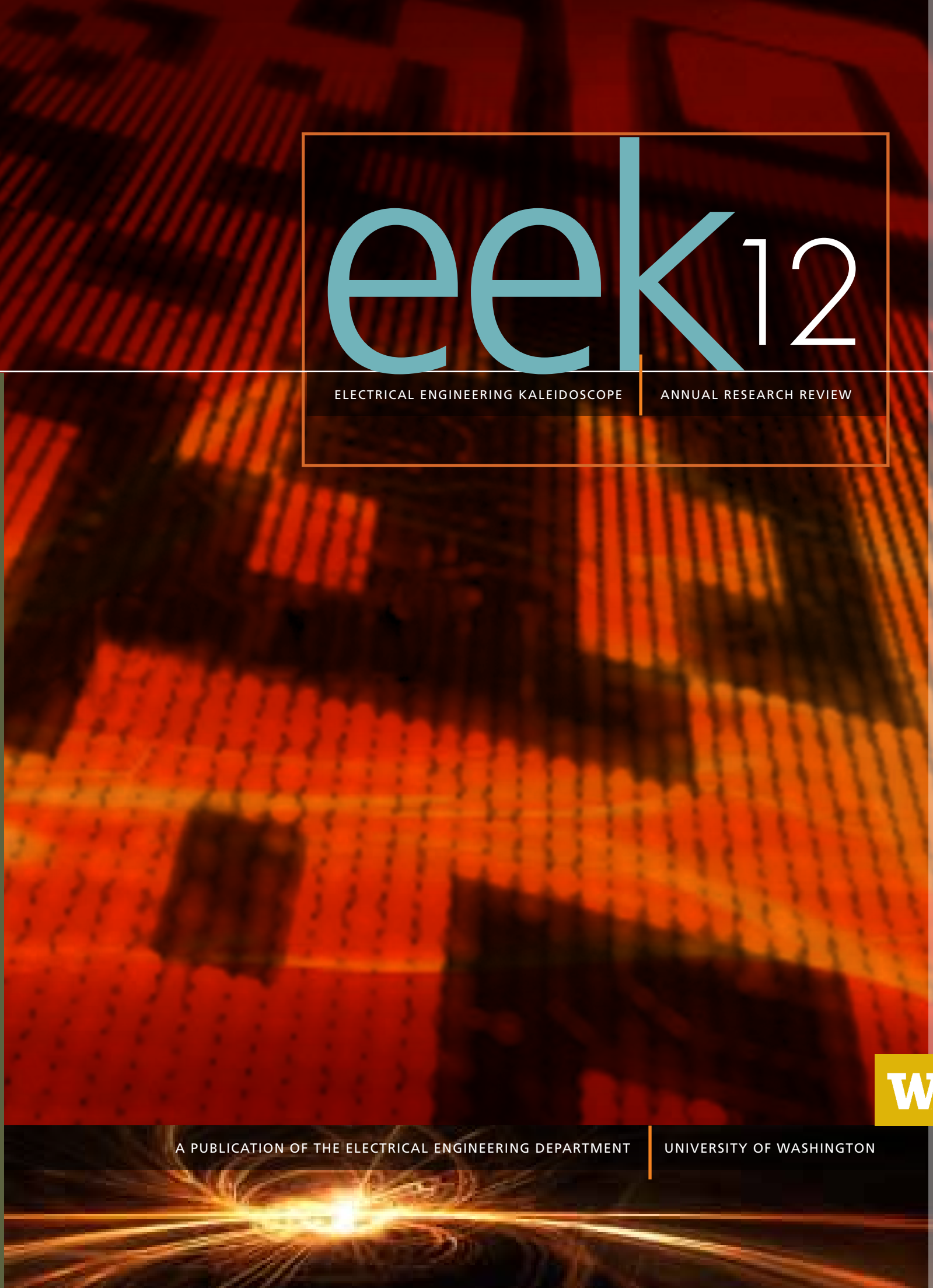

eek 12

ELECTRICAL ENGINEERING KALEIDOSCOPE | ANNUAL RESEARCH REVIEW

A PUBLICATION OF THE ELECTRICAL ENGINEERING DEPARTMENT | UNIVERSITY OF WASHINGTON

Dear Supporters and Alumni of UW EE,

I am delighted to report on our department's continuing achievements in research and education through our top-notch students and faculty.

The recent success of the interdisciplinary Center for Sensorimotor Neural Engineering where several UW EE faculty play a lead role demonstrates the need and benefits of building large-scale research programs and centers that cut across a wide range of traditional disciplines. This will continue to be a priority in the ways UW EE strives to address today's most pressing issues. Engineering is often viewed as a toolset for solving specific well-defined problems. However, many challenging aspects that future generations face in the core areas of health, the environment, energy and people-centered systems can be tackled using engineering-based approaches. The National Academy of Engineering through its grand challenges in engineering resonates with this idea and goal of using engineering-based approaches to solve the problems of our time. It is also my belief and intention that pursuing and maintaining a larger connection of our research and education to such goals will also enhance the diversity of students and researchers interested in working with us on these challenges.

Our department's research successes traverse the spectrum of established and emerging areas in electrical engineering. Some highlights include Shwetak Patel's MacArthur "genius award" for his work in sensors and energy, the iGEM team's world championship win in Synthetic Biology with Eric Klavins, David Allstot's IEEE Circuits and Systems Valkenburg Award for his many years of excellence in analog circuit design, Daniel Kirschen's recent Department of Energy grant on Energy Positioning, and Blake Hannaford and Howard Chizeck's pioneering work on the surgical robot RAVEN and Kinect-based haptic rendering.

In our educational mission, we are enhancing our successful professional masters program that caters to the growing needs of industry, and implementing creative ways to further enhance the quality of our graduate and undergraduate programs. Advancement plays a key role in this, with our primary goal of establishing more endowed fellowships and professorships for attracting high-quality students and faculty.

There is no time like the present for looking at new models for education and outreach. In particular, erudition and entrepreneurship can go hand in hand. With the success of startups such as Zensi and Nimbic, we will continue to support and build scalable outreach and commercialization activities involving students and faculty.

I am looking forward to serving and working with all of our excellent faculty, staff and students in building shared meaning while we nurture tomorrow's creative electrical engineers. I truly believe that electrical engineering holds a special place in the future we all share, and it is more important than ever that we build and maintain the connection to the real challenges of our time in health, the environment, energy, and people-centered systems. This edition of EEK highlights the spectrum of high-quality research performed by our stellar students and faculty.

Happy reading and best wishes for 2012!

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ANNUAL RESEARCH REVIEW

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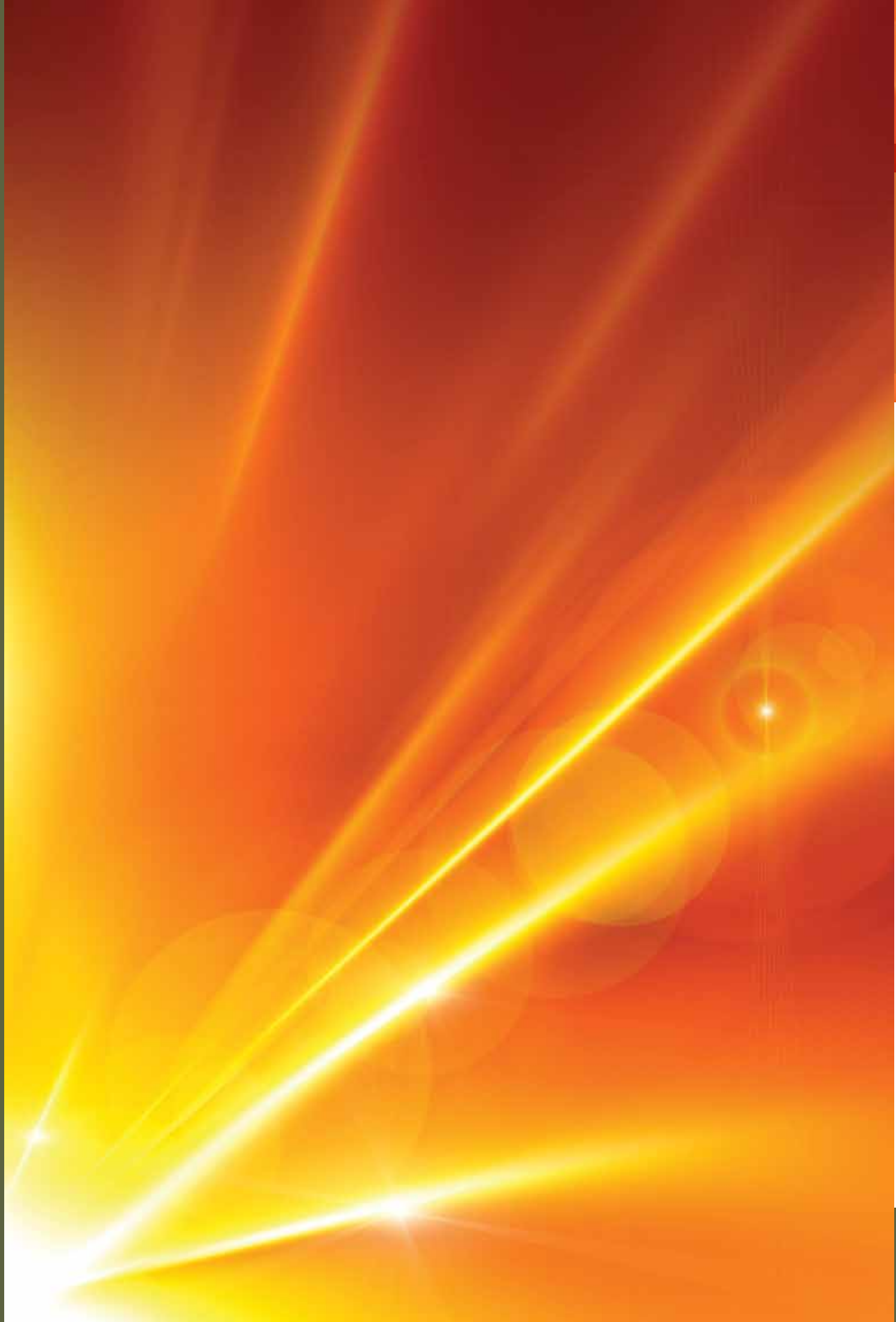

Robust Video Object Tracking in Distributed Camera Networks

Chun-Te Chu | Graduate Student (EE)

Tracking objects is one of the major tasks of a video surveillance system. Before the behavior of a specific target can be analyzed, the target's position needs to be correctly located in consecutive video frames. Normally, the surveillance cameras cover a large range of area to form a camera network. Robust tracking, as successfully investigated at UW EE's Information Processing Lab can reliably reliably track the objects within and across the cameras, as well as with or without overlapping field of views.

For single camera tracking, a multiple kernels tracking scheme is combined with adaptive Kalman filtering to overcome the occlusion problem while tracking within the camera. Besides the individual tracking within each kernel, this multiple kernels tracking scheme controls the kernels by some predefined constraints such as the geometrical relationship between them. The projected gradient method enables the tracking system to find the optimum and satisfy the constraint at the same time. The Kalman filtering scheme is employed to estimate the dynamic model of the objects efficiently. The proper coupling of the two makes this tracking approach robust to the occlusion problem.

Some scenarios for the single camera tracking. Database is from PETS2010 http://pets2010.net/ and i-Lids dataset for AVSS 2007.

In order to solve the correspondence problem for multiple camera tracking (i.e., to establish the consistent labels between the objects in different cameras), several features are considered. First, spatial-temporal features are included to model the transition time for an object traveling between two cameras. Moreover, the appearance features are utilized. However, even the same object may appear differently in different cameras due to the variant illumination, viewpoints and environments. Thus, the transfer functions between two cameras for all the appearance features are necessary. The brightness and tangent transfer functions are applied to compensate the deviation of the color and edge features. Re-identification can be successfully done by matching the above features.

Tracking across the cameras with overlapping views. The same people are given the same color bounding boxes and labels.

An example frame for tracking across the cameras with non-overlapping views.

This tracking system not only tracks the objects under occlusion within an individual camera but also tracks the objects across the cameras. The goal is to enhance performance and finally deploy the system on a camera network.

For more information scan code with smart phone or visit: allison.ee.washington.edu

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RESEARCH AREA
Video Analysis & Computer Vision

GRANT/FUNDING SOURCE
Industrial Technology Research Institute, Taiwan

Automatic Cable Detection for Millimeter-Wave Radar Video

Qirong Ma | Graduate Student (EE)

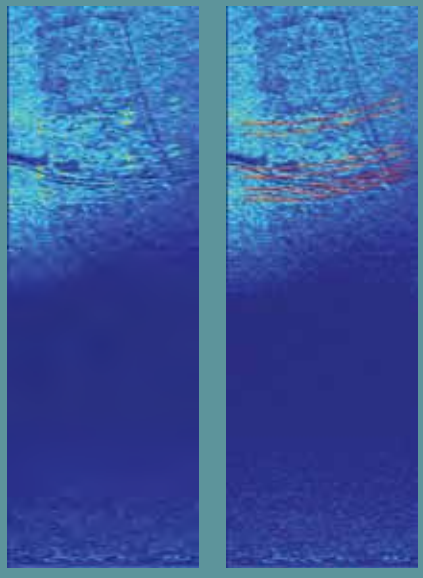
Signal and image processing technologies have found prevailing applications in every aspect of daily life, from Photoshop image editing to license plate recognition on highway SR 520 in Washington State. This project uses image processing technologies to develop an automatic high-voltage cable line detection and warning system to assist pilots of helicopters.

Cable lines are hard to recognize by the human eye, but they are evident in the millimeter-wave radar video. Unfortunately, the radar videos are very noisy. By processing the noisy radar video, researchers are able to systematically detect the cables and give a warning signal to the pilot.

High-voltage power lines present hazardous conditions for the helicopters because they are subtle objects for the pilot to see, and even more difficult to identify in rainy or foggy weather. Thus, wire-strike accidents are a major threat for helicopter safety. Radar image and video can provide more useful information to identify the power lines at a far distance, and the effectiveness is the same even in bad weather or at night. The radar imaging system operates at a millimeter-wave frequency of 94 GHz.

View from cockpit. The cables are out there but not very clear. If weather is bad or the towers are missing, it is very hard to recognize them.

The braiding structure of cable lines has a periodic pattern structure on the surface where the radar wave can be diffracted to form a Bragg pattern in the returned radar image. The Hough transform technique is applied to the image after thresholding to detect the straight lines as possible cable lines, and then a pre-trained Support Vector Machine (SVM) is used to classify true cable lines from noisy lines. Temporal correlation is considered by integrating the cable detection results from adjacent frames into a frame score which represents the probability for a frame to contain cables. A warning signal is subsequently issued based on this probability.



Left: The radar imaging result frame. Cables are on top of the image.

Right: The detection result with cable lines overlaid in red.

This algorithm can effectively detect cable lines in the radar video. Future work will aim to detect and track other kinds of objects, especially under low visibility conditions.

For more information scan code with smart phone or visit: allison.ee.washington.edu

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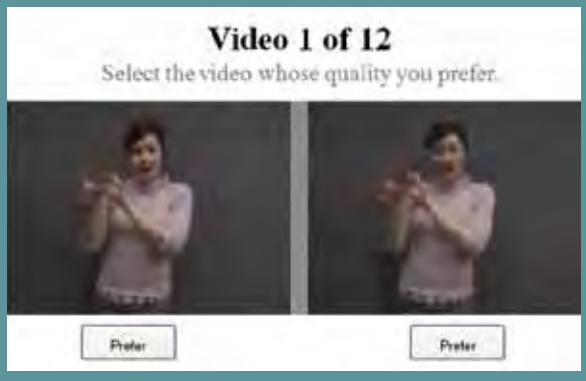
GRANT/FUNDING SOURCE
Honeywell Corporation

Evaluating PSNR vs. Subjective Video Quality of Real-Time Sign Language Video on Mobile Phones

Jessica J. Tran | Graduate Student (EE)

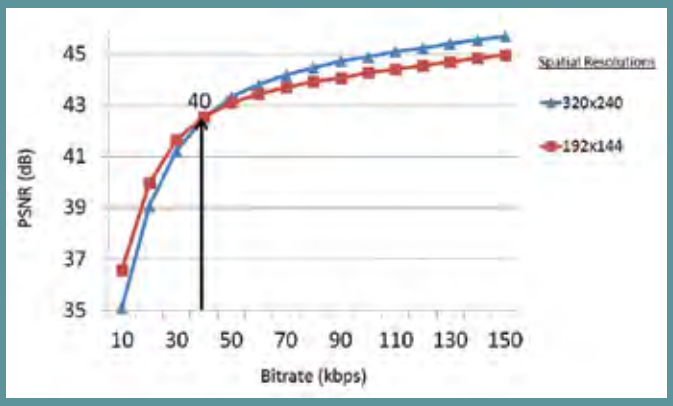
The experimental application, MobileASL (American Sign Language) explores ways to reduce bandwidth consumption and increase battery life while providing comprehensible sign language video at very low bandwidth over the US 3G cellular network. Recently, a national online video-based user survey of 103 respondents was conducted to investigate the relationship between human comprehension and the objective video quality metric called peak signal-to-noise ratio (PSNR).

Using low bitrates (10-60 kbps) and two low spatial resolutions (192×144 and 320×240 pixels), the survey results identified which spatial resolution respondents preferred at each bitrate. These did not match the objective results calculated for varying bitrates and spatial resolutions. For respondents fluent in ASL, we also investigated whether or not video quality preferences influenced the perceived ease of comprehension.



Screenshot of a 12-second video pair from the paired-comparison experiment on the web-survey. Respondents selected which video they preferred to watch.

We found a crossover point at 40 kbps where both spatial resolutions produced the same measured video quality. At bitrates lower than 40 kbps, the smaller spatial resolution produced a higher measured PSNR and at bitrates higher than 40kbps, the larger spatial resolution produced a higher measured PSNR. This information was used to study how user responses compared to these results.



PSNR (dB) vs. bitrate (kbps) for spatial resolutions displayed at 320×240 pixels. Higher PSNR means higher objective video quality. Notice at 40kbps both PSNR curves intersect each other.

From the web-survey, we found that at 20 kbps and higher, respondents preferred the video quality produced by the 320x240 spatial resolution over the 192x144 spatial resolution, which does not match what PSNR predicts. However, when comparing the perceived ease of comprehension between spatial resolutions at each bitrate, respondents comprehended ASL video clips more easily with video transmitted at the 320x240 spatial resolution at 50 and 60 kbps ($Z=100.0$, $p<.001$). These results suggest PSNR may not be suitable for representing subjective video quality, but may be a reliable measure for ASL video comprehension while comparing spatial resolutions and bitrates of video transmission.

Future work will incorporate these results into the MobileASL application to improve mobile phone resources such as battery life and data consumption. Behavioral changes will be observed to see if users would elect to use a lower bitrate and spatial resolution to gain more talk time when they are informed of their resource consumption.

For more information scan code with smart phone or visit: mobileasl.cs.washington.edu

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GRANT/FUNDING SOURCE
National Science Foundation, grant IIS-0811884; Google Research

Health Sensing Using a Mobile Phone Microphone: Cough Frequency & Spirometry

Eric C. Larson | Graduate Student (EE)

Individuals with chronic diseases like COPD, cystic fibrosis and asthma need to evaluate their illnesses on a daily basis. In developing countries, physicians need ways to monitor lung function using low-cost, mobile equipment. Researchers from UW's Ubiquitous Computing Lab have developed algorithms to measure lung function using the microphone in a mobile phone.

These algorithms can automatically track how often a subject coughs, and subjects can perform pulmonary function tests (i.e., spirometry tests) by playing a game in which they blow at the screen of the phone. Each of these biomarkers can track the progression of pulmonary ailments and increase survival outcomes.

To sense coughing, techniques similar to those used in facial recognition are applied. Using the magnitude of the audio spectrogram, principal components analysis and a random forest classifier are used to identify coughs from the audio stream with 92% true positive rate and 0.5% false positive rate. This approach also has the ability to reconstruct the cough audio from the saved features, allowing physicians to listen to the cough sound. However, because privacy of collected audio is a major concern, the features are designed such that all other audio except the cough sound is incomprehensible.

Mobile phones placed to collect audible cough sounds as a patient walks around, performing normal daily activities.

A version of the blowing game used as a spirometry test.

For spirometry testing, the patient blows at the screen of the phone as part of a game, and the collected audio is then analyzed. By extending models of the vocal tract that were developed at AT&T in the 1960's, the audible reverberation of the lips is converted into a measure of the flow of air from the mouth. When calibrated correctly, this device can measure the speed (liters per second) and volume (liters) of air that a patient can blow from their lungs. Existing medical equipment for measuring these quantities can cost in excess of $3,000.

Currently, patients are being recruited for a clinical trial of the cough sensing device; the initial study will include infants with cystic fibrosis, and then trials will be conducted on adults in ambulatory settings. To evaluate the spirometry work, clinical trials of healthy volunteers will be conducted, then subjects with childhood asthma will be evaluated.

For more information scan code with smart phone or visit: ubicomplab.cs.washington.edu/wiki/Main_Page

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RESEARCH AREA
DSP, Pervasive Health, Sensing

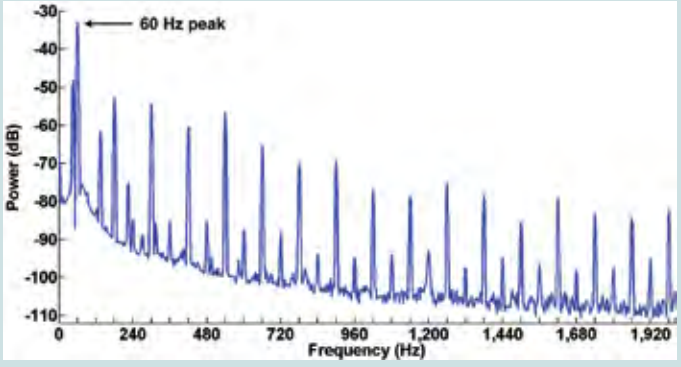
Humantenna: Using the Body as an Antenna for Real-Time Whole-Body Interaction

Gabe A. Cohn | Graduate Student (EE)

Natural user interfaces which allow users to interact with computers using only gestures are becoming increasingly popular. The current approaches use computer vision (e.g., Microsoft Kinect) or inertial measurements, and are limited in their ubiquity due to the high cost of instrumenting the interaction environment. Researchers from Microsoft Research and UW's Ubiquitous Computing Lab have developed an alternate method which uses the human body as an antenna for sensing whole-body gestures.

This approach requires no instrumentation to the environment, and only minimal instrumentation to the user, and thus enables truly mobile applications. A real-time system has been demonstrated where users interact with a computer using whole-body gestures.

To sense gestures without using additional instrumentation to the environment, existing signals already present in the places where people interact with computers are leveraged. Inside buildings, there is a rich signal space due to the low-frequency (<100 kHz) electromagnetic noise radiating from the power lines and appliances. This noise, which is dominated by the 60 Hz component and its harmonics, is received by the human body which acts as a broadband low-frequency antenna. Using machine learning techniques, a support vector machine can be trained to accurately classify which gesture the user is performing. The spatial variation in the electromagnetic noise, as well as the repeatable distortions to that noise due to changes in the shape of the body, allow the classifier to robustly determine the location of the user and the gesture being performed.



Frequency domain view of noise signals radiated from power lines and received by the human body.

The Humantenna system shows the feasibility of building truly mobile and ubiquitous whole-body interaction by eliminating the need for instrumenting the interaction environment. This system can sense a user's whole-body gestures with an accuracy of 93%, and classify the user's location at nearly 100% accuracy.

For more information scan code with smart phone or visit: research.microsoft.com/cue/Humantenna

Radiated electromagnetic noise received by the human body enables whole-body gesture interaction with computers.

An example set of 12 gestures which the Humantenna system can robustly classify at 93% accuracy.

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RESEARCH AREA
Human Computer Interaction

GRANT/FUNDING SOURCE
Microsoft Research

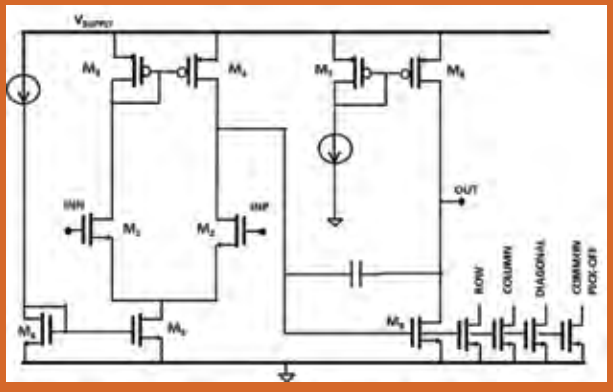
Integrated CMOS Electronics for a SiPM Array Interface

Samrat Dey | Graduate Student (EE)

The use of Silicon Photomultipliers (SiPMs) for Positron Emission Tomography (PET) is motivated by reductions in both form-factor and cost of imaging systems. The reduced size allows for a higher detector density which improves image resolution.

However, more channels are required for a SiPM array to interface with backend digital electronics used for signal processing. This work explores novel analog and mixed-signal electronic systems to reduce the required channels and simplify the interfaces between the individual elements in the SiPM array and the backend DSP.

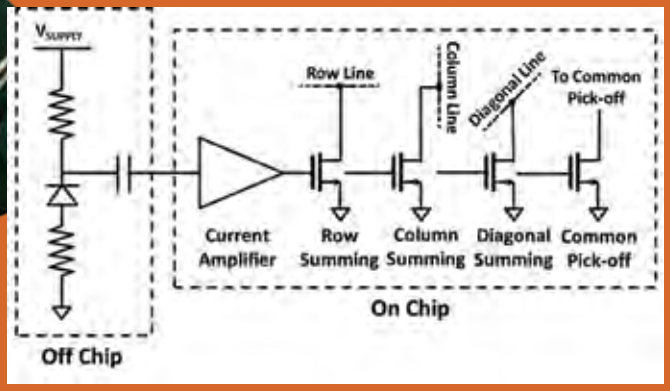
The research focuses on the use of row-column-diagonal decoding architecture analogous to addressing techniques used in digital memory. For an N by N SiPM array, this spatial decoding method can effectively reduce the number of electronic channels from N^2 to 2N for row-column decoding only, or to 4N-1 with the addition of a diagonal decoding channel. Decreasing the number of SiPM channels reduces the number of required analog-to-digital converters without significantly reducing energy resolution. The use of a single high-speed current amplifier is being explored to interface with the SiPM device and generate multiple outputs row, column, diagonal and a timing alignment signal.The goal is to optimize the bandwidth and linearity of the analog SiPM channel while minimizing thermal noise and power consumption. In addition, to lower the likelihood of errant photon detection due to "dark" noise, novel methods using threshold-level detection circuitry are also being investigated.



A two-stage amplifier with four current outputs.

This work seeks to eventually integrate the readout electronics either in the same package as the SiPM devices or on the same silicon substrate. This will allow sophisticated calibration methods to address mismatch and non-idealities in the readout electronics.

For more information scan code with smart phone or visit: www.ee.washington.edu/research/fast/FAST.html



The front end architecture.

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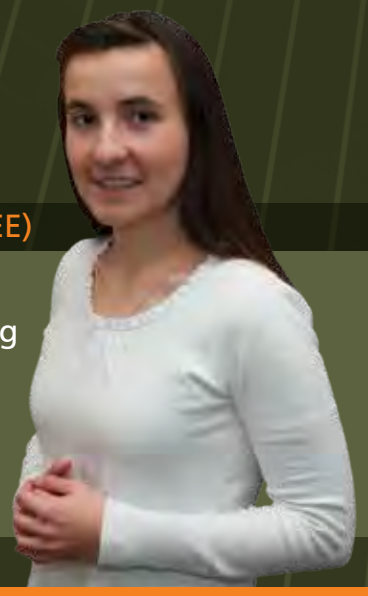
RESEARCH AREA
Analog/Mixed-Signal IC Design

GRANT/FUNDING SOURCE
NIH & Zecotek Photonics

Modeling & Mitigating Node Capture Attacks in WSNs

Tamara Bonaci | Graduate Student (EE)



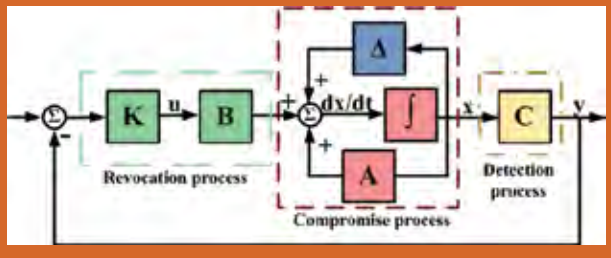
The security of a Wireless Sensor Network (WSN) is critical, particularly when it applies to smart infrastructure, patient monitoring, target tracking and border control. When deployed unattended, WSNs are vulnerable to node capture attacks, where an adversary physically compromises sensor nodes and extracts information known to them, including the assigned cryptographic material and the internal states of network protocols.

The obtained knowledge is used to create malicious copies of captured nodes (clones), which are then used to interfere with and disrupt the sensing operation.

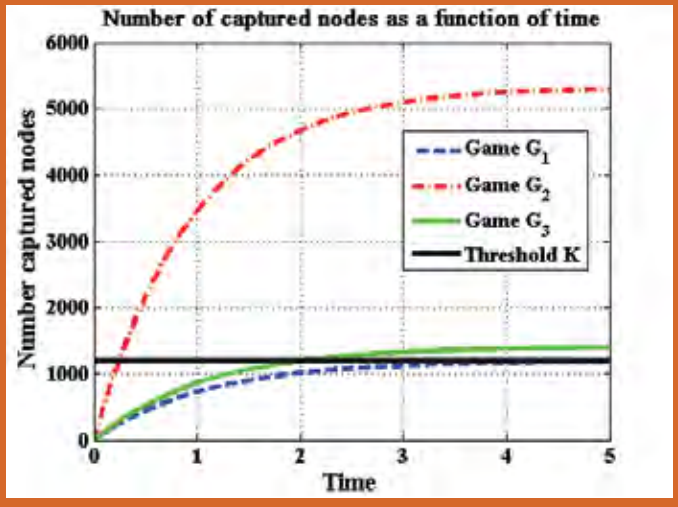
In prior work, researchers have developed methods to detect and revoke a subset of compromised nodes from the WSN. Currently, however, an adversarial model of node capture attack does not exist, thus preventing a comprehensive approach to model and mitigate actions of a time-persistent adversary.

In this work, the node capture attack is viewed as a dynamical process, and a joint analytical model of the attack and the corresponding network response is developed. First, a dynamical model is developed to characterize the impact of the node capture attack on the WSN. This model shows how control-theoretic methods can be used to manage mitigation actions.

The dynamical model is then used to characterize and formulate the strategic interaction between the adversary and the network owner. This interaction is explored in the game-theoretic setup and modeled as a two-player non-cooperative game. A variety of adversarial goals and different assumptions about the adversaries and the WSN constraints are investigated.



An abstract dynamical model of the node capture attack consisting of three components: the compromise process, the detection process and the revocation process.



Simulation results showing the interaction between the adversary and the WSN for three attack scenarios (games). The targeted network consists of 10,000 sensors and the adversary needs to capture 1,200 to compromise the WSN. The game G2 represents the adversary who does not have explicit constraints on the number of captured nodes. This adversary compromises the WSN fast, but wastes resources on capturing more nodes than needed.

The impact of this work is two-fold. The dynamical impact model enables the analysis of the WSN performance, stability and resilience to the attack. Combined with the game-theoretic interaction model, it provides a deeper understanding of the WSN operating point under attack. This in turn facilitates the development of novel mitigation algorithms, which guarantee WSN functionality under attack, while preserving WSNs' resources.

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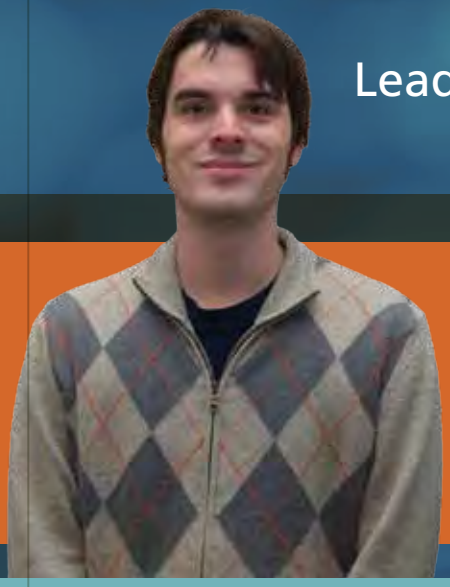
RESEARCH AREA
Secure-Control for Wireless Networks

GRANT/FUNDING SOURCE
Army Research Office



Leader Selection in Multi-Agent Systems

Andrew Clark | Graduate Student (EE)

Multi-agent systems (MAS) consist of networked, autonomous agents who influence each others' behavior. Examples include formations of unmanned vehicles, sensor networks, the electric grid and biological systems such as flocks of birds or fish.

Since each agent's current state affects the states of multiple neighboring agents, the overall behavior of the system can be determined by controlling a relatively small subset of "leader agents." However, for such networked systems, which agents should act as leaders in order to effectively control the remaining agents?

Selecting leader agents is challenging because control inputs sent via the leaders may be corrupted by noise as they propagate to the remaining agents. This project considers the problem of choosing leaders in order to minimize the overall error due to noise. For a broad class of MAS, the resulting error is a supermodular function of the set of leader agents.

Supermodularity is an increasing returns property, and analogous to convexity of continuous functions. This property allows for efficient and accurate algorithms for selecting leader agents. Two problems have been studied, which include:

1. Choosing up to k leaders in order to minimize noise error
2. Choosing the minimum-size set of leaders that meet an upper bound of error

Algorithms have been developed for each problem under a variety of network scenarios, including static networks, networks that experience random failures, networks that switch between predefined configurations, and networks that vary arbitrarily in time. For each problem type, this approach outperforms related heuristics, including random and node degree-based selection.

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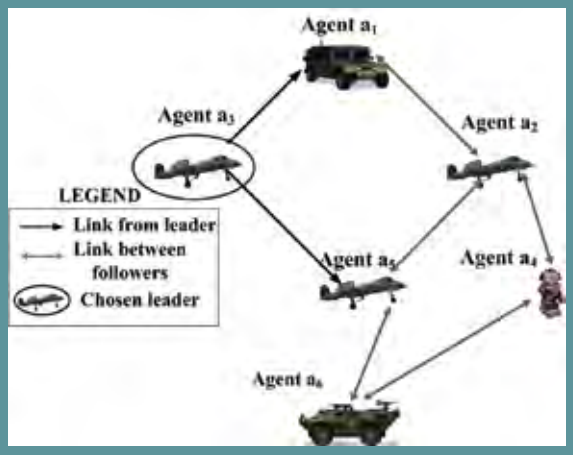
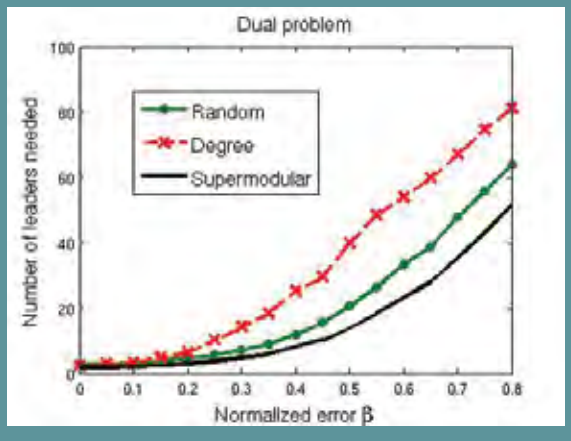
This research addresses fundamental questions in MAS, which may have applications in emerging areas such as control of autonomous vehicles and robots. The goal is to build on these results to develop a general framework for leader selection, which is a key design problem in MAS.



An example of a MAS consisting of networked vehicles controlled by a ground operator.



This proposed method requires fewer leaders to achieve the desired error bound compared to existing heuristics.

FACULTY ADVISORS
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RESEARCH AREA
Networking & Communications

GRANT/FUNDING SOURCE
Army Research Office

Vehicle-to-Grid Scheduling Strategies for Electric Vehicle Aggregators

Eric Sortomme | Graduate Student (EE)

Electric vehicles (EVs) are increasing in popularity due to the desire to reduce emissions and achieve energy independence. EVs offer many benefits over traditional internal combustion engine (ICE) vehicles such as lower operating costs and the potential to run on locally produced renewable energy.

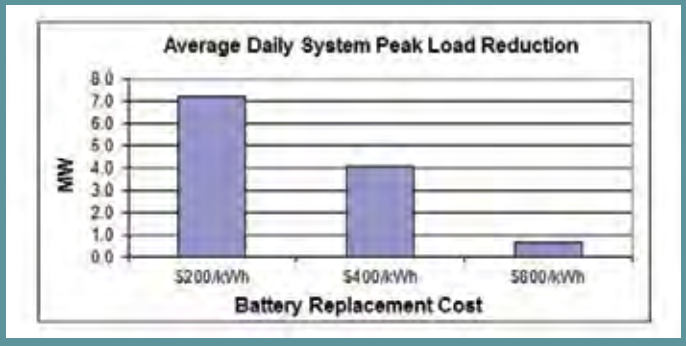
However, mass adoption of EVs is challenging because EVs are typically more expensive than ICE vehicles, and the public charging infrastructure is in its infancy. Additionally, mass unregulated charging of EVs can cause energy shortages in the power grid.

One way to address these challenges is through Vehicle-to-Grid (V2G), the provision of energy and ancillary services to the power grid from an EV. Through V2G, EV owners can generate revenue from their cars while parked and charging, which helps overcome the economic hurdles of EV adoption. The services provided by the EVs to the grid mitigate the impacts that are caused by charging. Since a single EV does not have sufficient capacity to participate in energy markets, the capacity of many vehicles and charging patterns are aggregated.

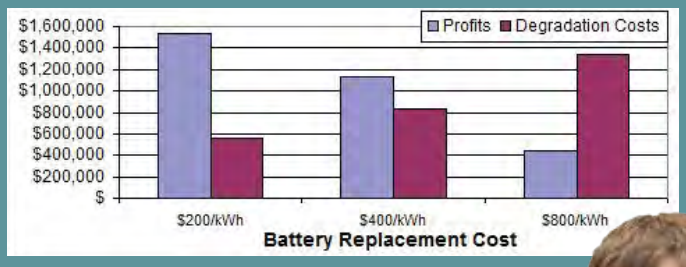
This research looks at profit maximization for a V2G aggregator. To do so, the algorithm must take into account customer driving patterns and charging requirements. Within these constraints the algorithm determines the optimal capacity of energy, regulation up, regulation down, and responsive reserves to bid into the market. These decisions are based on market prices forecasts, load conditions and forecasts, and costs associated with cycling the battery. Simulations on a hypothetical group of 10,000 EVs in Houston, TX show that significant profits can be realized while shaving the system load peak for different battery replacement costs. At all times, the customers receive sufficient charge for their trips and thus the V2G scheme makes no impact on customer behavior.

This technology enables a V2G aggregator to optimally schedule their assets. It is patent pending and one V2G company is in talks with the university about a licensing agreement which will implement the algorithms in their core revenue optimization module.

For more information scan code with smart phone or visit: cialab.ee.washington.edu



The average daily system peak load reduction as a result of V2G energy discharges to the grid.



Quarterly aggregator profits and battery degradation costs for different battery replacement costs.

FACULTY ADVISOR
Mohamed El-Sharkawi

RESEARCH AREA
Energy

Kinetic Lattice Monte Carlo Simulations of Diffusion Processes in Si & SiGe Alloys

Renyu Chen | Graduate Student (EE)

As the CMOS technology enters the nanometer range, atomic scale variation of transistors becomes a major fabrication issue. Random fluctuation of the dopant atoms is one of the major sources. In order to achieve controlled variability for the continuous scaling trend of transistors, it is crucial to understand the diffusion behavior of impurity atoms during device fabrication.

The kinetic lattice Monte Carlo (KLMC) approach, which treats diffusion at the atomistic level while overcoming the time-scale problem, can efficiently simulate atomistic diffusion processes at macroscopic system sizes and practical time scales.

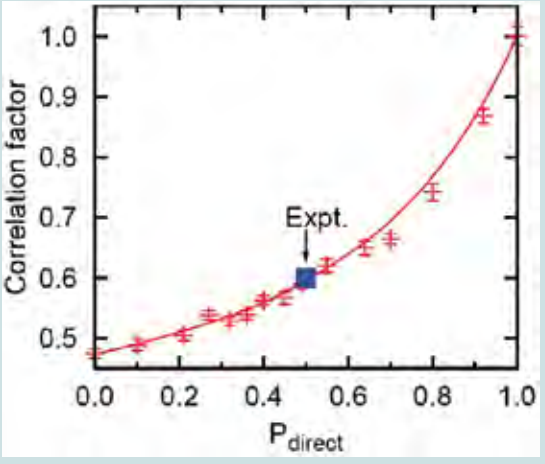
Researchers from UW EE's Nanotechnology Modeling Lab have developed a C++ based kinetic lattice Monte Carlo (LAMOCA) simulator which can simulate various diffusion phenomena during the fabrication process. Two notable features of the simulator are:

1. The incorporation of the augmented lattice domain (including high-symmetry interstitial sites) that allows simulations of interstitial-mediated diffusion
2. The inclusion of the stress effect on the diffusion migration barriers that facilitates simulations of stress-dependent inter-diffusion in strained silicon germanium (SiGe) alloys

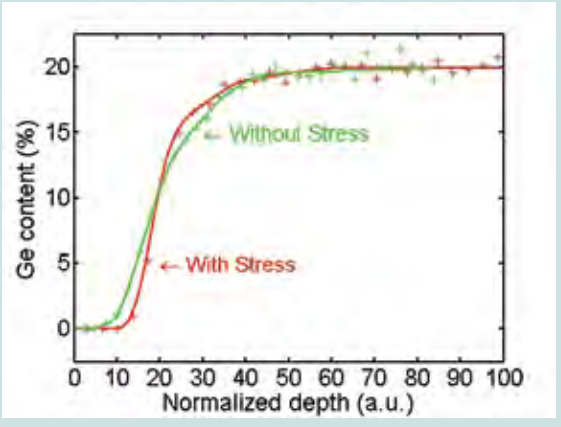
In the simulator, a rate catalog storing the rates of all the allowed transitions is maintained. The rate of a given transition is directly related to its associated energy barrier, which is in turn extracted a priori from first-principles quantum mechanical calculations. At each KLMC iteration, a particular transition is picked with the probability proportional to its rate. Next, the chosen transition is performed; the rate catalog is updated and system clock advances. By applying the iteration repeatedly, the evolution of the system can be tracked at large time scales.

Using this simulator, extensive studies have been performed on self-/inter-/impurity diffusion in Si and strained SiGe alloys. The results provide powerful insights into the optimization of nanoscale device fabrication.

For more information scan code with smart phone or visit: dunham.ee.washington.edu/



Calculated correlation factor of interstitial-mediated self-diffusion in silicon versus the probability of the direct hopping mechanism, assuming only two mechanisms, indirect (kick-out) and direct mechanisms, dominate. The blue square is the experimental value from Voronkov et al.



Calculated diffusion profiles for vacancy-mediated SiGe inter-diffusion with and without inclusion of the stress effect. Stress effect retards vacancy-mediated inter-diffusion. The results are obtained at 920 °C. "+"s are original data and lines are fitted curves.

FACULTY ADVISOR
Scott Dunham

RESEARCH AREA
Devices & Materials

GRANT/FUNDING SOURCE
SRC, SiSoC

Strong Room-temperature Chemiresistive Effect of TiO_2 Nanowires to Nitro-aromatic Compounds

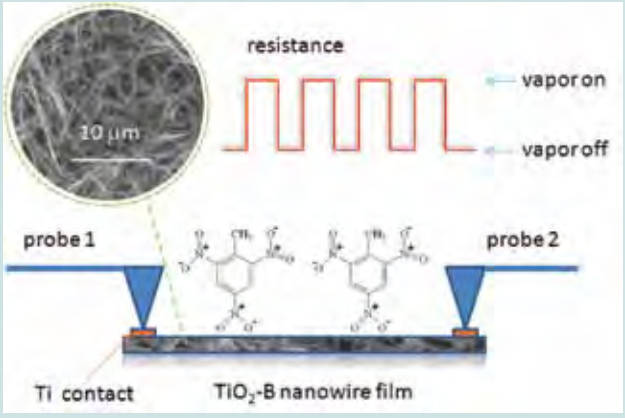
Danling Wang | Graduate Student (EE)

Detecting nitro-aromatic explosives is crucial for ensuring the safety and security of society. Although several technologies have shown great promise, their size, weight and power consumption are a serious concern. Since the TiO_2 nanowires have sensitive and rapid chemiresistive response to sub-trace concentrations of nitro-aromatic compounds, they are a potential solution for building substantially smaller trace explosive detectors.

This project aims to achieve micro-sized sensing devices made of TiO_2-B nanowires with significantly reduced dimensions, weight and power consumption over current explosive detectors.

Chemiresistive sensors for detecting nitro-aromatic explosives depend on the choice of materials. Single crystalline TiO_2 nanowires can be chemically synthesized with a low-cost and high-yield hydrothermal method. Explosive sensors based on these TiO_2 nanowires are compatible with standard microelectronic manufacturing processes. Due to the high surface-to-volume ratio as well as large surface area for molecule adsorption, it was demonstrated that semiconducting TiO_2 nanowires meet these requirements very well. In addition, the hydroxyl groups on the surface of TiO_2 nanowires developed a potential method to minimize the cross-sensitivity to humidity during the sensing detection of nitro-aromatic explosives. The results presented both a strong and fast response when exposed to the vapor of explosives by means of a change in the electric conductance.

As-synthesized nanowires solution was drop-casted on the glass substrate and heated at 700C to attain a thin film. Patterned titanium electrodes were deposited by sputtering. The resistance change and response time of the sample is determined by measuring its resistance between two metal contacts when the gas applied to the thin film is cycled between air with nitro-aromatic vapor and pure air.



A schematic sketch of the chemiresistive effect of TiO_2 nanowires to nitro-aromatic and nitro-amine explosives. Inset is a SEM image of the TiO_2 nanowires film. The film is fabricated on glass substrate and its resistance is modulated as the vapor (TNT) switches between "on" and "off."

A strong chemiresistive sensor of TiO_2 nanowires in response to vapors of nitro-aromatic compounds at room temperature has been investigated. Experimental results indicate that the response originates from a depletion of electron carriers by the surface states produced by adsorbed molecules of explosive compounds via hydroxyl groups on TiO_2 nanowires surface.

For more information scan code with smart phone or visit: photonics.apl.washington.edu/Research.htm#nano-wires

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RESEARCH AREA
Photonics

GRANT/FUNDING SOURCE
Office of Naval Research, National Science Foundation, UW WRF-APL Fellowship

Haptic Rendering from Time Varying Point Cloud Data

Fredrik Ryden | Graduate Student (EE)

The release of Microsoft's Xbox Kinect started a trend of inexpensive RGB-D cameras with good resolution and adequate frame rate, which provided new possibilities in the field of haptics. Researchers from the UW EE's BioRobotics Lab have found a way to capture data in the real world using the Kinect camera and then make it available for haptic interaction in real-time.

Using a commercially available haptic device, they have achieved "remote touch," which could be useful in virtual reality tele-conferencing or in controlling tele-operated robots.

This research aims to change traditional proxy algorithms which use polygons for haptic rendering, and make them work with time-varying point clouds instead (representing the real world as captured by the Kinect camera). This has been achieved by implementing a novel iterative proxy to estimate the surface in the vicinity.

The three steps for capturing a point cloud to force on the haptic device include:

1. Capturing the point cloud data from a camera and transforming this data into a Cartesian coordinate frame
2. Moving the proxy towards the haptic interface point (HIP) without penetrating any points
3. Representing the force on the haptic device as a damped spring force based on the vector between the proxy and the HIP

Using this algorithm, users can "touch" moving objects seen by the camera. That is, users can haptically interact with dynamic point clouds.

This work shows that a large amount of point cloud data can be processed for haptic rendering while meeting the real-time timing constraints. Because of its' structure, the algorithm can easily be extended to virtual fixtures in tele-robotics, something that is currently being implemented.

Haptic rendering from time varying point clouds demonstration setup at the IROS Conference in September, 2011. The user moves the haptic device to interact with point clouds captured by the Kinect camera. The haptic rendering runs on a laptop computer and is visualized on an external display.

A point cloud of a hand captured by the Kinect camera. The red sphere illustrates the haptic proxy.

For more information scan code with smart phone or visit: http://brl.ee.washington.edu/~ryden/

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RESEARCH AREA
Haptics, Telerobotics, Control

GRANT/FUNDING SOURCE
National Science Foundation (NSF grant # 0930930), Natural Sciences & Engineering Research Council of Canada (NSERC)

Raven II: An Open Platform for a Surgical Robotics Research Network

H. Hawkeye King | Graduate Student (EE)

Currently, there is no open platform for surgical robotics research, so innovation in this field requires either restrictive licensing agreements on human-approved systems, or an institution must build its own. Researchers at UW EE are leveraging the Raven surgical system developed by the UW BioRobotics Lab to create a surgical robotics research network with peer institutions across the country.

Soon, Raven II systems will be installed at the UW, Johns Hopkins, U. of Nebraska, UC Santa Cruz, Harvard, UC Los Angeles and UC Berkeley.

Research is already ongoing using first generation Raven systems at UW and UC Santa Cruz. Now, seven pairs of Raven II surgical robot arms have been built which will be distributed to partner groups. All the control electronics, manipulator hardware and software architecture has been built. A new US patented 10mm diameter, four degree of freedom surgical tool invented by alumnus Manuel Moreyra (MSEE '96) was developed for these new robots. The Raven II robot is an evolution of the Raven I design, with mechanical improvements from the UC Santa Cruz and Diana Friedman (PhD '11) and all new electronics designed by alumnus Philip Roan (PhD '11). The robot software uses the new open-source Robot Operating System (ROS) so it can easily incorporate open-source robotics tools.

Each partner institution has an independent intellectual agenda. By using common research hardware and software, heightened collaboration and innovation is expected since improvements from each group will be shared across the consortium and results can be validated on a uniform platform.

Many benefits can be expected from using new robotics techniques in surgery, all with the goal of improving patient care. One goal is to improve accuracy in manipulation to reduce complication rates, surgery duration and recovery time. Another goal is to improve the safety of operations through machine assistance at the controller level, the human-machine interaction level, or at the decision-making level.

For more information scan code with smart phone or visit: http://brl.ee.washington.edu/ravenIIwiki/index.php/Main_Page

UW EE doctoral student Hawkeye King demonstrates how a surgeon watching a screen would operate the controls. The electronics package (right) would then send those controls to the Raven II robot (center).

The Raven II's mechanical arms have tiny hands to perform surgery on a simulated patient. In back are the electronics that deliver commands from the surgeon to the robot.

FACULTY ADVISOR
Blake Hannaford

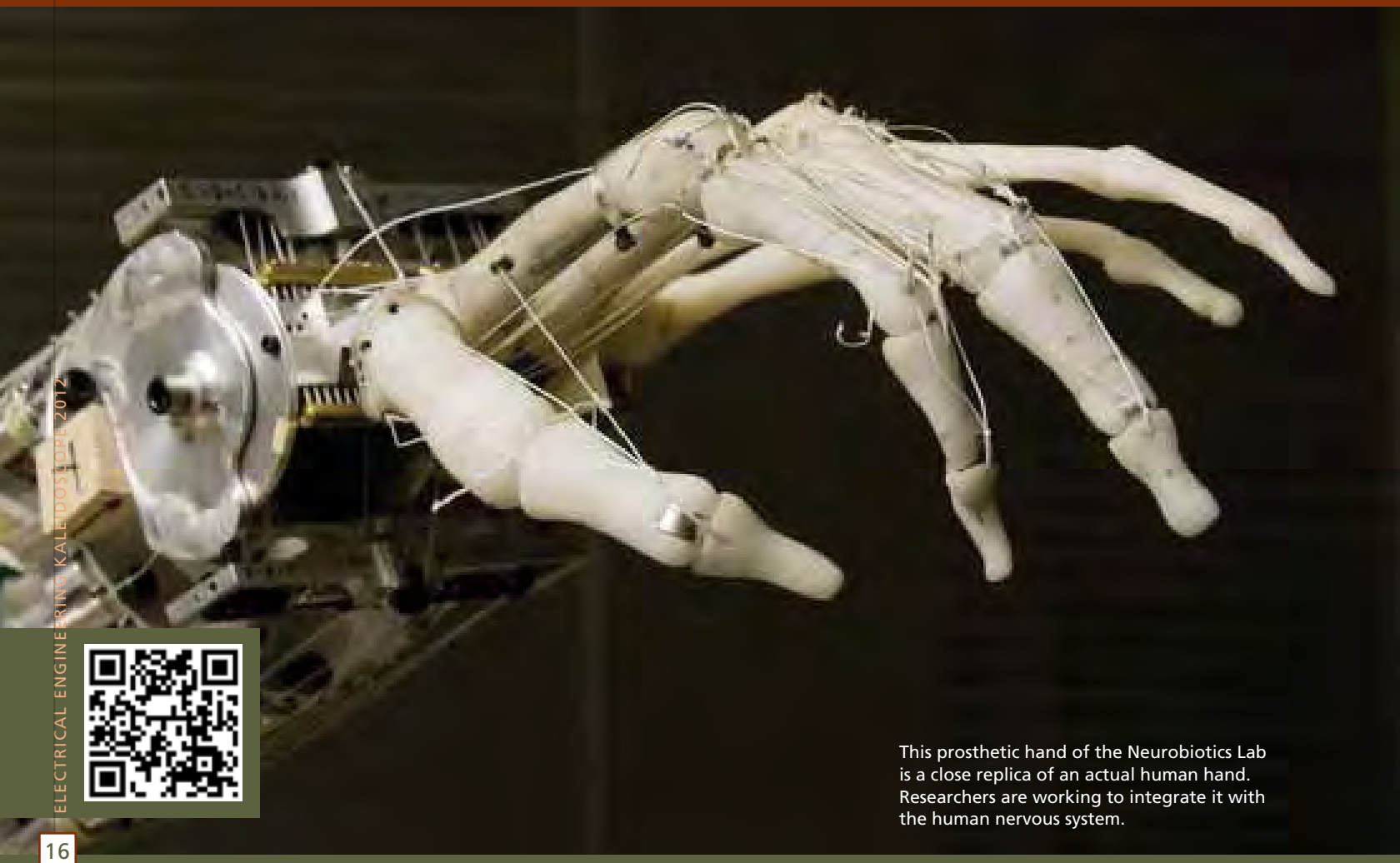
COLLABORATORS
UC Santa Cruz, Harvard Univ., Johns Hopkins Univ., Univ. of Nebraska, UC Los Angeles, UC Berkeley, Graduate Students Levi Cheng (ME), Sina Nia Kosari (EE), Timothy Kowalewski (EE), Lee White (BioE)

RESEARCH AREA
Controls & Robotics

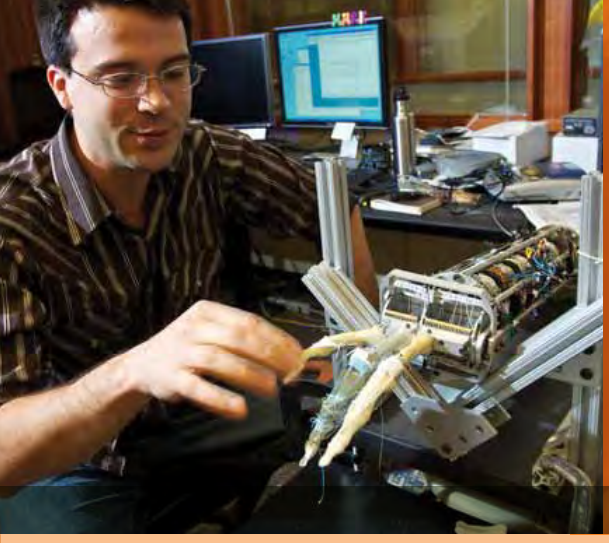
GRANT/FUNDING SOURCE
National Science Foundation: CNS-0930930

NSF Engineering Research Center for Sensorimotor Neural Engineering

The Engineering Research Center for Sensorimotor Neural Engineering has been established by the National Science Foundation with a five year, $18.5 million grant (with the possibility of renewal for another five years). The center, based at the UW, will work on robotic devices that interact with, and help to understand the nervous system. These robotic devices will combine advances in robotics, neuroscience, electromechanical devices and computer science to restore or augment the body's abilities for sensation and movement.



This prosthetic hand of the Neurobiotics Lab is a close replica of an actual human hand. Researchers are working to integrate it with the human nervous system.



EE graduate student Eric Rombokas with a prototype prosthesis built in the Neurobotics Lab.

GRADUATE STUDENTS AND POST-DOCS INVOLVED IN CSNE RESEARCH

Graduate Students
Agrawal, Sweta *(Neurobiology and Behavior)*
Huang, Yanping *(Computer Science and Engineering)*
Jiang, Iris *(Bioengineering)*
Matlack, Charlie *(Electrical Engineering)*
Morgan, Sara *(Rehabilitation Medicine)*
Presnyakov, Georgiy *(Industrial and Systems Engineering)*
Redfield, Morgan *(Electrical Engineering)*
Rombokas, Eric *(Electrical Engineering)*
Smarr, Benjamin *(Neurobiology and Behavior)*
Wander, Jeremiah *(Bioengineering)*
Waters, Benjamin Herron *(Electrical Engineering)*
Zabala, Xisco *(Biology)*

PostDocs
Sample, Alanson *(MSEE '08)*
Larson, Eric *(Speech and Hearing Sciences)*
Widge, Alik *(Psychiatry and Behavioral Sciences)*

Researchers at the UW and partner institutions will work to perform mathematical analysis of the body's neural signals, design and test the implanted and wearable prosthetic devices and neural prosthetic systems, as well as build new robotic systems.

The research efforts of the center combine the contributions of three core engineering research thrusts:

- Communication and Interface
- Reverse and Forward Engineering
- Control and Adaptation

The Communication and Interface research thrust develops devices and data handling/learning algorithms for neural signal extraction and interpretation and feeds back external sensor signals into the neural system. The Reverse and Forward Engineering research thrust defines intricate biological systems and computations to help design neural interface and control devices to further enrich neural modeling. The Control and Adaptation research thrust develops devices to express sensorimotor functions for individuals and for devices that explore remote locations. In addition, it designs algorithms for closed-loop control and adaptation between humans and devices. It also takes the leadership role in end-to-end system integration for developing robust and reliable closed-loop solutions.

The center includes researchers from UW, MIT, San Diego State University, Spelman College, Morehouse College, Southwestern College, the University of British Columbia and the University of Tokyo. The center's headquarters are in Russell Hall on the UW Seattle campus.

The Center's first Director was Yoky Matsuoka, a former Professor of Computer Science and Engineering and Adjunct Professor in Electrical Engineering at the UW. Currently, the Center is being led by Interim Director, Tom Daniel, Joan and Richard Komen Endowed Chair of Biology at the UW.

A diverse group of faculty from the UW College of Engineering, UW College of Arts and Sciences and the UW Medical Center will be involved in the new center. Electrical Engineering core faculty involved in the center include: Josh Smith (Communication and Interface research thrust leader), Brian Otis (former Communication and Interface research thrust leader), Howard Chizeck (Control and Adaptation research thrust leader), Jeff Bilmes, Karl Böhringer, Maya Gupta, Blake Hannaford and Jacques (Chris) Rudell.

The center has more than twenty industry partners, including Microsoft, Intel, Lockheed Martin, as well as smaller companies and startups such as Impinj, NeuroSky and NeuroVista. There are also affiliated industry organizations and venture capitalists that will help to translate the research of the center into commercial products. Collaborators also include nonacademic research institutions such as the Allen Institute for Brain Science, the La Jolla Bioengineering Institute, and hospitals in Seattle, WA and San Diego, CA.

The majority of the funding will support undergraduate and graduate student research. As with all NSF-funded engineering research centers, this center's mission is to integrate research with education and community outreach. New K-12 curricula will be developed to create a diverse pool of students literate in neuroscience and neural engineering who can enrich the national university and industry talent pools. The center will expand and diversify the pipeline of underrepresented groups prepared for college and advanced degree completion in neural engineering disciplines by expanding partnerships with minority-serving institutions on K-12 project-based experiences (such as those provided by MESA programs), and by working with programs that serve students with disabilities nationwide (such as the DO-IT program). The center will also provide a Research Experience for Undergraduate program and active recruitment of underrepresented groups that include women, minorities, and individuals with disabilities.

> "The Engineering Research Center for Sensorimotor Neural Engineering will bring together university and industry researchers to establish Seattle as an education, research and commercial hub for 'neurobotics,'" said Matt O'Donnell, the UW's dean of engineering. "We have fantastic partners and a strong leadership team to accelerate innovations and help prepare students to advance the field."

For more information scan code with smart phone or visit: www.csne-erc.org/

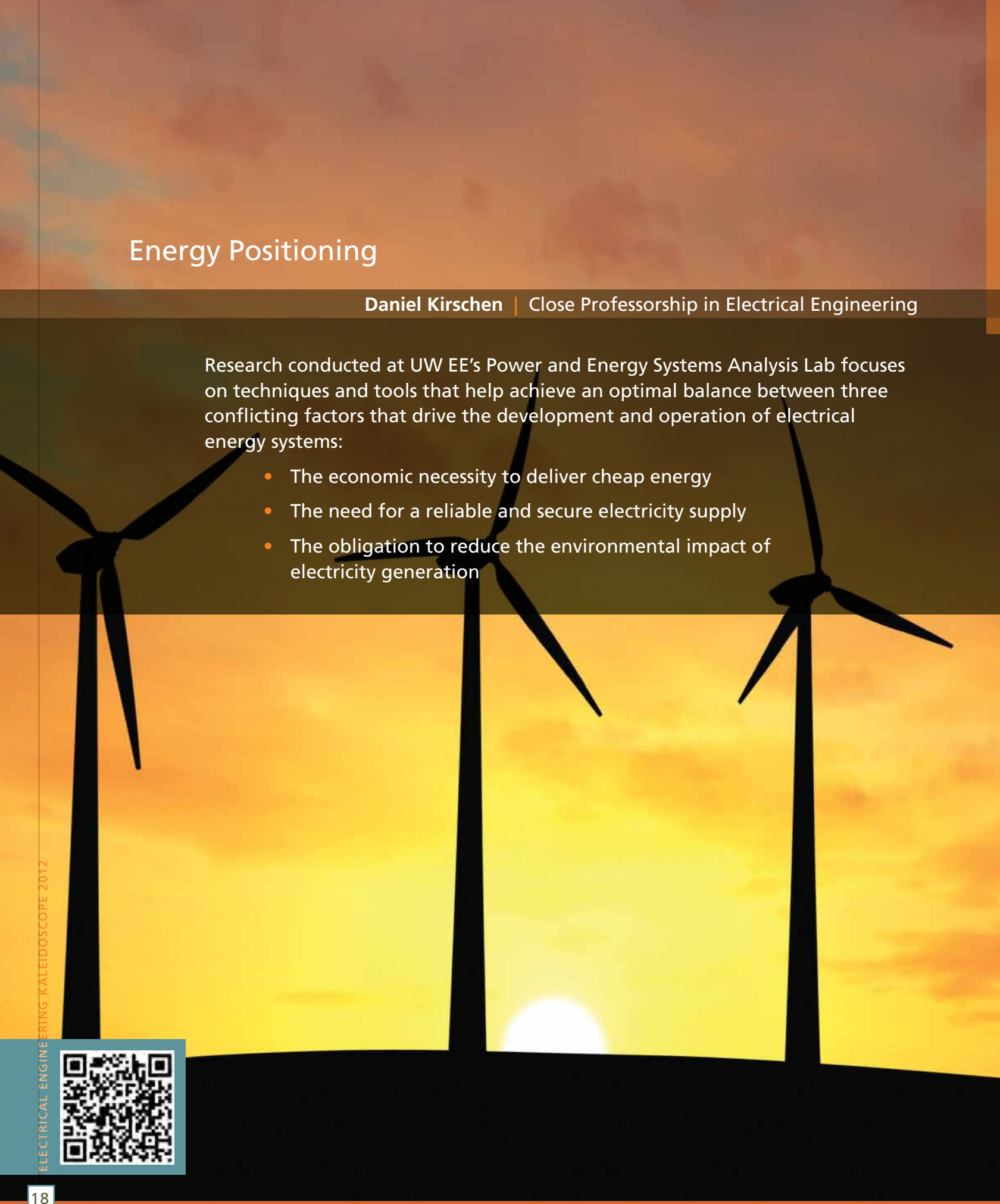
GRANT/FUNDING SOURCE
National Science Foundation Center for Sensorimotor Neural Engineering (grant number EEC-1028725)

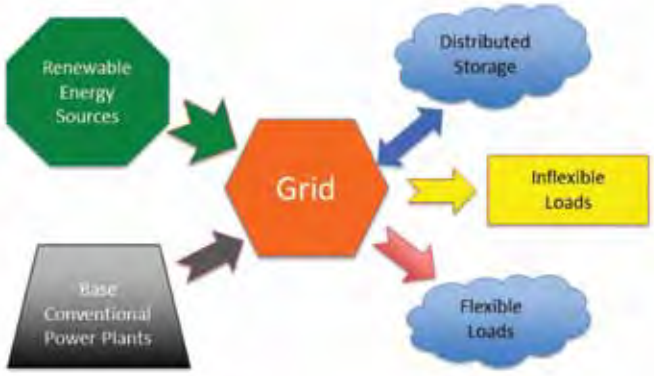
Energy Positioning

Daniel Kirschen | Close Professorship in Electrical Engineering

Research conducted at UW EE's Power and Energy Systems Analysis Lab focuses on techniques and tools that help achieve an optimal balance between three conflicting factors that drive the development and operation of electrical energy systems:

- The economic necessity to deliver cheap energy
- The need for a reliable and secure electricity supply
- The obligation to reduce the environmental impact of electricity generation





A conceptual representation of the energy positioning paradigm.

As the proportion of decentralized generation increases, the intermittency and stochastic nature of their output begins to affect the stability and the security of the power system. Ramping conventional generating units up and down to keep the system in balance may not be sufficient or technically possible. Other resources, such as storage and demand response may need to be deployed.

The dominant power system operating paradigm is that "supply follows demand," i.e. consumers are able to change their load at will but generators have to adjust their output correspondingly to maintain stability. While this paradigm has worked extremely well for over a century, two issues make it increasingly difficult to uphold:

1. Wind and solar generation are ill-suited to following the load.
2. Renewable energy resources are usually located far from the load centers. This creates congestion in the network and increases the risk of cascading outages.

These two issues must be considered together because coordinated control of well-positioned and properly sized storage facilities and demand response schemes (distributed energy control resources) would not only facilitate the large-scale integration of renewable generation, but would also significantly reduce the need for transmission expansion and would improve system reliability. These additional benefits could tip the balance when considering the economic case for widespread deployment of storage and fast-acting load controllability.

In collaboration with Professor Ian Hiskens of the University of Michigan, UW EE's Power and Energy Systems Analysis Lab recently obtained a $1.4M grant from the Department of Energy's ARPA-E program to study how these resources should be deployed. In particular, they will be exploring the following issues:

- How should storage and demand flexibility be controlled to maximize the economic benefits of renewable energy sources?
- Can storage and demand flexibility be used to improve the security of the grid, i.e. restore the system's stability following an outage?
- How much storage should be installed and where should it be located?
- How can we quantify the value of this storage?

This project will develop the control technologies needed to establish an "energy positioning" operating paradigm: Excess production from renewable energy sources is either consumed directly by flexible loads or directed to the storage facilities where it is best pre-positioned for later use. Under normal operating conditions, this paradigm would reduce congestion, operating costs and the need to build new transmission lines. Furthermore, following a contingency, control on a faster timescale would reallocate the distributed stored energy and the flexible demands to alleviate overloads and stabilize the system. This approach could thus substantially improve power system reliability.

The specific objectives of this project are to develop control technologies and computational techniques for operating distributed energy control resources under both normal and contingency conditions. The project will also help quantify how cheap energy storage must be to provide an economically viable alternative paradigm for operating the grid.

For more information scan code with smart phone or visit: http://wp.ee.washington.edu/energy-group/

COLLABORATORS
Dr. Ian Hiskens, University of Michigan

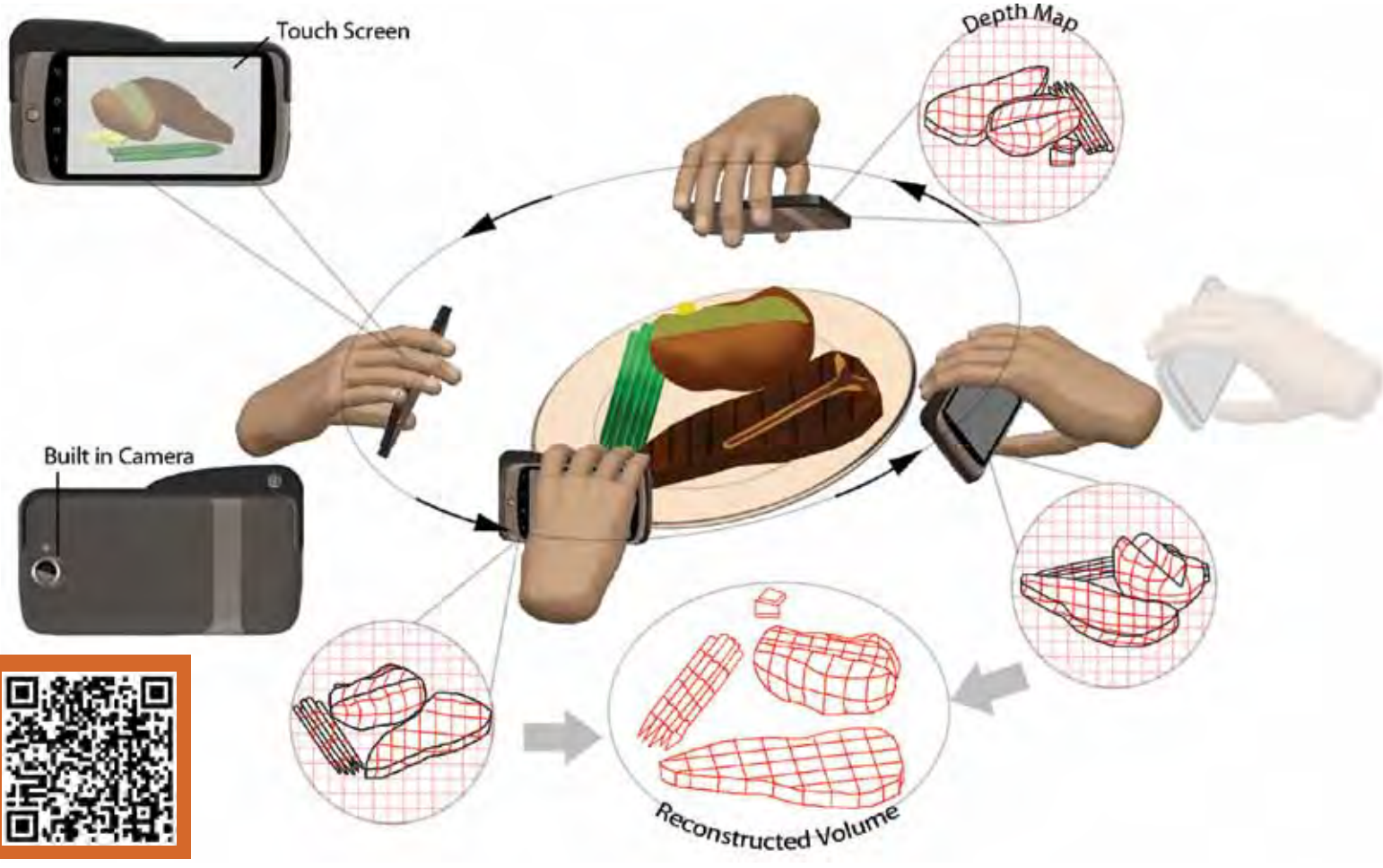
GRANT/FUNDING SOURCE
U.S. Department of Energy: Green Electricity Network Integration (GENI)

STUDENTS INVOLVED
Graduate Students Ting Qiu & Yishen Wang

UW Dietary Data Recorder Offers Phone-Based Laser-Assisted Diet Monitoring

Alexander Mamishev | Associate Professor

The Sensors, Energy, and Automation, Laboratory (SEAL) at the University of Washington, in partnership with the Fred Hutchinson Cancer Research Center, developed a fully functional Dietary Data Recorder (DDR) system. The DDR system estimates food volume and individual energy intake through video analysis and personal annotations.



The DDR employs 3D modeling to estimate food volume.

Photograph of the DDR prototype.

The device functions in real-time, allows users to view an up-to-date summary of their eating habits, and grants them the necessary awareness to make better choices.

The DDR system transcends the capabilities of traditional dietary intake monitoring systems, which typically rely on user estimation to calculate the caloric content of food. This results in a drastic reduction in accuracy because individuals tend to underestimate or under report their food intake. Through laser-based 3D model reconstruction based on pre- and post-meal video, the DDR system creates objective volume estimations of food items. Users are able to supplement this estimation with audio and text annotations that help determine the composition of the food. Coupled with a robust nutritional database and a powerful server, the DDR system can provide highly accurate energy intake data, giving users, doctors, and researchers the ability to objectively observe even the smallest details about eating habits.

SEAL has created a fully functional DDR prototype, which is currently undergoing clinical testing at the Fred Hutchinson Cancer Research Center. With roughly 90% accuracy, the DDR can measure the volume of common foods. In addition to video feed, the system records the transaction's time of day and prompts the user to provide additional information, such as food identification. This is a significant improvement over traditional, paper-based food surveys.

The DDR functions by rapidly firing a laser on and off, while the device is rotated around the food collecting video. After the video is collected, food volume is estimated through 3D reconstruction, which consists of three primary steps:

- Depth image generation
- Fusion of depth images from each direction
- Food volume estimation

The DDR does not require the camera to remain at a fixed distance, the algorithms have been designed to accommodate incomplete and inconsistent rotations. To establish the accuracy of this volume estimation algorithm for objects of irregular shape and size, the volume of a mango is estimated under laboratory conditions. The algorithm estimated the volume of the mango at 280 cm^3, while the true volume by water displacement was 260 cm^3, representing 92.3% accuracy.

The DDR is designed for personal health monitoring and diet recording in clinical settings and free-living conditions. The market for personal healthcare devices is growing, as Americans spend an estimated $42 billion annually on weight loss foods, products and services. In addition to the general weight-loss community, plans are underway to market the device to individuals who require highly accurate monitoring (e.g., diabetics, cancer patients).

For more information scan code with smart phone or visit: www.ee.washington.edu/research/seal/projects.html

COLLABORATORS
Alan Kristal, Fred Hutchison Cancer Research Center

GRANT/FUNDING SOURCE
NIH

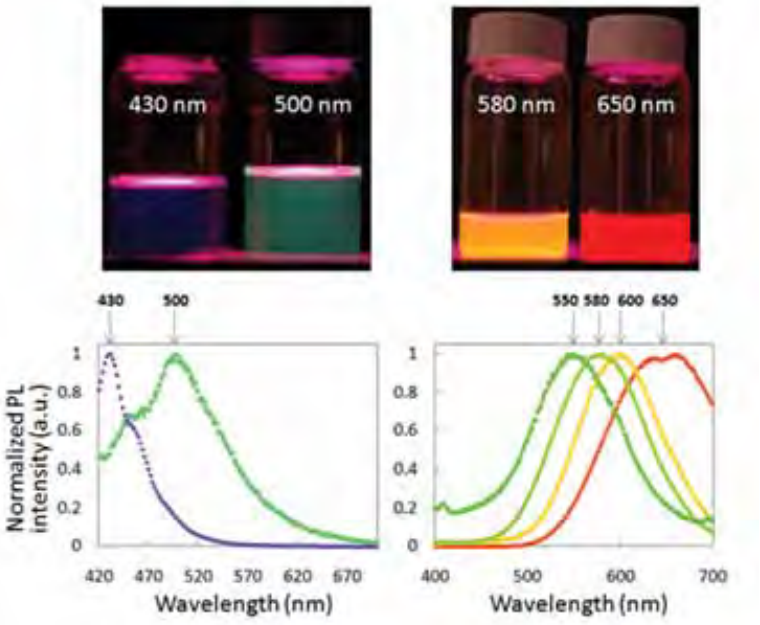
STUDENTS INVOLVED
Junqing Shang

Visible-Wavelength Phosphor Materials Based on SiQDs

Lih Y. Lin | Professor | **Chang-Ching Tu**

Semiconductor quantum dots (QDs) with size-tunable band gaps, high photoluminescence (PL) quantum efficiency, and high color purity have shown a great potential for the next-generation lighting and displays.

"UW" written by printing with the red-light-emitting SiQD-phosphors on a glass side. The photograph was taken under 365 nm UV illumination.



(Top) The photographs of the SiQD-phosphors in solution (PL = 430, 500, 580 and 650 nm) under illumination of 365 nm UV. (Bottom) The normalized PL spectra of the SiQD-phosphors with different emission peaks (PL = 430, 500, 550, 580, 600 and 650 nm).

However, previous QD-light-emitting devices were predominantly based on group II-VI compound semiconductors, such as CdSe QDs. High synthesis cost and heavy-metal-toxicity are the main barriers for their commercialization and acceptance by the general public. However, silicon QDs (SiQDs) are receiving more attention due to their heavy-metal-free composition, chemical stability and bio-compatibility. Most importantly, the abundance of silicon as starting materials (about 28% by mass in the earth crust) implies a great potential for low-cost and large-scale production.

This project uses SiQD-based phosphor materials which exhibit PL in the visible-wavelengths. The colloidal composites of nanocrystal SiQDs which are attached on micro-size silicon particles are synthesized by the electrochemical etching method. The subsequent isotropic etching by HF/HNO_3 not only controlled the QD size and subsequently changes the PL emission accordingly due to quantum confinement effect, but it also capped the material surface with a high-quality oxide passivating shell. The phosphor materials with hydroxyl termination can further react with alkoxysilanes to form a stable suspension in non-polar solvents for solution-processing, such as spin-coating or inkjet printing. The resulting red-light-emitting phosphors in chloroform exhibit PL external quantum efficiency of 15 to 20%. Their thin films can be efficiently excited by InGaN blue light-emitting diodes (LEDs) and are stable in room condition.

SiQD-based phosphor materials have great potential applications for low-cost, heavy-metal-free, air-stable, and wavelength-tunable light-converters in general lighting and display backlight systems.

For more information scan code with smart phone or visit: www.ee.washington.edu/research/photonicslab/

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GRANT/FUNDING SOURCE
National Science Foundation & Royalty Research Fund of the University of Washington

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Congratulations to Brian Otis who was promoted to associate professor and to Jeff Bilmes who was promoted to full professor.

We apologize for any errors, omissions or misspellings in 2012 EEK. We would like to extend special appreciation to the faculty, staff and students who assisted in producing this publication and to the sponsors whose generosity made it possible.

In Memory of Edward Guilford

The department was saddened by the death of Professor Emeritus Edward Guilford on October 31, 2011 at the age of 91. Professor Guilford received his BA and MS from the University of Utah in 1942 and 1950, respectively, and his PhD in Electrical Engineering from the University of California, Berkeley in 1959. He was hired by the department as an Assistant Professor the same year.

His research area was in energy conversion. After about a year and a half in the department, Professor Guilford was promoted to Associate Professor, surprisingly fast work. He became a full professor in 1971.

In 1962, the Minuteman missile program was discontinued. Professor Guilford obtained a Minuteman computer, modified it, and used it for several applications which greatly enhanced the educational labs and kicked off what we now see as the signal processing and machine learning research efforts in the department. In addition, he also maintained his continuing interest and participation in the later department programs on energy and energy conversion.

Many faculty in the department fondly remember Professor Guilford's wry sense of humor. "Ed had a great sense of humor and kept my spirits up back when I was a struggling new assistant professor," says Professor Les Atlas. Professor Emerita Irene Peden recalls asking Guilford how he kept his many cactus plants looking so healthy. Guilford replied by saying that he watched the newspapers and every time it rained in Phoenix, he would water his cacti.

Guilford loved to describe himself as an "old curmudgeon," but in reality, he was a good faculty friend and mentor. Ed Guilford will be missed, and our thoughts are with his family.

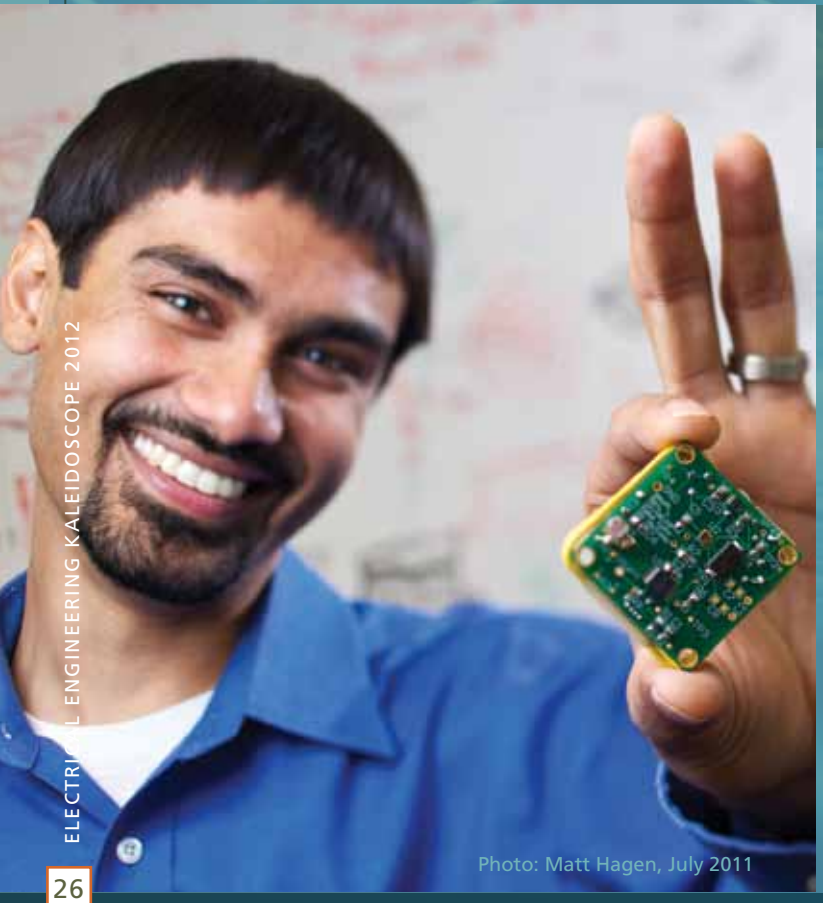

Photo: Matt Hagen, July 2011

Patel Receives Prestigious 2011 MacArthur Fellow

UW EE and CSE Assistant Professor Shwetak Patel was one of 22 honorees to be named a 2011 MacArthur Fellow. The five-year, $500,000 "Genius Award" was given to Patel for "inventing low-cost, easy-to-deploy sensor systems that leverage existing infrastructures to enable users to track household energy consumption and to make the buildings we live in more responsive to our needs."

MacArthur Fellowships are awarded to "individuals who show exceptional creativity in their work and the prospect for still more in the future." The selection criteria included exceptional creativity, a track record of significant achievement, and showing promise for important future advances. Fellowships are given without specific reporting requirements or obligations with the intent of encouraging awardees to pursue their most innovative ideas without restriction.

"We're all so proud of Shwetak and his recent accomplishment," says Vikram Jandhyala, Professor and Chair. "We are indeed fortunate to have someone so innovative teaching and inspiring our students and helping nurture tomorrow's creative electrical engineers and computer scientists."

Students Win World Synthetic Biology Competition

A UW student team won the 2011 iGEM World Jamboree synthetic biology competition, which was held at MIT in Cambridge, Mass last November.

The 23 undergrads forming the team represent the departments of biochemistry, microbiology, bioengineering, material science and computer science, reflecting the interdisciplinary nature of synthetic biology. This year's faculty advisors were UW EE's Eric Klavins, along with David Baker and Herbert Sauro from the departments of biochemistry and bioengineering, respectively. The graduate student advisors were Rob Egbert of electrical engineering, Ingrid Swanson of microbiology, and Justin Siegel of biochemistry who recently received his doctorate in biomolecular structure and design.

The iGEM students were given a kit of biological parts and asked to design and build biological systems using parts from the kit or by building and characterizing new parts. Their work in iGEM included months of lab work and genetic engineering of microbes—one to build a metabolic pathway that produces diesel fuel and another to design a new protein enzyme that could someday treat the difficult digestion problems for people with gluten intolerance. The research done by these students is currently being prepared for publication.

Photo: David Appleyard

Mission Possible: Robot Protocol

UW EE Robots Play a Part in 11yr-old's Wish

The Make-A-Wish Foundation and several organizations across the greater Seattle region participated in an elaborate wish experience called "Mission Possible: Robot Protocol" for 11-year old, Alex of Olympia, WA.

The EE department was one of the locations for the secret mission of Alex, whose wish involved robots for peace. Alex visited Professor Chizeck and his graduate students in the Biorobotics Lab, where he had an opportunity to "touch" remote objects using a haptic rendering system and an Xbox connect camera system. Then he explored Josh Smith's lab, where he had a chance to interact with and operate a mobile robot. After visiting EE Alex and his family went to Red Square, where there was a surprise flash mob of 1500-2000 people. This included the UW Dance team, and a large number of people in robot and Star Wars costumes. The entire event was organized by the Make-A-Wish foundation.

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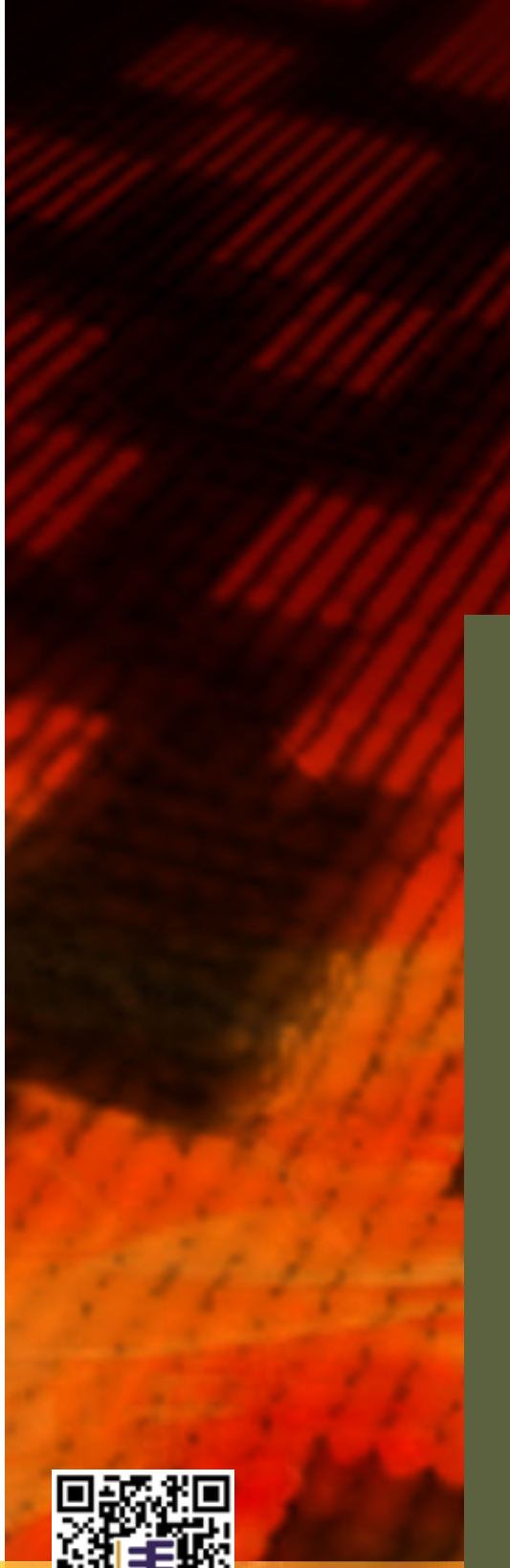

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