EDINBURGH

ROBOSOFT

APRIL 4-8 - 2022

INTERNATIONAL CONFERENCE ON

SOFT ROBOTICS

SOFT ROBOTS FOR THE PLANET

THE NATIONAL ROBOTARIUM
PEOPLE CENTRED :: INTELLIGENCE DRIVEN

RoboSoft 2022 Sponsor information

Intro

Established jointly by Heriot-Watt University and the University of Edinburgh, the National Robotarium, due to open in 2022, is a world-leading centre for Robotics and Artificial Intelligence, creating innovative solutions to global challenges.

Advancing Research

Our goal at the National Robotarium is to advance research on a global stage. We promote a vibrant ecosystem of national and international robotics and AI research across three distinct areas, Robotics & Autonomous Systems (RAS), Human & Robotics Interaction (HRI) and High Precision Manufacturing.

Working with industry

Informed by sectoral needs, we work collaboratively with industry partners around the globe and act as a gateway to the UK Robotics sector and Government support. We aim to have a positive impact on the UK economy by aiding the rapid transition of solutions from laboratory to market, supporting start-ups and SMEs from Heriot-Watt University, the University of Edinburgh and across the UK.

World-class specialist facilities

Opening in autumn 2022 on Heriot-Watt University's Riccarton campus in Edinburgh, the National Robotarium boasts world-class specialist facilities for the advancement and testing of applied and industrial research, including dedicated laser labs, an autonomous systems laboratory, and a living lab for trialling technology in a realistic home setting.

The building itself has been designed with sustainability and energy efficiency at its heart, with an intelligent façade that will provide solar heat and recycle warm air, and includes an ecological zone to integrate sustainable urban drainage systems.

Funding information

The National Robotarium is part of the Data-Driven Innovation initiative supported by £21 million from the UK Government and £1.4 million from the Scottish Government through the £1.3 billion Edinburgh and South-East Scotland City Region Deal, a 15-year investment programme jointly funded by both governments and regional partners.

THE UNIVERSITY *of* EDINBURGH
Robotics SUPERLAB

THE ROBOTICS SUPERLAB

Where we Invent, Play, Build and Explore 'What is a Robot ?'

Centered in Edinburgh, the Robotics SuperLab provides an open & holistic environment. Where, human meets technology, design & engineering across robotics.

The objective is to be a world-leading robotics research laboratory.

Our aim is to be problem led with a focus on unmet requirements. To generate ideas and kickstart the innovation pipeline of the future using next generation robotics.

Working collaboratively across disciplines within The University of Edinburgh, in a true multidisciplinary approach.

Inventing new concepts and transformative technologies to solve significant stakeholder held problems.

Bringing together academia with industry and small businesses to expand opportunities and to integrate robotics, as a disruptive technology, through co-creation to industry applications. The SuperLab works at Technology Readiness Level 0-3, with a strong focus on research.

Key differentiators - extensive ecosystem that exists in Edinburgh and our focus on building. Work conducted will be a feeder into higher TRL initiatives in Edinburgh e.g. The National Robotarium.

Through creation of innovation - adding value to the Edinburgh Centre for Robotics by bringing in our key themes of engineering novel robotics systems to student education and training.

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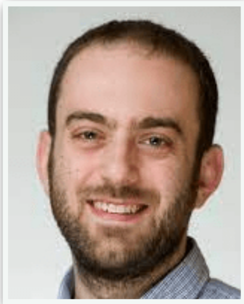
Student Activities



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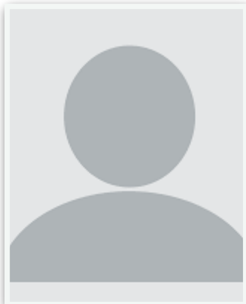


Katrina Saridakis
The University of Edinburgh

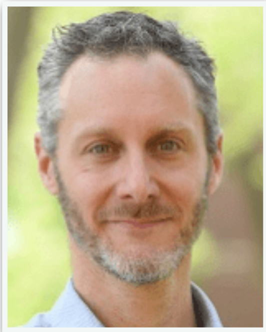
Plenary Talks

Katia Bertoldi

Katia Bertoldi is the William and Ami Kuan Danoff Professor of Applied Mechanics at the Harvard John A.Paulson School of Engineering and Applied Sciences. She is the recipient of the NSF Career Award 2011 and of the ASME's 2014 Hughes Young Investigator Award. She published over 150 peer-reviewed papers and several patents. Dr Bertoldi's research contributes to the design of materials with a carefully designed meso-structure that leads to novel effective behavior at the macroscale. She investigates both mechanical and acoustic properties of such structured materials, with a particular focus on harnessing instabilities and strong geometric non-linearities to generate new modes of functionality.

Harnessing Instabilities to design Soft Robots

From minimally invasive surgical tools and assistive devices to compliant grippers and video game addons, inflatable soft robots have claimed an entire domain of applications for which safe interactions with the surrounding environment is the priority. They are inherently compliant, easy to fabricate, and able to achieve complex motions harnessing the input pressure. This simplicity, however, brings strict limitations: soft actuators are often restricted to unimodal and slow deformation. Here, we embrace instabilities as a paradigm to improve the functionality of inflatable soft robots. First, we show that buckling-induced directional frictional properties of kirigami surfaces enable a simple extending soft actuator to efficiently crawl. Then, we demonstrate that shell snapping can be exploited to make soft actuators jump even when inflated at a slow rate. Finally, we embrace multistability to to realize inflatable cylindrical structures capable of supporting multiple deformation modes, while being globally actuated using a single pressure input. Together, these examples highlight the potential of instabilities in enabling the design and fabrication of soft robotic systems with enhanced functionality.



Josh Bongard

Josh Bongard is the Veinott Professor of Computer Science at the University of Vermont and director of the Morphology, Evolution & Cognition Laboratory. His work involves automated design and manufacture of soft-, evolved-, and crowdsourced robots, as well as computer-designed organisms: the so-called “xenobots”. A PECASE, TR35, and Cozzarelli Prize recipient, he has received funding from NSF, NASA, DARPA, ARO and the Sloan Foundation. He is the co-author of the book How The Body Shapes the Way We Think, the instructor of a reddit-based evolutionary robotics MOOC, and director of the robotics outreach program Twitch Plays Robotics.

From Rigid to Soft to Biological Robots

Organisms and robots must find ways to return to a viable state when confronted with unexpected internal surprise such as injury, or external surprise, such as a new environment. Rigid robots can only confront such challenges by adapting behaviorally. Soft robots have the added option of morphological adaptation: changing shape, material properties, topology, plurality, and/or mass. Finally, biological robots — machines built completely from biological tissues — inherit the protean nature of their donor organisms, providing them with forms of morphological and behavioral adaptation beyond even today’s most morphologically plastic soft robots. In this talk I will review our recent efforts to create biological robots, and how their protean natures have led us to rethink how we approach soft robotics, embodied cognition, and intelligence in general.

Telmo Pievani

Telmo Pievani is Full Professor at the Department of Biology, University of Padua, where he covers the first Italian chair of Philosophy of Biological Sciences. Past President (2017-2019) of the Italian Society of Evolutionary Biology, he is Fellow of several academic Institutions and scientific societies. He is author of 276 publications, included several books. Fellow of the Scientific Board of science festivals in Italy, since 2014 he is fellow of the International Scientific Council of MUSE in Trento. He is Director of “Pikaia”, the Italian website dedicated to evolution. He is Director of the University of Padua web magazine, Il Bo LIVE. With Niles Eldredge, Ian Tattersall and Luigi Luca Cavalli-Sforza, he was the Curator of International science exhibitions. Author of books for children and theatre scientific shows, he is a columnist for Il Corriere della Sera, and the magazines Le Scienze and Micromega.

Inspired by Evolution: Insights for Soft Robotics Evolvability

Adaptation to ever-changing and unpredictable ecological niches, morphological tinkering and functional co-optations in new contexts (exaptation), redundancy as a source of innovation, functional and energy efficiency: evolution can offer many original ideas to think about the future developments of Soft Robotics, mostly in terms of innovation and environmental sustainability.

Rob Shepherd

Rob Shepherd is an associate professor at Cornell University in the Sibley School of Mechanical & Aerospace Engineering. At Cornell, he runs the Organic Robotics Lab, which focuses on using methods of invention, including bioinspired design approaches, in combination with material science to improve machine function and autonomy. We rely on new and old synthetic approaches for soft material composites that create new design opportunities in the field of robotics. He is the recipient of an Air Force Office of Scientific Research Young Investigator Award, an Office of Naval Research Young Investigator Award. He is an advisor to the American Bionics Project which aims to make wheelchairs obsolete. He is also the co-founder of the Organic Robotics Corporation, which aims to digitally record the tactile interactions of humans and machines with their environment.

Embracing Complexity for Enduring and Adaptive, Organic Robots via Autonomous Materials

Animals are semi-discretized. Systems of organs that perform multiple functions and are spatially discrete from each other, yet interconnected chemically and electrically. The complexity of animals such as vertebrate mammals allow for adaptation within a single generation that has allowed many examples of species that have thrived without genetic modification even during periods of significant environmental change. In the search for generally adaptive robots, useful for far field exploration missions, we believe that a similar model of complex, multifunctional, and interconnected organ systems of animals should be embraced, rather than avoided. Of course, it is not yet that simple to be complex, but we will present approaches we have used to distribute sensing, actuation, energy, and computation in soft robots. The framework we use for guiding our design evolution is Autonomous Materials, where we push the manufacturing of robots towards forming processes, and multifunctional use of material chemistry. The resulting machinery presented will be organic both in chemical makeup and subsystem analogy to organisms.

Thomas Speck

Thomas Speck is full professor for ‘Botany: Functional Morphology and Biomimetics’ and Director of the Botanic Garden, University of Freiburg. He is spokesperson of the Cluster of Excellence “Living, Adaptive, and Energy-autonomous Materials Systems (livMatS @ FIT)”, deputy managing director of the “Freiburg Center for Interactive Materials and Bio-Inspired Technologies (FIT)”, and scientific member of the Materials Research Centre Freiburg (FMF). Thomas Speck is also spokesperson of the Competence Network Biomimetics and vice-chair of the Society for Technical Biology and Bionics. He received several scientific awards, is (co-)editor of several scientific books and journals and has published more than 300 scientific articles in peer reviewed journals & books.

Plant Movements as Models for Soft Robotics and Soft Machines in Technology, Architecture and Medicine

Today, biomimetics attracts increasing attention as well from basic and applied research as from various fields of industry and building construction. Biomimetics has a high innovation potential and offers possibilities for the development of sustainable technical products and production chains. Novel sophisticated methods for analysing and simulating the form-structure-function-relation on various hierarchical levels allow new fascination insights in multi-scale mechanics and other functions of biological materials syste,s. Additionally, new production methods enable for the first time the transfer of many outstanding properties of the biological models into innovative biomimetic products at reasonable costs.
In recent decades, plants have been recognized as valuable concept generators for biomimetic research in many field of application in technology in general, and architecture and medicine in particular. Plant-inspired developments in the fields of soft machines and soft robotics are demonstrated by research projects currently carried out in the Plant Biomechanics Group Freiburg and the Cluster of Excellence livMatS. Examples include liana-inspired soft robots, leaf- and flower-inspired façade shading systems, demonstrators for pine cone-inspired self-adaptive building hulls and artificial Venus flytraps. As example for a medical application a prototype for an adaptive wrist-forearm splint developed in collaboration with the ICD at the University of Stuttgart is presented. A particular focus of current research is on embodied energy and intelligence found in moving plant organs, which offer a huge potential for a new generation of materials systems for soft robots, bioinspired architecture and technical applications in general.

Barbara Webb

Barbara Webb completed a BSc in Psychology at the University of Sydney then a PhD in Artificial Intelligence at the University of Edinburgh. Her PhD research on building a robot model of cricket sound localization was featured in Scientific American and established her as a pioneer in the field of biorobotics – using embodied models to evaluation biological hypotheses of behavioural control. She has held lectureships at the University of Nottingham and University of Stirling before returning to a faculty position in the School of Informatics at Edinburgh in 2003. She was appointed to a personal chair as Professor of Biorobotics in 2010, and awarded an EPSRC Established Career Fellowship in 2021.

Bodies and Brains: Insights from Insect-i15 nspired Robotics

One motivation for investigating alternative approaches to robot actuation, such as soft mechanisms, is the observation that many biological systems acheive task success as much through their body design as through their brains. We have investigated a range of insect behaviours from this point of view, from simple steering through to complex navigation. This talk will reflect on some of the general insights gained, particularly into the need to combine multiple methodological approaches to understand biological function.

Workshops and Tutorials

WS1 – New Directions for Simplified Control of Soft Robots (Full-day workshop)

Organisers: Egidio Falotico, Daniel J. Preston, and Tommaso Ranzani

Abstract:
The field of soft robotics has experienced tremendous growth over the past decade, drawing interest due to the utility of soft robots in applications involving handling of fragile objects or close collaboration with humans, their relatively low cost and light weight, and their resistance to impact and harsh conditions. To fully realize these advantages, researchers are now investigating methods to simplify or replace the existing hard, bulky control infrastructure ubiquitous to soft robots with a combination of onboard control methods and advances in external software control. Research in this area has been fast-paced, with many concurrent and complementary developments in just the past three years, but opportunities for further advances remain. This workshop will bring together a diverse group of researchers investigating the simplified control of soft robots to identify promising future directions.

WS2 – Soft Sensing: Environment, Morphology, Brain in Biology and Robotics (Full-day workshop)

Organisers: Van Ho, Lucia Beccai, Helmut Hauser, and Fumiya Iida

Abstract:
Recent advances in materials and manufacturing approaches have opened new possibilities for sensor design in the context of soft robotics. Inspired by the remarkable performance of biological sensing systems we believe that understanding biological solutions can provide useful design guidelines to develop bio-inspired soft sensors. However soft sensing is still far from allowing natural-like perception. This is mainly due to the multiple aspects that need to be considered in the design including materials and structure the implementation of an appropriate computational layer (neurons) and their interplay with sensed environment. In this workshop we aim to discuss how the lessons from biology in morphological sensing may inform and benefit feasible implementation of embodied sensing in soft robotics. Besides the presentation the workshop will feature in-depth panel discussions among biologists, roboticists, neuroscientists, and material scientists about current challenges and ways towards a more holistic pipeline from biological system to abstraction to practical soft robotics applications.

WS3 – Soft Robotics and Embodied Intelligence (Full-day workshop)

Organisers: Arsen Abdulali, Fumiya Iida, Josie Hughes, and Matteo Cianchetti

Abstract:
There has been a long-standing philosophical debate about the relationship between body and mind. Today this debate still powers a profound scientific desire to deepen our understanding of the nature of both animals' and machines' intelligent, adaptive behavior. To gain further insights into intelligence and explore how our brain and whole selves develop through physical interactions with the world, Embodied Intelligence places the physical entity of the human body at the center of this subject. In the age of AI and Machine Learning, Embodied Intelligence research remains highly important as it can deliver valuable input which enhances the impact of conventional AI technology.
Soft Robotics research has recently shown how conceptual issues of Embodied Intelligence can be turned into physical reality. Only by promoting the soft robotics technologies towards a more Embodied Intelligence framework, will the technologies reach the next level of autonomous adaptive systems.
The proposers for this workshop also annually organize the International Conference on Embodied Intelligence (https://embodied-intelligence.org/) conference to discuss these various challenges. Last year, the conference attracted over 100 speakers and 1000 participants, reflecting both the importance and the necessity of this research discussion within the collaborative community.
This workshop aims to continue the stimulating discussions in the workshop and strengthen the participation of soft robotics researchers.

WS4 – Software for Soft Robotics Research (Full-day workshop)

Organisers: S.M.Hadi Sadati, Anup T Mathew, James Bern, You Wu, Robert Katzschmann, and Josie Hughes

Abstract:
Soft Robotics is a trending multi-disciplinary research topic inspired by highly dexterous and deformable biological bodies in the form of intrinsically soft robotic platforms. However, the compliance offered by soft robots has disadvantages resulting in modeling, design optimization, system analysis, control, and automation challenges hindering their real-world deployment. Developing software frameworks for addressing the aforementioned needs in Soft Robotics research is receiving

increased attention recently. Such frameworks should be easy to use to be widely accepted by the multidisciplinary Soft Robotics research community that gathers researchers from different expertise and backgrounds. This workshop brings together the academic and industrial viewpoints on the requirements and ways to address the grand challenge of achieving a unified software framework for Soft Robotics Research.

The main aim of the workshop is to introduce the already available toolkits to the wider community and to inspire new approaches in developing such platforms for soft robots with the application and user experience in mind. We will bring together recognized experts in both modeling and control of soft robots, trying to answer questions such as: What are the impacts of such frameworks? What are the immediate and most general requirements in the Soft Robotics community to be addressed by a soft robotic platform? How to decide between existing soft robotic toolkits for a given simulation, analysis, or control task? How to design an easy-to-use toolkit to be widely accepted for multidisciplinary Soft Robotics research? What are the means of achieving fast yet accurate computational performance for a variety of tasks such as modeling, design optimization, controller design, and deep-learning research? How to achieve inter-operable platforms compatible with standard platforms in the community such as (e.g. C/C++, Python, Matlab, and ROS? What problems can not be solved with a 'perfect' simulator?

WS5 – Energy-based approach to analyze and develop soft robotic systems (Half-day workshop)

Organisers: Derek Chun, Pham Huy Nguyen, and Saivimal Sridar

Abstract:
The field of Soft Robotics is broad in terms of actuation technologies from pneumatic/fluidic, or thermal, or electrical, or chemical to mechanical domains, and from the microscopic to the macroscopic scale. Applying these actuation technologies in real world application comes with the challenge of developing energy-efficient systems. Energy is the lingua franca of engineering, and an energy-based approach has the potential to define a single approach that highlights the key features of a system. This workshop aims to educate researchers working on soft robotic systems on energy-based approaches specifically applied to the systems they are developing by using concepts such as the port-Hamiltonian approach and bond-graph theory. Several examples of these approaches will be provided through case studies presented by the speakers of this workshop.

WS6 – Soft Robotics modeling: What are we missing? (Half-day workshop)

Organisers: Cecilia Laschi, Gianmarco Mengaldo, and Federico Renda

Abstract:
To model, or not to model? That is a question in soft robotics. Is modeling the way towards next- generation soft robot design, control and best use of embodied intelligence? To what extent can we model the interaction of a soft robot body with the environment and fully grasp the essence of embodied intelligence? Can we achieve digital twins of our soft robots? What is the required relation between accurate modelling and accurate fabrication? How to overcome the reality gap? Those and other questions will be discussed at the workshop. We argue that a wider adoption of computational modeling in soft robotics provides opportunities for progressing towards a model- informed discipline, ultimately responding to societal needs. The challenges involved stand as research opportunities in multiple fields. Transition from prototype-based to model-informed design in soft robotics is within grasp, in an interdisciplinary dialogue that we wish to promote starting with this workshop.

WS7 – Soft Aerial Robotics (Half-day workshop)

Organisers: Pham Huy Nguyen, Begoña Arrue, Anibal Ollero, and Mirko Kovac

Abstract:
In recent years, the field of soft aerial robotics has benefitted from the utilization of reconfigurable, flexible, soft, and morphologically adaptive structures. This workshop highlights the current and future utilization of soft and morphologically adaptive structures in aerial robot related applications: such as (1) improving maneuverability and flight efficiency; (2) multi-modal mobility across terrain interfaces and fluid boundaries; (3) robustness to landing and collision (4) manipulation, perching, resting, and energy management in complicated environments; (5) bio-inspired aerial construction and nesting; (6) bio-hybrid flying structures, biodegradability; (8) self-regeneration and self-healing. The workshop aims to host the leading researchers in the fields of bio-inspired, reconfigurable, morphing, and soft aerial robots to create a dialogue on state of the art, identify technical/conceptual barriers, and outline key challenges and opportunities for soft aerial robotics. The workshop will outline instances where inspiration from biology is utilized to develop the next generation of aerial vehicles. Highlighting various enabling technologies and system features desired in novel aerial robots, that can perform multi-capabilities, multi-modal tasks, and autonomously operate in real-world conditions.

WS8 – Grand Challenges for Burrowing Soft Robots (Full-day workshop)

Organisers: Osman Dogan Yirmibesoglu, Yasemin Ozkan Aydin, and Trevor Buckner

Abstract:
State-of-the-art soft robots that can burrow into soil or granular media are limited. Due to sub-terranean forces acting on the robot body, enabling burrowing soft robotic applications is highly challenging and requires deeper research. Nature provides many examples of successful burrowing mechanisms, exhibited by organisms as varied as worms, bivalve mollusks, and plants. How can we learn from biology and create more capable soft burrowing robots? By analyzing soft biological burrowing mechanisms, and identifying the grand challenges we need to overcome, we can manufacture next-generation soft burrowing robots. In this workshop, we will convene experts across disciplines: physics, biology, robotics, mechanical engineering, and materials science to discuss the grand challenges and how to solve them. Furthermore, with an additional speaker from industry, this workshop will also highlight how the advantages of soft robots can be harnessed for burrowing applications, minimize disruption to the environment while digging and real-world use cases.

WS9 – How to make better soft robots through design optimization (Full-day workshop)

Organisers: Robert Baines, Benjamin Gorissen, Atoosa Parsa, and Sree Kalyan Patiballa

Abstract:
The design of soft robots involves many choices spanning materials, actuators, sensors, and geometric and force considerations. Often, these choices are made heuristically with limited or no systematic framework. A heuristic-based design approach can lead to significant time spent iterating on hardware, incur extra costs, material waste, leading to underperforming robots. This workshop will highlight existing design optimization (inverse design) methodologies for soft robots and provide a forum for discourse on approaching soft robotics with systematic design thinking. Key questions include: Are the same design pipelines for conventional mechanisms applicable to soft robots? Can we leverage knowledge from other domains for soft robotics? What are trade-offs in deterministic vs. non-deterministic methods? How can we mitigate the Sim2Real gap?

WS10 – Alt-AI: End Robotics. Begin Synthetic Organisms (Full-day workshop)

Organisers: Tarin Ziyaee, Filip Piekniewski, and Todd Hylton

Abstract:
In his 2018 book “Where’s my flying car?”, the author J Storrs Hall asks why, some 60 years later, the future envisioned in the 1960s has never really come to materialize. Where for example, are the fully interactive robots that were supposed to walk amongst us? Why instead, do we hear about Teslas running into the back of parked fire-trucks on the highway, or Waymo cars getting stuck in front of a cone in a construction zone until a service operator arrives and gets it unstuck? The reason is simple: Both the fields of “artificial intelligence” and robotics have been taken hostage by a litany of unquestioned intellectual hegemonies that rule supreme. The solution therefore requires a complete and total reframing of the problem at hand. More concretely however, the “Alternative AI” framework calls for the creation of synthetic organisms, replete with fully respecting the lineage of how natural intelligence arises, and a strong and rigorous rejection of a multitude of harmful ideologies that have thus far held us back.

WS11 – Tensegrity Robotics (Half-day workshop)

Organisers: Valter Böhm, Dario Floreano, Rebecca Kramer-Bottiglio, John Rieffel, and Vishesh Vikas

Abstract:
Following on the successes of our 2018 and 2019 workshops, the purpose of this workshop is to provide a forum to discuss recent advances and challenges in the field of tensegrity robotics. As compliant structures with tunable stiffness, tensegrities are a compelling platform with which to study the spectrum of robotic morphologies, from soft to rigid. Tensegrities are relatively simple to design and fabricate, and yet they present all the same challenges and pathologies of more conventional robots. Most valuably, they are incredibly modular, requiring few distinct parts, and allowing them to scale quite well in complexity. This workshop will provide participants with an opportunity to present and discuss the current state-of-the-art in tensegrity robotic research, through a series of invited talks, a solicited poster session, and an interactive panel discussion.

T1 – Modeling, Simulation, and Control of soft-robots with SOFA (Half-day workshop)

Organisers: Yinoussa Adagolodjo, Christian Duriez, Damien Marchal, Hugo Talbot, and Felix Vanneste

Abstract:
This workshop will provide a series of in-depth tutorials on how to use the open-source simulation framework SOFA and the SoftRobots plugins made by the DEFROST research team to model, simulate and control deformable robots. At the end of the tutorial session, we expect attendees to be capable of modeling and controlling basic soft robots with SOFA including being able to precisely model contact with inverse control. A special moment will be allocated on the new SofaPython3 API, and how to upgrade previously done simulations. The workshop can be done on-site and remotely. We will do our best for remotes attendees, so they have the best experience. The sessions will be streamed and recorded and dedicated live video-conference room will be created. For the "hands-on" sessions, additional member of the DEFROST team will be present online to support and guide remote participants in their modeling soft-robots.

Plenary Lecture - Telmo Pievani

Chair *Barbara Mazzolai, Istituto Italiano di Tecnologia*
Co-Chair

Design of flexible actuators

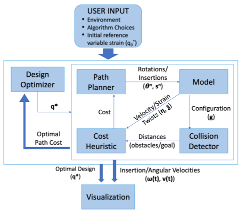
Chair *Robert Shepherd, Cornell University*
Co-Chair *Markus Nemitz, Worcester Polytechnic Institute*

10:00–10:15	TuAT1.1

CTR DaPP: A Python Application for Design and Path Planning of Variable-strain Concentric Tube Robots

Conor Messer[1], Anup Teejo Mathew[1], Nenad Mladenovic[2], and Federico Renda[1]
[1]Department of Mechanical Engineering, Khalifa University, Abu Dhabi, UAE.
[2]Department of Industrial and Systems Engineering, Khalifa University, Abu Dhabi, UAE.

- Introduction of CTR DaPP, a Piecewise Variable Strain (PVS) based concentric tube robot (CTR) design and path planning application
- A modular platform for implementing and testing of path planners and design optimization algorithms
- Optimal design of PVS CTRs for various environments and cost heuristics
- Follow the leader study of PVS CTRs.



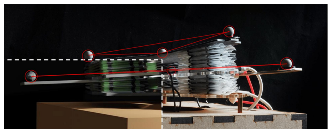
Overview of the CTR DaPP application

10:15–10:30	TuAT1.2

Simulating Electrohydraulic Soft Actuator Assemblies Via Reduced Order Modeling

Travis Hainsworth[1], Ingemar Schmidt[1], Vani Sundaram[1], Gregory L. Whiting[1], Christoph Keplinger[1,2,3], and Robert MacCurdy[1]
1) Paul M. Rady Department of Mechanical Engineering, University of Colorado, Boulder, CO, USA
2) Robotic Materials Department, Max Planck Institute for Intelligent Systems, Stuttgart, Germany
3) Materials Science and Engineering Program, University of Colorado, Boulder, CO, USA

- Simulating soft robotic assemblies
- Robots actuated via HASELs
- Data driven, reduced order, mass-spring-damper model
- Validated via motion capture data



Presented is a method to simulate robots made of HASELs in the time domain (the simulation is represented by the green render), with a data driven model validated via motion capture data (solid red lines).

10:30–10:45	TuAT1.3

A Simulation-Based Toolbox to Expedite the Digital Design of Bellow Soft Pneumatic Actuators

Yao Yao, Liang He and Perla Maiolino
Oxford Robotics Institute, University of Oxford, United Kingdom

- Propose a standardized bending bellow soft pneumatic actuator (SPA) design with parameterized design features.
- Provide a design toolbox of the bellow SPA contains:
  1. A MATLAB GUI for fast iterative design based on actuators' workspace via theoretical modelling.
  2. An automatically generated CAD of the SPA.
  3. A background Finite Element Analysis simulation in COMSOL Multiphysics to show the actuator deformation, force, material stress and strain.

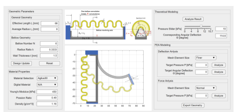


Figure: GUI of the bellow SPA design toolbox.

10:45–11:00	TuAT1.4

WPI ROBOTIC MATERIALS GROUP

The Soft Compiler: A Web-Based Tool for the Design of Modular Pneumatic Circuits for Soft Robots

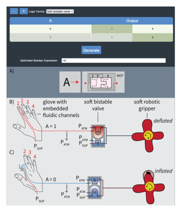
Savita V. Kendre and Lauryn Whiteside
Markus P. Nemitz
Department of Robotics Engineering, Worcester Polytechnic Institute, USA

Problem: Developing soft circuits from individual soft logic gates lead to inefficiencies due to mathematically unoptimized circuits.

Approach: A web-based graphical user interface, *the Soft Compiler*, generates optimized soft fluidic circuit.

Results: We demonstrate different soft circuits with a novel pneumatic glove as an input interface.

Web-tool: The soft compiler is accessible under: www.roboticmaterialsgroup.com/tools



Soft actuators

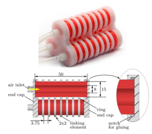
Chair
Co-Chair

11:00–11:45	TuPo1S.1

A systematically derived design for a modular pneumatic soft bending actuator

Frederik Lamping, Daniel Müller and Kristin de Payrebrune
Institute for Computational Physics in Engineering, TU Kaiserslautern, Germany

- Design aspects of multi chamber bending actuators are systematically investigated
- The investigation comprises the number of chambers, the chamber cross section, the connection of chamber, the chamber dimensions and the reinforcement
- From that, we derive a modular actuator that is beneficial for modeling and requires little manufacturing effort
- The bending performance of the actuator is satisfactory


The actuator and its dimensions and components

11:00–11:45	TuPo1S.2

Thermoelastic Strain-limiting Layers to Actively-control Soft Actuator Trajectories

P.D.S.H. Gunawardane, N. Budiardjo, G. Alici*, C. W. de Silva, M. Chiao
Deparatment of Mechanical Engineering, University of British Columbia, Canada
*Department Mechanical Engineering, University of Wollongong, Australia

- Field's metal particles less than $< 300\mu m$ were used to prepare Field's metal silicone (FMSi).
- 70% Field's metal wt. % was selected after experiments to develop the thermoelastic strain-limiting layer (TSLL).
- A new soft pneumatic actuator (SPA) with TSLL with two coils sandwiched into two FMSi layers was developed.
- The new SPA demonstrated two different trajectories with approximately 10° difference for the same pressure input.

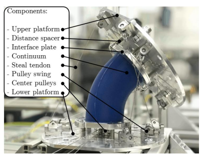

Soft Pneumatic Actuator with Thermoelastic Strain-limiting layer

11:00–11:45	TuPo1S.3

Open Source Tendon-driven Continuum Mechanism: A Platform for Research in Soft Robotics

Bastian Deutschmann, Jens Reinecke and Alexander Dietrich
Institute of Robotics and Mechatronics, German Aerospace Center (DLR)

- Research platform for design, modeling, state estimation, and control
- Purpose is benchmarking and transferability of results, approaches, and designs among the robotics community
- Design including all components is open source via GitHub: https://github.com/DLR-RM/TendonDrivenContinuum



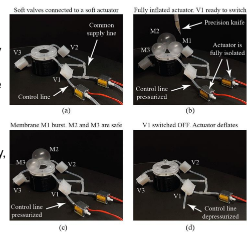
11:00–11:45	TuPo1S.4

Development and Characterization of a Soft Valve for Automatic Fault Isolation in Inflatable Soft Robots

Marco Pontin, Shuhei Miyashita and Dana Damian
Department of Automatic Control and Systems Engineering, University of Sheffield, United Kingdom

- Pneumatic soft robots show versatile capabilities, but they can be subject to failure e.g. bursts.
- We present a novel fault detection and isolation technique based on pressure-difference triggered soft valves.
- The valve reacts to bursts in less than 30ms stopping the airflow and preventing the fault from propagating.
- The valves are characterized for varying internal geometry, membrane thickness and supply pressure level.

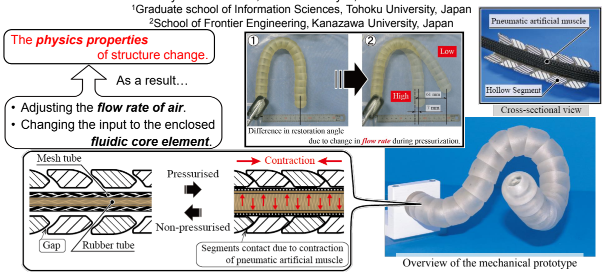
The University Of Sheffield. SHEFFIELD BIOMEDICAL ROBOTICS LAB.



11:00–11:45	TuPo1S.5

Highly Articulated Tube Mechanism with Variable Stiffness and Shape Restoration Using a Pneumatic Actuator

Issei Onda[1], Kenjiro Tadakuma[1,*], Masahiro Watanabe[1], Kazuki Abe[1], Tetsuyou Watanabe[2], Masashi Konyo[1], Satoshi Tadokoro[1]
[1]Graduate school of Information Sciences, Tohoku University, Japan
[2]School of Frontier Engineering, Kanazawa University, Japan

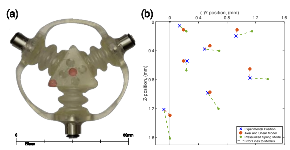


11:00–11:45	TuPo1S.6

Characterization of Soft 3D Printed Actuators for Parallel Networks

Shashank Khetan and Laura Blumenschein
Mechanical Engineering, Purdue University, USA

- Active and passive forces characterization of one degree-of-freedom (DOF) soft actuators
- 3D printed soft bellows actuator modeled as pressurized parallel linear and torsional spring with $R^2 > 0.93$
- Position of delta mechanism using characterized actuators predicted with 4% average error
- Multi-DOF soft actuator movements can be analyzed through single DOF models


(a) Realized delta mechanism
(b) Position prediction of axial plus shear model versus previous pressurized spring model

Soft actuators

Chair

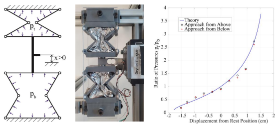
Co-Chair

11:00–11:45	TuPo1S.7

Programmable Pressure Amplification Using a Soft Folding Actuator

Zachary Brei and Brent Gillespie
Mechanical Engineering, University of Michigan, United States

- Fluid driven soft actuators act as fluid-mechanical transmissions.
- Harnessing the transmission of two folding actuators in a double-chamber device results in a continuously variable fluid-fluid transmission.
- Untethered and wearable applications in which high pressure sources are not available can benefit from the programmable pressure amplification of the fluid-fluid transmission.



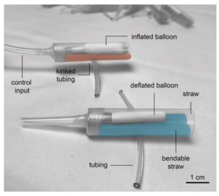
Experimental results show model-predicted transmission ratios within the range [0.2, 2.5] were achieved.

11:00–11:45	TuPo1S.8

Tube-Balloon Logic for the Exploration of Fluidic Control Elements

Jovanna A. Tracz and Savita V. Kendre
Markus P. Nemitz
Department of Robotics Engineering, Worcester Polytechnic Institute, USA

- **Problem**: Current soft logic gates are complex to fabricate.
- **Approach**: Our tube-balloon logic device consists of straws, tubes, and a balloon; when the balloon inflates, air flow through PVC tubing is occluded (actuated state).
- **Results**: Devices can be fabricated in 5 minutes by a novice and assembled as NOT-, NAND-, and NOR-gates or into a ring oscillator.
- **Impact**: Permits the educational exploration of Boolean logic operators for the control of soft robots.

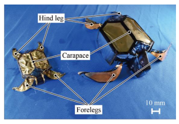


11:00–11:45	TuPo1S.10

Design and Fabrication of 3D Papercraft IPMC Robots

Hiroyuki Nabae, Keita Kubo, Kazuki Shishikura, Gen Endo and Koichi Suzumori
Department of Mechanical Engineering, Tokyo Institute of Technology, Japan
Tetsuya Horiuchi, Kinji Asaka
Hybrid Actuator Group Inorganic Functional Material Research Institute,
National Institute of Advanced Industrial Science and Technology, Japan

- We proposed the 3D papercraft IPMC robots using clinching for ion-exchange membranes
- 3D papercraft of IPMC made it possible to fabricate complicated 3D shaped IPMC robots
- Joint force depending on the shape and size of the clinching was evaluated
- We fabricated turtle-shaped IPMC robots with two different sizes and conducted driving experiments



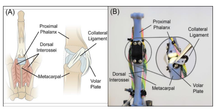
Prototypes of turtle-shape papercraft IPMC robots

11:00–11:45	TuPo1S.11

A Multi-Material, Anthropomorphic Metacarpophalangeal Joint with Abduction and Adduction Actuated By Soft Artificial Muscles

Samuel Dutra Gollob, Jonhenry Poss, Garrett Memoli
Mechanical Engr. Dept., Massachusetts Institute of Technology, USA
Ellen T. Roche
Mechanical Engr. Dept. and IMES, Massachusetts Institute of Technology, USA

- Finger joint made with hybrid rigid and soft materials
- Soft-actuated ab/adduction characterized for linear positional control and repeatable position and force outputs.
- Cartilage-inspired soft joint interface with improved precision and smoothness of motion over plastic-on-plastic joint.
- Future applications in prosthetics, personalized therapy and disease modelling, robotic grippers.



Relevant anatomy of the human MCP hand joint alongside our adapted design

11:00–11:45	TuPo1S.12

Waterproof Soft Robot Hand with Variable Stiffness Wire-driven Finger Mechanism Using Low Melting Point Alloy for Contact Pressure Distribution and Concentration

Toshinori Hirose, Shingo Kitagawa, Shun Hasegawa,
Yohei Kakiuchi, Kei Okada, Masayuki Inaba
Graduate School of Information Science and Technology, The University of Tokyo, Japan

- We proposed a various stiffness wire-driven finger mechanism using a low melting point alloy (LMPA)
- This finger mechanism can realize both of contact pressure distribution and concentration
- We developed a waterproof soft robot hand with this finger mechanism
- Using this robot hand, we conducted massage and hair washing experiments by remote control

Waterproof Soft Robot Hand

Soft actuators

Chair

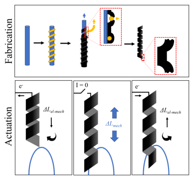
Co-Chair

11:00–11:45	TuPo1S.13

A Self-commutated Helical Polypyrrole Actuator Fabricated by Filament Patterning

Kadri-Ann Valdur, Tarmo Tamm, Alvo Aabloo and Indrek Must
Institute of Technology, University of Tartu, Estonia

- Reversible attachment and compliant grip retainment transits traditional stationary (bio)scaffolding towards biohybrid robotics
- A mm-scale **PPy-helix** with 180° electrically controlled tip rotation and 63% reversible structural strain
- Filament patterning enables assembly-free self-commutated continous 3D structures



Active adaptable structures

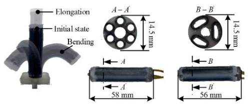
Chair *Helge Arne Wurdemann, University College London*
Co-Chair *Francesco Giorgio-Serchi, University of Edinburgh*

11:45–12:00	TuBT1.1

Design and Characterisation of Cross-sectional Geometries for Soft Robotic Manipulators with Fibre-reinforced Chambers

Jialei Shi, Wenlong Gaozhang, Helge A. Wurdemann
Department of Mechanical Engineering, University College London, UK

- Background: In minimally invasive surgery (MIS), soft manipulators should **fit through narrow openings**, e.g., Trocar ports (**diameter ≤15mm**).
- Main work: This work explores two individual reinforced chamber geometries, **circular and semi-circular**, to determine, if there is a difference in performance.
- Conclusion: Exploring the cross-sectional geometries can vary the performances of robots and provide **new design possibilities**, e.g., reducing dimensions of soft robots.



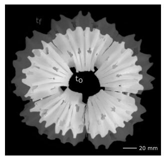
Soft, pneumatic-driven manipulators with different cross-sectional geometries

12:00–12:15	TuBT1.2

Design and Analysis of Origami-Inspired, Large-Elongation, Reconfigurable Soft Robot Modules

Kristan Hilby, Vineet Padia and Ian Hunter
Mechanical Engineering, Massachusetts Institute of Technology, United States of America

- Reconfigurable soft robot (RSR) modules inspired by Yoshimura origami achieve elongations up to 800%
- RSR groups can collectively achieve linear, curvilinear, rotary, or locomotion types of motion
- Computational analyses offer insight into localized strain and stress, as well as buckling modes
- Experimental analyses offer validation of computational results and further insight into performance operational lifetime

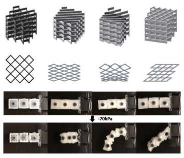

Five pneumatically reconfigurable soft robots connected in series.

12:15–12:30	TuBT1.3

MORI-A: Soft Decompression Module with 3D-Printable Deformation Structure

Jun Ogawa, Tomoharu Mori, Yosuke Watanabe, Masaru Kawakami, MD Nahin Islam Shiblee and Hidemitsu Furukawa
Department of Engineering, Yamagata University, Japan

- This study developed the pneumatic module "MORI-A" combining 3D-printed deformable structures with a silicone shell
- This module has uniaxial or uniform shrinkage, bending, shear, and unchanged drive patterns
- The MORI-A allows easy assembly of underwater swimming and walking robots with various drive modes
- Grippers constructed with MORI-A can grasp slippery and fragile objects.


MORI-A modules

12:30–12:45	TuBT1.4

ReRobot: Recycled Materials for Trustworthy Soft Robots

Alix Partridge, Hsing-Yu Chen, Nguyen Hao Le, Ciqun Xu, Hendrik Eichorn, Emanuele Pulvirenti, Arianna Manzini, Andrew T. Conn and Jonathan Rossiter
Bristol Robotics Laboratory, University of Bristol, United Kingdom

- A novel recycling process for the reuse of silicone elastomer material
- Successful reuse of silicone within ballooning and curving FEA structures is demonstrated
- Recycled material fractures at a lower strain, potentially due to microbubbles in the material

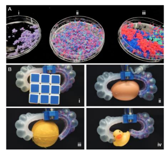


Figure: A) Granulated silicone. B) Gripping systems consisting of one pristine and one recycled FEA

Plenary Lecture - Robert Shepherd

Chair *Matteo Cianchetti, Scuola Superiore Sant'Anna*
Co-Chair

Control and Learning

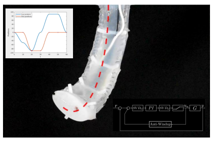
Chair *Helmut Hauser, University of Bristol*
Co-Chair *Egidio Falotico, Scuola Superiore Sant'Anna*

14:45–15:00	TuCT1.1

Robust Control of a Multi-Axis Shape Memory Alloy-Driven Soft Manipulator

Zach Patterson and Carmel Majidi
Mechanical Engineering, Carnegie Mellon University, USA
Andrew Sabelhaus
Mechanical Engineering, Boston University, USA

- We present a method for control of multi-input, three dimensional soft actuators that:
- Is provably stable and robust
- Tracks angular displacement trajectories with low-error and high-speed
- Rejects disturbances such as large impacts and gravity



Trajectory tracking (red dashed line is desired shape) and a high-level block diagram of the control

15:00–15:15	TuCT1.2

Visual Servoing for Pose Control of Soft Continuum Arm in a Structured Environment

Shivani Kiran Kamtikar, Samhita Marri, Benjamin Thomas Walt, Naveen Kumar Uppalapati, Girish Krishnan, Girish Chowdhary
University of Illinois at Urbana Champaign, USA

- Controlled the 3D position and the orientation of the soft continuum arm using a tip camera.
- Demonstrated feasibility of control using a single tip camera, thereby avoiding the need for multiple sensors that currently limit SCA control.
- Presented two different methods, *integrated* and *modular*.
- Methods are generalizable and adaptable to different conditions in a structured environment.

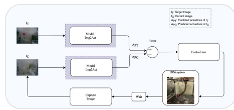


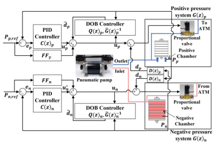
Fig: Workflow of our method to reach the target image given current image

15:15–15:30	TuCT1.3

Simultaneous Positive and Negative Pressure Control using Disturbance Observer Compensating Coupled Disturbance Dynamics

Chanyong Park, Myeongyun Doh, Hyungpil Moon*, et al.
Department of Mechanical Engineering
Sungkyunkwan University, South Korea

- This paper introduces a simultaneous positive and negative pressure controller for a pneumatic pump.
- When the positive and negative pressures are regulated, coupled dynamics caused by the pressure change affect the controller performance.
- A pressure controller based on a disturbance observer is designed to compensate for the coupled pressure dynamics.
- A verification of the effectiveness of the controller is done through a step and sinusoidal response experiments.



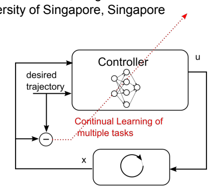
Pressure controller schema with the pneumatic circuit

15:30–15:45	TuCT1.4

Controlling Soft Robotic Arms Using Continual Learning

Francesco Piqué[1], Hari Teja Kalidindi[1,2], Lorenzo Fruzzetti[1], Cecilia Laschi[3], Arianna Menciassi[1] and Egidio Falotico[1]
[1]The BioRobotics Insitute, Scuola Superiore Sant'Anna, Italy
[2]Institute of Neuroscience, Université Catholique de Louvain, Belgium
[3]Department of Mechanical Engineering, National University of Singapore, Singapore

- Machine learning methods for control of soft robots may incur into catastrophic forgetting.
- Continual Learning mitigates this and enables the controller to adapt to changing soft robot dynamics.
- We use elastic weight consolidation to continuously re-tune a neuro-controller while changing the external loading.
- We demonstrate that the proposed controller can learn multiple tasks without forgetting.



Forward dynamic model

Bioinspiration and Control

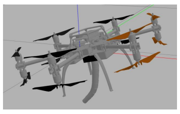
Chair
Co-Chair

15:45–16:30 | TuPo2S.1

Modeling and Control of an Omnidirectional Micro Aerial Vehicle Equipped with a Soft Robotic Arm

Róbert Szász and Minghao Han and Robert Kevin Katzschmann
Soft Robotics Lab, ETH Zürich, Switzerland
Mike Allenspach and Marco Tognon
Autonomous Systems Lab, ETH Zürich, Switzerland

- Modeling the system using the Augmented Rigid Body Model and Piecewise Continuous Curvature hypotheses
- Designing a hierarchical controller tailored for the coupled system
- Showing nullspace exploitation, disturbance rejection and trajectory tracking capabilities of the platform



The Aerial Vehicle with the Soft Robotic Arm used in simulations

15:45–16:30 | TuPo2S.2

Signalling Emotions with a Breathing Soft Robot

Troels Aske Klausen and Ulrich Farhadi
Faculty of Engineering, Univ. of Southern Denmark (SDU), Denmark
Evgenios Vlachos
MMMI and Univ. Library of Southern Denmark, Univ. of Southern Denmark (SDU), Denmark
Jonas Jørgensen
Center for Soft Robotics, SDU Biorobotics, MMMI, Univ. of Southern Denmark (SDU), Denmark

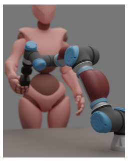
- A non-humanoid pneumatically actuated soft robot was developed to signal emotions by altering its shape, movements, and breathing rates
- In a user study we investigated how observers perceived the robot's emotional state at different breathing rates
- We found that a slow breathing rate between 7-12.5 breaths per minute corresponds to a high level of pleasure, whereas a high breathing rate of 40 breaths per minute corresponds to a high level of arousal

15:45–16:30 | TuPo2S.3

WISARD: Weight Informing Soft Artificial Robotic Dermis

Bjarke Larsen
Faculty of Engineering, Univ. of Southern Denmark (SDU), Denmark
Poramate Manoonpong
ENS Lab, SDU Biorobotics, MMMI, Univ. of Southern Denmark (SDU) / VISTEC, Thailand
Jonas Jørgensen
Center for Soft Robotics, SDU Biorobotics, MMMI, Univ. of Southern Denmark (SDU), Denmark

- We propose a soft robotic addition (WISARD) to a collaborative robot arm that emulates tensed muscles to visually inform a human receiver of the approximate payload weight
- Physical tests indicate that people can use the system to predict the weight of lifted objects and to respond appropriately when receiving them
- In an online video survey, we also found WISARD to increase the perceived warmth of the robot arm

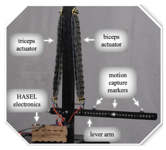


15:45–16:30 | TuPo2S.4

Model-Based Data-Driven System Identification and Controller Synthesis Framework for Precise Control of SISO and MISO HASEL-Powered Robotic Systems

Angella Volchko and J. Sean Humbert
Paul M. Rady Department of Mechanical Engineering, University of Colorado Boulder, USA
Shane K. Mitchell and Timothy G. Morrissey
Artimus Robotics, USA

- The biceps-triceps system uses an antagonist pair of electrohydraulic actuators to manipulate the lever arm
- A data-driven linear model was used for control design
- The system's closed-loop response demonstrates excellent tracking and disturbance rejection



15:45–16:30 | TuPo2S.5

A Desktop-sized Platform for Real-time Control Applications of Pneumatic Soft Robots

Brandon Caasenbrood[1], Femke van Beek[1], Hoang Khanh Chu[1], and Irene Kuling[1]
[1] Department of Mechanical Engineering, Eindhoven University of Technology, the Netherlands

- Development of an open-hardware platform for real-time pneumatic control of soft robotic systems;
- Intended for fast, precise, and accurate (closed-loop) control;
- Compatibility with Matlab, Matlab/SIMULINK, Unity; easy interface through minimal programming;
- Presented use-cases: model-based control and system identification, haptic feedback in VR, and tele-operation.

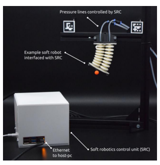


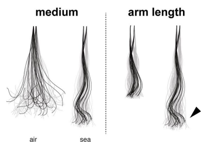
Fig. 1. Close-up of Soft Robotics Control-unit (SRC) with 2D soft robot.

15:45–16:30 | TuPo2S.6

Echo state property and memory in octopus-inspired soft robotic arm

Katsushi Kagaya[1], Bowei Yu[1], Yuna Minami[1], Kohei Nakajima[1,2]
1:Graduate School of Information Science and Technology, The University of Tokyo, Japan
2:Next Generation Artificial Intelligence Research Center, The University of Tokyo, Japan

- Soft robots function in the media, air or water
- Previous work demonstrated that octopus-inspired soft robotic arm can be a computational resource
- We demonstrate that the medium and arm length matter
- Echo State Property (ESP) is broken down in air, thus the memory capacity was low
- Better ESP in either sea- or tap-water was in line with high memory capacity



medium, arm length dependency

Bioinspiration and Control

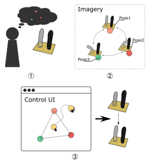
Chair
Co-Chair

15:45–16:30	TuPo2S.7

Task-oriented robot control user interface designer for cable-driven soft robots without kinematic models

Haoyan Li, Tomoka Nishino, Binod Dhakal, Hironori Mitake, Shoichi Hasegawa
School of Engineering, Tokyo Institute of Technology, Japan

- Task-oriented robot control UI designer for cable-driven soft robots
- Compared to kinematic model methods, our method does not need prior knowledge and reduces the time and labor costs
- The task space created by the proposed method provides more freedom, especially for casual users

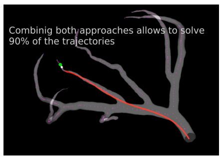


15:45–16:30	TuPo2S.8

Automated planning for robotic guidewire navigation in the coronary arteries

Pierre Schegg[a,b], Jérémie Dequidt[a], Eulalie Coevoet[a], Edouard Leurent[a]
[a] Univ. Lille, Inria, CNRS, Centrale Lille, UMR 9189 CRIStAL, F-59000 Lille, France
Rémi Sabatier[c], Philippe Preux[a] and Christian Duriez[a]
[b] Robocath, Rouen, France [c] Caen University Hospital, Caen France

- Inverse Model based controller (Quadratic Programming) achieves 20% success rate.
- Monte Carlo Tree Search based planning achieves 43% success rate.
- Our novel algorithm fusing the advantages of both achieves 90% success rate.
- Future work includes shape optimization of the instrument, manipulating several instruments and guaranteeing patient safety.



15:45–16:30	TuPo2S.9

A Data-Efficient Model-Based Learning Framework for the Closed-Loop Control of Continuum Robots

Xinran Wang, Nicolas Rojas
Dyson School of Design Engineering, Imperial College London, UK

- Learning methods requires thousands of real-data to train and fill sim-to-real gap.
- Our proposed framework only needs 100 real-data points to achieve comparable/better performance.
- Framework utilized recurrent network and Gaussian process regression to form hybrid controller.
- Three control policies proposed based on the data-efficient model-based learning framework.

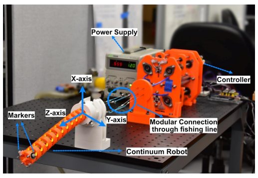


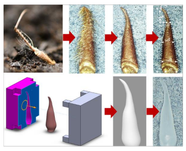
Fig 1. The continuum robot used in real experiments

15:45–16:30	TuPo2S.10

ROBOSOFT 2022
3D micromolding of seed-like probe for self-burying soft robots

Isabella Fiorello[1], Laura Margheri[1], Carlo Filippeschi[1] and Barbara Mazzolai[1]
[1]Bioinspired Soft Robotics Laboratory, Istituto Italiano di Tecnologia, Italy

- Plant seeds are mimicked for the prototyping of miniature self-burying devices for soil penetration and in situ monitoring of environmental parameters
- The morphometric and biomechanical benchmarks were extracted from natural capsules
- A biomimetic seed-like capsule is built via 3D micromolding and casting of biodegradable material
- The penetration forces of natural and artificial capsules in natural and artificial soil are characterized



From natural to artificial probes inspired by *Erodium malacoides*

15:45–16:30	TuPo2S.11

Anisotropic Forces for a Worm-Inspired Digging Robot

Dylan Drotman, Shivam Chopra, Nick Gravish, and Michael T. Tolley
Mechanical and Aerospace Engineering, UC San Diego, CA

- In this work, we designed a bioinspired soft digging robot inspired by polychaete worms (or bristle worms) that used reciprocal elongation and contraction to dig through granular material.
- Our study investigated the use of asymmetric features for producing anisotropic friction to achieve directed motion.

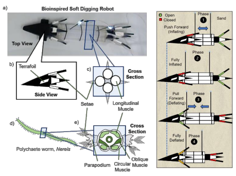


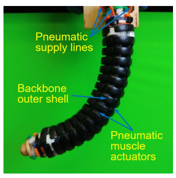
Figure: Bioinspired air-powered soft digging robot

15:45–16:30	TuPo2S.12

Hybrid Soft Robots Incorporating Soft and Stiff Elements

Dimuthu D. K. Arachchige and Isuru S. Godage
School of Computing, DePaul University, USA

- This paper proposes a bioinspired hybrid soft robot (HSR) design.
- The proposed HSR has about a 100% stiffness range increase than a previous soft robot design with identical physical dimensions.
- The HSR design can achieve independent stiffness and shape control.



Bioinspiration and Control

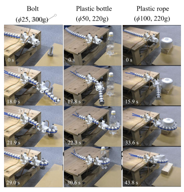
Chair
Co-Chair

15:45–16:30	TuPo2S.13

A Woodpecker's Tongue-Inspired, Bendable and Extendable Robot Manipulator With Structural Stiffness

Ryota Matsuda, Ujjal Krishnanand Mavinkurve, Ayato Kanada, Koki Honda, Yasutaka Nakashima, Motoji Yamamoto
Mechanical Engineering, Kyushu University, Japan

- Continuum robots with elastic backbones can bend and extend their body
- However, the lack of stiffness has restricted their deployment in real-world environments.
- Inspired by woodpeckers, we designed **a bendable and extendable manipulator with a rigid backbone**
- The manipulator hold three objects with weights between 220~300g and diameters between 25~100mm

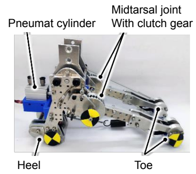


15:45–16:30	TuPo2S.14

Design of a Robotic Foot with Midtarsal Joint Locking Mechanism

Kazuma Enomoto, Tsung-Yuan Chen, Takumi Kawasetsu and Koh Hosoda
Engineering Science, Osaka University, Japan

- Developing the robotic foot with midtarsal joint locking mechanism
- Investigating the relationship between the locking angle of midtarsal joint and GRF and propulsive force
- The proposed foot could facilitate the design of biped robot feet



Picture of the proposed robotic foot using the midtarsal joint locking mechanism

Bioinspired systems

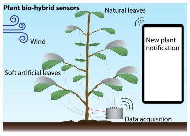
Chair *Simona Aracri, National Research Council*
Co-Chair *Ardian Jusufi, Max Planck Institute for Intelligent Systems; ETH Center for Learning Systems*

16:30–16:45	TuDT1.1

ROBOSOFT 2022
Living Plants as Climate Monitoring System

Serena Armiento, Alessio Mondini, Fabian Meder and Barbara Mazzolai
Bioinspired Soft Robotics, Italian Institute of Technology (IIT), Italy

- Local weather conditions can strongly affect crop yields
- Soft robotics provides solutions for devices that can interact with living organisms without harming them
- We present a plant biohybrid system which employs triboelectric signals to estimate the wind speed and gives a warning by sending a tweet on a dedicated account (@SensorPlant)
- While this is a proof-of-concept study, the system can be customized according to necessities.



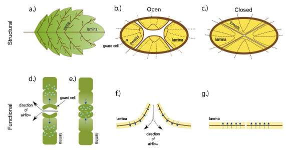
Schematic of the climate monitoring system.

16:45–17:00	TuDT1.2

A leaf-inspired robot combining embroidered structure with ion-induced actuation

Mona Küüts, Alvo Aabloo and Indrek Must
Institute of Technology, University of Tartu, Estonia

- Embroidery enables seamlessly integrated robotic applications on conventional textile platform
- Robot's program is defined by placement of a single uninterrupted fiber via embroidery
- Case study: tunable transpiration textile, structurally and functionally inspired by plant leaves



17:00–17:15	TuDT1.3

Data-driven Simulation Framework for Expressive Piano Playing by Anthropomorphic Hand with Variable Passive Properties

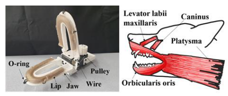
Huijiang Wang, Toby Howison, Josie Hughes, Arsen Abdulali and Fumiya Iida
Bio-Inspired Robotics Lab (BIRL)
Department of Engineering

17:15–17:30	TuDT1.4

Lip-Inspired Passive Jamming Gripper

Jooyoung Hong, Dhruv C Mathur, and Joohyung Kim
Kinetic Intelligent Machine LAB(KIMLAB), University of Illinois Urbana-Champaign, U.S.A.

- Gripper is inspired by lips and muscles near the lips.
- Passive particle jamming effect is utilized to generate soft and rigid characteristics of the lips.
- Lips assist grasping when holding objects.
- The gripper also shows re-grasping ability through repeating sequences.



Lip-inspired gripper and anatomy of lip muscles.

17:30–17:45	TuDT1.5

A biomimetic suction cup with a V-notch structure inspired by the net-winged midge larvae

Haoyuan Xu[1], Fuqiang Yang[1], Yiyuan Zhang[2] , Xinyu Jiang[1], and Li Wen[1]
[1]School of Mechanical Engineering and Automation, Beihang University , China.
[2]School of General Engineering, Beihang University, China.

- The conjoint actuation movement mechanism of the V-notch and Piston
- Susceptibility of the sucker's adhesive capacity to the values of V-notch angle and depth
- Morphological features of the sucker with a V-notch structure in the circumferential directions
- The V-notch structure's function as a water outlet

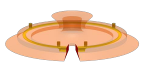


Diagram of the biomimetic sucker

17:45–18:00	TuDT1.6

A plant tendril-like soft robot that grasps and anchors by exploiting its material arrangement

Fabian Meder, Saravana P. M. Babu, and Barbara Mazzolai
Bioinspired Soft Robotics, Istituto Italiano di Tecnologia, Genoa, Italy
Saravana P. M. Babu
SDU Biorobotics, University of Southern Denmark, Denmark

- Tendrils are attachement systems that plants use to support their body on supports to reduce their own biomass during growth
- We extracted the basic tendril functions a) grasping-by-coiling b) anchoring and c) reinforcement by lignification (stiffening) in a soft robotic tendril that mimics the plant tendril
- Through material 'design and programming' the robotic tendril requires a only a short energy input during grasping and does not consume any energy during attachment.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Plenary Lecture - Barbara Webb

Chair *Adam Andrew Stokes, University of Edinburgh*
Co-Chair

Modeling and simulation

Chair *Christian Duriez, INRIA*
Co-Chair *Federico Renda, Khalifa University of Science and Technology*

10:00–10:15	WeAT1.1

Soft Passive Swimmer Optimization: From Simulation to Reality Using Data-Driven Transformation

Nana Obayashi and Josie Hughes
CREATE Lab, EPFL, Switzerland
Carlo Bosio
Sant'Anna School of Advanced Studies, Italy

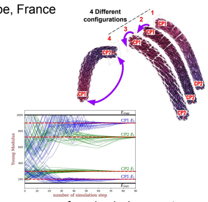
- Cheap second-order dynamics model of a parameterized tentacle surrogate with hydrodynamic forcings predicts thrust.
- Rigid transformation from sparse experimental thrust to simulations closes the reality gap.
- Thrust improvement for a tentacle demonstrates a low-cost simulation-driven design approach.
- Gains in tentacle performance are extended to a squid robot platform.

10:15–10:30	WeAT1.2

Enabling the control of a new degree of freedom by using anisotropic material on a 6-DOF parallel soft robot

Félix Vanneste, Olivier Goury and Christian Duriez
DEFROST team, Inria Lille-Nord Europe, France

- Formulation of a material parameters optimisation problem as a convex optimisation over several configurations of a soft robot.
- Application of the method on anisotropic mechanicalparameters.
- Demonstration of the method in the use case of simulation calibration for more accurate open-loop control of an anisotropic soft robot.



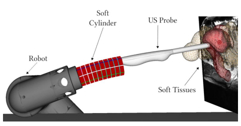
Convergence of mechanical parameters independently of their starting values thanks to multi-configuration optimisation problem

10:30–10:45	WeAT1.3

Planning of soft-rigid Hybrid Arms in Contact with Compliant Environment

Eulalie Coevoet[1,2], Yinoussa Adagolodjo[2], Meichun Lin[1,2], Christian Duriez[2], and Fanny Ficuciello[1]
[1]University Federico II Naples, Italy
[2]INRIA Lille, France

- Rigid robot hybridized with a soft part to improve its properties of relative positioning and safe interaction with soft tissues
- Pre-operative planning of the robot based on numerical models of both robotic system and soft tissues
- FEM to model the soft parts, and a mapping mechanism to propagate forces between soft and rigid models
- Inverse kinematics of the robotic system to guide the tip of the probe around the area of interest as it interacts with the soft tissues

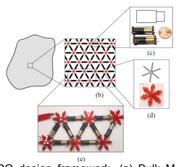


10:45–11:00	WeAT1.4

Finite Element Modeling of Internally Actuated Triangular Lattice and its Variants for Modular Active Cell Robots (MACROs)

Gaurav Singh and Aaron M Dollar
Department of Mechanical Engineering and Materials Science, Yale University, CT, USA

- MACRO: Modular design approach for soft robotic hardware that uses only two components, actuators and flexure nodes
- Investigate triangular MACRO mesh and its variants
- Use Finite Element model to quantify deformation for various choice of edges actuated withing a MACRO mesh.
- Demonstrate trade-off between actuation energy and passive stiffness
- Refine triangle mesh by removing edges and identify optimal mesh for desired behavior



MACRO design framework. (a) Bulk MACRO material, (b) constitutive triangular mesh, (c) linear contracting actuators, (d) compliant joints, and (e) physical prototype.

Modelling and simulation

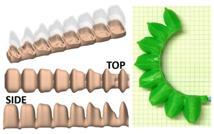
Chair
Co-Chair

11:00–11:45 WePo1S.1

Automated Synthesis of Pneumatic Bending Soft Actuators

Lawrence Smith, Travis Hainsworth, Jacob Haimes, and Robert MacCurdy
Mechanical Engineering, University of Colorado Boulder, USA

- Automated design tools augment human design intuition and enable rapid exploration of soft actuator design spaces
- We present fitness functions to incentivize the automated discovery of compliant yet forceful bending soft actuators
- We discover a selection of high performance actuators and quantify their simulated and empirical performance relative to other notable published results in the field



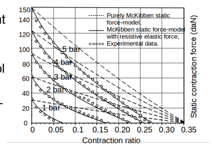
Automatically designed pneumatic bending soft actuator; visualization and fabricated test specimen

11:00–11:45 WePo1S.2

Static Modeling of Pneumatic Artificial Muscle Actuator

Bertrand Tondu
Université Fédérale de Toulouse and LAAS/CNRS, Toulouse, France

- The MIMO-actuator made of two antagonist McKibben-like artificial muscles makes possible a biomimetic control of both joint position and joint stiffness
- Among available static force models, this in the form $F(P,\varepsilon)=f(\varepsilon)P-g(\varepsilon)$ is particularly relevant for a model-based control
- Justification of this model by combining the classic theory of McKibben muscle applied to a thick-walled inner tube with a Neo-Hookean model of rubber elasticity
- A four-parameter model results applied, in particular, to the popular Festo DSMP-20-400 air muscle

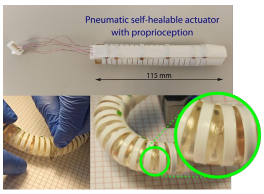


11:00–11:45 WePo1S.3

Hydrogel-based soft pneumatic bending actuator with self-healing and proprioception capabilities

Antonio López-Díaz[1], Andrei Braic[1], Francisco Ramos[1], Ismael Payo[2], Ester Vázquez[3], Andrés S. Vázquez[1]
{ [1]ETS Ingeniería Industrial de Ciudad Real, [2]Escuela de Ingeniería Industrial y Aeroespacial de Toledo, [3]Instituto Regional de Investigación Científica Aplicada }, Universidad de Castilla-La Mancha (Spain)

- Self-sensing and self-healing soft bending actuator based on a cationic network hydrogel.
- Curvature measured through a custom conditioning circuit with high linearity.
- Self-healing achieved autonomously with high efficiency and without any apparent effect in the sensing ability.
- Further studies are necessary to assess the effect of large changes in humidity conditions.

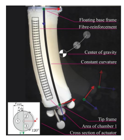


11:00–11:45 WePo1S.4

Dynamic Modeling of Soft-Material Actuators Combining Constant Curvature Kinematics and Floating-Base Approach

Maximilian Mehl and Max Bartholdt
Institute of Mechatronic Systems, Leibniz University of Hannover, Germany
Moritz Schappler
Institute of Mechatronic Systems, Leibniz University of Hannover, Germany

- For control, robust information on the system's state is critical
- Force torque sensors are used to measure the forces and moments at the robots base
- Floating-Base Approach to insert measured forces and moments into model
- Additional information on the system's state is obtained and used in an identification scheme

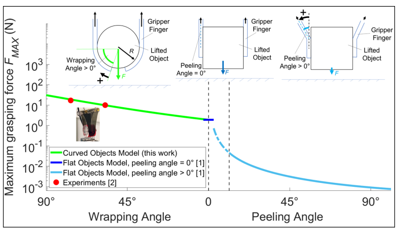


11:00–11:45 WePo1S.5

High-Force Soft Grippers with Electroadhesion on Curved Objects

Massimiliano Mastrangelo and Vito Cacucciolo
Department of Mechanics, Mathematics and Management, Polytechnic of Bari, Italy

- Electroadhesive soft grippers grasping curved objects generate higher grasping forces than with flat objects
- Current models don't account for curvature and predict lower forces; our model accounts for curvature
- Curved tension in the fingers pushes the fingers against the object, increasing friction force
- Grasping force is higher with smaller radius and with higher wrapping angle



[1] Cacucciolo et al., 2022; [2] Cacucciolo et al., 2019

11:00–11:45 WePo1S.6

Design, Characterization, and Dynamic Modeling of BEAST: a Bistable Elastomeric Actuator for Swift Tasks

Weijia Tao and Wenlong Zhang*
Ira A. Fulton Schools of Engineering, Arizona State University, USA
Zhi Qiao
School for Engineering of Matter, Transport, and Energy, Arizona State University, USA

- This actuator enables fast actuation, mechanical compliance, and continuum motion.
- A set of design rules and a novel fabrication method are presented.
- A hybrid linear parameter varying (HLPV) model is developed to describe the pressure-dependent dynamics.
- Both fast and gentle behaviors of the actuator are demonstrated in an object sorting task.

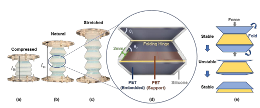


Figure 1. Overview of the BEAST actuator

Modelling and simulation

Chair
Co-Chair

11:00–11:45	WePo1S.7

Energy-based shape regulation of soft robots with unactuated dynamics dominated by elasticity

Pablo Borja[1], Azita Dabiri[2], and Cosimo Della Santina[1,3]
[1]Department of Cognitive Robotics, Delft University of Technology, The Netherlands
[2]Delft Center for Systems and Control, Delft University of Technology, The Netherlands
[3]Institute of Robotics and Mechatronics, German Aerospace Center (DLR), Germany.

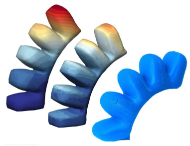
- We propose dynamic models for soft robots based on energy arguments.
- We present a family of regulators for soft robots.
- We establish conditions underactuated soft robots via collocated feedback.
- We validate the proposed approach via simulations.

11:00–11:45	WePo1S.8

Stretching The Boundary: Shell Finite Elements for Pneumatic Soft Actuators

Lawrence Smith, Jacob Haimes, and Robert MacCurdy
Mechanical Engineering, University of Colorado Boulder, USA

- Shell finite elements offer an attractive balance between computational cost and accuracy relative to traditional methods
- We present quantitative metrics for accuracy and computational cost and compare them for simulations of twelve pneumatic soft actuators
- We extend our analysis to investigate improving the accuracy of shell finite element simulations



Deformations predicted by shell and tetrahedral finite element simulations compared to reality

11:00–11:45	WePo1S.9

Self-Organization of Physics-Informed Mechanism in Recurrent Neural Networks: A Case Study in Pneumatic Artificial Muscles

Wentao Sun, Nozomi Akashi, Yasuo Kuniyoshi, and Kohei Nakajima
Graduate School of Information Science and Technology,
The University of Tokyo, Japan

- Echo state network (a type of recurrent neural network) with autonomously switching readouts
- Enhancement in accuracy of predicting the length of PAM
- The different gates become self-organized as experts in different situations
- Self-structuring within neural network of physical properties of PAM associated with hysteresis and deadband

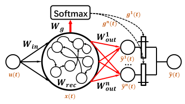


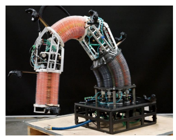
Fig.1 Echo state network with switching readouts.

11:00–11:45	WePo1S.10

Tractable and Intuitive Dynamic Model for Soft Robots via the Recursive Newton-Euler Algorithm

Spencer Jensen, Curtis Johnson, Alexa Lindberg, Marc Killpack
Mechanical Engineering, Brigham Young University (BYU), USA

- Extends the recursive Newton-Euler algorithm to serial chains of soft/rigid segments
- Simplifying assumptions make this lumped parameter model more intuitive
- Simulation model matches real system with approximately 3.15 degrees median absolute error
- Simulation model is computed faster than real-time while including rotational inertial effects



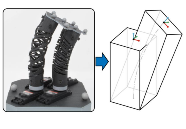
Hybrid soft robot with flexible joints and rigid links

11:00–11:45	WePo1S.11

Kinematic Modeling of Handed Shearing Auxetics via Piecewise Constant Curvature

Aman Garg, Ian Good,Daniel Revier, Kevin Airis, and Jeffrey Lipton
Mechanical Engineering, University of Washington, USA

- We make examine a platform of Handed Shearing Auxetics (HSA) by model the interactions between individual HSAs on a platform and
- Adapt the Piecewise Constant Curvature model to a HSA driven platform with 4 lengths
- Our model achieves a positional accuracy with mean error of 5.5mm or 4.5% body length and standard deviation of 1.72mm.
- We achieve an angular accuracy with mean error of -2.8 degrees and standard deviation of 1.9 degrees



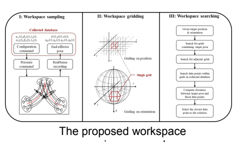
H.S.A. Platform modeling

11:00–11:45	WePo1S.12

Kinematic Analysis of Soft Continuum Manipulators Based on Sparse Workspace Mapping

Jing Li, James Lam,
Department of Mechanical Engineering, the University of Hong Kong, China
Xiaojiao Chen, Wenping Wang
Department of Computer Science, the University of Hong Kong, China
Yinyin Su, Zheng Wang*
Department of Mechanical and Energy Engineering, Southern University of Science and Technology, China

- Proposed an intuitive approach for modelling and control of soft continuum manipulators
- Proved the feasibility of simplifying the inverse kinematics problem to an intuitive space searching problem
- Established a quantitative relation between control accuracy and efficiency



The proposed workspace mapping approach

Modelling and simulation

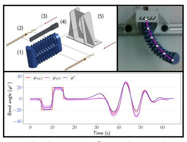
Chair
Co-Chair

11:00–11:45	WePo1S.13

Trajectory Optimization for Thermally-Actuated Soft Planar Robot Limbs

Anthony Wertz[1], Andrew P. Sabelhaus[2,3], and Carmel Majidi[1,3]
Robotics Institute, Carnegie Mellon University, USA
Mechanical Engineering, Boston University, USA
Mechanical Engineering, Carnegie Mellon University, USA

- Open-loop control of soft, thermally-actuated systems is challenging, largely due physical complexity.
- Simplifying assumptions can make dynamics and kinematics tractable while still tracking well.
- Strategic data collection allows for model calibration to be used for trajectory optimization.
- Optimization results define both the closest feasible trajectory and the control inputs to realize it.



Hardware configuration and open-loop tracking

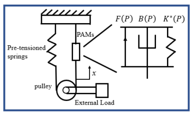
11:00–11:45	WePo1S.14

Optimization of spring constant of a pneumatic artificial muscle-spring driven antagonistic structure

Zhongchao Zhou, Shota Kokubu Wang Yuanyuan, Yuxi Lu, Pablo Enrique Tortós
Department of Medical System Engineering, Chiba University, Chiba, Japan
Yu Wenwei
Center for Frontier Medical Engineering, Chiba University, Chiba, Japan

Novel pre-tensioned PAMs-spring antagonistic structure

- ➢ To devise a method for determining the optimal spring constant with GDM
- ➢ To compare the performance of different spring constants with the optimal spring constant
- ➢ Sensitivity between dynamical model and optimal spring constant



PAMs: Pneumatic Artificial Muscles
GDM: Gradient descent with Momentum

Self-X

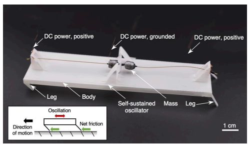
Chair *Majid Taghavi, Imperial College London*
Co-Chair *Seppe Terryn, Vrije Universiteit Brussel (VUB)*

11:45–12:00	WeBT1.1

A crawling robot driven by a folded self-sustained oscillator

Wenzhong Yan
Department of Mechanical and Aerospace Engineering, UCLA, USA
and Ankur Mehta
Department of Electrical and Computer Engineering, UCLA, USA

- Propose a locomotion mechanism through the combination of directional friction and transient impact-induced oscillation,
- a method that enables building functional robotic systems purely through cut-and-fold, only requiring universal materials, and
- an origami crawling robot fabricated out of the proposed design and verified by experiments.



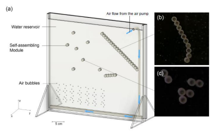
A proposed origami-inspired crawling robot (~3.8 g) driven by a folded self-sustained oscillator.

12:00–12:15	WeBT1.2

Size Changing Soft Modules for Temperature Regulated Self-assembly and Self-disassembly

Junyi Han, Quentin Lahondes and Shuhei Miyashita
Automatic Control and Systems Engineering, University of Sheffield, United Kingdom

- A novel cluster formation method of self-assembly modules by inducing the shape-changing mechanism by heat
- Inducing a directed disassembly using a temperature-responsive volume-changing hydrogel, pNIPAM
- Modules experiencing buoyancy and agitation from air bubbles and magnetically interacting with other modules

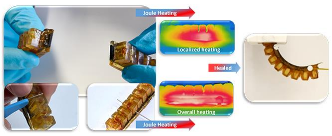


12:15–12:30	WeBT1.3

A Healable Resistive Heater as a Stimuli-Providing System in Self-healing Soft Robots

Seyedreza Kashef Tabrizian[1], Fatemeh Sahraeeazartamar[2], Joost Brancart[1,2], Ellen Roels[1,2], Pasquale Ferrentino[1], Julie Legrand[1], Guy Van Assche[2], Bram Vanderborght[1], Seppe Terryn[1,2]
[1]Brubotics, Vrije Universiteit Brussel (VUB) and Imec, Belgium
[2]FYSC, Vrije Universiteit Brussel (VUB), Belgium

- An optimum healing solution of damage resilient soft robots requiring heat as stimulus
- Providing a healing quality assessment and a healing on-demand mechanism
- Detection and localization of damage
- Monitoring the health of the system

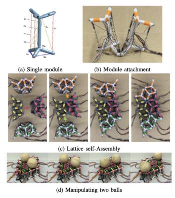


12:30–12:45	WeBT1.4

Soft Lattice Modules that Behave Independently and Collectively

Luyang Zhao†, Yijia Wu†, Julien Blanchet†, Maxine Perroni-Scharf §, Xiaonan Huang‡, Joran Booth‡, Rebecca Kramer-Bottiglio‡, Devin Balkcom†
Dartmouth College†, Yale University‡, Princeton University §

- Soft modular robots can locomote independently and connect to perform manipulation and locomotion collectively.
- Modules with flexibility can self-assemble into different structures with different capabilities.
- Non-prehensile manipulation and prehensile module-based gripper are explored.



Plenary Lecture - Josh Bongard

Chair *Fumiya Iida, University of Cambridge*
Co-Chair

Grasping and manipulation

Chair *Matteo Cianchetti, Scuola Superiore Sant'Anna*
Co-Chair *Jonathan Rossiter, University of Bristol*

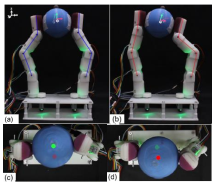
14:45–15:00	WeCT1.1

In-Hand Manipulation with Soft Fingertips

Soheil Sarabandi*
Institut de Robòtica i Informàtica Industrial, Spain
Genliang Chen
Shanghai Jiao Tong University, China
Qiujie Lu* and Nicolas Rojas
Dyson School of Design Engineering, Imperial College London, UK

- Proposed a 3D soft fingertip contact model
- An efficient method for computing joint angles to move a grasped object without losing grasp equilibrium.
- The proposed technique is based on keeping the initial grasp equilibrium condition as a constraint to resolve finger redundancy.

* These two authors contributed equally to this paper.



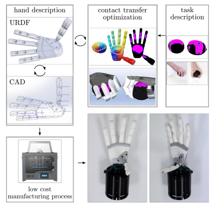
In-hand rotate and translate a sphere by a 4-DOF-finger hand with soft fingertips

15:00–15:15	WeCT1.2

Towards Very Low-Cost Iterative Prototyping for Fully Printable Dexterous Soft Robotic Hands

Dominik Bauer, Cornelia Bauer, Arjun Lakshmipathy, Roberto Shu and Nancy S. Pollard
Robotics Institute and Computer Science Department, Carnegie Mellon University, USA

- Design and fabrication framework for fully printable soft robotic hands
- Evaluate and test design candidates quickly against their ability to perform certain dexterous grasps
- Systematically take advantage of low-cost multi-material printing
- Very low-cost, durable and customizable



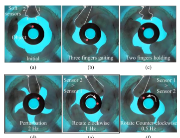
Iterative Design and Fabrication Framework

15:15–15:30	WeCT1.3

Embedded Soft Sensing in a Soft Ring Actuator for Aiding with the Self-Organisation of the In-Hand Rotational Manipulation

Ryman Hashem and Fumiya Iida
Department of Engineering, University of Cambridge, UK

- Soft sensor embedded in a soft ring actuator with five fingers.
- Soft hand to identify the bifurcation of manipulated objects during the in-hand manipulation process.
- Self-organisation behaviour with soft fingers rotating an object without a required control for the rotation.
- Soft sensors detecting the behavior with no interference with the manipulated object.



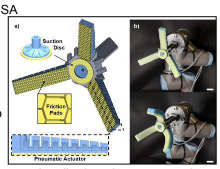
The concept of the gaiting of soft fingers to rotate an object with embedded sensors

15:30–15:45	WeCT1.4

Combining suction and friction to stabilize a soft gripper to shear and normal forces, for manipulation of soft objects in wet environments

Jessica A. Sandoval, Iman Adibnazari, Dimitri D. Deheyn, Michael T. Tolley
University of California San Diego, USA
Thomas Xu
Carnegie Mellon University, USA

- A wet environment poses a challenge to soft gripping due to surface lubrication.
- We demonstrated that suction and friction stabilized the grasp of a soft gripper in wet environments.
- The contribution of suction and friction was linearly additive to the resulting force to resist disturbances.
- The adhesive gripper demonstrated a stable grasp of submerged samples (including biological specimen).



An adhesive gripper composed of a central suction disc flanked by three textured fingers.

Smart structures and manipulation

Chair

Co-Chair

15:45–16:30 WePo2S.1

OobSoft Gripper: A reconfigurable soft gripper using Oobleck for versatile and delicate grasping

Francisco Yumbla and Hyungpil Moon
Department of Mechanical Engineering, Sungkyunkwan University, Republic of Korea
Wendy Yumbla and Emiliano Quiñones Yumbla
Faculty of Mechanical and Production Sciences Engineering, ESPOL Polytechnic University, Ecuador

- Reconfigurable soft gripper (OobSoft) based on Oobleck.
- Combination of soft materials, including the properties of Oobleck, rubber, and a bio-inspired design.
- The fingers (Oobleck inside a rubber membrane) flow around the object and conform to its shape. Grasping and holding capabilities successfully by a simple actuation mechanism.
- The viscosity of the Oobleck increases, so it quickly hardens to pinch and hold the object without requiring sensory feedback.

OobSoft Gripper

15:45–16:30 WePo2S.2

One-shot Learning Closed-loop Manipulation of Soft Slender Objects Based on a Planar Polynomial Curvature Model

Lars Besselaar
Delft University of Technology (TU Delft), The Netherlands

Cosimo Della Santina
Delft University of Technology (TU Delft), The Netherlands
Deutsches Zentrum fur Luft- und Raumfahrt (DLR), Germany

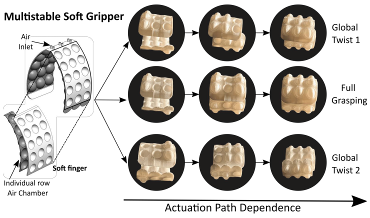
- This paper proposes to look at manipulation of deformable objects through the lenses of closed loop control of soft robots.
- We show that the only non-geometrical information needed to perform this task is the stiffness distribution.
- We thus propose a strategy to learn this function from a single interaction with the object, testing it experimentally.
- We then propose a closed-loop controller that exploits this learned information to perform the manipulation task and test it with simulations.

15:45–16:30 WePo2S.3

Programmable multistable soft grippers

Juan C. Osorio, Harith Morgan and Andres F. Arrieta
Department of Mechanical Engineering, Purdue University, USA

- Soft robotic gripper with multiple programmable stable states
- Pneumatic actuation with repeatable open loop control
- Gripper configuration depends on order of actuation



15:45–16:30 WePo2S.4

Getting a Grip: *in Materio* Evolution of Membrane Morphology for Soft Robotic Jamming Grippers

David Howard[1], Jack O'Connor[1,2], Jordan Letchford[1,3], James Brett[1], Therese Joseph[1,3], Sophia Lin[1,4], Daniel Furby[1,3] and Gary Delaney[1]
[1]Data61, CSIRO, Australia, [2]University of Queensland, Australia
[3]QUT, Australia [4]University of Melbourne, Australia

- Some soft robotic design spaces are not amenable to current modelling techniques, including granular jamming grippers.
- We use a pure-hardware evolutionary algorithm and 3D print an entire generation at once. We run 15 generations for a total of 75 physical grippers.
- Grippers are defined by an evolvable Bezier curve, which is rotated around a central axis to create a radially symmetric gripper and evolved towards high grip force on a test object.
- Final grippers show 5X performance compared to standard, commonly-used membrane shapes from the literature.

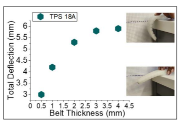
Sample evolved grippers

15:45–16:30 WePo2S.5

Case study of a rapid prototyping method for optimizing soft gripper structures with integrated piezoresistive sensors

Antonia Georgopoulou, Louisa Marie Eckey, Somashree Mondal, Frank Clemens
Department of Functional Materials, Empa – Swiss Federal Laboratories for Materials Science and Technology, Switzerland

- Pellet-based material extrusion is cost and time efficient for design optimization of soft robots
- Increasing the geometrical stiffness of soft robotic grippers increases the deflection and activation force
- The total deflection and activation force increases with the Shore hardness of the elastomer
- Sensing elements in the gripper of higher Shore hardness show low drift and good sensitivity

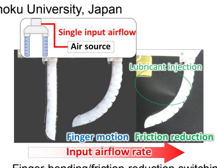


15:45–16:30 WePo2S.6

Soft robotic hand with finger-bending/friction-reduction switching mechanism through 1-degree-of-freedom flow control

Toshihiro Nishimura, Yosuke Suzuki, Tokuo Tsuji and Tetsuyou Watanabe
Institute of Science and Engineering, Kanazawa University, Japan
Kensuke Shimizu and Seita Nojiri
Graduated school of Natural science and Technology, Kanazawa University, Japan
Kenjiro Tadakuma
Graduation School of Information Sciences, Tohoku University, Japan

- Pneumatic soft robotic hand with the friction-reduction function, using the airflow-path-switching mechanism
- A single airflow control allows for the finger motion control, friction-reduction function with the lubricant injection, and the switching between these functions
- The switching mechanism is analyzed, and its performance is evaluated experimentally
- The effectiveness of the developed robotic hand for the grasping objects and manipulation is demonstrated experimentally



Finger-bending/friction-reduction switching according to the input airflow rate

Smart structures and manipulation

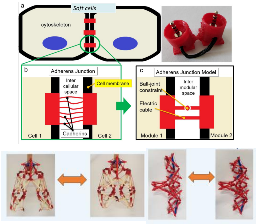
Chair
Co-Chair

15:45–16:30	WePo2S.7

ROBOSOFT 2022 Digest Template
Unleashing Soft Modular Robots by means of a Bio-inspired Connection Strategy

D. Zappetti, W. J. Stewart., M. Boutot, and D. Floreano
Laboratory of Intelligent Systems, EPFL, Switzerland

- We present a new bio-inspired inter-module connection strategy that connects soft modules mechanically and electrically without sacrificing the high deformability of the robot nor the low electrical resistance.
- We show that our strategy allows connected modules to retain stiffness in the same order of magnitude as individual modules while providing low electrical resistance.
- We demonstrate the strategy with two untethered soft modular tensegrity robots, a gripper capable of holding two times its body weight and grasp objects of different shapes and a crawler that can move up to 4.5cm/min.

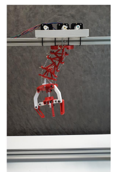


15:45–16:30	WePo2S.8

HEDRA: A Bio-Inspired Modular Tensegrity Robot With Polyhedral Parallel Modules

Vishal Ramadoss*, Keerthi Sagar*, Mohamed Sadiq Ikbal, Jesus Hiram Lugo Calles, Raghuveer Siddaraboina and Matteo
PMAR Robotics Group, University Of Genova, Italy

- The emerging field of tensegrity robotics aims to combine the advantages of conventionally stiff and the continuous compliant mechanisms.
- The design process of the bio-tensegrity manipulator in three-dimensions based on the tetrahedral parallel structure linked by tensegrity joint is presented.
- An alternative design methodology to either rigid or soft robots are tension-integrity systems.



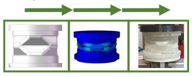
*Equal contribution

15:45–16:30	WePo2S.9

Sensitivity Analysis for 3D Printed Soft Pneumatic Actuators from 2D Origami Patterns to Functional Systems

Ditzia S. Garcia Morales and Chaoming Jiang and Annika Raatz
Institute of Assembly Technology, Leibniz University Hannover, Germany

- Using origami for simple and easy soft pneumatic actuators design
- Sensitive analysis of the design parameters and their compromise between strength and displacement
- Rapid selection for desired strength/performance combination based on application

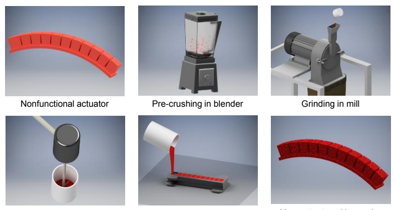


15:45–16:30	WePo2S.10

Recycling-oriented fabrication of soft robots

Anh Minh Nguyen & Arthur Seibel

Fraunhofer

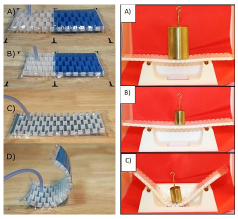


15:45–16:30	WePo2S.11

R3VAMPs - Recyclable, Reconfigurable, and Recoverable Vacuum Actuated Muscle-inspired Pneumatics

Portia Rayner, Luka Mortia, Xiaoruo Sun and Dan Sameoto
Department of Mechanical Engineering, University of Alberta, Canada

- 3D printed infill patterns can act as reconfigurable actuators or jamming composites
- Polypropylene is used for nearly all structural components, which is extremely low cost and potentially fully recyclable
- Vacuum driven actuation can produce linear, bending or jamming actuation through simple changes of sleeve properties
- R3VAMPs can be a simple building block for more complex soft robotic systems.

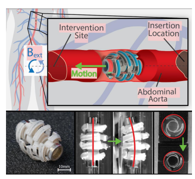


15:45–16:30	WePo2S.12

ROBOSOFT 2022 Digest Template
A Magnetically-Actuated Flexible Capsule Robot for Untethered Cardiovascular Interventions

Gijsbert Michiel van Vliet, Sarthak Misra, Venkatasubramanian Kalpathy Venkiteswaran
Surgical Robotics Laboratory, Department of Biomechanical Engineering, University of Twente, The Netherlands
Department of Biomedical Engineering, University of Groningen and University Medical Centre Groningen, The Netherlands

- A new, wireless, magnetically-actuated capsule robot (CMCR) as an untethered tool for cardiovascular surgery
- CMCR has radial adaptability, axial flexibility and embedded magnetic components
- Experiments are performed on prototypes of the CMCR to demonstrate its function as a proof-of-concept



Smart structures and manipulation

Chair

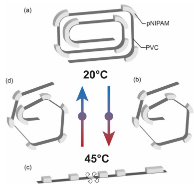
Co-Chair

15:45–16:30	WePo2S.13

Temperature Driven Soft Reversible Self-folding Origami String

Quentin Lahondes and Shuhei Miyashita
Automatic Control and System Engineering, The University of Sheffield, United Kingdom

- Development of temperature-driven self-folding and self-unfolding of strings
- Novel fabrication process for pNIPAM hydrogel and PVC bilayers with a success rate of 95% per hinge
- Self-folding and self-unfolding of 2D patterns: triangle, square and rectangular coil

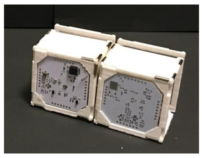


15:45–16:30	WePo2S.14

Module-W: Reconfigurable Modular Robots Forming Compliant Structures

Daisuke Kaneishi and Kota Takijo
BionicM Inc., Japan

- Introduce a modular robot named Module-W, which has the abilities of self-reconfiguration and compliant interaction
- Develop an extendable rod which enables the robot to place its bodies on the diagonal
- Design a low-level controller for self-reconfiguration and for compliant actuation in response to external force
- Validate empirically that Module-W has the potential to perform as structures with variable stiffness



Module-W (M-W)

Smart structures and mechanisms

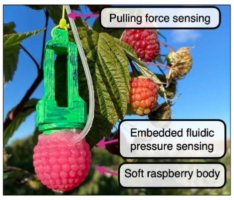
Chair *Indrek Must, Istituto Italiano di Tecnologia*
Co-Chair *Josie Hughes, EPFL*

16:30–16:45	WeDT1.1

Soft Sensorized Physical Twin for Harvesting Raspberries

Kai Junge and Josie Hughes
CREATE Lab, EPFL, Switzerland

- A physical twin of a raspberry captures the properties of a real raspberry.
- A sensorized physical twin was designed and fabricated to assist development of harvesting robots.
- The physical twin measures the pulling and compression force on and off the plant.
- The sensor readings can be used to assess the quality of the harvesting motion.

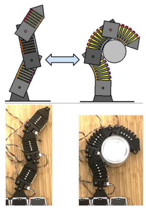


16:45–17:00	WeDT1.2

Contact-Rich Soft-Rigid Robots Inspired by Push Puppets

James M. Bern, Leonardo Zamora Yañez, Emily Sologuren and Daniela Rus
Computer Science and Artificial Intelligence Laboratory, MIT, USA

- We present soft-rigid robots inspired by push-puppets.
- We extend a differentiable FEM-based simulator to include soft body contact and revolute joints.
- We compose multiple modules into a shape-shifting arm.

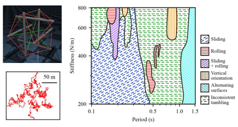


17:00–17:15	WeDT1.3

Behavioral Diversity Generated from Body–Environment Interactions in a Simulated Tensegrity Robot

Ryo Terajima, Katsuma Inoue, Shogo Yonekura, Kohei Nakajima, and Yasuo Kuniyoshi
Graduate School of Information Science and Technology, the University of Tokyo, Japan

- Analyze the types of movement produced by actuating ***tensegrity robots*** with sinusoidal commands
- Nonlinear relationship between behavior and system parameters (actuation ***period*** / tendon ***stiffness***)
- Anomalous deterministic diffusion, chaotic behavior
- Generated behavior map can be exploited to achieve adaptive behavioral switching



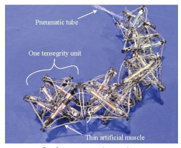
The robot (top left), an example of diffusion (bottom left), and categories of robot behavior (right).

17:15–17:30	WeDT1.4

Soft Tensegrity Robot Driven by Thin Artificial Muscles for the Exploration of Unknown Spatial Configurations

Ryota Kobayashi, Hiroyuki Nabae, Gen Endo, and Koichi Suzumori
Department of Mechanical Engineering, Tokyo Institute of Technology, Japan

- We have developed a novel method called "4/3 muscle winding."
- We realized large deformation of the tensegrity structure by using the method.
- By connecting the tensegrity structures, a lightweight soft tensegrity robot was created.
- The robot was demonstrated to possess passive shape adaptability in a three-dimensional environment.



Soft tensegrity robot

17:30–17:45	WeDT1.5

Pitch-up Motion Mechanism with Heat Welding by Soft Inflatable Growing Robot

Yuki Satake
Department of Modern Mechanical Engineering, Waseda University, Japan
Hiroyuki Ishii
Human Robotics Institute, Waseda University, Japan

- We developed a novel pitch-up motion mechanism for the soft inflatable growing robot.
- We developed stiffness and deformation models of the welded bending tube.
- We confirmed that the pitch-up motion agreed the models of the bending tube.

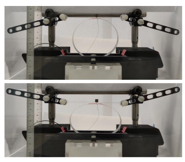
Pitch-up motion of soft inflatable growing robot

17:45–18:00	WeDT1.6

Electro-Ribbon Muscles for Biomimetic Wing Flapping

Jian Huai Chong[1,2], Christian Romero[1,2], Majid Taghavi[1,3] and Jonathan Rossiter[1,2]
1 Department of Engineering Mathematics, University of Bristol, UK
2 SoftLab, Bristol Robotics Laboratory, University of Bristol, UK
3 Department of Bioengineering, Imperial College London, UK

- We discuss mimicking the bumblebee thorax structure with indirect flight muscles.
- The actuator resembles the dorsoventral muscles and exhibits flexible and elastic characteristics that provide energy storage.
- The soft electro-ribbon actuator can be easily fabricated from any combination of conducting and insulating materials such as thin steel electrodes and PVC tape or even paper and pencil.
- The Solenoid Electro-Ribbon Actuator (SERA) is a linear contractile elastic muscle unit and demonstrates a biomimetic proof of concept of the use of SERA for a flapping-wing mechanism.



(top) Downstroke and (bottom) upstroke of the SERA biomimetic flapping-wing mechanism

Plenary Lecture - Thomas Speck

Chair *Barry Trimmer, Tufts University*
Co-Chair

Wearable structures

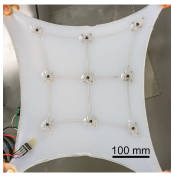
Chair *Laura Blumenschein, Purdue University*
Co-Chair *Arianna Menciassi, Scuola Superiore Sant'Anna - SSSA*

10:00–10:15	ThAT1.1

Self-Sensing, Stretchable, Active Circuit Arrays: Liquid Metal Paste as a Combination Interconnect and Strain Sensor

Callen Votzke[*,†], Yiğit Mengüç[§,†], and Matthew L. Johnston[*,†]
[*]School of Electrical Engineering and Computer Science,
[†]Collaborative Robotics and Intelligent Systems Institute,
Oregon State University, Corvallis, OR 97331, USA
[§] Facebook Reality Labs, Redmond, WA 98052, USA

- An approach for fabricating fully-stretchable, multi-layer active circuit arrays in silicone
- Liquid metal paste power and data wires re-purposed as strain sensors
- Grid deformation can be estimated from self-sensing of voltage drops between electronic nodes
- Potential for proprioceptive soft skins with additional sensors distributed throughout



10:15–10:30	ThAT1.2

Towards a Soft Exosuit for Hypogravity Adaptation: Design and Control of Lightweight Bubble Artificial Muscles

Emanuele Pulvirenti, Richard S. Diteesawat, Helmut Hauser,Jonathan Rossiter

Bristol Robotics Laboratory and Department of Engineering Mathematics, University of Bristol, UK

- The work was aimed at developing a preliminary control strategy for Bubble Artificial Muscles for space applications.
- Two control modes – force and displacement – were developed for two actuators with different physical characteristics.
- Both controllers show good steady-state error and allow dynamic control under changing load conditions.
- Future work will be focused on antagonistic configurations of the actuators and exploration of adaptive controllers.

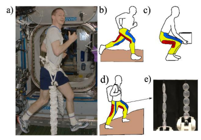


Fig 1 - Conceptual design of the HEXsuit and typical uses on Mars.

10:30–10:45	ThAT1.3

Soft Wearable Robot with Shape Memory Alloy (SMA)-based Artificial Muscle for Assisting with Elbow Flexion and Forearm Supination/pronation

Jaeyeon Jeong, Kyujin Hyeon, Seung-Yeon Jang,
Chongyoung Chung, Sajjad Hussain, and Ki-Uk Kyung
Mechanical Engineering, Korea Advanced Institute of Science and Technology, Republic of Korea
So-Young Ahn and Soo-Kyung Bok
Rehabilitation Medicine, Chungnam National University Hospital, Republic of Korea

- Soft wearable robot with SMA-based muscle is designed and fabricated.
- The proposed robot can assist 2-DoF motions including elbow flexion and forearm supination/pronation.
- The enhancement of range of motions and torques were evaluated by user experiments.
- High SUS scores were obtained from patients with low spasticity and high muscle force.

10:45–11:00	ThAT1.4

Flexible Fiber Inductive Coils for Soft Robots and Wearable Devices

Aby Raj P.M[1] , Thileepan Stalin[1] and Pablo Valdivia y Alvarado[1,2]

[1] Engineering and Product Development, Singapore University of Technology and Design (SUTD)
[2] Digital Manufacturing and Design Centre (DManD),
Singapore University of Technology and Design (SUTD), Singapore 487372

- Novel fabrication of soft inductive coils by patterning steel conductive fiber using Automated Fiber Embedding (AFE).
- Versatility of tailored coils for various applications include wearables, soft NFC tags, wireless charging and communication devices.
- Flexible Fiber Inductive Coils (FFIC) can undergo large elastic deformations with minimum bending radii (≤1 mm).

Various applications of soft inductive coils

Wearable and Locomotion

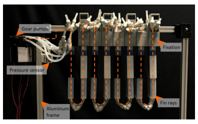
Chair
Co-Chair

11:00–11:45	ThPo1S.1

The Validation of Viscosity Induced Chord-wise Undulation on Soft Fin Ray Array towards a Novel Robotic Manta Ray

Yi Sun, Hongjian Wang
School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, Australia
Liao Wu
School of Mechanical and Manufacturing Engineering, University of New South Wales, Australia
Kaspar Althoefer
Centre for Advanced Robotics, Queen Mary University of London, United Kingdom
Peng Qi
Department of Control Science and Engineering, Tongji University, China

- This paper validates the feasibility of using viscosity induced motion sequencing method to generate the chord-wise undulation (CWU) of an soft fin ray array (SFRA).
- The undulations are tested with serial/parallel connections, single/dual channels, 4/6mm tube diameters.
- The viscosity effect successfully achieved the CWU in the SFRA, while the most desirable undulation was based on serial connection, dual channel and 6mm tube diameter.
- The results provided guidance for future manta ray robot fin design.



Undulation test setup with serial connection

11:00–11:45	ThPo1S.2

Towards half-moon-shaped soft pneumatic cilia

Edoardo Milana, Sam Peerlinck, Sean Flaherty, Dominiek Reynaerts and Benjamin Gorissen
Department of Mechanical Engineering, KU Leuven, Belgium

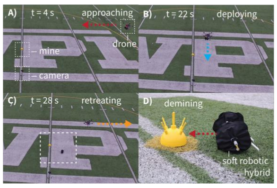
- Inflatable bending actuator with half-moon cross-section for ciliary propulsion
- Design optimization through FEM simulations
- Precision manufacturing of metal moulds for complex geometries
- 60° bending angle at 50 kPa inner pressure

11:00–11:45	ThPo1S.3

Air-Releasable Soft Robots for Explosive Ordnance Disposal

WPI
ROBOTIC MATERIALS GROUP
Tyler Looney and Nathan Savard
Markus P. Nemitz
Department of Robotics Engineering, Worcester Polytechnic Institute, USA

- **Problem**: Demining landmines using drones is inherently inaccurate due to complex deployment trajectories and constrained visual awareness by drone pilots.
- **Approach**: Low-cost, robust, and lightweight soft robots can more precisely align over landmines.
- **Results**: We developed a lightweight (296 g), untethered soft hybrid robot that incorporates a new type of a vacuum-based flasher roller actuator system.
- **Access**: The design files for our robot are accessible at: www.roboticmaterialsgroup.com/tools

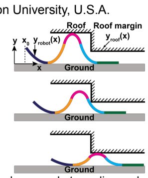


11:00–11:45	ThPo1S.4

Model-Based Control of Planar Piezoelectric Inchworm Soft Robot for Crawling in Constrained Environments

Zhiwu Zheng, Prakhar Kumar, Yenan Chen, Hsin Cheng,
Sigurd Wagner, Minjie Chen, Naveen Verma and James C. Sturm
Department of Electrical and Computer Engineering, Princeton University, U.S.A.

- This work develops a **model-based full-shape controller** to reach a target shape and to crawl under overhead constraints, validated and demonstrated by experiments
- A five-actuator **piezoelectric planar soft robot** is constructed for inchworm-like motion
- The controller uses a **soft-body continuous model** for shape planning and control
- An approach to **background model calibration** is developed for material parameter variations and drift



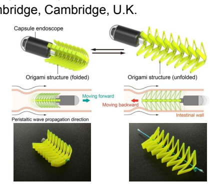
Inchworm robot crawling under a step-shaped roof, showing the necessity of full-shape control.

11:00–11:45	ThPo1S.5

Origami Inspired Design for Capsule Endoscope to Retrograde using Intestinal Peristalsis

Yukun Ge[1,2], Thilina Dulantha Lalitharatne[1,3] and Thrishantha Nanayakkara[1]
[1]Dyson School of Design Engineering, Imperial College London, London, U.K.
[2]School of Design, Royal College of Art, London, U.K.
[3]Department of Engineering, University of Cambridge, Cambridge, U.K.

- A novel origami inspired design for capsule endoscope to retrograde or anterograde using intestinal peristalsis.
- Simulation and experimental validation of the proposed design.
- Motion mechanism and dynamics analysis of the origami structure.



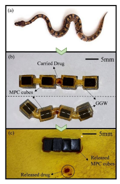
Folding and unfolding of the origami structure would allow to control the movement direction of the capsule endoscope.

11:00–11:45	ThPo1S.6

A Snake-Inspired Multi-Segmented Magnetic Soft Robot towards Medical

Chen Wang and Sarthak Misra
Department of Biomedical Engineering,
University of Groningen and University Medical Centre Groningen, Netherlands
Venkata Rithwick Puranam, Venkatasubramanian Kalpathy Venkiteswaran and Sarthak Misra
Department of Biomechanical Engineering, University of Twente, Netherlands

- Magnetically-actuated soft robots have potential for clinical application but require further innovation on functionality and biocompatibility
- In this paper, we propose a biodegradable multi-link snake-inspired magnetic soft robot
- The combination of biodegradable materials and snake-like locomotion endow the robot with drug delivery function
- The robot is verified to be dissolvable, controllable and functional



Wearable and Locomotion

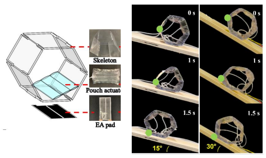
Chair
Co-Chair

11:00–11:45	ThPo1S.7

Electro-pneumatic Shape Morphing Rolling Robot with Variable Locomotion Modes

Chen Liu[1], Oliver Edwards[2], Kaspar Althoefer[1], Ketao Zhang[1] and Hareesh Godaba[2]
1. Centre for Advanced Robotics, Queen Mary University of London, UK
2. School of Engineering and Informatics, University of Sussex, UK

- A novel rolling robot whose body can shape-morph and execute multiple gaits.
- Integration of soft pneumatic actuators and electroadhesion feet with deformable body to achieve stable and accurate locomotion.
- Simple sequential control technique to steer the robot forward and backward.

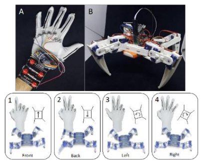


11:00–11:45	ThPo1S.8

Tailor-made smart glove for robot teleoperation using printed stretchable sensors

Manuel Reis Carneiro, Luis Rosa, Anibal de Almeida and Mahmoud Tavakoli
Insitute of Systems and Robotics, University of Coimbra, Portugal

- stretchable piezoresistive elements for strain and pressure sensing and conductive interconnects were directly printed on a user-fit textile glove using a carbon and silver-based inks
- No delamination or cracking of printed sensors was observed
- The fabricated glove is used for teleoperation of a mobile platform by recognition of 10 distinct hand poses corresponding to different gaits and actions of the robot

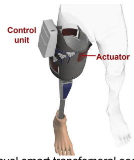


11:00–11:45	ThPo1S.10

Variable stiffness and shape prosthetic socket based on layer jamming technology

Linda Paternò[1, 2], Michele Ibrahimi[1, 2], Emanuele Gruppioni[3], and Arianna Menciassi[1, 2]
[1] the BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy
[2] the Department of Excellence in Robotics & AI, Scuola Superiore Sant'Anna, Pisa, Italy
[3] INAIL Centro Protesi, Bologna, Italy

- For adapting the stiffness and shape of the prosthetic interface to the physiological changes of the residual limb, a new smart transfemoral socket with integrated soft actuators is presented.
- Each actuator is constituted by one inflatable chamber and two layer jamming ones.
- A control unit was designed to allow for shape and stiffness changes of the actuator (weight: 450 g; dimension: 43 x 140 x 80 mm^3).



Novel smart transfemoral socket with variable stiffness and shape pneumatic actuators

11:00–11:45	ThPo1S.11

A Comparison of Silicone and Fabric Inflatable Actuators for Soft Hand Exoskeletons

Cem Suulker, Ahmed Hassan, Sophie Skach, and Kaspar Althoefer
Centre for Advanced Robotics at Queen Mary University of London, United Kingdom

- For **hand exoskeleton** applications most commonly used **two silicone** actuators and **two fabric** actuators are **compared**.
- Comparison points are: **bending angle**, **force output** and **grip strength** potentials of the actuators.
- **Fabric based** actuators **outperformed silicone ones** in force output, and grip strength tests.
- To have **large bending angle, stretch fabric** and **silicone** actuators should be preferred.
- For most **hand exoskeleto**n applications **fabric actuators** found to be a **more reliable** option.

11:00–11:45	ThPo1S.12

A Textile-Based Approach to Wearable Haptic Devices

Barclay Jumet, Zane A. Zook, Doris Xu, Nathaniel Fino, Anoop Rajappan, Mark W. Schara, Jeffrey Berning, Nicolas Escobar, Marcia K. O'Malley, Daniel J. Preston
Mechanical Engineering, Rice University, United States

- We show a squeeze band made from textiles, which represent a comfortable sheet-based material class for wearables.
- The squeeze cue is produced by serial pouch motors that contract to imbue a uniform, normal Laplace pressure.
- Force responses vary from 1.7 N to 67 N for pressures ranging from 50 kPa to 100 kPa.

Squeeze band manufactured in the sleeve of a shirt.

Wearable and Locomotion

Chair
Co-Chair

11:00–11:45	ThPo1S.13

Selective Patterning of Conductive Elastomers Embedded with Silver Powders and Carbon Nanotubes for Stretchable Electronics

Gyowook Shin and Sudong Lee
Mechanical Engineering, Seoul National University, Republic of Korea
Yong-Lae Park
Mechanical Engineering, Seoul National University, Republic of Korea

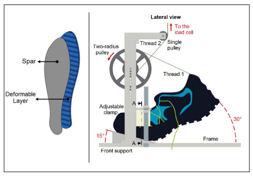
- Developed a method of fabricating stretchable electronics using a multi-material conductive elastomer structure
- Patterned conductive elastomer simply by laser cutting.
- Reduced noise by separating signal wires from sensor components: target-specific sensing with free wire-routing.
- Demonstrated the applicability of the proposed method with a wearable strain sensor, a rosette strain gauges array, and a stretchable RLC circuit.

11:00–11:45	ThPo1S.14

Layer jamming for variable stiffness shoes

Luca Arleo and Matteo Cianchetti
The BioRobotics Institute, Scuola Superiore Sant'Anna, Italy
Matteo Dalvit and Massimiliano Sacchi
Oberalp AG-SPA, Italy

- Layer Jamming technology successfully exploited in the real case scenario of variable stiffness shoes
- Achievement of satisfactory stiffness variation without the shape locking effect
- Adoption of a composite two-layer structure made of rubber and steel as filler material
- Development of a setup useful to conduct experimental tests both on different shoes and their components



Two-layer jamming structure and testing setup

Terrestrial locomotion

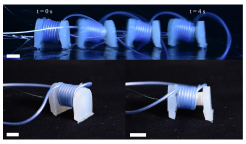
Chair *Marcello Calisti, The University of Lincoln*
Co-Chair *Fumiya Iida, University of Cambridge*

11:45–12:00	ThBT1.1

An Electromagnetic Soft Robot that Carries its Own Magnet

William R. Johnson III, Stephanie J. Woodman, and Rebecca Kramer-Bottiglio
Mechanical Engineering and Materials Science, Yale University, USA

- An electromagnetic soft robot exhibits *environment-independent* locomotion by carrying its magnet on-board
- Electromigration, a failure mode in liquid metals with high currents, is prevented with a new technique
- Magnetic blocking force and locomotion speed are characterized, and turning trajectories are demonstrated



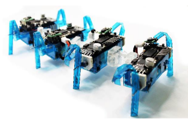
The robot achieves locomotion by alternately attracting and repelling an on-board permanent magnet

12:00–12:15	ThBT1.2

Effect of Feet Failure and Control Uncertainties on the Locomotion of Multi-Legged Miniature Robots

Nima Mahkam, Mustafa Uğur, Onur Özcan
Mechanical Engineering Department, Bilkent University, Turkey

- We build a miniature, origami-inspired, modular robot, SMoLBot.
- Manufacturing methods in small-scale robots cause failures, and miniature sensors are often unreliable.
- We investigated the effect of control uncertainties and feet failure on robot's locomotion.
- The effects are highly dependent on the total number of legs and the type of backbone (soft/rigid) attached to the robot.



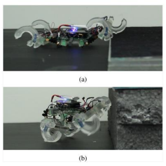
Eight-legged four-module Soft Modular Legged roBot (SMoLBot)

12:15–12:30	ThBT1.3

Detecting Scalable Obstacles Using Soft Sensors in the Body of a Compliant Quadruped

Doga Ozbek, Talip Batuhan Yilmaz, Mert Ali Ihsan Kalin, Kutay Senturk, Onur Ozcan
Mechanical Engineering Department, Bilkent University, Turkey

- Modular Soft Quadruped (M-SQuad)
- Soft sensors serve as both structural elements and sensing elements.
- Soft sensors are utilized for environmental perception.
- M-SQuad successfully identified obstacles as scalable or non-scalable via soft sensor responses.

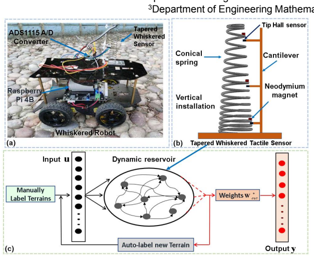


M–SQuad encounters (a) scalable obstacle, (b) non-scalable obstacle.

12:30–12:45	ThBT1.4

A Semi-Supervised Reservoir Computing System Based on Tapered Whisker for Mobile Robot Terrain Identification and Roughness Estimation

Zhenhua Yu[1]*, S.M.Hadi Sadati[2], Peter R. N. Childs[1], Helmut Hauser[3], Thrishantha Nanayakkara[1]
[1]Dyson School of Design Engineering, Imperial College London, UK
[2]Department of Surgical and Interventional Engineering, King's College, UK
[3]Department of Engineering Mathematics, University of Bristol, UK UK



Schematic of a tapered whisker-based semi-supervised reservoir computing system.
(a) Whiskered Robot setup.
(b) Tapered whisker sensor design.
(c) Semi-supervised reservoir computing system, showing the internal reservoir, auto-label new terrain, and a readout function.

- This paper present for the first time the use of tapered whisker-based semi-supervised reservoir computing (TWSSRC) system with limited readouts mounted on a mobile robot for new terrain identification, surface properties estimation and terrain classification.
- The robot could learn from prior physical experiences through cost-efficient self-supervised reservoir computing to achieve terrain property vagus estimation for traversability assessment with low computing cost and auto-labeling of new terrain.
- The experiment results have shown the potential of proposed method for the terrain classification of a completely unknown world without an excessive amount of human intervention and the whiskered robot

Plenary Lecture - Katia Bertoldi

Chair *Cecilia Laschi, National University of Singapore*
Co-Chair

Force and strain sensing

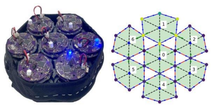
Chair *Kaspar Althoefer, Queen Mary University of London*
Co-Chair *Perla Maiolino, University of Oxford*

14:45–15:00	ThCT1.1

Strain-Based Consensus in Soft, Inflatable Robots

Alexandra Nilles, Steven Ceron, Nils Napp, and Kirstin Petersen
Cornell University, USA

- Soft robot collectives with physical contact between the modules are just beginning to be understood, but the coupling between sensing and actuation is promising for reducing communication hardware
- We introduce a new soft robotic module design, a simple model for collectives of these modules, implement an efficient simulator, and validate the simulator against hardware data
- We investigate methods for coordination without explicit module-to-module communication, and show a proof-of-concept of a proprioceptive consensus algorithm with 209 modules in simulation.

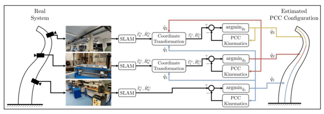


15:00–15:15	ThCT1.2

Sensing soft robots' shape with cameras: an investigation on kinematics-aware SLAM

Emanuele Rosi*[,1,2], Maximilian Stölzle*[,1], Fabio Solari[2], Cosimo Della Santina[1,3]
[1]Cognitive Robotics, Delft University of Technology, Netherlands
[2]Department of Computer Science, University of Genoa, Italy
[3]Institute of Robotics and Mechatronics, German Aerospace Center (DLR), Germany

- The nature of continuum soft robots calls for novel perception solutions for estimating the robot's shape while not interfering with the inherent softness.
- We propose a shape sensing strategy that combines a SLAM algorithm with nonlinear optimization based on the robot's kinematic model.
- We prove the method's effectiveness in simulation and with experiments of a single-segment continuous soft robot with a camera mounted at the tip.



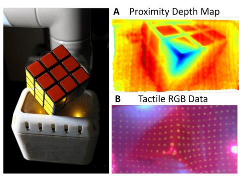
Cameras are attached to a soft continuum robot. We propose to use ORB-SLAM to gather a pose estimate for each camera. The results are refined by projecting the resulting postures onto the manifold of configurations attainable with the PCC kinematics.

15:15–15:30	ThCT1.3

Multimodal Visuotactile and Proximity with a Selectively Soft Membrane

Jessica Yin, Greg Campbell, James Pikul, and Mark Yim
GRASP Lab, University of Pennsylvania, USA

- Novel sensor provides simultaneous visuotactile and proximity data
- Integration of RGB camera, air pressure sensor, and time-of-flight depth camera with selectively transmissive membrane enables both modalities
- Applications in sensor fusion, dexterous and dynamic manipulation

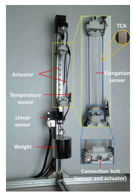


15:30–15:45	ThCT1.4

Soft artificial muscle with proprioceptive feedback: design, modeling and control

Tuan Luong, Sungwon Seo, Hyungpil Moon*, et al.
Department of Mechanical Engineering
Sungkyunkwan University, South Korea

- A biologically inspired soft robotic muscle from TCAs with embedded proprioceptive position feedback is proposed.
- The embedded elongation sensor fabricated from EcoFlex and liquid metal has little hysteresis and is soft, which can help detect the muscle's displacement.
- The position of the muscle module is controlled by applying an adaptive backstepping sliding mode control algorithm which can provide finite-time convergence, high tracking performance with no singularity, and less chattering.
- The muscle can be controlled with an average steady state error of 0.15mm and follow a sinusoidal waveform with composite frequencies of 0.01Hz and 0.03Hz using natural cooling.



Twisted-coiled actuator with proprioceptive feedback

Sensors

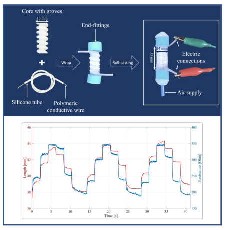
Chair
Co-Chair

15:45–16:30 ThPo2S.1

A Self-sensing Inverse Pneumatic Artificial Muscle

Lucrezia Lorenzon, Giulia Beccali, Martina Maselli and Matteo Cianchetti, *Member, IEEE*
The BioRobotics Institute, Scuola Superiore Sant'Anna, Italy

- Inverse pneumatic actuator that fully integrates a piezoresistive helical structure
- Upon pneumatic actuation, both the actuator length and the electric resistance vary
- Electro-mechanical characterization of the actuator and development of a calibration model
- Prediction of the actuator strain during dynamic testing from the electric resistance reading

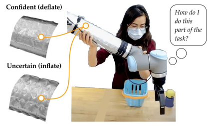


15:45–16:30 ThPo2S.2

Wrapped Haptic Display for Communicating Physical Robot Learning

Antonio Alvarez Valdivia [1], Ritish Shailly [2], Naman Seth [2], Francesco Fuentes [1], Dylan P. Losey [2], Laura H. Blumenschein [1]
[1] School of Mechanical Engineering, Purdue University, USA
[2] Department of Mechanical Engineering, Virginia Tech, USA

- Soft haptic systems that provide feedback to a human teacher can improve human-robot communication.
- Adding haptic feedback at existing points of contact makes intuitive, non-distracting signals.
- Wrapped haptic feedback improves human demonstrations, enhancing teaching efficiency.

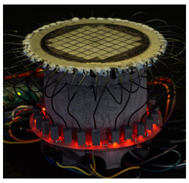


15:45–16:30 ThPo2S.3

Real-Time Pressure Estimation and Localisation with Optical Tomography-inspired Soft Skin Sensors

Abu Bakar Dawood, Brice Denoun and Kaspar Althoefer
Advanced Robotics at Queen Mary, Queen Mary University of London, UK

- Optical Tomography based Soft Sensor skin
- Real-Time pressure estimation and localization
- Increased sampling rate and performance by using multiple light sources concurrently

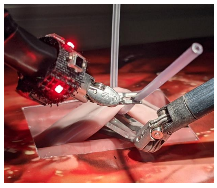


15:45–16:30 ThPo2S.4

A Physical Simulator Integrated with Soft Sensors for Mastering Tissue Manipulation in Robotic Surgery

Andrea Mariani, Selene Tognarelli, Arianna Menciassi
BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy
Dario Galeazzi, Elena De Momi
Department of Electronics, Information and Bioengineering, Politecnico di Milano, Italy

- Robot-assisted minimally invasive surgery requires the surgeons to **learn how to avoid excessive forces** applied to delicate tissues as blood vessels.
- This work focuses on the development of an **anatomy-based physical simulator of pulmonary vein** for training on tissue manipulation while using a surgical robot.
- The silicone-based simulator was **integrated with soft strain sensors for objective skill assessment** and for providing the trainee with a visuo-acoustic feedback.
- Preliminary user studies allowed us to assess the construct validity of the simulator, as well as the effectiveness of the feedback to reduce the stress applied to the vein.

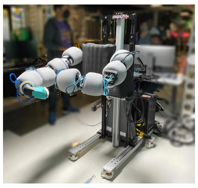


15:45–16:30 ThPo2S.5

Punyo-1: Soft tactile-sensing upper-body robot for large object manipulation and physical human interaction

Aimee Goncalves, Naveen Kuppuswamy, Andrew Beaulieu, Avinash Uttamchandani, Katherine M. Tsui, Alex Alspach
Toyota Research Institute

- We present the design of a soft, tactile-sensing humanoid upper-body robot using a module-based design philosophy to make *hard* off-the-shelf robots *soft*.
- We leverage mechanical intelligence with tactile sensing to develop and demonstrate motion primitives for whole-body grasping of large domestic objects.
- Our results demonstrate the importance of exploiting compliance and tactile sensing and provide a path forward for whole-body force-controlled interactions with the world.

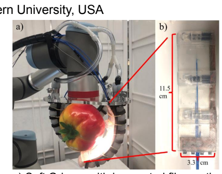

Punyo-1 robot

15:45–16:30 ThPo2S.6

In-Hand Object Recognition with Innervated Fiber Optic Spectroscopy for Soft Grippers

Nathaniel Hanson, Hillel Hochsztein, Akshay Vaidya, Joel Willick, Kristen Dorsey and Taşkın Padır
Institute for Experiential Robotics, Northeastern University, USA

- Our gripper contains full-spectrum lights with lensed fiber optic cables within an optically clear gel
- Hybrid manufactured pneumatic soft gripper provides modular platform for novel sensor tray
- Visible to Near-Infrared spectral reflectance curves are acquired from multiple points over objects
- Sensors and methods enable the categorization of similarly shaped and textured items


a) Soft Gripper with innervated fiber optic cables and full spectrum light sources mounted to a robotic arm. b) Profile of gripper pad

Sensors

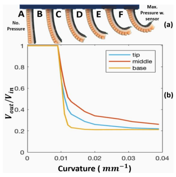
Chair
Co-Chair

15:45–16:30 ThPo2S.7

Curvature and Contact Sensing with Optical Waveguides for Soft Silicone Pneumatic Actuator

Faisal Aljaber, Ahmed Hassan,
School of Engineering and Materials Science, Queen Mary University of London, UK
Ivan Vitanov and Kaspar Althoefer
School of Electronic Engineering and Computer Science, Queen Mary University of London, UK

- Improvements to our previous soft multi-point waveguide sensor, in which 3 waveguides are configured in a staggered fashion.
- Improvement over the sensor responses to compression and bending.
- Use of a parsimonious approach to waveguide fabrication as compared to the more expensive approach used in a previous design.
- Sensor performance comparison juxtaposing Soft Silicone Pneumatic Actuator with a fabric-based actuator

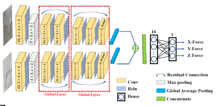


15:45–16:30 ThPo2S.8

Y-Net: A Deep Convolutional Architecture for 3D Estimation of Contact Forces in Intracardiac Catheters

Pedram Fekri[1], Hamidreza Khodashenas[1], Kevin Lachapelle[2], Renzo Cecere[2], Mehrdad Zadeh[3], Javad Dargahi[1]
1. Mechanical, Industrial and Aerospace Engineering Department, Concordia University, Canada
2. Division of Cardiology and Cardiac Surgery, McGill University Health Centre, Canada
3. Electrical and Computer Engineering Department, Kettering University, USA

- A novel deep learning architecture for force estimation.
- This senor-free method estimates applied forces to the tip of a ablation catheter in 3D directly from the biplane fluoroscopy images.
- The deep learning receives a two-channel image of a catheter at a time.
- It maps the catheter's deflections to the corresponding forces in x, y and z direction.



15:45–16:30 ThPo2S.9

Measuring Motion of Deformed Surfaces for Soft-bodied Robots/Animals with Multi-colored Markers

Kohei Hanaoka and Takuya Umedachi
Faculty of Textile Science and Technology, Shinshu University, Japan
Masahiro Shimizu and Shunsuke Shigaki
Department of Systems Innovation, Osaka University, Japan

- Capable of measuring **multiple** deformed shapes
- Simple Design and RGB Camera: **Low-cost**, **High versatility**
- Capable of measuring various targets (e.g., **humans** and **animals**)

15:45–16:30 ThPo2S.10

Hybrid Mechanism of Electromagnetic and Piezoresistive Sensing Using a Soft Microfluidic Coil

Byungjun Jeon, Bomin Jeong, and Yong-Lae Park
Soft Robotics and Bionics Lab., Department of Mechanical Engineering, Seoul National University, Republic of Korea

- Hybrid mechanism of electromagnetic and piezoresistive sensing modes.
- High-density microfluidic coil fabricated using a direct printing method for piezoresistive sensing.
- Hall effect sensor embedded in the elastomer body for electromagnetic sensing.
- Pressure sensing with a large dynamic range without reduction in sensitivity.
- Switching between two sensing modes using a mechanical relay.

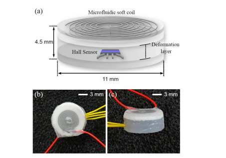


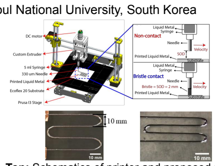
Fig. 1. Design of soft pressure sensor with a hybrid mechanism of electromagnetic and piezoresistive sensing using a soft microfluidic coil and a Hall effect sensor.

15:45–16:30 ThPo2S.11

Open-loop printing of liquid metal for the low-cost rapid fabrication of soft sensors

Junda Chen, Iman Adibnazari, and Michael T. Tolley
Department of Mechanical and Aerospace Engineering, University of California San Diego, USA
Benjamin Shih
School of Engineering and Applied Sciences, Harvard University, USA
Yong-Lae Park
Department of Mechanical Engineering, Seoul National University, South Korea

- We present two methods for printing soft, liquid metal sensors without the need for closed-loop control of standoff distance of extrusion head
- Both methods are well-suited for low-cost and high-speed printing of liquid metal traces with up to 1 mm resolution onto non-planar surfaces.
- We characterize the performance and robustness of each method and provide best practices surrounding their use



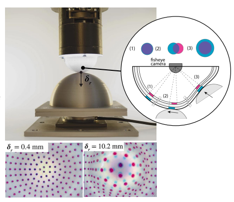
Top: Schematics of printer and proposed methods
Bottom: Sample traces printed via non-contact (left) and bristle contact (right) methods

15:45–16:30 ThPo2S.12

Rapid manufacturing of color-based hemispherical soft tactile fingertips

Rob Scharff*[1], Dirk-Jan Boonstra*[2], Laurence Willemet[2], Xi Lin[3], Michaël Wiertlewski†[2]
[1] *Bioinspired Soft Robotics Laboratory, IIT, Italy*
[2] *Cognitive Robotics Department, TU Delft, The Netherlands*
[3] *Carl Zeiss Meditec AG, China*
These authors contributed equally to this paper †Corresponding Author (E-mail: m.wiertlewski@tudelft.nl)

- Additive manufacturing of high resolution ChromaTouch tactile fingertips
- Normal and lateral forces transduced into changes in hue, centroid and apparent size of markers
- Demonstration of the tactile sensor capabilities in a curvature estimation task



Sensors

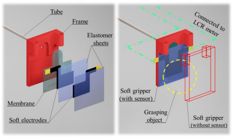
Chair
Co-Chair

15:45–16:30	ThPo2S.13

Grasping State and Object Estimation of a Flat Shell Gripper by Strain and Proximity Measurement using a Single Capacitance-Based Sensor

Takahiro Matsuno, Rikuya Miyagoshi, Mana Ishihara and Shinichi Hirai
Department of Robotics, Ritsumeikan University, Japan
Keita Shimizu, Shuya Watanabe and Jun Shintake
Mechanical and Intelligent Systems Engineering, The University of Electro-communications, Japan
Kaspar Althoefer
Faculty of Science & Engineering, Queen Mary University of London, UK

- A method to estimate grasping state and object of a flat shell gripper with single capacitance-based sensor is presented.
- The strain and proximity are measured by using a single capacitance-based soft sensor.
- The strain of the sensor is estimated from the capacitance measured at low frequency.
- The proximity of an object with high permittivity is estimated from the capacitance measured at high frequency.



Haptics and tactile sensing

Chair *Stefano Mintchev, ETH Zurich*
Co-Chair *Michael Wiertlewski, TU Delft*

16:30–16:45	ThDT1.1

Whisker-based Haptic Perception System for Branch Detection in Dense Vegetation

Leiv Andresen[1], Emanuele Aucone[1,2] and Stefano Mintchev[1,2]
[1]Environmental Robotics Laboratory, ETH Zurich, Switzerland
[2]Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland

- Haptic system capable of detecting branches occluded by foliage with an array of soft artificial whiskers
- The array of whiskers enters the vegetation and a repetitive sampling motion is performed
- An algorithm estimates branch locations based on the deflection of the whiskers
- Whisker deflection estimated using a vision-based tactile sensing approach with fiducial markers and a camera

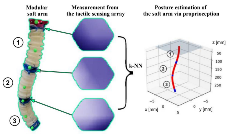

The system comprises soft artificial whiskers with fiducial markers and a camera

16:45–17:00	ThDT1.2

A Modular Soft Robotic Arm with Embedded Tactile Sensors for Proprioception

Wenye Ouyang, Liang He, Alessandro Albini and Perla Maiolino
Department of Engineering Science, University of Oxford, United Kingdom

- Design of a modular soft arm with integrated in-joint sensors for proprioception
- Each module is composed of a 3D printed omnidirectional actuator
- An embedded tactile sensor to capture the stress distribution over the base of one module
- A k-NN regressor is trained to correlate the tactile sensor responses with the corresponding posture

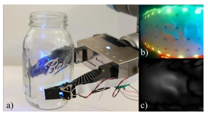


17:00–17:15	ThDT1.3

GelSight Fin Ray: Incorporating Tactile Sensing into a Soft Compliant Robotic Gripper

Sandra Q. Liu and Edward H. Adelson
CSAIL, Massachusetts Institute of Technology, USA

- Design of a novel sensorized GelSight Fin Ray gripper with touch sensing
- Can conform to and grasp many objects while using tactile feedback
- Performs tactile reconstruction, orientation estimation, and slip detection
- Combination of compliance and high resolution sensing enables complex manipulation tasks

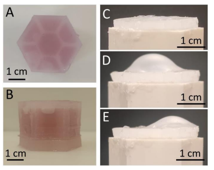

GelSight Fin Ray gripper grasping a mason jar, with the tactile reconstruction images on the right.

17:15–17:30	ThDT1.4

Soft Morphing Interface for Tactile Feedback in Remote Palpation

Leone Costi and Fumiya Iida
The Bio-Inspired Robotics Lab, University of Cambridge, UK
Perla Maiolino
Oxford Robotics Institute, University of Oxford, UK

- In the case of remote palpation, tactile feedback is of fundamental importance to achieve telepresence.
- We propose a pneumatic platform able to change its morphology accordingly to the remote environment.
- The device is fully soft, mimicking human soft tissues.
- We show that the overall system can deliver feedback with an accuracy up to 88%.



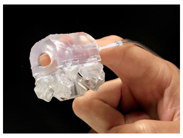
Proposed MFI (left) and example of single chamber actuation (right).

17:30–17:45	ThDT1.5

FingerPrint: A 3-D Printed Soft Monolithic 4-Degree-of-Freedom Fingertip Haptic Device with Embedded Actuation

Zhenishbek Zhakypov and Allison M. Okamura
Mechanical Engineering, Stanford University, USA

- Designing and fabricating a compact, multi-degree-of-freedom, and forceful fingertip haptic interface is challenging due to trade-offs among miniaturization, multifunctionality, and manufacturability.
- We developed a fully 3-D printed, soft, monolithic fingertip haptic device based on an origami pattern that embeds foldable vacuum actuation and produces 4-DoF of motion on the fingerpad with tunable haptic forces (up to **1.3 N** shear and **7 N** normal) and torque (up to **25 N-mm**).
- This work advances assembly-free mass fabrication of miniature and multifunctional haptic devices.

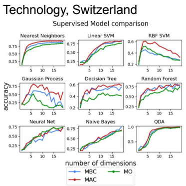

FingerPrint prototype

17:45–18:00	ThDT1.6

Magneto-Active Elastomer Filter for Tactile Sensing Augmentation through Online Adaptive Stiffening

Leone Costi and Fumiya Iida
The Bio-Inspired Robotics Lab, University of Cambridge, UK
Perla Maiolino
Oxford Robotics Institute, University of Oxford, UK
Arturo Tagliabue and Frank Clemens
Swiss Federal Laboratories for Materials Science and Technology, Switzerland

- What is the right stiffness of a tactile filter between a sensor and the environment?
- We propose a Magneto-Active Elastomer filter able to perform online adaptive stiffness modulation.
- We compare 3 stiffening strategies: Magnet Off (MO), Magnet Before Contact (MBC) and Magnet After Contact (MAC).
- Online adaptive stiffening leads to a better data structure and higher classification accuracy.



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