UMR IRISA

# Activity Report 2025

## Team RAINBOW

Sensor-based Robotics and Human Interaction

*Joint team with Centre Inria de l'Université de Rennes*

D5 – Virtual Reality, Virtual Humans, Interactions and Robotics

Université de Rennes | ENS rennes | INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES RENNES | cnrs | Inria | Inserm | CentraleSupélec | IMT Atlantique Bretagne-Pays de la Loire École Mines-Télécom | Université Bretagne Sud ubs

# Project-Team RAINBOW

*Creation of the Project-Team: 2018 June 01*

## Keywords

**Computer sciences and digital sciences**

A5.1.2. – Evaluation of interactive systems

A5.1.3. – Haptic interfaces

A5.1.6. – Tangible interfaces

A5.1.7. – Multimodal interfaces

A5.1.9. – User and perceptual studies

A5.6. – Virtual reality, augmented reality

A5.6.1. – Virtual reality

A5.6.2. – Augmented reality

A5.6.3. – Avatar simulation and embodiment

A5.6.4. – Multisensory feedback and interfaces

A5.9.2. – Estimation, modeling

A5.10.1. – Design

A5.10.2. – Perception

A5.10.3. – Planning

A5.10.4. – Robot control

A5.10.5. – Robot interaction (with the environment, humans, other robots)

A5.10.6. – Swarm robotics

A6.4.1. – Deterministic control

A6.4.3. – Observability and Controlability

A6.4.4. – Stability and Stabilization

A6.4.5. – Control of distributed parameter systems

A6.4.6. – Optimal control

A8.2.3. – Calculus of variations

A9.2. – Machine learning

A9.5. – Robotics and AI

A9.7. – AI algorithmics

A9.9. – Distributed AI, Multi-agent

A9.10. – Hybrid approaches for AI

A9.12.4. – 3D and spatio-temporal reconstruction

A9.12.6. – Object localization

A9.12.7. – Visual servoing

**Other research topics and application domains**

B2.5. – Handicap and personal assistances

B2.5.1. – Sensorimotor disabilities

B2.5.2. – Cognitive disabilities

B2.5.3. – Assistance for elderly

B5.1. – Factory of the future

B5.6. – Robotic systems

B8.1.2. – Sensor networks for smart buildings

B8.4. – Security and personal assistance

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# 2 Overall objectives

The long-term vision of the Rainbow team is to develop the next generation of sensor-based robots able to navigate and/or interact in complex unstructured environments *together* with human users. Clearly, the word "together"' can have very different meanings depending on the particular context: for example, it can refer to mere co-existence (robots and humans share some space while performing independent tasks), human-awareness (the robots need to be aware of the human state and intentions for properly adjusting their actions), or actual cooperation (robots and humans perform some shared task and need to coordinate their actions).

One could perhaps argue that these two goals are somehow in conflict since higher robot autonomy should imply lower (or absence of) human intervention. However, we believe that our general research direction is well motivated since: $(i)$ despite the many advancements in robot autonomy, complex and high-level cognitive-based decisions are still out of reach. In most applications involving tasks in unstructured environments, uncertainty, and interaction with the physical world, human assistance is still necessary, and will most probably be for the next decades. On the other hand, robots are extremely capable of autonomously executing specific and repetitive tasks, with great speed and precision, and of operating in dangerous/remote environments, while humans possess unmatched cognitive capabilities and world awareness which allow them to take complex and quick decisions; $(ii)$ the cooperation between humans and robots is often an implicit constraint of the robotic task itself. Consider for instance the case of assistive robots supporting injured patients during their physical recovery, or human augmentation devices. It is then important to study proper ways of implementing this cooperation; $(iii)$ finally, safety regulations can require the presence at all times of a person in charge of supervising and, if necessary, of taking direct control of the robotic workers. For example, this is a common requirement in all applications involving tasks in public spaces, like autonomous vehicles in crowded spaces, or even UAVs when flying in civil airspace such as over urban or populated areas.

Within this general picture, the Rainbow activities will be particularly focused on the case of **(shared) cooperation between robots and humans** by pursuing the following vision: on the one hand, empower robots with a *large degree of autonomy* for allowing them to effectively operate in non-trivial environments (e.g., outside completely defined factory settings). On the other hand, include *human users* in the loop for having them in (partial and bilateral) control of some aspects of the overall robot behavior. We plan to address these challenges from the **methodological**, **algorithmic** and **application-oriented** perspectives. The main *research axes* along which the Rainbow activities will be articulated are: three supporting axes (**Optimal and Uncertainty-Aware Sensing**; **Advanced Sensor-based Control**; **Haptics for Robotics Applications**) that are meant to develop methods, algorithms and technologies for realizing the central theme of **Shared Control of Complex Robotic Systems**.

# 3 Research program

## 3.1 Main Vision

The vision of Rainbow (and foreseen applications) calls for several general scientific challenges: $(i)$ high-level of autonomy for complex robots in complex (unstructured) environments, $(ii)$ forward interfaces for letting an operator giving high-level commands to the robot, $(iii)$ backward interfaces for informing the operator about the robot 'status', $(iv)$ user studies for assessing the best interfacing, which will clearly depend on the particular task/situation. Within Rainbow we plan to tackle these challenges at different levels of depth:

- the **methodological and algorithmic side** of the sought human-robot interaction will be the **main focus** of Rainbow. Here, we will be interested in advancing the state-of-the-art in sensor-based online planning, control and manipulation for mobile/fixed robots. For instance, while classically most control approaches (especially those sensor-based) have been essentially *reactive*, we believe that less myopic strategies based on online/reactive trajectory optimization will be needed for the future Rainbow activities. The core ideas of Model-Predictive Control approaches (also known as Receding Horizon) or, in general, numerical optimal control methods will play a role in the Rainbow activities, for allowing the robots to reason/plan over some future time window and better cope with constraints. We will also consider extending classical sensor-based motion control/manipulation techniques to more realistic scenarios, such as deformable/flexible objects ("**Advanced Sensor-based Control**" axis).

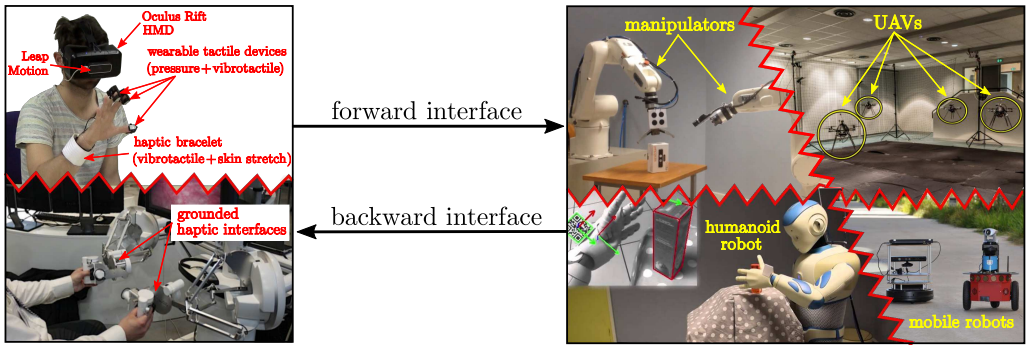



Figure 1: An illustration of the *prototypical* activities foreseen in Rainbow in which a human operator is in partial (and high-level) control of single/multiple complex robots performing semi-autonomous tasks

Finally, it will also be important to spend research efforts into the field of *Optimal Sensing*, in the sense of generating (again) trajectories that can optimize the state estimation problem in presence of scarce sensory inputs and/or non-negligible measurement and process noises, especially true for the case of mobile robots ("**Optimal and Uncertainty-Aware Sensing**" axis). We also aim at addressing the case of coordination between a single human user and multiple robots where, clearly, as explained the autonomy part plays even a more crucial role (no human can control multiple robots at once, thus a high degree of autonomy will be required by the robot group for executing the human commands);

- the **interfacing side** will also be a focus of the Rainbow activities. As explained above, we will be interested in both the *forward* (human → robot) and *backward* (robot → human) interfaces. The forward interface will be mainly addressed from the *algorithmic* point of view, i.e., how to map the few degrees of freedom available to a human operator (usually in the order of 3–4) into complex commands for the controlled robot(s). This mapping will typically be mediated by an "AutoPilot" onboard the robot(s) for autonomously assessing if the commands are feasible and, if not, how to least modify them ("**Advanced Sensor-based Control**" axis).
  The backward interface will, instead, mainly consist of a visual/haptic feedback for the operator. Here, we aim at exploiting our expertise in using force cues for informing an operator about the status of the remote robot(s). However, the sole use of classical *grounded* force feedback devices (e.g., the typical force-feedback joysticks) will not be enough due to the different kinds of information that will have to be provided to the operator. In this context, the recent interest in the use of *wearable* haptic interfaces is very interesting and will be investigated in depth (these include, e.g., devices able to provide vibro-tactile information to the fingertips, wrist, or other parts of the body). The main challenges in these activities will be the mechanical conception (and construction) of suitable wearable interfaces for the tasks at hand, and in the generation of force cues for the operator: the force cues will be a (complex) function of the robot state, therefore motivating research in algorithms for mapping the robot state into a few variables (the force cues) ("**Haptics for Robotics Applications**" axis);

- the **evaluation side** that will assess the proposed interfaces with some user studies, or acceptability studies by human subjects. Although this activity **will not** be a main focus of Rainbow (complex user studies are beyond the scope of our core expertise), we will nevertheless devote some efforts into having some reasonable level of user evaluations by applying standard statistical analysis based on psychophysical procedures (e.g., randomized tests and Anova statistical analysis). This will be particularly true for the activities involving the use of smart wheelchairs, which are intended to be used by human users *and* operate inside human crowds. Therefore, we will be interested in gaining some level of understanding of how semi-autonomous robots (a wheelchair in this example) can predict the human intention, and how humans can react to a semi-autonomous mobile robot.

Figure 1 depicts in an illustrative way the *prototypical* activities foreseen in Rainbow. On the righthand side, complex robots (dual manipulators, humanoid, single/multiple mobile robots) need to perform some task with high degree of autonomy. On the lefthand side, a human operator gives some high-level commands and receives a visual/haptic feedback aimed at informing her/him at best of the robot status. Again, the

main challenges that Rainbow will tackle to address these issues are (in order of relevance): (*i*) methods and algorithms, mostly based on first-principle modeling and, when possible, on numerical methods for online/reactive trajectory generation, for enabling the robots with high autonomy; (*ii*) design and implementation of visual/haptic cues for interfacing the human operator with the robots, with a special attention to novel combinations of grounded/ungrounded (wearable) haptic devices; (*iii*) user and acceptability studies.

## 3.2 Main Components

Hereafter, a summary description of the four axes of research in Rainbow.

### 3.2.1 Optimal and Uncertainty-Aware Sensing

Future robots will need to have a large degree of autonomy for, e.g., interpreting the sensory data for accurate estimation of the robot and world state (which can possibly include the human users), and for devising motion plans able to take into account many constraints (actuation, sensor limitations, environment), including also the state estimation accuracy (i.e., how well the robot/environment state can be reconstructed from the sensed data). In this context, we will be particularly interested in (*i*) devising trajectory optimization strategies able to maximize some norm of the information gain gathered along the trajectory (and with the available sensors). This can be seen as an instance of Active Sensing, with the main focus on *online/reactive* trajectory optimization strategies able to take into account several requirements/constraints (sensing/actuation limitations, noise characteristics). We will also be interested in the coupling between optimal sensing and concurrent execution of additional tasks (e.g., navigation, manipulation). (*ii*) Formal methods for guaranteeing the accuracy of localization/state estimation in mobile robotics, mainly exploiting tools from interval analysis. The interest of these methods is their ability to provide possibly conservative but guaranteed accuracy bounds on the best accuracy one can obtain with the given robot/sensor pair, and can thus be used for planning purposes or for system design (choice of the best sensors for a given robot/task). (*iii*) Localization/tracking of objects with poor/unknown or deformable shape, which will be of paramount importance for allowing robots to estimate the state of "complex objects" (e.g., human tissues in medical robotics, elastic materials in manipulation) for controlling its pose/interaction with the objects of interest.

### 3.2.2 Advanced Sensor-based Control

One of the main competences of the previous Lagadic team has been, generally speaking, the topic of *sensor-based control*, i.e., how to exploit (typically onboard) sensors for controlling the motion of fixed/ground robots. The main emphasis has been in devising ways to directly couple the robot motion with the sensor outputs in order to invert this mapping for driving the robots towards a configuration specified as a desired sensor reading (thus, directly in sensor space). This general idea has been applied to very different contexts: mainly standard vision (from which the Visual Servoing keyword), but also audio, ultrasound imaging, and RGB-D.

Use of sensors for controlling the robot motion will also clearly be a central topic of the Rainbow team too, since the use of (especially onboard) sensing is a main characteristic of any future robotics application (which should typically operate in unstructured environments, and thus mainly rely on its own ability to sense the world). We then naturally aim at making the best out of the previous Lagadic experience in sensor-based control to propose new advanced ways of exploiting sensed data for, roughly speaking, controlling the motion of a robot. In this respect, we plan to work on the following topics: (*i*) "direct/dense methods" which try to directly exploit the raw sensory data in computing the control law for positioning/navigation tasks. The advantages of these methods is the little need for data pre-processing which can minimize feature extraction errors and, in general, improve the overall robustness/accuracy (since all the available data is used by the motion controller); (*ii*) sensor-based interaction with objects of unknown/deformable shapes, for gaining the ability to manipulate, e.g., flexible objects from the acquired sensed data (e.g., controlling online a needle being inserted in a flexible tissue); (*iii*) sensor-based model predictive control, by developing *online/reactive* trajectory optimization methods able to plan feasible trajectories for robots subject to sensing/actuation constraints with the possibility of (onboard) sensing for continuously replanning (over some future time

horizon) the optimal trajectory. These methods will play an important role when dealing with complex robots affected by complex sensing/actuation constraints, for which pure reactive strategies (as in most of the previous Lagadic works) are not effective. Furthermore, the coupling with the aforementioned optimal sensing will also be considered; (*iv*) multi-robot decentralised estimation and control, with the aim of devising again sensor-based strategies for groups of multiple robots needing to maintain a formation or perform navigation/manipulation tasks. Here, the challenges come from the need of devising "simple" decentralized and scalable control strategies under the presence of complex sensing constraints (e.g., when using onboard cameras, limited fov, occlusions). Also, the need of locally estimating global quantities (e.g., common frame of reference, global property of the formation such as connectivity or rigidity) will also be a line of active research.

### 3.2.3 Haptics for Robotics Applications

In the envisaged *shared* cooperation between human users and robots, the typical sensory channel (besides vision) exploited to inform the human users is most often the force/kinesthetic one (in general, the sense of touch and of applied forces to the human hand or limbs). Therefore, a part of our activities will be devoted to study and advance the use of *haptic* cueing algorithms and interfaces for providing a feedback to the users during the execution of some shared task. We will consider: (*i*) multi-modal haptic cueing for general teleoperation applications, by studying how to convey information through the kinesthetic and cutaneous channels. Indeed, most haptic-enabled applications typically only involve kinesthetic cues, e.g., the forces/torques that can be felt by grasping a force-feedback joystick/device. These cues are very informative about, e.g., preferred/forbidden motion directions, but are also inherently limited in their resolution since the kinesthetic channel can easily become overloaded (when too much information is compressed in a single cue). In recent years, the arise of novel cutaneous devices able to, e.g., provide vibro-tactile feedback on the fingertips or skin, has proven to be a viable solution to *complement* the classical kinesthetic channel. We will then study how to combine these two sensory modalities for different prototypical application scenarios, e.g., 6-dof teleoperation of manipulator arms, virtual fixtures approaches, and remote manipulation of (possibly deformable) objects; (*ii*) in the particular context of medical robotics, we plan to address the problem of providing haptic cues for typical medical robotics tasks, such as semi-autonomous needle insertion and robot surgery by exploring the use of kinesthetic feedback for rendering the mechanical properties of the tissues, and vibrotactile feedback for providing with guiding information about pre-planned paths (with the aim of increasing the usability/acceptability of this technology in the medical domain); (*iii*) finally, in the context of multi-robot control we would like to explore how to use the haptic channel for providing information about the status of *multiple* robots executing a navigation or manipulation task. In this case, the problem is (even more) how to map (or compress) information about many robots into a few haptic cues. We plan to use specialized devices, such as actuated exoskeleton gloves able to provide cues to each fingertip of a human hand, or to resort to "compression" methods inspired by the *hand postural synergies* for providing coordinated cues representative of a few (but complex) motions of the multi-robot group, e.g., coordinated motions (translations/expansions/rotations) or collective grasping/transporting.

### 3.2.4 Shared Control of Complex Robotics Systems

This final and main research axis will exploit the **methods, algorithms and technologies** developed in the previous axes for realizing applications involving complex semi-autonomous robots operating in complex environments together with human users. The *leitmotiv* is to realize advanced *shared control* paradigms, which essentially aim at blending robot autonomy and user's intervention in an optimal way for exploiting the best of both worlds (robot accuracy/sensing/mobility/strength and human's cognitive capabilities). A common theme will be the issue of where to "draw the line" between robot autonomy and human intervention: obviously, there is no general answer, and any design choice will depend on the particular task at hand and/or on the technological/algorithmic possibilities of the robotic system under consideration.

A *prototypical* envisaged application, exploiting and combining the previous three research axes, is as follows: a complex robot (e.g., a two-arm system, a humanoid robot, a multi-UAV group) needs to operate in an environment exploiting its onboard sensors (in general, vision as the main exteroceptive one) and deal with many constraints (limited actuation, limited sensing, complex kinematics/dynamics, obstacle avoidance,

interaction with difficult-to-model entities such as surrounding people, and so on). The robot must then possess a quite large autonomy for interpreting and exploiting the sensed data in order to estimate its own state and the environmental one ("**Optimal and Uncertainty-Aware Sensing**" axis), and for planning its motion in order to fulfil the task (e.g., navigation, manipulation) by coping with all the robot/environment constraints. Therefore, advanced control methods able to exploit the sensory data at its most, and able to cope *online* with constraints in an optimal way (by, e.g., continuously replanning and predicting over a future time horizon) will be needed ("**Advanced Sensor-based Control**" axis), with a possible (and interesting) coupling with the sensing part for optimizing, at the same time, the state estimation process. Finally, a human operator will typically be in charge of providing high-level commands (e.g., where to go, what to look at, what to grasp and where) that will then be autonomously executed by the robot, with possible local modifications because of the various (local) constraints. At the same time, the operator will also receive *online* visual-force cues informative of, in general, how well her/his commands are executed and if the robot would prefer or suggest other plans (because of the local constraints that are not of the operator's concern). This information will have to be visually and haptically rendered with an optimal combination of cues that will depend on the particular application ("**Haptics for Robotics Applications**" axis).

# 4 Application domains

The activities of Rainbow fall within the scope of Robotics. Broadly speaking, our main interest is in devising novel/efficient *algorithms* (for estimation, planning, control, haptic cueing, human interfacing, etc.) that can be general and applicable to many different robotic systems of interest, depending on the particular application/case study. For instance, we plan to consider

- applications involving remote telemanipulation with one or two robot arms, where the arm(s) will need to coordinate their motion for approaching/grasping objects of interest under the guidance of a human operator;
- applications involving single and multiple mobile robots for spatial navigation tasks (e.g., exploration, surveillance, mapping). In the multi-robot case, the high redundancy of the multi-robot group will motivate research in autonomously exploiting this redundancy for facilitating the task (e.g., optimizing the self-localization of the environment mapping) while following the human commands, and vice-versa for informing the operator about the status of a multi-robot group. In the single robot case, the possible combination with some manipulation devices (e.g., arms on a wheeled robot) will motivate research into remote tele-navigation and tele-manipulation;
- applications involving medical robotics, in which the "manipulators" are replaced by the typical tools used in medical applications (ultrasound probes, needles, cutting scalpels, and so on) for semi-autonomous probing and intervention;
- applications involving a direct physical "coupling" between human users and robots (rather than a "remote" interfacing), such as the case of assistive devices used for easing the life of people with disabilities. Here, we will be primarily interested in, e.g., safety and usability issues, and also touch some aspects of user acceptability.

These directions are, in our opinion, very promising since nowadays and future robotics applications are expected to address more and more complex tasks: for instance, it is becoming mandatory to empower robots with the ability to predict the future (to some extent) by also explicitly dealing with uncertainties from sensing or actuation; to safely and effectively interact with human supervisors (or collaborators) for accomplishing shared tasks; to learn or adapt to the dynamic environments from small prior knowledge; to exploit the environment (e.g., obstacles) rather than avoiding it (a typical example is a humanoid robot in a multi-contact scenario for facilitating walking on rough terrains); to optimize the onboard resources for large-scale monitoring tasks; to cooperate with other robots either by direct sensing/communication, or via some shared database (the "cloud").

While no single lab can reasonably address all these theoretical/algorithmic/technological challenges, we believe that our research agenda can give some concrete contributions to the next generation of robotics applications.

# 5 Social and environmental responsibility

## 5.1 Footprint of research activities

Much of the team's work results in algorithms with low computational costs, allowing them to be run onboard robots with limited computational and energy consumption.
The team is also committed to reducing the carbon footprint of its professional travel. We prioritize low-CO2 transport, such as trains, for attending conferences and meetings whenever feasible. This policy aims to minimize air travel and promote more sustainable mobility within our research community.

## 5.2 Societal impact of research results

The Rainbow activities on assistive robotics are carried out in collaboration with a very wide range of users with a focus on promoting autonomy and creating more inclusive spaces. The work is carried out in conjunction with the social sciences using a user-centered design approach that addresses needs, expectations, barriers to technology use, acceptability, and so forth. Evaluations are carried out with target users in clinical settings, but also in ecological settings that can be cultural sites. For example, we carried out experiments of our shared control wheelchair navigation assistance in museums in Rennes, which allowed to assess the acceptability of the solution among users, caregivers, and museum staff.

All doctoral students systematically undergo training in ethics and scientific integrity. In addition, when human participants are involved in laboratory experiments or clinical trials, we systematically assess the risk/benefit balance and establish risk management measures in the protocol. The team is accustomed to working with clinicians to obtain ethical approvals for clinical trials. Out of the clinical trial scope, each protocol is designed in compliance with the GDPR and with good practices for obtaining ethical approvals as well as recruiting, informing, and obtaining informed consent from participants.

# 6 Highlights of the year

- Marco Tognon: publication in Science Robotics [41]
- Paolo Robuffo Giordano has been appointed President of the "Georges Giralt"' PhD award committee
- Paolo Robuffo Giordano co-organized the JNRR 2025 (Journées Nationales de la Recherche en Robotique) at IRISA, Rennes
- Claudio Pacchierotti has been appointed Distinguished Lecturer of the IEEE Robotics & Automation Society for the field of haptics (Region 8: Europe, Middle East and Africa, 2025 onwards).
- Starting of ANR AAPG 2024 PRC project "MATES: Multi-drone-human collaboration teams for high-risk assembling and handling tasks", coordinated by Claudio Pacchierotti.
- Maud Marchal has been appointed as a Board Member of the Virtual Worlds Association, representing CNRS and in charge of the Strategic Research and Innovation Agenda document.

## 6.1 Awards

- P.-A. Cabaret, co-supervised by M. Babel, M. Marchal and C. Pacchierotti, received the Best PhD award (2025) of IFRATH (Federative Research Institute for Assistive Technologies) [80]
- Fabien Grzeskowiak, Emilie Leblong, Sébastien Thomas, Francois Pasteau, Louise Devigne, Marie Babel, Anne-Hélène Olivier received the Best Demo Award (honorable mention) of IEEE VR Conference 2025, "Power wheelchair driving: a multisensory simulator using VR to learn inrehabilitation centers"
- Marco Tognon and Phillip Maximilian Mehl obtained the Best Paper Award (AI in Robotics) at the 2025 European Robotic Forums [65].

- Maud Marchal obtained Best Presentation Award at ACM Siggraph Motion, Interaction and Games 2025, Zurich, Switzerland [30]

# 7 Latest software developments, platforms, open data

## 7.1 Latest software developments

### 7.1.1 HandiViz

**Name:** Driving assistance of a wheelchair

**Keywords:** Health, Persons attendant, Handicap

**Functional Description:** Preserving the autonomy and the mobility is essential for disabled people well-being. The HandiViz software proposes a semi-autonomous navigation framework of a wheelchair relying on visual servoing along corridors. This control system relies on the combination of two tasks: first the manual steering and second wall avoidance task obtained by a dedicated visual based servoing approach. The idea is then to correct the trajectory indicated by the patient by servoing only the necessary degrees of freedom. This visual servoing process is based on both the vanishing point and wall plane detection. A smooth transition from manual driving to assisted naviga- tion is obtained thanks to an adapted weighting function, thus avoiding discontinuities that can lead to unpleasant experience.

It has been registered to the APP ("Agence de Protection des Programmes") as an INSA software (IDDN.FR.001.440021.000.S.P.2013.000.10000) and is under GPL license.

**Contact:** Marie Babel

**Participants:** François Pasteau, Marie Babel

**Partner:** INSA Rennes

### 7.1.2 ViSP

**Name:** Visual servoing platform

**Keywords:** Computer vision, Robotics, Visual servoing (VS), Visual tracking

**Scientific Description:** Since 2004, we develop and release ViSP [1], an open source library available from https://visp.inria.fr. ViSP standing for Visual Servoing Platform allows prototyping and developing applications using visual tracking and visual servoing techniques at the heart of the Rainbow research. ViSP was designed to be independent from the hardware, to be simple to use, expandable and cross-platform. ViSP allows designing vision-based tasks for eye-in-hand and eye-to-hand systems from the most classical visual features that are used in practice. It involves a large set of elementary positioning tasks with respect to various visual features (points, segments, straight lines, circles, spheres, cylinders, image moments, pose...) that can be combined together, and image processing algorithms that allow tracking of visual cues (dots, segments, ellipses...), or 3D model-based tracking of known objects or template tracking. Simulation capabilities are also available.

ViSP also provides an open-source dynamic simulator called FrankaSim based on CoppeliaSim and ROS for the Panda robot from Franka Robotics [2]. The simulator fully integrated in the ViSP ecosystem features a dynamic model that has been accurately identified from a real robot, leading to more realistic simulations. Conceived as a multipurpose research simulation platform, it is well suited for visual servoing applications as well as, in general, for any pedagogical purpose in robotics. All the software, models and CoppeliaSim scenes presented in this work are publicly available under free GPL-2.0 license.

A module dedicated to deep neural networks (DNN) is also available to facilitate image classification and object detection. This module can infer the convolutional networks Faster-RCNN, SSD-MobileNet,

ResNet 10, Yolo v3, Yolo v4, Yolo v5, Yolo v7, Yolo v8 and Yolo v11, which simultaneously predict object boundaries and prediction scores at each position.

A new module dedicated to the visual tracking of an object using its model has been introduced. Called RBT for Render-Based-Tracker, it enables complex objects to be localized in real time by robustly combining geometric features, colour-based features and depth map features in the minimisation process. We also introduced Python bindings to populate ViSP into the vision and robotics community.

[1] E. Marchand, F. Spindler, F. Chaumette. ViSP for visual servoing: a generic software platform with a wide class of robot control skills. IEEE Robotics and Automation Magazine, Special Issue on "Software Packages for Vision-Based Control of Motion", P. Oh, D. Burschka (Eds.), 12(4):40-52, December 2005. URL: https://hal.inria.fr/inria-00351899v1

[2] A. A. Oliva, F. Spindler, P. Robuffo Giordano and F. Chaumette. 'FrankaSim: A Dynamic Simulator for the Franka Emika Robot with Visual-Servoing Enabled Capabilities'. In: ICARCV 2022 - 17th International Conference on Control, Automation, Robotics and Vision. Singapore, Singapore, 11th Dec. 2022, pp. 1–7. URL: https://hal.inria.fr/hal-03794415.

**Functional Description:** ViSP provides simple ways to integrate and validate new algorithms with already existing tools. It follows a module-based software engineering design where data types, algorithms, sensors, viewers and user interaction are made available. Written in C++, ViSP is based on open-source cross-platform libraries (such as OpenCV) and builds with CMake. Several platforms are supported, including OSX, iOS, Windows and Linux. ViSP online documentation allows to ease learning. More than 307 fully documented classes organized in 18 different modules, with more than 475 examples and 114 tutorials are proposed to the user. ViSP is released under a dual licensing model. It is open-source with a GNU GPLv2 or GPLv3 license. A professional edition license that replaces GNU GPL is also available.

**URL:** https://visp.inria.fr

**Contact:** Fabien Spindler

**Participant:** 5 anonymous participants

### 7.1.3 DIARBENN

**Name:** Obstacle avoidance through sensor-based servoing

**Keywords:** Servoing, Shared control, Navigation

**Functional Description:** Diarbenn is a semi-autonomous robotic assistance module for elec- tric wheelchairs (EW), i.e., a control system shared with the user. This module is designed to accessorize Powered wheelchair (PWC) to improve safety conditions when driving. The device consists of several sensor boxes and a control box. The sensor boxes measure the distances around the PWC. The measurements from the sensor boxes are then processed by the control box to ensure safe operation of the PWC.

Speed Constraint of the PWC are calculated based on distances measured around the wheelchair. These constraints, derived from the environment, are then merged with the user's command (data from the control box) in order to recalculate the speed to be applied to the wheelchair to gradually modify its trajectory and avoid collisions with the environment, while respecting the user's intention as closely as possible. With the module activated, the PWC will stop when it approaches an obstacle at a desired distance. In the event of an oblique approach, the PWC will autonomously bypass the obstacle by running alongside it. At any time, the user can interrupt the assisted maneuver by releasing the control, as with a traditional PWC. In addition, these sensors have been designed and positioned to be protected or resistant to collisions with the environment. Their robustness has been proven in laboratory tests.

**Contact:** Marie Babel

**Participant:** 3 anonymous participants

**Partner:** INSA Rennes

#### 7.1.4 telekyb3

**Name:** Free and open source collection of software for Unmanned Aerial Vehicles (UAVs)

**Keyword:** Robot system

**Functional Description:** The main features of telekyb3 include access to all low-level components and closed-loop control of each robot actuator—critical elements for research in aerial physical interaction and manipulation.

Moreover, it is designed with a strong focus on modularity and code reusability. Components use and provide common interfaces, which makes it possible to easily swap between interface-compatible modules. Additionally, the framework is designed to be middleware-independent: users need only focus on writing the code related to their chosen algorithm, while the remaining boilerplate required to run it is automatically generated for the target middleware (e.g., ROS, YARP, pocolibs).

Lastly, it can support a wide variety of aerial robots: it allows controlling not only one or multiple platforms, but also robots with different actuator configurations.

The project originally started at LAAS–CNRS in Toulouse in 2015. Over the years, the framework has been extensively used within the laboratory, and several researchers who moved to other institutions chose to continue using it for its features, strong modularity, and its ability to adapt easily to evolving research needs.

Today, IRISA–Inria counts roughly a dozen users and contributors. Since 2023, it has been supporting LAAS in maintaining the software, developing new modules, and adding new features. The framework is now also used by international partners, including the University of Twente and Saxion University of Applied Sciences in the Netherlands, and University College London in the United Kingdom.

**URL:** https://git.openrobots.org/projects/telekyb3

**Contact:** Gianluca Corsini

**Partner:** CNRS

### 7.2 New platforms

The platforms described in the next sections are labeled by the University of Rennes and are parts of the French Research Infrastructure ROBOTEX 2.0 labeled by the French Ministry of Research.

#### 7.2.1 Robot Vision Platform

**Participants:** François Chaumette, Eric Marchand, Fabien Spindler *(contact)*.

We are using an industrial robot built by Afma Robots in the nineties to validate our research in visual servoing and active vision. This robot is a 6 DoF Gantry on which it is possible to mount a gripper and an RGB-D camera on its end effector (see Fig. 2). This equipment is mainly used to validate vision-based visual servoing and real-time tracking algorithms.

In 2025, this platform has been used to validate experimental results in 1 accepted publication [23].

#### 7.2.2 Mobile Robots

**Participants:** Marie Babel, François Pasteau, Fabien Spindler *(contact)*.

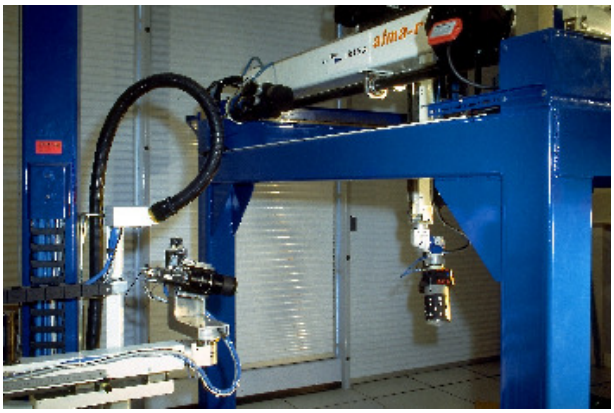


Figure 2: Rainbow robotics platform for vision-based manipulation

To validate our research in personally assisted living topic (see Sect. 8.3.2), we have now five electric wheelchairs (see Fig. 3.a). The control of the wheelchair is performed using a plug and play system between the joystick and the low level control of the wheelchair. Such a system lets us acquire the user intention through the joystick position and control the wheelchair by applying corrections to its motion. The wheelchairs have been fitted with cameras, ultrasound and time of flight sensors to perform the required servoing for assisting handicapped people. A wheelchair haptic simulator completes this platform to develop new human interaction strategies in a virtual reality environment (see Fig. 3.b). Moreover, for fast prototyping of multi-robot control algorithms, since end of 2025 the platform provides about ten DJI RoboMaster S1 mobile ground robots (see Fig. 3.c).

In 2025, these robots were used to obtain experimental results presented in 1 PhD thesis [75] and in multiple papers [17, 19, 31, 59, 62, 63].



(a) (b) (c)

Figure 3: Mobile Robot Platform. a) wheelchairs from Permobil, Sunrise and YouQ, b) Wheelchair haptic simulator, c) DJI RoboMaster mobile robot

### 7.2.3 Advanced Manipulation Platform

**Participants:** Alexandre Krupa, Claudio Pacchierotti, Paolo Robuffo Giordano, François Chaumette, Fabien Spindler *(contact)*.

This platform consists of by 2 Panda lightweight 7 DoF arms from Franka Emika and 1 from Franka Robotics acquired end of 2025. They are equipped with torque sensors in all seven axes. The following end effectors can be mounted on the robot: an electric gripper, a camera, a soft hand from qbrobotics (see

Fig. 4.a) and a Reflex TakkTile 2 gripper from RightHand Labs. A force-torque sensor from Alberobotics is also attached to one of the robots end effector to provide greater accuracy in torque-controlled tasks.

Two Adept 6-DoFs arms (one Viper 650 robot and one Viper 850 robot) and a 6-DoFs Universal Robots UR5 complete this platform category.

Moreover, since June 2025, the platform has been supplemented by the acquisition of a new TRIAGo robot from the company PAL Robotics (see Fig. 4.b). This robot is unique in the world. It was funded by the TIRREX Equipex and by Inria. It consists of a holonomic mobile base, on top of which sits a motorized torso, to which three 7-degree-of-freedom arms are attached. The end-effectors of these arms are modular and can be equipped with ATI force sensors and Allegro hands whose phalanges are fitted with Xela tactile sensors. This platform category is mainly used to validate our research in coupling force and vision control when attempting to manipulate deformable and soft objects. Other haptic devices can also be paired to any robot in this category.

This platform (see Fig. 4.c) is mainly used to manipulate deformable objects and to validate our activities in coupling force and vision for controlling robot manipulators (see Section 8.3.1) and in controlling the deformation of soft objects (Sect. 8.1.8). Other haptic devices (see Section 8.2) can also be coupled to this platform.

In 2025, 1 paper [58] and 1 PhD thesis [71] were published including experimental results obtained with this platform.



(a)




(b)



(c)

Figure 4: Rainbow advanced manipulation platform. a) One of the two Panda lightweight arms from Franka Emika, with mounted the Pisa SoftHand, b) the TRIAGo robot from PAL Robotics, c) The 5 arms composing the platform with in the foreground a Franka, in the second plan our two Viper robots, then in the background, a UR 5 arm and our second Franka robot.

### 7.2.4 Unmanned Aerial Vehicles (UAVs)

**Participants:** Gianluca Corsini *(contact)*, Paolo Robuffo Giordano, Marco Tognon, Claudio Pacchierotti, Fabien Spindler, Esteban Restrepo.

Rainbow is involved in several activities concerning conception, modelling, control and perception for single and multiple aerial robots (ARs). Two indoor flying arenas are used to carry out the related experimental activities. The first arena is relatively small (3m x 5m x H1.8m) and is equipped with 11 Vicon cameras for motion capture. The second one, spanning a larger volume (about 9m x 9m x H2.5m), is equipped with 14 Qualisys cameras. However, the latter room is only available within the period from January to August. Compared to the former, the larger arena grants us with the possibility to fly multiple drones at the same time thanks to the larger volume and the great coverage offered by the larger number of cameras.

In these flying arenas, we operate several customized ARs which have been heavily customised by: reprogramming from scratch the low-level firmwares running on the onboard electronics (comprising flight

and motor controllers), equipping each robot with an onboard computer (for instance a Jetson or a NUC board) running Linux Ubuntu and the telekyb3 software framework, and adding Realsense RGB-D cameras for onboard visual odometry and visual servoing.

The framework telekyb3 is an open-source architecture based on the Genom3 software tool which has been developed at LAAS in Toulouse. It features a modular and formal structure tailored to code reusability, high performance and middleware abstraction. It comprises a set of algorithms dedicated to localization, navigation and low-level control of aerial robots in maneuvering and physical-interaction-based tasks.

The aerial robotic platform of the team includes quadrotors and hexarotors (see Fig. 7.2.4.a and 7.2.4.b, respectively) which have been internally designed both at the mechanical and the electronic level. While the quadrotors have a standard (in jargon, collinear) propeller orientation, the hexarotors have the motors tilted w.r.t. the main body. This property grants them with maneuvering capabilities that cannot be replicated by conventional and commercial drones with collinear rotors.

For most of the mechanical components, we rely on custom parts which are then realized by exploiting 3D printing technology and water-jet and milling processes of carbon-fiber material. From the electronic standpoint, our robots feature a Mikrokopter-based flight controller running custom firmware. However, due to the unavailability and aging of the latter board, a newer flight controller named Paparazzi, has been adopted and consequently the firmware adapted to the new board. The Paparazzi flight controller is part of an open-source and open-hardware project started at ENAC in Toulouse. This board has been chosen as it fits well our needs: it comprises more precise onboard sensors and sufficient programmable peripherals used to communicate with the other electronic modules and sensors.

Smaller commercial drones, namely the BitCraze Crazyflie, have been added to this robotic platform. Thanks to the tiny dimensions of these drones and considering the limited available space for experiments, these robots are perfect candidates to carry out research related to the control and perception of a team of multiple robots.

Among the different successful experiments, we can annoverate a visual servoing using ViSP to position the drone w.r.t. a target and to manipulate deformable objects (e.g. a cable), accurate positioning of a swarm of (more than 5) robots, contact-based interaction with flat surfaces (for instance, drawing on a whiteboard) by means of a hexarotor equipped with a rigid end-effector.

In 2025, multiple papers [33, 37, 43, 44, 18, 65, 22, 34, 20] contain experimental results obtained with this platform.



(a) (b)

Figure 5: Unmanned Aerial Vehicles Platform. a) one of our customized quadrotors, b) our hexarotor with tilted propellers.

### 7.2.5 Interactive interfaces and systems

**Participants:** Claudio Pacchierotti, Paolo Robuffo Giordano, Maud Marchal, Marie Babel, Fabien Spindler *(contact)*.

Interactive technologies enables the communication between artificial systems and human users. Examples of such technologies are haptic interfaces and virtual reality headsets.

Various haptic devices are used to validate our research in, e.g., shared control and extended reality. We design some wearable haptics devices to enhance the user robotic interaction with sensorial feedback, while some other devices are bought from off-the-shelf products, such as a Virtuose 6D device and Desktop 6D

device acquired fall 2025 from Haption (see Fig. 6.a). For instance, the latter equipment is used as the master device in many of our shared control activities. An Omega 6 (see Fig. 6.b) from Force Dimension and devices from Ultrahaptics (see Fig. 6.c) complete this platform that could be coupled to the other robotic systems.

Similarly, in order to augment the immersiveness of virtual scenarios, we make use of virtual and augmented reality headsets, namely HTC Vive headsets for VR tasks and Microsoft Hololens for Augmented Reality interactions. (see Fig. 6.d).

In 2025, this platform was used to obtain experimental results presented in multiple papers [24, 34, 46, 47, 64, 53, 66, 56, 57, 54, 55].



(a) (b) (c) (d)

Figure 6: Haptics and Shared Control Platform. a) Virtuose 6D, b) Omega 6 haptic devices, c) Ultraleap STRATOS, d) Hololens 2.

# 8 New results

## 8.1 Advanced Sensor-Based Control

We contributed a chapter on visual servoing to the book “Robotics Goes MOOC: Knowledge" edited by Bruno Siciliano [68].

### 8.1.1 Integrated Robust Planning and Control for Uncertain Robots

**Participants:** Tommaso Belvedere, Paolo Robuffo Giordano.

The goal of this research activity is to propose an integrated approach for robust planning and control of robots whose models are affected by uncertainty in some of their parameters. The results are based on the notion of *closed-loop state sensitivity* developed in our group since several years, and are also related to the ANR project CAMP (Sect. 10.4.8) and of the recent Cluster SequoIA HARMONY (Sect. 10.4.16).

Over the past years, we have developed several trajectory optimization algorithms leveraging the notion of closed-loop “state sensitivity”, “input sensitivity” and derived quantities. In particular, exploiting these metrics we were able to construct tubes enveloping the bundle of perturbed trajectories given an uncertainty model (a range of variation for the parameters around a nominal value). During this year we have continued working on this subject with the following contributions:

- in [40], we experimentally validated the sensitivity framework in the context of robust manipulation control for a robot manipulator. Our objective was to assess how to enhance the closed-loop robustness against payload variations during precise manipulation tasks. We conducted a series of experiments to validate our optimization approach across different trajectories, focusing primarily on evaluating the precision of the manipulator’s end-effector at critical moments where high accuracy is essential like, for example, while tossing objects. The experimental campaign confirmed the validity of the approach.
- in [38], we performed a principled study on the “sensitivity tubes”. Indeed, these tubes are traditionally built from ellipsoidal uncertainty sets and used to robustify system constraints. These ellipsoids,

however, are themselves smooth approximations of underlying hyperboxes in the parameter space, leading to an inaccurate estimation of the parameter set. We then extended our framework by proposing two new formulations that more precisely represent the real closed-loop behavior of the system through improved computation of the sensitivity tubes. The first constructs tubes directly from hyperboxes, exactly preserving the original parameter bounds but producing a non-differentiable description. The second employs superquadrics, which smoothly approximate the hyperbox with user-tunable fidelity while preserving differentiability, as in the ellipsoidal case. Both methods were extensively validated in a simulation campaign.

- in [20, 50] we proposed an 'online' reactive trajectory optimization based on sensitivity metrics for increasing the robustness against model uncertainties. In particular, in [20] we developed a MPC scheme leveraging the sensitivity formulation: one key contribution lied in the introduction of a computationally efficient robust MPC formulation with a comparable computational complexityto a standard MPC (i.e., an MPC not explicitly dealing with parametric uncertainty). An extensive simulation campaign was presented to demonstrate the effectiveness of the proposed approach in handling parametric uncertainties and enhancing task performance, safety, and overall robustness, complemented by an experimental validation of the approach in real-world conditions. In [50], we instead proposed a MPPI scheme based on sensitivity for generating online robust trajectory by exploiting the parallelizability of the MPPI scheme on a GPU hardware

- in [45] we proposed a review paper where we summarized the various main contributions of sensitivity-based robust planning achieved over the last years

- in [21], we developed Feedback-MPPI (F-MPPI), a framework that augments standard MPPI by computing local linear feedback gains, enabling high-frequency closed-loop corrections without full re-optimization at each timestep. The key innovation lies in recognizing that MPPI, despite being sampling-based, implicitly defines a smooth policy through the weighted average in parameter space. Compared to prior work on Feedback MPC (which extracts Riccati gains from Differential Dynamic Programming or NLP solvers), the key contribution is the extension of this concept to gradient-free, sampling-based controllers. The gain computation leverages automatic differentiation to evaluate cost gradients for each rollout in parallel alongside trajectory evaluation, maintaining GPU-accelerated efficiency. The method was validated on multiple robotic platforms in simulation and experiments on a quadcopter, involving GPU-accelerated onboard computation. The code was released as an open-source Python library

- To handle generic constraints in the sampling-based MPPI setting, in [49] we developed BC-MPPI (Bayesian-Constraints MPPI), which uses probabilistic surrogates to reshape the MPPI sampling distribution toward constraint satisfaction. The fundamental limitation of penalty-based constraint handling is that if no feasible samples are drawn, violations become inevitable. Inspired by Constrained Bayesian Optimization, BC-MPPI attaches a Bayesian Neural Network (BNN) surrogate to each constraint, predicting both the mean constraint value and its variance for the sampled inputs. The feasibility probability is then multiplied across constraints and incorporated into the MPPI weights. This automatically down-weights unsafe rollouts without explicit rejection, pushing the sampling distribution toward the safe subset while preserving useful exploration. The approach was validated in simulation with an aerial robot navigating around obstacles. Compared to classic MPPI with hard rejection, BC-MPPI achieved larger obstacle clearances, closer target tracking, fewer collisions in complex scenarios, and lower rejection rates (indicating more efficient sample use).

### 8.1.2 UWB navigation of assisted power wheelchair

**Participants:** Vincent Drevelle, Marie Babel, François Pasteau, Theo Le Terrier.

Ultra-wideband (UWB) radio technology is a promising solution for indoor localization and object tracking. Unlike vision-based systems, UWB provides a low-cost, non-intrusive, and easy-to-install alternative

for wheelchairs. By measuring time-of-flight between fixed beacons and a mobile tag, UWB yields accurate distance estimates. However, in cluttered indoor environments, multipath or non-line-of-sight (NLOS) propagation can introduce large positive errors in these measurements.

To address this, we developed a robust set-membership positioning approach for a smart wheelchair equipped with UWB beacons [31]. The method employs interval constraint propagation to explicitly account for multipath and NLOS effects, which may cause measured ranges to exceed the true distance [62]. This produces a reliable feasible pose set for the wheelchair at each measurement epoch, ensuring conservative but trustworthy localization.

We also investigate Model Predictive Control (MPC) for autonomous navigation of the wheelchair toward a learned target pose using UWB range measurements [63, 59]. The MPC framework incorporates nonholonomic and user-comfort constraints and can ensure obstacle avoidance via time-of-flight infrared sensors. This integrated approach enables safe and efficient navigation, paving the way for enhanced user mobility and independence.

#### 8.1.3 Visual field for parts assembly

**Participant:** François Chaumette.

This study was done in collaboration with IRT Jules Verne in Nantes (see Section 9.1.1). Its goal was to accurately control the complete trajectory of a robot during the assembly of two parts [48].

#### 8.1.4 Visual servoing with respect to a cylinder

**Participants:** Alessandro Colotti, François Chaumette.

We developed a new method able to position an eye-in hand camera with respect to a cylinder. We proposed new visual features and a new control scheme enabling to demonstrate the global stability of the system even in the presence of a very bad estimation or approximation of the cylinder radius: the value injected in the control scheme has just to be positive [23].

#### 8.1.5 Proximetry-based control with respect to a cylinder

**Participants:** François Chaumette.

This study was done in the scope of the BPI Lichie project (see 10.4.7) as part of John Thomas's PhD, which was defended last year. Its goal was to design sensor-based control strategies based on proximetry data for positioning a robot inside or outside of a cylinder [58]

#### 8.1.6 Visual Exploration of an Indoor Environment

**Participants:** Eric Marchand, François Chaumette.

This study was done in collaboration with the Creative company in Rennes (see Section 8.1.6). It was devoted to the exploration of indoor environments by a mobile robot for a complete and accurate reconstruction of the environment through Thibault Noël's PhD [75].

### 8.1.7 Active vision for 3D object reconstruction

**Participant:** François Chaumette.

This study takes place in the context of the BIFROST project (see Section 10.1.2). Its goal was to design an active vision system based on visual servoing for enabling the complete reconstruction of an object observed by an RGB-D camera [35].

### 8.1.8 Shape servoing of soft objects using Finite Element Model

**Participants:** Mandela Ouafo Fonkoua, Alexandre Krupa, François Chaumette.

This study takes also place in the context of the BIFROST project (see Section 10.1.2). We proposed a fast visual servoing approach using a RGB-D camera that relies on a coarse Finite Element Model (FEM) to autonomously guide a volumetric soft object towards a target shape represented by its projection in a reduced latent space. This latent space is defined by a mapping which can be obtained through various techniques, including learning-based methods (e.g., PCA or auto-encoders) or non-learning approaches (Laplacian spectral descriptors) [71]. This framework considers the dynamic behavior of the object deformation without assuming that the object is in static equilibrium during the manipulation. We have successfully formulated the analytical relationship expressing the variation of the reduced representation of the object shape to the 6 degrees of freedom motion of a robot gripper. Experimental results have demonstrated that our approach can deform the soft object to a desired shape very rapidly.

### 8.1.9 Multi-Robot Control Localization and Estimation

**Participant:** Paolo Robuffo Giordano, Claudio Pacchierotti, Esteban Restrepo, Antonio Marino.

Systems composed by multiple robots are useful in several applications where complex tasks need to be performed. Examples range from target tracking, to search and rescue operations and to load transportation. We have been very active over the last years on the topics of coordination, estimation, localization and control of multiple robots under the possible guidance of a human operator (see, e.g., Sect. 10.4.9 and Sect. 10.4.16), and we recently started to explore the use of machine learning for replicating, or replacing, more analytical control/estimation strategies (with benefits in terms of reduced computational power and communication load).

During this year we have produced the the following contributions:

- in [39] we address the problem of managing the arbitrary addition and removal of agents in open multi-robot systems in an autonomous energy-aware and passive way. For this purpose we propose a passivity-preserving energy-tank-based framework for the analysis and control design of multi-mode multidimensional switched systems. A new design of hybrid energy tank is proposed, modeled as an impulsive switched system and that allows to account for the sudden (and possibly non-passive) jumps in energy of the system due to the change of dimension of the state at the switching instants. Under this framework we establish passivity of the plant-plus-tank system via an energy-based condition for the switching signal.
- In [33], we address the challenge of allocating heterogeneous resources among multiple agents using a decentralized method called Liquid-Graph-Time Clustering-IPPO. This approach integrates dynamic cluster consensus with Independent Proximal Policy Optimization, allowing agents to form local sub-teams based on resource demands. We demonstrate that this strategy improves coordination and scalability compared to standard baselines and a centralized expert solution, enabling efficient resource

reallocation even with dynamic resources. Extensive experiments demonstrate that this proposed approach achieves more stable rewards, better coordination, and robust performance in a scalable way. Additionally, the experimental campaign illustrates how dynamic clustering enables agents to reallocate resources efficiently in dynamic scenarios.

- in [32] we considered the problem of "dynamic average estimation": this is a critical problem in multi-agent systems, enabling agents to collaboratively estimate time-varying signals using only local information exchange. Traditional model-based approaches often face challenges related to convergence speed and sensitivity to network topology changes. In this work we introduced a novel learning-based solution leveraging Gated Graph Neural Networks (GGNNs) for fast convergent dynamic average estimation in a fully distributed manner. Taking advantage of the inherent structure of GGNNs, the proposed method models the estimation process as a distributed autoregressor, ensuring rapid convergence while maintaining stability. Extensive numerical experiments demonstrate that our approach significantly outperforms conventional model-based estimators in terms of both convergence speed and precision, making it a promising alternative for multi-agent applications that require dynamic average estimation.

- in [37] we considered the problem of coordinating a group of mobile robots for distributedly estimating the parameters of a diffusion model that generates a time-varying spatial field. To this end, we developed a decentralized online motion strategy aimed at minimizing a Gramian-based information metric that improves the estimation convergence. Additional constraints, among which collision avoidance, are integrated as Control Barrier Functions (CBFs) in a Quadratic Program (QP). A set of statistical comparisons against three baselines showed the improved performance of the proposed method in a range of simulated scenarios, and we also performed experiments carried out with the drones in our group to demonstrate the actual implementability of the approach and its effectiveness in generating online, collision-free, and informative motions.

## 8.2 Haptic Cueing for Robotic Applications and Virtual Reality (VR)

We contributed a chapter on Virtual Reality and Haptics to the book "Robotics Goes MOOC" [69]. This work introduces the main concepts of VR and haptic interaction. It describes the hardware and software components necessary to create immersive experiences, with a specific focus on their application in robotics.

### 8.2.1 Wearable haptics for human-centered robotics, Virtual Reality (VR), and Augmented Reality (AR)

**Participants:** Claudio Pacchierotti, Maud Marchal, Eric Marchand, Lisheng Kuang.

We have been working on wearable haptics since few years now, both from the hardware (design of interfaces) and software (rendering and interaction techniques) points of view. This line of research has continued also in this year.

In [25], we review the state of the art in wearable multi-sensory haptic devices. These devices communicate complex information by delivering multiple types of haptic stimuli simultaneously, such as vibration, skin stretch, and pressure. We discuss the engineering challenges in packaging these mechanisms and the perceptual issues related to cue masking and human acuity. We provide guidelines for designing future multi-sensory devices to enhance human-machine interaction.

In [36], we discuss recent advancements in wearable haptics, highlighting a new 18-gram haptic ring capable of delivering strong force feedback while detecting multi-directional touch inputs. This device addresses the common trade-off between portability and performance in haptic technology, offering potential applications in interacting with virtual environments.

In [46], we propose "Flexible Reality," a concept to enhance haptic feedback intensity in co-located Augmented Reality (AR) using pseudo-haptics. We conducted a user study comparing vibration intensity perception in AR versus VR. The results show that pseudo-haptics can effectively modulate perceived intensity. We also found that user agency and self-causality significantly increase interaction believability.

In [47], as part of the DORNELL project (see Sect. 10.4.6), we propose a multi-actuator haptic handle that acts as a physical representation of the user's surroundings in VR. The device displays directional haptic patterns to inform the user about obstacles. Our user studies demonstrate that this in-hand feedback enables users to avoid dynamic obstacles effectively and intuitively understand the spatial location of threats relative to their avatar.

In [77], we investigate the use of passive finger movements for calibrating Brain-Computer Interfaces (BCIs) as an alternative to motor imagery. We recorded EEG activity from participants performing both tasks. We observed significantly stronger brain activity in the $\alpha$ and $\beta$ bands during passive movements. These findings suggest passive movements could improve BCI accessibility for applications like extended reality.

In [53, 78], we study whether vibrations applied to the hands can support the sensation of walking in VR, serving as an alternative to foot vibrations. We compared hand vibrations, foot vibrations, and no vibrations during a passive walking simulation. Results indicate that hand vibrations significantly increase the walking sensation and embodiment compared to no vibrations, offering a cost-effective solution for immersive VR locomotion.

In [57], we investigate vibrotactile perception on the arm using a modular wearable sleeve. We examined localization, apparent haptic motion, and two-point discrimination across the wrist, forearm, upper arm, and shoulder. Users could identify stimulus locations with high accuracy. We found that spatial acuity decreases from the wrist to the upper arm, though the shoulder shows better discrimination than expected.

In [54], we investigate the manipulation of fingertip contact plane tilt to enhance the visuo-haptic coherency of virtual objects. We designed a compact device capable of adjusting the tilt of the contact plane to simulate diverse 3D shapes. User studies demonstrated that this approach yields significant improvements in haptic realism, enjoyment, and operability compared to conventional methods.

In [55], we present FresnelDeformable, a technique conveying the softness of virtual objects by combining pseudo-stiffness with dynamic fingertip plane tilt manipulation. The method uses a custom device that tilts the fingertip contact surface according to the applied force to align tactile feedback with visual deformation. Results from a user study indicated that tilt manipulation significantly increases the coherence between visual and tactile cues and expands the range of perceived softness in virtual environments.

### 8.2.2 Encounter-Type Haptic Devices

**Participants:** Claudio Pacchierotti, Lisheng Kuang, Elodie Bouzbib.

Encounter-Type Haptic Displays (ETHDs) provide haptic feedback by positioning a tangible surface for the user to encounter. This allows users to freely elicit haptic feedback with a surface during a virtual simulation. ETHDs differ from most of current haptic devices which rely on an actuator always in contact with the user.

In [64], we analyze an origami-inspired wearable haptic device designed for cutaneous interaction with the palm. The device uses a structured mechanism to render edges, tips, and surfaces by adjusting force and velocity. We evaluate the device's reachable configurations and trajectory execution through inverse kinematics analysis, contributing to the design of adaptable wearable haptic systems.

## 8.3 Shared Control Architectures

### 8.3.1 Shared Control for Remote Manipulation

**Participants:** Paolo Robuffo Giordano, Claudio Pacchierotti, Marco Ferro, Leon Raphalen, Paul Mefflet.

As teleoperation systems become more sophisticated and flexible, the environments and applications where they can be employed become less structured and predictable. This desirable evolution toward more challenging robotic tasks requires an increasing degree of training, skills, and concentration from the human operator. In this respect, shared control algorithms have been investigated as one of the main tools to design

complex but intuitive robotic teleoperation systems, helping operators in carrying out several increasingly difficult robotic applications such as assisted vehicle navigation, surgical robotics, brain-computer interface manipulation, rehabilitation. Indeed, this approach makes it possible to share the available degrees of freedom of the robotic system between the operator and an autonomous controller.

Along this line of research, in the context of the Horizon Europe Rego project (Sect. 10.3.1), we are starting to investigate how to employ shared control strategies for allowing a human operator to control a group of micro-robots for drug delivery and micro-assembly.

In [24], we presented the experimental evaluation of a haptic shared control teleoperation framework for the locomotion of multiple microrobots, relying on a kinesthetic haptic interface and a custom electromagnetic system. Six combinations of haptic and shared control strategies are evaluated during a safe 3D navigation scenario in a cluttered environment. 18 participants are asked to steer two spherical magnetic microrobots among obstacles to reach a predefined goal, under different conditions. For each condition, participants are provided with different obstacle avoidance and navigation guidance cues. Results show that providing assistance in avoiding obstacles guarantees safer performance, regardless if the assistance is autonomous or delivered through a haptic repulsive force.

In [52], we introduce a “Stiffness Regulation Co-pilot" to assist operators in bilateral teleimpedance control. This virtual agent infers optimal stiffness actions based on task performance and communicates them to the operator via feedback. A preliminary study suggests that cutaneous feedback, possibly combined with other modalities, improves task performance and reduces the cognitive load required to regulate stiffness manually.

In [66], we present a haptic shared control system for teleoperating a pair of magnetic microrobots. We formulate a Quadratic Programming approach with Control Lyapunov and Barrier Functions to ensure safe navigation. We combine this with a shared control architecture that provides visuo-haptic cues. The system improves navigation accuracy and stability compared to unassisted teleoperation.

In [56], we address the problem of occlusions in vision-constrained teleoperation. We propose an occlusion-safe shared control framework using High-Order Control Barrier Functions to prevent robots from entering unobserved regions. The system provides haptic feedback to signal proximity to occlusion zones, helping the operator maintain visibility and control safety.

### 8.3.2 Shared Control of a Wheelchair for Navigation Assistance

**Participants:** Louise Devigne, François Pasteau, Emilie Leblong, Marie Babel.

Power wheelchairs allow people with motor disabilities to have more mobility and independence. In order to improve the access to mobility for people with disabilities, we carefully designed a semi-autonomous assistive wheelchair system which progressively corrects the trajectory as the user manually drives the wheelchair and smoothly avoids obstacles. During the past 5 years, we successfully conducted several clinical trials with more than 300 users [17].

The Cirris laboratory at Univeristy of Laval (Canada) has acquired and set up our collision avoidance wheelchair kit composed of 48 sensors and a control board running the shared control algorithm. With the help of the Fondation Saint Hélier (Emilie Leblong), we designed an experimental protocol to conduct international multicentric clinical trials and find new use cases for this solution inside the rehabilitation process.

A cooperation with Clinatec / CEA Leti led us to defined assist-as-needed sensor-based shared control (SC) methods relying on the blending of BCI and depth-sensor-based control. The proposed assistance targets the BCI-teleoperation of effectors for tasks that answer mobility and manipulation needs in a at-home context. We demonstrated the ability of the proposed method to provide effective assistance for wheelchair mobility and reach-and-grasp tasks through a clinical trial with a quadriplegic patient implanted with a wireless 64-channel ElectroCorticoGram recording implant named WIMAGINE. The time to perform the tasks and the number of changes of mental tasks were reduced. Unwanted actions, such as wheelchair collisions with the environment, and gripper opening that could result in the fall of the object were avoided [19].

### 8.3.3 Integrating social interaction in a VR power wheelchair driving simulator

**Participants:** Emilie Leblong, Fabien Grzeskowiak, Sebastien Thomas, François Pasteau, Anne-Hélène Olivier, Marie Babel.

Navigating in the city while driving a powered wheelchair, in a complex and dynamic environment made of various interactions with other humans, can be challenging for a person with disabilities. Learning how to drive a powered wheelchair remains then a major issue. Immersive environments provide solutions to learn and transfer skills to real life. This opens up new areas of application, such as rehabilitation, where people with neurological disabilities can learn to drive a power wheelchair through immersive simulators. In this context, we collaborated with clinicians to design a Virtual Reality based power wheelchair simulator. We received in 2025 an award for the best research demo (honorable mention). This multisensory power wheelchair simulator has been duplicated and set up at the Cirris Laboratory at University of Laval (Canada) to develop new usage scenarios and perform multicentric clinical studies (SocNav project 10.1.1). To promote the transfer of skills from virtual to real, the use of such a platform requires the deployment of environmentally friendly interactive populated virtual environments. However, these are currently empty of any pedestrians, even though the question of social interaction in the framework of an inclusive urban mobility is fundamental. Hence, to expose these users to daily-life study interaction situations, it is important to ensure realistic interactions with the virtual humans that populate the simulated environment. We then investigate the regulation of interpersonal distance (i.e., proxemics) between a pedestrian and a PWC user in real and virtual situations, and proposed a model to regulate the virtual agent behavior while sharing the same virtual environment. We conducted clinical trials (March to June 2025) to evaluate the performances of our system. Results indicated high potential for learning and safety, with users feeling secure and better understanding urban risks. Professionals saw it as a tool for progressive training and detailed observation. Further studies are required to validate its clinical efficacy and integration into care pathways.

### 8.3.4 Upper-limb exoskeleton for reach-to-grasp assistance for power wheelchair users

**Participants:** Marie Babel, Maxime Manzano, Mael Gallois, Sylvain Guégan, Elise Larribeau, Charles Pontonnier.

Wearable Upper-Limb (UL) assistive robots are designed to increase autonomy and social participation for people with UL impairments as they assist tasks involved in Activities of Daily Living (ADLs). When an active device is coupled with a power wheelchair, it is usually controlled through push-buttons located near the wheelchair joystick, thus preventing bimanual tasks and requiring a large mental load to perform complex UL trajectories. Therefore, there is a need for strategies to detect user intent and get rid of manual control, allowing a distinctive, intuitive control of devices with multiple active degrees of freedom.

Assistive devices are then to be designed with the objective of use in daily-life as well as broad adoption by end users. In this context, it is necessary to tackle usability challenges by properly detecting and acting in accordance to user intents while minimizing the device installation complexity as well.

We designed an exoskeleton prototype with a control interface leveraging human–exoskeleton interaction forces relying on intent detection methods. We then developed a shared control strategy exploiting user force impulses to mitigate physical effort required to use the exoskeleton through a variable admittance controller with adjustable parameters [60], allowing to avoid instabilities or overly conservative settings that compromises user experience. This work is supported by models of users' force generation capabilities to personalize the assistance [61, 51, 26]. Indeed, exoskeletons are challenging to use because of the multiple degrees of freedom one needs to control, in addition to their exposure to misalignments which cause discomfort due to kinematic incompatibilities with the human upper-limb. We then explored the possibility to assess joint torque capacities of patients presenting post-stroke sequels or multiple sclerosis impairment to use it as guidance in a shared control scheme [67].

## 8.4 Aerial Physical Interaction

### 8.4.1 Controlled Shaking of Trees With an Aerial Manipulator

**Participants:** Marco Tognon.

Aerial shaking of flexible structures, and in particular trees, has recently emerged as a promising application of aerial manipulators for agriculture and environmental monitoring. By inducing controlled vibrations, UAVs can enable tasks such as fruit detachment or structural assessment while avoiding heavy, ground-based machinery. The main challenge lies in understanding and exploiting the coupled dynamics between the aerial platform and the flexible structure to achieve effective vibration generation in a controlled and robust manner.

In [29], the authors take a first step in this direction by proposing a self-excited oscillation strategy for shaking flexible systems with an aerial manipulator. The method exploits the natural dynamics of the coupled UAV–tree system to automatically excite vibrations at the structure's resonant frequency, without requiring prior knowledge of the tree parameters. A simplified one-degree-of-freedom model, derived using the Rayleigh–Ritz method, is used to analyze the interaction dynamics and predict vibration characteristics. Indoor experiments validate the approach, showing accurate prediction of oscillation frequency and amplitude, and demonstrating the feasibility of autonomous vibration-based interaction with flexible structures.

Building on this modeling foundation, the more recent work [28] extends the problem formulation by explicitly exploiting the full actuation capabilities of aerial manipulators. Instead of limiting interaction to translational push–pull motions, the paper introduces two complementary shaking strategies: a translation strategy based on force-induced linear motions, and a rotation strategy based on torque-induced rotational motions. By integrating both strategies into a Rayleigh–Ritz model of the tree, the closed-loop dynamics of the coupled system are derived and analyzed. This analysis addresses a previously unexplored question: which interaction strategy is more effective for a given contact point on the tree. The results show that the optimal choice depends solely on the aerial platform's physical properties, such as mass and inertia, rather than on the tree itself. Indoor experiments with a fully actuated platform and a hand-made bamboo tree validate the theoretical findings.

Together, these two works establish a coherent research direction on aerial shaking of flexible structures: from exploiting self-excited oscillations to induce vibrations without prior knowledge, to systematically comparing force- and torque-based interaction strategies through unified modeling and experimental validation.

### 8.4.2 Design and Control of Aerial Manipulators for Physical Interaction Tasks

**Participants:** Marco Tognon, Paolo Robuffo Giordano, Lorenzo Balandi, Phillip Maximilian Mehl, Lluis Prior, Giulio Franchi, Igor Angelini, Alessandro Borgherini, Emanuele Bua Odetti, Luigi Graziosi.

The design and control of novel aerial manipulators aim to improve precision, stability, and efficiency in mobile robotic applications, particularly for aerial manipulation tasks. Aerial manipulators often face challenges due to reaction forces and torques induced by motion, impacting performance and control complexity.

The work in [42] presents a design methodology for the high-level analysis of inherently force-balanced robotic manipulators and applies it to three closed-chain, two-degree-of-freedom planar concepts based on four-bar and five-bar linkages. The manipulators are modeled at an abstract component level, explicitly accounting for link mass distribution, counter-masses, and attachment constraints.

An optimization-based approach is used to determine suitable counter-mass configurations while exploring tradeoffs between workspace, total mass, and balancing effectiveness. Multibody simulations comparing balanced and unbalanced designs along representative trajectories quantify reaction forces, moments, and joint torques. The results highlight how inherent force balancing can substantially reduce dynamic reactions, while also exposing key design tradeoffs that influence manipulator performance.

A series of works have progressively addressed the challenge of achieving accurate and robust control of aerial robots in the presence of model uncertainties, disturbances, and hardware limitations, all converging toward architectures that tightly couple high-level optimal control with robust, high-rate inner-loop strategies.

In [43], the authors investigate the combination of Nonlinear Model Predictive Control (NMPC) with a fast acceleration-based inner loop to improve trajectory tracking under disturbances and modeling errors. By studying Incremental Nonlinear Dynamic Inversion (INDI) and Time Delay Control (TDC), the paper clarifies their close relationship and proposes a TDC-based inner loop running at 1 kHz. Extensive simulations on a fully actuated hexarotor show significant performance improvements, while also highlighting fundamental limitations arising from input saturation, thereby motivating more constraint-aware inner-loop designs.

Complementing the control-side robustness, [44] focuses on improving the quality of inertial feedback by addressing mechanical vibrations affecting IMUs on multirotor aerial vehicles. Through analysis of real flight data and vibration theory, the work identifies motor–propeller units as the dominant vibration source and develops theoretical models to guide effective damping strategies. A redesigned, low-cost damping configuration significantly reduces vibration levels in both acceleration and angular velocity measurements, directly benefiting high-bandwidth control architectures that rely on accurate inertial sensing.

Building on these insights, [18] proposes a constraint-aware, optimization-based inner-loop controller inspired by TDC and formulated as a Quadratic Program (QP). Unlike classical feedback inner loops, this approach explicitly handles actuation limits and preserves stability under saturation and model mismatches. The controller uses acceleration feedback and does not require precise inertial parameters, further enhancing robustness. Experiments on a fully actuated hexarotor demonstrate that the proposed QP-based inner loop substantially improves NMPC tracking performance in aggressive scenarios where traditional inner-loop strategies fail.

Finally, [65] extends the pursuit of robustness beyond classical control by introducing a model-based reinforcement learning framework for end-to-end UAV control. To overcome the sim-to-real gap and the impracticality of unsafe real-world training, the authors encapsulate a high-fidelity simulator into a Gaussian Process model, enabling efficient policy learning with reduced computational cost. The learned policies are successfully transferred to a real quadrotor, with experimental results showing close agreement between simulation, learned models, and real flight data. This work demonstrates the feasibility of combining model-based learning and optimal control principles to achieve robust performance on real aerial platforms.

Together, these contributions outline a coherent research direction toward robust, high-performance aerial robot control, combining accurate sensing, fast and constraint-aware inner loops, optimal outer-loop control, and learning-based methods to bridge modeling gaps between simulation and reality.

### 8.4.3 Cooperative Multi-Aerial Robot Manipulation

**Participants:** Marco Tognon, Paolo Robuffo Giordano, Szymon Bielenin, Nicola De Carli, Valeria Braglia.

Cooperative transportation of cable-suspended loads with UAVs is a key problem in cooperative aerial manipulation, motivated by applications such as search and rescue, construction, and logistics in cluttered or hard-to-reach environments. By distributing the payload across multiple aerial robots, these systems can overcome the payload and actuation limits of a single UAV while enabling full-pose control of large or heavy objects. However, the strong dynamic coupling introduced by the cables and the load makes control particularly challenging, often forcing existing approaches to operate at low speeds and accelerations or to rely on centralized solutions that limit scalability.

In [41], the focus is placed on agility. The paper proposes a centralized, trajectory-based Model Predictive Control framework that explicitly accounts for the coupled quadrotor–cable–load dynamics and constraints in a whole-body kinodynamic planning problem solved online. The resulting trajectories are tracked in a receding-horizon fashion by onboard controllers that estimate and compensate for cable tension, without requiring sensors on the load. Real-world experiments show dramatic performance gains, achieving accelerations up to eight times higher than state-of-the-art methods and enabling aggressive maneuvers such as high-speed flight through narrow passages, while remaining robust to load uncertainty and wind disturbances.

Complementarily, [22] addresses the challenge of scalability in cooperative aerial manipulation. Instead of a centralized controller, the authors introduce a Distributed Nonlinear Model Predictive Control (DNMPC) architecture in which each UAV solves a local optimization problem and exchanges only a reduced set of variables with its neighbors over a peer-to-peer network. This distributed scheme preserves the benefits of NMPC while significantly reducing computational and communication burdens. The approach is validated in simulation and through real-world experiments on the Fly-Crane platform, demonstrating effective cooperative manipulation of a cable-suspended load with improved scalability and robustness.

Together, these two works advance cooperative aerial transportation by tackling complementary aspects of the same problem: one pushing the limits of agility through centralized, whole-body MPC, and the other enabling scalable deployment through distributed predictive control.

### 8.4.4 Physical Human–Aerial Robot Interaction and Shared Control

**Participants:** Marco Tognon, Marco Cognetti.

Physical interaction between humans and aerial robots represents a critical step toward deploying UAVs in collaborative and assistive tasks, where safety, intuitiveness, and robustness are paramount. Unlike ground robots, aerial platforms are inherently underactuated, dynamically unstable, and subject to strict safety constraints, making direct physical human–robot interaction particularly challenging. Recent works have begun to address these challenges by combining predictive control, compliance, and human-centered interface design to enable effective collaboration between humans and aerial robots.

In [27], the authors propose a control framework that enables an aerial robot to physically collaborate with a human in a shared transportation task. The approach is based on a nonlinear Model Predictive Control (NMPC) formulation that explicitly incorporates the coupled dynamics of the human, the aerial robot, and the manipulated object. To ensure safe interaction, the NMPC is complemented with a compliant control layer and a motion preference strategy that favors forward motion, aligning the robot's behavior with the human's natural movement. Indoor experiments with a fully actuated hexarotor demonstrate stable and effective human–robot cooperation, highlighting the aerial robot's ability to assist the human while improving comfort and efficiency during physical manipulation.

Complementing physical collaboration, [34] addresses the human-in-the-loop aspect of aerial manipulation through teleoperation. The paper investigates how richer feedback modalities can enhance operator awareness and task performance compared to conventional 2D visual interfaces. A human–robot interface providing immersive 3D mixed-reality visual feedback and 3D haptic feedback is developed and evaluated. Through real-world manipulation experiments and a controlled human-subjects study, the results show that both mixed-reality vision and haptic feedback significantly improve dexterity and reduce cognitive workload in teleoperated aerial manipulation tasks, while also revealing that operator experience remains a dominant factor.

Together, these works advance human–aerial robot interaction from both physical collaboration and interface design perspectives, contributing toward safer, more intuitive, and more effective shared-control paradigms for aerial robots operating in close proximity to humans.

## 8.5 Sensor design for physical interaction and shared control

### 8.5.1 Capacitive and pressure sensor through one-shot 3D printing

**Participants:** Marie Babel, José Eduardo Aguilar-Segovia, Sylvain Lefebvre.

Measuring interaction forces between robots and humans is a major challenge in physical human-robot interactions. Nowadays, conventional force/torque sensors suffer from bulkiness, high cost, and stiffness, which limit their use in soft robotics.

Additive manufacturing (AM) enables the fabrication of multi-material 3D structures with sensing capabilities by integrating conductive materials alongside flexible or rigid parts. Recent research focuses on

embedding sensing elements into 3D structures using complex algorithms or intricate design approaches to create interactive or monitoring devices. A challenge in manufacturing bespoke devices is performing user-specific ergonomic and anthropomorphic adjustments to multi-material 3D models. We proposed a novel computational fabrication method that operates directly within the layered fabrication space. The method transforms simple sensing structures into complex designs through layer transformations – rotation, translation, and scaling – while addressing constraints from design for additive manufacturing (DfAM). These constraints include ensuring electrical conductivity in conductive parts and preventing unintended electrical connections during fabrication. A custom-fit handle with embedded capacitive sensors is manufactured as a one-shot multi-material print and forces applied to the embedded sensors by the user's fingertips and palm are measured. A user study validates that our method successfully adjusts the handle to a set of users, ensuring ergonomic comfort. Our results demonstrate the potential of our method for fabricating personalized sensing devices, enabling designers to explore diverse structures by transforming a single template design [15][16].

# 9 Bilateral contracts and grants with industry

## 9.1 Bilateral contracts with industry

### 9.1.1 IRT JV Happy2

**Participant:** Romain Lagneau, Fabien Spindler, François Chaumette.

No Inria Rennes 13521, duration: 72 months.

F. Chaumette is in secondment (at 20%) at IRT Jules Verne in Nantes since 2018. This year, he was involved the Happy 2 project with Airbus & Naval Group to give his expertise in visual servoing. Based on ViSP, a model-based tracking algorithm was transfered and integrated in a demonstrator at IRT to assemble two airplane parts.

### 9.1.2 Trasys/NRB

**Participants:** Romain Lagneau, Fabien Spindler, François Chaumette.

No Inria Rennes 2023000390, duration: 19 months.

This project started in May 2023. It was in collaboration with the Trasys/NRB company in Belgium. Its goal was to develop an embedded vision-based localization system with respect to satellite parts.

### 9.1.3 Sopra-Steria

**Participants:** François Pasteau, Marie Babel, Sylvain Guegan, Fabien Grzeskowiak.

INSA Rennes, duration: 72 months.

This project funded by Sopra Steria aimed to design new assistive robotics and to support clinical trials activities.

## 9.2 Bilateral grants with industry

### 9.2.1 IRT JV Perform

**Participant:** François Chaumette.

No Inria Rennes 16107, duration: 42 months.

This project funded by IRT Jules Verne started in November 2021. It was achieved in cooperation with Stéphane Caro from LS2N in Nantes to support Sophie Rousseau's PhD at IRT Jules Verne about sensor-based control and vibration reduction of cable-driven parallel robots. Sophie Rousseau defended her PhD entitled "Sensor-Based Control and Vibration Reduction of Cable-Driven Parallel Robots" in May 2025 at Ecole Centrale de Nantes.

#### 9.2.2 Commande partagée centrée sur l'humain pour la télémanipulation robotique à différentes échelles

**Participant:** Claudio Pacchierotti, Paolo Robuffo Giordano.

Convention cifre 2023/1119. Duration: 36 months.

This project is funded by Haption, Laval, and funds the PhD of Paul Mefflet on shared control for tele-manipulation

# 10 Partnerships and cooperations

## 10.1 International initiatives

### 10.1.1 Inria associate team not involved in an IIL or an international program

**SocNav**

**Participants:** Anne-Hélène Olivier, Julien Pettré, Marie Babel, François Pasteau, Louise Devigne, Fabien Grzeskowiak, Sebastien Thomas.

**Title:** Studying complex social navigation with an innovative, co-developed immersive platform

**Duration:** January 2024 - December 2026

**Coordinator:** Anne-Hélène Olivier (Virtus team) O

**Partners:** Université Laval Quebec (Canada) - Fondation Saint Hélier

**Inria contact:** Anne-Hélène Olivier

**Summary:** The objective is to the study of locomotor navigation in more socially complex environments representative of daily life, while considering the confounding effects of one's physical limitations for different modes of transport (i.e., biped vs wheeled). We aim to not only improve our understanding of the trade-offs in anticipatory and reactive control for locomotor navigation of complex social environments, but also significantly contribute to improving assessment and training tools, and the development of intelligent mobility aids (smart wheelchairs).

#### 10.1.2 Participation in other International Programs

**BIFROST**

**Participants:** Mandela Ouafo Fonkoua, Alexandre Krupa, François Chaumette, Fabien Spindler.

**Title:** A Visual-Tactile Perception and Control Framework for Advanced Manipulation of 3D Compliant Objects

**Duration:** July 2021 - December 2025

**Coordinator:** Sintef Ocean (Norway)

**Partners:**

- Sintef Ocean (Norway)
- MIT (USA)

**Inria contact:** Alexandre Krupa

**Summary:** This project is granted by The Research Council of Norway. Its main objective is to develop a visual-tactile perception and Control framework for advanced manipulation of 3D compliant objects. The Rainbow group is in charge of elaborating novel visual servoing approaches for dexterous manipulation of soft objects.

### 10.2 International research visitors

#### 10.2.1 Visits of international scientists

**Other international visits to the team**

**Ekrem Misimi**

**Status:** researcher

**Institution of origin:** Sintef Ocean

**Country:** Norway

**Dates:** February 17 to July 18, 2025

**Context of the visit:** partner in the BIFROST project

**Mobility program/type of mobility:** research stay

### 10.3 European initiatives

#### 10.3.1 Horizon Europe

REGO project on cordis.europa.eu

**Title:** Cognitive robotic tools for human-centered small-scale multi-robot operations

**Duration:** From October 1, 2022 to September 30, 2026

**Partners:**

- INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET AUTOMATIQUE (INRIA), France
- CENTRE HOSPITALIER UNIVERSITAIRE DE RENNES (CHU RENNES), France
- UNIVERSITEIT TWENTE (UNIVERSITEIT TWENTE), Netherlands
- SCUOLA SUPERIORE DI STUDI UNIVERSITARI E DI PERFEZIONAMENTO S ANNA (SSSA), Italy
- FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA (IIT), Italy
- HAPTION SA (HAPTION), France
- CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS), France
- HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF EV (HZDR), Germany

**Inria contact:** Claudio Pacchierotti

**Coordinator:** Claudio Pacchierotti

**Summary:** Robots are still often regarded as large machines with links, gears, and electric motors, autonomously interacting with the surrounding environment. Despite the great research efforts in robotics and human-robot interaction (HRI), the way we design, use, and control robots has not fundamentally changed in the past 20 years. We see in small-scale wireless multi-robot systems and cognitive HRI a revolutionary answer to nowadays robots limitations. Instead of large, tethered machines, that are difficult for the human user to control, REGO proposes an innovative set of AI-powered, modular, microsized swarms of robots. They are wirelessly steered by electromagnetic fields as well as able to react to other external stimuli, and then naturally controlled by humans through intuitive dexterous interfaces and interaction techniques. Taking advantage of AI multi-robot control strategies, these robots can team up and collaborate to fulfill complex tasks in a robust and unprecedented flexible way. By exploiting multisensory interaction techniques and cognitive shared control, the operator will achieve an unparalleled level of seamless interaction and continuous collaboration with the robotic team. According to the application at hand, the robotic team will feature different task-specific characteristics (e.g., biocompatibility for medical procedures, biodenitrification for cleaning water, ability to carry drugs to fight infections) and be dispatched through various delivery systems, including a stimuli-responsive milli-scale wireless robotic carrier developed within the project. To achieve this revolution, REGO will develop magnetic multi-robot motion control systems, autonomous swarm control techniques for micro-sized robots, human-robot haptic-centered interfaces, and cognitive shared-control techniques. REGO enables the next generation of AI-powered interactive small-size multi-robots systems, with increased capabilities to work with each other and their human operators.

**euROBIN** euROBIN project on cordis.europa.eu

**Title:** European ROBotics and AI Network

**Duration:** From July 1, 2022 to June 30, 2026

**Partners:**

- INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET AUTOMATIQUE (INRIA), France
- C.R.E.A.T.E. CONSORZIO DI RICERCA PER L'ENERGIA L AUTOMAZIONE E LE TECNOLOGIE DELL'ELETTROMAGNETISMO (C.R.E.A.T.E.), Italy
- PAL ROBOTICS SLU (PAL ROBOTICS), Spain
- KUNGLIGA TEKNISKA HOEGSKOLAN (KTH), Sweden
- INSTITUT JOZEF STEFAN (JSI), Slovenia
- FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV (Fraunhofer), Germany

- FUNDACION TECNALIA RESEARCH & INNOVATION (TECNALIA), Spain
- TECHNISCHE UNIVERSITAET MUENCHEN (TUM), Germany
- DHL EXPRESS SPAIN SL, Spain
- COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (CEA), France
- INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM (IMEC), Belgium
- TEKNOLOGISK INSTITUT (DANISH TECHNOLOGICAL INSTITUTE), Denmark
- UNIVERSITEIT TWENTE (UNIVERSITEIT TWENTE), Netherlands
- ASEA BROWN BOVERI SA (ABB), Spain
- ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE (EPFL), Switzerland
- STV MACHINERY AS, Slovakia
- DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV (DLR), Germany
- IST-ID ASSOCIACAO DO INSTITUTO SUPERIOR TECNICO PARA A INVESTIGACAO E O DESENVOLVIMENTO (IST ID), Portugal
- UNIVERSITA DI PISA (UNIPI), Italy
- FUNDINGBOX ACCELERATOR SP ZOO (FBA), Poland
- UNIVERSITAET BREMEN (UBREMEN), Germany
- FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA (IIT), Italy
- KARLSRUHER INSTITUT FUER TECHNOLOGIE (KIT), Germany
- EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH (ETH Zürich), Switzerland
- CESKE VYSOKE UCENI TECHNICKE V PRAZE (CVUT), Czechia
- OREBRO UNIVERSITY (ORU), Sweden
- CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS), France
- VOLKSWAGEN AKTIENGESELLSCHAFT (VW AG), Germany
- SIEMENS AKTIENGESELLSCHAFT, Germany
- SORBONNE UNIVERSITE, France
- UNIVERSIDAD DE SEVILLA, Spain

**Inria contact:** Serena Ivaldi

**Coordinator:**

**Summary:** As robots are entering unstructured environments with a large variety of tasks, they will need to quickly acquire new abilities to solve them. Humans do so very effectively through a variety of methods of knowledge transfer – demonstration, verbal explanation, writing, the Internet. In robotics, enabling the transfer of skills and software between robots, tasks, research groups, and application domains will be a game changer for scaling up the robot abilities.

euROBIN therefore proposes a threefold strategy: First, leading experts from the European robotics and AI research community will tackle the questions of transferability in four main scientific areas: 1) boosting physical interaction capabilities, to increase safety and reliability, as well as energy efficiency 2) using machine learning to acquire new behaviors and knowledge about the environment and the robot and to adapt to novel situations 3) enabling robots to represent, exchange, query, and reason about abstract knowledge 4) ensuring a human-centric design paradigm, that takes the needs and expectations of humans into account, making AI-enabled robots accessible, usable and trustworthy.

Second, the relevance of the scientific outcomes will be demonstrated in three application domains that promise to have substantial impact on industry, innovation, and civil society in Europe. 1) robotic manufacturing for a circular economy 2) personal robots for enhanced quality of life 3) outdoor robots for sustainable communities. Advances are made measurable by collaborative competitions.

Finally, euROBIN will create a sustainable network of excellence to foster exchange and inclusion. Software, data and knowledge will be exchanged over the EuroCore repository, designed to become a central platform for robotics in Europe.

The vision of euROBIN is a European ecosystem of robots that share their data and knowledge and exploit their diversity to jointly learn to perform the endless variety of tasks in human environments.

### 10.3.2 H2020 projects

**GuestXR** GuestXR project on cordis.europa.eu

**Title:** GuestXR: A Machine Learning Agent for Social Harmony in eXtended Reality

**Duration:** From January 1, 2022 to December 31, 2025

**Partners:**

- INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET AUTOMATIQUE (INRIA), France
- UNIWERSYTET WARSZAWSKI (UNIWARSAW), Poland
- VIRTUAL BODYWORKS SL (Virtual Bodyworks S.L.), Spain
- UNIVERSITEIT MAASTRICHT, Netherlands
- UNIVERSITAT DE BARCELONA (UB), Spain
- FUNDACIO EURECAT (EURECAT), Spain
- REICHMAN UNIVERSITY (REICHMAN UNIVERSITY), Israel
- CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS), France
- G.TEC MEDICAL ENGINEERING GMBH (G.TEC MEDICAL ENGINEERING GMBH), Austria

**Inria contact:** Anatole LECUYER

**Coordinator:** Mel Slater

**Summary:** Immersive online social spaces will soon become ubiquitous. However, there is also a warning that we need to heed from social media.

User content is the ‘lifeblood of social media’. However, it often stimulates antisocial interaction and abuse, ultimately posing a danger to vulnerable adults, teenagers, and children.

In the VR space this is backed up by the experience of current virtual shared spaces. While they have many positive aspects, they have also become a space full of abuse.

Our vision is to develop GuestXR, a socially interactive multisensory platform system that uses eXtended Reality (virtual and augmented reality) as the medium to bring people together for immersive, synchronous face-to-face interaction with positive social outcomes.

The critical innovation is the intervention of artificial agents that learn over time to help the virtual social gathering realise its aims. This is an agent that we refer to as “The Guest” that exploits Machine Learning to learn how to facilitate the meeting towards specific outcomes.

Underpinning this is neuroscience and social psychology research on group behaviour, which will deliver rules to Agent Based Models (ABM).

The combination of AI with immersive systems (including haptics and immersive audio), virtual and augmented reality will be a hugely challenging research task, given the vagaries of social meetings and individual behaviour. Several proof of concept applications will be developed during the project, including a conflict resolution application in collaboration with the UN. A strong User Group made up of a diverse range of stakeholders from industry, academia, government and broader society will provide continuous feedback. An Open Call will be held to bring in artistic support and additional use cases from wider society. Significant work is dedicated to ethics “by design”, to identify problems and look eventually towards an appropriate regulatory framework for such socially interactive systems.

## 10.4 National initiatives

### 10.4.1 Equipex+ Tirrex

**Participants:** Fabien Spindler, François Chaumette, Alexandre Krupa.

no Inria Rennes OIP 03-22-01, duration: 8 years.

This large national project devoted to open robotics platforms started in December 2021. Rainbow is responsible of the manipulation axis for which a new TRIAGo platform (Multi-arm Multi-sensor Mobile Manipulator) was designed by PAL Robotics and installed in our lab in April 2025.

### 10.4.2 PEPR O2R

**Participants:** Maud Marchal, Marie Babel.

duration: 8 years.

The Organic Robotics program proposes to implement a responsible and socially acceptable robotics. This PEPR will intensify the multidisciplinary approach of the community (digital, life sciences, engineering, environmental, social sciences) in a strategy that radically differs from the current vision of robotics and its limitations. The Organic Robotics program therefore aims to initiate a shift in robotics allowing to create a new generation of robots capable of interacting and working in symbiosis with humans. We propose to consider the robot, no longer as an automation machine, but as a tool, in line with those that humans have created, used and optimized in order to explore and act on their environment. More efficient, modular, reconfigurable and adaptive, organic robots will become an extension of humans. The PEPR O2R started in September 2023. M. Marchal has contributed to the proposal writing and is a member of the executive committee.

Marie Babel participates to the ASSISTMOV project that aims to design innovative robotic assistance through upper-limb exoskeleton. She is a member of the steering committee of ASSISTMOV project.

Maud Marchal participates to the REINVENT and AS4 projects.

### 10.4.3 PEPR O2R - AS2 structuring action

**Participants:** Alexandre Krupa, Fabien Spindler.

**Title:** PEPR O2R - AS2 structuring action “Robot motion with physical interactions and social adaptation”

**Duration:** January 2024 - December 2031

**Coordinator:** LASS-CNRS (Toulouse)

**Partners:**

- Gepeto (LAAS), IDH (LIRMM), Willow (Inria), Auctus (Inria), Rainbow (Inria), Robioss (PPRIME), CERCA (CNRS), ICNA (ONERA), Habiter le Monde (UPJV)

**Summary:** In the context of the national PEPR O2R robotic exploration program, Alexandre Krupa is involved in the AS2 structuring action. This structuring action aims to rethink the problem of motion generation in robotic systems, taking a global approach and redefining research objectives in conjunction with the Human and Social Sciences. Within this AS2 action, the Rainbow group is involved on the development of multi-sensor control strategies for the control of physically interacting

robotic systems. Since January 2024, Alexandre Krupa has been co-supervising a PhD student based at LIRMM with Philippe Fraisse (LIRMM) and Andrea Cherubini (LS2N), whose thesis focuses on the robotic manipulation of deformable objects using the LIRMM dual-arm robot BAZAR.

#### 10.4.4 PEPR eNSEMBLE

**Participant:** Maud Marchal.

duration: 8 years.

The purpose of eNSEMBLE (Future of Digital Collaboration) is to fundamentally redefine digital tools for collaboration. To address this challenge, a paradigm shift in the design of collaborative systems is needed, comparable to the one that saw the advent of personal computing. To collaborate in a fluid and natural way while taking advantage of computer capabilities, collaboration and sharing must become native features of computer systems, in the same way that files or applications are today. To achieve this goal, we need to invent mixed (i.e. physical and digital) collaboration spaces that do not simply replicate the physical world in virtual environments, enabling co-located and/or geographically distributed teams to work together smoothly and efficiently. The PEPR eNSEMBLE started in September 2023. M. Marchal has contributed to the writing of the proposal and is one of PC1 project leaders.

#### 10.4.5 ANR Marsurg

**Participants:** Eric Marchand, François Chaumette, Fabien Spindler.

no Inria 16162, duration: 48 months.

This project started in September 2021. It involves a consortium managed by ISIR (Paris) with Pixee Medical and Rainbow group. It aims at researching markerless augmented reality solution for orthopedic surgery

#### 10.4.6 Inria Challenge DORNELL

**Participants:** Marie Babel, Claudio Pacchierotti, Maud Marchal, François Pasteau, Sylvain Guegan, Louise Devigne, Marco Aggravi, Inès Lacôte, Pierre-Antoine Cabaret, Lisheng Kuang.

**Title:** DORNELL: A multimodal, shapeable haptic handle for mobility assistance of people with disabilities

**Duration:** November 2020 - December 2024

**Coordinators:** Marie Babel, Claudio Pacchierotti

**Partners:**

- Potioc Inria team
- MFX Inria team
- LGCGM (Rennes)

- Centre de rééducation Pôle Saint Hélier (Rennes)
- ISIR (Paris)
- Institut des jeunes aveugles (Yzeure)

**Inria contact:** Marie Babel, Claudio Pacchierotti

**Summary:** While technology helps people to compensate for a broad set of mobility impairments, visual perception and/or cognitive deficiencies still significantly affect their ability to move safely and easily. We propose an innovative multisensory, multimodal, smart haptic handle that can be easily plugged onto a wide range of mobility aids, including white canes, precanes, walkers, and power wheelchairs. Specifically fabricated to fit the needs of a person, it provides a wide set of ungrounded tactile sensations (e.g., pressure, skin stretch, vibrations) in a portable and plug-and-play format – bringing haptics in assistive technologies all at once. The project will address important scientific and technological challenges, including the study of multisensory perception, the use of new materials for multimodal haptic feedback, and the development of a haptic rendering API to adapt the feedback to different assistive scenarios and user's wishes. We will co-design DORNELL with users and therapists, driving our development by their expectations and needs.

### 10.4.7 BPI Lichie

**Participants:** François Chaumette.

no Inria 14876, duration: 72 months.

This project started in March 2020. It involves a consortium managed by Airbus Defense and Space (Toulouse) with many companies, Onera and Inria. It aims at designing a new constellation of satellites with on-board imaging facilities. Robotics for the assembly of the satellites is also studied. François Chaumette is the Inria scientific coordinator of this project who funded 9 PhD and 9 post-doc for the Rainbow, Sairpico, and Sirocco groups in Rennes, Auctus in Bordeaux and Ayana in Sophia-Antipolis.

### 10.4.8 ANR CAMP

**Participants:** Paolo Robuffo Giordano, Fabien Spindler, Ali Srour, Tommaso Belvedere, Salvatore Marcellini.

**Title:** Intrinsically-Robust and Control-Aware Motion Planning for Robots in Real-World Conditions

**Duration:** October 2020 - June 2026

**Coordinator:** P. Robuffo Giordano

**Partners:**

- LAAS (Toulouse)
- Univ. Twente (Netherlands)

**Inria contact:** P. Robuffo Giordano

**Summary:** An effective way of dealing with the complexity of robots operating in real (uncertain) environments is the paradigm of "feedforward/feedback" or "planning/control": in a first step a suitable nominal trajectory (feedforward) for the robot states/controls is planned exploiting the available information (e.g., a model of the robot and of the environment). While there has been an effort in proposing "robust planners" or more "global controllers" (e.g., Model Predictive Control (MPC)), a truly unified approach that fully exploits the techniques of the motion planning and control/estimation communities is still missing and the existing state-of-the-art has several important limitations, namely (1) lack of generality, (2) lack of computational efficiency, and (3) poor robustness. In this respect, the ambition of CAMP is to (1) develop a general and unified "intrinsically-robust and control-aware motion planning framework" able to address all the above-mentioned issues, and to (2) demonstrate the applicability of this new framework to real robots in real-world challenging tasks. In particular we envisage two robotics demonstrators for showing at best the effectiveness and generality of our methodology: (1) an indoor pick- and-place/assembly task involving a 7-dof torque-controlled arm for a first validation in "controlled conditions" and (2) an outdoor cooperative mobile manipulation task involving an aerial manipulator (a quadrotor UAV equipped with an onboard arm) and a skid-steering mobile robot with an onboard arm for a final validation in much less favorable experimental conditions (see Sect. 8.1.1)

### 10.4.9 ANR MULTISHARED

**Participants:** Paolo Robuffo Giordano, Claudio Pacchierotti, Vincent Drevelle, Nicola De Carli, Maxime Bernard, Esteban Restrepo.

**Title:** Shared-Control Algorithms for Human/Multi-Robot Cooperation

**Duration:** September 2020 - October 2025

**Coordinator:** P. Robuffo Giordano

**Inria contact:** P. Robuffo Giordano

**Summary:** The goal of the Chaire AI MULTISHARED is to significantly advance the state-of-the-art in multi-robot autonomy and human-multi-robot interaction for allowing a human operator to intuitively control the coordinated motion of a multi-UAV group navigating in remote environments, with a strong emphasis on the division of roles between multi-robot autonomy (in controlling its motion/configuration and online decision-making) and human intervention/guidance for providing high-level commands to the group while being most aware of the group status via VR and haptics technology (see Sect. 8.1.9).

### 10.4.10 ANR MATES

**Participants:** Claudio Pacchierotti, Paolo Robuffo Giordano, Marco Tognon, Valeria Braglia, Francesco Russo, Esteban Restrepo.

**Title:** Multi-drone-human collaboration teams for high-risk assembling and handling tasks

**Duration:** March 2025 - February 2029

**Coordinator:** Claudio Pacchierotti

**Partners:**

- LAAS (Toulouse)

**Inria contact:** Claudio Pacchierotti

**Summary:** Despite the great recent progress in automation, computer science, and machine learning, robots still have many limitations (e.g., limited cognitive/manipulation capabilities) and they cannot fulfill alone the wide range of tasks that humans can perform. Achieving an effective collaboration between robots and humans could clearly enlarge the nature of tasks that can be addressed together. The aim of this project is to propose a multi-robot system that allows humans to remotely perform tasks at high locations eliminating any potential risk for the operator. Since ground robots cannot be employed in such conditions, we propose a human-multi-drone team in which a human user remotely controls a group of drones in completing a complex task that requires advanced coordination and manipulation capabilities. To achieve such an ambitious goal, it is essential that drones acquire manipulation capabilities as well as improve their interaction and coordination with humans. Moreover, several advancements in the theory, control, and interaction of coordinated human-drone teams should be accomplished. As a representative example of a high-impact scenario, we plan to carry out a peg-in-hole task at a high location: A group of drones collaboratively transports an object, i.e., a peg, to a target location, i.e., a hole. Once it has been reached, an aerial manipulator grasps the lower part of the peg and inserts it into the hole, coordinating its motion with the one of the transport team. These actions are remotely imparted by a human operator, who controls the synergistic motion of the aerial team using a grounded haptic interface and shared-control techniques. At the same time, the operator receives information about the task, the team, and the interaction with the environment, through a combination of grounded and wearable haptic feedback. A view of the remote environment is provided to the operator through a VR headset thanks to a group of supporting drones equipped with cameras.

#### 10.4.11 ANR JCJC AirHandyBot

**Participants:** Marco Tognon, Paolo Robuffo Giordano, Lorenzo Balandi, Maximilian Mehl, Gianluca Corsini, Fabien Spindler.

**Title:** Aerial Robots for True Manipulation of Dynamic and Uncertain Environments

**Duration:** November 2023 - October 2026

**Coordinator:** Marco Tognon

**Inria contact:** Marco Tognon

**Summary:** One of the main goals of robotics is to realize autonomous systems that can help human operators in tasks that are hard and dangerous (e.g., in elevated areas). It is therefore important to conceive robots that can perform physical work executing complex tasks requiring the interaction with the environment and the manipulation of objects. In particular, having aerial robots able to interact with the environment, would open the door new applications in dangerous and hardly accessible area, like manipulation of objects, contact-based inspection, and construction. Aiming to show the feasibility of Aerial Physical Interaction (APhI), previous works focused on the design and control of aerial manipulators. However, current investigations and applications are still limited to simple interaction tasks, involving limited contact behaviors with static and rigid surfaces, moreover performed in known and structured environments. To deploy aerial manipulators in real scenarios, they must be able to perform more complex manipulation tasks in less structured situations. Because of the application, scientific interest, and possible future impact of APhI, FlyHandyBot aims to enhance APhI capabilities of highly dynamical aerial manipulators by considering: - manipulations tasks of movable and articulated objects, relying on onboard sensors only; - real scenarios characterized by disturbances and uncertainties due to system modeling errors, noisy and imprecise measurements coming from lightweight onboard sensors, imprecise actuation models due to complex aerodynamic effects, and partially unknown environments. The investigation, including fundamental theoretical results, real experiments and practical demonstrations, will focus on the design of new conception, modeling and control methods to make aerial robots much more precise, robust and safe while performing physical interaction tasks in real environments. This will allow aerial robots to be in the future valid companions of human operators.

#### 10.4.12 ANR DyNNAMo

**Participants:** Marie Babel, François Pasteau, Louise Devigne.

**Title:** Shared-Control Algorithms for Human/Multi-Robot Cooperation

**Duration:** April 2025 - October 2029

**Coordinator:** S. Le Nours

**Inria contact:** Marie Babel

**Summary:** The DyNNAMO project aims to define and validate a modeling and analysis workflow for the design and optimization of an innovative hardware-software architecture, specifically tailored to enhance detection capabilities in power wheelchairs. The proposed architecture leverages dynamic neural networks (DNNs), which autonomously adjust their computational workload in response to real-time operating conditions.

#### 10.4.13 AeX AEROTouch

**Participants:** Marco Tognon, Tommaso Belvedere, Lluis Prior, Gianluca Corsini, Fabien Spindler.

**Title:** Aerial Robots with the Sense of Touch

**Duration:** November 2023 - October 2029

**Coordinator:** Marco Tognon

**Inria contact:** Marco Tognon

**Summary:** Researchers are trying to make aerial robots perform physical work. Current methodologies show promising results, but they fail in real scenarios, mostly because of inaccurate visual perception. Inspired by nature, this project investigates how to also provide aerial robots with the sense of touch and how to use it for improving their manipulation capabilities.

#### 10.4.14 AeX RobotiCore

**Participants:** Marco Tognon, Tommaso Belvedere, Gianluca Corsini.

**Title:** Integrated Hardware Acceleration: the Brain and Heart Behind Next-Generation Robots

**Duration:** November 2025 - October 2028

**Coordinator:** Marco Tognon and Marcello Traiola (team TARAN)

**Inria contact:** Marco Tognon and Marcello Traiola (team TARAN)

**Summary:** RobotiCore proposes a methodology to accelerate robotic algorithms on a unified hardware accelerator, to improve performance and energy efficiency for small-scale robotic systems. By efficiently accelerating fundamental robotic operations, RobotiCore addresses the limitations of traditional power-hungry hardware platforms, which currently limit scalability and affordability in robotics.

#### 10.4.15 Inria AeX MusMaps

**Participants:** Marie Babel, Mael Gallois, Louise Devigne.

**Title:** Muscle Mapping for Shared-Control assistance of people with disabilities

**Duration:** 2024 - 2028

**Coordinator:** Charles Pontonnier (Combo team) and Marie Babel

**Inria contact:** Charles Pontonnier and Marie Babel

**Partner:** Fondation Saint Hélier

**Summary:** The Inria Exploratory Action MusMapS uses effort measurements (mapping of physical capacities) from disabled patients to personalize the assistance of an upper-limb exoskeleton using shared control to help these patients with their everyday movements. The coupling of a musculoskeletal model representative of the patient's physical capabilities with a shared control system for pathologies such as multiple sclerosis or the after-effects of a stroke is innovative and forms the core of the approach.

#### 10.4.16 SequoIA Chair HARMONY

**Participants:** Paolo Robuffo Giordano, Esteban Restrepo, Claudio Pacchierotti, Andrea Perna.

**Title:** Human-AI Robotic Merging for Optimal cooperatioN and efficiency

**Duration:** September 2025 - August 2029

**Coordinator:** Paolo Robuffo Giordano

**Inria contact:** Paolo Robuffo Giordano

**Summary:** Robots embody Artificial Intelligence (AI) through physical interaction with the environment, yet achieving full autonomy in unstructured settings remains challenging due to limitations in perception, decision-making, and actuation. Human–robot cooperation, and in particular shared control, offers a promising way to enhance autonomy by combining robotic precision with human cognitive capabilities. While shared control has shown success in domains such as telemanipulation, navigation, and medical robotics, current approaches rely on static role allocation between AI and human operators, lack robustness to uncertainty, and often increase human cognitive load. Moreover, the design of intuitive multi-sensory interfaces remains an open challenge. The HARMONY project addresses these limitations through three research axes: (A1) real-time adaptive role allocation based on confidence metrics, (A2) robust AI algorithms resilient to perception uncertainty and dynamic environments, and (A3) advanced multi-sensory and VR-based interfaces to improve human situational awareness. These contributions will be validated on two demonstrators: (D1) shared control of heterogeneous aerial–ground robot teams for cooperative manipulation in a Phygital Twin environment with haptic feedback, and (D2) shared control of an anthropomorphic mobile manipulator for human–robot collaborative object transport with dynamic role adaptation.

### 10.5 Regional initiatives

#### 10.5.1 Academic Chair IH2A

**Participants:** Marie Babel, François Pasteau, Louise Devigne, Vincent Drevelle, Maud Marchal, Emilie Leblong, Anne-Hélène Olivier, Charles Pontonnier, Thomas Voisin, Sebastien Thomas, Fabien Grzeskowiak, Claudio Pacchierotti, Maxime Manzano, Mael Gallois, Theo Le Terrier, Elyse Larribau.

**Title:** Academic Chair on Innovations, Handicap, Autonomy and Accessibility (IH2A)

**Duration:** 2020-...

**Coordinator:** Marie Babel

**Inria contact:** Marie Babel

**Partners:** INSA Rennes, Université Rennes, Université Rennes 2, Centre de médecine physique et de réadaptation Fondation Saint Hélier (Rennes), CHU Pontchaillou Rennes, M2S

**Summary:** This research chair (Innovations, Handicap, Autonomy and Accessibility - IH2A) aims to propose the most appropriate technological solutions to compensate for sensorimotor impairments that limit people's mobility and autonomy in everyday tasks and leisure activities. The IH2A Chair aims to structure these activities from a social, scientific and clinical point of view and to be an effective and innovative tool for the development of large-scale research in this field. This multidisciplinary research and innovative collaborative experiments allow the clinical and scientific validation of the technical assistance offered, while ensuring the accessibility of the solutions deployed.

### 10.5.2 AAP PME HUBERT

**Participants:** Marie Babel, François Pasteau, Vincent Drevelle, Emilie Leblong, Fabien Grzeskowiak.

**Title:** HUBERT

**Duration:** January 2023 - June 2026

**Coordinator:** BA Healthcare

**Inria contact:** Marie Babel

**Partners:** INSA Rennes, BA Healthcare, Centre de médecine physique et de réadaptation Fondation Saint Hélier (Rennes)

**Summary:** The aim of this project is to create a range of robotized walkers for geriatric use in health and social care establishments, to give residents or patients greater independence.

### 10.5.3 AAP PME ARDEB

**Participants:** Marie Babel, François Pasteau, Fabien Grzeskowiak.

**Title:** ARDEB

**Duration:** January 2024 - December 2027

**Coordinator:** BA Healthcare

**Inria contact:** Marie Babel

**Partners:** INSA Rennes, BA Healthcare, DK Innovation

**Summary:** The ARDEB project aims to develop an innovative inclusive mobility solution based on a combination of a Segway and a robotic system that is verticalized, stabilized, and secure. This alternative to wheelchairs is designed to be both compact and versatile, promoting independence and social interaction while minimizing the physiological risks associated with sitting.

# 11 Dissemination

## 11.1 Promoting scientific activities

### 11.1.1 Scientific events: organisation

**General chair, scientific chair**

- Paolo Robuffo Giordano has been the general co-chair of the Journées Nationales de la Recherche en Robotique (JNRR) 2025

**Member of the organizing committees**

- Claudio Pacchierotti has been Student Volunteers Co-Chair for IEEE Virtual Reality (VR), Saint-Malo, France, 2025.
- Claudio Pacchierotti has been Program Committee Member for IEEE Virtual Reality (VR), 2025.
- Claudio Pacchierotti has been Demonstrations Co-Chair for IEEE World Haptics (WHC), Suwon, Korea, 2025.

### 11.1.2 Scientific events: selection

**Chair of conference program committees**

- Marco Tognon has been Program Co-chair of the 2025 International Conference on Unmanned Aircraft Systems, ICUAS 2025
- Esteban Restrepo has Program Co-chair of the Conference on Artificial Intelligence for Defence, CAID 2025, Rennes, France
- Maud Marchal has been Program Chair (Conference Editorial Board) for IEEE World Haptics (WHC), Suwon, Korea, 2025.
- Maud Marchal has been Technical Program Chair for IEEE Symposium on Mixed and Augmented Reality), Daejeon, Korea, 2025.
- Maud Marchal has been Associate Program Chair for IEEE Virtual Reality (VR), 2025

**Member of the conference program committees**

- Maud Marchal has been a Program Committee Member for ACM Siggraph Asia Technical Papers, 2025

**Workshop Organization**

- Paolo Robuffo Giordano and Tommaso Belvedere co-organized the ICRA 2025 workshop Beyond the Lab: Robust Planning and Control in Real World Scenarios
- Paolo Robuffo Giordano and Marco Ferro co-organized the ICRA 2025 workshop Empowering Humans with Miniaturized Sensing and Control: Shared Autonomy for Small-Scale Robots

- Claudio Pacchierotti co-organized the ICRA 2025 workshop on "Human-Centric Robotics for Telepresence".
- Vincent Drevelle organized the SWIM 2025 international workshop on interval methods in Rennes in July 2025.
- Marco Tognon co-organized the ICRA 2025 workshop "25 years of Aerial Robotics: Challenges and Opportunities"
- Marco Tognon co-organized the GdR-TS3 and GICAT Workshop "Advancing Multi-Robot Systems: A Joint GdR-TS3 & GICAT Workshop"
- Marco Tognon co-organized the IROS 2025 workshop "Advancements in Aerial Physical Interaction"

**Reviewer**

- Marco Tognon: IEEE ICRA (1)
- Claudio Pacchierotti: IEEE ICRA (7), IEEE Conference on Telepresence (2), IEEE IROS (1)
- Paolo Robuffo Giordano: IEEE ICRA (2)
- Esteban Restrepo: ECC (2)
- Eric Marchand: ICCV (3)

### 11.1.3 Journal

**Member of the editorial boards**

- Marco Tognon is Associate Editor of the IEEE Transactions on Robotics
- Claudio Pacchierotti is Associate Editor of the International Journal of Robotics Research (IJRR).
- Claudio Pacchierotti is Associate Editor of the IEEE Transactions on Haptics.
- Paolo Robuffo Giordano is Senior Editor of the IEEE Transactions on Robotics
- Marie Babel is Associate Editor of the IEEE Robotics and Automation Letters
- Maud Marchal is Associate Editor in Chief of IEEE Transactions on Visualization and Computer Graphics.
- Maud Marchal is Associate Editor of IEEE Transactions on Haptics.
- Maud Marchal is Associate Editor of Computers & Graphics.
- Maud Marchal is Associate Editor of ACM Transactions on Applied Perception.

**Reviewer - reviewing activities**

- Marco Tognon: Autonomous Robots (1), IEEE TRO (1), Nature Communications (1), IEEE RAL (2), Npj Robotics (1)
- Claudio Pacchierotti: IEEE Trans. Haptics (2), Philosophical Transactions of the Royal Society B: Biological Sciences (1), International Journal of Human-Computer Interaction (1), Virtual Reality (2), Nature Electronics (1), Multisensory Research (1), IEEE Transactions on Human-Machine Systems (1), IEEE Transactions on Visualization and Computer Graphics (1), IEEE Robotics and Automation Letters (1)
- Paolo Robuffo Giordano: IEEE CSS-L (2)
- Alexandre Krupa: IEEE RAL (1)

- Esteban Restrepo: IEEE RAL (1), IEEE TRO (2), IEEE L-CSS (6), IEEE TAC (3), IEEE TCST (1), IEEE IoT (1), Automatica (1)
- Eric Marchand: IEEE TRO (1)

#### 11.1.4 Invited talks

- Marco Tognon. “Advancements in aerial physical interaction: design control and collaborations”. LAAS-CNRS, Toulouse, France. March 2025.
- Marco Tognon. “Advancements in aerial physical interaction: design control and collaborations”. University of La Reunion, Saint Denis, La Reunion. September 2025.
- Paolo Robuffo Giordano. “Intrinsic Robust Planning for Uncertain Robots”. Sapienza Univ Rome, Italy, January 2025
- Paolo Robuffo Giordano. “Shared Control for Tele-manipulation and Tele-navigation at the Macro and Micro scale”’. GdR Thematic day on “Shared Control”, Paris, France, January 2025
- Paolo Robuffo Giordano. “Introduction to Sensitivity-Based Robust Planning”. ICRA 2025 Workshop on Beyond the Lab: Robust Planning and Control in Real World Scenarios, May 2025
- Paolo Robuffo Giordano. “Introduction to Sensitivity-Based Robust Planning”. JNRR 2025 Workshop on Introduction to Sensitivity-Based Robust Planning, October 2025
- Paolo Robuffo Giordano. “Shared Control for Tele-manipulation and Tele-navigation at the Macro and Micro scale”’. European Cyber Week 2025, November 2025
- Claudio Pacchierotti. “Haptique: la science du toucher.” Visites insolites du CNRS, Rennes, France, 2025.
- Claudio Pacchierotti. “Haptique: la science du toucher.” Visites insolites du CNRS, Rennes, France, 2025.
- Claudio Pacchierotti. “Haptic shared control for telerobotics.” Journées Nationales de la Recherche en Robotique (JNRR), Rennes, France, 2025.
- Claudio Pacchierotti. “Cutaneous Haptic Feedback for Human-Centered Robotics: a 10-years retrospective.” Eindhoven University of Technology (TU/e), Eindhoven, The Netherlands, 2025.
- Claudio Pacchierotti. “Cutaneous Haptic Feedback for Improving Telepresence.” Workshop on “The Importance of Haptics in Telepresence” at IEEE World Haptics Conference (WHC), Suwon, Republic of Korea, 2025.
- Claudio Pacchierotti. “Wearable cutaneous haptics: an historical overview.” Workshop on “Emerging Challenges in Wearable Haptics” at IEEE World Haptics Conference (WHC), Suwon, Republic of Korea, 2025.
- Claudio Pacchierotti. “Haptics: the science of touch.” Introduction for the keynote session on Haptics at the IEEE International Conference on Robotics and Automation (ICRA), Atlanta, USA, 2025.
- Claudio Pacchierotti. “Haptics for small-scale robotics” Workshop on “Empowering Humans with Miniaturized Sensing and Control: Shared Autonomy for Small-Scale Robots (SASSR)” at the IEEE International Conference on Robotics and Automation (ICRA), Atlanta, USA, 2025.
- Claudio Pacchierotti. “Haptics for biomedical applications.” Seminar for the M2 course on Biomedical Engineering, University of Twente, Enschede, The Netherlands, 2025.
- François Chaumette. "Geometric and end-to-end robot vision-based control". Plenary talk at the IEEE International Conference on Emerging Technologies and Computing (ICETC), Brest, June 2025

- Fabien Spindler presented the national 2RM network of roboticists and mechatronics engineers at the National Robotics Research Days (JNRR 2025), October 2025.
- Gianluca Corsini, Romain Lagneau, Olivier Roussel, Fabien Spindler, and Samuel Felton each gave presentations on the ROBSTAR robotics platform and robotics-related software to promote ViSP and telekyb3 within the community during the 2RM national meeting (June 2025) and at the first meeting of Inria's thematic robotics network (Sept. 2025).
- Esteban Restrepo. "Open Multi-Robot Systems for Resilient Teams." GdR Robotique TS3 & GICAT Workshop on Multi-Robot Systems, Rennes, France, 2025.
- Esteban Restrepo. "Towards Resilient and Autonomous Human-Multi-Robot Collaboration." Seminar for the École normale supérieure de Rennes, Rennes, France, 2025.

#### 11.1.5 Leadership within the scientific community

- Marco Tognon is the co-organizer (co-animateur) of the scientific thematics 3 "Heterogeneity and Complexity" (TS3 "Hétérogénéité et Complexité", 2024 onwards) of GdR Robotique.
- Marco Tognon is Co-Chair of the IEEE Technical Committee Aerial Robotics and UAVs (2024 onwards).
- Paolo Robuffo Giordano was member (elected) of the Section 07 of the Comité National de la Recherche Scientifique.
- Paolo Robuffo Giordano has started an appointment as President of the EuRobotics Georges Giralt Award
- Paolo Robuffo Giordano is co-Chair of the "IEEE RAS Young Reviewers Program", which is part of the IEEE RAS Member Activities Board (MAB)
- Paolo Robuffo Giordano is Distinguished Lecturer for the IEEE RAS Technical Committee on Multi-robot Systems

  Claudio Pacchierotti is Distinguished Lecturer of the IEEE Robotics & Automation Society for the field of haptics (Region 8: Europe, Middle East and Africa, 2025 onwards).

  Claudio Pacchierotti is Co-Chair, IEEE Technical Committee on Telerobotics (2023 – 2026).

  Claudio Pacchierotti is Scientific Advisory Board, "TOAST: Touch-enabled Tactile Internet Training Network and Open Source Testbed," Marie Skłodowska-Curie Action (2025 – 2026).

  Claudio Pacchierotti is Secretary, Eurohaptics Society (2018 – 2022, 2022 – 2026).

  Claudio Pacchierotti is Responsible for the GdR Robotique at IRISA (2025 onwards).

  Claudio Pacchierotti is Organization Committee, Program Committee, and "Code of Conduct" Officer, Journées Nationales de la Recherche en Robotique (JNRR), Rennes, 2025.

  Claudio Pacchierotti is Co-organizer (co-animateur) of the scientific thematics 4 "Human-centered robotics" (TS4 "Robotique centrée sur l'humain", 2024 onwards).

  François Chaumette was president of the jury for the 2024 best French thesis in robotics organized by the the "GdR Robotique".
- Fabien Spindler co-organized the first workshop of Inria's thematic network dedicated to robotics in sept. 2025.
- Fabien Spindler was a member of the HCERES evaluation committee of the LIRIS laboratory in Lyon
- Marie Babel serves as the Deputy Director of the GdR Robotique since 2024.

- Alexandre Krupa was the organizer of the session “Robotic manipulation” of the French National Robotics Research Days (JNRR 2025).
- Alexandre Krupa is responsible (since November 2025) of the “manipulation” axis of the national Equipex+ Tirrex project devoted to open robotic platforms.

#### 11.1.6 Scientific expertise

- Paolo Robuffo Giordano served as expert/reviewer for the euRobotics “George Giralt” award for the best European PhD thesis in robotics. He was reviewer for EU Consolidator and Advanced Grants. He was member of the HCERES committee for evaluating the LIRMM lab, and committee member of the Chaire professeur junior (CPJ) CNRS “Véhicules autonomes et transport”, Heudiasyc, France. Finally, he is member of the Steering Committee (Comité de Pilotage) for the PEPR “Accélération en Robotique”
- Marie Babel is the vice-president of the Comité d’évaluation of ANR (CE33 - Interaction, robotique - 2024, 2025). She leads an Academic Chair on Innovations, Handicap, Autonomy and accessibility since 2020. She serves since 2017 as an expert for the International Mission of the French Research Ministry (MEIRIES). She serves as a member of the Selection and Validation Committee of the Pôle Images et Réseaux since 2022.

#### 11.1.7 Research administration

- Alexandre Krupa is the president of the CUMIR (“Commission des Utilisateurs des Moyens Informatiques pour la Recherche”) of Centre Inria de l’Université de Rennes since February 2023.
- Vincent Drevelle is an elected member of the IRISA laboratory council since 2023.
- Eric Marchand is the head of the doctoral school Matisse

### 11.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

Marco Tognon:

- Master 2 DRONE “Introduction to Aerial Physical Interaction” 2h, M2, Ecole Centrale de Nantes, Nantes, France
- Master ENS: “Robotics 2”, 33 hours, M1, Ecole Nationale Supérieure de Rennes

Paolo Robuffo Giordano:

- Master SIVOS: “Modeling and Control of Collaborative Mobile Robots (MOCO)”, 6 hours, M2, Université de Rennes, France, December 2025.

François Chaumette

- Master Mecatronics: “Visual servoing”, 6 hours, M1, ENS Rennes

Alexandre Krupa:

- Master ESIR3: “Ultrasound visual servoing”, 9 hours, M2, ESIR Rennes
- Master ESIR3: “Visual servoing”, 9 hours, M2, ESIR Rennes
- Master SIVOS: “Visual servoing”, 11 hours, M2, Université de Rennes

Claudio Pacchierotti

- Master AI & Advanced Visual Computing: “INF644 – Virtual/Augmented Reality & 3D Interactions”, 6 hours, École Polytechnique, Paris, France, Feb 2025.
- Master SIVOS: “Haptics for robotics”, 24 hours, M2, Université de Rennes, France, Oct 2025.

- Master SIF: “Virtual Reality and Multi-Sensory Interaction”, 4 hours, M2, Université de Rennes, France, Dec 2025.
- Master SPIA: “Mechatronics Assistive Devices”, 2 hours, Université de Rennes, France, Oct 2025.

Fabien Spindler

- Master ESIR3: “Robot Vision”, 12 hours, M2, ESIR Rennes
- Master SIVOS: “Visual Servoing”, 12 hours, M2, Université de Rennes

Esteban Restrepo

- Master SIVOS: “Modeling and Control of Collaborative Mobile Robots (MOCO)”, 6 hours, M2, Université de Rennes, France, December 2025.

Vincent Drevelle

- Master IL: “Artificial intelligence”, 20 hours, M1, ISTIC, Univ Rennes
- Master IA: “Artificial intelligence algorithmics”, 10.5 hours, M1, ISTIC, Univ Rennes
- L1: “Principles of computer systems”, 52 hours, ISTIC, Univ Rennes
- L3 Miage: “Computer programming”, 72 hours, ISTIC, Univ Rennes
- L3 Info: “Advanced computer programming”, 23 hours, ISTIC, Univ Rennes
- M2 EEEA: “Localization, Multisensor data fusion”, 22 hours, ISTIC, Univ Rennes
- M2 IL: “Mobile robotics”, 32 hours, ISTIC, Univ Rennes
- M2 SiVOS: “Perception of environment, human and robot”, 6 hours, Univ Rennes

Eric Marchand

- Master Esir2: “BINP”, 9 hours, M1, Esir Rennes
- Master Esir2: “Computer vision: geometry”, 24 hours, M1, Esir Rennes
- Master Esir3: “Robotics Vision 1”, 12 hours, M2, Esir Rennes
- Master Esir3: “Robotics Vision 2”, 7 hours, M2, Esir Rennes
- Master SIVOS: “Geometric Computer Vision”, 8 hours, M2, Université de Rennes
- Master ENS: “Computer vision”, 6 hours, M2, ENS Rennes
- Master MIA: “Augmented reality”, 4 hours, M2, Université de Rennes

Marie Babel

- M1, "Image and video processing", 26h, INSA Rennes,
- L3, "Probability", 24h, INSA Rennes
- L3, "Concepts de la logique à la programmation", 20h, INSA Rennes
- L3, "Remedial math courses", 24h, INSA Rennes
- M1, "Computer sciences project", 30h, INSA Rennes
- Tutoring and support for students with disabilities, 12h, INSA Rennes
- Master 2 SIVOS, "Mecatronics for healthcare", 12h, ENS Rennes
- Master 1 IEAP, "Handicap and technologies", 6h, Université Rennes 2

François Pasteau

- M1, "Image and video processing", 6h, INSA Rennes,
- L3, "Concepts de la logique à la programmation", 12h, INSA Rennes
- L3, "Practical studies", 16h, INSA Rennes
- M1, "Introduction to robotics", 22h, INSA Rennes
- M1, "Internet Of Things", 20h, INSA Rennes

Maud Marchal

- L3, "Complexity and algorithms", 26h, INSA Rennes,
- M1, "Computer Graphics", 26h, INSA Rennes
- M2, "Human-Computer Interaction", 14h, INSA Rennes
- M2, "Computer Graphics", 20h, Univ. Rennes
- Master 2 SIVOS, "Haptics", 10h, ENS Rennes

### 11.2.1 Supervision

- Ph.D. completed: Maxime Manzano, “Reach-to-grasp in activities of daily living: shared control of a multisensory assistive device to compensate for upper extremity neuromuscular disorders.”, defended in December 2025, supervised by Marie Babel, Ronan Le Breton, and Sylvain Guégan [73]
- Ph.D. completed: Emilie Leblong, “Taking into account social interactions in a virtual reality power wheelchair driving simulator: promoting learning for inclusive mobility”, defended in July 2025, supervised by Marie Babel and Anne-Hélène Olivier (Virtus team) [72]
- Ph.D. completed: Thibault Noël, "Autonomous Exploration of an Unknown 3D Environment" defended in January 2025, supervised by François Chaumette and Eric Marchand [75].
- Ph.D. completed: Erwan Normand, “Augmenting the interaction with everyday objects with wearable haptics and AR,” defended in January 2025, supervised by Claudio Pacchierotti, Maud Marchal and Eric Marchand [76].
- Ph.D. completed: Maxime Bernard, “Shared control for multi-robot systems”, defended in April 2025, supervised by Paolo Robuffo Giordano and Claudio Pacchierotti [70]
- Ph.D. completed: Lendy Mulot, “Advancing Ultrasound Mid-Air Haptics: Perception Studies, Rendering Methods, and Design of Virtual Reality Interactions,” defended in November 2025, supervised by Claudio Pacchierotti and M. Marchal.
- Ph.D. completed: Antonio Marino, “Learning-based Formation Control and Localizaton for Multiple Robots”, defended in December 2025, supervised by Paolo Robuffo Giordano and Claudio Pacchierotti [74]
- Ph.D. completed: Mandela Ouafo Fonkoua,“Vision-based shape servoing of soft objects using finite element model”, defended in December 2025, supervised by Alexandre Krupa and François Chaumette [71].
- Ph.D. in progress: Sylvain Jannin, “Collaboration and navigation of multi-robot systems at the small-scale for clinical applications,” started in October 2025, supervised by Claudio Pacchierotti.
- Ph.D. in progress: Francesco Russo, “Shared autonomy for intuitive collaboration between humans and multiple robots,” started in December 2025, supervised by Claudio Pacchierotti and E. Restrepo.

- Ph.D. in progress: Jessé De Oliveira Santan Alves, “Human-robot interaction and shared control for robotic telemanipulation,” started in November 2024, supervised by Claudio Pacchierotti.
- Ph.D. in progress: Sara Rossi, “Tactile haptic perception and rendering for robotic prosthesis,” started in February 2024, supervised by Claudio Pacchierotti and M. Marchal.
- Ph.D. in progress: Yuxin Jin, “Detection and tracking of microagents using Artificial Intelligence,” started in September 2023, supervised by Claudio Pacchierotti and S. Misra.
- Ph.D. in progress: Léon Raphalen, “Human-centered shared control of multi-robot systems at the microscale,” started in September 2023, supervised by Claudio Pacchierotti.
- Ph.D. in progress: Andrea Perna, “Coordination of Heterogeneous Multi-robot systems for Multi-objective Missions”, started in November 2025, supervised by Esteban Restrepo and Paolo Robuffo Giordano
- Ph.D. in progress: Valeria Braglia, “Perception-Aware Cable Suspended Multi-Drone Transportation”, started in February 2025, supervised by Marco Tognon and Paolo Robuffo Giordano
- Ph.D. in progress: Lorenzo Balandi, “Full-Body Design and Control of an Aerial Manipulator for Advance Physical Interaction”, started in October 2023, supervised by Marco Tognon and Paolo Robuffo Giordano
- Ph.D. in progress: Szymon Bielenin, “Robust and Agile Transportation of Cable Suspended-Loads with Multi-Drone Systems”, started in October 2024, supervised by Marco Tognon, Paolo Robuffo Giordano and Claudio Pacchierotti
- Ph.D. in progress: Phillip Maximilian Mehl, “Learning-based Control of an Aerial Manipulator for Complex Manipulation Tasks”, started in January 2024, supervised by Marco Tognon
- Ph.D. in progress: Lluis Prior Sancho, “AEROTouch – AErial RObots with the sense of Touch”, started in November 2024, supervised by Marco Tognon
- Ph.D. in progress: Johan Berrier-Gonzalez,“Forming carbon fiber fabrics by visual servoing”, started in October 2025, supervised by Alexandre Krupa.
- Ph.D. in progress: Simone Rotondi,“Shape visual servoing of deformable objects robust to model uncertainties”, started in November 2025, supervised by Paolo Robuffo Giordano, Alexandre Krupa and Tommaso Belvedere.
- Ph.D. in progress: Jose Eduardo Aguilar Segovia, “Design of haptic feedback using innovative shapeable materials”, started in October 2022, supervised by Marie Babel, Sylvain Lefebvre (MFXteam, Nancy) and Sylvain Guégan
- Ph.D. in progress: Maël Gallois, “Shared control by muscle mapping for upper limb assistance in neuromuscular and neurodegenerative pathologies”, started in September 2024, supervised by Marie Babel, Charles Pontonnier (Combo team), Nicolas Vignais (Combo) and Sylvain Guégan (LGCGM)
- Ph.D. in progress: Théo Le Terrier, “Sensor-based control of a power wheelchair with interval set-membership methods”, started in October 2023, supervised by Marie Babel and Vincent Drevelle.
- Ph.D in progress: Elyse Larribau, "Conception et commande d’un exosquelette de poignet-main basé sur la modélisation de biomécanique personnalisée d’usagers en situation de handicap à mobilité résiduelle.", started in October 2025, supervised by Marie Babel, Charles Pontonnier (Combo), Nolwenn Fougeron (Combo), Sylvain Guégan
- Ph.D. in progress: Amine Ouasfi, "Apprentissage auto-supervisé pour la reconstruction de formes implicites", started in 2022, supervised by Adnane Boukhayama and Eric Marchand

### 11.2.2 Juries

**HdR and PhD juries**

- Paolo Robuffo Giordano: Yoko Watanabe (HDR, ONERA Toulouse), Elio Jabbour (PhD, member, Inria Bordeaux), Pietro Pustina (PhD, reviewers, Univ Rome La Sapienza)

- Claudio Pacchierotti: Baptiste Rohou-Claquin (PhD, Sorbonne Université, France), Bin Ren (PhD, Univ. Pisa, Italy), Giuseppe Saviano (PhD, Univ. Siena, Italy), Shehzaib Shafique (PhD, Univ. Genova, Italy), Alexis Boulay (PhD, Inria Bordeaux and Univ. Bordeaux, France), Marion Pontreau (PhD, CEA and Sorbonne Université, France), Chiwoong Hwang (PhD, Aarhus University, Denmark)

- François Chaumette: Erol Ozgur (HdR, reviewer, Université Clermont-Auvergne), Claire Dune (HdR, Université de Toulon)

- Esteban Restrepo: Lorenzo Govoni (PhD, reviewer, Univ Rome La Sapienza)

- Marie Babel: Obaida Alrazouk PhD, president, Université Paris Saclay, Lendy Mulot PhD, president, INSA Rennes, Claire Dune HDR, reviewer, Université Toulon, Zhenyu Gao PhD, reviewer, Sorbonne Université, Olivier Kermorgant HDR, president, Ecole Centrale Nantes, Alexandre Oliveira Souza PhD, reviewer, Université de Lorraine, Julia Peladeau PhD, president, ENSAM Paris, Kevin Riou PhD, president, Nantes Université

- Maud Marchal: David Algis (PhD, reviewer, Univ. Poitiers), Mine Dastan (PhD, reviewer, Politecnico di Bari, Italy), Maxime Bernard (PhD, president, Univ. Rennes), Elise Bonnail (PhD, reviewer, Univ. Paris Saclay), Julien Cauquis (PhD, reviewer, IMT Atlantique), Camille Dupré (PhD, reviewer, Univ. Paris Saclay), Siyuan He (PhD, reviewer, Ecole Nationale des Ponts et Chaussées), Radhouane Jilani (PhD, member, Univ. Lorraine), Claire Martin (PhD, reviewer, Univ. Strasbourg), Nicolas Mellado (HdR, reviewer, Univ. Toulouse), David Algis (PhD, reviewer, Univ. Poitiers), Anderson Brazil Nardin (PhD, president, Sant'Anna Pisa, Italy), Steven Picard (PhD, reviewer, Univ. Luxembourg), Mathieu Pietri (PhD, reviewer, Aix Marseille Université), Pierre-Frédéric Villard (HdR, member, Univ. Lorraine), Sophie Villenave (PhD, reviewer, Centrale Lyon)

- Eric Marchand Karim Slimani (PhD, member, Sorbonne Université)

### 11.2.3 Educational and pedagogical outreach

- Claudio Pacchierotti organized a one-day educational workshop introducing 8 middle-school students to mobile robotics, including robot control exercises, Rennes, France, 2025.

- Claudio Pacchierotti organized a one-day educational workshop introducing 20 high-school students to mechatronics and mobile robotics, including hands-on assembly and robot control exercises, Rennes, France, 2025.

## 11.3 Popularization

- M. Babel, F. Pasteau, L. Devigne, T. Voisin, S. Thomas, F. Grzeskowiak, M.Manzano, P.A. Cabaret, J.E. Aguilar Segovia, M. Gallois: During the Fête de la Sciences, within the Village des Sciences in INSA Rennes, they hosted a booth for school students, featuring demonstrations of mobility assistance devices for people with disabilities, in October 2025

- M. Babel, L. Devigne: General audience conference, middle school workshops and intergenerational exchange – "Ambition réussite" action, Saint Nicolas du Pelem, 22/05/2025

#### 11.3.1 Productions (articles, videos, podcasts, serious games, ...)

- In [79], we present a perspective on engineering human-cyberphysical synergy, exploring how machines can evolve from tools into collaborative teammates that perceive touch and context. We discuss the necessary convergence of robotics, materials science, and neuroscience to realize systems such as aerial manipulators and drone swarms capable of physical interaction. The article highlights the role of affective haptics and embodied AI in achieving intuitive collaboration, while also addressing the ethical and societal implications of these emerging technologies.

#### 11.3.2 Participation in Live events

- Claudio Pacchierotti organized the Visites Insolites du CNRS à l'IRISA, "Toucher le virtuel: les fascinantes interactions entre humains et machines," a public engagement event on human-computer interaction and haptics, Rennes, France, 2025.

# 12 Scientific production

## 12.1 Major publications


[1] M. Aggravi, C. Pacchierotti and P. Robuffo Giordano. 'Connectivity-Maintenance Teleoperation of a UAV Fleet with Wearable Haptic Feedback'. In: *IEEE Transactions on Automation Science and Engineering* (June 2020), pp. 1–20. DOI: 10.1109/TASE.2020.3000060. URL: https://hal.inria.fr/hal-02866459.

[2] T. Belvedere, M. Cognetti, G. Oriolo and P. Robuffo Giordano. 'Sensitivity-Aware Model Predictive Control for Robots with Parametric Uncertainty'. In: *IEEE Transactions on Robotics* 41 (2025), pp. 3039–3058. DOI: 10.1109/TRO.2025.3554415. URL: https://hal.science/hal-05021224.

[3] A. Colotti, J. García Fontán, A. Goldsztejn, S. Briot, F. Chaumette, O. Kermorgant and M. Safey El Din. 'Determination of All Stable and Unstable Equilibria for Image-Point-Based Visual Servoing'. In: *IEEE Transactions on Robotics* 40 (2nd July 2024), pp. 3406–3424. DOI: 10.1109/TRO.2024.3422050. URL: https://hal.science/hal-04628273.

[4] M. Ferro, F. Piñan Basualdo, P. Robuffo Giordano, S. Misra and C. Pacchierotti. 'Experimental Evaluation of Haptic Shared Control for Multiple Electromagnetic Untethered Microrobots'. In: *IEEE Transactions on Automation Science and Engineering* 22 (2025), pp. 8069–8080. DOI: 10.1109/TASE.2024.3477308. URL: https://inria.hal.science/hal-04725498.

[5] M. O. Fonkoua, F. Chaumette and A. Krupa. 'Deformation Control of a 3D Soft Object using RGB-D Visual Servoing and FEM-based Dynamic Model'. In: *IEEE Robotics and Automation Letters* 9.8 (Aug. 2024), pp. 6943–6950. DOI: 10.1109/LRA.2024.3416801. URL: https://hal.science/hal-04622538.

[6] C. Gabellieri, M. Tognon, D. Sanalitro and A. Franchi. 'Force-based Pose Regulation of a Cable-Suspended Load Using UAVs with Force Bias'. In: IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2023). Michigan, United States: IEEE, Oct. 2023, pp. 6920–6926. DOI: 10.1109/IROS55552.2023.10342240. URL: https://hal.science/hal-04345267.

[7] M. Gonzalez, E. Marchand, A. Kacete and J. Royan. 'TwistSLAM: Constrained SLAM in Dynamic Environment'. In: *IEEE Robotics and Automation Letters* 7.3 (July 2022), pp. 6846–6853. URL: https://inria.hal.science/hal-03676527.

[8] A. Kheddar, S. Caron, P. Gergondet, A. Comport, A. Tanguy, C. Ott, B. Henze, G. Mesesan, J. Englsberger, M. A. Roa, P.-B. Wieber, F. Chaumette, F. Spindler, G. Oriolo, L. Lanari, A. Escande, K. Chappellet, F. Kanehiro and P. Rabate. 'Humanoid robots in aircraft manufacturing'. In: *IEEE Robotics and Automation Magazine* 26.4 (Dec. 2019), pp. 30–45. DOI: 10.1109/MRA.2019.2943395. URL: https://hal-lirmm.ccsd.cnrs.fr/lirmm-02303117.

[9] E. Marchand. 'Subspace-based Direct Visual Servoing'. In: *IEEE Robotics and Automation Letters* 4.3 (July 2019), pp. 2699–2706. DOI: 10.1109/LRA.2019.2916263. URL: https://inria.hal.science/hal-02123993.

[10] B. Penin, P. Robuffo Giordano and F. Chaumette. 'Vision-Based Reactive Planning for Aggressive Target Tracking while Avoiding Collisions and Occlusions'. In: *IEEE Robotics and Automation Letters* 3.4 (Oct. 2018), pp. 3725–3732. DOI: 10.1109/LRA.2018.2856526. URL: https://hal.inria.fr/hal-01836586.

[11] P. Salaris, M. Cognetti, R. Spica and P. Robuffo Giordano. 'Online Optimal Perception-Aware Trajectory Generation'. In: *IEEE Transactions on Robotics* (2019), pp. 1–16. DOI: 10.1109/TRO.2019.2931137. URL: https://hal.inria.fr/hal-02278900.

[12] M. Selvaggio, J. Cacace, C. Pacchierotti, F. Ruggiero and P. Robuffo Giordano. 'A Shared-control Teleoperation Architecture for Nonprehensile Object Transportation'. In: *IEEE Transactions on Robotics* (June 2021), pp. 1–15. DOI: 10.1109/TRO.2021.3086773. URL: https://hal.inria.fr/hal-03246629.

[13] L. Smolentsev, A. Krupa and F. Chaumette. 'Shape visual servoing of a cable suspended between two drones'. In: *IEEE Robotics and Automation Letters* 9.12 (Dec. 2024), pp. 11473–11480. DOI: 10.1109/LRA.2024.3494655. URL: https://hal.science/hal-04763696.

[14] S. Sun, X. Wang, D. Sanalitro, A. Franchi, M. Tognon and J. Alonso-Mora. 'Agile and Cooperative Aerial Manipulation of a Cable-Suspended Load'. In: *Science Robotics* 10.107 (29th Oct. 2025), pp. 1–46. DOI: 10.1126/scirobotics.adu8015. URL: https://hal.science/hal-05360829.

## 12.2 Publications of the year

**International journals**

[15] J. E. Aguilar-Segovia, F. Grzeskowiak, S. Lefebvre, M. Babel and S. Guégan. 'Parametric Foam-Like Capacitive Sensors for 3D Printing of Deformable Parts with Sensing Capabilities'. In: *IEEE Sensors Journal* 25.3 (Feb. 2025), pp. 4261–4272. DOI: 10.1109/jsen.2024.3510138. URL: https://hal.science/hal-04891580 (cit. on p. 32).

[16] J. E. Aguilar-Segovia, S. Perchy, P.-A. Hugron, S. Guégan, M. Babel and S. Lefebvre. 'Customization of 3D printed sensing devices in the layered fabrication space'. In: *Computers and Graphics* 133 (Dec. 2025), p. 104459. DOI: 10.1016/j.cag.2025.104459. URL: https://hal.science/hal-05358243 (cit. on p. 32).

[17] M. Babel, S. Guégan and L. Devigne. 'Robotique d'assistance : conception et commande pour l'autonomie en fauteuil roulant électrique'. In: *Les Techniques de l'Ingenieur* (June 2025), pp. 1–45. DOI: 10.51257/a-v1-s7794. URL: https://hal.science/hal-05116178 (cit. on pp. 18, 27).

[18] L. Balandi, P. R. Giordano and M. Tognon. 'QP-Based Inner-Loop Control for Constraint-Safe and Robust Trajectory Tracking for Aerial Robots'. In: *IEEE Robotics and Automation Letters* 10.7 (July 2025), pp. 6640–6647. DOI: 10.1109/LRA.2025.3568319. URL: https://hal.science/hal-05061950 (cit. on pp. 20, 30).

[19] A. Bellicha, L. Struber, F. Pasteau, V. Juillard, L. Devigne, S. Karakas, S. Chabardes, M. Babel and G. Charvet. 'Depth-sensor-based shared control assistance for mobility and object manipulation: toward long-term home-use of BCI-controlled assistive robotic devices'. In: *Journal of Neural Engineering* 22.1 (14th Feb. 2025), p. 016045. DOI: 10.1088/1741-2552/adae36. URL: https://hal.science/hal-04972378 (cit. on pp. 18, 27).

[20] T. Belvedere, M. Cognetti, G. Oriolo and P. Robuffo Giordano. 'Sensitivity-Aware Model Predictive Control for Robots with Parametric Uncertainty'. In: *IEEE Transactions on Robotics* 41 (2025), pp. 3039–3058. DOI: 10.1109/TRO.2025.3554415. URL: https://hal.science/hal-05021224 (cit. on pp. 20, 22).

[21] T. Belvedere, M. Ziegltrum, G. Turrisi and V. Modugno. 'Feedback-MPPI: Fast Sampling-Based MPC via Rollout Differentiation – Adios low-level controllers'. In: *IEEE Robotics and Automation Letters* 11.1 (2026), pp. 1–8. DOI: 10.1109/LRA.2025.3630871. URL: https://hal.science/hal-05115336 (cit. on p. 22).

[22] N. de Carli, R. Belletti, E. Buzzurro, A. Testa, G. Notarstefano and M. Tognon. 'Distributed NMPC for Cooperative Aerial Manipulation of Cable-Suspended Loads'. In: *IEEE Robotics and Automation Letters* 10.10 (2025), pp. 10546–10553. DOI: 10.1109/LRA.2025.3604703. URL: https://hal.science/hal-05239115 (cit. on pp. 20, 31).

[23] A. Colotti and F. Chaumette. 'Globally-stable and robust image-based visual servoing for positioning with respect to a cylinder'. In: *IEEE Robotics and Automation Letters* 10.11 (Nov. 2025), pp. 12071–12078. DOI: 10.1109/LRA.2025.3619710. URL: https://hal.science/hal-05290577 (cit. on pp. 17, 23).

[24] M. Ferro, F. Piñan Basualdo, P. Robuffo Giordano, S. Misra and C. Pacchierotti. 'Experimental Evaluation of Haptic Shared Control for Multiple Electromagnetic Untethered Microrobots'. In: *IEEE Transactions on Automation Science and Engineering* 22 (2025), pp. 8069–8080. DOI: 10.1109/TASE.2024.3477308. URL: https://inria.hal.science/hal-04725498 (cit. on pp. 21, 27).

[25] J. Fleck, Z. Zook, J. Clark, D. Preston, D. Lipomi, C. Pacchierotti and M. O'Malley. 'Wearable multi-sensory haptic devices'. In: *Nature Reviews Bioengineering* 3.4 (Apr. 2025), pp. 288–302. DOI: 10.1038/s44222-025-00274-w. URL: https://hal.science/hal-04981056 (cit. on p. 25).

[26] M. Gallois, M. Millan, N. Vignais, S. Guégan, M. Babel, J. Carpentier and C. Pontonnier. 'Human-Robot Co-Simulation method for upper limb assistive force calculation using polytopes'. In: *Multidisciplinary Biomechanics Journal* 2 (2025), pp. 287–289. DOI: 10.46298/mbj.16161. URL: https://hal.science/hal-05191713 (cit. on p. 28).

[27] A. Gonzalez-Morgado, J. Soueidan, G. Heredia, A. Ollero, P. Fraisse, M. Tognon and M. Cognetti. 'A Nonlinear MPC for Physical Human-Aerial Robot Interaction in Collaborative Transportation Tasks'. In: *IEEE Robotics and Automation Letters* 10.10 (2025), pp. 9670–9677. DOI: 10.1109/LRA.2025.3597854. URL: https://hal.science/hal-05208698 (cit. on p. 31).

[28] A. González-Morgado, E. Cuniato, G. Heredia, A. Ollero, R. Siegwart and M. Tognon. 'How to Shake Trees With Aerial Manipulators? A Theoretical and Experimental Study'. In: *IEEE Robotics and Automation Letters* 10.8 (2025), pp. 8067–8074. DOI: 10.1109/LRA.2025.3583603. URL: https://hal.science/hal-05151538 (cit. on p. 29).

[29] A. González-Morgado, E. Cuniato, M. Tognon, G. Heredia, R. Siegwart and A. Ollero. 'Controlled Shaking of Trees With an Aerial Manipulator'. In: *IEEE/ASME Transactions on Mechatronics* 30.2 (Apr. 2025), pp. 1026–1037. DOI: 10.13039/501100011033. URL: https://hal.science/hal-04618213 (cit. on p. 29).

[30] G. Kerbiriou, Q. Avril and M. Marchal. 'Data-driven modeling of subtle eye region deformations'. In: *Computers and Graphics* 133 (Dec. 2025), p. 104425. DOI: 10.1016/j.cag.2025.104425. URL: https://inria.hal.science/hal-05477608 (cit. on p. 15).

[31] T. Le Terrier, M. Babel and V. Drevelle. 'Ultra-Wideband Smart Wheelchair Pose Estimation Using Interval Analysis'. In: *Acta Cybernetica*. Special issue of SWIM 2023 / 2024 / 2025 (2025), pp. 1–20. URL: https://hal.science/hal-05383751. In press (cit. on pp. 18, 23).

[32] A. Marino, C. Pacchierotti and P. Robuffo Giordano. 'A Gated Graph Neural Network Approach to Fast-Convergent Dynamic Average Estimation'. In: *ACM Transactions on Intelligent Systems and Technology* 16.3 (May 2025), pp. 1–18. DOI: 10.1145/3725857. URL: https://hal.science/hal-05005887 (cit. on p. 25).

[33] A. Marino, E. Restrepo, C. Pacchierotti and P. R. Giordano. 'Decentralized Reinforcement Learning for Multi-Agent Multi-Resource Allocation via Dynamic Cluster Agreements'. In: *IEEE Robotics and Automation Letters* 10.8 (Aug. 2025), pp. 8123–8130. DOI: 10.1109/LRA.2025.3581126. URL: https://hal.science/hal-04972227 (cit. on pp. 20, 24).

[34] J. Mellet, M. Allenspach, E. Cuniato, C. Pacchierotti, R. Siegwart and M. Tognon. 'Evaluation of Human-Robot Interfaces based on 2D/3D Visual and Haptic Feedback for Aerial Manipulation'. In: *Journal of Intelligent and Robotic Systems* 111.3 (2025), p. 104. DOI: 10.1007/s10846-025-02284-7. URL: https://hal.science/hal-05313710 (cit. on pp. 20, 21, 31).

[35] E. Misimi, S. Herland and F. Chaumette. 'Visual Servoing-Based Active Vision for 3D Object Reconstruction'. In: *IEEE Robotics and Automation Letters* (Nov. 2025), pp. 1–8. URL: https://hal.science/hal-05397812 (cit. on p. 24).

[36] C. Pacchierotti. 'Haptic feedback that rings true'. In: *Nature Electronics* 9 (18th Dec. 2025), pp. 1–4. DOI: 10.1038/s41928-025-01513-z. URL: https://hal.science/hal-05416956 (cit. on p. 25).

[37] F. Pagano, N. de Carli, E. Restrepo, A. Marino and P. R. Giordano. 'Distributed Multi-Robot Active-Sensing of a Diffusive Source'. In: *IEEE Robotics and Automation Letters* 10.10 (2025), pp. 10807–10814. DOI: 10.1109/LRA.2025.3606376. URL: https://hal.science/hal-05289886 (cit. on pp. 20, 25).

[38] A. Pupa, T. Belvedere, C. Secchi and P. R. Giordano. 'On the Computation of Sensitivity Tubes'. In: *IEEE Robotics and Automation Letters* 10.9 (July 2025), pp. 8802–8809. DOI: 10.1109/LRA.2025.3587562. URL: https://hal.science/hal-05158394 (cit. on p. 21).

[39] E. Restrepo, C. Secchi and P. Robuffo Giordano. 'Passivity Preserving Energy-Aware Design for Multi-Dimensional Switched Systems: Application to Open Multi-Robot Systems'. In: *Automatica* 181 (Nov. 2025), p. 112496. DOI: 10.1016/j.automatica.2025.112496. URL: https://hal.science/hal-04330519 (cit. on p. 24).

[40] A. Srour, A. Franchi, P. Robuffo Giordano and M. Cognetti. 'Experimental Validation of Sensitivity-Aware Trajectory Planning for a Redundant Robotic Manipulator Under Payload Uncertainty'. In: *IEEE Robotics and Automation Letters* 10.2 (Feb. 2025), pp. 1561–1568. DOI: 10.1109/LRA.2024.3519857. URL: https://hal.science/hal-04816507 (cit. on p. 21).

[41] S. Sun, X. Wang, D. Sanalitro, A. Franchi, M. Tognon and J. Alonso-Mora. 'Agile and Cooperative Aerial Manipulation of a Cable-Suspended Load'. In: *Science Robotics* 10.107 (29th Oct. 2025), pp. 1–46. DOI: 10.1126/scirobotics.adu8015. URL: https://hal.science/hal-05360829 (cit. on pp. 14, 30).

[42] Y. Vyas, M. Bottin, M. Tognon and S. Cocuzza. 'Design and comparative analysis of force balanced 2 degree of freedom planar robot manipulator concepts'. In: *Journal of Mechanisms and Robotics* (2025), pp. 1–17. DOI: 10.1115/1.4069221. URL: https://hal.science/hal-05190785. In press (cit. on p. 29).

**International peer-reviewed conferences**

[43] L. Balandi, P. Robuffo Giordano and M. Tognon. 'Acceleration-based Inner-loop Control and MPC for Aerial Robots: Advantages and Drawbacks'. In: *European Robotics Forum 2025*. ERF 2025 - European Robotics Forum. Stuttgart, Germany, 2025, pp. 1–6. URL: https://hal.science/hal-05022328 (cit. on pp. 20, 30).

[44] L. Balandi, P. Robuffo Giordano and M. Tognon. 'Enhancing IMU Accuracy in MRAVs: A Theoretical and Experimental Approach to Vibration Damping'. In: ICUAS 2025 - International Conference on Unmanned Aircraft Systems. Charlotte (North Carolina), United States, 2025, pp. 1–7. DOI: 10.1109/icuas65942.2025.11007828. URL: https://hal.science/hal-05025884 (cit. on pp. 20, 30).

[45] T. Belvedere, A. Afifi, S. Wasiela and A. Pupa. 'Planning under Uncertainties with Closed-Loop Sensitivity: Recent Results and Perspectives'. In: ERF 2025 - European Robotics Forum. Stuttgart, Germany, Mar. 2025, pp. 1–5. DOI: 10.1007/978-3-031-89471-8_9. URL: https://hal.science/hal-05021252 (cit. on p. 22).

[46] E. Bouzbib, G. Gendreau, N. Guillaumin, M. Teyssier, C. Pacchierotti and A. Lécuyer. 'Flexible Reality: Can Pseudo-Haptics Enhance Vibration Intensity Perception in Co-Located AR Interaction?' In: IHM 2025 - 36e Conférence Internationale Francophone sur l'Interaction Humain-Machine. Vol. IHM'25 : Articles Scientifiques de la 36ème conférence Francophone sur l'Interaction Humain-Machine. Toulouse, France, 4th Nov. 2025. DOI: 10.1145/3765712.3765724. URL: https://hal.science/hal-05294843 (cit. on pp. 21, 25).

[47] P.-A. Cabaret, C. Pacchierotti, M. Babel and M. Marchal. 'In-Hand Haptic Representation of User's Surroundings in Virtual Reality'. In: WHC 2025 - IEEE World Haptics Conference. Suwon, South Korea: IEEE, 2025, pp. 1–7. DOI: 10.1109/WHC64065.2025.11123356. URL: https://hal.science/hal-05093077 (cit. on pp. 21, 26).

[48] G. Chabert, F. Chaumette and A. S. Roos. 'Clevis and Tenon Assembly Using Visual Guiding Fields'. In: IROS 2025 - IEEE/RSJ International Conference on Intelligent Robots and Systems. Hangzhou, China: IEEE, 2025, pp. 1–8. URL: https://hal.science/hal-05163570 (cit. on p. 23).

[49] O. Ezeji, M. Ziegltrum, G. Turrisi, T. Belvedere and V. Modugno. 'BC-MPPI: A Probabilistic Constraint Layer for Safe Model-Predictive Path-Integral Control'. In: *Communications in Computer and Information Science (AREA 2025)*. AREA 2025 - 5th Workshop on Agents and Robots for reliable Engineered Autonomy. Vol. 2700. Communications in Computer and Information Science. Bologna, Italy: Springer Nature Switzerland, 12th Oct. 2025, pp. 131–143. DOI: 10.1007/978-3-032-08049-3_8. URL: https://hal.science/hal-05317578 (cit. on p. 22).

[50] F. Falk Nyboe, A. Afifi, P. Robuffo Giordano, E. Ebeid and A. Franchi. 'Embedded Robust Model Predictive Path Integral Control using Sensitivity Tubes and GPU Acceleration'. In: ICRA 2025 - IEEE International Conference on Robotics & Automation. Altlanta, United States, May 2025, pp. 7174–7180. DOI: 10.1109/icra55743.2025.11127520. URL: https://hal.science/hal-05066734 (cit. on p. 22).

[51] M. Gallois, M. Manzano, S. Guégan, N. Vignais, M. Babel and C. Pontonnier. 'Effort generation capabilites mapping for personalized robotic assistance of the elbow'. In: ICORR 2025 - IEEE International Conference on Rehabilitation Robotics. Chicago, United States: IEEE, 2025, pp. 1–6. DOI: 10.1109/ICORR66766.2025.11063068. URL: https://inria.hal.science/hal-04926088 (cit. on p. 28).

[52] P. Gomez Hernandez, J. M. Jakobsen, C. Pacchierotti, F. Chinello and C. Fang. 'Stiffness regulation co-pilot in bilateral teleimpedance control: a preliminary user study'. In: ICRA 2025 - IEEE International Conference on Robotics and Automation, Atlanta (Georgia), United States: IEEE, 2025, pp. 5622–5628. DOI: 10.1109/ICRA55743.2025.11127810. URL: https://hal.science/hal-04981046 (cit. on p. 27).

[53] J. Manson, A. Lécuyer, C. Pacchierotti and J. Saint-Aubert. 'Walk on Hands: Can Vibrations in the Hands Support Walking Experience in Virtual Reality?' In: WHC 2025 - IEEE World Haptics Conference. Suwon, South Korea: IEEE, 2025, pp. 1–7. DOI: 10.1109/WHC64065.2025.11123244. URL: https://inria.hal.science/hal-05093641 (cit. on pp. 21, 26).

[54] H. Ota, Y. Hirao, M. Perusquía-Hernández, H. Uchiyama, K. Kiyokawa and M. Marchal. 'Enhancing Visuo-Haptic Coherency by Manipulating Fingertip Contact Tilt'. In: 2025 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW). Saint Malo, France: IEEE, 8th Mar. 2025, pp. 1308–1309. DOI: 10.1109/VRW66409.2025.00300. URL: https://hal.science/hal-05443508 (cit. on pp. 21, 26).

[55] H. Ota, M. Perusquía-Hernández, K. Kiyokawa, Y. Hirao, H. Uchiyama and M. Marchal. 'FresnelDeformable: A Softness Presentation Technique Combining Fingertip Plane Tilt Manipulation and Pseudo-Stiffness'. In: CHI EA 2025 - Extended Abstracts of the CHI Conference on Human Factors in Computing Systems. Yokohama, Japan: ACM, 26th Apr. 2025, pp. 1–6. DOI: 10.1145/3706599.3719778. URL: https://hal.science/hal-05443500 (cit. on pp. 21, 26).

[56] L. Raphalen, T. Goalard, M. Ferro, P. R. Giordano and C. Pacchierotti. 'Occlusion-Safe Shared Micromanipulation in Vision-Constrained Environments'. In: Telepresence 2025 - Second IEEE Conference on Telepresence. Leiden, Netherlands, 8th Sept. 2025, pp. 1–4. URL: https://hal.science/hal-05190024 (cit. on pp. 21, 27).

[57] S. Rossi, C. Pacchierotti and M. Marchal. 'Studying the Perception of Vibrotactile Stimulation on the Arm via a Modular Wearable Sleeve'. In: WHC 2025 - IEEE World Haptics Conference. Suwon, South Korea: IEEE, 2025, pp. 499–505. DOI: 10.1109/WHC64065.2025.11123226. URL: https://hal.science/hal-05093086 (cit. on pp. 21, 26).

[58] J. Thomas and F. Chaumette. 'Positioning with respect to a cylinder using proximity-based control'. In: IROS 2025 - IEEE/RSJ Int. Conf. on Intelligent Robots and Systems. Hangzhou, China, 2025, pp. 1–8. URL: https://hal.science/hal-05289868 (cit. on pp. 19, 23).

**National peer-reviewed Conferences**

[59] T. Le Terrier, M. Babel and V. Drevelle. 'Model Predictive Control for Autonomous Navigation of Smart Wheelchairs Using Ultra-wideband Sensors'. In: *Actes du Colloque Jeunes Chercheurs, Jeunes Chercheuses 2025, Campus Condorcet, Aubervilliers, 10 juin 2025*. JCJC 2025 - Colloque Jeunes Chercheurs, Jeunes Chercheuses. Aubervilliers, France, June 2025, pp. 33–38. URL: https://hal.science/hal-05384328 (cit. on pp. 18, 23).

[60] M. Maxime, G. Maël, G. Sylvain, L. B. Ronan, D. Louise and B. Marie. 'Enhancing the Usability of Upper-Limb Assistive Robots with a Variable Admittance Controller'. In: *Actes du Colloque Jeunes Chercheurs, Jeunes Chercheuses 2025, Campus Condorcet, Aubervilliers,10 juin 2025*. JCJC 2025 - Colloque Jeunes Chercheurs, Jeunes Chercheuses 2025. Aubervilliers (Campus Condorcet), France, 2025, pp. 14–19. URL: https://hal.science/hal-05356901 (cit. on p. 28).

**Conferences without proceedings**

[61] M. Gallois, M. Manzano, S. Guégan, N. Vignais, M. Babel and C. Pontonnier. 'Commande partagée par cartographie musculaire pour l'assistance du membre supérieur'. In: SOFAMEA 2025 - XXIIIe Congrès de la Société Francophone d'Analyse du Mouvement chez l'Adulte et l'Enfant. Paris, France, 2025. URL: https://hal.science/hal-04897551 (cit. on p. 28).

[62] T. Le Terrier, M. Babel and V. Drevelle. 'Ultra-wideband Based Smart Wheelchair Static Pose Estimation using Interval Analysis'. In: SCAN 2025 - 20th International Symposium on Scientific Computing, Computer Arithmetic, and Verified Numerical Computations. Oldenburg, Germany, 2025. URL: https://hal.science/hal-05383986 (cit. on pp. 18, 23).

[63] T. Le Terrier, M. Babel and V. Drevelle. 'Ultra-wideband Sensor Based Robust Model Predictive Control'. In: SWIM 2025 - Summer Workshop on Interval Methods. Rennes, France, 2025, pp. 1–4. URL: https://hal.science/hal-05383932 (cit. on pp. 18, 23).

[64] M. Malvezzi, L. Kuang, C. Pacchierotti and F. Chinello. 'Model-Based Analysis and Evaluation of an Origami Encounter-type Wearable Device'. In: TELEPRESENCE 2025 - Second IEEE Conference on Telepresence. Leiden, Netherlands, 2025, pp. 1–6. URL: https://hal.science/hal-05190244 (cit. on pp. 21, 26).

[65] M. Mehl, A. D. Libera, R. Carli and M. Tognon. 'Model-Based Reinforcement Learning for Robust End-to-End UAV Control from Simulation to Real System Application'. In: ERF 2025 - European Robotics Forum. Stuttgart, Germany, 2025, pp. 1–6. URL: https://hal.science/hal-05021288 (cit. on pp. 14, 20, 30).

[66] L. Raphalen, M. Ferro, S. Misra, P. Robuffo Giordano and C. Pacchierotti. 'Haptic Shared Control of a Pair of Microrobots for Telemanipulation using Constrained Optimization'. In: IROS 2025. Hangzhou, China, 19th Oct. 2025. URL: https://hal.science/hal-05157735 (cit. on pp. 21, 27).

[67] A. Tomezzoli, B. Cassard, E. Larribau, M. Babel, E. Leblong and C. Pontonnier. 'Développement de modèles personnalisés de génération d'effort chez les patients présentant un déficit neurologique : étude préliminaire'. In: SOFAMEA 2025 - XXIIIè congrès de la Société Francophone d'Analyse du Mouvement chez l'Adulte et l'Enfant. Paris, France, 2025, pp. 1–2. URL: https://inria.hal.science/hal-05020810 (cit. on p. 28).

**Scientific book chapters**

[68] F. Chaumette. 'Visual Control'. In: *Robotics Goes MOOC*. Springer Nature Switzerland, 14th June 2025, pp. 135–164. DOI: 10.1007/978-3-319-74095-9_5. URL: https://hal.science/hal-05289994 (cit. on p. 21).

[69] M. Marchal and C. Pacchierotti. 'Virtual Reality and Haptics'. In: *Robotics Goes MOOC*. Springer Nature Switzerland, 1st May 2025, pp. 111–158. DOI: 10.1007/978-3-319-77270-7_4. URL: https://hal.science/hal-05055958 (cit. on p. 25).

**Doctoral dissertations and habilitation theses**

[70] M. Bernard. 'Haptic shared control for multi-robot systems'. Université de Rennes, 30th Apr. 2025. URL: https://hal.science/tel-05466076 (cit. on p. 52).

[71] M. O. Fonkoua. 'Vision-based shape servoing of soft objects using finite element model'. Université de Rennes, 12th Dec. 2025. URL: https://theses.hal.science/tel-05446843 (cit. on pp. 19, 24, 52).

[72] É. Leblong. 'Social interaction in virtual reality powered wheelchair driving simulation: Fostering learning for inclusive mobility'. INSA Rennes, 9th July 2025. URL: https://theses.hal.science/tel-05471671 (cit. on p. 52).

[73] M. Manzano. 'Contributions to Ergonomics and Control Methods for Upper-Limb Assistive Exoskeletons'. Institut National des Sciences Appliquées - Rennes, 4th Dec. 2025. URL: https://theses.hal.science/tel-05468986 (cit. on p. 52).

[74] A. Marino. 'Learning to Communicate and Coordinate: Distributed Learning-based Control for Multi-Robot Systems'. Université de Rennes, 4th Dec. 2025. URL: https://theses.hal.science/tel-05466512 (cit. on p. 52).

[75] T. Noël. 'Autonomous exploration of an unknown 3D environment'. Université de Rennes, 24th Jan. 2025. URL: https://theses.hal.science/tel-05127636 (cit. on pp. 18, 23, 52).

[76] E. Normand. 'Study of the perception and manipulation of virtual objects in augmented reality using wearable haptics'. Université de Rennes, 27th Jan. 2025. URL: https://theses.hal.science/tel-05071005 (cit. on p. 52).

**Other scientific publications**

[77] T. Lefeuvre, K. Won, M. Malvezzi, M. Dragusanu, C. Pacchierotti, A. Lécuyer, M. J.-M. Macé and L. Pillette. 'Toward EEG discrimination of fingers movements during motor imagery vs passive movement'. In: 2025 - Doctoriales Laval Virtual. Laval, France, 2025, pp. 1–4. URL: https://hal.science/hal-05096010 (cit. on p. 26).

[78] J. Manson, A. Lécuyer, C. Pacchierotti and J. Saint-Aubert. *Walk on Hands: Experiencing Vibrations in the Hands to represent Virtual Walking*. 2025. URL: https://inria.hal.science/hal-05093667 (cit. on p. 26).

[79] C. Pacchierotti and M. Tognon. *When Machines Feel and Cooperate: Engineering Human-Cyberphysical Synergy*. 28th July 2025. URL: https://hal.science/hal-05200610 (cit. on p. 55).


## 12.3 Cited publications


[80] P.-A. Cabaret. 'Design of multi-actuator haptic devices and rendering methods for navigation and virtual interactions'. Theses. INSA de Rennes, Dec. 2024. URL: https://theses.hal.science/tel-05035338 (cit. on p. 14).