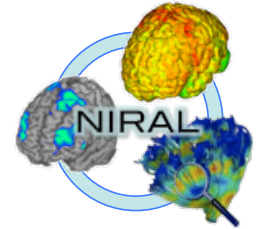




NA-MIC

National Alliance for Medical Image Computing

<http://na-mic.org>



DTI Atlas Registration via 3D Slicer and DTI-Reg

Martin Styner, UNC

Francois Budin, UNC





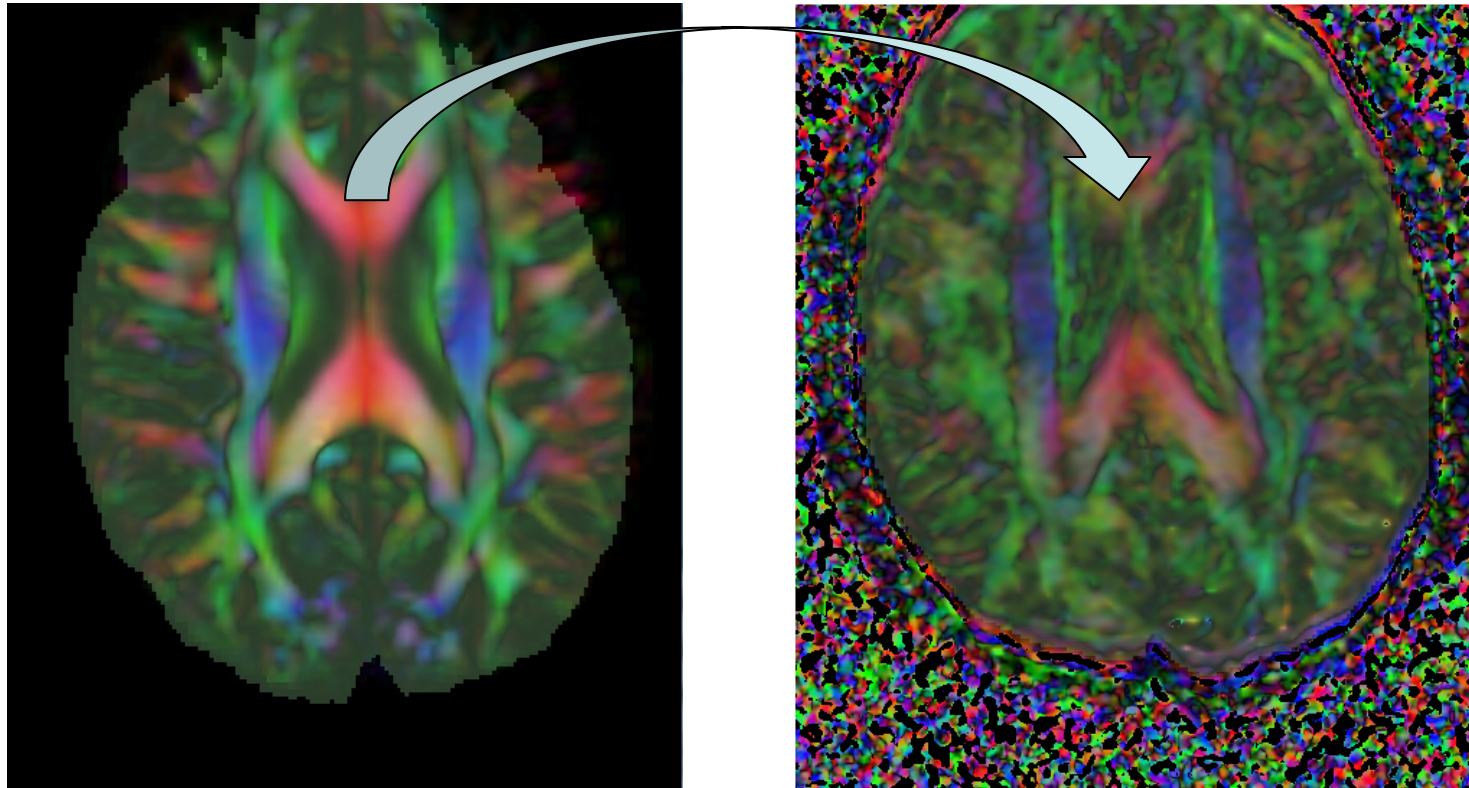
DTI Registration



- This tutorial teaches you how
 - Load DTI datasets & masks
 - Perform a pair-wise registration to a prior atlas via DTI-Reg
 - Affine transform and deformable transform
 - Save the transformed images and the deformable transform



Concept of Registration



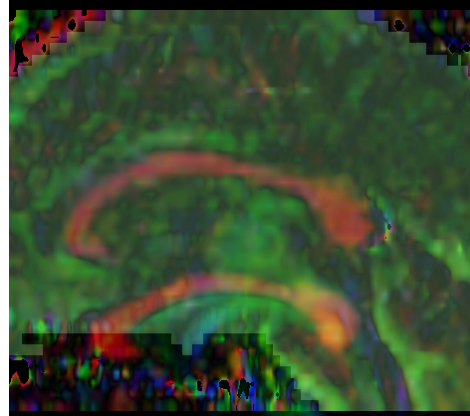
Combining information from multiple images requires the geometric relationship between them to be known...



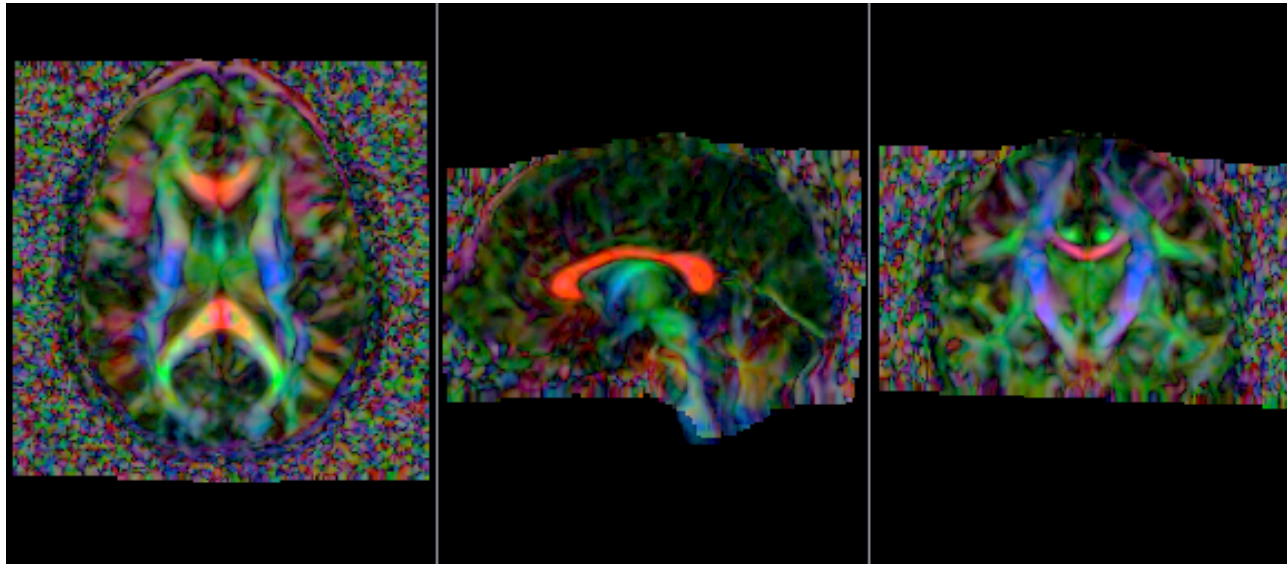
Concept of Registration: Overlay of pair of images



misaligned



aligned

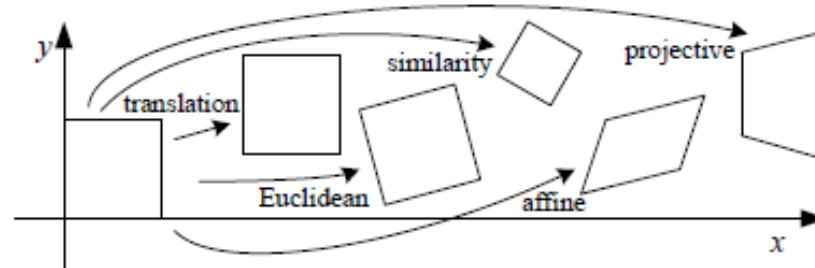




Transformation for Image Registration



Choice of transformations (complexity of transformation, #degrees of freedom depends on application).



Transformation	Matrix	# DoF	Preserves	Icon
translation	$\begin{bmatrix} I & & t \end{bmatrix}_{3 \times 4}$	3	orientation	
rigid (Euclidean)	$\begin{bmatrix} R & & t \end{bmatrix}_{3 \times 4}$	6	lengths	
similarity	$\begin{bmatrix} sR & & t \end{bmatrix}_{3 \times 4}$	7	angles	
affine	$\begin{bmatrix} A \end{bmatrix}_{3 \times 4}$	12	parallelism	
projective	$\begin{bmatrix} \tilde{H} \end{bmatrix}_{4 \times 4}$	15	straight lines	

credit: R. Szelisky, Computer Vision



3D Transformations

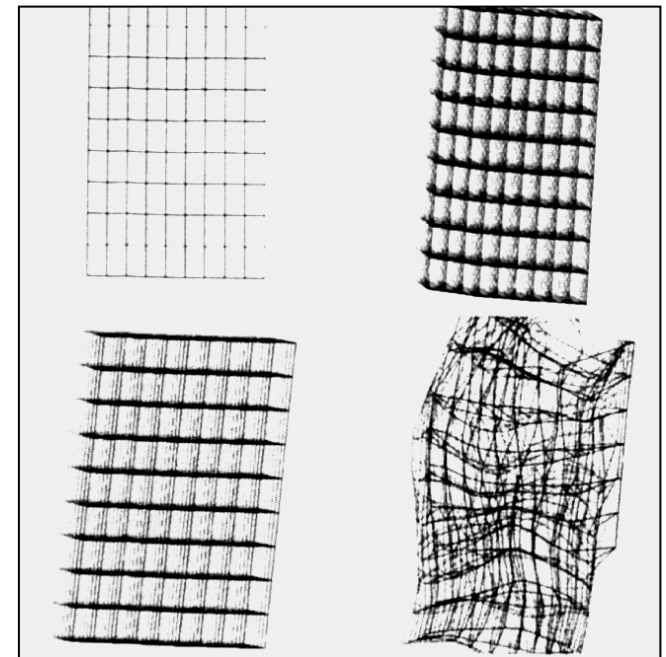


Linear Transformations (invertible, low DOF):

Translation (3 DOF) $x' = \begin{bmatrix} I & t \end{bmatrix} \bar{x}$

Rigid:
Trans & Rot (6 DOF): $x' = \begin{bmatrix} R & t \end{bmatrix} \bar{x}$

Affine (12 DOF) $x' = \begin{bmatrix} a_{00} & a_{01} & a_{02} & a_{03} \\ a_{10} & a_{11} & a_{12} & a_{13} \\ a_{20} & a_{21} & a_{22} & a_{23} \end{bmatrix} \bar{x}$.



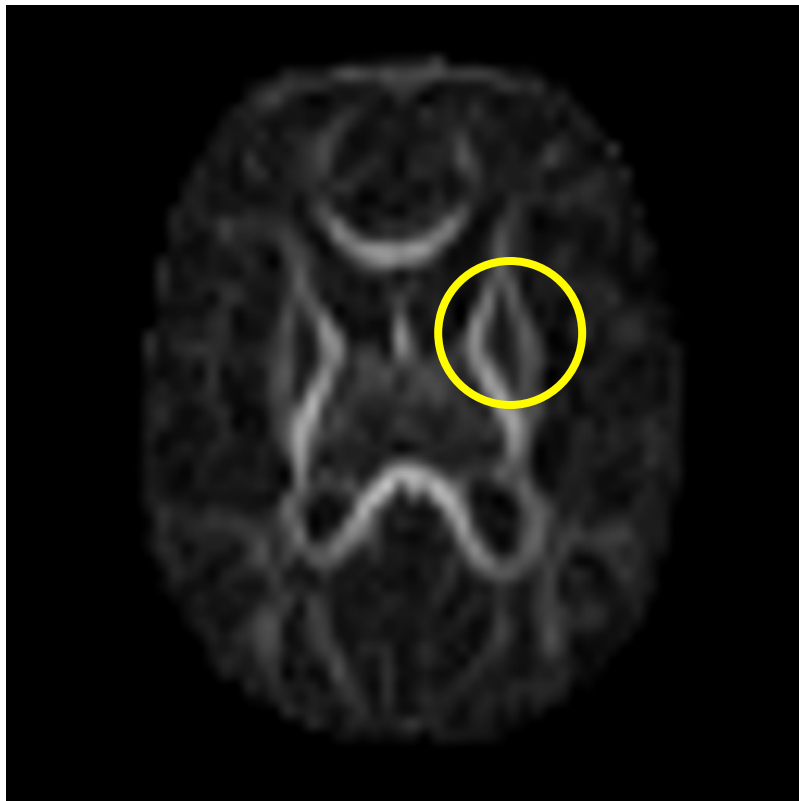
Nonlinear, deformable transformations (high DOF):

B-spline (deformable,
grid of control points)

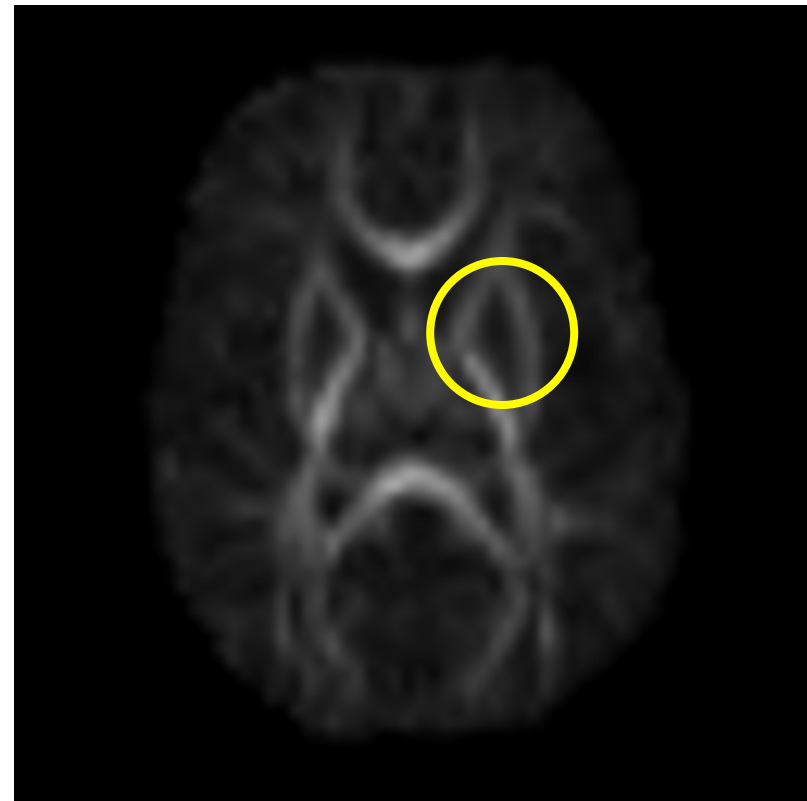
Diffeomorphic (highly deformable,
smooth transformation, invertible)



Co-registration: From linear to nonlinear



Linear registration (affine)

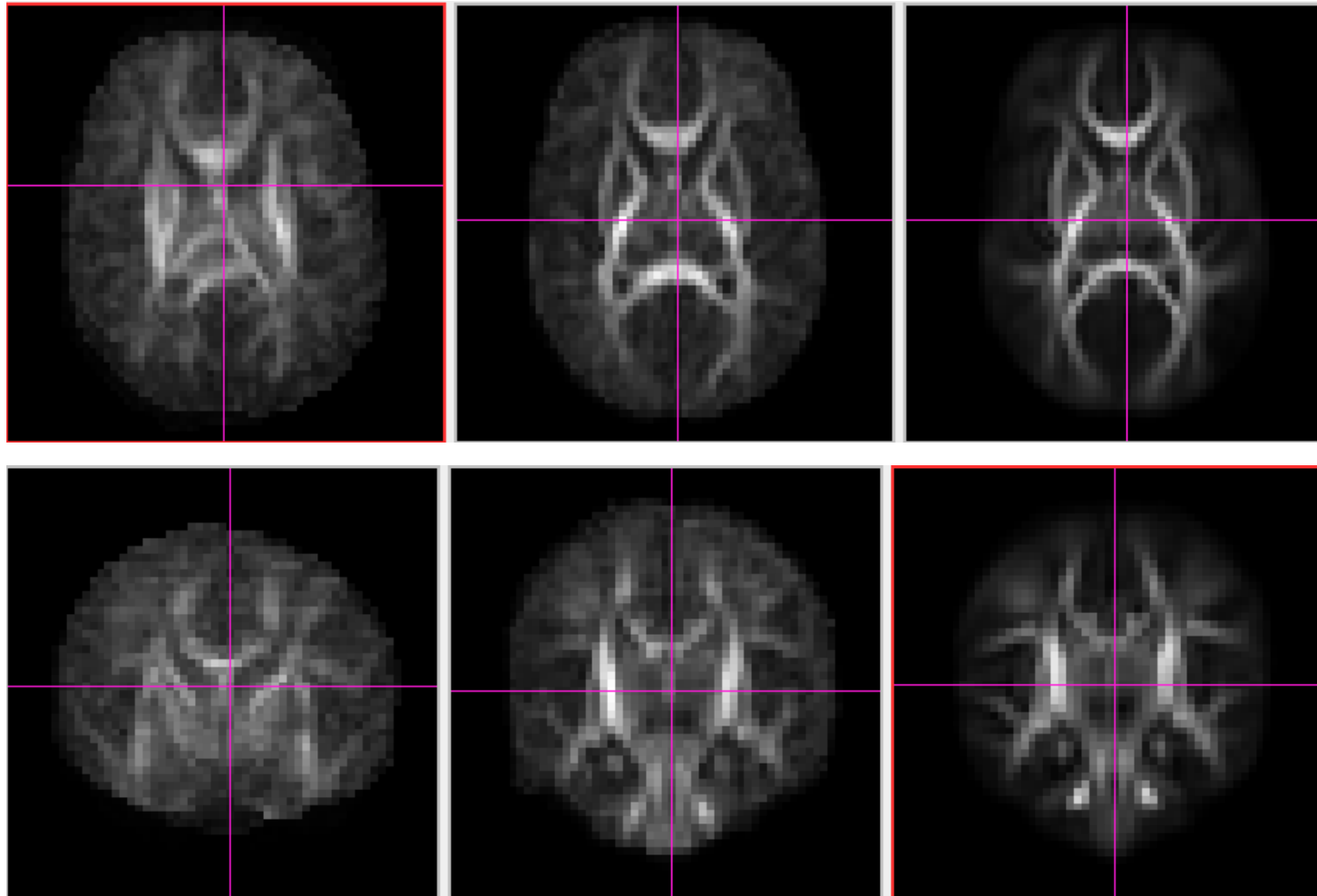


Nonlinear registration (diffeom.)

Example: Registration of DTI to atlas template



Atlas Building: Averaging registered FA images



Quality (sharpness) of atlas improves with deformable transformations.

raw

linear

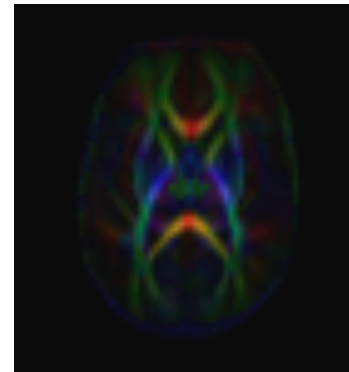
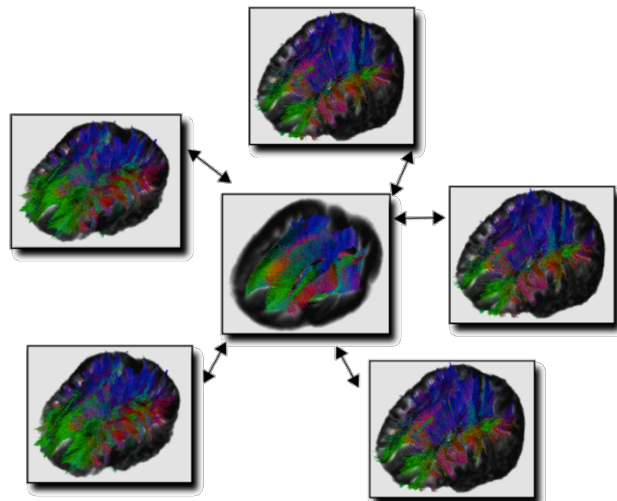
nonlinear



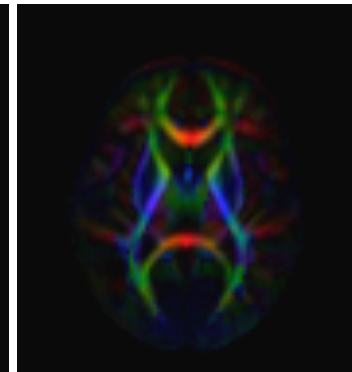
DTI Population Atlases



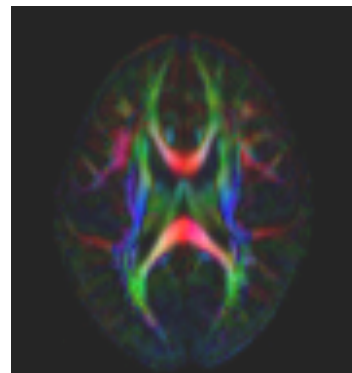
- Definition of standard, normative space
- Templates to become available to researchers



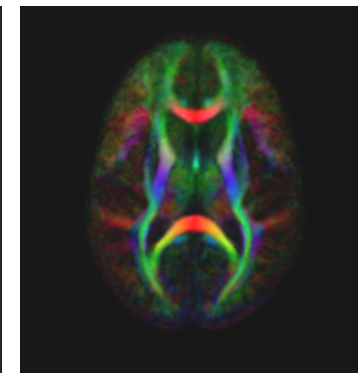
Neonate



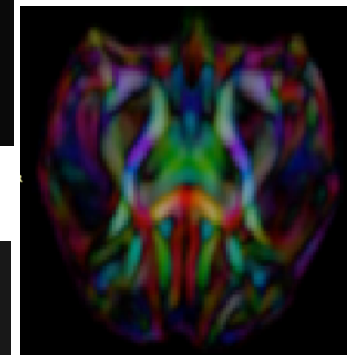
1 year



2 year



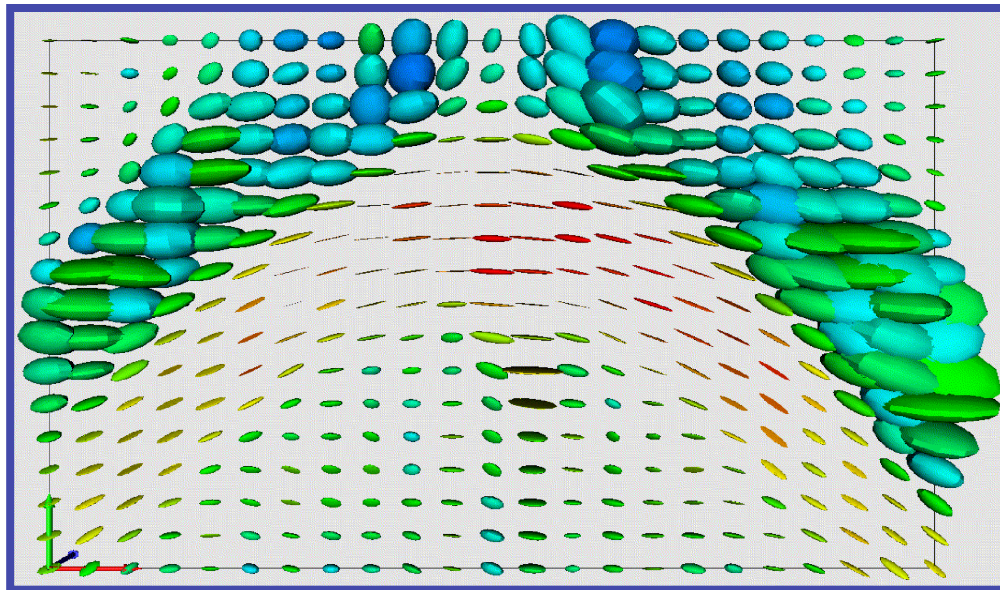
Adult



Rhesus (15mo)

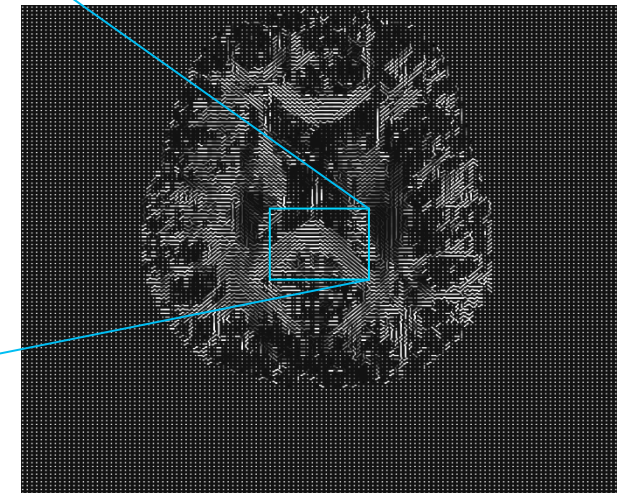


Spatial Transformations of Diffusion Tensors



Warmer colors indicate higher anisotropy

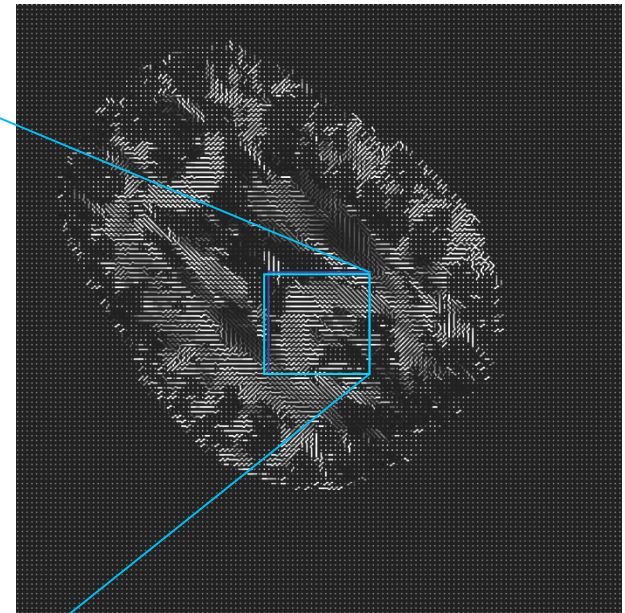
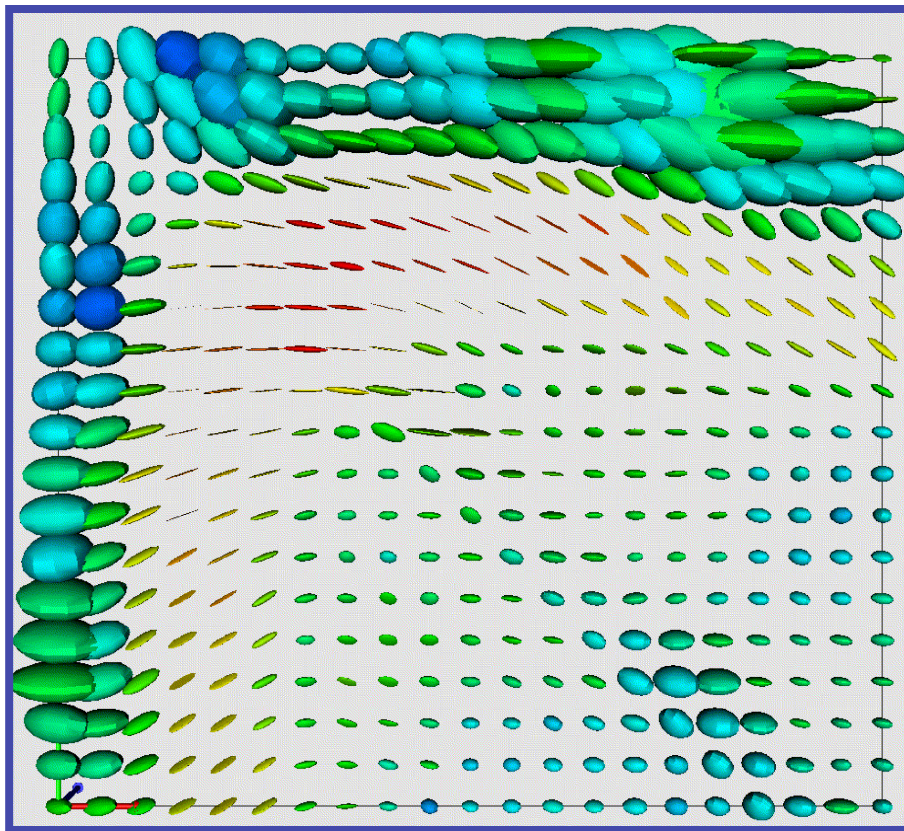
Principal diffusion directions in anisotropic regions of a DT-MR image slice



James Gee, Department of Radiology
University of Pennsylvania



Rotation without DT Reorientation: Transform voxel grid, leave tensors

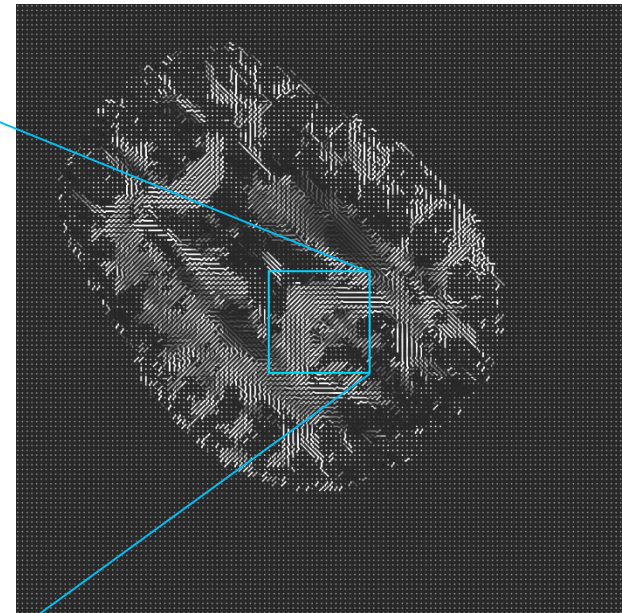
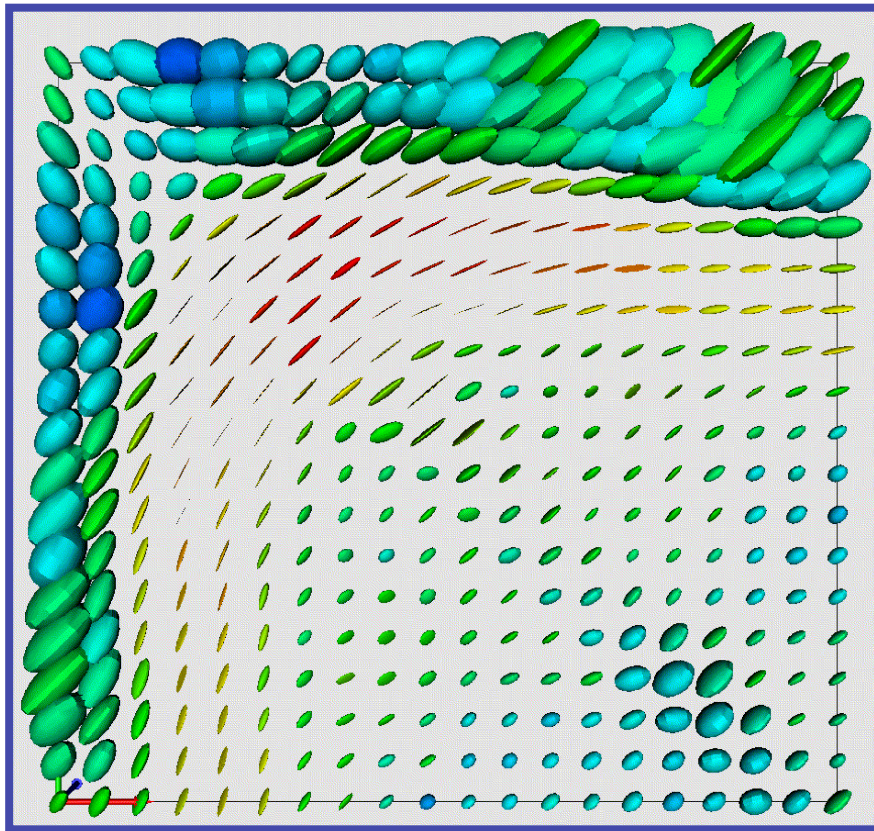


- Directional structure is lost.
- DTs orientations are no longer consistent with the anatomical structure of the image.

James Gee, Department of Radiology
University of Pennsylvania



Rotation with DT Reorientation



- $D \rightarrow R \cdot D \cdot R^T$.
- Directional structure preserved.
- DTs orientations remain consistent with the anatomy.

James Gee, Department of Radiology
University of Pennsylvania



Affine Tensor Transformations

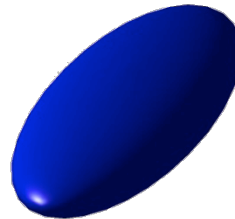
(Alexander et al, MICCAI 1999)



Original
Tensor

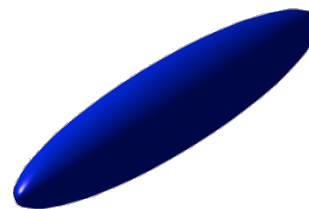


Transformed
Tensor



$$D \rightarrow F \cdot D \cdot F^T$$

- We wish to **preserve the shape** of the DTs.
- But we must reorient them appropriately.
- Require R that reflects reorientation due to F .



$$D \rightarrow R \cdot D \cdot R^T$$

- For an affine transformation, $D \rightarrow F \cdot D \cdot F^T$?
- **No...**

Finite Strain Estimation

- Decompose F into:
 - Rigid rotation, R , and
 - Deformation, U :
$$F = R \cdot U$$
$$R = F \cdot (F^T \cdot F)^{-1/2}$$
- Then reorient D using R :
$$D' = R \cdot D \cdot R^T$$



Dataset



For this tutorial you will need DTI data files that can be found following this link :

<http://hdl.handle.net/1926/1759>

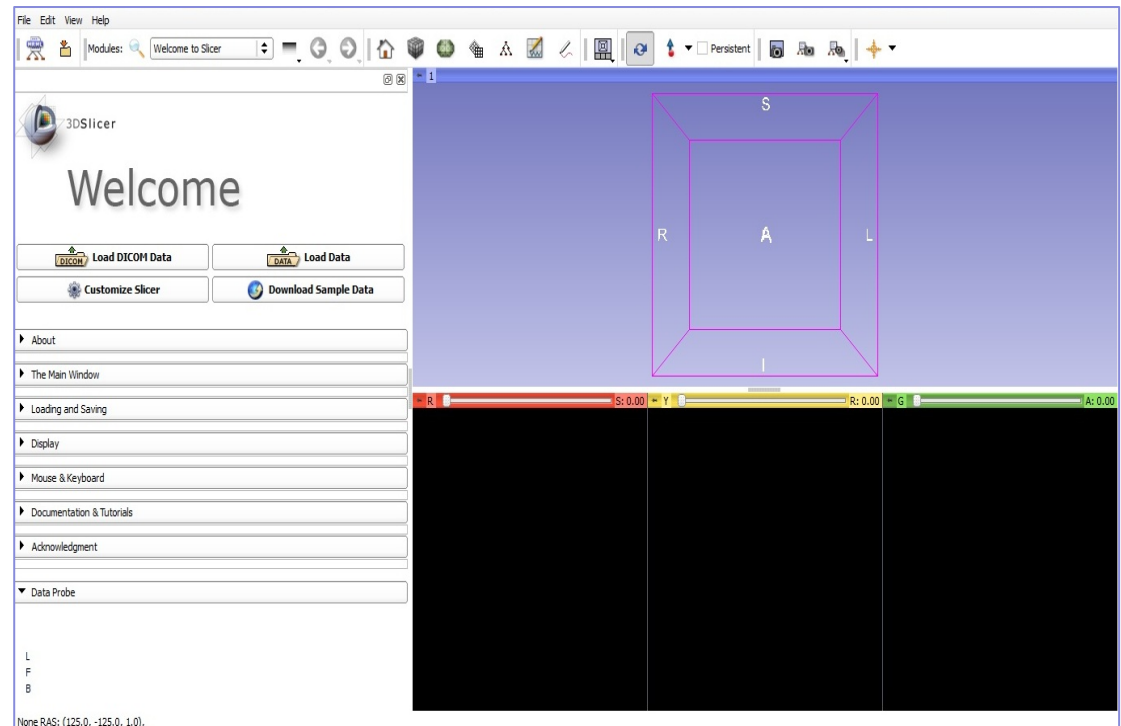


Start Slicer 4



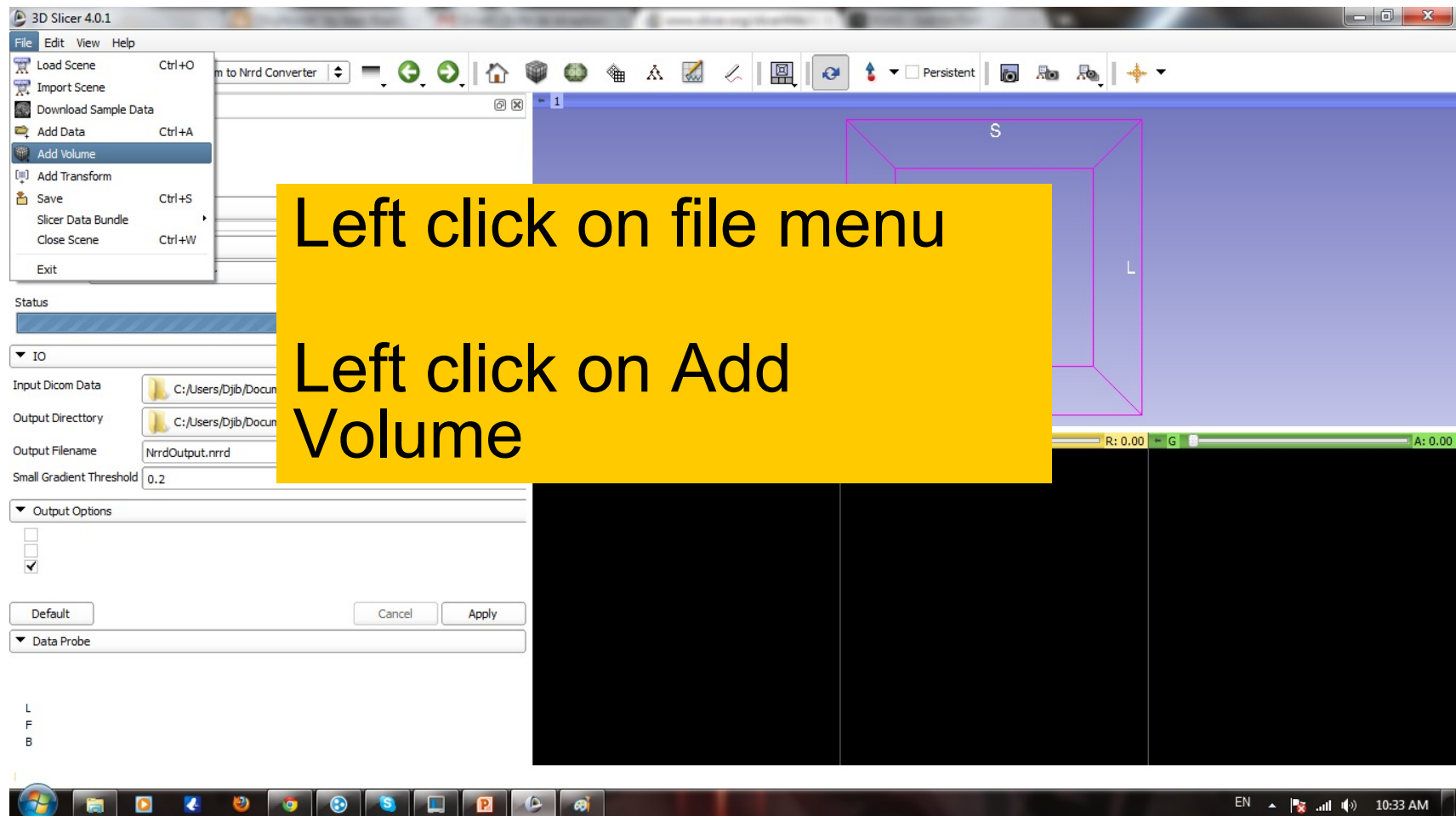
Linux/Mac users :
Launch the Slicer executable located in the Slicer4 directory

Windows users :
Select Start→All Programs→Slicer4.0.1→Slicer
Or launch the Slicer executable from Slicer4 directory



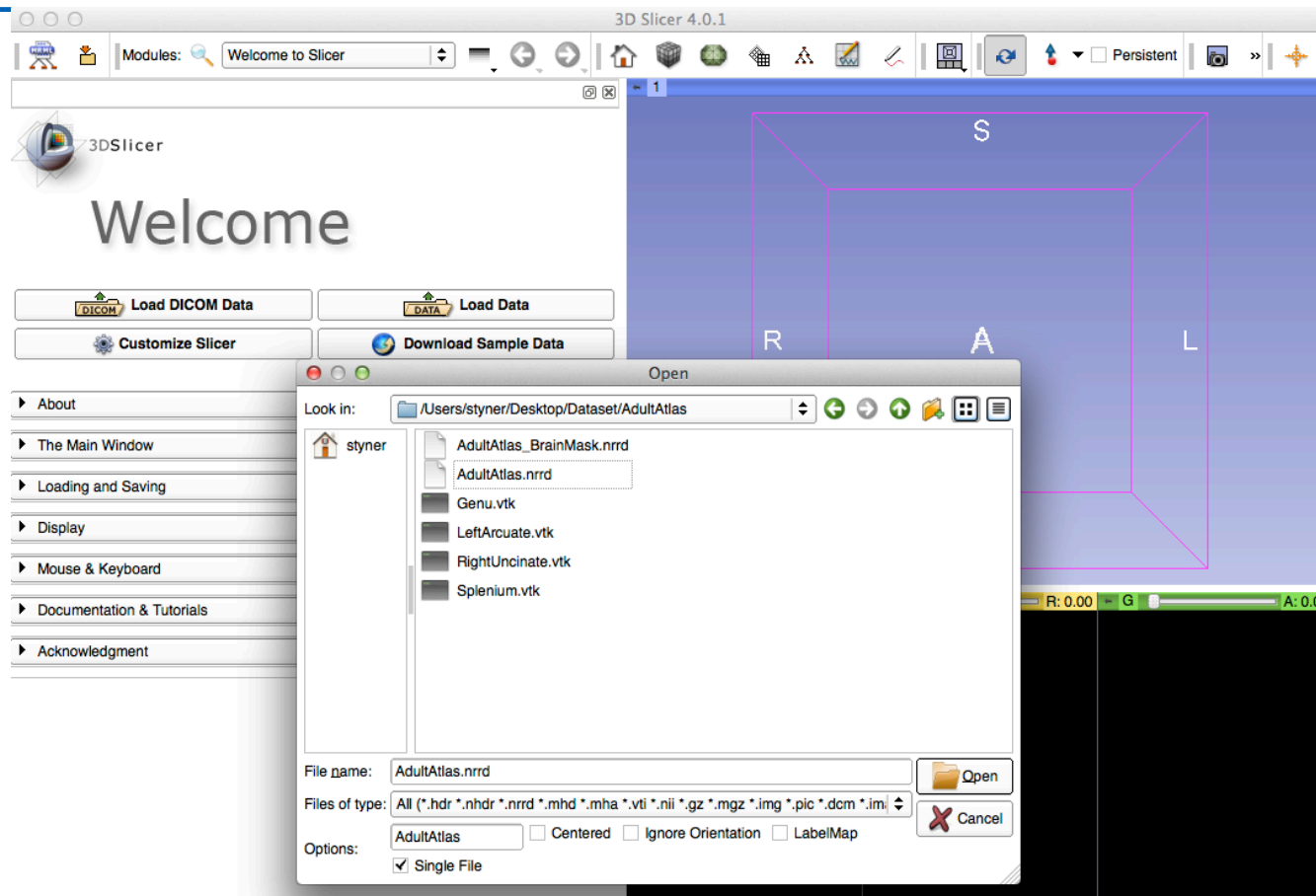


Loading DTI Atlas





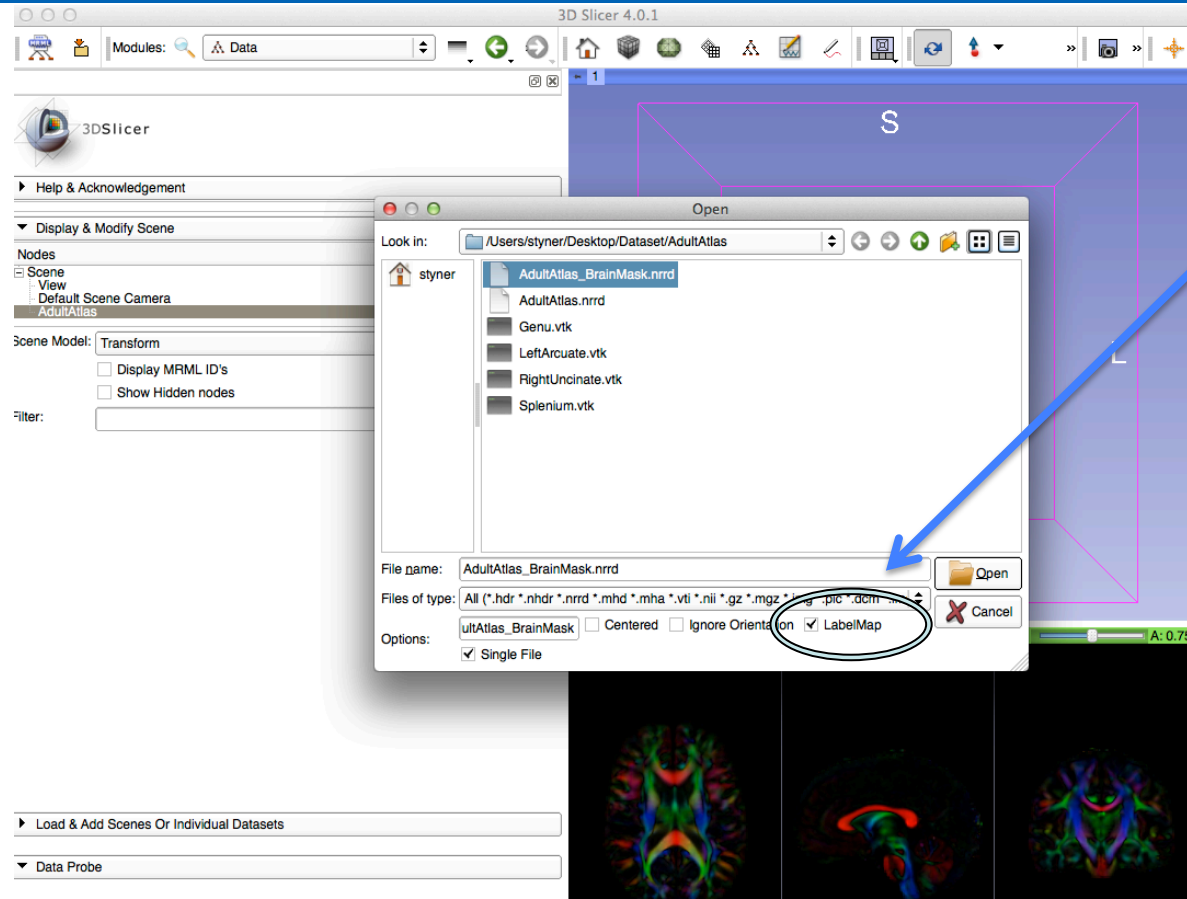
Loading DTI Atlas



Select the AdultAtlas.nrrd volume



Loading DTI Atlas **Mask**



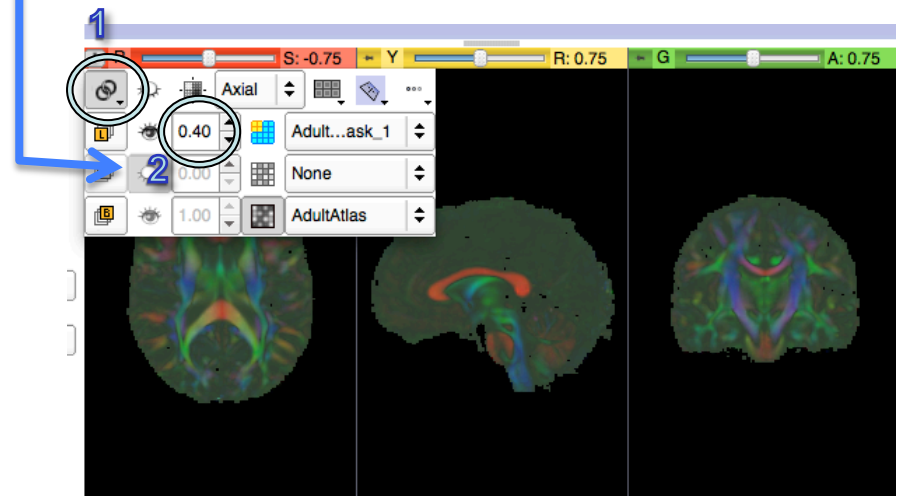
Load AdultAtlas_BrainMask.nrrd label map



Adjust View



- Adjust view to see both mask and atlas
 1. Link all 3 viewers
 2. Opacity change

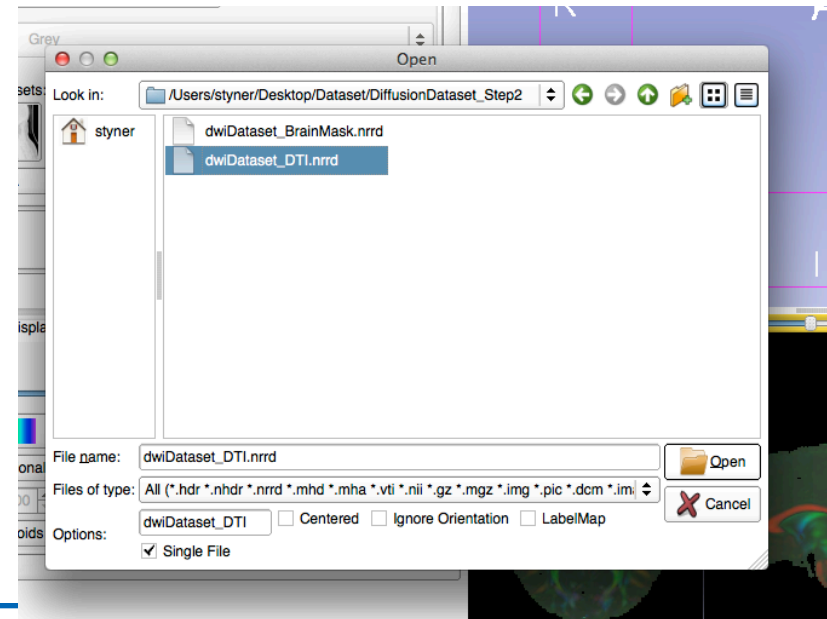




Loading 2nd DTI dataset



- File Menu =>Add Volume (or see previous tutorial)
- Directory: DiffusionDataset_Step2
- Load **dwiDataset_DTI.nrrd**

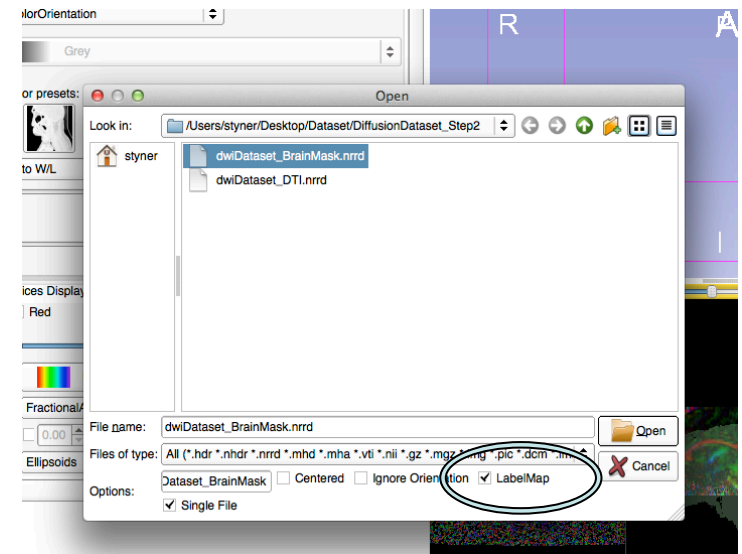
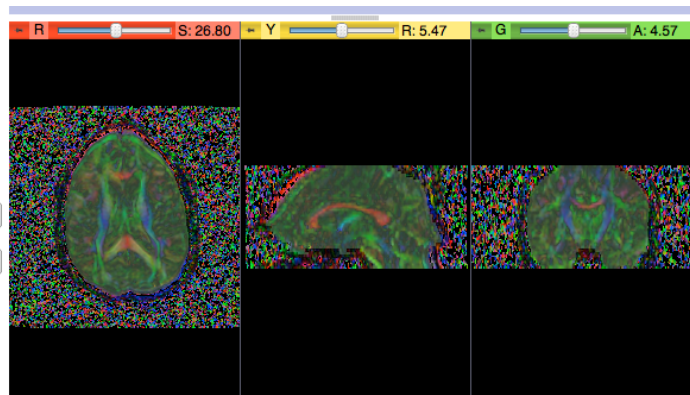




Loading DTI dataset mask



- File Menu =>Add Volume (or use from previous tutorial)
- DiffusionDataset_Step2
- Load BrainMask
- “LabelMap” checkbox



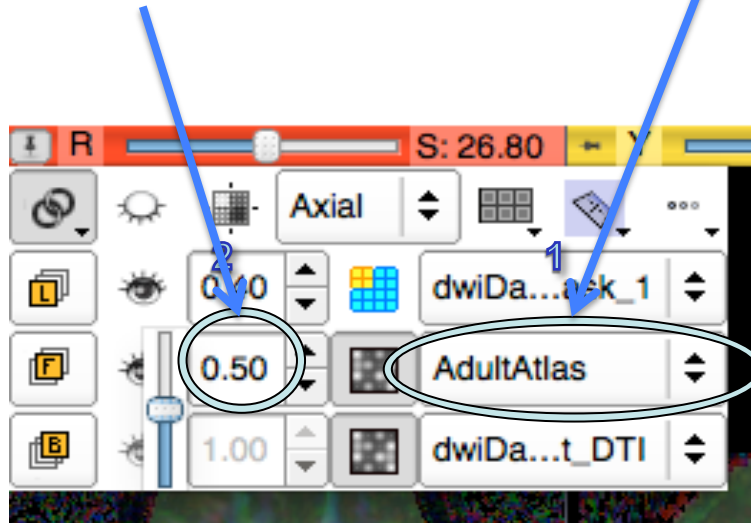


Overlay DTI datasets



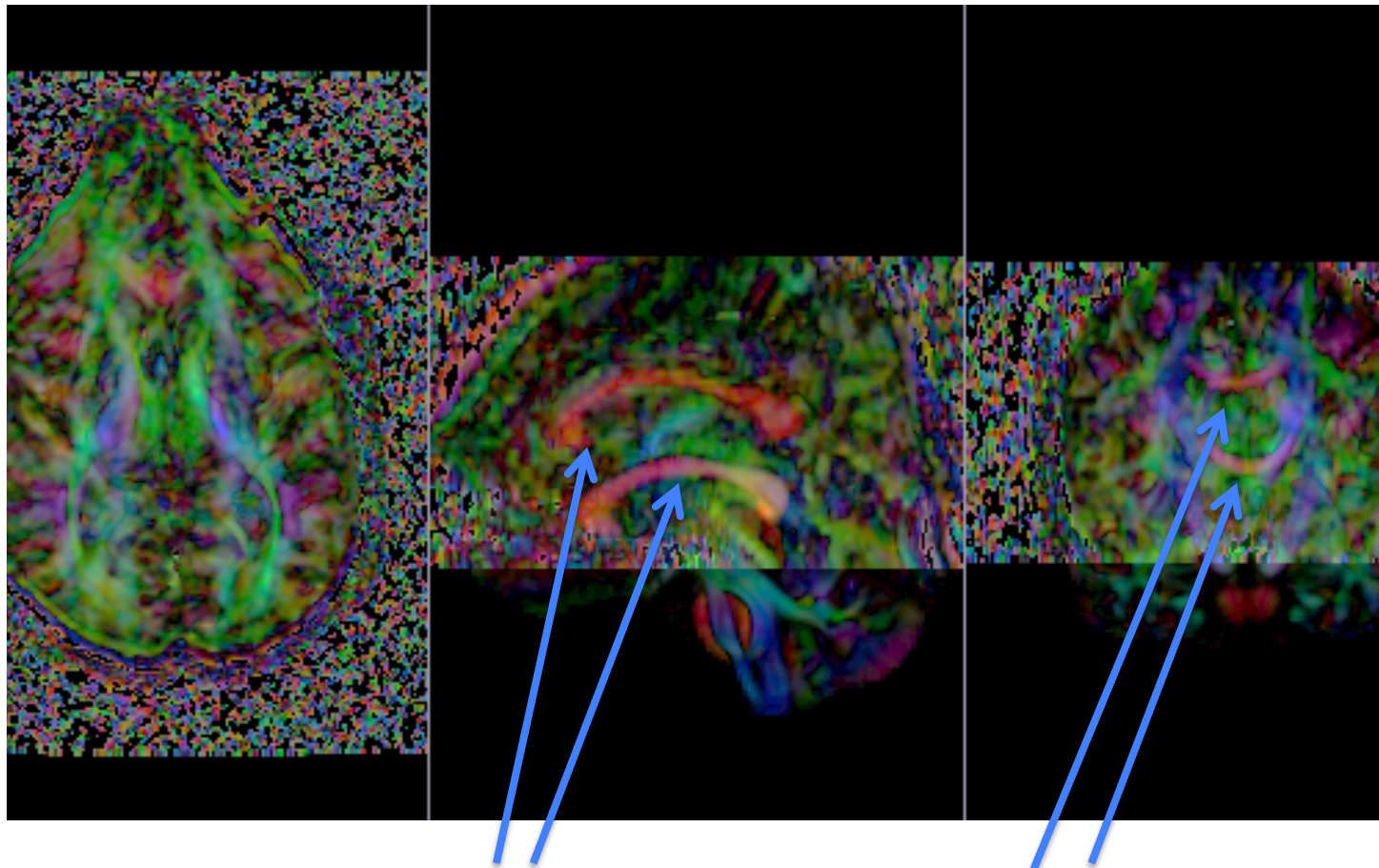
- How can we check alignment?
- Overlay the DTI images!

1. Select AdultAtlas for Foreground
2. Set Opacity to 0.5





Overlay



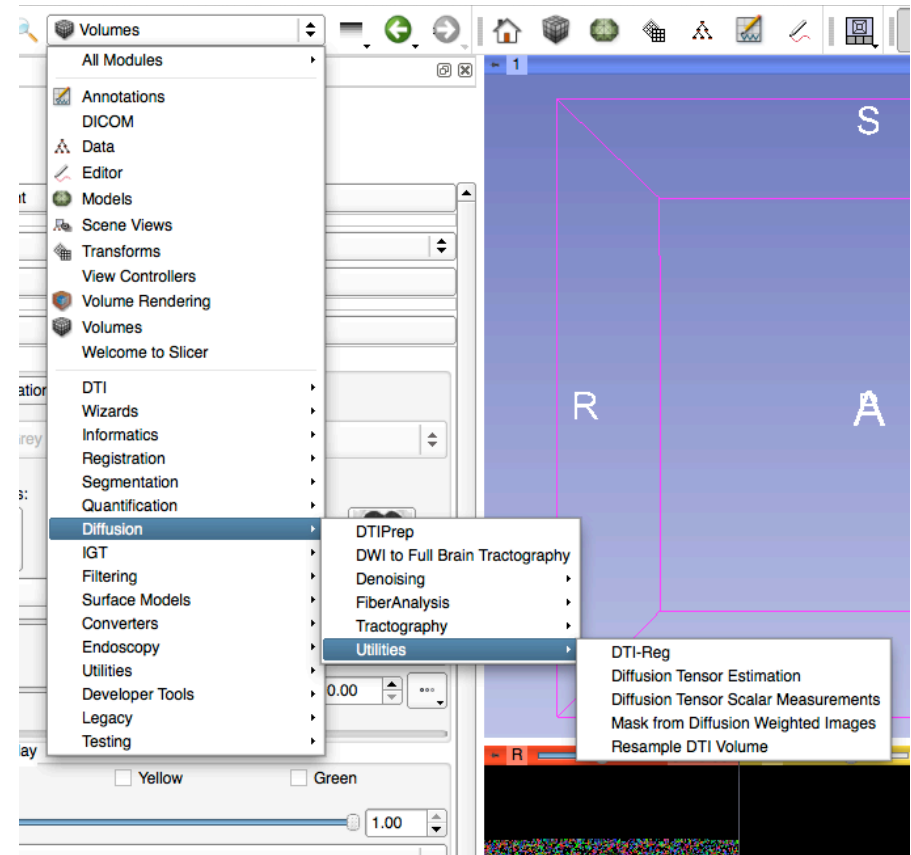
Bad alignment: 2 separate corpus callosum



Select DTI-Reg Module



- Slicer modules
 - Diffusion
 - Utilities
 - DTI-Reg
- DTI-Reg:
 - Pairwise DTI registration module

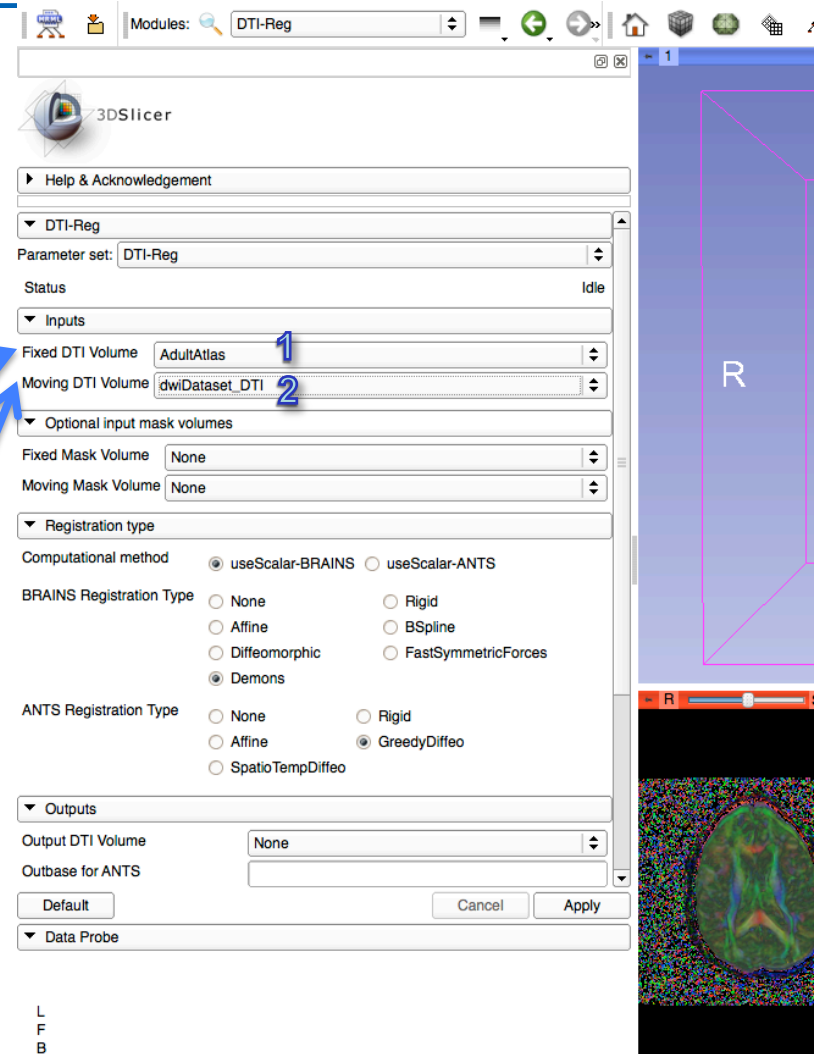




Volumes for Registration



1. Fixed Volume:
Target of registration =
AdultAtlas.nrrd
2. Moving Volume:
Image to be transformed:
dwiDataset_DTI





Set Masks for Registration



1. Set Fixed Mask to
Atlas Mask:
`AdultAtlas_BrainMask.nrrd`

2. Set Moving Mask to
dwiDataset Mask:
`dwiDataset_BrainMask.nrrd`

The screenshot shows the DTI-Reg software interface. The 'Inputs' section is expanded, showing 'Fixed DTI Volume' set to 'AdultAtlas' and 'Moving DTI Volume' set to 'dwiDataset_DTI'. Under 'Optional input mask volumes', 'Fixed Mask Volume' is set to 'AdultAtlas_BrainMask' (marked with a blue '1') and 'Moving Mask Volume' is set to 'dwiDataset_BrainMask' (marked with a blue '2'). Blue arrows point from the text in the first two steps to these settings. The 'Registration type' section shows 'Computational method' set to 'useScalar-BRAINS' and 'BRAINS Registration Type' set to 'Affine'. A tooltip is visible over the 'BRAINS Registration Type' options, listing: 'BRAINS Registration type: None, Rigid, Affine, BSpline, Diffeomorphic, FastSymmetricForces, Demons'. The 'Outputs' section shows 'Output DTI Volume' set to 'None'.



Set Transform to Affine



- Set registration transform to **Affine**
- Deformable Registration is performed in 2 steps: Affine followed by nonlinear.
- ANTS generally better but much slower

The screenshot shows the DTI-Reg software interface. The 'Registration type' section is expanded, showing the 'BRAINS Registration Type' with 'Affine' selected and circled. A blue arrow points from the text 'Set registration transform to Affine' to this selection. The 'Computational method' section shows 'useScalar-BRAINS' selected. The 'ANTS Registration Type' section shows 'GreedyDiffeo' selected. The 'Outputs' section shows 'Output DTI Volume' set to 'None'.



Select Outputs



- Create & rename volumes for output
- 1. Affinely registered DTI dataset
- 2. Affine transform
- Apply to run & wait

Registration type

Computational method useScalar-BRAINS useScalar-ANTS

BRAINS Registration Type None Rigid
 Affine BSpline
 Diffeomorphic FastSymmetricForces
 Demons

ANTs Registration Type None Rigid
 Affine GreedyDiffeo
 SpatioTempDiffeo

▼ Outputs

Output DTI Volume

Outbase for ANTS

Output Transform File for BRAINS

Output Deformation Field Volume

fixed FA Volume

moving FA Volume

Resampled FA Volume

► BRAINS registration parameters

► ANTs registration parameters

Default Cancel Apply

Sp

None

AdultAtlas

dwiDataset_DTI

Output DTI Volume

Rename current DiffusionTensorVolume

Create new DiffusionTensorVolume

Delete current DiffusionTensorVolume

Volume



Registration



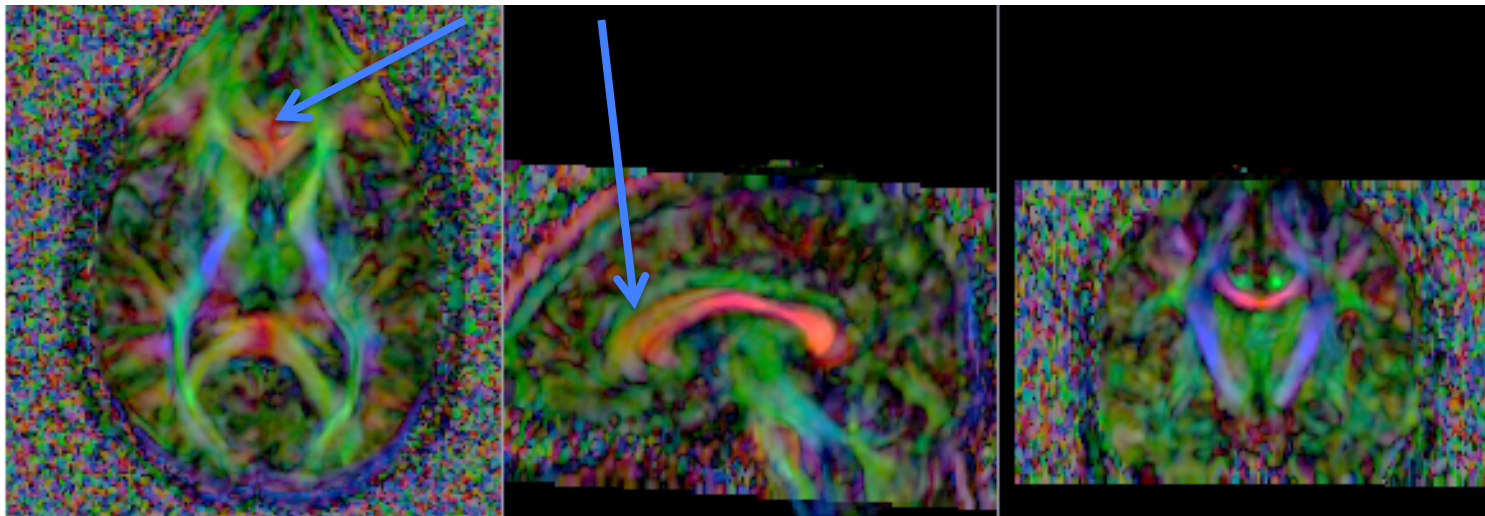
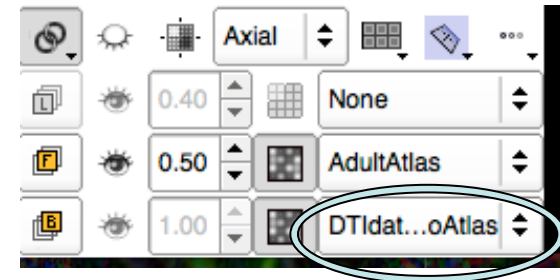
- Several pairwise registration methods available.
- **DTI-Reg** supports several registration methods based on normalized FA images:
 - Affine, B-spline, Demons-variants from within Slicer
 - ANTS as external call
- Plan: DTI-TK support
 - Registration based on full tensor.



Affine Results



- Select DTI-Reg result as background
- Result: single corpus callosum, but fuzzy, insufficient registration





Deformable Registration



Concept: Use affine registration as initialization for deformable registration:

1. Change moving volume to affinely registered data
2. Change moving mask to atlas mask
3. Change registration to Diffeomorphic (Demons)
4. Create/rename output names for deformable transformation

The screenshot shows the ANTS registration software interface with the following settings:

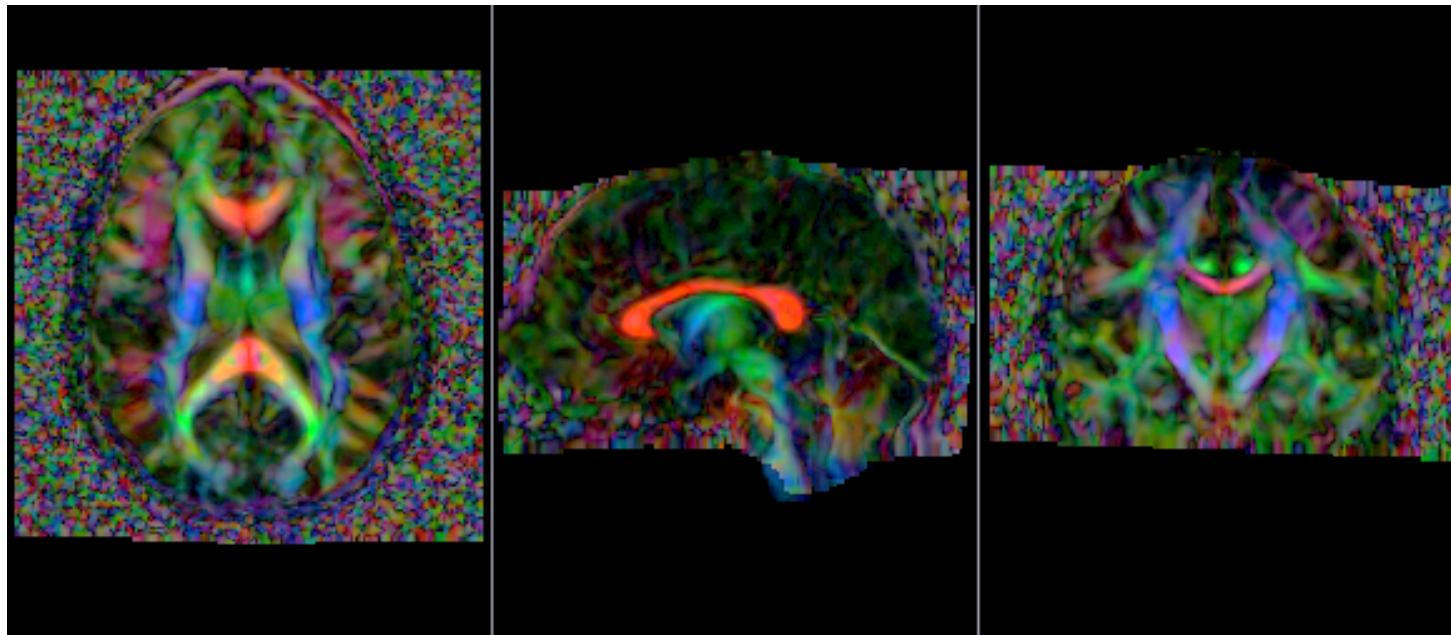
- Fixed DTI Volume: AdultAtlas
- Moving DTI Volume: DTIdata_AffineRegAtlas (1)
- Optional input mask volumes:
 - Fixed Mask Volume: AdultAtlas_BrainMask
 - Moving Mask Volume: AdultAtlas_BrainMask (2)
- Registration type:
 - Computational method: useScalar-BRAINS useScalar-ANTS
 - BRAINS Registration Type:
 - None Rigid
 - Affine BSpline
 - Diffeomorphic (3) FastSymmetricForces
 - Demons
 - ANTS Registration Type:
 - None Rigid
 - Affine GreedyDiffeo
 - SpatioTempDiffeo
- Outputs:
 - Output DTI Volume: DTIdata_DeformToAtlas (4)
 - Outbase for ANTS: Output DTI image
 - Output Transform File for BRAINS: AffineTransform_DTIdataRegAtlas
 - Output Deformation Field Volume: Deformation_DTIdataAffineRegAtlas (5)
 - fixed FA Volume: None
 - moving FA Volume: None



Deformable Results



- Select DTI-Reg deformable result as background
- Result: No longer fuzzy, significantly better registration





Save Outputs and Done



- Save selected volumes and transforms
- File → Save → (deselect/select checkboxes)
- Choose common directory: “destination for all selected”

Save Scene and Unsaved Data

<input type="checkbox"/>	Node Name	Node Type	Node Status	File Format	File Name	Data Directory
<input type="checkbox"/>	(Scene Description)	(SCENE)	Modified	MRML (.mrm)	Slicer4.0	/Users/styner/Desktop/Dataset/DiffusionDataset-Reg
<input type="checkbox"/>	dwiDataset_DTI	DiffusionTensorVolume	Not Modified	NRRD (.nrrd)	dwiDataset_DTI.nrrd	/Users/styner/Desktop/Dataset/DiffusionDataset_Step
<input type="checkbox"/>	dwiDataset_BrainMask	Volume	Modified	NRRD (.nrrd)	dwiDataset_BrainMask.nrrd	/Users/styner/Desktop/Dataset/DiffusionDataset-Reg
<input type="checkbox"/>	AdultAtlas_BrainMask	Volume	Modified	NRRD (.nrrd)	AdultAtlas_BrainMask.nrrd	/Users/styner/Desktop/Dataset/DiffusionDataset-Reg
<input type="checkbox"/>	AdultAtlas	DiffusionTensorVolume	Not Modified	NRRD (.nrrd)	AdultAtlas.nrrd	/Users/styner/Desktop/Dataset/AdultAtlas
<input checked="" type="checkbox"/>	DTIdata_AffineRegAtlas	DiffusionTensorVolume	Modified	NRRD (.nrrd)	DTIdata_AffineRegAtlas.nrrd	/Users/styner/Desktop/Dataset/DiffusionDataset-Reg
<input checked="" type="checkbox"/>	AffineTransform_DTIdataToAtlas	LinearTransform	Modified	Transform (.tfm)	AffineTransform_DTIdataToAtlas.tfm	/Users/styner/Desktop/Dataset/DiffusionDataset-Reg
<input checked="" type="checkbox"/>	Deformation_DTIdataAffineToAtlas	VectorVolume	Modified	NRRD (.nrrd)	Deformation_DTIdataAffineToAtlas.nrrd	/Users/styner/Desktop/Dataset/DiffusionDataset-Reg
<input checked="" type="checkbox"/>	DTIdata_DeformRegAtlas	DiffusionTensorVolume	Modified	NRRD (.nrrd)	DTIdata_DeformRegAtlas.nrrd	/Users/styner/Desktop/Dataset/DiffusionDataset-Reg

Destination for all selected: /Users/styner/Desktop/Dataset/DiffusionDataset-Reg

OK Cancel



Conclusions



- DTI registration is available in Slicer
- 2-step process currently, to be improved soon
- Brainmasks are needed (unless data is skull stripped already)
- This tutorial taught you how to register to an atlas
 - How to get atlas?
- **Alternative: Build atlas from data**



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- Utah: Guido Gerig, Sylvain Gouttard
- Iowa: Hans Johnson, Joy Matsui