BFP: BrainSuite fMRI Pipeline

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Introduction

The BrainSuite fMRI pipeline (BFP) is an opensource software workflow for processing raw resting fMRI data. The pipeline (Fig. 1) processes resting fMRI and anatomical (T1) imaging data using a combination of software that includes BrainSuite[1], AFNI[2], FSL[3], and MATLAB scripts to produce processed fMRI data represented in a common grayordinate system. Unique features of the BFP pipeline include cortically constrained volumetric registration[4], GPDF non-local means filtering[5], and BrainSync[6], a method for temporal synchronization of resting fMRI data across subjects.

Methods

The BFP pipeline consists of three stages: anatomical processing, functional processing, and grayordinate generation. Anatomical preprocessing: First, the T1 image is resampled to 1mm isotropic resolution. Next, the brain is separated fromthe skull and other surrounding tissues in the resampled T1 image. The extracted brain image is then co-registered to the BCI-DNI atlas[1]. The cortical surface extraction sequence in BrainSuite is then executed on the co-registered image to perform tissue classification and generation of inner, mid and pial cortical surface representations. This is followed by the brain surface and volume registration and labeling using SVReg with BCI-DNI as the atlas[4].

Volumetric fMRI preprocessing: We generate a 3mm isotropic representation of the BCI-DNI atlas as a standard reference; fMRI data is resampled to the same resolution. The fMRI data is then deobliqued to be in FSL friendly space. Next, motion correction is performed followed by a skull stripping. Then spatial smoothing is performed using a Gaussian kernel with full-width-half-maximum (FWHM) of 2mm. This is followed by grand-mean scaling. Temporal bandpass filtering is then applied with the bandwidth of 0.009-0.1 Hz. Detrending is performed to remove linear and quadratic trends. Nuisance signal regression is done using tools from FSL and the tissue fraction image generated by BrainSuite. Global, cerebrospinal fluid and white matter average signals are regressed out from the fMRI data using FEAT model in FSL.

Grayordinate Identification and fMRI processing: First, we identified surface and volumetric grayordinates on the BCI-DNI volume. In order to be consistent with the HCP grayordinate system, we transfer HCP's grayordinates to the BCI-DNI atlas using FreeSurfer processing of BCI-DNI atlas and the spherical maps of surfaces shared by HCP. To identify subcortical grayordinates we use SVReg. The preprocessed fMRI data volumes are interpolated to the subject's midcortical surface meshes using linear interpolation. This data is then transferred the grayordinates from BCI-DNI atlas to the subject using the co-registered flat maps and the inverse map of SVReg. The fMRI data at the grayordinates is sampled using linear interpolation (Fig. 2) to form a vector of size 96k (32k each hemisphere + 32k sub-cortex). Optional global PDF-based temporal non-local means (GPDF) filtering[5] is applied on the grayordinates (both surface and volume) to generate filtered data. Finally, data can also be synchronized across subjects using the BrainSync transform[6].

Results

Starting from raw T1 and fMRI images, BFP produces processed fMRI data represented both on surface and volume coregistered with BrainSuite's BCI-DNI atlas as well as a grayordinate based representation. A workflow is shown in Fig. 1 and anatomical and functional mapping illustrated in Fig. 2. Linux command line and a graphical interface are available.

Conclusion

BFP is a pipeline that can be used with the BrainSuite tools (structural and anatomical connectivity analysis for analyzing diffusion, fMRI data). By representing data with respect to the BCI-DNI (combined surface/volume) atlas and the HCP's grayordinate representation, we aim to facilitate the use of BFP with existing analysis tools while offering unique functionality within the BrainSuite workflow.

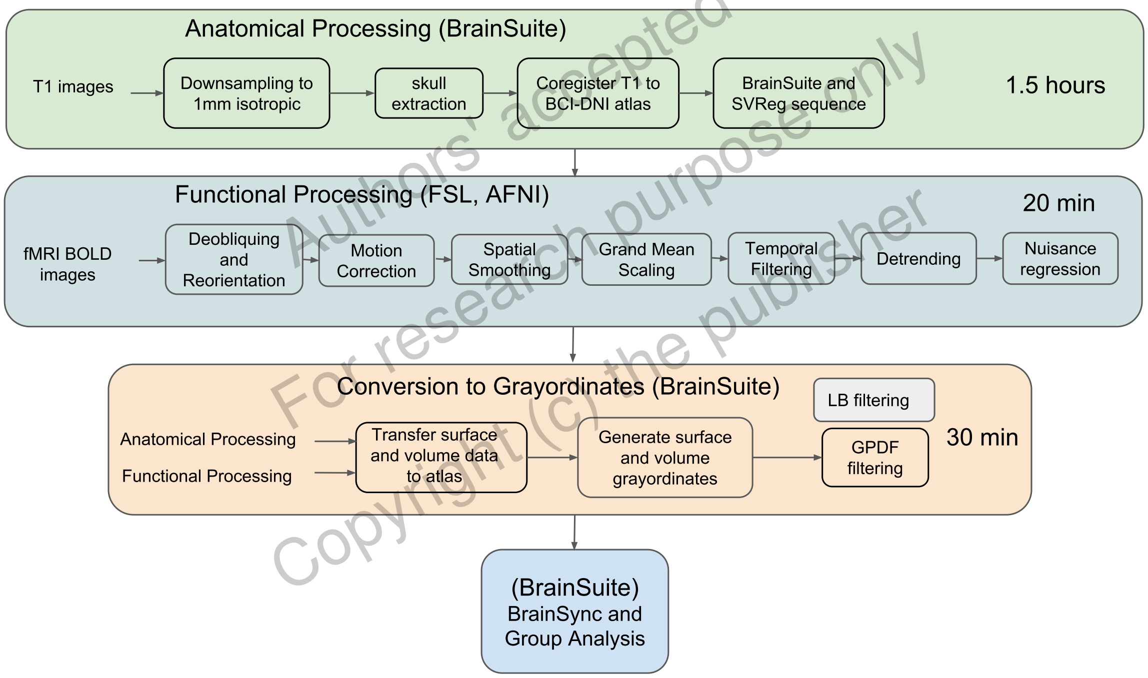

Figure 1: Anatomical processing is followed by volumetric functional preprocessing. Outputs of both are used for grayordinate conversion and optional nonlocal means filtering and synchronization.

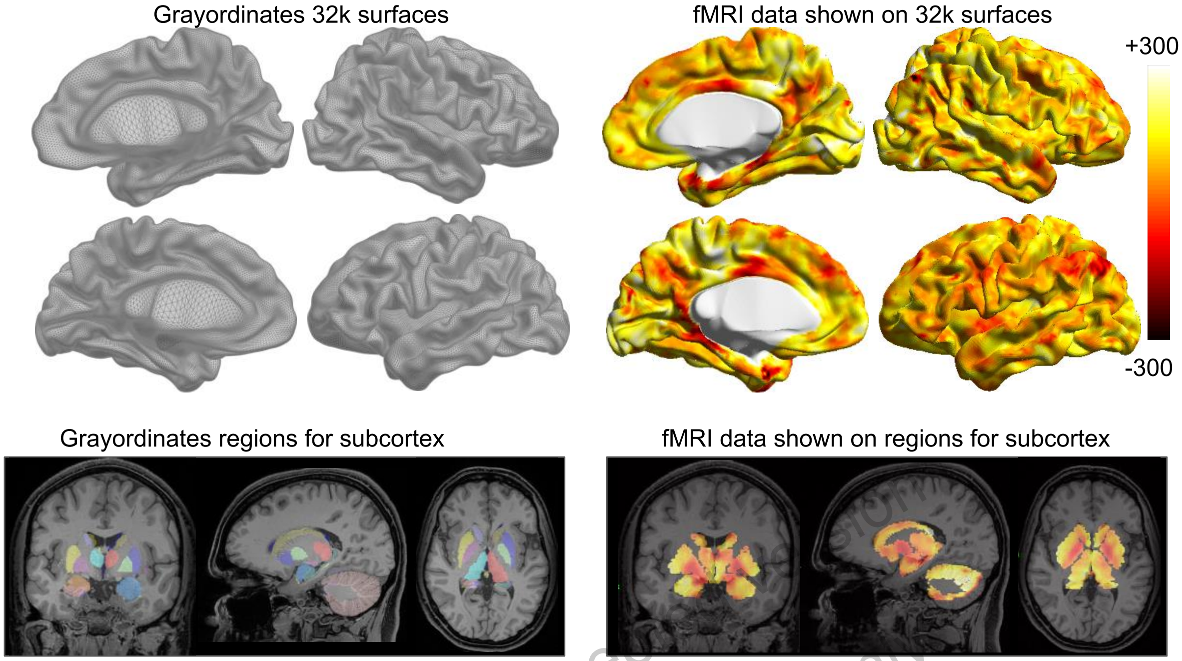

Figure 2: Cortical surface tessellations (first two rows) and subcortical brain regions on which fMRI signal is resampled to form grayordinate data (third row). Left: Grayordinate regions of the brains; Right: preprocessed fMRI data resampled on the grayordinates.

References

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