Spatio-temporal Analysis of Connectivity Patterns for White Matter Injury Detection in the Preterm Infant Brain

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(with Steven P. Miller[2] and Ghassan Hamarneh[1])

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BC Children's Hospital

Geometry for Anatomy Workshop, August 30, 2011

Motivation

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Hypothesis:

- Flag abnormalities via differences in brain connectivity.

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Scans manually scored for:

- White matter injury
- Intraventricular hemorrhages

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Capturing the Bounds of Normal Development

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- Use only subject scans marked as healthy
- Three week time windows to reduce variability
- Full tensor atlases and scalar atlases (*i.e.* FA, MD, $\lambda_1, \cdots$)

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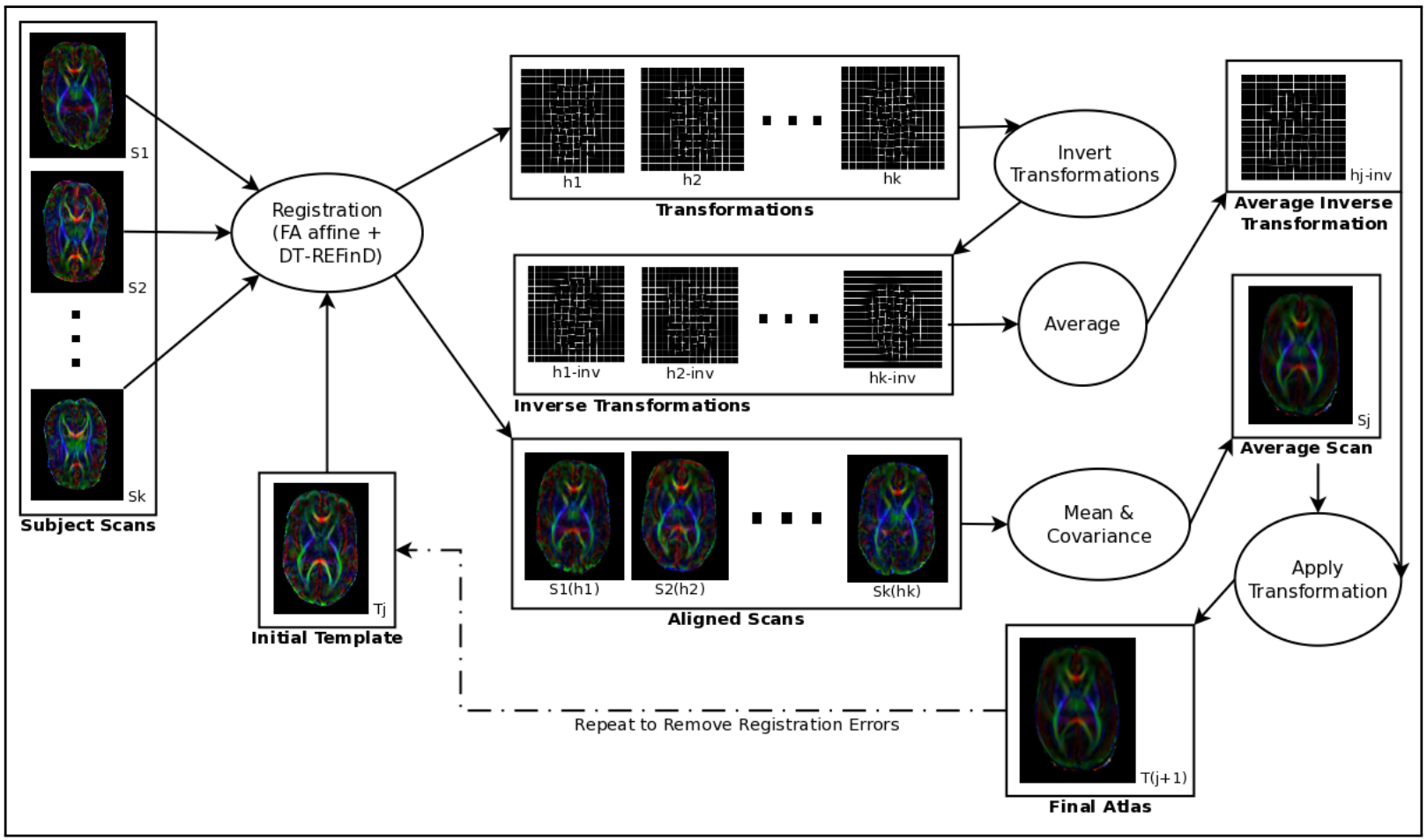
Why?

- Provide voxel-wise mean and (co-)variance
- Provide a standard space for tractography
- Examine intra-window variance

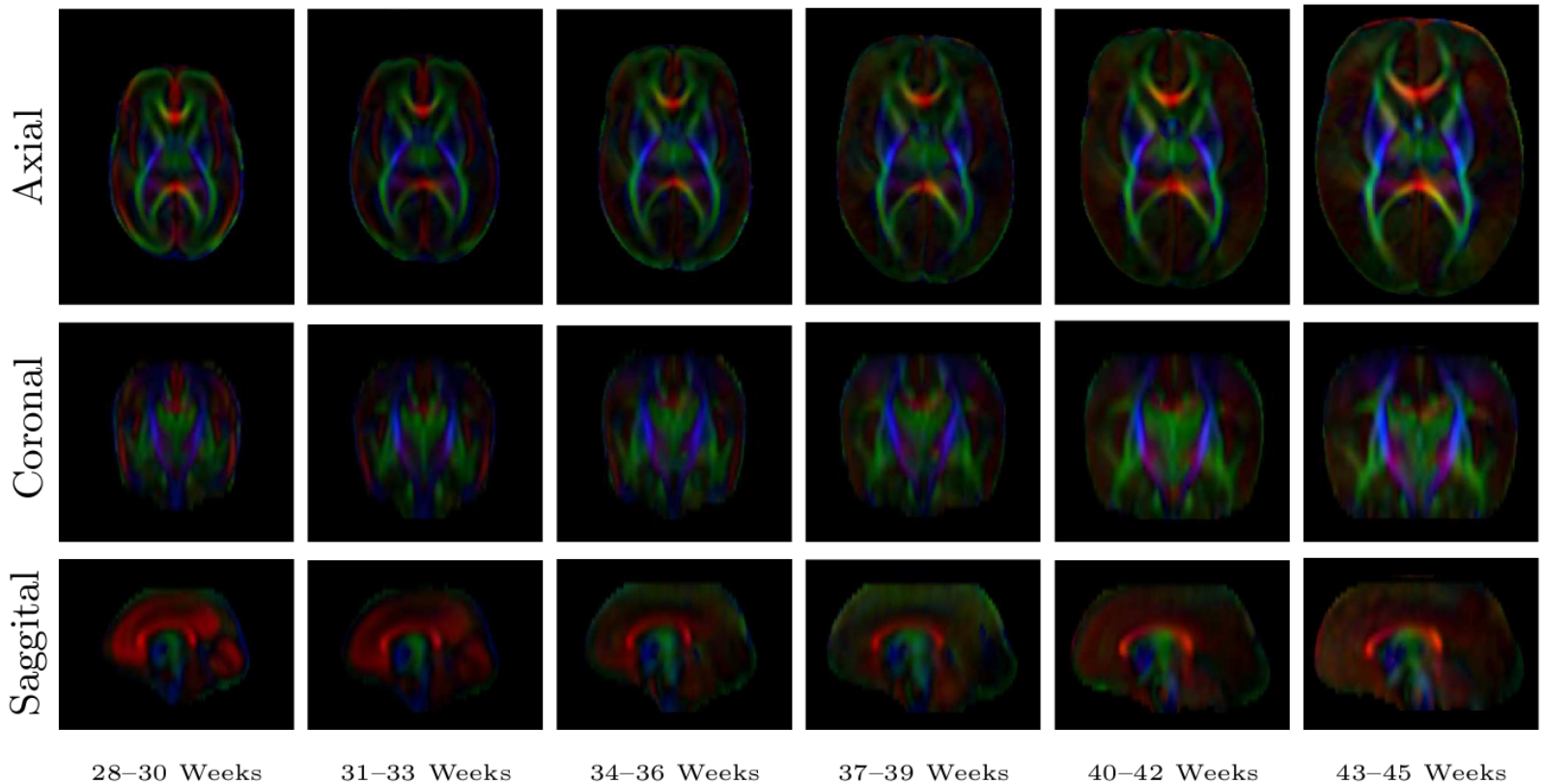
DTI Atlas Creation Workflow

Atlas Creation by Pairwise Registration [Guimond et al., 2002]



Preliminary Atlas Results

Tensor Means:



- Repeat for scalar maps (i.e. FA, MD, $\lambda_1, \cdots$)

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There are limitations to tractography

- Error accumulation along tract
- Decisions are made locally & independantly
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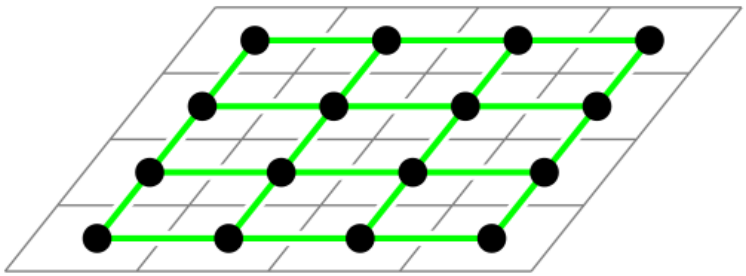
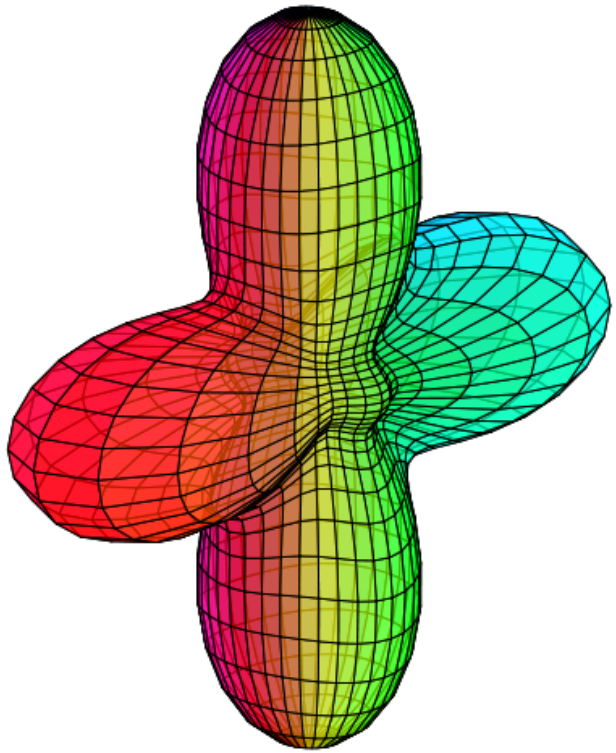
Graph encoding by ODF Integration





- Diffusion ODF $\rightarrow$ Edge Weight

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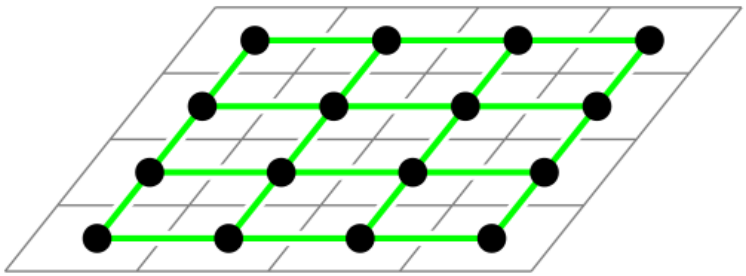

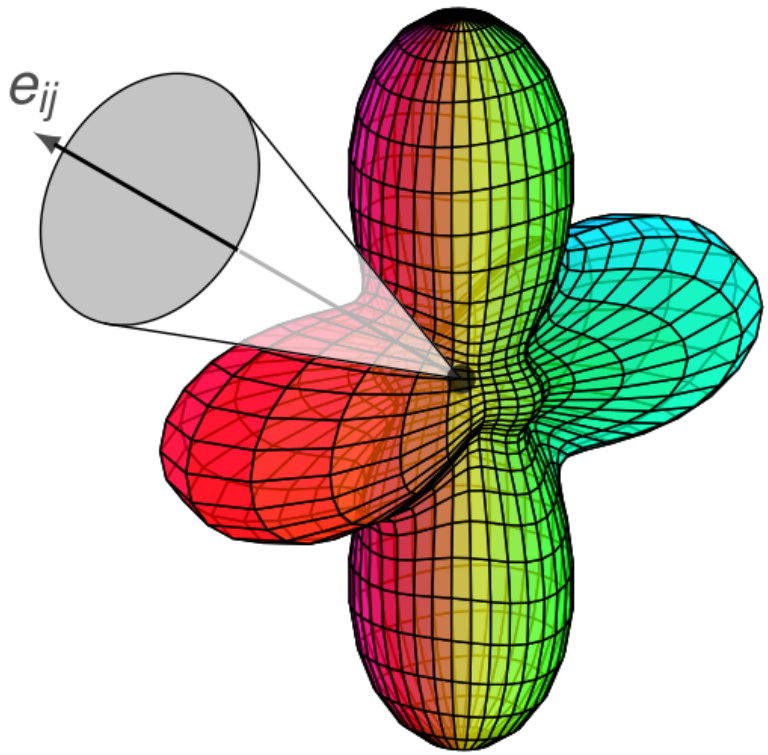

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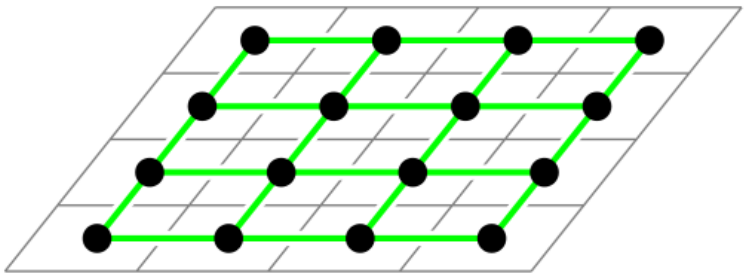
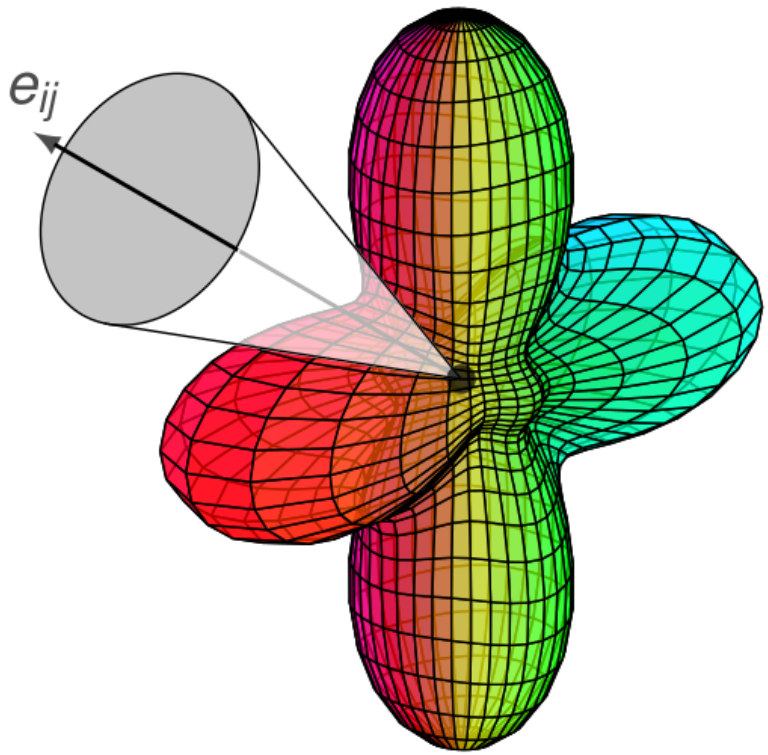


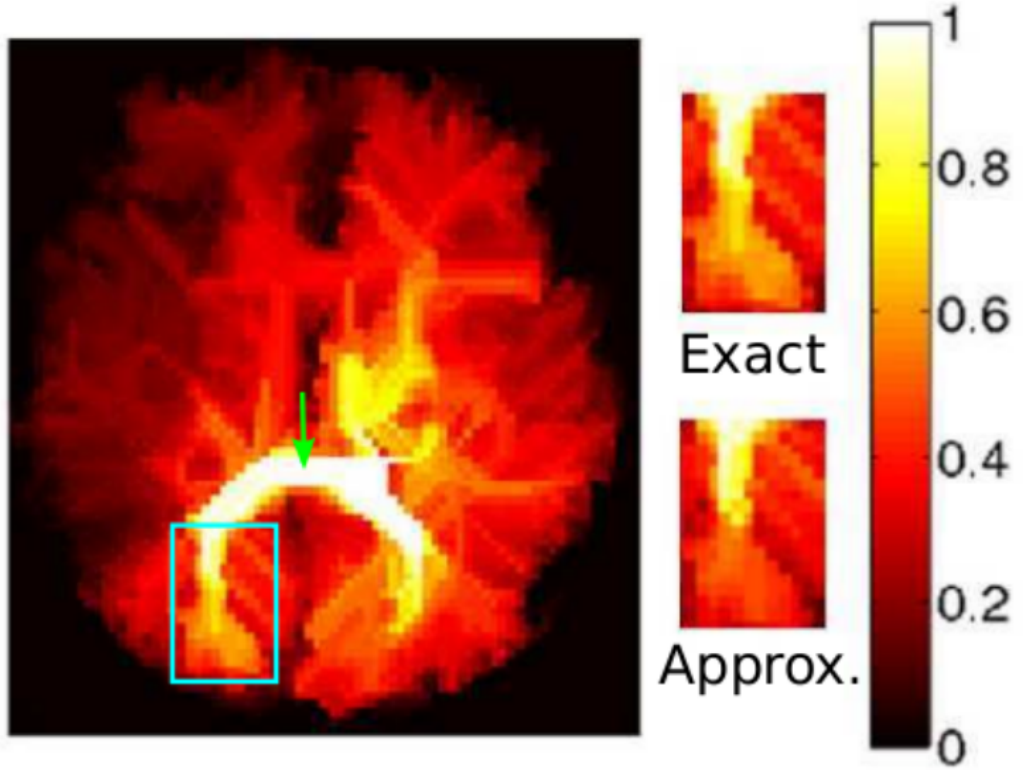


- Diffusion ODF $\rightarrow$ Edge Weight
- Integrate ODF over cone
- We contribute an analytical solution
  - Avoid adding approximation error

The Effect of the Graph Encoding[1]

Testing graph encoding with minimal path tractography

[Zalesky, TMI, 2008]



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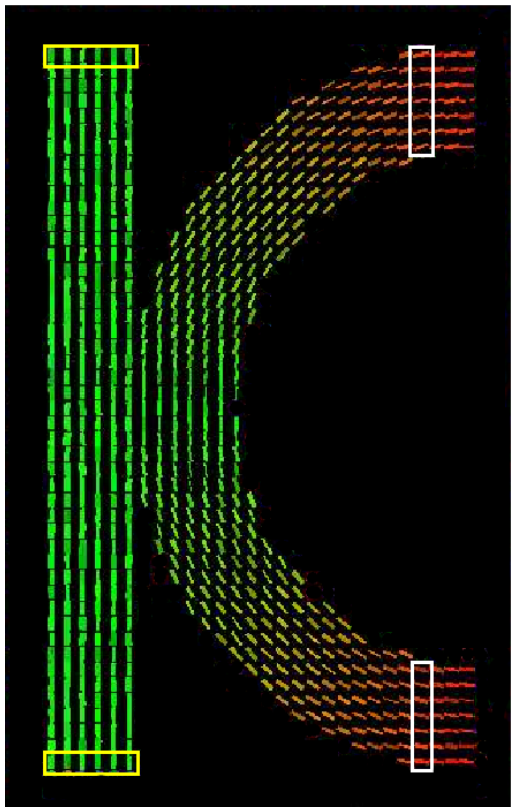

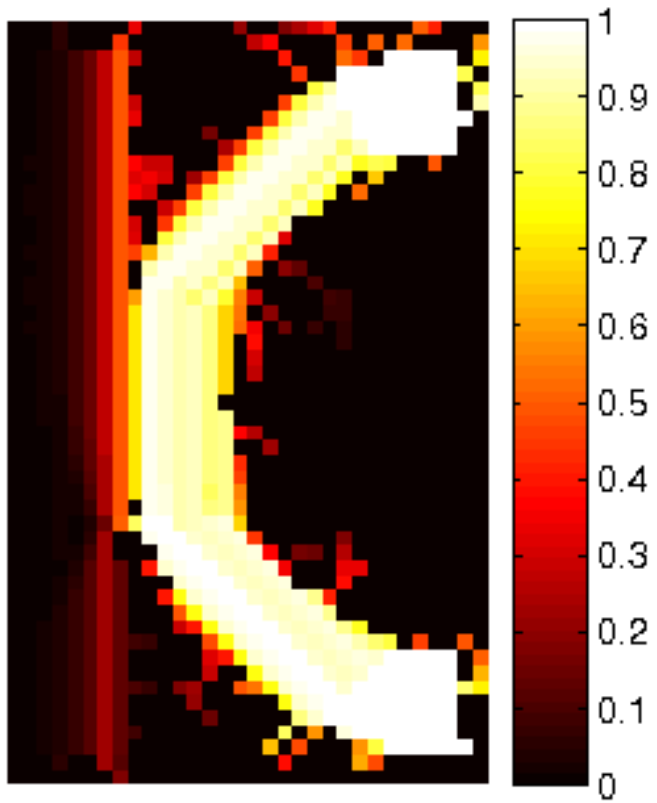

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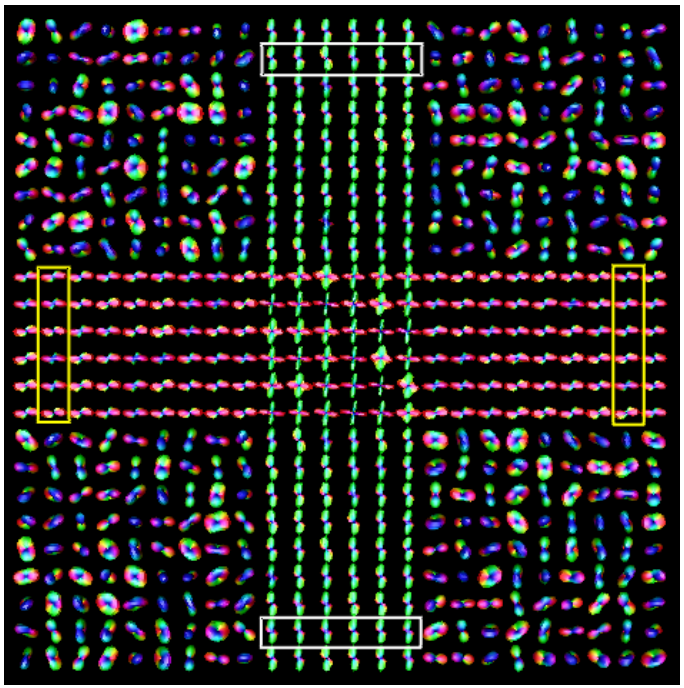

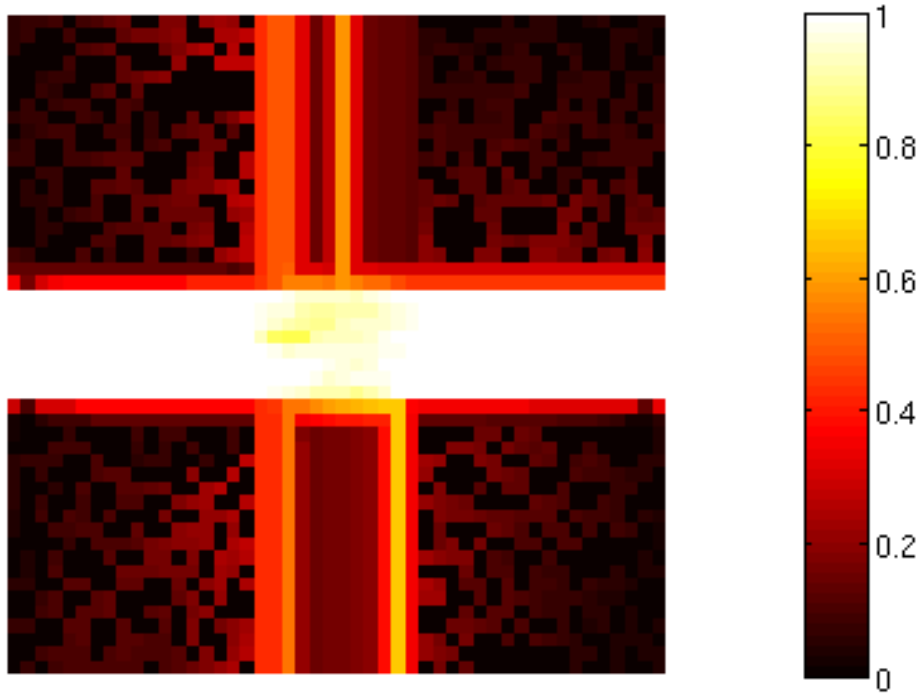

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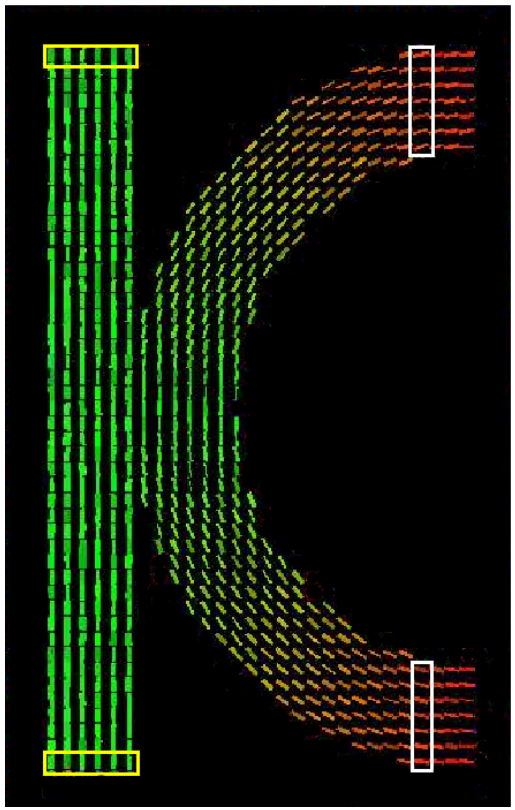
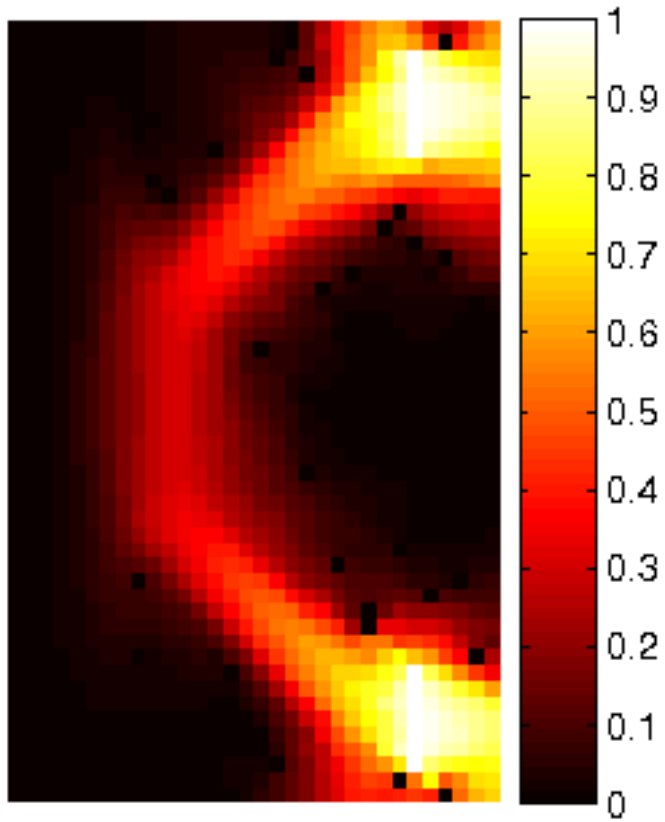
  - Note: Background (FA $< \tau$) included as a seed region

Preliminary Results





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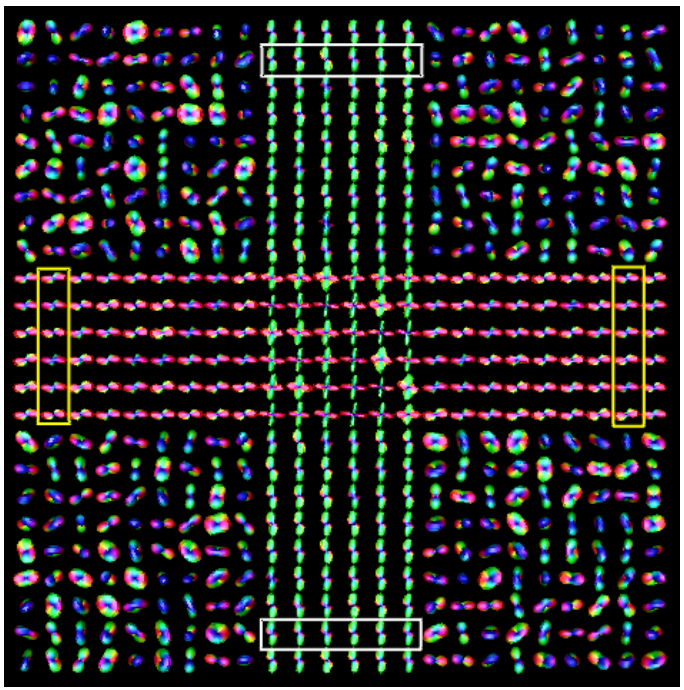

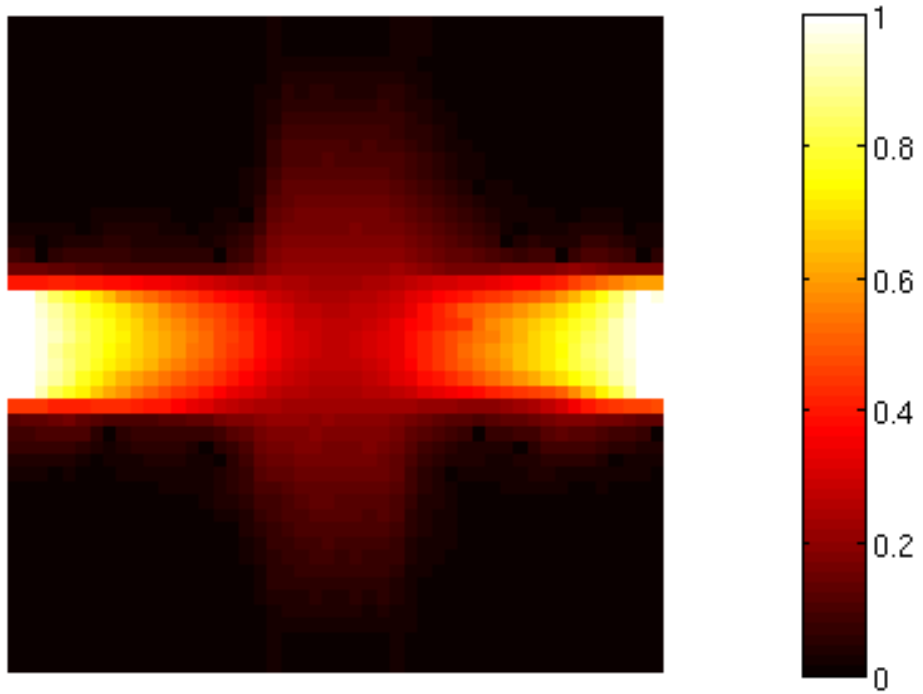

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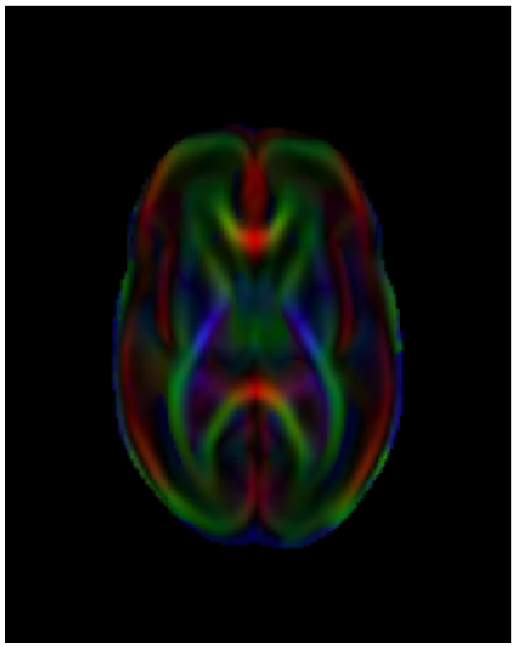
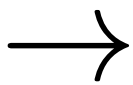
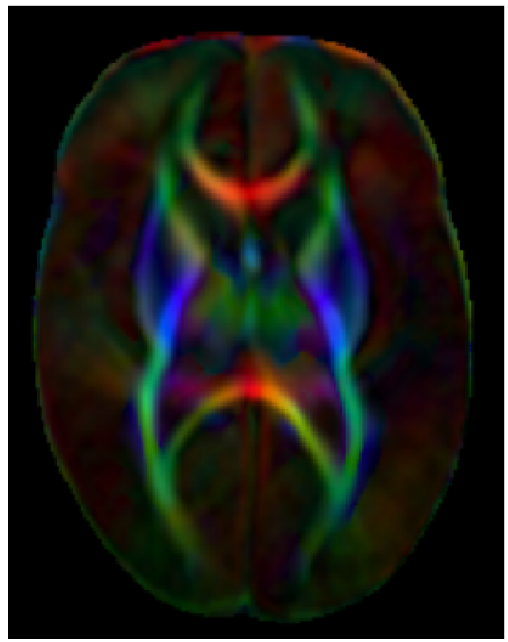
Standard Space for Voxel-Based Analysis



29 Weeks GA





44 Weeks GA

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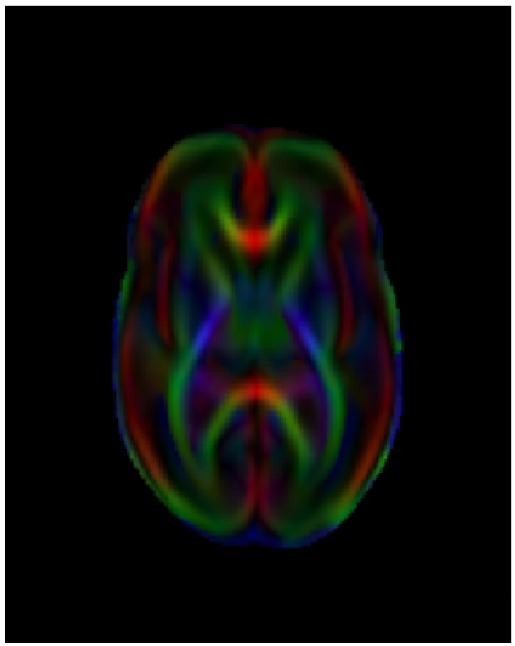

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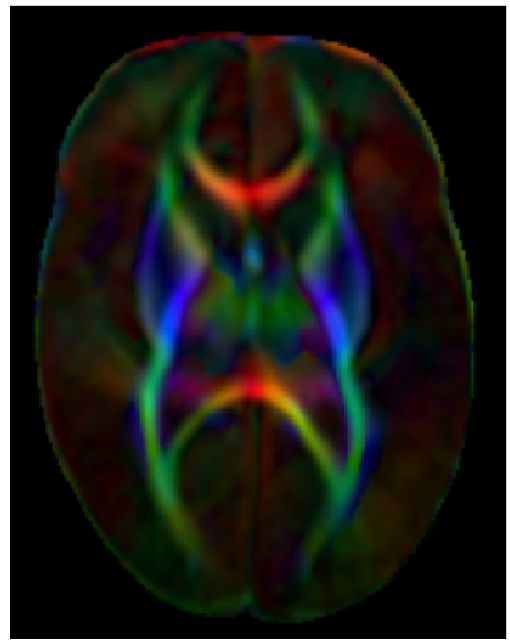

44 Weeks GA

- Longitudinal registration

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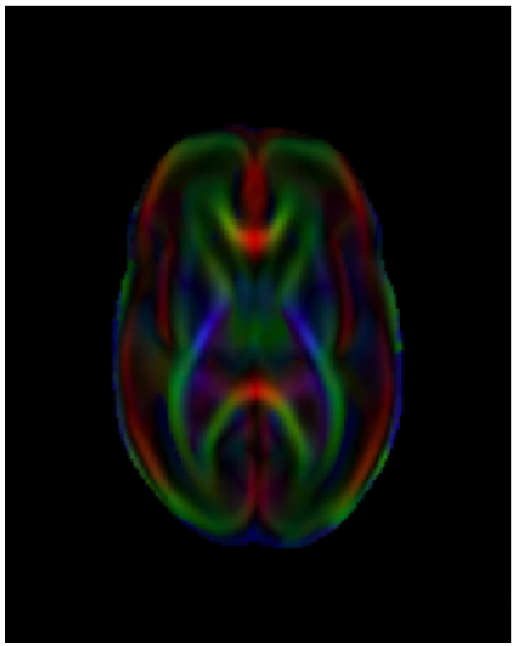

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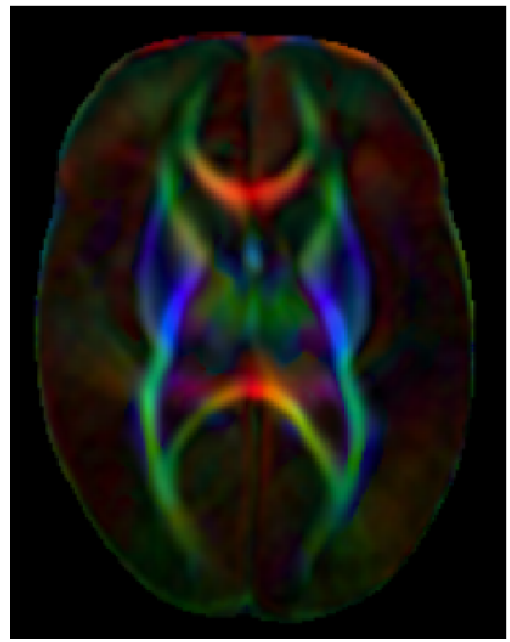

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- Longitudinal registration $\rightarrow$ Robust metric

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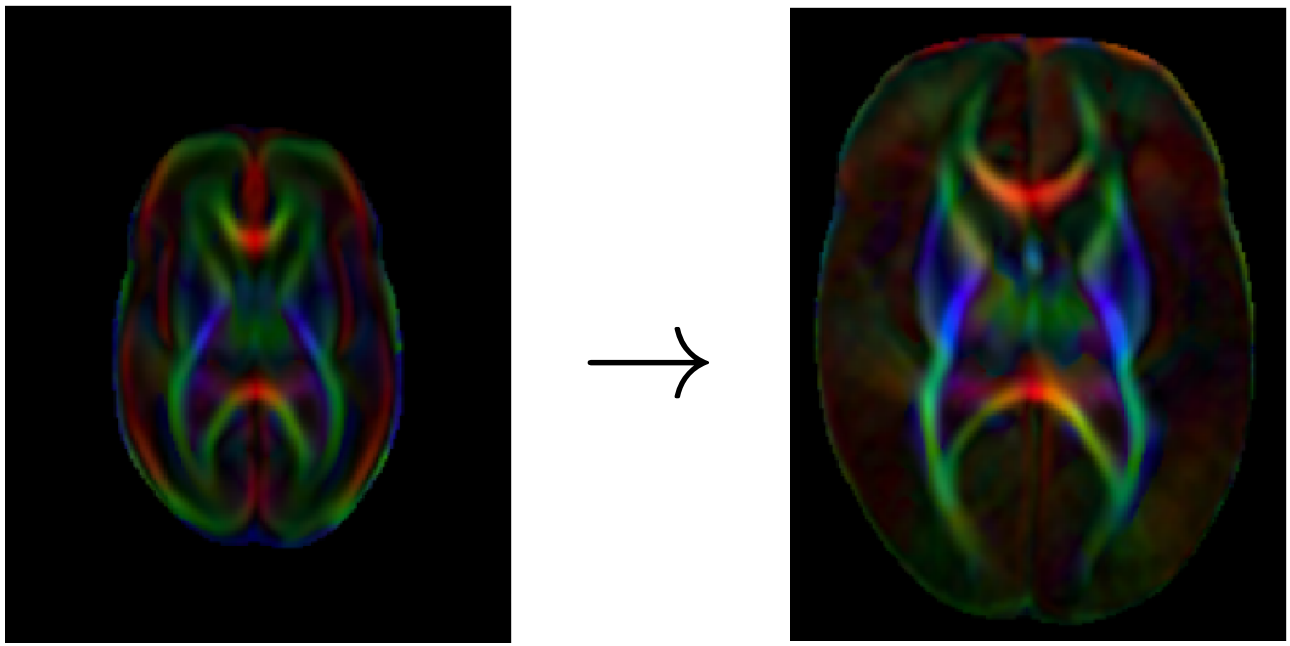

29 Weeks GA → 44 Weeks GA

- Longitudinal registration $\rightarrow$ Robust metric
- Idea: Diffusion Tensor Mutual Information

Measuring DT Mutual Information

Existing Approaches:

- Dimensionality Reduction $\rightarrow$ Histogram Binning

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- Estimate MI from nearest-neighbour distances
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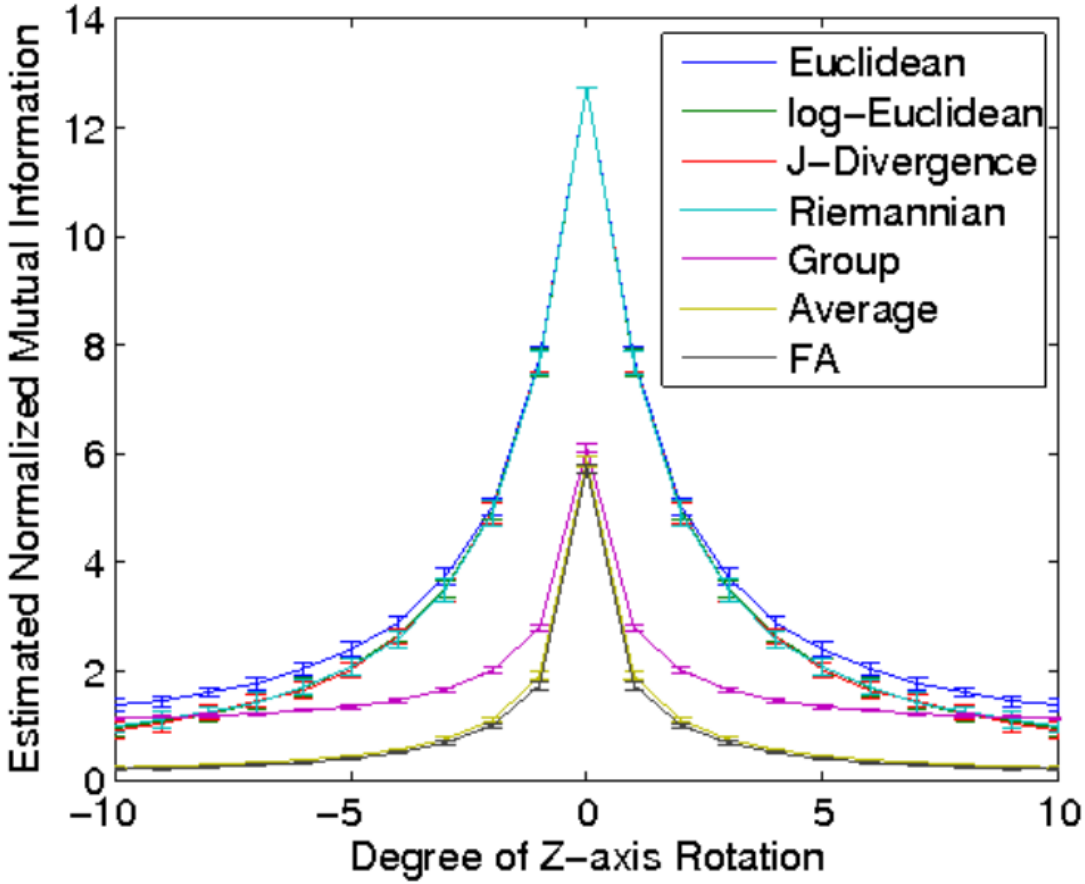
- Nearest-Neighbour MI Estimator [Neemuchwala and Hero, 2005]

$$MI(\mathbf{X}, \mathbf{Y}, \alpha) = \frac{1}{\alpha - 1} \log \left[\frac{1}{N^{\alpha}} \sum_{i=1}^{N} \left(\frac{\eta(\mathbf{z}_i)}{\sqrt{\eta(\mathbf{x}_i)\eta(\mathbf{y}_i)}} \right)^{2d(1-\alpha)} \right]$$

Metric Evaluation[2]



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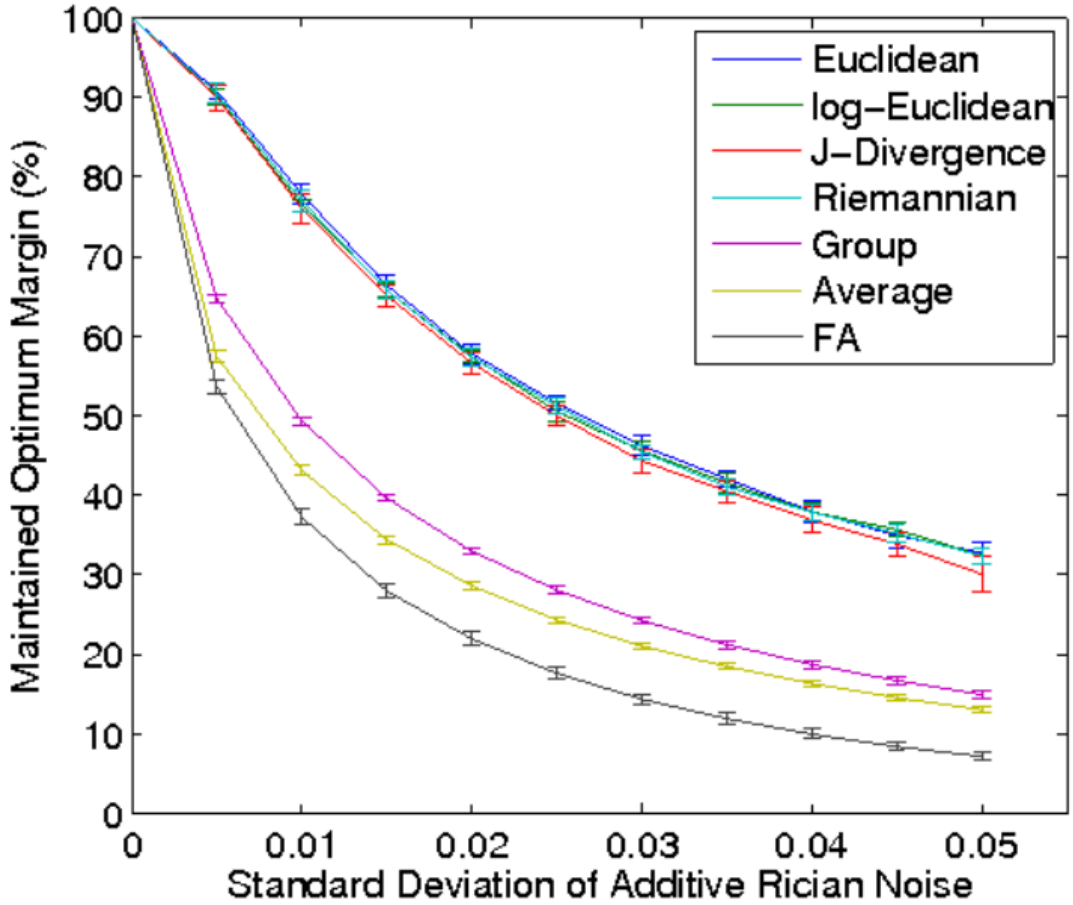

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   - Longitudinal Registration
   - New Metric: Full Tensor Mutual Information

Summary of Contributions

1. DTI Atlas of normal development
2. Tractography via Graph-based Random Walks
3. Full Tensor Mutual Information

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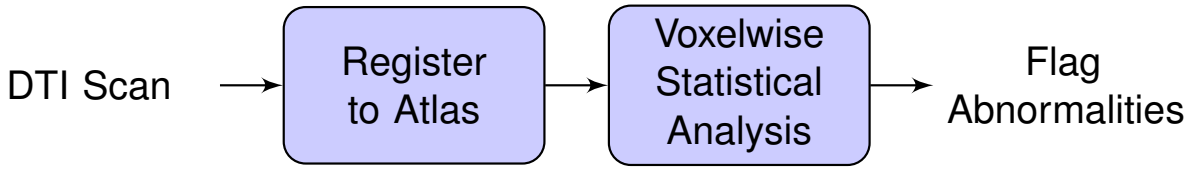

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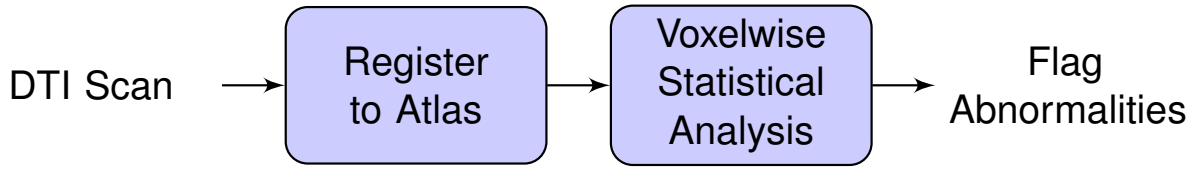

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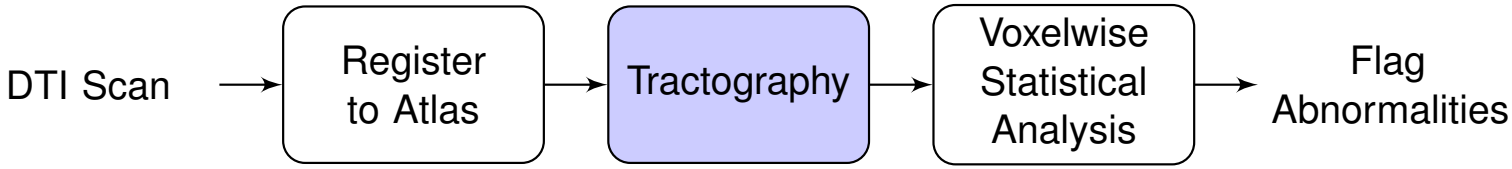

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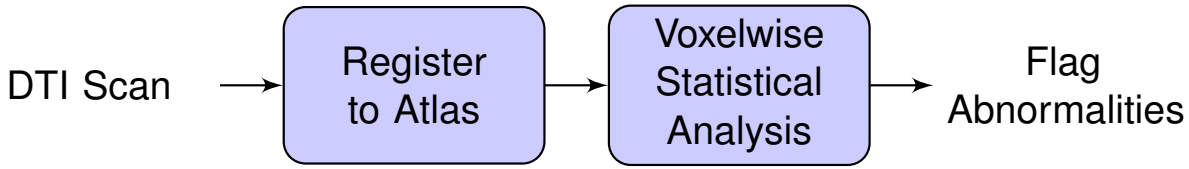

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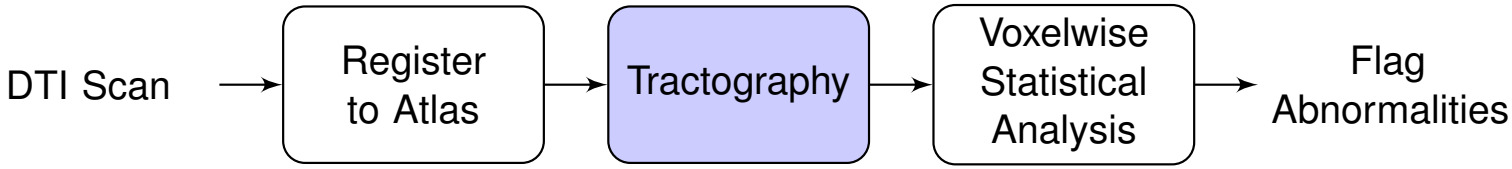

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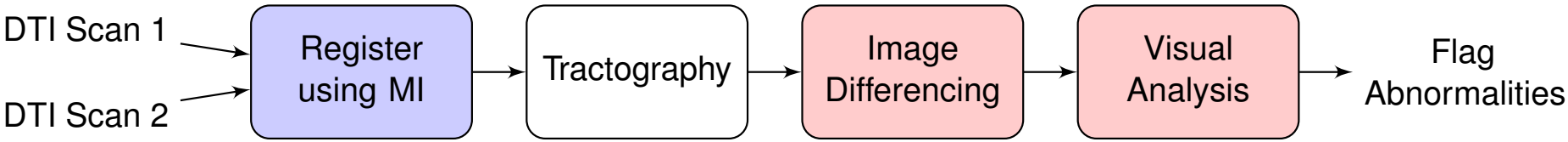

Thank You

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