Reduction of Partial Volume Artifacts in DTI Tractography by Post-Processing

D. H. Hwang[1], A. Shetty[1], A. Rajagopalan[1], and M. Singh[1]
[1]Radiology and Biomedical Engineering, University of Southern California, Los Angeles, CA, United States

Introduction

Partial volume effects can manifest as tract merging in diffusion tensor imaging (DTI) tractography. The general solution is to reacquire data at a higher resolution. Often researchers are not afforded the opportunity for rescan. Some disease conditions also cause increased partial volume effects. Alzheimer Disease (AD) probable subjects exhibit ventricular dilation due in part from white matter loss in the brain. The tractographical manifestation of ventricle dilation is a compression of the remaining white matter and severe partial volume effects near the ventricles. Color Fractional Anisotropy (FA) maps show a change in eigenvector direction inconsistent with the orientation of known tracts (Fig.1). The objective of this work was to develop a retrospective processing algorithm to mitigate partial volume effects at specific locations in tractography, thereby allowing for lower resolution data set inclusion and facilitating quantitation of tractography.

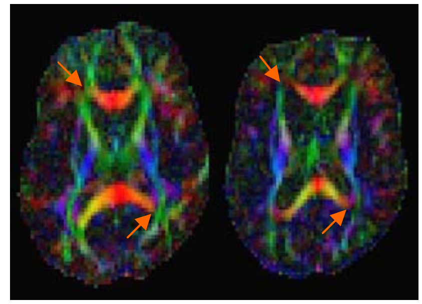

Fig 1. Normal control (left); AD Probable (right)

Method

The data used were acquired on a 1.5T Siemens scanner using a DTI pulse sequence that relies upon a fluid attenuated inversion recovery (FLAIR) based diffusion sequence to null CSF contributions. Multi-slice (2.34 x 2.34 x 5 mm voxel size, 5 mm thick slices no gap) data were acquired using six encoding gradient directions at b-values of 0, 160, 360, 640, and 1000 sec/mm2 with an acquisition matrix of 128x128. In addition, a second set of data was acquired with gradient polarity reversed and the two sets are averaged to reduce eddy current and field inhomogeneity effects. Streamline tractography incorporating tensor interpolation with 0.2 mm steps was conducted on anatomically equivalent seed points defined in individual subjects by inverse normalization using an SPM template, and individual tracts were warped back to the SPM template.

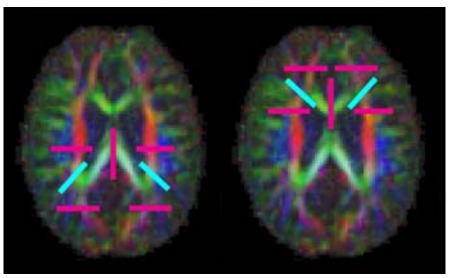

Fig. 2. Identification planes (magenta); Filter planes (cyan) on color FA (slice 30); Splenium filter set (left); Genu filter set (right)

Our algorithm makes use of a series of intersection planes and filters in normalized space for the identification and filtering of tracts. Normalization of subject tracts to a standard template allows for a consistent definition of the seven planes for all subjects. Planes are selected by using FA and tractography results as reference for tract morphology. The five identification planes as well as the two cut planes for splenium and genu merging are show in Fig. 2. The planes, extending in the inferior/superior direction of the brain, were chosen because the tracts of interest are predominately in the axial plane.

The algorithm processes all tracts in series. The first layer of filtering checks to make sure the tract would only exist because of partial volume effects. We identified three main types of tracts that may form due to partial volume effects. These tracts show merging of anterior/posterior tracts with tracts located in the splenium and genu of the corpus callosum. The tract selection criteria are based on the intersection of the tract being tested with the identification planes governed by a set of Boolean logic. Tracts identified as tract due to partial volume effects are subject to the next round of testing while all other tracts are safely passed on to the result file.

The second round of filtering makes use of the two cut planes. The tracts are severed along the planes, but only when there is a merging of the anterior/posterior tract and the splenium/genu. The algorithm then checks the seed point and saves only the portion of the tract which contains the seed point. If the seed point lies inside one of the cut planes, the tract is deleted altogether. The cut planes have a minimum thickness of one pixel. The algorithm is purely subtractive and will not generate new tracts.

Results and Discussion

Examples of pre and post filtered tracts are presented in Fig. 3. Our algorithm does not reconnect tracts disrupted by the partial volume effects. The algorithm helps facilitate a more accurate regional count of tracts and partially corrects for the overestimation of individual tract length, both important parameters toward achieving quantitation in DTI tractography.

Often researchers are limited in what data is available. Restrictions such as limited control of scan parameters, subject availability, and consistency of data received forces many researchers to work with less than optimal data. It is with this in mind that our algorithm was designed. This retrospective processing method cleans the tractography and reduces looping and over-extended tracts due to partial volume effects. It is our hope that this tool may enable inclusion of previously discarded data in quantitative/semi-quantitative studies.

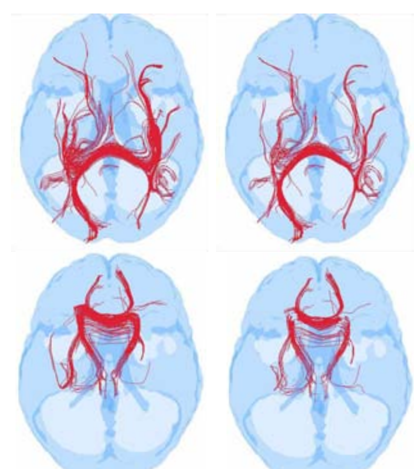

Fig 3. Unfiltered (left); Filtered (right)