NETWORKED SENSING

CENTER FOR EMBEDDED NETWORKED SENSING CENS

IMAGINE IF:

Mobile technologies could be used to help individuals and their doctors monitor and manage health symptoms, treatments, and side effects throughout the day.

Ecosystems could be equipped with chemical, physical, acoustic, and image sensors to continuously monitor environmental change.

Buildings could detect their own structural faults and respond to seismic events.

These are the kinds of dreams that researchers at the Center for Embedded Networked Sensing are turning into reality through a collaboration between computer scientists, statisticians, biologists, and engineers under the leadership of center director Deborah Estrin.

The approach uses sensors, computers, and wireless communication in systems that are distributed throughout the environment. These smart sensors and actuators allow people to monitor aspects of the world as a function of time and space in order to derive new knowledge that couldn't be obtained otherwise.

Embedded and networked sensing systems promise to reveal previously unobservable phenomena widely affecting our society by exploiting connections between the physical world and the Internet. In the same way that the development of the Internet transformed our ability to communicate, the ever-decreasing size and cost of sensors, mobile technologies, and computing components are setting the stage for detection, processing, and communication technology to be embedded throughout the physical world. The approach is aimed at fostering a deeper understanding of the natural and built environments and, ultimately, enhancing our ability to understand and manage these complex systems.

Center researchers are working to harness the power of mobile phones and the ubiquitous wireless infrastructure for applications in areas as diverse as public health, environmental protection, urban planning, and cultural expression.

Sustainable design, healthy living, and effective stewardship of the world's limited resources all require a deeper understanding of how countless individual actions generate global effects and how individuals relate to their local environments.

Previously, scientists, policy-makers, and the public have had to choose between examining the broad characteristics of large populations and looking at small groups in detail. With the approach of participatory sensing, CENS researchers are developing ways to help individuals, families, and communities monitor and improve their own health behaviors, adopt sustainable practices in resource consumption, and participate in civic processes.

PARTICIPATORY SENSING

The proliferation of smartphones with built-in GPS, high-quality cameras, excellent user interfaces, and easily downloaded applications has opened the door for participatory sensing. The power in this approach comes not only from the devices, but also from their connection to the Web.

Smartphones have already transformed cellular phones into something much more than personal communication devices. Now, with growing interest in community engagement and a greater appreciation for the importance of the environmental and social determinants of health, smartphones have become vital, accessible, and affordable public resources for environmental assessment and health promotion, says Estrin.

CENS research applications include data-gathering campaigns, in which participants make observations about the world around them; and mHealth, in which individuals use their devices to manage a wide range of health concerns, from diabetes, high blood pressure to depression and obesity.

Data capture can be defined from the top down, as when volunteer groups or

Engineers for CENS installing a robotic sensing system on the San Joaquin River in the California central valley.

Water quality and flow sensors positioned at the surface of the river.

individuals collect data for researchers, public officials or clinicians; or from the bottom up, as when communities with a common interest organize to systematically identify, document, and communicate issues that concern them.

PARTICIPATORY MHEALTH

Participatory mHealth leverages the power and ubiquity of mobile technologies to assist individuals and their doctors in monitoring and managing symptoms, side effects, and treatment for chronic illnesses outside the clinical setting, and to address the lifestyle factors that can bring on or exacerbate these conditions.

"We are taking advantage of the massively proliferated cell phone technology to apply mobilized and in-situ sensing observations to community health and public health issues," says CENS director Deborah Estrin.

People may be exposed to different levels of environmental and health risk depending on their particular lifestyles, which involve familiar variables such as diet and exercise but also where they go, what they breathe, how they travel, and other factors.

Principles of embedded network sensing may help researchers gain a better understanding of exposure levels encountered by individuals in their daily lives. In the case of asthma, for example, data from weather information and smog and pollution sensing stations might be combined with detailed location information and activity level information on patients collected through a cell phone to gain a better understanding of the disease.

By empowering individuals to track and manage their key health-related behaviors and outcomes, this approach has the potential to greatly improve people's health and quality of life while simultaneously reducing healthcare costs, says Estrin.

Participatory mHealth incorporates a variety of techniques, including automated activity traces, reminders, and prompted inputs. Intended to be used episodically rather than continuously, it can assist patients with adherence to their treatment regimen and provide useful information for clinicians. Employed by individuals, it can glean insights into what might be contributing to the recurrence of a chronic problem, or help them track and sustain a plan to become healthier through better diet, exercise, sleep, and stress management.

The software and methodology are adaptable for a wide variety of chronic disease interventions. For example, a pre-diabetic woman can use an application to keep tabs on how her eating and exercise habits affect her weight and energy levels. Her mobile phone prompts her for self-reports on her daily intake of carbohydrates and her daily exercise, while reminding her to check and record her weight and fatigue levels. A middle-aged man who doesn't respond well to the latest medication for psoriasis is trying to understand what combination of diet, stress and environmental exposure are most likely to lead to flare-ups. He can launch a data campaign via a social networking site for psoriasis sufferers, asking each volunteer member to download and use an application for systematic self-monitoring. The result: a large data set from which patterns can be mined to unravel the mystery of the condition.

VIEWPOINT

FROM THE DIRECTOR

Deborah Estrin

"I grew up with the Internet research community, which taught me about the value and the transformative effect of a community going after a vision together. No one person can create it—no one person could create the Internet, for example. That's my technical culture. That's how you have impact."

— CENS DIRECTOR DEBORAH ESTRIN

ENVIRONMENTAL APPLICATIONS

In another area of the CENS program, research has focused on developing embedded networked sensing technology to study soils, groundwater, and riparian systems. One application was a large-scale deployment on a major river segment: the confluence of the San Joaquin and Merced Rivers in Central California, a very important agricultural base for the nation.

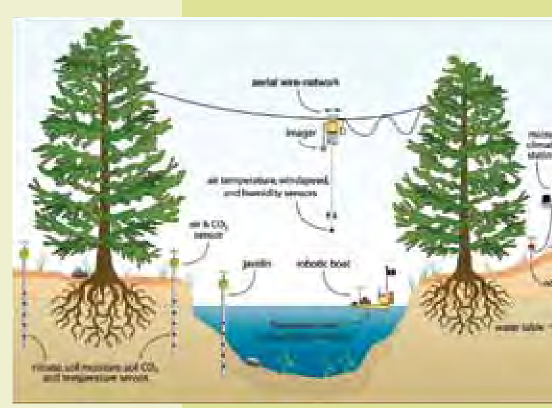
"In the Central Valley, there is a long-standing problem of high salt concentrations from agricultural runoff," explains Jeffrey Goldman, program development director at CENS. Previously, the state made makes measurements only very sparsely along the river at a single point. CENS research was aimed at providing a much more detailed view of the mixing, says Goldman, obtaining data that would be needed to better manage the flow of water and irrigation in the Central Valley.

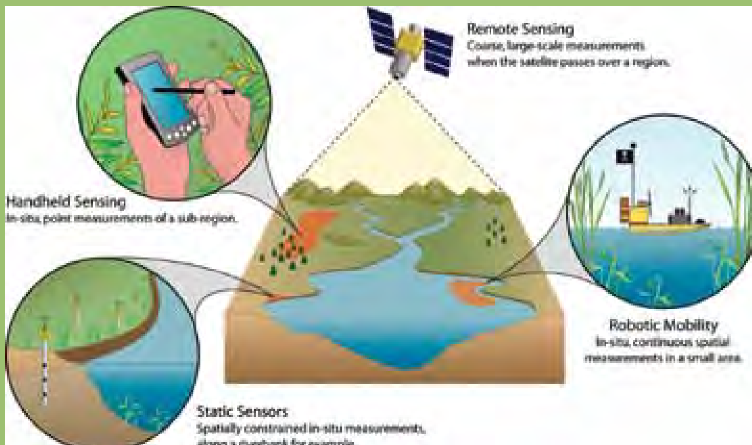
CENS researchers strung cables across the river and suspended a robotic shuttle from the cables. The shuttle can be controlled to move across the river and then up and down within the water in a grid pattern to make measurements on properties like nitrogen levels, dissolved oxygen, salt concentration, and flow."By deploying these technologies we've been able to see how mixing occurs, something that wasn't previously understood," notes Goldman.

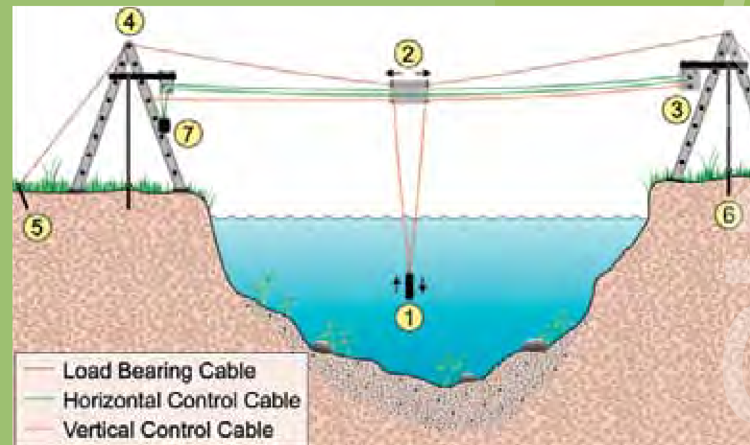
FUTURE DIRECTIONS

Besides these and many other applications, CENS researchers are exploring the fundamental research questions about the scientific and engineering design of embedded systems, and that work has helped this emerging field to evolve. "We've ended up in a different place than anticipated," Estrin admits. "Five to ten years ago we had an initial conception about what the problems were. But we've really learned from the experience what the real problems are and where the real challenges and opportunities are."

Throughout this process, communication has been key, says Goldman. "Engineers and computer scientists (each) have their own language. Left to their own devices, they would come up with something very neat, but not necessarily the most useful in the field," he laughs. "Explaining from the perspective of the biologist or seismologist in the field how the instrumentation needs to work—what's important and what's not—is critical to making things work."







CENS RESEARCHERS "MOBILIZE" IN SUPPORT OF EDUCATION

The goal of Mobilize is to strengthen computer science instruction in the educational system and to develop innovative methods for educating and engaging students–particularly those in underserved schools–in the area of computational thinking. At the heart of Mobilize is "participatory sensing"–a method of data collection and analysis in which students use mobile phones and web services to systematically collect and interpret data about issues important to them and their communities.

Mobilize is an NSF-supported partnership between the Los Angeles Unified School District (LAUSD), UCLA (through CENS and the Graduate School of Education), and the Computer Science Teachers Association (CSTA).

Smart phones are critical to the process of the kind of participatory sensing that is the heart of the Mobilize project. On the ground level, students use the phones to collect and record data in real-time. Observations are automatically tagged with geo-location and timestamp. Students can also use the phone to take pictures that are important for the data analysis component of the Mobilize curriculum.

The phones are more than a "hook" used to appeal to kids' fascination with technology--they are an invaluable tool for data collection and analysis, which is the crux of computer science education and key to the goals of the project," says center director Deborah Estrin.

The partners have designed a high school curriculum in which students learn about spatial analysis, temporal analysis, and text interpretation through their own data collection and analysis project. Through the use of custom designed participatory sensing software, students will embark on data campaigns using mobile phones and web services to learn about: the nature of data, its representation, formats, and protocols for sharing. They learn principles of computational thinking, problem-solving, and gain experience with algorithms, the rules governing data collection and strategies for analysis. They use tools of statistics and visualization and experience first-hand the intersection of mathematics, science, and civic engagement.