On the thresholding of probabilistic fibre tracking maps.

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Introduction

Fibre tracking has proven to be a very useful technique to elucidate anatomical connectivity in vivo. Recently, probabilistic fibre tracking algorithms have been proposed to quantify our confidence in the existence of a track [1-3]. This is done by developing a probability model for the fibre direction at the voxel level and then by performing multiple fibre tracking runs, each with a random draw from the local probability distributions. The number of times that a voxel is 'hit' by this procedure then provides a direct measure of the probability that this voxel is connected to the seed region.

A common problem with all existing approaches is that the probability of connection decreases with distance from the seed voxel: making the detection of distal connections problematic and making it impossible to apply a meaningful threshold. In this abstract we demonstrate a method to normalize the probability, depending on the distance from the seed voxel. When the probabilities are normalized they can be readily subjected to standard thresholding procedures.

Theory

The probability of a connection is essentially equal to the line integral of the local probability distribution functions in the direction of the track. Because these probability distribution functions will never be delta functions, there will always leak some probability into other (often spurious) tracks. We therefore propose to normalize the probability as follows:

$p(normalized) = \sqrt[n]{p(connection)}$ where n is the number of voxels a track has passed at the voxel under consideration

We interpret this measure as the average probability of the voxels, having a principal diffusive direction along the local direction of the track, which will be independent of the distance of a voxel to the seed region.

Methods

DTI was performed at 1.5 T on a Sonata system (Siemens Erlangen) on a male right-handed subject using PGSE echo-planar imaging (EPI) with the following parameters: 5 images with no diffusive weighting, 60 directions, b = 700 s/mm^2, 64 slices, slice thickness = 2.5 mm, flip angle = 90°, repetition time = 9900 ms, echo time = 88 ms, matrix = 128 x 128, field of view = 320 x 320 mm^2, no gap (2.5 mm^3 isotropic voxels). The images were coregistered using routines in SPM2. We have implemented a Bayesian estimation scheme for the diffusion tensor using Markov Chain Monte Carlo sampling of the posterior distribution. We have employed uniform priors for all parameters, except for the variance in the measurement, which we have modelled as being drawn from a gamma distribution. We have used a 'burnin' period of 1000 samples and then obtained 200 samples for the posterior distribution. These samples were then used for 200 runs of fibre tracking from a seed region in the visual cortex.

Results/Discussion

The probabilistic fibre tracking shows connections throughout the visual cortex and extending into parietal and prefrontal cortex. When the threshold p = 0.9 is applied on the original probability map, only local connections survive the threshold. When the same threshold is applied to the normalized probability map, a substantial number of connections survive the threshold. At the threshold p = 0.95, substantially fewer voxels survive the threshold, suggesting that at this level there is a better trade-off between sensitivity and specificity.

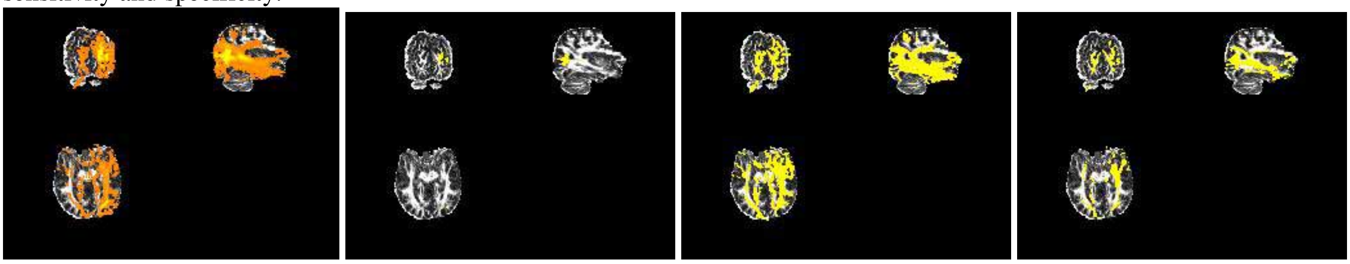

Figure 1. a. probability map of connections from a seed region the in visual cortex. b. probability map, thresholded at p = 0.9. c. normalized probability map, thresholded at p = 0.9. d. normalized probability map, thresholded at p = 0.95.

In the Bayesian framework, probability values can be interpreted as the confidence the experimenter has in the existence of a track, given the data. A threshold of 0.9/0,95 thus seems reasonable. We have shown that fibre probability maps thresholded at this level only show local connections, and have developed a normalization procedure for the probability maps, This new approach allows the experimenter to threshold the fibre images uniformly, thus opening new possibilities for quantitative measures of the strength of anatomical connectivity that are unbiased by distance.

1. Koch, M.A., et al., Neuroimage, 2002. **16**(1): p. 241-50. 2. Parker, G.J., et al., J Magn Reson Imaging, 2003. **18**(2): p. 242-54. 3. Behrens, T.E., et al., Magn Reson Med, 2003. **50**(5): p. 1077-88.