Job vacancy #2023-06732

PhD Position F/M Full-Body Design and Control of an Aerial Manipulator for Advance Physical Interaction

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 the Rainbow 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 systems, 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:
In this PhD we want to go beyond the current approaches for Aerial Physical Interaction looking at aerial manipulators as a whole system, both from the design and control perspectives. In particular we want to conceive a new aerial manipulator with torque controlled joints, the then design a proper full-body controller fully exploiting the system capabilities for physical interaction.

Description:
Aerial robots (commonly called “drones”) are nowadays extensively used to see the environment in applications like agriculture, mapping, etc. But, if aerial robots were also able to effectively manipulate the environment, the application domains could be further extended toward new areas like contact-based inspection, assembly and construction, and so on. The research community has previously focused on the design and control of aerial manipulators [1]. This opened the door to new applications, e.g., contact-based inspection [2]. However, current methodologies are still limited to very simple interaction tasks, involving limited contact behaviors with static and rigid surfaces (e.g., touching a flat wall with a stick attached to the robot) and in very controlled environments.

So far, aerial manipulators have been treated as a combination of two subsystems: the aerial vehicle and the robotic arm mounted onboard. Both design and control methods for aerial manipulators also follow this separation principle. However, this approach leads to poor results in terms of task execution and robustness. Aggressive maneuvers, complex manipulation tasks, and effective rejection of disturbances
are not possible due to the missing coordination between the two parts of the aerial manipulator.

In this PhD we want to go beyond the current approaches looking at aerial manipulators as a whole system, both from the design and control perspectives. This should allow obtaining more precise and robust aerial manipulators that could be used in more complex task, e.g., in construction sites helping humans for burden operations.

Related references:

5. P. Braut, Q. Delamare, P. Robuffo Giordano. Robust Trajectory Planning with Parametric Uncertainties. In IEEE Int. Conf. on Robotics and Automation, ICRA’21, Pages 11095–11101, Xi’an, China, May 2021

Main activities

Envisaged Activities:

The work will start from the previous platform and full-body control method presented in [3]. From there, the PhD is expected to give contributions to the following points:

1. **Mechatronic Design**: we believe that considering actuation inaccuracies already at the design level can allows to conceive an aerial manipulator that is intrinsically more robust. We will rely on the concept of “state/input sensitivity” [4,5] to design a platform where the actuation configuration minimizes the effect of their inaccuracy on the overall force/torque generation. Such a design problem can be casted in an optimization framework where additional criteria as the energy efficiency and the manipulability can be considered. We will also investigate the use of proper force/torque-controlled actuators for both thrusters and joints to have high precision and robustness during physical interaction tasks.

2. **Control**: if previous methods controlled the aerial platform and the arm as separate systems, here we aim at a proper full-body controller where a task is accomplished exploiting at best all the robot’s degrees of freedom, considering the limitations and properties of the robot dynamics, as well as its actuation limits. Previous attempts were always limited by the poor design which did not allow to properly control each actuator at the force/torque level [3]. Thanks to the new design envisaged in this PhD, this will be finally possible and we will be able to properly design full-body controllers. Initially, we will use model-based methods. However, due to the complexity of the system, errors due to modelling errors are expected. We plan to tackle this problem in two ways, which will then be compared. The first one is to enhance first principles modelling with data-based modelling. The second one is to use model-free approaches based on reinforcement learning. One output of this project will then be the investigation and comparison of the performance and limitations of both approaches.

3. **Experimental validation**: the new platform and control methods will be validated and tested firstly on benchmark tasks, like following a trajectory in free flight, apply a certain force to a rigid wall, and sliding an end–effector along a surface. This will allow to properly assess the advancement with respect to the state of the art. However, we will also demonstrate the new system capabilities on complex tasks that are extremely challenging for current aerial manipulators, e.g., opening a door or physically interacting with humans. The tests experimental tests will be carried out in the robotic room and drone arena of the Rainbow team.

Benefits package

- 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
  Instrumentation et expérimentation (BAP C)
- **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**: 2023-11-21

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 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.