University of Stuttgart

Institute for Nonlinear Mechanics

Bachelor's thesis
Master's thesis
Term paper

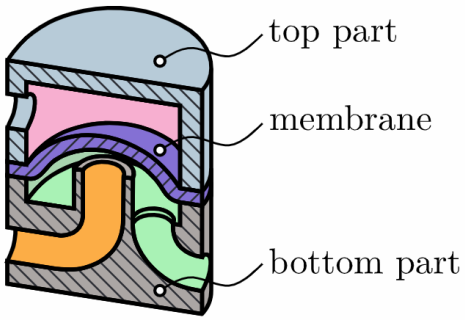
Control of Soft Robotic McKibben Actuators using Fluid-Driven Membrane Valves

Topic Areas:	Control Theory, Soft Robotics, Simulation, Hardware Implementation
Advisor:	Nikola Velimirović, nikola.velimirovic@inm.uni-stuttgart.de
Responsible Professor:	Prof. C. David Remy
Prerequisites/Prior Knowledge:	Control Theory, Matlab

Robotic systems based on a soft-bodied architecture have the potential to revolutionize the field of robotics. Among many other benefits, they allow for a reduced cost of manufacturing, safer human-robot collaboration, and the handling of delicate objects.
In this project, we are establishing the foundation for controlling fluid-driven hyper-actuated soft robots with potentially hundreds of actuator cells. To avoid that each of these cells is connected to a dedicated fluid supply line, we will do so via fluid-driven membrane valves [1]. These valves can be seen as the fluidic equivalent to an electronic transistor and they can be directly embedded into the structure of the actuator to create fluid-based logic circuits that can regulate a whole array of soft actuator cells. Such membrane valves have, however, a nonlinear characteristic and feature unstable internal feedback, which poses a substantial challenge for control.

In this project, you will tackle this challenge by developing control algorithms and dedicated hardware for the pressure control of a soft robot made from McKibben actuators.
Starting with the control of a single actuator cell, you will explore the use of different control techniques in simulation and hardware experiments. Initially, you will do so by using fluid control lines to directly regulate the inflow and outflow of the actuator cell. In this context, you will also modify the membrane valves to reduce the inherent nonlinearity and instability. You will then move on to develop and manufacture fluid logic systems, which will allow us to control an array of actuators through a demultiplexing circuit. As a starting point, you will first attempt to control the two valves of a single actuator cell via a single fluid line.
The overall scope of this project can be adjusted based on the thesis type.

Hyper-Actuated Soft Robot Concept for Search & Rescue Missions



Cross-Section of the Fluid-Driven Membrane Valve

[1] Dai, Velimirović et al. *Modeling and Experimental Validation of High-Flow Fluid-Driven Membrane Valves for Hyper-Actuated Soft Robots*, 2024, Advanced Intelligent Systems