Empa EPFL
Laboratory of Sustainability Robotics

Department of Engineering Sciences
Laboratory of Sustainability Robotics
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Student Project Task Agreement

Student:	**Name:** ______________	
	Student ID: ______________	**Department:** ______________
	University: ______________	
Thesis:	**Title:** Learning-Based Control of a Hybrid Aerial-Aquatic Multirotor	
	Kind of thesis: MSc	**Semester:** HS 2026 – FS 2027
Supervisor:	Prof. Dr. Mirko Kovac	
Advisor:	Junghwan Ro	
Co-Advisor:	Dr. Ioannis Mandralis; Dr. Pham Huy Nguyen	

Start of the project:	September 2026
Final report deadline:	TBD

1 Introduction

Aerial–aquatic locomotion is important for ocean, lake, and river exploration where efficient sampling and mapping remain major bottlenecks to large-scale scientific data-collection campaigns. A complete robotic solution that could autonomously achieve both aerial and underwater locomotion would greatly enhance researchers' ability to probe out-of-reach locations and gather valuable data. In an effort to close this gap, we are interested in using a typical quadrotor, or drone, to achieve hybrid aerial and underwater locomotion.

However, typical off-the-shelf drone control stacks are unable to track position waypoints both outside and inside the water since the onboard cascaded drone controller is tuned for flight only. When the drone meets the water, the fluid density changes by three orders of magnitude — changing the system dynamics and resulting in poor trajectory tracking or even instability.

This thesis will replace the drone control stack with a learning-based controller that can compensate autonomously for the changes of dynamics between air and water — achieving smooth aerial–aquatic locomotion. The developed controller will draw from the literature of deep reinforcement learning, simulation to reality transfer, and real-to-sim fine-tuning to achieve robust control on real hardware. The developed solution will be compared against conventional control structures like cascaded PID, or model-reference adaptive controllers that are tuned to solve the same task. The performance differences will be quantified against a comprehensive experimental test campaign of dives, aquatic exits, and general aerial/underwater waypoint tracking.

2 Objectives

This project aims to:

- Build a fully waterproof, lightweight drone. The first phase of the project will involve sourcing parts and electronics that will be waterproofed using a silicon-based coating technique. We will assemble the drone and ensure it can operate in both air and water. We have pre-existing waterproof drone designs, but the student will work on improving reliability and ease-of-use.

- Develop a massively parallelized simulation environment for an aerial–aquatic quadrotor that incorporates effects like added mass, buoyancy, interface effects, and the decrease of rotor efficiency when submerged in water. This will be based on an already working simulation environment and the aim will be to verify the correctness of the dynamics and ensure the general behavior matches experimental data.
- Develop a deep RL policy that can achieve waypoint tracking between air and water. This will involve reward design, episode definition, domain randomization, and parallelized training on the previously developed GPU accelerated simulator.
- Successfully transfer the deep RL policy that was trained in simulation to hardware and showcase waypoint tracking between air and water in our Aerial-Aquatic Arena facility which is equipped with a pool, and state-of-the-art motion tracking technology.
- Deploy two sets of conventional controllers on the hardware: 1. A cascaded PID controller with gain-scheduling based on the location of the drone relative to the water surface. 2. A model-reference adaptive controller that adapts the gains to match the changes in dynamics between air and water. The performance of the RL policy will be compared against these two to determine how and why a learned policy might contribute to solving the problem of hybrid aerial-aquatic locomotion.

3 Deliverables and assessment

The student is expected to deliver:

- A written report following the host university's guidelines, submitted by the deadline stated above.
- A final presentation to the laboratory (20 min plus questions).
- A documented code repository, comprising the extended simulation, the RL and controller implementations, and the raw validation data, structured so it can be reused directly in follow-up research projects.

Assessment follows the host university's regulations, with weight on the scientific quality of the work, the independence shown during the project, the quality of the documentation and the reproducibility of the results.

Zürich, September 2, 2026

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