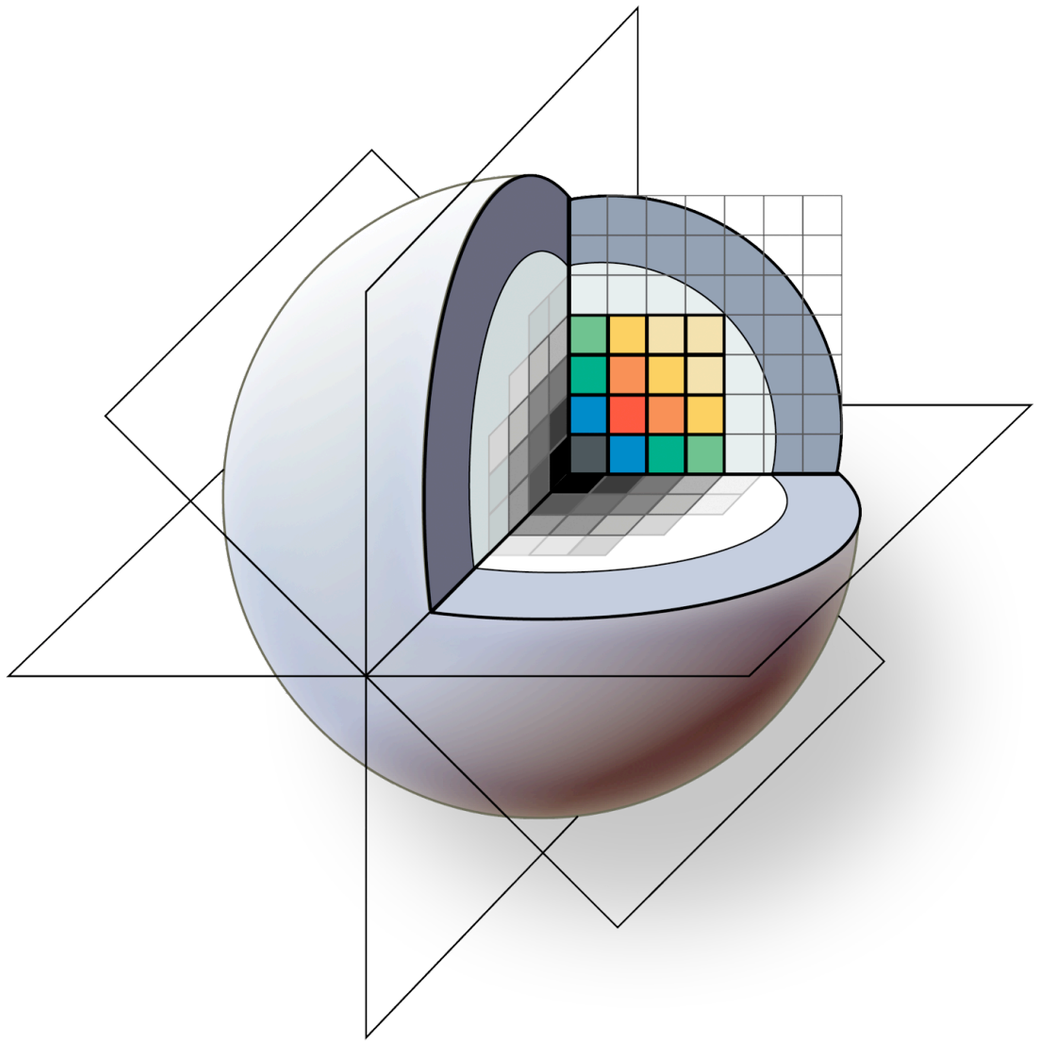
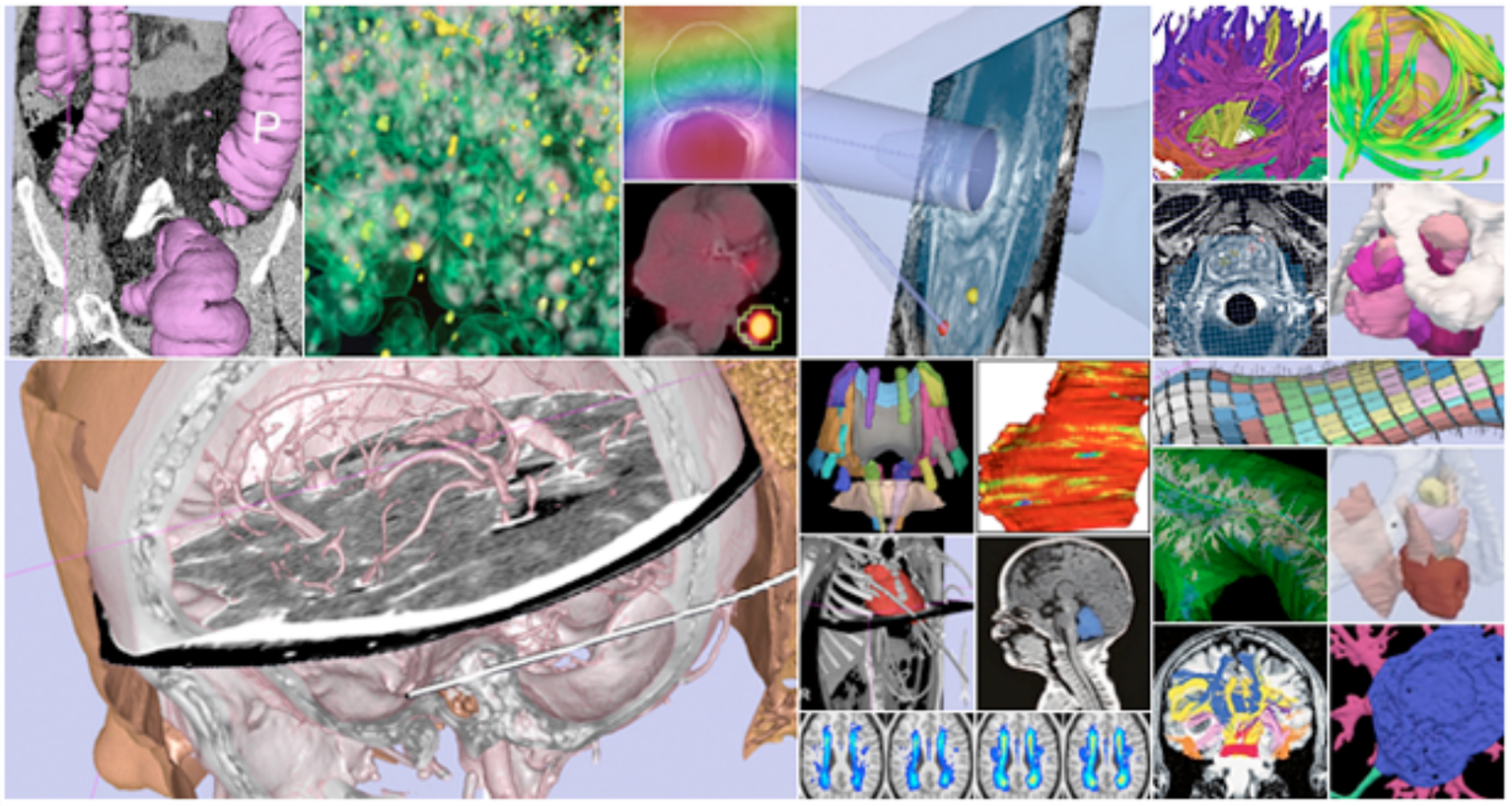


3D Slicer: A Free & Open Source Platform For Medical Image Analysis and Visualization

Brigham and Women's Hospital

3D Slicer: An overview

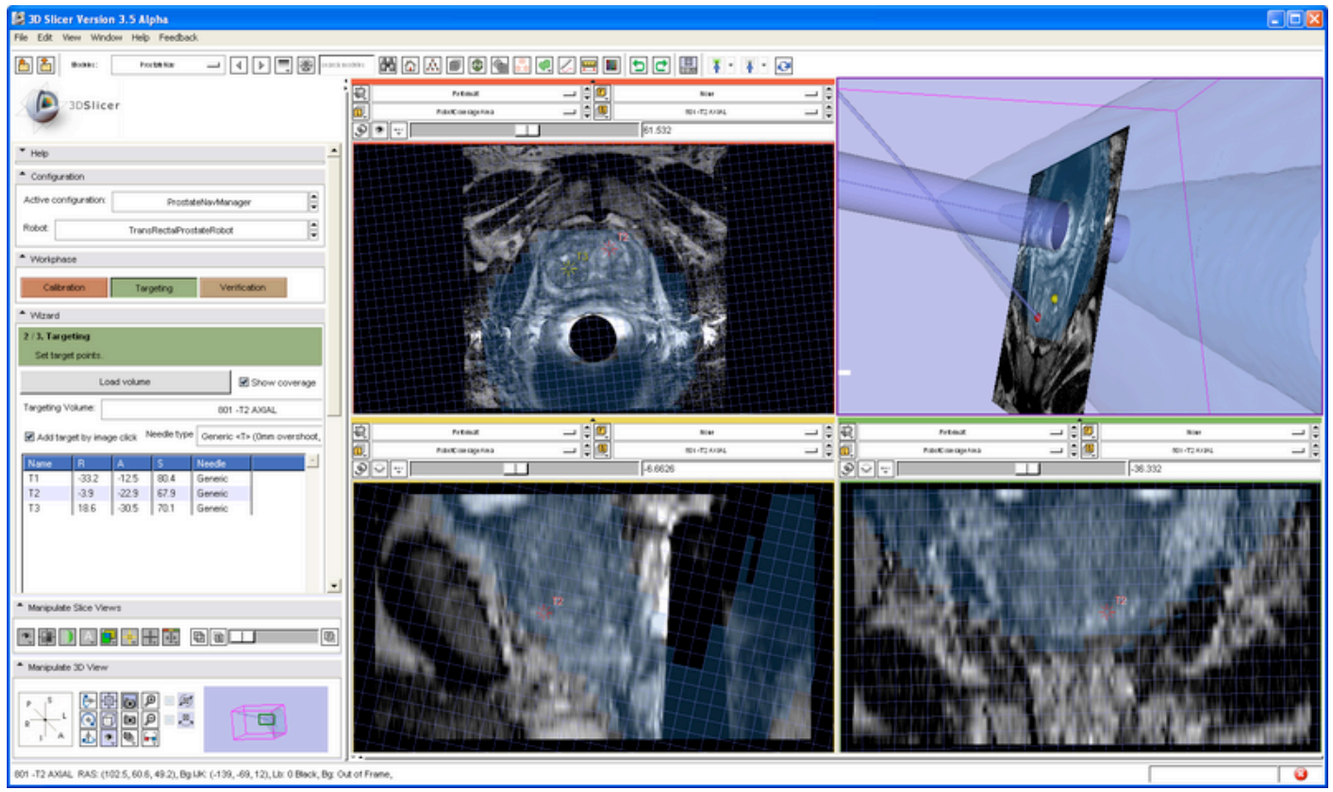
3D Slicer is a multi-platform, free and open source software package for visualization and medical image computing.



www.slicer.org

3D Slicer: An

The software platform is community created for the purpose of subject specific medical image analysis and visualization. Slicer includes support for:



(Sample screenshot of the ProstateNav module: targeting using the transrectal robot device. Slicer3 visualizes the target planning image, target point, needle trajectory, transrectal probe, and robot coverage area.)

- Multi-modality imaging including, MRI, CT, US, nuclear medicine, and microscopy
- Multi organ from head to toe
- Bidirectional interface for devices
- Expandable and interfaced to multiple toolkits

3D Slicer: An

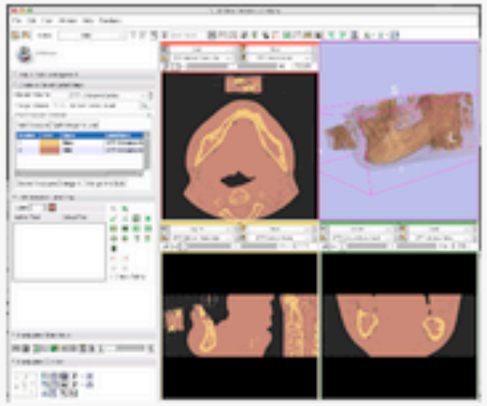
Types of users:

Algorithm researchers who work within 3DSlicer's development environment and with associated toolkits)
Biomedical engineers (who rely on 3DSlicer's interactive enironment and scripting capabilities)
Application scientists (who use 3DSlicer as a desktop application and turnkey system)

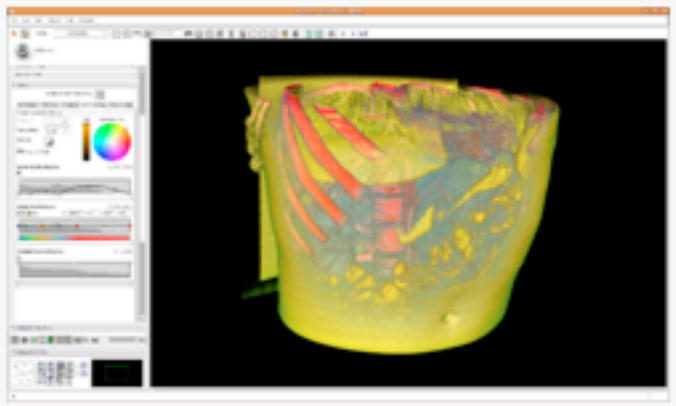
Core use scenarios:

- Longitudinal and multi-channel dataset analysis
- Individual and group analysis
- Real-time control and tracking in the operating theater
- Neurosurgical planning and guidance

3D Slicer: Version 3.6 Highlights

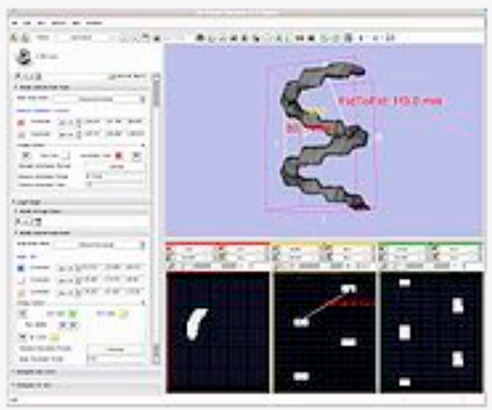


The Interactive Editor can be used to create and edit label maps for quantitative analysis and surface model generation (Steve Pieper)

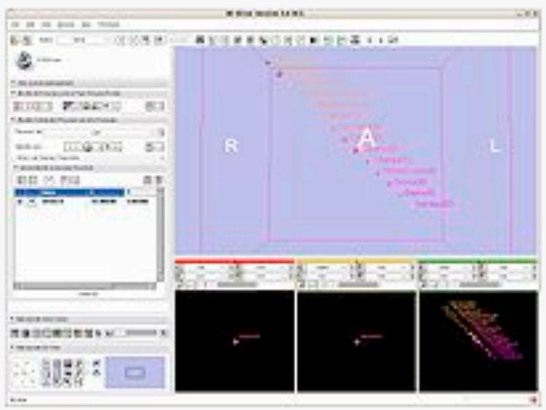


Volume Rendering (Yanling Liu, Julien Finet, Lisa Avila)

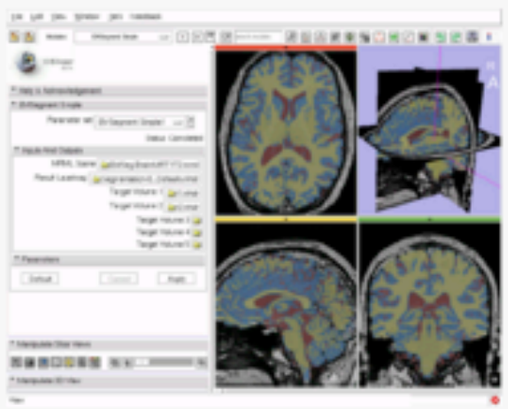
Colors (Nicole Aucoin)



Measurements (rulers and angles) (Nicole Aucoin)

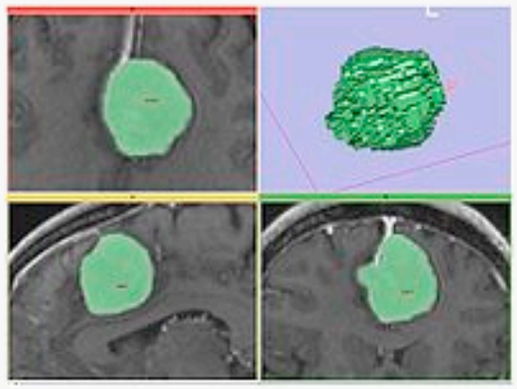


Fiducials (Nicole Aucoin)

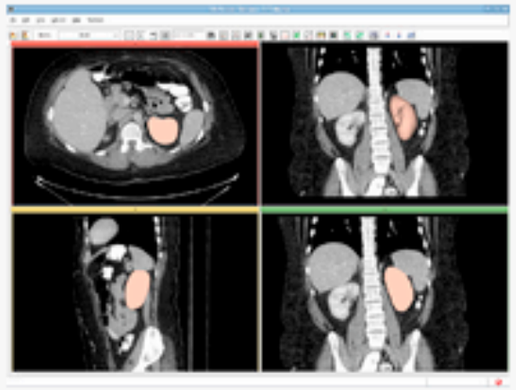


EM Segmenter, simple version (Kilian Pohl)

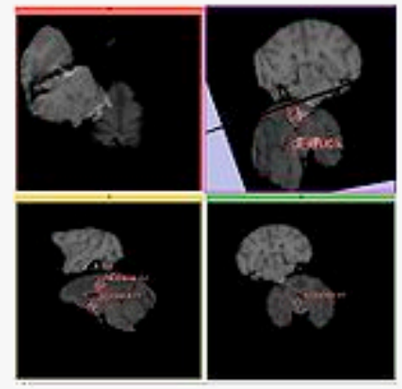
3D Slicer: Version 3.6 Highlights



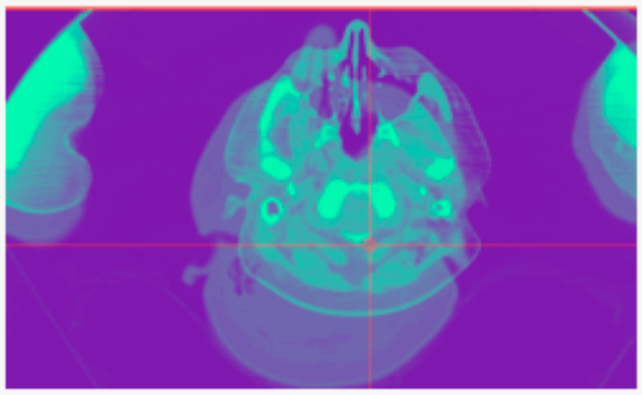
Fast Marching segmentation (Andriy Fedorov)



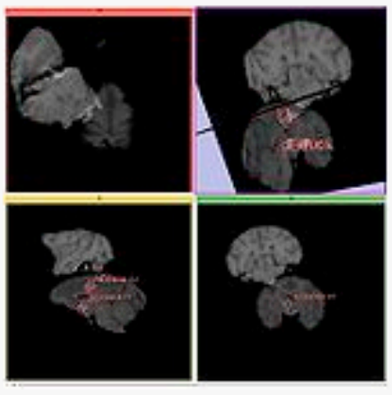
Robust Statistical Segmentation (Yi Gao)



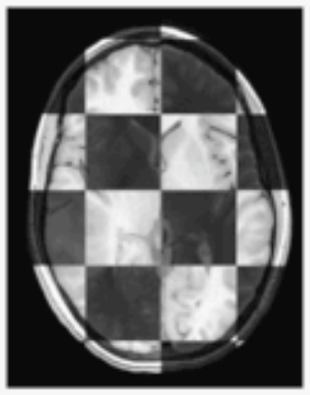
NEW: Multiresolution Affine registration (Casey Goodlett)



Improved: Expert Automated Registration (Casey Goodlett)



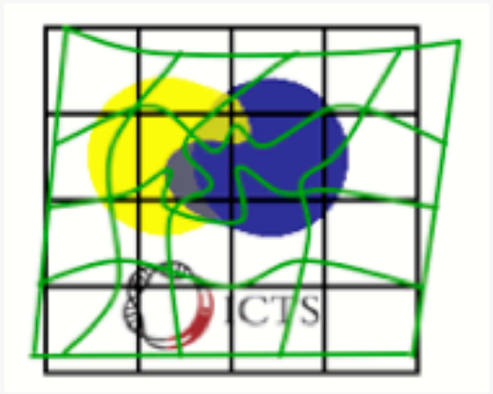
NEW: Fiducial Registration (Casey Goodlett)



NEW: BRAINSFit Registration (Hans Johnson)

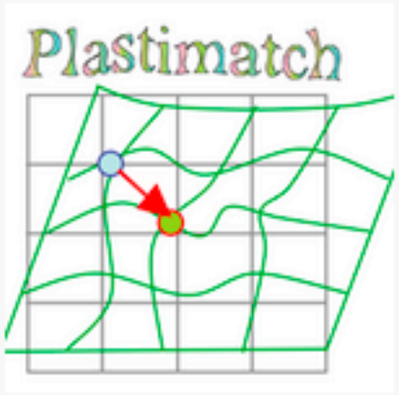
3D Slicer: Version 3.6 Highlights

NEW: BRAINSDemonWarp (Hans Johnson)

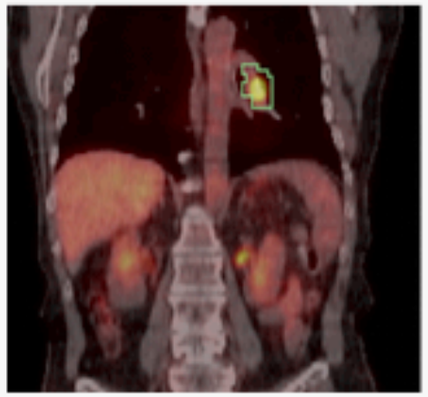


NEW: BRAINSResample (Hans J. Johnson)

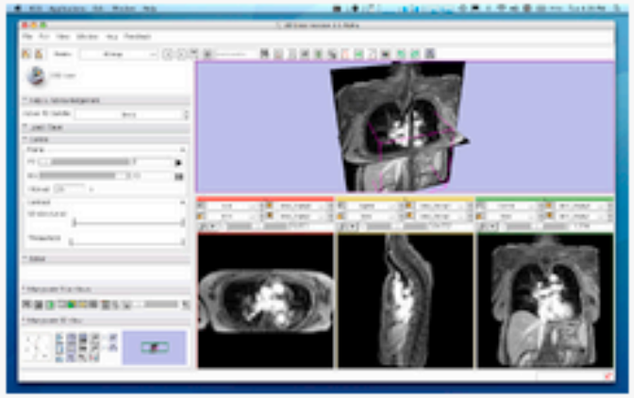
NEW: BRAINSROIAuto (Hans J. Johnson)



NEW: Plastimatch non-rigid registration (Greg Sharp)

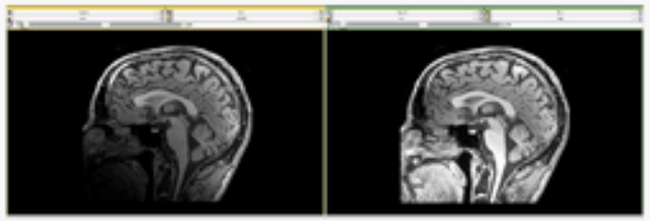


PETCTFusion (Wendy Plesniak)

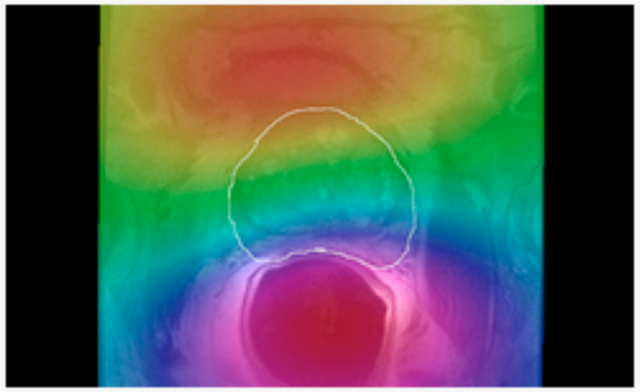


4D Image Viewer (Junichi Tokuda)

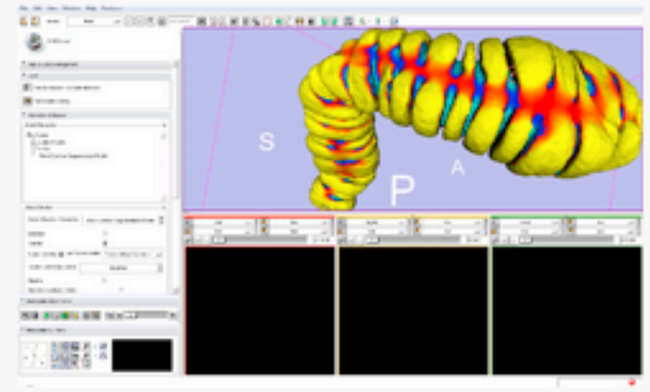
3D Slicer: Version 3.6 Highlights



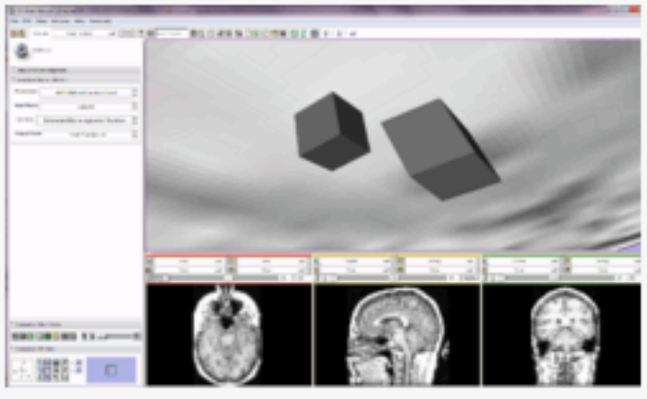
MRIBiasFieldCorrection correction of MRI intensity inhomogeneity i.e. bias field (Sylvain Jaume)



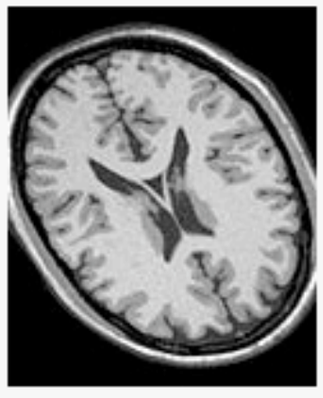
N4 Bias Field Correction (Andriy Fedorov)



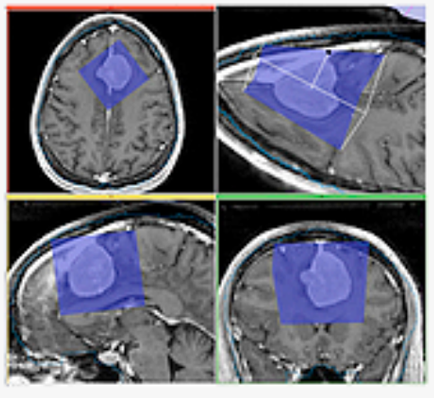
Mesh Contour Segmentation (Peter Karasev)



Model Transform (Alex Yarmarkovich)

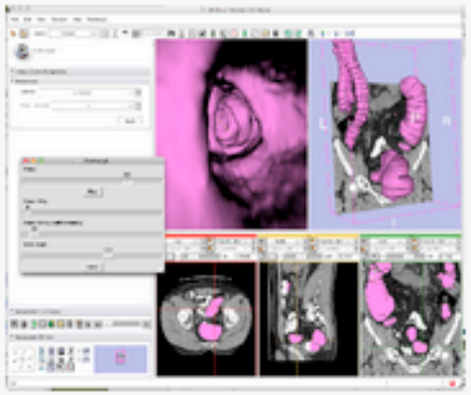


Resample Scalar/Vector/DWI Volume (Francois Budin)

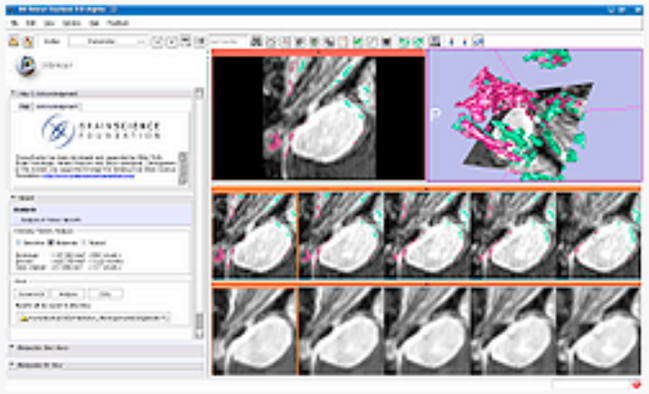


Crop Volume (Andriy Fedorov)

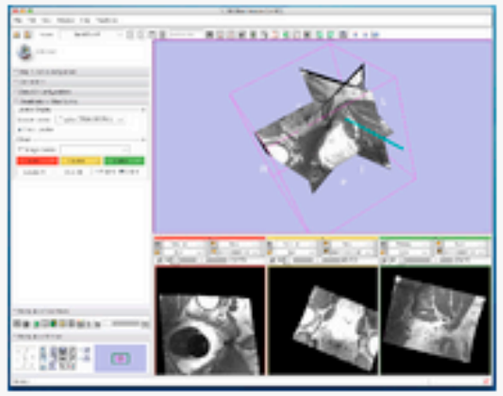
3D Slicer: Version 3.6 Highlights



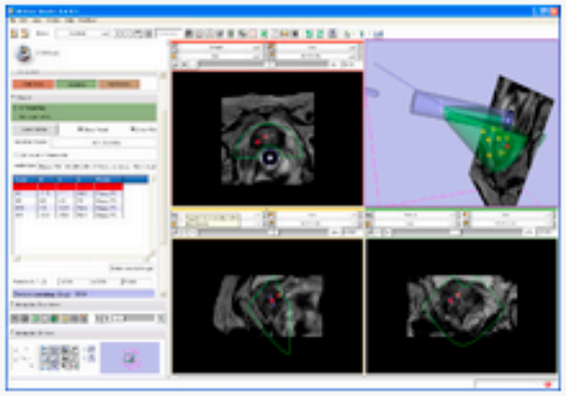
Virtual Endoscopy (Steve Pieper)



ChangeTracker (Andriy Fedorov)

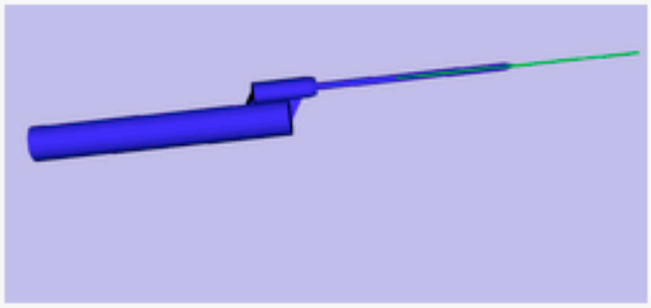


OpenIGTLinkIF (Junichi Tokuda)



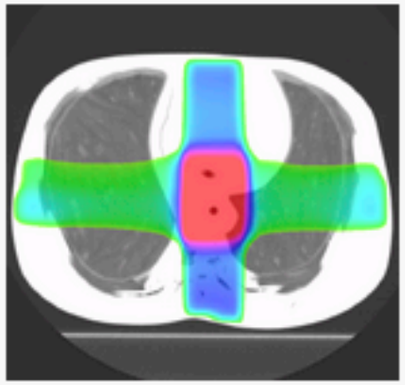
ProstateNav (Andras Lasso, Junichi Tokuda)

NeuroNav (Haiying Liu)

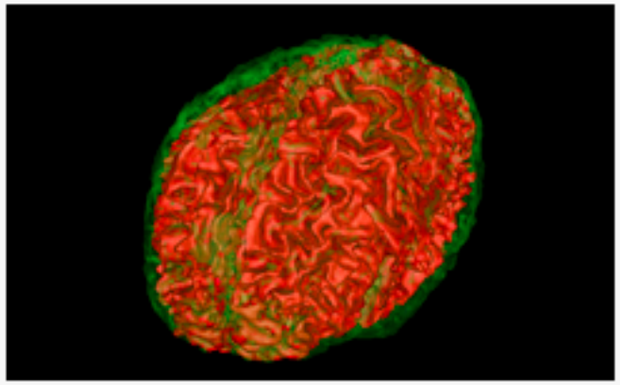


IGT tool selector (A. Wiles)

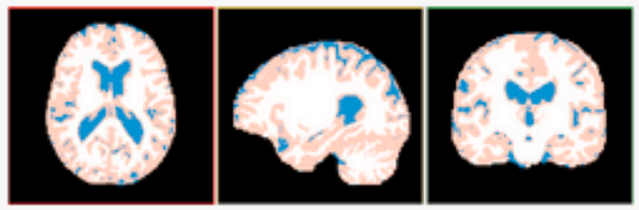
3D Slicer: Version 3.6 Extensions



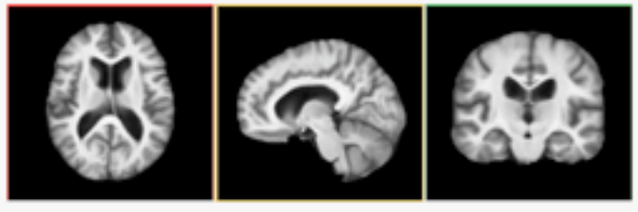
The Plastimatch DICOM RT reader allows import and conversion of data in that format. (Greg Sharp)



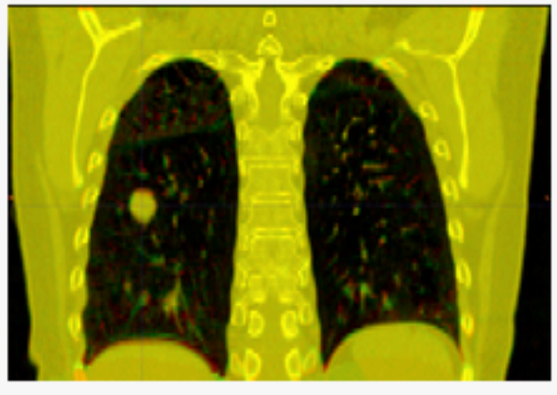
The ABC Segmenter is based on ITK EM technology.



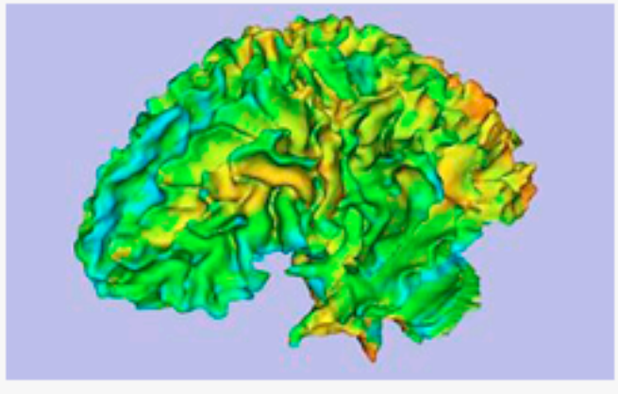
Fuzzy segmentation



Hammer Registration can be used to build statistical brain atlases

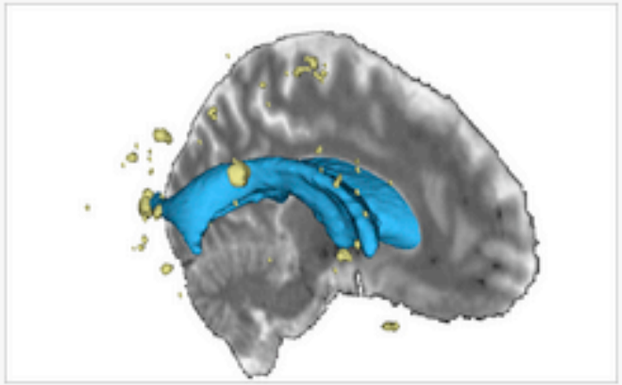


Plastimatch non-rigid registration (Greg Sharp)

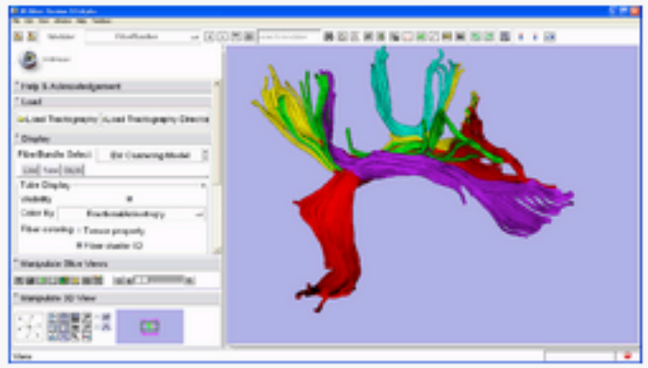


Arctic wizard (Automatic Regional Cortical ThICkness)

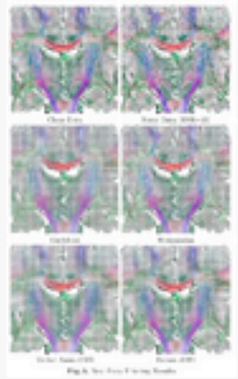
3D Slicer: Version 3.6 Extensions



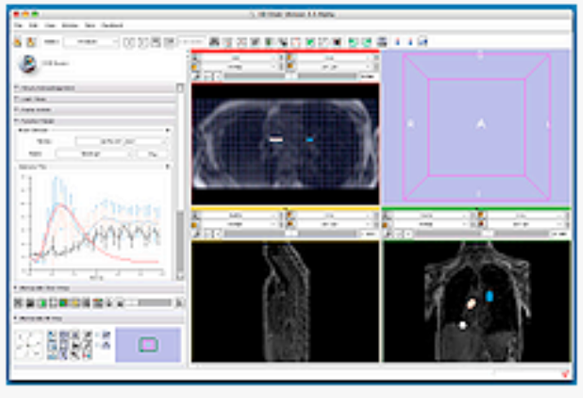
Lupus white matter lesions segmentation (Jeremy Bockholt, Mark Scully)



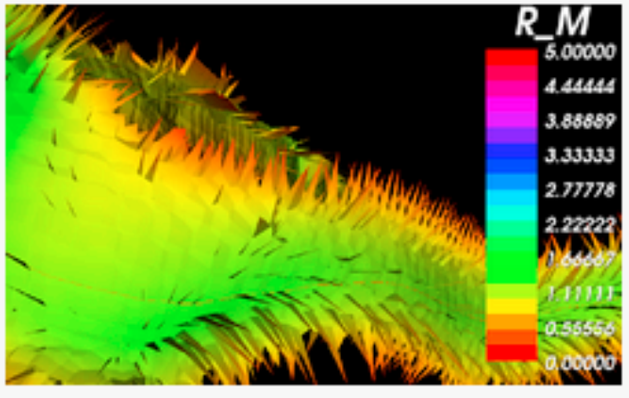
EM DTI clustering (Mahnaz Maddah)



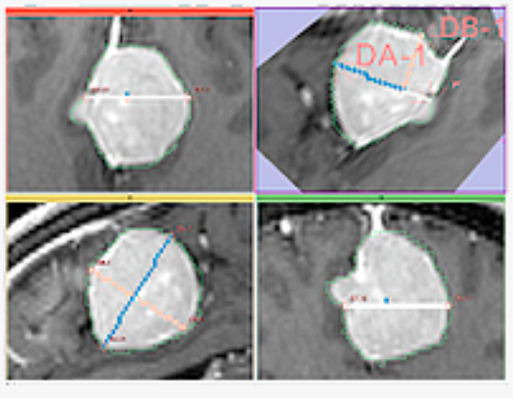
Rician Noise Filter for noise removal in DWI data



The FourD Analysis module was designed for time series analysis (Junichi Takuda)



Centerline extraction using Voronoi diagrams (Luca Antiga, Daniel Haehn)



Label diameter estimation (Andriy Fedorov)

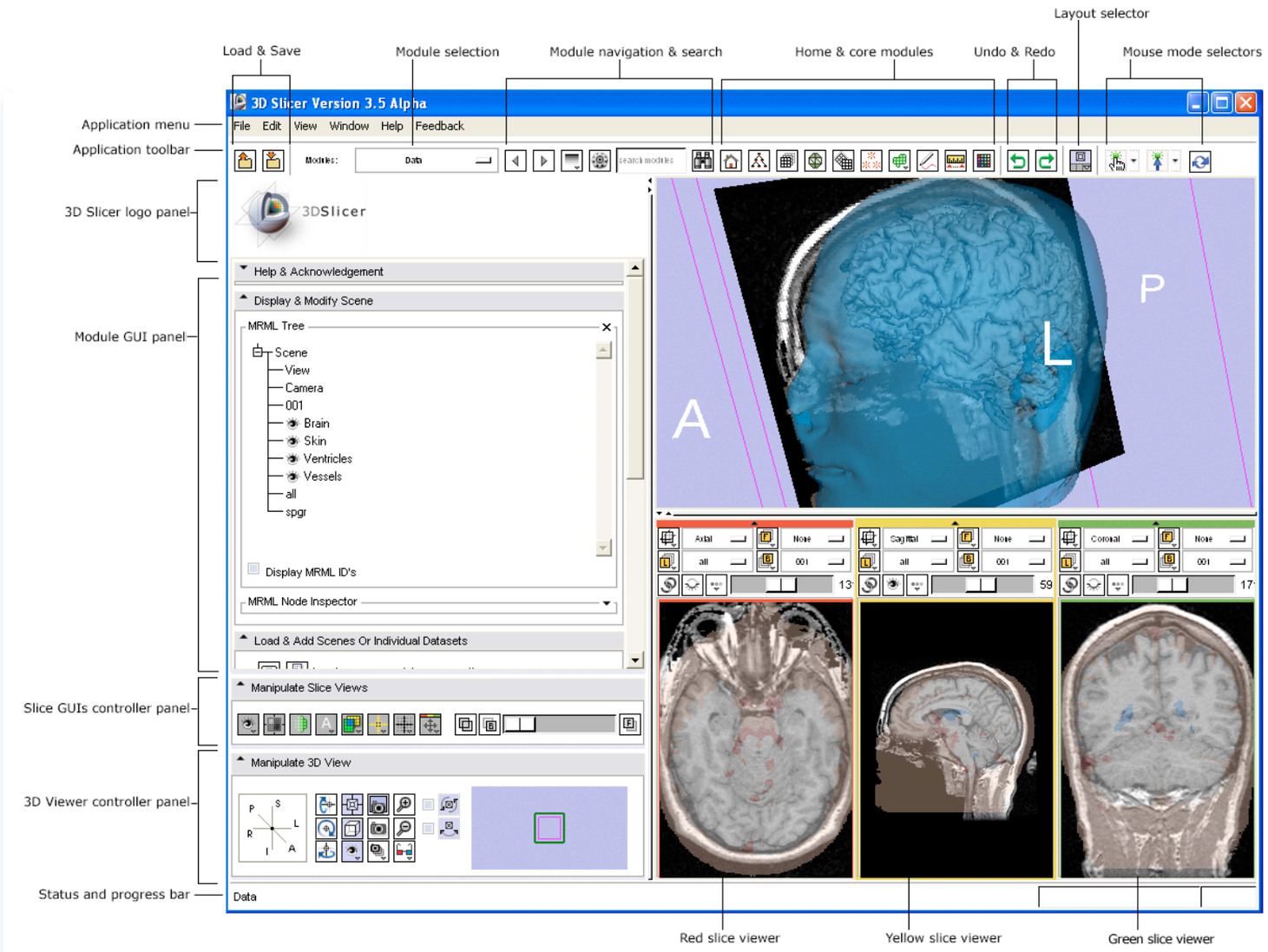
3D Slicer: What extensions afford...

- Keep the base package "lean and mean"
- Modules have individual identity
  - Per-module web site, svn, downloads, mailing lists, wiki…
- Users can assemble their own set of tools
  - Customized 'Bundles' by task or application
- Easy to download compatible extensions
  - Analogous to Firefox extensions
  - Integrate extension builds into developer/nightly/ release processs
- NITRC Supplement to NA-MIC providing additional infrastructure (Neuroimaging Informatics Tools and Resources Clearinghouse)
  - NITRC can host neuroimaging projects (gforge implementation)

3D Slicer: Integration options

Slicer Libs	• ModuleDescriptionParser • GenerateCLP • vtkITK • MRML	Non-slicer specific support libraries
Slicer Base	• Application logic • Widgets	Common infrastructure for Slicer applications
Built in modules	• Slice viewers • Models • Fiducials • Transforms	Full access to Slicer internals
Loadable modules	• Query Atlas • QDEC • Volume rendering • ChangeTracker • EMSegment	Full access to Slicer internals
Scripted modules	• Editor • Teem Two Tensor Tractography • VMTK	Limited access to Slicer internals
Command line modules	• Registration	Restricted access to Slicer internals
Daemon	• OpenIGTLink • Stochastic Tractography	Access to MRML

3D Slicer: Application



User-centered design:

- User guidance and feedback incorporated into design process where possible
- KWWidgets-based thin GUI layer
- Presentation layer independent of application logic & state
- Architecture supports scripting and command-line use

3D Slicer: Quick Start for New Users

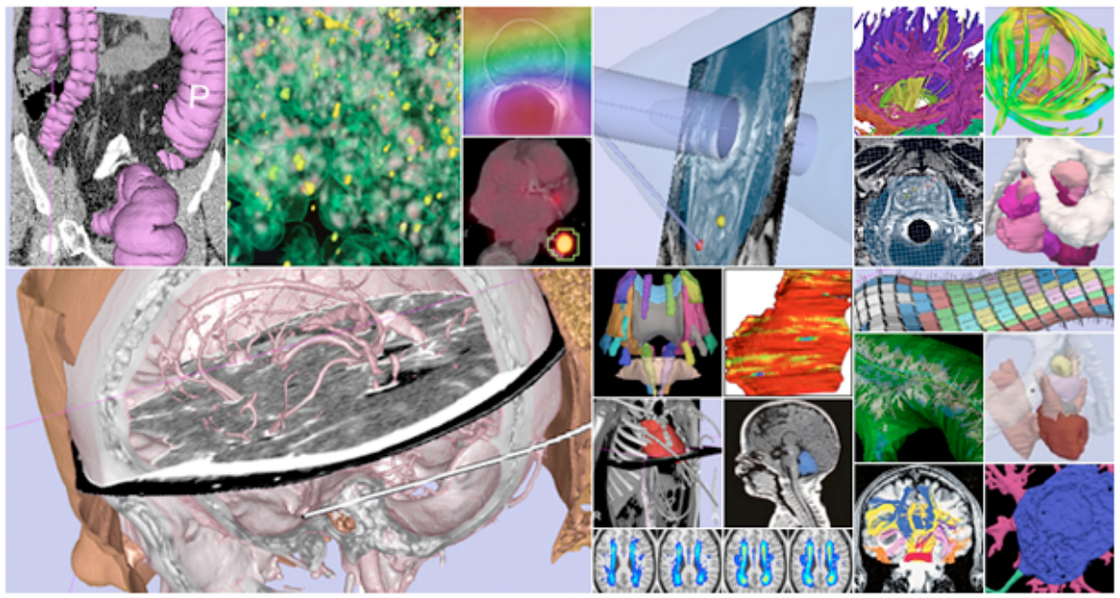
Greetings and guidance from

Slicer's Welcome Module

Default start-up module for new users:

- Brief friendly overview of the application interface
- Describes core modules
- Describes basic data loading and saving
- Provides tips for adjusting data display
- Describes how to change layouts
- Points users to more detailed resources
- and more...

3D Slicer: Advanced Visualization in Use



A Example endoscopy session for virtual colonoscopy (CT colonography) in Slicer's Endoscopy Module.
B Volume rendering on multi-channel confocal microscopy image in Slicer's Volume Rendering Module.
C Example of recovered bias field computed with Slicer's N4ITKBiasFieldCorrection Module.
D Example PET/CT visualization in 3D Slicer's PETCT Fusion Module.
E Queens Roadmap Project (Transrectal MRI-guided robotic prostate biopsy)
F O'Donnell L., Westin C-F. High-Dimensional White Matter Atlas Generation and Group Analysis. Int Conf Med Image Comput Comput Assist Interv. 2006;9(Pt 2):243-51. PMID: 17354778.
G Interactive seeding of DTI fiber tracts using vertices of a model in 3D Slicer's Fiducial Seeding Module.
H Queens Roadmap Project (Transrectal MRI-guided robotic prostate biopsy)
I Margulies R.U., Hsu Y., Kearney R., Stein T., Umek W.H., DeLancey J.O.L. Appearance of the Levator Ani Muscle Subdivisions in Magnetic Resonance Images. Obstet Gynecol. 2006 May;107(5):1064-9. PMID: 16648412. PMCID: PMC1479224.
J An example of fast hardware accelerated volume rendering with VTK version 5.6, available in Slicer 3.6.
K Maddah M., Zollei L., Grimson W.E.L., Westin C-F., Wells III W.M. A Mathematical Framework for Incorporating Anatomical Knowledge in DT-MRI Analysis. Proceedings of the 5th IEEE International Symposium on Biomedical Imaging: From Nano to Macro 2008; 4543943: 105–108. PMID: 19212449. PMCID: PMC2638065.
L Jayender J., Patel R., Michaud G., Hata N. Optimal Transseptal Puncture Location for Robot Assisted Left Atrial Catheter Ablation. Int Conf Med Image Comput Comput Assist Interv. 2009;12(Pt 1):1-8. PMID: 20425964.
M Cardiac segmentation and CT Volume Rendering, February 2008 using data and segmentations from collaboration with Boston Children's Hospital Pediatric Cardiology.
N Limperopoulos C., Soul J.S., Gauvreau K., Huppi P.S., Warfield S.K., Bassan H., Robertson R.L., Volpe J.J., du Plessis A.J. Late Gestation Cerebellar Growth Is Rapid and Impeded by Premature Birth. Pediatrics. 2005 Mar;115(3):688-95. PMID: 15741373.
O Moscufo N., Guttmann C.R.G., Meier D., Csapo I., Hildenbrand P.G., Healy B., Schmidt J., Wolfson L. Brain Regional Lesion Burden and Impaired Mobility in the Elderly. Neurobiol Aging. 2009 May 8. PMID: 19428145.
P NA-MIC NCBC Collaboration: Automated FE Mesh Development
Q Close-up of centerline extraction of coronary arteries computed by Slicer's VMTKCenterlines module.
R Margulies R.U., Hsu Y., Kearney R., Stein T., Umek W.H., DeLancey J.O.L. Appearance of the Levator Ani Muscle Subdivisions in Magnetic Resonance Images. Obstet Gynecol. 2006 May;107(5):1064-9. PMID: 16648412. PMCID: PMC1479224.
S Tharin S., Golby A.J. Functional Brain Mapping and Its Applications to Neurosurgery. Neurosurgery. 2007 Apr;60(4 Suppl 2):185-201; discussion 201-2. PMID: 17415154.
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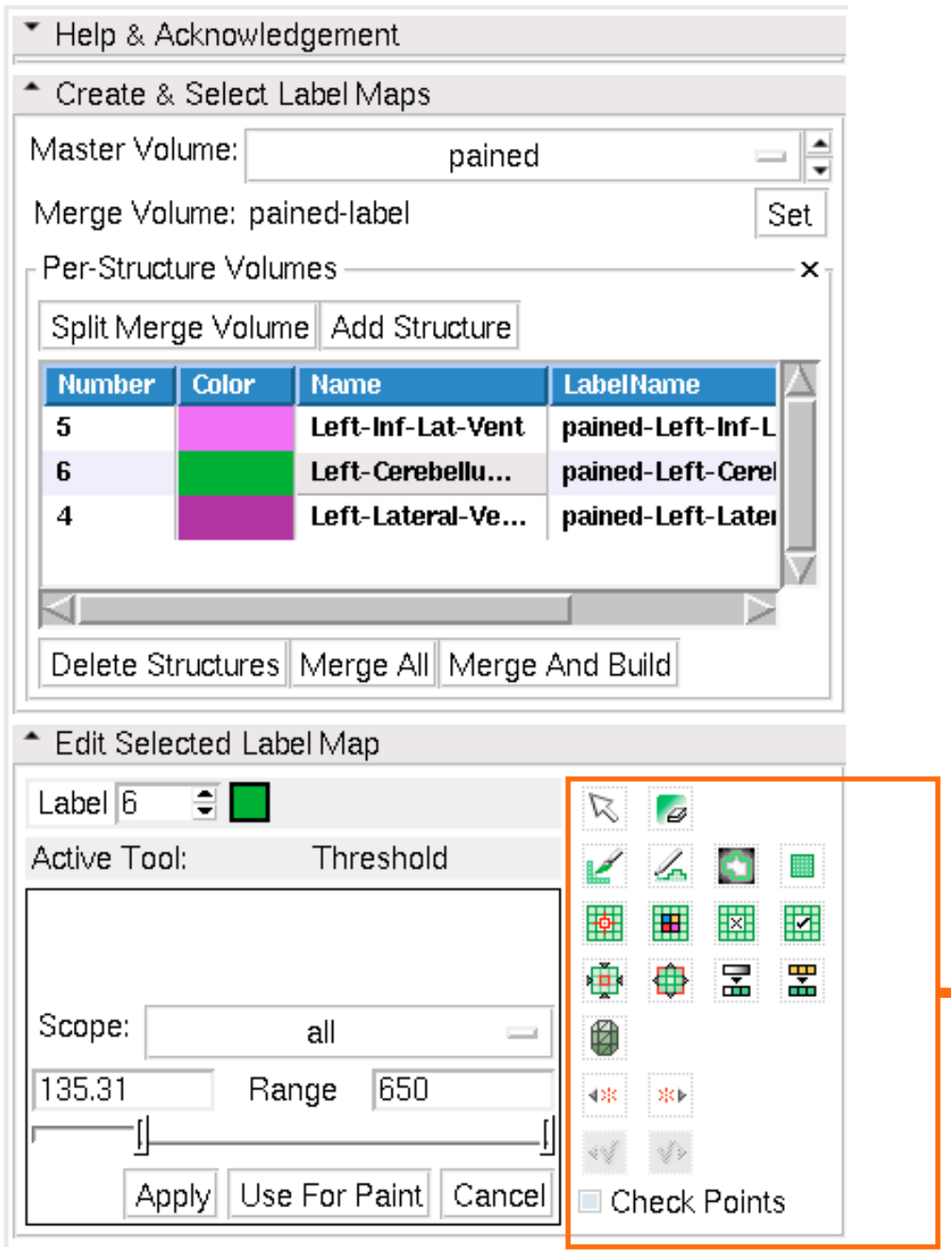
3D Slicer: Interactive Editor

Tools for manual segmentation & model building

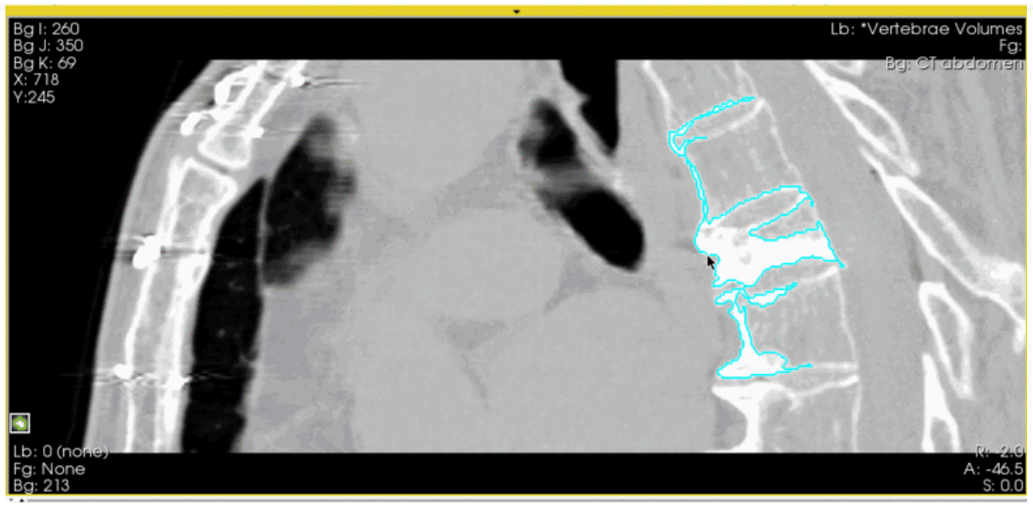


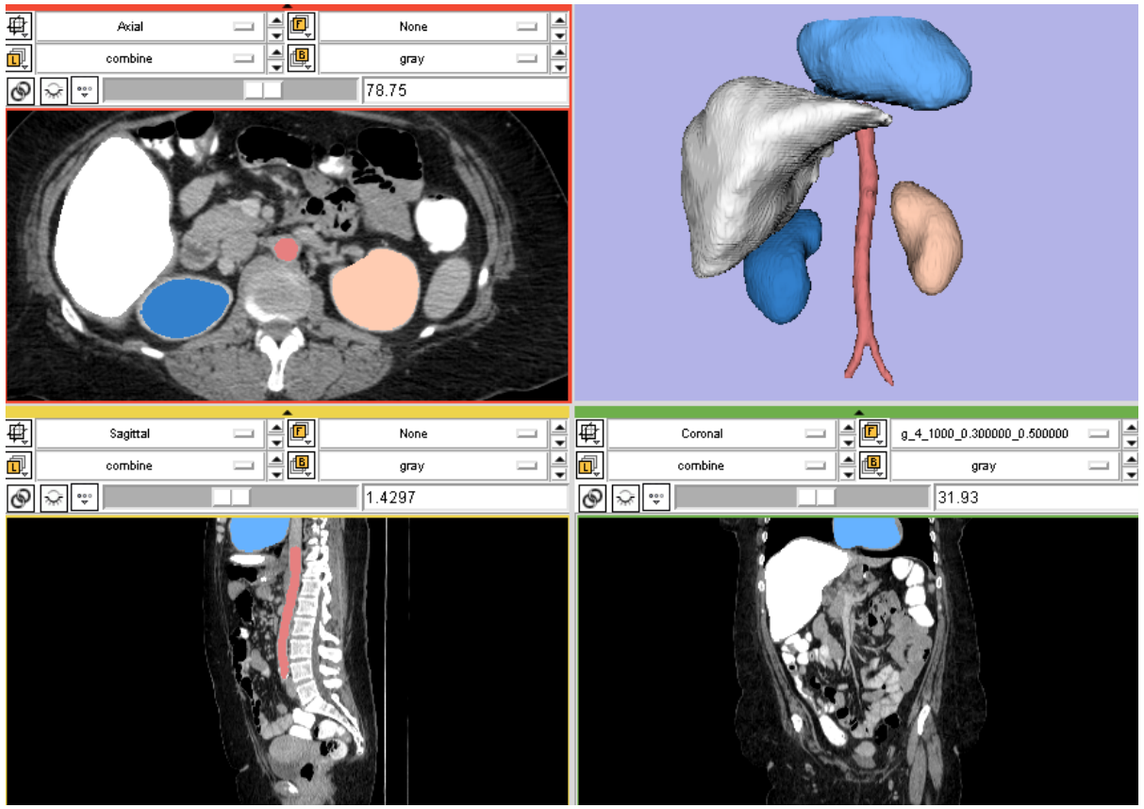
Tools include:

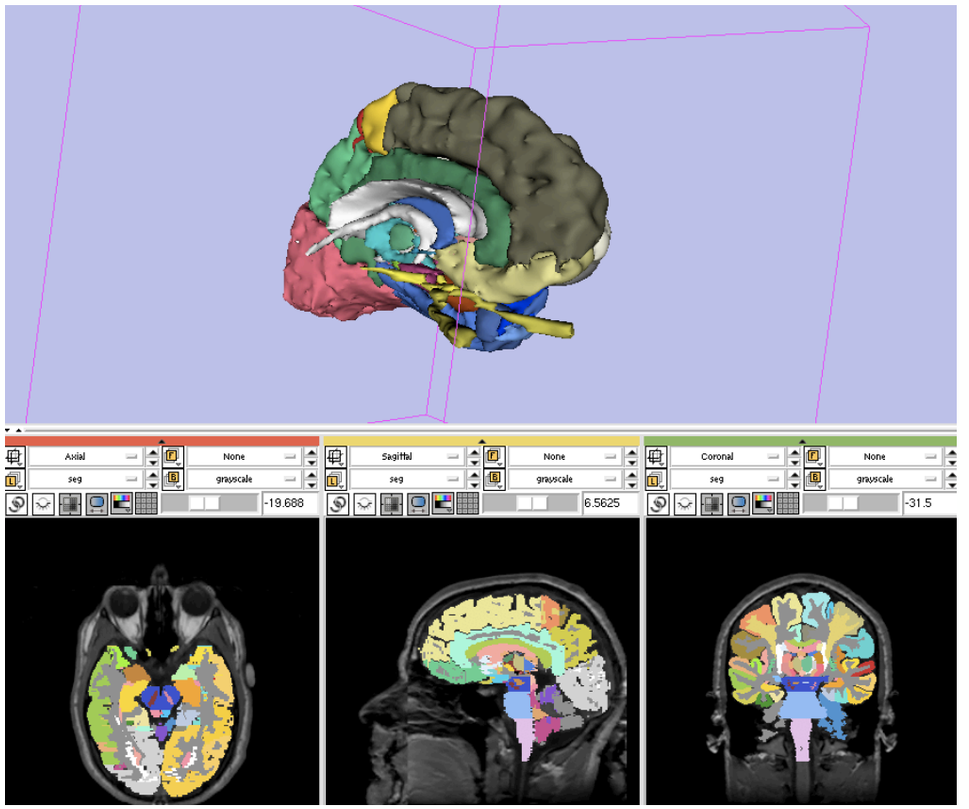
- Paint
- Draw
- Rectangle
- Level Tracing
- Change Label
- Identify Islands
- Remove Islands
- Save Island
- Erode
- Dilate
- Model Maker
- Undo / Redo

3D Slicer: Interactive Editor

Tools for manual segmentation & model building

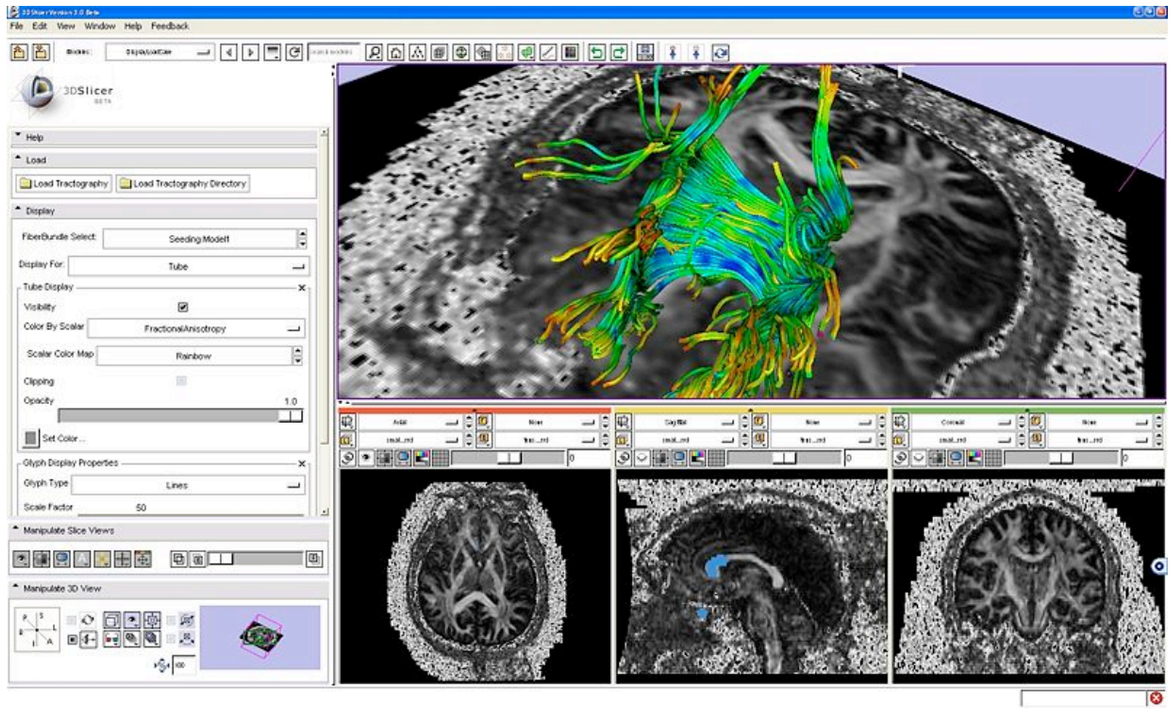




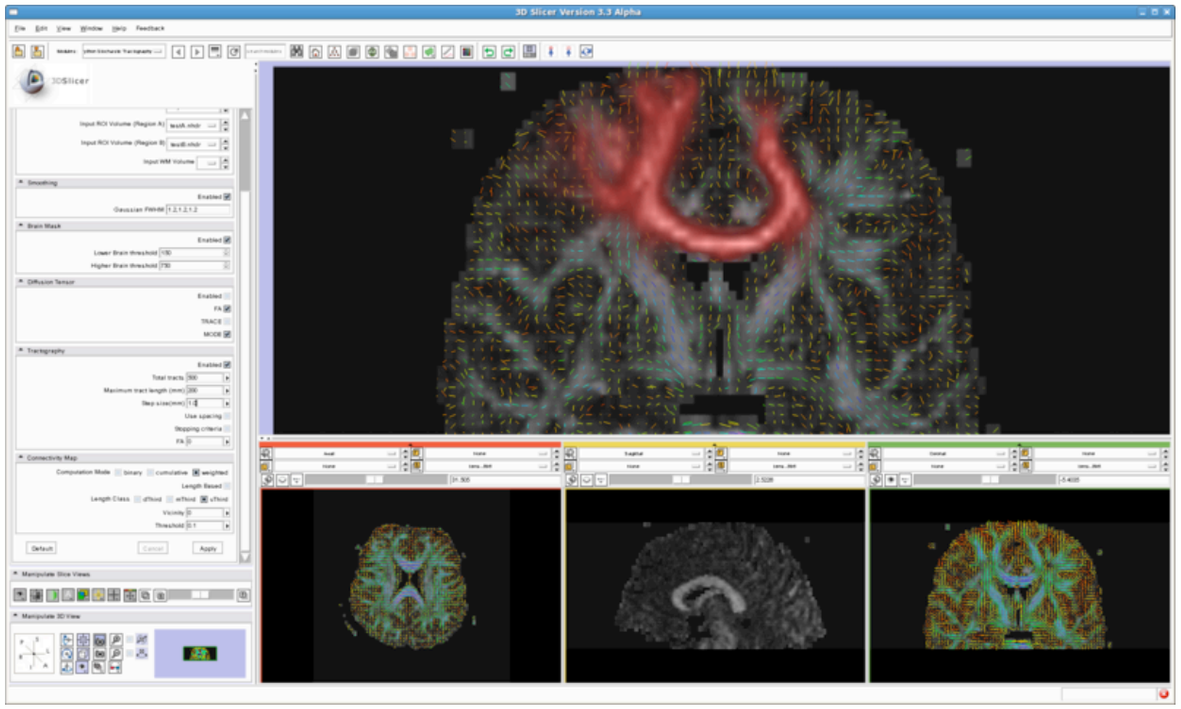


3D Slicer: Tractography Tools

Deterministic tractography result produced with the Label Seeding or Fiducial Seeding modules.



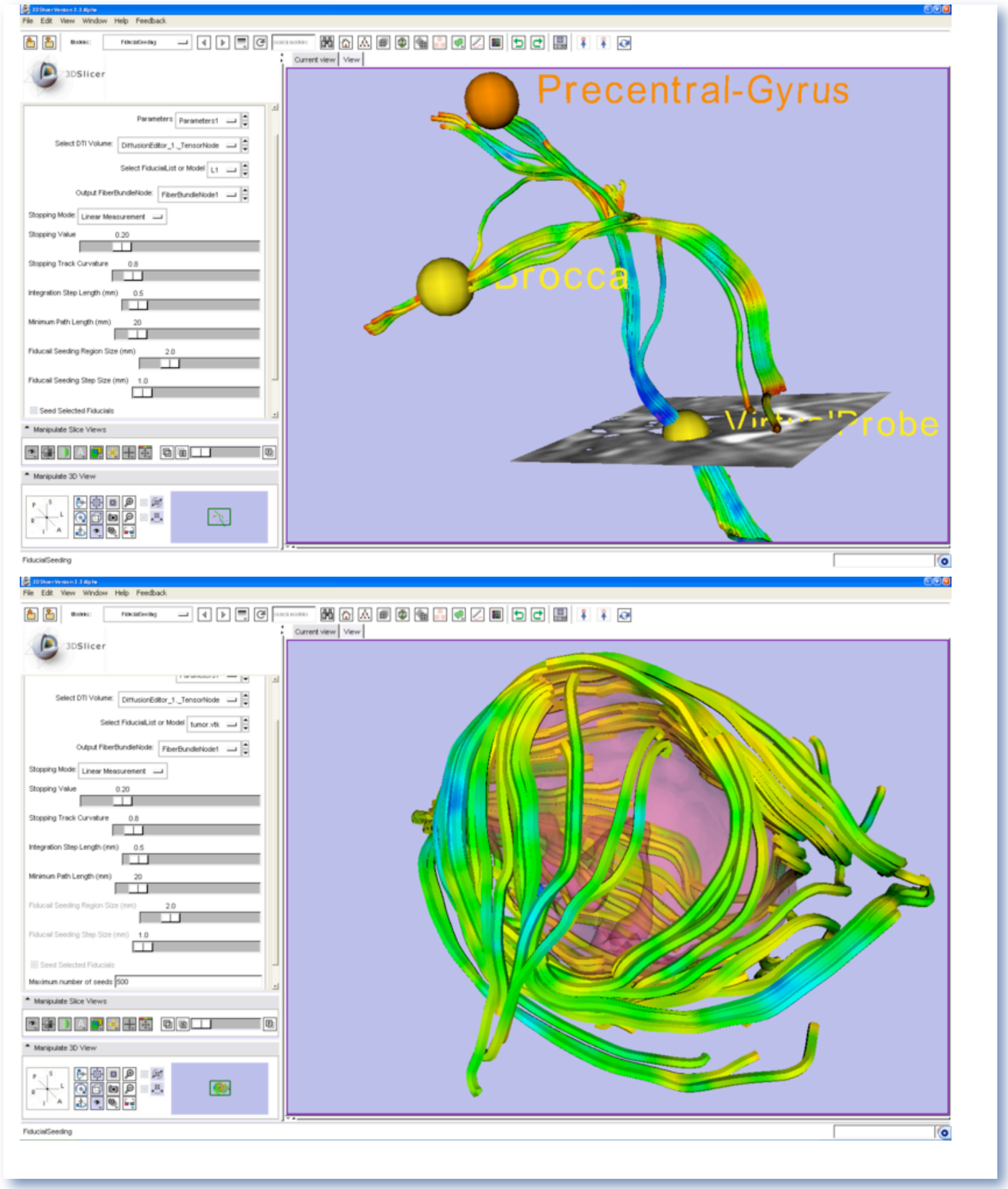
Stochastic tractography result produced with the Stochastic Tractography module.



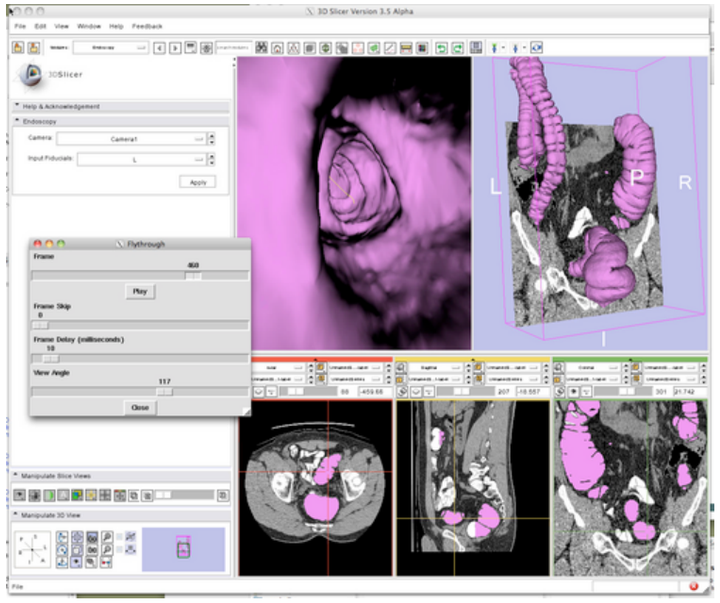
3D Slicer: Tractography Tools

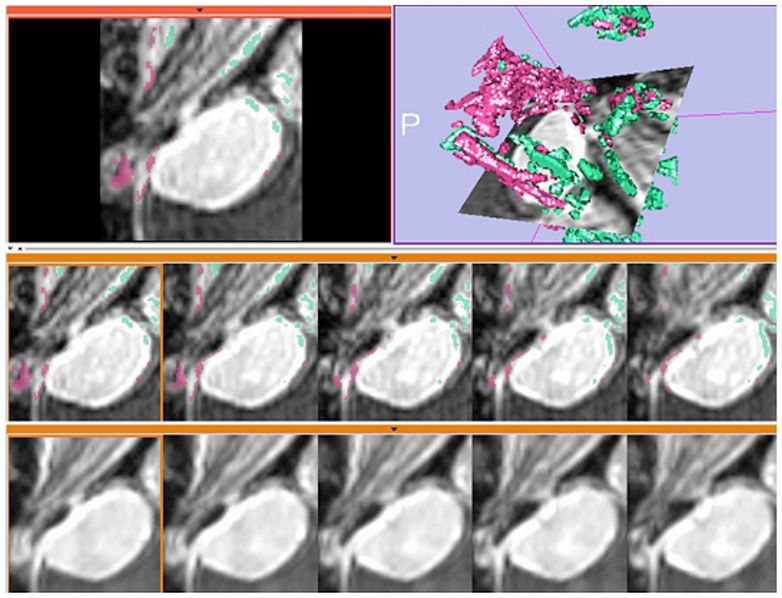
Seeding tracks interactively generated from fiducial markers.

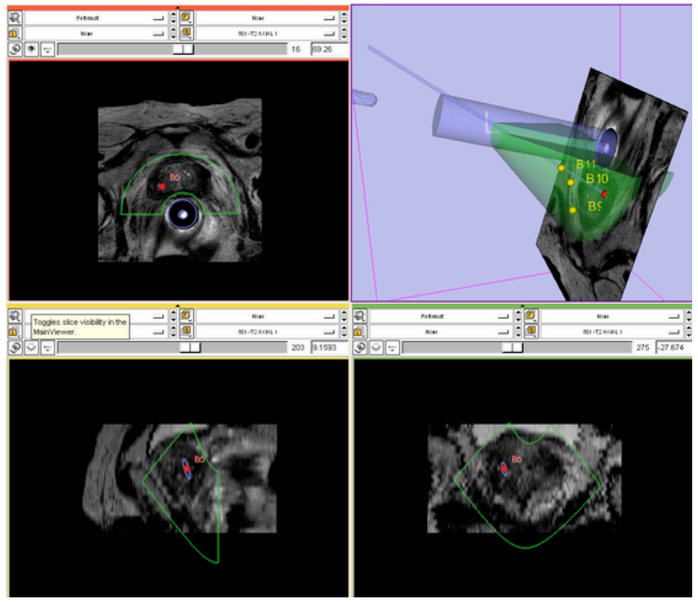
Seeding tracks from models.

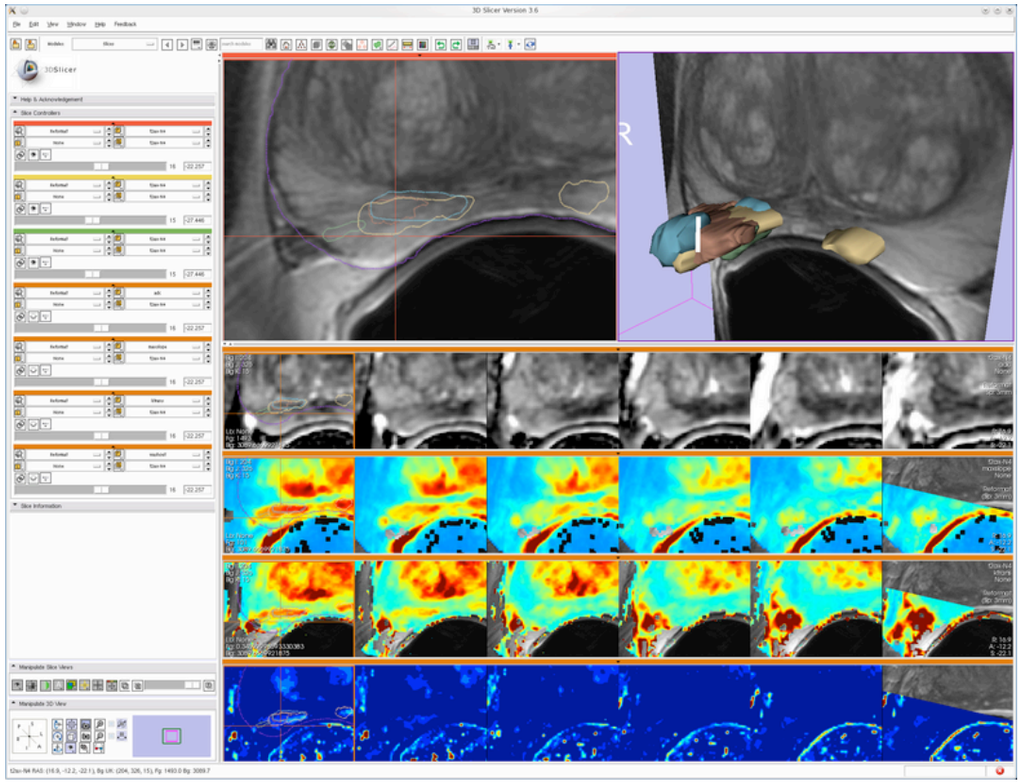


3D Slicer: Layouts





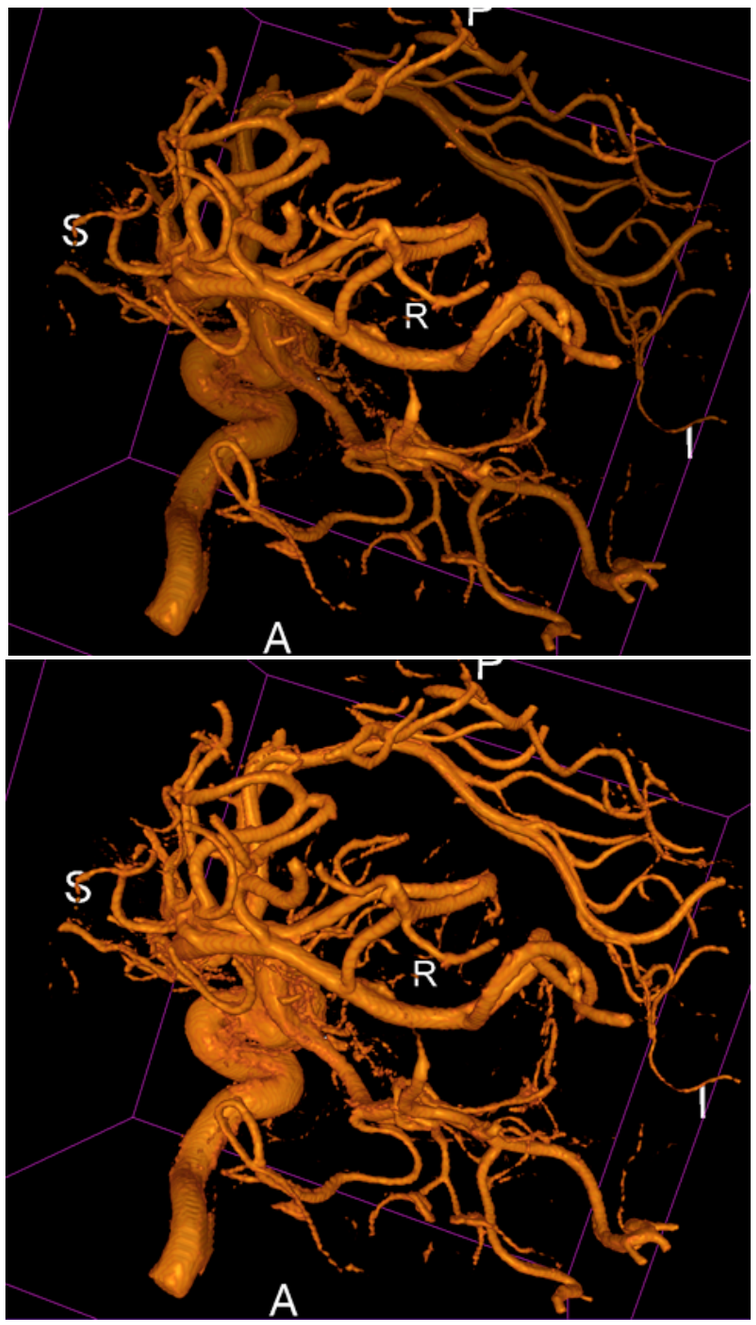




A variety of **standard and specialized layouts** are available including:

- Lightbox view
- Study comparison view
- Dual 3D view
- Large slice viewer
- and others...

3D Slicer: Volume Rendering



Rendering Methods

VTK CPU Ray Casting

- Uses the CPU for volume rendering,
- is parallelized and can take advantage of multi-core capabilities.
- Uses level-of-detail approach where low resolution is rendered while moving, and high resolution is rendered once motion ceases.
- Allows zbuffer compositing with texture map cross sections and non-transparent triangulated surface model.

VTK GPU Ray Casting

- Uses GPU accelerated ray caster.
- Allows z-buffer compositing with non-transparent polygon models only.
- This is currently working on Linux and Win32, but not on Mac (bug in the OpenGL drivers).

VTK OpenGL 3D Texture Mapping

- Uses texture mapping approach to volume rendering
- compared to the two render methods above, it has slightly lower performance and slightly coarser appearance.

NCI GPU Ray Casting

- This is a GLSL-based ray caster with several experimental mapping techniques.
- No z-buffer compositing with polygon models.
- Good performance and quality.
- No hardware restrictions on this method.

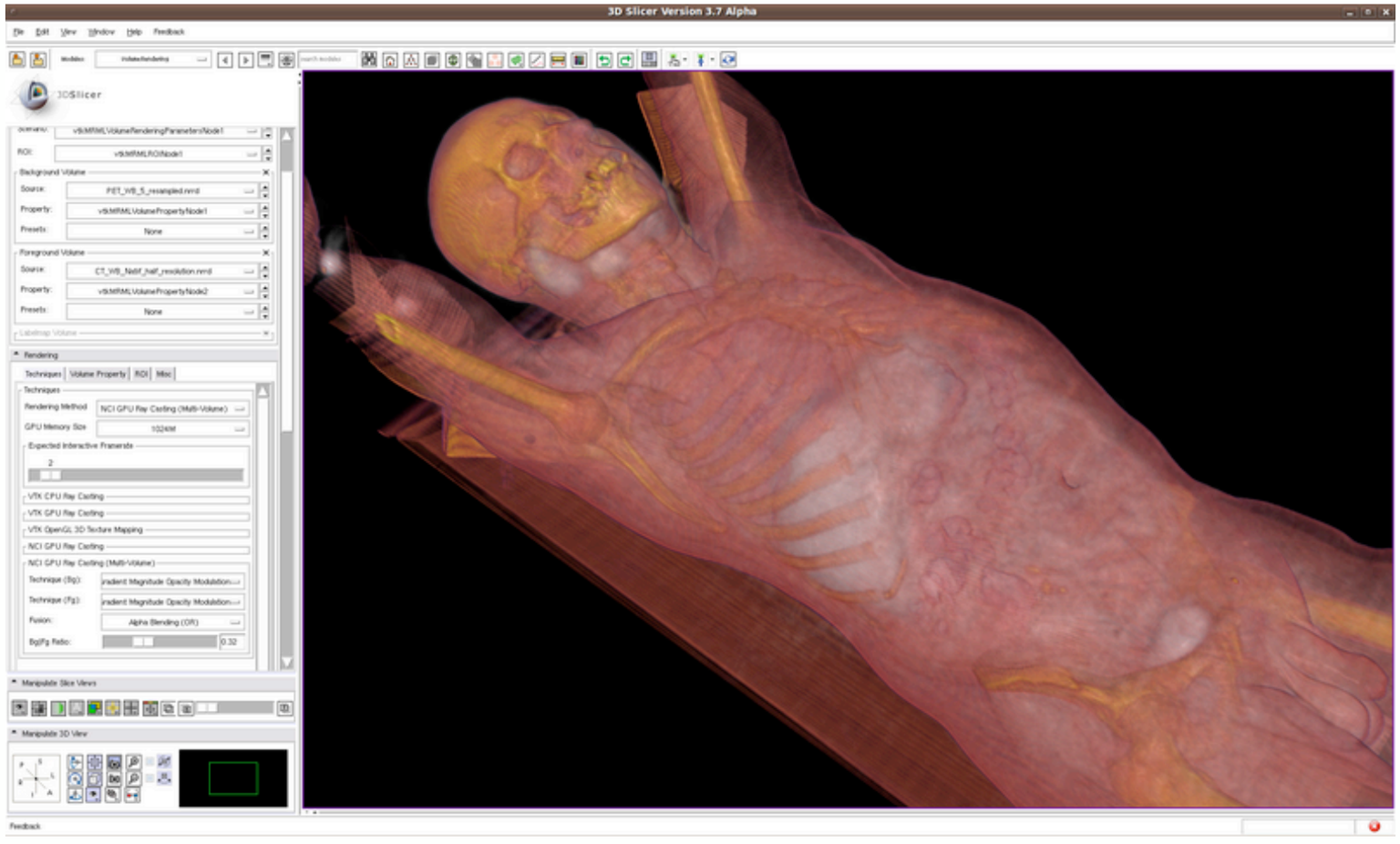
NCI GPU Ray Casting (Multi-Volume)

- *Note: this is a newly added mode that should be considered experimental.*
- Allows two volumes to be volume rendered and performs an alpha blend between the two volumes.
- This method requires enough graphics memory to hold all data for stable performance.

3D Slicer: GPU Volume Rendering

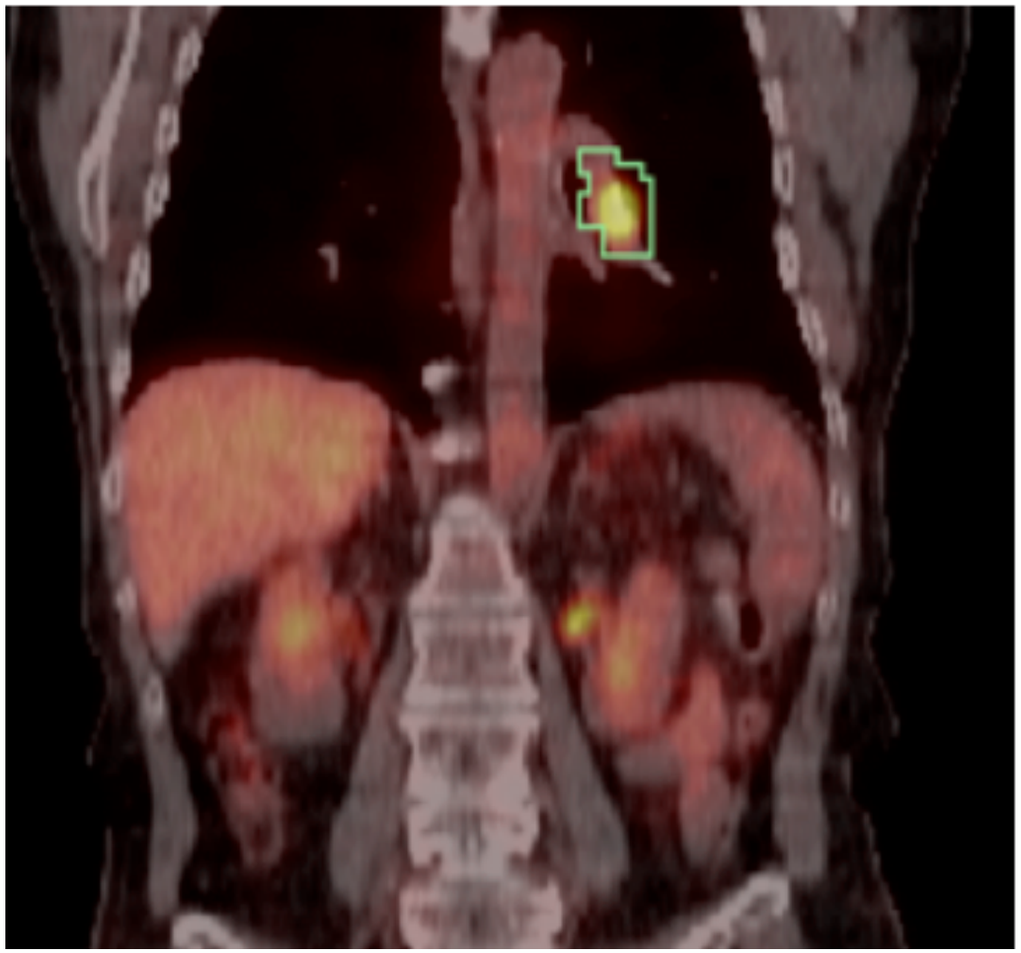
VTK supports several volume rendering techniques for both regular rectilinear grids and tetrahedral meshes.

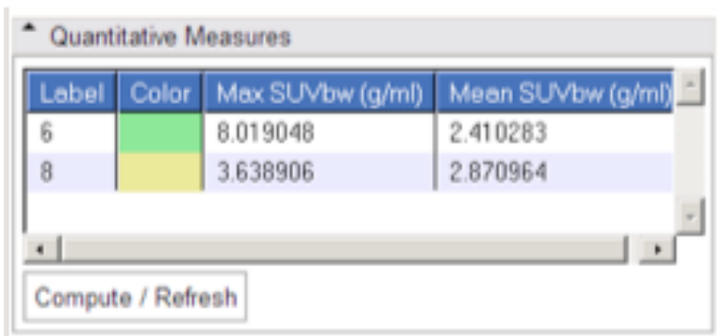
The *vtkKWEGPURayCastMapper* in VTKEdge uses the latest advancements available on recent GPUs including fragment programs with conditional and loop operations, multi-texturing and frame buffer objects in order to deliver significantly improved performance over the CPU-based ray casting, while still maintaining high rendering quality.

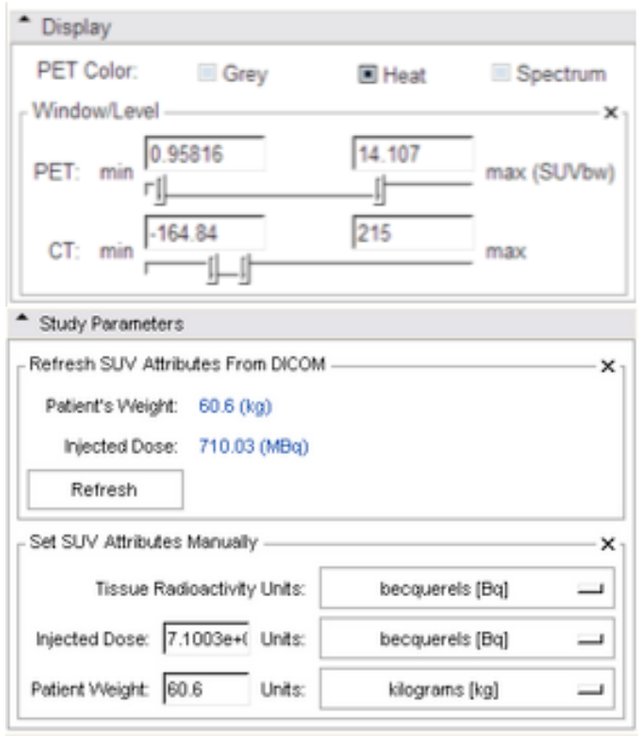


Dedicated GPUs with dedicated GPU memory are recommended for GPU accelerated methods.

3D Slicer: PET/CT SUV computation







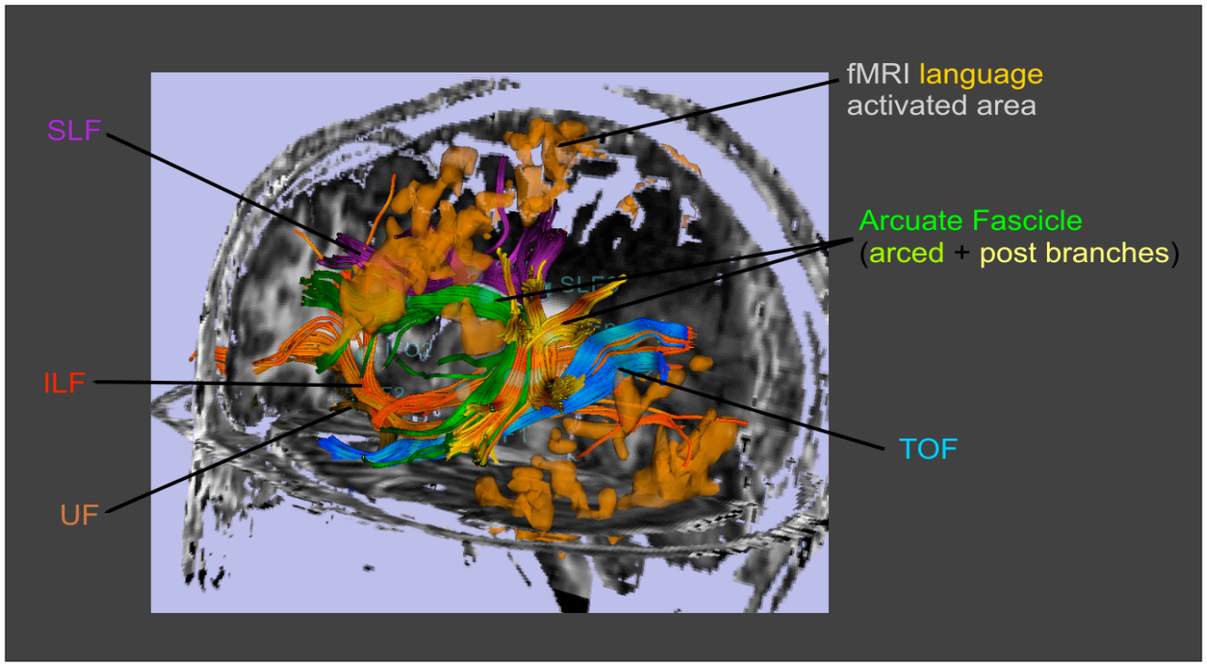
- Combined visualization of structural and colorized functional images
- VOIs defined in Slicer's Editor Module
- extracted DICOM study parameters used in computation
- Computation of Standardized Uptake Value (based on patient body weight) per VOI.

3D Slicer: Image-Guided Therapy

3D Slicer has been used in clinical research, with IRB clinical protocols appropriately created and managed.

In **image-guided therapy** (IGT) research, Slicer is frequently used to construct and visualize collections of MRI data that are available pre- and intra-operatively, and to display the tracked spatial position of surgical instruments.

3D Slicer: Image-Guided Therapy

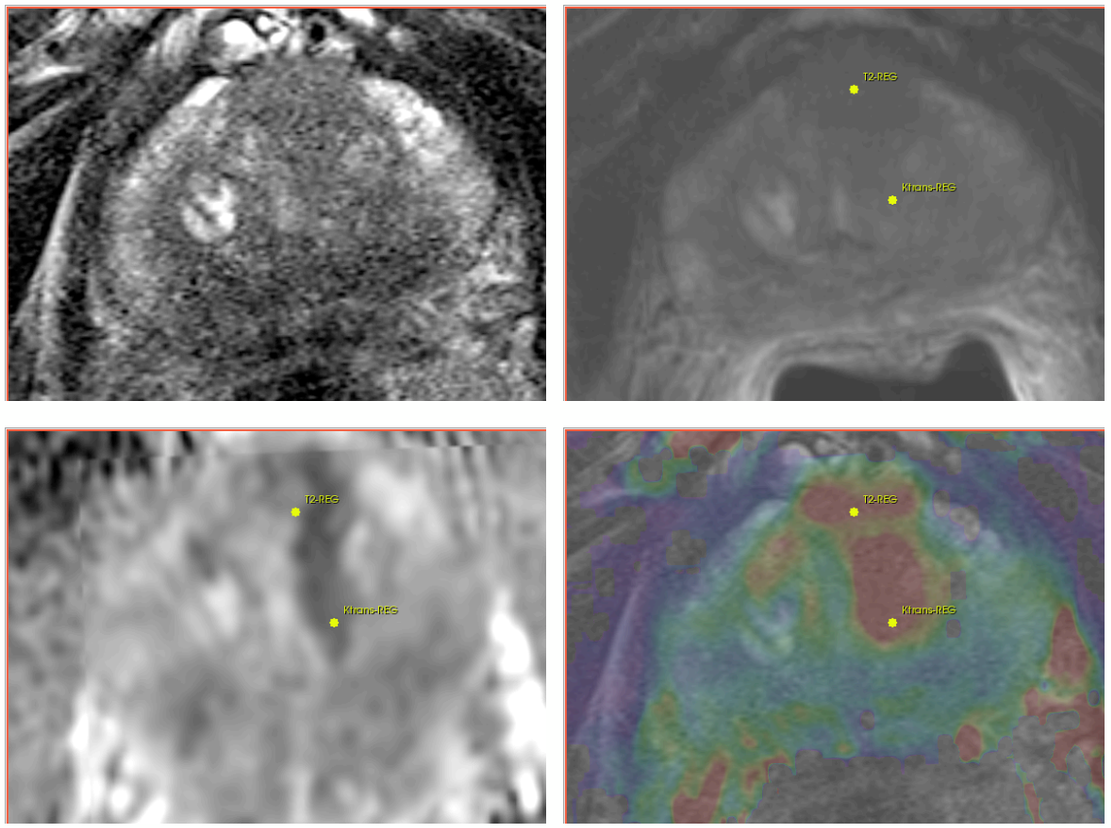


3D Slicer has been used extensively for brain tumor resection planning and guidance during surgery.

Integration of 3D Slicer with the surgical navigation BrainLab system allows to track surgical instruments in real-time, and transfer the position to 3D Slicer.

This project is a joint collaboration between BWH, Yale University and BrainLab.

3D Slicer: Image-Guided Therapy



3D Slicer is used for MRI visualization and fusion, target planning, deformable registation, and needle trajectory planning.

Targeted MRI guided prostate cancer biopsy attempts to improve the biopsy precision while reducing the number of tissue samples that need to be collected.

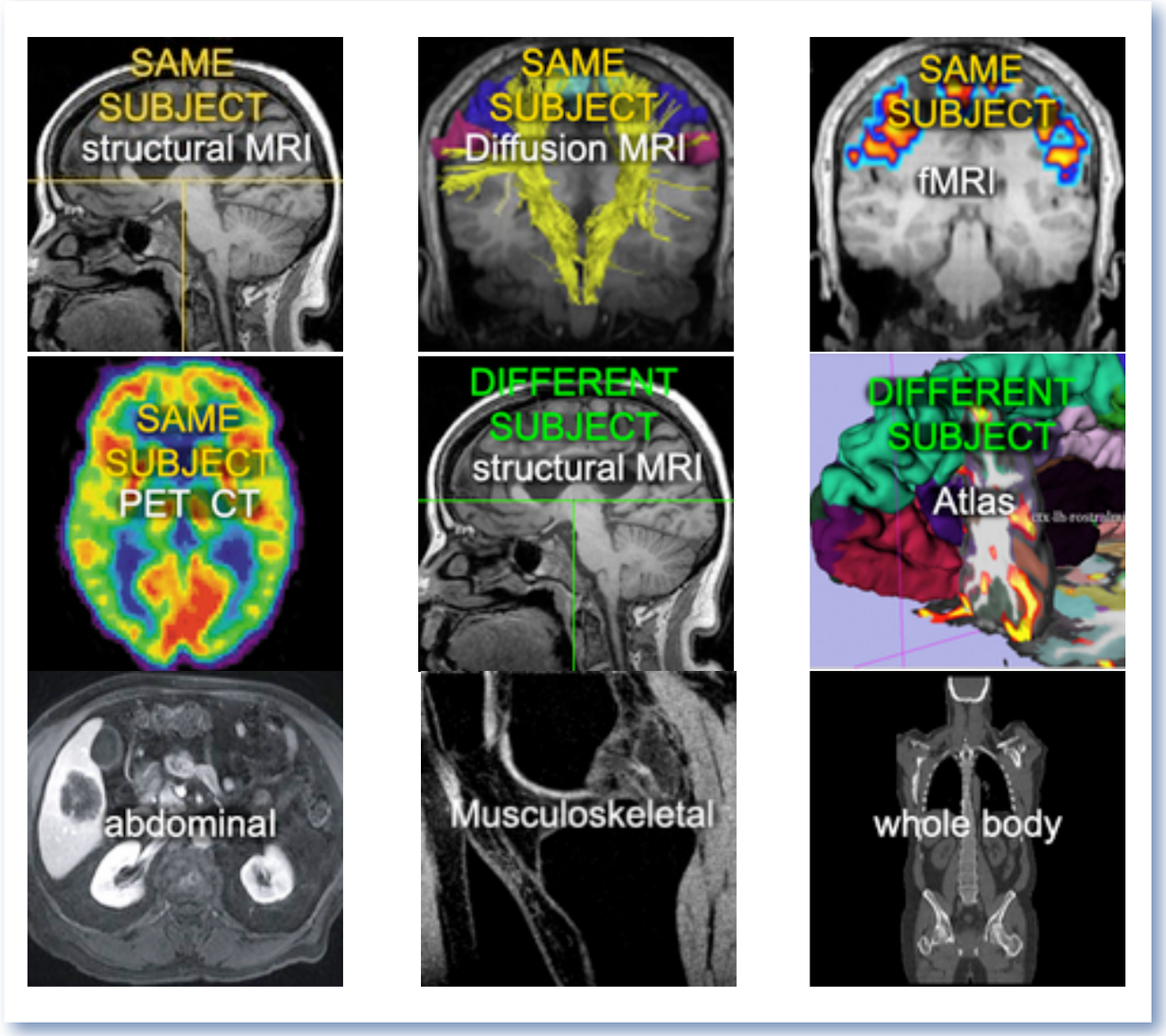
This is achieved by first using diagnostic multi-parametric MRI to highlight the suspicious areas. The biopsy procedure takes place in the MR bore.

Deformable registration is used to fuse the diagnostic image data to the intra-procedural configuration of the gland.

3D Slicer: Registration Tools

Slicer also provides a variety of **registration methods** and **resources** to support versatile applications:

- Deformation models: rigid, affine, non-rigid, fluid
- Algorithm types: fiducial-, surface-, intensity-based
- Image types: scalar, vector, tensor

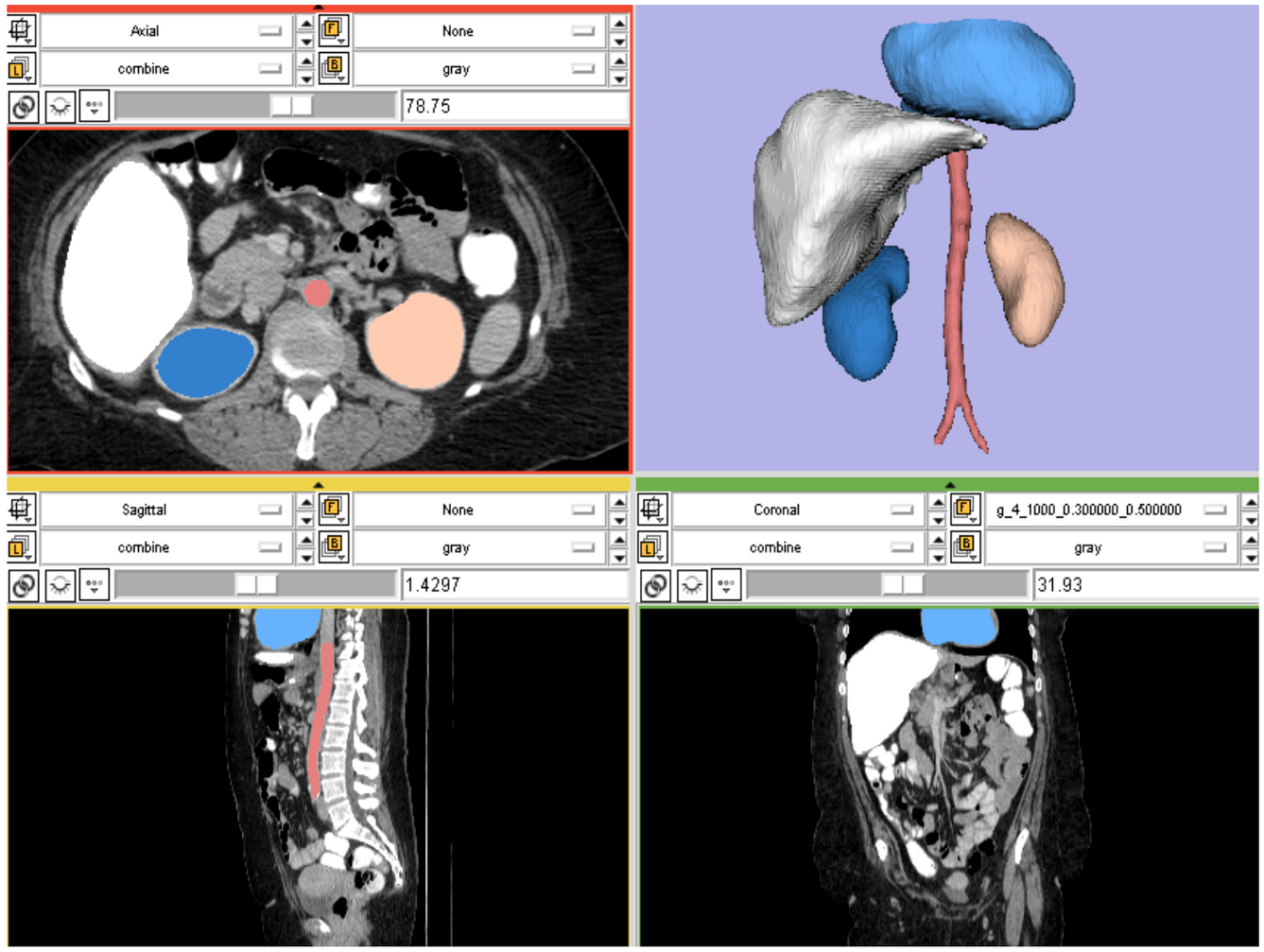


Resource: find an extensive collection of Slicer registration cases and recipes at:

www.slicer.org/slicerWiki/index.php/Slicer3:Registration

3D Slicer: Segmentation Tools

Segmentation is required for defining features of interest in imaging data for quantification and analysis.

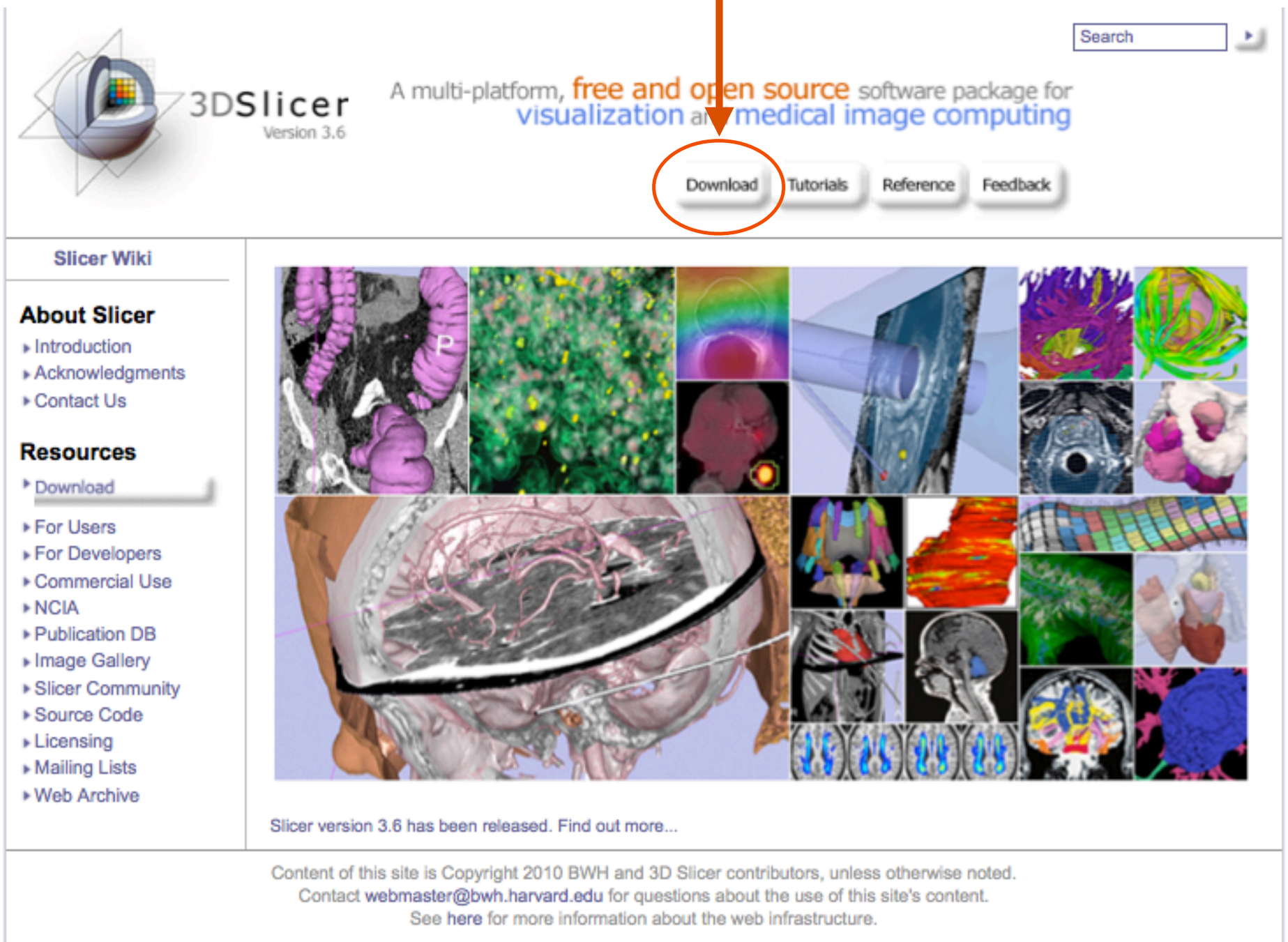


3D Slicer has a variety of interactive and automated segmentation methods:

- Editor Module for manual contouring and editing
- region growing and level sets
- graph cuts with gesture support
- skull stripping and hierarchical brain segmentation for morphological studies

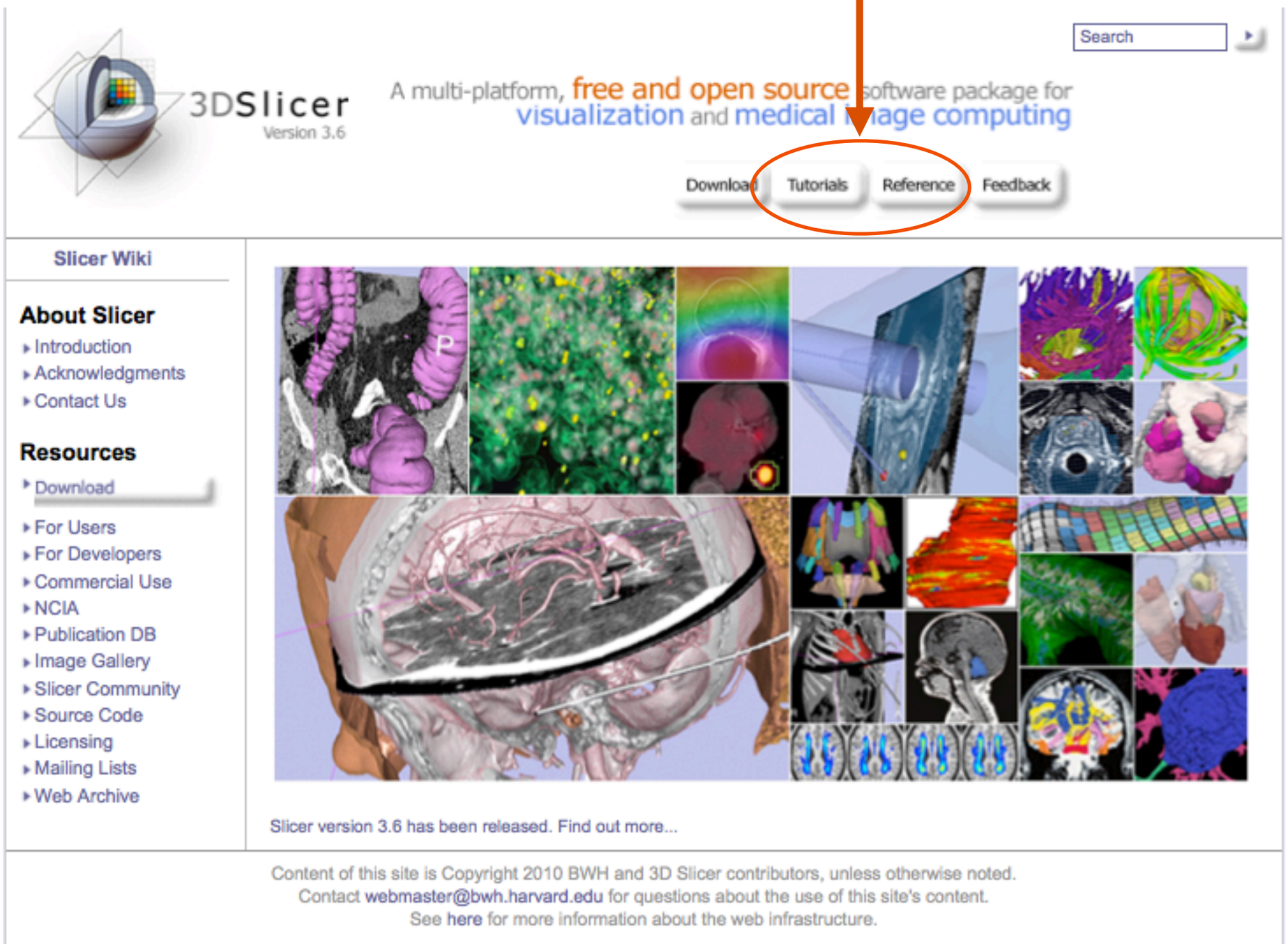
3D Slicer: Get the software

www.slicer.org



3D Slicer: Find Tutorials & More

www.slicer.org



3D Slicer: Information for Developers

www.slicer.org/pages/DeveloperOrientation

Slicer 3.x (Current development version)	
Slicer Developer Documentation	Development Project Homepage, Execution Model Documentation and Building a Slicer 3 Module GUI
Build Instructions	Slicer 3 Build Instructions
Coding Considerations	Slicer 3 Coding Style and Slicer 3 Interface Design
SVN Source Code Repository Browsing	View VC
API	Slicer 3 Doxygen Source Documentation,
Slicer 3 SVN Repository and SVN Instructions	svn Repository and Introduction to Slicer 3 svn
Dashboard	Slicer 3 Dashboard
Bug Tracker	Slicer 3 Bug Tracker
Visual Blog	Visual Blog
Developer Discussion	Developer's Mailing List
Module Execution Documentation	Execution Model and Adapting Slicer to Large Scale Experiments

3D Slicer: Acknowledgements

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National Cancer Institute

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Georgia Institute of Technology

New Energy and Industrial Technology Development Organization, Japan

Neuroimaging Analysis Center

Center for Integration of Medicine and Innovative Technology

National Alliance for Medical Image Computing

National Center for Image Guided Therapy

Biomedical Informatics Research Network

GE Global Research

Neuroinformatics Tools and Resources Clearinghouse

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The Harvard Clinical and Translational Science Center

Surgical Navigation and Robotics Laboratory

3D Slicer User Community

3D Slicer Developer Community