DOI: 10.3217/978-3-85125-467-9-68

Full Body Spatial Tactile BCI for Direct Brain-robot Control

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Introduction: We present a study of a stimulus-driven tactile BCI, in which somatosensory stimuli are given to the full body of the user in order to evoke P300 responses. Six spatial tactile stimuli are applied to various body locations of the user's entire back. The classified BCI results are employed for an intuitive robot control. The robotic control is designed for paralyzed users who are in bedridden conditions. We define this approach as full body BCI (fbBCI) and we investigate how it could be applied for people in need soon.

Material, Methods and Results: The fbBCI is one of the P300-based stimulus driven paradigms [1], which identify intentional responses to spatial somatosensory patterns. The presented approach is developed in mind for clinical conditions and for locked-in syndrome (LIS) bedridden users, although at the current stage we test it only with healthy participants. For this reason, we develop a tactile stimulus generator applying vibration patterns to a full body of the user's back [1]. Tactile transducers DAYTON TT25-16 are embedded within a mattress in order to generate somatosensory evoked potentials (SEP) with intentional P300 responses to attended stimulus patterns applied to six distinct areas of user's back and limbs (namely the both arms and legs; waist and shoulder areas). NAO humanoid robot is also tested as a practical application of the fbBCI usability of direct brain-robot control. Six robot movements preprogrammed in the robot are mapped to the fbBCI commands (e.g. walk straight, back, left, or right; sit down; and say goodbye). The direct brain-robot control application is depicted in Figure 1.

Figure 1. *The fbBCI user lying on a mattress with tactile transducers embedded. NAO robot depicted seating is controlled using the fbBCI. One of the tactile transducers used in experiments is depicted in the lower left panel.*

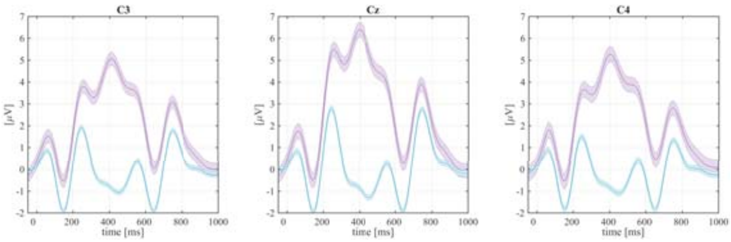

Figure 2. *Grand mean averaged ERP results of all ten subjects for target (purple lines) and non-target (blue lines) stimuli. Electrodes C3, Cz and C4 are depicted with very clear P300 responses, together with standard error intervals, in latencies of 200 ~ 600 ms. Eye blinks have been rejected with an absolute threshold of 80 μV.*

In the fbBCI online experiments, the EEG signals were captured with a bio-signal amplifier system g.USBamp (g.tec Medical Instruments, Graz, Austria) and processed using in house extended BCI2000 environment. The P300 responses were classified using a stepwise linear discriminant analysis (SWLDA) method. Active EEG g.LADYbird electrodes were attached to eight locations of Cz, Pz, P3, P4, C3, C4, CP5 and CP6, as in 10/10 international system. The EEG sampling rate was set to 512 Hz. The high- and low-pass filters were set at 0.1 Hz and 60 Hz respectively. A notch filter to remove power line interference was set for a rejection band of 48~52 Hz. The vibration frequency of the tactile transducers was set to 40 Hz. Ten healthy subjects (five males and five females; mean age of 21.9 years with standard deviation of 1.45) took part in the experiments approved by the Ethical Committee of the Faculty of Engineering, Information and Systems at the University of Tsukuba, Tsukuba, Japan. Grand mean averaged ERPs from the online experiments have been depicted in Figure 2. SWLDA classification accuracies in the fbBCI experiments resulted with 53.67% on average.

Discussion and Significance: In the presented project, which shall be considered as a relatively novel approach, we could successfully apply a full body tactile BCI to realized the concept of direct brain-robot control application [2]. The presented fbBCI results are a step forward in development of a clinical application and the assistive robotic control for bedridden patients.

Acknowledgments: We would like to thank Dr. Andrzej Cichocki and Peter Jurica for support and rental of the NAO robot from RIKEN Brain Science Institute, Wako-shi, Japan.

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