Fibre tracking on q-space data

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INTRODUCTION

Fibre tracking on water diffusion tensor data is considered as a promising tool to visualize and assess prominent axon bundles in brain white matter. However, some regions of the brain do not exhibit Gaussian diffusion, which is assumed in diffusion tensor imaging (DTI) [1]. In particular, this is the case in the region of fibre bundle crossings, where the fibre directions cannot be inferred from the measured apparent diffusion tensor. This drawback of DTI can be overcome by measuring an approximation of the full displacement probability density function (DPDF) without recourse to a model of its shape, which is known as 3-dimensional q-space imaging [2]. In this abstract, we propose a method to perform fibre tracking in the human brain based on the full displacement probability function.

MATERIALS AND METHODS

Diffusion weighted imaging was performed with a whole body MR system (Siemens Magnetom Trio) operating at 3 Tesla, using a standard birdcage head coil. After written informed consent was obtained, diffusion weighted single-shot echo planar images of the brain of healthy volunteers were acquired with different diffusion weighting gradients, using 20 axial 4-mm thick slices with 3×3 mm^2 in-plane resolution (TE = 160 ms, TR = 3.9 s). The apices of the gradient vectors were distributed over a spherical section of a regular grid of $11\times11\times11$ points in q-space with a maximum b-value of 10 000 s/mm^2, resulting in 515 different diffusion gradients. The scan time was approximately 30 min for the q-space data set.

The approximate DPDF was calculated by applying the discrete Fourier transform to the measured signal data (zero-filled to a resolution of 16 points in each dimension). To avoid Gibbs ringing, the q-space data were multiplied by a 3d Gaussian before Fourier transform. Then for 162 direction vectors (whose apices were distributed over a spherical surface) the intersection with the isosurface of the DPDF at an arbitrary probability threshold was calculated.

Fibre tracking was performed with a modified version of a probabilistic tracking algorithm based on repeated jumps of a virtual particle [3]. The distance of the 162 points on the isosurface to the origin was used to generate a probability distribution for selecting one of the 162 possible jump directions, with a higher probability for jumps in a direction with a large distance. As the DPDF decreases with distance from the origin, these are directions along which large displacements have a high probability. In order to allow a large number of jump directions, the restriction to jumps between the voxel centres as in [3] was relaxed, and the jump length was set to a fixed value (voxel size/2). Successive jumps were allowed to deviate from each other by 90° at most.

RESULTS AND DISCUSSION

The results along prominent fibre tracts are very similar to those of a comparable tracking on DTI data. A tracking result for the pyramidal tract is shown in Fig. 1. Deviations from the behaviour of DTI tracking occur in regions of fibre crossings. However, distorted isosurfaces can occur in voxels with residual Gibbs ringing. Because the deviation of the DPDF isosurface from an ellipsoid is very small methods for its enhancement should be used in order to exploit it for fibre tracking applications.

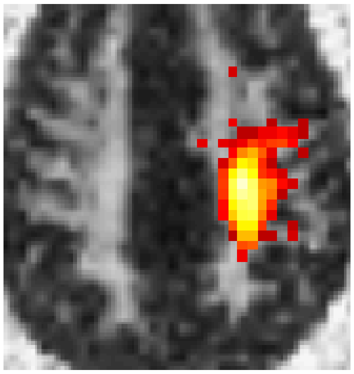

Fig. 1: Map of the number of visits in a voxel produced by the probabilistic tracking algorithm on q-space data, overlaid on a map of fractional anisotropy [4] of the diffusion tensor calculated from the same images. Yellow voxels were reached more often by a jump than red voxels. The start voxel was placed in the internal capsule, the image shows the pyramidal tract 6 slices above this point.

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