3 new methods for signal analysis and denoising

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Summary and Conclusions

Noise degrades data from electrophysiological recordings such as EEG, MEG, optical, multielectrode array, etc. Three new denoising methods target three main sources: environmental, sensor, and physiological noise.

TSPCA uses signals from reference sensors as regressors to remove environmental noise, with time shifts to compensate for convolutional mismatch between reference and brain sensor pathways. SNS replaces each sensor channel by its projection on the subspace spanned by other channels, thus removing sensor-specific noise. The DSS algorithm takes advantage of high density recordings to form a spatial filter that maximizes a target criterion (e.g. proportion of evoked response) while minimizing noise components. An improvement in SNR on the order of 40 dB is obtained with minimal distortion of brain patterns. Denoising is complementary with other standard techniques of brain signal analysis.

Time-Shift PCA (TSPCA)

Assumption: environmental noise observed by reference sensors, but with possible convolutional distortion (filtering, delay).

Algorithm:
1. take set of delayed reference signals
2. orthogonalize to obtain basis
3. project brain signal on reference basis, subtract projection

Sensor Noise Suppression (SNS)

Assumption: every source of interest is picked up by several sensors => a component specific to one sensor is artifact.

Algorithm:
1. project each sensor on subspace spanned by other sensor signals
2. replace by projection

Optimal Spatial Filter (DSS)

Assumption: (1) Target and noise sources are spatially distinct (may overlap) and temporally distinct (may be correlated). (2) There exists an objective criterion to distinguish target and noise (here: evoked power).

1. PCA, normalize (spatial whitening)
2. apply bias function (average over trials)
3. PCA to align data with maximum bias (rotation matrix)
4. Apply rotation matrix to whitened data (DS components)
5. Select best DS components, discard others
6. Project back to sensor space

SNR improvement on several systems:

