A Guided Approach to Segmentation of Volumetric Data

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1 Introduction

Recent advances in imaging techniques have made a fundamental impact on biomedicine. However, imaging produces volumetric data which, in its raw form, consists of colored pixels or voxels. This information needs to be processed in order to reveal useful knowledge about the physiology, morphology, and mechanics of the imaged subject. This data-to-knowledge pipeline usually starts with the delineation of the anatomical structure of interest (e.g., an organ, a tissue, a cell, etc.), a process commonly known as segmentation, to produce a 3D model of the structure(s).

Segmentations are critical for a wide range of processes found in practical applications such as: rendering visualizations; quantitative analysis of geometry, topology, shape, morphology, and statistics of image data within the structure; and computation of physical properties for treatment planning and virtual simulations. So not only do segmentations need to be accurate, but they also need to be created efficiently. When segmentation is the bottleneck in the data-to-knowledge pipeline, it slows the rate of research and analysis and can result in health risks in clinical practices [Foppiano et al. 2003], [Fiorino et al. 1998]. Automatic or semi-automatic segmentation methods are becoming more reliable [Wirjadi 2007], but in many cases they cannot be used because they require strong image gradients or templates. They are still highly susceptible to noise and poor image quality, thus requiring manual human interaction.

In this work, we consider reducing this significant bottleneck by creating a novice-friendly manual segmentation system that would allow crowdsourcing the task of segmenting 3D data. We focus on making volumetric data understandable and helping non-experts produce usable results. We use contouring guidelines, navigation aids, and other interface enhancements to allow any level of user to produce a 3D segmentation. This work builds off of [Sowell et al. 2009], a similar system designed for expert use.

2 Our Approach

To alleviate the challenges posed by manual 3D image segmentation and work towards a novice usable system, we focused on two major design points: reducing 3D navigation and increasing 3D spatial understanding through visualizations. For this work we assume that the segmentation task is repeated; the goal is to segment the same basic structure on multiple 3D volumes. For instance, segmenting the liver on different patients.

Since 3D navigation and understanding where to draw boundaries is difficult, we limit the amount of manual navigation needed and provide easy to understand visual cues about the 3D data when drawing contours. We propose a guided method for 3D image segmentation that uses an expert-driven contouring protocol. The protocol provides a step-by-step navigation path to slices to draw contours on, as well as images of example contours and text instructions for each step. The navigation path allows large-scale navigation to be done automatically and the example images help the user discern where to draw the boundary. The contouring protocol effectively guides the user to draw quality contours on meaningful planes selected by the expert, and provides the expert the flexibility to define what they deem to be a useful segmentation.

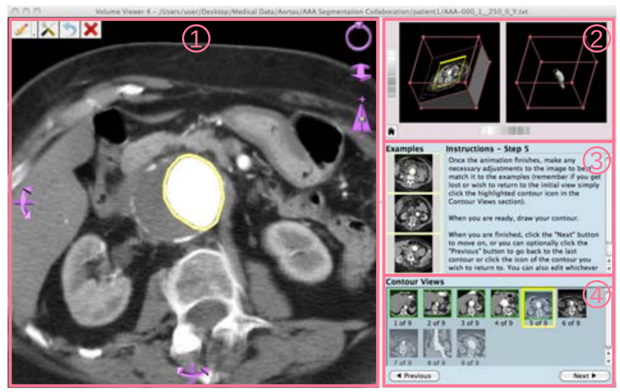

Figure 1: *VolumeViewer Interface: 1) Where the majority of interaction takes place; shows the current data slice and provides in screen navigation and drawing tools. 2) Rotatable views provide 3D localization within the volume and shows drawn contours and the resulting segmentation. 3) Provides text instructions and example images of contours for the current step. 4) Visualizes the contouring protocol navigation path as clickable icons.*

We designed a simple interface around the contouring protocol, shown in Figure 1, that provides intuitive visualizations of the 3D data and localization within the volume, the drawn contours and resulting segmentation, and the protocol navigation path. We expose all functionality visually through in screen elements rather than menus, and we maintain maximum context so the user is always clear as to where they are what they are suppose to do.

We performed a user study with 20 novice participants on three data sets (human liver, human aorta, and ferret brain), and demonstrated that the interface was understandable and usable and that the results were comparable to expert segmentations and inter-user consistent.

Funded in part by NSF grants DEB 1053554 and IIS 1302142.

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SIGGRAPH 2014, August 10 – 14, 2014, Vancouver, British Columbia, Canada.

ACM 978-1-4503-2958-3/14/08