Chapter 8
Processing of 3D Unstructured Measurement Data for Reverse Engineering

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ABSTRACT

One of the most difficult problems in reverse engineering is the processing of unstructured data. NURBS (Non-uniform Rational B-splines) surfaces are a popular tool for surface modeling. However, they cannot be directly created from unstructured data, as they are defined on a four-sided domain with explicit parametric directions. Therefore, in reverse engineering, it is necessary to process unstructured data into structured data which enables the creation of NURBS surfaces. This paper presents a methodology to processing unstructured data into the structured data for creating NURBS surfaces. A projection based method is established for constructing 3D triangulation from unstructured data. An optimization method is also established to optimize the 3D triangulation to ensure that the resulted NURBS surfaces have a better form. A triangular surface interpolation method is established for constructing triangular surfaces from the triangulation. This method creates five-degree triangular surfaces with \( C^1 \) continuity. A series of segment data are obtained by cutting the triangular surfaces with a series of parallel planes. Finally, the structured data is obtained by deleting repetitive data points in each segment data. Results demonstrate the efficacy of the proposed methodology.

INTRODUCTION

Reverse engineering has become an effective method to create a 3D computer model of a physical object by dimensional measurement and surface modelling (Varady et al., 1997; Beccari et al., 2010). It has many applications in different fields, such as medical imaging, entertainment, cultural heritage, web commerce, collaborative design and obviously engineering. The physical object can be measured using 3D scanning technologies such as coordinate measuring machines or computed tomography scanners, which provide outputs in the form of a large set of vertices in a
3D coordinate system. For the objects with good structured shapes, unstructured data can be avoided if an appropriate scanning direction is selected during the measurement process. However, for the objects with complex shapes, unstructured data cannot be avoided no matter what scanning directions are used. The unstructured data do not have explicit parametric directions, especially in comparison with the structured four-sided data which has explicit parametric directions (Figure 1). NURBS (Non-uniform Rational B-splines) surfaces are the popular surfaces modelling tools and have been extensively used in reverse engineering and product design activities (Ma & Kruth, 1998; Yin et al., 2003; Jiang & Wang, 2006; Pal & Ballav, 2007; Pal, 2008). As they are defined on a structured four-sided domain with explicit parametric directions, they cannot be created from unstructured data directly. Therefore, in reverse engineering, it is necessary to process unstructured data into the structured data for creating NURBS surfaces, thus enabling surface operations such as joining, filleting and blending for creating complex-shaped objects. In this paper, a methodology is presented for processing unstructured data into the structured data for 3D object reconstruction. A projection based method is established for triangulation of 3D unstructured data. This method simplifies the complex 3D triangulation problem by converting it into the 2D triangulation problem. The 3D triangulation is directly obtained from the 2D triangulation obtained by an improved 2D triangulation algorithm. An optimization method is established for optimization of the 3D triangulation to ensure that the surfaces constructed from the spatial triangulation have the better form. A triangular surface interpolation method is established to construct five-degree triangular surfaces with $C^1$ continuity by interpolating each triangle. Subsequently, a series of segment data are obtained by cutting the triangular interpolation surfaces with a series of parallel planes. Structured data are finally generated by deleting repetitive points in each segment data, and smoothing and uniforming each segment data for NURBS surface modelling.

Reverse engineering is the process of measuring an object and then generating the object’s computer model which captures the object’s physical features (Lin et al., 1997; Meng et al., 1996; Tuohy et al., 1997; Varady et al., 1997; Wang & Wang, 1997). The processing of unstructured data, which is the one of key issues in reverse engineering (Ma & He, 1998; Seiler et al., 1996; Yau & Chen, 1997; Jiang & Wang, 2006, Pal & Ballav, 2007; Pal, 2008; Beccari et al., 2010, Tang et al., 2010). However, because of the complexity of unstructured data, the existing studies suffer from different problems. Focusing on engineering applications, this paper presents an approach for processing unstructured data into structured data for creating NURBS surfaces.

**METHOD DESCRIPTION**

The procedure for processing unstructured data into structured data is illustrated in Figure 2. The first step is to construct 3D triangulation over 3D unstructured data. A projection based method is established for this purpose. The 3D unstructured data is projected onto a reference plane to generate the 2D unstructured data with the same topological structure as the 3D unstructured data.

*Figure 1. Structured data in the form of structured four-sided grid*
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