Variance of structural network for different fiber tracking schemes

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Introduction: White matter fiber tracking from MRI diffusion imaging has made structural network analysis a promising methodology to study the segregation and integration of brain functions[1]. The nodes of the network are anatomically parcellated small regions, while the edges of the network are the fiber density between those parcellated regions[2]. Current literature has shown many variants in constructing the network from the data acquired with Diffusion Tensor Imaging, a pulse sequence that is available on most of the scanner. A direct comparison between those different methods is lacking. In this report, our comparisons are of two diffusion models: high angular resolution diffusion imaging (HARDI)[3] and the default diffusion tensor model (DTI); and two deterministic tracking algorithms: fiber assignment by continuous tracking (FACT)[4] and Tensorline[5]. Since these methods have been previously examined in great detail, our focus of discussion and comparison is on the variance of constructed network (VON)[6]. We also investigate the effect of seed masking.

Methods: 6 subjects participated in this study, each subject took two back-to-back whole brain DTI scans (2 mm isotropic voxel, 48 diffusion directions, 8 b0 images, b value = 1000) and a high resolution T1-weighted MP-RAGE imaging as anatomical reference for subsequent parcellation and coregistration. The data were acquired on a Siemens TIM Trio 3 T scanner using a 32-channel head coil. Parcellation was done on the T1 anatomical image using FreeSurfer (http://surfer.nmr.mgh.harvard.edu/) to obtain 68 labeled ROIs of gray matter and these ROIs were then warped to the DTI image space. Fiber trackings were performed on Diffusion Toolkit (http://trackvis.org/) using three different fiber-tracking schemes: HARDI-FACT, DTI-FACT, and DTI-tensorline. The stop angle threshold was set to 35 degree. For FACT fiber tracking, two different seed masks were used: white matter mask and whole brain. The white matter mask was warped from segmented white matter from the T1 anatomical image using probabilistic segmentation in FSL (http://www.fmrib.ox.ac.uk/fsl/) with the threshold of 0.95. Ten random seeds per voxel were used for all the trackings. Once the fibers were obtained, the weighted network was constructed with weight between node *i* and *j* defined as

$$w_{ij} = \frac{2}{n_i + n_j} \sum_m \frac{1}{L_{ij}^m} \quad ,$$

where n_i denotes the number of voxels in ROI_i, and L_{ik}^m denotes the length of the m^{th} track between ROI_i and ROI_j. The variance of network was calculated based on the difference between two networks. In the comparison between HARDI and DTI, VON was computed between two scans. In the comparison between FACT and Tensorline, VON was computed between two fiber trackings of the same DTI dataset.

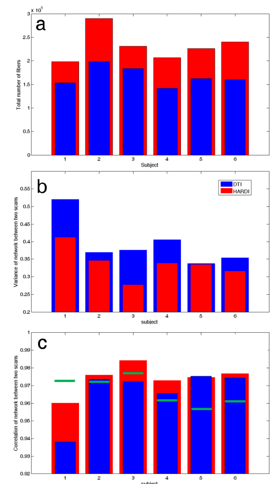

Fig. 1. Comparison between HARDI and DTI. The green bars in (c) indicate the correlation coefficients between HARDI and DTI.

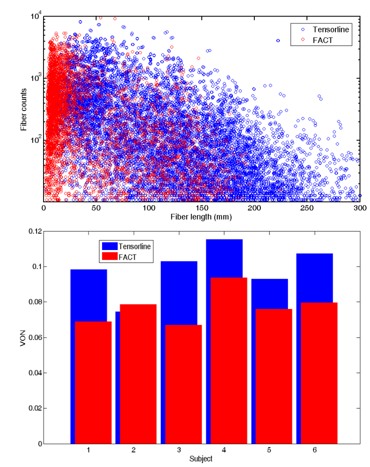

Fig. 2. Comparison between FACT and Tensorline.

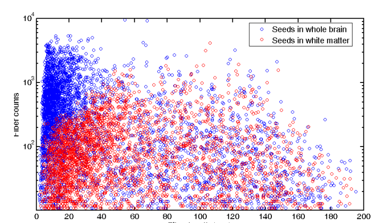

Fig. 3. Effect of seed mask.

Results: The comparison between HARDI and DTI is shown in Fig. 1 for total number of fibers (a), variance of network between scan1 and scan2 (b), and the correlation of the two networks between scan1 and scan2 (c). For all subjects, HARDI produces more fibers and maintains smaller variance across runs. The correlation of networks between two scans is also higher for HARDI. The networks constructed using different models are highly correlated, comparable to those between-scan correlations. The Tensorline approach resulted in longer fibers than FACT as shown in the top panel of Fig. 2. Number of fibers from Tensorline is about 10% greater than FACT. However, the variance of network between two fiber trackings of the same DTI dataset is higher for Tensorline method. The networks constructed using FACT and Tensorline have a correlation coefficient of 0.91±0.01. A scatter plot of fiber counts versus fiber length indicates that many short connections are missing if the white-matter mask is used (Fig. 3). The white matter mask has little effect on the long fibers. The correlation coefficient between networks constructed with and without white matter mask are 0.57±0.05.

Discussion: Our results show that HARDI and DTI result in similar networks with correlation coefficients ~ 0.96. HARDI is superior to DTI in terms of tracking efficiency and test-retest reliability. Therefore, it is recommended to use HARDI reconstruction if there are sufficient diffusion gradient directions. Tensorline algorithm is able to track longer fibers than FACT but also produces more variances and unrealistic fibers (e.g. fibers with length > 500 mm). Both methods tend to introduce biases into the network analysis. *In vivo* validation is needed for the choice between FACT and Tensorline. The use of white matter mask can effectively remove spurious fibers that normally cannot survive long range tracking. Therefore, the constructed fibers are more reliable and the network is expected to be less sensitive to seed density. However, the networks constructed with and without white matter mask are very different. The white matter mask may lose substantial amount of real fibers connecting nearest ROIs, affecting various network metric such as clustering coefficient and path length.

References: 1.Hagmann P. etl al., PloS ONE. 2007;2:e597. 2. Rubinov M. et al., Neuroimage. 2010;52:1059-69. 3. Frank L., Magn. Reson. Med., 2001;45:935-939. 4. Moris, S., Ann Neurol. 1999;45:265-269. 5. Weinstein D. et al., Proc. IEEE Visualization. 1999;249-253. 6. Cheng, H. et al., 10.1016/j.jneumeth.2011.09.021.