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Fraunhofer
MEVIS



Universität Bremen

Translational Research in the Field of Medical Image Computing and Computer Assisted Intervention

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-
- Founding Director, Surgical Planning Laboratory, Brigham and Women's Hospital
 - Institutsleiter, Fraunhofer MEVIS
 - Principal Investigator, National Alliance for Medical Image Computing, and Neuroimage Analysis Center,
 - Research Director, National Center for Image Guided Therapy

Acknowledgments



National Alliance for Medical Image Computing

www.na-mic.org

- Ferenc Jolesz, MD, my mentor
- Collaborators and colleagues



Neuroimage Analysis Center

nac.spl.harvard.edu



**Surgical Planning Laboratory,
Brigham and Women's Hospital**

spl.harvard.edu



National Center For Image Guided Therapy

www.ncigt.org

Introduction

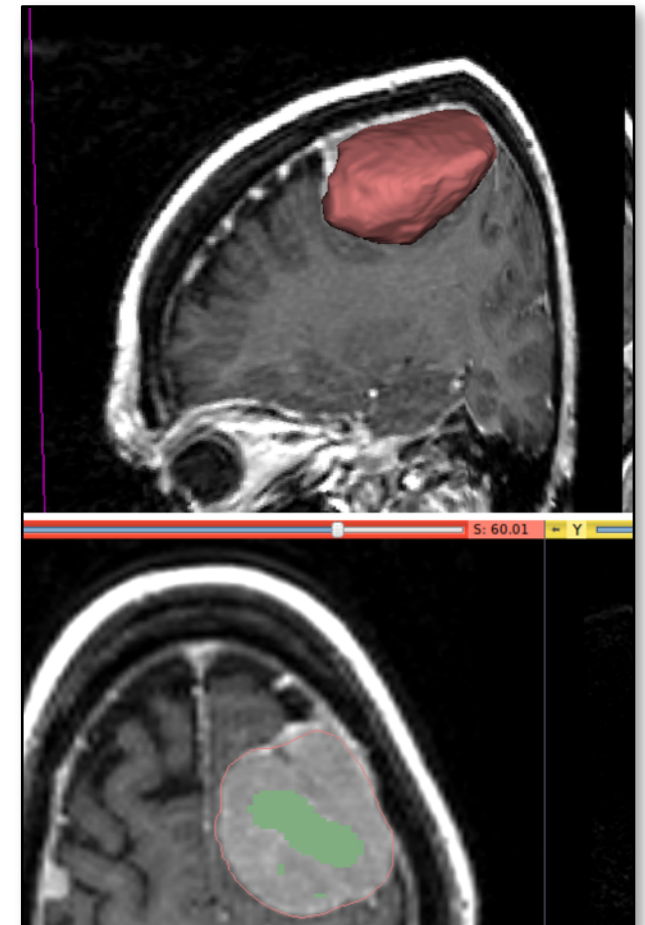
- **Medical Image Computing**
- 3D Slicer
- NA-MIC
- Open source

What is MIC

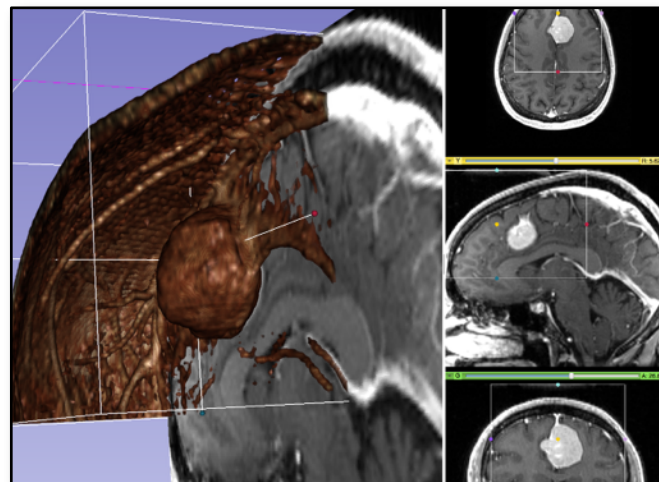
- Goal: extraction of clinically relevant information and knowledge from medical images using computational methods such as:
 - image segmentation
 - image registration
 - image-based physiological modeling
 - visualization

<http://wiki.slicer.org/slicerWiki/index.php/Documentation/Nightly/Modules/RobustStatisticsSegmenter>

result



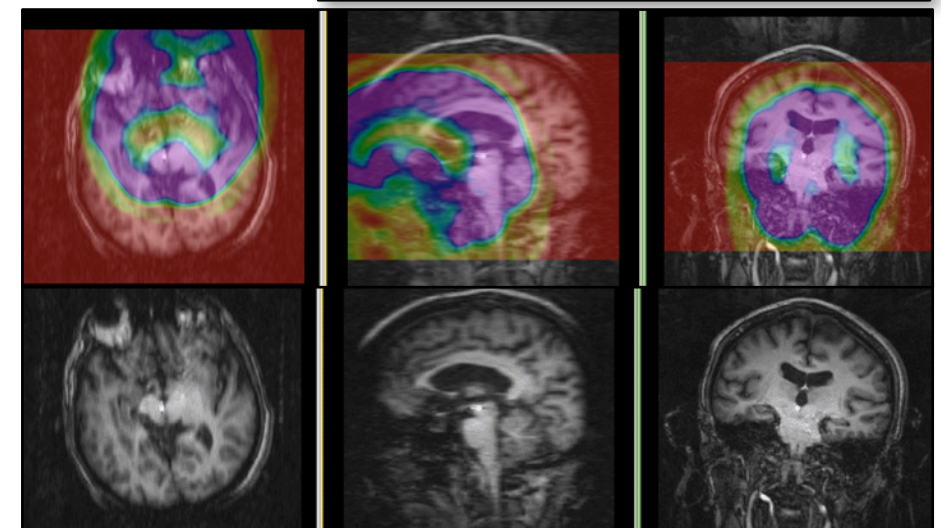
initialization



Volume rendering

before

after

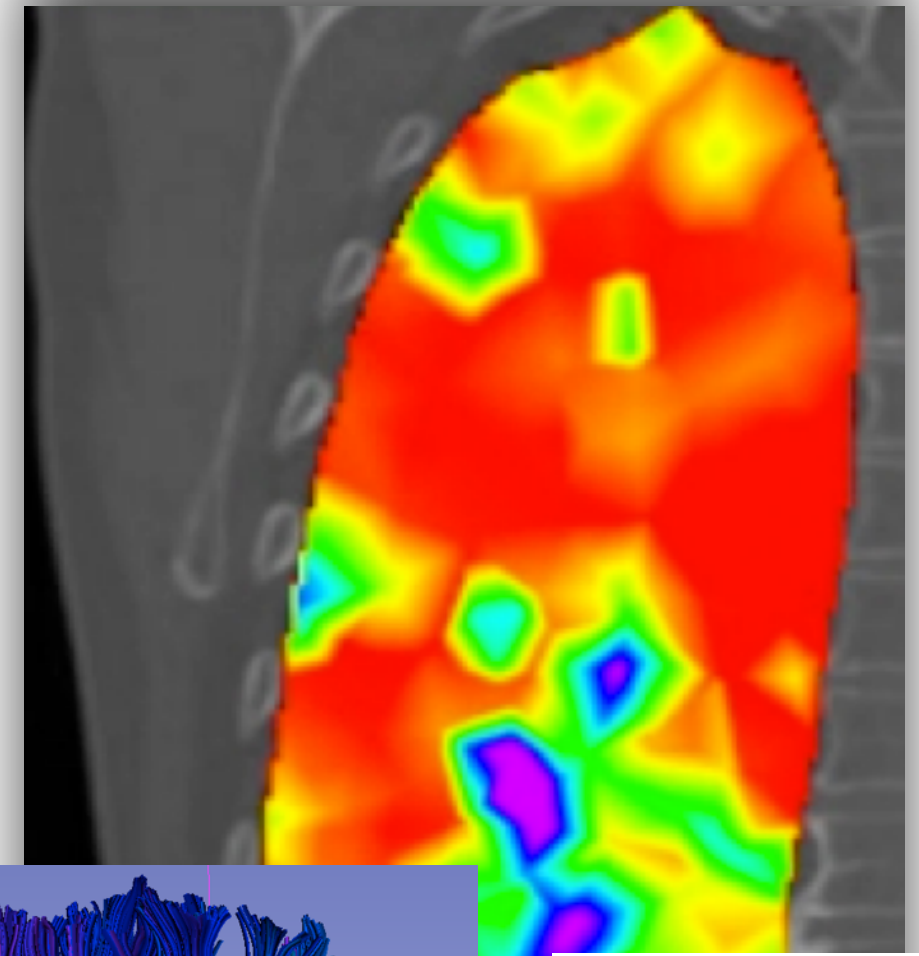


http://wiki.slicer.org/slicerWiki/index.php/Documentation/Nightly/Registration/RegistrationLibrary:RegLib_C14

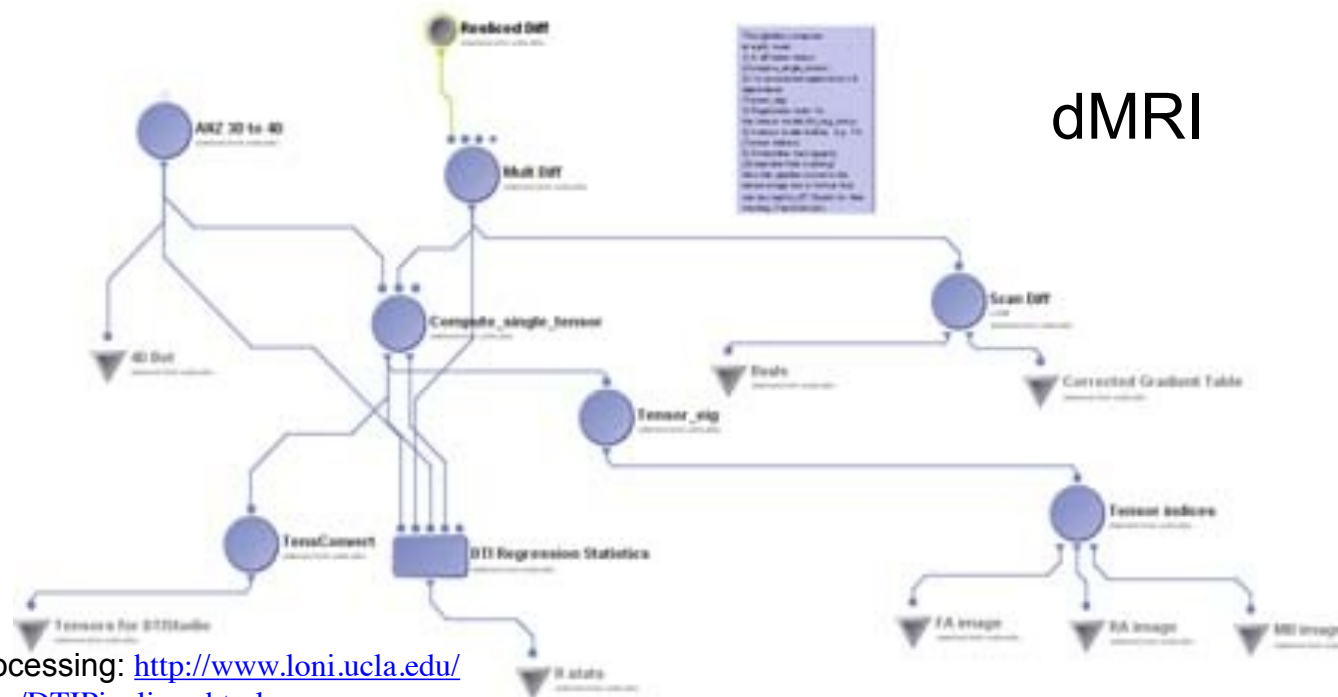
Increasing Importance of MIC

- **More data:**
gigabytes to terabytes
- **More complexity**
fMRI, parametric maps, dMRI,
4D ultrasound
- **More applications**
Discovery, Diagnosis
Therapy monitoring

Parametric map of emphysema severity



Risholm P., et al.
*Probabilistic
Elastography:
Estimating Lung
Elasticity*. Inf Process
Med Imaging.
2011;22:699-710.
PMID: 21761697.



DTI processing: <http://www.loni.ucla.edu/~ophillip/DTIPipelines.html>

From Research To Clinical Tools

Questions and answers

- Can it be done?
 - Prototypes
- **Is it worth doing?**
 - Tools
- Standard of care
 - Commercially available clinical “devices” with regulatory approval

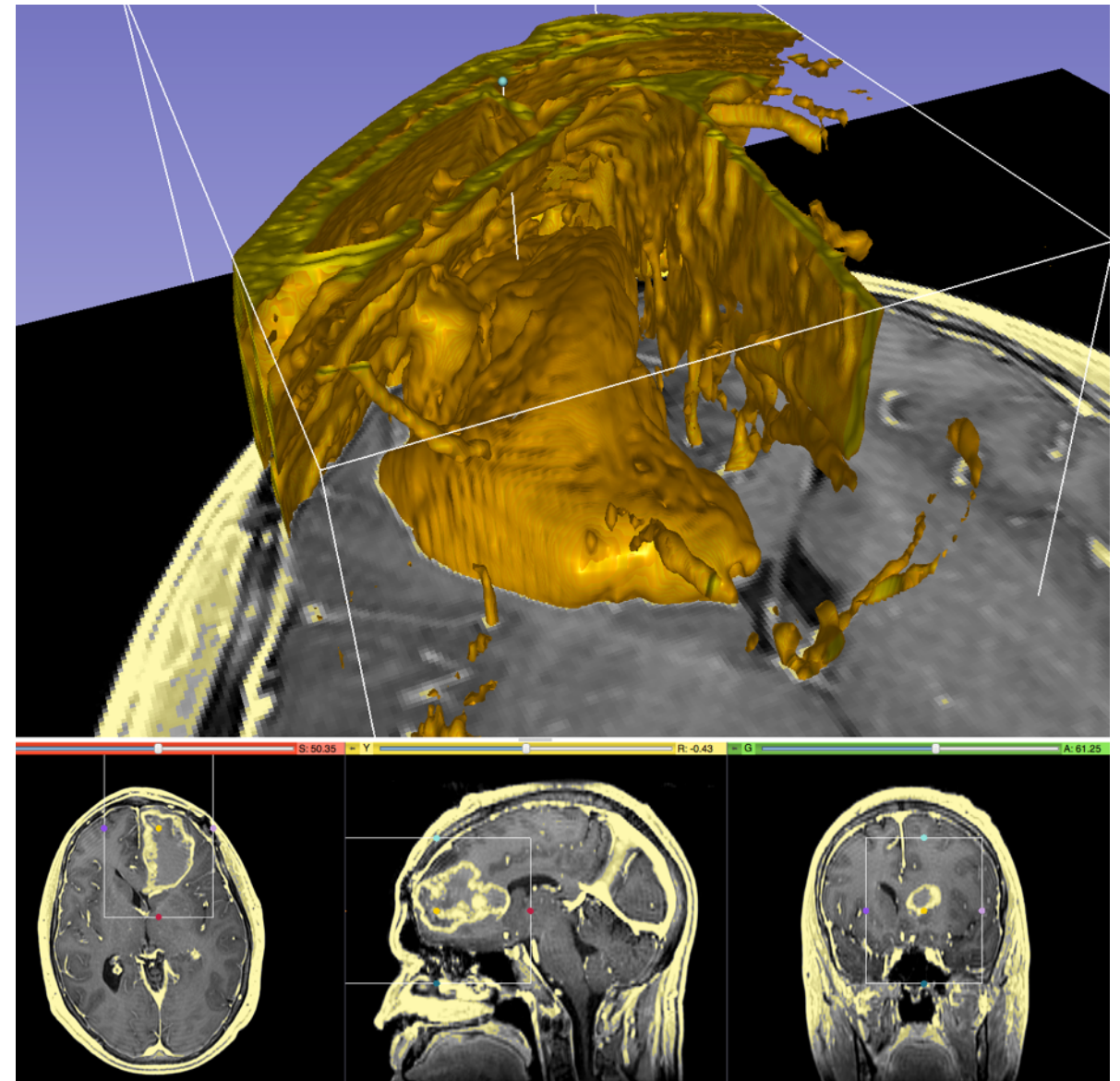
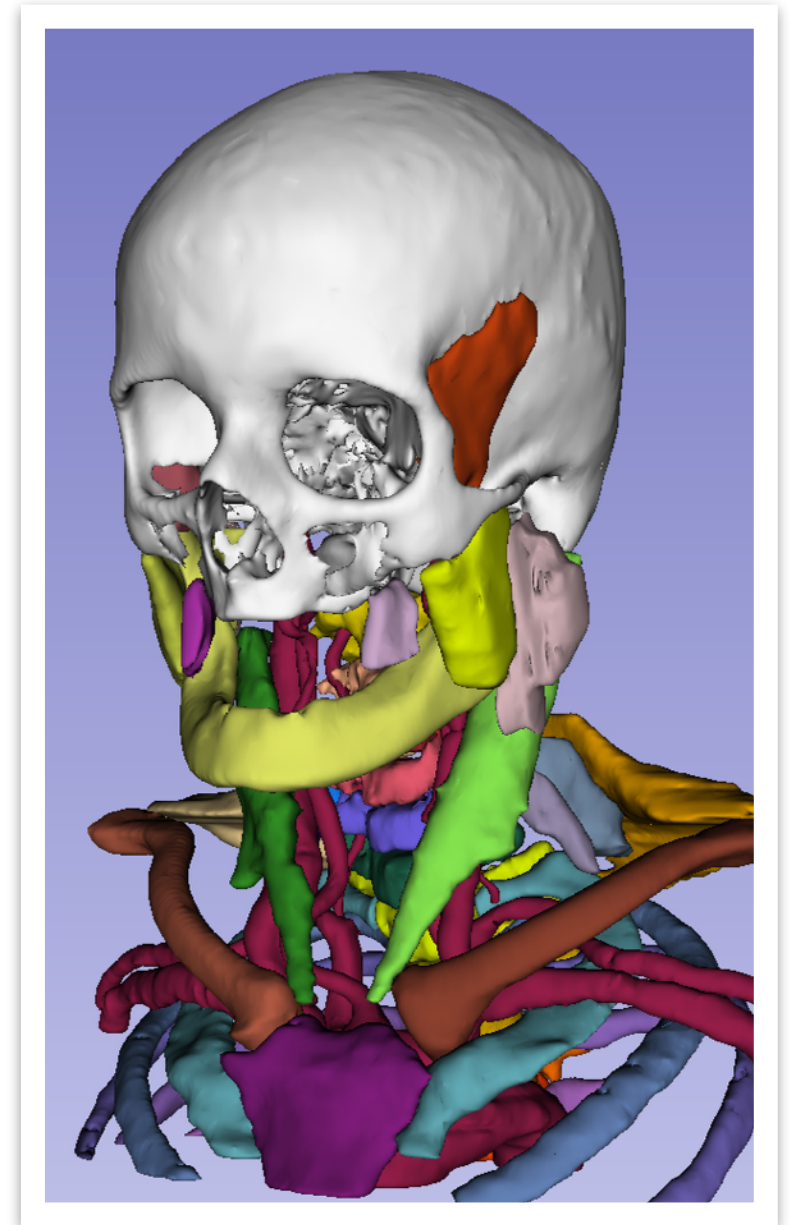


Image provided by R. Kikinis

Translation Requires Tools

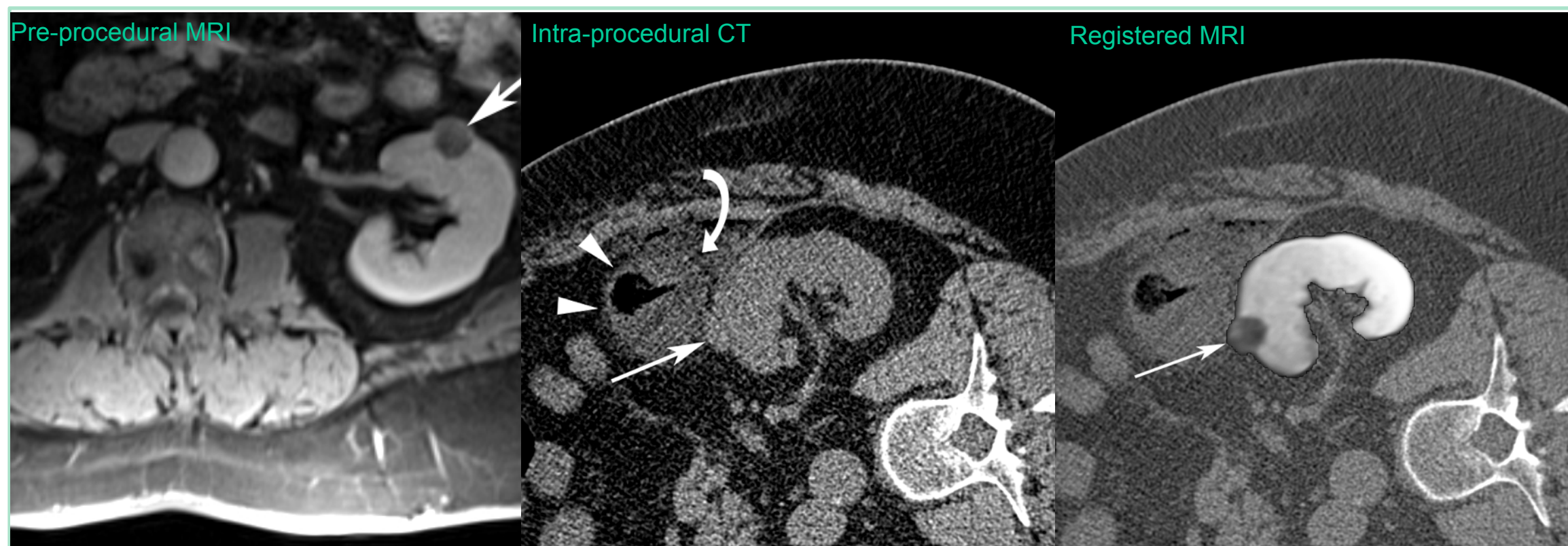
- A **prototype** works for the grad student's thesis
 - Not portable
 - Unstable, no support
- A **tool** works in your environment
 - Easy to install
 - Easy to use
 - Stable, supported
- Significant resources are needed to get from a prototype to a tool



The Valley of Death

The translation pipeline is failing to create tools enabling biomedical research

- Scientist: Tools do not help academic promotion
- Funding agencies: Toolmaking is not innovative
- Companies: not proven, it is too risky

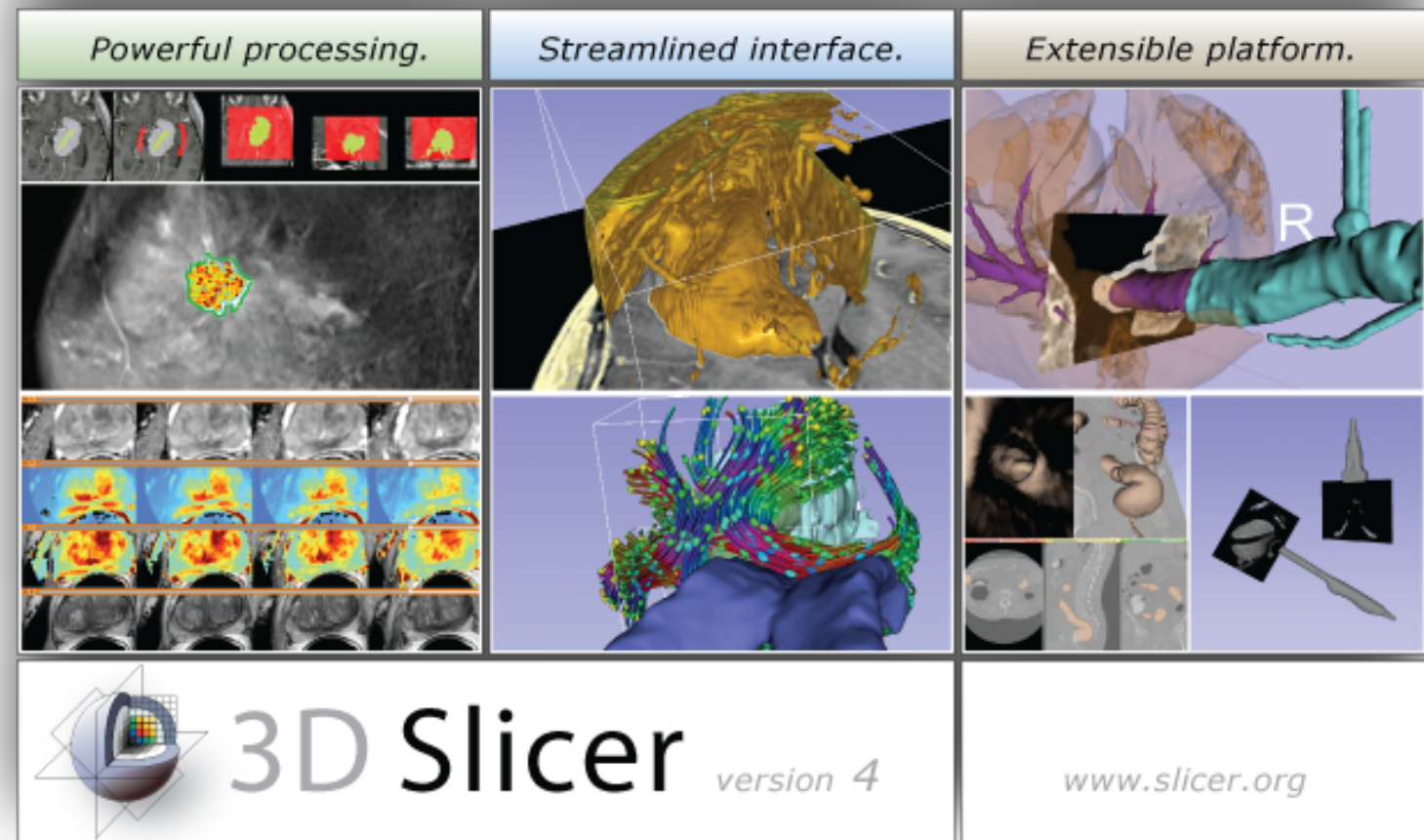


Introduction

- Medical Image Computing
- **3D Slicer**
- NA-MIC
- Open source

3D Slicer

- An end-user application
- A platform for delivering software tools
- Targets subject specific analysis

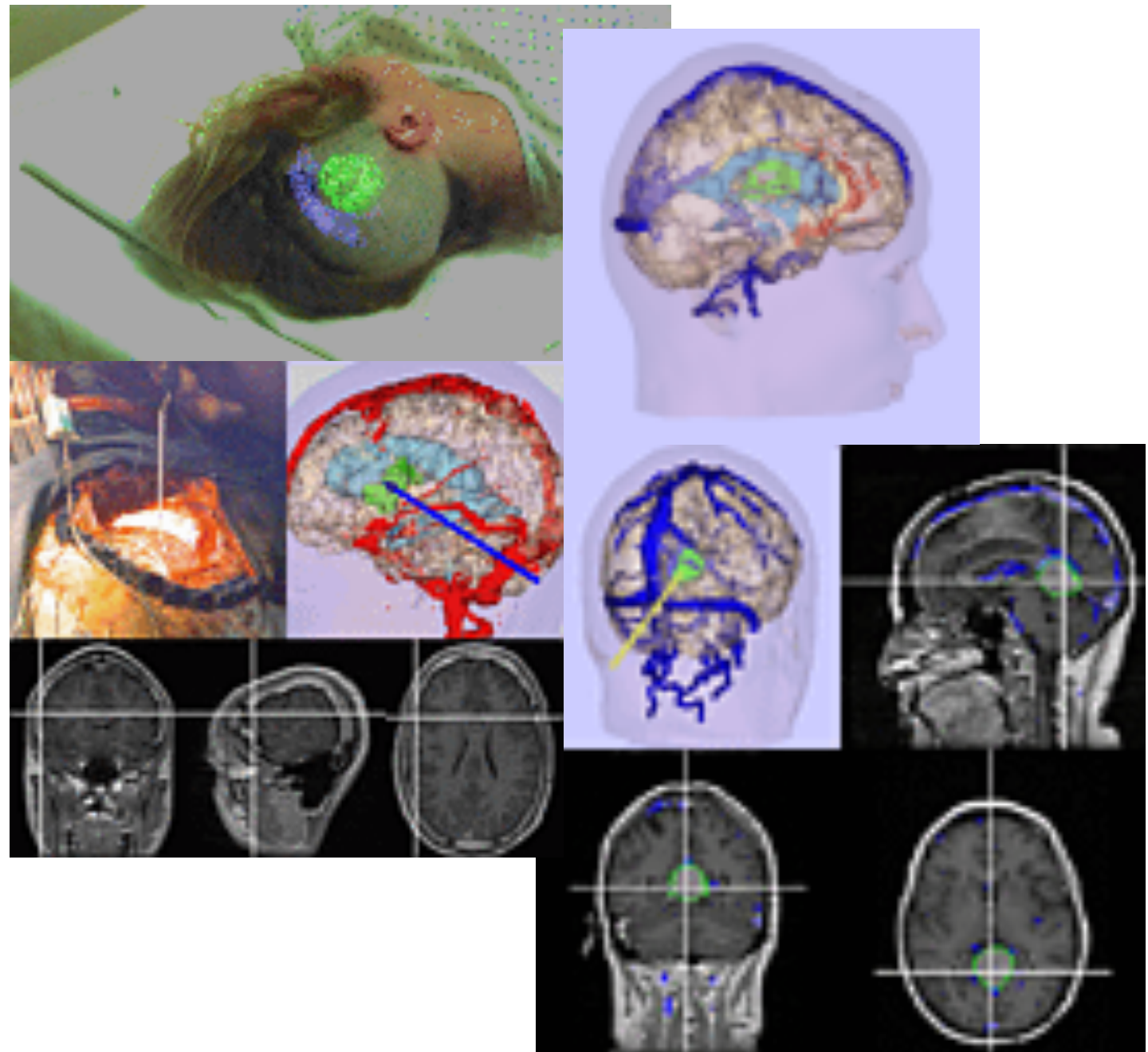


- Free open source software
 - Enables scientific collaboration
 - License allows painless translation to proprietary clinical tools
- Well-engineered high-performance core
 - Software engineering methodology, multi-platform
- Many options for extensions
- Fully leverages the NA-MIC Kit




3D Slicer History

1997: Slicer started as the masters thesis of David Gering, a collaboration between the Surgical Planning Lab (Harvard) and the CSAIL (MIT)



3D Slicer Today

- Multi-institution effort
- Professionally engineered core



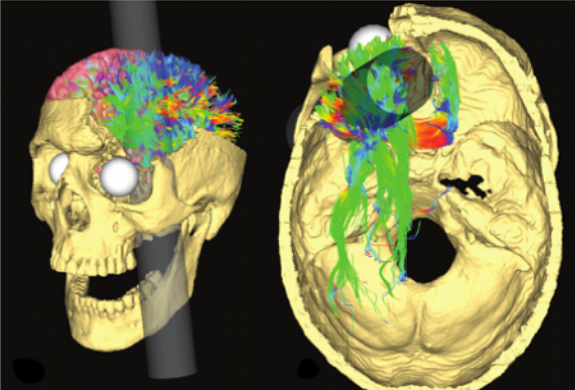
National Alliance for Medical Image Computing

A National Center for Biomedical Computing
Funded under the NIH Roadmap Initiative

Google Custom Search

NA-MIC Wiki

- General
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- Center Components
 - Algorithms
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 - Driving Biological Projects
 - Collaboration Grants
- Resources
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The 98th Annual Meeting of the Radiological Society of North America will be held on November 25-30, 2012 at McCormick Place, in Chicago, IL. RSNA is an international society of radiologists, medical physicists and other medical professionals with more than 50,000 members across the globe.

[Read more...](#)

[NEWS ARCHIVE](#)


Modeling the path of the tamping iron through the Gage skull and its effects on white matter structure [Read more...](#)

1 of 24 Photos

The National Alliance for Medical Image Computing (NA-MIC) is a multi-institutional, interdisciplinary team of computer scientists, software engineers, and medical investigators who develop computational tools for the analysis and visualization of medical image data. The purpose of the Center is to provide the infrastructure and environment for the development of computational algorithms and open-source technologies, and then oversee the training and dissemination of these tools to the medical research community.

Supported by the National Institutes of Health, [Roadmap Initiative](#).

Information about collaborating with NA-MIC is available [on our wiki](#).



Neuroimage Analysis Center

"understanding the human brain through imaging"

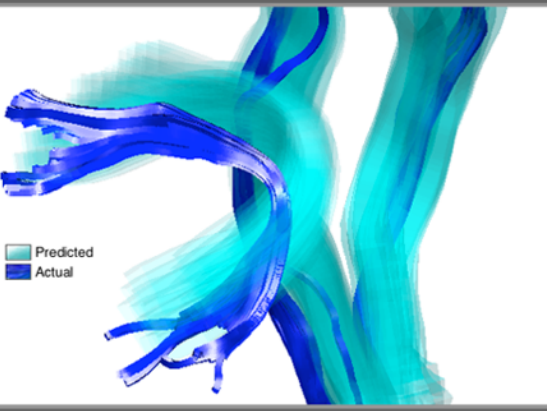
Google Custom Search

About the NAC

- Overview
- Organization
- Research Cores
- Collaborations

Resources

- Contact Us
- Publication DB
- Image Gallery
- Downloads
- Training
- Web Archive



Predicted
Actual

fMRI-DTI Modeling via Landmark Distance Atlases for Prediction and Detection of Fiber Tracts


Leave-one-out prediction of tract location according to the landmark distance atlas (LDA). Each subject's fMRI activation peaks and anatomic landmarks, plus the leave-one-out LDA from the other subjects, were used to predict the location of the AF, left CST, and right CST. The true structures for each subject are shown in dark blue, and the 68% confidence interval for the predicted trajectory is shown in transparent cyan. These results provide an alternative visualization of the data in the learned landmark distance model and they demonstrate reasonable model generalization to novel subjects.


[More...](#)

[Featured Image Archive](#)

The Neuroimage Analysis Center (NAC) develops image processing and analysis techniques for basic and clinical neurosciences. The NAC research approach emphasizes both specific core technologies and collaborative application projects. The activities of the NAC are centered at the Harvard Medical School and the Surgical Planning Laboratory at the Brigham and Women's Hospital in Boston, with collaborators throughout the United States and the rest of the world.

The NAC is a major research center supported by the National Center for Research Resources (through December 2011) and the Institute of Biomedical Imaging and Bioengineering (NIBIB), components of the National Institutes of Health.





National Center for Image-Guided Therapy

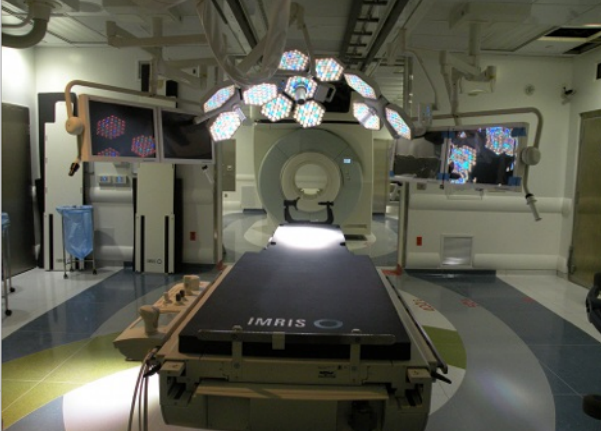
NCIGT Wiki

About Us

- Overview
- Research Labs
- Research Cores
- Research Projects
- DBPs
- People

Resources

- Publication DB
- Image Gallery
- Downloads
- AMIGO
- News and Events
- Contact Us



Advanced Multimodality Image Guided Operating (AMIGO) Suite

The Advanced Multimodality Image Guided Operating (AMIGO) Suite is an innovative surgical and interventional environment that is the clinical translational test bed of the National Center for Image-Guided Therapy (NCIGT) at the Brigham and Women's Hospital (BWH) and Harvard Medical School. The AMIGO is an integrated, 5,700 square foot area divided into three sterile procedure rooms in which a multidisciplinary team will treat patients with the benefit of intra-operative imaging using multiple modalities. [More...](#)

[Featured Image Archive](#)

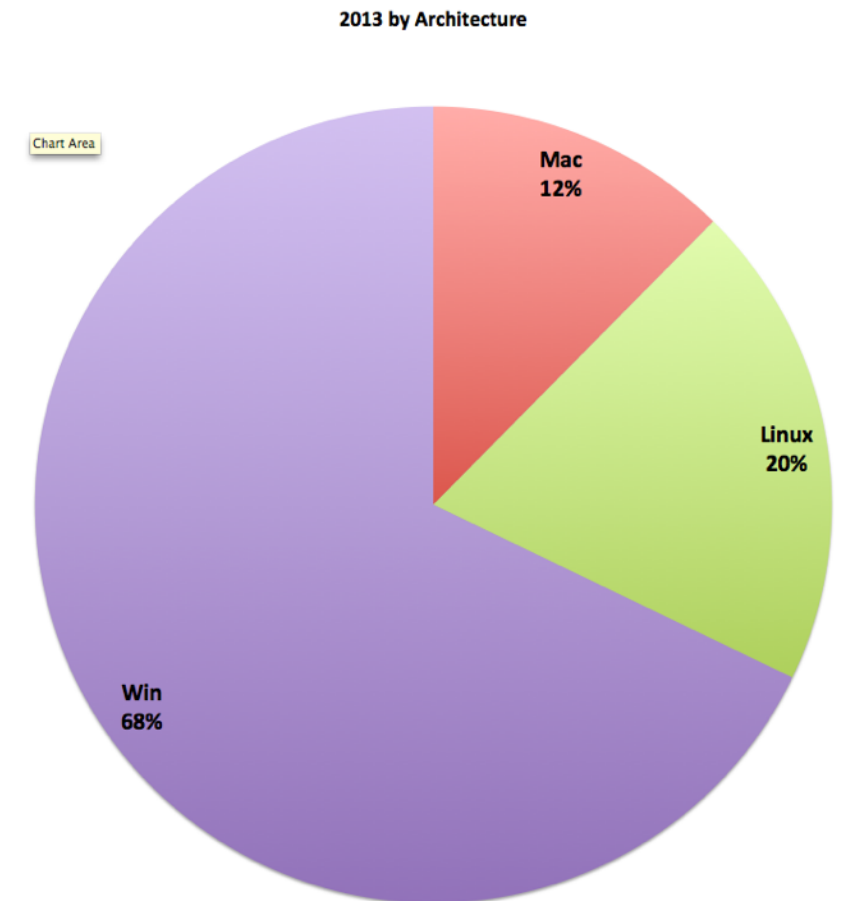
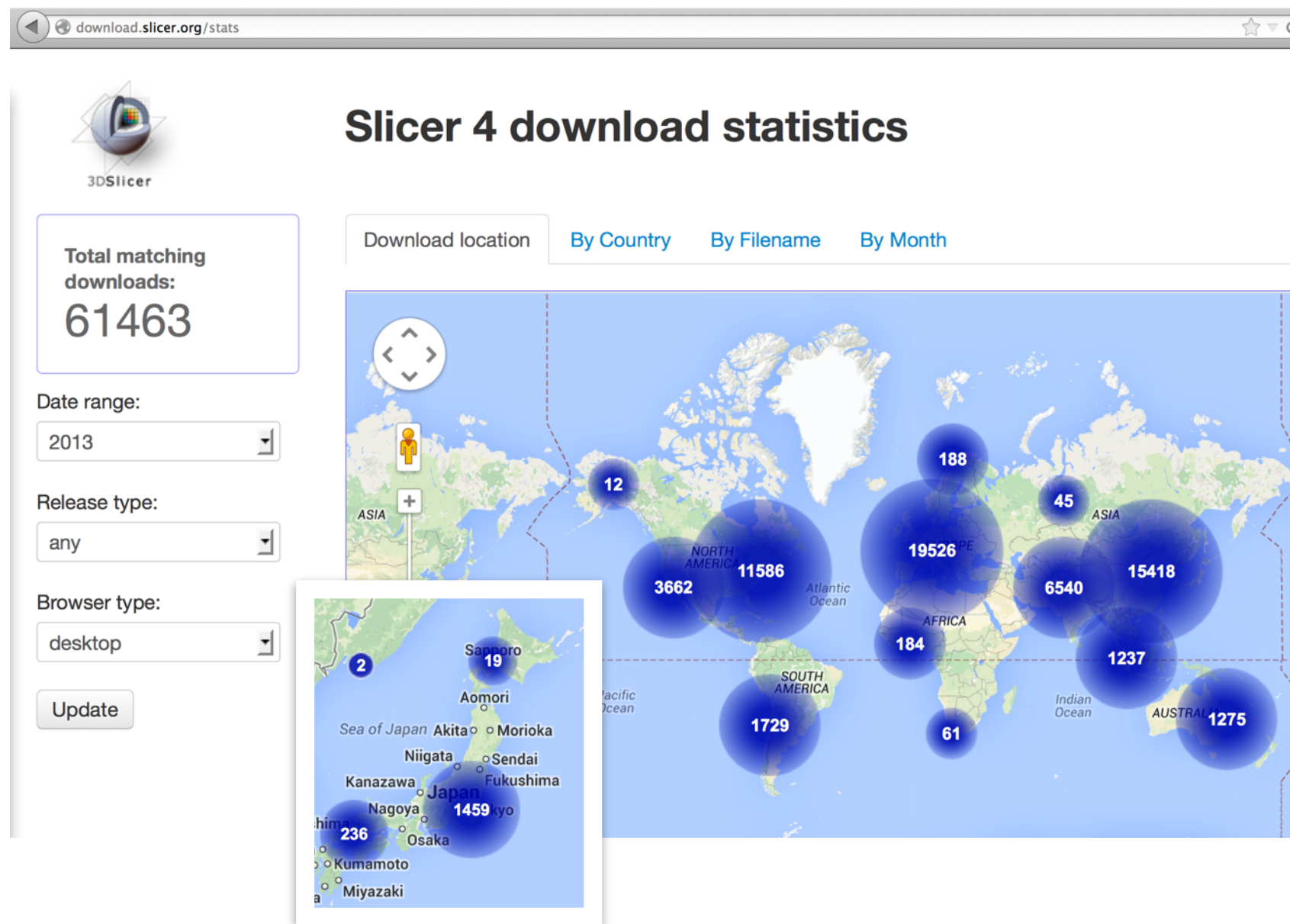
The National Center for Image Guided Therapy (NCIGT) is a Biomedical Technology Resource Center supported by the [NCRR](#) and [NIBIB](#) institutes of the [NIH](#). The NCIGT serves as a national resource for all aspects of research into medical procedures enhanced by imaging, with the common goal of providing more effective patient care.

Based at the Brigham and Women's Hospital and Harvard Medical School in Boston, Massachusetts, the NCIGT is lead by Ferenc A. Jolesz M.D. and Clare Tempany M.D. and includes the work of more than one hundred physicians, scientists, and technical staff members. Download a movie (80MB) [here](#) about the NCIGT team work.

PI: Ron Kikinis, M.D.

PIs: Ferenc Jolesz, M.D., Clare Tempany, M.D.

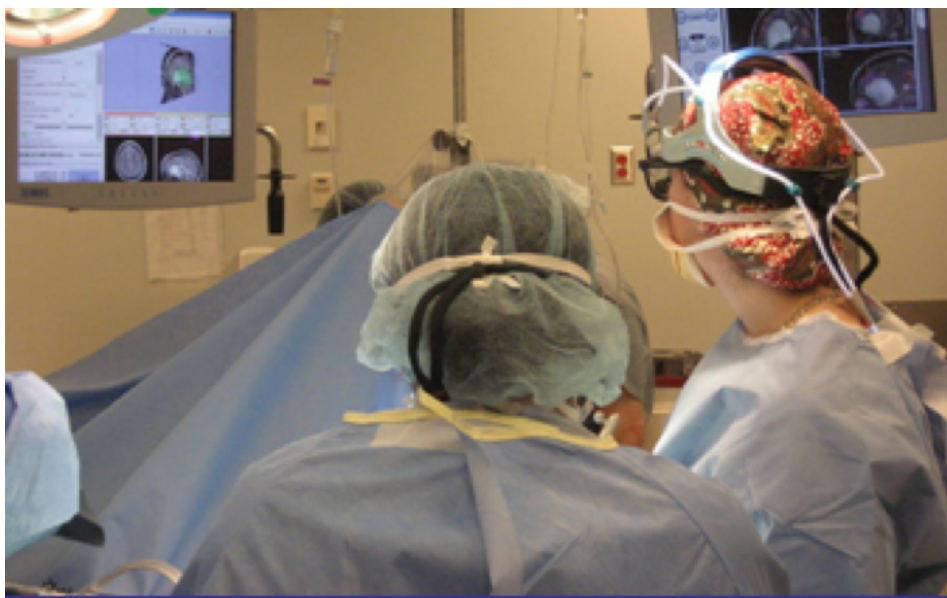
Impact acceleration



Slicer2 and Slicer3 Downloads: 69,000+ in 3.5 Years, 54 / day

Slicer4 Downloads 2013: 61,000+ in 1 Year, 168 / day

Easy to Use, Easy to Extend



What does a user expect ?

- Easy Install and Upgrade
- “Standard” Clinical Behavior
- Advanced Functionality
- Consistent Interface
- Easily Deployable
- Extensible and Reconfigurable
- Rich Utility Libraries



What does a developer need ?

- Easily Deployable
- Extensible and Reconfigurable
- Rich Utility Libraries
- Stable Base

3D Slicer: a cross platform system for translating innovative algorithms into clinical research applications

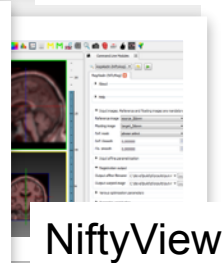
Features

CLI Plug-ins

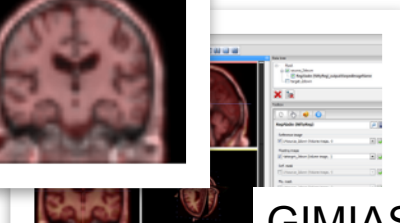
Shareable across several platforms



MevisLab



NiftyView

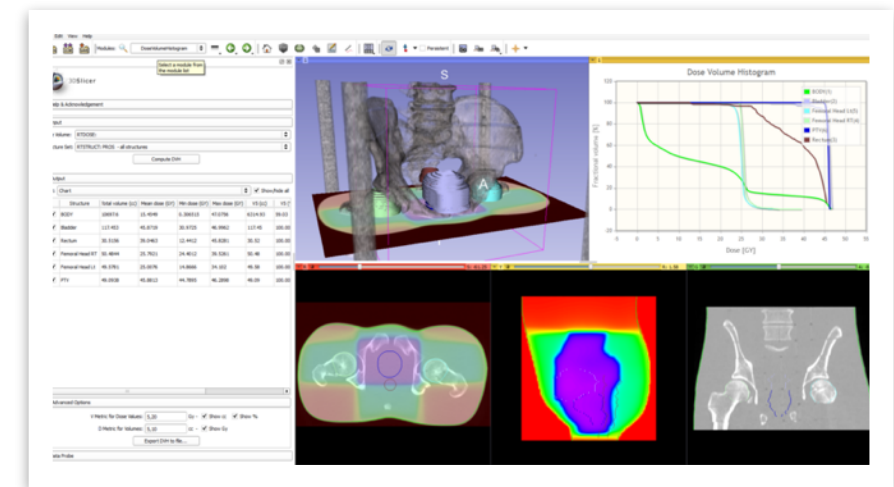


GIMIAS

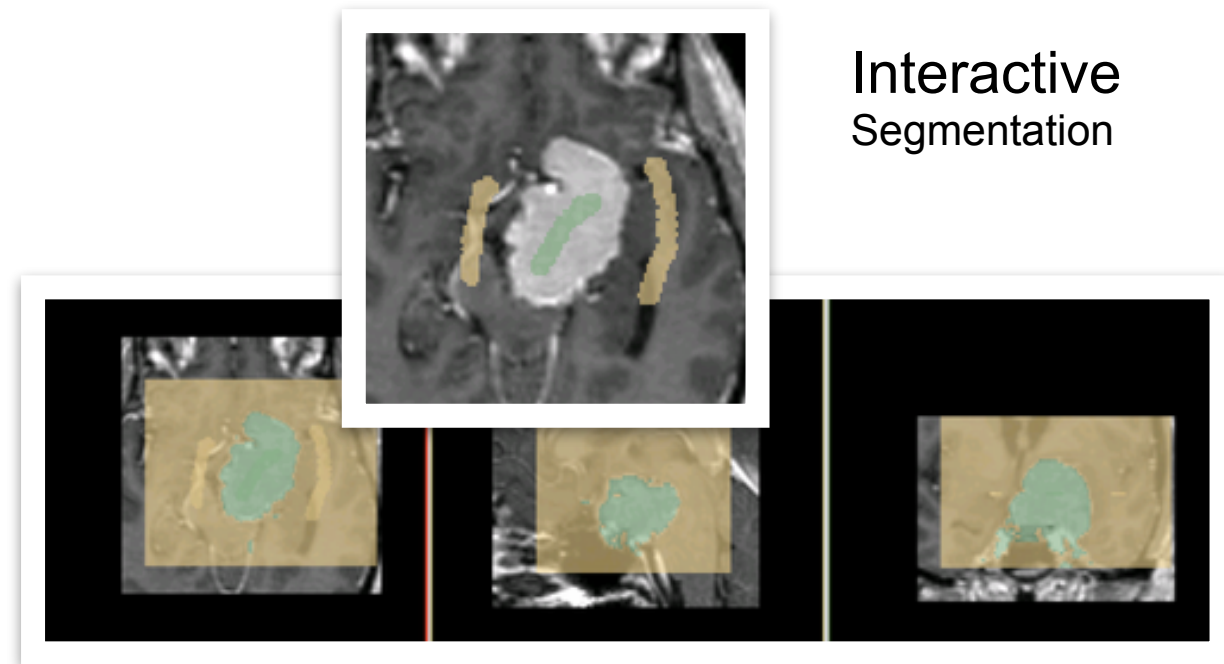
- Volume Rendering
- .mrb files
- Layouts
- Sceneviews
- Annotations
- DICOM

Quantitative imaging

Line, scatter, bar charts

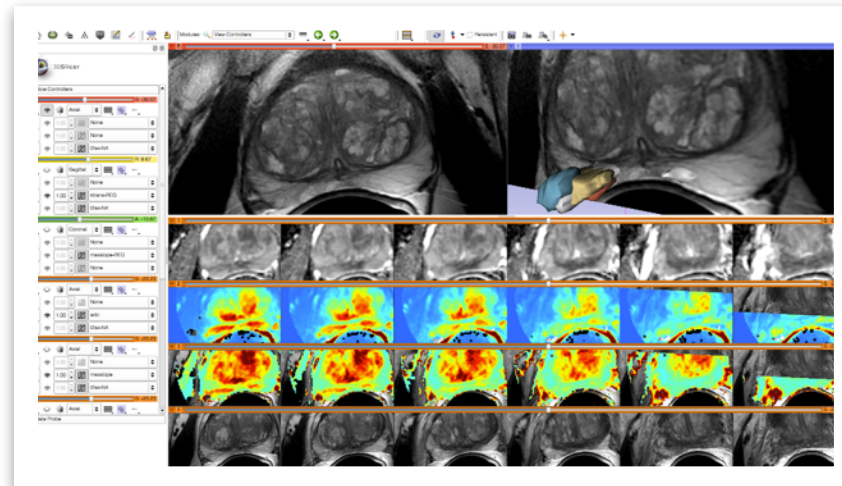


Interactive Segmentation



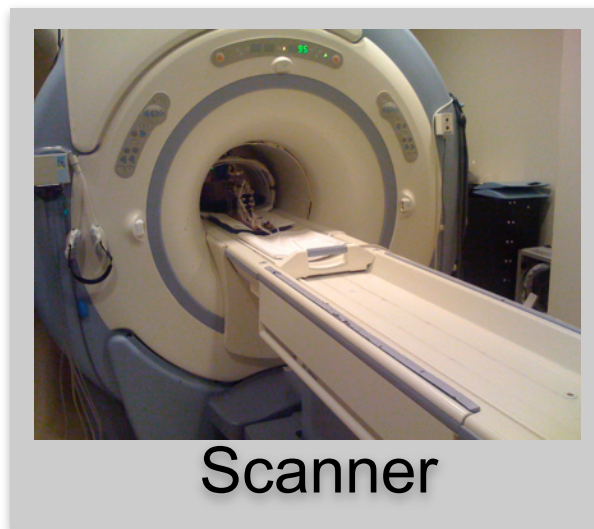
Support for multi-dimensional data

Compare view, Lightbox, crosshair

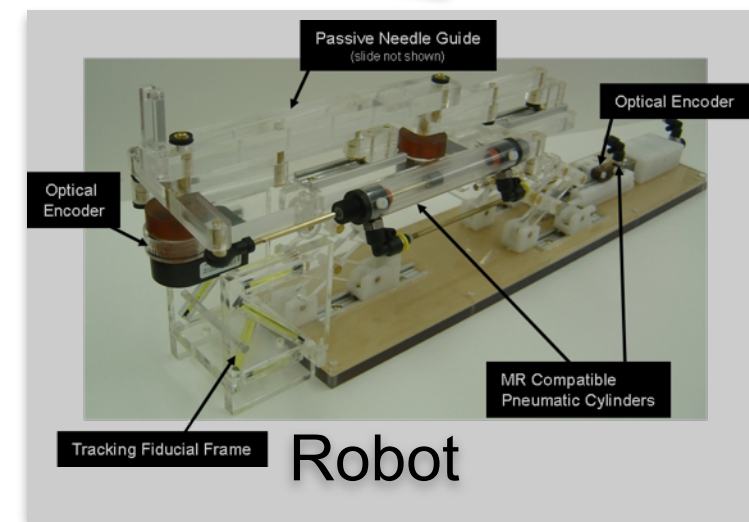
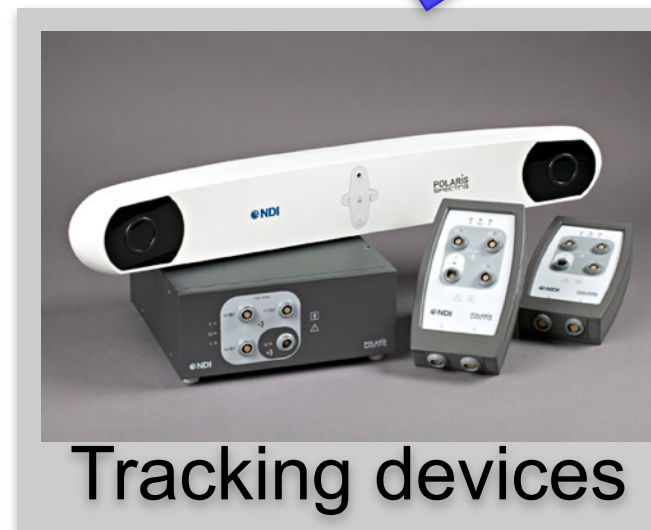
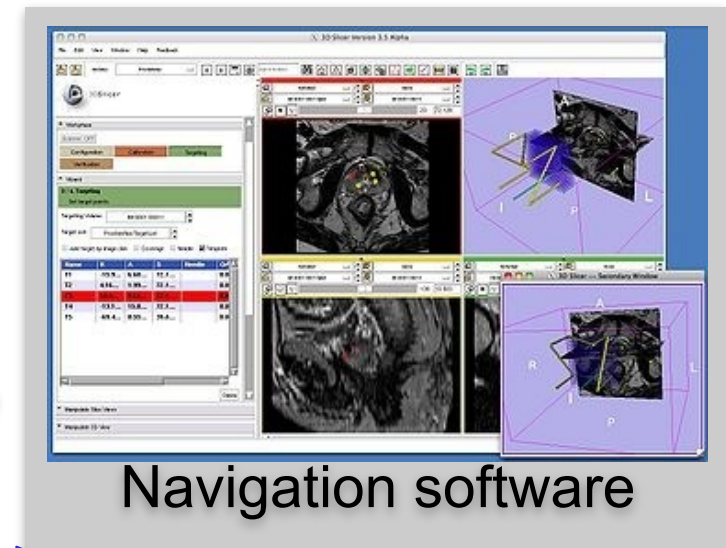
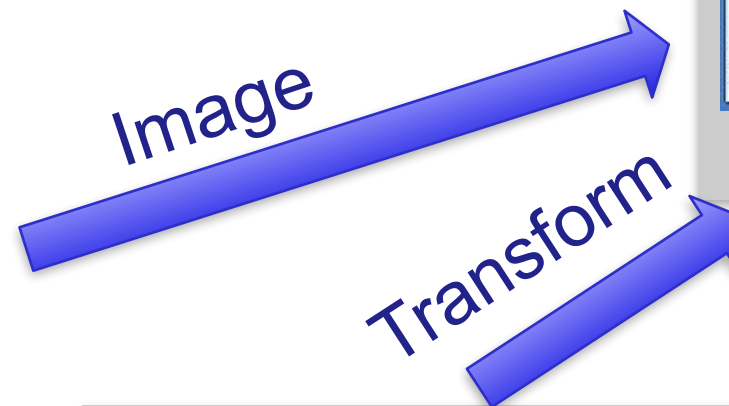


Slicer and Devices

- Two-way communication
 - Imaging devices
 - Optical tracking devices
 - Robotic devices
 - More



OpenIGTLink



3D Printing

- 3D printing is a commodity today
- Will revolutionize prototyping
- Hardware increasingly resembles software: the value is in the design



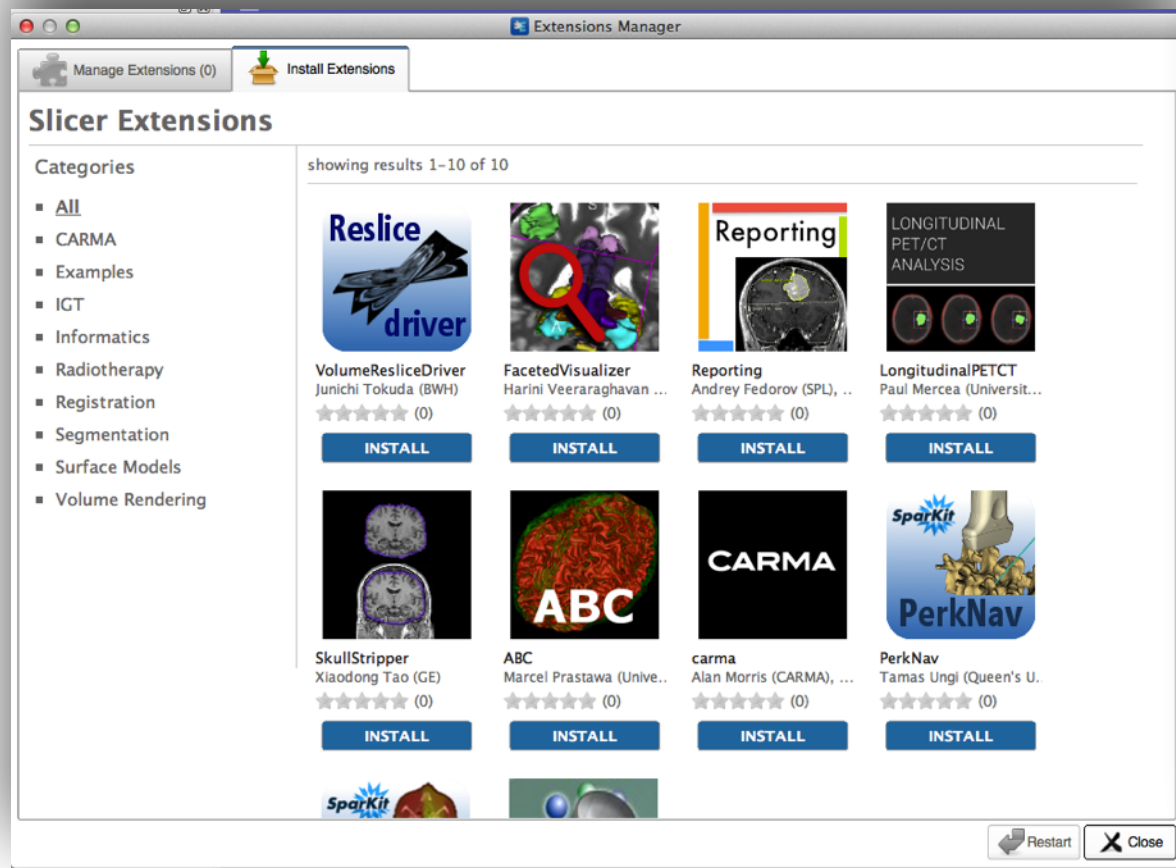
Image courtesy N. Farhat

Web Capabilities

QtWebKit enables Web services

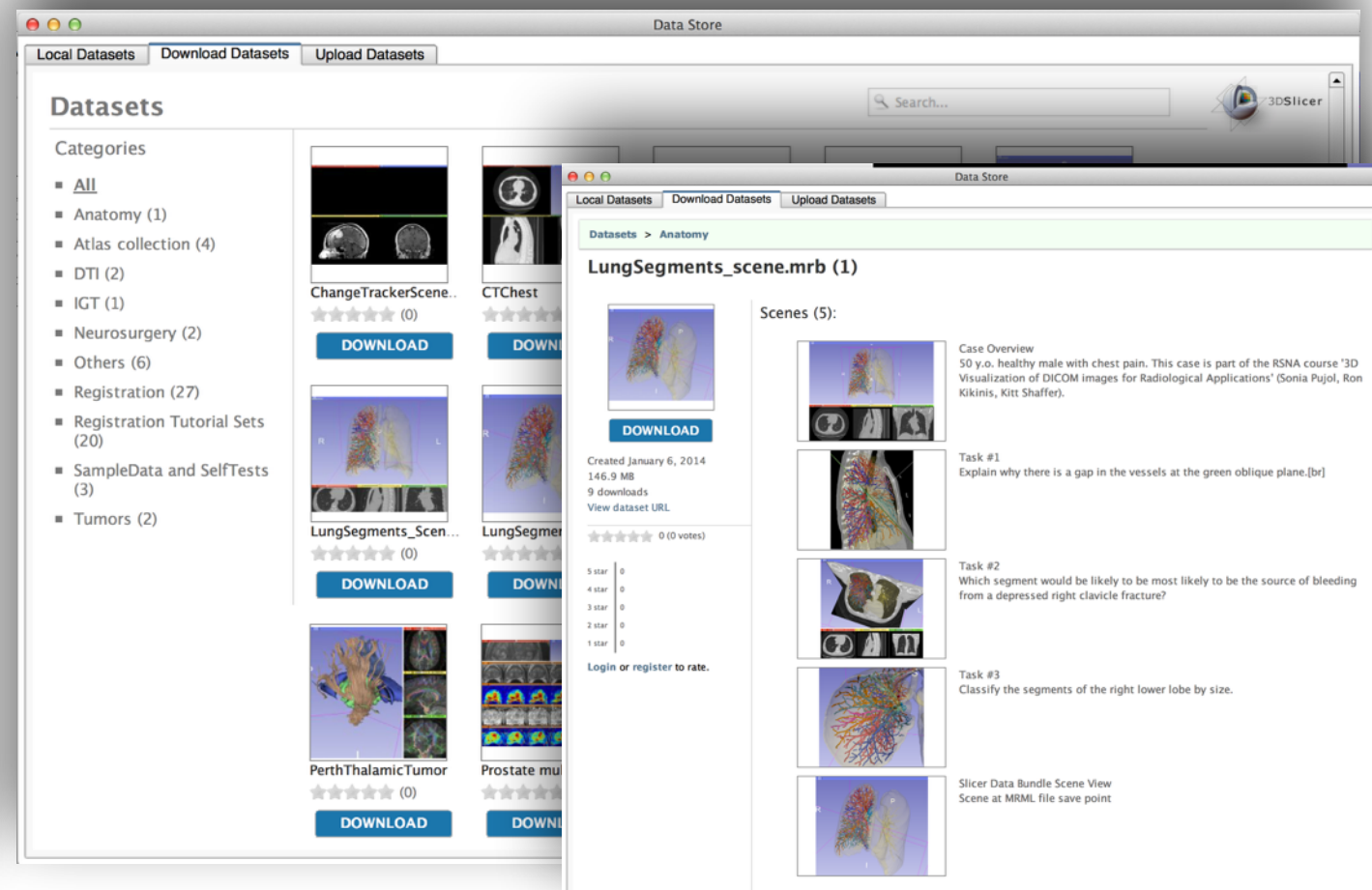
Extension Manager and catalog

- Share plug-ins with users
- Easy Installation



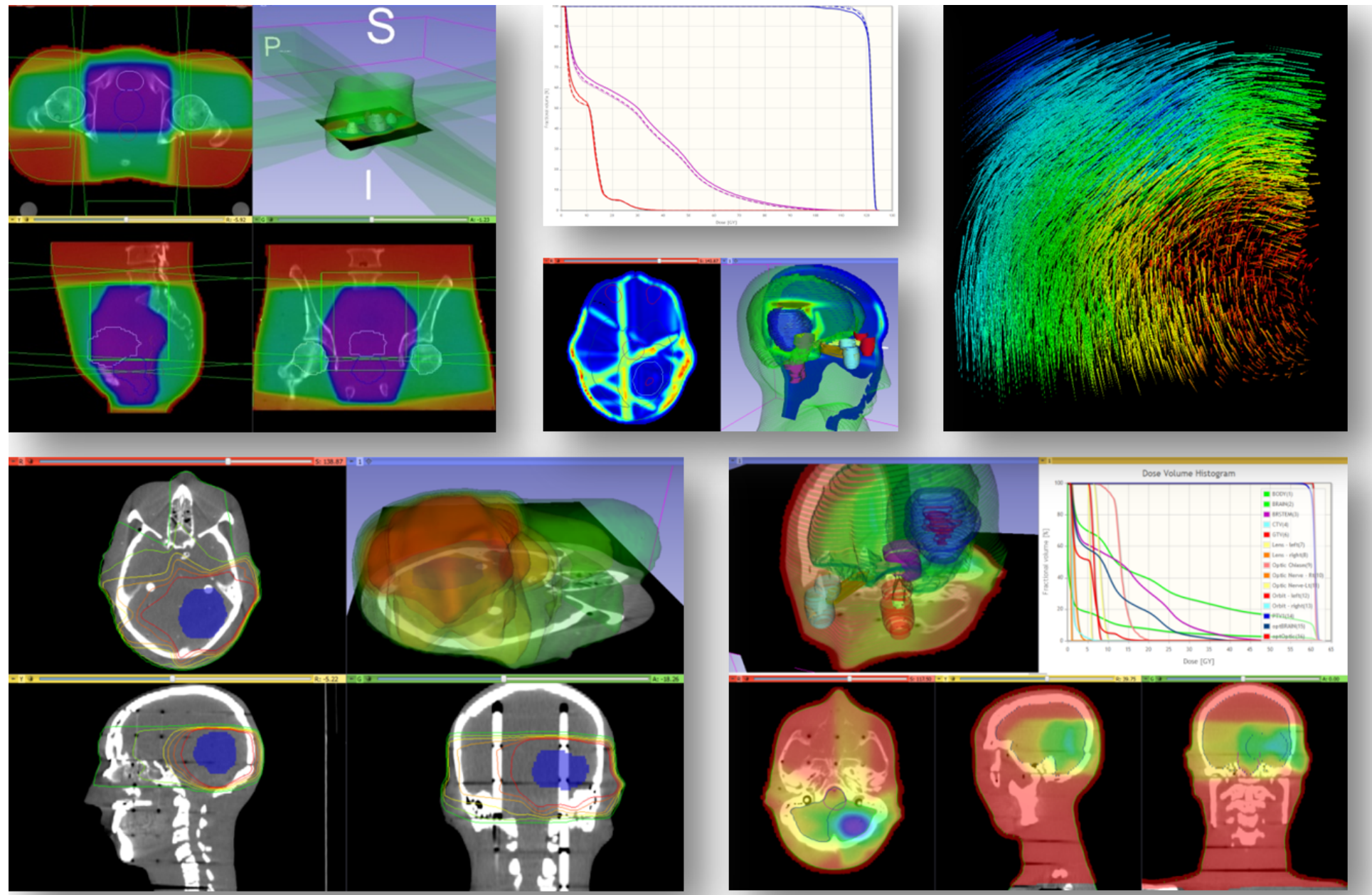
Data Store

- Web-based public repository of .mrb files allows sharing
- Sceneviews are exposed in the web interface



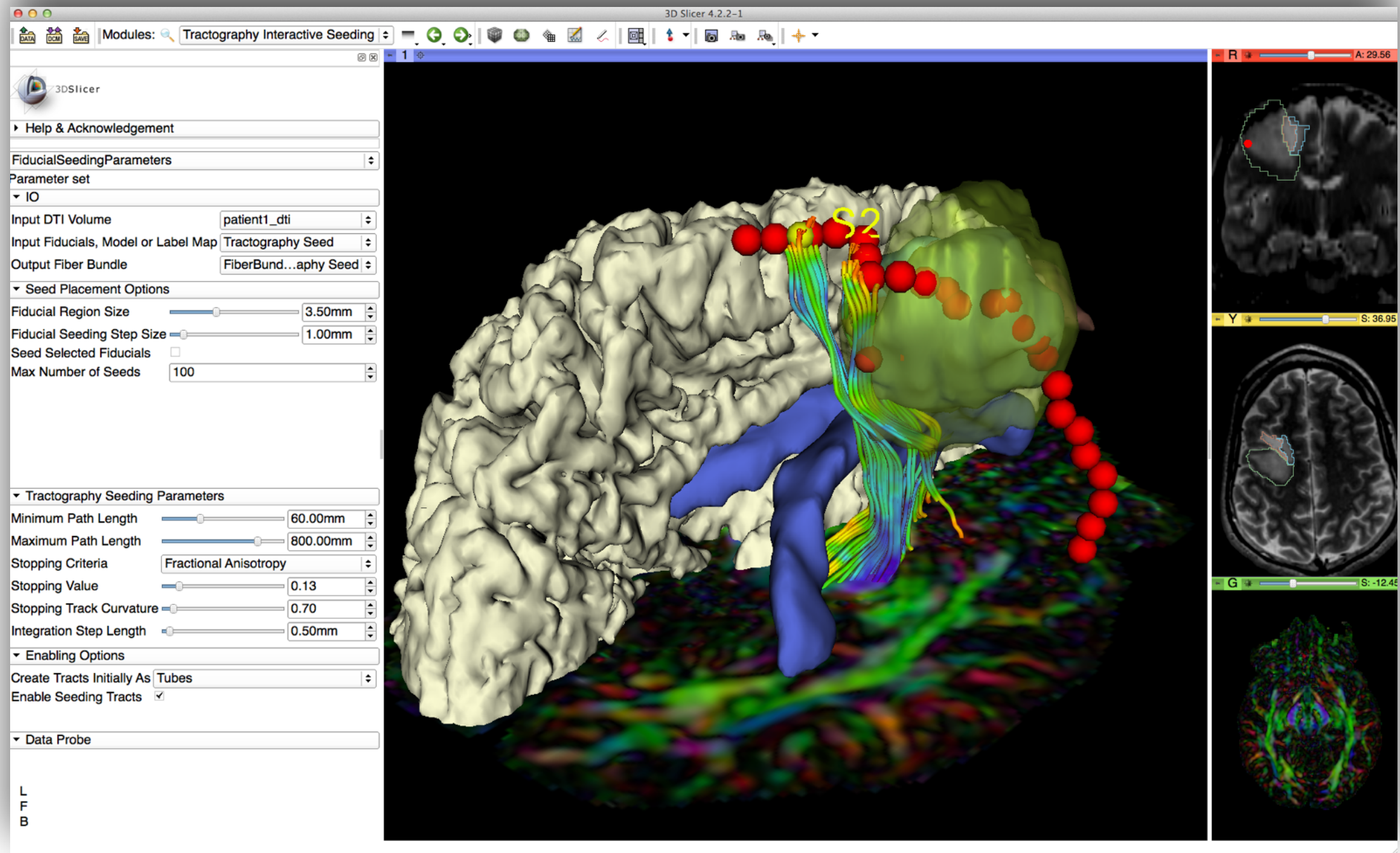
Clinical Example 1

- Radiotherapy research extensions: Dicom RT, dose distributions and many more....



Clinical Example 2

- Surgical planning

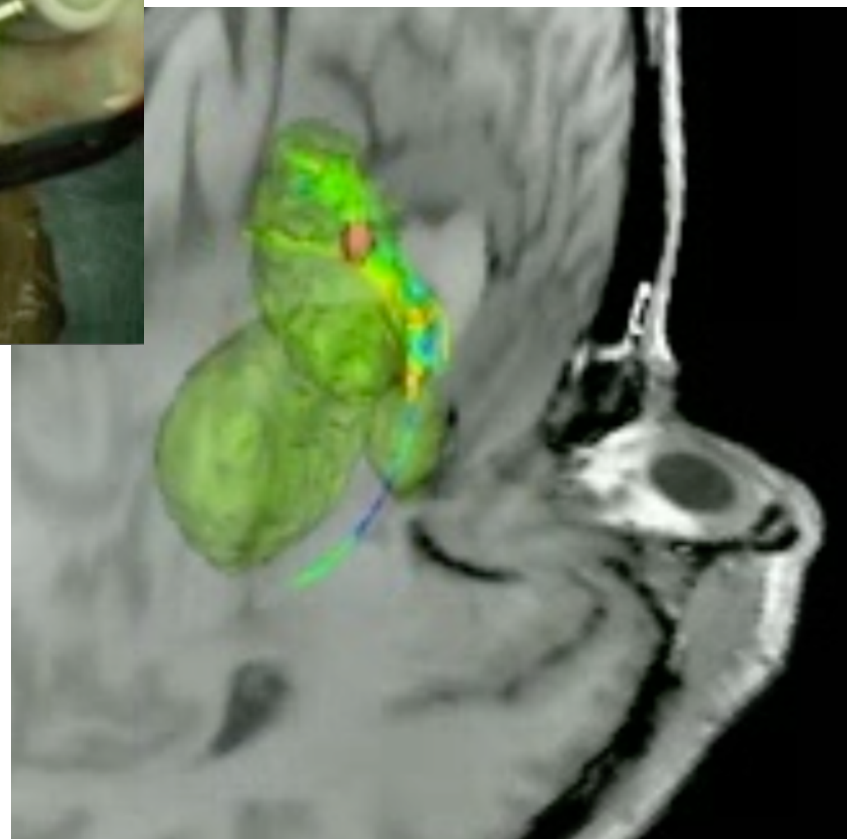
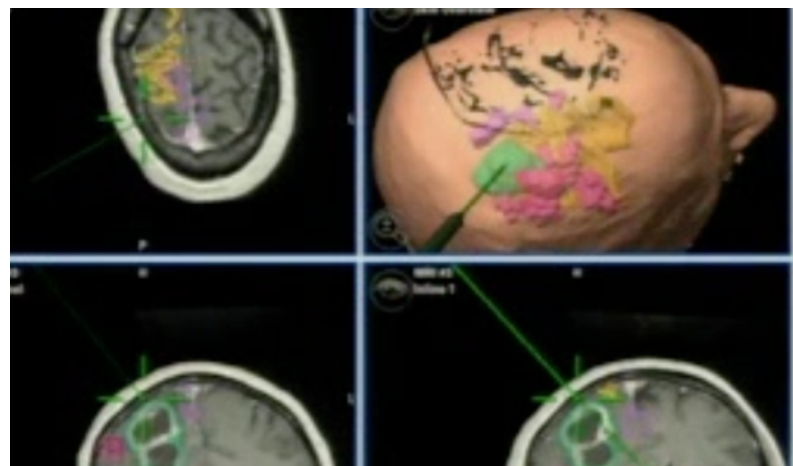
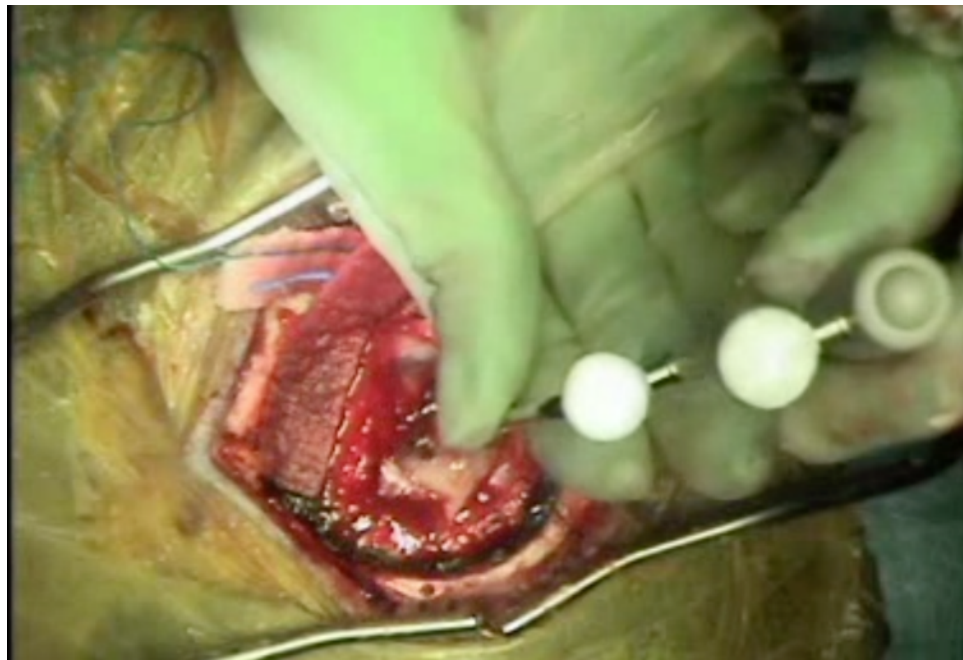




Clinical Example 3

Image Guided Therapy Interfacing to clinical devices

- Intraoperative Fiber Tracking
- Relies on pre-op data
- Slicer+Brainlab



Introduction

- Medical Image Computing
- 3D Slicer
- **NA-MIC**
- Open source

NA-MIC

- The National Alliance for Medical Image Computing (NA-MIC), is a distributed community of researchers
- Focus on
 - Subject specific image analysis
 - NA-MIC kit, including 3D Slicer as a platform for dissemination
- Funded by NIH through the NCBC program since 2004

NA-MIC Wiki
General

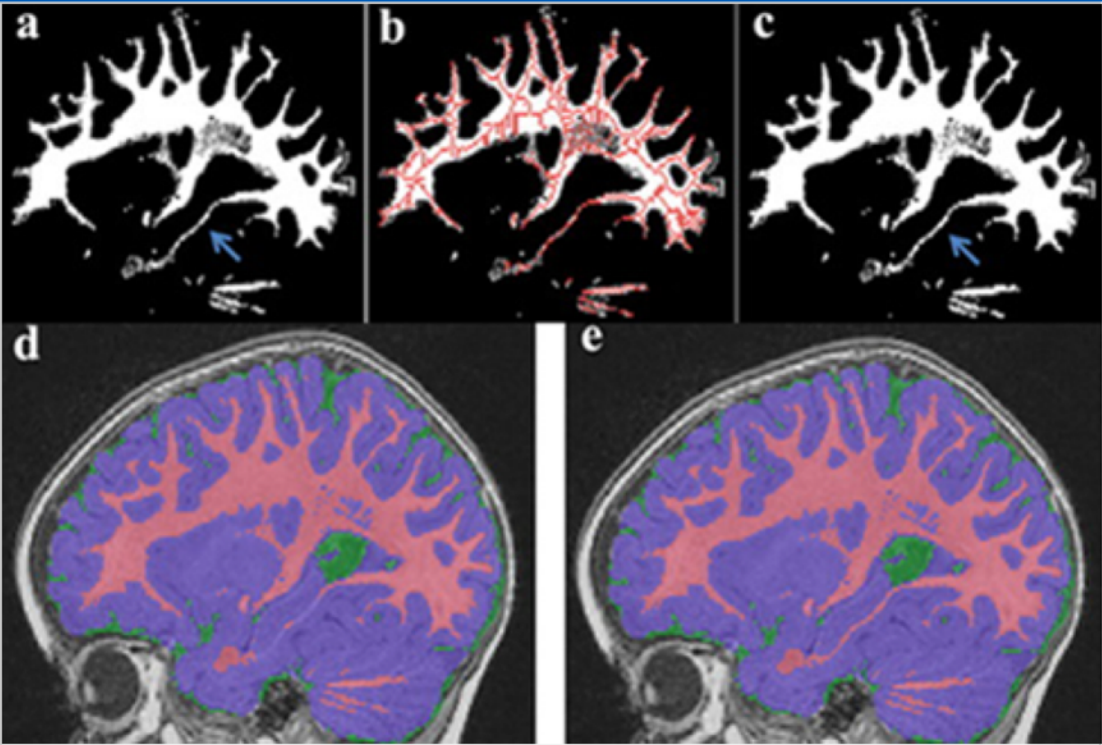
- Overview
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Center Components


- Algorithms
- Engineering
- Driving Biological Projects
- Collaboration Grants

Resources

- Publication DB
- Image Gallery
- Downloads
- Service
- Training
- Dissemination
- Events
- Links



Adaptive Prior Probability and Spatial Temporal Intensity Change Estimation for Segmentation of the One-Year-Old Human Brain. [Read more...](#)



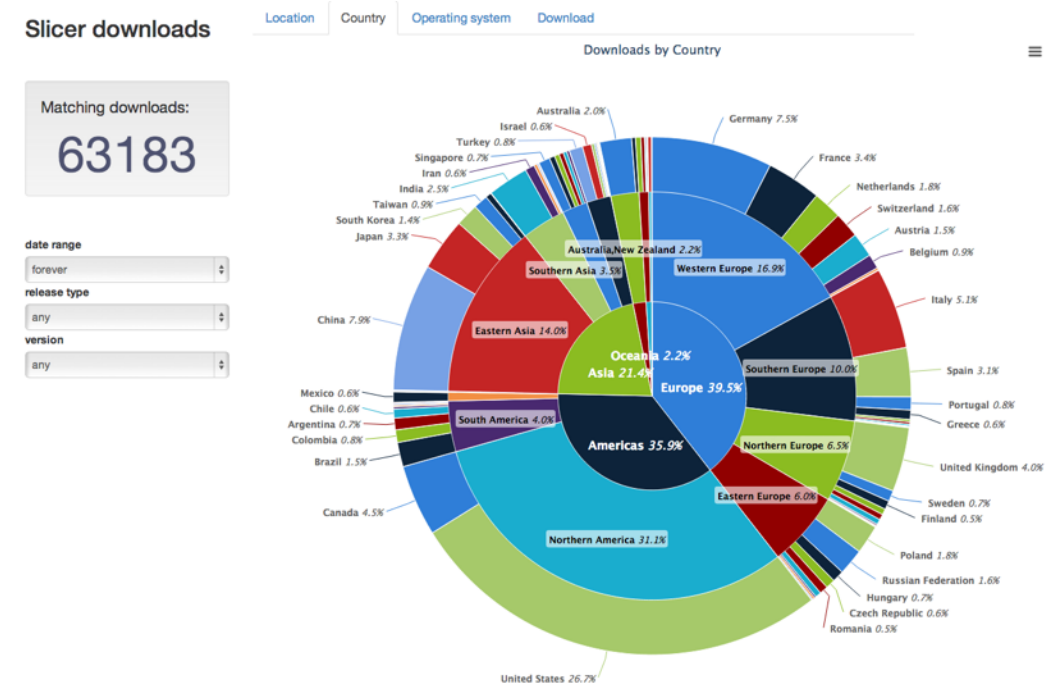
6th NCIGT and NIH Image Guided Therapy Workshop
This event will be held on **March 21-23, 2013**, in Doubletree by Hilton Washington DC in Crystal City, VA. The topic for this year is Interventional applications for a changing healthcare environment.

[Read more...](#)

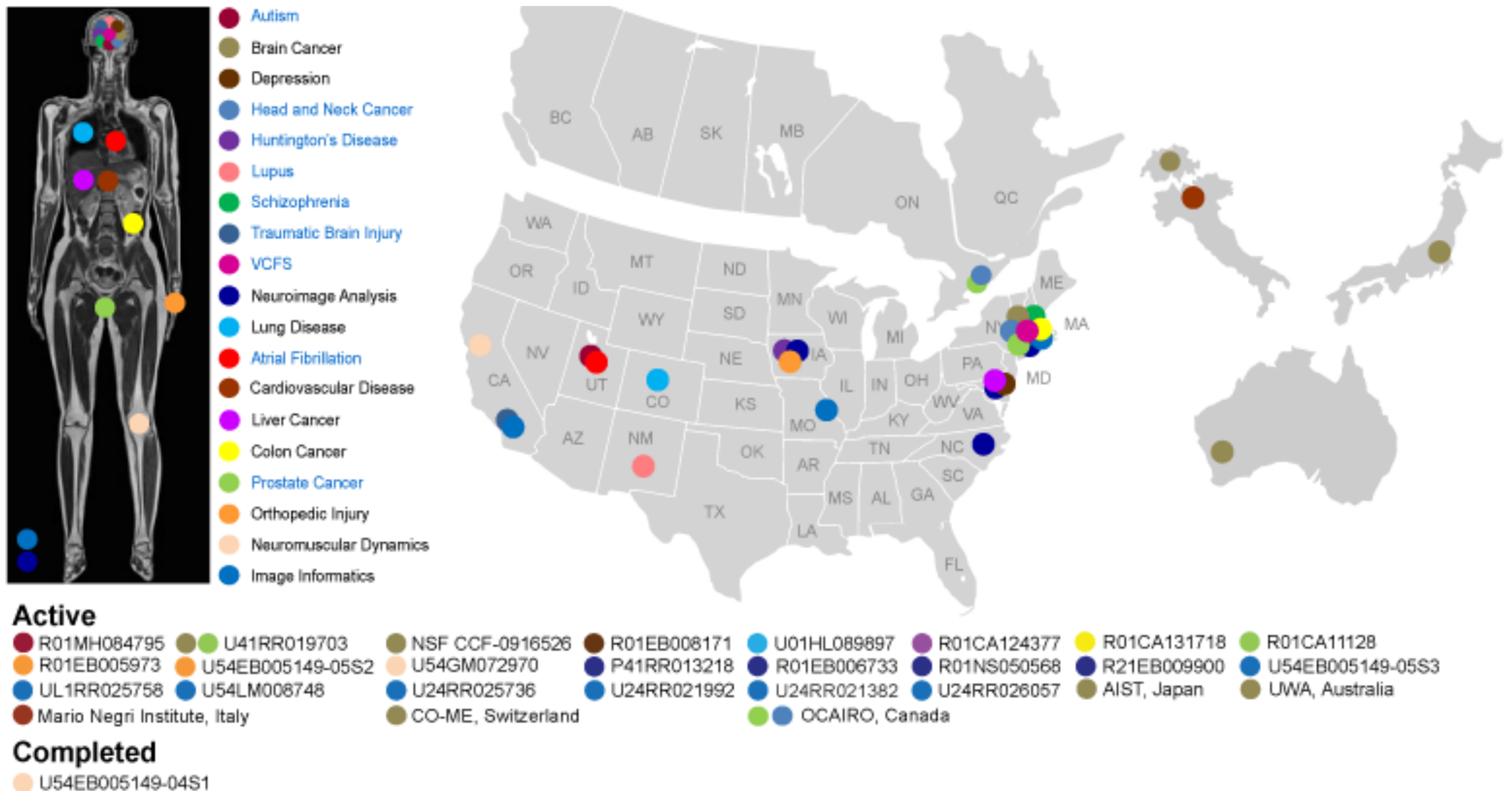
[NEWS ARCHIVE](#)

NA-MIC in Numbers

- 3D Slicer software used worldwide as platform for development and sharing
- Large impact on NIH grantees: 31 funded collaborations across schizophrenia, lupus, autism, lung disease, cardiac disease, brain cancer, liver, colon, prostate, musculoskeletal disorders.
- International funding: Canada, Germany, Spain, Italy, Japan, Australia.
- “Common Toolkit”: joint transatlantic effort
- Trained 55 engineers, 35 grad students, 20 post-docs.
- 2000+ investigators trained in 63 workshops
- 500+ full size papers, including awards
- 15 “Project-weeks”, weeklong working events twice a year: over 650 participants



NA-MIC Community



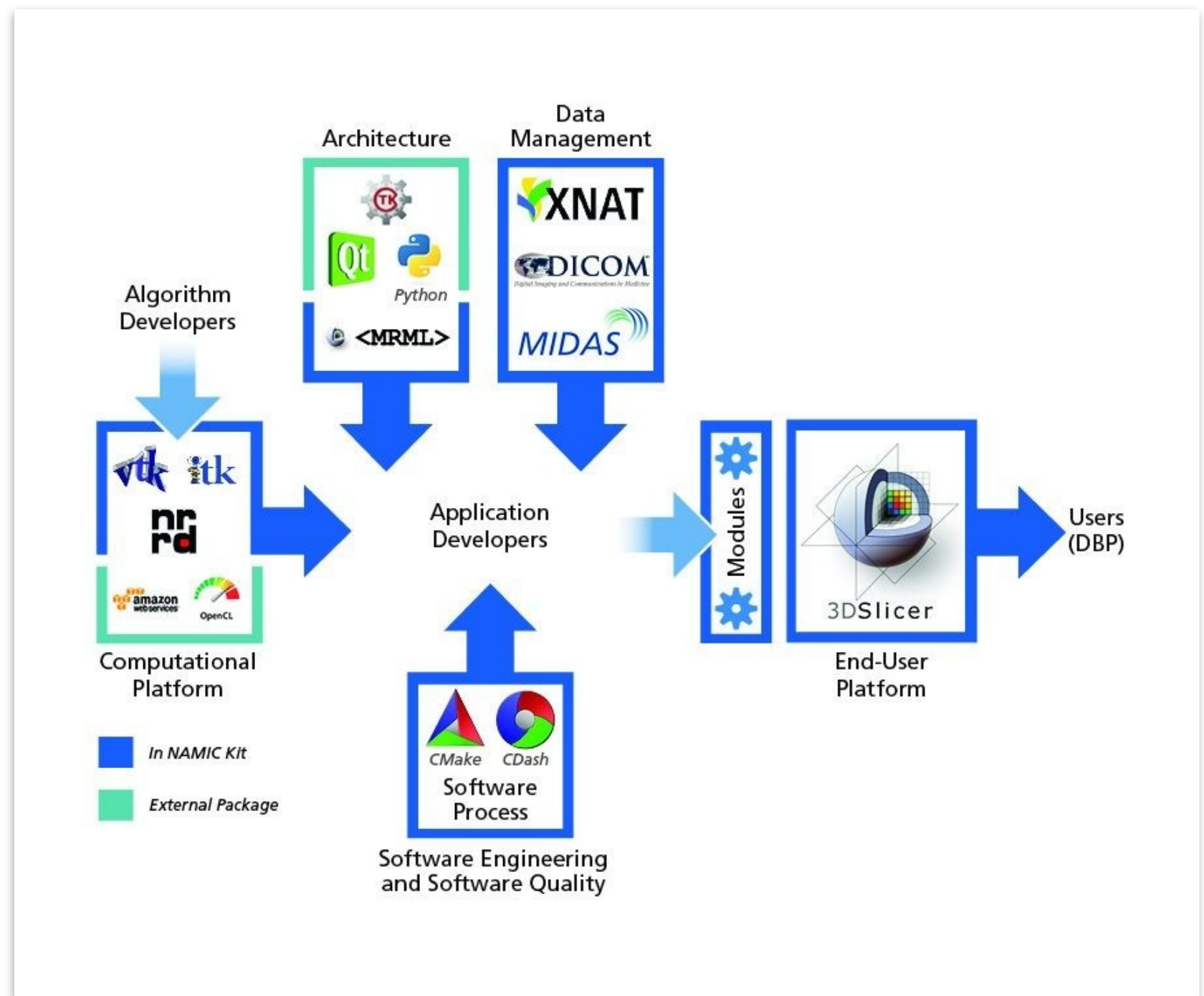
The NA-MIC Kit

The NA-MIC Kit is a free open source platform to support translational research in MIC

Slicer is built on the NA-MIC Kit

Common Features

- BSD style Open Source
- No known IP liabilities
- Compiled on all supported platforms
- Optimized Interoperability of the components

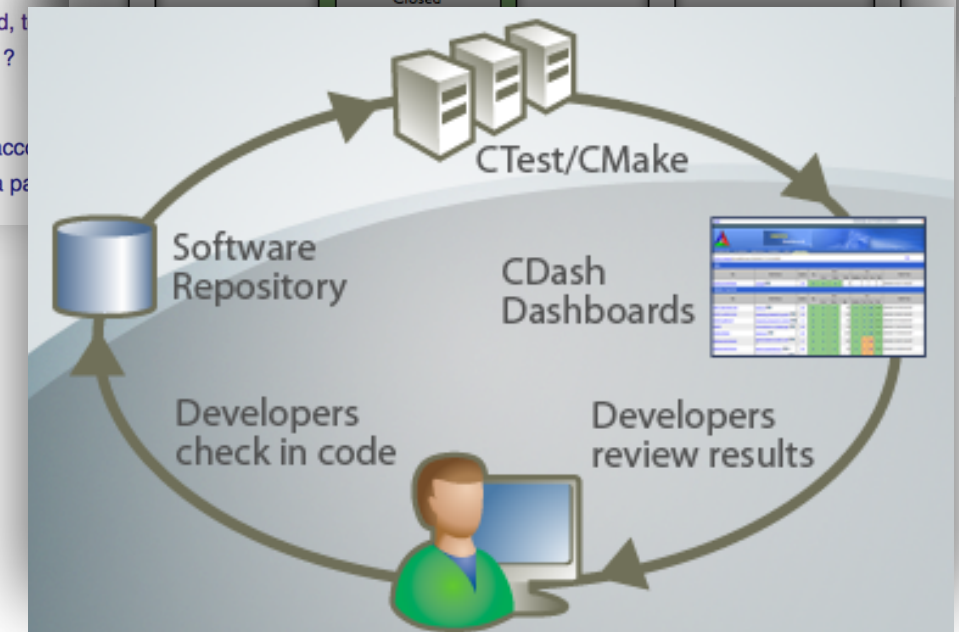
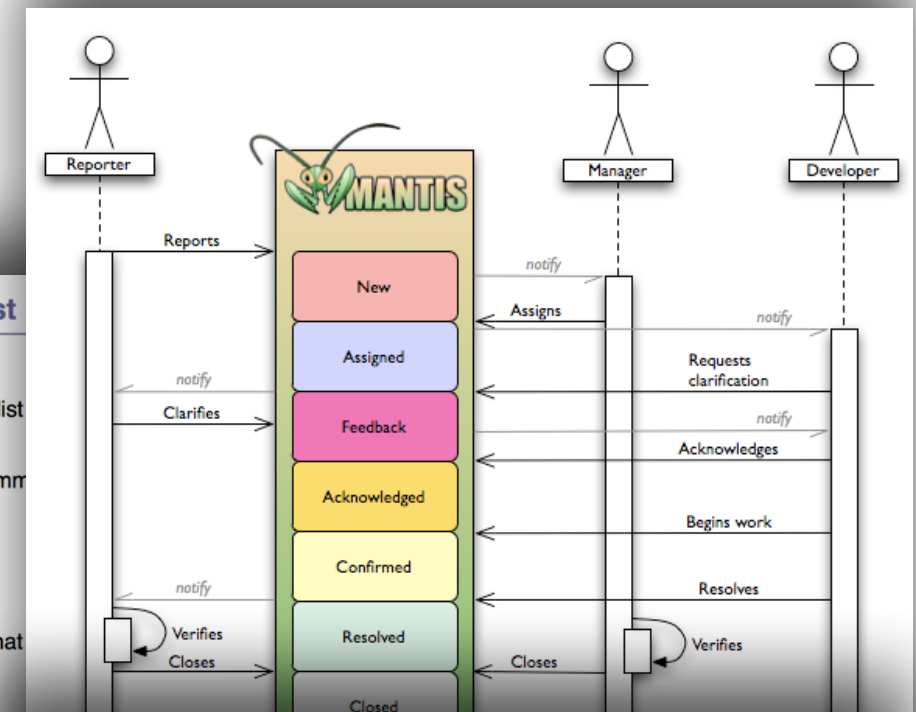


Principled Software Process

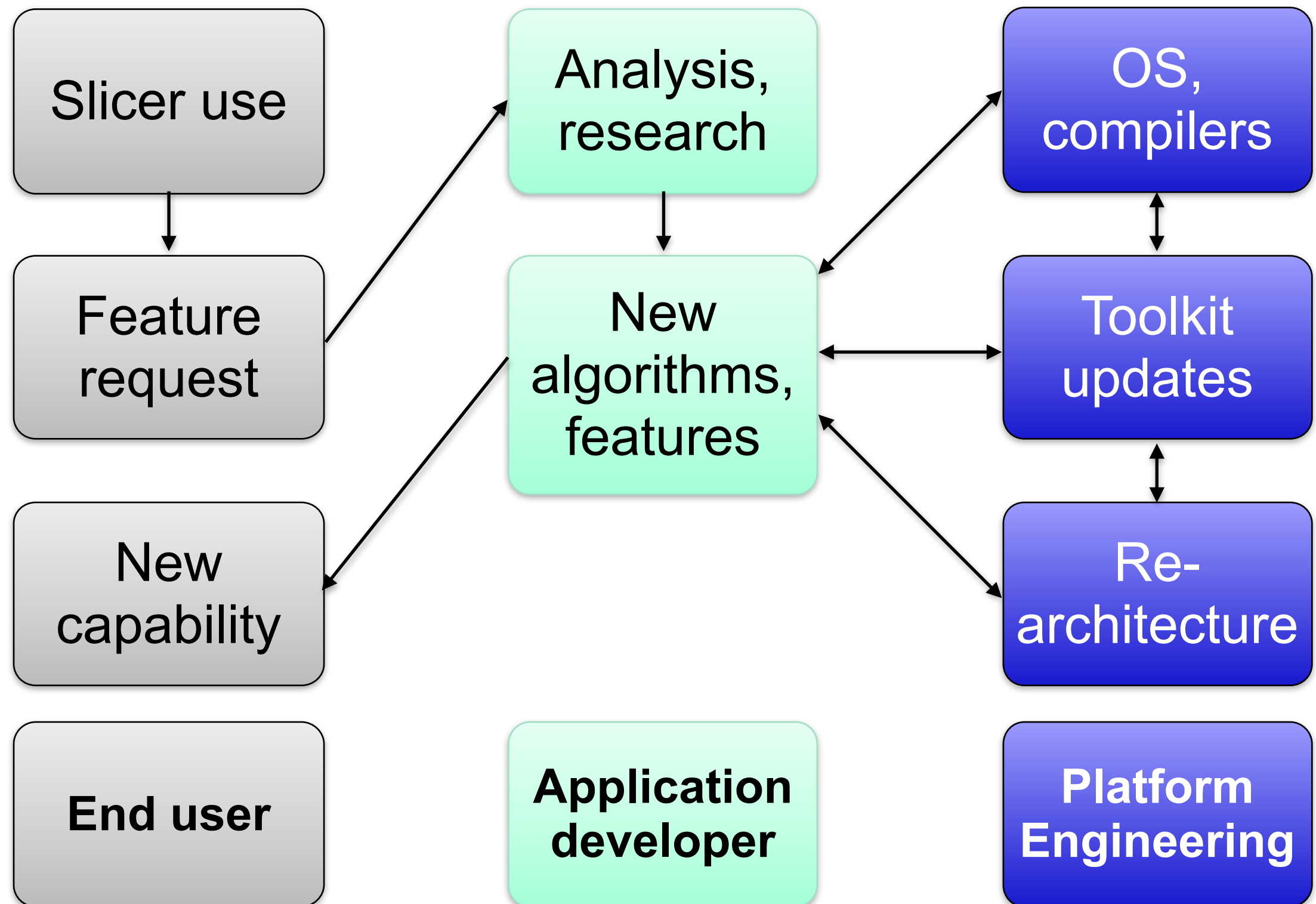
- Documented workflows
- Github is used as repository
 - distributed
 - allows offline work
 - sharing with granularity
- Slim trunk, most functionality is in plug-ins

New community member checklist

- ✓ Join
 - Sign-up [on the developers mailing list](#)
 - Register [on the issue tracker](#)
 - Join the [3DSlicer BarCamp](#) [G+ comm](#)
 - Sign-up on [github](#)
- ✓ Read
 - Scan through [developer FAQ](#).
 - Read the [Slicer Style Guidelines](#) so that
- ✓ Create
 - Step-by-step: [How to create, build, t](#)
 - Step-by-step: [How to build Slicer ?](#)
- ✓ Contribute
 - To improve this wiki: [request an acc](#)
 - Step-by-step: [How to contribute a p](#)



Slicer Development Process



Application Development

- Algorithm research comes first
- Implementation workflow once the algorithms are known:
 - Create individual modules as plug-ins
 - Create workflows based on the modules
 - Use the extension manager for distribution

Platform Engineering

- The Slicer platform is based on many toolkits and libraries
- Operating systems change constantly
- Ongoing effort is needed for updating the versions used by the NA-MIC kit and Slicer
- Modifications and patches are pushed downstream to the toolkits and libraries

What it takes

- Money, money, money
- Time, time, time
 - Platform engineering for translational MIC is expensive and difficult to find funding for
 - It takes time to bring together an interdisciplinary community

Work

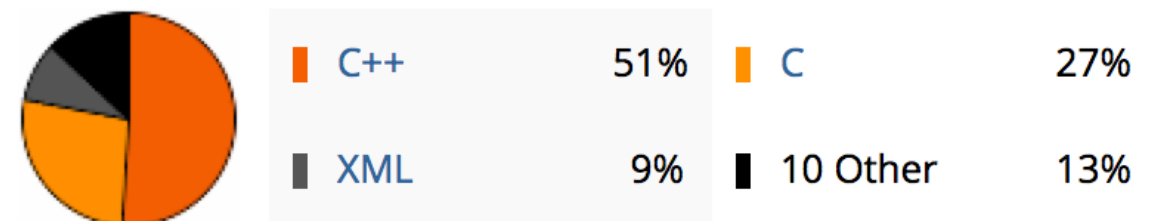
- 1 Ph.D. thesis is one to two person-years of actual work
- Slicer represents over 100 person years in direct effort

In a Nutshell, Slicer4...

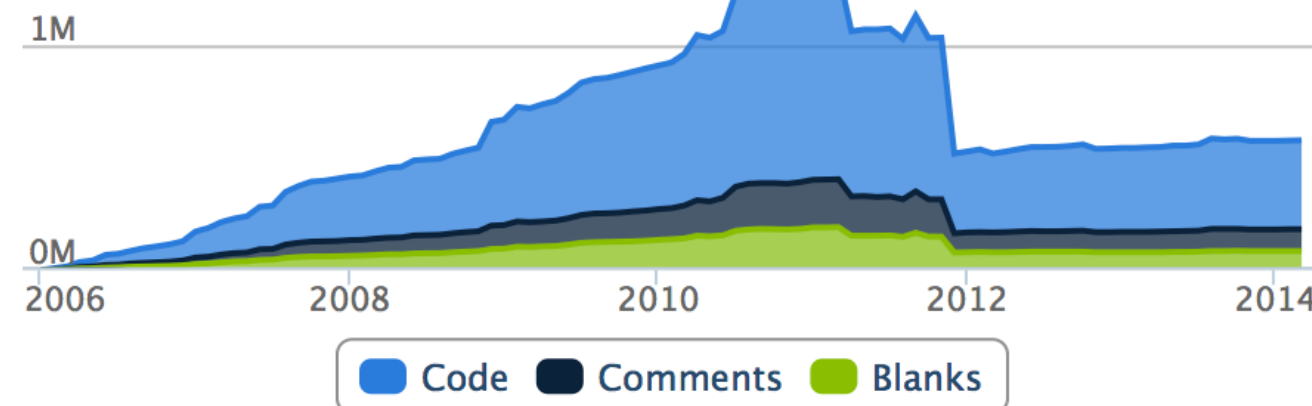
- ... has had 20,538 commits made by 97 contributors representing 397,670 lines of code
- ... is mostly written in C++ with an average number of source code comments
- ... has a well established, mature codebase maintained by a large development team with decreasing Y-O-Y commits ← work moved to plug-ins
- ... took an estimated 105 years of effort (COCOMO model) starting with its first commit in January, 2006 ending with its most recent commit 2 days ago

<http://www.ohloh.net/p/slicer>

Languages



Lines of Code



NA-MIC Kit Engineering Team

FeiZhao	clisle	hliu	kquintus	nobyhata	taylor
Michael.jeulinl	davisb	hong	lantiga	padfield	tgl
Yong	demian	hyang	lassoan	partyd	tokuda
alexey	domibel	ibanez	lauren	pieper	tringo
andy	dpace	ilknur.kabul	lorensen	pinter	ungi
atriveg	fedorov	inorton	maddah	pkarasev	vmagnotta
awiles	finetjul	jcfr	malaterre	pkarasev3	vrnova
aylward	francois_budin	jcross186	matthew.bowman	pohl	wjp
barre	freudling	joe.snyder	mccormic	rjosest	ygao
benjamin.long	gcasey	johan.andruejol	mike	rsierra	yumin
bess	haehn	jvs	millerjv	samset	zach.mullen
blezek	harveerar	karthik	mscully	sankhesh	zack.galbreath
casey.goodlett	hayes	kedar_p	naucoin	sylvain	
christopher.mullins	hjohnson	kerstin	nicky	taox	

Special thanks to Jean-Christophe Fillion-Robin, Julien Finet, Steve Pieper, Nicole Aucoin, Andrey Fedorov, Jim Miller

Introduction

- Medical Image Computing
- 3D Slicer
- NA-MIC
- **Open source**

Why Open Source

- Collaborate and move freely
 - Good match for the migratory lifestyle of scientist
 - Advantageous for collaborations
 - Neutral territory in multi-vendor settings
- Extensible

Why Open Source (OS) For Complex Software?

- Potential advantages to industrial development activities:
 - Access to world class algorithms and architectures.
 - Training is current and user-focused.
 - Active community is more capable to track advances in hardware and systems computer architecture than closed systems.
 - Community can be engaged to the extent desired
- Open Source approaches are practical
 - Costs are potentially lower, even when a minimal level of sophisticated management is necessary.
 - They permit the organization to focus on its key product skills.

What are the risks of OS use in a big industrial development?

- It can't be assumed that the OS environment/community will have a canned solution to every need. Some internal development will likely be needed.
- Internal staff will need to have clear rules and supported strategies for interaction with the OS community to avoid leakage of proprietary information, product and market strategies, etc.
 - The “crown jewels” can always be kept as private extensions
- OS communities and their development approaches are subject to their own market forces and dominant interests, which may, over time, diverge from the industrial needs.
- Summary: these risks are manageable, as long as the company sets things up correctly and stays alert.

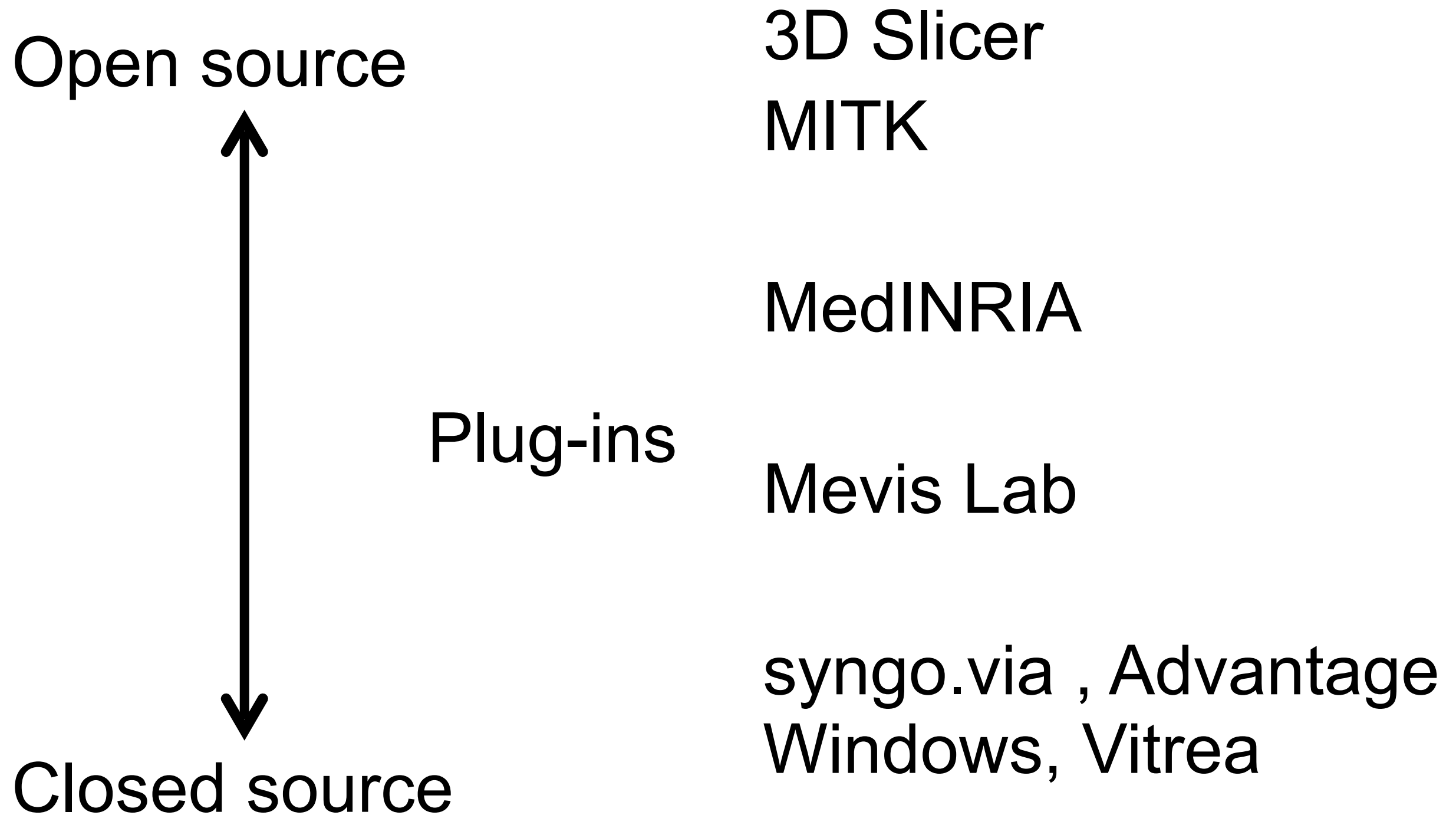
Conclusions

- Free Open Source Software
 - Facilitates translation: bridging the valley of death
 - Is a win-win proposition: the OPM principle
 - Requires proper policies and governance
- Slicer and the NA-MIC kit are a good example of FOSS for translational work

From Tools to Medical Product

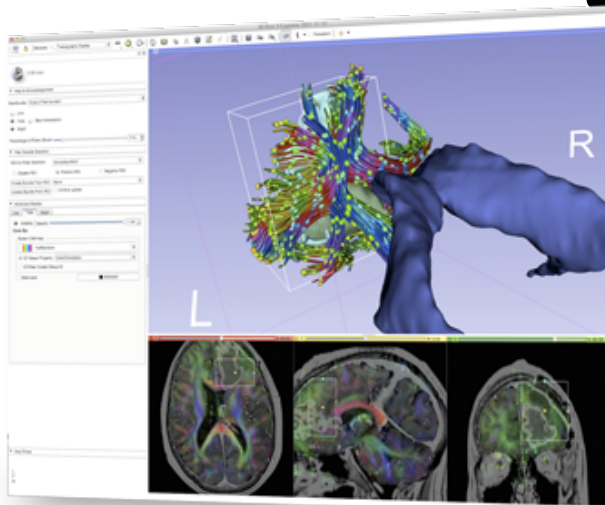
- Open Source facilitates scientific exchange
 - Open Source means **no restriction on use**
(i.e. no restriction on commercial use)
- Medical Products are closed source
 - Significant Regulatory Requirements
- How to accomplish the transition?

From Open to Closed Source



Social Engineering

- How to build an Open Community?
 - Mutual Self Interest:
If I get more out of something than I put into it, it is attractive
 - Community building:
 - Us versus them.
 - Combine social media with in-person events.
 - Interdisciplinary nature is an additional challenge



User Training Events

- Hands-on training workshops at national and international venues
- More than 2,700 clinicians, clinical researchers scientists trained since 2005



Project Week

- Every 6 months, alternating between Boston and Utah
- A working week: Focus on programming and platform updates
- In-person nature encourages socializing
- A key for community building

16th Project Week: Salt Lake City, Utah, January 2013

- 80 attendees: 17 academic institutions, 4 companies
- 54 Projects: TBI, Atrial Fibrillation, Slicer 4 Extensions, Huntington's Disease, Head and Neck Cancer, Stroke, IGT, Radiation Therapy, Medical Robotics, Infrastructure Engineering

17th Project Week: MIT, Summer June 2013

- 104 attendees: 22 academic institutions, 13 companies
- 75 Projects: Huntington's Disease, TBI, Atrial Fibrillation and Cardiac Image Analysis, Radiation Therapy, IGT and Device Integration with 3D Slicer, COPD, and Infrastructure Engineering



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www.na-mic.org

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Neuroimage Analysis Center

nac.spl.harvard.edu



Surgical Planning Laboratory, Brigham and Women's Hospital

spl.harvard.edu



National Center For Image Guided Therapy

www.ncigt.org