Design of High Precision Image Measurement System for Small Workpiece

Xuelin Zhang, Fengzhi Fu, JunPeng Fan and Hua Fan*

Laser Institute, Qilu University of Technology (Shandong Academy of Sciences), Jinan, China

*Corresponding author: h_fan@sdlaser.cn

Abstract. At present, there are many problems in the measurement of small machined parts (size $\leq 70$mm, such as micro circuit board, small non-standard parts, etc.), such as the difficulty and low efficiency of detection, the large data of sizes to be detected, and mainly rely on manual work. A high-precision image measurement system based on machine vision is designed in this paper, and the systematic error and random error of the machine vision measurement system are improved from hardware and software. Experiments show that size measurement of small workpiece with high efficiency and high accuracy can be realized by the system successfully. The measurement accuracy reaches micron level, which fully meets the testing requirements of production line, and has great value of industrialization promotion.

Keywords: Machine vision, dimension measurement, image measurement.

1. Introduction

The optical or mechanical measuring instruments are mainly used to measure parts as traditional workpiece measurement methods with low efficiency and poor accuracy, and the measurement results are easily interfered by human factors [1]. Machine vision technology mainly uses sensors to collect and process the image of the object to be measured in real time. Compared with the traditional measurement method, machine vision technology has the advantages of non-contact, high time efficiency and etc.

Fan Shuai [2] et al. used the Laplace algorithm to extract the edge of the bearing based on machine vision technology and then used the Hough transform to measure the inner and outer diameter of the bearing. Lei Jingfa [3] et al. obtained the three-dimensional data of the hydraulic component corresponding position based on the binocular vision system, and realized the high robustness measurement of the hydraulic component. Xie Zexiao [4] et al. realized the circular hole profile measurement of thin-walled parts based on binocular vision. Li Zhiyu [5] et al. proposed a circular pose measurement method based on line structured light. Zhu Ge [6] et al. designed a part concentricity measurement system based on machine vision.

For the complex size measurement of small workpieces, the application of machine vision technology is still relatively scarce, because of the variety of small workpieces, complex structure, large volume, and more location points need to be measured and detected, at the same time, using manual measurement is difficult and inefficient. For this reason, a high-precision image measurement
system based on machine vision is designed in this paper, and the accuracy of machine vision measurement system is improved from hardware and software aspects, so as to realize the rapid detection of micro workpiece with high efficiency and high accuracy.

2. Overall System Design
The whole system is mainly composed of two parts: the hardware part and the software part. The two parts communicate through the network port. The overall design diagram of the system is shown in Figure 1.

![Figure 1. Schematic diagram of overall system design.](image)

The overall system can be divided into two parts: software part and hardware part. Among them, the software part mainly relies on the industrial computer to complete the communication with the camera, light source and motor. By realizing effective control of the camera, light source and mechanical movement, a clear image of the workpiece can be obtained. Through the image processing, the size measurement of the micro-small workpiece is finally completed; the hardware part mainly includes the industrial computer, camera, telecentric lens, light source controller and light source, etc., to ensure that the image can be accurately detected after being transmitted back to the industrial computer.

3. Hardware Design

3.1. Camera and light source
The hardware structure of the system is the framework that supports the entire system and is responsible for completing all the work before the image processing of the workpiece, which involves functions of transmission, data collection and related processing of the workpiece. The hardware part mainly includes industrial cameras, light sources, sensors, and industrial computers. The industrial camera uses Hikvision’s 5 million pixel 2/3" CMOS Gigabit Ethernet industrial camera named MV-CA050-10GM, as shown in Figure 2. The camera uses a global shutter, and the transmission frame rate can reach 23.5fps/s. The frame rate can effectively ensure that the industrial camera can obtain the image of the workpiece on the production line.
In terms of light source, first of all, the metal surface of the workpiece will reflect light. In combination with the actual operating conditions of the production line, a backlight source is selected to cooperate with image collection to obtain high-quality images. The light source is shown in Figure 3.

![LED backlight](image)

**Figure 3.** LED backlight.

### 3.2. Telecentric lens design

Industrial lenses are very important imaging components in machine vision systems. For the system to fully perform its functions, industrial lenses must meet the requirements. With the widespread application of machine vision systems in the field of precision inspection, it is difficult for ordinary industrial lenses to meet the inspection requirements. To make up for the shortcomings of ordinary lens applications and meet the needs of precision inspection, telecentric lenses came into being. Based on its unique optical characteristics: high resolution, ultra-wide depth of field, ultra-low distortion and unique parallel light design, the telecentric lens brings a qualitative leap to machine vision precision inspection. The schematic diagram of the double telecentric optical path is shown in Figure 4. For this reason, we specially designed a 2/3" double telecentric industrial lens, as shown in Figure 5.
4. Software Design

4.1. Software framework design

The system software processing flowchart is shown in Figure 6, which mainly includes image acquisition module, image processing module, measurement module, data processing module and so on. After the industrial camera collects the workpiece image, it undergoes a series of mathematical morphology processing by the image processing module to complete the size measurement, obtain the measurement data, and output the inspection report after the result statistics and analysis.
4.2. Software interface design

The software interface runs on an industrial computer and is developed using the VS +QT development environment. The main operation interface is shown in Figure 7. The interface is simple and friendly, and the operation is simple. Through simple operations, you can turn on the camera and light source, create a measurement module, set various parameters, measure the workpiece in real time, and display the processing results on the software interface. For data processing results, you can call the data processing sub-interface (Figure 8) for data analysis and comparison, and generate a test report with one click.

Figure 6. Software processing flowchart.

Figure 7. Software main interface.
5. Experiment and Analysis

In actual production, product size measurement of small processed parts is a crucial link. The high-precision image measurement system designed in this paper is used to actually measure a batch of small processed workpieces, and compare the data with traditional manual intervention measurement methods. Each set of experimental data is the average of 6 measurements. The results are shown in Table 1.

Table 1. Experimental data.

| Number of experimental groups | Measurement methods | Number of measurement items | Required time (s) | measurement accuracy (um) | False detection rate (%) |
|------------------------------|---------------------|----------------------------|------------------|---------------------------|--------------------------|
| 1                            | system Artificial   | 1                          | 298, 920         | <5, 10                    | 0.3, 1                   |
| 2                            | system Artificial   | 2                          | 588, 2145        | <5, 10                    | 0.4, 2.5                 |
| 3                            | system Artificial   | 3                          | 892, 2860        | <5, <15                   | 0.4, 3.7                 |
| 4                            | system Artificial   | 4                          | 1158, 3858       | <5, <15                   | 0.5, 5.5                 |
| 5                            | system Artificial   | 5                          | 1480, 6150       | <5, <20                   | 0.5, 8                   |

From the experimental results, it can be analyzed that the high-precision image measurement system designed in this paper measures 1000 qualified products simultaneously with the traditional manual intervention measurement method, which has obvious advantages in terms of measurement speed, error detection rate and measurement accuracy. As the passage of time, artificial gradually tired,
so the more the workpiece, the more the measurement of project indicators, the more obvious the advantage will be.

6. Conclusions
The design based on machine vision image measurement technology has good detection performance. The system can successfully realize the size measurement of small workpieces with high measurement efficiency and measurement accuracy of micron level. It fully meets the production testing requirements of automated production lines, has broad market prospects and has great industrialization promotion value.

Acknowledgments
This work was financially supported by Young Doctor Cooperation Foundation of Qilu University of Technology (Shandong Academy of Sciences)[Grant number 2018BSHZ009] and Key R & D projects in Shandong Province[Grant number GG201809200157].

References
[1] Han Liang. Measuring method of bearing inner and outer diameter based on machine vision [J]. Machinery Manufacturing and Automation, 2020, 49 (02): 229-231.
[2] Fan Shuai, Tang Qiting, Lu Manhuai. Detecting and classifying the inner - outer ring size of bearings based on machine vision [J]. Rocess Automation Instrumentation Vol. 37 No. 11 November 2016: 77-80, 87.
[3] Lei Jingfa, Wei Wang, Li Yongling, Zhang Miao, He Yu. Dimensionality Measurement of Weak Texture Hydraulic Components Based on Binocular Vision [J/OL]. Laser & Optoelectronics Progress: 1-14 [2020-08-18 ].
[4] Xie Zexiao, Wang Xiaodong, Gong Hanlei. Round-Hole Profile Measurement of Thin-Walled Parts Based on Binocular Vision[J]. Chinese Journal Of Laser, 2019, 46(12): 179-186.
[5] Li Zhiyu, Lin Jiarui, Sun Yanbiao, Chu Jigui. A method for measuring circular pose based on line structured light sensor [J/OL]. Acta Optics Sinica: 1-17 [2020-06-14].
[6] Zhu Ge, Pan Shuaijia, Yu Xiaoyu, Pu Zhiwei, Chen Fan. Design of concentric measurement system for precise parts based on machine vision [J]. Transducer and Microsystem Technologies, 2020, 39 (04): 77-79, 82.