 DOI: 10.3217/978-3-99161-050-2-036

A Continuously Learning Neural Decoder for Versatile and Transferable Motor Control

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Introduction: Brain-computer interfaces (BCIs) offer individuals with conditions such as paraplegia or ALS the ability to gain control of assistive devices. Most BCIs rely on fixed neural decoders that require a long initial calibration to achieve accurate functionality. The non-stationarity of brain signals however often causes performance degradation over time, making frequent recalibration necessary – a time consuming and frustrating process that limits BCI practicality. To address these limitations, we present a novel neural decoder that combines short calibration time, continuous learning, and versatile feature selection - making it robust to a wide range of neural oscillations and implant locations. This approach allows for dynamic adaptation to changing brain signals, fostering co-adaptation between the user and the decoder while reducing the need for frequent recalibration.

Methods: We recorded brain activity using intracranial electroencephalography (iEEG) from multiple epilepsy patients undergoing presurgical monitoring. All patients engaged in a short, supervised calibration to initially train a closed-loop decoder on executed and imagined movement. The decoder uses a novel feature selection strategy that combines distributed low-frequency and localized high-frequency signals to enhance performance. Prior to testing the closed-loop system, patients used Neurofeedback to learn to control the continuous decoder output. The decoder then enabled control of a racing game, integrating continuous learning via real-time finetuning using pseudo-labeled data.

Results and Discussion: The decoder accurately identified motor intention above chance in all participants. After just one minute of calibration, the algorithm achieved over 90% of each participant's personal maximum performance. Patients found that the neurofeedback prior to the closed-loop game helped make the BCI feel more intuitive, as they could directly manipulate and observe the movement probability in real-time. Throughout the closed-loop sessions, the decoder was updated every minute with the newly acquired data, enabling continuous adaptation to evolving brain signals.

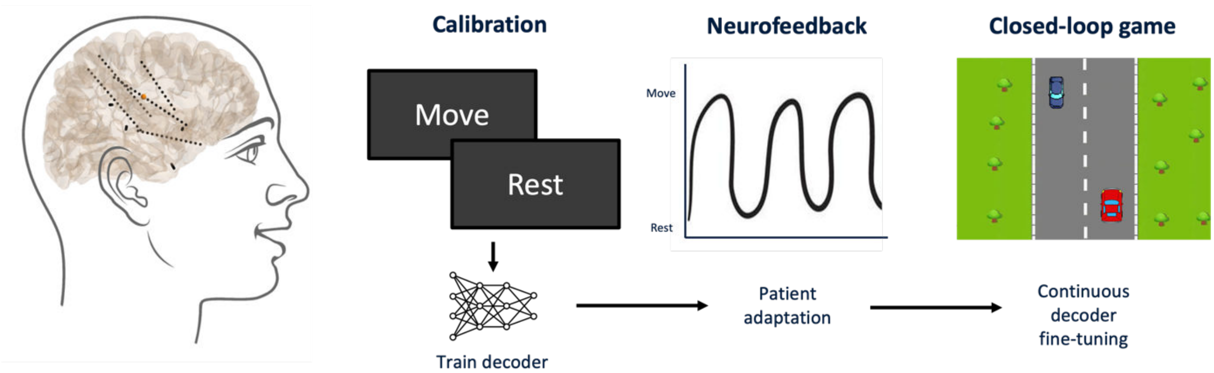

Figure 1. *Experimental setup for a continuously learning decoder, featuring an initial calibration, neurofeedback, and a closed-loop game to fine-tune the decoder and facilitate patient adaptation.*

Significance: This work contributes to improving the usability of brain-computer interfaces by reducing calibration time and the need for frequent re-calibration. With continuous adaptation and minimal manual setup, the system becomes more autonomous, empowering patients with greater control and making long-term use more practical.

Published by Verlag der Technischen Universität Graz