Multi Axis Robot Coordinate Detection Method Based on LabVIEW

Guoxu Zhang1*, Shifeng Yang1, Zhongji Guo1 and Qingfeng Peng1,2

1 College of Electronic Information and Automation, Tianjin University of Science and Technology, Tianjin, 300200, China
2 Department of Electronic Technology, Tianjin Electronic Information Vocational College, Tianjin, 300200, China
*Corresponding author’s e-mail: 348117033@qq.com

Abstract. In view of the fact that the need of high precision and safe production of multi-axis robot, a real-time coordinate detection method is designed by using virtual instrument software structure VISA. Programmable multi-axes controller (PMAC) is used as the control system of the lower computer, LabVIEW as the upper computer, PMAC board communicates with the upper computer through industrial Ethernet, and sends command data and pulse signal to the servos through the bus. LabVIEW uses VISA software interface to communicate with the servo drivers, uses Modbus protocol to obtain absolute position data, and calculates the current coordinates of the workbench. Experiments show that the multi-axis robot coordinate detection method based on LabVIEW can realize the coordinate detection of the moving platform, and the following error current value can also be displayed in the working interface.

1. Introduction
In the field of mechanization replacing artificial, multi-axis motion robot is the inevitable product of industrial development. In recent years, multi-axis motion controller combined with virtual instrument technology has been widely recognized in the field of grinding technology due to its superior control performance and good human-machine interface.

With the development of virtual instrument technology, the multi-axis motion system based on virtual instrument has become the trend of development. In China, there are multi-axis motion control systems based on virtual instrument LabVIEW2009 and programmable multi-axes controller (PMAC) as slave computer. This system uses Active X automation technology to realize the communication between the upper computer and the lower computer. The motion test on the X-axis shows that the system has high accuracy[1-2]. Compared with Active X automation technology, it is easier to develop the system by using Virtual Instrument Software Architecture VISA(Virtual Instrument Software Architecture) to read servo motors position data.

In this paper, virtual instrument LabVIEW is adopted as the development platform. Combined with programmable multi-axes controller , industrial Ethernet, servo motors, Modbus communication protocol, etc[3-5], the single-loop and multi-loop data of servo motor encoders are read by VISA to realize the position detection of motion platform. For the industrial control site, LabVIEW integrates the position coordinate and function menu, which not only satisfies the real-time position display, but also realizes the upper computer following error setting and warning function[6].
2. Electrical system construction

The design adopts a typical distributed control system, which consists of a host computer, a lower computer, an actuator, and a detecting device. The lower computer adopts PMAC as the core of the control system, and is connected to IPC through Industrial Ethernet. After power-on, the program is programmed for the motion controller through Pewin32PRO2. The optical coupling isolation board DTC-8B is connected between the controller PMAC and the servo drivers to implement data interaction between the PMAC and the servo drivers. After the device executes the program, the absolute position data of the motor is read from the motors by the absolute encoders and transmitted to the servo drivers. Finally, the servo drivers send the data to the host computer through the RS232 serial port. At the same time, the PMAC is connected to two Accessory-34AA (I/O) boards. The Accessory-34AA boards can not only read the parameter values of each sensor (such as limit, photoelectric switch, etc.) into the PMAC, but also assist the equipment [7-8]. Organizational logic control. The structural diagram of the electrical system is shown in Figure 1.

3. System control principle

The manual pulse generator generates a pulse signal, and the pulse signal is input by the JHW interface of the PMAC, and the input pulse is processed in the PMAC, and output to the servo system by the JMAC interface, and the absolute value is performed when the motor performs the pulse. Photoelectric encoders are used as the feedback elements to compose the closed-loop system. The upper computer LabVIEW reads the motor position data of each axis in the servo system through the software interface VISA. The control principle can be simplified as shown in Figure 2.
When the manual pulse generator controls the motor operation, the setting of the motor master scale factor and the motor position scale factor are especially important. In the motion control card PMAC, the variables corresponding to the master scale factor and the position scale factor are \( I_1 \) and \( I_2 \). The hand pulse input quantity and the PMAC board output pulse quantity satisfy the following relationship:

\[
K = Q / 360 \times N \times P
\]  

(1)

In the formula: \( N \) is the reduction ratio of the reducer; \( P \) is the number of pulses required for the motor to rotate one revolution[9-10].

If the manual pulse generator sends a pulse to drive the U-axis rotation angle \( Q \), the master scale factor \( I_1 \) should satisfy:

\[
I_1 = KI_2 / 4
\]  

(2)

Substituting equation (1) into equation (2):

\[
I_1 = Q / 360 \times N \times P \times I_2 / 4
\]  

(3)

4. Software design

4.1. PMAC program configuration

PMAC programming using Pewin32PRO2 programming software, written in C language. The PMAC project program is divided into several subroutines according to the action content, and when the main program is executed, the single-segment program code is executed according to the device logic state. Pewin32PRO2 supports variable monitoring. The output status is represented by \( Q \) variable. The upper computer can update the variable status in real time through the variable monitoring function. At the same time, the \( I \) and \( M \) variables of PMAC also support the upper computer to write the value.

4.2. Host computer parameter configuration

The host computer is programmed with LabVIEW 14.0. When the program is running, LabVIEW cyclically scans the front panel Boolean state. When the current panel is triggered by Boolean, the corresponding event structure is executed, and the read and write commands to the lower computer are executed. The instruction writes the variable value to the lower computer through the PMAC dynamic link library, and returns the variable status after the lower computer responds.

The LabVIEW communicates with each axis servo driver through Modbus protocol, and uses VISA and servo drivers to realize data reading and writing. The VISA parameters configuration are shown in Figure 3.

Figure 3 VISA parameter configuration diagram
4.3. Design and implementation of early warning function
LabVIEW can read the output pulse value of the lower computer from the monitored variables. The absolute position of each axis is different from the output pulse. The maximum following error is compared with the set allowable error value. When less than 60% of the allowable error, the current error value shows green; The current error value is yellow when it is greater than 60% and less than the allowable error value; the current error value is red when the allowable error value is exceeded.

5. Position coordinate reading

5.1. Absolute position calculation
According to the absolute position calculation formula, you can get:
\[ S = M_q + D_q \]  
\[ M_q = B_L + P_H \times 256 \]  
\[ D_q = D_L + P_M \times 256 + W_H \times 65536 \]  

The simultaneous (4), (5), (6) can get:
\[ S = B_L + P_H \times 256 + D_L + P_M \times 256 + W_H \times 65536 \]  

In the formula: \( S \) is the absolute position data, \( B_L \) is multi-turn data “L”, \( P_H \) is multi-turn data “H”, \( P_L \) is single-turn data “L”, \( P_M \) is single-turn data “M”, and \( W_H \) is single-turn data “H”.

5.2. Instantaneous angle solution for each axis
The motor of each axis is grouped and recorded as 1, 2, … i, and the initial angles of each axis are \( \alpha_1, \alpha_2, \ldots, \alpha_i \) respectively, and get the origin of the space coordinate system calibrated. The servo motor pulses of each axis are respectively calibrated as \( d_1, d_2, \ldots, d_i \), and the real-time pulse numbers of the servo motors are \( H_1, H_2, \ldots, H_i \) respectively (can be read by the encoder). The design adopts Panasonic A6 servo motors, whose encoders resolution are 8388608, and the reciprocal of the reduction ratio of each axis reducer are \( gr_1, gr_2, \ldots, gr_i \), so the instantaneous angle \( R_i \) of the motor can be obtained:
\[ R_i = \frac{1}{8388608} (H_i - d_i) \times 2\pi \]  

The instantaneous angle of each axis is:
\[ S_i = \alpha_i + R_i \times gr_i \]  

Substituting equation (8) into equation (9) yields:
\[ S_i = \alpha_i + \frac{1}{8388608} (H_i - d_i) \times 2\pi \times gr_i \]  

Selecting the U-axis to do positioning accuracy to measure, and control U-axis to rotate with the pulse generator.

5.3. Precision analysis
The pulse signal is input by the pulse generator. In the PMAC, after the input pulse is processed, the output pulse is calculated according to equation (3) and sent to the U-axis servo driver to complete the U-axis rotation action. Axis positioning accuracy, repeated positioning accuracy measurement, test data as shown in Table 1 and Table 2.

| U-Axis Target Degree/ (°) | Measured Angle/ (°) | Error Value/ (°) |
|--------------------------|---------------------|-----------------|
| 10                       | 10.000              | 0               |
| 30                       | 30.000              | 0               |
| 50                       | 49.999              | 0.001           |
| 70                       | 69.998              | 0.002           |
### Table 2 U axis repeated positioning test data

| Starting Point/ (°) | Measured Operating Angle/ (°) |
|--------------------|------------------------------|
| 0～50              | 49.998                       |
|                   | 49.999                       |
|                   | 49.998                       |
|                   | 49.997                       |
|                   | 49.998                       |
| 50～110            | 59.998                       |
|                   | 59.998                       |
|                   | 59.998                       |
|                   | 59.997                       |
|                   | 59.998                       |
| 110～150           | 39.999                       |
|                   | 39.999                       |
|                   | 39.998                       |
|                   | 39.997                       |
|                   | 39.999                       |

In the clockwise rotation range of the U axis, select a measurement point every 20 ° for measurement. It can be seen from the data in Table 2 that the cumulative error will gradually increase with multiple rotations in one direction. After the pulse detection and analysis, the cause of this phenomenon is that the pulse sent by the lower computer to the servo motor is not 100% executed. A small number of pulses (0 to 2) are lost or not performed for some reasons, but the error is still less than 0.002° in the range of 0 to 90°.

Randomly select three angles for repeat positioning measurement in the range of 0°～150°. According to the data in Table 3, the U-axis repeat positioning accuracy error is less than 0.003°.

### 6. Conclusion

The virtual instrument LabVIEW is used as the upper computer development platform, and the PMAC is used as the lower computer controller. The virtual instrument software structure VISA can realize the position detection of each axis. The practical application shows that VISA communicates with the servo system, and the operation is simple, and the reading and warning function of the following error of the upper computer is realized. Based on the multi-axis robot system of the upper computer LabVIEW, the human-computer interaction interface is more beautiful, and the operation is smoother.

### References

[1] Noman Naseer & Keum-Shik Hong. (2013) Classification of functional near-infrared spectroscopy signals corresponding to the right- and left-wrist motor imagery for development of a brain–computer interface. Neuroscience Letters, 553: 84-89.

[2] Heui-Seol Roh. (2010) Heat transfer mechanisms in solidification. International Journal of Heat and Mass Transfer, 68: 391-400.

[3] Pan Yong, Shan Yue-kang, Zhang Shi-bo. (2009) 3-axis vision measuring system based on virtual instrument technique. Mechanical & Electrical Engineering Magazine, 26:4-6.

[4] Gao Tie-hong, Shi Kai, Nan Ya-fang. (2013) The vision system and realization of pick-and-place parallel robot for blocky food. Journal of Hebei University of Technology, 42: 8-10.

[5] Ali Can Ispir, Eren Diikeç & Seyhan Uygur Onbasoqlu. (2016) Solution of Leakage Problem in a Guarded Hot Plate Device. Procedia Engineering, 157: 488-495.

[6] Xianjie Sheng & Lin Duanmu. (2017) Energy saving factors affecting analysis on district heating system with distributed variable frequency speed pumps. Applied Thermal Engineering, 121: 779-790.

[7] Vinh Nguyen, Pierre Petit, Fabrice Mauffay, Michel Aillerie, Ali Jafaar & Jean-Pierre Charlesa. (2013) Self-powered High Efficiency Coupled Inductor Boost Converter for Photovoltaic Energy Conversion. Energy Procedia, 36: 650-656.

[8] Karkri M. (2017) Biopolymer Composites in Electronics. Elsevier, Netherlands.

[9] Marielle Soniat, Meron Tesfaye, Daniel Brooks, Boris Merinov, Goddard William A. & Adam Z. Weber, et al. (2018) Predictive simulation of non-steady-state transport of gases through rubbery polymer membranes. Polymer, 134(3): 125-142.

[10] Sha Yu, Qing Tan, Meredydd Evans, Page Kyle, Linh Vu & Pralit L. Patel. (2017) Improving building energy efficiency in India: State-level analysis of building energy efficiency policies. Energy Policy, 110: 331-341.