



**Offer #2025-09114**

## **PhD Position F/M PhD on Modular Model Predictive Control Architecture for Human-Robot Collaboration**

**Contract type :** Fixed-term contract

**Level of qualifications required :** Graduate degree or equivalent

**Fonction :** PhD Position

**Level of experience :** Recently graduated

### **About the research centre or Inria department**

The Inria center at the University of Bordeaux is one of the nine Inria centers in France and has about twenty 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 SMEs, large industrial groups, competitiveness clusters, research and higher education players, laboratories of excellence, technological research institute...

### **Context**

This PhD thesis will take place within the Auctus team at the Inria center at the University of Bordeaux.

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The Auctus team is composed of 20 people (5 permanent researchers, 1 permanent research engineer, 4 postdocs, 4 engineers, 4 PhD students, 3 interns currently) whose core expertise ranges from robotics to cognitive sciences including biomechanics and numerical constrained optimization. This research team aims to meet the challenges of collaborative robotics for humans at work. The team's research is divided into three scientific areas: 1) analysis and modeling of human behaviors (both from biomechanical and cognitive perspectives); 2) human-robot interaction, coupling and mediation; 3) design and control of robotic systems. The team also has a strong background in experimental robotics which is a key ingredient to the scientific validation of robotic control concepts developed to tackle dynamic contexts, especially when humans are implied. This PhD thesis

will mostly contribute to develop a novel control architecture (axis 3) but will benefit both from axes 1 and 2, considering factors influencing human motion as well as human-robot interaction modalities. Beyond the available hardware (3 Kuka IIWA, 1 Franka Panda, 1 Flexiv Rizon10s, multi-cameras Optitrack motion capture system, 1 6-Dof Omega Haptic interface from ForceDimension, 1 Hololens, 2 6-axis FT sensors, several tactile sensors ...) and software resources of the team's experimental platform, the recruited PhD candidate will benefit from the research network of the team at the regional (R4 research network, Rhoban team, ROBIOSS@Pprime), national (GDR Robtotique, ISIR, LAAS, INRS, Onera DTIS, CEA LIST, Rainbow@Inria, Hucebot@Inria, Combo@Inria, Willow@Inria, Camin@Inria,...) and international (NYU, Stanford, KAIST, IIT, TU Eindhoven, TU Munich,...) levels. Finally the PhD thesis will also benefit from the scientific context and collaborations within the COURRIER ANR project which aims at studying the role of intention signals sent by the robot in human-robot collaboration. The control framework proposed in this PhD thesis will contribute to provide the project with a generic and open control architecture dedicated to Human-Robot collaboration.

The recruited candidate will be co-advised by:

- Vincent Padois, senior research scientist at Inria, whose core scientific expertise focuses on robot control, especially in the collaborative context;
- Sébastien Kleff, postdoctoral scholar at Inria, whose core scientific expertise lies in Model Predictive Control for robots in physical interaction.

## Assignment

While the first industrial robots were conceived to relieve humans from strenuous and hazardous tasks, robots are now primarily seen as a means to enhance productivity - both in mass production environments and in settings that demand industrial agility. Nevertheless, humans remain, for both organizational and societal reasons, the cornerstone of industry at large. Fully replacing them is still far from being technically feasible - despite the media hype following recent advancements in artificial intelligence - and remains highly debatable from a societal model perspective. It is therefore of paramount importance to continue improving workers' health and working conditions. This is not only an ethical imperative but also an economic necessity [1], particularly in the context of a rapidly aging European workforce.

The growing ability of robots to produce both advanced motion and complex physical interaction - enabled by progress in actuation and sensing - makes them increasingly attractive as assistive systems. Yet, their capacity to effectively support humans in physically demanding tasks necessitates close human-robot collaboration (HRC), which raises several challenges. In particular, effective assistance requires the robot to adapt its behavior to the dynamic context of collaboration, such as human movement or environmental changes. Pre-planned motions or finely tuned controllers tailored to specific use-cases often lead to impasses. Recently, however, modern control techniques based on numerical optimization - such as nonlinear Model Predictive Control (MPC) [2] - have demonstrated strong potential for automating the synthesis and online execution of complex motions.

Nonetheless, applying these techniques in the context of human–robot collaboration poses several fundamental scientific challenges, particularly concerning the robot’s ability to adapt and act autonomously. These challenges are closely linked to the need for systematically incorporating predictions of human and environmental motion into the control process. This is all the more complex given the stochastic nature of these motions. Overall, the central question tackled by this PhD thesis is the following: which, generic enough, control architecture would allow to handle uncertain robotic scenarios, both ensuring optimal control decision and reactivity to the environment dynamics while ensuring the respect of intrinsic and extrinsic safety constraints?

The proposed PhD thesis aims at addressing this issue through a modular control architecture centered on MPC. It is hypothesized that such an architecture is essential for equipping assistive robots with a general control framework capable of producing reactive yet optimal control decisions in uncertain environments.

Indeed, MPC and more particularly nonlinear MPC has shown great successes in synthesizing online complex motions on various robots ranging from industrial manipulators [3, 4] to quadrupeds [5, 6, 7] and humanoids [8, 9, 10]. The main advantage of MPC lies in its ability to re-optimize on the fly the robot’s trajectories based on a predictive model and physical constraints. However constructing accurate predictive models of the human and the shared environment is notoriously difficult [11, 12, 13].

Concurrently, learning methods (reinforcement learning [14], learning from demonstration [15]) have led to remarkable results on real hardware thanks to their ability to learn control policies mapping high-dimensional observations to low level robot actions [16] or latent representations [17] (e.g. human model). While they allow to push robots robustly to their performance limits in complex tasks, learned policies are often task-specific and lack generalization: transferring them across different tasks (e.g. to new control objectives or physical settings) is not trivial and usually requires to re-train from scratch. Lastly, they do not naturally allow to specify operating constraints, which is critical in HRC.

In face of these challenges, we propose to investigate scenario MPC [18, 19] which extends classical MPC by planning trajectories over a set of possible future evolutions or scenarios arising from discrete or continuous uncertainty distributions. By considering structured hypotheses about the future, scenario MPC (s-MPC) may provide the robustness and flexibility required for HRC applications where, for example, the multimodality and the stochasticity of human motion prediction models needs to be accounted for. Specifically, s-MPC is expected to improve the robustness in face of uncertain human behavior and environmental changes while maintaining the advantages of MPC (online re-planning, constraint satisfaction, and interpretability).

In such a framework, higher-level semantic planning can feed s-MPC with a list of, context dependent, desirable control objectives. Given these objectives, s-MPC replans online with robustness and safety guarantees the robot control action. This control action accounts both for stochastic prediction models related to the environment dynamics (including the human) and sensor feedback allowing to update these models (e.g. through estimation). Hence the proposed architecture could directly address the shortcomings of modern ”end-to-end” policy learning by preserving model-based optimization as a central component, while allowing the

use of data-driven human models.

The PhD work will start with a review of the literature in different related domains. In order to position the work in the large perspective of robot control, the candidate will focus on reviewing existing control architectures aiming at handling dynamic and constrained robotic contexts where the ability to compute the robot control input in a online fashion so as to robustly accommodate uncertain environment dynamics is central. The focus of this review of the literature will also be placed on nonlinear model predictive control approaches on the one hand and on scenario-based MPC on the other hand as they provide the cornerstone of the envisioned control approach.

Given this review of the literature, an initial version of the overall architecture including high-level task planning, low level control, perception processing, uncertain prediction models and scenario-based MPC will be delineated.

Given this architecture, the PhD work will consist in formulating the MPC problem considering, as generically as possible, the connections with its different constitutive blocks (propagation of task objectives, constraints, sensor feedback, etc.). Attention will be paid to the optimization problem's structure in order to benefit from the framework of scenario-based MPC while maintaining a computational complexity compatible with real-time control [20].

The architecture will be instantiated and experimentally tested on a collaborative sorting task, in which a human operator and the robot must pick and place objects from a shared tray.

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[4] A. Jordana, S. Kleff, A. Meduri, J. Carpentier, N. Mansard, and L. Righetti, "Stagewise implementations of sequential quadratic programming for model-predictive control," Subm. IEEE TRO, 2023.

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- [20] D. Kouzoupis, “Structure-exploiting numerical methods for tree-sparse optimal control problems,” Ph.D. dissertation, Albert-Ludwigs-Universität Freiburg im Breisgau, 2019.

## Main activities

- **Literature Review:** Reading and synthesizing academic papers to understand the field.
- **Conducting Research:** Making a scientific proposition, Formulating the corresponding optimal control problem, proposing solvers
- **Validating Research:** Designing experiments, collecting data, analyzing results.
- **Writing:** Producing research papers, thesis chapters, grant proposals.
- **Meetings:** Regularly meeting with advisors, collaborators, and lab groups.
- **Presenting:** Giving talks or posters at conferences, seminars, or workshops.
- **Professional Development:** Attending workshops, learning new tools or methods, networking.

## Skills

From an academic and technical point of view, the candidate should have excellent skills in:

- Robotics;
  - Control theory;
  - Applied Mathematics (linear algebra, optimization, numerical methods);
  - C++ and Python programming;
  - A knowledge of the ROS middleware and associated tools can be an asset.
- The candidate is also expected to be:

- rigorous and intellectually honest;
- curious and eager to learn;
- able of strong analytical and abstract thinking;
- independent and well-organized;
- team-oriented with good communication abilities.

## Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of partial teleworking and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities

## Remuneration

The monthly salary will be 2200€ in 2025 and 2300€ in 2026 (before social security contributions and monthly withholding tax)

## General Information

- **Theme/Domain** : Robotics and Smart environments
- **Town/city** : Talence
- **Inria Center** : [Centre Inria de l'université de Bordeaux](#)
- **Starting date** : 2025-10-01
- **Duration of contract** : 3 years
- **Deadline to apply** : 2025-07-21

## Contacts

- **Inria Team** : [AUCTUS](#)
- **PhD Supervisor** :  
Padois Vincent / [vincent.padois@inria.fr](mailto:vincent.padois@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.

**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 apply via the jobs.inria website by sending the following documents:

- cv
- covering letter
- letter of recommendation (if applicable)
- transcripts and rankings of Master's years (or equivalent)

### **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.