Illustrative Uncertainty Visualization for DTI Fiber Pathways

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1. Introduction
Diffusion Tensor Imaging (DTI) and fiber tracking provide unique insight into the 3D structure of fibrous tissues in the brain. However, the output of fiber tracking contains a significant amount of uncertainty accumulated in the various steps of the processing pipeline. Existing DTI visualization methods do not present these uncertainties to the end user. This creates an impression of certainty that can be misleading and even dangerous in applications such as neurosurgery which rely heavily on risk assessment and decision-making. However, adding uncertainty to an already complex visualization can easily lead to cognitive overload. In this work we propose illustrative confidence intervals to reduce the complexity of the visualization and present only those aspects of uncertainty that are of interest to the user. We look specifically at the uncertainty in fiber shape due to noise and modeling errors. Any method that produces a set of streamlines with associated confidence values can be visualized with our framework.

2. Our Approach
To demonstrate the flexibility of our framework, we implemented two methods for generating streamlines with associated confidence values. The first method is based on the wild bootstrap suggested by Jones et al. [Jon08]. This method generates multiple tensor volumes by repeatedly fitting the tensor model to the data after randomly perturbing the model residuals. For each seed point we track multiple fibers (one for each tensor volume). The confidence value per fiber is based on the fiber distance to a selected ‘mean’ fiber. The second method involves probabilistic fiber tracking suggested by Sherbondy et al. [SDBS\textsuperscript{*}08] which assigns a connectivity score to each streamline. The streamlines are sorted by confidence (either based on fiber distance or connectivity score) and selectively rendered for a given confidence interval $[a, b]$ with $0 \leq a \leq b \leq 1$. We extended the GPU-based rendering algorithm from Otten et al. [OVW10] to visualize multiple confidence intervals using a silhouette and contour representation (see Figure 1). Different visual styles can be interactively applied using a specially designed histogram widget (see Figure 1 top insets). The histogram represents the distribution of confidence values in the complete set of streamlines. The colored boxes define different confidence intervals. The height of each box encodes a selected visual parameter, such as opacity, outline thickness or blurring. To reduce visual clutter we provide a Focus+Context uncertainty lens that shows uncertainty only in a selected region of interest, for example directly surrounding a tumor (see Figure 1 top-right). We asked three neurosurgeons and one neurologist to provide feedback on the visualization of uncertainty. The overall response was very positive.

Figure 1: Top: example renderings and corresponding confidence histograms. Bottom: visual styles of optic radiation

References