Application Research of Computer Aided Design Control System in Numerical Control System

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Abstract. With the development of computer technology, computer technology has been popularized in various industries. It has also become the basic technology for the development and design of various systems. For the numerical control system, computer-aided technology makes the numerical control system more improved. This article mainly analyzes the architecture of CNC system.

Keywords: Computer Aided Design of Control System, Open CNC System

1. Introduction

At present, the numerical control system is developing in the direction of high-speed operation, high-precision processing, compound function, intelligent control, open system, and interactive network. Among them, speed and precision are directly related to processing efficiency and product quality. This is also the goal that the CNC system has been pursuing.

2. Computer aided control system

Computer Aided Control System Design (CACSD). It is developed on the basis of computer simulation of the control system. The early CACSD software was basically simulation software. Control engineers use computers to design control systems, which can improve design quality, ensure design accuracy and reliability, improve design efficiency, shorten design cycles, and reduce design finalization test costs [1].

3. The architecture of CACSD

3.1. Open CNC system architecture

Since the 1990s, in the field of industrial control, there is an urgent need to provide a unified interface between hardware suppliers and CNC system software providers to meet the requirements of product...
interoperability, portability, and scalability. The open CNC system has the characteristics of openness, modularization and reconfiguration. The interfaces between its components are standardized and follow uniform specifications. The system is easy to maintain and has strong interoperability between systems. It is a CNC system The development trend of [14]. Therefore, the research of open CNC system has attracted people's attention. Among them, there are three main ones with greater influence:

1. OSACA (Open system architecture for controls with automation systems) is a European project that started in 1992 and defines an interface independent of hardware and communication protocols. Its goal is to establish an open structure to improve the compatibility and flexibility between providers and control system users. Although OSACA has some successful prototype implementation examples in the industry, since it was produced in the early 1990s, some software solutions used are outdated.

2. OSEC (open system environment for controller) is an open system environment designed by a working group that develops open systems in Japan. It provides a development platform with open architecture characteristics for PC-based digital control equipment. The OSEC specification only supports PC platform and WINDOWS environment, and does not support distributed control [2].

3. OMAC (open modular architecture controller). In 1994, the three major US automakers announced their requirements for open and modular controllers and began to formulate OMAC specifications. OMAC can use the experience of software developers to speed up the development process of open controllers by using well-defined interfaces. OMAC has the following characteristics: defines the IDL interface, and can develop OMAC applications on any platform; Use the finite state machine to describe the state changes of the motion control components caused by the internal actions of the module;

Using component technology, components are implemented using DCOM, but CORBA components can also be easily implemented. These features make OMAC have outstanding advantages in terms of portability, modularity, and functional reuse customization.

3.2. Network structure of CNC system based on fieldbus

Fieldbus was gradually developed in the late 1980s and early 1990s, and used for field intelligent device interconnection communication networks in process automation, manufacturing automation, building automation and other fields. Fieldbus is a comprehensive technology with intelligent sensing, control, computer, digital communication and other technologies as the main content. It is the basis of the digital communication network between field devices [3]. It has the following technical characteristics:

1. The openness of the system. Openness means that the communication protocol is open, and devices from different manufacturers can be interconnected and exchange information. Users can combine products from different suppliers into any system according to their needs.

2. Interoperability and interoperability. Interoperability refers to the realization of information transmission and communication between interconnected devices and systems, which can implement point-to-point and point-to-multipoint digital communication. Interoperability means that devices with similar performance from different manufacturers can be interchanged to achieve interoperability.

3. Intelligent control. The field bus disperses part of the functions of sensing measurement, compensation calculation and so on to the field equipment to complete. Only the field equipment can
complete the basic functions of automatic control, and can diagnose the operating status of the equipment at any time.

4. The highly decentralized system structure. Fieldbus is a new fully distributed control system architecture, which simplifies the system structure and improves reliability.

5. Adaptability to the site environment. As the field bus at the bottom of the factory network, field devices are designed for working in a field environment. They can support various physical transmission media and have strong anti-interference capabilities [4].

Due to these characteristics of the fieldbus, the use of fieldbus to realize the interconnection of the underlying equipment conforms to the development trend of open CNC system architecture. The open CNC system based on fieldbus has also become a research hotspot, such as the research on the structure of open CNC system based on CAN bus and Profibus bus.

The general network structure model of open CNC system based on fieldbus is shown in Figure 1:

![Network structure model of CNC system based on fieldbus](image)

**Figure 1.** Network structure model of CNC system based on fieldbus

From the network structure model of the open CNC system based on the fieldbus, it can be seen that the use of fieldbus to realize the interconnection of the underlying equipment of the CNC system has good openness and scalability, which makes the configuration and upgrade of the software and hardware of the CNC system become more simple and convenient [5].

3.3. "Blue Sky" open CNC system architecture based on fieldbus

The "Blue Sky" CNC system developed by the National Engineering Research Center of High-end CNC is an open CNC system based on fieldbus. The open CNC system follows the OMAC interface specification, divides the CNC system into functional modules, and realizes the interconnection between the modules, as shown in Figure 2-2. Among them, the man-machine interface provides a variety of man-machine operation interfaces for the operator, which is convenient for the operator to send commands to the machine tool and observe various status information of the machine tool. The task controller interprets the G and M codes sent by the user, and at the same time determines the sequence logic of the command execution after the interpretation, and then sends the logic to the motion controller or I/O controller to perform lower-level functions. The motion controller completes motion trajectory planning and interpolation functions. For servo, the motion controller produces output based on the PID compensation algorithm. The realization of the I/O controller depends on the hardware.
The result interpreted by the task controller is copied to the shared memory of the user space and the kernel space. If the interpretation is an I/O command, it will be read by the I/O controller and issued to the underlying hardware to replace the tool; otherwise, it will be generated by the motion The controller reads the planning and interpolation of the motion trajectory, and then sends the speed/position command through the fieldbus communication protocol software to the servo for execution through the buffer [6].

The left side of Figure 2 is the software and hardware architecture installed on the industrial computer, and the right side of Figure 2 is the network part of the field processing equipment. The system structure is based on the field bus, which is connected with the communication interface card installed on the industrial computer, servo driver and servo motor.

Figure 2. "Blue Sky" CNC system architecture

3.4. Architecture of CNC system CACSD

The application of CACSD in the open CNC system is to realize the modeling environment for the CNC system, and the real-time application model (the mathematical model of the control algorithm or the application model for optimizing the parameters of the CNC system, etc.) is collectively called the real-time application model. The software part and the field bus, Servo drive, servo motor and other hardware parts are combined to complete functions such as design simulation of motion control algorithm and measurement and adjustment of CNC system parameters that users expect.

The principle is to combine the real-time application model designed with the support of the modeling environment and the hardware connected to the fieldbus into a whole, and send the servo and other hardware information to the mathematical model in real time within a time period, and the mathematical model performs real-time operation. Then send the processed command data to the servo and other hardware for execution. In the execution process, the real-time monitoring software dynamically displays the system status and provides a graphical interface for online parameter
adjustment. Real-time applications communicate with the fieldbus communication protocol software through the fieldbus command interface [7,8].

At the software level, the CNC system CACSD includes a modeling environment for the CNC system, real-time monitoring software, and fieldbus communication protocol software. Among them, the fieldbus communication protocol software connects the modeling environment for the numerical control system and the communication interface card and other hardware devices. The real-time application established by the user calls the fieldbus command interface, and exchanges data with the external processing hardware through the fieldbus communication protocol software, so as to realize the function of the control algorithm hardware in loop simulation or parameter online adjustment. The real-time monitoring software displays the real-time system status when the real-time application is executed.

At the hardware level, the fieldbus communication interface card is installed on the industrial computer, and the fieldbus connects the communication interface card, servo drives, servo motors and other hardware devices [9].

Under the architecture of CNC system CACSD, the data flow design for real-time application execution is as follows:

1. When the real-time application starts to execute, first initialize the parameters of the model, initialize the real-time operating environment, and open the connection with the hardware device.

2. Real-time applications are executed periodically according to the frequency of the model.

   (1) In each execution cycle, first determine whether the conditions for ending execution are met. If not satisfied, continue to execute (2), if satisfied, execute 3;

   (2) Call the fieldbus communication protocol software, read the feedback data from the hardware from the fieldbus;

   (3) Calculate the model system output according to the feedback data and algorithm of real-time application;

   (4) Calculate The command data of the next execution cycle is output, and the fieldbus command data is sent to the servo through the fieldbus communication protocol software;

   (5) The real-time application calculates and updates the state of the system, and the real-time monitoring software visualizes the updated state data of the system;

   (6) Then, increase the time according to the sampling frequency of the model, and turn to (2) to calculate the next execution cycle;

3. When the real-time application finishes execution, it needs to complete work such as disconnecting from the hardware device and exiting the real-time operating environment. The specific process is shown in Figure 3 [10].
4. Conclusion

This paper analyzes the architecture of open CNC system, which is based on fieldbus. On the basis of the "Blue Sky" CNC system architecture, the architecture of the CNC system CACSD was designed. At the software level, it integrates the numerical control system-oriented modeling environment with the numerical control system through fieldbus communication protocol software. At the hardware level, it integrates industrial computer with servo and other hardware devices through fieldbus.

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