Laboratory of Sustainability Robotics

Department of Laboratory of Sustainability Robotics

Empa
Überlandstrasse 129
8600 Dübendorf, Switzerland

Student:	Name:	
	Student ID:	Departement:
	University: EPFL, ZHAW, or ETHZ	
Thesis:	Title: A Modular Snap-Fit Electromagnetic Hinge for Undulatory / Jellyfish Robots	
	Kind of Thesis: MSc, BSc, or Semester Project	Semester: HS 2026
Supervisor:		
Advisor:	Mr. Ryo Kanno	
Co-Advisor:	Prof. Dr. Mirko Kovac	

Start of the Project:	01.09.2026
Deadline delivery final report:	Depends on the project type

Introduction

Electromagnetic motors are essential components for robots. They provide driving force by comsuming electrical power. For the fundamental principle of motor in general, a motor consists of stator and rotor. The stator contains winded copper coils that generate an electromagnetic field to attract and drive rotor. The rotor rotates due to the electromagnetic field generated by stator.

These motors are wildely used for underwater robots. However, the efficiency of motor in underwater environment is far lower than that of the biological muscles [1]. The main reason is that motors typically operate at high rotational speeds to generate sufficient thrust, which also results in increased drag. In contrast, swimming fish use low frequency flapping motions that reduce drag while still producing high output force. Therefore, mimicking fish locomotion offers a promising approach to improve efficiency. The fundamental research question in this field is that although many types of underwater robots have been developed already, few achieve performance and efficiency comparable to real fish [2].

In previous work, we sucessfully developed a electromagnetic flpaping fin capable of low frequency with high power output and low electrical power input. As a proof of concept for underwater application, we now aim to develop bio-inspired robots exhibiting undulatory swimming and jellyfish robot coupling with developed fins.

The initial goal of this project is to develop a bioinspired robots exhibiting undulatory swimming robot and jellyfish-like robot.

Objectives

The ultimate goal of this project is to develop a multi-modal locomotion robots. These robots are intended to operate in confined and extreme cross-environments, such as undewater and air, including locations like nuclear power plants and glaciers where human access is limited.

The work packages of this thesis are listed below.

Work breakdown

The work will be subdivided in the following tasks:

1. Literature Survey

- **Review of Aquatic Locomotion Mechanics:** Investigate the kinematics and fluid dynamics of biological undulatory swimming (e.g., fish) and jet-propulsion (e.g., jellyfish).
- **Analysis of Low-Frequency Flapping Mechanisms:** Review existing research on translating low-frequency, high-torque electromagnetic actuation into efficient underwater thrust.
- **Cross-Environment Scaling:** Study the physical requirements for transition and operation in confined, extreme cross-environments (e.g., nuclear power plants, glaciers).

2. Design and Simulation

- **Robot Multi-Body Design:** Design the mechanical structure for the **undulation swimming robot**, optimizing the multi-joint links to couple with the developed flapping fins.
    - Design the flexible bell/umbrella structure for the **jellyfish robot** to maximize water displacement during contraction.
- **Waterproofing & Environmental Isolation:** Design robust sealing, encapsulation, and pressure-tolerance techniques for the actuators and electronics to ensure survival in deep underwater or confined, hazardous environments.

3. Characterization

- **Prototyping:** Fabricate the physical structures using lightweight, waterproof, and flexible materials (e.g., soft polymers for the jellyfish body, rigid/flexible composites for the undulation joints).

- **Actuator Performance Testing:** Characterize the existing flapping fin's behavior specifically within the new robotic frameworks (measuring flapping amplitude, frequency response, and power consumption).
- **Hydrodynamic Thrust & Drag Evaluation:** Test the robots in a controlled water tank to measure thrust output, drag coefficient minimization, and net swimming velocity.
- **Efficiency Analysis:** Quantify the energy conversion efficiency and compare the performance metrics directly against real biological counter-parts (fish/jellyfish efficiency benchmarks).

4. Integration and Demonstration

- **System Integration:** Integrate the fins, power source, onboard microcontrollers, and potential sensors into fully untethered or tethered robotic platforms.
- **Locomotion Control:** Develop control algorithms for smooth undulatory wave propagation in the fish robot and synchronized pulsing intervals for the jellyfish robot.
- **Multi-Modal & Cross-Environment Testing:** Demonstrate stable underwater swimming and maneuvering for both robotic configurations.
- **Conduct preliminary testing or layout the conceptual framework** for the transition phase between underwater and air environments (multi-modal locomotion).
- **Application Assessment:** Evaluate the robots' performance capabilities against the constraints of targeted fields like nuclear plant inspection and glacier exploration.

The work location will be the Laboratory of Sustainability Robotics at Empa (Dübendorf, Zurich) and will be conducted in collaboration with the EPFL. The formal supervision will be performed by (Host university supervisor to be decided). The project starting day would be discussed with Ryo Kanno.

Requirements

- Student belongs either EPFL, ZHAW, or D-MAVT of ETHZ.
- Student is highly motivated for engineering-based research topic mechanical engineering).
- Student has strong experience of CAD

Bibliography

[1] Koiri, M.K., Sharma, A.K., Jha, A. and Kumar, J., 2025. A comprehensive review of bio-inspired swimming in robotic fishes. *Sensors and Actuators A: Physical*, p.116913.

[2] Ijspeert, A., Mondada, F., Standen, E. and Theraulaz, G., 2026. Swimming with robots: investigating fish locomotion, sensing, and schooling behavior with robotic swimmers. *Nature Communications*.

Zürich, 09/06/2026

Supervisor:

Advisor:

Mr. Ryo Kanno,
EMPA Dübendorf

Co-Advisor:

Prof. Mirko Kovac,
EMPA Dübendorf

Student: