ISSN: 2664-9640

Research on Automatic Assembly System Based on Machine Vision

Fei Zhao, Jia Wang, Tao He, Manman Wang, Renqiang Li

Sichuan University of Science & Engineering, Yibin 644000, Sichuan, China

Abstract

In the assembly process, most enterprises (especially small and medium-sized enterprises) use manual assembly at present, which results in large amount of labor and low assembly efficiency. Taking yb100 rotor oil pump as the research object, the 3D structure of virtual prototype is designed by SolidWorks software, the camera internal parameter calibration is done by Halcon, the hierarchical system control and human-computer interaction platform are built, and the physical construction and assembly process description are completed. Finally, through the calculation of repeatability test and the experimental analysis of assembly time, it can be concluded that the repeated positioning accuracy of automatic assembly is 0.02mm, and according to the positioning time of test parts, it can be concluded that each part is within 500ms, which meets the requirements of oil pump assembly in accuracy and efficiency.

Keywords

Machine vision;Automatic assembly;Platform construction;Experimental analysis.

1. Introduction

With the continuous development of the automation industry, the labor cost is rising, and the labor shortage is becoming more and more serious. In all fields of social production, industrial robots show powerful functions. As the last and most important part of the manufacturing process, assembly has the characteristics of repeatability and large time proportion. Industrial robots have the advantages of high speed, high precision and miniaturization in assembly. The use of robot assembly can solve the impact of the flow of manufacturing personnel in enterprises, improve the consistency of product quality, expand production capacity, reduce material waste and increase output rate. At the same time, it plays an important role in promoting industrial upgrading and improving market competitiveness. However, at present, the widely used industrial robot assembly mostly has the disadvantages of low automation and intelligence, poor flexibility, and high-precision assembly can not meet the requirements. In this regard, the integration of machine vision technology, robotics, digital image processing and automatic control technology is used to achieve the goal of automatic assembly process [1-2].

2. Overall scheme design of automatic assembly system

The design and assembly object is the rotor oil pump for yb100 motorcycle. Its size is 64 mm*8 mm. It is composed of pump body, inner rotor, outer rotor, pump cover and drive shaft. It has compact structure and small volume. It is more and more used in internal combustion engines, as shown in Figure 1.

The assembly process and requirements of yb100 oil pump are as follows: (1) the pin shaft is inserted into the pump body and pressed into the inner rotor, so that the shaft and the inner rotor can be smoothly matched. At the same time, the torque of the shaft and the torque of the inner rotor should be consistent when the inner rotor and the pin shaft are matched, and the assembly angle deviation of the parts should be ≤ 0.2 °; (2) Press in the outer rotor. Since the outer rotor and the inner rotor are eccentric, they need to be assembled at a certain angle to engage. Finally, install the pump body cover, and tighten three M5 fixing bolts with a tightening torque of 3~5N · m.

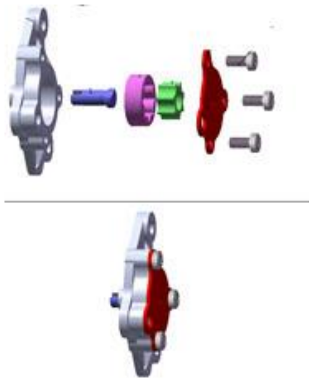


Fig. 1 main structure of YB100 oil pump

Design the assembly platform according to the assembly process and requirements.

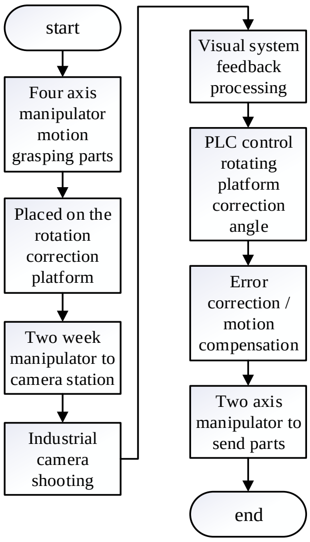


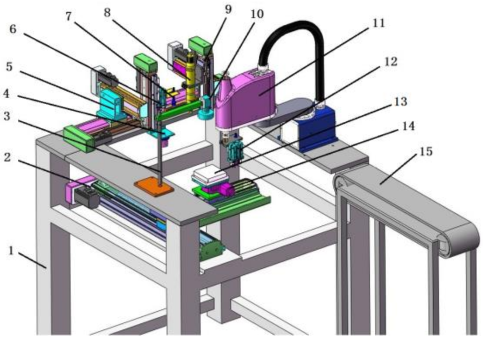
Figure 2 assembly flow chart

The design platform consists of a four degree of freedom SCARA manipulator, two three degree of freedom manipulators, a two degree of freedom manipulator, a rotating platform and a CCD camera. The full-automatic assembly process is shown in Figure 2.

Firstly, the four axis manipulator grabs the target part, loads it to the rotating platform, detects the sensor, and takes images with the industrial camera. After the recognition and processing of the visual system, the angle deviation value of the part is fed back to the rotating platform for correction, and then grabs and assembles after the assembly pose angle reaches the ideal state [3].

2.1. mechanical structure design

Based on the above assembly process and process requirements, SolidWorks software is used to carry out three-dimensional modeling of the automatic assembly platform, virtual simulation of assembly, design structure and rationality analysis of assembly process [4]. As shown in Figure 3.



1-workbench support；2-two axis manipulator；3-camera bracket；4-assembly station；5-three axis manipulator；6-pneumatic grab；7-vacuum sucker；8-pneumatic tightening gun；9-three axis manipulator；10-industrial camera；11-four axis manipulator；12-pneumatic grab；13-light source； 14-rotating platform；15-feeding device

Figure 3 design scheme of automatic assembly platform

It includes four DOF SCARA manipulator (ar4215), three DOF Manipulator (Panasonic A5), two DOF Manipulator (Panasonic A5), Medvedev MV-GED500C-T industrial camera, one rotating platform, one OMRON Programmable Controller CJ2M, three 4-axis motion control modules CJ1W-NC413, etc.

2.2. visual system design

The vision system is the core part of the whole system. Under the condition that the target parts can meet the requirements, the eye to hand system is selected to fix the industrial camera on the workbench [5]. The vision system in automatic assembly can be divided into three main parts: (1) industrial camera and camera, which are mainly responsible for image acquisition of target parts; (2) PC and machine vision software module are responsible for processing and analyzing the collected images; (3) The rotating platform and two axis manipulator correction module are responsible for correcting the attitude angle deviation of parts [6]. The camera system is shown in Figure 4.

Figure 4 vision system

In the process of image acquisition, the photographed parts may be distorted. The vision system should first complete the camera calibration. According to the calibration requirements and convenience, the camera is calibrated by Halcon software, and the operator Gen in Halcon software library is used_ Caltab generates a calibration chart. Then input the initial parameters of the camera into the Halcon calibration assistant, and generate internal parameter data by loading calibration plates (15~30 pieces) [7]. The specific calibration process is shown in Figure 5.

ISSN: 2664-9640

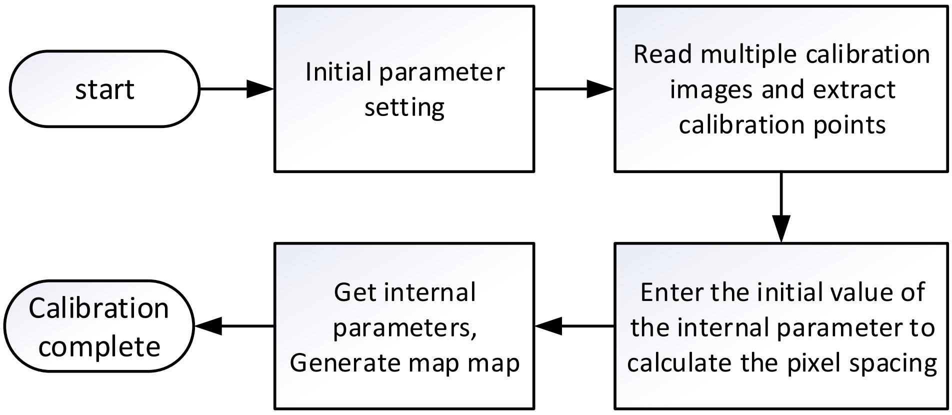


Figure 5 camera calibration process

The obtained internal parameter data are shown in Table 1.

Table 1 camera calibration internal parameter data

project	parameter	project	parameter
K1（μm）	1750.30e-6	Cx（pixel）	582.632
K2（μm）	-1.00375e8	Cy（pixel）	523.485
K3（μm）	6.3452e12	Sx	3.3822
P（μm）	-0.95642	Sy	3.47

2.3. control system design

In the whole control system, the automatic assembly platform is mainly controlled by OMRON CJ2M PLC. SCARA robot has its own output and input port to output and input the switching value. The machine vision system transmits the image to PC for image feature extraction after image acquisition, and then sends the processed information to PLC through RS232 serial port. Finally, PLC controls the action of each part of the mechanism. The control system framework is shown in Figure 6. The whole software control system can be divided into presentation layer, function layer, control layer and remote service layer. Each layer is connected with each other, and the automatic assembly platform is jointly controlled under the connection of RS232 and other serial ports [8].

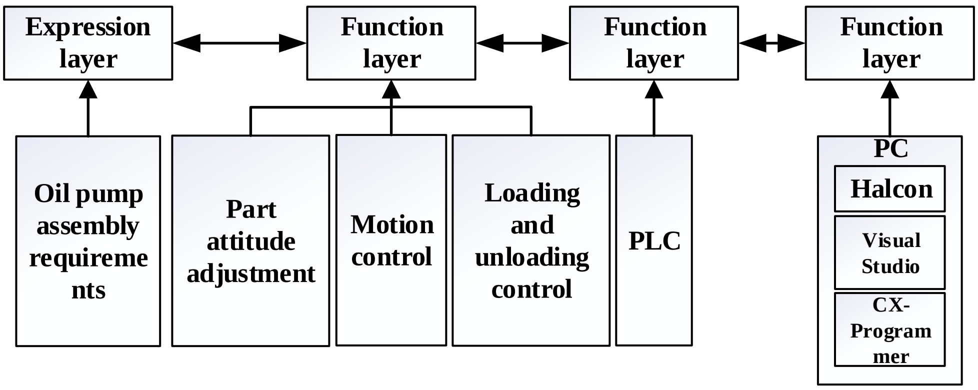


Figure 6 system software architecture

A complete and mature control system should have the following functions: (1) calibrating the internal / external parameters of industrial cameras; (2) Real time display and acquisition of target part image; (3) Carry out efficient and accurate recognition, image enhancement and other preprocessing for the collected images; (4) Data processing, which can extract and display effective information in the identified image; (5) It can select and classify the features of the image; (6) Save the acquired parameters, etc., and conduct real-time communication with the upper computer /plc through communication requirements; (7) Realize human-computer interaction. Through the human-computer interface, the entire automatic assembly platform can be operated and monitored on the PC side [9-10].

3. Physical construction and experimental analysis of assembly platform

3.1. physical construction

Under the virtual verification of 3D modeling, the whole design platform can complete the assembly process, which can be divided into SCARA joint robot system, Cartesian coordinate system robot system, visual processing system and upper computer control system. The physical drawing is shown in Figure 7.

Figure 7 assembly platform

3.2. Software interface design and image acquisition

According to the assembly requirements and modular function requirements, the software interface that can conduct human-computer interaction is designed by using visual studio and Halcon to compile[11]. The interface has complete functions and camera operation functions, such as turning on the camera, turning off the camera, etc; With observation window, the assembly can be viewed and monitored in real time; The PLC communication parameters are fully configured, and the operation status and communication status settings can be selected; You can select, set and generate templates. For image acquisition, image acquisition based on Halcon visual library is used, and the SDK provided by the manufacturer is used for real-time image acquisition. The acquired images are shown in Figure 8. This method has the characteristics of wider face, better secondary development, multiple functions and convenience.

Figure 8 image acquisition picture

3.3. Assembly process of automatic assembly platform

In the automatic assembly system, according to the assembly requirements, the assembly sequence of yb100 oil pump parts is: pump body, pin shaft, inner rotor, outer rotor, cover plate and bolt.

The SCARA manipulator motion control program is written in AR language of the teaching pendant. The SCARA manipulator moves at a certain speed and angle to grasp the target parts on the conveyor belt. The end of the SCARA manipulator is equipped with a gripper cylinder to realize pneumatic grasping. After the capture is completed, the rotating manipulator places the parts on the waiting rotating workbench, the two axis manipulator moves the target point of the workbench in a straight line, the sensor detects that the target has reached the predetermined location, the industrial camera collects the image, transmits the collected image to the PC, compares the collected image with the preset template image, and obtains the positioning deviation and attitude angle deviation according to the geometric center point, Then the information is transmitted to PLC for motion control, and the two axis manipulator and the rotating platform are controlled to correct the position and angle. After the correction, collect again and collect again to further feed back the position and pose of the parts. After "qualified", the two axis manipulator moves, the linear manipulator cooperates with the clamping claw cylinder to clamp the parts and place them on the platform, which completes the first part assembly. According to the assembly sequence, the pump body and pin shaft are assembled in turn until the whole assembly is completed. Figure 9 shows the part loading and grabbing, and figure 10 shows the part grabbing to the rotating platform.

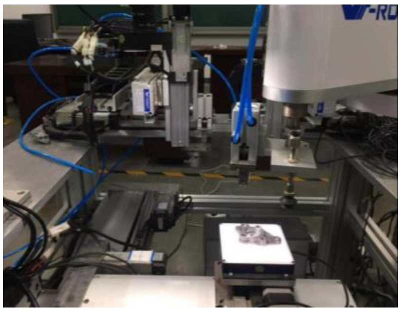


Figure 9 part loading diagram

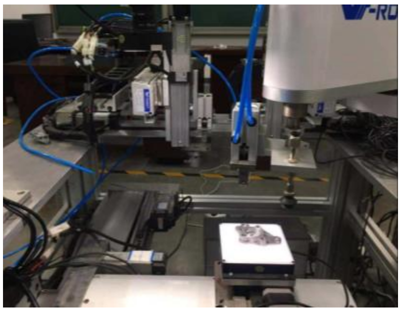


Figure 10 grab to rotating platform

After the feeding process is completed, the rotating platform is moved to the acquisition position by the two axis manipulator, and the image is collected according to the preset shooting frequency. The collected images are classified by GMM (Gaussian mixture model) and other algorithms in Halcon software library. NCC template matching based on gray scale is used to locate the position and orientation of the parts. Finally, it is matched with the position and orientation of the part template in the pre training library to obtain the position and angle deviation of the parts for matching. Figure 11 shows the part acquisition diagram.

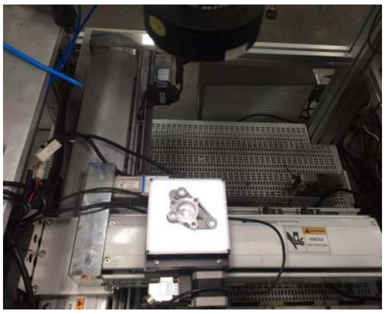


Figure 11 part acquisition diagram

After the pose adjustment is completed, move the rotating platform to the gripping point for gripping. Finally, after the parts are assembled to the preset station, prepare for the gripping of the next part, as shown in Figure 12.

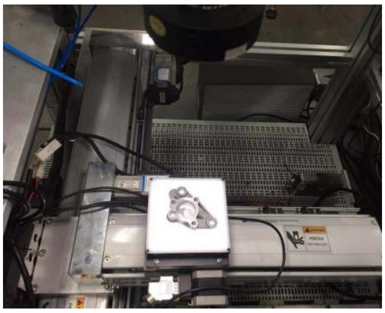


Figure 12 part acquisition diagram

3.4. Verification and test of automatic assembly experiment

Due to the influence of equipment accuracy and image processing method, there will be some errors in the repeated positioning of assembly, which will lead to assembly instability and even assembly failure. This requires the repeated error analysis of the position coordinates of the acquired image. The error analysis process takes the coordinates in the teaching pendant of SCARA manipulator as the standard, selects the outer rotor as the object, grabs the part to the image acquisition point through SCARA manipulator for acquisition, and reads the coordinates of the starting center of the part and the coordinates of the image acquisition point after image processing.

According to multiple groups of repeated experimental data, the standard deviation of appeal repeatability experiment can be calculated according to formula (2.1) [12].

$$\begin{cases} \bar{P} = \frac{1}{n}\sum_{i=1}^{n} p_i \\ u(p) = \sqrt{\sum_{i=1}^{n}(p_i - \bar{p})^2/n} \end{cases} \tag{2.1}$$

Where, P_i - data of the i th test; u(p) - repeatability test error.

Repeat the automatic test position coordinates on the same part for 10 times, read the position coordinates measured for different times of the part, and analyze the repeated positioning error of the outer rotor part, as shown in Table 2.

Table 2 repeatability test of outer rotor parts

position	X1	Y1	X2	Y2
1	236.33	658.48	845.69	759.15
2	237.05	658.25	846.95	759.58
3	236.58	658.36	845.36	760.80
4	236.40	659.28	845.22	759.37
5	236.90	658.17	845.69	759.88
6	237.16	658.89	846.25	758.64
7	235.98	657.93	845.88	757.42
8	236.91	658.32	845.13	759.68
9	236.60	658.76	845.72	759.43
10	236.02	658.59	846.29	758.94

According to formula (2.1) and the above table, it can be calculated that: $u(p)X_1$ =0.014mm; $u(p)Y_1$ =0.010mm; $u(p)X_2$ =0.012mm; $u(p)Y_2$ =0.013mm.According to the repeatability test error calculation, the repetitive positioning accuracy of automatic assembly is 0.02mm, which meets the assembly accuracy requirements.

Efficiency is a very important indicator to judge whether a device can be used in the factory. This automatic assembly requires statistics on the positioning time, including image acquisition and image processing. When the visual acquisition hardware is determined, the main time consumption depends on the visual algorithm. The classification algorithm and matching time will affect the assembly efficiency of parts[13-15]. Test positioning time: four parts in YB100 are taken for 10 times respectively. The time from shooting to the end of part positioning (position and angle) is obtained by using the least root mean square analysis method, as shown in Table 3.

Table 3 positioning time of test parts

Part name	Average positioning time /ms
Pump body	437.56
Outer rotor	405.72
Inner rotor	458.23
Bolt	485.39

4. Conclusion

This paper focuses on the research on the automatic assembly system of oil pump based on machine vision. Taking YB100 oil pump as the research object, aiming at the problems of low assembly efficiency, high labor intensity and low flexibility of semi-automatic assembly existing in the traditional manual assembly, the full-automatic assembly is designed. This design uses the existing mature technology and adopts an innovative way to combine vision and control to improve automation and intelligence. Through experimental analysis, it can be concluded that the repeated positioning accuracy of automatic assembly is 0.02mm in 10 times of repeated positioning of two points, and according to the positioning time of four different parts, it can be concluded that each part is within 500ms, which meets the accuracy and efficiency requirements of automatic assembly of oil pump.

References

[1] Wei Meng. Research on visual robot assembly technology under visual guidance [D]. Shandong: Shandong University, 2019

[2]Zhang WuJie, Ye Feng. Design of manipulator assembly system based on machine vision [J]. Computer measurement and control, 2018, 26 (8): 168-176

[3]Lu Zhengmao, Ma Boyuan. Research on automatic assembly system based on industrial robot [D]. Xi'an: Xi'an University of Electronic Science and technology, 2018

[4]Qiu Ruifang. Research on virtual assembly system of mobile four coordinate robot [D]. Shaanxi: Shaanxi University of science and technology, 2019

[5]Fu Gui, Liu Liwen. Research on bearing pedestal classification and recognition system based on machine vision [J]. Electromechanical engineering, 2019, 36 (10): 1115-1118

[6]Han Hao. Research on vision based industrial robot assembly line [D]. Tianjin Polytechnic Normal University, 2021

[7]Yang weijiao, Yang Xianhai, Xue Peng, et al. Hand eye calibration method based on Halcon [J]. Machine tools and hydraulics, 2021,49 (08): 35-37 + 71

[8]Cai Jinquan, sun Xinyue. Development of oil pump assembly line control system based on PLC [J]. Industrial control computer, 2018, 31 (2): 124-126

[9]Lei Tao, he Qingzhong, Wang Jia, et al. Research on intelligent assembly system of oil pump based on machine vision [J]. Machine tools and hydraulics, 2021,49 (07): 97-101

ISSN: 2664-9640

[10]Li Yanan, Zhang xinju. Development and key technology research of automatic assembly machine for unidirectional device [D]. Hebei: Hebei University of science and technology, 2018
[11] Guo W Y, An-Zhu Y U, Liu H Y, et al. Regularized total least squares used in remote sensing image positioning of optical line array[J]. Optics & Precision Engineering, 2017, 25(1):236-244.
[12]Chen Xin, Gu Quan, Du Tianzhen, et al. Research on measuring device of industrial dispenser based on non-contact technology [J]. China adhesives, 2014, 23 (10): 20-21
[13]Li Bowen. Calibration and compensation of automatic assembly positioning error of large industrial robot [D]. University of Chinese Academy of Sciences (Changchun Institute of optics, precision machinery and physics, Chinese Academy of Sciences), 2021
[14] Guo W Y, An-Zhu Y U, Liu H Y, et al. Regularized total least squares used in remote sensing image positioning of optical line array[J]. Optics & Precision Engineering, 2017, 25(1):236-244.
[15]Wen Qingping. Design of multi position machining line based on industrial robot loading and unloading [J]. Machine tools and hydraulics, 2020,48 (17): 49-52