2024 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)
July 15-19, 2024. Boston, MA, USA

Shared Robotic Arm Control Using an Augmented Reality Brain-Computer Interface

Kirill Kokorin, Syeda Zehra, Jing Mu, Peter Yoo, David B. Grayden, and Sam E. John,

***Abstract*—Augmented reality brain-computer interfaces (AR-BCIs) can be used to control a robot using a goal selection paradigm. As some users may prefer more manual control, we developed an AR-BCI for continuous control of robot translation, which we tested in a robotic reaching experiment. To improve performance, we developed a shared control system that significantly improved task success rate (paired two-tailed *t*-test, p <0.001, mean = 36.1%, 95% CI [25.3%, 46.9%]).**

I. Introduction

Brain-computer interfaces (BCIs) can assist a person with paralysis to perform activities of daily living by allowing them to control a robot using their brain activity. BCIs that use steady-state visually evoked potentials (SSVEPs) and augmented reality (AR) allow a user to observe stimuli and a robot simultaneously [1], usually adopting a goal selection paradigm, where control authority is traded between the user and the robot. However, users may prefer to directly control robot motion [2], [3]. For this reason, we developed an AR SSVEP-BCI for continuous control of robot translation, which we tested in a 3D reaching task. To improve system performance, we designed a shared control system that predicted what object the user was trying to reach and provided them with autonomous assistance [3], [4].

II. Methods

The system comprised a Reachy robotic arm (Pollen Robotics, France), a HoloLens 2 (Microsoft Inc., USA) and a g.USBamp amplifier with nine wet g.Scarabeo recording electrodes (g.tec medical engineering GmbH, Austria) placed above the parietal and occipital lobes. Participants completed 24 reaching trials using direct and shared control each (Fig. 1A). Eighteen healthy participants (10 male and 8 female, mean age: 29 years, range: 23–37 years) took part in the study, which was approved by the University of Melbourne Human Research Ethics Committee (ID: 20853). Written informed consent was obtained from each participant before starting the experiment.

Every 0.2 s, the system decoded which stimulus the user was attending to using canonical correlation analysis on the last 1 s of electroencephalography data. In direct control trials, the decoder output was converted to a directional velocity control vector. In shared control trials, the user input was fused with an assistance vector towards the predicted object, while the ratio of the two commands was regulated by the confidence of the system in the prediction [3], [4].

III. Results & Discussion

Reaching the orange object meant a trial was a success, while colliding with anything in the workspace, exceeding its limits, or exceeding 38.5 s meant the trial was a failure. There was a significant increase in mean task success rate across the 18 participants (paired two-tailed *t*-test, $p < 0.001$, $\mu = 36.1\%$, 95% CI [25.3%, 46.9%]), when using shared control ($\mu = 76.6\%$, 95% CI [65.8%, 87.4%]) compared to direct control ($\mu = 40.5\%$, 95% CI [24.4%, 56.6%]) (Fig. 1B). Therefore, our shared control system can provide users with the experience of manual control, while mitigating the impact of BCI decoder errors by leveraging robot sensor data. This system can be adapted to other tasks (e.g., wheelchair control), where a person is continuously controlling a robot to reach specific locations in the environment using an unreliable noisy interface.

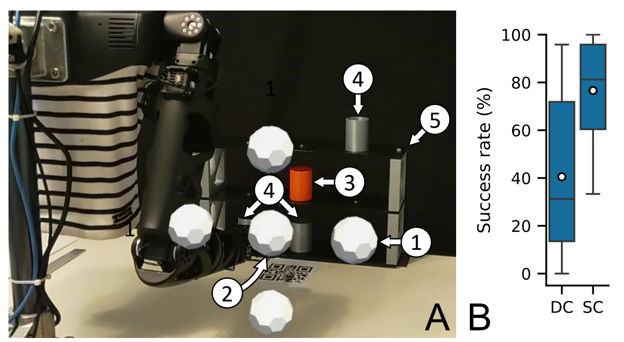

Fig. 1. A: Five flashing stimuli (1) are displayed around the end-effector (2, behind middle stimulus). Attending to a stimulus moves the robot in that direction (middle = forward). The participant needs to touch the orange object (3) with the end-effector, while avoiding the other three grey objects (4) located on the shelf (5). Four objects were randomly arranged across nine possible positions for each participant. B: Percentage of successful trials across participants using direct (DC) or shared control (SC). Boxes, whiskers and circles show quartiles, range and mean, respectively.

References

[1] H. Si-Mohammed *et al.*, “Towards BCI-based interfaces for augmented reality: feasibility, design and evaluation,” *IEEE Trans. Vis. Comput. Graph.*, vol. 26, no. 3, pp. 1608–1621, 2018.

[2] D.-J. Kim *et al.*, “How autonomy impacts performance and satisfaction: Results from a study with spinal cord injured subjects using an assistive robot,” *IEEE Trans. Syst. Man. Cybern. A Syst. Hum.*, vol. 42, no. 1, pp. 2–14, 2012.

[3] A. D. Dragan and S. S. Srinivasa, “A policy-blending formalism for shared control,” *Int. J. Rob. Res.*, vol. 32, no. 7, pp. 790–805, 2013.

[4] K. Kokorin *et al.*, “Predictive shared control of robotic arms using simulated brain-computer interface inputs,” in *IEEE EMBC*. IEEE, 2023, pp. 1–5.

This work is supported by the ARC Industrial Transformation Training Centre in Cognitive Computing for Medical Technologies (IC170100030).

K. Kokorin, S. Zehra, J. Mu, D. B. Grayden, and S. E. John are with the Department of Biomedical Engineering and the Graeme Clark Institute, University of Melbourne, Australia (e-mail: k.kokorin@student.unimelb.edu.au).

P. Yoo is with Synchron Inc., New York, United States of America and the Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne, Australia.