‘Liminal Beings’: Soft Pneumatic Actuators as Breathing Objects

Gizem Oktay

Experimental Animation Lab, University of Texas at Dallas, gno200000@utdallas.edu

Cross-pollinations between materials science and user-centered design enabled the use of soft pneumatic actuators as an interface tool. However, just as HCI research brings together diverse fields of study for embodied experiences, it needs to extend the bridge to include artistic applications to become available for a broader audience. Through its kinetically-rich affordances, soft pneumatic actuators can aid artists and designers in creating multi-sensory experiences that draw inspiration from living systems. In this paper, such works that utilize soft robotics techniques are presented, along with my project titled ‘Liminal Beings,’ representing soft pneumatic actuators as breathing objects and therapeutic devices. Approaches developed by artists and designers show how art practice benefits from interaction design and questions how HCI methods can be better fitted into practice-based artistic research.

CCS CONCEPTS • Human-centered computing → Interaction design → Interaction design process and methods → Contextual design

Additional Keywords and Phrases: Soft Robotics, Interaction Design, Pneumatic, Shape Change, HCI, Actuated Materials

1 INTRODUCTION

Soft robotics as an interface tool belongs to a research body at the intersection of materials science and human-computer interaction. These kinetic interfaces emerge as part of the paradigm shift that HCI has been going through for the past two decades, namely the shift from graphical user interfaces (GUI) to tangible user interfaces (TUI) [1], and to organic user interfaces (OUI). The last step describes how computer interfaces -no longer limited to rigid flat surfaces- can exhibit shape, deformation, and non-planar forms [2]. Many OUI examples take advantage of state-of-the-art materials science developments, which provide the type of embodied interaction that current strands in HCI research try to achieve. Shape-changing interfaces that use soft robotics employ a variety of applications including volumetric displays [3], the inflatable mouse [4], physical buttons [5], shape-changing garments [6], and feminist health design products [7]. Other types of applications include the use of shape memory alloys (SMA) and polymers, deployable structures such as foldable and rollable materials, and stretchable structures such as elastomers and auxetic materials [8].

Similarly, with HCI, the realm of art and design is also going through a paradigm shift, from conventional materials to living systems as a means to incorporate them into artistic processes [9]. What these shifts have in common is they put bodily engagement and embodied experience to the forefront. Texturally-rich, kinetic interfaces like soft robotics integrate aesthetic and structural elements [10], therefore assisting with the creation of multi-sensory experiences that fully engage user’s senses. Leveraging the affordances of kinetic interfaces help art practice reach a level of interaction that has the inherent value of artistic merit as they mimic the living systems that artists and designers draw inspiration from.

1.1 Related work

Figure 1: Art projects that leverage soft robotics. Here, three examples are shown (a) Soft actuator responding to light with touch via Linnea Ekelof (http://linneaekelof.com/selected-work/gauissa), (b) Soft robotic sleeve as an interface between a plant and a human by Christiansen et al. (https://jar-online.net/en/exposition/abstract/soft-robotics-and-posthuman-entities), (c) Soft actuator made of lycra with multiple air chambers by Bewley and Vallgårda (http://dx.doi.org/10.1145/3064857.3079154), respectively.

Numerous art projects leverage soft actuators outside their conventional use. I present three research projects, all utilizing the aesthetic qualities of soft actuators. France-based artist and designer Linnèa Ekelof explores how pneumatic actuators afford 'soft interactions' in her ongoing research. Through multiple actuator iterations, Ekelof connects elements from biotic life, such as the bioluminescent deep-sea creature *Gaussia* [11] by creating actuators that respond to touch by lighting up, and the brittle star *Ophiura ophiura* [12]. Ekelof claims the strange familiarity that actuators perform is a safe yet intimate interaction in contrast to many conventional robots and machines. Her research is drawn to the life-likeness of actuators, inviting the audience to interact with them, and be aware of their breathing.

Christiansen et al. focus on mediating relations that technologies afford and how soft robotics can be seen as a field that blurs the boundaries between biological organisms and machines in their research project published in the Journal of Artistic Research [13]. Focusing on iterative modes of making, the team developed a soft robotic interface to mediate signals between a vascular plant and a human body. The project "...interrogates soft robotics technology from an explorative design and arts perspective to couple it with wider considerations on the relations that humans maintain to their surroundings and nonhuman organisms." [14]

Designers Harvey Bewley and Anna Vallgårda focus on expanding the design space of soft robotics through performative objects with the material affordances of lycra, latex, and foil sheet in their DIS'17 paper. They use "provocations with new interactive experiences in the physical realm," arguing that by using performative objects as inspiration, they can ultimately design more connected and bodily engaged experiences with computational devices [15].

2 LIMINAL BEINGS: PROJECT OVERVIEW

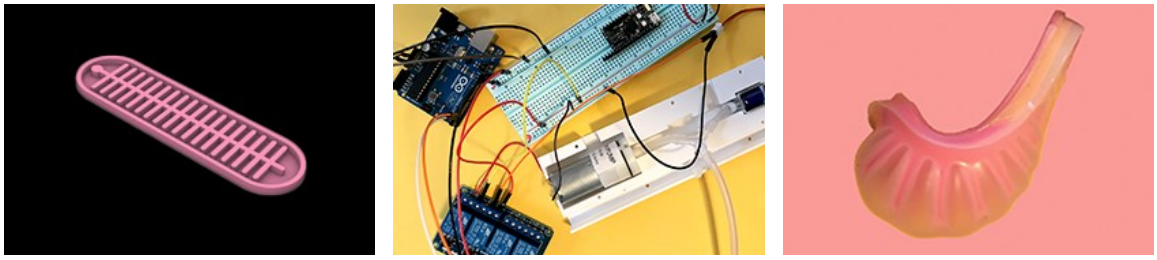

Figure 2: Liminal Beings project stills from various phases. (a) 3D-printed single-leg gripper mold, (b) Driving system including an Arduino microcontroller, four-channel relay board, air pump, solenoid valve, 5V power source, (c) Soft actuator in inflated position, respectively (http://gizemoktay.com/liminal-beings).

Analogous to related works presented, my research prioritized the aesthetic and kinetic affordances of soft pneumatic actuators. I focused on the breathing behavior they exhibit and used them as therapeutic devices that facilitate an aware state in one's breathing. 'Liminal Beings' consist of three types of silicone actuators that vary in shape and size, cast with Ecoflex 00-30 silicone rubber using 3D-printed single-leg and multiple-leg gripper molds, actuated with an electro-pneumatic system [16].

The system is an altered version of one demonstrated on the Soft Robotics Toolkit (SRT) website [17]. This version uses TIP120 transistors, 1N001 diodes, an LM2596S switching voltage regulator, and 10Kohms resistors. I replaced these components with a four-channel relay board that made it easier to program the system. Having little to no prior experience with pneumatics, programming through the relay board made the circuit more user-friendly as air input-output depended on the on and off state of the board. Another component of the system was an ASDX pressure sensor, however, since I could not calibrate it to sense pressure inside the air chamber, I decided to solely focus on the breathing movement. I removed the pressure sensor and instead coded on Arduino an algorithm with an air pump and the solenoid valve. However, not including a pressure sensor into the system took away the possibilities of programming more complex actuation behavior. Therefore, I had to conceptualize the actuators as breathing objects that serve a therapeutic function in one's breathing, inviting the participant to be more aware of their breathing and to think how the body moves through breathing. The actuators were colored with pink and salmon tones using silicone coloring pigment, to have a skin-like look and to invoke a more intimate response from the viewer.

This project was completed during the COVID-19 lockdown in 2020, and therefore, further iterations on actuation behavior and fabrication with different materials were not possible. If replicated again, I would like to try different materials such as lycra and latex, and biodegradable and compostable materials such as bioplastic. A second iteration route would involve programming a more environment-responsive actuator behavior.

3 CONCLUSION

Soft robotics are a useful interaction tool as it mimics the living systems artists and designers draw inspiration from, creating materially-rich and embodied interactions with multi-sensorial user experiences. This extended abstract presented four projects prioritizing the aesthetic qualities of soft actuators, painting a picture of how recent advances in materials

science and human-computer interaction research get interpreted in art and design spaces. The projects presented in this paper all utilize the breathing movement that actuators exhibit, as that is comparably the easiest actuation style one can program. Therefore, streamlined driving systems created through HCI research can help artists and designers to focus on the creative affordances of their work, enabling them to develop more complex interactions.

REFERENCES

[1] Hiroshi Ishii. 2008. Tangible bits: beyond pixels. In *Proceedings of the 2nd international conference on Tangible and embedded interaction (TEI '08)*. Association for Computing Machinery, New York, NY, USA, xv–xxv. https://doi.org/10.1145/1347390.1347392

[2] David Holman and Roel Vertegaal. 2008. Organic user interfaces: designing computers in any way, shape, or form. *Commun.* ACM 51, 6 (June 2008), 48–55. https://doi.org/10.1145/1349026.1349037

[3] Hiroo Iwata, Hiroaki Yano, and Naoto Ono. 2005. Volfex. In *ACM SIGGRAPH 2005 Emerging technologies*. 31–es.

[4] S. Kim, H. Kim, B. Lee, T.-J. Nam, and W. Lee. 2008. Inflatable mouse: volume-adjustable mouse with air-pressure-sensitive input and haptic feedback. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '08)*. ACM, New York, NY, USA, 211–224. DOI: http://dx.doi.org/10.1145/1357054.1357090

[5] Chris Harrison and Scott E. Hudson. 2009. Providing Dynamically Changeable Physical Buttons on a Visual Display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Boston, MA, USA) (CHI '09)*. Association for Computing Machinery, New York, NY, USA, 299–308. https://doi.org/10.1145/1518701.1518749

[6] Laura Perovich, Philippa Mothersill, and Jennifer Broutin Farah. 2014. Awakened Apparel: Embedded Soft Actuators for Expressive Fashion and Functional Garments. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction (Munich, Germany) (TEI '14)*. Association for Computing Machinery, New York, NY, USA, 77–80. https://doi.org/10.1145/2540930. 2540958

[7] Madeline Balaam, Nadia Woytuk, Marianela Felice, Ozgun Afsar, Anna Stahl, Marie Sondergaard. 2020. Intimate touch. *Interactions* 27, 6 (November-December 2020), 14-17. http://doi.org/10.1145/3427781

[8] Isabel P. S. Qamar, Rainer Groh, David Holman, and Anne Roudaut. 2018. HCI meets Material Science: A Literature Review of Morphing Materials for the Design of Shape-Changing Interfaces. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, Paper 374, 1–23. https://doi.org/10.1145/3173574.3173948

[9] Carolina Ramirez-Figueroa, Aurelie Guyet, Luis Hernan, Martyn Dade-Robertson.. 2016. Bacterial Hygromorphs: Experiments into the Integration of Soft Technologies into Building Skins. In *Fosthuman Frontiers: Data, Designers, and Cognitive Machines (Ann Arbor, Michigan) (Acadia'16)*. 244-253. http://papers.cumincad.org/data/works/att/acadia16_244.pdf

[10] Marcelo Coelho and Pattie Maes. 2008. Sprout I/O: a texturally rich interface. In *Proceedings of the 2nd international conference on Tangible and embedded interaction (TEI'08)*. Association for Computing Machinery, New York, NY, USA, 221-222. http://doi.org/10.1145/1347390.1347440

[11] Linnea Ekelof Personal Website. Retrieved Feb 24, 2022 from http://linneaekelof.com/gaussia

[12] Linnea Ekelof Personal Website. Retrieved Feb 24, 2022 from http://linneaekelof.com/ophiura-ophiura

[13] Soft Robotics and Posthuman Entities. Retrieved Feb 24, 2022 from http://jar-online.net/en/exposition/abstract/soft-robotics-and-posthuman-entities

[14] Soft Robotics and Posthuman Entities, Introduction. Retrieved Feb 24, 2022 from http://researchcatalogue.net/view/549014/597063

[15] Harvey Bewley and Anna Vallgarda. 2017. Provoking Performing Objects: Expanding the Design Space for Soft Robotics. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems (DIS'17 Companion)*. Association for Computing Machinery, New York, NY, USA, 243-248. https://doi.org/10.1145.3064857.3079154

[16] Gizem Oktay Personal Website. Retrieved Feb 24, 2022 from http://gizemoktay.com/liminal-beings

[17] Soft Robotics Toolkit. Retrieved Feb 24, 2022 from http://softroboticstoolkit.com/low-cost-ep-circuit