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RESEARCH ARTICLE

RESEARCH ON CURVED SURFACE RECONSTRUCTION BASED ON GEOMAGIC DESIGN X

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ABSTRACT

Through reverse modeling, the modeling of complex parts of curved surface bodies can obtain editable CAD data models. This paper analysis and compares the common reverse modeling methods of complex parts of curved surface bodies and carries out the reverse modeling of somatosensory controllers with complex surfaces by using the reverse software Geomagic Design X as the platform, using the methods of surface sheet fitting, lofting, lofting wizard, and surface filling. And the modeling files obtained can be directly applied to the 3D design software. This shortens the product development cycle while improving model accuracy, providing a quick and effective solution for "reverse engineering-based geometry reconstruction."

KEYWORDS

Curved surface body, complex parts, reverse reconstruction, modeling, geomagic design x

1. Introduction

With the progress of the society, people pay more attention to the appearance of products. In life, most articles such as ergonomic chairs, mice, toothbrush handles, etc. are all irregular polyhedrons, with complex curved surfaces with varying curvatures. In the traditional manufacturing industry, most of them can only be manufactured by using moulds, and it is usually difficult to produce relatively complex parts. Aiming at some parts with complex structure, more irregular curves and curved surfaces and difficult measurement sizes, using the traditional CAD software for surveying and mapping will cause too large deviation. Whereas, the reverse engineering starts from the final object of the product and the advanced point cloud scanning mode is used to replace the traditional measuring mode (Dumortier et al., 2021; Liu et al., 2019; Guo et al., 2019). Thus, the obtained component data will be more accurate and reliable (Huang et al., 2019). At present, the main applications of reverse engineering include: ①3D design of new parts; ②duplication and modification of existing parts without drawings; ③ repairing and restoration of worn parts; ④product detection (Gao, 2019). The specific flow of reverse engineering includes three parts: data acquisition, data preprocessing, curved surface reconstruction, data post-processing and 3D printing (Li et al., 2019).

This paper compares several reverse modeling methods of curved surface body (Zhang, 2021). Using the reverse software Geomagic Design X as the platform, through data acquisition, preprocessing, curved surface reconstruction and other processes, this paper conducts the reverse-modeling of the somatosensory controller with complex curved surfaces by surface sheet fitting, lofting, lofting wizard, surface filling and other methods. In the process of product development. Thus, the development cycle has been greatly shortened, which creats conditions for the innovation of handle shape.

2. Curved Surface Modeling Method Based on Geomagic Design X

If a product is shaped of simple curved surfaces such as a plane and a spherical surface, it can be completed by three-dimensional software using forward modeling. For the complex model with free curved surface and regular curved surface, first, according to the physical structural characteristics, use the software data point function to divide into different regions according to the structural characteristics and reconstruct the different curved surfaces respectively in each area (Hu and Zhong, 2015). And then use the methods of "surface intersection" or "transition between surfaces" (extension, trimming, bridging) to connect the different surfaces to form a shape. The main methods of curved surface modeling are surface and surface sheet fitting, lofting, lofting wizard and surface filling. Each of which specified for a different curved surface feature.

2.1 Forms A Curved Surface with Surface Sheet Fitting.

In the curved surface reconstruction, surface sheet fitting is the simplest method to obtain the curved surface, which is suitable for the region with small curvature change. The accuracy depends on the unit surfaces and domains being constructed. Complete the creation of the curved surface by selecting the unit surface or domain to build the curved surface. As shown in Figure 1, set "Allowed Deviation" in the "Resolution" drop-down bar through "Surface sheet Fitting Command" in the "Model" → "Wizard", and slide the slider to the appropriate position in the "Smooth" column. Drag the boundary point to adjust the direction and angle according to the specific shape of the model in the window (Wu, 2020). Ensure that the generated curved surface completely covers the selected unit surface or area.

Surface sheet fitting is not appropriate for curved surface reconstruction if the domain contains a large curvature range. You can split the realm and do it by using lofting connections.

2.2 Build the Curved Surface Splicing with Lofting

In Geomagic Design X software, the adjacent curved surfaces formed by surface sheet fitting can not be automatically spliced, and the boundary areas are difficult to fit. Under the condition that the two curved surfaces are spliced, a lofting mode can be adopted to create a connecting curved surface to realize the connection of the two curved surfaces. The specific process is as follows: building at least two lofted surface profiles with similar contours through a Lofting command in "Model" → "Creating a

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Curved Surface". The newly-created lofted surface profile is used as a guide curve, and select Curve in the Lofting Command and Tangent to Surface in Constraints.

2.3 Build a curved surface with Lofting Wizard

In the Geomagic Design X software, if the surface features are not suitable for surface sheet fitting, the curved surface can be constructed by lofting guide, the loft object can be extracted from the unit surface or domain, and the lofting path can be created based on the contour in an intelligent way.

As shown in Figure 2, select the corresponding area and unit curved surface at the same time through the "Lofting Wizard" command in "Model" → "Guide", and determine a certain number of sections. According to the size of the area, the more the number, the better the fitting effect.

After the lofting wizard is completed, the model tree is displayed as a 3D sketch lofting. The essence of the lofting guide command is based on the selected surface and area, the lofting process is completed according to the divided face after automatic segmentation. The modeling results are better than manually drawn spline lofts, as shown in Figure 3.

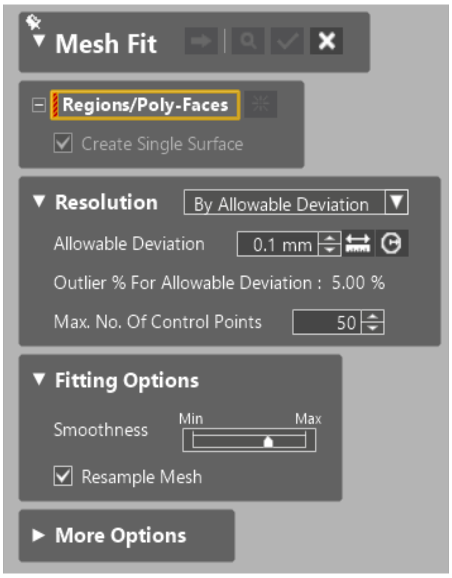

Figure 1: Surface sheet fitting Command

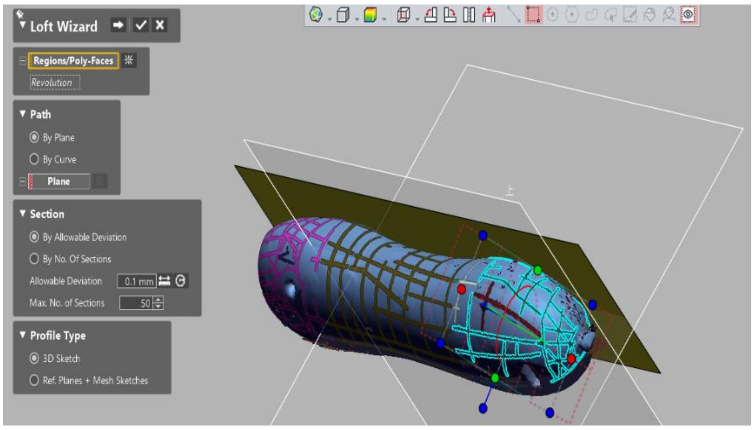

Figure 2: Operation process of lofting wizard

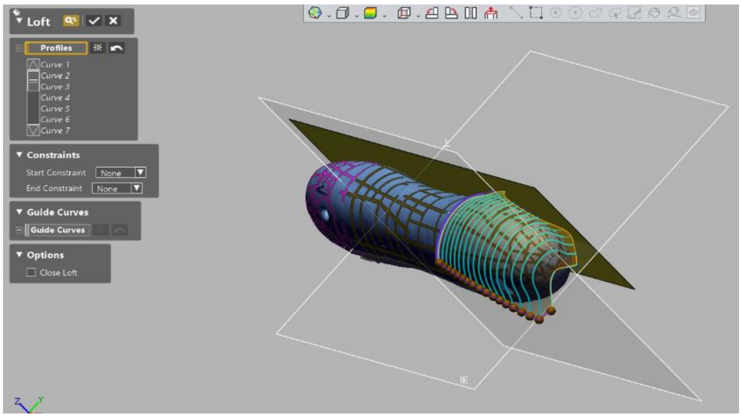

Figure 3: The situation after the lofting wizard is completed

2.4 Build the Surface Splice With Surface Filling.

In Geomagic Design X software, [3D Sketch] module includes [3D surface sheet Sketch] and [3D Sketch] two modes. The processed objects can be surface sheet and solid bodies. In [3D Sketch] mode, spline curves, section curves and boundary curves can be created. The specific operation process selection is to create the curved surface based on the selected edge line through surface filling in Model → Edit. Determine the position relationship tangent to the surface through the edge line drawn by the 3D sketch or 3D surface sheet sketch, and select the edge line corresponding to the surface to be filled in the surface filling command, as shown in Figure 4.

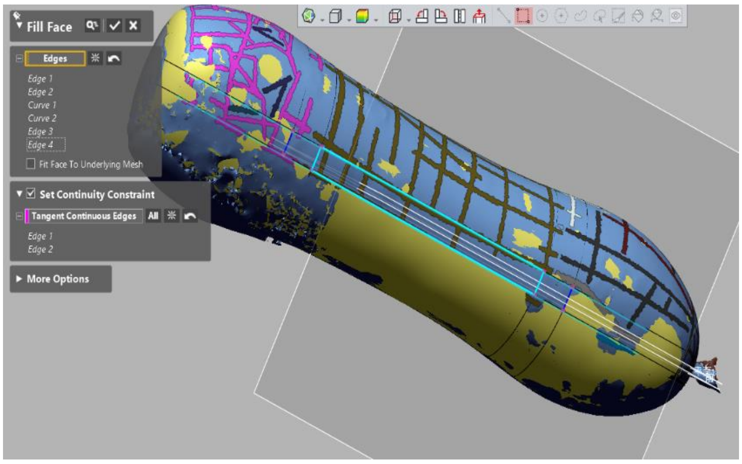

Figure 4: Operation of Surface Filling to Build Curved Surface

3. Data Acquisition Based on Somatosensory Controller

3.1 Obtain Point Cloud Data.

Due to the poor reflection effect between the light in the scanning environment and the color of the surface of the somatosensory controller, the quality of the scanning data is further affected. In order to obtain accurate measurement results, it is necessary to spray paint uniformly on the reflective part of the surface to enhance the diffuse reflection of the surface of the somatosensory controller, so as to obtain an accurate number of point cloud (Liu et al., 2019).

3.2 Paste the Mark Points

Because the curvature of the somatosensory controller changes greatly, it is not possible to collect all the data at one time in the process of obtaining the point cloud data of the somatosensory controller. Therefore, it is necessary to collect the scanning data of the somatosensory controller from different angles to obtain the complete point cloud data model (Zhang, 2021). In order to better splice the point cloud data, a certain number of mark points shall be pasted on the surface of the somatosensory controller, as shown in Figure 5

Figure 5: Mark Point

3.3 Data Scanning

The three-dimensional scanner completes the data acquisition of each angle of the somatosensory controller. And in the scanning process, the scanner system automatically identifies the point cloud data according to the mark points, realizes automatic splicing, and finally obtains the complete point cloud data (Hu and Zhong, 2015). Place the workpiece on the stage to complete the first scanning. After rotating the stage by a certain angle, continue scanning. Due to the role of the mark points, the system will realize the automatic splicing of the point cloud data, as shown in Figure 6.

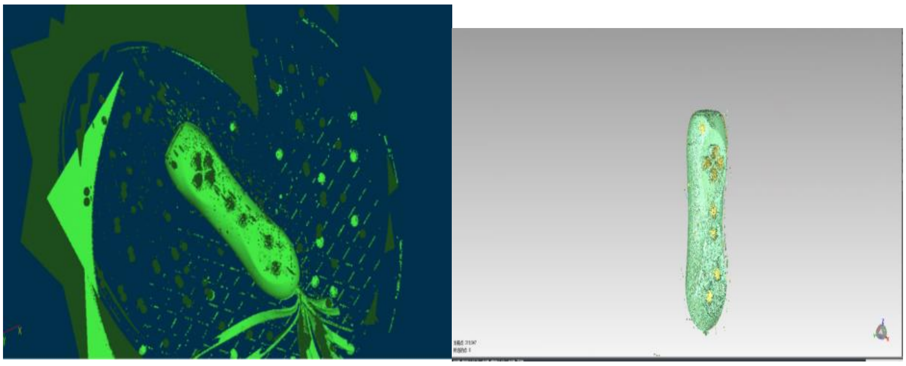

Figure 6: Removal of In-vitro Solitary Points in Point Cloud Data

The point cloud data obtained by scanning is relatively large. If the point cloud data is directly used for processing and curved surface reconstruction, the calculation amount will be large, and topological calculation errors are easy to occur in the surface fitting process (Huang et al., 2019). Therefore, the point cloud data needs to be streamlined. Use “Unified Sampling” preserve boundary points commands in the Geomagic Studio software. The “Unified Sampling” command can reduce the number of point clouds and delete overlapping point clouds while retaining the original shape of the model. Set the Unified Sampling spacing to 0.05 mm (Cai, 2018). In Geomagic Studio, you can manually select the in-vitro points to be deleted by using the Lasso Tool (Chang and Mingzhe, 2016). Click “Delete Selected” to delete the in-vitro points. All in-vitro points can be deleted through multiple repeatedly operations, and only useful scanning data will be preserved.

3.4 Point Cloud Noise Reduction

When using a non-contact laser scanner to scan an object, noise and in-vitro solitary points will be included in the scanned data due to the influence of the scanning mode, method and surrounding environment and these useless points need to be deleted in Geomagic Studio software (Ding et al., 2022). The point cloud shall be noise-reduced by the combination of “manual delete” and “software automatic delete”. “Manual Delete” adopts the method of rounding the useless points and using the delect command to delete. “Software Automatic Delete” by using the “Select In-vitro Solitary Point” command and then the “Noise Reduction” command.

3.5 Point Cloud Mesh Processing

Obtain a polygon mesh from the optimized point cloud data through the “encapsulation” command. There are some defects such as self-intersecting polygons, highly refracted edges, spikes and holes in the process of point cloud “encapsulation”. We need to optimize the polygon mesh with Geomagic Studio software. Use the “Mesh Doctor” command to check and repair defects in the polygon mesh, and finally save the data in stl format.

4. Curved Surface Reconstruction of Somatosensory Controller

Curved Surface reconstruction based on scanning data is the most complex and critical step in reverse engineering (Rineh et al., 2023).

4.1 Domain Division

Due to the complex shape and structure of somatosensory controller, the domain shall be divided by manual segmentation (Wang et al., 2021). The somatosensory controller is in a symmetrical structure as a whole. So select half of the somatosensory controller to complete the domain division of the middle and two ends of the somatosensory controller through manual division, segmentation and editing (insertion, merging, etc.), as shown in Figure 7.

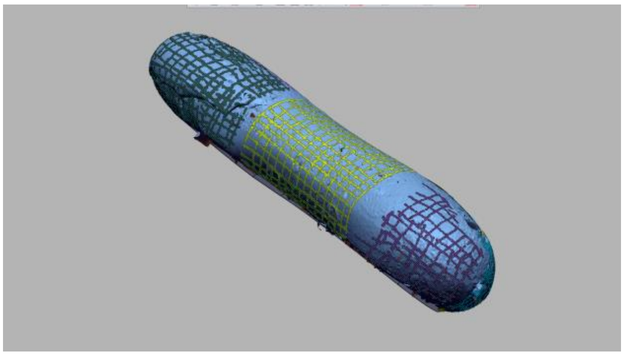

Figure 7: Domain Division

4.2 Lofting Wizard

Use the [Lofting Wizard] command for divided three domains. Since there are deviations in the surface sheets obtained by lofting fitting, we need to open the volume deviation (software deviation detection module) to observe whether the surface sheets fit the model at any time, and thus to adjust the fitting angle of the surface sheets in time to make the surface sheets fit with the model as much as possible, as shown in Figure 8 (Guo et al., 2020).

4.3 Surface Sheet Trimming, Lofting and Stitching

After lofting, the excess surface sheets need to be trimmed. Since the surface sheets from the middle domain lofting are overlapped, a plane needs to be built in the middle of the overlapped parts, and the redundant parts shall be trimmed off, and then connect in accordance with the curvature. As shown in Figure 9.

Select the [Face Offset] command in plane. As shown in Figure 10, offset the plane by 4mm to the left and right. The offset plane can be used as a tool for cutting a curved surface. Select [Lofting] command in curved surface creation. It is necessary to note that the [Tangent to Surface] must be selected as the start condition and end condition in constraint conditions. Click [Stitch] command, and select the surface body to be stitched, and finally finish stitching the somatosensory controller model, as shown in Figure 11.

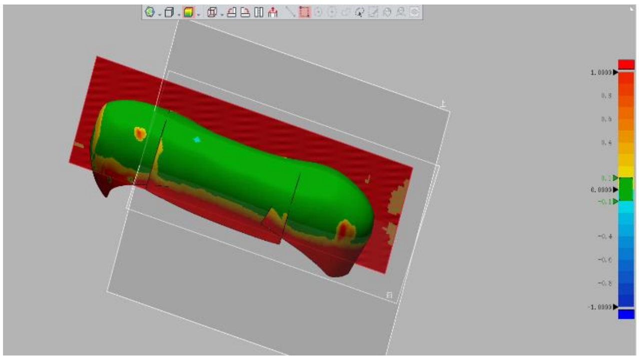

Figure 8: Volume Deviation Diagram of the Model

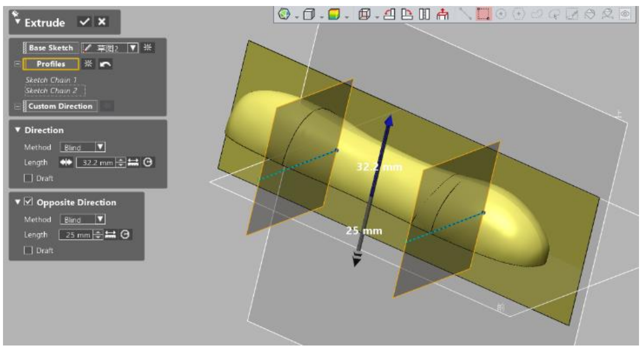

Figure 9: Building Plane

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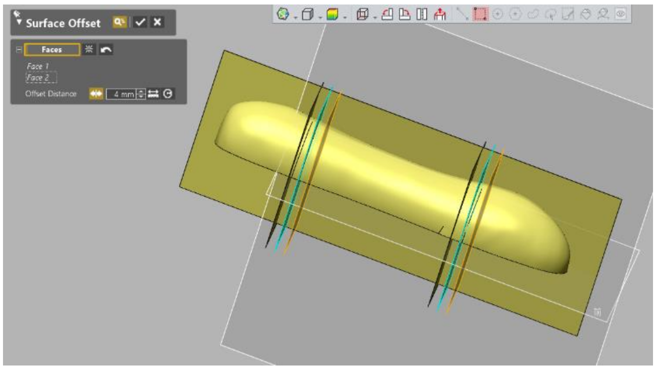

Figure 10: Surface offset

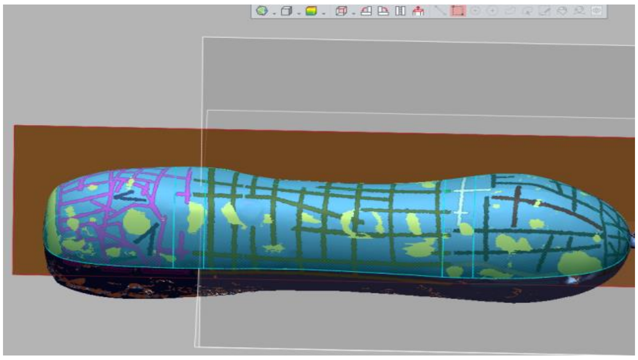

Figure 11: Stitching Complete

4.3 Build Surface Filling

For the parts after stitching, click [3D Surface Sheet Sketch] command in [3D Sketch] to draw four splines to connect two sections. Select the [3D Sketch] command again, to create the 4 built splines on the surface sheet. As shown in Figure 12.

After mirror image is complete, the reconstruction of the middle part of the model can be done by using lofting mode or surface filling mode. Due to the large curvature of the curved surface of the somatosensory controller, the reconstructed surface sheet using the lofting method can only be tangent to both sides of the mirror image body and cannot be connected with the lofted part in Figure 10, so that the later model cannot be converted into a solid body. Therefore, in order to ensure the quality of the model, the surface filling method shall be adopted to build the curved surface.

Adopt the 3D sketch to draw the lofting curve of the model for surface filling, and then click the [Surface Filling] command to fill in turn and observe the volume deviation of the model, as shown in Figure 13.

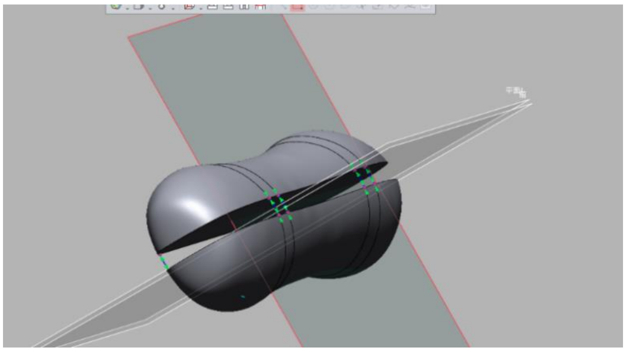

Figure 12: 3D Drawing 3D Sketch

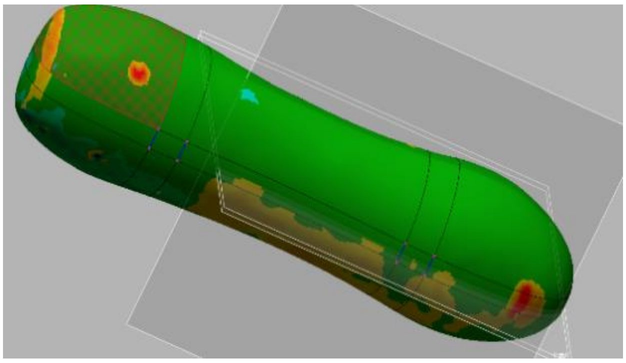

Figure 13: Deviation for body

4.5 Button Part Reverse

The button part of the somatosensory remote controller is a feature that can be completed by stretching. Select the maximum projection contour through the [Surface Sheet Sketch] command to obtain the projection of the curve of the button part, fit the graph with appropriate size with the projection shape in the drawing mode, and complete the modeling of the buttons through [Extension], as shown in Figure 14.

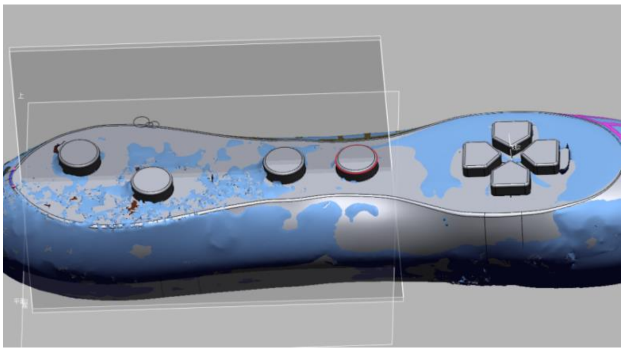

Figure 14: Modeling Complete

After the creation of the curved surface, compare the deviation between the curved surface and the point cloud. As shown in Figure 15, after the accuracy requirements are met, it can be output as an igs format file, which can be directly applied to the 3D design software. This greatly reduces the 3D forward modeling process and improves the model accuracy at the same time.

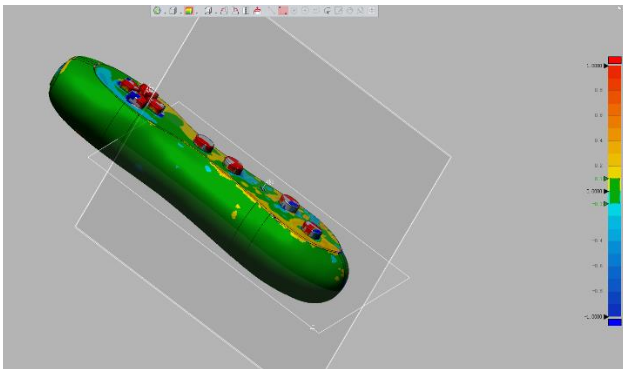

Figure 15: Comparison of volume deviation

5. Conclusion

This paper analyzes and summarizes the surface modeling methods such as surface sheet fitting, lofting, lofting wizard and surface filling. For different curved surface features, we can use different ways to complete the reverse. Taking the somatosensory controller as an example, this paper uses 3D scanning technology and Geomagic design software to conduct reverse design research and practice proof of its outer shell. When the curved surface quality requirements of the parts are not too high and the measurement points are relatively dense, the reverse design of the Geomagic software can significantly improve the design efficiency and shorten the product development cycle. The curved surface modeling and curved surface connection treatment methods in this paper have certain reference significance for the modeling and secondary innovation of other complex parts.

Acknowledgments

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