DTI Processing and Analysis with MedINRIA

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Introduction:
Although the MedINRIA software has been out for three years, it has never been formally presented to the ISMRM community. The goal of this work is to expose the rationale of MedINRIA, its current status and its future. Clinicians (radiologists, neurologists, neurosurgeons) are often in demand of cutting-edge technologies to analyze data, but cannot in general spend time learning new, potentially complicated, softwares. Similarly, computer science researchers need the expertise of clinicians to interpret images. The MedINRIA project was born to facilitate exchanges between them. The rationale for its development is to provide an ergonomic graphical user interface with a fast learning curve while offering users state-of-the-art algorithms. In this work, we take the example of diffusion tensor imaging (DTI) processing and detail its implementation in MedINRIA.

Material and Methods:
DTI has gained popularity due to its unique ability of characterizing in-vivo the fibrous architecture of the white matter. However, its practical use can be difficult for the non-expert: going from the raw DICOM data to the final tractography result imposes several steps that are prone to errors if one does not control them carefully. The DTI Track module of MedINRIA was purposely developed to facilitate the processing and analysis of DTI to non-experts in DTI. First, a wizard guides the user importing data (a DICOM conversion utility is available). The diffusion gradients can be imported as a simple plain text file listing all gradient coordinates one after the other (FSL bvec files are supported). Once data is imported, tractography can be performed with a single click. This simple click proceeds to the following pipeline. First, a fast linear least-squares fit of the tensor coefficients is performed. Repeated diffusion gradients (including b0 images) are automatically averaged to increase signal-to-noise ratio (SNR). Second, non-positive tensors are removed (the linear estimation does not ensure the positive definiteness of the result) by replacing matrices with null or negative eigenvalues with the log-Euclidean average of their positive neighbors [1]. This step is fast and does not introduce outliers, which is the case for instance when zeroing out negative eigenvalues (it tends to create regions of artificially high fractional anisotropy (FA)). The tensor field can be further denoised using a Perona & Malik anisotropic diffusion scheme [2] extended to tensors. Such procedure preserves the discontinuities of the field by smoothing preferably along fiber bundles than across them. Finally, tractography is performed using a modified version of the advection-diffusion algorithm of [3] including tri-linear log-Euclidean tensor interpolation and a 4th order Runge-Kutta integration scheme, which was proved to be more accurate numerically. Fibers are eventually displayed as lines in a dedicated 3D view. The overall procedure permits to perform tractography on DWI of moderate SNR and with few encoding gradients (from 6 to 30) typical of clinical acquisitions. Refinement of processing parameters is possible for advanced users.

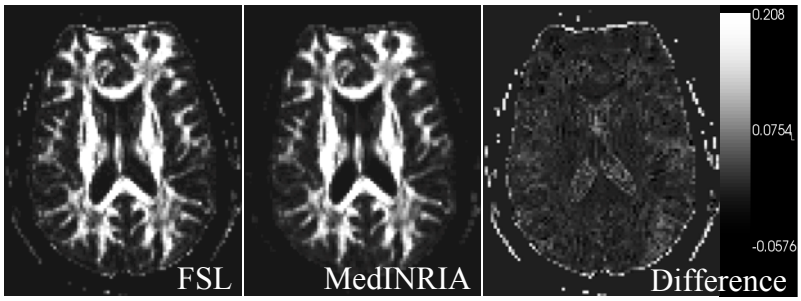

Fig. 1. FA maps obtained with FSL (left) and MedINRIA (middle). The smoothing option of MedINRIA was set to medium. The right image shows the difference image between both FA maps (FSL - MedINIRA). The colorbar indicates the difference range.

Furthermore, DTI Track offers an interactive fiber tract-of-interest (TOI) selection tool. A fiber selection box, which can be resized and translated in 3D, restricts the visualization to fibers that pass through it. By making it very small or very large, it is possible to isolate a particular set of fibers. Moreover, the box can be used recursively to refine their selection. Once a TOI has been identified, it can be labeled, saved, and analyzed: one can compute the average and standard deviation of various tensor coefficients (such as FA) of the entire bundle. A graph summarizing the result is finally shown.
Example of a typical DTI analysis using MedINRIA is show in Fig. 1 and 2. A DWI dataset composed of 6 diffusion gradients (b-value: 1000s.mm^{-2}) and one baseline image acquired on a Siemens Trio (3T) was used in this study (image resolution: 128x128, 58 slices, 2mm isotropic). Fig. 1 shows the FA image calculated with MedINRIA and its comparison with FSL's dtifit algorithm [4]. The smoothing removed most of the noise while keeping the white matter structures almost intact (as shown by the difference image), resulting in a cleaner FA map than FSL. An example of TOI extraction and analysis is shown in Fig. 2.

Conclusion and Future Work:
MedINRIA proposes an integrated solution for DTI processing and analysis, giving in a few clicks the possibility to reconstruct and extract statistical values from fiber tracts. Notably, a denoising algorithm has been purposely developed to allow the processing of datasets of moderate SNR typical of clinical acquisitions.
MedINRIA's functionalities are not limited to DTI or diffusion imaging. For instance, a Q-ball extension has been recently incorporated and is still in beta stage. An ImageFusion module dedicated to image registration is also available: it allows performing from manual rigid to fully automatic non-linear registration of scalar and tensor images in an intuitive way. Nevertheless, practical use of MedINRIA is not optimal yet. First, it lacks connectivity to PACS servers to rapidly retrieve patient exams when acquired. Second, the interface could be further adapted to the clinicians needs. Finally, it lacks the possibility to stop and resume an analysis. This is in this spirit that the version 2.0 of MedINRIA is being developed: it is a complete rewriting of the software with a PACS connection, a data management system, and an intuitive interface mimicking commercial PACS clients. The first release is scheduled in 2011.
MedINRIA version 1.9.2 is freely available on Windows, MacOSX and Linux: http://www-sop.inria.fr/asclepios/software/MedINRIA/.

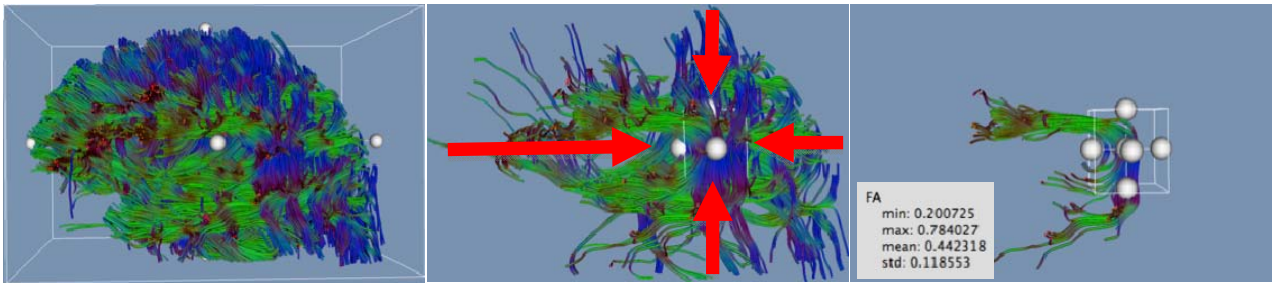

Fig. 2. Example of TOI selection and analysis. **Left**: The initial fiber set. **Middle**: Fibers after resizing of the selection box with the spherical handles. **Right**: Final selection. Statistics of tensor-derived quantity is available (FA in the example).

References:
[1] Fillard et al., IEEE TMI 26(11): p. 1472-1482, 2007
[2] Perona & Malik, IEEE PAMI 12(7): p. 629-639, 1990
[3] Weinstein et al., Proc. of IEEE Viz, p 249-253, 1999
[4] http://www.fmrib.ox.ac.uk/fsl/