PhD open position

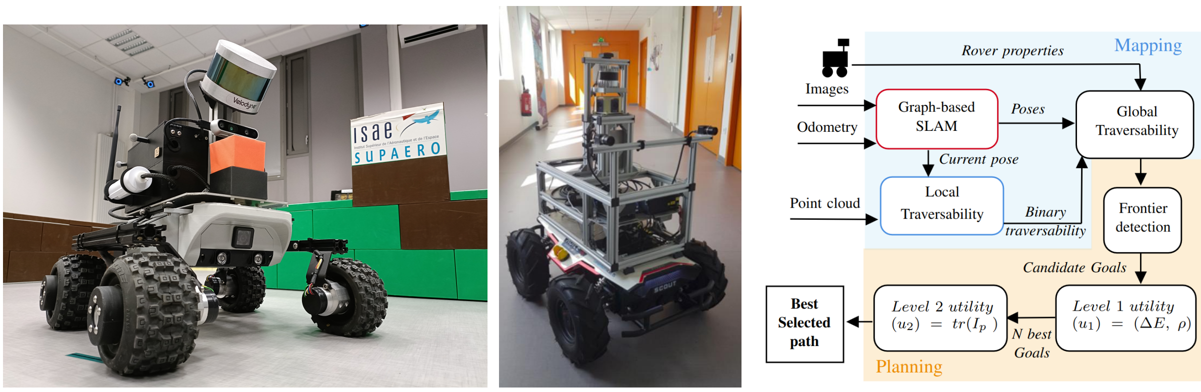
ISAE-SUPAERO | DEOS-DCAS | AID Project SamurAI

PhD Title	Système Autonome MultiRobot pour l'exploration Active Intelligente (SAMuR-AI) (Multi-robot autonomous system for Inteligent Active exploration)
Assignment	ISAE-SUPAERO | DEOS-DCAS
Supervision	Damien Vivet, Research Director, ISAE-SUPAERO, DEOS Caroline P. C. Chanel, Associate Professor, ISAE-SUPAERO, DCAS
Eligibility	**European Union citizen only**

PhD proposal

This project falls within the thematic of autonomous multi-robot system navigation. Such systems consist of robots that must be able to localize themselves in their environment, perceive it, interpret it without any human interaction or assistance, interact with other robots by exchanging relevant information, and ultimately make safe and relevant decisions to accomplish their mission.

Through this study, we aim to propose and evaluate a new collaborative multi-robot approach for intelligent active exploration of unknown and constrained environments where GNSS signal is unavailable or unreliable (indoors, underground, conflict zones, space exploration).



(a) Leo rover (b) Agilex scout (c) General FIT-SLAM approach [11]

FIGURE 1 – ISAE-SUPAERO robots and facilities, and previous works.

The proposed approach will be based on probabilistic exploration techniques such as Collaborative Active Simultaneous Localization and Mapping (CA-SLAM).

Two key aspects will be studied :

- The mapping and positioning system of the different robots will aim to provide a semantic mapping of the explored environment, whether in terms of navigation (traversability) or scene interpretation (relevant elements). We will also consider system constraints from the perspective of memory for mapping and computational power for position estimation.
- The mission and path planning system will aim to simultaneously address the exploration needs of the mission while maintaining the best relative positioning integrity of the robots and environmental elements. In this context, it will be necessary to evaluate the relevance, in terms of information acquisition and position estimation, of different paths to reach a given location, and, at the same time to decide to which location each robot should move for exploration purposes.

The ultimate **goal is to achieve an intelligent multi-agent system capable of exploring an environment to provide precise, compact, and reliable mapping while begin effective and respecting mission constraints**. Through this study, we aim to implement techniques for active mapping of unknown environments by integrating visual and LiDAR modalities from a fleet of heterogeneous robots (not necessarily equipped with the same perception modality)- see Figure 1. In this context, this PhD proposal and work will be an extension of our previous work refereed in [11].

Even if some works have investigated Collaborative SLAM recently [8, 7] very few are dealing with Collaborative Active SLAM and, to date, very few works have focused on the close fusion of the two considered complementary modalities [6]. LiDAR provides reliable metric mapping while cameras offer excellent semantic interpretability of observed areas. We propose autonomously generating a hybrid 3D map based on the use of octrees or quadtrees augmented with semantic information [12] from a fleet of collaborative robots and in the absence of absolute positioning signals such as GNSS (for applications like search and rescue, conflict zones, underground areas, indoors, etc.).

A strong constraint addressed in this project is the complementary perception of the different agents involved in the mission : for example, one robot equipped with a LiDAR sensor and another instrumented with visual sensors. This configuration reflects operational conditions where two robotic systems are not equipped similarly due to differences in payload capacity, such as in the case of a collaboration between a ground robot and an aerial drone. Finally, this collaborative perception is currently heavily dependent on a source of absolute positioning such as GNSS, which allows for map alignment and fusion. We propose to study multimodality alignment techniques in the absence of GNSS by relying on semantic information extracted from raw sensor data.

However, the multi-agent targeted application is only feasible if we have an effective mission management system in place. This management system will be responsible for determining which positions should be visited by the robots while considering the contribution in terms of improving precision and reducing the overall system uncertainty. The challenge lies in the consideration of multi-robot coordination (in the short or medium term) and in the path planning for each robot accounting with the impact of information acquisition during path execution [2]. Regarding this last aspect, this thesis will extend the work proposed in [11] from one to multiple robots. Regarding the multi-robot coordination aspect, this thesis will extend works which have proposed decentralized approaches for multi-robot coordination [5], accounting with communication constraints [3], or multi-robot multi-task assignment [10]. Coordination and path planning should enable the selection of an optimal strategy based on uncertain knowledge of the currently explored environment and a multi-criteria mission objective (localizability, exploration coverage, energy consumption, communication maintenance, etc.). Note such a multi-criteria decision-making objective extends state-of-the-art approaches such as [9, 1, 4].

In summary, this study will have two main components :

- The proposal and evaluation of estimation techniques for distributed multimodal mapping (multi-robots) integrating visual and/or LiDAR modalities.
- The proposal and evaluation of information-aware path planning and multi-agent coordination techniques in uncertain environments.

Expected skills

- ROS2, C++ and Python coding.
- SLAM theory, Bayesian estimation approaches
- Computer vision, 3D mapping, Stereovision
- Graph-based or sampling-based path planning approaches
- Multi-robot task assignment, multi-robot coordination protocols
- Probabilistic planning approaches.

Applications

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- Curriculum Vitae (CV)
- Presentation and motivation letter
- (optional) Recommendation letters, MSc grades
- **European Union citizen only**

ISAE-SUPAERO

ISAE-SUPAERO, an aerospace engineering school, has a research policy that is strongly oriented towards the future needs of industries in the aerospace engineering and high-technology fields.
It combines interdisciplinary collaboration with cutting-edge research on scientific knowledge, models, methodological approaches, and tools for the design of aerospace, space, and embedded systems.

Research teams involved

This PhD position will be supervised by two research Labs from ISAE-SUPAERO.
The Department of Electronics, Optronics, and Signal Processing (DEOS) develops and creates payloads for advanced aerospace and space applications of the future. The expertise of its teams spans a wide range of technologies, from silicon sensor design to interplanetary scientific payloads, and from theoretical signal studies to advanced communication and navigation systems.
The "Navigation, Radar and Remote Sensing" group (NAVIR²eS) focuses on the theoretical study of information sources and hybridization approaches within the context of autonomous navigation for vehicles and robots.
The Department of Aerospace Vehicles Design and Control (DCAS) develops methods, simulation tools and experimental platforms for the design and control of aerospace vehicles. DCAS is developing training and research activities to meet the scientific challenges on tomorrow's air transport and future

space systems such as reducing environmental impacts (consumption, noise, emissions), optimizing the design cycle and operating costs, increasing the safety of aerospace systems and improving the efficiency of human-machine systems.
The "Decision and Control" group DC focus on decision-making approaches and decentralized multi-robot cooperation strategies to enhance systems efficiency and adaptability.

References

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