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An evaluation of methods for detecting brain activations from functional neuroimages

Ana S. Lukic[a], Miles N. Wernick[a,*], Stephen C. Strother[b]

[a]*Department of Electrical and Computer Engineering, Illinois Institute of Technology, 3301 South Dearborn Street, Chicago, IL 60616, USA*

[b]*Neuroimaging Consortium (11P), VA Medical Center, University of Minnesota, 1 Veterans Drive, Minneapolis, MN 55417, USA*

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Abstract

Brain activation studies based on PET or fMRI seek to explore neuroscience questions by statistically analyzing the acquired images to produce statistical parametric images (SPIs). An increasingly wide range of univariate and multivariate analysis techniques are used to generate SPIs in order to detect mean-signal activations and/or long-range spatial interactions. However, little is known about the comparative detection performance of even simple techniques in finite data sets. Our aims are (1) to empirically compare the detection performance of a range of techniques using simulations of a simple image phantom and receiver operating characteristics (ROC) analysis, and (2) to construct two near-optimal detectors, both generalized likelihood ratio tests as upper performance bounds.

We found that for finite samples of (10–100) images, even when the *t*-test with single-voxel variance estimates (single-voxel *t*-test) is the "correct" (i.e. unbiased) model for simple local additive signals, better detection performance is obtained using pooled variance estimates or adaptive, multivariate covariance-based detectors. Normalization by voxel-based variance estimates causes significantly decreased detection performance using either single-voxel *t*-tests or correlation-coefficient thresholding compared to pooled-variance *t*-tests or covariance thresholding, respectively. Moreover, we found that SVD by itself, or followed by an adaptive Fisher linear discriminant, provides a detector that is (1) more sensitive to mean differences than a single-voxel *t*-test, (2) insensitive to the large local signal variances detected by covariance thresholding, and (3) much more sensitive to signal correlations than correlation-coefficient thresholding. Adaptive, multivariate covariance-based approaches and pooled-variance *t*-tests represent promising directions for obtaining optimal signal detection in functional neuroimaging studies.

Keywords: PET; fMRI; Signal detection; ROC; Multivariate statistics

* Corresponding author. Tel.: +1-312-567-8818; fax: +1-312-567-8976.
E-mail address: mwernick@ece.iit.edu (M.N. Wernick).

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