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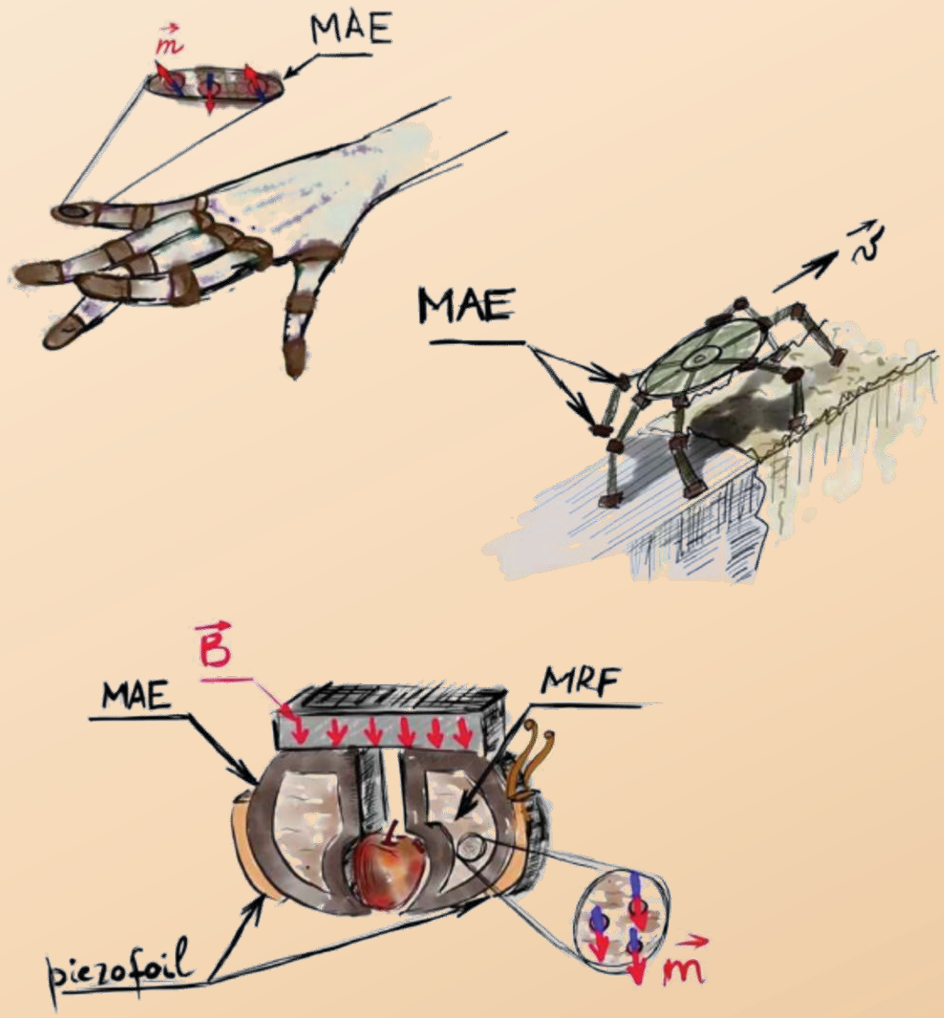

MAESTRI · BOOK OF ABSTRACTS

Magnetic Soft Matter For Robotics

2nd Annual Conference · 3-4 September 2026 · Odense, Denmark

MAESTRI Annual Conference in Odense 2026

SDU
Syddansk Universitet

Funded by the European Union

Book of Abstracts

For the given lectures and the presented posters.

2nd Annual Conference
3–4 September 2026, Odense, Denmark

Website: https://maestri-project.eu/maestri2026/

Organizing committee:
Poramate Manoonpong, Xiaofeng Xiong, Jawad Mehmood Butt
University of Southern Denmark

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Funded by the European Union

Foreword

Welcome to Odense, home to the Faculty of Engineering at the University of Southern Denmark, and welcome to the 2nd International Conference on Magnetic Soft Matter for Robotics. This conference series was initiated within the framework of the Marie Skłodowska-Curie Doctoral Network MAESTRI (Grant Agreement No. 101119614), with the aim of creating a dedicated platform for this emerging application field (magnetic soft matter for robotics), which we believe holds great promise for groundbreaking technologies in the near future. The conference series will serve as a forum for researchers from diverse disciplines and industry sectors to come together, exchange ideas, and present the latest advancements in the field. We hope your excitement for the topic will continue, and we look forward to meeting you at the next MAESTRI events.

Organizing committee

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Invited Speakers

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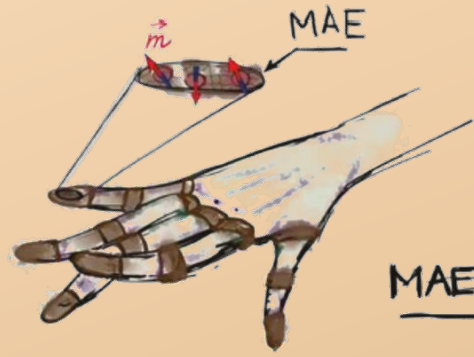

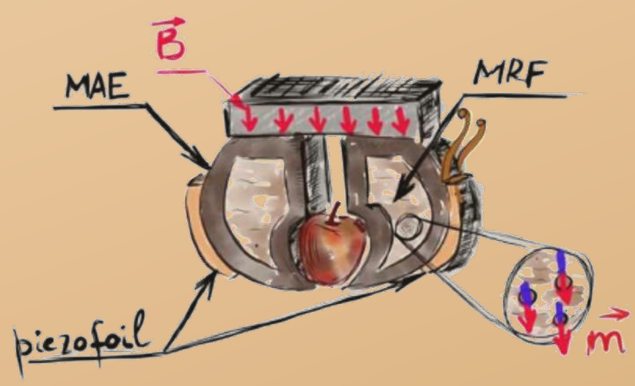

Electric field-driven morphing matter

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Magnetic fields have long been used for non-contact remote manipulate of soft robots. However, to generate such fields requires bulky and expensive electro or permanent magnets. Electric fields, in contrast, can be established using nanometre-thin and ultralight electrodes. Here we explore how electric fields can be used to remotely control new electrogel morphing matter. We present nanoparticle-loaded, ionic, and edible gel materials and show how they can be made to bend, twist, and move in non-uniform electric fields. Interactions between the materials, fields and charges also lead to emergent swarm-like collective behaviours and the potential for self- and programmed assembly of larger structures and robots.

Magnetic Composites for Soft Robotics

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Magnetic soft robotics enables lightweight, untethered systems capable of adaptive and multifunctional motion [1-2]. This talk presents a co-design framework integrating material composition, structural architecture, magnetization programming, and sustainability to engineer next-generation magnetic soft machines. First, bioinspired morphing structures are fabricated via laser powder bed fusion of a TPU/Nd-Fe-B composite [3-4]. Architected butterfly-wing designs incorporate sub-millimeter hinges, graded membranes, and programmed magnetization, enabling large-angle folding/wing-clapping, and multistable morphing through geometry and shape programming. Second, muscle-inspired magnetic actuators achieve contraction-dominated motion [5]. Zig-zag hinge and radially expandable geometries produce axial shortening, lift loads multiple times their weight, and enable gripping, crawling, and anchoring under low magnetic fields. Pre-deformation magnetization imprints functional patterns for large reversible contractions in monolithic bodies. Third, a sustainable magnetoactive composite (Figure 1) using recycled Nd–Fe–B microparticles in a gelatin-based organogel supports actuation, sensing, and closed-loop recycling [6]. Together, these platforms demonstrate tailored magnetic composites and their programmable behavior with circular material strategies for adaptive, multifunctional, and resource-responsible soft robotic systems.

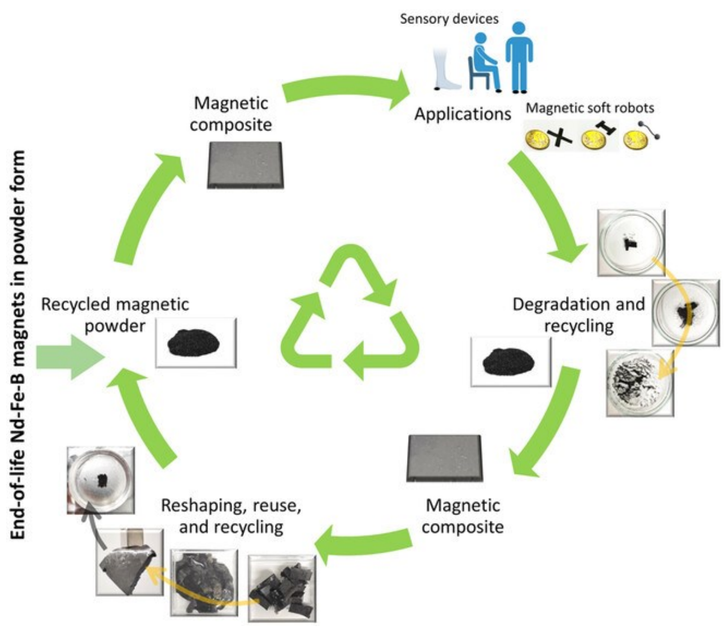

Figure 1. An overview of a sustainable, circular recycling process of magnetic composite for sustainable soft robotics.

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Magneto-elastic shells: from buckling instabilities to tunable friction

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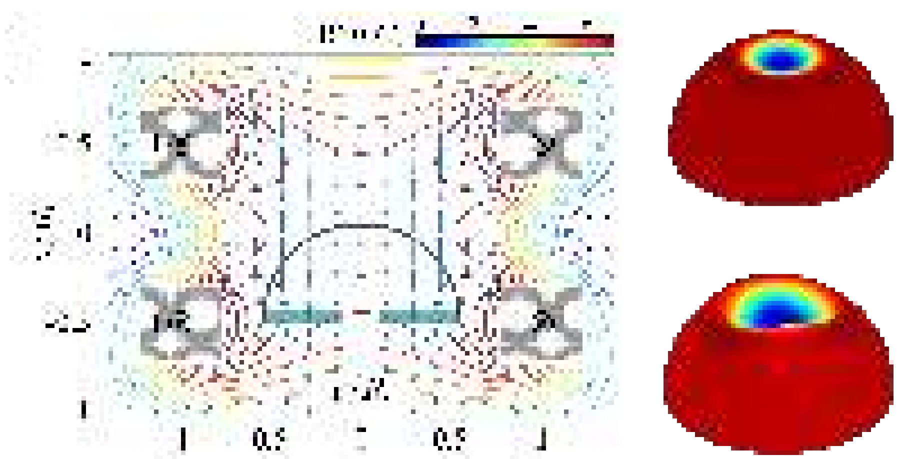
Thin elastic shells under external pressure can undergo a buckling instability, which is extremely sensitive to imperfections. While buckling has traditionally been viewed as a structural failure mechanism, it can instead be exploited as a functional design principle. In this talk, I will discuss how magnetic actuation enables active control of instability-driven behavior in thin shells, transforming buckling into a programmable mechanical response. We study hard-magnetic elastomeric shells whose deformation can be remotely controlled through external magnetic fields. Combining theoretical modeling, numerical simulations, and experiments, we demonstrate that magneto-elastic coupling enables dynamic tuning of the critical buckling pressure of shells. Building on these results, I will outline how field-controlled shell instabilities may be leveraged to design adaptive surfaces with reconfigurable topography. Arrays of magnetically responsive shells can modify contact geometry under external actuation, providing a potential route toward dynamically tunable friction. This emerging direction connects shell mechanics, magneto-elasticity, and tribology, where friction becomes a controllable outcome of instability-augmented surface morphology.



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Soft Robot Aesthetics: Leveraging Embodied-Meaning in Human-Soft Robot Interaction.

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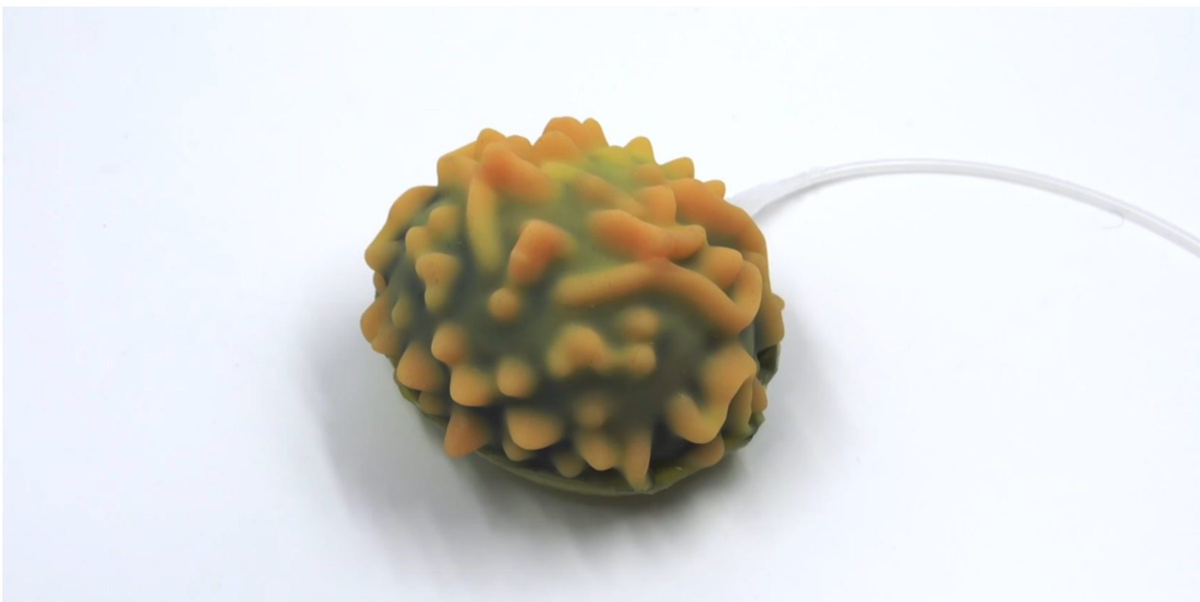
In this talk, I focus on human-robot interaction research dealing with soft robotics. Through a presentation of selected examples of our work, I will consider how aesthetic perspectives can be integrated with human-robot interaction and soft robotics design research. I argue that considerations on aesthetics are a prerequisite for actualizing the full range of possibilities for intelligent interaction soft robotics technology affords.



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Quasi-Analytic Strategies for a Powerful Modeling of Magneto-Active Elastomers

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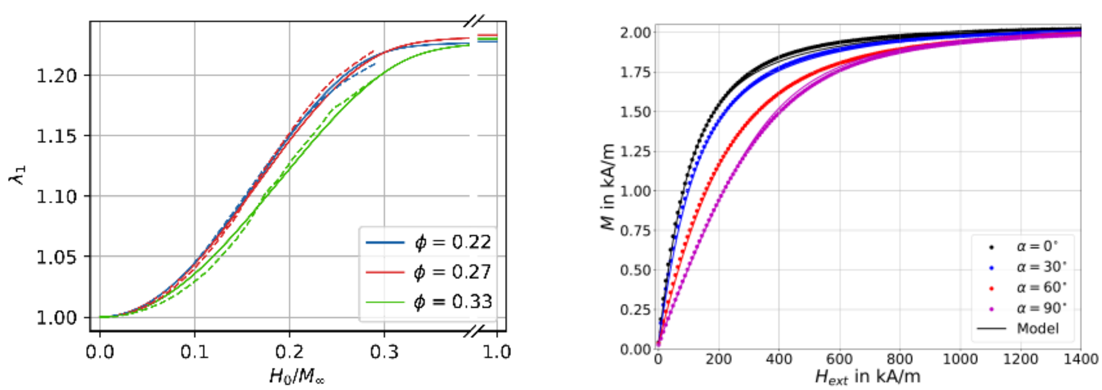
A prominent example of field-controllable functional polymers are magneto-active elastomers (MAEs). Their material properties can be remotely and reversibly changed by a magnetic field. These modifications include magnetization behavior, magnetically induced deformations and actuation stresses, as well as anisotropic enhancement of mechanical moduli depending on strength, orientation, or modulation of the magnetic field. Due to the strong magneto-mechanical coupling which is interlinked on short and long length scales, a theoretical description of the material behavior is very challenging and requires complex multi-scale models. The large computational effort together with the almost endless parameter space makes it extremely difficult to establish a comprehensive characterization of MAEs. Based on dipole interactions and effective medium theory for filled elastomers, our group introduced a physically-based unified mean-field model which is constantly being developed further. It allows to illustrate various aspects of the magneto-mechanical coupling within a single semi-analytic approach. Adapting our theory to different experimental setups, various field-induced effects can be even described within quantitative agreement [1,2,3]. I will discuss the model in general, its adaptations to specific experimental conditions and highlight some aspects of the intrinsic interplay between macroscopic and microscopic properties. Furthermore, current advances in modeling magnetic interactions beyond the classic dipole approximation will be presented. These interactions are crucial when particles get close to each other and form dense aggregates in MAEs.



Left: Comparison between experiment (dashed) and theory (solid) for field-induced deformation of isotropic MAEs [1].
Right: Comparison between experiment (dots) and theory (solid) for magnetization behavior in structured MAEs [3].

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SENSORS AND OTHER MICRO-PHOTONICS STRUCTURES CREATED AT THE TIP OF AN OPTICAL FIBER

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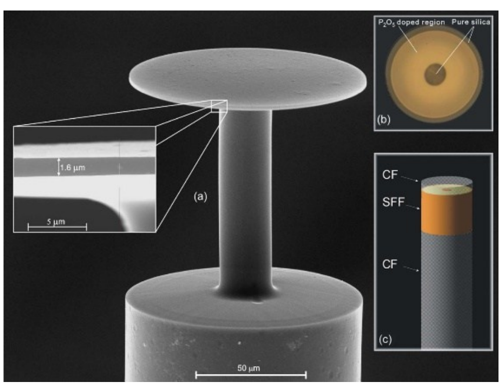
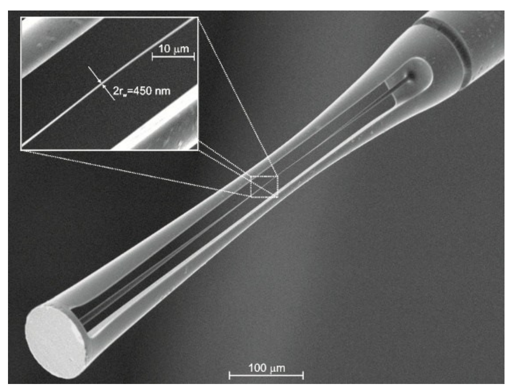
Modern fiber optic sensors (OFS) represent a paradigm shift in instrumentation, offering unique advantages such as extreme miniaturization, high sensitivity, and immunity to electromagnetic interference. This presentation highlights the R&D activities of the Laboratory for Electro-Optics and Sensor Systems (LEOSS) at the University of Maribor, which focuses on the design and fabrication of specialty optical fibers and novel micro-photonic devices. Using an in-house-developed non-lithographic process based on the selective etching of specialty doped silica fibers, we fabricate functional miniature sensors and actuators directly at the fiber tip. Our work incorporates a diverse range of sensing principles and specialty fiber applications. We demonstrate high-resolution Fabry-Perot (FP) interferometers for measuring pressure and strain, alongside advanced spectral interrogation systems for Fiber Bragg Gratings (FBG). We also present multi-parameter platforms capable of the simultaneous measurement of pressure [1], temperature, and refractive index [2]. Beyond standard interferometry, we employ vanadium-doped fibers for thermo-optic applications, such as liquid-level gauging and thermal-conductivity sensing. Furthermore, we explore contactless magneto-optic rotation sensors [3] and resonant opto-thermo-mechanical micro-actuators. In the context of robotics, our miniature all-silica sensors, some with diameters as small as 125 μm, are ideal candidates for force and tactile sensing. Their biocompatibility, fast response time, and robust design make them well-suited for, for example, medical robotics and minimally invasive surgical tools, where high-resolution feedback in confined, high-EMI environments is paramount.





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Self-Healing Polymers Advancing Sustainable Strategies in Soft Robotics

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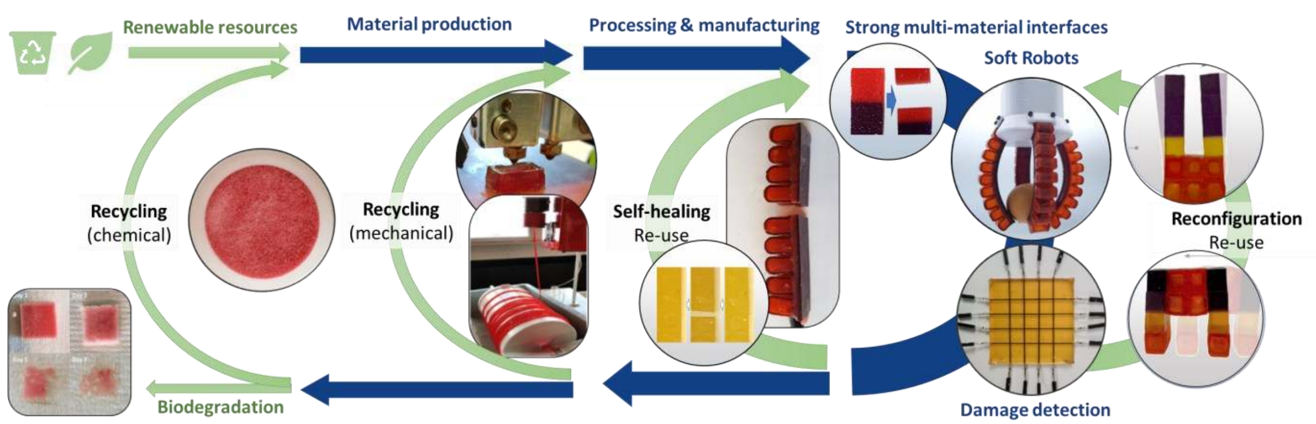
Abstract – Despite the significant potential of soft robots for new applications, their widespread adoption in industrial settings is hindered by their susceptibility to damage [1]. This clear limitation have driven the Brubotics group at VUB to develop self-healing polymers for soft robotics [2]. These are elastomers that incorporate reversible bonds, including the dynamic covalent Diels-Alder bond, enabling them to recover from macroscopic damages [3]. These were used to create various soft robots, such as soft grippers, which can fully recover from minor damages like punctures within seconds and from more significant damages, such as having one of their fingers cut in half, within minutes. As this self-healing can occur repeatedly at the same location (e.g., up to 60 cycles [4]) due to full material recovery after each healing event, these polymers have the potential to significantly extend the lifetime of soft robotic components, making them more economically competitive and sustainable across a wide range of applications. Unlike most elastomeric materials used in soft robotics (e.g., silicones), their reversible crosslinks enable recyclability through both thermomechanical and chemical reprocessing, further enhancing their sustainability and value. By combining these polymers with liquid metals such as Galinstan, it is possible to create self-healing sensors and circuits that can recover not only their mechanical integrity but also their sensory and electrical performance [5]. Moreover, they can be leveraged for damage localization and health monitoring [6]. By adjusting the polymer composition, highly flexible yet also very rigid self-healing polymers can be synthesized [7]. Utilizing the same chemistry, these polymers can form covalent bonds with one another, creating strong interfaces that enable the fabrication of durable multi-material soft robots [8]. Moreover, this approach has facilitated the development of modular soft robots, such as voxel-based designs [9], opening the door to additional sustainable strategies, including module replacement, reconfigurability, and upgradability.



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Adaptive crawling with a soft skin

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For soft, limbless robots, operating in natural settings involves embedding the right physical intelligence into the robot's morphology. This work presents Rectobot, a modular, untethered snake-inspired robot that leverages rectilinear locomotion—a specialized gait utilizing waves of muscle contraction and asymmetric ventral friction to generate forward movement. Unlike traditional serpentine robots that rely on discrete joints, Rectobot achieves locomotion through a synergy of body compliance and surface interaction enabled by mechanical metamaterials. Embedded proprioceptive sensing allows the robot to perceive body deformation and surface interaction without compromising flexibility. Using sensory feedback as input to a central pattern generator (CPG) controller, Rectobot achieves adaptive crawling across varying terrains. We argue that this combination of mechanical metamaterials, embodied sensing, and bio-inspired control offers a pathway for soft robots to navigate unstructured and natural environments. We show the design's scalability through a multi-module structure capable of propagating contraction waves, providing a robust framework for autonomous and adaptive rectilinear crawling in soft robotic systems.

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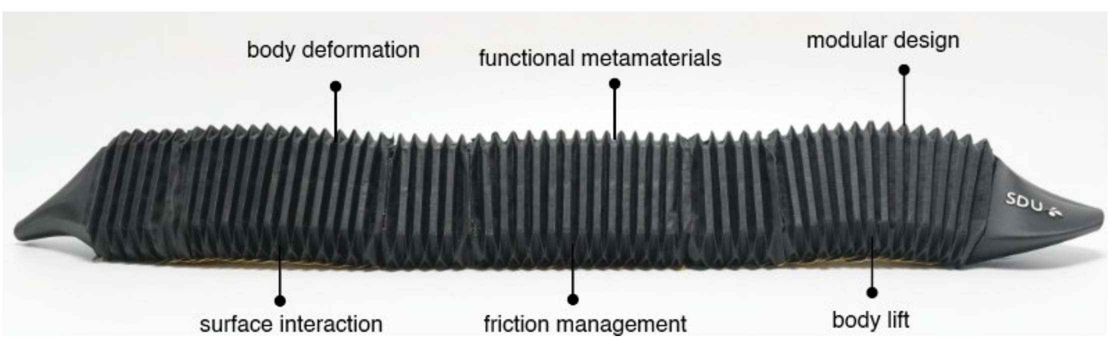

From Perception to Precision: Sensing, Modelling, and Control of Continuum Surgical Robots

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Abstract

Continuum surgical robots are increasingly used in minimally invasive procedures due to their high dexterity in confined anatomical environments. This talk presents a set of technologies for closing the control loop of continuum surgical robots. Advanced sensing techniques are introduced to enable accurate perception of robot state, while data-driven modelling methods are used to compensate for robot nonlinearities and achieve precise control. Digital twins are further leveraged as a cost-effective alternative to augment robotic data, and Augmented Reality (AR) is employed to enhance intraoperative visualization during complex procedures. The integration of these techniques is demonstrated through surgical/interventional applications such as robot-assisted endovascular interventions.

Empowering Flexible Automation: How OnRobot Gripper Solutions Drive Productivity and ROI in Modern Manufacturing

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As industries worldwide face growing challenges in labor shortages, rising production costs, and increasing demand for customization, automation is no longer optional — it is essential. However, many small and medium-sized enterprises (SMEs) still perceive robotic automation as complex, costly, and difficult to integrate. This talk explores how OnRobot is changing that perception by delivering a complete ecosystem of end-of-arm tooling built around one simple philosophy: zero complexity. OnRobot offers a unified hardware and software platform that works seamlessly across all major collaborative and light industrial robot brands, enabling manufacturers to automate faster with lower upfront investment and minimal engineering effort. From gripping and palletizing to machine tending and surface finishing, OnRobot's plug-and-produce solutions allow businesses to deploy, redeploy, and scale applications in hours rather than weeks. This presentation highlights real-world success stories from customers in manufacturing, food and beverage, automotive, and logistics, showing how the right tooling strategy can dramatically improve throughput, reduce cycle times, and deliver measurable return on investment. We also discuss emerging market trends in collaborative automation, the growing role of software-driven deployment platforms, and how OnRobot's vision aligns with the future of flexible, human-centered production environments.

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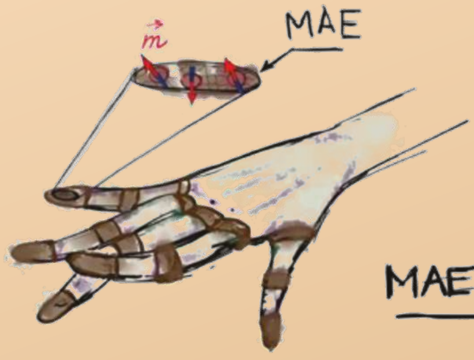
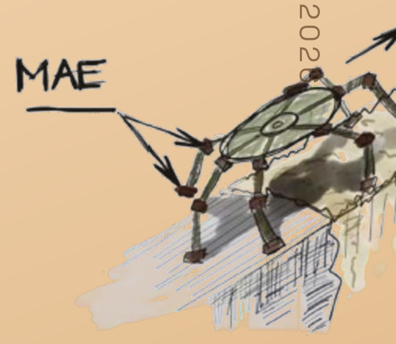
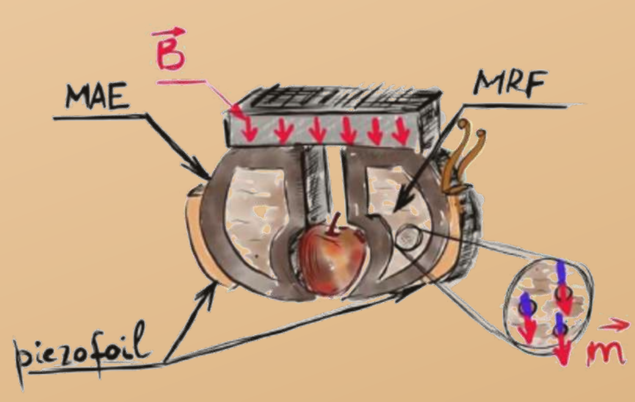
Posters

Abstracts of the posters presented at the 2nd MAESTRI Annual Conference.

MAESTRI ANNUAL CONFERENCE IN ODENSE 2026







Field-Tuneable Magnetoactive Elastomers: Matrix Formulation and Particle Alignment Effects on Dynamic Actuation

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Magnetoactive elastomers (MAEs) allow for rapid, reversible, and non-contact tuning of mechanical properties under an applied magnetic field, and this behaviour has made them attractive for soft robotics and bio-inspired actuators. Before such materials can be used in complex functional elements, however, their basic dynamic behaviour needs to be understood. In this work, we investigate a fundamental model system consisting of a single magnetoactive elastomer (MAE) cantilever in an external magnetic field.

Here, MAE cantilever beams were fabricated from three commercial elastomer matrices, each filled with 70 wt% carbonyl iron powder. Samples were cured either without an applied field (isotropic) or within a uniform magnetic field to induce particle chaining (anisotropic) in two directions, along the length and perpendicular to the length. Bending tests under an electromagnet were first used to establish how effective stiffness varied with field for each matrix formulation. For dynamic functionality, the single-cantilever model was subjected to periodic magnetic excitation using a custom rotating multi-pole magnet assembly. Video tracking was employed to capture kinematic responses, specifically deflection amplitude and angular dynamics, as a function of drive frequency and magnetic field strength.

We evaluate the interplay between matrix compliance and structural anisotropy in governing the dynamic responsiveness and operational frequency window of the cantilever. By systematically characterizing this single-beam model system, this study provides foundational insights into field-dependent mechanical behaviour, establishing the prerequisite groundwork for scaling up to more complex functional soft robotic elements, such as multi-finger grippers.

Engineering filler–matrix interfaces in hexaferrite-based magnetoactive elastomers

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Magnetoactive elastomers (MAEs) are magnetic particle-filled polymer composites capable of reversibly adjusting their mechanical properties in response to external magnetic fields, making them attractive for soft robotics, sensors, and adaptive devices [1–3]. However, achieving homogeneous filler distribution and enhanced filler–matrix compatibility remains a key challenge, as interfacial interactions affect particle aggregation and the final microstructure and magnetic response of MAEs.

In this study, poly(dimethylsiloxane) (PDMS)-based MAEs containing strontium hexaferrite (HF) microparticles were prepared to investigate how filler surface modification, concentration, and magnetic field exposure during crosslinking affect composite fabrication, its microstructure, and magnetic behaviour. Compared with untreated HF filler, DBSA surface modification improved filler distribution within the PDMS matrix and reduced particle agglomeration. Additionally, magnetic-field-assisted crosslinking induced magnetic anisotropy, which was further enhanced by DBSA modification. Ongoing investigations focus on expanding this surface-engineering approach by evaluating alternative ligands, including fatty acids and silanes. Their effects on hexaferrite–PDMS compatibility, filler distribution, microstructure formation, and magnetic response will be compared with the DBSA-modified system.

By systematically comparing different surface modification strategies, these studies aim to establish relationships between filler surface chemistry, interfacial interactions, and the resulting microstructure and magnetic response of MAEs, enabling their rational design.

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Experimental Relationship Between Axial and Transverse Young's Moduli of Magnetoactive Elastomers

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(MSCA MAESTRI Project, Grant No. 101119457)

Abstract: Magnetoactive elastomers (MAEs) are smart composite materials whose mechanical properties can be reversibly tuned by external magnetic fields, making them promising candidates for soft robotics, adaptive interfaces, and vibration-control applications. Under magnetic-field actuation, initially isotropic MAEs develop field-induced particle structures that induce mechanical anisotropy. While numerous studies have investigated the elastic response parallel to the magnetic field, the transverse mechanical behavior remains largely unexplored.

In this work, we present the first systematic experimental characterization of the transverse Young's modulus of isotropic MAEs using a micro-indentation technique. Silicone-based MAEs containing 60–80 wt% carbonyl iron particles were tested under magnetic flux densities of 240 and 360 mT, with the magnetic field applied perpendicular to the indentation direction. The experimental configuration was designed to enable a direct comparison with our previous measurements performed under axial loading.

The results show that the transverse Young's modulus increases significantly with both particle concentration and magnetic field strength, following the same overall trend as the axial response. Moreover, structural saturation is observed in the transverse direction at high particle concentrations, indicating that this phenomenon is independent of the loading direction. A quantitative comparison between the two loading configurations reveals a robust linear relationship, with the transverse Young's modulus remaining approximately 70% of the corresponding axial modulus over the entire investigated range of particle concentrations and magnetic fields.

These findings provide new experimental insight into the directional mechanical behavior of MAEs under magnetic-field actuation and establish a quantitative benchmark for future anisotropic constitutive models and the design of magnetically tunable soft materials.

Keywords: Magnetoactive elastomers, Magneto-mechanical coupling, Field-dependent stiffness, Young's modulus, Micro-indentation, Transverse elasticity

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INTEGRATED SHAPE SENSING OF MAGNETOACTIVE ELASTOMERS WITH FIBER-OPTIC BRAGG GRATING SENSORS

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Magnetoactive elastomers (MAEs) exhibit large, reversible deformations under magnetic actuation, making them promising materials for soft robotic applications. However, their practical implementation requires reliable methods for monitoring deformation and shape changes during operation. We investigate the integration of magnetically insensitive fiber Bragg grating (FBG) sensors into MAE actuators to enable strain-based reconstruction of magnetic-field-induced bending and axial deformation. Finite element method (FEM)-based simulations were employed to optimise the placement of two embedded optical fibers relative to the neutral axis (Fig. 1), while single-fiber pull-out tests quantified the interfacial bond strength between the fibers and the elastomer matrix. Ongoing work focuses on calibrating the embedded sensors for strain sensing and evaluating the influence of sensor integration on the mechanical behaviour of the actuators. The presented approach establishes the foundation for combining magnetic actuation with embedded optical sensing and provides a basis for closed-loop feedback and shape control of MAE-based soft robotic components.

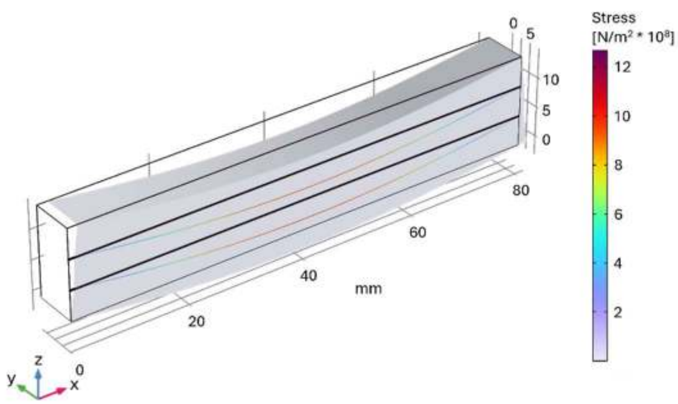

Figure 1: Simulation of stress distribution in an MAE beam with 2 embedded optical fibers

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Surface Roughness and Filler Restructuring in Magneto-Active Elastomers: Magnetically Hard versus Magnetically Soft Particles

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Magneto-active elastomers (MAEs) — composites of magnetic nano-/microparticles embedded in a soft polymer matrix — are promising for soft robotics, as their shape and mechanical properties can be controlled by an applied magnetic field [1]. Most MAEs are filled with magnetically soft (MS) particles, such as carbonyl iron powder (CIP), yet existing molecular dynamics models treat the filler as permanent point dipoles [2]. We extend such a model to include MS particles, and study the differences between thin MAE layers with MS and magnetically hard (MH) filler particles having the same saturation magnetization. We find that both MH and MS elastomers converge to the same high-field state — a labyrinth of bundled, field-aligned chains — but do so through distinct pathways: MH MAEs break their zero-field chains, which lie parallel to the MAE layer plane, and rotate them into alignment with the external field, whereas MS MAEs gradually build up field-aligned chains from neighboring particles. We show that the MS model reproduces the magnetization curves and roughness of CIP-based MAEs, for fields close to magnetic saturation, while maintaining the observed qualitative features down to lower fields [3].

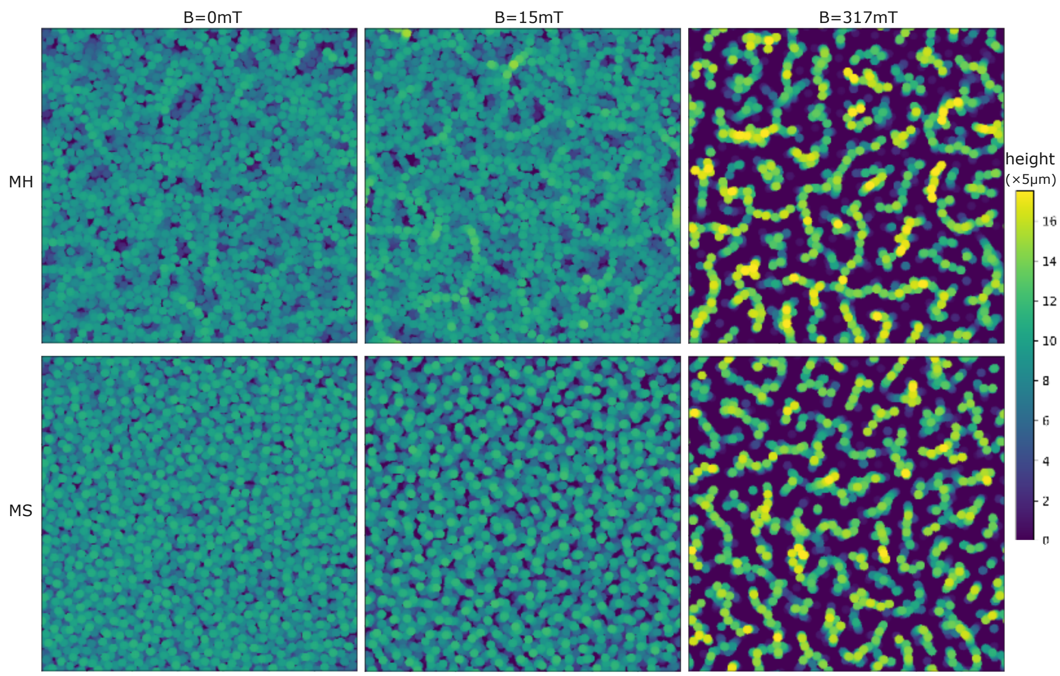

Fig. 1. Height maps of the MAE filler particles from simulation snapshots with MH or MS particles at different fields.

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Multi-modal Neural Geometric Learning for State Prediction and Tracking of Magneotactive Soft Robots with Proprioceptive and External Vision Feedback

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Magnetoactive soft robots (MSRs) are made up of magnetoactive soft or hard materials, which can be actively controlled with remote magnetic fields. Promising the emerging future of dexterous manipulation and multi-modal locomotion, they simply lack the feedback, essential for their elastic or kinematic control. In this work, we propose a dome-shaped magnetoactive soft robot (DMSR) equipped with an inertial measurement unit (IMU) as a proprioceptive sensing feedback and an external camera for vision feedback. Driven by a single translating magnet system, DMSR can achieve controlled roll and pitch maneuvers, enables the possibilities for precise maneuvering control. To achieve the DMSRs state prediction and tracking for precise maneuvering control, we propose a multi-modal neural geometric learning framework, that unifies the DMSR kinematic (orientation) and elastic (strain) state with proprioceptive feedback and external vision observations. By incorporating physics-driven regularization, the framework's strain prediction network achieves an accuracy of 91%, significantly outperforming physics-less models. Furthermore, the framework's inverse kinematic network effectively translates combined IMU and vision-based orientation profiles to inversely identify the corresponding actuation magnet positions. Experimental results demonstrate that the multi-modal neural geometric model learning enables precise state tracking in human-operated and goal-oriented DMSR maneuvering scenarios. Taken together, this study establishes a foundation for the development of precisely controllable, state-predictive magnetoactive soft robotic systems.

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Reference: J.M. Butt, X. Xiong, P. Manoonpong, 'Multi-modal neural geometric learning for state prediction and tracking of magnetoactive soft robots with proprioceptive feedback' (In submission to Advanced Materials Technologies).

Validation of Multiphysics Environments for Simulating Magnetoactive Elastomers

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Magnetically active elastomers, or MAEs are an increasingly popular material in Soft Robotic applications. They are made by mixing micro and nanoscale magnetic powders with elastomer matrix during the curing process. Under an external magnetic field, the magnetic particles try to align with the field; altering their microscopic arrangement to generate interactions that deform the surrounding elastomer matrix. This can lead to magnetostriction, a bulk deformation of the body; or a magnetorheological effect, a change in the materials stiffness. While these materials are often studied through the lens of materials science, their growing application in the robotics field has created a need for accurate models capable of predicting their behavior and interactions.

In order to design novel actuators, engineers often rely on simulations to model how the system will react to loads from the environment. MAEs are particularly complex to model, with coupled magneto-mechanical interactions that require multiple layers of physics solvers. Because specialized multiphysics software can be inaccessible or require extensive add-on scripts, researchers often develop their own FEA framework to tackle the specific magneto-mechanical interaction they are researching.

This work evaluates the use of LS Dyna to simulate MAE bodies exposed to external magnetic fields; using experimental results and custom-developed numerical models from literature to benchmark its performance [1]. Simulations are compared across multiple combinations of material properties and applied magnetic fields to assess the solvers' ability to reproduce the coupled magnetic and mechanical response of complex MAE systems. The agreement between these approaches demonstrates the potential for a general-purpose environment to simulate MAE deformation.

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This research is funded by European Union's Horizon Europe research program under the Marie Skłodowska-Curie Actions Doctoral Network MAESTRI (grant agreement No. 101119614). Views and opinions expressed here are not reflective of the European Union or European Research Executive Agency.

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Magnetic Modulation of Joint Compliance for Adaptive Grasping

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Abstract

Compliance refers to the ability of a mechanical system to adjust its shape or motion in response to external forces. This property has gained increasing relevance in robotics over the past years, as it contributes to safer interactions both between robots and their surroundings.

Conventional robotic and prosthetic hands tend to be structurally rigid, achieving compliant behavior only through passive elements placed along the transmission chain, such as springs or mechanisms that lock the joint [1]. A different strategy is offered by soft robotics, where adaptability is built directly into the mechanical structure through the use of soft materials or fluid-filled chambers, although this typically reduces precision and control accuracy [2].

Looking at a typical grasping task, the compliance requirements are not uniform throughout its execution. During approach and grasping, a high degree of compliance is beneficial, as it allows the system to tolerate unintended contact, conform to the shape of the object, and increase the number of contact points established. Once the object is held, however, greater stiffness becomes preferable, since it ensures stability and helps the grasp resist external perturbations [3].

Building on these considerations, this work explores the design of variable-stiffness joints intended for humanoid grippers. The goal is to develop a joint whose compliance can be tuned according to the specific phase of the grasp, exploiting magnetic field modulation together with magneto-active elastomers [4]. Two distinct approaches, both relying on magnetically-induced changes in material behavior, are examined to obtain this tunable stiffness. The first exploits a magnetorheological fluid (MRF) [5]: modulating the magnetic field changes the yield stress of the fluid contained within a piston chamber, which in turn influences piston displacement and regulates the resistive force acting against the rotation of the joint. The second approach is based on friction control, using two magneto-active elastomer (MAE) surfaces that have been laser-textured into lamellar patterns [6]. Under an external magnetic field, these lamellar structures orient themselves along the field lines, which modifies the friction coefficient between the two surfaces and, as a result, changes the resistance encountered during joint motion.

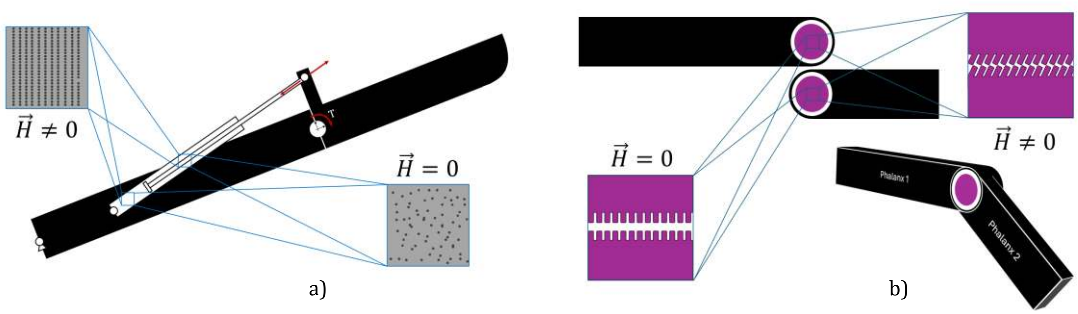

Figure 1. *a) Viscosity-based mechanism. b) Friction-based mechanism.*

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Topology Optimization of Viscoelastic Functional Surfaces for Enhanced Gripping in Soft Pneumatic Grippers

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Viscoelastic materials are widely used in gripper surfaces because their compliance enables safe grasping of delicate, irregularly shaped objects. While these surfaces are routinely tailored for specific applications, their design is largely guided by engineering intuition and empirical testing rather than a systematic, physics-based approach. Additionally, the inherent dissipative nature of viscoelastic materials offers an opportunity to improve grip stability [1, 2, 4, 5]. However, increasing energy dissipation generally reduces structural stiffness and load-bearing capability. This work presents a topology optimization framework for the computational design of 3D viscoelastic functional surfaces intended for soft pneumatic grippers [3]. The objective is to maximize energy dissipation at a prescribed excitation frequency while simultaneously satisfying constraints on material usage and structural compliance, thereby balancing grip stability and load-bearing capability [4, 5].

The proposed approach employs gradient-based topology optimization with the Method of Moving Asymptotes (MMA) and a frequency-domain finite element analysis of a viscoelastic cantilever beam [4]. Material interpolation is performed using a RAMP penalization scheme with Heaviside projection to obtain manufacturable designs. A volume constraint limits the amount of high-loss viscoelastic material, while a compliance constraint prevents convergence toward excessively compliant designs [4, 5]. Frequency-response analyses are used to compare the optimized and initial designs over a range of excitation frequencies [4]. Additional optimizations are conducted for multiple target frequencies to investigate the evolution of optimal topologies as excitation frequency increases [4, 5].

The results demonstrate that topology optimization can substantially increase energy dissipation while maintaining acceptable structural stiffness under prescribed loading conditions. The evolution of the optimized layouts as the target frequency increases highlights the dependence of optimal material distribution on dynamic operating conditions. Frequency sweeps further show improved damping performance relative to the initial uniform design, demonstrating the potential of computationally designed viscoelastic surfaces to enhance grip stability in soft robotic systems. Future work will focus on fabricating the optimized 3D surfaces and experimentally validating their dynamic response and gripping performance on pneumatic soft grippers through harmonic testing and pick-and-place tasks.

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GENERATION OF LIQUID FLOW BY A MAGNETOACTIVE LAMELLAR MICROSTRUCTURE

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We investigated the velocity field, **v**(**r**), generated in a water–glycerine mixture by a microlamellar structure fabricated from a magnetoactive elastomer (MAE) using laser-micromachining method. The liquid, confined in a container significantly larger than the lamellar dimensions, was seeded with light-reflective titanium dioxide particles for flow visualization. The lamellas were actuated by the rotating magnetic field of a quadrupolar permanent magnet (Fig. 1a). Owing to the pronounced asymmetry of the magnetic field-induced lamellar bending motion, the velocity field during the stroke phase (Fig. 1b) differs substantially from that during the recovery phase, producing a net fluid flow. The maximal flow rate reached the value of around 20 mL/min. We also examined the dependence of the flow on the water-to-glycerine ratio and found that the flow direction reverses at the viscosity of around 3.5 mPa·s. Our results demonstrate that MAE microlamellar structures can efficiently and contactlessly convert the rotational motion of a permanent magnet into a directed fluid transport, highlighting their potential as magnetically driven micropumps.

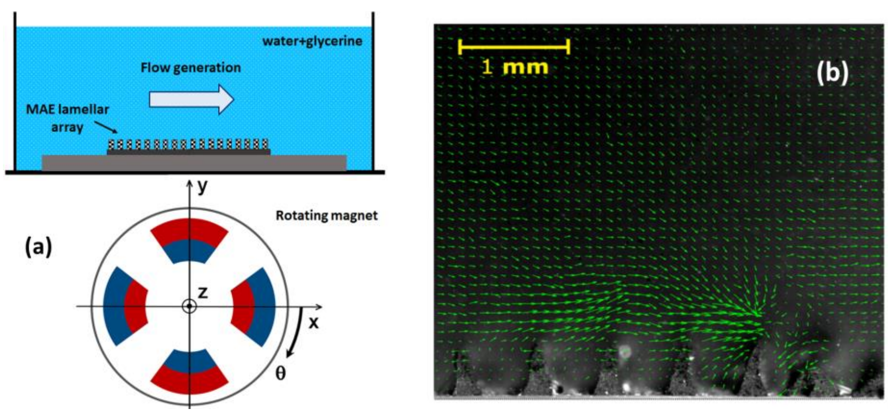

Figure 1: (a) Schematic drawing of the setup. (b) Velocity profile **v**(**r**) during the "stroke" phase.

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