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A 3-D point sets registration method in reverse engineering

Jin Tao *, Kuang Jiyong

Institute of Chemical Machinery, Zhejiang University, Hangzhou, Zhejiang 310027, PR China

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Abstract

When acquiring the surface data of the sample part, it is not easy to get the full data on one scan due to the configuration or topology of the part. In addition, some special parts have special assembly request, for example the joint surface smooth and the boundary share. The process usually requires multiple scans for an assembly model. Some identical points have different coordinate data because of the moving of the part. As a result, before the model reconstruction the digitized data must be registered or aligned. According to the geometric graphics transform theory, this work develops a digitized point sets registration method, which is based on the coordinate transform. The method utilizes measured three datum-point data in different coordinate systems to calculate the rotation and translation matrix. If the measurement error cannot be ignored, the least-square method may be applied to find the closest points. Finally, this method is adopted to the clay model of the motorcycle surface in reverse engineering, the data registration meets the design precision.

Keywords: Reverse engineering; Points registration; Least-squares; Coordinate transform

1. Introduction

In reverse engineering, we often meet the question which the surface data of the sample part can not be acquired by one scan, for example the bottom of part and the region where the probe cannot contact. Even though we can replace the probe (increase probe length and change tactile angle, etc.) to solve the interference problem, there are still some areas that need to move object and change the position to finish scan process.

In addition, some parts have assembly request, for example the joint surface smooth and the boundary share especially to the part with free-form surface, which usually requires multiple scan to the surface of the assembly part. Some identical points have different coordinate data because of the moving of the part. As a result, before the model reconstruction the digitized data must be registered or aligned.

In the computer vision applications, notably the estimation of motion parameters of a rigid object and the determination of the relative attitude, a rigid object with respect to a reference usually uses 3-D point sets registration. Besl and Mckay (1992) describes manifold 3-D shape registration methods, including 3-D point sets, free-form curves and surfaces. Among these methods, the 3-D point sets registration method is used in most

* Corresponding author.
E-mail address: cejintao@zju.edu.cn (J. Tao).

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places, especially in reverse engineering where the object shape is described as 3-D scan point sets. To carry out 3-D point sets registration, first construct least-square distance object function between the corresponding points, solve the object function based on the quaternions and the singular value decomposition (SVD) the rotation and the translation of the rigid movement (Arun, Huang, & Blostein, 1987; Faugeras & Hebert, 1986; Horn, 1987).

The multiple view combination of the scan data can be regarded as a special rigid movement problem. Therefore, the above discussed method may be used to solve it. Because three points can construct a coordinate system, when measuring shape data, operator need to create three points (datum-points) in different view, make those three points align one another, the multiple view scan data may be registered and combined in a coordinate system.

2. Datum-points creation

Before measuring surface or the part operator need to create three datum-points on the different position of the surface and mark them. When the part is moved to another position to measure the bottom of part, three datum points must be measured again to each position movement. If scan data need to be unified to assembly model, the operator should measure part datum-points and assembly datum-points separately. By making three datum-points belong to two-condition type registration, the whole scan data can be transformed to one modeling coordinate system (see Fig. 1). Therefore the scan data transform problem may be converted to three datum-points align problem, the multiple scan data can be transformed to the one coordinate system.

3. Geometric transform method

When scaning the object surface, the coordinate position of those mark points will be changed because the object movement, the coordinate position of the same points are different in multiple measuring process. This change is equivalent to the coordinate system transform. Therefore the original data registration problem will be changed as the coordinate transform.

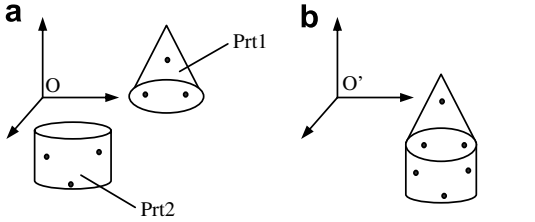
3D Coordinate transform comprise rotation, translation, scale, and reflection etc., the measurement data registration problem only is involved in rotation and translation. By three points only one coordinate system can be constructed, therefore multiple scan data registration can be finished by the transform relation of three datum-point.

The coordinate transform method by three points is: measuring three datum-points $p1$, $p2$ and $p3$, on secondly measuring, datum-points coordinate changes to $q1$, $q2$ and $q3$, rigid motion can be estimated by three steps (See Fig. 2) (Mortenson, 1985):

(1) Move p_1 to q_1.
(2) Align the vector $(p_2 - p_1)$ and $(q_2 - q_1)$ (only considering direction).
(3) Transform the plane including three points p_1, p_2 and p_3 to the plane including the points q_1, q_2 and q_3.

Algorithm

Step1: Construct the vector $(p_2 - p_1)$, $(p_3 - p_1)$, $(q_2 - q_1)$ and $(q_3 - q_1)$.



(a) Parts measuring (b) Assembly measuring

Fig. 1. Datum registration.