PhD position: Formal methods for Programming and Analysis of Robust Behaviors of Autonomous Systems

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Location: *Main location* : ONERA, Toulouse
Secondary location : LIRMM, Montpellier.

Duration: 3 years.

Requirements: Programming skills, notions in formal methods.

Context

The development of autonomous robotic systems involves intelligent functionalities, such as system control, data processing, or motion planning. These functionalities are implemented in programming environments such as ROS, which produce complex software architectures, involving several dozens of processes.

The realization of autonomous missions requires the ability to specify high-level behaviors, which rely on functionalities provided by the robotic system, without requiring the user to have a detailed understanding of the deployed processes. These functionalities, or skills [1], provide an abstraction of the capabilities of the robotic system. From these capabilities, it is necessary to have tools for the specification of higher-level behaviors, and to establish links between the different levels of abstraction of the system [4]. The increase in abstraction is necessary on the one hand to limit the expertise required for the programming of a complex mission. This is particularly necessary when interacting with non-expert users (e.g. marine biologists or hydrogeologists). On the other hand, it is also a way to limit the level of details of the description of the system behavior while keeping the information necessary to formalize the execution of these behaviors, and to verify them.

Moreover, this thesis project aims at developing underwater robots for biodiversity observation. The marine environment is a challenge for autonomous robotics, for many reasons: the control of the robot's movements in 3D in the aquatic environment; the perception of a complex and dynamic environment with sensors that are often very (too) expensive and/or inaccurate; the difficulty of communication in the aquatic environment, the partial ignorance of this environment leading to a difficulty in modeling the environment, etc...

In this context, the design of autonomous systems is even more complex. The specified behaviors must be robust to the occurrence of failures on the robotic system (e.g., sensor failure) or to external events. Moreover, in critical contexts, it is necessary to provide a priori proofs on the robust and correct behavior of the robotic system, and on the success of its mission. This is particularly the case for exploration applications in difficult environments such as underwater, where the environment is complex, dynamic and often partially unknown. Moreover, the use of underwater systems for the observation of marine biodiversity in fragile and protected environments imposes specific constraints [2] linked to the obligation to respect data collection protocols specific to the biologists, in order to guarantee data consistency, while ensuring the safety of the robot and of the surrounding ecosystem.

This thesis aims at addressing the problem of specifying and analyzing behaviors for autonomous systems by means of formal methods. If these methods are already used to analyze models of the system, the originality of the work proposed in this thesis consists in using formal models as tools for programming behaviors, so as to be able to both execute and analyze these models.

The Petri net formalism will be studied in particular because of its suitability for the specification of concurrent behaviors, the possibility of synthesizing executable models, and the availability of analysis tools. The work done in this thesis will be based on various works done at LIRMM, on failure analysis for submarine missions [2], on the use of model-checking or formal methods to model robotic missions [3,4]; and at ONERA, on the formalization of capabilities by formal models [1], or the definition of a mission specification framework by Petri nets [5]. *This work will be applied to the specification of exploration missions for autonomous underwater robots, and test campaigns in real environment (lac, pool, sea) will validate the work done.*

Scientific teams of the collaboration

The Explore team in LIRMM is interested in mobile robotics, and in particular in the scientific chain allowing the control of autonomous missions in complex environments. The main application filed is underwater robotics, for example for the observation of biodiversity [6]. This PhD subject is in the continuity of work dealing with the safety of operation and the definition of complex missions [2,4]. They must be completed by a more formal modeling of the robot's capabilities, and a methodology integrating the verification steps. The work done at ONERA [1,5] for autonomous drone applications, brings complementary aspects that will allow to result in a common methodology for the specification and the analysis of autonomous behaviors.

References

[1] C. Lesire, D. Doose, C. Grand, "Formalization of Robot Skills with Descriptive and Operational Models", IROS 2020.

[2] A. Hereau, K. Godary-Dejean, J. Guiochet, C. Robert, T. Claverie, D. Crestani : "Testing an underwater robot executing transect missions in Mayotte", TAROS 2020.

[3] R. Sadden-Yagoubi, O. Naud, K. Godary-Dejean, D. Crestani, "Model-checking precision agriculture logistics: the case of the differential harvesting", DEDS(30), 2020.

[4] S. Louis, K. Godary-Dejean, L. Lapierre, T. Claverie, S. Villéger, "Formal method for mission controller generation of a mobile robot", TAROS 2017.

[5] C. Lesire, F. Pommereau, "ASPiC: an Acting system based on Skill Petri net Composition", IROS 2018.

[6] M. Maslin, S. Louis, K. Godary-Dejean, L. Lapierre, S. Villéger, T. Claverie, "Underwater robots provide similar fish biodiversity assessments as divers on coral reefs ", soumis, 2021.