

Regularized probabilistic tracking with Q-ball fields

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Most of the approaches dedicated to fiber tracking use tensor model. This poor approximation of the diffusion process leads to spurious tracking at crossing bundle location. Here we describe an alternative strategy using Qball Model [1] and Monte Carlo sampling.

Algorithm description:

Water molecule displacement probability in each voxel is given by Qball imaging. From this data we want to track fiber bundles. To resolve this inverse problem, we consider n particles in each starting voxel. Speed of particles is a trade-off between two terms: inertia (v_{in}) and Qball data influence (v_{out}). This influence is randomly chosen from Qball orientation distribution with Gibbs sampler. So $\vec{v} = \alpha \vec{v}_{out} + (1 - \alpha) \vec{v}_{in}$, where α , ranging between 0 and 1, depends on the voxel. This parameter, which is the normalized standard deviation of the Qball distribution, represents local anisotropy. In isotropic voxels the algorithm follows the incident direction, otherwise the Qball distribution is trusted. This memory based approach regularizes the random walk. The particle trajectory is sampled step by step from speed estimation. To regularize further the trajectory curvature, we introduce a cone angle, that depends on incident orientation, to limit the set of directions used by the Gibbs sampler.

Materials and methods:

Our algorithm is designed to untangle bundle crossing. A diffusion phantom (Fig.1) made up of two haemodialysis fiber bundles, crossing at 90 degrees was designed and dedicated to ex vivo validation. The probabilistic algorithm has been run also on whole human brain to detect primary auditory bundle (Fig.3). This small bundle is not detected by tensor-based approaches because of complex crossing with pyramidal bundles and optic radiation. Thalamus and Heschl gyrus are manually drawn [2] (Fig.4). We perform acquisitions with a clinical scanner using a spin echo EPI sequence. b value is set to 700 s mm^{-2} . We use 512 gradients orientations for phantom and only 41 directions for human brain.

Results and discussion:

Tracking results are obtained for the phantom (Fig.2) and for human brains (Fig.5). In both cases we choose a limited cone angle of 30° . For the phantom we set 400 particles at the left of the most horizontal bundle and at the top of the other one. The two crossing bundles are reconstructed correctly as seen in Fig.2, which validates the algorithm. For the human brains 20 particles were uniformly located in each voxel of Heschl gyrus, which led to a total of about 20 000 particles. The trajectories crossing both ROIs are selected first. A map of the trajectory densities is then computed to create a mask of the voxels crossed by more than 3 particles. This mask is used to clean up the bundle (Fig.5). The results are very promising: we processed three subjects and obtained similar bundles. A standard streamline-based method applied on the same data with tensor models and the same 20 000 initial points did not lead to any connection between both ROIs. Further work will be based on human brain data with better angular sampling.

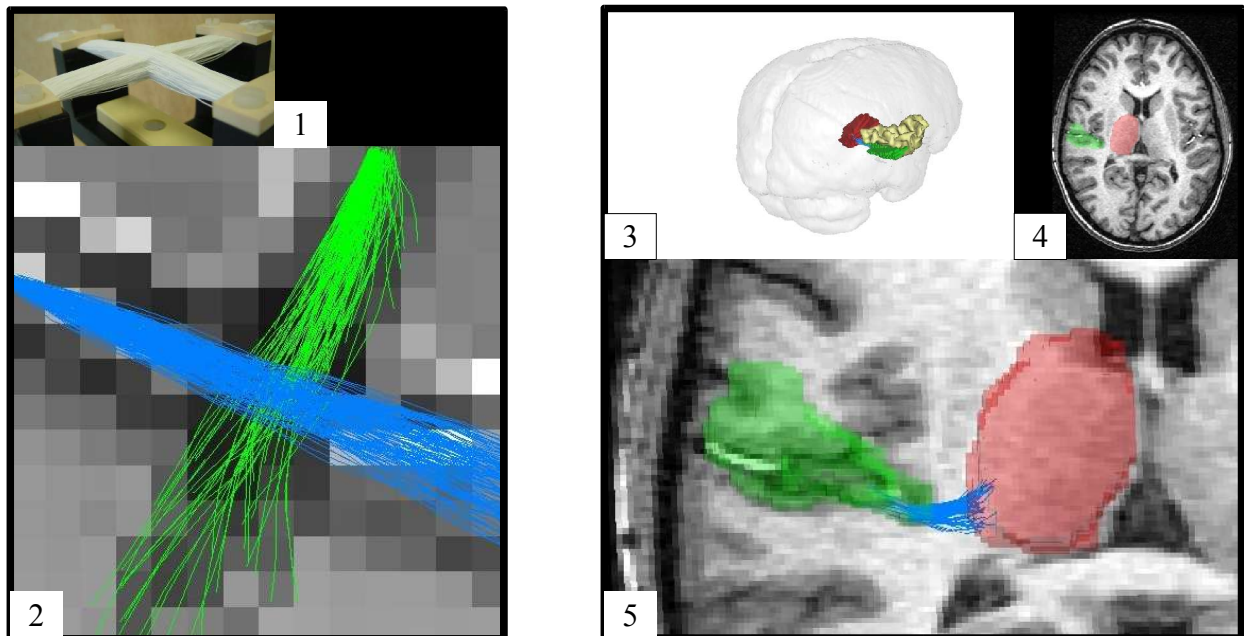


Figure.1 Fiber crossing phantom. Figure.2 Fiber tracking on diffusion phantom.

Figures 3, 4 and 5. 3D Primary auditory bundle (blue) between Heschl ROI (green) and Thalamus (red). T1 slice is superimposed (Figures 4, 5). Insula and Lateral Fissure (yellow) are drawn in corner with full view (Figure 3).

References:

[1] D. S. Tuch. Diffusion MRI of complex tissue structure. PhD thesis, MIT 2002.

[2] J. Rademacher, U. Bürgel and K.Zilles. Stereotaxic localization, Intersubject Variability and Interhemispheric Differences of the human Auditory Thalamocortical System. NeuroImage, 17:142-160, 2002.