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|---------------------------------|---|----------------|-------------------|
| Title | Plant grippers for non-invasive environmental exploration robotics | | |
| Supervisor | Prof. Dr. Mirko Kovac | Advisor | Dr. Kyung-Sub Kim |
| Laboratory / Institution | Laboratory of Sustainability Robotics EPFL ENAC IIE (Lausanne) and Empa (Dübendorf, Zurich) | | |
| Research Site | GR B2 390, EPFL ENAC IIE LSR | | |
| Project Period | 01.07.2026 - 31.12.2026 (To be discussed) | | |
| Contact | kyung-sub.kim@epfl.ch (Dr. Kyung-Sub Kim) | | |
| Requirements | <i>The student belongs to EPFL.</i> The student is motivated to work on an interdisciplinary research topic encompassing material/electrical/ environmental/mechanical science & engineering. | | |



Figure 1. Previously reported shrimp shell-derived biohybrid gripper (left)^[1], sundew (right)^[2] as inspiration for plant-based hybrid grippers.

Introduction

With the recent advances in robotics, increasing attention has been directed toward **bio-hybrid robotics for environmental exploration, biological sampling, and soft manipulation applications**. Unlike conventional rigid grippers, bio-hybrid grippers utilizing biological structures offer unique advantages such as **high compliance, low-power actuation, and adaptability to complex environments**. Recent studies have demonstrated shrimp shell-derived chitin soft grippers, necrobionic grippers using post-mortem spiders, and bio-hybrid systems employing live snails mounted on drones for gripping and attachment functions, highlighting the potential of nature-derived robotic structures^[1,3,4]. These systems are attracting considerable interest as next-generation exploration robotic platforms due to their ability to achieve high energy efficiency and environmental adaptability without complex actuation mechanisms.

However, existing **animal-based bio-hybrid systems may involve ethical concerns** regarding the acquisition and maintenance of biological tissues, as well as limitations associated with biological degradation, hygiene issues, and limited operational lifetime. In particular, the use of living organisms or post-mortem biological tissues may impose social and ethical constraints on the large-scale deployment of environmental exploration systems. In contrast, **plant-based bio-hybrid systems involve significantly fewer ethical concerns than animal-based systems while offering substantial advantages in sustainability and non-invasive operation.** Plants can passively or actively change their structures in response to external stimuli while achieving adaptive mechanisms without nervous systems. For example, the Venus flytrap performs rapid closing motions upon mechanical stimulation, while sundew captures small insects using mucus-based adhesive surfaces. Such plant-derived structures are highly suitable for micro-organism collection, low-damage sampling, and environmentally friendly robotic platforms.

In this project, **we propose a plant-based hybrid gripper utilizing carnivorous plant structures such as Venus flytrap and sundew.** To achieve this goal, the structural characteristics, stimulus-response mechanisms, and surface adhesion properties of the plants will be systematically investigated, followed by the development of structural designs and actuation methods for robotic gripper integration. Furthermore, the **plant-based gripper will be integrated with drone platforms to realize environmentally friendly exploration robotic systems capable of low-damage collection of insects and micro-organisms in natural environments.** Ultimately, this study aims to establish a new strategy for non-invasive and eco-friendly bio-hybrid exploration robotics through the integration of natural biological structures and robotic systems.

Objectives

- Development of plant-based hybrid gripper structures and optimization of structural stability
- Realization of insect capturing and sampling mechanisms based on plant stimulus-response behaviors
- Development of an environmental exploration robotic system through integration of plant-based grippers with drone platforms

Work breakdown

- Literature review
 - Existing bio-hybrid grippers and necrobotic systems
 - Structural characteristics and stimulus-response mechanisms of carnivorous plants
 - Eco-friendly soft robotics and environmental exploration robotic systems
- Experimental training

- Laboratory safety training and training on equipment operation (optical microscope, laser cutting machine, 3D printer, high-speed camera, etc.)
- Training on structural design and visualization software (Origin, Arduino, AutoCAD, Rhino, KeyShot, etc.)
- Acquisition of fundamental skills for plant sample preparation and bio-hybrid structure fabrication
- Material and structure optimization
 - Mechanical characterization of Venus flytrap- and sundew-based structures
 - Optimization of adhesion properties and stimulus-response speed
 - Structural optimization for low-damage insect capturing
 - Evaluation of structural stability and cyclic operation behavior under various environmental conditions
- Device fabrication
 - Fabrication and structural integration of plant-based hybrid grippers
 - Implementation of stimulus-response measurement systems through electrode and sensor integration
 - Fabrication of lightweight gripper modules for drone platforms
- System demonstration
 - Demonstration of a drone-gripper integrated system for insect and micro-organism collection in natural environments
 - Evaluation of non-invasive sampling performance and environmental adaptability
- Report writing
 - Acquisition of knowledge on report writing and presentation material preparation

References

- [1] S. Kim et al., Dead Matter, Living Machines: Repurposing Crustaceans' Abdomen Exoskeleton for Bio-Hybrid Robots. *Adv. Sci.* **13**(15), e17712 (2025)
- [2] URL:
https://newsteacher.chosun.com/site/data/html_dir/2022/08/14/2022081401021.htmlelectronics/?srsltid=AfmBOor9OvBJ7htB1_9UZ8rIEmpwK2Y2Bf2BD1_vAxeiJahx8IoexgEg
- [3] T. F. Yap et al., Necrobotics: Biotic Materials as Ready-to-Use Actuators. *Adv. Sci.* **9**(29), 2201174 (2022)
- [4] J. Galipon et al., Biological Organisms as End Effectors. *arXiv:2306.03906* (2023)