Eurographics Symposium on Geometry Processing (2005)
M. Desbrun, H. Pottmann (Editors)

Reconstruction of Solid Models from Oriented Point Sets

Michael Kazhdan[†]

Abstract

In this paper we present a novel approach to the surface reconstruction problem that takes as its input an oriented point set and returns a solid, water-tight model. The idea of our approach is to use Stokes' Theorem to compute the characteristic function of the solid model (the function that is equal to one inside the model and zero outside of it). Specifically, we provide an efficient method for computing the Fourier coefficients of the characteristic function using only the surface samples and normals, we compute the inverse Fourier transform to get back the characteristic function, and we use iso-surfacing techniques to extract the boundary of the solid model.
The advantage of our approach is that it provides an automatic, simple, and efficient method for computing the solid model represented by a point set without requiring the establishment of adjacency relations between samples or iteratively solving large systems of linear equations. Furthermore, our approach can be directly applied to models with holes and cracks, providing a method for hole-filling and zippering of disconnected polygonal models.

Categories and Subject Descriptors (according to ACM CCS): I.3.5 [Computer Graphics]: Computational Geometry and Object Modeling

1. Introduction

Reconstructing 3D surfaces from point samples is a well studied problem in computer graphics. The ability to reconstruct such surfaces provides a method for zippering samples obtained through scanning, filling in holes in models with degeneracies, and re-meshing existing models. While there has been much work in this area, we provide a novel approach that is based on basic calculus, providing a simple method for reconstructing solid models from oriented point sets (point samples with associated normals).

Our approach takes advantage of the fact that an oriented point set sampled from the surface of a solid model provides precisely enough information for computing surface integrals. Thus, by formulating the solution of the surface reconstruction problem in terms of volume integrals, we can apply Stokes' Theorem to transform the volume integrals into surface integrals and compute a discrete approximation using the oriented point samples.

In practice, our approach provides a method for reconstructing a water-tight model from an oriented point set in three easy steps: (1) The point-normal pairs are splatted into a voxel grid. (2) The voxel grid is convolved with an integration filter. (3) The reconstructed surface is extracted as an iso-surface of the voxel grid.

The advantage of our approach is its simplicity: Splatting the oriented point samples into the voxel grid can be done without necessitating the establishment of adjacency relations between the samples. Convolving with a filter can be efficiently performed using the Fast Fourier Transform [FFTW]. And finally, standard methods such as the Marching Cubes algorithm [LC87] can be used to extract the reconstructed surface, returning a triangulation that is guaranteed to be water-tight.

Figure 1 demonstrates our method for an oriented point set obtained by sampling the surface of a dinosaur head. The original model is shown on the left, the samples are shown in the middle, and the reconstructed model is shown on the right. Note that even though the points were sampled from a model which was not water-tight, (there are holes in the eyes, the nostrils, and the mouth) our method succeeds in returning a seamless mesh that closely approximates the input data, accurately capturing the fine model details.

Our method addresses the surface reconstruction problem by approximating integration by a discrete summation and a direct implementation of our method assumes that the samples are uniformly distributed over the surface of a model. However, in many situations, the input samples are not uni-

[†] Johns Hopkins University