EEG-based Machine Learning Model for Personalized Power Nap Identification in Brain-Computer Interface

Proceedings - 2025 10th International Conference on Information and Communication Technology for the Muslim World, ICT4M 2025 • Conference Paper • 2025 •
DOI: 10.1109/ICT4M68001.2025.11363540

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Abstract

Electroencephalography (EEG) based Brain Computer Interface (BCI) systems provide a non-invasive means for monitoring sleep and cognitive states. Power naps, typically lasting between 10 and 30 minutes, are known to enhance alertness, memory, and cognitive recovery; however, their effectiveness varies widely across individuals due to differences in neural activity patterns. Current nap detection approaches often rely on generalized sleep staging or subjective reports, limiting their reliability and personalization. This study proposes a machine learning framework for personalized power nap identification using EEG signals from the Sleep-EDF Expanded Database. Two bipolar EEG channels (Fpz-Cz and Pz-Oz) sampled at 100 Hz were preprocessed with bandpass filtering (0.5-

49 Hz), segmented into 30-second epochs, and transformed into feature vectors combining statistical descriptors (mean, standard deviation, skewness, kurtosis, RMS) and spectral powers (total PSD and band-specific δ, θ, α, β, γ). The features were standardized and used to train a Multi-Layer Perceptron (MLP) model with class-weighted loss to address label imbalance. Experimental results demonstrated an overall accuracy of 94% on test data, with strong precision, recall, and F1-scores across Wakefulness, Light Sleep (N1+N2), Deep Sleep (N3+N4), and Rapid Eye Movement (REM). The confusion matrix revealed occasional misclassifications between light sleep and wakefulness, reflecting their overlapping EEG patterns. Training and validation curves confirmed stable convergence without overfitting. The model required <15 ms per segment for inference, indicating feasibility for real-time deployment on modest hardware. In summary, the proposed MLP framework demonstrates high accuracy, strong generalization, and low computational cost, making it a promising foundation for adaptive, real-time power nap detection. Future work will focus on integrating this system into a closed-loop BCI capable of detecting light sleep onset and optimizing nap timing to maximize recovery while avoiding sleep inertia.

Author keywords

BCI; Cognitive Recovery; EEG; Machine Learning; MLP; Personalized Rest; Power Nap Detection; Sleep Stage Classification

Indexed keywords

Engineering controlled terms

Bandpass filters; Biomedical signal processing; Brain; Cognitive systems; Computer system recovery; Electroencephalography; Electrophysiology; Eye movements; Higher order statistics; Interface states; Interfaces (computer); Learning systems; Machine learning; Neurophysiology; Recovery; Sleep research

Engineering uncontrolled terms

Cognitive recovery; Interface system; Machine learning models; Machine-learning; Multilayers perceptrons; Personalized rest; Power; Power nap detection; Real- time; Sleep stages classifications

Engineering main heading

Brain computer interface

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