Offer #2024-07469

PhD Position F/M Robust and Agile Transportation of Cable Suspended-Loads with Multi-Drone Systems

Contract type : Fixed-term contract

Level of qualifications required : Graduate degree or equivalent

Fonction : PhD Position

About the research centre or Inria department

The Inria Centre at Rennes University is one of Inria's eight centres and has more than thirty research teams. The Inria Centre is a major and recognized player in the field of digital sciences. It is at the heart of a rich R&D and innovation ecosystem: highly innovative PMEs, large industrial groups, competitiveness clusters, research and higher education players, laboratories of excellence, technological research institute, etc.

Context

Conditions:

- The work will be carried in English in theRainbow team at the Inria Rennes Bretagne Atlantique research center.
- The Ph.D. position is full-time for 3 years (standard duration in France). The position will be paid according to the French salary regulations for PhD students.
- We do high quality and impactful research in robotics, publishing on the major journals and conferences.
- We often collaborate with other top researchers in europe and worldwide.
- You will have access to a well established laboratory including:
- two flying arenas equipped with motion tracking system, several quadrotors, and a few fully-actuated manipulators,
- one robotic manipulation lab equipped with several robotic arms, like the Franka Emika Panda.
- You will be part of an international and friendly team. We organize several events, from after works, to multi-day lab retreat.
- Regular visits and talks by internationally known researchers from top research labs.

Supervisors : M. Tognon, P. Robuffo Giordano

Assignment

Context

A predominant objective of robotics is developing autonomous systems capable of assisting humans in challenging, laborious, or hazardous tasks, particularly in environments that are difficult to access, such as high altitudes, outer space, or places with radiation exposure. To overcome these problems, **aerial vehicles (a.k.a. drones or UAVs) are an effective solution.** On one side, they have already proven to be excellent in performing several tasks – spanning from navigation [1] to surveillance [2] – mostly thanks to their agility and ability to move quickly. On the other side, despite recent advancements on these "navigation" tasks and promising application scenarios, current results on drones are still very preliminary in terms of (1) collaborative manipulation skills and strategies, (2) payload and endurance capabilities, as well as (3) human-drone interaction and control [3]. However, possible applications requiring physical contact and manipulation skills are numerous: structure assembly, contact-based inspection, transportation, harvesting, etc.

The most frequent approach to endow a drone with manipulation capabilities is the installation of dedicated equipment, such as grippers or robotic arms. Alternatively, the manipulation/transportation of objects can be performed cooperatively by multiple agents using **cables or tethers**. This latter approach has the advantage of simplicity and flexibility, as it allows the transportation or manipulation of possibly large, bulky, or heavy objects, like a stretcher in search and rescue scenarios. However, this approach requires accurate planning/control algorithms, as well as the precise coordination of the drones for the cooperative transportation/manipulation. Depending on the task at hand, such cooperative actions can also be carried out by multiple drones remotely controlled at high-level by a human operator (see Fig. 1 for an illustrative example). This allows blending the autonomy of the multi-drone system with the higher cognitive capabilities of a human operator who can be in charge of general aspects of the mission (what object to pick, where to release it, etc.).

The work will be carried out at**IRISA-CNRS in Rennes** as part of the Rainbow team, which is

internationally recognized for its scientific activity as well as for technology transfer experience in the field of shared control, multi-robots, haptics, sensor-based control, visual tracking, and visual servoing.

References

Cable-suspended multi-drone system
[a] D. Sanalitro, M. Tognon, A. Jimenez-Cano, J. Cortes, and A. Franchi, “Indirect Force Control of a Cable-suspended Aerial Multi-Robot Manipulator”. In : IEEE Robotics and Automation Letters, vol. 7, no. 3, pp. 2377-3766, 2022.
[b] A. E. Jiménez-Cano, Sanalitro, D., Tognon, M., Franchi, A., and Cortés, J., “Precise Cable-Suspended Pick-and-Place with an Aerial Multi-robot System”, Journal of Intelligent & Robotic Systems, vol. 105, pp. 1–13, 2022.
[c] D. Sanalitro, Savino, H. J., Tognon, M., Cortés, J., and Franchi, A., “Full-Pose Manipulation Control of a Cable-Suspended Load With Multiple UAVs Under Uncertainties”, IEEE Robotics and Automation Letters, vol. 5, no. 2, pp. 2185-2191, 2020.

Human/Multi-Drone Interaction
[e] M. Aggravi, C. Pacchierotti, P. Robuffo Giordano. Connectivity-maintenance teleoperation of a uav fleet with wearable haptic feedback. IEEE Transactions on Automation Science and Engineering, 18(3), 1243-1262, 2020
[f] M. Aggravi, A. Alaaeldin Said Elsherif, P. Robuffo Giordano, C. Pacchierotti. Haptic-Enabled Decentralized Control of a Heterogeneous Human-Robot Team for Search and Rescue in Partially-known Environments. IEEE Robotics and Automation Letters (also presented at ICRA’21), 6(3):4843-4850, July 2021
[g] M. Aggravi, G. Sirignano, P. Robuffo Giordano, C. Pacchierotti. Decentralized control of a heterogeneous human-robot team for exploration and patrolling. IEEE Transactions on Automation Science and Engineering, 19(4):3109-3125, September 2022.

Active Sensing and Localization for Multiple Drones
[h] L. Balandi, N. de Carli, P. Robuffo Giordano. Persistent Monitoring of Multiple Moving Targets Using High Order Control Barrier Functions. IEEE Robotics and Automation Letters, 8(8):5236-5243, August 2023
[i] N. de Carli, P. Salaris, P. Robuffo Giordano. Multi-Robot Active Sensing for Bearing Formations. In IEEE Int. Symp. on Multi-Robot and Multi-Agent Systems, Boston (MA), United States, December 2023
[j] Nicola De Carli, Paolo Salaris, and P. Robuffo Giordano. Distributed Control Barrier Functions for Global Connectivity Maintenance. In 2024 IEEE Int. Conf. on Robotics and Automation (ICRA 2024), 2024

Robust Trajectory Generation for Drones
[k] P. Robuffo Giordano, Q. Delamare, A. Franchi. Trajectory Generation for Minimum Closed-Loop State Sensitivity. In IEEE Int. Conf. on Robotics and Automation, ICRA’18, Pages 286-293, Brisbane, Australia, May 2018
[l] S. Wasiela, P. Robuffo Giordano, J. Cortes, T. Simeon. A Sensitivity-Aware Motion Planner (SAMP) to Generate Intrinsically-Robust Trajectories. In IEEE Int. Conf. on Robotics and Automation, ICRA’23, Pages 12707-12713, London, UK, May 2023
[m] A. Srour, A. Franchi, P. Robuffo Giordano. Controller and Trajectory Optimization for a Quadrotor UAV with Parametric Uncertainty. In IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, IROS 2023, Pages 9999-10005, Detroit (MI), United States, October 2023

Bibliographie
[1] C. Goerzen, Z. Kong, and B. Mettler. “A survey of motion planning algorithms from the perspective of autonomous UAV guidance”. In: Journal of Intelligent and Robotic Systems 57 (2010), pp. 65–100.
[2] E. Semsch, M. Jakob, D. Pavlicek, and M. Pechoucek. “Autonomous UAV surveillance in complex urban environments”. In: 2009 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology. Vol. 2. IEEE. 2009, pp. 82–85.
[3] A. Ollero, M. Tognon, A. Suarez, D. Lee, and A. Franchi. “Past, present, and future of aerial robotic manipulators”. In: IEEE Trans. on Robotics 38.1 (2021), pp. 626–645

Main activities

Envisaged Activities

The goal of this PhD Thesis is to advance the state-of-the-art in the field of **multi-drone transportation of cable-suspended loads** along several key directions:

- **Perception and Localization:** Most previous experiments in this domain have relied on precise localization provided by external motion capture systems. This thesis aims to relax this assumption by using onboard drone cameras to localize the relative positions between the drones, the suspended platform (e.g., using visual markers), and the overall system position. This is a non-trivial challenge due to the limited field of view of the cameras and the potential conflicts between the task requirements and the need for each drone to maintain the platform and other drones in their field of view. The researchers plan to address this using a distributed approach based on Control Barrier Functions, which can help relax the constraints on maintaining visibility.
- **Robust and Online Motion Generation:** Cable-suspended multi-drone systems face numerous constraints related to perception, actuation, geometry, and stability. The thesis will address these challenges by leveraging Nonlinear Model Predictive Control (NMPC) techniques, which can generate online feasible motion plans that meet the constraints and optimize for factors like task error, energy consumption, and completion time. A key focus will be on generating **aggressive maneuvers** that minimize time while dampening load oscillations, in order to fully exploit the drones’ actuation capabilities. Additionally, the researchers will incorporate **robustness**

guarantees into the NMPC formulation, using metrics they have recently developed to quantify the system's resilience to parametric uncertainties in the models.
- **Human-Multi-Drone Interaction:** The project will address the problem of interfacing a human operator with the multi-drone system by developing **shared control techniques**. The goal is to allow the human to provide intuitive high-level commands (e.g., commanding the load's linear velocity) that will then be processed by the group autonomy (the NMPC algorithm) to produce a feasible motion plan. This will help the human operator effectively accomplish the assigned task **together** with the robots, while providing the operator with rich information about the robots' actions (e.g., through force or visual cues) to increase task performance and trust in the robotic system.

Benefits package

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    - Subsidized meals
    - Partial reimbursement of public transport costs
    - Possibility of teleworking (90 days per year) and flexible organization of working hours
    - Partial payment of insurance costs

Remuneration

Monthly gross salary amounting to 2082 euros for the first and second years and 2190 euros for the third year

General Information

- **Theme/Domain :** Robotics and Smart environments
- **Town/city :** Rennes
- **Inria Center :** Centre Inria de l'Université de Rennes
- **Starting date :** 2024-01-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2024-08-14

Contacts

- **Inria Team :** RAINBOW
- **PhD Supervisor :**
  Tognon Marco / marco.tognon@inria.fr

About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

The keys to success

Requirements:

- M.Sc. degree in mechatronics, robotics, engineering, computer science (or related fields)
- Excellent written and spoken English skills
- Good experience in C/C++ , ROS, Matlab/Simulink, CAD
- Good experience with numerical trajectory optimization tools for robotics (e.g., use of CaSaDi, Acado, Autodiff, Crocoddyl, etc.)
- Scientific curiosity, large autonomy and ability to work independently
- Experience with visual sensors and visual perception for robotics is a plus
- Experience with robotic systems and/or aerial robots is a plus

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

Instruction to apply

Please submit online : your resume, cover letter and letters of recommendation eventually

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated

in a ZRR would result in the cancellation of the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.