AutoROI: Fast and automatic generation of ROIs for real-time fMRI paradigms

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Target Audience: Real-time fMRI researchers who must compute regions of interest (ROIs) quickly and objectively for use within the same scan session.

Purpose: Real-time fMRI (rtfMRI) is the processing and interpretation of fMRI data as fast (or faster) than it is acquired. This enables a multitude of applications such as quality assurance, brain-computer interfaces and novel therapeutics [1]. In order to increase the signal-to-noise ratio, the fMRI signal is often averaged over a set of neighboring voxels known as a region of interest (ROI) [2]. Therefore, most rtfMRI paradigms require a method to quickly and objectively calculate ROIs.

Methods: We've designed and implemented a framework (AutoROI) to quickly create ROIs for rtfMRI applications. On the scanner, a module is inserted into the image reconstruction pipeline to open a socket as send the data to the analysis PC. This is done immediately after the image has been reconstructed, before the DICOM is created. The module can send both functional (EPI) and structural (MPRAGE) data. On the receiving end, AutoROI is highly configurable via xml and leverages tools from FSL [3] and FreeSurfer [4] as well as the real-time software murfi [2]. It can be configured to: 1) receive volumes from the scanner, 2) register volumes (using either flirt or mri_robust_register) and apply the resulting transformations 3) compute functional maps (using feat) and 4) perform basic arithmetic and morphological operations (using fslmaths). With these basic operations in place, we've defined 3 practical ways to create ROIs:

1) Functional ROI: The subject performs a functional localization task, and the EPI data is sent to the analysis PC. AutoROI uses this EPI data in conjunction with data specifying the functional paradigm to create a functional ROI. 2) Structural ROI: A structural scan (2mm isotropic MPRAGE) of the subject is acquired and sent to the analysis PC. Additionally, a 1TR EPI scan is also acquired and sent to the analysis PC.

A reference volume along with the ROI defined in this reference space is defined. This reference data can either be a previous scan of the subject (i.e.: MPRAGE with FreeSurfer segmentation) or from an atlas. AutoReg creates the structural ROI by registering the reference volume to the acquired structural volume, registering the acquired structural volume to the EPI volume and then transforming the reference ROI to the EPI space.

3) Functional+Structural ROI: This is a combination of the 2 previous use cases. A functional ROI is created as in 1), but is constrained to regions defined by the structural ROI which is computed as in 2). The ROIs are available within minutes, avilable for same-session use (e.g. for rtfMRI with feedback using murfi).
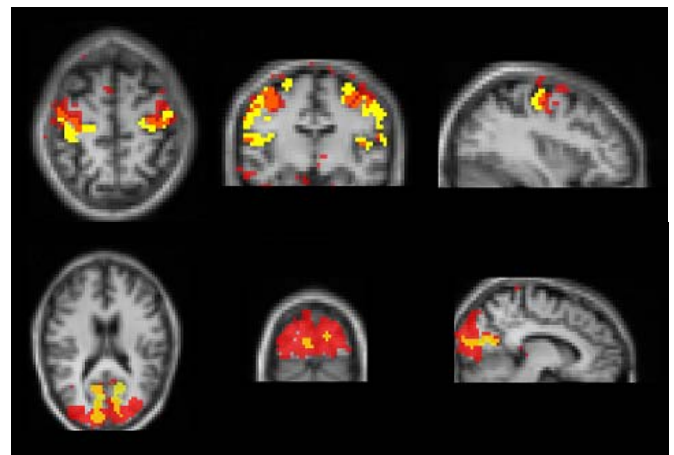

Fig 1: ROIs generated for the finger-tapping paradigm (top) and visual paradigm (bottom). Yellow: Functional, Red: Structural, The intersection of these ROIs defines the Fuctional+Structural ROI

Results: We've tested each of the 3 uses cases with a healthy subject under both a finger-tapping and flashing checkerboard paradigm using a 3T scanner and a 32-channel phased array head coil. The finger-tapping paradigm consisted of 20 second blocks alternating between rest, left finger-tapping, and right finger-tapping for a total of 3 minutes. Figure 1 shows the resulting ROIs created by AutoROI. The functional ROI was created by thresholding the computed z-map at a value of 5.0 (Fig 1 top, red). The structural ROI was created registering the 'precentral cortex' label from a FreeSurfer cortical parcellation of the subject, generated using data from a previous session, to EPI space (Fig 1 top, yellow) The intersection of these 2 ROIs defines the 'functional+structural ROI'. The checkerboard paradigm consisted of alternating 20 second blocks of a blank screen and a checkerboard stimulus whose pattern would invert at frequency of 8hz. The functional ROI was created by thresholding the computed z-map at a value of 5.0 (Fig 1 bottom, red). The structural ROI was created using the 'pericalcarine cortex' label from FreeSurfer (Fig 1 bottom, yellow).) The intersection of these 2 ROIs defines the 'functional+structural ROI'. The realtime signal, averaged over the 3 ROI's for the checkerboard paradigm is shown in Figure 2. (Averages are computed by weighting the voxels by the inverse of the variance of the GLM fit as in [2])
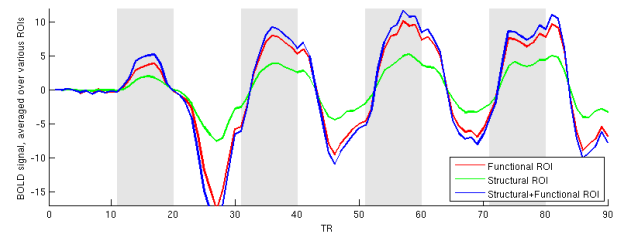

Fig 2: Realtime data averaged over the 3 ROIs (checkerboard paradigm)

Discussion: The selection of suitable ROIs is critical to the outcome of any rtfMRI study. We have designed software to quickly generate ROIs using 3 common methods. The most appropriate ROI, however, will depend on the experimental design. Generating structural ROIs from freesurfer's cortical parcellations may not be appropriate in a realtime setting. A custom crafted ROI defined in an atlas space might make a more appropriate reference. Future work will extend this framework to applications outside of rtfMRI, such as automatic slice positioning in structural MR and voxel positioning for MR spectroscopy.

Conclusion: By augmenting rtfMRI systems to process structural data in addition to functional, and by leveraging existing software packages, ROIs for rtfMRI paradigms can be computed reliably and in minutes for use within the same scan session.

References: 1. deCharms, C. (2008) Applications of real-time fMRI. *Nature* / 2. Hinds, O. et al. (2010). Computing moment to moment BOLD activation for real-time neurofeedback. *NeuroImage* / 3. M. Jenkinson, et al. (2012) FSL. *NeuroImage* / 4. Reuter, M. et al., (2010). Highly Accurate Inverse Consistent Registration: A Robust Approach. *Neuroimage*