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Comparison of new mental tasks with Imaginary motor movements in EEG based Brain Computer Interface (BCI)

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ABSTRACT

A group of new cognitive (or mental) tasks were investigated to find out their suitability in BCI. Performance of mental tasks associated with "*imagination of hitting a given square by an imaginary arrow from above (or below) and right, (or left)*" (This group of mental tasks are named as HS) were evaluated along with the well known (in BCI community) imaginary motor movements (MI) for comparison purposes. EEG signals recorded from three subjects were analyzed to identify changes in EEG due to these mental tasks. Bandpass filtering was used to filter out the undesired frequencies from the signal. The feature vectors were constructed using Band powers contained in the signal and classification was carried with Polynomial Support Vector Machines method.

All three subjects performed well for all the metal tasks in both HS and MI. However, performances of first two subjects for HS were much better than for MI while overall performance of third subject is slightly better for MI than HS. Therefore mental tasks in both HS and MI can be used as a hybrid system to construct a better BCI system with larger vocabulary.

1. INTRODUCTION

Many physiological disorders such as Amyotrophic Lateral Sclerosis (ALS) or injuries like high level spinal cord injury can disrupt the communication path between the brain and the body. Especially, patients diagnosed with neurological diseases such as Guillain-Barré Syndrome (GBS), subcortical stroke, brainstem stroke, or severe cerebral palsy, may lead to severe or complete motor paralysis. On the other hand healthy individuals may also lose their muscle movements partially or completely due to accidents while mental and sensory functions remain intact [1-2]. Those who are paralyzed or having restricted motor abilities may have lost all voluntary muscle control and hence, regrettably, cannot interact with their environment like others do [3-11]. As a result, they are enforced to accept a reduced quality of life and become totally depend on caretakers.

In order to lend a hand to individuals who have lost their muscle movements partially, many effective communication aids have been constructed taking advantage of whatever motor abilities the individuals retain in an intelligent way. However, persons who are completely paralyzed cannot benefit from these devices or technologies since they do not retain any motor abilities [6]. The only possible way for these individuals to communicate effectively with outside world is to make use of the retained somatic sensation, cognition and audition which may still be intact. This is where the Brain Computer Interface technology becomes invaluable.

A Brain–Computer Interface (BCI) sometimes called a direct neural interface or a brain machine interface, is literally a direct technological interface between a brain and a computer not requiring any motor input from the user [5-6]. It is a system that uses electric, magnetic, or hemodynamic brain signals to control external devices as switches, wheelchairs, computers, or neuroprosthesis.

In this paper we evaluate performance of new mental /cognitive tasks which can be used in EEG based Brain Computer Interface systems.

2. BRAIN COMPUTER INTERFACE PROCEDURE

Brain Computer Interface involves five major steps given below

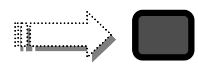
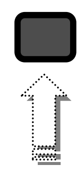
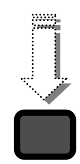
(1) Mental tasks of the subject initiate activities in the cerebral cortex.
(2) Activities in the cortex alter the EEG signals recorded from the scalp.
(3) EEG signals are then amplified and digitized.
(4) These digitized signals are read by a computer as time series data.
(5) Data will then be analyzed with help of Digital Signal Processing methods

In this study, a group of new mental tasks were investigated to find out their suitability in BCI. The group consists of mental tasks associated with "*imagination of hitting a given square by an imaginary arrow from above (or below) and right, (or left)*" and they are named as HS.

EEG signals (19 channels) were recorded from three subjects while they were performing the HS mental tasks. For comparison purposes, EEG signals corresponding to imaginary motor movements (MI: imaginary left middle finger movement, and imaginary right middle finger movements) were recorded from the same subjects. The signals were then filtered with band pass filter to remove undesired frequencies from signals. To reduce the dimension of the data size, feature vectors were constructed using Band powers contained in each EEG channel and then combined them to have a single feature vector. Finally, classification was carried with Polynomial Support Vector Machines method. In order to carry out the above mentioned signal conditioning and classifications, software was developed using MathLab. The Software was developed such a way that in a single run, it can carry out calculations for thousands of combinations of parameters such as number of EEG channels to be used, frequency interval in band pass filtering, width of the bands in band power calculations and order of the polynomial in Polynomial Support Vector Machines method. The optimized parameters are found automatically with a single run. In a single run, usually, several thousands of parameter combinations were tried out by the software for this purpose.

HS series consists of four different mental tasks which are labeled as Right Hit (RH), Left Hit (LH), Up Hit (UH), and Down Hit (DH). The details of these labels are as follows (Table 1),

Table 1: Mental task labels and showing the images of the arrows in HS series.

MENTAL TASKS LABELS	IMAGINATION	IMAGE
RH	Imagining a right arrow hitting a square from the left	
LH	Imagining a left arrow hitting a square from the right	
UH	Imagining an up arrow hitting a square from the bottom	
DH	Imagining a down arrow hitting a square from the top	

MI consists of two mental tasks namely Left Middle Finger Movement (LFM) and Right Middle Finger Movement (RFM).

3. RESULTS Results

We have used similar settings, same recording parameters and same subjects for both sets of mental tasks (HS and MI). Following parameters and settings were used in all the recording sessions (Table 2).

The Performance of mental tasks were calculated as a percentage,

$$Peformance = \frac{Number\ of\ \ sucessfully\ identified\ \ mental\ tasks}{Total\ \ Number\ of\ \ mental\ tasks\ to\ be\ identified} \times 100$$

The performance results of both HS and MI are given in the Table 1. The label BL is used to indicate Baseline. The baseline signal represents the mental stage of the subject when he/she is not thinking of any specific mental task used in controlling BCI.

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Table 2: Parameters and settings used in all the recording sessions.

Channels used for recording	All 20 channels according to 10 - 20 system
Sample rate	256 samples per second
Block size	768 bytes per block per channel
Preparation period used in alarm program	7 seconds
Recording duration	9 seconds
Number of Subjects	03
Number of Test trials per mental task per subject	30 trials
Number of Train trials per mental task per subject	90 trials
Total number of mental tasks including Baseline(BL)	08
Total number of test trials per subject	240 trials
Total number of train trials per subject	720 trials
Total number of trials per subject	960 trials

Table 3**:** Performance of the subjects for HS and MI. The best performance is achieved with the third order Polynomial Support Vector Machine.

HS	Subject 1	Subject 2	Subject 3
BL and DH	93%	98%	85%
BL and RH	87%	100%	87%
DH and RH	82%	98%	75%
MI	**Subject 1**	**Subject 2**	**Subject 3**
BL and RFM	77%	98%	97%
BL and LFM	62%	97%	97%
LFM and RFM	75%	77%	82%

4. CONVLUSION

It is evident from the results presented in the previous section that compared to MI, HS performed equally well when the classification is carried out with Polynomial Support Vector Machine technique while data are filtered with Bandpass filtering and feature vectors are constructed with Band powers. One of the major advantages of using mental tasks RH and DH (in HS) especially for moving a cursor on a computer screen is that compared to other mental tasks such as multiplication, letter composing, LFM or RFM in MI, it is very easy and natural for a user to imagine RH to move the cursor to the right while think of DH to move the cursor down. On the other hand, LFM and RFM can also be used similar manner to simulate clicking of left mouse button and right mouse button respectively. Therefore Hybrid system of MI and HS is ideal for controlling computers through icons in real time BCI systems.

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