PhD thesis subject

Inria Chroma and Dante teams, Lyon, France

Titre	Dynamic flocking based on link quality in swarm of UAVs
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Rémunération	Inria PhD grant within the DGA/Inria DYNAFLOCK project (2019-2022)
Mots clés	Distributed AI, swarm of UAVs, flocking, wireless network, simulation, robotic experiment.
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Context

Coordination among agents or robots allows to manage collision avoidance, in real time, and more generally to deploy them in constrained environment. In a swarm of robots, local coordination allows to decentralize the control and decision-making, providing robustness (due to the decentralization) and adaptation (*e.g*. self-configuration). In contrast, these local behaviors can generate contradictory decisions potentially leading to a distortion of the swarm or to a disconnection in sub-groups. However, many applications require that communication remains possible all the time in the swarm (to share information, to disseminate constraints, to give order to the agents, etc.). This requires to ensure the connectivity of agents in the network. Nevertheless, this continuous connectivity has a strong impact on the agent mobility [6]. The problem grows when the environment holds obstacles, limiting agent displacement and communication.

This PhD thesis aims to study decentralized spatial coordination models allowing to deploy a swarm of agents in complex 2D and 3D environments (urban-type) while maintaining its connectivity.

Approach

This PhD falls within Distributed AI domain, more precisely in the framework of swarm intelligence, formalized as decentralized multi-agent systems (*e.g.* [2]). The work will also rely on distributed constraint optimization formalism (DCOP) and wireless communication protocols.

The proposed approach, to deal with coordination under connectivity constraint, will consist in combining the force based approach (flocking) and the propagation of constraints about the measured quality of connections. The « Flocking » model, introduced by Reynolds [1], has inspired several decentralised controllers for the navigation of swarm of agents, *e.g.* [2, 5]. This model is built on three local forces: attraction force (gathering), separation force (collision avoidance), and alignment force (common direction). Flocking models can be very efficient in open environments (*i.e.* without obstacles) [2,3,5], but they degrade in environments with many obstacles. Thus, we must to take into account 1) the topology of the environment (perceived by the agents) and 2) the quality of connections between agents, including losses of exchanged data.

It has been shown that propagation of radio wave is unstable over time and non-homogeneous throughout space [9]. This prevents to build *a priori* efficient solutions. So we aim to define swarm models integrating dynamically connection constraints, by considering continuous measurements of the communication quality between the agents. We will also consider the idea of generating virtual forces when the connection is lost in order to push the reconnection.

Two properties will be studied and optimized:

- Maximal deployment without lost of connection
- Deployment with the ability to repair a lost of connection

The validity and efficiency of the models will be evaluated with simulations, in 2D and 3D cluttered environments. We aim to optimize/learn the parameters of the force combination, and to evaluate the connectivity robustness (simulation of noise, loss). We will exploit the UAVs simulator developed in CHROMA and DANTE teams, relying on GAZEBO (robots simulator) and NS3 (network simulator), cf. https://team.inria.fr/chroma/en/software/ .

We will consider two kinds of scenarios in unknown and complex environments: 1) maximal deployment (or coverage) of a swarm of n agents starting from a common origin, 2) maximal coverage of a swarm of n agents moving from a common origin to a common destination. Coverage means here the 2D surface or 3D envelope observed during the mission (also called multi-robot exploration problem [7,8]).

After showing the efficiency of the models with simulations, we will aim to demonstrate their validity with real UAVs. To do this, we will experiment the models with the quadri-rotor UAVs of the CHROMA team (IntelAero platform). Experiments will be carried out on La Doua Campus (Lyon), with the help of an engineer of the team.

Profile and competencies

The candidate will have a Master's degree or equivalent, in computer science, artificial intelligence or robotics. Experience in modeling/simulation of distributed systems or in robotics/networks would be an advantage.

Application :

Contact by email Olivier Simonin (olivier.simonin@insa-lyon.fr) or Isabelle Guerin-Lassous (isabelle.guerin-lassous@ens-lyon.fr) and join:

- a CV
- any document that could support your application.

References

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