Atlas Building and Tractography for Statistical Analysis of DTI

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Summary: Perform tract-oriented comparisons of diffusion properties between populations using a tract-oriented framework.

Introduction

- Diffusion tensor imaging (DTI) provides information about both the **geometry** of white matter structures and the **diffusion properties** of the tracts
- Manual analysis of diffusion properties is time consuming
  - Region of interest (ROI) analysis
  - Quantitative tract analysis [1]
- Voxelwise analysis requires broad null hypothesis (no difference in images)
- Goal: align tract geometry by atlas building to compare diffusion properties

Atlas Building and Tract Segmentation

- Clinical studies require finding corresponding structures
- Demonstration study comparing one to two year olds presented here
- Atlas constructed from both populations [2]
- Tractography performed in atlas for improved SNR and consistent parametrization
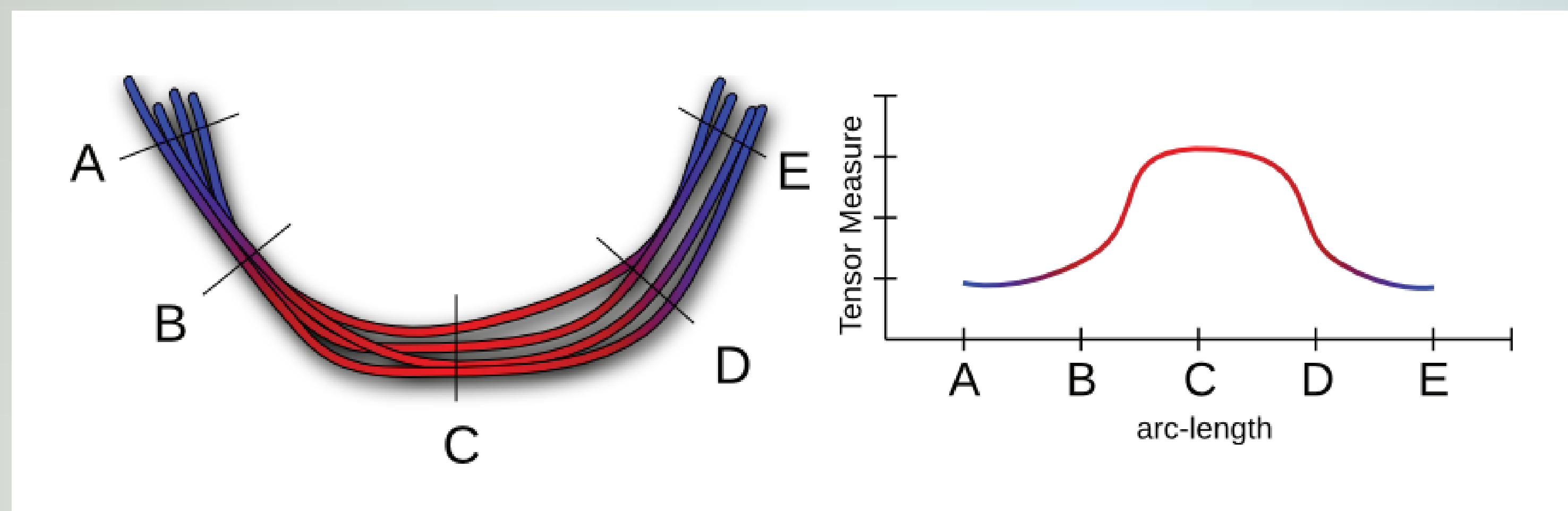- Diffusion properties mapped from individuals to atlas tract

Fig. 1: (a) Fiber bundles are sampled starting at origin C. (b) Corresponding arc-length values such as points A, B, C, D, E are averaged to produce a sampled representation of the along tract statistic of interest, such as fractional anisotropy (FA).
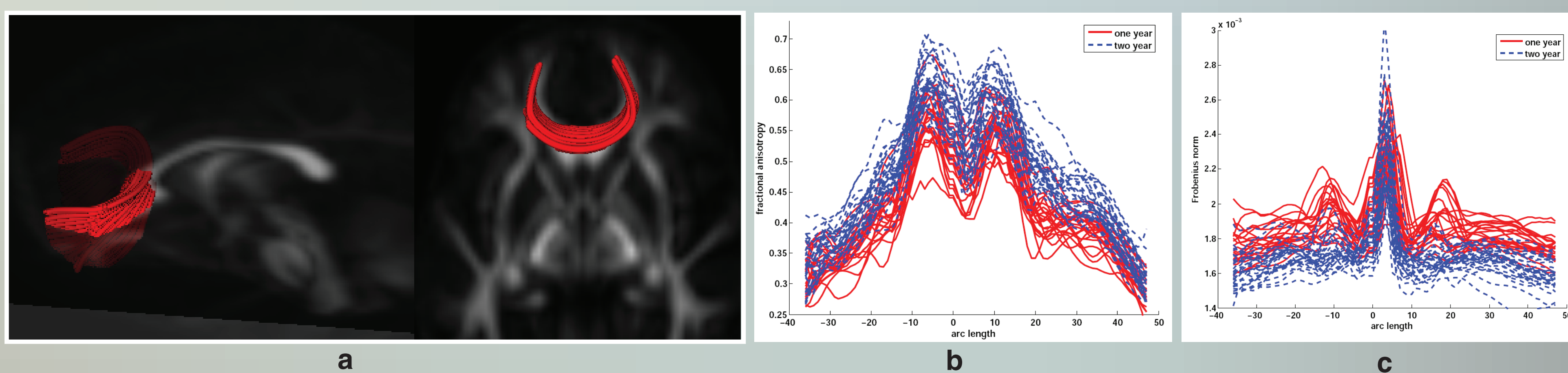

Fig. 2: (a) Genu tract is extracted in atlas (b) FA and (c) Frobenius norm curves sampled from individual data as shown in Fig. 1.

Tract-Oriented Hypothesis Testing

- Fit b-spline model to sampled tract-oriented functions
- Joint analysis of FA and Frobenius norm functions
- Principal component analysis (PCA) for dimensionality reduction

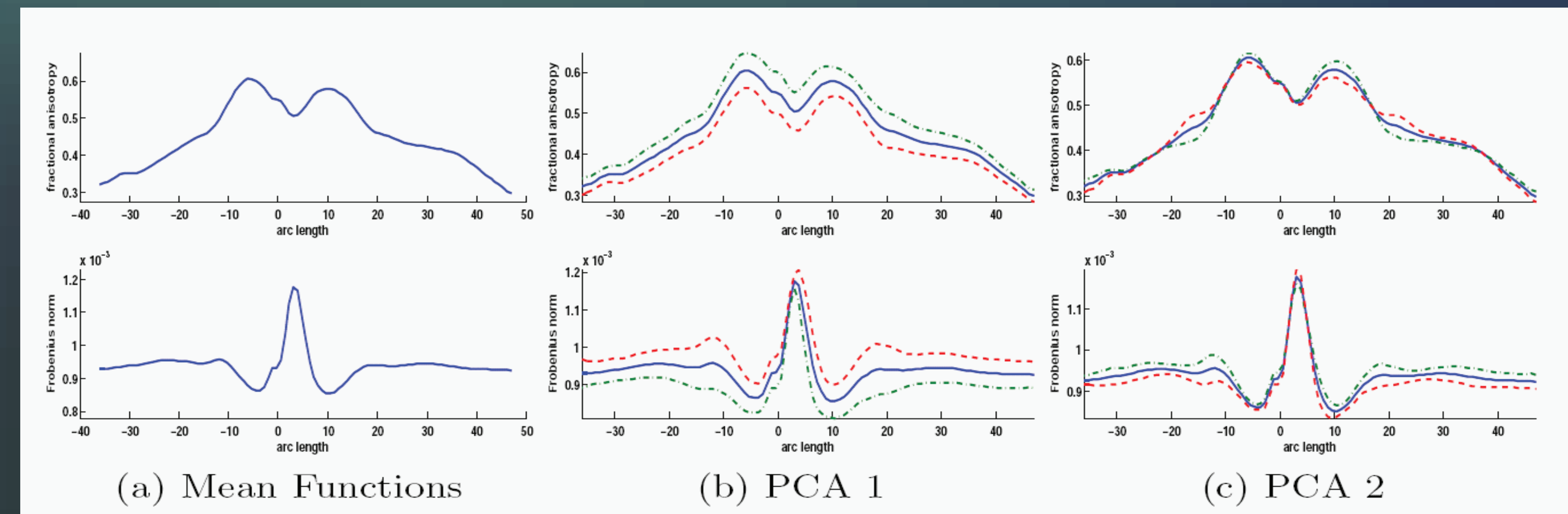(a) Mean Functions   (b) PCA 1   (c) PCA 2

Fig. 3: PCA of functions from Genu of entire cohort including (a) mean and (b) 1st and (c) 2nd principle modes of variation. The first principle mode captures a large portion of the variation and highlights the strong correlation of the along-tract measures.

- Single global hypothesis test per-tract – joint FA and norm
- Hotelling T2 statistic used as basis for permutation test
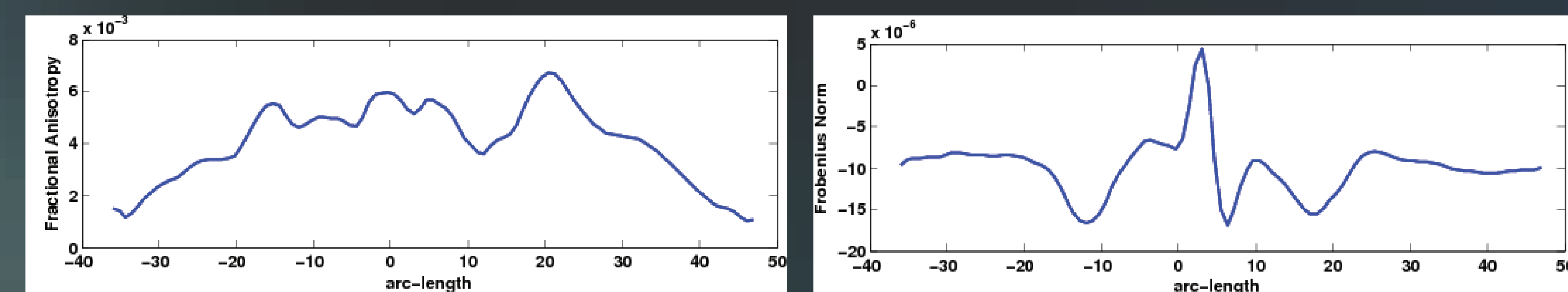- Discriminant embedded in T2 metric can be plotted in arc-length coordinates

Fig. 4: Discriminant functions for (a) FA and (B) Frobenius norm. The FA function shows a global increase in FA from one to two years that is concentrated toward the center of the tract. The Frobenius norm function shows a global decrease from one to two years.

Conclusion

- Global comparison of tract populations
  - Single hypothesis test with no multiple comparison correction
  - Explicit handling of along tract correlation
- Joint analysis of tensor shape measures
- Current work is applying the method to a clinical study of at-risk pediatric populations and an adult study of Schizophrenia
- Software being made available as open source package http://www.sci.utah.edu/~gcasey/software

References

[1] Corouge, I., Fletcher, P.T., Gilmore, J.H., Gerig, G.: Fiber tract-oriented statistics for quantitative diffusion tensor MRI analysis. Medical Image Analysis 10(5), 786–798 (2006)
[2] Casey B. Goodlett, P. Thomas Fletcher, John H. Gilmore, Guido Gerig. Group Analysis of DTI Fiber Tract Statistics with Application to Neurodevelopment. NeuroImage 45 (1) Supp. 1, 2009. p. S133-S142.