

Poster & Demonstration Abstracts

2009 CENS Annual Research Review

Wednesday, October 28, 2009

8:30 AM – 2:30 PM

Grand Horizon Ballroom, Covel Commons

UCLA Campus

SYSTEMS (SYS 1–12)

SYS 1 Systems Research Overview

Jeff Burke, Deborah Estrin, Ramesh Govindan, Richard Guy, Mark Hansen, William Kaiser, Eddie Kohler, Rupak Majumdar, Todd Millstein, Jens Palsberg, Miodrag Potkonjak, Mani Srivastava, Gaurav Sukhatme, John Villasenor

SYS 2 Controlled Personal Data Stream in Mobile Personal Sensing

Min Mun, Shuai Hao, Nilesh Mishra, Katie Shilton, Jeff Burke, Mark Hansen, Ramesh Govindan, Deborah Estrin

Mobile Personal Sensing (MPS) is a new kind of participatory sensing where individuals and communities use mobile phones and web-based services to collect and analyze data for use in discovery. While MPS enables people to participate in sensing and analyzing aspects of their lives that were previously invisible, it introduces some constraints due to the inherently intimate nature of the data captured with MPS, which results in concerns for protecting individual privacy, for personal data stream ownership, and for visibility into the web of processing that is used to contextualize and interpret the data. We propose to develop a Personal Data Vault (PDV), a privacy architecture allowing people to control over their data flows over time, with emphasis on controlling the granularities of location data. In addition, we suggest a new method to allow users to use less-granular data for the applications requiring exact location information by partitioning the applications.

SYS 3 Dynamic Data Compression in Multi-hop Wireless Networks

Abhishek Sharma, Leana Golubchik, Ramesh Govindan, Michael Neely

Data compression can save energy and increase network capacity in wireless sensor networks. However, the decision of whether and when to compress data can depend upon platform hardware, topology, wireless channel conditions, and application data rates. In this paper, using Lyapunov optimization theory, we design an algorithm called SEEC that makes joint compression and transmission decisions with the goal of minimizing energy consumption. SEEC has a centralized controller that is not suited for large sensor networks. Hence, we also designed a practical distributed variant of SEEC, called dSEEC, that is able to achieve more than 30% energy savings and adapts seamlessly across a wide range of conditions, without explicitly taking topology, application data rates, and link quality changes into account.

SYS 4 Efficiently Synchronizing Sharing between Loosely-coupled Sensornets

Unkyu Park and John Heidemann

Today most sensornet deployments stand alone, providing data internally or perhaps to a custom Internet portal. In the future, we look to standardized ways of sharing data over the Internet so research results can build on each other. As data becomes shared in real-time streams, timely data synchronization is increasingly important. Today, such sharing is often hard-coded or driven by fixed-interval polling. Fixed-interval polling provides poor worst-case performance (mean latency approaches the data polling period), and best performance is unstable without careful manual configuration of both poll period and phase. We instead propose Data Publication Tracking (DPT), a new family of adaptive polling algorithms that learn and predict good times to pull data to minimize both latency and unfruitful queries.

SYS 5 Energy Delay Tradeoffs in Smartphone Applications

Moo-Ryong Ra, Jeongyeup Paek, Abhishek Sharma, Ramesh Govindan, Martin Krieger, Michael Neely

Many emerging smartphone sensing applications are data-intensive and often need to transport large volumes of data. To support such applications, recent smartphones have multiple wireless interfaces – 3G/EDGE and WiFi – that enable access to the Internet. However, there is considerable variability in the availability and achievable data transfer rate for these networks. Moreover, the energy costs for transmitting a given amount of data on these wireless interfaces can differ by an order of magnitude. On the other hand, these sensing applications are often naturally delay-tolerant, so that it is possible to delay data transfers until a lower energy WiFi connection becomes available. In this work, we present a principled approach for designing an optimal online algorithm for this energy-delay tradeoff using the Lyapunov optimization framework. Our algorithm uses a single parameter, can automatically adapt to channel conditions and requires only local information to decide whether and when to defer a transmission.

SYS 6 Energy-Efficient Activity-Detection via Multi-hypothesis Testing for Pediatric Obesity

Gautam Thatte, Ming Li, Adar Emken, Urbashi Mitra, Shri Narayanan, Murali Annavaram, Donna Spruijt-Metz

We consider multi-hypothesis activity-detection in a wireless body area network (WBAN). The fusion center receives biometric samples from heterogeneous sensors, and the number of samples collected from each of the sensors is optimized to minimize the probability of misclassification between the multiple hypotheses. As each sensor has different discrimination capabilities, optimal sample allocation results in an overall energy savings in our Bluetooth-based experimental WBAN. In addition, as the number of samples is an integer, further energy reduction is achieved by developing an unconstrained approximation to the probability of misclassification which allows for a continuous-valued vector optimization. The unconstrained optimization yields approximately optimal allocations with significantly lower complexity.

SYS 7 Location Discovery Infrastructure

Caleb Leak and Miodrag Potkonjak

The issue of creating a location discovery infrastructure (LDI) conducive to effective location discovery (LD) has received little attention. On this poster we formalize the issue and address it by providing (i) A new effective measurement error model (ii) A new atomic LD discovery objective function (iii) Several ways for accurately predicting LD error based on network topology (iv) A non-linear program (NLP) that effectively places beacon nodes to minimize LD error.

SYS 8 Minimizing Log Bandwidth for Wireless Embedded Systems

Roy Shea, Young Cho, Mani Srivastava

Wireless embedded systems are characterized by severe bandwidth limitations, tight timing constraints, and minimal processing capabilities. These constraints limit the application of traditional interactive monitoring and debugging techniques, forcing developers to turn towards diagnostic logs to understand the runtime behavior of deployed systems. This work introduces the Log Instrumentation Specification (LIS). LIS provides a language to help developers describe logging tasks, analysis and instrumentation to efficiently accomplish the logging task, and support to collect runtime logs.

SYS 9 Putting Usage in the Loop: adapting smartphone energy management to user behavior

Hossein Falaki, Ramesh Govindan, Deborah Estrin

One of the challenges of running participatory/personal sensing applications on smart phones is managing energy consumption of these applications. The industry does not expect rapid increase in the capacity of mobile phone batteries in the near future, but the energy demand is growing at a much faster rate due to new applications. In this poster we present a new approach to energy management on mobile phones: Instead of trying to simply reduce energy consumption of individual applications to increase battery life time, we place the users in control of their battery life. Our system translates the user specified deadline to an "energy budget" for each application, including background sensing applications. Applications then have to live with their given budget or die. We present our architecture and design for

this new power management system. We will also discuss the technical challenges of such a system and how we intend to address those using statistical learning techniques.

SYS 10 Time in Wireless Embedded Systems

Thomas Schmid, Dustin Torres, Mani Srivastava

Wireless embedded networks have matured beyond academic research as industry now considers the advantages of using wireless sensors. With this growth, reliability and real-time demands increase, thus timing becomes more and more relevant. In this dissertation, we focus on the development of highly stable, low-power clock systems for wireless embedded systems. Wireless embedded networks, due to their wire-free nature, present one of the most extreme power budget design challenges in the field of electronics. Improvements in timing can reduce the energy required to operate an embedded network. However, the more accurate a time source is, the more power it consumes. To comprehensively address the time and power problems in wireless embedded systems, this dissertation studies the exploitation of dual-crystal clock architectures to combat effects of temperature induced frequency error and high power consumption of high-frequency clocks. Combining these architectures with the inherent communication capabilities of wireless embedded systems, this dissertation proposes two new technologies; (1) a new time synchronization service that automatically calibrates a local clock to changes in temperature; (2) a high-low frequency timer that allows a duty-cycled embedded system to achieve ultra low-power sleep, while keeping fine granularity time resolution offered only by high power, high frequency clocks.

SYS 11 TOSThreads: Thread-Safe and Non-Invasive Preemption in TinyOS

Kevin Klues, Chieh-Jan Mike Liang, Jeongyeup Paek, Razvan Musaloiu-E., Philip Levis, Andreas Terzis, Ramesh Govindan

Many threads packages have been proposed for programming wireless sensor platforms. However, many sensor network operating systems still choose to provide an event driven model, due to efficiency concerns. We present TOSThreads, a threads package for TinyOS that combines the ease of a threaded programming model with the efficiency of an event-based kernel. TOSThreads is backwards compatible with existing TinyOS code, supports an evolvable, thread-safe kernel API, and enables flexible application development through dynamic linking and loading. In TOSThreads, TinyOS code runs at a higher priority than application threads and all kernel operations are invoked only via message passing, never directly, ensuring thread-safety while enabling maximal concurrency. The TOSThreads package is non-invasive; it does not require any large-scale changes to existing TinyOS code. We demonstrate that TOSThreads context switches and system calls introduce an overhead of less than 0.92% and that dynamic linking and loading takes as little as 90 ms for a representative sensing application. We compare different programming models built using TOSThreads, including standard C with blocking system calls and a reimplement of Tenet. Additionally, we demonstrate that TOSThreads is able to run computationally intensive tasks without adversely affecting the timing of critical OS services.

SYS 12 Verifying Time-Dependent Program Properties Using Timed Automata

Xiaoli Gong, Kannan Goundan, Jens Palsberg

We've written a tool that converts small embedded software programs (written in an object-oriented programming language, Virgil) into timed automata. The automata is then fed to the Uppaal model checking software, which analyzes the automata to determine whether certain properties are satisfied. For example, "does the interrupt handler finish running in time?" Timed automata are a good translation target because they have explicit support for timed delay and multiple simultaneous processes.

MULTI-SCALE ACTUATED SENSING (MAS 1—9)

MAS 1 Multi-scale Actuated Sensing Overview

G. S. Sukhatme, D. Caron, D. Estrin, U. Mitra, G. Pottie, S. Soatto, K. Yao, F. Arrichiello, D. Liu, R. Smith, A. Ali, J. Binney, N. Chehade, C.E.Chen, C.K. Chen, K. Dantu, J. Das, H. Heidarsson, R.E. Hudson, J. Hyman, J. Kelly, T. Ko, F. Lorenzelli, R. Mottaghi, A. Pereira, S. Poduri, S. Yerramalli

MAS 2 A Benthic Robotic Sentinel

Jnaneshwar Das, Arvind Pereira, Hörður Heiðarsson, Beth Stauffer, Carl Oberg, Lindsay Darjany, David Caron, Gaurav Sukhatme

This work presents a novel benthic robotic observing system designed to periodically patrol a transect while capturing images of the water above it. Using a combination of inertial sensing, absolute position measurements at the transect endpoints, and a simple dynamic model, we are able to apply a Kalman smoother to obtain accurate position estimates for the robot. These estimates are used a posteriori to align sensor scans of the water made by the main observational instrument on the robot - an Acoustic Doppler Current Meter (ADCM). The aligned scans produce a map of unprecedented accuracy and coverage (presently such measurements are typically made by manually lowering the ADCM or winching it down).

MAS 3 Active Learning of Sunfleck Distributions by Continuous Mobile Sensing

Andrew Parker and Mark Hansen

There are many examples of environmental phenomena that can be approximated by a random set on a 2-D field. A well studied example of a random set is the Boolean Model, realizations of which can be generated from the union of random closed sets located at points corresponding to a Poisson point process. We will demonstrate a method for reconstructing a realization of a Boolean model conditioned on a series of line segment observations, as well as how to choose the next series of observations. We will also present the results of applying this technique to the sampling and reconstruction of sunfleck distributions in a simulated framework.

MAS 4 Design and Implementation of Trajectories for Autonomous Underwater Vehicles based on Predictions from a Regional Ocean Model

Ryan Smith, Arvind Periera, Yi Chao, Carl Oberg, Matthew Ragan, David Caron, Burton Jones, Gaurav Sukhatme

Trajectory design for Autonomous Underwater Vehicles (AUVs) is of great importance to the oceanographic research community. Intelligent planning is required to maneuver one or many vehicles to high-valued locations to collect data with scientific merit. We consider the use of ocean model predictions to determine the locations to be visited by a team of AUVs, which then provides near-real time, in situ measurements back to the model to increase model skill and the accuracy of future predictions. Iterative application of this procedure determines relevant points of interest that allow an AUV fleet to monitor and track an evolving oceanographic feature. One interest of this study is to track a freshwater plume, as their nutrient-rich water promotes productivity, and may result in the formation of a Harmful Algal Bloom (HAB). Monitoring and predicting the formation and evolution of HABs is an area of active research for Southern California coastal communities due to their production of harmful toxins that can affect humans and marine wildlife. Movement of the chosen feature is predicted by use of the Regional Ocean Modeling System (ROMS) oceanic model applied to our primary area of interest, the Southern California Bight (SCB). Based on the particular feature, the ROMS prediction, the available number and type of AUVs and the duration of the sampling mission, an algorithm determines waypoints (sampling locations) for the AUV(s) to visit. A trajectory for each vehicle is then generated based on the computed waypoints. We design sampling missions and present simulated scenarios and results from field deployments for AUV feature tracking in the Southern California coastal ocean. This research represents a first approach to an end-to-end autonomous prediction and tasking system for aquatic, mobile sensor networks.

MAS 5 Imagers as Sensors: tracking pollinator visitation

Josh Hyman, Mark Hansen, Deborah Estrin

Pollinator behavior and their impact on the ecosystems is currently undergoing significant biological study. However, biologists typically resort to observing the flower or plant of interest directly (either in person or via video) in order to gather occupancy and pollination data. We describe a process for automatically detecting pollinator occupancy from video, showing only interesting clips to the end-user.

MAS 6 NatureCam: detecting animals in the natural environment through video analysis

Teresa Ko, Deborah Estrin, Stefano Soatto

Cameras are a natural choice of sensors for monitoring natural habitats. They are cheap, both in terms of cost and energy, and at the same time data-rich. They are remote - not requiring contact - and passive - not requiring signals to be broadcast. At the same time, they can be tuned to be sensitive to different bands, most commonly the visible and near-infrared spectra. Sensing the environment with images requires modeling the complex spatio-temporal statistics of the objects and events of interest, as well as the nuisances, for they often overlap due to natural adaptation of species to their habitats. Unlike monitoring indoor or urban environments, where one can assume a static background, monitoring natural environments requires modeling the distributional properties of portions of images (natural textures) and their temporal evolution, and learning the natural statistics from training data. For instance, detecting the presence of a bird at a feeder station from an image collected by an embedded imaging sensor can be difficult even for a trained expert. However, extended observation reveals the characteristic variability of the object and enables successful detection, localization and species recognition. Different species can exhibit different appearance, depending on their pose, and different patterns of typical motion. These in turn are different from the characteristic background motion, for instance foliage moving in wind. We describe algorithms for recognizing objects and events based on extended observations of spatial and temporal statistics.

MAS 7 Informative Path Planning for an AUV

Jonathan Binney and Gaurav Sukhatme

We present an algorithm for autonomously planning paths for an Autonomous Underwater Vehicle (AUV). Our approach is based on an existing informative path planning algorithm for robots, which we have extended to handle the unique challenges presented by AUVs. The presented algorithm handles edge based (rather than node based) sample locations, and also avoids high traffic areas during specified time windows. Results are shown for paths planned using actual pilot data collected on a specific AUV, the Webb Slocum Glider.

Robust Connectivity in Robot Networks

Karthik Dantu and Gaurav Sukhatme

Reliable wireless connectivity is a fundamental requirement for many cooperative tasks performed by a robot team. Redundancy is one way to achieve reliability. We study the following redundant connectivity problem in a robot network. Given a network of mobile robots, plan and execute a minimal sequence of robot movements that will cause the network to become biconnected. We address this problem in situations where accurate robot localization is non-trivial e.g., indoors or other GPS-denied environments. While autonomous localization is often a challenge, we observe that in such situations robots are able to approximately measure relative bearing to their neighbors using local sensing. Here, we propose, implement, and evaluate an algorithm to plan a sequence of robot movements to attain biconnectivity in a robot network. The algorithm uses inter-robot coarse relative bearing, obtained from RSSI measurements, as input. We prove that the execution of the algorithm under a disk communication model is: 1. guaranteed to cause a monotonic increase in the number of edges in the network graph, and 2. guaranteed to add the minimum number of edges required to attain biconnectivity. In practice, when robots execute movements, they do not do precisely and their communication characteristics do not conform to the disk model. Extensive simulations suggest that the proposed algorithm is robust to noise in robot odometry and robot turn angle. Importantly, it is also robust to error in relative bearing measurement, tolerating up to 25 average errors without failure. We report simulation results showing that the biconnected robot network exhibits a decrease of 20 - 30% in the average path length between all

node pairs. The average number of vertex-disjoint paths to each node increases by approximately 60%. The cost of these increases is a 33% reduction in the physical area enclosed by the convex hull of the nodes in the network. In experiments using a network of physical robots we show how commodity radios can be used to compute relative bearing. The resulting bearing estimates, while coarse, are sufficient for the algorithm to terminate successfully. These experiments show a 5 - 8% increase in packet reception rate while increasing throughput by approximately 12%. Our results establish theoretical optimality for the proposed algorithm and demonstrate its feasibility and noise tolerance empirically, while characterizing its effect on network connectivity and coverage.

Self-Calibration of Omnidirectional Visual and Inertial Sensors for Mobile Environment Mapping

Jonathan Kelly and Gaurav Sukhatme

Omnidirectional cameras are versatile sensors that are able to provide a full 360 degree view of the environment. When combined with inertial sensing, omnidirectional vision offers a very robust solution for mobile environment mapping. However, in order to correctly fuse the data from an omnidirectional camera and an inertial measurement unit (IMU) into a single reference frame, the six degrees-of-freedom (6-DOF) transform between the sensors must be accurately known. Calibration of this transform is time consuming and usually requires additional equipment. We describe an algorithm, based on the unscented Kalman filter, for self-calibration of the transform between an omnidirectional camera and an IMU. Our approach explicitly accounts for the time correlation between IMU measurements, and does not require any additional hardware.

SENSOR DEVELOPMENT (SEN 1–4)

SEN 1 New Wireless Miniature Sensor Technologies for CENS

Buddy Aswin, Christopher Butler, David Caron, Jay Chang, Thomas Harmon, Chih-Ming Ho, Jack Judy, Dohyun Kim, Mike Liu, Alexander Rat'ko, Leyla Sabet, Astrid Schnetzer, Erica Seubert, Wendian Shi, Beff Stauffer, Yu-Chong Tai

SEN 2 Field Operational Electrochemical Sensor for Studying the Impact of Marine Environmental Changes on Production of Domoic Acid

Leyla Sabet and Chih Ming Ho

In field operational electrochemical sensor, for studying the impact of marine environmental changes on production of Domoic Acid project, an electrochemical immunosensor is engineered for detection of Domoic Acid (DA) with a competitive assay. Domoic Acid is a neurotoxic amino acid responsible for the "Amnesic Shellfish Poisoning" (ASP) syndrome. The immunosensor is portable therefore it potentially can be used on the field. The time required for detection is less than 2 hours. Competitive assays generally have a very narrow detection range. Our results show that the detection range of the immunosensor is wider by an order of magnitude compared to the Elisa plates using the same antibody. The sensitivity of the immunosensor for the DA in buffer is two times better than the Elisa. The immunosensor is tested with DA in buffer, culture medium and also spiked in the solution of lysed cells. The performance of the immunosensor is best with DA in buffer and it is better in the lysed cell solution than in the culture medium.

SEN 3 In-situ UV Nitrate Sensor for Environmental Monitoring

Dohyun Kim, Buddy Aswin, Jack Judy

A microfabricated optical sensor is proposed for a miniature, inexpensive and sensitive in-situ nitrate-monitoring system. Spectrochemical methods are the most widely used method for nitrate determination due to the excellent limits of detection, selectivity, and a long-term stability. We will construct a highly-minaturized spectrochemical system (deuterium UV source, liquid-core-capillary-waveguide sensor, integrated spectrometer module, and data-acquisition PC). Then, we will measure nitrate concentration in groundwater with multi-variate, UV spectral analysis to distinguish nitrate spectra from erroneous signals suppress interference. The capillary waveguide will be designed and microfabricated to increase the sensitivity [of the sensor]. As a first application, the nitrate concentration in groundwater measured with a bench-top commercial UV spectrophotometer and multivariate analysis. The linearity of nitrate

determination using the bench-top spectrometer over wide range (i.e., 10^{-7} to 4×10^{-4}) was obtained. After we construct the miniaturized optical sensor the result will be compared with a result from the bench-top spectrometer.

SEN 4 Lab-on-Chip Aquatic Microorganism Analysis System

David Caron, Han-Chieh (Jay) Chang, Chih-Ming Ho, Mike Liu, Leyla Sabet, Astrid Schnetzer, Wendian Shi, Beth Stauffer, Yu-Chong Tai

This is a project that aims to expedite research in marine biology using chip-based and state-of-the-art detection technology. The project is a joint effort that will incorporate the expertise of three different groups, Dr. Chih-Ming Ho at UCLA, Dr. David Caron at USC and Dr. Yu-Chong Tai at Caltech. One main focus of the project is to develop lab-on-a-chip devices that reduce total sample volume and detection time. Also, the chips can be fabricated in large quantities with minimal cost so many experiments can be run in parallel. Here at Caltech, a portable cytometer for counting and identifying different types of algae and a chip to culture a small number of algae and screen for factors inducing toxin production will be developed. The cytometer can allow researchers to quickly know the algae concentration to monitor algae growth. Algal bloom and toxins produced by different algae have always caused problems to the environment and marine ecology. Pseudo-nitzschia is one type of algae that produces a neural toxin called domoic acid, which when transferred through the food chain causes sickness and mortality in marine mammals and seabirds. However, during Pseudo-nitzschia bloom, domoic acid is not always produced. In another word, growth of algae does not equal domoic acid production. Studies done by other groups have suggested that many factors (such as trace metal, macronutrient, or ionic concentration) might induce or suppress algae to produce toxin. Yet, exact causes are unclear. To completely elucidate the causes of toxin production, many potential compounds will have to be screened. This leads to an enormous amount of experiments to be performed and large quantity of reagents and cells to be used. To speed up the process of screening for possible factors inducing toxin production, we would like to make a chip to culture Pseudo-nitzschia under different growing conditions. At the same time, an Ultra Sensitive Electrochemical Sensor will be developed for detection of domoic acid at Dr. Chih-Ming Ho's lab at UCLA. The current state-of-the-art detection technology indicates that per cell toxin load may range over 2 or 3 orders of magnitude but its sensitivity is limited since a sample size of at least 100 cells/mL is required. The new sensor will be able to push the sensitivity to 10 cells/mL or to even single molecules of domoic acid. This sensor will not only enable the detection of domoic acid produced by algae cells inside the culture chip, such sensor will also have the broad application of detecting domoic acid from field samples.

STATISTICS & DATA PRACTICES (STA 1–6)

STA 1 Overview of CENS Statistics & Data Practices Research

David Fearon, Matt Mayernik, Keith Mayoral, Sheela Nair, Andrew Parker, Alberto Pepe, Erick Romero, Abhishek Sharma, Jillian Wallis, Yuan Yao, Richard Guy, Mike Taggart, Christine Borgman, Deborah Estrin, Leana Golubchik, Ramesh Govindan, Mark Hansen

STA 2 Fault and Anomaly Detection in Sensor Systems

Yuan Yao, Abhishek Sharma, Leana Golubchik, Ramesh Govindan

In this work we focus on fault and anomaly detection in sensor network systems. Various sensor network measurement studies have reported instances of transient faults in sensor readings. In this work, we seek to answer a simple question: How often are such faults observed in real deployments? We focus on three types of transient faults, caused by faulty sensor readings that appear abnormal. To understand the prevalence of such faults, we first explore and characterize four qualitatively different classes of fault detection methods. Rule-based methods leverage domain knowledge to develop heuristic rules for detecting and identifying faults. Estimation methods predict "normal" sensor behavior by leveraging sensor correlations, tagging anomalous sensor readings as faults. Time series analysis based methods start with an a priori model for sensor readings. A sensor measurement is compared against its predicted value computed using time series forecasting to determine if it is faulty. Learning-based methods infer a model for the "normal" sensor readings using training data, and then statistically detect and identify classes of faults. We find that these four classes of methods sit at different points on the accuracy/

robustness spectrum. And we apply these techniques to four real-world sensor data sets and find that the prevalence of faults as well as their type varies with data sets. All four methods are qualitatively consistent in identifying sensor faults. We are trying to expand our work to anomaly detection which focuses on a broader range of events. We propose a similarity based method to detect longer duration anomalies.

STA 3 Making CENS Data Visible: facilitating the discovery and use of data products

Matthew Mayernik, Jillian Wallis, Christine Borgman

Research data is a valuable intellectual product of CENS. Data produced by CENS researchers have many potential uses, including in policy and educational settings, as well as by researchers both inside and outside the center. This poster describes our work in making CENS data more visible for sharing and use. We describe the requirements for making CENS data "discoverable". This includes two main steps: 1) creating metadata descriptions that allow potential users can find out that CENS data exists, assess that it may be useful to them, and find out how they can either get direct access to the data or contact the relevant person in CENS for more information, and 2) presenting those metadata descriptions online in a way that allows them to be found through web search engines. We outline our current and planned efforts in designing workflows and systems to facilitate these goals.

STA 4 Micro-blogging from the Field: capturing contextual information in highly mobile research

Erick Romero, Matthew Mayernik, Alberto Pepe, Christine Borgman

We present the conceptual design of a mobile phone application that collects and stores descriptive contextual data from field research activities in the form of micro-blog posts, or brief text updates. We present current work in the context of ongoing research at CENS to develop an application for the Windows Mobile platform that allows simple forms of field data collection and note-taking. We discuss how micro-blogging tools can accommodate very well the variable and unpredictable nature of highly mobile research and represent a suitable mechanism to augment the context of information collected in real-world environments. Our goal is to facilitate the collection of clean, well described, and interconnected data that can be easily used and re-used by the researchers who collected them, and potentially by people outside CENS.

STA 5 Trade off in Sample Sizes and Reconstruction Complexity

Yu-Ching Tong and Greg Pottie

We compare adaptive sampling with compressive sampling in the reconstruction problem. Several examples demonstrate that an adaptive, local cooperation approach can be nearly as effective as the optimal global approach, and in some cases more robust to modeling error.

STA 6 your.flowingdata: an application to collect data about yourself with twitter

Nathan Yau & Mark Hansen

We make tiny choices every day. Those choices become habits, and those habits develop into behaviors. your.flowingdata (YFD) helps you record and explore these choices. YFD takes advantage of Twitter's ubiquity and a simple data entry language to make personal data collection easy. About 100,000 data points have been entered by 2,000 users tracking things like calorie consumption, sleep patterns, mood, and time spent on the subway. Users have also taken advantage of Twitter's API to automate data logging programmatically with metrics such as weather and online music listening. Finally, some users are not using YFD for themselves at all; rather they are using YFD to log data about their newborn children, pets, or their surroundings. Once data are logged, users can login to the YFD site to explore their data with interactive visualizations.

AQUATIC OBSERVING SYSTEMS (AQU 1–3)

AQU 1 Networked Aquatic Microbial Observing Systems: an overview

David Caron, Beth Stauffer, Lindsay Darjany, Carl Oberg, Arvind Pereira, Jnaneshwar Das, Hordur Heidarsson, Ryan Smith, Ellen Smith, Erica Seubert, Marie-Eve Garneau, Meredith Howard, Burt Jones, Ivona Cetinic, Gaurav Sukhatme

AQU 2 Networked Robotic Sensor Platform Deployments for use in Coastal Environmental Assessment in Southern California

Arvind de Menezes Pereira, Jnaneshwar Das, Hordur Heidarsson, Ryan Smith, Beth Stauffer, Erica Seubert, Marie-Eve Garneau, Meredith Howard, Lindsay Darjany, Carl Oberg, Ivona Cetinic, Matthew Ragan, Ellen Smith, Gerardo Toro-Farmer, Filippo Arrichiello, David Caron, Astrid Schnetzer, Burton Jones, Gaurav Sukhatme

Mobile sensor platforms such as Autonomous Underwater Vehicles (AUVs) and robotic surface vessels, combined with static moored sensors compose a diverse sensor network that is able to provide macroscopic environmental analysis tool for ocean researchers. Working as a cohesive networked unit, the static buoys are always online, and provide insight as to the time and locations where a federated, mobile robot team should be deployed to effectively perform large scale spatio-temporal sampling on demand. Such a system can provide pertinent in situ measurements to marine biologists whom can then advise policy makers on critical environmental issues. This poster presents recent field deployment activity of AUVs demonstrating the effectiveness of our embedded communication network infrastructure throughout southern California coastal waters. We also report on progress towards real-time, web-streaming data from the multiple sampling locations and mobile sensor platforms. Static monitoring sites included in this presentation detail the network nodes positioned at Redondo Beach and Marina Del Ray. One of the deployed mobile sensors highlighted here are autonomous Slocum gliders. These nodes operate in the open ocean for periods as long as one month. The gliders are connected to the network via a Freewave radio modem network composed of multiple coastal base-stations. This increases the efficiency of deployment missions by reducing operational expenses via reduced reliability on satellite phones for communication, as well as increasing the rate and amount of data that can be transferred. Another mobile sensor platform presented in this study are the autonomous robotic boats. These platforms are utilized for harbor and littoral zone studies, and are capable of performing multi-robot coordination while observing known communication constraints. All of these pieces fit together to present an overview of ongoing collaborative work to develop an autonomous, region-wide, coastal environmental observation and monitoring sensor network.

AQU 3 Physical, Chemical, and Biological Factors Shaping Phytoplankton Community Structure in Santa Monica Bay and Redondo Beach, California

Beth Stauffer, Lindsay Darjany, Jnaneshwar Das, Carl Oberg, Ellen Smith, Gaurav Sukhatme, David Caron

Through the NAMOS project, our team of biologists and engineers are assisting municipalities in understanding the underlying causes and effects of harmful microalgal blooms. Since early 2007, we have been studying system-level dynamics of the chemical, physical, and biological processes in King Harbor, a shallow, semi-enclosed urban harbor in Redondo Beach, California. For the last two years a network of dock-based water quality sensors in the harbor has continuously provided data on the environmental parameters relevant to bloom formation. Additionally, intensive human-mediated studies of the phytoplankton community distribution and structure are testing several hypotheses on the biological and physical factors affecting algal growth in this system. Recent field experiments have sought to explain the roles of tidal forcing and phytoplankton behavior and physiology in the structuring and distribution of bloom-forming algal communities.

CONTAMINANT TRANSPORT OBSERVING SYSTEMS (CON 1–8)

CON 1 An Overview of CENS Contaminant Transport Observation and Management Research

Thomas Harmon, Jenny Jay, Jose Saez, William Kaiser, Steve Margulis, Alexander Rat'ko, Chu-Chin Lin, Jason Fisher, Che-Chuan Wu, Christopher Butler, Dolvin Buchanan, Gary Byrn, Henry Pai, Kelly Havens, Marvin Hermosillo, Nithia Mananathan, Patrick Barnes, Sandra Villamizar Amaya, Thanos Stanthopoulos, Tiffany Lin, Yeonjeong Park

CON 2 Assessing Stream Light Incidence Using Digital Cameras and Inexpensive Light Sensors

Patrick Barnes, Jinxia Zhu, Donghai Li, Sandra Villamizar-Amaya, Christopher Butler, Henry Pai, Qinghua Guo, Thomas Harmon

The energy balance within a river reach is influenced significantly by the availability of light that can be used by primary and secondary producers. We are proposing a method to rapidly and inexpensively characterize the amount of available light within a river reach. We tested our approach within a 50 meter segment of the lower Merced River in California, where flows are heavily affected by the current reservoir operations and agricultural withdrawals and inputs. Overhead images taken with a network security camera were used in conjunction with inexpensive, self-logging temperature and light sensors installed at multiple locations at the water surface (used as ground truth points) to capture changes in the light and shade patterns within the study reach. The Multivariate Alteration Detection (MAD) technique with decision thresholds was used to identify changes in shadow for a given image pixel. The changes in shadow (increase or decrease) were classified based on scale, color (spectral properties), and shape (smoothness and compactness). A strong inverse relationship between changes in shadow and changes in light intensity was observed. The preliminary results suggest the feasibility of the proposed method for rapidly characterizing riparian vegetation-stream shading conditions over time and space, and their relation to river metabolism.

CON 3 Assimilation of Soil Measurements from an Embedded Sensor Network (Palmdale, CA) into a Hydrologic and Solute Transport Model to Estimate Soil States, Parameters, and Fluxes

Che-Chuan Wu, Steven Margulis, Thomas Harmon

In the past decades, high-quality water availability has become a serious concern around the world due to the rapid population growth and finite supply of natural freshwater. To reduce the demand of freshwater, farmers are increasingly using alternative water supplies for irrigation including urban waste waters which contain elevated solutes (e.g. NaCl and Nitrogen). In Los Angeles, the County Sanitation District applies four million gallons of treated wastewater per day in Palmdale, CA, with a goal of wastewater reuse via irrigation. However, excessive chemical from wastewater could restrain crop growth and even pollute the groundwater beneath the irrigated lands. To avoid these adverse impacts on the infiltration basins used for wastewater disposal, a monitoring and modeling system providing current soil state and flux estimates is absolutely necessary to guide the management of wastewater release. In this study, the Palmdale site is treated as a testbed, and a state-of-the-art methodology, data assimilation, is applied to estimate real-time soil states, fluxes and soil hydraulic parameters, which control the residence time of the chemicals in the vadose zone. In our current work, we have verified the feasibility of an ensemble data assimilation approach, (Ensemble Kalman Filter [EnKF]), to estimate system state variables, fluxes, and even soil hydraulic parameters in a complex, stratified soil system provided adequate placement of the embedded sensing network. The system is designed to be flexible and can assimilate multiple data streams including soil moisture, temperature, and solute (e.g. salinity, nitrate) concentration measurements.

CON 4 Bangladeshi Site-Based Investigation of Arsenic Mobilization Mechanisms: a comparison of mineral dissolution and iron hydroxide respiration

Tiffany Lin, Rita Kampalath, Jenny Jay

The presence of arsenic in the groundwater has led to the largest environmental poisoning in history. Although it is a worldwide issue that affects numerous countries, including Taiwan, Bangladesh, India, China, Mexico, Peru, Australia, and the United States, the issue is of greatest concern in the West Bengal region. In the Ganges Delta, as many as 2 million people are diagnosed with arsenicosis each year. Additionally, the World Health Organization (WHO) estimates 200,000 to 270,000 arsenic-induced cancer-

related deaths in Bangladesh alone. 50% of the 8 million wells in Bangladesh contain groundwater with arsenic levels greater than 10 $\mu\text{g/L}$. As a result, more than 100 million people in the country consume groundwater that exceeds the WHO limit. Despite the tragic public health implications of this problem, we do not yet have a complete answer to the question of why dissolved arsenic concentrations are so high in the groundwater of the Ganges Delta. Since 1999, we have been intensively studying a field site in Munshiganj, Bangladesh with extremely high levels of arsenic in groundwater (up to 1.2 mg/L). It was previously believed that the rice paddies are key sites of arsenic mobilization; however, irrigation ponds near the paddies have also been hypothesized to be an important site for arsenic release as well. To further investigate the importance of irrigation ponds, we have collected soil from both the Bangladeshi rice paddy and a nearby irrigation pond to use in comparative microcosm studies. It is currently accepted that arsenic release is related to the reduction of iron hydroxides and in the reduced state, aqueous arsenic is transported to depth. However, a recent study by Mailloux et al, 2009, has proposed mineral dissolution under phosphorus-limited conditions as an important mechanism for arsenic mobilization. Their incubation studies showed that dissolution of apatite by microbes for nutrient acquisition resulted in increased levels of both phosphorus and arsenic and that arsenic release is greatest at low levels of phosphorus. This mechanism may be important to our field site because phosphorus levels there are very low (10-2 mM). Using microcosms with paddy and pond sediment from our field site, we will quantitatively compare contribution to arsenic release via this mechanism with that resulting from biologically driven pyrite oxidation and iron oxide reduction at our site.

CON 5 Combining Spectroradiometry and In-Situ Sensing to Enable Wetland Plant Characterization and Biomass Mapping

Donghai Li, Qinghua Guo, Patrick Rahilly, Gary Phelps, Thomas Harmon

The Grassland Ecological Area (GEA) is the largest remaining contiguous block of freshwater wetlands remaining in California, encompassing an area of 160,000 acres. It provides important habitat for a broad range of species including millions of wintering waterfowl. Competition for water supplies to this managed resource, and uncertainty associated with that supply due to climate changes suggest that we must try to understand how to optimally manage this resource. For example, swamp timothy, which is one of the key forage species of the GEA wetlands, is highly sensitive to soil moisture and salinity conditions. In seasonally flooded wetlands these are spatially (salinity) and spatiotemporally (moisture) distributed soil properties which are challenging to manage on a large scale. The focus of this study to create efficient spatial strategies for characterizing key plant species status and community structure by (1) testing the potential of estimating EC_a-plant effects using in-situ spectroradiometry, 2) detecting plant water content (PWC) through in-situ spectroradiometry, and 3) mapping swamp timothy seed productivity through high resolution aerial photos.

CON 6 Multi-scale Data Characterization and 2-D model Development for the San Joaquin River-Merced River Confluence

Henry Pai, Jason Fisher, Sandra Amaya, Chris Butler, William Kaiser, Thomas Harmon

Questions pertaining to stream restoration ecology, environmental flows, and hydrology may require higher resolution observation and simulation capabilities than are typical of hydrologic investigations. Multi-dimensional models can provide more insight into the coupled biogeochemical processes needed to fully understand these systems. Of course, such models require a large amount of data relative to more simplistic models to accurately represent real conditions. This work summarizes an end-to-end exercise spanning from data collection to model calibration at the shallow confluence of the San Joaquin River (SJR) and Merced River in Central California. A raster pattern of point velocity measurements was collected using an automated device known as Rapidly Deployable Networked Inomechanical System (NIMS RD) transporting an acoustic Doppler velocimeter (ADV) over river cross sections, and flow was then calculated using the midsection method. Flow estimates were within 12% of those from a nearby USGS gaging station. Bathymetric data were collected by surveying depths for shallow stretches and by echosounding for deeper stretches, and then smoothed using multilevel B-spline interpolation (MBI). The resulting flow, bathymetry, and water surface elevation (WSE) datasets were used as boundary conditions in a commercially available modeling software package, Surface water Modeling Systems (SMS), comparing two different finite element modeling modules: FESWMS and RMA2. Modeled flow and WSEs

were compared to observed values to determine model performance and evaluated for three cases with differing mesh element sizes, model type, and bathymetry interpolation method (MBI or inverse distance). Simulations indicated that for similar numerical discretization, FESWMS outperformed RMA2, with finer mesh size and interpolated bathymetry leading to better model performance in both cases. Overall, the integrated field characterization and modeling approach demonstrates the feasibility of high resolution model development within a reasonable timeframe.

CON 7 Reach-scale Spatial and Temporal Variations in Whole-stream Metabolism Estimates within the lowland Merced River in California

Sandra Villamizar, Pai Henry, Christopher Butler, Patrick Barnes, Thomas Harmon

Stationary and distributed estimates of river metabolism developed during a 4-day period allowed us to identify spatial and temporal variations not related to the River Continuum Concept (RCC) but to local factors. The estimates of whole-stream metabolism (Primary Productivity and Community Respiration) were obtained using a one-station approach at both a stationary sampling point, and at an array of 11 points along a 23-m river cross section using a robotic Networked Info-Mechanical System (NIMS). An in-river meteorological station, and distributed self-logging light sensors were used to assess spatiotemporal photosynthetically active radiation (PAR) availability. Temporally, PAR was found to be the limiting factor during the last day of analysis, explaining the variation in estimated P/R ratios (0.79, 0.77, 0.76 and 0.56 for days one through four, respectively). Spatially, the distribution of metabolism estimates found along the river cross section, with P/R ratios ranging from 0.51 to 0.94, may be attributed to (1) the variable availability of PAR due to both the influence of the riparian vegetation and the daily radiation and shade patterns; and (2) a heterogeneous distribution of the respiration rates within the cross section (on a volumetric basis, respiration rates were two-fold higher in the shallow zone than in the deep zone of the cross section). A comparison of the results obtained with the two approaches (stationary and distributed) suggests that only one sampling point within the cross section may not be sufficient to characterize reach-scale processes related to stream metabolism in the context of habitat quality, groundwater-surface water exchanges, and other spatiotemporally complex issues.

CON 8 Response of Nitrate Sensors in a Saturated Soil Column

Sarika Doshi, Joseph Ferrer, Jessy Avelar, Jose Saez

This study builds upon work done in previous years towards emulating field conditions in a lab environment in order to test the readiness for the deployment of sensor networks in full-scale irrigation applications. Laboratory tests of six ion-selective nitrate sensors were conducted using a 38-inch long, 4.5-inch diameter saturated soil column. Soil for the column was collected from a 30-acre alfalfa field irrigated with recycled water using a center pivot. The soil, consisting of fine sand, was characterized for relevant parameters, which included grain size distribution, bulk density, specific gravity, porosity, and hydraulic conductivity. Laboratory calibrations of the nitrate sensors were conducted to test the sensors' reliability before and after the experiment by immersing the sensors in known nitrate concentrations ranging from 0.1 mg/l to 100 mg/l as nitrogen (N). Potable water flowed through the column at an average flow rate of 27 ml/min. An instantaneous spike of nitrate (5 mg-N) was injected in the column and the sensors' readings were recorded every minute over a 72-hour period using two data loggers. The data from the sensors were plotted and their curves were analyzed to determine relevant parameters, which helped understand solute transport and sensor reliability in the column. These parameters included mass recovery, modal time and mean residence time. This study also discusses improvements obtained due to the use of newer sensors and better experimental setup techniques; particularly the reduction in drift from calibration during the column experiments, which was observed in past efforts. Future work includes, testing nitrate sensors under unsaturated conditions and conducting tests with ammonium sensors.

SEISMIC OBSERVING SYSTEMS (SEI 1–6)

SEI 1 Developments on the CENS Structural Health Monitoring Front

Derek Skolnik, Martin Lukac, Robert Nigbor, John Wallace, William Kaiser, Monica Kohler, Nilesh Mishra, Shuai Hao, Ramesh Govindan

SEI 2 Analysis of Teleseismic Events Arriving at the Mexico Slab Region Using Rayleigh Wave Dispersions and Hough Transforms

Igor Stubailo, Martin Lukac, Luis Antonio Dominguez Ramirez, Emily Foote, Richard Guy, Paul Davis, Deborah Estrin

We present azimuthally anisotropic fundamental mode Rayleigh wave phase velocity maps for the Mexico area and interpret an anomalous phase in the seismic records obtained from the collected by MASE wireless seismic network. We analyzed data recorded at 100 broadband stations (MASE array) installed from Acapulco to Tampico in Mexico over a period of 1.5 years and 38 permanent Mexican stations for 155 teleseismic events of magnitude 6.0 and above. We employed a two station method to measure phase velocity dispersion curves between periods of 20 to 170s, using events located within 2-3 degrees of the great circle path between the two stations. Considering that Rayleigh waves at 170s are sensitive to shear-wave velocity structure down to about 300 km, this should enable us to reveal the upper part of the slab. The anisotropic phase velocity maps are being constructed from the path-averaged phase velocity measurements using a LSQR inversion method. The fast directions and strength of the anisotropy obtained will be compared to shear-wave splitting results. For an anomalous phase, analysis of teleseismic events crossing the Pacific trench of Mexico in Northeast direction shows branching-off of the PS and SS arrivals. Retracing of the initial split of the incident body waves using the Hough transform reveals a direct correlation between the location of the trench and the source of the secondary phase. The Hough transform, a technique commonly used in image processing, was used to detect linear patterns in a matrix representation of the seismograms. The first step consists in obtaining an interpolated matrix at a regular grid in space and time of the seismograms. Then, a Canny edge detector is apply to the matrix to mark the arrival of the possible phases. Finally, the Hough transformation of the resulting edge map produce a set of lines families that best fit the arrivals of the seismic waves. We have to constraint this process to the following assumptions: 1) We consider that the phases of interest lined up along the whole seismic record; and that 2) the travel time between adjacent stations is constant (fixed apparent velocity). The processing of the data demonstrated to be highly effective in estimating the apparent velocity and to determine the relation between the scattered and generating phases. Using this methodology, we were able to observe this phenomenon in seven teleseismic events magnitude larger than 7.0 during the period of the experiment and to identify possible sources of near to surface scattering that may affect studies of the upper mantle in this region.

SEI 3 GeoNet: a platform for rapid distributed geophysical sensing

Igor Stubailo, Martin Lukac, Dustin McIntire, Paul Davis, William Kaiser, John Wallace, Deborah Estrin

The science objectives are to use a rapidly installable wirelessly linked seismic network to measure earthquake or volcano sources in the near field to understand the underlying physics, or in buildings to understand earthquake damage. To accomplish these objectives, we collaborated with Reftek to construct a new generation digital acquisition system (DAS) based on the CENS-developed LEAP (low-power energy aware processing) system and a newly developed low-power A/D converter from Texas Instruments (TI) that became recently available. During the past year of GeoNet, one of the leading manufacturers of seismic recording systems, Refraction Technology, Dallas Texas, or Reftek, constructed several prototypes. They will be extensively tested in a field environment during a number of deployments. In preparation for GeoNet, we have used the Mexico and Peru networks to test the software including improving Disruption Tolerant Shell (DTS), measurement of radio link quality (ETT), network logging, an embedded web interface based on Emstar for deployment and maintenance, network timing, a new routing protocol that caches the routes across sleep cycles for a fast startup. The Peru network has already been installed and we can add to it GeoNet nodes for further testing and debugging.

SEI 4 Correlation of Microseisms Properties with Global Ocean Wave Effects

Martin Lukac, Paul Davis, Robert Clayton, Nicholas Graham, Deborah Estrin

We are exploring the correlation of daily microseism travel times, amplitude, and azimuth along the linear MASE seismic array with global wave height and global sources of microseisms. The MesoAmerican Subduction Experiment (MASE) was a 100 station 500km linear broadband seismic array deployed for 2 years across Mexico. The time series of daily travel times between pairs of stations, determined from noise correlation, fluctuates by up to two seconds, and are correlated with one another across independent pairs of nearly aligned stations. It is well known that the fluctuations are due to the changing location of microseisms sources over time. The sources must be in the far-field because the travel time fluctuations are common mode across the array. We have successfully modeled the fluctuations between stations by describing the phase change introduced by the biased energy from the off receiver-line sources. We have begun searching for an external model to correlate our results to and potentially track the bias sources over time. Our search has focused on the global wave height, wave-wave interaction intensity (psi), microseism source intensity (psi_c), and other wave parameters obtained by running the Wavewatch III wave modeling framework. Our most successful correlation has been between the observed microseism azimuth with the predicted microseism azimuth derived from the global wave height. Further, the predicted azimuth provides a solution to the microseism travel time fluctuations found from the noise correlation which are biased by asymmetrically arriving energy.

SEI 5 Peru Subduction Experiment (PERUSE) Preliminary Results of Gravity Measurements, Earthquake Locations and Regional Seismicity in Southern Peru

Emily Foote, Martin Lukac, Luis Dominguez, Igor Stubbailo, Helen Feng, Steven Skinner, Kristin Phillips, Richard Guy, Victor Aguilar, Hernando Tavera, Laurence Audin, Paul Davis, Deborah Estrin, Rob Clayton

The Peru Subduction Experiment (PERUSE) is a collaborative project developed by UCLA, Caltech, the French L'Institut de Recherche pour le Développement (IRD) and Instituto Geofisico del Peru (IGP) to improve geophysical models of the Andean Orogenic Belt and to image the subduction process in Southern Peru. One area of particular interest is where the Nazca Plate transitions from a normally subducting slab at an angle of about 30° to a shallow subducting slab beneath the South American Plate. The PERUSE project, which started in the summer of 2008, consists of a linear array of 50 broadband seismic stations that are evenly spaced about 6 kilometers apart. They are aligned perpendicular to the coast of Peru, from Mollendo to Juliaca. Caltech will deploy 50 more stations by the end of 2009. Their line will run perpendicular to the current line, from Juliaca to Cusco. By the end of 2010, a third linear array will be installed north of and perpendicular to Caltech's line in the Altiplano. Preliminary results from gravity measurements indicate that the crustal root of the Andes dips approximately 20° on both sides of the range, and extends to a depth of approximately 70km. This also agrees well with the receiver function results, which show that the crust thickens from the coast of Mollendo through the Altiplano to Juliaca to a depth about 70km (Phillips et al, Fall AGU 2009). Teleseismic studies also indicate that the crustal thickness varies laterally below southern Peru. We are developing a heterogeneous model from the topographic and gravity data, teleseismic events, and the receiver function results to accurately locate earthquakes in the area of interest and to provide a better crustal model of the region.

SEI 6 ShakeNet: a tiered wireless accelerometer network for rapid deployment in civil structures

Nilesh Mishra, Shuai Hao, Monica Kohler, Ramesh Govindan, Robert Nigbor

ShakeNet is a portable wireless sensor network for instrumenting large civil structures such as buildings and bridges. It will consist of 25-30 sensor nodes each equipped with a 24-bit analog-to-digital conversion (ADC) board supporting triaxial MEMS accelerometers suitable for vibration sensing, an imote2 CPU board for wireless communication, and battery. The system comes preloaded with sensing software as well as deployment tools that will enable civil engineers to rapidly deploy the network. In addition to the sensors, the system contains 5 to 10 master-tier nodes that provide increased communications capacity. The ShakeNet software subsystem is built upon Tenet, a programmable wireless sensing software architecture designed for tiered sensor networks. ShakeNet software is being developed at USC's Embedded Networks Laboratory. ShakeNet will be field tested in a variety of structures including steel moment-frame and base-isolated reinforced concrete buildings, a large earth-and-rock-fill dam, and a

steel truss bridge that supports a water distribution pipe. An earlier prototype was successfully tested on the 1500-ft-span, suspension cable, Vincent Thomas Bridge in the Los Angeles harbor.

TERRESTRIAL ECOLOGY OBSERVING SYSTEMS (TER 1–5)

TER 1 Terrestrial Ecology Observing Systems: overview of embedded networked systems

Michael Allen, Eric Graham, Niles Hasselquist, Josh Hyman, Kuni Kitajima, Teresa Ko, Erin Riordan, Phillip Rundel, Laurel Salzman, Mike Taggart, Eric Yuen

TER 2 Effects of Environmental Factors on the Production, Mortality, and Turnover Rate of Fine Roots and Mycorrhizal Hyphae

Kuni Kitajima, Rebecca Hernandez, Michael Allen, Mike Taggart

Our interest is to elucidate the carbon flux from the soil to the tree canopy and to the atmosphere using sensing and imaging technology. We observe fine roots with Conventional Minirhizotrons (CMR) on daily basis. We continuously measure soil efflux and sap flow. By combining these data and Eddy flux tower data, we can estimate carbon (C) allocation and C sequestration in an ecosystem. Our goal here is how environmental and biological variables affect carbon flux in an ecosystem. Here we present how seasonal pattern of fine root production, mortality and turnover rates and how environmental variables are affecting these. We also show the latest information about mycorrhizal growth rate and growth pattern with time using Automated Minirhizotron (AMR). We found a yearly hysteresis between soil temperature and soil water content plays a role in the hysteresis of fine root production, mortality and turnover rates. This in return possibly plays a role in the hysteresis of soil efflux.

TER 3 Engaging Citizen Scientists with Mobile Phones - What's Invasive!

Christy Brigham, Deborah Estrin, Eric Graham, Cameron Ketcham, Keith Mayoral, Nicolai Petersen, Sasank Reddy, Eric Yuen

Rapid detection and removal of infestations of invasive species increases the likelihood of treatment success and reduces cost. Weed maps allow managers to identify the extent of the invasive species problem and identify threats to high priority areas. Mobile phones are nearly ubiquitous and can contain sensors (GPS, cameras) to provide data for scientific and management programs. Citizen science participation has expanded dramatically in the last decade and current concerns about the environmental are driving more people to want to participate in citizen science campaigns. Leveraging the millions that visit the Santa Monica Mountains and other parks, we have developed a system to help combat the spread of invasive species using mobile phone technology.

TER 4 Leveraging Internet-connected Cameras to Create a Transcontinental Phenology Monitoring System

Erin Riordan, Eric Graham, Eric Yuen, John Hicks, Eric Wang, Deborah Estrin, Philip Rundel

Phenology, measured as the timing of recurring biological events, is highly sensitive to changes in environmental conditions and can vary widely across landscapes. Detection of shifts in the timing of plant phenological events is limited by the constraints of existing technologies for observing phenology and difficulties in integrating those technologies. Current technologies are either (1) ground-based for small-scale, high precision but labor-intensive measurements or (2) remote sensing-based for large-scale but low spatial resolution measurements, often too coarse to detect species and community level responses. Development of inexpensive, instrument-based approaches to field measurement is necessary to advance large scale phenology monitoring. The recent use of digital cameras as environmental sensors holds great potential for phenological monitoring. We propose the use of Internet-connected cameras as a novel means for detecting and monitoring plant phenology at a continental scale to augment current satellite-based measurements. We provide methodologies for detecting the timing of phenological events from webcam images and compare our detection with that of remote sensing products currently used for large-scale environmental monitoring.

TER 5 Using Imagers for Scaling Ecological Observations

Eric Graham, John Hicks, Erin Riordan, Eric Wang, Eric Yuen

A nation-wide network of webcams: Twice-daily images from over 1000 internet-connected cameras have been collected since February 2008. The advance of spring can be tracked as a "green-up" and related to satellite remote sensing signals. Scaling soil surface temperatures: Soil surface temperature tracks air temperature in the shade but rises sharply because of solar radiation. Sunflecks captured with a camera taking a panoramic mosaic can be used to estimate the radiation load for large areas of understory. Photosynthesis over large areas with HDR: High Dynamic Range imaging captures an absolute (vs. relative) amount of reflected light in an image. For a meadow composed of similarly reflecting species, we can apply a physiological model to estimate photo-synthesis over a large area. Scaling from leaf to the landscape: Pan-Tilt-Zoom cameras can be zoomed in on a tight focus on individual plants and then zoomed out to get a landscape view, composed of the same and similar species for an integrated "green-up" date estimation (double-sigmoid).

URBAN & PARTICIPATORY SENSING (URB 1–8)

URB 1 Urban Participatory Sensing

Farnoush Banaei-Kashani, Jeff Burke, Christian Cenizal, Suming Chen, Wesley Chu, Ian Cinnamon, Betta Dawson, Gleb Denisov, Chandni Dhanjal, Deborah Estrin, Hossein Falaki, Ramesh Gavindan, Zheng Guan, Mark Hansen, Nan Jia, Donnie Kim, Younghun Kim, Isaac Kim, Derek Kuliński, Brendan Kutler, Brent Longstaff, Olmo Maldonado, Roozbeh Mottaghi, Min Mun, Luciano Nocera, John Ong, Nicolai Petersen, Nithya Ramanathan, Sasank Reddy, Jason Ryder, Vids Samanta, Cyrus Shahabi, Victor Shia, Katie Shilton, Houtan Shirani-Mehr, Mani Srivastava, Senglong Taing, Fabian Wagmister, Gene Wang, Ruth West, Kelsey Whitesell

URB 2 Control, Engagement & Participation: exploring ethics in participatory sensing

Katie Shilton, Jeffrey Burke, Deborah Estrin, Mark Hansen

For decades, the privacy of personal data has been protected by governments and corporations. But professional data management and protection do not take into account a world of distributed, participatory data collection, nor the realities of data mining and easy, almost uncontrolled, dissemination. Emerging models of information gathering create an environment where recording devices, deployed by individuals rather than organizations, disrupt expected flows of information in both public and private spaces. We suggest new principles, protections, and data sharing architectures are needed to protect privacy in this new data reality.

URB 3 Improving Personalized Health Care Through Mobile Self-monitoring: a robust architecture, engaging interfaces, and pilot studies

Nithya Ramanathan, Hossein Falaki, John Hicks, Donnie Kim, Brent Longstaff, Min Mun, Sasank Reddy, Vids Samanta, Betta Dawson, Dallas Swendeman, Deborah Estrin, Mark Hansen, Mary Jane Rotheram-Borus, Mike Swiernik

Propose to use mobile phones to personalize health care by providing more accurate and reliable data from individuals. A mobile architecture needs to provide privacy, engaging interfaces to improve compliance, a way to present the large quantities of data, and must be evaluated. We propose to build a three tiered architecture consisting of the mobile phone, a personal data vault, and a back-end server. A website will provide 1) trigger authoring 2) real-time Feedback 3) place labeling 4) PDV interface 5) visualizations and patient dashboards 6) usage Monitoring statistics. The mobile phone will provide 1) an engaging UI 2) power management 3) automated activity classification. The mobile phone will include components to monitor usage. The entire system will be built using standardized data formats and modular components for robustness. We will evaluate the system through three pilot studies involving real patients. Our first pilot will support chronic disease management. Our second pilot aims to evaluate the impact of configurability and privacy concerns on compliance in young men at risk for HIV. Our third pilot aims to evaluate the validity and reliability of prompted input and automated activity monitoring data in young moms at risk for heart disease.

URB 4 Mobile Phones to Measure the Public Health Impacts of Introducing Energy Efficient Stoves in Rural India

Chandni Dhanjal, Taimur Hassan, Nithya Ramanathan, Martin Lukac, Deborah Estrin

Project SURYA, a joint effort by the Center for Embedded Networked Sensing lab at UCLA and the Center for Clouds, Chemistry and Climate at UCSD, aims to exploit solar and other energy-efficient cooking techniques in order to reduce indoor air pollution in developing nations. An important component of project SURYA is to measure the resulting reductions in human exposure to indoor air pollution, to demonstrate the efficacy of the approach. We developed a mobile phone application to monitor an individual's activity throughout the day. These activity traces will be used in epidemiological models to calculate an individual's pollution exposure. The two major challenges faced during the development phase were: 1) to develop an application that was robust to the harsh environments that characterize developing regions, such as irregular power supply and unreliable GPS service, and 2) to design a locally and culturally relevant user interface that can be used in a context where most people may not be able to read. We developed an activity classification algorithm that identifies when a user is "still", "walking", or "driving", from a GPS-speed trace collected on the phone. The algorithm is robust to irregular, incorrect, or missing data and timestamps, and operates well even when there are short bursts of activity. The classification algorithm (called SmartKNN) combines the simplicity of the K-Nearest Neighbor (KNN) clustering algorithm with the temporal sequencing capabilities of Hidden Markov Models (HMMs). While the HMM perform as well as SmartKNN on the ideal dataset, in our 4 non-ideal datasets SmartKNN outperforms the HMM and regular KNN by almost 50%. In order to make our application accessible, we designed a text-free user interface comprising of graphics and some audio data.

URB 5 Participatory Sensing: factors, models, and algorithms for recruitment

Sasank Reddy, Jeff Burke, Deborah Estrin, Mark Hansen, Mani Srivastava

In traditional sensor systems, one of the fundamental problems concerns the placement of sensors. The analogous problem in participatory sensing is choosing users to perform a particular data collection task. This work details a recruitment framework that is designed to help with this process. Specifically, the framework considers the capabilities in terms of sensors available by a particular user, the availability of the user to participate in terms of spatial and temporal contexts, the reputation of the user as a data collector, and the incentive cost associated with the user participating as elements involved in the process of choosing data collectors. The utility of the recruitment service is shown through a series of campaigns related to sustainability monitoring.

URB 6 PEIR Model Verification and Architecture Update

Nathan Langholz, Masanao Yajima, Betta Dawson, Mark Hansen

The Personal Environmental Impact Report (PEIR) provides people with the ability to use their mobile phone to investigate their environmental impact and the environment's impact on the person. The mobile phone takes a GPS trace for each user which it uses to combine current weather conditions and traffic patterns for a users location in scientific models to estimate particulate matter exposure, fast food exposure, carbon impact, and particulate matter impact on sensitive sites. Previously there had been no attempt at validating any of the modeling done in the PEIR system. The initial goal was to validate the model for particulate matter (PM 2.5) using data collected through use of the DustTrak Aerosol Monitor as ground-truth for the model used in PEIR. Additionally, previous data collected from an UCLA Environmental Health Sciences study was used in comparison to PEIR's model. This study reconsiders what PEIR communicates to a user about PM 2.5 exposure, outlines an update of the model, as well as introduces another model. Also, due to a tight schedule during creation the PEIR system was developed without much effort put into coherency, efficiency, nor flexibility. It was apparent that a reassessment of the system was necessary to prepare PEIR for any future expansion. Based on the initial PEIR architecture review the PEIR system was found to be in need of: 1. (System restructuring) Restructure the PEIR system design so as to make it more coherent, flexible, and resilient. 2. (Process restructuring) Improve the ways in which information is processed which makes the system more comprehensible and efficient. With such a goal in mind the PEIR system was redesigned. Some key changes are incorporation of SQLAlchemy + GeoAlchemy in place of raw SQL, removal of system parameters to unified

configuration module, changing the basic unit of the process from point to trip, and separation of model calculation to be defined per user.

URB 7 Urban Texture Documentation: efficient planning

Houtan Shirani-Mehr, Bei Pan, Nicholas Bopp, Luciano Nocera, Farnoush Banaei-Kashani, Jeff Burke, Cyrus Shahabi

We envision participatory texture documentation (PTD) as a process in which a group of users (dedicated individuals and/or general public) with camera-equipped mobile phones participate in collaborative collection of urban texture information. PTD enables inexpensive, scalable and high resolution urban texture documentation. One of the main research challenges in enabling PTD is to find optimal plans for the participants such that they can collect as much of data as possible without violating their constraints. In this poster, we present our two-phase PTD planning framework. At the first phase, termed "viewpoint selection", a minimum number of points in the urban environment are selected from which the visible texture of the entire urban environment can be collected/captured [1]. At the second phase, called "viewpoint assignment", the selected viewpoints are assigned to the participating users such that given a limited number of users with various user constraints (e.g., specific participation time) users can collectively capture maximum amount of texture information within a limited time interval [2]. We have implemented and evaluated this PTD planning framework as part of GeoSIM, our prototype PTD system (please see our demo proposal for more details on GeoSIM).

References: [1] H. Shirani-Mehr, F. Banaei-Kashani and C. Shahabi, "Efficient Viewpoint Selection for Urban Texture Documentation", GSN 2009. [2] H. Shirani-Mehr, F. Banaei-Kashani and C. Shahabi, "Efficient Viewpoint Assignment for Urban Texture Documentation", ACMGIS 2009.

URB 8 ViridiScope: fine-grained resource monitoring systems for homes

Younghun Kim, Thomas Schmid, Zainul Charbiwala, Jeff Burke, Mani Srivastava

Buildings consume approximately 73% of the total electrical energy, and 12% of the potable water resource in the United States. Even a moderate reduction in this sector results in significant monetary and resource savings. Fine-grained resource monitoring is regarded as one technology that could help consumers and building owners to understand, and thus reduce, their resource waste. Unfortunately, the current generation of reporting devices only provides partial and coarse grained information or requires expensive professional installation. This limitation stems from the presumption of in-line measurements: flow rate in a pipe and current-voltage measurement in AC line. However, since resource-consuming end-points typically emit measurable signals when they operate, we can estimate their consumption using indirect sensing. In this poster we present a fine-grained power and water monitoring system that furnishes users with an economical, self-calibrating tool that provides resource consumption of virtually every resource-consuming end-point in the home. ViridiScope uses ambient signals from inexpensive sensors placed near end-points to estimate resource consumption, thus no in-line sensor is necessary. We use a model-based machine learning algorithm that automates the sensor calibration process. Through experiments in a real house, we show that ViridiScope can estimate the end-point consumption within 10% error.

EDUCATION (EDU 1–2)

EDU 1 CENS Education Overview

Deborah Estrin, Karen Kim, Wesley Uehara

EDU 2 Summer@CENS Evaluation: CENS High School and Undergraduate Scholars Programs

Tiffani Riggers and Cynthia Milstein

CENS High School and Undergraduate Scholars Program directly involves high school and undergraduate students in CENS research through a comprehensive summer internship experience. The program is the core of CENS educational pipeline and is an excellent example of aligned Center research and education activities. The program brings together talented undergraduates from around the country and local high school students to engage in Center research for 8-10 weeks over the summer. This poster highlights the summative and formative evaluation findings from the 2009 summer.