PhD Position 2026

Title: **Large-Scale Multi-Robot Decision-Making and Coordination via Mean-Field Game Theory**

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Context and objectives

A fully funded joint PhD position is available between Polytechnique Montreal, Canada, and the CNRS LAMIH laboratory at Université Polytechnique Hauts-de-France (UPHF) in Valenciennes, France. The topic is distributed optimization and control of multi-agent systems, with a particular emphasis on the coordination of networked multi-robot systems. This research will investigate resource allocation problems and develop distributed optimization algorithms for cooperative multi-agent systems, leveraging tools from networked control systems, mean-field games, reinforcement learning and optimal transport. The proposed project will develop methodologies for the control of distributed large-scale systems composed of a large number of agents, whose distribution must be shaped to match them efficiently to a set of tasks.

Recent advances in computing, communication, and control technologies have enabled the deployment of large-scale networks of interconnected agents [1], such as mobile robots [2] and sensor networks, which must cooperate through local interactions to achieve shared objectives. Cooperative multi-agent systems offer significant advantages over isolated agents, including improved robustness to individual failures, enhanced flexibility, and the ability to solve complex tasks that would otherwise be intractable. As a result, distributed control and optimization of multi-agent systems have attracted sustained research interest [3], with applications ranging from multi-robot coordination and formation control [4] to traffic management and autonomous vehicles. In modern large-scale settings, however, communication constraints and network scalability pose major challenges, motivating the development of communication-efficient and fully decentralized decision-making strategies.

In parallel, game-theoretic approaches provide a powerful framework for modeling competitive and cooperative interactions, but they suffer from prohibitive computational complexity in ultra-dense networks. Mean-field game theory offers a promising solution by enabling the computation of scalable, decentralized, and asymptotically optimal strategies for large populations of agents [5]. This PhD project aims to extend mean-field game methodologies to large-scale multi-robot decision-making and coordination problems, addressing challenges related to constrained optimal control, communication efficiency, and resource management, and exploring synergies with

reinforcement learning to ensure applicability in complex real-world scenarios.

The student will spend roughly half of her/his time in Montreal and the other half in Valenciennes. In Montreal, she/he will be affiliated with the department of electrical engineering at Polytechnique Montreal and with GERAD, a multi-university research center on decision systems. Experimental facilities are also available with the Mobile Robotics and Autonomous Systems Laboratory. More information on graduate studies at Polytechnique Montreal can be found here https://www.polymtl.ca/futur-etudes-superieures/en. In Valenciennes, she/he will be affiliated with UPHF and the LAMIH UMR CNRS laboratory, in the Automatic Control Department. LAMIH UMR CNRS 8201 (Laboratory of Industrial and Human Automation control, Mechanical engineering and Computer Science) is a joint research unit between University Polytechnic Hauts de France (UPHF) and CNRS, focused on activities at the intersection of Transport and Security, Mobility, and Disability. The supervisors have strong experience in robust control for multi-robot systems. Experimental facilities are also available, consisting of several mobile robots, at LAMIH. More information on the LAMIH can be found here https://www.uphf.fr/lamih.

Requirements and documents

Interested applicants should have a master's degree in engineering, applied mathematics, computer science, or a related field. A strong background in mathematical methods applied to an area such as control theory, robotics, dynamical systems, machine learning, signal processing, optimization, etc. is desirable.

Interested students are encouraged to send their application, as pdf file(s), to Profs. Defoort, Le Ny, Chen and Moulay at michael.defoort@uphf.fr, jerome.le-ny@polymtl.ca, emmanuel.moulay@univ-poitiers.fr, yiwen.Chen@uphf.fr.

An application should include:

1) A cover letter (maximum one page), stating your research interests and prior experience, and how they relate to the control of multi-agent systems;

2) A full CV;

3) Transcripts;

4) 1 or 2 samples of past contributions/publications (which could be unpublished project reports), in English or French, and for which the candidate is the main or sole author.

The preferred starting date is September 2026 or January 2027. A successful applicant will then need to submit an official complete application to Polytechnique Montreal before one of the upcoming deadlines:

https://www.polymtl.ca/admission/en/graduate-studies/check-application-deadlines

Information about Polytechnique Montreal and UPHF

Polytechnique Montreal is the engineering school affiliated with the Université de Montréal and is one Canada's leading engineering teaching and research institutions. While courses are typically taught in French, non-French-speaking students can take their courses in English at McGill University or Concordia University. Montreal is regularly ranked one of the best student cities in the world. Polytechnique Montreal is deeply committed to employment equity, diversity and inclusion. Accordingly, we encourage women, members of visible and ethnic minorities, Indigenous individuals, and persons with disabilities to apply.

The Université Polytechnique Hauts-de-France (UPHF) is a public university located in Valenciennes, in the North of France. It is known for its strong focus on engineering, technology, and applied sciences. UPHF emphasizes interdisciplinary research and innovation, particularly in areas such as transportation and mobility, industry of the future, digital technologies, automation, robotics, artificial intelligence, and human-centered systems. The university maintains close ties with industry and regional partners, fostering applied research, technology transfer, and professional-oriented education. With a strong commitment to research-led education, UPHF hosts several recognized research laboratories, including CNRS joint research units, and offers a wide range of undergraduate, master's, and doctoral programs. Its international outlook is reflected in active international collaborations, exchange programs, and joint research projects.

References:

[1] T. Menard, S. A. Ajwad, **E. Moulay**, P. Coirault, and **M. Defoort**, "Leader-following consensus for multi-agent systems with nonlinear dynamics subject to additive bounded disturbances and asynchronously sampled outputs," Automatica, Vol. 121, 2020.
[2] **J. Le Ny**, A. Ribeiro, and G. J. Pappas, "Adaptive communication-constrained deployment of unmanned vehicle systems," IEEE J. on Selected Areas in Communications, vol. 30, no. 5, 2012.
[3] P. De Villeros, R. Aldana-López, J. Sánchez-Torres, **M. Defoort**, and A. Loukianov, "Robust fixed-time distributed optimization with predefined convergence-time bound," Journal of the Franklin Institute, vol. 361, 2024.
[4] S. A. Ajwad, **E. Moulay**, **M. Defoort**, T. Menard, and P. Coirault, "Distributed time-varying formation tracking of multi-quadrotor systems with partial aperiodic sampled data," Nonlinear Dynamics, vol. 108, 2022.
[5] F. Li, R. P. Malhamé, and **J. Le Ny**, "Mean field game based control of dispersed energy storage devices with constrained inputs," in IEEE 55th Conference on Decision and Control (CDC), 2016.