

## EEG artifacts detection for application in a Brain Computer Interface

EEG artifacts to detect:

- Eye Blinking
- Eye Movements
- EMG

How does FORCe work?

- 1) Decompose the EEG on each channel into a set of approximation and detail coefficients via a wavelet decomposition. Denote  $c_j^i \in C$  the  $j$ th coefficient set from the set of all coefficients  $C$ , from channel  $i$ .
- 2) Group all coefficients at the same decomposition level from each channel into sets of coefficients,  $A_n = c_j^i \in C \mid \forall i \in K, j = n$ , where  $K$  is the set of channels and  $n$  denotes the decomposition level.
- 3) For the set of approximation coefficients ( $A_1$ ) estimate an ICA demixing matrix to separate the coefficients into maximally statistically independent coefficients (ICs).
- 4) Multiply the set of approximation coefficients by the demixing matrix.
- 5) Identify ICs which contain artifacts and remove them.
- 6) Invert the ICA decomposition to obtain an estimate of the cleaned approximation coefficient set  $\tilde{A}_1$ .
- 7) Identify spike zones in both the approximation and detail coefficient sets and apply soft thresholding to reduce their magnitude.
- 8) Reconstruct the cleaned EEG from the wavelet approximation and detail coefficient sets.

In FORCe there are a lot of criteria to identify the sources of artifacts. These criteria are applied to the independent components (ICs) or to the projection of each IC.

ICs are identified as likely to contain an artifact when they exceed thresholds for one or more of these criteria. However, it is possible for a period of clean EEG to exceed a threshold (a false positive identification). Therefore to attempt to minimize the influence of such a false positive artifact detections, the number of thresholds exceeded by each IC is counted.

For ARTIFACT REMOVAL ICs which exceed more than three thresholds are removed.

For ARTIFACT DETECTION it is important to recognize the criteria related to a precise artifact.

### Eye Blinking Criteria:

- The projections of each IC are thresholded to  $\pm 100 \mu V$ , with any IC which exceed this threshold marked for removal. (remICsPF in FORCe)
- The peak-to-peak differences between the maximum and minimum amplitudes in the IC projections are thresholded to  $90 \mu V$ , instead of the original  $60 \mu V$  (remICsP2P in FORCe).
- To reduce the number of False Positive in Eye Blink Detection a threshold in the number of ICs that exceed these two criteria is set. If there is at least one IC that exceed one of these two parameter, the Eye Blink Artifact is detected.

### EMG:

- High power spectral density (PSD) in the gamma frequency band and above ( $> 30 \text{ Hz}$ ) could indicate the presence of EMG artifact contamination in the EEG. The mean PSD of the scalp projection of each IC in frequencies above  $30 \text{ Hz}$  is thresholded above  $2.4$  instead of the original  $1.7$  (gammaRem in FORCe).
- High standard deviations in the EEG have also been reported to indicate the presence of EMG. Standard deviation of the projection of the ICs is thresholded via  $\theta_p > \mu(\theta_p) + (w \times \sigma(\theta_p))$ , where  $\theta_p$  denotes the standard deviation of the scalp projection of a single IC,  $\mu(\theta_p)$  denotes the mean of all  $\theta_p$  values, and  $\sigma(\theta_p)$  the standard deviation of all  $\theta_p$  values.  $w$  is a parameter to control the threshold: it has been set equal to  $1.65$  instead of the original value  $w=2$  (remSTD in FORCe).

- Also in this case a threshold on the number of ICs that exceed these two criteria is set. If the number of ICs that exceed the first criteria is greater than 3 and the number of ICs that exceed the second criteria is greater than 0, the artifact is recognized.

#### EYE MOVEMENTS:

- *Peak-to-peak difference between the maximum and minimum amplitudes in the IC projections is thresholded in the range [56-90]  $\mu$ V (remICsEOG in FORCE).*
- *High Power Spectral Density in the lower frequency part ( i.e. < 9Hz) of the spectrum is thresholded at 5.*
- If the number of ICs exceed together the two criteria more than 1, the Eye Movement artifact is detected.

ROC CURVE Analysis to improve the FORCE performances:

- Definition of a Ground-Truth for each recorded trial.
- Computation of False Positive Rate (FPR) and True Positive Rate (TPR).
- For each threshold value in its proper range we save the related FPR and TPR. Plotting the TPR vs the FPR we obtain the ROC curve. The aim is to choose the threshold that takes a FPR < 0.2 and a TPR > 0.8

This is useful for two things:

- Improve the performance of FORCE as Artifact Detector.
- Evaluate if the parameter for detection are good also for artifact detection.

In the folder it is present the code and the data related to the final results.

It is possible to see the final performances after the ROC curve analysis and the threshold selection.

It is possible to run FORCE on one of these recordings:

- Blink\_artifact
- NeckLR\_artifact
- Eyeroll\_artifact
- SitCalm\_artifact

The output is the recorded signal and the related result of artifact detection.