Anisotropic acquisition and analysis for diffusion tensor magnetic resonance imaging

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Diffusion tensor magnetic resonance imaging (DT-MRI) is a non-invasive imaging method for assessing the characteristics and organization of tissue microstructure. The diffusion tensor provides information about the magnitude, anisotropy, and orientation of water diffusion in biological tissues. The number of DT-MRI applications is rapidly expanding; however, diffusion tensor measurements are also highly sensitive to noise in the raw diffusion weighted images, and consequently the variance of DT-MRI measurements occurs. The variance of DT-MRI measures may impair the ability to detect and characterize subtle differences either between regions or subjects. In this thesis, new acquisition and analysis methods for reducing measurement noise effects are investigated.

For the case where the diffusion tensor orientation and shape may be estimated a priori, changing the diffusion-weighting with encoding direction may improve the overall accuracy of the diffusion tensor measurements. In this study, optimized anisotropic diffusion weighting reduced the variance of fractional anisotropy (FA) and mean diffusitivity (MD) measurements by roughly 50% in the corpus callosum.

Anisotropic Gaussian kernel smoothing was used to reduce the errors and noise for the entire regions of DT-MRI data. The direction of greatest diffusitivity is often assumed to be parallel to the direction of the local white matter tracts, thus the measured diffusion tensor is a good candidate for anisotropic kernel smoothing. This reduces the partial averaging effects with high levels of smoothing. Using this characteristics advantage, anisotropic Gaussian kernel smoothing was applied to DT-MR data from a group of autism subjects to investigate the differences of DT-MRI measurements between the autism and control groups. Amsotropic Gaussian kernel smoothing provided more consistent results for the group differences as compared with manual ROI analysis.

Finally, anisotropic Gaussian kernel smoothing may be useful for estimating anatomic connectivity as the diffusion will be greatest along the white matter pathways. In this study iterative convolution with anisotropic Gaussian kernels was used to estimate connectivity patterns in DT-MRl fields. Preliminary results in both phantoms and human brain were promising. Future developments will constrain the diffusion propagation to white matter to eliminate erroneous pathways.