Center for Sensorimotor Neural Engineering (CSNE)

an NSF Engineering Research

Participating Laboratories

(additional labs may be added later)

University of Washington Labs (REU, REV, YSP, RET)

Laboratory of Dr. Chet Moritz

Research Mission: The Moritz lab is developing methods for bypassing damage to the brain or spinal cord and restoring conscious control of movement to paralyzed limbs. The team's goal is to record neural signals from intact areas of the brain and to use these signals to control stimulation delivered to paralyzed muscles or the spinal cord below the injury. Previous Research Experience for Undergraduate (REU) students demonstrated that stimulation within the cervical spinal cord is capable of evoking hand and arm movements both before and after injury. This intraspinal stimulation evokes functional and synergistic movements that may be the ideal means to awaken paralyzed limbs.

A Good Match for: Those who are interested in discovering new ways to help restore function for people suffering from paralysis. People interested in the intersection between rehabilitation medicine, physiology, biophysics, neurobiology, and electrical engineering.

UW Department: Rehabilitation Medicine
Website: http://depts.washington.edu/moritlab/

Laboratory of Dr. Steve Perlmutter

Research Mission: The Perlmutter lab studies the neural computations performed by the spinal cord and cerebral cortex to generate skillful movements of the arm and hand. Researchers in the lab also investigate the capacity of damaged motor systems for neural plasticity and adaptation, and are developing neuroprosthetic strategies to improve recovery after central nervous system damage.

A Good Match for: People interested in motor behaviors of the arm and hand, neural recordings of primate behavior, and improving motor function after injury to the nervous system. People who want to learn neurophysiological, anatomical, behavioral, and computational research techniques.

UW Department: Physiology & Biophysics, Neurobiology & Behavior
Websites: http://depts.washington.edu/pbiopage/faculty/sperlmutter
http://depts.washington.edu/behneuro/people/faculty/perlmutter.shtml

Laboratory of Dr. Jeffrey Ojemann

Research Mission: The Ojemann lab is interested in using electrocorticography (ECoG) to answer basic neuroscience questions as well as to develop tools for clinical and rehabilitative applications. ECoG, which is used for long-term clinical monitoring of epilepsy patients, provides a unique opportunity to collect data directly from the surface of the brain in awake, active humans. The group represents researchers from a wide range of backgrounds including neurosurgery, neurology, rehabilitative medicine, engineering, neuroscience, and physics. A major focus of the group is brain-computer interfaces; current projects include learning mechanisms, tactile feedback, and recursive stimulation. Ojemann's team is also investigating more fundamental questions about cortical representation of simple and complex hand movements, the dynamics

of cognition, language, and higher-order nonlinear interactions between brain areas. Other projects include integration of ECoG and fMRI (functional magnetic resonance imaging) and studies of temporal lobe epilepsy

A Good Match for: People interested in neurosurgery, epilepsy surgery, and brain research. People curious about the intersection between cognitive neuroscience, physics, applied math, and computer science.

UW Department: Neurological Surgery
Website: http://neurosurgery.washington.edu/research/labs/ojemann.asp

Laboratory of Dr. Jay Rubinstein

Research Mission: Dr. Rubinstein's lab explores cochlear implant signal processing to develop and improve implantable devices that combat the effects of hearing loss and disequalibrium. The Rubinstein Lab uses novel signal processing strategies to enhance function of current cochlear implant technology, and to understand the processing of auditory information in the brain. In addition, the group is developing novel instruments to evaluate auditory processing in patients.

A Good Match for: People concerned with or interested in the treatment of deafness and other communication disorders. People interested in the intersection of neurophysiology, otolaryngology, audiology, computer science, and neural engineering.

UW Department: Otolaryngology
Website: http://depts.washington.edu/coursejo/ESVN/rubinstein.html

Laboratory of Dr. Kat Steele

Research Mission: The Ability & Innovation Lab is focused on using engineering and design to improve movement for individuals with neurologic injuries such as cerebral palsy and stroke. Our team uses a variety of tools including musculoskeletal simulation (https://opensim. stanford.edu), motion analysis, 3D-printing, and electromyography to determine new ways to improve human movement. Previous students with the CSNE have worked on projects using 3D-printing to improve the design of orthoses for individuals with impaired hand function and using electromyography to develop new systems to track and train muscle activity in daily life.

UW Department: Mechanical Engineering
Website: http://depts.washington.edu/uwsteele/

Laboratory of Dr. Adrian KC Lee

Research Mission: The Lee Lab uses advanced brain imaging techniques such as magnetoencephalograpy (MEG), electroencephalography (EEG) and magnetic resonance imaging (MRI) to investigate high-level cognitive processes like attention and decision-making. The lab seeks to discover unique patterns of brain activity, or neural signatures, that can be used to identify different brain states. The ultimate goal of this research is to combine this information with modern engineering approaches to improve brain-computer interface technologies; this method could enable neuroprosthetic users to dynamically tune their devices using only their minds.

A Good Match for: People interested in speech and hearing sciences and auditory brain sciences. A good match for people curious about how the human brain processes the sounds we hear and how to develop brain-computer interface devices to help people with disabilities better communicate.

UW Department: Speech and Hearing Sciences
Website: http://depts.washington.edu/labsn/

Laboratory of Dr. Fred Rieke

Research Mission: The research in the Rieke lab focuses on sensory signal processing, particularly in cases where sensory systems perform at or near the limits imposed by physics. The central goal of the work in the Rieke lab is to relate biophysical mechanisms operating in the retina to defined roles in computation and ultimately behavior. The experimental basis for this work comes from several physiological preparations that allow researchers to track responses generated by the rod and cone photoreceptors across the retinal circuitry, and recently also from human behavioral work.

A Good Match for: People who want to research vision and visual processing. People interested in studying physiology and biophysics.

UW Department: Physiology and Biophysics
Website: http://rieke-server.physiol.washington.edu/index.html

Laboratory of Dr. Adrienne Fairhall

Research Mission: The Fairhall group develops theoretical approaches to understand processing in nervous systems. The lab collaborates closely with experimental labs investigating a range of different systems, from single neurons to behaving animals. Their work aims to uncover neural algorithms of information processing. They are particularly interested in the way in which neural coding and representation is affected or shaped by the complex statistics of the natural world.

A Good Match for: People who want to apply a love for mathematics and data analysis to uncovering algorithms of information processing in a range of systems.

UW Department: Biophysiology & Biophysics
Website: http://fairhalllab.com/

Laboratory of Dr. William Moody

Research Mission: Research in the Moody lab concerns the roles of spontaneous electrical activity in the development of the nervous system. Ongoing experiments ask how such activity is controlled and what roles it plays in nervous system development. Patch clamp and calcium imaging methods on living slices of developing mouse brain are some of the techniques being sued to study these questions. The laboratory is small, with people at all levels (faculty from other universities on sabbatical visits, technicians, postdoctoral fellows, graduate students, and undergraduates; not all necessarily at the same time) working closely together.

A Good Match for: People who want to learn about electrical activity in the brain and how the brain develops. People interested in neurobiology and behavior.

UW Department: Biology
Website: http://faculty.washington.edu/profbill/

Laboratory of Dr. Thomas Daniel

Research Mission: The Daniel lab is interested in sensorimotor control of animal locomotion. Projects in the lab include the study of flight control, implantable microelectronics to control behavior, and the dynamics of muscle contraction. The goals of these projects are to learn about neuronal dynamics and networks, synaptic interactions between neurons, and how neuronal signaling, behavior, and environmental stimuli are linked.

A Good Match for: People who want to work with insects, are fascinated by flight, or interested in building mathematical models and algorithms. People interested in the intersection between neurobiology, neural engineering, bioengineering, mechanical engineering, electrical engineering, and mathematics.

UW Department: Biology
Website: http://faculty.washington.edu/danielt/

Laboratory of Dr. Rajesh Rao

Research Mission: The Rao lab studies the computational principles underlying the brain's remarkable ability to learn, process, and store information. Using a combination of probabilistic techniques, computer simulations, and collaborative neurobiological experiments, researchers are investigating how the brain learns efficient representations of objects and events occurring in the natural environment, the algorithms that allow useful sensorimotor behaviors to be learned, and how the knowledge gained through computational studies of the brain may be used in biomedical applications such as brain-computer interfaces.

A Good Match for: People fascinated by brain-computer interfaces. People interested in the intersection between computer science, mathematics, and neural engineering.

UW Department: Computer Science & Engineering
Website: http://homes.cs.washington.edu/~rao/

Laboratory of Dr. Howard Chizeck

Research Mission: The University of Washington's BioRobotics Lab is home to a number of students and faculty dedicated to improving the lives of people through cyberphysical systems. The lab's mission is to develop science, technology, and human resources at the interface between robotics, control theory and the biological sciences. Their goal is to produce useful, innovative research and technology as well as trained researchers capable of driving technological advancement in medical and biological systems. The lab has ongoing projects investigating privacy and security in brain-computer interfaces, brain-computer interface optimization, closed-loop deep brain stimulation, and lower-limb targeted muscle reinnervation.

A Good Match for: People interested in the intersection between electrical engineering, robotics, and electromechanical design.

UW Department: Electrical Engineering

Website: https://brl.ee.washington.edu/

Laboratory of Dr. Jacque (Chris) Rudell

Research Mission: The Rudell lab studies a broad range of topics related to analog, mixed-signal, RF, and mm-wave circuits. The emphasis of the work is on novel architectures and circuits which overcome the challenges presented by future low cost, advanced silicon technologies, such as ultra-low voltage, low-intrinsic device gain, and poor matching characteristics. Typical projects in the lab focus on applications which are challenging to integrating as a single-chip. Some examples include devices for high-speed communication, imaging, and biological interfaces including neural stimulation. Students in our lab will focus both on system-level design issues as well as nuts and bolts implementation of an integrated circuit.

A Good Match for: People who want to design hardware for neural engineering applications, such as tiny implantable chips that stimulate neurons. People interested in electrical engineering.

UW Department: Electrical Engineering
Website: http://www.ee.washington.edu/research/fast/FAST.html

Laboratory of Dr. Joshua Smith

Research Mission: The Smith lab aims to improve the connection of information systems to the physical world. Researchers in the lab work to invent new sensor systems, devise innovative ways to power and communicate with them, and develop algorithms for using them. This research has applications for implanted devices, including those used for recording from and stimulating the nervous system.

A Good Match for: People curious about new sensor system technologies and their use in robotics and medical devices. People interested in the intersection of bioelectronics, robotics, ubiquitous computing, electrical engineering, and neural engineering.

UW Department: Electrical Engineering; Computer Science & Engineering
Websites: http://sensor.cs.washington.edu/jrs.html
http://sensor.cs.washington.edu/index.html

Laboratory of Dr. Andrea Stocco

Research Mission: Dr. Stocco's research concerns how human use abstract mental representations (like, rules, instructions, and plans) to perform complex tasks. He uses computational and mathematical models, neuroimaging techniques, and brain stimulation methods determine and predict how these mental representations are encoded in the brain, how they are transformed into behavior, and how this knowledge can be used to improve learning and skill acquisition.

UW Department: Psychology
Website: http://ilabs.washington.edu/institute-faculty/bio/i-labs-andrea-stocco-phd

Laboratory of Dr. Visvesh Sathe

Research Mission: The VLSI systems lab led by Professor Sathe explores circuits and architectures for energy efficient digital and mixed-signal processing. The lab is focused on advancing the state-of-the-art in the area of

neural signal recording, and power/energy-constrained neural signal processing by enabling hundreds of neural signal recording channels with extremely low power. Other areas of active research include clocking, supply voltage regulation, machine-learning, low-power cryptography, and ultra-low-power VLSI design.

A Good Match For: Students interested in circuits, computer architecture and hardware design in general. An interest in signal-processing and/or programming is a plus.

UW Department: Electrical Engineering
Website: http://vlsi.ee.washington.edu/

Laboratory of Dr. David Gire

Research Mission: Our brains utilize noisy, fluctuating sensory signals from the surrounding environment to guide valuable behaviors such as finding food or avoiding danger. Precise coding of relevant information in spatial and temporal patterns of neural activity is a key element of this function, with efficient coding adapted to both the statistical structure of sensory input as well as the changing behavioral demands of a given situation. This coding is achieved through complex circuits of synaptic interactions between populations of neurons and occurs as an animal explores and actively samples its environment. A mechanistic understanding of neural coding during active sensing and behavior is an important step towards the development of targeted therapeutics for psychiatric and neurodegenerative disorders. We seek to define the neural circuit operations that support complex and flexible behavioral responses to natural sensory stimuli. We study the olfactory system of rodents as a model for sensory information processing and connect neural activity to behavior by employing a variety of techniques including electrophysiology, multiphoton imaging, optogenetics, and automated behavioral analysis.

A Good Match For: Students interested in circuits, computer architecture and hardware design in general. An interest in signal-processing and/or programming is a plus.

UW Department: Psychology
Website: http://www.psych.uw.edu/psych.php?p=358&type=1&PersonID=11750

Laboratory of Sara Goering

Research Mission: The neuroethics group (Goering "lab") studies ethical issues arising from emerging neural engineering technologies. Issues include questions of privacy, security, moral and legal responsibility, changes in our understanding of agency, shifts in personal identity, and social justice. We have a commitment to the inclusion of disability perspectives in the design of devices intended to benefit people with disabilities. Our group does both normative theoretical research and writing, and empirical studies such as focus groups with intended end-users.

A good match for: Students interested in neural engineering and particularly drawn to the ethical and policy implications of new technologies. Interest in philosophy, disability studies, and social justice. Engineering, neuroscience, social science and humanities majors welcome.

UW Department: Philosophy
Websites: https://www.phil.washington.edu/users/goering-sara

Massachusetts Institute of Technology Labs (REU only)

POLINA ANIKEEVA: optoelectronic neuroprosthetics, flexible neural probes, minimally invasive neural stimulation

ED BOYDEN: tools for mapping, controlling and building brain circuits

EMERY BROWN: design of algorithms for neural signal processing and studies of mechanisms of general anesthesia

KWANGHUN CHUNG: brain imaging and molecular/genomic profiling, connectomics, drug screening platforms

JIM DICARLO: mechanisms of object recognition, tools for measuring and interacting with brain activity

MICHALE FEE: novel technologies for recording and manipulating neural circuits in behaving animals

POLINA GOLLAND: medical image analysis, functional brain imaging, functional organization of the brain

ANN GRAYBIEL: behavioral, electrophysiological, optogenetic and molecular biological studies of cortico-basal ganglia circuits

JAY HAN: functional electrical stimulation, neural prosthetics

ALAN JASANOFF: brain activity imaging, molecular probes, fMRI, magnetic Neurotechnology

MEHRDAD JAZAYERI: optogenetics, cognitive control, neural circuit dynamics

ROGER KAMM: microfluidics, stem cells, optogenetics, neuromuscular junctions

JEFFREY LANG: flexible sensory skins for delivery sensory stimuli

STEPHEN LIPPARD: mobile zinc and nitric oxide signaling in biology as revealed by fluorescent MRI sensors, maps of sensory perception

TOMASO POGGIO: artificial intelligence, intelligence, machine learning

PETER SO: intravital neural imaging, super-resolution imaging, memory plasticity, connectomics

RUSS TEDRAKE: robotics, state estimation in the face of uncertainty

JOEL VOLDMAN: in vitro neural networks, penetrating recording probes, flexible probes for recording and stimulation

RON WEISS: synthetic biology, stem cell differentiation, synthetic neurobiology

MATTHEW WILSON: multiple electrode recording, behavioral neurophysiology, neural decoding

FENG ZHANG: epigenetics, genome engineering, circuit modulation, neuropsychiatric disorders

San Diego State University Labs (REU only)

SAN DIEGO STATE UNIVERSITY

Laboratory of Dr. Sam Kassegne

Research Mission: The Kassegne NeuroMEMS Lab is developing a new class of mechanically compliant and tunable neural probes for brain signal recording and stimulation. The Lab's core contribution in this area is in developing a new class of sensing and stimulating electrodes based on patternable carbon. While carbon has been considered as the gold-standard in electrochemistry, its use as *in-vivo* use has not been investigated well yet, due to challenge of patterning it as part of micro-devices and supporting it on a flexible substrate. Our research group has developed fabricating techniques for addressing this challenge. We now have such electrodes implanted in animal models (rats) at our collaborator's Lab at University of Washington. Our group is interested in achieving orders of magnitude tunability in the mechanical, electrical, and electrochemical properties of these electrodes.

A Good Match for: Those interested in microfabrication of neural probes and integrating them with measuring and stimulating electronics. Also for people interested in the intersection of device manufacturing, characterization, bioengineering, and neuroscience.

SDSU Department: Mechanical Engineering
Web-site: http://www.digitaladdis.com/sk/

Laboratory of Dr. Yusuf Ozturk

Research Mission: The Ozturk Lab is developing brain computer interfaces for recording from and stimulation of the brain. The Lab's core contribution in this area is development of a small form factor implantable wireless bi-directional BCI circuit and associated software. We have developed a family of wireless wearable and implantable devices for recording physiological and kinematic information from subjects and issue neural stimulation under algorithm control. Our research group developed neural recording, processing and stimulation circuits that can record 32 channels of neural signals and induce up to 4 channels of stimulation. We are currently working on a spinal cord stimulator that will wirelessly be paired to Neurochip 3 to provide stimulation to the spinal cord based on interpretation of the neural signals acquired by neurochip 3 via intracortical electrodes. Our group is interested in online spike detection, spike sorting, spatiotemporal analysis of neural signals, stimulation and recording electronic and embedded real time software.

A Good Match for: Those interested in embedded software, wireless body areas networks, recording physiological signals, stimulation electronics, system on chips, spike detection and spike sorting.

SDSU Department: Electrical Engineering
Web-site: http://ozturk.sdsu.edu/