

Toolkits & Wearables: Developing Toolkits for Exploring Wearable Designs

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Figure 1: Example toolkits for wearables. (Left) An e-textile prototype built with Arduino Lilypad[2]; (middle) Wearable bits, a toolkit for wearable e-textiles [16]; (right) shape changing fabric samples for exploring interactive fashion design [31].

ABSTRACT

Designing wearables is a complex task that includes many layers, such as wearability, interactivity, functionality, social and cultural considerations. For decades now, prototyping toolkits are proposed to aid diverse types of audiences in exploring the design of smart accessories and garments. However, the task of designing toolkits for wearables has not received a comprehensive discussion and systematic reflection. In this workshop, we look into challenges, opportunities, and lessons learned in using, developing and evaluating wearable toolkits by focusing on their target groups, purposes,

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effects on the final designs. By bringing together researchers and practitioners who are experienced with the design, use and assessment of wearable toolkits, we see a particular opportunity in providing a broader perspective on defining the future of wearable toolkit designs.

CCS CONCEPTS

• **Human-centered computing** → *Ubiquitous and mobile computing*.

KEYWORDS

Wearables, toolkit, design, prototyping, e-textiles, smart jewelry.

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1 BACKGROUND & MOTIVATIONS

Wearable computers have emerged from research and a increasing number of commercial products, including form factors such as watches, bracelets, rings and garments have been proposed. While much of commercial product use cases address wellbeing and health [13], wearables are expanding towards a wider set of functions and designs. In contrast to other interactive objects, share the same design space with traditional clothes and accessories. As a consequence, novel design considerations emerged such as wearables' social and cultural roles (e.g., in expressing style and/or appropriateness for a context [1, 5, 8]), wearability and body-placement [7, 12]. Apart from these parameters, the inclusion of electronic components on wearables together with traditional materials of apparel and accessory design, such as textiles, fibers, chains, and jewels has created further challenges about how to experiment with this merger within design processes [8]. Additionally, as the wearable technologies allows applications of extended reality (XR), it also became important to design relevant digital services and interfaces around them [28, 32]. All these new design dimensions introduced by wearable technologies make the design and prototyping process a complex task especially for novices [8].

Until now, one way to aid individuals for designing wearables is to provide toolkits to prototype and experiment with unique design considerations of wearables. An early example for toolkits is Arduino Lilypad [2]. This toolkit revolutionized the wearable design processes by introducing sewable electronic components that can be used with textiles, i.e., conductive threads and fabrics. Toolkits with similar approaches are now available as commercial products (i.e., [3, 11]) for a wide target group. Naturally, people are increasingly using them for creating their own wearables as a recreational activity. The results have been contributing to the so-called Maker Movement, a DIY culture focused on sharing ideas and knowledge [4]. This also has given rise to online (i.e., [21]), physical communities (i.e., [6]) to be formed and instructive books to be published (i.e., [9]) in the area of wearable technologies.

On the other hand, researchers also put effort on proposing alternative approaches to wearable toolkits, empowering the diverse groups of people varying from designers (i.e., [31]) to children (i.e., [19]) and elderly (i.e., [14]). A branch of work in this area of research focuses on removing the technical barriers with kits consisting modular components (i.e., [16, 25, 26, 29, 30, 30]). These kits usually rely on combining modules together and experiment wearable designs without going through a burdensome process of assembling electronic components. Instead of using a modular design, kits also allow users to easily adapt rapid fabrication by providing sets of materials adaptable with easy-to-use techniques. An example in this domain is Rapid Iron-On User Interfaces [20] which propose a library of functional tapes and patches, such as conductive fabrics, to apply on textiles by using an iron to create interactive textiles. In a similar fashion, some recent toolkits proposed techniques and platforms to try out e-textile applications by reusing conductive threads [10, 17]. For example, Jones et al. [17]

presents Punch Sketching technique that is based on punching conductive threads on a embroidery hoop to build circuits and pulling them out for iterative rapid prototyping. Furthermore, for production techniques and methods that are not immediately accessible or challenging for non-expert users (i.e. shape and color changing fabrics), proposing interactive demonstrators to foster creativity in design processes is another way explored by academia (i.e. [18, 31]).

Despite the trend of designing and developing wearable toolkits for varying purposes, technologies and audiences, these lack a broader discussion and reflection on designing the toolkits. We believe that sharing the insights and lessons learned in designing and evaluating various wearable toolkits, we can critically reflect on our approaches for revealing the challenges and opportunities around designing wearable toolkits.

2 WORKSHOP AIM AND THEMES

In this one-day workshop, we aim to provide a venue to discuss specific challenges, opportunities, and lessons learned around developing and evaluating toolkits for designing wearables. For this purpose, the workshop gathers together researchers, designers, and practitioners that have experience in designing, evaluating and using wearable toolkits. We encourage multi-disciplinary participation with a background in, but not limited to, HCI, design, arts, fashion, and social sciences. The workshop invites submission of toolkit implementations, case studies, methodological notes, and position papers. The submission should highlight the toolkits, their audiences and purposes in design process, and share reflections on using and/or evaluating the toolkits for designing wearables.

During the workshop, discussions will be structured into four main themes:

- **Audience of wearable toolkits:** We will discuss what kind of specific challenges there are while designing toolkits for different audiences (e.g., designers, engineers, makers, students). Designing and prototyping wearables require practical skills such as fashion production techniques (i.e. sewing, garment construction techniques), electronic assembly, and programming, as well as an understanding of social and cultural considerations that emerge from designing worn artifacts. Yet, not all user groups might have all the required skills. Under this theme, participants will reflect on their experiences with wearable toolkits for different user groups. We will identify strategies on how toolkits appropriate their approach to user groups with different skill sets.
- **Purposes of wearable toolkits:** The different toolkits might aim for different purposes, such as introducing basic skills to design wearables, fostering exploration and creativity while designing different types of wearables (i.e. interactive accessories, garments and wearable XR applications), or focus on certain technology aspect such as flexible screens [15]. They can allow quick try-outs about different design parameters like interactivity, wearability etc., or provide a platform for building final design of the wearable. We will discuss participants' targetted goals while developing wearable toolkits, as well as identifying what kind of wearable toolkits might suit better for different purposes.

- **Toolkits' impact on wearable designs:** The general incentive of the toolkits is to facilitate the creation of technology by simplifying and speeding up the process [22, 23]. However, there is often a tension between easy to use wearable toolkits and enabling wide explorations (i.e. with different materials, interaction possibilities and wearable form factors): For instance, toolkits that are easy to put together usually have hard PCBs and doesn't enable individuals to explore what's possible with textiles (i.e. soft/fuzzy/stretchy) [27]. We will discuss how wearable toolkits impact what can be designed, the challenges behind helping users explore a wide range of opportunities, and how these are or can be addressed in wearable toolkits.
- **Deployment and evaluation:** Researchers have different ways to apply and evaluate wearable toolkits such as conducting co-design workshops [16], or collecting crowdfunding and shipping the kits to a larger audience [24]. The last theme focuses on the challenges and opportunities of different methodologies in evaluating wearable toolkits. Within the scope of this theme, we will also ask participants to reflect on the evaluation results and comment on the broader impact that the toolkits might create in society.

3 PRE-WORKSHOP PLANS

Prior to the workshop, we will publish a workshop website including detailed information about the workshop call, the organizers, and the submission process. We will also advertise the call through relevant HCI mailing lists, social media, and direct invitations. Submissions will be in the format of 500-word abstract accompanied with a poster. The submissions will be peer-reviewed by at least two reviewers. Prior to the workshop date, the accepted submissions will be made available through the website.

4 WORKSHOP STRUCTURE & OUTCOME

The workshop will be conducted in a hybrid manner, allowing both in-person and virtual attendance. It will consist two sessions (morning and afternoon):

- **Show and Tell.** Participants will present and reflect on their own toolkit experience through the lens of four themes. The presentations will be made in the form of posters streamed through video conferencing software that will be projected on a screen in the workshop space. In-person attendees will be encouraged to bring demos to support their presentations. The demonstrations will also be streamed to online attendees through a webcam. After and during each presentation, discussions will be encouraged.
- **Group Work - Round Table Discussions.** Small groups will be formed based on participants' experiences in wearable toolkits (i.e., different target audiences and purposes). While grouping we will also consider online vs in-person attendance to combine participants with the same type of attendance in the same groups for convenient discussions. Groups will discuss four themes based on the similarity and differences of each participant's experiences about designing, implementing and/or evaluating their wearable toolkit. The discussions and brainstorming sessions will be captured

through templates prepared in an online whiteboard platform (i.e. Miro), enabling synchronous and asynchronous contributions. At the end of the session, all participants will discuss the outcomes together from a broader perspective identifying wearable toolkit design challenges and opportunities for each theme.

5 POST-WORKSHOP PLANS

An outcome of this workshop will be the distribution of the accepted submissions through the workshop website, as well as an established mailing list of the participants for future collaborations. Additionally, we will put together a visual poster that summarizes the outcomes of the workshop and use social media channels to share it with a wide audience. Finally, we will summarize the specific challenges and opportunities of design, implementation and evaluation of different approaches to wearable toolkits for publishing an journal article, e.g., the Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies.

6 ORGANIZERS

Caglar Genc (main contact) is a Post-doctoral researcher at the University of Lapland, the faculty of Art and Design. During his Ph.D., he researched the relationship between fashion and computation materials to design wearable displays. His current works include prototyping tools for interactive jewelry and sustainable materials for tangible interaction.

Oguz 'Oz' Buruk is a Marie Curie Fellow in the Gamification Group at Tampere University, Tampere, Finland. He holds a PhD in Interaction Design (2017) from Koç University-Arçelik Research Center for Creative Industries (KUARI). His work focuses on designing playful wearables, and he leads two research projects focusing on integrating wearables to mainstream gaming and extended reality environments.

Shiva Jabari is a Doctoral researcher at the Gamification group, Tampere University. She holds M.Sc. in Design for the Fashion System from the Polytechnic University of Milan. She has worked as a Fashion designer, Fashion Consultant and Stylist. Her main interest areas are the integration of design and technology, playful smart clothing design and interaction design.

Lee Jones is a PhD Candidate at Carleton University. In her research she focuses on e-textile crafting toolkits and learning scaffolds to help support novices as they learn this hybrid craft. Her recent projects have focused on personal fabrication, sustainability, and DIY repair.

Kirill Ragozin is a Postdoctoral researcher at Keio University Graduate School of Media Design with a cross-disciplinary background in design and computer science. His major research contributions are in the fields of mixed reality and embodied interactions. His work explores immersive media, physiological tracking, digital art, user interaction and experience design.

Kate Hartman is an Associate Professor at OCAD University, where she is Graduate Program Director of Digital Futures and the founding Director of Social Body Lab - a research and development team dedicated to exploring body-centric technologies in the social context. She is the author of the book *Make: Wearable Electronics*,

was an artist-in-residence at Autodesk's Pier 9, and has work included in the permanent collection of the Museum of Modern Art in New York.

Johanna Virkki is an Academy Research Fellow at Tampere University, Faculty of Medicine and Health Technology. She is heading Intelligent Clothing Research Group focusing on design, fabrication and reliability improvement of clothing-integrated wireless systems. The goal of the Group is to use intelligent clothing to enable the functional capacity of people with special needs.

Oskar Juhlin is a Professor at Stockholm University at the Department of Computing and Systems Sciences. He is also professor II at the Department of Information Science and Media Studies at Bergen University. He has an interdisciplinary background spanning technology and social science. Oskar has conducted research and managed groups in many design fields such as fashion tech, social media and road traffic, animal computer interaction, and video interaction.

Kai Kunze works as a Professor at the Graduate School of Media Design, Keio University, Yokohama, Japan, where he leads the interdisciplinary research group Geist, exploring the topics of Augmented Humans and applied Wearable Computing research with a focus on eyewear computing and physiological sensing. In addition, he serves as the co-chair of the International Wearable Computing Academic Research Community.

Jonna Häkkinen is a Professor for industrial design at the Faculty of Art and Design, University of Lapland, Finland. Her work focuses on user-centric design of mobile and ubiquitous computing. She is currently leading cross-disciplinary research projects addressing TechFashion, wearable displays, and combining traditional handcraft with HCI.

7 CALL FOR PARTICIPATION

Designing wearables is a complex task that includes many layers, such as wearability, interactivity, functionality, social and cultural considerations. For decades now, toolkits are proposed to aid users in the design of smart accessories and garments. However, the task of designing toolkits for wearables has not received a comprehensive discussion and systematic reflection.

This one-day workshop gathers researchers and practitioners, who are experienced with the design, use and evaluation of wearable toolkits. It aims to provide a venue to discuss specific challenges, opportunities, and lessons learned around developing and evaluating toolkits for wearables. What are the challenges while designing toolkits for particular audiences (i.e., designers, engineers, makers)? In what ways do the toolkits help individuals in design processes? How do toolkits impact the outcoming designs? How should we evaluate them?

We invite candidates to submit a 500-word abstract and a complementing poster. The submission should highlight the toolkits, their audiences and purposes in design process, and share reflections on using and/or evaluating the toolkits for designing wearables. Submissions (in PDF only) should be sent through Easy Chair (<https://easychair.org/conferences/?conf=towear2022>). They will be reviewed based on the relevance to the workshop

theme and potential for contributing to discussions. The accepted submissions will be available online through the workshop website(<http://techfashion.design/wearable-toolkits>).

The workshop will be conducted in a hybrid format (both in-person and virtual). At least one author of each accepted submission must attend the workshop and all participants must register for both the workshop and for at least one day of the conference.

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REFERENCES

- [1] Malcolm Barnard. 2013. *Fashion as communication*.
- [2] Leah Buechley, Mike Eisenberg, Jaime Catchen, and Ali Crockett. 2008. The LilyPad Arduino: using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 423–432.
- [3] Tiny Circuits. 2020. Tiny Circuits. <https://tinycircuits.com/>
- [4] David Cuartielles, Jonathan Bean, and Daniela Rosner. 2015. Conversations on making. *Interactions* 22, 1 (2015), 22–24.
- [5] Lucy E Dunne, Halley Profita, Clint Zeagler, James Clawson, Scott Gilliland, Ellen Yi-Luen Do, and Jim Budd. 2014. The social comfort of wearable technology and gestural interaction. In *36th annual international conference of the IEEE engineering in medicine and biology society*. IEEE, 4159–4162.
- [6] Collective E-stitches. [n. d.]. <https://www.e-stitches.co.uk/>
- [7] Francine Gemperle, Chris Kasabach, John Stivoric, Malcolm Bauer, and Richard Martin. 1998. Design for wearability. In *digest of papers. Second international symposium on wearable computers (cat. No. 98EX215)*. IEEE, 116–122.
- [8] Çağlar Genç, Oğuz Turan Buruk, Sejda İnal Yılmaz, Kemal Can, and Oğuzhan Özcan. 2018. Exploring Computational Materials as Fashion Materials: Recommendations for Designing Fashionable Wearables. *International Journal of Design* 12, 3 (2018), 1–19.
- [9] Kate Hartman. 2014. *Make: Wearable Electronics: Design, prototype, and wear your own interactive garments*. Maker Media, Inc.
- [10] Chris Hill, Michael Schneider, Ann Eisenberg, and Mark D Gross. 2021. The ThreadBoard: Designing an E-Textile Rapid Prototyping Board. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 1–7.
- [11] Adafruit Industries. 2020. Adafruit Circuit Playground Express. <https://www.adafruit.com/product/3333>
- [12] Virve Inget, Heiko Müller, and Jonna Häkkinen. 2019. Private and public aspects of smart jewellery: a design exploration study. In *Proceedings of the 18th International Conference on Mobile and Ubiquitous Multimedia*. 1–7.
- [13] Pradthana Jarusriboonchai and Jonna Häkkinen. 2019. Customisable wearables: exploring the design space of wearable technology. In *Proceedings of the 18th International Conference on Mobile and Ubiquitous Multimedia*. 1–9.
- [14] Ben Jelen, Anne Freeman, Mina Narayanan, Kate M Sanders, James Clawson, and Katie A Siek. 2019. Craftec: Engaging older adults in making through a craft-based toolkit system. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 577–587.
- [15] Walther Jensen, Ashley Colley, Jonna Häkkinen, Carlos Pinheiro, and Markus Löchtefeld. 2019. TransPrint: A method for fabricating flexible transparent free-form displays. *Advances in Human-Computer Interaction* 2019 (2019).
- [16] Lee Jones, Sara Nabil, Amanda McLeod, and Audrey Girouard. 2020. Wearable Bits: scaffolding creativity with a prototyping toolkit for wearable e-textiles. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 165–177.
- [17] Lee Jones, Miriam Sturdee, Sara Nabil, and Audrey Girouard. 2021. Punch-Sketching E-textiles: Exploring Punch Needle as a Technique for Sustainable, Accessible, and Iterative Physical Prototyping with E-textiles. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 1–12.
- [18] Oskar Juhlin, Yanqing Zhang, Cristine Sundbom, and Ylva Farnaeus. 2013. Fashionable shape switching: explorations in outfit-centric design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 1353–1362.
- [19] Majeed Kazemitabaar, Jason McPeak, Alexander Jiao, Liang He, Thomas Outing, and Jon E Froehlich. 2017. Makerwear: A tangible approach to interactive

- wearable creation for children. In *Proceedings of the 2017 chi conference on human factors in computing systems*. 133–145.
- [20] Konstantin Klamka, Raimund Dachselt, and Jürgen Steimle. 2020. Rapid Iron-On User Interfaces: Hands-on Fabrication of Interactive Textile Prototypes. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–14.
- [21] DIY Kobakant. [n. d.]. How to get what you want. <https://www.kobakant.at/DIY/>
- [22] David Ledo, Steven Houben, Jo Vermeulen, Nicolai Marquardt, Lora Oehlberg, and Saul Greenberg. 2018. Evaluation strategies for HCI toolkit research. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–17.
- [23] Nicolai Marquardt, Steven Houben, Michel Beaudouin-Lafon, and Andrew D Wilson. 2017. HCITools: Strategies and Best Practices for Designing, Evaluating and Sharing Technical HCI Toolkits. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. 624–627.
- [24] Troy Nachtigall, Oscar Tomico, and Ron Wakkary. 2019. Oneday shoes: a maker toolkit to understand the role of co-manufacturing in personalization. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 105–115.
- [25] Grace Ngai, Stephen CF Chan, Hong Va Leong, and Vincent TY Ng. 2013. Designing i* CATch: A multipurpose, education-friendly construction kit for physical and wearable computing. *ACM Transactions on Computing Education (TOCE)* 13, 2 (2013), 1–30.
- [26] Andreas Peetz, Konstantin Klamka, and Raimund Dachselt. 2019. BodyHub: A Reconfigurable Wearable System for Clothing. In *The Adjunct Publication of the 32nd Annual ACM Symposium on User Interface Software and Technology*. 39–41.
- [27] Irene Posch, Liza Stark, and Geraldine Fitzpatrick. 2019. eTextiles: reviewing a practice through its tool/kits. In *Proceedings of the 23rd International Symposium on Wearable Computers*. 195–205.
- [28] Kirill Ragozin, Kai Kunze, Teresa Hirzle, Benjamin Tag, Yuji Uema, Enrico Rukzio, and Jamie A Ward. 2021. Eyewear 2021 The Forth Workshop on Eyewear Computing—Augmenting Social Situations and Democratizing Tools. In *Adjunct Proceedings of the 2021 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2021 ACM International Symposium on Wearable Computers*. 458–461.
- [29] Teddy Seyed, James Devine, Joe Finney, Michal Moskal, Peli de Halleux, Steve Hodges, Thomas Ball, and Asta Roseway. 2021. Rethinking the Runway: Using Avant-Garde Fashion To Design a System for Wearables. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–15.
- [30] Teddy Seyed and Anthony Tang. 2019. Mannequette: Understanding and Enabling Collaboration and Creativity on Avant-Garde Fashion-Tech Runways. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. 317–329.
- [31] Daniela Ghanbari Vahid, Lee Jones, Audrey Girouard, and Lois Frankel. 2021. Shape Changing Fabric Samples for Interactive Fashion Design. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 1–7.
- [32] Anna Vasilchenko, Jie Li, Bektur Ryskeldiev, Sayan Sarcar, Yoichi Ochiai, Kai Kunze, and Iulian Radu. 2020. Collaborative learning & co-creation in XR. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–4.