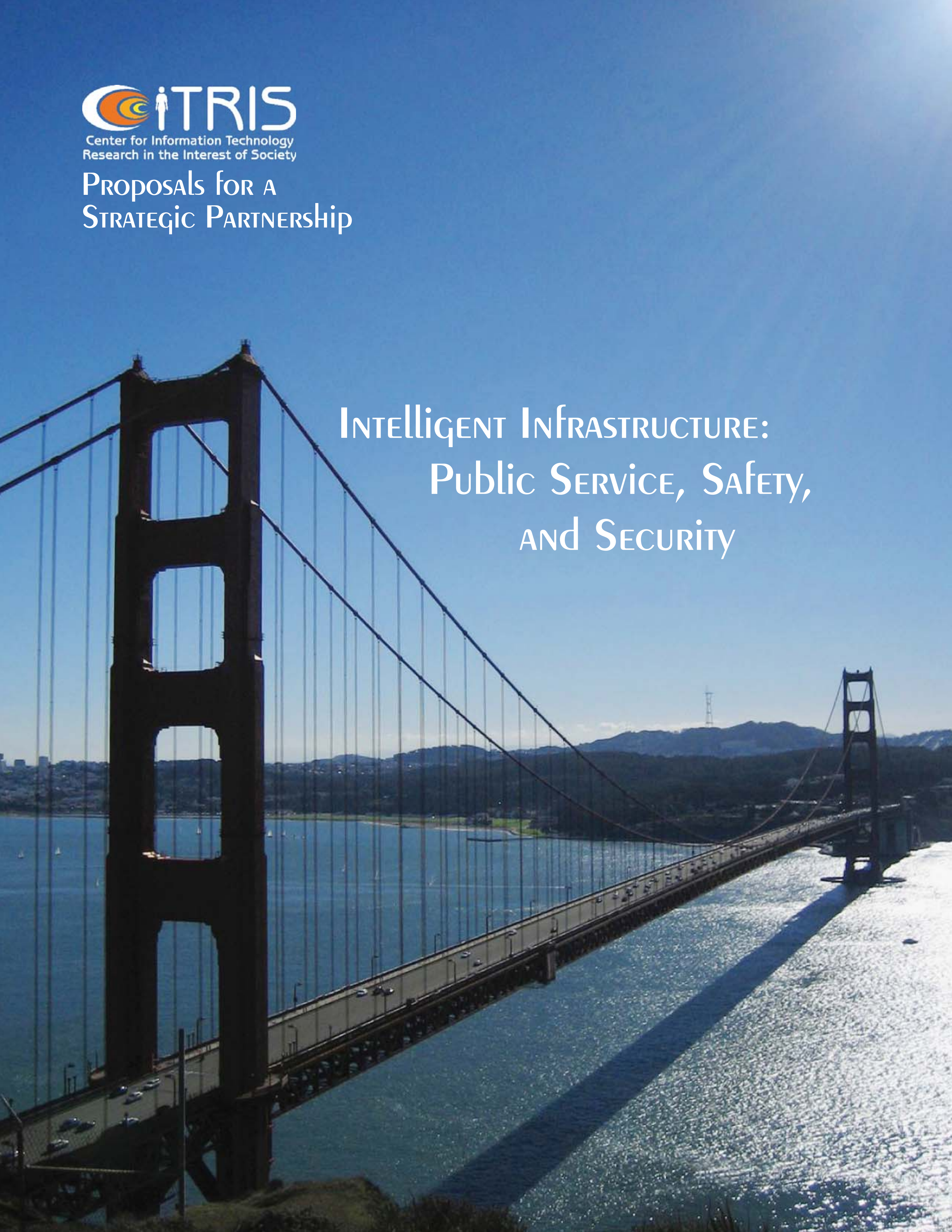
CITRIS

Center for Information Technology Research in the Interest of Society

Proposals for a Strategic Partnership

Intelligent Infrastructure: Public Service, Safety, and Security



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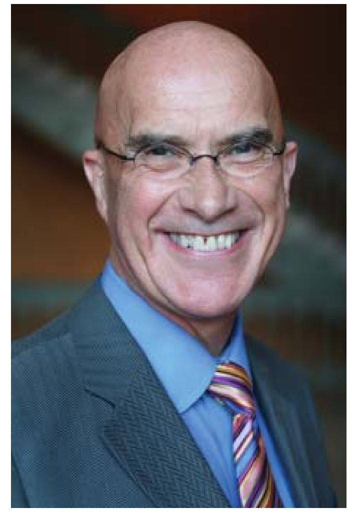


CITRIS: Using Intelligent Infrastructures for Smart Decision-Making and Increasing Public Safety and Security

Greetings from Berkeley, California, headquarters of CITRIS, the Center for Information Technology Research in the Interest of Society.

CITRIS was created to maintain California's leadership in safety, security, health and prosperity, and our Intelligent Infrastructures thrust is an essential component of that mission. People want to know that the water is clean, that firefighters and emergency responders can do their jobs—potentially finding their loved-ones in an emergency—that traffic will flow smoothly on our highways, and that their neighborhoods are safe. As telecommunications companies are installing ubiquitous mesh networks, CITRIS researchers are building applications that will allow us to address these concerns by using micro-integrated hardware and software, along with embedded wireless sensors and special cameras.

Since its inception, CITRIS has succeeded in channeling innovative research toward societal problems at each of our four University of California campuses (Berkeley, Davis and its Medical Center Campus, Merced, and Santa Cruz). In doing so, it has also served as the focal point of research collaboration between industry, academia and the public, as a conduit for educating a new wave of innovators to enter the workforce, and as a locus of intelligent discourse and innovation. For example, the contributions of CITRIS researchers to wireless sensor network technology have proven instrumental to creating a new industry in radio frequency identification technology (RFID), and we will continue to strive for success as we focus on our six major research initiatives in Energy and the Environment, Intelligent Infrastructures, Healthcare, the Arts, Services, and Technology for Emerging Economies.

We have assembled this brochure, which highlights of just a few of Intelligent Infrastructures projects that we are working on, and hope that it can serve as a basis of discussion for finding mutual research interests that we can pursue together. I would also like to extend an invitation to you to visit the (mostly) sunny California and visit us at CITRIS so that we can discuss these topics in person.

Modeling and Analysis of California's Hydrologic Resources and Operations
Managing California's Water

Water management in California currently lacks a broad and consistent water management accounting and modeling capability that allows policy makers to meet the current and future challenges of population and economic growth, environmental sustainability, and climate change. This is an immense challenge.

Modeling and Analysis of California's Hydrologic Resources and Operations (MACHRO) at the UC Davis Center for Watershed Sciences will develop and support innovative models, the correct data, and their combined application for providing insights for water policy and management. This enterprise will work cooperatively with agencies, NGOs, consultants, and academic researchers to provide a venue for the water community to better understand and develop solutions to water and environmental problems in California and elsewhere.

Next Steps:
The UC Davis Center for Watershed Sciences seeks to provide a collaborative venue for research in water-related subjects for researchers on and off the UC Davis campus. The Center's approach has been successful for projects on the Cosumnes River, Klamath and Shasta River system, Sacramento-San Joaquin Delta, and other water management issues where scientific and technical aspects have been insufficiently explored or developed.

Taking this approach into the quantification and modeling realm, MACHRO venture will develop water management modeling and databases. The program will take a collaborative approach to developing, testing, documenting, and applying major water and environmental management models, primarily for California.

Envisioning Futures for the Delta

The Cosumnes River is the last river without major dams on the western slope of the Sierra Nevada. Thus, it is one of the few systems in which the ecological impacts of natural variation in seasonal flows can be studied. In addition, the Cosumnes River Preserve occupies large stretches of the river's lower reaches and has sought, by means of levee breaches and other strategies to reinstate seasonal flooding, restore riparian vegetation, and improve conditions for native plant and animal species.

Two projects at the UC Davis Center for Watershed Sciences focused primarily on the relationship between hydrologic conditions and aquatic ecosystems, emphasizing the connection between aquatic and terrestrial systems in floodplain environments.

For example, the researchers have looked at the relationship between restoration activities and the spread of invasive species; measured and modeled the surface and subsurface water balance to better understand the interaction between groundwater and riparian zone processes; and examined the links between aquatic and terrestrial habitats via a study of interaction through food webs. In addition, building on a decade of time-series and spatial data, they have continued to monitor birds as an indicator of restoration success.

Reports and papers to date are posted at: http://baydelta.ucdavis.edu

Floating and Cellular Sensors

CITRIS researchers at UC Berkeley are exploring new ways to use sensors to monitor our infrastructure—including water and traffic. The Lagrangian Sensor project, led by Professor Alexandre Bayen, is developing new technologies for managing estuarial water systems like the Sacramento/San Joaquin Delta of Northern California. Bayen and his colleagues build innovative floating sensor packages that gather and transmit data while floating in the river; the engineers also develop the analytical tools needed to "assimilate" the data: to put it into context with other sources of information and deliver a complete, integrated view of the state of the water system. They are currently investigating the use of "active" sensor devices that are able to modify their trajectory through the water, delivering themselves to the places where they are needed most. By collaborating with environmental engineers and hydrologists, they will develop an innovative sensing technology that meets the need for high-quality, real-time data.

Another flowing network—that of highway traffic—also requires innovative monitoring to help alleviate congestion and allow for smoother rides to work. With the emergence of GPS-equipped cellular phones, the possibility of gathering large amounts of data on highways at a very low cost is launching a new era of mobile traffic-sensing technologies. In collaboration with Nokia, Caltrans, and the California Center for Innovative Transportation, Bayen and coworkers are planning to obtain position and velocity measurements of vehicles using on-board cellular phones equipped with GPS. The researchers will study how the incorporation of mobile sensing can add value to already existing monitoring infrastructures and add information to areas which are currently unmonitored.

Tracking Snow and Water in the Sierras

Two-thirds of the Sierra Nevada precipitation is snow, much of which falls when the temperature is just below 0°C. Therefore, a few degrees increase in temperature will turn this snow into rain and also cause an earlier snowmelt. UC Merced professor Roger Bales using blended satellite and ground-based data to estimate the amount of mountain snow and thus, accurately predict the availability of water.

The current operational water measurement system in the Sierra Nevada does not allow for quantitative, real-time estimates of snowpack and downstream water quantities. The lack of these accurate estimates for water managers underscores deficiencies in the current measurement network and provides an impetus for designing a representative measurement network across mountain basins.

In addition, Bales and colleagues are building prototypes of a better ground-based sensor network whose data can be blended with satellite information to increase its utility to water managers. Given the physiographic and vegetation variability of the mountain landscape, developing strategies for deciding where to measure also involves research; but this is a challenge that Bales and colleagues are meeting by strategically placing the instrument clusters across latitudinal and elevation gradients.

Ongoing deployment of snow and water-balance instrument clusters in the Sierra Nevada is designed to overcome current deficiencies and provide low-cost, spatial information on snowpack, soil moisture, evapotranspiration, streamflow and energy balance.

Localization for Urban Search and Rescue Robots

Life-Saving Robots

The goal of this project is to develop field-suitable robotic technologies to assist first-responders in the aftermath of natural and/or man-made disasters. After an earthquake, for example, robots can provide a great deal of help to minimize the operational risks for rescuers, while at the same time increasing the chances to locate survivors quickly and save human lives.

UC Merced professor Stefano Carpin plans to develop a software/hardware module that can be plugged into mobile robots to solve the localization problem in unstructured environments typical of rescue scenarios. Specifically, his team plans to use off-the-shelf hardware components to implement and improve an innovative algorithm they have developed. This practical study will not only lead to a first working prototype of the system, but will also provide extensive experimental data to better understand the problem and stimulate further theoretical investigations to produce more accurate localization results.

Traditional approaches to localization assume the availability of known and detectable landmarks. Such landmarks, however, cannot be assumed to be present in the aftermath of a natural disaster. To overcome this, the engineers propose to use a fleet of robots that is split in two groups. A first group of robots acts as detectable landmarks, while the second group moves around and relies on the first group to solve the localization problem. The roles of the two groups are swapped from time to time, so that all robots move.

Next Steps:
Carpin and colleagues will implement and evaluate the proposed algorithm in a realistic search and rescue scenario to identify further needs for theoretical investigations. They will then develop ready-to-use hardware/software module to outfit mobile rescue robots. Details are at https://robotics.ucmerced.edu.

CITRIS researchers aim to use a fleet of robots that can both act as landmarks and use those land-marks to move properly through the aftermath of disasters.

Intelligent Infrastructures for First Response

Helping Out Those Who Help Us

A UC Berkeley project known as FIRE—the Fire Information and Rescue Equipment technology system—will help increase the safety and efficiency of firefighting and other emergency first response activities. Fire accounts for more deaths in the United States than all other natural disasters combined and destroys more than $10 billion worth of property each year. Improved search and rescue and communication methods are a national priority.

Discussions between CITRIS researchers and with professional firefighters have revealed a crucial gap in current technology: the ability to track personnel and conditions spatially during search and rescue operations.

The primary goals of the FIRE system are to improve the safety, efficiency, and effectiveness of urban/industrial firefighting and emergency response. Information and communication are implemented through a three-part system: the SmokeNet wireless sensor network (WSN), the electronic Incident Command System (eICS), and the FireEye Head-Mounted Display (HMD). Research has been ongoing in each of these areas to understand responder needs and how to best design a system to meet these needs. Already, researchers have conducted interviews and usability tests.

The enhanced information and communication features of the FIRE system have the potential to reduce injuries and save lives. The trends of terrorist attacks, natural disasters, and other large scale incidents are only increasing in severity as society becomes more complex. Buildings are becoming larger and more difficult to evacuate and weather is becoming more extreme with global warming. The FIRE system technology will address societal wellbeing by advancing discovery and understanding for applications in firefighting, disaster response, law enforcement, and security.

Next Steps:

Research will be conducted to improve incident remote sensing, information collection, routing, information access, and visualization to help allow more effective decision-making and navigation capabilities in a complex indoor environment.

http://fire.me.berkeley.edu/about_fire.htm

By developing smart firefighting equipment, CITRIS scientists can improve the ability of first-responders to function during fires and related emergencies.

Creating a Computer-Based, Collapsed Structure Rescue Training Simulator

Whenever a major earthquake occurs, there are inevitably buildings that collapse, often trapping people inside. A natural impulse is to rescue them, yet worldwide statistics indicate that for every person rescued from a collapsed structure, a rescuer dies in the attempt. Ideally, collapsed structure rescue training should be given to a broad range of emergency response personnel, in addition to the search-and-rescue robots being developing through CITRIS and other organizations. In the United States, there are only two collapsed structure training facilities (one is at the NASA Ames Research Center in California) capable of training just a few hundred people a year.

With CITRIS, UC Santa Cruz computer science professors Michael Mateas and Jim Whitehead and their colleagues are creating a computer-based, collapsed structure rescue training simulator. The training simulation, developed using a high-end 3D game engine, will help expose rescue workers to the types of situations they are likely to encounter in real-world collapsed structure rescue situations. Key goals of the project include creating a realistic simulation of the conditions experienced by rescue workers, and a technique for procedural generation of rescue scenarios to create an infinite number of unique rescue situations.

Wireless Infrastructure for Environmental Quality and Hazard Monitoring in Mines

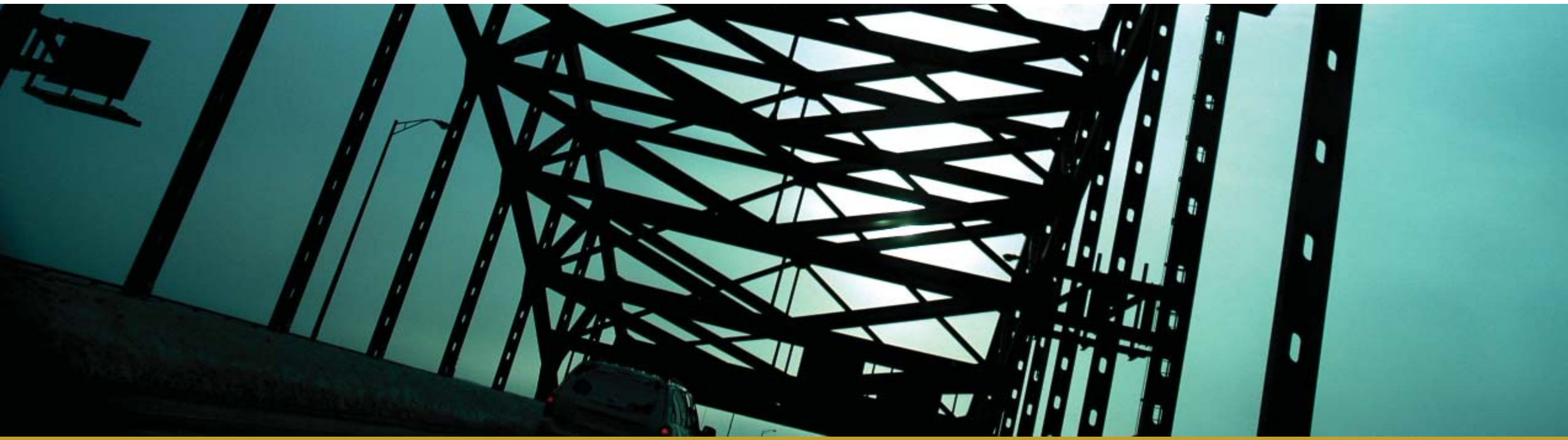
Wireless sensors will improve the safety of mine conditions and allow personnel and equipment to be tracked if needed.

The recent disasters at the Sago Mine in West Virginia and the Crandall Canyon Mine in Utah have highlighted the need for better communications and sensor networks at underground facilities. Underground mines have a variety of potentially hazardous conditions, including rock mass collapses, noxious gases, lack of oxygen, fire, and dust. Environmental sensors such as temperature, humidity, and pressure can record data that will create a better understanding of conditions inside a mine, particularly when correlated with changes in air quality or seismic activity. While mine safety monitoring does occur in deep underground facilities, it is done via expensive wired systems and therefore has limited spatial extent and communications potential.

The wireless platform eliminates expensive and vulnerable cabling, lowers the cost of a larger installation, allows sensors to be placed in difficult locations, and allows mobility. Mobile sensor motes could be attached to people, equipment, or frequently moved along with an actively mined face.

Wireless motes can also be used as communication and localization devices, allowing real-time tracking of people and equipment throughout the mine. In emergency situations where the location of personnel is unknown, reestablishing a connection via the underground wireless network via a borehole could provide direct communication, a measure of oxygen levels inside parts of the mine, even the last know location of personnel in the mine and a direct assessment as to whether or not their position has been changing.

Prototype motes with accelerometers have already been deployed for other applications and there is an excellent opportunity to explore their application in this environment.

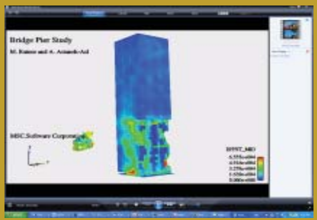


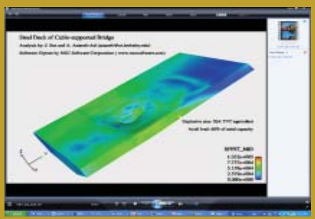
Protecting Bridges from Blast and Fire

Blast Protection of Bridges is a CITRIS project aimed at determining the response of long-span bridges and elevated freeways to blasts that occur on the roadway. Led by Professor Abolhassan Astaneh-Asl and funded by the NSF as well, researchers will establish how bridge responds to blast and how much damage can occur due to certain size explosives. Once that is understood, the engineers will develop technologies that can be used to minimize such damage and, more importantly, to prevent progressive and catastrophic collapse of the bridges. Obviously the results of first phase, to establish the extent of the damage, are not in public domain, but the technologies to prevent the damage and the resulting catastrophic progressive collapse are widely published to enable engineers and bridge designers to implement such technologies at the design level for new bridges and also apply them to existing bridges as a measure of retrofit. Such technologies can only be used to enhance the blast resistance of the bridge and not for malicious purposes.

Another related project is that of how to protect bridges from fire and, more specifically, the study of the April 2007 collapse of the MacArthur Maze, a complex of freeway interchanges in Oakland, California, that was caused by an overturned tanker truck. In this NSF project, researchers from CITRIS and Lawrence Livermore National Laboratory have studied and collected data on the collapsed maze and now are continuing to analyze the data. The goal is to build a structural/fire model of the collapsed area, to simulate the fire and collapse, and to study how fire and structure interacted that night. This collapse offers us a valuable opportunity to see what can be learned and to improve fire resistance of other steel bridges and overpasses. For more information see

http://www.ce.berkeley.edu/~astaneh.



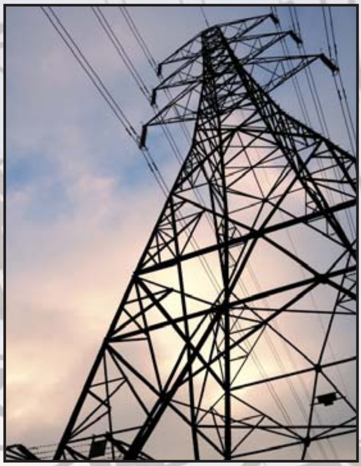


Professor Astaneh-Asl studied the collapse of the MacArthur Maze in Oakland, California, after it was struck by a truck.

Safety in Electric Power Delivery Systems

A little-known problem threatens systems that deliver electric power to residential and commercial customers: the underground distribution cables that operate at 12,000 volts or higher will perform well for a few decades and then suddenly fail with a dramatic one-nanosecond arc.

Pacific Gas & Electric alone has 25,000 miles of three-phase distribution circuits (75,000 miles of aging underground cables), and no real economical way of telling which ones are unhealthy. The California Energy Commission has just funded a three-year interdisciplinary (electrical engineering, mechanical engineering and material science engineering) research program at University of California, Berkeley, to understand the failure mechanisms and find feasible ways of checking the health of cables to prioritize replacement.



Professors at Berkeley study ways to monitor the failure of underground power cables.

The primary goal of this research led by Professor Richard White, is to develop and Intelligent Infrastructure to monitor in-situ maintenance and to explore the degradation of underground AC power distribution cables. Two sub-teams have been created to tackle specific sub-goals:

During the course of this research, the interdisciplinary research team will work closely with the California Energy Commission and the three investor-owned utilities in the state of California (PG&E, Southern California Edison, and San Diego Water and Power) to understand the needs of all the stakeholders involved and be able to produce a user-friendly infrastructure.

UC Merced Smart Infrastructure for Energy Control and Management

As part of its effort to achieve efficiency in is central plant and building operation, UC Merced Facilities Management administers an extensive control and monitoring system. This system deploys tens of thousands of control algorithms to continuously satisfy heating ventilation, and air conditioning (HVAC) requirements across campus with a minimum of energy consumption. Monitoring data from this system is the primary mechanism through which operational and energy performance goals are achieved and verified at the zone, equipment, building, or plant level.

While this system is critical from a facilities operation perspective, it is also an asset to the academic community. Its underlying database of temperatures, flows, equipment status, electrical loading, concentrations, occupancy, weather, and solar insulation provides a rich dataset for building science research. With comprehensive coverage of all HVAC and electrical systems throughout campus, it provides an excellent integration point for additional monitoring data associated with campus-based research projects. Finally, it provides an ideal medium for instruction. For these reasons, this energy control and management system forms the cornerstone of a Living Laboratory that supports and integrates research and instructional endeavors at UC Merced.

Current efforts emphasize benchmarking of building energy performance and IT power densities, as well as developing renewable generation opportunities as a complement to efficiency in achieving the university's commitment to climate neutrality. UC Merced Facilities Management actively seeks partnership with faculty and students that advances such efforts and enhances UC Merced's Living Laboratory.

Keeping the Internet Safe

It has been estimated that malicious code (viruses, worms, and Trojan horses) have caused over $75 billion in economic losses in the U.S. through 2007. As a result, continuous traffic monitoring and accurate detection of traffic anomalies and attacks are extremely critical for large network operators, as well as for enterprise networks that provide important services such as banking, law enforcement, and healthcare. Aiming to alleviate this very significant problem, CITRIS researchers will leverage parallelism available in many-core chip multi-processors (CMP) to deliver comprehensive and programmable analysis of network traffic in real-time. This project output finds application in automatic detection and prevention of security attacks, which has far-reaching societal impacts.

Most Intrusion Detection Systems (IDSes) are host-based and not scalable to high-speed networks, especially for the emerging sophisticated attacks. In addition, almost all of the previous hardware design research presumes a nearly stateless approach to attack detection. Instead, UC Davis Computer Science Professor Soheil Ghiasi will take a more sophisticated approach by leveraging parallelism available in many-core chip multi-processors (CMP) to perform real-time and comprehensive analysis of network traffic in an efficient manner.

Ghiasi and colleagues anticipate developing a solution for programmable, real-time, and comprehensive analysis of traffic in networks to detect anomalies, and security breaches. This solution will contribute to secure exchange of data, trusted collaboration among geographically distant professionals, and a flurry of other applications that demand secure communication. For example, this project can be integrated into the on-going effort at CITRIS at UC Davis to establish a research center on IT-enabled healthcare.

A proof-of-concept CMP prototyping framework using an FPGA board and a uni-processor based programmable network measurement (ProgME) infrastructure has been developed. The researchers hope to be able to secure larger extramural funding to continue this important work.

Respectful Cameras for Security with Privacy

An emerging class of digital video cameras provides unprecedented ability to zoom in and capture high-resolution video images. This capability is desirable in many applications from security to public relations.

However, such high-resolution scrutiny raises significant privacy concerns. CITRIS researchers Ken Goldberg and Deirdre Mulligan are investigating a new approach to providing a measure of visual privacy by masking an individual's identity while allowing observation of his or her physical actions and other motion in the scene. Their objective is to develop "respectful cameras." The key idea is to introduce wearable "markers" that can be detected by image processing software in real time. For example, the software can track markers, such as inexpensive hats of a particular color or pattern, at the border of the space where the camera is present.

The researchers have created a Respectful Cameras visual privacy system that tracks visual markers to robustly infer the location of individuals wishing to remain anonymous. The resulting image is that of people with colored elliptical disks obscuring their face, while allowing their bodies, motions, and actions to be observed. The researchers use a static-image classifier that determines a marker's location using pixel colors and an AdaBoost statistical classifier. They then extended this to marker tracking and a marker model which incorporates velocity and inter-frame information by using a particle filter based approach.

Experiments are currently underway at the CITRIS construction site to evaluate the perceptions of construction workers regarding being observed by a robotic camera while they work.

In future work, experiments will be undertaken with different markers to identify preferred colors or patterns. It may be possible to build a Respectful Cameras method directly into the camera (akin to the V-chip) so that faces are encrypted at the hardware level and can be decrypted only if a search warrant is obtained.

More information, sample videos, and press coverage:
http://www.cs.berkeley.edu/~jschiff/RespectfulCameras/

An example of the Respectful Camera system obscuring the face of the construction worker wearing a green vest.

Center for Advanced Radio Spectrum Utilization

Making a New Wireless Venue

The goal of the Center for Advanced Radio Spectrum Utilization (CARSU) is to fundamentally change the operation of wireless communication systems. Due to the explosive growth of wireless communications over the last decade, the majority of people rely on their mobile telephones for daily voice and data communication, and often for first contact in case of emergency. Present methods of frequency allocation combined with a reliance on fixed infrastructure threaten to halt this growth. In addition, it leads to the deployment of fundamentally less robust systems, prone to disruption in major disasters or overload. By enabling the secondary use of spectrum on an opportunistic basis, we can create ubiquitous, robust, and agile wireless systems that are able to support further traffic growth and demand while ensuring operation in case of emergencies

CARSU will lay the theoretical foundation, develop the necessary systems knowledge, and demonstrate a prototype of a new kind of a wireless system, which will operate in a very broad frequency spectrum with bands of operation that can be dynamically allocated. Such a system would be able to reuse the frequency bands that the primary users are not using at a particular time and a particular location.

Demonstration of a wireless terminal, a prototype device, will be a centerpiece of this program. This wireless terminal will replace today's mobile phone, and will interoperate with a 'connectivity broker,' a device that will replace today's access points, to support a diversity of radio technologies as well as innovative rules of cooperation to couple to the wireless infrastructure. The terminal will be able to migrate from infrastructure-supported operation to forming a mesh network, based on either centralized frequency allocation or intelligent and cooperative sensing of unutilized bands.


"A successful society is characterized by a rising living standard for its population, increasing investment in factories and basic infrastructure, and the generation of additional surplus, which is invested in generating new discoveries in science and technology."
- Robert Trout, Pioneering Broadcast Journalist