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An Effective Approach for Sleep Stage Classification Based on PSG Recordings

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ABSTRACT

A person spend his one-third of life in sleep. So, paying attention on sleep is necessary at present times. Appropriate scoring of sleep stages is essential part in recognition of particular sleep disorder. Sleep stage classification is the process of categorizing polysomnographic (PSG) recordings into different classes. PSG contains EEG, EMG, EOG signals. In proposed methodology, Power spectral density is used to extract power features of EEG and EMG signals. A machine learning model of Stochastic Gradient Descent algorithm is used for classifying extracted features into multi-class sleep stages.

Keywords: Polysomnography, Sleep Stage, Stochastic Gradient Descent, Power Spectral Density

I. INTRODUCTION

Sleep is the essential part of life. Required amount of sleep is necessary for human being. Sleep has tremendous effect on our physical health, mental health and quality of life. Sleep analysis is the important factor for recognition of sleep disorders[1]. The common problem is occurred in people is having trouble in sleeping. Not getting sufficient sleep leads to the physical and mental illness. Sleep disorders includes sleep apnea, insomnia, narcolepsy, etc. And for identification of sleep disorders sleep analysis is important[2].

Sleep stage classification is the process of classifying physiological signals into different stages. Basically there are two types of sleep stages named as Rapid Eye Movement(REM) and Non-rapid Eye Movement(NREM). Sleep is a cyclical process. Each sleep cycle contains three NREM stages and one REM stage and it continues[3]. Typically, a sleeper goes through 4 to 6 sleep cycles each about 90 to 120 minutes. As specified by American Academy of Sleep Medicine(AASM), sleep stages are classified into five stages named as Awake, Sleep Stage 1(NREM1), Sleep Stage 2(NREM2), Sleep Stage 3(NREM3) and REM. In sleep stage 1, a person is in light sleep and move towards sleep stage 2. In sleep stage 2, a person is in deep relaxation state and move towards sleep stage 3. In sleep stage 3 a person is in deep sleep where no eye movement exist. In REM sleep stage, the movement of eyes occurred and brain gets active. In this stage dreams occurs. And cycle continues[4]. Physiological information is recorded for sleep analysis which contains continuous time signals and it is called as Polysomnography (PSG). Polysomnographic recordings includes Electroencephalogram (EEG), electrooculograms (EOG), electromyograms (EMG), electrocardiograms (ECG), oxygen saturation and respiration. PSG signals are divided into short period of time called sleep epoch. Each sleep epoch is of 30-second. Among all of these signals, EEG signal and EMG signals has more significance. EEG signals has different characteristics at different sleep stages in

frequency bands. These frequency range or waves named as alpha, delta, theta, beta, sleep spindles and k-complex[5]. Figure 1 shows characteristics of EEG and EMG signals related to sleep stages. Table 1 shows frequency range of EEG signal in sleep stages.

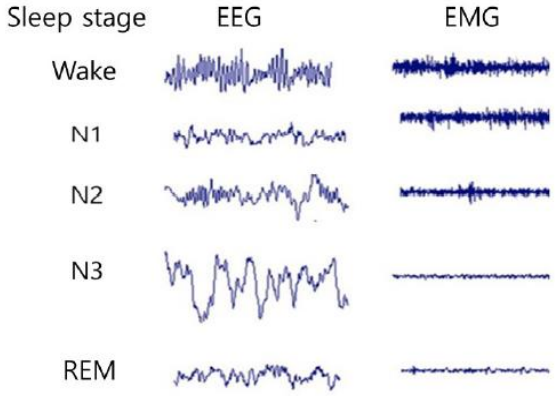

Figure 1 : Sleep stages and characteristics of EEG and EMG signals

Table 1. Occurrence of EEG signal frequency range in sleep stages

Sleep Stage	Frequency range	Bandwidth(Hz)
NREM3	Delta	0.5 to 4
NREM1, NREM2, REM	Theta	4.0 to 8.0
Awake, NREM1	Alpha	8.0 to 13.0
Awake	Beta	13.0 to 30.0
NREM2	Sleep Spindles	12.0 to 14
NREM2	k-complex	0.5 to 1.5

II. Related Work

In sleep stage classification, EEG sleep stages are classified automatically. This process of automatic sleep stage classification by using PSG recordings is complex and difficult problem to solve. Convolutional Neural Network(CNN) is one of the method used by[6]. Michael Sokolovsky et al. [6] designed a deep CNN architecture for classification of sleep stages. . In, CNN unlabelled data is taken as input and class membership is the output. In this approach, processing layers are used. CNN consist of three main processing layers: Convolution layer, pooling layer and fully connected layer. In convolution layer, linear transformation is applied to gain each individual component of data vector. The components of data vector are then passed to the next layer. In pooling layer, aggregation function is used to control over fitting of the parameters in the network. And in fully connected layer, Non-linear activation function is applied on the input of previous layer. In this approach publicly available physionet database is used. For pre-processing three signals are given, Two EEG signals and one EOG signals. Those signals are segmented into 30-5 epoch and overlapping 150-5 or 5 epoch are taken for further process. This architecture contains multiple stages with layers. Pooling layers separates each convolutional layers[6].

H. Kim and S. Choi[7] used EMG and EEG signal of PSG with Support Vector Machine model of machine learning. Only EEG signals are not enough for classification so they used EMG signals with EEG signals. One channel of EEG signal and one channel of EMG signal were used as input data. Power and movement feature of EEG signal and EMG signal were extracted. On this extracted data support vector machine algorithm is applied. SVM is the classification algorithm used for classifying signals into sleep stages. Three key features are defined in temporal method of classification using multimodal time series and multivariate time series : linear spatial filtering, convolutive layers and separate pipelines for EEG/EOG and EMG signals. This model handles multiple input channel and several modalities parallel[8].

A two stage neural network has been proposed by Sun, Chenglu & Fan et al.[9]. There are two phases in this technique. First phase is feature learning phase. In this phase, 40 features are extracting using sliding

window technique. And then for reducing the impact of artifacts z-score normalization procedure is used. To obtain network trained features Window deep belief network is used. After extracting features this method enters to the second phase which is sequence learning phase. In this phase bidirectional long short-term memory network is used for obtaining the information in forward and backward. For balancing of classes and oversampling purpose, data augmentation strategy is effectively used here. Again this model designed a pre-training process to maintain temporal information which might be destroyed in oversampling method[9].

III. Proposed Methodology

In this proposed system, Stochastic Gradient Descent(SGD) algorithm is used for sleep stage classification. Basically, there are two phases in this method. First phase contains processing of data and second phase contains classification and results. In first phase, data has been taken for pre-processing and feature extraction will be done. In second phase, SGD algorithm will be applied on selected features and in result will get classified sleep stages. According to sleep stages, a specified sleep disorder will be predicted.

Input Data

The standard database is obtained from physionet Sleep-EDF database expanded[10]. This database includes polysomnographic recordings of 197 people which contains EEG, EMG and EOG signals. Some recordings even contains respiration and body temperature. From those 197 recordings, 153 recording were taken from healthy Caucasians who aged between 25-101 and called as sleep cassette study and data. And 44 recordings were taken from 22 Caucasian people who has some problem in falling asleep. EEG, EMG and EOG signals from PSG are sampled at 100Hz and rectal body temperature sampled at 1Hz.

Preprocessing

PSG signals contains all the frequency bands messed up with each other. It contains unnecessary information which is called as artifacts. Artifacts might causes inaccuracy or wrong results. To remove artifacts preprocessing is needed to be done[8]. In preprocessing, these frequency bands get divided into 30-second epoch and digital filtering will be done.

Feature Extraction

Basically, features are categorize into four types as follows : time frequency domain frequency domain, time domain, and nonlinear[8]. Frequency of EEG signal is versatile in nature. For feature extraction, we are using the power of EEG and EMG signals. Non-parametric Welch method of Power Spectral Density will be used. Power of each frequency band will be specified by this method. The Welch PSD method is based on Fast Fourier Transform(FFT) and it reduces number of computations. Figure 2 shows the processing flow of proposed methodology.

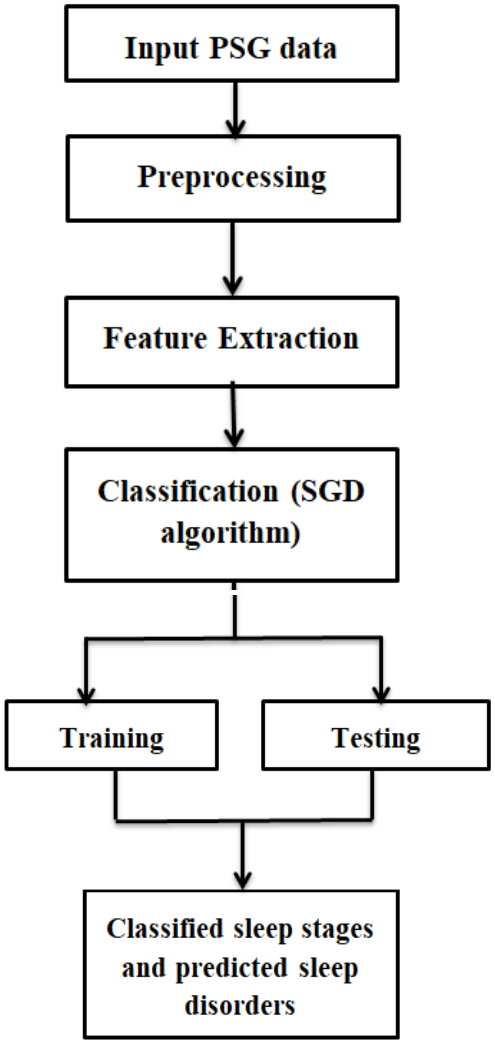

Figure 2 : Flow diagram of proposed methodology

Classification

For classification purpose, Stochastic Gradient Descent(SGD) will be used. SGD algorithm is simple and easy to implement and that's why this algorithm is popular and many applications used it. SGD algorithm is iterative in nature. It usually calculates cost of one point, find the result and uses that updatable values for next iteration. Multi-class classification is supported by SGD algorithm. Here, sleep stages are get classified as classes. At the end, we will get classified sleep stages and it's related sleep disorders.

IV. CONCLUSION

Sleep is the main constituent of human life. Inefficiency in sleep may cause health issues. To detect sleep efficiency, sleep stage classification is required. Polysomnographic recordings needed for sleep stage classification. It contains EEG, EMG, EOG signals. In proposed system, first preprocessing will be done. In feature extraction, power feature will be extracted using power spectral density. For classification, Stochastic Gradient Descent algorithm will be used. This sleep stage classification will be useful for medical purpose.

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