Variation in fiber spreading from the human corpus callosum: a statistical study on DT-MRI data

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Abstract
Introduction:
Diffusion tensor imaging is an interesting technique to investigate brain connectivity[1]. Though widely studied, the trajectories of callosal axons still remain not fully characterized[2]. By means of a statistical approach on diffusion tensor MRI data we explore the divergence of the nerve fiber-tracts radiating from different positions on the midline of the corpus callosum into the hemispheres.

Methods:
The brain images were acquired on a 1.5 Tesla Siemens Magnetom Symphony system with a DT-DWI single-shot EPI sequence.
The statistical connectivity mapping of the corpus callosum was obtained with a Monte-Carlo type simulation. A scalar field is obtained where at each position corresponds a count of the number of particles that passed this position[3].
In order to obtain a measure of the divergence of the fibers passing by a chosen point in the corpus callosum and spreading in both hemispheres, a parameterized plane of finite dimension is placed orthogonal to the particle main stream and at a distance defined as the mean distance the particles have traveled when passing through the center of the distribution. The particles that pass through the surface define a 2D probability density function (pdf) from which we can infer statistical information about the spreading of fiber-tracts. We can estimate the covariance-matrix. Imposing that the mean distance from the seed point to the plane is the same, we can compare two distributions and apply significance testing under Gaussian hypothesis.

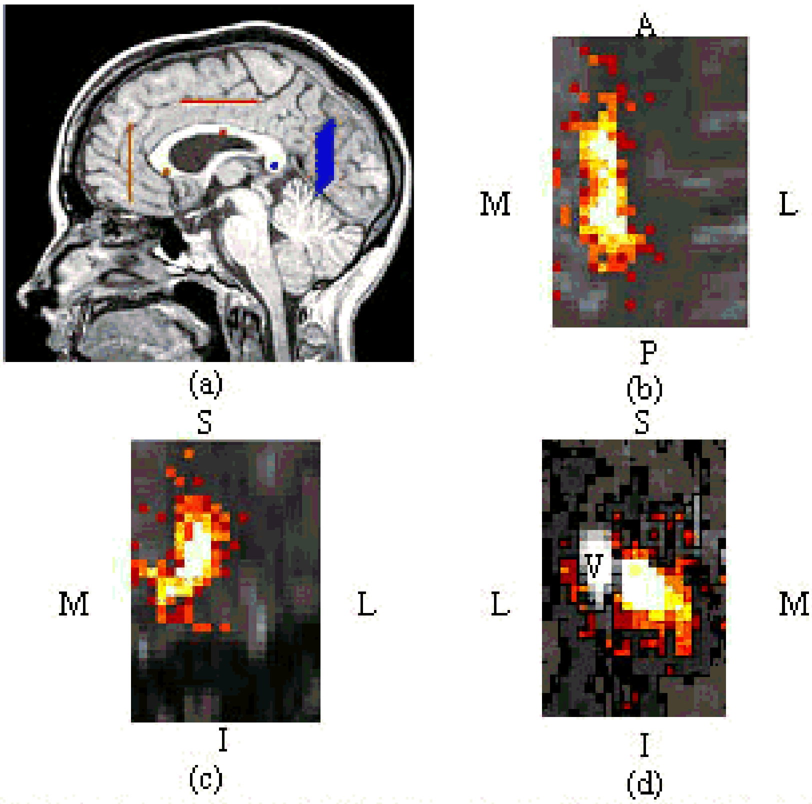

Figure: (a) The three small boxes are the seed points and the lines show the location of the corresponding planes and for each the bi-dimensional pdf is shown: (b) for the mid, (c) for the rostral and (d) for the caudal corpus callosum. The pdfs are color-coded and displays the number of particles that passed the plane at a certain position. M=medial, L=lateral, P=posterior, A=anterior, S=superior, I=inferior, V=ventricle.

Results:
We made three experiments, choosing the most rostral, the mid and the most caudal part of the corpus callosum as seed points. In each case 2000 virtual particles were launched under the same constraints, the pdfs were mapped and the covariance matrices of the distributions estimated. It showed strong variation of spreading according to the location of the experiment. Rostral and caudal distributions where narrower and rotationally more symmetric than the one placed in the mid corpus callosum which fanned out antero-posteriorily.
A test of homogeneity of covariance (Box's M test) was also performed. The M value had to be tested against the 5% critical value 7.8 provided by the Chi-square distribution with three degrees of freedom. Since the M-values of the mid against the rostral (M=210) and of the mid against the caudal (M value = 251) corpus callosum are highly significant we conclude that the respective covariance matrices are not equal.

Seed point	Variance along main axis	Variance along minor axis
Rostral corpus callosum	21.0	9.3
Mid corpus callosum	33.8	4.6
Causal coprus callosum	26.2	12.4

Conclusion:
These pdfs suggest that fibers passing by the mid corpus callosum fanned out antero-posteriorly whereas the projections in the rostral and caudal corpus callosum formed rather dense bundles. These differences in axon trajectories are most likely related to local differences in corpus callosum topography[2].

Reference:
[1] Le Bihan D. et al. J Magn Reson Imaging 2001, 13, 534-46.
[2] Clarke S. et al. Exp Brain Res 1995, 104, 534-540.
[3] Diploma Project LTS-EPFL C647, ltswww.epfl.ch