



# 3D SLICER

## GOVERNANCE AND POLICY

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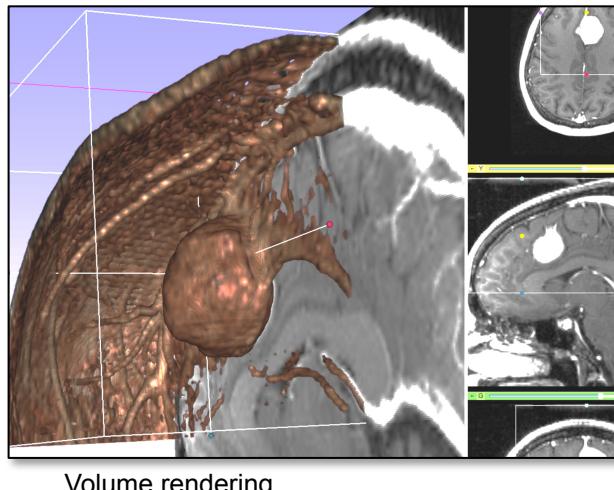
# What is MIC

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

The extraction of information and knowledge from medical images using computational methods

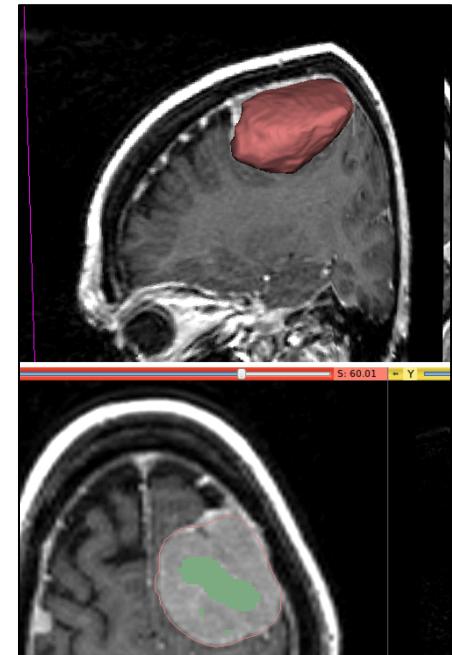
- Technologies:

- image segmentation
- image registration
- image-based physiological modeling
- visualization



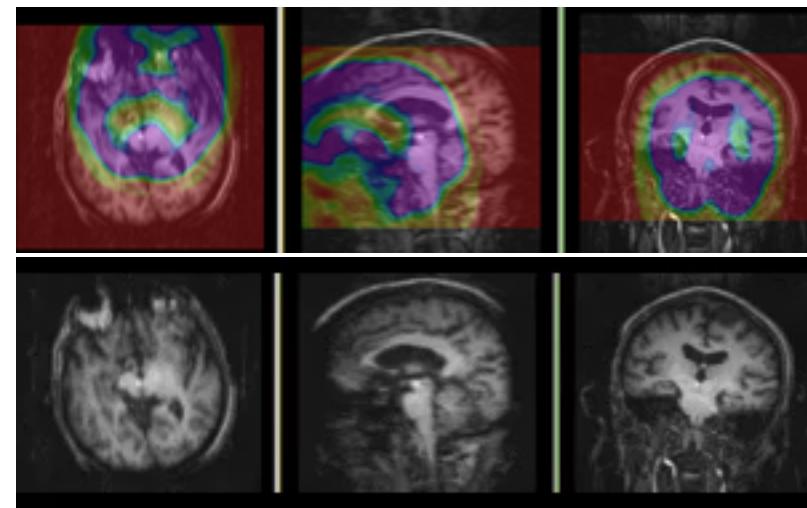
Volume rendering

result



initialization

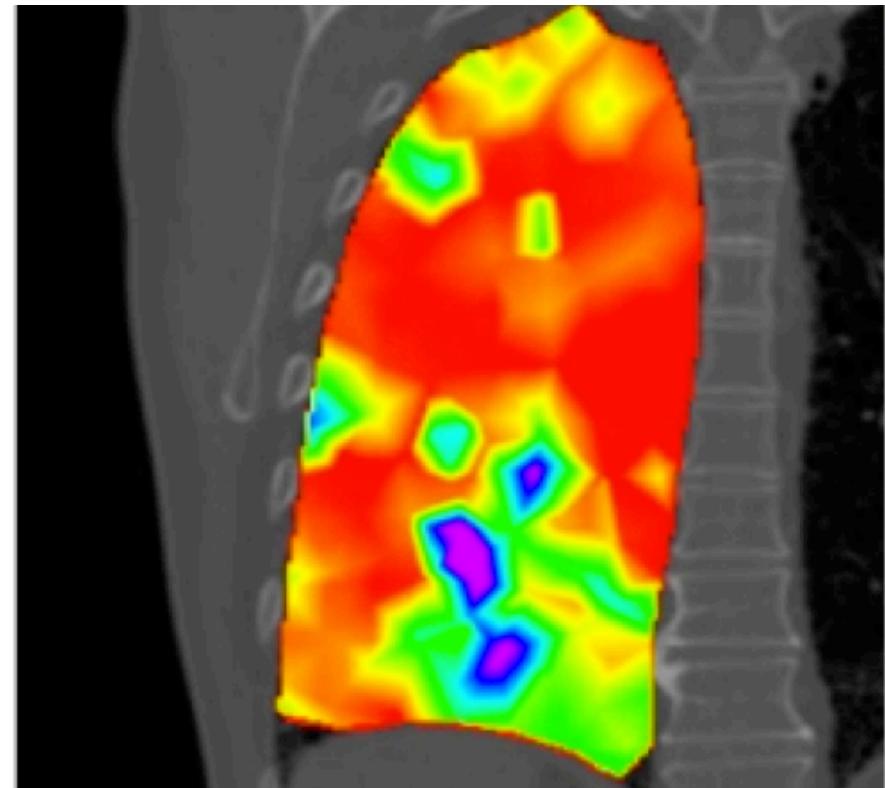
before



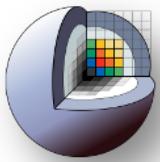
after

**MIC =**  
**Medical Image**  
**Computing**

- More applications
  - Discovery, Diagnosis
  - Therapy monitoring
- More data and complexity
  - Gigabytes to terabytes
  - fMRI, molecular imaging, dMRI, 4DUS
- Translational infrastructure is needed

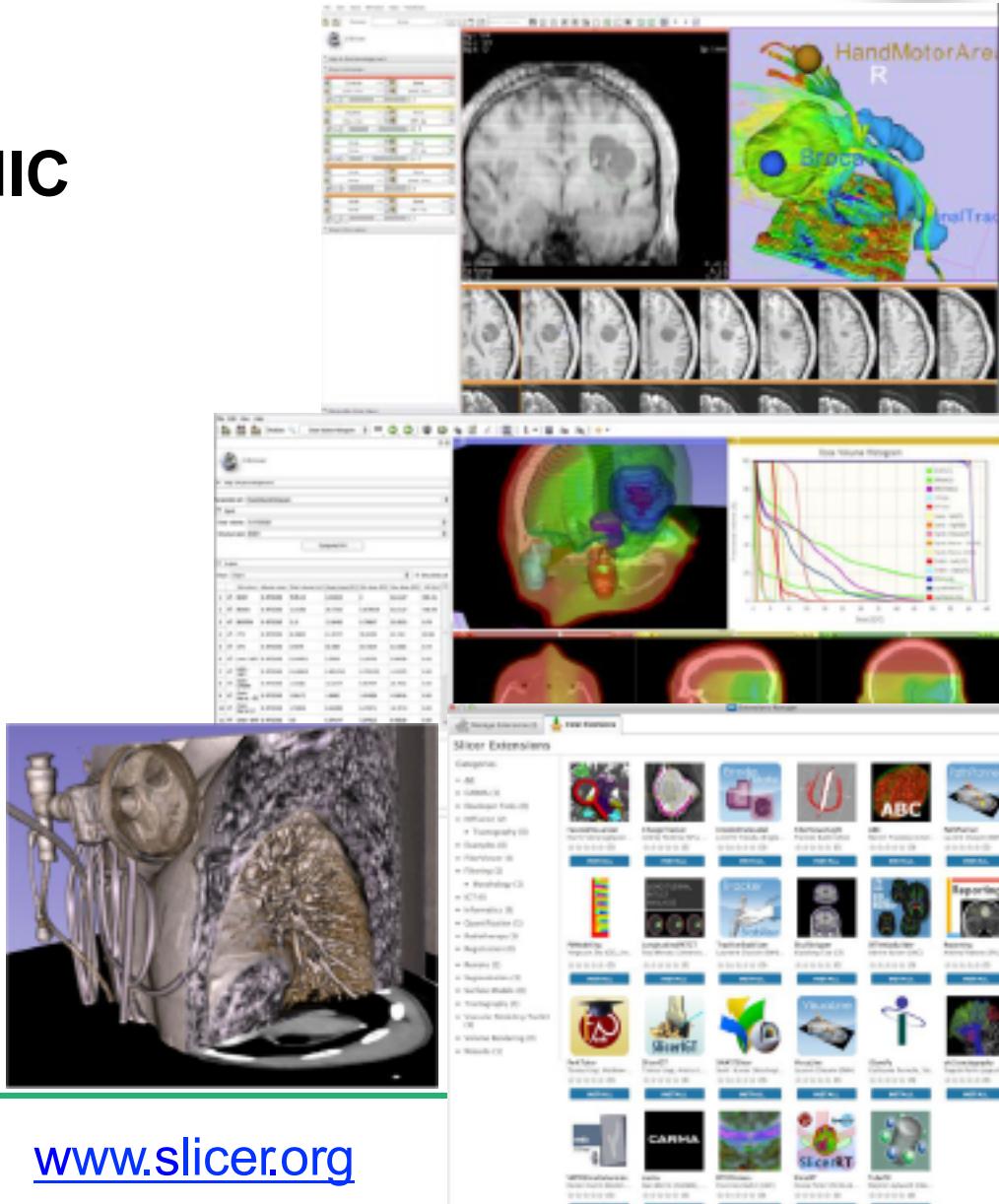


Risholm P., Ross J., Washko G.R., Wells III W.M. *Probabilistic Elastography: Estimating Lung Elasticity*. Inf Process Med Imaging. 2011;22:699-710. PMID: 21761697. PMCID: PMC3249413.

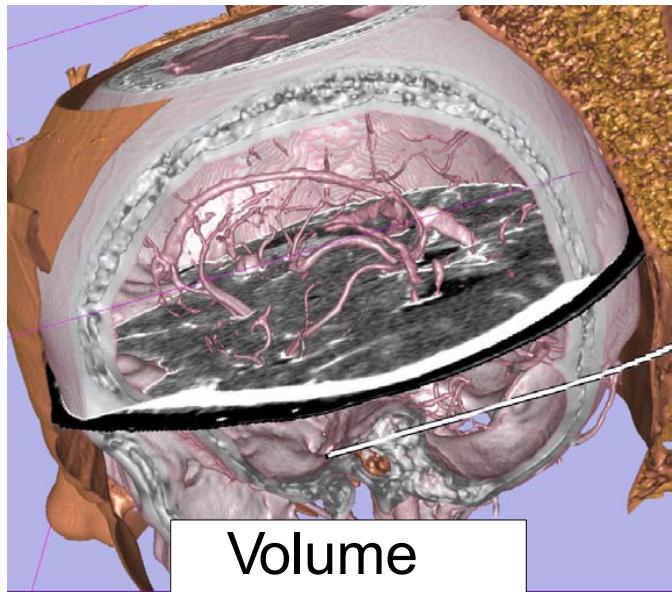


## 3D Slicer is software for MIC

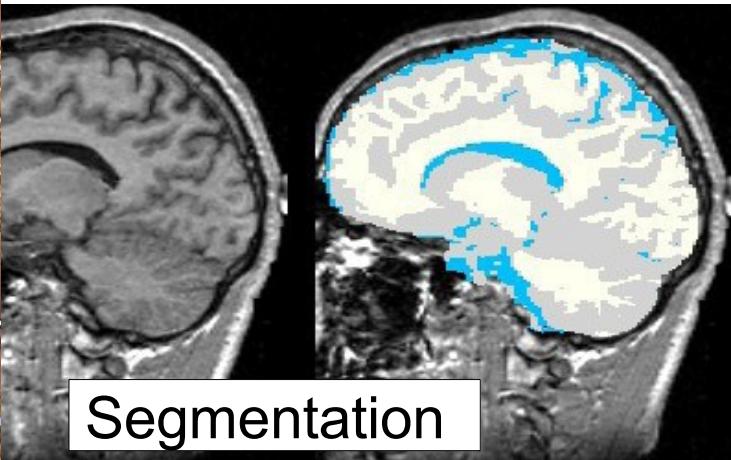
- Free open source
  - no reciprocity requirements
  - you choose what to share
- Cross-platform
  - “One-click” installers for Windows, Mac and Linux
- Support and training
- Industry-strength engineering
- Extensible
  - Community “App store”
- Research software
  - not FDA approved



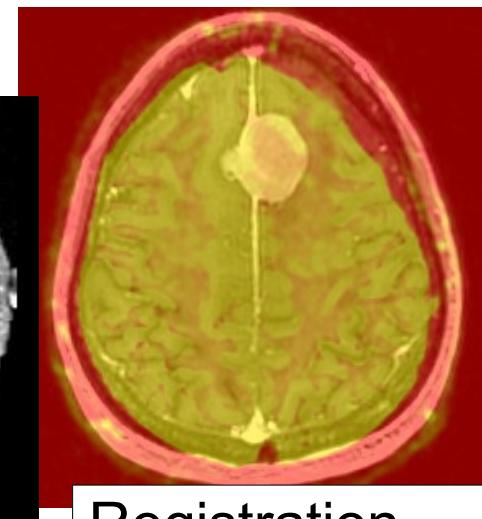
# The Engines of Slicer



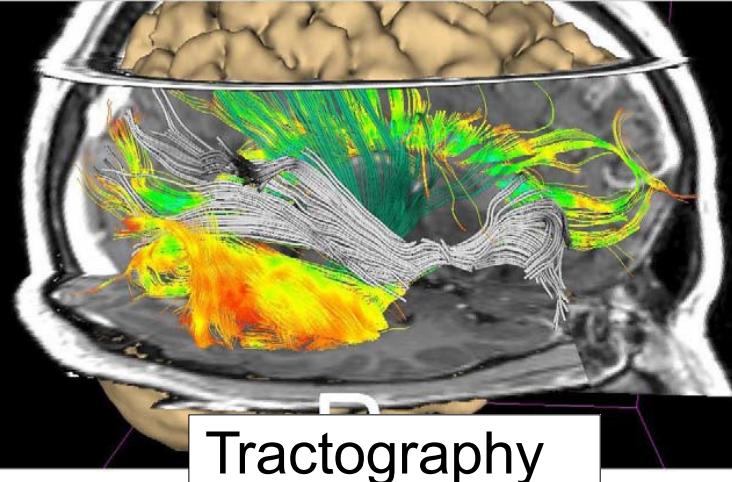
Volume rendering



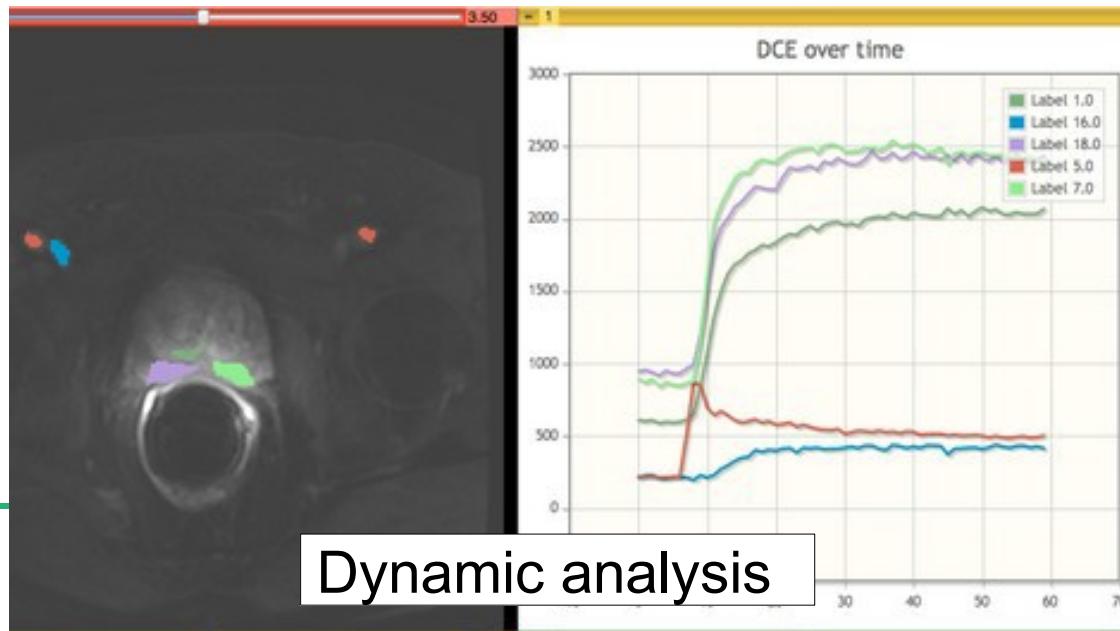
Segmentation



Registration



Tractography



Dynamic analysis



# Slicer Enables Reproducible Science

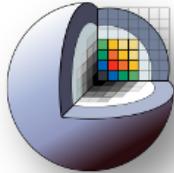
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- Reproducible Science requires access to:
  - Software
  - Data
  - Parameters
- See the following:
  - Collins F., Tabak L. (2014). Policy: NIH plans to enhance reproducibility. *Nature*. 505, 612–613. doi:10.1038/505612a
  - Topalidou M, Leblois A, Boraud T, Rougier NP. A long journey into reproducible computational neuroscience. *Frontiers in Computational Neuroscience*. 2015;9:30. doi:10.3389/fncom.2015.00030.



# Slicer Addresses Unmet Needs

- Stability and longevity
- Unique combination of high level features:
  - Usable by non-programmer
  - Free
  - Open source
  - Modular
  - Multi-platform
  - Customizable UI
  - Extensible
  - Business-friendly license (BSD)



# Slicer Community

In a Nutshell, Slicer...

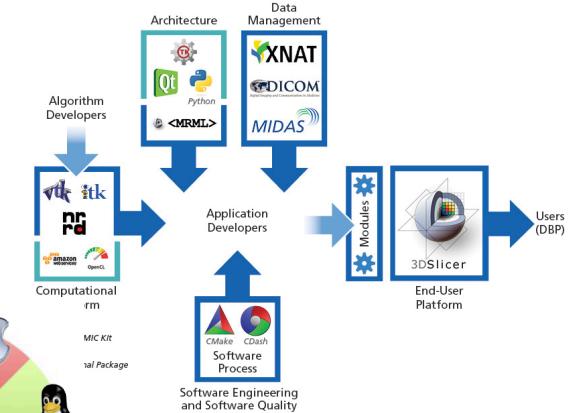
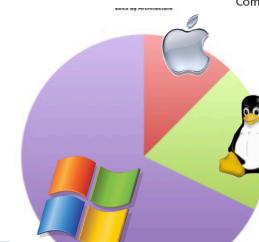
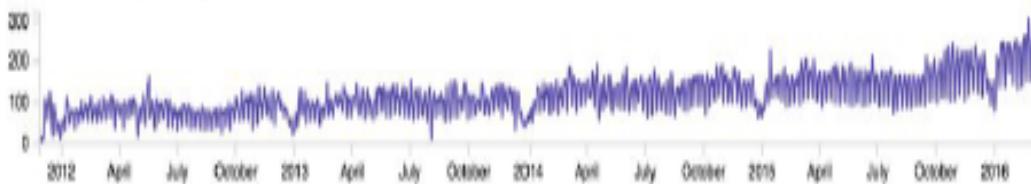
... has had 41,724 commits made by 127 contributors representing 1,437,273 lines of code

... is mostly written in C++ with an average number of source code commits

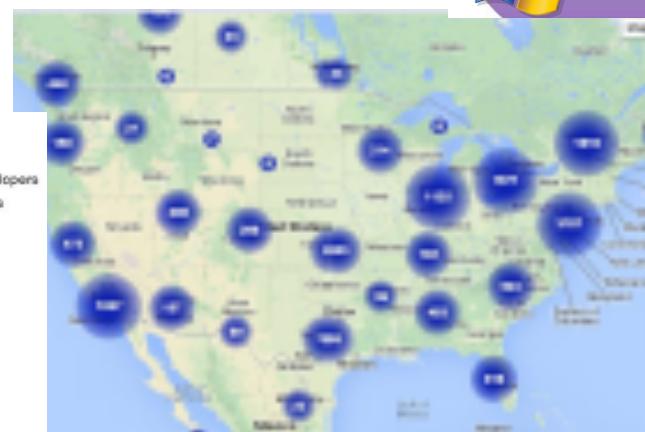
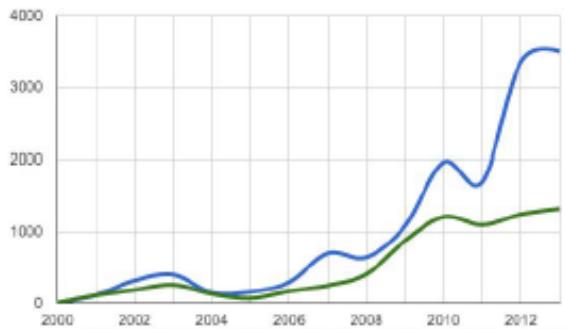
... has a well established, mature codebase maintained by a large development team with stable Y-O-Y commits

... took an estimated 406 years of effort (COCOMO model) starting with its first commit in January, 2000 ending with its most recent commit 6 days ago

Downloads per day



3D Slicer mailing list messages posted 2000-2013





# Slicer User Community

- Increasing use of Slicer is reflected in a large number of publications
- Volunteer contributions include participation in the mailing list and providing training materials

The Research Bazaar

## 3D Slicer Alpha Training Summary

By [Louise van der Werff](#)

Last week I ran my newly developed 3D Slicer training workshop over three content-packed afternoons. Five willing participants were able to come along and get their first peek at the training material, provide very helpful feedback related to the structure of the workshop, and brainstorm ways in which this software may be harnessed in their own work.

Day 2 of the #resbaz #3dslicer alpha training. @LouWerff talks segmentation #3dmed @resplat @ozvasedoc @dflanders pic.twitter.com/wW2BcoZNeT

— Paul Mignone (@PJMignone) [July 22, 2015](#)

For those who may not be familiar with 3D Slicer, it is an open source software package for image visualisation and analysis. More specifically, 3D Slicer is tailored towards the analysis of medical scan data such as that generated via MRI and CT scans. Although 3D Slicer has a wide range of functionalities, this workshop was primarily focussed on generating 3 dimensional volume renderings and surface models of anatomical features

## Documentación en Español NEW

- [Introducción a 3D Slicer en Español](#)
- [Reconstrucciones volumétricas con 3D Slicer](#)
- [Crear modelos/contornos de órganos con 3D Slicer](#)
- [Endoscopías virtuales con 3D Slicer](#)

Breve descripción de proyecto y un breve viaje por sus principales herramientas y funcionalidades.

Guía de uso para la herramienta de creación de reconstrucciones volumétricas de 3D Slicer.

Guía rápida introductoria para la creación de contornos de órganos para generar vistas volumétricas.

Manual de uso de la herramienta para 3D Slicer desarrollada por Steve Pieper para realizar endoscopías virtuales.

YouTube

3D Slicer 4.4.0-2015-07-26

DICOM Browser

Slices: R, P, S

Be part of the conversation

Learn to turn your CAT (CT) or MRI scan into a 3D model.

All Things 3D

Subscribe 543

68 views



# Slicer Developer Community

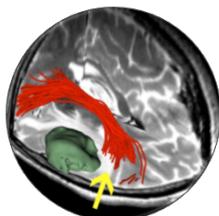
- Worldwide, distributed community
- Internet based technologies for development and communication
- Face-to-face meetings twice a year play a critical role



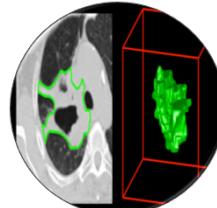
# Examples of Clinical Research

Tracking peritumoral white matter fibers

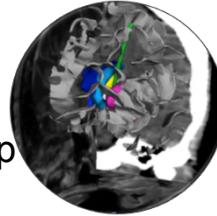
Radiation dose calculations



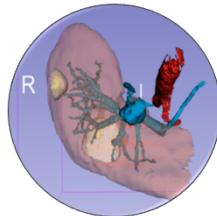
Diagnosis of Different Tumors in Lung Cancer



Model-Guided Deep Brain Simulation



Surgical navigation



Clinical users drive creation of technology

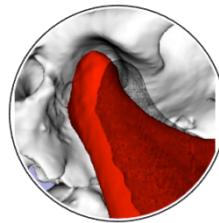
Prostate procedures



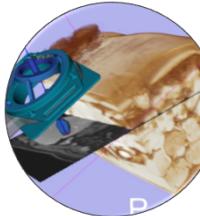
Breast cancer surgery guidance



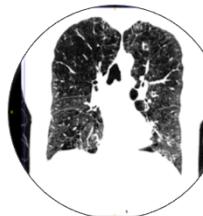
Diagnosis of Osteoarthritis Degeneration



Liver procedures



Quantitative assessment of COPD





# Companies Use Slicer



**SIEMENS**

**KUKA**

**Canon**

Known commercial activities range from use “as is” to full blown product development:

- Xstrahl (small animal radiation product)
- mebio (radiology product, prostate guidance)
- SonoVol (ultrasound product) (R43CA192482...)
- Novartis (quantitative imaging clinical trials)
- New Frontier (navigation system)
- KUKA (surgical robotics)
- Siemens (diagnostic and interventional research)
- Canon (robotic interventions)
- GE (research and products)
- NDI (trackers for surgical navigation)
- Isomics (research, consulting)
- Kitware (research, consulting)
  - 10+ Slicer based projects in the past two years
  - 5 commercial products being launched



# Business Model

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- Enable science
  - Apply for infrastructure funds
- 
- Underlying philosophy:
    - Open community-based approach
    - Free open source software with liberal license



# Slicer Enables NIH Research

wiki.slicer.org/slicerWiki/index.php/Main\_Page/SlicerCommunity

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2016  
2.1 Accuracy of Open-Source Software Segmentation and Paper-based Printed Three-Dimensional Models  
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2.5 In Vivo Visualization of the Facial Nerve in Patients with Acoustic Neuroma using Diffusion Tensor Imaging-Based Fiber Tracking

3 2015  
3.1 Low-cost Interactive Image-based Virtual Endoscopy for the Diagnosis and Surgical Planning of Suprasellar Arachnoid Cysts  
3.2 MRI-Only Based Radiotherapy Treatment Planning for the Rat Brain on a Small Animal Radiation Research Platform (SARRP)  
3.3 Potential of Diffusion Tensor Imaging and Relaxometry for the Detection of Specific Pathological Alterations in Parkinson's Disease (PD)  
3.4 High Contrast Microstructural Visualization of Natural Acellular Matrices by Means of Phase-Based X-Ray Tomography  
3.5 Treatment Planning and Delivery of Whole Brain Irradiation with Hippocampal Avoidance in Rats  
3.6 Performance of Single And Multi-Atlas Based Automated Landmarking Methods Compared to Expert Annotations in Volumetric MicroCT Datasets of Mouse Mandibles  
3.7 A Novel Procedure for Rapid Imaging of Adult Mouse Brains with MicroCT using Iodine-Based Contrast  
3.8 Comparison between Magnetic Resonance Imaging Estimates of Extracranial Cerebrospinal Fluid Volume and Physical Measurements in Healthy Dogs  
3.9 Automatic Classification of Prostate Cancer Gleason Scores from Multiparametric Magnetic Resonance Images  
3.10 Association Between Vascular Anatomy and Posterior Communicating Artery Aneurysms  
3.11 An Open Tool for Input Function Estimation and Quantification of Dynamic PET FDG Brain Scans  
3.12 Seeing More by Showing Less: Orientation-Dependent Transparency Rendering for Fiber Tractography Visualization  
3.13 MR Diffusion-weighted Imaging-based Subcutaneous Tumour Volumetry in a Xenografted Nude Mouse Model using 3D Slicer: An Accurate and Repeatable Method  
3.14 Spinal Cord Segmentation by One Dimensional Normalized Template Matching: A Novel, Quantitative Technique to Analyze Advanced Magnetic Resonance Imaging Data  
3.15 A Multidimensional Dynamic Quantification Tool for the Mitral Valve  
3.16 Two-Center Prospective, Randomized, Clinical, and Radiographic Study Comparing Osteotome Sinus Floor Elevation with or without Bone Graft and Simultaneous Implant Placement  
3.17 Isometric Scaling in Developing Long Bones Is Achieved by an Optimal Epiphyseal Growth Balance  
3.18 A Statistical Shape Model of the Human Second Cervical Vertebra  
3.19 Bone Engineering of Maxillary Sinus Bone Deficiencies using Enriched CD90+ Stem Cell Therapy: A Randomized Clinical Trial  
3.20 Three-Dimensional Eyeball and Orbit Volume Modification After LeFort III Midface Distraction  
3.21 A Method for the Assessment of Time-varying Brain Shift during Navigated Epilepsy Surgery  
3.22 High-field Functional Magnetic Resonance Imaging of Vocalization Processing in Marmosets  
3.23 Optimizing Parameters of an Open-source Airway Segmentation Algorithm using Different CT Images  
3.24 Cross-Validation of 3D Gamma Comparison Tools  
3.25 Effect of Pulse Sequence Parameters On Geometric Distortions Induced by a Titanium Brachytherapy Applicator  
3.26 Panorama Ultrasound for Navigation and Guidance of Epidural Anesthesia  
3.27 Towards the Personalized Treatment of Glioblastoma: Integrating Patient-Specific Clinical Data in a Continuous Mechanical Model  
3.28 Intraoperative Image-guided Transoral Robotic Surgery: Pre-clinical Studies  
3.29 Morphology Parameters for Mirror Posterior Communicating Artery Aneurysm Rupture Risk Assessment  
3.30 Intraoperative High-field Magnetic Resonance Imaging Combined with Functional Neuronavigation in Resection of Low-grade Temporal Lobe Tumors Involving Optic Radiation [Article in Chinese]  
3.31 Fibrin-based 3D Matrices Induce Angiogenic Behavior of Adipose-derived Stem Cells  
3.32 MIDA: A Multimodal Imaging-Based Detailed Anatomical Model of the Human Head and Neck  
3.33 Craniofacial Reconstruction using Rational Cubic Bézier Curves  
3.34 Volumetric Alterations in the Nucleus Accumbens and Caudate Nucleus in Bulimia Nervosa: A Structural Magnetic Resonance Imaging Study  
3.35 Validation of Osteoarthritis Synthetic Defect Database via Non-rigid Registration  
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3.37 Comparison between an Alternative and the Classic Definition of Chronic Bronchitis in COPDGene  
3.38 Quantitative Trait Loci Affecting the 3D Skull Shape and Size in Mouse and Prioritization of Candidate Genes in-silico  
3.39 Automatic Segmentation of Deep Intracerebral Electrodes in Computed Tomography Scans  
3.40 Openiglink Interface for State Control and Visualisation of a Robot for Image-Guided Therapy Systems  
3.41 Safe and Rapid Contouring of Fibro-osseous Lesions in the Orbital Area using Navigation with Minimally Invasive Cranial Bone Registration  
3.42 Open Source Software in a Practical Approach for Post Processing of Radiologic Images  
3.43 Functional Mapping of the Human Visual Cortex with Intravoxel Incoherent Motion MRI  
3.44 Factors Affecting Capsular Volume Changes and Association with Outcomes after Bankart Repair and Capsular Shift  
3.45 A Gradient in Cortical Pathology in Multiple Sclerosis by *in vivo* Quantitative 7 T Imaging  
3.46 Role of MRI-Based Tumor Volume Measurements in Surgical Treatment of Breast Cancer  
3.47 Factors Affecting Capsular Volume Changes and Association with Outcomes after Bankart Repair and Capsular Shift  
3.48 B-Mode and Acoustic Radiation Force Impulse (ARFI) Imaging of Prostate Zonal Anatomy: Comparison with 3T T<sub>2</sub>-Weighted MR Imaging  
3.49 Optical Polarization Tractography Revealed Significant Fiber Disarray in Skeletal Muscles of a Mouse Model for Duchenne Muscular Dystrophy  
3.50 Hippocampal Volume is Reduced in Schizophrenia and Schizoaffective Disorder but Not in Psychotic Bipolar I Disorder Demonstrated by Both Manual Tracing and Automated Parcellation (FreeSurfer)

Hundreds of  
papers  
published  
using  
3D Slicer

# Licensing model

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License has to:

- Facilitate scientific exchange
- Enable commercial use
- Be acceptable to the institution
- Result: BSD open source license
  - **you** choose what to share
  - Key concept: “Not intended”



# Long-Term Funding Strategy

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Developed an “ecosystem” of funded efforts, both US and internationally

- Community based approach: no single point of failure
- Slicer is attractive as a platform for solution development:
  - Stability
  - Longevity
  - Supported
  - Maintained



# Toolmakers Use Slicer



- SlicerCIP (Raul San Jose Estepar)-R01 HL116931, R01 HL116473
- SlicerCMF (Lucia Cividanes, Martin Styner, Beatriz Panagua)-R01 DE024450
- SlicerProstate (Clare Tempany)-U01 CA151261, R01 CA111288, U24 CA180918, P41 EB015898
- SlicerRadiomics (Hugo Aerts)-U01 **CA190234**, U24 **CA194354**
- QIICR (Ron Kikinis, Andriy Fedorov)-U24 **CA180918**
- SlicerGyn – Pelvic floor research (John DeLancey, U Michigan)  
P50 HD044406, R01 HD038665, P30 AG024824
- OpenIGTLink (Junichi Tokuda)-R01 EB020667
- SlicerTractography (Lauren O'Donnell)-U01 **CA199459**
- SlicerIGT (Gabor Fichtinger, Andras Lasso, Tamas Ungi)-Ontario Govt. funded
- SlicerRT (Csaba Pinter, Gabor Fichtinger, Greg Sharp)-Ontario Govt. funded
- SlicerDBS (Pierre Jannin)-French Govt. funded
- IASEM (Bradley Lowecamp)-NLM intramural funding
- Bender (Stephen Aylward)-AFRL
- VesselView (Stephen Aylward)-R44 **CA165621**
- Slicer remote rendering (Al Johnson)-P41 EB015897
- Slicer (Ron Kikinis, Carl-Frederik Westin)-P41 EB015902



Green indicates clinical research focus



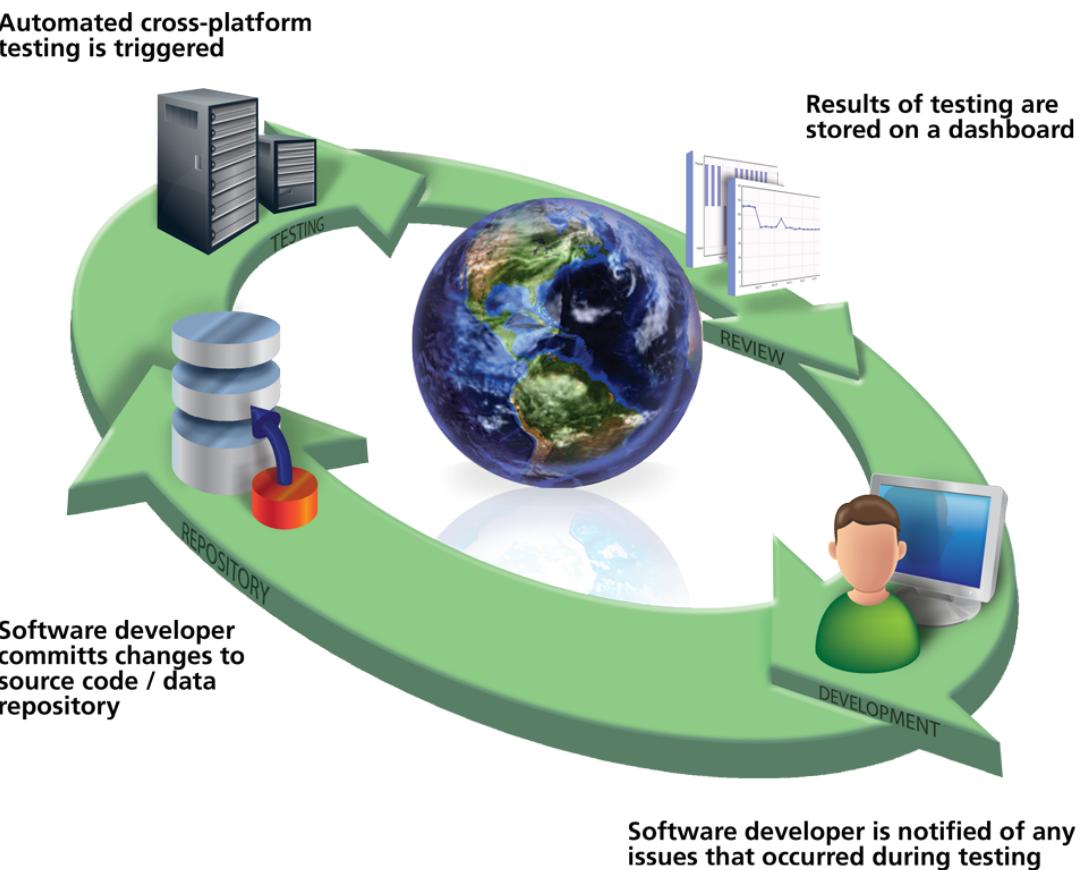
# Maintenance

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- A documented and principled software engineering methodology is key
- 3D Slicer has a core engineering team consisting of professional software engineers
- The Slicer community is actively participating in maintenance

# Software Engineering Methodology

- Designed for a geographically distributed team
- Community driven activities
- More than 600 automatic tests
- Extensive documentation
- Extreme programming approach: publish early, publish often





# Core Engineering Activities

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Ongoing need for maintenance to keep Slicer attractive to end-users and developers

Maintenance means:

- Review contributed code
- Porting to new OS releases
- Update software components such as ITK and VTK
- Investigate and resolve bug reports
- Maintain factory machines for nightly and stable builds across platforms and including extensions
- Monitor and troubleshoot extensions
- Maintain download servers and data bases
- Update wiki pages
- Write tutorials
- Answer emails
- ....



# Core Engineering Team

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Available funding amounts to 4.5 FTE in 2015:

- NAC: 0.75 FTE (IC: EB)
- NCIGT: 0.25 FTE (IC: EB)
- QIICR: 0.5 FTE (IC: CA)
- Kitware: 1 FTE (multiple IC's)
- Queen's University: 2 FTE (mostly Canadian funding)

Funding for core engineering is spread across several projects and requires foresight in the grant application process

P.S. Core engineering is different from application engineering.



# Community Contributions

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Participants outside the core engineering team

- Developers
  - Mailing lists,
  - weekly electronic meetings,
  - focus meetings on particular topics
  - twice a year weeklong in-person events
- Users
  - Mailing lists
  - Electronic training materials with sample data sets
  - Hands-on training events at conferences and on request
  - Individual support



# Challenges

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- Funding for core engineering
- Healthy balance between stability and innovation
- The academic culture and reward system: Reviewers often lack understanding of the role of engineering



# Summary

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3D Slicer is an effective tool for **translation** of MIC and informatics technologies **into clinical research**.

- NIH funded projects have enabled a huge range of scientific activities:
  - Major NIH-supported projects use 3D Slicer
  - Grassroots activities worldwide
- This is due to an effective operational model:
  - A strong leadership team
  - A robust software with no liabilities
  - A “community of the willing”
    - Developers who write, share, and maintain the software
    - Users who request features and report problems



# Thanks For Your Attention

Questions and comments?

<http://www.slicer.org>



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