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Towards a Low Cost Mu-Rhythm Based BCI

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Abstract. The purpose of this paper is to evaluate whether mu rhythm based BCIs can be implemented using the low cost Emotiv Epoc EEG device. Synchronisation in the high alpha and low beta band caused by continuous imagery and real toes movement was recorded on 6 healthy subjects. We apply LDA and SVM classifiers in order to classify a trial as movement or non-movement by computing the power of the band of interest on C3, C4, FC3, FC4 standard positions. 10-cross validation results indicate that sensorimotor ERS takes some seconds to develop both in the case of imagery and real movement. The performance is better when classification occurs 5–7 seconds after the movement starts. A simple musical application where the user can move the pitch of a tone up and down in a musical scale is built based on real or imagery toes movement.

Keywords: Event-Related Synchronisation, Emotiv Epoc, Mu Rhythm, Brain Computer Musical Interface, Motor Imagery

1. Introduction

Brain Computer Interfaces can provide a communication pathway for people with severe motor paralysis such as total-locked in Syndrome patients. Using a medical EEG system might be the optimum solution for building a reliable BCI. These systems though require a big preparation time and their high cost might make them inaccessible to the majority of the end-users. On the contrary Emotiv Epoc is a low cost commercial user friendly EEG device and recent research indicates that it is capable of capturing real EEG activity and can be used for building low cost BCIs (e. g., a P300 speller [Duvinage et al., 2012]). In this paper we evaluate the potential of Emotiv Epoc to capture Event Related Synchronisation caused by continuous real and imagery toes movement.

2. Methods

2.1. Empirical Observation

Continuous feet movement has been reported to cause ERS in the high alpha and low beta band, around the FC3 and FC4 standard positions of the EEG [Pfurtscheller et al., 2006; Wang et al., 2010; Jeon et al., 2011]. In order to capture this area of the cortex we had to move the Epoc backwards, placing the four frontal electrodes in the C3, C4, FC3, FC4 positions. Using OpenVibe software, in an on-line scenario, the signal was filtered in the 10–17 Hz band using a fourth order Butterworth band pass filter. The overall power of all four electrodes was computed using a 2 s window with hop size of 100 ms. The power was then plotted on a diagram. Toes movement was observed to cause a gradual increase of the computed power as opposed to the resting state, as a result of ERS in the sensorimotor cortex. This can also be observed when comparing the real movement with non-movement spectrograms of the subjects (Fig. 1).

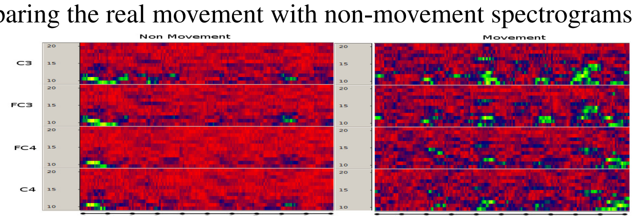

Figure 1: *Non-movement and real movement 10-seconds frequency spectra (7–20 Hz) of one subject.*

2.2. Controlled Experiment

Six male right-handed healthy subjects, of average age 34 years, took part in one real and one imagery movement experiment. All subjects initially observed how real and imagery movement affected the mu power diagram described above. Each session consisted of the following steps: Twelve trials (6 movement and 6 non-movement) of 10 seconds each were randomised. When an arrow pointing upwards appeared on the screen continuous real (in the case of the real movement session) or imagery (in the case of imagery movement session) toes movement should be performed

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lasting for 10 seconds , while if the arrow pointed downwards they should stay relaxed for 10 seconds. The subjects were instructed to avoid any unnecessary muscular activity.

The data recorder for each subject were used to train an LDA and a third degree polynomial SVM classifier. The signal was filtered in the 10–17 Hz band using a fourth order Butterworth band pass filter. A moving 2 seconds window of hop size 100 ms was applied on each channel and the power of each window was used as a feature for the classifier. The classifiers were trained using different time intervals within the 10 seconds period of each trial. When using time intervals close to the end of each 10 seconds trial the performance of 10-fold cross validation was optimised, while time interval close to the beginning of each trial resulted in worse performance.

As a case study a simple musical application was designed, where the last 3 seconds of a 10 seconds movement or non-movement trial were used to control the control of a melody. Initially the threshold of an LDA classifier is computed by asking the user to perform three ten seconds long movement and non movement trials. Then every ten seconds the user performs a movement or non movement trial depending on whether we wishes to move the melody up or down. When movement is detected (value higher than the threshold) the melody moves up while in the opposite case it moves down.

3. Results and Discussion

In Table 1 the average 10-cross validation performance and variance for 6 subjects, for different time intervals is displayed. Looking at the table we can make the following observations: (i) The polynomial SVM classifier always outperforms the LDA classifier. (ii) Mu rhythm synchronization needs some time to develop both in the case of real and imagery movement. When the last 3 out of 10 seconds are used for the classification, the average SVM 10-fold cross validation performance is 91.65 % in the case of real movement and 85.57 % in the case of imagery movement. The overall performance falls when earlier intervals are used. ERS needs some time to develop. (iii) Real toes movement resulted in stronger ERS than imagery movement. Although in the case of 7–10 s window with SVM polynomial classifier the 85.57 % average performance indicates that an imagery movement based interface is feasible.

Table 1: *10-fold cross validation performance average and variance for 6 subjects for different time intervals after start of a trial.*

	Real Movement				Imagery Movement			
	Performance [*100%]		Variance [*100]		Performance [*100%]		Variance [*100]	
Time Interval [s]	LDA	SVM	LDA	SVM	LDA	SVM	LDA	SVM
7–10	87.79	91.65	0.43	0.36	79.65	85.57	0.81	0.29
5–10	77.95	82.25	0.51	0.84	70.41	75.62	0.41	0.34
2–5	71.17	75.30	1.55	1.31	69.15	74.97	0.82	0.64
0–10	69.31	71.51	1.04	0.80	65.88	69.55	0.12	0.17

As a case study a simple musical application was designed, where the last 3 seconds of a 10 seconds movement or non-movement trial were used to control the contour of a melody. Initially the threshold of an LDA classifier is computed by asking the user to perform three 10s real movement and non-movement trials. Then every 10s the user performs a movement or non-movement trial depending on his intention. When movement is detected (value higher than the threshold) the melody moves up while in the opposite case, it moves down. Preliminary results on one subject indicate that the contour of the melody is controlled with enough accuracy.

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