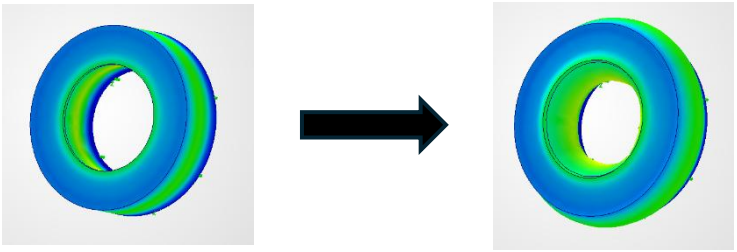
Thesis Title: "Development, Manufacturing, and Design Optimization of Pneumatic Soft Actuators"





Abstract

Soft actuators can establish contact with their surroundings through controlled deformation generated by pneumatic actuation. By exploiting this property, the aim of this thesis is to develop pneumatically actuated soft actuators and investigate how their geometry, material properties, and manufacturing parameters influence the energy required to achieve a desired deformation. Potential applications include anchoring mechanisms for soft robotic locomotion and stabilization in confined environments.

This thesis focuses on the design, fabrication, and experimental evaluation of soft actuators to investigate the relationship between pneumatic energy input and structural deformation. Design optimization will be performed using Constrained Bayesian Optimization (CBO), with a Gaussian Process (GP) surrogate model and an Expected Improvement (EI) acquisition function. The GP surrogate will predict actuation energy and deformation while quantifying the uncertainty associated with each prediction. At each iteration, CBO will select the design with the highest constrained Expected Improvement, prioritizing reduced actuation energy while satisfying the required deformation and safe-pressure constraints.

Key Research Objectives

- Design and manufacture pneumatically actuated soft actuator prototypes, exploring different geometries and fabrication parameters.
- Develop an experimental setup to characterize deformation and pneumatic energy input during actuation.
- Apply constrained Bayesian optimization to reduce the energy required to achieve a target deformation while satisfying safe operating-pressure constraints.
- Optimize actuator designs to reduce the energy required to achieve a target deformation.

Expected Contributions

✓ Insights into the influence of geometry, material properties, and manufacturing parameters on energy-efficient deformation.
✓ Development of a fabrication and testing framework for pneumatically actuated soft actuators.
✓ Experimental validation of an optimized actuator design based on its deformation behavior and actuation energy requirements.

Background Knowledge

• A solid foundation in robotics, mechatronics, mechanical engineering, or a related field.
• Basic computer-aided design (CAD) skills and an interest in prototyping and manufacturing.
• Basic programming skills for experimental control and data acquisition.

Experimental & Analytical Thinking

▪ Ability to design experiments, analyze measurements, and validate results.
▪ Strong problem-solving mindset for addressing challenges related to soft material fabrication, pneumatic actuation, and mechanical design.

What Will You Learn?

This thesis will provide hands-on experience and deepen your expertise in:

- **Design and Manufacturing:** Gain practical experience in soft actuator design, mold development, and fabrication techniques such as 3D printing and silicone casting.
- **Experimental Evaluation:** Learn how to characterize structural deformation and quantify the pneumatic energy required for actuation.
- **Design Optimization:** Explore how systematic changes in geometry and fabrication parameters can reduce actuation energy requirements.
- **Data-Driven Design Optimization:** Gain experience with Latin Hypercube Sampling, Gaussian Process surrogate modelling, and constrained Bayesian optimization using an Expected Improvement acquisition function.
- **Multidisciplinary Research:** Work at the intersection of soft robotics, materials, manufacturing, and mechanical design.

Supervisors: Dimitrios Xydianos (email: dimitrios.xydianos@taltech.ee) , Tayyab Tahir

Experiments will take place within the lab of the Centre for Biorobotics.

Actuator Display