Research and Development of Open CNC System Based on PC and Motion Controller

XU Xiao-ming\textsuperscript{a}\textsuperscript{*} LI Yi\textsuperscript{a} SUN Ji-hong\textsuperscript{a} WANG Shuo-gui\textsuperscript{b}

\textsuperscript{a}New Star Research Inst. Of Applied Tech  Hefei 230031  Anhui ,china
\textsuperscript{b}Dept.of Precision Machinery and Precision Instrumentation  USTC , Hefei 230031  Anhui ,China

Abstract

An open CNC system based on PC and motion controller is discussed, Software and hardware of the system based on the idea of modularization construction is described. According to requirements of system management software, a kind of inheritance modular concentric rings structure as the system management software development model is designed. Then a high degree of integration, low coupling system management software is developed. Finally algorithms based on motion controller two-order interpolation are adopted, rough interpolation using Cubic b-spline curve chord segmentation interpolation algorithm. The actual application shows that the CNC system is effective.

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1. Introduction

The development tendency of Computer numerical control (CNC) systems is open, intelligent. PC has been one of the preferred hardware platform of open CNC system for it’s good openness, high performance-price ratio\cite{1}. At present, with the PC as the hardware platform, and real-time operating system as software platform, open architecture CNC system based on the development of CNC technology, has been the mainstream direction of open CNC system. Now open CNC system is stepping into the “Soft CNC” (Soft CNC) stage\cite{2}. By taking the PC as the hardware platform, using Windows as software platform, and designing the hardware and software of NC based on the GT400-SV motion controller, A good openness, universal CNC system is developed.

\textsuperscript{*} Corresponding author. Tel.: 86-0551-5740713; fax: 86-0551-5769965.
\textit{E-mail address:} luckxuxm@126.com.
2. System hardware system

In the hardware structure of CNC system, motion control card is of fixed high production company GT series GT400-SV motion controller that controller can simultaneously control four axis of motion, realize multi-axis coordinated motion. GT400-SV motion control card is embedded in the PC machine through the PCI slot, card special CPU and PC's CPU master-slave dual CPU control mode. PC front end management non real time tasks\[2\], such as man-machine interface, network and other functions. GT400-SV real-time tasks, such as interpolation, servo control, I/O etc.. PC via ISA/PCI bus ISA/PCI and GT400-SV interface, GT400-SV does not take up PC resources, and is easy to let users focus energy to solve the complex problem of motion control, formed with the PC for the PC, motion control card for the computer distributed control.

3. System software system

3.1. Software structure design

The software sub-system structure is shown in figure 1. The system software uses a single document, view and multi thread structure. The main thread is used to handle the user interface of the operation and management, such as: the menu switch, parameter setting, the code editor. The salve thread processes some pure operational nature of the work, such as: the code compiling, the interpolation arithmetic, graphic simulation. According to the requirements of open CNC system and thought\[3\], the system software is designed as Figure 2, a concentric rings structure. Through the class definition, the modularization by using encapsulation and inheritance is realized. Diagram of the module core near the center of a circle that the higher degree, the core task scheduling represents the main user interface, which is responsible for the whole system task scheduling, is the main thread of the application, therefore its generation and destruction represents the application of start and end; the middle ring is divided into 7 functional modules, each function module contains a variable number of modules, each module is controlled by a separate category for identification and treatment, in these class design and encapsulation of a series of member functions and variables, in order to complete each corresponding subtasks.

Communication between modules is mainly by two ways, the annular same layer communication and the linear more layer communication. The same layer communication is responsible for same core layer in communication between the modules. The first layer is implemented mainly by the object and the pointer operation. The second layer is implemented mainly by the creation of a data buffer and structures. The linear more layer communication is responsible for the same category of different core layer module communication. is implemented mainly by the menu management and view of management. the module in the same sector is the same category of modules.

For such a modular communication framework of concentric ring structure, any two modules communicate easily. When applied to different occasions, only need extracting and modifying the modules which are need to modify individually. When the need to increase or reduce the system module, without substantial change the code, one module’s changes will not cause a great disturbance to the other modules communication . This enhances the scalability of the system. GT400-SV provides the C language function library and Windows dynamic link library, The user invokes the corresponding library functions through the host program, In addition the control function and data processing, display interface, user interface application program module which control system is required are integrated together, then the related parameters and the motion trajectory description is passed to the motion controller, that is a motion control commands.
Fig 1. system task scheduling analysis

Motion controller according to the host request, completes automatic trajectory planning, safety detection and servo refresh and so on complex calculation, The calculation results are converted into an analog voltage or pulse to control motor movement, the user need not write communication procedures, and from the 32 drive library freed, all the energy are applied to develop CNC system application.

3.2. Cubic B-spline curve chord segmentation interpolation algorithm

B-spline curve interpolation is one of the commonly used interpolation algorithm in the high-end CNC system, It can accurately represent curve (such as a straight line, conic curve) and free curve (such as the uniform B-spline curve) With a unified mathematical form. So it is convenient for unified database storage, management, and program quantity can be greatly raised. In this system, GT400-SV doesn't support spline curve interpolation currently, taking into account the future’s application of B-spline curve, therefore two interpolation algorithm, namely the rough interpolation and fine interpolation are applied in spline interpolation. Using three order B-spline curve interpolation algorithm of string segmentation in the rough interpolation, performed off-line by computer, in each interpolation cycle its output is not a single pulse, but a line segment (coordinate value of incremental placement); fine interpolation is completed by motion controller in real-time, mainly to complete each control axis trajectory planning and precise positioning movement.

In this system Using three-order B-spline curve interpolation algorithm of string segmentation in the rough interpolation. Only 4 adjacent point position data are required to construct a smooth curve in the calculation process. To set up the number of input points, the allowing error and interpolation cycle parameters of course. Cubic B-spline curve interpolation chord segmentation process is shown in figure 2.

3.3. CNC code compiler design

The CNC system data pretreatment process is defined the whole process which from the CNC code be read to interpolation, including decoding, cutter compensation, processing of speed, coordinate transformation and auxiliary function processing. Due to relatively large amount of information between
preprocessing module and interpolation. which is a non real time domain, the other in a time domain, so how to coordinate the operation and ensuring reliable information transmission is the key problem[2], a direct impact on the whole the performance of NC system, so the CNC code compiler designing is one of the core design of CNC system. CNC code compiler acquires processing file from the local machine or network , then translates into processing data according to the agreed format, and is stored in the code buffer.

![Diagram of interpolation algorithm]

Fig 2. Cubic b-spline curve Equal chord segmentation interpolation algorithm
After follow-up pretreatment of the data in the buffer, it will be stored in the interpolation buffer for the interpolation thread. From the view of function, CNC code compiler can be divided into lexical analysis module, syntax analysis module and a auxiliary module 3 parts\cite{4}.

Auxiliary module based on bit operator method\cite{5}, This method provides a convenient to syntax analysis, subsequent extension character, and extending code check rule library, combined with NC code key words, it enhances the code compiler extensibility.

For the convenience of bit operation, respectively, G code group code (according to G code table) and X, Y, Z ..., F, P characterize will be set up corresponding symbolic constants. For the convenience of operation, these symbolic constants are defined by 2 times magnification. If the character is expanded, new symbolic constant will be established in accordance with the same magnification. And the use of GWordState and ValueState respectively to save the program line reflects the G packet and XYZ character presence state value. Through bitwise OR operation between GWordState and the symbolic constants corresponding to G code groups, 1 will be set to the corresponding position in GWordState, which stores the program segment G code in the various subgroups of the existing state. As long as a bitwise and operation between GWordState, ValueState and the corresponding object, you can determine whether the code has a syntax error in the follow-up examination, Figure 3 is the CNC code compiler structure, it has the code editor and management, breakpoint debugging, variable tracking and simulation function of the integrated development environment.

3.4. graphical user interface management module design

The user interface is the top layer of the application in the open CNC system architecture, and also is the bridge between the NC system and the workers. Its role is not only to provide users with complete functions, convenient operation, intuitive graphical user interface, but also provide the system's opening and function expansion with a good environment and support.

In addition to meet the functional requirements of industrial production and processing in general in this design, the man-machine interface also have the following function:

1) Component based design: GUI isolation layer is designed as the interface of GUI and other parts, the GUI as system external shell, a different graphics library is choosed to develop GUI for different application. Users complete human-computer interaction and process management through the GUI interface, then minimize coupling between different applications, to achieve "plug-and-play" system requirements;

2) Providing users with system configuration and parameter configuration function. according to the different module selection, CNC system may be integrated to meet specific functions requirements. Figure 4 is the GUI interface in the process of the management and monitor.

4. The ending

1) The CNC system has been used in practical projects, practice has proved: the system is practical and reliable, soft hardware is feasible;

2) Two interpolation algorithm is designed based on motion controller interface, overcome the lack of which not supporting spline curve interpolation of motion controller, so as to enhance the function of numerical control system;

3) Management software of CNC system has high integration, low coupling characteristics, and reserve interface for further development and expansion of new functional modules;

4) The open CNC system has been the inevitable trend of the development of NC technology, abundant software and hardware resources of the PC and strong technical advantage are made full use in the
development process of the system, it shortens the development cycle, and reflects the open CNC system superiority and flexibility.

Fig 3. structure of NC code compiler

Fig 4. CNC system user interface

Reference


