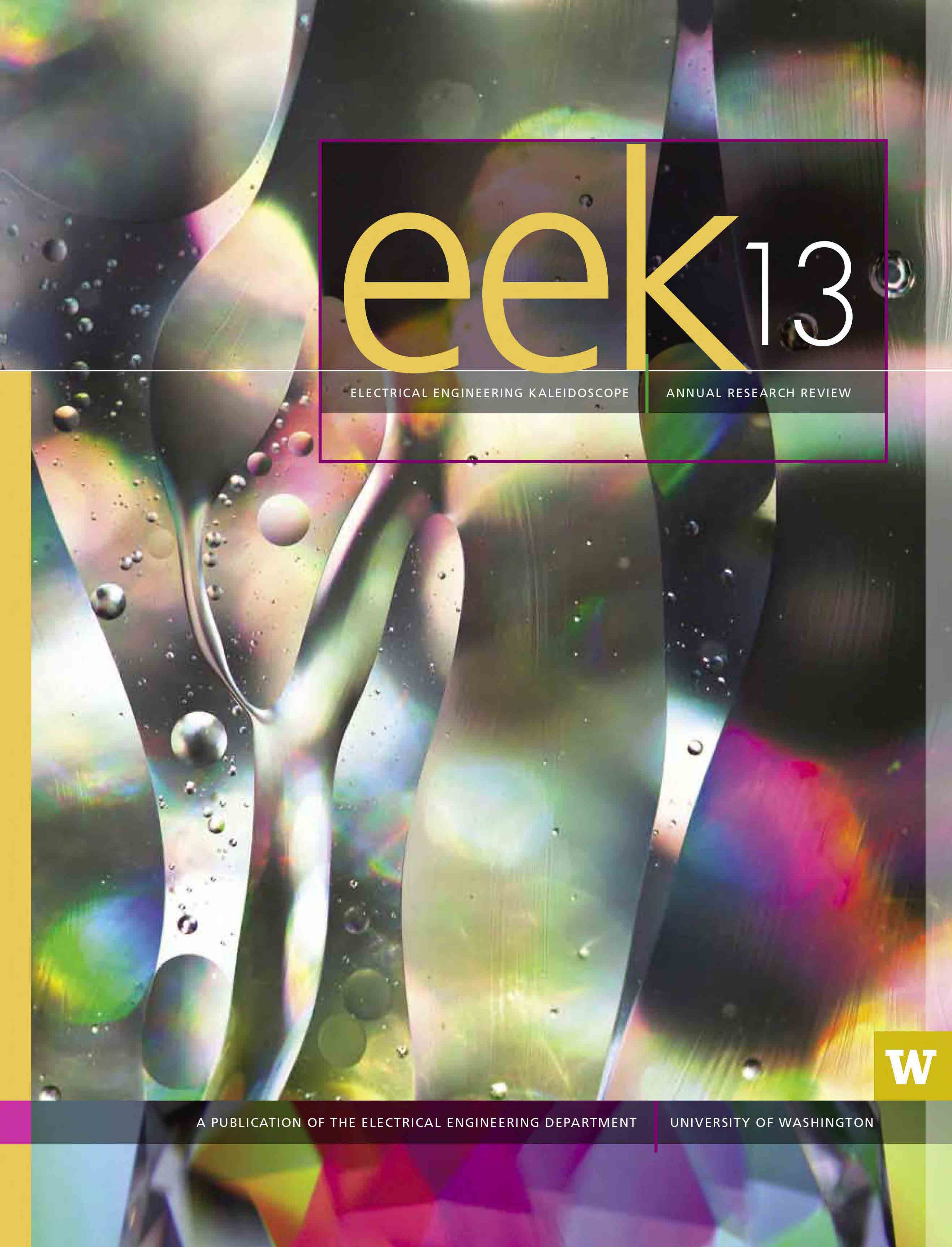


eek 13

ELECTRICAL ENGINEERING KALEIDOSCOPE | ANNUAL RESEARCH REVIEW

A PUBLICATION OF THE ELECTRICAL ENGINEERING DEPARTMENT | UNIVERSITY OF WASHINGTON

Dear Supporters and Alumni of UW EE,

Electrical engineering is a fast evolving field, and it is more important than ever that we identify and solve the real challenges of our time in health, the environment, energy, and human-centered systems. With this goal, we are focused on five strategic research areas that blend the expertise and strengths of UW EE, the university, and local industrial ecosystem: Sustainable Energy, Medical Systems & Devices, Molecular Systems & Devices, Big Physical Data: Computational Design Tools, and Big Physical Data: Sensing Systems & Networking. These areas will be at the forefront of research at UW EE, and will be featured in this edition of EEK.

We have much to celebrate in terms of faculty and student achievements. Professor Leung Tsang received the IEEE Electromagnetics award, affiliate professor and chairman of our advisory board Dr. Rico Malvar was elected to the National Academy of Engineering, and affiliate professor Dr. Bishnu Atal received the IEEE Kilby Signal Processing Medal. Professors Kai-Mei Fu and Georg Seelig received the NSF CAREER and DARPA Young Investigator awards, and the latest member of our faculty, Professor Brandon Pierquet, received the Washington State's STARS Researcher honor. Seven undergraduate students received scholarships from the IEEE Power and Energy Society, and three graduate students received NSF Graduate fellowships.

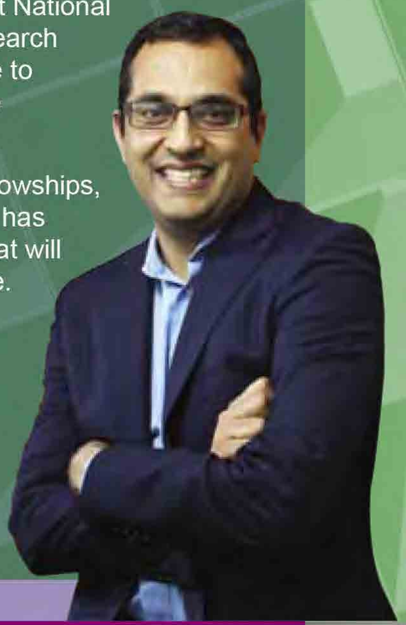
As a respected higher education department representing an evolving real-world discipline at a prestigious state-funded university, we face constant challenges in maintaining and growing our influence and reputation. We as a department are addressing these challenges and opportunities through several initiatives. A newly constituted Advisory Board, comprised of high-profile industrial leaders and alumni, held its first meeting last fall to help develop an excellent plan focusing on strategic research areas, curricular advances, and interactions with industry. Our new Corporate Affiliates Program (CAP), with founding company members such as Agilent and Intel, will bring industry, faculty and students together through curricular projects, internships and research. On January 2013, CAP held its first EE Career Fair event.

This year, we are looking to hire multiple faculty members in these strategic research areas to enhance collaboration and research stature. Building centers and institutes is another aspect of collaborative research, and UW EE will play a leading role, along with Computer Science and Engineering and Applied Math, in the new Northwest Institute for Advanced Computing. This is a venture with the Pacific Northwest National Laboratory wherein new scientists located in our departments will lead collaborative research projects with UW and PNNL. Our successful Professional Masters Program will continue to expand with new course offerings at the cutting edge of new technologies, online course experiments, and international expansion.

Reaching out to alumni and supporters to build advancement programs for endowed fellowships, labs and spaces, professorships and endowed chairs is a core priority. Recently, Agilent has supported UW EE at a level that is recognized by a new Agilent Technologies RF Lab that will be operational this year and provide students with the latest RF technology and software.

Happy reading and best wishes for 2013!

VIKRAM JANDHYALA
Chair and Professor
Department of Electrical Engineering



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ANNUAL RESEARCH REVIEW

this issue...

Department Research

Big Physical Data: Computational Design Tools

Massive online data sets, known as big data in the computer science field, is now around us. Big 'physical' data refers to the data associated with the operation, design, and optimization of engineered systems. The term 'physical' refers to the fact that the signals associated with these systems are not merely bits of information, but are rooted in the physics of signals and systems. Large-scale networks, sensing systems, communications and embedded circuits require complex design tools to optimize and synthesize them, as well as scalable simulation and computation tools to understand their operation and process the data. Big Physical Data: Simulation, Computation, and Design Tools relates to the tools required for designing systems that function with big physical data, and for efficient modeling of such data.

This strategic area encompasses several computation-heavy branches of UW EE including computational electromagnetics, device physics, nanotechnology and biotechnology, as well as the associated optimization and design automation.

Electromagnetic Scattering Models of Vegetated Surfaces In Active Microwave Remote Sensing

Tien-Hao Liao | Graduate Student (EE)

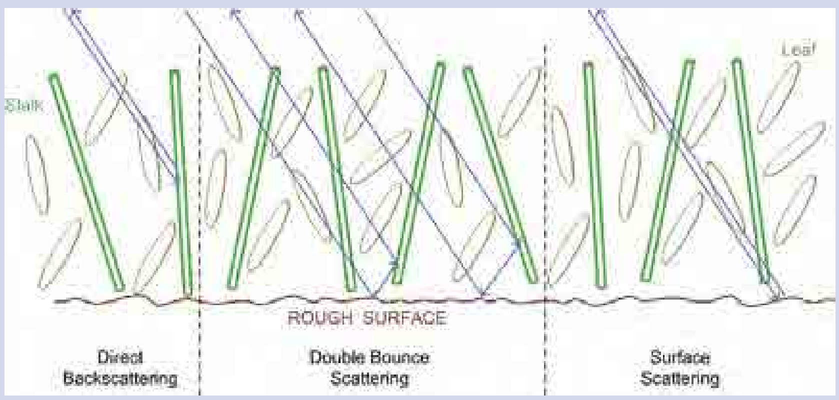
This work studies the scattering of electromagnetic waves by vegetated surface in global soil moisture mapping for NASA's Soil Moisture Active Passive (SMAP) satellite mission that is scheduled to launch in October, 2014. The goal is to study the water cycle so as to improve weather forecast, flood prediction, and drought monitoring.

Soil moisture is also a key variable in climate models of global climate change. Vegetated surfaces such as grassland and croplands are important because large percentages of land surfaces consist of vegetation. The relation between L-band radar backscatter and vegetated surface can be understood by electromagnetic scattering models for both vegetation and rough soil surface.

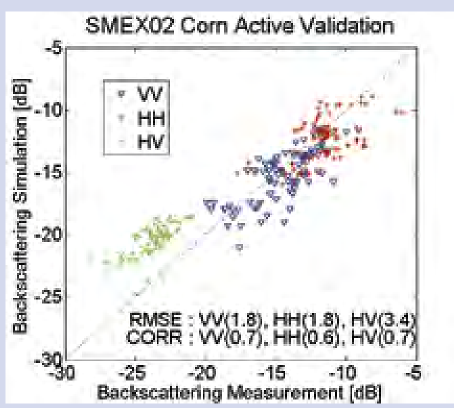
Researchers from UW EE's Laboratory of Applications and Computations in Electromagnetics and Optics model the vegetated surface in two parts: the vegetation on top, and the rough soil surface below. The vegetation part according to its structure is modeled to accurately simulate the backscatter. Discrete scatter approximation is applied by using shapes like cylinders, disks, or ellipsoids for stalks, branches or leaves. For example, a corn structure is composed of cylinders for stalks and ellipsoids for leaves in the growing phase of its life cycle. Each single scatter of a cylinder or ellipsoid is solved by Maxwell's equation either through infinite cylinder approximation (ICA), or by body of revolution (BOR) which is performed with method of moment. The surface scattering is calculated by using the 3-D full wave Maxwell equation method (NMM3D). The vegetation-surface interaction is performed with Distorted Born Approximation. Overall there are three scattering mechanisms including direct volume backscattering, double bounce scattering of volume-surface interaction, and surface scattering. In preparation for the SMAP mission, calibration and validation efforts have been carried out through extensive ground, aircraft and UAVSAR measurements in various parts of US, as well as in Canada and Australia. Below, we illustrate the comparison of theoretical results with field measurements in SMEX02 for radar backscatter, VV, HH, and HV. The validation shows that the forward model can be useful for the predictions of radar backscattering from the vegetated surface.

From the physical forward model, theoretical results are tabulated in data cubes with soil moisture, vegetation water content (VWC), and rms heights of soil roughness. For the SMAP mission, they can be applied to the retrieval algorithm to recover soil moisture. Physical models are also being developed based on the same principles for passive microwave remote sensing.

For more information scan code with smart phone or visit: http://smap.jpl.nasa.gov/



The forward scattering model of a corn field and the three scattering mechanisms.



Backscattering validation of a forward model with SMEX02 field measurement for VV, HH, and HV.

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RESEARCH AREA
Electromagnetics, Microwave Remote Sensing

GRANT/FUNDING SOURCE
SMAP Science Definition Team, Jet Propulsion Laboratory, NASA

PHYSENSE: Physics-based Influence Diffusion for Social Networks

Chuanjia Xing & Albert Yu | Graduate Students (EE)

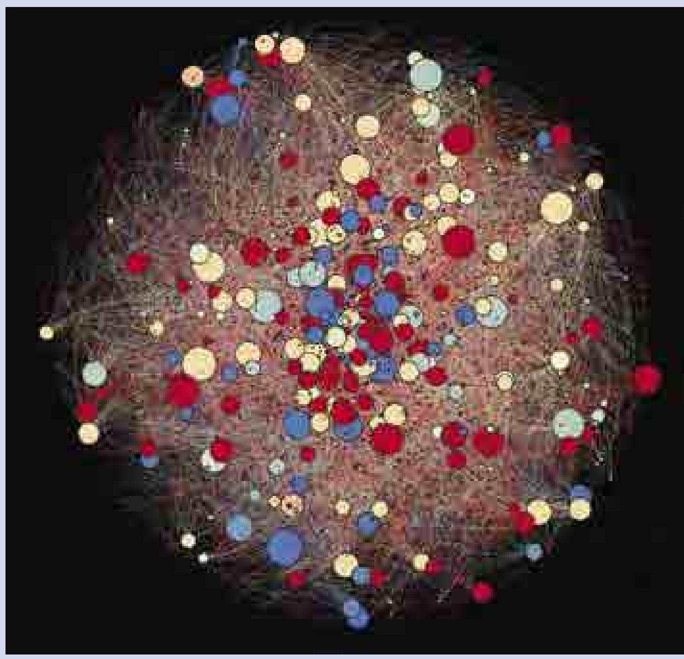
Social media is revolutionizing the way people interact, share information and influence each other. With hundreds of millions of users taking part in various social networks, strong potential exists for next-generation personalized services such as social search, personalized ads, automated expert search, social media marketing campaigns and mobilization for collective action.

With massive amounts of data generated by user activity, there is an increasing need for getting relevant actionable information in a rapid and scalable manner. PHYSENSE is a physics-based influence detection methodology and implementation that provides the capability of precise, personalized and rapid signaling in social network scenarios.

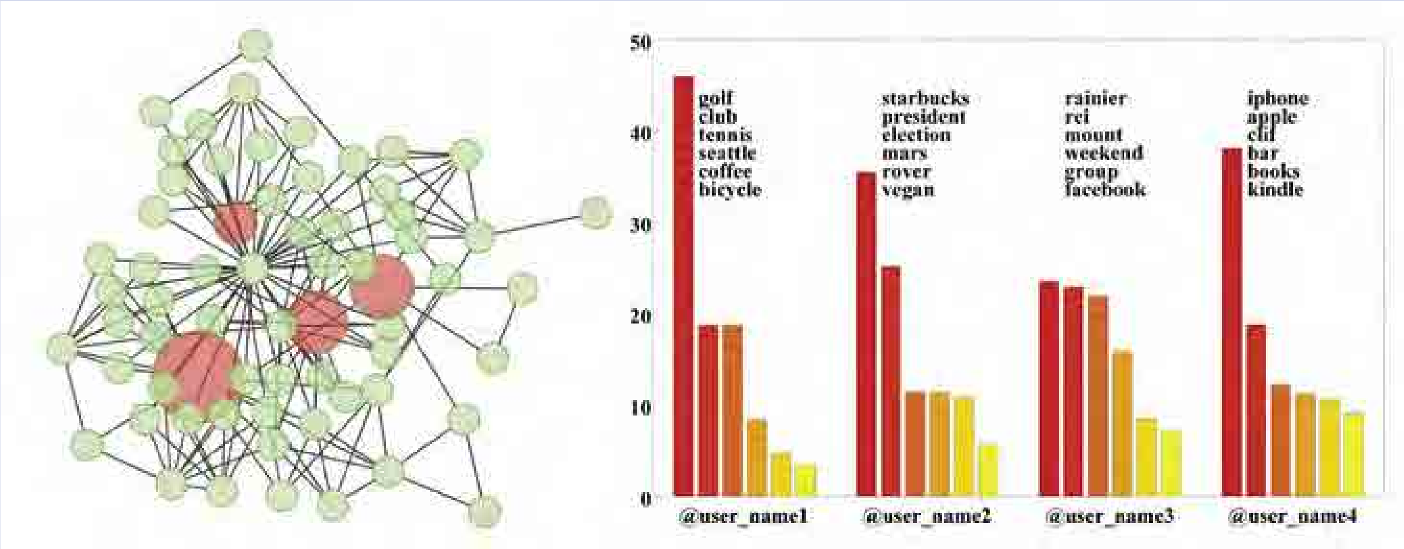
PHYSENSE provides a unique and novel approach to modeling and predicting information and influence propagation in networks by replacing graph methodologies with physics-based diffusion of fields using discretized Green's functions. Information propagates from the "source" users to "receiver" users according to the topology of the network, similar to the field propagation in electromagnetics. It has been demonstrated that the PageRank algorithm, which is used to determine the importance of pages on a web-graph, morphs into a graph representation of the wave equation in electromagnetics. Green's function-based methods have been successfully employed in the solution of the PageRank equation, and its more relevant non-linear counterparts in social networks. The Born approximation method has also been leveraged from electromagnetic theory to temporally track the dynamic nature of the influence landscape originating from the altering nature of the network topology.

PHYSENSE can also deal with the more complicated non-linear influence detection problem. Real social networks are complex; the information and influence propagation are not simply dependent on the connections between users. Factors such as topic-dependence and decision-making will also affect the propagation process. PHYSENSE can use the generalized swept-topic Green's functions over graphs to uncover topic-dependent, dynamic individual and group behavior.

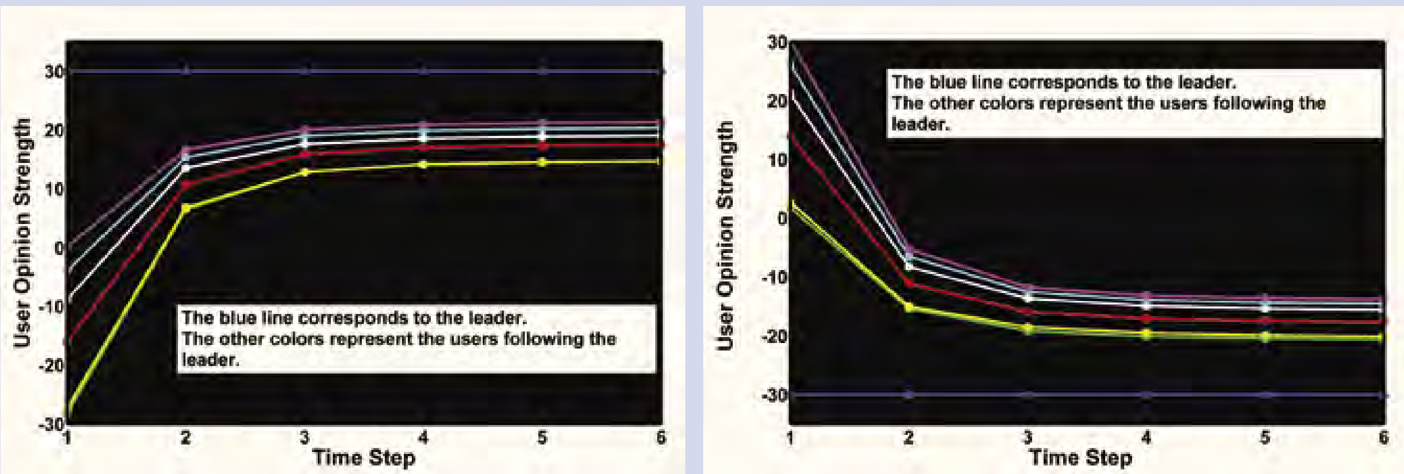
PHYSENSE promises to bring to fruition, a variety of applications in the context of social networks. They include influencer detection, personalized advertising, organization of marketing campaigns, automated expert discovery and discovery of covert groups. Future research will focus on the generalized topic-dependent non-linear activity models in large social networks and prototyping with Twitter data.



A sampling of Twitter users participating in conversations on the 2012 Election Day. The colors denote the various strongly connected groups of users.



The influencers on a part of the network (large red nodes) and their other interests ranked by their activity composition over a time window. Influencers are identified by measuring their activity propagation potential and not just by follower count or number of tweets.



On a small subset of users following a leader, using a social influence model, the graphs illustrate how an obstinate leader with high positive (left) or high negative (right) opinion can sway the opinions of the followers over time.

For more information scan code with smart phone or visit: www.acelabuwee.org

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RESEARCH AREA
Electromagnetics, Big Data/Data Science

GRANT/FUNDING SOURCE
UW Center for Commercialization Gap Fund

Big Physical Data: Sensing Systems & Networking

The deployment of integrated platforms with embedded sensors, (wireless) communications and processing capabilities, and their large-scale deployment leads to a natural coupling of numerous large scale sensing systems that result in big physical data. This thrust focuses on the coupling of the underlying sensing physics and the (wireless) communication infrastructure to support data collections, representations and the subsequent intelligent data analysis. The methods developed apply to many sensing modalities that are largely EE-centric, which include RF/acoustic/optical communications over geographic scales large and small, and the interplay between the local platform capabilities (i.e., 'software defined' attributes) and the end-to-end (system level) goals.

UW EE is the home for a wide swath of enabling research in this theme, all the way from sensor devices to computational/communication platforms and the needed intelligence (signal processing/analysis, communications/networking, algorithms) to tie everything together.

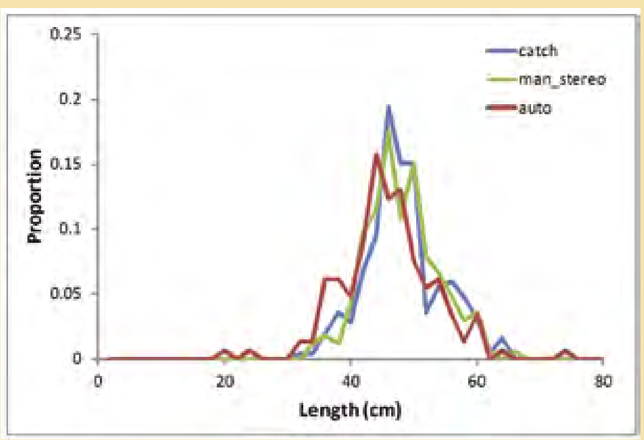
Length Measurement & Tracking of Fish for Trawl-Based Underwater Cameras

Meng-Che Chuang | Graduate Student (EE)

Fish abundance estimation, which often uses bottom and mid-water trawls, is required for the commercial fish populations in fisheries science. An automated system with the aid of visual analysis techniques can provide a non-extractive approach that improves the quality and efficiency of abundance surveys.

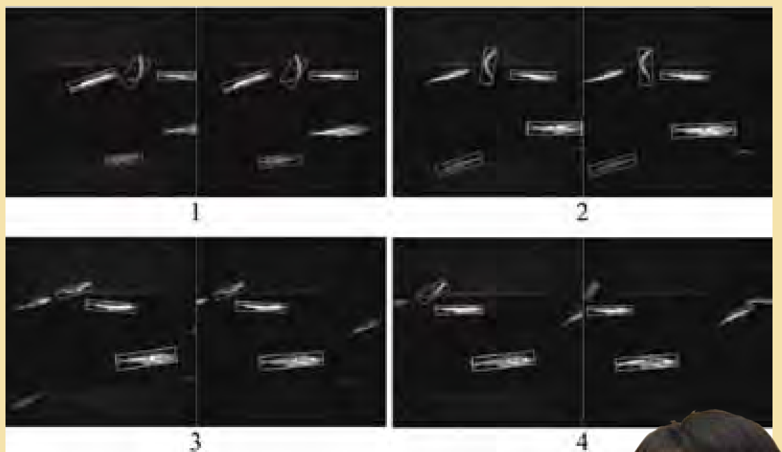
With a self-developed trawl-based underwater stereo camera system, researchers from The National Oceanic and Atmospheric Administration (NOAA) and UW EE's Information Processing Lab have developed a reliable live fish length measurement and tracking algorithm for low-contrast and low-frame-rate stereo videos.

To overcome the low-contrast and non-steady illumination in an underwater video, a histogram backprojection approach is adopted on double local-thresholded images for accurate segmentation on the fish shape boundaries. Double local thresholding based on Otsu's method produces two object masks with different sizes, and the histogram backprojection merges the two masks by exploiting their correlation identified in a pixel intensity histogram. With the stereo cameras, depth information is extracted by employing stereo matching based on a computationally efficient block-matching method. This enables a fish-body tail compensation scheme to greatly reduce segmentation error and result in an accurate fish length measurement.



Length frequency of a fish according to physical measurements (catch), measurements using manual selection (man_stereo) and measurements using the proposed algorithm (auto).

Conventional multiple-target tracking algorithms are unable to process well in a low-frame-rate underwater video due to the ubiquitous noise, poor motion continuity and frequent entrance/exit of targets. In order to resolve these, a reliable object matching method considers various attributes, including spatial features, temporal features and appearance features. A matching cost function between two objects is established accordingly. Using this cost function as the distance metric and a simple motion projection for the position prediction, a novel multiple-target tracking algorithm based on the Viterbi data association technique successfully tracks multiple live fish simultaneously.



An example of tracking multiple fish in a stereo underwater video clip.

The fish length measurement and tracking algorithm measures the fish length and tracks multiple fish in low-contrast and low-frame-rate underwater video clips. This system seeks to expand to scenarios with uncontrolled backgrounds as well as incorporate it with an automatic fish species classification framework.

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

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RESEARCH AREA
Video Analytics & Computer Vision

GRANT/FUNDING SOURCE
National Oceanic & Atmospheric Administration

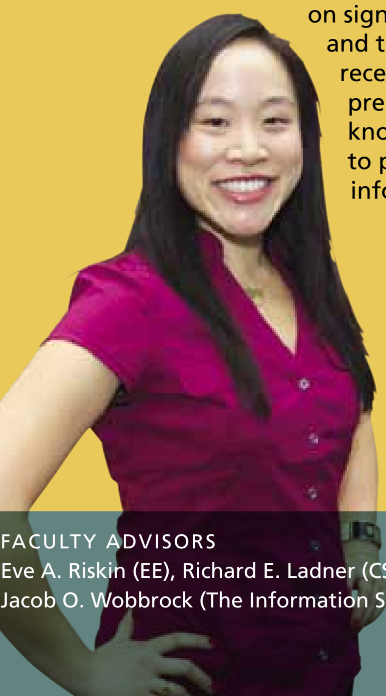
Human-Centered Tradeoffs in Mobile Sign Language Video Quality & Intelligibility

Jessica J. Tran | Graduate Student (EE)

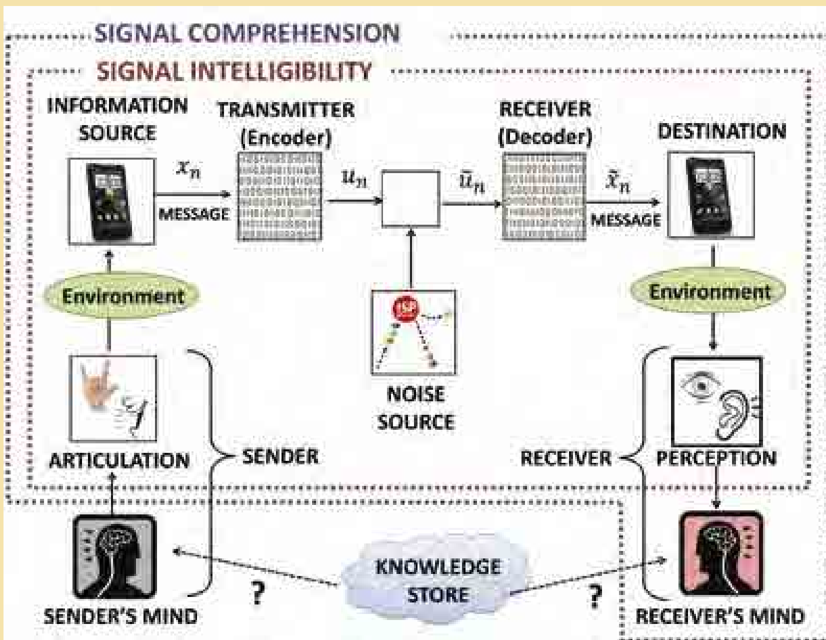
Major U.S. cellular networks throttle down network speeds in response to high data consumption rates. This limits mainstream adoption of mobile video communication, especially for deaf and hard-of-hearing people, who natively sign American Sign Language (ASL), which is a visual language with distinct grammar and syntax. Currently, cellular phone companies do not subsidize the extra cost of mobile video communication used by deaf and hard-of-hearing people.

This research contributes to an ongoing research project called MobileASL that aims to make mobile video communication accessible to deaf and hard-of-hearing people. Applying video compression algorithms reduces bandwidth consumption, however, intelligibility may be sacrificed. The goal is to determine how much video quality can be reduced before intelligibility is sacrificed when transmitting real-time ASL video at lower frame rates and bitrates.

Currently, a standard human-centered method to evaluate video intelligibility is lacking. The Human Signal Intelligibility (HSI) model is being developed to evaluate intelligibility of lowered video quality for the purpose of reducing bandwidth consumption. The HSI model: (1) extends Shannon's theory of communication to include the human and environmental influences on intelligibility and comprehension, and (2) identifies and separates the components that make up intelligibility from comprehension. This distinction is important because intelligibility does not imply comprehension. Intelligibility depends on signal quality, specifically how the signal is captured, transmitted, received, and perceived by the receiver. Comprehension relies on signal quality and the human receiver having prerequisite knowledge to process the information.



Identifying where intelligibility breaks down is important to determine how much video quality can be reduced.



A block diagram of the Human Signal Intelligibility model. Note that the components comprising intelligibility is a subset of signal comprehension.

The HSI model is being validated through rigorous empirical evaluations in a two-part mixed-methods study that includes a national web study and a laboratory study. It is anticipated that validation of the HSI model could assist in evaluating intelligibility of other video streaming media such as Hulu, Skype, and YouTube.

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

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RESEARCH AREA
Digital Signal Processing-Video Compression

GRANT/FUNDING SOURCE
Google, National Science Foundation

Detection of Targets Using Digital TV Broadcast

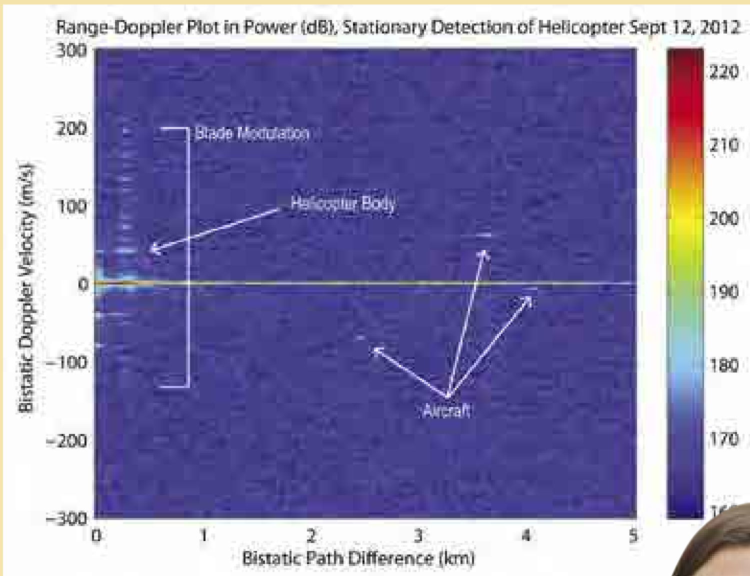
Laura Vertatschitsch | Graduate Student (EE)

Passive radar offers a stealthy, safe and inexpensive method for detecting targets. Instead of controlling a transmitter, this technology relies on transmitters of opportunity such as FM or DTV broadcast to illuminate targets. By receiving the direct transmission from these towers, echoes can be found from ground clutter, aircraft, meteor trails and space weather events.

The Manastash Ridge Radar (MRR) operated by the UW EE's Radar Remote Sensing Lab (RRSL) uses commercial FM broadcast to detect these targets with 1 km of range resolution. Researchers from the RRSL are currently working on a new generation receiver that will utilize any transmitter of opportunity up to 1.5 GHz.

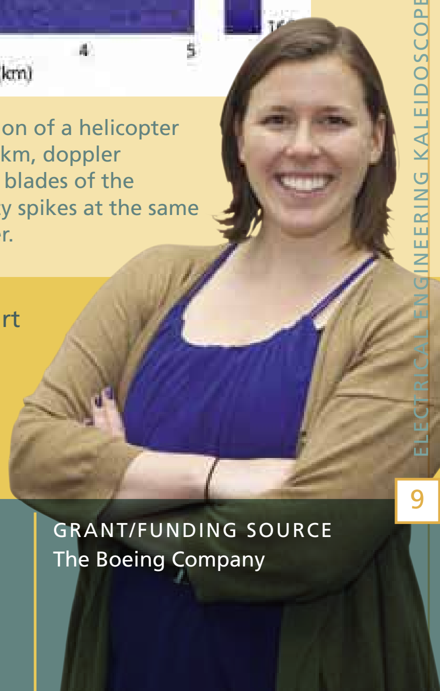
The current focus of this new receiver is to detect aircraft using DTV broadcast. This presents a challenge of building a system with high instantaneous dynamic range and managing incredibly large data rates; researchers are using the first 10 Gigabit Ethernet (GbE) link in the department. The Range-Doppler plot to the right presents an echo from a helicopter, delayed enough in time from the direct path transmission (4 km away) to account for an extra 0.3 km in flight path. The plot verified that this was indeed the very close helicopter researchers saw flying over the UW. The Doppler velocity (y-axis) is the rate of change of this path difference, which is related to the velocity of the target projected toward the radar. The body of the helicopter presents a Doppler velocity of 40 m/s, a positive Doppler indicating approach. Helicopter blades are like spinning wires, and they produce many harmonics in the Doppler shift as seen by the vertical spreading of power, which not only allows researchers to detect this target but classify it as well. Powered by an uninterruptible power supply (UPS) the radar can operate mobile for up to an hour.

The receiver is designed with the latest radar technologies including a fast digitizer and a field-programmable gate array (FPGA). In the near future it will utilize a graphical processing unit (GPU) for fast and parallel computation. Goals include close to real-time detection of aircraft from mobile operation, and demonstrations of simultaneous FM and DTV broadcast usage on a single antenna from a single digitizer.



A range-Doppler plot that shows the detection of a helicopter near the UW (bistatic path difference of 0.3 km, doppler velocity of 40 m/s) using DTV broadcast. The blades of the helicopter produce different Doppler velocity spikes at the same range as seen by the vertical spread in power.

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



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RESEARCH AREA
Passive Radar, Remote Sensing

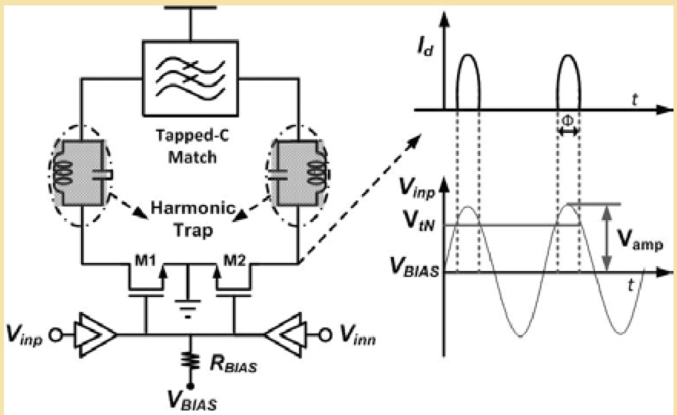
GRANT/FUNDING SOURCE
The Boeing Company

A Robust PLL-based Power-Scalable Transmitter Architecture for MedRadio & ISM (433MHz) Standards

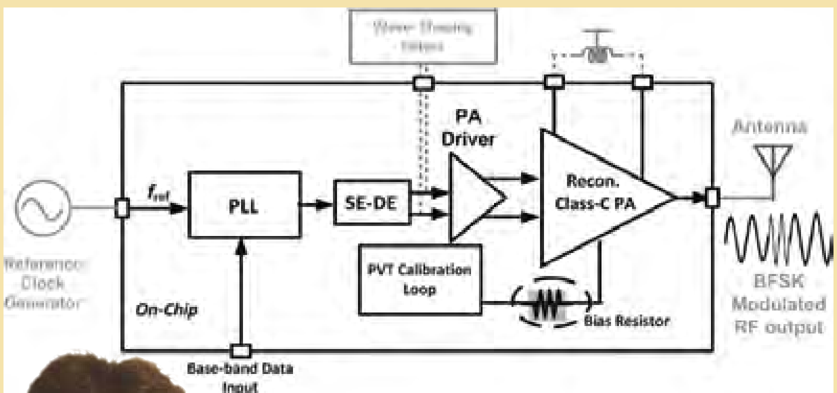
Karthik Natarajan | Graduate Student (EE)

Reconfigurable bio-sensor radios promise new opportunities in healthcare. A bedridden patient may be connected with short-haul radios that transmit bio-signals in the MedRadio band to a bedside monitoring station. Because doctors soon encourage patients to move around, reconfigurable sensor nodes that reconfigure from the MedRadio band to the longer-range ISM band enable continuous un-tethered monitoring of recovering ambulatory patients.

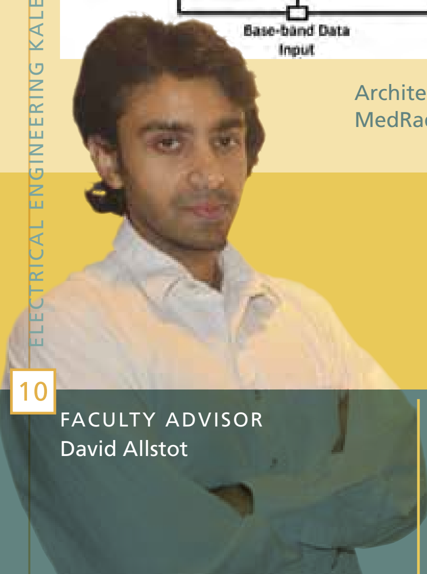
Security of healthcare information is an emerging issue. Switching to a low-power mode to enable operation in a secure multi-hop peer-to-peer network or transmitting at high-power to swamp the jammer are two methods to prevent security breaches in the communication channel. This research presents the first reconfigurable bio-sensor transmitter for such applications.
At the core of the transmitter is a PVT tolerant, reconfigurable power amplifier core based on a class-C architecture. Data modulation is performed using an ultra-low-power on-chip PLL. Drain current I_d flows when $|V_{amp}| > V_{tN}-V_{BIAS}$. The conduction angle of $\Phi < 90^\circ$ defines the class-C operation. The power drawn from VDD is reduced because I_d flows for a small fraction of the period. A class-C PA gets high efficiency for EIRP < 0dBm and the PLL-based BFSK modulator eliminates frequency pulling.



Proposed pseudo-differential class-C PA with operating waveforms. The operation of a class-C PA with the DC-bias of M1-M2, V_{GS} ($=V_{BIAS}$) is below V_{tN}.



Architecture of the reconfigurable dual-band MedRadio/ISM (433 MHz) BFSK transmitter.



An on-chip PLL provides closed-loop modulation of the baseband data for BFSK transmission. The PLL employs a low-power integer-N type-II third-order PLL and a NMOS delay-based ring oscillator (NDRO). Rather than controlling V_{DD} to set the oscillation frequency, NDRO controls the resistances of switches in series with the gate capacitances of inverters. However, both V_{tune} and (V_{DD}-V_{tune}) signals are required for transmission-gate switches. The latter requires a level shifter that adds area, power, and noise coupling from V_{DD} to the output. These concerns are eliminated from the designed PLL where only NMOS switches are tuned.

An RF transmitter that uses closed-loop PLL-based BFSK modulation and is reconfigurable for both the MedRadio and 433 MHz ISM bands is introduced. Innovations include the first reconfigurable class-C PA, the first class-C PA with automatic calibration against PVT variations, and a low-power NMOS delay-based ring-VCO PLL. This work opens up possibilities for innovations in healthcare applications.

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

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RESEARCH AREA
RF/Analog

GRANT/FUNDING SOURCE
Semiconductor Research Corporation

Sustainable Energy

Industrialized societies depend on the availability of a reliable supply of cheap electrical energy. Sustainability requires that an increasing fraction of this energy be produced from renewable sources. The research at UW EE involves understanding and mitigating the impact that stochastic renewable energy sources have on the operation of the power system, and harnessing the demand-side (in particular electric vehicles) to help control the power system more effectively. Additionally, this area encompasses the development of sensing technologies for energy monitoring, and designing power electronics systems for renewable energy and the smart grid.

The goal is to design power transmission, distribution and delivery systems that achieve the optimal balance between cost, reliability and environmental impact. This strategic research area aims to integrate these renewable sources in the grid using advanced computing, communication, sensing, power electronics and control techniques.

Harvesting Energy from Ambient Radio Sources

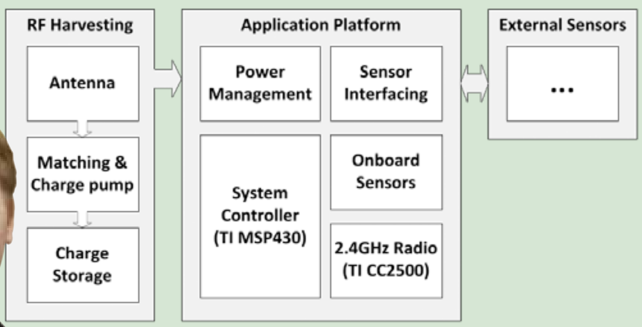
Aaron N. Parks | Graduate Student (EE)

Advances in the energy efficiency of modern electronics have made it possible for a wireless sensor node to derive all the energy required for operation from its environment. Existing work in energy harvesting technologies has focused on solar, mechanical, and thermal ambient energy sources. Recently, ambient radio frequency energy present in populated areas has also been explored.

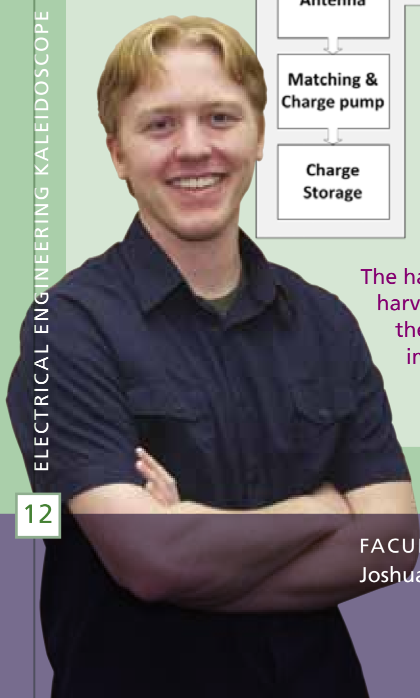
Television and radio broadcast, WiFi devices, and mobile phone infrastructures have all been targeted as ambient sources of a useful quantity of energy. This work demonstrates a fully functional wireless sensor node operating entirely on energy harvested from a nearby cell tower.

To explore the problem space around radio frequency harvesting, a harvesting sensor node prototype was developed. Various radio frequency harvesting circuits were built and characterized, with the most sensitive harvester operating with as little as -18 dBm (15.8 μW) incoming RF power. A small capacitor provides the minimal amount of charge storage required for sensor node operation. An onboard 2.4 GHz wireless transceiver allows transmission of sensor data to a nearby access point, and a low power microcontroller with an energy optimized firmware set orchestrates sensor node operation. A photometer and a temperature sensor were added to the prototype to demonstrate sensing capability.

A prototype test rig was constructed to demonstrate harvesting from a cellular base transceiver station. The antenna used for these tests was a typical broadband UHF digital television antenna with 6 dBi gain.



The hardware architecture of the radio energy harvesting wireless sensor node. All aspects of the sensor node are tailored to the constraints imposed by an energy harvesting power supply.



An on-campus cellular base transceiver station (cell tower) was targeted as a test site for ambient radio harvesting. Eight locations around the cell tower were tested, with the sensor node being able to cold-start, perform some sensing, and transmit data at six of the eight locations. The most distant point at which the node successfully operated was more than 200 meters from the cell tower.

Radio frequency energy harvesting can enable long-term wireless sensor deployment without the need for periodic battery replacement. Future work will focus on exploring low power communication techniques, and producing an adaptive harvesting system which automatically maximizes its use of the available radio frequency energy in a particular environment.

For more information scan code with smart phone or visit: http://sensor.cs.washington.edu/WARP.html

FACULTY ADVISOR
Joshua R. Smith

RESEARCH AREA
Energy Harvesting, Low Power Design

GRANT/FUNDING SOURCE
Intel Science & Technology Center (ISTC), Google Faculty Research Award

Wind Scenarios for Energy Scheduling

Adam Greenhall | Graduate Student (EE)

Wind and other renewable energies have become a significant source of the world's electricity. However, developing a grid capable of handling the unpredictable nature of wind remains a challenge.

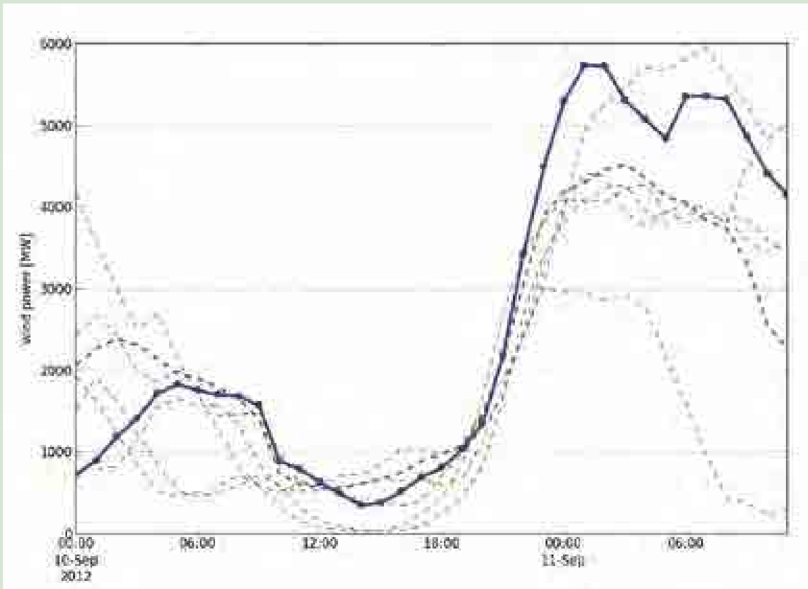
Renewable integration engineers focus on energy storage, better forecasting or improving system scheduling. However, storage remains expensive. Forecasting techniques will improve, but will never produce perfect predictions. The demand for electricity still must be met in real-time with an uncertain supply.

An alternative to relying on a single, imperfect forecast is to consider many possible wind scenarios and to choose the schedule that does the best overall. In power systems, this idea is called stochastic unit commitment.

This work focuses on how scenarios are created. Of all the possibilities, which ones are credible, likely, and should inform the scheduling decision? Stochastic unit commitment becomes very computationally expensive as the number of scenarios increase, so another key consideration is the number of scenarios needed.

Two methods to create scenarios are used in this research: building statistical models of forecast error, and mining the past for similar events. With a statistical model for error and a forecast, a process called "moment matching" is used to synthesize a set of errors with statistics (moments) which are similar to the model. With the similar events or analogs method, a historical archive is searched for forecasts that look like tomorrow's forecast. Then, the observed wind power time series on those analogous days are used as scenarios for tomorrow.

These scenario creation methods are evaluated using models and past operations records of real power systems. Current experiments are based on the Texas power system (ERCOT), and a model of the Northwest's Bonneville Power Administration system is in development. Current scheduling practice uses deterministic forecasts; experimental results are evaluated against this metric. Recent results suggest that stochastic unit commitment could have significantly reduced operating costs for the ERCOT system in 2012.



Scenarios provide a sense of the uncertainty around a forecast. Observed wind power is shown in blue, starting on September 10th, 2012. The original forecast for that date is shown in green. The top five analog scenarios are also shown in light gray. One of the analogs anticipates the over-forecast in the first few hours and another anticipates the significant under-forecast in the early hours of the second day.

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RESEARCH AREA
Energy Systems

GRANT/FUNDING SOURCE
Hydro Research Fellowship

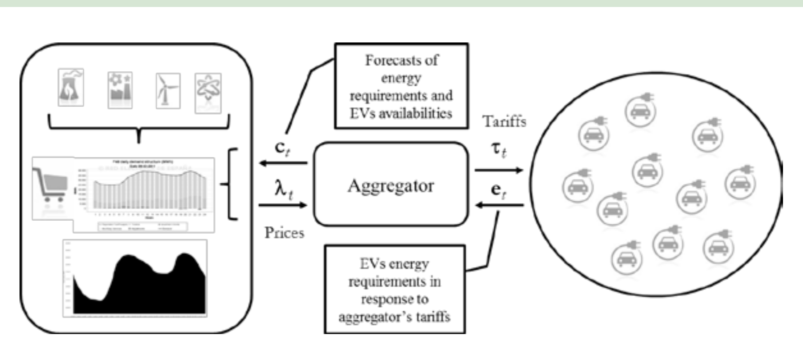
Integration of Electric Vehicles

Miguel Ortega-Vazquez | Research Assistant Professor

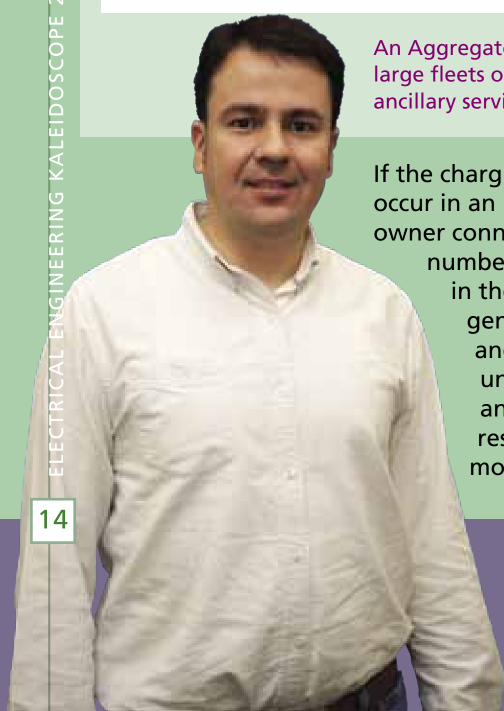
The supply side of power systems has undergone major changes to curb its gaseous emissions. Many solutions invest in sustainable renewable energy sources such as wind and solar. With these joint efforts to decarbonize the supply side, road transport is also due to part ways with carbon-generating fossil fuels.

A natural substitute to gasoline and diesel is lower carbon electricity coming from the sustainable sources. In the near future, it is expected that large fleets of electric vehicles (EVs) will constitute a significant share of the wide system demand.

Unlike most of the existing loads, EVs are equipped with batteries to store energy and to defer their power consumption over time. This unique feature can be exploited to assist the power system by providing a share of the needs for flexibility. However, in order to have an impact on the system's flexibility, the operation of large volumes of EVs needs to be orchestrated.



An Aggregator acting as a mediator between large fleets of EVs and the energy and ancillary services markets.



If the charging process of the EVs is allowed to occur in an uncontrolled manner (when the EV owner connects them to mains), only a limited number of EVs can be accommodated in the system because of insufficient generation capacity to meet the demand and the reserve requirements. The uncontrolled case produces higher and more frequent peaks of system residual demand, which translates into more frequent deployment of expensive peaking generation. Energy prices subsequently increase and thus the overall running costs of the system. This has profound impacts in the short-run and long-run of the system, since earlier generation expansion would be required to serve the ever-increasing peaks of demand.

At a household level, determining when to schedule the EVs to charge can be made as a response to a price signal. If the price is high the EVs would not charge, but if the price is low the EV would charge. Being equipped with a battery, the EVs can even transfer cheap energy from the early periods to later periods when it is more expensive. For instance, the EVs charging and discharging in vehicle-to-grid (V2G) can be scheduled.

These storage capabilities can also be exploited at the transmission level by aggregating large EVs fleets and operating them as ensembles. Large ensembles of EVs equip system operators with an additional flexibility source that not only provides better management of the EVs demand, but also absorbs stochastic generation from renewable energy sources that can eventually lower operating costs and greater overall sustainability.

The results obtained with these tools to manage EVs loads are promising. However, further research is being conducted to develop the required tools at different levels (e.g., transmission, distribution, residential) to accommodate these new devices to the grid in the most economical and effective manner.

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GRANT/FUNDING SOURCE
Supported in part by NSF Award #1239408 ("CPS Synergy Architectural and Algorithmic Solutions for Large Scale PEV Integration into Power Grid")

Medical Systems and Devices

The University of Washington has a world-leading enterprise in biomedical research, and this proximity is a key strategic advantage for the UW EE department compared to other EE departments. Substantial interactions already exist to exploit this resource, but as biological ideas grow to have greater technological impact, and as society has greater needs for higher quality healthcare, exciting opportunities for electrical engineering are emerging. UW EE is particularly well-positioned to develop novel and functional devices that can be immediately leveraged and co-developed with the University of Washington Medical School.

Medical devices require the gamut of EE technologies from the delivery of energy (particularly laser, RF, and high intensity focused ultrasound), to acquisition and processing of signals (signal and image analysis, low power instrumentation, machine learning), to systems theory and control (medical robotics and teleoperation). Close collaborations between EE faculty and clinicians are already well established and have led to breakthroughs.

A CMOS Neural Stimulator Integrated Circuit

Eric Pepin | Graduate Student (EE)

The nervous system is composed of billions of electrically active cells called neurons. By exploiting these electrical characteristics, targeted artificial generation of the nervous system's natural communication signal (action potential) becomes possible using electrodes and specialized stimulator electronics. Depending on the location of this electrical stimulation (ES), the induced signal may actuate motor movement or generate sensory perception, both desired functionalities of neuroprosthetics.

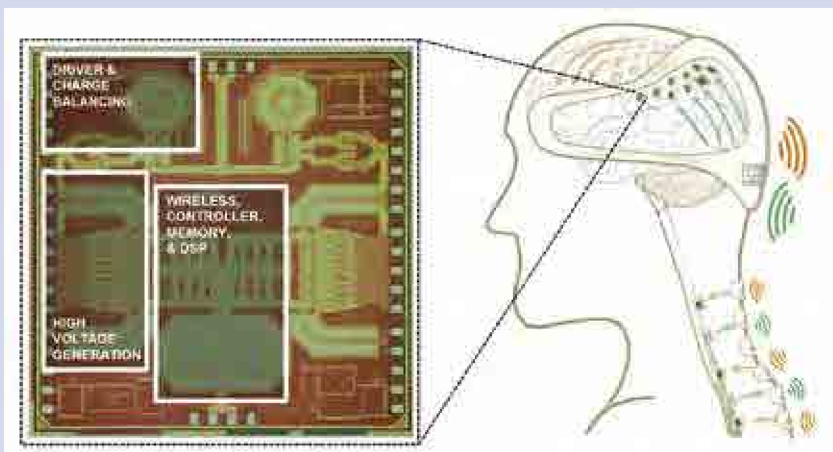
However, ES techniques are inherently invasive, and wires traversing the skin greatly increase the risk of infection. Therefore, all front-end stimulator electronics need to be chronically implantable, requiring integrated circuit (IC) solutions.

This research focuses on exploring and developing neural interface electronics for testbed use within the National Science Foundation Center for Sensorimotor and Neural Engineering (CSNE). The challenges of integrating stimulator electronics are multi-faceted. On top of being low-power, fail-safe, and able to drive charge-balanced waveforms into high-impedance electrodes, many critical applications of ES require high stimulation voltages (well past ±10V). Using traditional stimulation architectures, these high voltages are incompatible with modern low-voltage CMOS technologies due to concerns of gate oxide failure.

Accordingly, high-voltage compatible integrated solutions feature large off-chip components and/or are fabricated in a specialized process; these alternative approaches preclude high-density, small form-factor, analog/digital co-integration (a desired quality for implantable systems), which is easily afforded by low-voltage CMOS technologies. Ultimately, the goal of this research is to develop novel circuit techniques that employ standard CMOS devices to realize highly functional and implantable stimulator electronics capable of driving high-voltage signals.

A major motivation for this project is the prospect of combining ES with neural recording, DSP, and wireless communication on to the same chip. By implanting such a chip throughout the nervous system, bidirectional neuroprosthetics (systems capable of relaying both sensory and movement signals across permanently damaged regions of the nervous system) could become practical.

The immediate application of this research is to supplement the work of other CSNE affiliated groups in making instrumentation currently used for epilepsy treatment implantable. Longer-term, ES-enabled neuroprosthetics could help millions of people throughout the world who suffer from spinal cord damage and limb loss.



Wireless bidirectional neuroprosthesis and stimulator IC concepts (die photo is conceptual only). Movement-related neural signals (orange) are recorded from the cortex and injected into spinal cord via ES to bypass a damaged region. Likewise, sensory signals (green) are recorded from the spinal cord and injected into the brain via ES.

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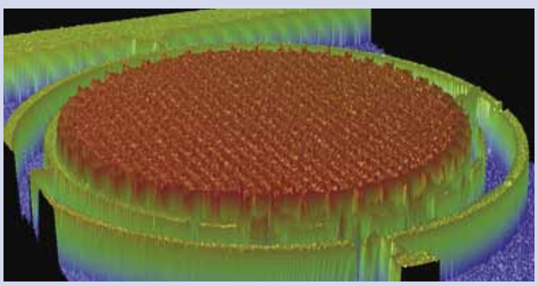
MEMS Micromirror Scanner for Endoscopic Imaging

Matt Strathman | Graduate Student (EE)

This research aims to enhance current endoscopic diagnosis capabilities for esophageal cancer. High resolution, 3-D images can be obtained by using optical coherence tomography and a micro-electromechanical systems (MEMS) based micromirror scanner. MEMS micromirrors have undergone extensive investigation for use in medical imaging.

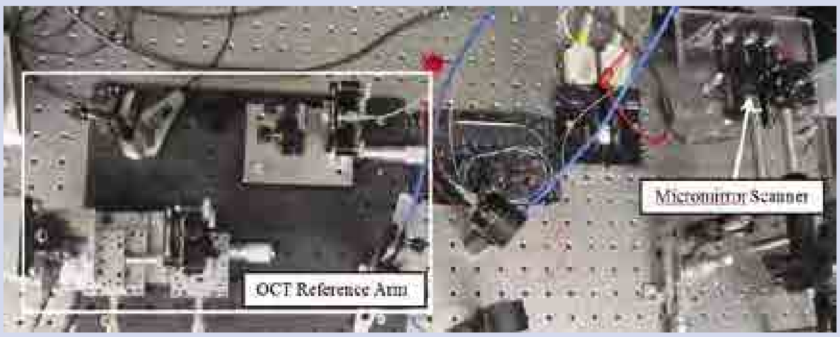
However, existing MEMS micromirror-based endoscopes have large distal scanning heads (~5-8mm), which makes accessing certain gastrointestinal channels impossible. The aim of this research is to develop a micromirror endoscope scanning head with a less than 3mm packaging diameter with several performance improvements.

The first step in this research was the design and fabrication of the MEMS based micromirror scanner. A 2-axis gimbal mirror structure was employed to achieve 2-D raster scanning. New designs for torsion springs that support the micromirror were explored to achieve high-resonant frequency without incurring higher-order mode instability. To achieve dynamic focus-tracking, a two-layer micromirror structure was incorporated into the device. The structure consists of a thin SiN/Au reflecting membrane surface suspended on top of a silicon layer with actuation electrodes beneath the entire structure. Dynamic focus-tracking was achieved by controlling the radius-of-curvature of the reflecting membrane through electrostatic actuation.



A 3-D micrograph of a fabricated device.

Using optical coherence tomography (OCT) as well as the focus-tracking capability of the micromirror, high resolution 3-D images can be acquired. The focal control also allows the elimination of additional focusing components that would degrade the imaging resolution. Successful tests of devices fabricated in the UW Microfabrication Facility have demonstrated large scanning angle and radius of curvature control. Currently, these devices are being integrated into an OCT setup for full scale testing of the imaging system.



The optical setup for the OCT system with the micromirror scanner.

The small 800 micrometer mirror diameter and the 3mm package size of this device enables the integration of the scanning head with a standard GI endoscope by delivery through the 3.7mm diameter accessory channel. Future efforts will improve the performance and reliability of the micromirror scanner as well as the optimization of the imaging system and device packaging.

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MEMS

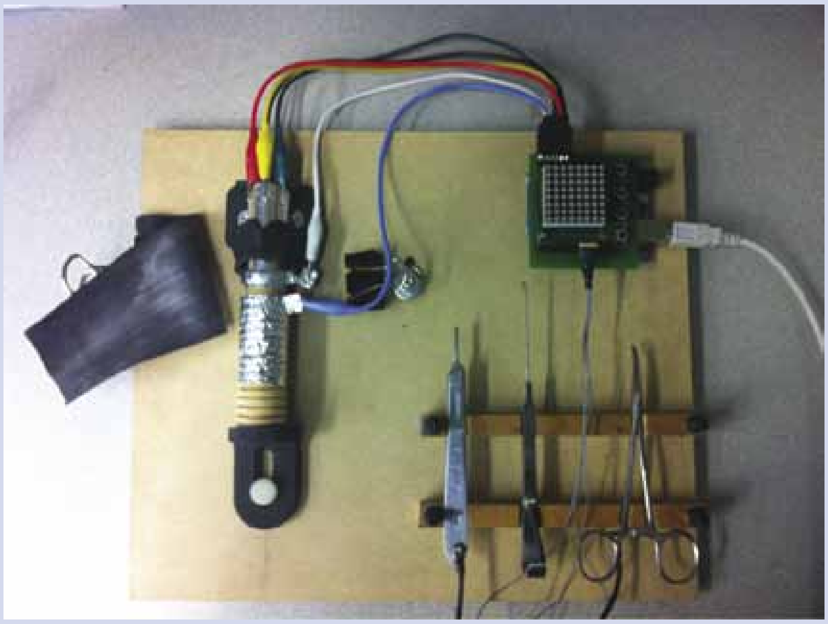
GRANT/FUNDING SOURCE
National Institutes of Health

Low-cost Cricothyroidotomy Simulator for the Developing World

Lee White, PhC[1] , Randall Bly, MD[4], Daniela D'Auria[2], Nava Agdasi[3], Levi Cheng[3], Paul Bartell[3], Blake Hannaford, PhD[3]

Cricothyroidotomy is an important emergency surgical intervention procedure to secure a difficult airway when other measures fail. In the developing world where specialized medications and equipment are not available, it may have an expanded life-saving role. The procedure involves a small neck incision to directly access the trachea through the cricothyroid membrane. Establishing a secure airway by first-responders such as paramedics is essential for patient survival.

Researchers from UW EE's Biorobotics Lab (BRL) have designed a simulator for learning and practicing this technique using low-cost materials appropriate for the developing world. The performance of already-trained medical personnel was also recorded to assess the simulator's performance.



The simulator prototype developed by UW EE's Biorobotics Lab.

In the developed world, there is a growing emphasis on using simulators for hands-on training for procedural interventions. This technology is often expensive and requires significant technical support to be feasible in the targeted setting. This simulator involves a cardboard tube coupled with extra features to simulate the human trachea. Copper or Aluminum foil marks key spots in the anatomy and a wire connects the metal instruments to form a circuit. Bicycle inner tubes act as skin, and an Arduino microcontroller acts as the brain of the system.

Study participants of 20 residents were selected from the UW's Department of Otolaryngology - Head and Neck surgery. After watching an instructional video, each participant performed the procedure on the simulator while contacts between the instruments and the foil pads in the simulator were recorded. Procedures were also video recorded for further analysis, and subjects answered a questionnaire to measure subjective impressions.

Three expert surgeons evaluated videos of the subjects' performance using an accepted medical rubric called OSATS. These grades were compared to task time, level of training and experience level. By comparing the data between the experts and novices, four essential parameters of proficiency were identified for this procedure. These parameters include:

- Time to spot the correct zone on trachea
- Sequence of using instruments in the procedure
- Amount of overlap between instrument use
- Duration of procedure

Collaboration with the Department of Otolaryngology helped refine the design through ongoing experiments and obtaining feedback from subjects and other researchers. Researchers are still in the process of analyzing the data to define additional metrics for rating the performance more accurately. The next step will integrate the simulator with an Android™ cell phone. The system will be fully open source. A website with instructions on how to build the system with training and assessment curriculum is currently being developed. Finally, wider validation studies will be performed, and simulators for different procedures using the same base of technology will be created.

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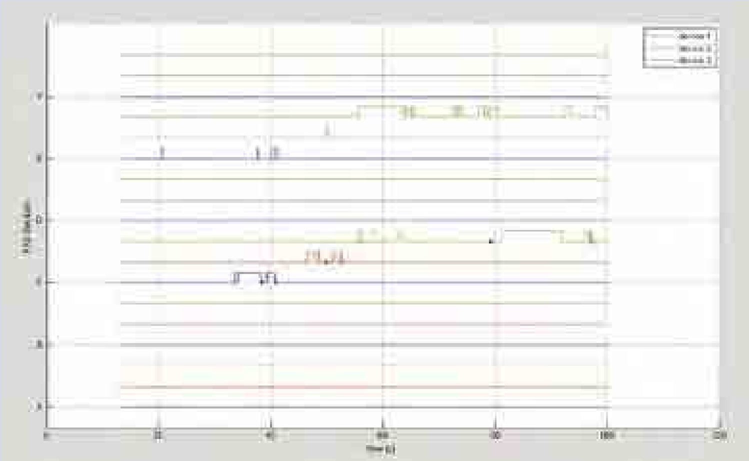
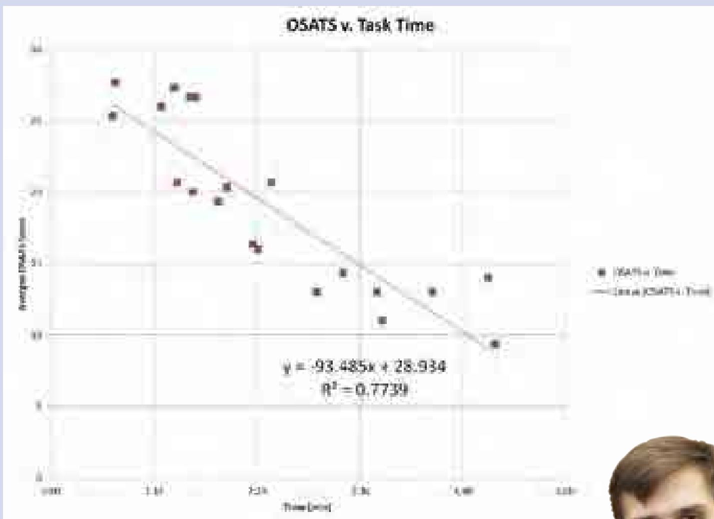


Visulized Results: Pad C represents the correct contact zone. The correct sequence of touched instruments is: Scalpel-Kelly Forceps-Hook (Blue-Red-Green).



OSATS scores vs. Task Time for cricothyroidotomy emergency procedure: higher scores for shorter task time.

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2. Dipartimento di Informatica e Sistemistica, Università degli Studi di Napoli Federico II
3. Electrical Engineering Department, University of Washington
4. Department of Otolaryngology Head and Neck Surgery, University of Washington

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RESEARCH AREA
Surgical Technology

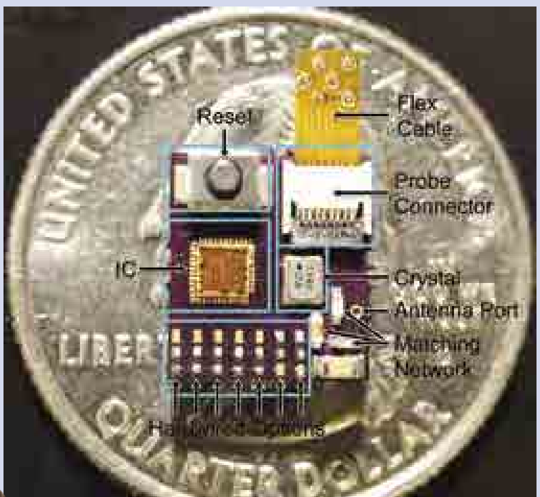
GRANT/FUNDING SOURCE
UW Departments of Global Health & Electrical Engineering seed funding

Low-Power Wireless Biosignal Monitoring for Size Constrained Environments

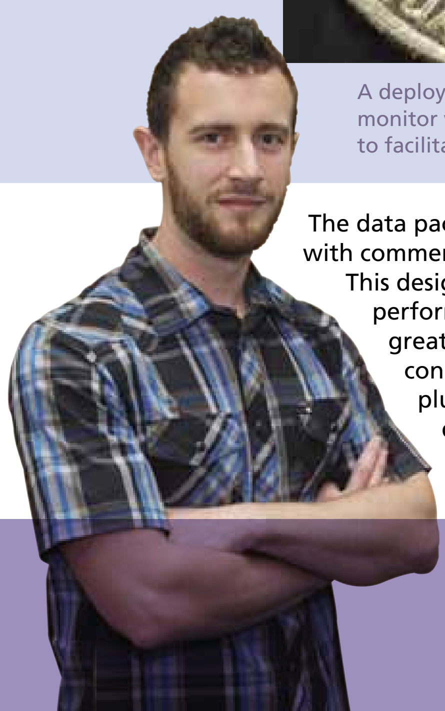
Tim Morrison | Graduate Student (EE)

Important advances in continuous health monitoring will be enabled by the next generation of tiny, low power wireless sensors. Existing commercially-available devices are bulky, which limits the number of suitable applications. Recording biosignals in an unobtrusive form-factor (like a bandaid), requires a self-contained device capable of amplifying the desired signal(s) and transmitting this data to a display. Not only must this device be small and light, it must be robust and easy-to-use.

After a few years of development, a new device developed by the Otis Wireless Sensing Lab drastically reduces its size compared to currently available commercial products. Miniaturization is achieved by integrating all functionality onto a single chip using low power designs to reduce battery size and extend operational lifetime. It consists of four low-noise and variable gain amplifiers, biosignal analog-to-digital converter, digital logic and a low-power MICS/ISM band wireless transmitter.

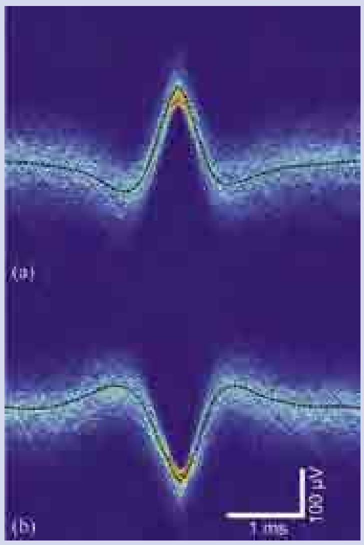


A deployable 0.8cm^2 wireless biosignal monitor with removable flexible connector to facilitate electrode connections.



The data packets were designed to interface with commercially available ISM band receivers. This design choice leverages the high performance commercial receivers, greatly strengthening the wireless connection. A USB receiver board plugs into a PC to log and display the data. The device operates with a single button press after inserting a battery. An off-chip infrared sensor is included so that a simple remote can program the device wirelessly without consuming nearly as much power as a full RF receiver.

This device has been deployed in a wide range of biosensing environments, from monitoring the heart of an ambulatory human (ECG) to recording neurons firing in the brain of a freely moving mouse. This single device can accomplish these very different tasks due to the configuration of the whole system.



At least two recorded neurons (a) and (b) firings in a freely moving mouse overlaid in a heat-map fashion.

The combination of small size, wide programmability and ease of use makes this device well-suited for research scientists wishing to record biological signals in size/weight constrained experiments. Future revisions are optimized for human ECG and will increase programmability further, allowing a microcontroller full control which will let the user further customize to their specific use.

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

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RESEARCH AREA
VLSI

Molecular Systems & Devices

Molecular systems and devices constructed from interacting proteins, DNA, RNA, and other organic molecules can act as highly sensitive molecular sensors, signal processors or feedback control systems. Molecular systems encoded in genetically engineered cells are being applied to the diagnosis of disease states, directed gene therapy, tissue and organ engineering, neural interface engineering, plant and food stock engineering, bioremediation and bio-defense against emerging infectious diseases. Core concepts in electrical and computer engineering, such as modularity, impedance matching, and noise rejection have been applied to the construction of molecular systems, as do ideas from biology such as adaptation and evolution. The result is a highly interdisciplinary effort to engineer living matter from scratch.

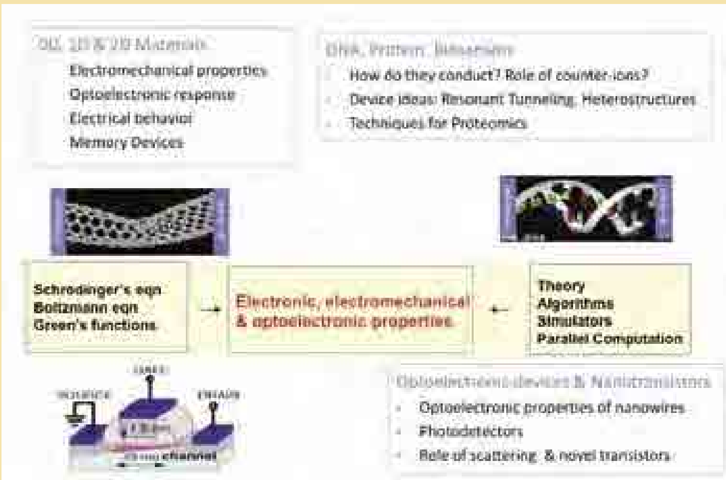
Ultimately, living systems are organic computational systems, and subjects such as molecular computing and synthetic biology can be seen as most closely related to computer engineering. Research in this area also involves control and dynamical systems, mathematical modeling and simulation, data acquisition and image processing. UW EE has developed strong interdisciplinary collaborations with various UW departments such as biology, microbiology, bioengineering, genome sciences, as well as with local biotech and biomedical research and development agencies.

Modeling of Nanoscale Devices

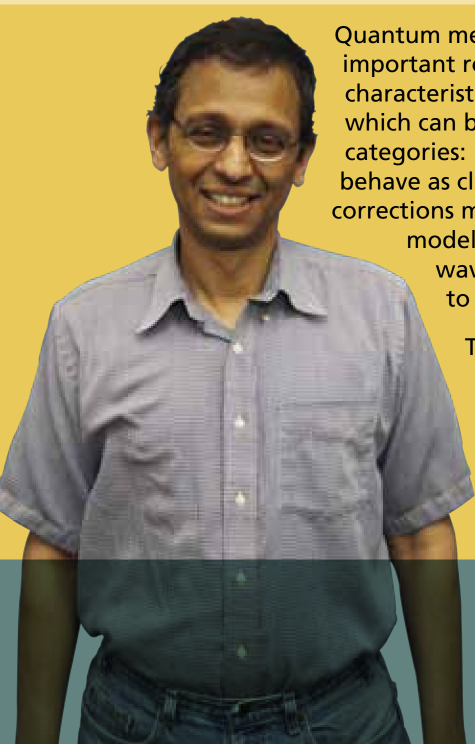
M. P. Anantram | Professor

Research conducted in Professor M.P. Anantram's Lab aims to develop novel algorithms and a simulator using quantum mechanics to model nanoscale devices in 2-D and 3-D. Algorithms will also be developed to model both the DC and AC current response.

Potential applications include devices based on carbon nanotubes, graphene, nanowires and quantum well superlattices for electronics, and bio/nano structures for disease detection.



Modeling of electrical properties of semiconductor and molecular nanostructures.



Quantum mechanical effects play an important role in determining the characteristics of nanoelectronic devices, which can be classified into two different categories: 1.) devices where electrons behave as classical particles, but quantum corrections may be necessary for accurate modeling, and 2.) devices where the wave nature of electrons are central to device operation.

The main bottleneck for realizing practical simulation of nanoscale devices using the equations of quantum mechanics is the immense computational time required to calculate the electron density. The current algorithm to calculate the electron density is known as the recursive Green's function method. In collaboration with Professor Ulrich Hetmaniuk of the UW's Applied Mathematics department, the group has demonstrated a new algorithm to model nanoscale devices that speeds up the calculation of electron density by up to ten times faster than the recursive Green's function method in 2-D structures. This algorithm exploits recent advances of an established graph partitioning approach. The developed method can accurately handle open boundary conditions, which are required for realistic modeling of nanoscale devices.

These methods can be applied to a variety of technologies such as:

- Conventional nanoscale transistors, where quantum corrections are necessary for accurate modeling of tunneling and capacitance
- Purely quantum devices such as tunnel transistors, superlattice-based quantum cascade devices, device concepts based on topological insulators, and quantum interference devices
- Emerging devices such as phase change and resistive memories
- Devices based on nanomaterials such as nanotubes, graphene, MoS2 and nanowires, where atomistic methods of modeling are important
- Electrical flow in biomolecules to investigate disease detection

Methods are currently being researched to extend this approach to 3-D nanostructures and to model the AC response. The methods are being applied to nanotransistors and superlattices, and to explain experimental results involving current flow in DNA and peptides.

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www.ee.washington.edu/faculty/anant/

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GRANT/FUNDING SOURCE
National Science Foundation

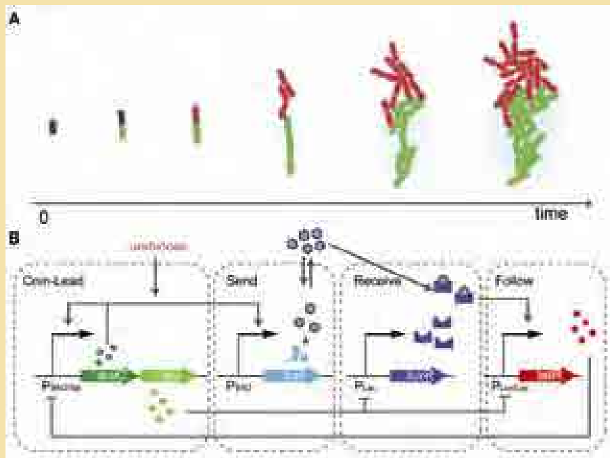
Leader Election in a Bacterial Microcolony

Seunghee Shelly Jang | Graduate Student (EE)

Symmetry breaking describes a phenomenon where the uniformity of a system is broken to generate a more structured and improbable state. Some speculate that increasing the broken symmetry in many-body systems, such as cells can increase functional specialization. In biology, functional specialization underlies differentiation of multicellular organisms. Thus, studying symmetry breaking has implications for understanding morphogenesis and development, and for facilitating the advancement of regenerative medicine and cancer research.

Synthetic biology approaches the complexity of biological systems with bottom-up investigation methodologies, where relatively simple gene regulatory networks are used as model systems to study emerging complex behaviors. It provides an unobstructed view of nature's design principles, and establishes primitives for engineering novel synthetic behaviors.

This project designs, constructs and analyzes synthetic gene regulatory networks (GRNs) in E. coli that mimic the differentiation process of multicellular organisms. A synthetic differentiating E. coli in a growing microcolony would initially be in a null state, and differentiates into a population with two or more distinct phenotypes. The logic of the design is consistent with not only the principles of naturally occurring symmetry breaking systems, such as positive feedback and spatial heterogeneity, but also with the logic from the Leader Election (LE) algorithm from computer science (Lynch, 1996). Using a specification and simulation language for engineering multicellular behavior called `gro` (Jang, 2012), researchers from UW EE's Self Organizing Systems Lab have developed and verified a series of LE programs, starting from a high level abstract representation free of biological implementation details, and ending with a program that can be matched with biological parts readily available through gene synthesis or BioBrick parts registry. Taking a modular composition approach, the GRN decomposed into four independently functional gene expression cassettes, COIN-LEAD, FOLLOW, SEND and RECV, and these cassettes were constructed and verified individually.



(A) The specification of a synthetic differentiation GRN. A single E. coli, initially in a null state (grey), grows and divides to form a microcolony. At a random time, a daughter cell differentiates into a leader cell (green) and the information is broadcast to the microcolony. The cells still in the null state, switches to a follower state (red) and the final population in the microcolony is differentiated into two phenotypically distinct populations. (B) The GRN is designed to implement the logic of the LE algorithm. The GRN contains three principle mechanisms required to implement the LE algorithm: 1) Positive feedback motif to facilitate the all-or-none behavior observed with the motif, 2) Bistable toggle-switch motif, to facilitate distinct state designation, and 3) Quorum sensing to facilitate intercellular communications. The GRN is triggered with arabinose and falls into one of two mutually exclusive states, AraC-high or TetR-high, and then determines whether each cell is a leader or a follower.

Considering that each cassette may be modular pieces of the full circuit, a set of quantities can be identified that specify the cassette's role in the full circuit performance. Once the specifications are specified, a library of functional analogs can be built with variations in these quantities to facilitate modular tuning of the circuit.

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Ph.D., 1995 University of Texas, Austin
NSF CAREER Award, ONR Young Investigator Award, IEEE Fellow

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Electric Power Systems, MEMS, Sensors
Ph.D., 1999 MIT
NSF CAREER Award

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MacArthur Fellow, Sloan Research Fellowship

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Ph.D., 2011 MIT

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NSA Rising Star Award, NSF CAREER Award, ARO YIP & ONR YIP Awards, PECASE Award

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NSF CAREER Award, Sloan Research Fellowship, DARPA Young Faculty Award

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NSF CAREER Award, IEEE Fellow

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NSF CAREER Award

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Power Electronics & Semiconductor Device Modeling
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Computers & Digital Systems
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Ph.D., 1962 Stanford University
NSF "Engineer of the Year" Member, National Academy of Engineering, IEEE Fellow, IEEE Harden Pratt Award, U.S. Army Outstanding Civilian Service Medal

PORTER, ROBERT B.
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ASA Fellow, OSA Fellow

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Signal Processing/Ocean Acoustics
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IEEE Fellow, ASA Fellow, MTS Fellow, A.B. Wood Medal, IEEE Oceanic Engineering Society Technical Achievement Award

YEE, SINCLAIR
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Ph.D., 1965 UC – Berkeley
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Ph.D., 1974 University of Michigan

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 2013 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 | Dr. Brandon Pierquet

The department welcomes Brandon Pierquet, who joined the UW EE faculty as an assistant professor last fall. Dr. Pierquet adds significant strength to the department, college, and university's growing leadership position in the multidisciplinary and strategic area of sustainable energy.

Dr. Pierquet received his Ph.D. and S.M. degrees from the Massachusetts Institute of Technology in 2011 and 2006 respectively, and his B.S. degree from the University of Wisconsin-Madison in 2004, all in electrical engineering. After graduating from M.I.T. he worked for Enphase Energy as a senior design engineer, developing grid-tied power converters for distributed solar applications.

Most recently, Pierquet was selected to receive $764,000 from the Washington STARS Research Program. The Strategically Targeted Academic Researchers (STARS) program supports new faculty conducting innovative research in the State to promote productive innovation and longer-term statewide economic development. His research focuses on the design of electronic systems, with particular interest in power electronics and their control. This includes applications in smart-grids, photovoltaic systems, electric vehicles, and high-efficiency circuits.

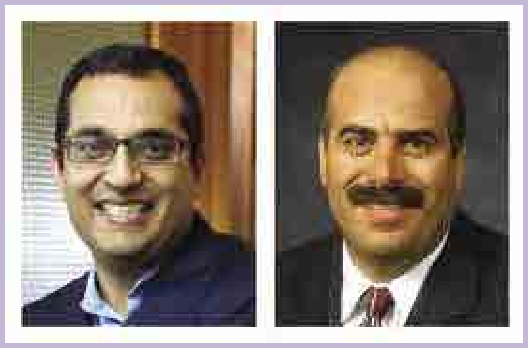
UW EE's 1st Annual CarEEr Fair and HKN Poker Night

The department's first annual CarEEr Fair and HKN Poker Night took place on January 23rd, 2013, with 15 company participants and more than 200 student attendees. Participating companies included: Analog Devices, Boeing, CIA, Cypress, Digital-Control, Intel, Philips, Phytec America, Puget Sound Energy, Tethers Unlimited, T-Mobile, US Navy, Verizon, Viverrae, and VMware. Student and company feedback was extremely positive and set the stage for what we hope will be many future networking opportunities!

For more information about our Corporate Affiliates Program and/or how to connect with the EE Department, please contact Erin Olnon at erin@ee.washington.edu.

New Northwest Institute for Advanced Computing

The University of Washington and the Pacific Northwest National Laboratory have announced the creation of the Northwest Institute for Advanced Computing, a joint institute based at the UW that will foster collaborative computing research between the two institutions. “This collaboration will open up new avenues for research,” said co-director Vikram Jandhyala, UW professor and chair of electrical engineering, who leads the Applied Computational Engineering Lab. “We are creating an interdisciplinary place to work with colleagues at PNNL on data-intensive science and engineering.” Co-director with Jandhyala is Pacific Northwest National Laboratory’s Moe Khaleel, leader of the Computational Science and Mathematics research division.



Vikram Jandhyala
Co-director

Moe Khaleel
Co-director

The new institute will initially draw from the UW’s departments of Computer Science & Engineering, Electrical Engineering and Applied Math, but all UW faculty whose work advances data-driven discovery and large-scale computing will be invited to affiliate.

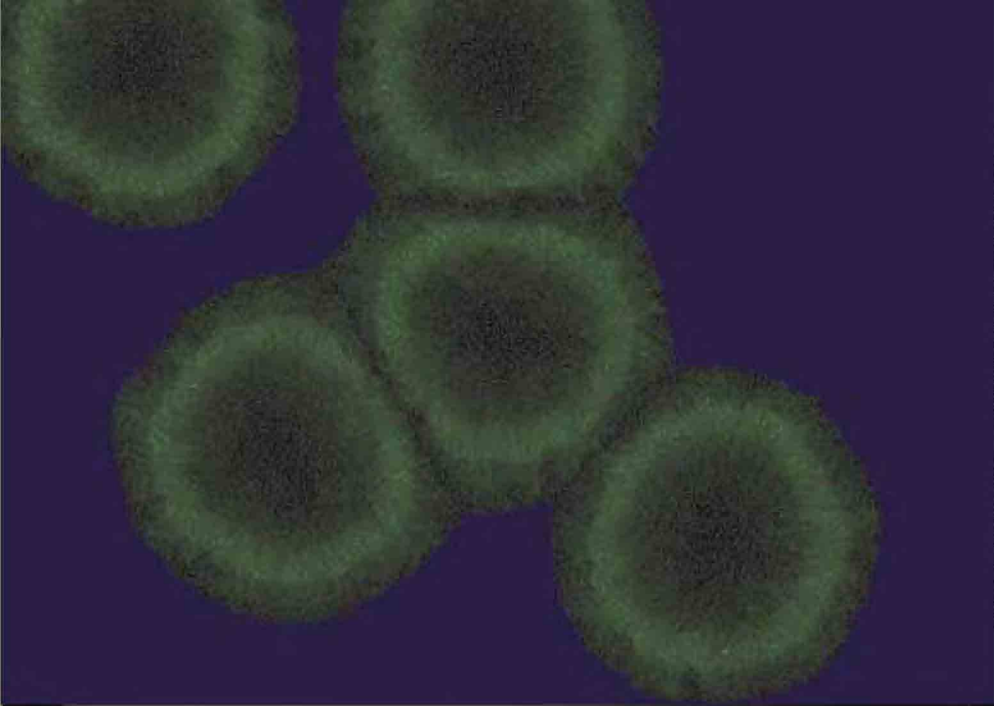
Pacific Northwest National Laboratory already has two scientists based at the UW who are conducting Department of Energy research related to big data and nuclear physics. About eight more PNNL researchers are expected to join them in UW’s Sieg Hall by the end of 2013. Other researchers will join the center but stay in their existing labs.

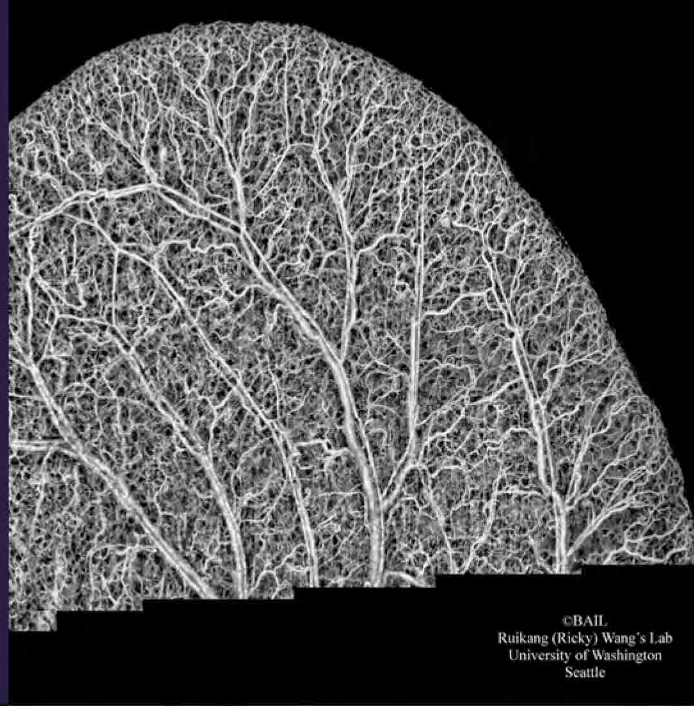
All institute members will have access to computational resources at both institutions including the UW’s Hyak supercomputer, developed by the eScience Institute and UW-IT, and the Olympus supercomputer as well as other elements of PNNL Institutional Computing. Researchers will also make extensive use of cloud resources.

Jandhyala also hopes to develop relationships with the region’s business and startup communities.

“In the short term, we aim to promote collaboration among university and government scientists who are working with big data,” he said. “In the longer term, we hope this becomes a Northwest hub for advanced computing research.”

Initial projects will include algorithms and software for large graph analyses, smart grid simulation and encryption for cloud computing. The institute will draw on UW expertise in computer science, engineering, applied math and natural sciences, and Pacific Northwest National Laboratory expertise in designing high-performance computers and running large-scale environmental simulations.





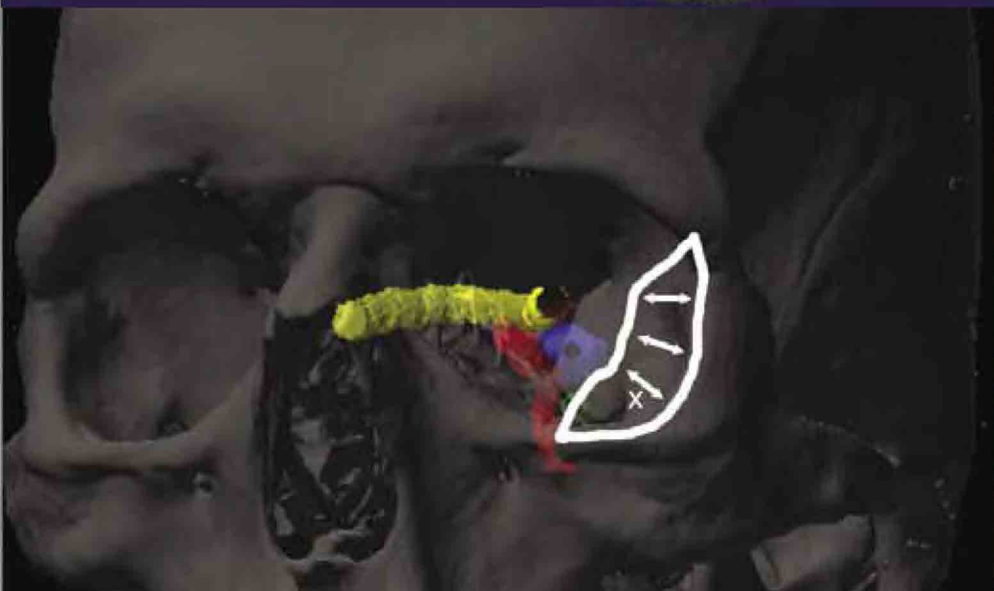
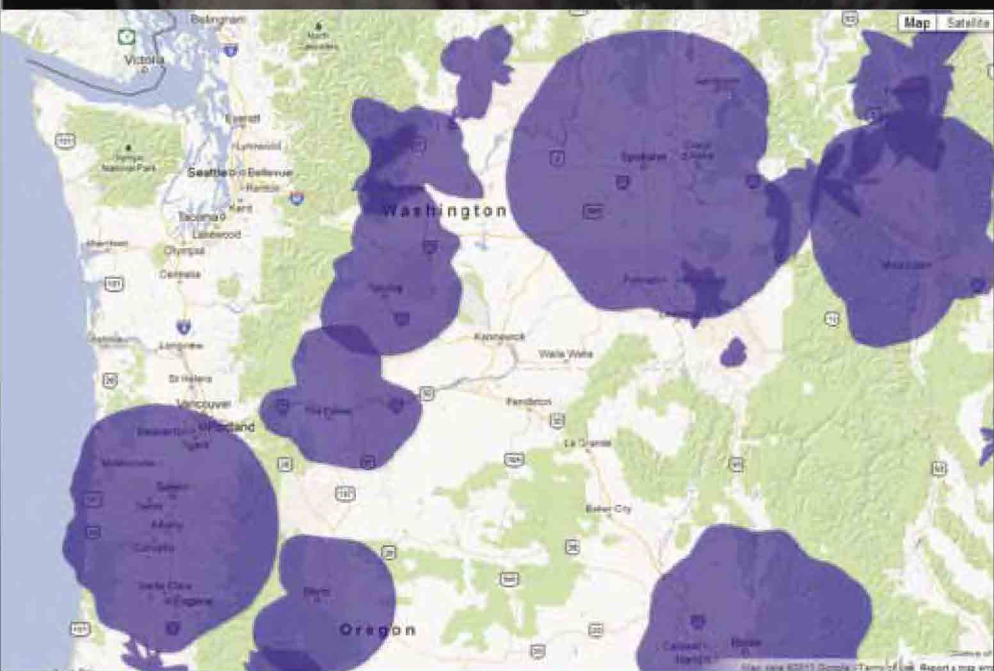
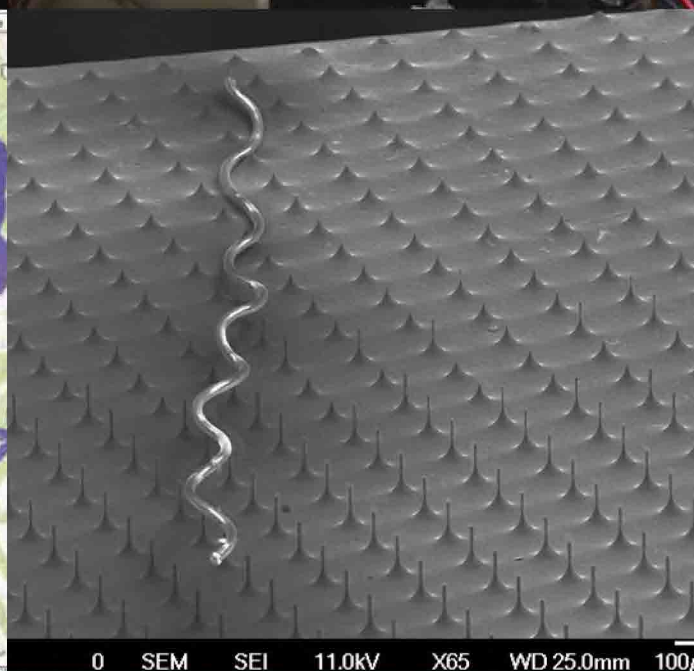


Photo: Bly RA, Su D, Hannaford B, Ferreira M, Moe KS. Computer Modeled Multiportal Approaches to the Skull Base. Journal of Neurological Surgery: Skull Base. Accepted August 13, 2012.





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