IEEE PerCom 2015

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The 2015 IEEE International Conference on Pervasive Computing and Communications (PerCom 2015) was held in Saint Louis, Missouri. With 13 years of history, PerCom has become one of the premier venues for ubiquitous computing research. Several cutting-edge workshops ran in parallel on March 23rd and 27th, while the main conference took place March 24–26th as a single-track event.

KEYNOTES
PerCom 2015 featured three excellent keynotes, by Maja Mataric’, of the University of Southern California (see Figure 1), Guruduth Banavar of IBM Watson Research, and James Kurose of the National Science Foundation (NSF).

Socially Assistive Robots
Mataric’, a professor of computer science, neuroscience, and pediatrics at USC, introduced the concept of socially assistive robots (SARs), which are designed to influence and motivate people through social rather than physical interaction. Within the application domains of assistive living and rehabilitation, SARs leverage the human tendency to engage with life-like social behavior. Robots acting as companions or coaches attempt to motivate people to perform certain physical activities for improved health or well-being. As an example, Mataric’ demonstrated how the presence of a small robot—a “tiny friend,” as she referred to it—can motivate a patient to walk for rehabilitation by simply following or leading the patient.

Drawing from her experience working with SARs, Mataric’ outlined some interesting lessons learned. She started by pointing out that “all our robots are autistic.” They have problems with social interaction, so designing them to be social is challenging. Furthermore, when dealing with human-robot interaction, Wizard of Oz studies are dangerous. Instead, she said that technical faults should become part of the interaction; a robot declaring, “I am sorry my mouth does not work today” can appear more friendly and help ease interaction.

Understanding and responding to human activity is also difficult. Vision isn’t a reliable option at the moment, so wearable technology is the only feasible approach. Another issue is that robots can’t accurately detect emotions. So, instead of attempting to classify affect, it’s better to build classifiers that predict key events and then have the robot respond to those events.

Mataric’ concluded with a prediction that tabletop robots will become mainstream in the next 10 years, but mobile robots will remain unreliable and possibly dangerous.

Figure 1. Maja Mataric with Ali Hurson of the Missouri University of Science & Technology, one of the co-chairs of the conference. Mataric presented the keynote on socially assistive robots on the first day of the PerCom conference.
Cognitive Computing
On the second day of the conference, Banavar, vice president of cognitive computing at IBM Research, presented a keynote titled, “Watson and the Era of Cognitive Computing.” Banavar is responsible for creating the next generation of cognitive systems in the Watson family. He introduced cognitive systems, which rose from reasoning systems coupled with the availability of massive amounts of data, advances in machine learning, and the advent of high-performance computing technologies. Cognitive systems aim to automatically learn from the data to interact naturally with humans and perform tasks that a human could do. Furthermore, they can be invaluable in helping humans make better decisions by exploiting big data. For example, they can help doctors by mapping the symptoms and diagnosis results with data from medical journals, other patients’ data, and the patient’s medical history.

Banavar also discussed Watson in particular, which debuted on Jeopardy! (a popular TV quiz show) and overcame the show’s two champions. He then discussed various applications of cognitive systems in a diverse set of domains. Surely, we are in for a very exciting time ahead, where most of our day-to-day tasks can be offloaded to robots, including long commutes to work! However, many challenges must be addressed first.

Research Grants
Kurose, Assistant Director of the Computer and Information Science and Engineering (CISE) directorate at the NSF, presented the keynote on the last day of the conference. He pointed out that CISE is at the center of an ongoing long-term societal change. He presented a series of “tire track” illustrations—that is, timelines of parallel development in academia and industry. These demonstrate the interplay between academic research, industrial research, and products that eventually affect our lives. He also discussed how computer science research both in academia and industry will be instrumental in the future development of our society.

Kurose also indicated that a significant slice (approximately 87 percent) of basic and applied research conducted by the computer science academic community in the US is funded by the NSF. Moving forward, he presented the key priorities for the NSF, including brain science; food, energy, and water nexus; cyber-physical systems; and security and trustworthy computing. Pervasive computing and sensor technologies are integral domains that cut across all these priority areas.

Finally, Kurose emphasized the importance of establishing partnerships between academia and industry, both as a way to link innovation with industry but also as a way to increase research funding in the US.

TOPICS EXPLORED
The technical sessions of PerCom were organized in eight sessions, and the related papers covered the following broad themes.

Smart Homes
Several presented papers explored challenges in the domain of smart homes. “Mining Relations and Physical Grouping of Building-Embedded Sensors and Actuators” (a candidate for the best paper award), from the University of Passau, introduced a framework for mining relations between embedded sensors and actuators. The framework exploits the fact that readings from different sensors at the same location will change value in a temporal relation that can be discovered.

A work from the University of St. Andrews, “Fault Detection for Binary Sensors in Smart Home Environments,” demonstrated a technique for anomaly detection that can discover faulty sensors in smart homes. The technique leverages sensor semantics and statistical-driven outlier detection to detect abnormal events, without prior training or ground truth annotations.

“Online Unsupervised State Recognition in Sensor Data,” from EPFL, Switzerland, considered the detection of pervasive computing...
of state changes of sensors in smart environments. This work described an unsupervised state-recognition algorithm that works on symbolic time series of sensor data.

“DOSE: Detecting User-Driven Operating States of Electronic Devices from a Single Sensing Point,” from the University of Washington, presented the detection of human activities through the sensing of appliance use. The DOSE system detects electromagnetic interference patterns, which could be used to discover the state of different appliances (for example, vacuuming on a rug versus a hardwood floor).

Within the same domain of appliance state identification, there was a presentation of “Acoustic Based Appliance State Identifications for Fine-Grained Energy Analytics,” from the University of Maryland at Baltimore County. By establishing a relation between the power consumption of appliances and their acoustic state, this work demonstrated a classifier that can be used for the energy disaggregation of multiple appliances in a smart home.

Energy Consumption

Given the PerCom community’s increasing interest in mobile phone sensing, energy consumption now plays a more central role in smartphones.

The recipient of the Best Paper Award was “Energy Modeling of System Settings: A Crowdsourced Approach,” from the University of Helsinki. It presented a novel approach in creating energy models for smartphones using crowdsourced data. Through the collection of a large dataset from 725,000 smartphones, this work demonstrates the feasibility of drawing fine-grained conclusions about energy consumption using crowdsourced data. Interesting findings included the fact that a Wi-Fi signal strength drop of one bar can result in a 13 percent loss in battery life, and that a smartphone sitting in the sun can experience a 50 percent loss in battery life.

“CrowdTasker: Maximizing Coverage Quality in Piggyback Crowdsensing under Budget Constraint,” from Mines-Télécom, explored the use of “piggyback sensing”—that is, piggybacking sensing activities and data communication on activities that are performed by the smartphone user. The paper presented a task allocation mechanism that can use piggybacking to reduce energy consumption but still maintain maximum coverage for a crowdsensed task.

“When to Type, Talk, or Swype: Characterizing Energy Consumption of Mobile Input Modalities,” from NICTA, Australia took a detailed look at the input methods for smartphones and their energy impact. The work compared the energy consumption for various text input—typing, swiping, and speech recognition. Interestingly, speech recognition can be more energy efficient for text input of more than 30 characters.

A work from the Singapore Management University, “Using Infrastructure-Provided Context Filters for Efficient Fine-Grained Activity Sensing,” presented a technique for low-energy activity detection using infrastructure sensors as triggers. This work showed how background context coming from sensors embedded in the environment can trigger activity recognition on wearable devices, thus resulting in high energy savings.

Activity Sensing

Activity sensing was another popular PerCom theme. “Attelia: Reducing User’s Cognitive Load due to Interruptive Notifications on Smart Phones,” a best paper candidate from Keio University, Japan, presented a system that detects breaking points in human activities—natural points for offering disruptive notifications. The detection of breakpoints uses applications as sensing input. This data stream is then used to construct a machine learning classifier to detect appropriate times for disrupting the user.

“Pervasive Self-Powered Human Activity Recognition without the Accelerometer,” from the University of New South Wales, demonstrated a system for activity recognition relying on the kinetic energy being harvested to power the mobile device. This work considered the use of harvested kinetic energy as an alternative to accelerometer-based activity sensing, enabling energy-free activity recognition.

A work from UCLA considered the use of activity sensing for realistic exercise and gaming applications. “Multiple Model Recognition for Near-Realistic Exergaming” demonstrated the use of wearable inertial sensors to develop a virtual soccer “exergame.”

“Joint Segmentation and Activity Discovery Using Semantic and Temporal Priors,” from EPFL, demonstrated a mechanism for activity discovery without the need for data labeling. The technique built on the idea that context words within one activity are semantically similar. The paper demonstrated the design of a fully unsupervised activity discovery mechanism that operates on unlabeled streams of context data.

Health and Wellbeing

“WiBreathe: Estimating Respiration Rate Using Wireless Signals in Natural Settings in the Home,” from the University of Washington, was the runner-up for the best paper award. It demonstrated a system for detecting respiration rates using wireless signals in the environment. The system captures the minute changes in the propagation of wireless signals caused by the movements of the human body when breathing, and it estimates the user’s respiration rate.

A work from the University of Milan, “Fine-Grained Recognition of Abnormal Behaviors for Early Detection of Mild Cognitive Impairment,” presented a system for detecting abnormal activity routines that could indicate the onset of early symptoms of mild cognitive impairment in elderly people. The system comprises sensor-based activity detection along with the identification of abnormal activities based on medical models of abnormal behavior.
“Smart Table Surface: A Novel Approach to Pervasive Dining Monitoring,” from DFKI, demonstrated a smart tablecloth for detecting dining activities. A tablecloth augmented with a resistive force distribution sensor matrix captures gestures around a dining table and measures the weight of the food handled or consumed.

Within the domain of novel hardware for gesture capture, “Inviz: Low-Power Personalized Gesture Recognition Using Wearable Textile Capacitive Sensor Arrays,” from the University of Maryland at Baltimore County, illustrated a wearable textile that can assist people with mobility impairment. Using a wearable capacitive sensor array, the system can capture touch gestures by users with limited upper limb mobility.

“Targeted Vaccination Based on a Wireless Sensor System,” from the Pennsylvania State University, described an algorithm for targeted vaccination using social contact information captured by mobile devices. The algorithm relies on a centrality-based algorithm for targeted vaccination to minimize the spread of a disease.

From Hong Kong Polytechnic University, “We Help You Watch Your Steps: An Unobtrusive Alertness System for Pedestrian Mobile Phone Users” described a system for helping pedestrian mobile users navigate through road hazards. This work presents a system that augments mobile phones with ultrasound sensors to detect sudden changes in the ground in front of pedestrian mobile phone users.

Location and Transportation
“Placer++: Semantic Place Labels Beyond the Visit,” from Microsoft, introduced a scheme for automatically labeling places—such as home, work, or school. Labels such as these are useful for generating user-friendly notifications, such as “Bob has just arrived at work,” or for automating phone settings, such as “reduce the phone’s ringer volume when Bob is at work.”

“Understanding the Unobservable Population in Call Detail Records through Analysis of Mobile Phone User Calling Behavior: A Case Study of Greater Dhaka in Bangladesh,” presented a study on capturing the location of an unobservable population (that is, unobservable on call datasets) by analyzing the Call Detail Records (CDRs) of a subset of the population. Their results show that for every user with available CDRs, there are approximately 2.4 to 2.8 unobservable people. The study has been conducted using a dataset of 810 household survey records and CDRs from 58 volunteers.

The work, “Beyond Location Check-Ins: Exploring Physical and Soft Sensing to Augment Social Check-in Apps,” from Samsung Research America and the University of Cambridge, presented how mobile social check-in applications can be expanded considerably beyond just location check-ins by exploiting smartphone sensing. This work demonstrated that software sensor data, such as app usage, phone calls, battery level, and messages, can be used to predict the user’s activity while substantially reducing the phone’s battery drain compared to that of physical sensors (such as an accelerometer or a microphone).

“LaneQuest: An Accurate and Energy-Efficient Lane Detection System,” from Alexandria University, considered the challenges of detecting a car’s driving lane. LaneQuest is using the inertial sensors of smartphones on board a vehicle and cues in the environment to estimate the probable lane of the vehicle on the road.

In the domain of travel planning, “DoppelDriver: Counterfactual Actual Travel Times for Alternative Routes,” from Rutgers University, attempts to address the question “What would have happened had I taken the alternative route?” Using aggregated real-time data from other users, the DoppelDriver system offers an actual travel time comparison among alternative routes for the same destination.

“FINE: Frequency-Divided Instantaneous Neighbors Estimation System in Vehicular Networks” considered a novel approach for fast estimation of density in vehicular networks. FINE is based on dividing the 10MHz dedicated channel for vehicular communication into hundreds of fine-grained subchannels that can be used for instantaneous neighborhood discovery.

Security
“Curbing Mobile Malware Based on User-Transparent Hand Movements” from the University of Alabama at Birmingham and Aalto University, presented a scheme that detects the presence of malware on a smartphone, which exploits (or attack) the phone’s calling feature, camera, and near-field communication. The main idea is to detect the user’s gestures associated with using these feature. For example, when the user takes a picture with the phone’s camera, she opens a camera app and orients the device and then takes the picture. If a resource access isn’t associated with the corresponding gesture, then it could be due to the presence of a malware.

In “Measurement-Driven Mobile Data Traffic Modeling in a Large Metropolitan Area,” the presenter described a framework that classifies users into four distinct profiles based on their network data usage. The usage patterns of these four different types of users are then modeled according to peak and nonpeak hours. A deep understanding of users’ traffic usage patterns can help design effective strategies to address network scalability issues. For this study, the authors used a large dataset that captured the traffic usage patterns of 6.8 million subscribers over four months.

“Covert Channel Attacks in Pervasive Computing” from the University College London, presented a technique to transmit information from a compromised node (covert channels) within a secured network while making it statistically undetectable by other system components. The paper showed that in pervasive systems, creating undetectable
covert channels is practically possible. Therefore, the work suggests that individual keys (rather than group keys) are necessary to limit the exposure by a covert channel attack.

In “Sensor Use and Usefulness: Trade-Offs for Data-Driven Authentication on Mobile Devices,” the presenter described their study on the tradeoff between the cost of accessing a sensor’s data (battery consumption, for example) and the benefit of using the data for user authentication. The work explored how energy consumption and effectiveness of using sensor data for authentication varies with respect to sensor type and sampling rate used. The authors also presented an adaptive sensor sampling technique that reduces the battery drain while maintaining the effectiveness of user authentication.

The next PerCom will take place in Sydney, Australia on 14–18 March 2016. It will be organized by Mohan Kumar from the Rochester Institute of Technology, US and Aruna Seneviratne from NICTA, Sydney. Keep the conference dates in your calendar and consider submitting your latest work to PerCom 2016. For more information, visit www.percom.org.

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