Graph-based collaborative exploration with a swarm of drones

Stage Master 2, 2022–2023

Key words : Collaborative graph exploration
Swarm of drones
Distributed algorithms

Laboratory: U2IS, ENSTA Paris and CITI lab, INSA Lyon

Address: 828 boulevard des maréchaux 91762 Palaiseau Cedex

Advisors: Elena Ivanova **elena.ivanova@ensta-paris.fr**
David Filliat **david.filliat@ensta-paris.fr**
Olivier Simonin **olivier.simonin@insa-lyon.fr**

Duration: 6 months

Scholarship: according to the legislation (around 600€/month)

Context The use of unmanned aerial systems (UAS) is becoming increasingly frequent during search and rescue (SAR) operations conducted to find missing persons. In the VORTEX project, we believe that it is possible to deploy rapidly autonomous drones in indoor environments without using conventional communications or building maps but by leveraging cameras & vision-based processes. We propose to explore an approach where a swarm of small UAVs (quadrotors) will quickly deploy in the environment while forming a dynamic mesh, which can be seen as a swarm of sensors. By flying autonomously but keeping visual contact with at least another UAV, each drone will be able to estimate its relative localization but also to communicate information from drone to drone and so estimate its global localization. UAVs will not be connected through a wireless network but will communicate through visual signals and motions. As a consequence, they will form a dynamic topological graph of a part of the environment that could be exploited by the swarm but also by operators.

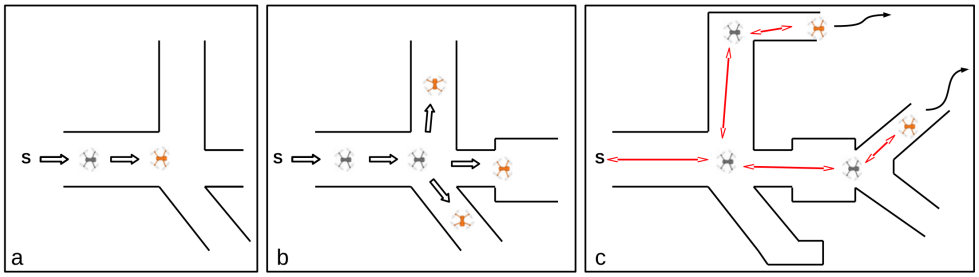

Figure 1: Principle of the swarm exploration from the entry S a) chain of visually connected UAVs (orange UAV is a "leaf", gray one is a "follower") b) simultaneous exploration of several branches from the intersection, c) reconfiguration after discovering a closed corridor (the visual connectivity graph is shown in red)

During the internship, we propose to focus on algorithms allowing us to explore n node graph with k agents while maintaining visual connectivity among the agents [3, 4]. The main idea is to merge depth-first and breadth-first search strategies to achieve time efficiency while managing the limited number of drones. The desired approach should allow fast reconfiguration when arriving in an irrelevant or closed space and should be robust to the loss of drones. It also deserves to be remarked, that most of the existing graph exploration algorithms are centralized. We propose to benefit from swarm intelligence [2] to overcome this limitation and provide a decentralised approach.

Goals The goals of the internship consist of

- exploring the state of the art of collaborative graph exploration algorithms (centralized and decentralized);

- proposing a time-efficient decentralized exploration algorithm maintaining visual connectivity among the agents.
- testing the proposed approach in a simulation environment of swarm-rescue competition organised in IP Paris [1].

Profile of a candidate. For this position, you should meet the following requirements:

- enrollment in a Master's program or equivalent in computer science, applied mathematics science, engineering, or related disciplines;
- rigorous knowledge in optimization, numerical calculus, and systems control;
- excellent programming skills (C++, Python);
- proficiency in spoken and written English;

The candidate will have to submit the documents following:

- a cover letter;
- a resume;
- a copy of diplomas; bachelor's and master's degree transcripts.

In case of a successful internship, a Ph.D. offer in INSA-Lyon might be proposed.

References

[1] Swarm-rescue challenge. `https://emmanuel-battesti.github.io/swarm-rescue-website/`.

[2] Alexandre Bonnefond, Olivier Simonin, and Isabelle Guérin-Lassous. Extension of Flocking Models to Environments with Obstacles and Degraded Communications. In *IEEE/RSJ International Conference on Intelligent Robots and Systems*, (IROS 2021), pages 9139–9145. IEEE, 2021.

[3] Dariusz Dereniowski, Yann Disser, Adrian Kosowski, Dominik Pajak, and Przemysław Uznański. Fast collaborative graph exploration. *Information and Computation*, 243:37–49, 2015. 40th International Colloquium on Automata, Languages and Programming (ICALP 2013).

[4] Indraneel Patil, Rachel Zheng, Charvi Gupta, Jaekyung Song, Narendar Sriram, and Katia Sycara. Graph-based simultaneous coverage and exploration planning for fast multi-robot search, 2023.