Proceedings of the Fifth International Brain-Computer Interface Meeting 2013 DOI:10.3217/978-3-85125-260-6-126

Robotic Arm Control Using a Non-Invasive EEG-Based BCI

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Abstract. EEG based BCI has the potential to become widespread owing to their ease of use and noninvasiveness. Previous studies have demonstrated control of anthropomorphic robotic arms through invasive brain computer interfaces. Using noninvasive scalp EEG, we demonstrate continuous control of a human sized robotic arm in two-dimensions to complete grasping and maneuvering tasks that mimic real world situations.

Keywords: EEG, Motor Imagery, Robotics, BCI

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1. Introduction

Brain computer interfaces have been shown to hold great promise to restore lost functions in patients suffering from various diseases and to enhance functions in healthy population [He et al., 2013]. Invasive brain computer interfaces have successfully demonstrated three-dimensional control of a robotic arm using an electrode arrays in humans [Collinger et al., 2012; Hochberg et al., 2012]. Invasive recording limits the usefulness of these approaches to only the most extreme cases. EEG based noninvasive control in two dimensions [Wolpaw and McFarland, 2004] and three dimensions has been recently shown in virtual cursor [McFarland et al., 2010] and virtual helicopter tasks [Royer et al., 2010; Doud et al., 2011]. These have been controlled solely by using motor imagination of the arm, leg, and tongue combined to control each dimension individually simultaneously with the other dimensions. Hybrid systems have been used to control 2 degree of freedom robotic arms [Horki et al., 2011]. Control in a virtual task is a useful proof of concept but does not insure an individual will be able to control an object in physical space in their immediate surroundings. Controlling physical objects and the interaction of these with an individual's environment is vital to allow a disabled individual to be more independent in their environment. We hutilized motor imagery to allow subjects to control two-dimensions of a robotic arm; one dimension of translation and opening/closing of the hand, to pick up and move blocks in a task similar to the box and block task used to evaluate upper limb mobility.

2. Material and Methods

Four healthy subjects participated in these experiments. Subjects performed multiple 2D control tasks with a robotic arm using both translation and hand opening/closing to allow us to evaluate the control enabled by motor imagery EEG-based BCI. To move the arm left and right, motor imagery of the left and right hand grasping, respectively were used. To move the arm up, motor imagery of both arms grasping was used, and relaxation was used to move the arm down. To open and close the hand, imagery of right foot movement was used as a switch to completely open or close the hand. Task 1 consisted of controlling the arm in two-dimensions in the XZ plane to move to a randomly selected target. Tasks 2 and 3 were 2D claw tasks consisting of either vertical or horizontal movement of the arm plus hand opening and closing. Claw tasks required three control steps performed in a specified order to correctly complete the entire task ('3 steps') but partial completion of two of the steps, moving to the target and closing the hand on the cube, were recorded ('2 steps'). Closing the hand prior to moving to the target position did not allow completion of the task. Grasp and translation were controlled simultaneously to allow the subject to parallel naturalistic limb movement when reaching for an object. The EEG signal was processed using a 16th order ARMA model and classified with a linear classifier. The arm was under complete subject control using visual feedback with no intelligent control assistance provided.

3. Results

All subjects were able to correctly complete all of the assigned arm tasks (Fig. 1). Subjects had the best performance with the 2D translation task wherein the subject controlled the X and Z direction simultaneously while guiding the hand to one of four indicated targets; mean performance over all subjects was 42%. The claw task where the subject needed to lower the hand, close the hand, and raise the hand back up had an intermediate performance

Published by Graz University of Technology Publishing House, sponsored by g.tec medical engineering GmbH

with an average of 27% correct two step and 18% correct three step trials. The claw task where the subject needed to move the hand either left or right to the target, close the hand, and move the hand back to the center had the lowest performance with an average of 11% correct two step and 3% correct three step trials.

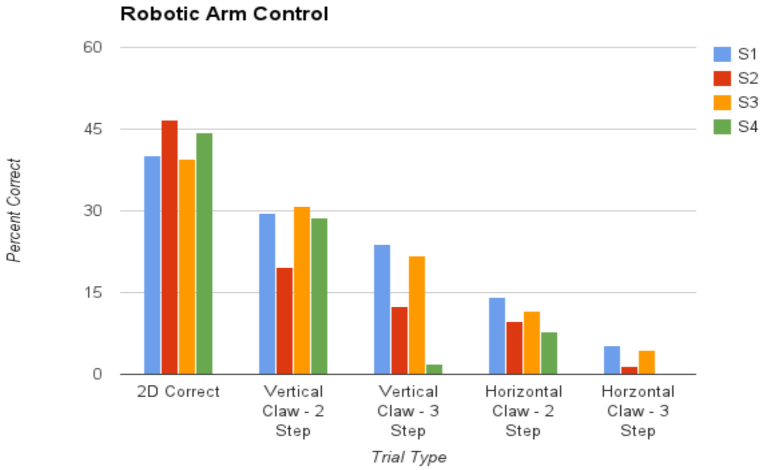

Figure 1. *Robotic Arm Control. The mean accuracy for each subject on the three different 2-D trial types. '2-Steps' indicates the subject correctly moved to the target and grasped the block. 3-Steps indicates the subject correctly moved to the target, grasped the block, and moved the block to the completion area.*

4. Discussion

We demonstrate successful control of a robotic arm in two-dimensions using a noninvasive EEG system to perform three different tasks that would be used in real world situations. Subjects demonstrated sufficient control to maneuver and successfully pick up and move a 2 cm cube across a table as well as lifting it from the table. This work illustrates the difficulty in performing high-dimensional control on devices located adjacent to the user. Future work in developing intelligent assistive control of the arm to generate shared human-computer control could be used to improve subject performance at the cost of increased sensing and computational calculations.

Acknowledgments

We would like to thank Kaitlin Cassady for her assistance performing experiments. This work was supported in part by NSF DGE-1069104, NSF CBET-0933067, and ONR N000141110690.

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