Design of Numerical Control Machining Simulation Teaching System Based on Mobile Terminal

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Abstract. Today's manufacturing industries all over the world widely use CNC technology to improve the manufacturing capacity and level, and improve the adaptability and competitiveness of the dynamic and changeable market. The research and development of CNC technology and the promotion and application of CNC products require a large number of high-quality CNC professionals, and CNC teaching and training are therefore in a very important position. In order to improve the success rate of system requests, a numerical control machining simulation teaching system based on mobile terminals is designed. Using the combination of PC and motion control card, combined with the oscillation circuit inside the PIC16F877 microcontroller to form a complete oscillation circuit; using 3D graphics technology to simulate the CNC machining process, optimize the CNC machining process, build a tool database, and transfer these parameters to the In the simulation program, the cutting process is simplified as a one-dimensional Boolean operation along the line of sight, and the function of the simulation teaching system is designed by using the mobile terminal. Experimental results: The request success rate of the designed system is high, indicating that its use effect is better.

Keywords: Mobile terminal · CNC machining simulation · Teaching system · CNC machine tool · Virtual environment · Part program

1 Introduction

The machining process of CNC machine tools is controlled by the part program. The correctness of the part program directly determines the quality and efficiency of machining, and an incorrect machining program can also lead to accidents. Due to the complex and changeable part shape, and the specific machine tool structure and workpiece clamping method are generally not considered in the process of tool path generation, the generated part program may not be suitable for the actual processing situation. CNC technology is the basic technology for the realization of automation, flexibility and integrated production in the manufacturing industry. It is not only an indispensable material means to improve product quality and labor productivity, but also related industries based on

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it are related to the national strategic position and The technical level of an important basic industry that reflects the level of a country's comprehensive national strength has become an important symbol for measuring a country's industrial modernization.

Although the current CNC programming technology has made great progress in surface modeling, trajectory planning, tool position calculation, etc., it still does not ensure that the generated part processing program is completely correct and reliable. The main problems are: over-cut and under-cut during processing, collision between tool and machine tool components and fixtures, and cutting overload during processing. Especially in high-speed machining, these problems are often fatal. In severe cases, tools, workpieces, machine tools and even personal accidents will be damaged. Therefore, after the part program is generated, it needs to be checked for correctness and modified according to its existing problems until a qualified part program is formed. NC machining simulation is the mapping of index-controlled machine tools in a virtual environment, which integrates manufacturing technology, machine tool numerical control theory, computer-aided design (CAD), computer-aided manufacturing (CAM), and modeling and simulation technology [1–3]. In recent years, both at home and abroad have attached great importance to the teaching and training of numerical control technology, and strived to develop new training technologies and means. At present, the commonly used NC machining simulation teaching systems mainly include the NC machining simulation teaching system based on virtual reality and the NC machining simulation teaching system based on PC platform. The former specifically divides the functional modules of the virtual reality NC machining simulation system, designs and develops them module by module, and combines the virtual reality external hardware equipment to design and implement a variety of three-dimensional display modes for different applications of the system. Thus a virtual reality NC machining simulation system with high model authenticity, complete machining functions, and preliminary cutting simulation effect and immersion effect is developed. The latter focuses on the input, modification, display and access simulation of the NC program code, the translation of the NC program, and the simulation of the machining process of the NC machine tool. Although the above simulation teaching system meets the teaching needs of CNC machine tools to a certain extent, there is a problem that the success rate of system requests is low.

Numerical control teaching has its own unique characteristics, and the rapid development of numerical control technology constantly puts forward new requirements for numerical control teaching. How to adapt to the characteristics of numerical control teaching and keep up with the pace of numerical control technology development is an important topic in numerical control teaching. With the help of mobile terminal technology, the virtual environment of the three-dimensional simulation model generated by the computer can be intuitively perceived, and the CNC machining of parts can be carried out in the virtual environment before the real manufacturing, and the correctness and reasonableness of the CNC program can be checked before designing a new scheme or changing the scheme. The advantages and disadvantages of the processing plan are evaluated and optimized, so as to ultimately achieve the purpose of shortening the product development cycle, reducing production costs, and improving product quality and production efficiency.

Under the above background, this paper designs a numerical control machining simulation teaching system based on mobile terminal. In the system hardware design, the system adopts a combination of power-on reset and button reset, which improves the convenience of system operation; in the decoding process In the program segment, the syntax check is performed, and if syntax errors are found, an alarm will be issued immediately to avoid damage to tools, workpieces, and machine tools, and to reduce the probability of personal accidents.

2 Hardware Design of NC Machining Simulation Teaching System

Before the system software and hardware design, the overall architecture of the NC machining simulation teaching system is first given, as shown in Fig. 1.

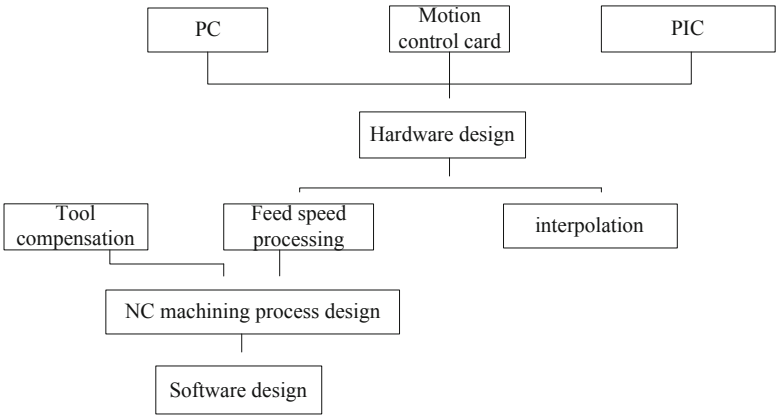

Fig. 1. Overall system architecture

When designing the hardware, try to use modular and standardized board-level modules, and use a combination of PC and motion control card in the system hardware. The motion control card is inserted into the PCI bus slot of the PC, and the A shared bus communication method is used between them. PIC is the prefix of the single-chip microcomputer series products produced by American Microchip Company. The hardware design of PIC series single-chip microcomputers is simple and the instruction system design is refined. It is easy to develop for beginners. It is one of the most widely used varieties of single-chip microcomputers. At the same time, efforts are made to reduce hardware costs, and economical stepping motors are used as driving components to form an open-loop feeding system with the stepping motor drivers. In this system, the PC system manages most of the control functions, including work mode scheduling, parameter and work state setting, emergency stop control, human-computer interaction, part program input, editing, translation, machine parameter interpolation, parts Graphic display, simulation processing display and dynamic display of tool coordinates etc.

At present, several well-known semiconductor companies in the world have developed a series of single-chip microcomputers that are compatible with pins by imitating

the PIC series of single-chip microcomputers. It can be said that the PIC microcontroller series represents a new direction of microcontroller development. PIC 16F87X is a new product with distinctive features introduced by Microchip. Its most important advantage is that the PIC16F877 series of microcontrollers have FLASH program memory and built-in ICD function, which can realize online debugging and online programming. This is the MCS51 and MC68 series microcontrollers. Not available, this is exactly what the majority of microcontroller users need. The motion control card is the MPC02 motion control card of Step-servo Company. It transmits digital pulses to the X, Y, Z stepper motor drivers respectively through the I/O interface, and drives the stepper motor to drive the XY table and the Z spindle to respond accordingly. Exercise. The motion control devices of the numerical control system mainly include stepper motors and their drivers, spindle motors, numerical control actuators and operation panels. In the PIC 16F87X series, the PIC16F877 includes the functions of other types of microcontrollers, and other microcontrollers are partially simplified on the basis of their functions. The superiority of the PIC series of microcontrollers is mainly due to the unique design method adopted in the architecture of this series of microcontrollers. Separate from the command bus and use different widths.

Because this machine tool is a CNC milling machine for three-coordinate linkage teaching developed for CNC teaching and vocational technical training. That is to consider the function, performance requirements, but also take into account the needs of economic and practical. The X, Y, Z coordinates of the machine tool are all driven by linear rolling guides and ball screws, and are driven by stepper motors. This facilitates the realization of the "pipeline operation" of instruction fetching, that is, while executing one instruction, the instruction fetch operation is performed on the next instruction, which facilitates the realization of single-byte and single-cycle of all instructions, which is conducive to improving the execution of instructions by the CPU. Speed, so this system adopts PIC16F877 type single chip microcomputer. In order to meet the needs of different cutting speeds, the main shaft of the machine tool is rotated by a variable frequency speed regulation motor, so this machine tool has the advantages of stable movement, high movement precision, and stepless speed regulation. The lifting table is used to expand the range of workpieces to be processed, and all movements during processing are gearless, which greatly improves the transmission accuracy and helps reduce machine tool noise. The machine can also be equipped with automatic cooling, oil pump lubrication and lighting systems. In order to obtain a relatively stable oscillation timing signal, the clock circuit design adopts the XT method, selects a 4 MHz crystal oscillator and two 22PF capacitors, and connects the crystal oscillator and two capacitors to the OSC1 and OSC2 pins, combined with the internal PIC16F877 microcontroller. The oscillator circuit constitutes a complete oscillator circuit. The reset circuit of the hardware part of the CNC machining simulation teaching system is shown in Fig. 2:

As can be seen from Fig. 2, according to the requirements of PIC16F877 single-chip low-level reset and reset time of 5ms, the system adopts a combination of power-on reset and button reset. Although an all-round software control panel is designed in this numerical control system, for the convenience of operation and equipment safety, it is also equipped with an electrical operation panel of the machine tool, which is mainly used for the start and stop of the numerical control machine tool, and the control and

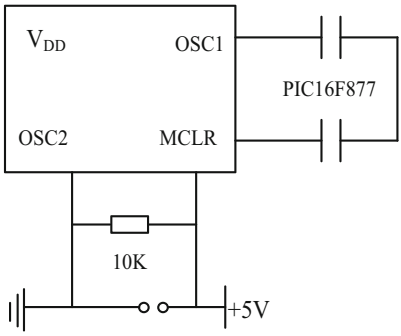

Fig. 2. System hardware reset circuit diagram

status display of the actuator. The machine tool is equipped with a special strong electric control cabinet, which is convenient for cognitive experiments of the control system. Such as the electrical control of spindle motor, stepper motor and cooling motor, as well as servo control, signal transmission, frequency conversion speed control and so on. The power-on reset is when the single-chip microcomputer is powered on, when the pin VDD rises to 1.6–1.8 V, the power-on reset circuit provides a reset pulse to reset directly. The key reset is to reset by the negative pulse generated by the key. The function of the peripheral output circuit is to indicate the current state of the machine tool by the light and shade of the indicator light on the machine tool operation panel. MPC02 control card as a platform for developing motion control system, its structure is open. The card is inserted into the PCI expansion slot of the PC, and the number of control cards and the number of control axes on each card can be easily configured. The MPC02 card provides a powerful motion control function library, and can make full use of the existing resources of the PC to develop a perfect motion control system. The MPC02 control card is divided into two types: A and B, and the number of control axes can be selected from 1 to 3 axes. Because the machine tool may be in a certain state for a long time, such as coolant startup, spindle forward travel, etc. Taking into account the characteristics of the status of the indicator light, a 8D latch tri-state unidirectional data buffer of a 74LS373 and a 8255A are used to expand, and the latch function of the 74LS373 is used to meet the requirements of the indicator light status.

3 Software Design of NC Machining Simulation Teaching System

3.1 Optimizing CNC Machining Process

The machining process of CNC machine tools is controlled by the part program. The correctness of the part program directly determines the quality and efficiency of machining, and an incorrect machining program can also lead to accidents. Input to the CNC controller usually includes part programs, machine parameters and compensation data [4, 5]. However, machine parameters and compensation data other than tool size are generally set during installation and debugging, so the main input is the part program and tool size compensation data. Due to the complex and changeable part shape, and

the specific machine tool structure and workpiece clamping method are generally not considered in the process of tool path generation, the generated part program may not be suitable for the actual processing situation. The CNC input working modes include storage mode and NC mode. The so-called storage method is to input the entire part program into the CNC internal memory at one time, and then call out the blocks one by one from the memory during processing. The so-called NC mode means that the CNC performs processing while inputting, that is, when the previous program is processed, the content of the next block is input. Because the PC memory is relatively large now, this system adopts the storage method. Decoding processing is to process a block of the part program as a unit. Therefore, although the current CNC programming technology has made great progress in surface modeling, trajectory planning, tool position calculation, etc., it still cannot ensure that the generated part machining program is completely correct and reliable. The main problems are: over-cut and under-cut during processing, collision between tool and machine tool components and fixtures, and cutting overload during processing. That is, the part contour information (such as starting point, end point, straight line or arc, etc.), feed speed information (CF code) and other auxiliary information (M, S, T code, etc.) are interpreted into the computer according to certain grammar rules. A data form that can be recognized and stored in a designated memory dedicated area in a certain data format. The main steps of the CNC machining process are shown in Fig. 3:

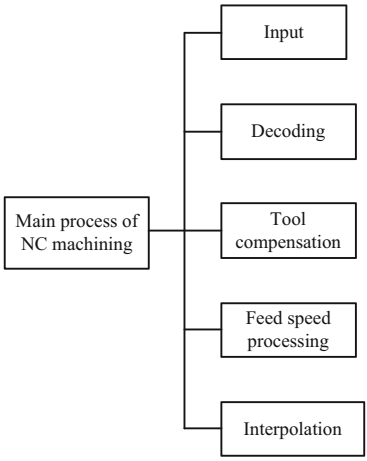

Fig. 3. The main process of CNC machining

As can be seen from Fig. 3, the main process of CNC machining mainly includes steps such as input, decoding, tool compensation, feed speed processing and interpolation. Especially in high-speed machining, these problems are often fatal. In severe cases, tools, workpieces, machine tools and even personal accidents will be damaged. Therefore, after the part program is generated, it needs to be checked for correctness and modified according to its existing problems until a qualified part program is formed. During the decoding process, the syntax check of the program segment should be completed, and if

any syntax error is found, an alarm will be issued immediately. Tool compensation refers to the compensation of tool length and tool radius. In order to make the compiled part program independent of the tool size, that is, the compiled program will not be changed due to the change of the tool size, usually the part program is programmed with the part contour trajectory. The function of tool compensation is to automatically convert (or convert) the contour of the part into the tool center path according to the set tool size data.

There are several ways to check the part program. One of the methods is to let the machine tool "dry run" before the formal processing. The dry run can only make a rough estimate of whether the machine tool movement is correct and whether there is interference or collision. However, if the method of "trial cutting" is adopted, a more accurate judgment can be made on whether the processing process is normal and whether the processing results meet the requirements. However, trial cutting is a time-consuming and expensive work, its efficiency is very low, and it needs to increase production costs. In addition, the safety of the trial cutting process cannot be guaranteed. Tool compensation also includes automatic transfer between blocks and over-cutting judgment, which is the so-called C tool compensation function. The moving speed of the tool relative to the workpiece given by the CNC machining program is the speed in the direction of the composite movement of each coordinate, that is, the command value of the F code. The first work to be done in the speed processing is to calculate the sub-speed in the direction of each feed motion coordinate according to the composition, so as to prepare for the calculation of the stroke amount of each feed coordinate during interpolation. Using three-dimensional graphics technology on the computer to simulate the CNC machining process can quickly, safely and effectively evaluate the correctness of the NC program, and quickly modify the NC program according to the simulation results, avoiding repeated Trial cutting process, reduce material consumption and production cost, improve work efficiency. Therefore, computer simulation of NC machining process is an efficient, safe and effective method for checking NC programs. In addition, the limit of the minimum and maximum speed allowed by the machine tool and the automatic acceleration and deceleration are also dealt with here [6–8]. The MPC02 motion card has speed processing capabilities, and these motions can work in normal speed mode or trapezoidal speed mode. Due to the limited information of the command stroke, for example, only the start and end coordinates are given for a straight line. For a segment of arc, in addition to the coordinates of its start and end points, its center coordinates or arc radius are also given. In this way, to perform trajectory processing, CNC must automatically perform data densification from a curve with a known start and end point, which is called interpolation.

3.2 Build Tool Database

In the process of CNC machining, the selection of tools should be carried out according to different machining surfaces, the setting of blank size, the selection of fixtures, and the assembly of blanks and fixtures should be carried out according to different parts. For the management and application of these data, in CNC It is very important in the simulation system. Therefore, it is necessary to establish a database to complete the storage and management tasks of these data. By selecting the tool from the turning tool library, the

main parameters of the turning tool are obtained, and these parameters are transferred to the simulation program, and the tool is drawn according to these parameters. Similarly, by setting the main parameters of the workpiece, these parameters are also passed to the simulation program, and the workpiece is drawn according to these parameters. In this paper, the main databases are: tool database, workpiece database, fixture database and assembly database. A database is the total container for data and its related objects. A table is a container for storing raw data. In order to reduce the memory footprint, a loop is used to read in a field—check and explain the field—record the field, and then read in a word—check and explain the field—record the field until the end of the NC code. In order to read in the NC code, a character array array with 10 elements is defined, which is used to temporarily store each character of a field of the NC code. As the user enters data, the table stores it in logical combinations of similar data. Tables organize information in rows and columns, where rows are called records and columns are called fields. The same column of data in the table has similar information, and the column entries of these data are fields.

When reading a file, first read a character from the NC code file, and then process it differently according to the character (this character can be letters, numbers, decimal points, spaces, line breaks, semicolons, Chinese characters, file terminators, etc.), for syntactic, semantic and error analysis. The first character in the string array gives the meaning of the character in the NC code, and the substring composed of the following characters gives the numerical information of the character. Each field is identified by a specific data type (e.g. text, number, date, etc.) and has a specific length. Each field also has a name that indicates its category of information. Rows of data in a table are records. Each piece of information is conceived as a separate entity that can be accessed or ordered as needed. The structure diagram of the tool definition in the database is shown in Fig. 4:

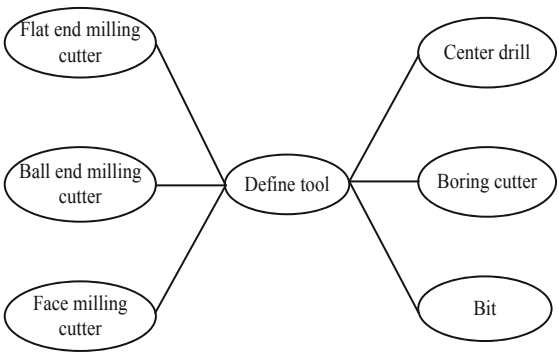

Fig. 4. Structure diagram of tool definition

As can be seen from Fig. 4, the structure diagram of the tool definition in the database includes six parts: flat end milling cutter, ball end milling cutter, face milling cutter, center drill, boring cutter and drill bit. There are three main purposes for checking and interpreting NC codes: checking the integrity and correctness of the entire field read

and the correctness of each character in the field. If there is an error, even if an error message is given, the user is prompted to modify and terminate the program. Separates a substring of the first character of a string and subsequent numeric characters and converts the substring to a numeric value. The data management part of the tool library includes the input interface of the basic parameters of the tool and the data interface of the auxiliary parameters of the tool. According to the needs of the system, seven data tables are established. The base table is "Define Tool", which has six fields, namely: Tool No., Tool Name, Diameter, Tool Type, Corner Radius, and Tool Radius Form. These six fields represent the properties of a tool. Necessary information. The remaining six tables are face milling cutters, flat end milling cutters, ball end milling cutters, bell cutters, drill bits and center drills. The obtained data information is given to the tool motion variables in the program and subdivided to meet the real-time nature of dynamic simulation. The task of setting is to set the pixel format by calling the interface function of the CGL class, create and activate the rendering description RC (Rendering Content), and then set the position and size of the viewport, and set the shape of the viewfinder when creating a 3D view client area., size, position, and set the depth buffer, the clear value of the color buffer and the polygon drawing mode, etc., and finally set the material and lighting model. From this information, the geometric parameters of each tool in the tool library can be known. The operator of the CNC machine tool selects the appropriate tool from the tool library to process the workpiece according to the geometric shape and material properties of the workpiece to be processed.

When simulating machining, it is necessary to define, select or modify various parameters such as the shape, size, material and so on of the blank to be machined. Therefore, a database about the workpiece must be established. Here you can define a new blank, or select a previously defined blank, or modify the blank parameters defined in the past, so as to prepare for the subsequent simulation processing. In the turning simulation system, two light sources are used in the scene, one is a chandelier in a similar room, and the other is a work light that moves with the tool holder. And a Boolean button is used. After pressing it, only the cutting of the turning tool and the workpiece can be displayed, and other redundant scenes can be removed.

3.3 Function of Mobile Terminal Design Simulation Teaching System

In the mobile terminal, the biggest feature of Objective-C is the message delivery model derived from Smalltalk, which is a mechanism that is very different from the mainstream delivery style of today's C++ style. In Objective-C, it is more accurate to say that object instances pass messages to each other than to say that object instances call methods to each other. The main difference between the two styles is the action of calling a method/passing a model. When the mobile terminal is running the program, the classification code can access all the member variables, including the private class member variables of course. If methods in two categories have the same name, it is unpredictable at runtime which method is called.

Maintainability requires that the software system must have sufficient elasticity and scalability, so that the software system can cope with changes in customer needs for a long period of time, while maintaining the invariance of its overall structure, without the need for redesign and For development, it is only necessary to add a functional

component in an appropriate place or replace an original functional module. In simulation technology, modeling is the key of simulation technology. It can be said that geometric simulation technology develops with the development of modeling technology. The description method of shape information by computer is referred to as modeling or modeling technology. The modeling technology is mainly composed of two parts: shape expression and shape operation. The task of shape expression is to simulate the structure of the shape with a data structure. This data structure describing the shape is called a model. Described in software engineering terms is to achieve "high cohesion, low coupling". For the numerical control teaching system, with the expansion of teaching breadth, more numerical control systems will be learned further, so how can many different types of numerical control systems be easily derived from one design structure, and how can one easily change a numerical control system? It is particularly important to reflect the shape characteristics of various CNC machine tools in order to reflect different types of machine tools and CNC systems.

The task of shape operation is to realize the operation of model generation, modification, synthesis, analysis, calculation, display, etc., so as to complete the modeling tasks in the design process. Solid modeling technology decomposes an object into a limited set of three-dimensional elements and a set of operations that can be applied to this set of elements. Depending on the different three-dimensional elements and their operations, solid modeling techniques can be divided into many types. In the design, it is more appropriate to design the part of the man-machine operation interface reflecting different types of CNC systems separately as a replaceable independent module. At the same time, as the process simulation part to deal with the corresponding type of CNC system processing, its core is the G/M code interpreter [9, 10]. Since different types of CNC systems use many common G/M codes, together with some exclusive special codes for special processing, they constitute all the processing codes of this type of CNC system. In addition, the solid modeling technology provides an accurate, complete and unambiguous description method for 3D solids, surfaces and curves. The direct Boolean operation algorithm based on the solid modeling technology is used for the geometric simulation of the machining process, and the cutting geometric information can be accurately obtained., not only for interference verification, but also for 3D dynamic simulation of multi-axis machining material removal process.

The task of the machining environment simulation module is to calculate and display the cutting condition of the workpiece in real time. Allows users to intuitively see the processing effect of each step. It directly accepts the tool path information sent from the machine state part, and then dynamically changes the corresponding position of the tool graphics in the graphics environment according to the information. The image space modeling method is to use the Z-Buffer idea similar to graphic blanking, to discretize the workpiece and the tool into a Z-Buffer structure according to the pixels of the screen, and the cutting process is simplified to a one-dimensional Boolean operation along the line of sight. This algorithm has a small amount of calculation, good real-time performance, and a better display effect in the simulation. Set (A_1, B_1) as the starting point of the tool movement and (A_2, B_2) as the end point of the tool movement, then the calculation

formula of the unit vector of the movement direction of the tool center is:

$$A_1 = \frac{(A_2 - B_1)}{\left[(A_2 - B_1)^2 + (B_2 - B_1)^2\right]} \tag{1}$$

$$B_1 = \frac{(B_2 - B_1)}{\left[(A_2 - B_1)^2 + (B_2 - B_1)^2\right]} \tag{2}$$

Since the tool radius vector refers to the vector that is always perpendicular to the programmed path during the machining process, and whose size is equal to the tool radius value, the direction points to the tool center, which is represented by R_m. On the basis of formula (1) and formula (2), the expression formula of tool radius vector is obtained:

$$R_m = \frac{|m - n|}{A_1 - B_1} \tag{3}$$

In formula (3), m represents the transition vector at any point on the arc, and n represents the motion vector at any point on the arc. When the viewpoint is determined, the data structure of the algorithm is also determined. If you want to change the viewpoint to observe from another direction, you need to recalculate the data. The computer screen is used as the reference surface, so it will completely depend on the view. At the same time, it is judged whether the tool collides with the machine tool and whether it is in the state of cutting the workpiece, so as to decide whether to feedback error information to the machine interface, whether to call the real-time cutting calculation and display module to change the shape of the workpiece, and to convert the final The tool and workpiece status are displayed.

The discrete vector intersection method is mainly used in the estimation of machining errors. Error detection is accomplished by calculating the distance between the discrete point vector and the tool swept surface. The "point-vector" technology developed by Chappel has laid the foundation of this method. This method approximates the surface by selecting some points on the surface, selecting the normal vector direction of the point as the direction of the point vector, and extending the vector until it intersects with the blank body of the part or other surfaces. By calculating the intersection of the tool swept surface and the point vector, and calculating the distance between the starting point and the intersection of the point vector, the cutting process of the tool is simulated.

Because in the process of software design and development, it is considered that a part of the staff is transplanting the tasks and motion control parts of the real CNC system to the Windows platform, and it exists in the form of a library file. A segment is a part or whole of a graph. In the raster system, the bitmap segment (icon) can be obtained directly from the screen, and the acquired image segment is stored as a bitmap file and block on the disk or in the buffer, and then another image segment display operation is called., place them at the specified position of the screen, and by changing different output screen positions, the continuous movement of the segment graphics is generated, and the segment transformation animation is also generated. So compared with the processing simulation part developed by oneself, the transplanted library undoubtedly has more comprehensive, perfect and authoritative characteristics. In the simulation software, if this porting library file can be fully utilized, the simulation similarity will be stronger

for the simulation software. Therefore, two interfaces are designed here, which can be switched between two different process processing modules as needed.

4 System Test

4.1 Test Preparation

This experiment chooses OpenGL as the main operating software. OpenGL is an open three-dimensional graphics software package, which is independent of the window system and operating system. The applications developed based on it can be easily transplanted among various platforms. In fact, in the CNC system, the conversion from NC code to tool path point is completed by continuously calling the NC code interpreter. OpenGL can be closely interfaced with Visual C++, which is convenient to realize the calculation and graphics algorithm of the manipulator, and can ensure the correctness and reliability of the algorithm. At the same time, OpenGL is easy to use and has high efficiency. In order to establish a realistic machining process simulation environment and improve the NC code processing process, a brand-new NC code interpreter is not directly implemented in the simulation system, but is further encapsulated on the basis of the existing SAItest version interpreter to make it Suitable for the current simulation environment.

4.2 Test Results

The CNC machining simulation teaching system based on virtual reality and the ARM-based CNC machining simulation teaching system are selected to compare and test with the CNC machining simulation teaching system designed this time. The request success rates of the three systems were tested under different system requests, and the experimental results are shown in Tables 1, 2 and 3:

Table 1. Number of requests 1000 system success rate (%)

Number of experiments	Numerical control machining simulation teaching system based on virtual reality	Simulation teaching system of CNC machining based on PC platform	The CNC machining simulation teaching system designed this time
1	86.915	89.645	95.001
2	87.104	85.117	93.678
3	88.699	86.302	92.515
4	86.815	87.944	93.008
5	87.649	88.964	92.548
6	86.774	889.311	94.316

(*continued*)

Table 1. (*continued*)

Number of experiments	Numerical control machining simulation teaching system based on virtual reality	Simulation teaching system of CNC machining based on PC platform	The CNC machining simulation teaching system designed this time
7	88.215	87.442	95.156
8	89.361	86.130	95.008
9	86.772	87.555	96.334
10	89.616	88.612	94.125
11	87.313	89.111	93.701
12	86.955	87.553	93.889
13	86.201	88.206	92.116
14	85.477	87.134	96.002
15	86.344	86.393	97.441

Table 2. The success rate of the system with 3000 requests (%)

Number of experiments	Numerical control machining simulation teaching system based on virtual reality	Simulation teaching system of CNC machining based on PC platform	The CNC machining simulation teaching system designed this time
1	65.312	65.205	73.644
2	63.014	66.449	74.812
3	65.802	65.813	76.915
4	64.812	64.919	77.388
5	59.133	63.485	76.512
6	61.225	63.145	78.454
7	62.948	66.312	75.911
8	63.462	62.588	76.021
9	64.815	64.051	77.535
10	63.775	63.974	78.446
11	65.004	64.802	75.904
12	63.815	63.114	74.119
13	62.901	64.819	73.464
14	64.228	63.550	75.008
15	63.455	64.122	76.499

Table 3. The number of requests 5000 system success rate (%)

Number of experiments	Numerical control machining simulation teaching system based on virtual reality	Simulation teaching system of CNC machining based on PC platform	The CNC machining simulation teaching system designed this time
1	43.615	44.815	62.145
2	42.779	43.712	59.887
3	41.080	46.330	63.001
4	43.664	45.877	58.132
5	44.812	44.212	59.877
6	45.903	45.913	65.447
7	46.774	46.822	66.115
8	45.812	47.114	65.923
9	46.337	45.993	66.748
10	45.208	44.877	65.264
11	46.977	43.606	64.717
12	46.288	44.555	65.808
13	45.317	45.182	64.144
14	46.211	46.907	65.312
15	45.667	45.316	66.715

It can be seen from Table 1 that the success rates of the CNC machining simulation teaching system designed this time and the other two CNC machining simulation teaching systems are: 94.323%, 87.347%, and 87.628% respectively; The success rates of the teaching system and the other two CNC machining simulation teaching systems are: 76.042%, 63.580%, and 64.423% respectively; from Table 3, it can be seen that the designed CNC machining simulation teaching system and the other two CNC machining simulation teaching systems have the same success rate. The success rates are: 63.949%, 45.096%, 45.415%.

5 Concluding Remarks

In order to improve the request success rate of the simulation teaching system, a numerical control machining simulation teaching system based on mobile terminal is designed. By combining power on reset and key reset, the convenience of system operation is improved; Build the cutter database, design the function of the mobile terminal design simulation teaching system, and complete the design of the simulation teaching system. The experimental results show that the request success rate of the system designed in this paper is significantly higher than that of the traditional system, which fully verifies its application value.

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