Project Proposal: 3-D Tractography with Experimental MRI using Compressed Sensing Method to Resolve Orientations of Crossing Fibers

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Project Topic

Diffusion MRI fiber tractography has become an useful tool for mapping white matter pathways in-vivo. However, diffusion tensor imaging (DTI) suffers serious limitations in regions of crossing fibers because traditional tensor techniques cannot represent multiple, independent intra-voxel orientations. In this project, we will devote most of our efforts on using Compressed Sensing techniques to resolve crossing fibers problems using a tensor mixture model.

Description

If we let y be the K attenuation observations measured by our sensing device, we can write it in a matrix form as:

$$y = Sf \cdot$$

where y is the the K attenuation observations, f is a Nx1 vector and S is a KxN matrix that comprises a set of the reconstruction basis (which are neural tensors). This can be further formulated as a compressed sensing problem as follow:

$$\hat{f} = \underset{f; f_i \in [0,\infty)}{\operatorname{argmin}} \{ ||\mathbf{S}f - y||_{L2} + \beta ||f||_{L1} \}.$$

Here we use β as a fine tune parameter to control the tradeoff between precision of model fitting and sparsity requirement. As β approaches zero, the estimate tends toward unregularized least-squares regression. As β increases, the sparsity term dominates. Note that several constraints need to be taken into considerations for this formulation. For example, our sparse signal f only comprises of nonnegative terms.

Preliminary plan

We plan to develop and test our algorithm in two datasets: phantom image and brain image. For each data, the algorithm will include these steps:

1. Diffusion tensor MRI Raw data pre-processing, including motion and susceptibility correction, registration, etc.
2. Diffusion tensor MRI processing, including diffusion tensor estimation and other anisotropy and macrostructural measures calculation (FA, MD)

In the above two steps, we will use some medical image processing software, such as FSL, Camino, JIST.

3. Compressed Sensing for estimation of mixing coefficinets f. We will try some different basis matrix S, criteria (like adding other constrain) and optimization methods (OMP, etc.)
4. Fiber tractography estimation based on previous results and compared it with ground truth.
5. Visualize tractography results using TrackVis.

Goals

Develop a new algorithm that can separate and assist visualization of two crossing fibers successfully.