Dynamic management of segmented structures in 3D Slicer

Csaba Pinter, Andras Lasso, Gabor Fichtinger
Laboratory for Percutaneous Surgery, School of Computing, Queen's University, Kingston, ON, Canada

Introduction: Image segmentation, i.e. delineation of anatomical structures of interest in images is a common operation in medical image computing. One of the many applications is in radiation therapy, where a segmented set of structures is used to determine the delivered dose to the target and the organs at risk in order to evaluate treatment plans. These segmented structures can be stored in various representations (Fig. 1), each optimal for a certain purpose. Planar contours come naturally for contouring on CT slices and are simple to store, closed surface models are optimal for 3D visualization, binary volumetric images (labelmaps) are the input format for most processing algorithms, and ribbon models are a quick way to visualize planar contours in 3D. Many other representations exist, such as fractional labelmaps, parametric functions, etc. Conversion between these representations is needed in nearly every case, however, it is a complex operation: (a) the structures (segments) that belong together must be converted together to preserve coherence, (b) when a segment representation changes, the others must follow so that no outdated data is used, and (c) relationships between the converted objects need to be preserved to be able to determine their origin and identity. The described method aims to address the above problems, and many more issues arising in the topics of visualization, transformation, and persistent and in-memory storage.

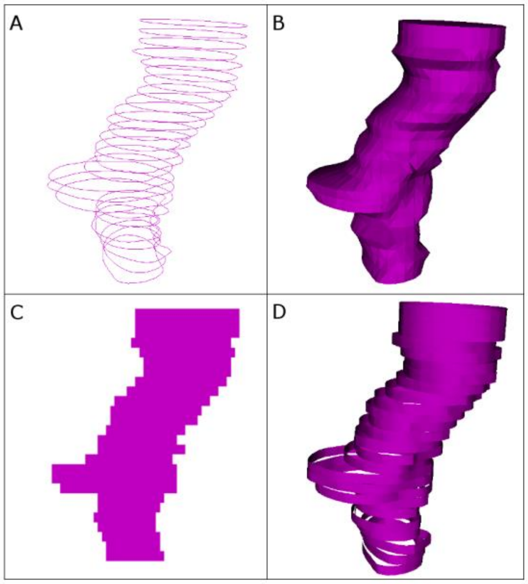

Fig. 1: Different representations of the same brain stem structure. A: Planar contours, B: Closed surface, C: Binary labelmap, D: Ribbon model

Methods: We propose a software infrastructure for dynamic management of segmentation results and conveniently perform conversions between representations. A storage object contains and manages segments and conversion parameters. It defines a *master* representation type that contains the spatial information in a lossless way as it was created: (a) all conversions use it as source, (b) when changed all other representations are invalidated, and (c) it is the representation that is saved to disk. Each segment contains all available representations. Representation types can be defined by registering conversion algorithms (rules) that specify their source and target representations, and an estimated cost metric. These converter rules constitute the edges of a conversion graph, where the nodes are the available representation types. This graph offers a dynamic way to define new representations and new converters. Conversions are automatically performed if a representation is requested that does not yet exist. The automatic conversion uses the cheapest path in the graph between the master representation and the requested one, calculated by summing the cost metrics for each rule. The user can override the default conversion parameters from the user interface.

Results: The Segmentations infrastructure has been implemented as a C++ module and library in the SlicerRT [1] (http://slicerrt.org) extension for the 3D Slicer medical image visualization and analysis platform [2]. The implementation contains an easy-to-use user interface for handling segments and representations, a base library with the objects and logic explained in methods including default conversion rules between the four basic representations, display managers allowing simultaneous visualization of multiple representations, and storage capabilities supporting various modalities in the DICOM standard and research file formats. Advanced features include the ability to apply rigid or deformable transformations on the segmented structure set at once with real-time visualization, efficient memory storage for labelmaps allocating only the effective image extent, custom conversion paths and parameters exposed to the user, and automatic calculation of segment opacity for optimal 3D visualization.

Conclusions: The Segmentations mechanism enables convenient, dynamic, deterministic, and generic management of segmentation results in a user-friendly way that is efficient both in terms of workflow and computational resources.

Acknowledgement: This work was in part funded by Cancer Care Ontario through Applied Cancer Research Unit and Research Chair in Cancer Imaging grants, and the Ontario Consortium for Adaptive Invention in Radiation Oncology.

[1] C. Pinter, et al. "SlicerRT: Radiation therapy research toolkit for 3D Slicer", Med. Phys. 39(10), 6332/7 (2012)

[2] A. Fedorov, et al. "3D Slicer as an image computing platform for the Quantitative Imaging Network." Magnetic resonance imaging 30.9 (2012): 1323-1341.