Automatic denoising of single-trial evoked potentials

Overview:

Event-related potentials (ERPs) are the changes in the ongoing electroencephalogram (EEG) due to stimulation (e.g. tone, light flash, etc.). By arranging sequences of stimuli in paradigms, it is possible to analyse the responses of the brain to different tasks, thus allowing the study of several sensitive and cognitive functions, states and pathologies.
Due to the low amplitude of ERPs, responses to several stimuli are averaged in order to distinguish them from the background EEG. Averaging gives an increase in the signal-to-noise ratio. However, when averaging, information concerning the variability between single trials is lost.
Single trial ERPs have been previously detected using a denoising implementation based on discrete wavelet decomposition. The denoising was obtained by manually selecting coefficients correlated with the ERPs in each scale of the decomposition, then setting to zero the uncorrelated coefficients and finally reconstructing the signal from the remaining coefficients. However the manual selection of coefficients is a very subjective and time consuming task. The EP_den provides an automatic denoising algorithm based on the NZT denoising techniques which helps to visualize the ERPs at the single-trial levels. Although it gives a first automatic denoising technique, this can be further modified by manual selection of coefficients.

Distribution and reference:

EP_den is free (and therefore without any warranty) for any non-commercial applications. For any commercial application please contact the authors (ma447@le.ac.uk & rqqg1@le.ac.uk). You can refer to this algorithm just by citing the paper where it is described:

Automatic denoising of single-trial evoked potentials.
M. Ahmadi, R. Quian Quiroga
Neuroimage, http://dx.doi.org/10.1016/j.neuroimage.2012.10.062

The software was developed by Maryam Ahmadi and Rodrigo Quian Quiroga.

Requirements:

EP_den runs under windows, linux and Mac. It requires matlab 6.5 (R13) or higher.

Brief Description of the code:

The code gives different options for automatic and manual denoising of event related potentials. It first averages the single-trial ERPs and then decomposes the average signal using wavelet decomposition. In each scale of decomposition the wavelet coefficients show the correlation of the average ERP with the wavelet function (biorthogonal B-spline) at different times. See [1] for a review of wavelet decomposition applied to ERP analysis. The manual denoising can be done by selecting coefficients correlated with the event-related responses and then reconstructing the signal using the set of selected coefficients [2]. However the automatic denoising selects the ERP-correlated coefficients automatically and similarly reconstructs the denoised average ERP using the selected coefficients. EP_den has two options for the automatic denoising:

Neigh: This uses the intra scale dependencies of wavelet coefficients and their deviation from baseline to select the event-related responses and remove the noise coefficients [3].

NZT: This option uses the inter and intra scale dependencies of wavelet coefficients and their deviation from baseline [3] [4].

In both cases of automatic and manual denosing techniques, the same set of coefficients is used for denoising single-trial ERPs.

Data input and results storing:

Input data should be a 1 column ASCII file in which trials should be concatenated one after the other without blanks (each trial including the pre- and post-stimulus data). The program assumes the number of samples per sweep is an exponent of 2. If not, use the function "Resample.m" before denoising. The baseline noise is estimated using the pre-stimulus ongoing EEG so be sure to have enough pre-stimulus data points.
The "Save" button stores the results in an output file with extension "_den". This file contains the matrix "YDEN", in which each row is the denoised trial, and the matrix "xx" with the original data in the same format. The possibility of getting the single-trial ERPs allows the study of variability between the single-trials [5] and how this influences the conventional ERP averages [6]. It also allows the study of systematic amplitude/latency changes due to habituation or sensitization [7], learning [8], etc.

Batch files:

The batch files give the possibility to do the denoising and save the results. There are five matlab *.m files. The main file, the EP_den_Auto, reads the input ASCII file,

denoises the ERPs based on the selected denoising technique, plots the original and denoised signals and outputs a matlab file with the original and denoised data.

Comments and updates:

If you have any comments please send them to me at ma447@le.ac.uk. I really hope this algorithm will be useful for you. If it does, or if for some reasons it is not adequate for your data please let me know. I can't promise that I can introduce suggestions immediately, but I'll try to do it in reasonable time. Also let me know by email if you want to keep updated on the release of any new version, related paper, etc.

References:

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