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Research on Rapid Imitation of Human Tibia and Five-axis CNC Machining Based on Computer-aided

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Abstract. The rapid imitation of the human humerus is the computer application of data acquisition, data processing and reconstruction of the mandibular model in reverse engineering. Based on the rapid imitation of the tibia of the NURBS patch in the Geomagic software computer application, the efficiency and quality of the mandibular surface reconstruction is effectively improved. Based on the five-axis NC programming module in the UG computer-aided software application, the five axes required for the mandible humerus processing are compiled. The CNC program uses Vericut computer software to build a virtual machine tool, simulates the actual machining process, detects machine collision and interference, and provides safety for the production of 5-axis machine tools.

Keywords: Mandible, NURBS Patch, Surface Reconstruction, Five-axis Machining, Computer-aided

1. Introduction

The vast majority of human body jaw bone sculptures and medical mannequin materials are made of plaster, glass, and ceramic. In order to better protect the mandible and quickly manufacture medical mannequins, advanced reverse modeling techniques and five-axis CNC machining techniques can be used to complete the rapid imitation of the mandible. This gives the lower jaw a "replacement". When the shin is under maintenance or damage, you can ask for a substitute and continue to exhibit ^[1-3].

One of the trends in modern advanced machinery manufacturing technology is the complexity and precision of product shape and structure^[4-5]. On the one hand, in order to meet the dynamic performance requirements, aviation and aerospace products often have very complicated shape and structure; on the other hand, in order to meet the needs of people's individualization and aesthetics. The design of some civilian products (toys, decorations) is weird, which provides opportunities and conditions for the wide application of multi-axis CNC machining technology. Because multi-axis CNC



machining technology has obvious advantages in manufacturing complex shape products compared to traditional machining methods, such as one-time clamping can process multiple surfaces of complex parts, and can guarantee high precision under certain conditions. effectiveness.

Since the programming of the five-axis machining center is generally impossible to use manual programming, the programming program must be automatically programmed using CAD/CAM software. Commonly used software are Unigraphics (UG), Delcam, Hypermill and so on. The generated program can generate a general-purpose code (G code) that can be recognized by the machine tool through the post-processing program of the CAD/CAM software. Due to the high cost of the five-axis machine tool and the complexity of the machining process, the program generated by the CAD/CAM software is generally not directly processed on the machine tool, and usually requires interference verification before it can be reused on the machine. The commonly used calibration method is to use software to build virtual machine tool simulation to verify the interference and collision situation. This form is more intuitive and provides security for the production of 5-axis machine tools.

2. Theoretical knowledge of surface reconstruction in Geomagic software

2.1. Point cloud data

In the design of the human humerus, the point cloud data is a data set reflecting the ideal design surface of the human humerus, which is obtained by measuring instruments. The point cloud of the measuring instrument is a massive amount of data (tens or even hundreds of mega-points), and there are repeated measurement data, system measurement errors and random errors, etc., which must be processed by the point cloud.

2.2. NURBS patch

The NURBS method is a unified representation of current curves and surfaces, and has become the mathematical basis for geometric models of CAD software such as catia, UG, and alias. Bi-zier and B-spline are special cases of NURBS.

The definition of the NURBS surface:

$$P(u, w) = \frac{\sum_{i=0}^n \sum_{j=0}^m B_{i,k}(u) B_{j,l}(w) W_{i,j} V_{i,j}}{\sum_{i=0}^n \sum_{j=0}^m B_{i,k}(u) B_{j,l}(w) W_{i,j}} \quad (1)$$

$$u \in [0, 1] \quad (2)$$

Where $V_{ij} (i = 0, 1, 2, \dots, n; j = 0, 1, 2, \dots, m;)$ is the position vector of the given feature grid fixed point; $W_{i,j}$ is the weight factor of the corresponding vertex. Among them, the basis function recursion formula is:

$$B_{j,0}(u) = \begin{cases} 1, u_i \leq u \leq u_{i+1} \\ 0, other \end{cases} \quad (3)$$

The NURBS surface accurately represents the standard analytical shape and free-form surface with a uniform expression, and has characteristics such as computational stability and geometric invariance when linearly changing.

3. Fast surface reconstruction based on point cloud data application and NURBS patch in Geomagic software

3.1. Measurement and processing of point cloud data of human tibia 3D

Reverse engineering is an effective way to shorten the development cycle of products (especially products with complex shapes or free-form surfaces). The reverse engineering process is shown in figure 1. Through accurate and high-speed scanning of existing samples or models through 3D scanners and coordinate measuring instruments, the 3D point cloud data is obtained, and the surface reconstruction is performed with reverse software (such as Geomagic, Imageware, etc.). The surface of the structure is analyzed for online precision, and the structural effects are evaluated. Finally, IGES or STL data is generated, and CNC machining or rapid prototyping can be performed to provide a new and efficient three-dimensional manufacturing route for the manufacturing industry.

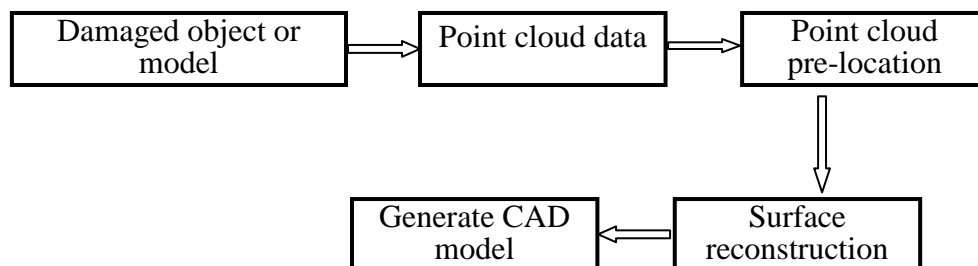


Figure 1. The reverse engineering process

3.2. Point cloud data collection

The method for acquiring the three-dimensional geometric data of the device point cloud can be divided into contact type and non-contact type in terms of working principle. The commonly used contact type is the coordinate measuring machine (CMM) and the coordinate measuring machine. However, the contact measuring probe is easy to wear and has low measurement efficiency. Non-contact measurement such as laser, structured light, etc., non-contact laser 3D scanner. Fast measurement speed for measuring thin, soft workpieces and workpieces with complex surfaces. According to the complex shape of the human humerus, the optical scanning measurement system is used for point cloud data acquisition.

3.3. Point cloud data measurement results of human lower jaw bone 3D

Place the human lower jaw bone and adjust the measurement distance between the laser scanner and

the human lower jaw bone, which is generally suitable between 250 and 1 000 mm. Using the software that comes with the laser scanner, the human skull surface is scanned and the software automatically analyzes and obtains 3D point cloud data.

3.4. Point cloud data processing of human body lower jaw bone 3D

Geomagic software is mainly used for reverse engineering. It takes only 1/3 of the time from the point cloud processing to the 3D surface construction. Geomagic software makes it easy to create perfect polygon models and meshes from scanned point cloud data and automatically convert to NURBS surfaces. It can change the traditional face-to-face approach from point to line to face from the point-to-face new facet. At the same time, the STL file can be quickly established for CNC machining or rapid prototyping. Read the measured human body lower jaw 3D point cloud data and splicing and repairing it completely. Use Geomagic's open point cloud command to read the scanned point cloud data. At the same time, the point cloud data is spliced to obtain a complete point cloud data, and the point cloud is optimized to remove the noise formed after the scanning, and the "move removal" command is applied, and the default tolerance value of the system is 0.014 26. The system calculates according to the given tolerance value, and the position where the noise appears is generally the boundary or the corner point. After the processing of the noise point, the triangle encapsulation processing is performed.

3.5. Rapid surface reconstruction of NURBS patches of human lower jaw bone

Complex surfaces generally have a mixture of multiple surfaces, mainly quadrics and free-form surfaces. The number of subdivisions does not have a limited number, which is based on the fact that the subdivision can be naturally distributed without distortion. In general, the face block should be divided according to the characteristic contour line or the parting line of the product. The relatively smooth partial area will be small and large. If the part is a development surface, the open surface boundary should be processed. If it is a closed surface, There will be no processing open surface boundaries. After scanning, the data of the open surface boundary is jagged, and the flat triangular mesh surface should be cut with a plane.

3.6. Construction of 3D solid model of human humerus based on UG software

Using the surface sheet of the human jaw bone constructed in the geomagic software, it is imported into the UG software, and uses the characteristic commands such as scanning, stretching, rotation, and reference plane to construct entities such as lines, faces, cylinders, and then Boolean operations, Complete the 3D solid model of the human body.

4. Based on UG software, the lower jaw five-axis CNC machining programming and virtual machine tool simulation actual machining effect

4.1. Five-axis CNC machining programming of the lower jaw based on UG software

4.1.1. Create a blank

The human body model is modeled using UG software. The model has a maximum diameter

of 63 mm and a model height of 73.4 mm. The model material is a POM rod. First, use the UG modeling function to create a part blank according to the dimensions shown in the drawing. Note that the coordinates of the blank should be kept with the coordinates of the part. Consistently, make sure that the model parts do not exceed the blank.

4.1.2. Roughing operation

First finish the upper part of the model part roughing, click create operation, select the contour milling (mill_contour) in the operation type, select the pocket milling (CAVITY_MILL) in the operation subtype, in the dialog box of the pocket milling, the cutting mode is "Follow the part", the cutting depth is 0.5 mm per tool, the step is "tool straight 50%", the range depth is set to 33 mm in the cutting layer dialog box, the tool path is generated and the machining program is verified using 3D simulation. Use the same method to finish the lower part of the model part.

4.1.3. Semi-finishing operation

First finish the semi-finishing of the upper part of the model part, click the Create Operation icon, select the contour milling (mill_contour) in the operation type, and select the root cleaning processing (FLOWCUT_REF_TOOL) in the operation subtype. The mode is "reciprocating", the step is "10% of the tool diameter", and the order is "change from outside to inside". Generate a tool path and validate the machining path using 3D simulation.

4.1.4. finishing operation

Model part finishing, click to create the operation icon, select multi-axis milling (mill_multi-axis) in the operation type, select variable contour milling (VARIABLE_CONTOUR) in the operation sub-type, in the variable contour milling dialog box, drive mode selection The "surface" method, the direction of the tool axis is "perpendicular to the drive body", generates the tool path and verifies the machining program using 3D simulation.

4.1.5. Post-processing of the tool path

Select all toolpath operations in the NX Operations Navigator, then click the post-processing icon in the action toolbar, select the newly created post-processing file and click OK to output the NC code.

4.1.6. Virtual machine tool simulation actual processing effect

Due to the high cost of the five-axis machine tool and the complexity of the machining process, the program generated by the CAD/CAM software is generally not directly processed on the machine tool, and usually requires interference verification before it can be processed on the machine tool. A common verification method is to use software simulation to verify the interference. This form is more intuitive.

The Vericut software is used to build a virtual machine tool that is consistent with the motion of the generated five-axis CNC machine tool. The structure and motion are consistent, and it has a tool

magazine. At the same time, the motion axes have x, y, z, a, b. Import the NC code to simulate the actual machining effect. There is no z or x collision on the human body parts after the simulation, indicating that it can be processed on the actual machine tool.

4.2. Human body lower jaw production type five-axis CNC machine tool processing

When the part is actually processed, the blank workpiece is fixed on the rotary table. After the alignment, the blank workpiece axis coincides with the B-axis rotation axis. After the workpiece coordinate system and the tool length are set, the automatic cutting process is selected. No collisions and interference occurred during processing.

5. Conclusion

Based on reverse engineering and five-axis CNC computer machining, it can realize the rapid imitation and rapid manufacturing of the human jaw bone and human medical model. Based on Geomagic software, it can realize the rapid imitation and rapid manufacturing of different human jaw bones, and make the human body squat by reverse modeling the human jaw bone. Bone data is converted to permanently stored data. Based on computer-aided, using Vericut computer software to build a simulation machine to build real machining results, reduce the risk of collision with the machine during the five-axis machining process, and provide safety for the processing of five-axis machine tools, thus greatly shortening the design and manufacturing cycle of the product, based on the new exploration of computer-aided. It provides a new way for the training of five-axis processing talents. From the computer technology point of view, more people have the opportunity to receive five-axis processing training. It provides a new idea for the large-scale popularization of five-axis processing talent training.

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