Visualize and analyze medical images in 3D Slicer

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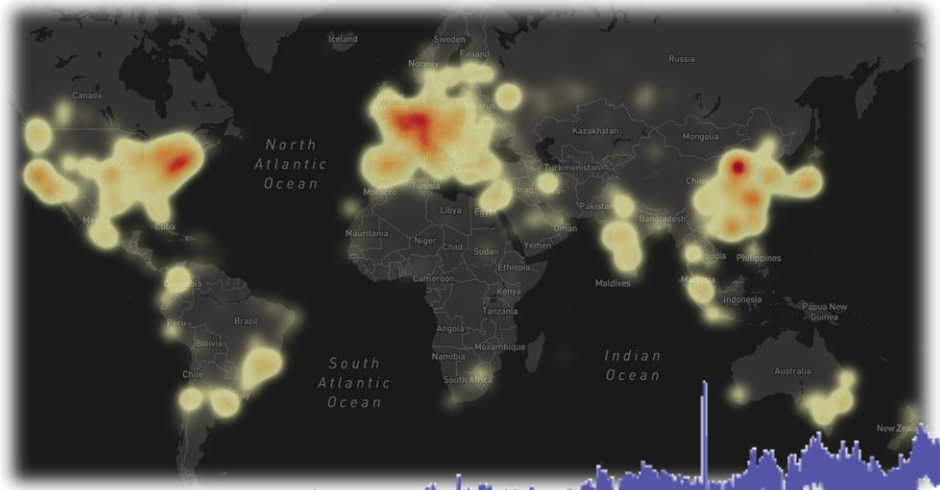
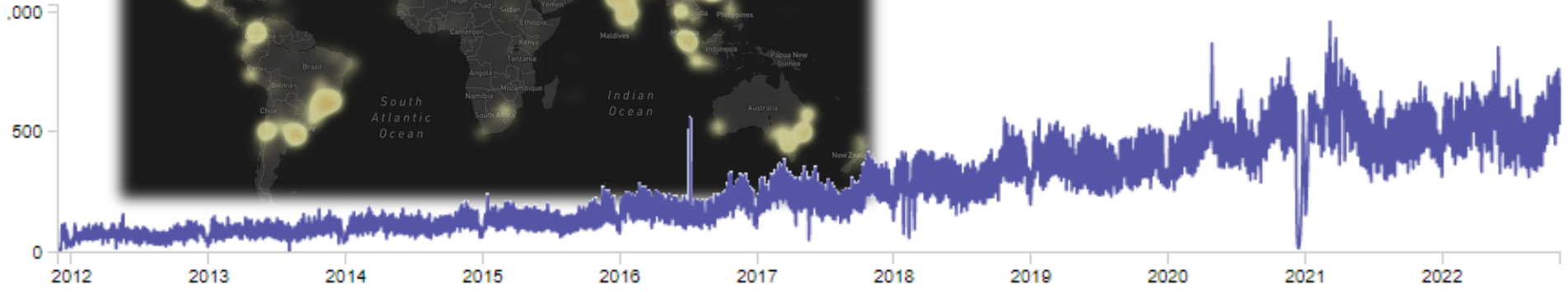
3D Slicer – Overview

- Desktop application for Windows, Mac, and Linux
- 5.0.3 released, 5.2.0 in the works
- Over 1.1 million downloads since 2011





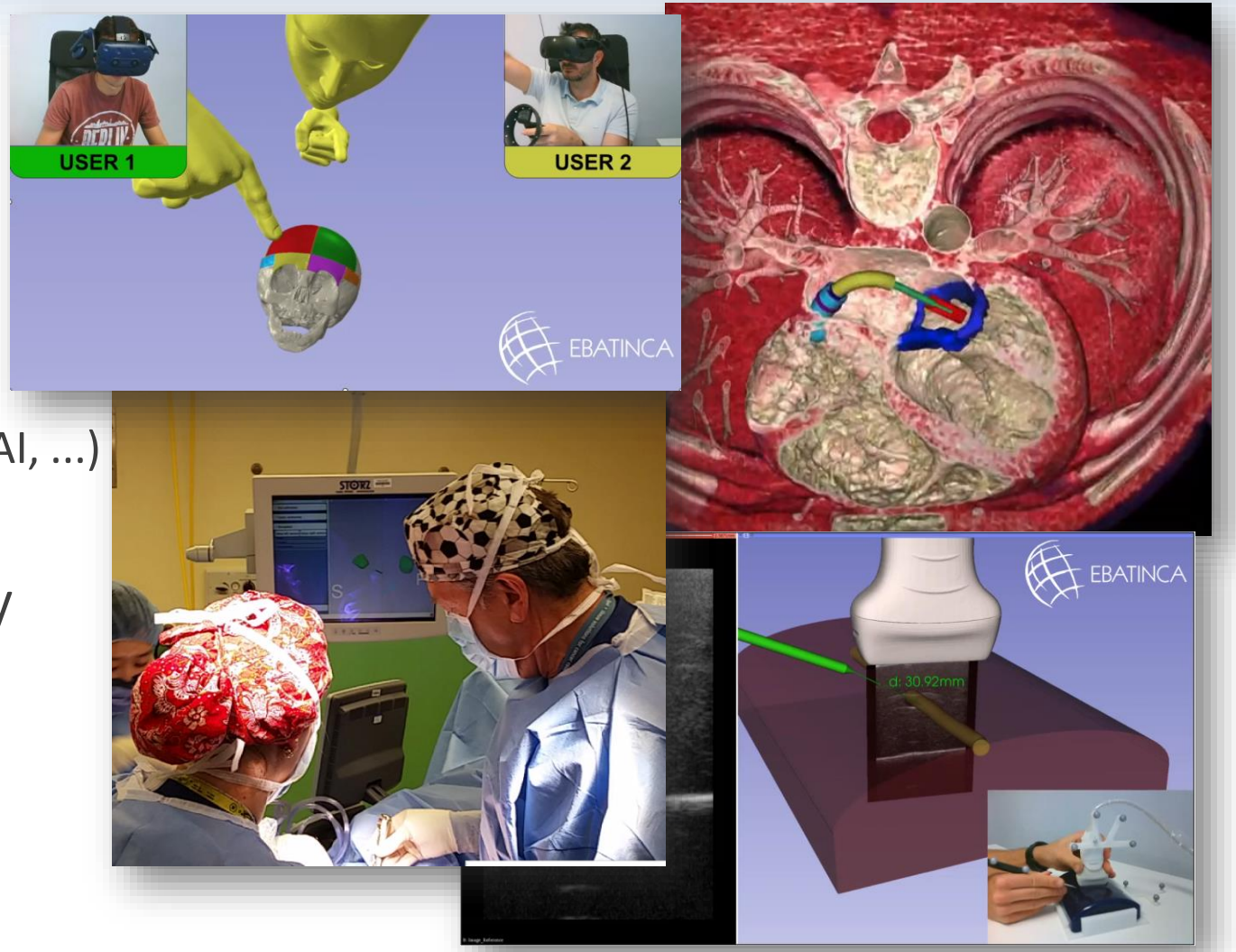
3D Slicer – History

- Pre-Slicer BWH/GE work on volumetric software and image guided therapy
- Vision of Ron Kikinis: a unified platform to avoid reinventing the wheel
- MIT AI Lab Collaboration
  - Dave's neurosurgery thesis 1999
  - Delphine's virtual endoscopy thesis 2002
  - Lauren's tractography thesis 2006

Courtesy of Ron Kikinis, M.D.

3D Slicer – Today

- Professionally engineered
- Documented & tested
- Extensively scriptable in Python
- Based on the best software libraries
  - VTK, ITK, Qt, WebEngine, DCMTK, …
  - Python ecosystem (numpy, PyTorch/MONAI, ...)
- Dozens of tutorials, hundreds of videos
- Very active online forum: ~16K posts / y
- Scientific publications: Over 15,000 citations on Google Scholar
- Twice a year developer project week



3D Slicer Software License

- BSD-style very permissive license
- Explicitly written for BWH / 3D Slicer goals
  - Promote multi-site collaboration
  - Encourage industry involvement
  - Allow use in medical products
- Written in 2005 after NIH workshop and consultation with legal experts
- Adopted by dozens of academic & commercial sites
- Contributor agrees
  - Applies to code and data
  - Allows re-licensing under same terms
  - No GPL "reciprocal licenses"
  - No known patent restrictions

```
For more information, please see:

                    http://www.slicer.org

The 3D Slicer license below is a BSD style license, with extensions
to cover contributions and other issues specific to 3D Slicer.


3D Slicer Contribution and Software License Agreement ("Agreement")
Version 1.0 (December 20, 2005)

This Agreement covers contributions to and downloads from the 3D
Slicer project ("Slicer") maintained by The Brigham and Women's
Hospital, Inc. ("Brigham"). Part A of this Agreement applies to
contributions of software and/or data to Slicer (including making
revisions of or additions to code and/or data already in Slicer). Part
B of this Agreement applies to downloads of software and/or data from
Slicer. Part C of this Agreement applies to all transactions with
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Your contribution of software and/or data to Slicer (including prior
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PART A. CONTRIBUTION AGREEMENT - License to Brigham with Right to
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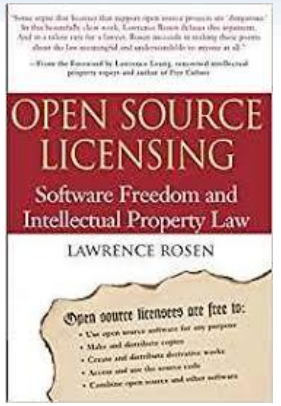


Lawrence Rosen, Eve Waterfall, Brian Hicks

Courtesy of Ron Kikinis, M.D.

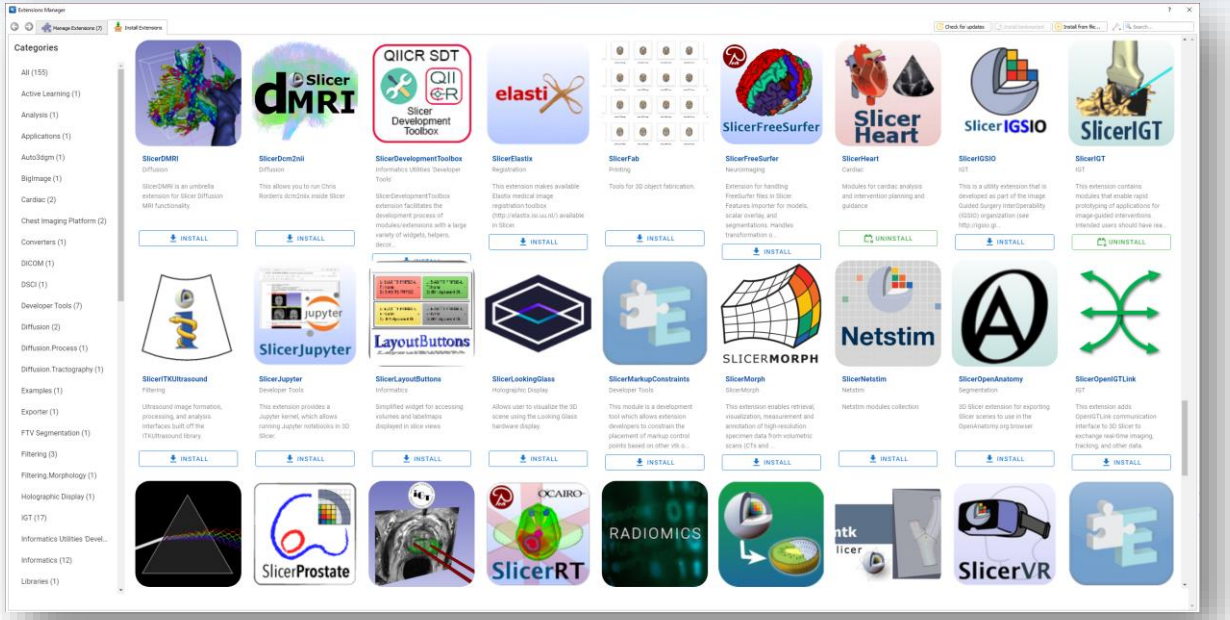
100% Open and Non-Restrictive Processes

- Public source repository: github.com/Slicer organization
  - Slicer source code and issues tracker
- Open discussion forum: discourse.slicer.org
- Weekly developer video conferences open to anyone (10am EST Tuesdays)
- Twice-yearly Project Weeks
  Next one here in Las Palmas!
  projectweek.na-mic.org
- "Meritocracy" to form group decisions

Courtesy of Ron Kikinis, M.D.

3D Slicer Extensions – “App Store”

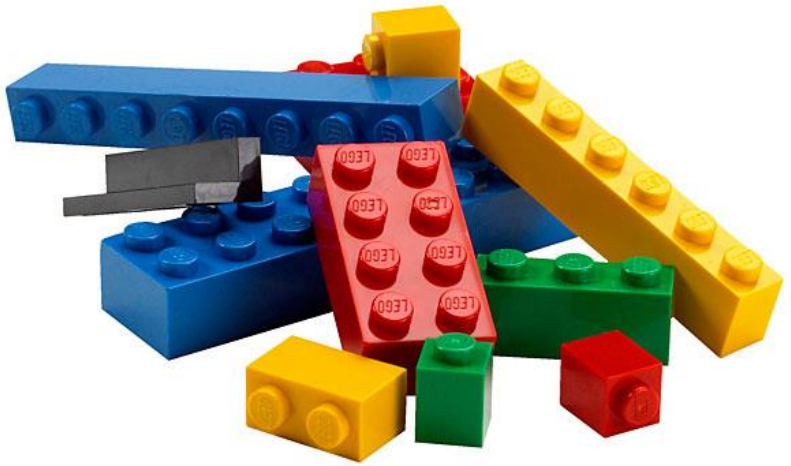
- 150+ Extensions from hundreds of developers
  Independent add-ons to core platform
- Built & tested nightly for Windows, Mac, Linux
- Different styles
  - Pure Python / Pure C++ / Hybrid C++ & Python
  - Extra modules to full custom app (aka "Solution")
- Everything we provide is open source
- Anyone can build compatible extensions under preferred distribution license



3D Slicer Solutions:

Modular and Reusable

- Medical Reality Markup Language (MRML)
  - In-memory dynamic scene description
  - Event-driven
  - Serializable to XML (.mrml)
  - Medical Reality Bundle (.mrb)
- Logic implements algorithms
  - Decoupled from UI for reuse in CLI or other app
- Graphical User Interface (GUI) modifies MRML and responds to events
- Displayable Managers and Widgets map between MRML and 2D / 3D rendered views

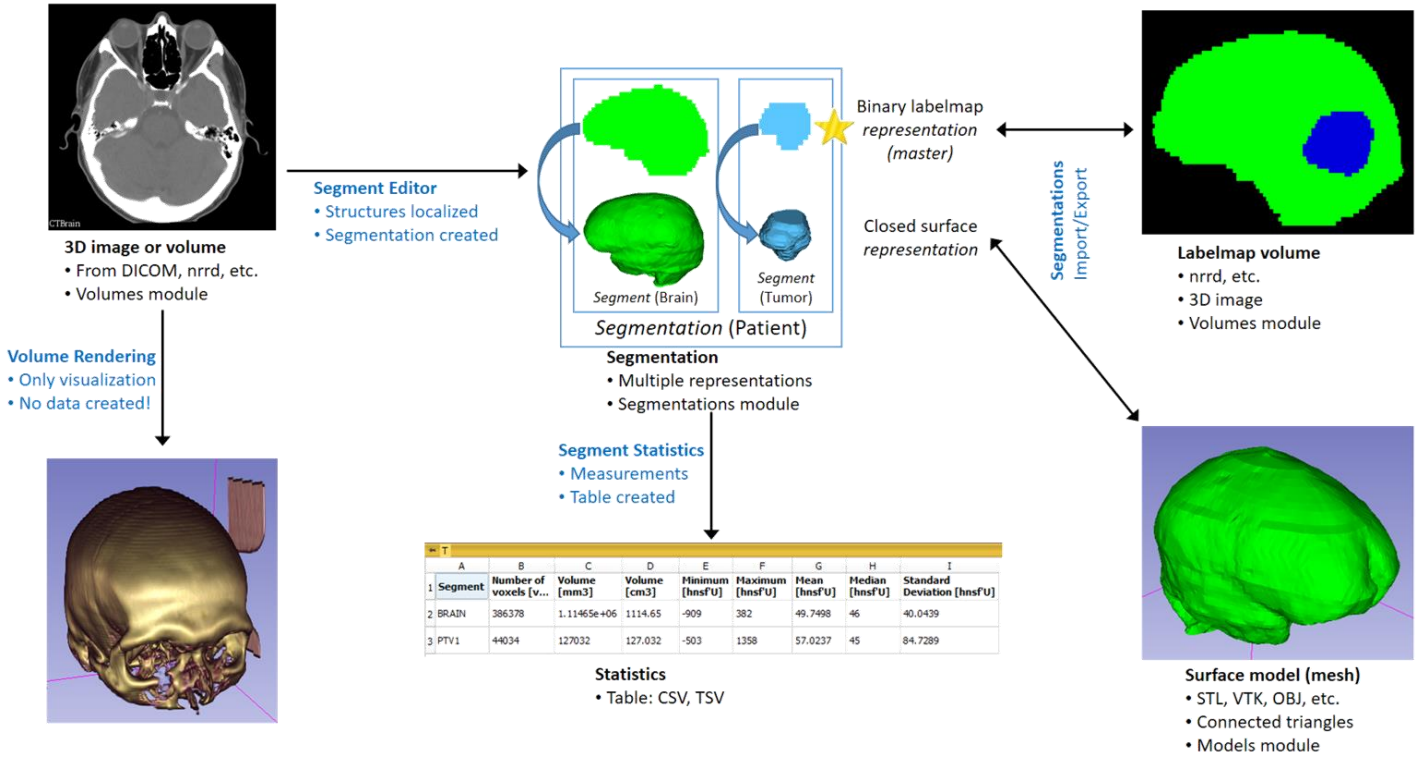


"Lego bricks, not jigsaw puzzle pieces!"

Courtesy of Ron Kikinis, M.D.

Interoperability

- Common and research formats
  - Images (nrrd, nii.gz, …)
  - Models (stl, ply, obj, …)
  - Tables (csv, txt)
  - Point lists (json)
  - etc.
- DICOM



DICOM

- DICOM: Digital Imaging and Communications in Medicine
- The industry standard for storage and transfer of medical images

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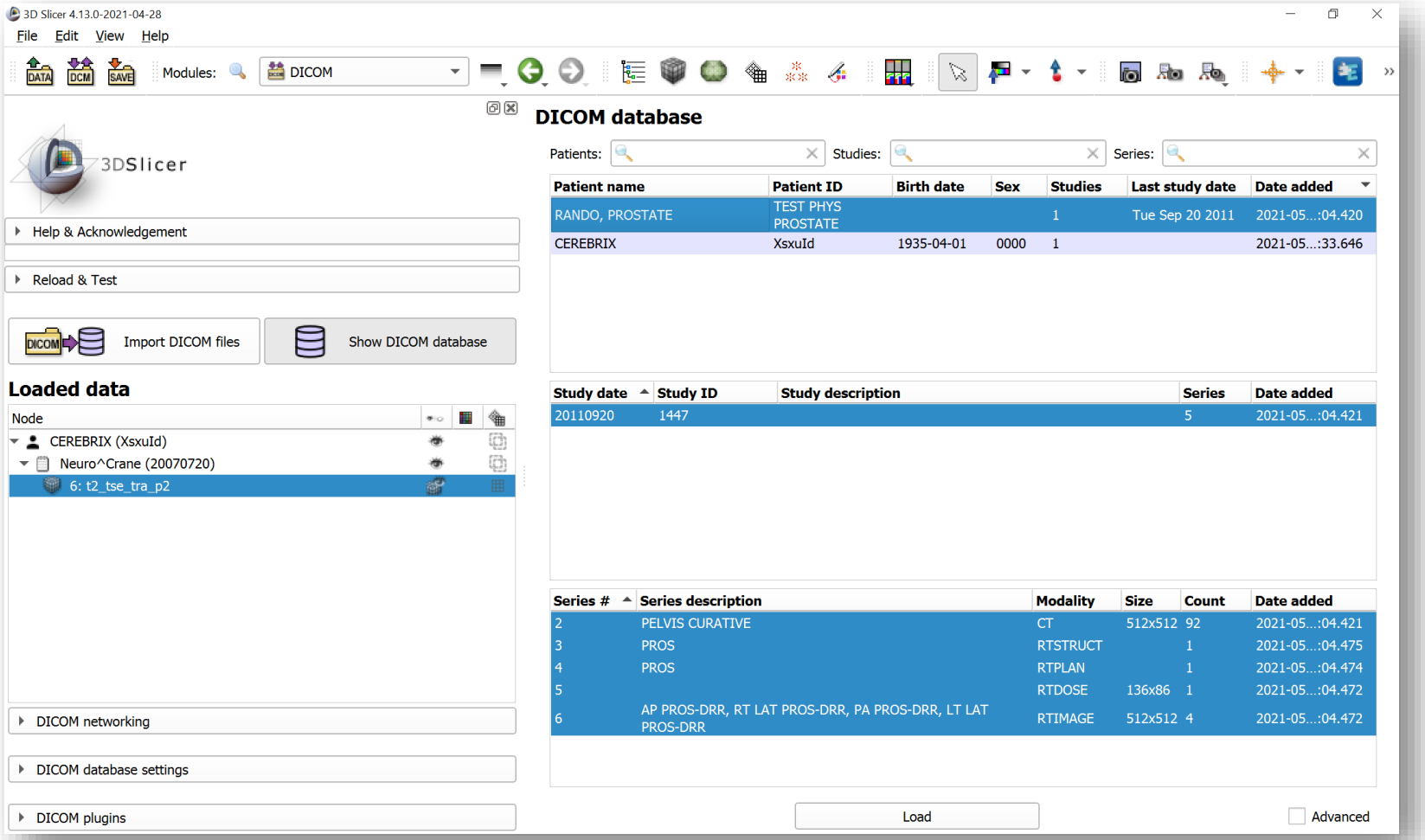
DICOM Support

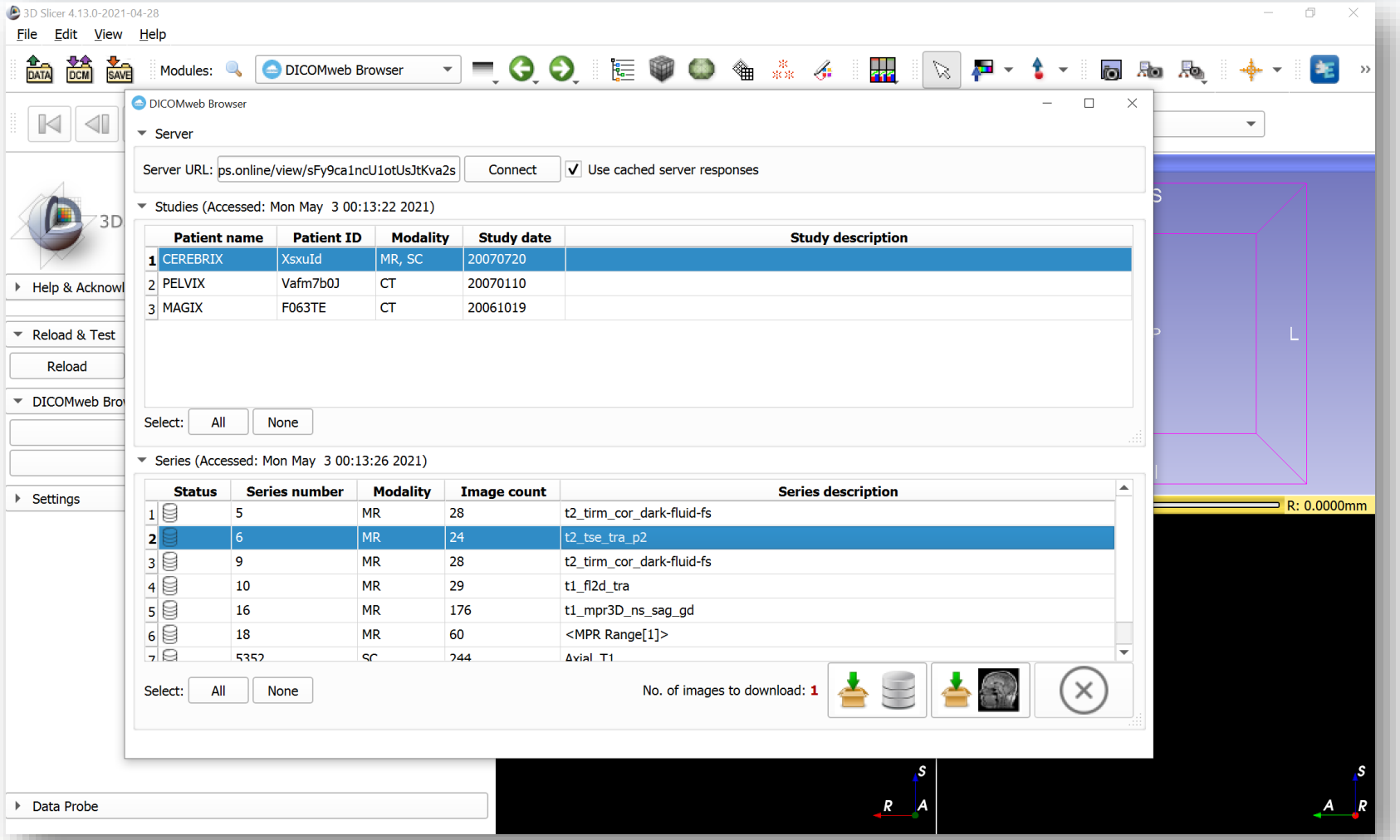
Modalities

- Image
  - Common: CT, MR, US, PET, …
  - 4D Ultrasound
- Segmentation: SEG
- Structured report: SR
- Radiation therapy
  - Dose: RTDOSE
  - Structure set: RTSTRUCT
  - Plan: RTPLAN
  - Planar image: RTIMAGE



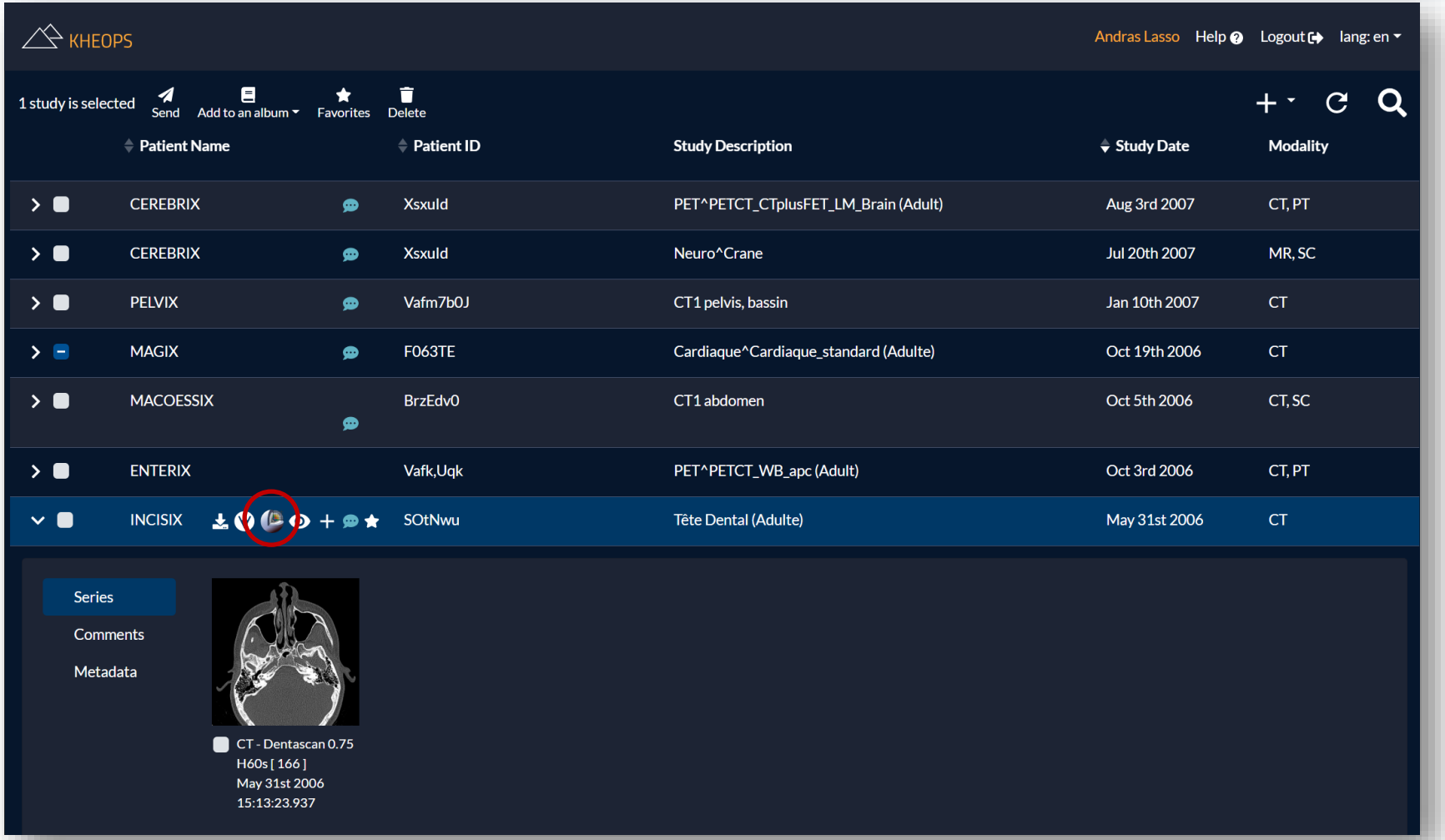
DICOM via DICOMweb

- DICOM Standard for web-based medical imaging
- RESTful API services



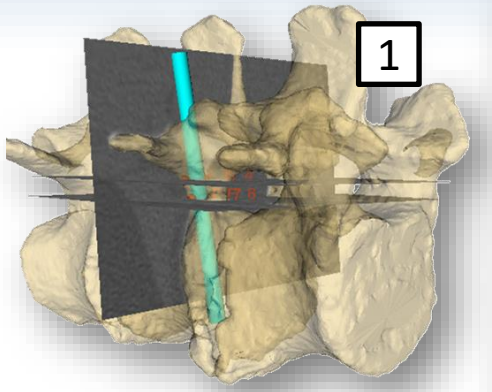
DICOM via Kheops

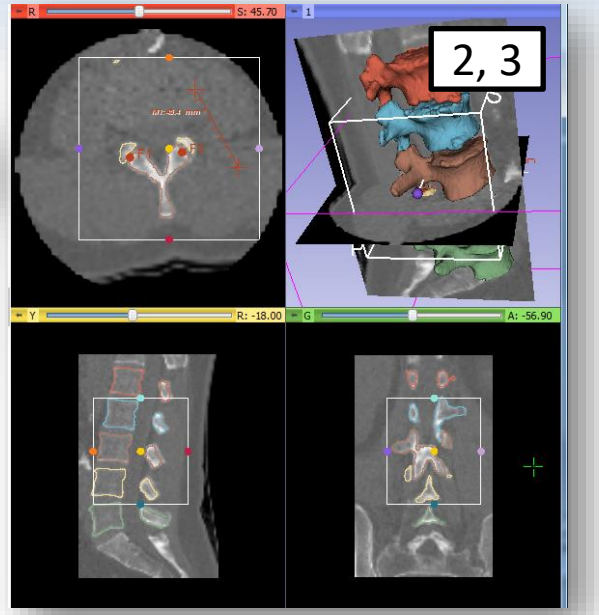
- Web-based DICOM database management
- Slicer plugin: download and open in Slicer

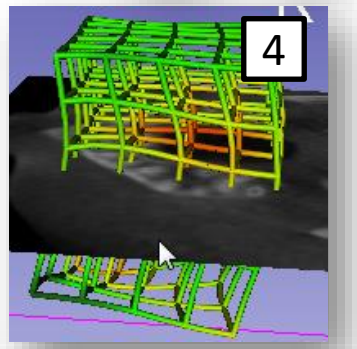


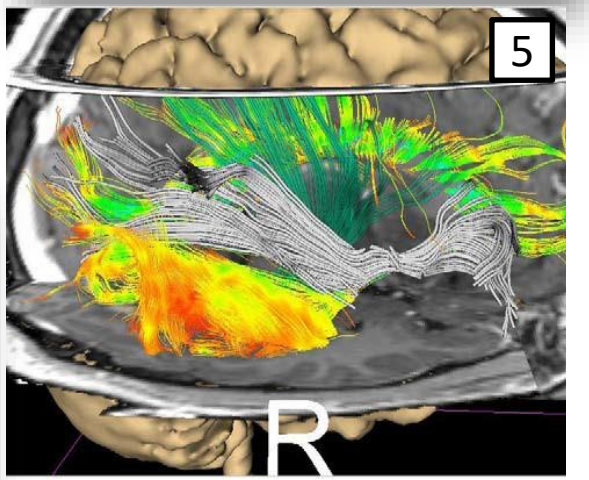
Features: Visualization

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



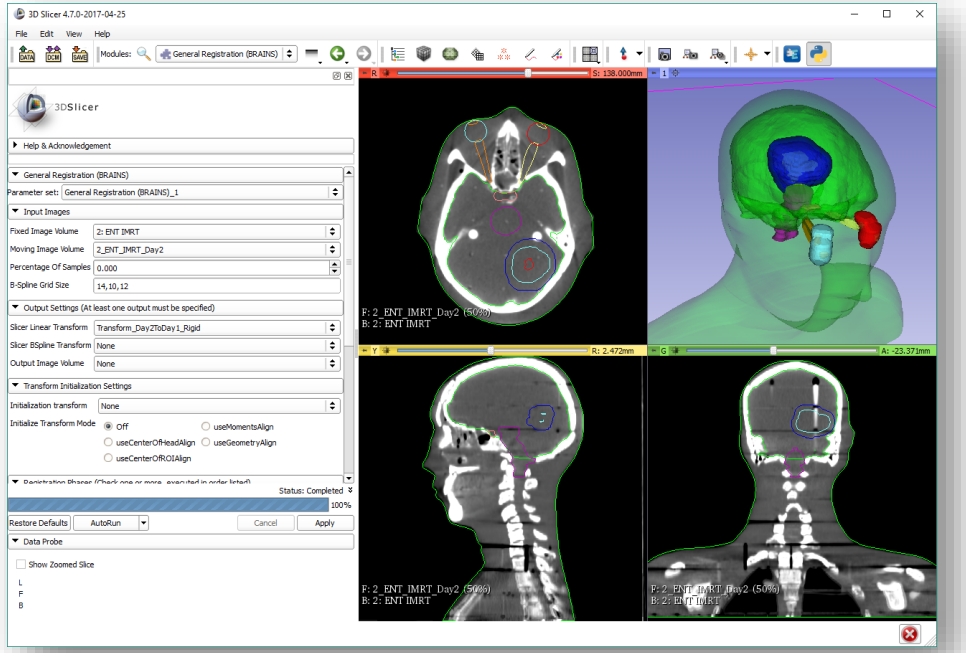


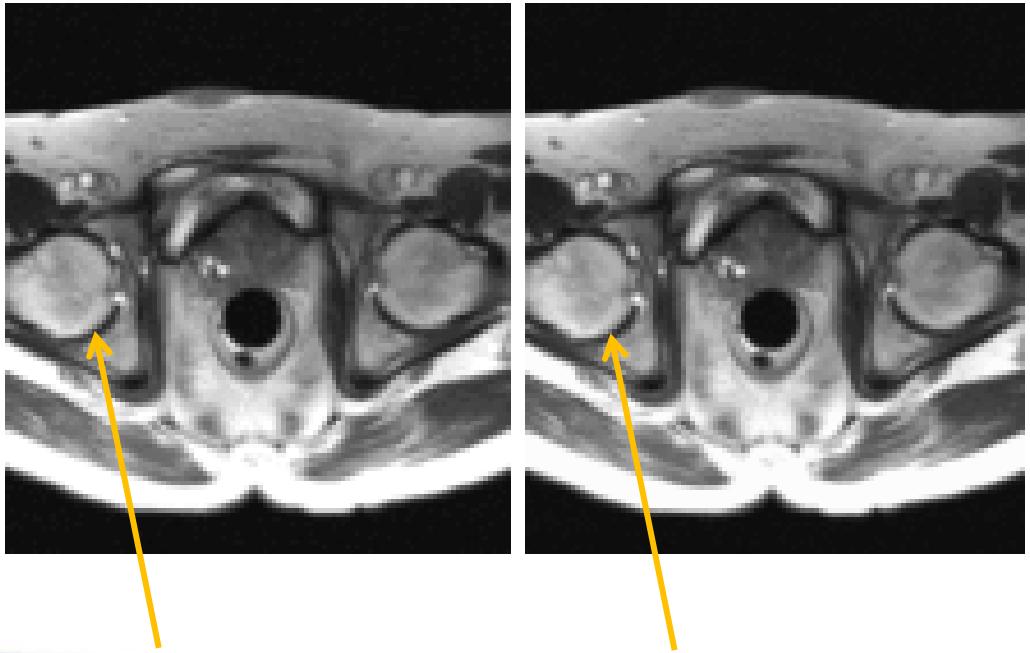




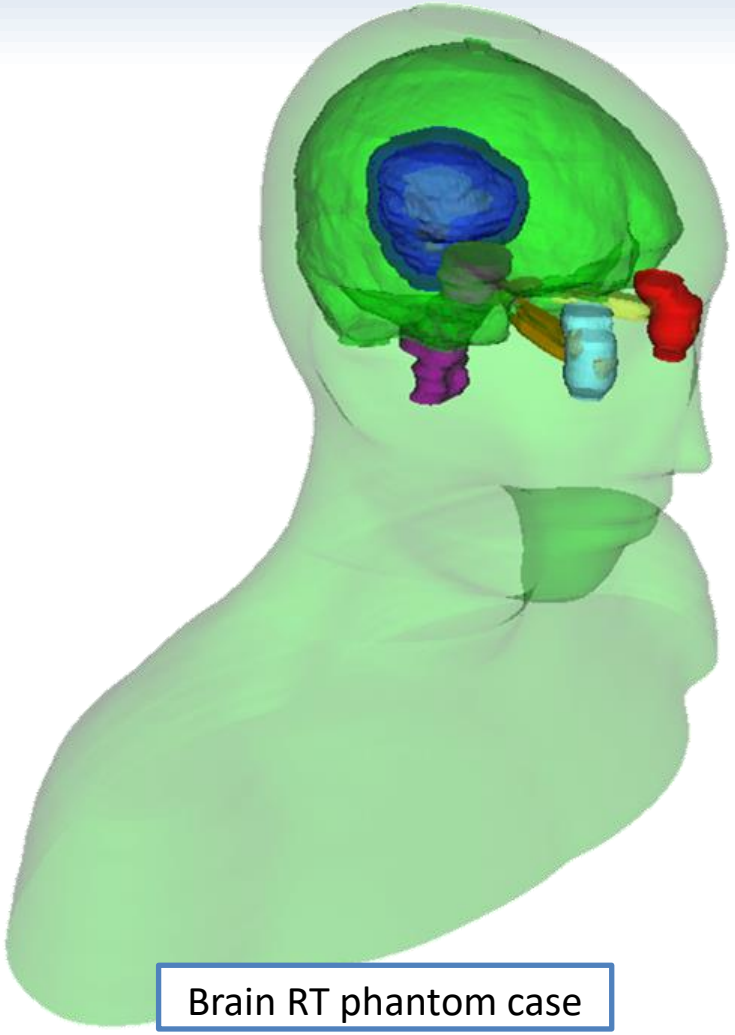
Features: Registration

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



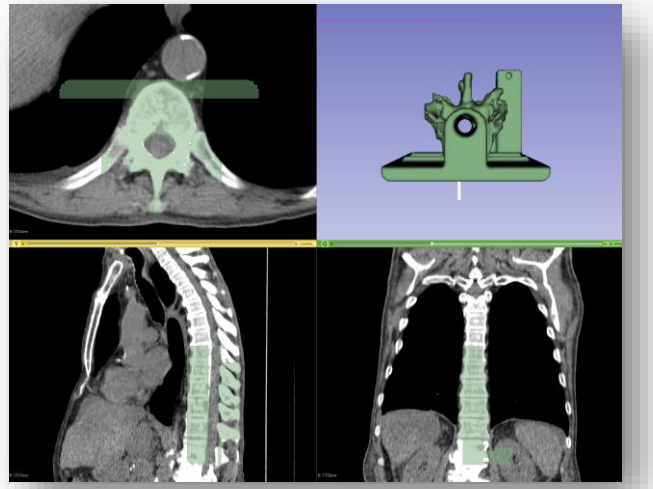


Features: Segmentation



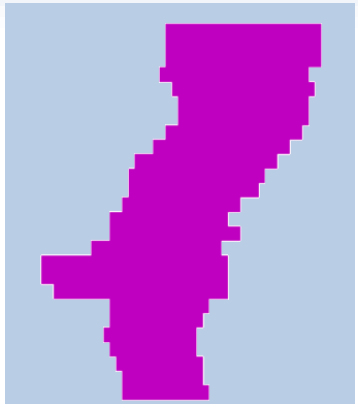
Brain RT phantom case

- Also known as contouring
- Delineates structures of interest
  - Manual contouring: slow
  - Semi-automatic: some interaction
  - Automatic: still needs editing
- Omnipresent in medical imaging
  - Surgical/radiation therapy **planning**
  - Intra-surgery **navigation**
  - Volume/shape **analysis**
  - 3D printing (**interventions**)
  - **Education**

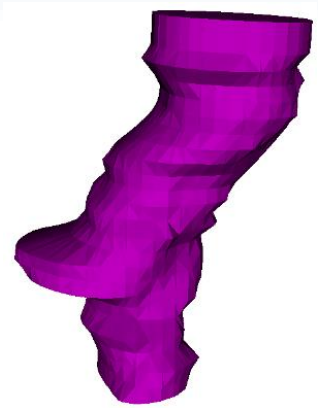


Representing Segmentations

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

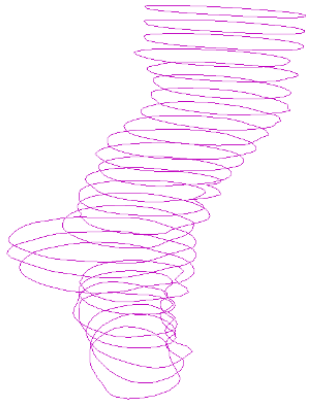


A: Binary labelmap



B: Closed surface

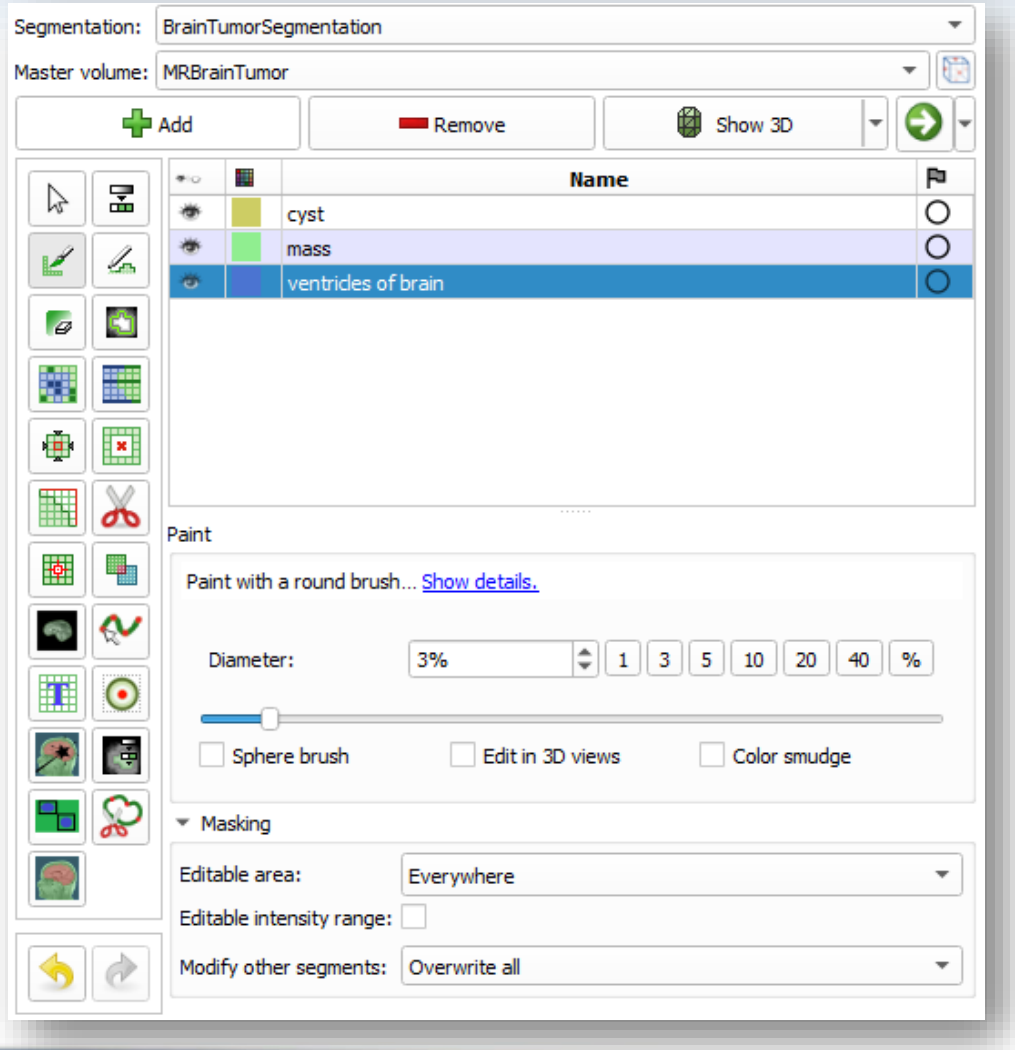
C: Fractional labelmap



D: Planar contours

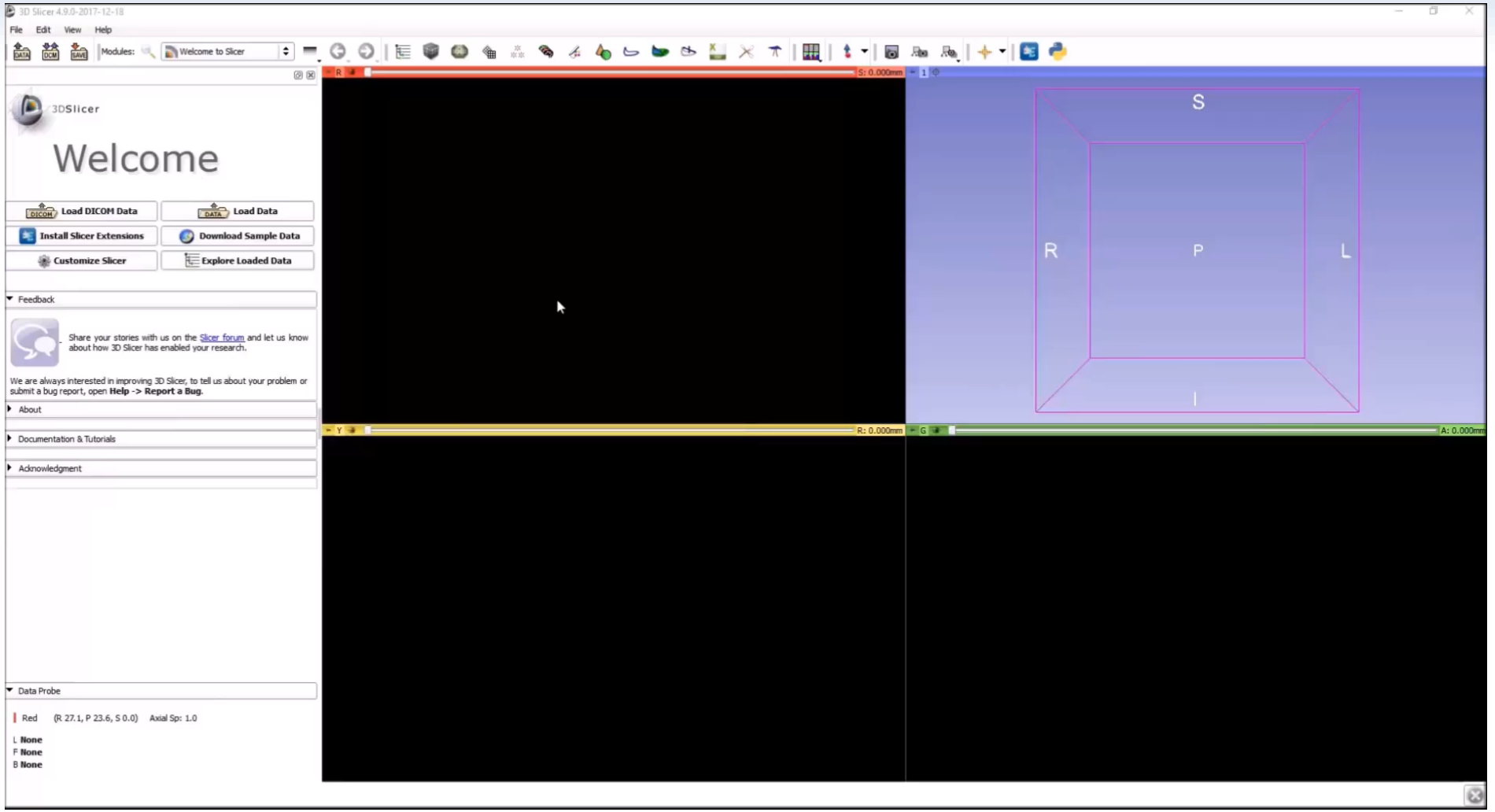
E: Ribbon model

Segment Editor



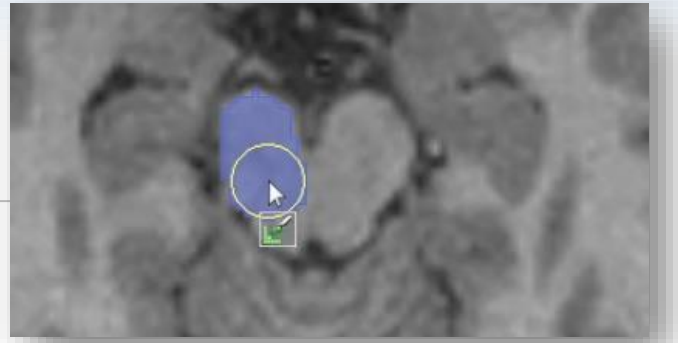
- Overlapping structures
- Real-time 3D surface visualization
- Direct file export (*e.g.* for 3D printing)
- Control over geometry
- Advanced masking options
- Standard medical terminologies
- Unique editing tools

Segment Editor: Example Workflow

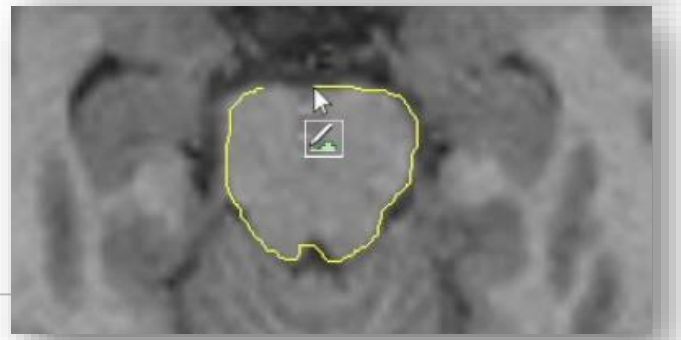


Segment Editor: Simple Manual Tools

Paint

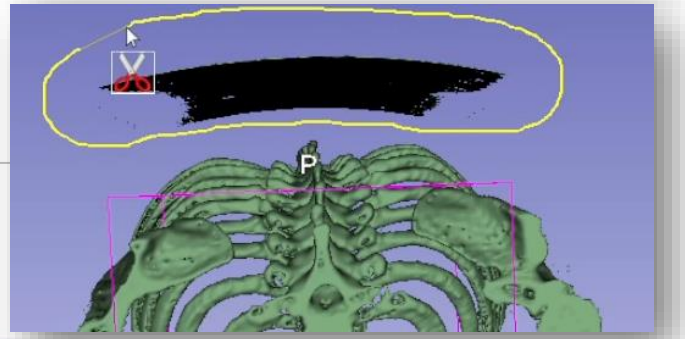


Erase



Draw

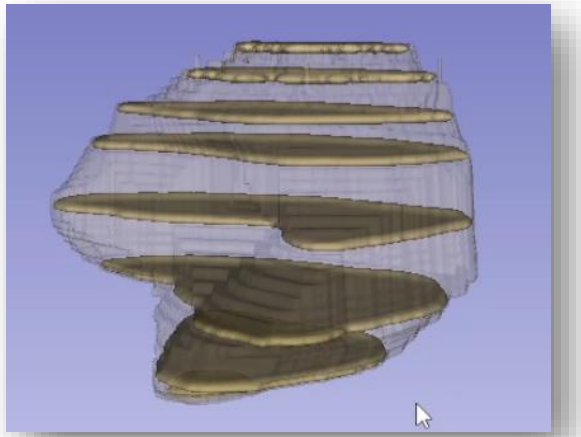
Scissors



Segment Editor: Semi-Automated Tools

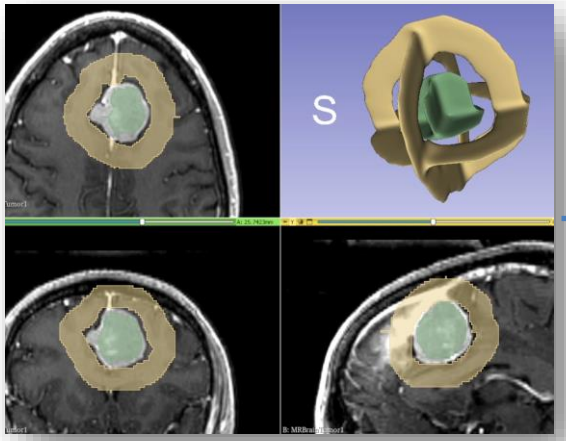
Threshold

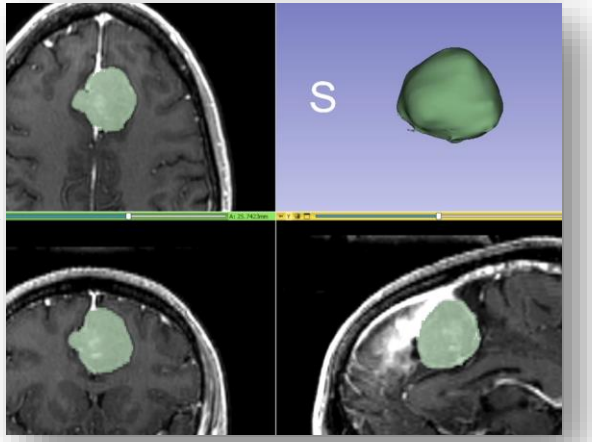
Fill between slices



Level tracing

Grow from seeds

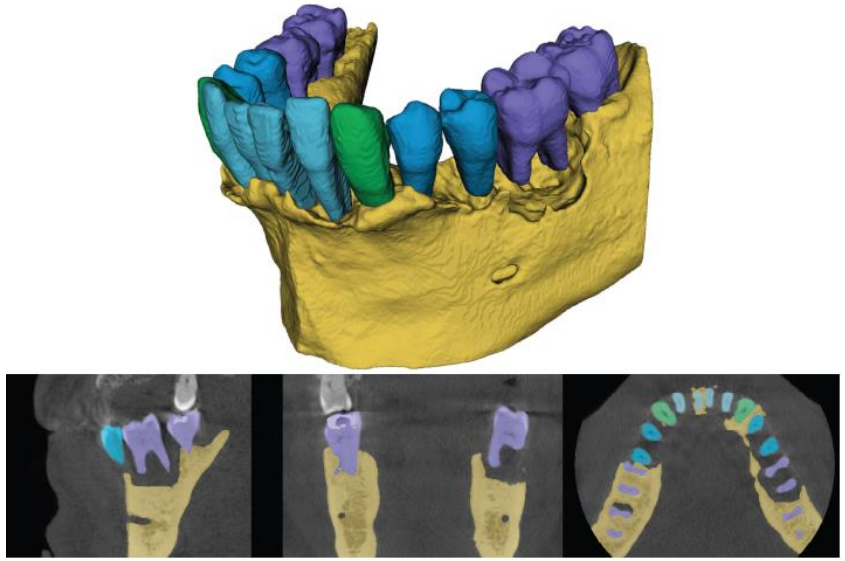


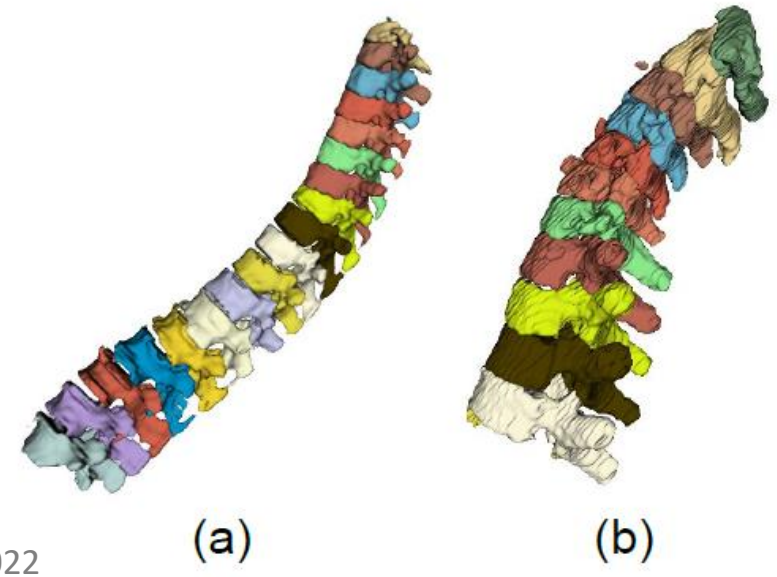


Segment Editor: Fully Automated (AI)

MONAI Label – Multi-label DeepEdit method

- Integrated in 3D Slicer already
- Training possible starting 5 segmented image per structure
- Large GPU needed for training (cloud option available via e.g. Amazon)



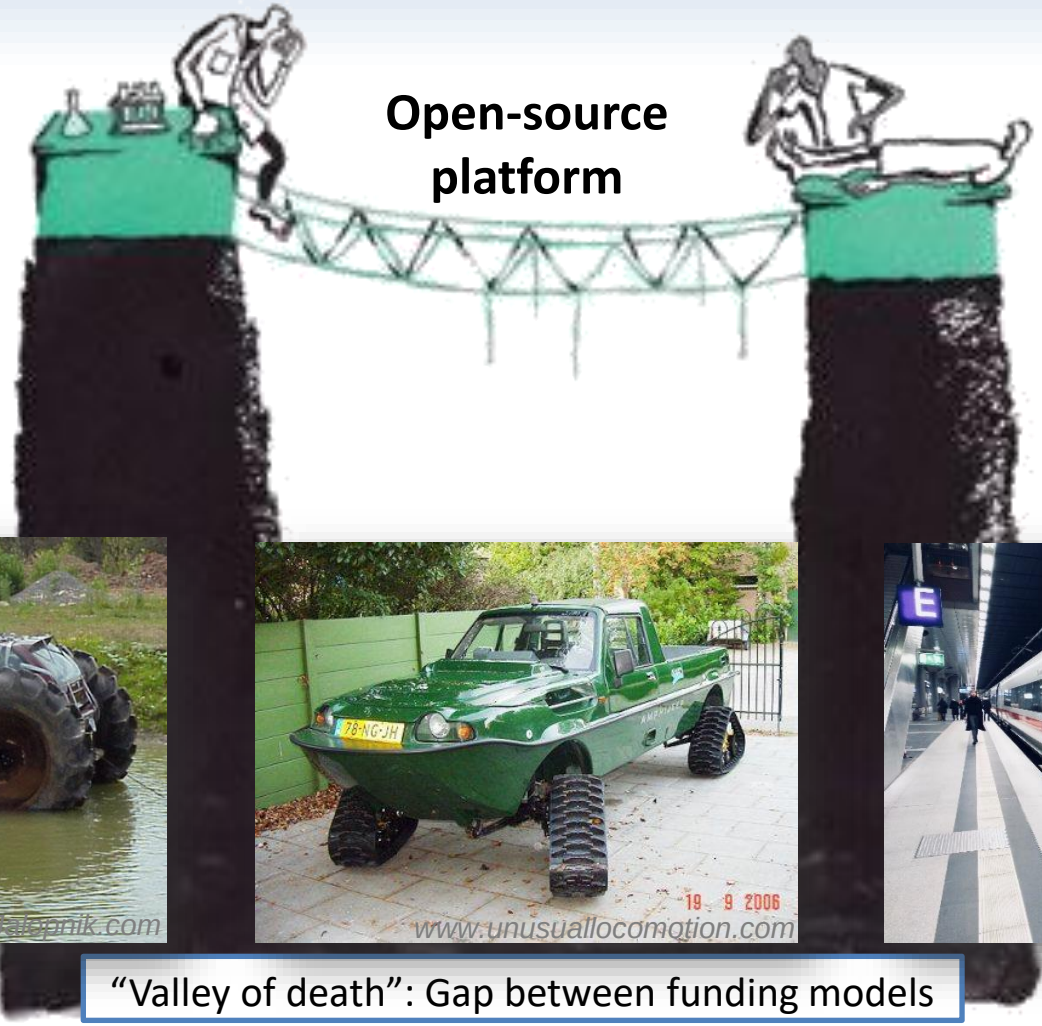


Díaz-Pinto, MICCAI 2022

Translational medical R&D

Bench

- Can it be done?
- Gov't grants
- Not robust



Bedside

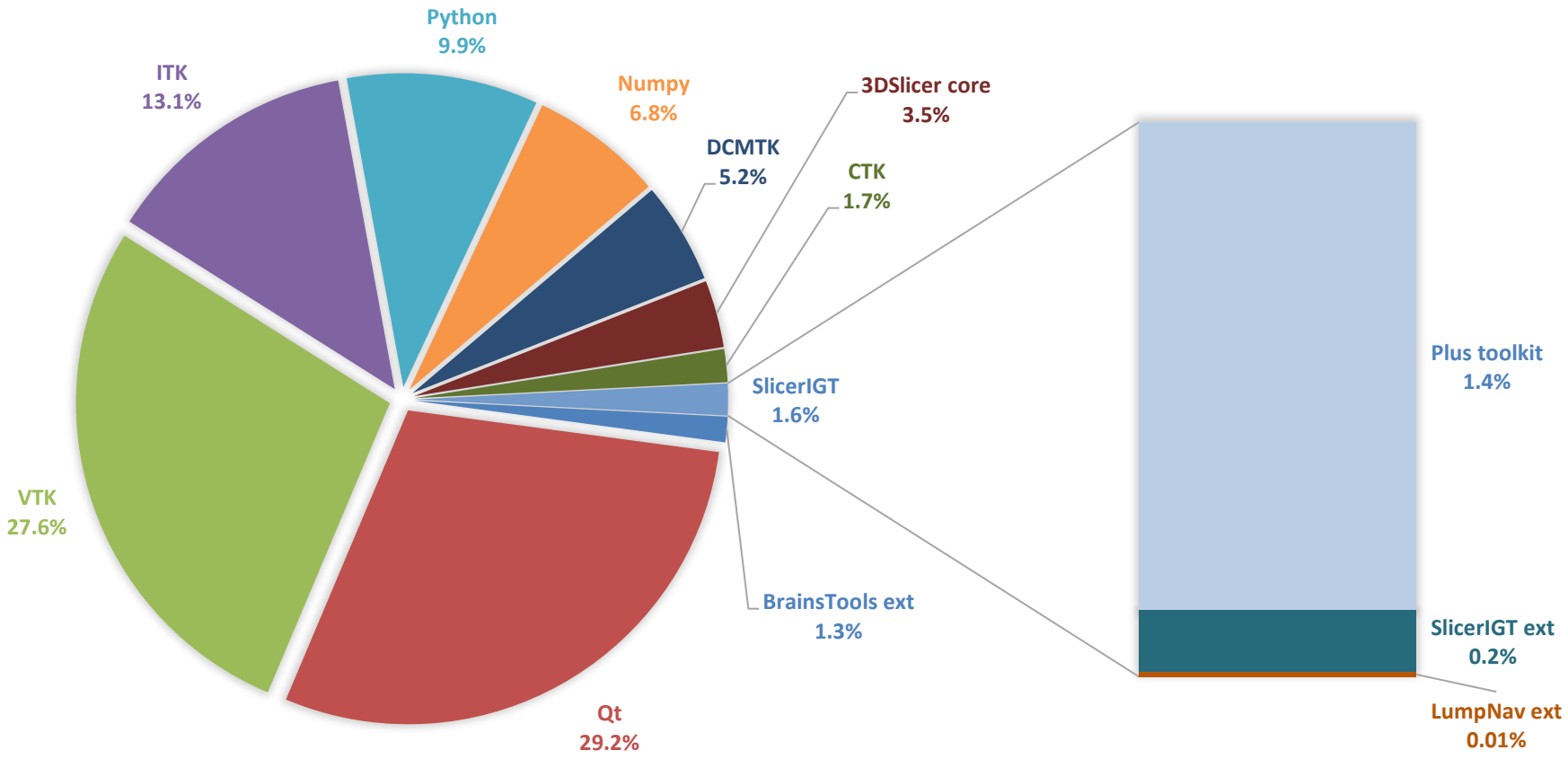
- Patient ready
- For-profit companies
- Closed source

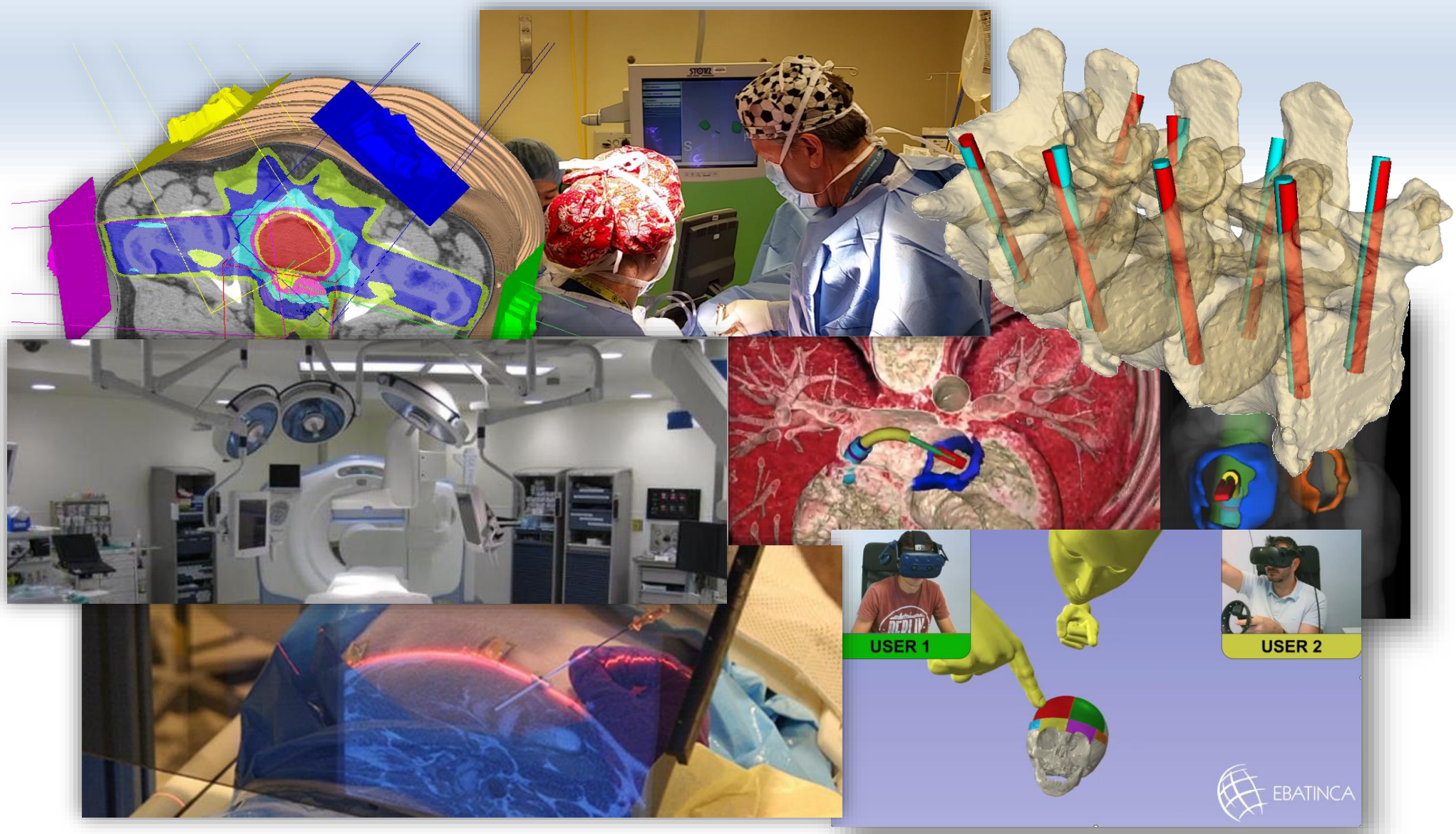
"Valley of death": Gap between funding models

Nature 453, 840-842 (2008) | doi:10.1038/453840a

Building on a platform

LINES OF SOURCE CODE - ILLUSTRATED THROUGH LUMPNAV
(NAVIGATION SOFTWARE FOR BREAST CANCER SURGERY)



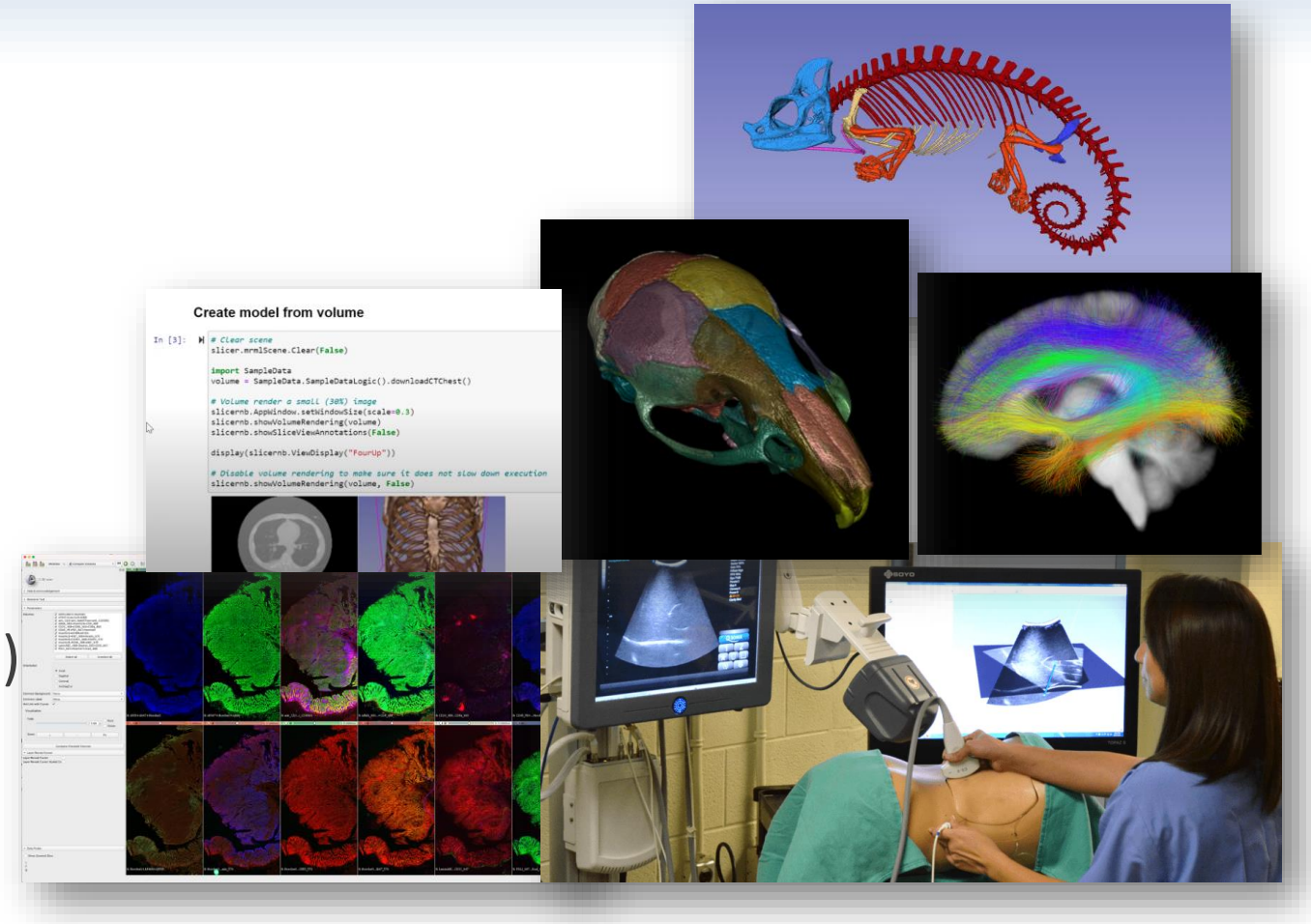


Email: csaba.pinter@ebatinca.com

Appendix

3D Slicer – Overview

- Medical image computing platform: import/export, visualization, segmentation, registration, quantification, real-time guidance
- Application framework: customizable, extensible custom modules
- Completely free (BSD)
  - Built from $$$ OPM
- Multi-platform (Windows, Linux, MacOS)
- User and developer support
- Training courses, documentation, tutorials



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

Many devices – one application

- Local
- Ethernet
- Wi-Fi

all sorts of devices

Hardware abstraction

Visualization / Analysis

data transfer protocol

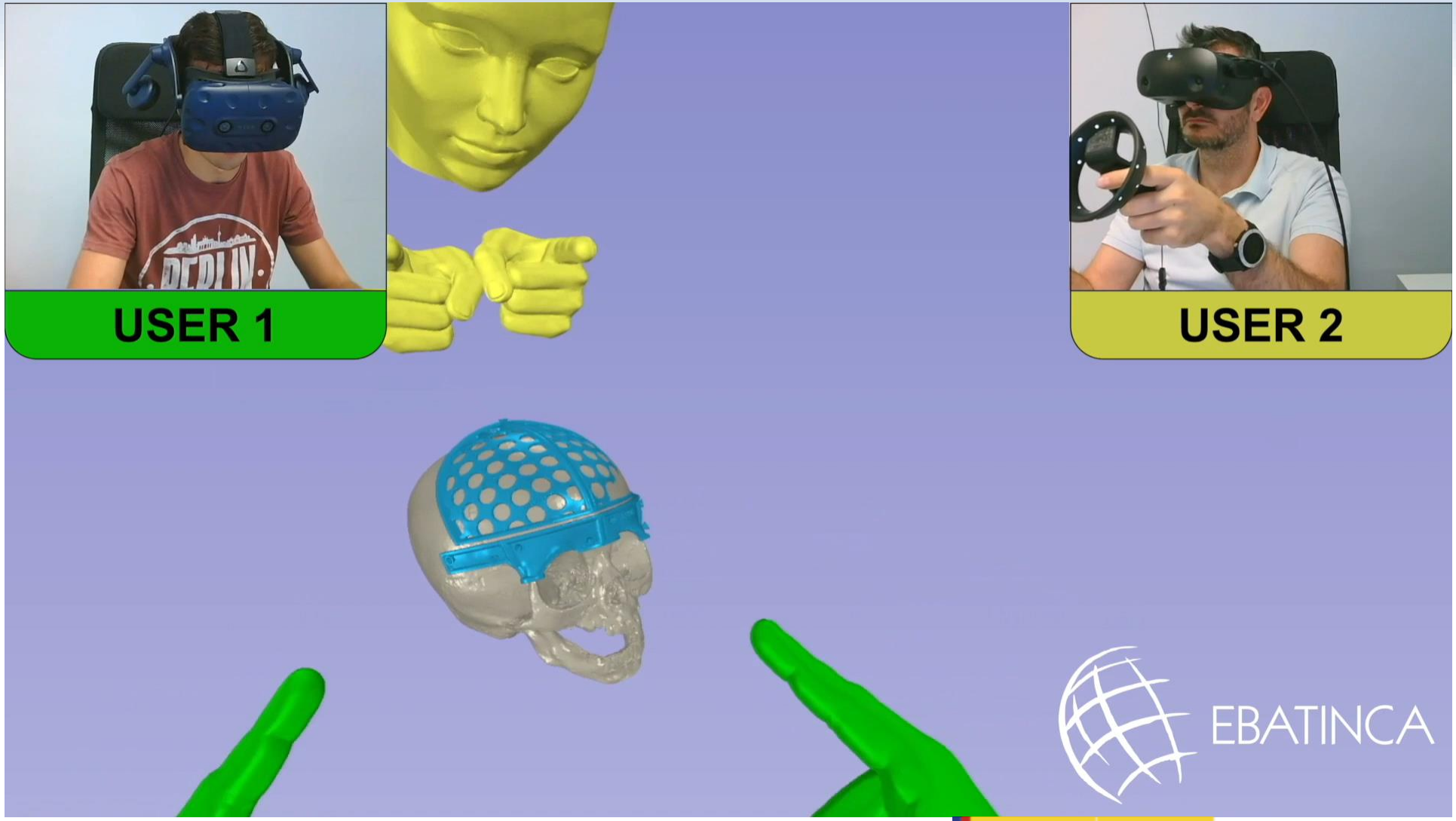
Intra-op. contouring & navigation for breast surgery

Source: Queen's University

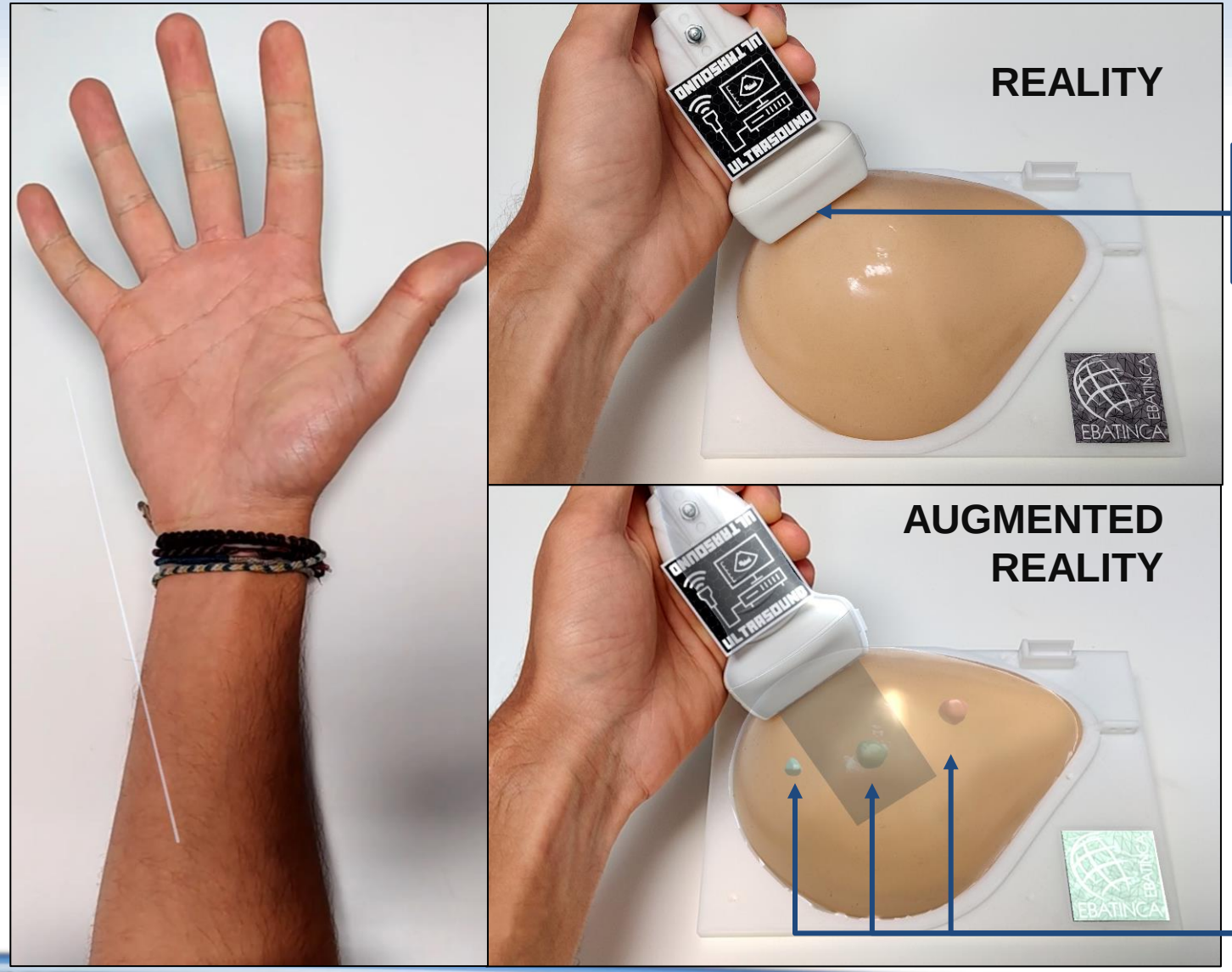
Example: Central Line Tutor

TrainUS platform

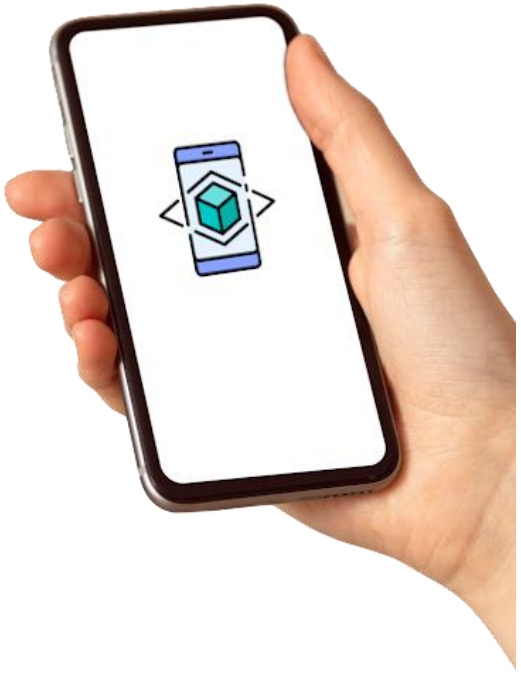
Example: Craniosynostosis collaborative VR



Augmented reality



ULTRASOUND PROBE



TUMORS