Offer #2025-09131

PhD Position F/M Hardware Acceleration for Unmanned Aerial Vehicle Control Algorithms

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 Rennes - Bretagne Atlantique Centre is one of Inria's eight centres and has more than thirty research teams. The Inria Center 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

Disclaimer

A PhD is not a continuation of coursework or a natural next step after a Master's degree. **A PhD is** a long-term, research-focused **commitment** that requires deep **curiosity**, **self-motivation**, **resilience**, and a certain degree of **autonomy**.

By research, we mean **creating new knowledge**, not just applying existing theories. Your task is to discover, design, or prove something that no one has done before—work that will become what future students study.

If you are mainly looking for structured classes, predefined assignments, or a repeat of your Master's experience, you will likely find this path **unfulfilling**. We welcome applications from candidates who are **excited by uncertainty**, driven to ask **original questions**, and eager to shape the frontier of their field.

Context & background:

Robots are physical agents that interact with their physical environment. Accordingly, their sensorimotor capabilities are essential and largely determine the activities that robots can perform. In recent years, great progress has been made in sensory capabilities thanks to significant advances in machine learning and

dedicated hardware. In contrast, much less progress has been made in motor skills. Examples of promising approaches in the current scientific literature are Model Predictive Control (MPC) [1] and Model Predictive Path Integral (MPPI) control [2], where control actions are optimized over a finite time horizon, considering the time evolution of robot dynamics to optimize a given cost or reward function that describes the robot motion. Such algorithms are particularly suited for **optimizing control trajectories and planning horizons in real time** due to their ability to handle dynamic environments.

From a control perspective, **planning a horizon that is as long as possible** to manage complex trajectories while considering the environment is essential. Additionally, maintaining **a high control frequency** is crucial to meet the **real-time** demands imposed by real-world physics and, if necessary, to adjust the sequence of movements. In the **resource-constrained context of small-scale UAVs**, such control algorithms are crucial as they enable **optimal trajectory generation and real-time decision-making** in complex, dynamic, and uncertain environments. However, particularly for **battery-powered UAVs**, achieving a high control frequency while planning for a long horizon is difficult due to limited computational power and energy constraints [3], and conventional GPU acceleration often requires excessive energy consumption.

In recent years, **hardware acceleration** [4] has become increasingly popular, using **dedicated platforms** such as **FPGAs** (Field Programmable Gate Arrays) and **ASICs** (Application-specific Integrated Circuits)**,** increasing energy efficiency by **orders of magnitude** [5]. However, **dedicated hardware acceleration for small-scale UAV control has not been proposed**.

The PhD is in collaboration between the computer architecture team (TARAN) and the robotics team (RAINBOW) at Inria Centre at Rennes University.

Contact people:

Marcello Traiola, marcello.traiola@inria.fr
Tommaso Belvedere, tommaso.belvedere@inria.fr
Marco Tognon, marco.tognon@inria.fr

[1] E. F. Camacho and C. Bordons, Model Predictive control. in Advanced Textbooks in Control and Signal Processing. London: Springer, 2007. doi: 10.1007/978-0-85729-398-5.
[2] G. Williams, P. Drews, B. Goldfain, J. M. Rehg, and E. A. Theodorou, “Aggressive driving with model predictive path integral control,” in 2016 IEEE International Conference on Robotics and Automation (ICRA), May 2016, pp. 1433–1440. doi: 10.1109/ICRA.2016.7487277.
[3] K. Nguyen, S. Schoedel, A. Alavilli, B. Plancher, and Z. Manchester, “TinyMPC: Model-Predictive Control on Resource-Constrained Microcontrollers,” in 2024 IEEE International Conference on Robotics and Automation (ICRA), May 2024, pp. 1–7. doi: 10.1109/ICRA57147.2024.10610987.
[4] W. J. Dally, Y. Turakhia, and S. Han, “Domain-specific hardware accelerators,” Commun ACM, vol. 63, no. 7, pp. 48–57, Jun. 2020, doi: 10.1145/3361682
[5] J. L. Hennessy and D. A. Patterson, “A new golden age for computer architecture,” Commun ACM, vol. 62, no. 2, pp. 48–60, Jan. 2019, doi: 10.1145/3282307.

Assignment

This Ph.D. thesis aims to use **algorithm-specific custom hardware acceleration** to implement **efficient real-time control for UAVs** with **long prediction horizons** and **high control frequencies**. The structure of the control algorithms is complex and sensitive to numerical errors or reduced arithmetic precision. Thus, applying a **hardware-algorithm Co-design** approach is necessary, i.e., adapting **the control algorithms to the hardware** and **designing the hardware to suit the control algorithms optimally.**

Main activities

After a detailed study of UAV state-of-the-art control algorithms, the student will identify HW acceleration opportunities, such as **parallelization**, **pipelining**, and **data specialization**. The student will apply **co-design** approaches to realize efficient accelerators, utilizing the control algorithms' properties to improve the hardware while adjusting the algorithms to the hardware's characteristics. **Simulations** will be carried out to validate the proposed approaches and prepare the final **integration in the UAV platform**, which is already available to the RAINBOW team.

Skills

Required technical skills:

- Good knowledge of **computer architectures** and **embedded systems**
- **HW design**: VHDL/Verilog basics, HW synthesis flow
- **Programming** knowledge (C/C++, python)
- Experience in **HW/SW co-design** and **robotics** is a plus

Candidates must have a Master's degree (or equivalent) in **Computer Engineering or related areas relevant to the PhD topic**

Languages: proficiency in written English and fluency in spoken English are required.

Relational skills: the candidate will work in a research team, where regular meetings will be set up. The candidate has to be able to present the progress of their work in a clear and detailed manner.

Other values appreciated are open-mindedness, strong integration skills, and team spirit.

Most importantly, we seek highly motivated candidates.

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 2200 euros

General Information

- **Theme/Domain :** Architecture, Languages and Compilation
- **Town/city :** Rennes
- **Inria Center :** Centre Inria de l'Université de Rennes
- **Starting date :** 2025-10-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2025-09-15

Contacts

- **Inria Team :** TARAN
- **PhD Supervisor :**
  Traiola Marcello / marcello.traiola@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

Candidates with knowledge and experience in at least one of the following areas are **highly valued**: **Hardware Design, Hardware/Software co-design,** and **Robotics fundamentals.**

We seek **highly motivated and passionate** candidates. **Autonomy** is a highly appreciated quality.

Essential qualities to fulfill a PhD thesis are feeling at ease in an environment of scientific dynamics and wanting to **learn**, **listen**, **share**, and **work in the**

unknown. There is no clear and definite answer, and often no clear-cut notion of “right” or “wrong” until the scientific community has weighed in. Expect long, probing discussions with your advisor, lab-mates, conference audiences, reviewers, and peers who may challenge or disagree with you. Debate is part of the process.

Candidates must have a Master’s degree (or equivalent) in **Computer Engineering or related areas relevant to the PhD topic**

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

For more information, please contact marcello.traiola@inria.fr

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.