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Research on Simulation Monitoring System of 828D Machining Center based on QT

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Abstract

Aiming at the problem of disconnection between machine tool processing and management in digital manufacturing workshops, a set of 828D machining center monitoring system based on OPC UA protocol data acquisition and QT OpenGL visualized three-dimensional model display terminal is designed. The QT OPC UA data acquisition module is constructed through the configuration of the data acquisition site environment, and the acquisition function program is written by the Open62541 plug-in and C++ language to access the built-in OPC UA server of the machine tool to realize data reading and writing to the database; further export the machine tool model to 3ds format and use QT standard graphics interface OpenGL development model reading and display program, using QT Creator to design the simulation monitoring interface; combined with the design database to realize the data transfer and binding interaction from the source to the terminal. Finally, the system communication connection test, real-time display of model actions and dynamic data, verified the feasibility of data collection and visual simulation, and the system can better monitor machine tool related information and real-time simulation.

Keywords

OPC UA ; QT OpenGL; 828D; Simulation monitoring.

1. Introduction

With the "Made in China 2025" strategy proposed and the integration of "Internet + manufacturing" advanced, industrial software is enabling domestic processing and manufacturing enterprises to develop in the direction of informatization, personalization and service. In the development requirements of industrial digital production management, achieving a high degree of connection between workshop physical systems and information systems, providing real-time production information and manufacturing equipment operating status information, is one of the effective ways to realize intelligent and automated manufacturing enterprises [1- 2].

As high-end precision processing equipment, CNC machine tools are widely used in the field of processing and manufacturing. With the increasing demand for intelligence and automation of manufacturing enterprises, there is no need for information interaction, remote monitoring and other technologies at all levels from the factory site equipment layer to decision management to realize the perception, monitoring and control of the processing and manufacturing entities, which requires data The collection is feasible and reliable, and the machine tool simulation monitoring interaction has the characteristics of simple operation, friendly interface and humanization [3]. At the same time, as one of the emerging research directions of human-computer interaction technology for manufacturing equipment, reconfigurable workshop modeling, simulation monitoring and other technologies are also being innovatively applied to industrial occasions, providing users with better interaction and imagination [4]. Therefore, building a set of equipment remote monitoring system has important practical significance and value for realizing visualization and information management of mapping equipment status, tapping the potential of equipment utilization, and increasing the market competitiveness of enterprises and promoting production efficiency.

In recent years, as the advantages of digital twins and intelligent monitoring and management technology continue to emerge, scholars at home and abroad have also conducted extensive research on their applications in smart factories and CNC machine tools. Some researchers have developed professional software with simulation and monitoring functions with the help of tools such as Unity3D, OpenGL and MFC. For example, Liu Jinsong et al. [5] proposed a FANUC CNC machine tool remote monitoring system with FOCUS communication mechanism, and integrated a three-dimensional visualization monitoring system on the Unity3D platform to realize the monitoring of CNC machine tools; Zhang Chi et al. [6] based on OPC UA technology A monitoring system for CNC machine tools is designed. Li Guoliang et al. [7] used MFC and OpenGL to design and develop a virtual simulation system for CNC lathe processing. Lu Tingting et al. [8] designed a state monitoring system for CNC machine tools using the combination of C/S and B/S architecture to realize state monitoring and data storage. Based on the above scholars' research on CNC machine tool monitoring and graphics visualization, it can be seen that there are still technical bottlenecks such as data acquisition, communication, and integration difficulties, and the system has single functions and poor cross-platform performance. On this basis, there are It is necessary to develop a more complete monitoring system.

This paper takes the SINUMERIK 828D processing center with Ethernet function as the research object, based on the Qt OPC UA module, using the Open62541 plug-in, combined with OpenGL on the QT platform to design a set of processing center integrating OPC UA protocol data acquisition and visualization 3D display terminal. Simulation monitoring system. Based on the OPC UA protocol, use the development kit to write a collection program to establish a connection with the machine tool server, access and read and write the data in the server and write it into the database; the database is then used as a data transfer center for the simulation monitoring system. In terms of simulation, Open GL technology is used for the development of the simulation monitoring terminal, modeling of the machining center, and 3D animation control through OpenGL. Comprehensive use of the above technologies has realized the data collection of the machining center, the real-time display, simulation and monitoring of machine tool status information.

2. Introduction to 828D System

Siemens SINUMERIK 828D CNC system is a compact control system that integrates CNC machine tools, programmable controllers, man-machine interface and drive control and integrated operation panel installation. Its core component PCU (panel control unit) combines CNC, PLC The integration of functions such as, man-machine interface and communication makes the processing data can be better accessed and interacted [9]. For Siemens 828D CNC machine tools, a variety of machine tool data collection methods are provided, including data collection based on PLC and electromechanical systems and collection based on the communication interface of the machine tool. This article uses the communication interface method (industrial Ethernet cable to connect to the machine tool communication port X130) to collect data. This collection method does not need to be configured with additional hardware, which is economical and cost-effective [10].

3. Overall system architecture

Collect the machine tool data, write it into the database and transmit it to the remote client, use 3D modeling and real-time processing data to realize accurate 3D mapping of the CNC machining process, and realize a good correspondence between the physical machine tool and the 3D model simulation. In response to the needs of information connection between the bottom and decision-making levels, and equipment visualization monitoring, the overall architecture of the 828D machining center simulation monitoring system is designed using modular ideas, as shown in Figure 1.

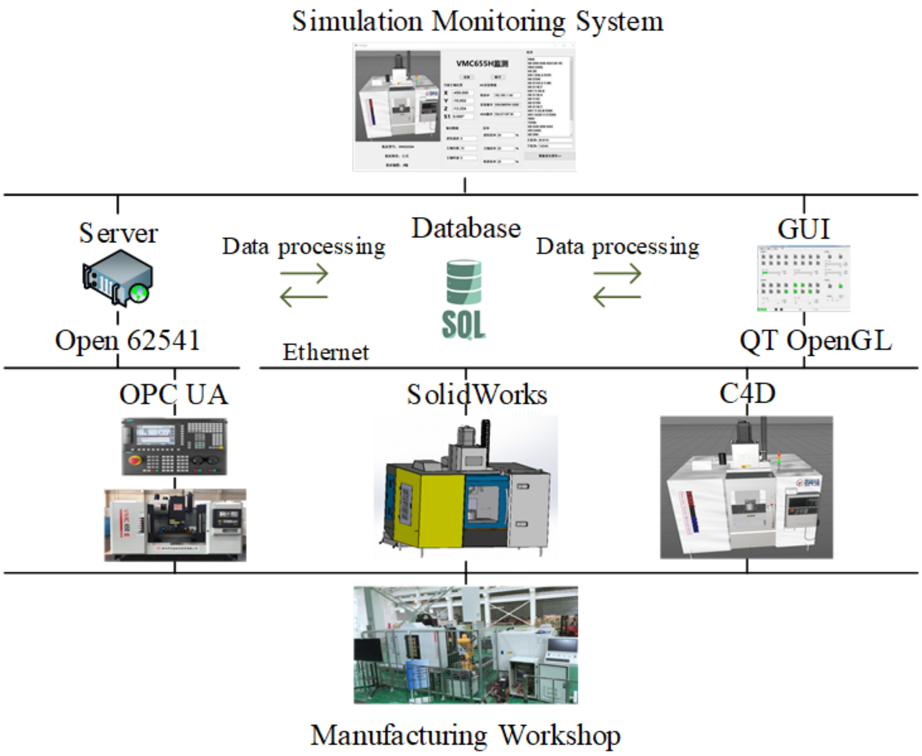

Fig. 1 The architecture of simulation monitoring system

Mainly divided into two parts:

Data collection.

Use Open62541 to write the acquisition program, establish a data communication connection with the processing center server, and visually display part of the data in the monitoring system. Research and analyze the OPC UA unified architecture specification, establish a correct connection with the built-in OPC UA server of the Siemens 828D system through authentication of user identity and configuration of security parameters, browse and read and write nodes and write to the database. The QT Creator platform connects and communicates with the database, and the simulation position coordinates are associated with the coordinate data of the master and slave stations of the monitoring system.

Visualization.

Present data and models to the interface, responsible for display and monitoring. Establish a three-dimensional model and import it into C4D software for rendering, and further complete the calibration of each component. QT OpenGL is used to build the kinematics of the model, and the graphics interface of Open GL is used to read and display the 3D model. GUI uses QT for planning, provides a simple man-machine interface, and uses QT's unique database communication mechanism and signal and slot message mechanism for message transmission.

Send the real-time position information of the machining center to the motion controller and controls to realize equipment dynamic simulation and visual data monitoring.

4. Data collection

The prerequisite for the realization of the entire system function is data acquisition, that is, to connect to the OPC UA server for data reading and writing. The machining center system is SINUMERIK 828D, which integrates OPC UA server. The server manages variables (Item, Node) through variable groups (OPC Group, Variant Group), and the variables store the data obtained through the relevant HMI services of the data communication in SINUMERIK Operator Machine related data. Use the SDK to construct the address space and information model, and access the server address space node data in the client/server mode. The application structure is shown in Figure 2.

The overall process of data collection. Configure server options and set the host computer IP to ensure that the host computer can find the server; create an OPC UA channel under QT, write C++ programs in the C/S data access mode, and use client API to achieve server access and test functions, including finding the server, Connect management, browse the address space, synchronize node reading and writing, and disconnect the server; finally, the data is processed and written to the database, as shown in Figure 3.

Configuration part. The built-in HMI of the Siemens 828D machine tool MiniWeb Server can only use the X130 Ethernet port for communication. The machining center and the server are connected by an RJ45 network cable. The 828D is configured to activate the OPC UA server and start the MiniWeb service of the system. It involves UA authorization, PCU Ethernet, IP Distribution etc. At the same time, set the server firewall and the IP address and gateway of the same network segment as the opc-ua server must be required. Detect and configure communication conditions through PING. The communication environment configuration process is shown in Figure 4.

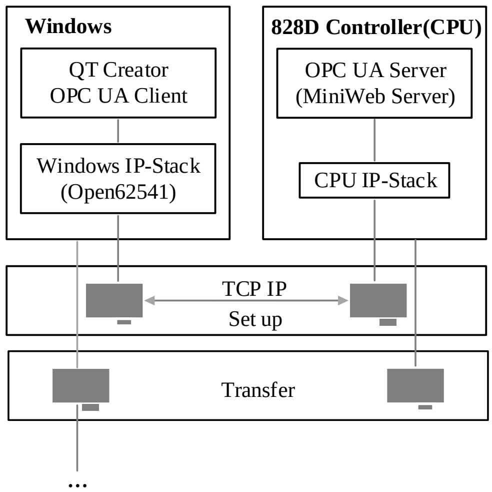

Fig. 2 Schematic diagram of data collection structure

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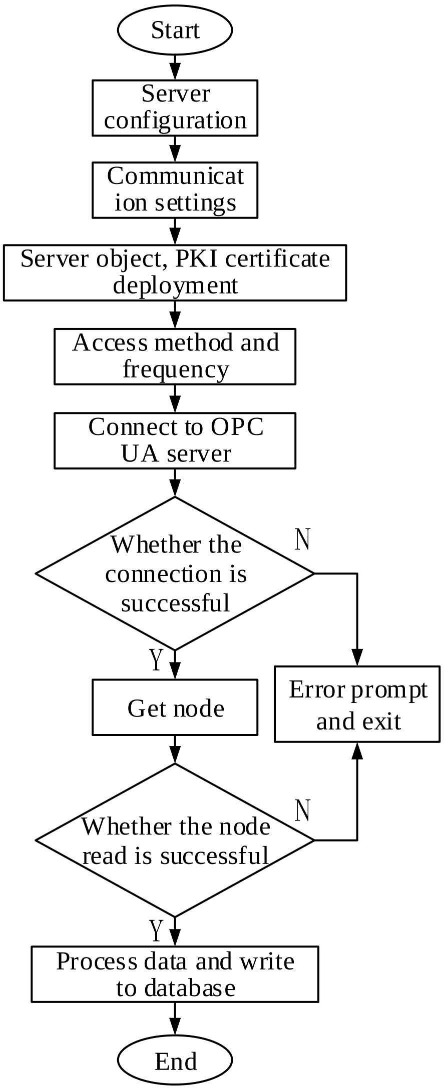

Fig. 3 The process of data collection

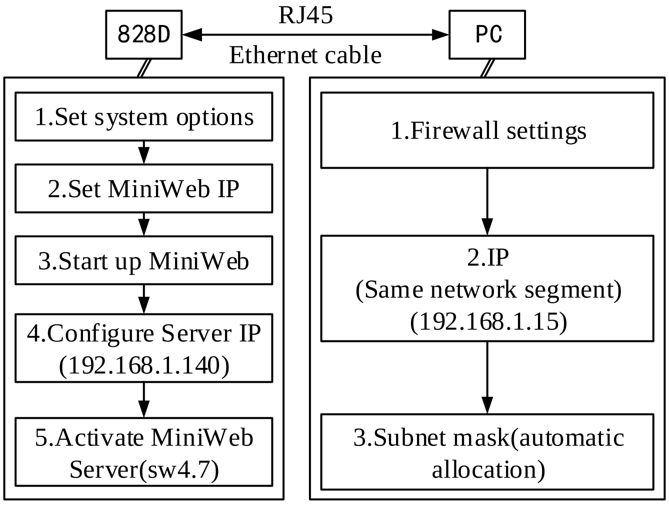

Fig. 4 The process of communication configuration

Collection part. The application development uses C++ language, the development tool is QT 5.13, downloads Perl related, cmake builds Open62541, mainly uses Open 62541 client API to realize server access and system test functions. Data access contains three nested levels of original connection, secure channel and session. First build the QT OPC UA Open62541 plug-in, use QOpcUaProvider to create a QOpcUaClient, use request Endpoints to request an endpoint list from the server, and then call connectToEndpoint() to connect to an available endpoint. The endpoint requires user name authentication. You need to set the user name in QOpcUaAuthenticatio-nInformation. Calling this function before setting the authentication information will use anonymous authentication. setPKIConfiguration() is used to configure the client certificate and establish a Secure Channel, including creating a matching public key pair Pair with a private key, create a self-signed certificate, and a certificate signing request to ensure that authentication can be performed without sending its credentials in clear text. After the connection is established, the QOpcUaNode object of the root node will be requested, which is the basic building block of the OPC UA address space. It has attributes such as browse name, value, and associated attributes. Rewrite the access function formal parameter object according to the DB node address of the monitoring system data block, and call functions such as setNodeId() to read the node attributes from the server. Through the use of these classes and related functions in the back-end, it communicates with the server to provide data abstraction and related operations, and processes the data according to the 828D variable document and writes it into the corresponding database table [9]. Create related interface components and use QT signals to associate data with the slot mechanism. The collection result is shown as in Fig. 5.

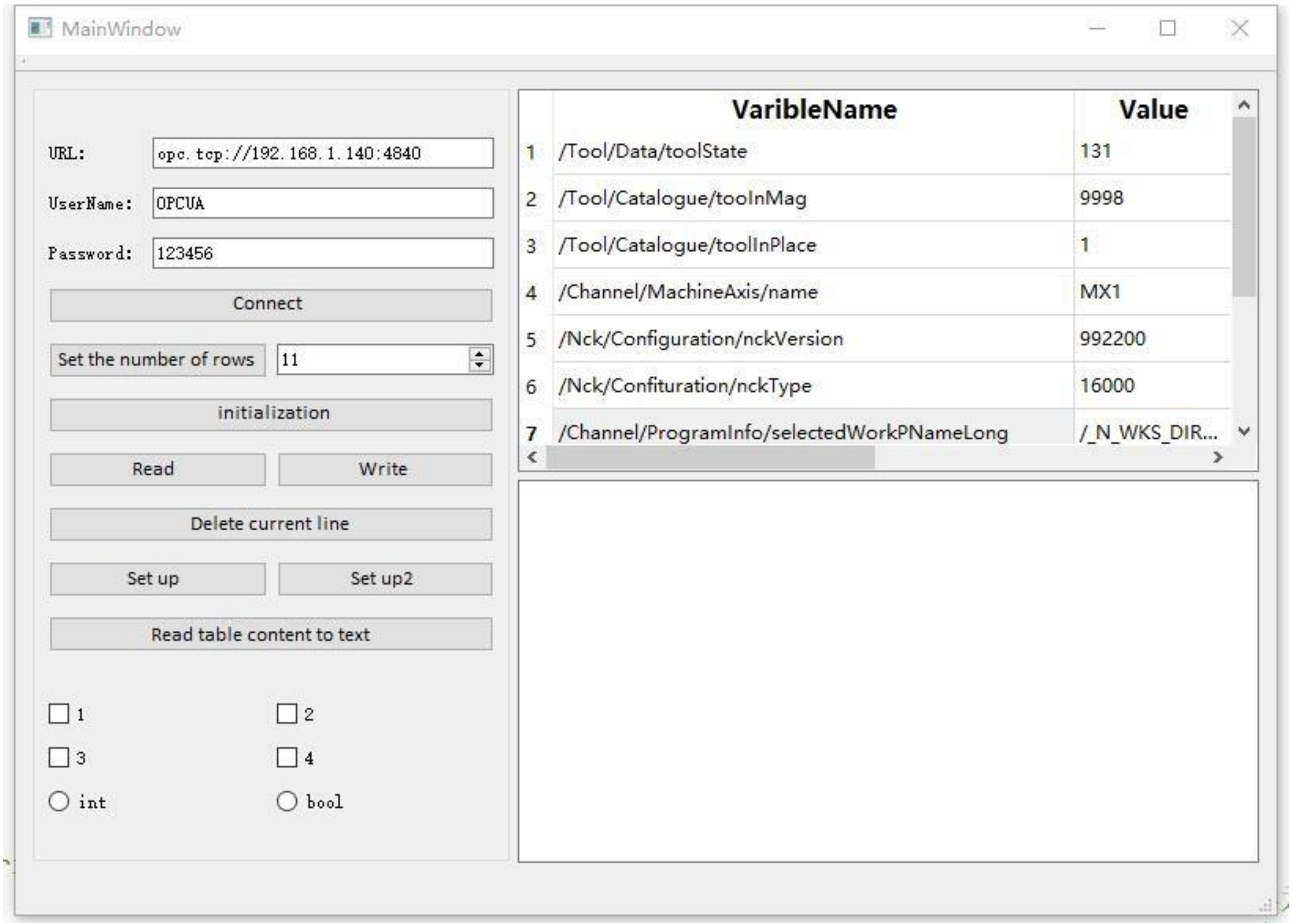

Fig. 5 The results of data collection results

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5. The Implementation of database and monitoring interface

5.1. Database implementataion

Considering that the monitoring system is developed using QT Creator, QT supports a variety of common databases, such as Mysql, Oracle, SQLite, etc. The Mysql database is a relational database with small size, fast speed, low total cost of ownership and is open source software, adapting to the development requirements of the system, so this system uses the Mysql database.

A large amount of dynamic information will be generated when the machining center is running, and the database needs to realize real-time storage and update of the collected data. In response to system data requirements, the E-R diagram model is used to design the database conceptual structure, and the system data entity set is determined, which is mainly divided into machine tool static and dynamic entities. The static information will not be updated in real time after being read and written into the database. The dynamic data mainly includes: machine tool status, coordinate information, spindle information, etc. After the conceptual design of each entity set of the ER model is completed, it will be converted into a database table. In fact, a "data transfer" will be created. Station" realizes the data interaction from the source to the terminal. The data table relationship diagram is shown in Figure 6.

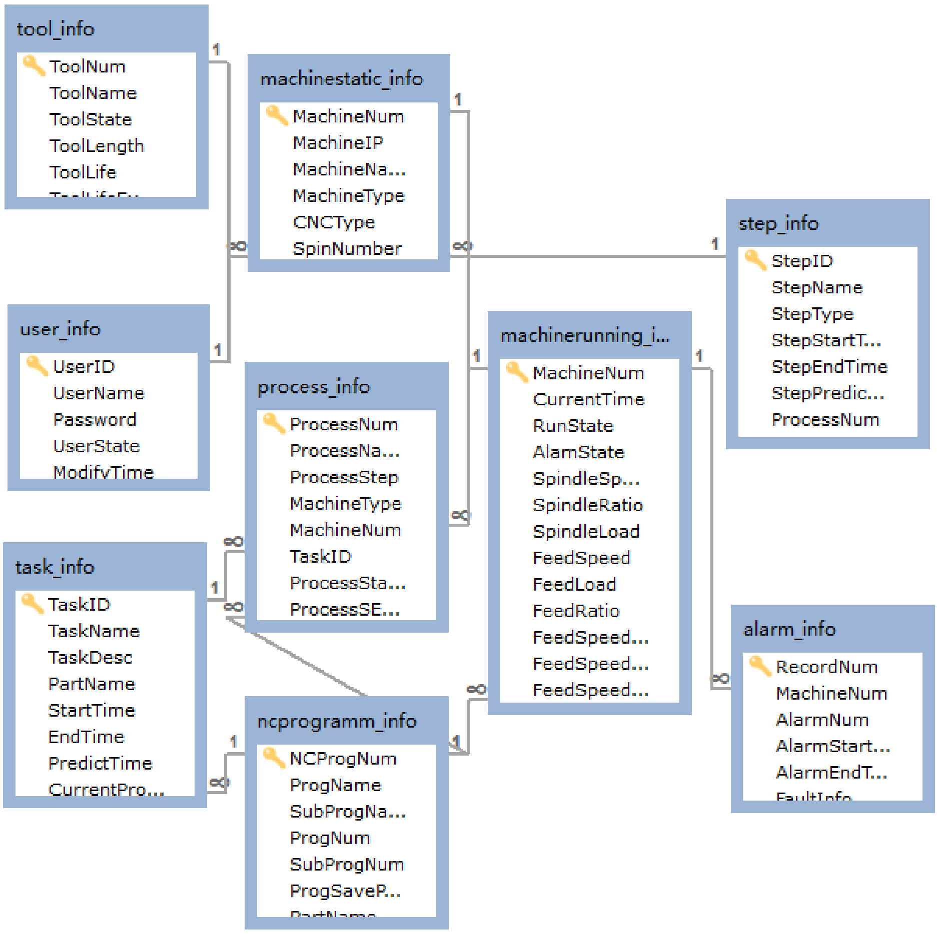

Fig. 6 The relationship of database table

5.2. Interface design and simulation implementation

The monitoring interface is implemented based on the QT Creator platform. QT is a cross-platform, lightweight interface application development framework that abandons the traditional MFC development model that is limited to Windows systems, and gives full play to

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the advantages of QT in interface design. QT has established a signal (SIGNALL) and slot (SLOT) mechanism, using SIGNAL can realize the transfer of any parameter. The entire monitoring interface mainly completes the following designs: simulation display, data display, database communication operation and key functions. When QT Creator is connected with Mysql, use the database API to add, delete, modify, and check database data; use interface controls (such as line Edit controls) to associate with the data to complete the display of related data; use OpenGL (standard API for drawing three-dimensional graphics) to call The related function controls the assembly of the model and sets the related button functions to complete the monitoring interface design. The process is shown in Figure 7.

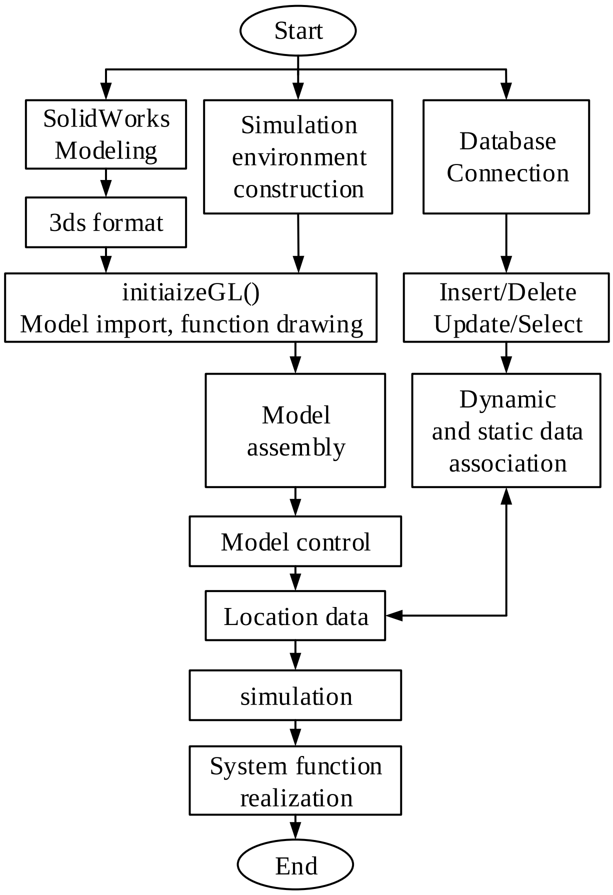

Fig. 7 The process of visual simulation

Machining center simulation, using SolidWorks and CINEMA 4D to establish rendering model objects, and using QT OpenGL, which supports a good graphics library, to design the animation control program of the machining center. Convert the model into 3ds or obj format that can be read by the OpenGL library. This article uses the 3ds format [13]. In QT, QGLWidget provides the function of displaying the OpenGL graphics integrated into the Qt application, so as to establish the OpenGL drawing window to assemble and visualize the machining center model, which mainly involves the following virtual functions [14]: initializeGL () The function completes the drawing loop initialization environment and 3ds file reading, uses resizeGL() to adjust the window size and projection mode, glTranslatef(), glRotatef() completes the assembly control (translation, rotation) of each module of the machining center. And set the sampling period in the program, the thread periodically reads the coordinate data input in the database, the update() function activates the PaintGL() function by receiving the signal, and the glRotatef() control interface redraws the 3D model according to the current coordinate data. glPushMatrix() and glPopMatrix() are paired to release drawing resources. Set the sampling period, refresh the visualization interface data in real time, and follow up the animation control effect in real time. The main interface design is shown in Figure 8.

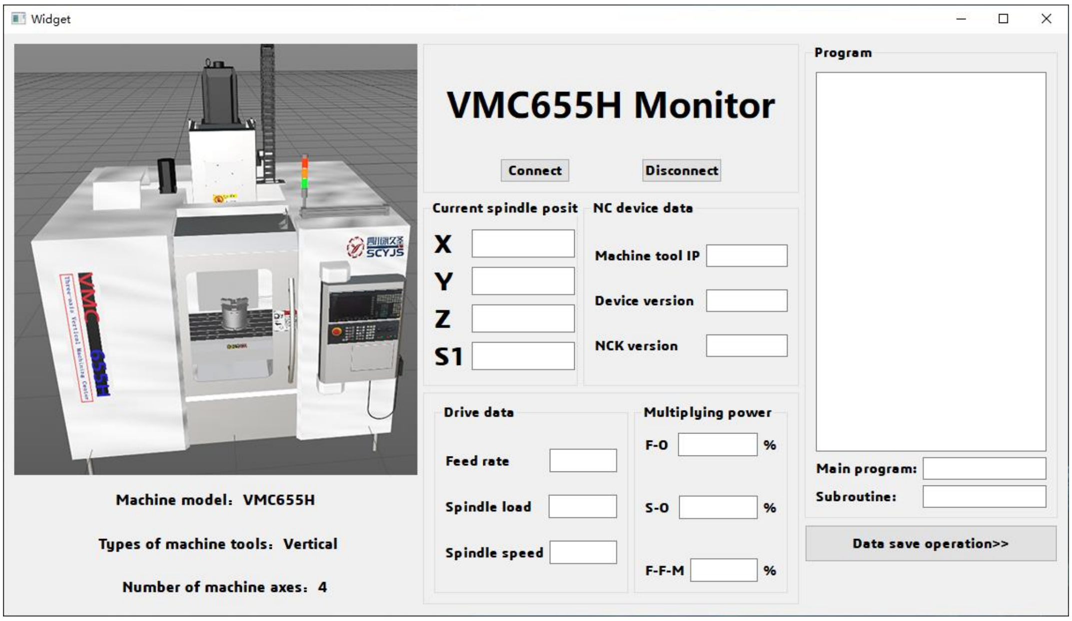

Fig. 8 The main interface of monitor system

6. System testing and verification

The simulation monitoring program runs on the PC and combines the VMC 655H machining center with Siemens 828D as the numerical control system as the research object. The function and performance of the development system are tested through experiments to verify the correctness of the system. Test work includes: data communication collection, data processing, database and simulation, status monitoring, etc., among which communication test is the focus of the entire monitoring system test.

On-line communication debugging of 828D system, server, PC and machining center body. The development system uses Open62541 and is based on OPC UA protocol to realize connection and access to the variable nodes of the server. The access process includes initializing the communication stack, server connection, node browsing and reading and writing related data. Wait. Specify access to the relevant nodes of the machining center, interpret the processing data to be written into the database in real time, and bind and associate the data with the interface data display, which can accurately feedback the coordinate instructions and status data to the simulation end and the interface end, and the machining center movement (such as tool movement), The dynamic coordinate data also changes accordingly, realizing the machining center simulation and real-time monitoring of related status data. The test results show that the data communication of the 828D system based on the QT platform and the real-time simulation of motion control using OpenGL are correct and effective, the data is displayed in real time, and the system runs reliably. The test results are shown in Figure 9 and Figure 10.

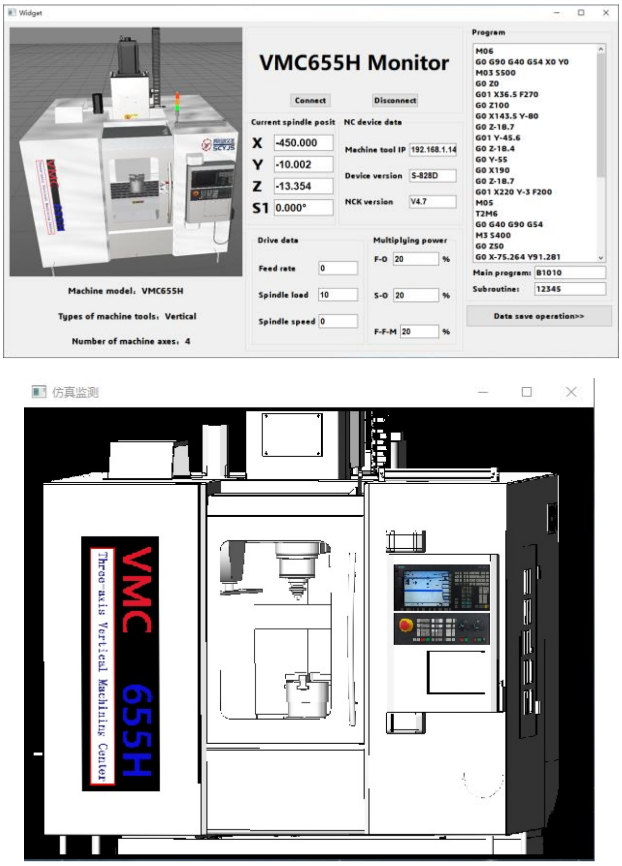

Fig. 9 Status 1

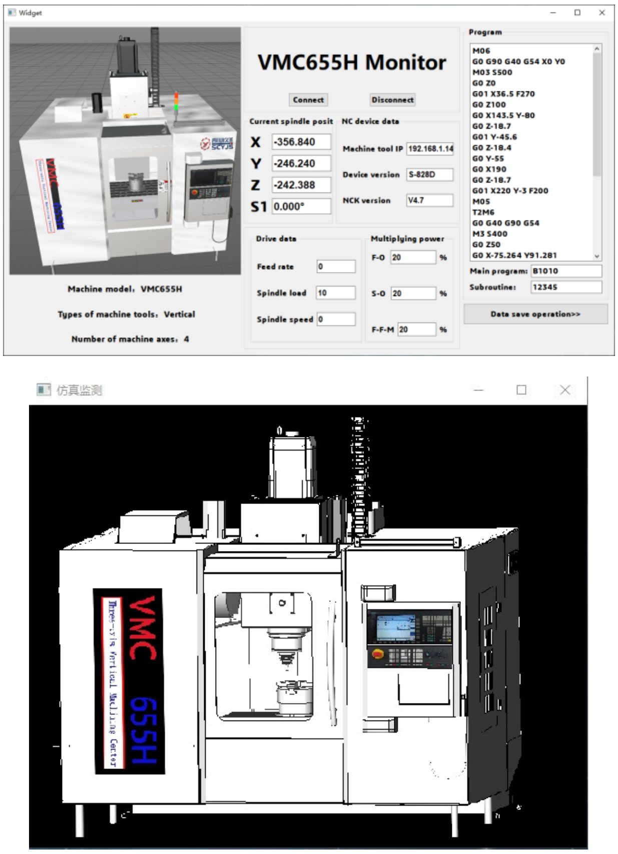

Fig. 10 Status 2

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7. Summary

In this study, the Siemens 828D machining center was used as the experimental platform, and the system debugging, configuration and programming were completed in the PC environment. Based on the OPC UA protocol, the QT platform and its OpenGL three-dimensional graphics interface are used to design and integrate a machining center simulation monitoring system. Through the test experiment of the development system, the correctness of using the Open62541 library to connect to the OPC UA server to realize the read and write nodes is verified, and the data is written into the database in real time and transferred to the model control function to realize the feasibility of simulation. It meets the diversified expansion function requirements of the underlying equipment, which has certain significance and reference value for eliminating information islands, promoting the design of other simulation monitoring systems, and realizing intelligent manufacturing in the workshop.

References

[1]. OUYANG Huabing. Research Status and Trend of Intelligent Manufacturing Technology. Journal of shanghai dianji university. Vol. 21 (2018) No. 6,10-16+23.
[2]. S.Wang,J.Wan,D.Li,C.Zhang.Implementing smart factory of industries 4.0:an outlool Int J Distrib Sens Netw(2016),10.1155/2016/3159805art.
[3]. X.Xu. Machine Tool 4.0 for the new era of manufacturing. Int J Adv Manuf Technol,92(2017), pp.1893-1900.
[4]. L.Wang,M.Törngren,M.Onori.Current status and advancement of cyb-er-physical systems in manufacturing. Proc N Am Manuf Res,37(2015).
[5]. Liu Jinsong. Research and Application of Intelligent Monitoring Technology for CNC Machine Tools. University of Chinese Academy of Sciences, 2017.
[6]. ZHANG Chi, WU Mingliang, LU Junqiang, et al. Design of Remote Monitoring System of 828D CNC Machine Tools Based on OPC UA [J], Machine Building & Automation,2018,47(06):186-189.
[7]. Li Guoliang, Study on Machining Simulation System of Virtual NC Lathe Based on OpenGL,Southwest Jiaotong University,2011.
[8]. LU Tingting ZHOU Lijuan. Research of Equipment Status Monitoring System for Domestic NC Machine [J]. Equipment Manufacturing Technology,2018(10):29-32.
[9]. A.G.Siemens. OPC UA server for SINUMERIK 828D and SINUMERIK 840D sl(2017).
[10]. OPC Foundation OPC unified architecture (Accessed 31 July 2018)
[11]. VDW and OPC Foundation. OPC-UA information model for CNC systems -companion specification release 1.0(2017).
[12]. Kevin J.Gucwa,Harry H. Cheng. An Interactive Virtual Environment for Programming Modular Robots. DETC2015-47705.
[13]. LiuFang,LiuXianmei. Research and Application on the Method of 3DS File Read, Render and Control. j.aasri.2012.06.028.
[14]. Chen Jiating. Research on the Key Technologies of Geometric Simulation of CNC Milling Based on Open GL, Harbin University of Science and Technology.2015.
[15]. Li Bangteng,Liang Wei,Ma Ping. Development and Simulation Application of OPC Server Based on Qt Platform [J]. Computer Measurement & Control,2017,25(11):154-158.