Conferences

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Ubicomp 2012

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Researchers recently gathered at Tsinghua University in Beijing, China, to share their accomplishments at the 13th annual ACM Conference on Ubiquitous Computing.[1] This multidisciplinary conference featured advances in sensing technologies and activity-recognition algorithms, novel applications, and results from end-user evaluations. Smartphones continued to provide a versatile research platform, facilitating application delivery, sensor data capture, and computational social science on captured data.

MOBILE PHONES AS UBIQUITOUS SENSING PLATFORMS

For many years, capturing sensor data at any scale involved substantial effort and expense. However, dependable smartphones and robust mobile networks are dramatically reducing data-collection costs. A robust, embedded GPS, for example, lets researchers gather large datasets of human movement on a city-wide scale. A computational analysis of these location traces lets researchers examine previously hard-to-see social patterns in the aggregate.

Location Analysis: Tacking Taxis

GPS-equipped taxicabs provide continuous, dynamic reports of driver and passenger location as they traverse city road networks. The routes selected and flow of movement effectively function as mobile traffic sensors. Yu Zheng and his colleagues examined how this sensing capability can support urban planning. They learned Beijing traffic patterns using GPS traces from 30,000 taxis and correlated them changes that urban planners had made to the road network. By visualizing the difference between expected and actual changes to traffic patterns, they can help urban planners reflect on the actual outcomes of their plans.

In a similar project, Daqing Zhang and his colleagues used GPS traces to learn common taxi trajectories and developed an anomaly-detection algorithm with over 90 percent accuracy. Their algorithm can help identify when changes occur in the road network, which could help commuters respond to dynamic traffic situations and help regulators identify taxi fraud.

Looking to optimize taxi-passenger services, Jing Yuan and his colleagues looked to use sensing to make taxis more economic and convenient for both the drivers and passengers. Their algorithm, which compares models of taxi and pedestrian movement, can offer recommendations to drivers as to where to find passengers and can help pedestrians find taxis.

As an alternative to GPS, which can be unavailable or unreliable, Richard Becker and his colleagues demonstrated that driving routes can be accurately classified using only cellular handoff patterns. They presented results of their two algorithms, demonstrating that cellular handoff patterns are stable across different routes, speeds, directions, phone models, and weather conditions.

Healthcare Applications

Researchers at Ubicomp 2012 demonstrated that mobile phones can facilitate the sensing of a great deal more than location. Noting that early symptoms of respiratory distress often manifest as coughing, Eric Larson and his colleagues presented an algorithm that uses the handset's microphone to reliably sense coughing. Similarly, Mashfiqui Rabbi and his colleagues demonstrated that standard mobile phone sensors, such as accelerometers and the on-board microphone, strongly correlate with standard medical diagnostic surveys of wellbeing. Both works demonstrated that useful information could be extracted from standard mobile phone sensors, even when their signals were sufficiently perturbed to preserve individual privacy.

Thomas Fahrni and his colleagues presented a study of a mobile phone application that compiles and presents UV-radiation-exposure data compiled from an external sensor. They demonstrated how the phone could reliably process sensor data and alert users when they're at risk of overexposure.

Power Conservation

Although mobile devices can support a variety of uses, liberal application of sensing and processing can also deplete batteries. A variety of research efforts presented aimed to moderate power consumption. Yifei Jiang and his colleagues demonstrated how they could significantly lower the power required to detect journeys by developing a trip-detection framework. Their framework learns to switch between a mode that learns cell-ID patterns

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using a combination of GPS- and Wi-Fi-based localization, and a mode that uses only cell IDs and learned patterns. Their five-month study of data from six individuals shows that energy consumption decreases rapidly as user activities become more predictable over time.

Heitor Ramos and his colleagues offered a way to lower computational costs of trajectory prediction by partitioning the GPS signal processing pipeline, shifting delay-tolerant position calculations to the cloud.

Andrew Pyles and his colleagues proposed saving power by turning off the Wi-Fi radio during conversation gaps. They presented a model that predicts the start and stop of periods of silence, allowing for 40 percent power savings while maintaining conversational fidelity.

To support problems of power consumption across more generalizable circumstances, Earl Oliver and Srinivasan Keshav presented a software toolkit that can help developers predict application energy consumption.

COMPUTATIONAL SOCIAL SCIENCE

Anonymous collection of data from mobile phones also lets researchers examine large-scale social phenomena in ways previously not thought possible.

Evaluating Incentives

Using mobile phones to measure physical activity levels, Nadav Aharony and his colleagues examined how different incentive structures could differentially motivate exercise in small, close groups. Interestingly, their longitudinal study revealed that subjects' whose rewards depended solely on the performance of their buddies outperformed subjects whose rewards depended on their own performance.

Researchers also examined some of the assumptions that drive application and service design. At the macro-economic level, for example, Neil Lathia and Licia Capra examined automatic fare collection data from the London Transit system to measure whether financial incentive affected transportation decisions. Their examination of 78 million rail trips showed that many financial incentives, including student discounts and peak travel-fare increases, didn't affect consumer behavior.

At the individual level, Brian Lim and Anind Dey examined the supposition that individual users would want applications that make inferences about the environment to make their reasoning more intelligible. Their experiment with a system that inferred a friend's availability showed that people valued explanations when the sensors were accurate. However, explanations harmed trust when accuracy was low.

Detecting Location

Researchers also examined assumptions that drive much of smartphone mobile application development. Since many applications seem to assume that phones will be constantly available to their users, Anind Dey and his colleagues re-ran an earlier study, examining how close mobile phones are to their users. Using experience sampling, their study showed that people now have access to their smartphones more than previously measured, but they're still within arms' reach less than half of the time. Similarly, because many applications would need an accurate list of a person's meaningful places, Donnie Kim, Kyungsik Han, and Deborah Estrin advanced the state-of-the-art in place detection, showing that they could identify meaningful places with 95 percent accuracy from unsupervised GPS streams.

Several researchers examined the motivations behind the disclosure of location. Vassilis Kostakos and his colleagues found that individuals central to their social networks are more likely to share real-time location information. Jason Wiese and his colleagues determined that, more than frequency of collocation, frequency of communication was the best predictor of both closeness and willingness to share information (such as current location and activity). When place information is shared, Karen Tang, Jason Hong and Daniel Siewiorek found that users demonstrated a strong bias in favor of text and map form—and against timeline form.

The open nature of information-sharing applications awakens a strong public response. While a survey by Eun Kyoung Choe and her colleagues showed that this discomfort varies with the kind of information that's shared, Sai Teja Peddinti and Nitesh Saxena showed that the use of aggregate statistical information alone isn't sufficient to obfuscate journey sharing at the individual level. Their statistical comparison showed that, even without a labeled history of journeys, query aggregation can identify between 20 to 40 percent of journeys.

NEW SENSORS AND APPLICATIONS

Advances in sensing are supporting ubicomp's fundamental goal of moving off the desktop.

Advances in Sensing

Sidhant Gupta and his colleagues demonstrated that a compact fluorescent (CF) bulb could be used to sense proximity. They observed that in a CF bulb, impedance levels vary with the relative distance of nearby people. They used changes in impedance level to detect when a person waved at a lamp, creating a way to remotely control the lamp's on/off state.

Zheng Sun and his colleagues showed that they could use ambient sounds (like footsteps or human speech) to localize the relative arrangement of networked devices. By using approximation based on the arrival time of ambient sounds, their technique achieved 10 cm accuracy without requiring configuration.

Rui Fukui and his colleagues showed that they could recognize eight different

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hand shapes with a minimally invasive device. They used reflectors to classify contours in the shape of the wrist with each characteristic gesture.

Hang Yu and his colleagues adapted a phone's FM radio to create a short-range, bit-level information beacon. Nan-Wei Gong, Steve Hodges, and Joseph Paradiso developed a new kind of indoor localization. By printing tiles made from conductive copper ink, they used changes to impedance to localize walking patterns.

Andreas Bulling and Daniel Roggen showed that eye tracking could reveal cognitive state. Their lab study, which showed that patterns of eye movement could indicate a cognitive state (whether a user had seen an image before) effectively turns an eye tracker into a type of visual history sensor.

New Apps

These new sensors were then applied to a variety of domains, enabling a variety of new applications. Christina Strohrmann and her colleagues, for example, used accelerometer data to classify runner skill level and fatigue. They identified that features like foot contact duration, foot strike location, and amount of heel lift varied as runners tired and could be detected with clustering, signal processing, and temporal analyses.

Vaiva Kalnikaitė and her colleagues showed that a simple barcode scanner embedded in a shopping cart handle to display the distance food traveled to reach a user could affect purchasing decisions. Daniel Avrahami, Michael Yeganyan and Anthony LaMarca showed that sensors could be used to track loose objects in the car. This application would be able to alert occupants when unfastened objects could pose a danger in a crash situation.

Observing that interactive tabletops falter when asked to recognize many objects, Juan David Hincapié-Ramos, Aurélien Tabard, and Jakob Bardram augmented test tube racks with RFID tag readers, and tagged individual test tubes. When placed on an interactive surface, the augmented rack let biologists access and annotate digital records of test tubes directly on the surface, simplifying the annotation process.

Various projects also saw the extension of both sensing and application use into a more broadly public phenomenon. Stacey Kuznetsov and her colleagues floated meter diameter balloons over two urban areas, varying their color in proportion the presence of certain environmental contaminants. As a public installation, their work created a spectacle while it communicated meaningful information to observers.

Sarah Clinch and her colleagues also explored the public experience of ubiquitous computing through large displays. They presented a longitudinal study of a public display system that doesn't rely on a single point of control for its content. Instead, their system relies on shared "content channels" that blend control between content providers and display owners, providing a more engaging experience that lead to broader adoption.

The home was featured as a location for various new types of applications. Hitomi Tsujita and Jun Rekimoto used a digital camera to detect smiles when people looked in mirrors in their homes. They reflected the user's state back to them using a digital display in the mirror. They also showed an accumulated smile history on a display on the refrigerator.

Jun Wei and his colleagues developed an application that lets participants to co-dine over a video stream that links two remote tables. They augmented a tablecloth to display messages, and created a food printer that translates text messages from social media into a tangible form using rice.

Frank Bentley, Santosh Basapur, and Sujoy Kumar Chowdhury brought the practice of geocaching into the family, creating an application where they stored messages in meaningful locations.

As fuel prices worldwide are on the rise, applications that use sensors to monitor energy consumption are finding purpose in the research community. Bo-Jhang Ho and her colleagues introduced a new way to monitor energy consumption at the level of the individual appliance. Their approach combines a thermal imaging camera with an inline power meter, correlating spikes in temperature with drops in current.

James Scott and his colleagues used home occupancy sensing and prediction to control home heating. Their six-month field deployment in five homes demonstrated they could save gas by automatically learning an optimal thermostat schedule, so users didn't have to learn to how to program their thermostats.

Hendrik Richter and his colleagues demonstrated a scalable way to produce sophisticated tactile feedback without complex electromechanical or electrostatic actuator setups. They use the psychological phenomenon of "phantom sensations" to allow a small array of simple actuators to provide users with the sensation of a variety of finely detailed types of tactile feedback.

Advising designers of all kinds of ubicomp applications, Ian Li, Anind Dey and Jodi Forlizzi reflected on their years of designing and deploying applications that collect and present information on behalf of users. They presented a model that consolidates the variety of ways that applications collect and present information to users. Their framework highlights common points of disconnect between the application designer and user, providing useful guidelines for many ubicomp-application designers.

OPENING NEW TERRITORY

Two best papers were awarded at this year's conference. Janet van der Linden and her colleagues introduced a novel type of multimodal theater that combined ambient sounds, narratives heard over headphones, and various thematic objects. The overall effect was to create a multisensory theater that looked to embody the experience of blindness for sighted people.

An additional best paper award was granted to Stacey Kuznetsov and her colleagues. Their work on "natural sensors" deconstructs and extends how we view sensors. Instead of silicon-based sensors, for example, they discuss the use of living organisms, such as plants and animals, as naturally embedded sensors. Their paper draws on a field study of 10 individuals who work with organisms like plants, fish, reptiles, and bees to infer environmental conditions. Their work reflects on future uses of this more expansive definition of a sensor.

This year also included the introduction of a "Visions of Ubicomp" film festival (http://visionsofubicomp.com). Ina See and Sean Chung's winning work depicts human desire as explored by a future, hyperconnected generation. The narrative follows how a young male uses his skills with the vast digital footprints of a future social media to nurture an unhealthy obsession with a young woman.

MORE FROM YOUR DATA

With the growing amount and types of data, techniques are evolving to more efficiently parse, reason, and act on that data. Jinfeng Zhuang and his colleagues used similarity graphs to demonstrate that search results that include place and time information can improve search results. Timothy Sohn and his colleagues demonstrated that searching across devices could be simplified using a unified Web history.

Nicholas Lane and his colleagues demonstrated that they could incorporate interperson similarity measurements to train what they called *community similarity networks*, which showed an increased predictive power over a more heterogeneous population. Hao Du and his colleagues demonstrated that by providing online feedback and hints, and tolerating human errors and alignment failures, a mixed initiative system allowed nonexperts to quickly create real-time 3D maps of both large and small indoor spaces.

REFLECTING ON 20 YEARS

A highlight of the conference was a panel of luminaries discussing the progress, foci, and future directions of research in ubicomp 20 years after the publication of Marc Weiser's seminal article, "The Computer for the 21st Century."[2]

Gregory Abowd, Distinguished Professor at Georgia Institute of Technology, declared victory on behalf of Weiser's vision of a ubiquitous computing. He pointed out that Weiser's visions of three ubicomp devices—pads, tabs, and boards—have become the dominant forms of modern computing, instantiated as smartphones, tablets, and (to a lesser extent) smartboards and large public displays. Elizabeth Mynatt, professor at Georgia Institute of Technology, also described Weiser's prediction that a ubiquitous computing would shape not only objects of our focus, but the mundane—the simple but meaningful tasks that largely define our days.

Jun Rekimoto, director of the Sony Computer Science Laboratory, envisioned how a world with ubiquitous networks could develop technologies to respond to emergency contexts, such as the massive tsunami that rocked Japan.

Two main questions emerged. Former Director of the Computer Science Lab at Xerox PARC (and Weiser's former boss) John Seeley Brown asked researchers to reconsider the cultural context in ubiquitous computing research should occur. He compared today's ubiquitous computing research labs, and their largely technical composition, with the lab Weiser described in his keynote to UIST 1994. Weiser passionately pleaded that ubicomp research "start with artists," pointing out their natural tendency to destabilize the current thinking.

Paul Dourish, professor at the University of California at Irvine, elaborated on Weiser's vision that ubiquitous computing appear invisible *in use*. He observed that even with the technical advances presented at the conference, the majority of ubicomp applications are more spectacle than invisible. Seeley Brown offered an analogy to guide developers—how is ubiquitous computing like riding a motorcycle? Despite its fantastic rate of computations and mechanical compensations every second, a motorcycle provides the rider with the feeling of power and control. When a rider is really in trouble, an automated feature like antilock brakes might act for only a moment, unnoticeable to the rider but critical to their mutual success.

It will be exciting to see if researchers can, or want, to adapt their work to this future vision. We'll find out next year.

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