M2 Research Internship – Master (M2) 2025

Title: **Distributed optimization of heterogeneous multi-agent systems (MAS): Applications to multiple autonomous robots coordination**

Supervisors: DEFOORT Michael (michael.defoort@uphf.fr)
CHEN Yiwen (yiwen.chen@uphf.fr)
Laboratory: LAMIH (Laboratoire d'Automatique, de Mécanique et d'Informatique Industrielles et Humaines) UMR CNRS 8201

Context and objectives

In the past decades, we have witnessed intensive research dedicated into the field of cooperative control of Multi-Agent Systems (MAS) due to its broad applications in various fields, such as multi-robot coordination, Unmanned Aerial Vehicles (drones) formation, and autonomous vehicles' coordination, to cite only a few. The distributed control algorithm allows that each agent updates its controller based on the local information received from its neighbor, which enables the whole MAS achieves coordination tasks such as consensus, containment and formation. Moreover, with the growing complexity of MAS applications, many practical scenarios require MAS to optimize performance metrics, such as minimizing energy consumption and or balancing resource allocation, which triggered the development of distributed optimization algorithms for MASs.

Distributed optimization of MAS has gained significant attention, which requires that each agent under nonidentical constraints, cooperatively minimize the sum of local cost functions and meanwhile achieve the coordination task by interaction with their neighbors. Compared to traditional distributed cooperative control schemes, distributed optimization introduces additional layers of complexity. This is due to the dual objectives of optimizing performance metrics and ensuring coordination, both of which must be achieved in a decentralized manner. The development of distributed optimization algorithms for multi-agent systems is crucial to the advancement of cooperative control of multi-robot systems. Most existing distributed optimization algorithms can only ensure all agents asymptotically converge to the optimal state, which implies the optimal state cannot be reached within a finite time. Note that, in practice, the coordination of multiple autonomous robots often demands quick and efficient control protocols to ensure that the overall multi-robot system operates cohesively and achieves its objectives. Thus, developing distributed optimization to ensure finite-time, fixe-time and even predefined-time convergence is of great importance.

From the theoretical point of view, this internship aims at develop a distributed optimization algorithm for multi-agent systems. Considering the heterogeneity of each agent, the optimization problem subject to nonidentical constraints on different agents. Moreover, different agents may utilize distinct sensors, leading to variations in their measurements. The proposed algorithm is expected to ensure the predefined-time convergence to the optimal state, which implies the coordination will be achieved in within a fixed, user-defined time, regardless of initial conditions. Compared with finite-time or fixed-time convergence, the proposed algorithm allows the convergence time to be explicitly set, offering extra predictability and reliability over the optimization process. In addition, to alleviate the transmission burden of communication network, techniques such as event-triggered control strategies and information quantization can also be taken into consideration.

From the practical point of view, in this internship, we expect to apply the theoretical results on an experimental setup at the SmartLab platform, more precisely: a swarm of MiR100 mobile robots. In the first stage, it is expected to simulate the motion of multiple MiR100 mobile robots in ROS Gazebo simulator, which acts as the foundation for the practical implementation. The second step focuses on the implementation on MiR100 with ROS. We require to obtain full or partial information of the state of each agent (e.g., position, velocity, orientation, ...) which are needed for control and estimation purposes.

View of the industrial mobile robots MiR100 available at LAMIH

Envisaged Activities:

1) Literature review of the related works and familiarize with the experimental setup in the team.
2) Develop a distributed optimization algorithm for multi-agent systems
3) Implement and validate in simulation the proposed algorithm (first using Matalab/Simulink then using ROS/Gazebo)
4) Validate experimentally the scenario on MiR 100 mobile robots

List of 5 bibliographical references:

[1] *De Villeros, P., Sánchez-Torres, J. D., Defoort, M., Djemaï, M., & Loukianov, A. (2023). Predefined-time formation control for multiagent systems-based on distributed optimization. IEEE Transactions on Cybernetics, 53(12), 7980-7988.*
[2] *De Villeros, P., Aldana-López, R., Sánchez-Torres, J. D., Defoort, M., & Loukianov, A. G. (2024). Robust fixed-time distributed optimization with predefined convergence-time bound. Journal of the Franklin Institute.*
[3]. *Chen, Y., Wen, G., Peng, Z., Rahmani, A. (2019). Consensus of fractional-order multiagent system via sampled-data event-triggered control. Journal of the Franklin Institute, 356(17), 10241-10259.*
[4]. *Chen, Y., Wen, G., Rahmani, A., Huang, T. (2022). Heterogeneous multiagent systems with different fractional order: An experience-based fusion controller. IEEE Transactions on Circuits and Systems II: Express Briefs, 69(8), 3520-3524.*
[5]. *Ren, W., Beard, R. W. (2008). Distributed consensus in multi-vehicle cooperative control (Vol. 27, No. 2, pp. 71-82). London: Springer London.*

Background:
We are looking for a candidate with a solid background on applied mathematics and automatic control. Knowledge in python, Matlab and ROS (either ROS1 or ROS2) will be appreciated.

Internship information
Duration: up to 6 months (spring/summer 2025)
Address:
LAMIH - Université Polytechnique Hauts-de-France
Campus du Mont Houy, bâtiment Malvache
59313 Valenciennes Cedex 9, France
Application: Please send an email with your most recent transcripts, CV and motivation letter to michael.defoort@uphf.fr and yiwen.chen@uphf.fr