

Hand Movement Classification Using Motor Imagery EEG

Rinkal G. Shah¹, Prof. Ritu Nayak²

P.G. Student, Department of Biomedical Engineering, Government Engineering College, Gandhinagar, Gujarat, India¹

Professor, Department of Biomedical Engineering, Government Polytechnic College Gandhinagar, Gujarat, India²

ABSTRACT: Brain computer interfaces (BCI) offers imagination of various limb movements for patients suffering from several physical hindrances. Moreover, BCI also offers analysis of motor imagery EEG, which can be shown is a new way of communication for these patients. Motor imagery data for hand movement classification like left hand & right hand movement are available on Physionet ATM or BCI competition datasetIII. Using different feature extraction and classification method, we can get best result in the form of accuracy for hand movement classification.

KEYWORDS: Motor imagery EEG, event related desynchronization/ event related synchronization (ERD/ERS), Wavelet transform, Independent component analysis (ICA), Support vector machine (SVM).

I. INTRODUCTION

With the development of novel technologies to study brain function, Electroencephalography (EEG) is widely used as a digital signal processing tool for diagnosis of various disorder related to brain disorder. EEG signals have now been popularly used in a wide variety of applications such as seizure detection/prediction, motor imagery classification, mental task classification, emotion classification, sleep state classification, and drug effects diagnosis^[1]. EEG is a quite small signal which can measure electrical activity of the brain generated by nerve firing in the brain which usually contain physiological & non physiological artifacts. These artifacts typically have much higher amplitude than brain signals so it produces great difficulty to interpret the EEG signal.

Brain computer interface (BCI) has the power to translate the neural command extracted from EEG signal into machine language. Therefore, improvement in the analysis of EEG signal is the goal of many researchers. EEG signals of motor imagery can be seen as a new way of communication for persons suffering from severe physical handicaps^[2]. Motor imagery is a mental task in which the subject imagines that he is doing an action. Motor imagery classification is very important for certain patients^[1] even though most other research focused on discriminating EEG signals between left hand, right hand, toe, and tongue imagined movement^[3].

In the EEG signal, event related potential is closely related with the neural activity on the cerebral motor cortex. When the human sensory system gets or feels a certain external stimulation, the corresponding regions of cerebral cortex will produce potential and change in event related potential. Researchers show that both sides of the brain hemisphere will have a certain frequency band (μ rhythm/ β rhythm) ERP signal and make EEG power spectrum strengthened (event related synchronization) and weakened (event related desynchronization) when human imagining or doing left-right hand movement^[4].

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

Sr. No.	Hand movement imagined by brain	Power spectrum	ERD (event related desynchronization) position	ERS (Event related synchronization)
1	Left	Weak	Right hemisphere of the brain	Left hemisphere of the brain
2	Right	Strong	Left hemisphere of the brain	Right hemisphere of the brain

Table:1 courtesy: ^[4]

As described in table the ERD phenomenon appears in the left hemisphere of the brain and ERS phenomenon appears in the right when the brain imaging the right hand movement. ERD phenomenon appears in the right hemisphere of the brain and its power spectrum is weakened. Meanwhile, ERS appears in the left hemisphere of the brain and makes its power spectrum strengthened ^[4]. In this paper, we present the review of various methodologies for right & left hand imagery movement analysis.

II. RELATED WORK

- Homri Ines, Yacoub Slim and Ellouze Nouredine "*EEG Classification using Support Vector Machine*" 10th International Multi-Conference on system, signal & devices, hammanmet, tunisia, 2013

In this paper the main goal of author is to classify the left & right hand movements using motor imagery EEG. In this Paper the author is used to EEG motor imagery data for the study is dataset III available in BCI competition II. Then this Dataset consists of 140 trials of training data and 140 test trials, each trial of 9s contains records acquired by electrodes C3 and C4 according to the international 10-20 system of electrode placement. then the Wavelet transform method is applied for extraction of different types of features like mean, power and standard deviation. Then the different feature matrix are used in svm classifier for classification of hand movements using the linear model for nonlinear data. As a result we get highest accuracy rate of SVM classifier compare to LDA & NN methods.

- So-Youn Park, Ju-Jang Lee, "*EEG Feature Extraction and Classification Using Data Dimension Reduction.*", IEEE international conference on industrial informatics, 2008

In this paper the Sleep EEG classified into 7 stages (Awake, Stage 1, Stage 2, Stage 3, Stage 4, REM, and Morning awake in order)

The author is then used 2 types of feature extraction method

1. Frequency domain feature extraction.
2. Non-frequency domain feature extraction.

3 features are classified using different classification method, which are central frequency, mean of the absolute amplitude, and the Itakura distance.

compare to these other classifier Such as PCA & MMC, the LDA gave better recognition rate.

- SuolinDuan, TingtingXu, Wei Zhuang, Dan Mao, "*The Feature Extraction of ERD/ERS Signals Based on the Wavelet Package and ICA*", 11th world congress on intelligent control & automation, china, july-2014.

The author used different types of methodology with again combination of different methods which described below.

- 1) Feature Extracting of Frequency Band by Wavelet Packet Transform.
- 2) Wavelet Domain ICA.
- 3) ERD/ERS Quantization Coefficients.

The author is proved that the WPICA (combine wavelet packet and ICA) algorithm is obviously higher than the classical ICA method.

III. METHODOLOGY

In this paper, figure 1 described the whole methodology for hand movement classification for that the raw EEG signal is utilized from the dataset III available in BCI competition II (2003) as well as from the physionet dataset. EEG signals are then filtered between 0.5 to 50Hz with 128 Hz sampling rate using the MATLAB© software. In this paper

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

the EEGLAB toolbox & the MATLAB© scripting were used for preprocessing of the EEG data, feature extraction method & feature classification.

ICA(Independent component analysis) method using EEGLAB and the wavelet transform method using Daubechies4 wavelet for feature extraction purpose allows to get further insights into the features like mean, power & standard deviation for hand movement classification.

Since relevant characteristics of hand movement imagination exist in mu (μ) and Beta (β) bands, wavelet coefficients of details D2 and D3 are considered and following statistical parameters are created in order to reduce the size of features vectors, where D1-D3 are the detail sub-bands and one final approximation is A3. Subsequently, the extracted features are going to be classified using the two classification methods namely K- means clustering & the SVM (support vector machine) classifier.

A. EEG Data acquisition

There are a number of ways to collect raw EEG data (described below). In this paper we used the datasets listed below.

- The raw EEG datasets are available in Physionet^[10] by the developers of the BCI2000^[11] instrumentation system.
- BCI Competition 2003 Data set III, provided by the brain computer interface research center of Austria Graz University, consists of 140 trials of training data and 140 test trials, each trial of 9s contains records acquired by electrodes C3, CZ and C4 according to the international 10-20 system of electrode placement. In each trial, subject imagined left or right hand movement between 3s and 9s. Dataset contains three records:
 - x-train contains 140 training trials
 - x-test contains 140 test trials
 - y-train contains trials labels {1, 2} for left and right hand movement, respectively, saved in x-train.

B. Channel selection for motor imagery dataset

The main purpose of the channel selection process is threefold: (i) to reduce the computational complexity of any processing task performed on EEG signals by selecting the relevant channels and hence extracting the features of major importance, (ii) to reduce the amount of over fitting that may arise due to the utilization of unnecessary channels, for the purpose of improving the performance, and (iii) to reduce the setup time in some applications. Filtering techniques, Wrapper techniques and Embedded techniques are the three most useful channel selection techniques for motor imagery data.

In this paper, hand movement classification EEG signals recorded from channels C3 and C4, over sensory-motor cortices activated during movement imagination, are analyzed to assess sensory-motor rhythms mu [8 13] HZ [17] and beta [13 30] HZ located in the Centro-temporal region of the scalp.

C. Signal pre-processing

As EEG signals are known to be noisy and non-stationary, filtering the data is an important step to remove the unnecessary information from the raw signals. **Band pass filter** is used to remove the DC (direct current) shifts and to minimize the presence of filtering artifacts at epoch boundaries. **FIR filter** is used to remove the 50 Hz line noise.

EEG Temporal Windowing: EEG dataset is composed of a train set and a test set including each 140 trials of 9s length. Each trial is segmented with sliding windows of 256 samples corresponding to 2 seconds with a shift of one point. In this way each trial is composed of 385 EEG segments.

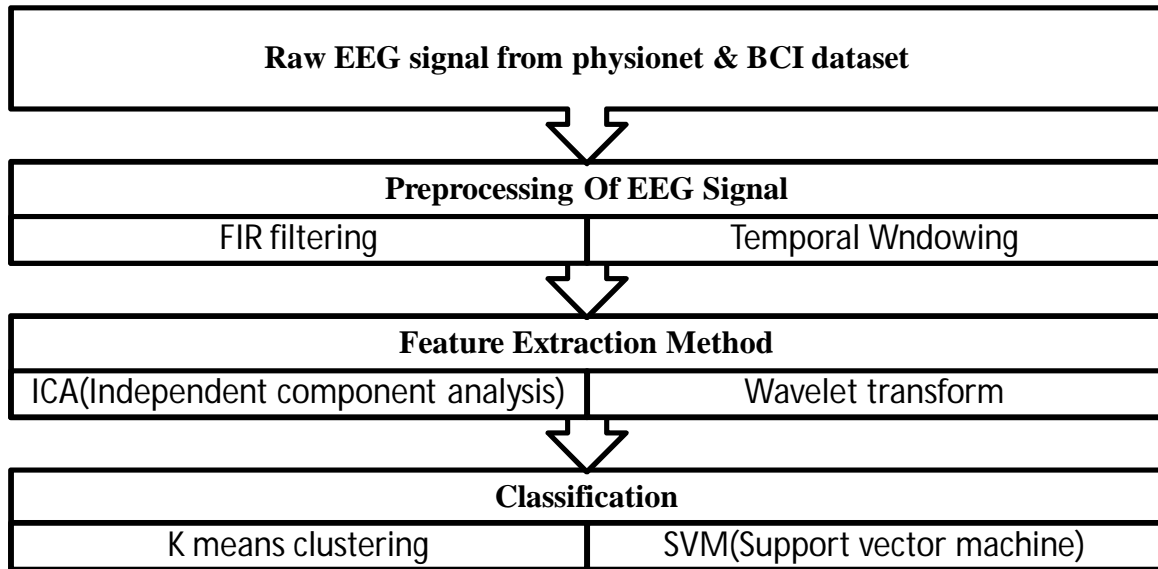


Fig. 1- Proposed algorithm

D. Feature extraction method

EEG signals recorded from channels C3 and C4, over sensory-motor cortices are activated during movement imagination. In this paper we used two types of methods for feature extraction.

1. **ICA:** Independent component analysis (ICA) is a computational method for separating a multivariate signal into additive subcomponents. ICA is widely used in the EEG research community to detect and remove eye, muscle, and line noise artifacts and also to separate biologically plausible brain sources whose activity patterns are distinctly linked to behavioral phenomena.
2. **Wavelet transform for feature extraction:** Daubechies4 wavelet is used to find appropriate EEG decomposition. EEG sampled at 128 HZ are decomposed into three levels, three details sub-bands D1-D3 and one final approximation A3. Wavelet coefficients of details D2 and D3 are considered, from which the following statistical parameters are created.
 - P1: Mean of the absolute values of wavelet coefficients of detail sub-bands {D2, D3} taken from {C3, C4} Channel.
 - P2: Standard deviation of wavelet coefficients.
 - P3: Average power of wavelet coefficients.

Parameters P1 and P3 provide information related to the power spectrum of the signal, and parameter P2 presents the variation in the power spectrum over time.

E. Feature Classification using SVM Classifier & k-means clustering: Hand movement classification using motor imagery EEG require to choose an accurate classifier for proper classification and as per study of existing methods SVM classifier is most widely used for Hand movement classification.

1. **K means clustering:** *k*-means clustering aims to partition *n* observations into *k* clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster.
2. **SVM (Support Vector Machine):** A support vector machine constructs a hyper plane or set of hyper planes in a high- or infinite-dimensional space, which can be used for classification, regression, or other tasks. A good separation is achieved by the hyper plane that has the largest distance to the nearest training-data point of any class (so-called functional margin), since in general the larger the margin the lower the generalization error of the classifier.

IV. RESULTS

In this section, we present the results of various methodologies of different algorithms applied to the raw EEG data as discussed in 'Methodology' section. The final results of two classifiers are described here.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

1. SVM classifier results: Described below are the graphs generated after the result we get from SVM classifier after performing the preprocessing & Feature extraction using wavelet transform.

Fig2Classification using SVM classifier
A) Left hand movement
B) Right hand movement

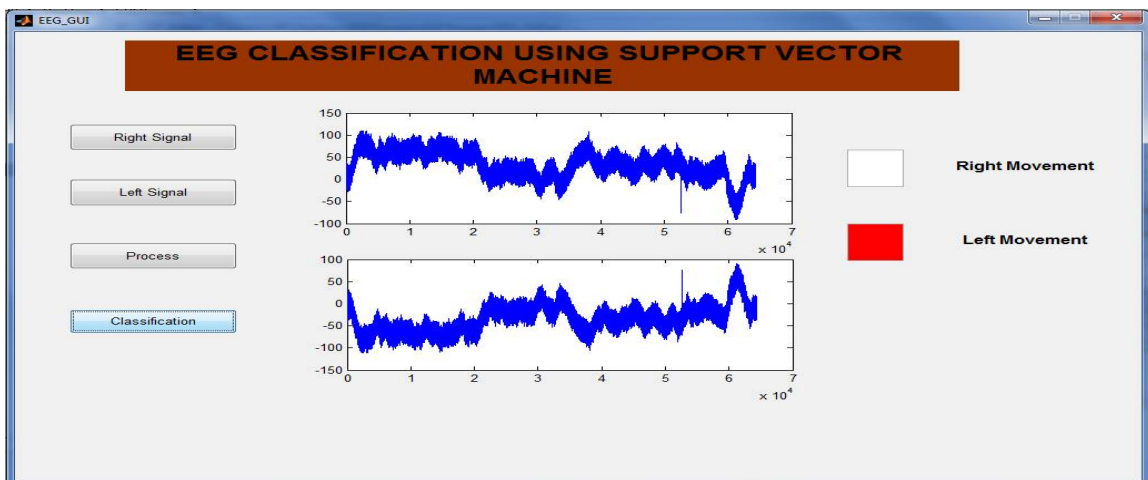


Fig. 3- GUI representation of final result

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

A

Number	Features of wavelet co-efficient in sub band of EEG	Value
1	Mean_d23	0.0606
2	Mean_d24	0.0689
3	Mean_d33	0.1277
4	Mean_d34	0.0987
5	Mean_l23	0.0384
6	Mean_l24	0.0372
7	Mean_l33	0.0544
8	Mean_l34	0.0431

B

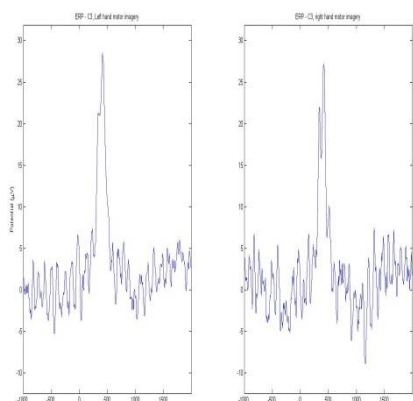
Number	Features of wavelet co-efficient in sub band of EEG	Value
1	Pwr_d23	183.78
2	Pwr_d24	180.88
3	Pwr_d33	1.0823e+03
4	Pwr_d35	1.0587e+03
5	Pwr_l23	162.17
6	Pwr_l24	158.67
7	Pwr_l33	10123e+03
8	Pwr_l34	1.0985e+03

C

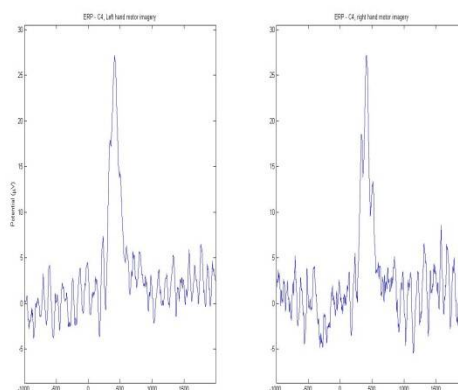
Number	Features of wavelet co-efficient in sub band of EEG	Value
1	Std_d23	13.55
2	Std_d24	13.44
3	Std_d33	32.90
4	Std_d34	32.54
5	Std_l23	12.73
6	Std_l24	12.59
7	Std_l33	33.52
8	Std_l34	33.14

Table:2 Statistical analysis of wavelet features

2. K-means clustering results using EEGLAB, after performing the FIR Filtering & the ICA(independent component analysis) are described here:



C3 Channel ERP for Left & right hand movements



C4 Channel ERP for Left & right hand movements

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

V. CONCLUSION & FUTURE SCOPE

This paper focuses on the classification of EEG signals for right and left fist movements based on a specific set of features. Very good results were obtained using K-means and SVMs showing that offline discrimination between right and left movement, for executed hand movements, is comparable to leading BCI research. This methodology is not the best, but it just simplifies the needs of researcher in the field of neuroscience.

In the near future, we aim to develop and implement our system in online applications, such as health systems and computer games. In addition, more datasets have to be analyzed for a better knowledgeable extraction and more accurate decision rules.

REFERENCES

- [1] TurkeyAlotaiby , Fathi E Abd El-Samie , Saleh A Alshebeili and Ishtiaq Ahmad, " A review of channel selection algorithms for EEG signal processing" Journal on Advances in Signal Processing, 2015.
- [2] J.R. Wolpaw, T.M. Vaughan and E. Donchin, "EEG based communication prospects and problems," IEEE Transactions on Rehab. Engineering, vol.04, pp. 425-430, 1996.
- [3] G. Schalk et al. "Decoding two-dimensional movement trajectories using electrocorticographic signals in humans," Journal of Neural Engineering, vol. 4, pp. 264-275, 2007.
- [4] SuolinDuan, TingtingXu, Wei Zhuang, Dan Mao, "The Feature Extraction of ERD/ERS Signals Based on the Wavelet Package and ICA."11th world congress on Intelligent Control and Automation, IEEE, July 2014.
- [5]Homri Ines, Yacoub Slim and EllouzeNoureddine"EEG Classification using Support Vector Machine." IEEE 10th International Multi-Conference on systems, signals &Devices. 2013.
- [6] P. Mark, K. Aleksandar, "Feature Extraction in development of brain-computer interface: a case study, " Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2003.
- [7] N. Brodu, F. Lotte, and A. Lécuycer, "Comparative Study of Band-Power Extraction Techniques for Motor Imagery Classification," IEEE Symposium on Computational Intelligence, Cognitive Algorithms, Mind, and Brain (SSCI'2011CCMB), pp. 1-6, 2011.
- [8] H. Ramoser, J. Muller-Gerking and G. Pfurtscheller, "Optimal spatial filtering of single –trial EEG during imagined hand movements," IEEE Trans. Neural Syst. Rehabil. Eng, vol.08, no.4, pp.441-446, 2000.
- [9] C.W. Anderson, E. Stolz, and S. Shamsunder, "Discriminating mental tasks using EEG represented by AR models," in IEEE 17th Annual Conference Engineering in Medicine and biology Society, vol.02 , 1995.
- [10] A. L. Goldberger, L. A. N. Amaral, L. Glass, J. M. Hausdorff, P. C. Ivanov, R. G. Mark, J. E. Mietus, G. B. Moody, C.-K. Peng, and H. E. Stanley, "PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals," Circulation, vol. 101, pp. e215-e220, 2000.
- [11] G. Schalk, D. J. McFarland, T. Hinterberger, N. Birbaumer, and J. R. Wolpaw, "BCI2000: a general-purpose brain-computer interface (BCI) system," IEEE Transactions on Biomedical Engineering, vol. 51, pp. 1034-1043, 2004.
- [12] TurkeyAlotaiby, Fathi E Abd El-Samie, Saleh A Alshebeili, Ishtiaq Ahmad, "A review of channel selection algorithmsfor EEG signal processing." Journal on Advances in Signal Processing, Springer, 2015
- [13] Homri Ines, Yacoub Slim and EllouzeNoureddine"EEG Classification using Support Vector Machine." IEEE 10th International Multi-Conference on systems, signals &Devices., 2013.
- [14] Ching-Chang Kuo, William S. Lin, Chelsea A. Dressel and Alan W.L. Chiu, "Classification of Intended Motor Movement using Surface EEG ensemble Empirical Mode Decomposition." 33rd Annual International Conference of the IEEE, 2011.
- [15] Chong Liu, Hong Wang, ZhiguoLu "EEG Classification for Multiclass Motor Imagery BCI." 25th Chinese Control and Decision Conference, IEEE, 2013.
- [16] Naoki Tomida, Toshihisa Tanaka, Shunsuke Ono, Masao Yamagishi, Hiroshi Higashi, "Active Data Selection for Motor Imagery EEG Classification.", IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, 2015.,
- [17] So-Youn Park, Ju-Jang Lee "EEG Feature Extraction and Classification Using Data Dimension Reduction." IEEE, 2008.
- [18] Shi-Yun Shao, Kai-QuanShen, Chong-Jin Ong, Xiao-Ping Li, " Automatic Identification and Removal of Artifacts in EEG Using a Probabilistic Multi-class SVM Approach With Error Correction", IEEE 2008.
- [19] O. A. Padierna Sosa, Y. Quijano, M. Doniz, J. E. Chong Quero, "Development of an EEG signal processing program based on EEGLAB."IEEE, 2011.
- [20] E. Urrestarazu, J. Iriarte, M. Alegre, M. Valencia, C. Viteri, and J.Artieda, "Independent Component Analysis Removing Artifacts in ictal recordings," Epilepsia, vol. 45, pp. 1071-1078, Sep. 2004.