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Clustering Method for Estimating Principal Diffusion Directions

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Introduction: High Angular Resolution Diffusion Imaging (HARDI) with a large number of diffusion synthesizer gradients is a non-invasive tool for investigating white matter structure in the brain. Using HARDI data, the fiber Orientation Distribution Function (ODF) on the unit sphere is calculated, from which the principal diffusion directions (PDDs) are extracted. Fast and accurate estimation of PDDs is a pre-requisite for fiber tracking algorithms that deal with fiber crossings.

Methods: We propose a clustering approach to estimate PDDs. The proposed method is an extension of fuzzy c-means clustering tailored for the ODF points that are on a sphere. We estimate the optimal number of clusters from the data distribution based on the Minimum Description Length (MDL) criterion. The proposed algorithm may be summarized as:

1. Calculate ODF of diffusion signal for each voxel.
2. According to the ODF value assign to each point, insert additional exact points.
3. Start with two cluster centers.
4. Repeat until the stopping criterion is met.
    a. Calculate the arc distance between ODF points and the cluster centers using spherical law of cosines.
    b. Update the memberships and the centers of the clusters.
5. Increase the number of clusters by two and repeat Step 4.
6. If MDL decreases, accept the new number of clusters and continue the algorithm in Step 5. Otherwise, stop.

We modified FACT (Fiber Assignment by Continuous Tracking) algorithm for dealing with more than one PDD and used it to reconstruct the fiber tracts in the brain.

Results: Simulated diffusion data are used to test the proposed method and compare it to previous methods. The results of the proposed methods are more accurate than those of the previous methods.

For the HARDI data of a normal subject acquired using the GE Signa Excite 3T MRI at Henry Ford Hospital (Detroit, MI) with 55 diffusion gradients, the proposed method estimates the PDDs accurately especially in crossing areas, e.g., in the intersection of corpus-callosum, corona radiata and longitudinal fasciculus tracts.

Conclusions: Experimental results illustrate that the proposed algorithm is more accurate, more robust to noise, and faster. The proposed method takes about 3 hour to find up to four PDDs for all imaging voxels.

Abstract Deadline: March 30, 2010

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