Medical Image Segmentation in the 3D Slicer

Lauren O'Donnell

Artificial Intelligence Laboratory
Massachusetts Institue Of Technology
Cambridge, Massachusetts 02139

http://www.ai.mit.edu

The Problem: The objective of the work is to integrate semi-automatic medical image segmentation methods into the 3D Slicer. The 3D Slicer is a software tool used for surgical planning, surgical navigation, and segmentation and registration of medical imagery. It is developed in a collaboration between the MIT AI Lab and the Surgical Planning Lab at Brigham and Women's Hospital.

Motivation: The purpose of image segmentation is to identify anatomical regions of interest for volume measurement, shape measurement, or creation of three-dimensional models. Manual medical image segmentation (tracing around anatomical structures on each slice of a medical dataset) is a tedious chore undertaken daily by many at the Surgical Planning Lab.

There exist many automatic and semi-automatic algorithms to perform segmentation, but they have not been brought to end users at the lab. This is an opportunity to investigate existing algorithms and implement and refine them for our setting. Modern segmentation algorithms include curve and surface evolution methods, such as snakes [2] and level sets [1], which evolve by minimizing an energy functional that takes into account image features such as gradients. Unlike snakes, level set methods can handle arbitrary changes in topology since a level set is a slice through a higher-dimensional surface. Another segmentation aid known as livewire [3] speeds manual tracing by seeking good contours between points clicked on by the user.

Approach: This effort will initially focus on the integration of several algorithms into the Slicer. Currently underway is the adaptation of Revolver [2], a fast level set method by Alan Tannenbaum, to our system. Additional possibilities include the incorporation of an active tracing aid, similar to livewire, and another different segmentation approach, perhaps a multiscale segmenter. Another goal is to improve the user interface to make image segmentation more intuitive. After the implementation, experiments will be run with the help of users of the software, in order to determine which method or combination of methods is the most effective, accurate, and/or rapid.

Difficulty: A significant engineering effort will be required, as well as an exploration of current work in the field. The testing of the algorithms will require some creativity to design a standard user interface across methods and quantify users' performance for comparison. This comparison should take into account the difficulty of performing the segmentation (perhaps based on time taken, mouse clicks, and/or user impressions) as well as its accuracy (ideally relative to a gold standard).

Impact: The potential impact for end users of the Slicer software is large. For example, research assistants at the Surgical Planning Lab routinely segment the cortex of the brain, a strong boundary that should be relatively easy to find automatically. So any new segmentation tool should provide a time savings if its output takes less time to correct than the time formerly required to do a manual segmentation.

It is hoped that the advantage will be even greater, that the synthesis of multiple techniques will provide practical advantages for users. For example, perhaps the cortex can be segmented with an automatic algorithm with minor corrections afterward, and then the smaller structures in the brain can be segmented semi-automatically using a tool that is under greater user control. In addition to the time savings, a more automated segmentation pipeline should help researchers by allowing higher throughput and better standardization across operators.

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References:

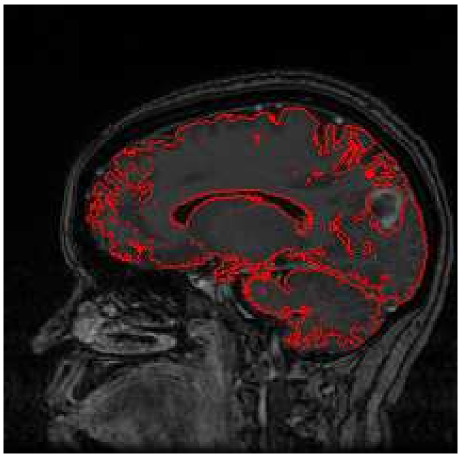

Figure 1: Example output of the Revolver automatic segmentation algorithm.

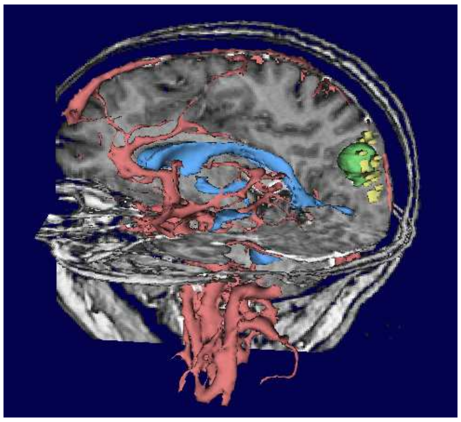

Figure 2: 3D Models made in the 3D Slicer from segmented medical images.

[1] V. Caselles, R. Kimmel, G. Sapiro, C. Sbert Minimal Surfaces: A Three Dimensional Segmentation Approach. Technion EE Pub 973, June 1995

[2] S. Kichenassamy, A. Kumar, P. Olver, A. Tannenbaum, and Y. Yezzi Conformal curvature flows: from phase transitions to active vision. *Archive for Rational Mechanics*, 134, 1996.

[3] J. Liang, . McInerney, D. Terzopolos Interactive Medical Image Segmentation with United Snakes *Medical Image Computing and Computer-Assisted Intervention - MICCAI'99*, 116, 1999.