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2007's Wearable Computing Advances

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This year, the 11th International Symposium on Wearable Computers returned to the city where it began: Boston, Massachusetts. ISWC is the premier conference in wearable computing, reporting the latest advances in research and technology. As in previous years, attendees came both from academia and industry, representing a broad spectrum of nationalities and technical interests. This year's program emphasized gesture and activity recognition but also reported on power considerations, augmented reality, evaluation, and new interaction modalities, among other topics.

GESTURE RECOGNITION

The first paper on gesture recognition, by Travis Deyle, Szabolcs Palinko, Erika Shehan Poole, and Thad Starner, was one of three nominees for the Best Paper Award. Their Hambone device uses two small piezoelectric sensors placed on the wrist or ankle (see figure 1). When a user moves his or her hands or feet, the sounds generated by the movement travel to Hambone via bone conduction. The system uses hidden Markov models to recognize the signals, which are mapped to a set of commands controlling an application. The paper presents the hardware and software implementation of Hambone, a preliminary evaluation, and a discussion of future opportunities in bioacoustic gesture-based interfaces.

Jungsoo Kim, Jiasheng He, Kent Lyons, and Thad Starner introduced the Gesture Watch, a mobile wireless device worn on a user's wrist that enables hand-gesture control of other devices. The device uses an array of infrared proximity sensors to sense hand gestures made over the device and interprets the gestures using hidden Markov models.

Figure 1. Hambone gesture recognition prototype: sound is generated by hand movements that travel to the device via bone conduction.

The Gesture Watch controls signals such as the play and pause commands commonly found on mobile media players. The authors' evaluation of the device reports high recognition accuracies and shows its usability while mobile and in indoor and outdoor environments.

Doo Young Kwon and Markus Gross presented a framework for 3D spatial gesture recognition combining visual and body sensors. In an experiment with limited training data (18 sample gestures), they compared the performance of two recognition methods, hidden Markov models and dynamic time warping, and analyzed different combinations of visual- and body-sensor features.

The last gesture recognition paper, by Georg Ogris, Matthias Kreil, and Paul Lukowicz, investigated the usefulness of muscle-monitoring information from arm-mounted force-sensitive resistors. They systematically investigated an FSR system's performance for 16 different manipulative gestures and two subjects and commented on the potential to combine FSR with other sensing modalities. The authors also presented a hardware setup that addresses key problems in previous work—namely, large variations in the attachment force and accuracy issues in sensor placement.

ACTIVITY AND POSTURE RECOGNITION

Another important topic of this year's ISWC was activity and posture recognition. Corinne Mattmann, Oliver Amft, Holger Harms, Gerhard Tröster, and Frank Clemens received this year's Best Paper Award for their article on a garment prototype using strain sensors to recognize upper-body postures. The system uses a novel thermoplastic elastomer strain sensor for measuring strain in the clothing (see figure 2). The sensors have a linear resistance response to strain and a small hysteresis, and they can be fully integrated into textiles. The authors conducted a study with eight participants, each wearing the garment and performing 27 upper-body postures. When they trained the

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system to specific individuals, recognition results were almost perfect. However, the recognition rate dropped when the system was trained on independent users. The garment prototype was also used in an experiment to explore its potential for rehabilitation and fitness training. Intensity, speed, and number of repetitions could be obtained from the garment sensor data.

Emmanuel Munguia Tapia, Stephen S. Intille, William Haskell, Kent Larson, Julie Wright, Abby King, and Robert Friedman presented a real-time algorithm for automatic recognition of physical activities and, in some cases, the activities' intensity levels. They used five triaxial wireless accelerometers and a wireless heart-rate monitor. The data sets they used to evaluate the algorithm consisted of 30 physical gymnasium activities collected from a total of 21 people at two different labs. The authors discussed their results for subject-dependent as well as subject-independent training. An interesting observation is that heart rate has relatively little discriminatory power.

Thomas Stiefmeier, Daniel Roggen, and Gerhard Troester described a new method for continuous activity recognition based on fusing string-matched activity templates. The underlying segmentation and spotting approach is carried out on several symbol streams in parallel, representing motion trajectories of body limbs acquired from body-worn inertial sensors. The authors reported results for activities in the context of car assembly.

POWER CONSIDERATIONS

Power efficiency is clearly one of the most fundamental challenges for wearable computing. At this year's conference, two papers explicitly dealt with this issue. The first, authored by Lu Luo and Daniel P. Siewiorek, introduced the Keystroke-Level Energy Model, a method for predicting the user-time and system-energy consumption it will take to perform an interactive task at runtime during the application design phase. KLEM is based on the Keystroke-Level Model, a psychological theory of human cognitive and motor capabilities that can predict execution time for a skilled user. Besides introducing this method, the authors also showed experimentally that their method obtains average prediction errors of 4 to 9 percent in a user study with 10 participants.

The second paper on power considerations (presented by Brian French, Daniel P. Siewiorek, Asim Smailagic, and Michael Deisher) analyzed the use of selective sampling strategies to help conserve power in sensor platforms for context-aware systems. In particular, the authors studied an activity-aware system based on the eWatch sensor and notification platform, developed at Carnegie Mellon University.

OTHER TOPICS

The remaining topics of the papers presented at ISWC ranged from evaluation and overaugmented reality to audio navigation and novel input interfaces.

Hendrik Witt presented a study evaluating the impact of five interruption methods in dual-task situations, which is a typical scenario for wearable computing. Results indicated that assuming speech interaction is available, speech can compensate for many typical challenges users must deal with in dual-task situations, and it can reduce the impact of an interrupting wearable computer.

Taehee Lee and Tobias Höllerer presented a markerless camera-tracking and user interface methodology for readily inspecting augmented-reality objects in wearable computing applications (the third nominee for Best Paper Award). They presented a robust real-time algorithm that recognizes fingertips to reconstruct the six-degrees-of-freedom camera pose relative to the user's outstretched hand. Figure 3 shows a sample output of the HandyAR system. The authors constructed a hand pose model in a one-time calibration step by measuring fingertip positions in the presence of ground-truth scale information. Through frame-by-frame reconstruction of the camera pose relative to the hand, they can stabilize 3D graphics annotations on top of the hand, enabling the user to inspect such virtual objects conveniently from different viewing angles in augmented reality.

Jeff Wilson, Bruce N. Walker, Jeffrey Lindsay, Craig Cambias, and Frank Dellaert presented the System

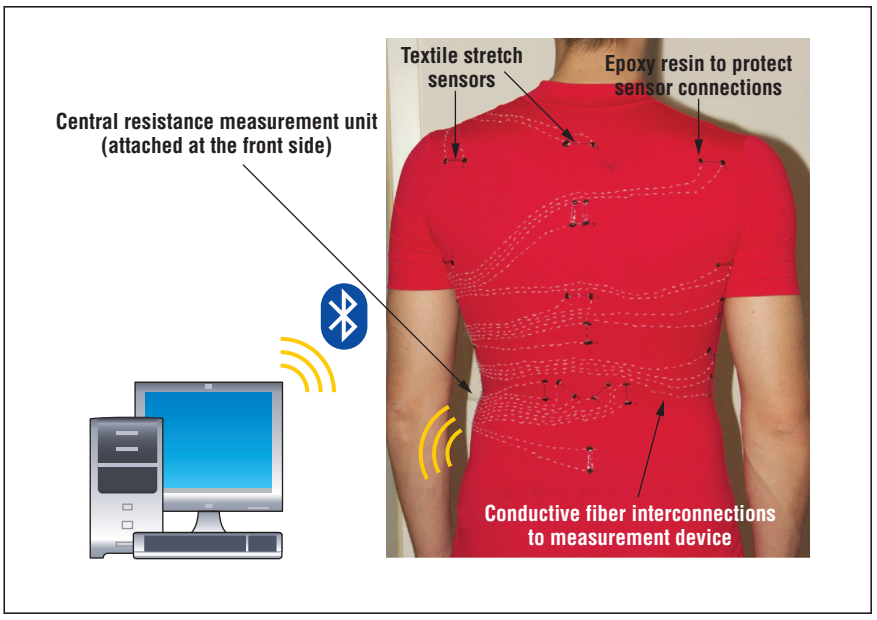

Figure 2. Prototype for recognizing upper-body postures using strain sensors.

WEARABLE COMPUTING

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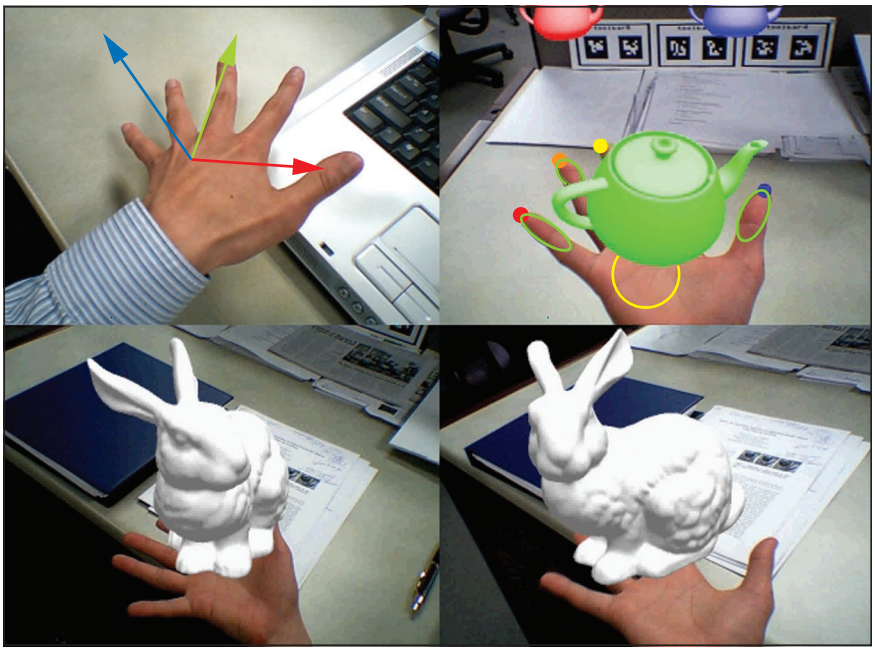

Figure 3. The HandyAR augmented-reality system based on robust hand and fingertip tracking to inspect virtual objects (such as a bunny) on top of the user's hand.

for Wearable Audio Navigation to serve as a navigation and orientation aid for people who are temporarily or permanently visually impaired. SWAN is a wearable computer consisting of audio-only output and tactile input via a handheld interface. It helps pedestrians to navigate safely and to create new geographic information system data relevant to their needs of wayfinding, obstacle avoidance, and situational awareness.

Finally, Yoshinari Takegawa, Tsutomu Terada, and Shojiro Nishio described the results of a study on a text input method specialized for pianists by exploiting characteristics of pianists and claviers. The proposed method achieves simple and quick text input by restricting users to pianists. The results of the evaluation suggest that the input speed achieved using their interface is twice as fast as that of Handy Key Corp.'s Twiddler, a combination mouse and keyboard device.

The ISWC program also contained a poster and demonstration session that gave participants a chance to experience many artifacts firsthand. As always, the program also included the Gadget Show, where attendees could present an interesting or cool gadget in front of the entire audience.

This overview is only a small portion of all the papers and posters presented at the conference. The full set is available from the IEEE Xplore digital library (http://ieeexplore.ieee.org). We encourage you to participate in ISWC 2008, which will be in Pittsburgh. Details will be available at www.iswc.net.

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