A Binary Detection Approach for fMRI

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Introduction: The detection of activated brain areas based on BOLD - fMRI data may be formulated as a classical binary detection problem. An effective algorithm to solve this problem should be able to estimate the Haemodynamic Response Function (HRF), coping with the Additive White Gaussian Noise (AWGN) corrupting the observations, and should also deal with the low frequency drift affecting the BOLD signal baseline. In this work, a unified Bayesian approach is proposed whereby the traditional estimation and inference steps are joined together and the activity cluster detection is obtained simultaneously with HRF estimation and drift removal.

Methods: The problem of detection and estimation is formulated as an optimization task where the minimization of a single energy function is used to estimate the binary beta coefficients describing the activation paradigm, the HRF and the drift at each voxel. The energy function is composed by two terms: the data fidelity term, which pulls the solution towards the data, taking into account the signal generation and the noise corruption processes; and the prior term, which incorporates the a priori physiological knowledge about the entities to be estimated such as the HRF and the drift signal. An additional post processing step is used to introduce spatial correlation between voxels in order to remove out-of-context misdetection voxels and promote piecewise constant solutions. This is done by solving a huge combinatorial optimization problem with a Graph-Cut (GC) based algorithm.

Results: To evaluate the performance of the proposed method, Monte Carlo tests were performed using synthetic BOLD – fMRI data with increasing noise levels (Fig. 1). These showed error probabilities down to less than 1% (Fig. 2). Real data was also analysed using the proposed algorithm and compared with the results obtained by a neurologist using the standard SPM approach implemented in the *BrainVoyager* software. The main areas of activation according to the specialist are also found with the proposed method (Fig. 3).

Conclusions: We have developed and validated a novel Bayesian method for fMRI activity detection, simultaneously with HRF and drift estimation. The results suggest that the proposed method may provide robust results, comparable to those found of interest using the standard approach but with the advantage of removing subjectivity by circumventing the need for a user-dependent threshold.

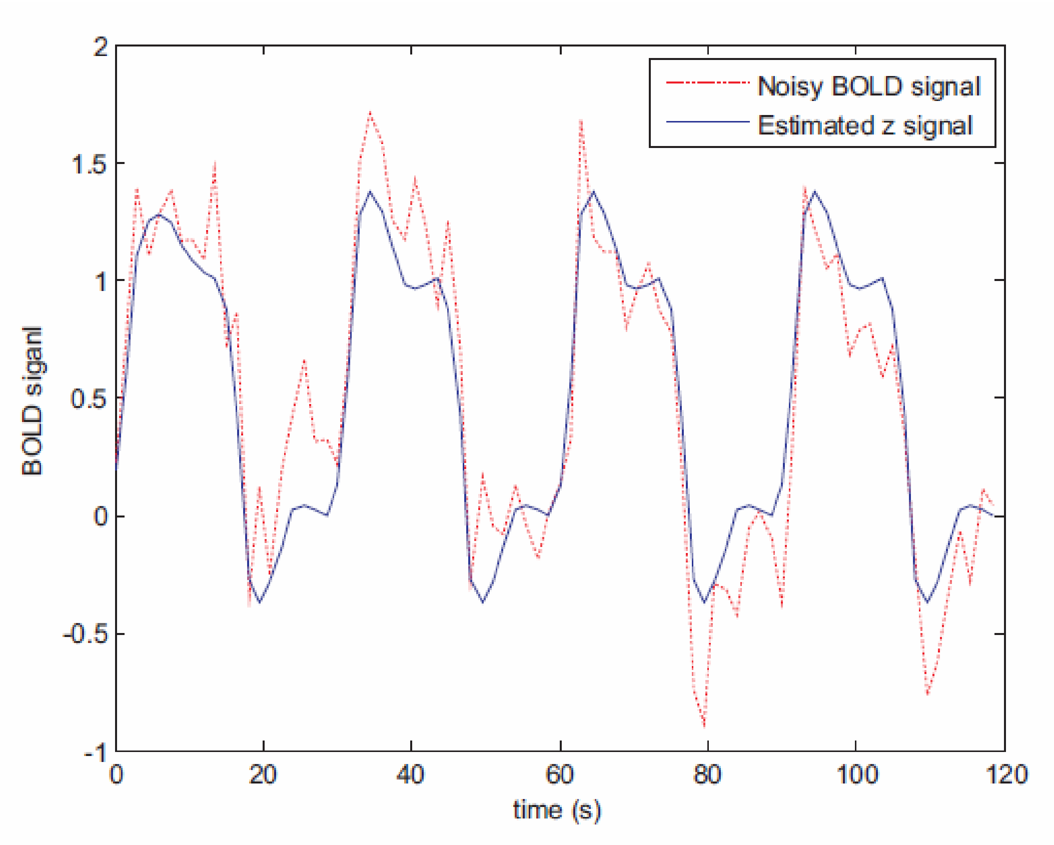

Fig. 1. Example of the BOLD signal and the respective estimated signal (SNR = 2dB).

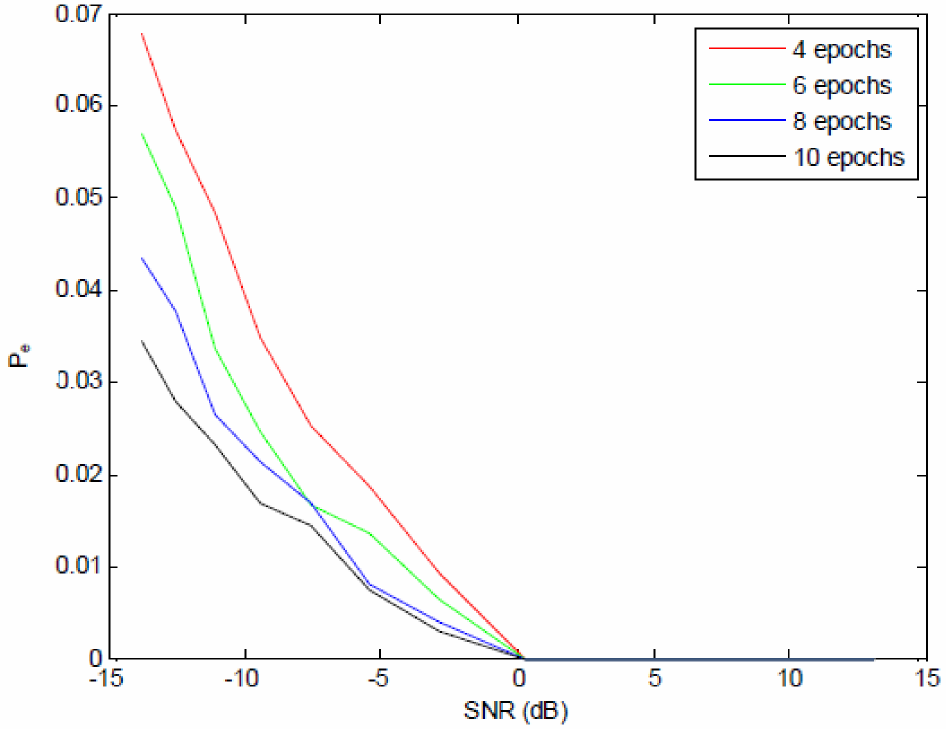

Fig. 2. Computed error probability for each noise level for paradigms with a number of epochs ranging from 4 to 10.

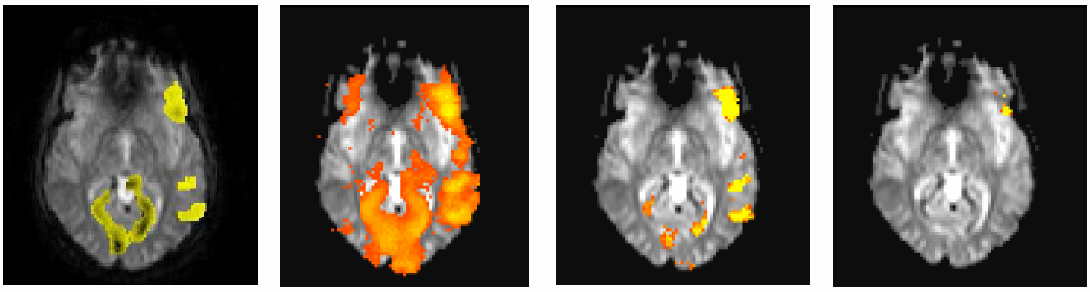

Fig. 3. Example of the results obtained from real fMRI data during a verb generation task: 1st row: proposed method; 2nd row: standard method (loose threshold); 3rd row: standard method (reference by neurologist); 4th row: standard method (conservative threshold).