

Automatic Cross-Sectioning Using 3D Field Topology Analysis

Yuki Mori*
The Univ. of Tokyo

Shigeo Takahashi†
The Univ. of Tokyo

Takeo Igarashi‡
The Univ. of Tokyo / JST PRESTO

Yuriko Takeshima§
Tohoku University

Issei Fujishiro§
Tohoku University

1 Introduction

It is difficult to comprehend the inner structures of volume datasets. Several techniques have been proposed to visualize these inner structures, such as volume rendering and isosurface extraction. However, these approaches are still limited in the ability to visualize the detailed structures and users frequently take cross-sections to inspect such detailed structures. The problem is that existing systems require the users to search for an ideal cross-section manually, which involves tweaking many parameters and is tedious and time-consuming. To address this problem, we present a method for automatically generating cross-sections that reveals the characteristic structures of a dataset.

2 The Volume Skeleton Tree

We use a 3D field topology analysis technique to analyze volume datasets. The Volume Skeleton Tree (VST) [Takahashi *et al.* 2004] is a level set graph that delineates volumetric structures. It represents the splitting and merging of isosurfaces with respect to the filed value. Each node of the graph represents a critical point where the topology of the evolving isosurface changes, and each link represents a region between the isosurfaces associated with the critical points.

For example, we consider the analytic volume function as shown in Fig. 1(a) [Takahashi *et al.* 2004]. This volume dataset includes six critical points: P_1 , P_2 (appearance), P_3 , P_4 (merging), P_5 (splitting), and P_6 (disappearance). Figure 1(b) represents the VST of the volume dataset. If a dataset is noisy, the resulting VST becomes complex and it becomes difficult to see the global structure. In such cases, we simplify the VST before computing cross-sections to obtain a clean VST.

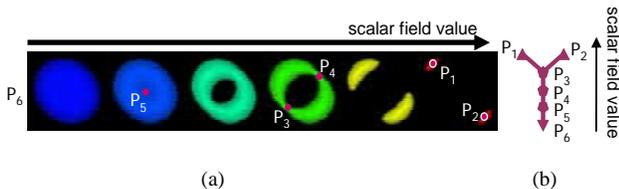


Figure 1: Topological analysis of the analytic function volume: (a) A change in the isosurface and critical points; (b) The corresponding VST.

3 Generating Cross-sections using VST

Our basic idea is to cut the dataset at the plane best-fitting the critical points of VST. A simple method to generate such a plane is least-square estimation. To make such a plane, we construct a covariance matrix of critical points and calculate three eigenvalues and eigenvectors. Then, we make three planes, each of which passes through the center of gravity of the critical points and includes any two of the three eigenvectors. The system cuts the dataset using a plane that includes two eigenvectors paired with the two major eigenvalues, but the user can select two other cross-sections. This selectivity is interesting from the viewpoint of user interface design.

Figure 2 shows that our method can yield appropriate cross-sections of the dataset shown in Fig. 1(a). Each volume-rendered

*e-mail: yuki@ui.is.s.u-tokyo.ac.jp

†e-mail: takahashis@acm.org

‡e-mail: takeo@acm.org

§e-mail: {takeshima, fuji}@vis.ifs.tohoku.ac.jp

image shows the dataset on the far side of the cutting plane. Figure 2(a) is rendered with the best-fitting plane, and Figs 2(b) and (c) are rendered with the next two candidates.

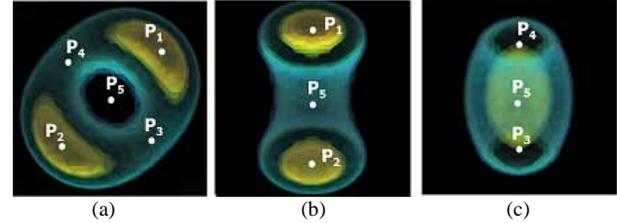


Figure 2: Cross-section samples of the analytic function volume: (a) A cross-section passing through many important critical points; (b), (c) Cross-sections passing through axes of symmetry.

4 Results

We applied our method to various volume datasets taken from quantum science and medical science. Figure 3 shows volume-rendered images of three target datasets using accentuated transfer functions. The top images show the entire datasets, and the bottom images show the datasets on the far side of the cutting planes. We can see that the bottom images better illustrates the detailed inner structures.

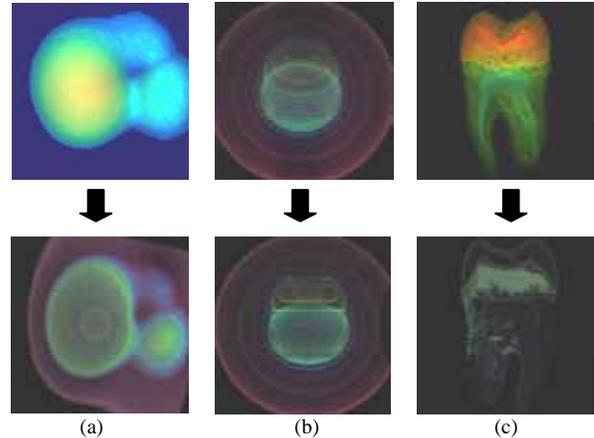


Figure 3: Volume-rendered images of target datasets: (a) The hydrogen ion-atom collision [Fujishiro *et al.*2000]; (b) The nucleon [Meibner]; (c) NML Tooth volume [Woo].

In the future, we plan to extend our algorithm to generate cross-sections including curved surfaces and multiple planes. We also want to try other methods to analyze inner structures, such as the medial axis and generalized symmetry, to apply automatic cross-sectioning to other model representations, mainly surface models. Finally, we would like to design better user interfaces for inspecting volume datasets.

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