Semi-Automated Segmentation of Brain Tumors
600.446: Computer-Integrated Surgery II
Project Proposal

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Stated Topic and Goal

In this project, we aim to apply theoretical improvements to the watershed transformation to MRI images of glioblastoma patients. This assisted segmentation tool aims to increase accuracy and reduce inter and intra-observer variability present in current segmentation practices. A C++ implementation of this algorithm will be developed within the Insight Toolkit (ITK) library.

Motivation & Significance

The segmentation of brain tumor MRI scans is of critical importance in the evaluation of tumor progression. To evaluate progression of a tumor and the subsequent treatment response, the most commonly used methods to determine treatment responses in brain tumors are the Macdonald criteria and the Response Evaluation Criteria in Solid Tumors (RECIST) criteria. The Macdonald criteria incorporates two-dimensional measurements with steroid dosing and the patients' neurological examinations, while the RECIST criteria evaluates tumor response based on measurement of the longest one-dimensional (1D) diameter. Both these criterions only consider two dimensions, and are ultimately rough estimates of a brain tumor's shape and features.

We aim to promote the use of volumetric analysis in brain tumors, which provides a more accurate quantification of tumor burden. This will allow both neurosurgeons and radiation oncologists to better asses intervention efficacy. We hope to create freely available, easy-to-use software that decreases segmentation time and reduces inter- and intra-observer variability, allowing for rapid determination of tumor volume. With this -robust segmentation tool, clinicians can fully and accurately leverage all information available in an MRI scan.

Technical Summary of Approach

There are no published segmentation methods that have been validated on the full variety of high grade gliomas. To ensure accurate segmentation of even the most difficult gliomas, we have chosen a semi-automated, or user-assisted, segmentation mode. Semi-automated methods include active contouring, intensity thresholding, level-set segmentation, and watershed segmentation. We have chosen to develop an interactive watershed-based segmentation method because it generates significant partitions of an image and relies on the user for high-level interpretation of each of these regions. The algorithm is very fast, and translates to a simple point-and-click interface where what you see is what you get. Additionally, the segmentation is always the same, which we hope will greatly reduce both intra- and inter-operator variability.

Besides reducing variability with the watershed approach, we can also increase the speed of segmentation compared to manual segmentation, since the user no longer needs to trace borders by hand.

Instead, the user is merely choosing regions that they consider to be part of a lesion. We hope to apply recent improvements to the watershed transformation that have not yet been used for medical image segmentation. Additionally, we will evaluate the software's performance (meaning accuracy and variability) on both simulated datasets (where absolute tumor volume is known) and real datasets, using multiple trained observers.

Deliverables

- Minimum
  - Implement a 2D watershed algorithm in ITK
- Expected
  - Implement 2D watershed algorithm in ITK
  - Integrate algorithm into ITK-SNAP
  - Test variability and accuracy of the program
    - Perform segmentations on simulated datasets
- Maximum
  - Implement 3D watershed algorithm in ITK
  - Integrate algorithm into ITK-SNAP
  - Test variability and accuracy of the program
    - Perform segmentations on simulated datasets
    - Investigate inter/intra-observer variability

Management Plan

- Weekly meetings with Dr. Adams: Wednesday 4-6pm

Dependencies

- **Resolved**: Machines capable of compiling VC++ code
- **Resolved**: Visual Studio 2008
- **Resolved**: ITK library – we plan to start here and develop our product in a similar fashion
- **Resolved:** IRB approval for MRI datasets
- **Resolved:** Three Neurosurgical Residents: (Dr. Shaan Raza, Dr. Chetan Bettegowda, Dr. Jose Undabeitia).
- Dr. Hadie Adams and Russell Taylor for feedback and guidance
- Dr. Alfredo-Quiñones-Hinojosa for lab space and support

Reading List

1. Kanaly CW, Ding D, Mehta AI, Waller AF, Crocker I, et al. 2011 A Novel Method for Volumetric MRI Response Assessment of Enhancing Brain Tumors. PLoS ONE 6(1): e16031. doi:10.1371/journal.pone.0016031
2. Marloes M.J. Letteboer, Ole F. Olsen, Erik B. Dam, Peter W.A. Willems, Max A. Viergever, Wiro J. Niessen, Segmentation of Tumors in Magnetic Resonance Brain Images Using an Interactive Multiscale Watershed Algorithm, Academic Radiology, Volume 11, Issue 10, October 2004, Pages 1125-1138, ISSN 1076-6332, DOI: 10.1016/j.acra.2004.05.020.
3. Cates, J.E., Whitaker, R.T. & Jones, G.M. Case study: an evaluation of user-assisted hierarchical watershed segmentation. Medical Image Analysis 9, 566-578 (2005).
4. Fiez, J. A., H. Damasio, et al. (2000). "Lesion segmentation and manual warping to a reference brain: Intra- and interobserver reliability." Human Brain Mapping **9**(4): 192-211.

5. Mazzara, G.P., Velthuizen, R.P., Pearlman, J.L., Greenberg, H.M. & Wagner, H. Brain tumor target volume determination for radiation treatment planning through automated MRI segmentation. International Journal of Radiation Oncology*Biology*Physics 59, 300-312 (2004).
6. Renz, D., et al. Accuracy and reproducibility of a novel semi-automatic segmentation technique for MR volumetry of the pituitary gland. Neuroradiology, 1-12 (2010).
7. Marcel Prastawa, Elizabeth Bullitt, Guido Gerig, Simulation of brain tumors in MR images for evaluation of segmentation efficacy, Medical Image Analysis, Volume 13, Issue 2, Includes Special Section on Functional Imaging and Modelling of the Heart, April 2009, Pages 297-311, ISSN 1361-8415, DOI: 10.1016/j.media.2008.11.002.

Timeline

Task	10-Feb	17-Feb	24-Feb	3-Mar	10-Mar	17-Mar	24-Mar	31-Mar	7-Apr	14-Apr	21-Apr	28-Apr
Minimum (Software Implementation)												
Project Proposal and Presentation												
Investigation of Segmentation Techniques												
Investigation of Libraries and Existing Framework												
Implementation of Watershed in Framework												
Nathaniel - Implement WatershedImageToGraphFunctor												
Alex - Implement WatershedGraphTraits												
Nathaniel - Implement WatershedCutGraphFilter												
Alex - Implement WatershedCutImageFilter												
Code Validation, Testing, and Debugging												
Checkpoint 1 - Demonstration of new Watershed vs. Old ITK Watershed												
Expected (Integration into ITK-SNAP, variability assessment)												
Integration into ITK-SNAP												
Segmentation of Simulated Phantoms												
Checkpoint 2 - ITK-SNAP Build Demonstration												
Maximum (Testing)												
Segmentation with Different Observers												
Investigation of Intra/Inter Observer Variability												