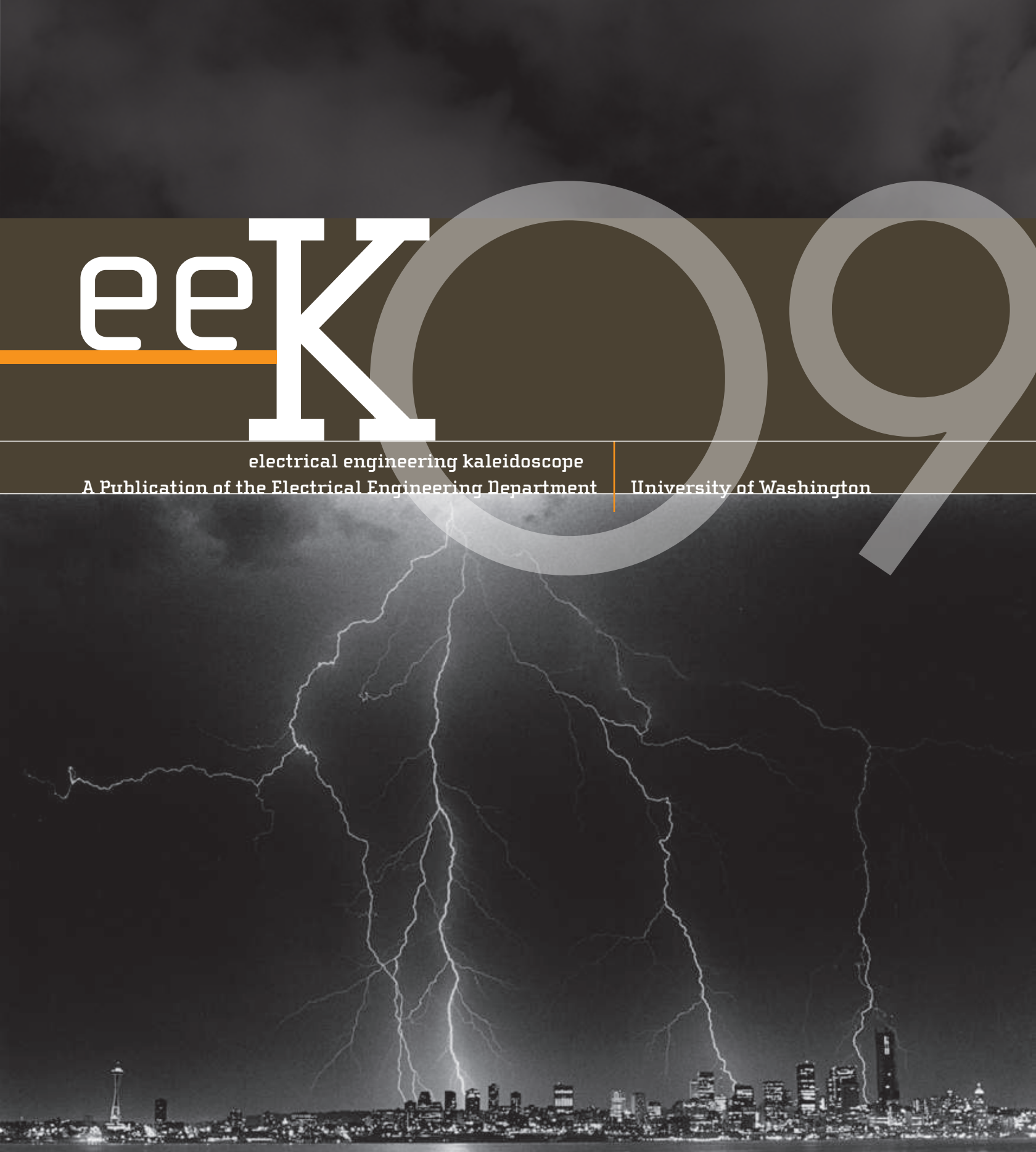
eeK09

electrical engineering kaleidoscope

A Publication of the Electrical Engineering Department | University of Washington



{ Annual Research Review }

The research in EE has continued to grow. Over the last 12 months, highlights included Professor Babak Parviz's invention of the contact lens with an imprinted electronic circuit and lights, Professor Eve Riskin's work on transmitting sign language over mobile phones, Professor Jeff Bilmes' Vocal Joystick project that uses voice to navigate the web, and Professor Michael Hochberg's article in *Nature* describing controlling forces of light in Nanotechnology. It has also been a great recruitment year with four new faculty starting this academic year: Chris Rudell in RFIC, Georg Seelig in Biological Circuits, Anant Anantram in Nanoelectronics and Shwetak Patel in User Interface Software and Technology. I hope that you enjoy reading about the research of the EE graduate students in this issue of EEK.

— LEUNG TSANG
Chair and Professor
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eeK09

[Annual Research Review]

this issue...

STUDENT RESEARCH

FACULTY PAGES

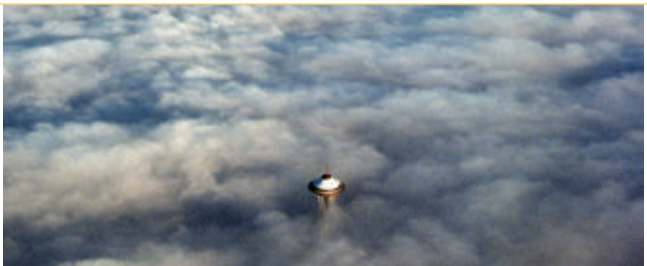


Photo by Dan DeLong/Seattle Post-Intelligencer

Election night rally on Capital Hill in Seattle, WA.
Photo taken by Seattle artist, Rebecca Chizeck.

The text of this page last year included the line, "2008 appears to be a year of accelerating political, economic and social change." With a year's hindsight, it is clear that this was an understatement. After 12 months of market collapse, extraordinary volatility in energy prices, financial recession and a monumental shift of power in the United States—we stand in the midst of a storm of unknown duration and ferocity. An underlying theme of all these changes is in new technology; consider the roles of Facebook, YouTube, twitter, Web 2.0 and text messaging in the political process. A second essence of our social and political transition is the generational transformation that is now underway. EEK09 captures aspects of both. Contained herein are reports of advanced technology research, in the words of our next generation of research scientists and engineering educators. Their efforts will contribute to the bright skies that will follow.

— HOWARD JAY CHIZECK
EEK Faculty Editor 2001-2009

A PERSONAL NOTE FROM THE EDITOR:

I established EEK in 2001, and it has been great fun to edit and produce these nine issues. This will be my last year of editing EEK. Beginning next year, EEK or its replacement will be edited by the Associate Chair for Research. Two outstanding individuals have worked with me on EEK for most of these years—Laura J. Haas of EE and Sarah Conradt of Sarah Conradt Design. I'd like to thank them for their amazing efforts. I would also like to thank all of the student contributors to EEK, who have provided content in the past few years.

Statistical Learning for Joint Deconvolution & Classification

HYRUM ANDERSON — Graduate Student (EE)

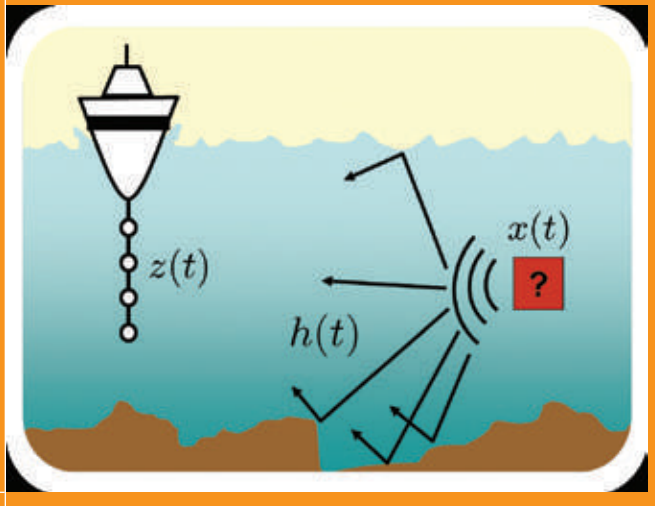
Consider the problem of telling two similar whales apart by their vocalizations. Recordings of each whale are available, captured in the open ocean where the background noise is minimal and multipath effects are negligible.

From this data, it is possible to tell the whales apart from only a few harmonics in their vocalizations. However, suppose you want to use the recordings to track the whales in a very different environment—the Puget Sound. Multipath reflections and shipping noise in the new environment muddle the whales' distinctive calls in random ways so that the whales are difficult to distinguish.

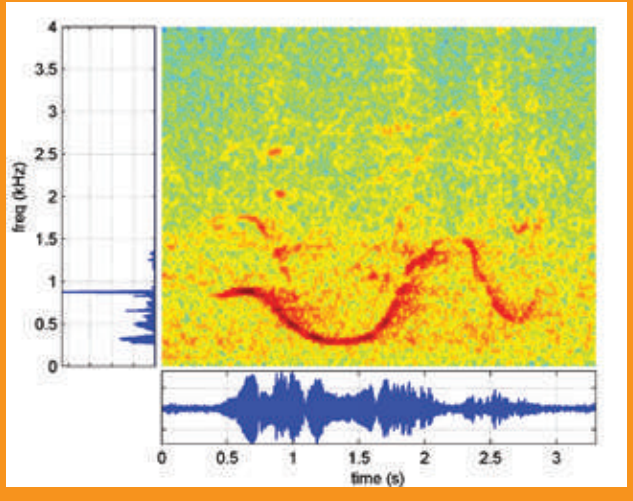
The problem of classifying a randomly corrupted signal by comparing to "clean" examples is present in many applications. Researchers in acoustics and signal processing have developed blind deconvolution schemes to estimate the unknown "clean" signal from the corrupted observation. In many cases, the signal estimate will then be classified using one of many statistical learning methods that employ the uncorrupted training examples. At the University of Washington, researchers are investigating methods which bring the strengths of "learning by example" to deconvolution in a single step; clean training examples are used to guide deconvolution in addition to providing a basis for classification.

For this application, joint deconvolution and classification compares the corrupted observations in the Puget Sound with clean training data obtained elsewhere. For example, the clean whale calls can be distinguished using a quadratic discriminant analysis (QDA) classifier on harmonic features. Using a crude statistical characterization of the acoustic channel (only first- and second-order feature statistics), a QDA joint deconvolution/classifier has been developed to allow appropriate comparison of the noisy observation with the clean recordings. This classifier performs better than traditional "deconvolve then classify" approaches, and can operate at a low signal-to-noise ratio.

Joint deconvolution and classification has been employed to develop several classifiers that mitigate the random corruption of an unknown channel, among them, support vector machines, local Bayesian discriminant analysis, and nearest neighbors. Other applications have been explored, such as example-based image deblurring. eek09



Problem description: classify z(t) given examples of x(t); h(t) is unknown.



A spectrogram of a bowhead whale song. The whale can be identified by its vocal harmonics.

Spectrogram created from data available at Moby Sound.org; used by permission.

FACULTY ADVISOR: Assistant Professor Maya Gupta
RESEARCH AREA: Statistical Learning/Signal Processing
GRANT/FUNDING SOURCE: ONR YIP

MobileASL: Video Mobile Phones for American Sign Language Communication in Real Time

JAEHONG CHON — Graduate Student (EE)

MobileASL is a video compression project that makes wireless cell phone communication for people who use sign language a reality.

While mobile sign language communication is already available in Japan and Europe, where they use the higher bandwidth 3G network, the quality is poor, the videos are jerky, and there is significant delay. Unfortunately, there is currently no equivalent service for mobile telecommunications in the U.S. that allows for real-time two-way video conversation. This system, which works on the HTC TyTN-II Cell phone, is the first time two-way has been demonstrated on a cell phone in the U.S.

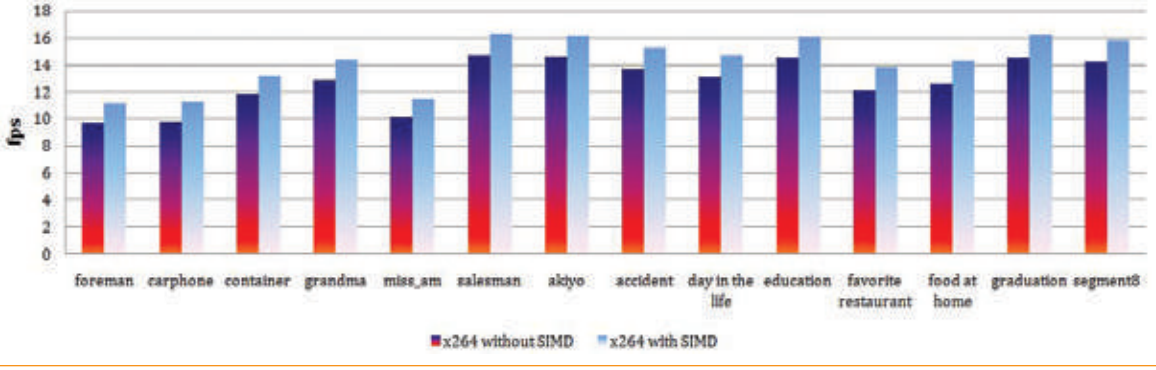
The MobileASL coder is based on the x264 Open-Source implementation of the H.264 compression standard. To encode in real-time on a cell phone, the encoder is simplified by selecting low-complexity H.264 parameter settings. To further speed up encoding, instruction optimization for motion compensation, mode decision, transforms, and quantization steps are applied using single instruction multiple data (SIMD) sets.

The ARM1136J-S processor used in HTC TyTN-II is built around the ARM11 core that implements the ARM architecture v6. It supports a range of SIMD DSP instructions that provide addition, subtraction, multiplication, selection, pack and saturation performed in parallel. This is used to speed up the encoder.

Experimental results demonstrate that our instruction optimization for H.264 reduces encoding time up to 15.3% for the MPEG data set and 13.4% for the ASL data set, respectively. Combined with simple front-end processing, as a result, a frame rate of 11-15 fps is achieved in real-time on the HTC TyTN-II.

A screenshot of the MobileASL codec on the HTC TyTN-II. Two UW EE graduate students are talking to each other.

This optimized encoder is suitable for video communication in very low bit rate wireless network environments. To further save battery life, region-of-interest encoding is being developed based on a skin map and frame dropping by reducing the number of packets sent over the network, and increasing the quality with respect to sign language. eek09



FPS comparison with QCIF MPEG and ASL test sequences.

FACULTY ADVISORS: Professors Eve A. Riskin (EE) & Richard E. Ladner (CSE)
COLLABORATORS: Professor Sheila S. Hemami (Cornell University), Graduate Students Rahul Vanam (EE), Anna Cavender (CSE) & Neva Cherniavsky (CSE)
RESEARCH AREA: Video Compression
GRANT/FUNDING SOURCE: NSF

Applying Speaker Recognition to Killer Whale Individuals

NICOLE NICHOLS — Graduate Student (EE)

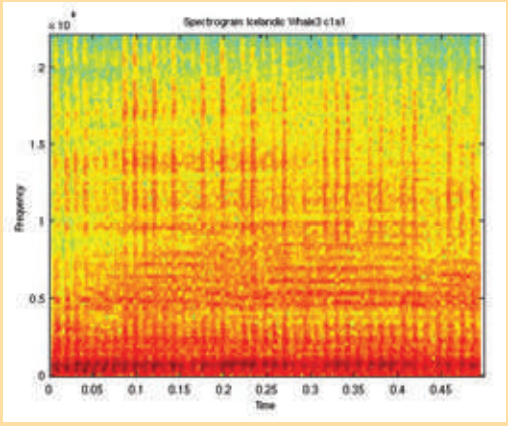
Whales are an iconic symbol of the oceans, yet many basic questions about their behavior, physiology and migration patterns are poorly understood.

One of the many hindrances of studying whales is the simple act of locating them. Ship time is expensive and impractical for long term studies. Identifying an individual whale is even more challenging and must be done by visual surveys with photo ID catalogs that must be continually updated, or tags that are difficult to apply and often fall off. The key to individual recognition is in the vocal repertoire of whales, which is complex and diverse between species and individuals.

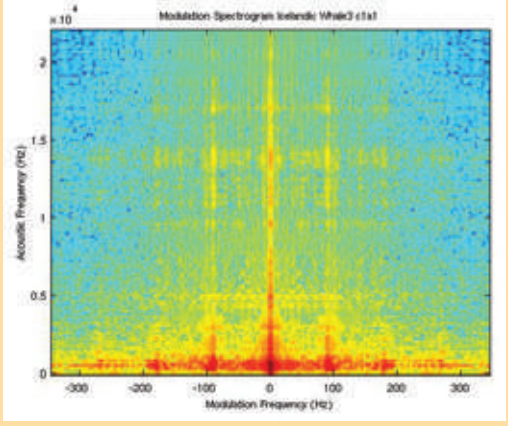
Photo by Nicole Nichols

Whale vocalizations are produced in a manner similar to human speech, and the specialized techniques for human speaker identification can be applied to whales. To develop an ID system, a "feature vector" is chosen which reduces a sound sample to a smaller set of numbers that encapsulate the identifying characteristics of the voice. Because voices change depending on the words spoken or if one has a cold, training data to characterize an average feature vector for each individual is used. A Hidden Markov Model (HMM) is then generated and given a new sound sample to calculate the probability of which individual was speaking.

This research focuses on the first step, the "feature vector," because it is critical for overall system accuracy. Cepstral coefficients are the standard used in human ID, but they have unknown accuracy for whales. UW EE's Interactive Systems Design Lab specializes in modulation spectrograms which contain identifying information different to that present in a regular spectrogram. A modulation-based feature vector and Cepstral coefficients are extracted from the same whale vocalization.



A sample spectrogram of a killer whale vocalization.



A sample modulation spectrogram from same killer whale vocalization.

By working with recordings from known individual whales, the optimal combination of feature vectors for whale identification can be determined, and this knowledge can build an HMM for use in field work.

An accurate identification method would allow improved population estimates and perform more complicated monitoring. A pair of autonomous underwater vehicles could even be programmed to follow a mother and calf to determine their interactions over the course of a year. Whales are an indicator species of the health of oceans, and improved monitoring is a vital step to recovery for these endangered species. eek09

FACULTY ADVISOR: Professor Les Atlas
COLLABORATORS: Ann Bowles (Hubbs-Sea World Research Institute)
RESEARCH AREA: Signal Processing
GRANT/FUNDING SOURCE: NSF Graduate Research Fellowship Program

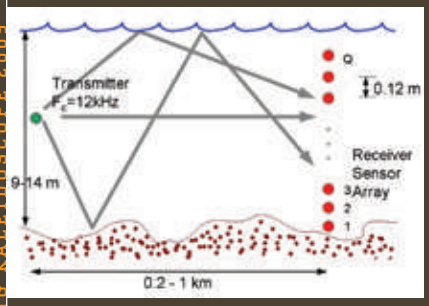
Reliable Communications Over Fading Underwater Acoustic Channels

CHANTRI POLPRASERT — Graduate Student (EE)

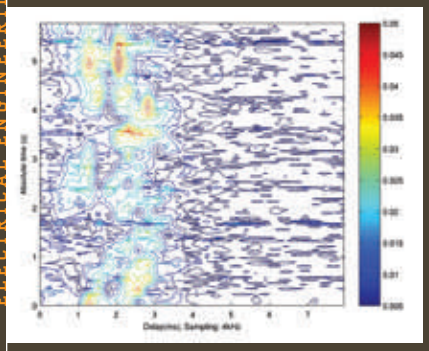
There have been a growing number of applications for underwater acoustic (UWA) communications such as ocean sampling networks for scientific exploration.

However, transmitting reliable data through the UWA channels poses many obstacles due to the reverberation effects in both time and frequency domains. The receiver observes signals corrupted by multi-path fading due to reflections from the ocean surface and bottom, which usually generates long delay spreads. Moreover, UWA channels exhibit large temporal variation due to change in the structure of the medium. Hence, there are many challenges to improving the reliability of data transmissions through UWA channels.

To combat the reverberation in UWA channels, a bit-interleaved frequency domain turbo equalization (Bi-FDTE) is implemented to investigate its performance in terms of the bit error rate (BER) as a function of the signal-to-noise ratio (SNR). Data is protected by forward error correction codes and separated into blocks where channel variation within each block is assumed negligible. The receiver uses an equalizer and decoder to combat the UWA fading. The signals were tested over a real UWA channel environment in the RACE08 experiment conducted at Narragansett Bay, RI.

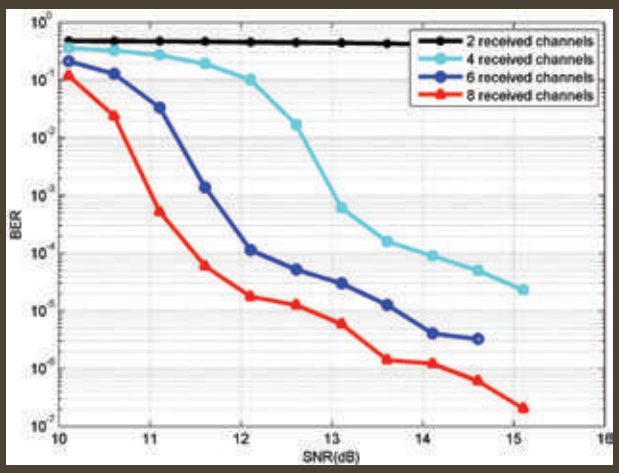


The telemetry configuration. Twelve receiver sensor arrays are located 1000 meters from the transducer. Water depth is approximately 9-14 meters.



The estimated channel impulse response from the receiving array at the bottom of the bay.

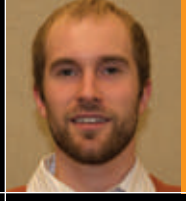
Data is transmitted at 12kHz carrier frequency with 4.8 kHz bandwidth. The spatial diversity of the UWA channels is exploited by combining and equalizing data from multiple receive channels to improve the BER performance. Results are displayed below where data from 2, 4, 6 and 8 received hydrophones are combined. Huge performance improvement is exhibited as the number of combined channels is increased.



Performance of the data transmission over real UWA channels using 2,4,6 and 8 received channels.

This algorithm exhibits excellent BER performance over real UWA channels with reasonable computational complexity. The next step focuses on high throughput data transmission under multiple input multiple output (MIMO) transmission scheme. eek09

FACULTY ADVISOR: Professor James A. Ritcey
RESEARCH AREA: Underwater Acoustic Communications
GRANT/FUNDING SOURCE: Office of Naval Research

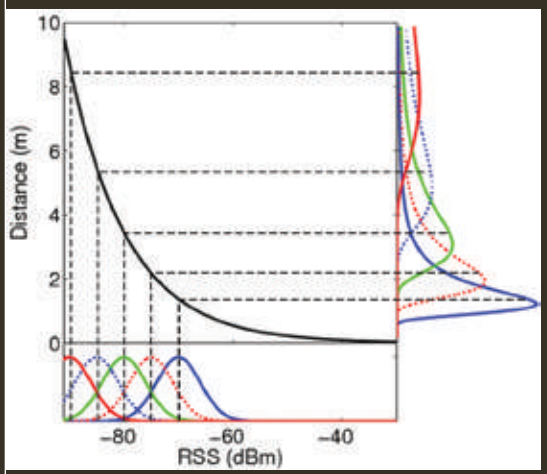



Reliable Location Estimation from Unreliable Signal Strength Measurements

JEFFREY VANDER STOEP & PATRICK TAGUE — Graduate Students (EE)

Location estimation, or localization, is becoming increasingly important in wireless networks as device location often plays a critical role in network operations and services.

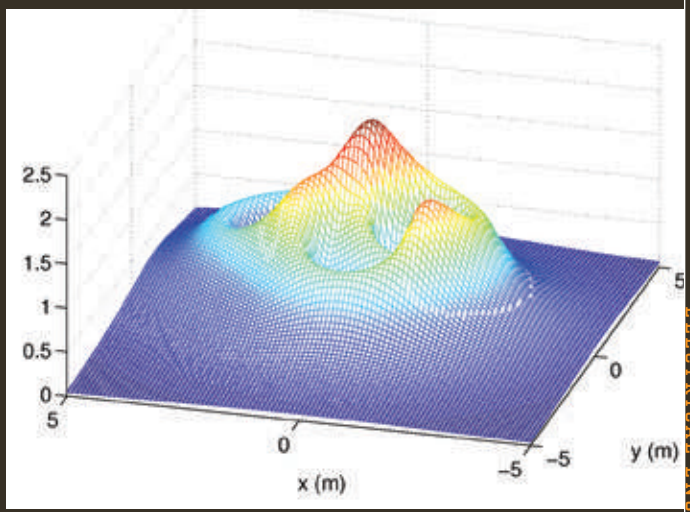
Received signal strength (RSS) provides a readily available and cost-effective solution for localization in wireless networks. Typically, RSS measurements are taken from neighboring devices with known location, referred to as beacons. Distance estimates are computed from these RSS measurements using an environment-specific path-loss model. These distance estimates are then passed to the localization algorithm along with the corresponding beacons' locations and used to estimate a location. This leads to a two step estimation problem where the estimated distances are used in the location estimate. This two step estimation would be a suitable method if each distance estimate had the same level of accuracy, but this is not the case.



The mapping from RSS measurements to distance estimates can be used to map the Gaussian distribution of RSS measurement error to a distribution of the beacon distance. Note that RSS measurements from distant beacons have high estimation variance illustrated by the wide distribution whereas RSS measurements from nearby beacons have low estimation variance as illustrated by the narrow distribution.

The uncertainty in the distance estimate increases with distance, suggesting that distance estimates become increasingly unreliable as distance increases. This work compensates for this fact by modeling each beacon distance probabilistically, using a probability distribution instead of a distance estimate. This approach allows for the execution of a single estimation step using all of the available information about the RSS measurements. An algorithm called ReLoc is presented which uses the set of RSS-derived distance distributions to compute a reliable location estimate.

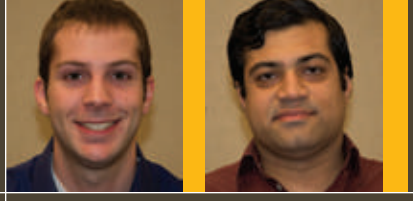
In ReLoc, a probability distribution of the distance to a beacon is mapped to a three-dimensional surface centered at the beacon's given coordinates. The height of the surface at each coordinate is proportional to the probability that the localizing device is the corresponding distance away from the beacon.



The surface represents the aggregation of RSS measurements from three beacons to indicate the device's probable location.

The proposed ReLoc algorithm provides a way of accounting for the variable accuracy of RSS-derived distance estimates thereby improving the accuracy of the localization. In future work, algorithms will be developed to estimate the confidence of a location estimate, and the issue of inaccuracies in reported beacon location will be addressed. eek09

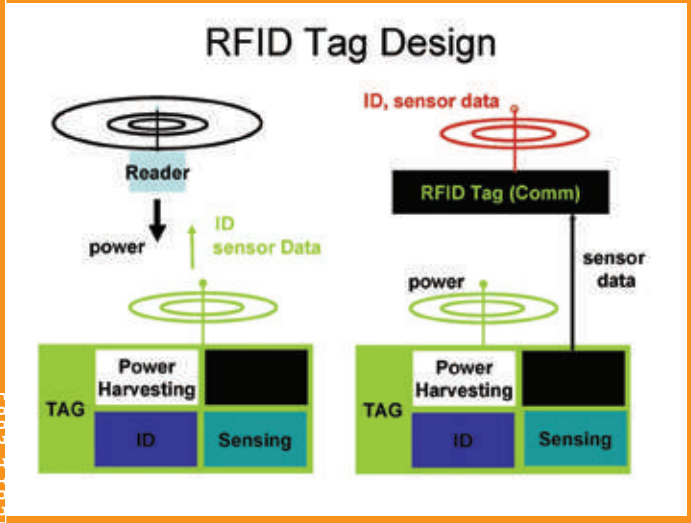
FACULTY ADVISOR: Associate Professor Radha Poovendran
RESEARCH AREA: Wireless Networks
GRANT/FUNDING SOURCE: ARO PECASE



Enabling RFID Sensor Nets:
Rethinking Key RFID Sub-System Components

DANIEL YEAGER & RITOCHIT CHAKRABORTY — Graduate Students (EE)

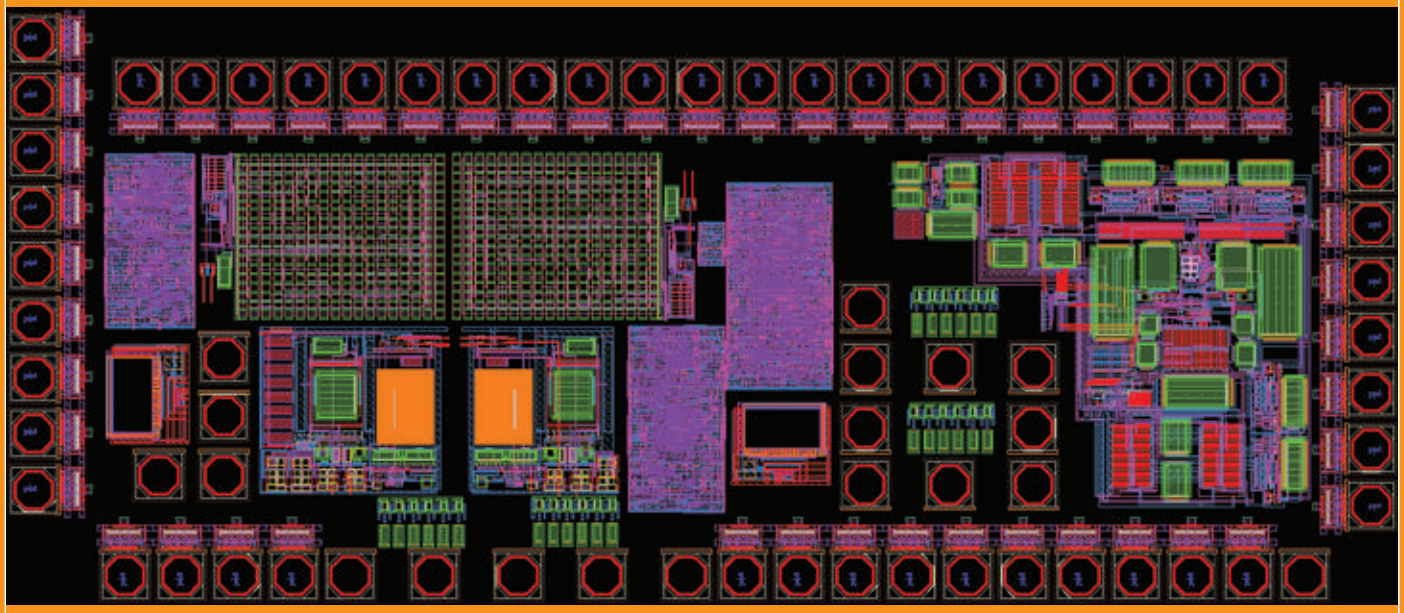
Low-power, low cost sensor nodes are key enablers for the vision of smart spaces or a pervasive sensor web. Of particular interest is the possibility of creating sensor nets from Radio Frequency Identification (RFID) technology. However, this requires considerable innovation vis-à-vis state-of-the-art current components (tags and readers) that are primarily designed for supply chain applications. Enhancements are needed at various levels: for the tag, improved mixed signal sections (antenna, power harvesting circuitry) as well as design for power efficient operation is paramount and for the reader, new link adaptation and multiple access protocol enhancements within the new Gen-2 standard will be essential.



RFID system diagram including tag circuit blocks.

This research is based on a new reconfigurable tag dubbed the Wireless Identification and Sensing Platform (WISP) designed and fabricated at Intel Research. WISP uses a 16-bit, ultra-low-power microcontroller to perform sensing and computation while operating exclusively from rectified RF power. The microcontroller firmware defines the communication protocol and tag functionality, allowing configuration for a variety of sensing tasks such as temperature, ambient light, rectified voltage and orientation. The goal is to leverage this configurability to study tag power consumption, develop power-efficient protocols and construct models for the tag-to-reader back-scatter communication.

WISP (Wireless Identification and Sensing Platform) from Intel Research Seattle.



New Intel-UW WISP Tag.

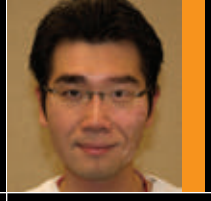
In terms of tag operation, the back-scatter mechanism is poorly understood, yet it is critical to achieve uplink communication rate. For typical scenarios, the mutual interference/coupling between antennas of nearby tags alters the radiation pattern of the reference tag in the near field. Moreover, during uplink communication, the antenna impedance and radiation pattern dictate the "modulated" power. The probability of error at the reader reduces with an increase in the modulated power. Interference between tag antennas will negatively impact this error. On the other hand, the modification of tag antenna impedance for the downlink may deteriorate the power match between antenna and tag chip resulting in less power being transferred and ultimately limiting the duration and rate of the uplink burst.

In summary, it is imperative for better design to understand the characteristics of tag RF/mixed signal front-end with a high degree of fidelity using electromagnetic (EM) solvers. A multitude of simulation studies will take place with situational variations in communication topology (distance, orientation etc). The goal is to develop a complete model for backscattered power and received signal structure as a function of antenna impedance and topology to the first order.

Tag power consumption places an upper limit on the achievable wireless range of passive tags and the battery life of active tags. However, the energy required for various tasks such as transmitting, receiving, and sensing varies. Detailed power models will be developed to allow optimization of the tag architecture for various sensing applications. Furthermore, by designing suitable wireless protocols around the tag power model, communication and sensing energy-efficiency can be improved.

Detailed tag models, both of the tag power consumption and backscatter radiation, will enable application of RFID technology to emerging fields such as biomedical sensing and smart environments. Leveraging these models will allow for the fabrication of new tag ICs for extended wireless range, compatibility with sensors, and efficient channel utilization. eek09

FACULTY ADVISORS: **Professor Sumit Roy, Associate Professor Vikram Jandhyala & Assistant Professor Brian Otis**
COLLABORATORS: **Affiliate Professor Joshua Smith (Intel)**
RESEARCH AREA: COMMUNICATIONS, **Circuits & EM**
GRANT/FUNDING SOURCE: **Supported in part by NSF ECS award, "Realizing the Internet of Things via RFID Sensor Nets" (2008-2011)**

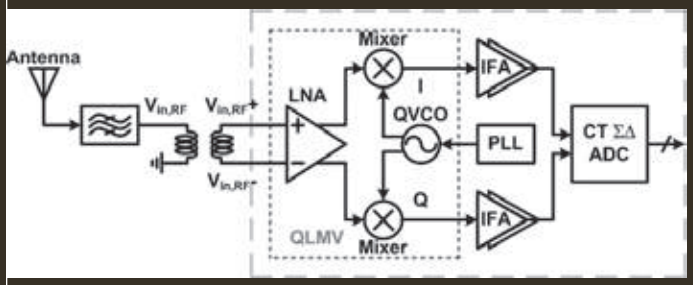


Ultra-Low-Power CMOS Receiver for GPS Applications

KUANG-WEI CHENG — Graduate Student (EE)

The fast growing Global Positioning System (GPS) market has created urgent demands for low-power and low-cost solutions to implement highly integrated receivers.

If GPS receivers were made smaller and with less power needs, many consumer products with GPS capabilities, such as navigation, positioning, and surveying, could be widely spread and become ubiquitous. These considerations motivate the present research to develop highly integrated CMOS solutions with very low power consumptions. The proposed low power GPS receiver architecture is shown below.

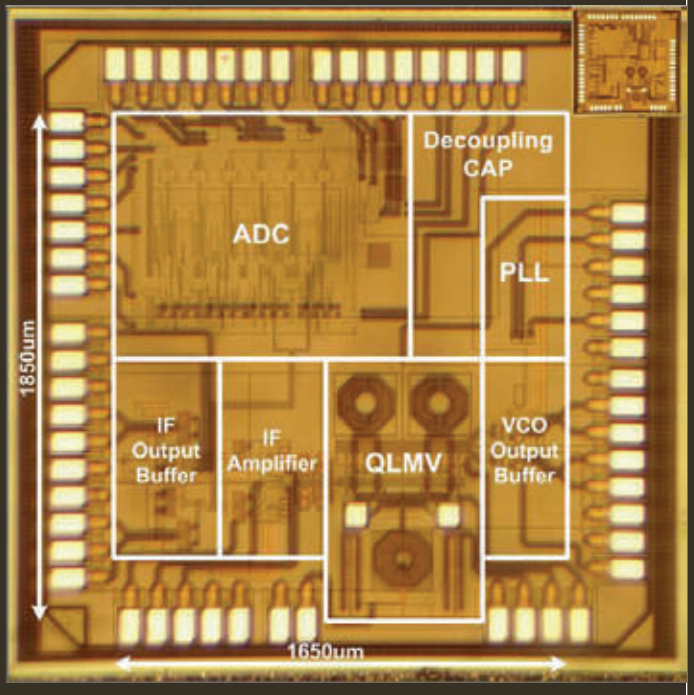


A block diagram of quadrature GPS receiver.

In the receiver path, the Radio Frequency (RF) signal is amplified by a low noise amplifier (LNA), the spectrum is translated to a lower frequency by down conversion mixers to facilitate subsequent Intermediate Frequency (IF) amplification, and the amplified signal is filtered and digitized by the continuous-time quadrature bandpass sigma-delta analog-to-digital converter (ADC).

The quadrature local oscillator signals generated from a novel coupled scheme quadrature voltage controlled oscillator (VCO) sits on top of the double-balanced Gilbert mixer, which is atop the differential LNA input stage. Taking advantage of the current-reuse in this stacked quadrature LNA-mixer-VCO (QLMV), the RF front-end consumes only 1mW of power consumptions, which is about three times less power than any previous design. In addition, high sensitivity is maintained using fully-differential IF amplifiers with variable gain.

A second-order continuous-time sigma-delta ADC performs the IF-to-digital conversion and achieves higher power efficiency in quadrature architectures. Power consumption is minimized using a single quadrature ADC rather than a lowpass or bandpass ADC on each of the I and Q channels, reducing the number of active components needed by twofold. Further power is saved using a continuous-time converter because it eliminates the need for anti-aliasing filters, and the op-amp requirements for the active-RC filters are relaxed compared to a discrete-time design. The quadrature GPS receiver front-end implemented in an IBM 0.13μm CMOS process consumes a total of 7.2mW with 1-1.2V power supply. eek09



The chip micrograph overlaid on the layout plot for clarity; the die area of the GPS receiver core circuitry (excluding pads) is 1.85mm x 1.65mm.

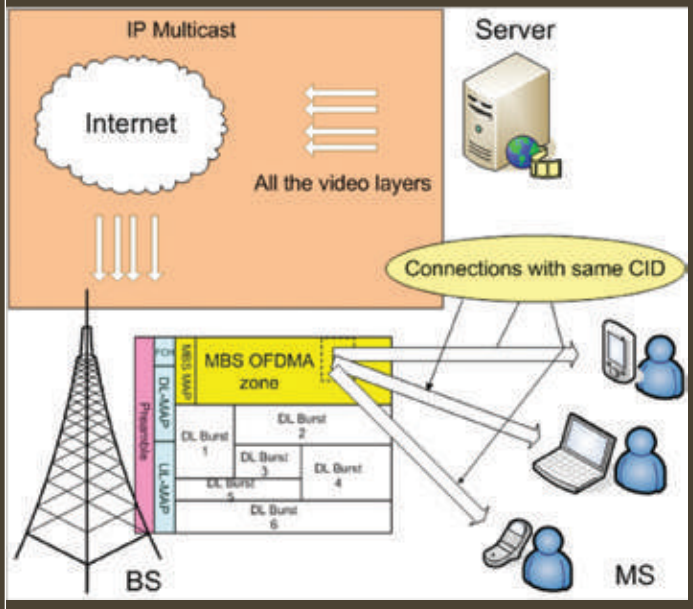
FACULTY ADVISOR: Professor David J. Allstot
COLLABORATORS: Graduate student Karthik Natarajan (EE)
RESEARCH AREA: Analog, RF & Mixed-Signal IC Design
GRANT/FUNDING SOURCE: NSF

Joint Scheduling & Resource Allocation For Layer Encoded Video over WiMAX

CHIH-WEI HUANG — Graduate Student (EE)

Mobile worldwide interoperability for microwave access (WiMAX) offers desired high bandwidth, broad coverage range, and flexibility to support future digital multimedia services.

Real-time video multicast, such as IPTV, characterized by groups of users acquiring popular video programs over a fading channel, is rapidly emerging as the most exciting application. Nonetheless, to succeed with integration, effective dissemination is the key. This research proposes a joint scheduling and resource allocation algorithm that provides enhanced quality of service (QoS) and efficiency for layered video multicast over Mobile WiMAX.



The end-to-end multicast architecture, which takes advantage of layered video, IP multicast, and technologies in WiMAX.

When a video is subscribed by a user in a WiMAX cell, all layers will be sent to the base station (BS), where each layer is sent as a multicast group. Then for each video layer, the BS determines the set of users to schedule by adapting modulation and coding scheme (MCS).

According to the layered video structure, optimization problems are formulated using opportunistic multicasting concept. The minimum effective throughput is maximized across all users for mandatory (base) layer delivery through adapting MCSs. At the same time, the MCSs for the optional (enhancement) layers and the scheduled users are determined to maximize total utility. Thus, the basic video quality can be efficiently guaranteed to all subscribers while making the most out of limited resources on enhancement information. The FEC rate adaptation scheme is further presented to approach theoretical performance. The advantage of the proposed algorithm is demonstrated by utilizing realistic Mobile WiMAX parameters. Simulations show that by incorporating the opportunistic concept, mandatory base layers can be transmitted using fewer resources while system utility can also be optimized for optional enhancement layers.

The advanced formulation and solution of multicasting layered video over WiMAX is suitable for all OFDMA systems. It appears that this is the first resource allocation proposal exploiting opportunistic multicasting on layered video and the gap between theoretical throughput and implementation concerns is fulfilled. eek09

FACULTY ADVISOR: Professor Jenq-Neng Hwang
COLLABORATORS: Graduate student Po-Han Wu (EE), Shian-Jiun Lin (National Chiao Tung University)
RESEARCH AREA: Multimedia Networking
GRANT/FUNDING SOURCE: Institute for Information Industry, Taiwan

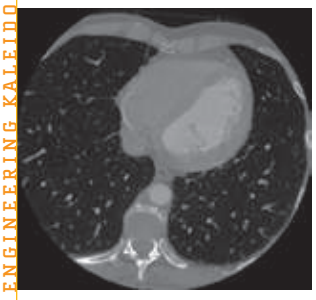

FPGA-Based Acceleration of Computed Tomography (CT) Image Reconstruction

JIMMY XU & NIKHIL SUBRAMANIAN — Graduate Students (EE)

Computed tomography (CT, or "CAT" scans) is a medical imaging technique used to reconstruct cross-sections or 3-D images of a patient from a series of one dimensional measurements acquired using X-rays.

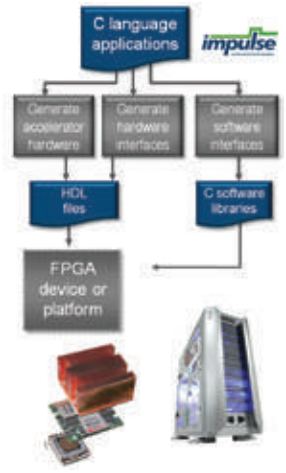
Image reconstruction is computationally intensive due to the large amount of data present. While FPGA acceleration can produce better results than traditional software on CPUs (due to the highly parallel nature of the process), it requires specialized hardware engineering expertise and takes longer to design. Impluse C, a software-to-FPGA compiler is a promising new technology that allows for reduction in both design time and complexity.

3-D rendering of an image volume reconstructed from a chest/abdomen/pelvis CT exam.



Single trans-axial image reconstructed from the coronary CT exam.

Arguably, the Iterative Back-Projection algorithm may revolutionize the world of medical imaging. This method of image reconstruction produces higher quality results, but is extremely computationally intensive and not practical for implementation on a stand-alone CPU. To solve this problem, UW EE's Adaptive Computing Machines and Emulators Lab is working with the UW's Department of Radiology to produce an FPGA accelerator to implement this exciting new algorithm.



Mapping of C-language applications to an FPGA platform using Impulse C.

The second goal of this project is to benchmark the performance of Impulse C. Impulse C is a library and related compiler that allows a subset of the C programming language to be used to create applications on FPGAs. While traditional FPGA design requires careful hand-crafted hardware descriptions by the application designer, Impulse C allows standard C language tools to be used instead. This provides a reduced workload for the designer, and serves to simplify and accelerate the design process.

The FPGA designs produced by Impulse C and hand coded VHDL designs will be compared for differences in performance. The strengths and weaknesses of Impulse C will be documented for future FPGA designers.

This project will create a practical accelerated implementation of the Iterative Back-Projection algorithm for future medical imaging tasks. The benchmarks generated will bring to light the trade-offs involved in using software-to-FPGA tools such as Impulse-C for FPGA design. eek09

FACULTY ADVISOR: Professor Scott Hauck
RESEARCH AREA: High Performance Computing
GRANT/FUNDING SOURCE: Impulse Accelerated Technologies, Washington Technology Center

Surface Ratchets

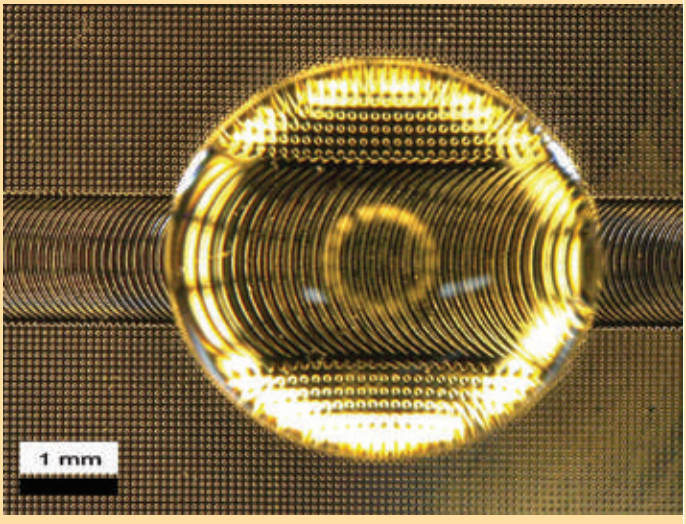
TODD DUNCOMBE — Undergraduate Student (EE)

Microfluidic devices perform physical, chemical, and biological functions on miniature "lab-on-chip" platforms, which have appeared in response to the growing demand for portable, fast, small-sample-size, safe, and low-cost bioanalysis tools.

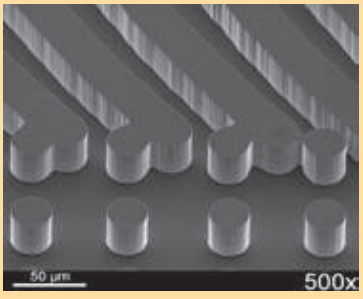
Typically, samples are directed through micromachined elements such as valves, filters, and pumps via continuous flow. However, droplet-based systems present an alternative approach that separates samples into discrete volumes, thereby tackling two key challenges in microfluidics: cross-contamination between samples, and dilution by diffusion.

A surface ratchet is a novel microfluidic device that reliably transports droplets using surface contact asymmetry and vibration. When a droplet is placed on a hydrophobic rough surface, it assumes its Fakir state, only making contact with the top of the surface asperities. By implementing repeating semi-circular asperities, an asymmetric bias in the contact forces is established. The side of the droplet aligned with the curvature has a more uniform surface contact than the side of the droplet not aligned. When the surface ratchet is vibrated, the droplet moves in the direction of the curvature. Due to the repetitive nature of the ratchet design, there is no gradient; droplet transport is achieved indefinitely as long as vibration continues, as seen in circular ratchets. Actuation via vibration is a passive, non-droplet-specific transportation method, enabling one energy source to transport numerous droplets simultaneously. This approach offers a simple alternative to other non-gradient droplet transport methods, which typically require an elaborate actuation mechanism, multiple electrical connections, and/or droplet-specific controls.

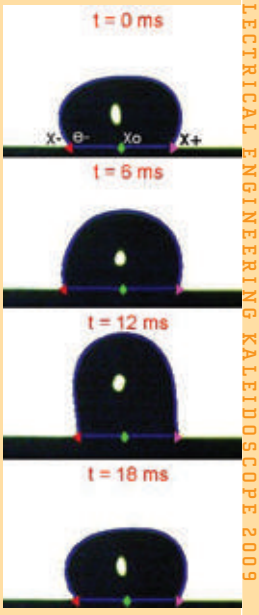
The long-term goal of microfluidic 'lab-on-chip' technology is to devise a reliable, self-contained system that maximizes efficiency and throughput in chemical or biomedical processes while reducing the cost, size and number of system components. Surface ratchets have the potential to serve this purpose. eek09



Top view of a 20 µl droplet sitting on a ratchet track. The arced rungs constitute the track that is limited by arrays of pillars.

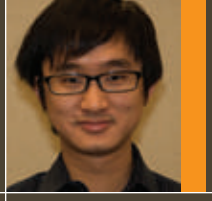


A scanning electron micrograph of a ratchet track etched in silicon and coated with FOTS. The image shows a partial view of the ratchet rungs and the adjacent pillar arrays.



Four frames during a full period of oscillation (18ms duration, 55 Hz frequency) are displayed. The amplitude of the stage is 0.18 mm.

FACULTY ADVISOR: Professor Karl Böhringer
COLLABORATORS: Research Associate Ashutosh Shastry
RESEARCH AREA: Microfluidics
GRANT/FUNDING SOURCE: UW Technology Gap Innovation Fund, Center of Excellence in Genomic Science, NSF International Research & Education in Engineering grant ECCS-05-01628



Making Batteries Last Longer
Without Changing the Batteries

LEO LAM — Graduate Student (EE)

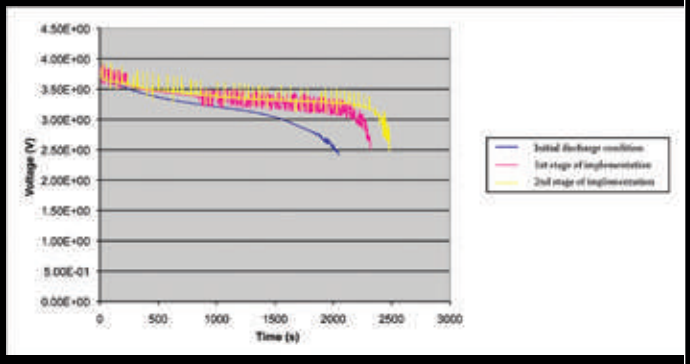
With a looming energy crisis and a continuously increasing demand for energy, it is imperative that energy be optimally conserved and used at every level. New emphasis in environmental protection has also led to a new surge of applications for batteries in automotive and other high current applications.

While the energy density of new battery chemistry and low-power microelectronic circuit designs have improved significantly in the past decade, the power demand for high performance has also increased, which results in little gain in the running time for many applications. There has been little emphasis on improving the efficiency of battery utilization itself, especially in high drain applications. In such applications, a good amount of energy is lost to heat due to internal resistance, which also leads to the premature end of charge for the batteries. Even though there are some advances in a battery's state-of-charge management, there is little to no optimization to this "charge and drain" method.

A lithium ion-based rechargeable battery is a prime candidate for research due to its widespread use in mobile electronics with high power needs, such as notebook computers. It has also been adopted to power the next generation of hybrid and plug-in vehicles. Selling at over five billion pieces, the per year collective energy savings from improving its discharge efficiency is very significant.

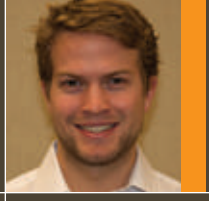
This research looks at the fundamental electrochemistry mechanisms inside the battery cells and recommends a specific, yet easy to implement method that effectively reduces the apparent current drawn through each cell. A mathematical model based on finite element analysis is employed to investigate the effect of high drainage on the lithium ion distribution within the cell to maximize the method's effectiveness. A highly configurable test bed has also been designed to test the discharge characteristic of this scheme.

The preliminary result shows that a 20% increase of running time is achievable, without changing the battery chemistry internally. With further optimization and innovative controller designs, this can enable high performance full day computing, and greatly improve the range for electric-powered vehicles. eek09



Results showing the discharge improvement.

FACULTY ADVISOR: Professor Bruce Darling
COLLABORATORS: Associate Professor Stu Adler (CE), Research Associate Liney Arnadottir (CE), Graduate Student Cortney Kreller (CE), Undergraduate Students Paul Gheorghiu & Jeff Beorse (EE)
RESEARCH AREA: Power Electronics, Sustainable Energy



Active Contact Lenses

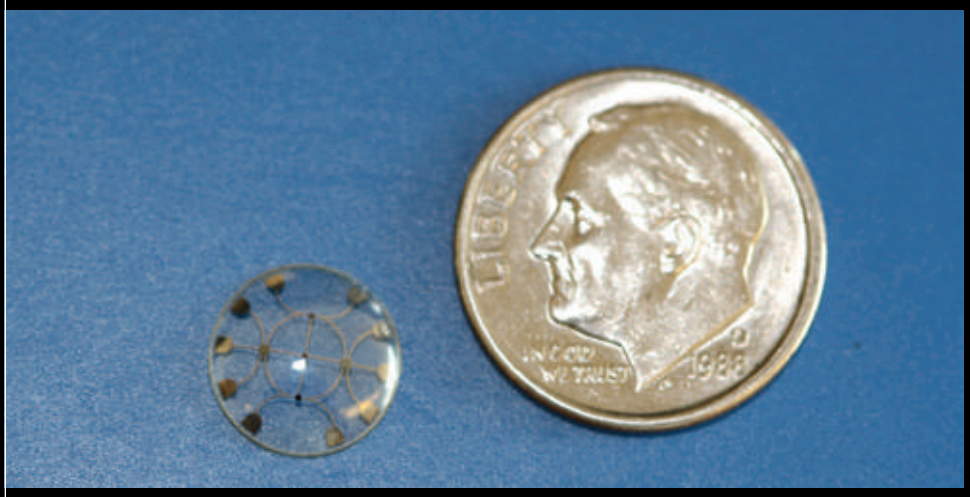
ANDREW LINGLEY — Graduate Student (EE)

The advances in nano and microfabrication, which enable the construction of exceedingly small electronic, photonic, and sensing devices, allow the transition of contact lenses from simple passive devices to sophisticated and functional microsystems.

In particular, the possibility of integrating display or biosensing components onto a contact lens may offer an avenue to device applications without precedence. For example, novel real-time biomarker monitoring of the tear fluid using these lenses may provide doctors a unique, non-invasive technique for studying and monitoring disease.

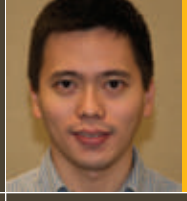
A functional contact lens, incorporating a low-resolution display or a set of miniature biosensors, requires the integration of a number of functions and components. Various units include power harvesting, antenna, wireless data transmitter/receiver, control and read-out circuitry, optoelectronic display pixels, and biosensors which would be electrically connected on a flexible, transparent, and thin plastic substrate. This research has made progress in developing such a set of micro-manufacturing processes; micron-scale silicon transistors, light emitting diodes (LEDs), and detectors have been fabricated and mass-produced. These are electrically connected on a planar surface which is then molded to the proper curvature without loss of functionality. The encapsulation of such a lens in parylene has been demonstrated, which is an FDA-approved, biocompatible polymer. In collaboration with the UW EE's Wireless Sensing Lab, a sub-millimeter scale rectification and amplification circuitry, as well as optimized antennas for data and power transmission, are also being developed.

This work could lead to the development of a new medical paradigm, in which the effect of drugs, exercise, or food could be monitored in individuals over extended periods to time. The next challenge will be to integrate wireless power and data transmission to yield the first fully functional contact lens. eek09



A contact lens containing compound semiconductor LEDs and single crystal silicon components.

FACULTY ADVISOR: Associate Professor Babak Parviz
COLLABORATORS: Assistant Professors Tueng Shen (Ophthalmology) & Brian Otis (EE)
RESEARCH AREA: Devices
GRANT/FUNDING SOURCE: UW College of Engineering



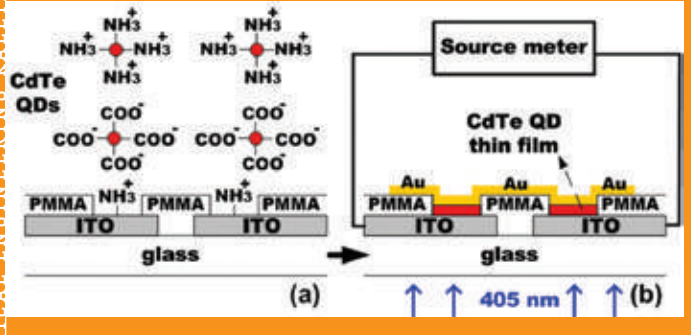
QD Photodetectors with "Epitaxial" Layer Structures Via Self-Assembly

CHANG-CHING TU — Graduate Student (EE)

Colloidal semiconductor quantum dots (QDs) have been widely investigated as photosensitizers for optoelectronic devices, such as photodetectors and solar cell, due to their size-dependent spectral properties and high quantum efficiency through the quantum confinement effect.

However, fabrication of these devices relies on the effective immobilization of dots smaller than five nanometers (nm). This research develops a technique for electrostatic layer-by-layer (LBL) self-assembly of QDs on a lithographically patterned substrate, such that the film thickness and coverage area can be precisely controlled. The QD thin films are then used as photodetectors, which exhibit promising responsivity.

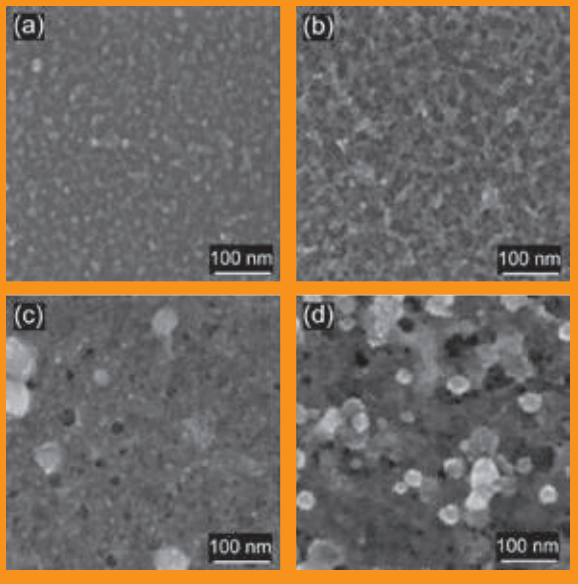
The CdTe QDs used in this work are synthesized and dispersed in aqueous solution with either positively charged 2-mercaptoethylamine or negatively charged thioglycolic acid as capping stabilizers. By electrostatic attraction, the charged QDs are assembled LBL on an indium tin oxide (ITO) substrate modified with a thin layer of (3-aminopropyl) triethoxysilane molecules, which carries positively charged amino groups. The assembly region is patterned by poly(methyl methacrylate) (PMMA) through e-beam lithography. After "epitaxial" deposition of QDs, a thin layer of Au is thermally evaporated on the top. The layer of Au serves as the top electrode, while the ITO substrate serves as the bottom electrode. Both electrodes are connected to a source meter for photocurrent measurement while the QD thin film is illuminated with a 405 nm laser.



(a) After e-beam lithography, PMMA windows are opened on each ITO substrate where the LBL self-assembly of CdTe QDs is performed. (b) A thin layer of Au is evaporated on the QD thin film to form the top electrode, while the ITO serves as the bottom electrode.

The ligands on the CdTe QD surface are extremely short, measuring less than 0.4 nm, such that the surfaces of adjacent QDs nearly contact one another. Since the high responsivity is associated with long carrier recombination time and short carrier transit time, the QD thin film (about 100 nm for 30 layers in this work) exhibits high responsivity—0.18 A/W under 0.1 V bias.

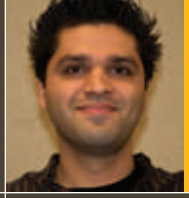
Based on the electrostatic self-assembly technique, another layer of semiconductor QDs can be epitaxially deposited on top of the existing CdTe QD film. A diode structure is formed at the interface, due to the work function difference of the two materials. This technology can be potentially utilized as a high efficiency QD solar cell. eek09



SEM images of the fabrication result after self-assembly of (a) 7, (b) 14, (c) 21, and (d) 30 layers of CdTe QDs on the ITO substrate.

Reference: C.-C. Tu, L. Y. Lin, Applied Physics Letters, vol. 93, No. 16, pp. 163107, October 2008.

FACULTY ADVISOR: ASSOCIATE PROFESSOR LIH Y. LIN
RESEARCH AREA: NANOPHOTONICS
GRANT/FUNDING SOURCE: UW NANOTECHNOLOGY UIF FELLOWSHIP, GIFT FUND FROM EBM TECHNOLOGIES



Optically Programmable Self-Assembly of Heterogeneous Components on Unconventional Substrates

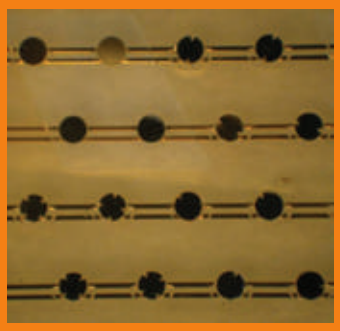
EHSAN SAEEDI — Graduate Student (EE)

The construction of microsystems increasingly requires the integration of multiple functions. Often, these functions are performed by micro-components made using incompatible fabrication processes, and therefore fast and cost-effective methods are needed to integrate a large variety of dissimilar parts to form complex systems.

Self-assembly is a strong candidate for performing system integration, particularly at small size scales. Using such methodology, functional micro-components are independently microfabricated and released from a carrier wafer to form a collection of free-standing parts suspended within a fluid. These components are subsequently passed over a template containing receptor sites that provide locations for the micro-components to be assembled and complete the system.

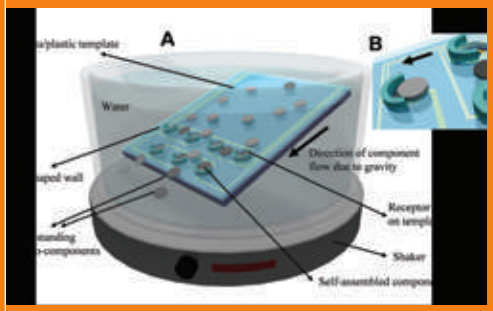
To achieve heterogeneous integration, methods are needed to "program" such a self-assembly process on the template surface. This research presents a method to optically program the micro-scale self-assembly process which is compatible to unconventional substrates such as plastic or glass. In this method, the proper binding site is "activated" upon light exposure immediately prior to introduction of the specified component type. To demonstrate this self-assembly process, four types of circular micro-components with different number of notches are fabricated. To perform the self-assembly process, the template was submerged in water and components were introduced and flowed over its surface. An available, or open, binding site accepted components as they were trapped by the c-shaped structures.

After the completion of the first step, the components were fixed in their location by spin-coating a thin polymer film, and then a new set of traps was made available by selectively exposing resist through an optical mask and removing the blocking photoresist once again. The newly available sites were populated with a new type of component in a manner similar to that explained above. As this cycle was repeated, various microcomponents were guided and placed onto the desired locations of the template to complete a heterogeneous system.



A zoomed out view of a small part of the completed chip after assembly of all four component types. The 1st type of components (circular 4-notch) was assembled within the 2×2 parallelogram pattern, shown on the bottom left corner of the image. The 2-notch, 1-notch and 0-notch components were assembled on top right, bottom right, and top left respectively.

Optically programmable micron-scale self-assembly offers an excellent method for the integration of complex microsystems made of incompatibly microfabricated components. The integration of this method with digital micro-mirror exposure promises to provide a versatile and flexible manufacturing method for microsystems of the future. eek09



The self-assembly process. (A) Microcomponents are introduced over a template submerged in water and moved toward the bottom of the template due to external agitation and gravity. Self-assembly occurs as microcomponents first hit the C-shaped traps and then fall into receptor site wells. (B) Magnified view of a component entering a c-shaped trap on the template.

FACULTY ADVISOR: Associate Professor Babak A. Parviz
RESEARCH AREA: MEMS/Devices
GRANT/FUNDING SOURCE: National Institute of Health NHGRI

Micro-Power Circuits for Neural Interfaces

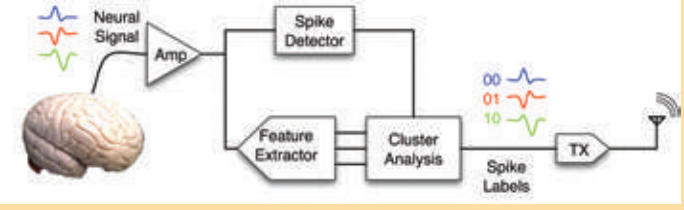
JEREMY HOLLEMAN — Graduate Student (EE)

The operation of the brain is one of the great remaining scientific mysteries. Neuroscientists investigate brain function by recording the electrical activity of neurons. Historically, the equipment needed to make these recordings has been large and cumbersome, and the animals being studied must be restrained.

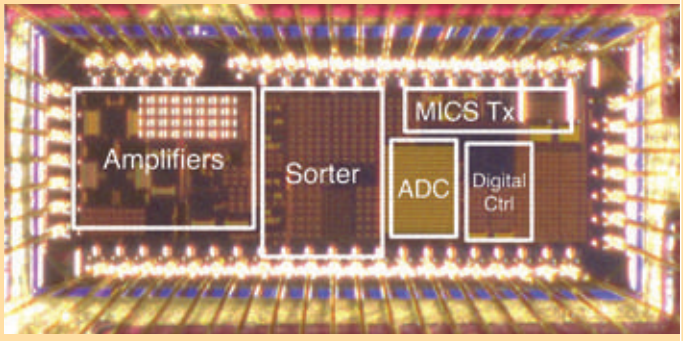
This research focuses on designing small, low-power chips to replace traditional rack-mounted recording equipment. Wireless recording systems that are small enough to be implanted or easily carried will enable long-term observations of neural activity in freely-behaving animals, and will eventually enable prosthetic devices to be controlled by neural signals.

One of the biggest barriers to long-term implantation of neural interfaces is power dissipation. Low-noise amplifiers, wireless communication links, and signal processing functions all consume significant amounts of power. Implanted devices have a hard limit on power dissipation to avoid thermal damage to neural tissue, and available power sources further limit consumption.

Power-efficient circuits for acquiring and processing neural signals are critical to the success of implantable devices. Recently designed neural amplifiers have exploited the unique characteristics of neural signals to achieve record-setting noise and power efficiency.



The architecture of a micro-power neural recording system. Signals from a cortical electrode are amplified and processed, and the results are transmitted through a wireless transmitter operating in the Medical Implant Communication System (MICS) band.



A die photo of the 1mm x 2.5mm neural recording chip.

Current work in the Wireless Sensing Lab focuses on developing analog circuits to extract the most important information from neural signals, reducing the throughput on the analog-digital converter and the digital processor. For example, spike sorting is one common task in neural recording. Neural spikes are separated into groups with similar waveform shapes in order to determine the source neuron responsible for each spike. Circuits have been developed to detect neural spikes, extract their salient features, and implement the K-means clustering algorithm for sorting spikes.

Power-efficient architectures for acquiring and processing neural signals will enable new neuroscience experiments and contribute to the development of prosthetic devices for patients who have lost function to disease or injury. The same circuit techniques should also be applicable to other sensing problems in the biomedical field and beyond, enabling a wide range of new devices. eek09

FACULTY ADVISOR: Assistant Professor Brian Otis
COLLABORATORS: Professors Chris Diorio (CSE) & Eb Fetz (PBIO), Research Assistant Professor Chet Moritz (PBIO), Graduate Students Jagdish Pandey, Shailesh Rai & Helen Zhang (EE)
RESEARCH AREA: VLSI
GRANT/FUNDING SOURCE: Office of Naval Research


Directed Evolution in Synthetic Biology

STEVE SAFARIK — Graduate Student (EE) & ALEX LEONE — Undergraduate Student (EE)

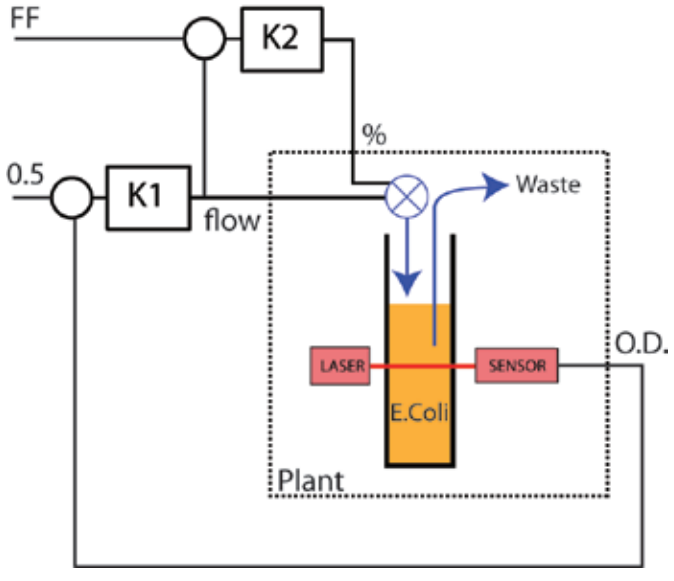
When engineering in the realm of the living world, as is the goal of synthetic biology, evolution cannot be ignored. Evolution can produce highly optimized systems with a minimal amount of design, but only with specific initial conditions, the right environment, and a time-scale of many generations.

This research focuses on both harnessing the power of evolution to optimize and better design synthetic systems, and using control systems to make evolution as efficient as possible.

The approach to synthetic biology in this research uses rational design to build enzymes for novel reactions such as utilizing a new carbon source or metabolizing a toxin. However, synthetic enzymes often show very low activity. To improve the performance of an enzyme, directed evolution is achieved in a turbidostat initially containing a strain of bacteria genetically modified to express the enzyme. A control loop maintains a constant volume and turbidity, or population size, by adding nutrients and removing bacteria.

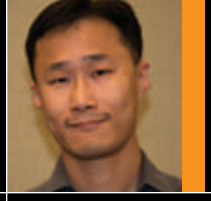
When constant population size is achieved, growth rate becomes the primary factor in natural selection; mutants that grow the fastest will eventually take over the population. The nutrient input, or environment, must be chosen so that the mutants with more effective enzymes grow faster. The effectiveness of the enzymes, or fitness, is proportional to the nutrient input rate, just as the fuel input rate of a car using cruise control is related to the slope of the road. Adding another control loop that keeps fitness constant while changing the composition of the nutrient input can lead to more efficient evolution.

A fast and efficient means to design and tune novel enzymes may enable many applications, such as new treatments for emerging diseases, or tailor-made drugs for specific patients. eek09



The bacteria grow in an optically transparent growth cell. A laser is shown through the cell, and an optical sensor measures the light transmitted to give a measure of turbidity (density of light-obstructing particles). One input is nutrient flow rate, and the rate also indirectly measures fitness. A second input specifies the nutrient mixture. Finally, a level sensor and waste pump keep the volume constant. Turbidity is controlled by adjusting the flow rate; fitness is controlled by adjusting the mixture. As the bacteria become more fit for the environment, the environment is changed thereby steering their evolution.

FACULTY ADVISOR: Assistant Professor Eric Klavins
COLLABORATORS: Professor David Baker (Biochemistry)
RESEARCH AREA: Synthetic Biology
GRANT/FUNDING SOURCE: DARPA & Microsoft



Control Methods for Automated Surgery

XIAOLONG YU — Graduate Student (EE)

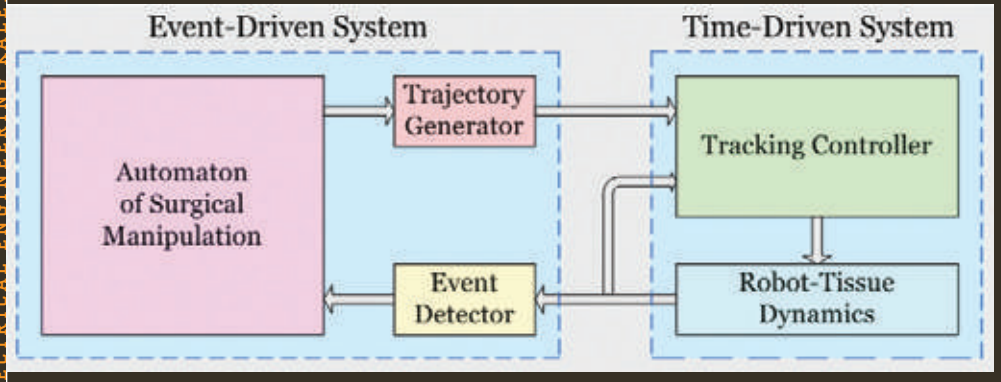
Automating certain surgical tasks provides possible opportunities for safer, faster and more cost-effective medical care. Thanks to the rapid development of surgical robotics, it is almost possible to automatically carry out some surgical tasks by machine. This research develops system modeling and control algorithms for the automation of these surgical subtasks.

A two-level hybrid dynamic system modeling is proposed to mathematically represent different surgical operations. On the upper level of this hybrid representation, the overall surgical procedure is characterized by automata driven by discrete events. On the lower level, the interaction between surgical tools and the patient soft tissue is described by differential equations and driven by time, using mathematical models of soft tissue and tools.

Bilateral mappings are established between the upper level discrete events and the lower level continuous states. Rule-based event detection recognizes events from sensor-derived measurements of the physical system (at the lower level). Desired trajectories for the surgical tool are generated in response to detected events and are sent to the lower level system as inputs to the tools (the robot end-effectors). This trajectory is generated in a manner that enforces surgeon-provided safety and effectiveness limits while accounting for the nonlinear properties of soft tissue and system uncertainties. At the lower level, nonlinear control methods are used to follow the specified trajectories.

This research investigates fundamental issues for automating surgical procedures. Potential benefits of automated surgery include freeing the surgeon to focus on the most complicated aspects of a procedure, improving the precision and speed of a surgical procedure, and enhancing the performance of telesurgery systems where a long distance separates the surgeon from the patient.

Future steps include implementing the control algorithms into robotic surgery systems, and developing software-based surgical training simulators. eek09



The hybrid dynamic system framework for surgical procedures. This includes an upper level event-driven system and a lower level time-driven system.

FACULTY ADVISOR: Professor Howard Jay Chizeck
COLLABORATORS: Professor Blake Hannaford & Affiliate Associate Professor Jacob Rosen, UW Biorobotics Lab
RESEARCH AREA: Controls & Robotics
GRANT/FUNDING SOURCE: US Army Telemedicine & Advanced Technologies Research Center (TATRC)

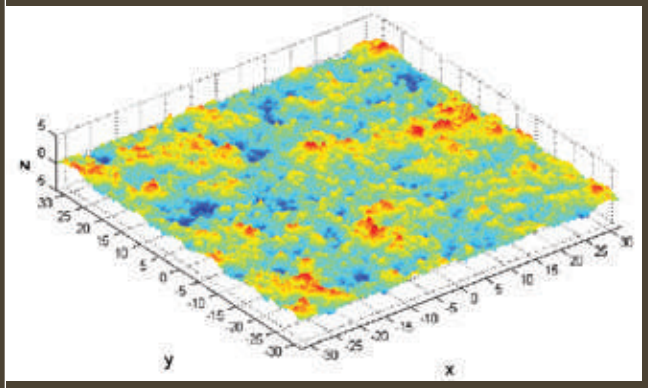
Scattering & Emission of Rough Surface in Microwave Remote Sensing of Soil Moisture

SHAOWU HUANG — Graduate Student (EE)

Observing and mapping soil moisture are important for hydrologic modeling, weather and climate prediction, drought and flood monitoring, and agricultural productivity estimation. The NASA Soil Moisture Active/ Passive (SMAP) Satellite Mission is scheduled to launch in 2013.

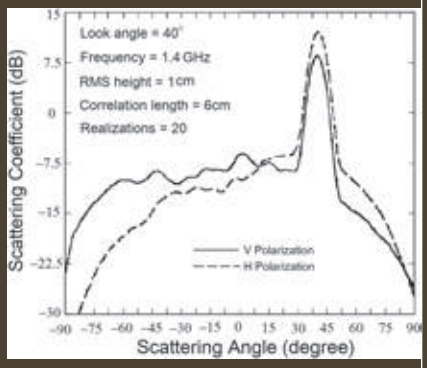
It will conduct the global mapping of soil moisture, including freeze-thaw. The SMAP mission will conduct the global mapping of soil moisture, including freeze-thaw, and will consist of a combined passive and active polarimetric sensor in the L-band (1.20-1.41 GHz), with an incidence angle of approximately 40º. Learning the interaction of microwaves with rough soil surfaces is required to understand the signatures of remote sensing. This research develops analytic and numeric techniques for solving Maxwell equations in wave scattering by random rough surfaces.

Analytic methods include the small perturbation method and the integral equation model. Full wave simulations are a formidable computational task because a rough surface with large surface area of ten thousand square wavelengths with many peaks and valleys is required to capture the physics of scattering by random rough surfaces. To formulate the scattering problem, the Green's function and surface integral equation are used. To solve the dense matrix equation the Sparse-matrix Canonical-grid (SMCG) method and the Multilevel UV method are developed. Hybrid methods that efficiently combine the methods and the fast multipole method have also proven useful.

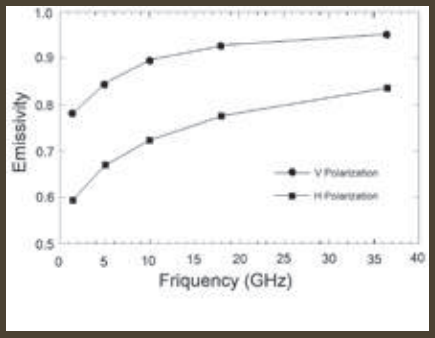


A random rough surface characterized by a Gaussian random process with an exponential correlation function. RMS height = 0.5 and correlation length = 2.5.

The results show that VV is stronger than HH at backward direction, but the former has a weaker peak at forward direction. The roughness effects increase with frequency making the L band SMAP mission essential for soil moisture monitoring. The permittivity of wet soil at 30.6% moisture content is adopted in these simulations.



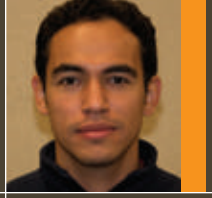
Right: The bistatic scattering coefficient for VV and HH polarization.



Left: The microwave emission dependencies of polarization, a look angle of 40º and frequency.

Simulation results show that the physical models are useful for microwaves signatures from scattering and emission of soils. These models also help develop inverse algorithms to retrieve soil moisture from microwave measurements. eek09

FACULTY ADVISOR: Professor Leung Tsang
COLLABORATORS: Graduate students Ding Liang, Xiaolan Xu & Zhiqian Gui (EE), Peng Xu, School of Electronic Information, Wuhan University
RESEARCH AREA: Electromagnetics, Microwave Remote Sensing
GRANT/FUNDING SOURCE: NASA SMAP Science Definition Team (SDT)



Evaluation of Wind Energy Enabling Technologies for Very High Wind Penetration Levels

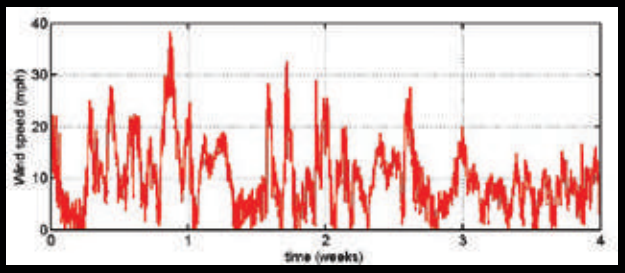
CESAR A. SILVA MONROY — Graduate Student (EE)

Wind penetration levels are expected to keep increasing at a fast pace stimulated by policies such as production tax credits and renewable portfolio standards.

Today, power systems use their demand-generation balance capability to integrate wind variations by handling wind generation as a negative load. As higher penetration levels of wind energy are reached, larger variations in wind output power will be observed, and current controllable power system resources will be insufficient to cope with them. This research focuses on identifying technologies that allow traditional power systems to further increase their wind energy penetration levels, and studies the effects of such scenarios on power system operations and reliability.

Wind turbines at Wild Horse wind farm in Washington State.

Besides conventional controllable generation, potential wind enabling technologies include specialized fast-responding generation, energy storage, real time customer demand response, and wind curtailments. Models of these technologies and other tools are needed to facilitate their expansion. Tools implemented as part of this research include algorithms for generation of artificial wind power time series, unit commitment, economic dispatch and hydro power plant operation. The latter is of special interest because of the large hydropower share in the generation mix of the Pacific Northwest.

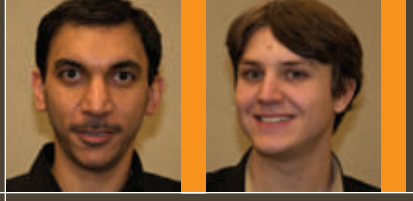


Sample of wind speed variations for a four-week period. Data source: Idaho National Lab.

Preliminary results were obtained for a power system consisting of coal plant models representing base-load units, natural gas turbine models acting as peaking units, and a wind energy penetration level higher than 30%. Simulations show that at these very high wind penetration levels, the capacity factor of base-load units decreases compared to the case with no wind power, while the capacity factor of peaking units increases. As a result, average energy cost raises since energy from wind and peaking units has a higher cost than the base-load energy being displaced. It also means higher start-up/shut-down frequencies for base load units, potentially reducing their reliability, but also reducing CO_2 emissions since natural gas produces significantly less CO_2 than coal to generate the same amount of energy.

Power systems need to incorporate enabling technologies in order to achieve higher wind energy penetration levels while maintaining efficient and reliable operations. Understanding high penetration wind energy effects will be essential to determine cost-effective combinations of enabling technologies. eek09

FACULTY ADVISOR: Associate Professor Richard D. Christie
COLLABORATORS: Assistant Professor Henry M. Louie (Seattle University), Sean Parker & Zachary Sanford (EE undergraduates)
RESEARCH AREA: Wind Energy Integration



Optimizing Power Grid Operation with Renewable Energy Sources

ALI AL AWAMI & ERIC SORTOMME — Graduate Students (EE)

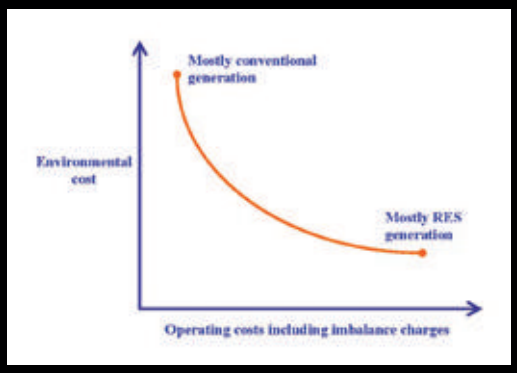
Conventionally, electric energy has been produced by fossil fuel generating units that are highly predictable and controllable.

However, due to the adverse effects on the climate from burning fossil fuels, scientists and engineers have started to consider cleaner alternatives to generate electricity, such as wind and solar. Unfortunately, these sources are highly unpredictable, and it is a challenge to optimize the operation of a power grid that has high penetration of such renewable energy sources. Storing large amounts of electric energy is not yet economically feasible, so the generation output of renewable energy sources must be balanced in real-time.

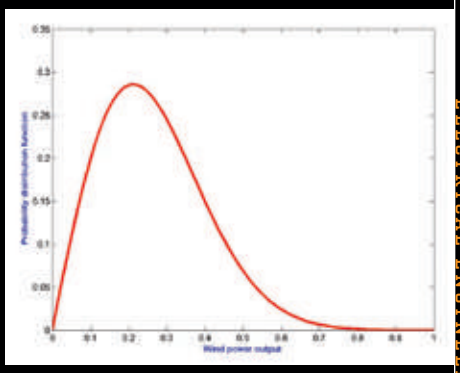
This work addresses the problem of optimizing the operation of the power grid with high penetration of renewable energy sources (RES). The target is to find the optimum mix of conventional and RES generation that meets a specified demand taking into account the stochastic nature of RES. Two conflicting objective functions are considered: minimizing operating cost and minimizing environmental impact. Because of the uncertainty accompanying RES, it is very likely that the actual power produced does not match the scheduled power. In many deregulated electricity markets, the RES owner has to pay a charge, called imbalance charge, for the mismatch between scheduled power and generated power. This charge is usually proportionally greater for under generation than for over generation. These charges are also included in the operating cost function.

Pareto optimization is considered, in which a group of optimal solutions (Pareto front) is obtained. Though the final decision of which solution to implement is left to the system operator, all solutions utilize higher levels of RES than they would without considering the environmental impacts. eek09

Wind power is one of the major renewable energy sources.



Multi-objective optimization of power system with RES.



The probability distribution function of wind power output.

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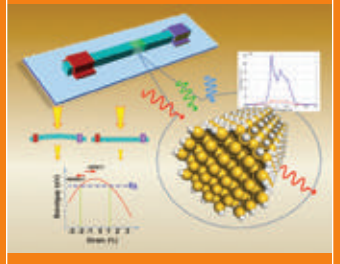
Congratulations to Babak Parviz who was promoted to Associate Professor, and to Hui Liu and Scott Hauck who were promoted to Full Professors.

We apologize for any errors, omissions or misspellings in 2009 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.

New Faculty

M. P. ANANTRAM

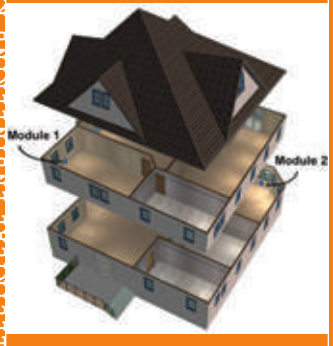


M. P. Anantram (Anant) joined the EE department as a Professor in Winter 2009. Prior to this he was a Professor in Nanotechnology Engineering at the University of Waterloo, which was preceded by nine years at the Center for Nanotechnology, NASA Ames Research Center, Silicon Valley. Anant has a varied educational background consisting of a BSc in Applied Sciences from PSG Tech, MSc in Physics from University of Poona, and a Ph.D in Electrical Engineering from Purdue University.

His research addresses theory and computational models to study molecular, semiconductor, and bio-nano structures. The Holy Grail is to build sophisticated enough design tools to understand the device physics and then perform extensive design-analysis before expensive fabrication. Theory, algorithms and development of computational code are the emphasis in this research. The use of the developed code in studying technologically relevant nanodevices is a major thrust.

Currently, this work consists of studying the electrical, optoelectronic and electromechanical properties of nanodevices such as nanotransistors, interconnects, electromechanical switches, solar cells and LEDs. Some of the nanomaterials considered in the last five years are semiconducting silicon and germanium nanowires, various carbon based nanostructures, carbon nanotube fibres/composites, and organic molecules. Charge transport in biomolecules such as DNA in various environments is also being explored with the aim to develop models for both observed phenomena and explore the possibility of nanodevices based on these bio-nano structures.

SHWETAK N. PATEL



Shwetak N. Patel is an Assistant Professor in both EE and CSE departments. He joined the faculty in September 2008 after receiving his Ph.D. in Computer Science from the College of Computing at the Georgia Institute of Technology. There, he was a member of the Ubiquitous Computing Research group, served as the assistant director of the Aware Home Research Initiative, and was a National Science Foundation Graduate Research Fellow. Dr. Patel's past work received the designation of a Top Technology Idea of the Year from New York Times Magazine in 2005 and has received various best paper awards. In addition, his research has also been the basis of various commercialization efforts.

Dr. Patel's research interests are in the areas of Human-Computer Interaction, Ubiquitous Computing, and User Interface Software and Technology, Sensors, and Embedded Systems with a particular emphasis on developing and applying new low-cost, easy-to-use hardware and software solutions to enable novel activity sensing applications. His most recent research has been in building a new class of low-cost and easy-to-deploy sensing systems for the home to enable in-situ human-centered research, called Infrastructure Mediated Sensing, which leverages existing utility infrastructures in a home to support whole house sensing. For example, he has explored repurposing the powerlines in a building for locating people and objects in the space. Dr. Patel's sensing work has been used in a variety of elder care and energy monitoring applications. His interests also extend to exploring novel mobile device interaction, haptic interfaces, wearable devices, and power harvesting solutions.

JACQUES RUDELL

In January 2009, Jacques Rudell joined the EE department as an Assistant Professor. He received a B.S. degree in electrical engineering from the University of Michigan, Ann Arbor and an MSEE and Ph.D. from UC Berkeley. Prior to joining UW EE, Rudell worked at Intel Corporation as a researcher in the Advanced Radio Technology Group. His work focused mainly on RF transceiver circuits and systems in advanced silicon processes.

In 1999, Rudell was the recipient of the Demetri Angelakos Memorial Achievement Award given by the EECS department at UC Berkeley. He received the 1998 ISSCC Jack Kilby Best Student Paper Award and was the co-recipient of the 2001 ISSCC Lewis Best Paper Award. He also received the 2008 ISSCC award for best evening session. In addition, Rudell is on the technical program committee for the International Solid-State Circuits Conference (ISSCC), serves on the MTT-IMS Radio Frequency Integrated Circuits (RFIC) Symposium steering committee, and has twice been the guest editor for the Journal of Solid-State Circuits (JSSC).

His research interests cover a broad area related to analog, mixed-signal, RF and mm-wave circuits. The emphasis of his work will focus on novel architectures and circuits which overcome the challenges presented by future low-cost, silicon technologies, such as ultra-low voltage, low-intrinsic device gain and poor matching characteristic. A recent example of Rudell's work involves implementing a 4G transmitter chain in 45nm CMOS, operating off of a 1.1V supply, using novel linearization techniques. Future research will explore architectures and circuits for highly integrated, concurrently operating, heterogeneous-wireless systems which overcome the evolving challenges associated with co-existence. Other research interests include mm-wave circuits for 60GHz and imaging applications, low-voltage highly-efficient transmitter systems, ultra-low power RF for cellular based sensor networks, high-speed I/O for chip-to-chip and core-to-memory applications and finally, integrated circuits for bio-medical applications.

GEORG SEELIG

Georg Seelig joined the faculty in spring 2009 as an Assistant Professor. He received his Diploma in physics from the University of Basel in 1999, and his Ph.D. in theoretical physics from the University of Geneva in 2003. For the last few years, he worked as a Research Associate at Caltech working with Erik Winfree and Michael Elowitz. In 2008 he received a Career Award at the Scientific Interface from the Burroughs Wellcome Fund.

Georg is interested in understanding how biological organisms process information using complex biochemical networks and how such networks can be engineered to program cellular behavior. The focus of his research identifies the systematic design rules for the de novo construction of biological control circuits with DNA and RNA components. His approach integrates the design of molecular circuitry in the test tube and in the cell with the investigation of existing biological pathways like the microRNA pathway. He is applying engineered circuits and circuit elements to problems in disease diagnostics and therapy.

iGEM Jamboree

In November 2008, seven undergraduate students from UW competed for the first time in the annual International Genetically Engineered Machine (iGEM) competition, held at MIT. For this contest in synthetic biology, teams were given toolkits that contain biological "parts" that can be joined and combined in novel ways to generate biological devices. Projects at the 2008 iGEM Jamboree ranged from bacterial kidneys to random number generators to a vaccine for Helicobacter.

Over the summer, the UW team constructed their project. They also modeled the behavior of the system using differential equations, and worked on a software tool to help future teams model and build genetic circuits. The UW team was advised by Professors Eric Klavins (EE), Herbert Saurio (BioE), and Stanley Fields (Genome Sciences). They won bronze medals and a prestigious special award.

The UW 2008 iGEM team consisted of Tyler Casey (EE), Paramjit Singh Sandhu (CompE/EE), Bryan Bartley and Scott Mason (Biochem), and Alec Nielsen, Faifan Tantakitti and Jeff Nivala (BIOE).

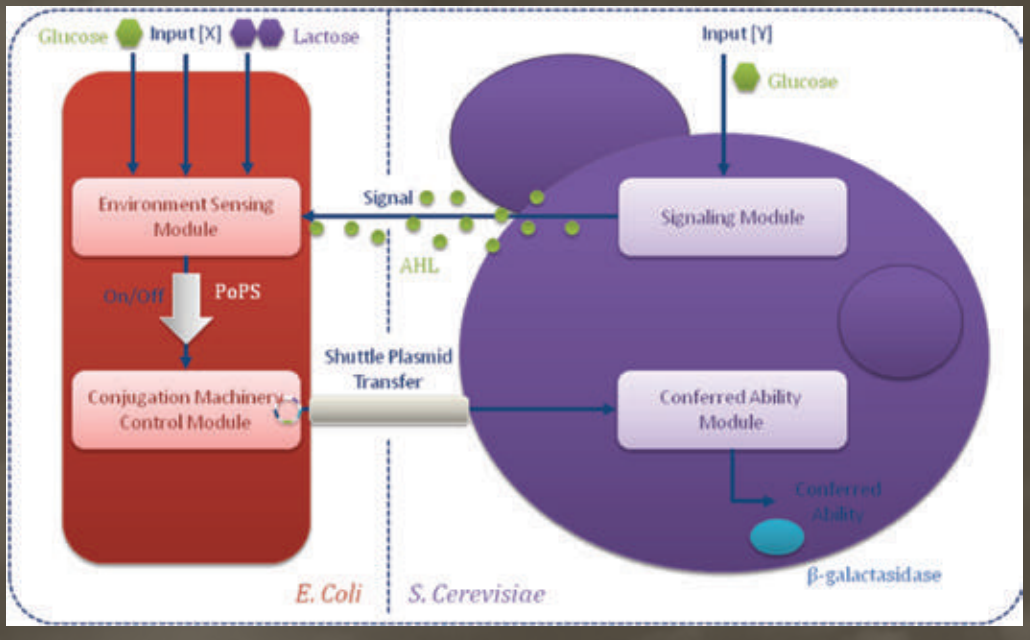
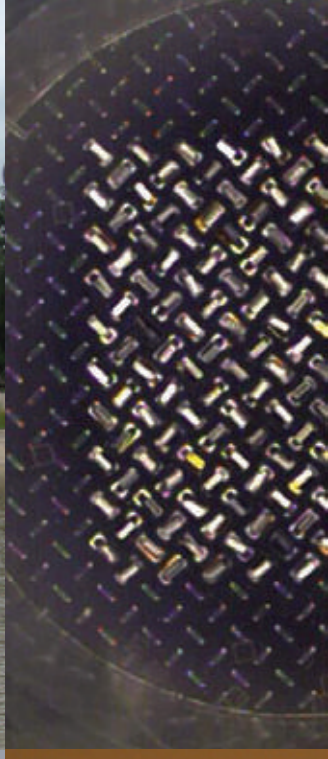
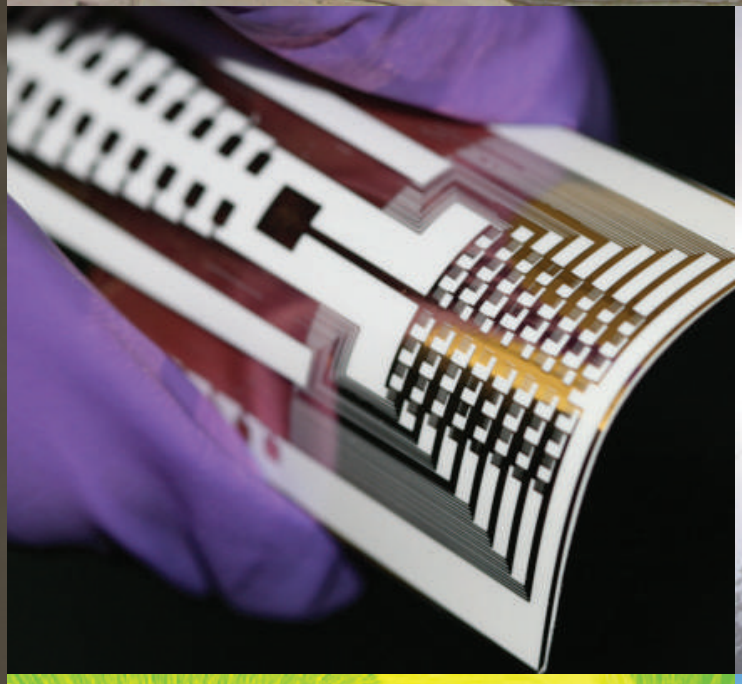
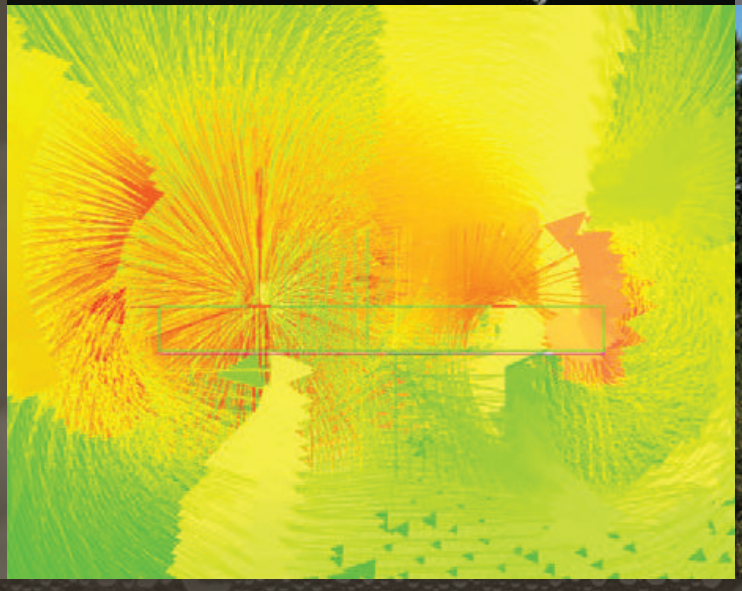


Figure: The UW team's "Vector-Jector" project design.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