Internship project, master level, 2025

Automated discovery of interference patterns in multi-core architectures

Supervision: Pierre-Yves Oudeyer and Clément Moulin-Frier (plus a research engineer who will soon be recruited).

Research group: Flowers team, Inria Bordeaux, France

Duration: 6 months, around February 2025 (with flexibility).

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 pierre-yves.oudeyer@inria.fr and clement.moulin-frier@inria.fr ; 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 Python and deep learning frameworks (e.g. Pytorch, JAX) are expected.

Context

A major contribution of the Flowers team in recent years has been the development of curiosity-driven learning algorithms (Baranes & Oudeyer, 2013). These algorithms, coupled with deep representation learning techniques (Laversanne-Finot et al., 2018), have enabled both a better understanding of learning mechanisms in humans (Gottlieb & Oudeyer, 2018), but also the construction of machines/robots capable of efficiently exploring and learning repertoires of diverse tasks in high-dimensional spaces (Colas et al., 2019), or solving complex optimization tasks with local minima (Colas et al., 2018). This work has helped to introduce and develop a new field of research in artificial intelligence: intrinsically motivated learning.

Recently, the Flowers team discovered that these algorithms could be applied to a family of problems of great scientific and industrial importance: the automated exploration of complex systems (e.g. physico-chemical, biological or numerical) in order to discover new structures, learn new representations of them (deep learning techniques), make a map of them, and use this map to make the optimization of target structures more efficient (Etcheverry, 2023).

To encourage and facilitate the re-use of these tools by a broader audience of chemists, biologists, artists and others, we are designing a fully open-source interactive software that aims to provide tools to easily use exploration algorithms (e.g. the developed curiosity-driven ones) for assisting discovery in various complex systems (*Flowersteam/Adtool*, 2024/2024). We call them Automated Discovery Algorithms.

The objective of this internship is to apply these automated exploration algorithms to a novel use case: the characterization of interference patterns in multi-core architectures. Indeed, whereas there exists reliable methods to predict worse-case execution time (WCET) in single-core architecture, these methods are not suited for predicting it in multi-core architecture (Courtaud, 2020; Courtaud et al., 2019; Maiza et al., 2020). The main reason is that multi-core architectures introduce temporal dependencies and strong interferences among programs executing in parallel, due to the concurrent access to shared resources (e.g. memory buses, caches etc …). Thus, 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: this is why we believe that our automated discovery algorithms can be very useful to characterize their behavior.

The proposed Research Engineer position is 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

The main objective of this Research Engineer position will be to apply automated discovery algorithms to the problem of characterizing interference patterns in multi-core architectures. This will include:

- Understanding the problem of interference characterization in such architectures, as well as automated discovery algorithms. This will involve a literature review on both topics, informed by discussions with the project partners.
- Studying and formalizing how automated discovery algorithms can be applied to the problem of interference characterization.
- Adapting and extending the automated discovery algorithms currently implemented in the adtools library to the considered problem.
- Considering the use of LLMs as a way to generate programs to be executed on the architecture (Pourcel et al., 2024)
- Running large-scale experiments to evaluate the method and refine it. In the context of the internship, we will consider using a simplified simulated model of mutli-core architectures.
- Analyzing the resulting data and potentially publishing the results.

Skills

Strong interest in IA 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. Pytorch, JAX)

Prior experience with LLMs or distributed computing architectures is a plus.

References

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