Hybrid Watch User Interfaces: Collaboration Between Electro-Mechanical Components and Analog Materials

Alex Olwal
Interaction Lab, Google Inc.
Mountain View, CA 94043, USA
olwal@google.com

a) Visual vibration **b) Content-awareness** **c) Transformation** **d) Cooperation in the UIs**

Figure 1. Our hybrid watch user interfaces (UIs) leverage coordination and collaboration between steerable physical hands and a dynamic watch dial. Hands and dial transform and cooperatively form new interfaces that leverage their respective strengths. a) The physical hands vibrate mechanically on a new message. b) The hands fold and move out of the way for text. c) and d) Steerable physical hands are used for menu selection to optimize responsiveness and to reduce power consumption.

ABSTRACT
We introduce programmable material and electro-mechanical control to enable a set of *hybrid watch user interfaces* that symbiotically leverage the joint strengths of electro-mechanical hands and a dynamic watch dial. This approach enables computation and connectivity with existing materials to preserve the inherent physical qualities and abilities of traditional analog watches.

We augment the watch's mechanical hands with micro-stepper motors for control, positioning and mechanical expressivity. We extend the traditional watch dial with programmable pigments for non-emissive dynamic patterns. Together, these components enable a unique set of interaction techniques and user interfaces beyond their individual capabilities.

Author Keywords
Wearable computing; programmable material; E-ink; actuation; analog watches; hybrid watches; smartwatches

CCS Concepts
- Human-centered computing → Interaction devices; Interaction techniques; User interface design

INTRODUCTION
Research studies [5, 8, 9] point to challenges in smartwatch adoption, due to dissatisfaction with the significantly different shapes, aesthetics, and looks of smartwatches, and the perception of smartwatches as utilitarian "wrist-worn electronic devices" rather than aspirational fashion accessories and jewelry.

This work focuses on computational capabilities that can co-exist with analog watch aesthetics and conventions. We build our contributions on the many creative approaches to novel display and output for wristworn devices [1, 3, 4, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17]. Shimmering Smartwatches may, however, be the project that is closest in spirit to ours [17]: "*an opportunity to create devices that provide smartwatch functionality that do not use the small high resolution graphical displays often associated with smartwatches.*"

We contribute a complementary approach to further broaden the design space for computational *analog watches*, where we innovate with existing analog watch components through computational control. We augment the watch's mechanical hands with micro-stepper motors for control, positioning and mechanical expressivity. We extend the traditional watch dial with programmable pigments for non-emissive dynamic patterns.

Our main contribution is how we use these two programmable materials to coordinate and trade responsibilities in novel hybrid watch user interfaces (UIs) that symbiotically leverage the strengths of physical hands and dynamic watch dials.

COOPERATIVE HYBRID WATCH INTERFACES
Analog watches were designed to show time. However, through connectivity and computation, additional

UIST '18 Adjunct, October 14–17, 2018, Berlin, Germany

ACM ISBN 978-1-4503-5949-8/18/10.
https://doi.org/10.1145/3266037.3271650

visualizations are relevant today. The ability to reconfigure the position of the hands mechanically and reprogram the pigments in the analog dial, allows us to adapt the interface along several dimensions.

Distributing UI between Pixels and Physical Hands. Pixels and physical hands cooperate to create optimal user interfaces by distributing responsibilities across different display mechanisms.

Deictic Reference: Hands Pointing to Pixels. Saving power and performance by using the hands to point to different parts of a static E-ink screen (See Figure 1c,d).

Prioritizing Visual Contents: Hands Avoiding Pixels. When the dial needs to display prioritized content (e.g., incoming notifications), the hands are moved out of the way, or collapsed, to minimize occlusion (See Figure 1b).

Prioritizing Mechanical Hands: Pixels Avoiding Hands. We may wish to preserve the position of the mechanical hands, while presenting prioritized contents on the dial. The notification icons could simply choose a suitable location on the dial, e.g., based on the amount of unoccluded space.

Intentional Occlusion: Repurposing Graphics. Use the hands to temporarily "hide" visual elements. The UI shows updates by moving the hands to occlude all but one option on a static screen. This method could address hardware limitations, e.g., refresh rate or transition quality.

Fusion: Matching appearance, shape and color. UI-elements can be constructed by aligning the hands with screen shapes, such that they become part of the geometry.

Mechanical Expressivity: Physical Motion. Visual mechatronic effects can be used as a complement or alternative to digital displays. Given our visual perception system's sensitivity to motion in the periphery, this technique provides an interesting opportunity to attract the user's attention with motion when light or sound is inappropriate or insufficient (See Figure 1a).

Tense: Past, Present or Future. Information from the past (reflection) or in the future (prediction) can be displayed at different scales. For example, reviewing the last 60 minutes of activity, or to preview the next 12 hours in the calendar.

Scale: Temporal and Semantic. The interface can also reconfigure to adapt the presentation to different scales, presented as visualizations relative to the physical hands.

HYBRID WATCH IMPLEMENTATION

Our proof-of-concept implementation contributes interactions with programmable pigments in a dynamic watch dial overlaid with steerable physical hands.

Programmable Pigments for Dynamic Dials

In this work, we leverage high-resolution e-ink displays as reprogrammable dials. For our dynamic dial, we chose a round panel from E-ink [2], which has a center hole to allow the combination with analog watch hands.

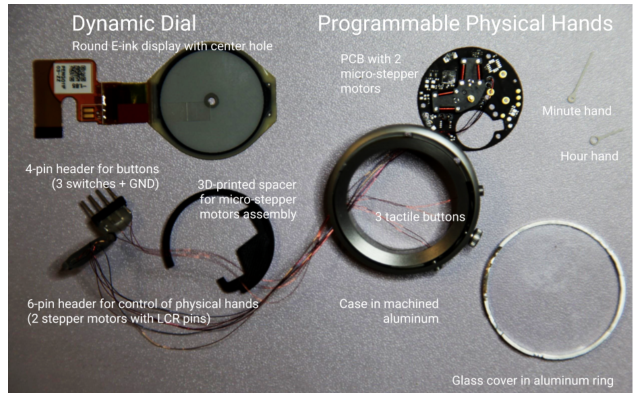

Figure 2. The user interface components for our prototype (microcontroller and E-ink driver board not shown) and machined aluminum housing.

Steerable Hands: Electro-Mechanical Movements

We leverage micro-stepper motors for bidirectional rotation through electrical pulses. We repurposed PCB-mounted stepper motors, for hour and minutes, from a Withings Activité watch. Through experimentation, we identified a suitable pulse width of 2 ms, and an inter-pulse timing of 5 ms. The minute and hour hands have 120 and 90 steps per revolution, respectively.

We designed a housing for the components, which we 3D printed for one prototype and machined out of aluminum for another. They both use an additional flexible PCB with three tactile switches connected to mechanical buttons on the housing. See Figure 2.

We use a a Bluetooth Low Energy-enabled (Nordic nRF8001) microcontroller (Atmel ATmega32U4) from Red Bear Labs (Blend Micro), to interface with the buttons, control the stepper motors (magnet wire to left, common, and right pins) and to control the E-ink display. The microcontroller is running our watch application framework written in C++ that we developed to enable rapid exploration of capabilities and interface concepts.

CONCLUSIONS

This work leverages opportunities for transformation and cooperation in a hybrid watch user interface, using two complementary dynamic materials; steerable hands and programmable pigments. We demonstrate a number of interaction techniques that we developed with custom hardware, guided by our design considerations.

We believe that this approach enables new opportunities and advantages for innovating with existing materials to preserve inherent qualities and abilities of analog devices.

ACKNOWLEDGEMENTS

We thank our collaborators in Google Aura and Wearables. Special thanks to Minh-Nhat Le, Philip Battin, Tyler Gough, Isabelle Olsson, Lew Layraman, Peter Cazalet, Livius Chebeleu, Jason Pi, and Ben Leung.

REFERENCES

1. Jesse Burstyn, Paul Strohmeier, Roel Vertegaal, DisplaySkin: Exploring Pose-Aware Displays on a Flexible Electrophoretic Wristband, Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction, January 15-19, 2015, Stanford, California, USA http://doi.org/10.1145/2677199.2680596
2. E-ink Round ePaper Display ET011TT3. https://shopkits.eink.com/product/1-1%CB%9D-round-epaper-display-et011tt2/. Last accessed August 2018.
3. Xiang 'Anthony' Chen, Tovi Grossman, Daniel J. Wigdor, George Fitzmaurice, Duet: exploring joint interactions on a smart phone and a smart watch, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, April 26-May 01, 2014, Toronto, Ontario, Canada
4. Jun Gong, Lan Li, Daniel Vogel, Xing-Dong Yang, Cito: An Actuated Smartwatch for Extended Interactions, Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, May 06-11, 2017, Denver, Colorado, USA
5. Hayeon Jeong, Heepyung Kim, Rihun Kim, Uichin Lee, and Yong Jeong. 2017. Smartwatch Wearing Behavior Analysis: A Longitudinal Study. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 1, 3, Article 60 (September 2017), 31 pages. DOI: https://doi.org/10.1145/3131892
6. Gierad Laput, Robert Xiao, Xiang 'Anthony' Chen, Scott E. Hudson, Chris Harrison, Skin buttons: cheap, small, low-powered and clickable fixed-icon laser projectors, Proceedings of the 27th annual ACM symposium on User interface software and technology, October 05-08, 2014, Honolulu, Hawaii, USA http://doi.org/10.1145/2642918.2647356
7. Kent Lyons, David Nguyen, Daniel Ashbrook, Sean White, Facet: a multi-segment wrist worn system, Proceedings of the 25th annual ACM symposium on User interface software and technology, October 07-10, 2012, Cambridge, Massachusetts, USA http://doi.org/10.1145/2380116.2380134
8. Kent Lyons, What can a dumb watch teach a smartwatch?: informing the design of smartwatches, Proceedings of the 2015 ACM International Symposium on Wearable Computers, September 07-11, 2015, Osaka, Japan
9. Vivian Genaro Motti, Kelly Caine, Smart Wearables or Dumb Wearables?: Understanding how Context Impacts the UX in Wrist Worn Interaction, Proceedings of the 34th ACM International Conference on the Design of Communication, September 23-24, 2016, Silver Spring, MD, USA
10. Simon Olberding, Kian Peen Yeo, Suranga Nanayakkara, Jurgen Steimle, AugmentedForearm: exploring the design space of a display-enhanced forearm, Proceedings of the 4th Augmented Human International Conference, p.9-12, March 07-08, 2013, Stuttgart, Germany
11. Henning Pohl, Justyna Medrek, Michael Rohs, ScatterWatch: subtle notifications via indirect illumination scattered in the skin, Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services, September 06-09, 2016, Florence, Italy http://doi.org/10.1145/2935334.2935351
12. Taptic Engine, Apple. https://appleinsider.com/articles/16/09/27/inside-the-iphone-7-apples-taptic-engine-explained. Accessed July 2018.
13. Teddy Seyed, Xing-Dong Yang, Daniel Vogel, Doppio: A Reconfigurable Dual-Face Smartwatch for Tangible Interaction, Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, May 07-12, 2016, Santa Clara, California, USA http://doi.org/10.1145/2858036.2858256
14. Sunghyun Song, Geeyoung Noh, Junwoo Yoo, Ian Oakley, Jundong Cho, Andrea Bianchi, Hot & tight: exploring thermo and squeeze cues recognition on wrist wearables, Proceedings of the 2015 ACM International Symposium on Wearable Computers, September 07-11, 2015, Osaka, Japan
15. Martin Weigel, Aditya Shekhar Nittala, Alex Olwal, and Jürgen Steimle. 2017. SkinMarks: Enabling Interactions on Body Landmarks Using Conformal Skin Electronics. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). ACM, New York, NY, USA, 3095-3105. DOI: https://doi.org/10.1145/3025453.3025704
16. Dirk Wenig, Johannes Schöning, Alex Olwal, Mathias Oben, and Rainer Malaka. 2017. WatchThru: Expanding Smartwatch Displays with Mid-air Visuals and Wrist-worn Augmented Reality. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). ACM, New York, NY, USA, 716-721. DOI: https://doi.org/10.1145/3025453.3025852
17. Robert Xiao, Gierad Laput, Chris Harrison, Expanding the input expressivity of smartwatches with mechanical pan, twist, tilt and click, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, April 26-May 01, 2014, Toronto, Ontario, Canada
18. Cheng Xu and Kent Lyons. 2015. Shimmering Smartwatches: Exploring the Smartwatch Design Space. In Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '15). ACM, New York, NY, USA, 69-76. DOI: https://doi.org/10.1145/2677199.2680599