

M2 Research Internship 2026

Title: Decentralized control and optimization of mobile robot networks

Supervisors:

DEFOORT Michael : michael.defoort@uphf.fr

MOULAY Emmanuel : emmanuel.moulay@univ-poitiers.fr

Laboratory: LAMIH (Laboratoire d'Automatique, de Mécanique et d'Informatique Industrielles et Humaines) UMR CNRS 8201, Université Polytechnique Hauts-de-France, Valenciennes

Web site: <https://www.uphf.fr/lamih>

Context and objectives

This internship focuses on the decentralized control and optimization of multiple cooperative mobile robot networks and will pay particular attention to the integration of enabling communication, multi-access edge computing and cloud computing technologies within the framework of Industry of the Future.

The perceptual, communicative and adaptive capabilities of mobile robots allow them to be both autonomous and collaborative. These robots, used in particular for handling operations in warehouses or product transport, must meet growing demands in terms of productivity, reliability, ergonomics and safety. Multiple robots capable of performing cooperative tasks simultaneously improve the flexibility and efficiency of a system and its resilience to potential failures [1]. The distributed nature of multiple robots poses a challenge for overall cost optimization, since each agent generally has access only to its local information and limited computing capacity [2]. It is therefore imperative to explore distributed optimization approaches that include computational considerations and data exchange between agents. Furthermore, multiple robots, which traditionally relied on ad-hoc networks, will increasingly be able to integrate 5G telecommunication network technologies, whether public or private.

In this proposal, it is planned to develop general methods to solve multiple robot deployment optimization problems while taking into account the communication and computational constraints of an underlying 5G network. Game-theoretic approaches, modeling network devices as competing agents, offer an interesting avenue to deal with conflicting QoS requirements, but also lead to complex computational problems in ultra-dense networks [3-5]. This challenge can be addressed using the mean-field game theory, which provides a way to efficiently compute approximate game equilibria and decentralized strategies for large-population games, assuming a limited number of agents. We therefore propose to extend the applications of the mean-field game methodology to end-to-end resource management problems in heterogeneous 5G networks for mobile robots. In this approach, each agent solves a local optimization problem that takes into account both its own state (e.g., channel conditions, power budget, latency requirements) and the “mean field” representing the collective behavior of the rest of the network. This approach naturally leads to equilibrium strategies that are efficiently computable and asymptotically optimal as the number of agents increases. Fixed-point algorithms allow for the a priori computation of the mean field, which should represent the time distribution of agents pursuing their locally optimal policy. A challenge to be overcome is solving the local optimal control problem in the presence of constraints on the agent states. Approaches combining mean-field game theory and reinforcement learning will also be explored to ensure applicability to complex scenarios of mobile robot and 5G networks [6].

From the theoretical point of view, this internship aims at investigating the decentralized control and optimization of multiple cooperative mobile robot networks. It is planned to study mean-field game theory to solve the resource management problem in 5G networks for mobile robots.

From the practical point of view, in this internship, an RRM simulator will be developed by combining ROS/Gazebo with ns-3 for network aspects, and a Matlab/Simulink interface. It is also expected that the proposed algorithms are implemented and tested on robotic platforms to verify their effectiveness and make the necessary adjustments to adapt them to real-world situations. The test bench available at LAMIH consists of four small non-holonomic robots, called ENOVA-Robot, as well as three MiR100 industrial mobile robots running using ROS.

References:

- [1] Ren, W., Beard, R. (2008). *Distributed consensus in multi-vehicle cooperative control*. London: Springer London.
- [2] De Villeros, P., Sánchez-Torres, J. D., Defoort, M., Djemai, M., Loukianov, A. (2023). *Predefined-time formation control for multiagent systems-based on distributed optimization*. *IEEE Transactions on Cybernetics*, 53(12), 7980-7988.
- [3] Feng, S. Guo, D. Liu, and Y. Yang, "Mean-field game theory based optimal caching control in mobile edge computing," *IEEE Trans. on Mobile Computing*, vol. 22, 2022.
- [4] C. Yang and et al., "Distributed interference and energy-aware power control for ultra-dense D2D networks : A mean field game," *IEEE Trans. on Wireless Communications*, vol. 16, 2017.
- [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.
- [6] M. Lauriere and et al., "Scalable deep reinforcement learning algorithms for mean field games," in *Proceedings of the 39th International Conference on Machine Learning*, vol. 162, 2022.

The required skills: We are looking for a candidate with a solid background in mathematics and/or automatic control. Knowledge of Python, Matlab and ROS2 will be appreciated.

Duration and salary: 6 months with a salary of 550 euros per month.

Note: Depending on the progress and obtained results, this internship may be followed by a joint PhD (cotutelle internationale de thèse) in Automatic Control between Polytechnique Montréal (PolyMTL) and Université Polytechnique Hauts-de-France (UPHF, LAMIH). The PhD topic will be an extension of this internship subject.