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TEMPORAL RELATIVE SPECTRAL POWER BASED REAL TIME MOTOR IMAGERY CLASSIFICATION

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ABSTRACT

After the advent of Biofeedback era, the requirement of an effective online processing algorithm for EEG data becomes very vital. In this paper, authors proposed a decent method for real time classification of EEG data for imagination of left hand and right hand movement, based on temporal variation of relative spectral power. The proposed Temporal Relative Spectral Power (TRSP) based algorithm is first and robust unsupervised machine learning algorithm for real time brain computer interface(BCI). The relative spectral power is used as feature. The estimated feature further processed for classification through probabilistic Bayesian classifier. The proposed method of EEG signal processing outperforms the conventional wavelet based BCI competition II results for movement imagery classification.

Keywords: Brain Computer Interface (BCI), Electroencephalogram (EEG), Movement Imagery, Temporal Relative Spectral Power (TRSP) and Wavelet.

INTRODUCTION

The BCI transforms signals originating from human brain into commands that can be used to control the devices. BCI systems provides adequate assistive and artificial intelligent systems for the paralytic disabilities and many supportive systems for the human society[1]-[2]. BCI system provides an intended action based on the decision provided by analyzing different brain signals explained in [3] Ali Bashashati et. al.

BCI systems consists of five stages such as Signal Acquisition, Signal Preprocessing, Feature Extraction, Feature Classification and Controlling External Equipment for intended action. A correct conclusion can be drawn through the BCI systems depends on the various signal processing and classification algorithms used in the preprocessing, feature extraction and feature classification.

Different pre-processing methods like Independent Component based EOG correction techniques explained in [4] A. Srinivasulu et.al..Different pre-processing methods like Common Spatial Patterns (CSP), Short Time Fourier Transform (STFT), Principal Component Analysis (PCA) etc explained in [3] Ali Bashashati, [5] S. Bhattacharyya et.al and [6] M. K. Mukul et.al.. Pre-processed brain signals further processed through different feature extraction algorithms like Hjorth Parameter, Power Spectral Density, Relative spectral power (RSP) , Temporal Relative Spectral Power (TRSP), Time Frequency Relation (TFR), Cepstral Coefficient, Cepstrum etc. explained in [7] B. Hjorth, [8] M. K. Mukul et.al, [9] S. Bhattacharyya et.al., [10] H. T. Ngoc et.al., [11] S. Bhattacharyya et.al..

The extracted features are further processed through different type of classification algorithms like Linear Discriminant Analysis (LDA), Support Vector Machine (SVM), Naive Bayes, different Bayesian Classifiers etc. described in [9],[11] S. Bhattacharyya et.al [12] R.O. Duda et al..

The proposed algorithm shows better performance than conventional Wavelet based BCI competition II results in different BCI evolution parameter like signal to noise ratio, mutual information, time complexity etc.

EEG signals have very low amplitude(micro volt range), low frequency(0-50 Hz approximately). Based on frequency bands EEG signals are classified as : Delta band (1-4 Hz), Theta band (4-8 Hz), Alpha band (8-12 Hz), Beta band (13-25 Hz), Gamma band (25-40 Hz) [13]. The nerve cells of primary sensory motor cortex regions got excited due to movement imagination. The electrodes placed in this area are C3 and C4. Primarily Alpha and Beta rhythms are affected by movement imagery related activity like the tongue movement, hand movements, foot movements etc.

The FIR band pass filter has been used as a preprocessing method. The filtered EEG signal has been used as feature extraction process [8]. The outcomes of the feature extraction process are subjected to feature classification. The extracted features are classified by the simple probabilistic Bayesian classifier [11-12]. This classification decision further used to control an external machine by the thought of the user [1-3]. This article is divided into five sections. Section II enlighten the experimental paradigm[14-15]. Section III explained proposed algorithm, Section IV narrate the result and discussions and Section V describes the conclusion and future work.

EXPERIMENTAL PARADIGM

The dataset III of the BCI competition II [14-15] was used for this study. This dataset has been provided by the Department of Medical Informatics, Institute for Biomedical Engineering, University of Technology Graz. Data set comprises of left hand and right hand movement imagination. The Data has been recorded from one healthy subject from 3 electrodes such as C3,Cz and C4. The Dataset contains 280 trials including training and testing data. The cue was scheduled from three second to nine second. It was recorded from a normal subject (female 25year) during a normal feedback session. The task was to control a feedback bar by means of imagination of left hand and right hand movement. The sampling frequency of the recorded data set was 128Hz.

The data set contains 3 EEG channels, 280 trials with 9 seconds each. The timing scheme of the paradigm is depicted in Fig. 1 [15]

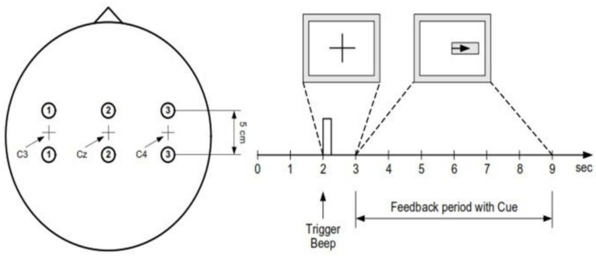

Fig. 2. Timing scheme of the BCI competition II, dataset III[15]

PROPOSED METHOD

Block diagram of the the Proposed algorithm of EEG signal preprocessing is shown in Fig. 3. The recorded EEG signals (shown in block I) may be contaminated with various kinds of physiological artifacts like eye blinking, eye movement etc. The EOG signal is the most dominant artifacts present in the recorded EEG signal [3-4].

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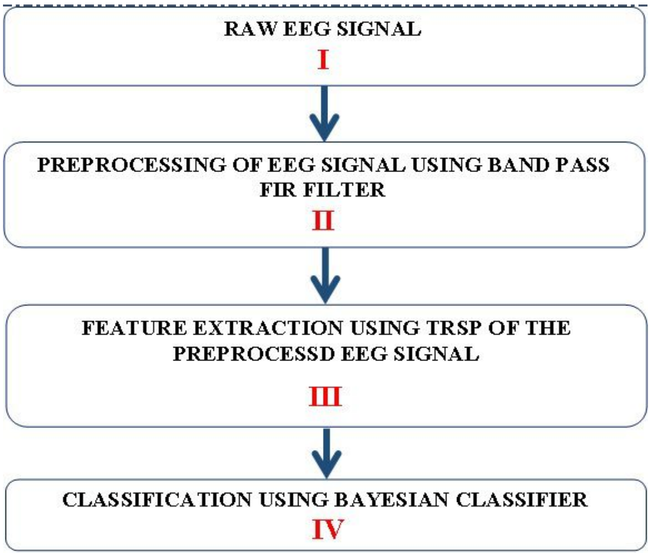

Fig. 3. Proposed Methodology

Recorded EEG signal has been processed to FIR band pass filter to extract motor band signal from the EEG signal (shown in block II).

The filtered signal is subjected to TRSP estimation method (displays in block III). The relative spectral powers are taken as feature matrix, those are further subjected to Bayesian classifier (shown in block VI).
The raw EEG signal is represented as $E_C^i(n)$ where C ∈ [C3, C4] and i ∈ [left, right].

A. Pre-processing

Band Pass Filter
maximum information of the EEG signals contain in some frequency bands depends on subjects. This frequency bands are frequently called as reactive frequency bands. In order to retrieve the frequency band information here band pass FIR filter has been used for filtering of the alpha(approximately 10-12 Hz) and beta (approximately 20-22 Hz) band. The FIR band pass filtered EEG signal $X_C^i(n)$ can be expressed as

$$X_C^i(n) = h(n) * E_C^i(n) \qquad (1)$$

where $h(n)$ is the impulse response of order five hundred and $E_C^i(n)$ is the raw EEG signal.

B. Feature Extraction

TRSP
Instead of calculating absolute power of the filtered EEG signal in the given frequency bands, the relative power has been taken for calculation of the Relative spectral power (RSP)[8]. RSP is defined as the ratio of band spectral power (BSP) to total spectral power (TSP).

$$RSP_i = \frac{BSP_i}{TSP} \quad , \qquad (2) \text{ where i } \in \text{ [left, right]}$$

Total spectral power (TSP) is the average power of C3 and C4 channel over 8Hz to 30Hz frequency range. In this article the BSP has been calculated at 10Hz to 12Hz and 20Hz to 22Hz band for both c3 and c4 channel separately, for each signal. The mean of estimated TRSP has been considered as a feature for each sample. The TRSP is evaluated keeping the Parseval's theorem in. The resulting TRSP for two frequency sub bands at two electrodes are then stacked together to form four dimensional feature vector.

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C. Classification

The simple Bayesian classifier is the probabilistic classifier, based on the Bayes' theorem. The Bayesian classifiers requires a number of features vectors to solve a learning problem[11-12]. The classifier can predict class membership probabilities, such as the probability for a given task belongs to a particular class. Bayesian classifiers have also exhibited high accuracy and low computation time when applied to large databases.

The core formulation of Bayesian Classifier is

$$p(y/a(t)) = \frac{p(a(t)/y).p(y)}{\sum_{m=1}^{2} p(a(t)/y_m).p(y_m)} , \qquad (3)$$

where of the two classes $y = \{L, R\}$ at each instance of sample. $a(t)$ is the feature vector and m has values one and two for left hand and right hand movement imagination respectively..

$$p(a(t)/y) = \frac{\left|\sigma_t^y\right|^{-0.5}}{(2\pi)^2} e^{(-0.5(a(t)-\mu_t^y)^T(\sigma_t^y)^{-1}(a(t)-\mu_t^y))}, \qquad (4)$$

where μ and σ are the mean and covariance matrix of the two classes.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The authors consider the BCI competition II dataset III for performance analysis of the proposed method.
The proposed TRSP feature has been used to classify the EEG signals using Bayesian classifier. Here the proposed feature (TRSP) with Bayesian classifier is compared with the result of the BCI competition winner on same data set. The winner group has been used morlet wavelet filtering followed by Bayesian classifier for classification. The MI and SNR for proposed method is higher than the BCI competition winner. The MI and SNR on testing data is 0.76 bit and 1.87 for the proposed method. The error rate and Classification time is 9.63 and 7.39 for the proposed method.

The Table 1 shows a comparative study between three online classification methods. The proposed TRSP applied on Bayesian classifier as feature gives better result than the other methods. Normally LDA has been used for binary classification problems. TRSP with LDA shows maximum MI of .42bit on testing dataset.

Table 1. Performance analysis of the proposed algorithm in terms of Error, SNR, MI and Classification time for testing data set.

Name of the Methods	**Min Error [%]**	**Max SNR**	**Max MI [bit]**	**Classification Time T [s]**
TRSP+LDA	14.85	0.99	0.42	8.35
BCI Competition II results of **Group C (Wavelet** filtering + **Bayesian** classifier)	10.71	1.34	0.61	7.59
Proposed Method (TRSP + Bayesian classifier)	9.63	1.87	0.7610	7.39

The minimum error of the proposed method is 1.08 percent lesser than the BCI competition II result of the group C and 5.22 percent lesser than the TRSP with LDA method.

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The maximum mutual information of the proposed method is 0.151 bits greater than the BCI competition II result and 0.341 bits greater than the TRSP with LDA method. The classification time of the of the proposed method is 0.2 second less than the competition II result and 0. 96 second less than the TRSP with LDA method.
The performance of the proposed method for testing data of the has been compared with the performance of the morlet wavelet filtering based BCI Competition II method shown in the Fig 4 and Fig 5.

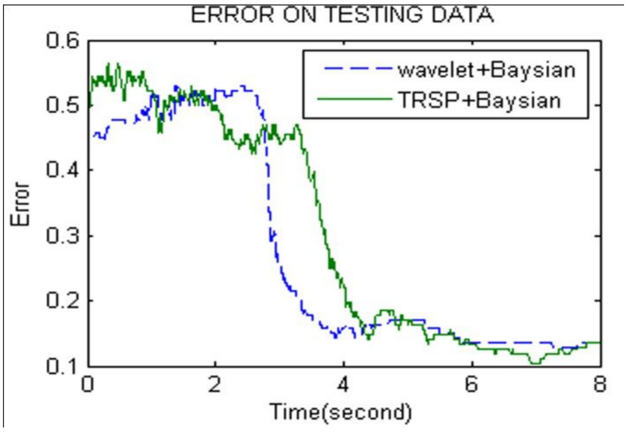

Fig. 4. Classification Error rate plot of proposed method and Wavelet based method for testing data

The maximum SNR of the proposed method is 0.53 greater than the BCI competition II result and 0.88 greater than the TRSP with LDA method.

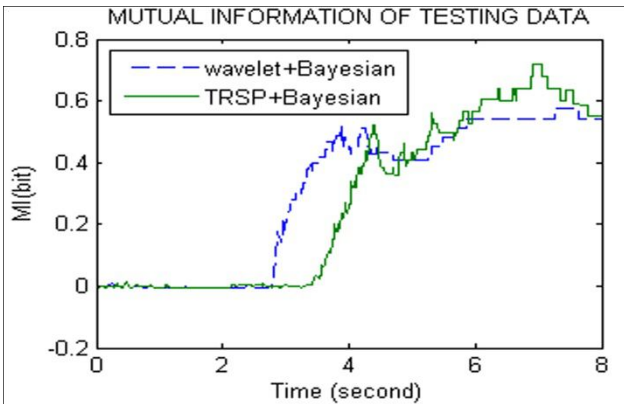

Fig.5.Mutul Information plot of proposed method and Wavelet based method for testing data

CONCLUSION AND FUTURE WORK

The proposed algorithm shows outstanding performance on movement imagery classification. The proposed method is extremely simple and simple for implement. The computational time of this proposed method fast as compared with the TRSP with LDA and the BCI competition result. Through this study, it has been concluded that the Bayesian classifier improves the performance level compared with other models. To achieve fast computational speed with higher mutual information is now a day main focus point of the research. The future work lies in detecting the cue and then classifies the trials using the proposed algorithm in case of asynchronous movement imagination. The algorithm is then be utilized to directly control embedded robot to help the patient with disability.

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REFERENCES

[1] Jonathan R. Wolpaw et. al.. "Brain-computer interface technology: A review of the first international meeting", IEEE Transactions on Rehabilitation Engineering. 8(2), pp.164–173, 2000.

[2] N. R. Carlson. Foundations of physiological psychology, Allyn and Bacon, 7th Edition, 2007.

[3] Ali Bashashati, Mehrdad Fatourechi, et al. A survey of signal processing algorithms in brain–computer interfaces based on electrical brain signals. Journal of Neural Engineering, 4, 32-57, 2007.

[4] A. Srinivasulu et. al.. Artifacts Removing From EEG Signals by ICA Algorithms. IOSR Journal of Electrical and Electronics Engineering (IOSRJEEE), 2(4), 11-16, 2012.

[5] S. Bhattacharyya, Manoj Kumar Mukul. Short Time Fourier Transform based Dominant Frequency Extraction Algorithm for Brain Computer Interface", International Journal of Scientific Research & Technology, ISSN 24549800, 2(1), 67-74, 2016.

[6] M. K Mukul & F. Matsuno. Comparative study between subband and standard ICA/BSS method in context with EEG signal for movement imagery classification. IEEE/SICE International Symposium, pp. 341-346, 2010.

[7] B. Hjorth. EEG analysis based on time domain properties. Electroencephalography and clinical neurophysiology, 29(3), 306-310, 1970.

[8] M. K. Mukul,., & F. Matsuno. Relative spectral power (RSP) and temporal RSP as features for movement imagery EEG classification with linear discriminant analysis. In SICE Annual Conference 2010, Proceedings of (pp. 439-448), 2010.

[9] S. Bhattacharyya, Manoj Kumar Mukul. Cepstral Coefficients Based Feature for Real Time Movement Imagery Classification, International Journal of Engineering and Technology, ISSN. 0975-4024, 8(1), 117-123, 2016.

[10]H. T. Ngoc, T. H. Nguyen, & C. Ngo. Average partial power spectrum density approach to feature extraction for EEG-based motor imagery classification. American Journal of Biomedical Engineering, 3(6), 208-219, 2013.

[11]S. Bhattacharyya, Manoj Kumar Mukul. Cepstrum Based Algorithm for Motor Imagery Classification, International Conference on Micro-Electronics and Telecommunication Engineering (ICMETE 2016) © 2016 IEEE, Sep 22-23, 397-402, 2016.

[12]R. O. Duda, P. E. Hart, & D. G. Stork. Pattern classification. John Wiley & Sons, 2012.

[13]S. Sanei, & J. A. Chambers. EEG signal processing. John Wiley & Sons, 2013.

[14]BCI Competition II. 2003. [Online]. [Accessed on 15th December 2016]. Available from: http://www.bbci.de/competition/ii/

[15]A. Schlögl, C. Neuper & G. Pfurtscheller. Estimating the mutual information of an EEG-based brain-computer interface. Biomedizinische Technik/Biomedical Engineering, 47(1-2), 3-8, 2002.

[16]BCI Competition II.- Results [Online]. [Accessed on 25 August 2016]. www.bbci.de/competition/ii/results/TR_BCI2003_III.pdf