Bayesian Estimation of Diffusion Tensors from Diffusion-Weighted Magnetic Resonance (DW-MR) Data

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Abstract

Mapping white matter tracts is an essential step towards understanding brain function. By measuring in vivo the microscopic diffusion of water molecules, diffusion Magnetic Resonance Imaging (dMRI) is currently the only noninvasive technique which can detect diffusion anisotropies and see details of nervous fibers in the living brain. Spectral data from the displacement distribution of water molecules is collected with a magnetic resonance scanner. From the statistical point of view, inverting the Fourier transform from sparse and noisy spectral data is a nonlinear regression problem. Diffusion tensor imaging (DTI) is the simplest modeling approach postulating a Gaussian displacement distribution at each volume element (voxel). Usually diffusion tensor estimation is based on a linearized log-normal regression model that fits dMRI data at low frequency (b-value). This approximation fails to fit the high b-value measurements which contain information about the details of the displacement distribution but have a low signal to noise ratio (SNR). In this work, we directly work with Rice noise model for the full range of b-values. Using data augmentation to represent the likelihood, the non-linear regression problem is reduced to the framework of generalized linear models. We propose a Bayesian hierarchical model to perform simultaneously estimation and regularization of the tensor field. The Bayesian paradigm is implemented by Markov chain Monte Carlo with Gibbs-Metropolis updates. This work is motivated by the need of diagnostics for Lewy bodies dementia, which are still not familiar by doctors and medical professionals.

Key words: Bayesian regularization, Data Augmentation, Generalized linear models, Markov chain Monte Carlo, Rice noise.

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