White matter tract atlas on NTU-DSI-122 template

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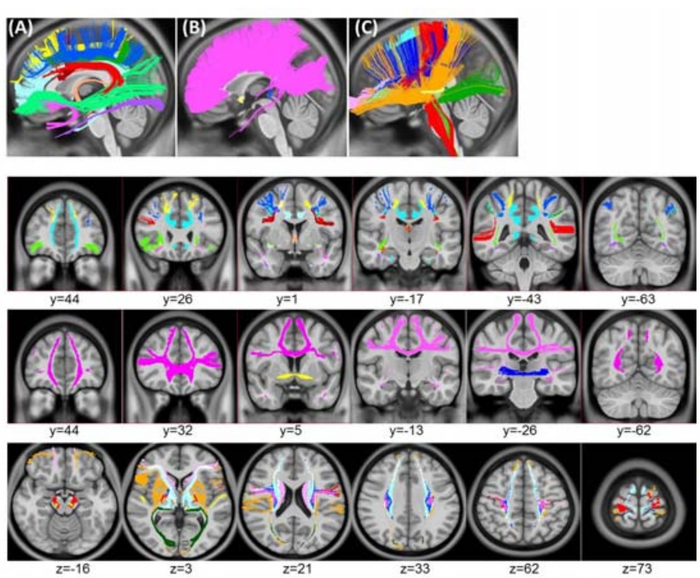
Objective White matter tract atlas has gained interests in the neuroscience community because it provides 3D anatomy of white matter fiber pathways in the human brain. Recently, we constructed a diffusion spectrum imaging (DSI) template (NTU-DSI-122) from 122 healthy adults' DSI datasets. The DSI template is advantageous in reconstructing fiber pathways owing to its high signal-to-noise ratio and high angular resolution. These advantages allow us to reconstruct "difficult" fiber pathways which are of small sizes or have frequent crossings with other fiber tracts. Therefore, the aim of this study was to reconstruct a full set of fiber tract bundles, the anatomy of which agreed closely with those described in the textbooks of neuroanatomy.

Methods All DSI data were acquired using a twice-refocused balanced echo diffusion echo planar imaging sequence. 102 diffusion encoding gradients with the maximum diffusion sensitivity $b_{max} = 4000$ s/mm^2 were sampled on the grid points in a half sphere of the 3D q-space. To obtain the transformation between individual's DSI and the DSI template, we employed a registration method under the framework of Large Deformation Diffeomorphic Metric Mapping (LDDMM) fitted to 6D features of DSI datasets, 3D in the image space and 3D in the diffusion-encoding (q) space [1]. The DSI template was constructed from 122 healthy participants' DSI datasets and was coregistered to the Montreal Neurobiology Institute (MNI) space. Diffusion tractography was performed by an expert using a multiple-regions-of-interest (ROIs) strategy with whole brain seeding. Specifically, Automated Anatomical Labeling (AAL) atlas was invoked to define cortical and subcortical regions as ROIs for each of the targeted tract bundles. A streamline-based fiber tracking algorithm was then performed based on the resolved fiber vector fields provided by the DSI template. Targeted tracts were reconstructed on the DSI template using DSI studio (http://dsi-studio.labsolver.org).

Results A total of 39 tract bundles were reconstructed using 57 pre-defined ROIs. The 3D anatomy of the reconstructed tracts can be viewed on the website (http://140.112.137.122/NTU122_tractatlas). The 39 tract bundles included 20 association fibers, 3 main commissural fibers, and 16 projection fibers. The association fibers, fiber tracts connecting ipsilateral cortical regions of different lobes, included arcuate fasciculus, cingulum bundle, frontal aslant tracts, fornix, inferior frontal-occipital fasciculus, inferior longitudinal fasciculus, superior longitudinal fasciculus, and uncinate fasciculus. The commissural fibers, fiber tracts connecting bilateral hemispheres, consisted of anterior commissure, corpus callosum, and posterior commissure. The projection fibers included the tracts connecting cortical regions and thalamus, caudate nucleus or putamen as well as the corticospinal tracts and medial lemniscus. The auditory tracts, optic radiations, and corona radiata were also reconstructed. Once the tract bundles were reconstructed, the entire trajectory was verified to ensure its consistency with the established anatomical landmarks, as well as with the fiber pathways shown in current tractography studies [2, 3, 4]. The tract bundles reconstructed in this study were displayed in Figure 1.

Conclusion In this study, we have segmented most of well-known tract bundles in the human brain. Meanwhile, some tract bundles that are rarely defined in diffusion tractography, such as auditory tracts, medial lemniscus, frontal aslant tracts, anterior commissure, and posterior commissure, are also reconstructed successfully on the NTU-DSI-122 template. The trajectory of each tract bundles is highly consistent with known anatomical landmarks. The tract atlas constructed on the DSI template can be used to understand the geometric features of the white matter fiber pathways. Moreover, It allows us to implement a template-based approach that enables a high-throughput automated analysis of the microstructural integrity of the tracts in the human brain.



Reference [1] Y.C. Hsu, et al., 2012; [2] M. Catani et al., 2013; [3] P. M. Sanjuan, et al., 2013; [4] S. Mori, et al., 2005

Figure 1. Tract bundles constructed on the NTU-DSI-122 template. (a) The association fiber bundles, (b) the commissural fiber bundles, and (c) the projection fiber bundles. The background was the 1-mm-thick averaged T1-weighted image. (A-1), (B-1), and (C-1) showed the brain regions that tract bundles passed through on different slices. Values showed below each slice indicated the x, y or z coordinate in millimeters on MNI space.