 DOI: 10.3217/978-3-85125-467-9-187

Movement Related Cortical Potential based on Multi-Class Motor Imagery

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Introduction: The movement-related cortical potential (MRCP) is one of the slow negative cortical potential generated during voluntary motor execution or imagery (MI). The MRCP has physiological 4 components during about 2 s at intervals of about 0.5 s [1]. The components are premotor positivity (PP), motor potential (MP), reafferent potential (RP), and P+90 [1, 2]. In the previous study, the MRCP showed the higher classification results than the event-related (de)synchronization in MI of patients groups [2]. However, MRCP-based multi-class classification and signal analyzing did not implement due to small amplitude and low frequency of the MRCP [3]. This study proposes the optimal feature extraction method for MRCP-based multi-class MI classification.

Material, Methods and Results: In our experiment, 5 healthy subjects participated. At the beginning of a trial, a fixation cross appeared on the black screen. After two seconds, a cue in the form of an arrow pointing to the left-right, and down direction (corresponding left-right hand, and foot) appeared and stayed on the screen for 5 s. The subjects performed 30 trials per tasks (left-right hand, and foot). The EEG data were acquired by the sampling rate 250 Hz based on 16 channels (F3, Fz, F4, F5, FC1, FC2, FC6, C3, C4, CP5, CP1, CP2, CP6, P3, PZ, and P4) in the international 10/20 system. The data were band-pass filtered at 0.1-1 Hz for pre-processing and segmented into 2 s long epochs according to the events. And then, the features of MRCP were extracted by mean values of time intervals of physiological components (PP, MP, RP, and P+90) for enhancing the multi-class classification performance. The 20 epoch intervals (0: 0.1: 1) were used to feature extraction in previous study. However we propose 4 epoch intervals (0-0.5; 0.5-1; 1-1.5; 1.5-2) based on the 4 physiological components, with heuristic decision. The regularized linear discriminant analysis was used to 5-folds cross-validation for our experimental results. The BCILAB toolbox was used to EEG signal processing. For comparison analysis, additional experiments were also implemented using 2 epoch intervals (0-1; 1-2), 3 epoch intervals (0-0.6; 0.6-1.3; 1.3-2), and 5 epoch intervals (0-0.4; 0.4-0.8; 0.8-1.2; 1.2-1.6; 1.6-2.0) that are not considered physiological components. And we validated the p-value by t-test for the statistical verification.

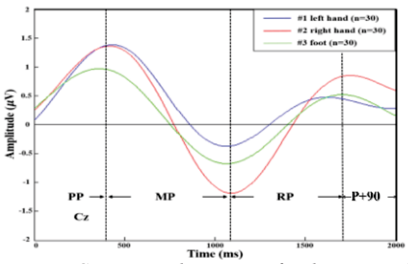

Figure 1. *MRCP temporal patterns of subject D in Cz channel*

Table 1. *Classification results of cross-validation and t-test*

Subject	2 epoch intervals	3 epoch intervals	4 epoch intervals	5 epoch intervals	20 epoch intervals
A	77.8	84.4	90.0	84.4	84.4
B	50.7	52.0	53.3	52.0	44.0
C	53.3	58.9	68.9	57.8	41.1
D	55.6	50.0	64.4	55.6	62.2
E	37.8	47.8	52.2	50.0	42.2
Average	55.1±14	58.7±14	65.8±15	60.0±13	50.8±23
P-value	0.0101	0.0356	-	0.0365	0.0684

Figure 1 shows the patterns of MRCP in Cz channel of subject D. The lines (blue, red, and green) show the each temporal patterns of multi-class MI. The vertical dotted lines are the interval of each component (PP, MR, RP, and P+90). The amplitude of each component was shown significant difference during 2 s. Table 1 represents the cross-validation results and p-values in all subjects. The proposed 4 epoch intervals-based feature extraction method had the highest classification accuracy (65.8±15) than the other intervals. The t-test also showed that proposed method has statistically significant (p<0.05) between the different methods except the 20 epoch intervals.

Discussion: The experimental results showed the possibility of classification using MRCP during multi-class MI tasks. The epoch intervals, which were not considered physiological components, showed a low accuracy. As a result, the proposed physiological 4 component based feature extraction method could enhance classification accuracy in multi-class MI.

Significance: The physiological 4 components of MRCP based feature extraction can classify the multi-class MI tasks by high classification accuracy (65.8±15 %), which is larger than the chance level of 33.3%.

Acknowledgements: This work was supported by ICT R&D program of MSIP/IITP. [R0126-15-1107, Development of Intelligent Pattern Recognition Softwares for Ambulatory Brain-Computer Interface].

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