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

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         Hadie Adams, M.D.

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 assess 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**


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<th>Timeline</th>
<th>Task</th>
<th>10-Feb</th>
<th>17-Feb</th>
<th>24-Feb</th>
<th>3-Mar</th>
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