Atlas Building in DTI

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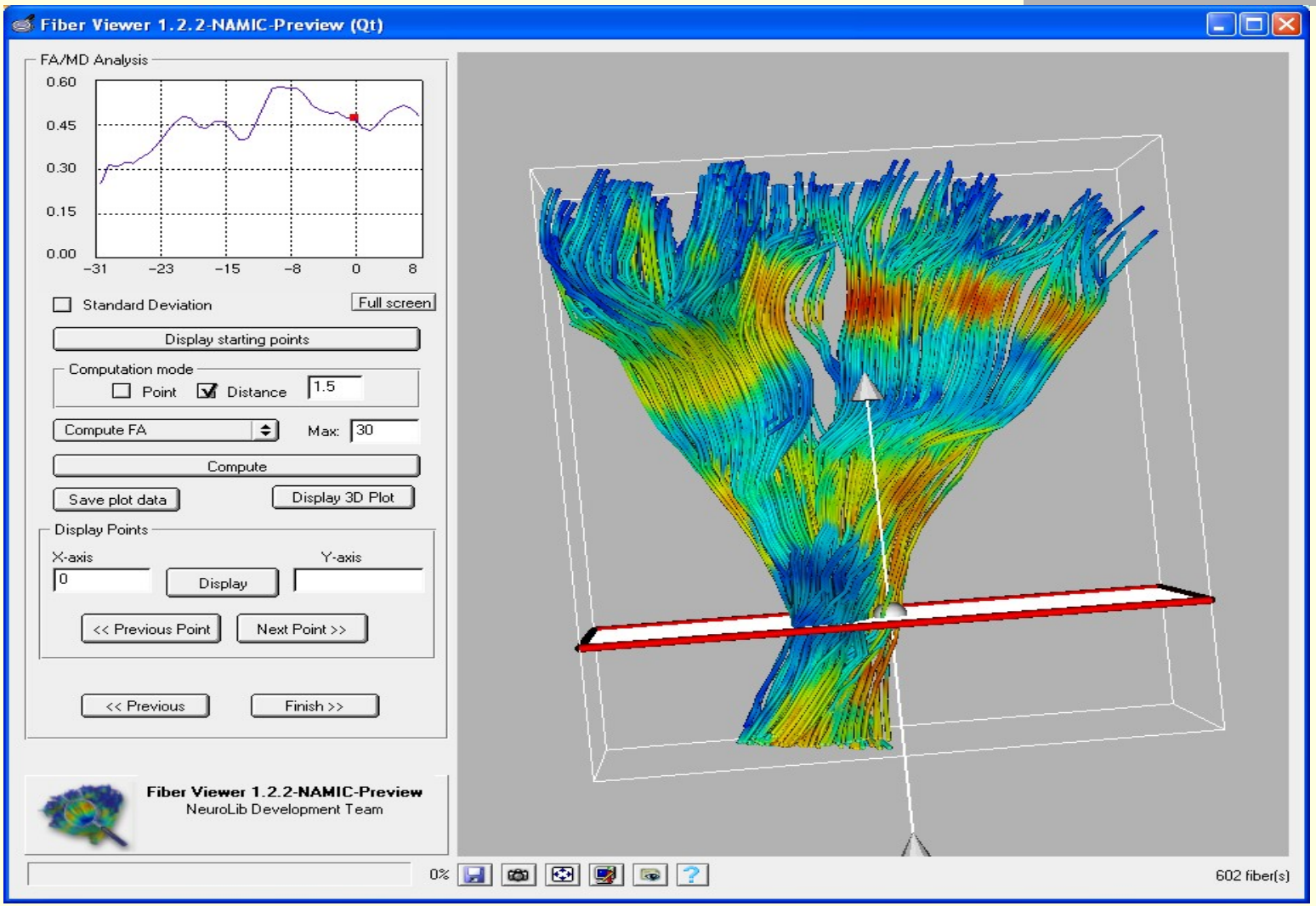
Outline

- Quantitative Tract Analysis
- Atlas-Building Methodology
- Application Areas
- Experiments
- Future Work

Quantitative Tract Analysis

- Isabelle Corouge
- Tractography
- Clustering of bundles
- Tensors statistics along fiber tract bundles

FiberViewer



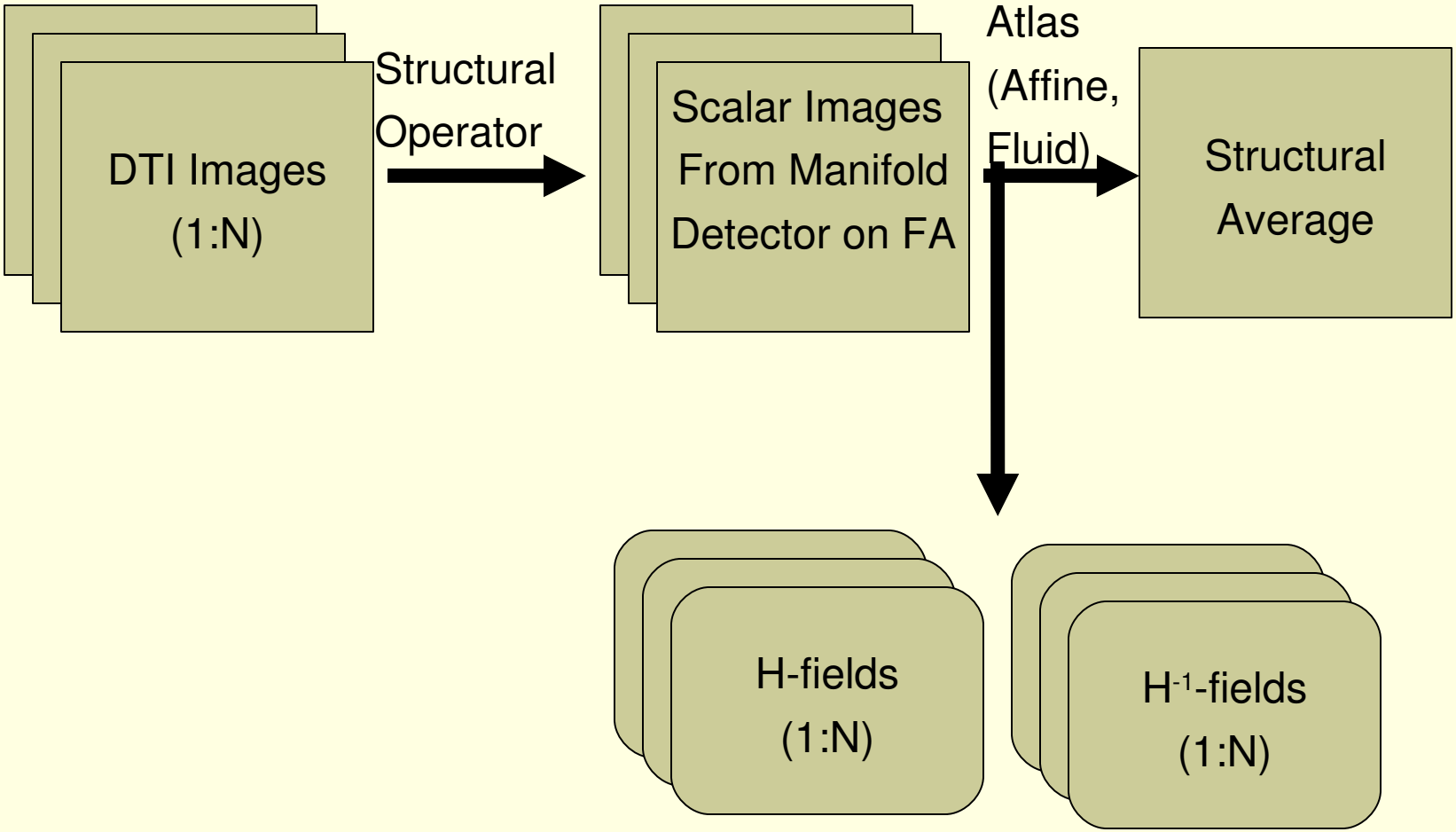
Problem Description

- Problem: Strategy for inter-patient comparison of DTI.
- Ideas
  - Solution should be fairly automatic
  - Atlas-building (Common coordinate system)
  - Framework that can answer many group comparison questions
    - Quantitative tract analysis
    - Region based analysis

Atlas Building in DTI

- Want to apply atlas building to DTI
- Challenges
  - Registration
  - Interpolation/Averaging
- Initial test
  - 5 DTI scans of 1 year old subjects

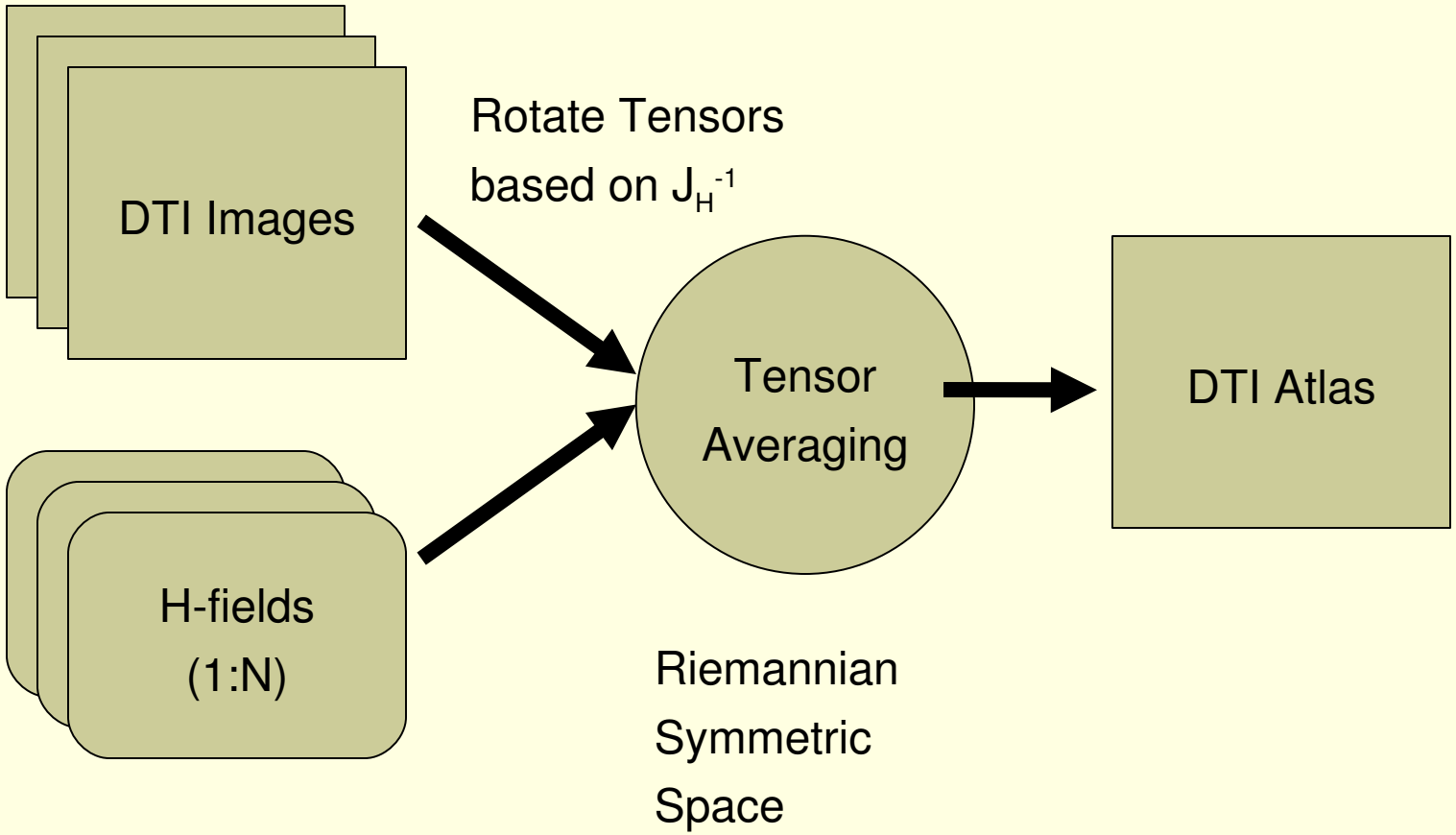
Registration



Registration Optimization

- Align template image (I_0) to coordinate system using T2 atlas
- Align remaining images (I_1-I_n) to template using affine alignment of structural image
- Use affine parameters to initialize diffeomorphic deformation fields for deformable registration
- Run deformable registration procedure of Joshi, Davis, et al.

Atlas formation



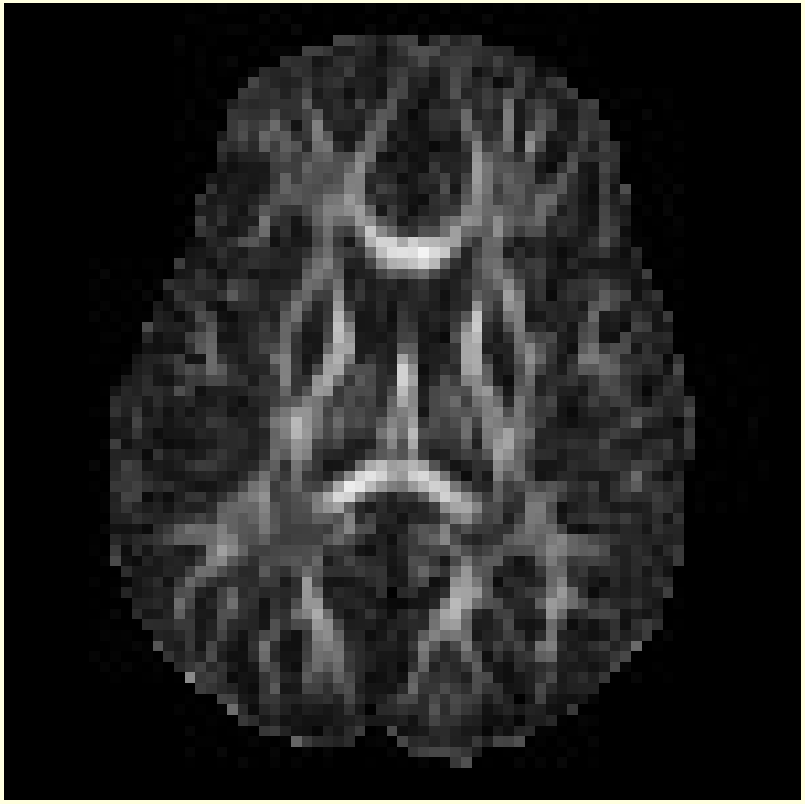
Registration Application

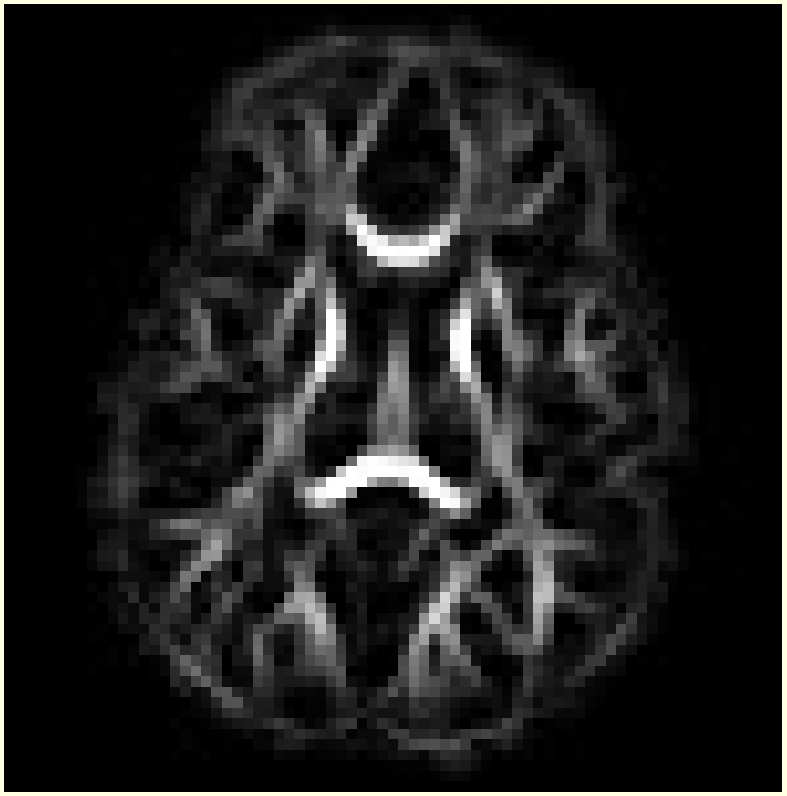
- Apply deformation field to each image
  - Finite strain model for tensor reorientation (Alexander)
  - Riemannian statistics (Fletcher, Pennec)
  - Log-Euclidean scheme with linear interpolation (Arsigny)
- Average deformed tensor volumes to create affine, deformable atlases

Structural Image

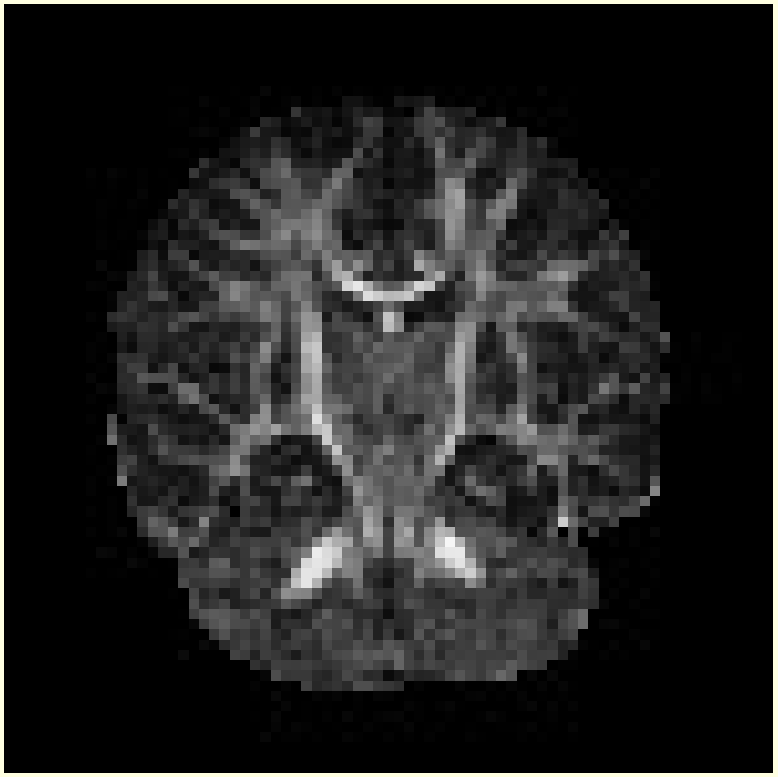
- Want images aligned by geometry of fiber tracts
- FA occurs in thin manifolds
  - sheets
  - tubes
- FA" highlights fiber geometry (maximum eigenvalue)
- FA" does not directly optimize correspondence of tensor derived property

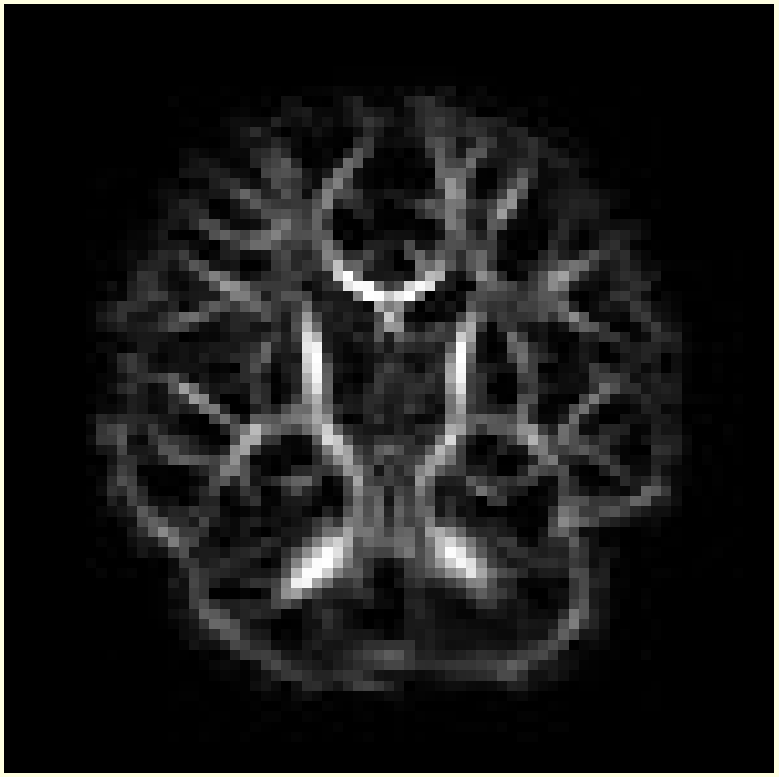
FA image and Curvature Image



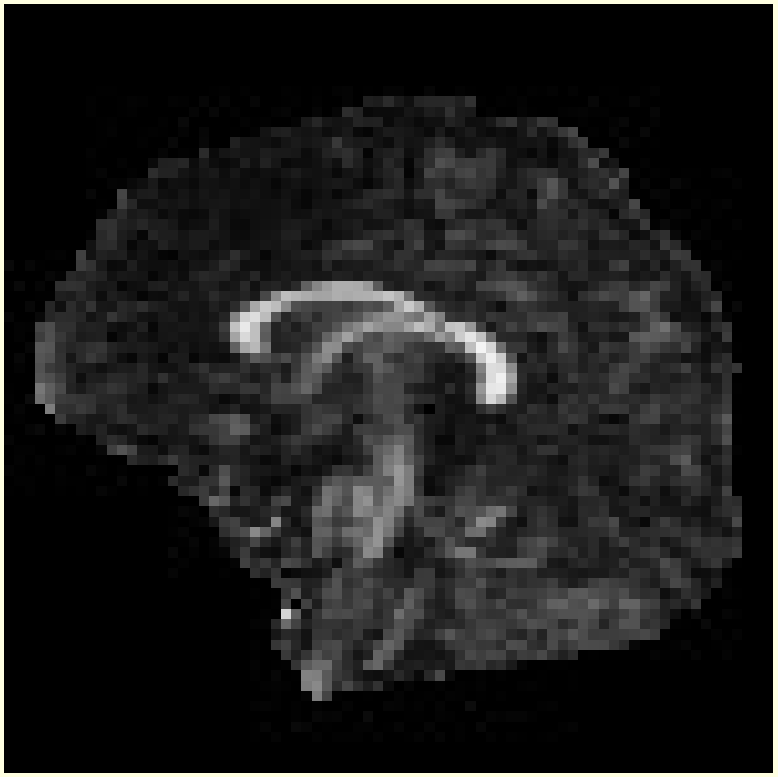


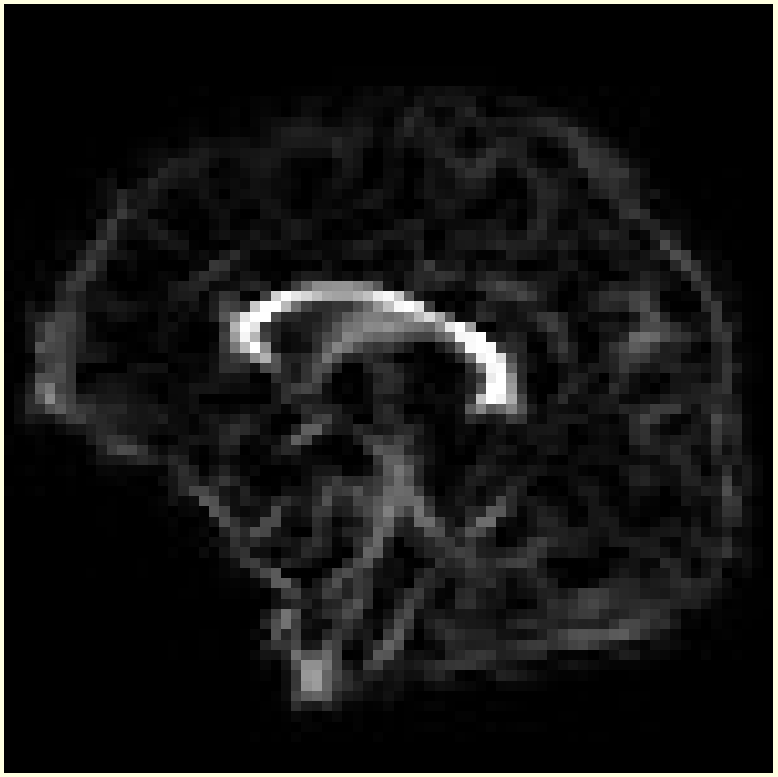
FA image and Curvature Image





FA image and Curvature Image





Spatial Transformation of DTI

- Tensors contain **oriented** measurements
- Diffusion measurements are physical measurements (in s/mm^2)
- For global transformation extract the rotation component
- For deformable transformation extract the local rotation of local linear approximation

Graphic Spatial Transformation

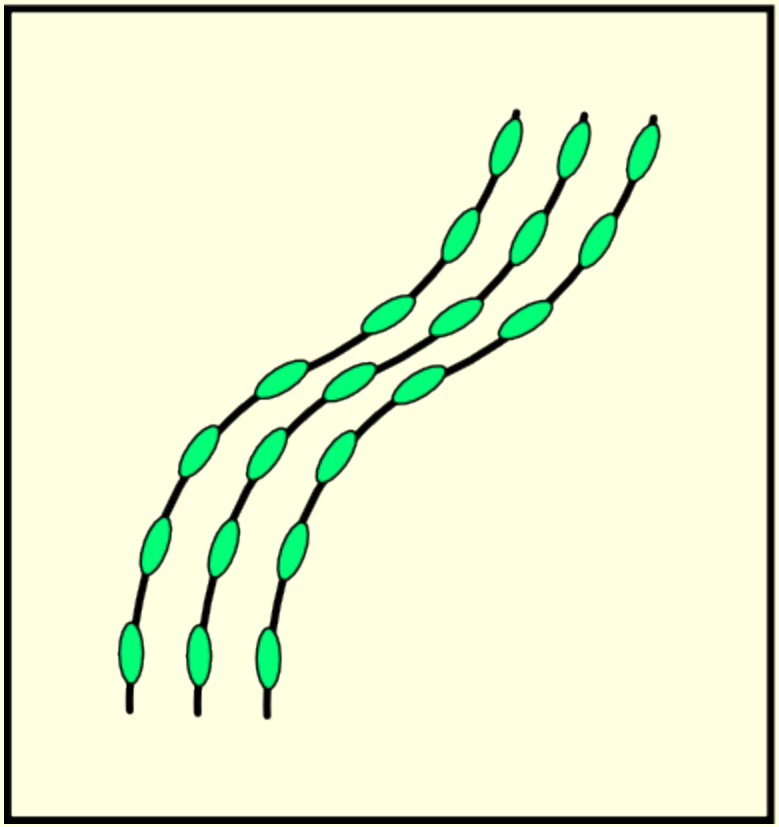


Image A

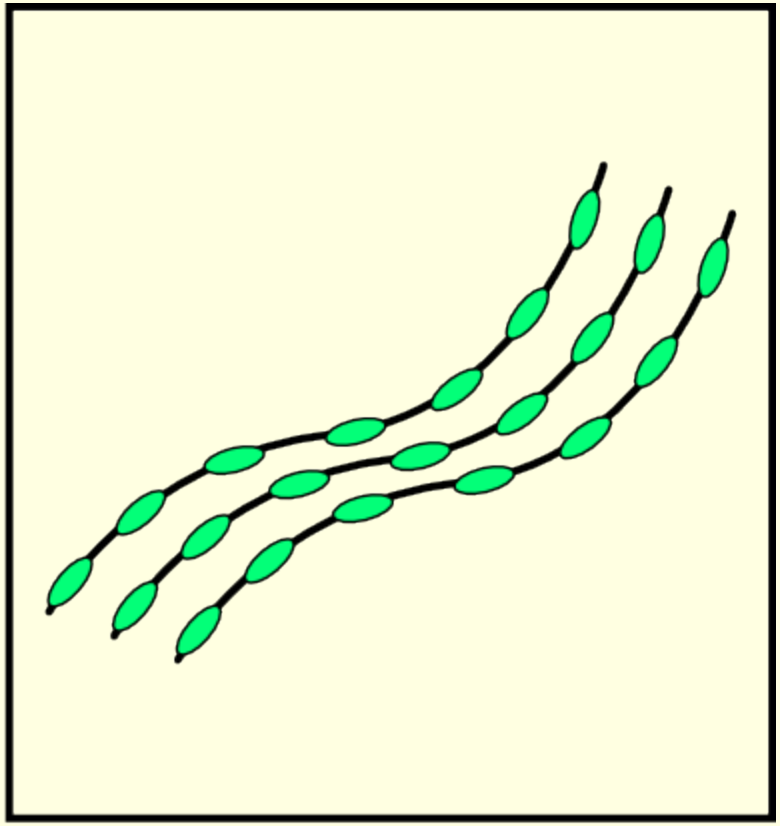


Image B

Mathematics of Spatial Transformation

h(x) is a mapping from R^3 to R^3. h(x) can be locally approximated as a linear function.

$$h(x) = x + Fx$$

F is the local Jacobian of the transformation and can be processed the same as for a global transformation. SVD can be used to extract the rotation component of F.

$$F = UR$$

$$D' = RDR^T$$

Processing of DTI

- Diffusion tensors are symmetric positive-definite matrices which can be interpreted as covariance matrices of Brownian motion
- Riemannian symmetric spaces (Fletcher, Pennec)

$$\hat{D} = \exp\left(\sum_{i=1}^{N} w_i \log(D_i)\right)$$

DTI Atlas

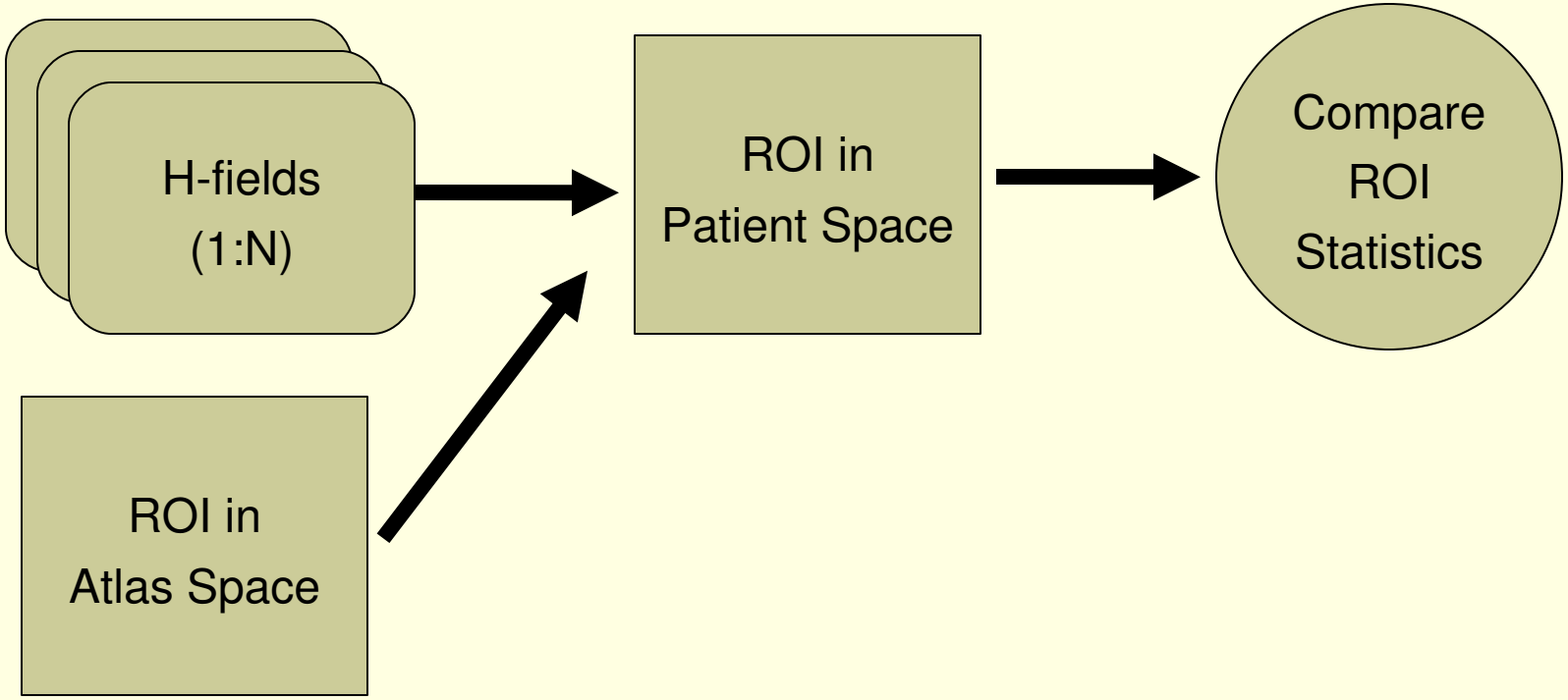
- An atlas is created of the mean diffusion tensor at each voxel
- Tensor images are aligned in atlas space
  - Statistics of voxels
  - Warp of fiber tracts

Average Atlases

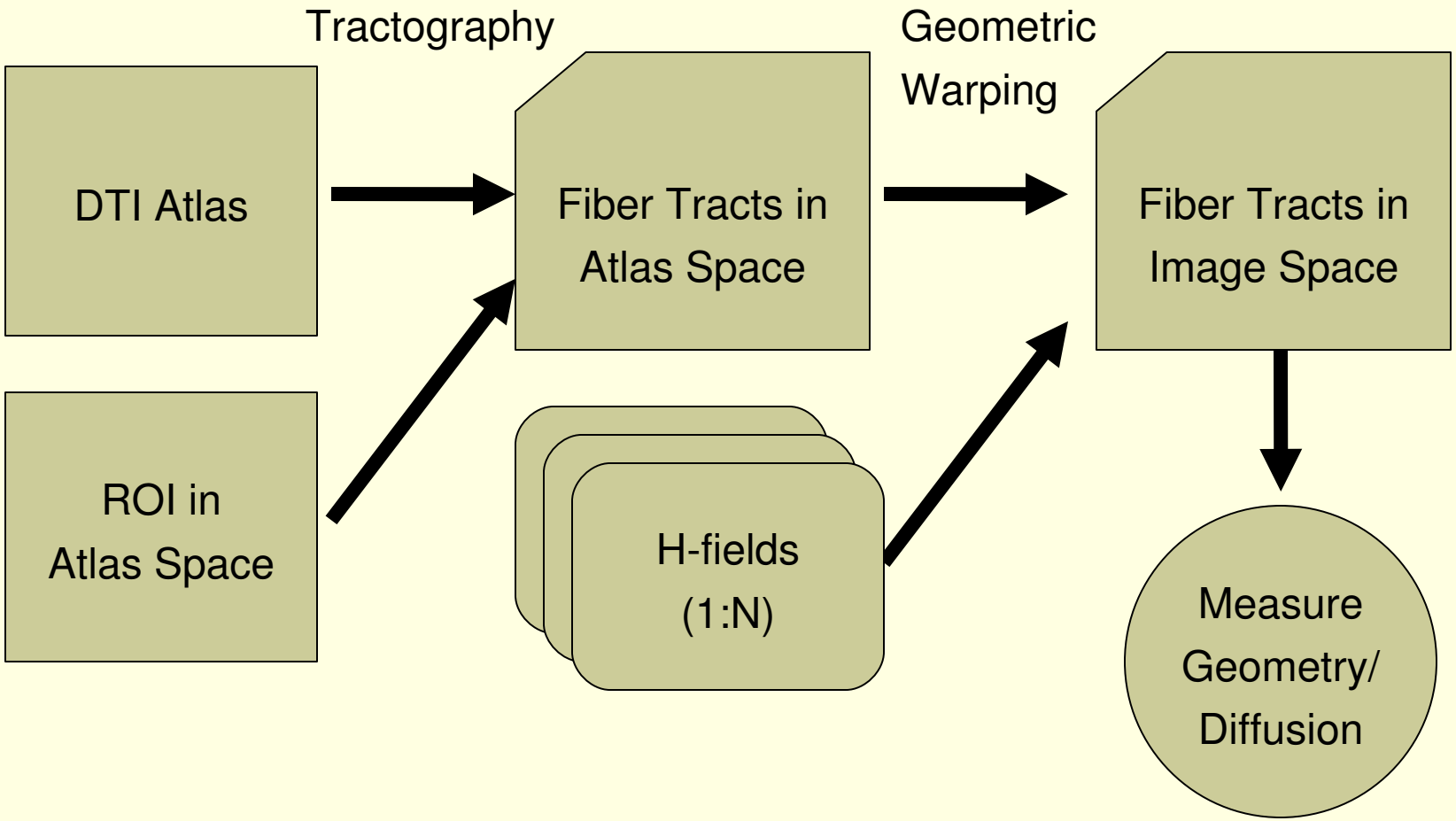
Affine Atlas

Deformable Atlas

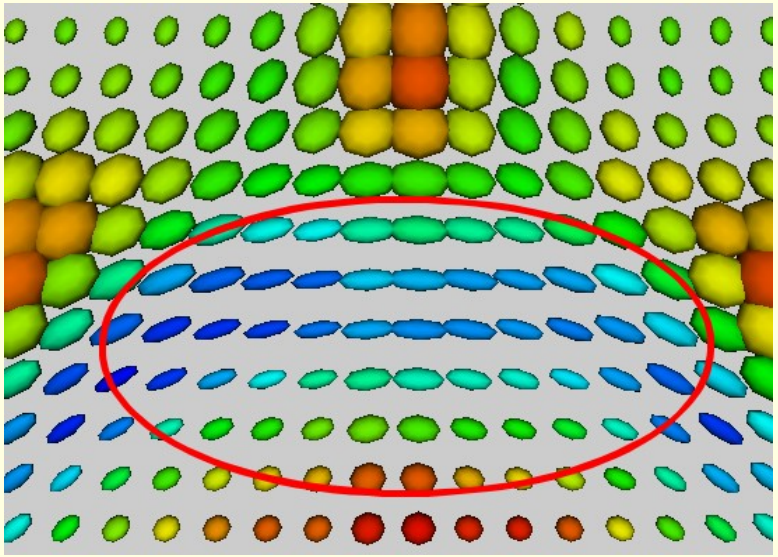
ROI Properties

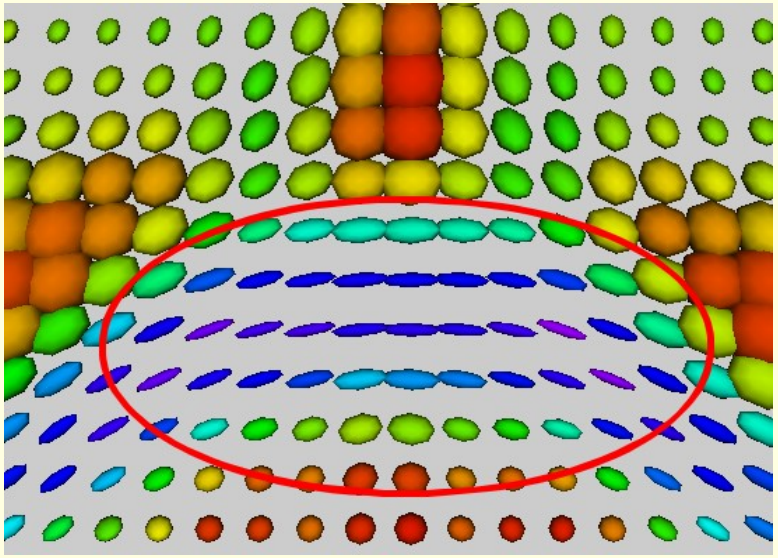


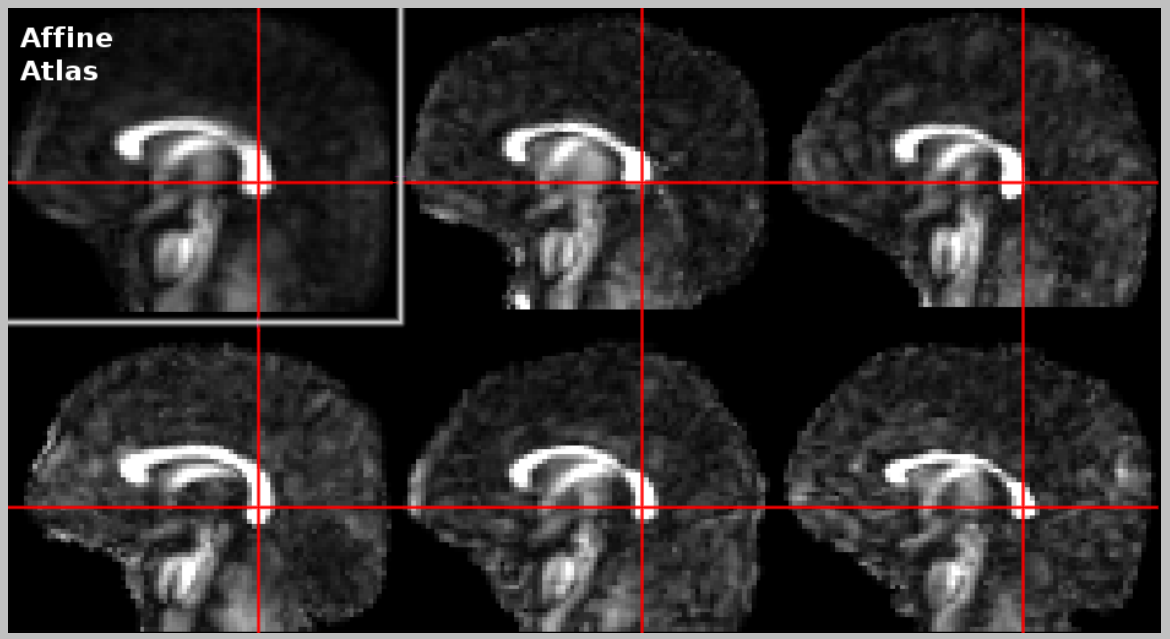
Tract Properties

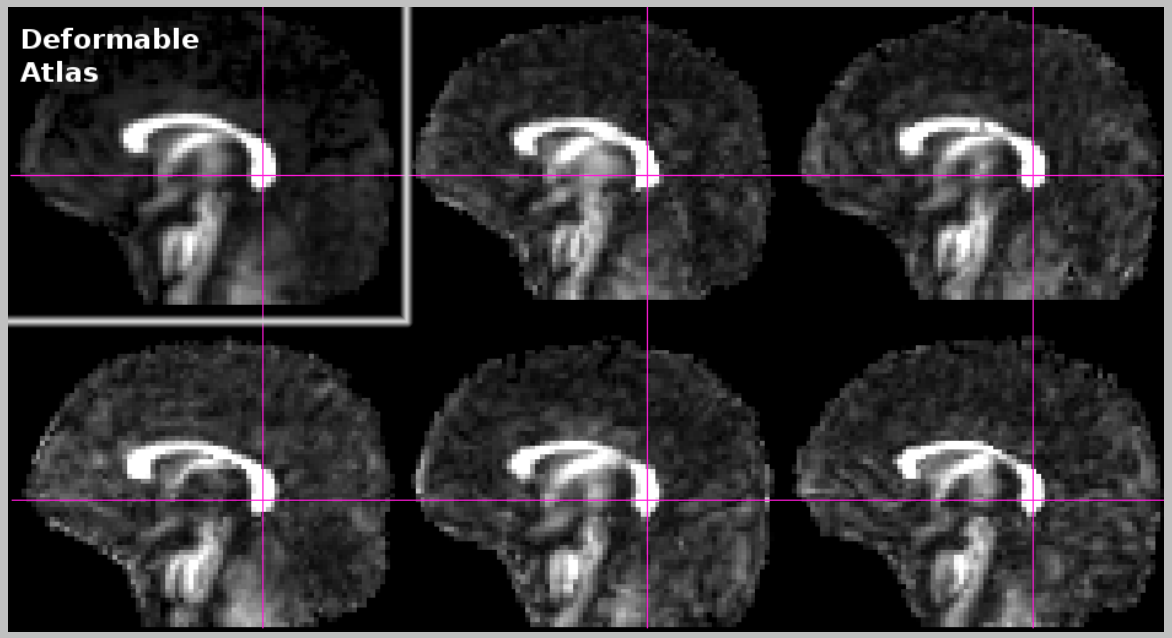


Average Atlases

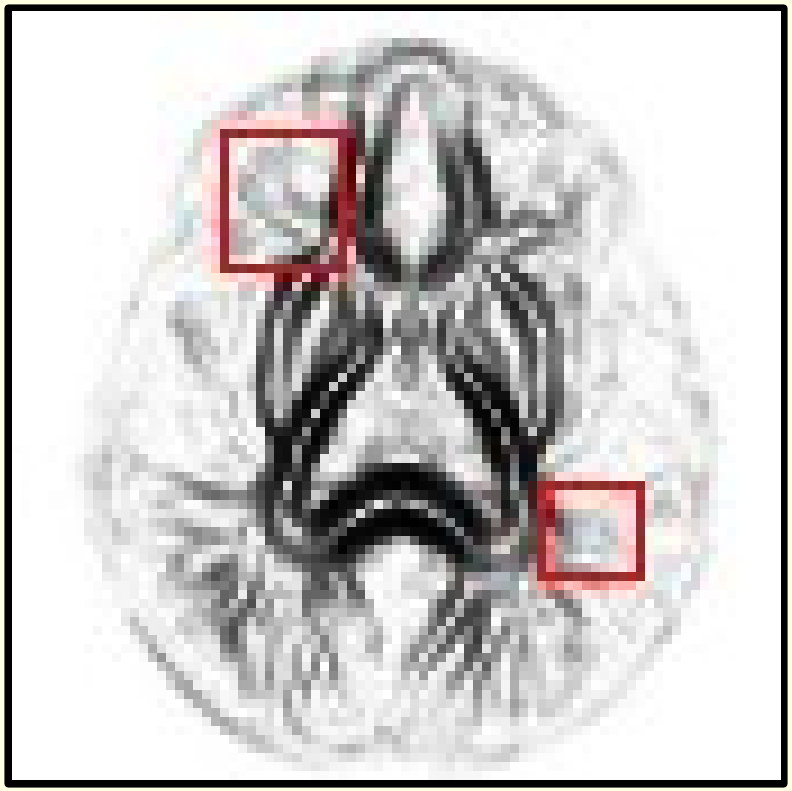


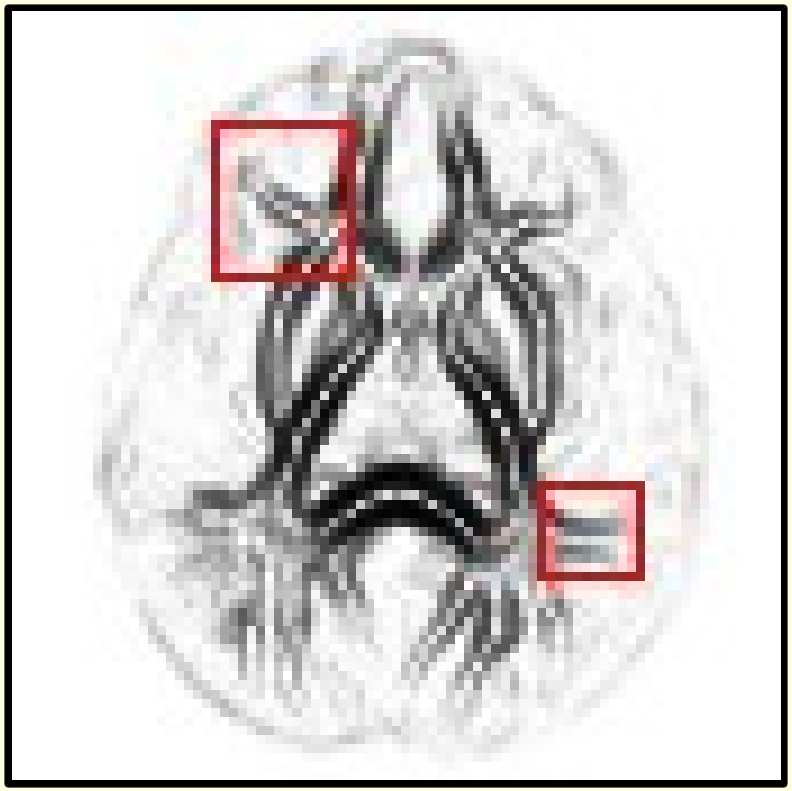



Affine
Atlas

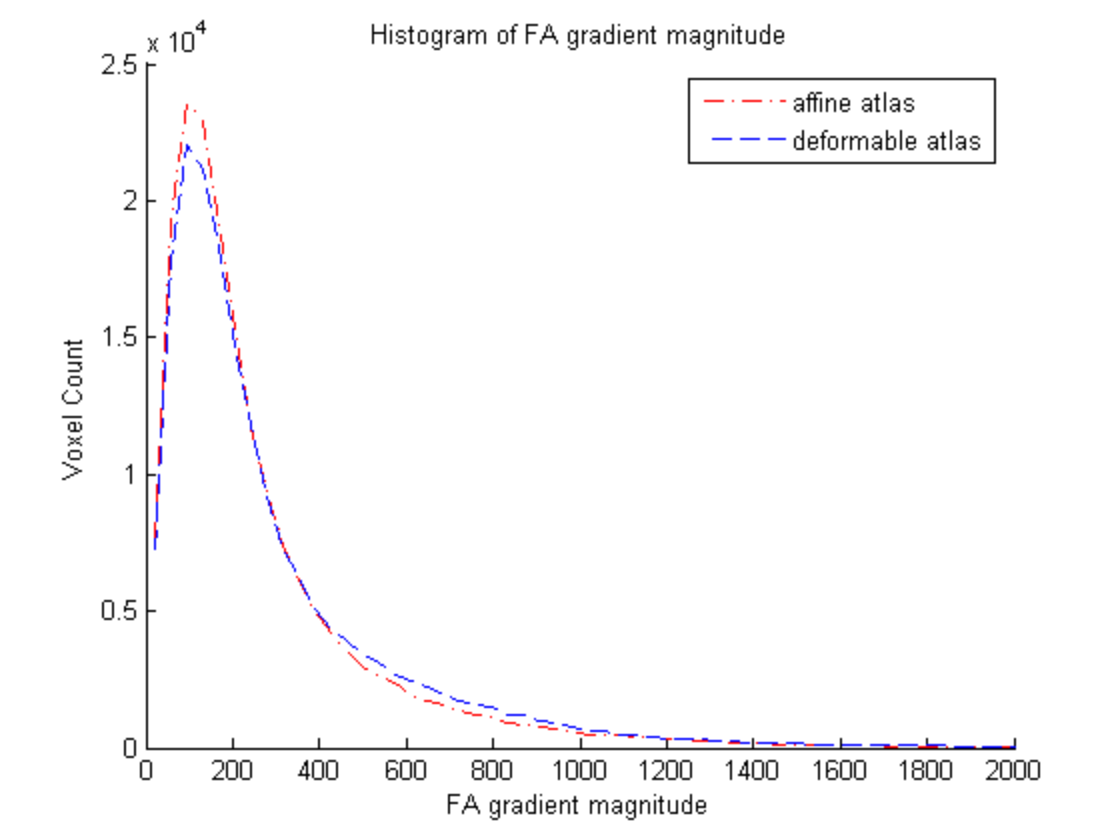

Deformable
Atlas

Gradient Magnitude Visualization

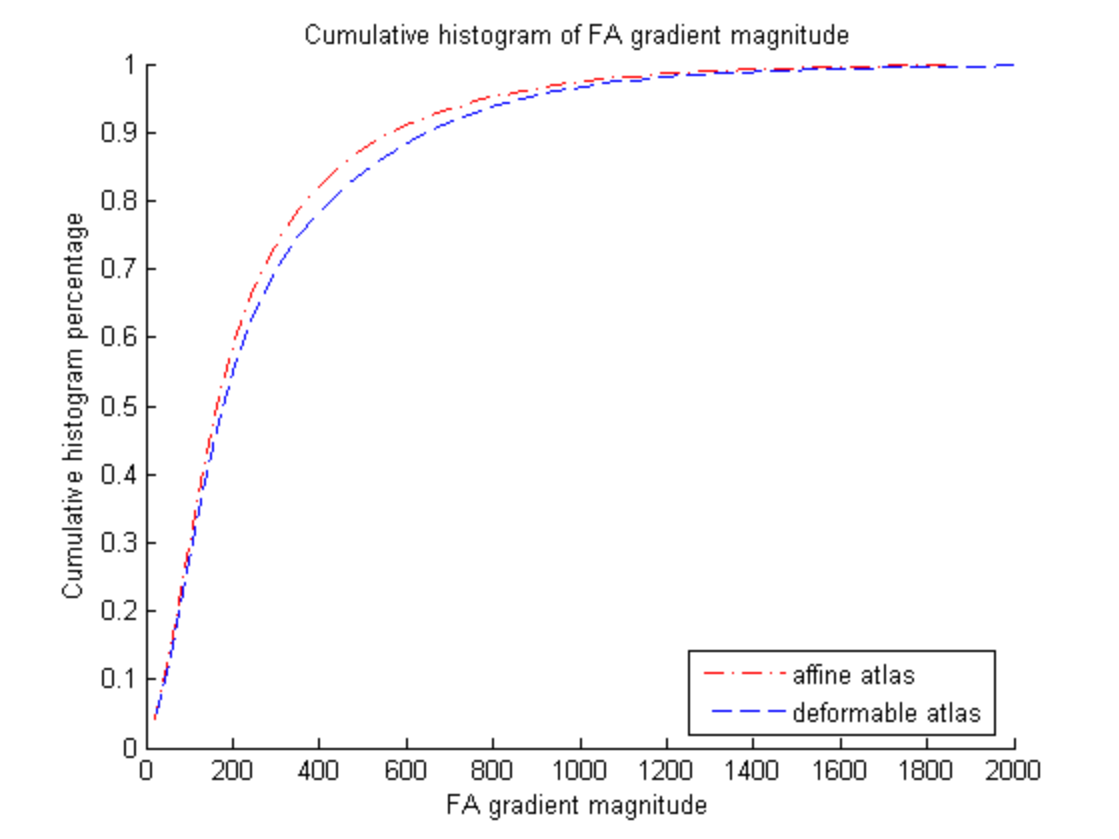




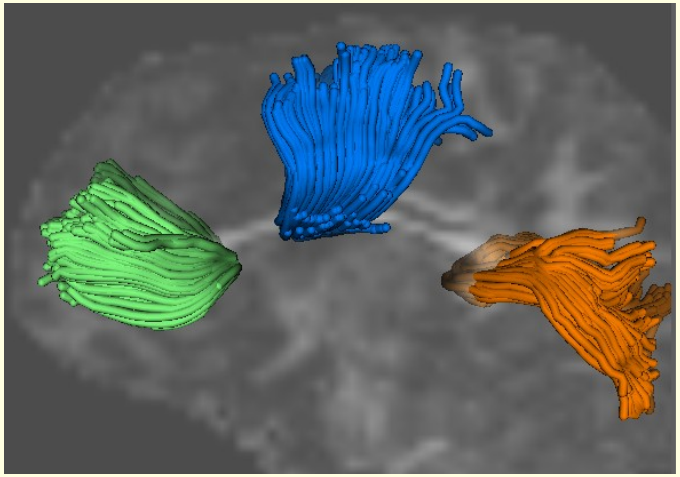
Histogram


Histogram of FA gradient magnitude
x 10^4
2.5
2
1.5
1
0.5
0
Voxel Count
affine atlas
deformable atlas
0
200
400
600
800
1000
1200
1400
1600
1800
2000
FA gradient magnitude

Cumulative Histogram



Atlas-Based Tractography



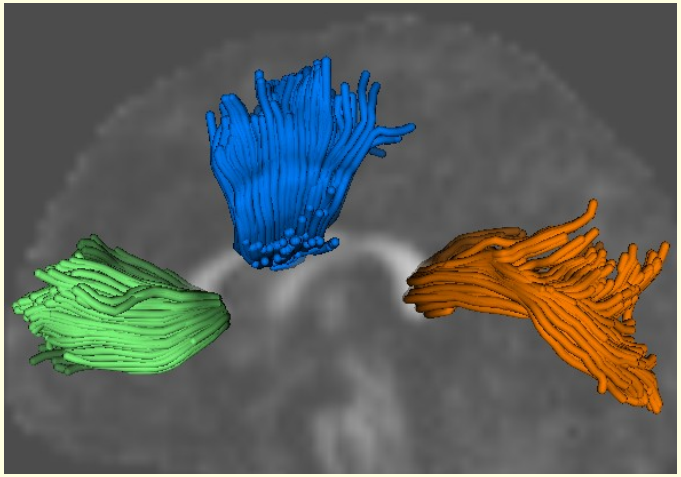
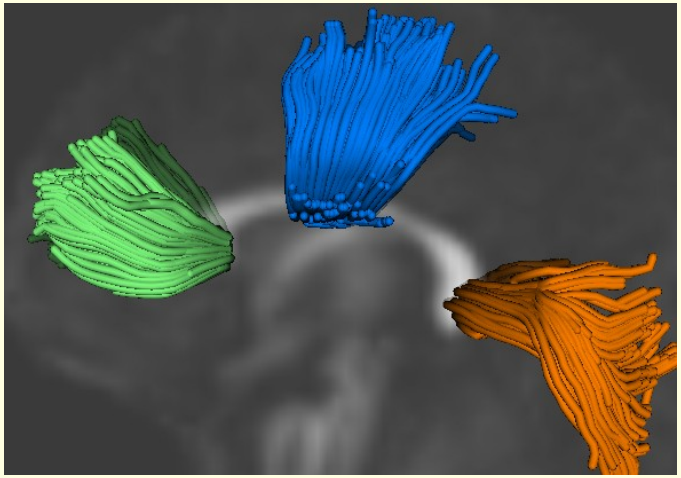


Image A

Image B



Atlas

Warped Tractography

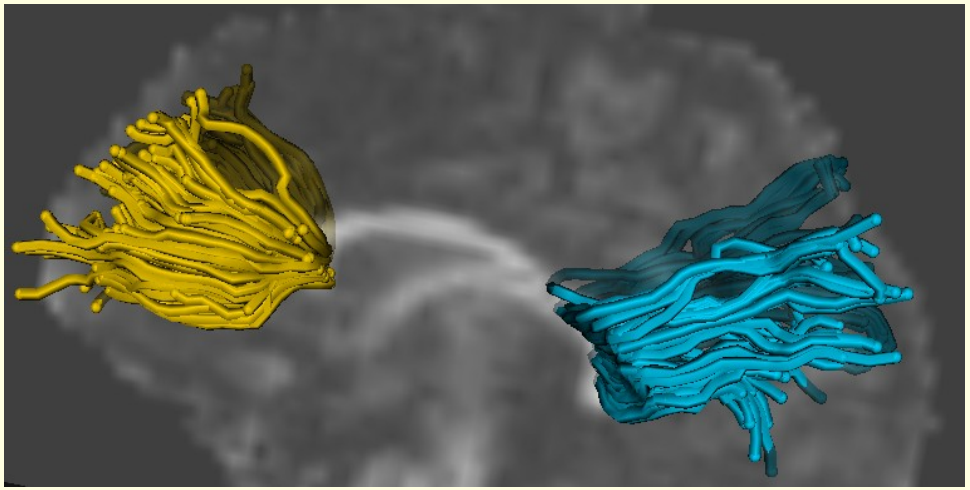


Image A

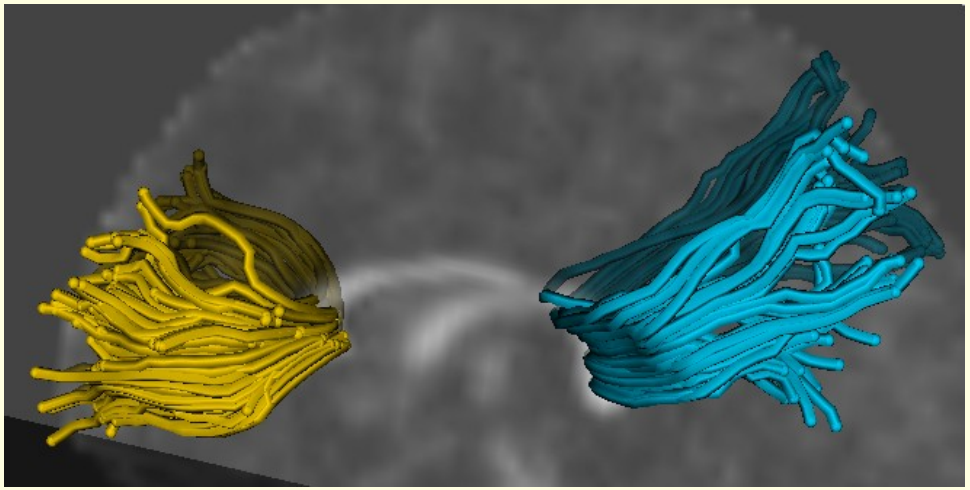
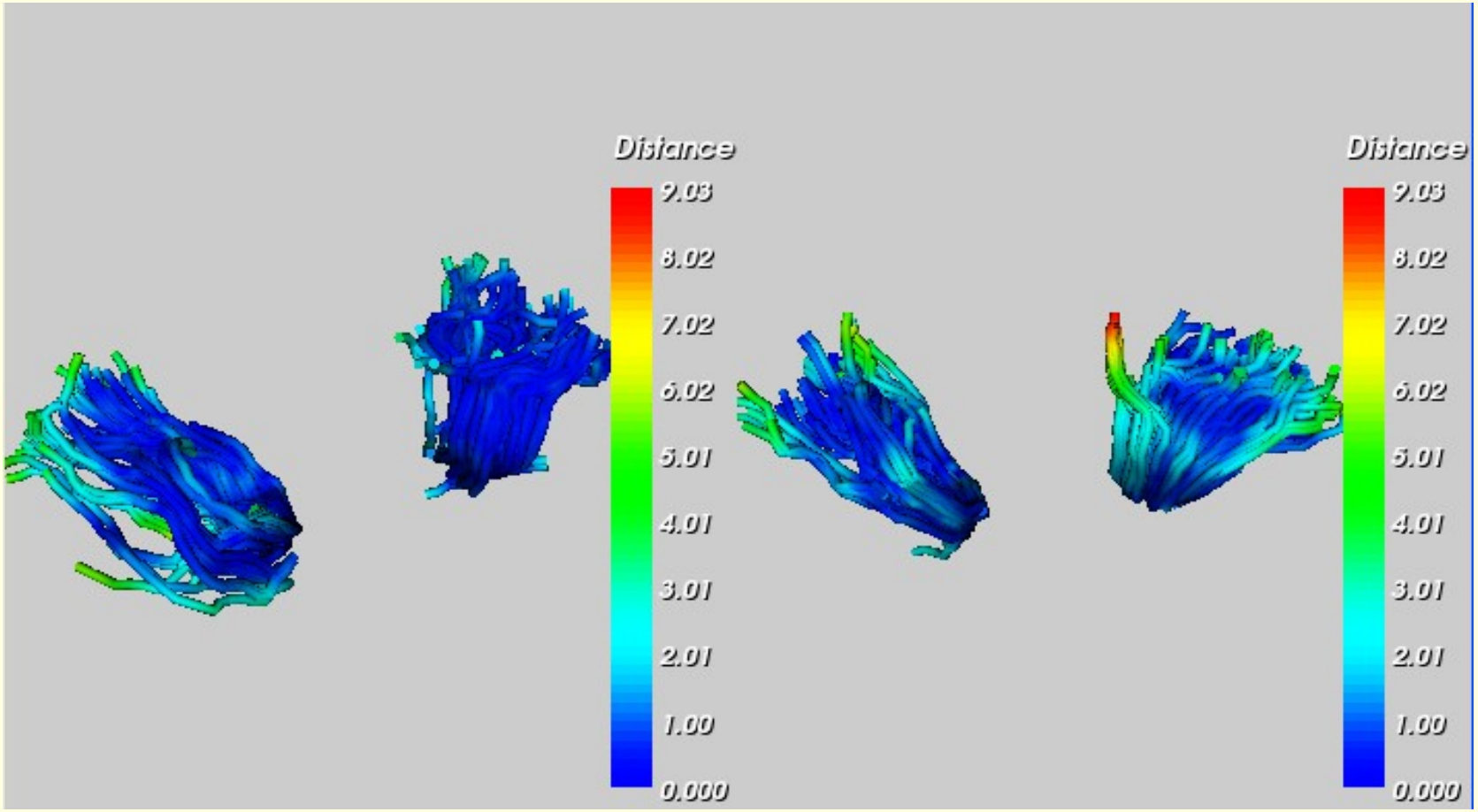


Image B

Initial Quantitative Comparison



In Progress

- Atlas construction on 50 datasets neonates, 1 year, 2 year
- Statistical analysis of fibers traced in atlas and warped to individual images
  - Tensor hypothesis testing
  - Tract analysis

Comments or Questions?