Appel à projets - Année 2025

Contrats doctoraux «Ordinaires»

Direction de la Recherche et de l'Innovation

ECOLE DOCTORALE : MATISSE **POLE DE RECHERCHE : Mathématiques-Numérique**

Unité de recherche d'accueil

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Equipe : Rainbow

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Sujet

Titre : Multi-objective coordination of heterogeneous multi-robot systems

Mots clés : Multi-robot systems, Control, Complex networks, Mobile Robots

Cotutelle internationale (oui/non) : non **Si oui, préciser l'établissement et le pays de rattachement** :

Descriptif (15-30 lignes) :
Contexte socioéconomique et scientifique ; Les hypothèses et questions posées ; Les grandes étapes de la thèse et démarche ; Approches méthodologiques et techniques envisagées

Multi-robot systems are increasingly being deployed in applications such as surveillance, environmental monitoring, and industrial automation. Most of the current works focus on homogeneous multi-robot systems collaboratively carrying out a single simple task such as coverage, exploration, object pushing, etc. [1]. However, achieving seamless collaboration among **heterogeneous robots** with diverse capabilities performing **complex missions** remains a challenge. These missions often consist of **multi-objective tasks** requiring different tools or capabilities in expansive and **dynamically changing environments**, necessitating advanced interaction models.

Interaction paradigms observed in social and biological networks such as, e.g., stubbornness, clustering, or inhibitory interactions, have the potential to improve the coordination of heterogeneous robots by enabling them to exhibit adaptive, resilient, and complex behaviors to execute multi-task missions in dynamically changing environments. **This PhD aims to enhance the coordination of heterogeneous multi-robot systems by leveraging the dynamic models used to describe complex interactions in social and biological networks** [2]. We plan to adapt the latter to multi-robot systems with sensing and actuation constraints. Initially we will directly model the interactions among the robots based on **nonlinear agreement protocols** [3], **opinion dynamics** [4] and **multi-layer graphs** [5], taking into account the different capabilities of the agents and the multi-objective tasks. Current works on opinion dynamics consider only static and unconstrained agents where the model of the opinion dynamics are used to explain different phenomena occurring in social or biological networks. We will investigate instead how the inclusion of an opinion layer in the interactions of multiple heterogeneous mobile robots with sensing and actuation constraints can lead to complex and resilient behaviors in the context of multi-objective missions. In a second time, and due to the complexity of the system, we will consider approaches based on reinforcement learning to increase the adaptability and robustness of the swarm to dynamic conditions.

Experimental validation: the control methods will be validated and tested on tasks progressively advancing from simpler missions such as forming clusters and simultaneously aggregating at different locations of interest, to a long-term dynamical mission that needs reconfiguration of the robotic team. The experimental validation will utilize the facilities of the Rainbow team, including two indoor and multi-robot arenas and several mobile robots.

References :

1. Cortés, J., & Egerstedt, M. (2017). Coordinated Control of Multi-Robot Systems: A Survey. *SICE Journal of Control, Measurement, and System Integration*, *10*(6), 495–503.
2. Bizyaeva, A., Franci, A., & Leonard, N. E. (2022). Nonlinear opinion dynamics with tunable sensitivity. *IEEE Transactions on Automatic Control*, *68*(3), 1415-1430.
3. Homs-Dones, M., Devriendt, K., & Lambiotte, R. (2021). Nonlinear consensus on networks: Equilibria, effective resistance, and trees of motifs. *SIAM Journal on Applied Dynamical Systems*, *20*(3), 1544-1570.
4. Zhang, Z., Chen, S., Mayberry, S., & Zhang, F. (2024, October). Opinion-based Strategy for Distributed Multi-Robot Task Allocation in Swarms of Robots. In *2024 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 3476-3481). IEEE.
5. Sorrentino, F., Pecora, L., & Trajković, L. (2020). Group consensus in multilayer networks. *IEEE Transactions on Network Science and Engineering*, *7*(3), 2016-2026.

➢ **Ce document est à renvoyer par la direction de l'unité de Recherche aux animateurs du Pole Recherche et à l'école Doctorale pour le 13 février 2025 au plus tard**