Soft Robotics and Actuated Materials for Human-Computer Interaction

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ABSTRACT

Recently, subdomains of Human-Computer interaction (HCI), such as Tangible Interfaces and Haptics, have experienced disruptive hardware transformations owing to advances in Soft Robotics and Programmable Materials. How will these fields shape the future of HCI over the next decade and beyond? Unfortunately, the transfer of fundamental advances from basic science to end-user experiences can take years due to many interdisciplinary challenges. These include challenges related to fabrication methods, durability, tools, access to resources, and transfer of knowledge. How can we most effectively overcome such challenges, what opportunities exist to accelerate progress, and what application possibilities can we envision and contribute to the future? We aim for a comprehensive approach to soft robotics design and fabrication and concepts of future applications for their integration into daily life. This workshop invites to explore how programmable materials develop new streams of HCI at the intersection of technology, design, art, and innovation.

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**; **Haptic devices**; *User interface toolkits*; *User studies.*

KEYWORDS

Workshop, Soft Robotics, Actuated Materials, Tools, Toolkits, Prototyping, Personal Fabrication, Haptics, Interfaces, Shape-Change, Access, Design

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1 BACKGROUND

Human-Computer Interaction (HCI), Human-Robot Interaction (HRI), Haptics, Interactive art and design (among other fields involving interactions between humans and dynamic hardware) are increasingly interested in leveraging novel actuation strategies, advanced materials, and soft robotics design approaches [6, 23]. Within HCI, this enables opportunities for highly dynamic tangible interfaces [15], haptic feedback technologies that feel more realistic [30], and user experiences that are more natural [20]. Soft and compliant actuated materials can better conform to different surfaces, including the human body; enable the adoption of bio-inspired principles, technologies, and actuators; have infinite degrees of freedom; and offer the ability to programmatically control physical structures at the material level [7]. Example characteristics include electrical conductivity under large strains [8], thermoregulation at thin form factors [19], high energy density [2], self-powered actuators [29], computation on compliant deformable substrates [9], on-demand stiffness control [26], and self-healing sensors [25] among others [10]. These abilities vastly expand the hardware design palette of HCI researchers and offer potential for disruptive changes in interfaces, haptics, art and design, education, and personal fabrication [3, 7, 11–13, 16–18, 27, 28]. Thus, we believe more focused attention and discussion is needed in the DIS community regarding how soft robotics and programable materials will continue to shape the future of HCI and the design of physical interfaces. In recent years a number of tutorial projects and methodologies for teaching programmable wearables, materials and soft robotics have emerged, in response to the resilience and access to sophisticated manufacturing laboratories, creating opportunities for resuming DIY home-based practices and continuing the development of research and creative approaches. The proposed one-day onsite workshop will provide a platform for discussing challenges, best practices, and possible future applications in the context of soft robotics and actuated materials. We hope to facilitate those as starting points to explore critical questions on how HCI researchers can benefit from a transfer of design-, fabrication-, and actuation strategies from recent research on soft robotics and programmable materials. The workshop will allow up to 20 participants to discuss and exchange their experiences of HCI and Soft Robotics and the future they can imagine.

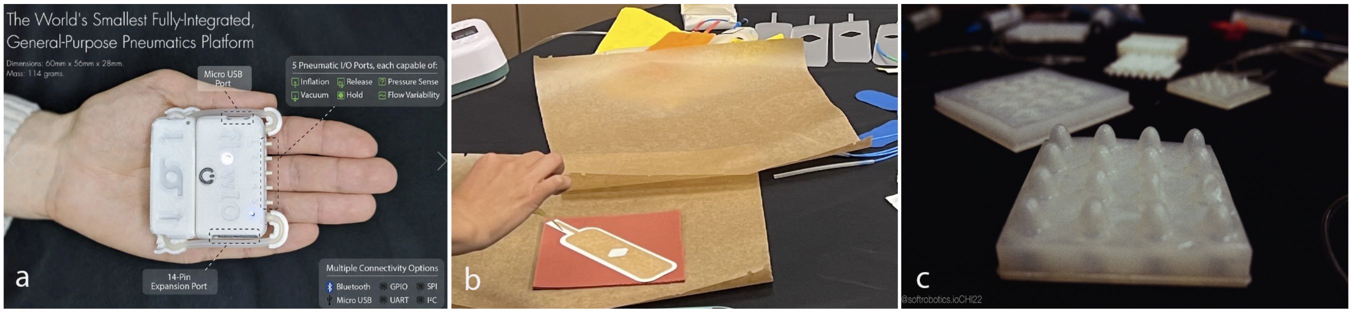

Figure 1: a) FlowIO device that will be introduced to workshop participants; (b) Hands-on activities and (c) soft robotic prototype demo from the workshop at CHI'22.

2 RESEARCH QUESTIONS AND AGENDA

The *Soft Robotics and Actuated Materials for Human-Computer Interaction* workshop at DIS 2023 attempts to investigate (1) the challenges and best practices of soft robotics and actuated materials, and (2) how technologies in Soft Robotics and Actuated Materials will enable the future design of prototyping, education and applications of human-machine interaction. We will bring together experts, interested researchers, designers and makers from all the relevant domains. The workshop focuses on technologies, their fabrication methods for prototyping, and integration into meaningful future applications. Particular emphasis is put on stimulating the exchange of ideas between intersectional fields such as health, engineering, learning, wearables, tangible user interfaces, etc. to identify novel application areas beyond the traditional scope of soft robotic research. Below we outlined the central questions and challenges of soft robotic methods in HCI and design research, which we address in our workshop. The central questions and challenges that arise when Soft Robotics strategies are leveraged in the context of HCI research are outlined in the following and serve as a basis for deeper discussions during the workshop.

2.1 Prototyping

Which fabrication methods are available to HCI researchers & hobbyists, and which are not? What are the fabrication pipelines, required work environments, materials, and equipment? How costly are these in terms of money and time? How can fabrication methods be made more accessible, affordable, faster, and simpler for everyone? What tools and resources are needed for or would aid in designing, simulating, and prototyping projects that utilize programmable and actuated materials? Some examples are silicone 3D printers, development platforms like FlowIO [21], websites like the Soft Robotics Toolkit, and CAD tools with embedded domain knowledge. Which educational formats between academia and industry can facilitate the introduction to this topic? How can novel tools and resources be made available to all interested users? What tools and resources do you find lacking in your own workflow that would significantly increase your productivity if they existed? How can we lower the entry barrier for people from technical and non-technical backgrounds to start incorporating programmable materials into their projects?

2.2 Education

Soft robotics is increasingly influencing interdisciplinary fields at the intersection of art, technology, health and science; how can we engage designers, artists, and educators who want to implement innovative projects? How might we integrate accessible soft robotics practices for makers and professionals? Researchers and practitioners applied hands-on experiments with different techniques, materials and methods, and learning strategies in craftmanship and digital practices. Can we enable the engagement of different audiences and learners? How can we teach the successful implementation of soft robotics? Material experimentation has a significant role in providing softness and compliance to the soft robot; what materials could we further explore, what socio-cultural aspects bring the materiality, and how could we explore suitable materials for soft robotics or bio-robotics? Recently, the exploration of robotics has been oriented toward research in educational contexts, how to promote activities around the empowerment of the use of technology, learning by doing and innovating in the intersection of technology, science, and art. This field has explored applications in wearables, textiles and soft materials where explorative learning and material-driven design play a fundamental role. These experimentations often carried out in labs, are increasingly attractive in connection with different actors involving universities, research institutions, schools, and incubator centres [1]. They foster interdisciplinary know-how as it is created in FabLabs, where learning-by-doing occurs.

2.3 Future Applications

We see a potential for research in the areas of fabrication, tools, and meaningful applications within HCI. For example, ubiquitous applications using actuated materials are imaginable [18]. How can we bring together HCI research, personal fabrication, and ubiquitous computing? What other research fields can be connected to HCI such as Materials Science, Soft Robotics, or Microsystems Engineering?

Actuated materials can create an autonomous expression of the material in different scenarios. What types of interactions can be realized using actuated materials? Which material affordances play a role in the interaction? How can humans interact with those materials? While soft robotics may provide designers and researchers with more powerful ways for interface designs, they also raise a set of new questions: What type of interfaces are possible using Soft Robotics? What kind of sensory systems already exist? What models of nature can we emulate as a haptic system? Examples are visual, haptic, audio, audiovisual, bio-inspired and other multimodal soft interfaces [4, 13, 14, 22, 24]. How can they be implemented into applications that are of interest to the HCI field? What are the different modalities? What are their affordances but also their limits before drifting towards the uncanny valley or becoming socially unacceptable?

The conformability of soft robots means they can assimilate into the form factor of a chosen object and surface. If coupled with more sensors and actuators, soft robots can then be conduits for user interfaces for selected appliances. How can we incorporate soft robots into the design of shape-changing interfaces for smart appliance control? What real-world metaphors can we rely on to enable our interactions with such shape-changing interfaces? What are the limits to this flexibility and how does it affect the robustness of a soft robot?

3 WORKSHOP STRUCTURE & GOALS

The workshop aims to provide time and opportunity for creative thinking and experimentation. The workshop will begin with an inspirational keynote from an invited speaker, highlighting their vision and perspective on the intersection of soft robotics and HCI. A moderated Q&A session after the keynote will provide an opportunity to expand upon the discussion and ideas among all workshop participants and the speaker.

Afterward, participants will present their workshop submissions. Depending on the type of submissions we receive, we may structure this as either individual talks or symposium-style poster presentations where participants can freely roam around the room. The keynote and the participant presentations will then serve as inspiration for ideas that will be discussed during the morning brainstorming sessions.

The afternoon will focus on hands-on activities and tangible interactions. Participants will be able to learn new skills (such as prototyping with pneumatics and thermo-responsive materials) and build rapid prototypes. Then participants will be asked to talk about their projects from the workshop. The hands-on activities will serve as inspiration for our afternoon brainstorming session, which will center on future applications. Here we encourage participants to bring their prototypes and demos to enrich the exchange between the audience while picturing opportunities for collaboration.

Our goal is to identify the various challenges that people face when working with soft materials and devices. Moreover, we aim to identify what new tools and techniques are needed to address these challenges and bridge the gap between designers and material scientists. Additionally, we would like to discuss what options exist to make the design, prototyping, and application of soft programmable materials more accessible to HCI researchers and designers.

4 TOPICS OF INTERESTS FOR PARTICIPANTS

For this one-day workshop, we invite submissions that demonstrate challenges and new opportunities related to the design, fabrication, education aspects, and deployment of soft robotic applications or tools, up to four pages. The workshop call for participation will be available at https://softrobotics.io/dis23. The complete program details will be posted on the website including the list of all speakers, participants, and organizers. Our DIS'23 workshop will be a one-day onsite event supporting synchronous participation in a virtual space if needed for unforeseen reasons. We will also provide asynchronous materials beforehand.

Our workshop last year (www.softrobotics.io/chi22) [5] brought together over two dozen cross-disciplinary academic researchers and industry professionals from HCI, Soft Robotics, Art, and Haptics for the first time to explore challenges, opportunities, and the future of HCI in the context of soft robotics and actuated materials.

During the workshop, we will aim to have a soft robotics starter kit with a FlowIO device [21] for the participants, where the total number of kits will depend on the availability of resources and funding we can secure. Our experiences from last year's workshop show that multiple participants can share devices and materials during the hands-on activities.

Participants will be encouraged to bring prototypes and demos at any stage that they can show and tell narratives about the process of fabrication and/or materials, tools, or projects of their interest to work with during the hands-on activities. More information regarding the hands-on part of the workshop will be disseminated four weeks prior to the conference start date. Participants can keep any artifacts they develop during the workshop, but they will have to return any FlowIO or electronic devices provided to them.

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