Detection of event-related fMRI signal with matched filters

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Purpose

The present work evaluates the matched filter technique for the detection and extraction of the hemodynamic response from event-related fMRI time series.

Introduction

A common problem in biomedical signal processing is signal detection in noisy data. If approximate signal features such as shape and duration are known, the signal's presence and position in time can be estimated by pattern recognition techniques. A matched filter approach, already shown to aide identification of physiological signals embedded within white [1] or colored [2] noise may have utility in extracting event-related fMRI signals. The matched filter technique combines waveform pattern recognition with cross-correlation analysis.

Methods

We applied matched filter techniques to simulated and experimental event-related fMRI data. Simulated data were produced using a gamma function to create an event-related hemodynamic response (HDR) [3]. Several replicas of the gamma function were used to create a time series in which the HDR was unevenly spaced in time (random fluctuation from -1 to +3 sec with respect to the expected event occurrence). Different levels of white gaussian noise (mean=0, σ =10-50%) were separately added to the time series to approximate varying experimental conditions. For each noise level, a first estimate of the HDR was obtained by averaging the individual events.

The matched filter technique was applied to the entire time series using the original gamma function as the filter impulse response. The positioning of the signal along the time series was performed on the basis of cross-correlation maxima. For each noise level, the signals were then extracted and averaged, yielding the matched filter estimate of the HDR. A box car function, the first HDR estimate, and the matched filter HDR estimate were used as reference wave forms for a correlation analysis of the simulated time series.

Experimental data were collected from one person performing a visually triggered, event-related finger tapping task (30 trials of single taps each, 15 sec trials). fMRI signals were collected using BOLD EPI methods (TE=60 msec, TR=1.1 sec, 64x64 matrix, 192 mm FOV, 7 slices, each 5 mm thick) on a Siemens Vision MR System Scanner operating at 1.5 T. An activated area in supplementary motor cortex was selected and time series from this area were analyzed by matched filter technique.

Results

The matched filter applied to the simulated data at all noise levels yielded a hemodynamic response similar to responses previously observed [3]. The analysis with the simulated data using the different correlation techniques revealed higher correlation coefficients for the matched filter at all noise levels ($p \leq 0.0005$, Fig. 1). No apparent difference was evident between the box-car and HDR first estimate.

The matched filter technique succeeds in extracting realistic HDR waveforms even when non-ideal matched filter templates are employed (Fig. 2). Matched filter methods appear to yield a higher HDR compared to the HDR first-estimate, probably due to better temporal alignment of the trials with the matched filter method.

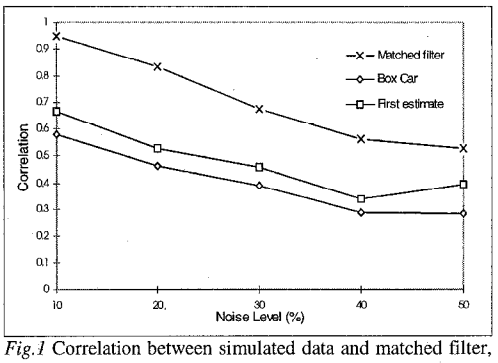

Fig.1 Correlation between simulated data and matched filter, box-car and HDR first-estimate respectively.

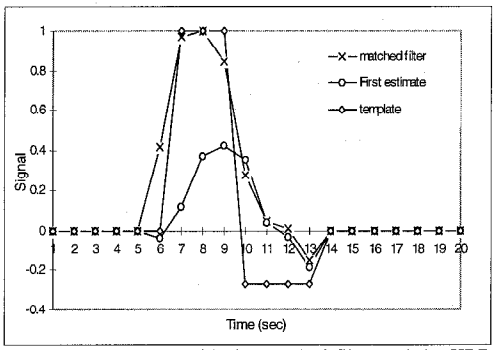

Fig.2 HDR responses with the matched filter and the HDR first-estimate from the time series of one voxel in supplementary motor area.

Discussion

The results obtained on simulated and experimental data demonstrate the validity of the matched filter technique to detect a HDR from noisy event-related fMRI time series. The matched filter method appears effective with ideal and non-ideal templates, and has higher sensitivity than other commonly applied methods to extract event-related fMRI signals from ongoing background events.

References

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[2]Unser M and Aldroubi A. Proceedings of the IEEE 84(4):626-38;1996.
[3]Boynton G.M., Engel S.A., Glover G.H. and Heeger D.J., J.Neurosci. 16(13):4207-4221;1996.