Development of Morphing Ducts for Resilient and Reconfigurable Multimodal Robots

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The AS2M Department at the FEMTO-ST Institute, Université Marie et Louis Pasteur, invites applications for a fully funded 3-year PhD position in Soft Robotics. The position is expected to start in October 2025. It will be in collaboration with ISM Marseille.

1 Context and Objective

Multimodal mobile robots have recently achieved major breakthroughs in combining various locomotion strategies to improve adaptability and performance. However, their deployment in unstructured and unpredictable environments remains a challenge due to limited resilience to impacts and collisions [SKN+23].

The ResiRob project aims to enhance the physical resilience of such robots by developing structures that can absorb shocks, sense collisions through embedded proprioception, and recover dynamically through adaptive reconfiguration. The central concept is to design morphing ducts—deformable aerodynamic or structural channels integrated within the robot's body—that adapt their shape in response to collisions or environmental changes [DPCPA22] [GRP+24].

The PhD work will focus on the design, modeling, and control of these morphing structures, exploring materials and actuation strategies suitable for rapid and reversible shape changes. The goal is to implement these systems in a hybrid aerial-ground robot prototype capable of switching between flight and ground locomotion while maintaining operational integrity after collisions.

This research will contribute to building resilient robotic platforms for critical applications such as search and rescue, exploration, and environmental monitoring.

2 Scientific content

This PhD project aims to develop new methods for designing soft actuators fabricated using additive manufacturing techniques. It will address the scientific and technological

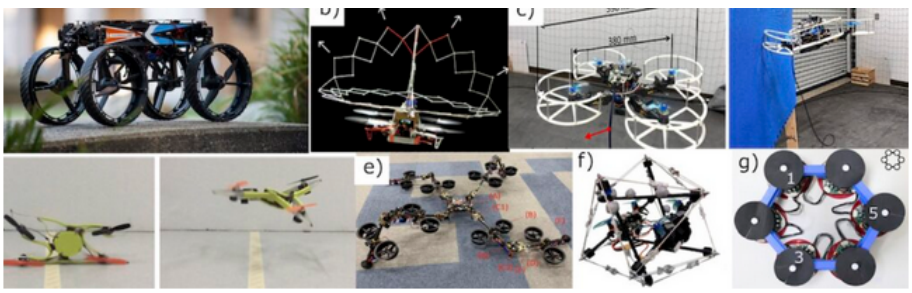

Figure 1: Several examples of resilient or multimodal robots

challenges involved in achieving actuator designs that meet specific performance requirements (e.g., stroke, force generation).

The multi-material design of the soft actuator will be subjected to an optimization workflow to meet the functional and mechanical specifications derived from the system architecture. This step will integrate modeling results to ensure physical realism and simulation accuracy.

Special attention will be given to the design parameters of the soft actuator, including surface area, wall thickness, inflated volume, and material properties (e.g., Young's modulus), to ensure precise and reliable actuation. Optimization algorithms, supported by finite element modeling (FEM), will be employed to refine the actuator design based on mechanical performance criteria and its integration within the complete multimodal system, while incorporating realistic models from prior studies.

The results will guide the final design and integration of soft actuator with complementary components before full integration into the multi-modal robot prototype.

3 Profile

We are looking for a highly motivated, creative, and ambitious student with a good command of English (written and spoken), who can work well in a team as well as independently and quickly acquire knowledge in new topics. The ideal candidate must fulfill the following requirements:

- Master degree in mechanical, mechatronics, robotics engineering or equivalent with distinction
- Strong background in solid mechanics, soft mechanics, mathematics, and manufacturing
- Familiar with Matlab, Python, C++, CAD softwares and Finite Element Methods
- Innovative and entrepreneurial mindset

4 Additional information

AS2M department is a rich environment for innovation within robotics and automation. The team RoMoCo is a new and growing research group at the institute. We design, build and program next-generation robots that use compliance as part of their intelligence to adapt to complex tasks.

For more information about the RESIROB project, please visit: https://resirob.cnrs.fr/

5 Application

Please send your Curriculum Vitae (CV), a covering letter including research statement and **the last year marks** to Wissem Haouas (wissem.haouas@femto-st.fr), Stéphane Viollet (stephane.viollet@univ-amu.fr) and Kanty Rabenorosoa (rkanty@femto-st.fr).

References

[DPCPA22] Paolo De Petris, Stephen J Carlson, Christos Papachristos, and Kostas Alexis. Collision-tolerant aerial robots: A survey. *arXiv preprint arXiv:2212.03196*, 2022.

[GRP+24] Luca Girardi, Giada Risso, Laura Pesaresi, Paolo Ermanni, and Stefano Mintchev. Multistable composite laminate grids as a design tool for soft reconfigurable multirotors. *Advanced Intelligent Systems*, page 2400356, 2024.

[SKN+23] Eric Sihite, Arash Kalantari, Reza Nemovi, Alireza Ramezani, and Morteza Gharib. Multi-modal mobility morphobot (m4) with appendage repurposing for locomotion plasticity enhancement. *Nature communications*, 14(1):3323, 2023.