Local DTI Connectivity Estimation using Bayesian Probability Theory

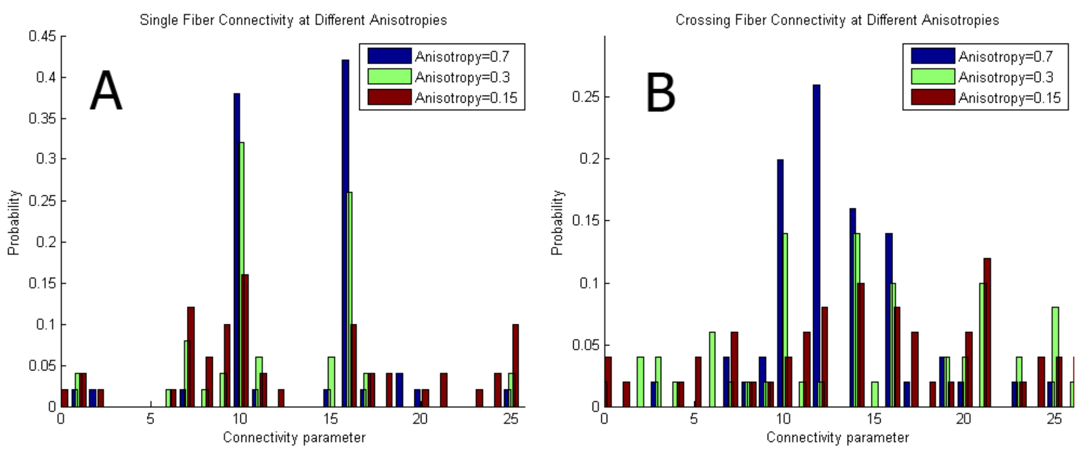
J. S. Shimony[1], A. A. Epstein[1], and G. L. Bretthorst[2]

[1]Mallinckrodt Inst. of Radiology, Washington University School of Medicine, St. Louis, MO, United States, [2]Department of Chemistry, Washington University School of Medicine, St. Louis, MO, United States

INTRODUCTION: We propose an enhancement of the DT model with a local connectivity parameter that better accords with the known anatomy of white matter (WM). In addition to providing diffusion tensor parameter estimation the calculation provides the probability that a given pixel is connected to one of its nearest neighbors. These probabilities can be used in further calculations to determine the probability of connectivity between different brain regions.

BACKGROUND: To evaluate the DT we routinely estimate the 3 eigenvalues, 3 eigenvectors, and the baseline T2 image. Some authors have demonstrated improved estimation of the data with the use of an additive constant [1]. These models for the DT estimate the parameter values for each pixel independently of its neighbors. It is well known anatomically that many WM fiber bundles extend over many pixels with only small changes in direction along their path. This information of local connectivity between neighboring pixels can be included as prior information in a Bayesian estimation of the parameter values. By better representing the underlying anatomy this information can potentially improve the model and provide accurate local connectivity information.

METHODS: In addition to the standard complement of parameters estimated by the DT for every voxel, *i*, we add a local connectivity parameter, Λij, with *j* being an index that runs from 1 to 26, representing the 26 nearest neighbors of each one of the voxels in the image. In each model calculation Λij can take on the value of one of the 26 nearest neighbors, the one that it is most closely connected with. When looking at a population of model calculations the values taken on by Λij represent the probability of the connection between pixel *i* and its neighbors. This converts the local estimation of the DT in each voxel to a more complicated global estimation problem since the result of each local estimation are communicated to its neighbors via the connectivity parameter. The benefit of this added complexity is the determination of the local connectivity profile. The calculation is done in an iterative manner in order to allow the local influences to propagate across the volume of the brain. Further details of the method are presented in [2].



RESULTS: The top figure demonstrates the result of the algorithm in a simulated data set with (A) one fiber and (B) two crossing fibers in a single voxel. The horizontal axis represents the 26 neighbors of the voxel in question, and the vertical axis the probability of connectivity with each one of these neighbors. The different colors represent different anisotropies. As expected (A) and (B) demonstrate a connection with 2 and 4 neighbors respectively, modulated by the anisotropy. The lower figure shows the connectivity parameter in a data set from the brain of a normal subject. The image on the left is an anisotropy image of a coronal section of the brain. The image on the right is a magnification of the region marked by the white square with superposed red whiskers indicating the value of the connectivity parameter in each pixel. Comparison of this method with standard DT processing is in progress.

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REFERENCES: [1] Kroenke, C.D., et al., Neuroimage 25(4):1205-13, 2005. [2] Shimony JS et al., Bayesian Inference and Maximum Entropy Methods in Science and Engineering, AIP, in press 2007.