RESEARCH PAPER

EEG Signal Based Sleep Stage Detection by Machine Learning Classifiers

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ABSTRACT

Sleep is one of the greatest things in human beings and healthy sleep maintains human health in good condition. EEG signals are useful for identifying sleep stages. Several disorders presents if person lags in sleeping, Frequency transforms such as Fast Fourier transform (FFT) and Short time Fourier transform (STFT) used in proposed research for feature extraction. Machine learning from artificial intelligence used in proposed research for sleep stage detection. Support Vector Machine (SVM), Logistic Regression (LR) and Random forest (RF) are the machine learning models used in proposed research for sleep stage prediction. RBF kernel is used in SVM models to predict sleep stages. LR model produces highest accuracy 85% over SVM RBF kernel and random forest algorithms. Early sleep stage prediction can save human health. Every human requires 8 hours of sleep per day otherwise it may cause serious concern in life

Keywords: Machine learning; Random forest; SVM; Logistic regression; sleep stage; EEG; Accuracy

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1. INTRODUCTION

These days, sleep issues are quite prevalent. There are numerous traditional techniques for analyzing these kinds of issues. However, these techniques are frequently costly, time-consuming, and require human intervention. Therefore, the need for an automated diagnostic tool is crucial. Deep learning and other artificial intelligence technologies guarantee that data is fully utilized with minimal information loss. This paper proposes a diagnostic tool based on machine learning techniques. The first module pre-processed the signals, and the power spectral density technique (PSD) was used to extract the features. The extracted features were then fed into an ensemble classifier, which is also referred to as a rotational support vector machine.

Filter is a device or element in electronics field to remove noise as well as artifacts. There are several filters exist such as analog filter as well as digital filter. Low pass filter, band stop filter, high pass filter and band pass filters are the categorization of analog filters. Butter worth as well as chebychev filters are the categorization of digital filters. Proposed research uses band pass filter.

Electrical activity in the brain is measured by EEG (electroencephalogram) signals. Alpha, beta, theta, and delta are the four types of brain waves that are identified by frequency analysis after the signals are pre-processed to remove any background noise. The Fast Fourier Transformation (FFT), which moves the signal from the time domain to the frequency domain, is used to achieve this classification. Extracting features from the dataset to distinguish between individuals with insomnia and healthy people is the next stage of the analysis. Logistic regression, a statistical method for estimating the likelihood of a binary outcome (in this case, whether or not a person has insomnia), is used for this.

Signal processing is an operation that changes characteristics of the signal which includes shape, amplitude etc. Frequency transforms used in signal processing to convert time domain signal into frequency domain operation. Discrete Fourier transform (DFT) replaces Fourier transform including Discrete time Fourier transform in terms of computation and performance. FFT is more efficient than DFT because FFT requires very less number of multiplications and additions required.

Despite being the gold standard, the traditional polysomnography (PSG) method for detecting sleep apnea has several disadvantages, such as patient discomfort, the need for overnight lab stays, high costs, and time-consuming procedures. In order to overcome these obstacles, this study suggests a portable, affordable, and energy-efficient biomedical system as a substitute, with the goal of preserving PSG's diagnostic precision while improving monitoring ease. The use of electroencephalogram (EEG) signals, which are essential for identifying sleep apnea because they can record brain activity, is a key component of this method. EEG is a focus of research because of its ability to accurately reflect brain electrical activity, which is essential for identifying the stages and quality of sleep.

STFT is used for non stationary signals to represent signal in time frequency representation. The signal beaked into sub signals and frequency transform applied for each sub signal. Resolution of time frequency spectrum will be improved. Sleep stage identified using PSD extracted from STFT. This is applied to machine learning classifiers for sleep stage prediction.

Non-REM (NREM) and REM are the two main phases of sleep. NREM has three stages (N3, N2, N1) for physical restoration, while REM is for mental/emotional processing and dreaming. The body cycles through N1 to N3, and REM approximately every 90 to 110 minutes, or four to five times per night. From light drifting (N1) to deep, rejuvenating sleep (N3) and vivid dreaming (REM), each stage is essential.

The machine learning from artificial intelligence is used for health care applications such as skin diseases, liver cancer, breathing issues, heart diseases, mental disorders and sleep stage prediction. SVM, RF and Logistic regression is used in proposed research to predict sleep stages. LR is more efficient than other models including existing research to predict sleep stages.

2. LITERATURE SURVEY

Literature survey addresses sleep stage prediction by several authors with advanced methods. Machine learning proposed for sleep stage detection using PSG. This research shows enhanced accuracy results over existing works [1]. Deep learning is future scope where complex pattern involved but machine learning is better choice for proposed research over deep learning.

Photoplethysmography (PPG), which has historically been used to measure heart rate and oxygen saturation, has become a promising non-invasive alternative for the diagnosis of sleep-related disorders. PPG provides a more economical and scalable alternative to the gold-standard polysomnography (PSG) carried out in-lab at the hospital. The accuracy of these techniques for sleep stage inference has been greatly improved by recent developments in deep learning. In this study, a clinical cohort of many patients with suspected sleep apnea is evaluated using a PPG-based deep learning model. Participants in an ongoing clinical trial were subjected to overnight PSG in addition to simultaneous recording of accelerometer and PPG signals using wearable devices from CSEM placed at the upper arm and wrist [2].

Machine learning models such decision tree, KNN and SVM introduced for cardiovascular abnormalities prediction. Deep learning network such CNN introduced to predict cardiovascular disorders including LSTM network shows enhanced accuracy [3]. Machine learning classifiers proposed by authors for real time health monitoring. Health monitoring abnormalities obtained with with highest accuracy over existing research [4].

The need for sleep studies is growing quickly as people become more aware of how important sleep is for social and health well-being. Machine learning models have been developed to help with automatic sleep stage classification, which is an essential component of sleep measurement. When these models use data from healthy individuals, their accuracy is on par with that of technicians. However, people with sleep disorders - like sleep apnea syndrome (SAS), one of the most prevalent - have different sleep patterns than people in good health. As a result, when applied to SAS patients, current models that were trained on data from healthy individuals do not achieve adequate accuracy. Clinical application is hampered by this work [5].

Mental health disorders predicted with deep analysis done by machine learning classifiers. This research creates awareness on sleep conditions for saving human health [6]. Deep learning network that predicted psychiatric disorders using CNN. This research gives better accuracy over machine learning including existing works [7]. This research is base for future researches who are going to implement artificial intelligence on sleep dataset.

An essential part of evaluating sleep health is sleep staging. Breathing variability may be a feature of specific sleep stages, according to recent research. In order to evaluate how well sleep stage can be identified from airflow signals, especially in subjects with sleep-disordered breathing, we train machine learning models on sleep airflow signals from pediatric patients. In a three-class classification task (Wake, NREM, and REM), we classify the sleep stage of healthy subjects with 66.9% balanced accuracy [8].

Signal processing techniques proposed for ECG signal to extract features like QRS interval and amplitude. Extracted features applied to machine learning algorithms for disease prediction and classification [9]. Vision transformers introduced for sleep apnea detection. This research also classifies sleep stages [10]. AI models such as machine learning as well as DL models used for traffic density prediction and also liver disease prediction [11-12].

3. PROPOSED METHOD

Sleep stage prediction by machine learning shown in Figure 1. EEG signal applied to pre processing stage, noise removal and artifacts removal task implemented in pre processing stage. FFT applied for converting time domain signal into frequency domain signal. Band pass filet is used to take certain band of frequencies. STFT is used for extracting PSD feature and it is processed to the machine learning such as SVM, RF and LR classifiers to predict sleep stages.

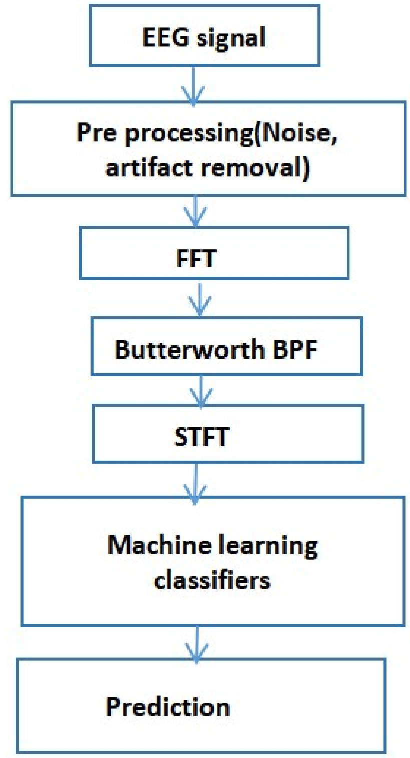

Figure 1: *Proposed Block*

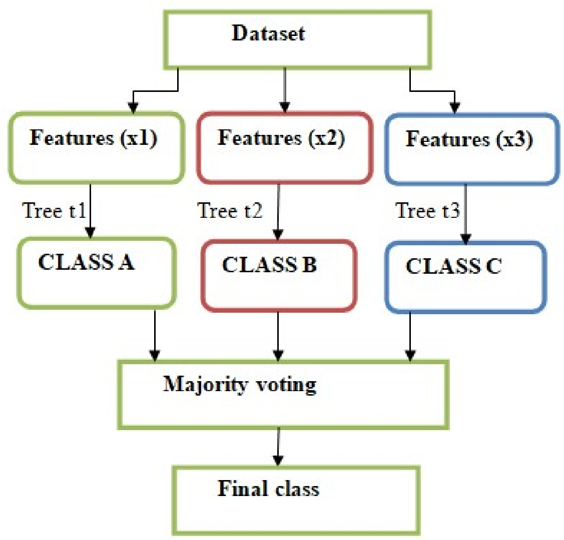

Figure 2: *Random forest*

RF used in proposed method to predict sleep stages shown in Figure 2. RF is combination of several decision tree. Individual tree has certain criteria. Large amount of data given for training and small amount amount of data given for testing.

- Datasets signal are divided into sub bands with features and then trees. Name of this is the root node also called decision node.
- Individual tree is divided as separate class.
- Highest voting from all major classes predicted as final class.

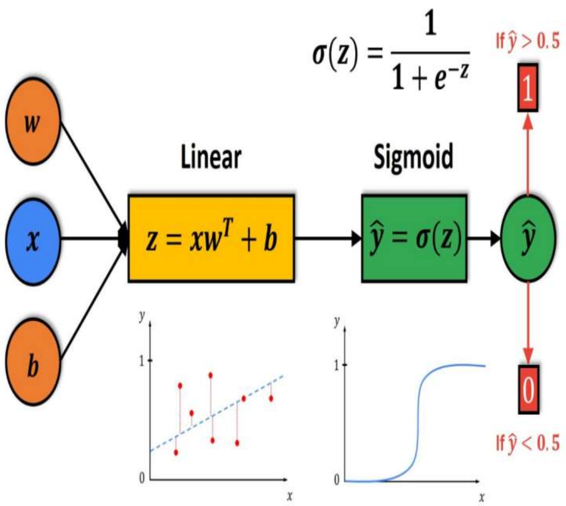

Figure 3: *Logistic regression model*

A logistic regression model for predicting sleep stage prediction and classification is shown in Figure 3. The input, weight, and bias components of a linear model are crucial to prediction. For binary classification, logistic regression employs the sigmoid function. Here, 0 represents the healthy sleep and 1 represents unhealthy sleep. When it comes to predicting sleep condition, the LR model outperforms better than SVM and random forest.

Figure 4: *SVM kernel*

SVM is supervised technique in machine learning used for task prediction and task classification. Support vector, margin and hyper plane are used for prediction. Hyper plane separates data into separate class. Data points near to hyper plane is support vector. Two data points gap is called margin. Margin is useful for making prediction. SVM depends on kernels shown in Figure 4. Proposed research uses RBF kernel for sleep stage prediction and this kernel produce better accuracy than other existing kernels such as polynomial and sigmoid kernel.

4. RESULTS AND DISCUSSION

Proposed method is to predict sleep stages using machine learning models such SVM, RF and LR techniques. EEG signal is the input for the sleep stage prediction shown in Figure 5. EEG signal consists of Delta (0.5-4Hz) shows deep sleep, Theta (4-7hz) shows mediation, alpha (8-12 Hz) shows wakefulness, Beta (13-30Hz) shows active thinking and gamma (30 Hz and above) shows higher level thinking. Figure 6 represents filtered EEG signal. Figure 7 represents FFT output that shows frequency spectrum. Frequency spectrum is used for feature extraction.

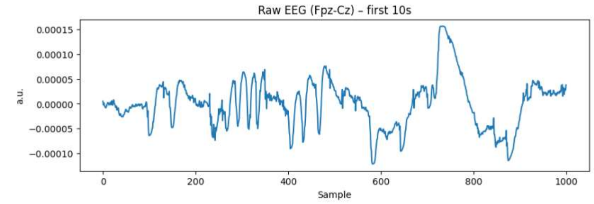

Figure 5: *EEG signal*

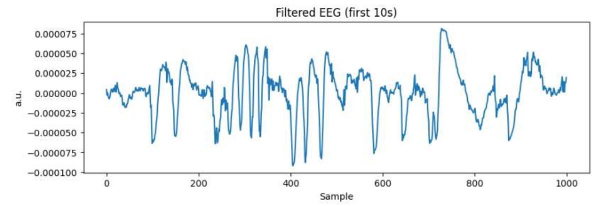

Figure 6: *Filtered EEG signal*

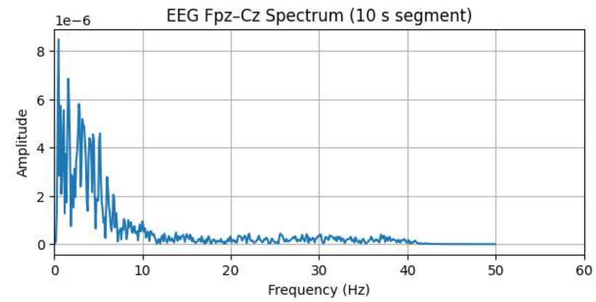

Figure 7: *Frequency spectrum*

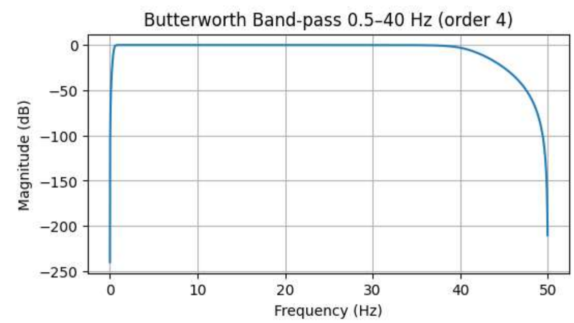

Figure 8: *Band pass filter output*

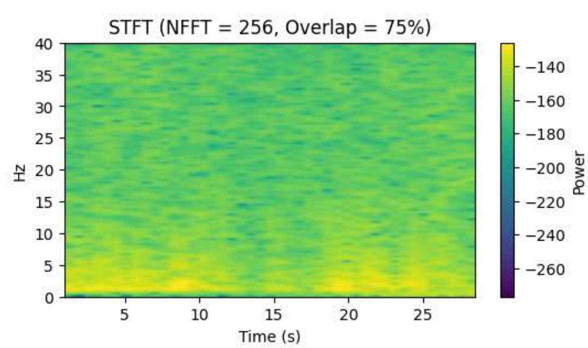

Figure 9: *Time-Frequency plot*

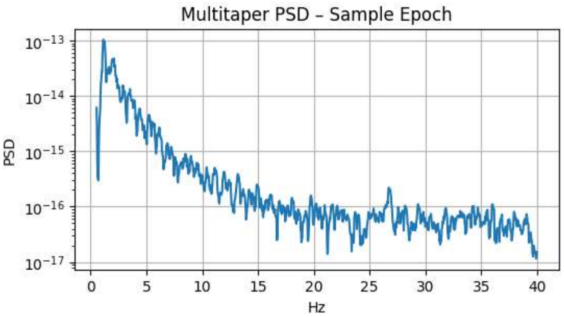

Figure 10: *Power spectral density*

Table 1: *Sleep Stage Detection Accuracy*

S.N	Model	Accuracy (%)
1	Random forest	75
2	SVM	80
3	Logistic regression	85

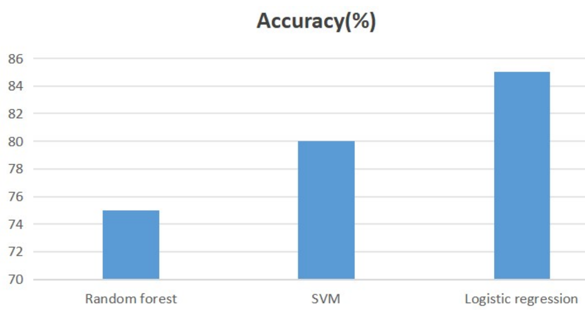

Figure 11: *Accuracy comparison*

Figure 8 represents Band pass filter. Figure 9 shows time-frequency representation from STFT. Figure 10 indicates power spectral density obtained from STFT used for sleep stage prediction. Sleep stage prediction accuracy listed in Table 1. LR model shows highest accuracy 85% over other proposed models such as SVM and RF. Comparison accuracy between proposed results shown in Figure 11. Figure 12 represents LR machine learning model confusion matrix.

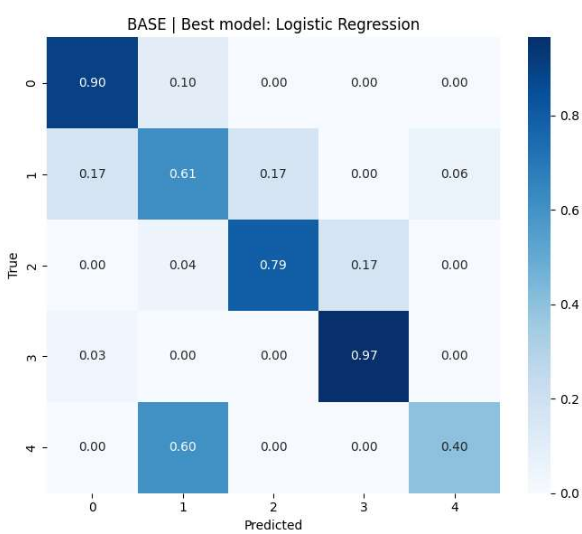

Figure 12: *LR Confusion matrix*

5. CONCLUSION

Proposed research have concentrated on sleep staging to support sleep regulation or the treatment of sleep disorders, despite recent advancements in automatic sleep staging. This paper proposes a novel network called machine learning that can accurately handle sleep stage prediction and calibration sleep staging. FFT and STFT are coordinated by the proposed network for EEG analysis in order to balance the network's operational efficiency and thorough feature extraction. SVM, RF and LR machine learning models used to predict sleep stages. Logistic regression model produces highest accuracy 85% in sleep stage prediction over SVM and RF models. Early sleep stage monitoring will create awareness on human to take care their health.

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