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 leads to poor results in terms of task execution and robustness. Aggressive maneuvers, for aerial manipulators also follow this separation principle. However, this approach to the missing coordination between the two parts of the aerial manipulator.

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 autonomous and able to effectively work independently, they could be used in more complex tasks, e.g., in construction sites helping humans for burden operations.

In 2023-06732 - PhD Position F/M Full-Body Design and Control of an Aerial Manipulator for Advance Physical Interaction

Type de contrat : CDD
Niveau de diplôme exigé : Bac + 5 ou équivalent
Fonction : Doctorant

A propos du centre ou de la direction fonctionnelle

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.

Contexte et atouts du poste

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 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

Mission confiée

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 tasks, e.g., in construction sites helping humans for burden operations.

Related references:


Informations générales

- Thème/Domaine : Robotique et environnements intelligents
- Instrumentation et expérimentation (BAP C)
- Ville : Rennes
- Centre Inria : Centre Inria de l’Université de Rennes
- Date de prise de fonction souhaitée : 2024-01-01
- Durée de contrat : 3 ans
- Date limite pour postuler : 2023-11-21

Contacts

- Équipe Inria : RAINBOW
- Directeur de thèse : Tognon Marco / marco.tognon@inria.fr

A propos d’Inria

Inria est l’institut national de recherche dédié aux sciences et technologies du numérique. Il emploie 2600 personnes. Ses 200 équipes-projets agiles, en général communiquées avec des partenaires académiques, impliquent plus de 3500 scientifiques pour relever les défis du numérique, souvent à l’interface d’autres disciplines. L’institut fait appel à de nombreux talents dans plus d’une quarantaine de métiers différents. 900 personnelles d’appui à la recherche et à l’innovation contribuent à faire émerger et grandir des projets scientifiques ou entrepreneuriaux qui impactent le monde.

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L’essentiel pour réussir

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, Crocodile, etc.)
- Scientific curiosity, large autonomy and ability to work independently
- Experience with robotic systems and/or aerial robots is a plus
5. P. Raub, Q. Delalamo, 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

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 allow to control 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 cast 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 [2]. 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.

**Avantages**
- Subsidized meals
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- Partial payment of insurance costs

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