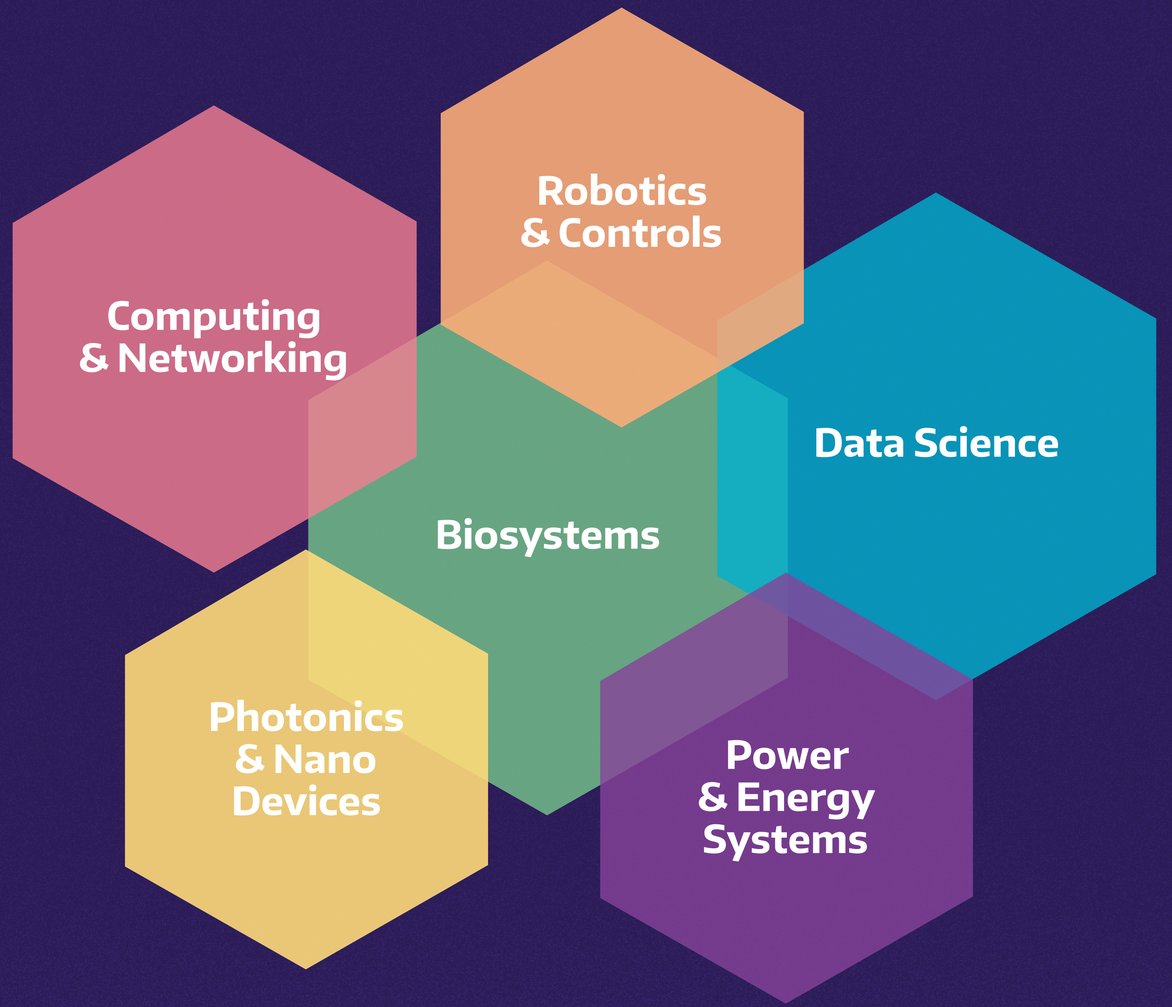
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UNIVERSITY of WASHINGTON

UW ECE Faculty Research Areas

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ECE Research Areas:

- Biosystems >
- Computing & Networking >
- Data Science >
- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >



UW ECE's Mission:

We educate and develop tomorrow's leaders to solve the world's biggest problems.

We are committed to merit-driven diversity for broadening participation in STEM.

We provide our students with a strong technical foundation, refined communication skills and group project work.

We hire and retain exceptional faculty to develop an innovation ecosystem.

We provide electrical and computer hardware fundamentals and promote an entrepreneurial mindset.

We foster an innovation hub by partnering with industry, government and regional sponsors.

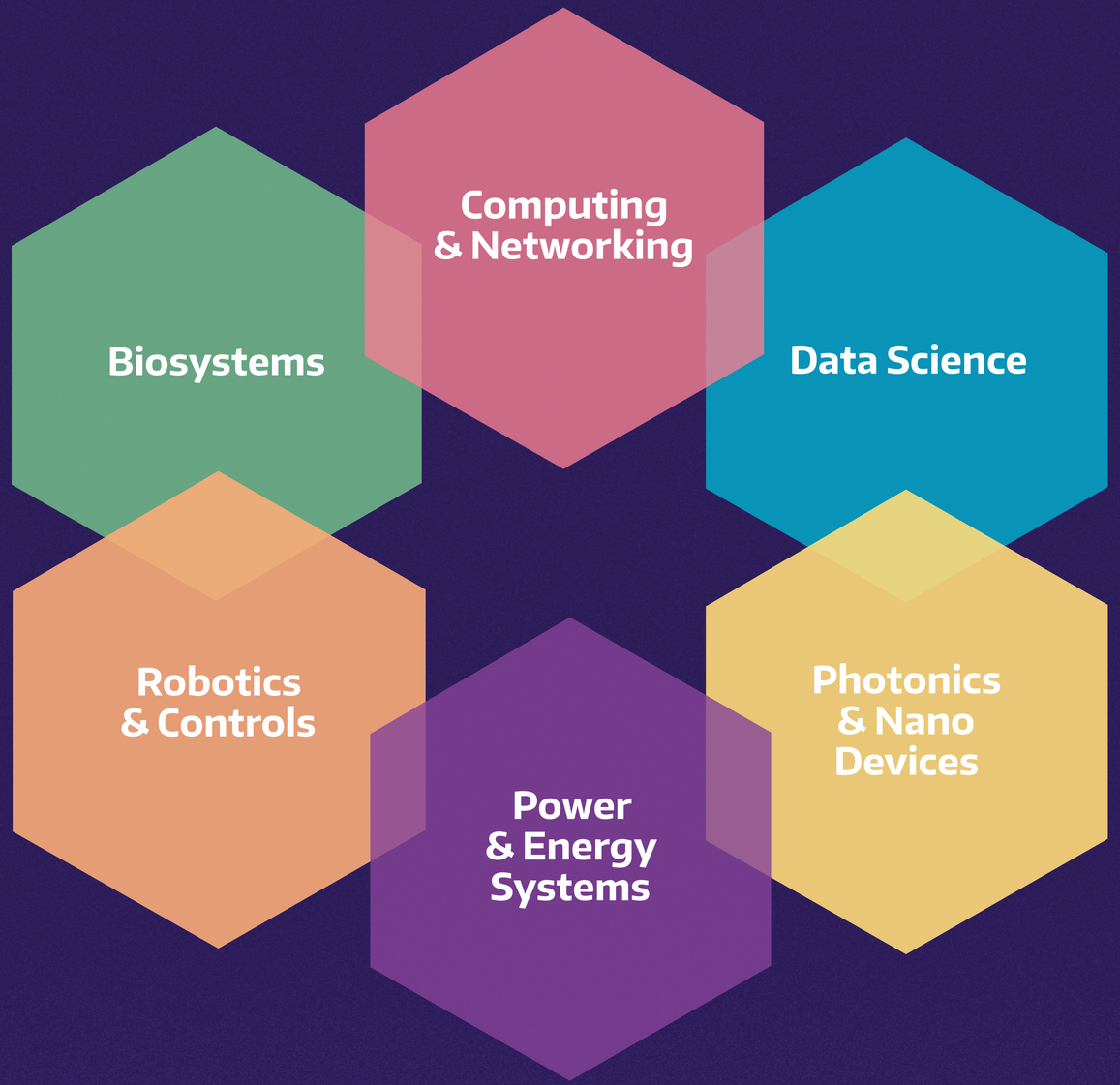
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UW ECE Faculty Research Areas

Click on a research area below or in the sidebar to view faculty members in each area.

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- Power & Energy Systems >
- Robotics & Controls >



UW ECE RESEARCH AREAS

ELECTRICAL & COMPUTER ENGINEERING
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Biosystems

Click on a faculty member to view their research.


Les Atlas


Jeffrey Bilmes


Samuel Burden


Blake Hannaford


Howard Chizeck


Eric Klavins


Chet Moritz


Amy Orsborn


Shwetak Patel


John Raiti


Matt Reynolds


Chris Rudell


Visvesh Sathe


Georg Seelig


Linda Shapiro


Eli Shlizerman


Joshua Smith


Azadeh Yazdan-Shahmorad

ECE Research Areas:

- Biosystems >
- Computing & Networking >
- Data Science >
- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >

Overview:

Biosystems research in UW's Department of Electrical & Computer Engineering is a highly collaborative endeavor. Our faculty focus on four areas of Biosystems research: synthetic & systems biology, neural engineering, biomedical devices, and mobile health. Many of our faculty hold secondary appointments and work closely with collaborators from other departments including Bioengineering, Computer Science and Engineering, Biology, Genome Sciences, Applied Mathematics, and the UW Medical Center. Our Biosystems faculty work with many cross-disciplinary institutes such as the eScience Institute, the NSF Engineering Research Center for Sensorimotor Neural Engineering, the Institute for Protein Design, the Bloedel Hearing Research Center and the University of Washington Institute for Neuroengineering.

Learn more about our research **here.**

ELECTRICAL & COMPUTER ENGINEERING
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Computing & Networking

Click on a faculty member to view their research.


Payman Arabshahi


Linda Bushnell


Scott Hauck


Rania Hussein


Sreeram Kannan


Yasuo Kuga


Shwetak Patel


Radha Poovendran


James Ritcey


Sumit Roy


Chris Rudell


Visvesh Sathe


Michael Taylor


Baosen Zhang

ECE Research Areas:

- Biosystems >
- Computing & Networking >
- Data Science >
- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >

Overview:

Computing & Networking research in UW's Department of Electrical & Computer Engineering is includes computer architecture and computer system engineering, VLSI, embedded computing, wireless networks, and wireless communication research. Several of UW ECE's Computers and Networking faculty hold joint and secondary appointments in computer science and engineering and teach jointly in the Electrical & Computer Engineering and Computer Science & Engineering departments.

Learn more about our research **here.**

ELECTRICAL & COMPUTER ENGINEERING
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Data Science

Click on a faculty member to view their research.


Les Atlas


Jeffrey Bilmes


Maryam Fazel


Hannaneh Hajishirzi


Rania Hussein


Jenq-Neng Hwang


Sreeram Kannan


Katrin Kirchhoff


Brian Nelson


Mari Ostendorf


Shwetak Patel


Radha Poovendran


Eve Riskin


Linda Shapiro


Eli Shlizerman


Ming-Ting Sun

ECE Research Areas:

- Biosystems >
- Computing & Networking >
- Data Science >
- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >

Overview:

Data Sciences are fundamentally transforming nearly every area of engineering, science, and society. The University of Washington's Electrical & Computer Engineering faculty are making fundamental contributions to many different areas of data sciences, including machine learning, AI, optimization, information theory, computer vision, and speech and natural language processing. Many of our data sciences faculty hold secondary appointments in applied mathematics, computer science and engineering, bioengineering, and other departments, and are active participants in cross-disciplinary institutes such as UW's eScience Institute, the Allen Institute of Artificial Intelligence and the Bloedel Hearing Research Center.

Learn more about our research **here.**

ELECTRICAL & COMPUTER ENGINEERING
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Photonics & Nano Devices

Click on a faculty member to view their research.

ECE Research Areas:

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- Data Science >
- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >


M.P. Anantram


Karl Böhringer


Bruce Darling


Scott Dunham


Kai-Mei Fu


Mo Li


Lih Lin


Arka Majumdar


Alex Mamishev


Sajjad Moazeni


Matt Reynolds


Joshua Smith


Denise Wilson

Overview:

Photonics and Nano Devices Research at UW ECE includes quantum electronics, nanoscale optics, novel photon sources, and optical metamaterials, with applications in quantum science, imaging, biomedical sensing, and other areas. Our faculty work closely with colleagues in the Department of Physics and several faculty hold joint and secondary appointments in Physics.“Many ECE faculty are members of the Institute for Nano-Engineered Systems (NanoES), a NSF National Nanotechnology Coordinated Infrastructure (NNCI) node that hosts the Washington Nanofabrication Facility (WNF) to support academic institutions and companies throughout the Pacific Northwest and beyond in designing and fabricating nanoscale materials, structures, devices and systems.

Learn more about our research **here.**

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

Power & Energy Systems

Click on a faculty member to view their research.


Richard Christie


Scott Dunham


Brian Johnson


Daniel Kirschen


Alex Mamishev


Joshua Smith


Baosen Zhang

ECE Research Areas:

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- Computing & Networking >
- Data Science >
- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >

Overview:

Power and Energy Systems research at UW ECE includes interdisciplinary work at all energy scales, ranging from nanowatts to gigawatts. Our faculty are active in smart grid, integration of renewable energy sources, grid security, energy economics, and solar and electromagnetic energy harvesting. ECE faculty are leaders in the Clean Energy Institute and work with local utilities and grid systems operators.

Learn more about our research **here.**

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

Robotics & Controls

Click on a faculty member to view their research.


Samuel Burden


Linda Bushnell


Howard Chizeck


Maryam Fazel


Blake Hannaford


Eric Klavins


Alex Mamishev


John Raiti


Lillian Ratliff


Matt Reynolds


Georg Seelig


Eli Shlizerman


Baosen Zhang

ECE Research Areas:

- Biosystems >
- Computing & Networking >
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- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >

Overview:

UW's **Robotics and Controls** researchers are leaders in the areas of surgical and bio-robotics, haptics, smart cities, and network control systems. They collaborate with and hold secondary appointments in computer science and engineering, bioengineering, and the UW Medical Center, and are active participants in research centers such as the Center for Sensorimotor Neural Engineering.

Learn more about our research **here.**

ELECTRICAL & COMPUTER ENGINEERING
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Eric Klavins // Biosystems; Robotics and Controls

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- Robotics & Controls >



Eric Klavins
Professor and Chair of Electrical and Computer Engineering
Adjunct in Paul Allen School of Computer Science
Adjunct in Bioengineering
Director, Center for Synthetic Biology
Research Theme: Control systems, synthetic biology, protein engineering.
Office: 101 ECE **| Email**: klavins@uw.edu
Research Webpage: https://klavinslab.org

Education

- BS in Computer Science and Engineering, San Francisco State University, 1996.
- MS in Computer Science and Engineering, University of Michigan, 1998.
- PhD in Computer Science and Engineering, University of Michigan, 2001.
- Postdoctoral Scholar, California Institute of Technology, 2001-2003.

Notable Publications

- J. Maguire, H. Haddox, D. Strickland, S. Halabiya, B. Coventry, M. Cummins, D. Thieker, E. Klavins, F. DiMaio, D. Baker, and B. Kuhlman, **Perturbing the energy landscape for improved packing during computational protein design**, *Authorea*. 2020.
- N. Panpradist, I. A. Beck,, J. Vrana, N. Higa, D. McIntyre, P. S. Ruth, I. So, E.C. Kline, R. Kanthula, Annie Wong-On-Wing, J. Lim, D. Ko, R. Milne, T. Rossou, U. D. Feuch, M. Chung, G. Jourdain, N. Ngo-Giang-Huong, L. Laomanit, J. Sori, J. Lai, E. Klavins, L. M. Frenkel and B. R. Lutz, **OLA-Simple: A software-guided HIV-1 drug resistance test for low-resource laboratories**, *EBioMedicine*. 2019.
- A. Khakhar, A. R Leydon, A. C. Lemmex, E. Klavins, and J. L. Nemhauser, **Synthetic hormone-responsive transcription factors can monitor and re-program plant development**, *eLIFE*. 2018.
- D. A. Younger, S. Berger, D. Baker and E. Klavins, **High-Throughput Characterization of Protein-Protein Interactions by Reprogramming Yeast Mating**, *Proceedings of the National Academy of Science*. 2017.
- M. Gander, J. Vrana, W. Voje, J. Carothers, and E. Klavins, **Digital logic circuits in yeast with CRISPR/dCas9 NOR gates**, *Nature Communications*. 2017.

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Eric Klavins // Biosystems; Robotics and Controls

ECE Research Areas:

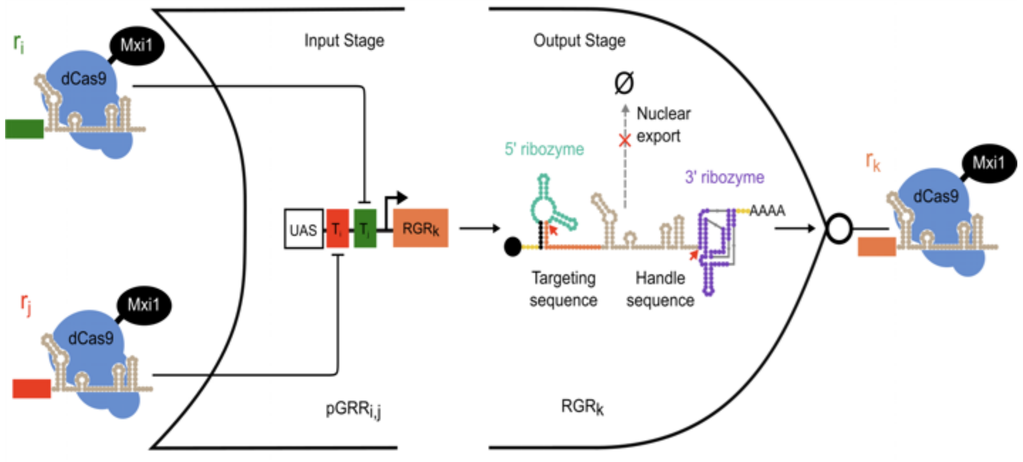
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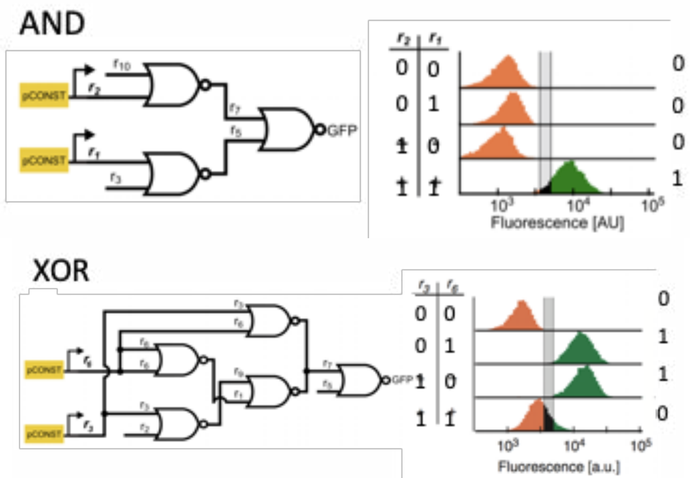
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- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >

Klavins
Project #1



Large Synthetic Gene Circuits in Yeast





Publications: M. Gander, J. Vrana, W. Voje, J. Carothers, and E. Klavins, **Digital logic circuits in yeast with CRISPR/dCas9 NOR gates**, *Nature Communications*. 2017.
Funding: Semiconductor Research Corporation, NSF.
Collaborators: James Carothers, UW Chemical Engineering.

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Eric Klavins // Biosystems; Robotics and Controls

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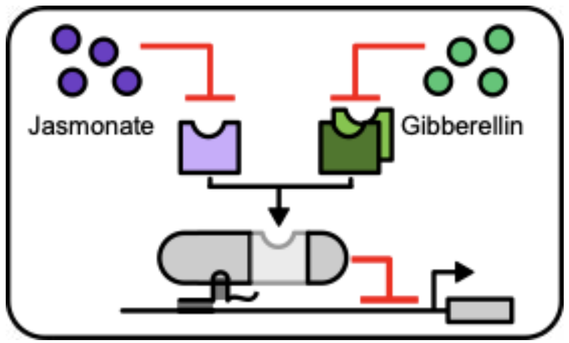
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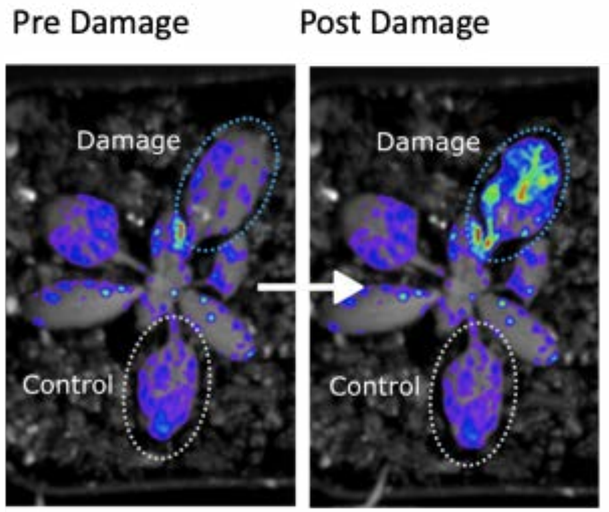
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- Robotics & Controls >

Klavins
Project #2



Genetically Reprogramming Plants





Custom designed CRISPR Transcription factors respond to plant hormones

- Jasmonate isoleucine – Insect herbivory triggered defense
- Salicylic acid – Microbial infection triggered hyper-sensitive response
- Gibberellin – Flowering, Germination
- Strigolactone – Branching, Mycorrhizal colonization
- Ethylene – Fruit ripening
- Karrikin – Smoke triggered, Germination

Publications: A. Khakhar, A. R Leydon, A. C. Lemmex, E. Klavins, and J. L. Nemhauser, **Synthetic hormone-responsive transcription factors can monitor and re-program plant development**, *eLIFE*. 2018.

Funding: NSF.

Collaborators: Jennifer Nemhauser, UW Biology.

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Eric Klavins // Biosystems; Robotics and Controls

ECE Research Areas:

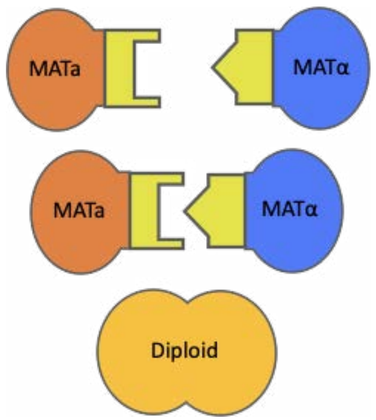
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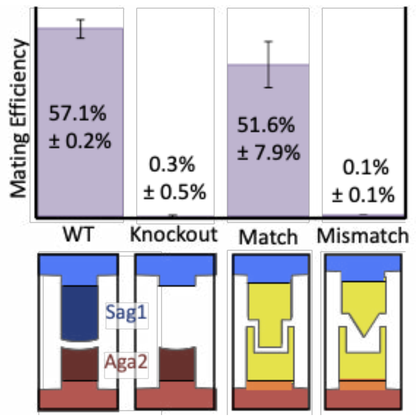
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Klavins
Project #2

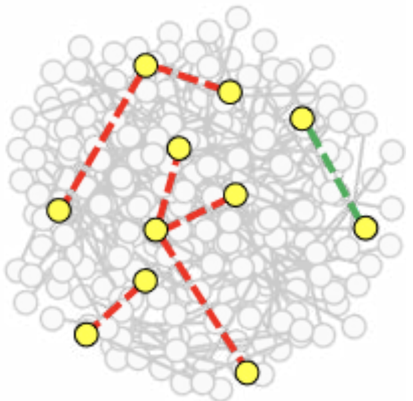


Characterizing Protein Interactions









The **Alpha-Seq** technology can be used to screen millions of protein-protein interactions in a single test tube, with applications to protein engineering and drug screening.

Publications: D. A. Younger, S. Berger, D. Baker and E. Klavins, **High-Throughput Characterization of Protein-Protein Interactions by Reprogramming Yeast Mating**, *Proceedings of the National Academy of Science*. 2017.
Funding: NSF, CoMotion, School of Business, NIH.
Collaborators: David Baker, Institute for Protein Design. David Younger, A-Alpha Bio.

ELECTRICAL & COMPUTER ENGINEERING
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Eric Klavins // Biosystems; Robotics and Controls

ECE Research Areas:

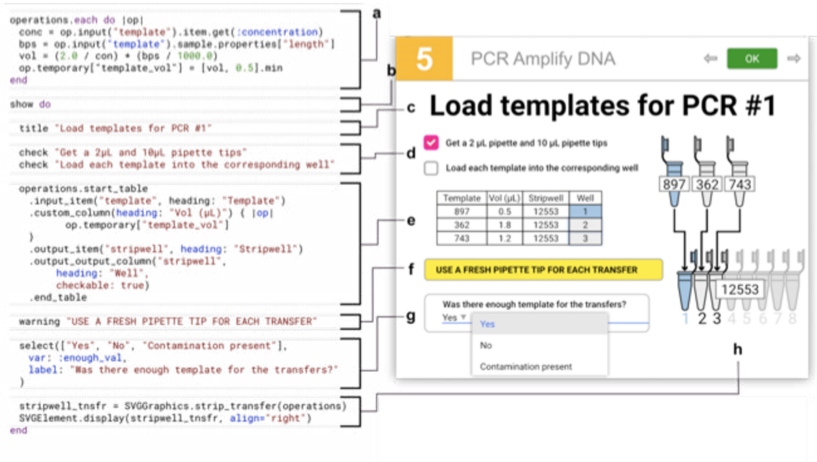
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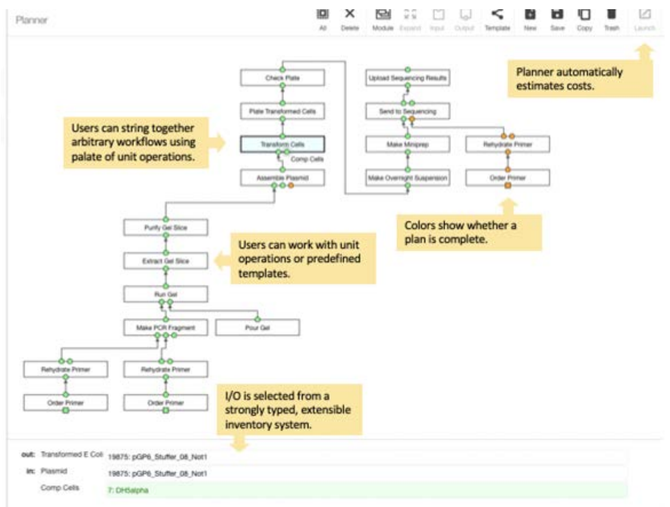
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- Power & Energy Systems >
- Robotics & Controls >

Klavins
Project #2



Automating the Lab





The **Aquarium** system provides a computer aided design framework for experimental lab work. It is used across the world in bio-foundries, testing facilities, DIY bio labs, educational settings, and low-resource clinics.

Publications: Web page: https://aquarium.bio/
N. Panpradist, I. A. Beck,, J. **Vrana**, et al. **OLA-Simple: A software-guided HIV-1 drug resistance test for low-resource laboratories**, *EBioMedicine*. 2019.
Funding: NSF, DARPA, CoMotion.
Collaborators: David Baker, Institute for Protein Design; Barry Lutz, UW Bioengineering; Steve Hasses Duke; Douglas Densmore, Boston University; Ron Weiss, MIT, and many others.

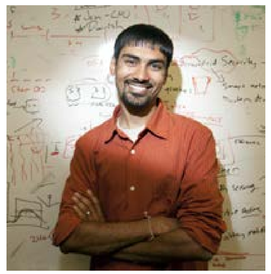
ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

Shwetak Patel // Biosystems; Computing & Networking; Data Science

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Shwetak Patel
WRF Entrepreneurship Endowed Professor, Computer Science & Engineering and Electrical & Computer Engineering
Research Theme: Ubiquitous computing, sensing, health, embedded systems
Office: CSE650 | Email: shwetak@uw.edu

Education

- BS. Computer Science, Georgia Institute of Technology, 2003
- PhD. Computer Science, Georgia Institute of Technology, 2008

Notable Awards and Recognition

- MacArthur Fellow (2011), Sloan Fellow (2012), ACM Fellow (2016), Microsoft Research Faculty Fellow (2011)
- ACM Prize in Computing (2018), TR-35 Award (2009), NAE Gilbreth Award (2016)
- PECASE (2016), NSF Career (2013)
- 30+ best paper awards and 3 test-of-time awards

Notable Publications

- Wang, E.J., Li, W., Hawkins, D., Grenheimer, T., Norby-Slycord, C., Patel, S.N., HemaApp: Non-invasive Blood Screening of Hemoglobin using Smartphone Cameras. Proceedings of the ACM International Conference on Ubiquitous Computing (Ubicomp 2016). 2016.
- Larson, E.C., Goel, M., Boriello, G., Heltshe, S., Rosenfeld, M., Patel, S.N. SpiroSmart: Using a Microphone to Measure Lung Function on a Mobile Phone. In the Proceedings of the ACM International Conference on Ubiquitous Computing (Ubicomp 2012). 2012.
- Gupta, S., Reynolds, M.S., Patel, S.N. ElectriSense: Single-Point Sensing Using EMI for Electrical Event Detection and Classification in the Home. In the Proceedings of the ACM International Conference on Ubiquitous Computing (Ubicomp 2010). pp. 139-148. 2010.
- Koscher, K., Czeskis, A., Roesner, F., Patel, S., Kohno, T., Checkoway, S., McCoy, D., Kantor, B., Anderson, D., Shacham, H., Savage, S. Experimental Security Analysis of a Modern Automo-bile. In the Proceedings of the 31st IEEE Symposium on Security and Privacy. pp. 447-462. 2010.

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

Visvesh Sathe // Biosystems; Computing & Networking; Data Science

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Visvesh S. Sathe
Research Theme: Energy-efficient computing, power management, clocking, runtime control and optimization.
Office: M314 ECE **| Email**: sathe@uw.edu
Research Webpage: https://psylab.ece.uw.edu/

Education

- B.Tech. in Electrical Engineering, Indian Institute of Technology, 2001.
- PhD. in Electrical Engineering and Computer Sciences, University of Michigan, Ann Arbor, 2007

Notable Publications

- X. Sun, F. Rahman, R. Pamula, S. Kim, N. John, V. S. Sathe, “An All-digital Fused PLL-Buck Architecture for 82% Average Vdd-Margin Reduction in a 0.6-to-1.0V Cortex-M0 Processor*”, IEEE Journal of Solid-State Circuits (JSSC)*, vol. 54, no. 11, pp.3215-3225 Sep. 2019.
- F. Rahman, R. Pamula, A. Boora, X. Sun and V. S. Sathe, “Computationally-Enabled Total Energy Minimization under Performance Requirements for a Voltage Regulated 0.38–0.58V Microprocessor in 65nm CMOS” in *IEEE J. Solid-State Circuits (JSSC),* vol 55, no. 2, pp. 494-504, Feb. 2020.
- F. Rahman, G. Taylor and V. S. Sathe “A 1-2GHz Computational-Locking ADPLL with Sub-20 Cycle Lock-time across PVT Variation”, *IEEE J. Solid-State Circuits (JSSC)*, vol. 54, no. 9 pp. 2487– 2500, Jul. 2019
- W. A. Smith, J. P. Uehlin, S. I. Perlmutter, J. C. Rudell, V. S. Sathe, “A 0.0023mm2/ch. Delta-Encoded, Time-Division Multiplexed, Mixed-Signal Recording Architecture with Stimulus Artifact Suppression”,
IEEE Transactions on Bio-medical Circuits and Sys-tems (TBioCAS), vol. 14, no. 2, pp. 319-331.

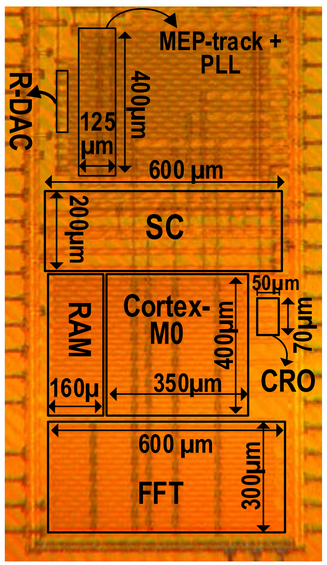
ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

Visvesh Sathe // Biosystems; Computing & Networking; Data Science

PSyLab
Thrust #1



Self-optimizing Integrated Systems



(ISSCC 2019, JSSC 2019)

Keywords: Runtime-optimization, elastic datapath design, on-chip sensors

The end of continued efficiency and performance improvements from CMOS scaling has led to the adoption of a number of circuit, methodology and architectural techniques to sustain power-constrained performance advances. A consequence of this trend has been the burgeoning complexity of modern SoCs – design time optimization is no longer sufficient to extract the efficiencies afforded by each of these techniques.

We envision the need for ***constrained run-time optimization*** of modern computing systems (SoCs, Racks and data-centers) enabled by (1) fast, efficient implementations (spanning hardware and firmware) of control and optimization methods (2) Circuit and architecture design that efficiently delivers operational tenability to the system and (3) Algorithm-circuit co-design to effectively sense key state parameters for optimization:

Publications:

1. F. Rahman et al. “Computationally-Enabled Total Energy Minimization under Performance Requirements for a Voltage Regulated 0.38–0.58V Microprocessor in 65nm CMOS”, in *JSSC 2019*

Funding: SRC

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ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

Visvesh Sathe // Biosystems; Computing & Networking; Data Science

ECE Research Areas:

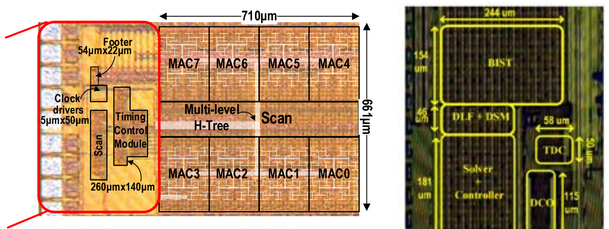
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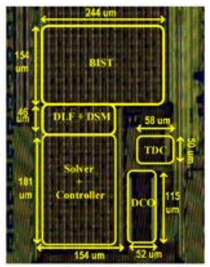
Clock Generation, Distribution and Adaptation

PSyLab
Thrust #2

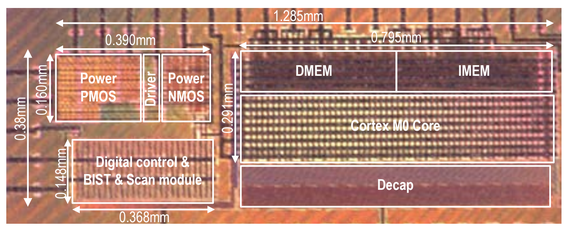




(ISSCC 2016, JSSC 2018)



(JSSC 2019)



(ISSCC 2018, JSSC 2019)

Keywords: Computationally-locked PLLs, Voltage-Frequency scalable resonant clocking, Unified Clock and Power Architecture (UniCaP), technology-translation.

Clock systems remain critical to modern computing and communication systems, impacting both performance and energy-efficiency. Clocking challenges span generation (PLLs), low-skew low power distribution and adaptation to voltage droop.

By effectively cross-pollinating ideas and applying learning in the areas of optimization and power-electronics, we have been able to make contributions across the domain-space. We demonstrated the first ***computationally locking*** PLLs demonstrating robust, rapid PLL lock. We built upon PI Sathe's work demonstrating the first resonant-clocked commercial microprocessor to demonstrate the first voltage-frequency scalable resonant clock distribution. Finally, we have recently introduced **UniCaP**, a broadly applicable unified clock and power architecture that achieves 0-delay clock adaptation without any average system-performance loss.

Funding: Intel, SRC

Publications:

1. X. Sun, et al., "An All-digital Fused PLL-Buck Architecture for 82% Average V_{dd}-Margin Reduction in a 0.6-to-1.0V Cortex-M0 Processor", in *JSSC, Sep. 2019.*
2. F. Rahman et al. "A 1-2GHz Computational-Locking ADPLL with Sub-20 Cycle Lock-time across PVT Variation", in *JSSC*, Feb. 2019.
3. F. Rahman et al. "Voltage-Scalable Frequency Independent Quasi-Resonant Clocking Implementation of a 0.7–1.2V DVFS System" in *JSSC* Mar. 2018.

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

Les Atlas // Biosystems; Data Science

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Les Atlas
Professor of Electrical and Computer Engineering

Research Theme: Signal processing, machine learning, data sciences, beamforming.
Office: ECE 410 **| Email**: atlas@uw.edu
Research Webpage: https://sites.google.com/a/uw.edu/isdl/

Education

- BSEE in Electrical Engineering, University of Wisconsin, 1978.
- MS in Electrical Engineering, Stanford, 1980.
- PhD. in Electrical Engineering, Stanford, 1984.

Notable Publications

- D Cohn, L Atlas, R Ladner, Improving generalization with active learning, *Machine learning* 15 (2), 201-221, 1994.
- S Wisdom, T Powers, J Hershey, J Le Roux, L Atlas, Full-capacity unitary recurrent neural networks, *Advances in neural information processing systems*, 4880-4888, 2016.
- L Atlas, SA Shamma, Joint acoustic and modulation frequency, *EURASIP Journal on Advances in Signal Processing* 2003 (7), 2003.
- JT Connor, RD Martin, LE Atlas, Recurrent neural networks and robust time series prediction, *IEEE transactions on neural networks* 5 (2), 240-254, 1994.

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ECE Research Areas:

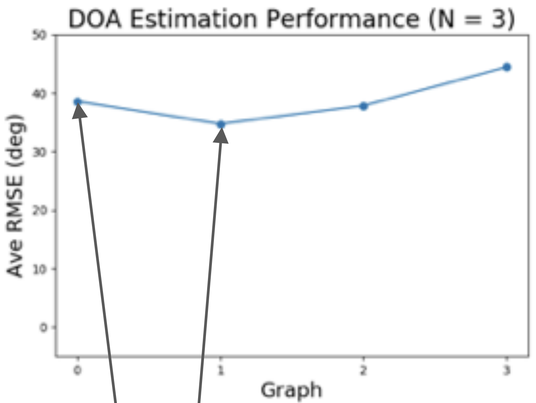
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Atlas
Project #1



Graph Signal Processing for Beamforming



Note that the new approach for graph 1 has lower RMSE error for direction of arrival (DOA) than the conventional approach of graph 0.

Over the last 3-5 years there has been the development of the area of graph DSP, which allows for relations between objects to be graphical instead of only spatial. For example, all sensors for an underwater acoustic array can be considered nodes of a graph. And edges can be relations, typically directed, which allow for new ways of posing algorithms, such as beamforming and direction-of-arrival (DOA).

As we are now starting to find, it should be possible to significantly reduce bias in direction-of-arrival algorithms using graph Fourier transforms of directed graphs. This will allow for better estimation of acoustic and radio sources, improving the state of the art in localization of mobile sources.

Graph 1 has an added directed edge and does better (lower RSME, average error) than conventional graph 0 because, mathematically, it contains a graph Fourier vector that is more aligned in phase with the source vector.

Publications:
Funding: Office of Naval Research.
Collaborators: Prof. Shima Abadi, UW Bothell, Eldridge Alcantara, Navy SMART Scholar

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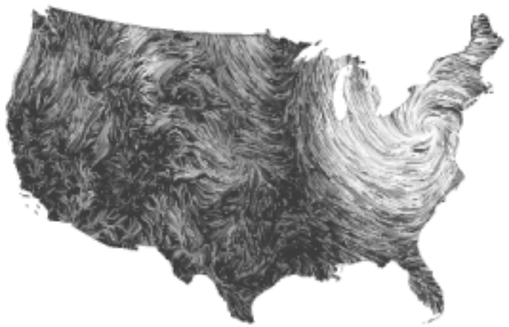
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Atlas
Project #2



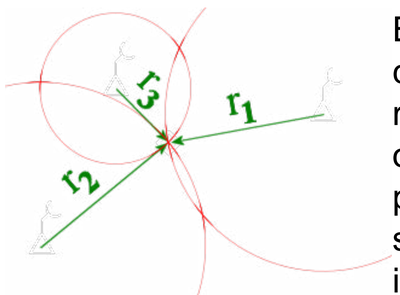
Confidential--A Coronavirus “Weather Map”



(Above is a mockup. Our first live web-based map is expected by mid-June 2020.) A state level map could help travelers plan safe routes, where there are fewer coronavirus cases on their route. This could help reduce the intensity of the pandemic as people plan their travel. The information in this map can also be used for understanding the pandemic and making policy decisions.

Determining the routes of transmission of Coronavirus still involves too much guesswork. Contact tracing is one way to track the routes. However, we are developing a another complementary and likely novel approach can make use of the increasing Coronavirus test data, at sites all over the world.

When we use GPS to determine a vehicle’s location and speed, an operation called “multilateration” combines signals from an array of satellite signals, each with a known location and transmit time. Similarly, it should be possible to estimate pathways of groups of coronavirus infections using multilateration, combined with the expected speed of disease propagation, coronavirus test sites’ locations and daily test numbers can be used as points for multilateration.



Each coronavirus test site can be assumed to be the center of a circle where the daily infection rate defines the radius of the circle. The location closest to the intersection of circles provides the location for a latent source for one pathway of disease. Solutions which provide several simultaneous latent source locations are currently being investigated.

Funding: The Office of Naval Research is supporting some of Atlas’ time.

Collaborators: Prof. G. Kohlberg, M.D, UW School of Medicine, Michael Rhoads, UW ECE.

Les Atlas // Biosystems; Data Science

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Atlas
Project #3



Voice Automation for Air Traffic Control



Current systems for voice communications for air traffic control.

Current pilot-tower communications is by voice. Both commercial and general aviation are dependent upon clear communications between pilots and air traffic controllers. The goal of our project is to investigate whether one side of this interaction can be replaced or supplemented by automatic speech recognition and language understanding.

The problem is challenging. Current technology does not perform well enough since a) the vocabulary used by pilots and controllers is quite special, and b) the aircraft to tower VHF voice channel distorts severely, where in spite of reasonable intelligibility, for an experienced pilots or controller, the waveforms are very distorted.

Our goals are to a) use existing data, some provided by Boeing and other data from the Linguistic Data Consortium, to provide a suitable language model and b) use existing data, collected under better transmission conditions, to come up with a data-trained network which reduces the distortion.

Funding: Boeing.
Collaborators: Prof. Mari Ostendorf, UW ECE.

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Samuel Burden // Biosystems; Robotics & Controls

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Sam A. Burden
Assistant Professor of Electrical and Computer Engineering
Co-director, AMP Lab and BioRobotics Lab
Research Theme: sensorimotor control in robotics and neuroengineering
Office: M442 ECE **| Email**: sburden@uw.edu
Research Webpage: http://faculty.uw.edu/sburden

Education

- BSEE in Electrical Engineering (cum laude), minor in Mathematics, University of Washington, Seattle, 2008.
- PhD. in Electrical Engineering, University of California, Berkeley, 2014.

Awards

- Washington Research Foundation Early Faculty Fellow (WRF-EFF), 2014
- Army Research Office Young Investigator Program (ARO-YIP), 2015

Notable Publications

- Banjanin, Burden. Nonsmooth optimal value and policy functions in mechanical systems subject to unilateral constraints. *IEEE Control Systems Letters (L-CSS)* 4(2):506--511, Apr. 2020. [bib | DOI | .pdf]
- Yamagami, Steele, Burden. Decoding intent with control theory: Comparing muscle versus manual interfaces. *ACM Conference on Human Factors in Computing Systems (CHI)* pp. 1--12, Apr. 2020. [bib | DOI | .pdf]
- Johnson, Burden, Koditschek. A hybrid systems model for simple manipulation and self-manipulation systems. *The International Journal of Robotics Research (IJRR)* 35(11):1354--1392, May 2016. [bib | DOI | .pdf]
- Ratliff, Burden, Sastry. On the characterization of local Nash equilibria in continuous games. *IEEE Transactions on Automatic Control (TAC)* 61(8):2301--2307, Aug. 2016. [bib | DOI | .pdf]

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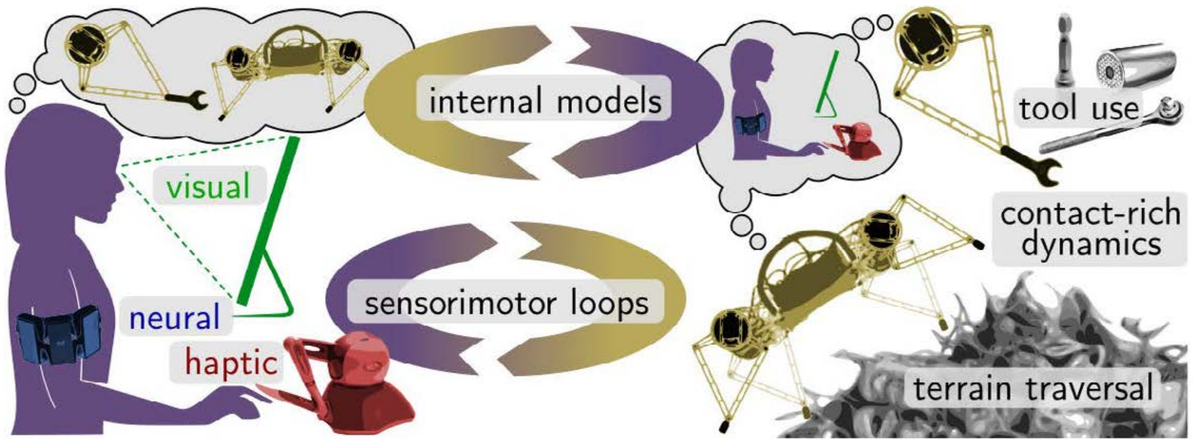
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Toward *telelocomotion*: human/machine collaborative learning and control of contact-rich dynamics

Burden Project #1





This project targets two fundamental research questions:
Q1 How do humans learn to control contact-rich dynamics?
Q2 How can a machine adapt to enhance human's controller?

Publications: Yamagami, Steele, Burden. Decoding intent with control theory: Comparing muscle versus manual interfaces. *ACM Conference on Human Factors in Computing Systems (CHI)* pp. 1--12, Apr. 2020. [bib | DOI | .pdf]

Funding (Apr 2015--Mar 2018): National Science Foundation Cyber-Physical Systems Award #1565529

Many applications of current and future interest (teleoperation, brain/machine interfaces, exoskeletons, prostheses) will require that humans learn to control devices whose dynamics change abruptly as the human and/or machine traverses terrain and uses tools, tasks that involve *contact-rich dynamics*.

Long term, we envision that enabling machines to adapt to and collaborate with human operators will *democratize physical work* by empowering all members of society to perform complex tasks involving dynamic interaction with the world, regardless of their level of ability, impairment, injury, or disease.

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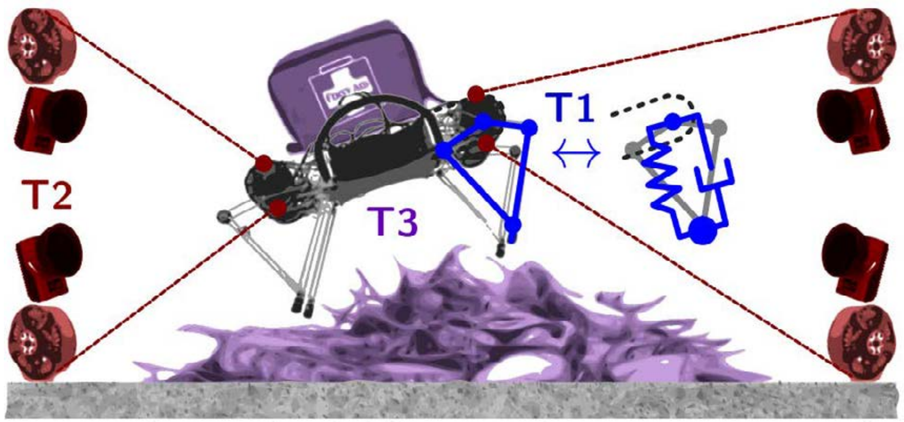
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Robust and adaptable terradynamics for autonomous legged robots

Burden
Project #2





Autonomous legged robots must be robust and adaptable to traverse tricky terrain

To maintain operational tempo in novel, adversarial, or changing environments, autonomous robots must employ dynamic behaviors that are *robust* (guarantee performance) yet *adaptable* (accommodate change). Performance should be maintained despite environmental variation or mechanical degradation, and increase with experience. Technical objectives:

T1 Implement control in (passive/analog) mechanics, evaluate tradeoffs and limitations with respect to conventional digital controllers.
T2 Determine robot designs that enable convergent reinforcement learning algorithms that scale to high-dimensional state/action spaces, train the algorithms using automated experiments.
T3 Predict and mitigate how performance degrades when environment varies or mechanics degrade.

Publications: Banjanin, Burden. Nonsmooth optimal value and policy functions in mechanical systems subject to unilateral constraints. *IEEE Control Systems Letters (L-CSS)* 4(2):506--511, Apr. 2020. [bib | DOI | .pdf]
Funding (May 2015--Apr 2018): Army Research Office Young Investigator Program (YIP) Award #W911NF-16-1-0158

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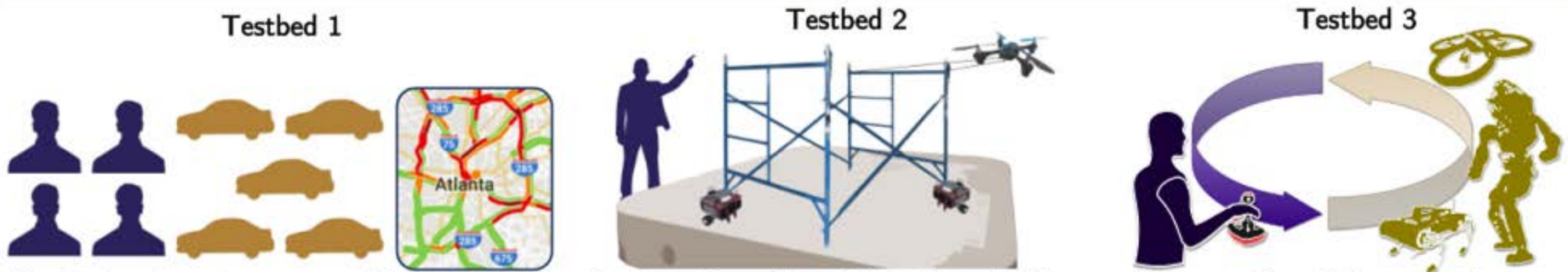
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Certifiable reinforcement learning for CPS
(CPS = cyber-physical systems)

Burden Project #3



Classical optimal control problem: $\min_u c(x,u)$ such that $\dot{x} = f(x,u)$



CPS have non-classical costs/dynamics:
- Hybrid or nonsmooth dynamics F
- Multiple decision-making agents with incomplete information (humans and autonomy)

Publications: Burden, Libby, Coogan. On infinitesimal contraction analysis for hybrid systems. arXiv:1811.03956.
Funding (Sep 2018--Aug 2021): National Science Foundation Cyber-Physical Systems #1836819
Collaborators: Lillian Ratliff (UW ECE), Sam Coogan (GATech ECE)

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Samuel Burden // Biosystems; Robotics & Controls

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Design of dynamic multibehavioral robots

Burden Project #4

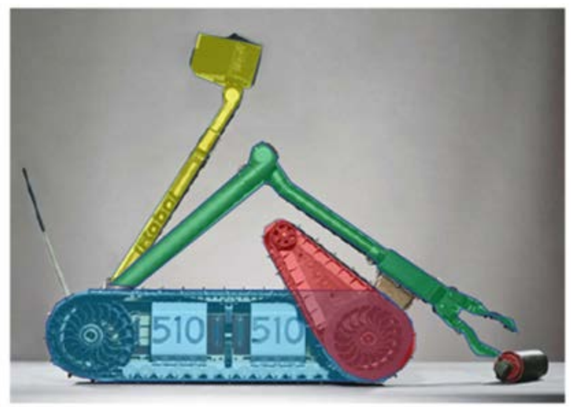


It is challenging to design a single robot that can perform multiple behaviors: first, due to the complexity of the dynamic relationship between design and behavior; and second, since an ensemble of behaviors may have conflicting design requirements. In this project, we will create and apply new techniques for analysis and synthesis of multibehavioral robot designs that enable systematic exploration of the complex performance tradeoffs that arise within and between behaviors.



robust design each part has multiple uses -- ***scales well!***

fragile design each part has only one use -- ***doesn't scale!***



animals like housecats reuse body parts (legs, feet, mouths) for mobility and manipulation

state-of-the-art (iRobot PackBot) built using "swiss-army knife" design

Publications: Burden, Libby, More, Donelan. Animals vs Machines: why do animals outperform robots? (in prep)
Funding (Sep 2019--Aug 2022): National Science Foundation National Robotics Initiative #1924303
Collaborators: Aaron Johnson (CMU ME)

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Linda Bushnell // Computing & Networking; Robotics & Controls

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Research Theme: Networked Control Systems, Cyber-Physical Systems
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Education

- BS in EE, University of Connecticut, 1985
- MS in EE, University of Connecticut, 1987
- MS in Mathematics, University of California, Berkeley, 1989
- PhD. in EECS, University of California, Berkeley, 1994
- MBA, UW Foster School of Business, 2010

Notable Publications

- S. Moothedath, D. Sahabandu, J. Allen, A. Clark, L. Bushnell, W. Lee, and R. Poovendran, “A Game Theoretic Approach for Dynamic Information Flow Tracking to Detect Multi-Stage Advanced Persistent Threats,” *IEEE Transactions on Automatic Control*, pp. 1-16. DOI: 10.1109/TAC.2020.2976040
- Clark, B. Alomair, L. Bushnell, and R. Poovendran, “On the Structure and Computation of Random Walk Times in Finite Graphs,” *IEEE Transactions on Automatic Control.* (Early Access; Nov 2019). DOI: 10.1109/TAC.2019.2895299
- Z. Liu, A. Clark, L. Bushnell, D. Kirschen, and R. Poovendran, “Controlled Islanding via Weak Submodularity,” *IEEE Transactions on Power Systems,* 34:3, pp. 1858-1868 (May 2019). DOI 10.1109/TPWRS.2018.2881163
- Z. Liu, Y. Long, A. Clark, L. Bushnell, D. Kirschen, and R. Poovendran, "Minimal Input and Output Selection for Stability of Systems with Uncertainties,” *IEEE Transactions on Automatic Control,* 64:4, pp. 1456-1471 (April 2019). DOI 10.1109/TAC.2018.2851232
- X. Ying, S. Sagong, A. Clark, L. Bushnell, and R. Poovendran, “Shape of the Cloak: Formal Analysis of Clock Skew-Based Intrusion Detection System in Controller Area Networks,” *IEEE Transactions on Information Forensics and Security*, 14:9, pp. 2300-2314, (Jan 2019). DOI: 10.1109/TIFS.2019.2895957

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Alex Mamishev // Photonics & Nano Devices; Power Systems; Robotics

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Alexander Mamishev
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Research Theme: Robotics and Controls, Photonics and Nano Devices, Power and Energy Systems
Office: 215K ECE | **Email**: mamishev@ece.uw.edu
Research Webpage: https://uwseal.org/projects/

Education

- BSEE in Electrical Engineering, Kiev Polytechnic Institute, Ukraine, 1992.
- MSEE in Electrical Engineering, Texas A&M University, Texas, 1994.
- Ph.D. in Electrical Engineering and Computer Science, Massachusetts Institute of Technology, 1999.

Notable Publications

- Makhsous, Sepehr, Hashem M. Mohammad, Jeannette M. Schenk, Alexander V. Mamishev, and Alan R. Kristal. "A Novel Mobile Structured Light System in Food 3D Reconstruction and Volume Estimation." Sensors 19, no. 3 (2019).
- Sep Makhsous, Aaron Zielinski, and Alexander V. Mamishev. “Post-Operative Stoma Management Based on 3D Image Reconstruction and Pattern Recognition.” Proceedings of FSDM 2018, vol. 309: 794-801.
- Wen, Tsrong-Yi, Hsiu-Che Wang, Igor Krichtafovitch, and Alexander V. Mamishev. "Novel electrodes of an electrostatic precipitator for air filtration." Journal of Electrostatics 73 (2015): 117-124.

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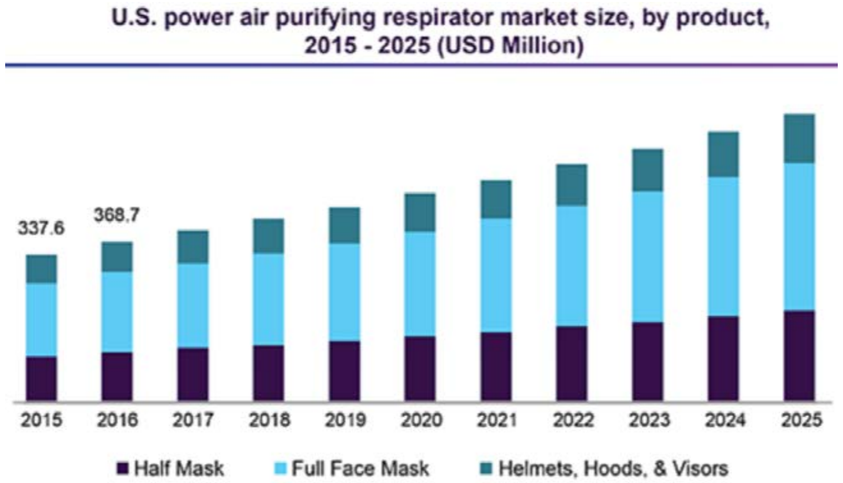
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Mamishev
Project #1



EHD Powered Air-Purifying Respirator



Potential growth of the respirator market in the upcoming years.

Due to the COVID-19 outbreak, many healthcare workers currently need reusable respiratory protection that can be worn for extended periods. We are developing a powered air-purifying respirators that is lighter, smaller, and quieter than what is on the market by replacing traditional mechanical fans in the supplied blower unit with electrohydrodynamic (EHD) pumps.

Advantages of this approach include:

- The blower unit will weigh less than 1 pound.
- The noise level will not exceed 60 decibels.
- The size of the blower unit will be less than 688 cm^3.
- The mask and blower unit can be sterilized after each use.

Publications: Wen, Tsrong-Yi, Igor Krichtafovitch, and Alexander V. Mamishev. "Reduction of aerosol particulates through the use of an electrostatic precipitator with guidance-plate-covered collecting electrodes." Journal of Aerosol Science 79 (2015): 40-47.
Funding: NIH, CPAC.
Collaborators: Agentis.

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Alex Mamishev // Photonics & Nano Devices; Power Systems; Robotics

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Mamishev
Project #2



AeroSpec



Each year, over 100,000 Americans lose their lives to heart attacks, strokes, and other illnesses caused by air pollution. We have developed a data-driven intervention solution which monitors personal exposure and concentration of air quality in real-time and alarms the user in case of any hazardous exposures.

Advantages of this approach include:

- Real-time, continuous data
- Modular design
- Archived samples for in-depth chemical analysis

Publications: Makhsous Sep, Igor Novosselov, Alex Mamishev, “Personal Exposure Monitoring Using Integrated Sensors and Cloud Computing.” 10th International Aerosol Conference for Aerosol Research, St. Louis, MO, Sept 2-7, 2018.
Funding: NIH, CoMotion Gap Fund, NSF I-Corps.
Collaborators: Boeing, CoMotion, Buerk Center (Jones Foster).

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UNIVERSITY of WASHINGTON

Alex Mamishev // Photonics & Nano Devices; Power Systems; Robotics

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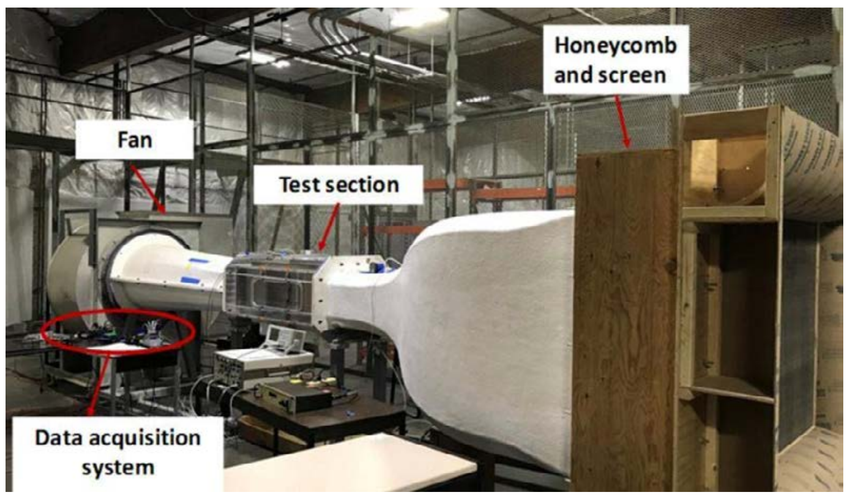
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Mamishev
Project #3



EHD Active Flow Control and Drag Reduction



Subsonic open type wind tunnel for UW EHD laboratory with 700 mm X 385 mm rectangular test section.

Electrohydrodynamic (EHD) thrusters (plasma actuators) have been demonstrated as remarkable devices for flow separation control, lift enhancement, and noise reduction. We developed a full-scale, two-dimensional aircraft wing section with an integrated EHD thruster module that can augment the lift characteristics by 60% and 20% for 35 mph and 45 mph free stream velocity respectively.

Potential developments include:

- Model unmanned airplane with EHD thrusters
- Miniature high voltage power supply for the prototype plane
- Partnership with IARPA and/or DARPA
- Commercialization of EHD propelled drones for the public and companies/organizations

Publications: Hsiu-Che Wang, Nels. E. Jewell-Larsen, and Alexander V. Mamishev, "Thermal Management of Microelectronics with Electrostatic Fluid Accelerators," Applied Thermal Engineering, Vol. 51, 2013, pp. 190-211.
Funding: Aerojet, IARPA, JCATI.
Collaborators: Aerojet Rocketdyne, Zephyr, Eagle Harbor Technologies, Flight House.

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Alex Mamishev // Photonics & Nano Devices; Power Systems; Robotics

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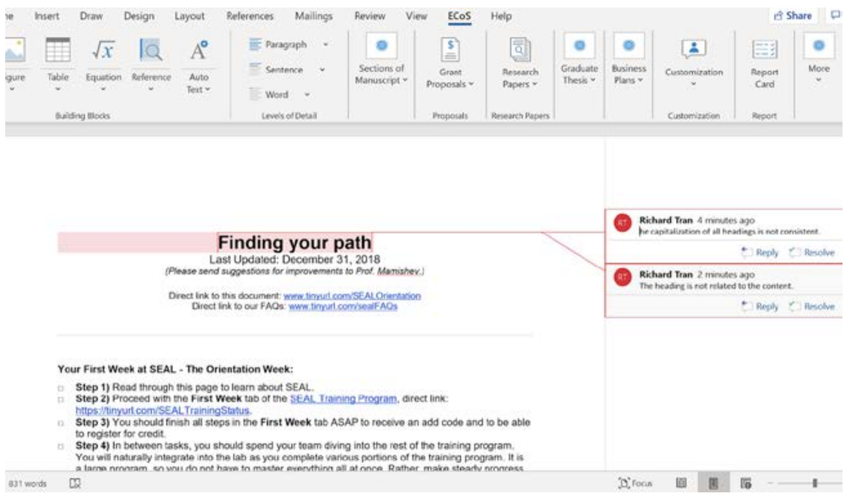
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Mamishev
Project #4



Efficiency, Content, and Style (ECoS) Tool



ECoS being used on a document.

Newer writers are generally unaware of the deep and complex expectations behind their field's professional writing. ECoS helps design, develop, and bring to market a variety of technical writing solutions that teach proper writing through fun and engaging methods.

Advantages of this approach include:

- Relieves personnel inexperience
- Time efficient
- Sets clear expectations
- Streamlines task delegation

Publications: A. V. Mamishev and M. Sargent, Creating Research and Scientific Documents Using Microsoft® Word, Microsoft Press, 2013.
Funding: NSF I-Corps.
Collaborators: Novosselov Research Group.

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Radha Poovendran // Computing & Networking; Data Science

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Research Theme: Cyber Physical Systems (CPS) security, game theory and control theory for security, networking, and ML/AI for security
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Research Webpage: http://labs.ece.uw.edu/nsl/faculty/radha/index.html

Education

- B. Tech. EE, Dept. of EE, Indian Institute of Technology, Bombay, India, 1988.
- M.S.E.E., Dept. of EECS, Univ. of Michigan, Ann Arbor, Mi, 1992.
- Ph.D., Dept. of Electrical and Computer Engineering, Univ. of Maryland, College Park, MD, 1999.

Notable Publications

- S. Moothedath, D. Sahabandu, J. Allen, A. Clark, L. Bushnell, W. Lee, and R. Poovendran, "A Game-Theoretic Approach for Dynamic Information Flow Tracking to Detect Multi-Stage Advanced Persistent Threats", *IEEE Transactions on Automatic Control*, 2020.
- B. Xiao, Q. Liu, B. Ramasubramanian, A. Clark, L. Bushnell, R. Poovendran. FRESH: Interactive Reward Shaping in High-Dimensional Spaces using Human Feedback. *Proceedings of the International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS), 2020, pp. 1512-1520.*
- S. Sagong, X. Ying, A. Clark, L. Bushnell, and R. Poovendran, “Cloaking the Clock: Emulating Clock Skew in Controller Area Networks,” *in ACM/IEEE International Conference on Cyber-Physical Systems*, 2018, pp. 32–42.

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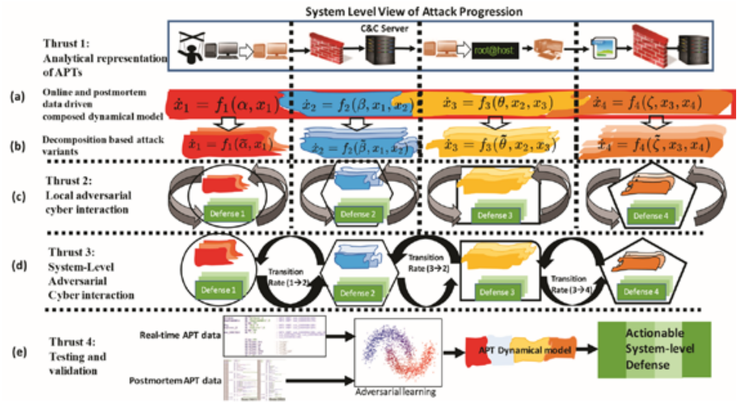
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Analytical Framework for Actionable Defense against Advanced Persistent Threats (ADAPT)

Poovendran
Project #1





Schematic of ADAPT framework

Description: Advanced persistent threats (APTs) infiltrate cyber systems over an extended period of time and compromise specifically targeted data and/or resources through a sequence of stealthy attacks. The temporal progression of the adversarial cyber interaction is inherently a game between cyber defense and adversary actions. However, economic game theory, which most modeling methods are grounded in, does not work well in modeling adversarial interaction that occurs in a cyber environment that is dynamic and prone to abrupt changes.

Goal: We develop a new scientific framework for modeling advanced and dynamic adversarial cyber interactions to propose actionable cyber defenses. Our framework integrates statistical modeling, adaptive game theory, machine learning, and control and systems theory to defend against and mitigate APTs.

Approach: We propose DIFT-APT games, a novel game theoretic approach that enables the efficient and effective Dynamic Information Flow Tracking (DIFT)-based defense against APTs. We use Information Flow Graph (IFG) to capture the feasible interactions between different system components based on the observation that Interaction of APTs with system induces Information flows.

Results: We show the best attack strategy of APT forms a shortest path problem on IFG. The best response of the defender, which is selecting a subset of IFG nodes to perform security analysis, is obtained by using the submodularity property of its payoff function. We characterize the set of Nash equilibria for single stage attacks. We provide a polynomial-time algorithm to compute a correlated equilibrium for the multi-stage attack case. We experiment and validate our model and algorithms on a real-world nation state attack dataset.

Representative Publication: S. Moothedath, D. Sahabandu, J. Allen, A. Clark, L. Bushnell, W. Lee, and R. Poovendran, "A Game-Theoretic Approach for Dynamic Information Flow Tracking to Detect Multi-Stage Advanced Persistent Threats", *IEEE Transactions on Automatic Control*, 2020.
Collaborators: Prof. Linda Bushnell, Prof. Maryam Fazel, **Universities:** Georgia Tech, UIUC, UC Berkeley, UC Santa Barbara
Funding: Office of Naval Research (ONR)
Project Webpage: https://adapt.ece.uw.edu/

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Radha Poovendran // Computing & Networking; Data Science

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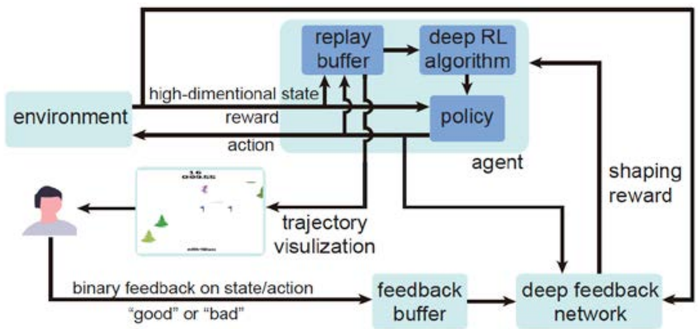
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Feedback-Driven Learn to Reason in Adversarial Environments for Autonomic Cyber Systems (L2RAVE)

Poovendran
Project #2





Schematic of FRESH (Feedback-based Reward Shaping)

Description: The growing complexities of cyber systems necessitates development of methods that integrate statistical learning with formal reasoning to provide adaptive situational awareness and resilient system response. Statistical methods, although fast and flexible to uncertainty, are limited by a lack of interpretability and generalizability. Formal reasoning methods, on the other hand, are interpretable, but rely greatly on human effort and domain expertise.

Goal: We integrate statistical learning and formal reasoning by using knowledge of operating conditions of cyber systems to improve the interpretability, generalizability and robustness of learning.

Approach: We devise a scheme called FRESH, that integrates human feedback with deep RL algorithms. Operator provides binary-valued feedback on states and actions in sample trajectories during training, which is converted to a shaping reward. A feedback neural network is used to allow the deep RL algorithm to generalize feedback signals obtained during training to unseen states and actions at test time.

Results: We evaluate FRESH in RL environments with sparse/ delayed rewards (Bowling and Skiing Atari games), where human players consistently outperform state-of-the-art algorithms. FRESH obtained a much higher score (~180) in Bowling than an expert human player (~150), and performed as well as an expert human player in Skiing.

Representative Publication: B. Xiao, Q. Liu, B. Ramasubramanian, A. Clark, L. Bushnell, R. Poovendran. FRESH: Interactive Reward Shaping in High-Dimensional Spaces using Human Feedback. *Proceedings of the International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS), 2020, pp. 1512-1520.*
Collaborators: Prof. Linda Bushnell
Funding: Office of Naval Research (ONR)
Project Webpage: http://labs.ece.uw.edu/nsl/faculty/ProjectWebPages/L2RAVE/

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Radha Poovendran // Computing & Networking; Data Science

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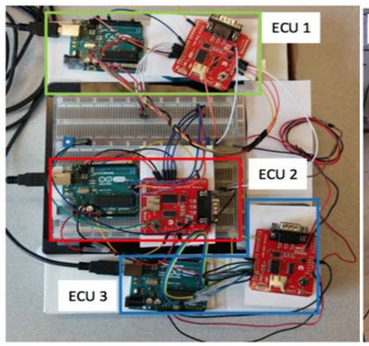
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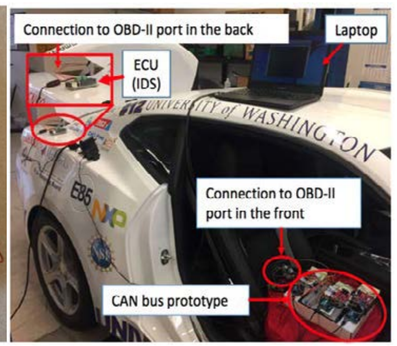
Security Analysis of Controller Area Network Protocols Based on Physical Properties of ECUs (CAN-BUS)

Poovendran
Project #3





CAN Bus prototype



EcoCar testbed

Description: Electronic Control Units (ECUs) in a contemporary vehicle exchange data in order to control the vehicle more effectively via in-vehicle network protocols such as Controller Area Network. These in-vehicle network protocols do not encrypt the data nor authenticate messages; thus the CAN bus is vulnerable to cyber attacks, in which the adversary may take full control of the vehicle.

Goal: We investigate various attack surfaces of the CAN bus and existing IDSs by exploiting vulnerabilities of the CAN protocol. We develop defense mechanisms that detect attack and promptly mitigate the attacks to minimize the consequences.

Approach: We propose the cloaking attack, an intelligent masquerade attack in which an adversary modifies the timing of transmitted messages to match the clock skew of a targeted ECU. The attack leverages the fact that, while the clock skew is a physical property of each ECU that cannot be changed by the adversary, the estimation of the clock skew by other ECUs is based on the timing of network traffic.

Results: We implement the proposed cloaking attack and test it on two IDSs, namely, the current state-of-the-art IDS and its adaptation to the widely- used Network Time Protocol (NTP). We implement the cloaking attack on two hardware testbeds, a prototype and a real vehicle, and show that it is able to deceive both IDSs. We introduce a new metric called the Maximum Slackness Index (MSI) to quantify the effectiveness of a clock skew-based IDS in detecting masquerade attacks when the adversary is unable to precisely match the clock skew.

Representative Publication: S. Sagong, X. Ying, A. Clark, L. Bushnell, and R. Poovendran, “Cloaking the Clock: Emulating Clock Skew in Controller Area Networks,” *in ACM/IEEE International Conference on Cyber-Physical Systems*, 2018, pp. 32–42.
Collaborators: Prof. Radha Poovendran, Prof. Linda Bushnell
Funding: National Science Foundation (NSF), Office of Naval Research (ONR), Army Research Office (ARO)
Project Webpage: http://labs.ece.uw.edu/nsl/faculty/ProjectWebPages/ECU/

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Radha Poovendran // Computing & Networking; Data Science

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NSL Alumni



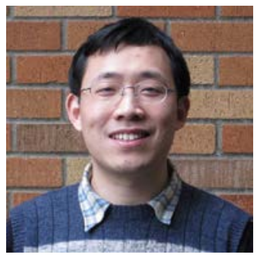
Prof. Loukas Lazos
Associate Professor, ECE, University of Arizona, Tucson



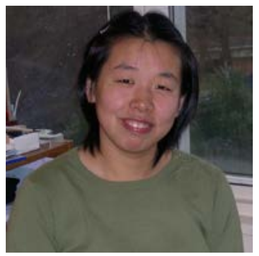
Prof. Andrew Clark
Assistant Professor, ECE, Worcester Polytechnic Institute



Prof. Patrick Tague
Associate Research Professor, CyLab/INI/ECE, Carnegie Mellon University, Silicon Valley Campus



Prof. Weiyao Lin
Professor in Electronic Engineering, Jiao Tong University, Shanghai



Prof. Ying Lin
Associate Professor, Western Washington University, Bellingham, WA



Prof. Krishna Sampigethaya
Chair and Associate Professor, Cyber Intelligence & Security Department, Embry-Riddle Aeronautical University, Prescott, AZ.



Sidharth Nabar
Sr. Product Manager at Amazon Alexa



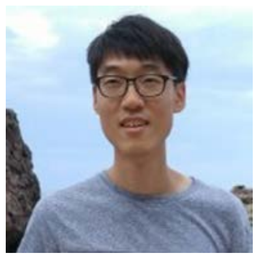
Javier Salido
Principal Program Manager, Windows & Devices Privacy, Microsoft, Redmond, WA



Hossein Hosseini
Qualcomm AI, San Diego, CA



Zhipeng (Leo) Liu
Deep Learning Engineer, Volvo Cars R&D



Sang Sagong
Section Chief at Hyundai Motor Company, Korea



Shana Moothedath
Professor, ECE, Iowa State University (starting 2021)

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John Raiti // Biosystems; Robotics & Controls

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Education

- BA in Neuroscience, The Johns Hopkins University, 2000.
- MS in Neuroscience, Syracuse University, 2002.
- ScM in Biomedical Engineering, Brown University, 2004.
- PhD in Biomedical Engineering, Brown University, 2012.

Notable Publications

- Boger, I., Chakalasiya, Christofferson, K., Wang, Y., and Raiti, J. *Induced Acoustic Resonance for Noninvasive Bone Fracture Detection Using Digital Signal Processing and Machine Learning* . 2020 IEEE Global Humanitarian Technology Conference (GHTC)
- Yang, R., Zhou, H., Wang, K., Cuneo, A., Murinova, N., Wang, Y., and Raiti, J. *Virtual Reality Biofeedback Therapy for Chronic Migraine.* 2020 IEEE Global Humanitarian Technology Conference (GHTC)
- Ngeh, C.J., Ma, C., Ho, T., Wang, Y., and Raiti, J.*Deep Learning on Edge Device for Early Prescreening of Skin Cancers in Rural Communities.* 2020 IEEE Global Humanitarian Technology Conference (GHTC)
- Lewis, A., Drajeske, D., Raiti, J., Berens, A., Rosen, J., and Hannaford, B. “RAVEN-S: Design and Simulation of a Robot for Teleoperated Microgravity Rodent Dissection Under Time Delay.” International Conference on Robotics and Automation (ICRA) 2020
- Wang, Y., Chen, Z., Li, H., Cao, Z., Luo, H., Zhang, T., Ou, K., Raiti, J., Yu, C., Patel, S., Shi, Y. “MoveVR: Enabling Multiform Force Feedback in Virtual Reality using Household Cleaning Robot”. Conference on Human Interaction (CHI) 2020
- Lin, T., Tran, C., Feng, T., Huang, L., James, J., Zaragoza, R., Hannaford, B., Wagner, L., and Raiti, J. “Empathics System: Application of Emotion Analysis AI through Smart Glasses.” *Proceedings of the 13th ACM International Conference on PErvasive Technologies Related to Assistive Environments*. 2020

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Georg Seelig
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Email: geelig@uw.edu
Research website: www.seeliglab.org

Education

- Diploma (BS/MS) in Physics, University of Basel, Switzerland
- PhD in Physics, University of Geneva, Switzerland

Notable Publications

- Paul J. Sample, Ban Wang, David W. Reid, Vladimir Presnyak, Iain McFadyen, David R. Morris and Georg Seelig, *Human 5'UTR design and variant effect prediction from a massively parallel translation assay*, Nature Biotechnology **37**, 803, (2019).
- Nicholas Bogard*, Johannes Linder*, Alexander B. Rosenberg and Georg Seelig, *A Deep Neural Network for Predicting and Engineering Alternative Polyadenylation*, Cell **178**, 91 (2019)
- Alexander B Rosenberg*, Charles Roco*, Richard A Muscat, Anna Kuchina, Paul Sample, Sumit Mukherjee, Wei Chen, David J Peeler, Zizhen Yao, Suzie H Pun, Drew L Sellers, Bosiljka Tasic, and Georg Seelig, *Single cell profiling of the developing mouse brain and spinal cord with split-pool barcoding*, Science **360,** 176 (2018).
- Randolph Lopez Barrezueta , Ruofan Wang, and Georg Seelig, *A molecular multi-gene classifier for disease diagnostics*, Nature Chemistry **10**, 746 (2018)
- Gourab Chatterjee, Neil Dalchau, Richard A Muscat, Andrew Phillips and Georg Seelig, *A spatially localized architecture for fast and modular DNA computing*, Nature Nanotechnology **12**, 920 (2017).

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DNA computing



It is hard to imagine that any device approaching the complexity of modern electronics could be built without a principled synthesis method. In contrast, engineering of biological and chemical systems to a large extent remains a process of trial and error. A framework for rapidly synthesizing functional molecular systems based on an abstract specification would thus open up a wide range of applications. In my work, I have developed systematic approaches for the design of molecular circuitry using DNA strand displacement. Working in cell-free settings and with a limited but well understood toolbox of molecular interactions, I could rapidly scale up system complexity and quantitatively characterize reaction mechanisms to an extent that is not feasible for engineered gene circuits or other cell-based technologies.

Publications: Nat. Nanotechnol. **12**, 920 (2017); Science **324**, 1585 (2006); J. Am Chem. Soc. **128**, 12211 (2006); Nat. Nanotechnol. **8**, 755 (2013); PNAS **107**, 5393 (2010); ACS Syn. Bio. **7**, 2737 (2018); Nat. Nanotechnol. **11**, 287 (2016); Nat. Nanotechnol. **10**, 748 (2015); Nat. Chemistry **10**, 746 (2018); J. Am. Chem. Soc. 138, 5076 (2016).; Nature Chemistry 5, 782 (2013).
Funding: NSF, ONR, DARPA
Collaborators: David Soloveichik (UT Austin), Andrew Phillips and Neil Dalchau (MSR Cambridge)

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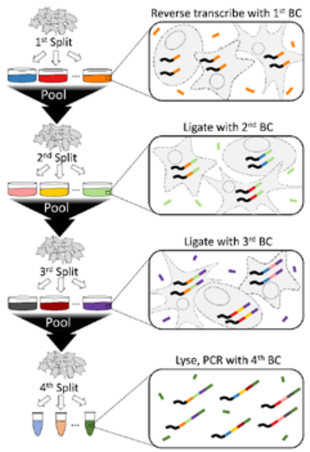
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Single cell RNA sequencing



Conventional scRNA-seq methods require complex fluidics and are costly which limits access to a relatively small number of labs. In recent work, we have developed a novel scRNA-seq technology, SPLiT-seq, a scRNA-seq method that labels the cellular origin of RNA through combinatorial indexing. SPLiT-seq is compatible with fixed cells, scales exponentially, uses only basic laboratory equipment, and costs one cent per cell. To complement our work on developing experimental methods we are also working on developing novel single cell analysis tools. A particular focus of our work is to create methods that can efficiently incorporate prior information.

This project also led to a UW startup company, Split Biosciences.

Publications: Science 360, 176 (2018); Bioinformatics 34, i124 (2018).
Funding: NIH
Collaborators: Bosiljka Tasic (Allen Institute for Brain Science), Suzie Pun (UW BioE)

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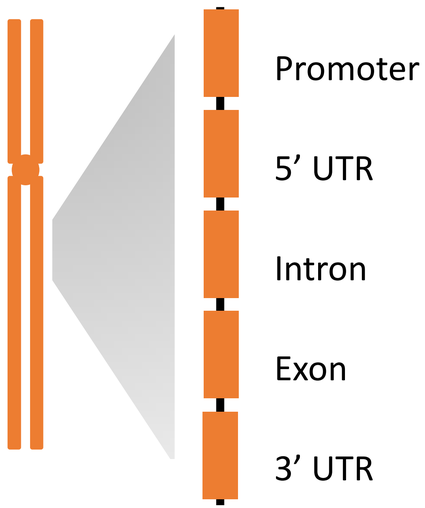
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Engineering gene regulation



A major hurdle for the de novo design of synthetic gene circuits is that we generally do not fully understand how the sequence of cis-regulatory elements --- promoters, enhancers, UTRs, splice regulatory regions or other --- relate to their function. In the absence of a well-characterized sequence-function relationship it is challenging to predictably modulate gene expression in synthetic constructs or to reliably predict how endogenous genes are expressed. In recent work, we showed that the grammar of biological cis-regulation can be learned from libraries for synthetic gene expression constructs with random sequence elements.

Publications: Cell **178**, 91 (2019); Cell **163**, 698 (2015); Nat. Biotech. **37**, 803, (2019); Genome Res. **27,** 2015 (2017)
Funding: NIH, Bluebird Bio, Moderna
Collaborators: Jay Shendure and Stan Fields (UW Genome Science), Kyle Havens (Bluebird Bio), David Reid (Moderna)

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Linda Shapiro // Biosystems; Data Science

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Name: Linda Shapiro
Professor, Electrical and Computer Engineering
Research Theme: Computer Vision and Medical Image Analysis
Office: 634 Paul G. Allen Center | Email: shapiro@uw.edu

Education

- BS in Mathematics, University of Illinois at Urbana Champagne, 1970
- MS in Computer Science, University of Iowa, 1972
- PhD. In Computer Science, University of Iowa, 1974

Notable Publications

- E. Mercan, S. Mehta, J Bartlett, L.G. Shapiro, D.L. Weaver, J.G. Elmore. Assessment of Machine Learning of Breast Pathology Structures for Automated Differentiation of Breast Cancer and High-Risk Proliferative Lesions. *JAMA Network Open.* Published online August 09, 20192(8):e198777. doi:10.1001/jamanetworkopen.2019.8777
- S. Mehta, E. Mercan, J. Bartlett, D. Weaver, J. Elmore, L. Shapiro, “Y-Net: Joint Segmentation and Classification for Diagnosis of Breast Biopsy Images,” *MICCAI*, 2018.
- S. Yang, L. Shapiro, M. Cunningham, M. Speltz, C. Birgfeld, I. Atmosukarto, S.-I. Lee, “Skull Retrieval for Craniosynostosis Using Sparse Logistic Regression Models,” *Proceedings of the MICCAI Workshop on Medical Content Based Retrieval for Clinical Decision Support*, Springer, 2012. Winner of the Best Paper Award, PMCID: PMC 4138604.
- M.S. Costa and L. G. Shapiro, “3D Object Recognition and Pose with Relational Indexing,” Computer Vision and Image Understanding, Vol. 79, No. 3, 2000, pp. 364-407.
- L. G. Shapiro. and R. M. Haralick, “Structural Descriptions and Inexact Matching”, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. PAMI-3, No. 5, Sept. 1981, pp. 504-519.

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Linda Shapiro // Biosystems; Data Science

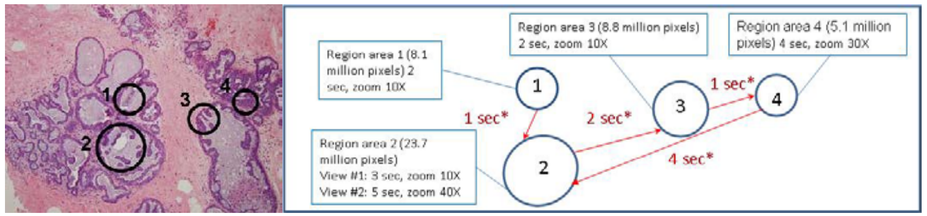


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Digital Pathology: Accuracy, Viewing Behavior and Image Characterization



Pathologic assessment for a cancer diagnosis has for years been the “gold standard” guiding clinical care and research endeavors. However, diagnostic misclassification that can compromise clinical and research outcomes occurs in the interpretation of breast biopsy specimens, particularly at the benign to malignant and in-situ to invasive thresholds. At this point in time, technological advances are enabling widespread use of digitized whole slides. However, while this new technology has not been verified compared to glass slides it provides a much more feasible medium for evaluating visual screening behavior than a traditional microscope. For these reasons, we have designed a research program that will evaluate diagnostic accuracy on digital compared to glass slides and evaluate individuals visual screening of digital images. In-depth scientific evaluation of the visual screening behind each pathologist’s review of a slide, including characteristics of both viewing behavior and image regions they deem important, is critical to understanding the possible sources of errors and identifying the most effective viewing techniques for reducing errors. Bringing together a multi-faceted group of investigators, will move us closer to our ultimate goal of ensuring high-quality clinical care.

https://homes.cs.washington.edu/~shapiro/digipath.html

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Linda Shapiro // Biosystems; Data Science

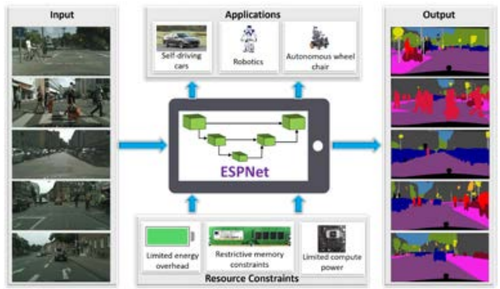
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Deep Learning for Computer Vision





We introduce a fast and efficient convolutional neural network, ESPNet, for semantic segmentation of high resolution images under resource constraints. ESPNet is based on a new convolutional module, efficient spatial pyramid (ESP), which is efficient in terms of computation, memory, and power. ESPNet is 22 times faster (on a standard GPU) and 180 times smaller than the state-of-the-art semantic segmentation network PSPNet, while its category-wise accuracy is only 8% less. We evaluated EPSNet on a variety of semantic segmentation datasets including Cityscapes, PASCAL VOC, and a breast biopsy whole slide image dataset. Under the same constraints on memory and computation, ESPNet outperforms all the current efficient CNN networks such as MobileNet, ShuffleNet, and ENet on both standard metrics and our newly introduced performance metrics that measure efficiency on edge devices. Our network can process high resolution images at a rate of 112 and 9 frames per second on a standard GPU and edge device, respectively.

Sachin Mehta, Mohammad Rastegari, Anat Caspi, Linda Shapiro, and Hannaneh Hajishirzi. ESPNet: Efficient Spatial Pyramid of Dilated Convolutions for Semantic Segmentation, ECCV, 2018.

Sachin Mehta, Ezgi Mercan, Jamen Bartlett, Donald Weaver, Joann Elmore and Linda Shapiro. Y-Net: Joint Segmentation and Classification for Diagnosis of Breast Biopsy Images, MICCAI, 2018
.
Sachin Mehta, Ezgi Mercan, Jamen Bartlett, Donald Weaver, Joann Elmore and Linda Shapiro. Learning to Segment Breast Biopsy Whole Slide Images, WACV, 2018.

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Linda Shapiro // Biosystems; Data Science



Expression Recognition with Deep Neural Networks



In order to create a successful animated story, the emotional state of a character must be staged so that it is unmistakable and clear. The viewer's perception of its facial expressions is key to successfully staging the emotion. Traditionally animators and automatic expression transfer systems rely on geometric markers and features modeled on human faces to create character expressions, yet these features do not accurately transfer to stylized character faces. Relying on human geometric features alone to generate stylized character expressions leads to expressions that are perceptually confusing or different from the intended expression. Our framework avoids these pitfalls by learning how to transfer human facial expressions to character expressions that are both perceptually consistent and geometrically correct.

Deepali Aneja, Bindita Chaudhari, Alex Colburn, Gary Faigin, Linda G. Shapiro, and Barbara Mones. Learning to Generate 3D Stylized Character Expressions from Humans, WACV, 2018.

Deepali Aneja, Alex Colburn, Gary Faigin, Linda G. Shapiro, Barbara Mones. Modeling Stylized Character Expressions via Deep Learning, ACCV, 2016.

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Joshua Smith // Biosystems; Photonics & Nano Devices; Power & Energy Systems

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Faculty Coordinator, ECE Professional Masters Program
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Research Webpage: https://sensor.cs.washington.edu/

Education

- BA Computer Science, Philosophy, Williams College, Williamstown, MA, 1991
- MA Physics, University of Cambridge, Cambridge UK, 1997
- PhD. / MS, Massachusetts Institute of Technology, 1999 / 1995

Notable Publications

- Analysis, experimental results, and range adaptation of magnetically coupled resonators for wireless power transfer, AP Sample, DT Meyer, JR Smith, IEEE Transactions on industrial electronics 58 (2), 544-554, 2010
- Ambient backscatter: wireless communication out of thin air, V Liu, A Parks, V Talla, S Gollakota, D Wetherall, JR Smith, Proceedings of the ACM SIGCOMM 2013 conference, Best Paper, 39-50, 2013
- Design of an RFID-based battery-free programmable sensing platform, AP Sample, DJ Yeager, PS Powledge, AV Mamishev, JR Smith, IEEE Transactions on Instrumentation and Measurement, 57 (11), 2608-2615, 2008
- Wi-Fi Backscatter: Internet Connectivity for RF-Powered Devices, B Kellogg, A Parks, S Gollakota, JR Smith, D Wetherall, Proceedings of the ACM SIGCOMM 2014 conference, 2014
- An electric field pretouch system for grasping and co-manipulation, B Mayton, L LeGrand, JR Smith, 2010 IEEE International Conference on Robotics and Automation, 831-838, 2010

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Joshua Smith // Biosystems; Photonics & Nano Devices; Power & Energy Systems

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Smith
Project #1



Wireless Power Transfer



Safely sending watts over several feet



We are developing methods to simultaneously transfer energy and information without wires or connectors. We developed adaptation methods that maintain high efficiency despite coil geometry changes. The technology enables fully-autonomous operation for Unmanned Aerial & Ground Vehicles. Additional applications in implanted medical devices. Commercialized via ECE spin-out Wibotic

Publications: Analysis, experimental results, and range adaptation of magnetically coupled resonators for wireless power transfer, AP Sample, DT Meyer, JR Smith, IEEE Trans industrial electronics 58 (2), 544-554, 2010
US Patent 8,299,652, AP Sample, JR Smith
Funding: NIH, NSF, UW
Collaborators: Wibotic Inc

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Joshua Smith // Biosystems; Photonics & Nano Devices; Power & Energy Systems

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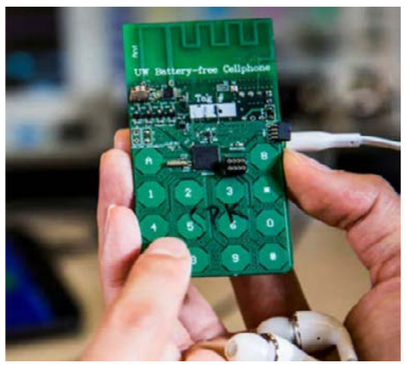
Smith
Project #2



Zero-power communication



Ambient Backscatter allows infrastructure-free communication by reflecting pre-existing radio signals



Energy-constrained devices can communicate without generating their own radio signals by reflecting pre-existing radio signals. This approach to communication requires far less power than conventional methods. We have developed numerous variants of this approach for various applications
Commercialized by UW ECE-CSE spinout Jeeva

Jeeva
REIMAGINING CONNECTIVITY

Publications: Ambient backscatter: wireless communication out of thin air, V Liu, A Parks, V Talla, S Gollakota, D Wetherall, JR Smith, Proceedings of the ACM SIGCOMM 2013 conference, Best Paper, 39-50, 2013
Funding: NSF, Intel, Google, Amazon
Collaborators: S. Gollakota; Jeeva Wireless

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Joshua Smith // Biosystems; Photonics & Nano Devices; Power & Energy Systems

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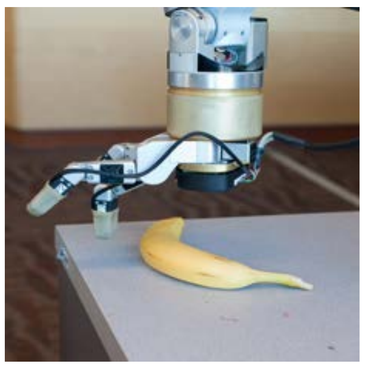
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Smith
Project #3



Pre-touch sensing for robotics







We are developing non-contact “pre-touch” sensing methods that improve the reliability and speed of robotic manipulation. We are interested in settings in which humans and robots interact closely

Publications: An electric field pretouch system for grasping and co-manipulation, B Mayton, L LeGrand, JR Smith, 2010 IEEE International Conference on Robotics and Automation, 831-838, 2010
Funding: NSF, Intel
Collaborators: S. Srinivasa, M Cakmak

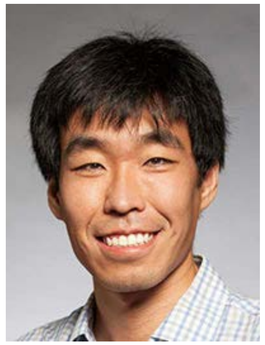
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Baosen Zhang // Computing & Networking; Power & Energy Systems; Robotics

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Baosen Zhang
Keith & Nancy Endowed Career Development Professor of Electrical and Computer Engineering
Research Theme: Power and energy systems, control, optimization, data science.
Office: M310 ECE **| Email**: zhangbao@uw.edu
Research Webpage: http://zhangbaosen.github.io/

Education

- B.A.Sc. in Engineering Science, University of Toronto, 2008.
- PhD. in Electrical Engineering and Computer Sciences, University of California, Berkeley, 2013.

Notable Publications

- Y. Chen, Y. Wang, D. Kirschen and B. Zhang, "Model-Free Renewable Scenario Generation Using Generative Adversarial Networks," in IEEE Transactions on Power Systems, vol. 33, no. 3, pp. 3265-3275, 2018.
- Y. Shi, B. Xu, D. Wang and B. Zhang, "Using Battery Storage for Peak Shaving and Frequency Regulation: Joint Optimization for Superlinear Gains," in IEEE Transactions on Power Systems, vol. 33, no. 3, pp. 2882-2894, 2018.
- A. Jaech, B. Zhang, M. Ostendorf and D. Kirschen, "Real-Time Prediction of the Duration of Distribution System Outages," in IEEE Transactions on Power Systems, vol. 34, no. 1, pp. 773-781, 2019.
- Y. Chen, Y. Shi, and B. Zhang. "Optimal Control Via Neural Networks: A Convex Approach." International Conference on Learning Representations (ICLR) 2019
- J. E. Contreras-Ocaña, Y. Chen, U. Siddiqi and B. Zhang, "Non-Wire Alternatives: an Additional Value Stream for Distributed Energy Resources," in IEEE Transactions on Sustainable Energy, 2020

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Baosen Zhang // Computing & Networking; Power & Energy Systems; Robotics



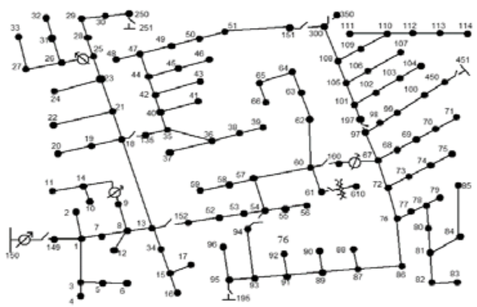
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Machine Learning for Energy Systems





A fundamental challenge in controlling energy systems is that they are governed by complicated functions with unknown parameters. At the same time, machine learning techniques are often developed without considering the physics and constraints of these systems.

Our approach is to explicitly design the machine learning architecture to match the physical characteristics and constraints of the physical system.

For example:

- Design the machine learning model to be convex for data-driven control of HVAC systems of buildings (field implementation)
- Make use of economic interpretation to design algorithms for power system operations

Publications: Y. Chen, Y. Shi, and B. Zhang. "Optimal Control Via Neural Networks: A Convex Approach." International Conference on Learning Representations (ICLR) 2019
Y. Chen and B. Zhang. "Learning to solve network flow problems via neural decoding." arXiv:2002.04091, 2020.
Funding: National Science Foundation

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Chet Moritz // Biosystems

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Chet Moritz

Associate Professor, Electrical and Computer Engineering

Research Theme: Neural Engineering

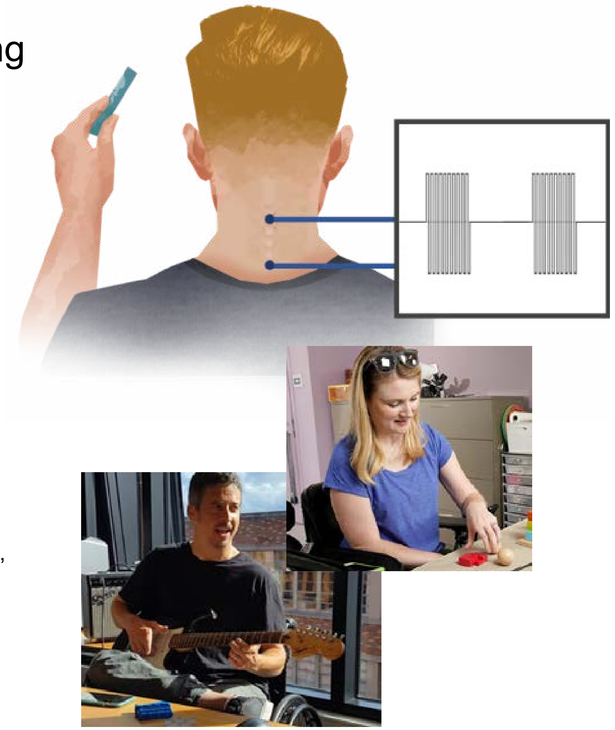
Office: M450 | **Email**: ctmoritz@uw.edu

Education

- BS University of Washington
- PhD. University of California, Berkeley

Notable Publications

- Moritz, C. T. , Perlmutter, S. I., Fetz, E. E. (2008) Direct control of paralyzed muscles by cortical neurons. **Nature**, 456 , 639-642.
- Lu, C., Park, S., Richner, T., Derry, A., Brown, I., Hou, C., Rao, S., Kang, J., Moritz, C.T. Fink, Y., and Anikeeva P. (2017) Flexible and Stretchable Nanowire Coated Fibers for Optoelectronic Probing Spinal Cord Circuits. **Science Advances**. 3(3) e1600955. DOI: 10.1126/sciadv.1600955
- Inanici, F., Samejima, S., Gad, P., Edgerton, V.R., Hofstetter, C., Moritz, C.T. (2018) Transcutaneous electrical spinal stimulation promotes long-term recovery of upper extremity functions in chronic tetraplegia: a case study. **IEEE Transactions on Neural Systems and Rehabilitation Engineering (TNSRE)**. 26(6) 1272-1278.
- Mondello, S.E., Sunshine M.D., Fischedick A.E., Dreyer S., Horwitz, G.D., Anikeeva, P., Horner P.J. Moritz C.T. (2018) Optogenetic surface stimulation of the rat cervical spinal cord. **Journal of Neurophysiology**. https://doi.org/10.1152/jn.00461.2017
- Bjanes, D.A. & Moritz, C.T. (2019) A Robust Encoding Scheme for Delivering Artificial Sensory Information via Direct Brain Stimulation, **IEEE Transactions on Neural Systems and Rehabilitation Engineering**. 27 (10) 1994-2004.



Spinal stimulation to engineer neuroplasticity & restore hand function after spinal cord injury

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Amy Orsborn // Biosystems

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Amy L. Orsborn
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Research Theme: Biosystems, neural engineering, multi-agent learning
Office: 430 ECE | **Email**: aorsborn@uw.edu
Research Webpage: http://faculty.washington.edu/aorsborn/

Education and Training

- BS in Engineering Physics, Case Western Reserve University, 2007.
- Ph.D. in Bioengineering, University of California Berkeley and UCSF, 2013.
- Postdoctoral researcher, Center for Neural Science, New York University, 2014 - 2018.

Notable Publications

- C.H. Chiang*, S.M. Won*, **A.L. Orsborn***, K.J. Yu*, et al.. (2020) Development of a neural interfaces for high definition, long-term recording in rodents and non-human primates, *Science Translational Medicine*, 12, eaay4682.
- M. Shanechi*, **A. L. Orsborn***, H.G. Moorman*, S. Gowda*, and J.M. Carmena (2017). Rapid control and feedback rates enhance neuroprosthetic control. *Nature Communications*, 8:13825, doi:10.1038/ncomms13825.
- **A.L. Orsborn**, H.G. Moorman, S.A. Overduin, M. M. Shanechi, D. Dimitrov, and J.M. Carmena (2014) Closed-loop decoder adaptation shapes neural plasticity for skillful neuroprosthetic control, *Neuron* 82, pp. 1380-1393.
- **A.L. Orsborn** and B. Pesaran (2017) Parsing learning in networks using brain-machine interfaces, *Current Opinions in Neurobiology*, 46:76-83, doi: 10.1016/j.conb.2017.08.002

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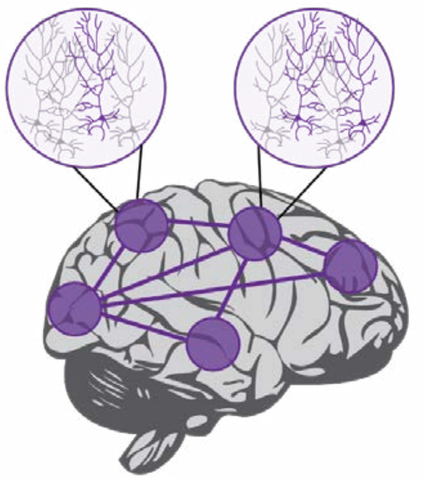
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Orsborn
Project #1



Optimal signal selection for neural interfaces



Brains are multi-scale networks with complex structure.

We can measure brain activity many ways. All measurements have trade-offs and capture different aspects of brain computation. Our goal is to understand how to maximize performance of a neural interface with the fewest sensors via “smart” sampling of brain networks.

Our approach is to:

- Make large-scale multi-modal measurements of brain networks in primates
- Compare subject’s motor neural interface performance with different measurement modalities
- Identify network structure through data-mining and find neural features that maximize information decoding
- Compare neural interfaces controlled with network-informed sampling and arbitrary sampling

Publications: AL Orsborn et al., *IEEE Neural Engineering Conference*, Montpellier France, 2015
Funding: UW Royalty Research Foundation, Interdisciplinary Rehabilitation Engineering Research career development grant.

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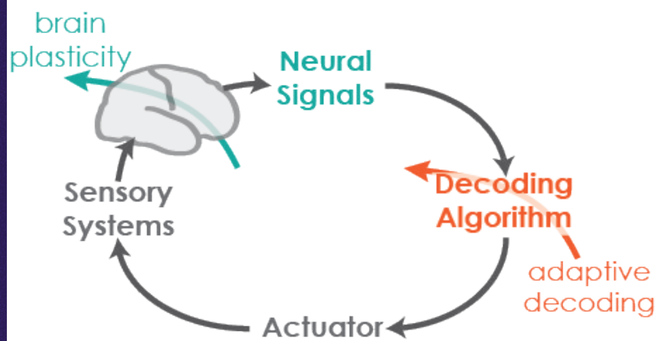
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Orsborn
Project #2



Modeling co-adaptation in neural interfaces



The brain and decoder can "co-adapt" in neural interfaces

Adaptive decoding and brain plasticity can both improve neural interface performance. How do we assure this multi-learner system is stable and optimal? We are building a model of co-adaptation to identify regimes of optimal performance.

We model neurons as performing stochastic gradient decent learning, combined with an adaptive decoder. Parameters are fit to experiment data.

We will characterize system performance to find:

- Optimal decoder adaptation algorithms
- Brain-decoder interactions that lead to sub-optimal solutions

Model predictions will be tested in new experiments

Publications: AL Orsborn et al., Closed-loop decoder adaptation shapes neural plasticity for skillful neuroprosthetic control *Neuron* 2014
Funding: DoD National Defense Science and Engineering Graduate Research Fellowship
Collaborators: Sam Burden

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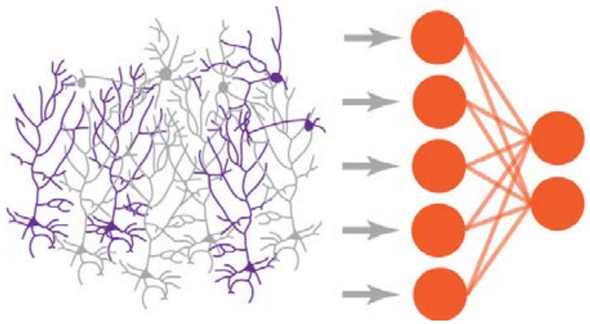
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Orsborn
Project #3



Guiding learning dynamics in neural interfaces



The "credit assignment" problem: only select (purple) neurons drive a neural interface

Optimal learning in neural interfaces requires the brain to solve a "credit assignment" problem. Often the brain only partially learns, leading to reduced performance. We aim to design training strategies to help the brain learn faster and more optimally.

We will use inspiration from training strategies in Artificial Neural Networks that improve network robustness like:

- *Drop-out training:* random decoder parameter perturbations
- *Adaptive scaling*: activity-based decoder parameter scaling

We will run experiments with primates to test whether these training paradigms accelerate brain learning and lead to more complete "credit assignment" learning.

Funding: Google Research Faculty Award
Collaborators: Guillaume LaJoie, Université de Montréal & MILA

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Amy Orsborn // Biosystems

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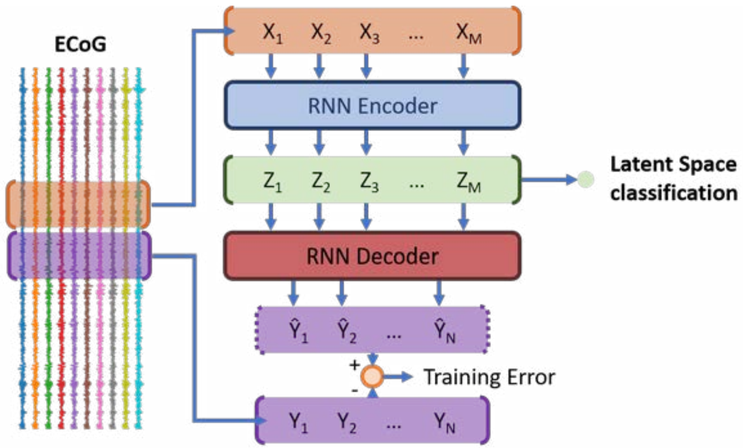
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Orsborn
Project #4



Unsupervised learning of brain states



Seq2Seq network to predict neural data (ECoG) timeseries and classify brain states

Neural interfaces must account for changes in brain state (e.g. wake vs. sleep). States are classically decoded via supervised training. Can we leverage large data to perform unsupervised classification?

We will train a sequence-to-sequence recurrent neural network to predict neural data timeseries. We will then use hidden layers of the network to perform state classification.

Using neural data recorded ~24/7 from primates during free behavior, we will test if we can:

- Classify macro-scale states (awake, asleep)
- Classify sleep stages (REM vs. non-REM)
- Identify different arousal states during behavior

Collaborators: Eli Shlizerman

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Azadeh Yazdan-Shahmorad // Biosystems

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Azadeh Yazdan-Shahmorad
Washington Research Foundation Innovation Assistant Professor of Neuroengineering, Bioengineering, Electrical and Computer Engineering
Research Theme: Neural Engineering, Engineering neuroplasticity, Brain Stimulation
Office: M454 ECE | Email: azadehy@uw.edu

Education

- BS in Biomedical Engineering, Tehran Polytechnic University, Tehran, Iran, 2001
- MS in Electrical Engineering, University of Tehran, Tehran, Iran, 2003
- PhD. In Biomedical Engineering, University of Michigan, Ann Arbor, Michigan, 2011
- Post-doctoral Training, Neuroscience, University of California San Francisco, 2017

Notable Publications

- A. Yazdan-Shahmorad*, D. Silversmith* (Equal contribution), P. N. Sabes, "Targeted cortical reorganization using optogenetics in non-human primates", eLife, 2018 May 29. PMID: 29809133.
- A. Yazdan-Shahmorad*, N. Tian*, V. Kharazia* (Equal contribution), A. Kells, J. He, J. Bringas, K. H. Rosenbluth, K. Bankiewickz, P. Sabes, "Widespread cortical expression of ChR2 in Macaque via MR-guided, convection enhanced delivery (CED) of AAV vector to the thalamus", Journal of Neuroscience methods, Volume 293, January 1, 2018. PMID: 29042259.
- A. Yazdan-Shahmorad, C. Diaz-Botia, T. Hanson, P. Ledochowitsch, M. M. Maharbiz, P. Sabes, "A large interface for optogentic stimulation and recording in non-human primates", Neuron; 2016 Feb 10. PMID: 26875625.
- P. Ledochowitsch*, A. Yazdan-Shahmorad* (Equal contribution), K. E. Bouchard, C. Diaz-Botia, T. L. Hanson, J.W. He, B. Seyboldt, E. Olivero, E. A. K. Phillips, T. J. Blanche, C. E. Schreiner, A. Hasenstaub, E. F. Chang, P. N. Sabes, M. M. Maharbiz, "Strategies for optical control and simultaneous electrical readout of extended cortical circuits", Journal of Neuroscience methods (2015). Dec;256:220-31. PMID: 26296286.
- J.W. He, G. Rabiller, Y. Nishijima, Y. Akamatsu, K. Khateeb2, X. Leinekugel, A. Yazdan-Shahmorad,J. Liu, "Experimental cortical stroke induces aberrant increase of sharp wave associated ripples in the hippocampus and disrupts cortico-hippocampal communication", Journal of Cerebral Blood Flow and Metabolism, 2019, Sep 26:271678X19877889.PMID: 31558106.

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Azadeh Yazdan-Shahmorad // Biosystems

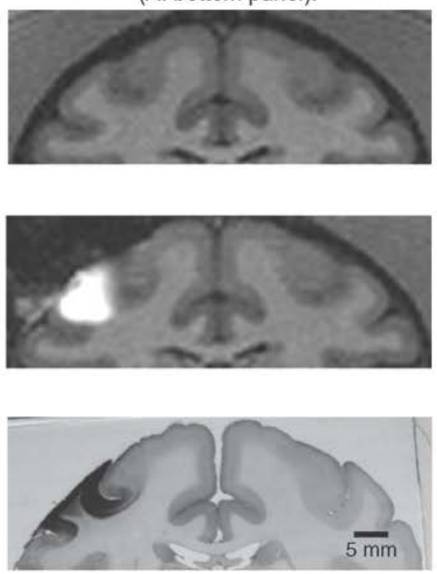
Large-scale neural interfaces for optical and electrical stimulation and recording

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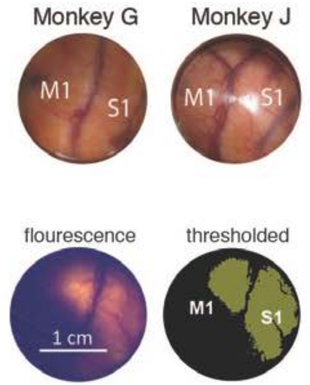
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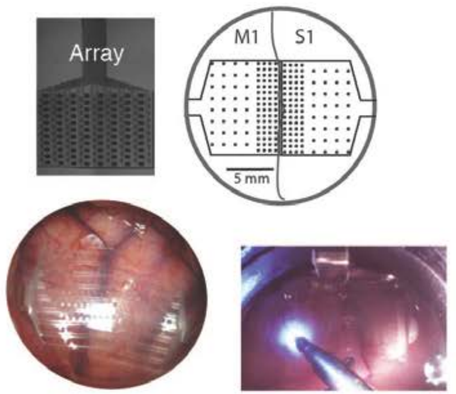
1. MR guided viral infusion techniques based on convection-enhanced delivery (CED, A: middle panel) enable us to achieve high levels of optogenetic expression across large cortical areas confirmed by histology (A: bottom panel).



2. Optical access through artificial dura (top panels). Epifluorescent imaging shows large expression in vivo (bottom pabels)



3. Semi-transparent μ-ECoG array implanted on top of the brain.



4. Examples of temporal and spatial light-evoked activity in Monkey J using the μ-ECoG arrays. Blue dots on the traces on the left panel show the stimulation times. Heat maps show the spatial distribution of the activity across the arrays on top of the brain.



Yazdan-Shahmorad et al., 2016, Neuron
Yazdan-Shahmorad et al., 2015, SPIE BIOS
Yazdan-Shahmorad et al, 2018, J NeuroSci Meth
Ledochowitsch & Yazdan-Shahmorad et al., 2015, J NeuroSci Meth
Griggs et al., 2019, SPIE BIOS

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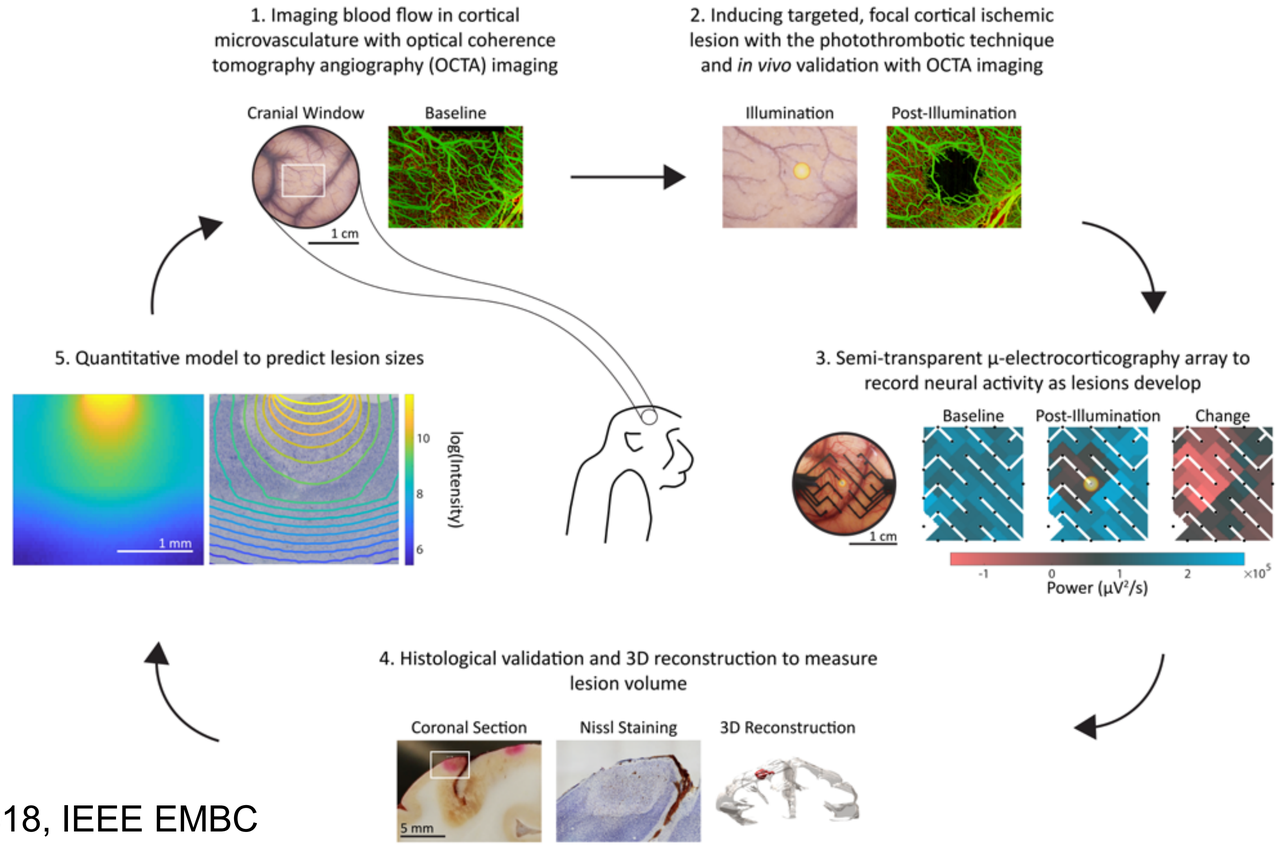
Azadeh Yazdan-Shahmorad // Biosystems

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Toolbox to study cortical physiology and stroke



Yao et al., 2018, IEEE EMBC
Khateeb et al., 2019, IEEE EMBC
Khateeb et al., 2019, Society for Neuroscience meeting

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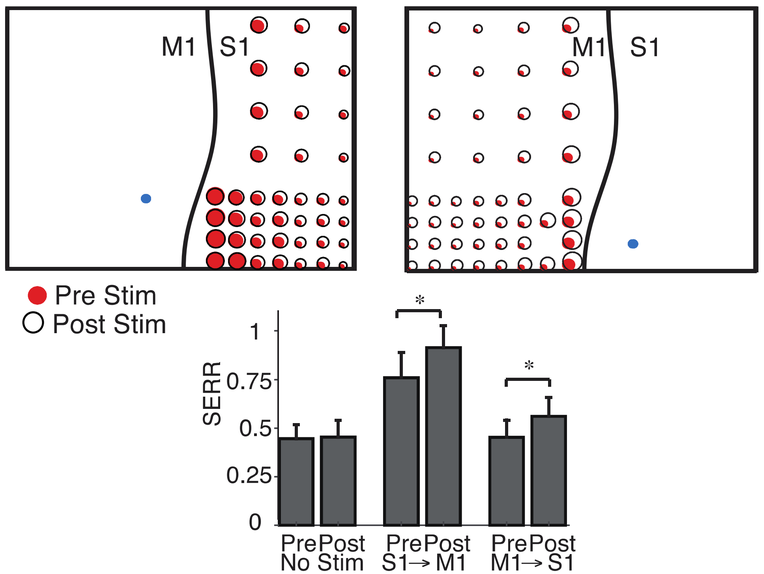
Engineering neuroplasticity using brain stimulation

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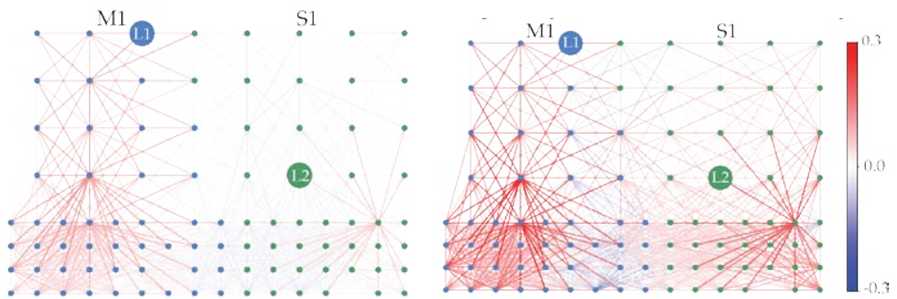
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Inducing targeted connectivity changes using stimulation



Predicating large-scale network changes using data-driven models



Yazdan-Shahmorad and Silversmith et al., eLife, 2018
Bloch et al., 2019, IEEE EMBC
Bloch et al., 2019, Society for Neuroscience meeting

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Azadeh Yazdan-Shahmorad // Biosystems

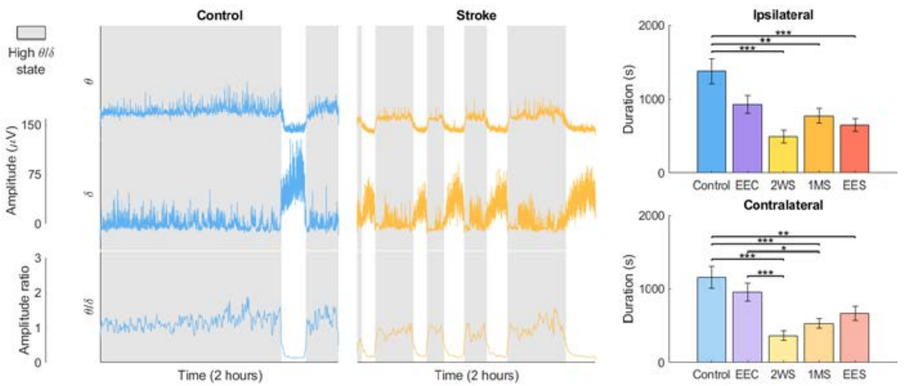
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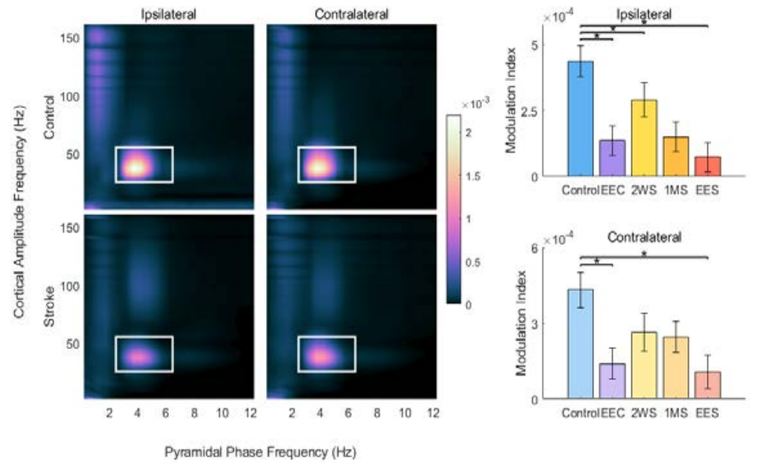
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Neurophysiology of stroke

Stroke affects brain states during sleep



Stroke affects communication between brain regions



He et al, JCNFM (2019)
Ip et al, IEEE EMBC (2019)

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Scott Hauck // Computing & Networking

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Scott Hauck
Gaetano Borriello Professor of Educational Excellence
Associate Chair for Education
Research Theme: FPGAs, High-Performance Computing, VLSI, CAD, Reconfigurable Computing, High-Performance Applications.
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Research Webpage: https://people.ece.uw.edu/hauck/

Education

- BS in Electrical Engineering & Computer Science, University of California, Berkeley, 1990.
- MS in Computer Science & Engineering, University of Washington, 1992.
- PhD. in Computer Science & Engineering, University of Washington, 1995.

Notable Publications

- Aaron Wood, Scott Hauck, "Offset Pipelined Scheduling: Conditional Branching for CGRAs", *IEEE Symposium on Field-Programmable Custom Computing Machines*, 2015.
- Corey B. Olson, Maria Kim, Cooper Clauson, Boris Kogon, Carl Ebeling, Scott Hauck, Walter L. Ruzzo, “Hardware Acceleration of Short Read Mapping”, *IEEE Symposium on Field-Programmable Custom Computing Machines*, 2012.
- S. Hauck, A. DeHon (editors), Reconfigurable Computing: The Theory and Practice of FPGA-Based Computation, Morgan Kaufmann/Elsevier, 2008.
- S. Hauck, Z. Li, E. J. Schwabe, “Configuration Compression for the Xilinx XC6200 FPGA”, *IEEE Symposium on FPGAs for Custom Computing Machines*, pp. 138-146, 1998.
- S. Hauck, "Asynchronous Design Methodologies: An Overview" (PDF), *Proceedings of the IEEE*, Vol. 83, No. 1, pp. 69-93, January, 1995.

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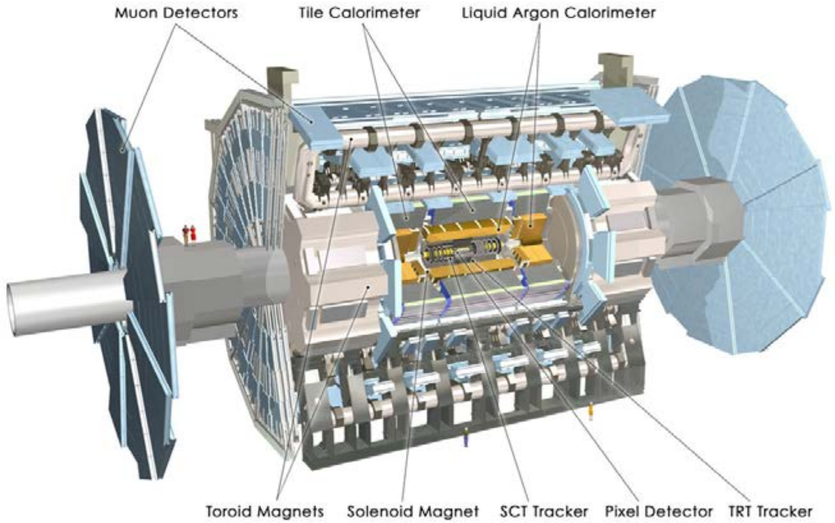


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FPGA Electronics for High Energy Physics



The Large Hadron Collider is the world's largest particle accelerator, which recently identified the Higgs Boson. It is also a giant application of high-performance computing and reconfigurable FPGA logic.

Our research develops new FPGA logic for high-performance filtering of event data, and emulation support for next generation detector electronics. We also look at machine learning alternatives to existing LHC flows.

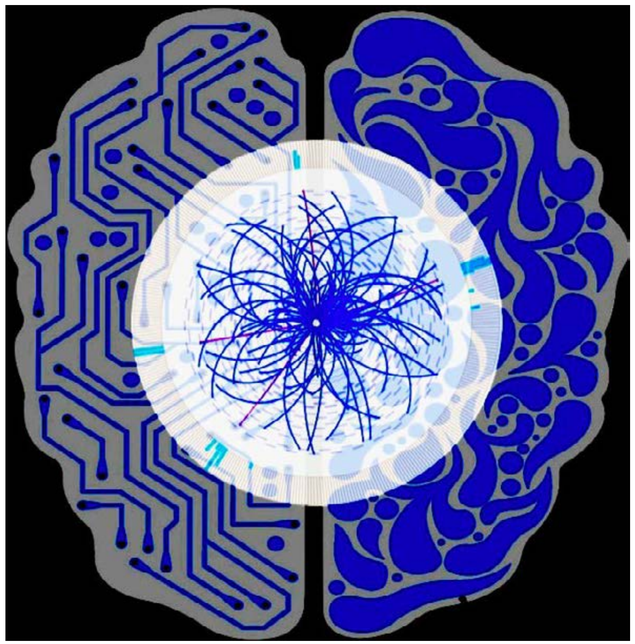
Publications: B. Abbot, et al, "Production and Integration of the ATLAS Insertable B-Layer", submitted to *Journal of Instrumentation*, 2018.
G. Balbi, et al, "The Read-Out Driver ROD card for the Insertable B-layer (IBL) detector of the ATLAS experiment: commissioning and upgrade studies for the Pixel Layers 1 and 2", *Journal of Instrumentation*, Vol. 9, Issue 1, Jan 2014.
S.P. Chen, S.C. Hsu, S. Hauck, "Firmware development and testing of the ATLAS IBL Read-Out Driver card", *International Conference on Technology and Instrumentation in Particle Physics*, 2014.
Funding: USA ATLAS.
Collaborators: Shih-Chieh Hsu (UW Physics), Timon Heim (LBNL).

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Scott Hauck // Computing & Networking



HLS4ML: High-Performance Machine Learning



HLS4ML is a research collective of physicists, engineers, and computer scientists focused on deploying machine learning algorithms for unique and challenging scientific applications. Our projects range from real-time, on-detector and low latency machine learning applications to high-throughput heterogeneous computing big data challenges. We are interested in deploying sophisticated machine learning algorithms to advance the exploration of fundamental physics from the world's biggest colliders to the most intense particle beams to the cosmos.

UW's focus includes automatic translation of deep neural nets to FPGAs and other high-performance fabrics, benchmarking of diverse architectures for challenging physics applications, and deployment into ongoing experiments.

Publications: Nhan Tran, et al, "FPGA-accelerated machine learning inference as a service for particle physics computing", *Computing and Software for Big Science*, 2019.
Javier Duarte, et al, "Low-latency machine learning inference on FPGAs", ML4PS, 2019.
Funding: NSF, Internet2.
Collaborators: MIT, Fermilab, UCSD, CERN, UIUC, Columbia, UIC.

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Jenq-Neng Hwang // Data Science

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Jenq-Neng Hwang
Professor of Electrical and Computer Engineering
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Research Theme: Machine Learning, Image/Video Analysis, Mobile Networking
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Research Webpage: people.ece.uw.edu/hwang/

Education

- BS in Electrical Engineering, National Taiwan University, 1981.
- MS in Electrical Engineering, National Taiwan University, 1983.
- PhD. in Electrical Engineering, University of Southern California, 1988.

Notable Publications

- Yu-Hen Hu, Jenq-Neng Hwang, ***Handbook of neural network signal processing***. Routledge, Taylor and Francis Group, 2002.
- Jenq-Neng Hwang, ***Multimedia Networking: from theory to practice***. Cambridge University Press, 2009
- J.N. Hwang, J.J. Choi, S. Oh and R.J. Marks II, "Query based learning applied to partially trained multilayer perceptrons", IEEE Transactions on Neural Networks, 2(1):131-136, January 1991.
- Jeng-Neng Hwang, Shyh-Rong Lay, M. Maechler, R.D. Martin, J. Schimert, “Regression modeling in back-propagation and projection pursuit learning,” IEEE Trans. on Neural Networks, 5(3):342-353, May 1994.
- Kuan-Hui Lee, Jenq-Neng Hwang, “On-road pedestrian tracking across multiple driving recorders,” IEEE Trans. on Multimedia, 17(9):1429-1438, September 2015.
- Gaoang Wang, Jenq-Neng Hwang, Craig Rose, Farron Wallace, “Uncertainty based active learning via sparse modeling for image classification,” IEEE Trans. on Image Proc., 28(1):316-329, Jan. 2019.

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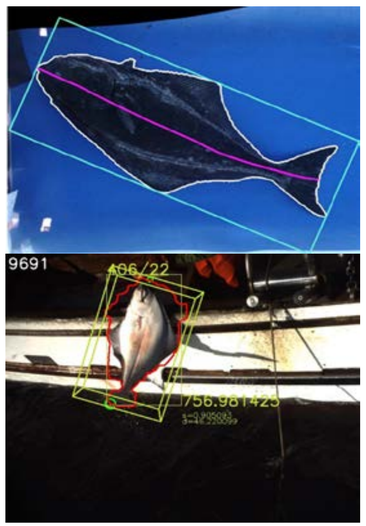
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Hwang
Project #1



Electronic Monitoring of Fishing Activities



Automated fish length measurement and species identification during catching

- Developing fishery analysis algorithms to automate fish catch counting, length measurement, species identification, as well as bycatch detection for systematic monitoring of fishing activities.
- The proposed rail-fishing tracking system consists of a deep-learning based fish object detector, which gives multiple 2D object proposals in terms of bounding boxes with different detection scores, and a Kalman filter-rescoring module in 3D. Besides, with the refined object segmentation result of RGB-D image derived from stereo images, the location of the object is further updated for better tracking and 3D length measurement performance.
- Used practically in the experimental fishing boats of NOAA, and will be deployed to most commercial fishing boats in the near future.

Publications: Tsung-Wei Huang, Jenq-Neng Hwang, Suzanne Romain, Farron Wallace, Farron Wallace, “Fish Tracking and Segmentation from Stereo Videos on the Wild Sea Surface for Electronic Monitoring of Rail Fishing," IEEE Trans. on CSVT, 29(10): 3146 - 3158, Oct. 2019.

Funding: Alaska Fisheries Science Center, NOAA

Collaborators: Farron Wallace, Craig Rose, Suzanne Romain

Jenq-Neng Hwang // Data Science

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Hwang
Project #2



Large-Scale Vehicular Tracking for AI City



Automated tracking of multiple vehicles within a camera and across multiple cameras based on the roadside traffic surveillance system.

- Multi-target and multi-camera tracking (MTMCT) for intelligent transportation and smart city applications has received more and more attention. The challenges of MTMCT include similar vehicle models, significant feature variation in different orientations, color variation of the same car due to lighting conditions, small object sizes and frequent occlusion, as well as the varied resolutions of videos.
- In this work, we propose an MTMCT system, which combines a tracklet-based single-camera tracking (SCT) and inter-camera tracking (ICT) which includes trajectory-based camera link model and deep feature re-identification.
- This system achieved the top-1 ranking in the Track-1 of the 2019 CVPR AI City Challenge, which tracks all the vehicles across 40 city-scale cameras in 10 intersection, with the longest distance between two simultaneous cameras being 2.5 km.

Publications: Hung-Min Hsu, Tsung-Wei Huang, Gaoang Wang, Jiarui Cai, Zhichao Lei, and Jenq-Neng Hwang, “Multi-Camera Tracking of Vehicles based on Deep Features Re-ID and Trajectory-Based Camera Link Models,” AI City Challenge Workshop, IEEE/CVF CVPR, June 2019

Funding: MindInTech Inc.

Collaborators: Seokyong Moon

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Jenq-Neng Hwang // Data Science

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Hwang
Project #3



Monocular Road Object 3D Localization



Automated car detection, 3D localization and orientation estimation from an on-board monocular dash camera

- Working with advanced driver-assistance systems (ADAS) to develop affordable and robust road objects (pedestrians, various car types, motorbikes, etc) detection and 3D localization based on the on-board monocular dash camera.
- Our system contains an RCNN-based Localization Network, which works in concert with fitness evaluation score (FES) based single-frame optimization, to get more accurate and refined 3D vehicle localization. We further use a multi-frame optimization technique, taking advantage of camera ego-motion and a 3D multi-object tracking (MOT), to improve both accuracy and consistency in our 3D localization results.
- This system achieved the top-1 ranking in Track 3 and top-2 ranking in Track 2 of the 2020 CVPR Multi-Object Tracking and Segmentation Challenge.

Publications: Yizhou Wang, Yen-Ting Huang, Jenq-Neng Hwang, “Monocular Visual Object 3D Localization in Road Scenes,” ACM Multimedia Conference (ACM-MM), Nice, France, October 21-25, 2019.
Funding: CMMB Vision Inc.
Collaborators: Guanbin Xin and Hui Liu

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Jenq-Neng Hwang // Data Science

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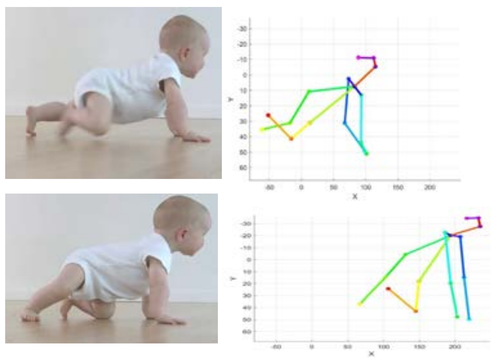
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3D Human Pose Estimation for Early Detection of Baby Autism

Hwang
Project #4





Automated 2D baby body keypoints are detected, followed by EDA optimization to infer 3D poses, based on a movable smart phone.

- Siblings of children already diagnosed with autism are up to 20 times more likely than the general population to develop the disorder. The researchers assessed motor ability using the Alberta Infants Motor Scale (AIMS), which is a questionnaire that tracks motor milestones by observing the poses a baby can achieve. To effectively categorize the baby's poses based on AIMS scoring, a video based 3D baby pose estimation technique is proposed and investigated.
- In our framework, the 2D poses estimated by OpenPose are post-processed by the KLT feature tracker, which is based on optical flow, for further refinement. The 3D human poses is estimated through regression based on EDA, with the cost function as the weighted sum of (1) spatial constancy loss, (2) temporal constancy loss, (3) body flatness loss, and (4) joint angle loss.
- This system can allow parents to film the baby videos at home, through a smart phone, to perform early autism detection of babies from 3-9 months old.

Publications: Renshu Gu, Gaoang Wang, Zhongyu Jiang, Jenq-Neng Hwang, "Multi-Person Hierarchical 3D Pose Estimation in Natural Videos," IEEE Trans. on CSVT, November 2019.
Funding: Electronics and Telecommunications Research Institute (ETRI), Korea
Collaborators: Janghee Yoo

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Mari Ostendorf // Data Science

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Mari Ostendorf
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Associate Vice Provost for Research
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Research Webpage: http://tial-uw.github.io/

Education

- BS Electrical Engineering, Stanford University, 1980.
- MS Electrical Engineering, Stanford University, 1981.
- PhD Electrical Engineering, Stanford University, 1985.

Selected Recent Publications

- Y. Luan, D. Wadden, L. He, A. Shah, M. Ostendorf and H. Hajishirzi, "A general framework for information extraction using dynamic span graphs," *Proc. NAACL,* 2019
- H. Cheng, H. Fang and M. Ostendorf, "A dynamic speaker model for conversational interactions," *Proc. NAACL,* 2019
- V. Zayats and M. Ostendorf, "Giving attention to the unexpected: using prosody innovations in disfluency detection," *Proc. NAACL,* 2019.
- A. Jaech and M. Ostendorf, "Low-rank RNN adaptation for context-aware language modeling," *Trans. Association of Computational Linguistics,* 2018
- V. Zayats and M. Ostendorf, “Conversation Modeling on Reddit using a Graph-Structured LSTM,” *Trans. Association of Computational Linguistics,* 2018.
- J. He, J. Chen, X. He, J. Gao, L. Li, L. Deng and M. Ostendorf, “Deep reinforcement learning with a natural language action space,” *Proc. ACL,* 2016.

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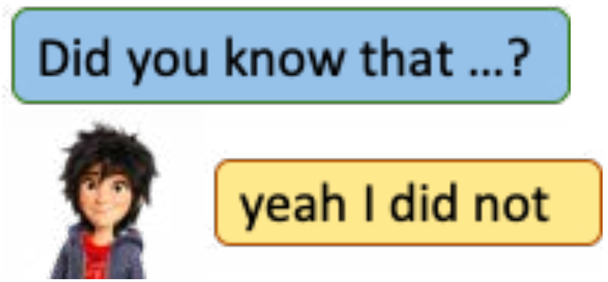
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Ostendorf
Project #1



Conversational AI







How can I help you?

Goal: Understanding & providing conversational interactions

Problems: Speech understanding, knowledge retrieval, response generation -- all with speech recognition errors and user differences

Approach: Sentiment-driven user model, knowledge graph grounding, error-sensitive policies

Publications: H. Fang, H. Cheng, E. Clark, A. Holtzman, M. Sap, Y. Choi, N. A. Smith and M. Ostendorf, "Sounding Board: A user-driven and content-driven social chatbot," *Proc. NAACL,* 2018.
Funding: Allstate, T-Mobile, Amazon
Collaborators: Noah Smith & Yejin Choi, UW Allen School

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Ostendorf
Project #2



Personalized Child-Robot Dialogic Reading



Goal: Support early childhood education through collaborative AI interactions

Problems: Current systems aim at answering questions; we need to ask questions.

Approach:

- Use acoustic-prosodic cues to assess engagement vs. uncertainty
- Leverage story knowledge graph for question generation

Funding: NSF.
Collaborators: Cynthia Breazeal, MIT; Abeer Alwan, UCLA

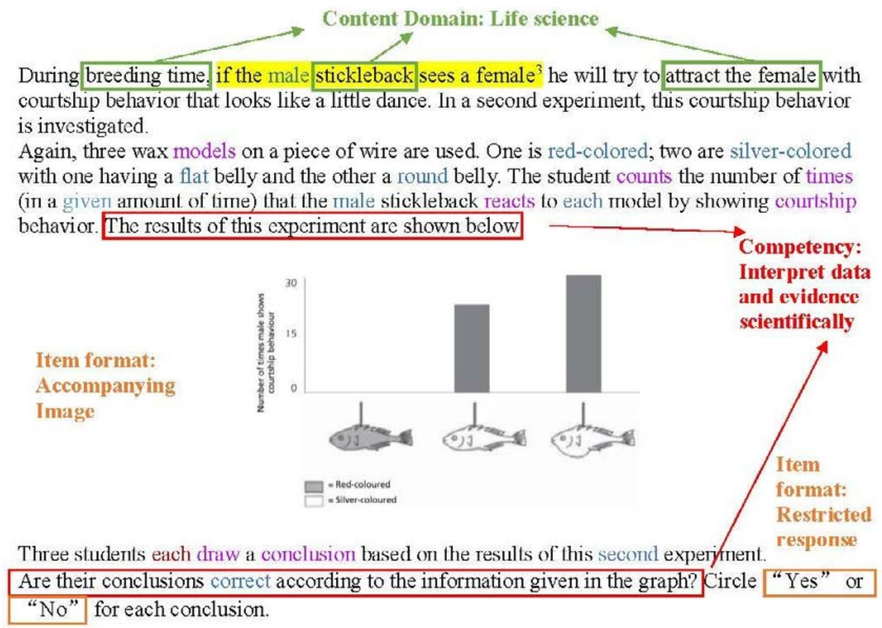
Mari Ostendorf // Data Science

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Ostendorf
Project #3



Automatic Profiling of Science Assessment Items



Funding: NSF.
Collaborators: Min Li, UW College of Education

Goal: Improve science assessment items by identifying characteristics that disadvantage some groups

Problem: Sources of bias are not well understood.

Approach:

- Use natural language processing to characterize (profile) items
- Identify sources of bias in items by analyzing differential student performance

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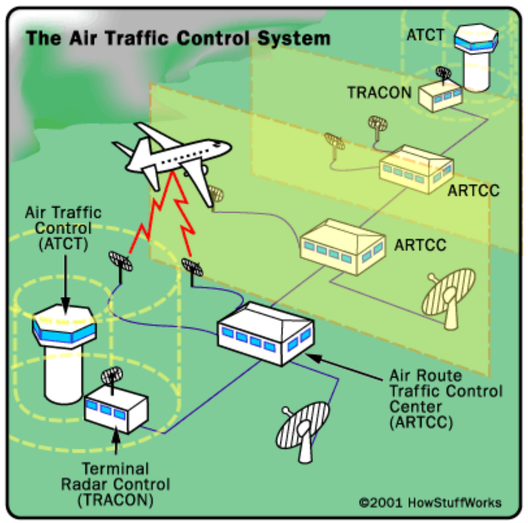
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Ostendorf
Project #4



ATC Speech Recognition in VHF Noise Environment



Current systems for voice communications for air traffic control.

Funding: Boeing.
Collaborators: Les Atlas, UW ECE.

Goal: Understand ATC communications

Problem: Severe channel distortion, limited data for training, airport-dependent characteristics
→ High error rates with commercial ASR systems

Approach:

- Highly specialized language use facilitates low-rank language model adaptation
- Airport-dependent distortion reduction

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Eve Riskin // Data Science

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Eve A. Riskin
Professor of Electrical and Computer Engineering, STARS Faculty Director, UW ADVANCE Faculty Director
Research Theme: Diversity in higher education, Human-Computer Interaction
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Education

- BS in Electrical Engineering, MIT
- MS in Electrical Engineering, Stanford University
- MS in Operations Research, Stanford University
- PhD in Electrical Engineering, Stanford University

Notable Publications

- Coleen Carrigan, Katie O'Leary, Eve Riskin, Joyce Yen, and Matt O'Donnell, On-ramping: following women scientists and engineers through their transition from nonacademic to faculty careers," The Journal of Technology Transfer, December 2015.
- Joyce Yen, Eve Riskin, Cara Margherio, Jan Spyridakis, Coleen Carrigan, and Ana Mari Cauce, Promoting gender diversity in STEM faculty through leadership development: From local and national leadership workshops to the online LEAD-it-Yourself! toolkit,“ Equality, Diversity and Inclusion: An International Journal, 38(3): 382-398, 2019.
- Coleen Carrigan, Jarman Hauser, Eve Riskin, Priti Mody-Pan, Jim Borgford-Parnell, Dawn Wiggin, Scott Winter, Scott Pinkham, and Sonya Cunningham, Active Agents and Fictive Kin: Learning from Pell-Eligible Engineering Students' Class Standpoint,“ Journal of Women and Minorities in Science and Engineering, 25(2): 149-168, 2019.
- Sefidgar, Y. S., Seo, W., Kuehn, K. S., Altho, T., Browning, A., Riskin, E., Nurius, P. S., Dey, A. K., and Manko, J., Passively-sensed Behavioral Correlates of Discrimination Events in College Students," Computer-Supported Cooperative Work and Social Computing, 2019.

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Ming-Ting Sun // Data Science

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Ming-Ting Sun
Professor, Electrical and Computer Engineering.

Life Fellow, IEEE.
Served as an Editor-in-Chief for three major journals.

Research Theme: Video compression, Video understanding, Machine learning.
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Education

- BSEE in Electrical Engineering, National Taiwan University, 1976.
- PhD. in Electrical Engineering, UCLA, 1985.

Notable Publications

- K.M. Yang, M.T. Sun, and L. Wu, "A Family of VLSI Designs for the Motion Compensation Block-Matching Algorithm," IEEE Transactions on Circuits and Systems, pp. 1317-1325, Oct. 1989. (486 citations)
- J. Xin, C.W. Lin, and M.T. Sun, “Digital Video Transcoding,” Proceedings of the IEEE, vol.93, no.1, pp. 84-97, 2005. (477 citations)
- J. Youn, M.T. Sun, and C.W. Lin, “Motion Vector Refinement for Transcoding,” IEEE Transactions on Multimedia, vol. 1, no. 1, pp. 30-40, March 1999. (346 citations)
- S.M. Lei and M.T. Sun, "An Entropy Coding System for Digital HDTV Applications," IEEE Transactions on Circuits and Systems for Video Technology, pp. 147-155, March 1991. (263 citations)
- M.T. Sun and A. Reibman, “Compressed Video over Networks,” Marcel Dekker, 2000. (251 citations)

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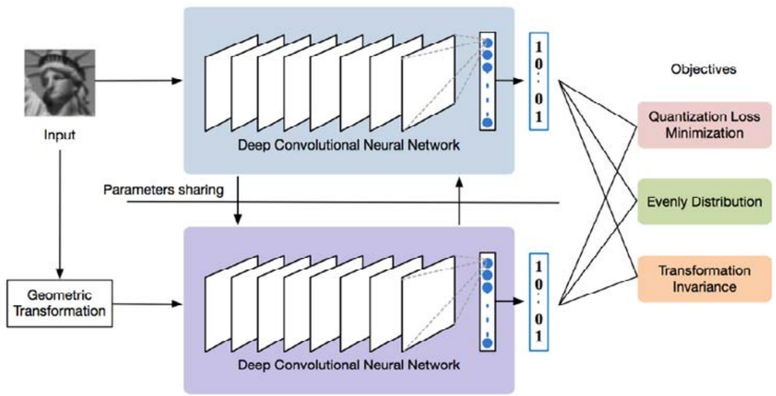
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Training Deep Learning Networks without Human Labeling

Sun
Project #1





Using Self-similarity to automatically generate labels for training deep neural networks.

Supervised training with deep convolutional neural networks (CNNs) requires large amount of well-annotated ground truth labels. How to learn effective deep CNNs without ground truth labels is a critical problem.

We developed several strategies to avoid expensive human annotations. We use the self-similarity property in images to automatically generate training labels. Human skeleton can be utilized to bridge the gap between synthetic and real data for multi-person human part segmentation. We also introduce Laplacian prior and part segmentation loss terms into the Graph CNN framework to learn the 3D human mesh construction without human labels.

Using the proposed approaches, we could achieve better performance compared to state-of-the-art approaches without needing human labels.

Publications:

- K. Lin, L. Wang, K. Luo, Y. Chen, Z. Liu, and M.T. Sun, “Cross-Domain Complementary Learning Using Pose for Multi-Person Part Segmentation,” accepted, IEEE Transactions on Circuits and Systems for Video Technology (TCSVT), 2020.
- K. Lin, J. Lu, C.S. Chen, J. Zhou, and M.T. Sun, “Unsupervised Deep Learning of Compact Binary Descriptors," IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI), vol.41, issue 6, pp. 1501-1514, June 2019.
- “Nonparametric Human Mesh Construction from a Single Image Without Ground Truth Mesh Labels,” *Under review in ACM International Conference on Multimedia (ACM MM) 2020.*

Collaborators: Z. Liu, Y. Chen, K. Luo, L. Wang, K. Lin, J. Lu, C.S. Chen, J. Zhou.

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Ming-Ting Sun // Data Science

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Next Generation Image/Video Compression



Sun
Project #2



Multiple views captured by cameras for surface light field representation

After participated in the development of H-series (H.261, H.263, H.264, and H.265) and MPEG-series (MPEG-1, MPEG-2, and MPEG-4) video coding standards, we continue to work on next generation video coding algorithms for various digital video applications. We proposed a point-cloud codec for compressing surface light fields for 3D image/video applications. We worked on stereo video compression and developed a hole filling algorithm with multiple reference views for DIBR (Depth Based Image Rendering) View Synthesis. We also looked into using machine learning based approaches for image and video compression.

Publications:

- X. Zhang, P.A. Chou, M.T. Sun, M. Tang, S. Wang, S. Ma, and W. Gao, “Surface Light Field Compression Using a Point Cloud Codec,” IEEE Transactions on Emerging and Select Topics in Circuits and Systems (JETCAS), vol.9, issue 1, pp. 163-176, March 2019.
- S. Li, C. Zhu, and M.T. Sun, “Hole Filling with Multiple Reference Views in DIBR View Synthesis,” IEEE Transactions on Multimedia, vol.20, no. 8, pp.1948-1959, Aug. 2018.

Collaborators: W. Gao, P.A. Chou, X. Zhang, M. Tang, S. Wang, S. Ma, C. Zhu, and S. Li.

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M.P. Anantram // Photonics & Nano Devices

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Research Webpage: https://sites.uw.edu/anantmp/

Education

- BSc in Applied Science, BA in Mathematics, University of Michigan, 1986.
- MSc in Physics, University of Poona, 1989.
- PhD. in Engineering, Purdue University, 1995.

Notable Publications

- Kinetic Monte Carlo Simulation of Interface-Controlled Hafnia-Based Resistive Memory, Xu Xu, Bipin Rajendran, M. P. Anantram, IEEE Trans. Elec. Dev. 67 (1), 118-124 (2020).
- Unified model for conductance through DNA with the Landauer-Buttiker formalism, J. Qi, N. Edirisinghe, M. G. Rabbani, M. P. Anantram, Physical Review B, vol. 87, article no. 085404 (2013)
- A nested dissection approach to modeling transport in nanodevices: Algorithms and applications, U. Hetmaniuk, Y. Zhao, M. P. Anantram, Int. J. Num. Meth. Eng., vol. 95, pages 587-607, DOI: 10.1002/nme.4518 (2013).
- Two Dimensional Quantum Mechanical Modeling of Nanotransistors, A. Svizhenko, M. P. Anantram, T. R. Govindan, B. Biegel and R. Venugopal, J. of Appl. Phys., vol. 91, p. 2343 (2002)

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M.P. Anantram // Photonics & Nano Devices

Anantram Overview



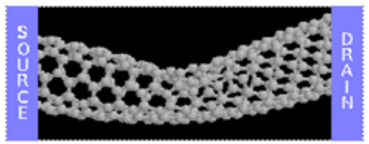
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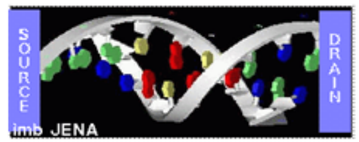
Nanomaterials

- Electromechanical properties
- Optoelectronic response
- Electronic properties



DNA, Origami, Biosensors

- Heterostructures, Memory
- Resonant Tunneling, Doping
- Disease detection, Sequencing



Schrodinger's eqn
Green's func
Kinetic Monte Carlo

→

Electronic, electromechanical & optoelectronic properties

←

Theory
Simulators
Parallel Computation

Resistive Memory – Conducting Bridge



Devices

- Quantum Devices
- Resistive Memory Device
- Phase Change Memory Device
- Graphene-BN Heterostructures

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M.P. Anantram // Photonics & Nano Devices

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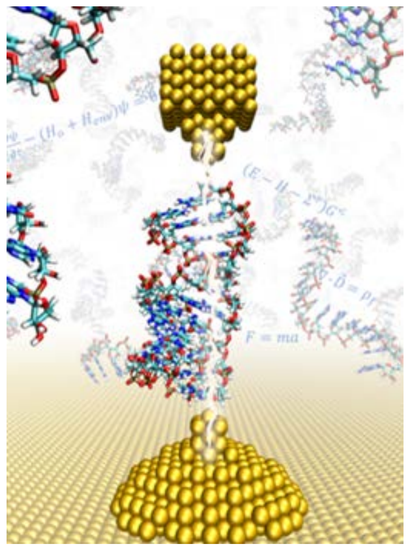
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Anantram
Project #1



Electrical Properties of DNA



DNA Heterostructure Device

DNA heterostructures are double stranded DNA whose energy levels / topology can be precisely controlled. Their electrical properties are of fundamental interest to (i) next generation sequencing technologies, (ii) emerging memory technologies, and (iii) new quantum device concepts.

In our computational approach, we calculate the quantum transport properties using state of the art algorithms developed in our group. Our computational framework also leverages advances in quantum chemistry and molecular dynamics.

- We were able to predict single base mutations in e-coli using our computational method.
- Proposed a Read Only Memory device.

Publications: Detection and identification of genetic material via single-molecule conductance, Y Li et. al, Nature nanotechnology 13, 1167-1173 (2018)
Funding: Semiconductor Research Corporation, National Science Foundation.
Collaborators: Hihath Group (UC Davis), Oren Group (TOBB U)

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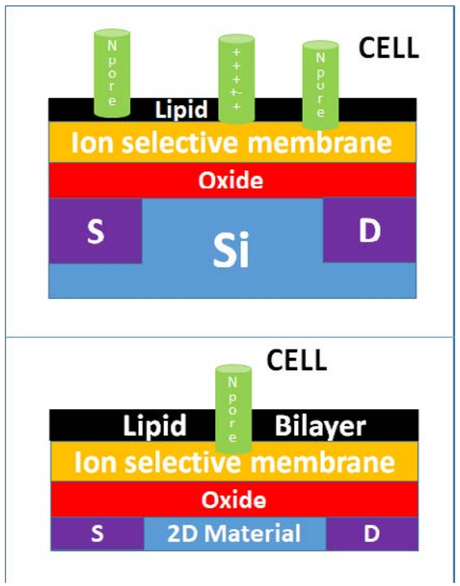
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Anantram
Project #2



DNA Origami based biotic-abiotic interfaces

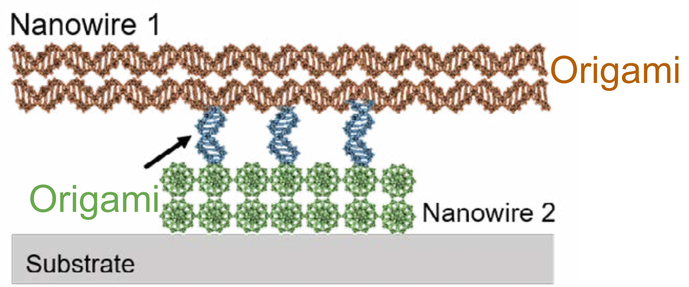


Nanopore (green) connecting a cell to a transistor for biotic-abiotic signalling

DNA origami based nanopores have the potential to revolutionize the interface between living systems with electronics. In this project we propose to computationally study the signalling from cells to transistors.

Multi-physics models involving fluid low and charge transport in nanopores and transistors are being developed.

This is new project with an anticipated start date in August 2020



Funding: Pending National Science Foundation.
Collaborators: Gopinath Group (MIT)

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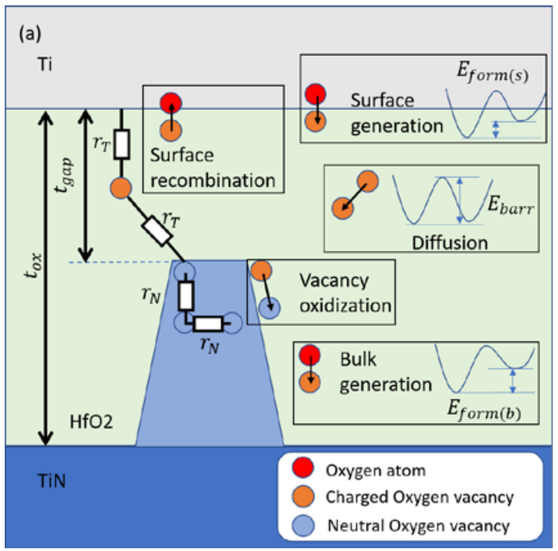
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Anantram
Project #3



Resistive Random Access Memory (RRAM)



Mechanism for filament formation in dielectric

RRAM is one of the leading contenders to replace Flash memory, which is reaching its scaling limits. Apart from being smaller in size, RRAM is attractive for both neuromorphic and radiation hardened space applications.

Our effort has focussed on developing multi-physics models that solve equations that govern heat dissipation, dielectric breakdown, Frenkel pair generation and motion of both atoms and electrons.

- Proposed mechanism for operation based on surface generation of vacancies in bipolar devices and negative Soret coefficient materials
- Proposed a mechanism for conducting filament growth in dielectrics

Publications: Kinetic Monte Carlo Simulation of Interface-Controlled Hafnia-Based Resistive Memory, Xu Xu, Bipin Rajendran, M. P. Anantram, IEEE Trans. Elec. Dev. 67 (1), 118-124 (2020)
Funding: Winbond Inc.
Collaborators: Winbond Inc .

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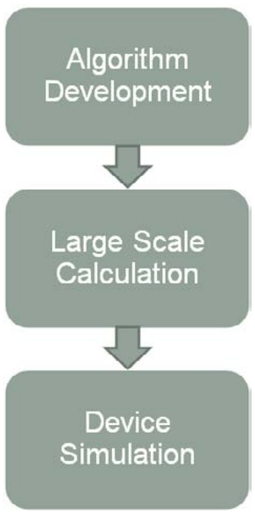
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Anantram
Project #4



Algorithms for Nanodevices



Quantum Modeling of current-voltage in nanodevices

Quantum mechanical effects play an important role in determining the characteristics of nanoelectronic devices. These devices can be classified into (i) devices where operation is classical but quantum corrections are necessary to model them accurately and (ii) nanodevices where quantum mechanics is central to their operation.

Our work focuses on developing computationally efficient algorithms to calculate the transmission and current in quantum devices. We use the non equilibrium Green's function approach combined with graph partitioning methods.

- Developed the state of the art direct-solve algorithm, and demonstrated its application in 2D and 3D quantum nanostructures.

Publications: A nested dissection approach to modeling transport in nanodevices: Algorithms and applications, Int. J. Num. Meth. Eng., vol. 95, pages 587-607 (2013)
Nested dissection solver for transport in 3D nano-electronic devices, Y Zhao, U Hetmaniuk, SR Patil, J Qi, MP Anantram, Journal of Computational Electronics 15 (2), 708-720 (2016)
Collaborators: Ulrich Hetmaniuk, Applied Mathematics Department, University of Washington

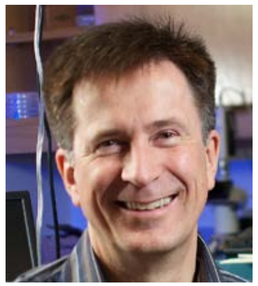
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Karl Böhringer // Photonics & Nano Devices

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Education

- Diplom in Information Sciences, Technical University of Karlsruhe, 1990.
- MS in Computer Science, Cornell University, 1993.
- PhD in Computer Science, Cornell University, 1997.

Notable Publications

- D Sun, KF Böhringer, Self-Cleaning: From Bio-Inspired Surface Modification to MEMS/Microfluidics System Integration, *Micromachines* 10(2):101, 2019.
- A Shastry, MJ Case, KF Böhringer, Directing droplets using microstructured surfaces, *Langmuir* 22(14):6161-6167, 2006.
- XR Xiong, Y Hanein, JD Fang, YB Wang, WH Wang, DT Schwartz, KF Böhringer, Controlled multibatch self-assembly of microdevices, *IEEE J. Microelectromechanical Systems* 12(2):117-127, 2003.
- JW Suh, RB Darling, KF Böhringer, BR Donald, H Baltes, GTA Kovacs, CMOS integrated ciliary actuator array as a general-purpose micromanipulation tool for small objects, *IEEE J. Microel.mech. Systems* 8(4):483-496, 1999.

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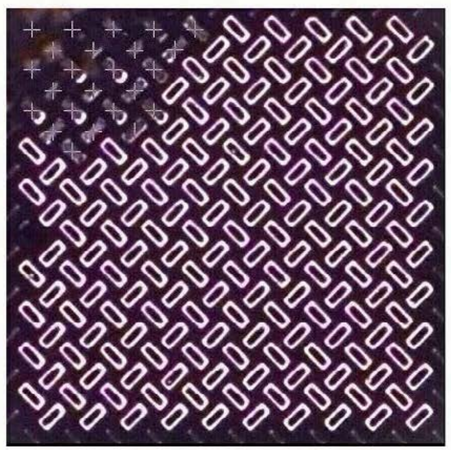
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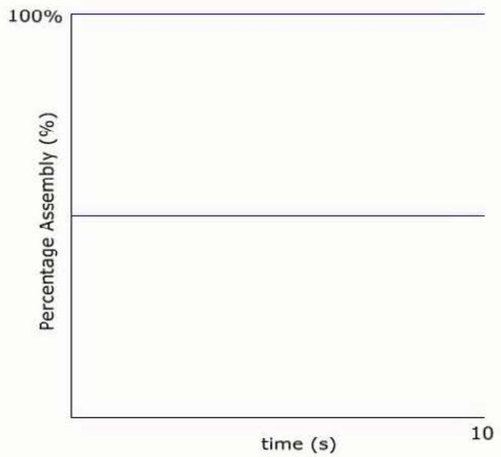
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Böhringer
Project #1



Assembling Large Numbers of Small Parts





Massively parallel self-assembly presents a promising alternative to conventional pick-and-place as the size of the components decreases and their number increases.

We take advantage of interfacial forces to drive the components towards a minimum energy state.

Self-assembly enables heterogeneous integration of parts with different materials and functionalities, e.g. for IoT applications.

Publications: KS Park, C Varel, JH Hoo, R Baskaran, KF Böhringer,"3D integration using self-assembly at air-water-solid interface." *IEEE J. Microelectromechanical Systems* 23(3):579-584, 2014.
JD Fang, KF Böhringer, “Parallel micro component-to-substrate assembly with controlled poses and high surface coverage.” *IOP J. Micromechanics and Microengineering*, 16(4):721-730, 2006.
Funding: NSF, DARPA, Intel, A*STAR IME.
Collaborators: R Baskaran (Intel).

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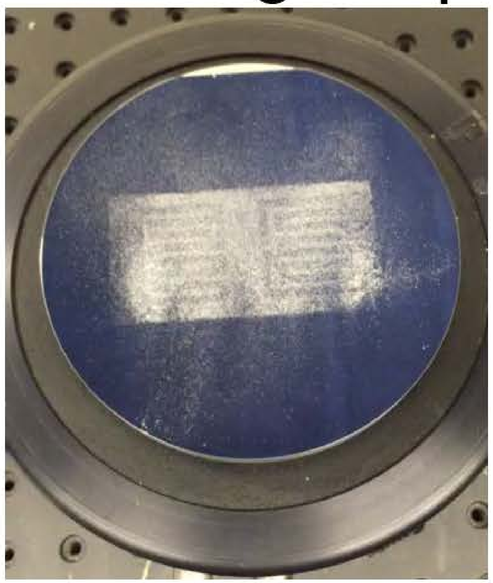
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Böhringer
Project #2



Directing Droplets on Microstructured Surfaces



Manipulating multiple droplets in parallel provides the basis for digital microfluidics, where discrete liquid samples are generated, transported, merged, mixed, and processed in a microfluidic "circuit."

Surfaces with microscale texture transport droplets along predefined paths on "anisotropic ratchet conveyors." ARCs can be fabricated with a low-cost etching or molding process, and droplet motion is effected by vibration.

This technology enables low-cost diagnostic devices and self-cleaning surfaces.

Publications: D Sun, KF Böhringer, "An Active Self-cleaning Surface System for Photovoltaic Modules Using Anisotropic Ratchet Conveyors and Mechanical Vibration," Microsystems & Nanoengineering, 2020.
HR Holmes, KF Böhringer, "Transporting Droplets through Surface Anisotropy", *Microsystems & Nanoengineering* 1:15022, 2015.
TA Duncombe, EY Erdem, A Shastry, R Baskaran, KF Böhringer, "Controlling Liquid Drops with Texture Ratchets." *Advanced Materials* 24(12):1545-1550, March 2012.
Funding: NIH, NSF, Amazon Catalyst. **Collaborators:** R Baskaran (Intel).

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Böhringer
Project #4



INSTITUTE FOR NANO-ENGINEERED SYSTEMS

- New NanoES building completed in 2017
- Focus areas:
  - Photonic and quantum devices
  - Scalable nanomanufacturing
  - Augmented humanity
- Partner Institutes:
  - Clean Energy Institute (CEI)
  - Molecular Engineering and Sciences (MolES)
  - Institute for Protein Design (IPD)
- Northwest Nanotechnology Infrastructure:
  - Washington Nanofabrication Facility (WNF)
  - Molecular Analysis Facility (MAF)

  A site in the NSF National Nanotechnology Coordinated Infrastructure (NNCI)



NanoES: nano.uw.edu
WNF: wnf.uw.edu
MAF: moles.washington.edu/maf/
NNCI: www.nnci.net

National Nanotechnology Coordinated Infrastructure
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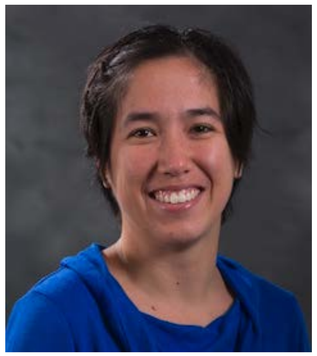
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Kai-Mei Fu // Photonics & Nano Devices

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Associate Professor in Physics
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Research Theme: Crystal defects for quantum information networks
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Research Webpage: https://sites.google.com/uw.edu/optospintronics-lab

Education

- AB in Physics, Princeton, 2000.
- MS in Applied Physics, Stanford University, 2003.
- PhD. in in Applied Physics, Stanford University, 2007.

Notable Publications

- S. Chakravarthi *et al.*, A window into NV center kinetics via repeated annealing and spatial tracking of thousands of individual NV centers, Physical Review Materials 4, 023402 (2020)
- A.D. Logan *et. al.*, 400%/W second harmonic generation conversion efficiency in 14 micron-diameter gallium phosphide-on-oxide resonators, Optics Express 26, 33687 (2018)
- X. Linpeng *et al.* Coherence properties of shallow donor qubits in ZnO, Physical Review Applied 10, 064061 (2018)
- E. Schmidgall *et al.* Frequency control of single quantum emitters in integrated photonic circuits, Nano Letters 18, 1175 (2018)

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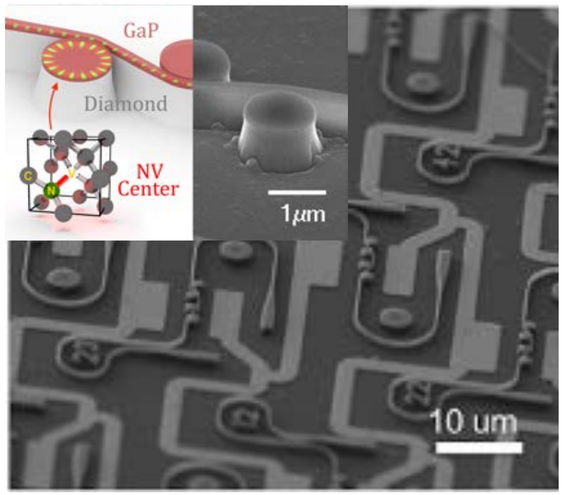
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Fu
Project #1



Device integration of quantum defects for quantum network applications



Small quantum networks of single defects in diamond, GaP optical waveguides and on-chip electrodes.

Single defects in crystals can behave like single atoms- the quintessential quantum entity. The crystal host enable device integration and thus using modern nanofabrication processing, we can imagine integrating single atoms in devices to realize quantum information systems.

Our approach is utilize relatively mature defects with know properties useful for quantum information, and learn how to integrate them into devices while still preserving their quantum properties.

In the devices shown here, we demonstrate that we can obtain routing of photons emitted by the defects into on-chip waveguides and also control the frequency of the emitted photons. We are also investigating quantum frequency conversion to alter photonic properties after emission.

Publications: E Schmidgall, S Chakravarthi, M Gould, IR Christen, K Hestroffer, F Hatamim, K-MC Fu, Frequency control of single quantum emitters in integrated photonic circuits, Nano Letters 18, 1175 (2018)
Collaborators: A Majumdar, M Li, A. Rodriguez, F. Hatami, F. Jelezko

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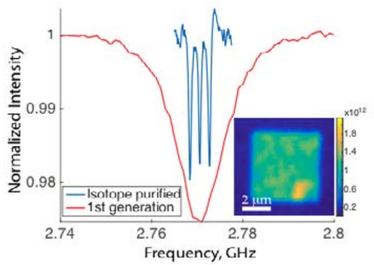
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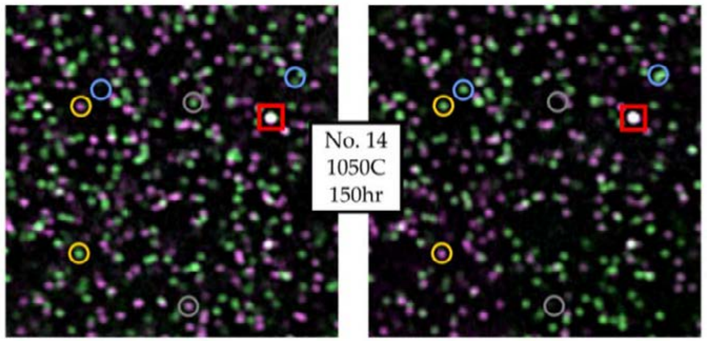
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Fu
Project #2



Quantum defect engineering for quantum information and sensing applications





Thus far, no defect we have discovered has the ideal properties for a given quantum information technology. We thus research ways to deterministically fabricate known defects and engineer their properties.

Our approach is a cycle of theory (to predict/understand properties), synthesis/treatment, and measurement. Our group's expertise is primarily in the measurement section- characterization of single qubit properties.

In the figures illustrate two examples of this engineering. The top figure illustrates the effect of isotope engineering the crystal substrate for defect-based sensors. We now apply these sensors to both biological and materials systems.. The bottom figure shows how longitudinal tracking of single defects can point to ways to engineer them.

Publications: S Chakravarthi, C Moore, A Opsig, E Hunt, A Ivanov, I Christen, S Dunham, K-MC Fu, A window into NV center kinetics via repeated annealing and spatial tracking of thousands of individual NV centers, Physical Review Materials 4, 023402 (2020)
Funding: NSF
Collaborators: S Dunham, P Wiggins, H Watanabe, K Itoh, D Budker

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Kai-Mei Fu // Photonics & Nano Devices

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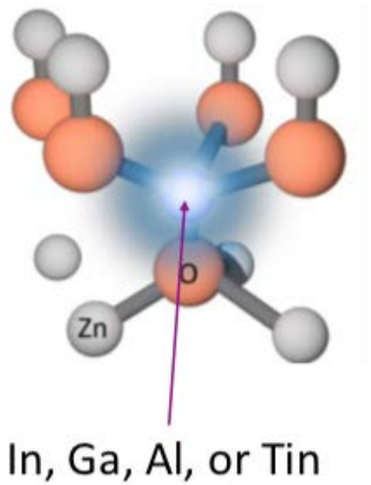
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Fu
Project #3



New defect candidates for quantum information: Semiconductor donors in ZnO



Thus far, no defect we have discovered has the ideal properties for a given quantum information technology. We have an active program at evaluate new defect candidates.

Our current focus is on semiconductor donor spins in ZnO (we have completed studies on GaAs, CdTe, and InP). Donors direct band gap semiconductors are particularly compelling because of the long term potential for both electrical and optical control. They also emit at a wavelength that enable coupling to trapped ions- a very mature qubit.

The results in ZnO are promising so we are now undergoing the next steps of isolating and controlling a single donor.

Publications: X Linpeng, MLK Viitaniemi, A Vishnuradhan, Y Kozuka, C Johnson, M Kawasaki, K-MC Fu, Coherence properties of shallow donor qubits in ZnO, Physical Review Applied 10, 064061 (2018)

Funding: NSF, ARO, DOE

Collaborators: B. Blinov, S Watkins, S Fraser, Y Kozuka, M Kawasaki

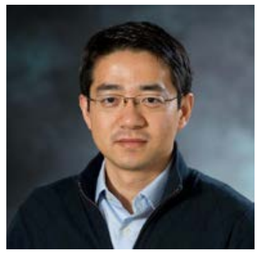
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Mo Li // Photonics & Nano Devices

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Associate Professor of Physics
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Education

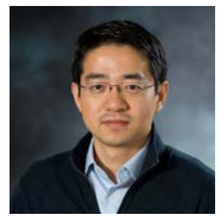
- B.S. in Physics, University of Science and Technology of China, 2001.
- M.S. in Physics, University of California, San Diego, 2003.
- Ph.D. in Applied Physics, California Institute of Technology, 2007.

Notable Publications

- Semere A. Tadesse, Mo Li, “Sub-optical wavelength acoustic wave modulation of integrated photonic resonators at microwave frequencies”, Nature Communications 5, 5402 (2014)
- Nathan Youngblood, Che Chen, Steven J. Koester, and Mo Li, “Waveguide-integrated black phosphorus photodetector with high responsivity and low dark current”, Nature Photonics 9, 247-252(2015).
- Mo Li, W. H. P. Pernice, C. Xiong, T. Baehr-Jones, M. Hochberg, H. X. Tang , "Harnessing optical forces in integrated photonic circuits", Nature 456, 480,(2008)
- Mo Li, H. X. Tang, M. L. Roukes, "Ultrasensitive, NEMS-based cantilevers for sensing, scanned probe, and very high frequency applications", Nature Nanotechnology 2, 114 (2007)

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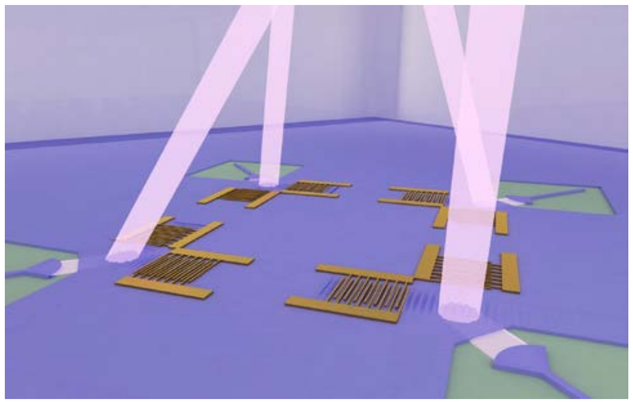


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Manipulate light with sound wave on chip



Envisioned chip-scale multi-beam steering device using integrated acousto-optic devices on a chip.

Acousto-optics has been around for decades and played an important role in optical instruments for frequency shifting, beam deflecting and Q-switching. But these bulk devices use Watts of power and operate at a low frequency.

Our approach is to integrate acousto-optics with nanophotonics using new acousto-optic materials (LiNbO3, AlN, GaP) and increase operation frequency to 10s of GHz. We aim to achieve efficient conversion between microwave and optical for both quantum and classical applications.

We also will develop integrated beam steering devices on a chip for Lidar, remote sensing and free-space communication.

Publications: Huan Li, Qiyu Liu, Mo Li, "Electromechanical Brillouin scattering in integrated plannar Photonics", APL Photonics 4, 080802 (2019)
Funding: NSF
Collaborators: Kai-Mei Fu (UW), Arka Majumdar (UW)

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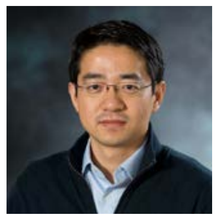
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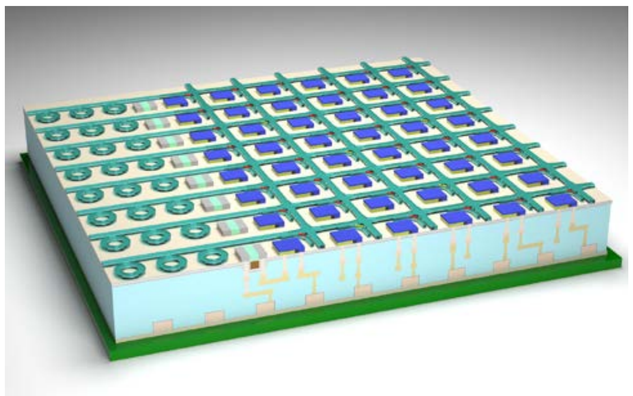
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Phase-change Photonics for Neuromorphic Computing





Envisioned monolithic photonic-electronic hybrid neural network accelerator

Optical neural networks (ONNs) have long been proposed as AI accelerators by utilizing the ultrahigh speed, ultrawide bandwidth, low propagation dissipation and coherence of light, which afford distinct advantages over electronic implementations in terms of latency, bandwidth, computing density, and most importantly, energy efficiency.

We are developing ONN based on phase-change materials (PCMs) to realize generic, programmable photonic networks with non-volatile, nanoscale optical switches and memories which operate with high-precision on nanosecond timescales. The ONN can perform large-scale vector-matrix multiplication (MVM) at “light speed”. Through hybrid integration with CMOS electronics, the photonic-electronic hybrid system combines the best of the two to achieve AI/ML acceleration.

Publications: Changming Wu, Heshan Yu, Seokhyeong Lee, Ruoming Peng, Ichiro Takeuchi, and Mo Li, "Programmable Phase-change Metasurface for Multimode Photonic Convolutional Neural Network", *submitted* (2020)
Funding: ONR
Collaborators: Ichiro Takeuchi (Maryland), Arka Majumdar (UW), Sajjad Moazeni (UW)

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Lih Lin // Photonics & Nano Devices

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Professor of Electrical and Computer Engineering
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Office: M-414 ECE | **Email**: lylin@uw.edu
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Education

- BS in Physics, National Taiwan University, 1990.
- MS in Physics, National Taiwan University, 1992.
- MS in Electrical Engineering, University of California Los Angeles, 1993.
- PhD. in Electrical Engineering, University of California Los Angeles, 1996.

Notable Publications

- Chen Zou, Cheng Chang, Di Sun, Karl Böhringer, and Lih Y. Lin, Photolithographic patterning of perovskite thin films for multicolor display applications, Nano Letters 20 (5), 3710-3717, 2020.
- Chen Zou, Yun Liu, David Ginger, and Lih Y. Lin, Suppressing efficiency roll-off at high current densities for ultra-bright green perovskite light-emitting diodes, ACS Nano 14 (5), 6076-6086, 2020.
- Chia-Jean Wang, Ludan Huang, Babak A. Parviz, and Lih Y. Lin, Sub-diffraction photon guidance by quantum dot cascades, Nano Letters 6 (11), 2549-2553, 2006.
- Lih Y. Lin, Evan Goldstein, and Robert Tkach, Free-space micromachined optical switches for optical networking, IEEE J Sel Top in Quantum Electronics, 5 (1), 4-9, 1999.

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Lih Lin // Photonics & Nano Devices

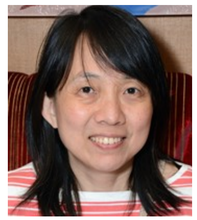
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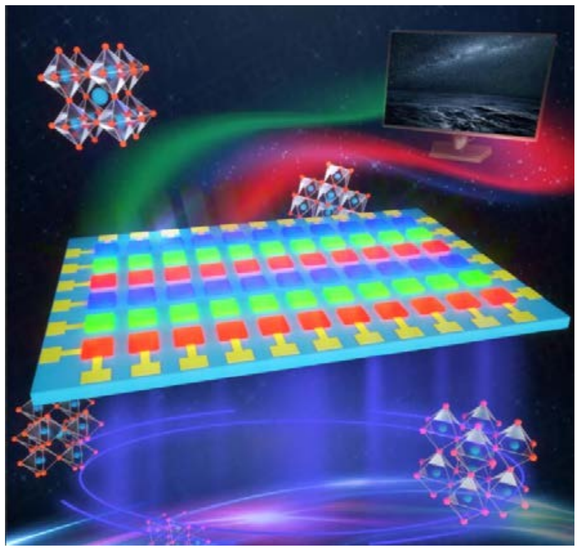
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Perovskite Optoelectronics

Lin Research overview





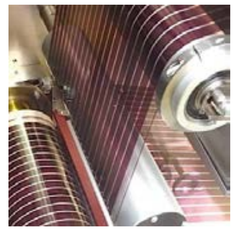
Artist rendering of perovskite micro-LED arrays. The perovskite semiconductor structure is shown in the background.

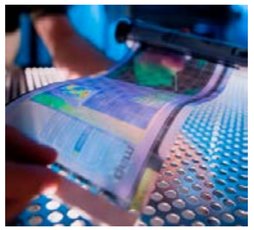
Perovskite semiconductors are solution-processed materials, which enables many opportunities:

- Low-cost, large-area manufacturing of optoelectronic devices.
- Flexible optoelectronics that are light-weight and shock-resistant.
- Facile integration with Si photonics and other photonic platforms.
- Light emitting devices with easily tunable emission wavelengths.

Advantages of metal halide perovskite semiconductors:

- High absorption coefficient
- High photoluminescence quantum efficiency
- Tunable emission color through varying material compositions and/or nanocrystal sizes
- High defect tolerance
- Long carrier lifetime and diffusion length
  → Good electron transport properties





Funding: National Science Foundation, UW Royalty Research Fund
Collaborators: J. M. Luther, K. Böhringer, A. Majumdar, D. Ginger, C. W. Schlenker.

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Lih Lin // Photonics & Nano Devices

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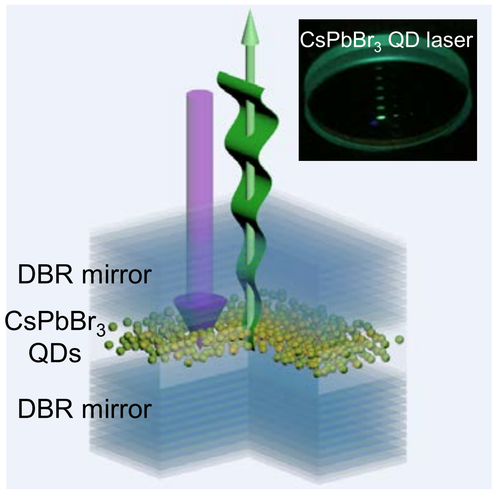
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Lin
Project #1

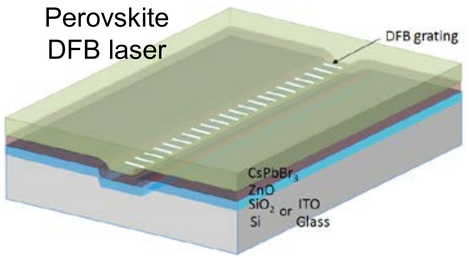


Perovskite Lasers and LEDs

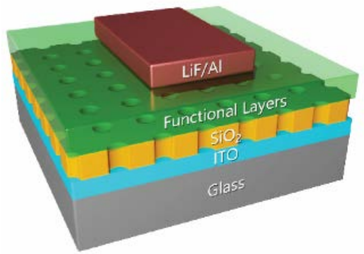


An overarching challenge in the field of photonics is to integrate electrically pumped lasers on Si platforms with a low-cost approach. Such realization can have impacts in optical communications, optical computing, sensing, … etc.

Our approach is to utilize solution-processed perovskite semiconductors and optimize the device designs for both optical performance and electrical properties. To achieve electrically pumped lasers, LEDs with high efficiency under high injection current density need to be demonstrated first.



For example, we implemented nano-apertures for current injection to minimize device degradation. We achieved record high luminance from perovskite LEDs at the time of publication of our work.



Publications:

- Chen Zou, Yun Liu, David Ginger, and Lih Y. Lin, Suppressing efficiency roll-off at high current densities for ultra-bright green perovskite light-emitting diodes, ACS Nano 14 (5), 6076-6086, 2020.
- Chun-Ying Huang, Chen Zou, Chenyi Mao, Kathryn L. Corp, Yung-Chi Yao, Ya-Ju Lee, Cody W. Schlenker, Alex K. Y. Jen, and Lih Y. Lin, $CsPbBr_3$ perovskite quantum dot vertical cavity lasers with low threshold and high stability, ACS Photonics 4 (9), 2281-2289, 2017.
- Chen Zou, Chun-Ying Huang, Erin M. Sanehira, Joseph M. Luther, and Lih Y. Lin, Highly stable cesium lead iodide perovskite quantum dot light-emitting diodes," Nanotechnology 28 (45), 455201, 2017.

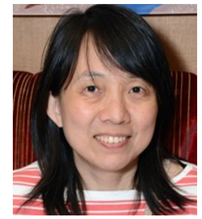
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Lih Lin // Photonics & Nano Devices

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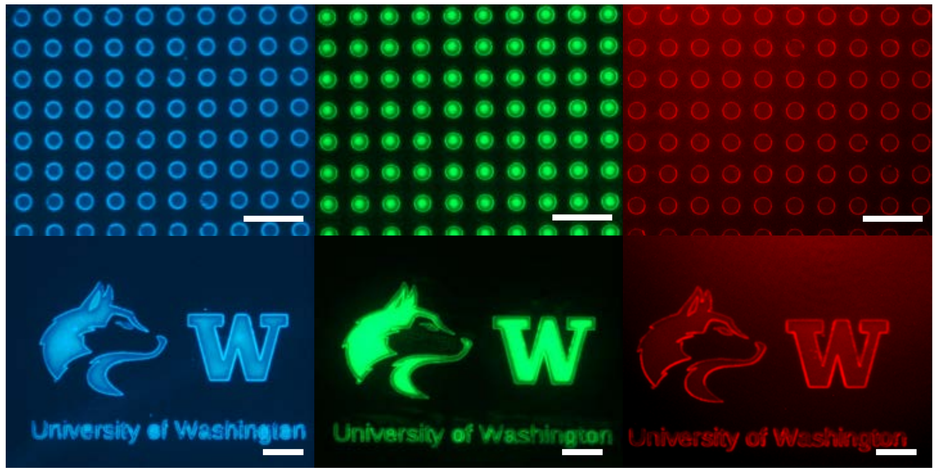
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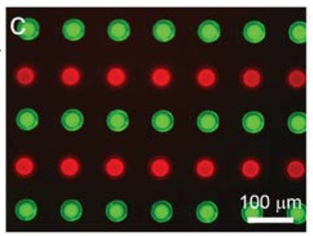


Lin
Project #2

Perovskite Color Converters and μ-LED arrays



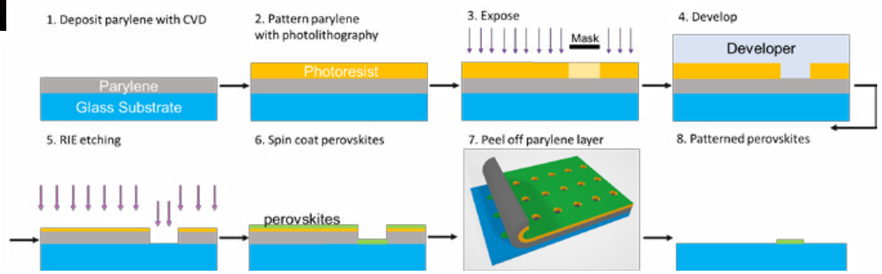
Top and right: Patterning of perovskite materials for color conversion applications.
Far right: A display made with a perovskite μ-LED array.





Many applications of perovskite devices ultimately require high-resolution patterning of the materials. However, it is challenging to pattern perovskite semiconductors due to their incompatibility with most solvents used in photolithography.

We developed a novel photolithographic patterning method utilizing dry liftoff of an intermediary parylene-C layer. We demonstrated high-resolution patterning of multi-color perovskite color converters and micro-LED arrays for the first time.



Publications:

- Chen Zou, Cheng Chang, Di Sun, Karl Böhringer, and Lih Y. Lin, Photolithographic patterning of perovskite thin films for multicolor display applications, Nano Letters 20 (5), 3710-3717, 2020.
- Cheng Chang, Chen Zou, Mark Odendahl and Lih Y. Lin, A dry lift-off method for patterning perovskites, Conference on Lasers and Electro Optics (CLEO), San Jose, CA, May 10-15, 2020.

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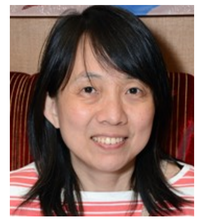
Lih Lin // Photonics & Nano Devices

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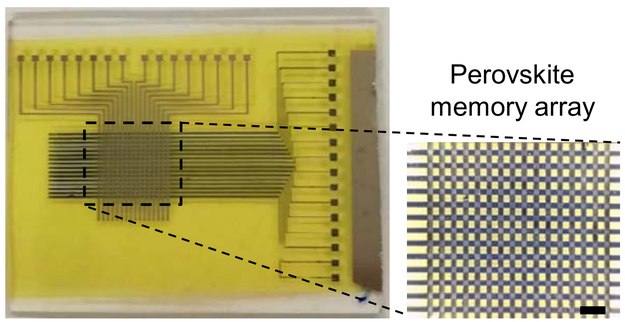
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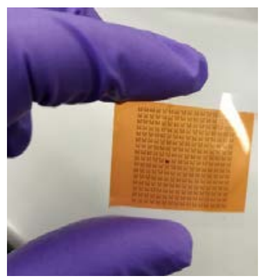
Lin
Project #3



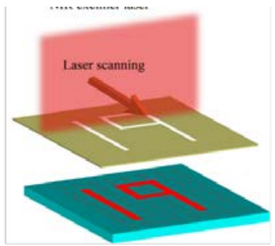
Perovskite Memories for Neuromorphic Computing

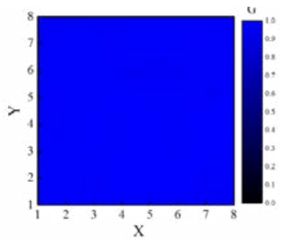


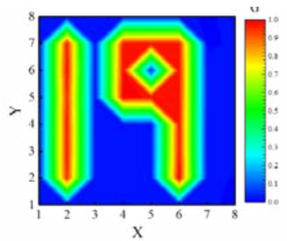
Perovskite memory array



Optical information storage







Neuromorphic computing aims to emulate human brains in performing massively parallel information processing and computation with ultra-low energy consumption. Neuron-like devices that can be integrated in large scale with low cost are necessary for realizing neuromorphic computers.

Perovskite materials exhibit ionic transport properties similar to neurons. We propose building perovskite neurons that can generate artificial synapses. In addition, the phase-changing property of perovskite semiconductors under illumination can be utilized for optical information storage.

We demonstrated resistive memory arrays as well as writing/storing/retrieving of optical information using perovskite materials.

Publications:

- Chen Zou, Lijun He, and Lih Y. Lin, Vacuum-deposited inorganic perovskite memory arrays with long-term ambient stability, Physica Status Solidi RRL 13 (9), 1900182, 2019.
- Chen Zou, Jiajiu Zheng, Cheng Chang, Arka Majumdar, and Lih Y. Lin, Nonvolatile rewritable photomemory arrays based on reversible phase-change perovskite for optical information storage," Advanced Optical Materials 7 (18): 1900558, 2019.

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Arka Majumdar // Photonics & Nano Devices

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Arka Majumdar
Assistant Professor of Electrical and Computer Engineering
Assistant Professor of Physics
Research Theme: Integrated Nanophotonics, Quantum Optics, Dielectric Metasurface, Computational Optics.
Office: 230 ECE | **Email**: arka@uw.edu
Research Webpage: https://labs.ece.uw.edu/amlab/

Education

- B. Tech (H) in Electronics and Electrical Communication Engineering, 2007.
- MS in Electrical Engineering, Stanford University, 2009.
- PhD. in Electrical Engineering, Stanford University, 2012.

Notable Publications

- Nano-cavity integrated van der Waals heterostructure light-emitting device, Chang-Hua Liu, Genevieve Clark, Taylor Fryett, Sanfeng Wu, Jiajiu Zheng, Fariba Hatami, Xiaodong Xu, Arka Majumdar, Nano Letters, 17 (1), pp 200–205, 2016.
- Metasurface Optics for Full-color Computational Imaging, Shane Colburn, Alan Zhan, Arka Majumdar, Science Advances, Vol. 4, no. 2, eaar2114, 2018.
- Controlling three-dimensional optical fields via inverse Mie scattering, Alan Zhan, Ricky Gibson, James Whitehead, Evan Smith, Josh Hendrickson, Arka Majumdar, Science Advances, Vol. 5, no. 10, eaax4769, 2019.
- Low-loss and broadband non-volatile phase-change directional coupler switches, Jiajiu Zheng, Peipeng Xu,

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Arka Majumdar // Photonics & Nano Devices

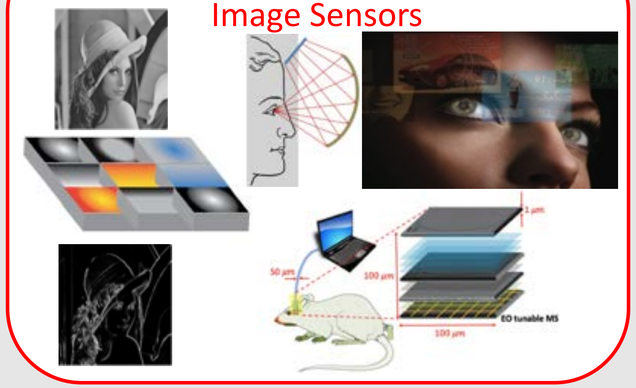
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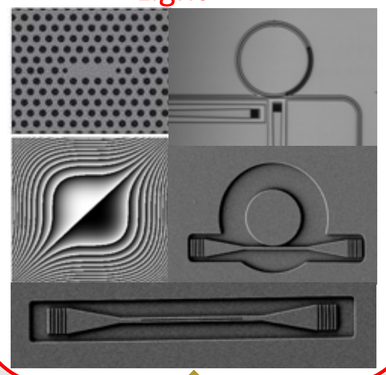
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Nano-Optoelectronic Integrated System Engineering (NOISE) Lab
(Electrical and Computer Engineering + Physics)

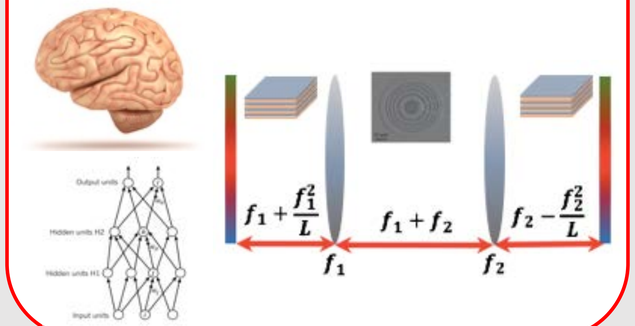
Nanophotonic Computational Image Sensors



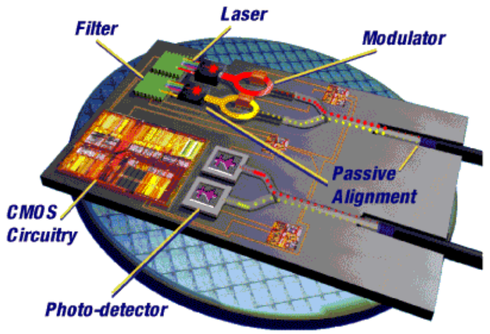
Light



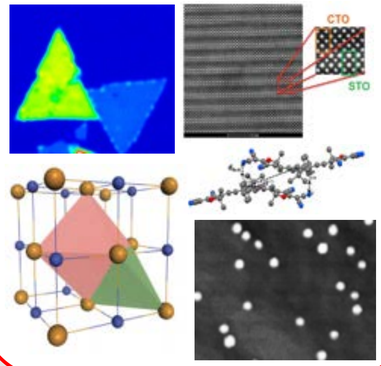
Nonlinear Image Processing and Monolithic Optical Neuron



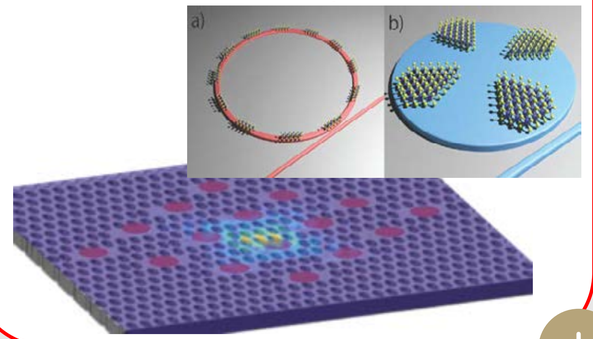
Hybrid Integrated Photonics



Matter



Quantum many-body simulation with photons



Sorger & Majumdar, Fundamental Scaling Laws in Nanophotonics, Scientific Reports 6, Article number: 37419, (2016).

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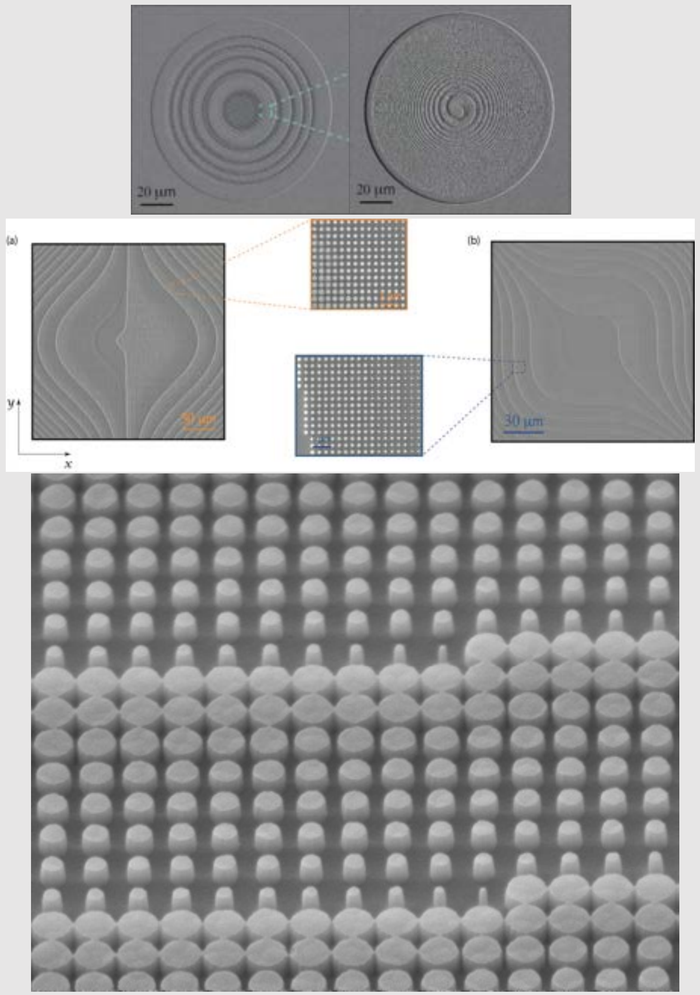
Arka Majumdar // Photonics & Nano Devices

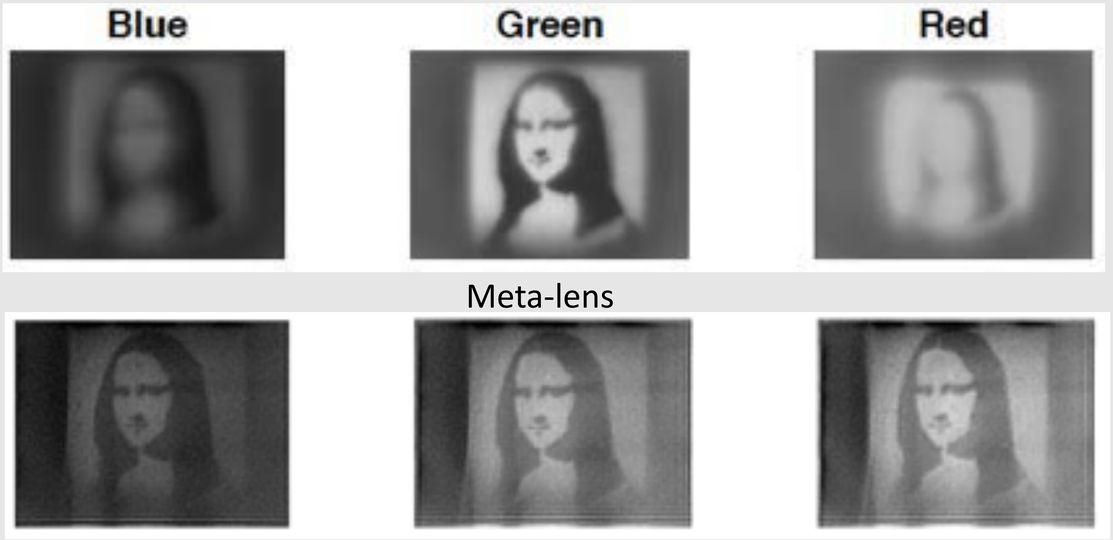
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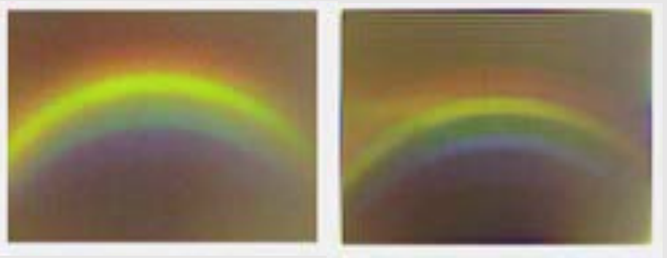
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NCIS: Nanophotonic computational image sensors





Metaform optics + computational imaging



Meta-lens Our Approach

Zhan et. al., Scientific Reports 7, Article number: 1673 (2017)
Zhan et. al., ACS Photonics, 2016, 3 (2), pp 209–214
Colburn et. al., Science Advances, 2018

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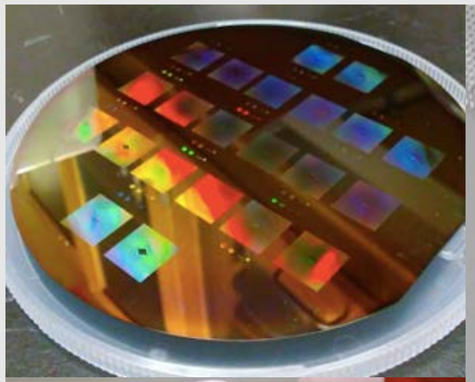
Arka Majumdar // Photonics & Nano Devices

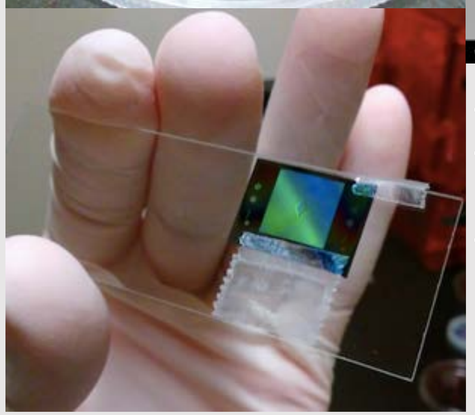
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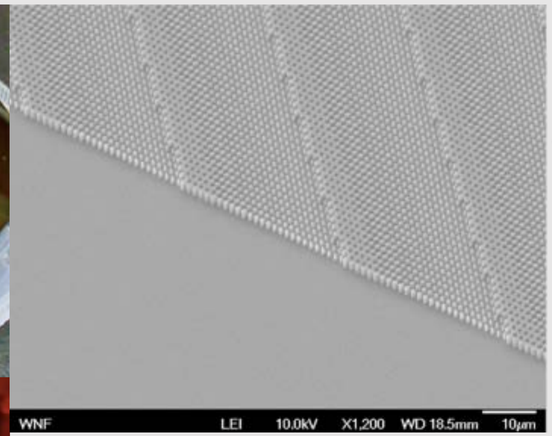
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NCIS: Inverse design and large area metasurface

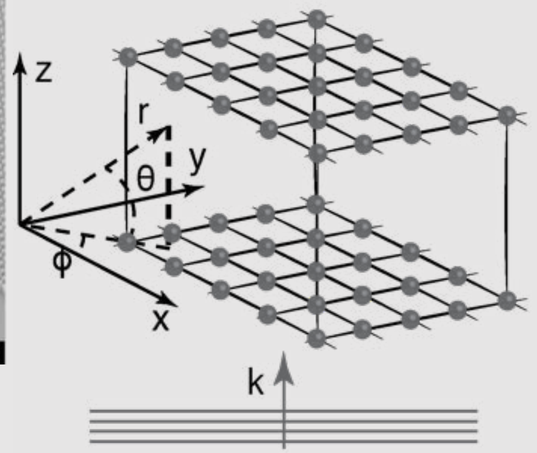


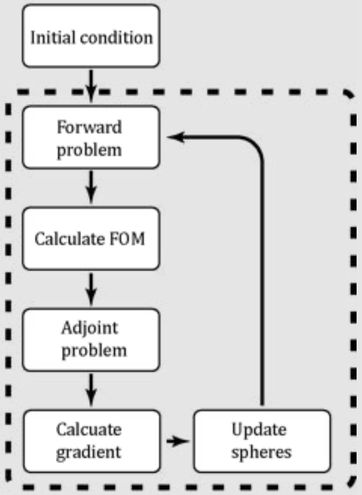


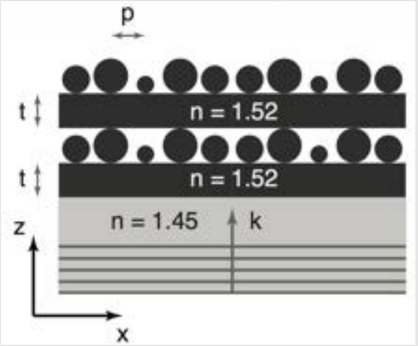


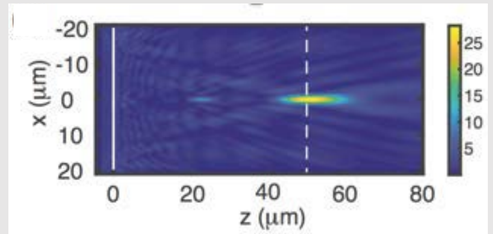
- Fabricate large area metasurface
- Photolithography can be used to make visible frequency MS
- Varifocal imaging has been demonstrated.

Colburn et.al., Optica, 2018









Zhan et.al., Applied Optics, 2018

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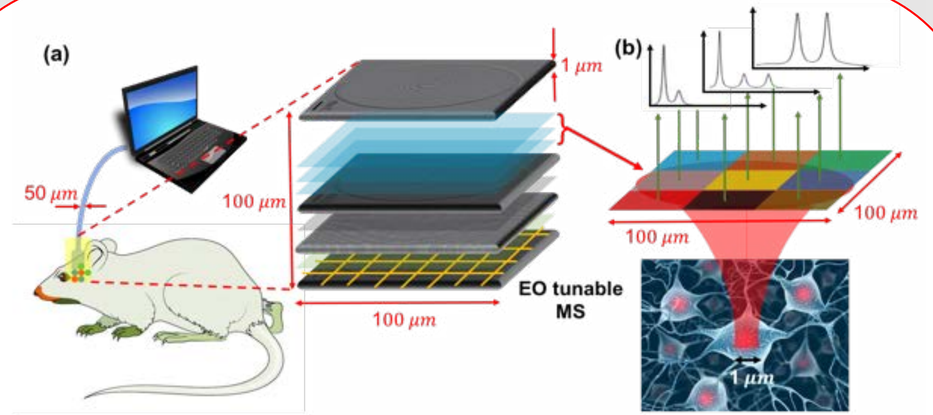
Arka Majumdar // Photonics & Nano Devices

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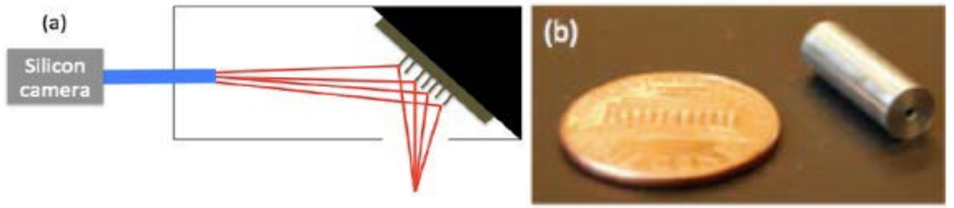
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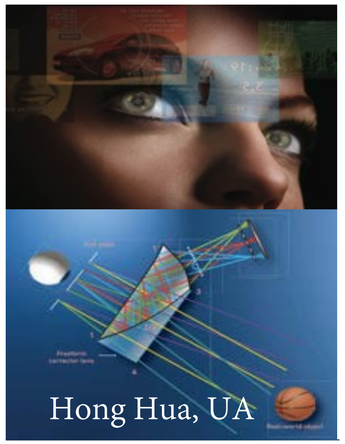
Metasurface Systems

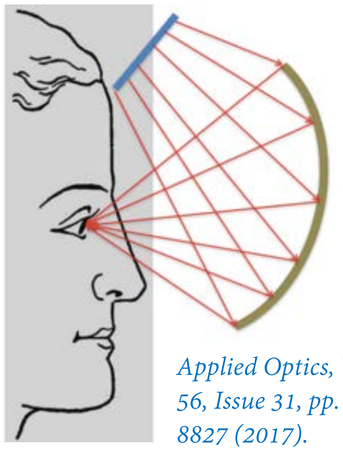






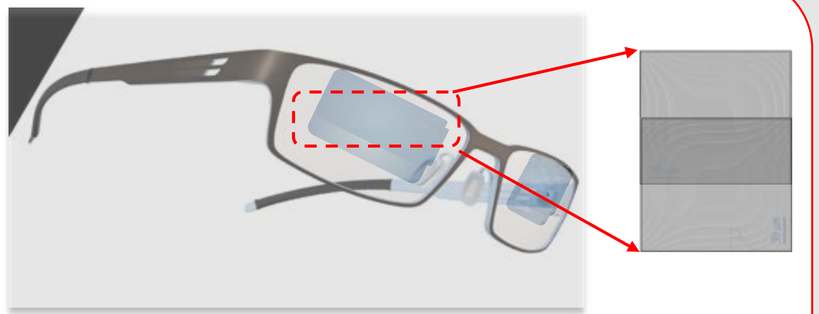
Implantable Bio-sensors





Applied Optics, Vol. 56, Issue 31, pp. 8822-8827 (2017).

Compact Display/Near-eye visors



Alvarez Lens based Eyewear

New Startup: Tunopti

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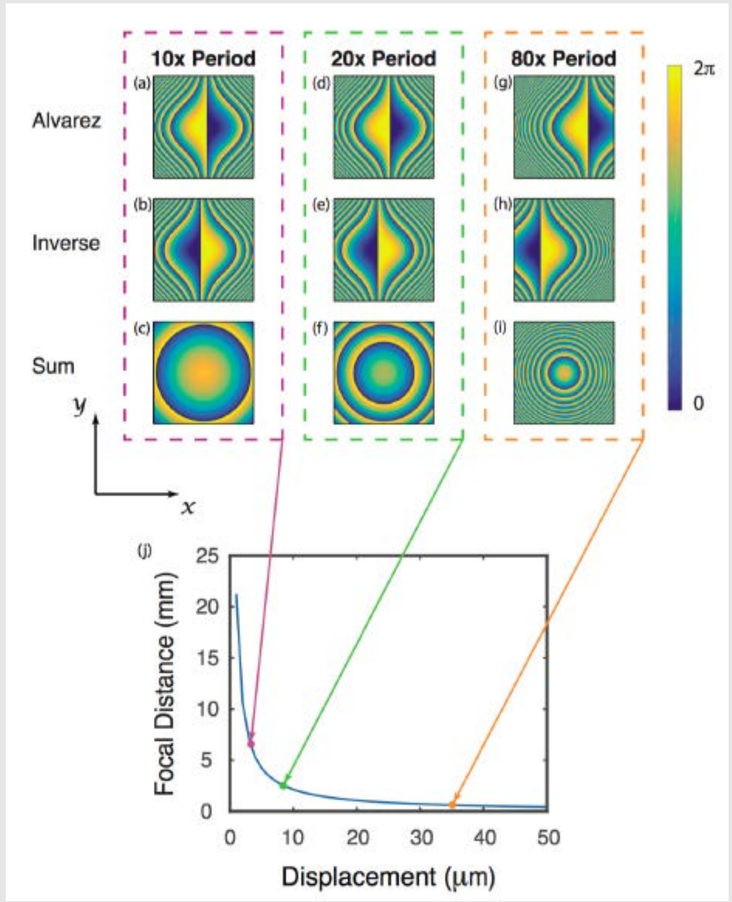
Arka Majumdar // Photonics & Nano Devices

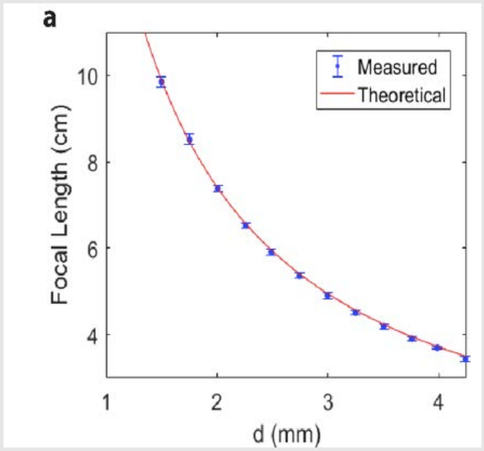
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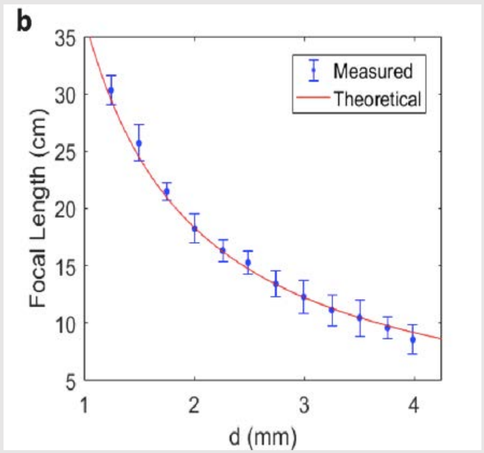
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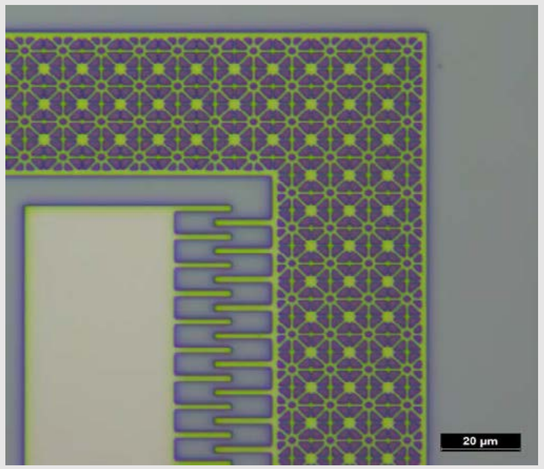
- Biosystems >
- Computing & Networking >
- Data Science >
- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >

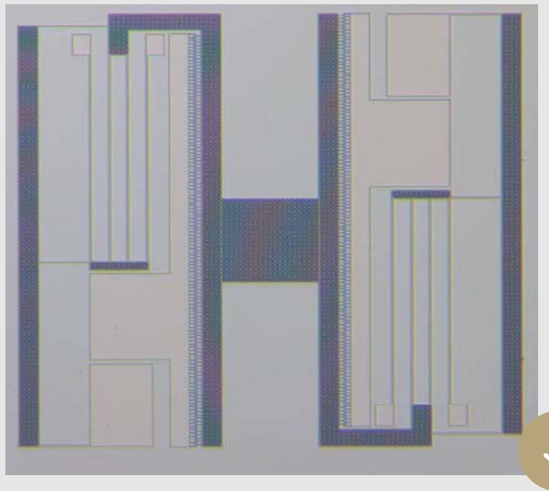
MEMS integrated tunable lens











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Arka Majumdar // Photonics & Nano Devices

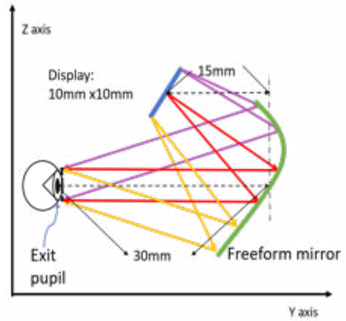
ECE Research Areas:

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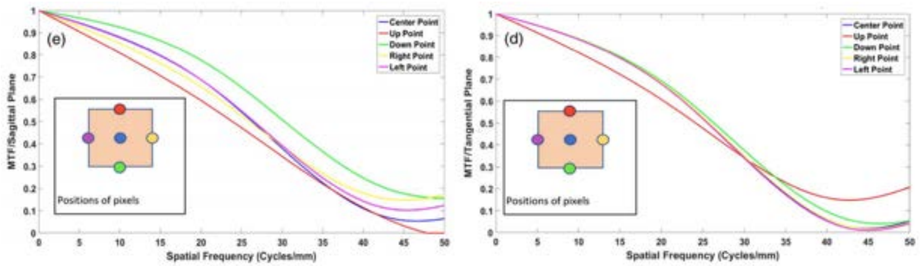
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- Data Science >
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- Robotics & Controls >

Near eye visors for Augmented Reality

Meta-visor-I



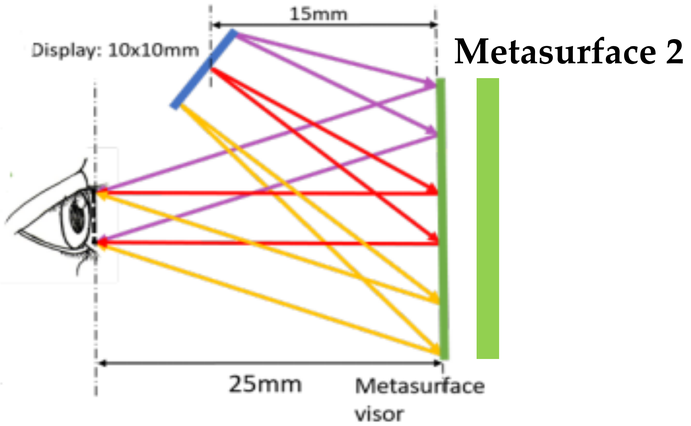




- 2.5 cm away from the eye
- 77 degree FOV

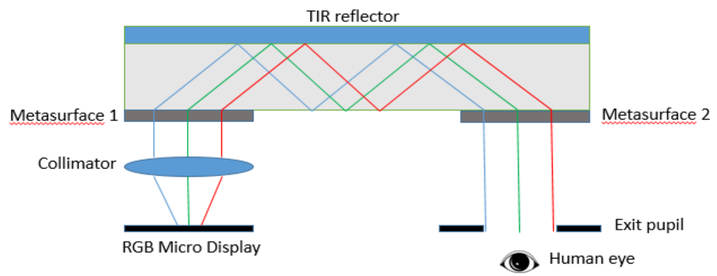
Part of UW reality lab: Google, Huawei and Facebook Reality

Meta-visor-II



Make another MS to remove distortion from real worl

Meta-visor-III



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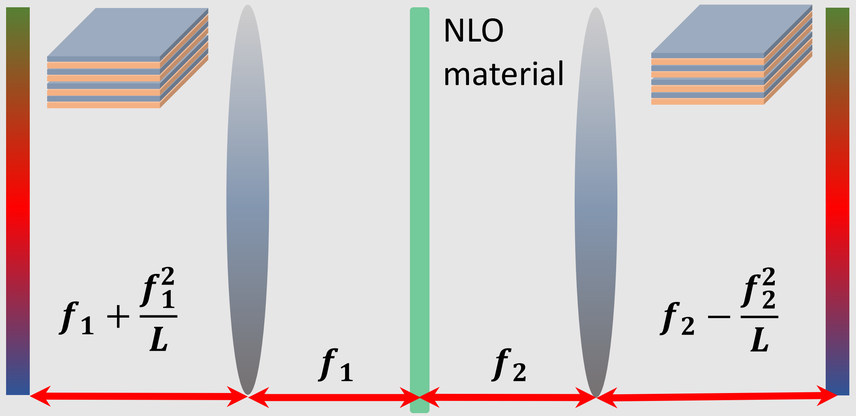
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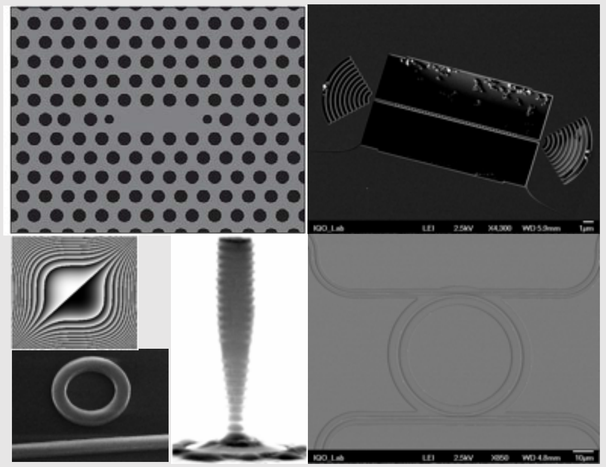
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- Photonics & Nano Devices >
- Power & Energy Systems >
- Robotics & Controls >

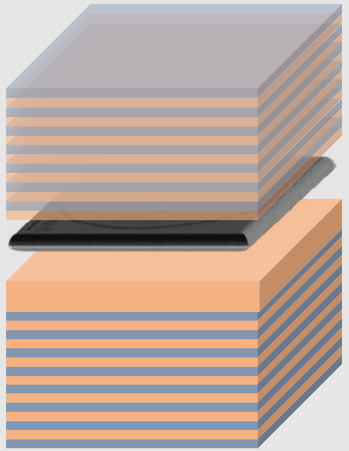
Nonlinear image processing



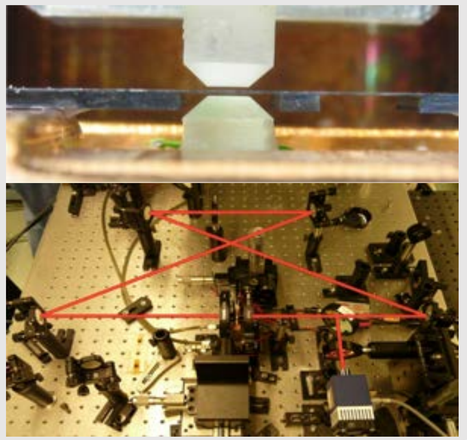




Nanophotonics and optical resonators



Metasurface-DBR cavity



Macroscopic atomic physics cavity

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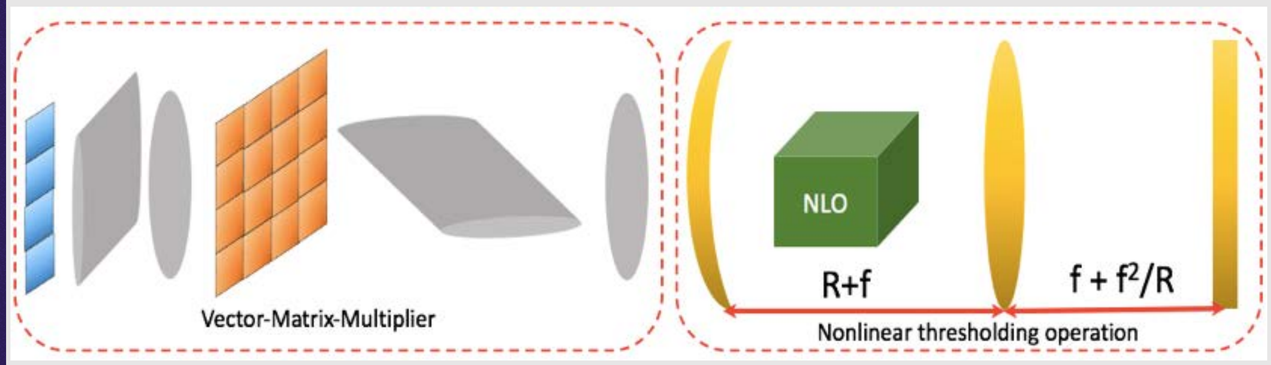
Arka Majumdar // Photonics & Nano Devices

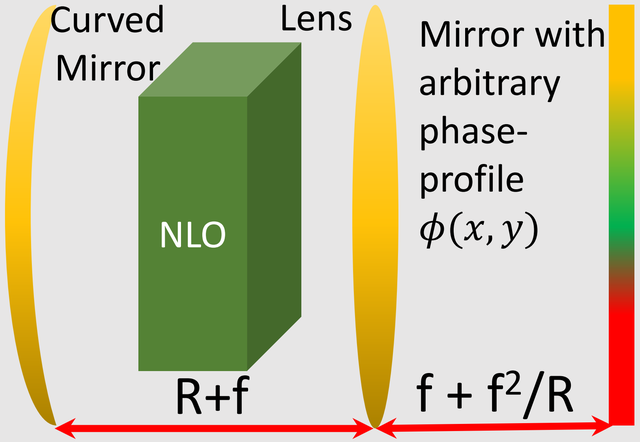
ECE Research Areas:

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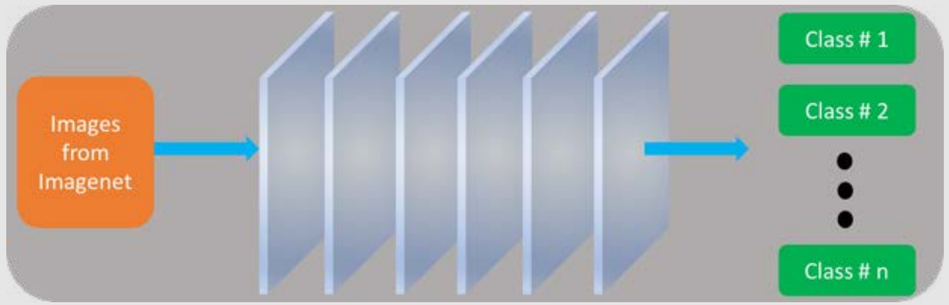
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- Computing & Networking >
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Monolithic Optical Neuron

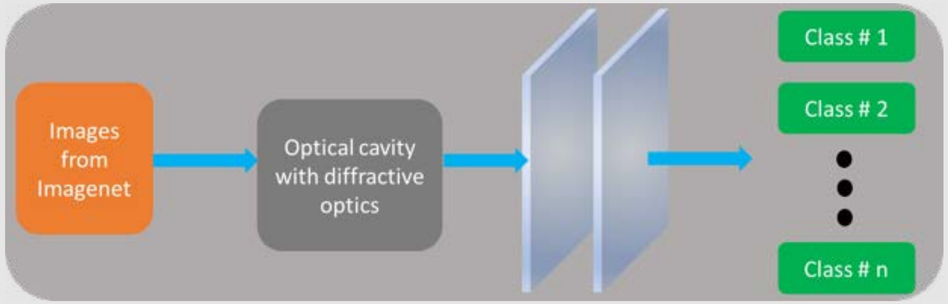




Metasurface and solid state photonic devices provide an opportunity for monolithic integration



Conventional Deep Neural Network



Hybrid Optical Deep Neural Network

- Simplify the geometry: can we make a VMM using an arbitrary phase profile inside the cavity?
- How can we reuse the layers?
- Is this network mimicking recurrent neural network?

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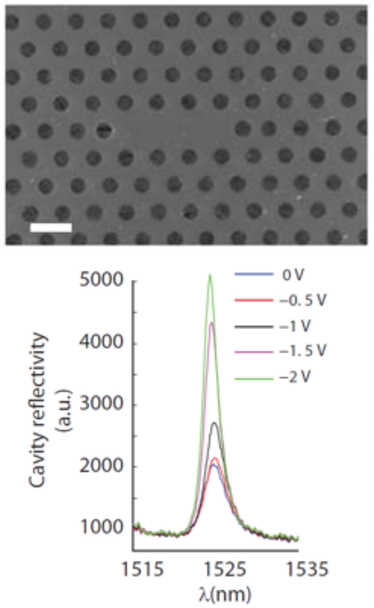
Arka Majumdar // Photonics & Nano Devices

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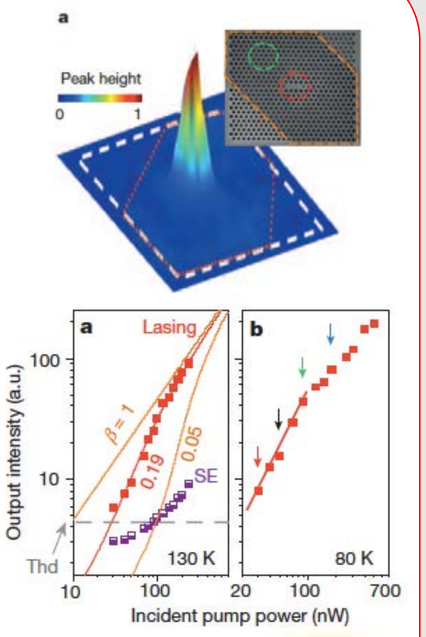
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Hybrid Integrated Photonics: Layered 2D material



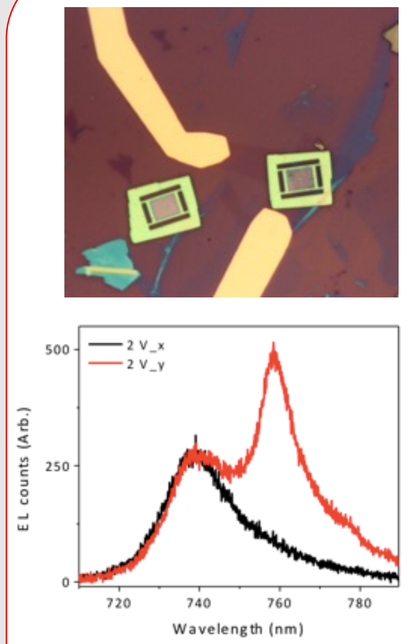
Graphene-silicon modulator, detector and self-electro optic switch

Majumdar, Nano Letters, 13 (2), 515-518, (2013).



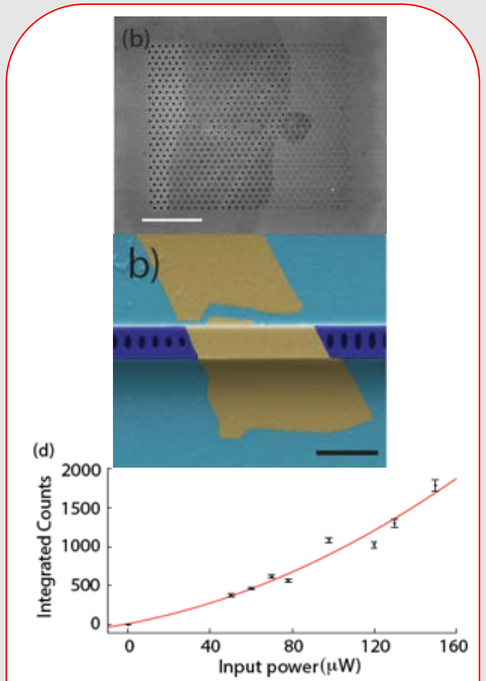
TMDC-cavity optically pumped laser

Majumdar & Xu, Nature, 520, 69-72, (2015).



Cavity enhanced electroluminescence

Majumdar & Xu, Nano Letters, 2016



Cavity enhanced second harmonic generation

Majumdar & Xu, ACS Photonics, 2016; 2D materials (2016)

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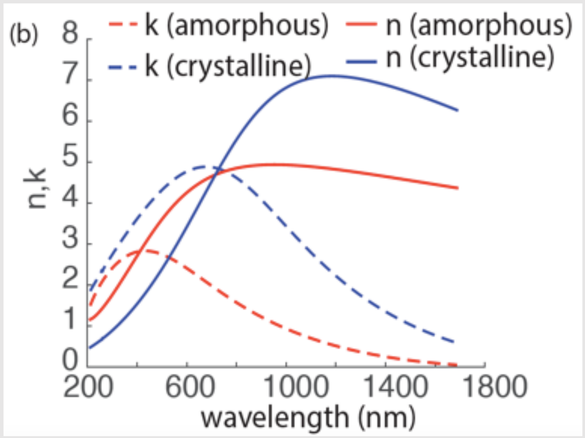
Arka Majumdar // Photonics & Nano Devices

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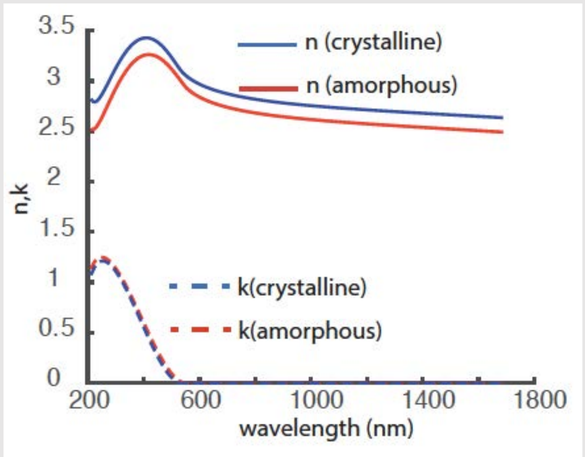
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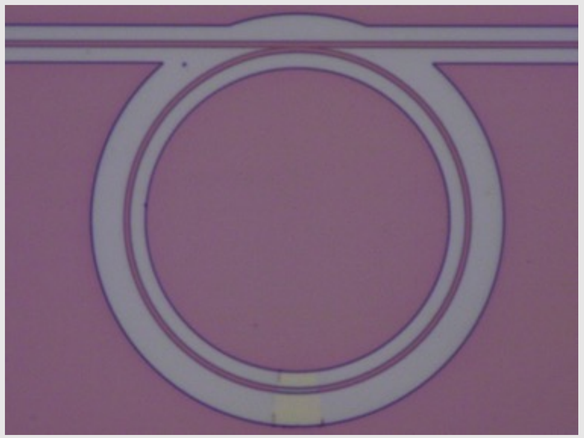
Hybrid Integrated Photonics: Phase change materials



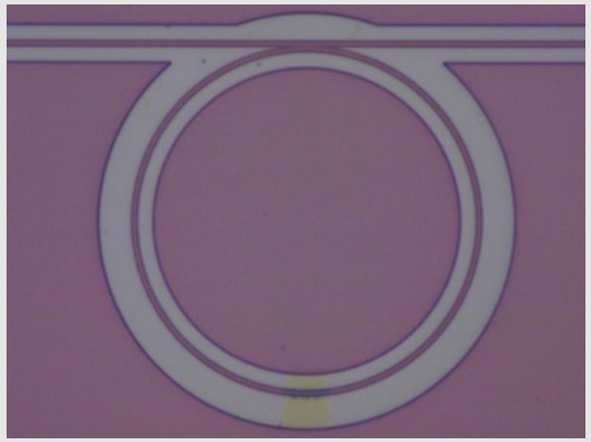
GST



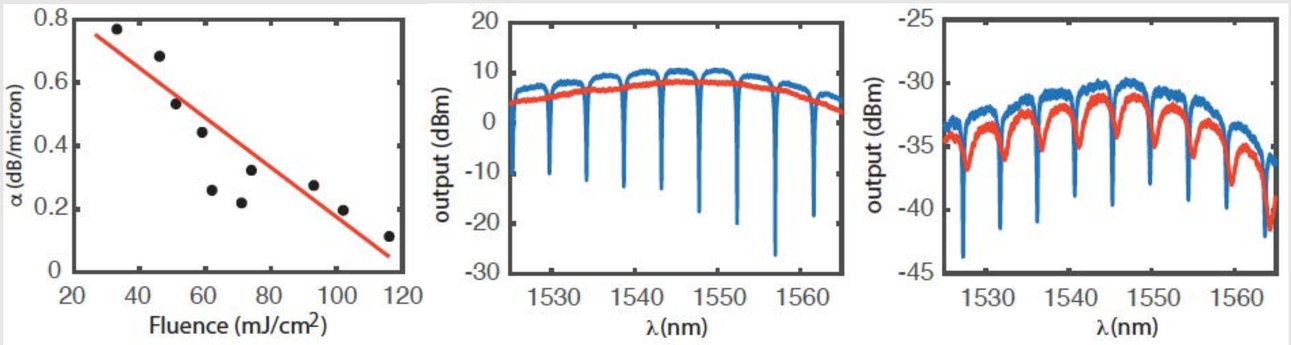
GeSe



Crystalline state



Amorphous state



Quasi-analog change observed in loss
More than 30dB optical switching observed
Electrical control needs to be demonstrated

Zheng et.al., OME, 2

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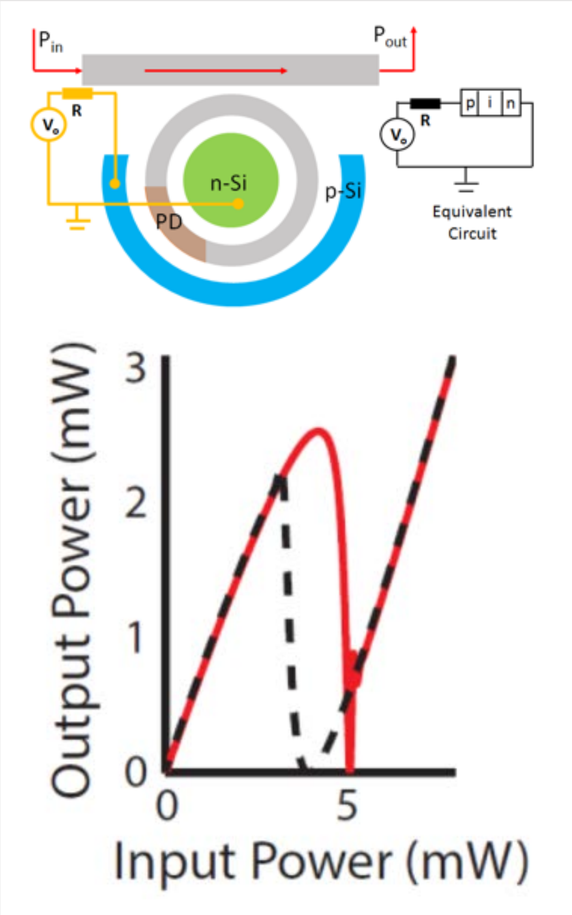
Arka Majumdar // Photonics & Nano Devices

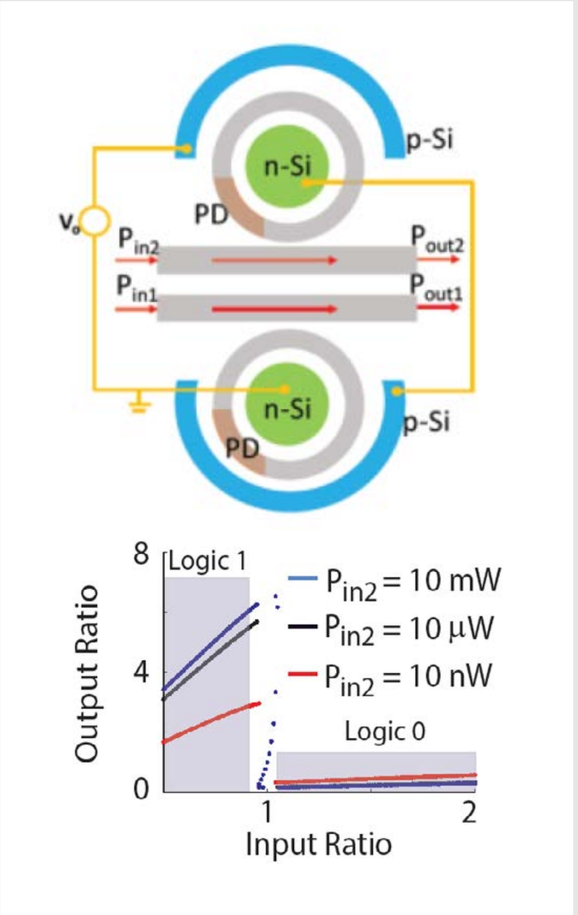
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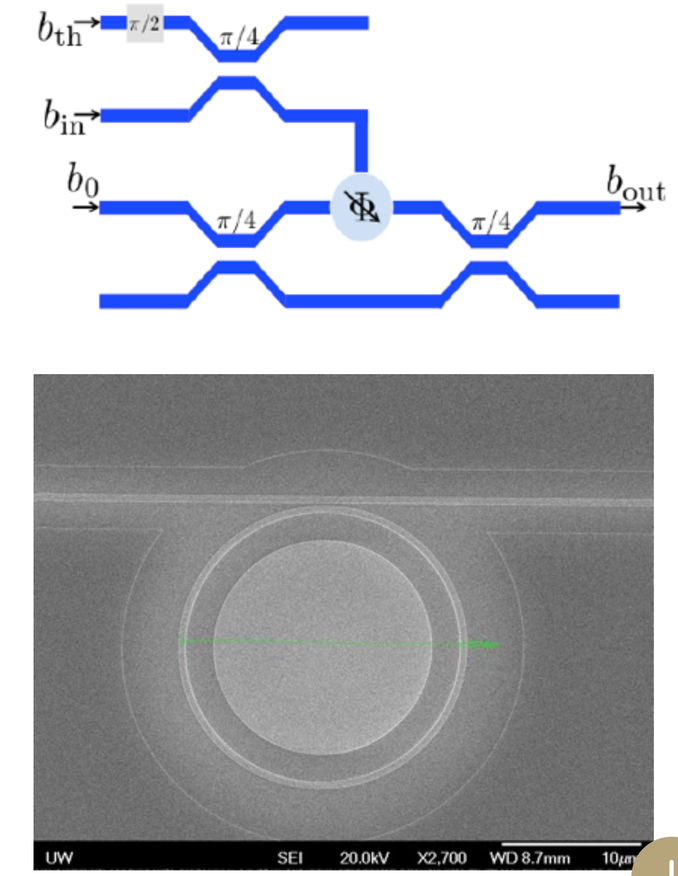
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Hybrid integrated photonics: Silicon photonic self-electro optic bistability







Majumdar et. al., Optics Letters, 39, 13, pp. 3864-3867, 2014

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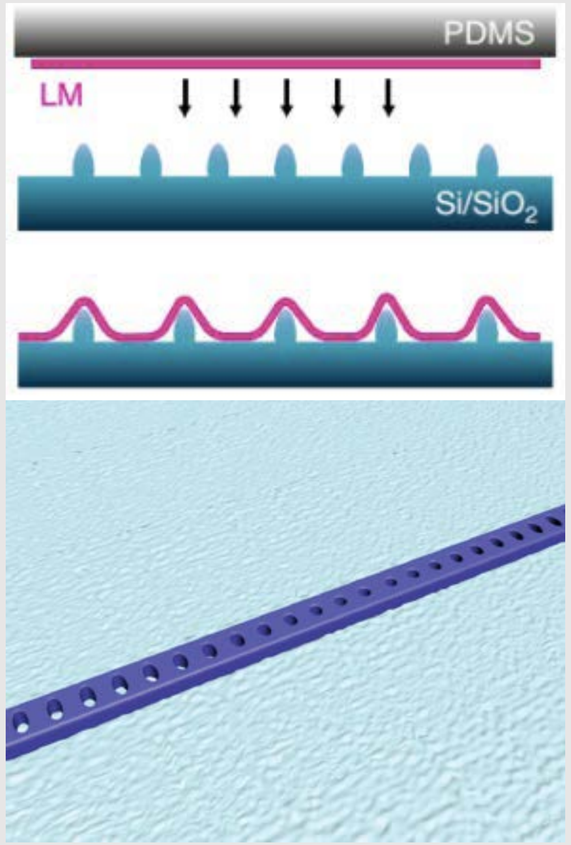
Arka Majumdar // Photonics & Nano Devices

ECE Research Areas:

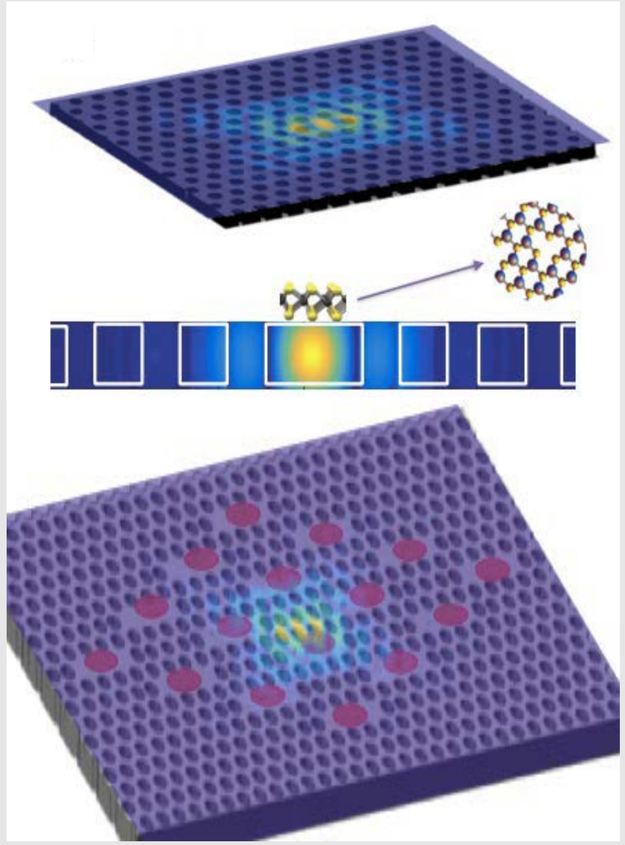
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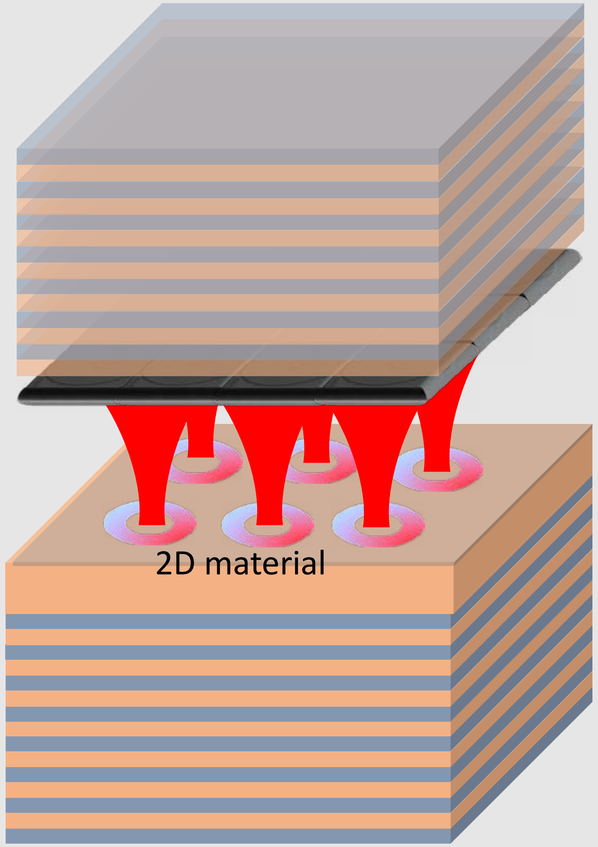
Quantum many-body simulation with photons



Deterministically localize single emitters in 2D materials



Pattern 2D material or place solution processed QDs to enhance the polariton-polariton interaction



Metasurface optics inside DBR cavities can create local potential

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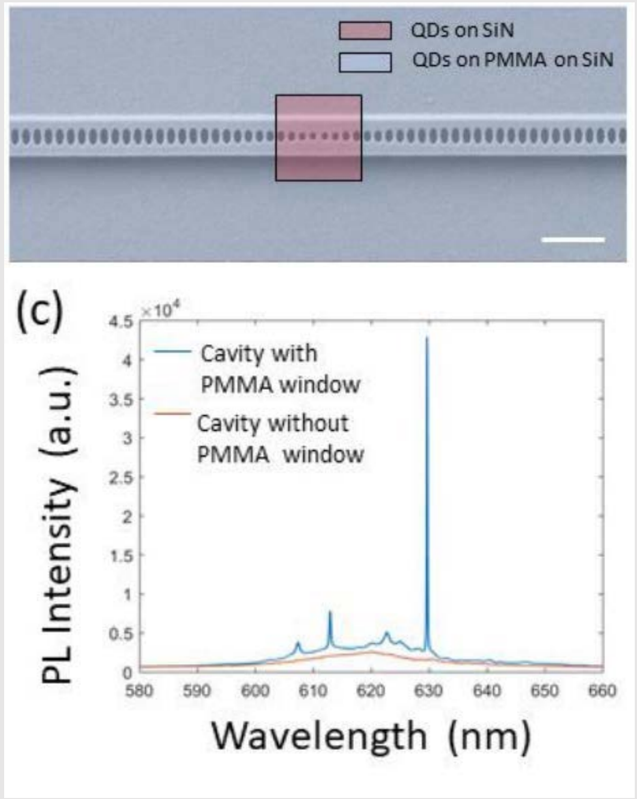
Arka Majumdar // Photonics & Nano Devices

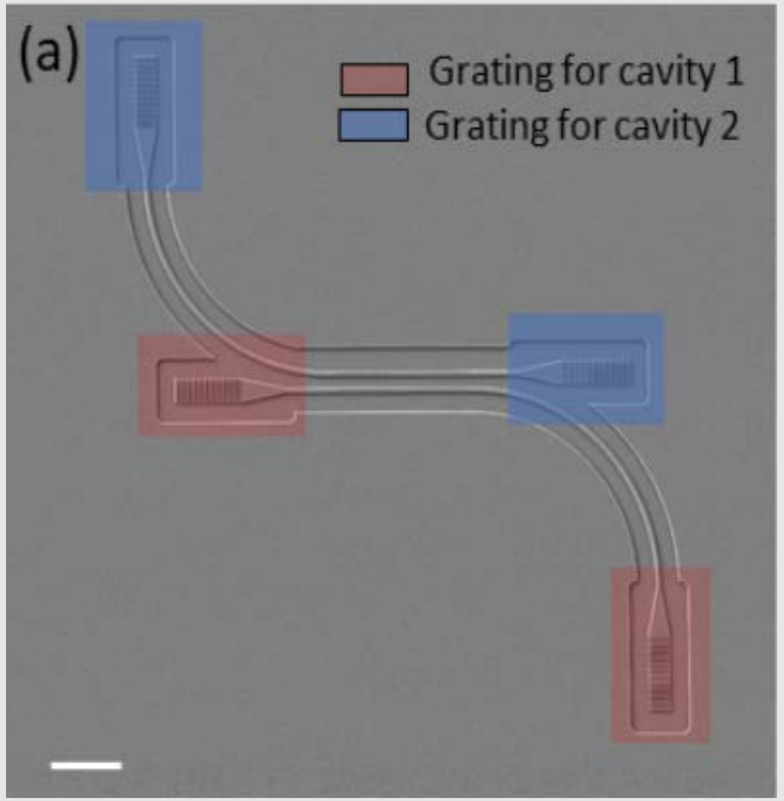
ECE Research Areas:

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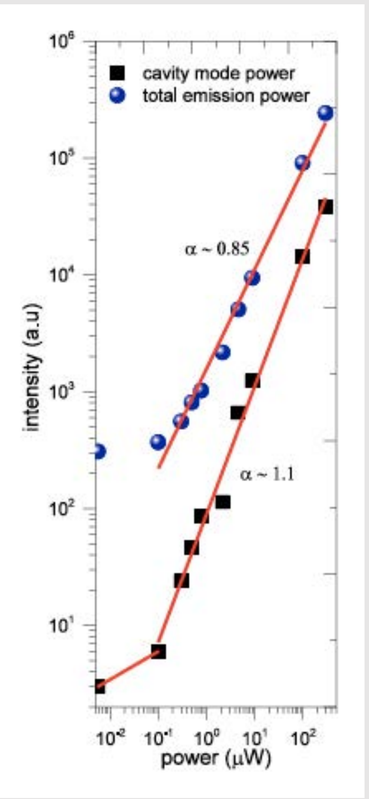
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Solution processed materials and cQED





Colloidal QD (Collaboration: Cossairt, UW)



Perovskites (Collaboration: Ginger, UW)

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Denise Wilson // Photonics & Nano Devices

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Denise Wilson
Professor of Electrical and Computer Engineering
Research Theme #1: Sensors and Sensor Systems
Research Theme #2: Engineering Education
Office: M222 ECE | **Email**: denisew@uw.edu
Research Webpage: https://labs.ece.uw.edu/dms/Distributed_Microsystems_Lab/
Dissemination Webpage: https://labs.ece.uw.edu/community/

Education

- BSEE in Mechanical Engineering, Stanford University, 1988.
- MS in Electrical Engineering, Georgia Institute of Technology, 1989.
- PhD in Electrical Engineering, Georgia Institute of Technology, 1995.
- M.Ed in Learning Sciences, University of Washington, 2008.

Notable Publications

- Wilson, D. (2019). Exploring the Intersection between Engineering and Sustainability Education. *Sustainability*, 11(11), 3134.
- Wilson, D. (2019). *Wearable Solar Cell Systems*. Boca Raton, FL: CRC Press.
- Wilson, D., Jones, D., Bocell, F., Crawford, J., Kim, M. J., Veilleux, N., Floyd-Smith, T., Bates, R., & Plett, M. (2015). Belonging and Academic Engagement Among Undergraduate STEM Students: A Multi-institutional Study. *Research in Higher Education*, 56(7), 750-776.
- Wilson, D.M., Hoyt, S., Janata, J., Abandao, L., & Booksh, K. (2001). Chemical Sensors for Portable, Handheld Field Instruments. *IEEE Sensors Journal*, 1(4), 256-276.

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Faculty, TA, and Peer Influences on Student Engagement

Wilson
Project #1





What faculty, teaching assistants (TAs) and peers do in classes, labs, and recitations influences students' choices to engage in the learning process both inside the classroom and outside of it. Engagement has been studied broadly using survey data in such nationwide surveys as the National Survey of Student Engagement. Engagement is a proven predictor of academic achievement and persistence and is often more important for under-represented groups than for majority students.

Our approach uses a mixed methods research approach that includes not only surveys but interviews (of students, TAs, and faculty) and observations of engineering classes, labs, and recitation sections to understand how faculty, TAs, and peers can uniquely stimulate engagement at multiple levels. Our research in this area has identified key, actionable differences in what students expect and desire from professors, TAs, and peers.

Publications:

Wilson, D., Summers, L., and Wright, J., & Summers, L. (2020). Faculty support and student engagement in undergraduate engineering, *Journal of Research in Innovative Teaching & Learning*.

Funding:

National Science Foundation, Division of Undergraduate Education

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Denise Wilson // Photonics & Nano Devices

ECE Research Areas:

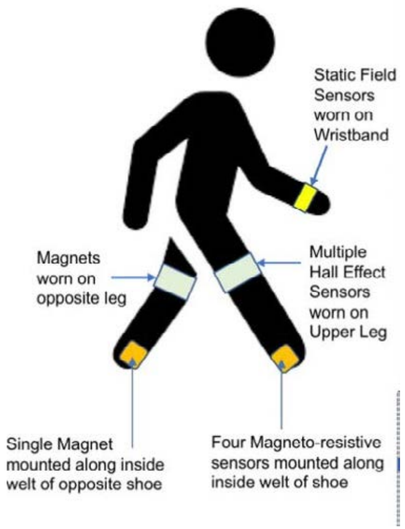
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Wilson
Project #2



Wearable Sensors for Gait Monitoring



Irregularities in gait (i.e. the way individuals walk) can be important early predictors of Parkinson's and Alzheimer's disease, cognitive decline, and other threats to quality of life among older adults.

Our approach is to complement existing camera-based techniques for evaluating gait that are largely confined to clinical settings by developing inexpensive, low power wearable sensors worn on the legs and arms which are capable of detecting variability in cadence, stride width, and stride length. The challenge in these systems is to extract features of gait that are most relevant to early indicators of disease (e.g. stride variability; absence or presence of gait) within the low power and low data transfer constraints that are typical of wearable systems.

Related Publications:

Wilson, D. M., Chheng, C., & Stimson, L. (2018). Safety Goggle Compliance Monitoring using Hall Effect Sensors. *IEEE Sensors Letters*, 2(1).

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Denise Wilson // Photonics & Nano Devices

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Wilson
Project #3



Why Leave Engineering? Perspectives of both Women and Men



A vast majority of studies of women in the engineering workforce focus only on women. Including men in such studies provides the opportunity to differentiate reasons for leaving that are systemic to certain engineering environments from those that may be specific to being a woman in the field.

This study takes a basic psychological needs perspective (autonomy, competence, relatedness) on the reasons that men and women choose to leave engineering for other jobs or leave the workforce altogether.

Our studies have found that women and men often speak to how relatedness and competence needs are met (or not met) in their workplaces in distinctly different terms. These results suggest that some engineering workplaces may be predisposed to stressing women by failing to meet these needs at rates greater than for men.

Publications:

VanAntwerp, J. & Wilson D. (2018). Differences in Motivation Patterns among Early and Mid-career Engineers. *Journal of Women and Minorities in Science and Engineering*, 24(3).

Collaborators: J. VanAntwerp, Calvin College.

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Brian Johnson // Power & Energy Systems

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Brian Johnson
Washington Research Foundation Assistant Professor of Clean Energy
Electrical and Computer Engineering
Research Theme: Power Electronics, Power Systems, Control Systems
Office: ECE M322 | **Email:** brianbj@uw.edu

Education

- Ph.D., Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, 2013.
- M.S., Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, 2010.
- B.S., Physics, Texas State University, 2008.

Notable Publications

- H. Villegas Pico and B. Johnson, "Transient stability assessment of multi-machine multi-converter power systems," in *IEEE Transactions on Power Systems*, vol. 34, no. 5, pp. 3504-3514, Sept. 2019.
- M. Sinha, J. Poon, B. Johnson, M. Rodriguez, and S. Dhople, "Decentralized interleaving of parallel-connected buck converters," in *IEEE Transactions on Power Electronics*, vol. 34, no. 5, pp. 4493-5006, May 2019.
- P. Achanta, B.. 181-190, March Johnson, and D. Maksimovic, "A multilevel DC to three-phase AC architecture for photovoltaic power plants," in *IEEE Transactions on Energy Conversion*, vol. 34, no. 1, pp. 181-190, March 2019.
- B. Kroposki, B. Johnson, Y. Zhang, V. Gevorgian, P. Denholm, B. Hodge, and B. Hannegan, "Achieving 100% renewable grids: Operating electric power systems with extremely high levels of variable renewable energy," in *IEEE Power and Energy Magazine*, vol. 15, no. 2, pp. 61-73, March 2017.
- M. Sinha, F. Dorfler, B. Johnson, and S. Dhople, "Uncovering droop control laws embedded within the nonlinear dynamics of Van der Pol oscillators," in *IEEE Transactions on Control of Network Systems*, vol. 4, no. 2, pp. 347-358, June 2017.

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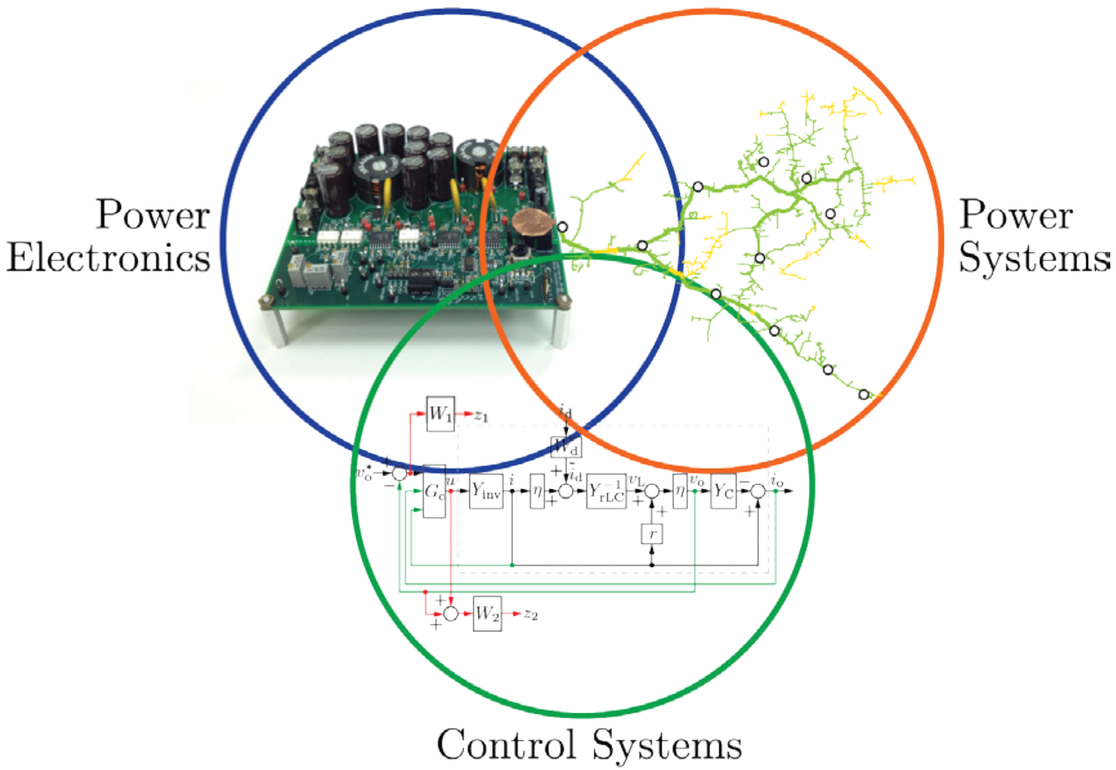
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What My Group Does



Johnson Overview



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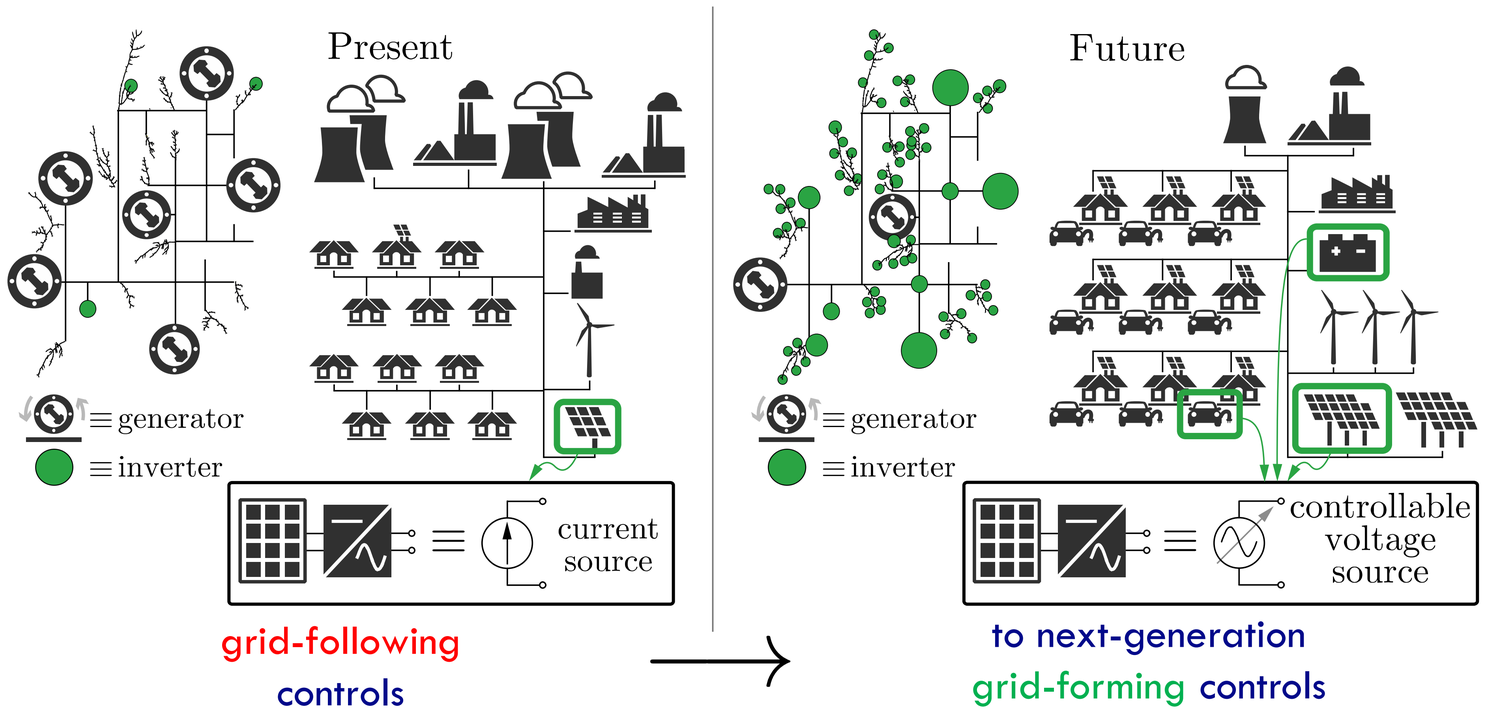
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Systems: Low-Inertia Power Grids

Johnson
Project #1



- Sponsor: New DOE-funded project from 2020-2023
- Goal: Develop models/controls to model/realize future grids based on electronics



grid-following controls → to next-generation grid-forming controls

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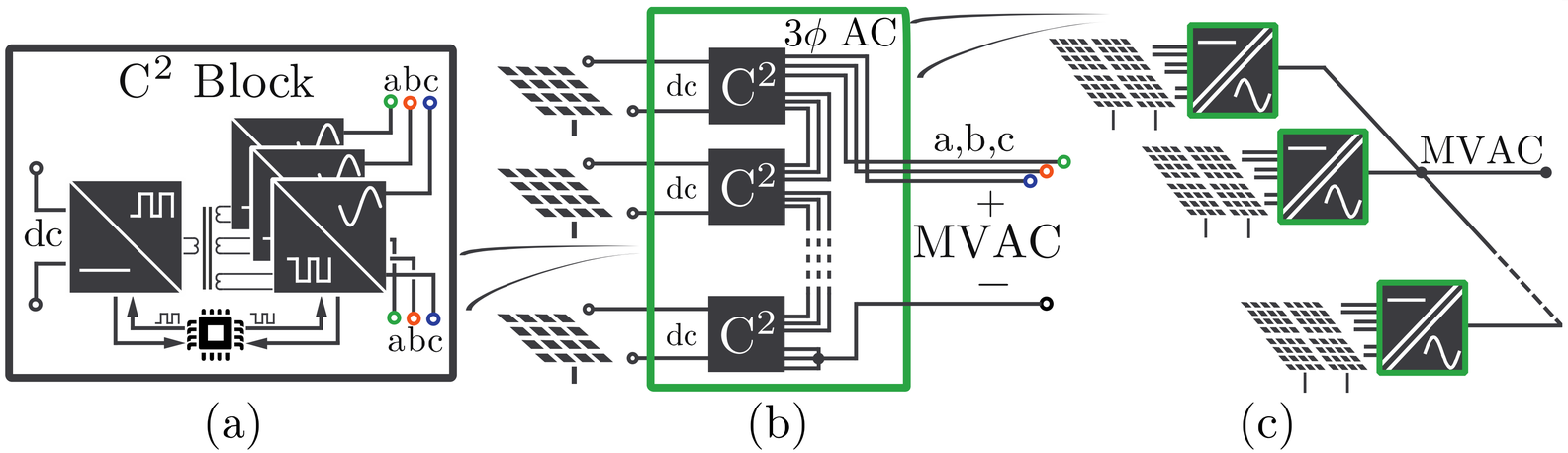
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Electronics: Medium-voltage Converters

Johnson
Project #2



- Sponsor: DOE-funded project, 2018-2021
- Goal: Engineer PV converters that go direct from low-voltage dc to 10's of kV ac



(a)

Circuit + Controls (C^2)
= Building-block

(b)

A modular medium voltage transformerless inverter

(c)

Ultra efficient and low-cost converters for PV plants

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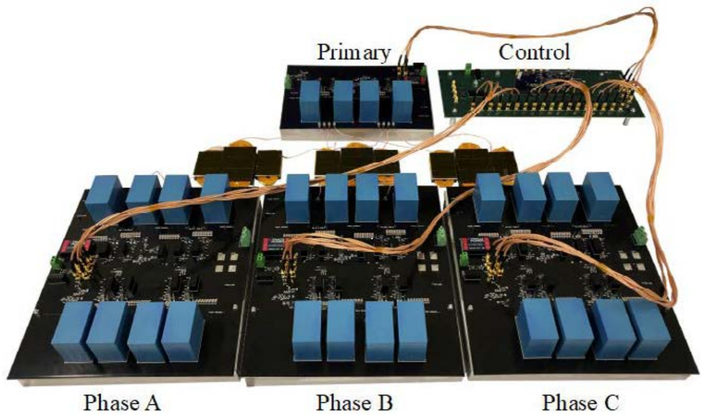
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Electronics: Medium-voltage Converters

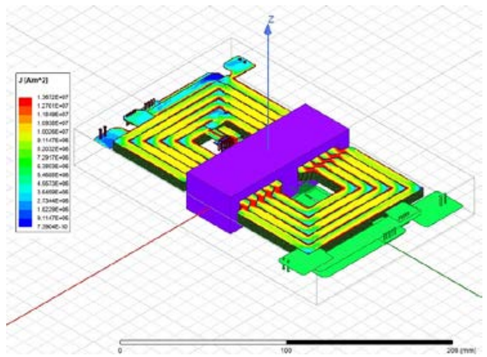
Johnson
Project #2



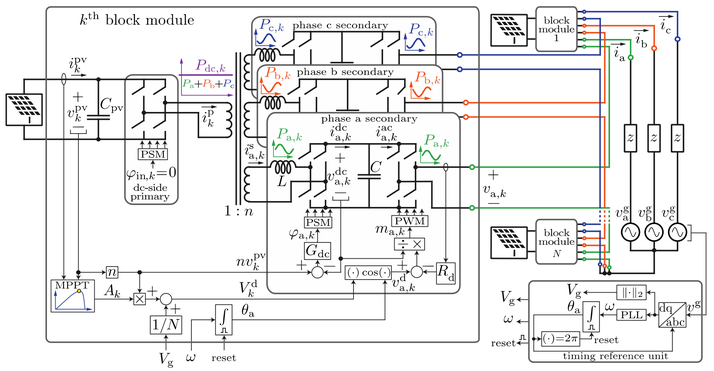
- Sponsor: DOE-funded project, 2018-2021
- Goal: Engineer PV converters that go direct from low-voltage dc to 10's of kV ac



New 5kW prototype



PCB-based 18 kV transformer



Digital controls modulate power delivery

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Brian Johnson // Power & Energy Systems

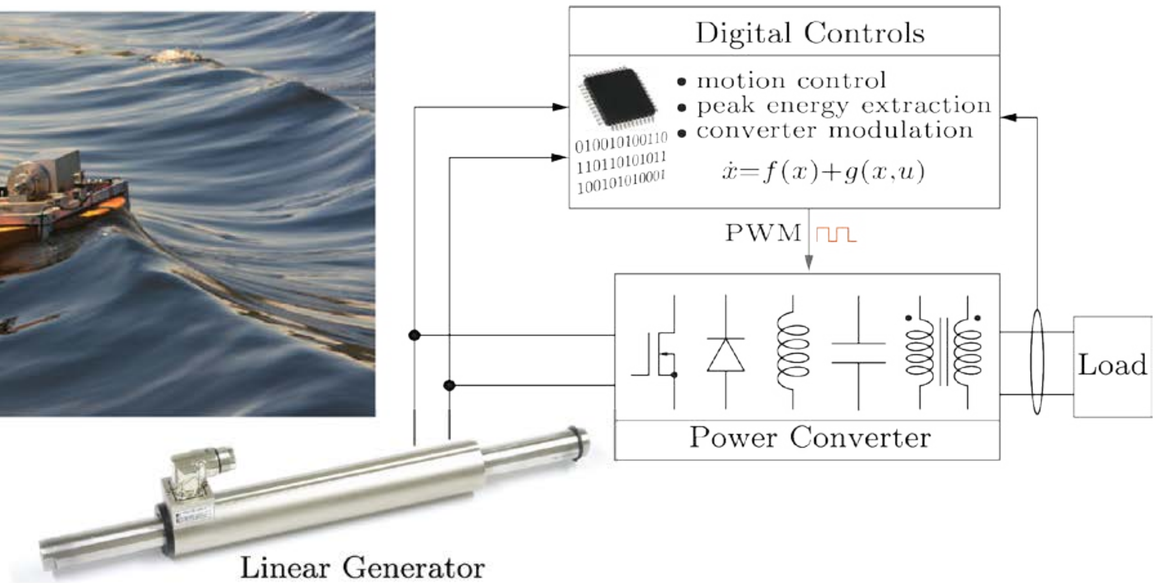
Electromechanical Systems: Wave Energy Harvesting

Johnson
Project #3



- Sponsor: NAVFAC-funded project
- Goal: Design power electronics and controls for wave energy electric machines





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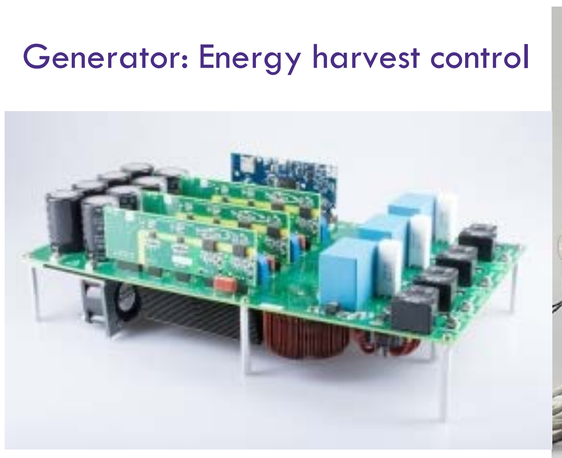
Electromechanical Systems: Wave Energy Harvesting

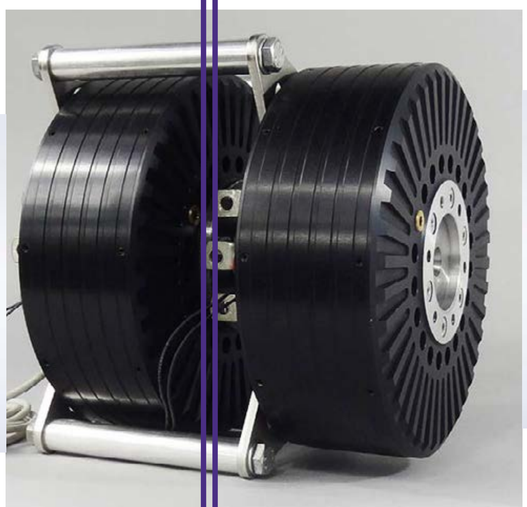
Johnson
Project #3



- Sponsor: NAVFAC-funded project
- Goal: Design power electronics and controls for wave energy electric machines

Generator: Energy harvest control





Motor/Dyno: Wave torque



Back-to-back machines and drives to emulate wave energy generation systems

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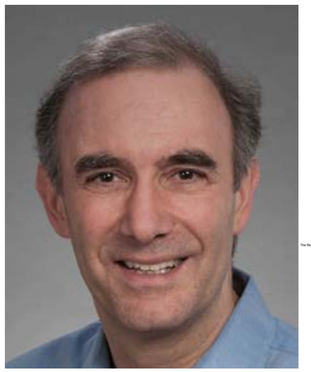
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Daniel Kirschen // Power & Energy Systems

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Daniel S. Kirschen
Close Professor of Electrical and Computer Engineering
Research Theme: Power system economics and operation.
Office: M326 ECE **| Email**: kirschen@uw.edu
Research Webpage: https://labs.ece.uw.edu/real/

Education

- Ingénieur Civil Mécanicien Electricien, Université Libre de Bruxelles, Belgium, 1979.
- MS in Electrical Engineering, University of Wisconsin-Madison, 1980.
- PhD. in Electrical Engineering, University of Wisconsin-Madison, 1985.

Notable Publications

- DS Kirschen and G Strbac, Fundamentals of Power System Economics, Second Edition, Wiley, 2018.
- D S Kirschen, “Demand-Side View of Electricity Markets”, IEEE Trans. on Power Systems, Vol. 18, No. 2, May 2003, pp. 520-527.
- M. Ortega-Vazquez, D S Kirschen, “Estimating the Spinning Reserve Requirements in Systems with Significant Wind Power Generation Penetration”, IEEE Trans. on Power Systems, Vol. 24, No. 1 February 2009, pp. 114-124.
- A Molina-García, F Bouffard, D S Kirschen, “Decentralized Demand-Side Contribution to Primary Frequency Control”, IEEE Trans. on Power Systems, Vol. 26, No 1, pp. 411-419, February 2011

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Daniel Kirschen // Power & Energy Systems

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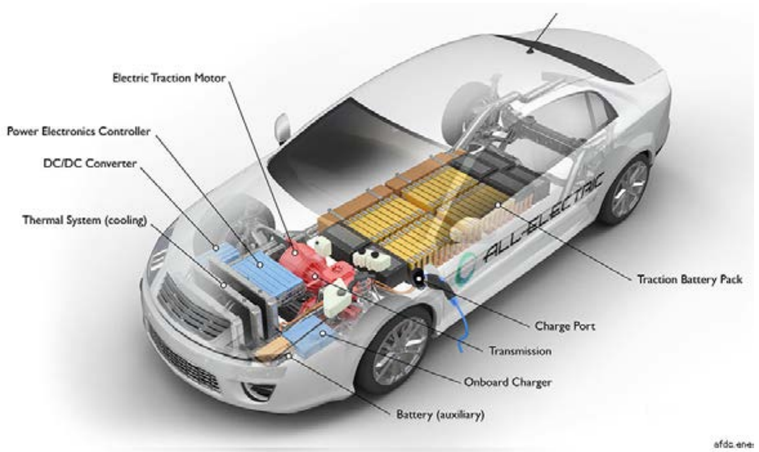
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Kirschen Project #1



Zero Emission Mobility



Transportation systems are undergoing dramatic changes. Rapid growth of e-commerce, delivery services, and ride-hailing represents a transformation in consumer behavior.

As global automakers retool for battery electric vehicles, Washington State is making massive investments in vehicle electrification infrastructure, light rail, electric buses, electric ferries, and has launched the nation's first electric aircraft working group, all with the goal to dramatically reduce transportation emissions.

This project brings together a group of faculty members from across the campus with expertise in transportation and energy systems to develop zero emissions solutions that meet technical constraints while incorporating behavioral responses and society's concerns for the environment, economic sustainability, equity, and affordability.

Collaborators: Anne Goodchild, Dan Schwartz, Don MacKenzie, Jessica Kaminsky, Mehran Mesbahi

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Daniel Kirschen // Power & Energy Systems

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Kirschen Project #2



Resilience of the Grid to Natural Disasters



Electricity distribution systems are often crippled by catastrophic damage caused by a natural disaster. Our goal is to reduce the harm that this inflicts on communities, particularly on disadvantaged populations.

We approach this problem from three directions:

- We develop algorithms to optimize the dispatch of repair crews in a way that minimizes a measure of the harm done to the community
- We explore how a limited budget for resilience improvements should be spent to harden power system components that are critical to the repair and restoration process
- We work with local utilities to quantify the benefits of microgrids.

Publications:

Y Tan, F Qiu, A K Das, D S Kirschen, P Arabshahi, J Wang, “Scheduling Post-Disaster Repairs in Electricity Distribution Networks”, IEEE Trans. on Power Systems, 34 (4), 2611-2621.

C Keerthisinghe, M Ahumada-Paras, L D Pozzo, D S Kirschen, H Pontes, W K Tatum, and M A Matos, “PV-Battery Systems for Critical Loads During Emergencies - A Case Study from Puerto Rico After Hurricane Maria”, IEEE Power and Energy Magazine 17 (1), 82-92.

Funding: NSF, Washington State Clean Energy Fund

Collaborators: Yushi Tan, Arindam Das, Payman Arabshahi, Mareldi Ahumada, Chanaka Keerthisinghe

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Daniel Kirschen // Power & Energy Systems

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Kirschen Project #3



Value of Grid-Scale Battery Energy Storage



The increasing amount of energy produced from variable renewable sources, such as wind and solar, creates or intensifies operational issues in the electricity transmission and distribution grids. My students and I are developing detailed and accurate models of how battery energy storage could be used to alleviate these problems. These models make it possible to compute realistic estimates of the value of storage and to determine the locations where deploying storage would be profitable.

Answering these questions requires the solution of large, non-convex bi-level optimization problems.

Publications:

H Pandzic, Y Wang, T Qiu, Y Dvorkin, D S Kirschen, “Near-Optimal Method for Siting and Sizing of Distributed Storage in a Transmission Network,” IEEE Trans. on Power Systems, 30 (5) 2288-2300.

B Xu, A Oudalov, A Ulbig, G Andersson, D Kirschen, "Modeling of Lithium-Ion Battery Degradation for Cell Life Assessment," IEEE Trans. on Smart Grid, 9 (2)1131-1140.

Y Dvorkin, R Fernandez-Blanco, D S Kirschen, H Pandzic, J-P Watson, C A Silva-Monroy, “Ensuring Profitability of Energy Storage”, IEEE Trans. on Power Systems, 32 (1) 611-623

Funding: DOE ARPA-E, Sandia National Laboratory

Collaborators: Y Dvorkin, H Pandzic, Q Ting, Y Wang, Y Long, B Xu

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Sajjad Moazeni // Photonics & Nano Devices

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Sajjad Moazeni
Assistant Professor of Electrical and Computer Engineering
Research Theme: System Integration for Emerging Technologies, Integrated Photonics, Mixed-signal Integrated Circuits, Neurophotonics & Biophotonics.
Email: smoazeni@uw.edu
Research Webpage: https://emitlab.ece.uw.edu

Education

- B.S. in Electrical Engineering, Sharif University of Technology, Iran, 2013.
- M.S. in Electrical Engineering and Computer Science, UC Berkeley, 2016.
- Ph.D. in Electrical Engineering and Computer Science, UC Berkeley, 2018.

Notable Publications

- A. Atabaki*, S. Moazeni* *et al.*, Integration of Thin-film Photonics with Silicon Nanoelectronics for Next-generation Systems-on-a-Chip, Nature, Volume 556, April 2018. (*equal contribution)
- S. Moazeni *et al.*, A 40Gb/s PAM-4 Transmitter Based on a Ring-Resonator Optical DAC in 45nm SOI CMOS, International Solid-State Circuits Conference (ISSCC) 2017, paper: 29.3.
- S. Moazeni *et al.*, Monolithic Integration of O-band Photonic Transceivers in a “Zero-change” 32nm SOI CMOS, International Electron Devices Meeting (IEDM) 2017 paper: 24.3.
- S. Moazeni *et al.*, An Implantable Neural Interface for Computational Imaging and Optogenetic Stimulation over 5.4×5.4mm^2 FoV, (Submitted to ISSCC 2021)

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Sajjad Moazeni // Photonics & Nano Devices

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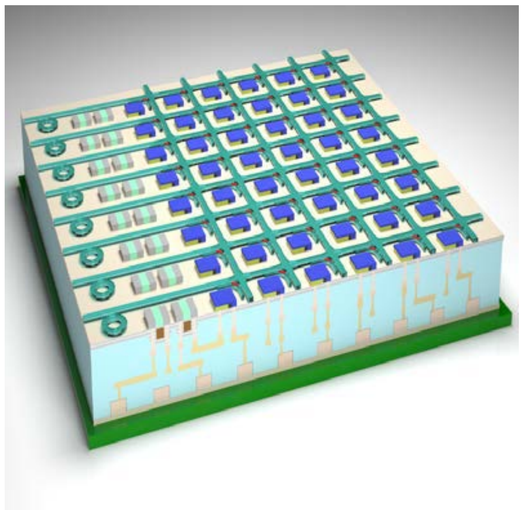
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Moazeni
Project #1



Electronic-Photonic Neuromorphic Computing



Monolithic integration of CMOS & PCM silicon-photonics

Advancements in AI have been challenging our conventional computing paradigms by demanding enormous computing power at a dramatically faster pace than Moore's law. Analog and eNVM based Neuromorphic computing showed a great promise to meet this need for edge devices, but they suffer from limited compute capacity and speed due to the electrical bandwidth limitations. Optical neural networks (ONN) have been proposed to break this barrier, however currently proposed methods cannot be scaled up for practical applications and have poor energy/area efficiencies.

To overcome these challenges, we are planning to build a hybrid electronic-photonic neuromorphic computing platform on a single-chip by:

- Monolithic integration of phase-change material (PCM) with commercial foundry silicon photonics in 45nm CMOS
- Design low-power mixed-signal circuit blocks for this system such as low-power optical digital-to-analog converters and ADCs
- Develop an end-to-end co-optimization framework

Collaborators: Mo Li.

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Sajjad Moazeni // Photonics & Nano Devices

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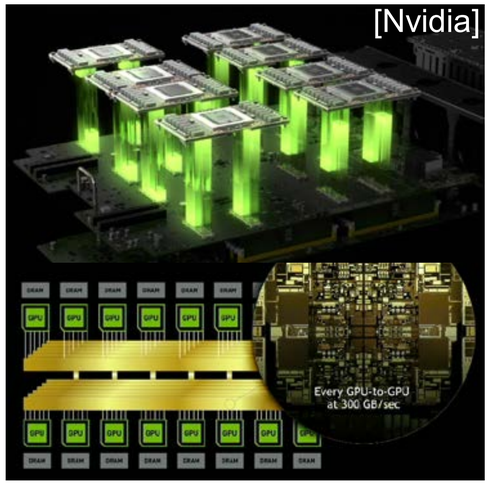
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Moazeni
Project #2



Smart Optical Interconnects for AI & HPC



Tb/s chip-to-chip bandwidths in AI supercomputers, limited by the electrical wire-lines!

In-package optical I/O chips are becoming imminent as CPU/GPU off-chip bandwidths are reaching 10Tb/s in AI & HPC supercomputing systems. Additionally such heterogeneous platforms require more advanced flexibility and functionalities (e.g. GPU-Direct, RDMA, etc.) to reduce memory-access latency for large datasets.

In this project we will develop smart optical interconnect architectures to enable:

- Multi-Tb/s WDM ring-resonator based optical transceivers with fast and high-dynamic range thermal tuning for microsecond-switching networks
- Direct data transfer in between processors (GPUs/CPUs) via smart optical interconnects and switches
- Other potential functionalities of in-package optical I/O transceiver chips besides electro-optical conversion

Publications: S. Moazeni *et al.*, Microsecond Optical Switching Network of Processor SoCs with Optical I/O, Optical Fiber Communication Conference (OFC) 2018.

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Sajjad Moazeni // Photonics & Nano Devices

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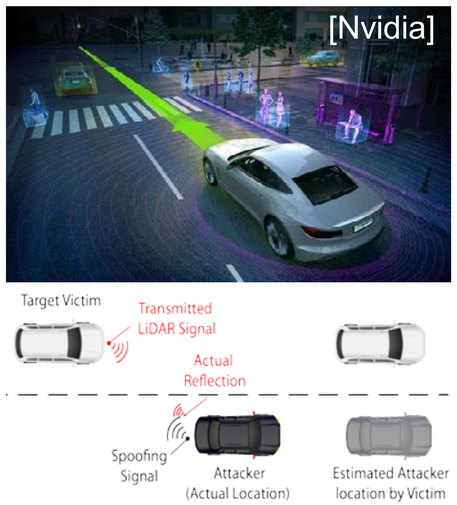
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Moazeni
Project #3



Secure & Low-cost LiDAR Systems



LiDARs for autonomous vehicles and their security vulnerabilities

LiDAR systems are essential for 3D imaging and ranging in autonomous robots, drones, and vehicles. Despite many industrial and academic efforts, the quest for a fully solid-state long-range (>100m) LiDAR that meets the cost, energy, frame-rate, and field-of-view, and security-level requirements of the autonomous car industry is still unanswered.

We are planning to address some of these challenges and demonstrate such a secure & low-cost LiDAR system by deploying:

- Meta-lenses in CMOS to build a focal plane array LiDAR
- Frequency encryption using physically unclonable keys for secure FMCW ranging
- A laser-comb assisted transmitted light to enable multi-beam scanning and relaxing constraints on the required laser

Collaborators: Arka Majumdar.

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Chris Rudell // Biosystems; Computing & Networking

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Jacques "Chris" Rudell
Associate Professor of Electrical and Computer Engineering
Research Theme: Analog, Mixed-Signal, RF and mm-Wave CMOS Integrated Circuit Design for IoT, 5G and Biomedical Applications
Office: M410 ECE | **Email**: jcrudell@uw.edu
Research Webpage: https://people.ece.uw.edu/rudell_chris/

Education

- BS in Electrical Engineering, University of Michigan, 1989
- MS in Electrical Engineering, University of California, Berkeley, 1994
- PhD in Electrical Engineering, University of California, Berkeley, 2000

Notable Publications

- J.P. Uehlin, J.C. Rudell, et al, "A Single-Chip Bidirectional Neural Interface with High-Voltage Stimulation and Adaptive Artifact Cancellation in Standard CMOS," *IEEE J. Solid-State Circuits*, 2020.
- T. Zhang, J.C. Rudell et al, "A Wideband Dual-Path Self-Interference Cancellation Architecture for Full-Duplex Transceivers," *IEEE J. Solid-State Circuits*, 2018.
- V. Bhagavatula, T. Zhang, A.R. Suvarna and J.C. Rudell, "An ultra-wideband millimeter-wave heterodyne receiver with a 17-GHz IF channel bandwidth using gain-equalized transformers," *IEEE J. Solid-State Circuits*, 2016.
- J.A. Weldon, J.C. Rudell, et al, "A 1.75-GHz Highly-Integrated Narrow-Band CMOS Transmitter with Harmonic-Rejection Mixers," *IEEE J. Solid-State Circuits*, 2001.
- J.C. Rudell, et al, J.A. Weldon and P.R. Gray, "A 1.9-GHz Wide-Band IF Double Conversion CMOS Receiver for Cordless Telephone Applications," *IEEE J. Solid-State Circuits*, vol. 32, pp. 2071-2088, 1997.

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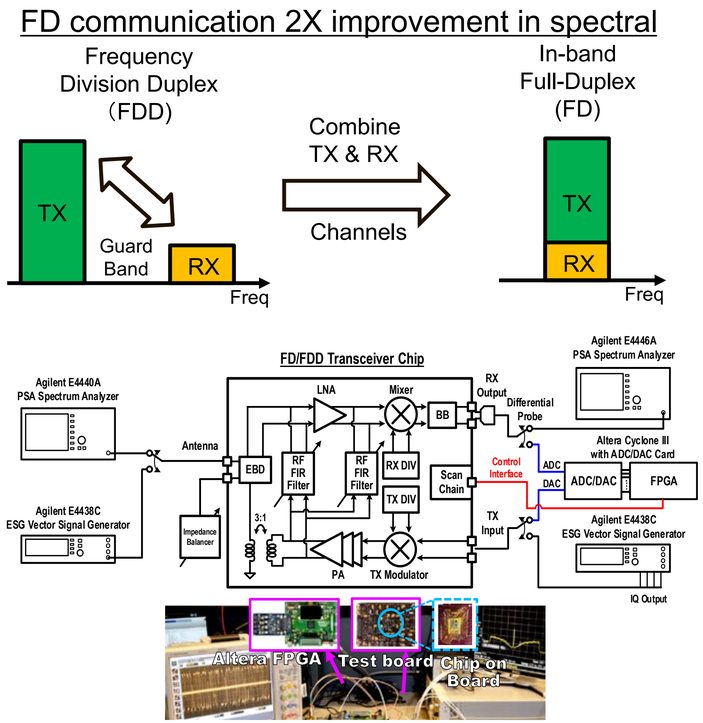
Chris Rudell // Biosystems; Computing & Networking

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Simultaneous Transmit and Receive (STARs) Xceivers



- STARs for Improved Spectral Efficiency.
- Single-Chip Self-Interference (SI) Cancellation for:
  - Full Duplex Communication
  - Radar Self-Interference Cancellation
  - Cable Modem Transceivers
  - Neural Stimulus Artifact Cancellation
- Introduced Concept of Multi-Path Cancellation Radio Architectures.
- UW Reports Deepest (70dB+) and Broadest BW (80MHz) SI Cancellation w/ Highest Linearity Canceler (+37dBm) in CMOS.

Publications: T. Zhang, J.C. Rudell et al, “A Wideband Dual-Path Self-Interference Cancellation Architecture for Full-Duplex Transceivers,” *IEEE J. Solid-State Circuits*, 2018.
Collaborators: S. Roy and V. Sathe.
Funding: NSF, Qualcomm, Intel, SRC, U.S. Army, Google and CDADIC

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Chris Rudell // Biosystems; Computing & Networking

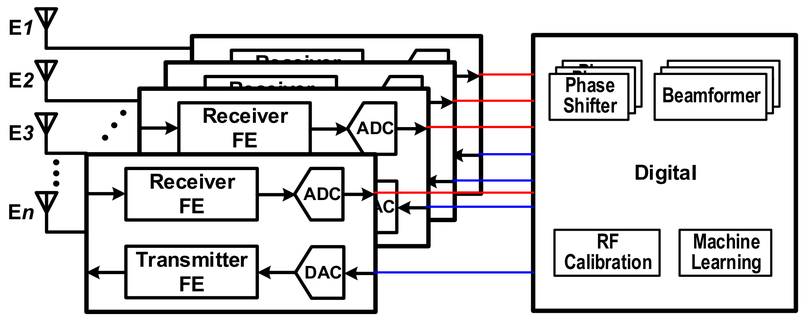
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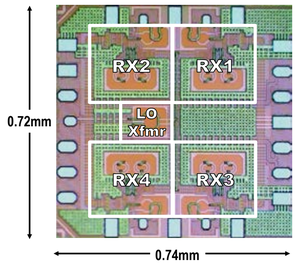
mm-Wave CMOS Front-ends for 5G and Radar

mm-Wave Digital Multibeam Phased Array Systems



- Digital Multibeam Phased-Array front-ends for 5G and radar applications.
- Highly digital front-end with analog and digital front-end tightly coupled.
- Joint project with V. Sathe group and Boeing.
  - ML Algorithms to enable beam tracking and enhance analog performance.
  - Extreme Bandwidth (20GHz) w/ an all CMOS single-chip solution.
  - Low Noise Figure Mixer-First mm-Wave Front-ends

UW 28nm CMOS 70 GHz mm-Wave mixer-first AFE



Publications: V. Bhagavatula, T. Zhang, A.R. Suvarna and J.C. Rudell, “An ultra-wideband millimeter-wave heterodyne receiver with a 17-GHz IF channel bandwidth using gain-equalized transformers,” *IEEE J. Solid-State Circuits*, 2016.
Collaborators: V. Sathe, S. Roy, M. Steed (Boeing), W. Snapp (Boeing), S. Pellarno (Intel)
Funding: Boeing, JCATI, NSF CAREER, Qualcomm, Google, Intel and CDADIC

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Chris Rudell // Biosystems; Computing & Networking

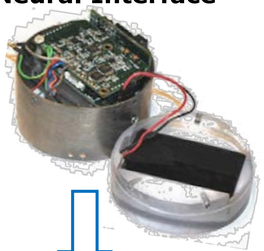
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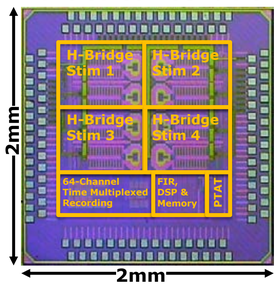
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All CMOS Neural Interfaces w/ Artifact Suppression

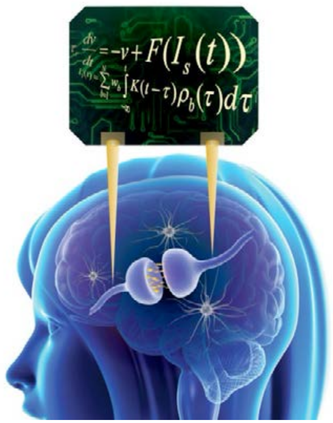
UW Board-Level Neural Interface



Reduced to UW Single-Chip Stimulation, Recording and Artifact Cancellation







- Integration of entire neural interface on single-chip.
- CMOS electronics to including:
  - High-Voltage Stimulation
  - Neural Recording
  - Wireless Communication / Energy Harvesting
- System-on-chip allows for implantable electronics systems to address complex problems with neural interfaces.
  - Low-Power Solution
  - Bidirection Brain Computer Interfaces
  - Elimination of Stimulus Artifacts.
- Used in reanimation, DPS, treatment of psychological disorders and scientific applications.

Publications: J.P. Uehlin, et al, V. Sathe, J.C. Rudell,, “A Single-Chip Bidirectional Neural Interface with High-Voltage Stimulation and Adaptive Artifact Cancellation in Standard CMOS,” *IEEE J. Solid-State Circuits*, 2020.

Collaborators: V. Sathe, S. Perlmutter, C. Moritz and E. Fetz
Funding: UW Center for Neural Technology (CNT) and Medtronic

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Chris Rudell // Biosystems; Computing & Networking

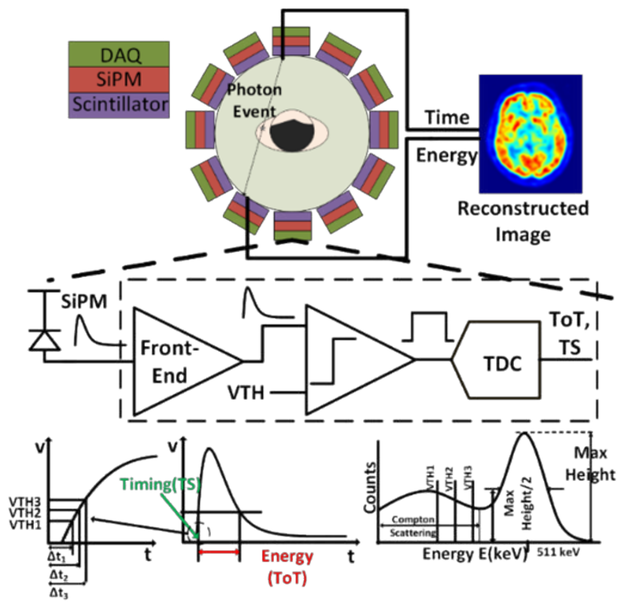
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Highly-Integrated Electronics for PET Imaging Systems

Integrated Mixed-Signal Front-end CMOS Chips for PET Imaging



- Integrated Interfaces for Positron Emission Tomography (PET) Imaging Detectors.
- All CMOS solutions all for:
  - Denser Detection Arrays (More Channels)
  - Higher BW channels to match Solid-State Detector speed
  - Potential High-Speed Wireless Data Delivery.
- Single-chip vs. Board Solutions lead to radically reduced size of the electronic solution and PET imaging unit. Substantial reduction in cost and size.
- UW Reports new architecture for analog-to-digital (ADC) conversion in PET detector channels based on Time-Over-Threshold (ToT) Methods.

Publications: CE Shannon, Programming a computer for playing chess, The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 41(314), 256-275, 1950.
Collaborators: R. Miyaoka, T. Lewellen
Funding: NIH and Zecotek

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Jeffrey Bilmes // Biosystems; Data Science

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Jeff A. Bilmes
Professor of Electrical and Computer Engineering, Adjunct Professor in Computer Science & Engineering, and in Linguistics
Research Theme: Machine learning, artificial intelligence, discrete optimization, submodularity, natural language/speech processing, computer vision, comp. biology
Office: 418 ECE **| Email**: bilmes@uw.edu
Research Webpage: https://melodi.ece.uw.edu/people/bilmes

Education

- BSEE in Electrical Engineering and Computer Science, U.C. Berkeley, 1991.
- MS in Computer Science, Massachusetts Institute of Technology, 1993.
- PhD. in Computer Science, U.C. Berkeley, 1999.

Awards: 2001 NSF Career award winner, 2002 CRA Digital Government Fellow,2008 NAE Gilbreth Lectureship award recipient, 2012/2013 ISCA Distinguished Lecturer. h-Index: 64 (July, 2020)

Notable Publications

- Wenruo Bai, Jeffrey Bilmes, and William S. Noble. Bipartite Matching Generalizations for Peptide Identification in Tandem Mass Spectrometry. In 7th ACM Conference on Bioinformatics, Computational Biology, and Health Informatics (ACM BCB), ACM SIGBio, ACM SIGBio, Seattle, WA, October 2016. **Winner of the Best Paper Award, ACM-BCB 2016**
- Rishabh Iyer, Stefanie Jegelka, and Jeff A. Bilmes. Fast Semidifferential-based Submodular Function Optimization. In International Conference on Machine Learning (ICML), Atlanta, Georgia, 2013. **Winner of the Best Paper Award, ICML 2013**
- Rishabh Iyer and Jeff Bilmes. Submodular Optimization with Submodular Cover and Submodular Knapsack Constraints. In Neural Information Processing Society (NeurIPS, NIPS), Lake Tahoe, CA, December 2013. **Winner Outstanding Paper Award, NIPS-2013**
- Jeffrey Bilmes and Wenruo Bai. Deep Submodular Functions. Arxiv, abs/1701.08939, Jan 2017**.**
- Tianyi Zhou, Shengjie Wang, Jeff Bilmes, Time-Consistent Self-Supervision for Semi-Supervised Learning, International Conference on Machine Learning, July 2020.

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Jeffrey Bilmes // Biosystems; Data Science

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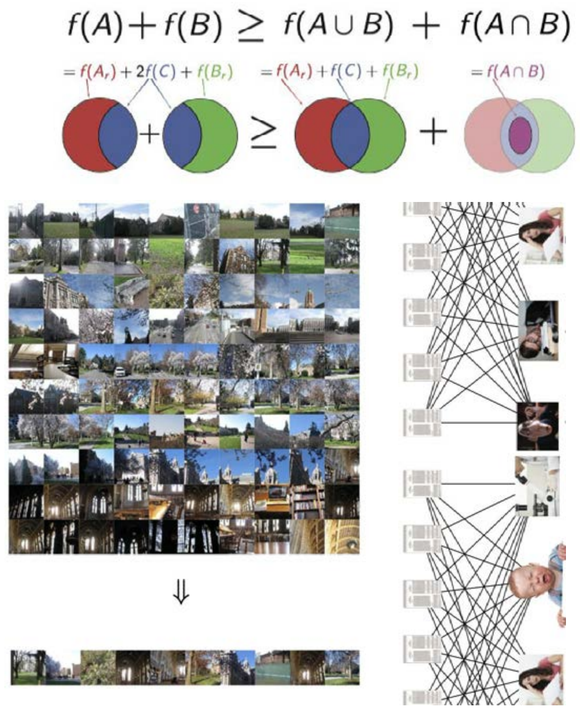
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Bilmes
Project #1



Submodularity in Machine Learning



- Submodularity is a powerful structure that, analogous to convexity, allows natural modeling of discrete physical phenomena while offering avenues for extremely efficient mathematical optimization over what otherwise would be exponential cost problems.
- Submodularity generalizes entropic quantities; it offers a good candidate for a universal information function, useful in many applications:
  - Massive size data set summarization, “green” AI.
  - Science of data management.
  - Data partitioning for efficient parallel computation
  - Modeling and measuring diversity and removing bias in data and machine learning systems
  - Efficient approximate probabilistic modeling without factorization requirements
  - Efficient large-scale discrete mathematical optimization
  - Complementary with other strategies (e.g., algorithmic or computing systems advances) for machine learning efficiency.
- Many publications and sub research themes in this area, see: https://people.ece.uw.edu/bilmes/p/pgs/class_rescat.html#Submodularity

Typical Publication: Rishabh Iyer and Jeffrey Bilmes. Near Optimal Algorithms for Hard Submodular Programs with Discounted Cooperative Costs. In 22nd International Conference on Artificial Intelligence and Statistics (AISTATS-2019), April 2019. But see https://people.ece.uw.edu/bilmes/p/pgs/class_rescat.html#Submodularity

Funding: NSF, DARPA, SRC, NIH

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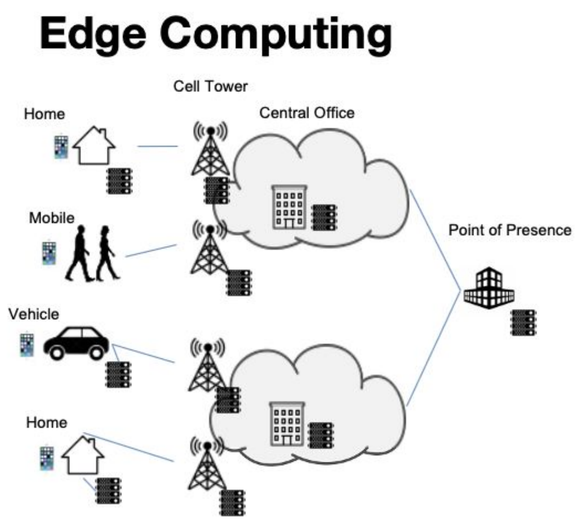
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Smart distributed machine learning

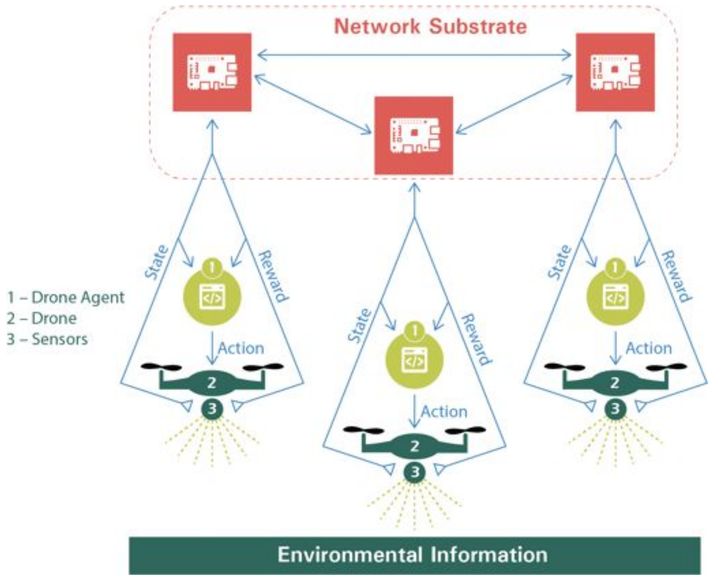
Example Bilmes Project #2



CONIX at the edge
RESEARCH CENTER



- Modern computing systems are cloud based but also edge based.
- Future computing systems are likely “everywhere” based, compute exists (and should be exploitable) in the cloud, at the very edge, and everywhere in between.
- How can we develop machine learning algorithms that are amenable to this computing platform inevitability?
- It’s all about the data: distributed machine learning and smart data partitioning



Typical Publication: Shengjie Wang, Wenruo Bai, Chandrashekhar Lavania, and Jeffrey Bilmes. Fixing Mini-batch Sequences with Hierarchical Robust Partitioning. In 22nd International Conference on Artificial Intelligence and Statistics (AISTATS-2019), April 2019.
Funding: SRC, DARPA

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Jeffrey Bilmes // Biosystems; Data Science

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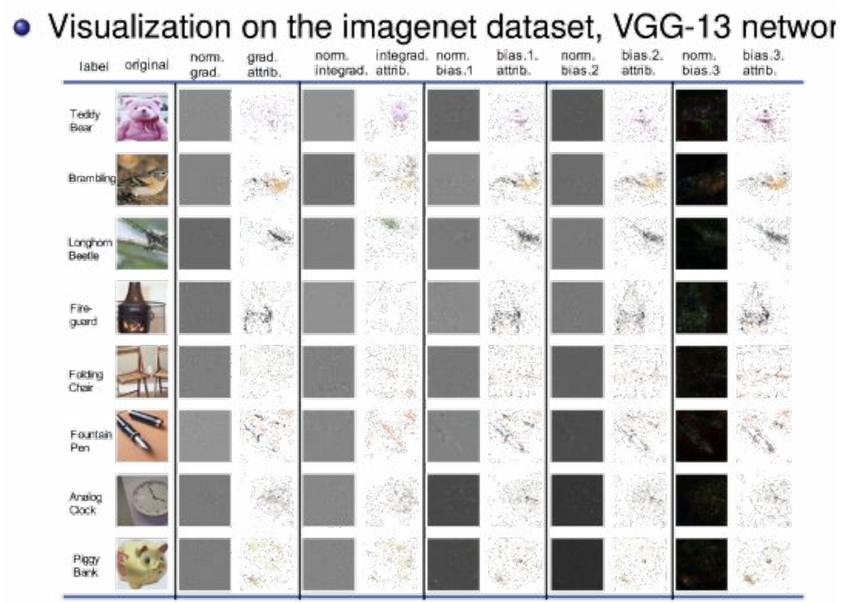
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Example Bilmes Project #3



Bias attribution

CONIX RESEARCH CENTER at the edge



- Why do DNNs do what they do?
- Attribution methods help answer this question.
- This method: DNN bias terms are also important in determining what is important.

Publications: Rishabh Iyer and Jeffrey Bilmes. Near Optimal Algorithms for Hard Submodular Programs with Discounted Cooperative Costs. In 22nd International Conference on Artificial Intelligence and Statistics (AISTATS-2019), April 2019. But see https://people.ece.uw.edu/bilmes/p/pgs/class_rescat.html#Submodularity

Funding: NSF, DARPA, SRC, NIH

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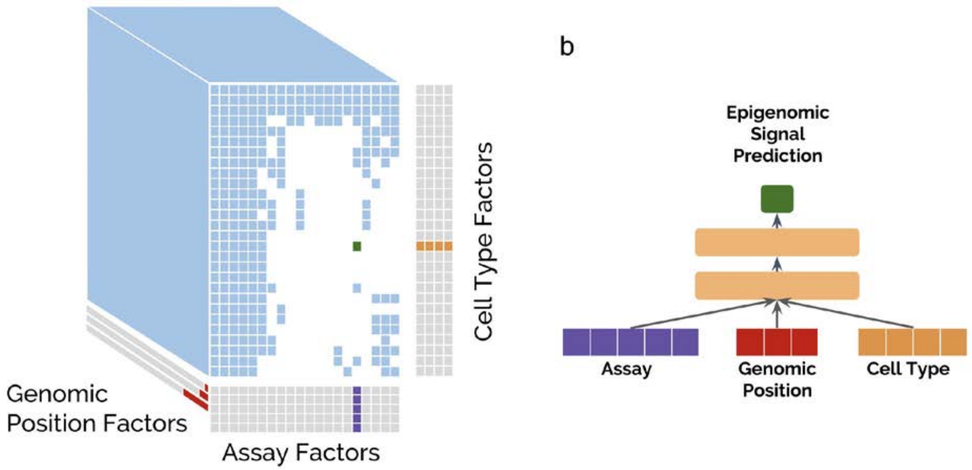
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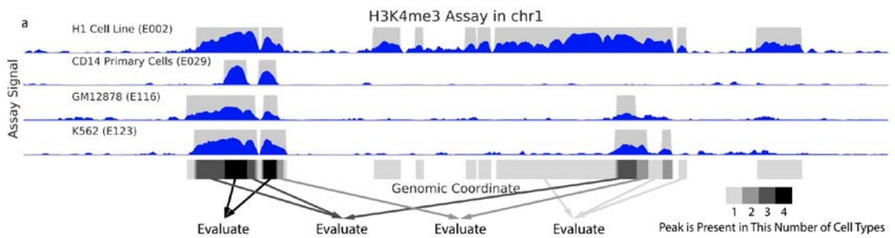
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Example Bilmes Project #4



Latent feature learning in human epigenome





- Compress epigenomic data into a dense, information-rich feature representation using multiple DNNs pillars.
- Useful for imputing other epigenomic data which can then be used for other tasks (one possible example being summarizing the human genome).

Publications: Jacob Schreiber, Timothy Durham, Jeffrey Bilmes & William Stafford Noble, Avocado: a multi-scale deep tensor factorization method learns a latent representation of the human epigenome, Genome Biology volume 21, Article number: 81 (2020)

Funding: NIH

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Maryam Fazel // Data Science; Robotics & Controls

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Maryam Fazel
Professor of Electrical and Computer Engineering
Associate Chair for Research
Research Theme: Machine learning, control theory, mathematical optimization
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Research Webpage: http://faculty.washington.edu/mfazel/

Education

- BS in Electrical Engineering, Sharif University of Technology, Iran, 1995.
- MS in Electrical Engineering, Stanford University, 1997.
- PhD. in Electrical Engineering, Stanford University, 2002.

Notable Publications

- S. Oymak, A. Jalali, **M. Fazel**, Y. Eldar, B. Hassibi, Simultaneously Structured Models with Application to Sparse and Low-rank Matrices. *IEEE Trans. on Information Theory,* 61(5): 2886-2908, May 2015. (citations: **228**)
- **M. Fazel**, T. K. Pong, D. Sun, P. Tseng. Hankel Matrix Rank Minimization with Applications to System Identification and Realization. *SIAM Journal on Matrix Analysis and Applications,* 34(3): 946-977, 2013. (citations: **338**)
- K. Mohan, **M. Fazel**, Iterative reweighted algorithms for matrix rank minimization*, Journal of Machine Learning Research* 13 (Nov), 3441-3473, 2012. (citations: **354**)
- B. Recht, **M. Fazel**, P. Parrilo. Guaranteed Minimum-Rank Solutions of Linear Matrix Equations via Nuclear Norm Minimization. *SIAM Review*, 52(3): 471-501, 2010. (citations: **3042)**

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Maryam Fazel // Data Science; Robotics & Controls

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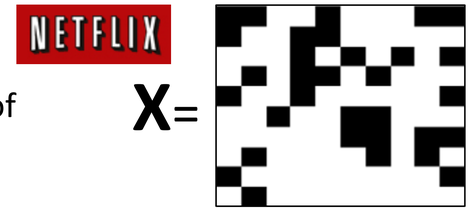
Regularization in learning

Fazel
Project #1



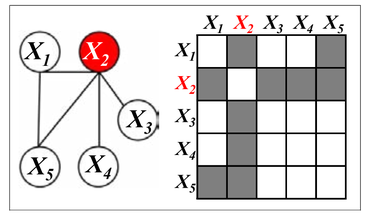
"learning models from data" as an optimization problem:

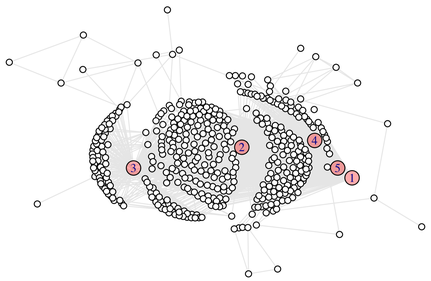
minimize Loss(model;data) + R(model)

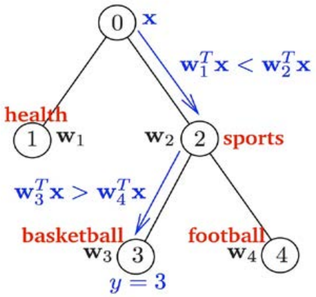


Choice of regularizer *R(.)* is key to learning structured models. Several of our projects fall under overarching theme of design and analysis of regularizers:

- sparse representations
  - compressed sensing (imaging; MRI)
- low-rank matrix recovery
  - recommender systems (e.g., movies); community detection
- graphical models w/ hubs
  - gene network structure
- variational Gram functions
  - selective orthogonality; hierarchical classification
- low-order linear system identification
  - learn dynamics from input/output data







Funding: NSF, ONR, DARPA, RRF

Collaborators: B. Recht, P. Parrilo, B. Hassibi, S. Oymak, P. Tseng, D. Witten, S.-I. Lee, L. Xiao, I. Dumitriu

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Maryam Fazel // Data Science; Robotics & Controls

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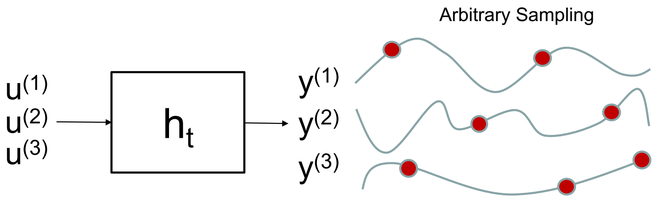
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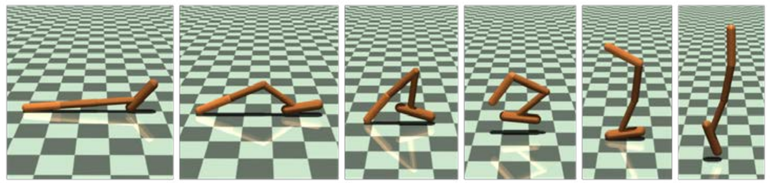
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Learning and Control

Fazel
Project #2







control & dynamical systems ⟺ ML/reinforcement learning (RL)

- Adhoc RL algorithms such as policy gradient methods are popular in practice, yet little understood theoretically. What pros and cons can be proven?
  - We start by revisiting the classical Linear Quadratic Regulator from a new viewpoint: direct "policy updates".
    Despite nonconvexity, we prove gradient descent in policy space converges to *globally optimal* control.
- Learning dynamics, or "system identification": classical analysis is often only asymptotic. Can we give finite-sample statistical guarantees? What is the complexity of inputs needed to identify dynamics from input-output data?
  - We prove learning linear dynamics with low-order regularization is sample-efficient.
- Many open questions beyond simplest settings: nonlinear dynamics, other costs and structures, robustness…

- **Publication:** M. Fazel, R. Ge, S. Kakade, M. Mesbahi, Global Convergence of Policy Gradients for the Linear Quadratic Legulator. *Proc. Intl. Conf. on Machine Learning (ICML),* July 2018 (citations: **142**)
- **Funding:** DARPA, NSF
- **Collaborators:** S. Kakade, M. Mesbahi

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Scott Dunham // Photonics & Nano Devices; Power & Energy Systems

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Scott T. Dunham
Professor of Electrical and Computer Engineering
Adjunct Professor of Physics
Adjunct Proessor of Materials Science & Engineering
Research Theme: Electronic, Optoelectronic, and Photonic Devices, Computational Materials Science, Nanotechnology Modeling
Office: 218 ECE | **Email**: dunham@uw.edu
Research Webpage: https://dunham.ece.uw.edu

Education

- BSEE in Electrical Engineering, Cornell University, 1979.
- MS in Electrical Engineering, Stanford University, 1980.
- PhD. in Electrical Engineering, Stanford University, 1985.

Notable Publications

- ST Dunham, A quantitative model for the coupled diffusion of phosphorus and point defects in silicon, Journal of the Electrochemical Society 139 (9), 2628, 1992.
- W Windl, MM Bunea, R Stumpf, ST Dunham, MP Masquelier, First-principles study of boron diffusion in silicon, Physical Review Letters 83 (21), 4345, 1999.
- C Ahn, N Bennett, ST Dunham, NEB Cowern, Stress effects on impurity solubility in crystalline materials: a general model and density-functional calculations for dopants in silicon, Physical Review B 79 (7), 073201, 2009.
- R Chen, ST Dunham, Kinetic lattice Monte Carlo simulations of interdiffusion in strained silicon germanium alloys, Journal of Vacuum Science & Technology B, 28(1), C1G18-C1G23, 2010.
- D Mutter, ST Dunham, Calculation of Defect Concentrations and Phase Stability in Cu_2ZnSnS_4 and $Cu_2ZnSnSe_4$ From Stoichiometry, IEEE Journal of Photovoltaics 5 (4), 1188-1196, 2015.

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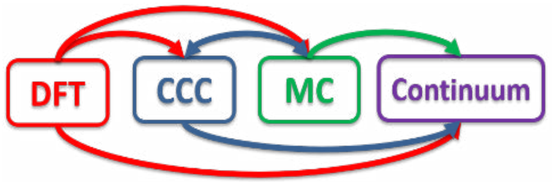
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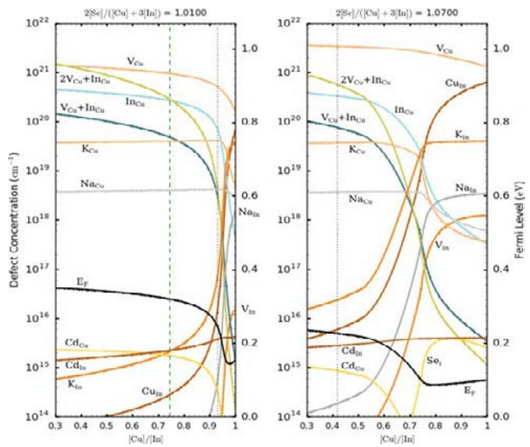
Dunham
Project #1



Fundamental Modeling of CIGS Photovoltaics



Above is modeling hierarchy. Below is output of CCC for fixed valence ratio



The goals of the proposed work are to provide modeling tools (and the associated insight which comes along with model development) for design and optimization of $CuIn_xGa_{1-x}Se_2$ (CIGS) manufacturing processes and to establish the foundation for comprehensive end-to-end predictive modeling tools to enable optimization of thin film photovoltaic technology for performance, cost, yield, and reliability.

We use a multiscale approach for predictive modeling of device performance based on the manufacturing process. Density functional theory (DFT) calculations are to calculate fundamental material/defect properties. We use the Chemical Constraint Calculator (CCC) developed in the project with DFT parameters to predict defect/complex concentrations. Monte Carlo (MC) simulations are used to explore defect/composition evolution in partially-ordered alloys, while continuum simulations connect process to device behavior, enabling technology optimization.

Publications: DE Sommer, D Mutter, ST Dunham, Defects in Na-, K-, and Cd-Doped CuInSe : Canonical Thermodynamics Based on Ab Initio Calculations, IEEE Journal of Photovoltaics 7 (4), 1143-1152, 2017.
Funding: Department of Energy, Solar Energy Technology Office
Collaborators: BJ Stanbery, A Arehart, D Kuciauskas, L Mansfield), T Magorian-Friedlmeier

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Scott Dunham // Photonics & Nano Devices; Power & Energy Systems

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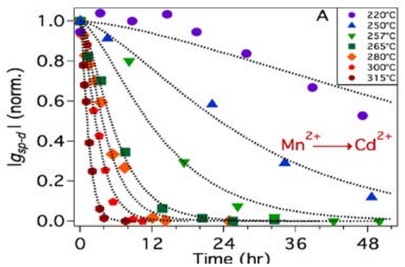
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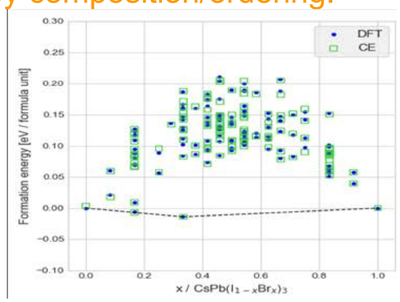
Engineering Defects in Nanostructures

Dunham
Project #2





Above is comparison of predicted cation replacement to experiment. Below is calculated energy as function of alloy composition/ordering.



As part of UW's Molecular Engineering Materials Center (an NSF MRSEC) our aim is to harness the power of defects (e.g., impurities, vacancies, etc.) in colloidal nanocrystals to transform their physical properties and add technological value. Working closely with colleagues in Chemistry, Physics, and Materials Science, we achieve this goal through application of theory and modeling to understand and control fundamental chemistries and identify creative application of these new materials. With the emergence of nanotechnology, we are confronted with new challenges of introducing and exploiting well-defined defects in materials with extraordinarily high surface/volume ratios, for which classical doping methods are not applicable, and where bulk structure/function relationships break down. Paralleling experiments, we will apply first-principles calculations and numerical simulation to obtain structure/energy relationships and analyze thermodynamic/kinetic aspects of NC defects. Predictions are used to help interpret experimental data and identify new targets with desirable functionality.

Publications: MC De Siena, DE Sommer, SE Creutz, ST Dunham, DR Gamelin, Spinodal Decomposition During Anion Exchange in Colloidal Mn2+-Doped CsPbX3 (X = Cl, Br) Perovskite Nanocrystals, Chemistry of Materials 31 (18), 7711-7722, 2019.

Funding: NSF Division of Materials Research

Collaborators: DR Gamelin , P Pauzauskie, K-M Fu, B Cossairt

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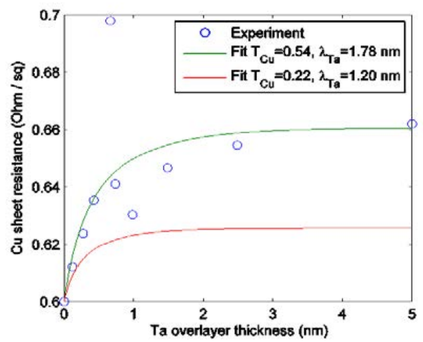
Dunham
Project #3



Conduction of Metal Nanowires

To right is Cu/Ta interface as calculated by DFT and used in NEGF calculation of interface reflection. Below shows comparison of model to data for Cu resistance vs Ta layer thickness





As metal wire dimensions shrink below about 100nm, their resistivity increases due to interface and grain boundary scattering. The aim of this work is the development of fundamental understanding and quantitative models for this conductivity degradation in order to help guide the development of processes for metal wire fabrication that maximize conductivity.

We use a combination of density functional theory (DFT), ab-initio transport (e.g., NEGF), Monte Carlo, and semi-classical analysis.

Our initial work was aimed at how to optimize Cu interconnect structures. We are now exploring alternative metals such as Co, Rh, Ni, and Ru in order to identify materials that can achieve higher conductance in ultra-scaled (~10nm and below) wires.

Publications: B Feldman, S Park, M Haverty, S Shankar, ST Dunham, Simulation of grain boundary effects on electronic transport in metals, and detailed causes of scattering, physica status solidi (b) 247 (7), 1791-1796, 2010.
Funding: Semiconductor Research Corp. (SRC), Lam Research
Collaborators: B Feldman, Michal Danek

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Eli Shlizerman // Biosystems; Data Science; Robotics & Controls

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Eli Shlizerman
Assistant Professor
Washington Research Foundation Professor for Data-Intensive Discovery
Research Theme: Machine Learning, Data-Science, Neurobiological Networks, Artificial Neural Networks, Dynamical Systems, Control.
Office: 446 ECE | **Email**: shlizee@uw.edu
Research Webpage: http://faculty.washington.edu/shlizee/

Education

- BSc, Computer Science and Mathematics, Cum Laude, Bar-Ilan University, Ramat Gan, Israel, 2002
- MSc, Computer Science and Applied Mathematics, Weizmann Institute of Science, Rehovot, Israel, 2004
- PhD, Computer Science and Applied Mathematics, Weizmann Institute of Science, Rehovot, Israel, 2009

Notable Publications

- K. Su, X. Liu, E. Shlizerman, **Predict & Cluster: Unsupervised Skeleton Based Action Recognition**, *IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, 2020
- J. Kim, W. Leahy, E. Shlizerman, **Neural Interactome: Interactive simulation of a neuronal system**, *Frontiers in Computational Neuroscience*, 2019.
- E. Shlizerman, L. Dery, H. Schoen, I. Kemelmacher-Shlizerman, **Audio to Body Dynamics**, *IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR),* 2018
- E. Shlizerman, J. Phillips-Portillo, D. Forger, and S. Reppert, **Neural integration underlying a time-compensated sun compass in the migrating monarch butterfly**, *Cell Reports (on cover)*, 2016.
- J. Riffell, E. Shlizerman, E. Sanders, L. Abrell, B. Medina, A.J.Hinterwirth, and J. N. Kutz, **Flower discrimination by pollinators in a dynamic chemical environment**, *Science*, 2014.

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Eli Shlizerman // Biosystems; Data Science; Robotics & Controls

ECE Research Areas:

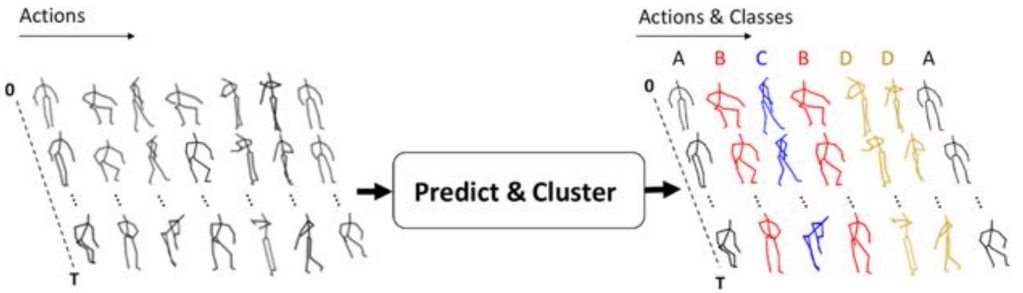
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Shlizerman
Project #1



Unsupervised Action Recognition with NN



How can neural networks be used to organize **sequences** into **actions** in an unsupervised way, i.e., perform action recognition without a need for annotation?

- We propose to train **recurrent encoder-decoder** networks to predict sequences.
- Such a setup does not require **annotation and can be done in an unsupervised way**.
- The network **self-organizes the sequences** into **distinct clusters**.
- We developed a way to make sure that learning is **optimal** by 'weakening' the decoder.
- Our system obtains **state-of-the art performance on action recognition of human body movements/gestures.**
- The approach could be **applied to various actions**. This might include anything from organizing recorded signals into classes (fMRI, neural recordings, etc), to fault prediction, to identification of malicious actions in activity.

Publications: K. Su, X. Liu, E. Shlizerman, Predict & Cluster: Unsupervised Skeleton Based Action Recognition, *IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, 2020
Funding: NSF.
Students: K. Su, X. Liu, J. Li

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Eli Shlizerman // Biosystems; Data Science; Robotics & Controls

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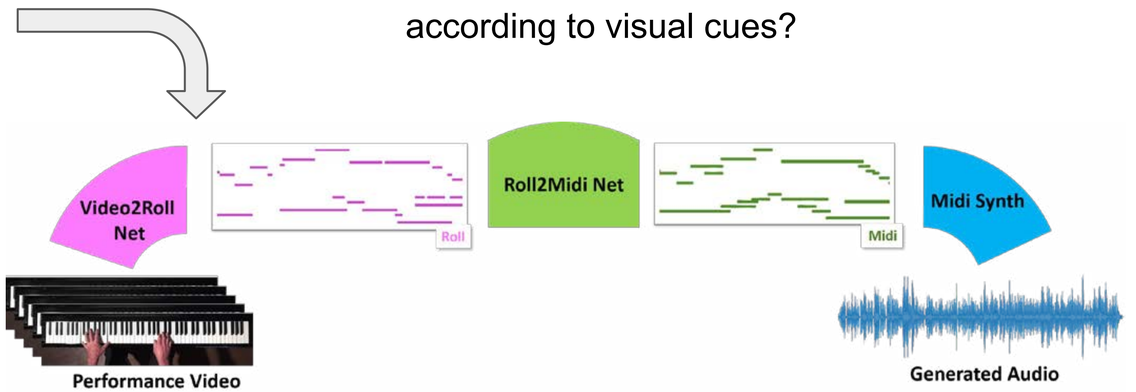
Shlizerman
Project #2



Audio-Visual Generation



How can audio be synthesized according to visual cues?



Audeo: We develop a novel system that gets a silent video of a musician playing the piano and generates the music for that video.

There are many applications to this approach, including timbre transform, recognition of music playing, correction and denoising sound, assisting in learning to play an instrument, etc.

Publications: K. Su, X. Liu, E. Shlizerman, Audeo: Audio Generation for a Silent Performance Video *(Submitted; Arxiv)*, 2020.
Funding: Pending.
Students: K. Su, X. Liu

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Eli Shlizerman // Biosystems; Data Science; Robotics & Controls

ECE Research Areas:

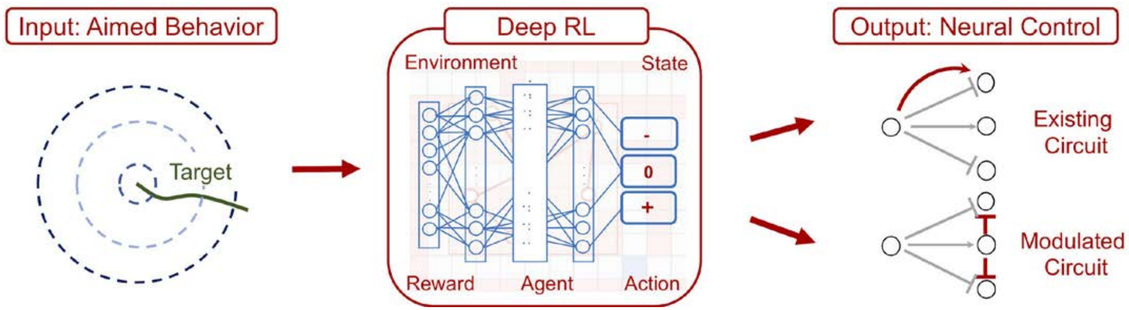
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Shlizerman
Project #3



Deep Reinforcement Learning for Neural Control



We aim to achieve **behavior** by generating (i) **Neuromodulation control** or (ii) **Connectome control** (novel configurations) for application in Brain Computer Interfaces or therapeutics. Both forms of control are challenging due to nonlinear and recurrent complexity of neural activity.

To infer candidate control policies, we develop approaches that map neural circuits and their connectome into a grid-world like setting and infers the actions needed to achieve aimed behavior. The actions are inferred by adaptation of deep Q-learning methods known for their robust performance in navigating grid-worlds.

Publications: Kim J., Shlizerman E.. Deep Reinforcement Learning for Neural Control. (Arxiv; Submitted), 2020.

Funding: AFOSR, NSF.

Students: J. Kim

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Eli Shlizerman // Biosystems; Data Science; Robotics & Controls

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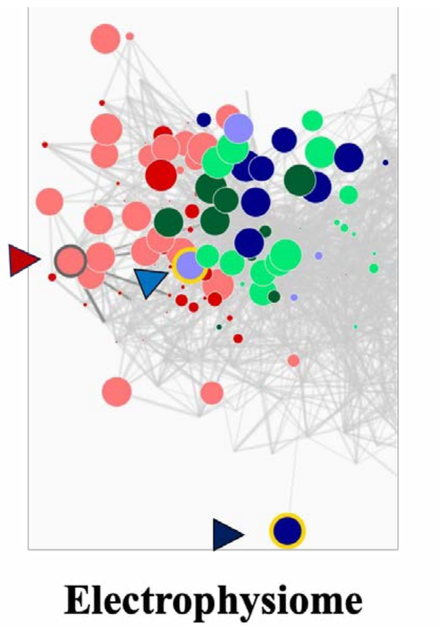
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Shlizerman
Project #4



Electrophysiome



Electrophysiome

The current challenge in neuroscience is to connect **recordings** from a finite number of cells to emerging **circuit-level and system-level properties** that give rise to behavior.

The brain of nematode *Caenorhabditis elegans* with 302 neurons and the complete connectome is the ideal model organism to apply this approach. However, eclipsed by the knowledge of the wiring diagram, little is known about the intrinsic biophysical properties of individual neurons in *C. elegans* due to the lack of systematic electrophysiological studies. This knowledge gap has hindered the theoretical endeavor to develop **quantitative models** to explain how this simplest brain works.

With collaborators I am developing the **electrophysiome – the complete electrophysiological characterization of every neuronal cell type in *C. elegans*** – and a comprehensive anatomically correct and biophysically correct whole-brain model to simulate and interpret neuron activity, circuit dynamics and behavior.

Publications: Kim, J., Leahy, W., & Shlizerman, E. Neural Interactome: Interactive Simulation of a Neuronal System. Frontiers in Computational Neuroscience, 2019.
Kim, J., Santos, J., Alkema, M.J., Shlizerman, E. Whole integration of neural connectomics, dynamics and bio-mechanics for identification of behavioral sensorimotor pathways in Caenorhabditis elegans, BioArxiv, 2020.
Funding: NIH (Pending).
Collaborators: Q. Liu (Rockefeller University), J. Kim.

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Sumit Roy // Computing & Networking

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Sumit Roy
Professor, Electrical and Computer Engineering
Research Theme: Wireless Networking (5G & Beyond), Spectrum Engineering
Office:M330 | Email: sroy@uw.edu
Webpage: https://depts.washington.edu/funlab

Education

- B. Tech, Indian Inst. of Technology, Kanpur (1983)
- M.S. ECE (1985); M.A. Applied Prob. & Stat. (1988) Univ. of California @ Santa Barbara
- Ph.D. ECE (1988) Univ. of California @ Santa Barbara

Notable Publications

- F. Hessar and S. Roy, `` Spectrum Sharing between a Surveillance Radar and Secondary Wi-Fi Networks," IEEE Trans. Aerosp. Electronic Systems, Jun 2016.
- M. Mehrnoush, V. Sathya, S. Roy and M. Ghosh, ``Analytical Modeling of WiFi and LTE-LAA Coexistence: Throughput and Impact of Energy Detection Threshold," IEEE/ACM Trans. Networking, Aug. 2018.
- S. Ashrafi, C. Feng and S. Roy, ``Compute-and-Forward for Random-Access: The Case of Multiple Access Points," IEEE Trans. Comm., Aug. 2018.
- X. Gao, G. Xing, S. Roy and H. Liu, ``Overview of Automotive Radar Test-bed at U.Washington,“ Proc. Asilomar Conf., Pacic Grove, CA, Nov. 2019.
- S. Mishra and S. Roy. ``Market Mechanisms for Dynamic Spectrum Access,” IEEE Trans. Wireless Comm., May 2018.
- V. Sathya, M. Mehrnoush, M. Ghosh and S. Roy, ``Wi-Fi/LTE-U Coexistence: Real-time Issues and Solutions," IEEE Access, Jan. 2020.

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Sumit Roy // Computing & Networking

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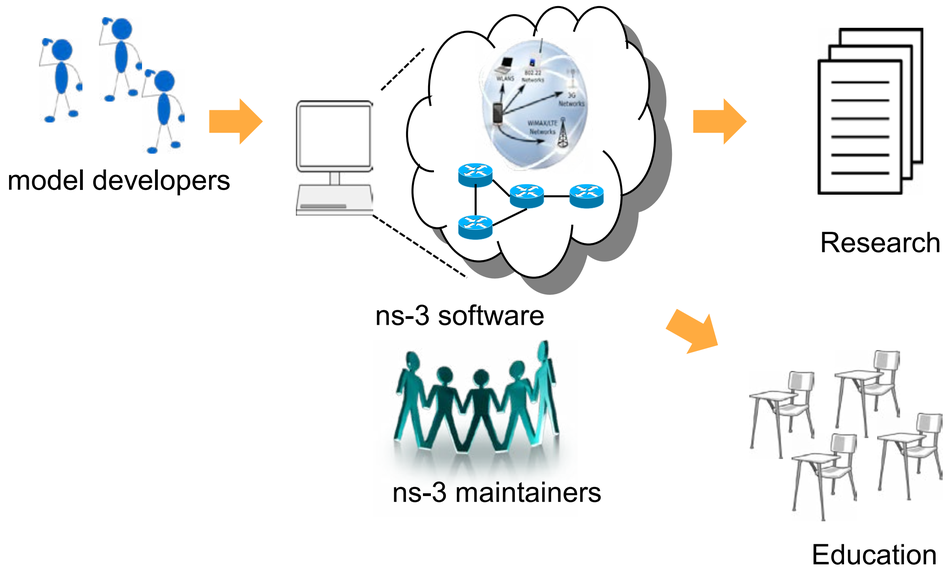
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Roy Project #2



ns-3: Simulator for 5G Performance Evaluation



- Software environment to build models of wireless computer networks & conduct performance evaluation studies
- Open source (GPLv2) license, packet-level simulator featuring a high - performance core enabling parallelization

➢ 5G networks will be more dense, heterogeneous → demand for predictive performance evaluation via network simulation will scale accordingly

Publications: S. Jin, S. Roy, W. Jiang and T. Henderson, ``Efficient Abstractions for Implementing TGn Channel and OFDM-MIMO Links in ns-3," Proc. Workshop on ns-3, Jun. 2020. www.nsnam.org
Funding: NSF, NIST
Collaborators: T. R. Henderson, S. Avallone, S. Deronne and several Ph.D. students

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Sumit Roy // Computing & Networking

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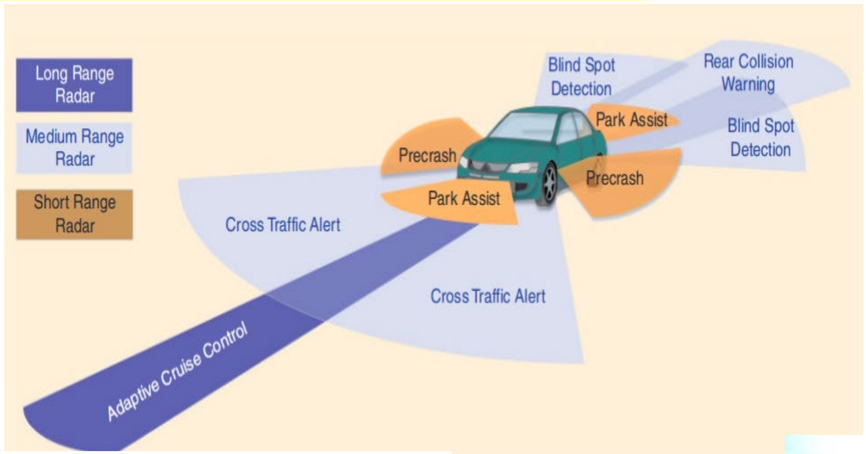
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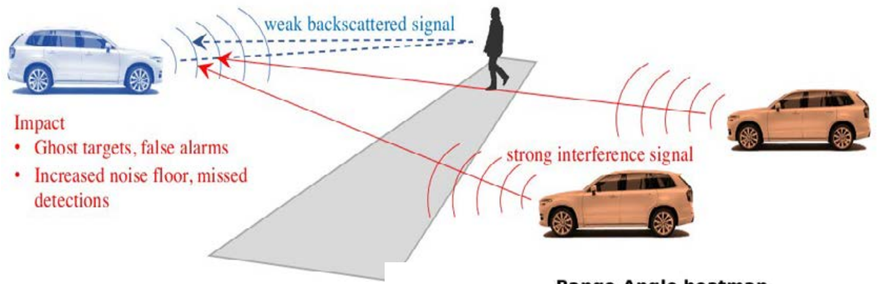
Connected Vehicles: Networked Radar

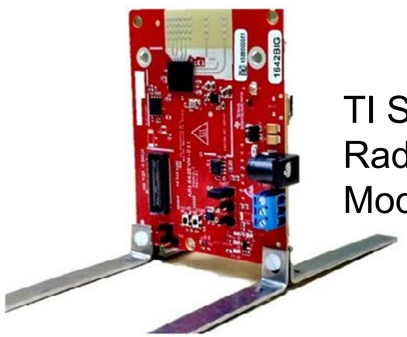
Roy Project #2





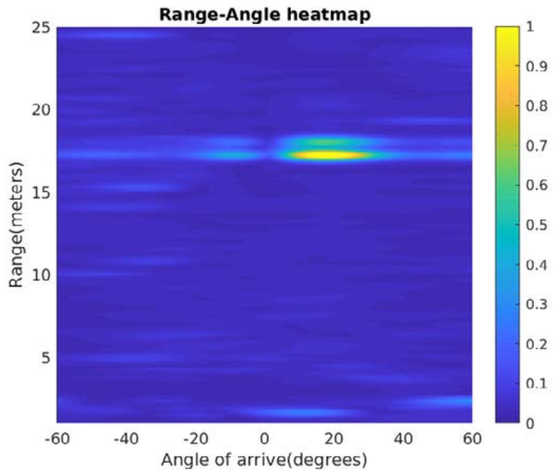
❑ Multi-access Interference





TI Single-Chip Radar Evaluation Module





Publications: X. Gao, G. Xing, S. Roy and H. Liu, ``Overview of Automotive Radar Test-bed at U.Washington,“ Proc. Asilomar Conf., Pacific Grove, CA, Nov. 2019.

Funding: CMMB Vision **Collaborators:** H. Liu, G. Xing and Ph.D. students

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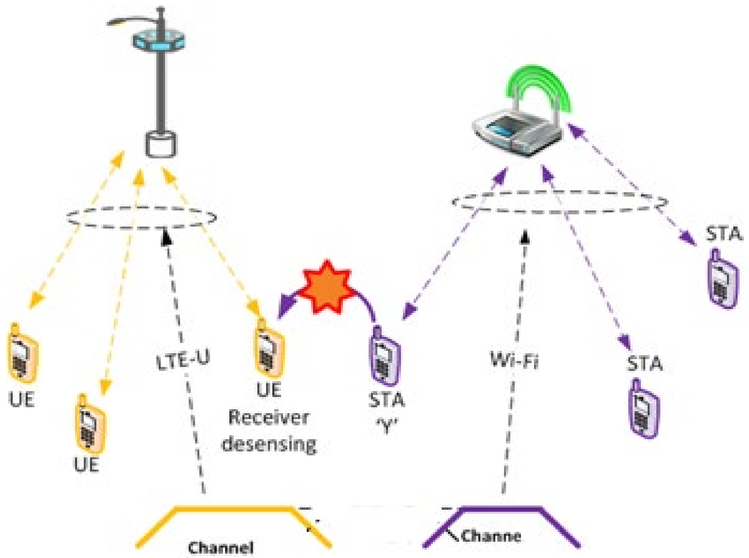
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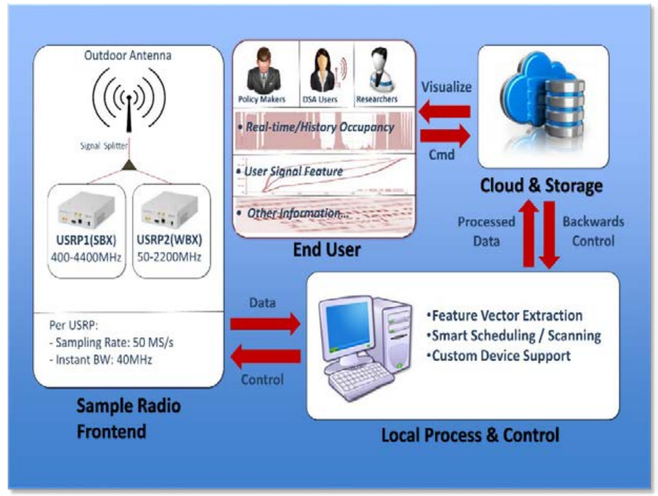
Roy Project #3



Dynamic Spectrum Sharing: Coexistence/Convergence



- ❑ Federal-Civilian Sharing (Primary/Secondary)
- ❑ Civilian-Civilian Sharing (Unlicensed)
  - e.g. LTE-LAA/WiFi in 5 GHz
  - 5G NR-U and WiFi6 in 6 GHz
- ❖ Key Enabler: Spectrum Monitoring & Databases



Publications:

X. Ying, M. Buddhikot and S. Roy, ``SAS-Assisted Coexistence-Aware Dynamic Channel Assignment in CBRS Band," IEEE Trans. Wireless Comm., Sep. 2018.
Y. Gao and S. Roy, ``Achieving Proportional Fairness for LTE-LAA and WiFi Coexistence in Unlicensed Spectrum," IEEE Trans. Wireless Commn., May 2020.

Funding: NSF, Intel, AFOSR

Collaborators: V. Sathya, M. Ghosh, Y. Gao and Ph.D. students

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Sreeram Kannan // Computing & Networking; Data Science

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Research Theme: Information science: Applications to Blockchains, Wireless & AI
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Research Webpage: http://infotheory.ece.uw.edu

Education

- B.E. ECE, College of Enginering Guindy, Anna University 2006.
- M.E. Telecommunications, Indian Institute of Science, 2008.
- M.S. Mathematics, University of Illinois, Urbana-Champaign, 2012
- PhD. in Electrical and Computer Engineering, University of Illinois, Urbana-Champaign, 2012

Notable Publications

- H Kim, Y Jiang, R Rana, S Kannan, S Oh, P Viswanath, “Communication algorithms via deep learning” in Proc. ICLR 2018
- W Gao, S Kannan, S Oh, P Viswanath, Estimating mutual information for discrete-continuous mixtures, in Proc. NeurIPS 2017
- V Bagaria, S Kannan, D Tse, G Fanti, P Viswanath, “Prism: Deconstructing the blockchain to approach physical limits” in Proc. CCS 2019
- Y Mao, S Deb, SB Venkatakrishnan, S Kannan, K Srinivasan, “Perigee: Efficient Peer-to-Peer Network Design for Blockchains” in Proc. PODC 2020.

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Sreeram Kannan // Computing & Networking; Data Science

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Blockchains: A First principles Redesign



Digital Intermediaries run the economy

Google facebook amazon airbnb Uber

Con: High Centralization of data and Power

Blockchains to *Democratize data and power*

	Security	Latency	Energy Efficiency	Throughput
Bitcoin	✓ 50% adv	✗ 3 hours	✗ ~Sweden	✗ 10 Tx/Sec
Prism	✓ 50% adversary	✓ 20 s	✓ No wastage	✓ 70,000 Tx/Sec

- V Bagaria, S Kannan, D Tse, G Fanti, P Viswanath, “Prism: Deconstructing the blockchain to approach physical limits” in Proc. CCS 2019

Layers of Blockchain

	Metrics	Ideas
Application	E.g., Decentralized finance	Game theory and Mechanism design
Sharding	Scale storage and compute	Codes for blockchain Resource allocation
Consensus	Security, throughput, latency, fairness	Protocol design Stochastic analysis
Peer2Peer	Optimize Latency and bandwidth	Network design for broadcast

https://arxiv.org/abs/2006.14186 (PODC 2020)
https://arxiv.org/abs/1910.01247 (FC 2020)
https://arxiv.org/abs/2005.09610
https://arxiv.org/abs/2005.10484

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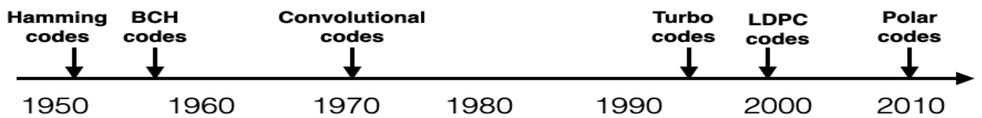
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Wireless algorithms via Artificial Intelligence

Wireless communication algorithms are powered by codes, discovered by deep mathematics and sporadic human ingenuity. Can AI accelerate such discovery?

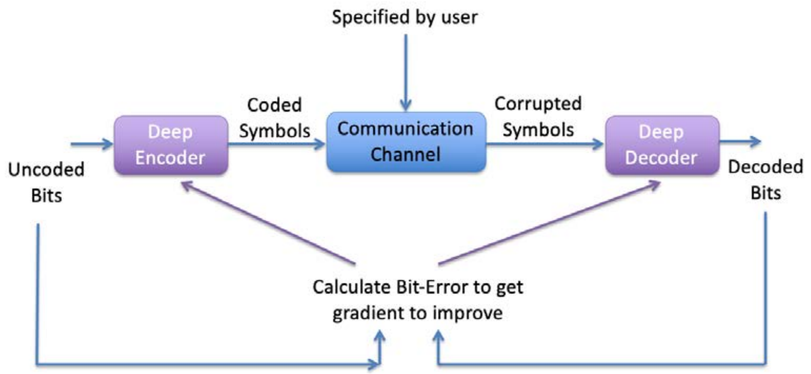
- Eureka moments



Huge impact



Aritifical Intelligence can power the discovery of codes. We have the first family of AI invented codes (DeepCode) that beat state-of-the-art codes (for the feedback channel)



Publications: H Kim, Y Jiang, R Rana, S Kannan, S Oh, P Viswanath, “Communication algorithms via deep learning” in Proc. ICLR 2018
H Kim, Y Jiang, S Kannan, S Oh, P Viswanath, Deepcode: Feedback codes via deep learning, NeurIPS 2018

Funding: National Science Foundation, Intel, Amazon

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Sreeram Kannan // Computing & Networking; Data Science



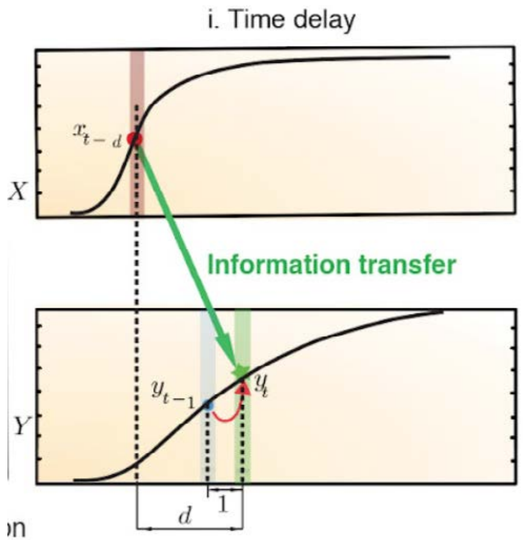
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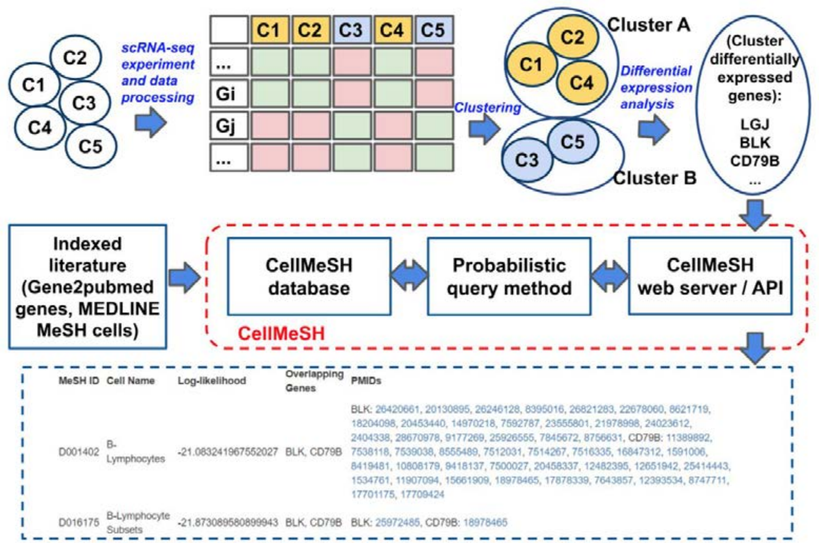
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RNA-Sequencing Data Analytics

Accurate Gene Network Inference via
Time Series Measurements in Single Cell RNA-Seq



NLP of biology papers
helps Cell Type Identification in single-cell Data



Publications: X Qiu, A. Rahimzamani …, C. Trapnell, S. Kannan, Inferring Causal Gene Regulatory Networks from Coupled Single-Cell Expression Dynamics Using Scribe, Cell Systems
S Mao, Y Zhang, G Seelig, S Kannan, CellMeSH: Probabilistic Cell-Type Identification Using Indexed Literature bioRxiv. **Funding:** National Science Foundation, National Institute of Health

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Lillian Ratliff // Robotics & Controls

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Richard Christie // Power & Energy Systems

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Bruce Darling // Photonics & Nano Devices

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Brian Nelson // Data Science

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Katrin Kirchhoff // Data Science

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Yasuo Kuga // Computing & Networking

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James Ritcey // Computing & Networking

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Michael Taylor // Computing & Networking

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Hannaneh Hajishirzi // Data Science

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Payman Arabshahi // Computing & Networking

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Matt Reynolds // Biosystems; Photonics & Nano Devices; Robotics & Controls

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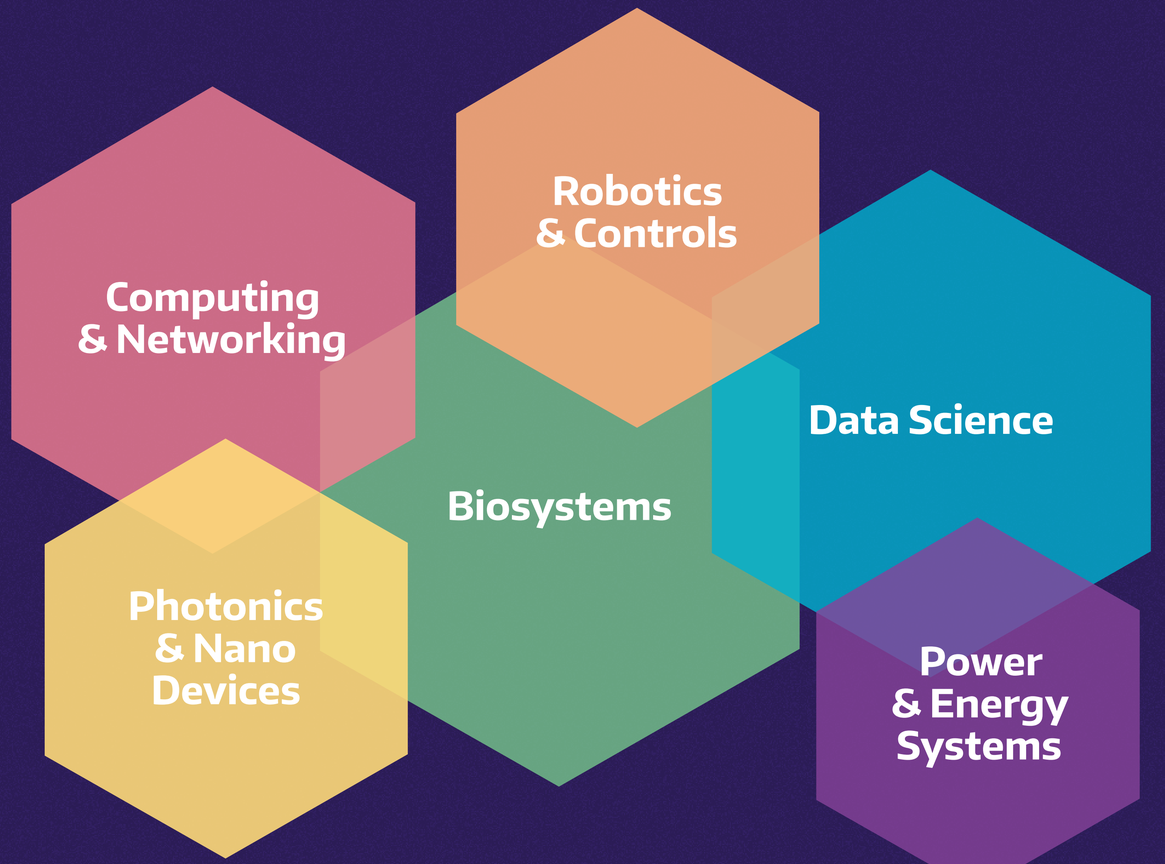
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