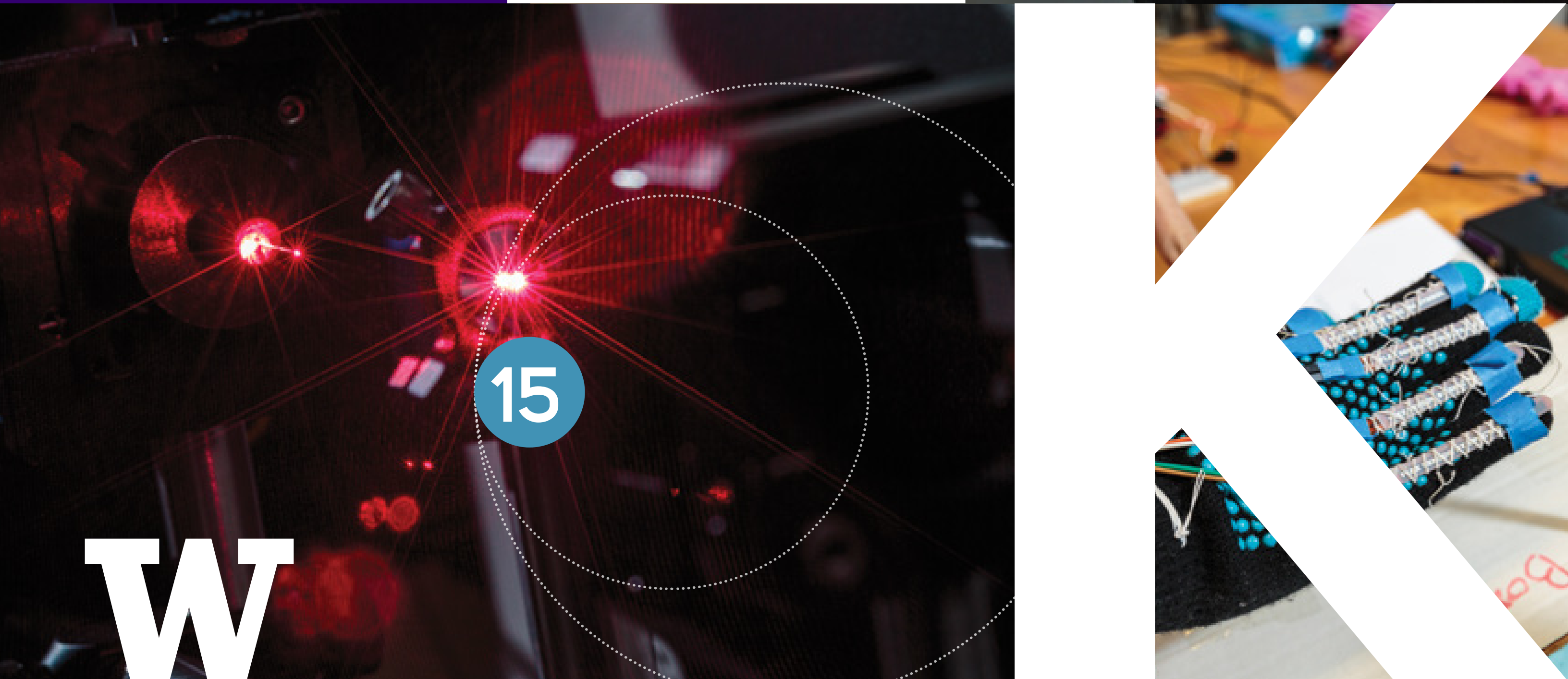
ELECTRICAL ENGINEERING KALEIDOSCOPE

ANNUAL RESEARCH REVIEW

A PUBLICATION OF THE
DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITY OF WASHINGTON



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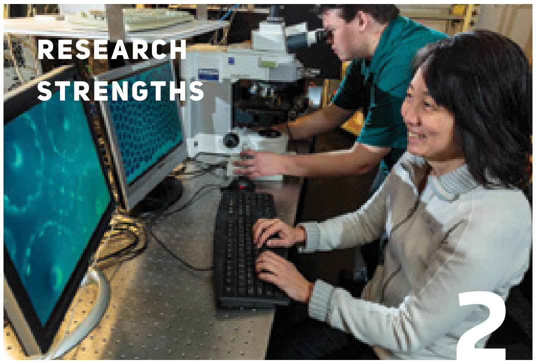

TABLE OF CONTENTS

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DEAR SUPPORTERS AND ALUMNI OF UW EE,

I am pleased to report on research and educational achievements of our faculty and students over the past year. I would also like to congratulate faculty, staff and students on our #18 ranking from U.S. News & World Report for best graduate schools for 2016.

First, I am delighted to introduce our new junior faculty: Arka Majumdar, Sreeram Kannan and Baosen Zhang, who joins the department in Spring 2015. Sam Burden will join the department in Fall 2015.

On the research front over the past year, our faculty have been increasingly collaborative, pushing the boundaries of their respective fields.

EE is now home to the Smart Ocean Technology Research Center with Sumit Roy as the UW Site Director. This industry-university cooperative research center is led by the University of Connecticut and funded by the National Science Foundation. Payman Arabshahi of EE and Applied Physics Laboratory is the co-investigator.

The TerraSwarm Research Center, funded by the Defense Advanced Research Projects Agency and the Semiconductor Research Corporation, is now also housed at EE, with Jeff Bilmes as the UW Site Director.

I am also delighted to report on faculty awards. Kai-Mei Fu was selected as one of the 2015 Cottrell Scholars. Chris Rudell was honored with a NSF CAREER Award. Mohamed El-Sharkawi was honored with two awards: an International Fulbright Fellow Award and 2014 IEEE Outstanding Educator Award. Arka Majumdar is a recipient of the 2015 Air Force Office of Scientific Research Young Investigator Award. Baosen Zhang has been recognized for his work in the energy industry and was named to *Forbes'* 30-under-30 list. Eric Klavins received one of only two UW Inaugural Innovator Awards. Shwetak Patel was appointed as the Washington Research Foundation Entrepreneurship Endowed Professor. Henrique (Rico) Malvar and Bishnu Atal received IEEE 20th Century Landmark Awards. Li Deng received an IEEE Outstanding Engineer Award.

Our graduate students continue to thrive as well. Julie Medero joined Harvey Mudd, Nils Naps joined SUNY Buffalo and Andrew Clark joined WPI as faculty.

This EEK issue is primarily focused on research being conducted at the NSF Center for Sensorimotor Neural Engineering (CSNE). Howard Chizeck and Brian Otis played key roles in formation of the center and as research thrust leaders. Blake Hannaford, Chris Rudell, Visvesh Sathe, Joshua Smith and Matt Reynolds are other EE faculty involved in the center.

I wish to thank our former chair Vikram Jandhyala for his leadership over the past three years. I also thank John Sahr, for guiding the ship as Interim Chair. I am looking forward to working with all of you in raising our department's visibility.

Best to all,

Radha Poovendran
Professor and Chair
Department of Electrical Engineering

RESEARCH

THE UNIVERSITY OF WASHINGTON DEPARTMENT OF ELECTRICAL ENGINEERING IS ACTIVE IN MOST RESEARCH AREAS OF ELECTRICAL ENGINEERING. RESEARCH STRENGTHS INCLUDE THE FOLLOWING:

COMMUNICATIONS AND NETWORKING

Communications, networking and related signal processing technologies have revolutionized computing. Specialties include the implementation of wireless devices and systems, optical communications, multi-user and multi-channel signal processing, routing and access control, modulation, network security and coding for error correction.

ELECTROMAGNETICS AND REMOTE SENSING

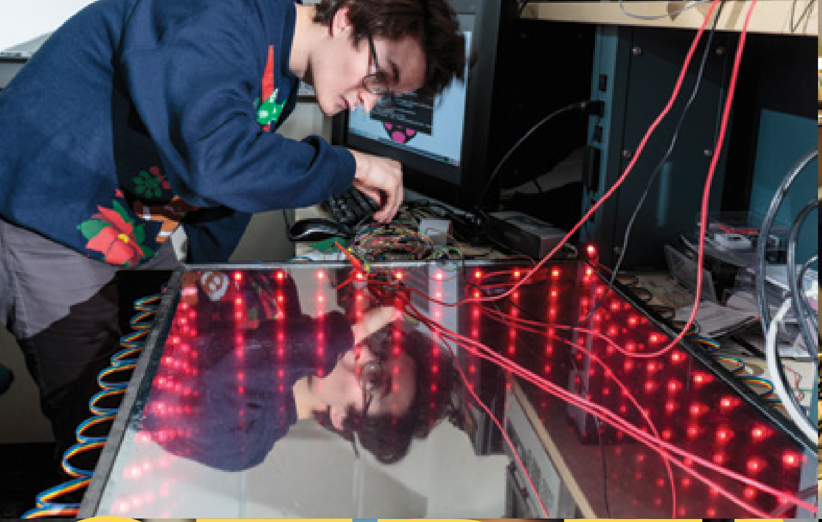
The study of electric and magnetic fields, electromagnetics entails theoretical, experimental and computational research. Topics include remote sensing of the earth, atmosphere, ionosphere and ocean; high-speed devices and circuits modeling; waves in random media and rough surfaces; material characterizations, antenna and RF circuit design; and advanced algorithms for radar signal processing.

INTEGRATED SYSTEMS, CIRCUITS AND VLSI

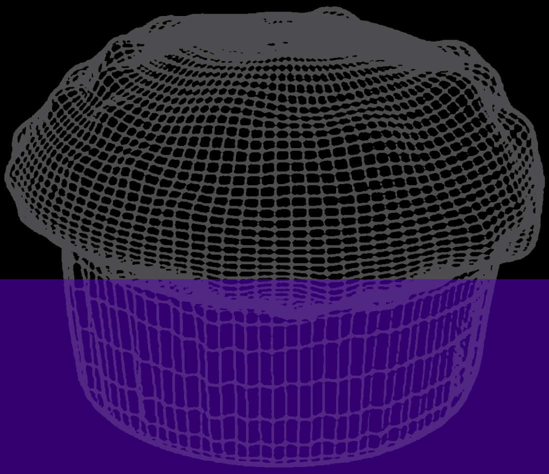
Integrated circuits have evolved into whole systems on chips. In descending order of complexity, future systems-on-chip will comprise high-speed and low-power digital gates, analog interface and signal processing circuits, radio frequency transceivers, and microelectromechanical systems (MEMS) sensors and actuators.

NANOTECHNOLOGY, MEMS AND PHOTONICS

Having revolutionized the way people live, as the basis for the integrated circuits and computer industry, this area continues to exert impact. Applied nanotechnology includes microelectromechanical systems (MEMS), microelectronics and nanoelectronics, and micro-optical switching devices for telecommunication applications; and portable surface plasmon resonance (SPR), optical bio and chemical sensing systems.



STRENGTHS



POWER AND ENERGY

Addressing the critical technologies that supply energy, this research area covers power systems, power electronics and electric drives. Research is highly interdisciplinary, involving power, sensors, signal processing, communications, control, economics, computer science and engineering, and engineering education.

SPEECH, IMAGE, AND VIDEO PROCESSING

Signal processing addresses a variety of engineering problems, from communications to human-computer interaction to medical signal information processing. Application areas include speech, image and video processing, with theoretical foundations in graphical models, time-frequency analysis, models of symbolic time series, pattern recognition and data compression.

SYSTEMS, CONTROLS AND ROBOTICS

Explores both experimental and theoretical issues in control, design and optimization for the following: biologically based robotics, haptics, autonomous mobile robotics, surgical robot technology, control engineering for rehabilitation, closed-loop drug delivery, control of jump parameter systems, intelligent transportation systems and genome automation.

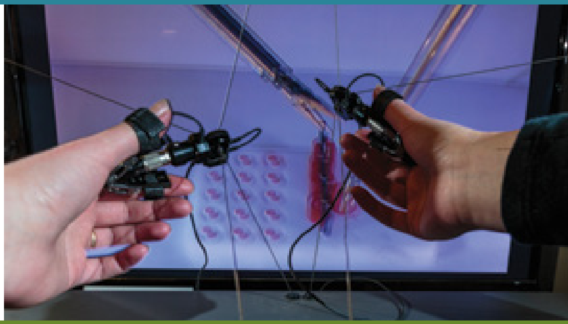
NOTABLE

UNDERGRADUATE PROGRAM

16%
UNDERGRADUATE APPLICATIONS
INCREASED 16% SINCE 2010

501
CURRENT ENROLLMENT

22%
WOMEN



GRADUATE PROGRAM

46%
GRADUATE APPLICATIONS
INCREASED 46% SINCE 2010

358
CURRENT ENROLLMENT

18%
WOMEN

OTHER NUMBERS

UW EE RANKED
#18
BEST GRADUATE SCHOOLS FOR 2016
U.S. News & World Report

MORE THAN
40
RESEARCH LABS

49
REPORTED INNOVATIONS
FY 2014

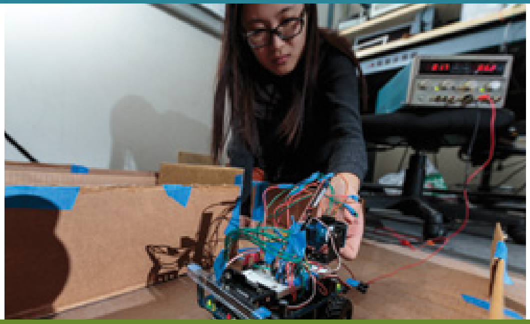
4
STARTUP COMPANIES
FY 2014

FILED **83** → ISSUED **15**
PATENT APPLICATIONS
FY 2014

NUMBERS

24%
INTERNATIONAL STUDENTS

10%
UNDERREPRESENTED MINORITIES



42%
INTERNATIONAL STUDENTS

6%
UNDERREPRESENTED MINORITIES

RESEARCH EXPENDITURES

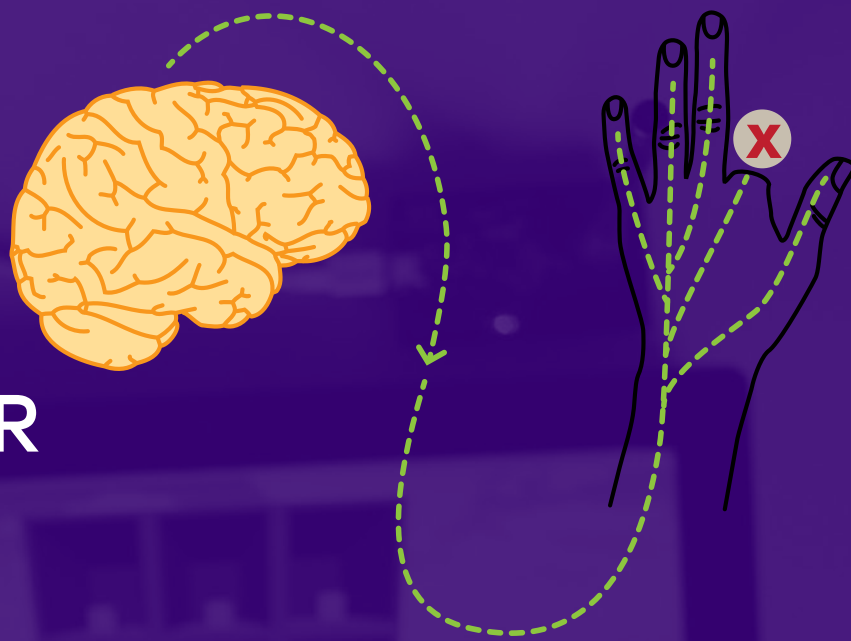
- 2014: **$12,059,801**
- 2013: **$10,719,631**
- 2012: **$10,127,659**
- 2011: **$12,560,594**
- 2010: **$11,058,463**

CURRENT AND EMERITUS FACULTY

FACULTY HONORS

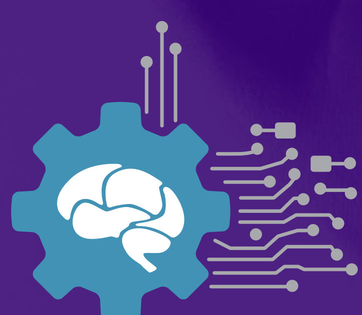
- **24** IEEE Fellows
- **2** Members of the National Academy of Engineering
- **3** Optical Society of America Fellows
- **4** Alfred P. Sloan Research Fellows
- **4** Acoustical Society of America Fellows
- **21** NSF Young Investigator/Early CAREER Awards
- **1** MacArthur Fellow

CENTER FOR SENSORIMOTOR NEURAL ENGINEERING



Improving Lives by Connecting Brains with Technology

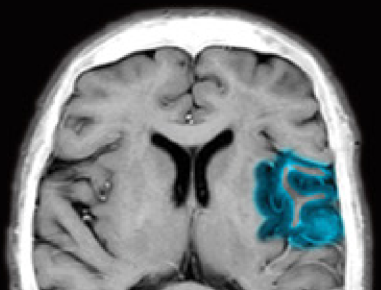
Based at the University of Washington, the Center for Sensorimotor Neural Engineering (CSNE) is one of 17 Engineering Research Centers funded by the National Science Foundation (NSF). With core partners located at the Massachusetts Institute of Technology and San Diego State University, CSNE research is being undertaken by an experienced multi-disciplinary team including numerous faculty members from the UW Department of Electrical Engineering.



The CSNE's objective is to build devices that interface with the human nervous system. Brain signals are studied with the aim of restoring motor skills in people who are disabled. Devices that interface with the human nervous system typically operate in open-loop mode and have yet to process neural data in a functionally meaningful way. For example, no implantable system currently exists for reanimating limbs and inducing neuroplasticity for stroke and spinal cord injury patients. To restore sensorimotor function and neurorehabilitation, the CSNE team is working to build closed-loop co-adaptive bi-directional brain-computer interfaces (BBCIs) that can both record from and stimulate the central nervous system.

The design of the co-adaptive BBCIs will integrate novel technologies for simultaneously recording and stimulating cortical and spinal circuits with a deep computational understanding of sensorimotor processing and plasticity in the nervous system. The revolutionary neurally-engineered systems will significantly improve the quality of life for people with sensorimotor disabilities, benefitting patient populations with complete cervical (C6 or higher) spinal cord injury and ischemic stroke with communication or motor impairments. The BBCI principles discovered will also have broader implications for developing closed-loop interfaces for other neurological diseases such as Parkinson's disease

By leveraging its clinical, neuroscience and engineering expertise, the CSNE works with industrial and clinical partners to bring innovations to the clinic and to the market to maximize impact on human health. Close partnerships with clinicians, practitioners and patients ensure that research activities and technology development directly address unmet needs and guide future neural engineering market directions.



IN THIS ISSUE

The research featured in EEK 2015 is a combination of CSNE projects and EE projects from other funding sources. For CSNE affiliated projects, graduate students and EE faculty are working together on novel breakthroughs in developing devices that interface with the human nervous system.

CSNE PROJECT FACULTY LEADERS FROM ELECTRICAL ENGINEERING

1 » **Professor Rajesh Rao, CSNE Director and Adjunct EE Professor**

2 » **Professor Howard Chizeck**

3 » **Professor Blake Hannaford**

4 » **Associate Professor Matt Reynolds**

5 » **Assistant Professor Chris Rudell**

6 » **Assistant Professor Visvesh Sathe**

7 » **Associate Professor Joshua Smith**

Developing Touch-Free Touchscreens

Enabling the Disabled to Use Touchscreens Controlled by Electrode Signals

Katherine Pratt, *Graduate Student*

While technology advancements have resulted in a variety of new products, many of these, such as touchscreens on phones, tablets and computers, are not useable by people who suffer from arthritis, tremor, paralysis or amputation. By enabling the millions of people with limited or no finger dexterity to manipulate touchscreens, graduate student Katherine Pratt aims to return a unique form of digital mobility.

Still in the preliminary stages of development, Pratt plans to analyze the minimal number of electrodes needed to track the location of two fingers on a touchscreen. A non-invasive band of dry electrodes will then be attached to an armband or headband to measure electromyography (EMG) signals from muscles and send signals via Bluetooth to software residing on a mobile phone or laptop. A custom-built app will translate the signals into virtual finger movements to control the touch screen. The system will be designed with auto-calibration, to ensure reliability and minimal adjustment.

Pratt's research project also has the potential to benefit individuals with Parkinson's and other diseases who are being treated with implanted deep brain stimulation devices that send electrical impulses via implanted electrodes to specific parts of the brain. The electrodes would use brain activity, instead of muscle signals, to operate touchscreens through the use of volitional brain-computer interfaces (BCIs).

Pratt's project aims to not only improve the quality of life for millions of individuals who currently cannot use existing technology, but the methods of sensing and auto-calibration are applicable to other engineering and scientific projects.

Using a band of electrodes (pictured here on an arm), electromyography (EMG) signals are translated into a virtual cursor that replaces fingertip gestures. The EMG signals can also be measured from other muscle groups, such as the neck.

MORE INFORMATION

FACULTY ADVISOR:
Howard Chizeck

COLLABORATORS:
Jeffery Herron, Department of Electrical Engineering

RESEARCH AREA:
Assistive technology

GRANT/FUNDING SOURCE:
Google, NSF Center for Sensorimotor Neural Engineering

Security System for Brainwaves

Enhanced Privacy and Security for Brain-Computer Interfaces

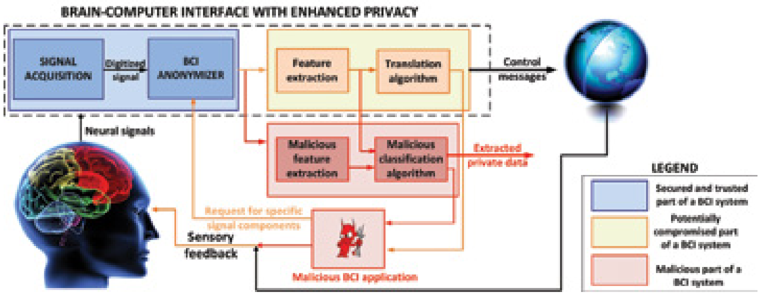
Tamara Bonaci, *Graduate Student*

Brain-computer interfaces (BCIs) provide a direct communication link between a person's brain and the environment. While non-invasive BCI systems have allowed even people with severe neuromuscular disorders to communicate, the systems are not without risks. Recent experimental results show that consumer-grade BCIs may be used to extract private information about users, such as their memories, intentions, conscious and unconscious interests, and emotional reactions. Understanding potential privacy and security risks that may arise from misuse of BCIs, and finding ways to prevent them, is an urgent and important task— and one that is being researched by graduate student Tamara Bonaci.

The goal of Bonaci's research is twofold: to understand how BCIs can be misused to extract private information about users and to research and develop the "BCI Anonymizer," a mitigation and prevention tool designed to protect against privacy threats. The proposed "BCI Anonymizer" is a new signal processing component of a BCI system, which allows for real-time decomposition of recorded signals into two categories: users' intended BCI commands, such as for neuroprosthetics control, and users' private information. The key aspect of the proposed tool is its real-time nature, preventing the original signal from being stored or transmitted to a third party application.

Bonaci's research project will be completed in two phases. The first phase entails identifying which components of an electroencephalography (EEG) signal may be used to extract private information. After identifying potential vulnerabilities, the amount of exposed information will be quantified. Based on the results, the second phase will be the development of a software tool aimed at preventing potential extraction of users' private information. The proposed tool, the "BCI Anonymizer," is based on a hypothesis that recorded brain signals can be decomposed into a collection of characteristic signal components in real-time. From these components, information corresponding to a user's intended BCI commands can be extracted while filtering out any potentially private information.

Bonaci's research project will further enhance BCI-enabled technology. The knowledge of how to decompose electro-physiological signals in real-time, without distorting useful information that is extracted, is expected to positively impact the speed of BCI communication.



A block diagram of a BCI with the proposed "BCI Anonymizer." Malicious components (blocks "malicious feature extraction," "malicious classification algorithm" and "malicious BCI application") may request data, but will not receive a response from the "BCI Anonymizer."

Image top of page: A graduate student plays Flappy Whale, the game used in the experimental part of the project. The position of the whale on the screen is controlled using EMG signals recorded from the arm while EEG signals are recorded from the skull.

MORE INFORMATION

brl.ee.washington.edu/neural-engineering/bci-security

FACULTY ADVISOR:
Howard Chizeck

COLLABORATORS:
Professor Ryan Calo
UW School of Law

Jeffrey Herron, Charlie Matlack
Department of Electrical Engineering

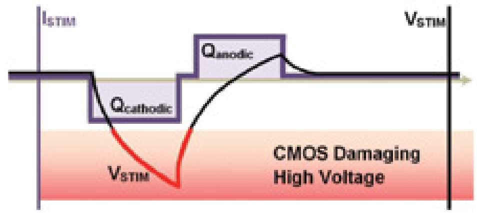
Tyler Libey, Brian Mogen
Bioengineering Department

Hannah Werbel
Skyline High School

RESEARCH AREA:
Security and privacy of cyber-physical systems

GRANT/FUNDING SOURCE:
NSF Center for Sensorimotor Neural Engineering

UW Tech Policy Lab



Brain Power:

Better Treatment of Neurological Disorders

Integrated Chip Reduces Size of Implantable Device in the Brain

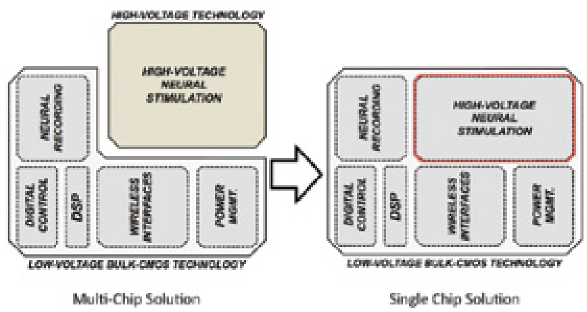
Daniel Micheletti and Eric Pepin, *Graduate Students*

Millions of people worldwide suffer from either a neurological disorder or physical damage to their nervous system. To aid individuals in their treatment and recovery, developments are underway to advance brain-computer interfaces (BCIs), which are neuroprosthetic devices that encompass stimulation and recording circuits to artificially "talk" and "listen" to the brain. Graduate students Daniel Micheletti and Eric Pepin, in collaboration with the National Science Foundation Center for Sensorimotor Neural Engineering (CSNE), are developing a smaller, integrated implantable stimulation microchip for use within BCIs. Their goal is to provide better treatment options to people with neurological disorders— ultimately restoring movement and senses.

With BCI systems, artificially generated stimulation signals are sent to the nervous system. Depending on the neuroprosthetic device, the signal may enable movement by activating a prosthetic limb, or travel from the cortex to the spinal cord to bypass a damaged area. Implanting stimulators in the body is an invasive process and requires integrated circuits that are smaller than a grain of rice. Current implantable stimulator systems require multiple microchips, making the system large and difficult to implant, and entails an expensive fabrication process to generate the signals required for stimulation. In addition to being low-power, reliable and able to drive charge-balanced stimulation signals into high-impedance electrodes, high-voltage neural stimulation technology is required.

To address these challenges, Micheletti and Pepin are developing novel circuit techniques using smaller and less expensive standard Complementary Metal Oxide Semiconductor (CMOS) devices capable of generating high-voltage signals. Utilizing a single chip, they devised high-voltage tolerant stimulation circuits in a low voltage process, which can interface with digital signal processing units and incorporate wireless data communication and power to synthesize a complete BCI. With millimeter dimensions, the chip may be easily implanted and is able to relay both sensory and movement signals across permanently damaged regions of the nervous system. Through the use of microelectrodes and specialized stimulator electronics, the chip can artificially generate a neuron's natural communication signal to activate a neuroprosthetic device, enable movement and restore sensory perception.

The integrated circuit implementation of a stimulator system addresses a unique set of circuit-design challenges including a smaller footprint, fail-safe operation and the ability to generate high voltages. The circuit techniques developed will aid in future high-density integration of electrical stimulator circuitry with other neural interfacing hardware. The integrated chip is currently under testing.



By developing high-voltage compatible circuits in a low-voltage CMOS process, all blocks of the system are placed onto a single chip, realizing drastic improvements to form factor and cost.

Image top of page: The stimulation currents required to evoke neurological responses, in combination with high-impedance electrodes, often generate high voltages that are damaging to bulk silicon CMOS processes, precluding the use of such technologies.

MORE INFORMATION

ee.washington.edu/research/fast/

FACULTY ADVISOR:
Chris Rudell

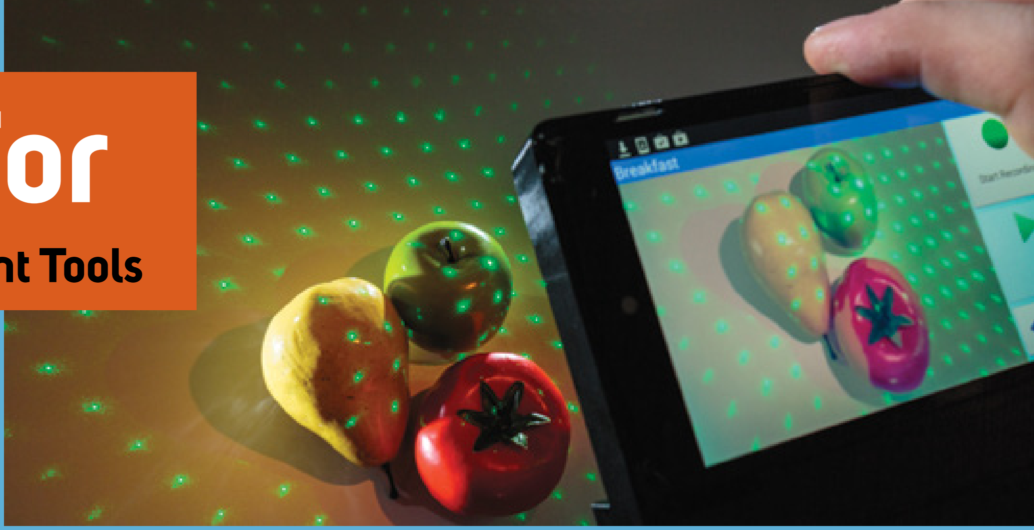
RESEARCH AREA:
Analog/Mixed-Signal IC Design

COLLABORATORS:
Steve Perlmutter
Department of Physiology and Biophysics

GRANT/FUNDING SOURCE:
NSF Center for Sensorimotor Neural Engineering

Hungry for

New Dietary Assessment Tools



Smartphone Laser Module Measures Dietary Data

Sep Makhsous, *Graduate Student*

As obesity rates soar, dietary assessment tools are becoming increasingly important for understanding the relationship between diet and health. Valid measurement of food intake is challenging as traditional paper-based dietary assessment methods are impacted by bias, user burden and cost. Improving upon existing methods, researchers in the Sensors, Energy and Automation Laboratory, in partnership with the Fred Hutchinson Cancer Research Center, developed a portable smartphone based system, the Dietary Data Recorder System (DDRS). Using a laser module to compute the volume of food on a plate, the DDRS has the potential to address important health issues related to diet.

The gold standard for measuring food intake in free-living conditions is doubly labeled water (DLW), in which the hydrogen and oxygen molecules of water are replaced with traceable isotopes. While DLW allows for precise measurement of metabolic rate by measuring both calories burned and consumed, there are limitations including high cost and lack of applicability. Alternative methods for measuring food consumption are often based on participants' reports, including interviewer-administered 24-hour dietary recalls, paper-based food diaries and food frequency questionnaires. As these methods require participants to remember both the foods consumed, as well as estimate portion sizes, they are compromised by bias, error, participant underreporting and staff and participant burden and cost. Studies have shown that such methods underestimate food intake by more than 37%.

Overcoming current dietary assessment challenges, the DDRS provides objective measurement of food intake in real time and at moderate cost. Using laser-based 3D reconstruction, the DDRS estimates the volume of food and beverages and can calculate the caloric content of more than 9,000 different types of food. The DDRS consists of a smartphone with a laser module attachment, an algorithm to process acquired data for food volume estimation (the largest source of error in calculating dietary intake) and a database for storing results.

The DDRS measures everyday food items with 90% accuracy and in addition to recording caloric content also provides advanced nutritional information, location, time of day and more. By using DDRS, the estimated food volume, together with direct entries of food questionnaires and voice recordings, may provide dietitians with not only more complete food descriptions, but more accurate food portion sizes. In partnership with the Fred Hutchinson Cancer Research Center, the DDRS will soon be trialed on humans.

The scanning process of DDRS.

Background image: Laser projected on a muffin.

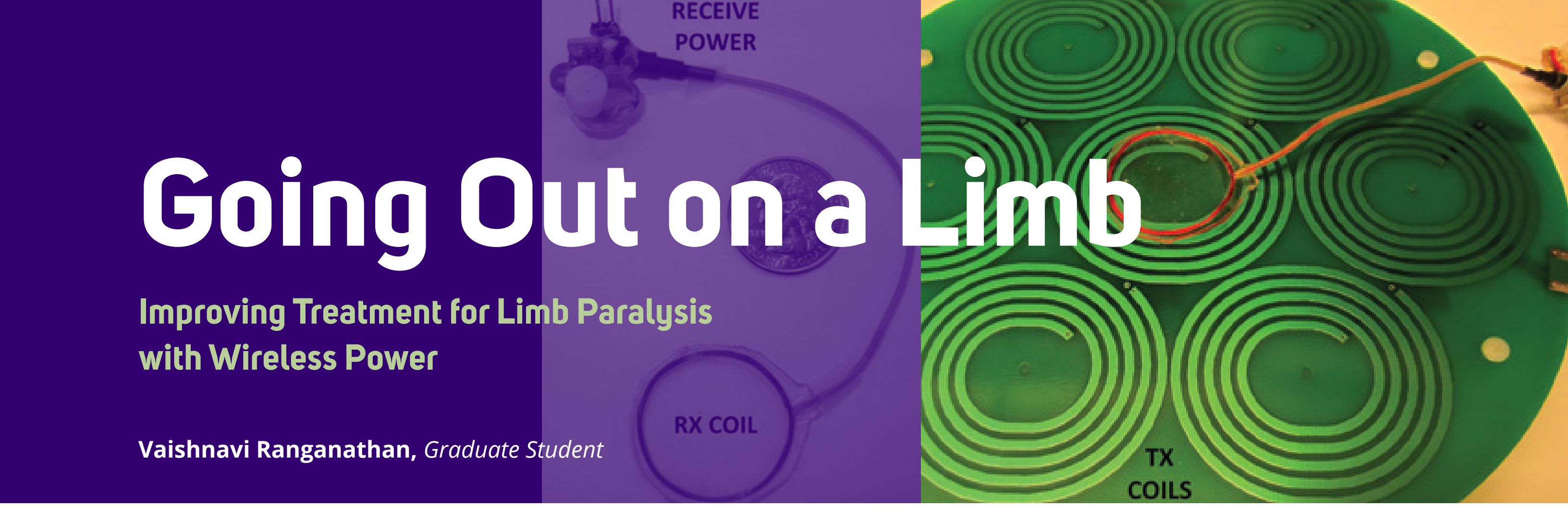
MORE INFORMATION

FACULTY ADVISOR:
Alexander Mamishev

COLLABORATORS:
Pavel Kulik, Lincong Li and Fred Hutchinson Cancer Research Center

RESEARCH AREA:
Medical Instrument

GRANT/FUNDING SOURCE:
National Institutes of Health



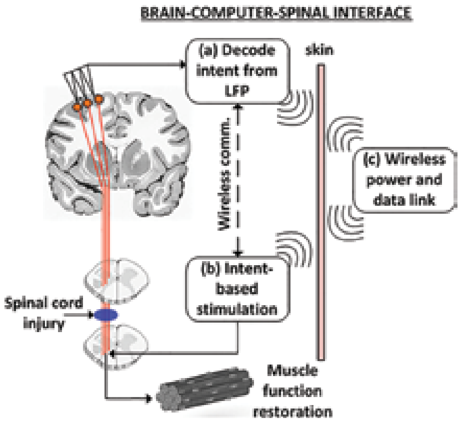
Going Out on a Limb

Improving Treatment for Limb Paralysis with Wireless Power

Vaishnavi Ranganathan, *Graduate Student*

For people who suffer from limb paralysis due to spinal cord injury or stroke, the rehabilitation and revival of paralyzed limbs has the potential to improve their quality of life. While stimulating paralyzed limbs faces many challenges, researchers from the Electrical Engineering and Physiology & Biophysics Departments are collaborating to develop a wireless Brain Computer Spinal Interface (BCSI). A small implantable system, a BCSI transmits signals from the brain to the spinal cord to detect user intention and deliver real-time stimulation to restore the functionality of paralyzed hands and arms.

While advancements in biomedical electronics and miniaturization have led to many developments in prosthetic devices, stimulating paralyzed limbs with a BCSI system is challenging. This is primarily due to the dynamic nature of neural signals, power delivery, communication to the implant and design issues such as cables exiting the surface of the skin that pose a risk of infection. The proposed solution to address these challenges consists of developing two separate systems. The first system records and processes neural signals from the brain to recognize the intention for limb movement. The information collected is then used to control a second stimulator system located below the injury in the spinal cord. By customizing both systems, significant reductions in power and size are possible.



The proposed BCSI system with wireless power and communication.

The Sensor Systems Laboratory is currently developing a wireless power transfer (WPT) and communication device to deliver power across tissue using optimized coupled resonators operating at a frequency of 13.56MHz. To test the WPT system's efficiency, a small receiver coil was implanted in a rat's abdomen and an external inductor coil array was positioned below the rat's cage as the transmitter. Adaptive frequency tuning mechanisms make the systems capable of achieving efficiencies greater than 80% with low temperature rise (less than 2OC). To maximize power delivery, further research into using different coil topologies and powering algorithms is necessary.

To enable communication between the brain and spinal cord with low-power and high data-rate, a protocol chip was designed using TSMC 65nm CMOS technology for wireless backscatter communication at 915MHz. The chip will be validated with tests on non-human primates.

Experts in neural disorders and rehabilitation from the Department of Physiology & Biophysics, Dr. Chet Moritz and Dr. Adrienne Fairhall are studying the feasibility of rehabilitation in rats with spinal cord injury and are developing efficient methods to analyze neural signals for recognizing intention. This close collaboration has enabled the development of prototypes with full understanding of the in-vivo challenges.

Image top of page: Receiver and transmitter coils designed optimally to test the efficiency of wireless power delivery across tissue.

MORE INFORMATION

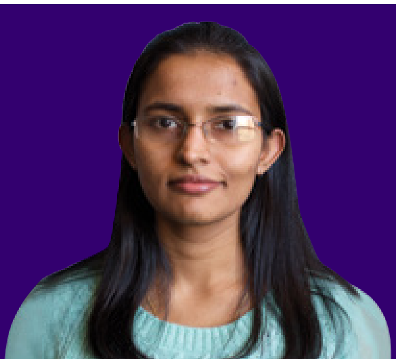
FACULTY ADVISOR:
Joshua Smith

COLLABORATORS:
Dr. Chet Moritz, Dr. Adrienne Fairhall, Department of Physiology and Biophysics

RESEARCH AREA:
Wireless power and communication for biomedical devices, specifically implantable neural prosthetic devices.

GRANT/FUNDING SOURCE:
Paul Allen Foundation

NSF Center for Sensorimotor Neural Engineering



Unheard of:

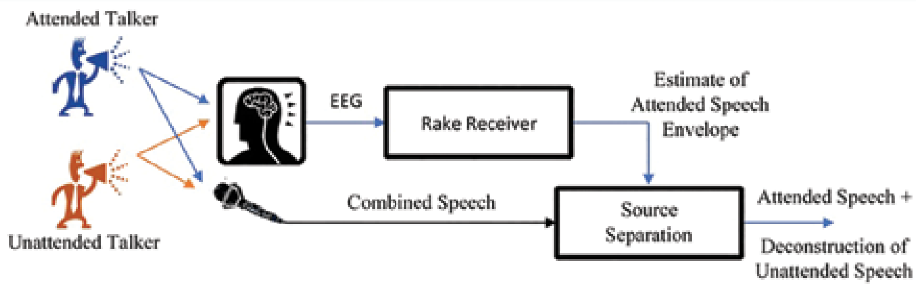
New Approach to Improving Hearing Aids

New Form of Modeling Speech Aims to Benefit the Hearing Impaired

Brad Ekin, *Graduate Student*

In a noisy room, most people can easily focus on a single talker and tune out background noise. However, this automatic filtering known as "the cocktail party effect" is challenging for people with hearing aids as they are unable to distinguish between competing sounds. Using a new form of speech modeling, graduate student Brad Ekin's research aims to allow people with hearing aids to better comprehend speech in noisy environments.

to speech stimuli show that amplitude modulations of speech, which discern sounds by changes in volume, are found in the neural activity of the brain. Furthermore, these signals are found to appear with multiple delayed copies of the original stimuli. This finding prompted Ekin to model the auditory cortex of the brain as a multipath fading channel, applying a rake receiver to brainwaves measured through an electroencephalography (EEG) cap attached to a subject's head.



Model of attended speech source separation driven from a listener's EEG estimate of the attended speech envelope.

In many modern digital communication systems, specifically technology used in cell phones, background noise is successfully minimized by implementing a technique known as a "rake receiver." This type of radio receiver utilizes the multiple paths a signal takes from the transmitter to the receiver by "raking" the multi-path signals into a single coherent signal, effectively improving the quality of what is received.

To better understand how humans can effortlessly focus on a single talker in a room congested with competing speech, Ekin applied the concept of a rake receiver to signals generated from the human brain. Studies on how the brain responds

As a result, an estimate of a primary talker's amplitude modulations of speech, also called a speech envelope, was extracted and used as the controlling signal for a multi-talker source separation algorithm. By estimating the attended talker's speech modulation frequency, the quality of voice is retained while deconstructing the voices of competing talkers in a room, turning it into unintelligible babble.

Preliminary results support the hypothesis that unattended speech can be made unintelligible via deconstruction. This processing is a new form of modeling how human listeners solve "the cocktail party effect" and may have future impact on hearing aids, auditory neuroscience and tracking listeners' attention.

MORE INFORMATION

sites.google.com/a/uw.edu/ieee-embs/

FACULTY ADVISOR:

Les Atlas

COLLABORATORS:

Postdoctoral Researcher Majid Mirbagheri

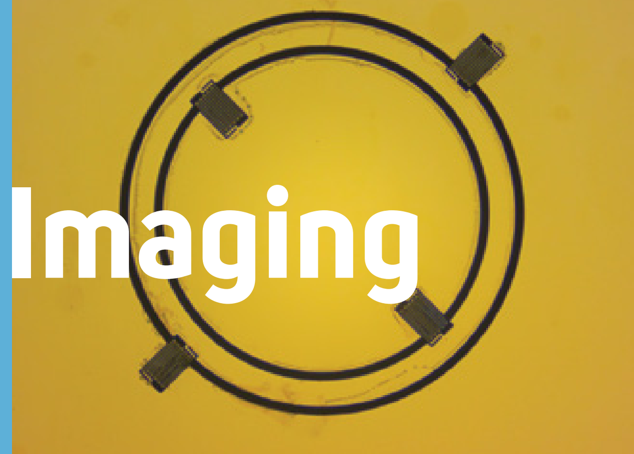
Institute for Learning & Brain Sciences, University of Washington

RESEARCH AREAS:

Speech Processing, Computational Neuroscience

GRANT/FUNDING SOURCE:

Army Research Office; Virginia Merrill Bloedel Hearing Research Center, University of Washington

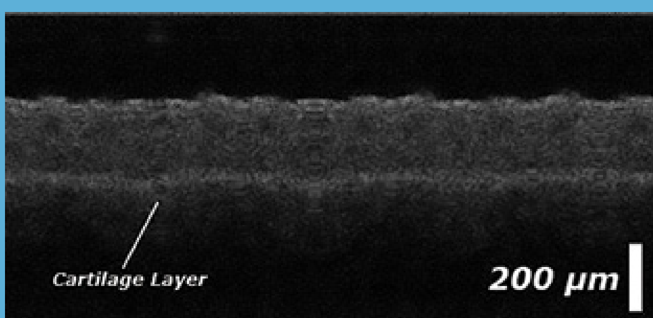


Reflecting on Advanced Gastrointestinal Imaging

Micromirror Enables Three-Dimensional Tissue Scanning

Ethan Keeler and Utku Baran, *Graduate Students*
Matthew Strathman and Yunbo Liu, *EE Graduates*

While many endoscopy systems provide a magnified view of the surface of biological tissue, they are not capable of deeper imaging in the gastrointestinal tract. To address this, graduate students in the Photonics Laboratory developed a micromirror device that allows for three-dimensional scanning of tissue. The micromirror has the potential to be integrated into endoscopic devices for early diagnosis of cancer and other diseases.



Spectral-domain OCT cross-sectional image of a mouse ear. The image provides both the tissue's topographic surface information and underlying microstructure, showing the cartilage layer within the ear.

The combining of endoscopy and optical coherence tomography (OCT) imaging, a technology that allows for high-resolution structural imaging, has advanced diagnostic capabilities in recent years. Using lightwaves, OCT provides three-dimensional tissue images, similar to how soundwaves are used for ultrasounds. OCT imaging reveals underlying microstructures in samples, such as tissue, with an impressive resolution on the order of microns. To meet advancing applications and techniques, the miniaturization of additional components is necessary through the technology of small-scale devices, Microelectromechanical Systems (MEMS), which have powerful functionality with features smaller than a strand of hair.

Building on the combined OCT imaging and endoscopy advances, Photonics Laboratory students developed and fabricated a MEMS scanning micromirror. The device facilitates OCT imaging of biological tissue by using moveable mirrors to steer a laser beam. Fabricated at UW's Washington Nanofabrication Facility using silicon-on-insulator techniques, the mirrors have an approximate diameter of 800 µm, about .0315 inches. The MEMS micromirror employs a biaxial gimbal structure, enabling it to rotate on two axes. This allows for two-dimensional scanning of the mirror, which is supported by serpentine springs.

After calibration, the scanning mirror enables OCT imaging utilizing a broadband, low-coherence light source split into both a sample arm and a reference arm (consisting of a flat mirror). The reflected signals from both paths are combined and a spectral interferogram is detected, which is then processed through Fourier transformation, a mathematical tool to deconstruct waveforms, to reveal the depth of the sample. The result is a three-dimensional image. While the system requires further optimization and image processing techniques, the results show the mirror's promise for integrated endoscopic imaging of biological tissue.

Image top of page: Optical microscope image of gold-coated micromirror.

MORE INFORMATION

ee.washington.edu/research/photonicslab/

FACULTY ADVISOR:
Lih Lin

COLLABORATORS:
Mingli Song[1], Jiefeng Xi[2], Ming-Ting Sun[1], Ruikang Wang[3], Xingde Li[2]

[1]Department of Electrical Engineering, University of Washington

[2]Department of Biomedical Engineering, Johns Hopkins University

[3]Department of Bioengineering, University of Washington,

GRANT/FUNDING SOURCE:
National Institutes of Health

Ethan Keeler and Matthew Strathman

Picture of Health:

New Way to Diagnose Jaundice

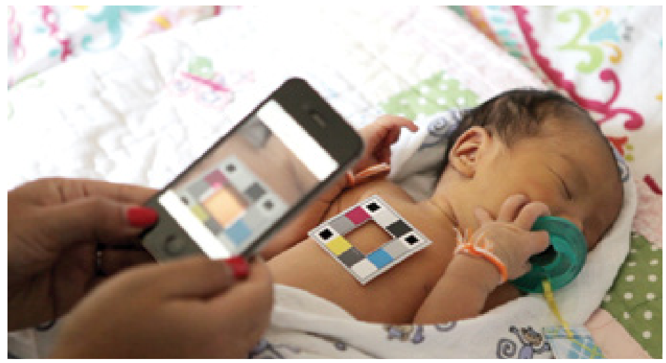
Using Smartphones to Monitor Newborn Jaundice

Eric Larson, *EE Graduate*

Lilian de Greef and Mayank Goel, *CSE Graduate Students*

Early detection of extreme jaundice is essential in preventing brain damage or death in newborns. About 84% of all newborns develop visible jaundice during the first week of life and 1 in 14 newborns in the U.S. receives phototherapy treatment for high jaundice. Manifesting as a yellow discoloration of skin from excess bilirubin in the blood, jaundice detection in newborns currently requires clinical tests with blood samples, requiring specialized and expensive equipment. Simplifying the detection process, a non-invasive medical device, called BiliCam, is under development by graduate students in the Ubicomp Lab. BiliCam utilizes technology that many people have on hand— a smartphone camera.

A complete software solution, BiliCam does not require a smartphone hardware attachment. The only additional requirement is a color calibration card that may be printed at a color-calibrated print shop such as FedEx. Considering that images vary considerably with different lighting conditions, the calibration card ensures that images are color-balanced. The software extracts intensities of various reflected wavelengths and other chromatic and achromatic properties from the skin and estimates bilirubin levels using machine learning. Subtle changes in skin color are detected using an ensemble of machine learning models from data from nearly 100 newborn babies. Multiple regression algorithms are used, including k-Nearest Neighbor, Least-Angle Regression, Elastic-Net Regression, Support Vector Regression and Random Forest Regression. The outputs of the regressions are averaged to produce a single bilirubin level estimate.



The user simply puts the color calibration card on the newborn's chest and aligns the card in the app's viewfinder.

If the output of different algorithms differs by more than two mg/dl, the 90th percentile value of the estimate is selected. This helps to bias the regression algorithm into selecting a large bilirubin value when the ensemble does not agree, prompting the software to err on the side of caution when used as a screening tool. It is preferable to have a false positive than to miss a potentially high bilirubin estimate.

The initial assessments of BiliCam are very promising, with bilirubin levels estimated with the technology closely matching the serum level (the gold standard). Clinical trials are currently under way in multiple locations around the country to collect data from a more diverse population.

TOP 10 TECHNOLOGY

BILICAM WAS NAMED ONE OF "TEN OF THE YEAR'S PROMISING TECHNOLOGIES FOR GLOBAL DEVELOPMENT" BY *ENGINEERING FOR CHANGE* IN DECEMBER 2014.

MORE INFORMATION

bilicam.com

FACULTY ADVISOR:
Shwetak Patel

COLLABORATORS:
Dr. James Stout,
Department of Pediatrics, UW

Dr. James Taylor,
Department of Pediatrics, UW

RESEARCH AREAS:
Mobile Sensing, Computer Vision, Machine Learning

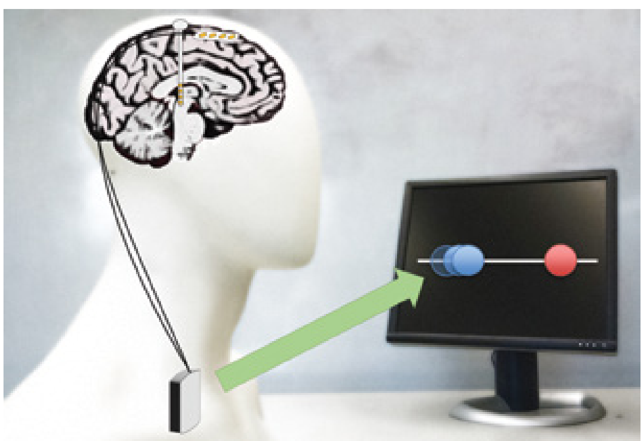
Developing Closed-Loop

Deep Brain Stimulation Systems

Using Sensors to Improve Treatment for Neurological Disorders

Jeffrey Herron and Margaret Thompson, *Graduate Students*

Deep brain stimulation (DBS) has become a widely adopted method for treating neurological and movement disorders such as Parkinson's disease, essential tremor and more. DBS treats these disorders by sending electrical impulses to specific parts of the brain through an implanted device called a deep brain stimulator (also sometimes called a brain pacemaker). One challenge with current systems is they are constantly "on" and may provide stimulation to patients when not needed, resulting in unintended side effects as well as reduced battery life. To address this problem, graduate students Jeffrey Herron and Margaret Thompson are building closed-loop systems to improve treatment for people with neurological movement disorders.



Closed-loop DBS systems with neural sensing capabilities have the potential to be used as a fully implanted brain-computer interface to control external devices.

To determine not only when stimulation may be necessary, but to also estimate the appropriate intensity of stimulation, Herron and Thompson are exploring using sensors to directly sense tremor symptoms. The DBS system's stimulation parameters would then automatically be adjusted based on the sensed data. By providing therapeutic stimulation only when necessary, and at a proportional intensity, patients will benefit from improved movement and the battery life of the implanted device will be extended. Currently, an implanted stimulator in the chest, which is connected to the stimulation electrode in the brain through electrical wires implanted under the skin, must be surgically replaced when the battery is depleted.

The closed-loop DBS systems that are being built by Herron and Thompson are based around a Medtronic neurostimulator, which performs neural sensing and stimulation simultaneously. The investigational implantable device allows them to perform chronic studies with essential tremor patients and simultaneously record neural signals while providing therapeutic stimulation when necessary.

The tools and experimental set-ups built to test closed-loop DBS concepts may also be used to investigate how people can learn to control their neural signals over time. As implanted DBS systems provide long-term invasive neural recordings, these same brainwaves could potentially be used by individuals to control devices using a brain-computer interface (BCI). This could include control of the DBS system with patients learning to trigger their stimulation on demand when needed. Since the systems are currently implantable in human subjects, using DBS devices for BCI bypasses extensive animal trials needed to develop other safe implants for long-term signal recording.

MORE INFORMATION

brl.ee.washington.edu/neural-engineering/closed-loop-dbs/

FACULTY ADVISOR:
Howard Chizeck

COLLABORATORS:
Tamara Bonaci, Tim Brown, Brady Houston

RESEARCH AREA:
Systems, Controls and Robotics

GRANT/FUNDING SOURCE:
Medtronic

Note Worthy:
Improving Music Recognition

Enabling Cochlear Implant Users to Hear Music

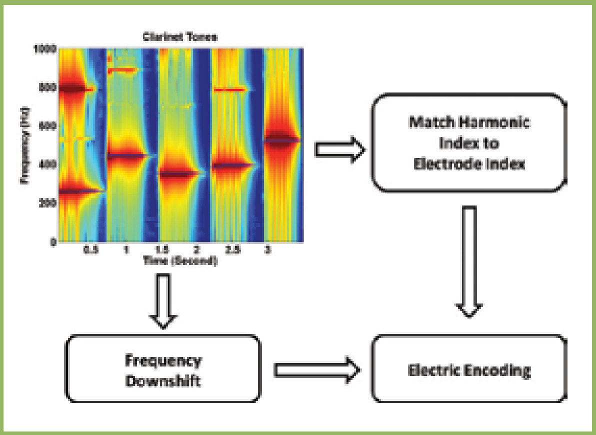
Xingbo Peng, *Graduate Student*

People with cochlear implants can hear others speak one at a time in a quiet setting, but when it comes to hearing music, sound quickly becomes inaudible. With more than 320,000 people worldwide having cochlear implants, enabling them to enjoy music would not only improve their quality of life, but may also lead to developments in hearing speech in noisy settings. With this aim, researchers in the Interactive Systems Design Lab are developing methods to encode more information about music in cochlear implants.

A cochlear implant allows a person who is profoundly deaf or severely hard-of-hearing to approach normal hearing by electrically stimulating the auditory nerve. While much progress has been made, exploring ways to make a cochlear implant convey clear speech with noise and music are remaining challenges. Traditionally, the amplitude modulations of speech, which distinguish sounds by changes in loudness, were considered the primary cue for speech coding in cochlear implants. However, recent studies show that amplitude modulations, also called a speech envelope, lack the information needed for cochlear implant users to hear music. This is the major reason for the large performance gap between cochlear implant users and normal-hearing listeners when listening to music.

To improve music perception for cochlear implant users, a harmonic-single-sideband-encoder (HSSE) strategy was developed [Xing Li et al., 2013], which improves music coding for cochlear implant users by employing novel signal processing techniques. In HSSE, the pitch of the source, rather than amplitude, is used to encode harmonics for cochlear implant users. Pitch is determined by the speed of vibrations, whereas amplitude is based on the size of vibrations. In the latest research, an efficient pitch estimation strategy based on the fast Fourier transformation (FFT) was adopted. Given the pitch, the input sound is coherently downward shifted to a low-frequency baseband. The resulting new coherent envelope signals are converted into electric pulses and sent to cochlear implant electrodes. This pitch estimation strategy performs well even in a noisy setting, in real time.

A significant advantage of the HSSE over the traditional signal processing strategy in cochlear implants has been demonstrated through subjects' music melody and timbre recognition. Future efforts will focus on fully implementing the HSSE in real time, to benefit many world-wide cochlear implant users including those who speak tonal languages such as Mandarin.



An example of the estimated clarinet music pitch (thin blue line in top left) and block diagram of HSSE processing for cochlear implants.

MORE INFORMATION

FACULTY ADVISOR:
Les Atlas

COLLABORATORS:
Jay Rubinstein, Virginia Merrill Bloedel Hearing Research Center

Kaibao Nie, Virginia Merrill Bloedel Hearing Research Center

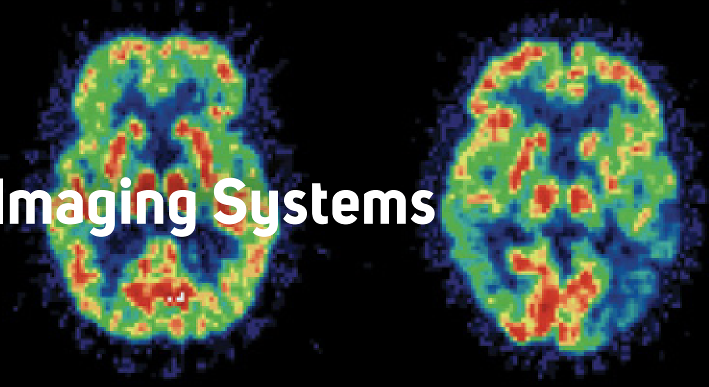
RESEARCH AREAS:
Speech Processing, Neural Coding

FUNDING SOURCE:
Virginia Merrill Bloedel Hearing Research Center, University of Washington

Coulter Translational Research Fund

Big Impact:

Reducing the Size of PET Imaging Systems

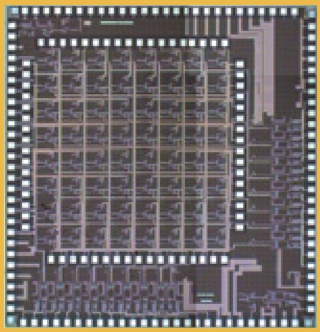


SiPM Based System Utilizes Novel Row-Column Architecture Chip

Samrat Dey, *Graduate Student*

Positron Emission Tomography (PET) imaging systems are commonly used to detect a variety of medical conditions such as heart disease and cancer. Unlike structural imaging techniques such as ultrasound, X-Ray and Magnetic Resonance Imaging (MRI), PET imaging, being a biochemical imaging technique, reveals information about the body's chemistry not available through other procedures. Despite its important role in diagnosing medical conditions, both the size and cost of PET imaging systems prohibit widespread use, particularly in developing countries. With the objective of enabling PET imaging systems to be more widely used, graduate student Samrat Dey is working in conjunction with the UW Department of Radiology to reduce the size and cost of existing units.

After injecting patients with a radioactive substance, PET imaging systems create 3D images by measuring the radiation emitted while patients are inside an imaging scanner. Traditionally, bulky vacuum tubes and photomultiplier tubes have been used as the photo detectors in PET imaging systems, but the advent of solid state photo detectors, known as Silicon Photomultipliers (SiPM) have led to the miniaturization of the scanners. The reduced size of the SiPM diodes, which are highly sensitive to detecting radiation, enables a greater density with the added benefit of improving image resolution. To further reduce the size of PET imaging systems currently used, Dey is replacing large rack-mounted discrete-component boards in the front end readout electronics with smaller integrated circuits.



A front-end chip was designed utilizing row-column architecture.

The increase in detector density, however, results in an increase in the number of channels interfacing with the backend digital electronics that construct 3D images. To reduce the required number of interface channels, Dey developed a chip with a novel row-column architecture (RCA), which parallelizes detection channels. Utilizing this new architecture, a 3.8mm x 3.6mm front-end chip was designed in STMicroelectronics CMOS 130nm process die. The RCA inherently reduces the N2 detection channels to 2N. In addition, the chip reduces errant photon detection due to accumulation of "dark" noise current through the use of a new threshold detection circuit. A separate high-speed timing channel also was designed to pass information at the speed it is obtained across all channels.

In addition to being embedded within a PET imaging system, the chip is currently being evaluated as a standalone device. The next phase of the project will interface the row-column channels of the chip with 64 PET imaging detectors and digital signal processing blocks, which perform image reconstruction algorithms. The RCA design will eventually be integrated with on-chip digitizing of the signals to offer a compact package to allow tight coupling between the SiPM array elements and the digital backend.

MORE INFORMATION

FACULTY ADVISORS:
Chris Rudell

COLLABORATORS:
Thomas Lewellen, Robert Miyaoka, Department of Radiology

RESEARCH AREA:
Analog/Mixed-Signal IC Design

GRANT/FUNDING SOURCE:
National Institutes of Health
Zecotek Photonics

In Synch with Treating Neurological Disorders

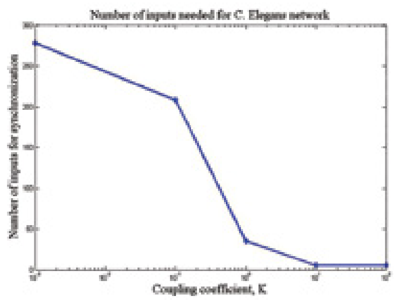
Using Synchronization to Treat Parkinson's Disease and Epilepsy

Andrew Clark, *EE Graduate*

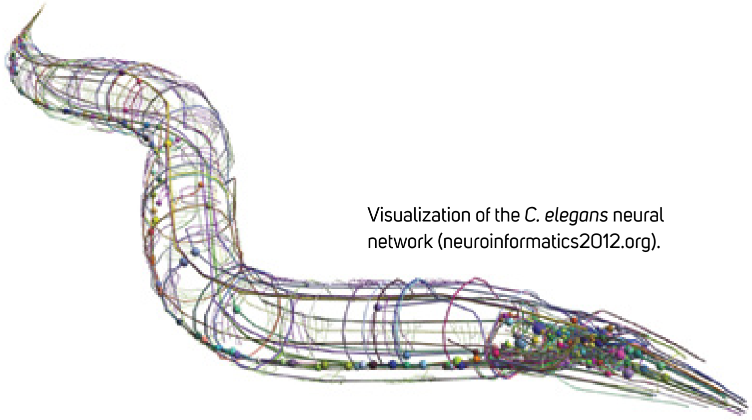
Synchronized, repetitive firing of nerve cells in the brain, which happens at regular intervals in healthy humans, controls a variety of brain functions such as motor skills, cognition and memory. Abnormal firing of neurons in the brain is therefore associated with a variety of disorders such as Parkinson's disease and epilepsy. One approach to treating such neurological disorders is to use deep-brain stimulation to send electrical impulses to specific parts of the brain via an implanted device. By providing electrical impulses at a desired frequency, the surrounding neurons are steered toward synchronization. While selecting a minimally invasive set of input points to ensure synchronization of a complex network has been an open research challenge, graduate student Andrew Clark has developed efficient algorithms that are capable of guaranteeing practical synchronization.

Taking an analytical approach to the problem, Clark developed novel conditions for practical synchronization based on the widely studied Kuramoto model, a mathematical model used to describe synchronization where each oscillator has a unique frequency and phase until paired with others, at which time the individual phases either increase or decrease to better align with the others. The conditions are interpreted as thresholds, in which a neuron achieves practical synchronization if a threshold number of neighbors are synchronized.

Based on the conditions for practical synchronization, Clark proved that the problem of selecting a minimum set of external input nodes to guarantee practical synchronization is inherently a submodular optimization problem, where adding an element to an input set has less impact as the size of the set increases. Based on this, Clark developed efficient algorithms for selecting the minimum-size set of external inputs with provable optimality bounds. In a numerical study on the *C. elegans* (roundworm) neural network, Clark found that the submodular optimization approach requires fewer input nodes to achieve practical synchronization than other selection algorithms. Clark's future work will explore the scalability of this approach to larger neural networks.



Number of inputs required for synchronization in the *C. elegans* network.



Visualization of the *C. elegans* neural network (neuroinformatics2012.org).

MORE INFORMATION

FACULTY ADVISORS:
Linda Bushnell and Radha Poovendran

RESEARCH AREA:
Communications and Networking

COLLABORATORS:
Professor Basel Alomair, King Abdulaziz City for Science and Technology

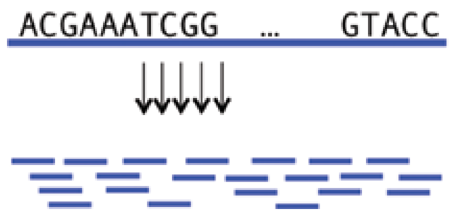
GRANT/FUNDING SOURCE:
King Abdulaziz City for Science and Technology

Office of Naval Research

NEW FACULTY Research

UW ELECTRICAL ENGINEERING WELCOMED SEVERAL NEW FACULTY MEMBERS THIS YEAR: ASSISTANT PROFESSORS ARKA MAJUMDAR, SREERAM KANNAN AND BAOSEN ZHANG. IN LESS THAN ONE YEAR, THEY ARE ALREADY BEING RECOGNIZED FOR THEIR CUTTING-EDGE RESEARCH. MAJUMDAR RECEIVED A THREE-YEAR AIR FORCE OFFICE OF SCIENTIFIC RESEARCH YOUNG INVESTIGATOR RESEARCH GRANT. ZHANG, WHO JOINS THE DEPARTMENT IN SPRING 2015, WAS NAMED TO *FORBES'* 30-UNDER-30 LIST FOR HIS WORK IN THE ENERGY INDUSTRY.

Decoding Gene Expression to Predict Disease



Improving RNA Sequencing Using Better Algorithms

Sreeram Kannan, *Assistant Professor*

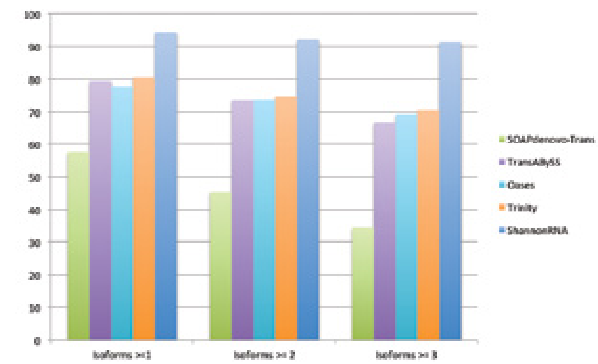
While DNA serves as a blueprint of each person's unique genetic code, RNA serves a key role in the process by which genes express themselves into visible traits. It is crucial, therefore, to know which RNA are present in a particular cell or tissue in order to understand the dynamics of gene expression. The typical method to sequence RNA involves cutting RNA into short fragments and using software, which is often inaccurate, to reconstruct the RNA. To address this problem, Assistant Professor Sreeram Kannan developed a novel algorithm that provides more accurate results, along with theoretical guarantees of optimality.

The success of the algorithm developed by Kannan lies in the methodology used. Existing software is developed using heuristic algorithms, without any notion of optimality. Kannan approached the problem through the lens of information theory to understand the amount of information (in terms of the length of short fragments, called "reads") required in order to accurately reconstruct a longer RNA sequence. After determining the informational limits, the next step involved designing a computationally efficient algorithm to solve the problem.

This is challenging as the general problem is equivalent to other problems (the so-called NP-hard problems) studied by computer scientists, for which no efficient algorithms are known. However, by exploiting certain features in the data characteristic of real biological samples, in particular the fact that RNA are present in varying proportions, Kannan and his collaborators derived a computationally efficient algorithm for the problem. The algorithm links short reads together based on their relative proportions in order to create longer reads in an iterative manner, solving the problem similar to solving a Sudoku puzzle: solving a particular entry helps solve other entries, which are then iteratively solved. The resulting algorithm performs significantly better than existing solutions and was used to build a new software package, named "ShannonRNA," which will soon be released as open source software.

RNA sequencing has applications in several areas of biology and medicine. RNA obtained from the diseased and healthy tissues of an individual may be compared in order to find out which genes are over or under-expressed in the diseased tissue. Applications to cancer biology and basic biological research are currently being explored with researchers at the Stanford University School of Medicine and Fred Hutchinson Cancer Research Center.

Success Rate of Algorithms (Percentage of RNA Reconstructed)



Kannan's algorithm, ShannonRNA, performs consistently better than others. The y-axis indicates the fraction of RNA recovered accurately by each algorithm. The x-axis is separated into three groups by the complexity of reconstruction as measured by the number of isoforms.

Image top of page: Reads being extracted from a DNA/RNA sequence. The relative location of reads is lost in the process.

MORE INFORMATION

COLLABORATORS:

David Tse (Stanford),
Lior Pachter (Berkeley)

GRANT/FUNDING SOURCE:

NSF Center for Science of Information

STUDENTS INVOLVED:

Joseph Hui (Berkeley), Kayvon Mazooji (Berkeley)

SREERAM KANNAN

Assistant Professor Sreeram Kannan joined the department in Fall 2014, from the University of California, Berkeley, where he was a postdoctoral researcher. Kannan's research interests are centered around information theory, which deals with the fundamentals of information processing and transmission, and its application to fields including genomics and wireless networks.

EDUCATION:

Ph.D. Electrical Engineering and M.S. in Mathematics, University of Illinois, Urbana-Champaign, 2012

M.Eng. Telecommunications, Indian Institute of Science, India, 2008

B.Eng. Electronics and Communication, Anna University, India, 2006

Enlightening Work:

Advancing Optical Communications

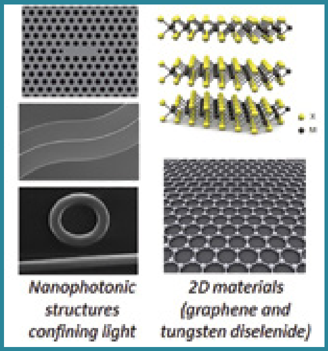
Low-Power Devices May Shape the Future of Information Transfer

Arka Majumdar, *Assistant Professor*

Current optoelectronic devices, which either produce light or are operated by light, are limited by their large size, high power consumption and low speed. To address these challenges, Assistant Professor Arka Majumdar in the Integrated Quantum Optoelectronics Lab is building ultra low-power nanoscale optoelectronic devices by engineering the interaction between light and matter. The devices Majumdar is creating have the potential to reshape the future of communication and computing by speeding up the transfer of information.

When designing new integrated photonics devices, there are tradeoffs in the extent to which the amplitude, phase and frequency of light and the energy, speed, active area and cost may be engineered. In Majumdar's research, he addresses these tradeoffs by exploring new materials, new photonic devices and new system architectures to sculpt and tune the properties of light at few photon levels. Majumdar builds photonic devices using two-dimensional (2D) materials, which are favorable due to their optoelectronic properties that enable low-power operation. With the control energy reduced to an extremely small value (tens of photons level), quantum optical effects play an important role in the devices.

With a trend toward increased cloud computing and larger data centers, high performance computing requires additional communication channels. The devices that Majumdar's research team is developing are specifically for use in optical communication and computing, which is still in the research and development stage. With optical computing, computers operate by light rather than electricity, using lasers or light-emitting diodes to send signals. At high frequencies, metallic interconnects, which currently move data from point to point inside computers, make computer systems power-hungry. Optoelectronic devices enable efficient signal conversion between the electronic and optical domain, making them a critical building block for short distance (~100m) optical interconnects primarily used in data centers. By developing a way to use optics to move data inside computers, information may be transferred more quickly and with less energy.



Nanophotonic structures (photonic crystal cavity, ring resonator or waveguide) coupled with two dimensional materials constitute a scalable platform for strong light-matter interaction. Such a platform is critical for engineering low-power opto-electronic devices.

Using 2D materials, Majumdar's team developed a graphene-clad silicon resonator based modulator, controlled with an external radio frequency signal. Due to the enhanced interaction between light and matter, the modulator is two orders of magnitude smaller than previous devices. Majumdar's team also constructed a nanoscale laser consisting of tungsten diselenide monolayer coupled to gallium phosphide photonic crystal cavities. The laser uses the world's thinnest possible gain medium and the technology can be easily translated to a silicon-compatible platform. In addition to creating these experimental devices, Majumdar's team has proposed creating optical switching devices to route light based on a hybrid silicon-photonic platform, which may be used to construct an optical computing system. These low-power devices may be thought of as precursors to future quantum optical devices.

MORE INFORMATION:

ee.washington.edu/research/amlab/

COLLABORATORS:

Xiaodong Xu (Physics, UW); Jelena Vuckovic (Stanford)

GRANT/FUNDING SOURCE:

NSF, Intel

STUDENTS INVOLVED:

Taylor Fryett (EE)

ARKA MAJUMDAR

Assistant Professor Arka Majumdar joined the department in Summer 2014. Previously he was a Postdoctoral Research Scientist at the Intel Labs in Santa Clara, CA. His research interests include devices in nanophotonics, nanometallics and quantum optoelectronics with a goal to explore the fundamentals and applications of photonics in information processing.

EDUCATION:

Ph.D. Electrical Engineering, Stanford University, 2012

M.S. Electrical Engineering, Stanford University, 2009

B.Tech. Electronics and Electrical Communication, Indian Institute of Technology Kharagpur, 2007

Creating a Smarter

Smart Grid

Combining Data and Physics for an Intelligent Electrical Grid

Baosen Zhang, *Assistant Professor*

With energy consumption continuing to increase and greenhouse gas emissions on the rise, conserving power is more important than ever before. Planning is underway to transition the current electrical grid, which transports power one-way to customers, to a smart grid. Featuring a two-way flow of energy and increased monitoring and analysis of consumption patterns, smart grid aims to maximize output while reducing consumption. By analyzing data to understand how people use energy, Assistant Professor Baosen Zhang's work contributes to designing a more intelligent power grid.

A smart grid allows power to be managed in real-time, with data sent to various parts of the grid for more efficient management and to more easily troubleshoot problems. With the emergence of sensors and measurement data in power, Zhang is able to analyze information and devise ways to conserve energy. One source of data is from smart meters, which record customer electricity consumption throughout the day. With this information, Zhang can propose solutions for energy conservation. For example, utility companies may want to enroll customers in demand response programs, which offer incentives for reducing energy consumption during peak times, but can only enroll a limited number due to budget constraints. Rather than select customers at random, which is standard procedure, smart meter data would allow customers to be selected based on energy usage data, leading to higher efficiencies.

Transitioning the current electrical grid to a smart grid is a pressing challenge for the energy industry, with issues to address including implementing a complex digital system with sensors and monitors, as well as information privacy concerns. When proposing ways to use data to conserve energy, Zhang considers theoretical questions such as "What is the correct tradeoff between privacy and usefulness of the data?" and "How do we provide some guarantees that targeting specific customers will lead to the desired response?" As Zhang and other researchers determine how to combine knowledge of the physical grid and advances in data science, implementing a smart grid will be closer to becoming a reality.

30 UNDER 30

BAOSEN ZHANG WAS ONE OF THREE RESEARCHERS FROM UW RECOGNIZED BY *FORBES'* "30 UNDER 30" LIST FOR HIS WORK TO CONSERVE ENERGY IN JANUARY 2015. ACCORDING TO FORBES, "BAOSEN WORKS TO DEVISE NEW WAYS OF DELIVERING ELECTRICITY WHILE MAKING THE GRID SMARTER AND MORE RESILIENT. HE USES BIG DATA ANALYSIS TO UNDERSTAND HOW CONSUMERS USE ENERGY, THEN USES THAT INFORMATION TO PROMOTE BEHAVIORS TO CONSERVE ENERGY."

BAOSEN ZHANG

Assistant Professor Baosen Zhang joins the department in Spring 2015. Zhang is currently a postdoctoral scholar at Stanford University. Zhang's research interest is in the area of energy systems, particularly the intersection between power systems control, economics and data analytics.

EDUCATION:

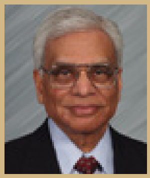
Ph.D. Electrical Engineering and Computer Science, University of California, Berkeley, 2013

B.A.Sc. Engineering Science, University of Toronto, 2008

FACULTY AWARDS

PAYMAN ARABSHAHI

Associate Professor Payman Arabshahi is one of 14 researchers, three of whom are from Electrical Engineering, to be honored with a 2015 UW Innovation Award. The Innovation Awards fund cutting edge projects that show promise, but may not yet qualify for external grants. During the next two years, $200,000 will help fund the creation of a web-based program to help students learn entrepreneurial thinking skills.



BISHNU ATAL

Affiliate Professor Bishnu Atal received an IEEE 20th Century Landmark Award in recognition of his contributions to digital speech coding. Inspired by the high cost of long-distance phone calls to India, Atal invented efficient digital speech encoding, which produces high-quality speech with compressed bandwidth. This is now the standard for all modern digital voice coding for cell phones, Skype and more.

LI DENG

Affiliate Professor Li Deng received an IEEE Region 6 Outstanding Engineer Award for his contributions to deep machine learning and neural networks. A Principal Research Manager at Microsoft Research, Deng's work has impacted speech recognition and areas of information processing and is used in Microsoft speech products and text and data products.

MOHAMED EL-SHARKAWI

Professor Mohamed El-Sharkawi received the International Fulbright Fellow Award. The three-year grant allows El-Sharkawi to spend three months each year participating in ambitious renewable energy research in Morocco, which plans to produce 40% of its energy from renewable resources. El-Sharkawi is also the recipient of the 2014 Institute of Electrical and Electronic Engineers (IEEE) Outstanding Educator Award for the Western United States.

KAI-MEI FU

Assistant Professor Kai-Mei Fu received the Cottrell Scholar Award (CSA), which funds early career faculty who excel in both undergraduate teaching and research. By emphasizing the importance of teaching and research, the CSA program hopes to increase the number of undergraduates who study science and pursue advanced degrees. Director of the Optical Spintronics and Sensing Lab, Fu's research focuses on the quantum properties of point defects in crystals.

VIKRAM JANDHYALA

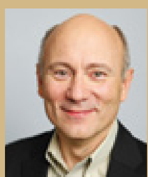
Professor and former Department Chair Vikram Jandhyala was appointed Vice Provost for Innovation for CoMotion. As the top federally funded public research university in the U.S., CoMotion helps UW researchers take their innovations out of the lab and into the market. In addition to boosting startups and patents, Jandhyala is leading entrepreneurial efforts across campus. Jandhyala was also one of 14 researchers recognized with a 2015 UW Innovation Award.

ERIC KLAVINS

Associate Professor Eric Klavins, who directs the UW Center for Synthetic Biology, received one of two inaugural 2014 Faculty Innovator: Teaching and Learning Awards from the UW College of Engineering. The award is presented to engineering faculty who demonstrate innovative and lasting contributions to engineering education, possess a high-level of commitment to students and are committed to improving education.

ADRIAN KC LEE

Adjunct faculty member Adrian KC Lee received a 2014 Office of Naval Research Young Investigator Award. UW Speech and Hearing Sciences Department Assistant Professor, Lee directs the Laboratory for Auditory Brain Sciences and Neuroengineering, working to create a revolutionary assistive hearing device that will selectively amplify sound based on listener intent via a brain-computer interface.

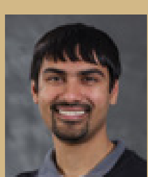


HENRIQUE MALVAR

Chair of the UW EE Advisory Board, Affiliate Professor Henrique (Rico) Malvar received an IEEE 20th Century Landmark Award for his contributions to multiresolution signal processing and media compression standards. A Chief Scientist for Microsoft Research, Malvar worked on the video compression format H.264, which is now the most widely used video format for digital TV and Internet video.

ARKA MAJUMDAR

Assistant Professor Arka Majumdar, who joined the Electrical Engineering and Physics Departments in Summer 2014, was awarded an Air Force Office of Scientific Research Young Investigator Research Program grant. Majumdar will receive $120,000 per year for three years to investigate a hybrid silicon/silica photonics platform for low-power digital optoelectronic switching and logic devices.



SHWETAK PATEL

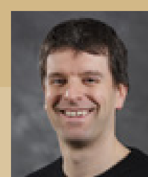
Associate Professor Shwetak Patel was appointed as the Washington Research Foundation Entrepreneurship Endowed Professor of Computer Science & Engineering and Electrical Engineering. Director of the Ubicomp Lab, Patel's research interests are in the areas of human-computer interaction, ubiquitous computing, sensor-enabled embedded systems, and user-interface software and technology. Patel was also one of 14 researchers recognized with a 2015 UW Innovation Award.

RADHA POOVENDRAN

Professor and Department Chair Radha Poovendran was the 24th UW EE faculty member to be elected an Institute for Electrical and Electronics Engineers (IEEE) Fellow. Poovendran, who founded the Network Security Lab in 2001, was honored for his contributions to security in cyber-physical systems. The number of IEEE Fellows selected each year is less than 0.1% of the total voting membership of the organization.

CHRIS RUDELL

Assistant Professor Chris Rudell was awarded a National Science Foundation CAREER Award, a five-year $500,000 grant that promotes the development of faculty research and educational programs. Rudell's proposed research seeks to explore and develop highly-integrated, ultra-broadband and low-power transceivers to address future wireless infrastructure demands.



GEORG SEELIG

Assistant Professor Georg Seelig is one of 24 early-career academic researchers to receive a 2014 Office of Naval Research Young Investigator Award. Director of the Seelig Lab, his research focuses on understanding how biological organisms process information using complex biochemical networks and how such networks can be engineered to program cellular behavior.

BAOSEN ZHANG

Assistant Professor Baosen Zhang, who joins the EE Department in Spring 2015, was named to *Forbes'* 30-Under-30 list for his work in the energy industry. According to *Forbes*, "Baosen works to devise new ways of delivering electricity while making the grid smarter and more resilient. He uses big data analysis to understand how consumers use energy, then uses that information to promote behaviors to conserve energy."

ELECTRICAL ENGINEERING **FACULTY**

Afromowitz, Martin
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MICROTECHNOLOGY/SENSORS
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NIH Career Development Award

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NANOTECHNOLOGY, MATERIALS & DEVICES
Ph.D., 1995 Purdue University

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Ph.D., 1994 University of Washington

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NSF Presidential Young Investigator
IEEE Fellow

Bilmes, Jeff
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NSF CAREER Award

Bohringer, Karl
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MICROELECTROMECHANICAL SYSTEMS (MEMS)
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CONTROLS & ROBOTICS
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NSF ADVANCE Fellow
Army Superior Civilian Service Award

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Poovendran, Radha
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COMMUNICATIONS NETWORKS & SECURITY
Ph.D., 1999 University of Maryland
IEEE Fellow, PECASE Award, ONR YIP & ARO YIP Awards, NSF CAREER Award, NSA Rising Star Award

Reynolds, Matt
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EMERITI

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Andersen, Jonny
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IEEE Fellow, OSA Fellow, IOP Fellow, IEEE Heinrich Hertz Medal,
URSI John Dillinger Medal, National Academy of Engineering

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Porter, Robert
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Spindel, Robert
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Yee, Sinclair
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IEEE Fellow

Zick, Greg
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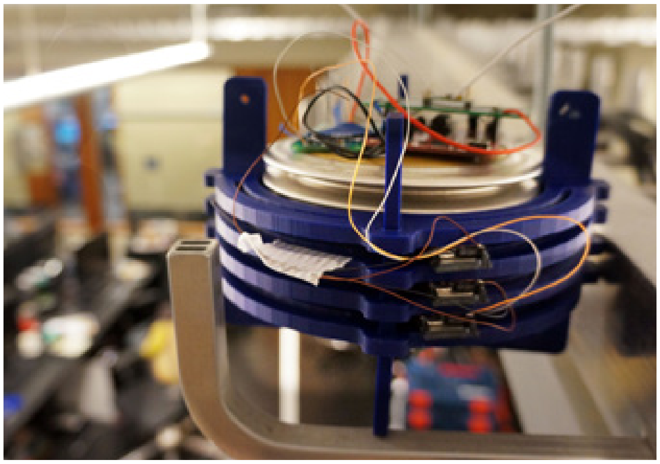
Ph.D., 1974 University of Michigan

RESEARCH BRIEFS

↑ A PR2 robot successfully navigates to a medication bottle.

ROBOTS FIND HOUSEHOLD OBJECTS

Associate Professor Matt Reynolds, together with researchers at Georgia Institute of Technology, developed a new search algorithm that improves a robot's ability to find tagged objects, making robots more useful in household settings. The team has implemented its system on a type of robot called a PR2, allowing it to travel through a home and correctly locate different types of tagged household objects, including a medication bottle, TV remote and phone. Most robots today view their surroundings with cameras and lasers, which makes it difficult for them to find objects, especially those hidden behind clutter. The research was funded by the National Science Foundation and the Willow Garage PR2 Beta Program.



↑ The device could be placed in hard-to-reach areas where temperatures fluctuate slightly.

CHANGING TEMPERATURE POWERS SENSORS

Using natural fluctuations in temperature and pressure as its power source, a power harvester was developed by a team led by Associate Professors Shwetak Patel and Joshua Smith. The device harvests energy in any location where temperature changes naturally occur. It can be used to power sensors that check for water leaks or structural deficiencies in hard-to-reach places and send out alerts via a wireless signal. The technology may be useful in places where sun and radio waves can't always reach, such as inside walls or bridges and even below ground where there may be small temperature fluctuations. Patents have been filed for the technology and researchers plan to work on reducing the size. The research was funded by the Intel Science and Technology Center for Pervasive Computing at the UW and the Sloan Foundation.

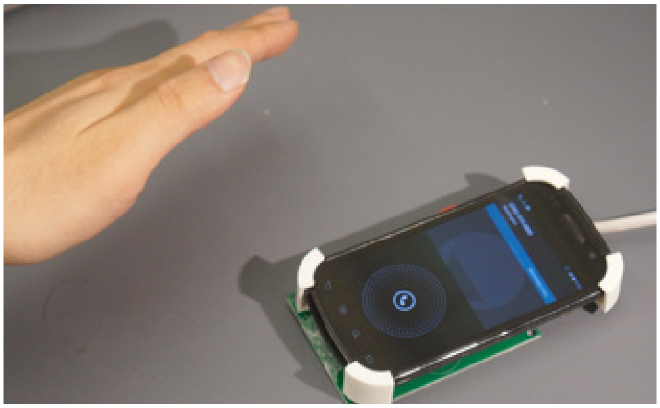
FACULTY INNOVATION

JIVA WIRELESS TO PRODUCE WIRELESS, BATTERY-FREE SENSING DEVICES

Associate Professor Joshua Smith, together with Computer Science and Engineering Faculty Member Shyam Gollakota and three students, founded Jiva Wireless. In the early stages of development, the company will produce battery-free wireless sensing devices, which are anticipated to be on the market by 2016. The technology has the potential to impact the Internet of Things, connecting everyday devices to the Internet, such as thermostats and appliances, and is currently limited by communication and power issues. Smith and his team are working to harvest ambient energy from cellular, Wi-Fi and TV networks. By leveraging existing wireless signals, ambient backscatter communication powers wireless devices and also allows them to communicate.

SMARTPHONE GESTURE CONTROL WITH SIDESWIPE TECHNOLOGY

Moving beyond a typical touchscreen interface, the entire space around a smartphone is now interactive with gesture control. Developed in the labs of Associate Professors Matt Reynolds and Shwetak Patel, the low-power wireless sensing technology enables smartphones to recognize and respond to specific hand gestures. The new technology, SideSwipe, uses the phone's wireless transmissions to sense nearby gestures, enabling it to work even when a device is out of sight in a pocket or bag. Early testing indicates the new technology, which can be easily built into future smartphones and tablets, recognizes gestures with 87% accuracy. The team has filed patents and will continue developing SideSwipe. The research was funded by UW.

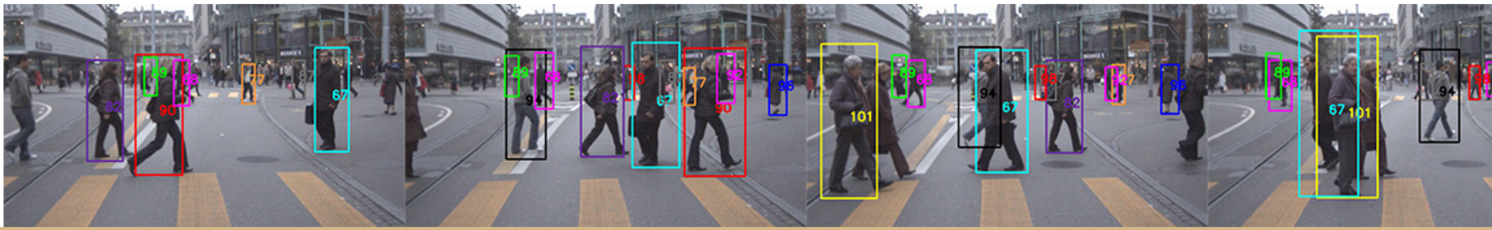


↑ The SideSwipe system uses the phone's wireless transmissions to sense nearby gestures.

MOVING CAMERAS TALK TO EACH OTHER TO IDENTIFY PEDESTRIANS

Video cameras are a powerful surveillance tool, but it can be hard to sift through large amounts of data to find pertinent information, such as identifying a person. Led by Professor Jenq-Neng Hwang, researchers have developed a way to automatically track people across moving and still cameras by using an algorithm that trains networked cameras to "talk." Previously, tracking a human across cameras of non-overlapping fields of view was challenging as appearances can vary in each video due to different perspectives, angles and color hues. The researchers overcame this by allowing for a calibration period, after which an algorithm automatically accounts for differences between cameras in order to effectively track people. The cameras first identify a person in a video frame, then follow that same person across multiple camera views. The research was funded by the Electronics and Telecommunications Research Institute of Korea and the Applied Physics Laboratory.

↓ Frames from a moving camera recorded by the Swiss Federal Institute of Technology in Zurich, Switzerland, show how UW technology distinguishes among people by giving each person a unique color and number, then tracks them as they walk. *Swiss Federal Institute of Technology*



STUDENT NEWS

THIRD ANNUAL CAREER FAIR AND CASINO NIGHT A SUCCESS

The third annual UW EE Career Fair connected more than 200 students with industry representatives on January 20, 2015. Invited based on student input, more than 20 companies participated including Micron, Sequoyah Electric, Pico Computing, T-Mobile, Philips, Daimler, F5 Networks, Technical Systems Inc., Cota, Cypress Semiconductor, Hitachi Consulting, Keysight Technologies, Seattle City Light and Cowlitz PUD. Thanks to the networking opportunity, students often receive job offers following the completion of their degree or obtain an internship in a field of interest.

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