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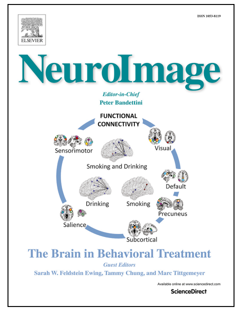

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Framework for Shape Analysis of White Matter Fiber Bundles

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Abstract

Diffusion imaging coupled with tractography algorithms allows researchers to image human white matter fiber bundles in-vivo. These bundles are three-dimensional structures with shapes that change over time during the course of development as well as in pathologic states. While most studies on white matter variability focus on analysis of tissue properties estimated from the diffusion data, e.g. fractional anisotropy, the *shape* variability of white matter fiber bundle is much less explored. In this paper, we present a set of tools for shape analysis of white matter fiber bundles, namely: (1) a concise geometric model of bundle shapes; (2) a method for bundle registration between subjects; (3) a method for deformation estimation. Our framework is useful for analysis of shape variability in white matter fiber bundles.

We demonstrate our framework by applying our methods on two datasets: one consisting of data for 6 normal adults and another consisting of data for 38 normal children of age 11 days to 8.5 years. We suggest a robust and reproducible method to measure changes in the shape of white matter fiber bundles. We demonstrate how this method can be used to create a model to assess age-dependent changes in the shape of specific fiber bundles. We derive such models for an ensemble of white matter fiber bundles on our pediatric dataset and show that our results agree with normative human head and brain growth data. Creating these models for a large pediatric longitudinal dataset may improve understanding of both normal development and pathologic states and propose novel parameters for the examination of the pediatric brain.

Keywords: White Matter, Shape Analysis, Development

1. Introduction

Advances in diffusion magnetic resonance imaging (dMRI) and tractography methods now allow in-vivo high resolution imaging of human white matter (WM) and extraction of the brain connectome - a large collection of WM fibers. As increasing numbers of dMRI datasets become publicly available, much of the recent work in the neuroscientific community revolves around analysis of specific WM bundles - subsets of fibers - with regards to population comparison, lateralization and neurological disorders. Most studies of WM variability focus on analysis of tissue properties estimated by different values extracted from the diffusion data, such as Fractional Anisotropy. The shape variability of white matter, however, is much less studied. The paucity of investigation into white matter shape is due to several factors. It is in part due to the fact that the shape of fiber bundles is irregular and complex, and in part because there are still ongoing debates in the community regarding the ambiguous nature of tractography methods used to extract these structures.

WM fiber bundles are essentially three-dimensional geometric structures with origination and termination regions, anatomically constrained by adjacent brain structures. Their geometric shape has been confirmed by postmortem brain anatomy studies, e.g. Mori et al. ,2017, and atlases have been constructed that determine both the common shape and the common location of different fiber bundles, Wakana et al. ,2004. At present, shape morphology of WM fiber bundles over the course of normal development and pathologic states represents an unexplored area of investigation that may yield new insights into normal and pathologic brain development. Specifically, the lack

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**L. Guibas and K. Yeom are Co-Principal Investigators in this work. LG oversaw the method development and KY oversaw the imaging data collection.