TU Delft
Faculty of Electrical Engineering, Mathematics, and Computer Science
Circuits and Systems Group

ET 4386 Estimation and Detection

ASSIGNMENT

Eye blink artifact removal from EEG

1 Context

Electroencephalogram (EEG) records electrical potentials generated in the brain. It is the most commonly used non-invasive technique to monitor brain activity. EEG has important application in diagnosing neurological disorder such as epilepsy, or realising brain-computer inferfaces (BCIs).

However, EEG is often contaminated by various artifacts which deteriorate the performance of subsequent analysis techniques. One commonly occurring artifact is eye blink artifact: eye movements cause deflections on frontal electrodes which are often of much higher amplitude than patterns of interest in the EEG. Therefore, it is important to remove such artifacts from the EEG.

This exercise consists of two parts: (a) derive and implement a suitable filter to remove eye blink artifacts (b) study the performance of the filter. In a group of 2 students, make a short report (4-5 pages; pdf file) containing the required MATLAB scripts, plots, and answers.

System model

We will consider the following signal model for a multichannel EEG signal with N channels. We assume a linear mixing model, where the kth frame of the observed signal on the nth channel can be written as

$$\mathbf{y}_n(k) = \mathbf{x}_n(k) + \mathbf{v}_n(k), n = 1, 2, ..., N \tag{1}$$

where $x_n(k)$ and $v_n(k)$ represent the eye blink component and the clean brain signal, respectively. Both vectors have size L, i.e the number of samples.

Our aim is to estimate the eye blink component $x_n(k)$ from the data and then subtract it from the noisy observation in order to retrieve the clean brain signal $v_n(k)$.

The eye blink component in the kth frame can be estimated by a linear transformation of the observed signal:

$$\hat{\mathbf{x}}(k) = \mathbf{H}\mathbf{y}(k) = \mathbf{H}(\mathbf{x}(k) + \mathbf{v}(k))$$

with

$$\begin{aligned} \mathbf{y}(k) &= \begin{bmatrix} \mathbf{y}_1^T(k) & \mathbf{y}_2^T(k) & ... & \mathbf{y}_N^T(k) \end{bmatrix}^T \\ \mathbf{x}(k) &= \begin{bmatrix} \mathbf{x}_1^T(k) & \mathbf{x}_2^T(k) & ... & \mathbf{x}_N^T(k) \end{bmatrix}^T \\ \mathbf{v}(k) &= \begin{bmatrix} \mathbf{v}_1^T(k) & \mathbf{v}_2^T(k) & ... & \mathbf{v}_N^T(k) \end{bmatrix}^T \end{aligned} \tag{2}$$

and $\mathbf{H}$ is a filter matrix of size $LN \times LN$.

We will assume that both the eye blink component and the brain signal component are short-time stationary, they are uncorrelated and zero-mean. Therefore, the signal is divided in overlapping time frames.

2 Assignment

You are given two EEG recordings, each with $N = 19$ electrodes, sampled at a rate of $F_s = 400$ Hz. Both recordings contain eye blink artifacts. For the first EEG recording (in Training_EEG.mat) the occurrence of eye blink artifacts are knowns. THe sample indices containing artifacts are stored in the variable 'blinks' witin the same .mat file.

1. **(5pts)** Using this recording and the known occurrence of eye blink artifacts, derive a suitable filter **H**! Explain your estimation approach, and derive the equations describing your solution. Specify any parameter settings that you may need to make!

2. **(3pts)** Apply this filter to remove the eye blink artifacts from the recording stored in Test_EEG.mat! Evaluate the effect of any parameter setting that you may have applied.

3. **(2pts)** Report writing and research.

3 Practical tips

If you are working in Matlab, you may want to download the EEGlab toolbox and use the eegplot function to visualize your EEG.

If you are using Python, you may look for the MNE-Python package for the same purpose.

4 References

[1] Adam Borowicz, "Using a multchannel Wiener filter to remove eye-blink artifacts from EEG data". Biomedical Signal Processing and Control, vol 25, August 2018, pages 246-255