

# Visualize and analyze medical images in 3D Slicer

**Csaba Pintér, PhD**

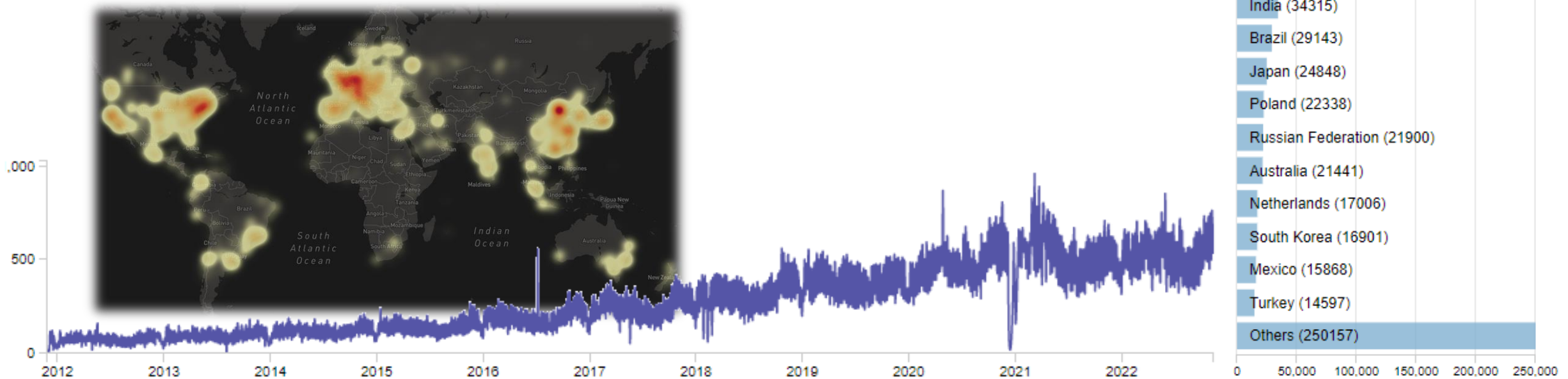
CTO, EBATINCA, S.L. (Las Palmas GC)

Email: [csaba.pinter@ebatinca.com](mailto:csaba.pinter@ebatinca.com)



# 3D Slicer – Overview

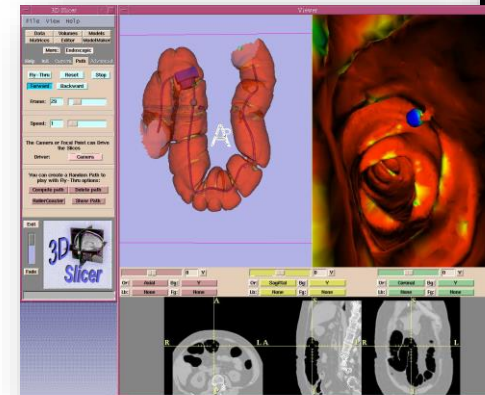
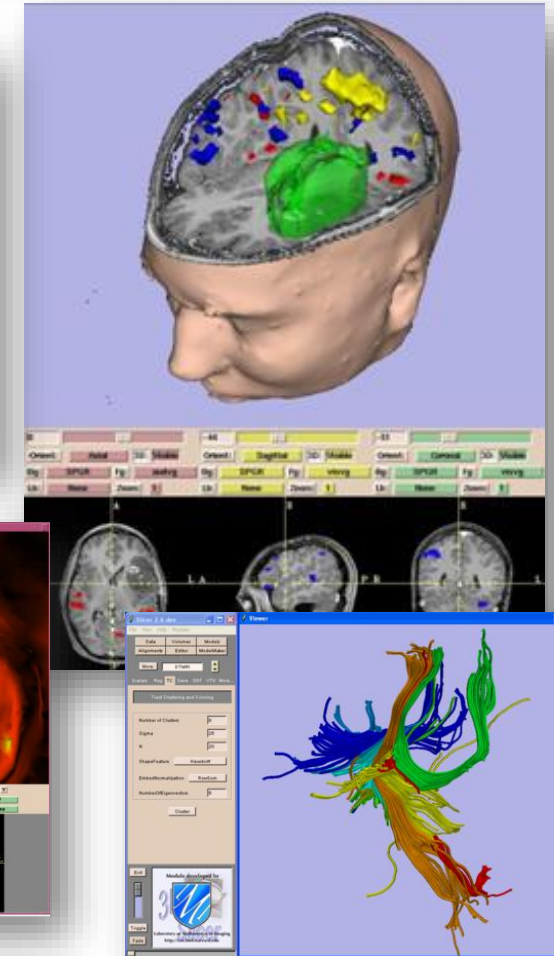
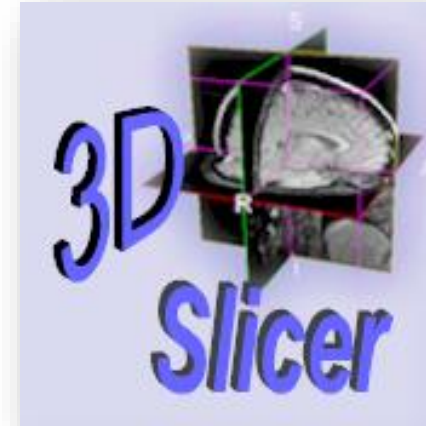
- Desktop application for Windows, Mac, and Linux
- 5.0.3 released, 5.2.0 in the works
- Over 1.1 million downloads since 2011



# 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

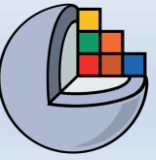


Courtesy of Ron Kikinis, M.D.

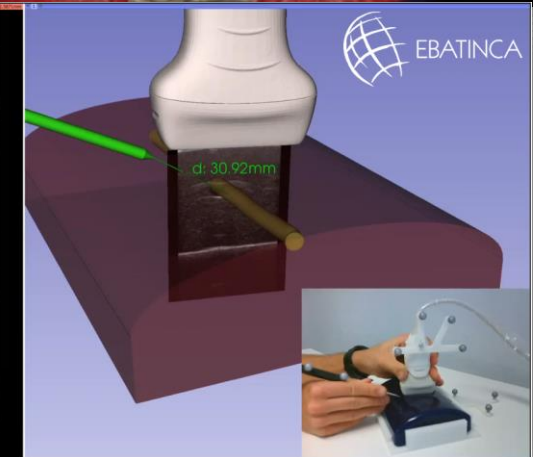
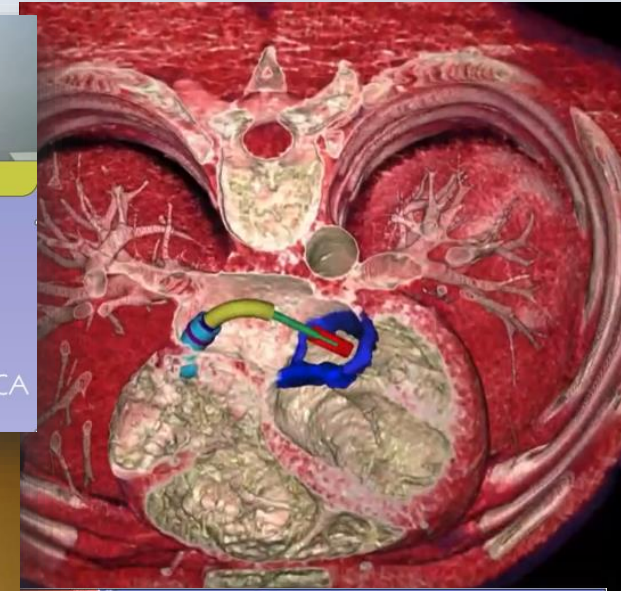
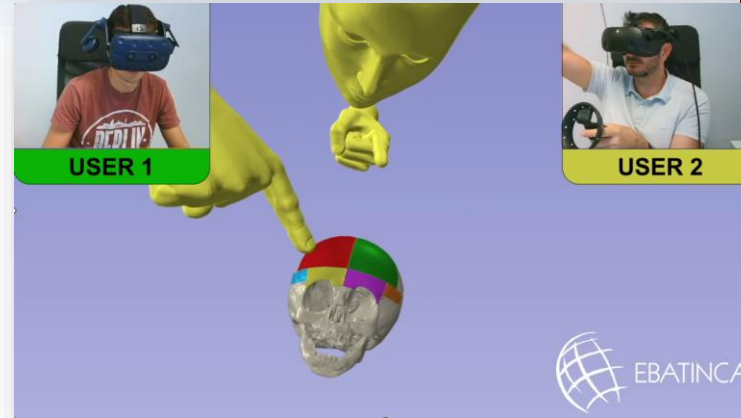




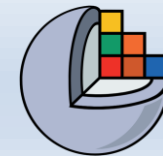
# 3D Slicer – Today



- 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

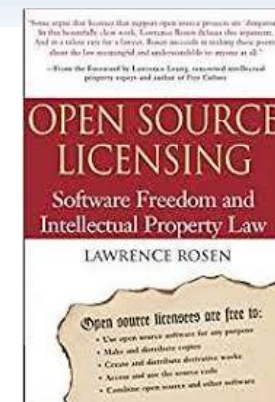


# 3D Slicer Software License



- 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

```
1
2 For more information, please see:
3
4 http://www.slicer.org
5
6 The 3D Slicer license below is a BSD style license, with extensions
7 to cover contributions and other issues specific to 3D Slicer.
8
9
10 3D Slicer Contribution and Software License Agreement ("Agreement")
11 Version 1.0 (December 20, 2005)
12
13 This Agreement covers contributions to and downloads from the 3D
14 Slicer project ("Slicer") maintained by The Brigham and Women's
15 Hospital, Inc. ("Brigham"). Part A of this Agreement applies to
16 contributions of software and/or data to Slicer (including making
17 revisions of or additions to code and/or data already in Slicer). Part
18 B of this Agreement applies to downloads of software and/or data from
19 Slicer. Part C of this Agreement applies to all transactions with
20 Slicer. If you distribute Software (as defined below) downloaded from
21 Slicer, all of the paragraphs of Part B of this Agreement must be
22 included with and apply to such Software.
23
24 Your contribution of software and/or data to Slicer (including prior
25 to the date of the first publication of this Agreement, each a
26 "Contribution") and/or downloading, copying, modifying, displaying,
27 distributing or use of any software and/or data from Slicer
28 (collectively, the "Software") constitutes acceptance of all of the
29 terms and conditions of this Agreement. If you do not agree to such
30 terms and conditions, you have no right to contribute your
31 Contribution, or to download, copy, modify, display, distribute or use
32 the Software.
33
34 PART A. CONTRIBUTION AGREEMENT - License to Brigham with Right to
35 Sublicense ("Contribution Agreement").
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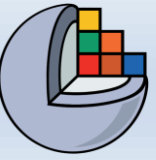
Lawrence Rosen, Eve Waterfall, Brian Hicks

Courtesy of Ron Kikinis, M.D.





# 100% Open and Non-Restrictive Processes



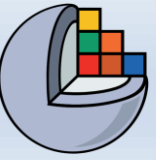
- Public source repository: [github.com/Slicer](https://github.com/Slicer) organization
  - Slicer source code and issues tracker
- Open discussion forum: [discourse.slicer.org](https://discourse.slicer.org)
- Weekly [developer video conferences](#) open to anyone (10am EST Tuesdays)
- Twice-yearly Project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



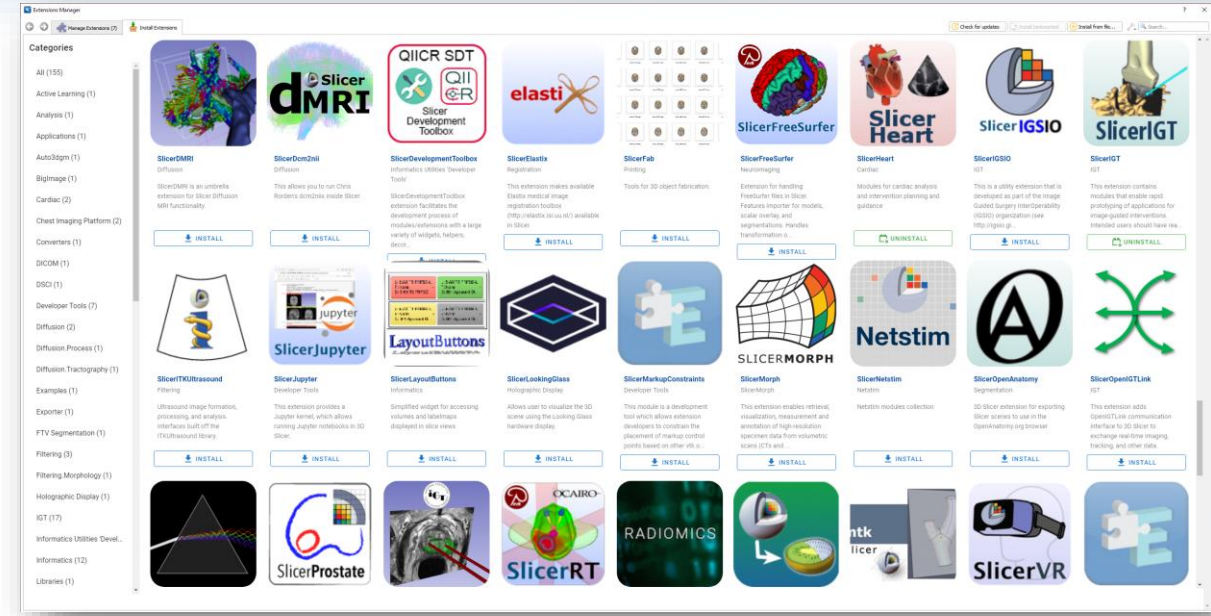
Courtesy of Ron Kikinis, M.D.



# 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



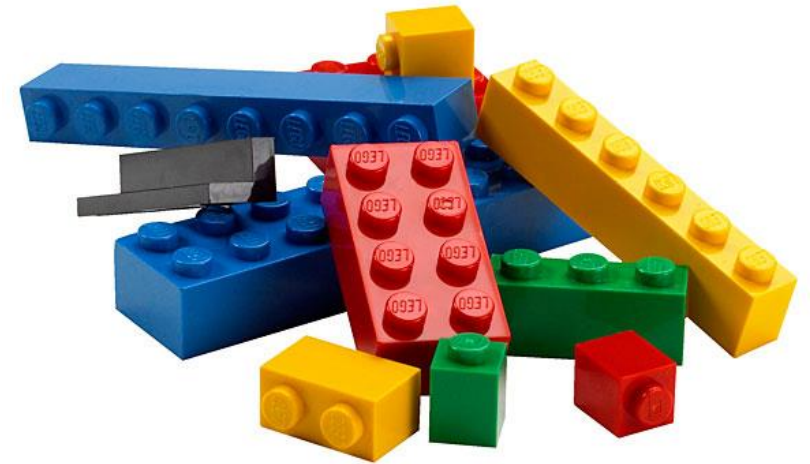
3D Slicer  
Solutions:



# 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

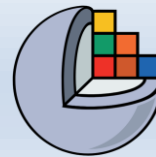


***"Lego bricks, not jigsaw puzzle pieces!"***





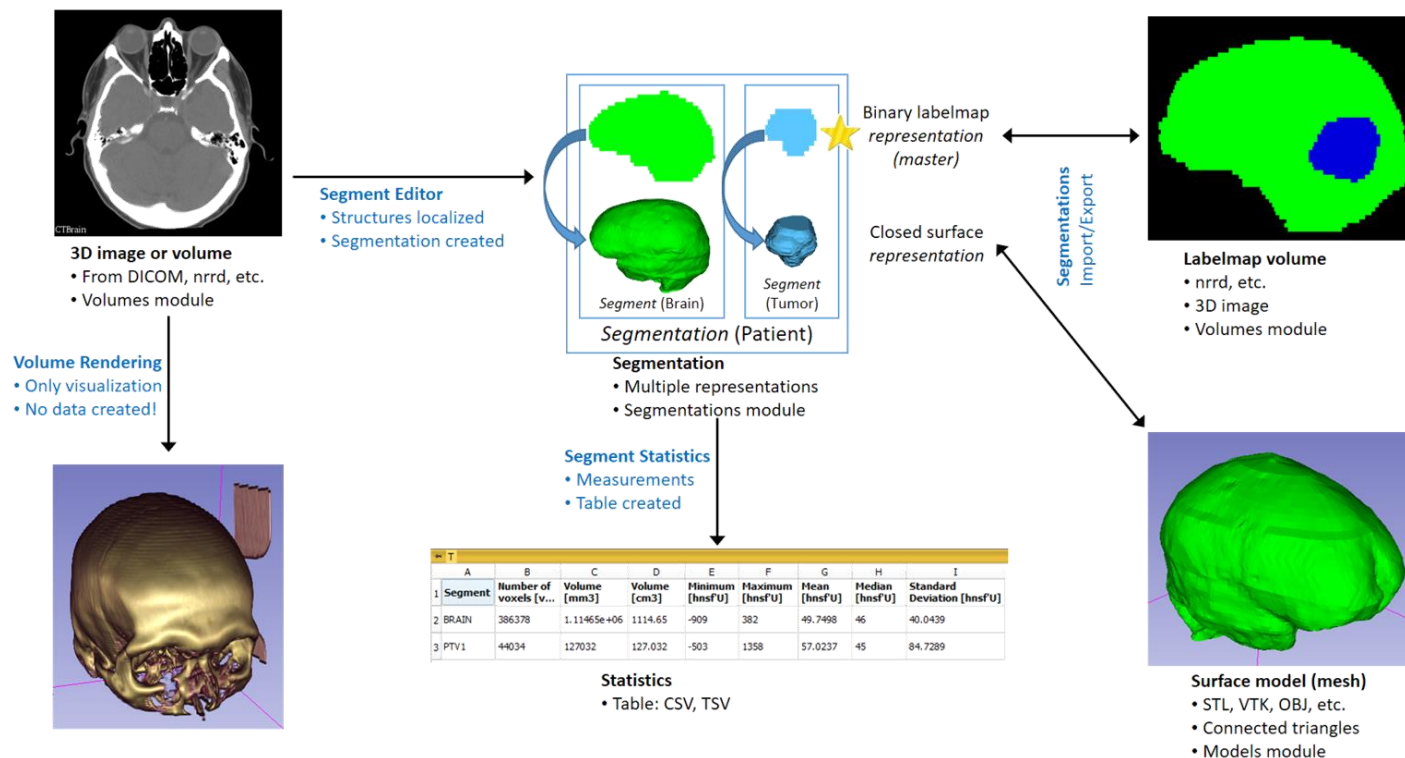
# Interoperability



- Common and research formats

- Images (nrrd, nii.gz, ...)
- Models (stl, ply, obj, ...)
- Tables (csv, txt)
- Point lists (json)
- etc.

- DICOM



# DICOM

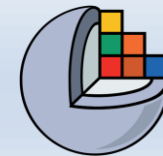


- DICOM: Digital Imaging and Communications in Medicine
- The industry standard for storage and transfer of medical images

```
(0008,0008) CS [ORIGINAL\PRIMARY\AXIAL] # 22, 3 ImageType
(0008,0012) DA [20110922] # 8, 1 InstanceCreationDate
(0008,0013) TM [161402] # 6, 1 InstanceCreationTime
(0008,0016) UI =CTImageStorage # 26, 1 SOPClassUID
(0008,0018) UI [1.2.840.113619.2.55.3.671756986.106.1316467036.466.1] # 52, 1 SOPInstanceUID
(0008,0020) DA [20110920] # 8, 1 StudyDate
(0008,0021) DA [20110920] # 8, 1 SeriesDate
(0008,0060) CS [CT] # 2, 1 Modality
(0008,0070) LO [GE MEDICAL SYSTEMS] # 18, 1 Manufacturer
(0008,0090) PN (no value available) # 0, 0 ReferringPhysicianName
(0008,103e) LO [PELVIS CURATIVE] # 16, 1 SeriesDescription
(0008,1090) LO [LightSpeed RT16] # 16, 1 ManufacturerModelName
(0010,0010) PN [RANDO^PROSTATE] # 14, 1 PatientName
(0010,0020) LO [TEST PHYS PROSTATE] # 18, 1 PatientID
...
(0020,0032) DS [-250\ -250\105] # 14, 3 ImagePositionPatient
(0020,0037) DS [1\0.0\0.0\0.0\1\0.0] # 20, 6 ImageOrientationPatient
...
(0028,0010) US 512 # 2, 1 Rows
(0028,0011) US 512 # 2, 1 Columns
(0028,0030) DS [9.76562e-1\9.76562e-1] # 22, 2 PixelSpacing
(0028,0100) US 16 # 2, 1 BitsAllocated
(0028,0101) US 16 # 2, 1 BitsStored
(0028,0102) US 15 # 2, 1 HighBit
(0028,0103) US 0 # 2, 1 PixelRepresentation
(7fe0,0010) OW 0018\0018\0018\0018\0018018\0018\0018... # 524288, 1 PixelData
```



# 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

The screenshot shows the 3D Slicer 4.13.0-2021-04-28 interface. The top menu bar includes File, Edit, View, and Help. Below the menu is a toolbar with icons for DATA, DICOM, SAVE, and various viewing tools. The main window is divided into several panels:

- Left Panel:** Contains a 3D Slicer logo, buttons for Help & Acknowledgement, Reload & Test, Import DICOM files, and Show DICOM database. Below these is the **Loaded data** panel, which shows a tree view of loaded data. The tree view includes a node for Cerebrix (XsxuId) and a sub-node for Neuro^Crane (20070720), which contains a series of 6: t2\_tse\_tra\_p2.
- Right Panel:** Contains the **DICOM database** panel. It has search filters for Patients, Studies, and Series. Below the filters are two tables:

Patient name	Patient ID	Birth date	Sex	Studies	Last study date	Date added
RANDO, PROSTATE	TEST PHYS PROSTATE			1	Tue Sep 20 2011	2021-05...:04.420
CEREBRIX	XsxuId	1935-04-01	0000	1		2021-05...:33.646

Study date	Study ID	Study description	Series	Date added
20110920	1447		5	2021-05...:04.421

Series #	Series description	Modality	Size	Count	Date added
2	PELVIS CURATIVE	CT	512x512	92	2021-05...:04.421
3	PROS	RTSTRUCT		1	2021-05...:04.475
4	PROS	RTPLAN		1	2021-05...:04.474
5		RTDOSE	136x86	1	2021-05...:04.472
6	AP PROS-DRR, RT LAT PROS-DRR, PA PROS-DRR, LT LAT PROS-DRR	RTIMAGE	512x512	4	2021-05...:04.472

At the bottom of the right panel, there is a **Load** button and an **Advanced** checkbox.





# DICOM via DICOMweb



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

3D Slicer 4.13.0-2021-04-28

File Edit View Help

Modules: DICOMweb Browser

DICOMweb Browser

Server

Server URL: ps.online/view/sFy9ca1ncU1otUsJtKva2s Connect ☒ Use cached server responses

Studies (Accessed: Mon May 3 00:13:22 2021)

	Patient name	Patient ID	Modality	Study date	Study description
1	CEREBRIX	XsxuId	MR, SC	20070720	
2	PELVIX	Vafm7b0J	CT	20070110	
3	MAGIX	F063TE	CT	20061019	

Select: All None

Series (Accessed: Mon May 3 00:13:26 2021)

	Status	Series number	Modality	Image count	Series description
1		5	MR	28	t2_tirm_cor_dark-fluid-fs
2		6	MR	24	t2_tse_tra_p2
3		9	MR	28	t2_tirm_cor_dark-fluid-fs
4		10	MR	29	t1_fl2d_tra
5		16	MR	176	t1_mpr3D_ns_sag_gd
6		18	MR	60	<MPR Range[1]>
7		5352	SC	244	Δvial T1

Select: All None

No. of images to download: 1

Buttons:

Data Probe



# DICOM via Kheops



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

The screenshot displays the KHEOPS web application interface. At the top, the KHEOPS logo is on the left, and user information (Andras Lasso, Help, Logout, lang: en) is on the right. Below the header, a table lists medical studies. The table has columns for Patient Name, Patient ID, Study Description, Study Date, and Modality. The 'INCISIX' study is selected and highlighted in blue. Below the table, a detailed view of the selected study is shown, including a list of series (Series, Comments, Metadata) and a thumbnail image of a CT scan. The thumbnail is labeled 'CT - Dentascan 0.75 H60s [ 166 ] May 31st 2006 15:13:23.937'. A red circle highlights the 'Download' icon (a download arrow) in the row of the selected study.

	Patient Name	Patient ID	Study Description	Study Date	Modality
> <input type="checkbox"/>	CEREBRIX	Xsxuld	PET^PETCT_CTplusFET_LM_Brain (Adult)	Aug 3rd 2007	CT, PT
> <input type="checkbox"/>	CEREBRIX	Xsxuld	Neuro^Crane	Jul 20th 2007	MR, SC
> <input type="checkbox"/>	PELVIX	Vafm7b0J	CT1 pelvis, bassin	Jan 10th 2007	CT
> <input checked="" type="checkbox"/>	MAGIX	F063TE	Cardiaque^Cardiaque_standard (Adulte)	Oct 19th 2006	CT
> <input type="checkbox"/>	MACOESSIX	BrzEdv0	CT1 abdomen	Oct 5th 2006	CT, SC
> <input type="checkbox"/>	ENTERIX	Vafk,Uqk	PET^PETCT_WB_apc (Adult)	Oct 3rd 2006	CT, PT
▼ <input checked="" type="checkbox"/>	INCISIX	S0tNwu	Tête Dental (Adulte)	May 31st 2006	CT

Series  
Comments  
Metadata

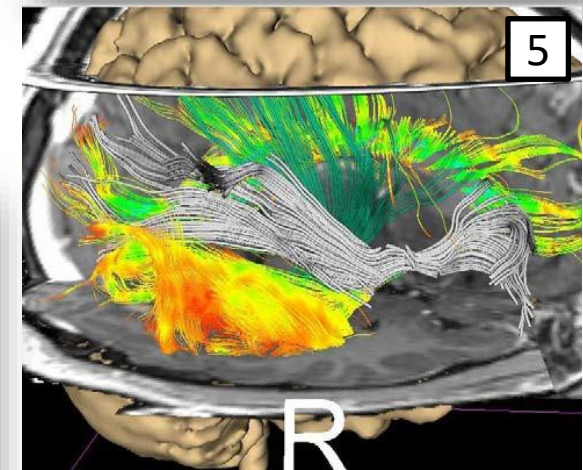
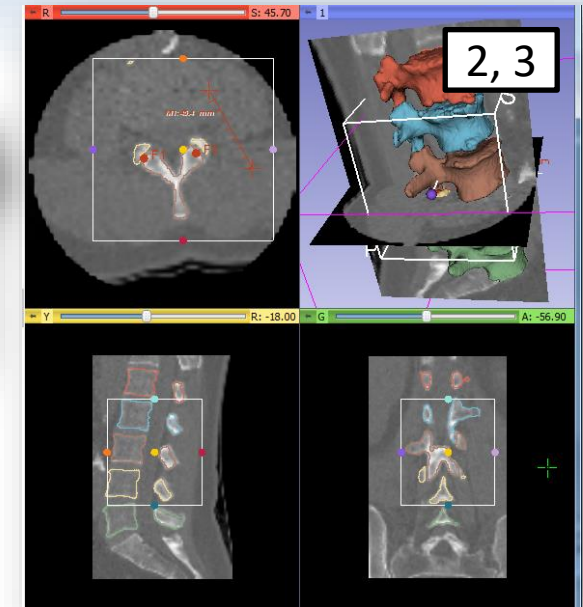
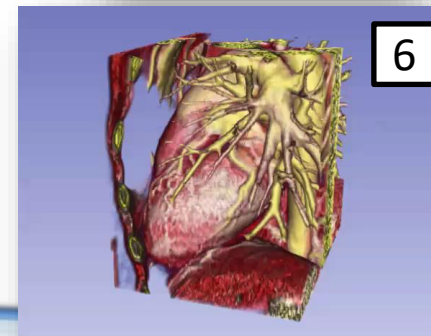
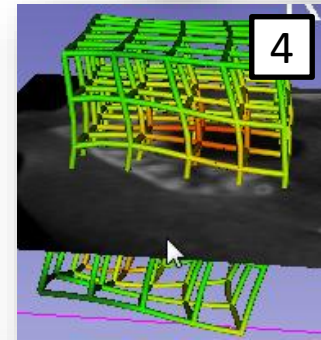
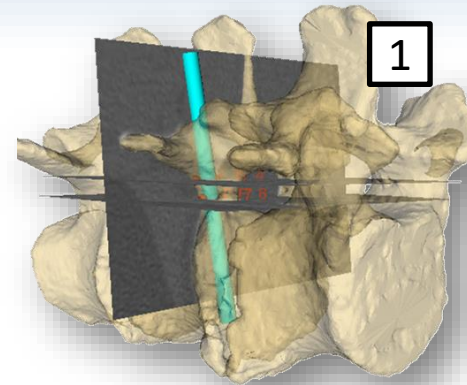
CT - Dentascan 0.75  
H60s [ 166 ]  
May 31st 2006  
15:13:23.937



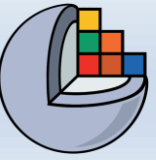
# Features: Visualization



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

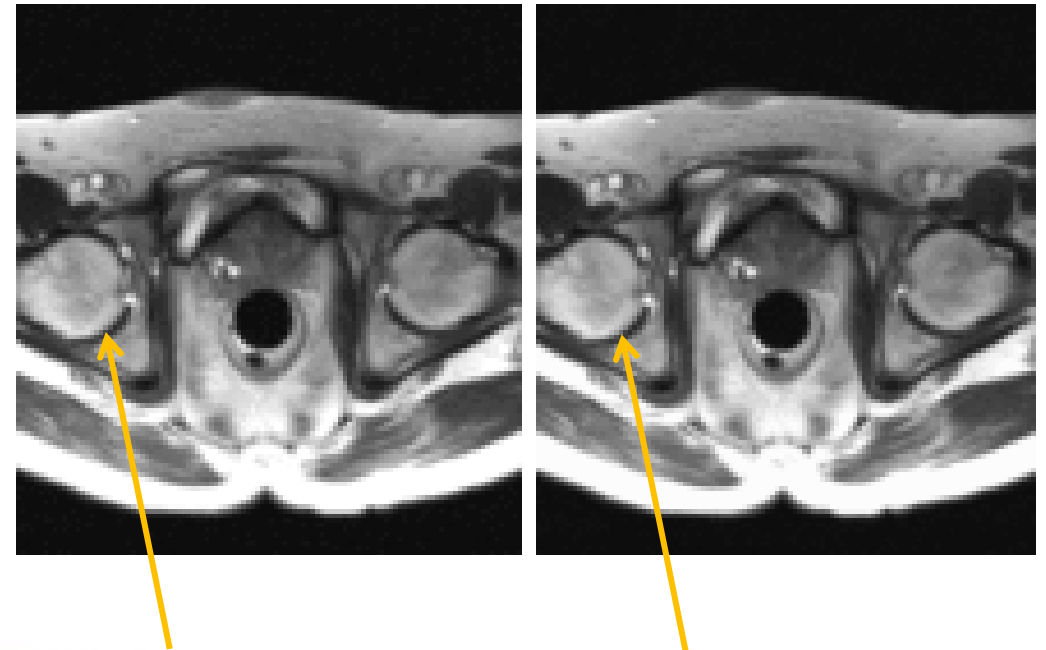
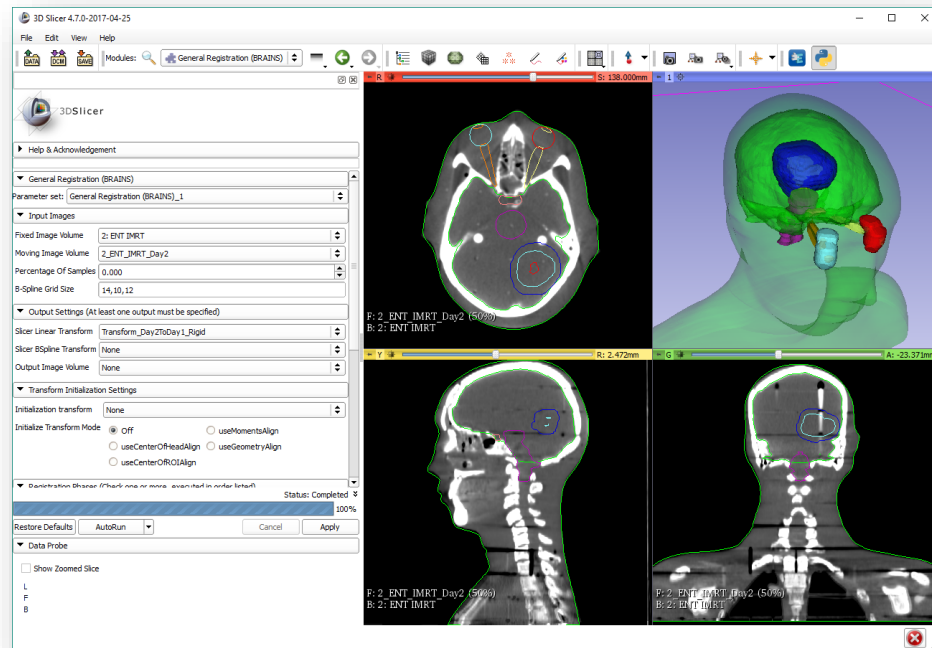






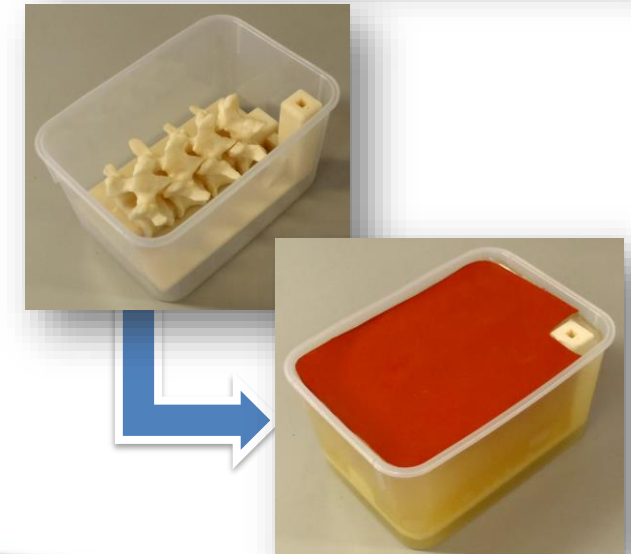
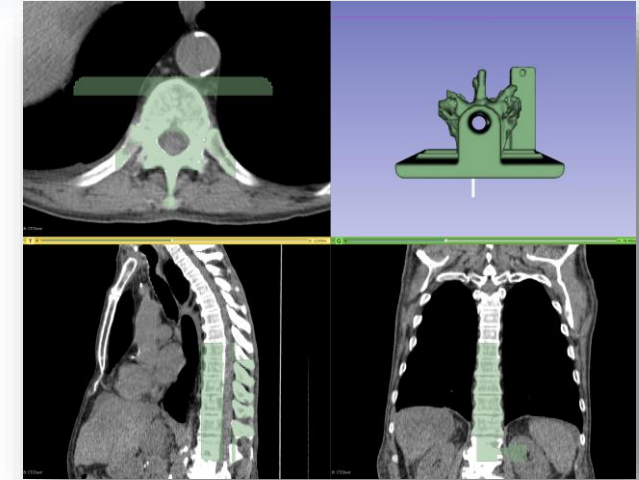
# Features: Registration

- 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

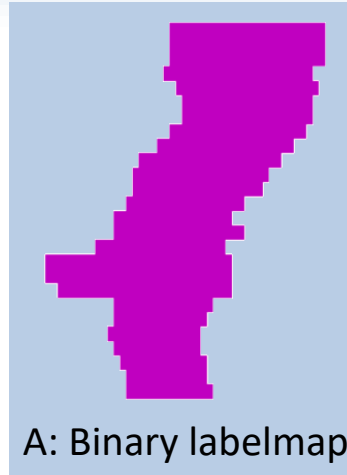
- Also known as contouring
- Delineates structures of interest
  - Manual contouring: slow
  - Semi-automatic: some interaction
  - Automatic: still needs editing
- Omnipresent in medical imaging
  - Surgical/radiation therapy **planning**
  - Intra-surgery **navigation**
  - Volume/shape **analysis**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



Brain RT phantom case

# Representing Segmentations

- Each optimal for
  - *either* storage (D)
  - *or* analysis (A,C)
  - *or* visualization (B,E)



A: Binary labelmap

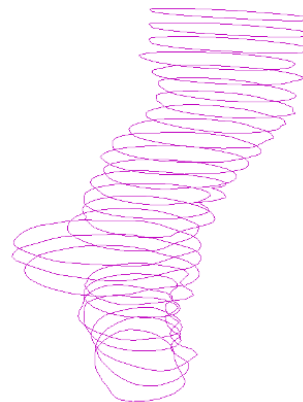


B: Closed surface

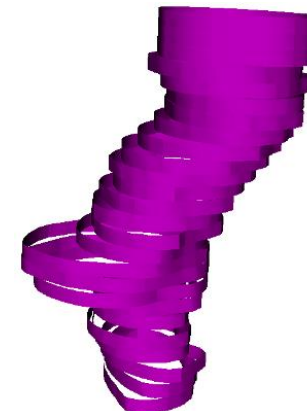


C: Fractional labelmap

- Imposed needs
  - Conversion
  - Simultaneous
    - Visualization
    - Transformation



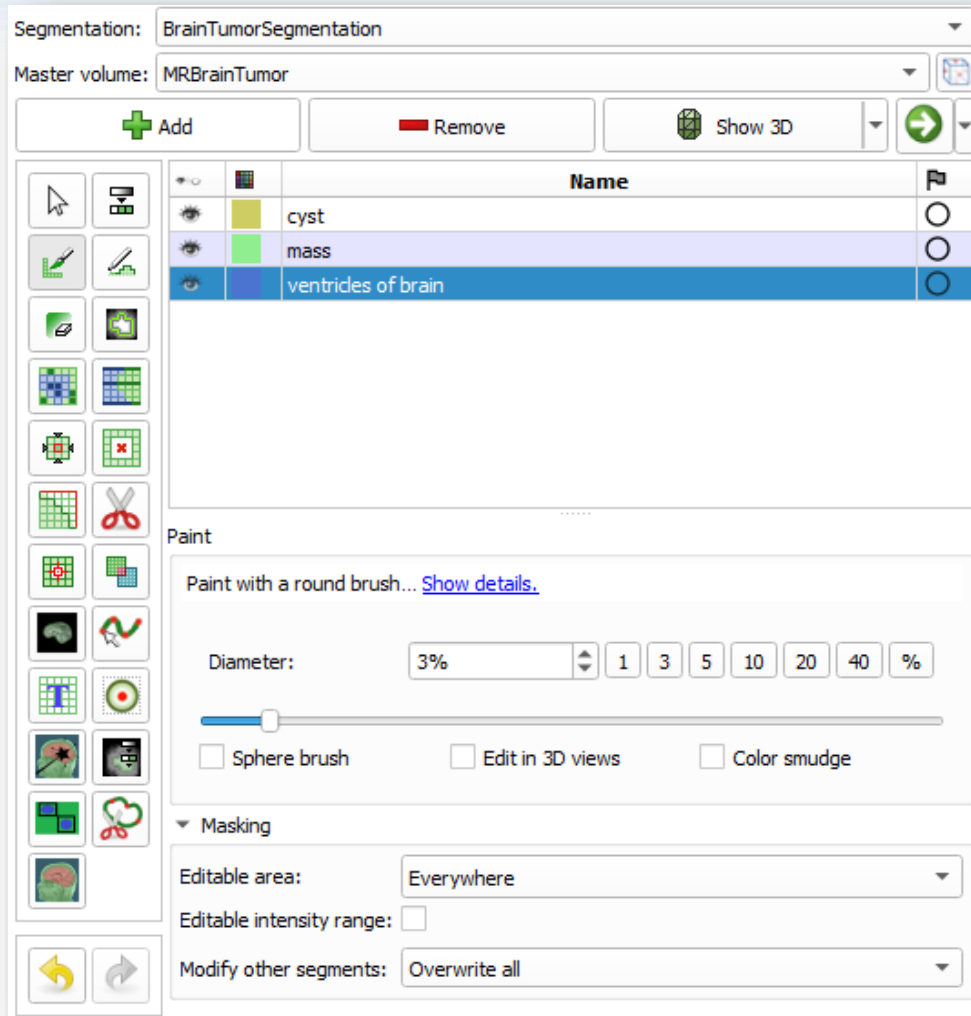
D: Planar contours



E: Ribbon model



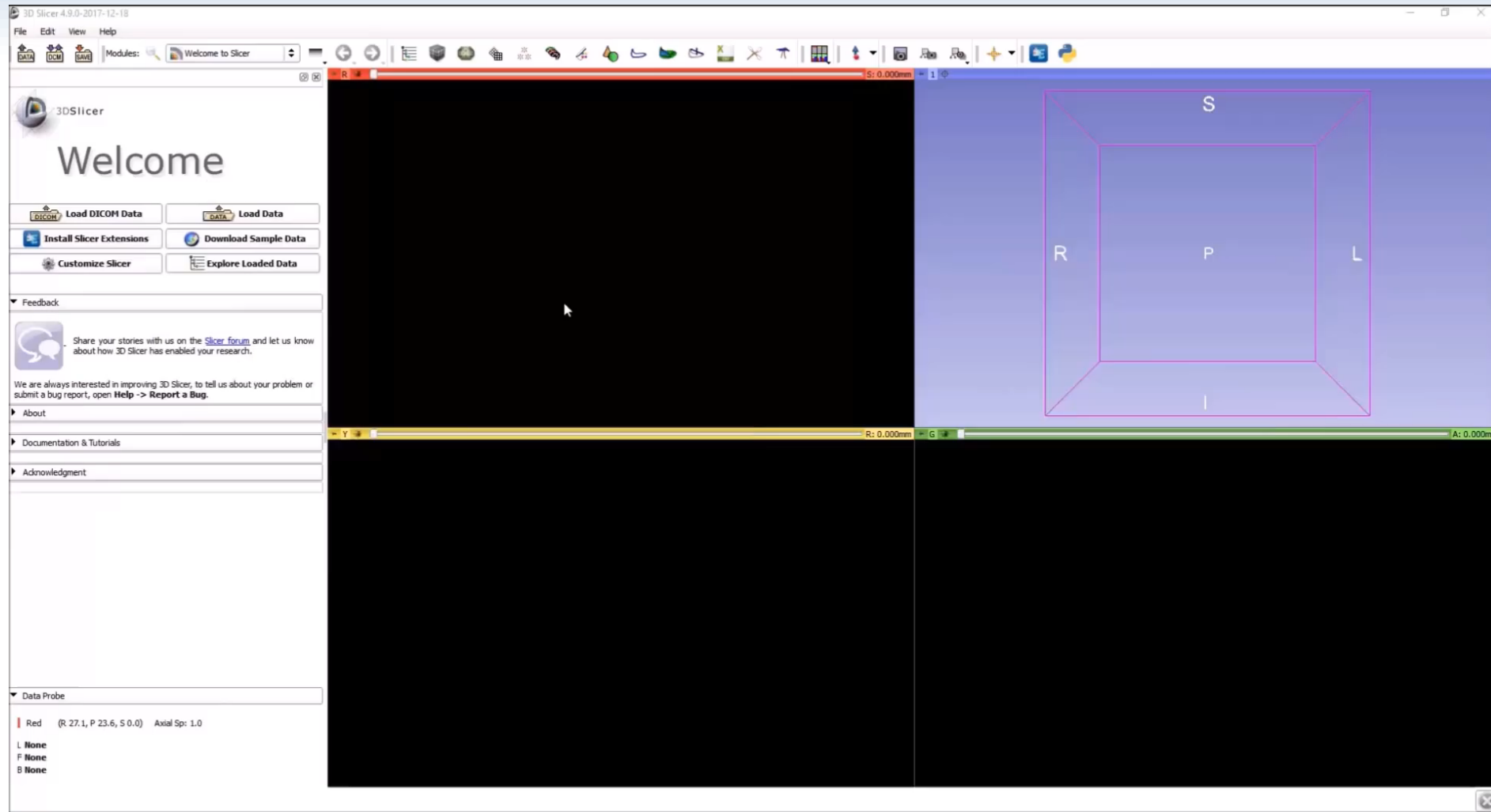
# Segment Editor



- 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



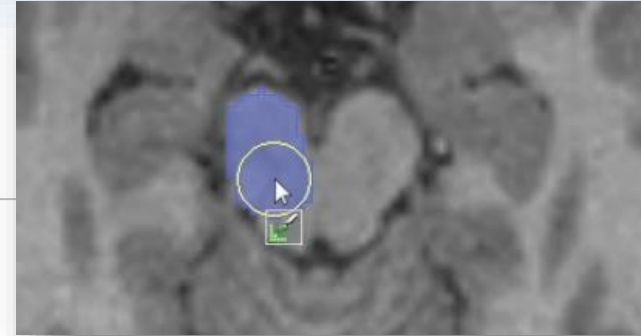
# Segment Editor: Example Workflow



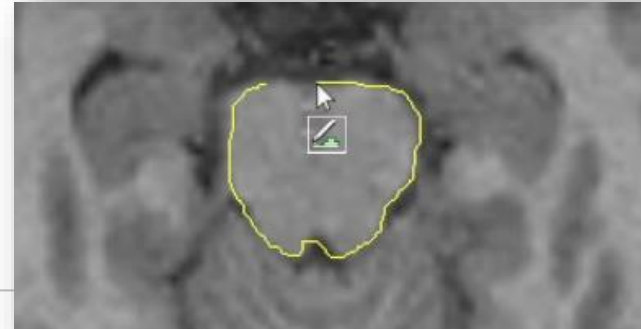
# Segment Editor: Simple Manual Tools



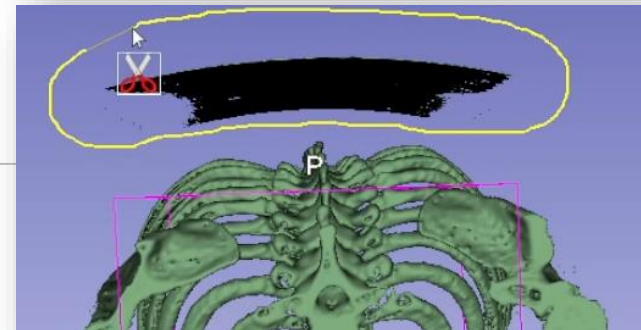
Paint



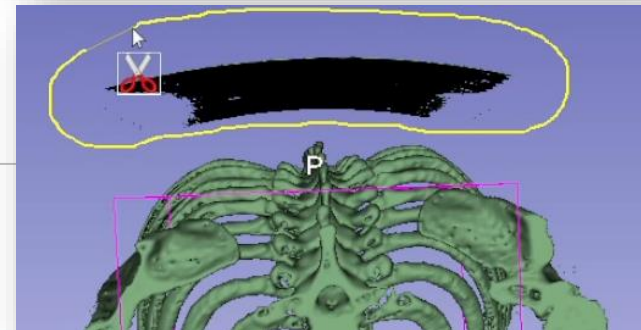
Erase



Draw



Scissors

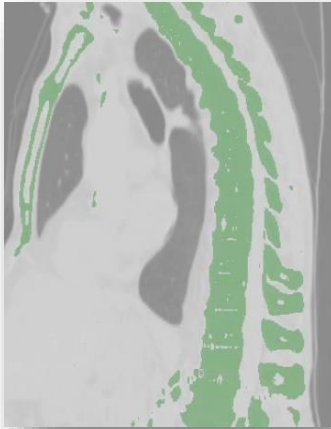




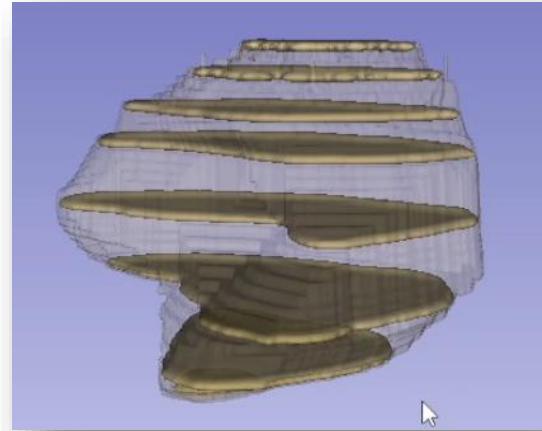
# Segment Editor: Semi-Automated Tools



Threshold



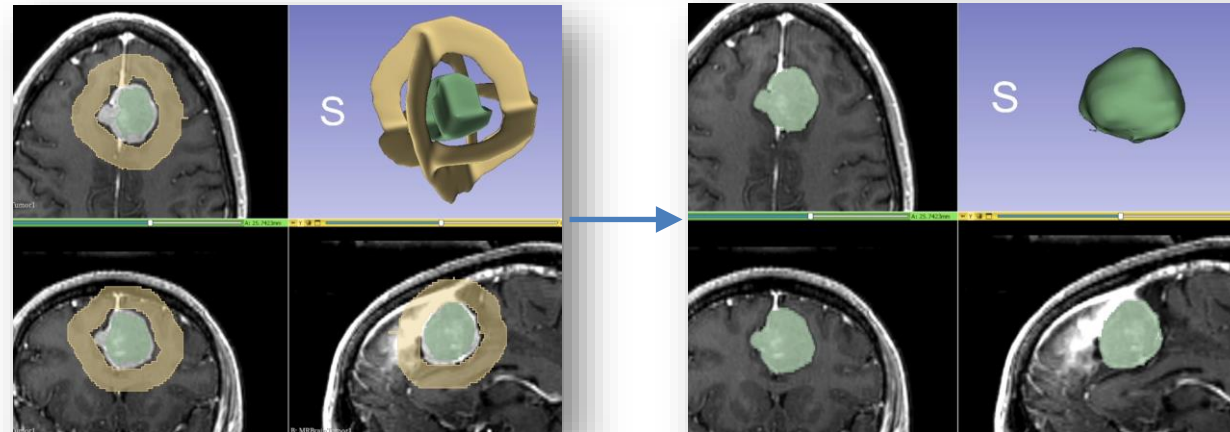
Fill between slices



Level tracing



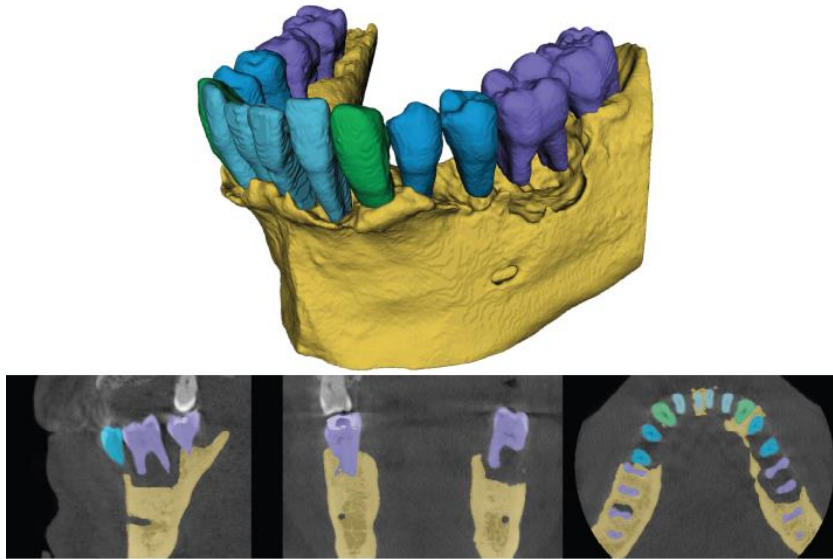
Grow from seeds



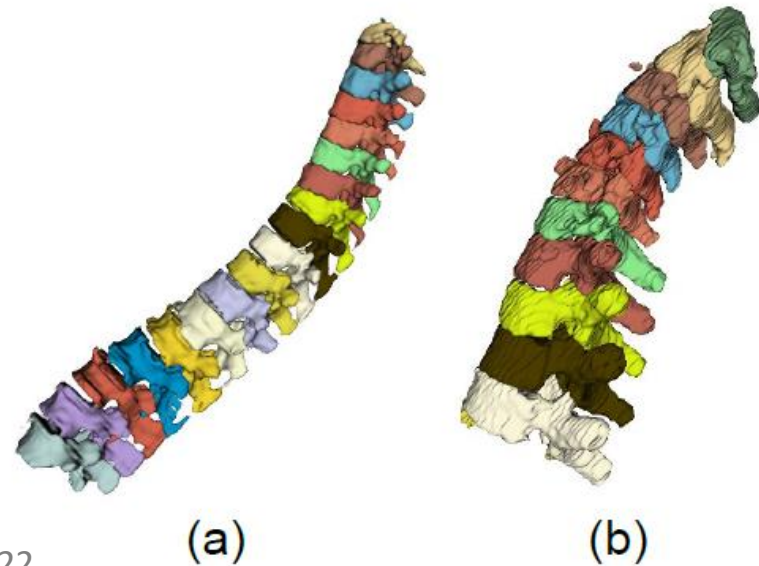
# Segment Editor: Fully Automated (AI)

## 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

Open-source  
platform

## Bedside

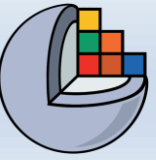
- Patient ready
- For-profit companies
- Closed source



“Valley of death”: Gap between funding models

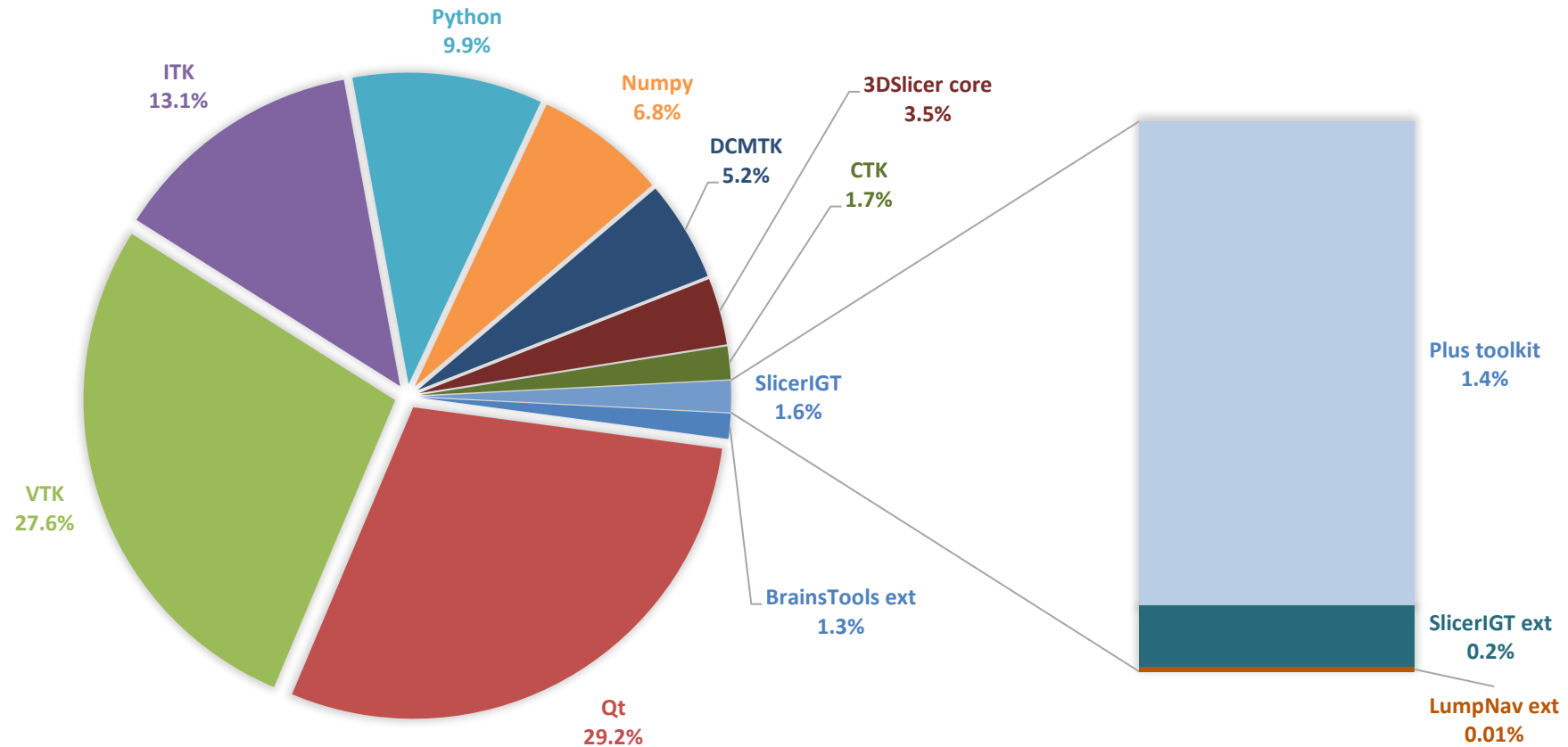
Nature 453, 840-842 (2008) | doi:10.1038/453840a



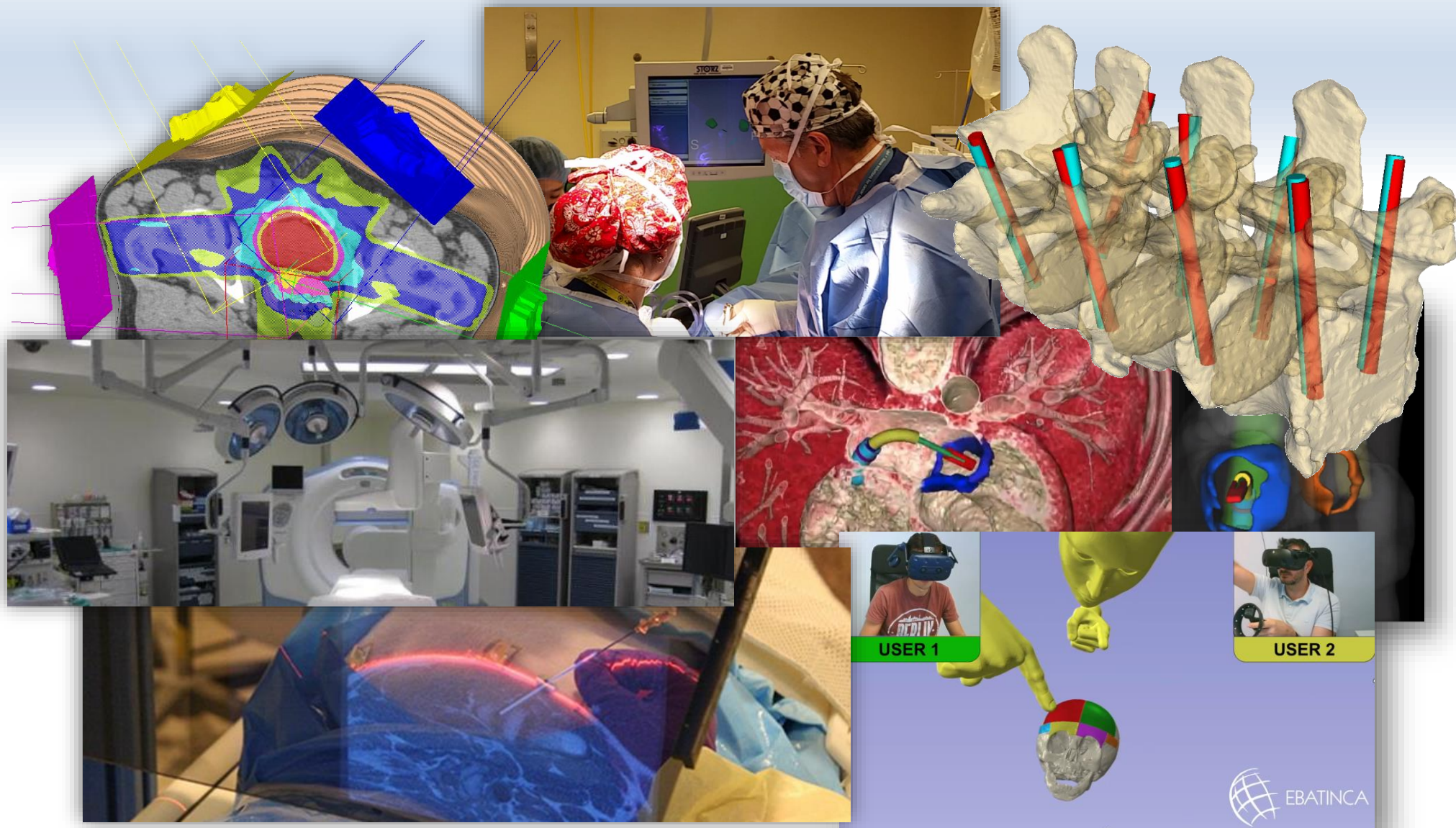
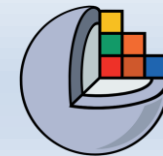


# Building on a platform

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

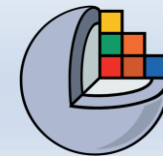






Email: [csaba.pinter@ebatinca.com](mailto:csaba.pinter@ebatinca.com)





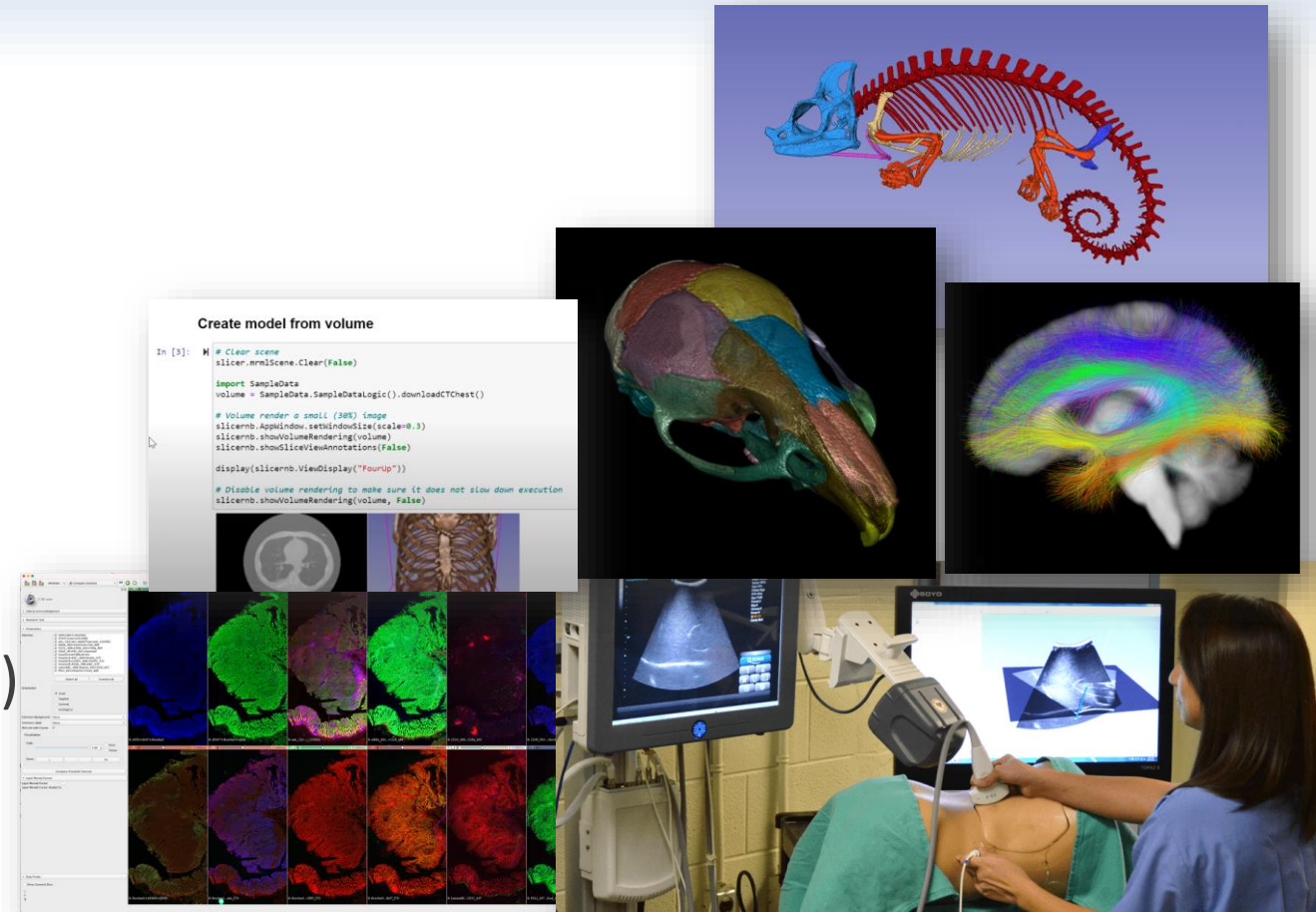
# Appendix



# 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

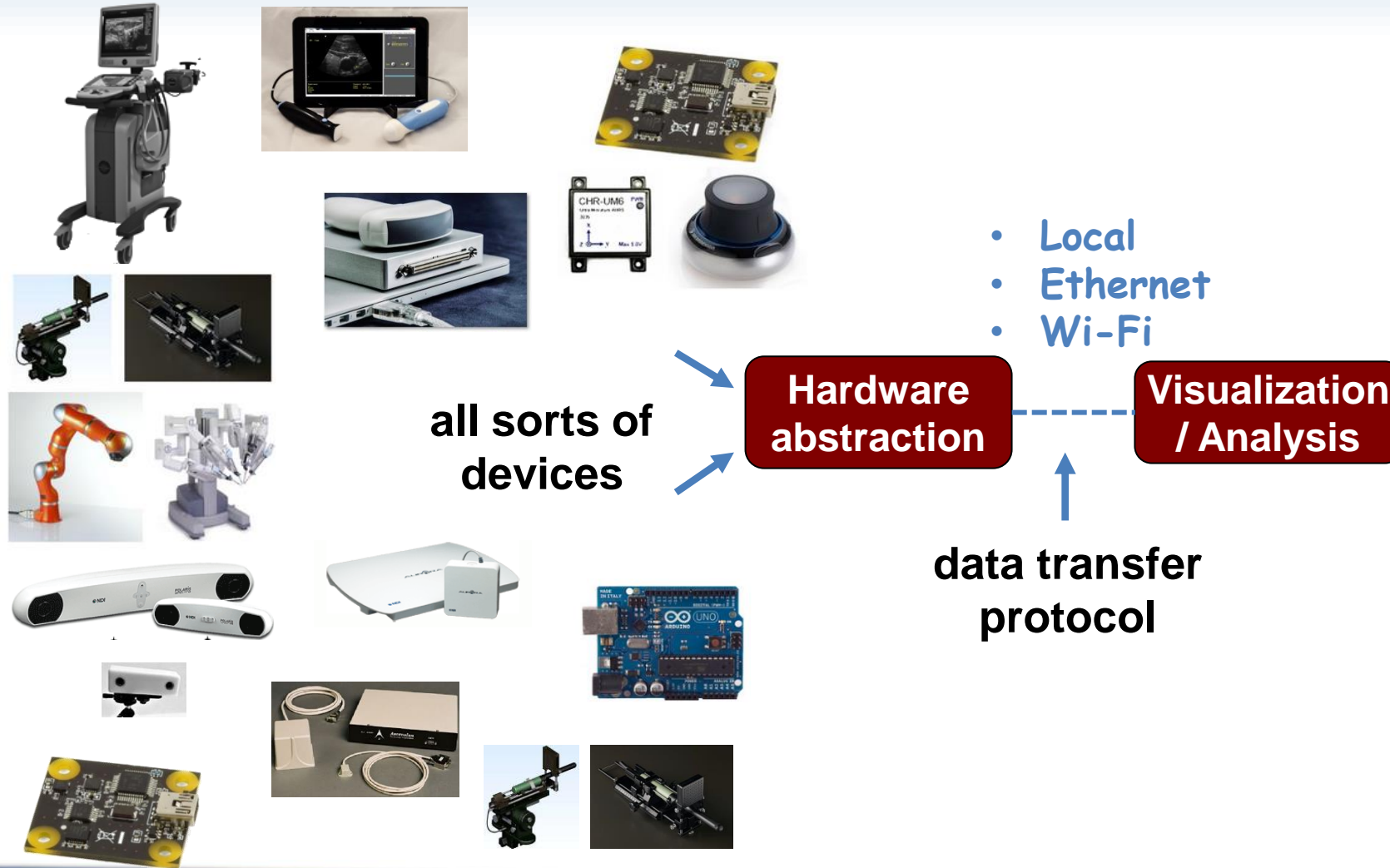


Fedorov, Andriy, et al. "3D Slicer as an image computing platform for the Quantitative Imaging Network." Magnetic resonance imaging 30.9 (2012): 1323-1341.





# Many devices – one application

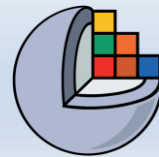


# Intra-op. contouring & navigation for breast surgery



Source: Queen's University

# Example: Central Line Tutor



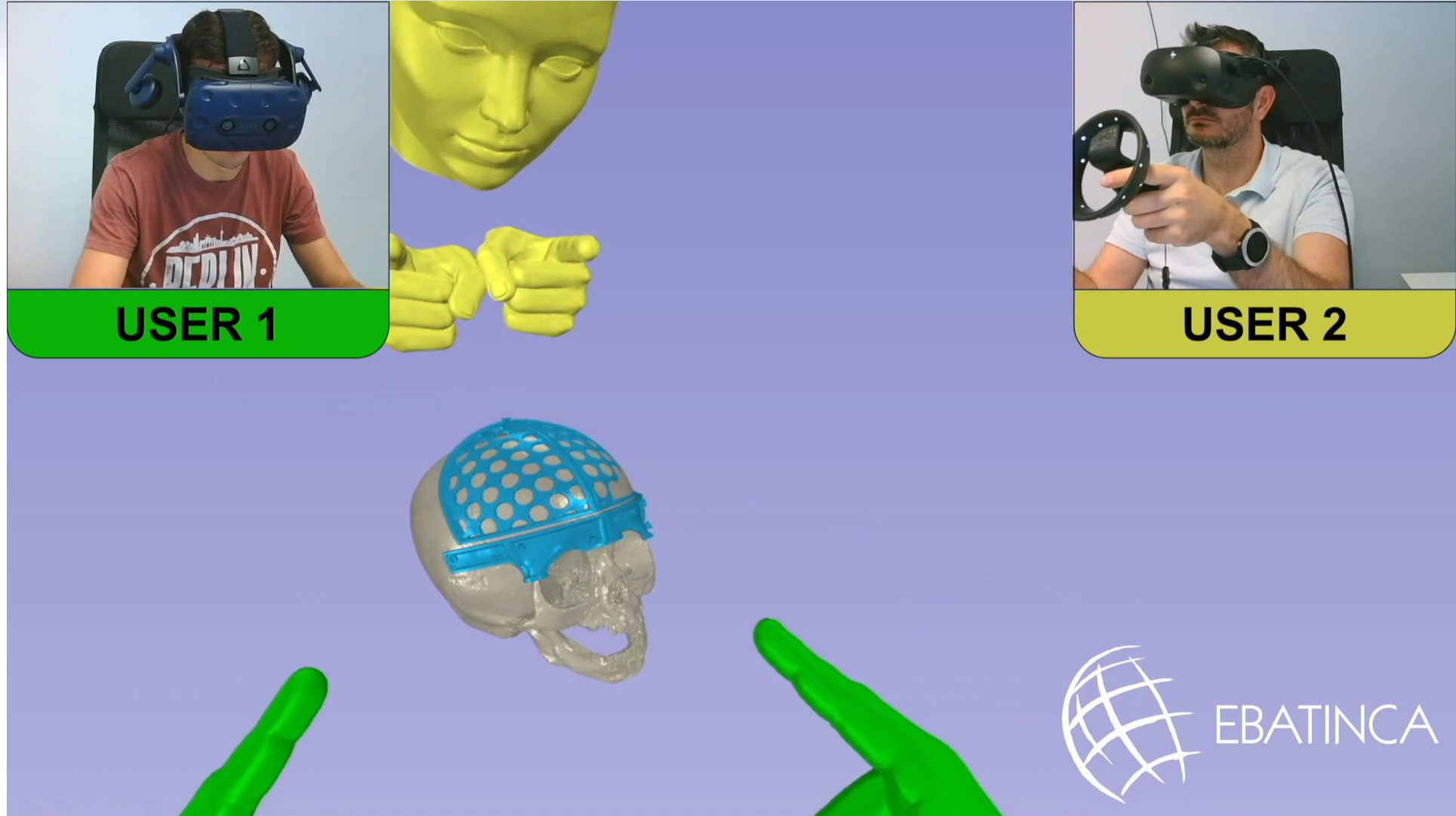


# TrainUS platform





# Example: Craniosynostosis collaborative VR



# Augmented reality

