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Decoding of Arm Reaching Targets from Time-Frequency Analysis of Human EEG

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Abstract. Brain computer interaction (BCI) has been an important channel for decoding subject's intention to interact with the world. This paper describes the analysis of electroencephalography (EEG) to extract movement directional information of different cortical regions during the planning and execution period of arm reaching movements. The results show that spectral analysis from electrodes on the parietal reach region (PRR) provides high decoding accuracy at the alpha-frequency band before the movement onset. The analysis has proven preliminary potentials for predicting directional movement planning for asynchronous BCI applications.

Keywords: Brain Computer Interfaces, EEG, Movement Directions, Parietal Reach Region, Movement Intention

1. Introduction

Invasive recordings with monkeys have shown promising results where objects can be reached by thoughts through reconstruction of trajectories [Nicolelis, 2001]. The EEG signal is known to represent a mixture of signals originating from many cortical sources, thus making it potentially less effective than invasive methods. However, recent works have shown that hand movement directions can be decoded *during movement execution* period from MEG and EEG signals above the motor area [Waldert et al., 2008]. Hammon et al. [2007] have proven that reaching targets can be predicted during the planning period in a *reaction task* from combinations of power spectrum of different frequency bands from EEG signals. In addition, the reconstruction of movement trajectories from EEG signals has been successful using low frequencies EEG signals from the range of 0.1-1Hz [Bradberry et al.,2010]. In this paper, contrarily to previous works, we investigate the decoding of arm reaching targets from human EEG *before* movement onset in a *self-paced* task.

2. Experiment Protocol

The experimental workspace consists of four targets (north, south, east, west) on the horizontal plane with respect to the mid-sagital plane of the subjects. Two subjects (A5 and A8) were instructed to perform natural self-paced center-out and center-in arm reaching tasks while fixating on a red point in the middle of the experimental platform. Each trial begins with the subject placing his/her right hand on the center position. Then, an audio cue tells the subject which target to reach. After more than 3 seconds, subject can voluntarily move their hands to reach the target, where subject has to keep their hand there for another 3 seconds before moving back to the initial position. The distance from the starting point to the target points was 20cm.

EEG signals from 64 electrodes based on standard 10/20 international system were recorded with a Biosemi ActiveTwo System at a sampling rate of 2048 Hz. Data was spatially filtered using common average reference (CAR) and then high pass-filtered at cutoff frequency of 0.5Hz using 3rd order Butterworth filter. The number of trials extracted for each subjects were 350 and 377 after discarding erroneous trials (i.e., reaching to the wrong target and starting the reaching movement before 3 seconds) .

2.1. Methods

For each trial, we computed the time-resolved amplitude spectra using the short-time discrete Fourier transform (STFT) between -2 seconds to 1.5 seconds with respect to the movement onset of the center-out movement for different brain regions such as prefrontal (PF), premotor (PM), primary motor (M1), central parietal (CP) and posterior parietal (P) as shown in Figure 1(a). The power spectrum computed from a sliding window of 500 milliseconds (ms) overlapping every 31.25 ms (64 samples) was decoded on single-trial basis using linear discriminant analysis (LDA). The features used are the power modulations in the individual delta, theta, alpha, beta and gamma bands for each channel. Decoding accuracy (DA) was calculated using 10-fold cross validation for each EEG channels.

3. Results and Discussion

Figure 1(b) shows the decoding accuracy of movement direction for subject A8 focusing on the [-1 0.5]s time segment window where accuracy for each cortical group are averaged across channels in highlighted regions as shown in Figure 1(a) . It is observed that by using alpha band power over the posterior parietal cortical group 500 ms *before* the movement onset (as highlighted in a square box in Figure 1(b)) yields higher performance (above chance level) compared to other brain areas which suggest discriminable activity in this region. Results from subject A5 also exhibits similar trends in the performance on the ipsilateral parietal area. The fact that we can see discriminative information in both the ipsilateral and contralateral region is in agreement with recent works [Ganguly et al., 2009]. As for the next step, feature extraction and selection based on this knowledge of relevant movement direction region and time window of interest will be done to evaluate its feasibility for applications in upper limb neuroprosthesis.

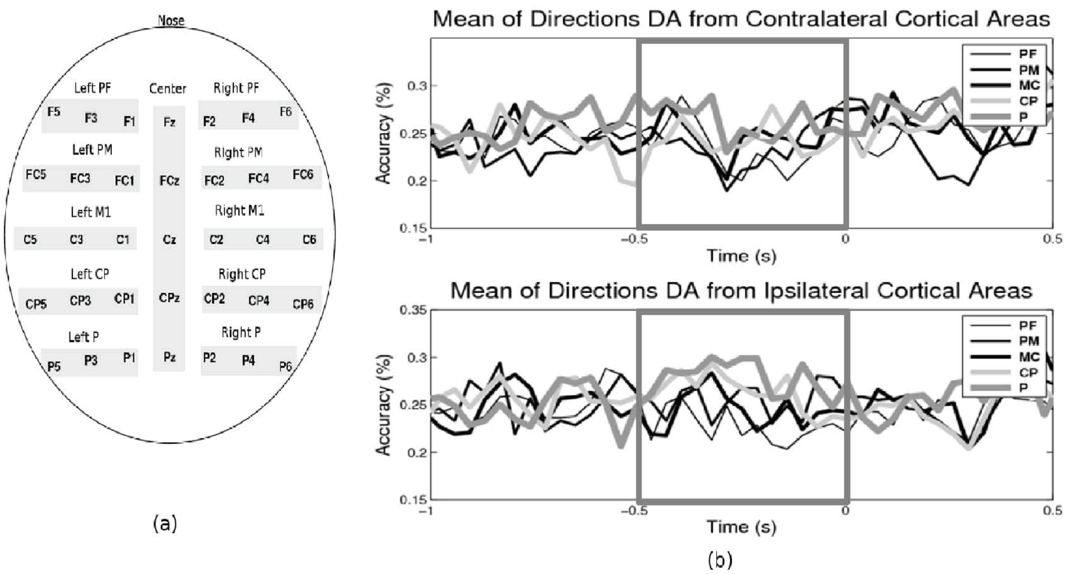

Figure 1. *a) Grouping of brain cortical region for analysis. (b) Upper: DA of Movement Direction based on cortical regions; Middle: Mean DA calculated from contralateral cortical areas; Lower: Mean DA calculated from ipsilateral cortical area, for subject A8, using features from the alpha band.*

References

Nicolelis, M. A. L. Brain-machine interfaces to restore motor function and probe neural circuits. *Nat Rev Neurosci,* 2003*, 4*, 417-422.

Waldert, S.; Preissl, H.; Demandt, E.; Braun, C.; Birbaumer, N.; Aertsen, A. & Mehring, C. Hand movement direction decoded from MEG and EEG. *J Neurosci,* 2008*, 28*, 1000-1008

Hammon, P.; Makeig, S.; Poizner, H.; Todorov, E. & de Sa, V. Predicting Reaching Targets from Human EEG *Signal Processing Magazine, IEEE,* 2008*, 25*, 69-77

Bradberry, T. J.; Gentili, R. J. & Contreras-Vidal, J. L. Reconstructing three-dimensional hand movements from noninvasive electroencephalographic signals. *J Neurosci,* 2010*, 30*, 3432-3437

Ganguly, K.; Secundo, L.; Ranade, G.; Orsborn, A.; Chang, E. F.; Dimitrov, D. F.; Wallis, J. D.; Barbaro, N. M.; Knight, R. T. & Carmena, J. M. Cortical representation of ipsilateral arm movements in monkey and man. *J Neurosci,* 2009*, 29*, 12948