DEPARTMENT: WEARABLE COMPUTING

ISWC 2020

A Gathertown of Cyborgs

Thomas Plötz [ID], *Georgia Institute of Technology, Atlanta, GA 30332, USA*

Jennifer Healey, *Adobe Research, San Jose, CA 95110-2704, USA*

Kristof Van Laerhoven [ID], *Ubiquitous Computing, University of Siegen, 57076 Siegen, Germany*

The International Symposium on Wearable Computers (ISWC) is the flagship conference on wearable computing focusing on design, algorithmic foundations, and deployments. It is the ideal venue to present and learn about the latest research in the field. The authors share their observations from the most recent gathering, held online in September 2020.

Each year the International Symposium on Wearable Computing showcases the best and most innovative body worn technologies and the algorithms that support the novel insights we gain from them. This year was no exception, despite the remote nature of the conference. ISWC received a total of 70 paper submissions, among them 58 notes, and 12 briefs. The papers had (first) authors from 14 countries, with a balanced representation from the Americas, Asia/Oceania, and Europe. The program committee had 25 members, representing all the major areas of wearable technology expertise. The final acceptance rate across all ISWC publication formats was 30%. We are grateful for the hard work our PC members and the external reviewers put in to make ISWC 2020 happen, maintaining the scientific standards and rigor the community is proud of.

ISWC 2020 HIGHLIGHTS

The conference program featured a wide range of innovations in the field of wearable computing, including (but not limited to) new devices, sensors, and actuators; new algorithms for and approaches to activity recognition; and a number of innovative health-related systems and applications.

DEVICES, SENSORS, ACTUATORS

Ever since its inception, the International Symposium on Wearable Computing has showcased innovation in all aspects related to sensing, which tends to be at the core of virtually every wearables system. Similarly, this year's conference featured a wide range of sensing-related papers.

Vasquez et al.[1] presented BraceIO, a system that integrated biosensing in dental ligatures. As shown in Figure 1, the authors literally brought sensing into the human body, aiming for robust and reliable recording of relevant biosignals, with potential applications to direct health monitoring but also to implicit interaction. Fang et al.[2] presented FLECTILE, an approach to produce three-dimensional-printable soft actuators that can be used for a wide range of wearable computing scenarios with potential to direct interaction, for example, in clothes. Röddiger et al.[3] explored in detail and systematically the new field of "earable" computing in which sensing and computing platforms are integrated into platforms that are worn around or in the ear.

Two more papers also demonstrated novel ways to creative use of sensing. Lyons[4] presented a detailed breakdown of how wearable magnetic field sensing can be used for effective and accurate finger tracking, which is an important means for interacting with many wearable computing devices. Takaki et al.[5] discussed aspects of coil design for wireless power transfer for and communication with smart glasses, tackling two of the most pressing issues for contemporary (and future) wearables scenarios.
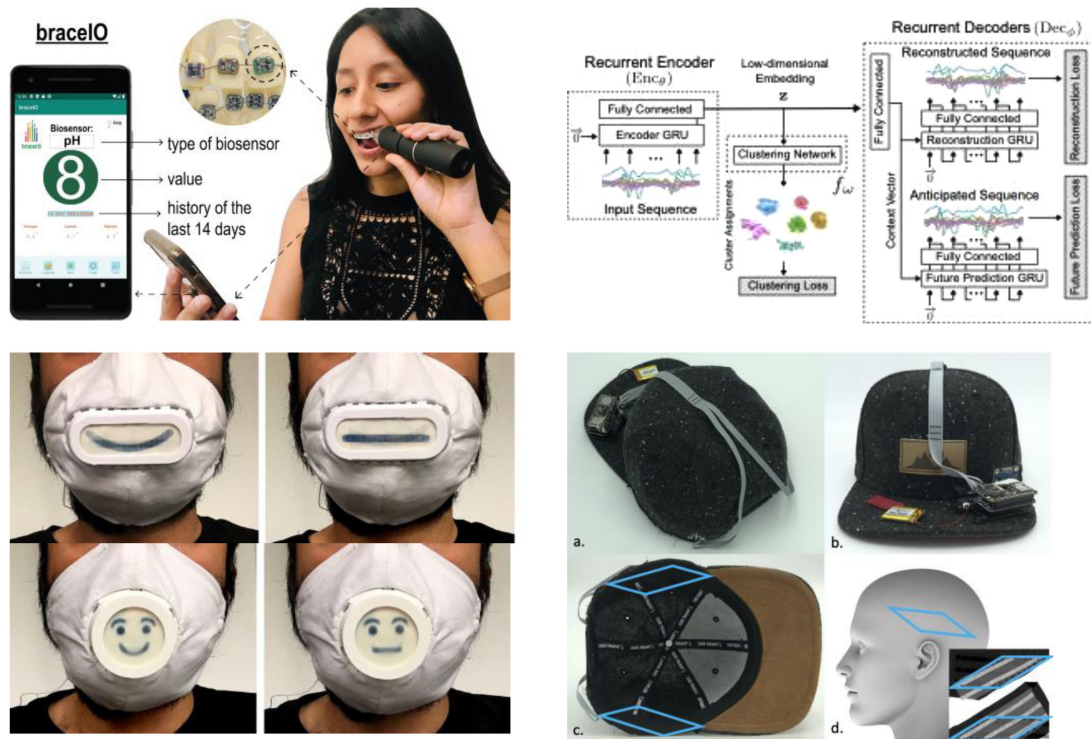
FIGURE 1. Examples of work presented at ISWC 2020. Top left: BraceIO—biosensing in dental ligatures.[1] Top right: Deep Sensory Clustering pipeline for analysis of human activities.[8] Bottom left: Face masks that mitigate occlusion of facial expressions.[10] Bottom right: Snacap apparatus for snacking detection with smart fabrics.[15] All photos used with permission of the authors.

ACTIVITY RECOGNITION

The field of activity recognition using wearable sensing and computing platforms and intelligent sensor data analysis methods has a long standing within the wearable computing research community. Over the years, a broad range of both sensing and analysis methods have been developed, as well as deployed in numerous application domains.

The main focus of most activity recognition papers that were presented at ISWC 2020 was on algorithmic innovation specifically aiming at a better understanding of the specific requirements and constraints in the field, and on new approaches to tackling the notorious lack of annotated training data. Given the prevalence of supervised machine learning techniques for deriving activity recognition systems, researchers have become creative in how to bootstrap even large deep neural network based recognition systems when only small amounts of labeled sample data are available.

Haresamudram *et al.*[6] presented an approach that utilized masked reconstruction based self-supervision to derive recognition systems. The key idea is to make economic use of existing (small) sets of training data and to use unlabeled data, in specifically modified versions, for pretraining feature extractors. Hoelzemann *et al.*[7] analyzed how transfer learning, another method for economic use of existing datasets and pretrained classifiers, can or cannot be used for wearable computing settings. Despite multiple attempts in the field in previous years, transfer learning has still not seen the success as in other fields such as computer vision or natural language processing. This ISWC 2020 paper provides an excellent analysis of transfer learning in the field of human activity recognition using wearables. Furthermore, Abedin *et al.*[8] contributed to the field of human activity recognition with a paper on clustering human activities (captured by wearable inertial measurement units) using a deep learning approach (see Figure 1).

INTERACTION

Traditionally, wearables have been developed and used for novel human computer interaction schemes that allow for, e.g., more intuitive, less burdensome use of computing devices and services. This year's ISWC showcased innovative interaction-related research. You *et al.*[9] presented the
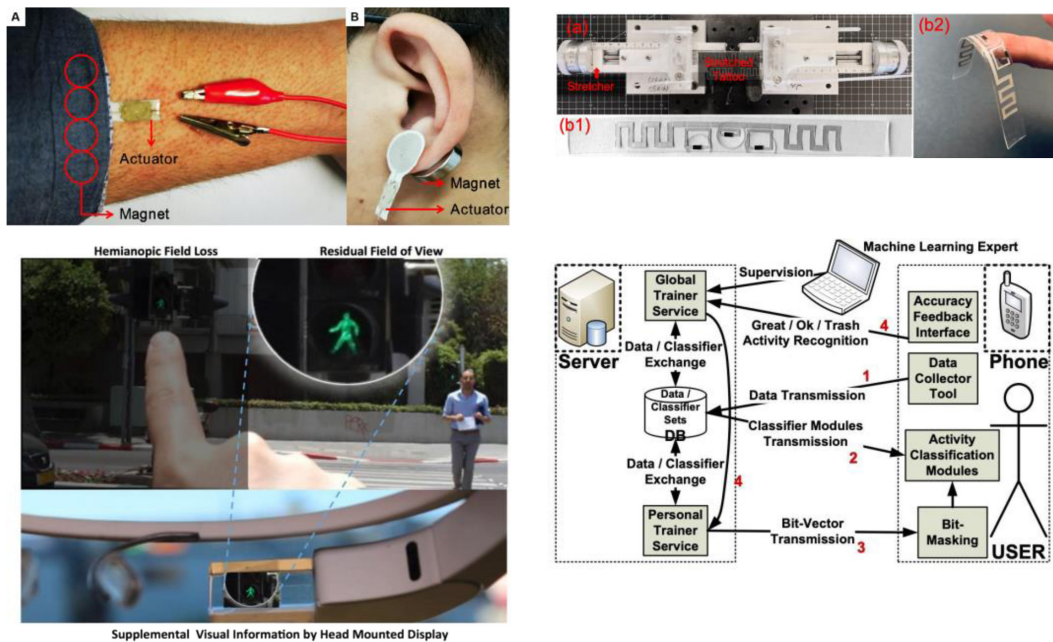
FIGURE 2. Contributions that received awards at ISWC 2020. Top left: FLECTILE applications in the form of vibration sleeves and earring-shaped haptic feedback system.[2] Top right: Rotary system for stretch evaluation of RFTattoo.[22] Bottom left: Supplemental visual information provided by the head-mounted display for hemianopic stroke patients.[18] Bottom right: ActiServ service architecture for activity recognition on mobile phones.[24] All photos used with permission of the authors.

results on an online survey study on social perceptions of color-changing on-skin displays, which outlines the design space for interactions with and through skin-based wearables.

Genç et al.[10] demonstrated how to design face masks with the goal of mitigating the occlusion of facial expression (see Figure 1). This work is of special importance during the ongoing COVID-19 pandemic, where facemasks arguably represent an effective means to limit the spread of the disease and keep people safe. Yet, the absence of facial cues represents a substantial burden for many, which this work seeks to alleviate. Luo et al.[11] presented Eslucent, an eyelid interface that facilitates the recognition of eye blinking, which can be used, for example, as input modality for wearables.

Two papers focused on supporting human-to-human conversations. Tu et al.[12] used head worn displays and their sensing as well as presentation capabilities to detect and communicate conversational greetings, and compared it to smartphone-based interaction. Ogawa and Maes[13] used smartwatches to suggest casual conversations in awkward encounters. Also potentially supportive in conversation scenarios, Frohn et al.[14] have developed and evaluated an in-ear sensor-based system that allows for characterization of emotional intent, so far with focus on scripted scenes.

HEALTH AND ASSISTIVE TECHNOLOGY

Wearable computing has potential to revolutionize health assessments and care. As such, these topics have been in the focus of the community of researchers as well as practitioners ever since computing equipment became small and light enough to be carried around. This year's program featured a number of papers that address how wearable computing technology can be used for the health and assistive technology domains.

Three ISWC 2020 papers focused on the automated analysis of eating behaviors, an area that has seen attention in previous years with a huge range of sensing and analysis solutions being proposed. Zhou and Lukowicz[15] presented Snacap, a wearable system based on smart fabric and smart sensor data analysis that allows monitoring of snacking behavior, a task that is challenging and of substantial importance in many medical applications (see Figure 1). Also targeting the analysis of eating and especially digesting behavior, Baronetto et al.[16] developed GastroDigital-Shirt, a smart shirt for digestion monitoring based on acoustic data captured using smart clothes. Chun et al. measured intraoral temperatures and captured relevant inertial measurements for automated dietary

assessments. They presented promising results of a first feasibility study.[17]

Furthermore, ISWC 2020 papers presented wearable computing systems that assess other health conditions and support patients with conditions such as hemianopic stroke (Amini et al.),[18] fatigue (Bai et al.),[19] or deaf users (Jain et al.).[20] Bian et al.[20] presented a system and first results of an evaluation study for monitoring COVID-19 social distancing based on a wearable magnetic-field-based proximity sensing approach.[21]

AWARDS

Following the tradition from previous conferences, a committee of experts selected best paper awards. Figure 2 showcases the awarded papers.

The competition for the ISWC 2020 best note award resulted in a tie. Hence, the committee presented two awards. Representing the best break-through sensing platform that is expect to support multiple new wearable applications in the future, the first award went to Likun Fang, Tobias Röddiger, Hongye Sun, Norbert Willenbacher, and Michael Beigl for their paper "FLECTILE: 3D-Print-able Soft Actuators for Wearable Computing."[2] Representing the best example of a well-tested population-specific wearable application, the second best note award went to Navid Amini, Jung S. Lim, Farnaz Mohammadi, Clinton Thodos, Benjamin Braun, Hassan Ghasemzadeh, Melissa W. Chun, and Kouros Nouri-Mahdavi for their paper "Design and Evaluation of a Wearable Assistive Technology for Hemianopic Stroke Patients."[18]

ISWC 2020 features short contributions of wearable computing (briefs and notes). Long papers are now published in the *PACM IMWUT* journal. As such, at the conference the Best Long Wearables Paper Award was selected from this year's IMWUT volume. The award went to Wang, Jingxian, Cheng-feng Pan, Haojian Jin, Vaibhav Singh, Yash Jain, Jason I. Hong, Carmel Majidi, and Swarun Kumar for their paper "RFID Tattoo: A Wireless Platform for Speech Recognition."[22]

Thad Starner and Kai Kunze announced the two impact awards this year. The 20 Year Impact Award, for the paper having the most impact from ISWC 2000, was given to Bruce Thomas, Ben Close, John Donoghue, John Squires, Phillip De Bondi, Michael Morris, and Wayne Piekarski for "ARQuake: An Outdoor/Indoor Augmented Reality First Person Application."[23] The ten Year Impact Award was given to Martin Berchtold, Matthias Budde, Dawud Gordon, Hedda R. Schmidtke, and Michael Beigl for "Actiserv: Activity Recognition Service for Mobile Phones."[24] The awards were given out in an entertaining online procedure during the closing of the joint Ubicomp/ISWC conference. Figure 2 highlights the award-winning papers.

CONCLUSION

Wearables research did certainly not stand still in the past year, despite the challenges posed by a global pandemic. Through presentations and panels in video sessions, combined with a space to casually meet each other virtually in Gather.Town, the community could exchange ideas and socialize. The full ISWC 2020 proceedings are available at https://dl.acm.org/doi/proceedings/10.1145/3410531.

News flash: The next ISWC meeting will be the 25th! Join us in October 2021 for an online conference with plenty of special sessions to celebrate the success of wearable computing (www.iswc.net).

REFERENCES

1. E. S. L. Vasquez, E. S. Lazaro Vasquez, A. K. Yetisen, and K. Vega, "BraceIO," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 87–89.
2. L. Fang, T. Röddiger, H. Sun, N. Willenbacher, and M. Beigl, "FLECTILE," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 32–36.
3. T. Röddiger, M. Beigl, and A. Exler, "Design space and usability of earable prototyping," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 73–78.
4. K. Lyons, "Wearable magnetic field sensing for finger tracking," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 63–67.
5. K. Takaki, T. Sasatani, H. Kasashima, Y. Kawahara, and T. Naemura, "Coil design for wireless power transfer and communication over hinges of smart glasses," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 79–83.
6. H. Haresamudram et al., "Masked reconstruction based self-supervision for human activity recognition," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 45–49.
7. A. Hoelzemann and K. Van Laerhoven, "Digging deeper," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 50–54.
8. A. Abedin, F. Motlagh, Q. Shi, H. Rezatofighi, and D. Ranasinghe, "Towards deep clustering of human activities from wearables," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 1–6.

9. C.-W. You, M.-W. Hung, X. Zhang, P.-C. Huang, and H.-L. (Cindy) Kao, "Online survey study on social perceptions towards color-changing on-skin displays," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 90–95.

10. Ç. Genç, A. Colley, M. Löchtefeld, and J. Häkkilä, "Face mask design to mitigate facial expression occlusion," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 40–44.

11. E. Luo, R. Fu, A. Chu, K. Vega, and H.-L. (Cindy) Kao, "Eslucent," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 58–62.

12. J. Tu, G. Lin, and T. Starner, "Conversational greeting detection using captioning on head worn displays versus smartphones," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 84–86.

13. H. Ogawa and P. Maes, "Smartwatch-based topic suggestions to enrich casual conversations in awkward encounters," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 68–72.

14. S. A. L. Frohn, J. S. Matharu, and J. A. Ward, "Towards a characterisation of emotional intent during scripted scenes using in-ear movement sensors," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 37–39.

15. B. Zhou and P. Lukowicz, "Snacap," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 96–100.

16. A. Baronetto, L. S. Graf, S. Fischer, M. F. Neurath, and O. Amft, "GastroDigitalShirt," in *Proc. nt. Symp. Wearable Comput.*, 2020, pp. 17–21.

17. K. S. Chun, S. Bhattacharya, C. Dolbear, J. Kashanchi, and E. Thomaz, "Intraoral temperature and inertial sensing in automated dietary assessment," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 27–31.

18. N. Amini *et al.*, "Design and evaluation of a wearable assistive technology for hemianopic stroke patients," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 7–11.

19. Y. Bai, Y. Guan, and W.-F. Ng, "Fatigue assessment using ECG and actigraphy sensors," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 12–16.

20. D. Jain, B. Chiu, S. Goodman, C. Schmandt, L. Findlater, and J. E. Froehlich, "Field study of a tactile sound awareness device for deaf users," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 55–57.

21. S. Bian, B. Zhou, H. Bello, and P. Lukowicz, "A wearable magnetic field based proximity sensing system for monitoring COVID-19 social distancing," in *Proc. Int. Symp. Wearable Comput.*, 2020, pp. 22–26.

22. J. Wang *et al.*, "RFID Tattoo," *Proc. ACM Interactive, Mobile, Wearable Ubiquitous Technol.*, vol. 3, no. 4, pp. 1–24, 2019.

23. B. Thomas *et al.*, "ARQuake: An outdoor/indoor augmented reality first person application," in *Proc. Dig. Papers. 4th Int. Symp. Wearable Comput.*, 2000, pp. 139–146.

24. M. Berchtold, M. Budde, D. Gordon, H. R. Schmidtke, and M. Beigl, "ActiServ: Activity recognition service for mobile phones," in *Proc. Int. Symp. Wearable Comput.*, 2010, pp. 1–8.

THOMAS PLÖTZ is currently an Associate Professor with the School of Interactive Computing, College of Computing, Georgia Institute of Technology, Atlanta, GA, USA, where he leads the Computational Behavior Analysis Lab. Contact him at thomas.ploetz@gatech.edu.

JENNIFER HEALEY is currently a Senior Research Scientist with Adobe Research, San Jose, CA, USA. Contact her at JeHealey@adobe.com.

KRISTOF VAN LAERHOVEN is currently a Full Professor and head of the Ubiquitous Computing group, University of Siegen, Siegen, Germany. Contact him at kvl@eti.uni-siegen.de.