MULTI-CLASS SVM BASED ON SLEEP STAGE IDENTIFICATION USING EEG SIGNAL

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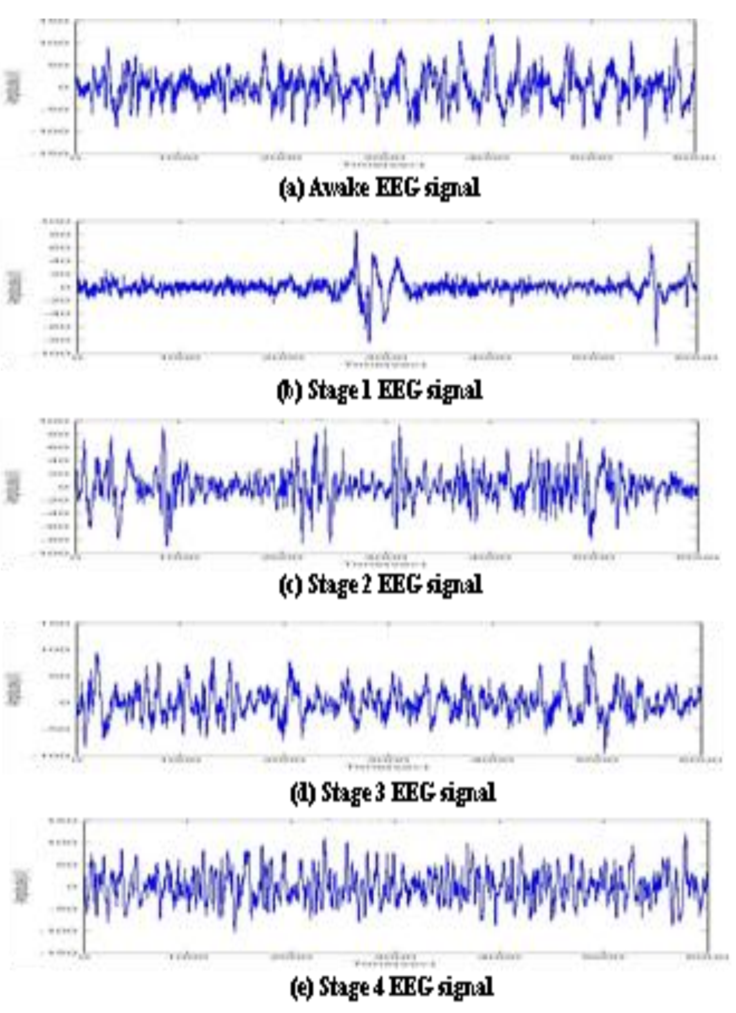
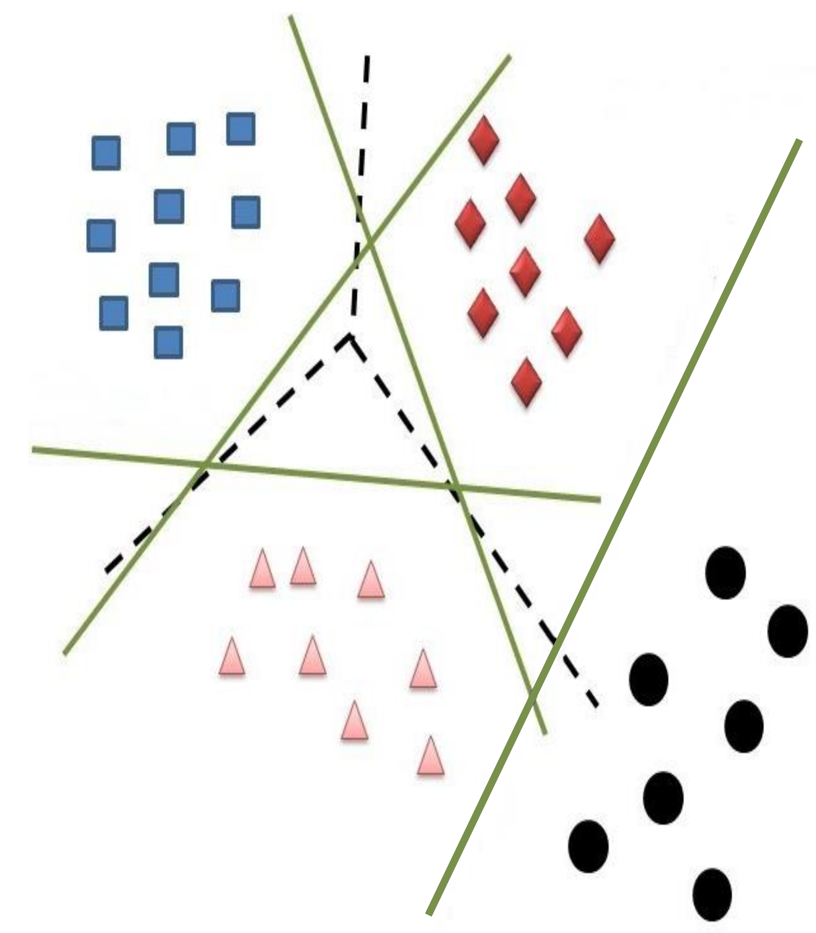
ABSTRACT

Currently, sleep disorders are considered as one of the major human life issues. Human sleep is a regular state of rest for the body in which the eyes are not only usually closed, but also have several nervous centers being inactive; hence, rendering the person either partially or completely unconscious and making the brain a less complicated network. This paper introduces an efficient technique towards differentiating sleep stages to assist physicians in the diagnosis and treatment of related sleep disorders. The idea is based on easily implementable filters in any hardware device and feasible discriminating features of the Electroencephalogram (EEG) signal by employing the one-against-all method of the multiclass Support Vector machine (SVM) to recognize the sleep stages and identify if the acquired signal is corresponding to wake, stage1, stage2, stage3 or stage4.The experimental results on several subjects achieve 92% of classification accuracy of the proposed work. A comparison of our proposed technique with some recent available work in the literature also presents the high classification accuracy performance.

SAMPLE EEG SIGNAL



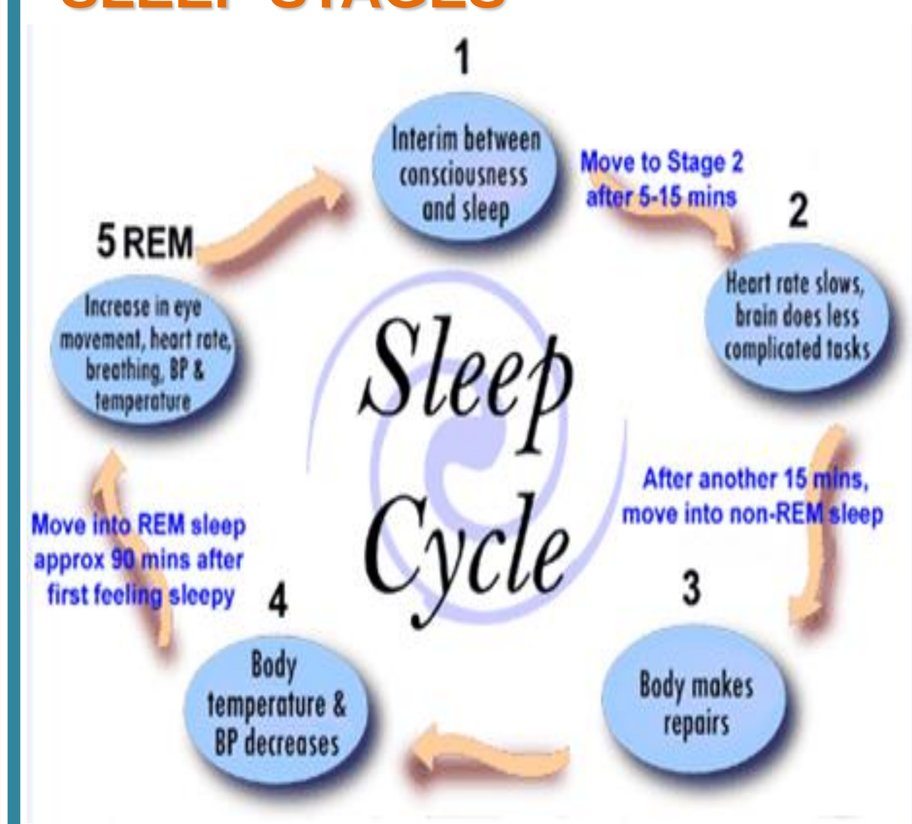
MULTI-CLASS SUPPORT VECTOR MACHINE



SIGNIFICANCE

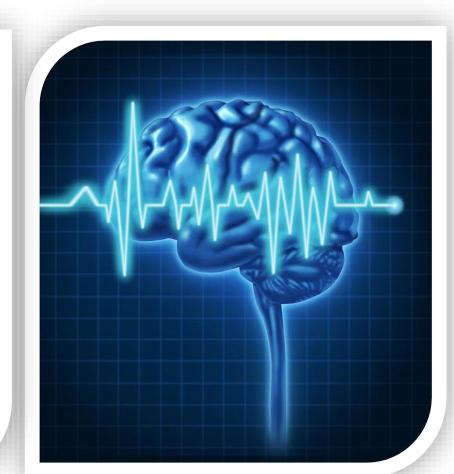
Sleep is an important part that plays a significant role in every brain development. Human spend about one-third of their lives asleep. The occurrence of sleepiness problem is high and has serious effect on people's physical health. According to National Highway Traffic Safety Administration, falling asleep while driving causes at least 100,000 automobile crashes annually in the United States. Also, driver drowsiness involves 30% of traffic accidents in Europe. Furthermore, sleep diseases such as insomnia and obstructive sleep apnea have a negative impact on human life quality. Approximately 33% of the world's population suffers from insomnia symptoms. Therefore, discriminating human sleep stages is very significant for diagnosis and treatment of sleep disorders such as apnea, insomnia and narcolepsy.

SLEEP STAGES

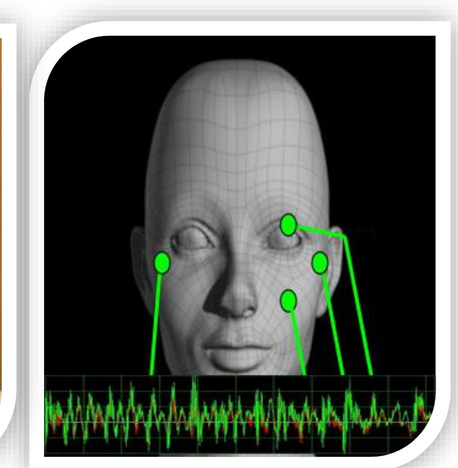


BIOMEDICAL SIGNALS


ECG


EEG


EMG


EOG

PROPOSED METHOD

1. Input EEG
2. Filtering and Decomposing in to five sub-bands
3. Statistical Feature Extraction
4. Multiclass Support Vector Machine
5. Classification

EEG SLEEP STAGE CLASSIFICATION

EEG DATASET

The dataset used in this paper is publicly available online from PhysioNet using the Sleep-EDF [Expanded] Database.

	Wake	Stage 1	Stage 2	Stage 3	Stage 4
Subject 1	18	18	10	8	20
Subject 2	12	12	11	11	19
Subject 3	-	24	20	11	1
Subject 4	-	19	29	9	2
Subject 5	-	11	12	4	4
Subject 6	-	16	8	4	11
Subject 7	10	-	10	10	-
Subject 8	10	-	-	3	13
Subject 9	10	-	-	10	-
Subject 10	10	-	-	4	2
Subject 11	10	-	-	4	4
Subject 12	10	-	-	14	2
Subject 13	10	-	-	8	22
Total	100	100	100	100	100

SUBJECTS INFORMATION

DATA DECOMPOSITION

The acquired EEG signal is decomposed into five different sub-bands using five efficient Infinite Impulse Response (IIR) Butterworth band-pass filters.

The minimum order is defined as:

$$N = \frac{1}{2} \times \frac{\ln(G_p/G_s)}{\ln(\omega_p/\omega_s)}$$

whereas G_p is pass-band gain, G_s is stop-band gain, ω_p is corner pass-band frequency, and ω_s is corner stop-band frequency.

Rythm	Frequency	Amplitude
Delta Δ	0-4 Hz	20-100μV
Theta θ	4-8Hz	10μV
Alpha α	8-12Hz	2-100μV
Beta β	12-22Hz	5-10μV
Gamma γ	>30Hz	-

AMPLITUDE AND FREQUENCY RANGE OF DECOMPOSED EEG SIGNAL

FEATURE EXTRACTION

(1) Energy

$$E = \sum_{n=1}^{N} \left| xi[n] \right|$$

$where\ 1 \le n \le 6000, 1 \le i \le 5$

(2) Entropy

$$EN = \sum_{j=1}^{N} (X_{ij}^2) \log(X_{ij}^2)$$

$1 \le j \le 6000, 1 \le i \le 5$

(3) Standard Deviation

$$STD = \sqrt{\frac{1}{N-1} \sum_{n=1}^{N} \left(y[n] - \frac{1}{N} \sum_{n=1}^{N} y[n] \right)^2}$$

$1 \le n \le 6000$

RESULTS

EEG Datasets	Sensitivity	Specificity	Total accuracy
Wake	100%	100%	92%
Stage 1	100%	97.30%	
Stage 2	90%	94.87%	
Stage 3	70%	100%	
Stage 4	100%	97.30%	

OVERALL PERFORMANCE RESULTS

Author name	Classifier	EEG Dataset	Accuracy
Yi Li et al 2009	Nearest Neighbor	8 Subjects (EDF dataset)	81.7%
Chih & Sheng 2011	Linear Discriminate analysis	20 Subjects	89.1%
Chih et al 2013	SVM	10 Subjects	77%
Mora 2010	KNN, SVM, GPROP and KANTS	9 Subjects	70%
Jacob 2013	Multiclass SVM	40 Subjects	91%
Proposed Method	Multiclass SVM	13 Subjects (EDF dataset)	92%

COMPARISON TABLE

CONCLUSION

In this work, the sleep stages identification for a single channel EEG signal based on a novel filtering and classification technique is presented. The experimental results using a linear kernel function of multiclass SVM indicate that the proposed methodology achieves the average classification accuracy of 92%. The filters used to extract the sub-bands are of less complexity compared to other relevant designs. Therefore, our simpler, quicker and more feasible design makes our work attractive for easy implementation in any embedded system/hardware engine as a personalized stand-alone device for identifying certain patterns such as detecting fatigue, drowsiness, and/or various sleep disorders like sleep apnea. When comparing the performance of this work with some recent available work on classification of sleep stages, the result show that the proposed work has certain advantages in terms of accuracy and feasibility.