

**UNIVERSITY OF WASHINGTON**

**COMPUTER SCIENCE & ENGINEERING**

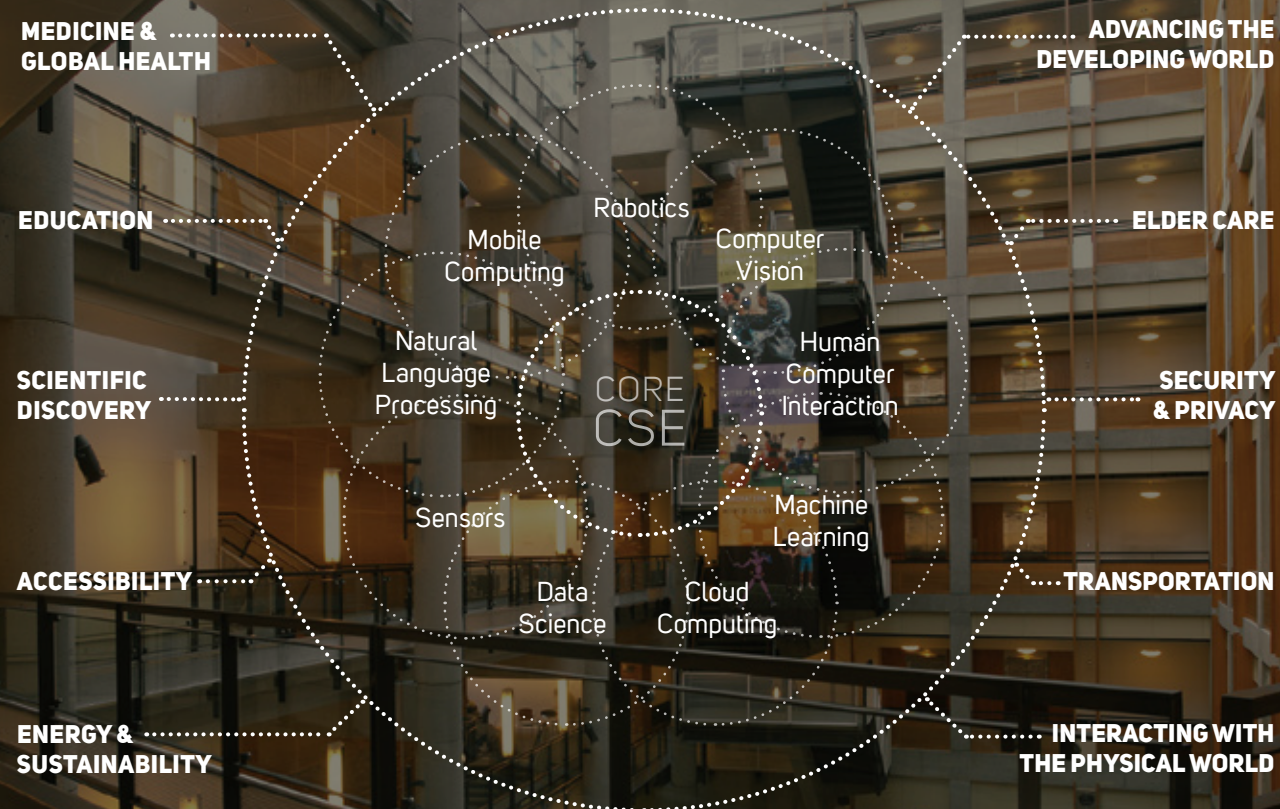
**CHANGING THE  
WORLD**



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## UW CSE'S 21ST CENTURY VIEW OF COMPUTER SCIENCE:

A field that is unique in its societal impact



UW CSE has led the way in positioning computer science as a discipline central to tackling critical national and global challenges. Our strong foundation in core computer science, coupled with our expertise in a broad set of emerging and interdisciplinary areas of the field, enables us to recruit world-class faculty and students who share this vision. Every day, UW CSE researchers are harnessing the power of computing to change the world.

**Advances in computer technology are transforming our world.**

**University of Washington Computer Science & Engineering is driving this transformation.**

Computing has the power to ignite radical, large-scale change. At UW CSE, we are revolutionizing the field, driven by a powerful vision of computing's expanding role in the modern university and in the modern world.

Our world-class faculty and student researchers are pushing technological boundaries and developing solutions to the most pressing problems in global development, health care, education, security, energy and more.

UW CSE has been instrumental in positioning the Northwest region at the forefront of computing innovation and in advancing multi-disciplinary collaborations to tackle humankind's greatest challenges. Here, we think outside the box and outside of laboratory and classroom walls.

Along with maintaining the highest standards of academic research and education, our faculty, students and alumni are generating global impact at a level that was unimaginable a decade ago.





# MEETING THE NEEDS OF UNDERSERVED Populations

**“THE USE OF OPEN DATA KIT HAS TRANSFORMED OUR APPROACH TO CONSERVATION IN AFRICA AND ENABLED US TO GREATLY ADVANCE OUR MISSION OF CREATING A WORLD WHERE PEOPLE, ANIMALS AND THE ENVIRONMENT CAN LIVE IN HARMONY.”**

*Jane Goodall, world-renowned primatologist*

**Through a powerful combination of emerging technologies, interdisciplinary expertise and entrepreneurial acumen, UW CSE works to improve the lives of people around the world. UW CSE is renowned for bringing game-changing technology tools to regions where infrastructure and economic opportunity lag far behind those of the developed world. Under the leadership of professor Richard Anderson in the Information & Communications Technology for Development (ICTD) Lab, UW CSE is committed to delivering innovative, culturally relevant solutions to people in developing communities around the globe.**

## **DATA COLLECTION & MANAGEMENT IN LOW-RESOURCE SETTINGS**

The Open Data Kit (ODK) is a suite of free and open-source mobile tools that was spearheaded by the late CSE professor Gaetano Borriello. ODK enables users in low-resource settings to easily collect, manage, and present data in meaningful and actionable ways, including places where paper records are still the norm.

ODK is in use in more than 40 countries around the world, both developed and developing, by humanitarian and conservation organizations such as the International Federation of Red Cross and Red Crescent Societies, the Jane Goodall Institute, the Carter Center and the Bill & Melinda Gates Foundation. It is in the hands of health care workers battling AIDS and infant mortality, preservationists fighting deforestation to protect sensitive wildlife habitat, election monitors witnessing the birth of fledgling democracies, and officials enforcing air quality standards—to name only a few of the high-impact ways people are using ODK. ODK even found its way onto the International Space Station: Astronaut Ronald Garan used it to monitor the Carbon for Water program, an initiative to reduce carbon emissions by more than two million tons annually while providing safe drinking water to four million people in Kenya.

After helping to launch the technology as students, UW CSE alumni Yaw Anokwa and Carl Hartung co-founded Nafundi, a company that supports the implementation of ODK applications in underserved communities across the globe.

## **DIGITAL FINANCIAL SERVICES FOR EMERGING MARKETS**

Building on the success of ODK, UW CSE recently launched a new Digital Financial Services research group that will draw upon the expertise of the ICTD Lab, Security and Privacy Research Lab, and other campus and external experts to increase the availability and adoption of digital financial services in underserved markets. With support from the Bill & Melinda Gates Foundation, UW CSE will accelerate the design and deployment of new technologies and tools that will yield dramatic improvements in efficiency, scalability, security and cost—bringing mobile banking solutions to people in some of the poorest regions on the planet.

UW CSE has a long and proud history in this area. As part of his Ph.D. thesis, alumnus Tapan Parikh, now on the faculty of University of California, Berkeley, developed a mobile phone-based architecture to support micro-finance in India—for which he was named “Humanitarian of the Year” by MIT Technology Review. Another alumnus, Kurtis Heimerl, is joining the faculty of UW CSE after developing Community Cellular, which enables the creation of independent, locally owned cellular networks in remote regions of the world.

Opposite page: UW CSE alumnus Yaw Anokwa (right) invites employees of a Ugandan non-profit to try out the ODK Collect tool, which is used to conduct surveys in rural communities.

This page: ODK has been instrumental in efforts to digitize medical records and fight the spread of HIV in sub-Saharan Africa.







# Creating Palm-Sized Health DIAGNOSTICS WITH LARGE-SCALE IMPACT

**The proliferation of smart phones with increasingly sophisticated sensors offers the opportunity to develop palm-sized health care solutions with large-scale impact. Thanks to the devices' ubiquity and relatively low cost, mobile health sensing is proving to be a powerful emerging tool for diagnosing and tracking medical conditions. Researchers in the UbiComp Lab, led by CSE & Electrical Engineering professor Shwetak Patel, and the Networks & Mobile Systems Lab, led by CSE professor Shyam Gollakota, are making full use of cutting-edge mobile and sensing technologies to address serious health challenges and improve outcomes for people everywhere.**

**“BY TEARING DOWN THE BARRIERS BETWEEN HARDWARE AND SOFTWARE, AND COMPUTER SCIENCE AND OTHER DISCIPLINES, WE ARE ENABLING NOVEL WAYS OF COMPUTATION, COMMUNICATION AND SENSING THAT WOULD NOT BE POSSIBLE IF RESEARCHERS WORKED IN THEIR SILOED FIELDS.”**

*Shyam Gollakota, Assistant Professor, UW Computer Science & Engineering*

## DETECTING NEWBORN JAUNDICE

Early detection of jaundice is essential to prevent permanent brain damage or death in vulnerable infants. To improve detection and intervention, UW CSE researchers developed BiliCam, a non-invasive, mobile system that uses a smart phone's camera to assess newborn bilirubin levels on location and in minutes. BiliCam is an effective screening tool that can be used to determine whether an infant requires the more expensive and invasive hospital-based blood testing that is the current standard for diagnosing jaundice.

In a clinical study of 100 newborns at the UW Medical Center, BiliCam performed as well as or better than the current blood-based screening method. When deployed, BiliCam will be a life-saving tool for parents and health care workers in developing countries, where the World Health Organization estimates 98 percent of all neonatal deaths occur.



## MONITORING LUNG FUNCTION

Hundreds of millions of people worldwide suffer from chronic respiratory diseases, which are among the major contributors to health care utilization. People with lung problems typically visit a doctor's office to measure their lung function using a spirometer, a device that measures the volume and speed of exhalation to determine levels of airway obstruction and typically costs more than \$500 USD.

To make the monitoring of chronic lung conditions less costly and more convenient, an interdisciplinary team led by UW CSE researchers developed SpiroSmart, a mobile phone-based application that uses the built-in microphone to analyze sound wave frequencies and determine the amount of air flow moving through the trachea and vocal tract. SpiroSmart, which requires the patient to simply blow air into the microphone, was shown in tests to be an effective solution that can increase patient compliance and monitoring. The system is currently deployed in clinics in the USA, India, and Bangladesh and used by hundreds of patients every week.

## DIAGNOSING SLEEP APNEA

Sleep apnea is a disorder involving temporary stoppage or shallowness of breathing during sleep that affects more than 18 million Americans. Diagnosis requires the expense and inconvenience of a polysomnography test, for which patients must stay overnight at a hospital or sleep clinic hooked up to special equipment that monitors their night-time breathing.

ApneaApp, the product of a collaboration between UW CSE and the UW Medicine Sleep Center, replaces the traditional test with a contactless smart phone app. The app transforms the phone into an active sonar system that emits frequency-modulated sound signals and listens to their reflections. Users simply place the phone next to the bed, and the app monitors the minute chest and abdomen movements caused by their breathing during sleep. In a clinical study of 37 patients, ApneaApp captured sleep apnea events as accurately as the polysomnography test between 95 and 99 percent of the time—promising a less invasive and more cost-effective way to screen for this potentially life-threatening condition.

Opposite page: UW CSE student Mayank Goel trains physicians at a clinic in Bangladesh on the use of SpiroSmart, a mobile app for monitoring lung function.

This page: UW CSE student Lilian de Greef and professor Shwetak Patel demonstrate BiliCam, a system for detecting newborn jaundice.



# SENSING AN OPPORTUNITY WITH the **INTERNET** of Things

**Over the coming years, sensors embedded in everyday objects will monitor and track everything from an individual's cholesterol levels to the structural safety of bridges. Increasingly sophisticated, ultra-low power sensors also can be used to build smarter systems—ones that will help humankind to use precious resources more efficiently. To enable exciting new capabilities in energy, health and a host of other applications, researchers in CSE professor Shyam Gollakota's Networks & Mobile Systems Lab, CSE & EE professor Shwetak Patel's UbiComp Lab, and CSE & EE professor Joshua Smith's Sensor Systems Lab are leading the charge to power the next generation of devices and harness the full potential of the Internet of Things.**

## **PULLING POWER OUT OF THIN AIR**

Finding ways to power next-generation devices efficiently poses a grand and previously unaddressed challenge for the computing community. With the anticipated proliferation of sensor-rich devices—both around us, and on our bodies—powering them becomes a key concern: wires are often not feasible, and batteries add weight, bulk and cost. Batteries also must be recharged or replaced, which is impractical on a large scale and in certain settings.

UW CSE researchers are devising ways to create self-sustaining systems that require no batteries and little or no human intervention. Devices using Ambient Backscatter harvest energy from radio signals in the air and communicate with each other by “backscattering” (or reflecting) existing TV and radio wireless signals. Regardless of their distance from the transmitting tower, receiving devices could pick up signals at a rate of one kilobit per second between devices placed 2.5 feet apart outdoors and 1.5 feet apart indoors in prototype testing.

Wi-Fi Backscatter similarly uses existing radio frequency signals as a power source, plus it reuses existing Wi-Fi signals for Internet connectivity. Researchers invented an ultra-low power circuit, or tag, with an antenna that can send messages to conventional Wi-Fi devices on the Internet. Using off-the-shelf Wi-Fi devices, the research team demonstrated communication rates of one kilobit per second at a distance of just over 6 feet.

Power over Wi-Fi (PoWiFi) taps harvestable energy from Wi-Fi routers to power devices without degrading Wi-Fi signal quality. UW CSE and EE researchers invented a way to keep transmitters – and thus power – running continuously, rather than only when they had messages to send. To demonstrate, the team used Wi-Fi energy to power a tiny VGA camera capable of capturing an image every 35 minutes from a distance of 17 feet. The PoWiFi system was named one of the most innovative technologies of 2015 by Popular Science magazine as part of its “Best of What's New” awards.

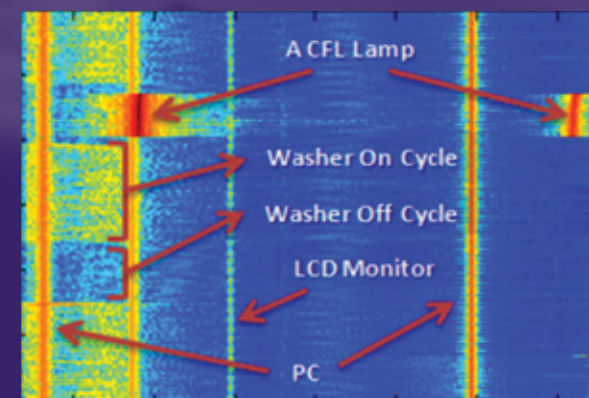
## **SMART SYSTEMS FOR SMARTER ENERGY USE**

To empower consumers to reduce natural resource consumption, UW CSE researchers are applying their expertise in sensing, embedded systems and human-computer interaction to develop online single-point sensors that measure home energy and water use. What sets these systems apart is their ability to recognize the unique signature given off by every appliance, electronic device, faucet and fixture.

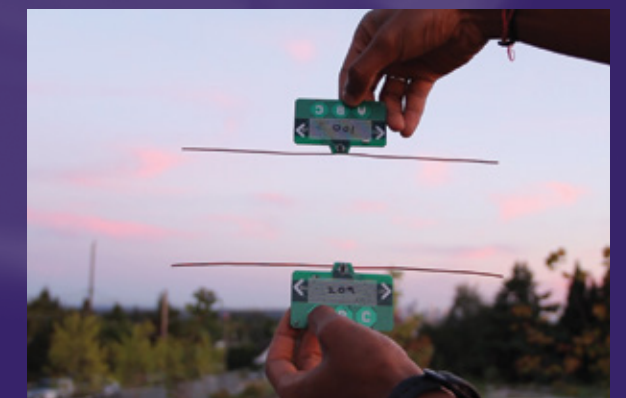
ElectriSense is a single plug-in sensor that detects individual electrical events by the unique electrical noise signal each emits. The system uses machine learning techniques to distinguish between each light switch, appliance, and electronic device and can measure the energy consumed by each—enabling consumers to make more informed choices about their energy use. HydroSense is a pressure sensor that measures water usage by individual fixture based on an analysis of the unique acoustic, vibration and pressure signatures of its water flow, using signal recognition software to distinguish between simultaneous events. The system could reduce home water usage by between 10 and 25 percent and save each household \$50 to \$120 USD per year.

While ElectriSense tracks how much energy a particular appliance gobbles up, no one knows who flicked the switch. But they will with MagnifiSense, a new wearable technology that senses what devices and vehicles a specific user interacts with throughout the day by monitoring the distinct electromagnetic radiation signatures. The technology promises a variety of uses, from tracking an individual's carbon footprint, to enabling new smart home applications, to assisting with elder care.

To power our smarter homes, UW CSE researchers thought outside the fuse box with SNUPI (Sensor Network Utilizing Powerline Infrastructure), a building-wide wireless network platform for low-power sensors. In a traditional network, data travels over the air between sensor nodes and base station receiver, and the power required to complete the transmission limits the battery life of the sensors. By contrast, SNUPI uses a building's entire powerline network as its receiving antenna. Sensor nodes couple to the nearest powerline in the walls and transmit data wirelessly to the base station. Because the transmit power is so low, SNUPI nodes can operate for decades on a single coin cell battery.



Researchers in UW CSE's UbiComp Lab developed ElectriSense to track power usage at the individual appliance level.



Ambient Backscatter harvests energy from radio signals in the air to power battery-free devices.





# Safeguarding SECURITY & PRIVACY IN A CONNECTED WORLD

As progress continues toward our increasingly Internet-connected world, previously unconsidered vulnerabilities come to light: attackers could remotely take over the controls of a car, tamper with the settings of an implanted medical device, or hijack remotely controlled robots. No longer in the realm of science fiction, new Internet-enabled devices require new solutions when it comes to ensuring user privacy and safety. Enter researchers from UW CSE's Security and Privacy Research Lab led by CSE professors Yoshi Kohno and Franzi Roesner, who aim to make embedded computer systems safe as well as smart.

## SECURITY OF IMPLANTABLE MEDICAL DEVICES

UW CSE researchers teamed up with colleagues at the University of Michigan and Harvard Medical School to analyze the security of implantable medical devices. Using an inexpensive software radio, the team intercepted signals sent from an implantable cardiac defibrillator that is designed to allow health care practitioners to monitor a patient's condition and wirelessly adjust therapy settings. The researchers discovered that they could obtain details about a hypothetical patient, including name, diagnosis, date of birth, and real-time information on the patient's condition, that should be private.

Next, the researchers exploited the device's vulnerability to control its functions, such as disabling the stored settings to render it incapable of responding to a cardiac event. They also were able to use the device to deliver a large shock that should not happen under normal circumstances—a shock that served as a wakeup call to manufacturers and the medical community. Despite these results, the researchers stress that the benefits of these devices far outweigh the risks, and patients should continue to obtain these devices if medically recommended. After identifying the potential vulnerabilities, CSE researchers and colleagues in the UW iSchool, Seattle Pacific University and Harvard Medical School produced guidelines for the design of future devices that would safeguard patients against such threats.

## SECURITY OF MODERN AUTOMOBILES

UW CSE researchers and colleagues at the University of California, San Diego were among the first to sound the alarm over the security of modern motor vehicles after discovering that the increasingly complex and connected computers found in today's automobiles are susceptible to attack. Using advanced telematics units – such as OnStar – that are now common in many cars, the researchers were able to gain access to the electronic control unit using a mobile phone. They were then able to insert malicious software that allowed them to override vehicle controls, such as the brakes and the ignition, from afar—a potentially life-threatening scenario in real life.

The team's work, which they recently demonstrated in a segment on CBS' *60 Minutes*, has inspired follow-on research and compelled automobile manufacturers and policy makers to focus on securing vehicle systems for the safety of everyone on the road.

Opposite page: UW CSE's Privacy and Security Research Lab was among the first to address security vulnerabilities of modern systems, from automobiles to implantable medical devices. Here, student Peter Ney (left) and research scientist Ian Smith conduct field research for a new project examining the timely topic of wireless security and privacy.

This page: UW CSE professor Franzi Roesner (left) works with students Kiron Lebeck (center) and Lucy Simko in the Security and Privacy Research Lab.



## PROACTIVE POLICY FOR EMERGING TECHNOLOGIES

While no evidence suggests that the safety loopholes in cars or implantable devices have been exploited by criminals, researchers at the UW are taking proactive measures to ensure that potential threats are identified and neutralized as new technologies emerge. With support from Microsoft Corporation, UW CSE, the iSchool and the School of Law have established the Tech Policy Lab to provide a rigorous research foundation and evidence-based recommendations to aid the development of a sound framework governing emerging technologies where none currently exists. Among the first fields to be studied: augmented reality, an area in which technology is used to extend human capability in many new directions and for which public policy is not keeping pace with the speed of innovation.

**“IN THE 1970s THE BIONIC WOMAN WAS A DREAM, BUT MODERN TECHNOLOGY IS MAKING IT A REALITY. PEOPLE WILL HAVE SOPHISTICATED COMPUTERS WITH WIRELESS CAPABILITIES IN THEIR BODIES. OUR GOAL IS TO MAKE SURE THOSE DEVICES ARE SECURE, PRIVATE, SAFE AND EFFECTIVE.”**

*Yoshi Kohno, Short-Dooley Professor and Co-director, Security and Privacy Research Lab, UW Computer Science & Engineering*





# Revolutionizing EDUCATION

## THROUGH PERSONALIZED LEARNING

Researchers in UW CSE's Center for Game Science (CGS) have set their sights on making learning adaptable, efficient, effective and, most of all, engaging for students. The theme of personalized learning is central to the vision of CSE professor and CGS director Zoran Popović and inspired the creation of a startup company, Enlearn, to help make that vision a reality in classrooms around the country.



### GAMES FOR LEARNING

Refraction is the award-winning game developed by CGS to teach fractions to children between 9 and 11 years of age. The game captured the Grand Prize in the Disney Learning Challenge at SIGGRAPH 2010 and won "Best Work in the Primary School Category" in the 38th NHK Japan Prize, an international competition for educational media. In announcing the latter, jurors described Refraction as "a brilliant solution to bring mathematical concepts to life in a rich environment that is fundamentally exciting while at the same time is rooted in pure education."

Other learning games developed at the center and made available to teachers, parents and students include RiddleBooks, which sharpens math and reading skills; Treefrog Treasure, which teaches fractions and numberline concepts; and Creature Capture, which builds understanding of whole and fractional numbers.

### RESPONSIVE EDUCATION PLATFORMS

Popović founded the non-profit startup Enlearn to develop and broadly distribute a new, adaptive education platform that is capable of learning and growing based on student and teacher interactions. The Enlearn platform evolves using real-time data based on a comprehensive set of variables, including information about the students, teachers, text, and time of day. It then uses the data to recommend new individual learning paths for each student as well as ways to optimize learning for small groups of students or an entire classroom.

Pilot testing in the Seattle area and in Minnesota public schools has demonstrated Enlearn's advantages over a paper-based classroom, as measured by the number of problems solved, frequency of teacher assistance required for struggling students, and improvement in collective scores.

**"THE TEACHER CAN SEE IN REAL TIME THE STATE OF THE ENTIRE CLASS AND MAKE INSTANT DECISIONS ON WHICH SUBGROUPS OF STUDENTS SHOULD BE WORKING JOINTLY ON WHICH SPECIALIZED ACTIVITY. THE IDEA IS NOT TO REPLACE TEACHERS, BUT TO "AMPLIFY THEM."**

*Zoran Popović, Director, UW Center for Game Science and Founder & Chief Scientist, Enlearn*

Opposite page, top: Young visitors to the Pacific Science Center enjoy playing Refraction and Treefrog Treasure during Science Expo Day in Seattle.

Opposite page, bottom: In the game Refraction, students master fractions by assembling lasers to power spaceships and rescue lost animals.

## GAMING FOR GOOD:

### UNRAVELING THE MYSTERIES OF DISEASE THROUGH CITIZEN SCIENCE

In 2011, thousands of gamers scattered across the globe—most lacking any biochemistry background—pieced together the structure of a protein-cutting enzyme related to the AIDS virus that had eluded scientists for years. And they did it in just three weeks by playing Foldit, an online game designed by UW CSE's Center for Game Science and the UW Department of Biochemistry.

Foldit engages "citizen scientists" in tackling problems related to the three-dimensional structure of proteins, or how they "fold." By understanding how proteins fold, researchers will gain new insights into how they function—potentially unlocking new ways to combat diseases, create new and more effective vaccines, and even develop novel biofuels. For particularly difficult proteins, Foldit players have outperformed the best known computational methods. Their achievements were reported in Nature, marking the first time the leading scientific journal has published a paper boasting over 57,000 authors.

By playing Foldit and other "citizen science" games developed at UW CSE, a worldwide, volunteer community of gamers is putting their skills to work for the scientific good every day.





## A MOVING STORY: REVERSING NEUROLOGICAL DAMAGE WITH NEXT-GENERATION DEVICES

Over the coming decade, groundbreaking research at the intersection of computing and neuroscience could enable people suffering from paralysis to move again. That's one of the goals of the Center for Sensorimotor Neural Engineering (CSNE), a cross-disciplinary collaboration among leading institutions that is housed at the University of Washington and funded by the National Science Foundation.

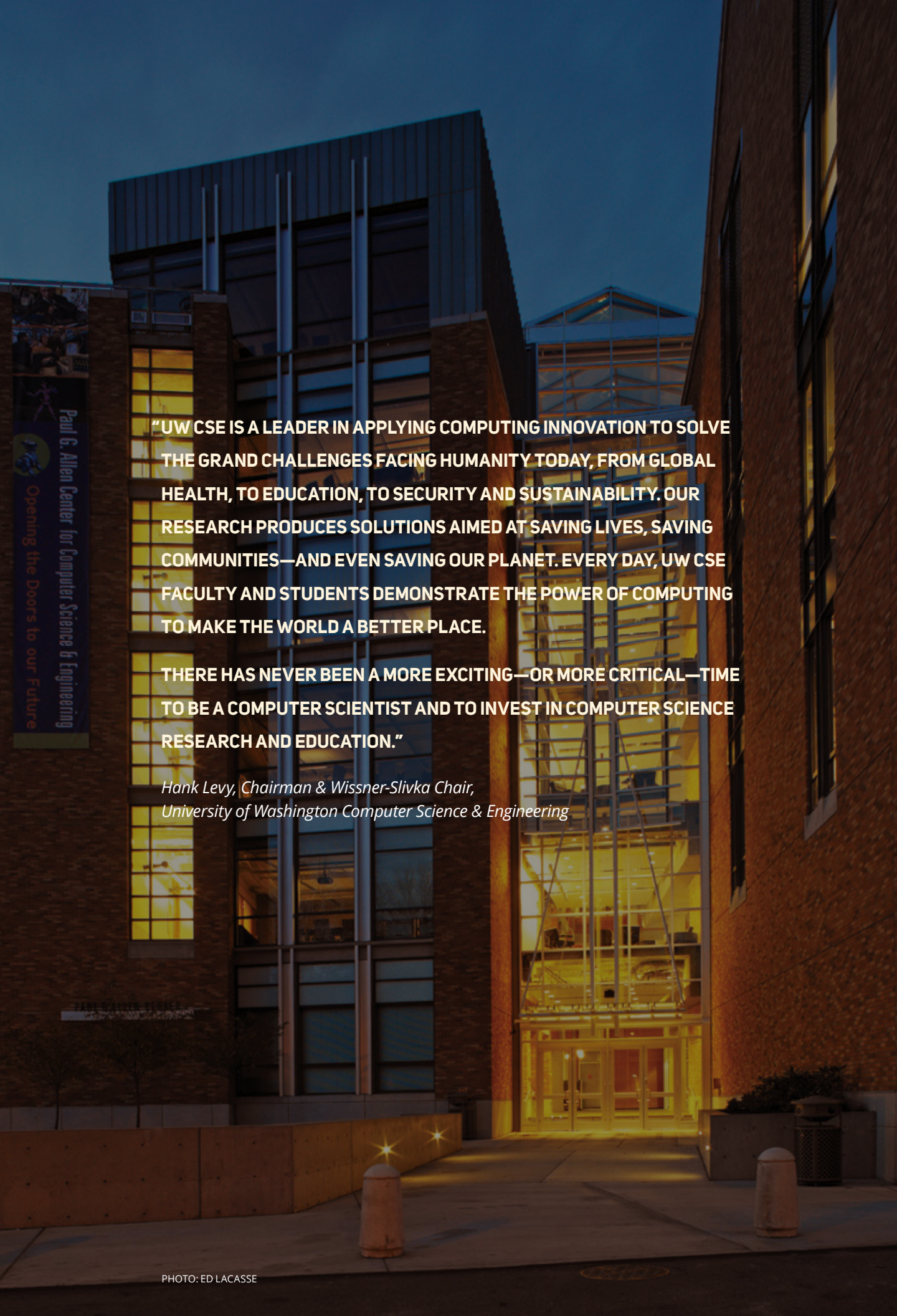
First established in 2011 by former CSE Professor Yoky Matsuoka, today CSNE is directed by CSE Professor Raj Rao, an expert on brain-computer interfaces. Rao and his colleagues are developing bi-directional brain-computer interfaces that can interpret and wirelessly transmit brain signals. The technology is being used to create next-generation

implantable devices that can bypass damaged regions of the nervous system to restore movement, promote neuroplasticity and support rehabilitation in patients who have suffered spinal cord injury or stroke. CSNE researchers are also working to improve existing implantable technologies—for example, deep brain simulators used to treat people with Parkinson's disease—to reduce negative side effects and cut down on the number of replacement surgeries required for patients living with such devices.

Thanks to UW CSE and its partners, patients may one day be able to not only bypass damage from injury and illness, but reverse it.



Under the leadership of UW CSE professor Raj Rao, the Center for Sensorimotor Neural Engineering is conducting groundbreaking research in brain-computer interfaces.



**"UW CSE IS A LEADER IN APPLYING COMPUTING INNOVATION TO SOLVE THE GRAND CHALLENGES FACING HUMANITY TODAY, FROM GLOBAL HEALTH, TO EDUCATION, TO SECURITY AND SUSTAINABILITY. OUR RESEARCH PRODUCES SOLUTIONS AIMED AT SAVING LIVES, SAVING COMMUNITIES—AND EVEN SAVING OUR PLANET. EVERY DAY, UW CSE FACULTY AND STUDENTS DEMONSTRATE THE POWER OF COMPUTING TO MAKE THE WORLD A BETTER PLACE.**

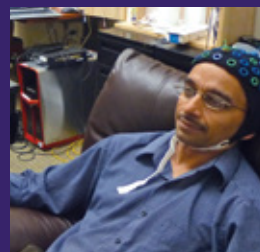
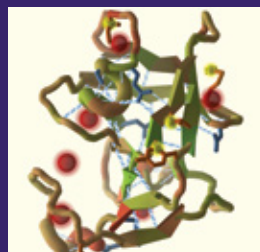
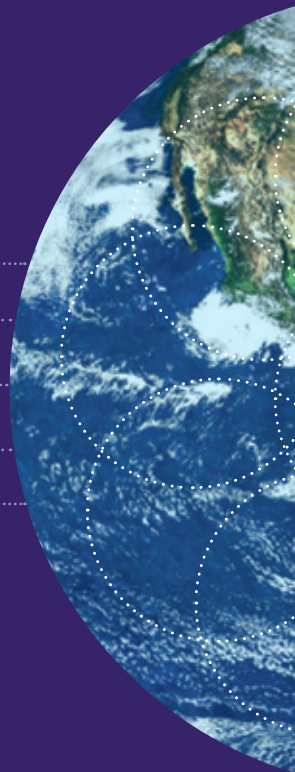
**THERE HAS NEVER BEEN A MORE EXCITING—OR MORE CRITICAL—TIME TO BE A COMPUTER SCIENTIST AND TO INVEST IN COMPUTER SCIENCE RESEARCH AND EDUCATION."**

*Hank Levy, Chairman & Wissner-Slivka Chair,  
University of Washington Computer Science & Engineering*



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Computer Science & Engineering  
University of Washington  
Box 352350  
Seattle, WA 98195-2350