Postdoctoral offer – Institute 3IA Côte d'Azur

Behavior without neurons

Supervisors and location

- **Supervisor:** Christophe Eloy, IRPHE, Marseille
- **Co-supervisor:** Médéric Argentina, INPHYNI, Nice
- **Laboratory:** IRPHE, Centrale Méditerranée, Marseille

Project

Unicellular organisms routinely display efficient and adaptive behaviors despite the absence of any nervous system. Bacteria such as *Escherichia coli* climb chemical gradients, while unicellular algae such as *Chlamydomonas reinhardtii* navigate toward light. These behaviors rely entirely on biochemical regulatory networks that take as input local sensory signals and output motor responses. While specific mechanisms have been extensively studied, it remains unclear how universal these non-neural control strategies are, how they can be described within a common theoretical framework, and whether they can inspire new paradigms for artificial control. Understanding how apparently intelligent behavior emerges without neurons raises fundamental questions at the intersection of biology, physics, and artificial intelligence.

The objective of this postdoctoral project is to develop a unified, AI-compatible framework for non-neural behavior based on dynamical systems and learning. Behaviors will be modeled as low-dimensional dynamical systems coupling sensing, internal regulation, and body dynamics. Inspired by nonlinear physics, we will investigate normal forms (i.e., universal weakly nonlinear descriptions) and determine when such reduced representations are sufficient to generate robust navigation. These tools will be used to classify behaviors and identify key parameters governing adaptation and stability. Building on this theoretical foundation, reinforcement learning will be employed to automatically discover and optimize non-neural controllers under physical constraints. In a deliberately contrasting perspective, *artificial intelligence* will be used to learn *non-neural intelligence*: learning algorithms will explore families of simple, interpretable dynamical controllers to solve navigation tasks such as gradient climbing, target localization, or escape responses, thereby revealing generic control principles.

Practical information

This work will be jointly supervised by Christophe Eloy (IRPHE, Centrale Méditerranée), whose research spans biophysics and deep reinforcement learning, and Médéric Argentina (INPHYNI, Université Côte d'Azur), an expert in nonlinear physics and learning in dynamical systems. By bridging artificial intelligence and biological minimalism, this project aims to contribute both to the understanding of non-neural behavior and to the design of novel, learning-based control strategies beyond neural architectures.

Expected skills

We are looking for a candidate with a PhD in physics, mechanical engineering, or applied mathematics. We expect a strong background in dynamical systems, reinforcement learning, and optimization algorithms. Good coding skills in Python, PyTorch, together with a general interest in biology are welcomed.

Application

Applications should contain a CV, a motivation letter, and the names and contact information of three references. Applications should be sent by email to christophe.eloy@centrale-med.fr.

References

- Leptos, K. C., Chioccioli, M., Furlan, S., Pesci, A. I., & Goldstein, R. E. (2023). Phototaxis of *Chlamydomonas* arises from a tuned adaptive photoresponse shared with multicellular *Volvocine* green algae. *Physical Review E*, **107**(1), 014404.
- Rand, D. A., Raju, A., Sáez, M., Corson, F., & Siggia, E. D. (2021). Geometry of gene regulatory dynamics. *Proceedings of the National Academy of Sciences,* **118**(38), e2109729118.
- Tu, Y., & Rappel, W.-J. (2018). Adaptation in living systems. *Annual Review of Condensed Matter Physics*, **9**(1), 183-205.
- Tu, Y., Shimizu, T. S., & Berg, H. C. (2008). Modeling the chemotactic response of Escherichia coli to time-varying stimuli. *Proceedings of the National Academy of Sciences*, **105**(39), 14855-14860.