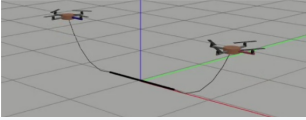
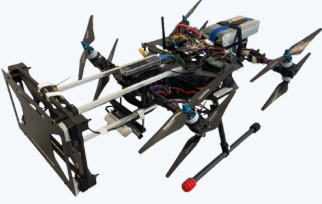




[AerRob-1] – Drone Teams for Inspection: Cooperative Transport, Pushing, and Force–Vision Control

Thesis sheet · PRISMA Lab



			
Cooperative Transportation	Leader Tilting UAV	Follower UAV	Crazyflie Swarm

THESIS OVERVIEW

Multi-UAV systems can extend aerial robotics beyond single-drone inspection, enabling teams of robots to transport objects, share sensing information, and physically interact with infrastructure in a coordinated way.

This research area focuses on the coordination of **robot fleets** for infrastructure inspection, maintenance, and contact-interaction tasks. Topics include collaborative object transportation via cables, robust connectivity maintenance under uncertainties, and force-vision integration for contact operations (pushing, drilling, sensor installation). Control methods leverage passivity-based approaches, graph theory, and sensitivity optimisation. The work includes simulation (Gazebo/ROS2) and experimental validation on PRISMA Lab platforms.

TOOLS

Simulation & Middleware: ROS2 (Humble), Gazebo GZ, Matlab/Simulink

Languages & Libraries: Python, C++, OpenCV (for vision-based tracks), PX4 Autopilot (for drones)

Other: GitHub, Docker

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KEYWORDS

multi-robot coordination; aerial manipulation; collaborative transport; force-vision control; connectivity maintenance; inspection and maintenance

EXAMPLES / POSSIBLE ACTIVITIES

• Track 1 – Robust Collaborative Transport of an Object by Aerial Manipulators

Develop trajectory planning algorithms for a team of aerial manipulators that collaboratively transport a common object via cables. The main challenge is to compute trajectories that are robust to parametric uncertainties (e.g., payload mass, cable lengths, inertia, friction).

• Track 2 – Cooperative Push & Slide

Design leader–follower control strategies for cooperative push & slide. A tilting drone (leader) equipped with a force sensor guides the interaction; one or more followers (non-tilting) maintain formation and share the load. Goal: formation stability and contact force distribution.

• Track 3 – Cooperative Force-Vision Control for Pushing/Drilling

Develop a dual-drone system for contact operations (pushing, sensor installation, drilling). One drone performs the physical task with force control; a second drone, equipped with a camera, provides visual feedback while autonomously choosing the optimal viewpoint (next-best-view) to guide the operation. Objective: robust integration of force and vision in a leader–follower setup.

PREREQUISITES / NOTES

Recommended courses: Field and Service Robotics, Robot Interaction Control, Robotics Lab, Control Engineering.

Recommended skills: Python/C++, familiarity with ROS/ROS2, advanced knowledge of control theory.

Target degree: Master's in Automation and Robotics Engineering.

Note: Tracks 1 and 2 are self-contained; Track 3 requires acquiring some knowledge of computer vision techniques.

RELATED BIBLIOGRAPHY

- ROS2 Documentation – <https://docs.ros.org/en/humble/>
- Gazebo Simulator – <https://gazebo.org/>
- C. Gabellieri et al., "Equilibria, Stability, and Sensitivity for the Aerial Suspended Beam Robotic System Subject to Parameter Uncertainty," (*IEEE Transactions on Robotics*, 2023).
- S. D'Angelo et al., Semi-autonomous unmanned aerial manipulator teleoperation for push-and-slide inspection using parallel force/vision control (*Robotics and Autonomous Systems*, 2025).
- F. Pagano et al., "Multi-Robot Nonlinear Model Predictive Control for Persistent Monitoring," (*IEEE Transactions on Control Systems Technology*, 2026).
- V. Lippiello et al., "Image-Based Visual-Impedance Control of a Dual-Arm Aerial Manipulator" (*IEEE Robotics and Automation Letters*, 2018).

[AerRob-2] – Touching the World with Drones: Tilting UAVs for Contact-Rich Aerial Manipulation

Thesis sheet · PRISMA Lab



Tilting Aerial Manipulator



Tilting H-shaped UAV



Haptic Device



Omnidirectional UAV

THESIS OVERVIEW

Tilting and omnidirectional UAVs are particularly promising for aerial manipulation because they can decouple position and attitude control, making physical interaction with the environment more stable and controllable than with conventional multirotors.

Main topics are haptic teleoperation, object pushing, redundancy allocation, autonomous navigation for environment interaction, and sensor fusion for position estimation under shocks and vibrations. Work includes simulation (Gazebo/ROS) and validation on real platforms (Baby Koala, NDT drone) with experiments in the Flying Arena.

TOOLS

Hardware Platforms: Tilting drone, aerial manipulator, Baby Koala, NDT drone, Flying Arena, Pixhawk, Haption haptic device

Software & Simulation: ROS/ROS2, Gazebo (GZ sim), PX4 Autopilot, Matlab

Languages: C++, Python

AI/ML (AI track): PyTorch/TensorFlow, world models, actor-critic

Other: Docker, GitHub

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KEYWORDS

tilting UAV; physical interaction; haptic teleoperation; robust estimation; redundancy allocation; autonomous navigation; actor-critic MPC

EXAMPLES / POSSIBLE ACTIVITIES

• Track 1 – Shared Control for Haptic Teleoperation of Aerial Manipulators

Develop and compare shared control algorithms for haptic teleoperation of aerial manipulators. Minimise operator's physical/cognitive effort through haptic guidance. Test in simulation (Gazebo) and on real robots.

• Track 2 – Energy-aware Object Pushing for Tilting Drones

Model drone-object interaction and minimize energy consumption during stable pushing. Validate in simulation and real experiments. The approach may include optimisation-based techniques, adaptive force modulation, or learning-based policies.

• Track 3 – Analysis, Synthesis and Comparison of Allocation Strategies for Tilting Drones with Redundancy Resolution

Study and compare allocation matrix strategies for tilting aerial platforms, focusing on efficient actuator redundancy resolution. Optimise for tasks with multiple priorities, test in simulation.

• Track 4 – AI Approaches for Physical Interaction

Develop and integrate AI algorithms for tilting drone control in physical interaction tasks. Focus on actor-critic MPC that combines reinforcement learning (policy) with model-based optimisation to guarantee stability and force adaptation. Apply to pushing, perching, or non-prehensile manipulation with tilting drones.

PREREQUISITES / NOTES

Recommended courses: Field and Service Robotics, Robot Interaction Control, Robotics Lab, Control Engineering.

Recommended skills: Python/C++, familiarity with ROS/ROS2, advanced control theory. For Track 4: basic knowledge of reinforcement learning.

Target degree: Master's in Automation and Robotics Engineering (or related).

Note: Each track can be assigned to a different student. Hardware (Baby Koala, NDT drone, haptic device) available at PRISMA Lab.





RELATED BIBLIOGRAPHY

- Ruggiero et al., "Aerial Manipulation: A Literature Review" (IEEE RAM, 2018)
- S. D'Angelo et al., A Semi-Autonomous Aerial Platform Enhancing Non-Destructive Tests (MDPI Drones).
- S. D'Angelo et al., Semi-autonomous unmanned aerial manipulator teleoperation for push-and-slide inspection using parallel force/vision control (RAS 2025).
- ROS2 Documentation – <https://docs.ros.org/>
- Gazebo Simulator – <https://gazebo.org/>

[AerRob-3] – Design, Build, Fly: Innovative UAV Platforms for Real-World Missions

Thesis sheet · PRISMA Lab



			
Aircraft for urban mobility	KOALA Drone	Dual-axis Tilting UAV	Mini Tilting UAV

THESIS OVERVIEW

The thesis will be carried out as an internship at Neabotics s.r.l., in collaboration with PRISMA Lab, giving the student the opportunity to work on industrially relevant aerial robotic platforms and real prototyping activities.

This category focuses on non-conventional aerial platforms: vertical take-off and landing (VTOL) **aircraft for urban mobility**, omnidirectional tilting drones, **hybrid drones**, and perching systems on infrastructure. The goal is to develop modelling, control, and transition strategies between different flight phases, ensuring robustness and adaptability in real-world scenarios. Work includes customization of PX4 firmware, 3D prototyping, simulation (Gazebo/ROS2) and experimental validation.

TOOLS

Hardware Platforms: X8 tilting drone, amphibious drone, mini tilting drone

Autopilot & Sensors: PX4 Autopilot, Pixhawk

CAD Design: Fusion 360, Catia

Software & Simulation: ROS2, Gazebo, Matlab/Simulink, Python, C++

Other: Flying arena, Docker

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KEYWORDS

VTOL; amphibious drone; perching; impedance control; tilting drone; sim-to-real; field and service robotics; robot interaction control.

EXAMPLES / POSSIBLE ACTIVITIES

• Track 1 – Modelling, Identification and Control of a VTOL Aircraft

Develop the dynamic model, identify parameters, and design a controller for an electric vertical take-off and landing flying taxi (wingless electric vertical take-off and landing platform). Validate in simulation (ROS2/Gazebo) and prepare for real-world tests.

• Track 2 – Control of an Unmanned Aerial System for Landing on Power Lines / Pipes

Apply interaction control theory for perching manoeuvres (attaching to structures). Use a tilting drone with gripping claws, implement impedance control, and experimentally validate on refinery pipelines.

• Track 3 – Dual-Axis Tilting UAV Based on Crazyflie Quadrotors with Passive Gimbal Mechanism

Modelling and control of a novel tilting UAV composed of four Crazyflie nano-quadrotors connected through a passive gimbal mechanism. The gimbal allows relative rotations around two axes, enabling the overall system to generate thrust vectoring without tilting the entire frame.

• Track 4 – Design and Control of an Omnidirectional Mini Tilting Drone

Develop a mini drone with tilting propellers for independent force and moment generation. CAD design (Fusion, Catia), integrate sensors for non-destructive testing (NDT), and implement a control algorithm for safe interaction with complex surfaces.

• Track 5 – Modelling, Estimation and Control of UAVs with Reconfigurable Payloads

Develop a multirotor UAV equipped with asymmetric and reconfigurable payload configurations. Analyze the effects of payload position and mass distribution on vehicle dynamics. Design modular payload support structures and investigate their impact on flight performance. Develop algorithms for online estimation of payload parameters and center-of-gravity variations using onboard measurements. Finally, implement and validate control strategies capable of compensating for payload-induced disturbances.

PREREQUISITES / NOTES

Recommended courses: Field and Service Robotics, Robotics Lab, Control Engineering, Mechatronics classes, Mechanical classes

Recommended skills: Python/C++, familiarity with ROS2 and PX4 firmware, advanced control theory. For Track 4: CAD skills (Fusion/Catia) are beneficial. Track 5 requires basics knowledge of mechanics.

Target degree: Master's in Automation and Robotics Engineering, Mechatronics Degree, .

Note: This thesis will be carried out as an internship at Neabotics s.r.l., in collaboration with PRISMA Lab. The specific activity will be selected among the proposed tracks according to the student's profile and the company/lab needs.

RELATED BIBLIOGRAPHY

• PX4 Autopilot Documentation – <https://docs.px4.io/>

• ROS2 Documentation – <https://docs.ros.org/>

• Gazebo Simulator – <https://gazebo.org/>

• Y. Su, P. et al., "Nullspace-Based Control Allocation of Overactuated UAV Platforms" (IEEE Robotics and Automation Letters, 2021)

• J. Haugen et al., Measurements and modelling of the three-dimensional near-field dispersion of particulate matter emitted from passenger ships in a port environment (Atmospheric Environment, 2022)

[AerRob-4] – Smart Drones for Sustainable Farms: Autonomous Ammonia Mapping

Thesis sheet · PRISMA Lab



<p>Ammonia Measurement</p>	<p>Path Planning</p>	<p>Grid Map</p>	<p>UAVs Swarm</p>

THESIS OVERVIEW

Autonomous environmental monitoring can help improve sustainability, animal welfare, and safety in livestock facilities by providing spatially detailed information about ammonia concentration and related environmental variables. This thesis focuses on the development of intelligent strategies for autonomous UAVs operating in livestock farming environments. The aim is to enable a drone to autonomously select the **most informative locations for measuring ammonia concentration**, instead of following predefined inspection paths. The UAV will continuously analyze environmental data and **dynamically decide where to sample** next in order to improve the quality of the reconstructed ammonia map while reducing mission time and energy consumption. The proposed approach will be implemented and tested within a ROS2/PX4 framework and validated in simulation using Gazebo, with realistic models of livestock environments and environmental variables such as ammonia, temperature, humidity, and airflow.

TOOLS

Hardware Platforms: PX4-based quadrotor UAVs, indoor aerial robotic platforms

Autopilot & Sensors: PX4 Autopilot, Pixhawk, environmental sensors (NH₃, temperature, humidity), Intel RealSense camera

Software & Simulation: ROS/ROS2, Gazebo, PX4 SITL

Languages: C++, Python

Other: Flying arena, Docker, GitHub

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KEYWORDS

UAV; environmental monitoring; ammonia mapping; informative path planning; livestock farming; multi-UAV systems

EXAMPLES / POSSIBLE ACTIVITIES

• Track 1 – Environmental Modelling for Ammonia Mapping in Livestock Facilities

Develop a voxel-based environmental model of a livestock facility including ammonia concentration, temperature, humidity, and airflow. Implement a ROS2-based environment server to simulate sensor readings for UAV navigation and data collection. Validate the model in Gazebo with realistic farm scenarios.

• Track 2 – Identification of Optimal Sampling Locations for Ammonia Monitoring

Define and study the problem of optimal sensing point selection in dynamic environmental fields. Develop methods to identify the most informative locations for ammonia measurement based on Artificial Potential Fields, gas gradients, uncertainty estimation, and spatial distribution of gas concentration. The output of this track is a set of “optimal sampling points” used by the planning system.

• Track 3 – Informative Path Planning for Autonomous UAV Sampling Missions

Given a set of optimal sampling locations, design and implement trajectory planning algorithms that allow a UAV to efficiently visit them. The focus is on minimizing flight time, energy consumption, and measurement redundancy while ensuring full coverage of the selected informative points. Validation will be performed in ROS2/Gazebo using PX4-based UAV models.

• Track 4 – Cooperative Multi-UAV System for Distributed Ammonia Sampling (Swarm Intelligence)

Develop a cooperative system of two UAVs for environmental monitoring. The UAVs share information about sampled regions and dynamically update the selection of optimal measurement points. One UAV can explore and update the environmental map, while the second focuses on high-precision sampling of the most informative regions. The system aims to improve coverage efficiency and map accuracy through collaborative decision-making.

PREREQUISITES / NOTES

Recommended courses: Field and Service Robotics, Robotics Lab, Control Engineering, Navigation and Planning.

Recommended skills: Python/C++, familiarity with ROS2 and PX4 firmware

Target degree: Master’s in Automation and Robotics Engineering (or related).

RELATED BIBLIOGRAPHY

• PX4 Autopilot Documentation – <https://docs.px4.io/>

• ROS2 Documentation – <https://docs.ros.org/>

• Gazebo Simulator – <https://gazebo.org/>