Internship project, master level, 2026

Curiosity-driven automated discovery of interference patterns in multi-core architectures

Supervision: Ludovic Matar, Clément Moulin-Frier (with help from PY Oudeyer)

Research group: Flowers team, Inria Bordeaux, France

Duration: 6 months, around February 2026 (with flexibility).

Location: Inria center at the university of Bordeaux or IRT Saint Exupéry B612 Toulouse

Level: Master 2 research internship

Keywords: Curiosity-driven learning, automated discovery, large language models, program synthesis, complex systems, distributed computing, hardware architectures

How to apply: contact ludovic.matar@inria.fr, pierre-yves.oudeyer@inria.fr and clement.moulin-frier@inria.fr using the tag [application] in the object of the email; with a CV and letter of motivation. We also recommend sending documents or reports describing previous projects you have been working on (even if they are not directly related to the topic), as well as your grades and links to code repositories.

Requirements: We are looking for highly motivated MSc students (Master II).

Programming skills and prior experience with real time embedded systems, computer hardware and parallel architectures, multi-core and multiprocessor architectures.

Or :

Interest in machine learning/applied mathematics. Experienced with python and deep learning frameworks (e.g. Pytorch, JAX).

Context

A major contribution of the Flowers team in recent years has been the development of curiosity-driven learning algorithms in order to efficiently explore the diversity of behaviors of complex systems (Etcheverry, 2023). A complex system is a system consisting of multiple entities interacting with each other, giving rise to emergent phenomena that are difficult to predict. Examples of complex systems in Nature are water molecules crystallizing into snow flakes, collective animal behavior forming complex patterns (e.g. bird flock), or chains of amino acids forming complex 3D protein structures. Complex system dynamics can also be simulated in silico, e.g. in cellular automata such as the Game of Life. Such dynamics are even present at the hardware level, e.g. in multi-core architectures exhibiting complex interference patterns due to the concurrent execution of multiple programs on shared computing resources.

Understanding, simulating and being able to predict the behavior of complex systems is an important challenge in many scientific fields. For this aim, scientists often need to build a model mapping the input parameters of the system (e.g. a sequence of amino acids) to its corresponding observed behavior (e.g. the resulting 3D shape of a protein). This is a challenging problem because the parameter space is often in high dimensions and the mapping from parameters to behaviors is highly non-linear and unpredictable.

To solve this problem, the Flowers team has proposed Automated Discovery Algorithms. The objective of these algorithms is to automatically discover all the diversity of behaviors a complex system can exhibit, with a limited experimental budget. Such algorithms were originally developed as a model of how children or artificial agents proactively explore their environment (Baranes & Oudeyer, 2013, hence the term “curiosity-driven”) and we have recently developed a framework for using them to explore any type of complex systems (Etcheverry, chapters 1,2,3, 2023). To encourage and facilitate the re-use of these algorithms by a broader audience of chemists, biologists, artists and others, we have released a fully open-source interactive software that aims to provide tools for assisting discovery in various complex systems (Flowersteam/Adtool, 2024/2024).

Recently, we have started to apply such algorithms to a very concrete use case: the discovery of diverse interference patterns in multi-core hardware architectures. Indeed, the shift from single-core to multi-core architectures is essential in safety-critical embedded systems in multiple domains such as aerospace and automotive, driven by both the need to enhance processor performance for increasingly demanding applications and adaptation to recent technology. However, this transition introduces new complexities, particularly hardware contention issues known as inter-core interferences. Due to the hardware complexities, the conditions under which interference occurs, as well as their effects, can vary greatly and often seem random, making them very difficult to model and to predict. In other words, such architectures are complex systems. Various approaches have been attempted, but often too complex therefore unsuited to industrial-case scenari [(Gonzalez, 2020),(Boniol, F. et al. ,2020),artificial intelligence (Courtaud,19)]. Thus we believe that our automated discovery algorithms can be very useful to characterize their behavior. We have recently developed a first prototype successfully showing how such algorithms can indeed discover non-trivial interference patterns in such architectures.

The proposed internship position will be conducted in the context of larger national research project on *Analysing Interferences with AI (AIxIA)*, involving several partners with a strong expertise in AI and onboard systems (IRT Saint Exupery), in multi-core architectures, system-on-chips, GPUs and temporal analysis (IRIT and IRISA), as well in automated discovery in complex systems and program synthesis with LLMs (Inria-Flowers, where the proposed internship will be located).

Mission

We have synthesized a prototype of the automated discovery of interference patterns with a simplified python simulator of a dual-core architecture. The exploration algorithm takes simplified assembly programs as inputs, simulates their parallel execution and returns various descriptors of the execution as outputs (hardware performance counters extracted from the simulator such as execution time, cache hits and misses etc …). The exploration algorithm aims to cover as much as possible the descriptor output space made of hardware performance counters extracted from the simulator.

This internship will involve a literature review on both topics for understanding the problem of interference characterization in such architectures, as well as automated discovery algorithms. As part of the research team, and according to the candidate profile, one of the two majors directions will be followed:

1. In order to go further in our study, it is essential to transfer this prototype with its synthesized automated exploration algorithms to a physical target device, namely T2080 (ref QorIQ). This direction will require adapting the underlying algorithms and data representations to the device and proposing solutions to the specificities of hardware architectures (IO, potential crashes, sample efficiency …). Interactions with project partners will help to develop appropriate strategies for handling the equipment.

2. Adapting and extending the algorithms currently implemented in ADTool (Flowers team, 2024), an open source library designed by Flowers which provides an integrated solution for studying complex systems through curiosity-search methods. This will require to adapt the existing prototype to the format of the ADtool library, e.g. wrapping the simulator code and other components of the exploration model with existing python framework, and to demonstrate its utility by establishing diversity measures for comparison. This direction does not require dealing with a real hardware architecture.

Skills

Skills articulated in one of the following two sets :

• Strong interest in AI and complex systems, with a strong motivation to apply state-of-the-art machine learning algorithms to concrete engineering problems.
Scientific programming
- ◦ Python
- ◦ Machine Learning algorithms and frameworks (e.g. sklearn, Pytorch, JAX)

OR
• Strong interest in industrial cases of distributed computing architectures. Theoretical and practical knowledge of embedded Real-time Systems, assembly programming and c.
- ◦ Knowledge of python is a required.

References

QorIQ® T2080 and T2081 Multicore Communications Processors,https://www.nxp.com/products/T2080

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Etcheverry, M. (2023). *Curiosity-driven AI for Science: Automated Discovery of Self-Organized Structures* [Phdthesis, Université de Bordeaux]. https://theses.hal.science/tel-04504878

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Gonzalez, A.M., Bouchebaba, Y. and Santinelli, L. (2020) ‘Multicore shared memory interference analysis through hardware performance counters’, in. 10th European Congress on Embedded Real Time,Software and Systems (ERTS 2020), Toulouse, France

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