PROCESSING TECHNIQUES OF POINT CLOUD DATA ON SMALL-SIZED OBJECTS WITH COMPLEX FREE-FORM SURFACE

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ARTICLE INFO

***Article history*:**
Received: 26.4.2015.
Received in revised form: 16.9.2015.
Accepted: 22.9.2015.

Keywords:
CATIA
Reverse engineering
Point cloud data processing
Complex free form surface
Small-sized objects

Abstract:

The scattered point cloud data, which comes from such small-sized objects with complex free-form surface as shelled shrimp, is processed as error points removing, points filtering, holes filling, clouds segmenting, etc. using CATIA V5 R20. The principle of data processing and skills utilized in the operation mentioned above apply also to the small-sized objects similar to the shelled shrimp in reverse engineering in other fields, such as optical components, irregular parts, ears, nose, etc.

1 Introduction

In the field of engineering, reverse engineering has got more and more attention and been widely used. The 3D digital model can be obtained from the product prototype and can be further processed using CAD/CAE/CAM and CIMS, etc [1].
The outer surface of the industrial products can be divided into two categories. One is the elementary analytic surface, such as: plane, cylindrical surface, circular conical surface, spherical surface, etc. The majority of mechanical parts belong to it. The other is complex free-changing surface, also called complex free-form surface, which is is more/very complex and commonly used in aviation, shipbuilding, automobiles, household appliances, mechanical manufacturing and other engineering. For example, the surface of airplane wing, automobile shell and mould belong to this kind.
Many operations in reverse engineering rely on the operator's experience and skills, such as model data gathering, data processing, geometric features recognizing and extracting in models, surface smoothing and balance accuracy controlling, etc, and the operators' experience and skills directly affect the quality of products. One of the important and difficult problems in reverse engineering has been how to process accurately and efficiently point cloud data of models with free-form surface, [2, 3]. At present, there are not any papers summarizing the regulation of reverse reconstruction of the scattered point cloud data gathered from small objects with complex free-form surface, like shelled shrimp.
In general, reverse engineering covers three stages: data gathering, data processing and surface reconstruction. The scattered point cloud data from shelled shrimp is taken as an example. The first step is data gathering, which is carried out with laser scanning system [4] composed of portable Faro Arm-Platinum three-coordinate measuring arm and Kreon KLS51 (class A). The second one is to process the gained data, such as removing error points, filtering points, segmenting clouds, etc. Finally, the further steps are to apply the processed data to CAD system, and to obtain the surface of samples by intersecting and jointing surface patches, completing the 3D modeling.
This paper focuses on the second step, in which scattered point cloud data is processed with reverse engineering module DSE of software CATIA V5 [5, 6]. The corresponding data processing principle and operation skills are presented.

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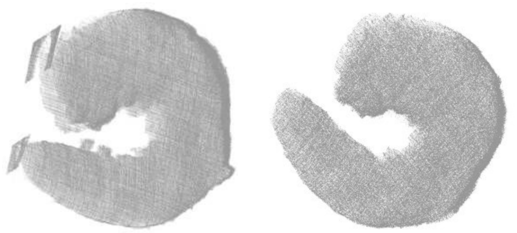
2 Experimental investigation

There would be some inevitable defects in the gathered scattered point cloud data, so these data are to be processed before reconstructing the surface. It is a key step in reverse engineering, for its result would directly affect the quality of model reconstruction later. Data processing includes removing error points, filtering points, creating mesh, filling holes, segmenting clouds, merging clouds, aligning and positioning clouds etc. But as far as these small objects like shelled shrimps are considered, there is no need for the operations of merging, aligning and positioning clouds.

2.1 Removing error points

During the operation, clamps, fixtures and other unwanted points would come into measurement area (error points), which makes up boundary buffer. All of these obvious error points must be manually removed. These error points can be removed by command of Activate Areas in CATIA. The gathered point cloud data of shelled shrimp sample and the point cloud data without error points are shown in Fig.1 (a) and (b).



(a) (b)

Figure 1. (a) The gathered point clouds of shelled shrimp sample. (b) The point clouds without error points.

2.2 Filtering points

Digital model is actually a set of plenty of discrete data. The amount of data is very large with much redundant data as well, so it is necessary to reduce the amount of data on the premise of guaranteed accuracy. In data preprocessing, filtering points is one of the important operations. At present, the commonly used methods of filtering points include the adaptative method, octree structure method, proportional method, average distance method and minimum distance method, etc [7, 8].

Software CATIA V5 provides two methods of filtering points, homogeneous and adaptative. Homogeneous method is suitable for processing the point cloud data of the model with regular curved surface; Adaptative method is suitable for those with complex free-form surface. The rule of filtering points is based on the curvature changes of surface in adaptative method. If the curvature change of surface is smaller, fewer points would be reserved. Otherwise, more points would be reserved.

For the point clouds of shelled shrimp, adaptative method should be chosen for filtering points and the adaptative value is set as 0.01mm. Filtered point clouds are shown in Fig.2.

Figure 2. The filtered point clouds.

2.3 Creating mesh

There are no topology relationships between points in these scattered point cloud data. So, the topology relationships must be established by the function of mesh creation. Mesh is the triangle image of point clouds. It's not a real surface, but it can improve the visibility of point clouds and the efficiency of surface molding.

Mesh is created by the command of Mesh Creation of CATIA with the radius of little sphere set to 5.5mm. Once the point-clouds have been created a 3D mesh is generated, which is shown in Fig.3. And then, the distance between mesh and point clouds is inspected.

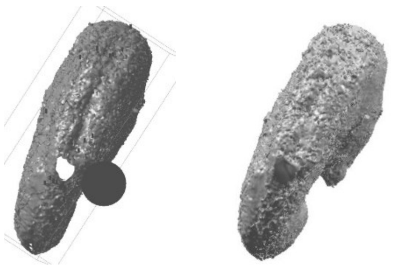
Figure 3. The point clouds after creating the mesh.

2.4 Filling holes

Because of geometry topology or blocks from other objects, partial surface of the models couldn't be measured. So, the gathered data of digital model is defective and should be repaired by interpolating some data.

Filling holes are to interpolate some data into the defect coordinate according to the information of points around. Methods of data interpolation in reverse engineering mainly consist of physical filling method, model design method, curve interpolation method and curved surface interpolation method, etc [9].

Meshes are chosen and holes are filled by the command of Fill Hole of CATIA. In this study, the value of each parameter is set as follows: Hole size=3mm, Sag=1mm, Step=5mm, Shape=0.15. The point clouds are to be filled holes and those filled holes are shown in Fig.4 (a) and (b).



(a) (b)

Figure 4. (a) The point clouds are to be filled holes. (b) Filled holes in point clouds.

2.5 Segmenting clouds

The outer surface of many real products is often made up of many different types of surface patches. So, during the course of CAD model reconstruction, the outer surface of a digital model can be divided into several curved surface patches according to the appearance feature of the surface. At first, each surface patch should be fitted. Then all of the curved surface patches would be stitched into a full surface through several edit functions such as blending, intersecting, cutting, rounding and combining, etc.

During point cloud segmentation we group out (segment) the data of the same type of each curved surface patch according to the types of curved surface patches. So, all the data will be divided into different data fields, which help the subsequent operation of reconstructing the surface [10, 11].

Point cloud data are segmented by the command of Create a Scan Line of CATIA. In this study, according to the structural characteristics of shelled shrimp, all the characteristic points are picked out and connected into the characteristic scan curves. In this way, point cloud data are segmented. The point cloud data segmented with the mesh hidden is shown in Fig.5.

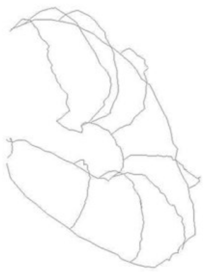
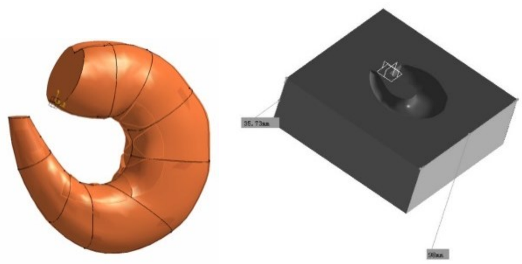


Figure 5. The point cloud data segmented with the hidden mesh elements.

Through processing means shown above, these mass scattered point cloud data become compact and orderly, and the characteristics of surface are easy to be identified. On this basis, the 3D modeling and cavity mould design of shaped parts of shelled shrimp could be successfully finished. The finished 3D model and cavity plate of shelled shrimp are shown in Fig.6 (a) and (b).



(a) (b)

Figure 6. (a)The finished 3D model of shelled shrimp; (b)The finished cavity plate of shelled shrimp.

3 Results and discussion

Since there are many methods to process data, the method should be chosen according to the concrete point cloud data. In this study, corresponding data processing principle and skills are presented after deeply researching into kinds of methods and accumulating personal experience.

3.1 Removing error points is a must

It is best to use Activate Areas command of CATIA to remove error points. In fact, this command only hides error points. So, they can be recovered if some points are removed by mistake. The point cloud removed by another command of Remove Points can never be recovered. So, when using this command, the point cloud to be removed should firstly be circled one by one. And then, in order to avoid removing useful point cloud, the angle of view should be adjusted using the rotation function and the depth of circle should be changed by pulling the lever. The operation of pulling the lever is shown in Fig.7.

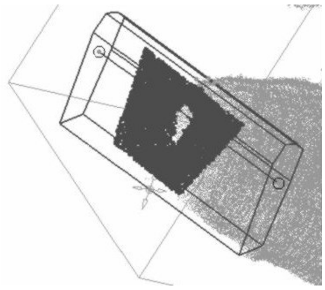


Figure 7. The operation of pulling the lever.

3.2 Filtering points depends on the concrete conditions

If there are fewer amounts of point cloud data and the digital model is more noticeable, points are not necessary to be filtered. Otherwise, points should be filtered. After points have been filtered, they help identify the characteristics of curved surface and reconstruct the surface. The selection of parameter is based on the principle that the characteristics of the curved surface should be clearly expressed after the process/operation of the triangulation. If it isn't clearly expressed or there are too many defected holes, the value of adaptations/adaptive systems should be increased slightly.

3.3 The selection of the value of neighborhood during creating mesh

As shown in Fig.8, the value of neighborhood means spherical radius in point clouds. As long as lines connected by any three points of the point clouds are embraced by the sphere, a triangular mesh based on these three points will be created. The larger the value of neighborhood, the better mesh is to be obtained and consequently, too many or too big defected holes can be avoided after meshing.

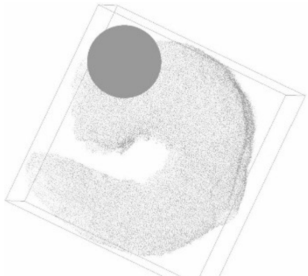


Figure 8. The spherical radius in point clouds.

3.4 Filling holes is needed

During creating the mesh, the point cloud could not be completely scanned. So, holes would appear unavoidably on the mesh. For the bigger holes, the value of Hole Size should be adjusted to fit with the size of holes.

3.5 Application techniques of segmenting clouds for the complex free-form surface

There are 2 special commands of segmenting clouds in QSR module of CATIA: according to the curvature and slope, respectively. Their functions are to create scan lines on the mesh according to the variation of curvature or the slope. Thereby, the mesh can be segmented. But these two commands are not suitable for the shrimp point clouds, and the needed scan lines could not be created. If another command, Create a Scan Line in DSE module in CATIA is applied, on the basis of object shape and structure characteristics, characteristic scan lines would be successfully created by drawing scan lines manually on the clouds.

The basic principles of segmenting clouds are as follows:

First, each mesh patch should be four-side-territory surface as far as possible.

Second, the curvature variation of each mesh patch should be as much as possible uniform. By doing so, the shape of the point clouds would be better captured and the fitting error would be reduced. For example, the curvature variation of the clouds near the shelled shrimp head could be considered as uniform and this part of clouds could be divided into 3D small mesh patches to construct the respective surfaces. The segmenting of clouds near the shelled shrimp head is shown in Fig. 9.

Figure 9. Segmenting of clouds near the shelled shrimp head.

4 Conclusion

The technology of reverse engineering is a comprehensive and practical technology. In practice, a large amount of human-computer interactive work is needed in the process. The experience and skills of the operator would directly influence the quality of modeling; the research results of one field don't apply directly to others. Based on a serious and profound analysis of basic theory and method about reverse engineering and a great deal of personal practical experiences, the scattered point cloud data processing technology focused on shelled shrimp are researched by using the software CATIA V5, and corresponding data processing principle and finally skills used in these operations are presented. These presented skills are also appropriate for reverse engineering of other similar small-sized objects in the field of engineering, such as optical components, irregular parts, artificial face, nose and ears, etc [12-14].

Acknowledgment

We kindly acknowledge financial support by the institutions of higher learning scientific research key project of Heibei province department of education (No ZD20131062).
The author is also very grateful for the support provided by the science and engineering foundation key project of Hebei Agricultural University (No ZD201409).

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