Extraction of the Hemodynamic Response Function using an Adaptive Filter

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Abstract: The Hemodynamic Response Function (HRF) is the impulse response of the blood oxygen level dependent (BOLD) signal in the brain. The BOLD signal is what FMRI is sensitive to; therefore, an estimate of the HRF provides valuable information about the underlying function of the brain. The normalized least mean squares adaptive filter estimates the HRF and extracts its shape for every voxel in a time series of fMRI data. Furthermore, this filter can estimate the HRF at each time point in an experiment allowing temporal tracking of the HRF.

Introduction: Studies have shown that the HRF varies across scanning sessions within subjects, across subjects, and even across brain regions [1]. An ideal situation is estimation of the HRF for each subject at each point in the brain. Adaptive filters are signal-processing tools used here to identify the HRF on a voxel wise basis. Adaptive filters, as their name implies, have the ability to track a non-stationary signal and find a system's response over the course of time. This is in contrast to FIR/Weiner type filters [2] that assume a stationary signal.

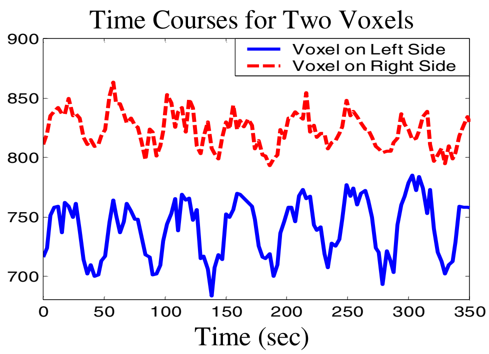

Figure 1: Time courses for voxels from the left and right sides of the brain during bilateral finger tapping.

Methods: Adaptive filters use two inputs, a desired signal and an input signal, to determine the filter that minimizes the mean square error between the two. When the desired signal is the boxcar describing the stimulus paradigm, and the input is the fMRI time course, the adaptive filter extracts the HRF. The adaptive filter used here was the normalized least mean square (nLMS) because of its ease of understanding and implementation [3].

A healthy subject (male, 37) was scanned for this study using a 3.0 T Siemens Allegra (head only) scanner. One hundred thirty two sequential gradient-echo EP images were obtained using the following imaging parameters: Matrix=64x64, TR/TE=3000/27 msec, FOV= 22cm^2, number of slices=32 with thickness = 4mm. The experiment used a boxcar bilateral finger-tapping paradigm. The subject alternated between no movement for eight scans and opening and closing both hands for eight scans over eight cycles. The time series was realigned, mean corrected and linearly detrended before application of the adaptive filter.

Results: Regression analysis on every voxel time-series using an idealized waveform representing the "ON/OFF" cycle identified active voxels. Where task related signal changes were present, the nLMS extracted the HRF. In regions without any task related signal change, the nLMS filter extracted small magnitude random noise. Figure 1 shows the raw time courses for two voxels during bilateral finger tapping and Figure 2 shows the HRF that the nLMS algorithm extracted from each one. Figure 3 shows the extracted HRF from the left side voxel at every point in time during the experiment.

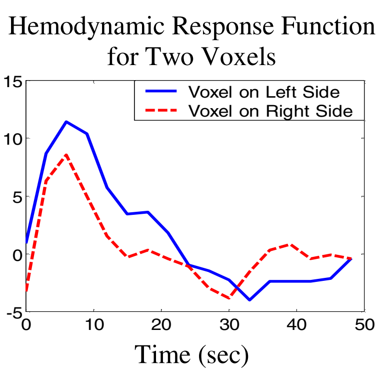

Figure 2: The extracted hemodynamic response function for two voxels extracted from the left side (blue solid line) of the brain and the right (red dashed line).

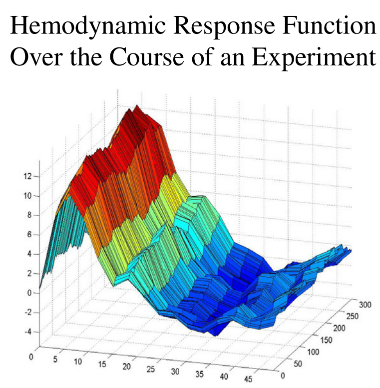

Figure 3: The Hemodynamic Response Function (HRF) at the left side voxel in time over the course of the experiment. The filter has the ability to show changes in the shape of the HRF over time. The bottom axis represents time in seconds for the HRF, the right side axis represents time in seconds over the course of the experiment.

Conclusions: The normalized least mean square filter has the ability to extract the hemodynamic response function at all voxels showing task related signal change. Knowledge of the HRF may be used to increase the fit of a multiple regression model or fit to a physiological model. Extraction of the HRF from a voxel at every time point in an experiment has potential to show subject adaptation to an experimental task.

References:

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