Physiological Noise Suppression for Functional Magnetic Resonance Imaging by Normalized Least Mean Square Adaptive Filtering


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Methods and Materials

NLMSADF (Fig. 1) has been widely used for its computational simplicity. By minimizing the mean square error, the filter coefficient adaptation is given by:

\[
e(n) = d(n) - y(n)
\]

\[
0 = W(n) R_e(n)
\]

\[
W(n) = \frac{W(n) R_e(n)}{|W(n) R_e(n)|}
\]

where

- \(d(n)\): input signal, the combination of desired signal \(s(n)\) and primary noise \(m(n)\).
- \(r(n)\): reference noise, correlated with \(r(n)\).
- \(W(n)\): NLMSADF’s coefficients.
- \(e(n)\): the estimated desired signal \(s'(n)\) if \(s(n)\) is uncorrelated with \(r(n)\).
- \(p\): convergence factor.

The convergence factor \(p\) was determined empirically to be 0.02, and order of filter to be 7 in this study.

Simulation

The synthetic signal was constructed as follows:

\[S(n) = S_{act}(n) + N_{noise} + N_{phys}(n)\]

**MRI Experiment**

Data from two healthy young male subjects were included. Single-slice gradient echo EPI was acquired repeatedly (400 time frames), with TR/TE = 250/35ms, matrix 64x64, FOV = 23cm, and slice thickness = 4mm. All experiments were conducted on a Bruker MedSpec 3T whole-body system (Ettlingen, Germany). The extraction of reference noise from the acquired images was described in (4). rPSD was defined as the ratio or cardiac noise power over that of the entire spectrum obtained from each pixel’s time course. Only pixels whose rPSDs exceed 0.05 were used for evaluation.

Results

The performance of NLMS adaptive filter under various levels of SNR is demonstrated in figure 2 and figure 3. rPSD improvements of the two subjects are shown in Table 1.

Discussions

From the simulation results, we show that NLMSADF can reduce nonstationary physiological noise to an acceptable level depending on the noise level. As expected, the proposed algorithm performs better under lower Gaussian white noise. In terms of physiological noise, it is interesting to note that the NLMSADF particularly works well under low SNR conditions. This is because as SNR gets higher, extraction of the reference signal becomes more difficult under nonstationary situations. In fact, it may not be necessary to use an adaptive filter when there exhibits sufficient SNR. We conclude that the efficacy of physiological noise suppression using NLMS adaptive filter is comparable with previous study (1) and is particularly suited for low SNR applications.

References