



3D Visualization and Morphometrics with SLICERMORPH

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&

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Workshop Instructors:

Sara Rolfe, PhD: Lead Developer for SlicerMorph & Research Scientist

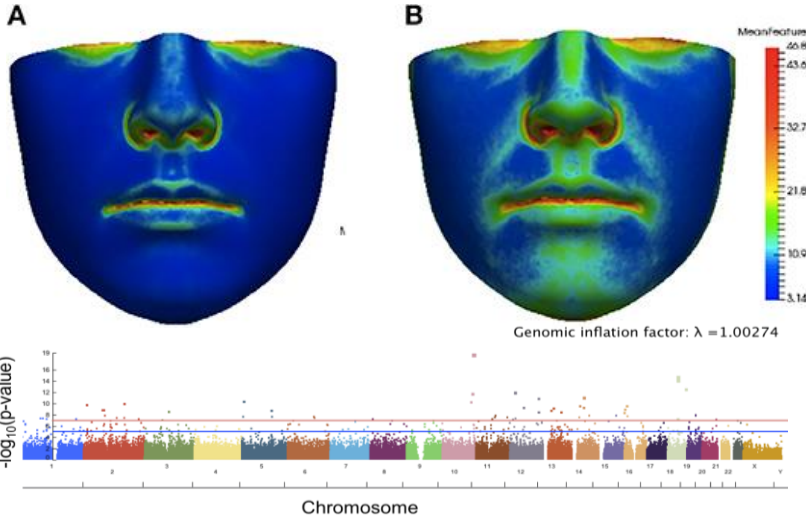
Kelly Diamond, PhD: Post-doc at Maga lab

Arthur Porto, PhD: Post-doc at Maga lab

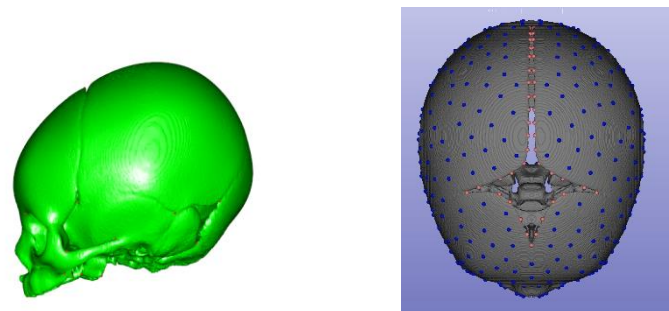
Ezgi Mercan, PhD: Research Scientist at Children's Craniofacial Center

Volunteers: Anne Kort, Rachel Fleming, Peter Kloess, Alyssa Sargent, Amanda Hewes

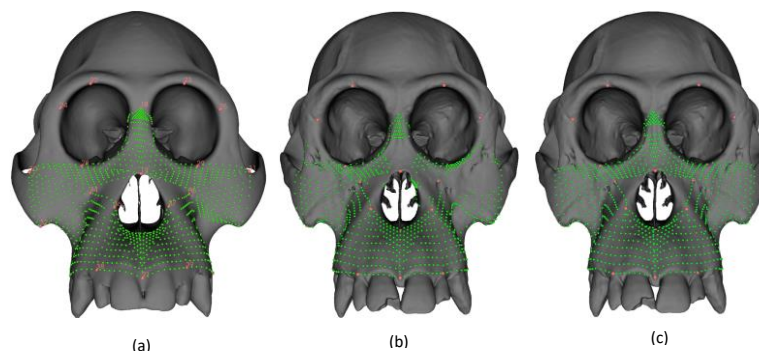




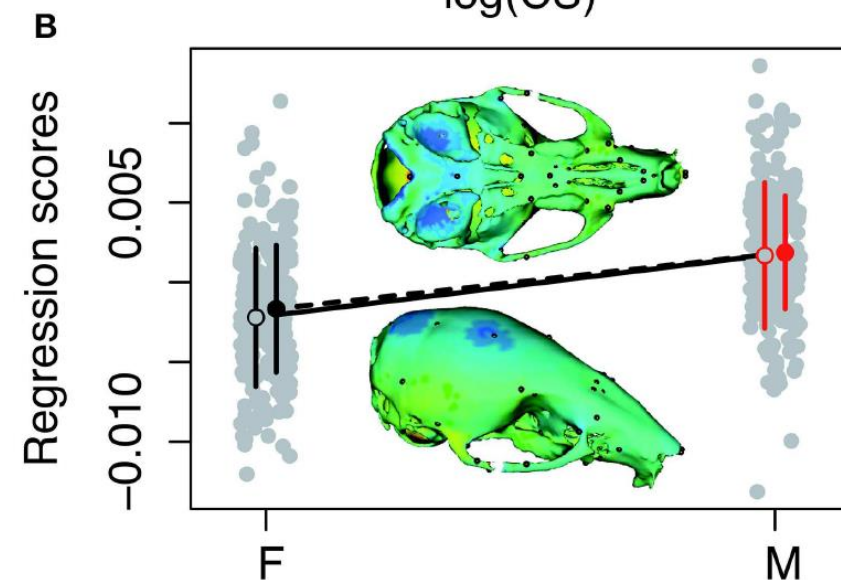
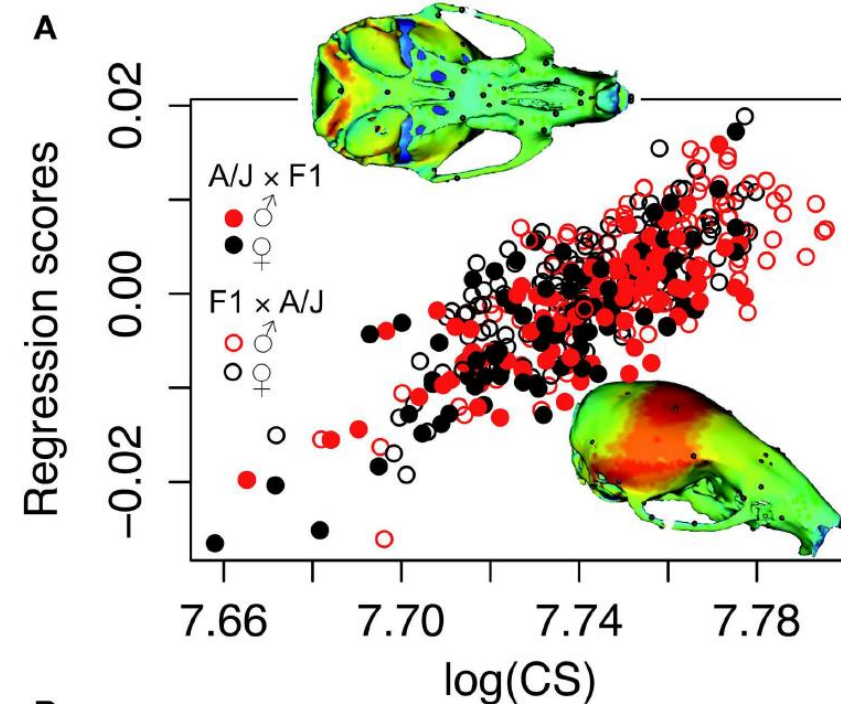
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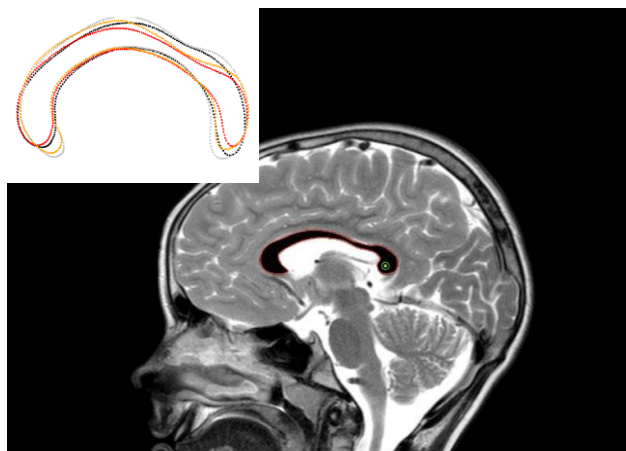


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A typical 3D morphometrics workflow:

1. Find your data (e.g., MorphoSource, DigiMorph, your lab etc).
2. Find a software that will enable 3D visualization/segmentation and conversion to mesh, then landmark digitization (commercial software like Aviso, Mimics, Geomagic, Analyze, or free ones like ImageJ, 3D Slicer, ITK-Snap)
3. Export landmarks/measurements data into a format that can be understood by the analysis software.
4. Analyze using R (or MorphoJ)
5. Go back and forth steps #2 and #4 until you clean up all your data for final analysis.

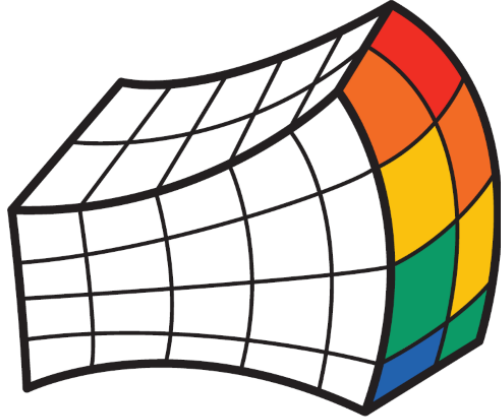
Let's fix that! (Thank you NSF!)

1. Find your data, download, visualize, segment, animate, measure, annotate, vet your landmarks, and construct your basic morphospace in **SlicerMorph**. Then, export result for:
2. Domain-specific analysis (symmetry decomposition, phylogenetic PCA, linear models based on Procrustes Anova, covariation) in R (geomorph, Morpho, momocs etc).

SlicerMorph Project Organization

- **SlicerMorph Core Team:**

- Lead-PI: **Murat Maga** (UW / Seattle Children's Research Institute)
- Co-PI: **Adam Summers** (UW FHL)
- Co-PI: **Doug Boyer** (Duke Evol. Anthropology & Director of MorphoSource.org)
- Consultant: **Steve Pieper** (Isomics Co., Chief Software Architect of 3D Slicer)
- Lead Developer: **Sara Rolfe** (UW FHL & Seattle Children's Research Institute)
- Post-Doc: **Arthur Porto** (Seattle Children's Research Institute)



SLICERMORPH

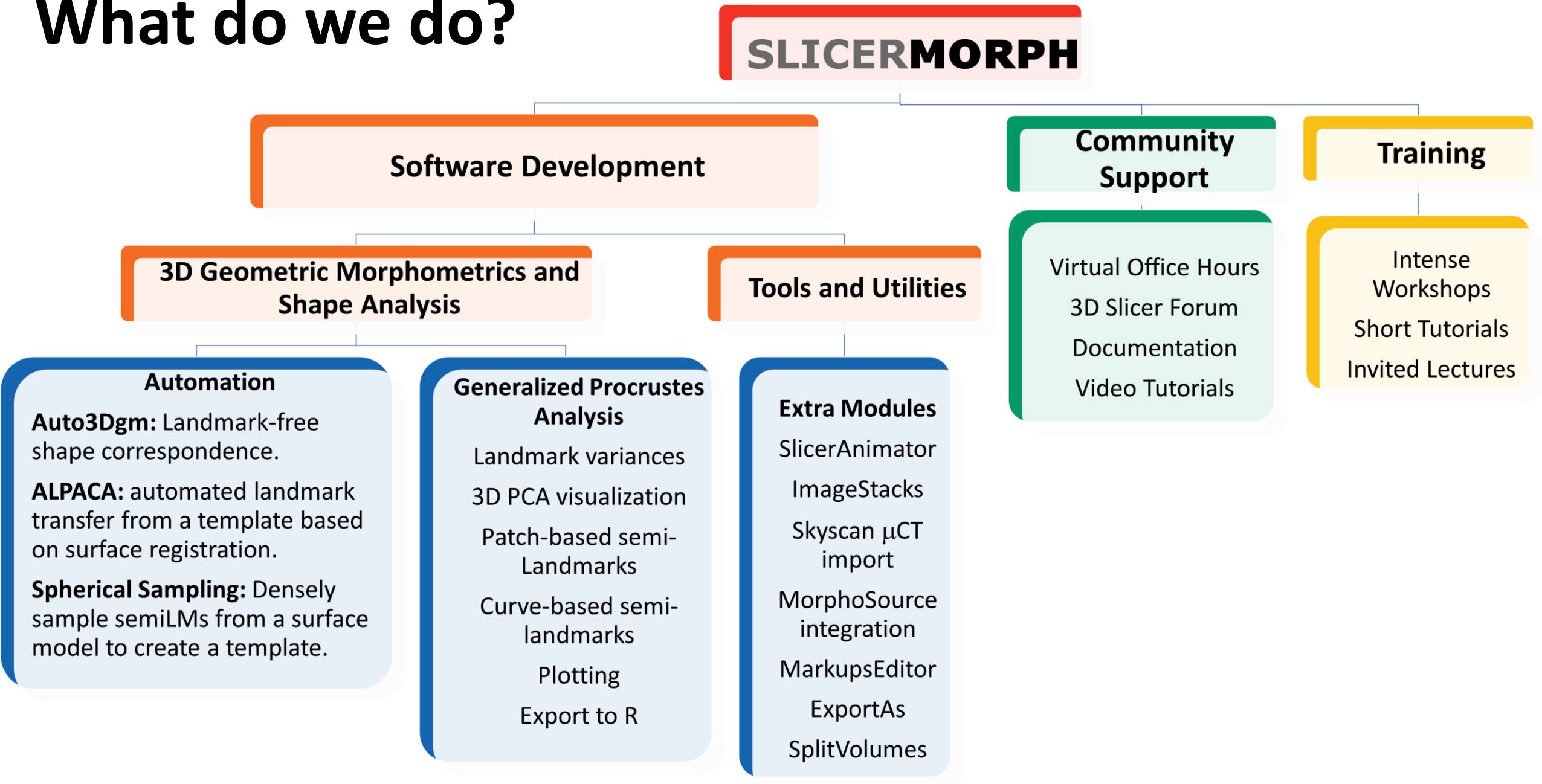
- **SlicerMorph Advisory Committee:**

- James Rohlf (Stony Brook U)
- Dean Adams (Iowa State U)
- David Polly (Indiana U)
- Anjali Goswami (Natural History Museum, London)

Collaborative Proposal: ABI Development: An Integrated Platform for Retrieval, Visualization and Analysis of 3D Morphology From Digital Biological Collections (ABI 1759883, 1759637, 1759839) 08/01/2018-07/31/2021

https://nsf.gov/awardsearch/showAward?AWD_ID=1759883&HistoricalAwards=false

What do we do?



Road Map since Summer 2018



Plan for the week normally

	2/16	2/17	2/18	2/19	2/20	2/21	2/22	2/23
7:45-8:15		Breakfast	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast	Brunch / Checkout
8:30-10:15		Introduction Maga 3D imaging Summers	Applied Imaging Concepts Rolfe	Introduction to Statistical Shape Analysis II: Semi- Landmarks and beyond Rolfe	Auto3Dgm and landmark-free correspondence of biological form Boyer	Applications of SSA: Phylogenetics Shan	Work on your on data / TBD	
10:15-10:30		Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break	
10:30-12:15		Attendee project Presentations - Initial	Slicer #3: Segmentation, mesh conversion Maga	SlicerMorph # 1: Statistical Shape Analysis: Work with sample data Maga	Auto3Dgm: Establishing Landmark-free correspondence Shan	Repetitive tasks, Scripting in Slicer Rolfe	Work on your on data / TBD	
12:15-12:45		Lunch	Lunch	Lunch	Lunch	Lunch	Lunch	
1:00-3:00	Course check- in & Self- Paced Pre Course Lab (Dining Hall)	Slicer #1: UI, overview of functionality, extensions, finding help Mercan	Introduction to Statistical Shape Analysis I: Landmark-based methods Maga	Template-based analysis and computational anatomy Maga	Application of SSA: Modeling growth Mercan	Building Statistical Shape Models in R Schlager	Setting your own lab / Concluding remarks SlicerMorph team	
3:00-3:15		Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break	
3:15-5.15		Slicer #2: Data formats, getting data from M/S, saving Maga	Slicer #4: Measurements and Visualization Rolfe	SlicerMorph # 2: Statistical Shape Analysis: Work on your data	Integrating SlicerMorph with R Mercan	Data processing in R: Plotting, modeling Schlager	Visualization Competition and Social	
6:00-6:30	Dinner	Dinner	Dinner	Dinner	Dinner	Dinner	Dinner	
7:00-8:00		Smores on beach	Study Hall @Dining Hall -	Study Hall @Dining Hall -	Study Hall @Dining Hall -	Study Hall @Dining Hall -		

Plan for this week

	8/17	8/18	8/19	8/20	8/21
9:30-11:30	Introduction Maga	Imaging Concepts Rolfe	GMM #1 Maga	SLICERMORPH (cont'ed) <ul style="list-style-type: none">Semi-landmarking<ul style="list-style-type: none">Curve-basedPatch-basedTemplate-based auto-landmarkingImporting data in RSurface Toolbox to edit 3D models Breakout sessions for semi-LMs and template-based landmarking.	Setting up a lab Maga
	GETTING STARTED WITH SLICER & SLICERMORPH <ul style="list-style-type: none">Navigating UI, extension catalogue, Data and Subject Hierarchy,Sample Data module, loading data	3D VISUALIZATION <ul style="list-style-type: none">Volume RenderingLightingAnimationsMeasurements<ul style="list-style-type: none">LandmarksLinesAnglesPlanesCurves	SLICERMORPH <ul style="list-style-type: none">Review MeasurementsReview Sample DataGPA in SlicerMorphSuperimpositionPlots OutputsPCA Visualization		ODDS and ENDS <ul style="list-style-type: none">Landmark RegistrationCalculating model to model distance and heatmapsFlattening curved structuresImporting raw dataFinding support and using forum
11:30-11:50	Break	Break	Break	Break	Break
11:50-2:00	GETTING STARTED WITH SLICER & SLICERMORPH <ul style="list-style-type: none">VolumesImageStacksMorphoSourceImportModelsDICOMBrowserCropVolumeTransformsSaving dataCustomization	SEGMENTATION <ul style="list-style-type: none">Image GeometryMask vs LabelMap vs SegmentationSegment Editor and Segmentation toolsSplit/Mask VolumeSegmentEndoCraniumSegment StatisticsExporting/Importing SegmentationsPointers to segmentation recipesCustomizing .slicerrc.py for shortcuts and keystrokes	SLICERMORPH (cont'ed) Breakout sessions for GPA tutorial and collect your own data.	SLICERMORPH (cont'ed) GMM #3: Auto3DGM Boyer/Shan Lecture, demo and breakout sessions	Q&A and Breakout sessions
			GMM #2 Semi-LMs Rolfe		

EVALUTIONS

- **Evaluation forms:** We need your feedback both right at the end of each day. Please find the online surveys at:
https://github.com/SlicerMorph/S_2020/blob/master/Evaluations.md
- A final survey for overall course feedback at the end Day 5. Same link as above.
- Critical for our renewal and continuation efforts.

Self-support resources

- **Review Course repository:** https://github.com/SlicerMorph/S_2020
- **SlicerMorph Project website:** <http://SlicerMorph.org> (links to tutorials, data etc)
- **Sign up for announcements and updates:** <http://bit.ly/SM-listserv>
- **Video tutorials for SlicerMorph specific functions:** http://bit.ly/SM_youtube
- **Engage with Slicer(Morph) community:** <https://discourse.slicer.org>
- **Signup for a semi-annual short-course at FHL** <http://workshop.slicermorph.org>
- **Monthly zoom user check-ins:** 4th Wednesday of each month @11 (PDT)

We need SlicerMorph champions

- “Volunteer” for your lab to be the resident-expert.
- Write and share SOPs on the SlicerMorph website (it is a git repository, we welcome ‘contributions’ *aka.* pull requests)
- Develop tutorials/use cases
- File bugs / report issues

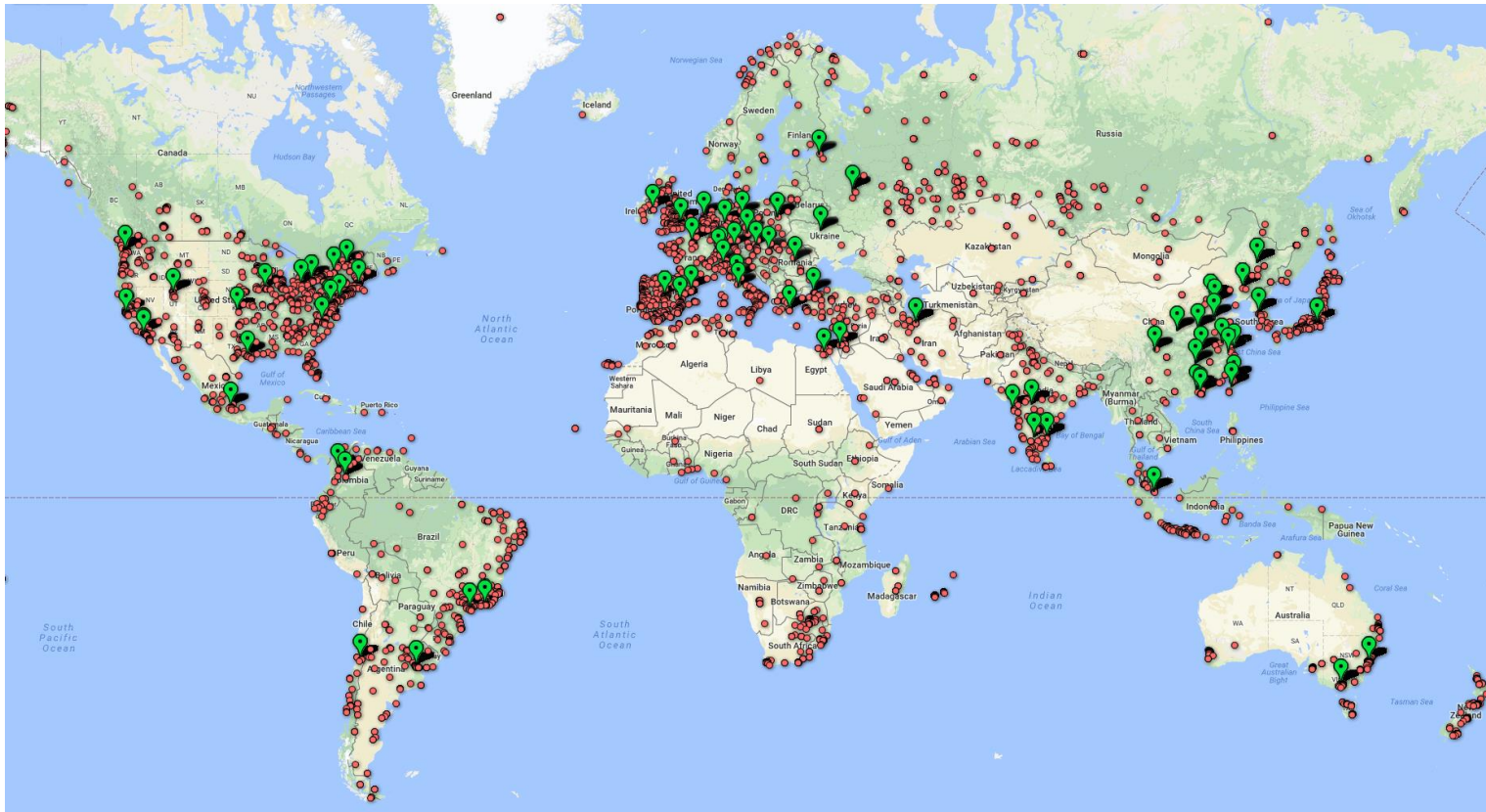


Why 3D Slicer? Large existing user community

500 downloads per week in 2012

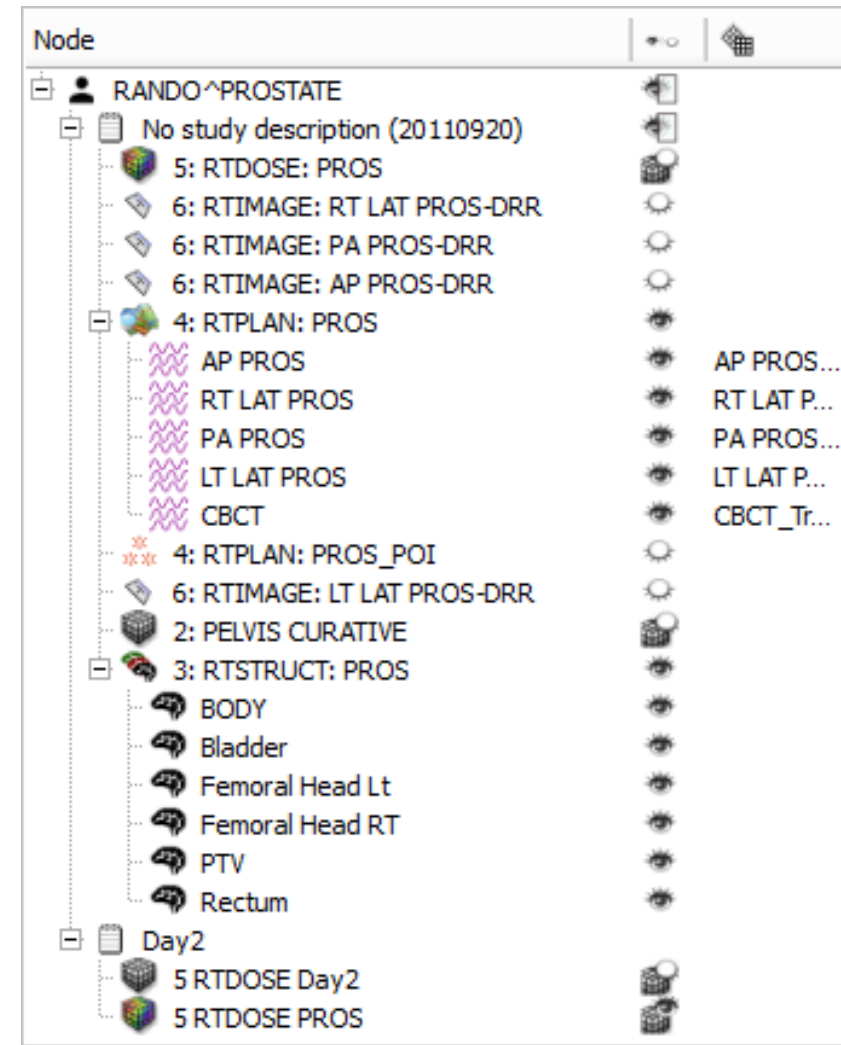
2800 downloads per week in 2018

330 000+ downloads over the past 5 years:



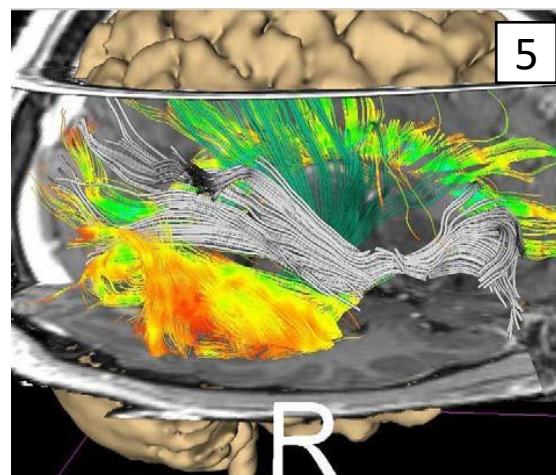
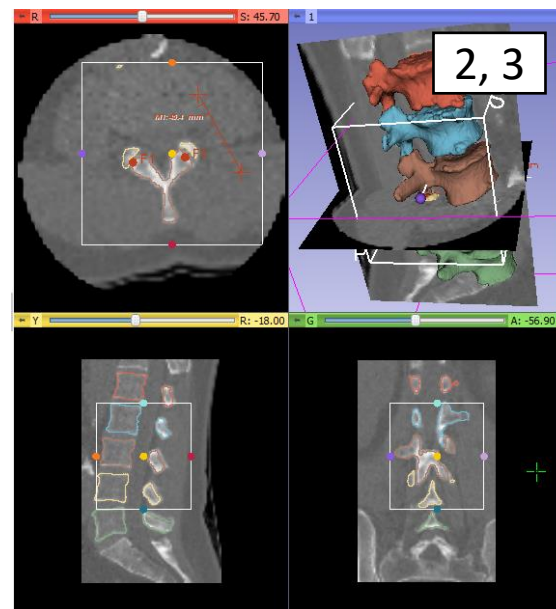
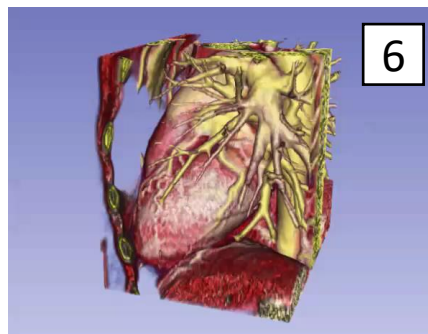
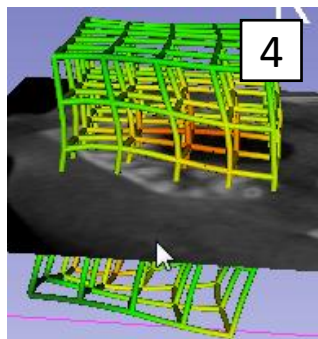
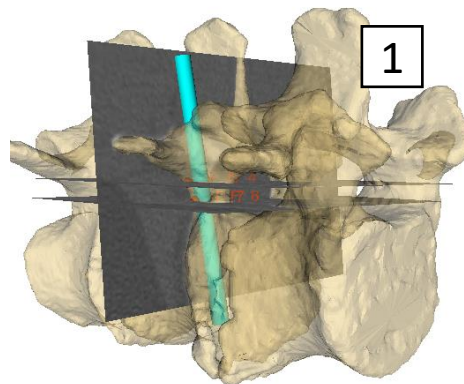
Data import/export

- 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



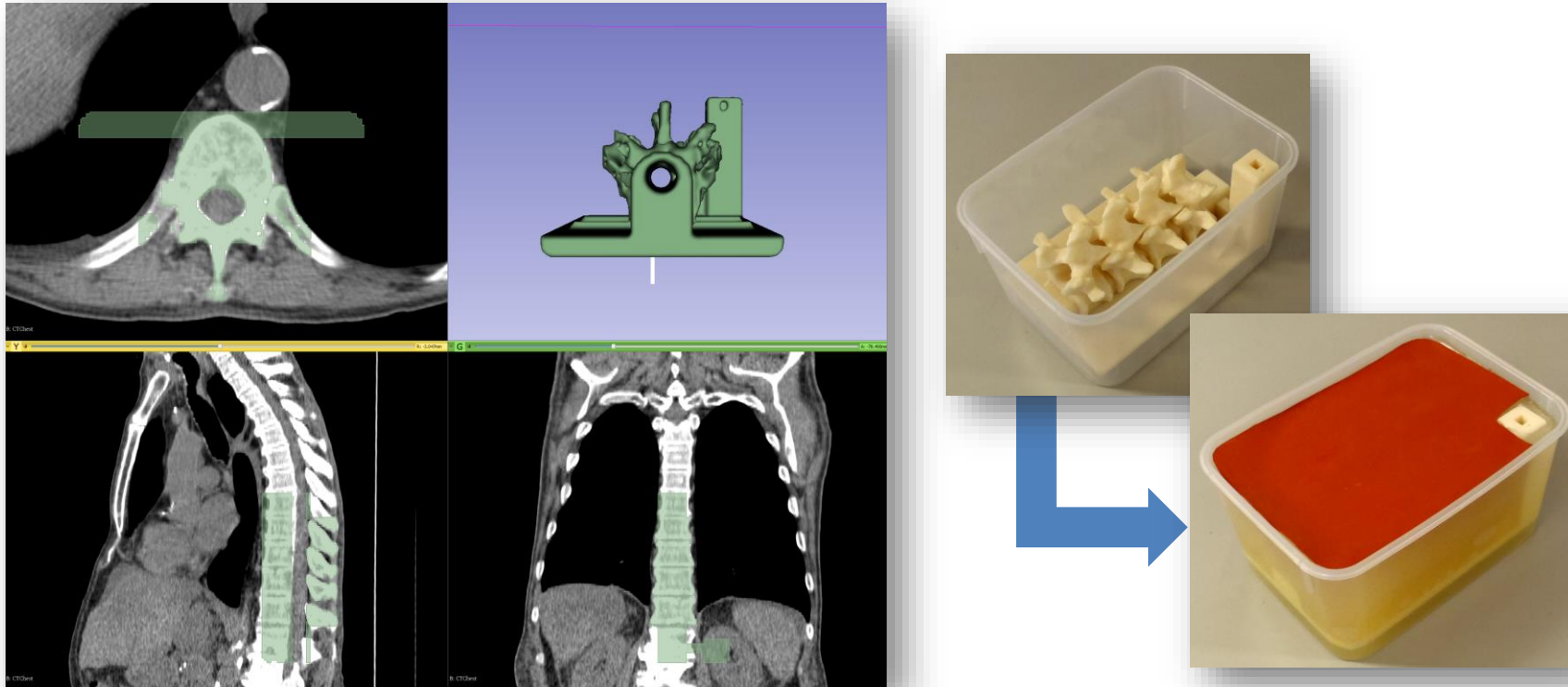
Extensive Visualization Capabilities

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

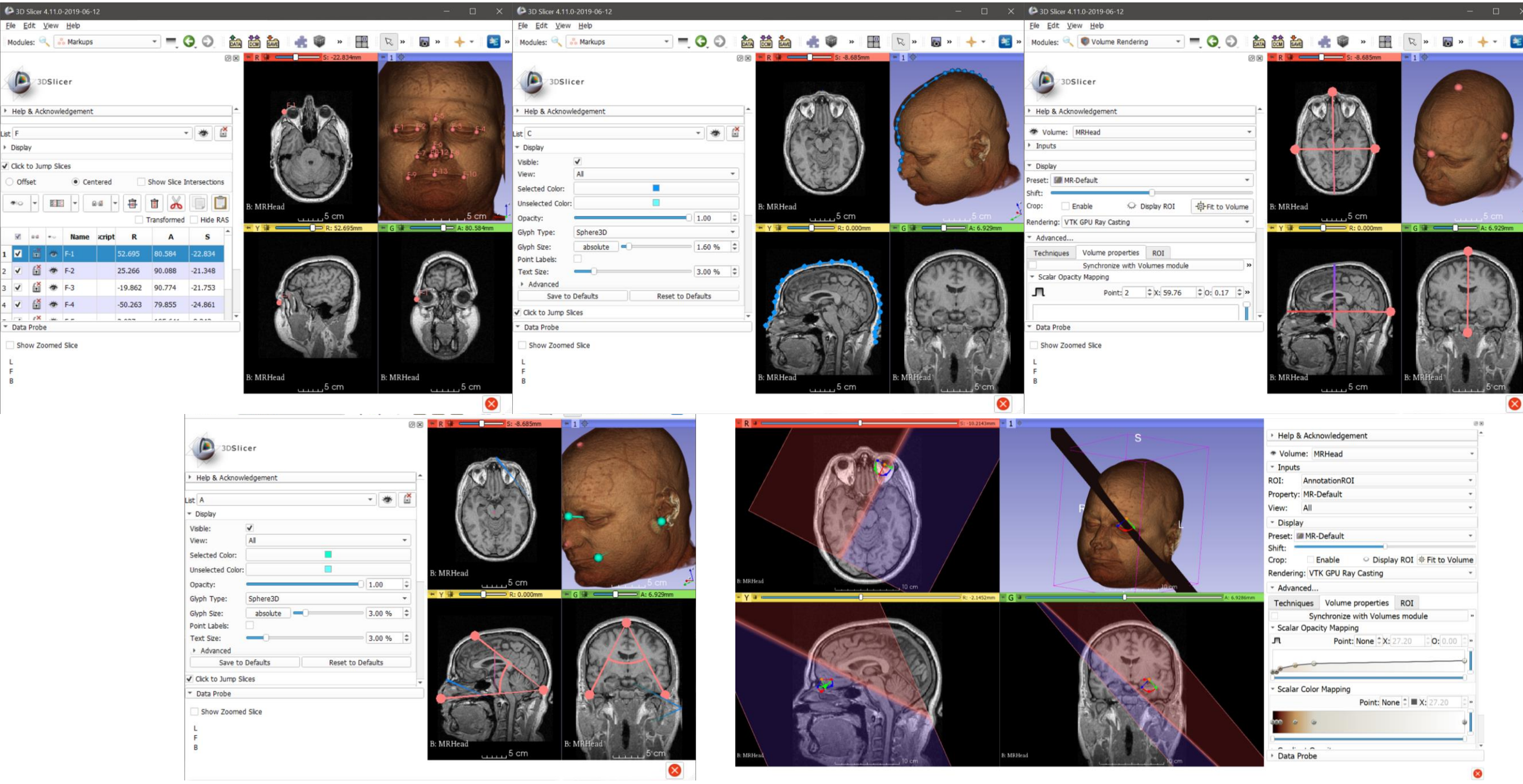


Segmentation

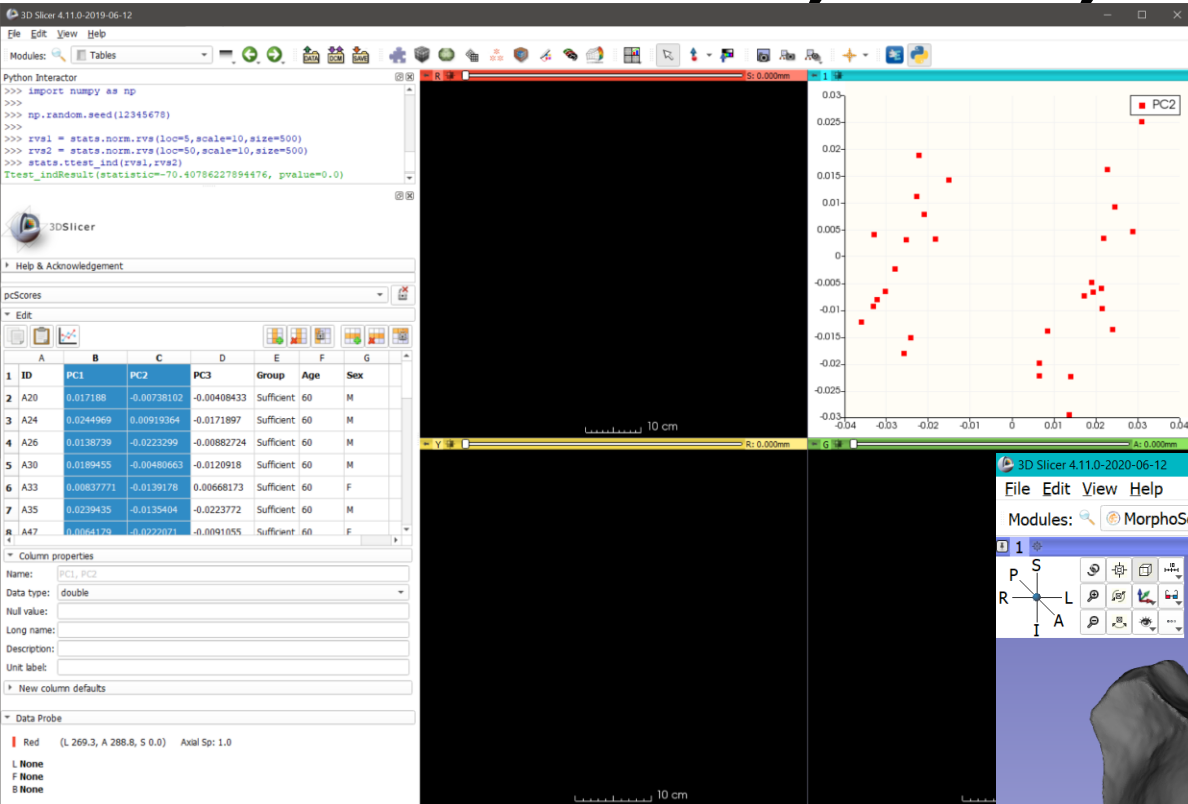
- Manual (paint, draw, scissor, threshold, etc.)
- Semi-automatic (region-growing, fill between slices, etc.)
- Automatic (atlas-based, robust statistics, etc.)



Markups (Landmarks, Lines, Angles, Curves, Planes)



Data Tables, Plots, and statistics (w/ Python)



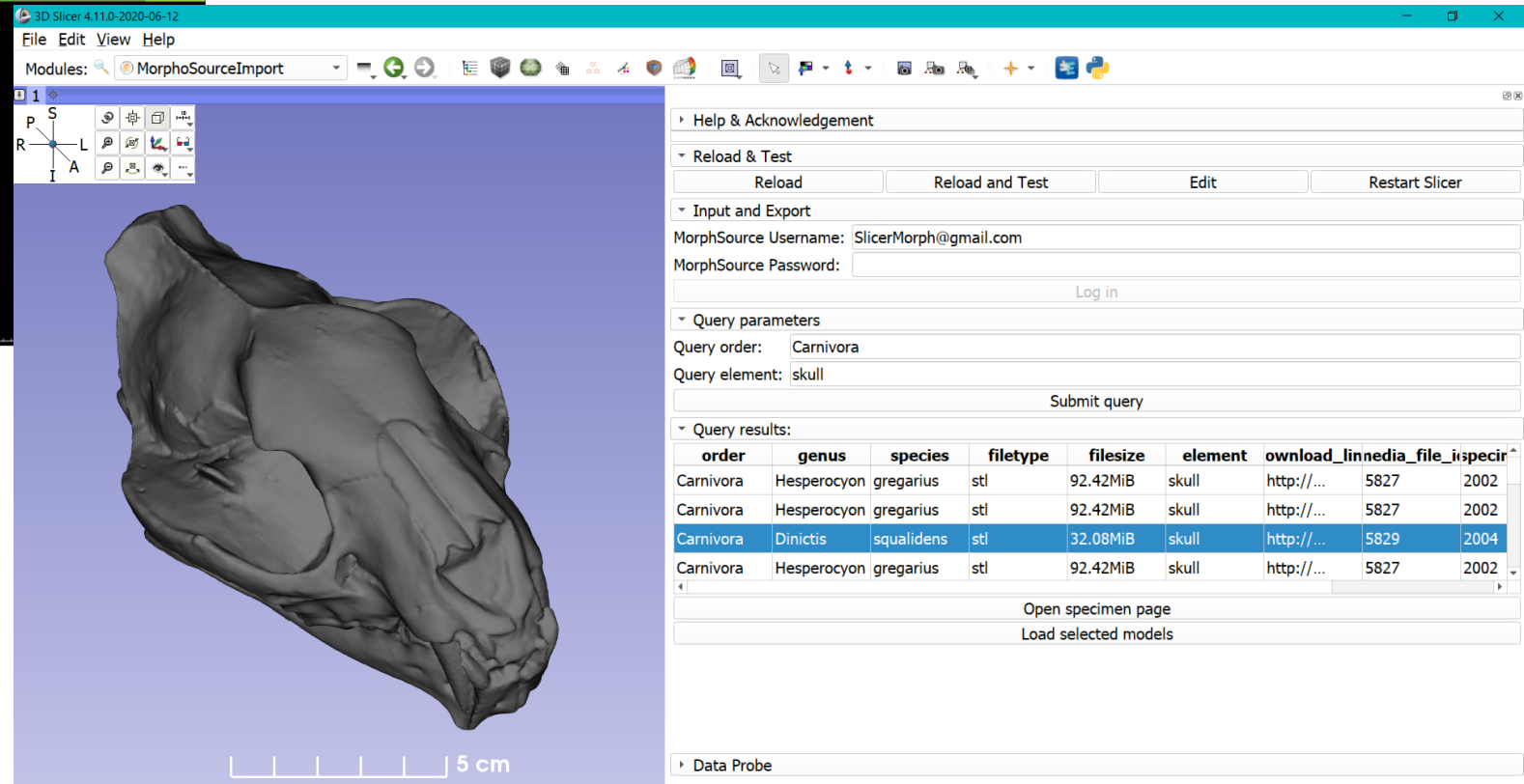
3D Slicer 4.11.0-2020-06-12

File Edit View Help

Modules: MorphoSourceImport

1

P S
R L
I A



The figure shows the 3D Slicer software interface. On the left, a 3D model of a skull is displayed. On the right, the 'MorphoSourceImport' module is active, showing a table of query results. The table lists specimens (Carnivora, Hesperocyon, Dinictis) and their associated files (stl, 92.42MiB, 32.08MiB). The 'Query results' section shows a table with columns: order, genus, species, filetype, filesize, element, download_url, linnedia_file_id, and year. The table lists specimens (Carnivora, Hesperocyon, Dinictis) and their associated files (stl, 92.42MiB, 32.08MiB). The 'Query results' section shows a table with columns: order, genus, species, filetype, filesize, element, download_url, linnedia_file_id, and year. The table lists specimens (Carnivora, Hesperocyon, Dinictis) and their associated files (stl, 92.42MiB, 32.08MiB).

order	genus	species	filetype	filesize	element	download_url	linnedia_file_id	year
Carnivora	Hesperocyon	gregarius	stl	92.42MiB	skull	http://...	5827	2002
Carnivora	Hesperocyon	gregarius	stl	92.42MiB	skull	http://...	5827	2002
Carnivora	Dinictis	squalidens	stl	32.08MiB	skull	http://...	5829	2004
Carnivora	Hesperocyon	gregarius	stl	92.42MiB	skull	http://...	5827	2002

Help & Acknowledgement

Reload & Test

Reload Reload and Test Edit Restart Slicer

Input and Export

MorphSource Username: SlicerMorph@gmail.com

MorphSource Password:

Log in

Query parameters

Query order: Carnivora

Query element: skull

Submit query

Query results:

Open specimen page

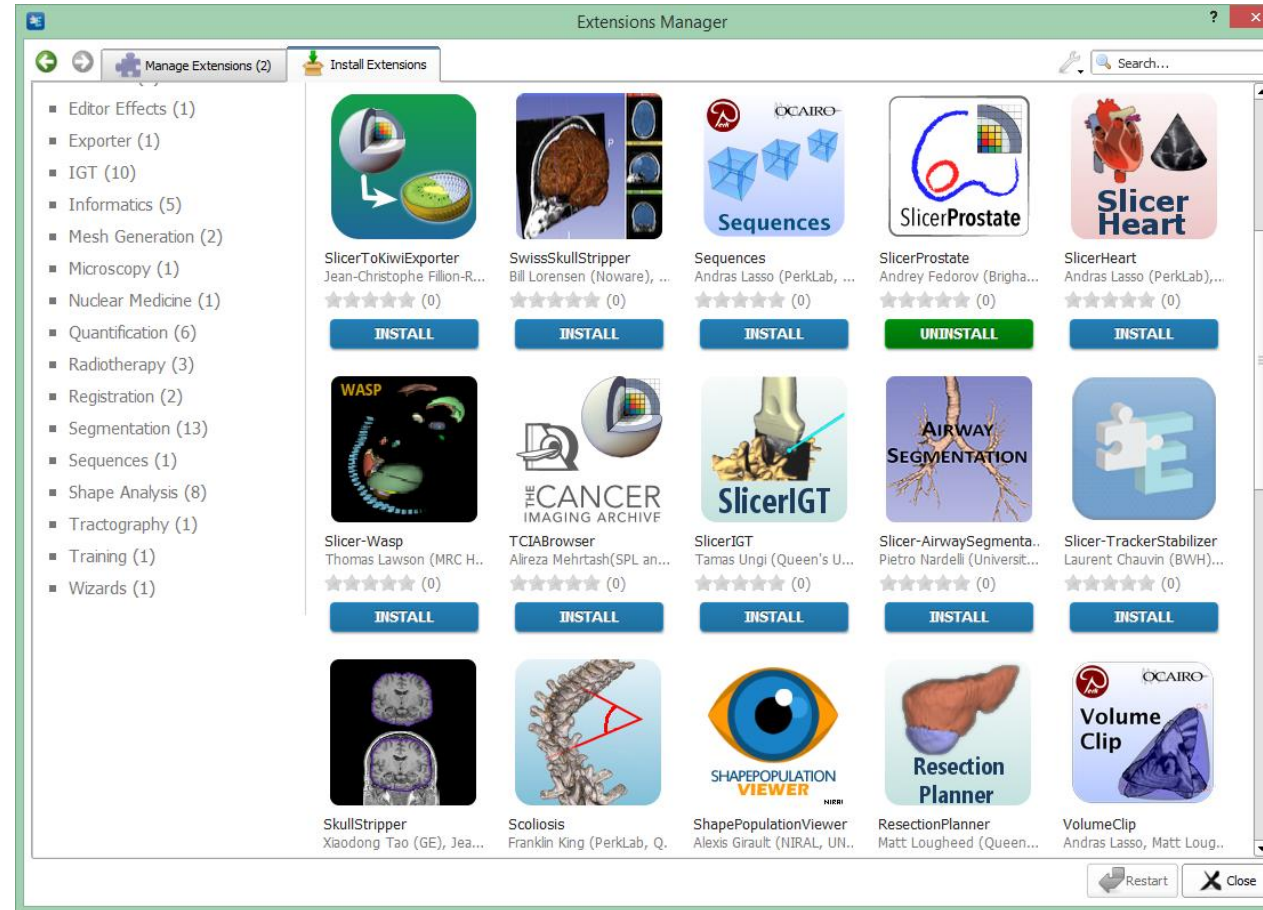
Load selected models

Data Probe

What's inside Slicer?

- **Slicer core:** Slicer GUI, I/O, visualization and developer interfaces
- **Slicer modules:** internal plugins that depend on the slicer core (e.g., Segmentation, Segment Editor)
- **Slicer extensions:** external plugins installed on-demand by the user (e.g., SlicerMorph, auto3Dgm)

Slicer is extensible



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

Benefit of open-source development

- Full access to analytic code enables transparency, and reproducibility
- Enables collaboration by recycling codes across different projects.
- Other can continue or contribute to the development
- It is a **pay-forward model**: i.e., you get free access to all the development that's already paid for over the years. That's why we managed to build SlicerMorph so quickly. If you need something additional, consider [hiring an independent developer](#), then share the result with the community. **Pls: This may cost less than single academic license of VG Studio Max, Avizo or Analyze.**
- It **SHOULD BE** particularly appealing for publicly funded projects.

But Slicer can't handle my datasets!!!

- Slicer is **only limited by the hardware capabilities of your system**:

Keep in mind:

- All operations in Slicer are done **in-memory**. I.e., you need to have quite a bit more memory than your dataset (more on this later). You can address this in two ways:
 1. Buy as much memory as your H/W will support (typically 64-128GB for i7 processors)
 2. Increase the virtual memory on your computer (everything will work but will be slower. Make sure the virtual/page memory set to run a fast NVMe or SSD disk).
- **For 3D rendering**, you need to have GPU that's capable of displaying large 3D texture dimensions and have lots of GPU memory (e.g., TITAN RTX will load datasets up to 24GB). A **2080TI** (about 1/3rd of price of TITAN) is more than sufficient for most mCT datasets.
- **Datasets are sacrosanct**, Slicer will NOT do anything to your data until you tell it to do explicitly (like automatically reducing intensity ranges to reduce memory footprint).

SlicerMorph vs 3D Slicer

SlicerMorph is our extension, as well as a customized version of 3D Slicer available for download independently. Its bundled with extension and additional extensions/modules we find that are useful for workflows around organismal biology. It contains:

1. Our SlicerMorph project specific modules

- Generalized Procrustes Analysis
- Bruker/Skyscan dataset import
- Morphologika/IDAV Landmark editor -> Slicer conversion
- Semi-Landmarks (template creation and transfer)

2. WIP modules from the 'SlicerMorph Labs' (that later graduate to #1)

- SlicerAnimator
- ImageStack import

3. Other extensions and modules that are not part of core 3D Slicer functions

- Image Guided Therapy Extension offers Fiducial (Landmark Registration)
- Sandbox offers Curved Planar Reformat (aka unbending) and RawImageGuess (to import undocumented data formats, e.g., from VGStudio Max)

Take Home Message

SLICER**MORPH** is not a traditional research project, but a chance to build a digital community of organismal biologists and quantitative morphologists around 3D Slicer that value open science and collaboration. We are looking forward to your engagement.

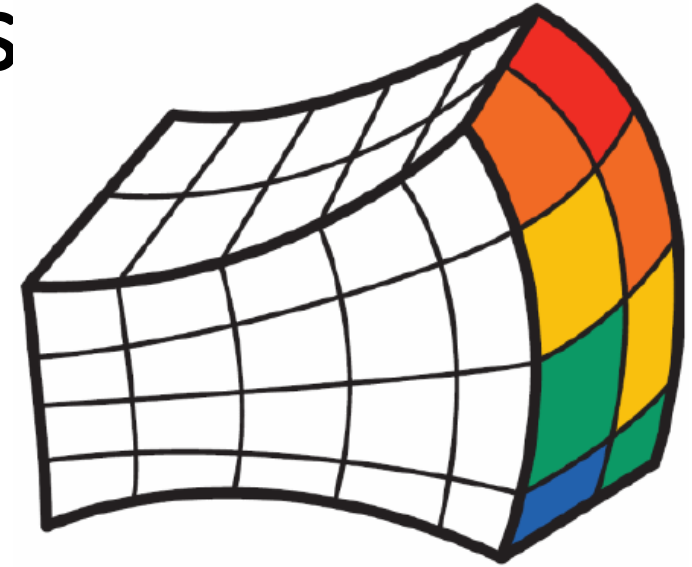
3D Slicer v5.0 (stable) will be released soon(ish)

- If you are a long-time Slicer user (particularly the stable 4.10.2). Expect these significant changes (already in the preview version).
 - Models and landmarks are saved in LPS coordinates (previously was RAS).
 - Non-landmark (fiducial) markups (e.g., curves, lines) default data format is now JSON (used to be fcsv). Landmarks are unchanged.
 - Existing SlicerDICOM databases will require a one-time upgrade.
 - Extension infrastructure is undergoing some H/W changes for the upcoming release and may have certain issues. If you do encounter issues, give it a couple try, at different times. Still not resolved? Post it on slicer forum.
 - Each night, entire Slicer project along with its 100+ extensions is rebuilt from scratch separately for Windows, Mac and Linux. This process may sometimes be delayed. Best time to download a new preview version of 3D Slicer for East Coast is typically after 12p.

Acknowledgements

Extended SlicerMorph Team

Sara Rolfe (UW/SCRI, Lead Developer)
Doug Boyer (Duke, SlicerMorph Co-PI)
Julie Winchester (Duke, MorphoSource)
Adam Summers (UW, SlicerMorph Co-PI)
Steve Pieper (Chief Software Architect of 3D Slicer)
Slicer Developer Community



SLICERMORPH

SlicerMorph Advisory Board

James Rohlf (Stony Brook University)
Dean Adams (Iowa State University)
David Polly (Indiana University)
Anjali Goswami (Natural History Museum, London)

Funding

NSF-Advances in Biological Informatics
Murat Maga (Seattle Children's): Award #1759883
Adam Summer (UW): Award #1759637
Doug Boyer (Duke University): Award #1759839