Surface Reconstruction for Cross Sectional Data

Xu Meihe (徐美和) and Tang Zesheng (唐泽圣)

CAD Center, Department of Computer Science and Technology
Tsinghua University, Beijing 100084
Email: xmh@csnet1.tsinghua.edu.cn, dcstzs@tsinghua.edu.cn.
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Abstract

In this paper, a new solution to the problem of reconstructing the surface of 3D objects over a set of cross-sectional contours is proposed. An algorithm for single branch contours connection, which is based on the closest local polar angle method, is first presented. Then the branching problems (including non-singular branching and singular branching) are completely solved by decomposing them into several single-branching problems. Finally, these methods are applied to the reconstruction of the external surface of a complexly shaped object such as the cellular region of human brain. The results show that the presented methods are practical and satisfactory.

Keywords: Contours connection, non-singular branching, singular branching, shading.

1 Introduction

The fundamental volume visualization algorithms generally fall into two categories: Direct Volume Rendering (DVR) algorithms and Surface Fitting (SF) algorithms. The SF approach includes Contours-Connecting, Marching Cubes Method, Dividing Cubes Method, etc. Marching Cubes Method and Dividing Cubes Method assume that data are available as a 3D grid. Contours Connection Method assumes that the data are defined by the intersection of a surface and a section plane. Which approach is most applicable depends on the nature of the data.

If the available data are a dense 3D lattice of values, as is the case for CT and MRI data, Marching Cubes Method or Dividing Cubes Method may be better[1]. Although the Marching Cubes Method has been successfully used to visualize anatomical structures, it does not provide us with an adequate representation of the human organ's geometry. The Marching Cubes Method usually adopts a threshold classification scheme to separate the organ voxel from the rest of the volume. This makes it difficult to distinguish between two adjacent but distinct anatomical entities which have the same density or color. It often brings on an incorrect result because of segmentation fault. So Contours Connecting Method is preferred in this

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sense. Contours Connection Method has also the advantage of being fast and well suit to today's graphics workstation which provides polygon rendering and spline computation firmware.

In many applications, an object or a set of objects is known by a sequence of cross sections. These cross sections may be obtained by intersecting the three-dimensional object with a collection of planes. For instance, in anatomy, the thin sections are obtained by moving a paralleled scalpel. And in medical diagnosis and therapy, cross-sectional images are obtained by moving a CT apparatus. The problem for reconstructing the three-dimensional surface from a set of planar contours at cross-sections is an important problem in these fields. For example, anatomists and students of medical university try to understand the shape of bones, organs and tissues within the human body from serial sections of the object.

A large number of algorithms for solving Contours Connection problem have been proposed in the literature. These methods can be divided into two categories: optimal and heuristic\textsuperscript{[2]}. Optimal methods provide the best triangulation in the sense of some given criterion. These methods are based on the use of a graph corresponding to a possible triangular patch. A given path in the graph defines a possible solution. A cost function is assigned to each arc of the graph and an optimal solution with respect to the selected cost criterion is obtained by finding an optimum path in this graph. For instance, one can obtain the maximal volume polyhedron (Keppel\textsuperscript{[3]}) or the minimal area polyhedron (Fuchs\textsuperscript{[4]}). Another method described by Boissonat\textsuperscript{[5]} makes use of the Delaunay triangulation to solve the problem in N-dimensional space. These optimal methods usually give good results, but are very time consuming.

Heuristic methods are computationally less expensive even if they are not optimal. The resulting surface can be visually correct and sometimes even better. They consist of defining triangular patch one by one using only a local decision criterion. For example, Christiansen\textsuperscript{[6]} chose the shorter one of two possible edges defining a patch. Cook\textsuperscript{[7]} joined the points with the condition that the orientation of the line segments connecting the points should be similar to the orientation of the line joining the centroid of the contours. For concave contours connection Cook's method results in fault. Most of them are sufficient when the contours have similar shape and orientation, and are mutually centered. However, if the processed contours are very different in shape and orientation, and are quite distorted, these approaches may provide incorrect results. In Ekoule's algorithm\textsuperscript{[2]}, the first step is to link convex hull of two consecutive contours based on a "minimum edge-length" criterion. Then the link between two arbitrary contours is performed by projecting each point of contours on their respective convex hull. It is efficient for many cases.

Furthermore, most of algorithms can only handle the case in which there is only one contour in each slice, which we call a single-branching. In many cases there are different numbers of contours in consecutive slices, which are referred to as multiple branching problem. There are few algorithms that deal with singular branching. Boissonat\textsuperscript{[5]} proposed a solution based on the Delaunay triangulation between two slices. Shantz\textsuperscript{[8]} has proposed a multiple-branching procedure based on