B, c = A^2 + B^2 - R^2$, another mathematical form of the circular equation can be obtained:

$$x^2 + y^2 + ax + by + c = 0 \tag{1}$$

Suppose that there are n points $\{(x_i, y_i)\}(i = 0,1,2, \cdots n - 1)$ to be fitted on the image, the difference between the square sum of the distance from the center of the circle and the square of the radius is: $\delta_i = (x_i - A)^2 + (y_i - B)^2 - R^2 = x_i^2 + y_i^2 + ax_i + by_i + c$ Then the sum of squares $E(a, b, c)$of $\delta_i^2$is:

$$E(a, b, c) = \sum_{i=0}^{n-1} \delta_i^2 = \sum_{i=0}^{n-1}\left[\left(x_i^2 + y_i^2 + ax_i + by_i + c\right)\right]^2 \tag{2}$$

Therefore, the problem of identifying circular primitives can also be transformed into an optimization problem. That is, solve $\tilde{a}, \tilde{b}, \tilde{c}$such that $E\left(\tilde{a}, \tilde{b}, \tilde{c}\right) = min\, E\,(a, b, c)$, calculate the partial derivative of equation (4) and make it equal to 0:

$$\begin{cases} \frac{\partial E(a,b,c)}{\partial a} = \sum_{i=0}^{n-1} 2\left(x_i^2 + y_i^2 + ax_i + by_i + c\right)x_i \\ \qquad = 0 \\ \frac{\partial E(a,b,c)}{\partial b} = \sum_{i=0}^{n-1} 2\left(x_i^2 + y_i^2 + ax_i + by_i + c\right)y_i \\ \qquad = 0 \\ \frac{\partial E(a,b,c)}{\partial c} = \sum_{i=0}^{n-1} 2\left(x_i^2 + y_i^2 + ax_i + by_i + c\right) \\ \qquad = 0 \end{cases}$$

Let $$\begin{cases} C = n\sum_{i=0}^{n-1} x_i^2 - \left[\sum_{i=0}^{n-1} x_i\right]^2 \\ D = n\sum_{i=0}^{n-1} x_i y_i - \sum_{i=0}^{n-1} x_i \sum_{i=0}^{n-1} y_i \\ E = n\sum_{i=0}^{n-1} x_i^3 + n\sum_{i=0}^{n-1} x_i y_i^2 - \sum_{i=0}^{n-1}\left(x_i^2 + y_i^2\right) \cdot \sum_{i=0}^{n-1} x_i \\ G = n\sum_{i=0}^{n-1} y_i^2 - \left[\sum_{i=0}^{n-1} y_i\right]^2 \\ H = n\sum_{i=0}^{n-1} y_i^3 + n\sum_{i=0}^{n-1} x_i^2 y_i - \sum_{i=0}^{n-1}\left(x_i^2 + y_i^2\right) \cdot \sum_{i=0}^{n-1} y_i \end{cases}$$

The solution is:

$$\begin{cases} a = \frac{HD-EG}{CG-D^2} \\ b = \frac{HC-ED}{D^2-GC} \\ c = -\frac{1}{n}\left[\sum_{i=0}^{n-1} \begin{matrix} \left(x_i^2 + y_i^2\right) + \\ a\sum_{i=0}^{n-1} x_i + b\sum_{i=0}^{n-1} y_i \end{matrix}\right] \end{cases}$$

Then the final solution is: $A = -a/2, b = -b/2, R = 1/2\sqrt{a^2 + b^2 - 4c}$, in this way, the equation of the circle is obtained, that is, the identification of the circle primitive is completed.

The primitive features in the background database of the system can be updated in real time. If the primitive library does not contain extracted primitive types and new primitives need to be added, the new primitive features will be dynamically added to the primitive feature library, and then the primitive will be trained to optimize the extraction and recognition program and improve the primitive recognition rate.

2.2. Intelligent recognition of workpiece

The extraction, identification and calculation process of the system based on the workpiece primitive to be tested are as follows:

1. The preprocessed image is input into the image processing module, and then threshold segmentation and edge extraction of workpiece image;
2. Call the primitive processing program, segment the edge contour to obtain the workpiece primitive, and identify the primitive and calculate the parameters;
3. If the primitive type is identified as ellipse, the primitive processing program will automatically determine the parameters to be calculated, including ellipse center coordinates, major axis, minor axis, area, inclination;
4. Determining the type of workpiece, call the corresponding processing program to display and store the measurement results according to the measurement requirements of the workpiece; Compare with the standard data of the workpiece to judge whether the measured workpiece is qualified.

The workpiece feature library designed by the system for a factory is shown in Figure 2.

Workpiece feature library

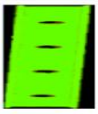
	Image acquisition	Surface area (mm²)	Primitive type and quantity	Identification results
Workpiece-1		8250. 65	four circular primitives two parallel segments	Model-17
Workpiece-2		953. 58	one circular primitive Two arcs	Model-1
Workpiece-3		1026132. 62	Two rectangles one ellipse two parallel segments	Model-32
...	...	...	...	...

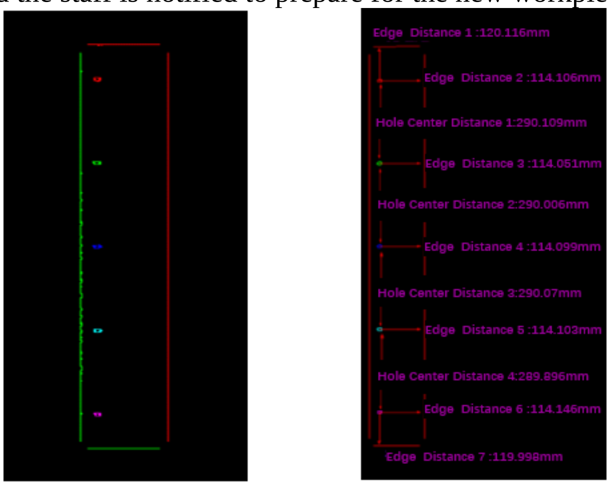
Figure 2: Workpiece feature library

According to the size of the area, we divide the workpieces into three categories: large, medium and small. Workpieces with a surface area of less than 1000 mm^2 are called small workpieces, and workpieces with a surface area of more than 100000 mm^2 are called large workpieces, and vice versa are medium workpieces; After using the surface area of the workpiece to screen the workpiece, the recognition speed of the workpiece can be accelerated and the measurement efficiency can be effectively improved.

2.3. System test and analysis

In the actual measurement process, the system can realize the automatic identification of workpiece types and the automatic measurement of parameters. Especially for the measurement of irregular shaped workpiece, compared with the traditional manual non-contact measurement method, the measurement efficiency and accuracy have been greatly improved.

For a new workpiece, after acquiring the workpiece image, it is processed by the image processing module to extract and segment the primitive of the measured workpiece image, as shown in Figure 3 a); The workpiece primitive to be measured has identified two pairs of parallel line segments and five circular holes. Call the relevant primitive processing program to calculate the hole center distance and hole edge distance of the workpiece. The measurement parameters are marked as shown in Figure 3 b); Since the workpiece does not exist in the system database, it is automatically defined as a new workpiece (Model-X) and the staff is notified to prepare for the new workpiece.



a) Image processing b) Measurement parameters

Figure 3: Example of new workpiece (Model-X) parameter measurement

In order to better verify the performance of the system and analyze the measurement effect of relevant parameters of the workpiece, Figure 4 shows the measurement example of the system for angle, curvature and radius parameters, and Figure 5 shows the measurement example of the system for complex parameters. The experimental results show that the system can effectively measure various complex parameters of the workpiece and accurately judge whether the workpiece is qualified or not.

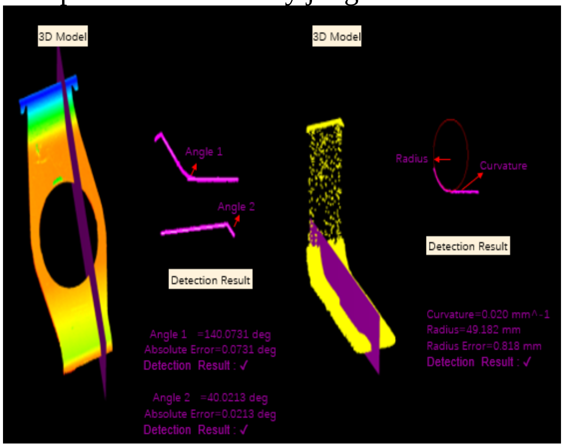


Figure 4: Example of common parameter measurement

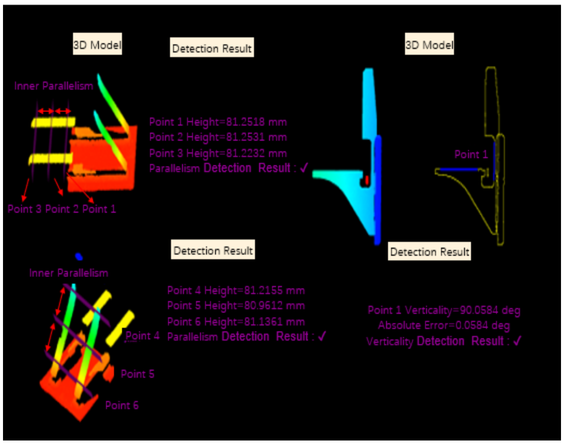


Figure 5: Example of complex parameter measurement

This system can not only realize the measurement of common parameters such as spacing, angle, radius and so on; It can also measure complex parameters such as parallelism, curvature and perpendicularity. The maximum measurement range of the system can reach 3000 mm*1000 mm*500 mm and the accuracy can reach 0.01-0.5 mm.

2.4. Conclusion

The system can be widely applied to the measurement of various workpieces, especially the measurement of irregular workpieces. It overcomes many shortcomings of manual measurement, such as poor consistency, large measurement error and no legal person measurement. At the same time, the system greatly improves the measurement efficiency; It can intelligently identify the type of workpiece to be measured, and realize the non-contact measurement of three-dimensional dimension of workpiece with high precision.

The system can also be used as an intelligent node in a modern factory or workshop. The detected data of this system can be transmitted to the cloud of the factory, and the system receive instructions from the cloud as an intelligent scene of an intelligent manufacturing enterprise.

The newly added measuring workpieces of this system are simple and fast, with a wide range of applications. It has good portability and is easy to migrate to different scenarios. It is especially suitable for industries with a large number of mechanical workpieces, or for the intelligent identification and measurement of workpieces in warehouses, such as automobile production lines, high-speed rail production lines, aviation production lines, military production lines, and so on. It has a broad application prospect.

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4. References

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