Efficient Sleep Stage Classification Based on EEG Signals

Khald A. I. Aboalayon
Department of Computer Science and Engineering
University of Bridgeport, CT 06604,USA
kaboalay@my.bridgeport.edu

Helen T. Ocbagabir
The Mathworks, Inc.
Natick, MA, 01760, USA
Helen.Ocbagabir@mathworks.com

Miad Faezipour
Computer Science & Engineering and Biomedical Engineering
University of Bridgeport, CT 06604,USA
mfaezipo@bridgeport.edu

D-BEST Lab
Digital / Biomedical Embedded Systems & Technology Lab

ABSTRACT

Currently, sleep disorders are considered as one of the major human life issues. There are several stable physiological stages that the human brain goes through during sleep. In this work, Butterworth band-pass filters are designed to filter and decompose the Electroencephalogram signal (EEG) into five sub-bands δ, Θ, α, β and γ. In addition, various discriminating features including energy, standard deviation, entropy are computed and extracted from above frequency sub-bands. The features are then fed to a supervised learning classifier; support vector machine (SVM) to be able to recognize the sleep stages and identify if the acquired signal is corresponding to awake or stage 1. The experimental results on a variety of subjects verify the high classification accuracy of the proposed work with 92.5 %.

SIGNIFICANCE

The Electroencephalogram (EEG) signal is the most important signal in sleep stage classification [1]. It can be calculated by placing dozens of electrodes at various sites on the head of a subject. According to [2] human sleep is divided into two stages, Rapid Eye Movement (REM) sleep and Non-REM (NREM) sleep. NREM sleep is further separated into 4 stages in which the eyes are usually closed and many nervous centers are inactive, so the brain awareness completely or partially loses consciousness and becomes a less complex system. Nowadays, many biomedical signals such as EEG, ECG, EMG, and EOG offer useful details for clinical setups that are used in identifying sleep disorders [3].

PROPOSED METHOD

The objective of this work is to propose an efficient technique that could easily be implemented in hardware to differentiate sleep stages which will assess physicians to identify certain patterns such as detecting fatigue, drowsiness, and/or various sleep disorders such as sleep apnea. The flow chart of the methodology is shown in Figure 1. First, EEG dataset inputs were obtained from PhysioNet [5] that were acquired and described by scientists for analysis and diagnosis of sleep stages. Infinite impulse Response (IIR) Butterworth band-pass filters are used to decompose the EEG signal into five different EEG frequency bands. Feasible set of features including energy, standard deviation and entropy are then computed and extracted from each δ, Θ, α, β and γ sub-band. Finally, the features are trained and tested using SVM algorithm to be able to recognize the sleep stages state.

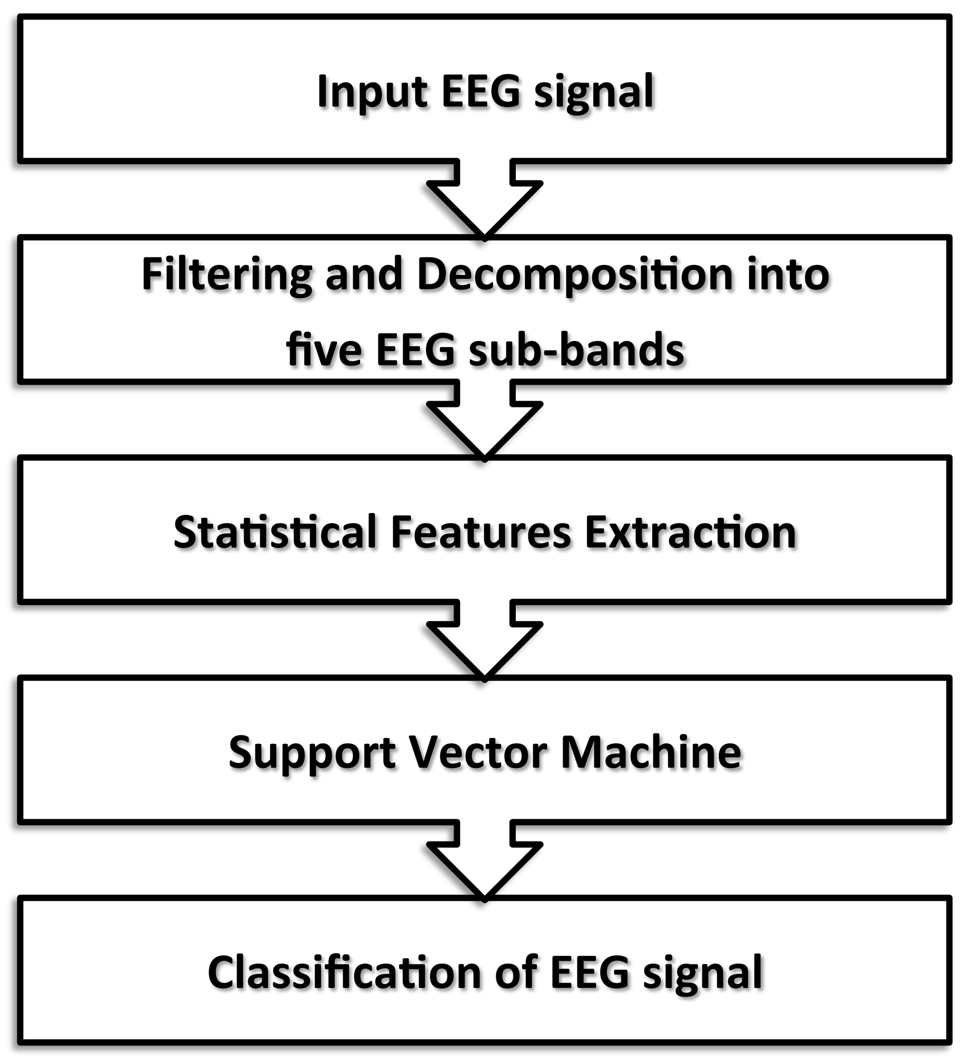

Figure 1. EEG classification methodology

RESULTS

The proposed method was implemented in MATLAB. This work discriminates between the awake stage and sleep stage 1 from the EEG signals in the PhysioNet database. A sample waveform of the EEG signal from the dataset is shown in the Figure 2.

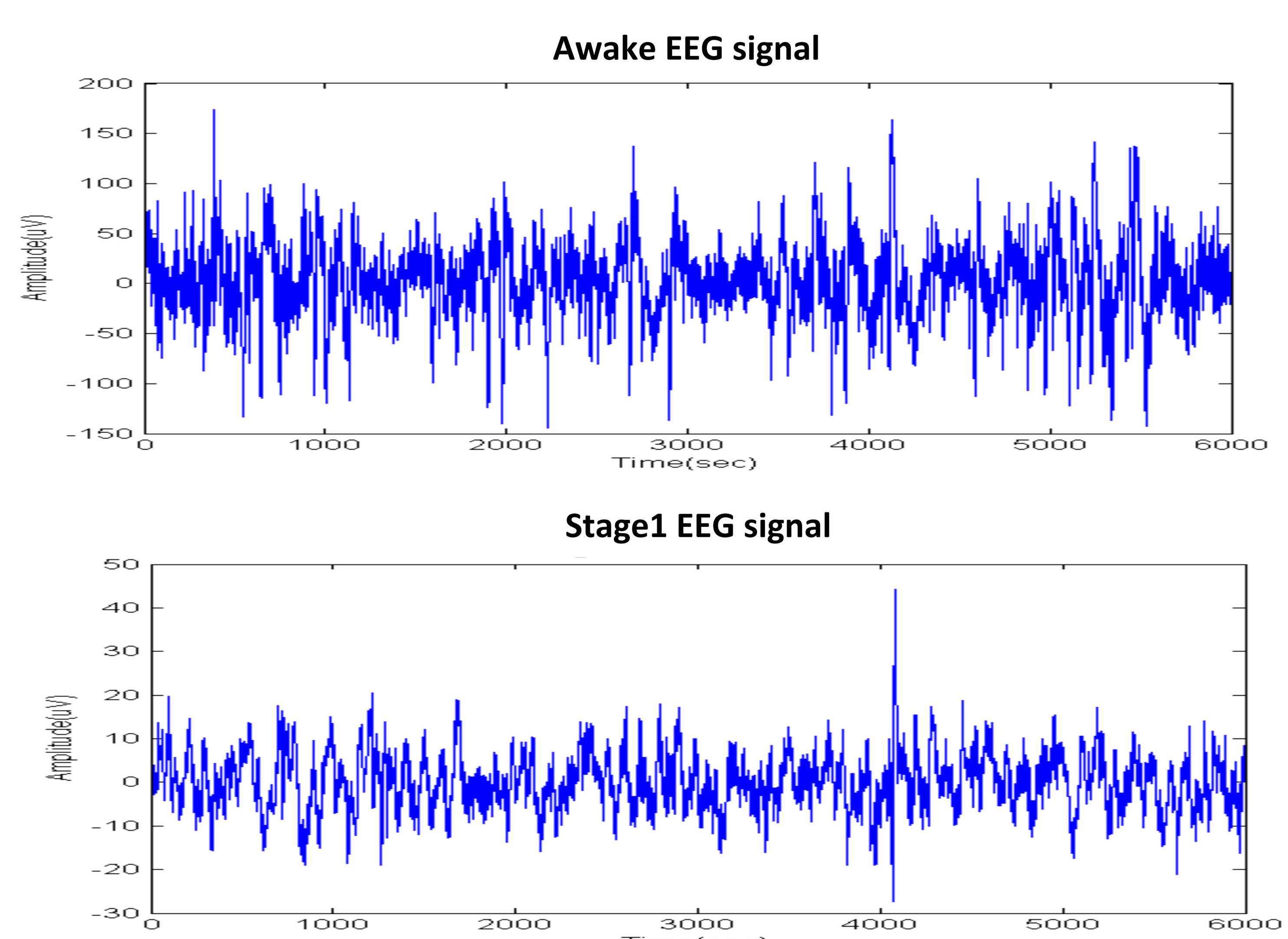

Figure 2. Sample EEG Signal (a) awake and (b) Stage 1

To evaluate the performance of our work, accuracy (Acc), sensitivity (Se) and specificity (Sp) are calculated and shown in Table I.

Category	No. of trained signals	No. of tested signals	Correctly detected	Acc. %	Se. %	Sp. %
	160	40	37	92.5	85	100

Table I: Performance Result

DISCUSSION and CONCLUSION

In this paper, we presented an efficient technique that could be implemented in hardware to differentiate sleep stages which will assess physicians in the diagnosis and treatment of related sleep disorders. IIR Butterworth band-pass filters are used to filter and decompose the obtained EEG signal from PhysioNet into five sub-bands δ, Θ, α, β and γ. These bands are used to predict changes in brain disorder state [4]. Then, the set of features including energy, entropy and standard deviation is computed for each sub-band. Linear kernel function in SVM classifier was used to train and test using the extracted features to classify/detect the sleep stage. In summary, the key novelty of this work is to identify the sleep stages from a publicly available EEG signal dataset by using a feasible set of features, easily implementable filters in any microcontroller device, and an efficient classification method.

REFERENCES

[1] E. Estrada, H. Nazeran, P. Nava, K. Behbehani, J. Burk, and E. Lucas, "EEG feature extraction for classification of sleep stages," 26th *Annual International Conference of the IEEE Engineering in Medicine and Biology Society,* vol. 1, pp. 196-199, Sept. 2004.

[2] M. Vatankhah, M-R Akbarzadeh-T, and A. Moghimi, "An intelligent system for diagnosing sleep stages usingwavelet coefficients," *Neural Networks (IJCNN), The 2010 International Joint Conference on* , vol., no., pp.1,5, 18-23 July 2010.

[3] F. Ebrahimi, M. Mikaeili, E. Estrada, and H. Nazeran, "Automatic sleep stage classification based on EEG signals by using neural networks and wavelet packet coefficients," 30th *Annual International Conference of the IEEE Engineering in Medicine and Biology Society,* pp. 1151,1154, Aug. 2008.

[4] L. Chen, E. Zhao, D. Wang, Z. Han, S. Zhang, and C. Xu, "Feature extraction of EEG signals from epilepsy patients based on Gabor Transform and EMD Decomposition," 6th *International Conference on Natural Computation (ICNC),* vol. 3, pp. 1243,1247, Aug. 2010.

[5] PhysioNet, www.physionet.org.