Enhancing the reproducibility of fMRI statistical maps using generalized CCA in the NPAIRS framework

Poster No:

1113 MT-AM

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Introduction:

The reproducibility of an fMRI processing pipeline may be defined as a correlation coefficient between the extracted maps of two independent sets of subjects in a study group (Strother et al., 2002). In this paper, we propose a new method to enhance the reproducibility of extracted statistical parametric maps (SPMs) in the NPAIRS framework (Strother et al., 2004) based on a generalized version of canonical correlation analysis (GCCA) (Kettenring, 1971). For each subject, GCCA explores a direction in its fMRI time-series space and calculates a spatial map by projecting the fMRI time-series to the explored direction. The directions are estimated in order to maximize the sum of pair-wise correlation coefficients between the spatial maps. The spatial maps of the subjects may be averaged to obtain a group spatial map.

Methods:

The block diagram of the proposed approach for enhancing reproducibility is shown in Figure 1. The fMRI time-series of each subject have their mean removed followed by normalization by their standard deviation; then the dimensions are reduced using PCA. The available N subjects are randomly split into two sets with equal numbers of subjects. Each set is processed using GCCA separately and two group spatial maps (Z1, Z2) are estimated from the independent sets. The reproducibility metric (r) and a SPM (Z) are calculated using the NPAIRS framework (Fig. 1).
The method is applied to the fMRI data of 10 young subjects (21-30 years) registered to an atlas. Four runs were acquired for each subject on a 3.0T Siemens Trio using a block design with eight alternating task-fixation blocks (FIX) per run for four tasks (ATT, DMS, PMT, RT) with two repetitions each (Grady et al., in press). We used the simple reaction time (RT) blocks and their two neighboring fixation blocks in each run to test our approach, compared to canonical variates analysis applied in NPAIRS (NPAIRS/CVA, Strother et al., 2004).

Results:

The GCCA approach was applied on the 10 young subjects for the RT task datasets and the maximum reproducibility of 0.78 was obtained with 32 principal components per subject. We also applied NPAIRS/CVA on the same datasets. The two transition scans from FIX-RT and RT-FIX blocks were dropped before applying CVA. The maximum reproducibility of 0.46 was obtained with 34 principal components per 5-subject split group for CVA. In Figure 2, some of the detected activation areas using CVA and GCCA are shown. CVA detects some significant voxels in the primary and supplementary motor cortices, and a few significant voxels in the default mode network. GCCA detects some significant voxels in primary motor cortex, although fewer than obtained with CVA, and all major negative activation areas of the default mode network.

Conclusions:

We applied the GCCA based method on real fMRI datasets and compared it with CVA implemented in NPAIRS by comparing the reproducibility of their generating maps. We showed that the acquired maps using GCCA have considerably higher reproducibility than CVA. GCCA extracts directions in the time-series space of the subjects that are most spatially reproducible without necessarily following the stimulation pattern. Therefore, GCCA is more successful in detecting default mode than CVA while CVA detects the task related network in the brain better than GCCA.

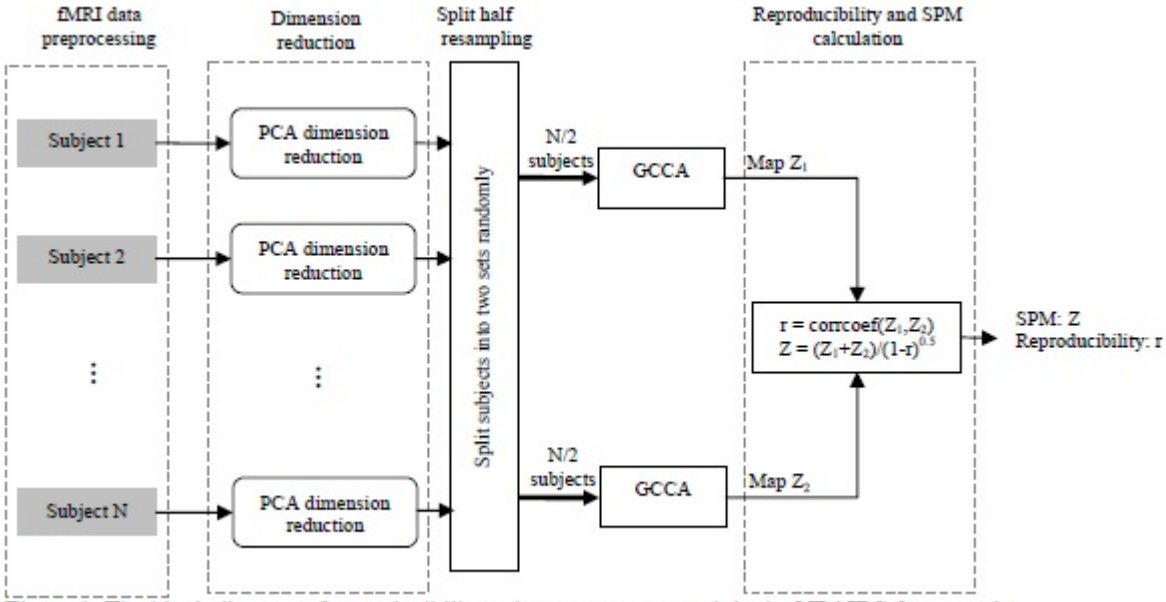

Figure 1. The block diagram of reproducibility enhancement approach in the NPAIRS framework.

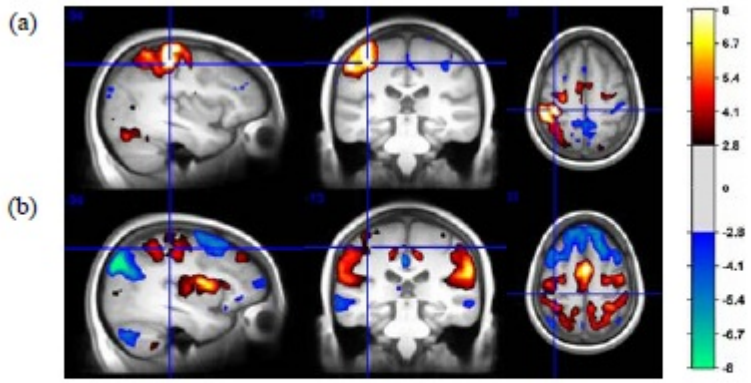

Figure 2. Detected activation areas for the RT task and false detection rate of 0.005 using (a): CVA (number of principle component per half split = 34, reproducibility=0.46) (b): GCCA (number of principle component per subject = 32, reproducibility=0.78). The primary motor cortex area is shown by crosshairs in all images.

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