High *b*-value Acquisition using CURVE-ball DTI

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Overview:

The characteristics of water diffusion parallel and perpendicular to white matter tracts are a sensitive indicator of tissue microstructure and cannot be fully determined from single *b*-value DTI. In order to obtain single- or two-tensor DTI data with multiple *b*-values and acceptable SNR in clinically reasonable times, a new data acquisition strategy is proposed – CURVE-ball DTI (CUbe Rays to Vertices and Edges). The basis of the method is the invariance of eigenvector directions to *b*-value, which has been verified *in-vivo* [1]. Thus the eigenvectors can be calculated from a conventional multi direction, single shell (single *b*-value) DTI acquisition (gradient directions shown in black in Fig.1). These measurements provide the single tensor (or multiple-tensor) eigenvectors. By adding a small number of higher *b*-value measurements, coupled with an appropriate diffusion model, diffusion attenuation curves for each eigenvector can be estimated.

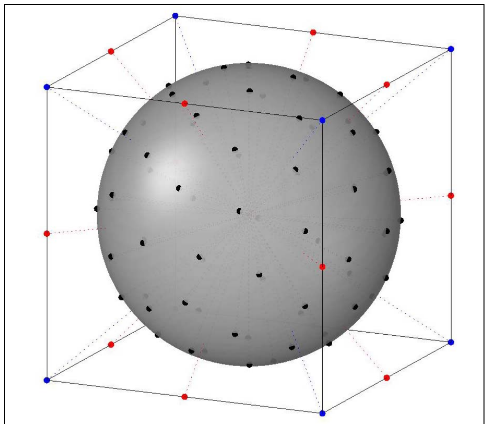

Fig.1: CURVE-ball gradient directions

Practical Example:

The DTI sequence on a General Electric 3T scanner was modified to acquire 36 directions at a basic *b*-value of 800 s/mm^2, 6 directions with *b*=1600 s/mm^2, and 4 directions with *b*=2400 s/mm^2, the latter with 2 averages for increased SNR. Within the same echo time (TE), the 6 gradient directions at strengths twice the basic value are based on acquisition from the edges of the enclosing cube, i.e. [1,1,0] etc. (red points in Fig.1) as first implemented for DTI in Ref. [2]. The additional 4 gradient directions at even higher *b*-values are obtained by utilizing the maximum gradient on all axes (i.e. [1,1,1] etc.) giving three times the basic *b*-value (blue points in Fig.1) as first suggested for optimizing SNR in Ref. [3]. Fig. 2 shows an example of diffusion curves calculated from this data with the help of the diffusion model from Ref. [4].

Advantages of the Strategy:

1. Short acquisition time: A dual-echo scan that also includes three directions at low *b* and one scan at *b*=0 (giving a total of 54 measurements for every slice location) takes approximately 3.5 minutes for 14 slices on a GE 3T scanner, with other image acquisition parameters being typical for EPI-based DTI.
2. High SNR: TE is short since it is determined by the length of the gradient pulses required for the low *b*-value, isotropically distributed, measurements on the unit sphere (b=800 in this case). This results in a relatively high SNR for all measurements.

Conclusion:

Brute force solutions in which multiple spherical shells are acquired are generally too long for clinical use. Once the eigenvector directions have been determined, it is unnecessary to sample high *b*-values in all directions – sparse sampling of high b-values suffices when it is combined with dense sampling at low *b*-values. This strategy has important implications for the feasibility of high *b*-value clinical DTI data acquisition and for the SNR of such experiments.

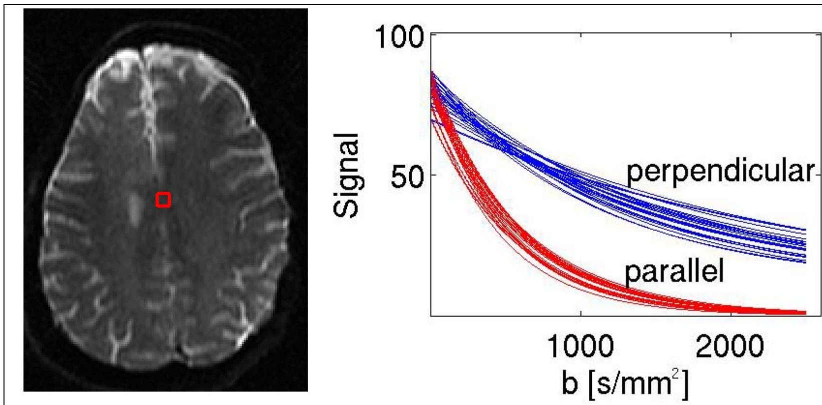

Fig.2: Calculated diffusion attenuation curves from all pixels in a region of interest in the corpus callosum, parallel and perpendicular to the principal eigenvector.

References:

[1] S. Maier et al *Magn Reson Med*. 2004, 51(2) p.321. [2] C. Pierpaoli et al. *Radiology*. 1996 201(3) p.637. [3] T.E. Conturo et al, *Magn Reson Med.* 1996 35(3):p.399. [4] S. Peled *IEEE TMI* 2007 26(11) p.1448.