Surface Network Construction from Non-parallel Cross-sections

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Figure 1: Construction of surface networks from non-parallel cross-sections with non-manifold (a) and manifold (d) curves. An intermediate result is shown in (b). The input curves are shown in purple in (a,d), and coloring indicates the material on each plane.

1 Introduction

Surface construction from incomplete data is a topic of wide interest in geometry processing. A common class of incomplete inputs that arises in several application domains, including bio-medicine and geology, is a stack of curves representing the planar cross-sections of a complete surface. In medical imaging, for example, these curves are typically hand-drawn by physicians to delineate contours of anatomical structures on 2D cross-sections of a 3D image volume generated by MRI, CT or ultrasound. Given a stack of planar cross-sections, a complete 3D surface is desired that connects the curves on each cross-section plane. In particular, such surface needs to be both topologically correct (i.e., closed and interpolating input curves) and geometrically smooth.

Devising an automatic computational approach that satisfies the above two criteria is a challenging task, especially for complex inputs. As shown in Figure 1, the cross-section planes may not be parallel to each other, and the curves on each plane may exhibit a non-manifold topology (i.e., a curve network), such as in (a), which is necessary to represent abutting anatomical regions such as cortex and cerebellum. Despite the intensive research in the past three decades in the area of surface construction from planar curves, generating topologically closed surfaces using existing methods is limited to parallel cross-sections and/or manifold curves on each plane.

In this paper, we introduce a novel method for cross-section planes that are arbitrarily orientated and possibly containing curve networks. Given any set of planar cross-sections with piece-wise linear curves, we method guarantees to produce a closed triangular surface network that smoothly interpolates the input curves. To the best of our knowledge, this is the first computational method that has such capability.

2 Method

The key of our method is to consider a partitioning of the space by the cross-section planes and utilizes the medial axis within each partitioned sub-space to determine surface topology. Additionally, mesh refinement and fairing techniques are employed and adapted to ensure a smooth appearance of the final geometry.

The input to our method consists of piece-wise linear curve networks lying on a set of 3D planes. Each plane is partitioned by the curves into closed, disjoint regions, each associated with a particular “material” (e.g., air, cortex, cerebellum, etc.). Our method proceeds in two stages to respectively determine the topology and geometry of the surface that interpolates the input curves.

Topology creation We consider a partitioning of the space by the set of all planes, and locally construct a closed surface network within each partitioned sub-space (called sub-space). The surface network is constructed by triangulating the interfaces between volumes of different materials partitioned by orthogonally projecting the curve networks onto the medial axes of the sub-space. Merging the individual surface network from each sub-space would result in a closed surface that interpolates all input curves.

Geometry creation The result of topology creation is a closed surface satisfying the topology criteria yet exhibiting a blocky appearance (Figure 1 (b)). To create a fair mesh that interpolates the input curves, we develop a novel constrained mesh fairing filter that is capable of creating smooth triangular meshes interpolating multiple stationary curve constraints from poor-quality and anisotropic meshes. We further couple this filter with mesh splitting to form an iterative framework that generates an isotropic surface network.

Results of our method are shown in Figure 1. In the special case when the input cross-sections are parallel, our method improves upon state-of-art methods, such as [Barequet et al. 2003] and [Ju et al. 2005], which construct surface networks from curve networks lying on parallel planes. In this case, both our method and [Ju et al. 2005] produce the same surface topology yet our method results in smoother-looking geometry due to the employment of mesh refinement and fairing. In addition, our method is designed for both parallel and non-parallel cross-sections.

References
