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Comparison of Time-Frequency Analyzes for a Sleep Staging Application with CNN

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Abstract. Sleep staging is the process of acquiring biological signals during sleep and marking them according to the stages of sleep. The procedure is performed by an experienced physician and takes more time. When this process is automated, the processing load will be reduced and the time required to identify disease will also be reduced. In this paper, 8 different transform methods for automatic sleep-staging based on convolutional neural networks (CNNs) were compared to classify sleep stages using single-channel electroencephalogram (EEG) signals. Five different labels were used to stage the sleep. These are Wake (W), NonREM-1 (N1), NonREM-2 (N2), NonREM-3 (N3), and REM (R). The classifications were done end-to-end without any hand-crafted features, ie without requiring any feature engineering. Time-Frequency components obtained by Short Time Fourier Transform, Discrete Wavelet Transform, Discrete Cosine Transform, Hilbert-Huang Transform, Discrete Gabor Transform, Fast Walsh-Hadamard Transform, Choi-Williams Distribution, and Wigner-Willie Distribution were classified with a supervised deep convolutional neural network to perform sleep staging. The discrete Cosine Transform-CNN method (DCT-CNN) showed the highest performance among the methods suggested in this paper with an F1 score of 89% and a value of 0.86 kappa. The findings of this study revealed that the transformation techniques utilized for the most accurate representation of input data are far superior to traditional approaches based on manual feature extraction, which acquires time, frequency, or nonlinear characteristics. The results of this article are expected to be useful to researchers in the development of low-cost, and easily portable devices.

Introduction

One of the most important factors affecting the quality of human life and health is sleep. Sleep has many biological and psychological effects on individuals [1, 2]. It plays a restorative and regulatory role in the body, so various disorders can be seen in the body as a result of insufficient or poor-quality sleep [3-6]. Although it varies from person to person, it is recommended for a healthy adult to sleep an average of 8 hours a day [7]. However, with the time spent asleep, sleep quality is also crucial. According to research, some adults and about 40% of the elderly have sleep problems [8].

To detect sleep diseases and measure sleep quality, individuals are put to sleep for a certain period by connecting various measuring devices to certain parts of their bodies under observation in sleep laboratories. The quality of sleep is determined by analyzing the information from these sensors by sleep experts. Polysomnogram (PSG) is a large number of physiological signals taken from these sensors implanted on the body and is the most used diagnostic tool in sleep analysis [9]. The staging of sleep is generally performed using electroencephalogram (EEG), electrooculogram (EOG) and electromyogram (EMG) records by the guidelines published by AASM. Each stage is divided into 30-second segments called epochs. Each epoch consists of a total of 5 labels: Awake (W), Stage 1 (N1), Stage 2 (N2), Stage 3 (N3), and Rapid Eye Movements (REM). After the sleep stages are labeled, the sleep/wake periods are separated from each other [10-12].

Sleep staging is done by specialist doctors. It is a long and tedious process and is also susceptible to human error. For this reason, automatic sleep-staging systems are needed and many studies are conducted in this area every year [13-15]. Multiple channels (EEG, EOG, and EMG) [16-18], or single-channel signals such as EEG can be used in automatic sleep staging studies [19-22]. Using