Research internship
Accounting for brain electrical stimulation in reinforcement learning

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- Domains: Machine learning, bandit and reinforcement learning algorithms, brain electrical stimulation.
- Places and environment: NeuroMod Institute, JAD Mathematics lab and I3S Computer Science lab of Université Côte d'Azur. JAD Mathematics lab is situated in Valrose Campus in Nice. I3S Computer Science lab and NeuroMod Institute are situated at the Sophia Antipolis technology park (Europe's leading technology park). Université Côte d'Azur is a leading place in mathematics and computer science, with one the four French Interdisciplinary Institute for AI (3IA).
- Competences: Statistics, machine learning and programming skills.
- Duration: 5-6 months.
- Starting date: any time early 2024.
- Stipend: 600€/month.
- Contacts: Send a CV and a motivation letter to: Luc Lehéricy (luc.lehericy@univ-cotedazur.fr), CNRS researcher and Alexandre Muzy (alexandre.muzy@univ-cotedazur.fr), CNRS researcher, director of NeuroMod institute and head of eXplAIn team.

1 Internship description

The goal of this internship is to develop new reinforcement learning models to better understand the relation between brain electrical stimulations and their impact on the speed or effectiveness of learning (Albouy et al., 2017, 2022). Considering real experiments, the learning behaviour of epileptic people is significantly altered (and improved) when stimulating them, either directly through implanted electrodes or by induction in their hippocampus, or indirectly through visual stimulation. The models developed will first be assessed on synthetic data, then applied to real experiments. In these experiments, the neuronal activity and actions, undertaken by the patients, are recorded in real-time over the course of the learning task.

The first approach will be to consider abstract models based on the Gradient Ascent Activity-based Credit Assignment (GAtACA) learning algorithm (Sabri et al., 2023), a new reinforcement learning algorithm aiming at better assigning credit to individual decisions. This algorithm offers a simple framework that can take into account additional information, in the form of an *activity*. Two types of activities will be considered: the intensity of stimulation, and the amplitude and synchronization of specific frequencies in EEG measurements, identified as significant by (Albouy et al., 2017).

Depending on the progress of the internship, two further approaches will be considered. The first involves developing models based on other reinforcement learning algorithms, such as contextual

bandits, to better reflect individual learning trajectories, before studying how the intensity of the stimulation alters the parameterization of the models.

The second approach is to explore the related neuroscience literature to develop bio-inspired models that natively exhibit the observed phenomenon of synchronization inside a cerebral region that appears central in the improved performance in learning tasks. This work will be done in collaboration with Philippe Albouy, neuroscientist at Université Laval, in Canada.

References

Philippe Albouy, Aurélien Weiss, Sylvain Baillet, and Robert J Zatorre. Selective entrainment of theta oscillations in the dorsal stream causally enhances auditory working memory performance. *Neuron*, 94(1):193–206, 2017. doi: https://doi.org/10.1016/j.neuron.2017.03.015.

Philippe Albouy, Zaida E. Martinez-Moreno, Roxane S. Hoyer, Robert J. Zatorre, and Sylvain Baillet. Supramodality of neural entrainment: Rhythmic visual stimulation causally enhances auditory working memory performance. *Science Advances*, 8(8):eabj9782, 2022. doi: 10.1126/sciadv.abj9782. URL https://www.science.org/doi/abs/10.1126/sciadv.abj9782.

Oussama Sabri, Luc Lehéricy, and Alexandre Muzy. Multi-agent learning via gradient ascent activity-based credit assignment. *Scientific Reports*, 13(1):15256, 2023.