Diffusion MRI Modeling: Theory and Applications

A. Pasha Hosseinbor

Under the supervision of Andrew L. Alexander

At the University of Wisconsin-Madison

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Diffusion magnetic resonance imaging (dMRI) is a non-invasive modality that quantifies the diffusion of water molecules in biological tissues, and thereby capable of probing tissue microstructure. An important mathematical descriptor of the diffusion profile is the ensemble average propagator (EAP), which describes the 3D average diffusion process of water molecules and possesses rich information regarding tissue architecture. The EAP is related to the measured MR signal attenuation by the Fourier transform. In this thesis we present two novel linear algorithms, each modeling the signal attenuation by a unique orthonormal basis, to estimate the EAP in dMRI: Bessel Fourier orientation reconstruction (BFOR) and the 4D hyperspherical harmonics (HSH). BFOR is an analytical EAP reconstruction scheme, while the HSH representation numerically estimates the EAP. Both methods can be used to estimate various clinically relevant quantitative features of the 3D diffusion profile. A significant portion of this thesis is dedicated to validating these two methods in synthetic and *in vivo* datasets and comparing them to existing analytical EAP algorithms. We will demonstrate that the proposed methods are better or just as effective as existing ones, and that the HSH representation may be more appropriate to sparser sampling schemes than BFOR.