Electro-actuated Materials for Future Haptic Interfaces

Daniel Leithinger
ATLAS Institute, University of Colorado, Boulder
Boulder, Colorado, USA
daniel.leithinger@colorado.edu

Ran Zhou
ATLAS Institute, University of Colorado, Boulder
Boulder, Colorado, USA
ran.zhou@colorado.edu

Eric Acome
Artimus Robotics
Boulder, Colorado, USA
eric@artimusrobotics.com

Ahad Mujtaba Rauf
Stanford University
Stanford, California, USA
ahadrauf@stanford.edu

Teng Han
Institute of Software, Chinese Academy of Sciences
Beijing, China
hanteng@iscas.ac.cn

Craig Shultz
Fluid Reality Inc
Chicago, Illinois, USA
craig@fluidreality.com

Joe Mullenbach
Fluid Reality Inc
Chicago, Illinois, USA
joe@fluidreality.com

ABSTRACT

Electro-actuated materials (EAMs) have received wide attention within material science and soft robotics for their ability to dynamically change physical properties, such as shape and stiffness, in response to electrical stimuli. While researchers have begun exploring the haptic characteristics of EAMs, their integration into Human-Computer Interaction (HCI) shows challenges, including limited commercial availability and a lack of interdisciplinary knowledge exchange. This workshop specifically focuses on electrostatic (ES), soft electrohydraulic (SEH), and electroosmotic (EO) actuators. By bringing together researchers in the field, we aim to facilitate the exchange of findings, techniques, fabrication practices, and tacit knowledge within the HCI community. The workshop combines interactive demos, focused discussions, and hands-on ideation, providing a platform to explore the haptic potential of EAMs, identify key challenges and opportunities, and envision how these programmable materials can unlock new haptic interactions and interfaces.

CCS CONCEPTS

• **Human-centered computing** → **Interaction techniques**; **Haptic devices**.

KEYWORDS

Workshop, Electro-actuated Materials, Haptics, Shape-Changing Interfaces, Tangible Interaction, Prototyping, Wearables, Soft Robotics, Fabrication

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1 BACKGROUND AND MOTIVATION

Electro-actuated materials (EAMs) are soft robotic material systems that change their physical properties in response to electric stimuli [12]. By controlling the electrostatic attractive force between two conductive surfaces separated by a dielectric material and held at a potential difference, they can achieve programmable adhesion between the two surfaces (electrostatic brakes) [7, 10, 11], a change in size or shape (soft electrohydraulic actuators) [1, 2, 6, 8], or direct kinetic motion when submersed in a dielectric fluid (electroosmotic pumps) [9]. These materials have gained increasing interest in soft robotics for their high force output given their low mass and power consumption [3], and haptic applications including wearable interfaces [2, 4, 5], shape displays [6, 7, 9], and active textiles [4]. Recent work has also demonstrated that EAMs can couple their actuation with high-frequency capacitive position sensing with no performance loss by adding a small AC signal to the DC actuation voltage [13], opening the potential for novel conformal, self-sensing haptic interfaces.

Motivated by the aforementioned findings and arising needs, this workshop specifically focuses on exploring the haptic potential for EAMs. Built from lightweight and soft materials, EAMs show shared characteristics with the potential to overcome long-standing challenges of traditional electromechanical haptic actuators, as they are silent, compact, responsive, and customizable. These features make them particularly appealing for integration into haptic, wearable, and shape-changing interfaces. However, due to limited commercial availability, HCI researchers, designers, and practitioners face interdisciplinary challenges when approaching these materials. EAMs require specialized fabrication processes

and non-conventional, high-voltage (0.1-10kV) control electronics, inhibiting rapid prototyping workflows when designing interactive systems. Additional considerations include the reliability, longevity, safety, performance, and haptic qualities of each approach. To explore these questions, our workshop brings together researchers in the field, aiming to facilitate knowledge exchange within the UIST community.

2 SCOPE

This workshop aims to bring researchers working on EAMs to share their findings, fabrication practices, and tacit knowledge with UIST community through hands-on, interactive demonstrations, semi-guided discussions, and low-fidelity prototyping sessions. The intended audiences are researchers, designers, and practitioners interested in novel soft actuators for haptics, wearables, and shape-changing interfaces. We aim to investigate: (1) What are HCI researchers' needs and expectations when integrating soft actuators and sensors into haptic systems? (2) What challenges, concerns, and questions emerge when experiencing and prototyping with EAMs? (3) How can we best transfer EAM fabrication and controls knowledge to the HCI community? (4) What application opportunities can we envision and contribute to future haptic interfaces?

3 WORKSHOP STRUCTURE & GOALS

This hands-on workshop aims to combine interactive demos, focused discussion, and low-fidelity prototyping. After a welcome from the organizers and brief social ice-breakers, the organizers will give an overview presentation introducing EAMs (i.e., ES, SEH, EO) for their underlying principles, state-of-the-art technologies, current fabrication pipelines, and example haptic applications.

We then plan to curate a demo session with the latest haptic and shape-changing interfaces designed in EAMs, including: HASEL (hydraulically amplified self-healing electrostatic actuator) developer kits from Artimus Robotics [1, 8]; scalable shape displays with embedded EO pumps from Fluid Reality [9]; a programmable shape-display controlled by ES clutches [7]; and compact HASEL tags for wearable haptics [2]. During this session, participants will be divided into small groups to take turns experiencing each demo and having a moderated discussion with the presenting organizers. Afterward, we will invite participants to showcase their previous or ongoing research through live demos or lightning talks based on abstract submissions and indicated interest in the workshop application.

The afternoon will focus on learning the needs and expectations, identifying challenges, and brainstorming opportunities for EAMs in haptics. In the first small group discussion, participants will be split based on similar backgrounds and expertise (e.g., haptic technology, touch perception, wearables, shape-changing). The groups are guided to discuss specific topics and challenges that emerge in the presentations and demonstrations. Each group will document their thoughts with whiteboards and sticky notes and will present their ideas in the following large-group discussion.

The brainstorming activity will be hands-on with low-fi prototyping. On our promotion website, we will motivate our attendees to think about, "What hypothetical project would you initiate if you could integrate electro-actuated materials in your research projects?" The prototyping segments encourage participants to explore different form factors and potential interactions for their prepared ideas or new inspirations. The participants will be divided into small groups with different backgrounds to encourage interdisciplinary collaboration in the ideations. They will then showcase their prototypes in the large-group discussion.

The workshop will end with the organizers summarizing the identified challenges, needs, and opportunities for integrating EAMs into future haptics. These results will be documented, analyzed, and shared with the HCI community through a position paper.

4 TOPICS OF INTEREST FOR PARTICIPANTS

For this one-day workshop, we invite participants from UIST community who are experienced or interested in EAMs, and are enthusiastic about integrating them into future HCI applications. We particularly welcome researchers, designers, and practitioners in haptics, wearables, and shape-changing areas, as our main focus will revolve around haptic applications for EAMs. The topics of interest for the workshop include but are not limited to:

- Introducing the underlying technology of EAMs
- Testing out their haptic experiences
- Sharing fabrication approaches
- Exchanging knowledge about electronic hardware controls
- Tuning haptic cues and ideating authoring methods
- Discussing safety concerns and potential solutions
- Ideating potential form factors and interactions
- Brainstorming future applications

REFERENCES

[1] Eric Acome, Shane K Mitchell, TG Morrissey, MB Emmett, Claire Benjamin, Madeline King, Miles Radakovitz, and Christoph Keplinger. 2018. Hydraulically amplified self-healing electrostatic actuators with muscle-like performance. *Science* 359, 6371 (2018), 61–65. https://doi.org/10.1126/science.aao6139

[2] Yanjun Chen, Xuewei Liang, Si Chen, Yuwen Chen, Hongnan Lin, Hechuan Zhang, Chutian Jiang, Feng Tian, Yu Zhang, Shanshan Yao, and Teng Han. 2022. HapTag: A Compact Actuator for Rendering Push-Button Tactility on Soft Surfaces. In *UIST (UIST '22)*. 1–11. https://doi.org/10.1145/3526113.3545644

[3] Stuart Diller, Carmel Majidi, and Steven H. Collins. 2016. A lightweight, low-power electroadhesive clutch and spring for exoskeleton actuation. In *ICRA*. 682–689. https://doi.org/10.1109/ICRA.2016.7487194

[4] Ronan Hinchet and Herbert Shea. 2020. High Force Density Textile Electrostatic Clutch. *Advanced Materials Technologies* 5, 4 (2020), 1900895. https://doi.org/10.1002/admt.201900895

[5] Edouard Leroy, Ronan Hinchet, and Herbert Shea. 2020. Multimode hydraulically amplified electrostatic actuators for wearable haptics. *Advanced Materials* 32, 36 (2020), 2002564.

[6] Purnendu, Sasha M Novack, Eric Acome, Christoph Keplinger, Mirela Alistar, Mark D Gross, Carson Bruns, and Daniel Leithinger. 2021. Electriflow: Soft Electrohydraulic Building Blocks for Prototyping Shape-Changing Interfaces. In *DIS '21*. 1280–1290. https://doi.org/10.1145/3461778.3462093

[7] Ahad M. Rauf, Jack S. Bernardo, and Sean Follmer. 2023. Electroadhesive Auxetics as Programmable Layer Jamming Skins for Formable Crust Shape Displays. In *ICRA '23*. 2591–2597. https://doi.org/10.1109/ICRA48891.2023.10161500

[8] Philipp Rothemund, Nicholas Kellaris, Shane K Mitchell, Eric Acome, and Christoph Keplinger. 2021. HASEL artificial muscles for a new generation of lifelike robots—recent progress and future opportunities. *Advanced materials* 33, 19 (2021), 2003375.

[9] Craig Shultz and Chris Harrison. 2023. Flat Panel Haptics: Embedded Electroosmotic Pumps for Scalable Shape Displays. In *CHI '23* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 745, 16 pages. https://doi.org/10.1145/3544548.3581547

[10] Craig Shultz, Michael Peshkin, and J. Edward Colgate. 2018. The Application of Tactile, Audible, and Ultrasonic Forces to Human Fingertips Using Broadband Electroadhesion. *IEEE Transactions on Haptics* 11, 2 (Apr 2018), 279–290. https://doi.org/10.1109/TOH.2018.2793867

[11] Sylvia Tan, Roberta L. Klatzky, Michael A. Peshkin, and J. Edward Colgate. 2023. PixeLite: A Thin and Wearable High Bandwidth Electroadhesive Haptic Array. *IEEE Transactions on Haptics* (2023), 1–6. https://doi.org/10.1109/TOH.2023.3272635

[12] Bruno Vermes and Tibor Czigany. 2020. Non-Conventional Deformations: Materials and Actuation. *Materials* 13, 66 (Jan 2020), 1383. https://doi.org/10.3390/ma13061383

[13] Zachary Yoder, Daniela Macari, Gavriel Kleinwaks, Ingemar Schmidt, Eric Acome, and Christoph Keplinger. 2023. A Soft, Fast and Versatile Electrohydraulic Gripper with Capacitive Object Size Detection. *Advanced Functional Materials* 33, 3 (2023), 2209080. https://doi.org/10.1002/adfm.202209080