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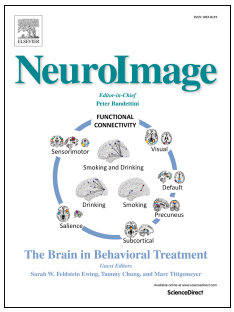

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Modelfree Global Tractography

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Abstract

Tractography based on diffusion-weighted MRI investigates the large scale arrangement of the neurite fibers in brain white matter. It is usually assumed that the signal is a convolution of a fiber specific response function (FRF) with a fiber orientation distribution (FOD). The FOD is the focus of tractography. While in the past the FRF was estimated beforehand and was usually assumed to be fix, more recent approaches estimate the response function during tractography. This work proposes a novel objective function independent of the FRF, just aiming for FOD reconstruction. The objective is integrated into global tractography showing promising results.

Keywords: Tractography, Diffusion MRI, Global Fiber Tracking, Connectomics, Structural Connectome

1. Introduction

Diffusion MRI (dMRI) has become a very important tool for understanding the living brain tissue. Tractography tries to characterize the structural connectome to understand the details of the interregional relationships of the human brain at the macroscopic level. As the dMRI signal is a convolution of the microstructural fiber response function (FRF) with the mesostructural fiber orientation distribution (FOD), tractography algorithms typically make assumptions about the FRF to infer the FOD. Most of the algorithms usually fix the FRF a-priori by analyzing samples of single fiber voxels. Novel algorithms (Reisert et al., 2014; Christiaens et al., 2015b) also estimate the FRF during tractography and let them spatially vary. However, this also includes the microstructural modeling of the FRF, sometimes by simple linear models, or by more complex multicompartment models, which is quite time consuming. Factorization approaches (Christiaens et al., 2015a) try to circumvent this, however rely on smoothness, or even constancy assumptions about the FRF. More recently, it became more and more apparent that, although microstructural and mesostructural information is deeply interwoven, information about them can be quite independently estimated. For example, the spherical means (Kaden et al., 2016) of the dMRI signal, which are independent of the FOD, are surprisingly informative for microstructure (FRF) estimation. Also in Reisert et al. (2017) and Novikov et al. (2016) it was demonstrated that there is actually no true need to have exact, higher order, knowledge about the FOD to estimate microstructural parameters reliably.

In this work we want to show that basically the same holds for FOD estimation. We introduce a novel way to infer FOD information with a minimal amount of a-priori assumptions about the nature of the FRF. Basically we impose two main constraints: 1) the dMRI signal in a single voxel is a convolution of the FOD with an axially symmetric, spatially-variable FRF, which is in a certain sense fiber-like shaped and 2) the FOD is sparse, i.e. the FRF accounts for all dispersion effects. The idea is pretty close to blind-deconvolution approaches. The corresponding energy is non-convex and difficult to optimize, therefore we adopt the global tractography framework proposed in Reisert et al. (2014), which is based on a RJMCMC algorithm and has the flexibility to optimize the proposed objective. In general, global regularization (Poupon et al., 2000; Reisert and Kiselev, 2011) and global tractography frameworks (Mangin et al., 2002; Kreher et al., 2008; Fillard et al., 2009; Reisert and Kiselev, 2011; Mangin et al., 2013; Teillac et al., 2017) are known to be quite robust and the prior information imposed about the fibrous nature of the tissue can help a lot to obtain more meaningful connectomes than what you usually get from ordinary streamline approaches.

In the remainder we will introduce the details of the method and demonstrate its abilities on a numerical phantom and compare it with alternative approaches using tractometer metrics (Côté et al., 2012, 2013). Then, to demonstrate the proposed method on in vivo data, several fiber bundles area extracted from full-brain reconstructions to provide a visual comparison to other state-of-the-art approaches. And finally, we will work out the differences to existing global tractography algorithms.