A Design of Information Extraction Method on CNC Machine Tools Using C/S Structure

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Abstract. This paper studies the information extraction technology and thermal error compensation technology of CNC machine tools, and realizes the extraction, storage and display of the internal data parameters of CNC machine tools and the data information of external sensors. At the same time, the thermal error compensation control module is embedded in the system to form a set of CNC machine tool information. The integrated system of extraction and thermal error compensation makes up for the shortcomings and deficiencies of the traditional method of information extraction of CNC machine tools and thermal error compensation based on external embedded devices. It provides a way of thinking for the development of a large-scale CNC machine tool information extraction and thermal error compensation integrated system, and has important engineering application value.

Keywords: CNC machine tools · information extraction · Socket · multithread

1 Introduction

1.1 Background

Industrial manufacturing is the main body of the development of a country's economic system, a solid foundation for ensuring sustainable economic development and prosperity, and an important part of the country's implementation of the strategic plan for economic development. To this end, in order to seize market opportunities and win strategic high ground, countries around the world have successively put forward strategic plans for industrial manufacturing [1]. In 2013, Germany's "Industry 4.0" national strategic plan was put forward, which identified three major economic development themes for the manufacturing system: smart factory + smart production + smart logistics. Once put forward, it caused a huge sensation in governments, enterprises, scientific and academic circles around the world, and it was widely recognized that "Industry 4.0" represented the fourth industrial revolution in human history. In the same year, General Electric Company (GE) of the United States proposed and clarified the

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concept of Industrial Internet. The development of industrialization involves a large number of machines, system networks, and on-site facilities, and the Industrial Internet uses sensors, control systems, and industrial software to connect these three factors together to promote green, energy-saving, and efficient industrial production. By integrating the advantages of informatization and network technology, the manufacturing industry will develop in the direction of digitization and intelligence [2]. In 2015, the Chinese government put forward the "Made in China 2025" national industrial strategic plan for the first time in the government work report in light of its own manufacturing development status. Three major goals are clarified: the transformation of Chinese manufacturing to Chinese creation, the transformation of Chinese speed to Chinese quality, and the transformation of Chinese products to Chinese brands. In addition, ten major fields are selected as breakthrough points, and the manufacturing level will enter the ranks of manufacturing powers by 2025. Among them, intelligent manufacturing technology represented by high-end CNC machine tools and robotics technology is also one of the major projects. The goal of intelligent manufacturing is to focus on key manufacturing links, integrate manufacturing equipment with new-generation information technology, and realize a complete closed-loop system capable of intelligent perception, control, execution, and decision-making. In the intelligent manufacturing process of modern manufacturing enterprises, CNC machine tools are widely used for cutting metal parts, but due to the wide variety of CNC machine tools and various structures, and the inability to automatically output internal information [3].

Therefore, the information extraction of CNC machine tools is the basic link to realize the intelligent manufacturing of modern manufacturing enterprises, and it is also an important prerequisite for building the Industrial Internet of Things and realizing the monitoring of the production process of all elements of products. Through the monitoring and management of CNC machine tool information extraction and interconnection, various abnormal states and potential problems of machine tool equipment can be discovered in time, which is of great significance to the stable, healthy and efficient operation of machine tool equipment. At the same time, the CNC machine tool information extraction technology is integrated with ERP (Enterprise Resource Planning), MES (Manufacturing Execution System, Manufacturing Execution System) systems, which can obtain a large number of real-time machine tools without the influence of human factors and other intermediate links. The operation data of the production process has guiding significance for the upper management of the enterprise to scientifically formulate the production plan and manage the process flow of the parts [4].

1.2 Related Works

In western countries, CNC machine tool information extraction and state monitoring operation and maintenance technology developed earlier, and in the development process, it was relatively mature, platform-based, and modular. A complete solution with remote control functions as one, creating great competitiveness for manufacturing enterprises. For example, the open Siemens.

MCIS (Motion Control Information System, motion control information system) information solution developed by Siemens, which integrates production data based on OPC interface and industrial Ethernet [5].

The MDC-Max machine tool data acquisition and monitoring system developed by CIMCO, a world-renowned DNC solution manufacturer, integrates equipment information extraction, network communication, Internet of Things and other technologies to accurately collect real-time data, understand machine tool performance and predict Potential alarm. The Extreme DNC information extraction software developed by American Ascend Technology Co., Ltd. can realize the functions of communication, information extraction, real-time monitoring and remote control of mainstream CNC machine tools in the market. The Massachusetts Institute of Technology in the United States has developed an integrated equipment for parts network processing and assembly based on the Industrial Internet. A research institution in Australia has developed a remote equipment status information extraction, monitoring and control system. Automatic acquisition and remote control platform [6]. The domestic research on CNC machine tool information extraction and state monitoring DNC platform started relatively late, and the technology is still immature. Dr. Fang Shuiliang from Nanjing University of Aeronautics and Astronautics proposed the concept of flexible DNC system, integrated development of two CNC wire cutting machine tools (WEDM) and one CNC milling machine (XK5040), and connected the machine tools into a hierarchical distributed management control flexible DNC system through Ethernet -FDNC system. Zhang Xumei, Liu Fei and others from Chongqing University put forward the concept of integrated DNC (IDNC) system. Based on communication and network technology, different types of manufacturing equipment are integrated with the central computer, so as to realize the integration of equipment and information in the machining workshop and functional integration [7].

1.3 Motivations and Contributions

The above mentioned numerical control machine tool information extraction and thermal error compensation research have made good progress in their respective aspects, but there are still some defects and deficiencies. It is difficult to integrate CNC machine tool information extraction and thermal error compensation because the thermal error compensation control in the traditional method is to develop the thermal error compensation function through hardware devices such as external embedded compensators based on ARM, DSP and other technologies to realize the output of compensation values and exchange data with the machine tool PLC to realize thermal error compensation control. But the compensator needs to communicate with the IO modules of the machine tool control cabinet (such as: the machine tool operation module of the FANUC system, the PP 72/48 module of the SIEMENS system, etc.), and a series of tedious operations such as hardware wiring, hardware configuration, and address assignment.

Meanwhile, if the thermal error compensation control of a large number of CNC machine tools is carried out, each machine tool needs to expand the IO module of the corresponding CNC system, and the cost is high. In addition, the external embedded compensator requires hardware development. Once the requirements change, the hardware compensator needs to be redeveloped to a large extent. The disadvantage is that the cycle is long and the cost is high. Nowadays, mainstream CNC devices have built-in network interfaces, and provide application development interface functions corresponding to CNC systems. Users can customize development according to their own needs, which provides the possibility for CNC machine tool information extraction and thermal error compensation control integration. Therefore, based on the respective application development interfaces of mainstream CNC systems, this paper proposes to use middleware technology to expand the information integration and thermal error compensation control integration of CNC machine tools. The data and thermal error compensation control are designed and realized by system integration.

To address this, in this paper, a set of information extraction and thermal error compensation control integration system for FANUC CNC machine tools is designed, and an interface is reserved for the information integration of other CNC systems. The integrated system can read the internal operating parameters of the numerical control system in real time, and output the compensation value in real time according to the thermal error prediction model established according to the thermal error measurement data to realize the thermal error compensation of the machine tool. The main contribution can be summerized as follows

- We first briefly expounds the subject source, research background and significance of this paper, introduces the research status of CNC machine tool information extraction technology and thermal error compensation technology, and expounds the research content of this paper.
- Then, we study the information extraction method of CNC machine tool. The hardware structure and function of each part of the numerical control machine tool are summarized. On this basis, the internal data signal and external data signal information transmission mechanism between CNC, PLC and the machine tool body in the working process of the numerical control system are analyzed, and the control process is realized. Four methods of information extraction of CNC machine tools are introduced, namely, information extraction methods based on PLC and electrical circuit, RS232 serial port combined with macro commands, FOCAS protocol and OPC UA protocol, and their advantages and disadvantages are described respectively.
- On the basis of the machine tool information extraction technology and the thermal error compensation technology in the network communication architecture of the integrated system is designed, and the middleware technology is introduced to expand the information integration of other CNC systems; the implementation of the integrated system is analyzed and discussed. Multi-threading mechanism and C/S communication principle based on Socket are introduced, and the design and implementation process of each functional module of the system is introduced in detail.

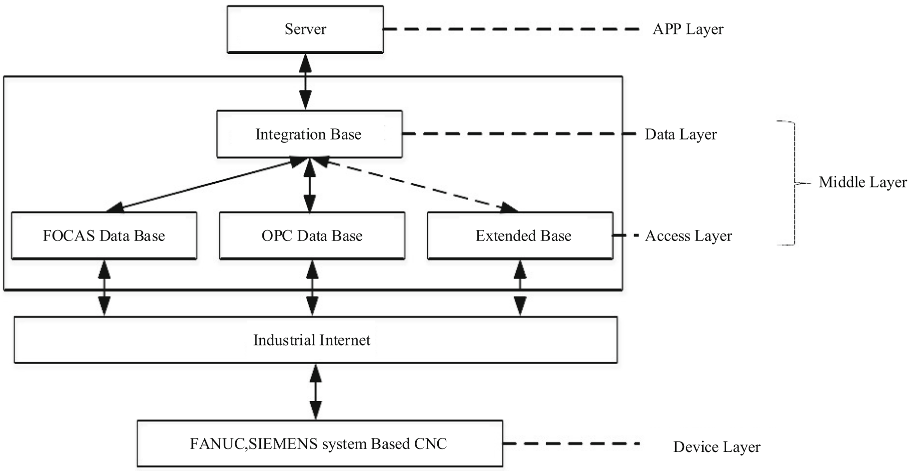

Fig. 1. An illustration of the communication principle of machine tool communication middleware technology

2 System Communication Architecture Design

In this paper, the LAN communication technology is used as the "medium" for information exchange between the host and the machine tool, that is, the industrial Ethernet communication based on the TCP/IP protocol. For the CNC machine tool of FANUC system, the FOCAS protocol class library is used as the interface for system communication and data access; for the CNC machine tool of the SIEMENS system, the OPC UA protocol class library is used as the interface for system communication and data access. However, CNC machine tools of various systems can only use their own communication libraries to communicate with machine tools and access data. In this regard, based on various communication libraries, in order to meet the needs of system expansion, this paper introduces a communication Middleware technology encapsulates the heterogeneous system subclass library, provides a unified data access interface, realizes the functions of heterogeneous system resource sharing, business coordination and allocation, and has the characteristics of flexibility and scalability. Figure 1 shows the communication principle of the machine tool communication middleware technology.

The communication middleware layer is located between the application layer (server program) and the machine tool equipment layer, and realizes the integrated design of the machine tool communication and data access class library, thereby encapsulating the general interface for integrated communication and data access. For better management and decoupling, the communication middleware layer is further divided into the data mezzanine layer (data acquisition adapter) of the communication integration class library and various subclass libraries (inherited from the corresponding parent class library, in order to pass the subclasses) Calling various methods, variables, enumerations, etc. defined in its parent class without changing the content in the parent class) data access layer two-layer logic layer. The data mezzanine provides instantiated objects for accessing various subclass libraries, and can call the data access methods of the objects, and encapsulates the communication connection and data access of various machine tools into a general interface method. Therefore, as long as the interface remains unchanged, changes to the logical content of the communication middleware layer will not affect the changes to the server program, and when new types of machine tools are added, only the data access layer of the communication middleware layer needs to be added. The new subclass library and the call to the subclass library in the communication integration class library, and the server program only needs to call the general interface method of the communication integration class library according to the system type, which reduces the difficulty of server program development and enhances the Extensibility, and realizes the decoupling between the server and machine tool interface access methods; and the data access layer stores various subclass libraries, this logic layer is mainly to access data sources, such as: database data The execution of commands such as add, delete, modify, query, etc., can also read and access some txt, ini and other text files and XML file information. The source of the underlying data in this article is mainly CNC machine tools And access is set in the data access layer, the main function is to encapsulate the communication connection method and data access method for various system machine tools.

3 System Network Architecture Design

The overall network architecture of the system designed in this paper is shown in Fig. 2. The system topology is divided into three layers, which are mainly composed of machine tool equipment layer, protocol layer and information extraction layer. The machine tool equipment layer is composed of CNC machine tools of FANUC system and SIEMENS system, as the carrier of CNC machine tool information extraction and thermal error compensation control. The protocol layer is mainly composed of serial communication protocol (RS232) and industrial Ethernet protocol (including FOCAS and OPC UA). Send commands to the temperature acquisition device (lower computer) regularly through USB to serial port. Once the temperature acquisition device receives the command sent by the host computer program in the interrupt service program, it will send the temperature value of the temperature sensor to the host computer through the serial communication channel. The program triggers the event function of the host computer, analyzes the temperature data in the event function, and brings the temperature value of the temperature-sensitive measuring point into the thermal error prediction model, and then outputs the compensation value. The industrial Ethernet protocol is mainly a channel for the transmission of the internal data information of the machine tool equipment layer and the data of the host computer program, and according to the difference of one-way or two-way transmission of data information, the data transmission through the

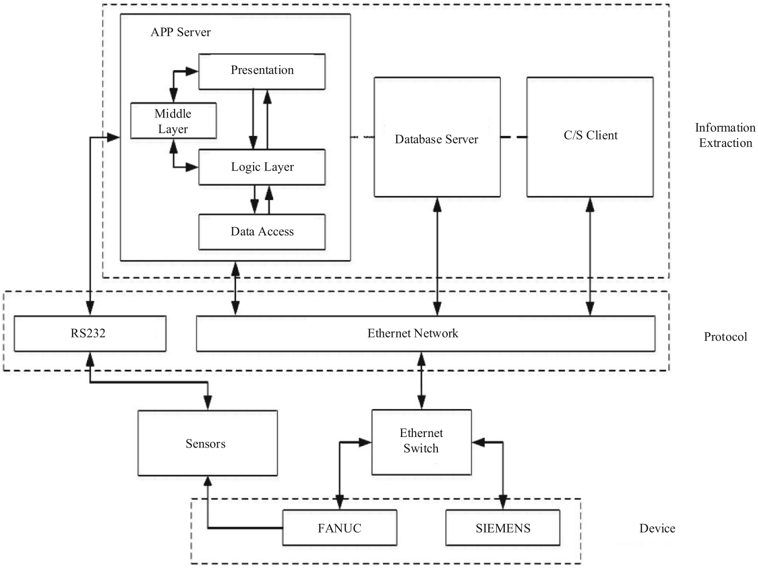

Fig. 2. An illustration of the network architecture of the proposed system.

industrial Ethernet is divided into real-time information extraction and thermal error compensation. Control two ways. The principle of the real-time information extraction control method is: the upper computer program sends the information extraction instruction, and transmits it to the machine tool equipment in real time through the industrial Ethernet. The machine tool also returns the sampled data information to the upper computer program through the industrial Ethernet, and the upper computer program obtains it. Once the data arrives, it can be further processed.

In this way, the data information transmission is bidirectional. The thermal error compensation control method is unidirectional for industrial Ethernet. The host computer program brings the temperature data sent by the external temperature acquisition device into the thermal error prediction model, outputs the compensation value, and transmits it to the numerical control system through the industrial Ethernet to achieve thermal error compensation control. The information extraction layer consists of application server, database server and C/S client. The main functions of the application server are human-computer interaction, outputting data to the database server or C/S client, and further processing the data information returned by industrial Ethernet or serial communication to realize data access, business logic processing and interface display functions; database server It is mainly used to store the real-time data extracted from the information for the client to access it; the main function of the C/S client is to query the database for interface display and the data information that the application server responds to through Socket communication.

4 System Development Environment and Key Technologies

In the designed system network architecture, for the CNC machine tool of the FANUC system, the FOCAS interface protocol is selected as the communication interface of the system; for the CNC machine tool of the SIEMENS system, the OPC UA interface protocol is selected as the communication interface of the system. From the research on the information extraction method of CNC machine tools, it can be seen that the FOCAS interface protocol and the SIEMENS interface protocol are encapsulated into a class library by the CNC system manufacturer, which supports the C.NET advanced application development language. The serial communication protocol is also encapsulated into a class library under the .NET platform, and developers can call it directly when using it. Therefore, this article is based on the above communication protocol and selects the C development language under the .NET platform to develop the host computer program of the CNC machine tool information extraction and thermal error compensation integrated system. Visual Studio 2019 is used as the integrated development environment, and the storage of data information is Sql Server database. In the field of computer communication, Socket is called "socket", which is the cornerstone of communication and the communication protocol between applications. Socket as a communication protocol has been widely used in many fields, such as: network communication, database management and so on. Through the agreement of Socket, a computer can also send data to other computers while receiving data.

The application server and client in this article communicate through Socket. Socket can be regarded as the endpoint of communication between two network applications. During communication, the data information to be transmitted by the client application is written into the Socket of the machine where it is located. Socket transmits the data information to the server application Socket of another machine through the network cable transmission medium, realizes the receiving and processing of the data information, and the server transmits the data to the client in the same way. In addition, when communicating, a Socket of a client application corresponds to a Socket of a server application one-to-one, that is, if there is a client Socket, there is a corresponding server Socket for data interaction with it. Socket is used in combination with IP address, port and transmission protocol. The IP address can be used to uniquely identify the host in the network program, and the transmission protocol and port can uniquely identify the application (process) in the host. There are two types of socket SOCK_STREAM and datagram socket SOCK_DGRAM. Stream socket SOCK_STREAM is based on the TCP (Transmission Control Protocol) of the transport layer, providing connection-oriented, reliable, sequential, byte stream data transmission services, while The datagram socket SOCK_DGRAM is based on the UDP (User Datagram Protocol) of the transport layer and provides connectionless data transmission services. It does not guarantee the reliability of data transmission, which may lead to data loss, duplication and confusion during transmission. The CNC machine tool information extraction and thermal

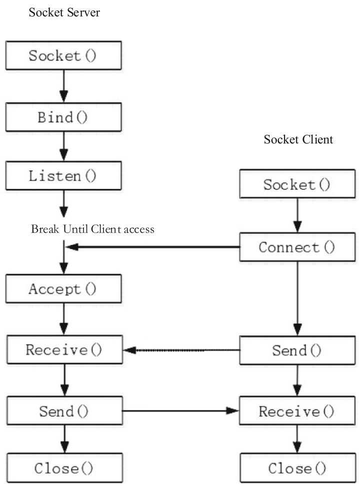

Fig. 3. An illustration of Socket Communication.

error compensation integrated system in this paper needs to meet the real-time, safe and reliable requirements of data information transmission. Combined with the analysis and comparison of the impact of the two transmission services on the data, it is decided to use the Socket communication based on the stream socket SOCK_STREAM protocol. Develop C/S applications. The principle of Socket communication is shown in Fig. 3.

5 Simulation Results

After the hardware experimental platform is built and the necessary preparations are completed, the test and verification of the integrated system can be carried out. The test and verification methods are as follows: Turn on the machine tool, turn on the power of the external acquisition equipment such as the temperature acquisition device and the eddy current sensor preprocessor device, run the server application program of the upper computer integrated system, configure the machine parameters in the program, and connect the machine tool, Start the server program, the Labview host computer program configures the serial port parameters and eddy current sensor channel related parameters, and connects the temperature acquisition device of the lower computer and the NI acquisition card.

Start the Labview host computer program, and measure the temperature acquisition device and displacement of the lower computer. The device sends a start measurement command, and the Labview host computer records the initial displacement data between each eddy current sensor and the standard test bar, and records the temperature data of the heat source sensitive parts of the machine tool at this moment. After the displacement and temperature

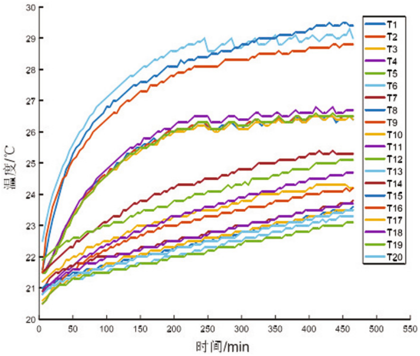

Fig. 4. An illustration of temperature v.s. time.

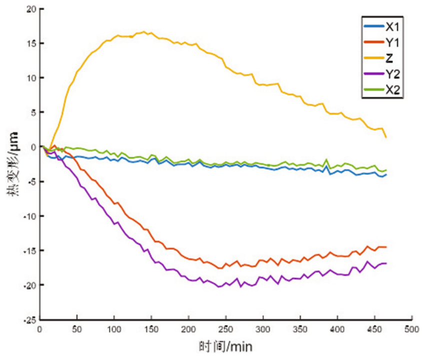

Fig. 5. An illustration of thermal deformation data curve.

data recording is completed, run the thermal error acquisition NC program on the machine tool side: the program controls the eddy current sensor on the machine tool table to slowly move away from the standard test bar clamped on the machine tool spindle from the initial measurement position, and reach a relatively safe After the interference position, control the feed axis and spindle of the machine tool to simulate the cyclic movement of the real processing scene. After continuous movement for about 5 min, stop the rotation of the spindle and make the eddy current sensor on the worktable return to the initial measurement position, and simultaneously record the displacement and temperature at this time data. Repeat the experiment for about 8 h until the temperature field of the machine tool is in a state of thermal equilibrium. At this point, the experiment of measuring the thermal error of the machine tool can be stopped.

It can be seen from Fig. 4 and Fig. 5 that the heat source sensitive parts and thermal deformation of the machine tool basically reach thermal equilibrium at about 450 mins after the start of the experiment, and the maximum thermal error in the X direction is 4.3 μm, the maximum thermal error in the Y direction is 20.3μm, and the maximum thermal error in the Z direction is 20.3 μm is 16.6μm, considering that the thermal error in the X direction of the Vcenter-55 CNC machining center, which is the object of this study, is small, and the thermal error in the Y and Z axes is large, so the thermal error compensation is performed on the Y and Z axes at the same time. The measured temperature data and thermal deformation data are used for the establishment of the thermal error prediction model. In the thermal error compensation experiment, the compensation value calculated in real time according to the prediction model is written into the numerical control system through the API interface protocol to realize reverse interpolation control.

6 Conclusion

Starting from the role of CNC machine tools in the digitalization process of modern manufacturing workshops and the practical significance of improving the accuracy and performance of machine tools, this paper designs an integrated system for information extraction and thermal error compensation for CNC machine tools with FANUC system. By integrating the two parts of the external sensor acquisition device and the internal information API function interface of the machine tool, and based on the .NET multi-threading mechanism, Socket communication and serial communication technologies, at the same time, considering the software design of "high cohesion and low coupling" Principles and the need to expand the information integration of other CNC systems, on this basis, a three-layer architecture model of "presentation layer, business logic layer, data access layer" combined with the system network architecture of "middleware layer" was proposed, and the system functions were designed and developed. Finally, based on the existing Taichung Seiki Vcenter-55 vertical CNC machining center in our laboratory, the integrated system is tested and verified. The experimental results show that the CNC machine tool information extraction and thermal error compensation integrated system developed in this paper is effective and efficient.

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