VitaBoot

Footwear with Dynamic Graphical Patterning

Jensen, Walther; Colley, Ashley; Löchtefeld, Markus

Published in:
ISWC 2019 - Proceedings of the 2019 ACM International Symposium on Wearable Computers

DOI (link to publication from Publisher):
10.1145/3341163.3346937

Publication date:
2019

Document Version
Accepted author manuscript, peer reviewed version

Citation for published version (APA):
Jensen, W., Colley, A., & Löchtefeld, M. (2019). VitaBoot: Footwear with Dynamic Graphical Patterning. In *ISWC 2019 - Proceedings of the 2019 ACM International Symposium on Wearable Computers* (pp. 279-283). Association for Computing Machinery. https://doi.org/10.1145/3341163.3346937

VitaBoot - Footwear with Dynamic Graphical Patterning

Walther Jensen
Aalborg University
Aalborg, Denmark
bwsj@create.aau.dk

Ashley Colley
University of Lapland
Rovaniemi, Finland
ashley.colley@ulapland.fi

Markus Löchtefeld
Aalborg University
Aalborg, Denmark
mloc@create.aau.dk

ABSTRACT

VitaBoot is a footwear concept incorporating dynamic graphical patterns which indicate the wearer's activity level. Whilst shoes are an important element in fashion wear and a lot of research has focused on shoes as input devices, comparable few concepts have explored the potential for their use as an output space. We created a boot design that incorporates dynamic patterning through the use of electrochromic (EC) displays embedded in the surface material. The boot was designed and constructed from scratch, using a faux leather material, ensuring the overall aesthetic of the design, including the integration of the required control electronics and power source. The boot connects wirelessly to a chest-worn heart rate belt, and pattern changes indicate when the wearer's heart rate is above a predefined threshold. VitaBoot demonstrates the potential for dynamic shoe patterning for aesthetic or functional means, and the suitability of flexible, low-power EC display technology in this domain.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; **Interaction techniques**; **Ubiquitous and mobile computing**; **Ubiquitous and mobile computing systems and tools**.

KEYWORDS

Footwear, Shoes, Ambient Display, Wearable Display, Activity Tracking, Electrochromic Display

ACM Reference Format:
Walther Jensen, Ashley Colley, and Markus Löchtefeld. 2019. VitaBoot - Footwear with Dynamic Graphical Patterning. In *Proceedings of the 2019 International Symposium on Wearable Computers (ISWC '19), September 9–13, 2019, London, United Kingdom.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3341163.3346937

ISWC '19, September 9–13, 2019, London, United Kingdom

ACM ISBN 978-1-4503-6870-4/19/09…$15.00
https://doi.org/10.1145/3341163.3346937

1 INTRODUCTION

Wearable technologies, in the form of smartwatches and wristbands are nowadays commonplace. Fueled by the availability of smart textiles, flexible computing and decreases in size and power consumption, concepts integrating various input and output mechanisms into garments are appearing. Whilst much work in the area of smart clothing has focused on garments, such as dresses, shirts and jackets, relatively less researched items include shoes and accessories such as handbags and jewelry. In this paper, we focus on shoes as a wearable computing platform, more specifically, on their use as a visual output platform through the integration of ambient display elements.

Directed by Weiser's calm computing vision, we aim to utilize the output modality of a clothing-integrated computational system as a fundamental design element in the overall aesthetic of the clothing. Due to their relative ease of integration and their colorful vibrant output modes, a majority of previously presented smart clothing design pieces have utilized light-emitting LEDs as the output technology. Whilst such approaches are suitable as exhibition pieces, less luminous approaches are more suited for daily wear, complementing existing design lines, rather than the light being an overpowering element. Thus, we focus on the use of Electrochromic (EC) display technology, which is non-emissive and particularly suited to wearables applications due to its flexibility, ability to be fabricated in non-rectangular shapes and its extremely low power requirements. Considering shoes, with their 3-dimensional curved surfaces, such flexibility is essential to avoid limitation in the placement of display elements.

In this paper, we present VitaBoot, footwear which provides the wearer with ambient notification of raised heart rate, measured by a connected smartwatch or chest-belt sensor. VitaBoot encourages the wearer to take bouts of beneficial light activity during the normal day, such as walking up a flight of stairs, which is then rewarded with a visible pattern change. The shoe is designed as a fashionable shoe

Figure 1: Raised heart rate indication in activated and deactivated states.

for daily wear, the ambient nature of display complementing the aesthetic, rather than drawing attention from bystanders.

2 RELATED WORK

Wearable Displays. As well as acting as data collection devices for activity tracking and bio-data, wearables have also been explored as output devices. Schneegass et al. present a design space for such, including e.g. who is viewing the display, what is the display content and where on the body it is situated [12]. Wearable displays have been incorporated in garments [8], and in accessories such as brooches [6], or handbags [1].

Smart Footwear. Prior works in the area of smart footwear have primarily explored instrumenting the foot with sensors e.g. for sports and medical applications [5]. Few commercial examples of shoes as an output space exist, beyond the novelty LED soled children's shoes, that illuminate with each step. A design space for shoe integrated displays has been presented by Colley et al., considering dimensions e.g. if the display is targeted for visibility during wear, or when the shoe is removed [2]. An initial prototype utilising EC displays in a running shoe has been presented by Müller et al. [9]. However, the approach of attaching displays to an off-the-shelf base shoe prevents the achievement of a holistically designed piece. In Nachtigall's EVA mocasin [10] methods of indicating the shoe's wear state are integrated into the design of the shoe.

Our Contribution. Whilst shoes and other footwear are a large and important segment of the fashion market, they have been so far little addressed as a space for dynamic visual output by the interaction design community. This reticence is likely fueled by the challenges of the space, presenting curved and flexible surfaces, difficult to work construction materials (such as leather), small spaces for embedding electronics and the need for a high level of prototype robustness to support normal wear. With Vitaboot we add to the few presented examples of visually adaptive footwear, highlighting the potential of addressing the task of dynamic shoe design from first principles, rather than as an addition to an off-the-shelf base model. The characteristics of the EC displays in our prototype enable going beyond the restrictions of rectangular rigidity faced by prior research (e.g. [4]).

Figure 2: VitaBoot worn and showing activated graphical patterning.

Figure 3: Final prototype with graphical pattern active.

3 VITABOOT

With similar motivation as Devendorf et al.'s "I don't Want to Wear a Screen" [3], we aim to create a wearable that prompts the wearer to include new experiences in their everyday life. We explore the potential of shoe based visualization, which is non-distracting, yet easily glanceable by the wearer (perhaps with small leg movement) in the majority of daily life contexts. Targeting to encourage the wearer to incorporate light exercise in their routines, such as taking the stairs or fast walking between appointments, we selected that the shoe should provide indication of elevated heart rate (measured by a separate body-worn sensor). Exertion during exercise is normally indicated by heart rate zones with each zone providing different health effects. Any exertion above a certain zone, however, provide health benefits in general and therefore we decided to provide a single state indicator that the wearer could affect in real-time shown through their actions. A pattern change on the shoe provides motivational feedback for the wearer's actions (Fig. 1).

Figure 4: Graphic design iterations.

Design Approach

As the start point for the design, we selected to utilise two existing toolkits, ONEDAY Shoes [11] and the TransPrint electrochromic display method [7]. The ONEDAY Shoes kit provide a pair of shoe soles, a set of downloadable templates and instructions on fabrication and assembly. TransPrint provides an easy method to design, print and fabricate transparent flexible free-form electrochromic displays; utilizing PET-ITO film, EC ink and electrolyte. As such electrochromic displays are flexible and can be fabricated in a free-form shape, they are a natural fit as embedded ambient shoe displays.

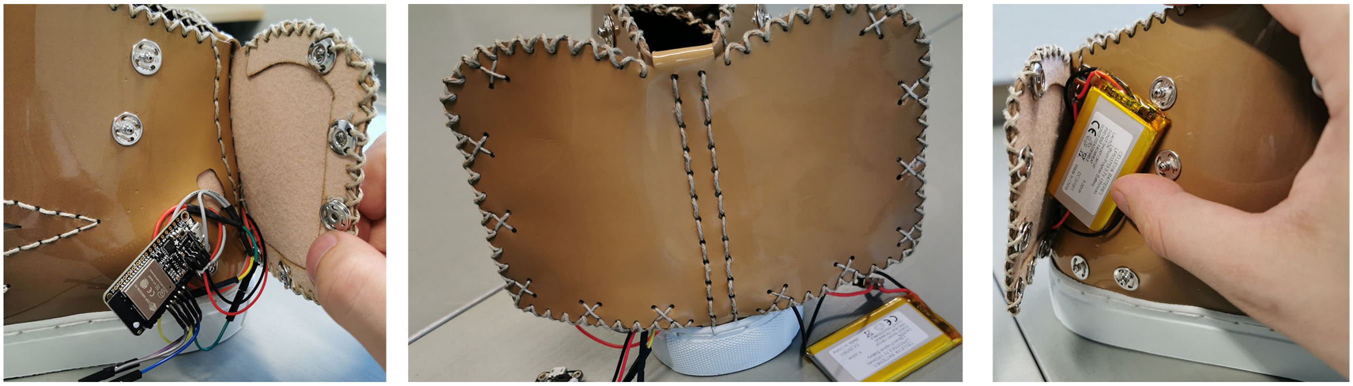

Figure 5: Electronic pocket design. Left side contains ESP32 board and right side the battery. Wires are hidden under the pocket flaps.

Figure 6: Side panel iterations of the VitaBoot during construction

Design Process

As we were aiming for a casual-retro inspired look, a faux leather material with a light-to-dark brown gradient was selected as our construction material. Based on the ONEDAY shoe templates, an initial design was created and the required panels to construct the shoe, including all the needed holes for sewing, were laser-cut from the material (Fig. 6). With this initial prototype, several different locations and formats for the dynamic graphical display area were explored. Approaches using typical segmented-bar type activity visualisations were rejected, as not contributing to the overall aesthetic of the footwear. Instead we settled on a concept inspired by 1980s-era workouts "*feel the burn*" and evolved a dynamic graphical motif in the shape of a flame (Fig. 1).

Figure 7: The electrochromic display design, showing counter electrode (black bar around flames), border areas (grey) and connection areas (dashed).

The size and placement of the dynamic graphic display element was constrained by the construction of the electrochromic display element, requiring a border area for the counter-electrode (CE) and 4-5mm non-functional adhesive strip. In our design, the display was located behind a cutout in the shoe's outer surface, such that only the central flame area of the display was visible, the CE and adhesive border being masked from view (Fig. 7).

We sketched several different designs for the dynamic graphical element, (Fig. 4), eventually settling on a simplified flame pattern design that was in keeping with the overall retro design direction of the piece (Fig. 4, right). The electrochromic display element was then constructed, following the guidelines of the TransPrint method [7]. Three layers of PEDOT electrochromic ink were used, printed with an ink-jet printer and oven dried after each layer.

To enable the shoe's functionality, a microcontroller and battery power source were also required to be integrated into the shoe. Here we needed to meet the requirements for size and rigidity of the electronic elements without degrading the overall aesthetic of the shoe. For example, locating the electronics in the insole of the is not possible due to the flexibility of that area during normal wear. Thus, we created a pair of secondary surface flaps on the heal area of the shoe, into which the electronics and battery were inserted (Fig. 5).

Technical Implementation

The system was controlled by an Adafruit ESP32 Feather microcontroller, programmed to connect to a BLE enabled heart rate monitor via the Bluetooth GATT heart rate protocol. One EC display was fitted on each side of the shoe and driven with 1.5V, the polarity being reversed to change the display state. When connected to a heart rate monitor, the display state is switched such that the flame pattern is visible when the heart rate is above a threshold of 100bpm. For heart rates below this threshold the flame pattern is not visible.

4 ACKNOWLEDGEMENTS

This work was funded by EU project DecoChrom, grant no. 760973 of European Union's Horizon 2020 research and innovation programme. Thanks to Troy Nachtigall for providing a ONEDAY Shoe kit.

REFERENCES

[1] Ashley Colley, Minna Pakanen, Saara Koskinen, Kirsi Mikkonen, and Jonna Häkkilä. 2016. Smart Handbag As a Wearable Public Display - Exploring Concepts and User Perceptions. In *Proceedings of the 7th Augmented Human International Conference 2016 (AH '16)*. ACM, New York, NY, USA, Article 7, 8 pages. DOI: http://dx.doi.org/10.1145/2875194.2875212

[2] Ashley Colley, Paweł W. Woźniak, Francisco Kiss, and Jonna Häkkilä. 2018. Shoe integrated displays: a prototype sports shoe display and design space. In *Proceedings of the 10th Nordic Conference on Human-Computer Interaction - NordiCHI '18*. ACM Press, Oslo, Norway, 39–46. DOI: http://dx.doi.org/10.1145/3240167.3240216

[3] Laura Devendorf, Joanne Lo, Noura Howell, Jung Lin Lee, Nan-Wei Gong, M. Emre Karagozler, Shiho Fukuhara, Ivan Poupyrev, Eric Paulos, and Kimiko Ryokai. 2016. "I Don'T Want to Wear a Screen": Probing Perceptions of and Possibilities for Dynamic Displays on Clothing. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, 6028–6039. DOI: http://dx.doi.org/10.1145/2858036.2858192

[4] Christine Dierk, Molly Jane Pearce Nicholas, and Eric Paulos. 2018. AlterWear: Battery-Free Wearable Displays for Opportunistic Interactions. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. ACM Press, Montreal QC, Canada, 1–11. DOI: http://dx.doi.org/10.1145/3173574.3173794

[5] Bjoern Eskofier, Sunghoon Lee, Manuela Baron, André Simon, Christine Martindale, Heiko Gaßner, and Jochen Klucken. 2017. An overview of smart shoes in the internet of health things: gait and mobility assessment in health promotion and disease monitoring. *Applied Sciences* 7, 10 (2017), 986.

[6] Jennica Falk and Staffan Björk. 1999. The BubbleBadge: A Wearable Public Display. In *CHI '99 Extended Abstracts on Human Factors in Computing Systems (CHI EA '99)*. ACM, New York, NY, USA, 318–319. DOI: http://dx.doi.org/10.1145/632716.632909

[7] Walther Jensen, Ashley Colley, Jonna Häkkilä, Carlos Pinheiro, and Markus Löchtefeld. 2019. TransPrint: A Method for Fabricating Flexible Transparent Free-Form Displays. *Advances in Human-Computer Interaction* 2019 (May 2019), 1–14. DOI: http://dx.doi.org/10.1155/2019/1340182

[8] Matthew Mauriello, Michael Gubbels, and Jon E. Froehlich. 2014. Social Fabric Fitness: The Design and Evaluation of Wearable E-textile Displays to Support Group Running. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, 2833–2842. DOI: http://dx.doi.org/10.1145/2556288.2557299

[9] Heiko Müller, Emma Napari, Lauri Hakala, Ashley Colley, and Jonna Häkkilä. 2019. Running Shoe with Integrated Electrochromic Displays. In *Proceedings of the 8th ACM International Symposium on Pervasive Displays (PerDis '19)*. ACM, New York, NY, USA, Article 33, 2 pages. DOI: http://dx.doi.org/10.1145/3321335.3329686

[10] Troy Nachtigall. 2017. EVA Moccasin: creating a research archetype to explore shoe use. In *Proceedings of the 2017 ACM International Symposium on Wearable Computers*. ACM, 197–202.

[11] 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 - TEI '19*. ACM Press, Tempe, Arizona, USA, 105–115. DOI: http://dx.doi.org/10.1145/3294109.3295637

[12] Stefan Schneegass, Sophie Ogando, and Florian Alt. 2016. Using On-body Displays for Extending the Output of Wearable Devices. In *Proceedings of the 5th ACM International Symposium on Pervasive Displays (PerDis '16)*. ACM, 67–74. DOI: http://dx.doi.org/10.1145/2914920.2915021