Towards a Brain-Computer Interface Framework for Multi-Party Robot Applications

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ABSTRACT

Studies featuring electroencephalography (EEG)-based robotic systems controlled by the brain have predominantly concentrated on single-user applications. However, there is a growing interest in exploring novel ways to engage users with Brain-Computer Interfaces (BCIs). This research contributes an EEG-Based multi-party closed-loop architecture built using the Neurosity™ SDK. Furthermore, this work extends knowledge regarding how to use consumer-grade EEG tools to implement a multi-party BCI application. Our observations suggest that while new SDKs may enhance our ability to create novel BCI applications, additional research is needed to validate this approach further.

CCS CONCEPTS

• **Human-centered computing → Collaborative interaction**.

KEYWORDS

Brain-Robot Interaction, Brain-Computer Interface, Competitive BCI

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1 INTRODUCTION

In the realm of Human-Computer Interaction (HCI), electroencephalography (EEG)-based brain-controlled robot architectures have gained significant attention. These innovative systems offer a promising avenue for enhancing our interaction with technology and are a subject of extensive research and development. While a considerable body of work focuses on medical applications of EEG-controlled robots, there is a growing interest in their non-medical applications and the use of active brain-computer interfaces (BCIs) in competitive multi-brain robot interactions.

In non-medical, competitive applications, researchers have explored using BCI technology to mitigate manual control in challenging scenarios. For instance, there has been work aiming to reduce the need for manual control of drones by utilizing brain signals to enhance control systems [2]. This research not only streamlines the operation of complex machinery but also contributes to our understanding of how brain signals can be effectively integrated into competitive applications.

To build upon these developments, our system uses motor imagery tasks in a multi-party context. Active BCIs allow users to control applications using consciously intended brain signals without relying on external events [1]. By leveraging active BCIs, we aim to expand our understanding of the design of multi-party control systems for competitive multi-brain robot interactions.

This research discusses an architectural design that leverages Neurosity's SDK subscription model to design machine intelligence (MI)-based competitive multi-party BCI experiences. This study's contribution lies in the knowledge shared regarding ways to design a multi-party motor imagery-based BCI system that leverages a consumer-grade API. It is expected that researchers and developers will be able to use these insights to develop additional multi-party applications in the future.

2 SYSTEM DESIGN

As shown in Figure 1, the design of our system expands from the architecture commonly found in previous multi-brain robot interaction systems, as detailed in Hernandez et al.'s work [2]. Our approach incorporates technology to achieve seamless and intuitive human-robot interactions.

2.1 EEG Apparatus

Central to our system is the utilization of the Neurosity™ Crown EEG headset. This device measures electrical activity from the brain using its sensors. Brain signals acquired with this device are recorded at a sample rate of 256 Hz. The pre-filters used on the device's operating system include a notch of 50 Hz - 60 Hz with a bandwidth of 1 and a bandpass between 2 Hz and 45 Hz while leveraging the Butterworth characteristic. The device consists of eight channels (CP3, C3, F5, PO3, PO4, F6, C4, CP4). The raw

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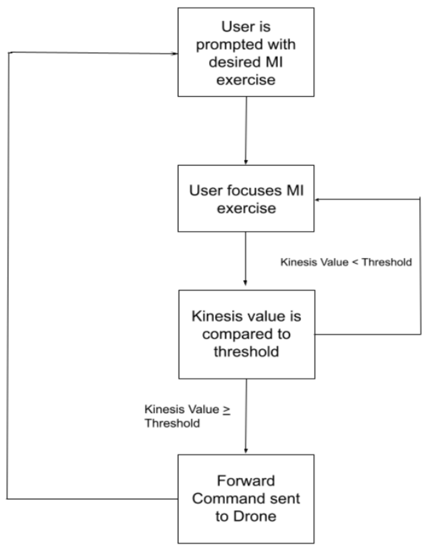

Figure 1: Decision Tree for Closed-Loop Architecture

EEG information captured by the Crown™ is the source of the neurological insights.

2.2 Drone

A Robolink™ Co-Drone is connected via Bluetooth and should contain its own set of modules. To ensure competitive fairness, each drone is placed equidistant from the finish line. The purpose of each drone is to receive commands from the central controller. This interaction between the drone and the central controller represents the closed-loop system.

2.3 User Interface

The central element of the user interface (UI) is a real-time MI progress display. This UI was developed in Python using the Tkinter library. Users can observe their current motor imagery levels as they engage in the competition as well as their cognitive input and how well they are focusing on the intended motor tasks.

2.4 Master Controller

The process starts by gathering EEG data from the user, which our system processes to build a classifier that translates brain activity into drone commands. Our system records brainwave patterns during specific tasks to train a machine-learning model, allowing it to predict the user's intentions based on their cognitive processes.

The master controller's user interface acts as a bridge between the user's thoughts and the drone, displaying action visualizations as well as incorporating understandable performance metrics. The model assesses the user's cognitive state with a probability metric between 0 and 1, indicating how likely the brain activity matches a desired action.

For the drone to execute a command, like moving forward, the probability metric must exceed a set confidence threshold. This ensures that the system only acts on commands it interprets with high certainty, merging technology with human cognition to enable control through imagination.

3 DISCUSSION AND CLOSING REMARKS

In order to study methods of facilitating multi-user robot interaction, we developed a competitive multi-user robot-interaction event: a drone race. This event required each participant to train the headset to respond accurately to their brainwave signals. In order to make the competition as fair as possible, each participant trained their own headset prior to racing and retrained after each round. Obviously, this retraining process slowed the overall competition. Moving forward, researchers should consider ways to leverage methods that do not require long training times.

In general, the results of the brain drone race revealed that the use of the Neurosity™ Crown device provided adequate 1-dimensional control over the drone. The Crown's signal acquisition and processing features offered a relatively easy way to implement our system compared to other available devices. During the times when the drone was being driven, participants were able to activate controls that pushed their drone to the finish line. They were prompted on which movement to imagine, which is the reason for training the headset prior to racing, in order to accelerate the drone forward. We do not yet fully understand what made some participants more effective at executing the prompted MI tasks. Our anecdotal evidence suggests that participants who stated high confidence in their ability to concentrate often perform well. However, additional research is needed to investigate this concept further in the context of competitive BCI applications. Currently, this Brain-Drone Race application is only intended for non-medical and entertainment purposes. As a result, this work focused on exploring ways to support closed-loop interaction and not performance results typically included in traditional BCI research. Insights shared in this study should only be used as a starting point regarding ways to implement MI-based multi-party applications. As this area matures, identifying ways to evaluate user and system performance will become critical. Furthermore, researchers interested in this area should also begin to explore ways to leverage these types of systems to assist with goals in the medical domain, such as rehabilitation.

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