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3D Slicer as a Tool for Interactive Brain Tumor Segmentation

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Abstract — **User interaction is required for reliable segmentation of brain tumors in clinical practice and in clinical research. By incorporating current research tools, 3D Slicer provides a set of interactive, easy to use tools that can be efficiently used for this purpose. One of the modules of 3D Slicer is an interactive editor tool, which contains a variety of interactive segmentation effects. Use of these effects for fast and reproducible segmentation of a single glioblastoma from magnetic resonance imaging data is demonstrated. The innovation in this work lies not in the algorithm, but in the accessibility of the algorithm because of its integration into a software platform that is practical for research in a clinical setting.**

Introduction

DUE to the large variability in composition and appearance of brain tumors, no current automated tools have been shown to provide robust automatic segmentation of these lesions. Therefore, the state of the art in clinical practice is manual or semi-automated segmentation. Usability by the target audience as a key design requirement for such tools. The segmentation results can be used for quantitative analysis or for generating three-dimensional surface models for image guided neuronavigation.

The quality requirements for the segmentation of brain tumors for image guided neuronavigation use are relatively modest. Typically, the segmentation is used as an anatomical reference and for general orientation. Actual surgical decisions are made after inspection of the surgical site and associated areas on two-dimensional images.

This paper discusses the interactive segmentation environment in 3D Slicer version 3.6.3 [1] and its application for brain tumor segmentation. Since our research incorporates algorithm development and clinical application, we have evolved an informal set of rules to describe the way image analysis software should behave in order to be appropriate for clinical users [2]. These rules are applied as much as possible when components of the interactive segmentation environment of Slicer are developed and added to the platform.

3D SLICER AND THE EDITOR

3D Slicer is an open software platform for the analysis and visualization of biomedical images and for research in image guided therapy. It is an extensible algorithm and application development platform with a powerful plug-in architecture. It is a free, open source package available on multiple operating systems (Windows, MAC, Linux), built on the NA-MIC Kit [3]. Documentation and tutorials for a wide variety of uses are available at the Slicer web site. One of the core modules in Slicer is the Editor [4]. The Editor is a framework for interactive segmentation of volumetric scalar data and contains a variety of tools, called effects. Effects cover a wide variety of capabilities, from painting, polygonal outlining, and thresholding through a variety of connectivity and morphology tools, all the way to a novel competitive region-growing algorithm called GrowCut [5]. The following section discusses an example case where a glioblastoma multiforme is segmented on a T2 weighted image volume.

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EXAMPLE SEGMENTATION

A T2-weighted, so-called baseline, image was extracted from diffusion weighted data using tools available in Slicer. The data used in this example is freely available on the Internet [6]. Fig. 1 shows the use of the GrowCut effect in the Editor for segmentation of a brain tumor into solid and cystic components (two different shades of green). GrowCut is a competitive region-growing algorithm using cellular automata [7]. A rejection class containing the surrounding structures (brown color) was used to help the algorithm to distinguish the target structure from the surrounding areas. The result of this process was a label volume containing three different tissue classes (light green, dark green, brown). The Editor contains an informatics infrastructure, which allows splitting the label volume into separate volumes for each of the labels. Further processing of the brown label was performed by applying a threshold and removing everything but the lateral ventricles. Finally, the individual labels were merged back together and triangulated surface models were created (see Fig. 2).

RESULTS

The workflow described in section III was intended for segmentation of the cystic and solid components of the tumor and ventricles. This type of segmentation can be used to create 3D reconstructions for topographic reference in neuronavigation. The workflow described in section III was repeated five times by one of the authors (RK). The entire procedure for creating the results displayed in Fig. 2 took, on average, two minutes and 21 seconds on a laptop [8]. The standard deviations, as a percentage of the average volumes of each of the three structures, were between 1.2 and 3.2 percent. The results of the repeat segmentations were also quite similar upon visual inspection.

DISCUSSION

3D Slicer provides a powerful, easy to use, image informatics framework for interactive segmentation of brain tumors. The availability of a large number of effects provides a lot of flexibility to address tumor specific issues. The broad availability of interactive segmentation frameworks is particularly important for image-guided therapy in neurosurgery. Time constraints during surgical planning and the large variability of the appearance and location of brain tumors make it difficult to develop and calibrate fully automatic pipelines, as is customary in basic neuroscience research, which is why interactive frameworks and single subject analysis are important in this domain. Equally, validation approaches require adjustment. This paper presents a tool for interactive segmentation which is based on a free open source software platform, the 3D Slicer. One advantage of this particular platform is its simple extensibility. As a matter of fact, two different groups contributed GrowCut and the connectivity algorithms. The short time needed for segmenting the tumor and the repeatability of the results are both important indications for the usability of the package.

The example presented here illustrates one aspect of the complex task of clinical assessment and treatment of brain tumors. Our neurosurgery colleagues have taken the lead in innovative application of these tools in a variety of clinical contexts (see, for example [9] or refer to the Slicer website for a more complete bibliography database). The authors strongly believe that the availability of a large number of algorithms in an open and integrated software package provides for significant analytical power when addressing many clinical image analysis scenarios. Free access to a fully functional image analysis tool provides a basis for development of new techniques that will further increase the efficiency and utility of these tools. Researchers facing tumor segmentation challenges can benefit from these developments to achieve useful results with a reasonable investment of time and effort.

CONCLUSION

3D Slicer provides a powerful, easy to use, image informatics framework for the interactive segmentation of brain tumors.

ACKNOWLEDGMENTS

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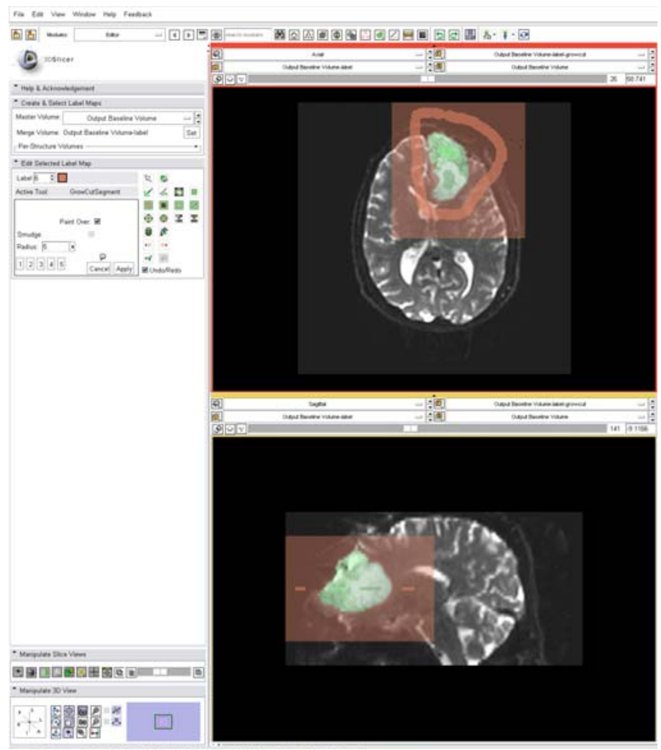

Fig. 1. Partial screenshot of 3D Slicer, demonstrating the use of the "GrowCut" effect for segmentation of the solid and cystic components of a brain tumor. Axial and sagittal cross-sections are displayed. The algorithm was initialized on a single slice, but segmented the entire tumor. Initialization is seen in solid colors; segmentation results are displayed as a semi-transparent overlay on the T2 weighted image. Note that two shades of green were used for the solid and cystic components.

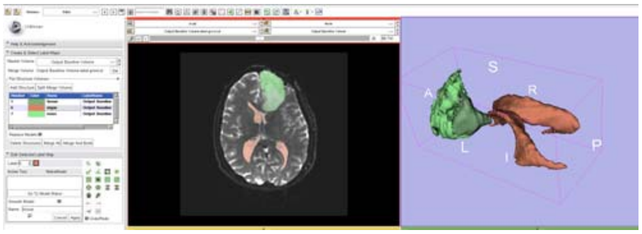

Fig. 2. Partial screenshot of 3D Slicer, demonstrating the use of the “Per Structures Volume” capability to split a multi label volume into each of the constituent volumes. Now it is possible to edit individual labels and then to combine them again. In this example, the rejection class label (brown color) was edited using a combination of thresholding and a 3D connectivity effect called “Save Island”. Subsequently, the three label volumes are combined and triangulated surface models are created for each of the labels. The solid component of the tumor is colored in a light green, the cystic component of the tumor is dark green, the ventricles are brown.