Research on Motion Control of the 2-DOF Packing Robot

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Abstract. Under the strategic background of “made in China 2025”, industrial robots are more and more widely used in the automatic production process. In this paper, the motion control system of the bearing packing robot is studied. The hardware of the system is mainly Delta PCI-DMC-B01 12 axis motion control card based on computer PCI bus, which is connected through DMCNET network and sends control instructions to the two axis servo driver of the robot. The system software is written in LabVIEW environment, including trajectory generation and transmission, zero calibration of robot mechanism, robot teaching, motion parameter setting and other functional modules. Taking the zero calibration function test of robot as an example, the union test of the control system is carried out. The results show that the hardware and software system can work coordinately. The zero calibration experiment provides the basis for the development of other motion control functions and lays the foundation for the application in production.

1. Introduction

Robot motion control [1] [2] is the real-time control and management of the position and speed of the mechanical moving parts, so that they can move according to the expected trajectory and specified motion parameters [3]. According to the output form of command signal, motion controller is divided into voltage output motion controller, pulse output motion controller and network-based motion controller.

The disadvantages of voltage output type and pulse output type controllers are that there are too many wiring, and multiple wiring is required for command signals; resolution is limited, and accuracy is limited for voltage output type by A / D, D / A digits, and pulse output type by the maximum pulse transmission speed; analog signal transmission is difficult to avoid interference and noise; there are too many parameters and status information in the servo driver to be transmitted. If the unified wiring mode is fully read, so the controller cannot fully understand the operation state. On the contrary, the network motion controller, which can avoid the above shortcomings, is the development direction of the future motion controller. In this paper, a network motion control system based on Delta DMCNET is designed for the bearing packing robot.

2. Design of control system based on Delta DMCNET

2.1. System hardware design

Among the existing commercial motion controllers, the PCI-DMC-B01 12 axis motion control card based on computer PCI bus[4] of Delta (a wholly-owned subsidiary of Delta Electronics Group in mainland China) is chosen, which runs on DMCNET network (Delta motion control network, a kind of network based on CANopen). According to the analysis of the loading weight, speed and robot
structure, the servo drive is selected. Additionally, I/O module is selected to deal with digital quantity such as holding brake [5]. The structure of its hardware system is shown in figure 1. The motion control card is inserted in the PCI slot of the industrial computer. The command of the control card is transmitted through the DMCNET network. The RJ45 network interface is set at the control card and the driver side. The RJ45 connector is cascaded through the network cable. The terminal type is the RJ45 connector with 150 Ω resistance indirectly at 1 and 2 pin positions.

![Figure 1. Hardware architecture of robot motion control system](image)

The construction of the hardware platform ensures the implementation of the motion control system. Because the system is based on the computer, it can make full use of its computing and processing performance, graphics display performance, rich application software development platform, and design the control system software. The design of the software can first check the control data through simulation to avoid unnecessary errors and personal and equipment injuries.

### 2.2. System software design

The software function planning of motion control is as shown in Figure 2, which is composed of robot zero calibration module, robot teaching module, motion parameter setting module, trajectory generation and transmission module.

![Figure 2. Block diagram of motion control design](image)

The robot zero calibration module completes the zero calibration of the mechanism, even if the physical coordinate system of the robot is consistent with the theoretical mathematical model, to determine the zero position of the mechanism; the robot teaching module provides the teaching record of the path point, which is convenient to complete the accuracy requirements of the grabbing point and the placement point record of the boxing action; the motion parameter setting module is used to adjust the robot's movement speed, and the grabbing and placing time and other parameters that can realize the adjustment of loading speed, which can be set as simple setting and advanced setting. Simple setting means that the parameters with better matching recorded by pre-debugging and adjustment can be divided into different files and solidified according to the actual requirements, while advanced setting can set the parameter size arbitrarily within the range of agreed parameter values to meet the
personalized needs and accurate adjustment. For the sake of safety, advanced setting authority control shall be increased regularly, and the access shall be password managed, which shall be operated by professional personnel familiar with the machine. The trajectory generation and transmission module is the core part of the motion control. According to the aforementioned track planning and path planning methods, the trajectory data that can be identified by the control card shall be generated according to the grasp and release point data recorded in the teaching and the set motion parameters. The essence of the trajectory data transmission is reading and writing operations to the control card buffer.

This part of control software is written by LabVIEW. LabVIEW can complete friendly interface design and convenient program writing through G code (i.e. graphical programming language). In addition, LabVIEW can also be easily connected with other languages. For example, in this system, the operation function of Delta motion control card can be called through the library function call node of LabVIEW. Figure 3 is the teaching interface of manipulator and figure 4 is the parameter setting interface.

![Figure 3. Manipulator teaching interface](image)

![Figure 4. Parameter setting interface](image)

3. Robot zero calibration experiment

The robot zero point calibration is to determine the zero position of the robot mechanism, even if the actual angle of each driving arm in the motion space is consistent with the angle of the theoretical mathematical model, which is the premise of controlling the robot movement. Of course, there are always errors in the zero point. From the single factor analysis, the accuracy of the zero point determines the accuracy of the end. Therefore, it is necessary to determine a more accurate zero position before the actual work of the robot.

For this experiment, from the point of view of the difficulty of the experimental equipment and operation, the selected experimental equipment is the level ruler, which adopts the indirect calibration
method, as shown in figure 5. Taking the angle of $\theta$ of the arm as an example, it is known that the angle between the calibration working face (which has high processing accuracy and high flatness) and the horizontal plane where the rotation center is located is $\theta_0$, and the steps of calibration implementation are as follows:

1) The calibration working surface of the arm is adjusted to the level by the single axis inching motion mode, and the level ruler is used for detection;

2) Turn the arm counterclockwise at a angle of $\theta - \theta_0$, and convert it into the number of pulses needed by the motor according to the number of pulses for one revolution of the servo motor, so that the angle between the arm and the horizontal plane is $\theta$.

The indirect calibration here refers to that the calibration depends on the angle between the working face and the rotating center plane, and the servo completes the final calibration by angle conversion. Therefore, the factors that can affect the calibration accuracy can be analyzed: the accuracy of the horizontal ruler, the angle error between the calibration working face and the rotating center plane, the transmission accuracy, and the servo accuracy. The practice shows that the calibration accuracy of this method meets the requirements.

![Figure 5. Single arm zero calibration process](image)

In the experiment, take the 45° calibration of the small arm of the bearing packing robot (the angle between the plane where its rotation center is and the horizontal plane) as an example. It is known that the angle between the calibration working surface of the small arm and the central plane (in the theoretical structure) is 7.97°. The calibration experiment process is shown in figure 6.

![Figure 6. The 45° calibration of the small arm](image)

### 4. Conclusion

In order to meet the requirement of the packing operation of the bearing robot for its movement and put it into production and application as soon as possible, the motion control system hardware and software design is completed, the coordination of the control system is tested through the zero calibration experiment of the robot, which provides a reference for the development of more complete motion functions.

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