Works in Progress

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Large-Scale Opportunistic Sensing

EDITOR'S NOTE:

In this issue, we feature a range of applications with potential to impact our everyday lives. The first two reports are related to this issue's theme, proposing sensor-based systems for energy management and eldercare. Also featured are three automotive computing proposals, which offer solutions for activity promotion, path prediction, and vehicle passing. Other proposals explore eyes-free solutions for the mobile Web, the use of humans as sensors for increased reliability, and a smartphone-based sensor that assists in early stroke diagnosis.

NEXT-GENERATION ENERGY MANAGEMENT FOR RESIDENTIAL BUILDINGS

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With the residential building sector a main contributor of global carbon emissions, advanced energy-management technologies are imperative if significant improvements in energy efficiency and peak electrical demand are to be realized.

Although first-generation residential demand-response technologies have effectively reduced peak demand and operating costs, they can't maximize these reductions at individual residences and predict the stability or firmness of response at the neighborhood level to benefit the electrical distribution network. Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) believes that coupling large-scale opportunistic sensing with adaptive and predictive distributed controls will realize significant improvements over first-generation technologies, enabling superior demand response and energy efficiency.

Having successfully developed optimized energy-management techniques for commercial buildings, CSIRO is applying similar techniques in the residential domain. When considering energy-intensive space cooling and heating, the key to effective energy management is the ability to predict indoor environmental conditions and energy consumption and generation for use in devising optimized control actions. Research challenges include designing predictive and adaptive control algorithms that operate within a distributed architecture and on low-cost resource-constrained computing devices; optimizing the trade-off between user comfort, operating cost, and carbon emissions; and integrating this optimized control with renewable energy generation and storage devices.

With the advancement of pervasive wireless sensors and efficient distributed control techniques, aggregation and coordination of optimally controlled residential energy-management systems (see Figure 1) that facilitate heterogeneous large-scale opportunistic sensing and control will be the key to unlocking superior demand response and energy efficiency.

Please contact Josh Wall at Josh.Wall@csiro.au with any questions about this work.

OPPORTUNISTIC SENSING FOR BEHAVIORAL INFERENCES IN ELDER CARE

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Mexican Social Security Institute

Atypical behavior in older adults can suggest early stages of dementia. For instance, getting lost or disoriented while running errands that are part of the daily activities can reveal cognitive impairment in an individual who usually performs these types of activities. This symptom, and others such as memory loss, can be difficult for even a close family member to notice. Indeed, most clinical evaluations are based on retrospective accounts of incidents of this sort and patients often don't remember or try to hide or minimize them.

InCense is a toolkit for collecting behavioral data from populations of mobile phone users (see Figure 2). InCense provides a GUI with high-level, configurable objects that can be connected. These objects represent the main InCense components: sensors, filters, triggers, data sinks, and sessions. InCense also offers on-device and in-cloud analytics and support for both

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opportunistic and participatory sensing paradigms. Moreover, it's usable at the individual and community levels and was designed with nontechnical users (such as social scientists) in mind.

Currently, we're planning to use this platform in a case study with older adults to detect anomalies in their behavior that might provide early evidence of physical or mental ailment.

For more information, contact Luis Castro at lcastro@cicese.mx.

ENCOURAGING PHYSICAL ACTIVITIES DURING LONG-DISTANCE TRAVEL

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Being confined to relatively small spaces for significant amounts of time is one of the less pleasant aspects of long-distance travel in cars and on planes. Being seated for long periods usually means a lack of physical activity, which has been linked to deep vein thrombosis (DVT) and can lead to serious health implications. Common advice given to travelers wishing to reduce the risk of DVT is to regularly stretch and move their limbs.

Our work investigates the potential of context-aware activity-promotion technologies for people confined to small spaces, such as during long-distance car travel. We mapped these environments' characteristics to options for activity-promotion technologies and identified several issues to consider when designing suitable technologies. To evaluate the effectiveness of activity-promotion technologies in increasing activity levels, we developed a prototype system featuring activity-motivating computer games and persuasive feedback with visualization.

We evaluated the prototype in a laboratory environment mimicking a constrained in-car or in-flight environment. The usage data indicate that systems using games as the activity-promotion technique are more effective at increasing the amount of activity undertaken by travelers than systems using persuasive feedback. The responses to a usability questionnaire uncovered several important considerations about the design of activity-promotion systems, including ways to improve the persuasive feedback and integrate the visualization into activity-motivating games.

Please contact Christopher Lueg at christopher.lueg@utas.edu.au with any questions about this work.

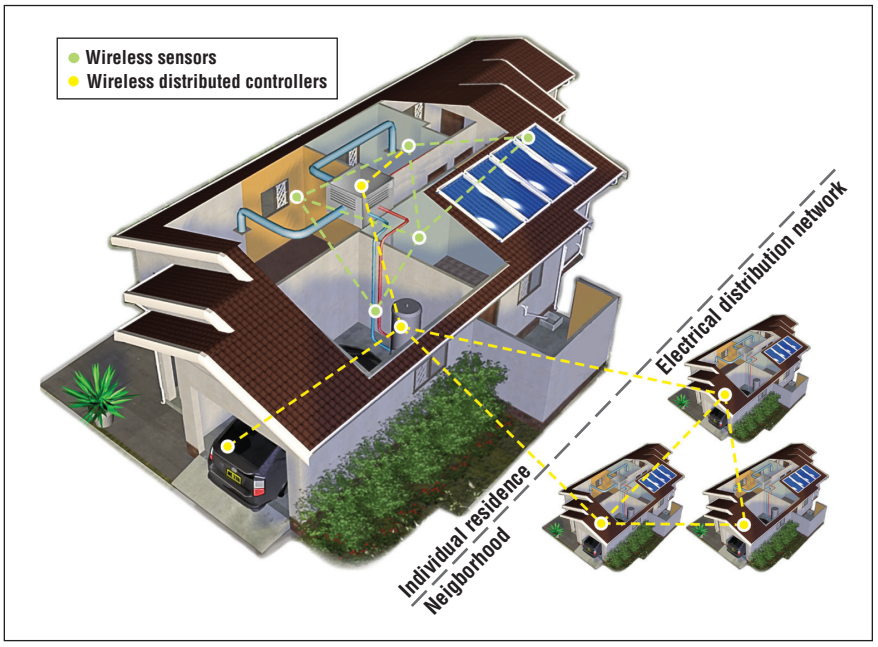

Figure 1. Large-scale residential energy management using pervasive sensing and distributed controls.

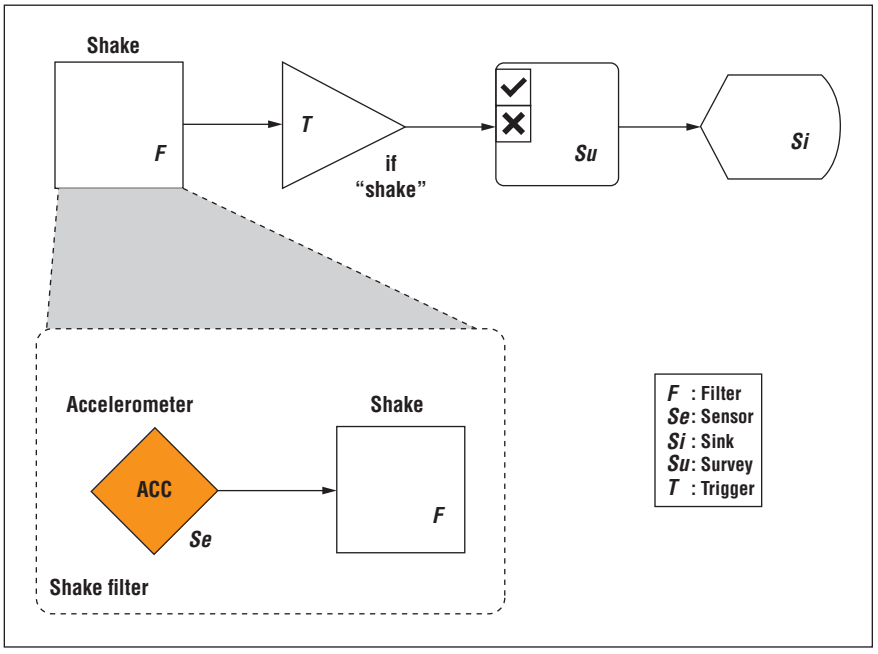

Figure 2. Schematic of an InCense project in which a survey is triggered after a user shakes the mobile device.

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Figure 3. The digital short-range communications (DSRC) equipped system: (a) the obstructed field of view of the driver intending to overtake a truck; and (b) the augmented reality presented to the driver after the activation of the overtaking assistant. Note how the blind spot is conveyed through the 3D virtual representation of the truck.

TRAJECTORY MODELING AND PREDICTION USING A DISTORTED GRAPH

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Trajectory prediction consists of determining which path a driver will choose when taking a trip. Our approach to this problem consists of transforming the map according to the driver's perceived preferences and then applying a classical route-planning algorithm to determine the route. The assumption, widely adopted in the areas of spatial cognition and cognitive mapping, is that individuals develop their own mental maps of the city. This *distorted graph* governs their route choices.

The major challenge is how to make the distortion in a way that optimizes the routing algorithm's precision with regard to the ground truth. We tested our approach with a portfolio of functions that determine a link weight's decay when it is traversed by the driver. The results showed an average improvement of 6 percent accuracy over the original (nondistorted) map, which already reaches 84 percent. However, experiments only focused on three drivers from two cities, which is manifestly insufficient in terms of validating the algorithm.

Current work is dedicated to testing the algorithm exhaustively and improving several aspects that were neglected in earlier versions. We now have access to 1,892 GPS-logged trips from 11 people from three different cities. We measure the results in terms of the percentage of correctly predicted routes, moment of determination of 100 percent correct route (the earlier the better), and computational performance

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MAKING VEHICLES TRANSPARENT THROUGH DSRC

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Digital short-range communications (DSRC) lets vehicles obtain data from sensors residing in nearby vehicles, greatly increasing their sensing range. Windshield cameras are proliferating as a main sensor in modern vehicles, supporting functions such as lane keeping or traffic sign recognition. We combine DSRC with windshield cameras to design a cooperative passing-maneuver assistant that increases the visibility of drivers trying to overtake vision-obstructing vehicles, such as trucks.

DSRC-equipped vehicles send periodic beacons to inform the vehicle behind them that they can stream a real-time video through DSRC from their windshield camera. The driver of the vehicle traveling behind can then activate the on-board component of the cooperative system, which asks for additional data from the truck, such as its dimensions and camera parameters. Distance sensors measure the space between the vehicles. The on-board component then generates a partially translucent image that merges the real-time video with a dynamic opaque frame that's computed trigonometrically, producing a virtual representation of the truck as a hollow tubular object, allowing the driver to see through it (see Figure 3). This image is then displayed on the windshield, using laser holographic projection, overlapping the rear of the truck. This sophisticated interface conveys an intuitive message to the driver, letting him or her perceive the blind spot caused by the distance to the camera capturing the video.

Our preliminary tests also show DSRC's suitability for this cooperative application, with delays less than 100 ms on the video streaming.

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NAVIGATING THE AURAL WEB

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Pervasive mobile computing shapes the fabric of our daily interactions with digital information. On-the-go user experiences with the mobile Web, however, are still constrained by a major limiting factor: the visual user interface. Although powerful and enabling, conventional user interfaces still force users to focus their attention and cognitive energy on the device itself to experience content and services. This problem is particularly manifested in those contexts in which users are engaged in another activity (such as walking in a city, jogging or driving a car) where it is inconvenient, distracting, or even dangerous to continuously look at a screen.

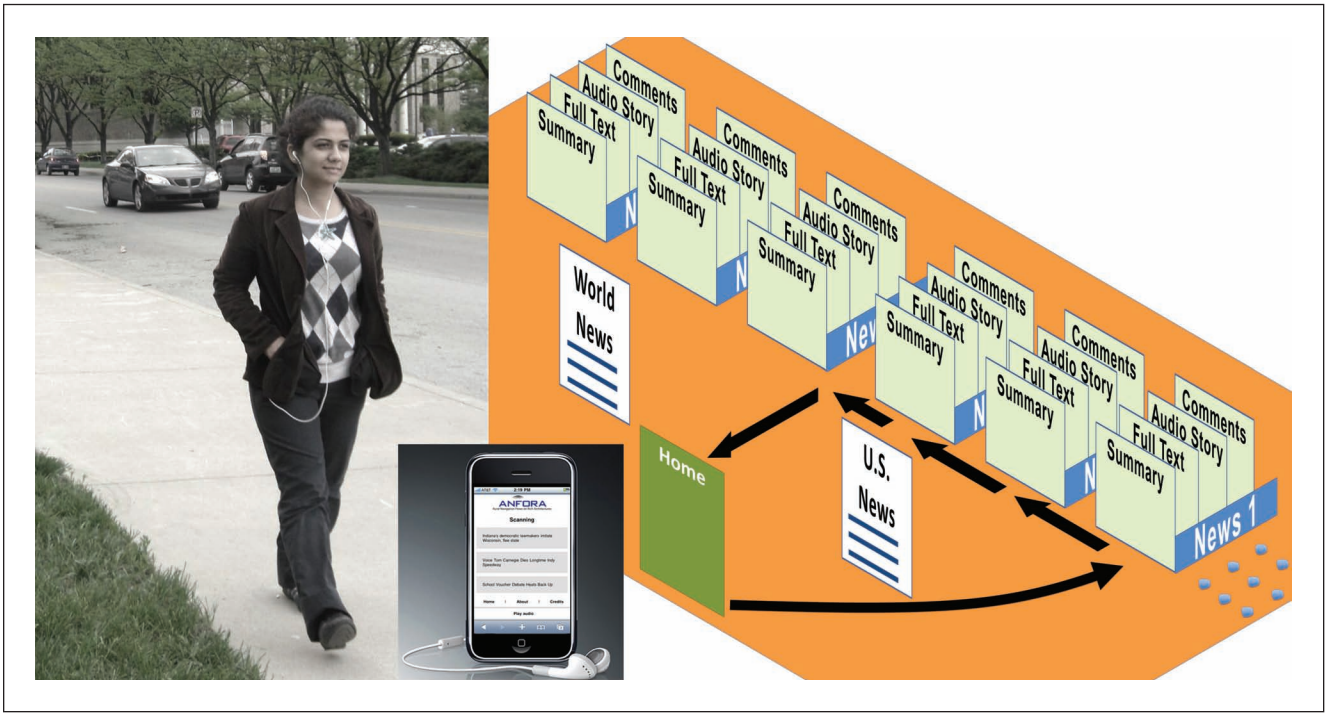

Figure 4. The Aural Navigation Flows on Rich Architectures (ANFORA) framework limits user interaction using aural design rules that determine which pages to automatically concatenate and at which point of the flow the user can interact.

Innovative aural interfaces offer new possibilities for eyes-free experiences with the mobile Web. The Human-Centered Interaction Design Research group at Indiana University School of Informatics, led by Davide Bolchini, is establishing novel design strategies for aurally navigating complex, highly structured information architectures. To support a graceful evolution of Web systems from a conventional to an aural experience, the group is developing Aural Navigation Flows on Rich Architectures (ANFORA), a framework for designing mobile Web systems based on automated, semicontrolled aural navigation flows on top of nonlinear, hypertextual information architectures, typical of large Web applications.

An aural flow is defined as a design-driven, concatenated sequence of pages that can be listened to, with minimal interaction required. Counterintuitively, in fact, minimizing interaction can be desirable in aural mobile scenarios. A flow is governed by aural design rules that determine which pages to automatically concatenate and at which point of the flow the user can interact (see Figure 4). ANFORA prototypes offer aural flows that can be listened to by the user while engaged in a secondary activity (such as walking). Aural flows are controlled by a simple interaction semantics (for example, pause, resume, stop, skip forward/backward, and fast forward/backward), which is independent of any input modality (vocal command, earphone buttons, and touch-gesture input), to be designed based on mobile context or user preference. Aural navigation can co-exist with conventional visual interfaces, and can unleash new interaction paradigms for pervasive computing.

This research material is based on work supported by the US National Science Foundation under grant number 1018054. For more information about this work, contact Davide Bolchini (dbolchin@iupui.edu, http://mypage.iu.edu/~dbolchin).

LEVERAGING HUMANS AS TRUSTWORTHY SENSORS

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Providing the right information at the right time to emergency workers in command-and-control centers is crucial. Available information can enhance decision-making processes, but can also cause information overload. Thus far, sensor networks have been used to deliver information about local events and environmental states in real time. However, using eye witnesses or humans as sensors can be crucial to complement the situational awareness. Humans can provide more intelligible reports and comprehensive digital pictures concerning an incident in order to speed up and guide initiated first responses.

Our project explores how to leverage humans as trustworthy sensors to support smart emergency management.

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Yet, humans can't be directly queried as a (technical) geosensor. Additionally, end-to-end confidentiality requirements imposed by emergency communications must be satisfied.

To meet these challenges, we use attribute-based messaging (ABM) concepts.[1] ABM lets senders contact receivers by specifying a logical combination of attributes. For example, all responders that satisfy the imposed attributes can be asked to send situation reports to the headquarters. To achieve trustworthiness and end-to-end security, we're developing fine-grained encryption-based access control, key-management, and messaging mechanisms that also account for dynamic location attributes and resource constraints of mobile communication devices. Our work also builds on experiences with real emergency managers.

For more information, contact Stefan G. Weber at Stefan.Weber@cased.de.

REFERENCE

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A HOSPITAL IN HANDS: USING SMARTPHONES AS HEALTHCARE TOOLS

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Early diagnosis and treatment of a stroke help minimize permanent damage. After acute treatment, patients should receive systematic rehabilitation therapy to improve paralysis. We've developed iStroke, a healthcare tool that runs on a smartphone, to make accurate and early diagnosis of stroke through real-time measurements of arm weakness and signs of neglect. Arm weakness is the most common presenting symptom of stroke and a neglect after a right hemispheric stroke makes a patient fail to respond normally to stimuli on the left side. Using a smartphone's built-in accelerometer, iStroke can measure the degree of drift and pronation of mild arm weakness with a motor score of IV or V and a US National Institutes of Health Stroke Scale (NIHSS) score of 0 or 2.

We evaluated the feasibility and usefulness of iStroke to differentiate patients from normal controls. The iStroke accurately predicts the hemispheric lesions involving motor pathways confirmed by brain CT or MRI. The system also detects the progression of weakness and compares results at different time points. Furthermore, nonspecialists or less-qualified medical personnel can use the iStroke to detect mild arm weakness and neglect. We plan to integrate the results with data on other neurological symptoms to make more accurate diagnoses.

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