Il Gatto Sta Ingrassando: Novel Connectivity Tools and Additions in AFNI-FATCAT

Paul A Taylor[1,2] and Ziad S Saad[3]

[1]*Faculty of Health Sciences, University of Cape Town, Cape Town, Western Cape, South Africa,* [2]*African Institute for Mathematical Sciences, South Africa,* [3]*NIMH, National Institutes of Health, Bethesda, MD, United States*

Target Audience: MR researchers and clinicians who analyze structural and functional connectivity, in particular their combination.

Purpose: Network and connectomic analyses are central for modern brain investigations. The AFNI-FATCAT[1,2] (Functional And Tractographic Connectivity Analysis Toolbox) has been designed to facilitate combining functional and structural connectivity analyses quantitatively. Functional MRI data may be either task-based or resting state. Diffusion-based imaging provides the base for tractographic estimation of white matter (WM) tracks that can be associated with gray matter (GM) regions of interest (ROIs).

We present recent developments to the software package that expand tracking capabilities by introducing novel usage of tensor parameter uncertainty in deterministic-like tracking; by permitting multi-directional tracking per voxel; by including anti-mask regions to limit track propagation; and by increasing interactive visualization and path generation in SUMA[3].

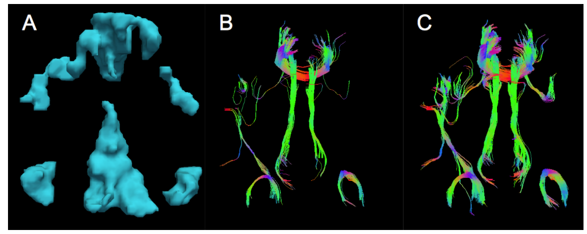

Figure 1: For the GM ROIs in panel A, panel (B) shows locations of AND-logic tracts with deterministic tracking, while the new "mini-probabilistic" option is used in (C). Note the greater extent and robustness of bundles in (C).

Methods and Results: In both DTI and HARDI (high angular resolution diffusion imaging) models, various noise sources are included in voxelwise fits. Deterministic algorithms ignore these uncertainties when propagating tracks, making them susceptible to error accumulation. While probabilistic methods account for model uncertainty, they generate voxelwise brain maps without linear track structure. FATCAT now implements a 'mini-probabilistic' option to include voxelwise model uncertainty while retaining track structure. As in Fig. 1, this feature generally exhibits more robust tracks and fewer false negatives than deterministic tracking alone (while false positives tend to be isolated and visually apparent). This provides a fast way to view more representative track fibers, and can be used, for example, for initial examination of data sets and highlighting likely locations of bundles, such as for ROI placement.

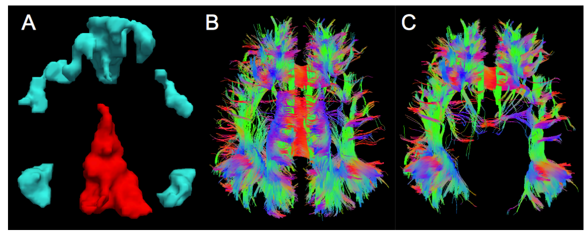

Figure 2: (A) GM ROIs. (B) OR-logic tracking with all ROIs in (A) included. (C) OR-logic tracking when the red region in (A) is set to anti-masking, allowing controlled specificity of intra-network connections.

Underlying WM tract patterns are known to be complicated, and all tracking algorithms are prone to false negatives and positives. Reasons for this include: smoothing, crossing/kissing fibers in voxels and noise. Compared to DTI, higher order HARDI models, which estimate multiple tract directions per voxel, allow algorithms to propagate through a larger number of regions, and multi-tracking is now available in FATCAT's 3dProbTrackID program. To control for false positives ('overtracking'), anti-ROIs can now be implemented among networks. These work by limiting a tract which comes into contact to the anti-ROI surface (but not eliminating the tract if OR logic is being used, unlike other implementations). These anti-ROIs can be used to eliminate known error paths or to investigate subsets of networks. Fig. 2 demonstrates changes in track patterns when implementing an anti-ROI.

Visualization and interaction is important in data investigations. Tracking with FATCAT can be done interactively with AFNI and SUMA, allowing for simultaneous generation of anatomically and functionally derived connectivity with AFNI's InstaCorr and for rendering of tracts, surfaces and volumes. Fig. 3 shows an example case of FATCAT tracking with SUMA+AFNI for the same ROIs and networks shown in Fig. 1; this interface allows for fast changing of ROIs to see changes in tracking, and vice versa.

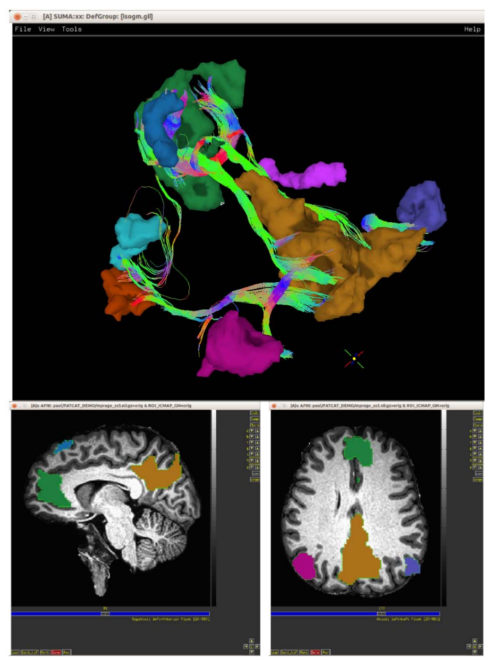

Figure 3: Simultaneous viewing of tracks and GM ROIs in SUMA (top) and AFNI (bottom).

Discussion and Conclusion: The recent additions to the AFNI-FATCAT package have been designed to increase the flexibility of tracking. These include the ability to track through more regions of fiber crossing via underlying HARDI models (which can be calculated using, for example, Diffusion Toolkit[4], DSI Studio[5], and other freely available programs), to limit tracks with anti-ROIs, and to enhance deterministic tracking by including model uncertainty. Combined with interactive investigation of fiber bundles with additional data sets, these additions to AFNI-FATCAT increase researchers ability to integrate functional and structural connectivity.

References: **[1]** Taylor PA, Saad ZS. FATCAT: (an efficient) Functional And Tractographic Connectivity Analysis Toolbox. Brain Connectivity 2013;3(5):523-535. **[2]** Cox RW. AFNI: software for analysis and visualization of functional magnetic resonance neuroimages. Comput Biomed Res 1996;29:162-173. **[3]** Saad ZS, Reynolds RC. 2012. SUMA. Neuroimage 62(2):768-73 **[4]** Wang R, Benner T, Sorensen AG, Wedeen VJ. Diffusion Toolkit: A Software Package for Diffusion Imaging Data Processing and Tractography. Proc Intl Soc Mag Reson Med 2007;15:3720. **[5]** F. C. Yeh, V. J. Wedeen and W. Y. Tseng, "Generalized q-sampling imaging," IEEE Trans Med Imaging 2010;29:1626-1635.