NCIGT Computation Core

NIH and NCIGT Joint Workshop on

Clinical Image-Guided Therapy: Opportunities and Needs

March 10-11, 2008

Rockville, Maryland

William (Sandy) Wells

Computation Core

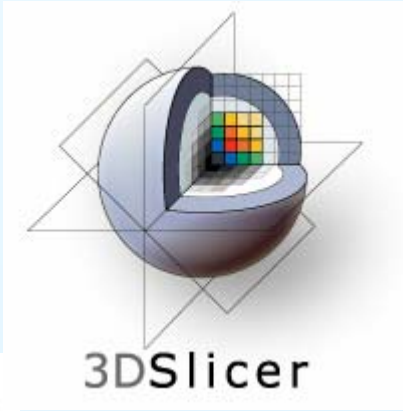
- Slicer Engineering
- High Performance Computation (HPC)
  - Interventional nonrigid registration
- Spatial Neuroinformatics (SNI)
  - fMRI for neurosurgery
- Endoscopic Navigation
- Neurosurgical Image Database

3D Slicer

- **Is Part of: NA-MIC Kit -** *Software* and *Methodologies for Medical Image Computing*
  - NAMIC: an NCBC: National Alliance for Medical Image Computing
  - Facilitate Research
  - Promote Interoperability
- Stable, Cross-Platform Run Time Environment
  - Full set of core features
- Flexible Module Architecture
  - Plug-ins added as needed

Fully Open, Interoperable Components

- End User Application
  - 3D Slicer
- Image Analysis, Visualization, and GUI libraries
  - ITK, VTK, KWWidgets
- Large Scale Data Processing Tools
  - Batchmake, XNAT, BIRN GRID tools
- Software Engineering Tools
  - CMake, Dart, CTest, CPack

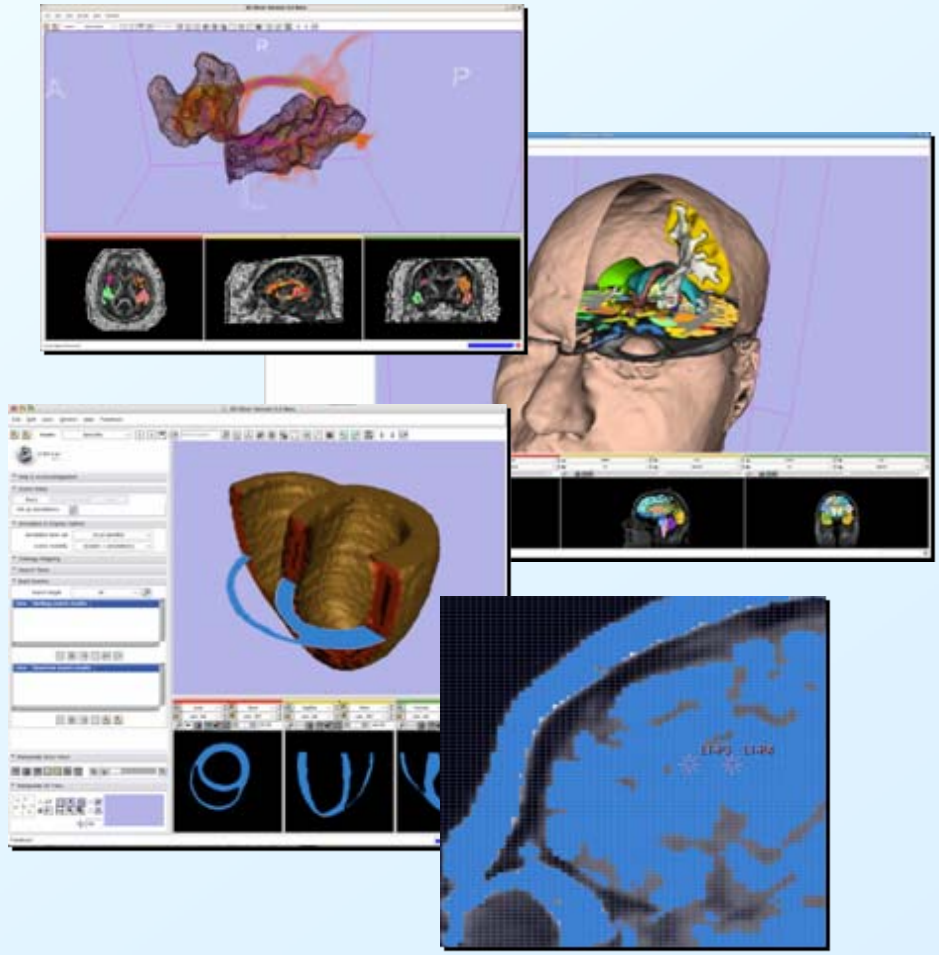


http://www.na-mic.org/Wiki/index.php/SoftwareInventory

Provided by Pieper, Kikinis

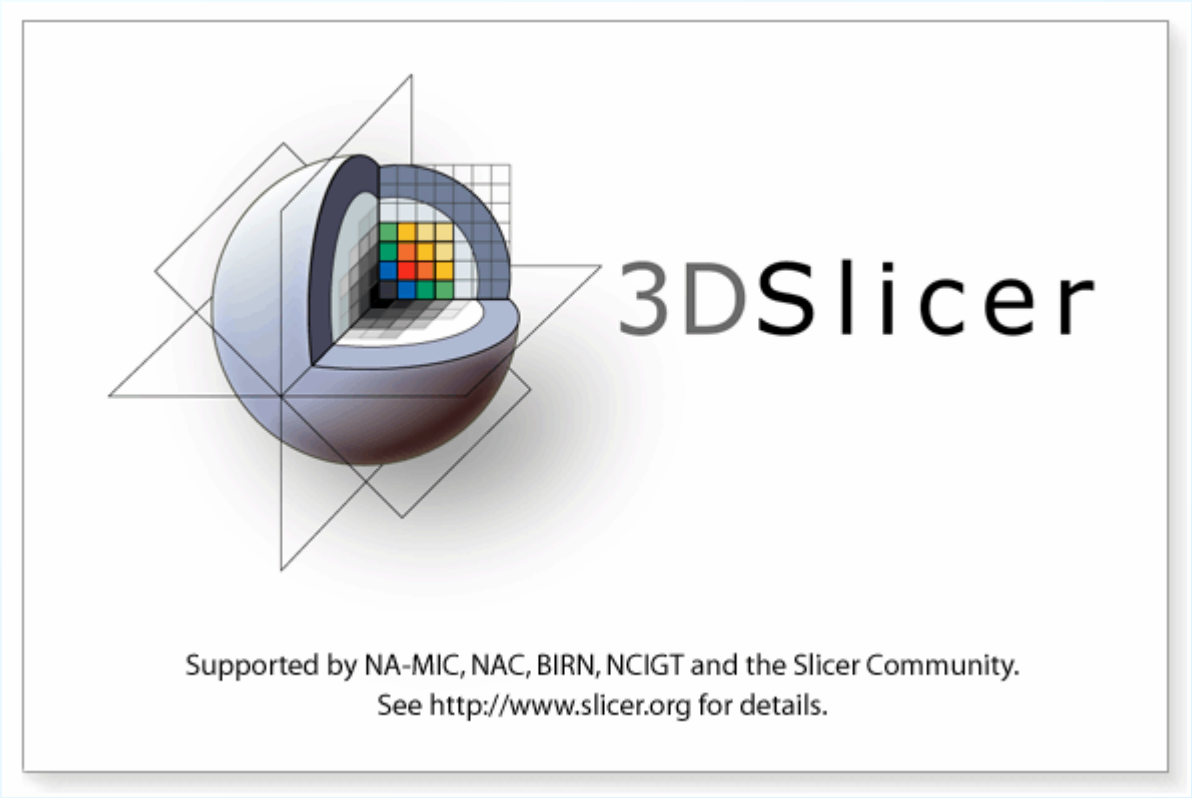
Image/Scene Management

- XML-Based MRML File Stores Scene Description
  - Volumes (Images, Label Maps)
  - Models
  - Hierarchical Affine Transforms
  - Scene Data (Cameras, Colors, Fiducials, etc)
  - Undo/Redo, Scene Snapshots
- Careful Attention to Coordinate Systems
  - Scalar Images
  - Diffusion Images
  - Time Series (fMRI)
  - Visualization

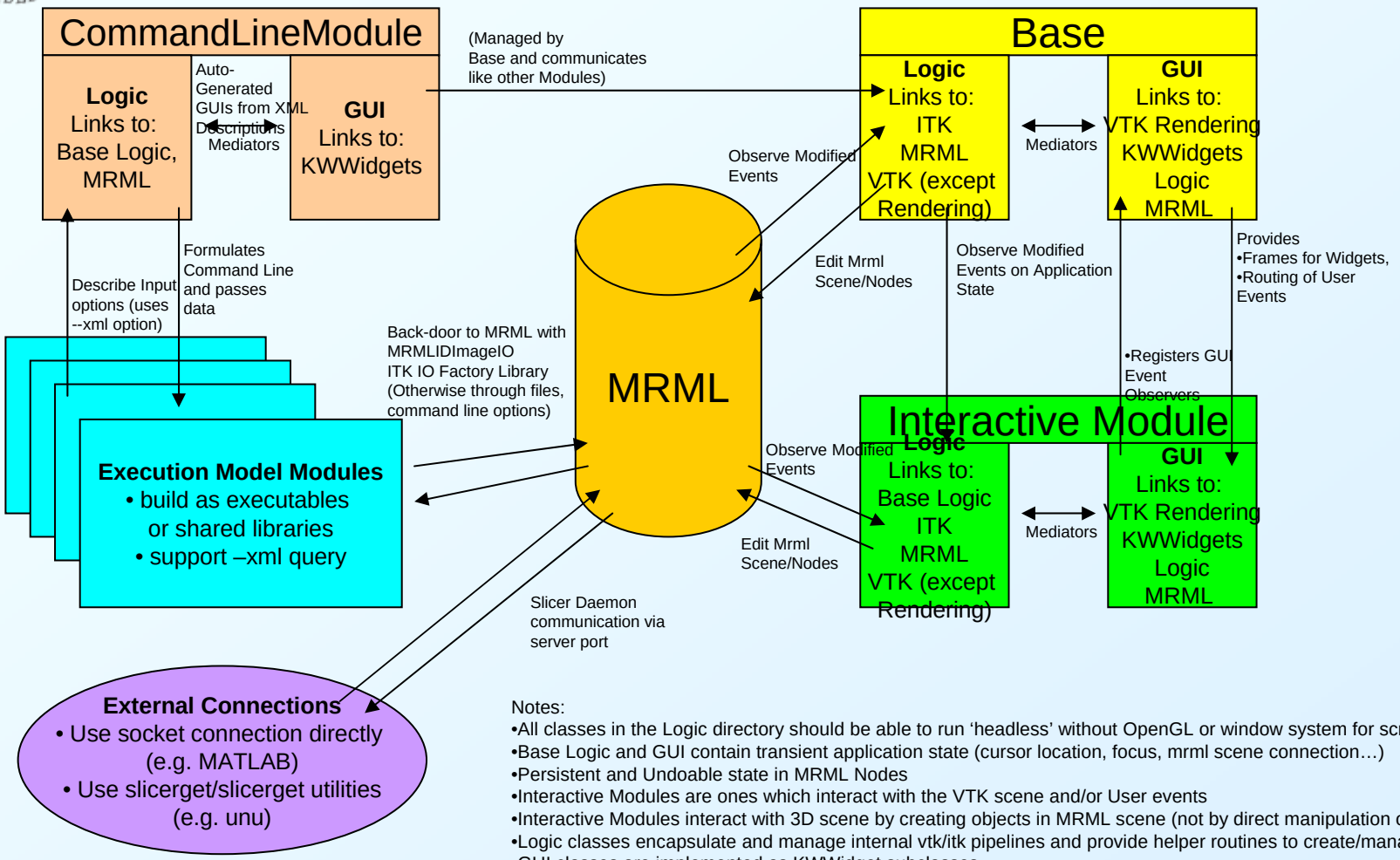


Provided by S. Pieper

Slicer3 Architecture



Slicer 3 Architecture Diagram (updated 2007-01-09)



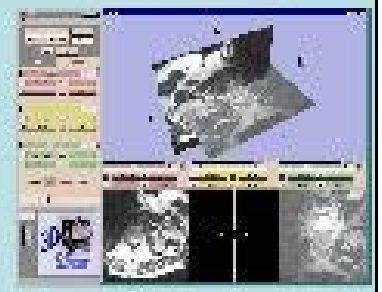
Notes:
- All classes in the Logic directory should be able to run 'headless' without OpenGL or window system for scripting and testing
- Base Logic and GUI contain transient application state (cursor location, focus, mrml scene connection…)
- Persistent and Undoable state in MRML Nodes
- Interactive Modules are ones which interact with the VTK scene and/or User events
- Interactive Modules interact with 3D scene by creating objects in MRML scene (not by direct manipulation of the Renderer)
- Logic classes encapsulate and manage internal vtk/itk pipelines and provide helper routines to create/manage nodes
- GUI classes are implemented as KWWidget subclasses
- Each Logic class defines Get/Set methods for internal state and Modified Events that GUI classes can Observe
- Code in Base implements "first order" Node types (Volumes, Models, Transforms, Fiducials, Colors, etc).
- Code in Modules provides application-specific extensions

NCIGT: Slicer Engineering

- Slicer 2.6
  - Intra op display DTI fMRI
  - GUI for non-rigid registration
  - Open tracker integration
  - IGT modules
    - MRProstate Care
    - Tractography for neurosurgery
    - NeuroNav module
    - 120 clinical applications
- Slicer 3.0: integrate IGSTK

Prostate biopsy with 3D Slicer

Slicer



Planning
Registration
Tool calibration
Scanner control
Guidance

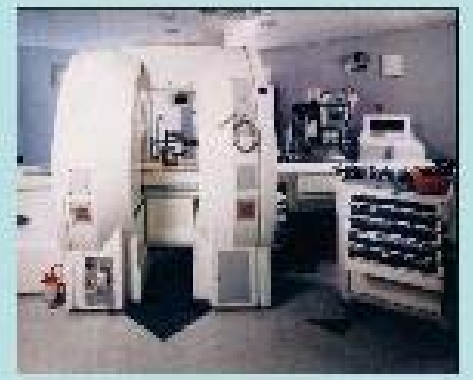
Optimized scan control

Image transfer

Guidance/visualization

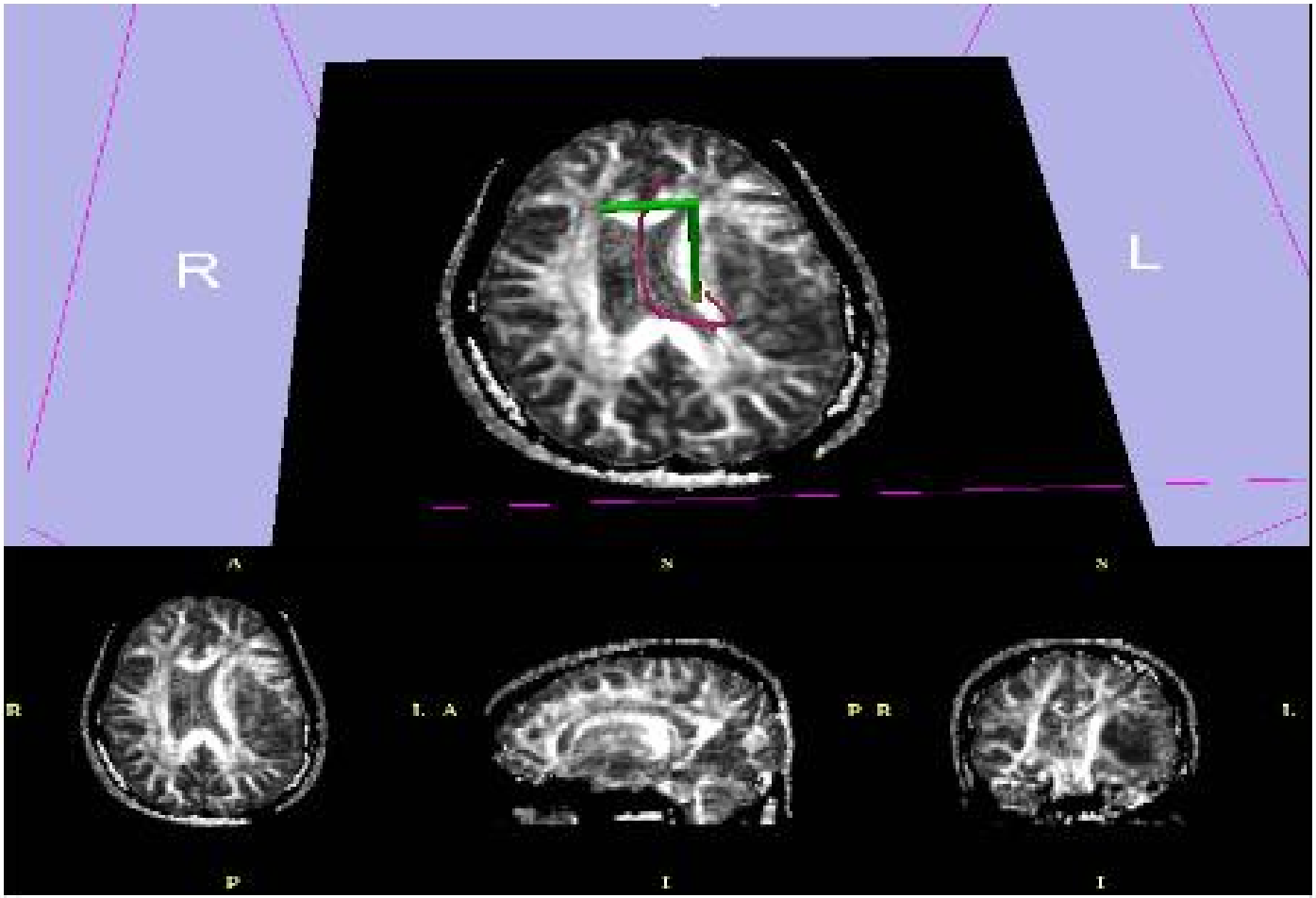
Advanced I/F

Intraop MR

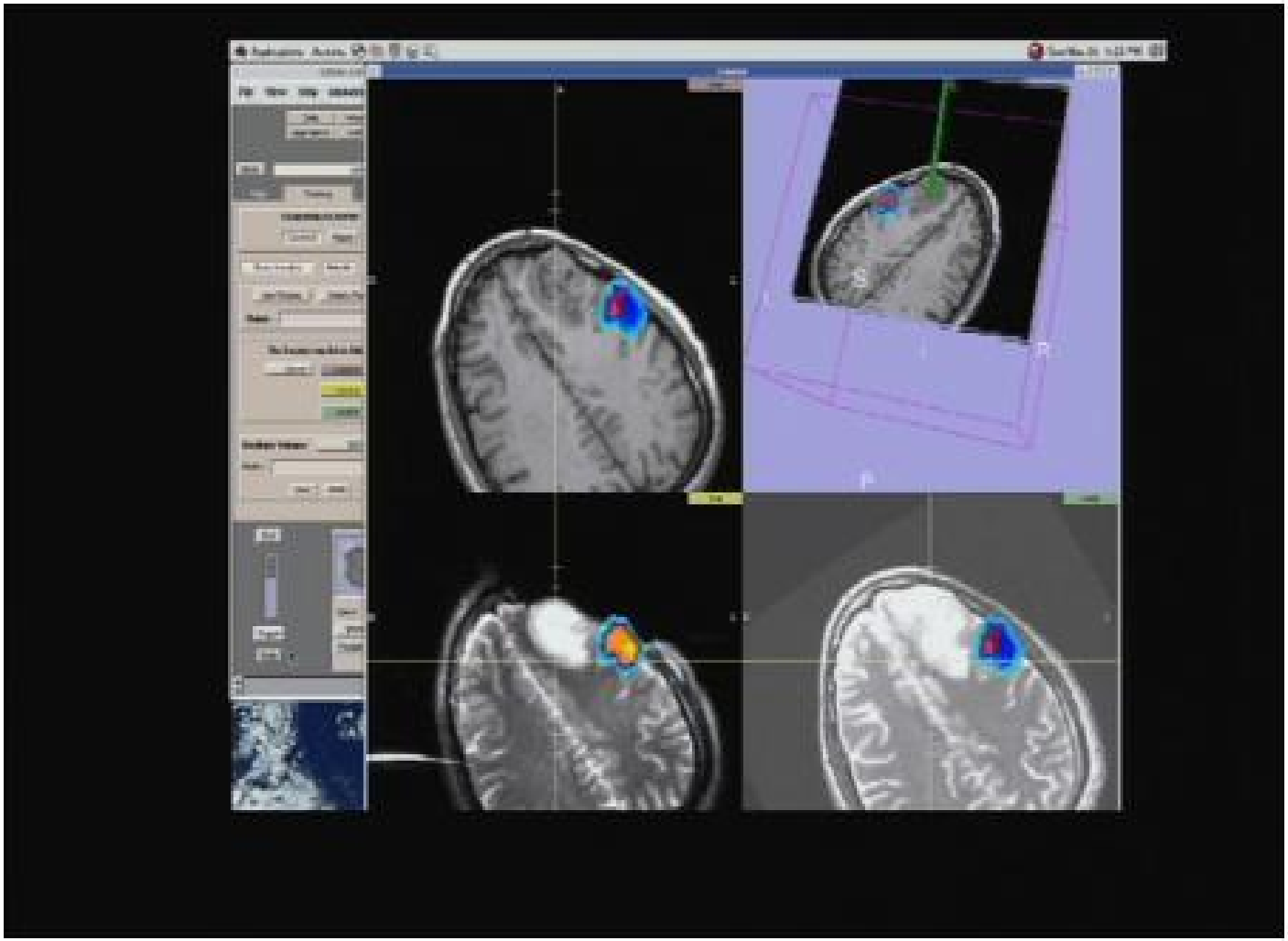


Pre-procedural T2w
Intra-procedural T1w

Tractography within neuro navigation

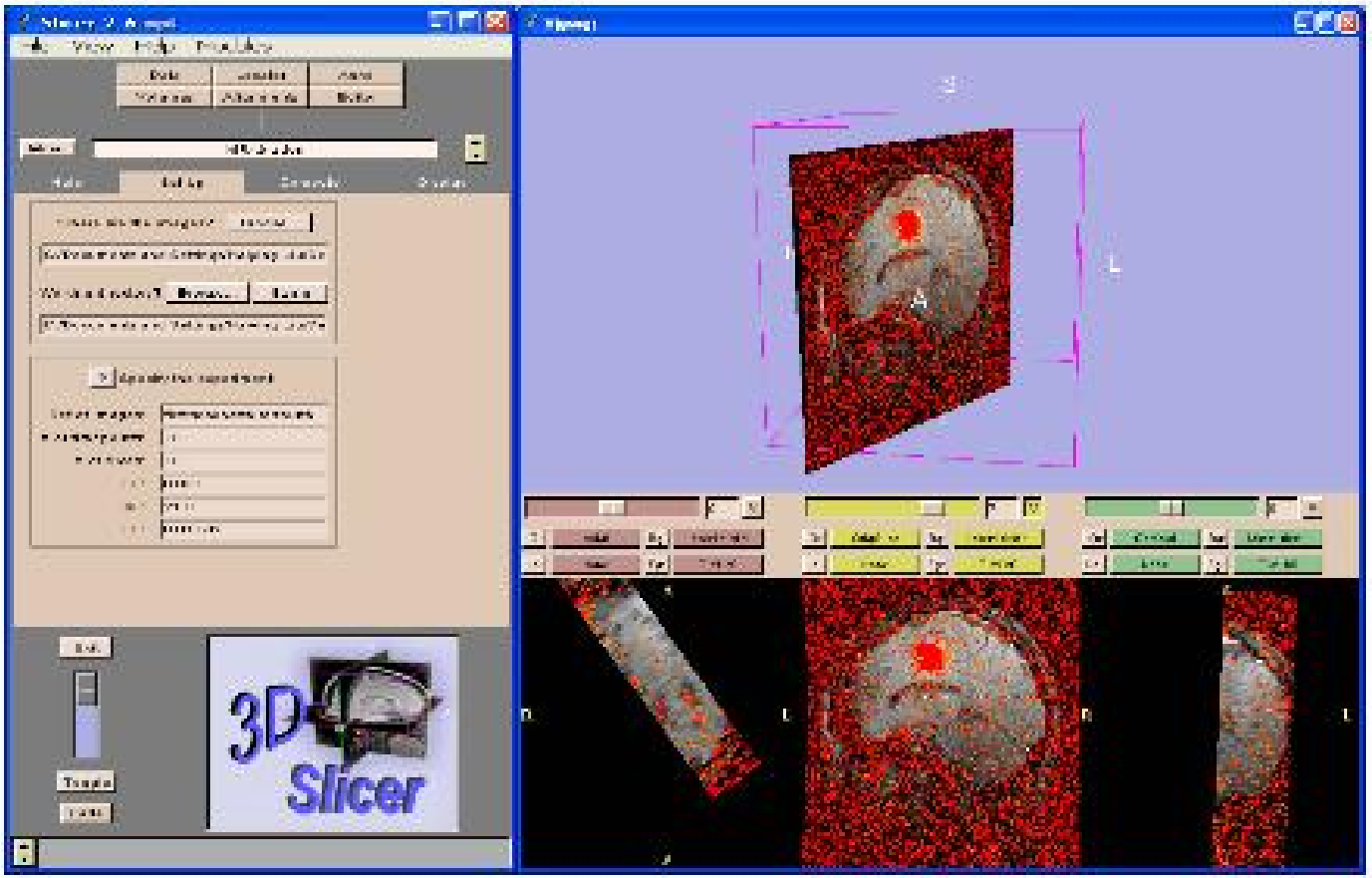


Neurosurgery with 3D Slicer

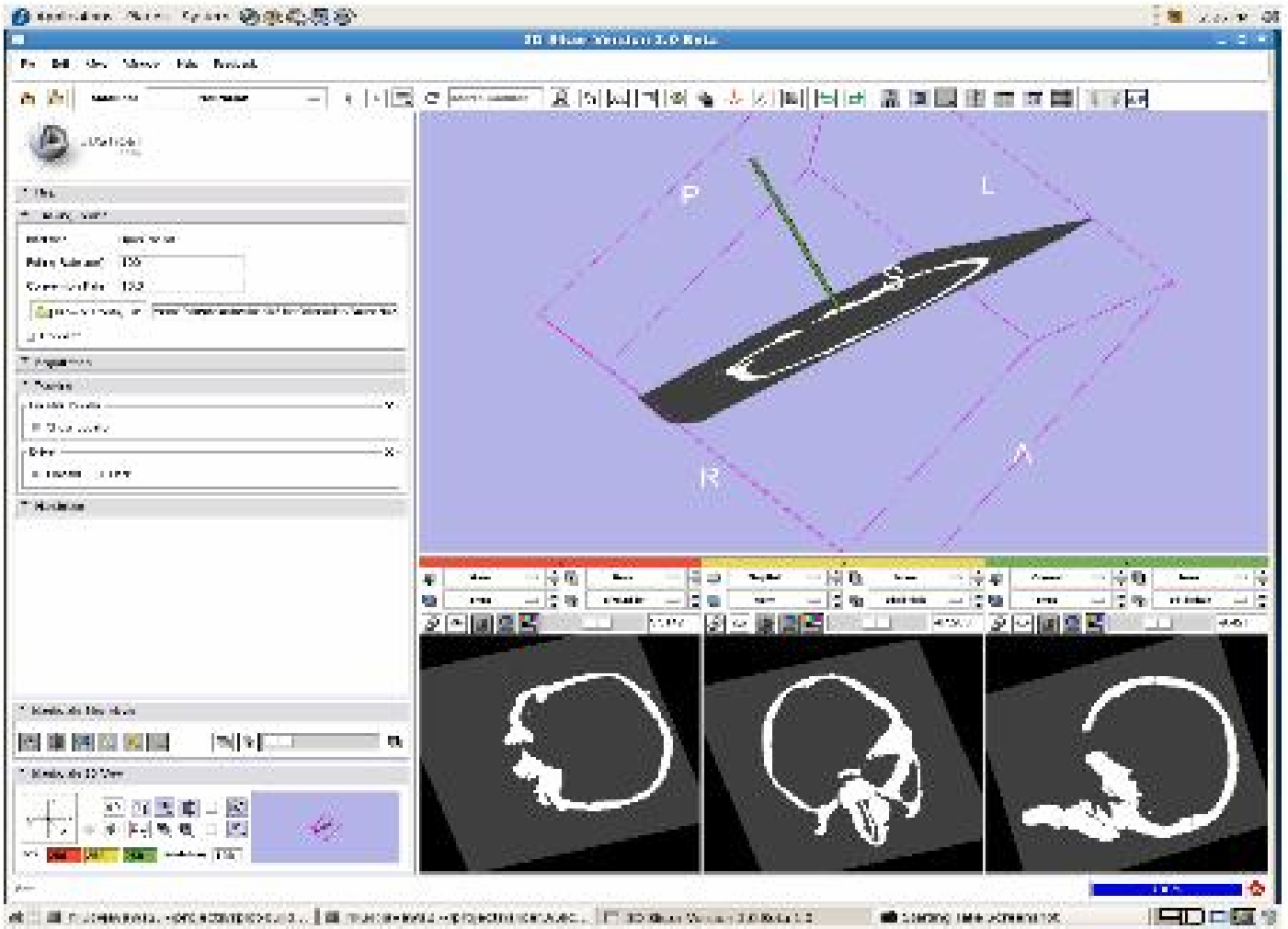


MRProstateCare module in Slicer2.6 for prostate biopsy

MRAblation module in Slicer2.6 for laser ablation



NeuroNav module in Slicer3

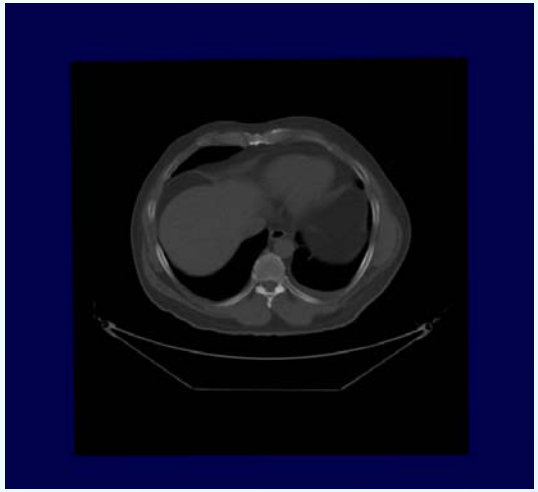


High Performance Computing

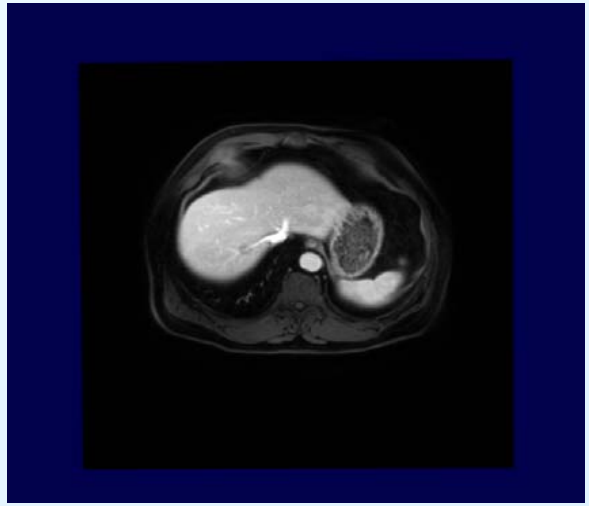
- Grid computing w/ William and Mary's
- block matching, visual feedback to surgeon
- Improved targeting IG ablation

Pre-procedural images: PET/CT and MRI – aligned using non-rigid registration

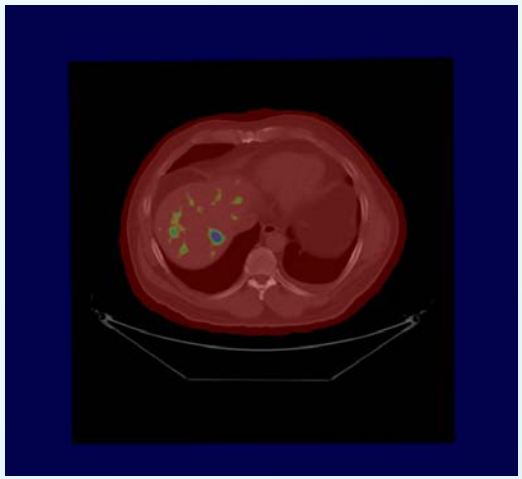
CT of patient with a liver tumor located adjacent to the diaphragm (lesion not visible on CT)



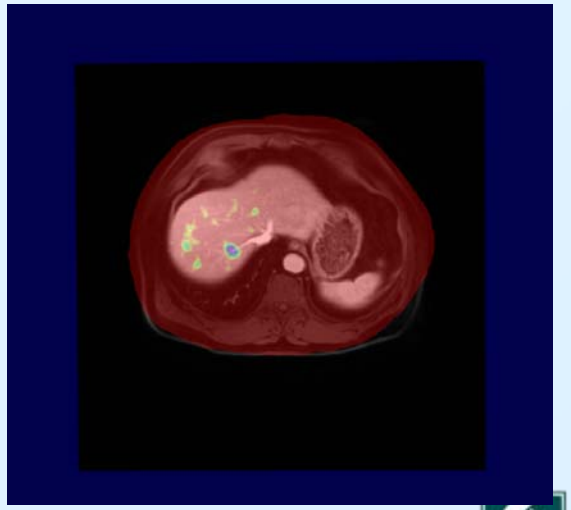
Pre-procedural axial MRI at the same level as the CT



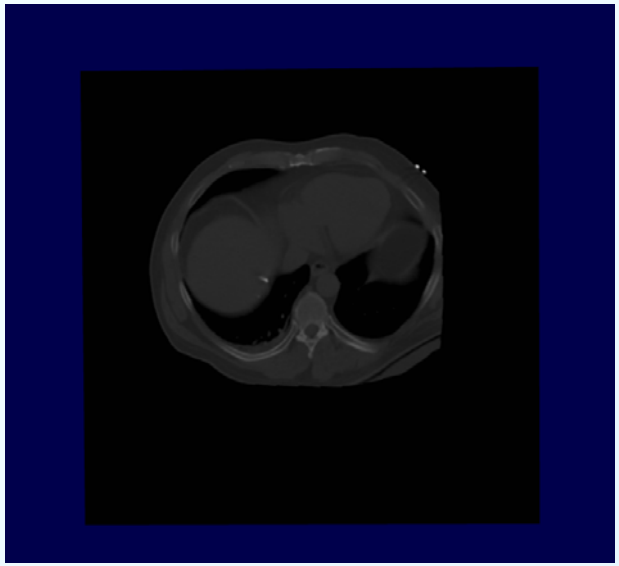
PET registered with CT (the tumor is clearly depicted on PET)



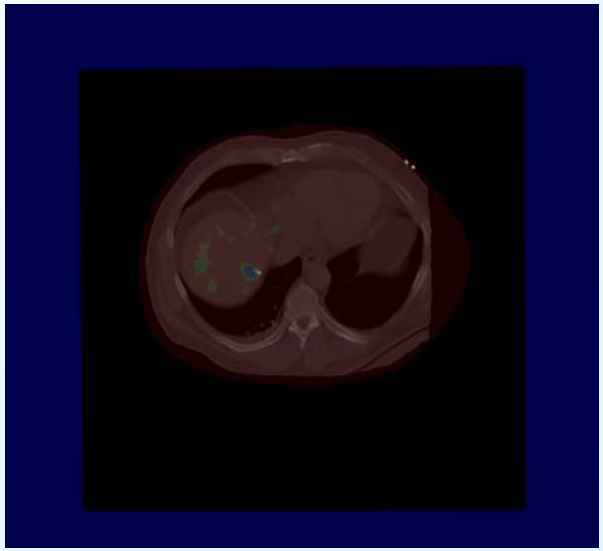
PET registered with MRI, using the same transformation field obtained from MRI to CT registration



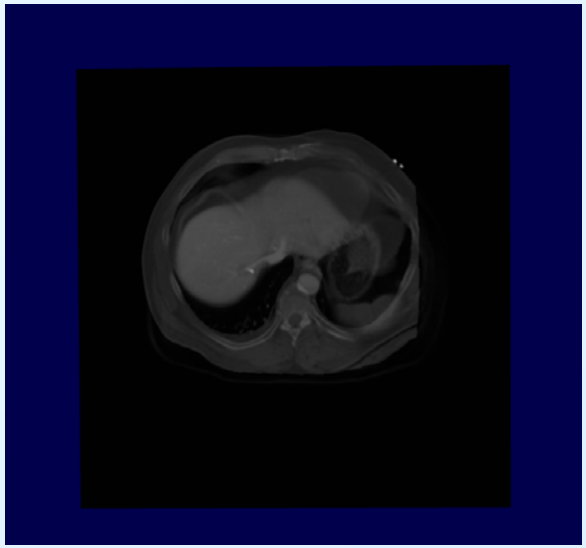
Intra-procedural CT images during targeting registered with pre-procedural PET/CT and MRI



Intra-procedural CT during targeting (tumor not visible)



Enhanced tumor visulation obtained by aligning intra-procedural CT with the pre-procedural PET

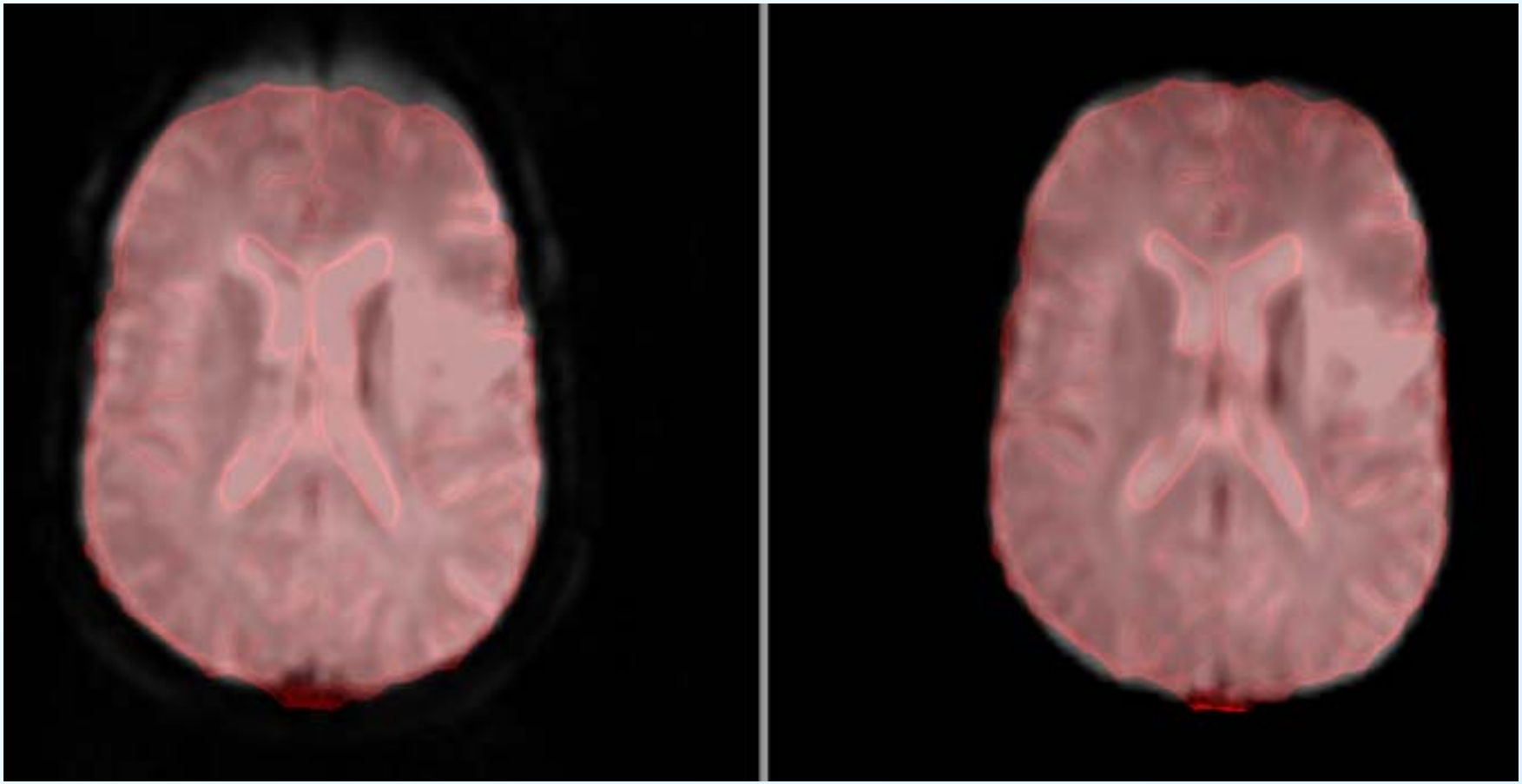


Intra-procedural CT during targeting, registered with pre-procedural MRI for enhanced tumor visualization

Spatial Neuroinformatics

- EPI dewarping: methodology, initial experiments
- EPI distortion
  - How bad is it
  - How good is “field map” solution?
  - Develop “MRI-based” correction

EPI / MRI agreement



Without fieldmap correction

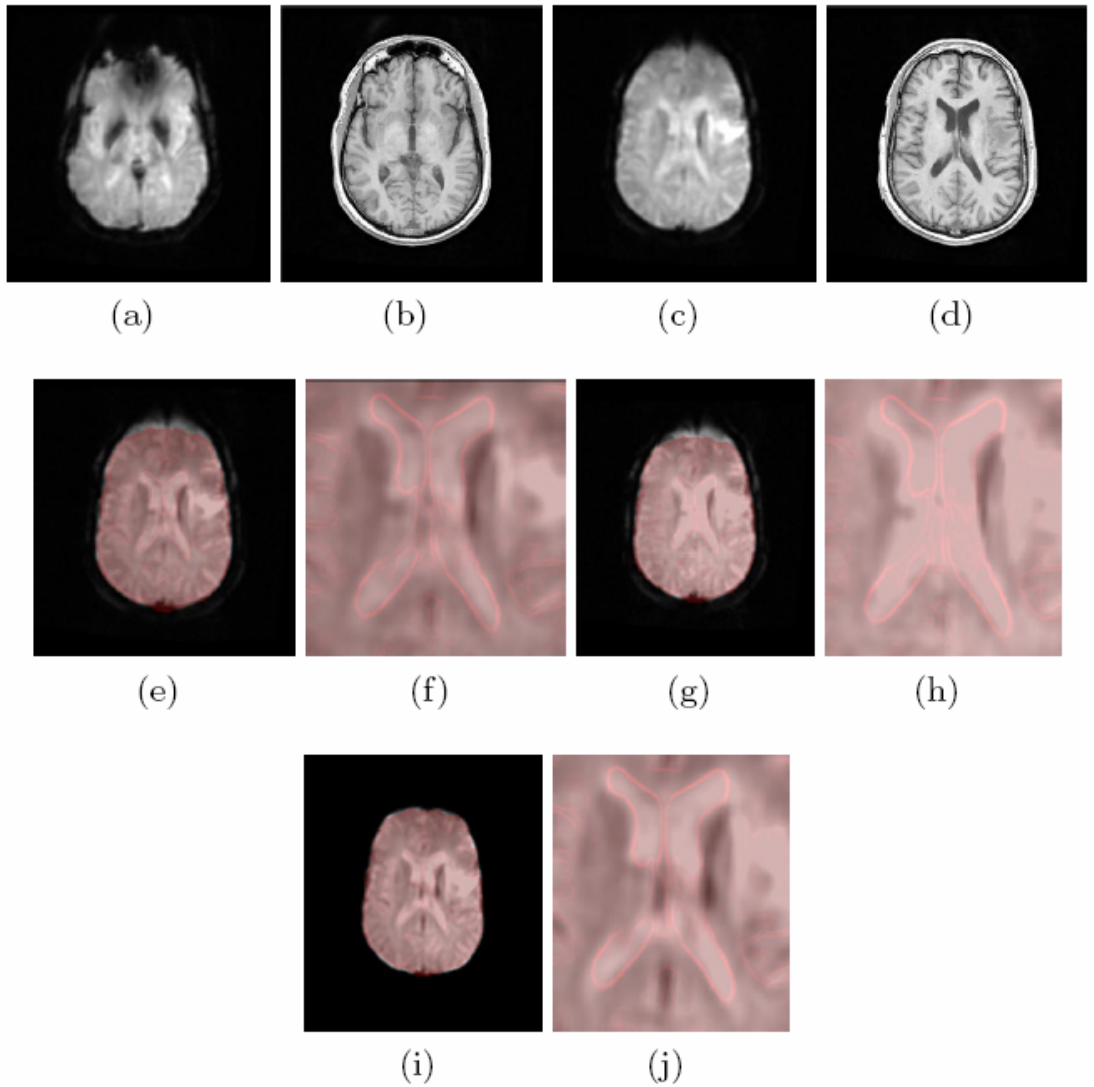
With FSL fieldmap correction

EPI registration

(e) (f): rigid registration
Without dewarping

(g) (h): affine registration
Without dewarping

(i) (j): dewarping with fieldmap

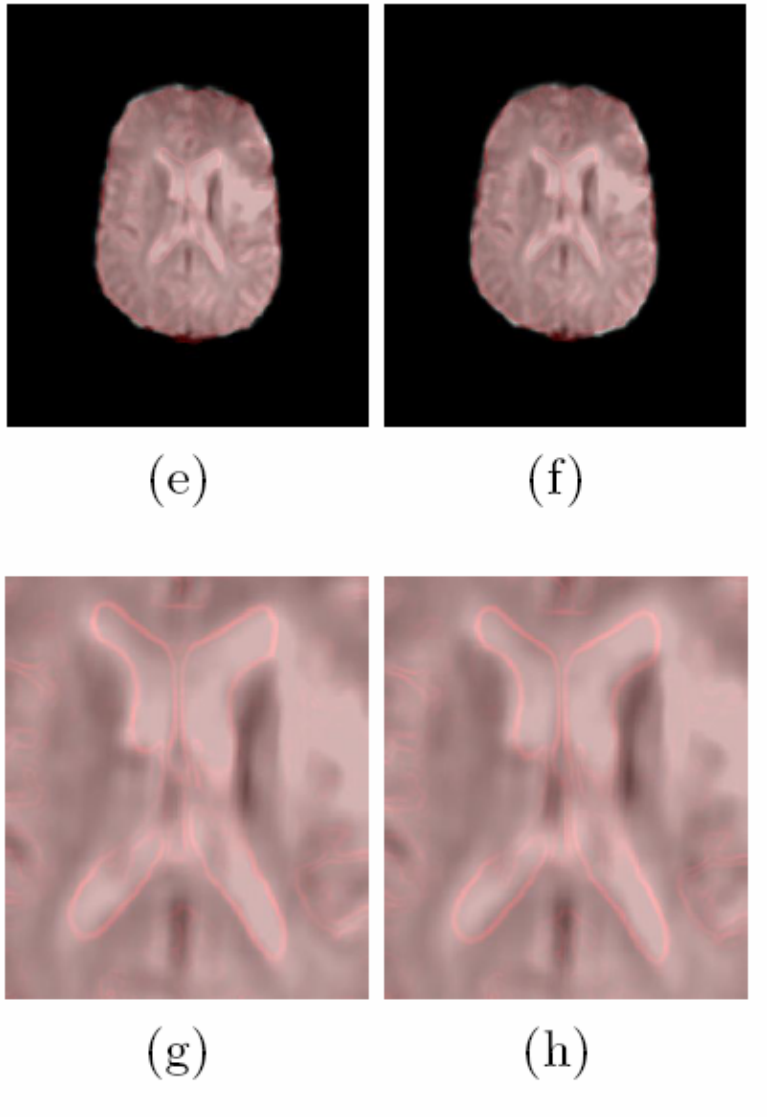


Recent Results

(e) (g): dewarping with Acquired fieldmap

(f) (h): dewarping with Fieldmap predicted Structural MRI

Clare Poynton MICCAI submission



Tracked (Image Registered) ENDOSCOPY

NCIGT March, 2008

Image Registered Endoscopy

- Overall Goal: Improve endoscopic imaging by integrating with other pre-operative and intra-operative imaging modalities

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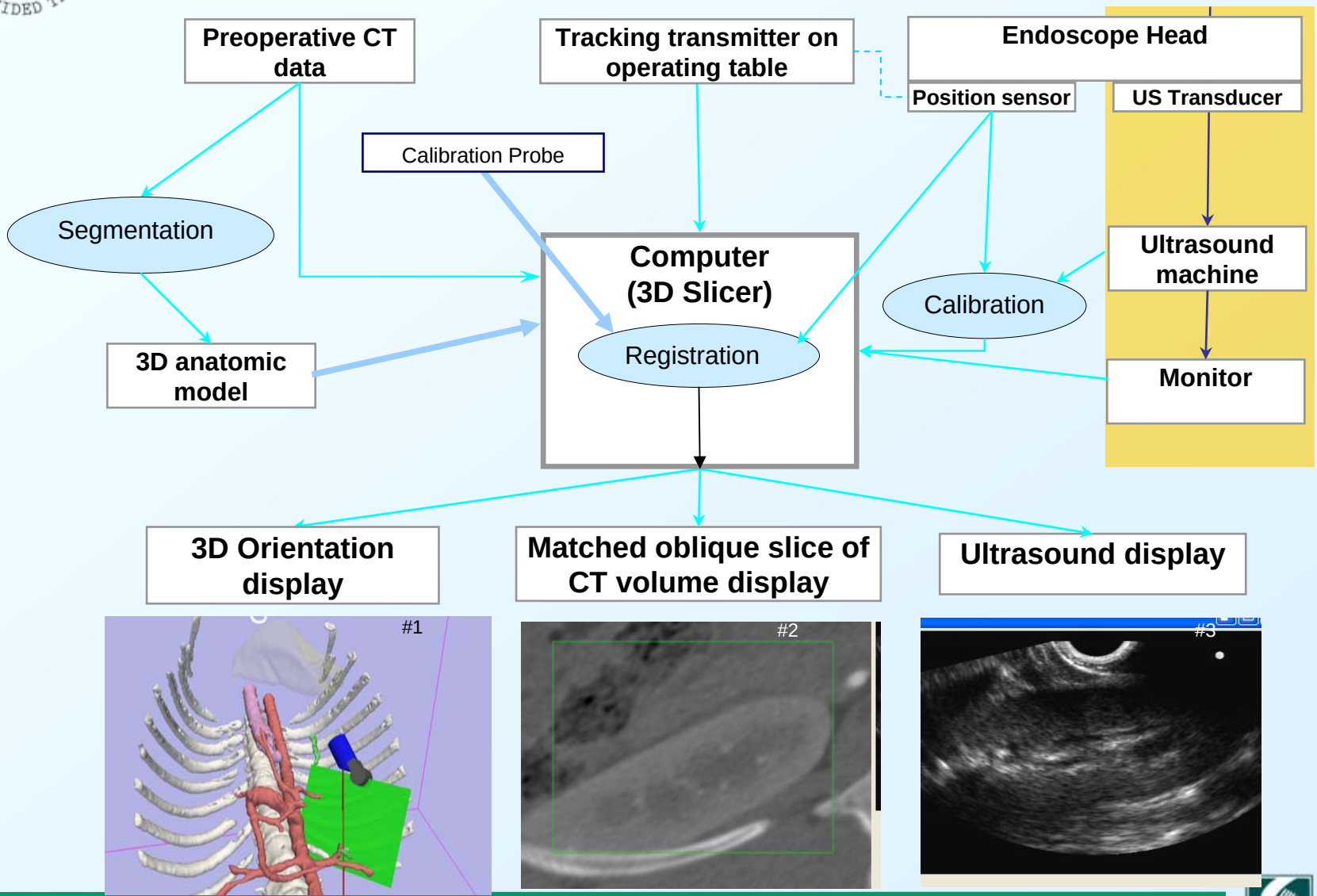
- The increasing quality and use of screening and diagnostic scans (CT, MRI, PET,…) will increase demand for minimally invasive biopsy and intervention
- Initial work is focused on Endoscopic Ultrasound (EUS) where image registration may have the most impact because the image plane position may be difficult to determine. Today, these techniques have not maximally adopted by gastroenterologists and surgeons due to:
  - Long learning curve
  - Lack of confidence in ultrasound interpretation
- We hypothesize that the display of the position and orientation of the ultrasound probe in anatomic context and display of CT (or MR) “Reference Images” will improve the accuracy and confidence of physician operators.

System Data Flows



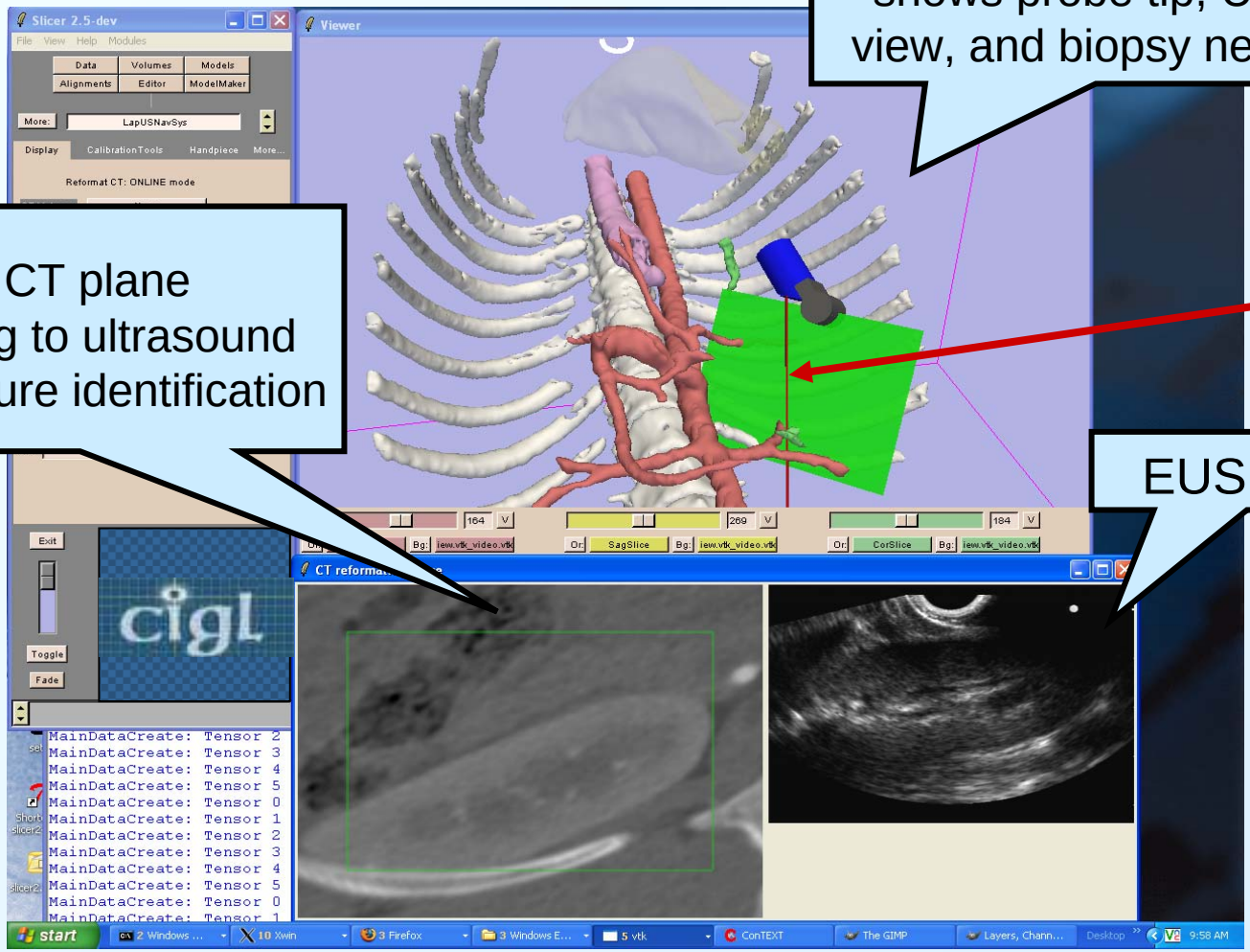
IRGUS Display

Segmented 3D CT for Orientation of probe. Icon shows probe tip, US field of view, and biopsy needle track

Oblique CT plane corresponding to ultrasound Image for feature identification

Needle Track

EUS image

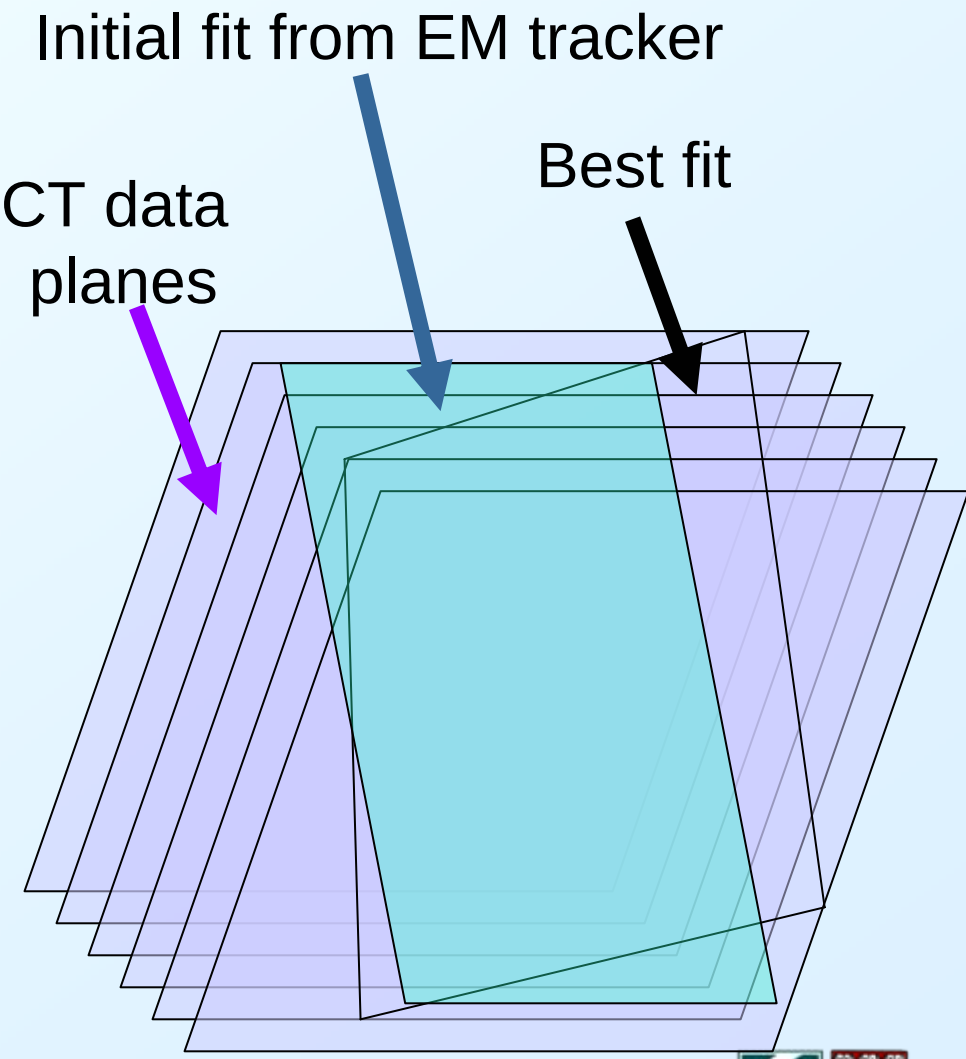


2008: Focus on Human Studies

- Validate registration in OR/endo suite setting
  - Lap pancreas surgery at Dalhousie
- Finish patient pose study (BWH)
  - What compensation is required when patients are lying on their side?
- Open pancreas surgery at MGH
- Gastroscopic Ultrasound/Endoscopy at BWH
- Technical development
  - Staged Registration (ANU Canberra)
  - Ultrasound image interpretation
  - C-PASS kinematics analysis for validation

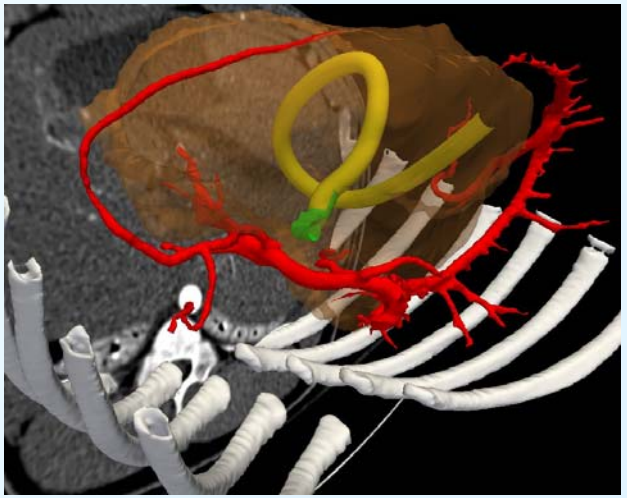
Robust Real-time Tracking

- Initial fit from registered electromagnetic tracker
- Use image content comparisons to improve fit
  - Vascular structures
  - 2D-2D comparisons
  - 3D-3D comparisons

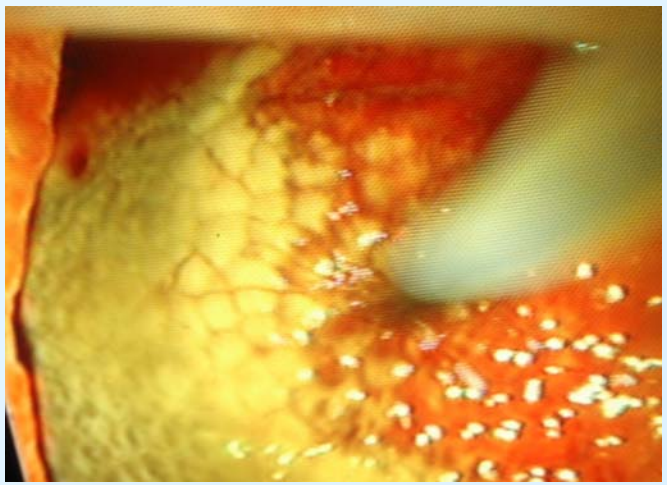


IRGUS For Gastric Access NOTES (IRGA)

- Show location of scope tip, shape of scope body
- Support interpretation of GUS image
- Mis-registration less than 5 mm
- Publications:
  - MMVR, CAS
- On hold for first human tests of IRLUS & IRGUS



First Image Registered Gastric Access (IRGA) (porcine model)



Neurosurgical Image Database

- Organize large retrospective collection of neurosurgical image data (with MRT)
- XNAT based: work in progress
- Neculai Archip, Steven Haker, Ion Florin-Talos

Publications Database hosted by SPL

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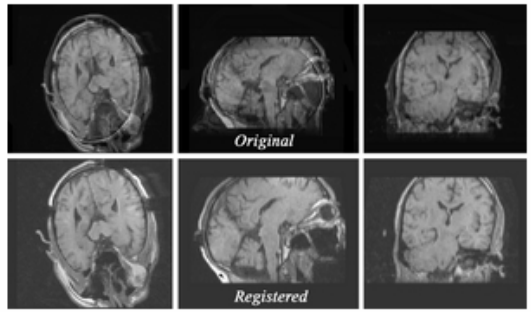
Title: Volumetric Non-Rigid Registration for MRI-Guided Brain Tumor Surgery



Authors: Ion-Florin Talos, Neculai Archip

Institution: Surgical Planning Laboratory, Harvard Medical School and Brigham and Women's Hospital, Boston, MA, USA.

Publisher: SPL 2007

Publication Date: Aug-2007

Citation: SPL brain tumor resection image dataset, Aug 2007

Appears in Collections: SPL, NCIGT, Download Data, NAC

Abstract: The accuracy of neurosurgical navigation systems is seriously compromised by brain shift, i.e. changes in the spatial position of the lesion and surrounding brain tissue, which inevitably occur during the surgical procedure, in response to surgical manipulation (resection, retraction, CSF leakage) and administration of anesthetic drugs. These changes in brain spatial configuration, summarized under the generic term of brain shift, occur according to a non-linear pattern and lead to significant mis-registration between pre-operative image data (MR, CT) and the intraoperative brain configuration. Non-rigid registration techniques are increasingly being employed to maintain an accurate alignment between pre-operative and intra-operative images. These techniques provide the ability to estimate transformations that model not only affine parameters (global translation, rotation, scale and shear), but also local deformations. Higher-order transformation models, with increased number of parameters and significant computing capabilities are usually required for this purpose. Our group was the first to demonstrate the feasibility of a non-rigid registration approach capable to compensate for the volumetric brain deformations within the time constraints imposed by neurosurgery (Archip et al., 2007). Augmented reality visualizations of functionally eloquent brain structures (based on pre-operative anatomic, functional and Diffusion Tensor MRI, non-rigidly registered with

People

- Mark Anderson
- Necu Archip
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