Multisubject fuzzy cluster analysis of functional MRI

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Purpose

Recently, fMRI multisubject analysis has emerged as a new topic to embrace differences of the brain responses in the analysis. Some of multisubject analysis methods suppose specific assumptions on the signal and noise structure. A novel method, based on feature space fuzzy cluster analysis for fMRI group inference is introduced to address this issue. In the proposed method a vector is obtained for each voxel using the cross-correlation analysis of its corresponding time-series. Then, a feature space is derived from the obtained vectors. Fuzzy cluster analysis of the proposed feature space generates an "active cluster membership map", which represent the group activity. Statistical significance of this membership map is then assessed using randomization. We show that the proposed method detects larger activated regions in an experimental visual task dataset (consisting of 11 subjects).

Method

The proposed method consists of the following 5 steps: 1) A vector is extracted for each brain voxel whose elements are the cross-correlation coefficients of time-series of that voxel (in different subjects) with the reference signal . In this step, for each voxel of the brain, we produce *n* features corresponding to *n* subjects. 2) Using L2 norm, elements of each vector are combined. Thus, in this step, we obtain a feature space whose elements are the L2 norms of vector elements obtained from step 1. 3) The Fuzzy c-means (FCM) algorithm is applied to the obtained feature space and the map of "membership degrees to the active cluster" is obtained. 4) The statistical parametric map corresponding to the "membership degree" (obtained in the previous step) is derived using the method proposed by Jahanian et. al in [1]. 5) The statistical parametric map is thresholded at the desired confidence level (p-value).

fMRI experiment and preprocessing

A set of sensory-motor fMRI data is analyzed in this research. This set is provided by fMRI data center (http://www.fmridc.org) [2]. They were acquired during an event-related experiment in a 1.5 T scanner. During the experiments, 128 T2*-weighted volume images were acquired using asymmetric spin echo pulse sequence. Each volume image consisted of 16 slices and each slice was composed of 64×64 pixels. A set of anatomical images was also acquired from each subject, which consists of 128 sagittal slices with 256×256 pixels. Eleven young non-demented subjects were randomly selected from these data. Their functional images were motion corrected using the AFNI software package (Medical College of Wisconsin, Milwaukee, WI). Then their anatomical images were transferred to the standard space of Talairach and Tournoux and the resulting transform is used for spatial normalization of functional images in the AFNI software package. The anatomical images were used to localize the active regions in the AFNI software. For each volume of functional data, the sub-sampling process produced a volume image with 54×64×50 voxels and voxel size of 3×3×3 mm. Linear drift and the mean component were removed from the time series of each voxel.

Results

Experimental fMRI datasets, described in the previous section, have been used to evaluate the proposed method. The proposed method was compared to (variance-ratio smoothing) GLM multi-subject analysis [3]. The comparison study should be done at the same false alarm rates. Since the proposed method is a single level analysis and GLM is a two level analysis method, we used the thresholds obtained from the simulated data to achieve similar conditions for both methods. Analysis of rest data produces realizations of statistical parameter (of each method) under the null hypothesis, which can be used to construct empirical histogram. This histogram is used for computing the thresholds of the GLM parameter for different false alarm rates. Fig. 1 shows activated regions in the experimental dataset at the false alarm rate of 0.0001 using the proposed method in row (a) and GLM method in row (b) at the same slices, superimposed on the corresponding anatomical MRI images. Single voxels were removed from the activation maps. As these images show, both methods detected activation in Occipital Cortex (BA 17, 18), Thalamus, and Precuneus which were also reported in previous fMRI investigations of visual task [4]. The proposed method also detected activations in Cerebellum, Superior Temporal Gyrus, Cingulate Gyrus (BA 24), Precentral Gyrus, Superior Frontal Gyrus and Cuenus, where GLM method did not detect any activation

Conclusion

A novel method, based on feature space clustering for activation detection in group fMRI data, is presented. This method is applied to experimental fMRI data. The proposed method detected more activated voxels in expected areas with much fewer false positives at the same false alarm rates (See Fig. 1) which means considerable higher activation detection sensitivity.

(a)

(b)

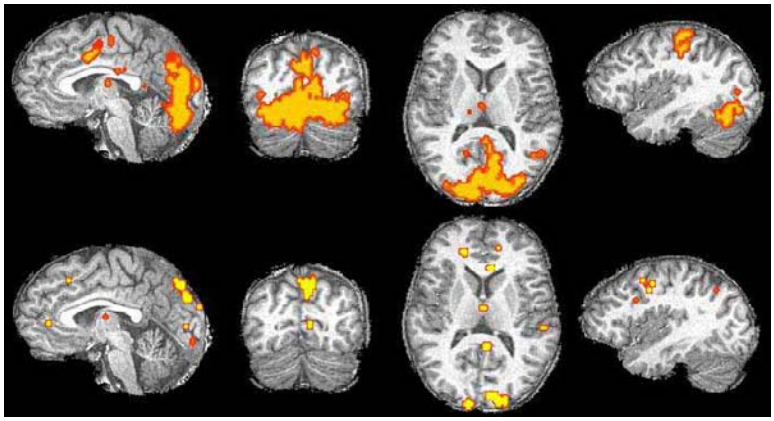

Fig. 1. Row (a) Activated areas detected by the proposed method (α = 0.0001): Occipital Cortex, Thalamus, Cingulate Gyrus, Cuneus, Superior Temporal Gyrus, Precentral Gyrus and Cerebellum.
Row (b) Activated areas detected by GLM (α = 0.0001): Occipital Cortex (*detected*), Thalamus (*detected),* Cingulate Gyrus (*not detected*), Cuneus (*not detected*), Superior Temporal Gyrus (*not detected*), Thalamus (*detected*), Precentral Gyrus (*not detected*) and Cerebellum (*not detected*).

References

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