3D Slicer as your platform: *why and how*

Steve Pieper, PhD. Isomics, Inc.
Hamlyn Symposium
June 26, 2023

Outline

- Why: Manager Perspective
- How: Developer Perspective

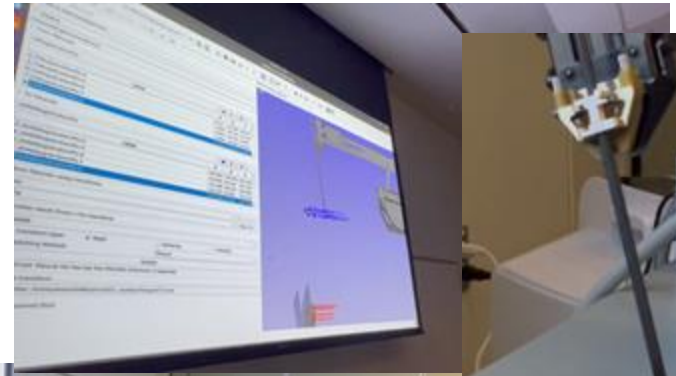
Theme: Slicer is complicated…
…because medical imaging and robotics are complicated

3D Slicer

Why

SlicerROS2

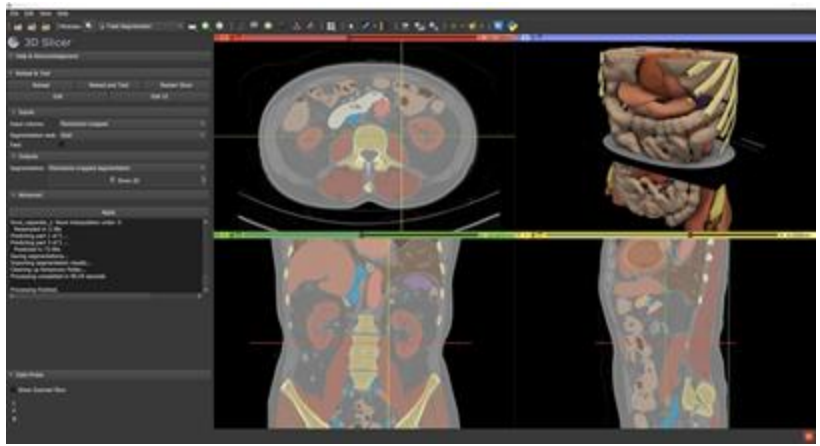
- High level, ready to use
- Free and open
- Demonstrated at ISMRM2023



Laura Connolly

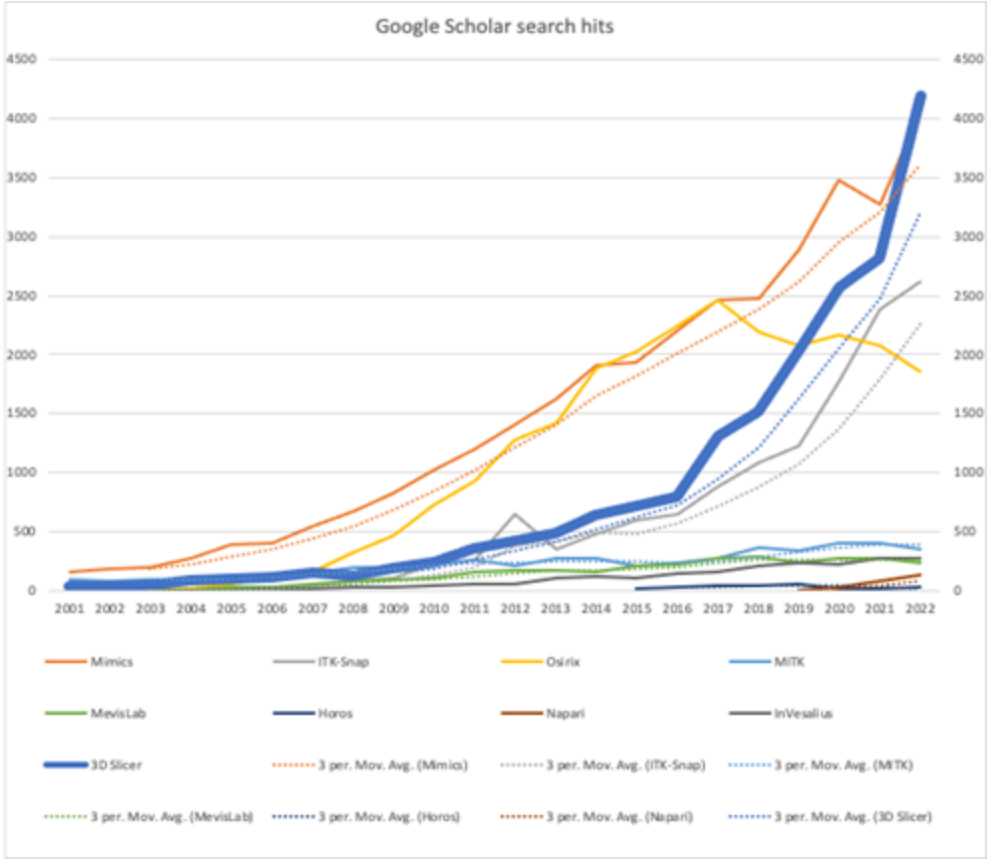
About 3D Slicer

- Application for Windows, Mac, Linux, and Cloud
- Actively maintained (current version 5.2.2)
- Over **one and a quarter million** downloads since 2011 (and growing)
- 7,400 members, 250K pageviews / month on discourse.slicer.org



3D Slicer Impact

- Citations-per-year leader 2022
  - Surpassed MIMICS, OSIRIX, ITK-Snap…
- Over 17,000 total google scholar hits
- Exponential citation growth



👍 Stats from Andras Lasso

Some 3D Slicer History

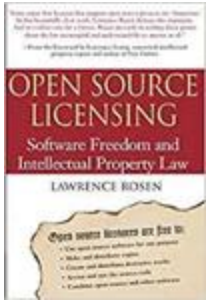
- Pre-Slicer BWH/GE work on volumetric software and image guided therapy
- Brainchild of Dr. Ron Kikinis: a unified platform to avoid reinventing the wheel
  - GE open magnet MR
  - Sun workstations, C++&Tcl/Tk, VTK
- MIT AI Lab Collaboration
  - Dave's neurosurgery thesis 1999
  - Delphine's virtual endoscopy thesis 2002
  - Lauren's tractography thesis 2006
- Basis for joint research funding
  - NAC, BIRN, NA-MIC, NCIGT, QIICR, PyRadiomics, IDC, Harmonization, LNQ…

👍 Ron Kikinis, Eric Grimson, Bill Lorensen, Dave Gering, Lauren O'Donnell, Delphine Nain, Tina Kapur, Noby Hata, C-F Westin, Steve Haker, Mike Halle, Sandy Wells...

3D Slicer Software License

- BSD-style very permissive license
- Explicitly written for 3D Slicer goals
  - Promote multi-site collaboration
  - Encourage industry involvement
  - Allow use in medical products
- Written 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

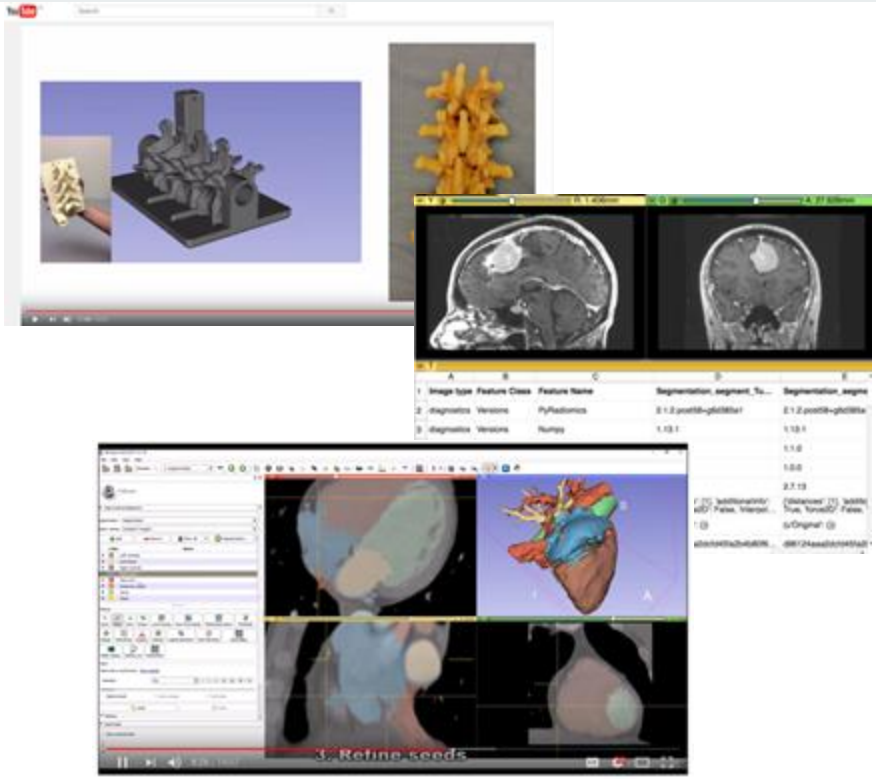
```
For more information, please see:

                    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
Slicer. If you distribute Software (as defined below) downloaded from
Slicer, all of the paragraphs of Part B of this Agreement must be
included with and apply to such Software.

Your contribution of software and/or data to Slicer (including prior
to the date of the first publication of this Agreement, each a
"Contribution") and/or downloading, copying, modifying, displaying,
distributing or use of any software and/or data from Slicer
(collectively, the "Software") constitutes acceptance of all of the
terms and conditions of this Agreement. If you do not agree to such
terms and conditions, you have no right to contribute your
Contribution, or to download, copy, modify, display, distribute or use
the Software.

PART A. CONTRIBUTION AGREEMENT - License to Brigham with Right to
Sublicense ("Contribution Agreement").
```



👍 Lawrence Rosen, Eve Waterfall, Brian Hicks

3D Slicer Today

- Modern C++ - documented & tested
- Extensively scriptable in Python
- Best in class libraries
- Dozens of tutorials, hundreds of videos
- Very active online forum
- Scientific publications
- Regular face to face working meetings
- Community sustained by research and commercial interests

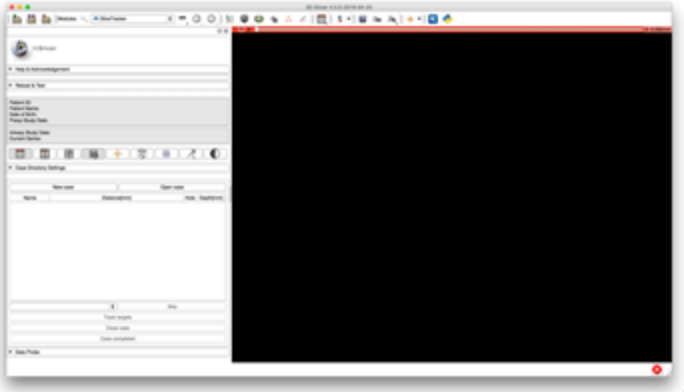


👍 Jean-Christophe Fillion-Robin, Andras Lasso, Csaba Pinter...

https://github.com/SlicerProstate/SliceTracker

Clinical Research

- Slicer is used in operating rooms
- Integrated with imaging, tracker, and therapy delivery systems
- Custom analysis tools
- "Slicelets" and "Guidelets" for custom interfaces (including sterile touch)
- Slicer Custom Applications

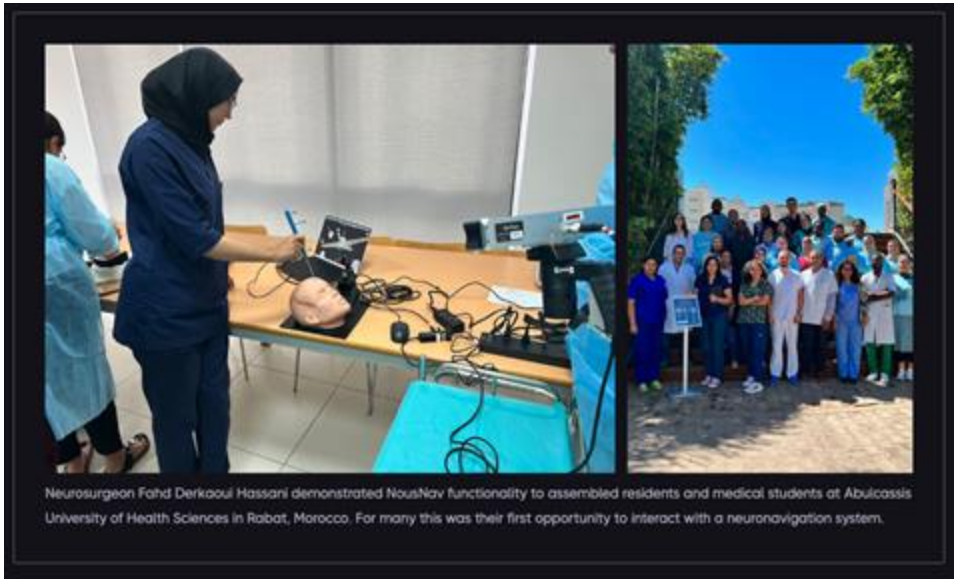


👍 Andrey Fedorov, Christian Herz, Peter Behringer, Alex Golby, Sarah Frisken Sam Horvath…

Clinical Translation

- 3D Slicer-based custom application
  - Philanthropy support and Fulbright Fellowship (Dr. Alexandra Golby)
  - Designed for LMICs
  - Custom streamlined workflow
- Reference implementation for open source medical devices

NousNav
OPEN SOURCE NEURONAVIGATION


Neurosurgeon Fahd Derkaoui Hassani demonstrated NousNav functionality to assembled residents and medical students at Abulcassis University of Health Sciences in Rabat, Morocco. For many this was their first opportunity to interact with a neuronavigation system.

👍 Alex Golby, Sarah Frisken, Tina Kapur, Sam Horvath, Sonia Pujol

3D Slicer Extensions

- 152 Extensions from hundreds of developers
- Independent add-ons to core platform
- Built and 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

SlicerVR

SlicerProstate

Slicer SALT

SlicerRT

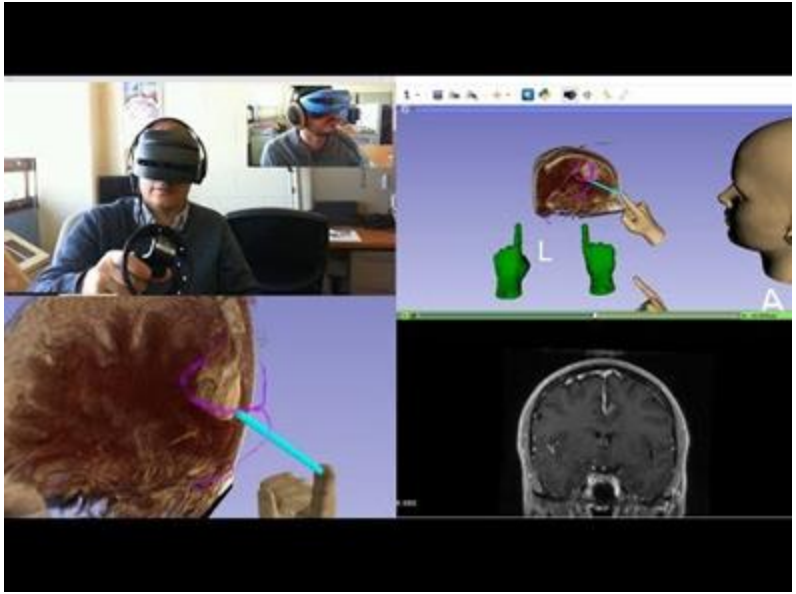
Slicer CMF
Cranio Maxillo Facial

Slicer Astro

SlicerMorph Project

3D Slicer Virtual Reality

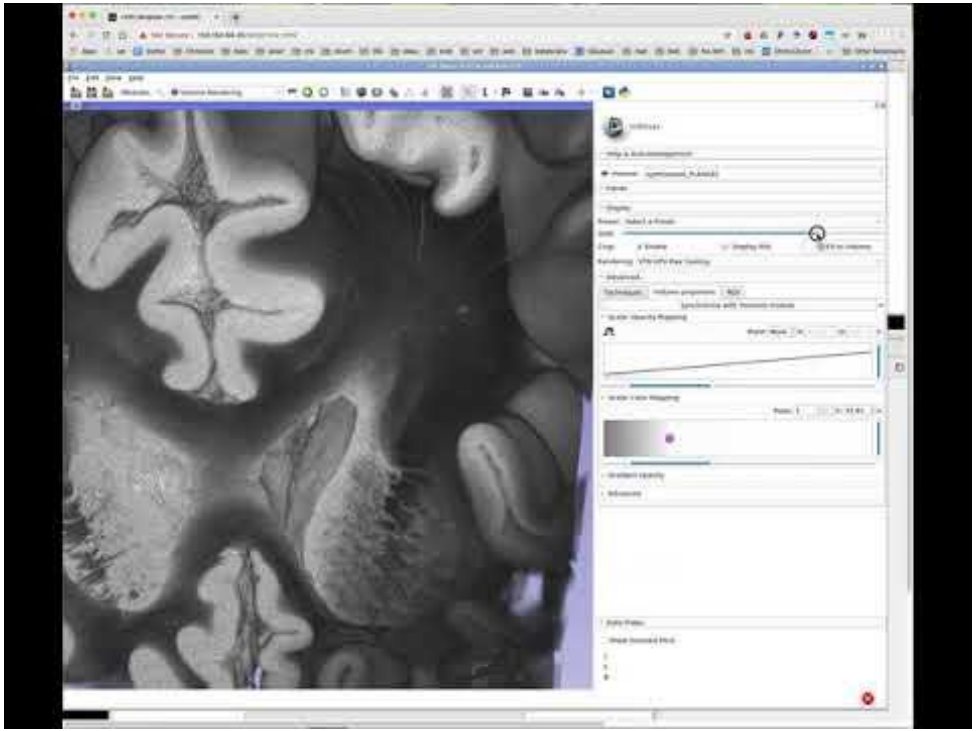
- Supports HTC, Quest, Window MR...
- Builds on OpenXR, VTKOpenXR
  - Virtual and Augmented Reality
- All normal Slicer 3D views available
- Slicer Qt widgets in VR
- New widgets in development



👍 Andras Lasso, Csaba Pinter, Ken Martin, Jean-Baptiste Vimort…

Cloud Rendering of Large Datasets

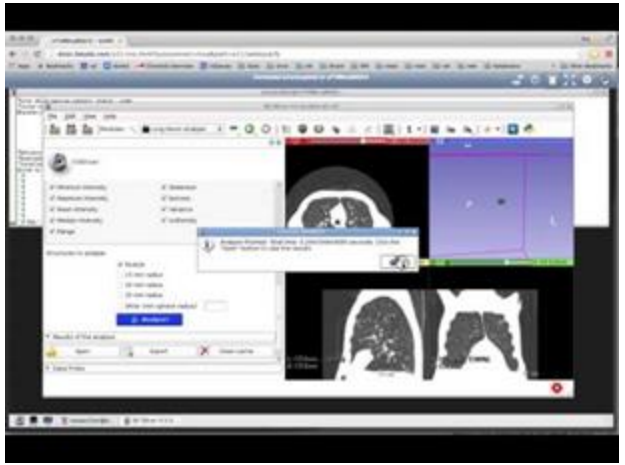
- Standard 3D Slicer binary
- Cloud-hosted Linux computer
- GPU accelerated rendering
- Interactive performance
- *Ex vivo* brain dataset from MGH
  - 0.1 mm isotropic voxels
  - 1700x1700x1200 floats
  - 100 hour scan at 7T
- Cloud GPUs with 80 GB available by the hour

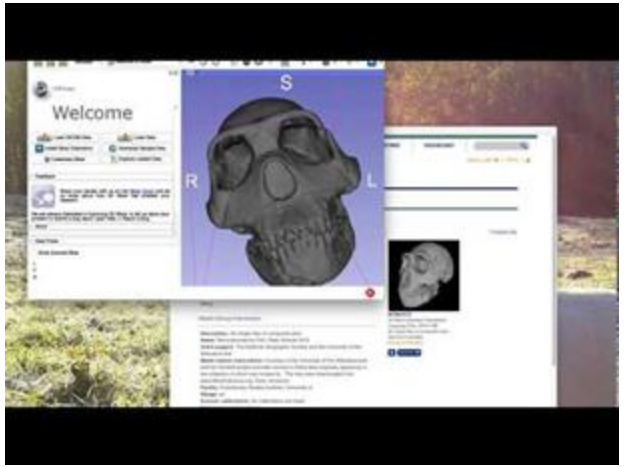


👍 Data: Brian Edlow, Bruce Fischl...

3D Slicer and Cloud/Web

- Slicer can run in a docker container
  - embedded web screenshare (NoVNC)
  - run locally or on any cloud
  - any Slicer-based workflow
- Slicer includes QtWebEngine (Chromium based)
  - display and download from any modern website
  - hybrid apps for auth, interface reuse
- Same Slicer binary for all platforms

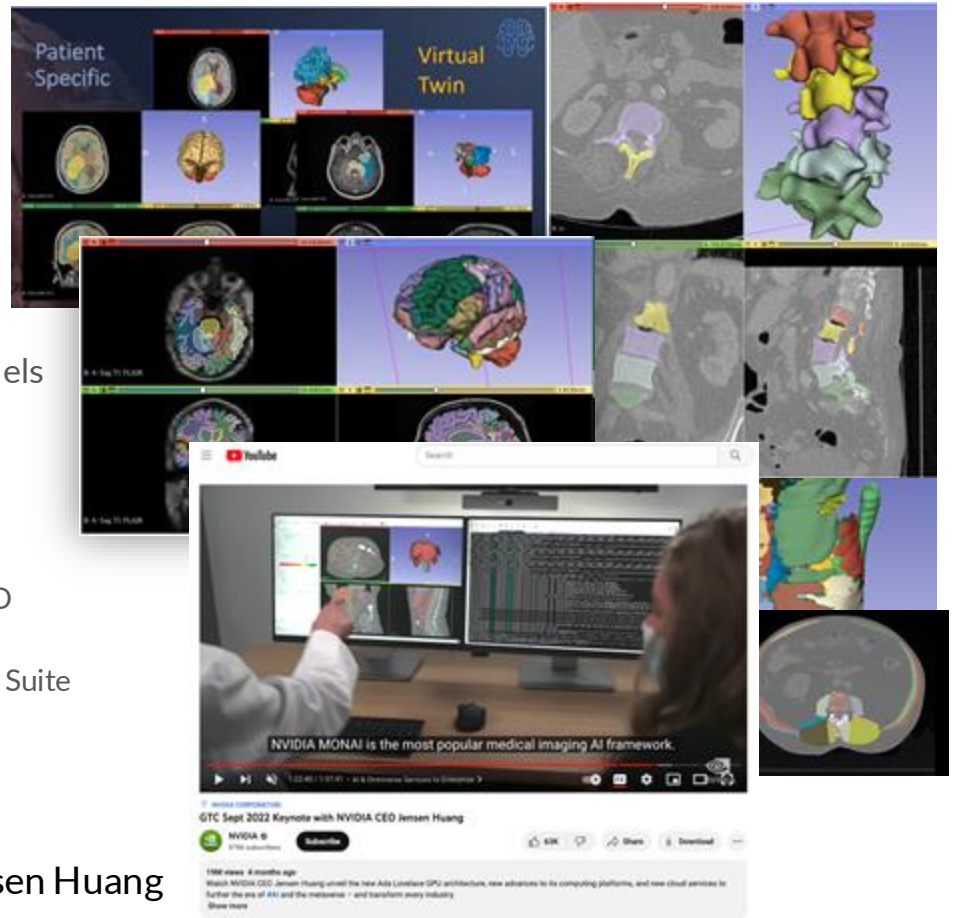




Tim Dettrick, Murat Maga

3D Slicer and AI

- Powerful tools for training and reviewing models
- Compatible with external tools like nnU-Net, MONAI Label, TotalSegmentator, SynthSeg…
- Adopted by Industry Leaders
  - Kitware, Isomics, Ebatinca, among core devs
  - AWS and NVIDIA develop MONAI code for 3D Slicer
  - Google uses 3D Slicer in their Medical Imaging Suite
  - Slicer appears in Nvidia CEO GTC Keynotes
- Rapid progress in segmentation will continue



Jensen Huang

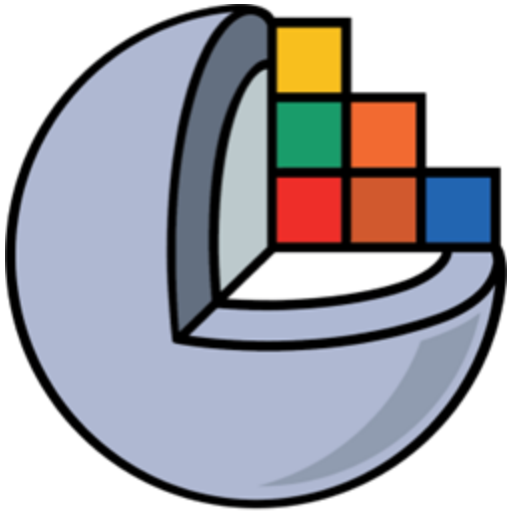
https://www.youtube.com/clip/UgkxSl8cwyERBGWniznsKRJcw7gNqPFXAd-H

3D Slicer

How

3D Slicer Programming Goals

- 100% Open and Non-Restrictive
- Cross-platform: Windows, Mac, and Linux
- Modular and Reusable
- Computationally Efficient
  - Handle large data
  - Leverage hardware (CPU cores and GPUs)
- Cover Medical Imaging
- Generalizable to Other Domains
- Fully Scriptable



You Benefit from the Slicer License

- You will never lose access to your platform
- You benefit from investment in developing skill sets
- You have options to make commercial products

199 lines (169 sloc) | 10.3 KB

```
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
Slicer. If you distribute Software (as defined below) downloaded from
Slicer, all of the paragraphs of Part B of this Agreement must be
included with and apply to such Software.

Your contribution of software and/or data to Slicer (including prior
```

100% Open and Non-Restrictive: Dependencies

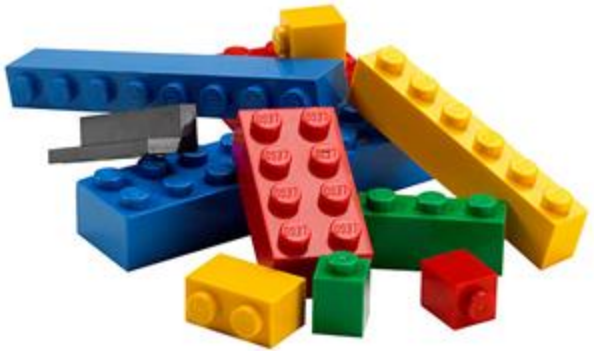
- Slicer builds on dozens of other projects
- Dependency library licenses must be compatible with Slicer License
- Examples include: LGPL (Qt, Teem), Apache 2.0 (ITK), BSD (VTK), PSF License (Python)
- Slicer coding conventions are inherited from parent classes
  - vtkMRML code is written like vtkObject code
  - qSlicer code is written like QWidget code
- You don't have to worry about future legal headaches from dependencies

100% Open and Non-Restrictive: Processes

- Public source repository: github.com/Slicer organization
  - Slicer source code and issues tracker
  - Forks of other packages to maintain fixes not yet upstream
- Open discussion forum: discourse.slicer.org
- Weekly developer video conferences open to anyone (10am EST Tuesdays)
- Twice-yearly Project Weeks: projectweek.na-mic.org
- "Meritocracy" to form group decisions

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!"

Computationally Efficient: Large Data

- MRML Volumes use vtkImageData, a dense array of voxel data
- MRML Models use vtkPolyData, arrays of vertex, cell, and field data
- 64-bit addressing
- Runtime polymorphic (int, short, float, double…)
- All MRML arrays exposed as numpy via python buffer protocol
- Runs on cloud machines with 11TB RAM available to rent by the hour

Computationally Efficient: Leverage hardware

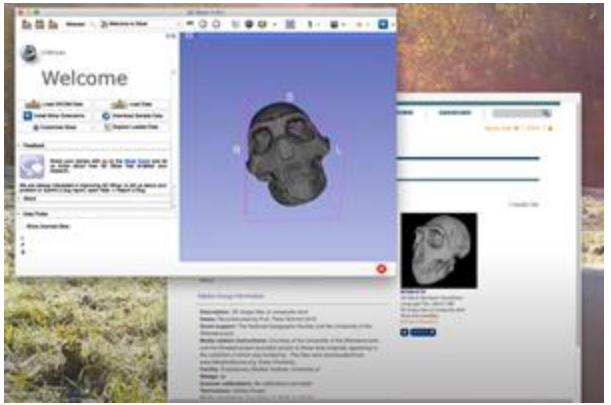
- Most ITK and VTK imaging algorithms are multithreaded
  - Volumes are divided into slabs
  - Slabs allocated to CPU cores
- VTK rendering uses OpenGL
  - Volume and Model arrays loaded in GPU
  - Rendering uses dynamically generated vertex and fragment shaders
  - WebGPU transition underway (enables Vulkan, Metal, and DirectX plus OpenGL compatibility)
- Custom hardware / software can be accomodated
  - Slicer on Nvidia A100
  - CUDA accelerated TensorFlow / PyTorch
  - Requires NVidia hardware and drivers

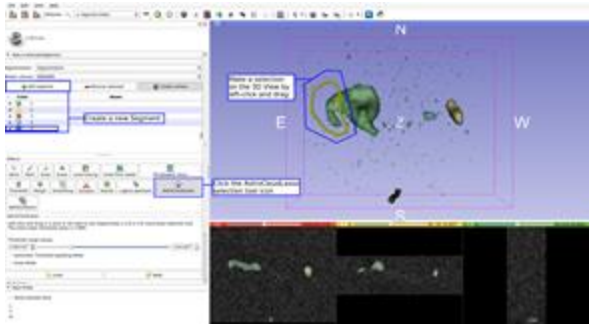
Cover Medical Imaging

- Sophisticated DICOM management
  - Extensible Import / Export of clinical datasets: 2D, 3D, 3D+T, CT, MR, PET, US, diffusion, perfusion…
  - Compatible with standard and common variants
- Patient-centric coordinate systems
- Linear and nonlinear transform hierarchies (longitudinal registration)
- Segmentation
  - Image or model based representations
  - Anatomical terminology support
- Standard clinical rendering modes
  - Axial / Sagittal / Coronal + MPR
  - Shaded surface and MIP volume displays

Generalizable to Other Domains

- SlicerMorph
  - Surface scans and microCT of non-human biological specimens
  - Population morphometric analysis tools
- SlicerAstro
  - Interactive 3D galactic exploration
  - Coordinates are azimuth, inclination, and velocity
- Other fields with volume data
  - Geology, material science, cultural preservation, Imaging of deep sea creatures, spacecraft materials…





Next Steps

- https://download.slicer.org
- https://slicer.readthedocs.io
- https://discourse.slicer.org
- https://github.com/Slicer
- https://projectweek.na-mic.org