ISWC 2018: Towards Smarter Wearable Technologies That Blend With Our Bodies

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■ **Wearables are often** associated with smart watches or clunky accessories. Yet the vision of wearable computing is to create computational systems that tightly couple with our bodies.

To discuss the newest trends in this field, wearable computing researchers, professionals, and enthusiasts met at the 2018 ACM International Symposium on Wearable Computers (ISWC) in Singapore in October 2018. Following long-standing tradition, the conference was colocated with the ACM International Joint Conference on Pervasive and Ubiquitous Computing. This year, we received 108 submissions (62 long papers, 29 short papers, and 17 briefs) with an acceptance rate of 27% for the long paper track.

HOT TOPICS

This year, several strong papers explored applied machine learning techniques for on-body activity recognition. Another emerging direction is blending wearables with the human body in the form of haptics and textiles. Last but not the least, as the field matures, continue to see wearable computing applied in a wider variety of real world, in the wild use cases. Although there were many interesting publications, here we highlight only a few articles focusing on

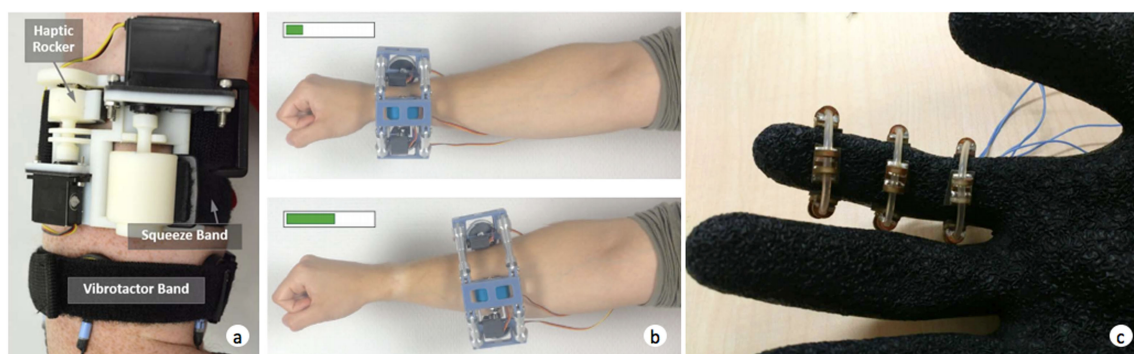Published by the IEEE Computer Society

Figure 1. Examples of some work at ISWC 2018. (a) Conveying language through haptics: A multisensory approach by Dunkelberger *et al.* (b) Movelet: A self-actuated movable bracelet for positional haptic feedback on the user's forearm by Dobbelstein *et al.* (c) Shape memory alloy wire actuators for soft, wearable haptic devices by Chernyshov *et al.*

recognizing activities, blending with the body, and studying systems in the wild.

Recognizing Activities Smarter

Murahari and Plötz[1] adapt attention models for human activity recognition based on sensor data. It is exciting to see state-of-the-art machine learning adapted and applied to human activity, as most sensing approaches still use fixed size temporal context to represent different activities. Attention models learn a set of weights over input data. The authors weight the temporal context to model individual sensor readings. They apply the models on large standard datasets of activity recognition and show their usefulness.

In another paper on activity recognition, Kwon *et al.*[2] show how to utilize distribution-based sensor representations to improve feature calculations for human activity recognition by adding temporal and frequency structures. This approach enables activity recognition chains to exploit the temporal structure of the data more easily.

Blending With the Body (Haptics and Textiles)

This year, we saw more fascinating papers related to wearable haptics systems and application cases (Figure 1). Two research groups presented work on communicating language through haptic stimuli. Dunkelberger *et al.*[3] describe a multiactuator haptic device that can be worn on the upper arm and is capable of producing brief cues to encode English phonemes. Luzhnica *et al.* train the skill of comprehending text from vibrotactile patterns using passive haptic learning, a method that teaches manual skills while requiring little to no active attention by the user.

Other work focused on encoding continuous information (e.g., progress) on a haptic channel. Dobbelstein introduce a sleeve-robotic bracelet that can move automatically along the user's arm and presented several application scenarios.[4] Chernyshov *et al.*[5] describe pressure feedback rings worn on the finger that create a one-dimensional information display.

Studying People in the Wild

ISWC this year also featured a wide variety of applications in domains such as health care, social engagement, and industrial use. Schiboni and Amft[6] show how to detect drinking a beverage, a sparse natural gesture, by testing with a realistic, free-living dataset that includes a total of 35 days of annotated inertial sensor recordings from seven participants. Ward *et al.*[7] show how to measure nonverbal social coordination in groups of people and study the social engagement of children with autism in a theatrical workshop.

AWARDS

The three best paper award nominees that were selected by the PC committee reflect the three hot topics described above (Figure 2). First, Zeng *et al.*[8] were nominated for their work on "Understanding and improving recurrent networks for human activity recognition by continuous attention." Computational neural networks applied to activity recognition are often difficult to interpret, and so, Zeng *et al.* propose two attention models for human activity recognition (temporal
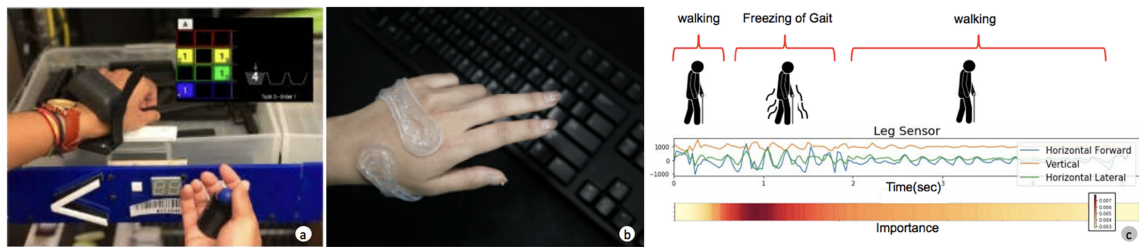
Figure 2. Award winning work at ISWC 2018. (a) "RF-pick: Comparing order picking using a HUD with wearable RFID verification to traditional pick methods" by Thomas *et al.* (best paper winner). (b) "SkinMorph: Texture-tunable on-skin interface through thin, programmable gel" by Kao *et al.* (best paper honorable mention). (c) "Understanding and improving recurrent networks for human activity recognition by continuous attention" by Zeng *et al.* (best paper honorable mention).

attention and sensor attention). They evaluate the models on three datasets and show that the results correlate well with human intuition.

The second best paper nomination went to Kao *et al.*[10] for their work on "Skinmorph: Texture-tunable on-skin interface through thin, programmable gel." Skinmorph presented an on-skin interface that can selectively transition between soft and rigid states to serve as a texture-tunable wearable skin output. In addition to the fabrication process details, the authors present interesting examples such as a carpal tunnel splint for rehabilitation, a protective layer for joints when engaging in high-impact activities, and foot pads when wearing uncomfortable shoes.

The final best paper nomination went to Thomas *et al.*[9] for the "RF-pick: Comparing order picking using a HUD with wearable RFID verification to traditional pick methods." This paper presents a method that uses a combination of RFID tags with a head-up display for reducing human errors during order picking in warehouses. The authors compare their method with three more traditional methods such as pick-to-light with button verification, pick-to-paper with barcode verification, and pick-to-paper with no verification.

The TPC Chairs and the Award Committee presented the Best Paper Award to Thomas *et al.* The other two works received Best Paper Honorable Mention awards.

In addition, the Technical Program Committee, headed by Michael Beigl and Roshan Peiris, awarded two impact awards this year. First, the 10-year Impact Award for the paper with most impact from ISWC 2008 went to "Using mobile phones to determine transportation by mode" by Sasank Reddy, Jeff Burke, Deborah Estrin, Mark Hansen, and Mani Srivastava. The 20-year Impact Award for the paper with most impact from the second ISWC in 1998 was awarded to the paper titled "Parasitic power harvesting in shoes" by Ioannis Kymissis, Clyde Kendall, Joseph Paradiso, and Neil Gershenfeld.

DESIGN EXHIBITION

ISWC's annual design exhibition brought together fashion designers, researchers, and product vendors to share advances in on-body technology. With participants from Finland, Germany, the Netherlands, Singapore, and the United States, the event showcased exciting interactive designs that gave the wearer actuated wings (for a theatrical play), encouraged empathy and connection between strangers using heat or visualization of common interests in social media, explored augmentation of human vision, networked garments to create a color-changing child's costume, sensed physiological signals and activities, mapped meaningful alerts to haptics across the body, and highlighted current issues such as the diminishing coral reefs and the importance of the microbiome.

JOIN US FOR ISWC 2019

The next ISWC will be held in London in September 9th–13th, 2019 (http://iswc.net/iswc19/). The paper submission deadline is April 26, 2019, and the tutorial proposals deadline is June 14, 2019.

■ REFERENCES

1. V. S. Murahari and T. Plötz, "On attention models for human activity recognition," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 100–103. [Online]. Available: https://doi.org/10.1145/3267242.3267287

2. H. Kwon, G. D. Abowd, and T. Plötz, "Adding structural characteristics to distribution-based accelerometer representations for activity recognition using wearables," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 72–75. [Online]. Available: https://doi.org/10.1145/3267242.3267258

3. N. Dunkelberger *et al.*, "Conveying language through haptics: A multi-sensory approach," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 25–32. [Online]. Available: https://doi.org/10.1145/3267242.3267244

4. D. Dobbelstein, E. Stemasov, D. Besserer, I. Stenske, and E. Rukzio, "Movelet: A self-actuated movable bracelet for positional haptic feedback on the user's forearm," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 33–39. [Online]. Available: https://doi.org/10.1145/3267242.3267249

5. G. Chernyshov, B. Tag, C. Caremel, F. Cao, G. Liu, and K. Kunze, "Shape memory alloy wire actuators for soft, wearable haptic devices," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 112–119. [Online]. Available: https://doi.org/10.1145/3267242.3267257

6. G. Schiboni and O. Amft, "Sparse natural gesture spotting in free living to monitor drinking with wrist-worn inertial sensors," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 140–147. [Online]. Available: https://doi.org/10.1145/3267242.3267253

7. J. A Ward, D. Richardson, G. Orgs, K. Hunter, and A. Hamilton, "Sensing interpersonal synchrony between actors and autistic children in theatre using wrist-worn accelerometers," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 148–155. [Online]. Available: https://doi.org/10.1145/3267242.3267263

8. M. Zeng *et al.*, "Understanding and improving recurrent networks for human activity recognition by continuous attention," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 56–63. [Online]. Available: https://doi.org/10.1145/3267242.3267286

9. C. Thomas, T. Panagiotopoulos, P. Kotipalli, M. Haynes, and T. Starner, "RF-pick: Comparing order picking using a HUD with wearable RFID verification to traditional pick methods," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 168–175. [Online]. Available: https://doi.org/10.1145/3267242.3267290

10. H.-L. (Cindy) Kao, M. Bamforth, D. Kim, and C. Schmandt, "Skinmorph: Texture-tunable on-skin interface through thin, programmable gel," in *Proc. ACM Int. Symp. Wearable Comput.*, 2018, pp. 196–203. [Online]. Available: https://doi.org/10.1145/3267242.3267262

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