UbiComp 2014

Alexis Hiniker, *University of Washington*
Seungchul Lee, *KAIST*
Mateusz Mikusz, *Lancaster University*

This year, the ACM International Joint Conference on Pervasive and Ubiquitous Computing was held in Seattle, Washington. It marked the second convening of the community since the merger of the Pervasive and UbiComp conferences in 2012. UbiComp 2014 set new records in participation with over 850 registrations, 71 full papers and 23 notes. For the first time, it was held as a triple-track conference.

This was also the first time that the conference supported remote participation using BEAM (Biology, Electronics, Aesthetics, Mechanics) robots. Remote participants operated the remote-controlled robots with built-in video-conferencing and used their personal robot as a vehicle to move about the conference venue during sessions, breaks, and demos. Although the integration of these Beam robots by Suitable Technologies is in the exploratory stage and came with the occasional collision, technical glitch, or inappropriate volume level, the experiment was largely successful and enabled many to attend who otherwise couldn't have participated. The robots also contributed to a bleeding-edge technical atmosphere and provided a source of entertainment for in-person attendees.

The UbiComp community awarded three 10-Year Impact Awards—one to Emanuel Tapia, Stephen S. Intille, and Kent Larson for their research paper, "Activity Recognition in the Home Using Simple and Ubiquitous Sensors," and another to Ling Bao and Stephen S. Intille for "Activity Recognition from User-Annotated Acceleration Data." Jeffrey Hightower and Gaetano Borriello received the third award for their work, "Particle Filters for Location Estimation in Ubiquitous Computing: A Case Study."

KEYNOTE: WEARABLES IN SPACE

Amy Ross of the NASA-Johnson Space Center opened the formal conference proceedings with a high-energy keynote describing the Z2 and Z3, the next two generations of NASA space suits. Although her design space technically qualifies as wearable computing, her astronaut users and Martian field site come with game-changing challenges not pertinent in typical e-textiles. She described the suits as "mini-spaceships," which must provide life support in merciless conditions. Design constraints range from enabling joint mobility in a sealed armor shell to shielding the wearer from meteorite debris.

In addition to describing challenges and incremental steps toward solutions, Ross discussed points of overlap with the ubicomp community and the ways in which researchers might improve the options available to suit designers. To date, embedding sensors that can detect injury and provide feedback about ease-of-use has been only partially successful. Sensing techniques that can withstand the rigors of space, require little physical space, not impede comfort, and provide detailed information about user experience would enable Ross and colleagues to perform more sophisticated monitoring. Today she relies almost entirely on verbal feedback from her users. Ross sparked imaginations as she described the many ways in which this research community might extend the pervasiveness and ubiquity of digital tools beyond our home planet.

UBICOMP AND WEARABLE COMPUTING SESSIONS

Here, we describe highlights from select talk sessions throughout the conference. We touch on only a subset of the many papers presented. The full program can be found at the UbiComp 2014 website (http://ubicomp.org/ubicomp2014), or see the conference proceedings (http://dl.acm.org/citation.cfm?id=2632048).

Activity and Group Interactions

This opening session focused on detecting, recognizing, and analyzing activity and group interactions using mobile devices. This was the first session to combine papers from both UbiComp and the International Symposium on Wearable Computers (ISWC), a new endeavor at this year's conference.

Rui Wang from Dartmouth College presented his work, "StudentLife: Assessing Mental Health, Academic Performance and Behavioral Trends of College Students using Smartphones." The authors developed a smartphone application that collects sensor data

Published by the IEEE CS ■ 1536-1268/15/$31.00 © 2015 IEEE

continuously and reports on the user's mental health. Analysis of results showed a number of significant correlations between behaviors as measured by sensor data, mental health, and academic performance. For example, students who engage in more conversations during the day and have less mobility around campus are more likely to have higher GPAs.

"High5: Promoting Interpersonal Hand-to-Hand Touch for Vibrant Workplace with Electrodermal Sensor Watches," by Yuhwan Kim from KAIST, was well-received by the session audience. Kim discussed the positive implications of interpersonal touch such as vitality and immediacy and the lack of touch-based interactions in today's workplaces. He suggested high-fives as a new medium to boost interaction and inspire a more vibrant workplace culture. The study explored promotion of high-fives via scenario-based user studies, with interactions tracked by electric-skin-potential levels. Audience members enjoyed high-fiving one another after the presentation.

Mobile Performance

This session included work on power management in mobile devices, a topic of interest to the research community that also has notable practical relevance for mobile phone users outside of the research sector. Grace Metri from Wayne State University introduced "Battery Extender: An Adaptive User-Guided Tool for Power Management of Mobile Devices," a best-paper nominee, which described a new power-saving tool for mobile phones. By analyzing the phone usage from different software and hardware layers of the phone, the tool extends battery life on demand by disabling unused components (such as Bluetooth, Wi-Fi, HID sensors, a camera, and so on). The research team found that this technique results in power savings of up to 20 percent depending on platform and device.

Using idle phone time more intelligently, a new system described by Maria C. Amarie in the paper, "Mobile Video Ad Caching on Smartphones" predicts whether advertisement-caching is necessary based on the length of the video advertisement. (Amarie and colleagues found that short advertisements are more likely to be shown than long ones.) This technique led to bandwidth savings of up to 50 percent.

In the Home

During this session, Clara Mancini presented "UbiComp for Animal Welfare: Envisioning Smart Environments for Kenneled Dogs." She and her colleagues explored the ways in which ubiquitous computing might improve quality of life for animals and in particular investigated design opportunities in rehoming scenarios for kenneled dogs. They conducted an ethnographic exploration to understand dogs' experience in a rehoming center, documented the consistent ways in which the quality of life for the dogs falls short of targets, and mapped these to potential design solutions. Their proposals included sensors and learning algorithms to understand play behaviors and smart partitions between kennels to support successful companionships between dogs.

In the same session, Blase Ur presented "Intruders Versus Intrusiveness: Teens' and Parents' Perspectives on Home-Entryway Surveillance" (a best-paper award winner). In this investigation, the research team conducted both an interview study and a deployment study to explore families' experiences with Internet-connected image-capture security systems in homes with at least one teenager. As teenager-parent relationships add complexity to family dynamics, the research team hypothesized that this would influence responses to rich surveillance systems. They found that teenagers' preferences varied systematically from parents' preferences (for example, teenagers preferred systems that don't take photographs when an individual enters the home) and that Internet-connected security systems in their current form pose threats to parent-child trust. Ur described several potential design solutions and pushed the community to consider the ways in which computing can be ubiquitous without leaving users feeling exposed.

Contextual Awareness on Mobile Devices

In this ISWC session, Mingming Fan from the University of North Carolina, Charlotte presented "Public Restroom Detection on Mobile Phone via Active Probing." Recognizing sensitive places is an important issue for applications with automatic image capture that use pervasive wearable cameras. To enable recognition, Fan relied on commonality in spaces' acoustic traits, such as the similar functionalities, structures, and materials that contribute to the acoustic character of public restrooms. He developed an impulse response-based technique, which achieved classification of public restrooms with 92 to 98 percent accuracy. The entertaining demo video was a hit with audience members.

In the same session, Jon C. Hammer from the University of Arkansas introduced his work, "Exploiting Usage Statistics for Energy-efficient Logical Status Inference on Mobile Phones." Currently, the research community has significant interest in the development of mobile technology to recognize users' logical status, such as physical activities and mobility patterns. One obstacle is the energy consumption, given that these applications continuously run the smartphone's hardware sensor devices, such as motion sensors. To overcome the issue, the authors proposed a novel idea of energy efficient inference based on usage statistics from the user's smartphone, such as application usage and screen states. Eventually, the system can infer four logical statuses—busy, social, happy, and stressful—at 87 percent accuracy with negligible battery consumption.

Indoor Location and Sensing

Indoor location was a highly attended session. Many ubicomp systems require

CONFERENCES

users to carry a portable device for location detection. Anindya Paul presented with MobileRF, an alternative system that doesn't require a device to accompany the user. Using wall-mounted access points and signal strength from radio frequencies in combination with a hidden Markov model classifier, the algorithm can determine indoor movement patterns in regions of 3 square meters. This system is particularly interesting for monitoring elderly patients who can't easily carry tracking devices. Separately, Sebastian Hilsenbeck presented "Graph-based Data Fusion for Indoor Positioning," an approach to improve the accuracy of Wi-Fi-based localization by incorporating data from pedestrian tracking systems. This approach can identify location within 0.5 meters 60 percent of the time.

In addition to people localization, this session covered object localization, a topic central to smart room applications. To reduce the maintenance costs of tracking devices, Yi Zhao from the University of Washington presented "Battery-free Object Localization and Motion Sensing Platform." The research team combined an RFID tag with acoustic sensors and an accelerometer to create a low-cost device that can be detected with a small number of receivers. Using this data, the system was able to detect the object's 3D location and its motion state.

Relatedly, Tobias Grosse-Puppendahl presented "Capacitive Near-Field Communication for Ubiquitous and Perception," a best-paper nominee on communication and interaction with "everyday objects" through a combination of capacitive touch and proximity sensors. The team's tool, CapNFC, supports different kinds of interaction: simple touch input, measuring the proximity of the human to the reception device or the connections to the common ground through the body. Example applications are tangible interaction for the visually impaired (using real-world objects as application launchers) or for the health sector (analyzing a user's sleeping behavior using electrodes in the bed).

Wearable Input and Output

Himanshu Sahnind and colleagues from Georgia Tech investigated detecting silence and pauses during speech. Sahnind presented a "Tongue Magnet Interface," a magnet glued to the user's tongue, which works in conjunction with a Google Glass receiver to detect separations between phrases. The team intends to further this work to fully decode human speech. One long-term application is to support verbal communication in individuals with hearing impairments. This work was nominated for a best-paper award.

Health and Children

This session presented novel techniques for improving wellness in a variety of contexts, with four of the five contributions targeting children. Lillian de Greef presented "BiliCam: Using Mobile Phones to Monitor Newborn Jaundice," a best-paper award nominee. Her team created a screening test for newborn jaundice that requires only a camera phone and a low-tech cardboard color-calibration card. Test results rivaled those of state-of-the-art instruments currently only available in hospitals and promise to improve jaundice screening in infants from a variety of backgrounds. Separately, Azusa Kadomura presented a digital fork and its companion app, along with results demonstrating improved mealtime behaviors among child users. Kadomura's team left open the question of how to transition children away from the app after achieving these behavioral gains.

Other contributions included an automated system for classifying individuals as children or adults based on input from 3D depth cameras, and wearable sensors as a tool for understanding interpersonal engagement and social ease in young children. This session demonstrated the diverse ways in which the UbiComp community is advancing healthy living in even the youngest technology users.

Sensing in the Home

In this session, Mathias Sundholm from the German Research Center for Artificial Intelligence presented "Smart-Mat: Recognizing and Counting Gym Exercises with Low-cost Resistive Pressure Sensing Matrix." Exercise tracking is a popular topic, so Sundholm and his colleagues investigated mechanisms for tracking gym exercises without relying on potentially annoying wearable sensors. To this end, they developed a resistive pressure mat to recognize and count exercises. This smart mat can distinguish 10 standard exercises with 82.5 percent accuracy, and it can count exercises with 89.9% accuracy. Audience members recommended future possibilities for this new sensing modality such as posture correction.

Chen Zhao from the University of Washington gave the last talk of this session, "Powering Wireless Sensor Nodes with Ambient Temperature Changes." He and his colleagues developed an energy-harvesting sensor node that harnesses ambient temperature fluctuations. The proposed sensor node harvests energy using linear motion harvesters, actuated by expansion and contraction of temperature-sensitive gases inside the bellow tube. Zhao showed that the sensor can harvest up to 21mJ of energy per cycle of temperature variations in the range of 5°C to 25°C. He further demonstrated 0.25°C of room temperature change is enough to transmit temperature data wirelessly and update an E-ink display.

Human Behavior

Mobile phones are powerful sensing devices that can be used to track comprehensive, personally identifiable information. In "Money Walks: A Human-Centric Study on the Economics of Personal Mobile Data," Bruno Lepri from Fondazione Bruno Kessler investigated perceptions about

sharing this information. In different study phases, participants were offered vouchers in exchange for personal information. Participants considered location to be the most sensitive and valuable piece of information. Lepri and his colleagues received a best-paper award for this work.

To investigate how personal information is used when connecting with others, Nicholas D. Lane from Microsoft Research and his colleagues automated detection of "networked community behavior." They developed a framework to improve accuracy when detecting an activity and contextual details, such as sleep, mode of transportation, mood, and diet. This led to a higher robustness in activity recognition for individuals.

Security

Although mobile and contactless payments have just recently been introduced to the public, Stefan Saroiu and his colleagues from Microsoft Research presented work to improve the status quo with their system for "Zero-Effort Payments." The system combines Bluetooth low energy and face recognition for reliable identification when accepting payments, with no effort from customers (although human assistance from the cashier is necessary as final confirmation of the payment). A short-term deployment in a controlled environment showed that this system can be used on a small scale.

Interruptibility and Notifications

This four-paper session on interruptibility and notifications presented a new theme for UbiComp. Veljko Pejovic and Mirco Musolesi earned a best-paper award nomination for their work, "InterruptMe: Designing Intelligent Prompting Mechanisms for Pervasive Applications." Using smartphone logs and real-time user-feedback about emotions and activity, the authors constructed an intelligent system for making context-dependent predictions about which interruptions will be valuable for a user and which are likely to offer low utility.

In the same vein, Hillol Sarker and his colleagues demonstrated the effectiveness of a machine-learning algorithm, combined with wireless sensors, to accurately predict an individual's availability. Other papers in the session investigated location-based services as a trigger for the delivery of notifications and the use of contextual information to predict the likelihood of a user answering an incoming phone call. Taken together, these investigations indicate a growing interest in modeling user availability and responsiveness. Whether such models will be used to exploit or respect expected pockets of availability remains to be seen.

DEMOS AND POSTERS

On the evening of the first day, a Demos & Posters session was held with 27 demos and over 70 posters. Hundreds of attendees participated in the session, talking to presenters in person, asking questions about their research, and experiencing demo devices.

One interesting demo was "Smarter Eyewear—Using Commercial EOG Glasses for Activity Recognition," presented by Shoya Ishimaru from Osaka Prefecture University. He showed that electrooculography (EOG) glasses with an accelerometer could detect eye blinking and classify four activities: typing, eating, reading, and talking.

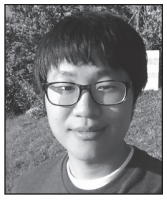
Sang-Ho Yoon from Purdue University demonstrated "Plex: Finger-Worn Textile Sensor for Mobile Interaction during Activities." Plex is a wearable sensor for a finger, which can detect finger bending and pressing. He showed that Plex could be used as an unobtrusive input for many applications in daily lives, such as a music controller and a private operator for an eyewear device.

One noteworthy poster was "SPELL: Affecting Thermal Comfort through Perceptive Techniques," presented by Annamaria Andrea Vitali from Politecnico di Milano. She and her colleagues explored dependability of individuals' reported thermal comfort. They found that actual temperature isn't directly associated with the perceived temperature and, separately, that the color of the light influences perception of temperature.

This year's UbiComp conference once again represented a wide variety of technologies, methodologies, user scenarios, and institutions. From wearable computing in outer space to smart mats for gyms, contributors pushed the boundaries on what's possible and continued to extend the reach of technology to be ever-more pervasive and ubiquitous. We congratulate contributors and organizers on a successful conference and look forward to UbiComp Osaka in 2015 (http://ubicomp.org/ubicomp2015).

Alexis Hiniker is a PhD candidate in human-centered design and engineering at the University of Washington. Contact her at alexisr@uw.edu.

Seungchul Lee is a PhD student in computer science at KAIST. Contact him at seungchul@nclab.kaist.ac.kr.



Mateusz Mikusz is a PhD student in computer science at Lancaster University. Contact him at m.mikusz@lancaster.ac.uk.