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Planar Control of a Quadcopter Using a Zero-Training Brain Machine Interface Platform

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Introduction: Brain Machine interface (BMI) enables promising applications in neuroprosthesis and neurorehabilitation by controlling robotic devices based on the subject's intentions. In contrast to the earlier techniques using sensorimotor rhythms, the method here intends to directly extract information of imagined body kinematics and thus can significantly reduce training time. We developed a zero-training BMI platform that controls a quadcopter using noninvasively acquired brain signals. Scalp electroencephalogram (EEG) signals of a user's imaginary movements are collected in real-time and translated by a computer to control a quadcopter along a designated path in a two-dimensional space. The results showed a promising performance using the zero-training paradigm that can be utilized in controlling neuroprosthetic limbs and neurorehabilitation devices by patients with BCI illiteracy.

Materials and Methods: EEG signals were acquired using an Emotiv EPOC device with 14 channels and through BCI2000 software (with high pass filter at 0.1Hz and low pass filter at 30Hz). The quadcopter (Parrot AR. Drone 2.0) flies at a constant height with a fixed forward velocity. The lateral movement of the quadcopter is controlled by a subject's imagined body kinematics. The subject was instructed to use a previously developed BCI cursor control model to control the quadcopter, where the left and right movements of the cursor on a computer screen are mapped to the counterclockwise and clockwise rotations, respectively. After initial calibration and testing, one recruited subject was instructed to fly the quadcopter around obstacles (Figure 1) by using the BCI cursor task application. The quadcopter movement is controlled by Node.js software platform, and the real-time communication between BCI2000 and Node.js is established by UDP protocol through JavaScript programming language.

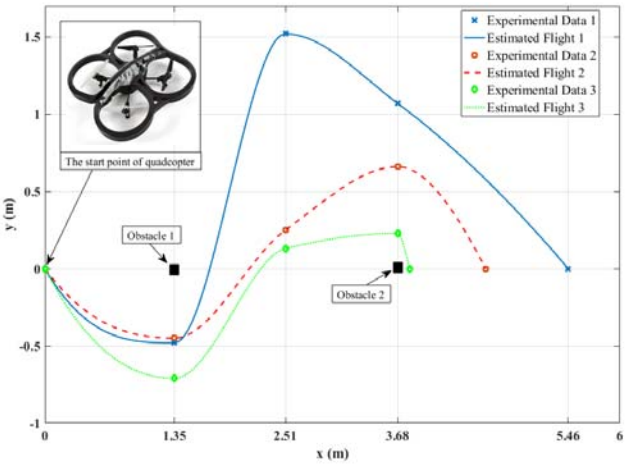

Figure 1. Example quadcopter trajectories. Three trajectories from the drone control experiments are shown. Along each trajectory, the drone position is read from a video captured during the experiment at x=0 (starting point), x=1.35 (position of first obstacle), x=2.51 (the middle point between the two obstacles), x=3.68 (position of the second obstacle), as well as the end point of the drone along the straight line at y=0.

Results: A regression model based on imagined body kinematics was developed using the cursor control task in BCI2000. Parameters of the model was obtained from fitting the training experiments of one subject. The model was used by a different subject to control the lateral movement of a quadcopter. For the subject who attempted to the control the quadcopter, there was no BCI training conducted. A minimum parameter calibration was done for the test subject to adjust the magnitude of the quadcopter rotating speeds. An experiment was designed for the subject to fly the quadcopter so that it takes an S-shaped trajectory to go beyond two obstacles. Figure 1 shows a few selected trajectories of the quadcopter. After a few trials, the subject was able to successfully control the quadcopter to fly from one end of the room to the other end and simultaneously go around the two obstacles in an S-shaped curve. The mean time of the selected trajectories was 11 seconds.

Conclusions: We developed and tested a novel BMI platform, which is noninvasive and requires zero-training with a minimum calibration time. For initial testing of the platform, one subject was recruited to fly a quadcopter around obstacles. The experiments here serve as a concept proof for the feasibility of zero-training BCI and BMI platforms. In future work, we would like to further develop our zero-training model to provide more stable results in BMI systems to be used more efficiently in two- and three-dimensional robotic assistive devices.

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