BRAIN COMPUTER INTERFACE BASED WHEELCHAIR FOR DISABLE PEOPLE USING EEG SIGNAL

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ABSTRACT

Brain computer interface causes direct operation between brain and computer. Interfacing of the Electroencephalography (EEG) signal produced by the brain with any control or communication device produces unidirectional communicating channel. To develop a practical BCI system, three components should be considered. These are i) to establish an appropriate multivariate signal processing technique to extract multiclass features from multi-channel EEG signals, ii) to look up suitable pattern classification technique to improve the performance of BCI and finally iii) to develop an approprite interfacing circuit to control a user device. Due to poor classification acuracy, practical BCI system has not been fully materialised yet. However, an advanced and simple classification algorithm for motor imagery related BCI system has been developed with Mahalanobis Discriminant Analysis (MDA) technique. It obtains 93% of kappa accuracy in evaluation phase, which is validated and acceptable, whereas the accuracy with others is maxmimum 86%. Moreover, the developed technique needs a very low computational requirement that makes it suitable for real-time BCI based system to control a wheelchair for the disabled people. To have a fruitful result, the next phase of hardware realization research and interfacing with users are essential which is highly desired factor in a practical/ commercial BCI system development.

Keywords: EEG Signal, BCI, Classification Technique.

INTRODUCTION

Classification of EEG signals is a challenging task, especially in the case where the classification result has to be used for controlling an electronic device. This is because the classification of EEG signals has to be done on a single-trial basis. Such a system which transforms the brain signals into corresponding control signals is known as a Brain Computer Interface (BCI) (Wolpaw & McFarland 1994). To establish a communication link between the brain and an electronic system (i.e. a computer or wheelchair), different neural signals can be used: EEG rhythms, slow negative potential shifts, and evoked potentials (Pfurtscheller et al. 1997). Additionally, it is necessary to analyse and classify the neural signals in real time for achieving an efficient communication channel. A wide variety of patients can be benefited from a BCI. Such interfaces can be extraordinarily useful for the patients in a late stage of amyotrophic lateral sclerosis, or any other patients with severe motor handicap and/or the people with total dysfunction of the neuromuscular system.

Electroencephalography (EEG) has been used for a number of years as a source of signals for enabling subjects with severe disabilities to communicate with computers and other devices. In reality, only limited success has been reached yet. Current Brain Computer Interfaces (BCIs) look mostly at signals from areas of the cortex that are expected to manifest activity that is directly related to a particular type of intention (e.g., movement intention). However, the well-off interconnectivity between the various cortical areas may allow for events in one area to be preceded or accompanied by detectable patterns in other unrelated areas. A BCI establishes a direct communication channel between a human brain and a control or communication device without involving neuro-muscular pathways. Such interfaces can be extraordinarily useful to the people with total dysfunction of the neuromuscular system. In order to successful operation of a BCI, the user must produce different brain activities that will be identified by the system and translated into commands to control external device (Fig. 1). The development of a BCI involves with three operations (Wolpaw, J. et al. 2002): (a) recording of the cerebral (brain) signal e.g., EEG; (b) extraction of mental task related features or information from the recorded signal; and (c) translation (classification) of the extracted information to a control command.

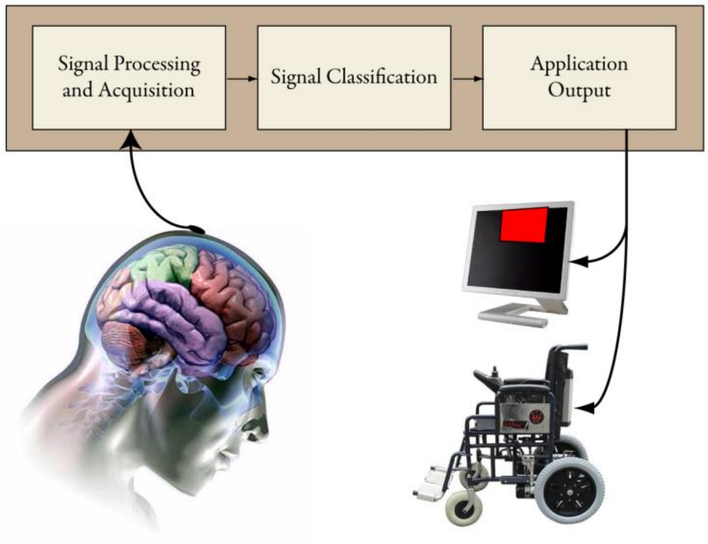

Fig. 1: An Overview of a BCI

PHYSICAL AND TECHNICAL ASPECTS

Brain Computer Interface is being examined as a rehabilitation device to help people for regain motor skills that are lost from stroke, as well as a prosthetic device to replace or compensate for motor skills that will never return. The study on human brain map describes the involvement of brain segment with any physiological or mental activity. The sensory and motor homunculus is the depiction of the body parts to each segment of the brain control. Thus, for any major EEG rhythms and for a variety of evoked potentials, the sites and mechanisms of originating EEG and their relationships with specific aspects of brain function are no longer wholly obscure. The imagery of motor movement could be detected from non-invasive EEGs by placing electrodes (with a brain cap) around motor and sensory cortex areas of the subject's scalp. Indeed, a numerous studies have demonstrated the correlation of mental tasks with the EEG signals for actual or imagined movements (Pfurtscheller et al. 1997).

Nowadays, there are few automated and robotic wheelchair is available for movement of disable people in their daily-life activities. However, these are not useful for the disable people with total dysfunction of the neuromuscular system. On the other hand, the advantage of the BCI based system is that the system can be controlled by using EEG singal i.e., intention of the user, which can be more reliable, robust and more degree of freedom compared to other systems.

MATERIALS AND METHOD

The key aim of this research is to develop a system (interface) that will be fed human's intention of motor movement in the form of multichannel EEG signals and in a return, will process (translate) the input signal to deliver a control signal (in binary bit) for an external device. The BCI has been developed in two stages as shown in Figue 2; training phase and evaluation phase. In training phase, all parameters related to signal processing have been extracted which have been used on online or evaluation phase. The line of art of the proposed research work can be described in four steps as follows.

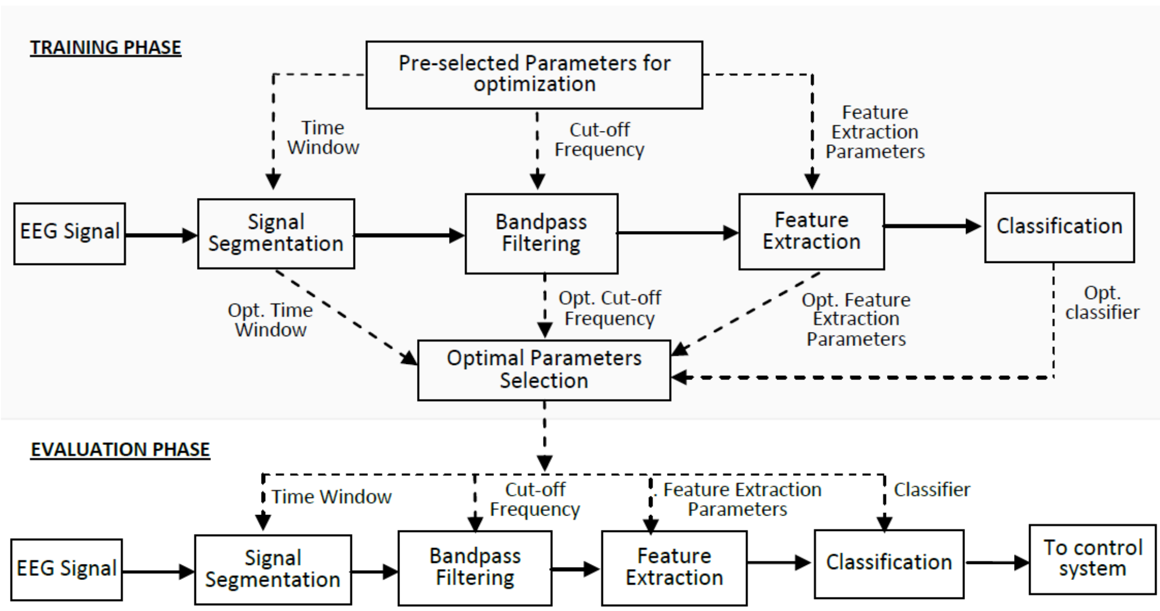

Fig. 2: Flow Diagram for Feature Extraction and Classification in a BCI

Data Acquisition and Paradigm:

One of the aims of this research work is to use multichannel EEG signal aquired from motor cortex area. A computer controlled thinking procedure (paradigm) will be used to record EEG signal. Up to 4 types of imagery (left, right, up and down) will be controlled by the paradigm.

Feature Extraction and Classification of EEG Signals:

To characterize the EEG signals in terms of any event of paradigm, a number of features will be extracted from the pre-processed EEG signal (usually after artifact removal and band pass filtering). All extracted features will be translated and generates binary commands at this stage of signal processing. In training phase, feature characteristics will be assessed and thought identification rule will be established.

Interface Circuit Development:

A microcontroller based interfacing circuit and its code will be developed. The circuit will control motors, pneumatics and wheels of the wheelchair using classification signals, which will lead to the steps toward a practical portable manufacturable version of Brain Computer Interface.

Performance Measurement:

The performance of the BCI based wheelchair will be tested and validated with the volunteers. The performance of proposed system will be compared with the same of contemporary wheelchair.

The performance of the extracted outcomes of the feature mostly is affected by the technique used for feature classification. Classification techniques of FLDA, MDA, QDA, Cauchy and GRB have been used in this research in training phase first. Performance of those classifiers have been evaluated and then the obtained optimized/best-performed classifier has been used for evaluation of MI based BCI. Multichannel EEG signal has been used, which are recorded from motor cortex region of human brain, where the subjects have been performed the MI movement. In order to get the correct features of the EEG signal, two features have been used which are μ-band and β-band between 8 to 30 Hz.

An advanced and simple classification technique for motor imagery related BCI system has been developed with Mahalanobis Discriminant Analysis (MDA) technique which has a very low computational requirement that makes it suitable for BCI system. Then percentage of accuracy has been measured to determine the detection accuracy of the motor imagery movement. In addition, the probabilistic accuracy has also been measured by using Cohen's kappa method.

CLASSIFICATION TECHNIQUE

Motor imagery related EEG signal classification is one of the main challenges in designing of a BCI system. Initially the signal is extracted into features. The power spectral density technique has been used to extract the non-linear features over some frequency components in motor imagery based EEG signals. In training phase Fisher Linear Discriminant Analysis (FLDA), Mahalanobis Discriminant Analysis (MDA), Quadratic Discriminant Analysis (QDA), Cauchy and Gaussian Radial Basis (GRB) classification techniques have been used for designing a motor imagery based BCI system. Then the optimized classifier MDA has been chosen. MDA is widely used as probabilistic distance function. It measures the distance between two points in a defined space for two or more associated variables. This distance depends on covariance matrix of attribute and sufficiently accounts for correlations. For correcting the cross covariance effect between two constituents of chance variable the covariance matrix is used.

RESULTS AND ANALYSIS

Training data has been classified to obtain the optimized parameters. In evaluation phase those optimized parameters have been used and performances have been compared to device an effective classification technique. Then percentage of accuracy has been measured to detect the motor imagery movement. The probabilistic accuracy has also been measured by using Cohen's kappa (Sim & Wright, 2005). Table 1 depicts a comparison of kappa co-efficiency within proposed technique using MDA for training data and existing techniques applied for MI based EEG signal classification. The proposed technique shows much better consistent performance than all other techniques used for BCI.

Table 1: Comparison with other works

Contributors	Used Classifier	Accuracy
Proposed technique	Mahalanobis discriminant analysis	95%

R. Sitaram et al., 2007	Hidden markov model	89%
D. Coyle et al., 2011	Spectral-filtering and common spatial patterns technique	80%
K. P. Bennett et al., 2000	SVM	73%
D. A. Peterson et al., 2003	FLDA	70%
K.K Ang et al., 2008	Common Spatial Pattern	65%
P. Rakshit et al., 2013	Artificial Bee Colony	64%

It obtains around 95% kappa in average in training phase using MDA. For contrastive justification, some other classification techniques have also been used to compare the obtained results. Result depicts that the MDA classifier could be a preferable classification technique for detecting different motor imagery related brain states.

CONCLUSION

To complete the implementation of the BCI based wheelchair, the next chanllenging task is to develop a hardware interfacing circuit to control the wheelchair by using our developed classification algorithm (Stamps, K. and Hamam, Y. 2010). A microcontroller based interfacing circuit needs to be developed to control motors, pneumatics and wheels of the wheelchair. Data acquisition system to acquire the EEG signal is essential for real-time validation. Finally, the performance of the developed BCI based wheelchair will be tested and varified using on-line EEG signal.

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