Université de Rennes

Direction de la Recherche et de l'Innovation

Appel à projets - Année 2026

Contrats doctoraux «Ordinaires»

ECOLE DOCTORALE : MATISSE **POLE DE RECHERCHE : Mathématiques-numérique**

Unité de recherche d'accueil

Unité de Recherche : IRISA, UMR 6074

Equipe : Rainbow

Encadrement

Directeur de thèse : Marco Tognon **Unité de recherche** : Inria Centre at Rennes University

Employeur/Établissement d'origine : Inria

HDR : ☒ oui ☐ non **Nb de thèses en cours** : 6 (two finishing end 2026/beginning 2027)

Mail : marco.tognon@inria.fr **Tél.** :

Co-directeur de thèse : **Unité de recherche** :

Employeur/Établissement d'origine :

HDR : ☐ oui ☐ non **Nb de thèses en cours** :

Mail : **Tél.** :

Sujet

Titre :

Mots clés : Aerial Manipulation, Hybrid Control and Artificial Intelligence, Optimal Control and Reinforcement Learning

Cotutelle internationale (oui/non) : oui **Si oui, préciser l'établissement et le pays de rattachement** : New York University (USA)

Descriptif (15-30 lignes) :
Contexte socioéconomique et scientifique ; Les hypothèses et questions posées ; Les grandes étapes de la thèse et démarche ; Approches méthodologiques et techniques envisagées

Socio-Economic and Scientific Context
Aerial robots have reached a high level of maturity for perception and navigation tasks; however, their ability to perform **physical interaction and manipulation** remains limited [1]. Aerial manipulation involves strongly coupled dynamics between the flying platform, the manipulator, and the environment, leading to significant challenges in stability, precision, and robustness. From a scientific standpoint, model-based control approaches such as optimal and predictive control provide principled frameworks with stability and constraint-handling guarantees, but their performance degrades in the presence of modeling errors and unstructured contacts [3,4]. Conversely, learning-based methods, particularly reinforcement learning, enable adaptive and dexterous behaviors but suffer from limited interpretability, safety guarantees, and data efficiency [2]. Bridging these paradigms is a key open challenge for enabling reliable and versatile aerial manipulation.

Hypotheses and Research Questions
The central hypothesis of this project is that **hybrid control architectures combining physics-based models and learning-based components** can overcome the intrinsic limitations of each paradigm when considered in isolation. The project addresses the following research questions:
1) How can predictive control architectures be designed to integrate learning while preserving stability and constraint satisfaction during aerial physical interaction?
2) How can such hybrid architectures enable **complex and dexterous aerial manipulation**, involving prolonged, multiple, or dynamic contacts?
3) How can visual and tactile sensing be coherently integrated into the control loop to handle uncertainty and partial observability during interaction?

Thesis Structure and Research Plan
The thesis will proceed in four main stages. First, the dynamics of aerial manipulators in contact-rich scenarios will be

analyzed, and baseline model-based controllers will developed and evaluated. Second, learning-based control policies for aerial manipulation will be designed and trained in simulation, with a focus on data efficiency and generalization. Third, hybrid control architectures combining model-based and learning-based components will be proposed and analyzed both theoretically and experimentally. Finally, the proposed methods will be validated on real aerial manipulation platforms, with a systematic evaluation of performance, robustness, and safety.

Methodological and Technical Approaches

The project will investigate **bidirectional interactions between optimal control and reinforcement learning**. This includes teacher–student schemes in which model predictive controllers guide policy learning through imitation or constrained reinforcement learning, as well as complementary approaches where learned policies provide informed initializations or motion priors for online optimization. Particular emphasis will be placed on **sensor-based control**, combining onboard vision with force or tactile feedback to close the control loop during physical interaction. The proposed approaches will be implemented and validated on aerial manipulators equipped with compliant actuation and force sensing, enabling the study of hybrid control strategies under realistic interaction conditions.

[1] Ollero, Anibal, et al. "Past, present, and future of aerial robotic manipulators." IEEE Transactions on Robotics 38.1 (2021): 626-645.
[2] Cuniato, Eugenio, et al. "Learning to open doors with an aerial manipulator." 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2023.
[3] Brunner, Maximilian, et al. "A planning-and-control framework for aerial manipulation of articulated objects." IEEE Robotics and Automation Letters 7.4 (2022): 10689-10696.
[4] Peric, Lazar, et al. "Direct force and pose NMPC with multiple interaction modes for aerial push-and-slide operations." 2021 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2021.