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Wearable Bio-HCI: Challenges & Opportunities

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Abstract

Biological Human-Computer Interaction (Bio-HCI) investigates the dynamic relationship between humans, computers, and biological systems. There has been a growing interest in integrating biological components into wearable human-computer interactions to expand their functional capabilities, material options, and design processes. Researchers have explored novel systems such as biofluid sensing for personal health, sustainable fabrication practices using biomaterials for creating wearables, and integrating living matter into wearable forms. However, as a rapidly growing, multidisciplinary field, Wearable Bio-HCI faces unique challenges and opportunities that demand collective efforts from a diverse group of researchers and practitioners. In this special interest group, we aim to gather researchers who are in this field or interested in integrating Bio-HCI approaches for creating novel interactive wearables. Our goal is to identify, brainstorm, and discuss challenges and opportunities that are unique to wearable Bio-HCI explorations. We aim to generate ideas on community engagement and cross-disciplinary collaboration for future research.

CCS Concepts

• **Human-centered computing → Human computer interaction (HCI)**; **Interaction design**; **Ubiquitous and mobile computing**; • **Social and professional topics → Sustainability**.

Keywords

Bio-HCI, Wearable, Biodesign, Sustainability

ACM ISBN 979-8-4007-1395-8/25/04
https://doi.org/10.1145/3706599.3716295

ACM Reference Format:
Jingwen Zhu, Fiona Bell, Katherine W Song, Katia Vega, Aditya Shekhar Nittala, Mirela Alistar, Leah Buechley, and Cindy Hsin-Liu Kao. 2025. Wearable Bio-HCI: Challenges & Opportunities. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25), April 26–May 01, 2025, Yokohama, Japan.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3706599.3716295

1 Introduction

Biological Human-Computer Interaction (Bio-HCI) investigates the dynamic relationship between humans, computers, and biological systems [32]. There has been a growing interest in integrating biological components into wearable human-computer interactions to expand their functional capabilities, material options, and design processes. For instance, biosensing body fluids such as saliva and sweat unlock unique interactive opportunities, providing rich insights into the human body that are difficult to achieve with other biosensing methods [31, 35, 41, 42, 46, 50]. Additionally, integrating biomaterials into fabrication methods for wearable applications introduces sustainable material choices that enhance both ecological responsibility and wearer comfort [5, 7, 30, 40]. Furthermore, explorations of the interaction between humans and biological living matter in wearable forms opens new opportunities for interspecies wearable interactions [7, 12, 29]. Integrating biological approaches into wearable technology enhances our understanding of the human body as a biological system while advancing sustainable fabrication practices to tackle issues such as fashion waste and electronic waste. These explorations of wearable Bio-HCI demonstrate how biological systems can be integrated into wearable computing, showcasing the expansive potential of human-computer interactions.

However, as a fast-growing multidisciplinary field, *Wearable Bio-HCI* faces unique challenges and opportunities that demand focus from a variety of different perspectives. There have been prior workshops and SIG hosted on adjacent topics such as Microbe-HCI at CHI'21 [18], Bio-Digital Interfaces at CHI'23 [14], Ecological HCI at CHI'24 [25], and Sustainable Unmaking at CHI'22 [36] and

CHI'24 [38]. However, less attention has been given to *wearable* considerations for Bio-HCI. In this special interest group, we aim to gather researchers who are exploring this area or interested in integrating Bio-HCI approaches for wearable applications to discuss the challenges and opportunities unique to wearable Bio-HCI explorations. We aim to generate ideas for community engagement, spark cross-disciplinary collaboration for future research, and reflect upon the potential impact wearable Bio-HCI holds for the broader HCI community.

2 SIG Topics

The activities and discussions of this SIG will center around four main topics, which we describe subsequently.

2.1 Topic 1: Translating Lab Science to HCI Wearables

The exploration of wearable Bio-HCI spans disciplines such as computer science, biology, materials science, biochemistry, design, art, and other emerging disciplines. A new wave of HCI research is bridging the gap between traditional science-lab research and everyday human experience by integrating wearable technologies. Researchers from different backgrounds contribute to this field through diverse lenses, such as material exploration for wearable devices [7, 17, 27, 44], the integration of new biological sensing mechanisms [35, 50], generating discussions on sensing intimate fluids [13], or the utilization of living organisms as bio-digital displays [12, 24]. Despite the exciting potential of these collaborations, they also present significant challenges, such as aligning vocabulary, methodologies, tools, and goals across disciplines. Further, translating biological research processes, which are typically specialized and require high cost, into more accessible fabrication environments that are typical in HCI has also been a research barrier. This SIG seeks to address these challenges by identifying opportunities for digital and tangible tools, platforms, resources, and programming approaches to facilitate the discovery, translation, and integration of biological insights from multiple disciplines into HCI wearables. For this effort, HCI researchers who collaborate with experts from (or themselves have intimate knowledge of) one or more adjacent fields can bring particularly valuable insights to such a discussion.

2.2 Topic 2: Understanding the Human Body as a Biological System

There has been a growing interest in HCI around approaching bodily fluids as a design material to deepen our understanding of the human body as a biological system. Bodily fluids, such as saliva and sweat, are critical indicators for monitoring health conditions. While biosensors for such fluids have traditionally been confined to medical devices and laboratory settings, recent HCI advancements have explored more accessible and diverse applications of these sensors. For instance, researchers have developed biofluid sensors in various forms, including epidermal devices [13, 31], textiles [50], jewelry [42, 49], cosmetics [41], othodontics [46] and tattoo inks [47]. These developments highlight the multidisciplinary nature of biofluid sensor research in HCI. For this topic, we foresee a fruitful union between HCI researchers who build devices and systems and HCI researchers who study health and wellbeing, with the former offering expertise in technical possibilities for hardware and the latter offering expertise in potential biosignals of the human body that can be leveraged in novel interactive systems.

2.3 Topic 3: Material Selection Challenges

Biomaterials include bio-based materials that originate from natural ingredients, biodegradable materials that can degrade in natural conditions, and living materials that can grow or decay. Recently, HCI researchers have adopted methods and techniques from adjacent fields, such as material science and biodesign, to utilize unique material properties to enable interactions. Biomaterials for wearables have been explored as substrate materials [10, 20, 27, 44], conductive traces [19, 24, 51], electronic components [17, 40], and biochemical sensors [35, 37]. In comparison to conventional systems, wearables that integrate such biomaterials not only offer possibilities for unique aesthetics and interactions but also have less material waste at the end of life. These explorations provide an alternative perspective to the current fabrication of wearable technology that prioritizes functionality over sustainability [16, 45]. Additionally, the wearable nature of these systems demands careful attention to wearability factors such as comfort, durability, and integration with daily activities [15, 33]. Especially, the use of biomaterials for close-to-body applications brings critical requirements for biocompatibility to ensure safety and user acceptance. Prior work has addressed some of these challenges by exploring wearability factors in skin interfaces [22] and body-worn colorimetric biosensors [43]. However, balancing the wearability and sustainability of such wearables can be challenging. In this SIG, we aim to review the existing uses of sustainable biomaterials in wearable Bio-HCI and brainstorm directions for continued material exploration, focusing on materials that are challenging to fabricate and integrate into wearable forms. Discussions will integrate insights from researchers actively working with emerging materials and those intimately familiar with Life Cycle Assessment analysis for sustainable design to examine every stage of the lifespan of Bio-HCI wearables – from raw material sourcing and transportation to usage and end-of-life considerations – to create lists of promising materials along with measurable sustainability indicators that can guide future work.

2.4 Topic 4: Towards Fully Biodegradable Wearables

While wearable Bio-HCI research primarily focuses on soft materials, interfacing with conventional hardware electronics is often essential to achieve certain functionalities. For example, decomposable electronic components [17, 39, 40] are expected to adhere to specific voltage and current requirements to ensure compatibility with conventional electronics. Moreover, interfacing conventional hardware with biomaterials presents challenges at the end of life, as the hardware must either itself be biodegradable or detachable to account for the entire sustainable life cycle of the system [51]. These challenges remain largely unaddressed within this specific context. However, valuable insights can be drawn from recent advancements in recyclable electronics, such as solderless printed circuit boards for reuse [48] and design tools for recycling e-waste [23]. In this SIG, we aim to brainstorm potential avenues of research to achieve fully biodegradable wearables. Such avenues include a continuation of aforementioned work in this area as well as new pursuits, such as the development of new hardware paradigms or control strategies that cater to the variable and transient nature of biomaterials; these paradigms may at first use conventional (non-degradable) components but ideally have a clearer path to full biodegradability than the modern digital electronics of today do. For this, we envision researchers from biodesign and materials science coming together with hardware engineers and systems architects to identify inherent limitations and requirements of biomaterials, opportunities to "misuse" conventional electronics components, and potential software to discover and generate new designs, among other possibilities.

3 SIG Goals and Expected Outcomes

This SIG aims to bring together researchers interested in integrating Bio-HCI approaches into wearable technologies to collaboratively identify ongoing challenges, propose potential solutions, and explore resources and platforms for advancing future works. The SIG will be hosted in a hybrid format, allowing in-person and online participation. By focusing on the four key topics outlined in Section 2, participants will brainstorm ideas and develop actionable approaches to address these challenges. The outcomes of the discussion will be summarized and shared on a dedicated webpage after the conference, ensuring broader accessibility and continued engagement. Additionally, we hope to leverage this SIG as a starting point for hosting future workshops and events, or publishing position papers to delve deeper into specific topics and challenges uncovered during these discussions.

4 Organizers

Jingwen Zhu is a PhD candidate in Human Centered Design at Cornell University. Her research bridges e-textiles, sustainable materials, and biosensing devices, integrating traditional crafting techniques with advanced technologies to explore new possibilities in Human-Computer Interaction (HCI). Her work emphasizes community engagement, actively involving artists, designers, and craftspeople from the maker community to broaden the impact and accessibility of emerging technologies.

Fiona Bell is a postdoctoral researcher in Computer Science at the University of New Mexico, working at the intersection of HCI, biodesign, and material science. Drawing on these disciplines, she develops novel biomaterials (e.g., biobased and biodegradable materials) that integrate with digital technologies to create sustainable bio-digital systems. By bridging the biological and digital worlds, she strives to build regenerative futures for planetary flourishing. She holds a PhD in Creative Technology & Design from the University of Colorado Boulder, where she began designing biomaterials.

Katherine Song is an Assistant Professor in Industrial Design Engineering at TU Delft. Her current research interests include developing hardware paradigms and software tools for designing interactive electronics that integrate and cater to the unique capabilities and needs of degradable and biological materials. She holds a PhD in Computer Science from UC Berkeley, where she developed degradable electronic components such as energy storage elements, skin-worn displays, and edible interfaces.

Katia Vega is an Associate Professor in Design at UC Davis, where she directs the Interactive Organisms Lab. She pioneered novel concepts in HCI, including Beauty Technology, Biocosmetic Interfaces, Animal Biosensing Computing, and Growable Interfaces, by integrating cosmetics, biosensors, and bio-based materials for health monitoring and sustainable design. She was a Postdoctoral Fellow at MIT Media Lab and holds a PhD and master's in Computer Science from PUC-Rio. Her research has received awards from SXSW, NSF CAREER, and Johnson & Johnson WISTEM2D.

Aditya Shekhar Nittala is an Assistant Professor in the Department of Computer Science and is an affiliate faculty member in the Department of Biomedical Engineering at the University of Calgary. He directs the DIFF Lab (Devices, Interaction, and Fabrication for the Future). His research probes the boundaries of human-device symbiosis, seeking to enhance and personalize user experiences through novel devices seamlessly integrating with the human body. His lab designs and develops novel interactive devices, studies and designs interaction techniques that aim to enhance our sensory, motor and perceptual capabilities. His research has received Best Paper Awards and Honorable Mention Awards at ACM CHI and UIST. He is also the receipient of NSERC (National Science and Engineering Research Council, Canada) Discovery Grant, NFRFe (New Frontiers In Research Fund) and is the Theme lead for the Alberta Medical Devices Innovation Consotium (A-MEDICO).

Mirela Alistar (she/her) is a bioartist, HCI researcher, and an Assistant Professor in Soft Materials at ATLAS Institute, University of Colorado Boulder, USA. Intersecting microbiology and HCI, her work extends the human to include interactions with their own microbiome and other living organisms [2, 5, 8, 9, 11, 21, 28]. She has developed tangible living-media interfaces [18, 26, 34], and biochip-based systems for personalized healthcare [1, 3, 4]. She has extensive experience organizing workshops in the context of DIYBio labs that she led or co-funded. In the academic context, her research attracts significant interest in the HCI research community: the workshop on bioplastics that she co-organized for TEI'22 [6] had over 50 participants.

Leah Buechley is an Associate Professor in the Department of Computer Science at the University of New Mexico. Her work explores the intersection of computer science, art, design, and education. Her goal is to engage broad and diverse audiences in understanding, designing, and building technology for themselves. She has done foundational work in paper- and fabric-based electronics and her inventions include the LilyPad Arduino, a construction kit for sew-able computing. Previously, she was an associate professor at the MIT Media Lab, where she founded and directed the High-Low Tech group. Her research was the recipient of an NSF CAREER award and the 2017 Edith Ackerman award for Interaction Design and Children.

Cindy Hsin-Liu Kao is an Assistant Professor in Human Centered Design, with graduate field faculty appointments in Information Science, and Electrical & Computer Engineering at Cornell University. She founded and directs the Hybrid Body Lab. Her research practice themed Hybrid Body Craft blends cultural and social perspectives into the design of on-body interfaces. The goal is to shift towards more inclusive and diverse designs for emerging soft wearable technologies, which often appear in the form of smart tattoos and close-body textiles. Kao also develops novel digital fabrication processes for crafting technology close to the body. Kao was awarded a National Science Foundation CAREER Award for her research agenda.

Acknowledgments

This work is partially supported by the National Science Foundation under Grant No. 2026218, No. 2146461, and No. 2047249, as well as the Cornell Atkinson Center for Sustainability Academic Venture Fund and the Cornell College of Human Ecology Faculty Sustainability Research Grant.

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