The Ecology of Open-Ended Skill Acquisition
Conceptual framework and computational experiments on the interactions between environmental, adaptive, multi-agent and cultural dynamics

Thesis document

An intriguing feature of the human species is our ability to continuously invent new problems and to proactively learn how to solve them: what is called *Open-Ended Skill Acquisition* (OESA). Understanding the mechanisms underlying OESA is an important scientific challenge in both cognitive science (e.g. by studying infant cognitive development) and in artificial intelligence (aiming at computational architectures capable of open-ended learning). Both fields, however, mostly focus on cognitive and social mechanisms at the scale of an individual's life. It is rarely acknowledged that OESA, an ability that is fundamentally related to the characteristics of human intelligence, has been necessarily shaped by ecological, evolutionary and cultural mechanisms interacting at multiple spatiotemporal scales.

In this talk, I will present a research program aiming at understanding, modeling and simulating the emergence of OESA in artificial systems, grounded in theories studying its eco-evolutionary bases in the human species. We will dive into three main research questions and, for each of them, I will present some of my related contributions.

What are the ecological conditions favoring the evolution of skill acquisition? My contributions on this topic include:

- Studying the role of environmental dynamics in the evolution of phenotypic diversity using eco-evolutionary models (Nisioti & Moulin-Frier, 2022),
- The emergence of sensorimotor control in cellular automata (Hamon, Etcheverry, Chan, Moulin-Frier & Oudeyer, 2022).

How to bootstrap the formation of a cultural repertoire in populations of adaptive agents? My contributions on this topic include:

- Modeling the self-organization of early vocal development through intrinsically motivated goal exploration, in a simulated vocal tract model (Moulin-Frier, Nguyen & Oudeyer, 2013),
- The emergence of phonological systems in populations of Bayesian vocal agents (Moulin-Frier, Diard, Schwartz & Bessière, 2015).

What is the role of cultural evolution in the open-ended dynamics of human skill acquisition? My contributions on this topic include:

- Leveraging language as a cognitive tool to imagine creative goals in intrinsically motivated reinforcement learning (Colas, Karch, Lair, Dussoux, Moulin-Frier, Dominey & Oudeyer, 2020)

- Studying how the structure of social networks impacts collective innovation in multi-agent reinforcement learning (Nisioti, Mahaut, Oudeyer, Momennejad & Moulin-Frier, 2022).

By developing these topics, we will reveal interesting relationships between theories in human evolution and recent approaches in artificial intelligence. This will lead to the proposition of a humanist perspective on AI: using it as a family of computational tools that can help us to explore the mechanisms driving open-ended skill acquisition in both artificial and biological systems, as a way to better understand the dynamics of our own species.

Committee members:

- **Jean-Baptiste Mouret,** Reviewer (Research Director, Inria, France)
- **Yukie Nagai,** Reviewer (Professor at The University of Tokyo, Japan)
- **Dan Dediu,** Reviewer (ICREA Research Professor, University of Barcelona, Spain)
- **David Ha,** Examinator (Head of Strategy at Stability AI, Japan)
- **Nicolas Bredeche,** Examinator (Professor at Sorbonne Université, France)
- **Emmanuel Dupoux,** Examinator (Director of Studies, ENS EHESS, France)
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