On clustering of fMRI time series

P. Toft[1], L.K. Hansen[1], F.Å. Nielsen[1], S.C. Strother[2], N. Lange[3], N. Mørch[1,4], C. Svarer[4], O.B. Paulson[4], R. Savoy[5], B. Rosen[5], E. Rostrup[6], P. Born[6]

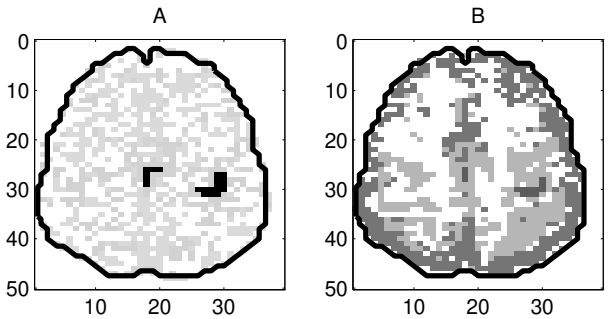
[1]*Dept. of Mathematical Modelling, B321, Technical University of Denmark, Denmark*
[2]*PET Imaging Service, Minneapolis VA Medical Center, Minnesota, USA*
[3]*Brain Imaging Center, McLean Hospital & Harvard University, Boston, USA*
[4]*Neurobiology Research Unit, Copenhagen University Hospital, Rigshospitalet, Denmark*
[5]*Massachussets General Hospital. Boston, USA* [6]*MR Unit, Hvidovre Hospital, Denmark*

Introduction. The spatio-temporal fMRI signal is a combination of several interacting components: The locally correlated hemodynamic response, the network of neuronal activations, and global components such as the cardiac cycle, breathing etc. *A priori* this implies that the signal is correlated in time and space, and that these correlations have both short and long range components. Clustering is a classical non-parametric approach to explorative analysis data. By clustering we can group signals according to a given objective function. Clustering of waveforms has already been used in fMRI signal analysis, see e.g. (1). Clustering of stochastic data, however, is hard optimization problem with many potential pitfalls. The "optimal" cluster configuration depends on the particular choice of clustering scheme (e.g. *k-means, k-medians, hierachical clustering*) examples are legio (2), but just as importantly *on the choice of distance metric*. Here we analyse a distance metric based on the activation reference function, hence, allowing for more informed clustering compared to distance metrics based directly on the fMRI signal.

Subjects. An fMRI activation image set of a single subject performing a left-handed finger-to-thumb opposition task was acquired. Multiple runs of 72 2.5-second (24 baseline, 24 activation, 24 baseline) whole-brain echo planar images were aligned, and an axial slice through primary motor cortex and SMA of 42 x 49 voxels (3.1 x 3.1 x 8 mm) extracted.

Methods. We use a k-mean clustering scheme based on a *cross-correlation metric*. First, we compute the cross-correlation function between the measured fMRI signal and the stimulus reference function (periodic square wave representing the on/off activation paradigm) for all voxels. Next, we extract a centered window of the cross-correlation function $-60 < \tau < 60$ to represent the response of each voxel. In this representation we apply a simple Euclidean metric for clustering. $K = 4$ cluster centers were initialised at cross-correlation functions corresponding to voxels with the highest peak cross-correlation. From this initial configuration we performed 20 iterations of k-means clustering (2), enough to stabilize the position of the cluster centers. Next, for comparison we investigate clustering based on Euclidean distance among the fMRI time functions. We initialize 4 centers as the mean time functions for the clusters obtained in the previous run. With these initializations another set of 20 iterations of k-means based on the time function metric were performed, again enough to stabilize the new cluster centers.

Results and Conclusion. In the figure we show the result of two runs as outlined above. In (A) is shown the result of clustering based on the cross-correlation metric. Primary motor area and SMA are picked up as two spatially separated voxel groups both belonging to the same cross-correlation cluster. In (B) we show for comparison the result of clustering based on time function metric. When clustering with a metric based on the time function we may or may not find regions that are functionally meaningful. As noted in (1) this clustering will find voxels that share some aspect of temporal change. By using the cross-correlation based metric we go directly for the regions that are similar with respect to activation while filtering out random noise and certain simple non-stationarities.



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References

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