Walking the Future: Bridging Foot Augmentation into Next Steps of Human Augmentation

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Abstract

Over the past decade, a noticeable increase in literature can be seen in wearable foot interfaces, which have evolved from activity tracking to enhancing human capabilities. Our legs, being the largest body limbs, play an essential role in various functions such as locomotion, maintaining balance, supporting proper posture and providing ground-contact using our feet. Hence, foot augmentations offer the opportunity to augment our entire body. However, most prior research focuses on specific application areas, thus affording a research agenda to further understand the full potential of feet in designing augmentations and to contextualize it in the

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broader human augmentation space. To achieve this, in this workshop, we invite researchers, designers, and practitioners, novice and expert, interested in designing human and foot augmentations. We will discuss how early foot interfaces helped in augmenting humans, and based on current work and trends in foot augmentation, we will formulate strategies for the next steps and discuss the applicability of such strategies in the broader space of human augmentation.

CCS Concepts

• **Human-centered computing → Interaction techniques**; *HCI theory, concepts and models*; *Interaction design process and methods.*

Keywords

foot augmentation, human augmentation, interaction techniques

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1 Introduction and Background

The world's first wearable computer was supposedly an instrumented shoe with a toe operated switch, designed to discreetly communicate outcomes of a casino roulette machine [36]. Since then, many foot interfaces have been developed [6, 40], and most early foot interfaces have been designed as foot-operated interfaces that can be used as an input device for a computer [40]. For example, Engelbart [11] explored different foot operated interfaces such as "Mole" as an alternative for a "Mouse". With the advancement of ubiquitous computing and miniaturization of electronics, the development of wearable interfaces, particularly envisioned foot-operated interfaces [24], have become popular. Meanwhile commercial smart-shoes, smart-insoles, and smart sensor tags attached to the foot penetrated the market, mostly focusing on gait and activity tracking [4], step count [31], fall detection [2], and ulcers prevention [33]. In research, a vast amount of foot interfaces were developed that enable a variety of sensing capabilities, such as detecting gait [13, 15], body posture [7, 14, 29], terrain [17, 41], acute stress [8, 10], leg length discrepancy [16], and more. Along with sensing, interfaces for actuation have also been developed for feet using different modalities such as vibrotactile for cutaneous feedback and force feedback and electrical muscle stimulation (EMS) for kinesthetic feedback, covering a range of applications, including training [32] and performance enhancement [7, 9], tactile augmented reality [43], real-world navigation [18], rehabilitation [1, 45], and in virtual reality [5, 23, 35]. It is also worth mentioning that foot interfaces have become increasingly complex and integrated [12], even enabling mid/long-term use for everyday applications beyond lab environments [41].

Moreover, the careful integration of foot's biomechanics and sensory extremities with sensing and feedback technologies have transitioned from foot interfaces to foot augmentations that can enhance human capabilities [6]. Given that the lower extremity of our body consists of the largest limb of the human body that enables, locomotion, balance and posture, foot augmentations have the opportunity to augment our entire body in different ways than augmentations of other body extremities such as the hands or torso. Besides, feet have a contact with a stable surface and augmenting interactions is easy since footwear provides plenty of space for embedding sensors and output devices that can be used to sense bodily parameters and augment our body.

Although, in past decades, there has been a steady increase in the number of research publications and commercial outputs related to foot interfaces [6], it seems that most of them focus on a specific application. Moreover, it is unclear how foot augmentations can fundamentally support the broader area of human augmentations. Hence, it is time to collectively articulate a research agenda for future research that facilitates utilizing the full potential of foot augmentations.

Thus, in this workshop, we invite researchers and practitioners who are interested in designing foot augmentations to learn from the past and develop the initial steps for future foot interfaces and human augmentation strategies. Areas we want to explore with this workshop are as follows:

- **Learn from Past Developments:** Explore the evolution of foot interfaces and augmentations, starting from early wearable computers to advanced smart shoes and insoles. Investigate how the integration of foot biomechanics with sensing and feedback technologies has contributed to the field of HCI.
- **Examine Current State of Foot Augmentations:** Understand the current technologies, modalities (e.g., vibrotactile, EMS), and methods used in foot interfaces with respect to the application domains like activity tracking, rehabilitation, virtual reality, and tactile augmented reality.
- **Strategize for Future Development:** Discuss initial steps and strategies for advancing foot augmentation research.
- **Bridge Foot Augmentations with Broader Human Augmentations:** Discuss how advancements in foot augmentations can be integrated into human augmentation technologies, leveraging the potential of the feet as a platform for enhancing the entire body.

One of our primary objectives of the workshop is to identify a set of strategies and design considerations for future foot augmentations that can complement future human augmentations. We think that, the foot augmentation is currently an underrepresented topic in the realm of CHI. Hence, another objective is to further discuss the importance of foot augmentations in multimodal interaction design. In particular, when the user is in motion and situations where the degree of freedom is limited in other body parts such as hands and heads [20].

2 Organizers

The organizing committee itself consists of an interdisciplinary group of scholars from HCI, Sports Science, Footwear and Textile Design, Interaction design and Computer Science. They are scholars at different career stages, from doctoral researchers and

associate - professors to full professors. It is an international group from Germany, India, Australia, Singapore, Turkey, Ireland, Austria, Netherlands, and Sweden.

Nihar Sabnis. is a PhD student at the Max Planck Institute for Informatics associated with University of Saarland. His research focuses on vibrotactile feedback to render material experiences [27] and forces to augment human movements while understanding how it affects user's objective and perceived control [26]. He is a biomechanical engineer and is curious to explore the foundations of human-technology interaction for augmenting movements and how it evolves over time.

Dennis Wittchen. is a researcher at Dresden University of Applied Sciences. His research focuses on tools and methods to augment human experiences and behavior through tactile stimuli. For instance, he builds instrumented footwear that can modify the experience of walking on different materials [43]. He is also interested in the design process and strategies that designers follow to create such interactions and augmentations (e.g., [28, 42]).

Ata Otaran. Ata Otaran is a postdoctoral research fellow in the Human Computer Interaction Lab at Saarland University. His primary research interests are in the field of physical human-machine interaction, particularly use of haptics for virtual reality and educational interfaces. His research background includes designing and evaluating foot-based locomotion (walking or vehicle driving) systems with haptic feedback. [3, 21, 22].

Fatima Badmos. is a PhD candidate at the Technological University Dublin, her PhD research focuses on how technology can codesigned outdoors to engage older adults in physical activities. General interest are in human computer interaction, human augmentation and Cyborg.

Siyi Liu. is a PhD candidate at the Exertion Games Lab of Monash University. Her research focuses on exploring human augmentation through superpower interaction with negative effects. Her work involves using multimodal biosensors and muscle stimulation to facilitate bodily interaction.

Aryan Saini. is a PhD candidate at the Exertion Games Lab, Monash University. He is interested in exploring the design of soft bodily augmentations that aim to promote embodiment in everyday life. He is an electronics engineer and enthusiast and specializes in building end-to-end systems.

Georg Regal. is a scientist at the AIT Austrian Institute of Technology. His research is focused on human augmentation, extended reality and interfaces for people with disabilities and how critical making and co-creation can be applied in these domains.

Vincent van Rheden. is a research fellow at the Human-Computer Interaction division of the University of Salzburg, Austria. His PhD focuses on supporting runners with breathing techniques through interactive sonification systems [39]. General interests are in embodied interaction, human augmentation and SportsHCI [37].

Suranga Nanayakkara. is an Associate Professor at the National University of Singapore. He is also an Honorary Professor at the Auckland Bioengineering Institute (ABI) at the University of Auckland (UoA). In 2011, he founded the *Augmented Human Lab* to explore ways of designing intelligent human-computer interfaces that extend the limits of our perceptual and cognitive capabilities.

Florian 'Floyd' Mueller. is a Professor of Future Interfaces at Monash University in Melbourne, Australia, directing the Exertion Games Lab. His research spans interaction design, human-computer interaction, game design, and sportsHCI. Floyd was general co-chair for CHI PLAY'18 and was selected to co-chair CHI'20 and CHI'24. Floyd has co-organized over 6 workshops and Dagstuhl seminars around HCI topics in general.

Denys J.C. Matthies. is an Associate Professor at the Technical University of Applied Sciences Lübeck and Fraunhofer IMTE. He jointly heads the cphs.group in Lübeck, Germany. Denys conducts research in the domain of Mobile HCI and Assistive Augmentation. This includes research on smart wearables, particularly footwear with medical applications.

Troy Nachtigall. He is a designer practicing and researching fashion and technology, and lecturer at Eindhoven University of Technology, Netherlands. Troy conducts *Research through Design* into sustainable computational craftsmanship, coming from a practice of fashion design concentrating on knitwear and shoes. His work focuses on technology and techniques needed for the personalization of clothing and accessories using data, along with the software that drives it.

Paul Strohmeier. He leads the Sensorimotor Interaction group (senSInt) at the Max Planck Institute for Informatics. His research focuses on tactile and kinesthetic perception, sensory augmentation, and on-body systems.

Laia Turmo Vidal. She is an Interaction Design researcher and a Digital Futures Postdoctoral Fellow at KTH Royal Institute of Technology, Sweden. Laia's work explores sensorimotor transformations facilitated by wearable technologies, with the aim to improve how we relate to ourselves and others in contexts of health and well-being.

Don Samitha Elvitigala. He is a Lecturer/Assistant Professor from the Department of Human Centred Computing of Monash University. His research focuses on developing novel on-body interfaces that can enhance human capabilities. During his PhD, he explored how sensing and actuation can be integrated with our foot to enhance capabilities [6, 7]. In particular, he explores how we can utilize everyday clothes and clothing accessories to develop human computer integrations.

Experiences in co-organizing workshops. The organizers of this workshop are actively involved in tactile augmentation research, and they have successfully organized related workshops in the past: Dennis and Paul hosted a workshop on sketching on-body vibrotactile patterns at TEI'21 called *TactJam* [42] and co-organized a workshop on *Sustainable Haptic Design* [30] at CHI'22. Also, Paul co-organized Shape Changing UI workshops at CHI'16 [34] and ACE'14. Dennis and Nihar co-organized a workshop on collaborative haptic experience design at the WorldHaptics conference 2023. Laia co-organized a workshop on exploring design and technical intersections between bodies and materiality at CHI'23 [25]; and

another workshop on exploring body-centered design methods and applications at DIS'24 [39]. Vincent and Floyd also conducted a workshop on embodied interaction in sports [38]. Recently, some of the authors co-organized a workshop dedicated to the design of augmented experiences at TEI'24 called *Foot Augmentation 101* [44].

3 Pre-Workshop Plans

We will connect with potential participants through mailing lists (e.g., the HCI Germany mailing list), and by personally contacting people of interest in research labs and companies focused on foot augmentation technologies. The workshop website[1] will serve as a primary resource of information which includes the call for participation, the schedule for the workshop and the list of speakers. For active engagement, participants will have access to a Discord server that will be the primary place for discussions before and after the workshop. Furthermore, we will create a list of reading materials and curate a document which would equip the participants to have an effective workshop and also serve as the short teaser of what to expect during the workshop. We will share this list on the workshop Miro board before the workshop that participants can use to already start brainstorming. The participants would also be asked to share their work and papers they find interesting that relate to foot and/ or human augmentation to facilitate group formation for richer discussions.

4 Hybrid Participation

We plan to host this workshop in a hybrid format, where in-person attendees and virtual participants can actively contribute and collaborate with each other. To ensure that lightning talks and breakout sessions are accessible to all participants, we will utilize Zoom with auto-captioning. Furthermore, we will use a projector and loudspeakers[2] in the on-site venue to allow virtual attendees to present their ideas and contributions. To allow collaboration between in-person and virtual attendees during the breakout sessions, we will use a Miro board[3]. In-person attendees are required to bring their own device (tablet or laptop) to access this board during the workshop. On this board, we will also provide supplementary material (e.g., relevant resources or articles) before the workshop. If all participants and speakers give their consent, we would like to record the presentations to provide asynchronous access for participants that are unable to access in-person or synchronous virtual space (e.g., due to time zones, see Table 1). All materials – recordings and Miro board – remain accessible for participants after the workshop concludes. A Discord server[4] provides the opportunity for all participants to (a/synchronously) engage with one another before, during, and after the workshop, bridging the gap between in-person attendees and virtual participants. We hope that this Discord server can foster a sense of community and collaboration, especially after the workshop. In addition to a workshop website, we will post updates regarding the workshop in a dedicated channel on the Discord server.

[1] https://derikon.github.io/WalkingTheFuture_Workshop/
[2] We will use Bluetooth loudspeakers if the venue does not have an audio system.
[3] Link to the Miro board will be shared with participants before the workshop.
[4] https://discord.gg/vGNsVnbY26

5 Workshop Structure

Walking the Future workshop focuses on learning from the evolution of foot interfaces over the years to strategize and derive guidelines for the future of foot and human augmentation. The workshop will last a full day (~6 hours) and be split in input and interactive sessions, see Table 2. This is justified by the time required to establish a common foundation, spark fresh ideas, and allow space for developing concepts, group reflection, and collective synthesis. The workshop is structured to promote knowledge exchange and collaborative learning, including informal breaks for networking. Participants will be grouped to ensure a diverse mix of disciplines and perspectives, encouraging dynamic and stimulating discussions.

The program begins with a 20-minute opening session dedicated to onboarding and participant introductions, aimed at creating a welcoming and inclusive environment for attendees. This is followed by the first set of Lightning Talks , where participants will deliver concise 5–10 minutes depending on the number of participants talks to present their position papers about foot augmentation and their vision to move the field forward. A 20-minute discussion segment follows these talks, which allows attendees to critically engage with the content, exchange ideas, spark questions and collaboratively explore key points that will serve as valuable references for the upcoming breakout sessions.

After a short break, we would have simultaneous group discussions for 45 minutes which focus on the evolution of foot interfaces over the years. The participants would be split into 3-4 groups (depending on the number of participants), where each group can have in-person as well as virtual participants. Each group would discuss themes such as – (a) modalities, approaches, or methods applied for foot augmentation, (b) design and fabrication of interfaces/systems to provide such augmentations, (c) design challenges and guidelines, or (d) connections between foot and human augmentation. However, themes will be finalized before the workshop, depending on interest areas and themes provided by participants in their position papers. Groups will use a dedicated frame on the Miro board to document their brainstorming and discussions that they will briefly present after the first breakout session (10 minutes in total). All other participants get the opportunity to comment or ask questions after each presentation. Finally, all participants collectively reflect on the intermediate results from this session (20 minutes).

The second half of the workshop will also start with Lightning Talks (40 minutes) and continue with follow-up group discussions (50 minutes) on the same topics introduced in the first session. Based on the foundation laid out in the first session, the second breakout session will offer the opportunity to responsibly think about the strategies, workflows and guidelines for the future of foot and human augmentation. After the group discussion, participants from each group will briefly present the outcome of their discussions to all attendees. Again, all other participants get the opportunity to comment or ask questions after each presentation. Overall, about 70% of workshop time, we will dedicate to discussions among participants, ensuring a collaborative and engaging workshop. And the rest of the time, we will dedicate to lightning talks(25%), onboarding, and participant introductions (5%),

Table 1: Workshop schedule considering different time zones.

Yokohama	*San Francisco*	*New York*	*Berlin*	*New Delhi*	*Hong Kong*	*Melbourne*
Sat, April 26	Fri, April 25	Fri, April 25	Sat, April 26	Sat, April 26	Sat, April 26	Sat, April 26
09:00 – 15:00	17:00 – 23:00	20:00 – 02:00	02:00 – 08:00	05:30 – 11:30	08:00 – 14:00	10:00 – 16:00

Table 2: Schedule of the one-day workshop.

Open	**09:00-09:20**	**Introducing the Workshop**
	10 minutes	on-boarding
	10 minutes	participant introductions
Talks	**09:20-10:10**	**Lightning Talks and Q&A**
Setup	**10:10-10:30**	**Introduce Topics and Set Groups**
Break	*10:15-10:45*	*coffee*
BS #1	**10:45-12:00**	**Breakout Session – Past to Present**
	45 minutes	discuss topics in breakout rooms
	10 minutes	present key insights
	20 minutes	discussion (all participants)
Break	*12:00-13:00*	*lunch*
Talks	**13:00-13:40**	**Lightning Talks and Q&A**
BS #2	**13:40-15:00**	**Breakout Session – Present to Future**
	50 minutes	discuss topics in breakout rooms
	10 minutes	present key insights
	20 minutes	discussion (all participants)
Break	*15:00-15:15*	*coffee*
Close	**15:15-17:00**	**Synthesize and Conclude**
	45 minutes	connecting the dots
	30 minutes	planning next steps

During the closing session, the organizers together with participants will review the group frames on the Miro board and extract anecdotes, strategies, and guidelines per theme. These will be used in the final discussion and a detailed synthesis of the groups' findings. Based on that, we will discuss our primary outcome of the workshop, a follow-up journal article on the next steps of foot augmentations.

6 Post-Workshop Plans

Based on the position papers and framework generated during the workshop, we will derive guidelines and invite participants to contribute to a journal paper on the next steps of foot augmentation, similar to work by Mueller et al. [19] who provided guidelines for the future of Human-Computer Integration (HInt). We also want to combine the outcomes of this workshop with our recent workshop on developing novel foot augmentations [44]. Further, the workshop short position papers will be published as workshop proceedings via https://ceur-ws.org or ArXiv using report numbers. Also, we aim to create a community that can develop the ideas we discussed in the workshop, and the organizers will actively support the participants in planned work by providing communication platforms to organize subsequent workshops and leading grant applications for the next steps. We would also like to map strategies for conducting systematic research in the areas of foot augmentation.

7 Call for Participation

Walking the Future workshop aims to serve as a platform to foster discussions on foot and human augmentation among researchers, enthusiasts, and practitioners. Moreover, the workshop should form the bridge between learnings of the past to deriving design guidelines and research strategies for the future of foot and human augmentation. We aim to advertise the workshop to an audience that designs wearable interfaces and embodied interfaces and, in general, is enthusiastic about human augmentation. To participate, you need to submit a 3-6 pages position paper (by Thursday Feb. 13, 2025) using the ACM Master Article Template[5] (publication version). Please use this form to upload your manuscript https://forms.gle/Hxy2nZKXf8pUGQa2A.

We encourage your position paper to focus on at least one of the areas which would be discussed during the workshop – (a) modalities and methods for foot augmentation, (b) design and fabrication of systems to provide augmentations, (c) design challenges and guidelines, (d) connections between foot and human augmentation, or another area you believe is worth discussing. The paper should briefly introduce yourself and provide an overview of what you believe needs discussion during the workshop. You are highly encouraged to present your work in this context. Position papers will form the basis of the group discussions. Finally, participants will have a choice to have their accepted paper published on the workshop website. For more information, please visit https://derikon.github.io/WalkingTheFuture_Workshop/.

Important Dates	
Submission Deadline	February 13, 2025
Notification	March 10, 2025
Position Paper	
Length	2–3 pages
Upload	https://forms.gle/Hxy2nZKXf8pUGQa2A

8 Website

Information about the workshop will be available online at https://derikon.github.io/WalkingTheFuture_Workshop/, before, during, and after the workshop. This information includes an introduction to the workshop topics, detailed schedule, and a call for participation. The website also links to an online form, where interested

[5]Use the template provided on https://chi2025.acm.org/chi-publication-formats/ and set the document class to `documentclass[sigconf]{acmart}`.

people can apply to participate by uploading a position paper. Participants can have their position papers published on the website, and reports on results from the workshop will also be made available through the website. Later, this website would also serve as a medium for researchers and practitioners to join the foot augmentation community.

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