Wearable Computing

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International Symposium on Wearable Computing (ISWC) 2008

Cliff Randell, Roy Want, Kent Lyons, and Asim Smailagic

The 12th International Symposium on Wearable Computing was held in September 2008 in Pittsburgh. As one of the longest-running pervasive computing conferences, it has matured into a forum that addresses a broad range of topics in depth. Dan Siewiorek and Asim Smailagic chaired this year's conference, along with the help of technical program cochairs Cliff Randell and Roy Want.

THE PAPERS

We received more than 60 submissions, mainly focusing on human interfaces, applications, and sensors. The submission pool included 31 long and 17 short papers as well as 13 posters, and we accepted eight, seven, and nine of them, respectively. This represents a 26 percent acceptance rate for long papers.

The papers selected by the program committee reflect the wide range of research topics and were presented in five sessions.

Location Mapping

Research has addressed the challenge of determining a wearable-computer user's location in many different ways. This year we had three papers using various technologies, which also supported the simultaneous creation of maps. The first paper, by Burcu Cinaz and Holger Kenn, described adapting SLAM (simultaneous location and mapping), a technique originally developed for robots, to wearables using head-mounted inertial and laser sensors. The authors introduced techniques to overcome the inaccuracies generated by body-worn sensors and head movement.

GPS continues to provide fertile ground for research in this area, with Kihwan Kim, Jay Summet, Thad Starner, Daniel Ashbrook, Mrunal Kapade, and Irfan Essa using signal-to-noise ratios to identify where buildings obstruct line-of-sight signals from orbiting satellites. With this technique, they were able to generate density maps with errors of roughly 14 to 22 percent.

Mobile phones have become the most successful wearable computer to date, and many of the submissions explored the possibilities these devices afford.

Robert Castle, Georg Klein, and David W. Murray won the Best Paper Award for their research on generating multiple maps using wearable video cameras. Their wearable computer was able to correctly identify and augment previously generated maps. They demonstrated that using numerous small, overlapping maps was more effective for real-time operation than using a single large map.

Mobile Phones and Human Interfaces

Mobile phones have become the most successful wearable computer to date, and many of the submissions explored the possibilities these devices afford. Sasank Reddy, Jeff Burke, Deborah Estrin, Mark Hansen, and Mani Srivastava used a GPS and accelerometer-equipped mobile phone placed at different locations on the body. They set out to determine transportation mode using a classifier employing a decision tree and a hidden Markov model. They achieved greater than 98 percent accuracy over five activities: remaining stationary, walking, running, biking, and motorized travel.

Katayoun Farrahi and Daniel Gatica-Perez had a different approach to identifying routine behavior—they used topic models generated from RF fingerprints on mobile phones. They successfully discovered daily routines and made correlations between individuals with similar schedules. Andreas Zinnen and Bernt Schiele reported on using inertial sensors integrated with a 3D magne-

Published by the IEEE CS ■ 1536-1268/09/$25.00 © 2009 IEEE

tometer to extract a limited range of gestures from a continuous data stream. They used the characteristics of turning points to reduce the amount of data and hence facilitate classification.

Haptics are of particular interest to wearable-computer users, and Kevin Huang, Ellen Yi-Luen Do, and Thad Starner presented their PianoTouch system for supporting passive learning of piano skills. Using a glove fitted with vibration motors, they showed that novice participants were able to improve their playing by reinforcing the finger's ordering, patterns, and rhythm.

Activity Recognition

The key to success with many wearable applications is accurate activity recognition. In this session, we had two of the nominations for the Best Paper Award. The first, from Gerald Pirkl, Karl Stockinger, Kai Kunze, and Paul Lukowicz, describes the ability to achieve 100 percent accurate recognition of Tai Chi moves using a combination of wearable modulated magnetic-field technology with accelerometers. They described how to construct body-worn sender and receiver units and how their design performed better than a gyro/accelerometer combination.

The other nominated paper in this section, by Georg Ogris, Thomas Stiefmeier, Paul Lukowicz, and Gerhard Troster, used motion, force, and position sensors in conjunction with a multistage processing algorithm. Their approach used recognition stages for each activity class followed by a reasoning stage. They showed that this approach provided the flexibility to enable additional sensors and activities to be easily added.

The third paper was by Kristof Van Laerhoven, David Kilian, and Bernt Schiele, who carried out a month-long study using wrist-worn motion, light, and temperature sensors to determine daily activities. They found that they could then use behavioral rhythms to improve activity recognition.

Figure 1. Panel discussion on future challenges for wearable computing. From right to left, Thad Starner, Bruce Thomas, Michael Lawo, Steve Feiner, Roy Want, and Mark Smith presented position statements.

Activity Support

In this session, three papers explored approaches to activity recognition. Kristof Van Laerhoven, Marko Borazio, David Kilian, and Bernt Schiele carried out studies to detect different sleep postures, again using wrist-worn sensors. Tilt switches provided coarse measurements of posture with a minimal power overhead. The researchers found that combining these switches with a light sensor in a single wrist-worn sensor provided an energy-efficient tool for accurately estimating sleep postures.

Another specialist application was explored by Brian French, Divya Tyamagundlu, Daniel P. Siewiorek, Asim Smailagic, and Dan Ding, who used accelerometers mounted in a wheelchair to help users avoid damaging forms of locomotion. Their Virtual Coach used common machine-learning algorithms to classify data and provide feedback to the user with 80 to 90 percent accuracy.

Maja Stikic, Kristof Van Laerhoven, and Bernt Schiele addressed the challenge of gathering labeled training data with two approaches designed to reduce this onerous task. The first employed semi-supervised learning with self-training and cotraining, and the second was inspired by active learning. The researchers found both methods were effective, and they could obtain higher accuracies with them than with fully supervised approaches.

Power and System integration

The final session addressed the ever-present problem of minimizing and distributing power in wearables. The PowerPack system by Travis Deyle and Matthew Reynolds was the final nomination for the Best Paper Award. The authors described a backpack-based system with wireless power distribution using a 125 kHz resonant inductive coupling system capable of providing a 10 kbps bidirectional data channel. Their experiments resulted in successful power transfers of up to 200 mW with a power transfer efficiency of 80 percent.

The final paper, presented by Yuvraj Agarwal, Trevor Pering, Roy Want, and Rajesh Gupta, described a general switching architecture. Their work, called SwitchR, reduced power consumption by considering interactions between multiple RF clients. Their design operated well even with multiple clients communicating simultaneously and achieved significant energy savings over other commonly used power-saving techniques.

A PANEL ON FUTURE CHALLENGES

Dan Siewiorek and Asim Smailagic chaired a panel discussion (see Figure 1) on "Future Challenges in Wearable Computing." Thad Starner of Georgia Tech, Bruce Thomas of the University of S. Australia, Michael Lawo of the

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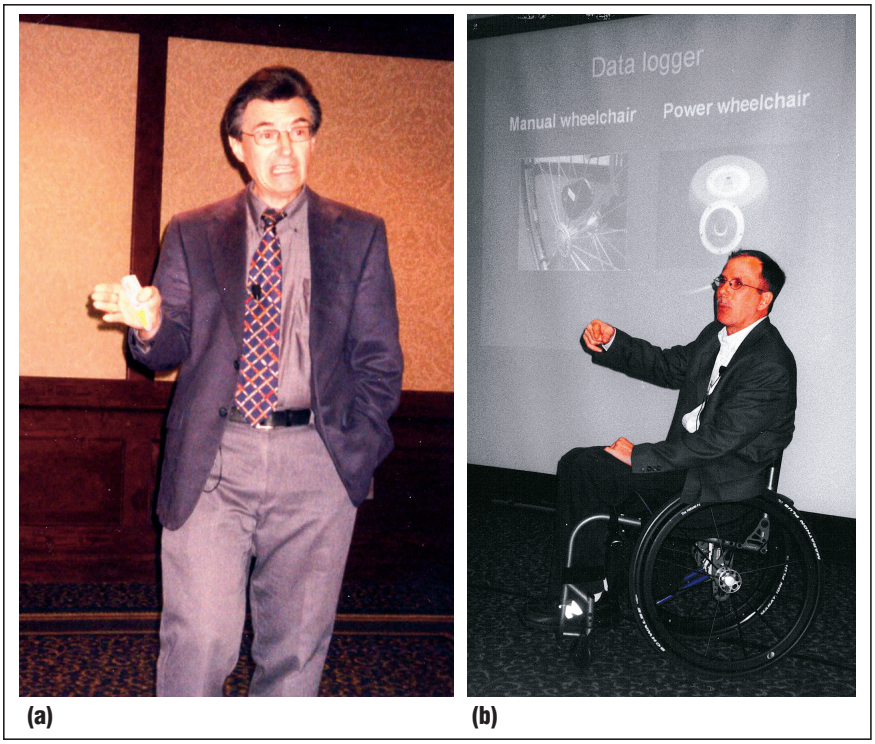

Figure 2. Keynote talks. (a) Marcel Just spoke about brain imaging in high-level cognitive tasks, and (b) Rory Cooper spoke about lessons learned from assistive and rehabilitative technology to improve the usefulness of wearable computing systems.

Figure 3. Invited talk by Raj Reddy titled "Missing Science in Wearable Computer Interfaces: Implications of Computational Limits of Human Thinking."

University of Brenan, Steve Feiner of Columbia University, Roy Want of Intel Research, and Mark Smith of Sweden's Royal Institute of Technology (KTH), all long-time veterans of the wearable computing field, presented position statements. Each described an evolution of wearable computing from his own perspective, ranging from head-mounted displays to the integration of wearable computing with cell or smart phone technologies.

DESIGN COMPETITION AND COMPANY VISIT

Ryoko Ueoka (University of Tokyo) won an award for the Wearable Forest project at the juried design competition.

Because the conference took place in Pittsburgh, we took advantage of the proximity of one of the commercial success stories of wearable computing, Bodymedia, whose headquarters were only a short walk away. The company kindly agreed to provide a tour of its facility, showed us its design processes, and provided a historical view of its products since Bodymedia's inception.

KEYNOTES

The keynotes (see Figure 2) framed the conference. The first, by Marcel Just of Carnegie Mellon University, was titled "Brain Imaging in High-Level Cognitive Tasks." Just's presentation described how researchers can use brain imaging via functional magnetic resonance imaging to study high-level cognitive tasks and investigate the neuroarchitecture that the brain uses to achieve them. In particular, his work considers language comprehension, spatial thinking, problem solving, and dual-task performance. This work resulted in a set of models that link cognitive function and brain activation and thus enable the prediction of brain activity resulting from external sensory stimuli, even without prior experience of that particular input. The presentation also reported on results when these techniques were used to study autism. The study found that one of this disorder's traits is that parts of the brain lack the coordination that would be present in people without the condition.

Raj Reddy presented an additional talk following the keynote on the first day, titled "Missing Science in Wearable Computer Interfaces: Implications of Computational Limits of Human Thinking." The talk focused on "SILKy" (speech, image, language, and knowledge) interfaces; forgiving interfaces (tolerating error and ambiguity in interactions); self-improving interfaces (incremental, nonintrusive knowledge acquisition and learning from examples and observations); intelligent help, advice, and tutoring (learning from examples and observations); and intelligent agents. These interfaces must possess several implied capabilities, such as behaving as a society of agents with specialized functions, and sharing knowledge with a community of coaches (Gnutell-like peer-to-peer networking, communicating with other

agents and human users, employing persistent knowledge bases, and having real-time responsive and mixed-initiative dialog).

Rory Cooper of the University of Pittsburgh gave the second keynote, titled "Lessons Learned from Assistive and Rehabilitative Technology to Improve the Utility of Wearable Computing Systems." Cooper, an engineer and the FISA (Federation of Independent School Alumnae) and Paralyzed Veterans of America Chair of the Department of Rehabilitation Science and Technology at the University of Pittsburgh, who is disabled himself, presented from a wheelchair. He described the issues that surround designing technology to support people with disabilities, including the elderly—technologies that can substantially increase their functional capabilities, independence, and quality of life. In particular, he covered issues such as the acceptance of assistive and rehabilitative technology and how it relates to needs, reliability, and usability. A key element for this technology's success is the design team, which should involve end users, clinicians, and engineers working closely together. Cooper presented factors that lead to greater success in this process and the common barriers that interfere with meeting the needs of people that must deal with disabilities on a daily basis.

If you're interested in following up on any of the papers mentioned in this article, a full set of papers and posters will be available from the IEEE Xplore digital library (http://ieeexplore.ieee.org). Next year's conference organization will be led by general chair Alois Ferscha (University of Linz) and program cochairs Paul Lukowicz (University Passau, Germany) and Kent Lyons (Intel Research). We encourage you to participate in ISWC 09 in Linz, Austria, in September. Details will be available at www.iswc.net.

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