Interactive / Steered Registration

Steve Pieper
2nd Medical Image Registration Retreat
San Juan February 19, 2014

Topics

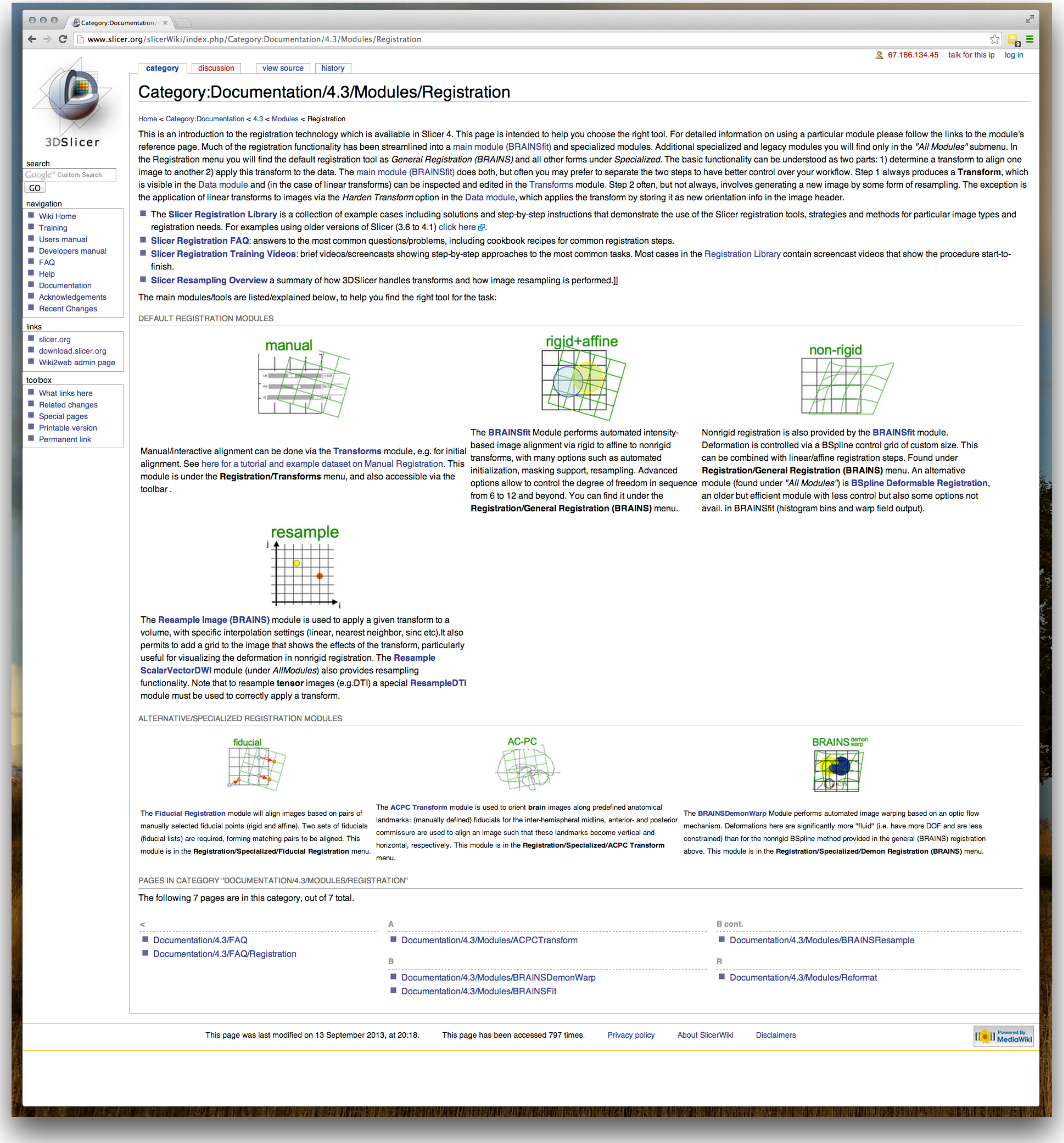
- 3D Slicer Registration Technologies
  - Current Implementations and Architecture
- Steered Registration
  - Goals and Works in Progress
- Clinical Applications and Active Projects
  - Examples of Unsolved Registration Problems

Isomics, Inc.

3D Slicer Registration Today

REGISTRATION

- Introduction to Registration (Dominik Meier)
- General Brainsfit Registration (Hans Johnson)
- Resample Image (BRAINS) (Hans Johnson)
- Specialized
  - ACPC Transform (Nicole Aucoin)
  - Demon Registration (BRAINS) (Hans Johnson)
  - Fiducial Registration (Stephen Aylward)
  - Vector Demon Registration (Hans Johnson)
  - Reformat (Michael Jeulin-Lagarrigue)
  - Segmentation Aided Registration (Yi Gao)



Category:Documentation/4.3/Modules/Registration

Home < Category:Documentation < 4.3 < Modules < Registration

This is an introduction to the registration technology which is available in Slicer 4. This page is intended to help you choose the right tool. For detailed information on using a particular module please follow the links to the module's reference page. Much of the registration functionality has been streamlined into a main module (BRAINSfit) and specialized modules. Additional specialized and legacy modules you will find only in the *"All Modules"* submenu. In the Registration menu you will find the default registration tool as *General Registration (BRAINS)* and all other forms under *Specialized*. The basic functionality can be understood as two parts: 1) determine a transform to align one image to another 2) apply this transform to the data. The main module (BRAINSfit) does both, but often you may prefer to separate the two steps to have better control over your workflow. Step 1 always produces a **Transform**, which is visible in the Data module and (in the case of linear transforms) can be inspected and edited in the Transforms module. Step 2 often, but not always, involves generating a new image by some form of resampling. The exception is the application of linear transforms to images via the *Harden Transform* option in the Data module, which applies the transform by storing it as new orientation info in the image header.

- The **Slicer Registration Library** is a collection of example cases including solutions and step-by-step instructions that demonstrate the use of the Slicer registration tools, strategies and methods for particular image types and registration needs. For examples using older versions of Slicer (3.6 to 4.1) click here.
- **Slicer Registration FAQ**: answers to the most common questions/problems, including cookbook recipes for common registration steps.
- **Slicer Registration Training Videos**: brief videos/screencasts showing step-by-step approaches to the most common tasks. Most cases in the Registration Library contain screencast videos that show the procedure start-to-finish.
- **Slicer Resampling Overview** a summary of how 3DSlicer handles transforms and how image resampling is performed.]]

The main modules/tools are listed/explained below, to help you find the right tool for the task:

DEFAULT REGISTRATION MODULES

Manual/interactive alignment can be done via the **Transforms** module, e.g. for initial alignment. See here for a tutorial and example dataset on Manual Registration. This module is under the **Registration/Transforms** menu, and also accessible via the toolbar .

The **BRAINSfit** Module performs automated intensity-based image alignment via rigid to affine to nonrigid transforms, with many options such as automated initialization, masking support, resampling. Advanced options allow to control the degree of freedom in sequence from 6 to 12 and beyond. You can find it under the **Registration/General Registration (BRAINS)** menu.

Nonrigid registration is also provided by the **BRAINSfit** module. Deformation is controlled via a BSpline control grid of custom size. This can be combined with linear/affine registration steps. Found under **Registration/General Registration (BRAINS)** menu. An alternative module (found under *"All Modules"*) is **BSpline Deformable Registration**, an older but efficient module with less control but also some options not avail. in BRAINSfit (histogram bins and warp field output).

The **Resample Image (BRAINS)** module is used to apply a given transform to a volume, with specific interpolation settings (linear, nearest neighbor, sinc etc).It also permits to add a grid to the image that shows the effects of the transform, particularly useful for visualizing the deformation in nonrigid registration. The **Resample ScalarVectorDWI** module (under *AllModules*) also provides resampling functionality. Note that to resample **tensor** images (e.g.DTI) a special **ResampleDTI** module must be used to correctly apply a transform.

ALTERNATIVE/SPECIALIZED REGISTRATION MODULES

The **Fiducial Registration** module will align images based on pairs of manually selected fiducial points (rigid and affine). Two sets of fiducials (fiducial lists) are required, forming matching pairs to be aligned. This module is in the **Registration/Specialized/Fiducial Registration** menu.

The **ACPC Transform** module is used to orient **brain** images along predefined anatomical landmarks: (manually defined) fiducials for the inter-hemispheral midline, anterior- and posterior commissure are used to align an image such that these landmarks become vertical and horizontal, respectively. This module is in the **Registration/Specialized/ACPC Transform** menu.

The **BRAINSDemonWarp** Module performs automated image warping based on an optic flow mechanism. Deformations here are significantly more "fluid" (i.e. have more DOF and are less constrained) than for the nonrigid BSpline method provided in the general (BRAINS) registration above. This module is in the **Registration/Specialized/Demon Registration (BRAINS)** menu.

PAGES IN CATEGORY "DOCUMENTATION/4.3/MODULES/REGISTRATION"

The following 7 pages are in this category, out of 7 total.

<

- Documentation/4.3/FAQ
- Documentation/4.3/FAQ/Registration

A

- Documentation/4.3/Modules/ACPCTransform

B

- Documentation/4.3/Modules/BRAINSDemonWarp
- Documentation/4.3/Modules/BRAINSFit

B cont.

- Documentation/4.3/Modules/BRAINSResample

R

- Documentation/4.3/Modules/Reformat

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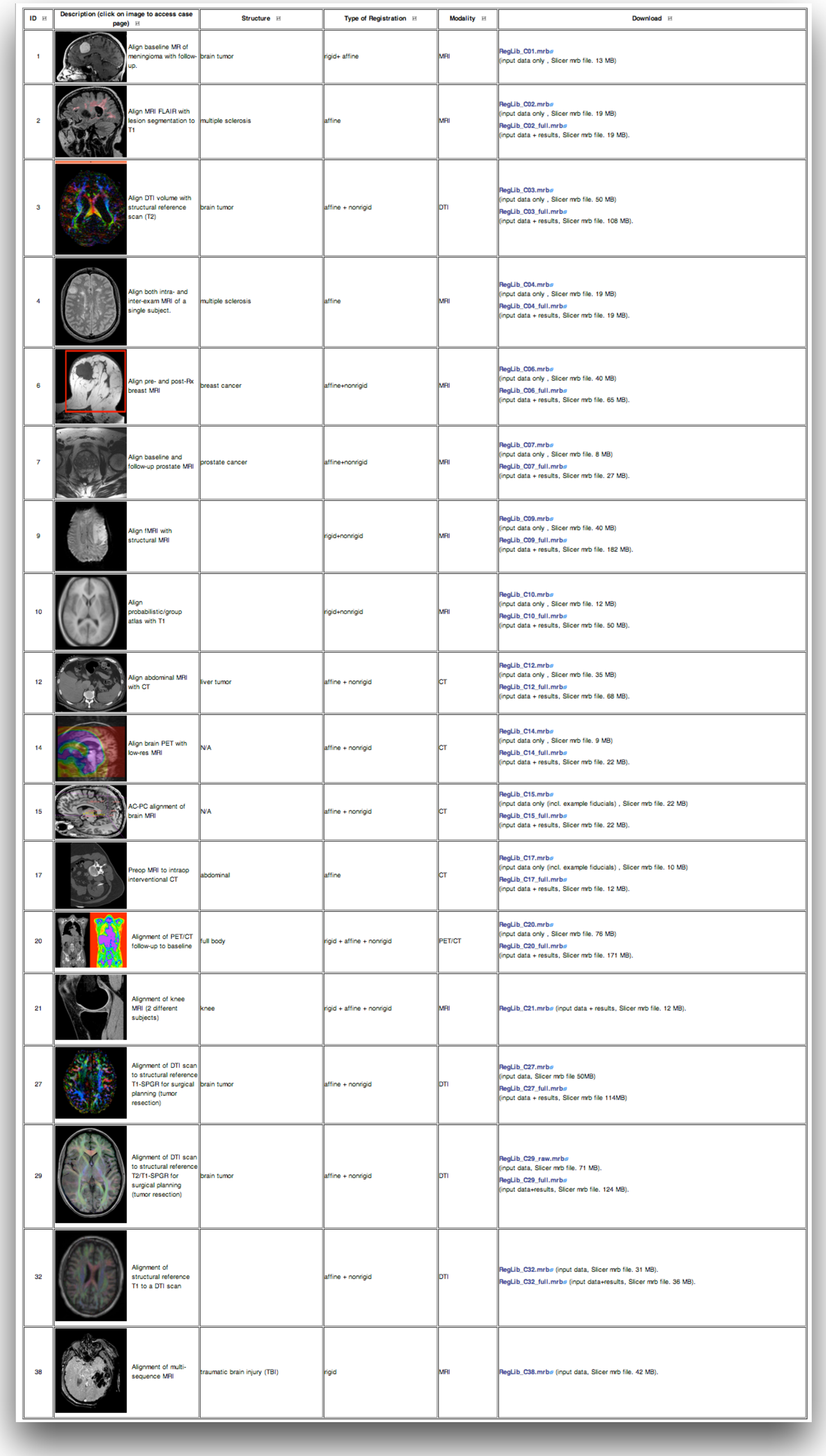
Special Thanks to Dominik Meier, BWH

Registration Use Case Library

- 38 Worked Out Examples
  - Cross-Modality, Cross-Subject, Longitudinal…
  - Linear, Nonlinear
  - Scalars, Vectors, Tensors
  - Brain, Breast, Prostate, Knee…
- All Data Provided as .mrb Scene Files

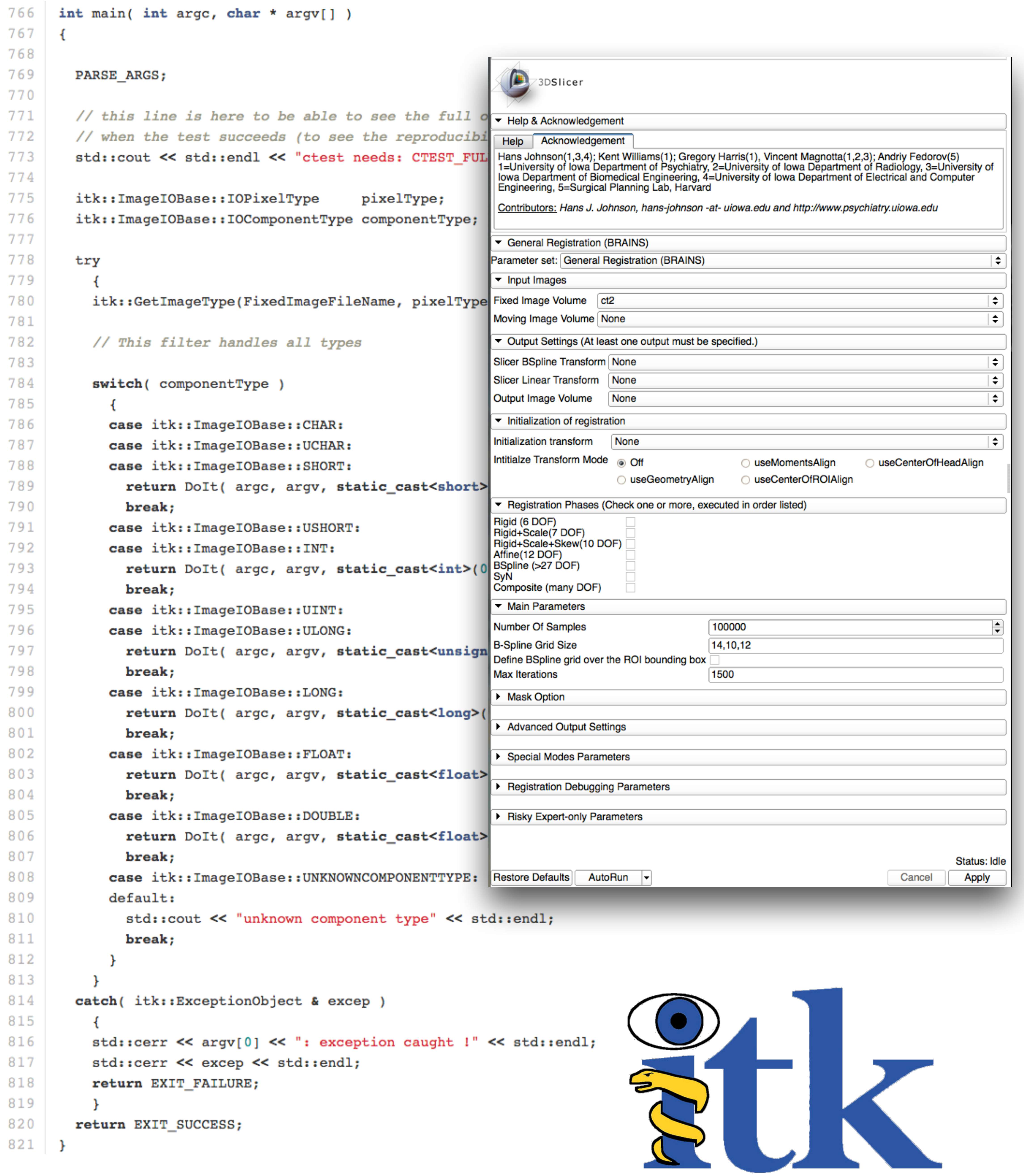


ID	Description (click on image to access case page)	Structure	Type of Registration	Modality	Download
1	Align baseline MR of meningioma with follow-up.	brain tumor	rigid+ affine	MRI	RegLib_C01.mrb (input data only , Slicer mrb file. 13 MB)
2	Align MRI FLAIR with lesion segmentation to T1	multiple sclerosis	affine	MRI	RegLib_C02.mrb (input data only , Slicer mrb file. 19 MB) RegLib_C02_full.mrb (input data + results, Slicer mrb file. 19 MB).
3	Align DTI volume with structural reference scan (T2)	brain tumor	affine + nonrigid	DTI	RegLib_C03.mrb (input data only , Slicer mrb file. 50 MB) RegLib_C03_full.mrb (input data + results, Slicer mrb file. 108 MB).
4	Align both intra- and inter-exam MRI of a single subject.	multiple sclerosis	affine	MRI	RegLib_C04.mrb (input data only , Slicer mrb file. 19 MB) RegLib_C04_full.mrb (input data + results, Slicer mrb file. 19 MB).
6	Align pre- and post-Rx breast MRI	breast cancer	affine+nonrigid	MRI	RegLib_C06.mrb (input data only , Slicer mrb file. 40 MB) RegLib_C06_full.mrb (input data + results, Slicer mrb file. 65 MB).
7	Align baseline and follow-up prostate MRI	prostate cancer	affine+nonrigid	MRI	RegLib_C07.mrb (input data only , Slicer mrb file. 8 MB) RegLib_C07_full.mrb (input data + results, Slicer mrb file. 27 MB).
9	Align fMRI with structural MRI		rigid+nonrigid	MRI	RegLib_C09.mrb (input data only , Slicer mrb file. 40 MB) RegLib_C09_full.mrb (input data + results, Slicer mrb file. 182 MB).
10	Align probabilistic/group atlas with T1		rigid+nonrigid	MRI	RegLib_C10.mrb (input data only , Slicer mrb file. 12 MB) RegLib_C10_full.mrb (input data + results, Slicer mrb file. 50 MB).
12	Align abdominal MRI with CT	liver tumor	affine + nonrigid	CT	RegLib_C12.mrb (input data only , Slicer mrb file. 35 MB) RegLib_C12_full.mrb (input data + results, Slicer mrb file. 68 MB).
14	Align brain PET with low-res MRI	N/A	affine + nonrigid	CT	RegLib_C14.mrb (input data only , Slicer mrb file. 9 MB) RegLib_C14_full.mrb (input data + results, Slicer mrb file. 22 MB).
15	AC-PC alignment of brain MRI	N/A	affine + nonrigid	CT	RegLib_C15.mrb (input data only (incl. example fiducials) , Slicer mrb file. 22 MB) RegLib_C15_full.mrb (input data + results, Slicer mrb file. 22 MB).
17	Preop MRI to intraop interventional CT	abdominal	affine	CT	RegLib_C17.mrb (input data only (incl. example fiducials) , Slicer mrb file. 10 MB) RegLib_C17_full.mrb (input data + results, Slicer mrb file. 12 MB).
20	Alignment of PET/CT follow-up to baseline	full body	rigid + affine + nonrigid	PET/CT	RegLib_C20.mrb (input data only , Slicer mrb file. 76 MB) RegLib_C20_full.mrb (input data + results, Slicer mrb file. 171 MB).
21	Alignment of knee MRI (2 different subjects)	knee	rigid + affine + nonrigid	MRI	RegLib_C21.mrb (input data + results, Slicer mrb file. 12 MB).
27	Alignment of DTI scan to structural reference T1-SPGR for surgical planning (tumor resection)	brain tumor	affine + nonrigid	DTI	RegLib_C27.mrb (input data, Slicer mrb file 50MB) RegLib_C27_full.mrb (input data + results, Slicer mrb file 114MB)
29	Alignment of DTI scan to structural reference T2/T1-SPGR for surgical planning (tumor resection)	brain tumor	affine + nonrigid	DTI	RegLib_C29_raw.mrb (input data, Slicer mrb file. 71 MB). RegLib_C29_full.mrb (input data+results, Slicer mrb file. 124 MB).
32	Alignment of structural reference T1 to a DTI scan		affine + nonrigid	DTI	RegLib_C32.mrb (input data, Slicer mrb file. 31 MB). RegLib_C32_full.mrb (input data+results, Slicer mrb file. 36 MB).
38	Alignment of multi-sequence MRI	traumatic brain injury (TBI)	rigid	MRI	RegLib_C38.mrb (input data, Slicer mrb file. 42 MB).

Special Thanks to Dominik Meier, BWH

Registration Implementation

- Command Line Interface Modules (CLI)
    - Written with “main(argc, argv)” style, but can be compiled to shared libraries with pointer access to image data
    - Standardized argument syntax and automatic GUI generation
    - “Pipleline” style autorun on changes to input data or parameters
- Leverages ITK
    - 1.5 Million Lines of Code
    - 14 Calendar Years
    - 454 Years of Effort (ohloh.net/p/itk)



```
int main( int argc, char * argv[] )
{

  PARSE_ARGS;

  // this line is here to be able to see the full o
  // when the test succeeds (to see the reproducibi
  std::cout << std::endl << "ctest needs: CTEST_FUL

  itk::ImageIOBase::IOPixelType     pixelType;
  itk::ImageIOBase::IOComponentType componentType;

  try
    {
    itk::GetImageType(FixedImageFileName, pixelType

    // This filter handles all types

    switch( componentType )
      {
      case itk::ImageIOBase::CHAR:
      case itk::ImageIOBase::UCHAR:
      case itk::ImageIOBase::SHORT:
        return DoIt( argc, argv, static_cast<short>
        break;
      case itk::ImageIOBase::USHORT:
      case itk::ImageIOBase::INT:
        return DoIt( argc, argv, static_cast<int>(0
        break;
      case itk::ImageIOBase::UINT:
      case itk::ImageIOBase::ULONG:
        return DoIt( argc, argv, static_cast<unsign
        break;
      case itk::ImageIOBase::LONG:
        return DoIt( argc, argv, static_cast<long>(
        break;
      case itk::ImageIOBase::FLOAT:
        return DoIt( argc, argv, static_cast<float>
        break;
      case itk::ImageIOBase::DOUBLE:
        return DoIt( argc, argv, static_cast<float>
        break;
      case itk::ImageIOBase::UNKNOWNCOMPONENTTYPE:
      default:
        std::cout << "unknown component type" << std::endl;
        break;
      }
    }
  catch( itk::ExceptionObject & excep )
    {
    std::cerr << argv[0] << ": exception caught !" << std::endl;
    std::cerr << excep << std::endl;
    return EXIT_FAILURE;
    }
  return EXIT_SUCCESS;
}
```

3DSlicer

▾ Help & Acknowledgement

Help | Acknowledgement

Hans Johnson(1,3,4); Kent Williams(1); Gregory Harris(1), Vincent Magnotta(1,2,3); Andriy Fedorov(5)
1=University of Iowa Department of Psychiatry, 2=University of Iowa Department of Radiology, 3=University of Iowa Department of Biomedical Engineering, 4=University of Iowa Department of Electrical and Computer Engineering, 5=Surgical Planning Lab, Harvard

Contributors: *Hans J. Johnson, hans-johnson -at- uiowa.edu and http://www.psychiatry.uiowa.edu*

▾ General Registration (BRAINS)

Parameter set: General Registration (BRAINS)

▾ Input Images

Fixed Image Volume: ct2
Moving Image Volume: None

▾ Output Settings (At least one output must be specified.)

Slicer BSpline Transform: None
Slicer Linear Transform: None
Output Image Volume: None

▾ Initialization of registration

Initialization transform: None
Intitialze Transform Mode: ● Off ○ useMomentsAlign ○ useCenterOfHeadAlign ○ useGeometryAlign ○ useCenterOfROIAlign

▾ Registration Phases (Check one or more, executed in order listed)

Rigid (6 DOF) □
Rigid+Scale(7 DOF) □
Rigid+Scale+Skew(10 DOF) □
Affine(12 DOF) □
BSpline (>27 DOF) □
SyN □
Composite (many DOF) □

▾ Main Parameters

Number Of Samples: 100000
B-Spline Grid Size: 14,10,12
Define BSpline grid over the ROI bounding box □
Max Iterations: 1500

▸ Mask Option

▸ Advanced Output Settings

▸ Special Modes Parameters

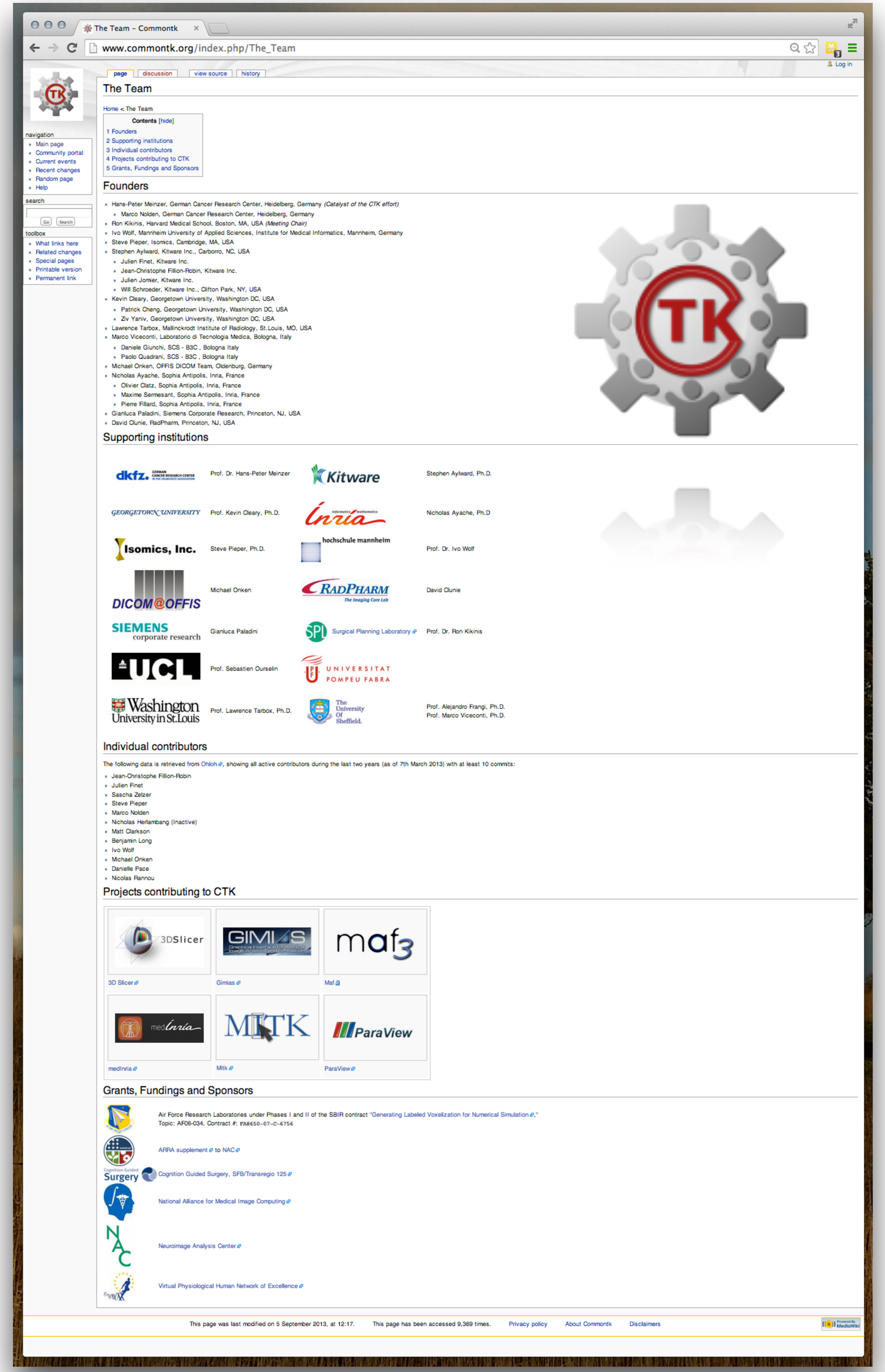
▸ Registration Debugging Parameters

▸ Risky Expert-only Parameters

Status: Idle

Common Toolkit
CTK

- Multinational Team of Likeminded Developers
  - DICOM, Visualization, IGT, Software Engineering…
  - Decades of Experience in Package Development
  - Multiyear History of Collaborative Development
- CTK has Adopted Slicer CLIs for Interoperability



The Team

Home < The Team

Contents [hide]

Founders

- Hans-Peter Meinzer, German Cancer Research Center, Heidelberg, Germany *(Catalyst of the CTK effort)*
  - Marco Nolden, German Cancer Research Center, Heidelberg, Germany
- Ron Kikinis, Harvard Medical School, Boston, MA, USA *(Meeting Chair)*
- Ivo Wolf, Mannheim University of Applied Sciences, Institute for Medical Informatics, Mannheim, Germany
- Steve Pieper, Isomics, Cambridge, MA, USA
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- Gianluca Paladini, Siemens Corporate Research, Princeton, NJ, USA
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Individual contributors

The following data is retrieved from Ohloh, showing all active contributors during the last two years (as of 7th March 2013) with at least 10 commits:

- Jean-Christophe Fillion-Robin
- Julien Finet
- Sascha Zelzer
- Steve Pieper
- Marco Nolden
- Nicholas Herlambang (Inactive)
- Matt Clarkson
- Benjamin Long
- Ivo Wolf
- Michael Onken
- Danielle Pace
- Nicolas Rannou

Projects contributing to CTK

3DSlicer
GIMIAS Graphical Interface for Medical Image Analysis and Simulation
maf3
medInria
MITK
ParaView

3D Slicer	Gimias	Maf
medInria	Mitk	ParaView

Grants, Fundings and Sponsors

Air Force Research Laboratories under Phases I and II of the SBIR contract "Generating Labeled Voxelization for Numerical Simulation,"
Topic: AF06-034, Contract #: FA8650-07-C-6756

ARRA supplement to NAC

Cognition Guided Surgery, SFB/Transregio 125

National Alliance for Medical Image Computing

Neuroimage Analysis Center

Virtual Physiological Human Network of Excellence

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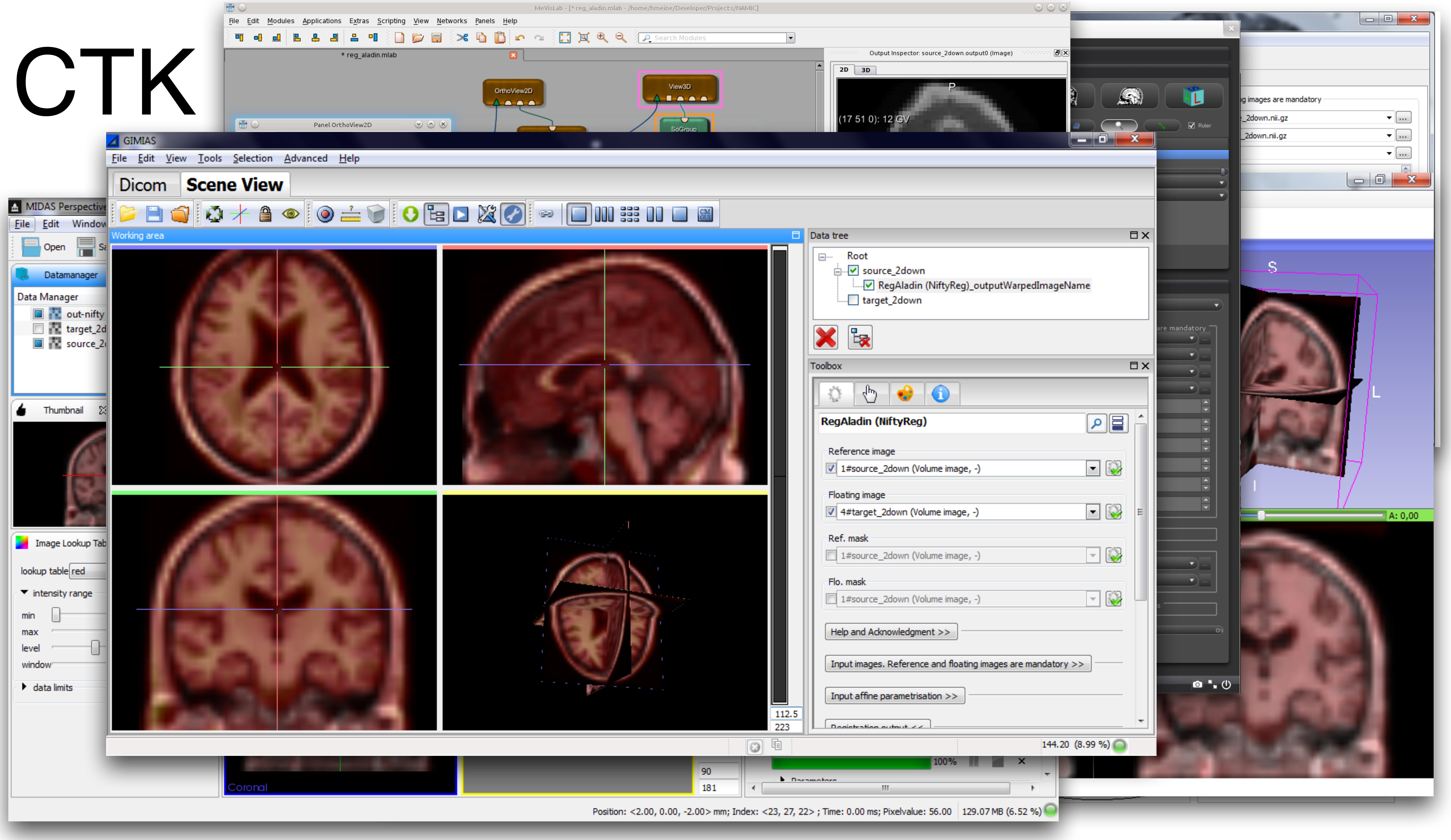
CTK



(17 51 0): 12 GV

Reference image: ☑ 1#source_2down (Volume image, -)

Floating image: ☑ 4#target_2down (Volume image, -)

Ref. mask: □ 1#source_2down (Volume image, -)

Flo. mask: □ 1#source_2down (Volume image, -)

lookup table red

112.5

223

90

181

100%

A: 0,00

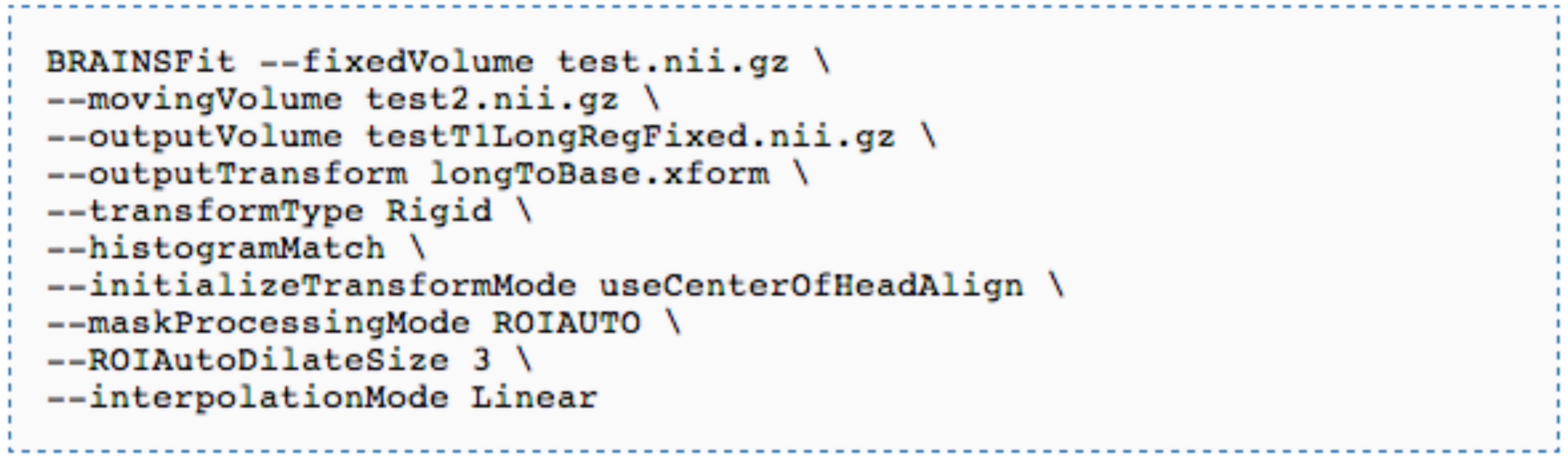
144.20 (8.99 %)

Position: <2.00, 0.00, -2.00> mm; Index: <23, 27, 22> ; Time: 0.00 ms; Pixelvalue: 56.00   129.07 MB (6.52 %)

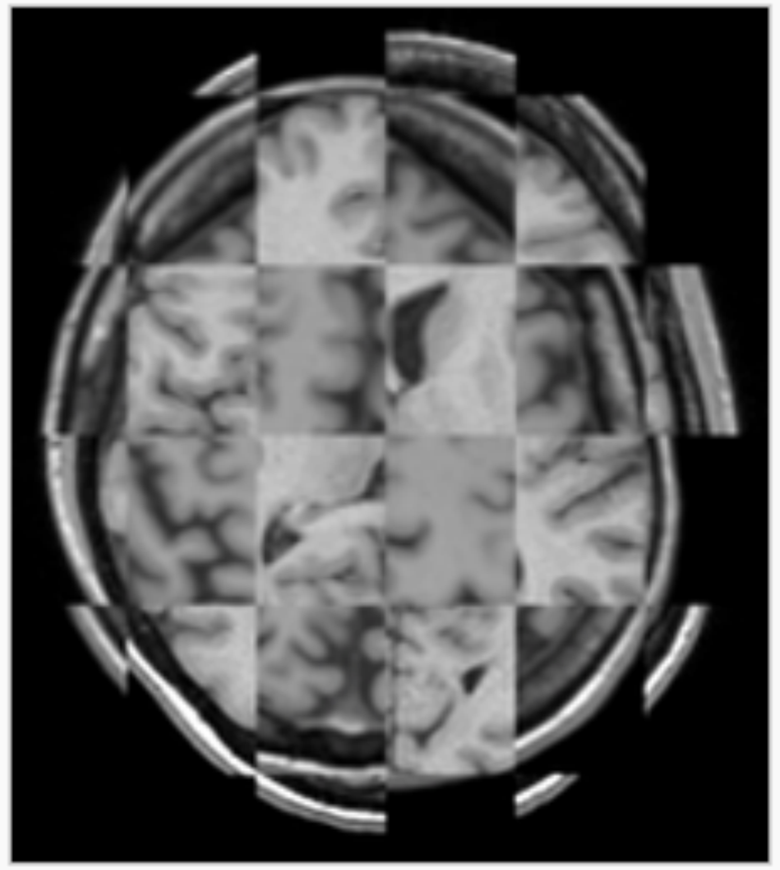
BRAINSFit

THE UNIVERSITY OF IOWA

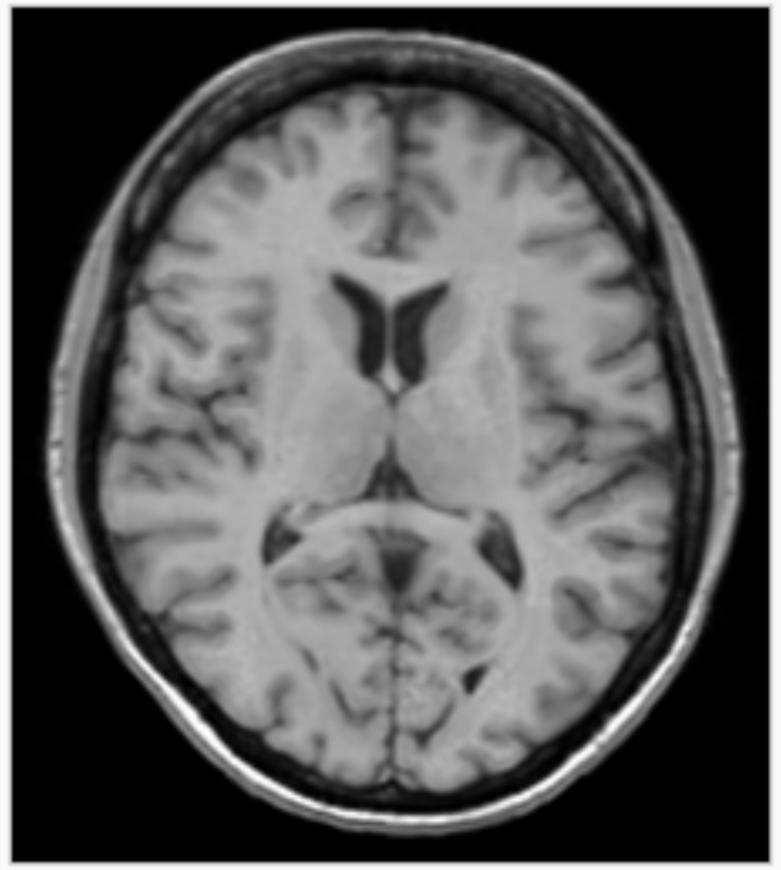
- De Facto Standard Slicer Registration CLI
  - Initializations: Transform, CenterOfHead, CenterOfROI, Moments, Geometry, Histogram Match
  - Transforms: Rigid, ScaleVersor, ScaleSkewVersor, Affine, BSpline, Symmetric Diffeomorphic (SyN), Composite
  - Dozens of Other Parameters
    - Normal Ones
    - Risky Ones
- Uses Range from Psychiatry to Prostate Biopsy



```
BRAINSFit --fixedVolume test.nii.gz \
--movingVolume test2.nii.gz \
--outputVolume testT1LongRegFixed.nii.gz \
--outputTransform longToBase.xform \
--transformType Rigid \
--histogramMatch \
--initializeTransformMode useCenterOfHeadAlign \
--maskProcessingMode ROIAUTO \
--ROIAutoDilateSize 3 \
--interpolationMode Linear
```



Longitudinal Checkerboard
Before registration

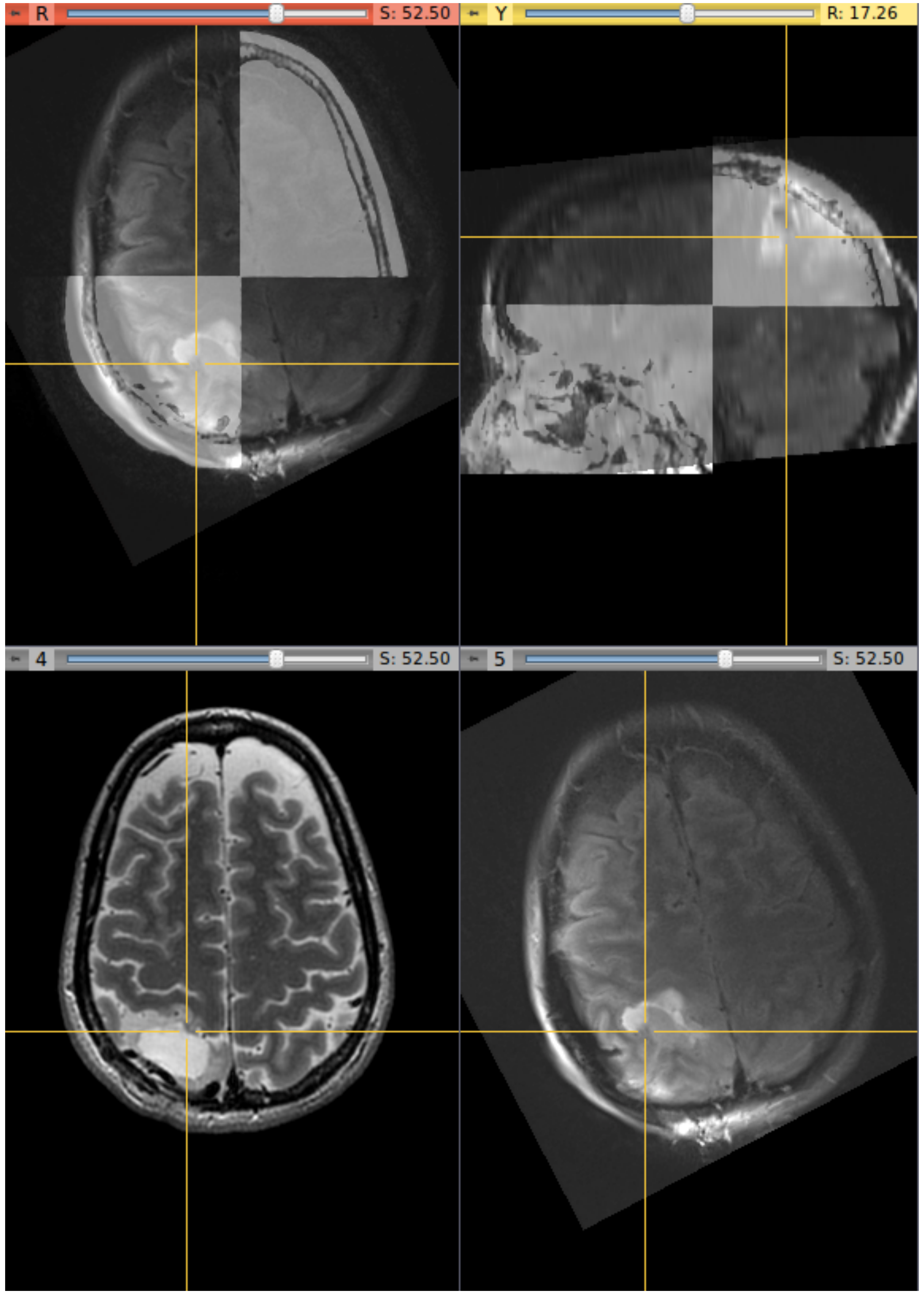


Longitudinal Checkerboard
After registration

So What’s Wrong with Registration Algorithms?

So What's Wrong with Registration Algorithms?

- Algorithms Don't Understand the Images
  - What to ignore
  - How the images were obtained
  - What was imaged
- Too Slow
  - Should be essentially instantaneous
- Hard to Tell if the Answer is Right
  - Requires visual inspection
- Too Many Parameters
  - Parameters are the last refuge of an algorithm developer*
  - If the answer is wrong, which parameter to change?

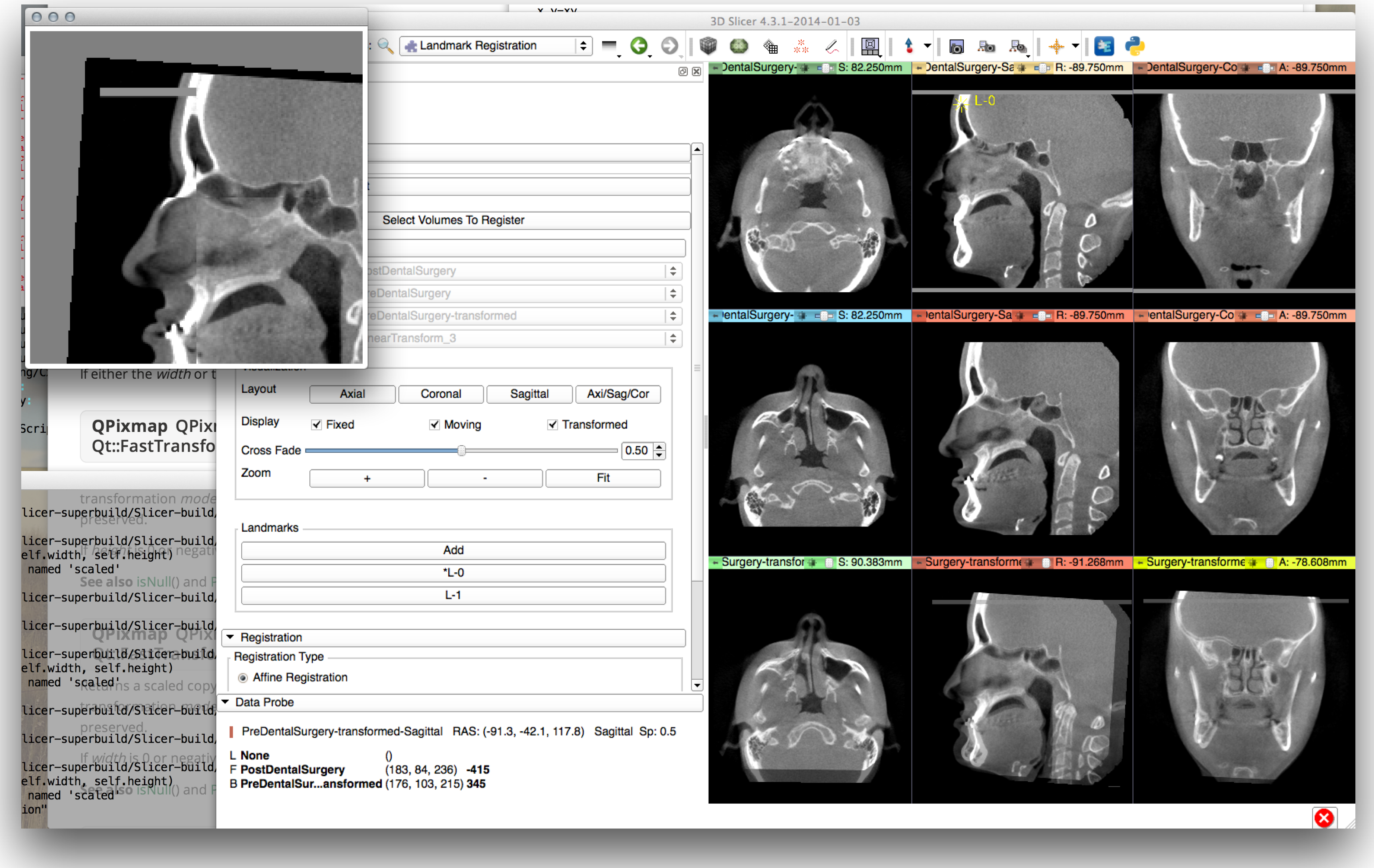


Preprocedure MR (bottom left) and intraprocedure MR (bottom right) after rigid registration. Data Courtesy Dr. Alexandra Golby.

* Apologies to Samuel Johnson

What can be done?

- Reach in and Grab It!
  - Tell the algorithm what parts should line up
  - Tell it what to ignore
  - Pin down the parts that are right and let the algorithm figure out the rest
- Fast Detailed Inspection Tools
  - Need to review anyway, so fix it at the same time
  - See the 3D deformation
- Learn from the Fixes
  - Use manual corrections to adjust parameters
  - “Task Level Control”
- Goal: Integrate the Parameter Setting and Quality Assurance Review Steps into the Algorithm Itself



Display ☑ Fixed ☑ Moving ☑ Transformed

Cross Fade 0.50

Zoom + - Fit

Landmarks: *L-0, L-1

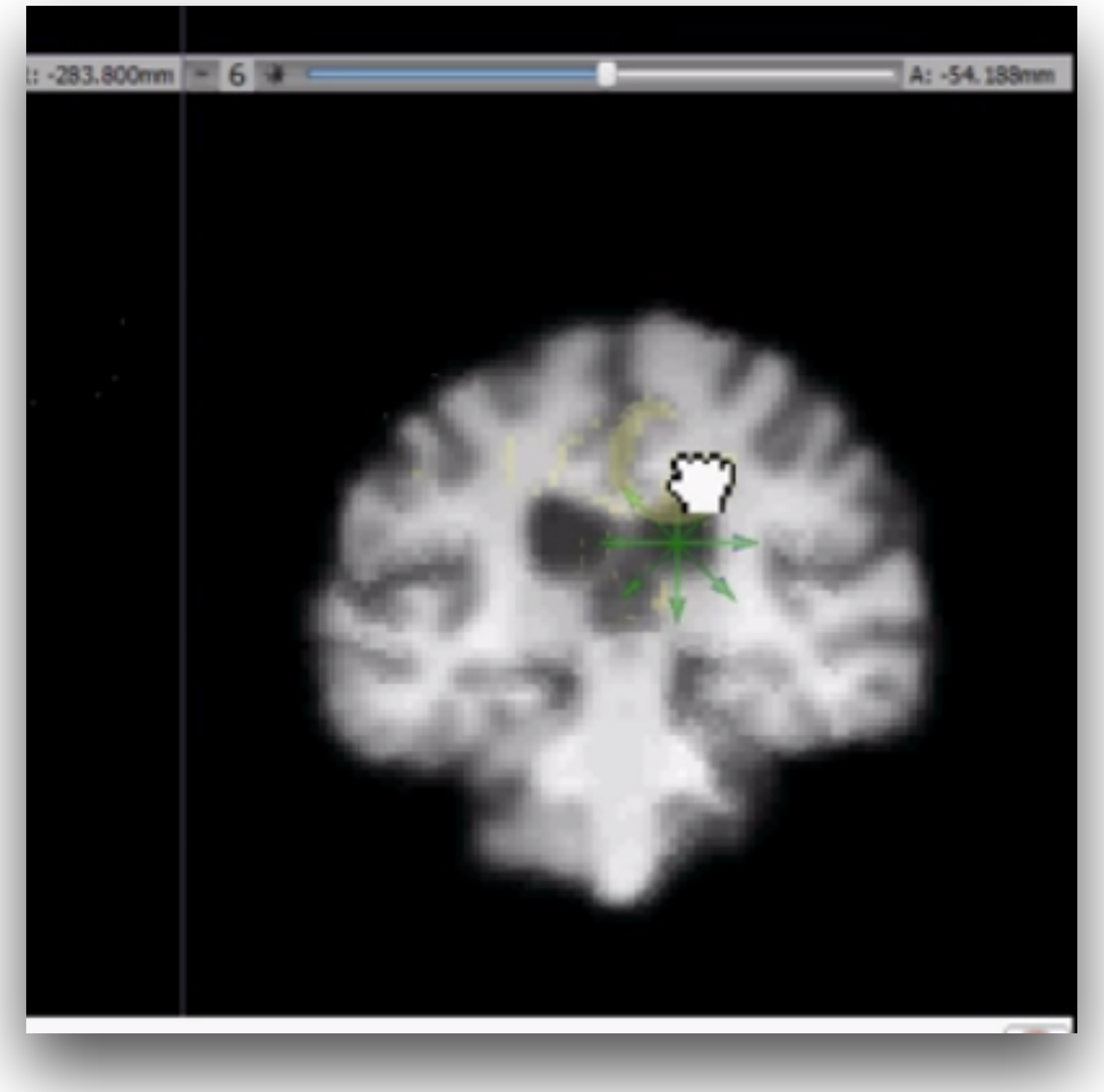
Registration Type: ● Affine Registration

PreDentalSurgery-transformed-Sagittal RAS: (-91.3, -42.1, 117.8) Sagittal Sp: 0.5

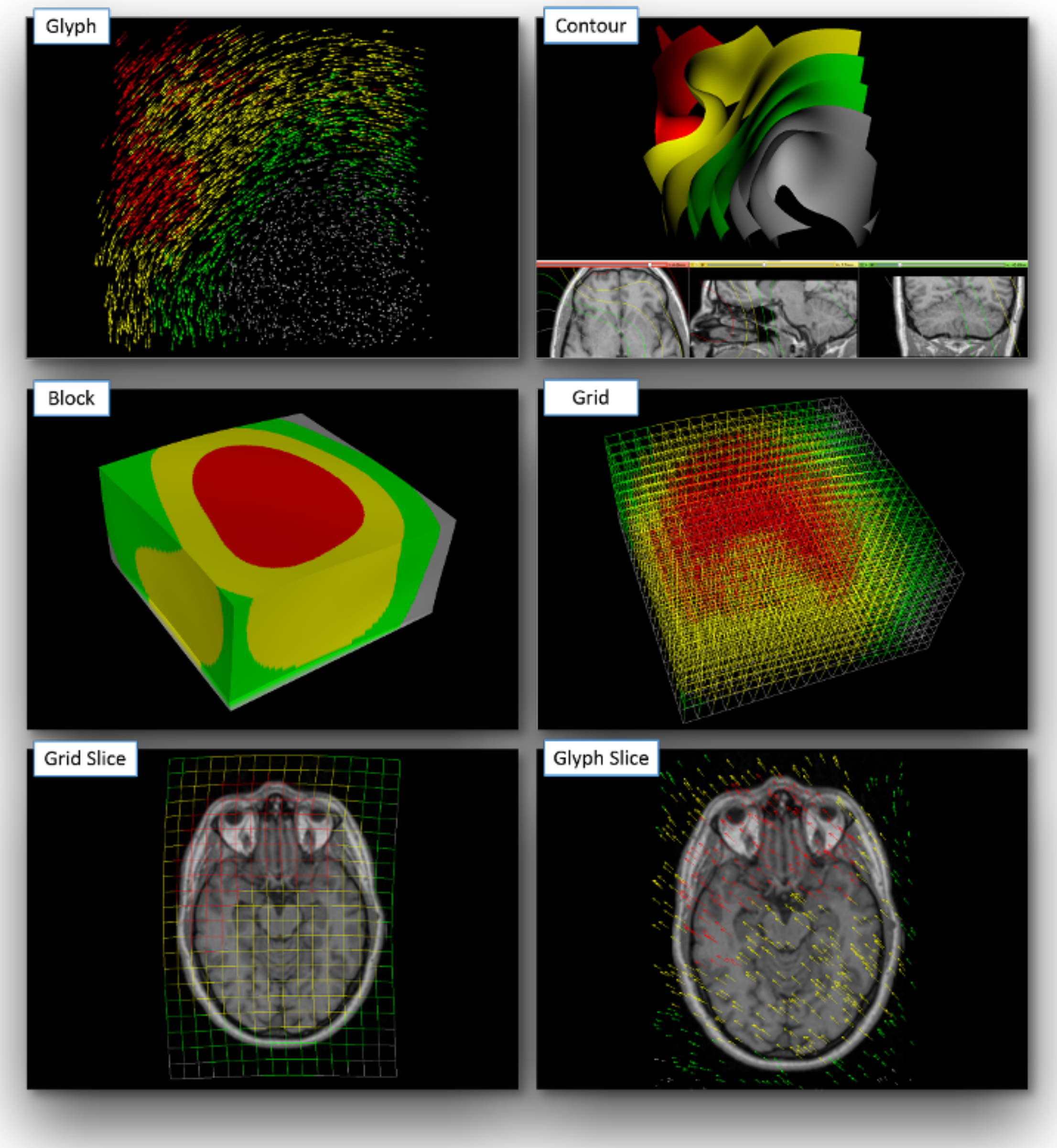
L None ()
F PostDentalSurgery (183, 84, 236) -415
B PreDentalSur...ansformed (176, 103, 215) 345

Landmark Registration: Pieper

Work in Progress



Registration Gestures: Prastawa, Miller



Transform Visualizer: King, SlicerRT

What can be done?

Visualization

Control

Automation

Steered Registration Goals

Visualization

- Data Fusion Tools
  - Color, Overlays, Crossfades, Animations
  - Interactive Inspection
- 3D Slice Plane Visualization
- Volume Rendering
  - Multiple Volume
  - Incorporating Nonlinear Transforms
  - Real Time
  - Interactive Data Fusion

Control

- Precise Placement
  - Reviewable
  - Editable
  - Undo/Redoable
- Native 3D Control
  - Optimal use of human eye hand coordination and spatial skills
  - Hand tracking, haptics…
- More than Just Points
  - Local Orientation
  - Surface Matching

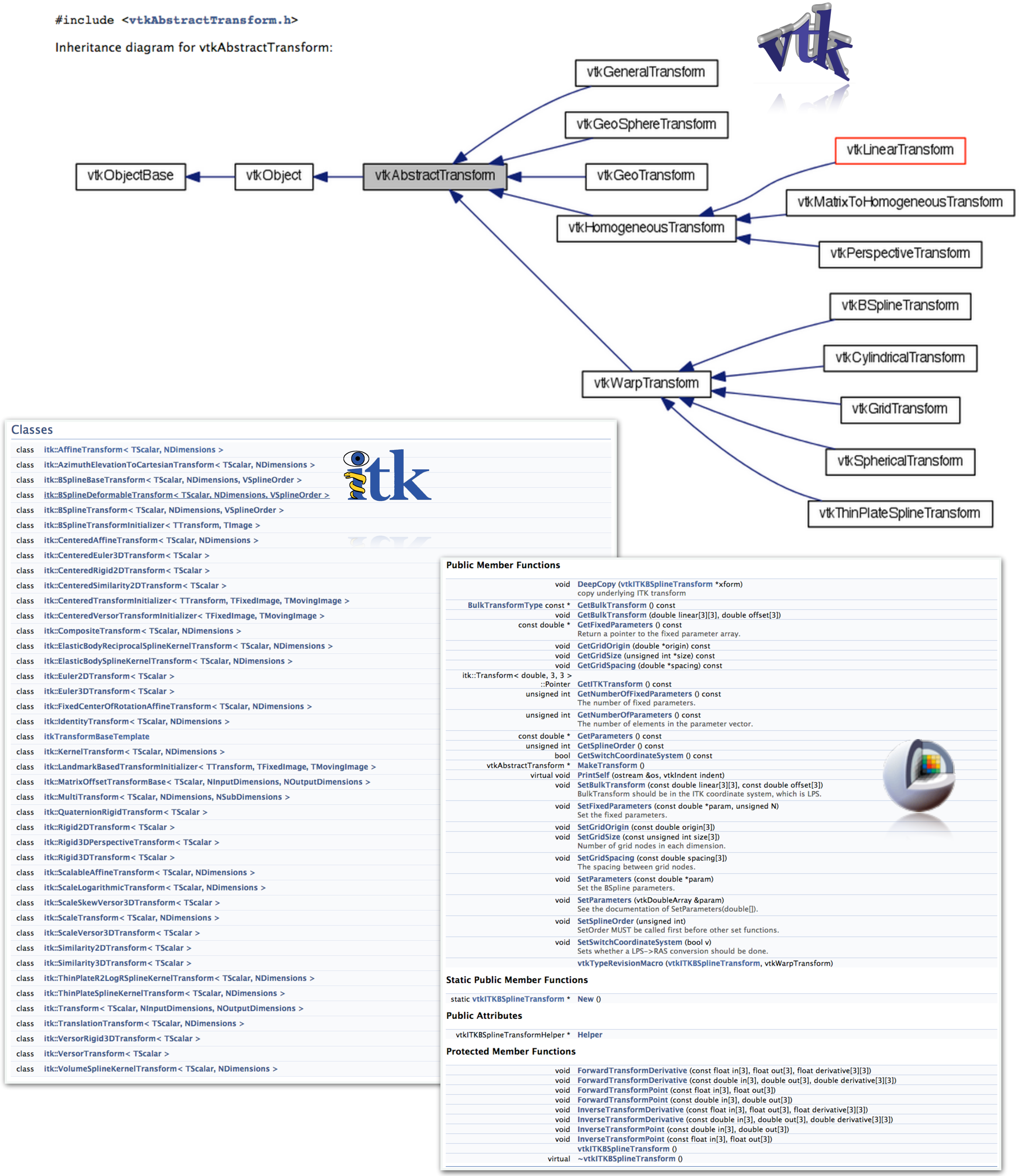
Automation

- Simplify Input
  - Interpret control in terms of current transformation
  - Snap to right answer
  - Extrapolate input (“zipper”)
- Learn from Input
  - Adjust optimization metrics based on user input so far
  - Learn from previous QC data
- Expose (Un)certainty
  - Identify local minima as needing QC

What is being done?

Software Support for Steered Registration

- VTK
  - PRO: Rich set of transform types closely integrated with visualization pipelines and vtkImageReslice
  - PRO: Very interactive by design
  - CON: No nonlinear transforms in volume rendering
- ITK
  - PRO: Rich set of algorithms
  - CON: Optimizers not set up for interaction
- vtkITK
  - PRO: Provides glue to expose ITK classes in VTK Pipelines
  - CON: Complex and imperfect match of pipelines



```
#include <vtkAbstractTransform.h>
```

Inheritance diagram for vtkAbstractTransform:

Classes

class	itk::AffineTransform< TScalar, NDimensions >
class	itk::AzimuthElevationToCartesianTransform< TScalar, NDimensions >
class	itk::BSplineBaseTransform< TScalar, NDimensions, VSplineOrder >
class	itk::BSplineDeformableTransform< TScalar, NDimensions, VSplineOrder >
class	itk::BSplineTransform< TScalar, NDimensions, VSplineOrder >
class	itk::BSplineTransformInitializer< TTransform, TImage >
class	itk::CenteredAffineTransform< TScalar, NDimensions >
class	itk::CenteredEuler3DTransform< TScalar >
class	itk::CenteredRigid2DTransform< TScalar >
class	itk::CenteredSimilarity2DTransform< TScalar >
class	itk::CenteredTransformInitializer< TTransform, TFixedImage, TMovingImage >
class	itk::CenteredVersorTransformInitializer< TFixedImage, TMovingImage >
class	itk::CompositeTransform< TScalar, NDimensions >
class	itk::ElasticBodyReciprocalSplineKernelTransform< TScalar, NDimensions >
class	itk::ElasticBodySplineKernelTransform< TScalar, NDimensions >
class	itk::Euler2DTransform< TScalar >
class	itk::Euler3DTransform< TScalar >
class	itk::FixedCenterOfRotationAffineTransform< TScalar, NDimensions >
class	itk::IdentityTransform< TScalar, NDimensions >
class	itkTransformBaseTemplate
class	itk::KernelTransform< TScalar, NDimensions >
class	itk::LandmarkBasedTransformInitializer< TTransform, TFixedImage, TMovingImage >
class	itk::MatrixOffsetTransformBase< TScalar, NInputDimensions, NOutputDimensions >
class	itk::MultiTransform< TScalar, NDimensions, NSubDimensions >
class	itk::QuaternionRigidTransform< TScalar >
class	itk::Rigid2DTransform< TScalar >
class	itk::Rigid3DPerspectiveTransform< TScalar >
class	itk::Rigid3DTransform< TScalar >
class	itk::ScalableAffineTransform< TScalar, NDimensions >
class	itk::ScaleLogarithmicTransform< TScalar, NDimensions >
class	itk::ScaleSkewVersor3DTransform< TScalar >
class	itk::ScaleTransform< TScalar, NDimensions >
class	itk::ScaleVersor3DTransform< TScalar >
class	itk::Similarity2DTransform< TScalar >
class	itk::Similarity3DTransform< TScalar >
class	itk::ThinPlateR2LogRSplineKernelTransform< TScalar, NDimensions >
class	itk::ThinPlateSplineKernelTransform< TScalar, NDimensions >
class	itk::Transform< TScalar, NInputDimensions, NOutputDimensions >
class	itk::TranslationTransform< TScalar, NDimensions >
class	itk::VersorRigid3DTransform< TScalar >
class	itk::VersorTransform< TScalar >
class	itk::VolumeSplineKernelTransform< TScalar, NDimensions >

Public Member Functions

void	DeepCopy (vtkITKBSplineTransform *xform) copy underlying ITK transform
BulkTransformType const *	GetBulkTransform () const
void	GetBulkTransform (double linear[3][3], double offset[3])
const double *	GetFixedParameters () const Return a pointer to the fixed parameter array.
void	GetGridOrigin (double *origin) const
void	GetGridSize (unsigned int *size) const
void	GetGridSpacing (double *spacing) const
itk::Transform< double, 3, 3 > ::Pointer	GetITKTransform () const
unsigned int	GetNumberOfFixedParameters () const The number of fixed parameters.
unsigned int	GetNumberOfParameters () const The number of elements in the parameter vector.
const double *	GetParameters () const
unsigned int	GetSplineOrder () const
bool	GetSwitchCoordinateSystem () const
vtkAbstractTransform *	MakeTransform ()
virtual void	PrintSelf (ostream &os, vtkIndent indent)
void	SetBulkTransform (const double linear[3][3], const double offset[3]) BulkTransform should be in the ITK coordinate system, which is LPS.
void	SetFixedParameters (const double *param, unsigned N) Set the fixed parameters.
void	SetGridOrigin (const double origin[3])
void	SetGridSize (const unsigned int size[3]) Number of grid nodes in each dimension.
void	SetGridSpacing (const double spacing[3]) The spacing between grid nodes.
void	SetParameters (const double *param) Set the BSpline parameters.
void	SetParameters (vtkDoubleArray &param) See the documentation of SetParameters(double[]).
void	SetSplineOrder (unsigned int) SetOrder MUST be called first before other set functions.
void	SetSwitchCoordinateSystem (bool v) Sets whether a LPS->RAS conversion should be done.
	vtkTypeRevisionMacro (vtkITKBSplineTransform, vtkWarpTransform)

Static Public Member Functions

static vtkITKBSplineTransform *	New ()

Public Attributes

vtkITKBSplineTransformHelper *	Helper

Protected Member Functions

void	ForwardTransformDerivative (const float in[3], float out[3], float derivative[3][3])
void	ForwardTransformDerivative (const double in[3], double out[3], double derivative[3][3])
void	ForwardTransformPoint (const float in[3], float out[3])
void	ForwardTransformPoint (const double in[3], double out[3])
void	InverseTransformDerivative (const float in[3], float out[3], float derivative[3][3])
void	InverseTransformDerivative (const double in[3], double out[3], double derivative[3][3])
void	InverseTransformPoint (const double in[3], double out[3])
void	InverseTransformPoint (const float in[3], float out[3])
	vtkITKBSplineTransform ()
virtual	~vtkITKBSplineTransform ()

MRML Registration Infrastructure

vtkMRMLTransformableNode Class Reference

MRML node for representing a node with a tranform. More...

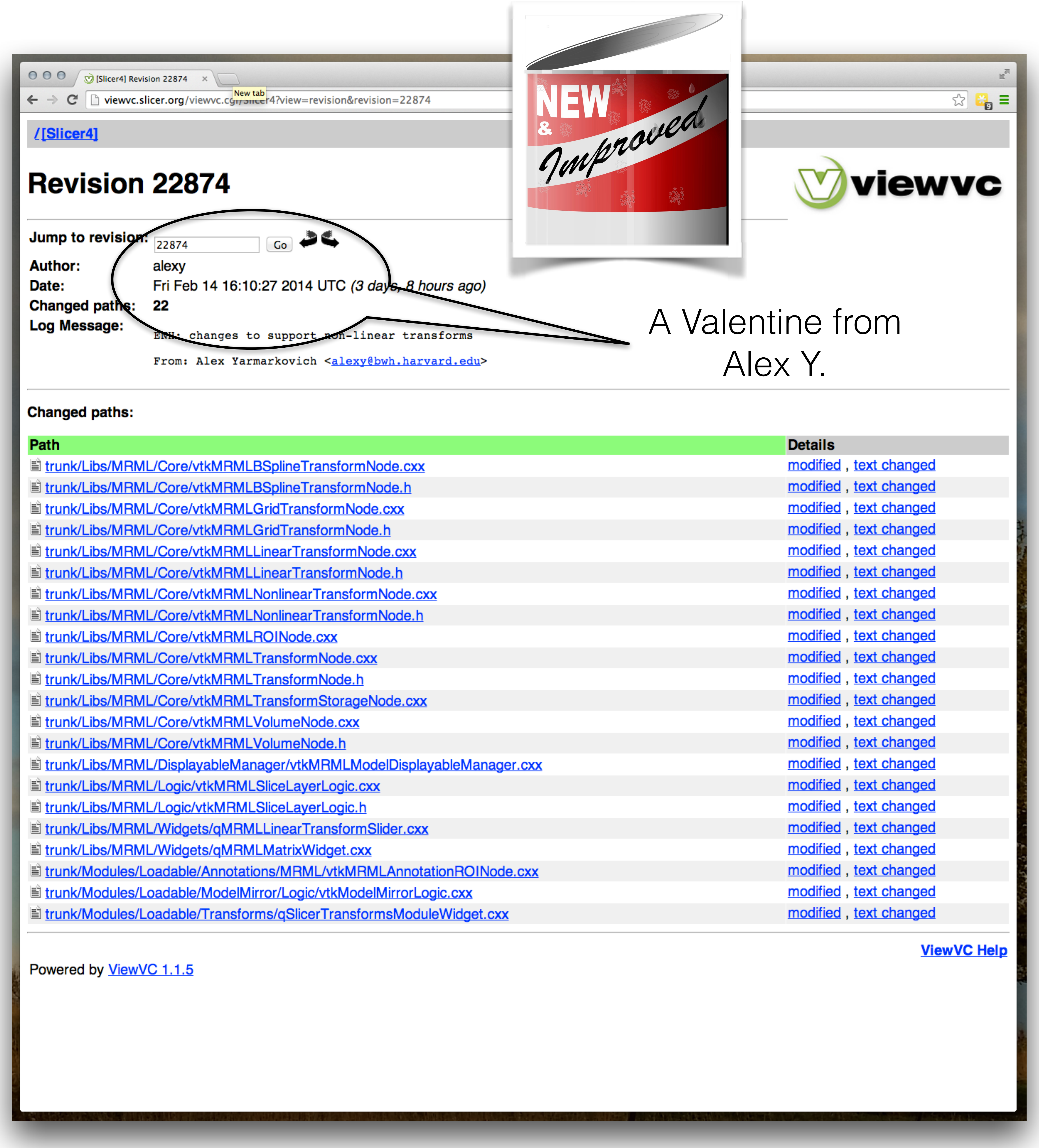
#include <Libs/MRML/Core/vtkMRMLTransformableNode.h>

Inheritance diagram for vtkMRMLTransformableNode:

vtkMRMLDiffusionTensorDisplayPropertiesNode
vtkMRMLColorTableNode
vtkMRMLGlyphableVolumeDisplayPropertiesNode
vtkMRMLdGEMRICProceduralColorNode
vtkMRMLColorNode
vtkMRMLProceduralColorNode
vtkMRMLFreeSurferProceduralColorNode
vtkMRMLPETProceduralColorNode
vtkMRMLAnnotationAngleNode
vtkMRMLAnnotationFiducialNode
vtkMRMLAnnotationBidimensionalNode
vtkMRMLAnnotationLinesNode
vtkMRMLAnnotationROINode
vtkMRMLMarkupsNode
vtkMRMLMarkupsFiducialNode
vtkMRMLAnnotationControlPointsNode
vtkMRMLAnnotationStickyNode
vtkMRMLAnnotationRulerNode
vtkMRMLCameraNode
vtkMRMLDisplayableNode
vtkMRMLModelNode
vtkMRMLAnnotationNode
TextNode
vtkMRMLAnnotationSplineNode
vtkMRMLNode
vtkMRML
eVolumeNode
vtkMRMLDiffusionTensorVolumeNode
umeNode
vtkMRMLSceneViewNode
vtkMRMLLinearTransformNode
vtkMRMLBSplineTransformNode
vtkMRMLTransformNode
vtkMRMLNonlinearTransformNode
vtkMRMLGridTransformNode
vtkMRMLVolumePropertyNode

Nonlinear Transforms

- Slicer Nightly Builds Support Live Nonlinear Transforms
  - Drag-and-Drop Transformable Nodes
    - Volumes, Models, Fiducials…
  - Slice Pipeline Applies Nonlinear Transform on Visible Slice
  - TransformToParent and TransformFromParent Calculated as Needed and Cached
  - CLIs Output or Programatic Modifications Update on the Fly
- TODO: Documentation, Nonlinear Transforms Module GUI, Further Testing…


[Slicer4] Revision 22874
New tab
viewvc.slicer.org/viewvc.cgi/Slicer4?view=revision&revision=22874
/[Slicer4]
NEW & Improved
viewvc
Go

Revision 22874

Jump to revision: 22874 Go

Author: alexy

Date: Fri Feb 14 16:10:27 2014 UTC *(3 days, 8 hours ago)*

Changed paths: **22**

Log Message:

```
ENH: changes to support non-linear transforms

From: Alex Yarmarkovich <alexy@bwh.harvard.edu>
```

A Valentine from Alex Y.

Changed paths:

Path	Details
trunk/Libs/MRML/Core/vtkMRMLBSplineTransformNode.cxx	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLBSplineTransformNode.h	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLGridTransformNode.cxx	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLGridTransformNode.h	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLLinearTransformNode.cxx	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLLinearTransformNode.h	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLNonlinearTransformNode.cxx	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLNonlinearTransformNode.h	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLROINode.cxx	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLTransformNode.cxx	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLTransformNode.h	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLTransformStorageNode.cxx	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLVolumeNode.cxx	modified , text changed
trunk/Libs/MRML/Core/vtkMRMLVolumeNode.h	modified , text changed
trunk/Libs/MRML/DisplayableManager/vtkMRMLModelDisplayableManager.cxx	modified , text changed
trunk/Libs/MRML/Logic/vtkMRMLSliceLayerLogic.cxx	modified , text changed
trunk/Libs/MRML/Logic/vtkMRMLSliceLayerLogic.h	modified , text changed
trunk/Libs/MRML/Widgets/qMRMLLinearTransformSlider.cxx	modified , text changed
trunk/Libs/MRML/Widgets/qMRMLMatrixWidget.cxx	modified , text changed
trunk/Modules/Loadable/Annotations/MRML/vtkMRMLAnnotationROINode.cxx	modified , text changed
trunk/Modules/Loadable/ModelMirror/Logic/vtkModelMirrorLogic.cxx	modified , text changed
trunk/Modules/Loadable/Transforms/qSlicerTransformsModuleWidget.cxx	modified , text changed

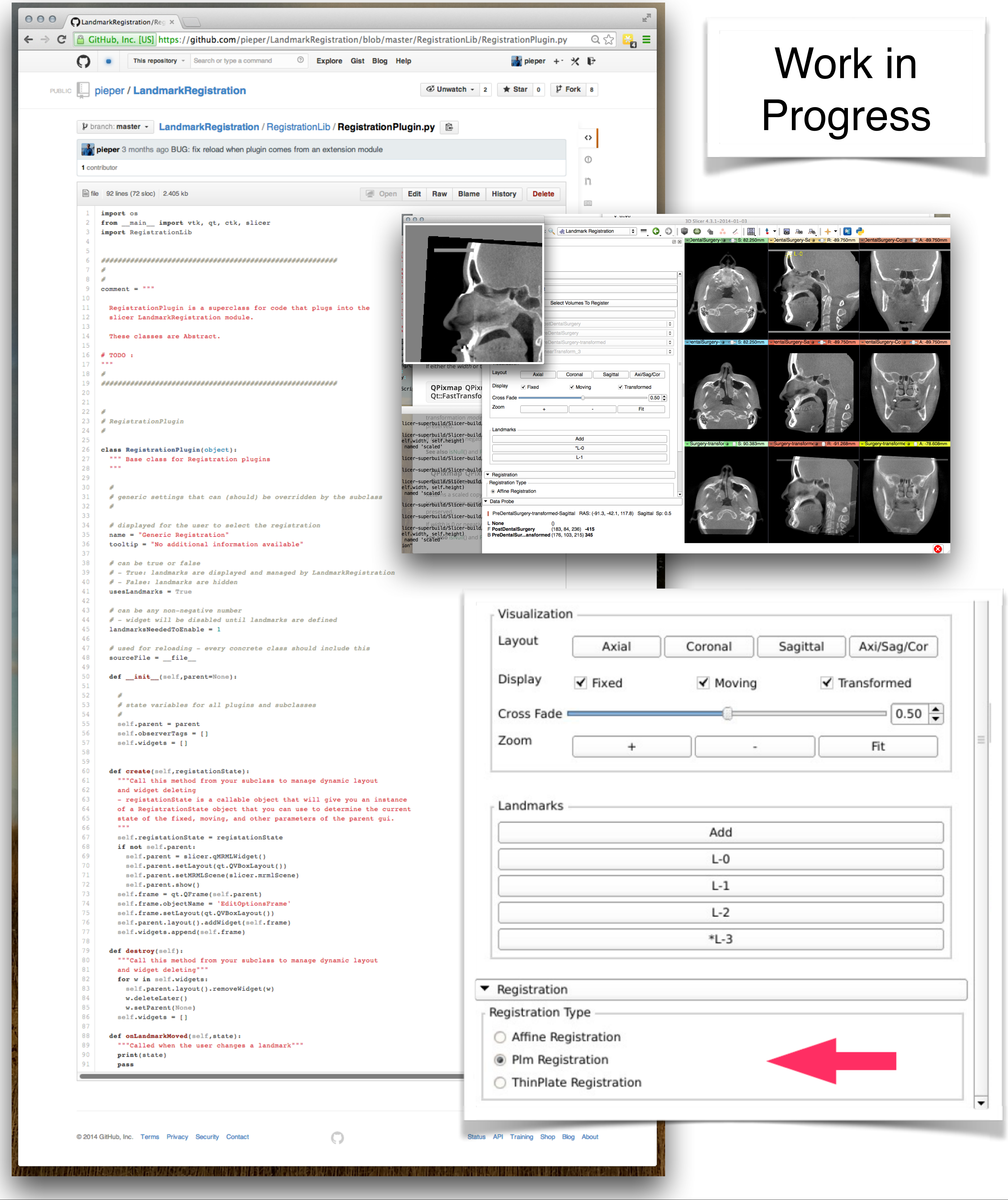
ViewVC Help

Powered by ViewVC 1.1.5

Landmark Registration and Registration Plugins

- LandmarkRegistration is Becoming a General Steered Registration Tool
  - Manages Fixed, Moving, and Transformed Volumes
  - Manages Landmarks
    - Defined as matched Fiducials on Fixed and Moving
  - Manages Visualization Modes
    - Viewer Per Volume, Cross Fade, Orientations
- Plugins Implement Steered Algorithms
  - Update Transforms in Response to User Input
  - Can call CLIs or loadable libraries

Work in Progress



https://github.com/pieper/LandmarkRegistration/blob/master/RegistrationLib/RegistrationPlugin.py

pieper / LandmarkRegistration

branch: master — LandmarkRegistration / RegistrationLib / RegistrationPlugin.py

pieper 3 months ago BUG: fix reload when plugin comes from an extension module

1 contributor

file 92 lines (72 sloc) 2.405 kb

```python
import os
from __main__ import vtk, qt, ctk, slicer
import RegistrationLib


#########################################################
#
#
comment = """

  RegistrationPlugin is a superclass for code that plugs into the
  slicer LandmarkRegistration module.

  These classes are Abstract.

# TODO :
"""
#
#########################################################



#
# RegistrationPlugin
#

class RegistrationPlugin(object):
  """ Base class for Registration plugins
  """

  #
  # generic settings that can (should) be overridden by the subclass
  #

  # displayed for the user to select the registration
  name = "Generic Registration"
  tooltip = "No additional information available"

  # can be true or false
  # - True: landmarks are displayed and managed by LandmarkRegistration
  # - False: landmarks are hidden
  usesLandmarks = True

  # can be any non-negative number
  # - widget will be disabled until landmarks are defined
  landmarksNeededToEnable = 1

  # used for reloading - every concrete class should include this
  sourceFile = __file__

  def __init__(self,parent=None):

    #
    # state variables for all plugins and subclasses
    #
    self.parent = parent
    self.observerTags = []
    self.widgets = []


  def create(self,registationState):
    """Call this method from your subclass to manage dynamic layout
    and widget deleting
    - registationState is a callable object that will give you an instance
    of a RegistrationState object that you can use to determine the current
    state of the fixed, moving, and other parameters of the parent gui.
    """
    self.registationState = registationState
    if not self.parent:
      self.parent = slicer.qMRMLWidget()
      self.parent.setLayout(qt.QVBoxLayout())
      self.parent.setMRMLScene(slicer.mrmlScene)
      self.parent.show()
    self.frame = qt.QFrame(self.parent)
    self.frame.objectName = 'EditOptionsFrame'
    self.frame.setLayout(qt.QVBoxLayout())
    self.parent.layout().addWidget(self.frame)
    self.widgets.append(self.frame)

  def destroy(self):
    """Call this method from your subclass to manage dynamic layout
    and widget deleting"""
    for w in self.widgets:
      self.parent.layout().removeWidget(w)
      w.deleteLater()
      w.setParent(None)
    self.widgets = []

  def onLandmarkMoved(self,state):
    """Called when the user changes a landmark"""
    print(state)
    pass
```

Visualization

Layout: Axial | Coronal | Sagittal | Axi/Sag/Cor

Display: ☑ Fixed ☑ Moving ☑ Transformed

Cross Fade: 0.50

Zoom: + | - | Fit

Landmarks

Add

L-0

L-1

L-2

*L-3

▼ Registration

Registration Type

○ Affine Registration

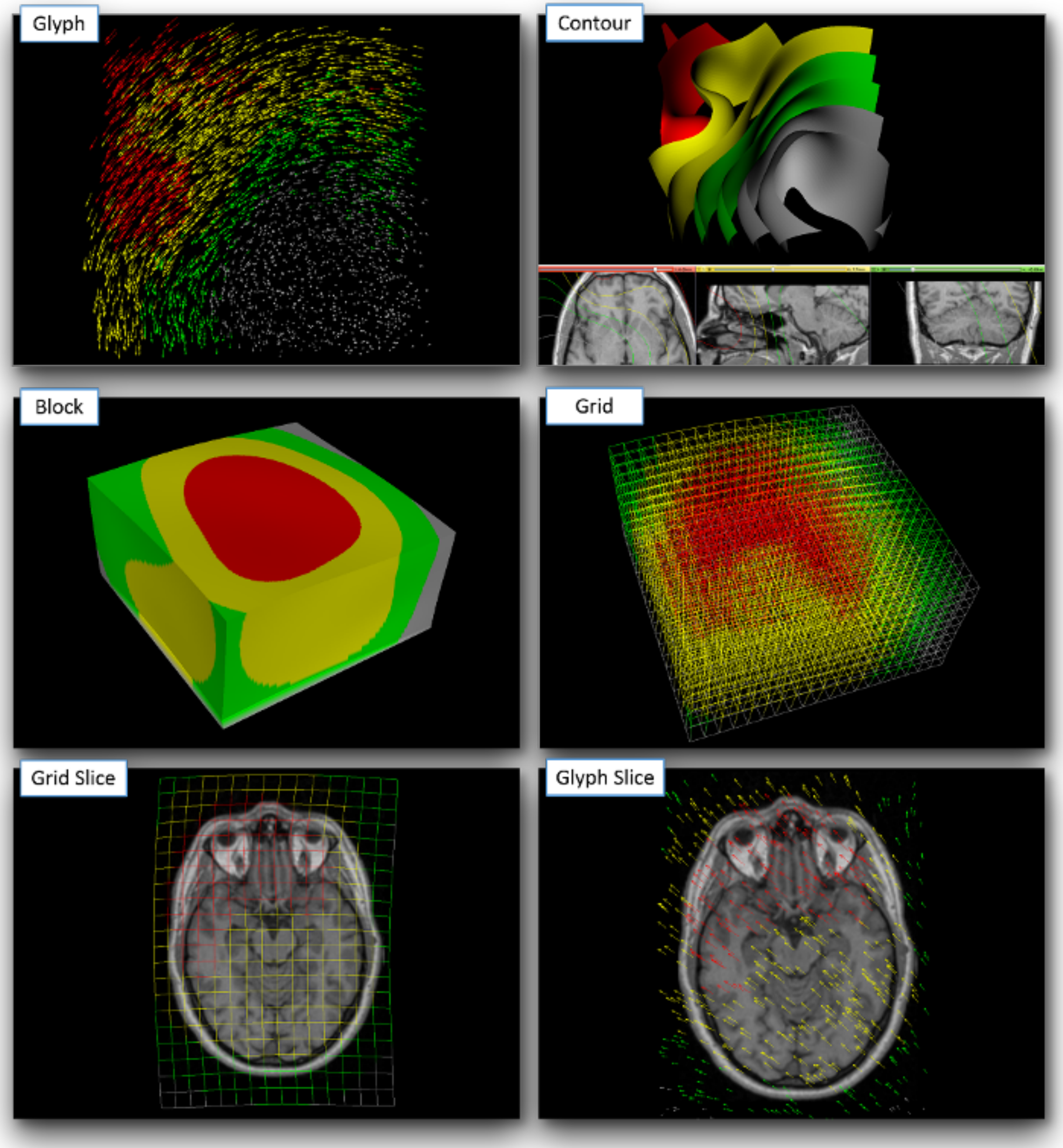
● Plm Registration

○ ThinPlate Registration

Visualization

- Transform Visualizer
  - Creates Models of Transforms
  - Support Linear and Nonlinear Transforms
  - User Control of Sampling/Display
  - Integrates with Other Slicer Visualization
  - Look at the Transformation Instead of the Effect of the Transformation
- Bundled with SlicerRT Extension

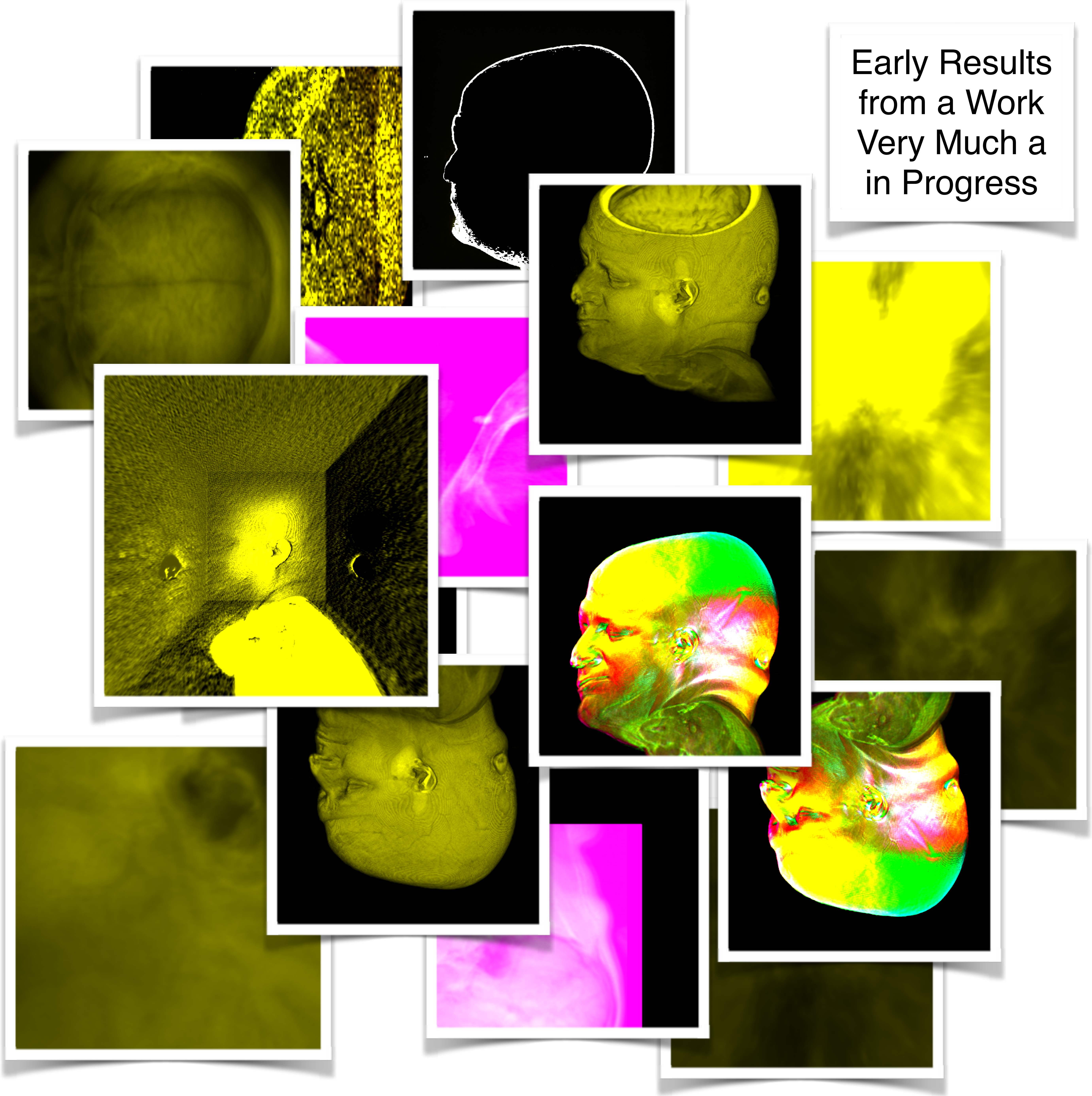
Work in Progress



King et al, Queens University

Visualization

- OpenCL Volume Rendering
  - Pixel-Parallel Ray Casting from Scratch
  - Hardware Trilinear Interpolation
    - Volumes, Transfer Functions, Vector Fields
  - PyOpenCL Integration with Slicer
  - Custom Render Kernels
- TODO
  - Coordinate Integration
  - Multiple Volumes
  - Linear and Nonlinear Transforms
  - Integration with Surface Rendering
  - Lighting/Shading Models
  - Cutaway Rendering

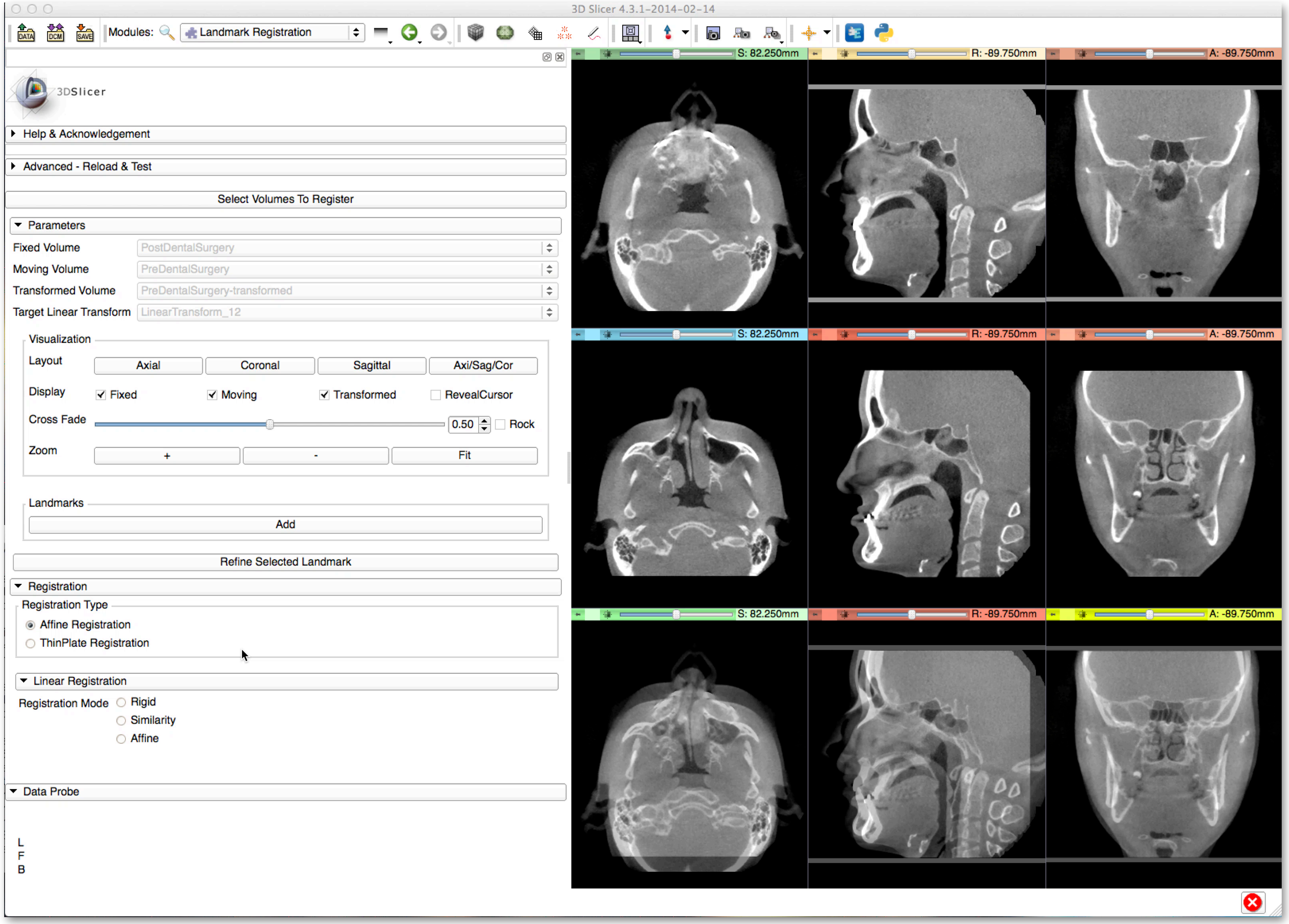


Early Results from a Work Very Much a in Progress

Work in Progress

Visualization/Control: Landmarks

- Manage Fiducials
  - Auto Create Matching Fiducials
  - Only Display on Proper Volume
  - Fiducial-Centered View Options
  - Arguably Allows Principled Control in 2D and 3D
    - Grab in Fixed or Moving, but watch Blended…
- Based on Current Slicer
  - Earlier Version in Nightly
  - Improved Version Soon
  - Needs Robustness, Documentation



Modules: Landmark Registration

▸ Help & Acknowledgement

▸ Advanced - Reload & Test

Select Volumes To Register

▾ Parameters

Fixed Volume	PostDentalSurgery
Moving Volume	PreDentalSurgery
Transformed Volume	PreDentalSurgery-transformed
Target Linear Transform	LinearTransform_12

Visualization

Layout: Axial | Coronal | Sagittal | Axi/Sag/Cor

Display: ☑ Fixed ☑ Moving ☑ Transformed □ RevealCursor

Cross Fade: 0.50 □ Rock

Zoom: + | - | Fit

Landmarks

Add

Refine Selected Landmark

▾ Registration

Registration Type

● Affine Registration
○ ThinPlate Registration

▾ Linear Registration

Registration Mode ○ Rigid
○ Similarity
○ Affine

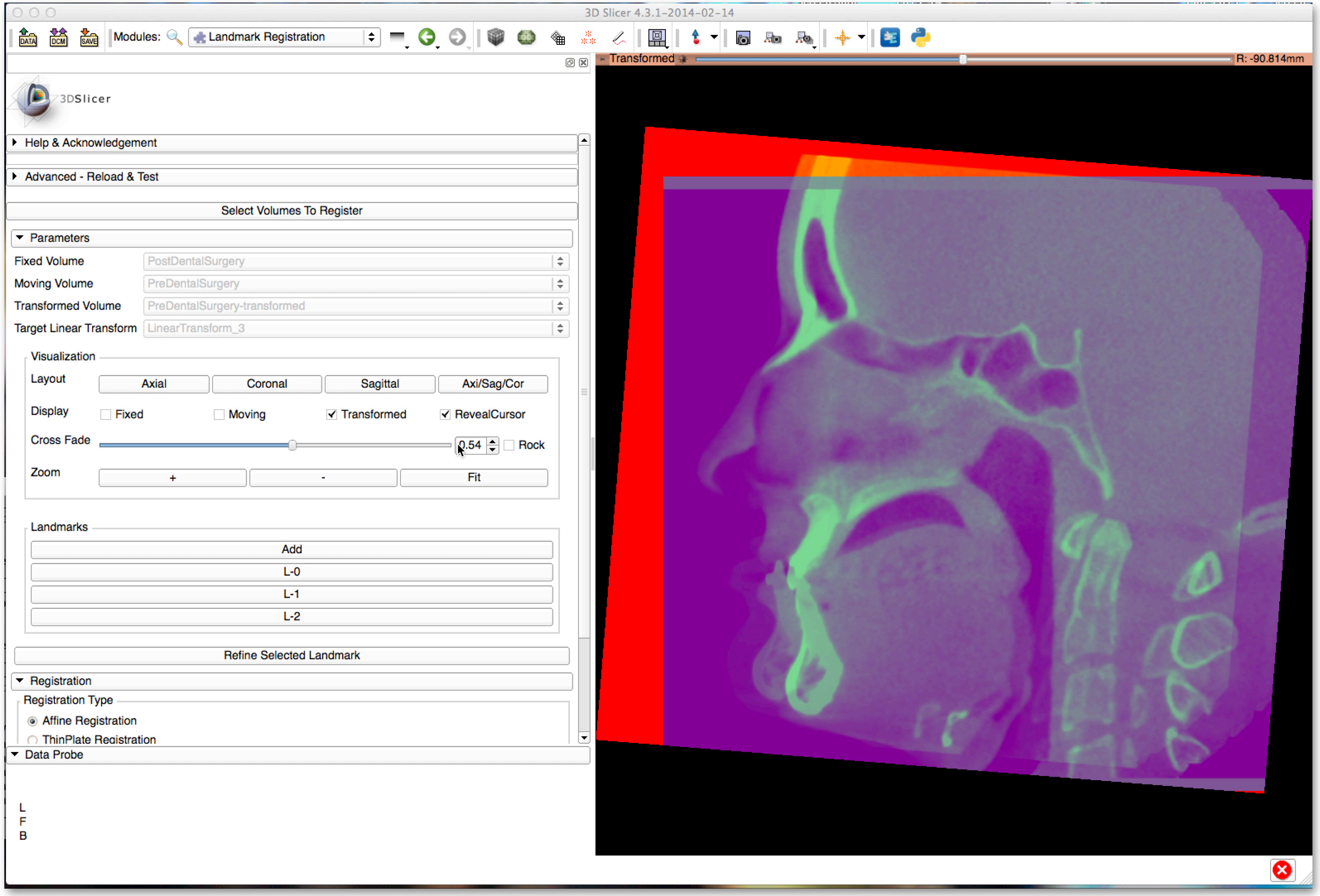
▾ Data Probe

L
F
B

Work in Progress

Visualization: Rock and Reveal

- Rock
  - Visualization Mode Implemented First by Patient who Used Slicer to Educate Surgeons about his Case
  - Passive Contemplation of the Registration
  - Other Color/Animation Modes Planned
- Reveal Cursor
  - Active Exploration and Comparison
  - Facilitates Visualization of Discontinuities



Modules: Landmark Registration

Fixed Volume: PostDentalSurgery

Moving Volume: PreDentalSurgery

Transformed Volume: PreDentalSurgery-transformed

Target Linear Transform: LinearTransform_3

Layout

Display: □ Fixed □ Moving ☑ Transformed ☑ RevealCursor

Cross Fade: 0.54 □ Rock

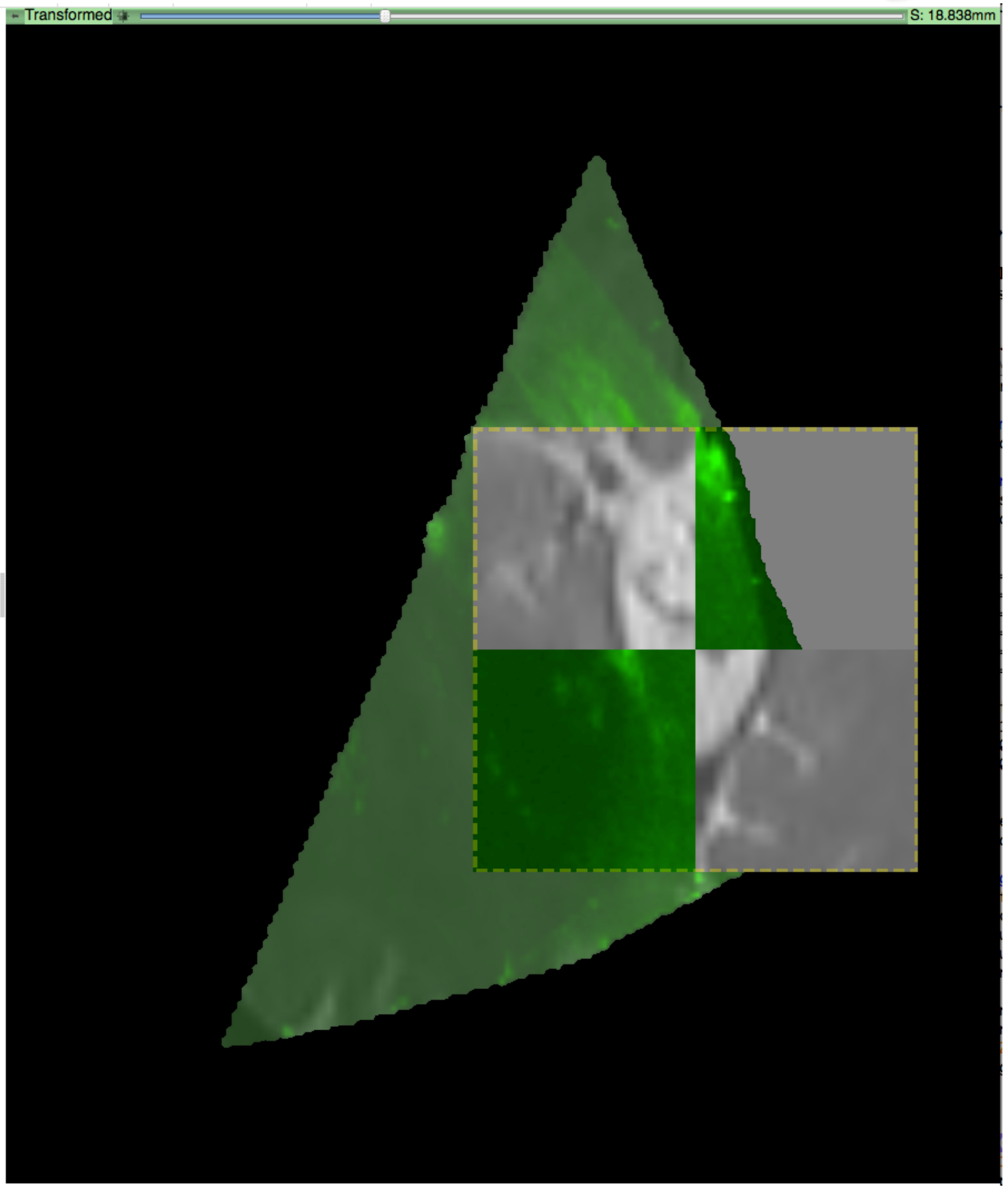
Zoom

Registration Type: ● Affine Registration ○ ThinPlate Registration

Work in Progress

Visualization

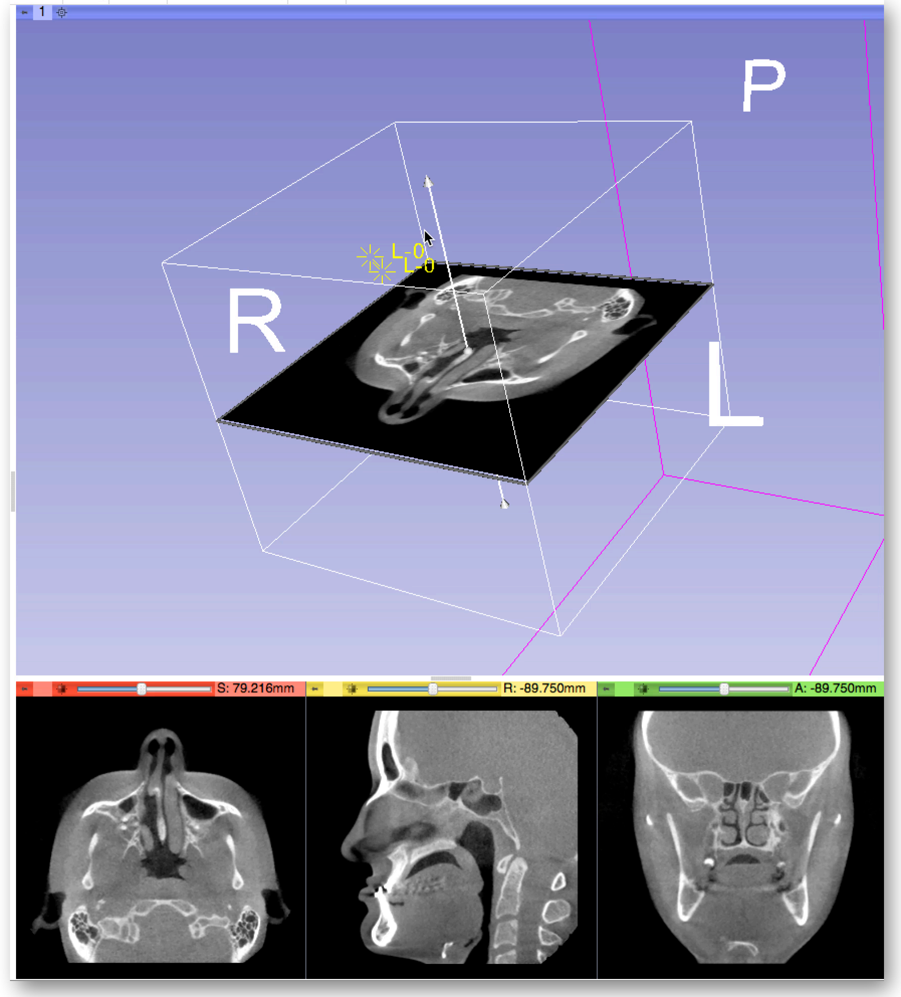
- Reveal Cursor
  - Highly interactive visual inspection
  - Checkerboard of FG/BG layers
  - Optional zoom
  - Integrates nicely with pan/zoom/scroll/crosshairs
  - Integrated with LandmarkRegistration
- Supports QC of Registration Results

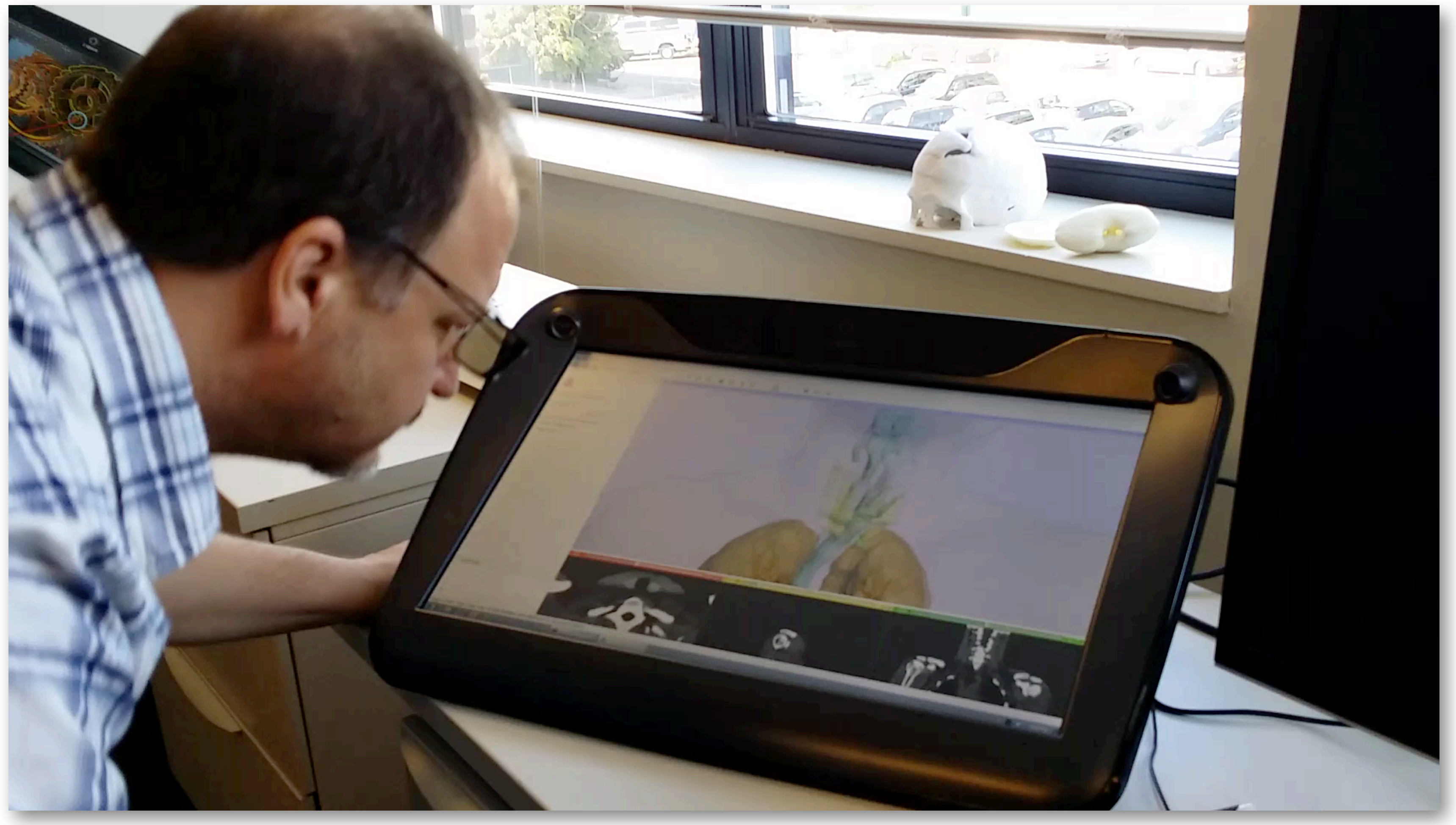


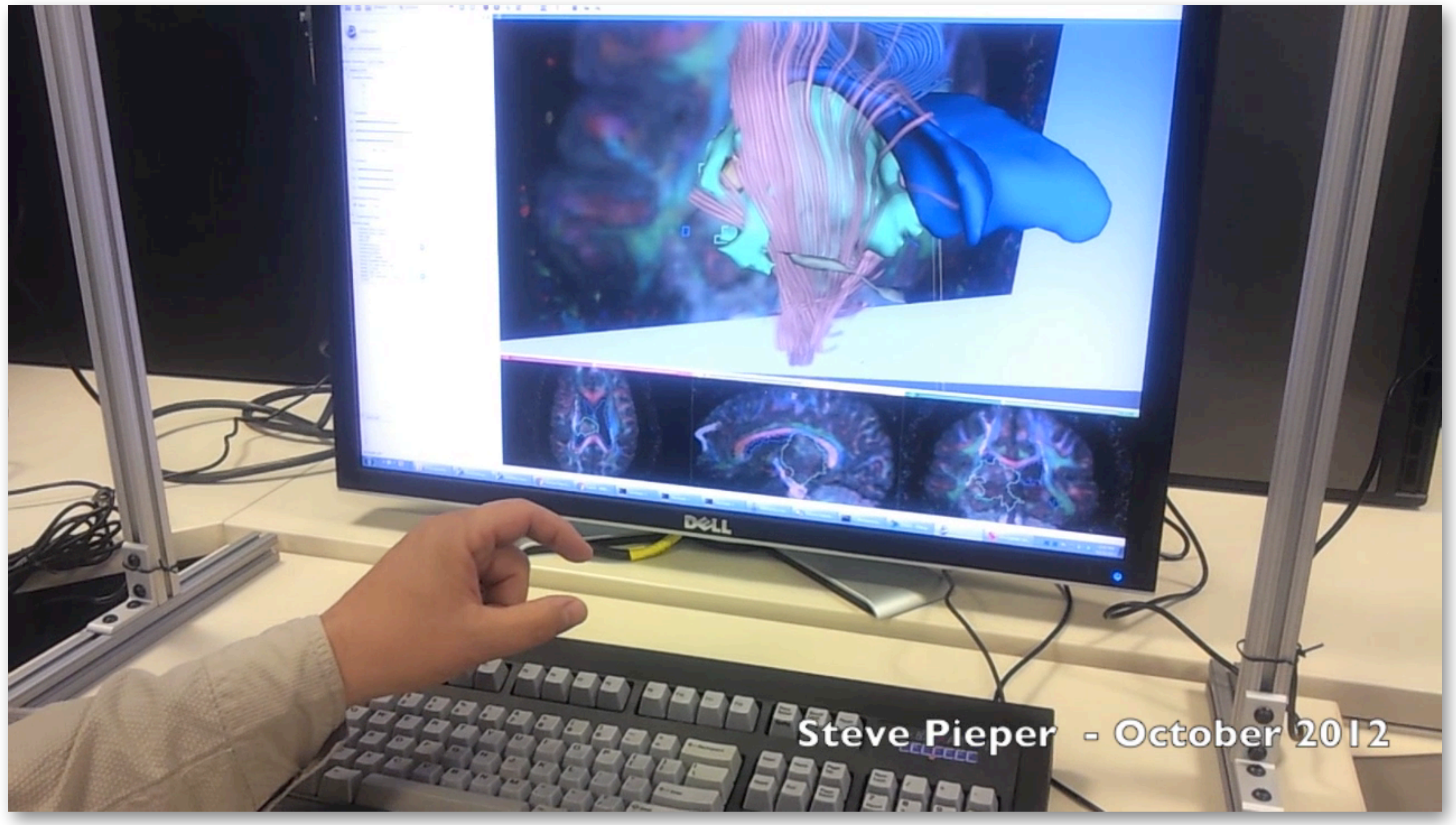
US (green) and T1 MR (gray) for AMIGO neurosurgery case

3D Control

- VTK Widgets
  - Traditional Mouse/Keyboard Interaction
  - Two DOFs
- Multitouch Screens
  - iPad in AMIGO
  - Three or More Simultaneous DOFs
- Hand Tracking
  - ThreeGear Kinect/PrimeSense, Leap, Structure Sensor
  - Twelve+ DOF? 72 DOFs?
- Visualization/Control
  - ZSpace “Virtual Hologoraphy”
  - Head Tracked Stereo Display
  - Haptic Stylus
  - Partial Slicer Integration



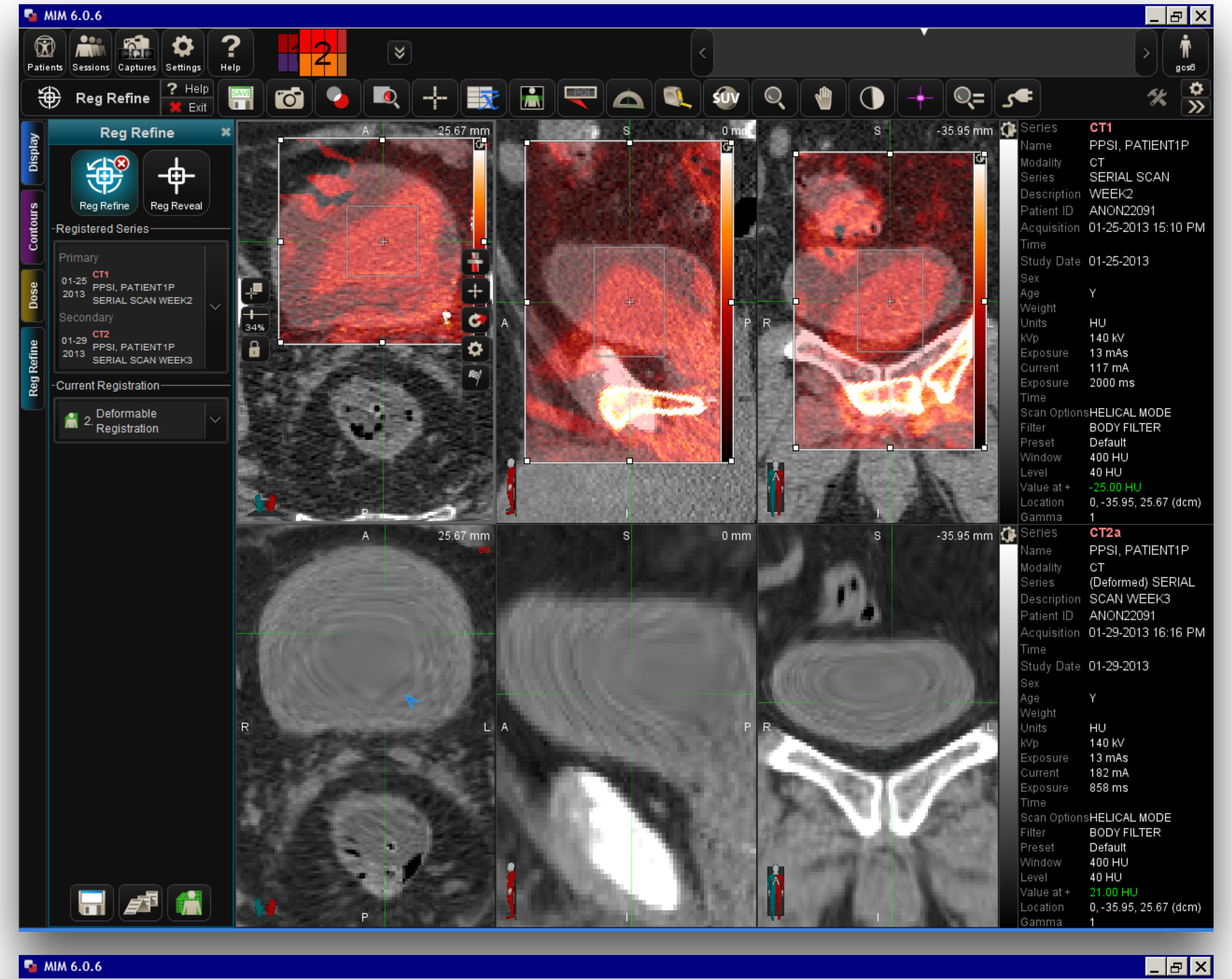




Works in Progress

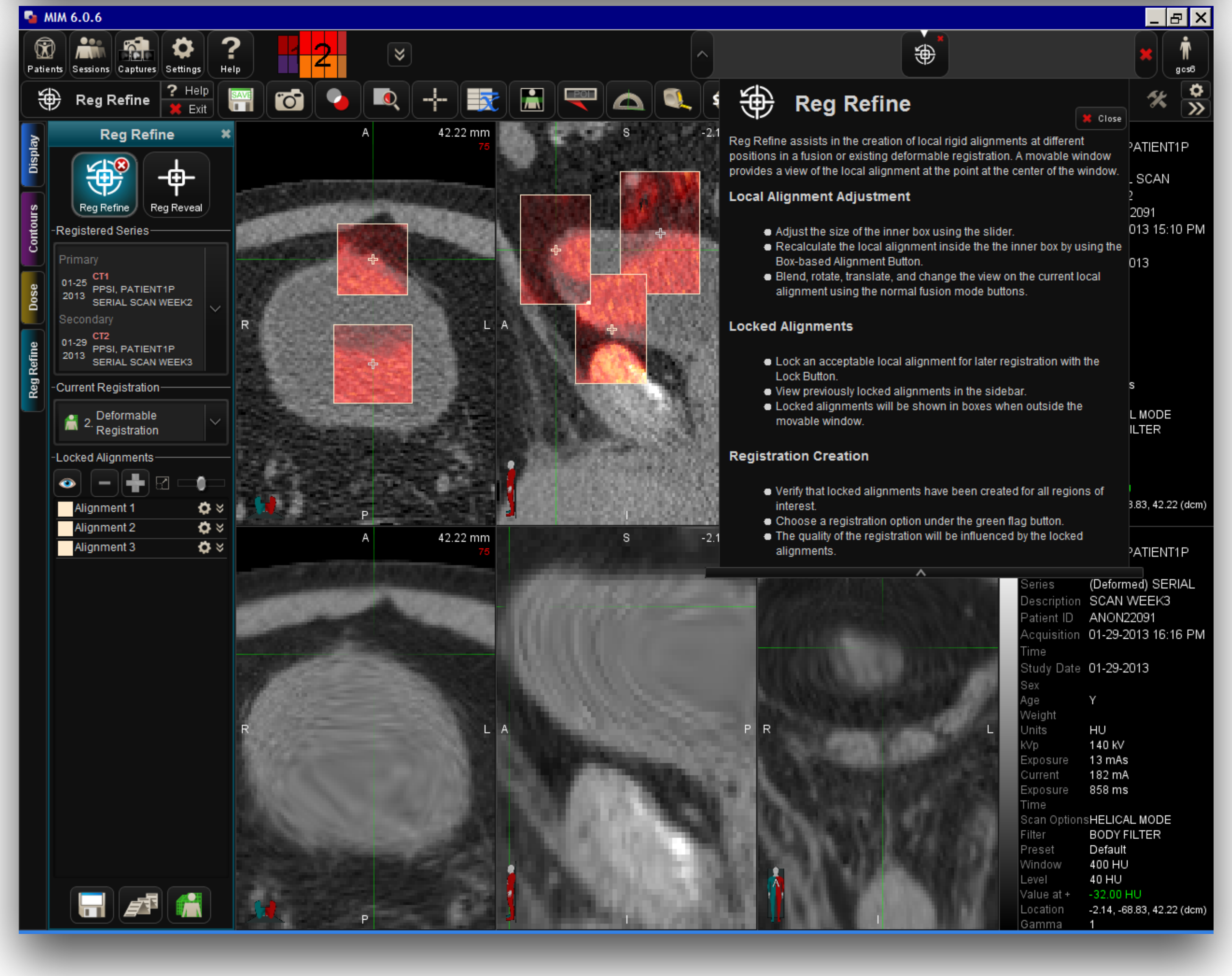
Control/Automation

- MIM RegRefine
  - Commercial Example of Registration Steering
  - User Provides Local Correspondence
  - Can be Fully Manual or Automatic within ROI
- WIP in Slicer LandmarkRegistration
  - Extract ROI Around Fixed and Moving Fiducials
  - Run BRAINSFit CLI on Extracted Volumes
  - Update Fidcucial Location
  - Miller, Prastawa, Pieper



Series	CT1
Name	PPSI, PATIENT1P
Modality	CT
Series Description	SERIAL SCAN WEEK2
Patient ID	ANON22091
Acquisition Time	01-25-2013 15:10 PM
Study Date	01-25-2013
Sex	
Age	Y
Weight	
Units	HU
KVp	140 kV
Exposure	13 mAs
Current	117 mA
Exposure Time	2000 ms
Scan Options	HELICAL MODE
Filter	BODY FILTER
Preset	Default
Window	400 HU
Level	40 HU
Value at +	-25.00 HU
Location	0, -35.95, 25.67 (dcm)
Gamma	1

Series	CT2a
Name	PPSI, PATIENT1P
Modality	CT
Series Description	(Deformed) SERIAL SCAN WEEK3
Patient ID	ANON22091
Acquisition Time	01-29-2013 16:16 PM
Study Date	01-29-2013
Sex	
Age	Y
Weight	
Units	HU
KVp	140 kV
Exposure	13 mAs
Current	182 mA
Exposure Time	858 ms
Scan Options	HELICAL MODE
Filter	BODY FILTER
Preset	Default
Window	400 HU
Level	40 HU
Value at +	21.00 HU
Location	0, -35.95, 25.67 (dcm)
Gamma	1



Reg Refine

Reg Refine assists in the creation of local rigid alignments at different positions in a fusion or existing deformable registration. A movable window provides a view of the local alignment at the point at the center of the window.

Local Alignment Adjustment

- Adjust the size of the inner box using the slider.
- Recalculate the local alignment inside the the inner box by using the Box-based Alignment Button.
- Blend, rotate, translate, and change the view on the current local alignment using the normal fusion mode buttons.

Locked Alignments

- Lock an acceptable local alignment for later registration with the Lock Button.
- View previously locked alignments in the sidebar.
- Locked alignments will be shown in boxes when outside the movable window.

Registration Creation

- Verify that locked alignments have been created for all regions of interest.
- Choose a registration option under the green flag button.
- The quality of the registration will be influenced by the locked alignments.

Images and Data courtesy Greg Sharp MGH

Work in Progress

Control/Automation

- Hybrid BSpline
  - Initialize from Landmarks
  - Include Landmark and Image Similarity Terms in Optimization
  - Support Iterative Refinement
- Part of Plastimatch
  - LandmarkRegistration Plugin
  - Bundled with SlicerRT Extension
  - MGH: Sharp, Shusharina

Work in Progress

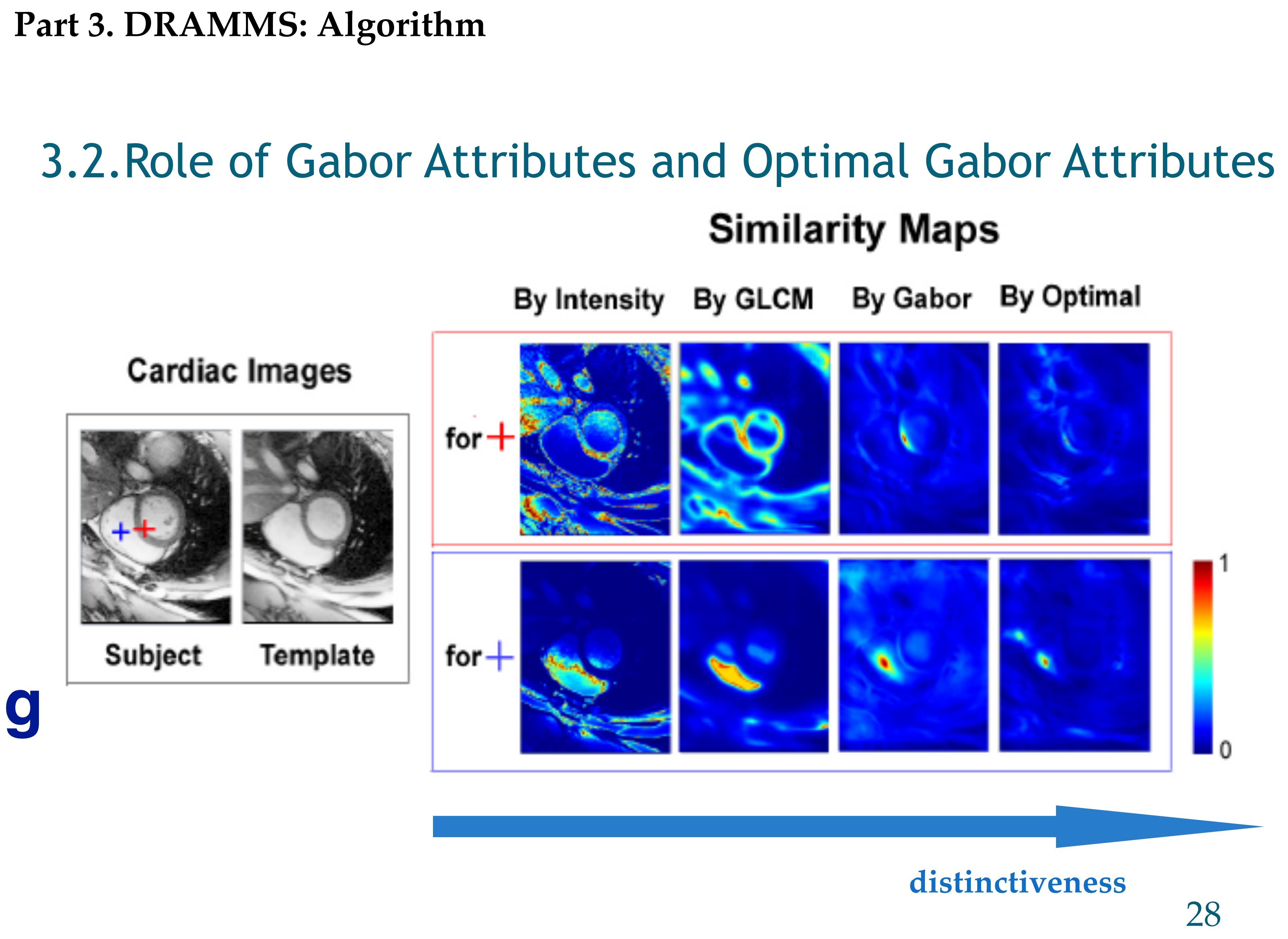
Automation

- Marcel’s GPU fluid registration

Automation

Work in Progress

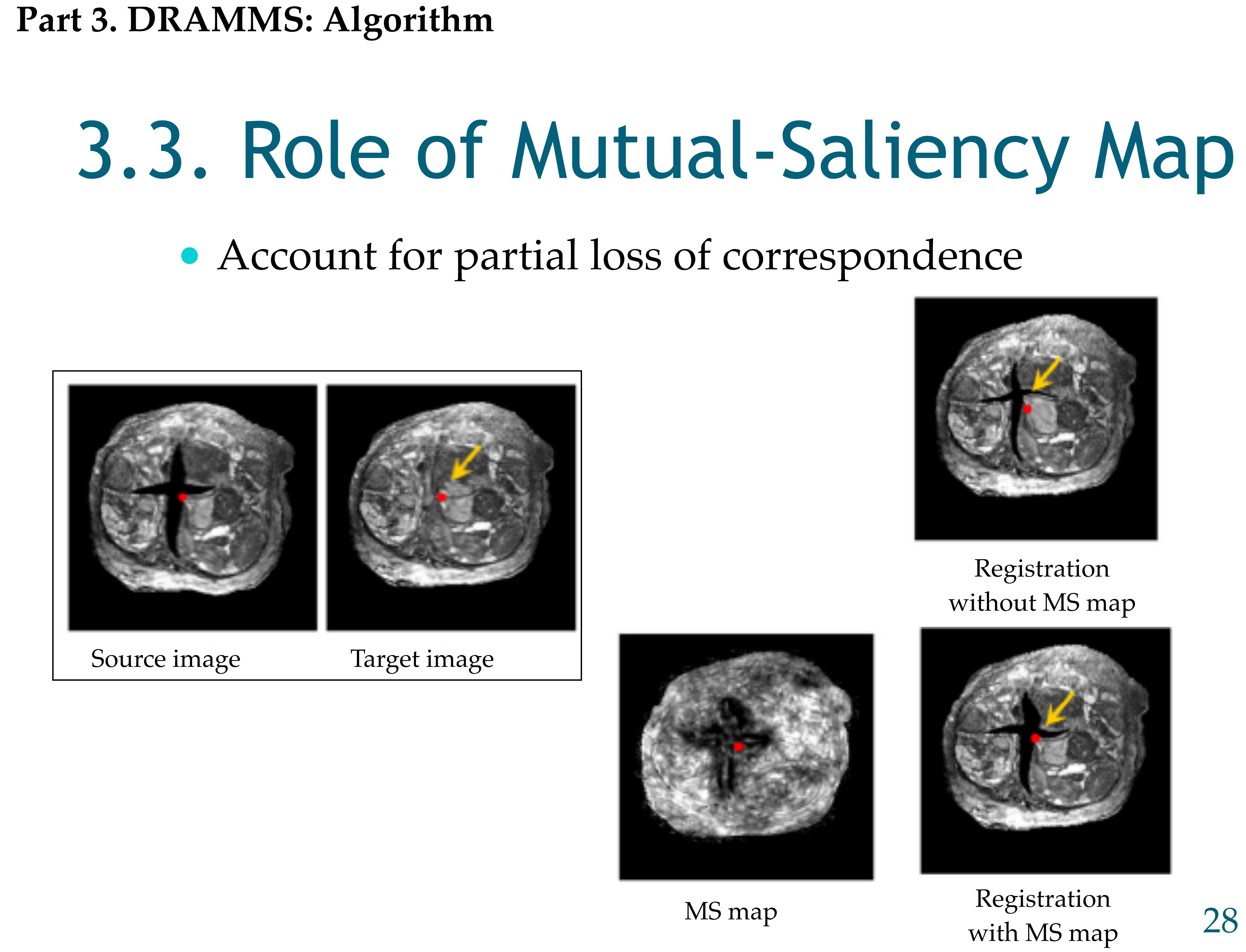
- Yangming Ou DRAMMS
  - Deformable Registration by **Attribute Matching** and **Mutual Saliency**
  - PhD with Christos Davitzikos at UPenn
  - Now Post Doc with Randy Gollub and Jayashree Kalpathy at MGH
  - Working on mi2b2 and QIICR Projects
  - Wrapping DRAMMS as CLI Extension
- Exploring Approaches to Weight Attribute Match Criteria Based on User Input
  - Train Weighting from Landmarks



Part 3. DRAMMS: Algorithm

3.2.Role of Gabor Attributes and Optimal Gabor Attributes

28



Part 3. DRAMMS: Algorithm

3.3. Role of Mutual-Saliency Map

- Account for partial loss of correspondence

Source image

Target image

Registration without MS map

MS map

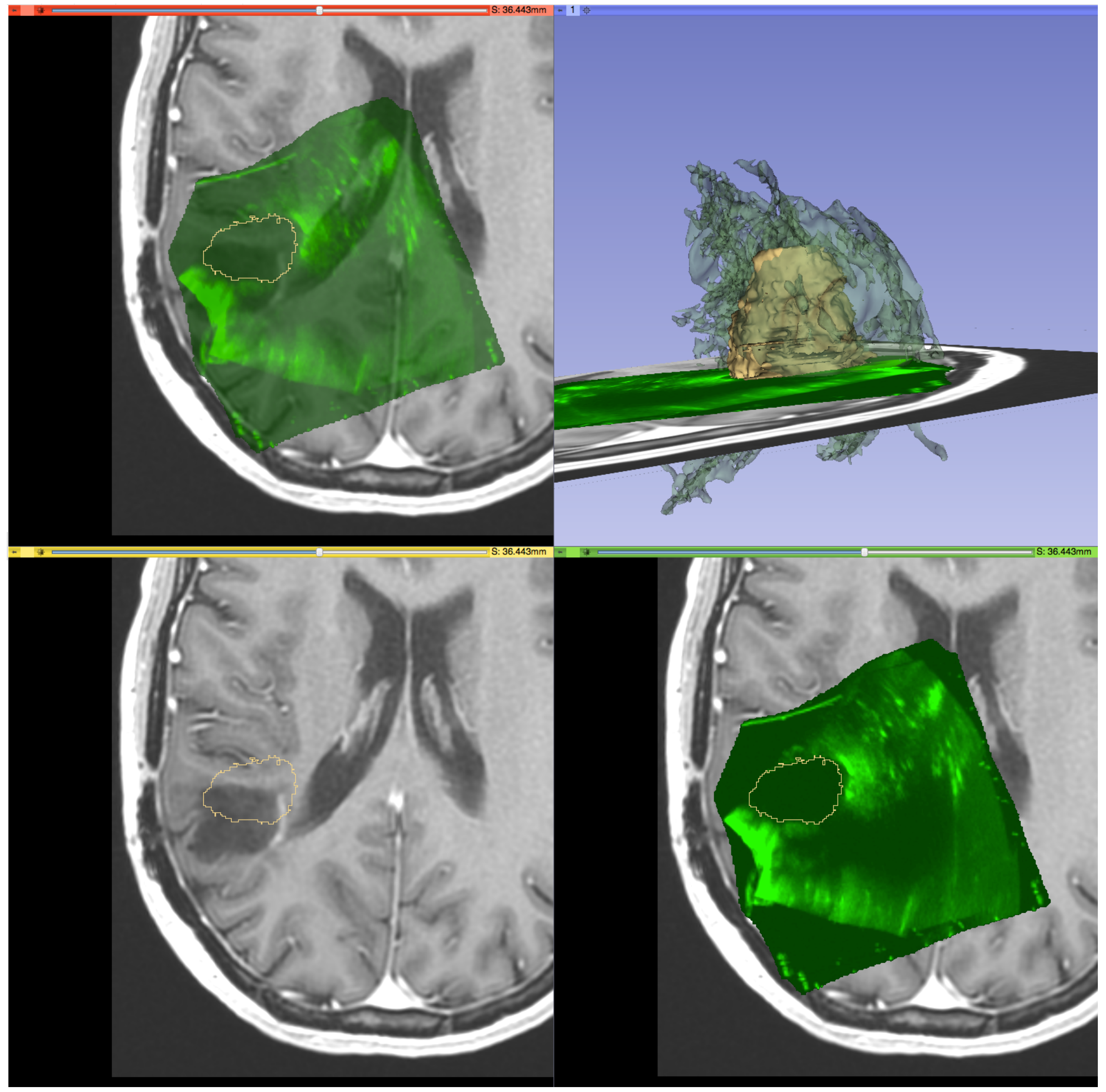
Registration with MS map

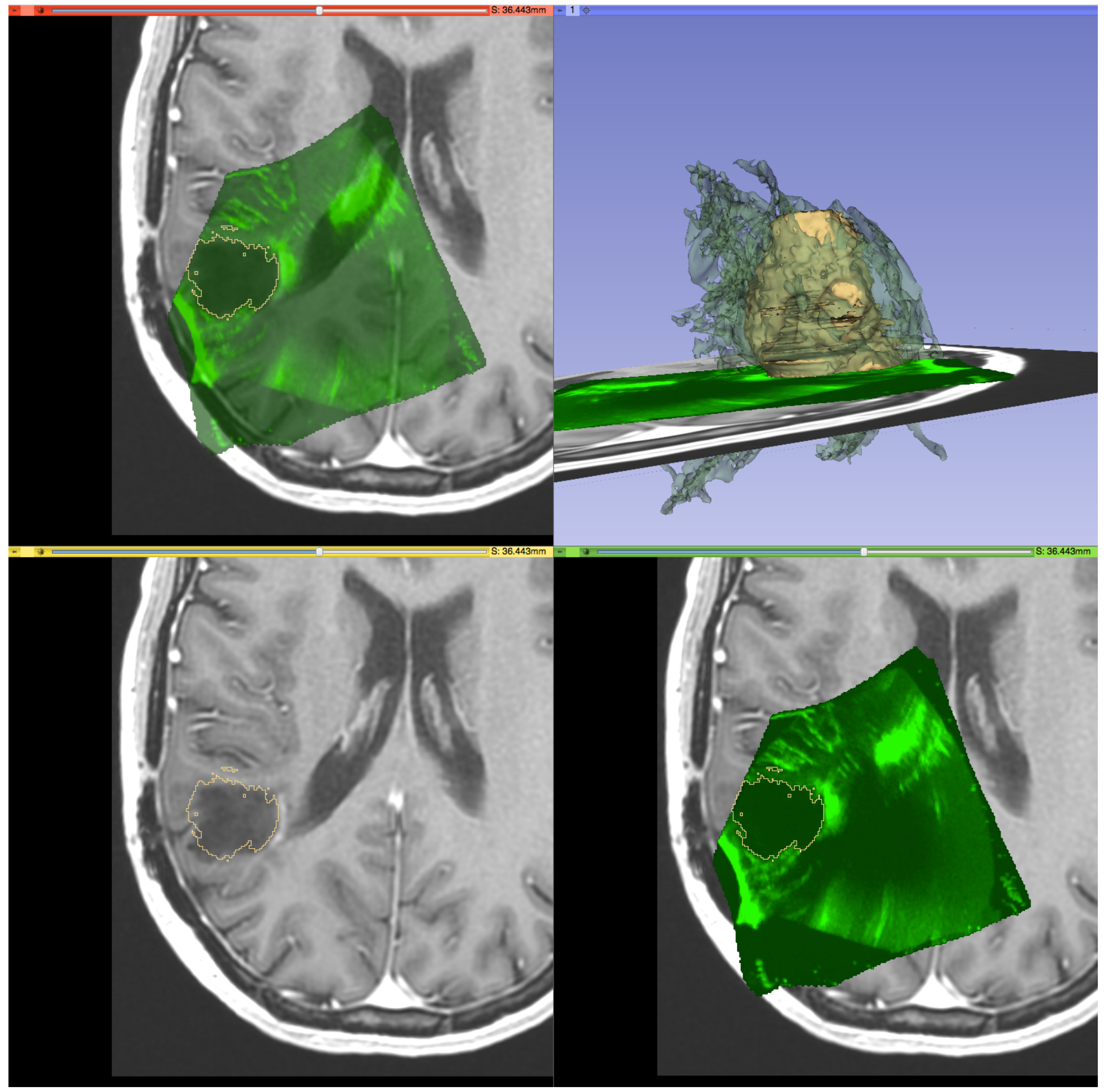
28

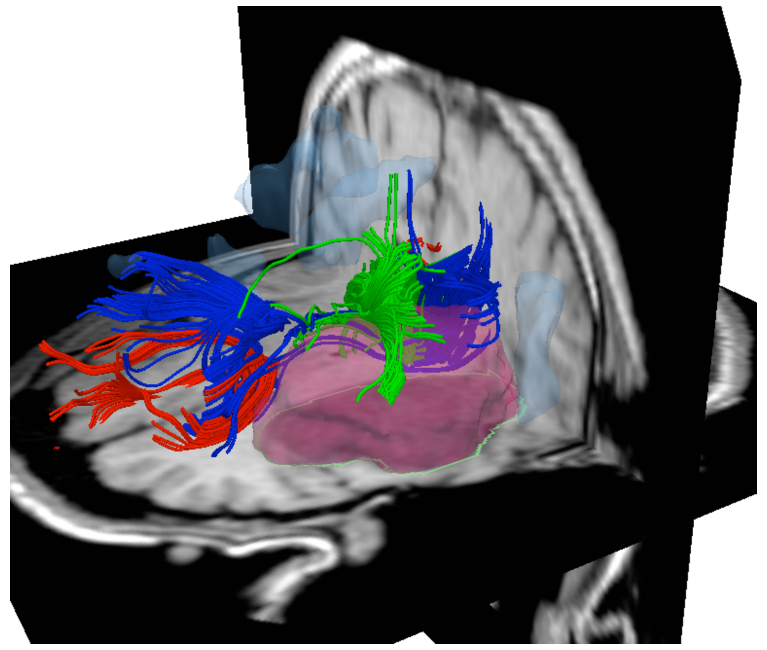
Why do this anyway?

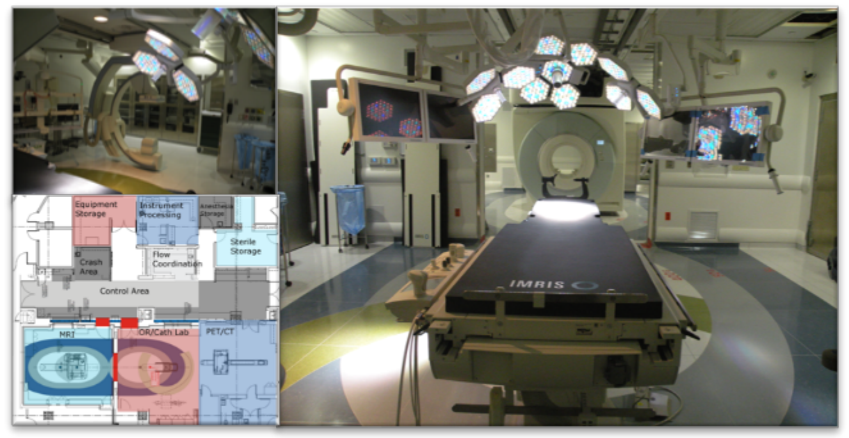
NAC / NCIGT

- Neurosurgery in AMIGO is DBP for current cycle of NAC (currently in year 1 of 5)
  - Improve the utility of iterated intra-procedural multi-modality imaging
    - Correct for calibration issues, distortion, resection, swelling…
    - Provide information in a clinically useful timeframe
  - Collect data during procedure: CaseHub
    - Multitrack recording of image data (video, ultrasound, vital monitors, navigation screen, MR console…)
    - Provide context for interpretation
- Active Participants
  - BWH: Golby, Norton, Mehrtash, Kikinis
  - GE: Miller, Prestawa
  - Isomics: Pieper, Blezek
- Registration Issues
  - MR/MR, MR/US, Video, Surface Scan
  - Warps, Brain Shift, Resection, Adema, Non-tissue, Lost Calibraion…









Images courtesy Alex Golby, BWH

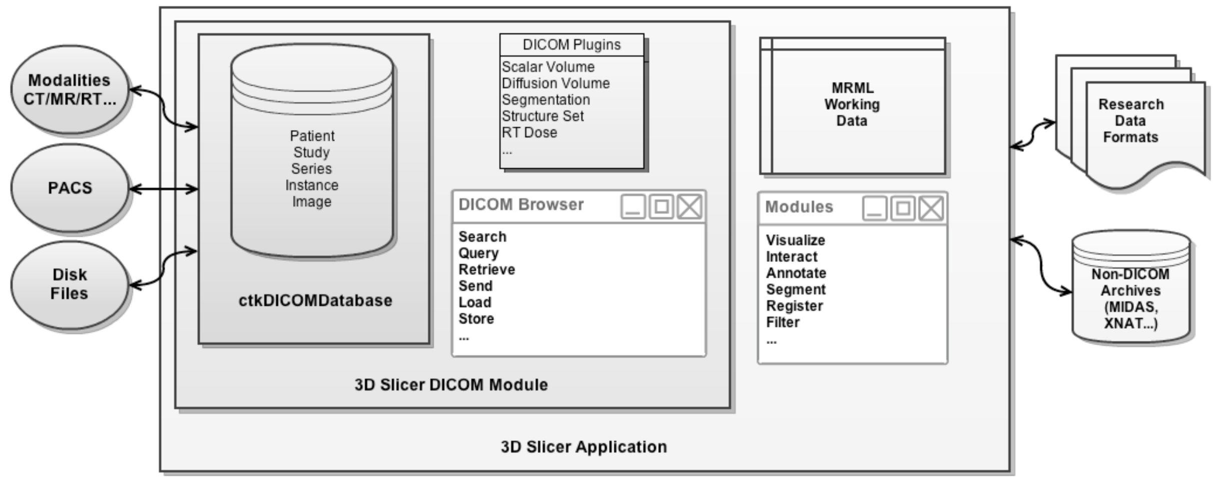
QIICR

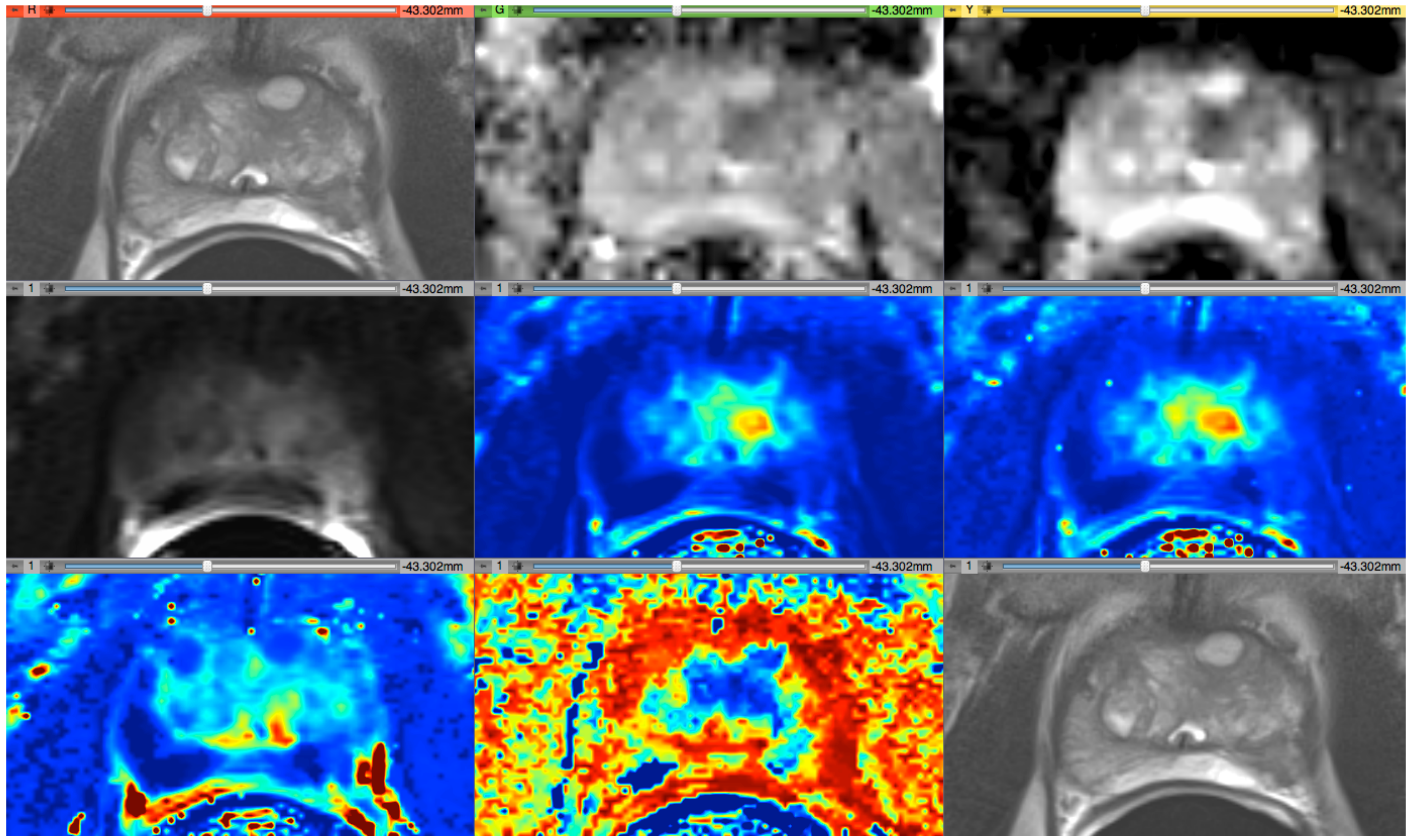
quantitative image informatics QIICR for cancer research

DICOM
Digital Imaging and Communications in Medicine

DICOM@OFFIS

- Quantitative Image Informatics for Cancer Research (currently in year 1 of 5)
  - NCI U24, Quantitative Imaging Network
- Active Participants
  - BWH Prostate: Fennesy, Fedorov, Kikinis
  - MGH GBM: Kalpathy, Ou
  - Iowa HNC: Beichel
  - Isomics: Pieper
  - PixelMed: Clunie
  - Open Connections: Onken
- Registration Issues
  - Longitudinal Tumor Tracking
  - mpMR, PET/CT

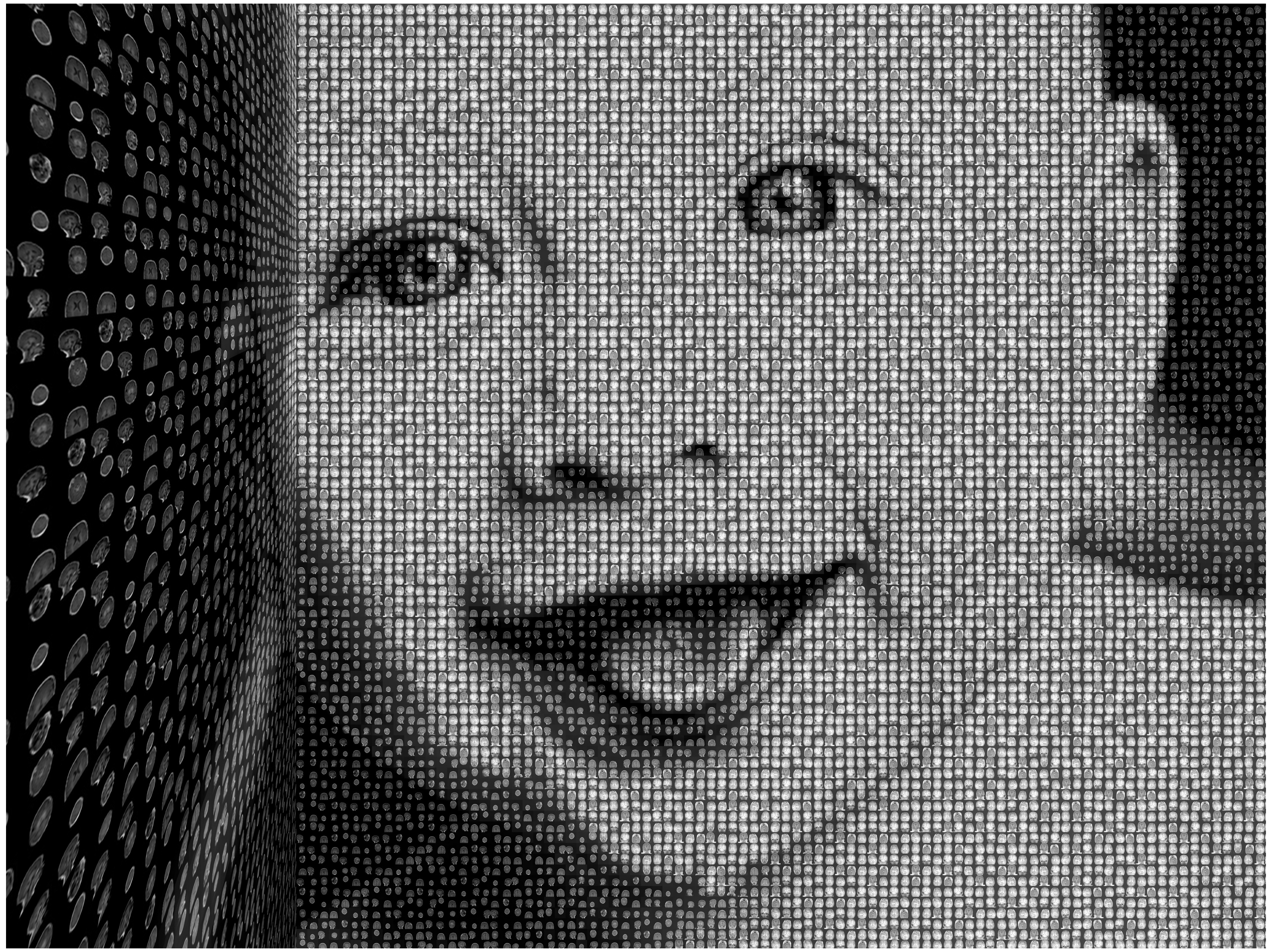




Images courtesy Andrey Fedorov, BWH

mi2b2

- Medical Image Informatics Bench to Bedside (currently in year 2 of 4)
  - NIBIB R01
  - Mine the Clinical PACS and EHR
  - Application to Pediatric Neurodevelopment
- Active Participants
  - MGH: Murphy, Gollub, Zollei, Herrick, Ou…
  - Childrens: Grant, Pienaar, Haehn…
  - Isomics: Pieper
- Registration Issues
  - Intersubject Atlas
  - Clinical Image Quality



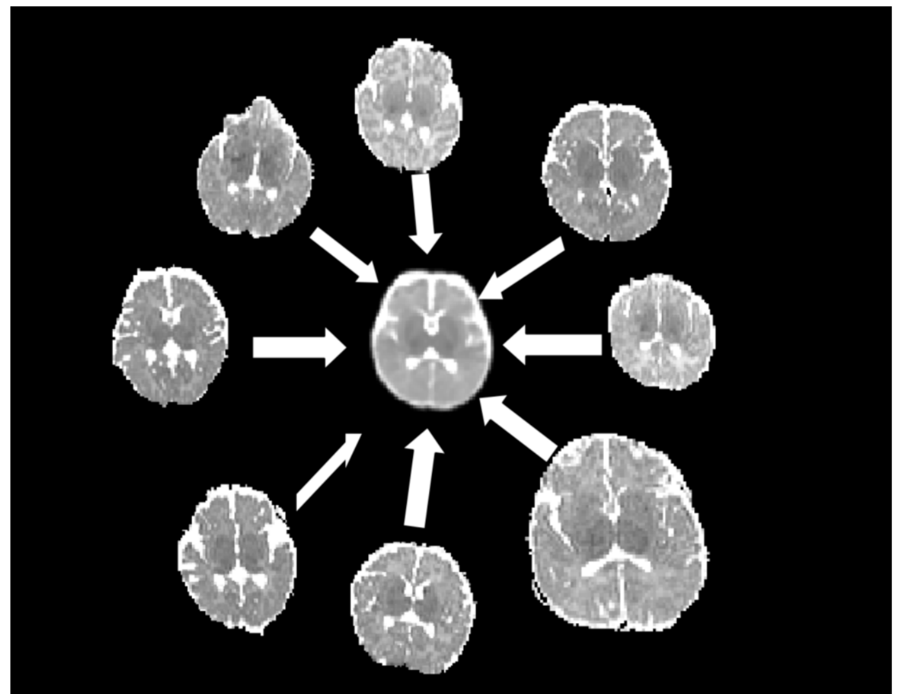


Figure 2. Unbiased atlas construction for subjects 2 months old. The atlas is representative of average geometry and average intensity.

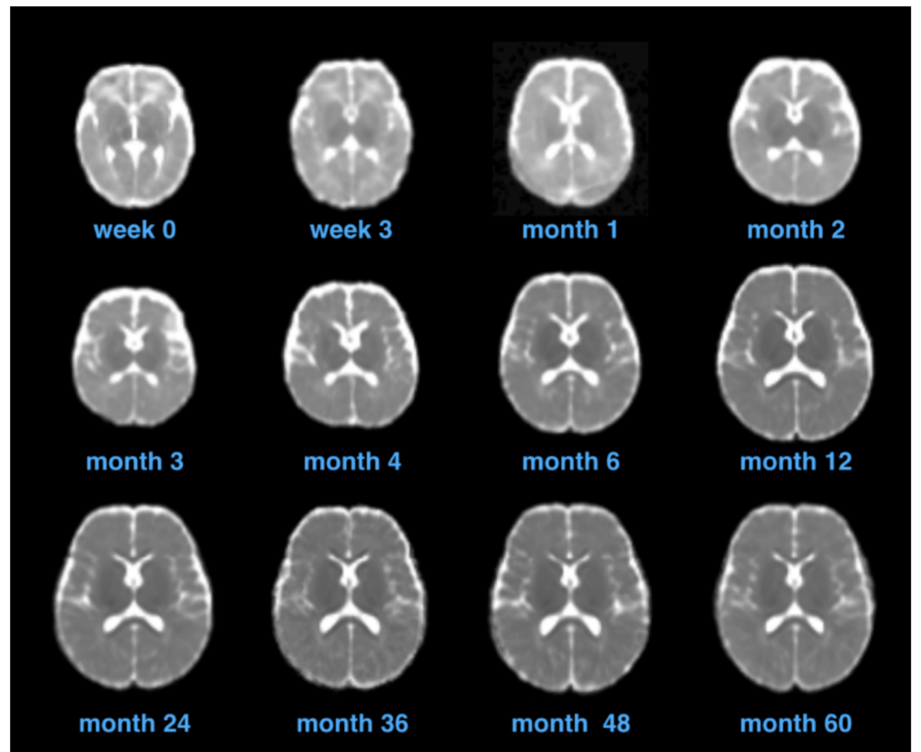
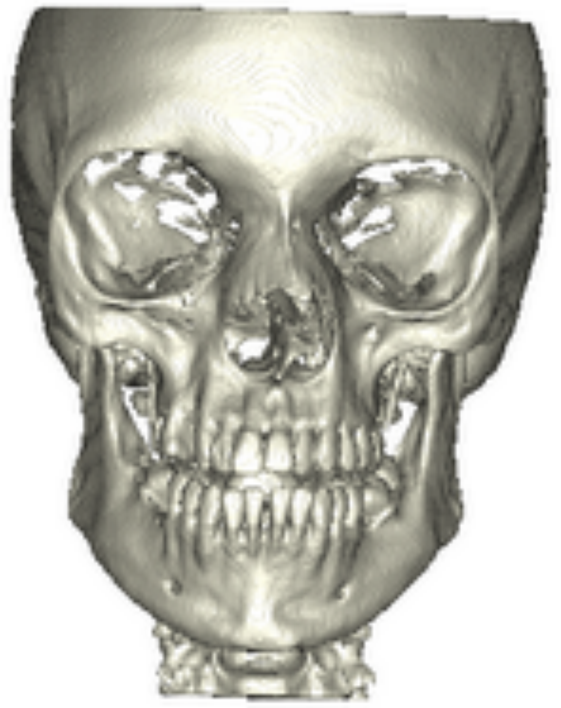


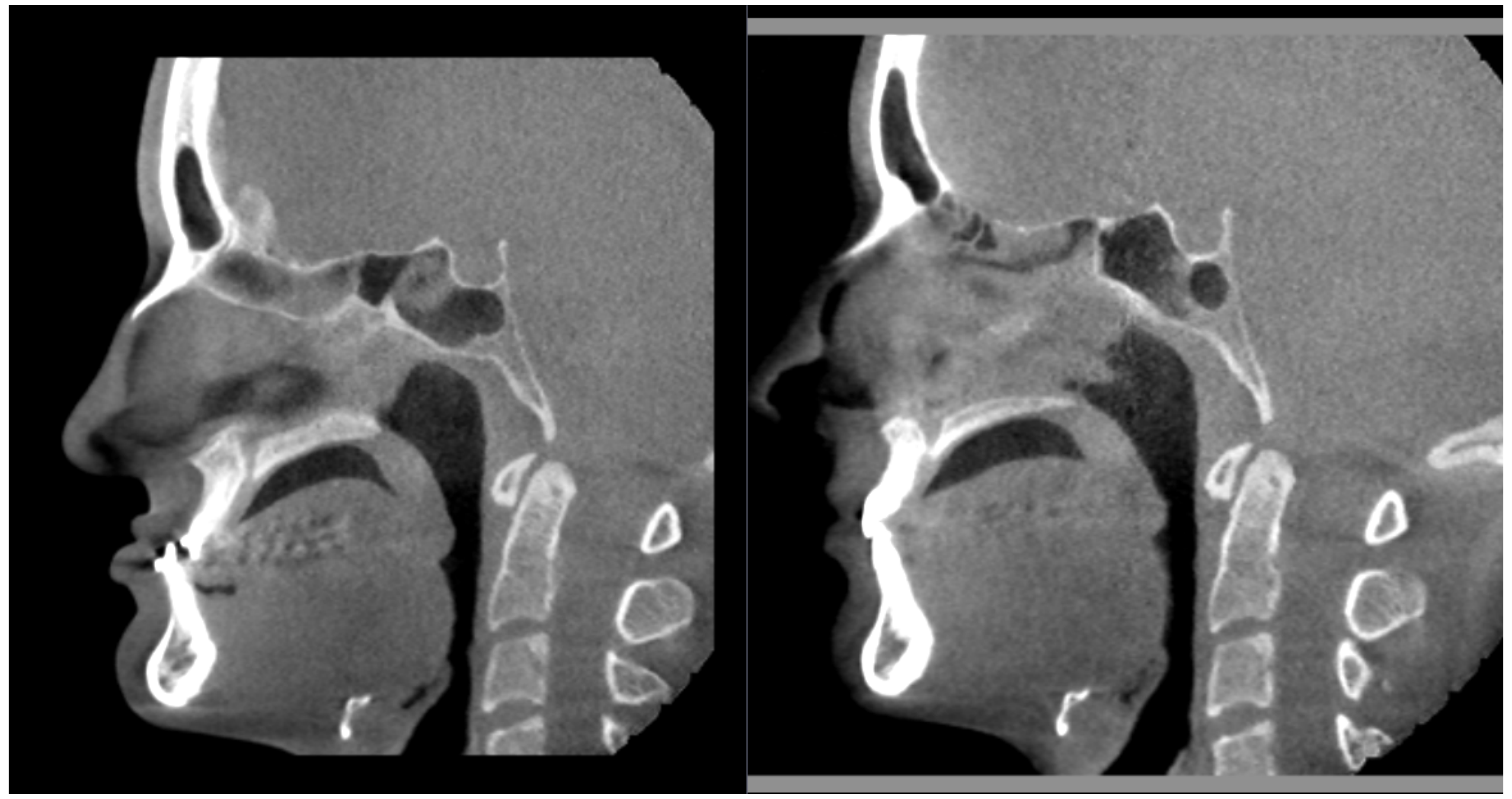
Figure3. Pediatric ADC atlases generated for different ages.

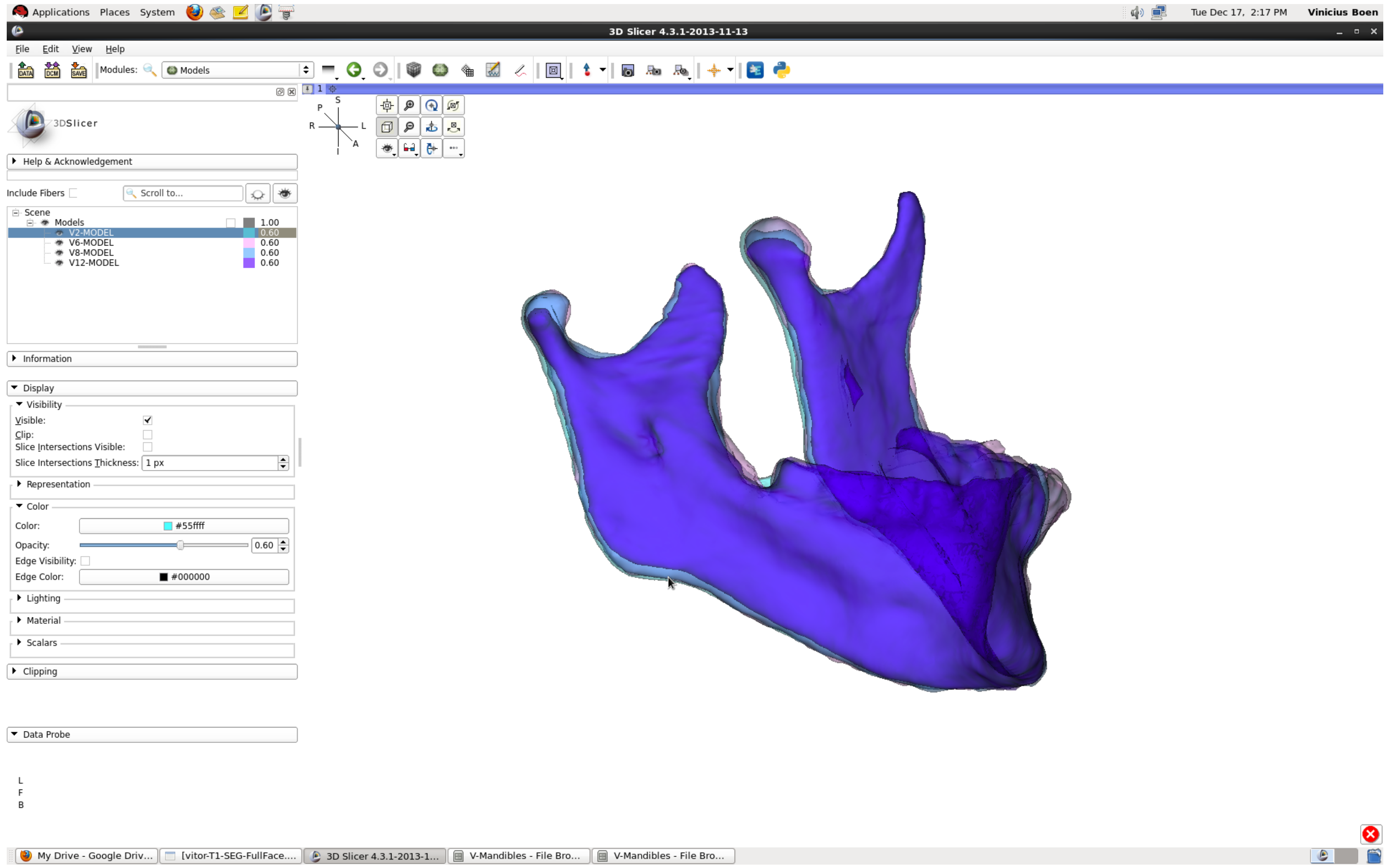
Images courtesy Pieper, Grant, Ou, Zollei

TMJ-OA

- Osteoarthritis of the Temperomandibular Joint (currently in year 1 of 4)
  - NIDCR/NIBIB R01
  - Before and After Craniomaxillofacial Surgery
  - Longitudinal Cone Beam CT to Track Atrophy
- Active Participants
  - Michigan: Cevedanes, Boen
  - UNC: Styner, Paniagua, Nguyen
  - Isomics: Pieper
- Registration Issues
  - Longitudinal CBCT
  - Atrophy, Surgical Intervention, Implant Artifacts
  - Quantifying Shape Change







Modules: Models

Include Fibers □

Scene	
Models	1.00
V2-MODEL	0.60
V6-MODEL	0.60
V8-MODEL	0.60
V12-MODEL	0.60

Visibility

Visible: ☑

Clip: □

Slice Intersections Visible: □

Slice Intersections Thickness: 1 px

Color

Color: #55ffff

Opacity: 0.60

Edge Visibility: □

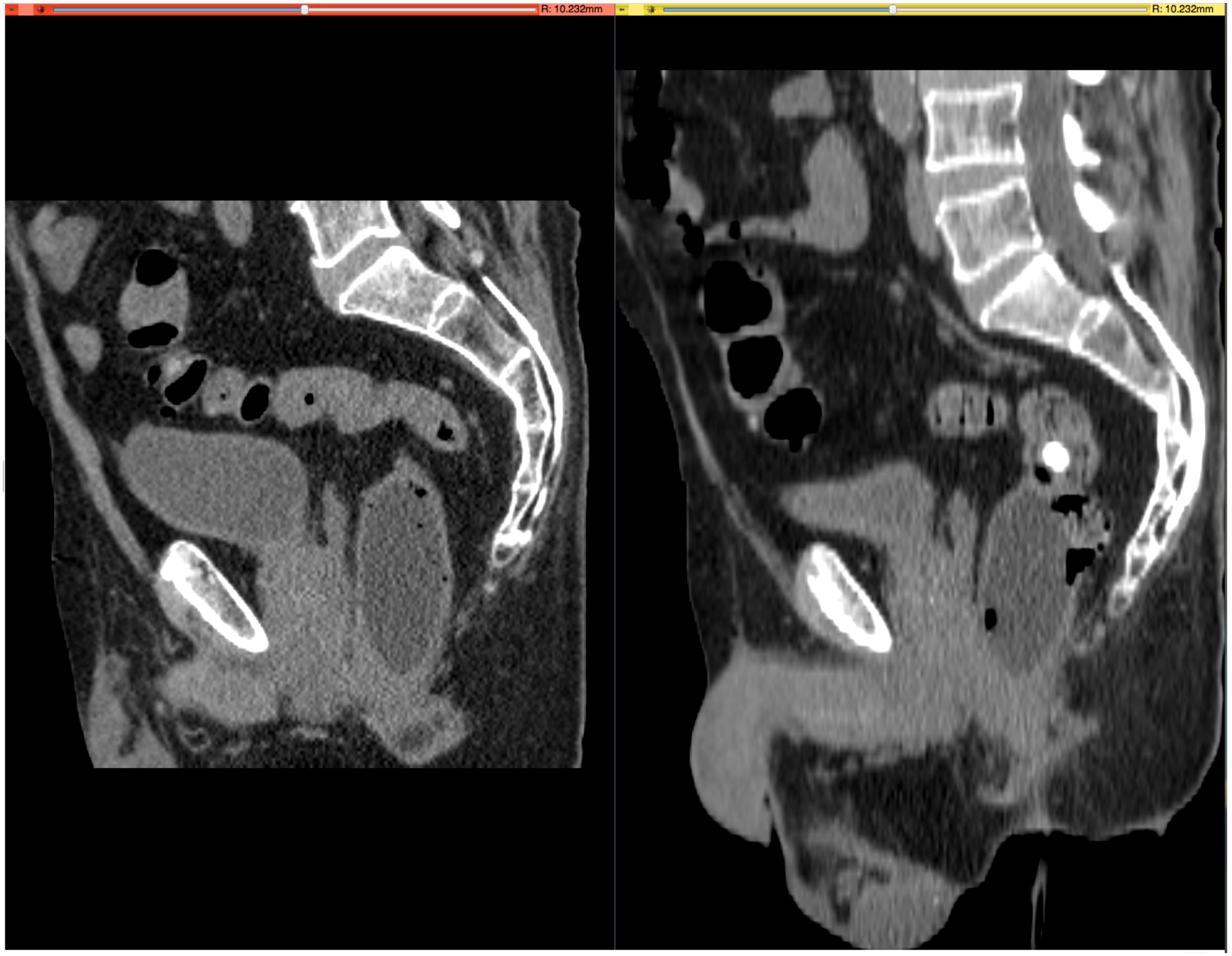
Edge Color: #000000

Images courtesy Lucia Cevedanes, Vinicius Boen, Michigan

NA-MIC

Plastimatch

- National Alliance for Medical Image Computing (currently in year 10 of 10)
  - NIH U54
  - Develop National Software Infrastructure for Medical Image Computing
  - DBP in Head and Neck Cancer Adaptive Proton Radiotherapy
- Active Participants in DBP
  - BWH: Kikinis
  - MGH: Sharp, Shusharina
  - GE: Miller, Prastawa
  - Isomics: Pieper, Yarmarkovich
- Registration Issues
  - CT/MR, CT/CBCT
  - Pose, Therapy Response, Physiology



Images courtesy Greg Sharp, MGH

Discussion Topics

- Algorithms for Steering Automation
  - MI? SIFT? Others?
- Other Precedents
  - Commercial? Academic? Daydreams?
- Live Demos
  - I have many datasets and prototypes with me
- Other Ideas?
  - ?