Diffusion Toolkit: A Software Package for Diffusion Imaging Data Processing and Tractography

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Introduction: There have been various existing software packages that can process diffusion tensor imaging (DTI) data as well as perform fiber tracking and visualization [1][2]. However, many of them do have various issues in the aspects of functionality, ease of use, speed, quality of visualization and portability, etc. Here we present a new software package called Diffusion Toolkit (DTK). DTK is a complete software package that does reconstruction, fiber tracking, analysis and visualization. It can not only handle diffusion tensor data but can also process high angular resolution diffusion imaging (HARDI) data as well as diffusion spectrum imaging (DSI) data and Q-Ball imaging data.

Methods and Results: Diffusion Toolkit is written in C++, using Qt 4.2 (Trolltech, trolltech.com) for the GUI and Visualization Toolkit 5.0 (VTK, vtk.org) for the visualization part. It is stand-alone, cross-platform (works on all major platforms, including Windows XP, Mac OS X and Linux), fast and efficient. The main workflow of DTK consists of 4 steps. (1) The unpacking program converts the raw DICOM images to Analyze format and a special image orientation information file. (2) With given gradient table and image orientation information, the reconstruction program reconstructs the diffusion image volumes to diffusion tensor maps (along with maps of FA, ADC, etc), in the HARDI/DSI/Q-ball case, to orientation distribution function (ODF) data. (3) The fiber tracking program takes tensor or ODF data and generates whole-brain fiber tracks which are saved to a track data file. (4) The visualization program, called TrackVis, reads in the track data file and visualizes and analyzes the tracks by user's manipulation. Fig.1 shows the main interface of Diffusion Toolkit. Fig.2 shows the main interface of TrackVis. The major features of Diffusion Toolkit are:

1) Handles various DTI/DSI/Q-Ball/HARDI models, works on all major platforms with native look and feel.
2) Streamlined workflow orientated. All the steps in the workflow are integrated into a GUI front-end. Going from raw DICOM images to fully rendered fiber bundles is practically one mouse-click away. At the same time, each step is easily user adjustable and can be independently executed.
3) Scriptable. A complete set of command-line programs can be executed independently without the GUI front-end. Thus, it allows users to write their own script for automatic processing of multiple datasets.
4) Track transformation. A track transformation program can take an existing registration matrix by external image registration tools, such as FLIRT [3], and map a whole-brain track set to the target space. Thus, it allows track comparison between time-points/subjects.
5) Fast data processing. On a Xeon 2.66GHz desktop with 2GB RAM, processing of a full brain DTI dataset (128x128x64, 2x2x2mm, 60 gradient directions) takes 90 seconds, while a DSI dataset (96x96x64, 2x2x2mm, 514 gradient directions, 362 ODF points) takes 15 min.
6) Powerful fiber tract visualization and analysis. The visualization program, TrackVis, reads in the whole-brain track data (usually ~15MB for a high-resolution human scan) and allows the user to apply multiple track "filters" (track selection methods) to select and display specific fiber bundles. Every parameter adjustment is applied interactively to the 3D render view in real-time. It provides users the experience of navigating through the sea of tracks. Features of TrackVis include:
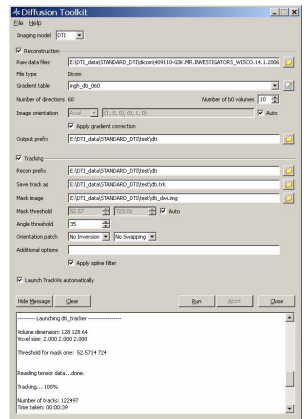

Fig.1 Main frontend interface of Diffusion Toolkit

- A variety of track filters allow user to explore and locate specific bundles with ease. For example, length and slice filters allow quick overview of the whole track family, while freely movable ROI spheres and ROI disks (spatial disks with certain angle selection, i.e., only fibers with certain orientation are selected) allow selecting specific fiber bundles quickly. Free-hand ROIs allow the user to select fibers directly from anatomical locations of interest. Boolean operations can be applied to the filters.
- Multiple rendering modes with customizable scalar-driven color codes.
- Open format of the track data file allows users to integrate customized scalar data into the track file and visualize and analyze it.
- Statistical scalar analysis of tracks and ROIs.
- Synchronized real-time multiple dataset analysis and display, which allows time-point/subject comparison. Synchronized analysis and display on same dataset can also be performed in real-time remotely over the network.
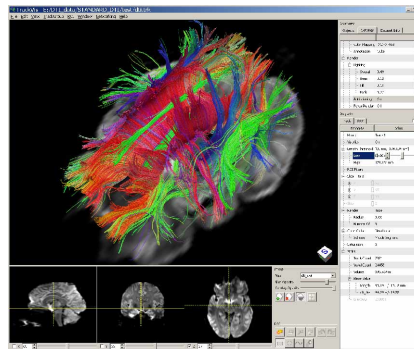- Upfront in-line parameter adjustment in real-time. No tedious pop-up dialogs.

Fig.2 (a) TrackVis display of DTI. Overview of fiber tracks with length > 8cm.
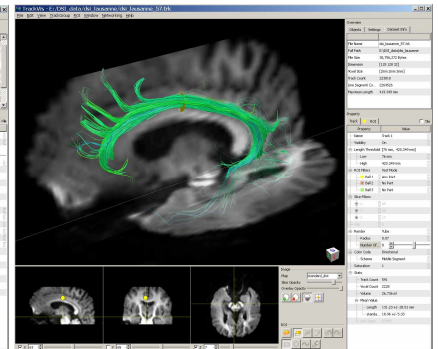
Fig.2 (b) TrackVis display of DSI. The cingulum bundle defined by a ROI disk with orientation thresholds.

Conclusion: Diffusion Toolkit is a cross-platform software package that can process various diffusion imaging data types and generate and visualize tractographic data. Because of its unique functionalities, easy usability and the capability of interactive track data manipulation in real time, the often laborious process of diffusion imaging data processing and tractographic data display and analysis becomes more efficient. Diffusion Toolkit will be freely available to the public for research use by early 2007. Please visit http://www.nmr.mgh.harvard.edu/~rpwang/dtk for more information.

References: [1] DtiStudio, CMRM, Johns Hopkins Medical Institutions, http://lbam.med.jhmi.edu/. [2] 3D Slicer, http://www.slicer.org/. [3] FSL, FMRIB, University of Oxford, http://www.fmrib.ox.ac.uk/.