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Research Article

Research and Application of CNC Machining Method Based on CAD/CAM/Robot Integration

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In order to improve the effect of intelligent CNC machining, this paper combines the CAD/CAM/Robot integration method to improve the CNC machining method and analyzes the tool path planning method and the path generation algorithm of the five-axis CNC machining machine. Through the tool processing calculation of the representative curved surface, this paper studies the basic theory, process planning, and tool parameter selection of the blade of the representative curved surface in the five-axis CNC machining and generates the blade CNC machining tool path through the simulation software. In addition, this paper analyzes the trajectory of the workpiece through the intelligent processing process and builds an intelligent processing system. Through the statistics of simulation test data, it can be seen that the CNC machining method based on CAD/CAM/Robot integration can effectively improve the intelligence of modern CNC machining and improve the effect of intelligent machining.

1. Introduction

With the development of intelligence and data, traditional machine tool processing has evolved into data processing. Compared with traditional machine tools, CNC machining has many differences. The biggest difference is technical problems. The operation of traditional machine tools and some basic technologies have become the basis of CNC machine tool processing, but they are not fully cited. The operator of the CNC machining process should have a clear understanding of the difference between the traditional process and the CNC process. Only in this way can they be better used in the operation and give full play to the advantages of both.

At present, the numerical control technology is undergoing a fundamental change, from a special closed open-loop control mode to a general open real-time dynamic full closed-loop control mode [1]. In terms of integration, the CNC system has achieved ultrathin and ultra-miniaturization; on the basis of intelligence, it has integrated computer, multimedia, fuzzy control, neural network, and other multidisciplinary technologies, and the CNC system has achieved high speed, high precision, and efficient control. Various parameters can be automatically corrected, adjusted, and compensated during the processing, realizing online diagnosis and intelligent fault handling [2]; on the basis of networking, CAD/CAM and CNC systems are integrated into one, machine tools are networked, and the central centrally controlled group control processing. For a long time, my country's CNC system has been a traditional closed architecture, and CNC can only be used as a non-intelligent machine tool motion controller [3]. The machining process variables are set in advance in the form of fixed parameters according to experience. The machining program is controlled manually or through CAD/CAM and automatic programming before actual machining. During the entire manufacturing process, CNC is just a closed open-loop actuator. Under complex environment and changeable conditions, machining parameters such as tool combination, workpiece material, spindle speed, feed rate, tool path, depth of cut, step length, and machining allowance cannot be used in the field environment according to external interference. Without real-time dynamic adjustment of random factors, and it is impossible to randomly modify the set amount in CAD/CAM through the feedback control link, thus affecting the work efficiency of CNC and product processing quality

[4]. The fixed program control mode and closed system structure of the traditional CNC system limit the development of CNC to multivariable intelligent control, and it is no longer suitable for the increasingly complex manufacturing process. Therefore, it is imperative to reform the numerical control technology [5].

The operation of CNC machining technology integrates many aspects. It is very important to understand the characteristics of the process during operation. In fact, the positioning of CNC machining technology must be accurate, and then the selection of tools and the formulation and parameters of lines. In the traditional processing technology, these complex steps are simply dealt with. From these aspects, we can see its complexity, and we can see many differences from the traditional technology [6]. Therefore, in the process of compiling the numerical control program, the operator needs to conduct a careful analysis and then formulate a detailed report and plan and operate in strict accordance with the plan [7].

CAD/CAM technology is developed on the basis of the development and application of graphics-assisted numerical control programming. GNC is a manufacturing-oriented technology, which combines the geometric modeling of parts, tool position calculation, graphics display, post-processing, and so on together [8]. CAD/CAM integration is a comprehensive high-tech, which is currently developing in the direction of integration, intelligence, visualization, and standardization [9]. The main research contents are as follows: CAD system is oriented to the entire life cycle of products, fully considers the inheritance of product information, and meets the requirements of concurrent design, the combination of CAD and product information standardization, the convertibility of product models, and the comprehensive and even global product information code [10]. As an important aspect of computer application, CAD/CAM is also inseparable from network technology. The processing capacity of a single computer limits its application scope. Only by interconnecting through the network can resources be shared, coordinated, and cooperated to achieve greater efficiency [11]. Integrate CAD, CAM, CAPP, and management and decision-making information systems together, interconnect each system through a computer network, realize data exchange, sharing, and integration, reduce the repeated input and output process of intermediate data, and greatly improve the entire system. The efficiency of the whole process from order, material preparation, design process to production, and supply is improved [12].

The numerical control machining program converts the technological process of mechanical parts, technological parameters, tool displacement amount and displacement direction, and other auxiliary actions (such as tool change, coolant switch, and workpiece clamping) according to the movement sequence and the command codes specified by the numerical control system, and the program format is compiled into the NC program list [13]. The compiled list of CNC machining programs can be recorded on information carriers such as paper tapes, magnetic tapes, and disks. Through the input device equipped on the CNC machine tool, the CNC machining program on the paper tape, magnetic tape, and disk is input into the workpiece storage area of the CNC system [14]. Due to the development of the manufacturing industry, the numerical control system has also been widely used. With the expansion of the scale of the processing program, the improvement of the interpolation accuracy, and the increase of the calculation amount, the numerical control system gradually cannot meet the requirements. The majority of users hope to solve this problem. And the development of computer network technology has accelerated the development of CNC machine tool network communication [15].

CNC machine tool machining parts are controlled by CNC command program. The current CNC programming technology has made great progress in surface modeling, trajectory planning, tool position calculation, and so on, but it still cannot ensure that the NC program is completely correct and reliable. There are many ways to check the NC program. One of the methods is to let the machine tool run dry before the formal processing. Dry run can only make a rough estimate of whether the machine tool is moving correctly and whether there is interference or collision; the second method is the trial cutting method; that is, check the correctness of wood or plastic workpieces by trial cutting; it is obvious that this process has a long cycle, high cost, and low efficiency; the third method is the trajectory display method; that is, a scribing needle or a pen is used instead of a tool, and a coloring board or paper is used instead of the blank. The two-dimensional graphics of the simulation tool movement trajectory (two-dimensional and half-processing trajectory) can also be displayed, but the limitations are very large. To this end, people have been looking for methods that can quickly, safely, and effectively verify the correctness of NC programs [16]. The development of computer simulation and modeling technology makes it possible to carry out computer simulation of CNC machining process. NC machining simulation is to use 3D graphics technology to simulate the NC machining process on the computer, and it has become an important part of CAD/CAM technology. Since NC simulation technology does not require raw materials and the verification process has the characteristics of agility, intuitiveness, and flexibility, it is an effective way to improve the efficiency of tool path verification and has considerable economic value [17].

In modern manufacturing systems, numerical control technology is the key technology. It integrates microelectronics, computers, information processing, automatic detection, automatic control, and other high-tech technologies. It has the characteristics of high precision, high efficiency, and flexible automation. Flexible automation, integration, and intelligence play a pivotal role [18]. At present, the optimization of CNC machining parameters mainly focuses on the optimization of feed speed. There are some commercial systems abroad that have the function of feed rate optimization, but most of the systems use the volume removal method to optimize the feed rate [19].

With the development of some new technologies, such as artificial intelligence, fuzzy control, and neural network, CNC technology is developing towards high speed, high precision, high flexibility, and intelligence. The selection of early cutting data is usually based on some manuals, production practice materials, or the processing experience of programming technicians, so the selection of cutting data is not very advanced in terms of information and methods: for specific production practice data, targeted relatively strong, not widely used, and so on, all make the processing efficiency relatively low. In order to solve the problem of economic benefits of the processing system and improve the utilization rate of the machine tool, various intelligent methods of processing parameters have been proposed one after another, mainly including two categories of online and offline parameter intelligent methods.

In order to improve the intelligent effect of CNC machining, this paper combines the CAD/CAM/Robot integration method to improve the CNC machining method and improve the intelligence of CNC machining.

2. CNC Machining Method Based on CAD/CAM/Robot Integration

2.1. CNC Milling Path Planning. Modern advanced manufacturing is mainly based on computer-aided manufacturing (CAM) processes (taking UG CNC-assisted machining as an example). First, it creates manufacturing or obtains a design model, and then after rationally planning various processing processes, it enters the main processing environment to perform operations such as NC creation of programs, geometry, and tools, thereby generating and completing tool path parameters and forming tool path files. Finally, after processing certification, the postprocessor is used to generate the NC code of the enterprise CNC machine tool. The CNC machining process is shown in Figure 1.

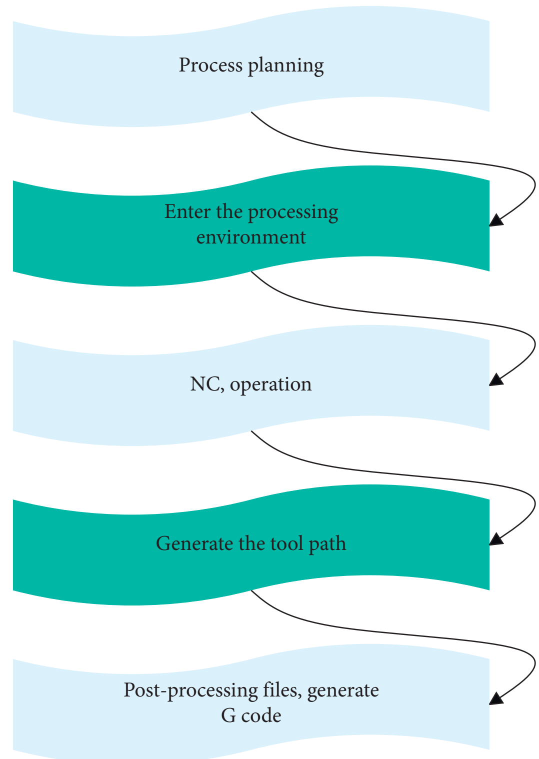

Figure 1: General flow of CNC machining.

The two main types of milling in milling are face milling and contour milling. As an important tool path generation process in CNC machining, it is necessary to set and optimize the machining path. In this process, the correct determination of the machining route of the tool will directly affect the machining quality and efficiency of the part, so the postprocessing of the tool will be involved in the modern CAM postprocessing. The tool path of the section method is determined by a series of intersection lines, which are obtained by using some sections to intercept the surface to be machined or its offset surface.

The residual height method is to determine the machining method by the height of the residual part between two adjacent tool paths on the machined surface of the workpiece, as shown in Figure 2. The basic idea of the residual height method: the surface is represented by a curve or surface composed of the initial tool position points of the tool, the subsequent trajectory is calculated from the previous trajectory, and the residual height between the two front and rear trajectories is required to be kept equal. At the same time, the residual height cannot exceed the tolerance required by the part.

The residual height of the equal residual height method is shown in Figure 2.

We assume that the effective cutting radius of the tool is Re, the row spacing is L, the residual height is h, and the curvature radius of the surface is Rb. The method of calculating the row spacing is as follows.

In flat machining,

$$h = R_e - \sqrt{R_e^2 - \left(\frac{L}{2}\right)^2},$$
$$L = 2\sqrt{R_e^2 - (R_e - h)^2}. \tag{1}$$

In actual processing, since R_e is much larger than h, the line spacing L can be approximated as

$$L = \sqrt{8R_e h}. \tag{2}$$

In convex machining,

$$h = (R_b - R_e)\sqrt{1 - \left(\frac{L}{2R_b}\right)^2} - \sqrt{R_e^2 - \left[\frac{(R_b + R_e)}{2R_b}L\right]^2} - R_b. \tag{3}$$

By the same simplification, we get

$$L = \sqrt{\frac{8hR_eR_b}{R_b + R_e}}. \tag{4}$$

It can be seen that the convex surface actually reduces the residual height compared to the flat surface.

$$h = (R_b - R_e)\sqrt{1 - \left(\frac{L}{2R_b}\right)^2} - \sqrt{R_e^2 - \left[\frac{(R_b + R_e)}{2R_b}L\right]^2} - R_b. \tag{5}$$

In concave machining,

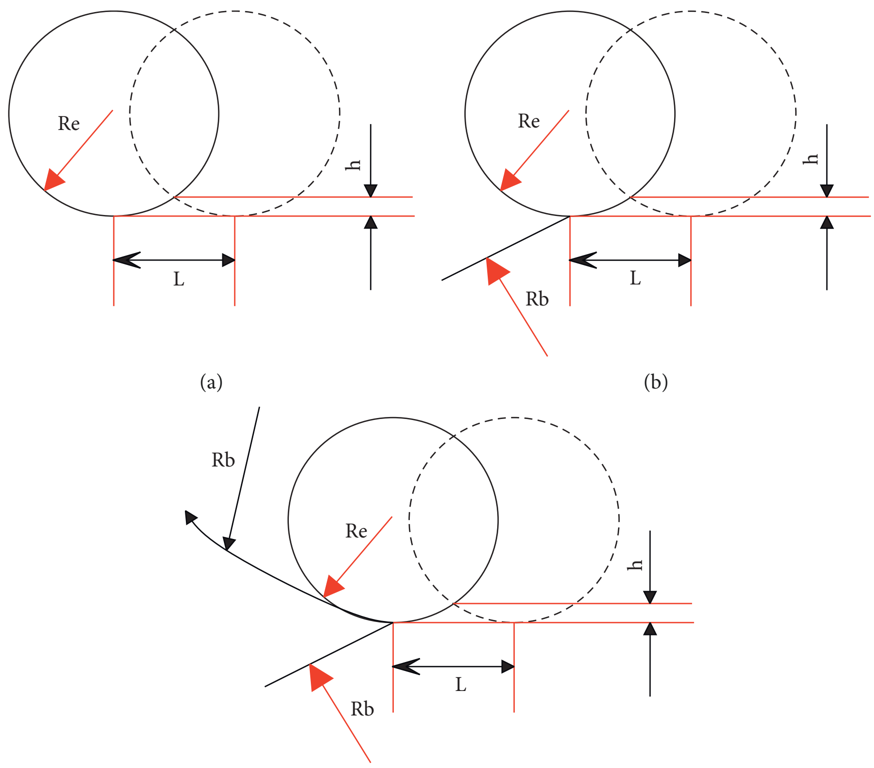

Figure 2: Residual height of equal residual height method. (a) Plane machining. (b) Convex Surface Machining. (c) Concave surface machining.

$$h = R_b - (R_b + R_e)\sqrt{1 - \left(\frac{L}{2R_b}\right)^2} - \sqrt{R_e^2 - \left[\frac{(R_b + R_e)}{2R_b}L\right]^2}. \quad (6)$$

By the same simplification, we get

$$L = \sqrt{\frac{8hR_eR_b}{R_b - R_e}}. \quad (7)$$

It can be seen that the concave surface actually increases the residual height compared to the flat surface.

Each tool path in the medium residual height method of the CNC machining method is dynamically generated. In order to improve the processing efficiency, a maximum value can be set. In order to control the surface of the part to obtain better processing quality, surface roughness, and surface shape, reasonable parameter values should be selected according to the actual processing system. In the processing method of the equal residual height method, the processing residual height is required to be based on the surface quality. Moreover, the maximum value can be processed while maintaining the surface quality. There are several path generation methods in CAM software: deep machining contour milling, deep machining contour milling in steep areas, surface area milling, surface milling, fine milling of side walls, and contour area milling.

When CNC machine tools process complex free-form surfaces, linear interpolation is mostly used to approximate the shape of the surface. Therefore, it is generally calculated on the basis of analyzing the tool path for NC machining errors so as to determine the reasonable step length of the tool, and the determination of the reasonable step length will improve the machining accuracy of the surface and the machining efficiency.

High-speed machining is a complex process system that includes many factors. High-speed machining is based on a full understanding of cutting force, cutting heat, tool wear, and machining process. Selecting machining parameters that match the machining material is a key technology. However, there are still many deficiencies in the optimization of high-speed cutting parameters in many enterprises, which results in that many high-end CNC machine tools and tools do not have real potential and cause a great waste of productivity. Only by exerting high-speed machining technology can high-efficiency machining be achieved. Therefore, in high-efficiency machining, we must first understand high-speed machining.

In high-speed machining, the cutting deformation law, cutting force change, cutting motion law, and so on are very different from conventional cutting methods. The main function in the processing is to remove the allowance, and it is necessary to consider the technical requirements that are very different from conventional processing and at the same time ensure that the finishing allowance is more balanced, as shown in Figures 3–6.

2.2. Process and Tool Path Planning of Surface CNC Machining. Any vector in the space can be represented by a six-dimensional coordinate, and a tool in the machining space is equivalent to a vector in the space, as shown in Figure 7. $T=(X, Y, Z, A, B, C)$, where (X, Y, Z) are the coordinates of the tool center (tool location point) and (A, B, C) are the rotation angles of the tool vector around the x-, y-, and z-axes. Since there are $\cos 2A+\cos 2B+\cos 2C=1$, the third angle can be derived by knowing two of the three angles A, B, and C. Therefore, the tool can be placed at any position in space with five coordinates, which theoretically means that any part of the curved surface can be processed to complete the complex processing of any part. To carry out the programming of multiaxis CNC machining, it is necessary to have a clear understanding of the relationship between the machine tool coordinate systems and the transformation relationship between them.

Representation of space vectors: a vector can be represented by three coordinates of start and end. If a vector starts at point A and ends at point B, then it can be expressed as

$$p_{ab}=(B_x-A_x)i+\left(B_y-A_y\right)j+(B_z-A_z)k. \tag{8}$$

In special cases, if a vector starts at the origin, as shown in Figure 7, there are

$$p=a_x i+b_b j+c_z k. \tag{9}$$

Among them, a_x, b_y, c_z are the three components of this vector in the reference frame.

The three components of the vector can also be written in the form of a matrix, as shown in formula (10), and the motion component will be represented in this form:

$$P=\begin{bmatrix} a_x \\ b_y \\ c_z \end{bmatrix}. \tag{10}$$

This notation can also be slightly changed: when adding a scaling factor w, if x, y, and z are each divided by w, we get a_x, b_y, c_z, which can be written as

$$P=\begin{bmatrix} x \\ y \\ z \\ w \end{bmatrix} \text{among } a_x=\frac{x}{w}, \tag{11}$$

$$b_y=\frac{y}{w}.$$

The variable can be any number, and as it changes, the size of the vector changes. If it is equal to 1, the magnitude of each component remains unchanged. Usually, a vector of unit length is used to represent the orientation of the tool in space.

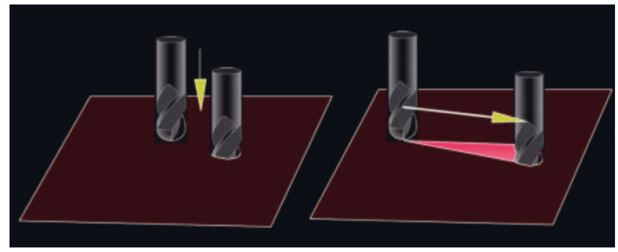

Figure 3: Schematic diagram of reducing the number of tool cuts.

Relationship between coordinate systems: a coordinate system centered at the origin of the original reference coordinate system can be represented by three vectors. Usually, these three vectors are perpendicular (orthogonal) to each other and are called unit vectors n, o, and a, which represent the normal direction, the feed direction, and the approach direction vector, respectively. Furthermore, each unit vector is represented by three components of the reference frame in which they are placed. In this way, the coordinate system F can be represented by three vectors in matrix form as

$$F=\begin{bmatrix} n_x & o_x & a_x \\ n_y & o_y & a_y \\ n_z & o_z & a_z \end{bmatrix}. \tag{12}$$

If a coordinate system is no longer fixed at the origin of the reference coordinate system, a vector is made between the origin of the coordinate system and the origin of the reference coordinate system to represent the position of the coordinate system (as shown in Figure 8). This vector is represented by three components relative to the reference coordinate system. This coordinate system can then be represented by three unit vectors representing direction and a fourth position vector. It is represented by a homogeneous matrix as follows:

$$F=\begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}. \tag{13}$$

As shown in formula (13), the first three vectors are the direction vectors of $w=0$, which represent the directions of the three unit vectors n, o, and a of the coordinate system. The fourth vector represents the position of the origin of this coordinate system relative to the reference coordinate system. Unlike the unit vector, the length of the vector P is important, so a scale factor of 1 is used. The attitude representation of the tool in space can be realized in this way. By fixing a tool coordinate system on it, the fixed coordinate system is expressed in space. Since this coordinate system is always fixed on the tool, as long as this coordinate system can be represented in space, the position of the tool relative to the original coordinate system is also known.

Homogeneous coordinate transformation: the transformation is defined as a motion in space. When a coordinate system in space (a vector, an object, or a motion coordinate system) moves relative to a fixed reference

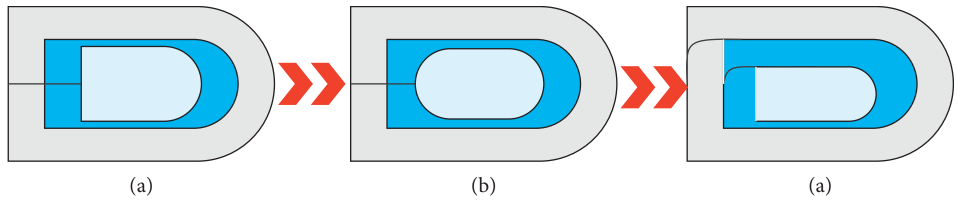

Figure 4: The effect of different feeds on the workpiece surface. (a) Not good. (b) Good. (c) Very good.

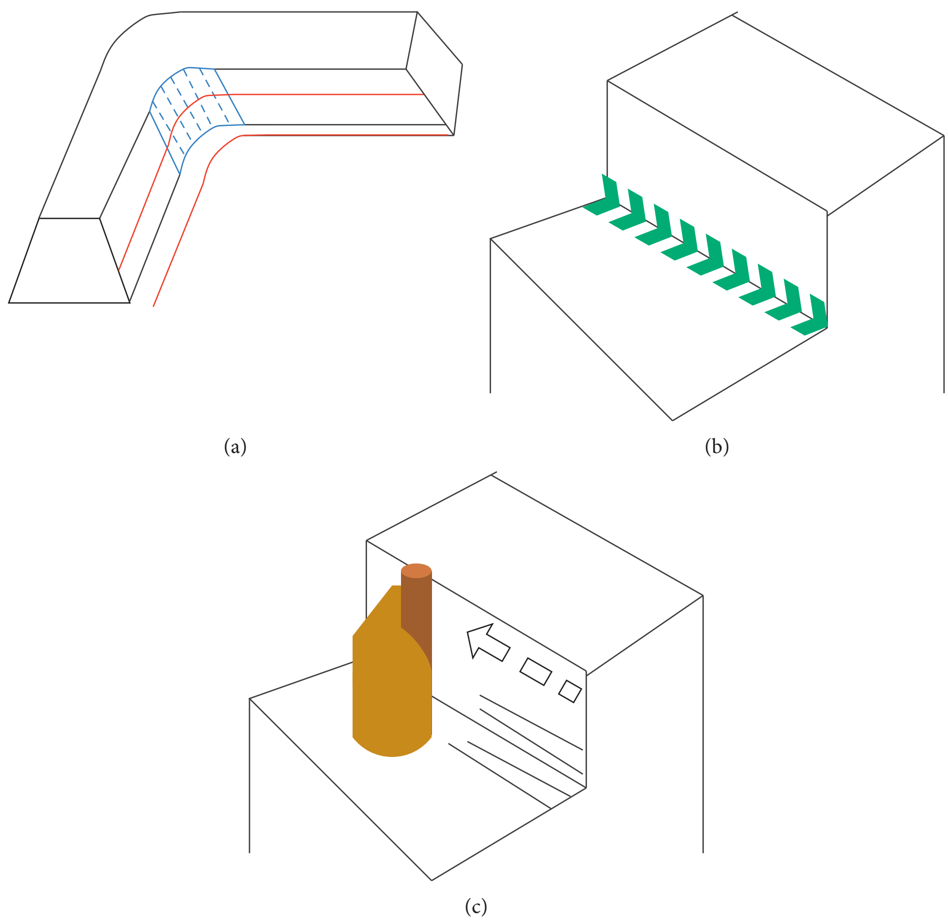

Figure 5: Schematic diagram of pen milling.

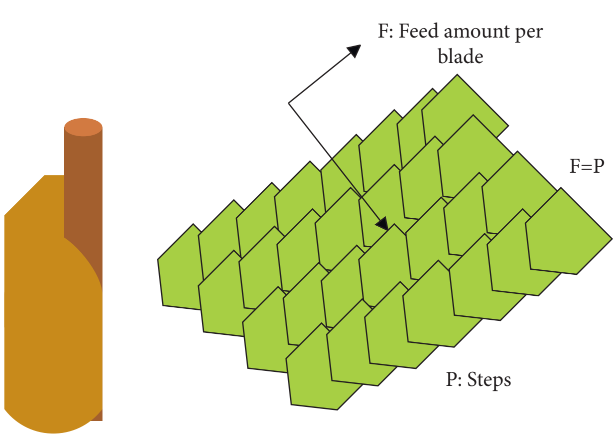

Figure 6: FP milling process.

coordinate system, this motion can be represented in a manner similar to how a coordinate system is represented. The reason for this is that the transformation itself is a change in the state of the coordinate system (representing a change in the position of the coordinate system), so the transformation can be represented by a coordinate system. The transformation can take one of the following forms: translation; rotation about an axis; a combination of translation and rotation.

2.2.1. Translation Transformation. If the coordinate system (which may also represent a tool) moves with a constant attitude in space, then the coordinate is a pure translation. In this case, its directional unit vector remains the same in the same direction, and all changes are only changes in the

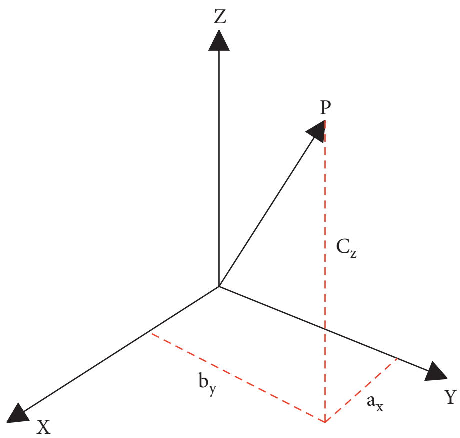

Figure 7: Space vector.

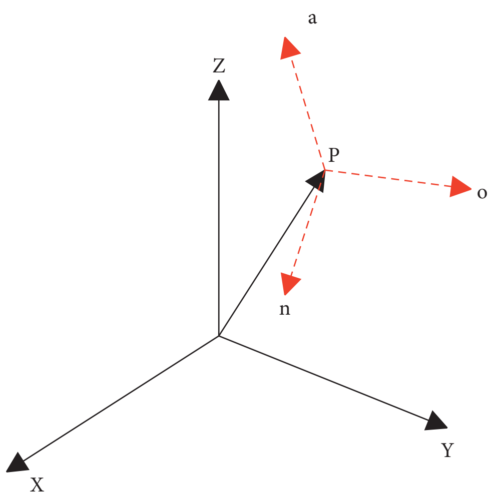

Figure 8: Relationship between the coordinates.

origin of the coordinate system relative to the reference coordinate system, as shown in Figure 9.

The position of the new coordinate system relative to the fixed reference coordinate system can be obtained by adding the vector representing the displacement to the origin position vector of the original coordinate system. In matrix form, the representation of the new coordinate system can be obtained by left-multiplying the transformation matrix of the coordinate system. Since the direction vector does not change during translation, the transformation matrix T can be simply expressed as

$$T = \begin{bmatrix} 1 & 0 & 0 & d_x \\ 0 & 1 & 0 & d_y \\ 0 & 0 & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix}. \quad (14)$$

It can be seen that the first three columns of the matrix represent no rotational motion (equivalent to the identity matrix), while the last column represents translational motion. The new coordinate system position is

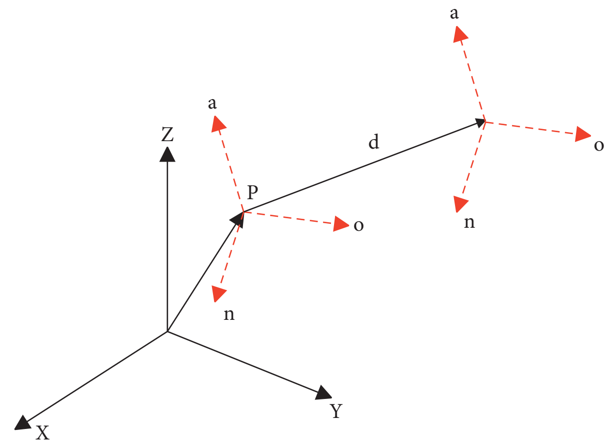

Figure 9: Relationship between the coordinates.

$$T = \begin{bmatrix} 1 & 0 & 0 & d_x \\ 0 & 1 & 0 & d_y \\ 0 & 0 & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} n_x & o_x & a_x & p_x + d_x \\ n_y & o_y & a_y & p_y + d_y \\ n_z & o_z & a_z & p_z + d_z \\ 0 & 0 & 0 & 1 \end{bmatrix}. \quad (15)$$

This equation can also be written notationally as

$$F_{\text{new}} = \text{Trans}\left(d_x, d_y, d_z\right) \times F_{\text{old}}\text{ò}F_{\text{new}} = \text{Trans}\left(\overline{\text{d}}\right) \times F_{\text{old}}. \quad (16)$$

First, as obtained earlier, the position of the new coordinate system can be obtained by left-multiplying the transformation matrix in front of the coordinate system matrix; as will be seen later, this method holds for all transformations regardless of the form. Second, it can be noticed that the direction vector remains unchanged after translation. However, the position of the new coordinate system is the result of adding the d and p vectors. Finally, it should be noted that the relationship between the homogeneous transformation matrix and the matrix multiplication is such that the resulting new matrix has the same dimensions as before the transformation.

2.2.2. Rotation Transformation. In order to simplify the derivation of the rotation around the axis, it is assumed that the coordinate system is located at the origin of the reference coordinate system and is parallel to it, and then the results are extended to other rotations and combinations of rotations. We assume that the coordinate system (n, o, a) is located at the origin of the reference coordinate system (x, y, z), and the coordinate system (n, o, a) is rotated by an angle θ around the x-axis of the reference coordinate system. Furthermore, we assume that there is a point P on the

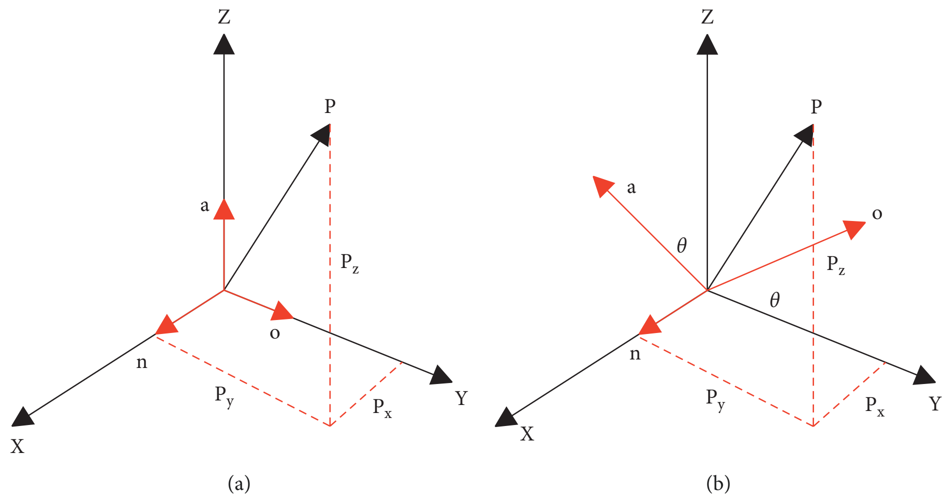

FIGURE 10: Rotation transformation diagram. (a) Before rotation. (b) After rotation.

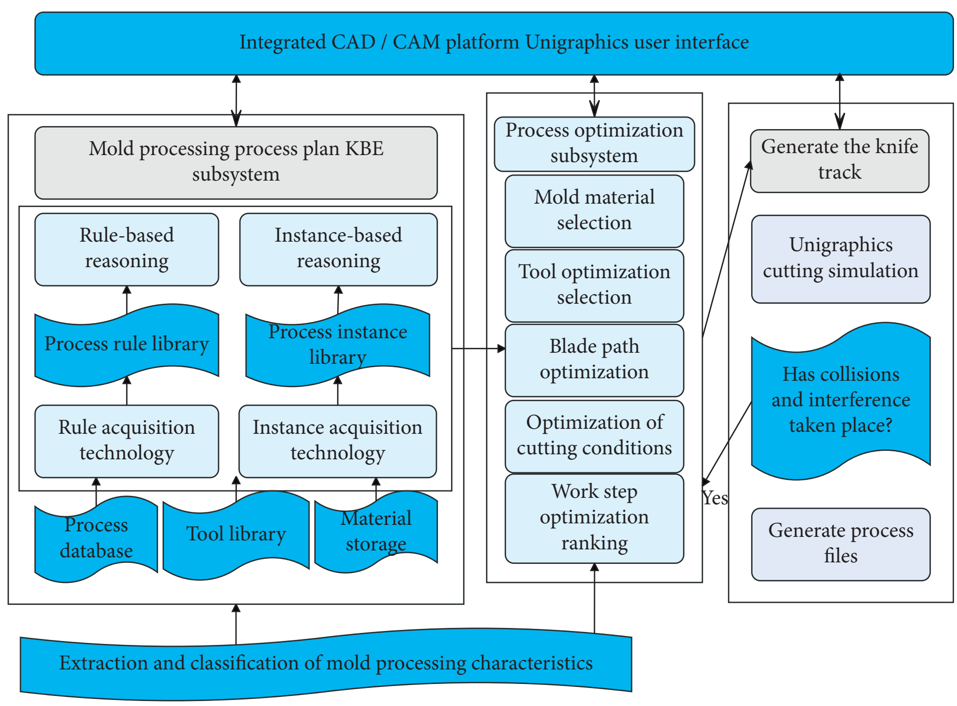

FIGURE 11: CNC machining method based on CAD/CAM/Robot integration.

rotating coordinate system (n, o, a) whose coordinates are p_x, p_y, p_z with respect to the reference coordinate system and p_n, p_o, p_y with respect to the moving coordinate system. When the coordinate translation transformation system rotates around the x-axis, the point P on the coordinate system also rotates with the coordinate system.

Before the rotation, the coordinates of point P in the two coordinate systems are the same (the two coordinate systems are at the same position and parallel to each other). After rotation, the point coordinate p_n, p_o, p_y remains unchanged in the rotating coordinate system (x, y, z), but in the reference coordinate system, p_x, p_y, p_z has changed (as shown in Figure 10). Now, it is required to obtain the new coordinates of P relative to the reference coordinate system after the rotation of the moving coordinate system. Figure 10 shows the coordinates of point P before and after the coordinate system is rotated.

$$\begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} p_n \\ p_o \\ p_a \end{bmatrix}. \quad (17)$$

To simplify writing, it is customary to use the symbol $C\theta$ for $\cos\theta$ and $S\theta$ for $\sin\theta$. Therefore, the rotation matrix can also be written as

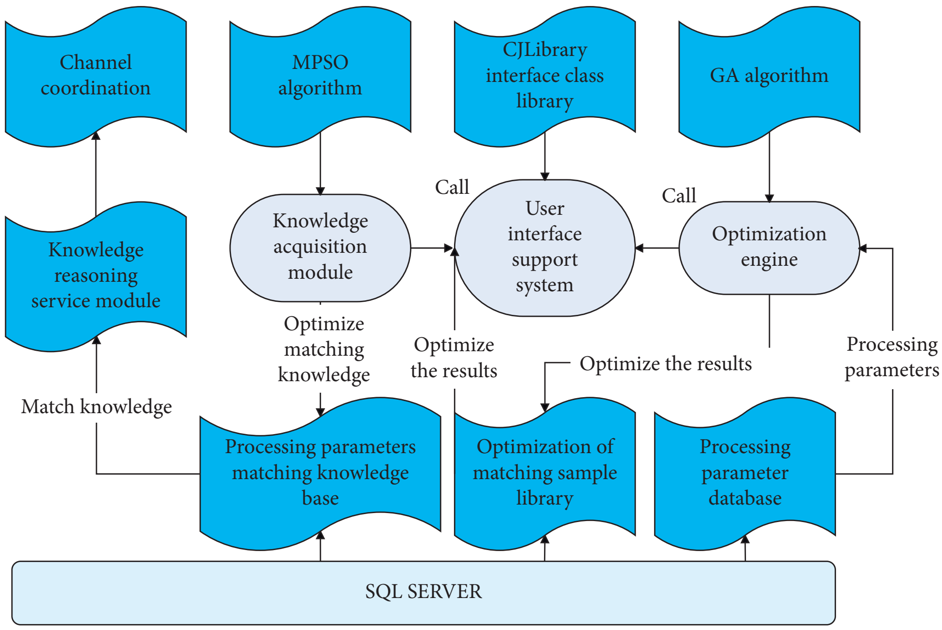

Figure 12: The structural principle diagram of the Agent software for optimization and matching of machining parameters.

$$\mathrm{Rot}(x,\theta)=\begin{bmatrix}1&0&0&0\\0&C\theta&-S\theta&0\\0&S\theta&C\theta&0\\0&0&0&1\end{bmatrix}. \quad (18)$$

Similarly, the result of the rotation of the coordinate system around the y-axis and the z-axis of the reference coordinate system is

$$\mathrm{Rot}(y,\theta)=\begin{bmatrix}C\theta&0&S\theta&0\\0&1&0&0\\-S\theta&0&C\theta&0\\0&0&0&1\end{bmatrix},$$

or (19)

$$\mathrm{Rot}(z,\theta)=\begin{bmatrix}C\theta&-S\theta&0&0\\S\theta&C\theta&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}.$$

It can also be written in a customary form to facilitate understanding of the relationship between different coordinate systems. To this end, the transformation can be expressed as

$$^{u}p={}^{u}T_{R}\times{}^{R}L. \quad (20)$$

2.2.3. Composite Transformation. The compound transformation is composed of a series of translation and rotation transformations along the axis of the current motion coordinate system, and any transformation can be decomposed into a set of translation and rotation transformations in a certain order. The coordinates of the point relative to the reference coordinate system after each transformation are obtained by left-multiplying the coordinates of the point by each transformation matrix. Of course, the order of the matrices cannot be changed. At the same time, it should also be noted that the matrix is left-multiplied for each transformation relative to the reference coordinate system. Therefore, the order in which the matrices are written is the opposite of the order in which the transformations are performed.

$$P_{xyz}=T_n\times T_{n-1}\times\cdots\times T_2\times T_1\times P_{\mathrm{noa}}. \quad (21)$$

If such a compound transformation first rotates around the x-axis, then translates d, and then rotates Ψ around the z-axis, the transformed coordinates are

$$\begin{aligned}P_{xyz}&=\mathrm{Rot}(z,\Psi)\times\mathrm{Trans}\left(d_x,d_y,d_z\right)\times\mathrm{Rot}(x,\theta)\times P_{\mathrm{noa}}\\&=\begin{bmatrix}C\Psi&S\Psi&0&0\\S\Psi&C\Psi&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}\begin{bmatrix}1&0&0&d_x\\0&1&0&d_y\\0&0&1&d_z\\0&0&0&1\end{bmatrix}\begin{bmatrix}1&0&0&0\\0&C\theta&-S\theta&0\\0&S\theta&C\theta&0\\0&0&0&0\end{bmatrix}\begin{bmatrix}p_n\\p_a\\p_o\\1\end{bmatrix}\\&=\begin{bmatrix}\left(d_x+p_n\right)\cdot C\Psi-d_y\cdot S\Psi-p_0\cdot C\theta\cdot S\Psi+p_aS\Psi\cdot S\theta\\\left(d_x+p_n\right)\cdot S\Psi+d_y\cdot C\Psi+p_o\cdot C\theta\cdot C\Psi+p_aC\Psi\cdot S\theta\\d_z+p_0\cdot(C\theta+S\theta)\\1\end{bmatrix}.\end{aligned} \quad (22)$$

The rotation transformations mentioned above are all performed relative to the coordinate axes of the reference coordinate system. In fact, the transformation can also be performed relative to the coordinate axes of the motion coordinate system, especially in the postprogramming of multiaxis CNC machine tools, which is usually the case. For each transformation relative to the motion coordinate system, the matrix is right-multiplied. Therefore, the order in which the matrices are written is the same as the order in which the transformations are performed.

$$P_{xyz} = T_1 \times T_2 \times \cdots \times T_{n-1} \times T_n \times p_{\text{noa}}. \tag{23}$$

In the transformation, if both exist, that is to say, both the transformation relative to the reference coordinate system and the transformation relative to the motion coordinate system, then multiply the transformation matrix to the left or right in their order. For example, it first rotates around the x-axis, then translates u along the current coordinate system, then rotates around the z-axis, and finally rotates Φ along the y-axis of the current coordinate system.

$$\begin{aligned} p_{xyz} &= \text{Rot}(z,\Psi) \times \text{Rot}(x,\theta) \times \text{Trans}\left(u_x, u_y, u_z\right) \\ &\quad \times \text{Rot}(y,\Phi) \times p_{\text{noa}} \\ &= \begin{bmatrix} C\Psi & -S\Psi & 0 & 0 \\ S\Psi & C\Psi & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C\theta & -S\theta & 0 \\ 0 & S\theta & C\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & u_x \\ 0 & 1 & 0 & u_y \\ 0 & 0 & 1 & u_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \\ &\quad \cdot \begin{bmatrix} C\Phi & 0 & S\Phi & 0 \\ 0 & 1 & 0 & 0 \\ -S\Phi & 0 & C\Phi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} p_n \\ p_a \\ p_o \\ 1 \end{bmatrix}. \end{aligned} \tag{24}$$

3. Effect Evaluation of CNC Machining Method Based on CAD/CAM/Robot Integration

As shown in Figure 11, the framework of the mold CNC machining process design and optimization system mainly includes two important parts: the mold machining process intelligent design system and the machining process optimization subsystem. It communicates with the user through the user interface of the integrated CAD/CAM platform. The user interface accepts the initial information of mold processing input by the user, including the processing section, processing features, and precision requirements. Moreover, it is preliminarily processed and passed to the intelligent process design system and the process optimization system, and the optimal value of the process design is obtained through reasoning and optimization. The intelligent design system is the core of the whole system. It includes two parts: rule reasoning and case reasoning, which are used to deal with different tasks in different stages of process planning. The intelligent design subsystem also includes a knowledge acquisition module, which uses data mining algorithms to discover new knowledge. The process optimization subsystem optimizes each process of the process planning, firstly establishes the optimization model of the process design of each process, and then uses the optimization method and soft computing technology to optimize the design results to obtain the optimal solution of the process design.

Table 1: Evaluation of the effect of CNC machining method based on CAD/CAM/Robot integration.

Number	Processing effect	Number	Processing effect
1	92.07306949	17	95.51363407
2	95.69260836	18	89.74365858
3	89.62001186	19	93.5404729
4	93.76353311	20	91.99655556
5	92.91247177	21	90.36172634
6	93.32544439	22	92.32117738
7	90.20722418	23	93.63610716
8	95.33332366	24	92.09115517
9	95.43350875	25	92.9742469
10	90.78897005	26	95.27095856
11	92.73761446	27	95.16634579
12	88.03577671	28	88.67660928
13	89.54906449	29	88.13680392
14	93.03325325	30	95.1361272
15	92.1890974	31	95.00001904
16	90.07661701	32	91.69920989

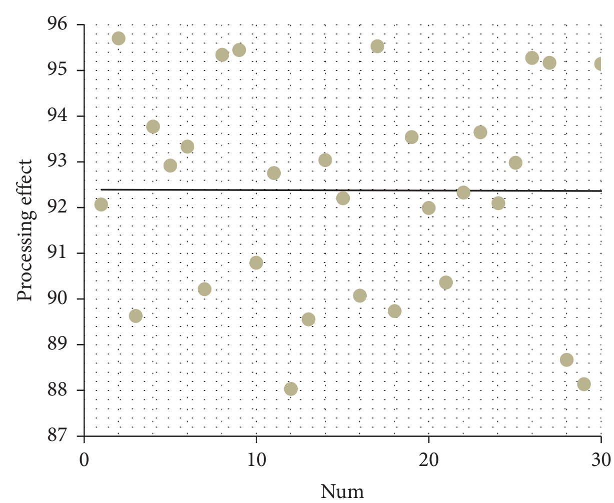

Figure 13: Statistical diagram of the evaluation of the effect of the CNC machining method.

Combining the design principles and methods given above and the corresponding algorithms, the Agent software with the principle structure shown in Figure 12 can be designed.

This paper verifies the effect of the CNC machining images shown above. Moreover, this paper simulates the processing process on the simulation platform by means of experimental processing, evaluates the processing effect, and obtains the simulation test results shown in Table 1 and Figure 13.

Through the statistics of simulation test data, it can be seen that the CNC machining method based on CAD/CAM/Robot integration can effectively improve the intelligence of modern CNC machining and improve the effect of intelligent machining.

4. Conclusion

In the process of CNC machining, especially in the machining of complex surfaces, the cutting conditions are not static. How to quickly and efficiently select cutting parameters and improve the quality of mold processing on the premise of improving processing and cutting efficiency and reducing processing costs is a problem that needs to be solved. In order to improve the cutting efficiency, this topic selects the cutting amount intelligently in CNC machining. The practical results show that the reasonable selection of processing parameters will greatly improve the work efficiency under the condition of certain equipment, materials, and processing strategies and achieve the best combination of processing efficiency, tool wear, and processing quality. In order to improve the intelligent effect of CNC machining, this paper combines the CAD/CAM/Robot integration method to improve the CNC machining method. Through the statistics of simulation test data, it can be seen that the CNC machining method based on CAD/CAM/Robot integration can effectively improve the intelligence of modern CNC machining and improve the effect of intelligent machining.

Data Availability

The labeled dataset used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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