Multichannel Phase Synchrony Analysis in SSVEP-based BCIs

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INTRODUCTION

Brain computer interfaces (BCIs) based on the steady state visual evoked potential (SSVEP) can provide higher information throughput as compared to other BCIs. Using a high frequency (in the range of 30 to 40 Hz) repetitive visual stimulus to elicit SSVEP is safer and more comfortable for the user. However, only few frequencies in this range can elicit a sufficiently strong SSVEP for BCI purposes. This limits the number of possible commands that can be executed and consequently the bitrate. In order to circumvent this limitation, we propose to use multiple oscillatory stimuli sharing the same frequency but with a different phase.

METHODS

Six subjects participated in our experiment. They were presented with four flickering LEDs at the same frequency but a different phase (0, $\pi/2$, π and $3\pi/2$). The frequency of stimulation per subject was selected by determining the largest SSVEP response in the range of 32 to 40 Hz. A photodiode was used to record the light signal (reference) from the0-phase LED.
Subjects were requested to focus their attention on each of the LEDs in a sequential manner. To detect the phase of the LED on which the subject was focusing, we first derived a univariate signal which resulted from the optimal linear combination(i.e. spatial filtering) [1] of EEG signals: O1, Oz, O2, PO3, PO4, P3, Pz and P4. The phase of the univariate signal was determined by estimating the mode of the distribution of the instantaneous phase difference between the univariate signal and the reference in a one-second long window. The classification was achieved using a support vector machine method.

RESULTS

Our analyses resulted in expected communication bitrates as shown in
Table 1. The bitrates were estimated as in [2].

Table 1 Accuracy and bitrates from Oz-Cz and spatial filtering for all subjects

Subject	Frequency (Hz)	Bitrate (bits/trial)	
		Oz-Cz	Spatial filtering
1	40	0.1	1.46
2	39	1.30	1.49
3	36	0.65	1.13
4	39	0.50	0.52
5	32	0.37	0.79
6	39	0.18	1.28

DISCUSSION

In this contribution we aim at motivating the use of high frequency stimulation to elicit SSVEP for BCI applications. We have successfully circumvented the frequency limitation in the high-frequency range by using phase modulation and showed that spatial filtering can significantly increase the bitrates. Furthermore, the adoption of the reference can mitigate the possible SSVEP phase shift caused by the phase shift of the stimuli and avoid the synchronization between a training session and an operation session.

References

[1] O. Friman, T. Lüth, I. Volosyak, and A. Gräaser, "Multiple channel detection of steady-state visual evoked potentials for brain-computer interfaces, "*IEEE Transactions on Biomedical Engineering*, vol. 54, pp. 742–750,2007.[2]A. Schlögl, J. Kronegg, J. Huggins and S.G. Mason, "Evaluation criteria for BCI research", *Towards Brain-Computer Interfacing*, pp.297-312, 2007