3D Slicer

Overview

Csaba Pinter

laboratory for Percutaneous Surgery

Queen's University

Right tool for the job

Innovative,
not robust,
usually single developer
supported

Robust and usable
enough for clinical
evaluation, flexible,
open, portable,
community
supported

FDA approved,
company supported,
closed source

Without an application platform

- Each application is developed from ground up
- Completely new software is developed for each problem/procedure/device
- Significant work is needed to integrate new, advanced algorithms

Quick start.

Huge waste of time, money, and effort overall.

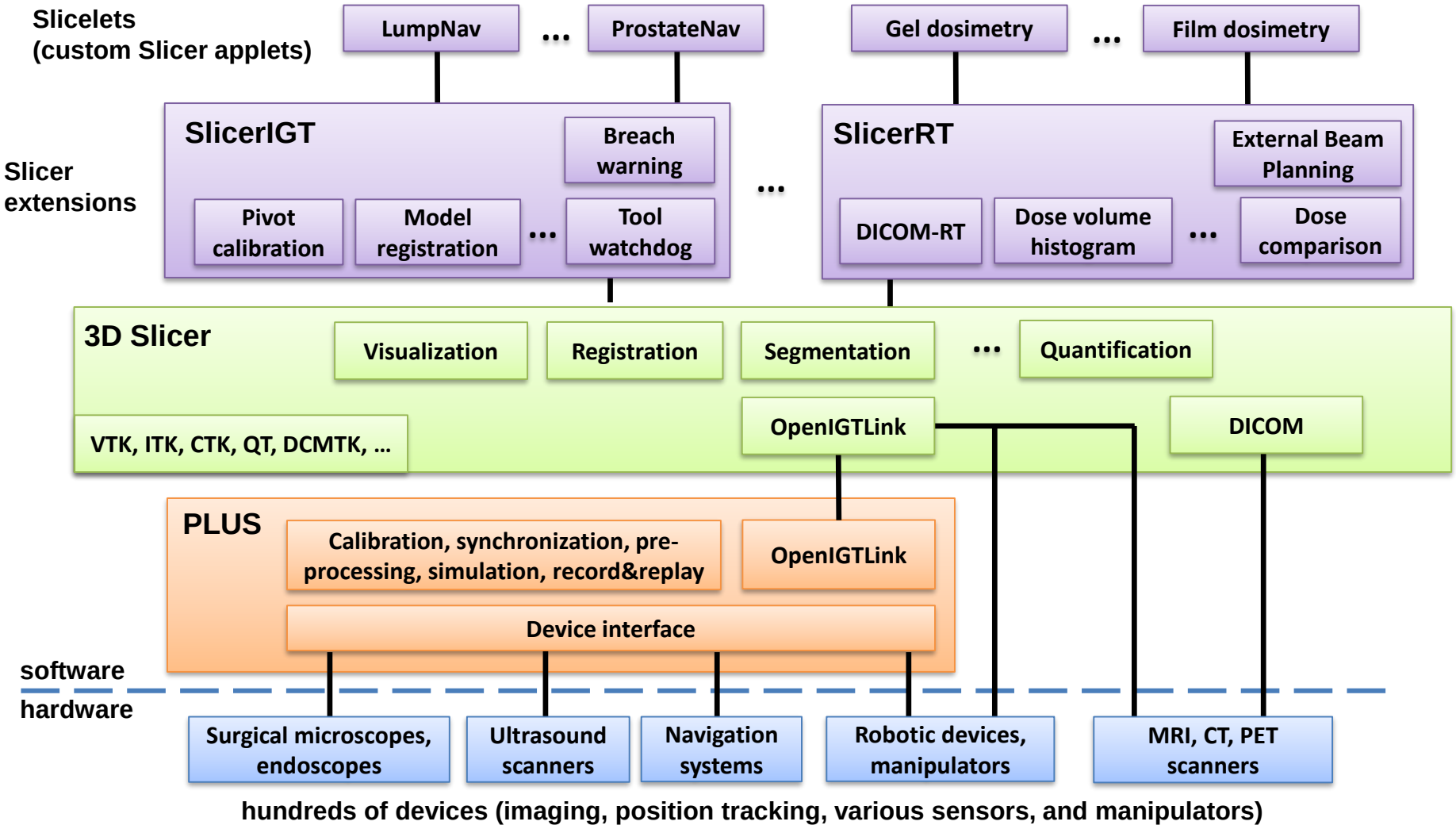
Building on an application platform

- Core functionalities are already implemented
- New software modules can be developed for specific needs
- Many new, advanced algorithms are available
- Well-supported with a large user and developer community

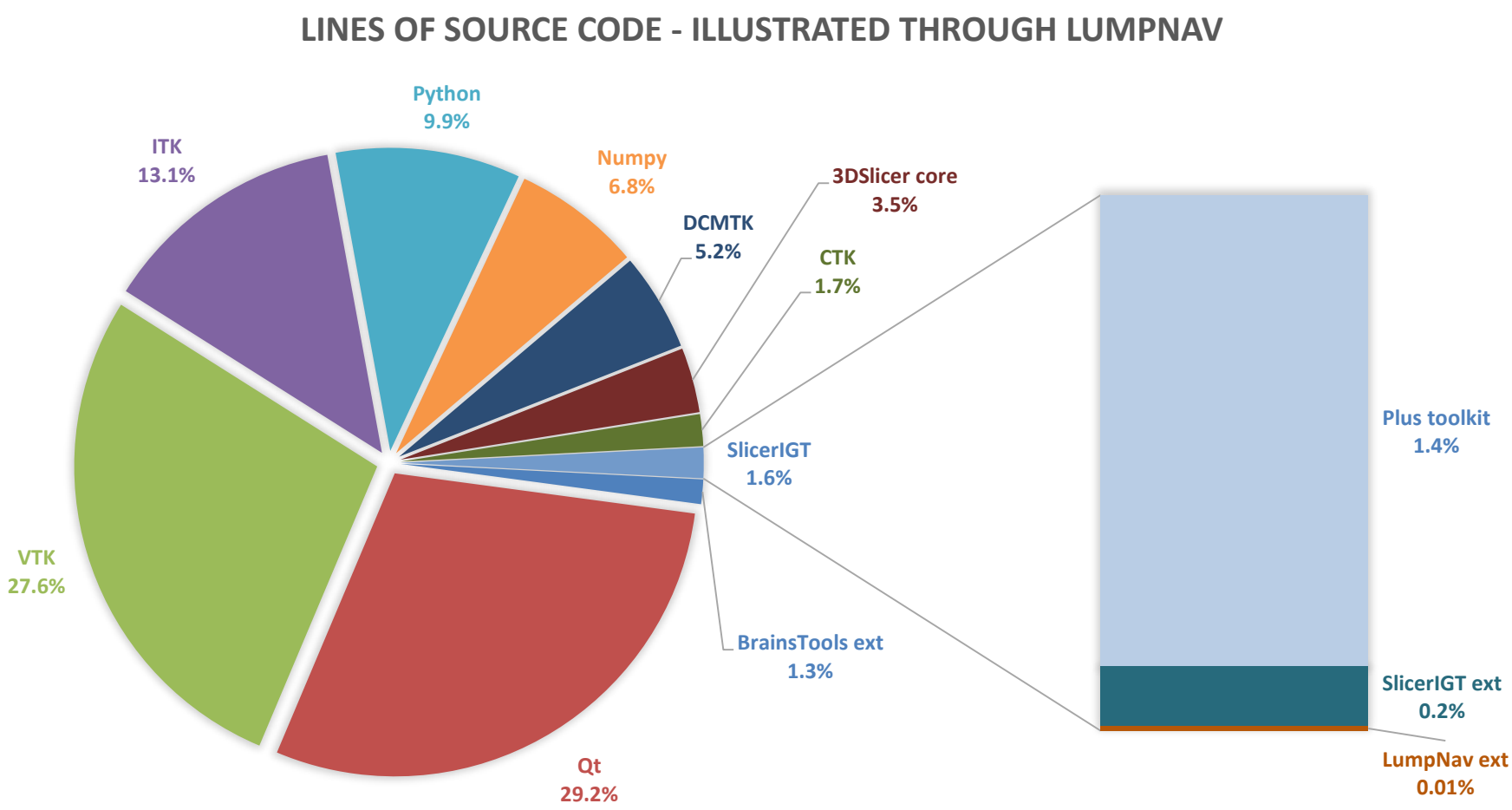
Investment at the beginning: learning.

Minimal wasted efforts.

PerkLab systems overview

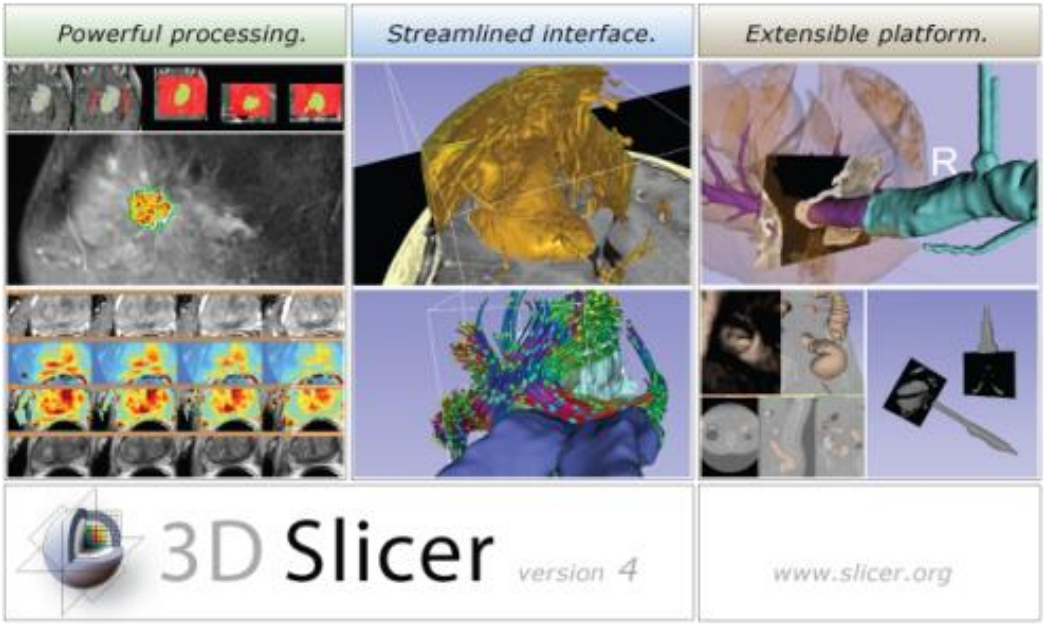


Building on a platform



Background for 3D Slicer

- Software application for medical image computing: data import/export, visualization, segmentation, registration, quantification, real-time guidance
- Application framework: customizable, extensible custom modules
- Completely free (BSD)
- Multi-platform



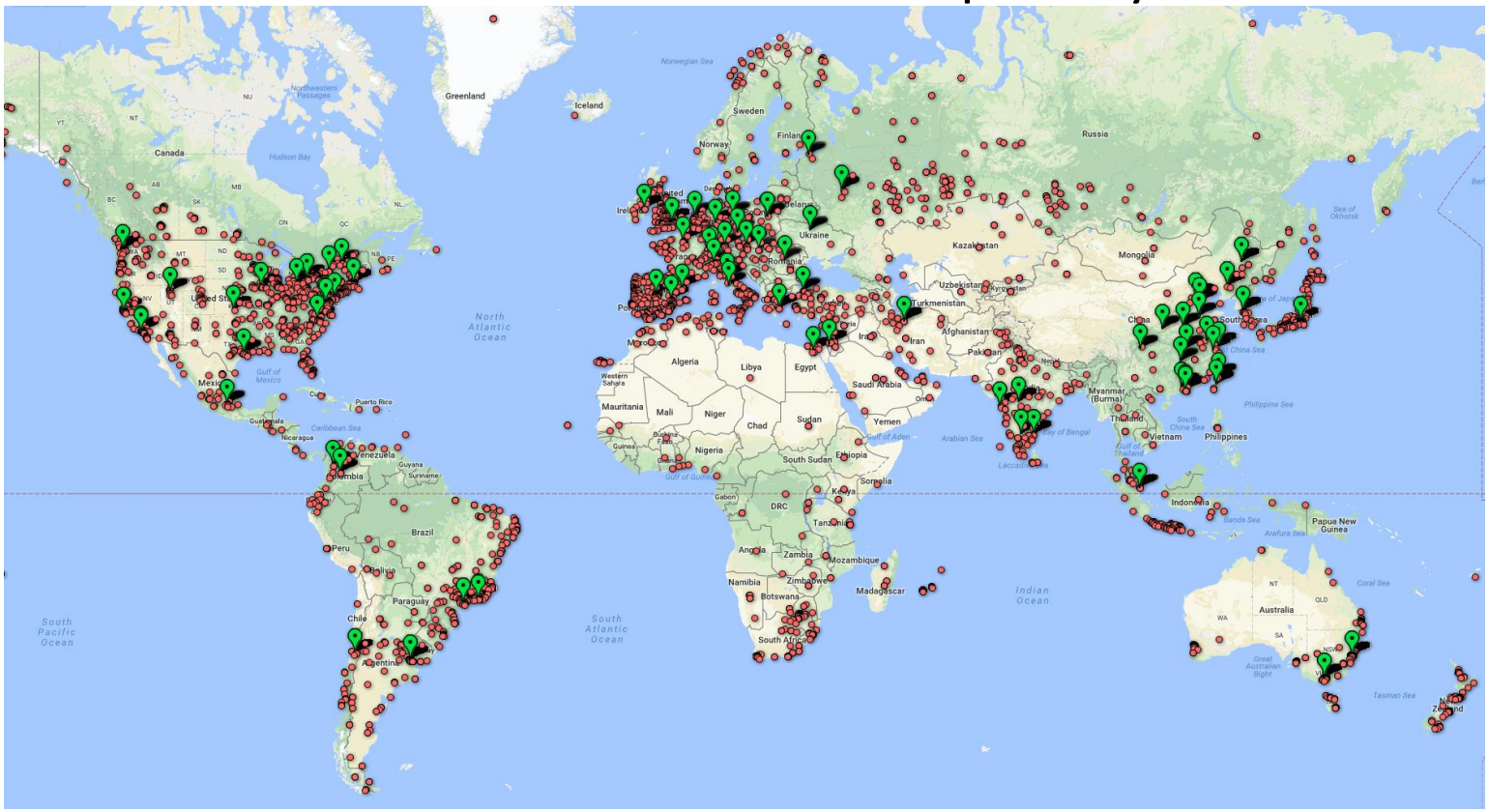
- User and developer support
- Training courses, documentation, tutorials

Fedorov, *et al.* "3D Slicer as an image computing platform for the Quantitative Imaging Network." Magnetic resonance imaging 30.9 (2012): 1323-1341.

Large user community

500 downloads per week in 2012
2800 downloads per week in 2018

330 000+ downloads over the past 5 years:



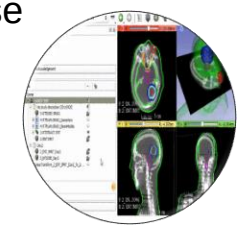
Project week

- Twice a year
- Bring your own project, work with experts
- Meetings, training
- Upcoming:
  June 26-30, Catanzaro Lido, Italy

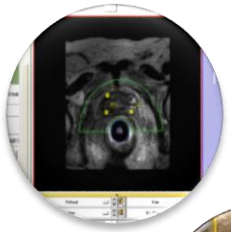
3D Slicer in clinical use

Clinical users drive creation of technology

Radiation dose calculations

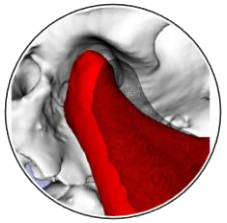


MRI-guided prostate biopsy



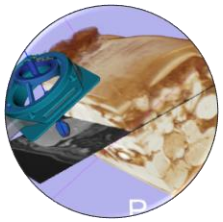
Breast cancer surgery guidance

Diagnosis of Osteoarthritis Degeneration

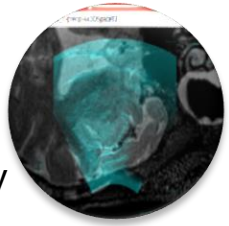


Quantitative assessment of COPD

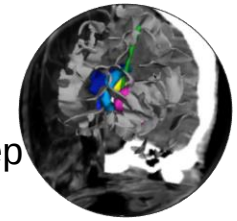
Surgical navigation



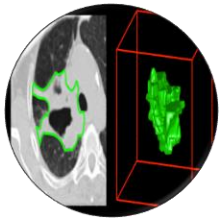
Brain surgery



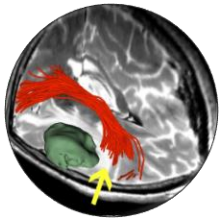
Model-Guided Deep Brain Simulation



Diagnosis of Different Tumors in Lung Cancer



Tracking peritumoral white matter fibers



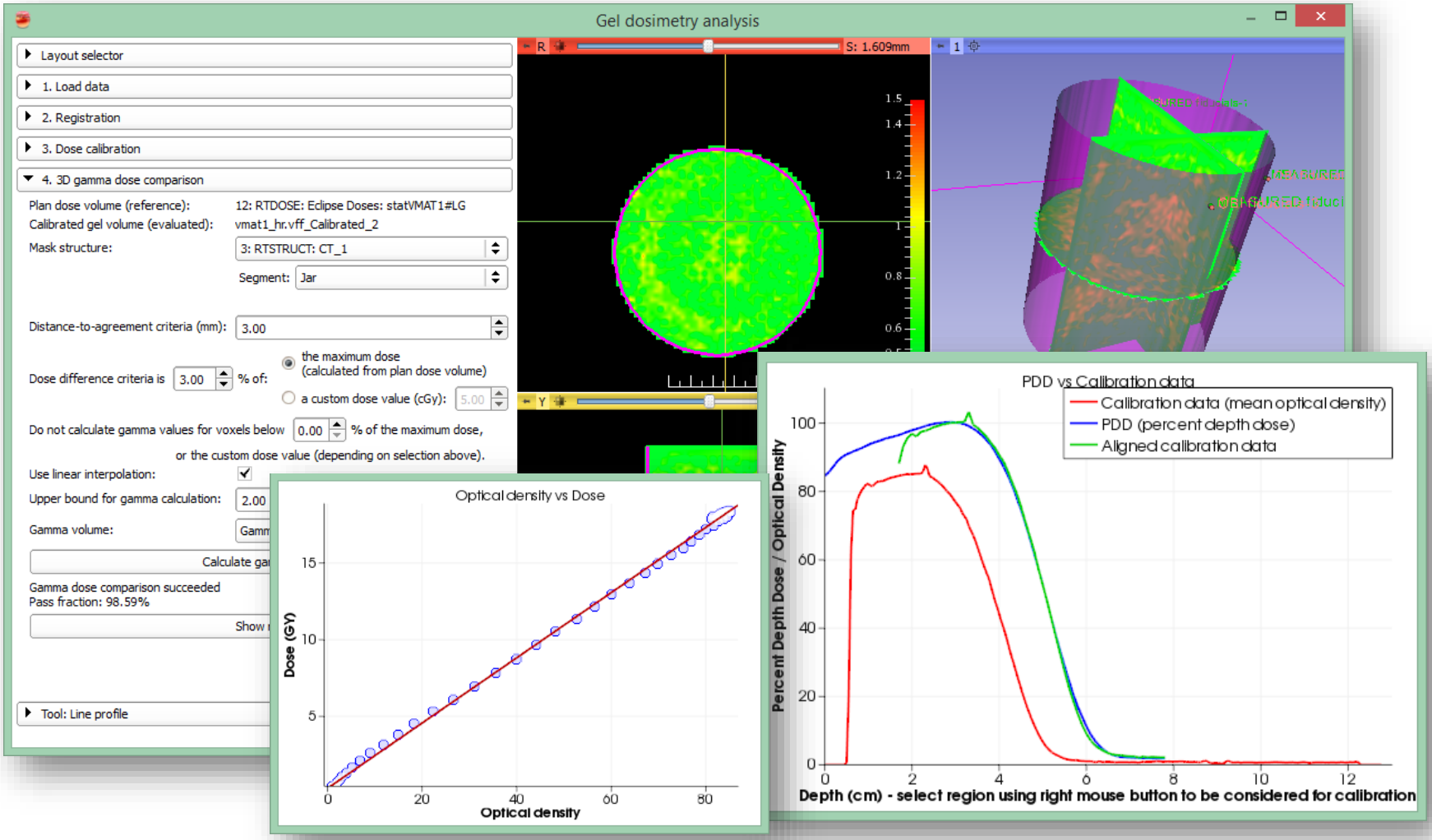
Commercial use



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

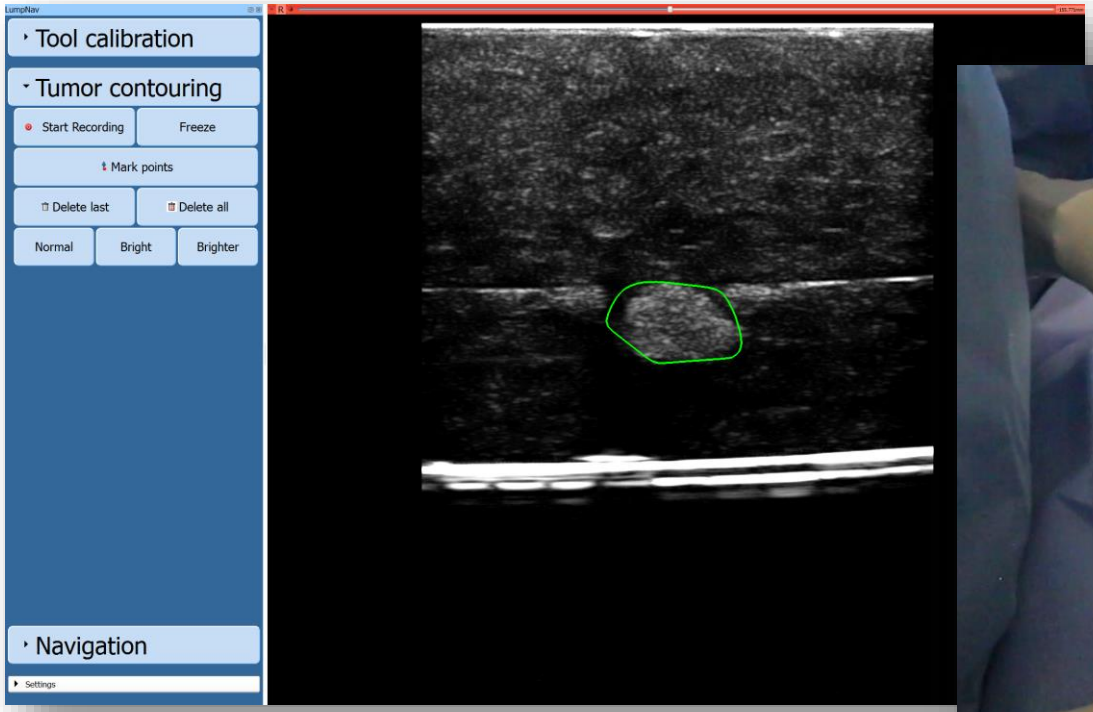
Example: Gel Dosimetry tool

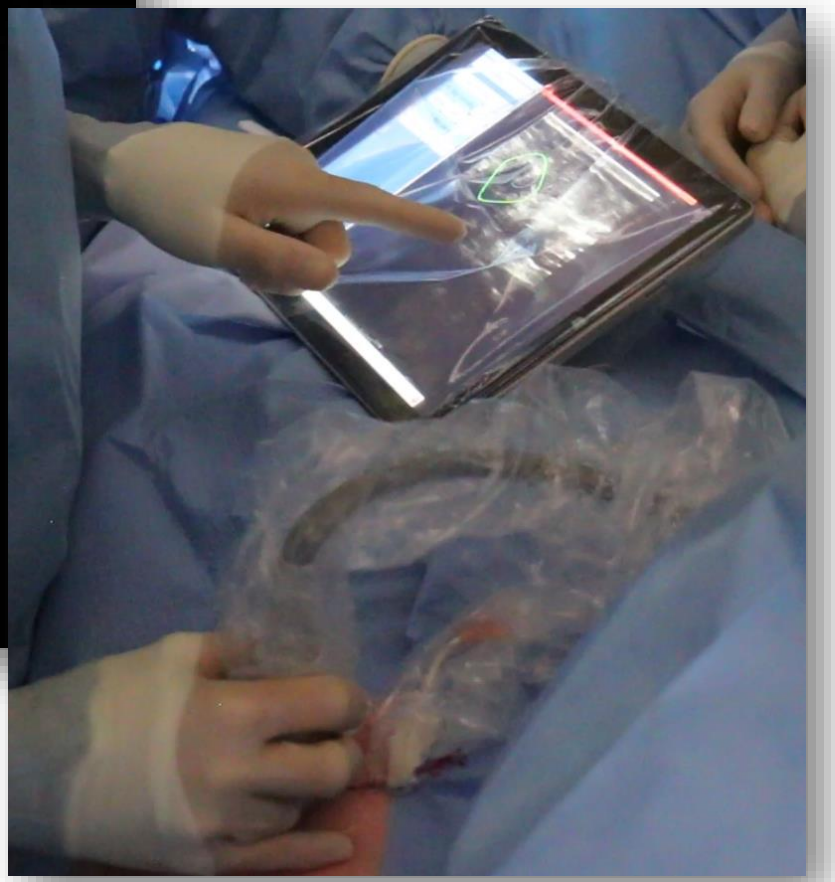


https://www.slicer.org/slicerWiki/index.php/Documentation/Nightly/Modules/GelDosimetry

Chosen option: “slicelet”

Example: LumpNav (touch optimized)



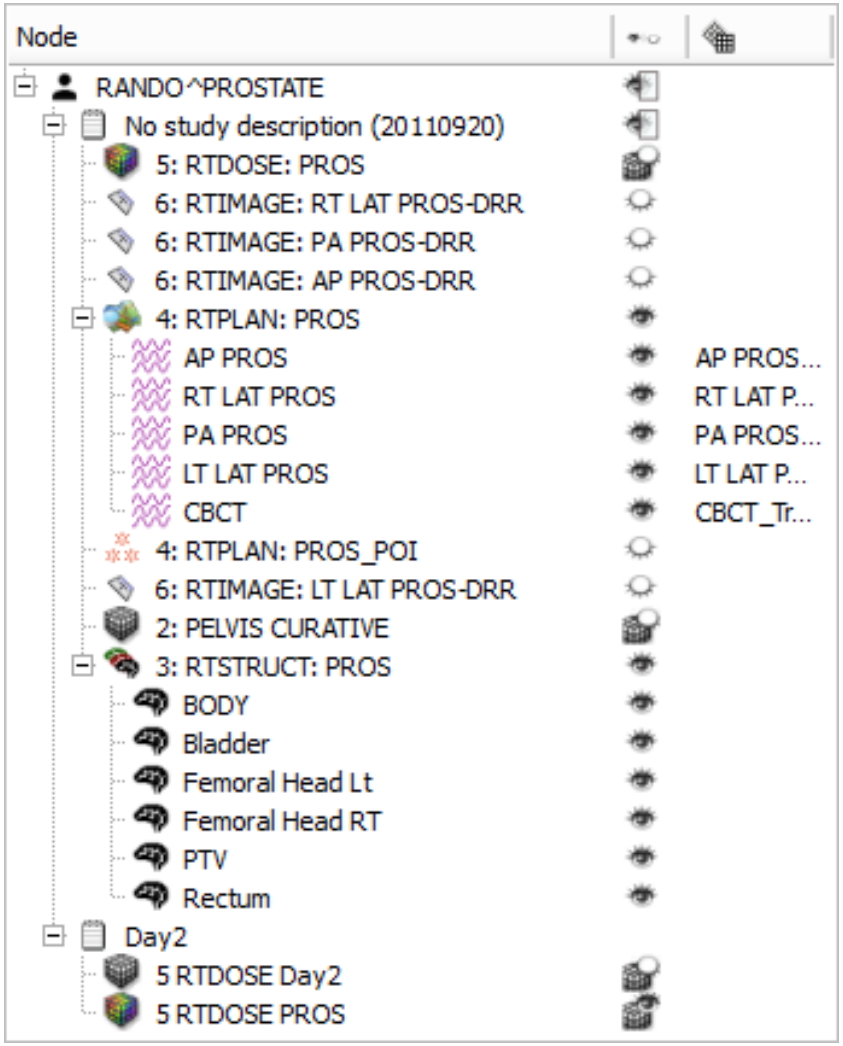


http://www.slicerigt.org/wp/breast-cancer-surgery/

Chosen option: “simplified main window”

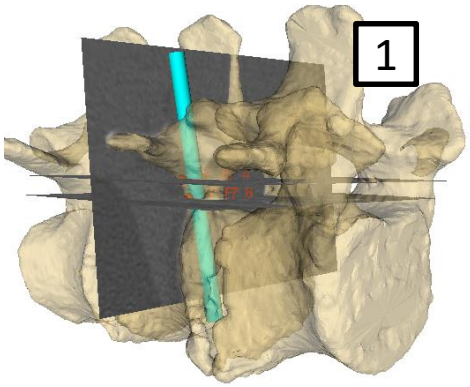
Data import/export

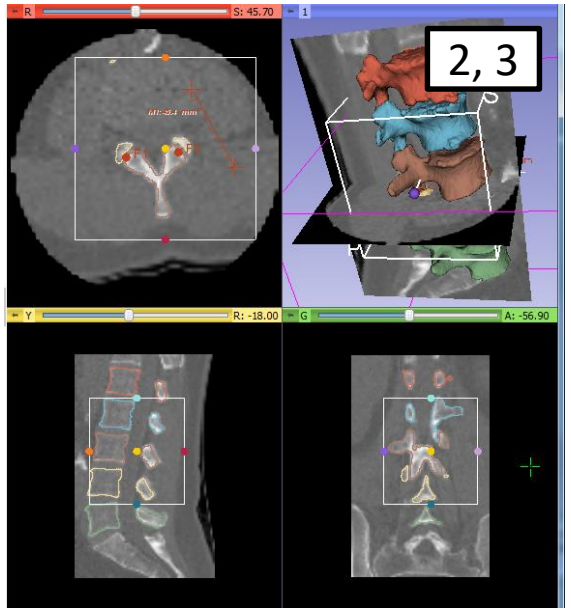
- DICOM: 2D/3D/4D volumes, structure sets, dose volumes, etc. (extensible without Slicer core changes)
- Research data formats for volumes, meshes, transforms (NRRD, MetaIO, VTK, HDF, etc.)
- Common non-medical data formats (JPEG, TIFF, etc.)
- Save and complete restore of application state

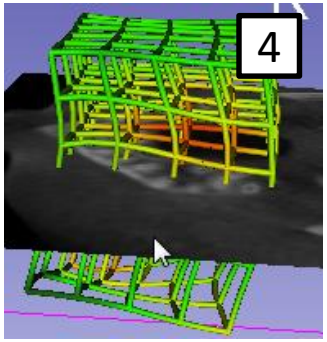


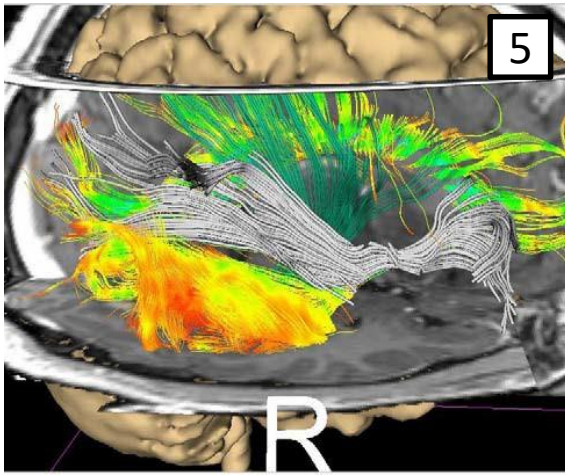
Visualization

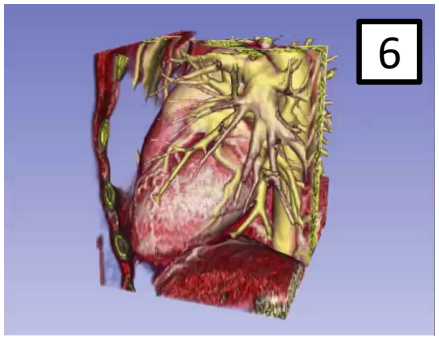
1. 2D (slice) and 3D views, chart views
2. Configurable layout
3. Multi-modality image fusion (foreground, background, label map)
4. Transforms, vector and tensor field visualization
5. Surface and volume rendering
6. Time sequence data





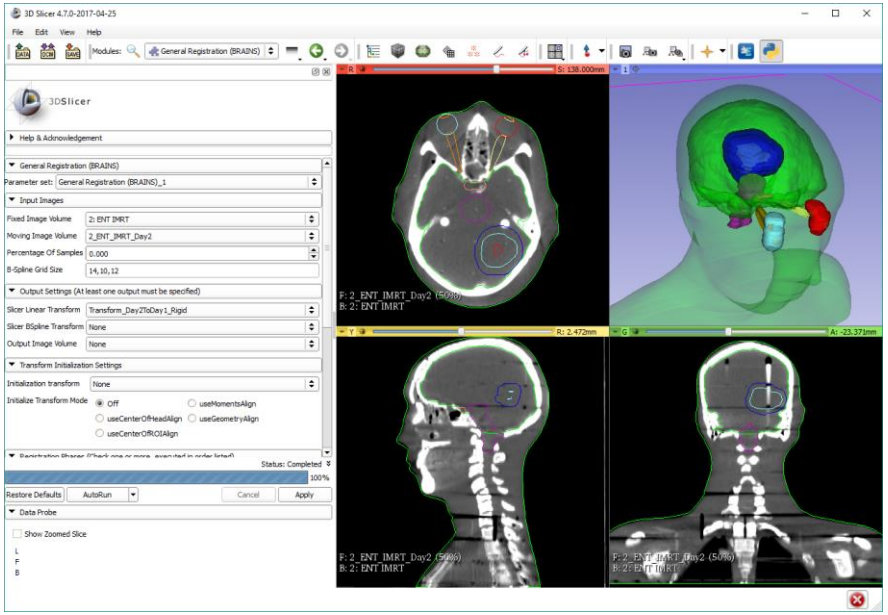


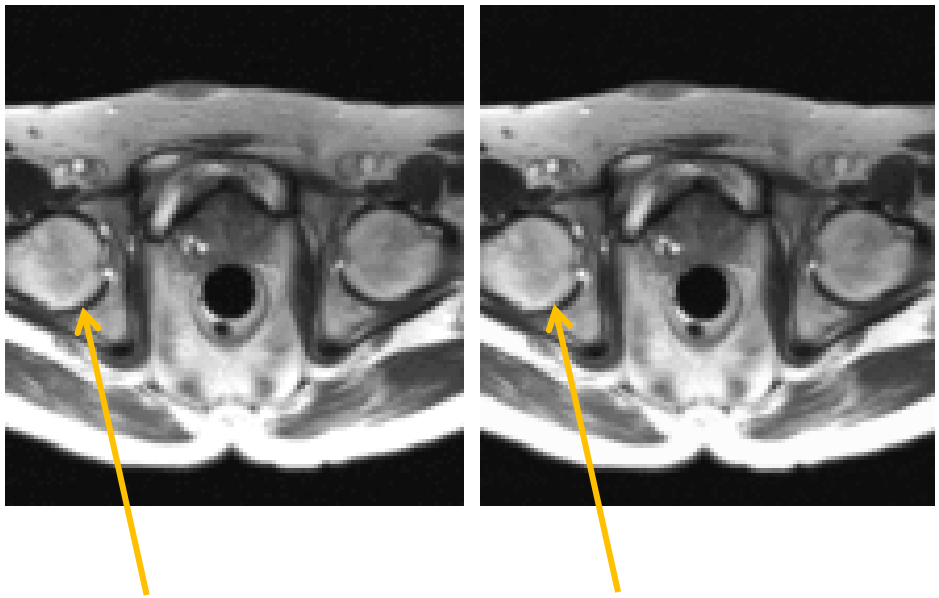




Registration

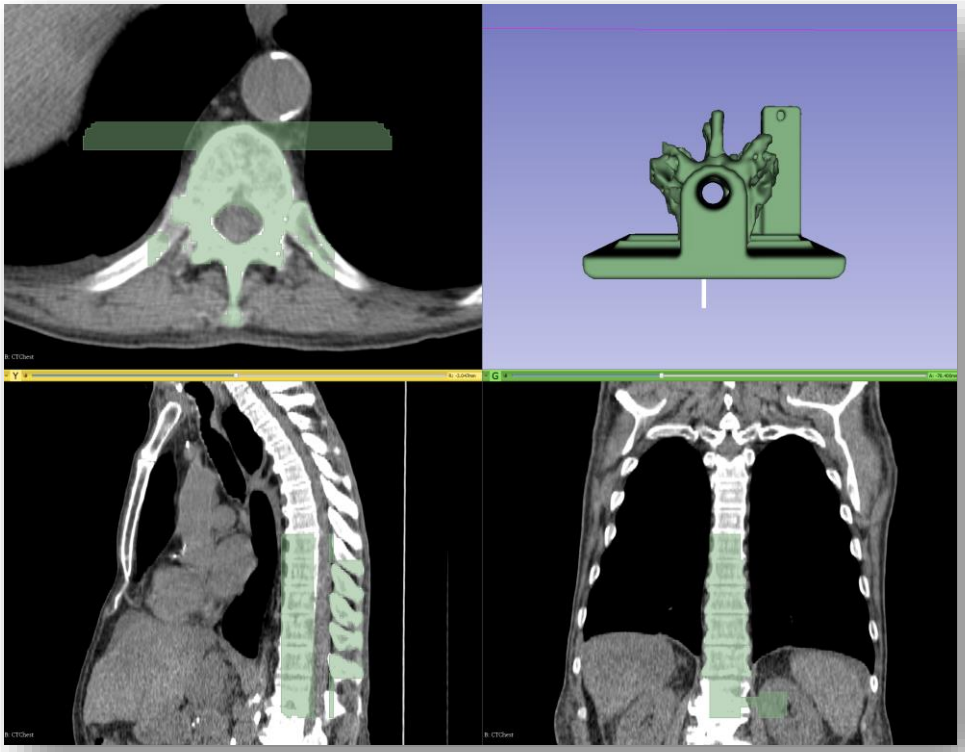
- Manual: translation, rotation in 3D
- Automatic: rigid, deformable, with various similarity metrics, initialization methods, optimizers, masking, etc.
- Extensions: structure-based registration, Elastix, etc.

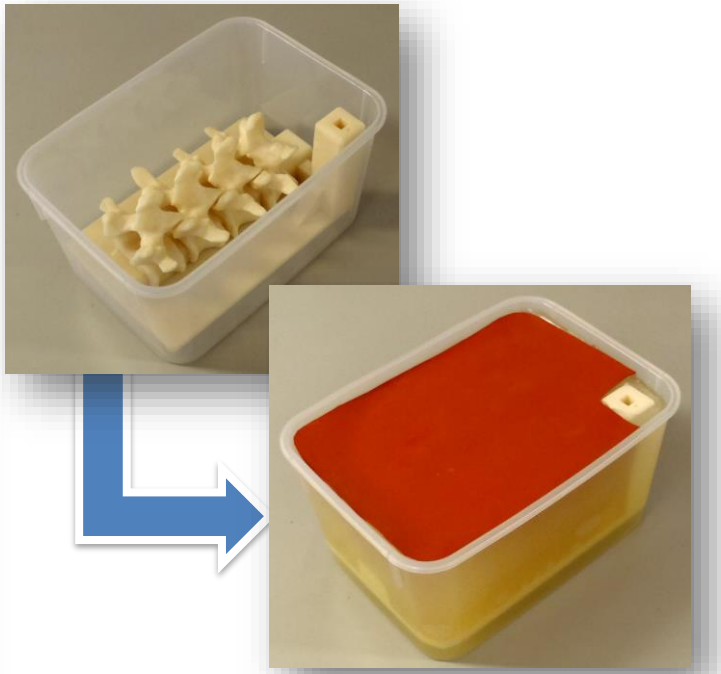




Segmentation

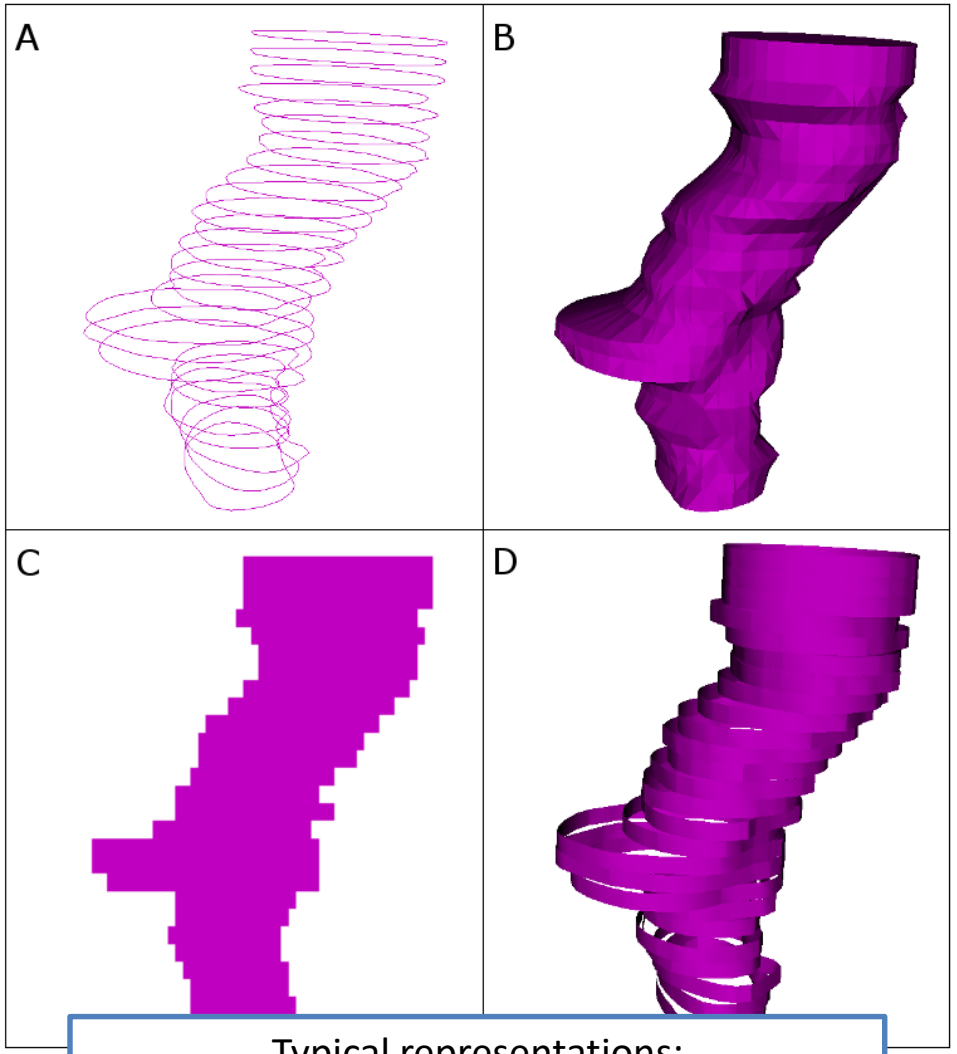
- Manual (paint, draw, scissor, threshold, etc.)
- Semi-automatic (region-growing, fill between slices, etc.)
- Automatic (atlas-based, robust statistics, etc.)





Various representations

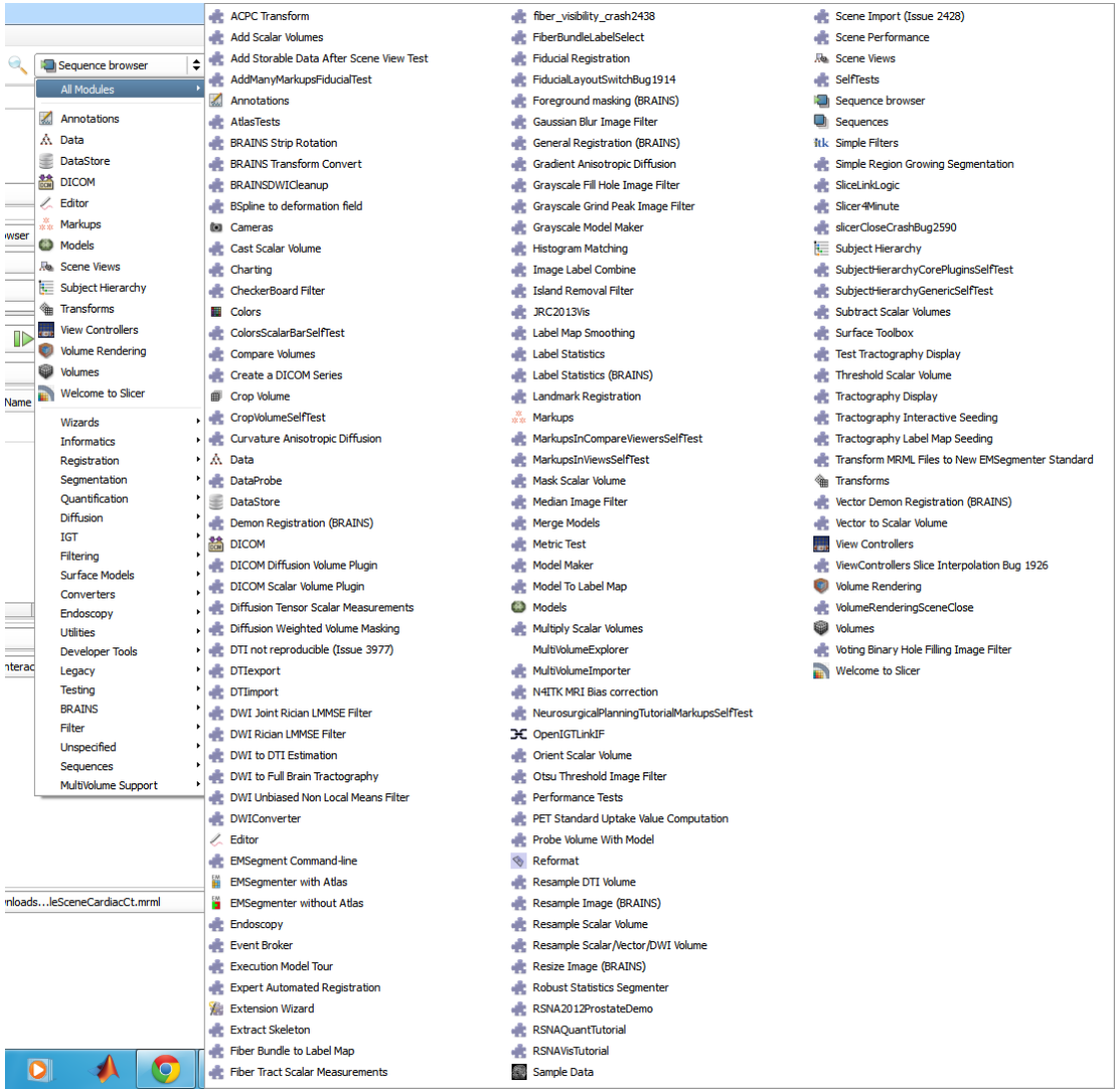
- Each optimal for
  - *either* storage (A)
  - *or* analysis (C)
  - *or* visualization (B,D)
- Imposed needs
  - Conversion
  - Simultaneous
    - Visualization
    - Transformation



Typical representations:
A: Contours, B: Surface, C: Image, D: Ribbons

Many other modules...

- Image filtering (image noise reduction, MRI bias correction, etc.)
- Surface processing
- Diffusion imaging
- Quantification, statistics
- …



Slicer for translational research

3DSlicer

What does a developer need ?

- Easily deployable
- Extensible and reconfigurable rich utility libraries
- Stable base

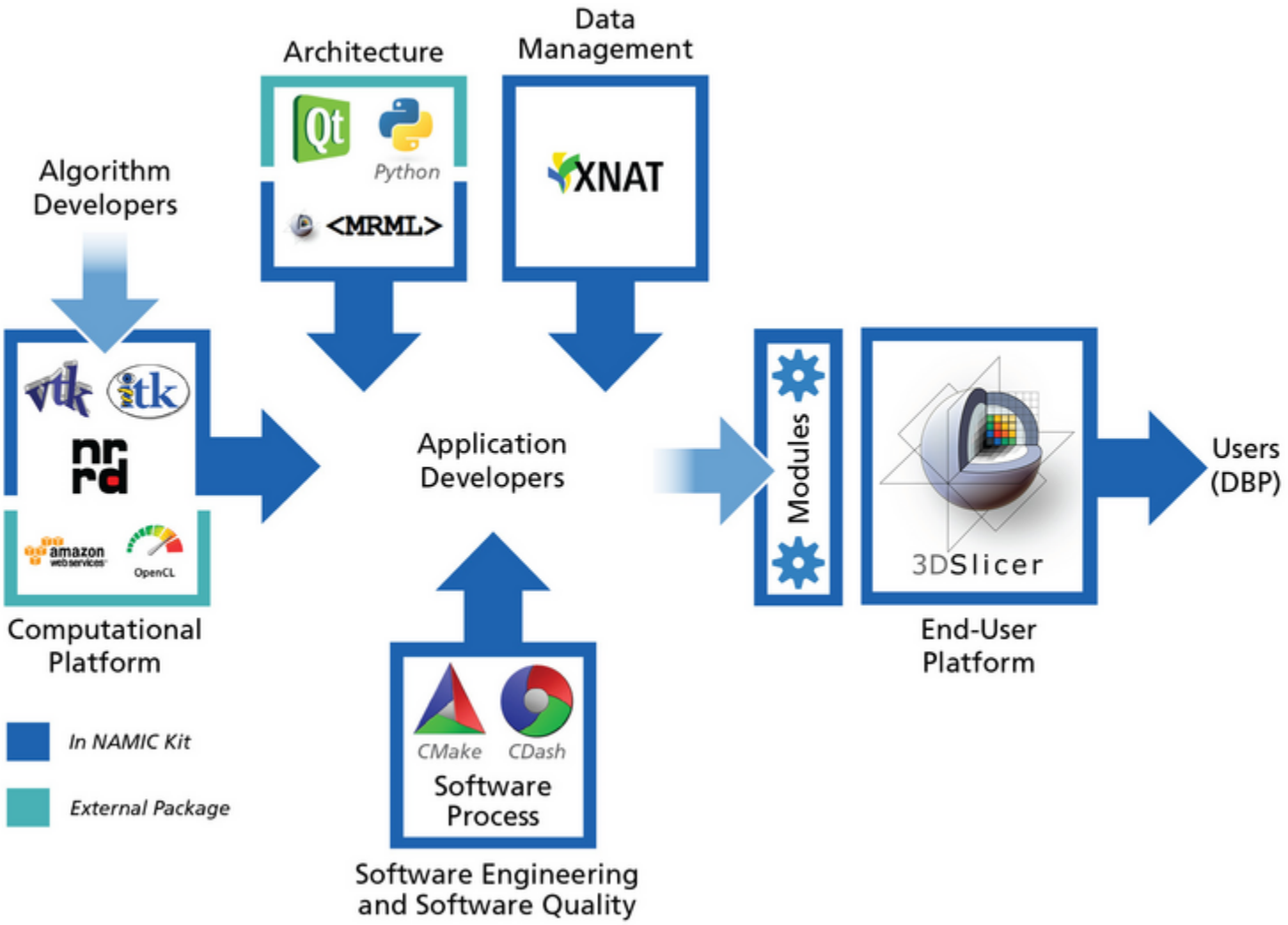
What does a user expect ?

- Easy install and upgrade
- "Standard" clinical behavior
- Advanced functionality
- Consistent interface

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

Courtesy R. Kikinis

The NA-MIC kit



What's inside Slicer?

- **Slicer core**: Slicer GUI, I/O, visualization and developer interfaces
- **Slicer modules**: internal plugins that depend on the slicer core
- **Slicer extensions**: external plugins installed on demand by the user

Data handling: the MRML scene

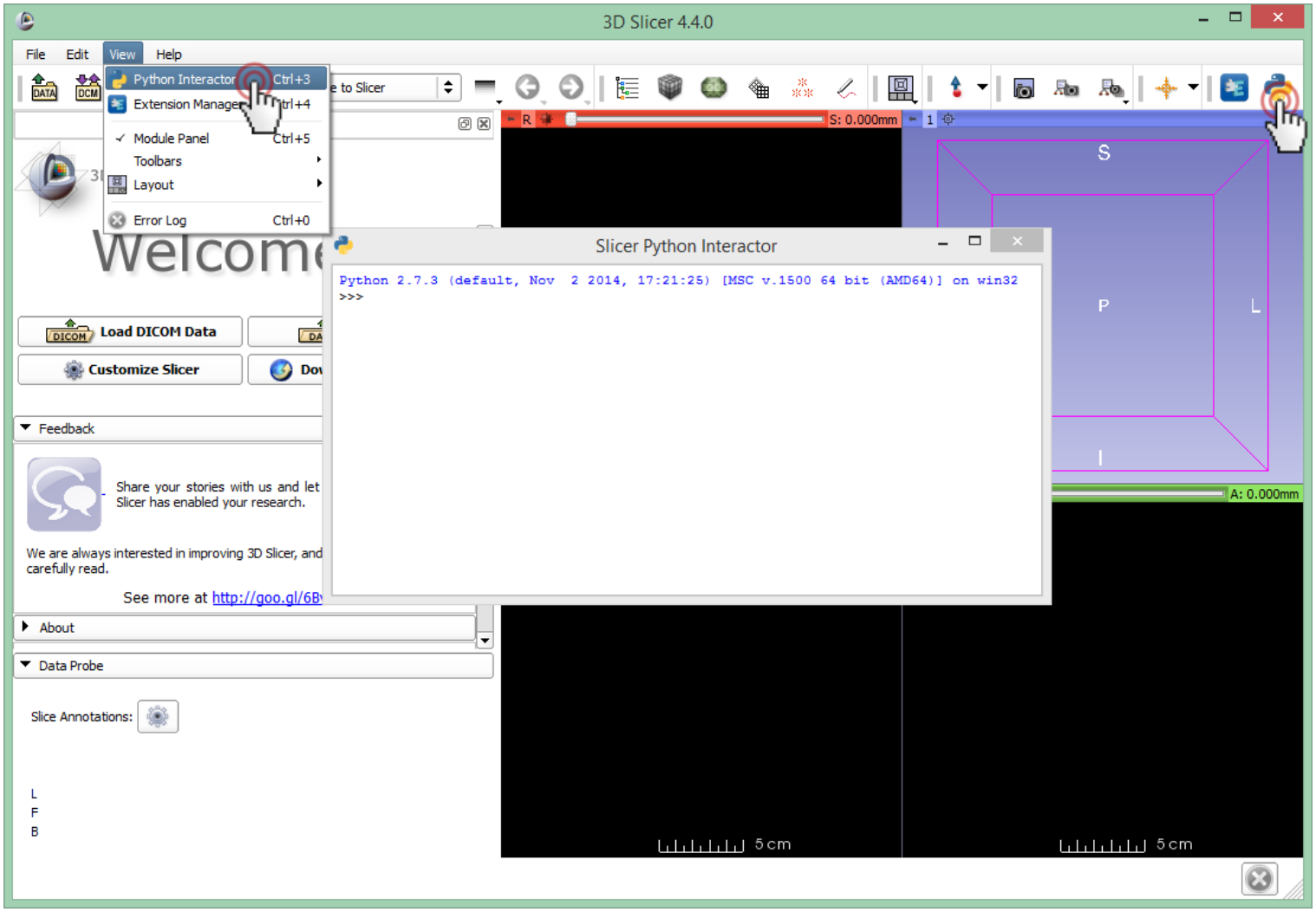
- MRML: Medical Reality Modeling Language
- All objects (volumetric images, surface models, transforms, etc.) are stored in a hierarchical structure of MRML nodes
- Each MRML node has its own list of custom attributes that can be used to specify additional characteristics for the data object
- Enables the modules to have access to the MRML tree, allowing new extensions to leverage existing processing and visualization functions without directly interfering with other modules

Python in Slicer

The Python console of Slicer4 gives access to

- Scene objects (MRML)
- Data arrays (volumes, models)
- GUI elements (Qt) that can be encapsulated in a module
- Processing Libraries
  - numpy
  - VTK
  - ITK
  - CTK

Python console in Slicer



Slicer modules

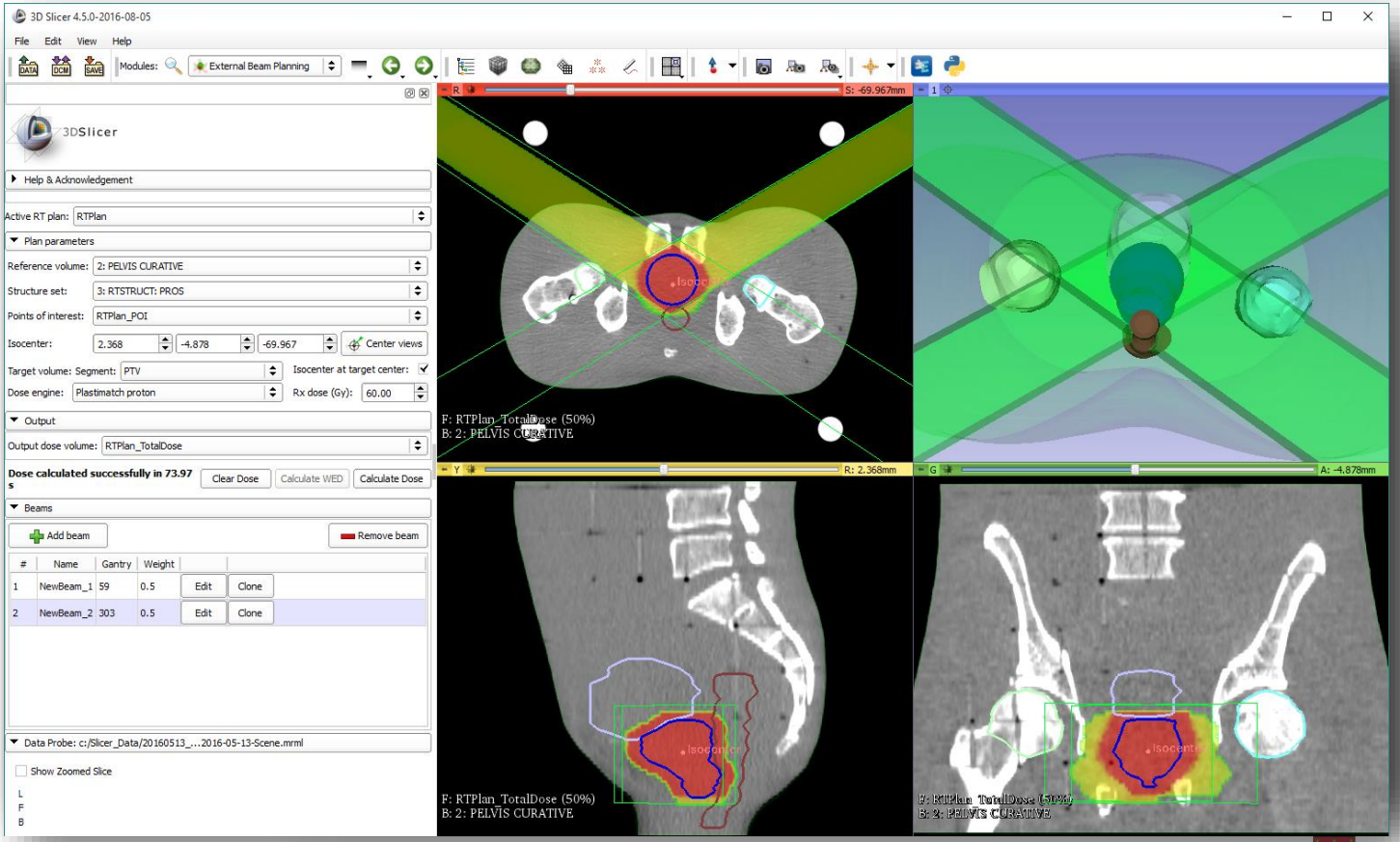
Three types of modules:

- Scripted modules – written in python
- Command-line modules (CLI) – use ITK
- Loadable (interactive) modules – written in C++

e.g. Tractography labelmap seeding

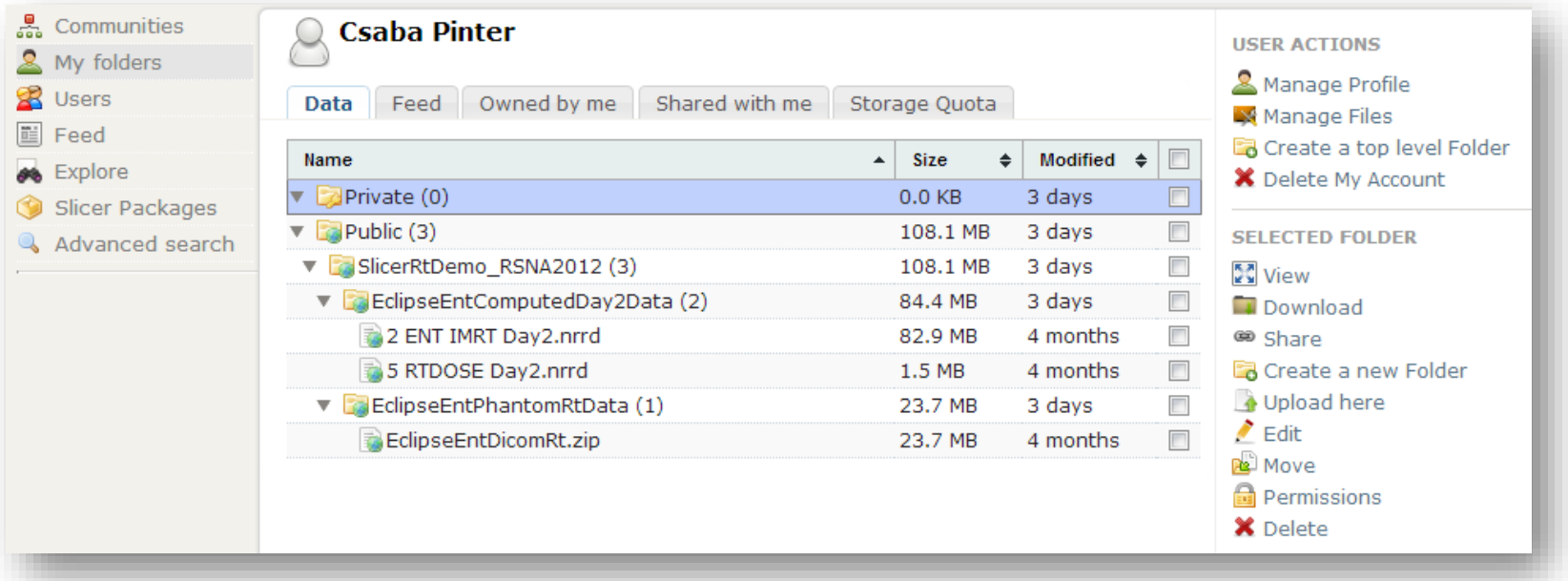
e.g. External beam planning

Image courtesy: Sonia Pujol



MIDAS

- Platform that provides a flexible, intelligent web-based data storage system
- Slicer has adopted MIDAS to store testing and algorithm validation dataset
- Dedicated NA-MIC MIDAS community has been created
- Slicer releases can also be downloaded from the server



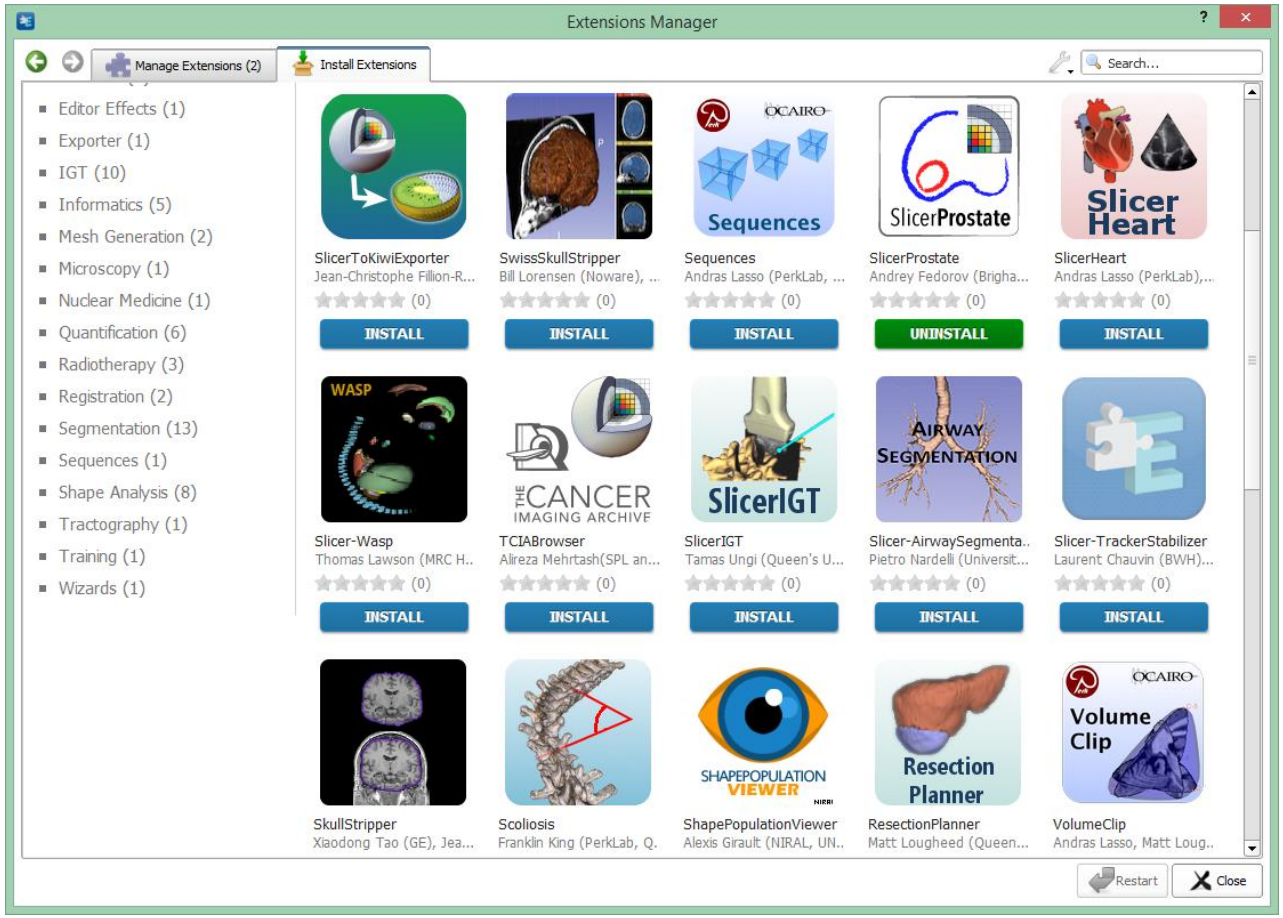
Automatic regression testing

- Automatic tests ensure detecting regression errors
- Results published on web-based dashboard
- Types
  - Qt generic tests – automatically generated
  - Logic tests – need to be written
    - Tests a custom module's underlying logic (algorithm)
    - In folder *CustomModule/Testing/Cxx*
  - Python self-tests
    - Comprehensive test for a custom module
    - In folder *CustomModule/Testing/Python*
    - Details: http://wiki.slicer.org/slicerWiki/index.php/Documentation/Nightly/Developers/Tutorials/SelfTestModule

Share your tools

- In the spirit of the open-source paradigm, it is encouraged to share your tools
- The shared extensions
  - appear in the Extension Manager
  - are nightly tested on the Slicer Factory platforms
- How to share?
  - Fork ExtensionIndex from GitHub and upload your extension description (.s4ext) file https://github.com/Slicer/ExtensionsIndex
  - Ask the core team to integrate (send a “pull request”)

Slicer is extensible



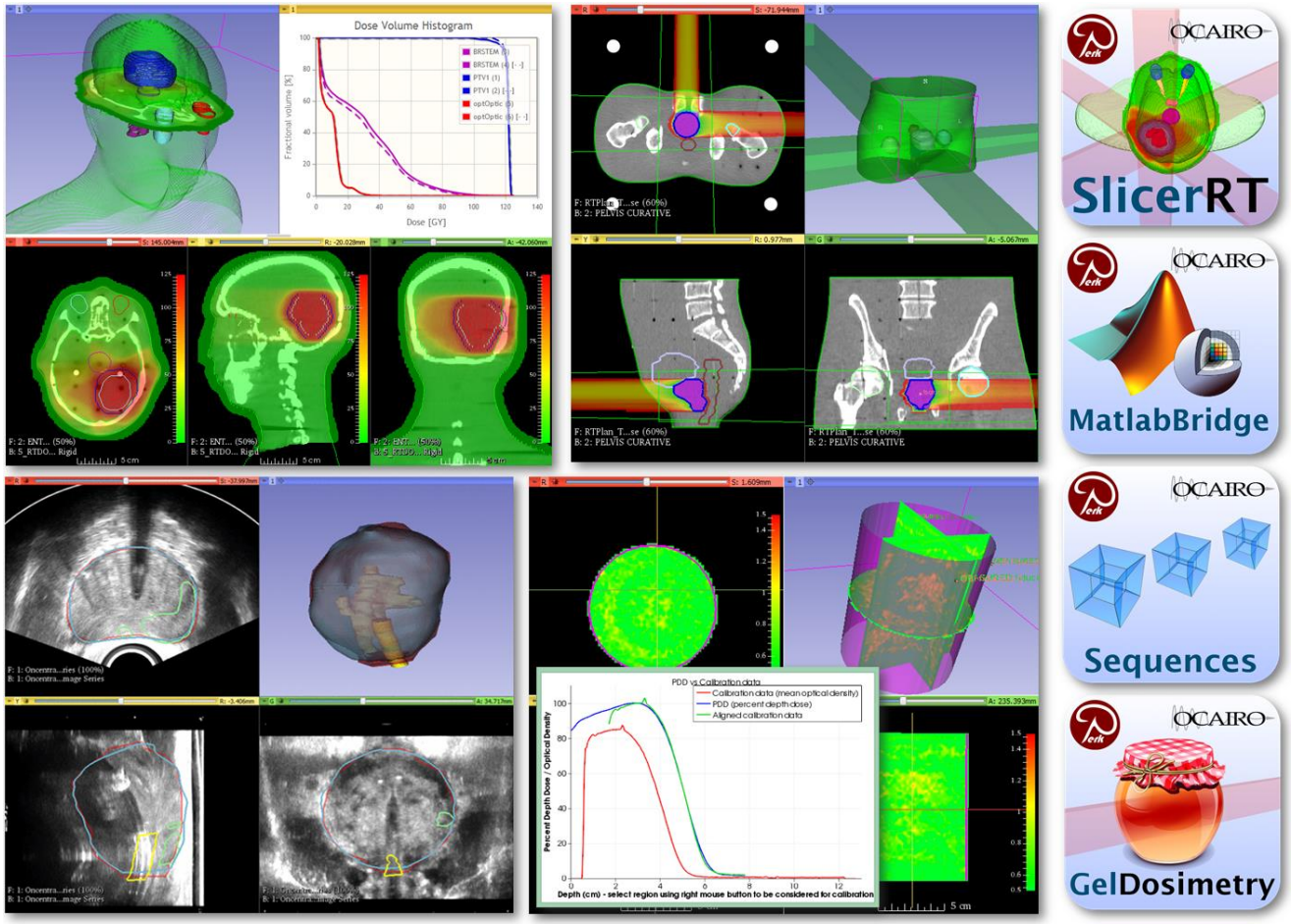
The Slicer Extension Manager offers the possibility to the user to download and install additional Slicer modules

Major extension: SlicerIGT

- Toolkit for image-guided therapy
- Basis for navigation “guidelets”

Major extension: SlicerRT

- Toolkit for radiation therapy



Further notable extensions

PerkTutor

SegmentEditorExtraEffects

DebuggingToolsForExtensions

Slicer introduction tutorials

- In this session, please use the nightly Slicer version you installed (4.9.0-2018-04-23)
- Please note that this is a cutting edge nightly build, so if anything happens differently than you expect, please let us know
  - Thanks for helping us test the latest Slicer ☺
- Linux users: Please use 4.8.1
- Mac users: Please use 4.8.1, only for the registration section

Tutorial sections

- Visualization
  - load/save, sample data, viewers, models, volume rendering (30 min)
- DICOM
  - tags, where to get them (web, TCIA browser), loading options, plugins, export (15 min)
- Segmentation
  - Segment Editor effects, workflows (45 min)
- Registration
  - BRAINS, Elastix, landmark registration, SegmentRegistration, transforms, transform visualization (45 min)
- Other: Sequences, MatlabBridge, Virtual reality (15 min)

Appendix

Segmentation "object"

- 1 *segmentation* contains N *segments* (structures)
- Each *segment* contains multiple *representations*
- Provides automatic conversions