Phase Segment Analysis Alleviates Contamination from Similar Frequency Targets in a 35 Target Phase Discriminating SSVEP BCI

John J Wilson, Ramaswamy Palaniappan
School of Computer Science and Electronic Engineering, University of Essex, Colchester, CO4 3SQ, UK
E-mail: jjwils@essex.ac.uk

Recently brain-computer interfaces (BCI) utilising the steady state visual evoked potential paradigm have begun to employ previously unutilised phase information [1, 2]. Absolute phase response can be used to discriminate between targets that flash at identical frequency rates but are offset in phase of their alternation rate [3]. In traditional frequency tagged SSVEP BCI's SSVEP response need only to be distinguished from ongoing brain rhythms and background EEG. However in phase tagged BCI's, frequency similar targets are subject to contamination from not only ongoing brain rhythms but crucially the other non-attended targets that share alternation rates within the system. A main motivation for phase tagging is to increase the number of stable targets presentable on typical computer monitors that operate at a 60Hz refresh rate. Screen realty is typically limited in terms of physical size and resolution. Thus increasing the number of targets dictates reducing the size of individual targets or the separation between them, increasing the likelihood of cross contamination. This paper introduces a vector segmentation analysis method that operates on single cycle Fourier components to classify phase angle and compares this to a phase weighting/projection approach. The comparison is facilitated by an offline study with five subjects using a 35 phase tagged target system.

The ITR of the system using the segmentation approach is improved in all cases but particularly for lower frequency targets that have smaller inter-target phase spacing and are more populous in the system.

Stimuli flashing frequencies used were 6.66 Hz, 7.5 Hz, 8.57 Hz, 10 Hz and 12 Hz at every available phase offset (Table 1). Targets were arranged so that no similar frequency stimuli were situated adjacently. Five subjects completed ten sessions in total, five for calibration of phase responses where only one target was displayed at a time and five for testing whereby all targets were displayed. Each session consisted of 35 trials corresponding to attending every target in the system.

Table 1 Target alternation details

Frequency (Hz)	Max # of Phase Tagged Targets	InterTarget Phase Separation (degrees)
6.66	9	40
7.50	8	45
8.57	7	51.42
10	6	60
12	5	72

Table 2 Individual frequency and system performance (bold)

Projection		Segment Summation	
Accuracy (%)	ITR (bits/min)	Accuracy (%)	ITR (bits/min)
59	28.90	66	36.75
61	28.20	69	37.09
66	30.10	67	31.18
76	36.97	78	39.41
90	49.58	91	51.16
70.4	**65.92**	**74.2**	**71.83**

Projection method*:** Fourier coefficients for each frequency from a two second EEG epoch are projected onto each of the 35 stored phase calibration angles. The maximal value is selected as the attended target. ***Segment method: A two second EEG epoch is segmented into single cycle epochs for each frequency and each vector plotted independently. Vectors lying within constructed segments centered on the stored calibration phase angles with width corresponding to phase separation are vector averaged. The maximal value is selected as the intended target.

Accuracy's and ITR's are improved in all cases (Table 2) with the segmentation method likely due to contaminated vectors being omitted from classification.

References

[1] Wilson JJ, R. Palaniappan: **Augmenting a SSVEP BCI through single cycle analysis and phase weighting.** *4th International IEEE/EMBS Conference on Neural Engineering*, 2009, 371-374.

[2] Kluge T, Hartmann M: **Phase coherent detection of steady-state evoked potentials: Experimental results and application to brain-computer interfaces.** *3rd International IEEE/EMBS Conference on Neural Engineering. 2007,* 425-429.

[3] Jia C, Gao X, Hong B, Gao S: **Frequency and phase mixed coding in SSVEP-based brain-computer interface.** *IEEE Transactions on Biomedical Engineering.* 2011, **58(1)**, 200-206.

Proceedings of the International UKIERI Workshop on Fusion of Brain-Computer Interface and Assistive Robotics, 7-8 July 2011, Londonderry, UK.