KALMAN FILTERING IN RECORDING AUDITORY EVOKED POTENTIALS (219)

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Hypothesis

The effect of sporadic noise can be reduced by Kalman averaging in applied evoked potentials, such as the Auditory Brainstem Response (ABR) and the Auditory Steady State Response (ASSR).

Background

- Noise in ABR and ASSR are orders of magnitude greater than the desired signal [1].
- Averaging of the signal is the classical approach to remove random noise and to strengthen the underlying signal (the evoked potential).
- Artifact rejection thresholds reject portions of the signal whose energy exceeds a threshold, effectively saying that the underlying signal is impossible to determine within this noise.
- Kalman averaging is designed to give more weight to signals with less noise, and to minimize the effect of the noisier signals, effectively "locking on" to the good signals.
- FFT examines the entire frequency spectrum and cannot be optimized for specific ASSR modulation frequencies.

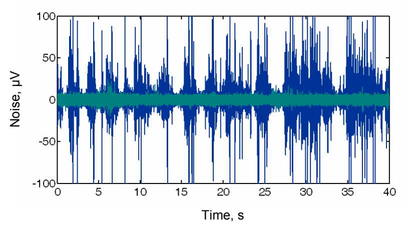
Purpose

Compare standard averaging and artifact rejection threshold with Kalman weighting for ABR.

Methodology

ABR

- EEG experimentally obtained with no applied stimulus in order to model noise
- EEG bandpass filtered (70-2500 Hz, -12 dB/oct)
- EEG sampled at 16,000 Hz

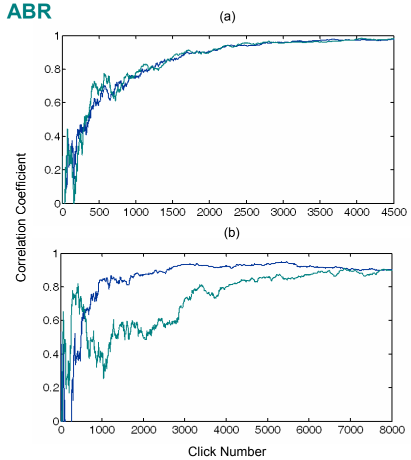


40s sample of EEG experimentally obtained, where the subject was resting (green) and eating (blue).

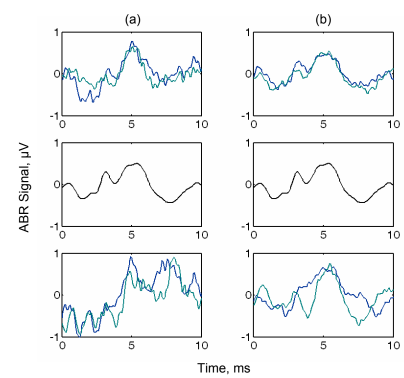
- EEG separated into windows of received signal
  - Each signal represents the received window from 1 click
- An idealized ABR (0.5 μV peak, obtained experimentally) was added to each EEG window
  - Removes variance from underlying ABR signals between subsequent responses
- Apply threshold of 10 μV [2] to EEG windows for the standard averaging calculations
- For both threshold-standard averaging and Kalman averaging:
  - Calculate ABR from each received window
    - Alternating assignment to A and B channels
    - Compare correlation

Results

ABR



Comparing correlation with click number, for threshold-standard averaging (green) and Kalman averaging (blue), for EEG noise taken (a) at rest and (b) while eating. The threshold rejected 2618 out of the 8000 clicks for the standard averaging.



Comparing ABR signals from the received windows for EEG noise taken while eating at click (a) 400 and (b) 2000. The top row displays the ABR processed with Kalman averaging, the second row displays the idealized ABR, and the bottom row displays the ABR processed with the threshold-standard averaging.

Discussion

ABR

- For the resting noise:
  - Minimal difference between Kalman filter and standard averaging
  - Statistics of noise constant
    - Kalman filter expected to behave similarly to the standard averaging method
- For the eating noise:
  - Kalman filter minimizes contribution from noisy samples (little change in correlation), whereas threshold removes the noisy EEG window entirely
    - Kalman filter performs better at noisy regions just under the threshold
  - Correlation between A and B ABRs calculated from the Kalman filter reaches acceptable levels before those of the threshold-standard averaging
  - Correlation by itself is not an adequate measure to determine if a sufficient number of clicks were obtained. As seen for click 400, the correlation coefficient was good, but the ABR signal itself was not.

ASSR

- Preliminary data for the resting noise:
  - Frequency specific Kalman weighted filter able to detect signal from noise faster than FFT-based algorithms
- Future work:
  - Extend to eating noise and other sporadic noises
  - Investigate filter performance for various ASSR signal intensity levels
  - Investigate filter performance for multiple modulation frequencies

References

[1] J. Culmore. Identifying and reducing noise in physiological recordings. Int J Physiol, 32: 129-150, 1999.

[2] L. Hood. Clinical applications of the auditory brainstem response. San Diego: Singular Publishing Group, Inc., 1998.

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