



An Approach to Detecting and Eliminating Artifacts from the Sleep EEG Signals

Rym Nihel Sekkal¹(✉), Fethi Bereksi-Reguig¹, Nabil Dib¹,
and Daniel Ruiz-Fernandez²

¹ Biomedical Engineering Research Laboratory, Biomedical Electronics
Department Science Engineering, University Aboubekr Belkaid,
Tlemcen, Algeria
sekrym@yahoo.fr,

{fethi.bereksi,nb_dib}@mail.univ-tlemcen.dz

² Ingeniería Bioinspirada e Informática para la Salud,
Department of Computer Technology, University of Alicante, Alicante, Spain
druiz@ua.es

Abstract. The objective of our ongoing work is to develop an algorithm for detecting and eliminating artifacts from the EEG polysomnographic signals thus helping practitioners in their diagnostic. The EEG signals play an important role in the identification of brain activity and thus in the sleep stage classification. However, it is well known that the recorded EEG signals may be contaminated with artifacts that affect the analysis of EEG signal. Our short paper proposes methods for detecting and eliminating non-physiological and physiological artifacts using filtering for the first and a mixed method based on ICA and wavelets for the second.

Keywords: Sleep analysis · Polysomnography · Artifact detection · Electroencephalogram · Independent component analysis

1 Introduction

People spend around a third of their lives sleeping, mostly during the night. Sleep quality is therefore essential for people's health. The consequences of poor quality sleep (reduced sleep, abnormal sleep patterns or desynchronized circadian rhythms) are numerous: lack of concentration, fatigue, and irritability [1]. They can also be severe ranging from sleep apnea to narcolepsy and neurodegenerative diseases).

The detection of the sleep disorders is therefore crucial for the human health. In this context, sleep stage classification is an important part of this detection process. Indeed, during sleep, one enters different stage defined by electrical activity recorded from sensors placed at different parts of the body [2]. Following the AASM, six sleep/wake stages are traditionally discerned in the human sleep: wakefulness, non rapid eye movement sleep (NREM) divided into sleep stages NI, NII, NIII and NIV, and rapid eye movement sleep (REM).

These stages are identified by the variations in electrical potential corresponding to the eye movements measured by the electroculogram, the electrical activity of the muscles measured by the electromyogram and the specific brain activities recorded using the electroencephalogram and which play a central role in sleep stage processing.

However, the EEG signal is frequently contaminated by several signals (artifacts) which come from sources other than neuronal activity and which lower the quality of electroencephalography. Hence, it is necessary to eliminate such noises to obtain more accurate and appropriate results.

2 Sources and Nature of Artifacts

Artifacts can be distinguished according to their sources [3]:

- Non-physiological artefacts which may be environmental or experimental such as detachment of the electrode, interference from the electrical network centered on the 50 Hz frequency and its multiples, patient movements, sweating, etc. recordings often give rise to flat waves, abrupt slopes, etc. [4].

Environmental artifacts can often be removed using a simple filter. This is either because they move around a narrow frequency band (50/60 Hz), or because their frequency band does not overlap with that of the useful signal [3].

- Physiological artefacts which come from the contamination of the signals of the EEG in the first place by the movement of the eyes which appears especially in the frontal electrodes (near the eyes) measured by the EOG, then by the cardiac signals and by the muscle tension signals measured by the EMG. Ocular contamination is the most important and most studied artifact [5].

However, physiological artefacts do not have a specific frequency band and often overlap with the frequency band of useful signals so that simple filtering techniques are not applicable. Several methods have been proposed to remove these artifacts, but the research on physiological artifact removal continues to be an open problem.

3 Database

For our purpose, we utilize the Physionet Sleep-EDF Database Expanded. This database contains 20 whole-night polysomnographic sleep recordings, containing EEG, EOG, oro-nasal respiration, chin EMG, and event markers. Corresponding hypnograms are manually scored by well-trained experts. In Fig. 1, an example of recorded PSG signals of an epoch is given.

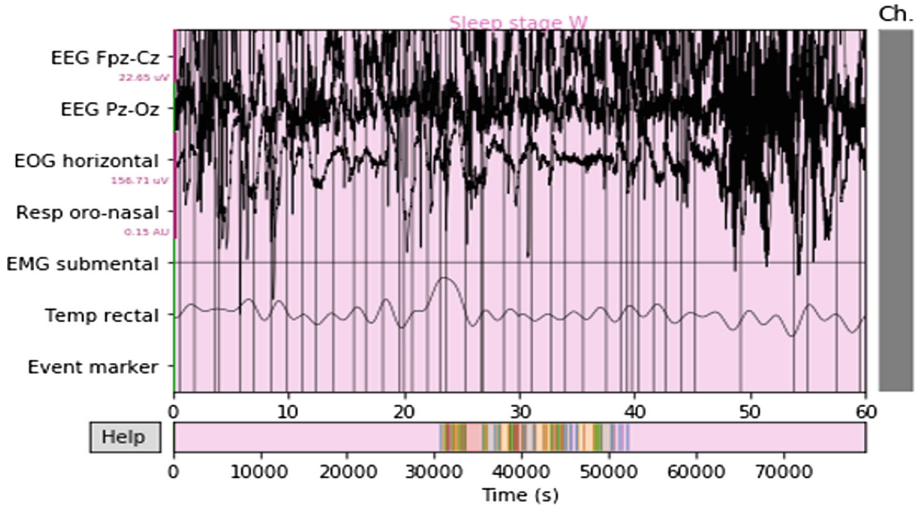


Fig. 1. PSG of the first patient in the database

4 Detection of Artifacts

4.1 DC Artifacts

This artifact results in a peak in the 50 Hz frequencies and its multiples. Figure 2 presents the power spectral density (PSD) of the two signals of the EEG (Fpz-Cz and Pz-Oz) of the first patient and a zoom on the frequency band: 30–50 Hz.

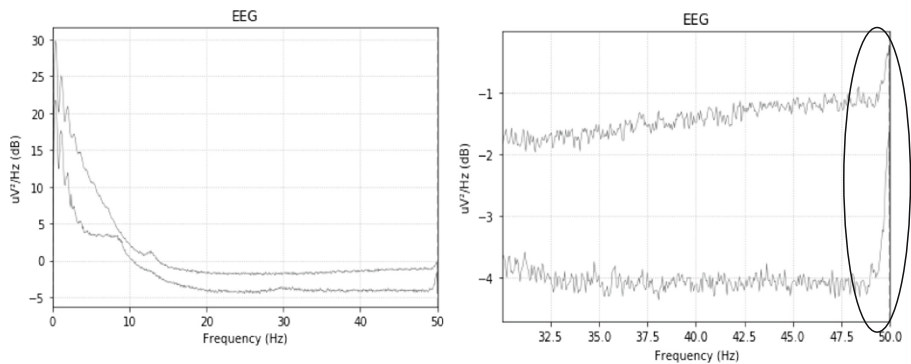


Fig. 2. DC artifact detection

4.2 Slow Ondulations Artifacts

These artifacts are the result of persistent source over time. The slow ondulations that appear on EEG signals are usually caused by breathing or sweating. When breathing,

body movements can affect the impedance of the electrodes. Whatever the cause, these long waves are easily detected because their frequencies are lower than those of the slowest sleep waves (delta rhythm).

4.3 EOG Artifacts

The EOG artifact is identified by the frequency band colored in blue in Fig. 3 through a peak in the electrooculogram followed by an abrupt slopes.

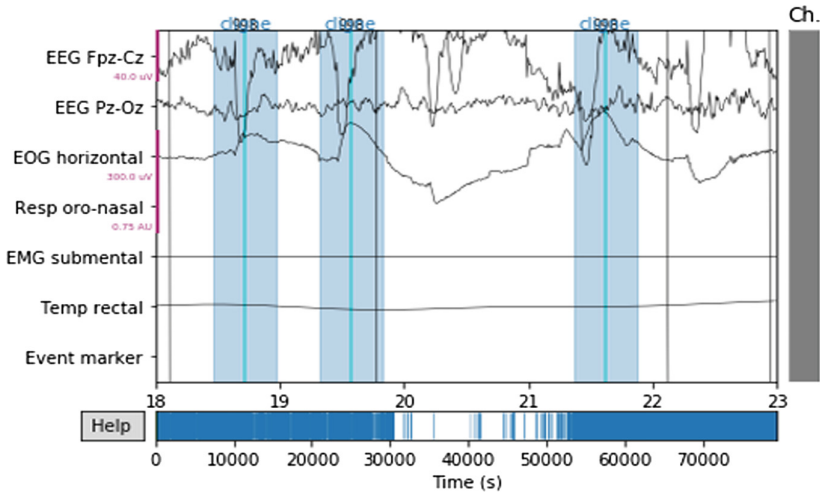


Fig. 3. EOG artefact detection (Color figure online)

5 Artifact Removal

Table 1 presents the approach used to eliminate the artifacts

Table 1. Approach for artifacts removal

Frequencies	Nature of artifacts	Artifacts removal
Cases where the artifacts frequency is known	Non-physiological artifacts	Filtering
Cases where the artifacts frequency is unknown or overlap with other signals	Physiological artifacts	Signal decomposition by ICA and Wavelets

1st Step: Treatment of Artifacts by Filtering

We apply a filter with a pass-band (0,5–45 Hz) with the results shown in the Fig. 4:

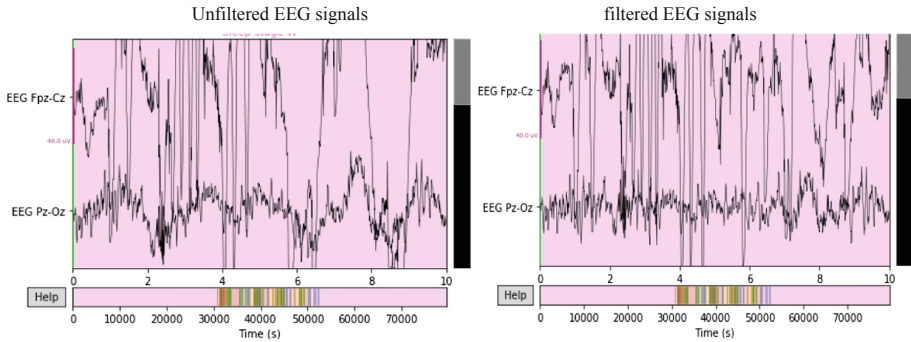


Fig. 4. Unfiltered and filtered EEG signals

We clearly see that the slow undulations in the unfiltered EEG signals have been removed in the filtered signals. This filtering will be useful for ICA decomposition because a high pass filter improves the signal to noise ratio (SNR) and allows better separation of sources [6].

2nd Step: Treatment of Physiological Artifacts by ICA and Wavelets

Following state of the art, there is not one method but several approaches to eliminate physiological artifacts from the EEG signals [7]. We adopt an hybrid method that combines independent component analysis (ICA) with wavelets decomposition. We follow the following three stages:

- Decomposition of the signal by ICA
- Decomposition of the rejected component by wavelets and
- Reconstruction of the useful signal (ICA-W).

The result of this blind sources separation by ICA is shown in the following figure (Fig. 5):

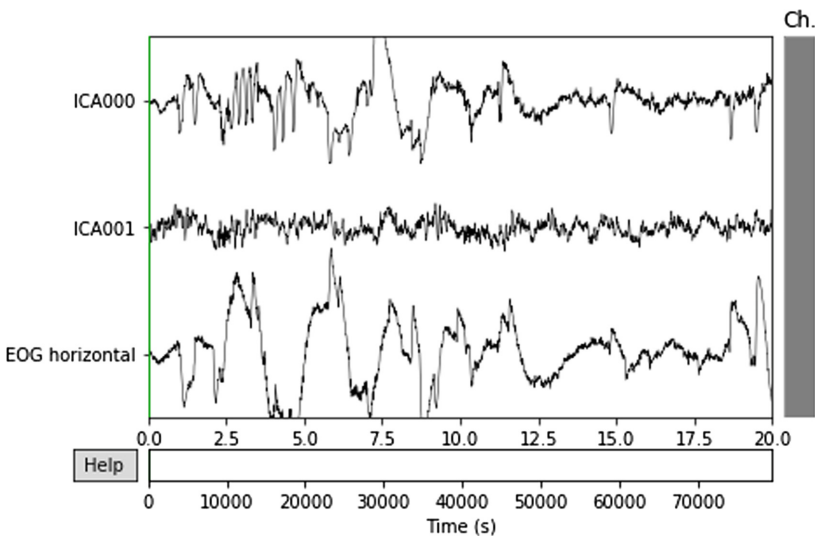


Fig. 5. Sources separation of EEG signals by ICA

The strong correlation between the ICA000 component and the EOG suggests that this component captures the EOG artifact and must therefore be rejected. However we argue that this rejected component actually contains a part of the EEG signal. This part of the useful signal is extracted using a decomposition of IC000 by wavelet and then will be used, with IC001, to reconstruct the signal without artifact. This is an ongoing work.

6 Conclusion

The perspective of our work is to compare this mixed method of artifact removal with simple methods such as ICA or linear regression. We hope to show the superiority of mixed methods and validate Urigüen and Garcia-Zapirain's hypothesis for whom 'the optimal method for removing artifacts from the EEG consists in combining more than one algorithm to correct the signal using multiple processing stages, even though this is an option largely unexplored by researchers in the area' [8].

References

1. Devuyst, S., et. al.: Automatic sleep spindles detection—overview and development of a standard proposal assessment method. In: Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE (2011)
2. Rechtschaffen, A., Kales, A. (eds.): A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects. Brain Information Service/Brain Research Institute, Washington, DC (1968)
3. Sweeney, K.T., Ward, T.E., McLoone, S.F.: Artifact removal in physiological signals—practices and possibilities. *IEEE Trans. Inf Technol. Biomed.* **16**(3), 488–500 (2012)
4. Dora, C., Biswal, P.K.: Automated detection of nonphysiological artifacts in polysomnographic EEG using conventional signal processing techniques. In: Region 10 Conference, TENCON 2017, pp. 1568–1572. IEEE (2017)
5. Schlögl, A., Keinrath, C., Zimmermann, D., et al.: A fully automated correction method of EOG artifacts in EEG recordings. *Clin. Neurophysiol.* **118**(1), 98–104 (2007)
6. Winkler, I., Debener, S., Müller, K.R., Tangermann, M.: On the influence of high-pass filtering on ICA-based artifact reduction in EEG-ERP. In: 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), pp. 4101–4105 (2015)
7. Mannan, M.M.N., Jeong, M.Y., Kamran, M.A.: Hybrid ICA—regression: automatic identification and removal of ocular artifacts from electroencephalographic signals. *Front. Hum. Neurosci.* **10**, 193 (2016)
8. Urigüen, J.A., Garcia-Zapirain, B.: EEG artifact removal—state-of-the-art and guidelines. *J. Neural Eng.* **12**(3), 031001 (2015)