Network research team
ICube laboratory (UMR CNRS 7357)

Thesis proposal 2024/2025

Robustness and adaptability in autonomous robot systems

Context

Robots have always fascinated human's imagination: autonomous artificial entities which can take decisions and are able to perform various tasks autonomously. What seemed to be a fantasy has now become a real reality. Indeed, various robots have been designed for different purposes: aerospace, disaster response, education, entertainment, industrial and also medical. On the other hand, collective autonomous behaviors observed in nature as within ant colonies when gathering food or birds while flocking, have also captivated various research interests to understand how such small and numerous entities can self-organize themselves in a complete decentralized fashion to perform complex tasks. Several researches aim at reproducing such behaviors within artificial systems. More precisely, instead of using a single intelligent and expensive robot to perform a given task, the aim is to emerge a collective intelligence from a set of basic and cheap robots which will collectively and autonomously collaborate together to achieve their given task.

The proposed thesis fits into this context and therefore focuses in swarm intelligence. The goal of the project is to provide autonomous and robust solutions for various collaborative problems under real constrains.

Objectives

The thesis will focus on swarm robotics where robots are endowed with visibility sensors and motion actuators and operate in cycles which include three phases: Look, Compute and Move [1]. During the first phase (Look), robots take a snapshot to observe their environment and see the positions of the other robots. In the second phase (Compute), based on the observation taken during the first phase, robots decide to either remain idle or move. In the latter case, they also compute a target destination. Finally, in the last phase (Move), they just move to the computed destination (if any). The objective is to define models, study their limits and develop decentralized solutions that can be implemented in a real context. The thesis will focus on three main collaborative problems:

- *The exploration problem.* The purpose is to design distributed solutions allowing the robots to explore a given network. Both the perpetual exploration and the terminating exploration will be considered. In the first version of the problem, robots need to explore infinitely often a given network while in the second version of the problem, robots need to detect the end of the exploration and stop moving eventually.
- *The Gathering problem.* Starting from an initial configuration in which robots are placed arbitrarily, the purpose is to make the robots agree on a given location, not known in advance, and meet there eventually.

- *The scattering problem.* Starting from an initial configuration in which robots are placed arbitrarily, the objective is to make the robots disperse themselves so that they cover completely a given surface or structure.

The aforementioned problems have been studied in the literature [2, 3, 4, 5, 6, 7]. However, the majority of the investigations do not address faults that could occur within the swarm or the dynamic environment on which the robots evolve. In this thesis, two main challenges will be addressed:

- *Fault-tolerance.* Various types of faults can occur within the swarm: transient (of limited duration), permanent (crashes) or byzantine (malicious). The first aim is to propose robust and fault-tolerant solutions applied to swarm of robots. These solutions would guarantee that the swarm retrieve a correct behavior by itself, without any external help or re-initialization in a finite time. The second objective is to study the impact of fault tolerance not only on the computing power of the swarm but also on the costs (in terms of time complexity) and robots' capabilities under different fault models.
- *Dynamic environments.* The environment strongly impacts the behavior of robots and therefore plays a major role in the development of distributed collaborative solutions. The objective is to design distributed solutions allowing the robots to adapt to their environment and solve their collaborative task. Different types of dynamicity will be addressed [8].

Work environment

The thesis will take place at the University of Strasbourg, in the Network research group, at the ICube laboratory. The PhD supervision team is composed of: Quentin Bramas, Anissa Lamani, Jean-Romain Luttringer and Pascal Mérindol.

Contact

Interested candidates can apply by sending a detailed CV, the grades of the last three years and a cover letter to reseaux-pos-2024@icube.unistra.fr.

References

[1] Suzuki, I., and Yamashita, M. (1999). Distributed anonymous mobile robots: Formation of geometric patterns. SIAM Journal on Computing, 28(4), 1347-1363.

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