Overview

Motivation
Software for Processing Images
Automatic Segmentation
Measuring Tumor Growth
Conclusion
Neuroscience Studies
Multiple Sclerosis Lesion
Finding Differences

Across Subjects

Within Subjects

courtesy of Istvan Csapo
Manual vs. Automatic

Manual Segmentation:
- Very expensive
- High risks related to observer reliability

Automatic segmentation:
- Relatively cheap
- Quality is often lower than manual segmentations
Goal

Develop tools for processing medical images:
- fast and flexible
- requiring minimal amount of training effort
- include prior information
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What is 3D Slicer?

• A platform for exploring novel image analysis and visualization techniques

• A freely-downloadable code and executables available for Windows, Linux, and Mac OS X

• Slicer is a research platform:
  – NOT FDA approved
  – NOT finished (work in progress)
• www.slicer.org
• Over 500k lines of code
• 32 active developer
• Tutorial:
  Google: slicer 101

Image provided by A. Golby, F. Talos, P. Black
Slicer Features

- Visualization
- Filtering
- Registration
- Segmentation
- DTI
- Quantification
- Real-time Integration
Algorithms: DTI

- Automatic extraction of anatomically meaningful fiber bundles
- Advanced Rendering methods for segmentation results using photon mapping

Rendering provided by Banks, Data by Odonnell, Shenton, Westin, et al.
• Active visualization of medical images to aid in decision making.

• Allows physician to
  – See Beyond the Surface
  – Define Targets
  – Control the Interventions

• Enables new procedures, decreases invasiveness, optimizes resection

U Iowa Meshing Project

- VTK/KWWWidgets based Mesh Quality Viewer (Lisle)
- Migration of Stand Alone Meshing Tool into Slicer Module (Lisle)
- Key Driver for 3D Widgets in Slicer3
Many More Examples
NA-MIC Kit Components

• End User Application
  – 3D Slicer

• Image Analysis, Visualization, and GUI libraries
  – ITK, VTK, KWWidgets

• Large Scale Data Processing Tools
  – Batchmake, BIRN GRID tools

• Software Engineering Tools
  – CMake, Dart, CTest, CPack

http://www.na-mic.org/Wiki/index.php/SoftwareInventory
Acknowledgments
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Tissue Classification

Software:
- EM
  Wells 96
- EMS
  Van Leemput 99
- SPM
  Ashburner 03
- MNI
  Zijdenbos 02
- FSL
  Zhang 01
Cortical + Subcortical Parcellation

Software:
- ANIMAL
  Collins 99
- EM-MF-LP
  Pohl 02
- Freesurfer
  Fischl 02
- BrainSuite
  Thompson 04
- FANTASM
  Tosun 04
Mission

- MRI
- Atlas
- Tool
- Label Map
Hierarchical Tree

Find Cranial Cavity: BG ICC
Find Tissue: CSF GM WM
Design of Algorithm

Image → BG → ICC → CSF, GM, WM → Segment

INFO

Kilian M. Pohl Slicer 3
Level 1

Prior Information

IMAGE

BG

ICC

CSF

GM

WM

Input
Level 2

Current Parameter

IMAGE

ICC

CSF  GM  WM

Input

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Slicer 3
Modify the Tree

Find Cranial Cavity: 
BG  ICC

Find Tissue: 
CSF  GM  WM

Find Substructures: Subcortex  Cortex
Segmentation of 31 Structures

Pohl et al., ISBI 04
Download: www.slicer.org
EM Segment Workflow

Specify Inputs
- Parameters
- Target Images
- Atlas Images

Default Pre-Processing
- Target Image
- Normalization
- Target-to-target Registration
- Atlas-to-target Registration

courtesy of Brad Davis
EM Segment Workflow

Specify Inputs
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Segmentation
- EM Segment Algorithm: Pohl et al.

courtesy of Brad Davis
EM Segment Workflow

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Segmentation
- EM Segment Algorithm: Pohl et al.

Review Results
- Slicer3 Slice Views
- Slicer3 Model Maker
- External Program

courtesy of Brad Davis
Dissemination

- Integration into Slicer 3

- Grid Computing

- Tutorial

NA-MIC
National Alliance for Medical Image Computing
[Link to website](http://na-mic.org)
Lesion Detection

Progression of Multiple Sclerosis lesions
courtesy of Istvan Csapo
Non-Human Primates

Measuring Alcohol and Stress Interactions with Structural and Perfusion MRI
courtesy of Chris Wyatt
CT Hand Bone Segmentation

Developing patient-specific kinematic models
courtesy of Austin Ramme and Vince Magnotta
Segmentation of Microscopy Images

courtesy of Brad Davis

Detecting patterns in biology
Publications


Papers are accessible through www.csail.mit.edu/~pohl
Alternative Prior Model

Simultaneous Registration and Segmentation


Shape Based Segmentation


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Monitor evolution of meningioma through periodic MR scanning of patient
The Problem

1\textsuperscript{st} Scan

2\textsuperscript{nd} Scan

Has this tumor changed? Bigger? Smaller?
Accuracy of Manual Inspection

<table>
<thead>
<tr>
<th></th>
<th>1% (10mm³)</th>
<th>5% (48mm³)</th>
<th>22% (195mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>real MRI</td>
<td>0/5</td>
<td>1/5</td>
<td>5/5</td>
</tr>
<tr>
<td>Expert</td>
<td>0/5</td>
<td>1/5</td>
<td>5/5</td>
</tr>
</tbody>
</table>

Konukoglu et al., “Monitoring Slowly Evolving Tumors”, ISBI 08
Infer change from largest diameter

\[ D_1 \gg D_2 \text{ or } D_1 \ll D_2 \]
Manually Determine Volume

1\textsuperscript{st} Scan

2\textsuperscript{nd} Scan

Infer Change from Largest Volume

\[ V_1 \gg V_2 \text{ or } V_1 \ll V_2 \]
Intra-Rater Reliability

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Scan 1

Scan 2

<table>
<thead>
<tr>
<th>First</th>
<th>Second</th>
<th>Third</th>
</tr>
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<tbody>
<tr>
<td>883.8 mm$^3$</td>
<td>545.8 mm$^3$</td>
<td>–99.8 mm$^3$</td>
</tr>
</tbody>
</table>

Konukoglu et al., “Monitoring Slowly Evolving Tumors”, ISBI 08
Inconsistency Between Scans

1st Scan

2nd Scan

- Changes in Head Position
- Artifacts through Image Acquisition
Mission

Scan 1 → Tool → Growth

- semi-automatic quantitative measures derived from MRI
- compatibility with clinical requirements
The implementation is based on a workflow approach

**Step 1:** Select scans
**Step 2:** Define tumor region
**Step 3:** Segment tumor
**Step 4:** Chose tumor metric

Automatic change detection is completed in less than 5 minutes
Step 1: Select Scans

Control Window

Viewers

Navigation Panel
Step 2: Define ROI in Scan 1

Simple mouse click around the tumor defines region
Step 3: Zoom into ROI

Grid shows original voxel size
Step 3: Outline Tumor

State of the art semi-automatic segmenter is calibrated by slider.
Step 3: Outline Tumor

Move slider until tumor is correctly identified
Step 4: Select Metric

Choice of Metric:
• Detect growth by analyzing intensity pattern (fast)
• Measure growth by analyzing deformation map (slow)
Step 5: Analysis - Registration

Volume Preserving Registration

Before

After
Step 5: Analysis – Normalize Intensities

Scan 1                  Scan 2                  Scan 2 - Norm
Statistical Model of Dormant Tissue

PDF of Dormant Tissue

$I_{x}^{(abs)}$
Step 5: Analysis – Adjust Sensitivity

Analysis

Mode: Aggressive
Growth (mm³): 2239
Growth (voxel): 1819
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Tumor Tracking

Analyze Deformation Map

Compute deformation field using diffeomorphic demons

Mode: Segmentation
Growth (mm³): 764
Growth (voxels): 619

Mode: Jacobian
Growth (mm³): 887
Growth (voxels): 718
Step 5: Analysis – Adjust Sensitivity

- Growth is shown in blue
- Outcome depends on Sensitivity
- Small sensitivity may include noise in growth
Imaging

Developed a protocol that is compatible with clinical work and can be used for image analysis

- Axial 3D SPGR T1 post Gadolinium
- Voxel dimension: 0.94mm x 0.94mm x 1.20mm
- FOV: 240mm Matrix: 256 x 256
- Scan time: 8 mins on 1.5T

IRB approval was not required
Synthetic Experiment

real MRI  1%  5%  22%

- Kilian M. Pohl
- Tumor Tracking
Our training data base consists of
• 8 subjects scanned twice
• 1 subject scanned three times

<table>
<thead>
<tr>
<th>Case</th>
<th>EXPERT</th>
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<th>INTENSITY</th>
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<th>JACOBIAN</th>
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<th>SEGMENT</th>
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<tr>
<td></td>
<td>%</td>
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<td>0.4</td>
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<tr>
<td>8b</td>
<td>-1.9</td>
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<td>1.3</td>
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<td>9</td>
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<td>25.1</td>
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<td>29.7</td>
<td>887</td>
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</tbody>
</table>
Test Database

Our training database consists of:
- 8 subjects scanned twice
- 1 subject scanned three times
Test Database

Our training data base consists of
• 8 subjects scanned twice
• 1 subject scanned three times

Comparison of Expert and Automatic Results

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Tumor Tracking
Dissemination (In Progress)

• Tool will be accessible via www.slicer.org
• Konukoglu et al., “Monitoring Slowly Evolving Tumors”, ISBI 08
• Online-Tutorial
• Hands-on training
  http://www.themeningiomaconference2008.org/
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Summary

• Publicly available software targeted towards medical imaging

• Automatic segmenter adoptable towards wide range of imaging problems

• Oncology tool for tracking tumor growth