SUBPROJECT 9: Control of complex three-dimensional spatial deformations of soft prototypes driven by SMA wires

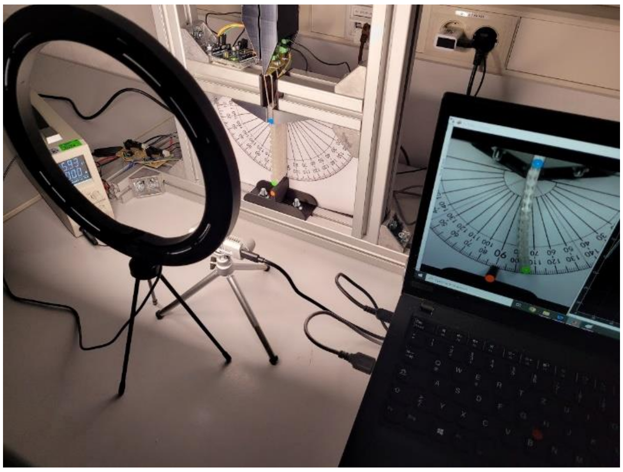
K. Röbenack in cooperation with N. MODLER;
external advisor: N. GEHRING (JKU Linz, AUT)

Motivation

The potential to enhance the capabilities of soft-stiff prototypes actuated with shape memory alloys (SMAs) towards achieving three-dimensional (3D) deformations taking into account the integration of an end effector, could be faced by developing suitable control strategies tailored to the desired tasks. These prototypes can achieve agile and precise manipulation by combining control strategies, taking advantage of advancements in sensing technologies, and utilizing model-based control techniques. Through this research, we aim to control the 3D spatial deformations in a targeted and reproducible manner by detecting the dynamic features of the prototypes using integrated sensor systems, constructing dynamic models, and designing real-time control algorithms.

State of the art and previous research

The literature encompasses various shapes and approaches for actuators driven by SMA wires. In the first cohort, models were developed to describe the one-dimensional deformation of fiber rubber composites, integrating theoretical and experimental analyses. Robust controllers were then designed based on these models and tested with various fiber rubber composite samples [1,2]. In the second cohort, the research extended beyond one-way actuators to incorporate two-way actuators. The accuracy of the measurement system implemented using computer vision in real-time, played a crucial role in enhancing the accuracy of the model and the performance of the proposed control laws. These control laws focus on tasks such as regulating the angle of deformation for different set points and trajectory-tracking control algorithms [2-5].



Scientific questions and project objectives

This research aims to understand the three-dimensional (3D) deformation features of soft-stiff prototypes driven by SMA wires manufactured by SP 11 and SP 1, and how integrated sensor systems can detect and interpret these dynamics in real time. The overarching objective is to achieve precise and agile manipulation capabilities within prototypes, enhancing their versatility and applicability. Through control algorithm design, accurate modeling strategies, and sensor feedback, the project aims to foster the reproducibility of different complex 3D deformation tasks while addressing challenges such as multi-variable control, nonlinearities, uncertainty in modeling, and obtaining reliable measurement data. By confronting these challenges, the project looks for ensure accuracy and reliability to achieve optimal performance.

The model-based controller design should take into account the models developed in SP1 and SP6. For technical demonstrators, the collaboration with SP7 and SP8 will be continued. With these subprojects, the integration of sensors and actuators into the system and the incorporation into the control loop are to be further improved. For more complex setups, direct cooperation with SP 11 will be sought.

References

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[3] Wang, Z.; Acevedo-Velazquez, A.I.; Annadata, A.R.; Winkler, A.; Röbenack, K.; Modler, N.: Closed-loop control of a 3D printed soft actuator with integrated flex sensors and SMA wires. Journal of Physics: Conference Series, 2024, 2716(1): 012050, https://doi.org/10.1088/1742-6596/2716/1/012050.

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[5] Acevedo-Velazquez, A.I.; Wang, Z.; Winkler, A.; Modler, N.; Röbenack, K.: Trajectory Tracking Control Based on Computer Vision of a Two-Way Soft Prototype Actuated with SMA Wires. GAMM 2024.