Segmentation of 3T Diffusion Tensor Images with Multiple Sclerosis Lesions

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Introduction: Diffusion Tensor Imaging (DTI) is a Magnetic Resonance Imaging (MRI) method for characterizing molecular diffusion and for extracting nerve fibers of brain. DTI is a suitable imaging modality for early detection of demyelination diseases such as Multiple Sclerosis (MS). The traditional way of using DTI for MS diagnosis [1], i.e. examining changes in the distributions of Fractional Anisotropy (FA) and Apparent Diffusion Coefficient (ADC), leads to the loss of some important directional information. In this work, we propose a new method to facilitate the detection of MS lesions, which is based on the segmentation of white matter (WM), gray matter (GM) and cerebrospinal fluid by using the entire tensorial information.

Materials and Methods: 10 patients diagnosed with MS and 5 healthy subjects were scanned with an 8 channel head coil in a 3T MR system (Achieva, Philips Medical Systems, Cleveland, OH). Diffusion tensor imaging (DTI) was performed using a single shot EPI sequence (SENSE factor=3, b=1000 s/mm2, 6 diffusion gradient directions) and the tensors are extracted using robust regression. Four images of healthy subjects and eight images of the patients were used as the training set. The remaining images were placed in the test dataset. The images in the training set were manually segmented into WM, GM and CSF. MS lesions were also labeled manually. Instead of computing FA maps and ADC maps, the tensors in the images were filtered with 3D Gabor filters, with 3 different scales and 4 different frequencies, on the Riemannian manifold of positive-definite tensors endowed with the log-Euclidean metric. 2D Gabor filters [2] are powerful directional filters widely used in image segmentation to capture the directional properties. We introduce 3D Gabor filters for the tensor space for diffusion tensor segmentation. The direction of the Gabor filters is chosen to be the direction of the main eigenvector of the diffusion tensor for each voxel. The resulting 12 Gabor tensors for each segment were then used as features to compute the class mean and covariance tensors on the manifold. These mean and covariance tensors were used in a Bayesian classification framework to detect the class labels of the voxels in the test images. Outlier voxels in WM were considered as abnormalities and their Gabor and diffusion properties are compared with the neighboring, correctly classified WM voxels and the training lesion voxels. High similarity to training lesions and the presence of more isotropic tensors with higher ADCs relative to the neighboring WM pixels, are indications of possible MS lesions.

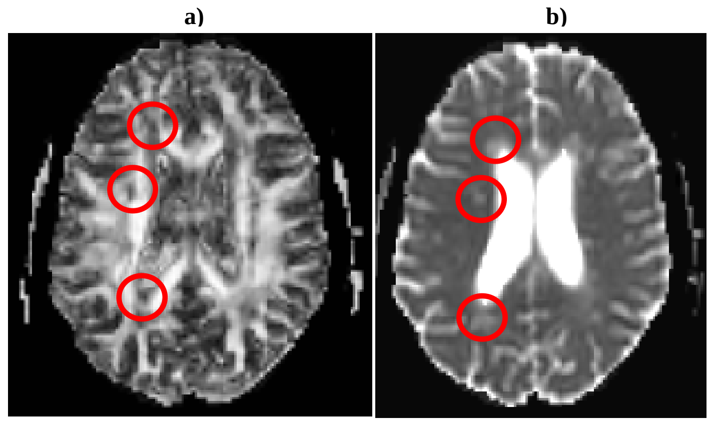

Figure 1. a) Axial FA map of a brain of a MS patient. b) Corresponding ADC map. The circles indicate the lesion locations.

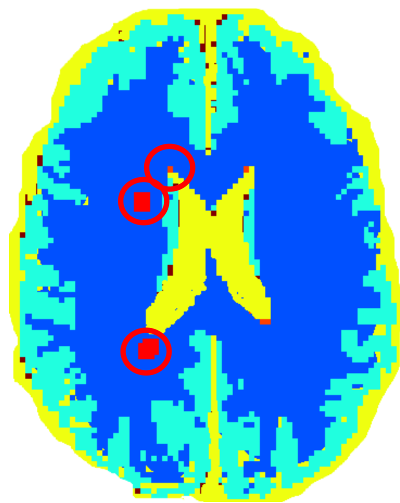

Figure 2. Segmentation of the brain slice in Figure 1. Dark blue codes for WM, light blue for GM, yellow for CSF and red for lesions. Lesions are identified correctly.

Results: 95% of WM voxels, 74% of GM voxels and 86% of CSF voxels in the entire test set were correctly classified with respect to manual labeling. For the MS patients, 53% of the lesions were automatically detected as abnormalities. The remaining 47% were labeled as small GM regions within WM, which facilitates their detection by radiologists.

Discussions: Segmentation of diffusion tensors using full tensor information on the Riemannian manifold of positive definite matrices proves to be promising compared to the scalar field based segmentation and is very capable of detecting anomalies such as lesions. The detection of candidate MS lesions can be further improved by using a different segmentation approach such as level sets, where the speed function will be a function white matter and lesion transition.

References:

[1] A. C. Guo, J. R. MacFall, J. M. Provenzale: Multiple Sclerosis: Diffusion Tensor MR Imaging for Evaluation of Normal-appearing White Matter. RSNA Radiology 2002;222:729-736

[2 N. Petkov: Biologically motivated computationally intensive approaches to image pattern recognition, Future Generation Computer Systems, 11 (4-5), 1995, 451-465.