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Semi-automatic Segmentation of MRI

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BACKGROUND

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Motivation

- Glioblastoma Multiforme (GBM)
  - Most common primary brain tumor
  - Median survival of 14 months
  - Diffuse, invasive, heterogeneous/non-enhancing profile
- Treatment dampens tumor enhancement

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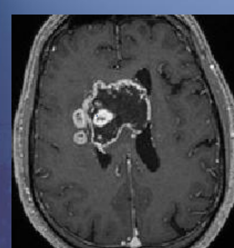

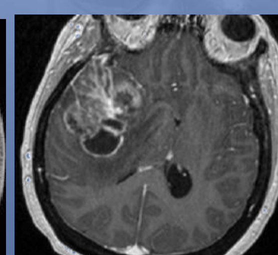

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The Problem

- Manual Segmentation
  - Slow = EXPENSIVE
  - Inter- and intra-observer variability [1]
- Current surgical outcomes studies contradictory [2-5]
  - Results only trend towards significance (even for N > 500)

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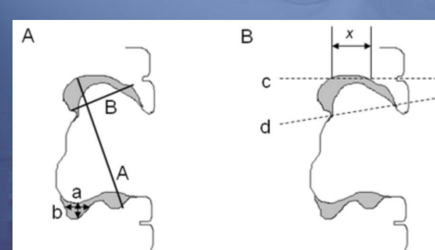
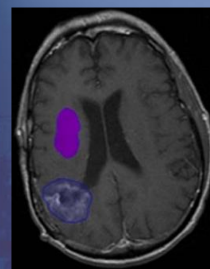
Current Failures

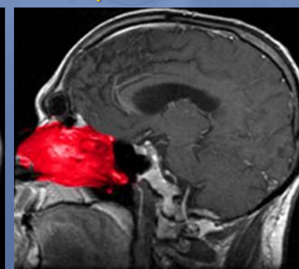


How does this help?

- Immediate benefit - surgical outcomes study
  - Current studies expensive, contradictory, and inconclusive [2]
- Future Benefits
  - Volumetric progression tracking [3]
    - prospective randomized trial for progression prediction – the ultimate test of efficacy
  - Improved radiotherapy targeting and evaluation [4]
  - Adaptable to similar segmentation problems!

Current Developments





Current Developments

interest, and a set 40% threshold of either the source-to-background (S/B) ratio or of the maximum standardized uptake value (SUV) are commonly advocated techniques.[34,35] Our results show a high degree of correlation between different threshold levels however, which supports the validity of this technique but also suggests that the specific threshold level chosen is not critical as long as the same level is used consistently.

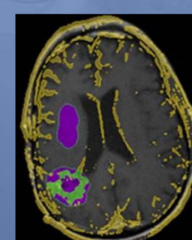
Despite these advantages, our novel volumetric approach is based on the measurement of tissue enhancement, and therefore will not accurately quantify tumor burden if there is a significant amount of non-enhancing tumor. Even in enhancing tumors, there has recently been increasing use of anti-angiogenic agents such as bevacizumab that normalize vasculature and decrease enhancement leading to potential over-interpretations.[36,37,38] Other

References

1. Jaffe CC (2006) Measures of response: RECIST, WHO, and new alternatives. J Clin Oncol 24: 3245–3251.

Current Developments

- Intensity thresholding (2011)
  - Cannot account for treatment effect
  - Relies on user-defined boundaries
  - Fails for non-enhancing tumors
  - Commercial affiliation



Inspiration: Interactive Watershed Transform

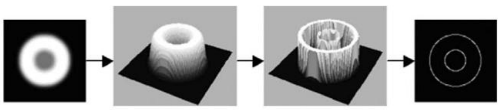
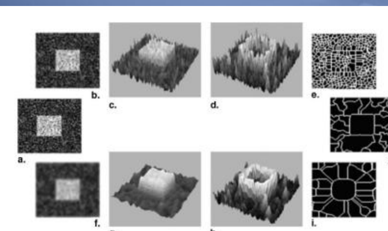


Figure 2. Watershed segmentation of a 2D volcano image **(a,b)**. For a correct segmentation, watersheds have to be created where the gray value changes most, so the watershed principle has to be applied to the gradient image **(c,d)**.

Inspiration: Interactive Watershed Transform



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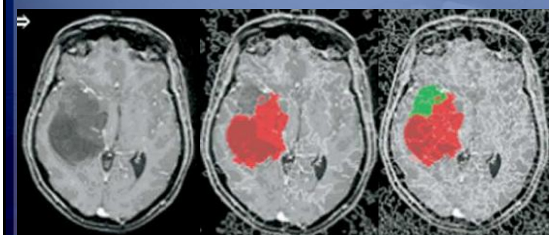
Inspiration: Interactive Watershed Transform



Inspiration: Interactive Watershed Transform

- Interactive Watershed – 2004
  - Reduces variability and increases speed
  - Operator determines tissue interpretation!!!
- Issues
  - Conservative segmentation of diffuse structures

SPECIFIC AIMS

Goals

- Implement a novel semi-automated method for brain MRI segmentation
- Stress-test algorithm on database of patient scans (N > 300)
  - Inter- and intra-observer variability study
  - Segmentation speed
  - Segmentation quality on wide variety of tumors
  - Segmentation volume comparison to phantom-generated ground truths

Deliverables

- C++ Code developed within Insight Toolkit (ITK)
  - Free, cross-platform, open source framework
  - Already used by most image analysis software packages
- Evaluation results of database study

TECHNICAL APPROACH

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Watershed Transform - Developments

- Select theoretical developments
  - B Marcotegui: Fast Implementation of Watershed Based on Graphs – 2005
  - C Vachier: The Viscous Watershed Transform – 2005
  - F Meyer: On the regularization of the Watershed Transform - 2007
  - C Jean: Watershed Cuts: Minimum Spanning Forests and the Drop of Water Principle - 2009
- Novel Representations of MRI as a Graph
  - Z Song: Integrated Graph Cuts for Brain Tissue Segmentation

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Implementation

- Point-to-click user interface
  - Minimal training; adaptable to touch interfaces
- ITK-Snap application framework
  - Succesfully compiled
  - Simple user interface
  - ITK integration

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PLAN

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Management Plan

- Regular weekly meetings with Dr. Hadie Adams for general supervision and support
- Project management with Dr. Russell Taylor
- Meetings as needed with Dr. Alfredo Quiñones-Hinojosa for consultation on software features and (retrospective) patient database access
- No hardware or budget requirements

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Dependencies

- Hardware
  - Machines capable of compiling VC++ code
- Software
  - Visual Studio 2008
  - ITK library –Already obtained and compiled. Source is freely available at itk.org.
- People
  - Dr. Hadie Adams and Russell Taylor for feedback and guidance
  - Dr. Alfredo-Quiñones-Hinojosa for retrospective database of sample images

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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												
Code Validation, Testing, and Debugging												
Expected (Accuracy and Variability Assessment)												
Segmentation of Phantoms												
Segmentation with Different Observers												
Segmentation with Public Real Datasets												
Segmentation of Actual Patient Datasets												
Segmentation of Large Dataset of Various Gliomas												

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Acknowledgements

Alfredo Quiñones-Hinojosa, M.D.
Hadie Adams, M.D.

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Brain Tumor Imaging Lab