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DTI Fiber Tracking: The Importance of Adjusting DTI Gradient Tables for Motion Correction

CATNAP – A Tool to Simplify and Accelerate DTI Analysis

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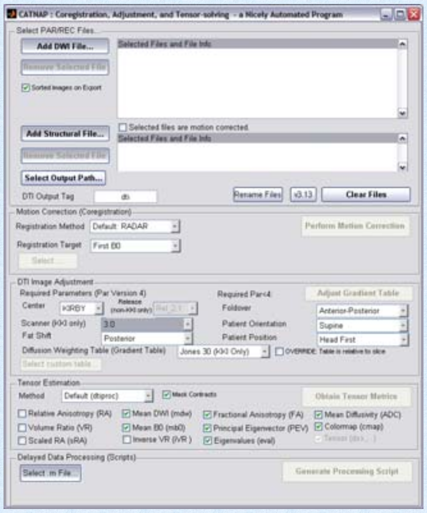
INTRODUCTION

- Diffusion Tensor Imaging (DTI) continues to gain prominence as a research tool and is increasingly part of clinical imaging protocols.
- Processing DTI data is not straightforward and combining DTI and anatomical datasets for analysis can be cumbersome and time consuming. If DTI is to become accepted as a clinical research tool, three issues must be addressed:
  - Coregistration of DTI and anatomical data requires familiarity with and correct selection of parameters for 3rd party image registration software.
  - Establishing the correct gradient table for DTI analysis is not simple, and typically requires specific knowledge of the scanner software.
  - Computing the diffusion tensor correctly for multiple DTI datasets is computationally intensive and requires dedicated resources.
- We present a graphical user interface resource, CATNAP (Coregistration, Adjustment and Tensor-solving, a Nicely Automated Program) with full command line/batch processing capability to meet these challenges for the clinical research community.

CATNAP is an end-to-end data processing pipeline for DTI and anatomical MRI data.

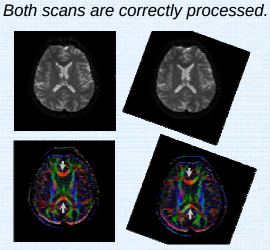
METHODS

- CATNAP performs volume-wise coregistration using RADAR (1), a method based on FSL FLIRT (2), to correct for subject motion. Custom Matlab (Mathworks Inc, Natick, MA) software interprets Philips DW tables into voxel space based on imaging and hardware parameters. Diffusion tensor calculations may be performed with a custom implementation of log-linear minimum mean squared error method or using either of the AFNI tensor estimation methods (linear or non-linear) (3). Data are block processed to accommodate memory restrictions.
- Voxel-wise intra- and inter-session reproducibility were evaluated on two sessions of 15 repeated DTI scans of a 24 y/o healthy volunteer (4). Fiber tracking was performed in DTIStudio (5) with and without correcting the DW gradient tables for motion for intra- and inter-session data analyses.

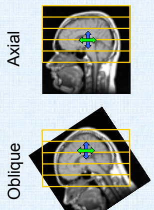


Tensor Orientation Depends on Anatomy and Diffusion Weighting

Observe Corpus Callosum Color.
Both scans are correctly processed.



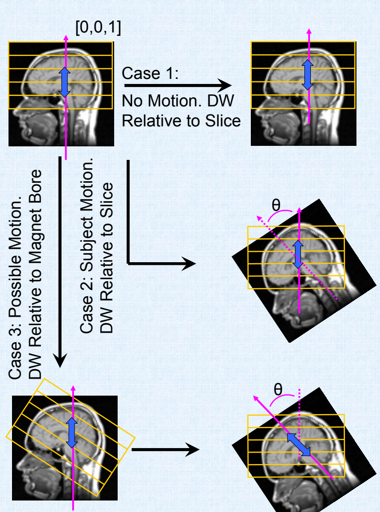
DTI Colormaps colors are defined relative to slice rather than anatomy.



Typical Colors
- Red: R-L
- Green: A-P
- Blue: S-I

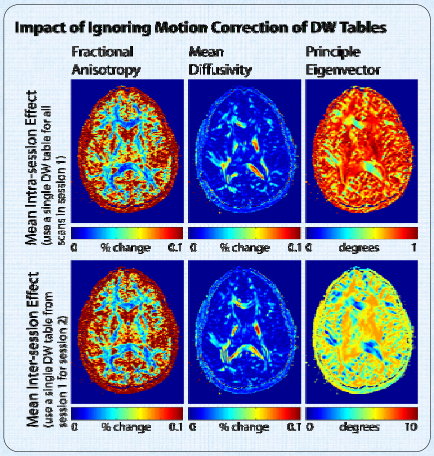
Alternate Colors
- Red: R-L
- Green: A/S-P/I
- Blue: P/S-A/I

Diffusion Weighting Depends on Anatomical Angulation Relative to MRI Scanner Coordinates

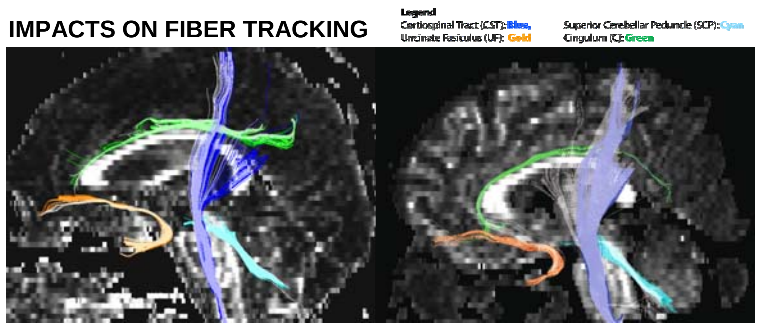


RESULTS

- Scalar contrasts (FA, ADC) were relatively unaffected (<0.1%) by failure to correct tables for motion correction with both intra- and inter-session variation.
- Orientations of the principle eigenvector varied by up to 1° with intra- and 7° with inter-session variations.
- Fiber tracking results were visually altered with both intra- and inter-session variations.
  - Some tracks exhibited increased fiber counts, while others showed decreased number of fibers when failing to correct gradient tables.
  - Changes in course (measured by mean Haussdorff distance) varied by anatomy.
  - Fiber tracking deviations were generally larger with inter-session than with intra-session variations.
  - The cingulum failed to track with a non-compensated inter-session gradient table.



IMPACTS ON FIBER TRACKING



Intra-Session
1 gradient table for scans from 1 session

Inter-Session
1 gradient table for scans from 2 different sessions

Fiber tracking in one DTI dataset using DW tables with (dark color) and without (light color) adjustments for motion correction.

White Matter Tract	Corrected # Fibers	Not Corrected # Fibers	Hausdorff Distance Mean ± Std. Dev (mm)
CST	193	119	5.50 ± 9.13
SCP	200	256	0.97 ± 0.71
Cingulum	522	488	2.07 ± 2.10
Uncinate	116	120	1.29 ± 0.79

White Matter Tract	Corrected # Fibers	Not Corrected # Fibers	Hausdorff Distance Mean ± Std. Dev (mm)
CST	834	509	5.51 ± 6.36
SCP	273	61	7.75 ± 3.09
Cingulum	67	0	∞
Uncinate	99	5	13.80 ± 7.87

CATNAP

- **Performs motion correction for both diffusion and structural images using FSL FLIRT.**
- **Adjusts the diffusion gradient directions for**
  - **Philips scanner settings (i.e., slice angulation, slice orientation, etc.) and**
  - **Motion correction (i.e., the rotational component of the applied transformation).**
- **Computes tensor and derived quantities (FA, MD, colormaps, eigenvalues, etc.).**
- **The results are readily compatible with DTIStudio, FSL, and other analysis packages.**

CONCLUSION

- **Given the simplicity of implementing motion correction of DW tables and the possibility for significant errors if ignored, the authors strongly recommend systematic use of proper DW table correction for all DTI studies.**
- **CATNAP integrates coregistration, gradient table parsing, and tensor estimation into a graphical, user-friendly package.**
- **CATNAP is documented and freely available as open source software (http://iacl.ece.jhu.edu/~bennett/catnap/catnap.html, supports: Solaris, Linux, Windows).**

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