Editor: Bernt Schiele ■ MPI Informatics ■ schiele@mpi-inf.mpg.de

ISWC 2013—Wearables Are Here to Stay

Daniel Roggen, Daniel Gatica Perez, Masaaki Fukumoto, and Kristof van Laerhoven

The 17th edition of the IEEE International Symposium on Wearable Computers (ISWC) was held in September in Zürich. With 17 years of history, ISWC is the perfect place to get a sense of what has been achieved, where our community stands today, and what lies ahead.

HOT TOPICS

In numbers, ISWC was a tremendous success. We received 101 submissions—the largest number in the last eight years—making for a selective 23 percent acceptance rate for oral presentations. Furthermore, ISWC was colocated with the ACM International Joint Conference on Pervasive and Ubiquitous Computing, which merged the UbiComp and Pervasive conferences. (See this issue's Conferences department for a full report.) More than 700 people registered for UbiComp 2013 and its associated workshops—and, for the first time, the conference sold out after reaching the (very large) venue's capacity limit.

The ISWC technical program covered a rich set of topics with oral and poster presentations. Because there are too many to cover, we emphasize a few highlights along context-awareness, textiles and sensor technologies, eyewear computing, and interaction.

Context Awareness

Topics related to context awareness remain very important in wearable computing.

We noticed an increase in location awareness research on indoor use cases. Daniel Gutierrez, from the University of Zaragoza, presented a vision-based indoor localization method based on optical simultaneous localization and mapping (SLAM) principles. Although the method requires an on-body camera, this year's conference showed that such cameras might not be far-fetched—numerous ISWC attendees were wearing cameras via Google Glass (more on that later).

In activity recognition, Nils Hammerla, from Newcastle University, used six datasets to demonstrate that deriving features from the empirical cumulative distribution of sensor signals led to better performance than using common statistical features. We also saw the technical program move toward personalization and adaptation in activity recognition. Attila Reiss, from the German Research Center for Artificial Intelligence, showed how to personalize activity models with ensemble classifiers whose weights are retrained at runtime.

Julien Rebetez, from the University of Applied Sciences, Western Switzerland, showed a form of active learning where users are queried about their activities only when needed, thereby incrementally building personalized models with reduced user effort.

Group activity recognition is also growing in popularity. Tomoya Hirano, from Osaka University, covered this with his work on hybrid unsupervised-supervised approaches for group activity recognition. Sebastian Feese, from ETH Zurich, also touched on this topic with his research into using mobile phones to assess group dynamics among firefighters.

Textiles and Sensors

This year also saw a renewed interest in sensor modalities. Cheng-Yuan Li, from the National Taiwan University, presented a surprising twist on dietary monitoring by showing an acceleration sensor directly integrated into a tooth (see Figure 1).

Hiroki Watanabe, from Kobe University, replaced the traditional acceleration sensor with a combination of an ultrasound emitter placed on the limbs and a receiver on the neck. By analyzing the Doppler shift, up to nine activities could be recognized. Interestingly, this approach doesn't require complex wireless protocols.

One challenge when integrating electronics into clothing is proper insulation of the wiring. Guido Gioberto, from the University of Minnesota, showed that uninsulated wires might be useful after all: by measuring the change of resistance in stitched conductive fibers, he could measure fabric fold, possibly letting researchers measure physical activity or the angle between body segments (see Figure 2).

Eyewear Computing

This year's call for papers featured a special category on "eyewear computing," motivated by the numerous activities centered on vision and

Published by the IEEE CS ■ 1536-1268/14/$31.00 © 2014 IEEE

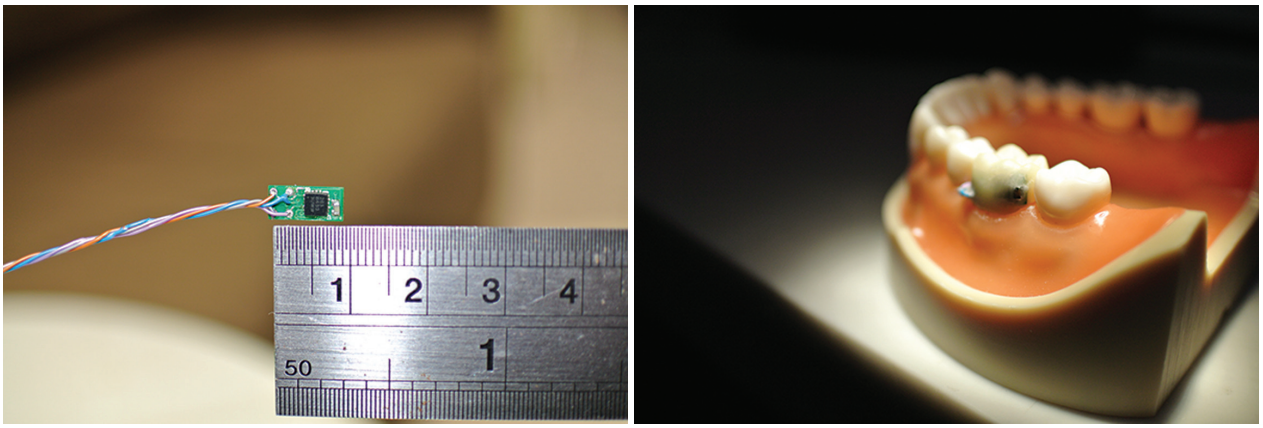


Figure 1. Dietary monitoring: (a) an acceleration sensor (b) integrated into a tooth.

perception in the last few years, partly fueled by rumors of Google Glass.

Teesid Leelasawassuk, from the University of Bristol, presented an approach to estimate the 3D shape of an object being observed. A wearable gaze tracker identifies the gaze direction and projects it into a 3D scene, estimated from a camera with SLAM techniques. Leelasawassuk and his colleagues concluded that, with appropriate gaze filtering, complex tasks such as hands-free object modeling become possible.

Kai Kunze, from Osaka Prefecture University, showed that eye movements can be analyzed to distinguish between five kinds of documents being read, possibly enabling new wearable reading assistants.

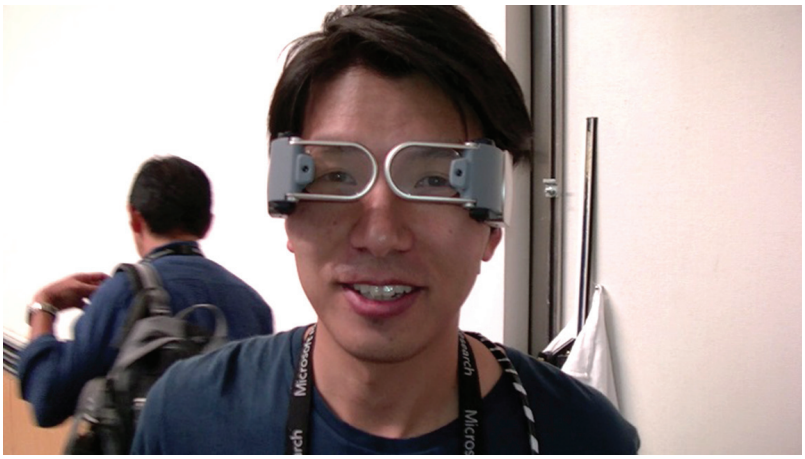
Shinji Kimura, from NTT Docomo, showed an eyeglass-based videoconferencing system. It fuses the images from four to six fish-eye cameras on the front glass frame to reconstruct the user's face and send it to the video-conferencing partner. Thus video-conferencing becomes possible with a wearable-only solution (see Figure 3a).

Figure 2. Using conductive fiber to measure a limb angle through the change of resistivity.

Interaction

An important aspect of wearable computing is outside perception. Halley Profita, from the University of Colorado at Boulder, analyzed the perception that

WEARABLE COMPUTING



(a)

(b)

(c)

Figure 3. Some of the gadgets presented at the gadget show: (a) an eyeglass-based videoconferencing system, (b) a smell-based navigator, and (c) a wearable keyboard built in the 1990s yet still working today.

various textile tactile interfaces generate across cultures, according to the interface's location on the body.

Ye Xu, from Dartmouth College, presented a framework to predict app usage on smartphones. The framework can outperform past approaches by combining user-preference patterns (with context inferred from the phone sensors) and community behavior. The approach uniquely leverages community behavior only from those who share traits similar to those of the user.

Tomoko Yonezawa showed a "wearable partner agent," which can communicate with its user through various forms of touch. With a detailed technical characterization and user evaluation, Yonezawa and his colleagues found that such a haptic interface increases the intelligibility of the agent and makes the agent more familiar to the user.

Best Papers

Five papers were considered for the best paper award. Their selection reflects the broad ISWC community interests, with topics including novel sensors, novel activity and context recognition algorithms, and even new use cases for user-assistance through wearable computing with an interface for occupational dogs.

Attila Reiss, from the German Research Center for Artificial Intelligence, presented a confidence-based boosting classifier to improve activity recognition performance.

Michael Hardegger, from ETH Zurich, showed an indoor localization system based on simultaneous localization and mapping technology that only relies on inertial measurement units at the foot and hip yet reaches submeter localization precision.

Shimon Akiyama, from Keio University, presented a thermal media system to influence the user's emotions while listening to music by changing the temperature of the headphones.

Hiroyuki Manabe, from NTT Docomo and the Tokyo Institute of Technology, presented a systematic

comparison of materials for conductive earphones capable of sensing eye movements by electrooculography, for instance to control a music player.

However, the best paper was awarded to Melody Jackson and her colleagues from Georgia Tech, who presented a wearable interface integrated into the vest of assistance dogs. With training, dogs could reliably activate the interface—using nose gestures, for example. This opens up a new space of assistance that working dogs can provide, such as remotely calling for help when the dog sees the user in distress.

BEYOND THE TECHNICAL PROGRAM

In addition to the technical program, ISWC organizes events such as a gadget show, a design exhibition, and often times an industry track. These are meant to reflect on wearable computing beyond the pure technical aspects covered in the traditional oral and poster presentations.

The Industry Track

Bernard Kress from Google[x] presented an exhaustive review of the state of the art in head-mounted displays (HMDs). He covered in details the various trade-offs in their design and the different approaches (such as mirror-based versus waveguide-based), with many details pertaining to optical challenges, such as the material stability (when plastics are used) and the complexity of the manufacturing process. This exhaustive survey placed Google Glass within the landscape of competing HMD technologies. It also showed that the design of HMDs is far from a solved problem and that there are possibilities for significant innovation depending on the target trade-offs.

Martin Wirz from Sensirion, a manufacturer of highly miniaturized humidity and temperature sensors, explained the challenges that the company faced in entering the mobile phone market. Having a proven technology in another market segment wasn't enough. The main challenges were to enable access to this sensor for application development and convince manufacturers that it added value for users. The solution consisted of upstreaming APIs to the Android code base early, modifying existing devices for prototyping, and presenting a set of compelling use cases. Finally, Samsung included the sensor in its Galaxy S4 (released in 2013). This might be a lesson to learn from, because phones will likely benefit from many additional sensor modalities, as this community often demonstrates.

The Gadget Show

The gadget show is an ISWC tradition, where conference attendees spontaneously come on stage to present their cool gadget. This year, 17 attendees presented their gadgets.

One participant had a Bluetooth chording keyboard connected to his Glass. Many others showcased sensor technologies: a multisensor watch for measuring heart-rate, galvanic skin response, and activity; a gesture recognition watch; a pressure-measuring vest and shoes; an air-pollution sensor for mobile phones; and various activity trackers. With its mix of spontaneity and humor, this was a fun event reflecting the community's ongoing research (see Figure 3).

The Design Exhibition

Another tradition of ISWC is its design exhibition, organized by Lucy Dunne from University of Minnesota, which promotes public acceptance of wearables by making them fashionable. This year, 14 designs in the categories "functional" or "aesthetic" were presented. The winner in the Aesthetic category was Lüme by Elizabeth Bigger and Luis Fraguada (from Jorge & Esther, built by Associative Data). Lüme is a clothing collection with built-in customizable luminescent elements (see Figure 4a).

In the functional category, the Haptic Mirror Therapy Glove from James Hallam at Georgia Tech was selected. It shows a proof-of-concept to augment the therapy of paretic limb following a stroke by linking the affected and unaffected hand with sensors and actuators (see Figure 4b).

GLASS AND WEARABLES

Although eyewear computers have always been present and ISWC, this is the year they finally became widespread. We saw a good proportion of participants wearing Glass, Google's eyewear computer with a head-mounted display, movement sensors, front-facing camera, microphone, and bone-conducting transducer.

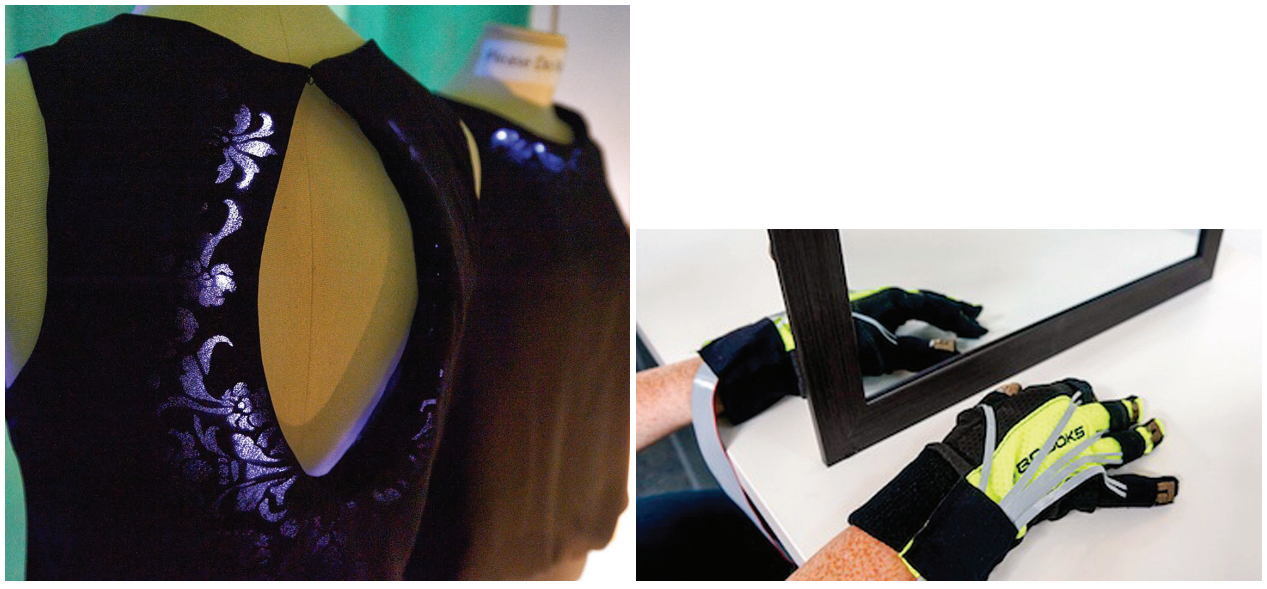
Thad Starner, from Georgia Tech and Technical Lead on Google's project Glass, gave the closing keynote in front of a packed ISWC/Ubicomp audience (see Figure 5). The keynote covered almost two decades of research with wearable computers—eyewear computers in particular.

Starner started by showing a famous CBS interview in 1997, where he demonstrated a real-time search of baseball statistics with a networked eyewear computer in front of an impressed journalist. Then, he put his ISWC and UbiComp audience to the test by asking how long it takes to know what time it is. Smartphone users were at a clear disadvantage, but they helped him make his point: time was only one single microinteraction away in Glass, triggered by simple head tilt.

Starner then emphasized the unique characteristics of wearables and detailed the design considerations leading to the realization of Glass in its current form. Key to the design was ensuring that microinteractions for accessing any function lasted only two to four seconds. He emphasized that wearables aren't about replacing reality but about seamlessly augmenting it, and that technology should stay out of the way when not needed, much like Glass turns off as soon as a microinteraction ends.

This summary covers a small part of this year's ISWC. Equally interesting were the posters and

WEARABLE COMPUTING



(a) (b)

Figure 4. The winners of the design exhibition: (a) Lüme and (b) the Haptic Mirror Therapy Glove.

Figure 5. Thad Starner's closing keynote discussing Glass.

demonstrations (see dl.acm.org/citation.cfm?id=2493988 for the full set of papers and posters). The program, our best reviewers, and best paper nominees and winner are published at www.iswc.net/iswc13.

In short, wearables are here to stay, as illustrated by Glass, bringing 20 years of academic research into a sleek industrial prototype, and a large number of other wearables that many audience members sported as part of the quantified-self movement. The technical program, demonstrations, gadget show, and design exhibition showed that there's a rich space for exploring new wearable devices. See www.iswc.net for information on next year's ISWC, which will again be colocated with Ubicomp and held in Seattle.

Daniel Roggen is a principal research associate at Culture Lab, Newcastle University, UK. Contact him at daniel.roggen@ieee.org.

Daniel Gatica-Perez is head of the Social Computing Group at Idiap Research Institute and Maître d'Enseignement et de Recherche at EPFL, Switzerland. Contact him at gatica@idiap.ch.

Masaaki Fukumoto is a lead researcher at Microsoft Research. Contact him at fukumoto@acm.org.

Kristof van Laerhoven is group leader of the Embedded Sensing Systems at TU Darmstadt. Contact him at kristof@ess.tu-darmstadt.de.