Training & Validation Update

Sonia Pujol, PhD
NA-MIC Training Core P.I.

NA-MIC Training Core Effort

Our mission:

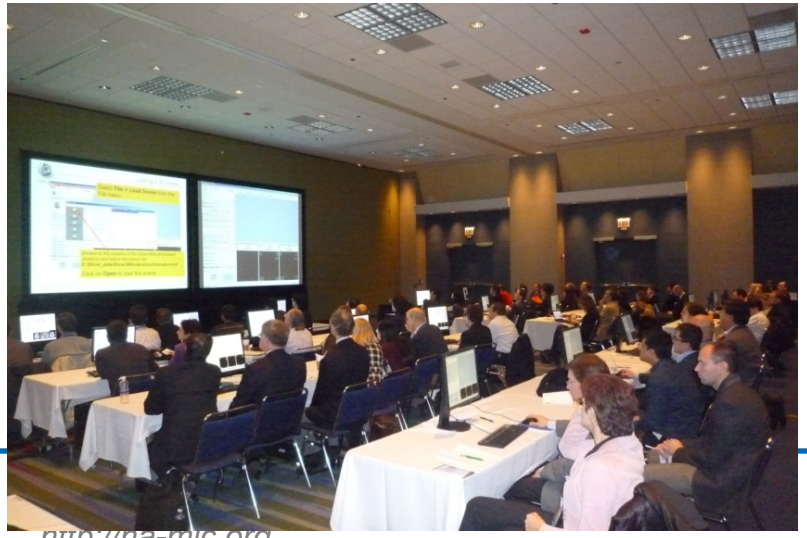
- **Teaching effort** to accelerate the transfer of NA-MIC technology to the community
- **Validation effort** to investigate the comparative performances of algorithms

2011 NA-MIC Training Workshops

12 workshops at 11 different national & international venues

- Harvard Medical School, Boston, MA. Feb-March,2011
- Johns Hopkins, Baltimore, MD. April 2011
- SCI Institute, Utah. April 2011
- University of Western Ontario, London, Canada. June 2011
- OHBM 2012, Quebec City, Canada. June 2011
- AAPM meeting, Vancouver, Canada. August 2011
- UBC workshop, Vancouver, Canada. August 2011
- MICCAI 2011, Toronto, Canada. Sept. 2011
- Cranio-Maxillo Facial workshop, Cleveland. Nov. 2011
- SfN 2011, Washington, DC. Nov. 2011
- RSNA 2011, Chicago, Il. Dec. 2011

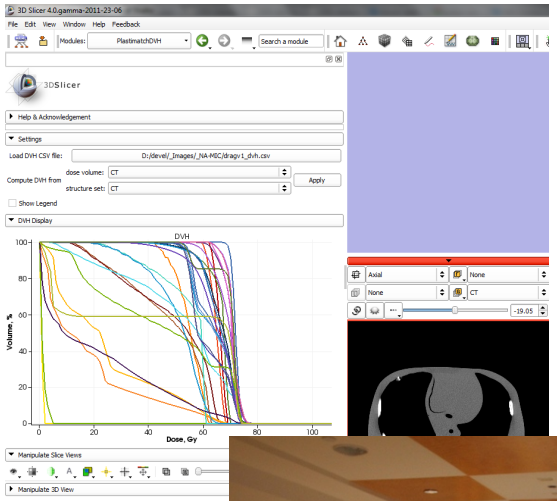
NA-MIC Workshops



Hands-on workshops tailored for clinicians, clinical researchers, and scientists at national events, invited seminars, and international conferences (MICCAI, RSNA, SfN…)

AAPM 2011, Vancouver

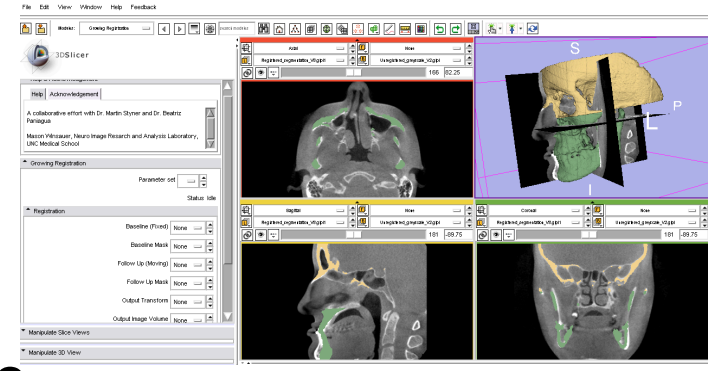
- Theme: 3DSlicer for radiotherapy research
- Gregory Sharp, MGH, Andras Lasso, Queen's University
- 20 participants



Joint meeting of the American Association of Physicists in Medicine (**AAPM**) and the Canadian Organization of Medical Physicists (**COMP**)

2011 Cranio-Maxillo Facial Workshop, Cleveland

- Theme: Slicer development in Orthodontics

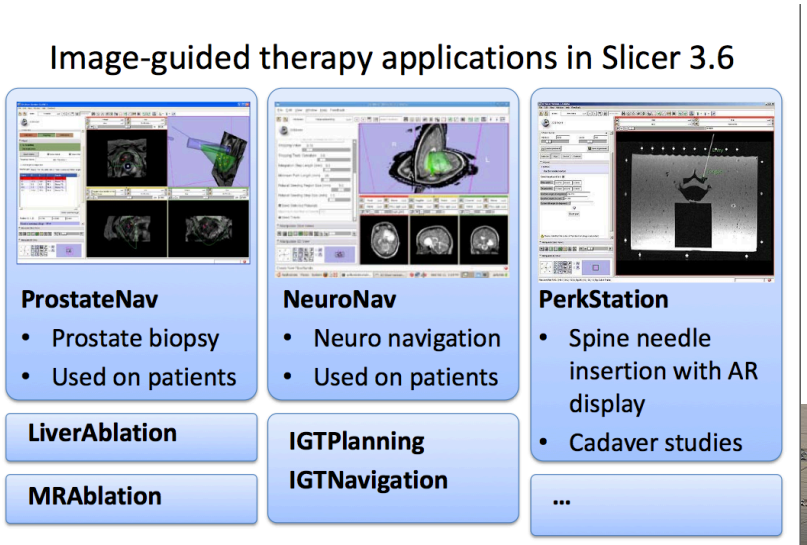


- Beatriz Paniagua, UNC
  Tung Nguyen, UNC
  Lucia Cevidanes, U.Michigan

Joint Cephalometric Experts Group 2011 - 20 participants

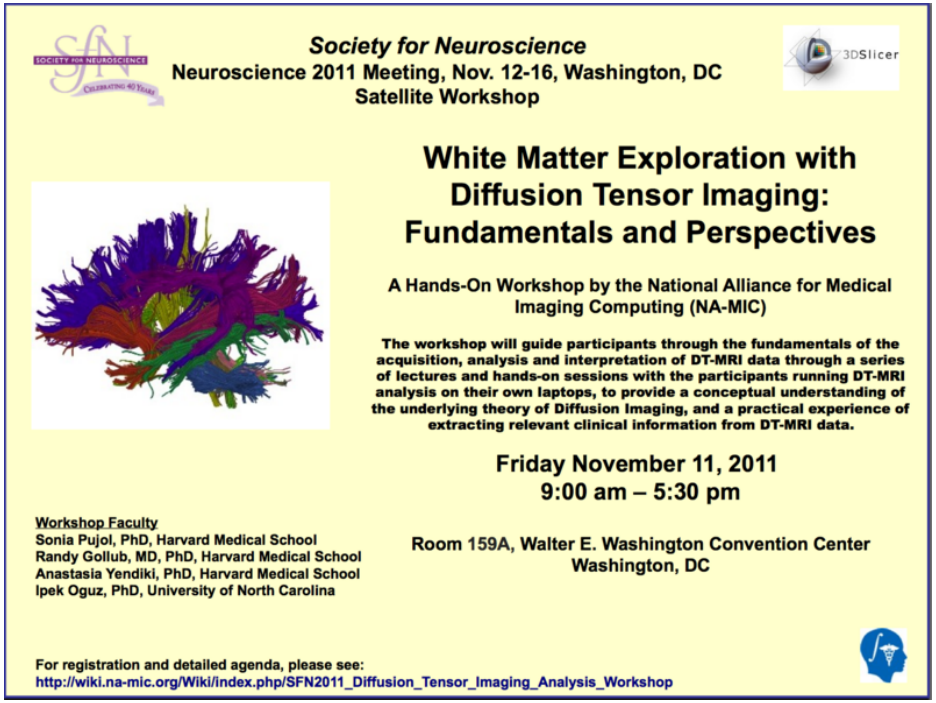
UBC 2011, Vancouver

- Theme: 3D Slicer for image-guided therapy research
- Andras Lasso and Tamas Ungi, Queen's University
- 21 participants



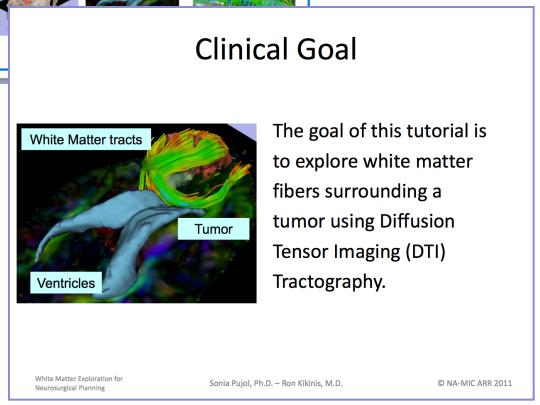
SfN 2011 DTI workshop

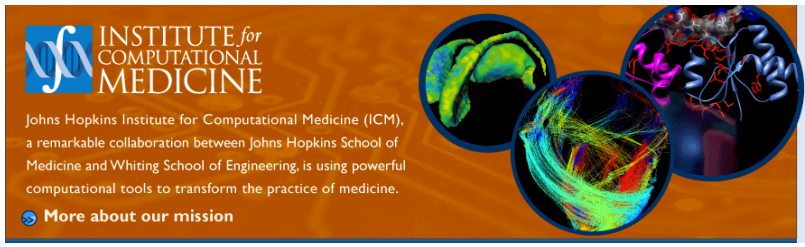
- Full day event on DTI analysis
- Lectures & hands-on sessions on acquisition, analysis and interpretation of DT-MRI data
- 23 neuroscientists



Johns Hopkins Workshop

- Local Host: Prof. Rai Winslow, Director, Institute for Computational Medicine, JHU
- ICM Distinguished Seminar Series: Ron Kikinis, MD. “3DSlicer”
- Full-day workshop
  - Basics of DTI
  - White matter tractography for neurosurgical planning
  - OpenIGTLink





Univ. Western Ontario, Canada

- Local Host: Prof. Terry Peters,

Director, Robarts Imaging Institute

- Image Registration, Programming OpenIGTLink
- BIRC Lecture: “Open Source Platforms for Collaborative Research Examples from 3DSlicer.” Ron Kikinis, MD
- 63 participants

BIRC
BIOMEDICAL IMAGING RESEARCH CENTRE
The University of Western Ontario

Slicer booths

- **OHBM 2011** June 2011

- **BWH 2011 Resident Fair**
  Nov 2011

BWH
BRIGHAM AND WOMEN'S HOSPITAL
A Teaching Affiliate of Harvard Medical School

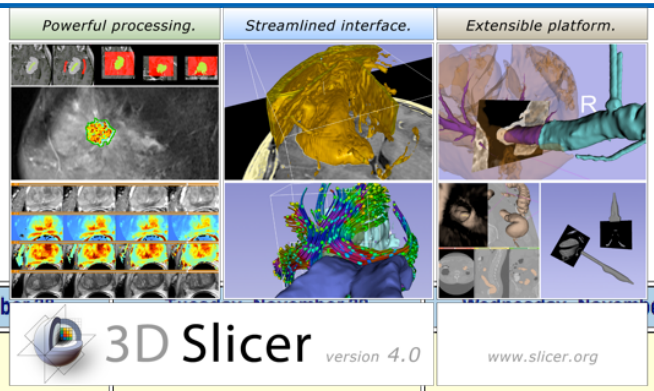
- **RSNA 2011 Slicer Booth**
  Nov 27-Dec 2, 2011

RSNA 2011

- Largest medical conference in the world - 60,000 participants

- NA-MIC presence:
  - 2 hands-on courses
  - 54 hours demos at the 3DSlicer Booth
  - paper presentation on SPL Brain Atlas

Slicer4 Premiere at RSNA 2011



NA-MIC and NAC at RSNA [edit]

Agenda [edit]

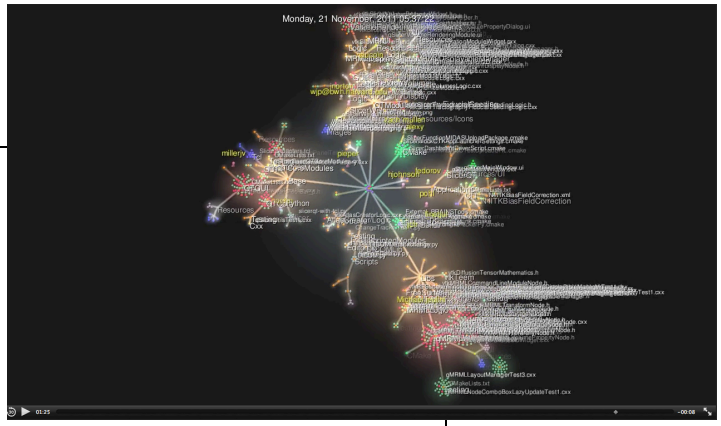
Sunday, November 27	Monday, Novemb	er 30	Thursday, December 1	Friday, December 2
8:00am-11:00am. 3D Slicer Exhibit, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E --- **11:00am-12:30pm**. RSNA Refresher Course: **Quantitative Medical Imaging for Clinical Research and Practice**. Room S401CD --- **12:30pm-6:00 pm**. 3D Slicer Exhibit Quantitative Imaging, Lakeside Learning Center, Hall E	**8:00am-11:00am**. 3D Slicer Exhibit,, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E --- **11:15am-11:45am**. QIRR Theater Presentation, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E --- **12:15pm-1:15pm**. Meet-The-Experts Session, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E --- **1:15pm-6:00 pm**. 3D Slicer Exhibit, Quantitative Imaging, Lakeside Learning Center, Hall E	**8:00am-11:00am**. 3D Slicer Exhibit, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E --- **12:30pm-2:00pm**. RSNA Refresher Course: **3D Visualization for radiological applications**. Room S401CD --- **12:30pm-6:00 pm**. 3D Slicer Exhibit, Quantitative Imaging, Lakeside Learning Center, Hall E	**8:00am-12:15pm**. 3D Slicer Exhibit Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E --- **12:15pm-1:15pm**. Meet-The-Experts Session, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E --- **1:15pm-6:00 pm**. 3D Slicer Exhibit, Lakeside Learning Center, Hall E --- **4:30pm-6:00pm**. RSNA Refresher Course: **Lifecycle of an Imaging Biomarker: From Validation to Dissemination** Room S501ABC	**8:00am-12:15pm**. 3D Slicer Exhibit, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E --- **Session starts at 10:30 am - Talk at 11:10am-11:20am**. RSNA Paper presentation: **Publicly Available RadLex-linked Anatomy Atlases for Image Analysis, Informatics and Education** Room S402AB --- **12:15pm-1:15pm**. Meet-The-Experts Session, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E --- **1:15pm-6:00pm**. 3D Slicer Exhibit, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E	**8:00am-12:45pm**. 3D Slicer Exhibit,, Quantitative Imaging Reading Room, Lakeside Learning Center, Hall E

Slicer4 Premiere at RSNA – Behind the scenes

- July 19, 2011

'Slicer4 review and Programming Sprint'

- RSNA 2011 targeted objectives and deadline for the first release of Slicer4



Slicer visual blog (S.Pieper)

Events:Slicer4-Review-07-2011

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1 RSNA 2011 Targeted Objectives
- 1.1 UI
- 1.2 Under the hood
- 1.3 Infrastructure
- 1.4 Beginning Of The Rest

2 What
3 When
4 Who
5 Where
6 Why
7 Work on
- 7.1 Full List
  - 7.1.1 UI
  - 7.1.2 Under the hood
  - 7.1.3 Infrastructure
  - 7.1.4 Compilation

8 Agenda
9 Attending

RSNA 2011 Targeted Objectives

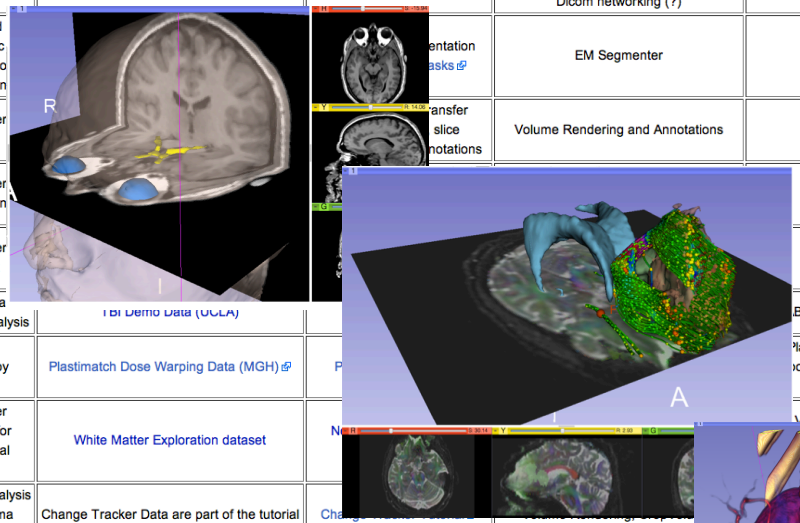
- Roadmap for the Slicer 4 release for the **series of demos at the** RSNA 3DSlicer Booth
- Most tasks need to be ready by end of September, to leave time to update tutorials, test and debug.
- List of open Mantis issues with RSNA Target

UI

- Main GUI Cosmetics
  - % face lift for the Slice viewers: reduce permanent non-image components. Reduce the number and depth of submenus. (J2) **done**
  - % Main Gui 3D viewers should have similar appearance to slice viewers (J2) **done**
  - % scenview and screensnapshot icons move to the icon bar at the top of the main gui. (J2-> Nicole) **done**
- Module Cosmetics
  - % Volume Rendering (J2) (in progress)
  - % Models module (J2) **done**
  - % Editor, see picture to the right (Steve) (Done)
  - % Welcome Module (Wendy)

RSNA 2011: Slicer Booth

Nb	DEMO	Datasets	Notes	Tools	Slicer Modules
1	Data Loading and Visualization	Slicer3Visualization Data	Slicer3Visualization Tutorial	Compare View, Clipping, Save, Restore, Scene Views, Dicom studies sorting, Dicom networking (?)	Data, Volumes, Models, Scene Views
2	MRI-based topographic parcellation o human brain		entation asks	EM Segmenter	EMSegmenter
3	Volume Render #1 Head		ansfer slice notations	Volume Rendering and Annotations	Volume Rendering, Annotations, Scene Views
4	Volume Render #2 Abdomen				Volume Rendering, Annotations, Scene Views
5	Volume Render #3 Thorax				Volume Rendering, Annotations, Scene Views
6	Traumatic Bra Injury Case Analysis	TBI Demo Data (UCLA)			LBC Segmentation, Model Maker, Editor, Annotations, Scene Views
7	Radiotherapy	Plastimatch Dose Warping Data (MGH)	P		Plastimatch Extension: DICOM/DICOM-RT Import, DICOM/DICOM- ort, B-Spine Deformable Registration,XFORMWARP Warping with transform Transforms,
8	White matter exploration for neurosurgical planning	White Matter Exploration dataset	N		Volumes, Editor, Fiducials, Diffusion Tensor Estimation, Diffusion aphy Fiducial
9	Longitudinal analysis of meningioma growth	Change Tracker Data are part of the tutorial	Cha	Crosshairs, BRAINSFit	Volume
10	Image-guided prostate interventions	Prostate Data updated for Slicer4, in progress *Can load RSNA2010 demo scene, mostly working, see [1]*	Pre-op/Intra-op registration; Use Case Demo Prostate Data	Linked Viewing	s
11	Brain Atlas	NAC Multi-modality MRI-based Atlas of the Brain	Work in progress - atlases are being updated	Linked Viewing	
12	Abdomen Atlas	Knee Atlas	Work in progress - atlases are being updated	Linked Viewing	
13	Knee Atlas Atlas	Abdominal Atlas	Work in progress - atlases are being updated	Linked Viewing	Data, Volumes, Models, Scene Views

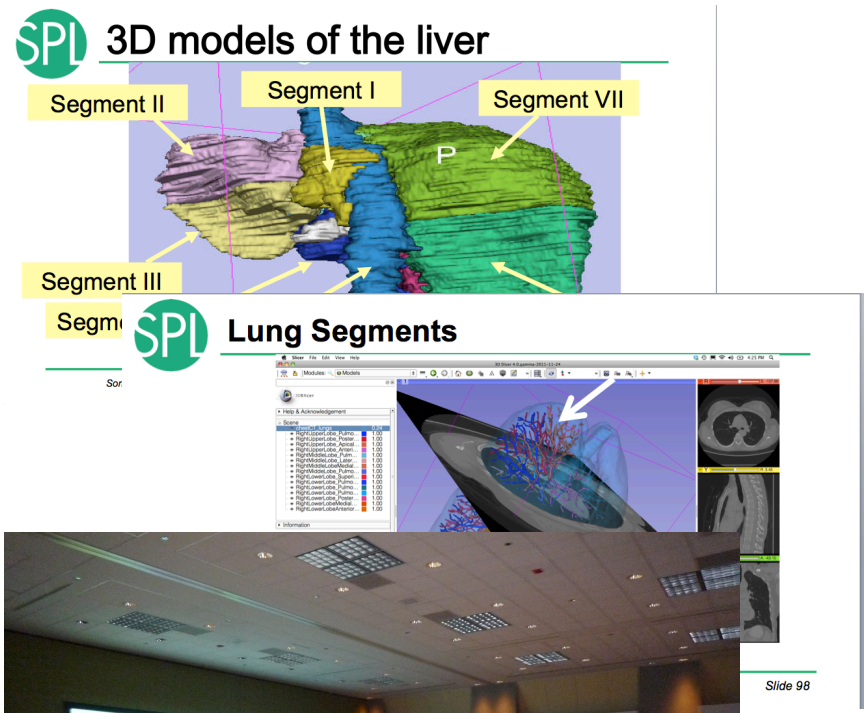


- 13 hands-on demos with pre-computed datasets
- ~10-20 visitors per day

"The 3D Slicer open source software platform for segmentation, registration, quantitative analysis and 3D visualization of biomedical image data"

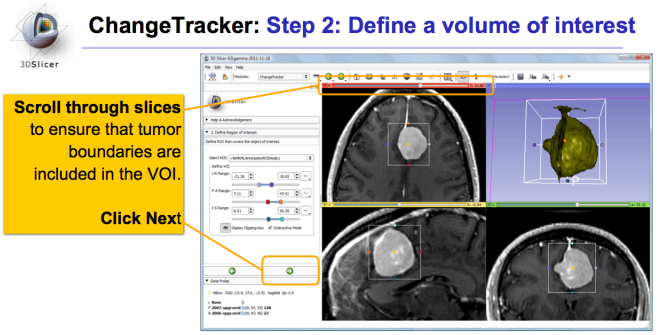
RSNA 3DVisualization Course

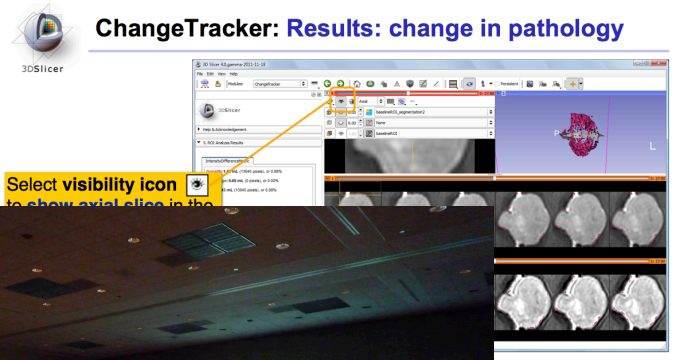
- 3D interactive visualization of liver & lung segments
- In Collaboration with Dr. Kitt Shaffer, Vice Chairman for Radiology Research, BU Medical Center
- 105 international attendees



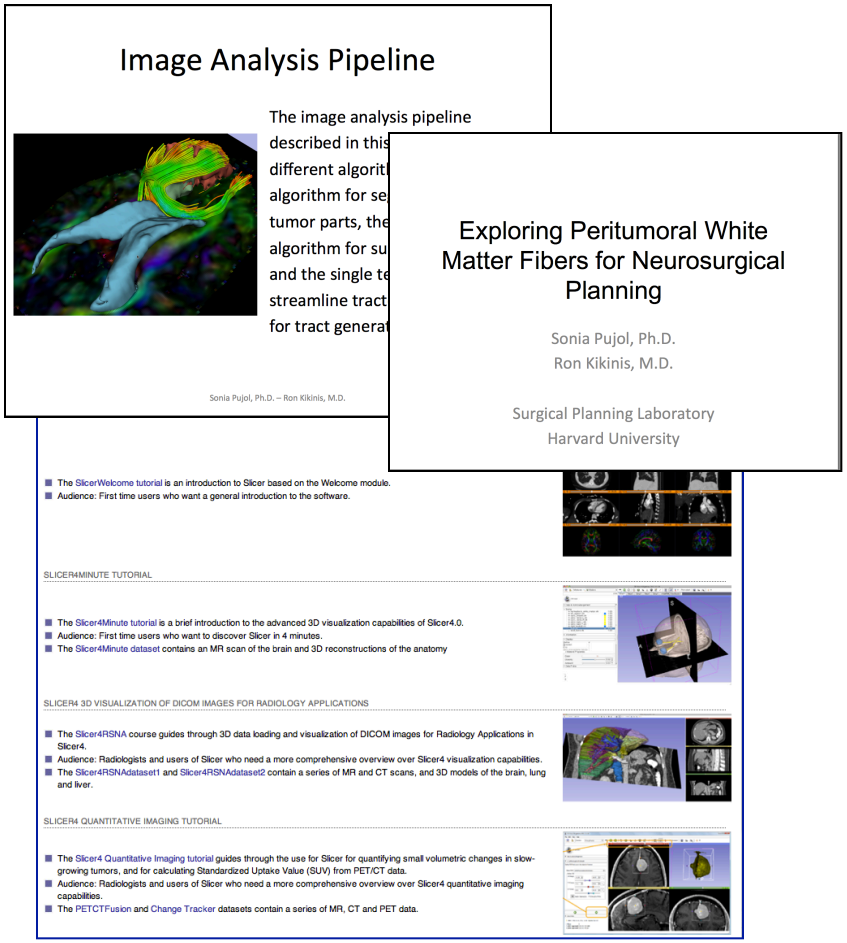
RSNA Quantitative Imaging Course

- Slicer4minute, Change Tracker& PET/CT Fusion
- In Collaboration with Harvard Catalyst
- 120 participants





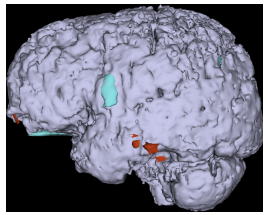
Slicer Training Compendium

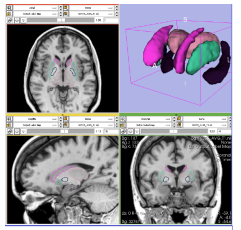


- New Slicer4 Compendium
- Development of new tutorials based on Clinical workflow: e.g., “White matter exploration for neurosurgical planning”
- Slicer tutorial contest

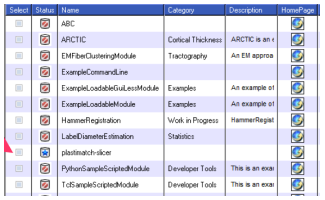
Summer 2011 Tutorial Contest

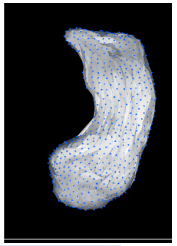
- 8 tutorial submissions
- First prize winner: ‘Automated Segmentation of TBI cases using ABC Segmentation’ (Andrei Irima, Jack Van Horn, UCLA)

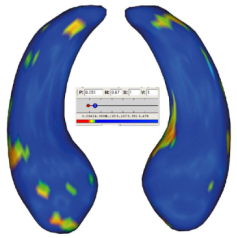


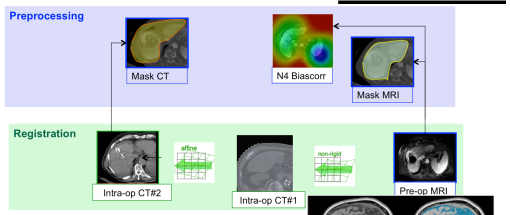


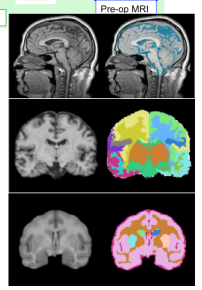
BRAINSCut Output example for sub-cortical structures

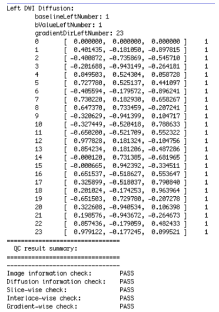






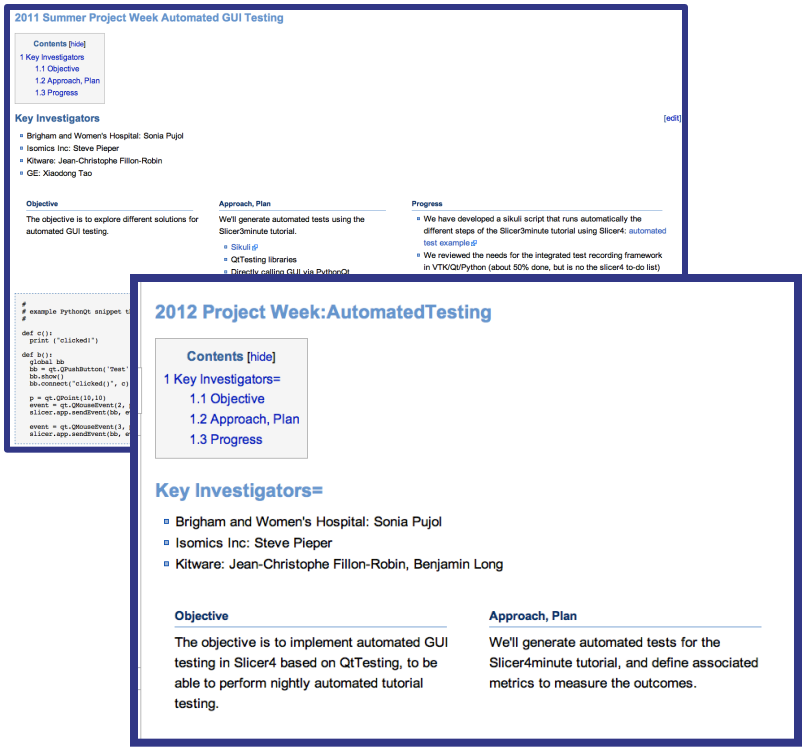






→ Next Tutorial Contest: NA-MIC Summer Project Week 2012

Slicer QA effort



- Automated GUI testing of Slicer4
- First implementation at 2011 Summer Project Week using Sikuli
- On-going development with Kitware using QtTesting (JC, Benjamin Long)

Development of nightly automated tutorial testing

Dissemination Update

12th Project Week: Salt Lake City, Utah, Winter 2011

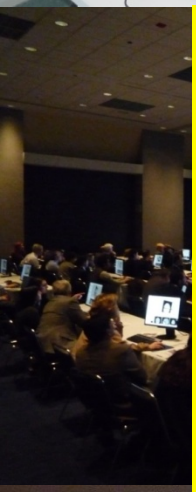
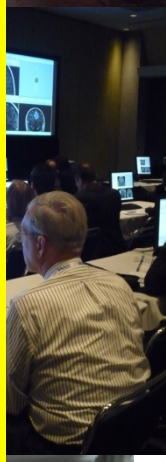
- 106 attendees: 20 academic institutions, 9 companies
- 59 Projects: Segmentation, Registration, IGT, Radiotherapy, Informatics, DTI, Engineering

13th Project Week: MIT, Summer 2011

- 101 attendees: 17 academic institutions, 8 companies
- 61 Projects: TBI, Radiation Therapy, Huntington's Disease, Atrial Fibrillation, IGT, Segmentation, Registration, Tractography, Vessels, Engineering

Tina Kapur, Ph.D., Co-PI
Steve Pieper, Ph.D., Co-PI



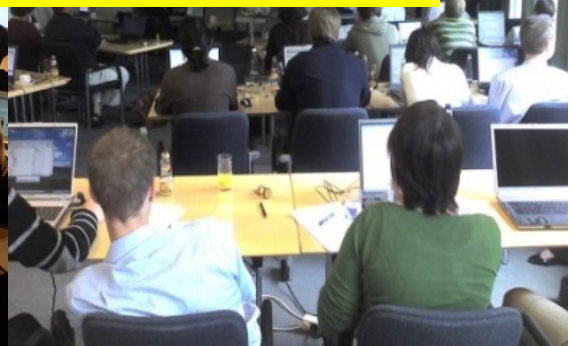
2011 outreach events:

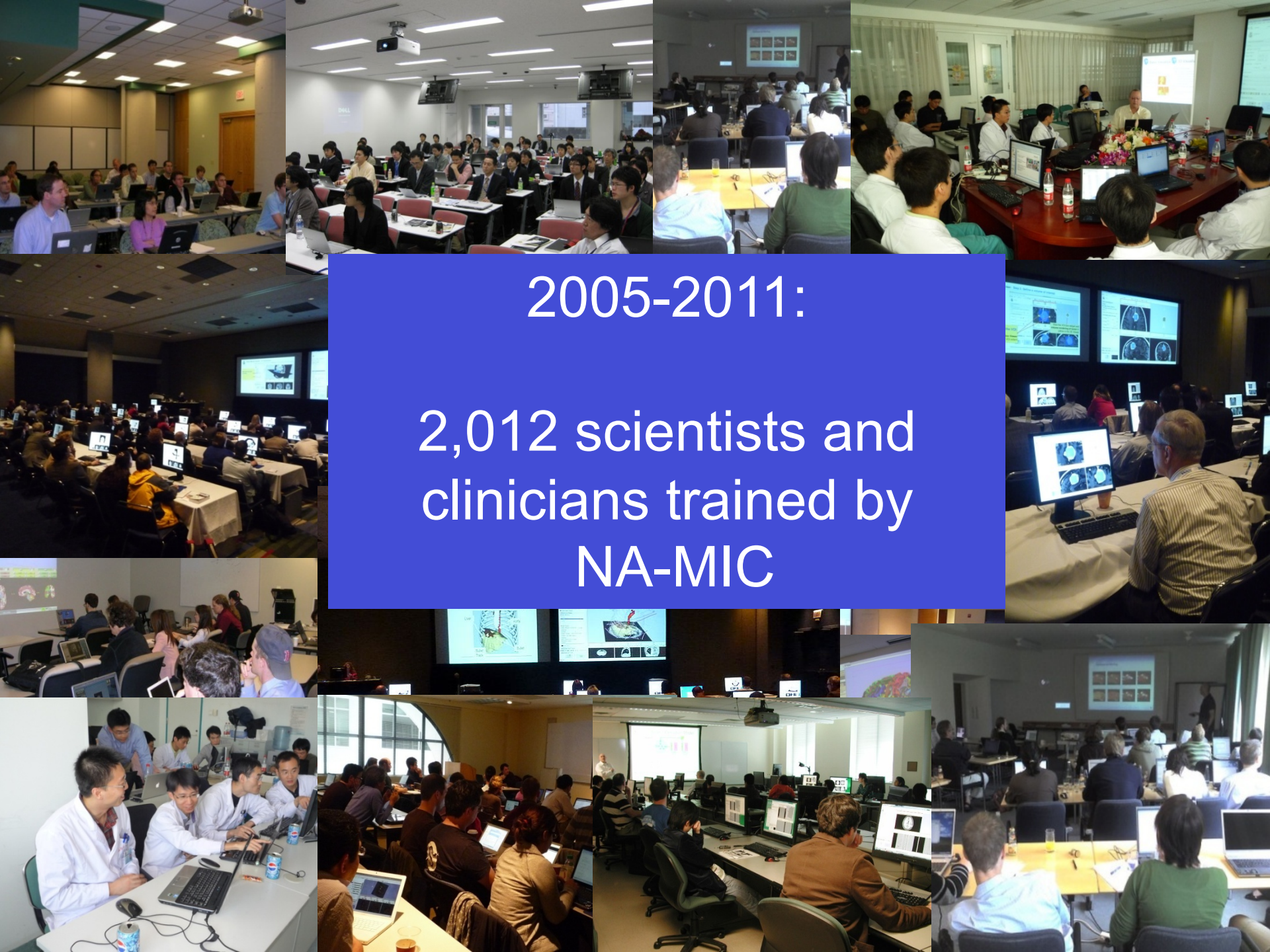
12 workshops

457 NA-MIC training workshop participants

207 NA-MIC project week participants






2005-2011:
2,012 scientists and clinicians trained by NA-MIC

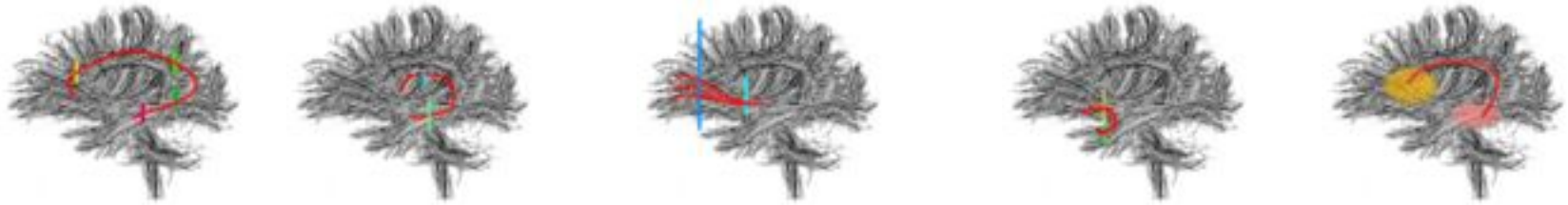
DTI Validation Update:

Challenges in clinical transfer of DTI tractography

NA-MIC pilot initiative

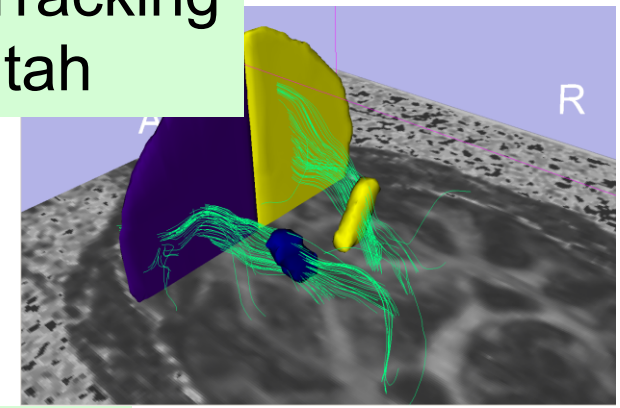
- Exploratory work on validation of DTI tractography

- Cross-comparison of tractography algorithms on major white matter fascicles

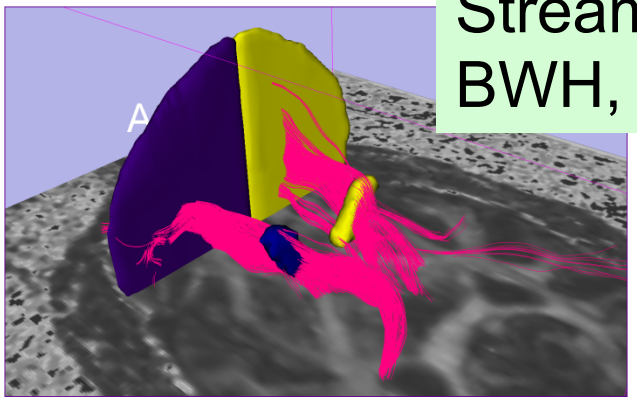


Early Implementation

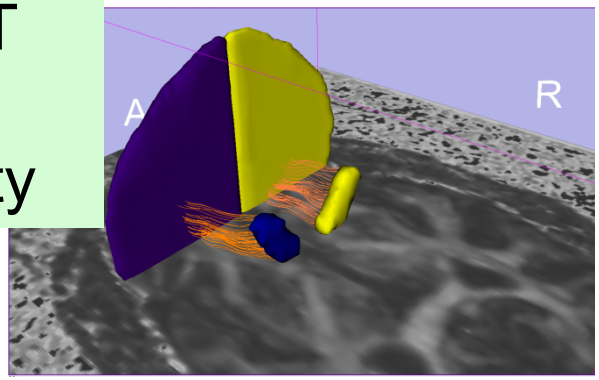
Fiber Tracking
SCI, Utah



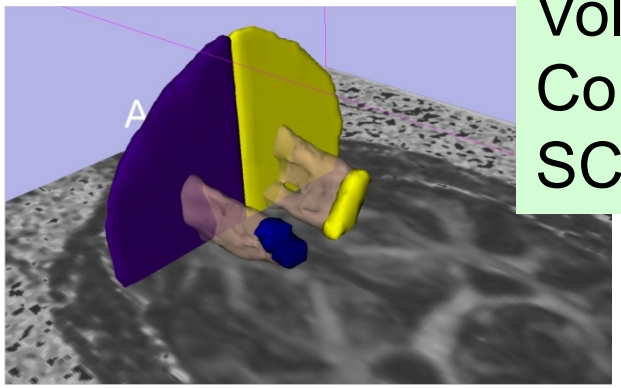
Streamline
BWH, Harvard



GTRACT
Iowa
University



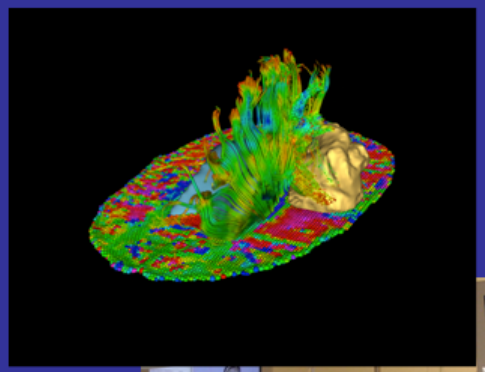
Volumetric
Connectivity
SCI, Utah

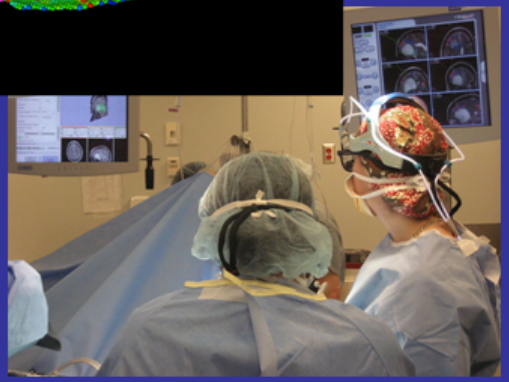


Pujol et al. ISMRM 2009

MICCAI 2011 DTI Challenge

14th International Conference on Medical Image Computing and Computer Assisted Intervention





DTI Tractography for Neurosurgical Planning: A Grand Challenge

MICCAI 2011 Workshop
Sunday September 18, 9am-6pm
Westin Harbour Castle
Toronto, Canada

Workshop Faculty

Sonia Pujol, PhD, Surgical Planning Laboratory, Harvard Medical School
Ron Kikinis, MD, Surgical Planning Laboratory, Harvard Medical School
Alexandra Golby, MD, Brigham and Women's Hospital, Harvard Medical School
Guido Gerig, PhD, The Scientific Computing and Imaging Institute, University of Utah
Martin Styner, PhD, Neuroimage Research and Analysis Laboratory, University of North Carolina
William Wells, PhD, Surgical Planning Laboratory, Harvard Medical School
Carl-Fredrik Westin, PhD, Laboratory of Mathematics in Imaging, Harvard Medical School
Sylvain Gouttard, MSc, The Scientific Computing and Imaging Institute, University of Utah

National Alliance for Medical Image Computing

http://www.na-mic.org/Wiki/index.php/Events:_DTI_Tractography_Challenge_MICCAI_2011

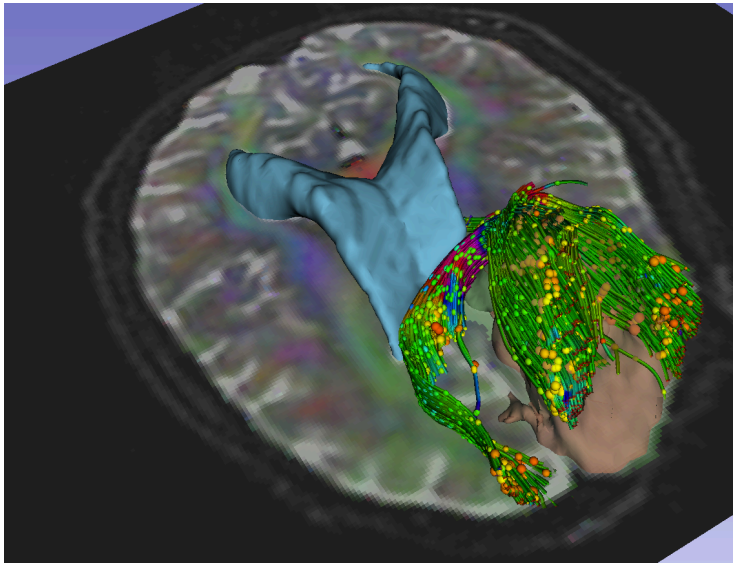
Workshop Faculty

- Sonia Pujol, BWH
- Ron Kikinis, BWH
- Alexandra Golby, BWH
- Guido Gerig, SCI Utah
- Martin Styner, UNC
- William Wells, BWH
- CF Westin, BWH
- Sylvain Gouttard, SCI Utah
- Arya Nabavi, Kiel Hospital, Germany

Special Thanks

- Hatsuho Mamata, BWH
- Isaiah Norton, BWH

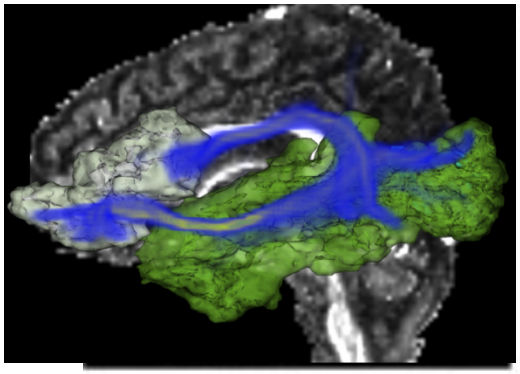
Tractography for neurosurgery

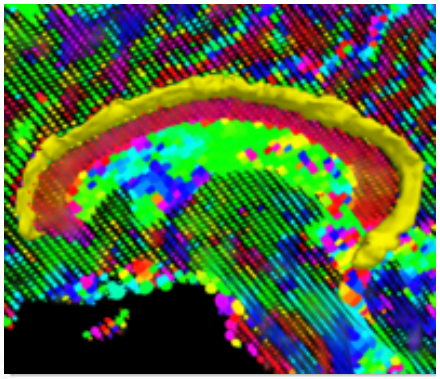


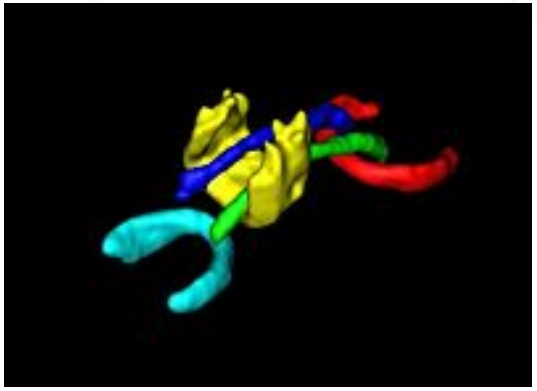
Tractography has the potential to bring valuable information to the neurosurgeon

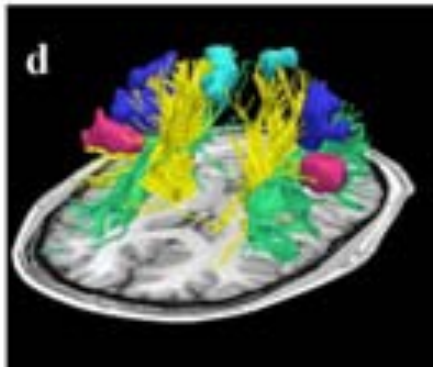
- Spatial relationship between the tract and the tumor
- Demonstration of tract displacement
- Assessment of tumor infiltration

Tractography Algorithms



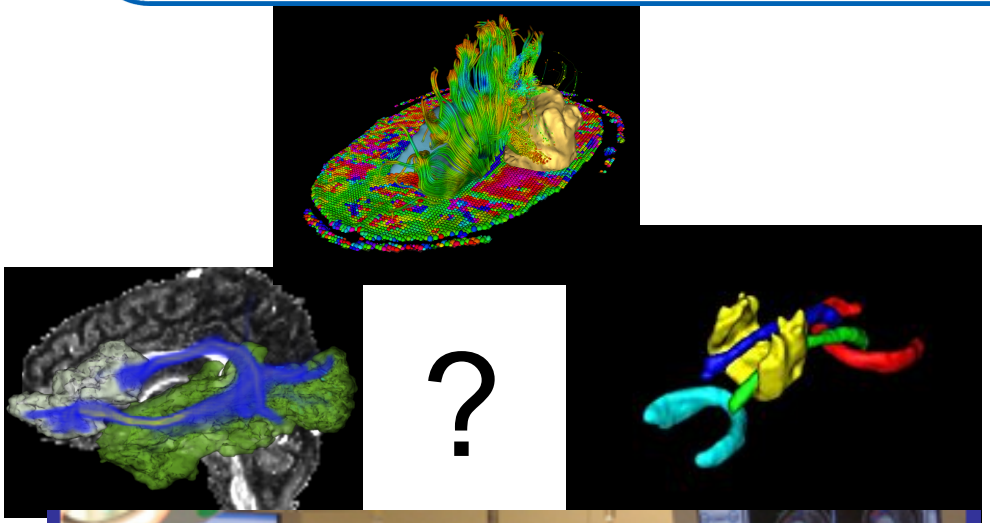


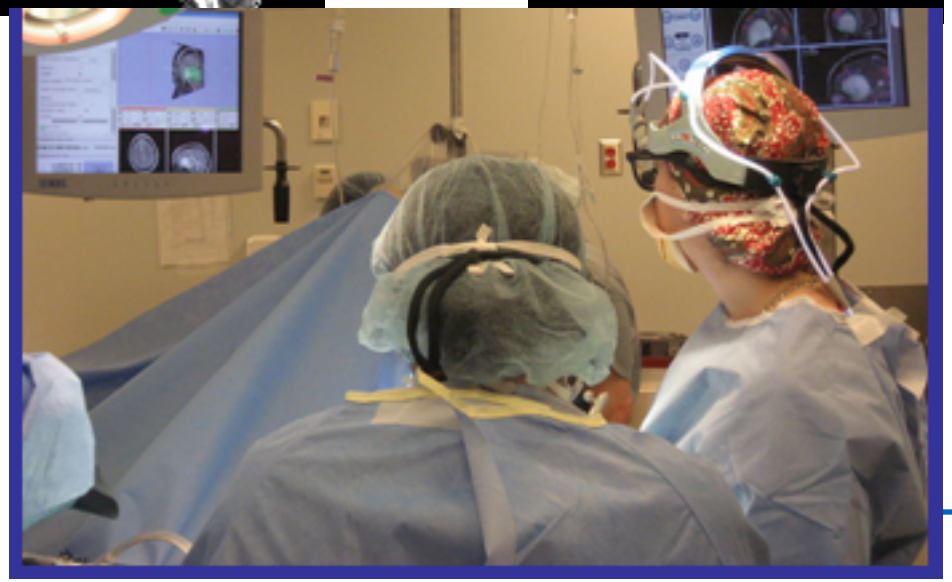




A wide variety of tractography techniques has been developed over the past decade (streamline, stochastic, volumetric, two-tensors…)

How to choose ?

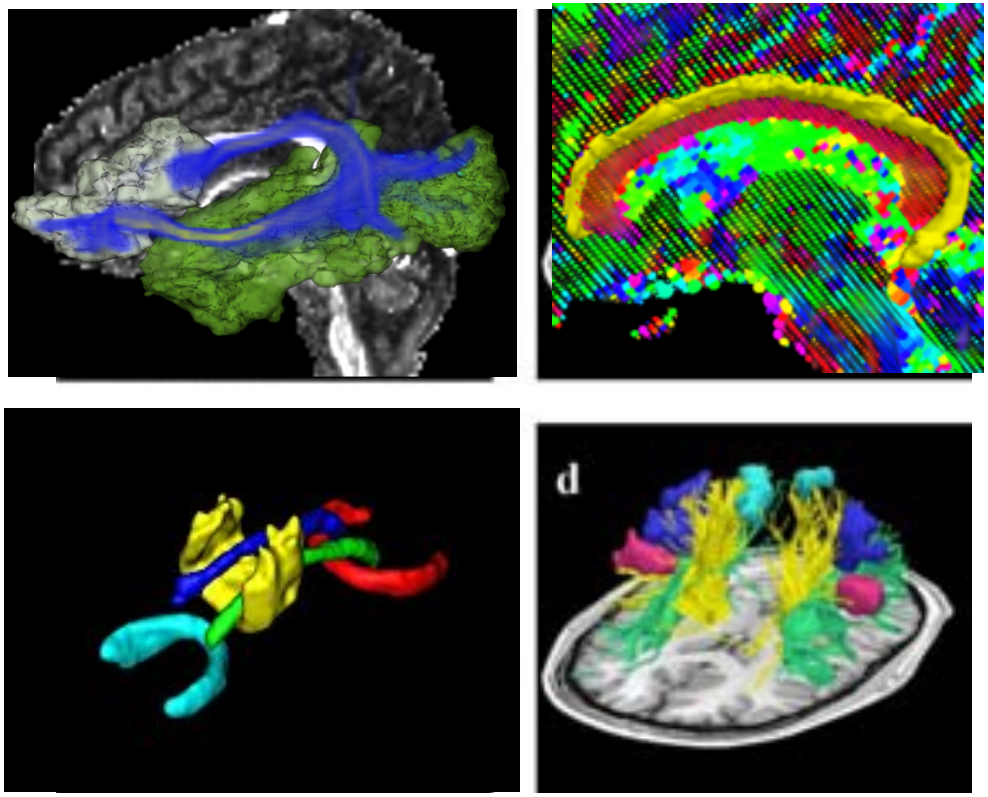




Neurosurgeons face the challenge of selecting the appropriate tractography method

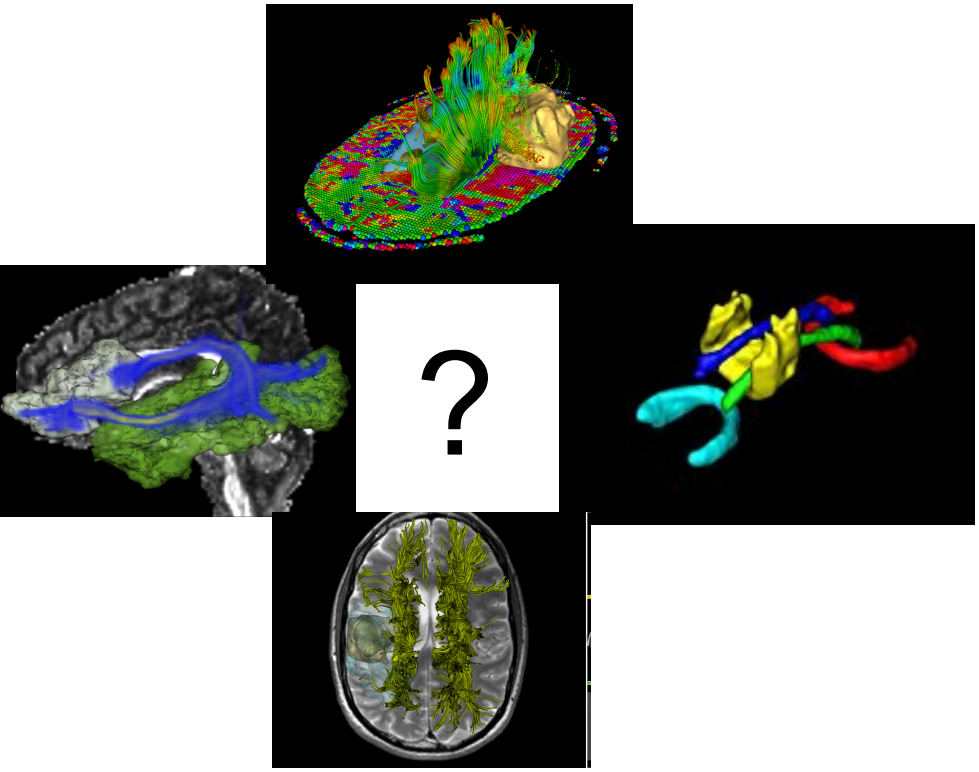
Need for tool comparison

Goal of the workshop



Qualitative and quantitative evaluation of multiple existing tractography algorithms

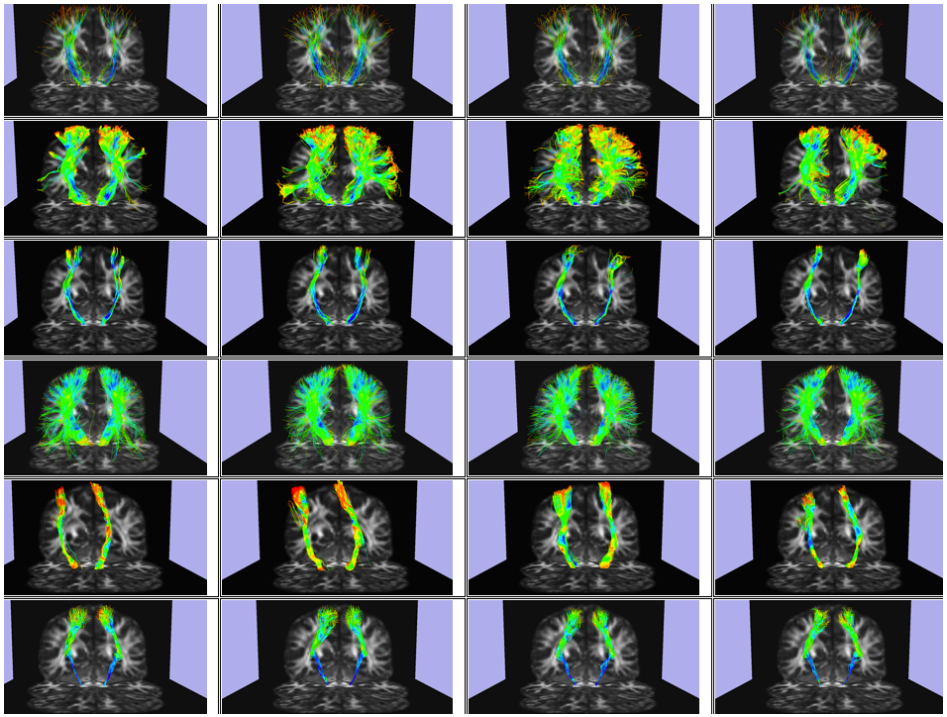
How to compare?



Many degrees of variability

(patient, MR sequence, tumor location, etc..)

How to compare?

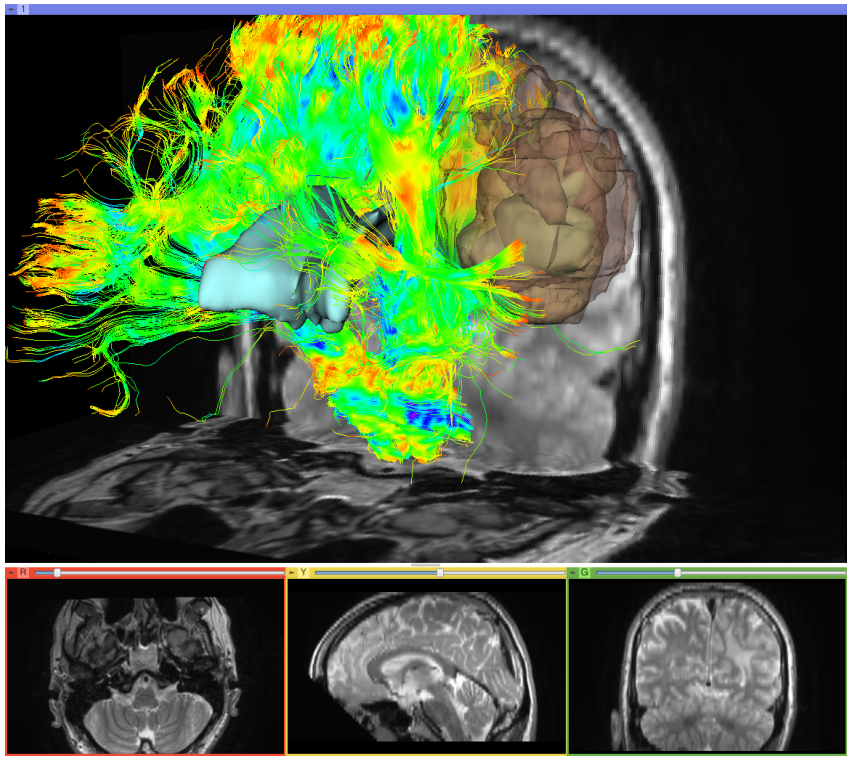


Many degrees of variability

(patient, MR sequence, tumor location, etc..)

Standardized evaluation on a common set of data

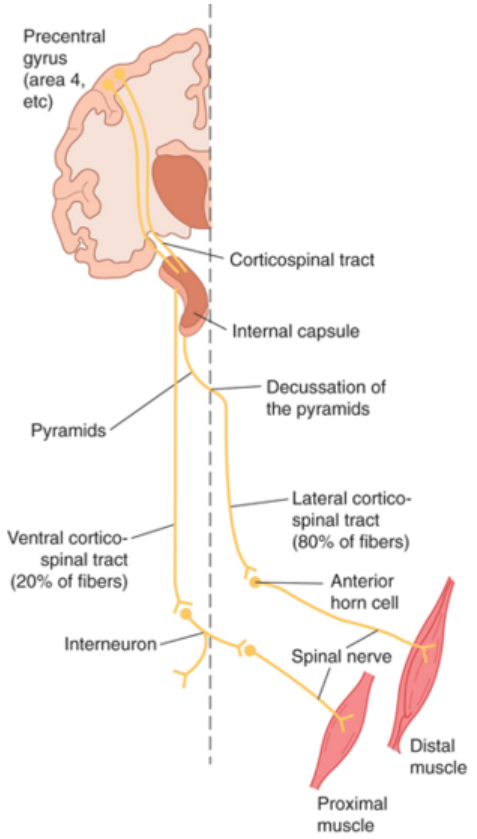
How to compare?



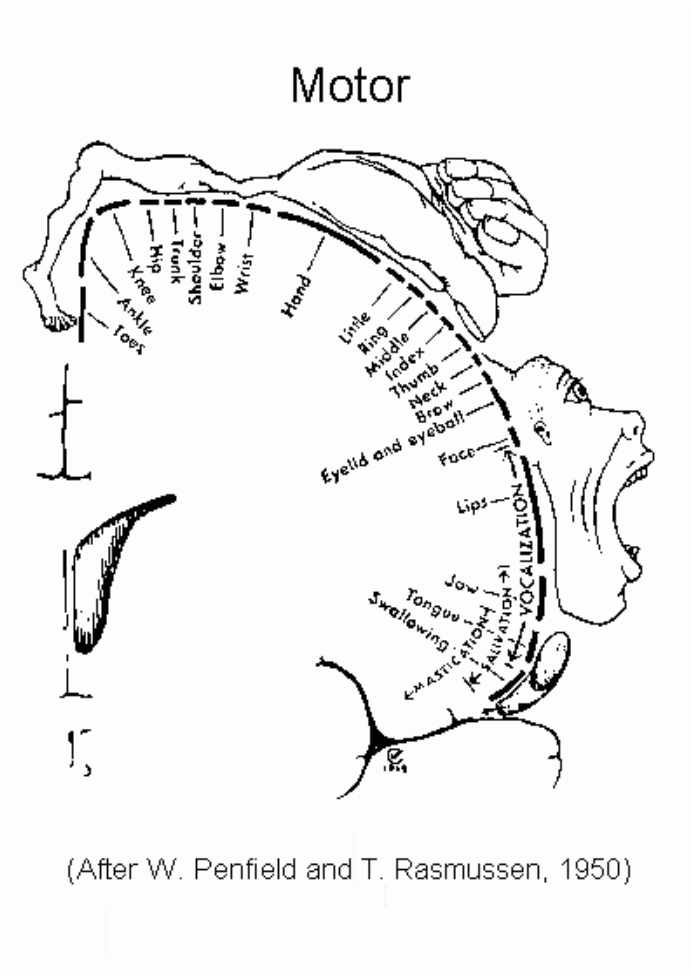
Absence of ground truth

Combination of qualitative and quantitative criteria to get closer to the ground truth

Corticospinal tract



Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology*, 23rd Edition: http://www.accessmedicine.com



(After W. Penfield and T. Rasmussen, 1950)

Workshop datasets

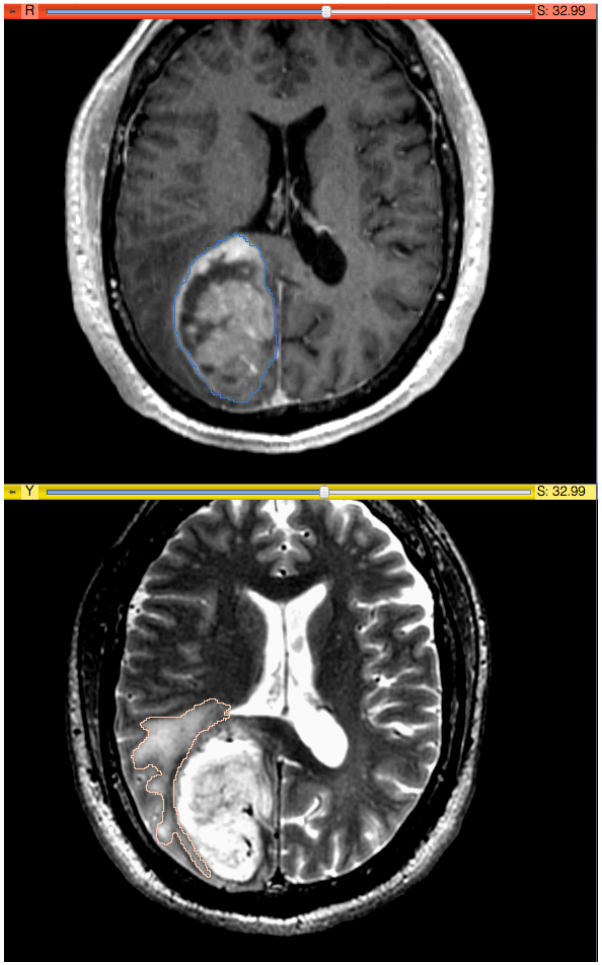
- Four neurosurgical cases involving the CST
  - Patient1: Residual anaplastic olygoastrocytoma
  - Patient2: Anaplastic olygoastrocytoma
  - Patient3: Anaplastic olygodendroglioma
  - Patient4: Glioblastoma grade 4

Cases provided by Dr. Alexandra Golby, neurosurgeon, BWH

- Two healthy subjects scanned twice on 5 different scanners

Datasets provided by Guido Gerig, Ph.D, SCI Utah

Workshop Datasets



- Each dataset included T1-weighted, T2-weighted, Pre-op DWI and DTI
- Manual segmentation of tumor and edema on T1 and T2 images
- Review by expert neuroradiologist

Evaluation Criteria

Two sets of metrics

- Qualitative assessment by clinicians and DTI experts
- Quantitative analysis based on five different metrics

Quantitative evaluation

Metric1: Dice coefficient of overlap

Metric 2: Hausdorff distance

Metric 3: Fiber FA and MD profile along tract

Metric 4: STAPLE sensitivity score

Metric 5: STAPLE specificity score

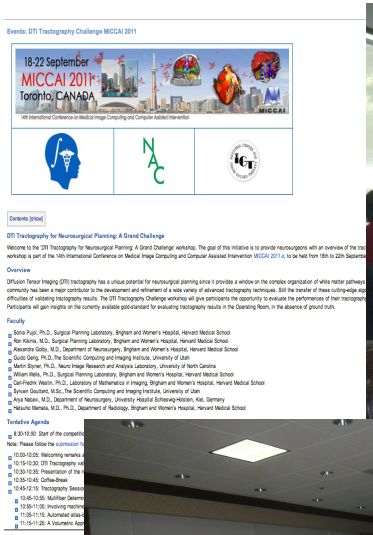
Clinical Evaluation Criteria

C1: Anatomical correctness of the tract
C2: Presence of false positive-tracts
C3: Presence of false negative-tracts
C4: Correct depiction of the distance between the tract and the lesion
C5: Demonstration of tract displacement
C6: Demonstration of tumor infiltration

→ **critical to the neurosurgeon**

MICCAI 2011 Workshop

- 8 international teams
- 10-hour long workshop
- 25 participants
- 352 corticospinal tracts generated
- 5,900 visits on challenge webpage



http://www.na-mic.org/Wiki/index.php/Events:_DTI_Tractography_Challenge_MICCAI_2011

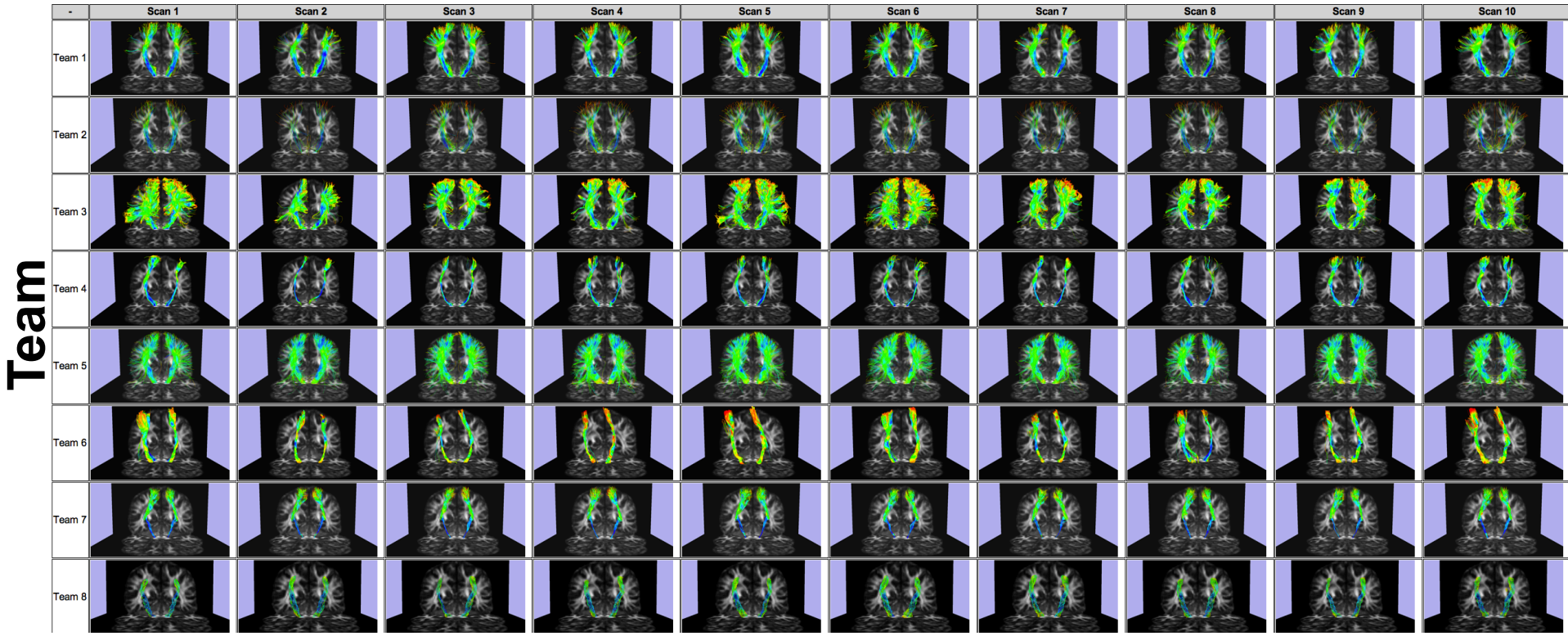
Challenge participants

- UPenn, Philadelphia, USA
- INRIA Rennes, France
- Robarts Research Institute, Toronto, Canada
- Scientific Computing and Imaging Institute, Salt Lake City, USA
- University of Florida, USA
- Laboratory of Mathematics in Imaging, Boston, USA
- German Cancer Research Centre, Heidelberg, Germany
- UNC Chapell Hill, USA

Tractography Algorithms

1. Intrinsic Unscented Kalman Filter
2. Global Fiber tracking based on Finsler Distance
3. Automated Atlas-Based Seeding
4. Machine Learning & Particle Mass based tractography
5. Streamline tractography based on a multi-compartment model
6. Filtered Multi-tensor tractography
7. Volumetric Tractography
8. MITK Global Tractography

Healthy subjects Results



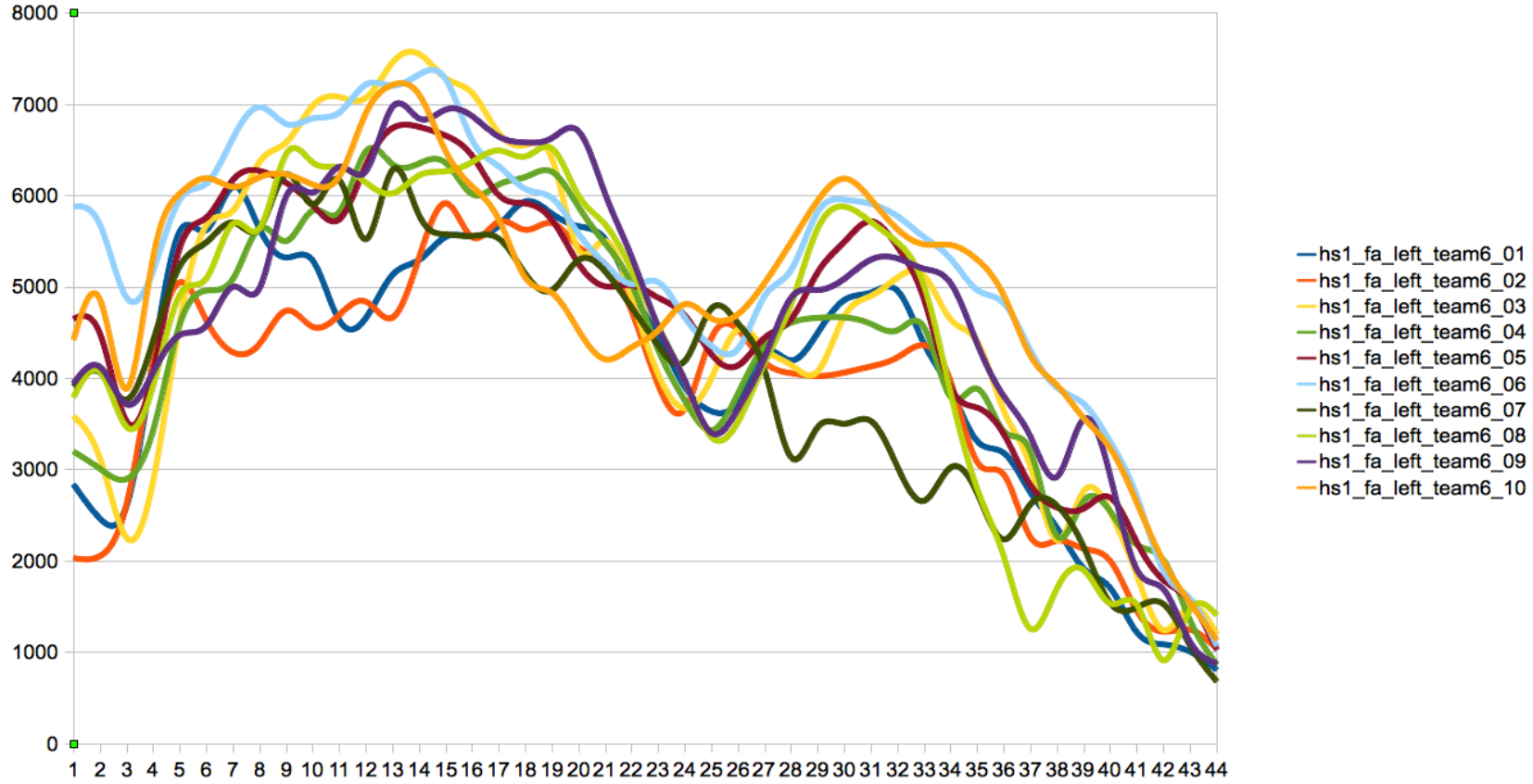
Healthy subjects Results

Team

Scan

Healthy Subject 1 (For each scan, the images show the comparison across teams.)

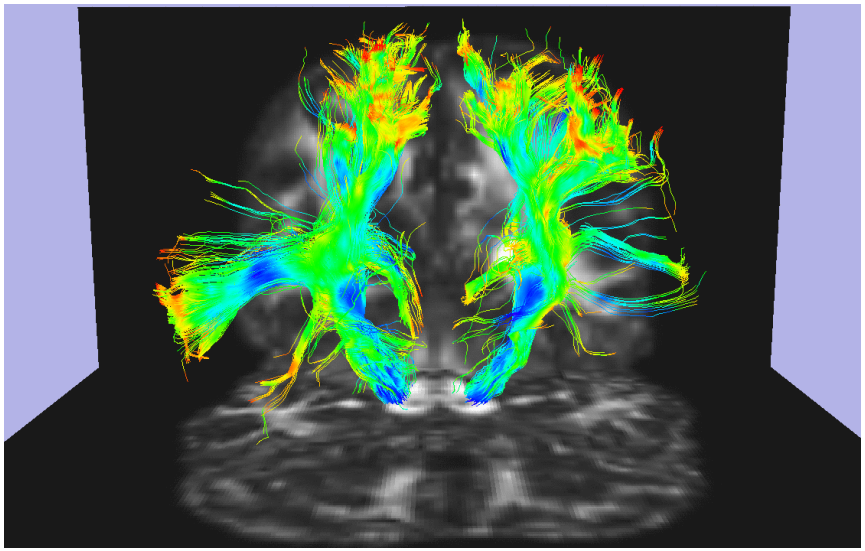
FA profile example



Results

Mean(STD)	Healthy Subject 1	Healthy Subject 2
Dice's coefficient	0.45(0.17)	0.40(0.27)
Hausdorff Distance	1.95(0.97) mm	2.7(2.10) mm
STAPLE sensitivity	0.45(0.09)	0.42(0.08)

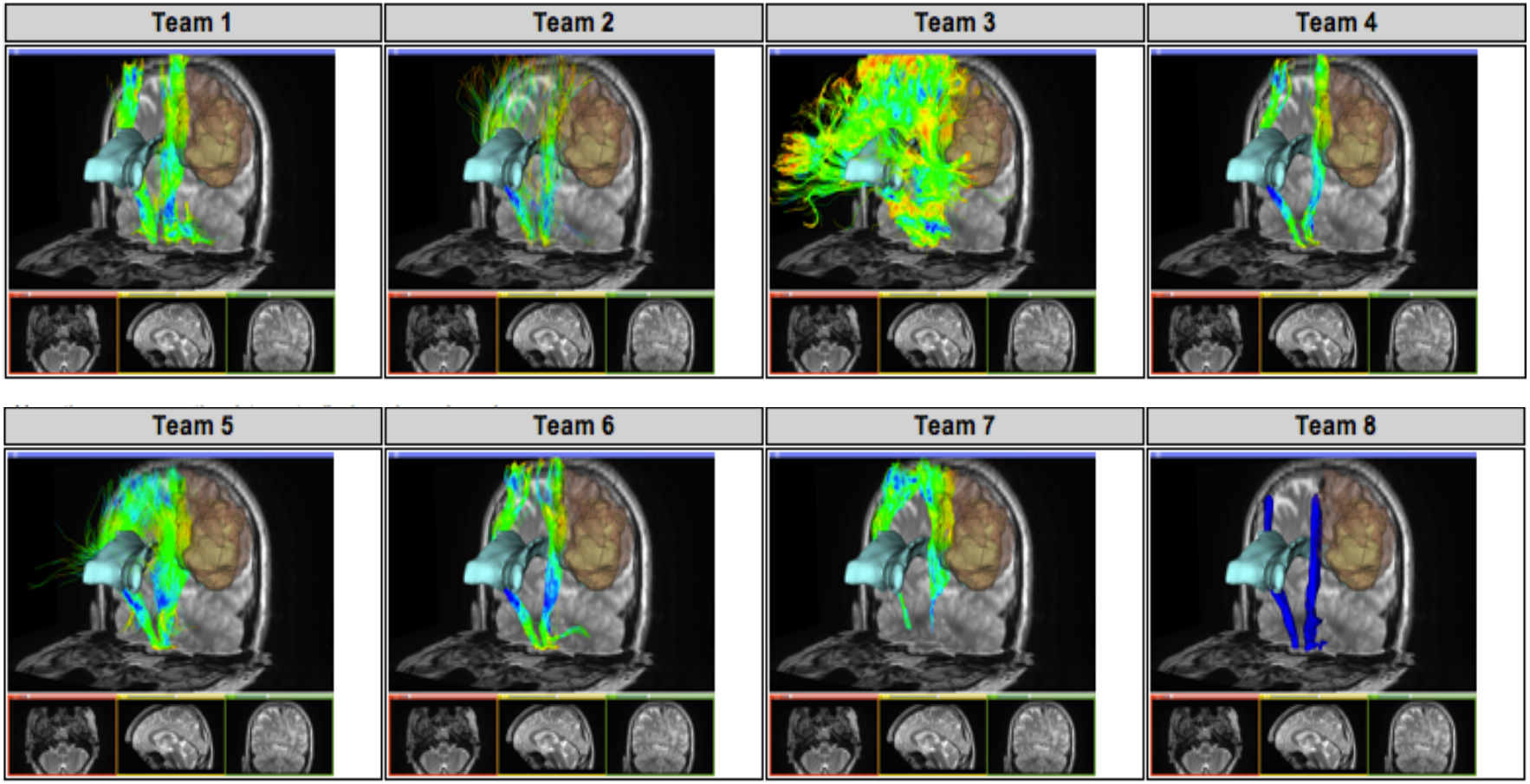
Workshop Outcomes



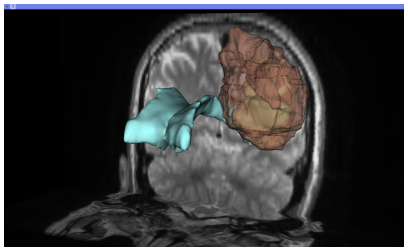
Healthy subject study

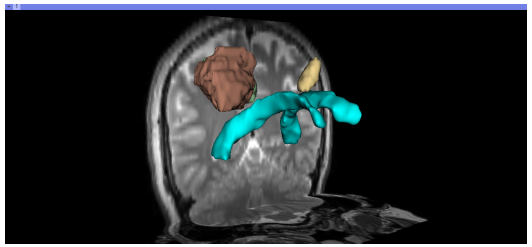
→ large **intra-algorithm** variability

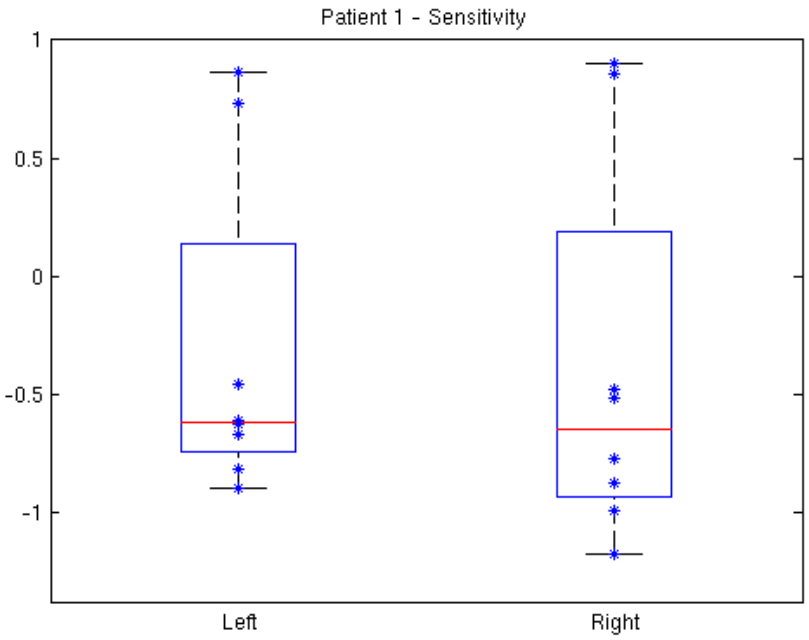
Clinical Cases Results

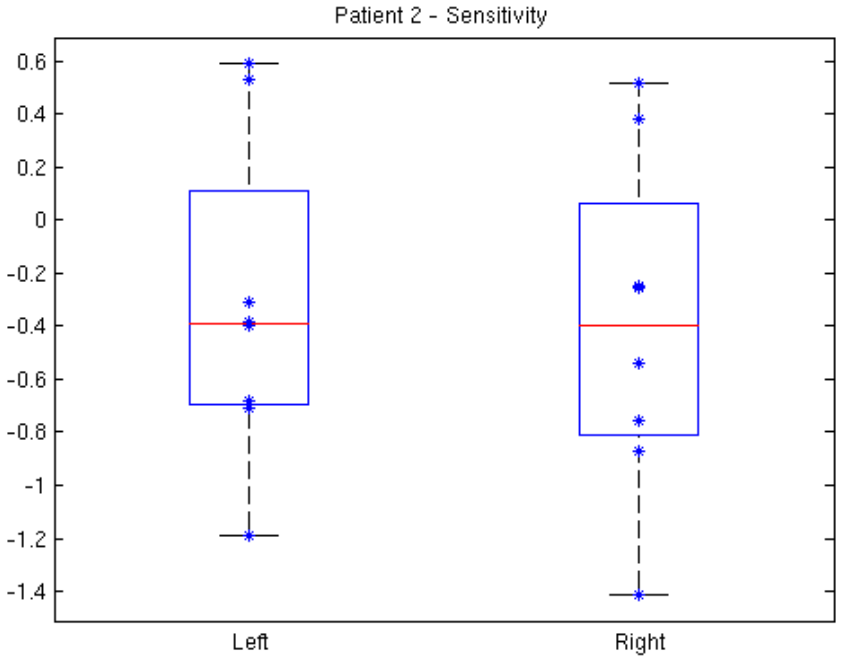


STAPLE results



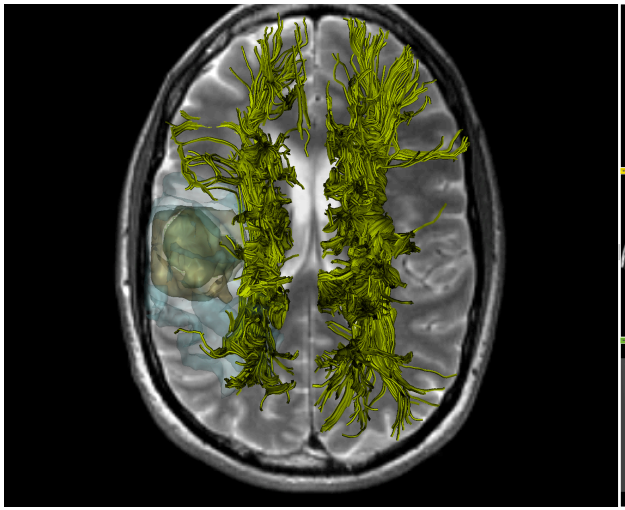
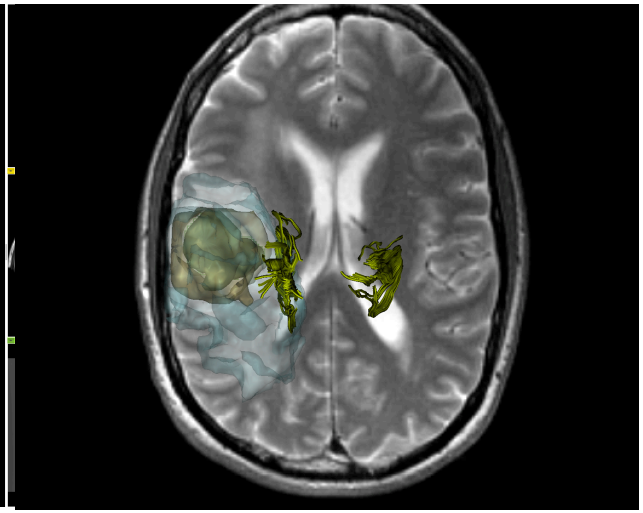
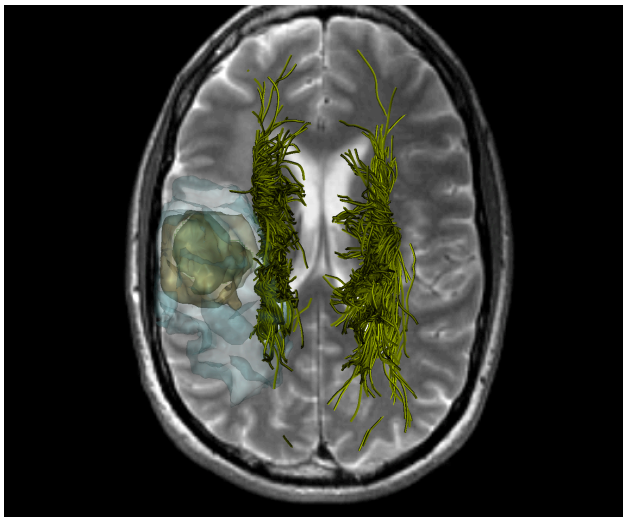




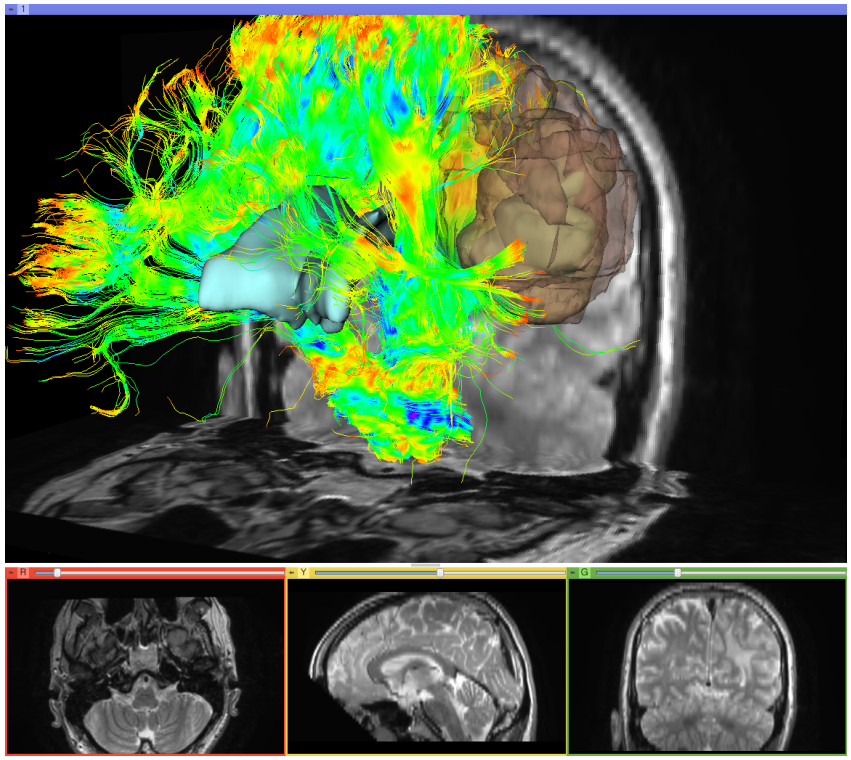


Weak agreement, large inter-algorithm variability

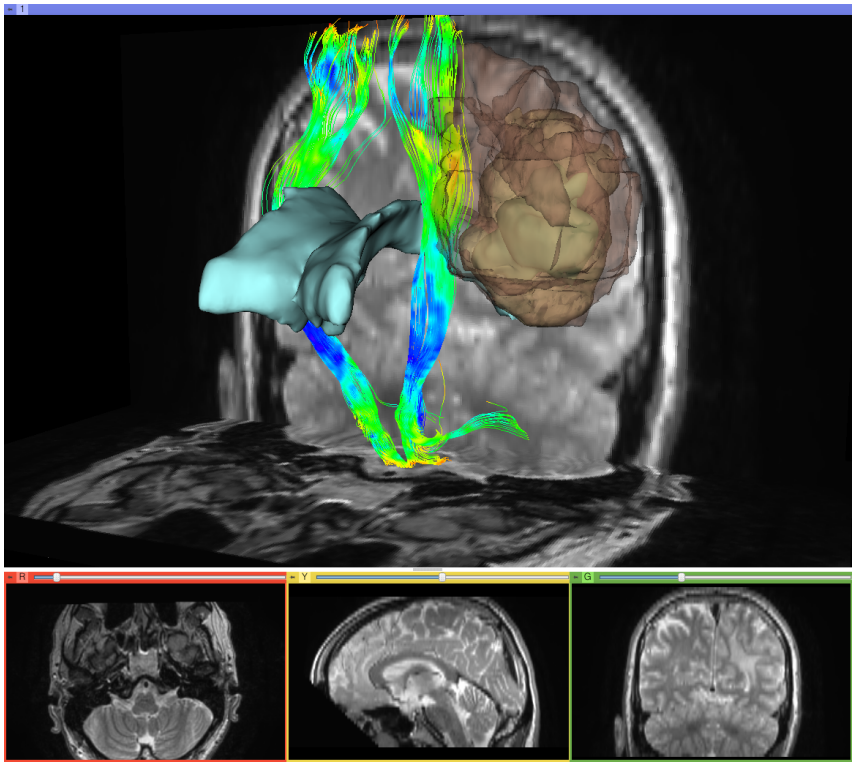
Clinical cases results

CST reconstructions

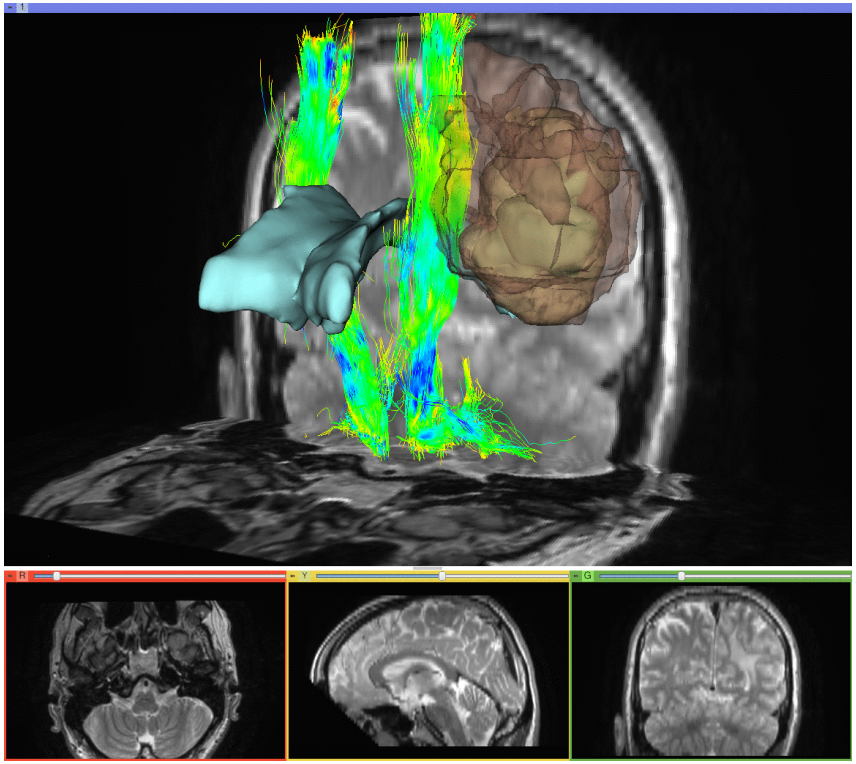


FP



FN

Clinical cases Results



Neurosurgical cases study

→ large **inter-algorithm** variability

Workshop outcomes

- Large variability among tractography methods
- Quantitative metrics selected based on hypothesis of successful targeting of CST
- Opportunity for review and feedback from leading neurosurgeons
- Positive feedback from the MICCAI community

Conclusion: the Challenge is the challenge!

$$\frac{\partial}{\partial x_i}\frac{\partial}{\partial x_k}A$$

$$\frac{\partial}{\partial x_k}\nabla \cdot \vec{A} = \nabla^2 A_k + \frac{1}{c}\frac{\partial}{\partial x_k}\frac{\partial}{\partial t} + \frac{1}{c^2}\frac{\partial}{\partial t^2} = \frac{4\pi}{c}J_k$$

$$-\nabla^2 A_k + \frac{1}{c^2}\frac{\partial^2 A_k}{\partial t^2} + \frac{\partial}{\partial x_k}\left(\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial \phi}{\partial t}\right) = \frac{4\pi}{c}J_k$$

$$-\nabla^2 \vec{A} + \frac{1}{c^2}\frac{\partial^2 \vec{A}}{\partial t^2} + \vec{\nabla}\left(\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial \phi}{\partial t}\right) = \frac{4\pi}{c}\vec{J}$$

```
domtk::logAsplus::Logger rootLo
rootLogger.setLogLevel(Context

QApplication app(argc, argv);

app.setOrganizationName("commo
app.setOrganizationDomain("com
app.setApplicationName("ctkDICO

QSettings settings;
QString databaseDirectory;

// set up the database
if (argc > 1)
{
  QString directory(argv[1]);
  settings.setValue("DatabaseDirectory", directory);
  settings.sync();
}

if ( settings.value("DatabaseDirectory", "") == "" )
{
  databaseDirectory = QString("./ctkDICOM-Database");
  std::cerr << "No DatabaseDirectory on command line or in settings.  Using \"" << databaseDirectory.toLatin1().data() << "\".\n";
} else
{
  databaseDirectory = settings.value("DatabaseDirectory", "").toString();
}
```

Algorithm Development

GAP

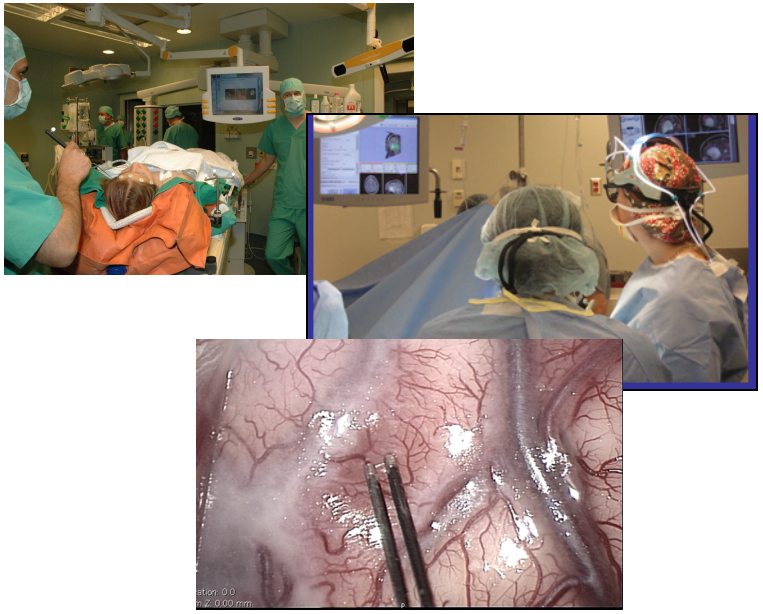


Image courtesy of Arya Nabavi, MD

Problem solving

Bridging the gap

- After the challenge, each team received a 14-page document containing the qualitative evaluation by the clinical and DTI experts, and the values of the quantitative metrics
- Participants were invited to re-process the data using the reviewers' feedback

Bridging the Gap

$$\frac{\partial}{\partial x_i}\frac{\partial}{\partial x_k}A$$

$$\frac{\partial}{\partial x_k}\nabla\cdot\vec{A} = \nabla\cdot\vec{A}_k + \frac{1}{c}\frac{\partial}{\partial x_k}\frac{\partial}{\partial t} + \frac{1}{c^2}\frac{\partial}{\partial t^2} = \frac{}{c}\vartheta_k$$

$$-\nabla^2 A_k + \frac{1}{c^2}\frac{\partial^2 A_k}{\partial t^2} + \frac{\partial}{\partial x_k}\left(\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial\phi}{\partial t}\right) = \frac{4\pi}{c}J_k$$

$$-\nabla^2\vec{A} + \frac{1}{c^2}\frac{\partial^2\vec{A}}{\partial t^2} + \vec{\nabla}\left(\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial\phi}{\partial t}\right) = \frac{4\pi}{c}\vec{J}$$

```
domtk::logAsplus::Logger rootLo
rootLogger.setLogLevel(ctkAbst

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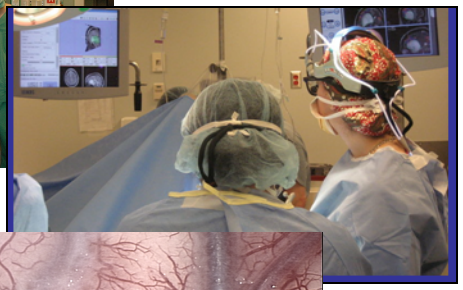

Image courtesy of Arya Nabavi, MD

DTI Challenge: Conclusion

- Appropriate reflection of the current state of the art in the field
- Submission to MICCAI 2012
- On-going learning effort for the community