List of Potential REU Projects for Summer 2020

Electrical and Computer Engineering Dept., Montana State University

Acoustical monitoring of parks, wilderness, and other natural areas in Montana

Mentor: Prof. Rob Maher (1–2 students)

According to current U.S. National Park Service (NPS) management policies, the natural soundscape of parks and historic sites is a protected resource just like the physical ecosystems, landscapes, and historic artifacts for which the parks were formed. While several NPS sites have been studied extensively for noise intrusions by tour aircraft and mechanized recreation, most parks and historic sites do not yet have an acoustic baseline for management purposes. Moreover, very little is known in a scientific sense about the diurnal and seasonal variations in natural sound, nor about the long-term trends in the natural soundscape. Understanding ecosystems and the role of human activity in the natural world benefits from observing natural acoustics of animal communication, environmental sound from wind, rain, and flowing water, and anthropogenic sound sources. Ongoing research at Montana State University involves long-term acoustical monitoring research at remote locations. Students participating in this research will gain a theoretical and practical understanding of environmental acoustics (the propagation, reflection, absorption, and attenuation of sound in the atmosphere), experience designing and conducting field research, scientific interpretation and documentation of acoustical recordings, and the development of new means for automated acoustical processing and analysis.

Drone-based river imaging

Mentor: Prof. Joe Shaw (1–2 students)

In this project, one to two students will work with graduate students and faculty to fly drones carrying hyperspectral, thermal, and RGB imagers in field experiments to study river ecology. The students will assist with field experiments and with calibrating and processing the images using Matlab and Python programming languages. The students also will perform optical calibration measurements in the lab. Students on this project should be interested in optics and imaging.

Volcanoes on Venus: Machine learning using radar images

Mentor: Prof. Brad Whitaker (1–2 students)

Modern spacecraft detect and record amazing information that is analyzed by scientists on Earth. These measurements have deepened our understanding of the universe and allow us to monitor terrestrial and extraterrestrial events. However, measurement devices deployed in space currently make many more measurements than they are able to send back to Earth. This communication bottleneck implies that only a subset of the data can be analyzed on the ground. The purpose of this project is to improve machine learning feature extraction and classification algorithms in order to more effectively determine what information should be transmitted to Earth. Specifically, we will analyze a set of radar images of the surface of the planet Venus with the goal of automatically detecting the presence of volcanoes in an image using sparse coding, support vector machines, and neural networks. Techniques developed during this project can be extended to other measurement devices in order to improve the quality of information that gets sent back to Earth.

Prototyping a LED-based stimulation device for closed-loop light excitation on microelectrode arrays
Mentor: Prof. Anja Kunze (1–2 students)

Stimulating neuronal cell activity through light has emerged as a versatile method to study cell communication and to overcome neuronal decline. To optically modulate a group of cells and to record their responding electrophysiological properties, simultaneously, this project aims to design and fabricate a light-based stimulation system using LEDs on top of a commercially available 64 microelectrode probe. The goal of the project is to demonstrate a system that allows for artifact-free electrical recording, and to build a closed-loop stimulation protocol which modulates optical stimulation parameters, e.g. intensity or frequency, responding to electrophysiological activity. The REU student will be exposed to the current challenges of light-based modulation techniques in neuroengineering, and will be integrated into a highly interdisciplinary, friendly and interactive bioengineering lab. Furthermore, if time permits the REU student can collaborate with on-campus researchers to test the closed-loop light excitation system with opsin-transduced cells. What the students should bring is a basic background in software programming and a high-level of independence to build a basic optical stimulation system.

Grid synchronization and resiliency analysis for inverter-based power grid
Mentor: Prof. Maryam Bahramipanah (1 student)

In this project, the REU student will work with graduate students in the power group to design a model to predict low-frequency unstable oscillations in a power system with high prevalence of renewable energy resources. This will help us to improve grid resiliency and mitigate oscillations and outages. With high integration of renewable resources and power electronic inverters, power grid synchronization becomes more challenging. The grid-synchronization problems and the potential resiliency issues between multi-paralleled power electronic inverters have not yet been well targeted. The REU student will have the opportunity to learn small-signal modeling methodologies to predict the low-frequency behaviors of the grid-synchronization loops in multi-paralleled inverter-based grids. The purpose of this project is to design a model that can predict the low-frequency unstable oscillations in grids with extensive renewable-energy resources. Moreover, the REU student will gain a good understanding of the resiliency of the power grid and different modern synchronization techniques. Prior knowledge of modeling power systems in Matlab/Simulink is essential; and a good knowledge in control systems and stability analysis would be very useful in this project.

Nanofabrication of optical devices
Mentor: Prof. Wataru Nakagawa (1-2 students)

Micro- and nano-fabrication technologies based on silicon have enabled a vast range of technological advances, including microprocessors, integrated systems, and optoelectronics. The Nano Optics group uses these manufacturing technologies to produce functional optical devices based on nanostructures in silicon and related materials, optimized for applications in polarimetry and optical imaging. The participating student will be given an introduction to these fabrication technologies and hands-on training in working in a clean room facility. Working with group members, the REU student will be assigned a sequence of steps in the fabrication process chain to understand and optimize, and to assist in fabricating functional optical devices in our facility.

Optical metamaterial characterization
Mentor: Prof. Wataru Nakagawa (1-2 students)

The Nano Optics group is developing and testing composite optical materials (metamaterials) with engineered polarization properties for sensing and other applications. The optical properties including polarization characteristics of these devices must be thoroughly measured and analyzed in order to understand their performance and give feedback to the design and manufacturing processes. This involves using an optical characterization system to measure the spectral and polarization properties of the metamaterials under test, including laboratory automation and signal processing/analysis tools. The REU student will be trained on the operation of this system, assist in its calibration and testing, perform measurements on fabricated metamaterial devices, and potentially assist in making improvements to the system.

Active optical devices and systems
Mentor: Prof. David Dickensheets (1-2 students)

Prof. Dickensheets' group is developing active optical devices for advanced imaging applications. One example is tunable reflective lenses (variable curvature mirrors) with fast and precise control over focal power and spherical aberration. These mirrors are useful for laser scanning systems such as confocal or two-photon microscopes, and also for fast-response zoom lenses for small format cameras. In addition to device engineering, Dickensheets' group is building complete optical instruments such as a miniaturized microscope for skin cancer detection, and a full-sized two-photon fluorescence microscope with advanced active and adaptive optics to facilitate research in developmental biology. These instrument development efforts are inherently interdisciplinary, and REU students engaged on these projects will work side by side with graduate and undergraduate students pursuing degrees in engineering, cell biology, neuroscience and physics. Depending on student interest, the REU student will be afforded the opportunity to learn microfabrication processing techniques in the Montana Nanotechnology Facility, optical characterization and metrology techniques applicable to micro-mirrors and active optical systems, or optical system control, modeling and software development. Importantly the student will learn tangible research skills while simultaneously learning about the cross-disciplinary applications and challenges these projects address.

Light and nanotechnology
Mentors: Prof. David Dickensheets, Prof. Recep Avci, Mr. Chris Arrasmith (1-2 students)

Several projects are available for students interested in learning about applications of nano/microfabrication to optical systems, and vice versa. We are developing light-based metrology tools to measure film stress, and new coating methods to make high-reflectivity optical mirrors, especially on flexible substrates. Other projects will advance our capabilities for assembly and packaging of optical MEMS devices so that they can be deployed in instruments outside the cleanroom laboratory. Finally, MSU is home to some of the most advanced thin films characterization and imaging instruments available today, and opportunities exist to learn advanced SEM and Auger spectroscopy techniques. Students interested in these applications will receive training to work in the Montana Nanotechnology Facility (MNF), which is part of a national network of such facilities called the National Nanotechnology Coordinated Infrastructure (NNCI). With additional support from NSF through NNCI, our Nanotechnology students will have the opportunity to visit one of the other NNCI sites and interact with REU students from around the nation doing research related to nanotechnology.