New BrainSuite13 Tools for Image Segmentation, Registration, Connectivity Analysis and Visualization

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Introduction:

Integration of structural and diffusion MRI data plays an increasingly important role in the study of the human brain. We present new additions to our BrainSuite software collection which provide automated and semi-automated methods for jointly processing and visualizing structural and diffusion MRI of the brain. In addition to visualizing results, the graphical interface guides users through the analysis process and facilitates interactive parameter modification and, where necessary, editing of image masks.

Methods:

We developed a new version of BrainSuite using Qt and OpenGL to provide a consistent cross-platform interface that runs natively on Windows, Mac, and Linux systems. Integrated processing modules were implemented in C++ and are also available as command line programs. We developed newer modules using MATLAB, which were compiled into command line programs that the GUI can invoke. The sequence can also be run via scripts.
BrainSuite's cortical surface extraction is applied to whole-head T1-weighted MRI to generate triangle meshes that model the interior and exterior surfaces of the cerebral cortex [5]. We apply a joint surface/volume registration algorithm [3,4] to align the subject image to a similarly processed single subject anatomical brain atlas. The atlas comprises surface and volume data that were delineated manually by an expert anatomist into 100 anatomical ROIs. The registration procedure performs an initial surface-based registration that aligns cortical features across the subject and template surfaces using a curvature-based approach. This registration is used to initialize a volumetric alignment, which is refined using an elastic deformation that matches image intensity between subject and template data. The procedure produces anatomical correspondence of both the cortical surface features and the interior volumetric data. This correspondence is then used to map the ROI labels from the atlas template to the subject data.
We correct diffusion weighted images for distortion using constrained non-rigid registration that uses the subject's T1-weighted MRI as an undistorted anatomical reference [1]. The corrected DWIs are mapped to T1-space using a rigid transformation so that diffusion tensors/ODFs and scalar diffusion indices can be calculated at the resolution of the anatomical image. Several diffusion estimation methods are available: classical DTI modeling, the Funk-Radon transform (FRT) [6] and the Funk-Radon and Cosine Transform (FRACT) [2]. We use a deterministic streamline algorithm to compute whole-brain fiber tracts.
We combine the ROI labels with the computed fiber tracts to analyze connectivity. For each possible pair of ROI labels, we count the number of fibers that traverse both labels. This yields a connectivity matrix for the labeled regions.
We developed visualization capabilities within BrainSuite13 to display orthogonal planes of 3D image data with overlays for coregistered images and anatomical labels. We also developed an integrated 3D view for visualizing the image plane data, surface meshes, DTI and ODF glyphs, and fiber tracts. The connectivity matrix is visualized using an interactive circular plot, with nodes

representing each labeled ROI and arcs between them representing connectivity strength. This view is synchronized with the 3D viewer, allowing users to select ROIs in the plot and view the fibers that are connected to those regions.

Results:

The BrainSuite13 GUI is shown in Fig. 1. A T1-weighted MRI that was segmented and labeled using our software is displayed; a labeled hemisphere, and several fiber tracts computed from the same subject are shown in the 3D view. An interactive connectivity analysis graph for this dataset is shown as Fig. 2.

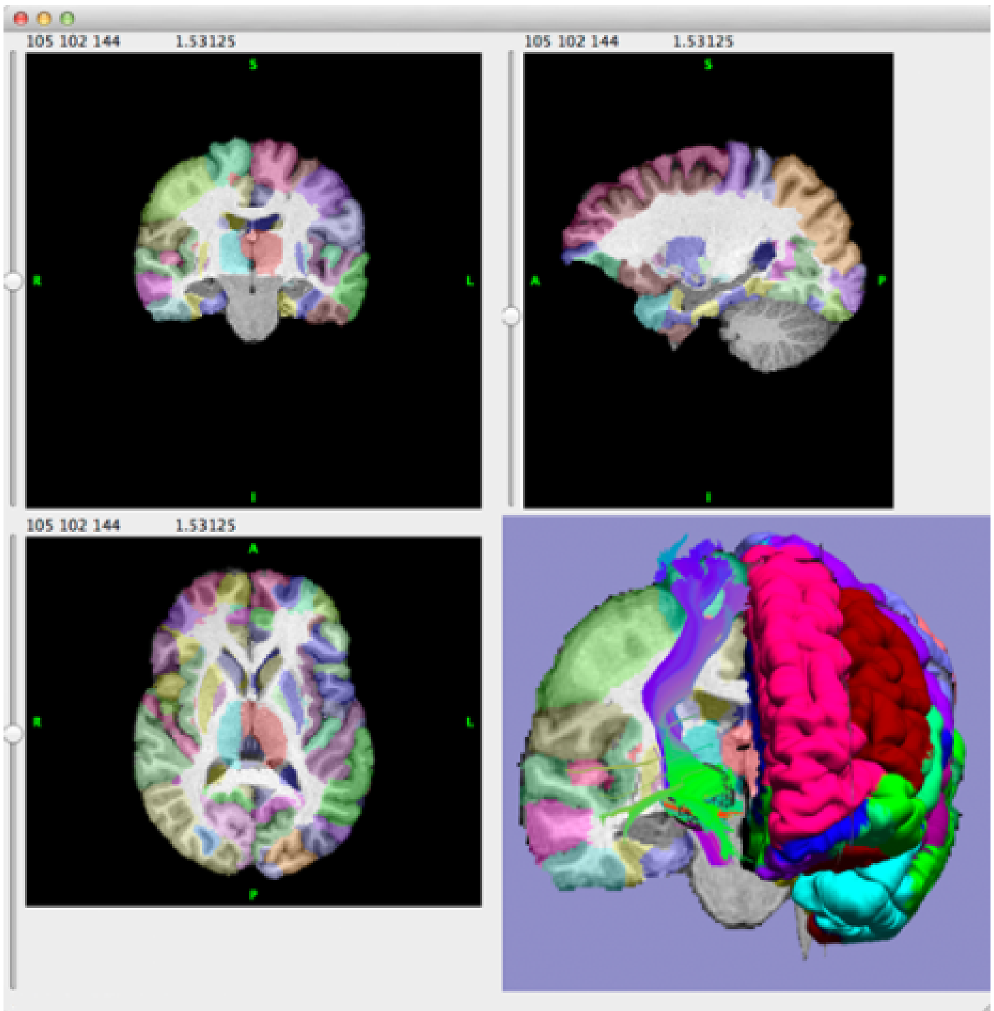

Fig. 1: The BrainSuite13 main window, with 3 orthogonal views of a T1-structural image and automatic SVReg ROI label overlay. The 3D view shows the labeled coronal slice, the labeled right hemisphere model computed from the subject MRI, and a subset of computed fiber tracts selected with a spherical ROI tool.

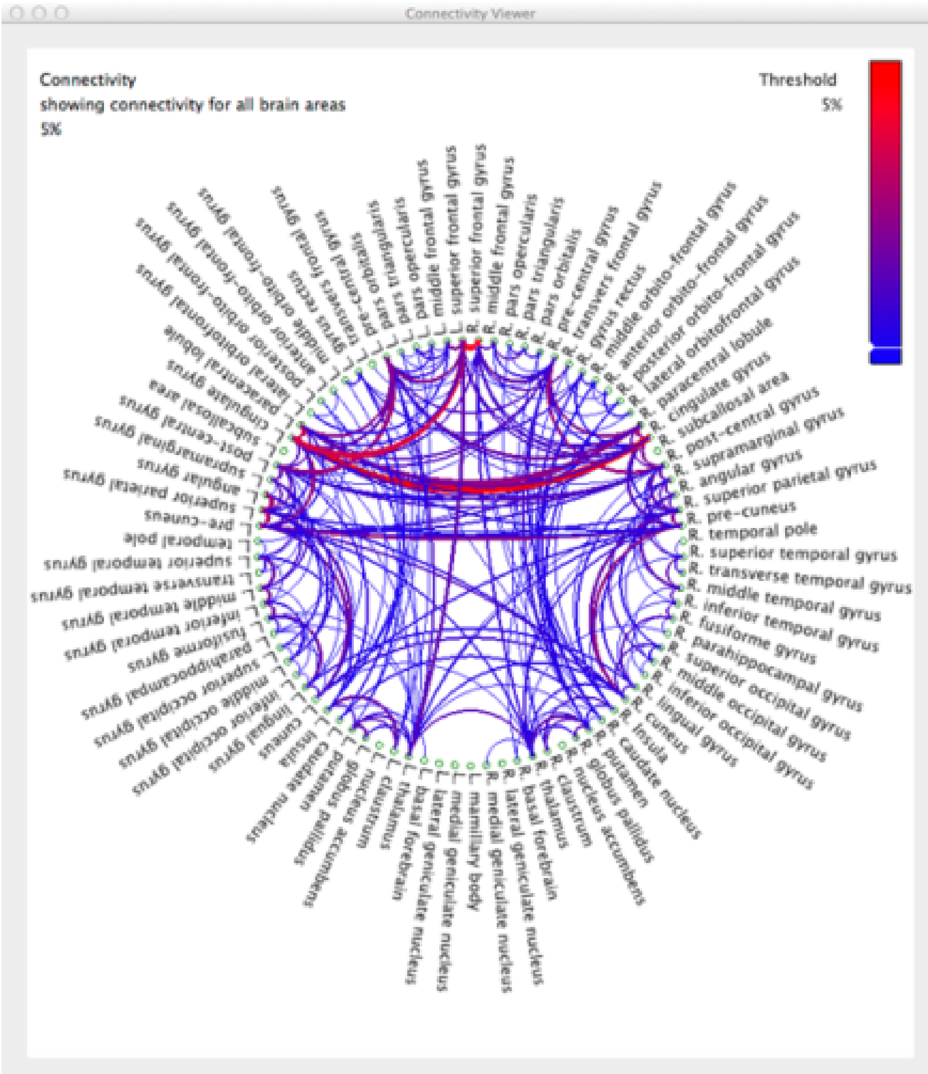

Fig. 2: The BrainSuite13 Connectivity Viewer tool, which visualizes the connectivity matrix computed from the data shown in Fig. 1. This view is synchronized with the main window and can be used to select fiber tracts that are connected to specific labeled ROIs.

Conclusions:

We developed new functionality in our BrainSuite software that enables the integrated processing of structural and diffusion MRI for automated ROI-based connectivity analysis. To download the software, please see: http://brainsuite.loni.ucla.edu.

Modeling and Analysis Methods:

Diffusion MRI Modeling and Analysis

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