Brain-computer interfaces for real-life applications

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PUBLIC PHD DEFENCE FOR THE DEGREE OF
Doctor of Interdisciplinary Studies: Computer Science and Movement and Sports Sciences (VUB) & Doctor in Computer sciences (CY Cergy Paris University)

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PROMOTIEZAAL D2.01, CAMPUS ETTERBEEK

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ABSTRACT OF THE RESEARCH

Brain-computer interfaces (BCIs) enable users to control devices through their thoughts, which is particularly beneficial in situations where individuals are unable to move or speak, whether due to environmental factors, such as working with their hands in a noisy setting, or physical disabilities. One application of this technology is controlling a physically assistive robotic arm that aids individuals suffering from paralysis in their daily activities, thus increasing their autonomy. Motor imagery (MI), the brain activity that occurs when imagining a movement, can be leveraged by linking a specific imagined movement to a device action, which can be decoded from brain signals like the electroencephalogram (EEG).

Despite its promise, BCI applications face significant challenges before they are ready for real-world usage, including the difficulty of accurately decoding EEG signals in real time and the absence of standardized evaluation protocols for BCI prototypes. This PhD research explored potential solutions to these problems, focusing on the development of a proof-of-concept BCI system to control a physically assistive robotic arm. The key research question was how to design a BCI control system that enables users to operate the arm without moving their limbs or speaking.

We first examined the most effective methods for MI decoding and investigated the possibility of reducing the number of sensors used to decode MI from EEG data. Subsequently, we incorporated innovative technologies like augmented reality and eye tracking to create a BCI prototype. This system combines MI with shared robot control strategy to optimize the usability of the control system. To evaluate the readiness of our system for real-world application, we also created a user evaluation framework for BCI prototypes, which we used to assess the practical usability of our system.

Our findings suggest that current EEG technology is sufficiently advanced for practical BCI applications and that our control approach is viable for operating a robotic arm using MI. Additionally, while eye tracking proved more practical for controlling the robotic arm, BCI technology already offers solutions for niche cases where users cannot shift their gaze. Although BCIs are not yet ready to be the standard interaction method for everyday devices, the development of targeted applications holds great potential. These contributions mark a significant step towards the practical deployment of BCI systems in real-world human-robot collaboration scenarios.

CURRICULUM VITAE

With a passion for automation and computer science, I began my studies at the Vrije Universiteit Brussel in 2013. Fascinated by artificial intelligence and science fiction, I pursued a master's specialization in AI, where I discovered brain-computer interfaces during my thesis research. After earning my master’s degree in 2018, I worked at the inter-university institute for bioinformatics (IB2) as a software engineer, developing a platform for sharing data on oligogenic diseases. In 2020, I began my PhD on "Brain-computer interfaces for real-life applications," completing it in 2024. For this PhD, we developed a proof-of-concept application where users can operate a robot arm with their thoughts.