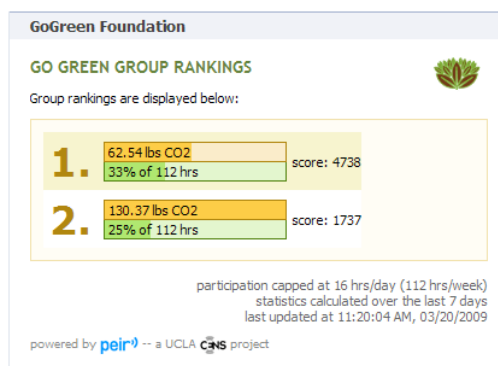


2.7 Urban Sensing (URB)

Urban sensing brings innovative measurement systems into everyday life. Sustainable design, healthy living, and effective stewardship of the world's limited resources require a deep understanding of how countless individual actions generate global effects and how individuals relate to their local environments—natural, built and cultural. Until now, scientists, NGOs, policy-makers, and the public have had to choose between examining the broad characteristics of large populations and looking at small groups in detail. Urban sensing targets technologies and applications that transform our capacity to help individuals, families, and communities to monitor and improve their health behaviors, adopt sustainable practices in resource consumption, and participate in civic processes. Its vision is of distributed data collection and analysis at the personal, urban, and global scale, often using “everyday” technologies like mobile handsets, in which participants make key decisions about what, where, and when to sense.

The area is entering its second generation of technology research and public pilots. We have learned from the initial deployments where our platforms need to be more robust and capable, and how to strengthen their relevance. New mobile handset, server and mote-class platforms have been incorporated into and we have expanded our user interface development efforts to provide more usable tools for individuals and groups. With the encouragement of the CENS External Advisory Board, we continue to deepen our approach to **participatory privacy regulation** of sensing that involves people, and are building the legal and technical foundations to support ethical design and deployment. Based on last year's experience in supporting medical and environmental science studies, CENS has developed the expertise to include IRB-authorized human subjects research in three of its projects this year, with another application in progress.

Health, sustainability, and civic engagement have solidified as key themes for our applications research. The technologies we're working with are well-suited to longitudinal and media-rich data collection needs in these areas. Faculty collaborations include new work in personal health and wellness with the Semel Center for Children and Families, as well as continued research on time-location travel patterns with the Dept. of Environmental Science and on cultural and civic applications with UCLA REMAP. The field continues to expand, as exemplified through a recent workshops and conferences (UrbanSense, MODUS, MobiUS) with submissions from CENS, Dartmouth, Carnegie Mellon, and many others. CENS research remains distinguished by the combination of (1) a participatory focus, which emphasizes the agency of individuals in deciding what to sense, when, and for whom, (2) the use of model-assisted sensing, in which widely-available modalities, such as location, are run through models to generate higher-level inferences, and (3) pilots with domain experts, as described below.



Pilot deployments

CENS has several ongoing pilot deployments of urban sensing systems, including mote-class hardware in the Spotlight project and mobile handset-based sensing in several projects. Over 150 Symbian, Windows Mobile, and Android mobile are currently distributed, with 66 active data plans supplied by CENS, through help from T-Mobile USA. This infrastructure supports real-world testing of a variety of applications. For example, the Personal Environmental Impact Report (PEIR) has been in continuous operation since the Spring of 2008, with a pool of about thirty test users, approximately five of which are active uploaders of location data at any given time. PEIR is an example of a “mobile plus web” application; it performs activity classification and model-based analysis of time-location traces gathered from mobile handsets to generate a personal report on environmental exposure and

impact. In February, 2009, we launched a public pilot of the project with high school students in the Bay Area in collaboration with the GoGreen Foundation, Nokia Research, and AT&T Mobility. The project plans to scale to about a hundred users within six months. PEIR was also invited for public demonstration at *Wired NextFest* last year, through which we learned of the deep interest of the public in such systems.

Experience from these and other deployments has guided our systems and testing approach for a second generation of systems included in this report. Specifically, it has (1) encouraged us to improve our representation of time-location traces from the basic “bag of points” approach (2) required near real-time model calculations in several cases, so that feedback can be provided to users soon after a sensed activity, (3) demonstrated the need for a robust framework for management, debugging, provisioning, and performance analysis of mobile sensing systems to enable more effective and scalable deployment, (4) shown that power consumption for continuous data collection remains a limiting factor for certain types of mobile sensing that will require improved sampling and communication techniques to mitigate, and (5) emphasized how important user interface design is to participant engagement and the ability to understand a system’s operation and data output.

Technology

Through support from NSF NeTS-FIND, Google, Nokia, Samsung, and Sun, we continue to develop technology platforms to support three types of urban sensing: (1) **Top-down** data gathering, in which domain experts design experiments or investigations and are the primary recipients of the resulting information. (2) **Bottom-up** data gathering, in which members of a community initiate, manage, and use coordinated data collection (3) **Self-reflective** data gathering, in which an individual gathers and consumes information from the system in a process of self-discovery. As our applications mature, it is clear that many systems are actually combinations of these three approaches.

Reusable platforms developed by CENS and used in many urban sensing projects include: (1) **Campaignr**, an XML-configurable mobile handset based data collection application, whose performance and stability on Symbian S60 was greatly improved this year and was ported from scratch to Windows Mobile; (2) **SensorBase**, described in the Data section of this report, whose query, programmatic control, speed, and storage capacity have been enhanced by its development team in response to urban sensing and other application area needs. Additionally, we are collaborating with Nokia Research Palo Alto on the use and power consumption analysis of **Nokoscope**, a modular background data collection platform for Nokia handsets, and USC has developed the **Urban Tomography** platform for robust mobile video collection. Through these and other application-specific platforms, we incorporated sensing on mobile handsets running Symbian, Windows Mobile, and Android, as well as SMS-based interaction from any phone, GPX data loggers, mote-class hardware, with a bridge to personal vehicle computers (and their sensors) available shortly. All of these data sources and platforms are used for insight into longitudinal assessment relevant to our key application areas described above.

Data collected and stored on these platforms is analyzed using a combination of activity classification, participation reputation and mobility profiling, and other approaches developed at CENS, as well as accepted scientific models (such as the California Air Resources Board’s Emissions Factors (EMFAC) model in PEIR) that have been incorporated into CENS systems. **Activity classification** algorithms are central to several projects. Similar to context awareness research, but intended to generate an annotated data stream for use in model-based processing and/or available to the participant, these apply statistical, signal processing, and geospatial analysis techniques to go from GPS time-location traces to classifications such as “driving”, “walking”, or “bicycling” or bluetooth proximity and audio level data to “at the dinner table” or “out for a walk.” To visualize and interact with raw and derived data we have focused on developing web standards based interfaces (e.g., the use of AJAX and CSS-based web interfaces for CycleSense and Flash for Remapping LA, and both in PEIR). Through the **GeoSIM** project, we have begun to explore next-generation 3D visualization and data fusion for community-based geospatial mapping and modeling.

Ethics, Law and Policy

This year, the area received funding from the NSF Ethics Education in Science and Engineering program for continued work to develop a formal ethics framework for participatory sensing, as well as study practices at CENS

and create related educational materials and courses. We have now applied for and received IRB approval for human subjects research in our own projects, including survey of our own participants and designers, and implemented an internal process at CENS to evaluate new pilot and study ideas for human subjects research issues. Our exploratory work on **participatory privacy regulation** and **selective sharing** mentioned in the last report has resulted in two new concrete efforts: first, to develop and implement an API for a “personal data vault” for time-location data and second, in collaboration with Professor Jerry Kang of the School of Law, to develop and propose legal principles and technical infrastructure that could help to protect not just data in the vault, but data shared and derived from it.

Planned Work

Based on this experience, we will delve deeper into the systems architecture and legal framework needed to support the “mobile personal sensing” that has become central to both participatory, community-oriented data collection and structured data collection in institutionally-organized settings. The data vault and privacy efforts are key to that, as well as work in parsimonious activity classification described in this report, which attempts to derive useful activity information from less intrusive (and less power-hungry) components than GPS. Geospatial data analysis and display continue to be important components for many of these systems, and we are exploring new research collaborations in these areas. Finally, the important opportunity to fuse data collection from multiple sensor classes, including application-specific wireless sensors, mobile handsets, and more complex instrumentation will be explored as we seek multiscale and multimodality sensing to best support our applications.