# Improving Relative Anisotropy Measurement using Directional Correlation of Eigenvectors

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## Introduction

The relative anisotropy (RA) exhibits a great contrast between brain white and gray matters [1]. However, RA is susceptible to the influence of noise [2, 3]. Although the proposed inter-voxel indices reduce noise influence on measured diffusion anisotropy [3], the partial volume effect originating from the inter-voxel operation adds uncertainty to the estimated anisotropy depending on tissues of interest.

To improve the accuracy of relative anisotropy determination without the unwanted partial volume effect, a newly proposed approach, i.e., intra-voxel directional-correlation weighted relative anisotropy (DRA), is examined. Tensor inner products will be performed on the individual voxels between the two identically acquired DTIs, without the local average of neighboring voxels, in combination with the calculation of RA. The effect of noise is reduced with such operation since random noise is not directionally correlated between repeated scans. In order to demonstrate the ability of the intra-voxel DRA to reduce the partial volume effect, an inter-voxel DRA, taking the diffusion tensor inner product weighted average of neighboring voxels, will also be examined. The noise influence of intra-voxel DRA will be compared with RA and inter-voxel DRA in different brain regions in vivo.

## Theorem

The derivation of intra-voxel DRA is achieved by repeating the DTI data acquisition on the same subject under examination. The intra-voxel DRA can be defined as

$$DRA = \frac{\sqrt{A : A'}}{\sqrt{< D > I :< D' > I}}, \quad [1]$$

where A is the anisotropic tensor, I is the identity matrix, < D > is a scalar defined as the mean of the three eigenvalues of D, and < D >I is the isotropic tensor. A' and D' represent the corresponding tensors in the same voxel of the repeated scan. If only a single DTI data acquisition is used to calculate DRA, A' and D' represent the eight closest neighbors of the voxel of interest. The inter-voxel DRA is then established by taking local average of the diffusion tensor inner products in neighboring voxels.

## Materials and Methods

Diffusion tensor imaging experiments were performed on five-month-old male Sprague-Dawley rats weighing 450g. Data acquisition performed on a 4.7 Tesla, 40cm bore super-conducting magnet (Spectrospin, Biospec 4.7 T, Fällanden, Switzerland) equipped with an actively shielded gradient coil (5.6 G/cm in 500 ms). A 20-cm inner diameter volume coil and a 2-cm outer diameter circular surface coil were employed as the transmitter and receiver respectively. A spin-echo imaging sequence was modified by adding the Stejskal-Tanner diffusion sensitizing gradient pair for DWI acquisition. Three coronal slices with a FOV of 4cm, a Slth of 1.5 mm, and an inter-slice distance of 0.5 mm were examined. Imaging acquisition parameters were: TR of 1sec, TE of 59.2ms, NEX of 1, gradient separation time of 27ms, gradient duration of 20ms, b-values = 0, and 800 sec/mm2, and data matrix size of 256*128 (zero-filled to 256*256). Diffusion sensitizing gradients were [Gx, Gy, Gz] = [1,1,0], [1,0,1], [0,1,1], [-1,1,0], [0, -1,1], and [1,0, -1]. Data acquisition was repeated eight times. The real and imaginary parts of the eight repeatedly acquired data sets were averaged and then fast Furrier transformation was performed to reconstruct DWI with NEX of 2, 4, and 8.

Selective regions of interest (ROIs) in white matters including the external capsule and the corpus callosum, and a region of gray matter represented by the cerebral cortex were defined as indicated in Fig. 1. The diffusion tensor and the anisotropy index maps were derived using software written in Matlab (MathWorks, Natick, MA, USA).

## Results

For all selected ROIs, gradually increasing levels for the estimated RAs were observed as the SNR decreased. The higher values of RA than DRA suggest the noise influence of RA resulted in an overestimation of RA. As the SNR increased, the values of the RA, inter-voxel DRA and intra-voxel DRA converged. For the cerebral cortex in Fig. 2a, estimated inter-voxel and intra-voxel DRA values are approximately equal at each indicated SNR showing that the tissue inhomogeneity in cerebral cortex is less as expected. For the external capsule (Fig. 2b) and the corpus callosum (Fig. 2c), a consistent underestimation of tissue anisotropy using inter-voxel DRA was found when it was compared to the intra-voxel DRA suggesting a partial volume effect.

## Discussion

The proposed intra-voxel DRA is not different from the widely used index RA in its definition but adds directional weighting without a partial volume effect introduced by inter-voxel operations. The operation of the inter-voxel DRA is similar to LI [3] by taking local coherence of neighboring voxels. The measured inter-voxel DRA values of the external capsule and corpus callosum in vivo are smaller than the values measured by intra-voxel DRA. The discrepancy between these two measurements is thus largely due to the partial volume effect introduced by local averaging of the inter-voxel DRA measurement. With the cerebral cortex, the inter-voxel DRA and intra-voxel DRA estimated relative anisotropy equally. This is not surprising as in the structurally uniformed cerebral cortex, the partial volume effect is minimized. The results demonstrate that intra-voxel DRA is superior to RA and inter-voxel DRA not only in reducing noise bias and the partial volume effect but also in presenting better perceptible differences between white matters and gray matters.

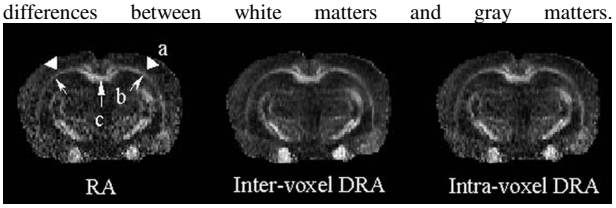


Fig. 1 Representative coronal sections of the anisotropy index maps of a rat brain in vivo are displayed. Regions of interest are labeled as the following: (a) cerebral cortex, (b) external capsule and (c) corpus callosum.

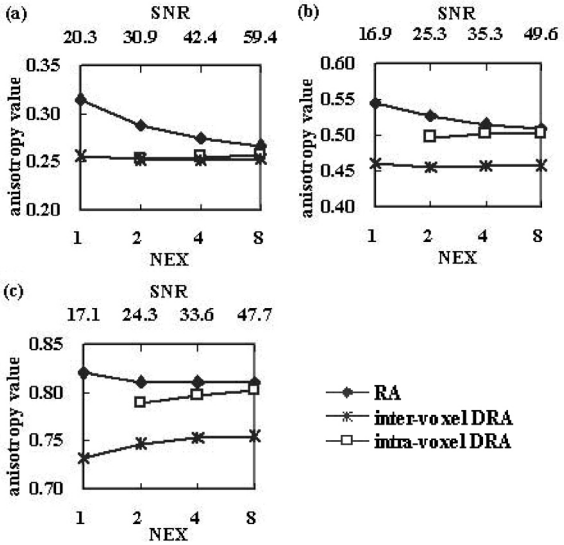


Fig. 2 The measured anisotropy obtained from RA, inter-voxel DRA and intra-voxel DRA determined on (a) cerebral cortex, (b) external capsule and (c) corpus callosum are displayed against the NEX.

## References

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