Offer #2024-07468

PhD Position F/M Sensors-based Distributed Control of Multi-Drone Systems for Agile Cooperative Aerial Manipulation

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

Short Abstract: This research focuses on coordinating multi-aerial robots for manipulating cable-suspended loads in industrial settings. By leveraging sensor data and distributed coordination, we aim to enhance system autonomy and efficiency. Experimental validation using a cable-driven platform will demonstrate the effectiveness of our approach, with potential applications in construction and inspection industries.

Description:

Over the past decade, there has been a surge in the exploration of aerial robots able to perform challenging physical interaction tasks. However, the inherent limitations in the payload capacity of individual drones have prompted researchers to explore the potential of **collaborative efforts among teams of aerial robots** [8]. This collaborative approach is envisioned to revolutionize various application domains, including construction, inspection, maintenance, and beyond. One of the preferred solutions to enable the aerial manipulation/transportation of objects is using cables or tethers to suspend leads to the robots (see the figure). This solution is lightweight and decouples the attitude dynamics of the aerial robots to the one of the load, which in turns increases the stability of the system.

Full pose manipulation of a cable-suspended load using multiple UAVs is a promising technique for a huge variety of future industrial applications. However, the physical interactions between UAVs, load and cables render collaborative manipulation a challenging task from both a planning and control perspective. Existing solutions have focused on one hand, on quasi-static regimes that limit the dynamic behavior and capabilities of the system [3]. On the other hand, most solutions are centralized [1,6] or consider access to system-wide information (poses, forces, etc.) [1], which reduces the autonomy and

robustness of the system and limits the applicability of these solutions to relevant real-world scenarios.

Research Objectives: The primary objective of this Ph.D. thesis is to explore **sensor-based and distributed coordination strategies for multi-aerial robot systems with cable-suspended loads**, facilitating collaborative object manipulation and transportation through local interactions. Distributed solutions pose particular challenges, especially when addressing communication constraints among the robots. The objective is then to consider hierarchical strategies where robots communicate at a low frequency and coordinate at a higher/planning level, subsequently executing the plan through local implicit communication based on sensor-based feedback such as vision and/or force sensing.

Related references:

1.

    1. S. Sun and A. Franchi, "Nonlinear MPC for Full-Pose Manipulation of a Cable-Suspended Load using Multiple UAVs," 2023 International Conference on Unmanned Aircraft Systems (ICUAS), Warsaw, Poland, 2023, pp. 969-975.
    2. Sanalitro, D. (2022). Aerial Cooperative Manipulation: full pose manipulation in air and in interaction with the environment (Doctoral dissertation, INSA de Toulouse).
    3. D. Sanalitro, H. Savino, M. Tognon, J. Cortés, and A. Franchi "Full-pose manipulation control of a cable-suspended load with multiple UAVs under uncertainties". IEEE Robotics and Automation Letters, 2020,5(2), 2185-2191.
    4. C. Gabellieri, M. Tognon, D. Sanalitro and A. Franchi, "Force-Based Pose Regulation of a Cable-Suspended Load Using UAVs with Force Bias," 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Detroit, MI, USA, 2023, pp. 6920-6926.
    5. N. de Carli, P. Salaris, P. Robuffo Giordano. Multi-Robot Active Sensing for Bearing Formations. MSR 2023 - IEEE International Symposium on Multi-Robot & Multi-Agent Systems, Dec 2023, Boston (MA), United States. pp.1-7.
    6. L. Guanrui, and G. Loianno. "Nonlinear Model Predictive Control for Cooperative Transportation and Manipulation of Cable Suspended Payloads with Multiple Quadrotors." arXiv preprint arXiv:2303.06165 (2023).
    7. A. Ollero, M. Tognon, A. Suarez, D. J. Lee, and A. Franchi. ``Past, present, and future of aerial robotic manipulators." IEEE Trans. on Robotics, 2021.
    8. S., Ola, and M. Schwager. "Distributed Model Predictive Control via Separable Optimization in Multi-Agent Networks." IEEE Transactions on Automatic Control (2023).
    9. L. Peric, Brunner, M., Bodie, K., M. Tognon, and Siegwart, R., "Direct Force and Pose NMPC with Multiple Interaction Modes for Aerial Push-and-Slide Operations", in 2021 IEEE Int. Conf. on Robotics and Automation, Xi'an, China, 2021

Main activities

Envisaged Activities:

Envisioned solutions will build upon existing centralized or kinematic results [2,3] and communication-less regulation approaches [4] to propose a fully **sensor-based**, **dynamics-based**, and **distributed** framework for *collaborative agile manipulation of cable-suspended loads*. For the control side, a starting point are the existing centralized approaches based on Model Predictive Control (MPC) for single- [9] and multi-aerial robots [1,6]. Our team has undertaken preliminary work exploring the extension of [1] through a distributed MPC solution based on [9], initially at a kinematic level. Should this endeavor yield promising results, a potential trajectory involves advancing the algorithm to operate at a dynamic level. For the sensing side, the starting point will be the works on sensor-based collaborative global state estimation for multi-robot systems such as [5].

Experimental validation: The devised coordination strategies for the manipulation and transportation of cable-suspended loads will undergo thorough validation and testing using the cable-driven platform, shown in the figure, already present at Rainbow.

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 :** 2024-10-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2024-10-31

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.