Visualizing tractography metrics of cortical-connectivity integrity in diffusion imaging

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Introduction: We present a circular visualization interface of the tractography metrics for assessing cortical-connectivity integrity (Fig. 1). We subdivided the gray matter into 80 regions-of-interest (ROIs) and calculated two metrics for each region-pair from the whole-brain tractography model produced from high angular resolution diffusion imaging (HARDI). Three healthy control (HC) and three bipolar patients (BP) were examined in the visualization for their difference in the tractography metrics.

Methods: First, we perform volumetric segmentation of a high-resolution T1 scan into 80 gray-matter ROIs from the Desikan-Killiany atlas [1] using FreeSurfer [2]. Then, we perform Q-Ball tractography of the 64-direction diffusion scan with DTK [3], using second-order Runge-Kutta track integration, 181 output directions, a 35-degree angle threshold, and two random seeds per voxel. Additionally, we compute volumetric maps of fractional anisotropy (*FA*) using DTK and linearly sample it the track vertices. Next, we map the gray-matter labels to the diffusion space using FSL's flirt, and select tracts-of-interest (TOIs) that start and end in each pair of ROIs. We calculate two metrics [4] for each TOI: mean fractional anisotropy (*FA*) and number of streamtubes (NS), where the mean was computed using a numerical integral. Also, we define $K = \frac{\text{mean}(BP) - \text{mean}(HC)}{\text{std}(HC)}$ to measure the difference in each tractography metric between BP and HC groups. We then visualize the each pairwise metric using hierarchical edge bundling [5] on a circular graph.

Results: Figure 1 shows cortical-connectivity map of *FA* and *NS* averaged from three HC. The intensity of the edge corresponds to the normalized value of the metric across all subjects. We color the edges with perceptually uniform coloring based on the relative distance of their origin and destination cortical region. The circular graph reduces the visual cluttering of traditional cortical-connectivity maps. Fig. 2a illustrates the absolute value of K in *FA* between the two groups. We can quickly and easily observe the strength of differences between groups in many of the areas with two connections most dominant. To understand the direction of the differences, we show the positive and negative K change in *FA* respectively in Figs. 2b and 2c. The change in positive K metric is similar to the absolute K while negative K shows notable changes, demonstrating that this representation can differentiate these cases. Since the negative K change was much smaller than the positive change, they did not show up as dominant change when we examined absolute K value in the visualization (Fig. 2a). The dominant changes were again consistent for *NS* metric in absolute and positive values of K between several region pairs (figures not shown). Therefore, using the visualization interface, we observed that positive increases in *FA* and *NS* are dominant in BP patients in specific regions that can be identified visually.

Conclusion: Our circular visualization interface allows users to analyze various tractography metrics and identify the location of cortical-connectivity difference between HC and BP. Our visualization extends prior work [3] in this area by letting the user examine white-matter integrity without performing tedious TOI selections and potentially compare a large number of subjects in a short time.

References
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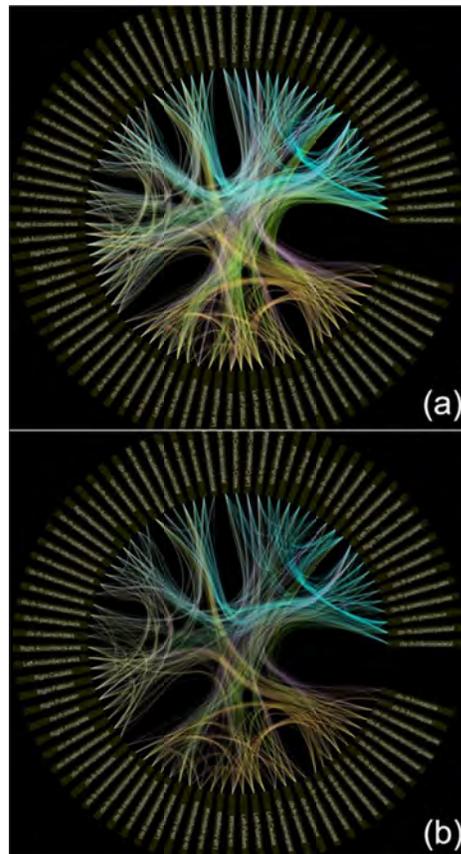
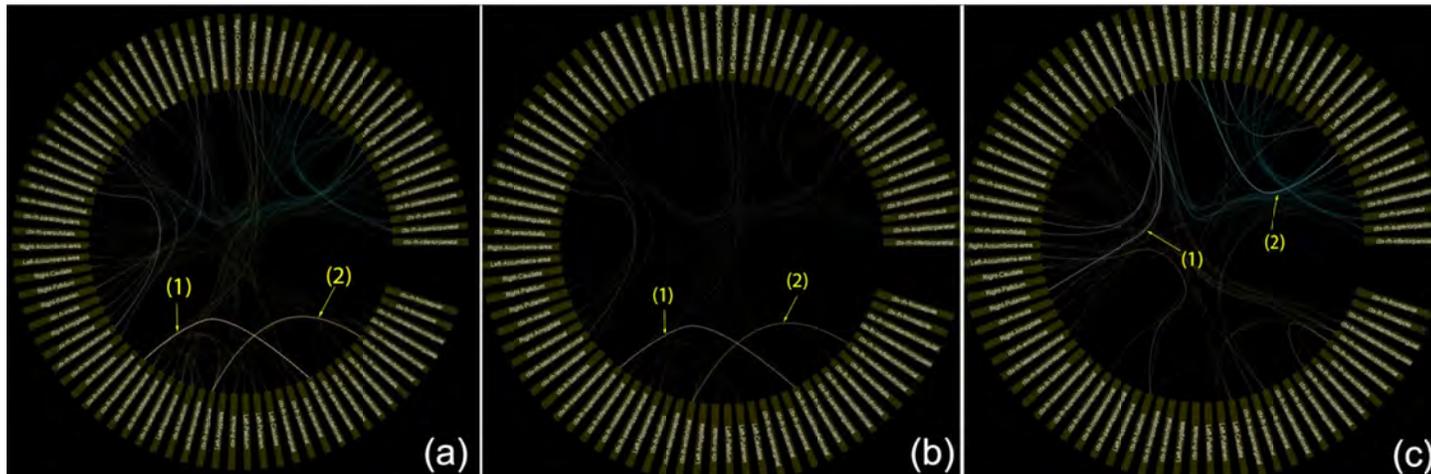Fig. 1: Cortical-connectivity map of (a) *FA* and (b) NS from three HC

Fig. 2: Visualizing difference tractography-measure K in FA between BP and HC: (a) absolute K values; (b) positive K values; (c) negative K values