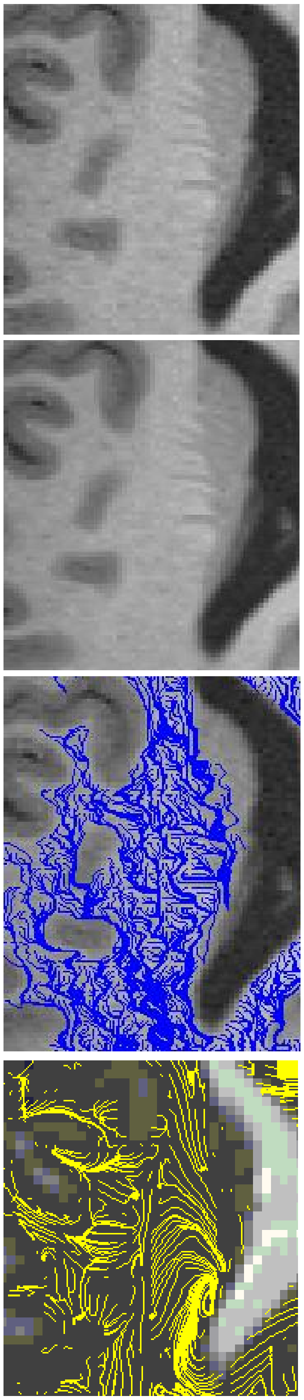
Structural Tensor Imaging

K-J. Jung[1], B. Frye[1], P. Prasad[1]

[1]Brain Imaging Research Center, University of Pittsburgh, Pittsburgh, PA, United States

Introduction

Tensor analysis in DTI is useful for determining the principal direction of anisotropic diffusion. It can estimate fiber direction as a continuous angle from a set of quantized measurements. Such characteristics of tensor analysis can be used to find the direction of any specific quantity in the image. This concept is applied to image enhancement and fiber extraction from high resolution 3D T1 images.



Methods

High resolution 3D T1 images exhibit detailed texture in white matter regions of the brain. Image intensity is relatively more uniform along the texture than other directions. This uniformity can be measured by the variance (V_q) of voxels along a specific direction of a template (***q***). The texture direction is assigned to the template direction of minimum variance. The anisotropic attenuation (A_q) in DTI for each diffusion encoding gradient ($\mathbf{g}_q$), i.e. $A_q = \mathbf{g}_q{}^{\mathrm{T}}\mathbf{D}\mathbf{g}_q = \left(\ln S_0 - \ln S_q\right)/b$, can be substituted with $A_q = 1/\left(1+\sqrt{V_q}\right)$ for each voxel, where S_0 and S_q denote the image intensity for $b = 0$ and $b > 0$ in the q-th diffusion encoding in DTI. The gradient square term in DTI can correspond to the square term in the calculation of variance. A set of templates can be defined to cover the sub window radially centered on a target voxel as done in DTI. For example, 4 (45° interval) and either 6 (diagonals of a cube surface) or 13 radial directions (45° interval in the cube) for 2D and 3D, respectively. From the template direction, the matrix for the calculation of $A_q = \mathbf{g}_q{}^{\mathrm{T}}\mathbf{D}\mathbf{g}_q$ can be obtained by substituting the gradient vector $\mathbf{g}_q$ with the template directional vector ***q***. We can follow the same mathematical procedure as in DTI to obtain the structural tensor **D** and the eigen decomposition. The primary eigenvector corresponds to the direction of the minimum variance of the texture. Assuming this fiber direction coincides with the fiber direction in the white matter, the texture direction can be used for fiber tractography.

Results and Discussions

3D MPRAGE (TI = 800 ms and voxel size = 0.78 x 0.78 x 1 mm^3 for sagittal view) and DTI (voxel size = 1.6 x 1.6 x 3 mm^3 for transaxial view with 6 diffusion encoding) images were acquired from a Siemens Allegra 3T system. For the MPRAGE image the structural tensor **D** and the eigenvectors were calculated from 4 or 13 template directions in 5 x 5 or 5 x 5 x 5 window for 2D or 3D, respectively. The direction of the primary eigenvector was used for the image SNR enhancement and for fiber tractography. The results are shown in the figure: (top) original image, (2nd) 2D SNR enhanced image, and fiber tractograms for (3rd) 3D STI and (bottom) 3D DTI, both projected to 2D. The tractorgram using STI shows more details in basal ganglia and internal capsule than the DTI result. Furthermore, this method can avoid image artifacts associated with DTI.