List of Potential REU Projects for Summer 2021

Electrical and Computer Engineering Dept., Montana State University

Long-term Acoustical Observation of Soundscapes for Natural History and Forensic Interpretation

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

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. Similarly, understanding the circumstances at the scene of a crime, accident, or civil incident can benefit from forensic details obtained by acoustical recordings. Ongoing research at Montana State University involves long-term acoustical monitoring research at remote locations, as well as signal processing techniques to understand the acoustics of both urban and wilderness scenes. 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, a student will help fly drones carrying hyperspectral and RGB imagers in field experiments to monitor for harmful algal blooms in rivers. The student will assist with regular field experiments by setting out calibration tarps and helping with drone flights, then will help calibrate, process, and georeference imagery from those flights. Analysis will be done using primarily Matlab and Python programming languages. The student also will conduct experiments to characterize the reflectance spectrum of different kinds of algae collected from the river or grown in the lab by river ecology colleagues. For this project, interest and experience in photography, imaging, and optical systems will be helpful.

Improving Touchless Respiratory Monitoring using Machine Learning

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

The Whitaker Lab is developing a touchless respiratory monitoring system to measure respiratory signals in subjects in a noninvasive manner. The end goal of the research is to be able to use this system to autonomously identify symptoms of respiratory disease (apnea, COVID, etc.) while improving the comfort of subjects in a clinical setting. Our current results indicate a high correlation between our novel touchless sensors (LiDAR and thermal measurements) and traditional contact sensors (spirometry, capnometry, respiratory inductance plethysmography) when measuring breathing rates and volumes. In this REU project, we will use machine learning tools to improve respiratory monitor measurements by automatically identifying irregular body positions that should be ignored. Considering various body positions will remove spurious when calculating respiratory information such as breathing rate and breath volumes.

Modeling the Spread of COVID using Convolutional Neural Networks
Mentor: Prof. Brad Whitaker (1–2 students)

In late 2019 SARS-CoV-2 (COVID-19) was exposed to the public. Since the preliminary Chinese outbreak, the virus has spread to the level of a worldwide pandemic. Attempts to contain the virus and mitigate its effects have been hampered by its easy transmissibility. Therefore, it has become necessary for government policymakers as well as healthcare organization policymakers to know where COVID-19 will spread to next so they can prepare for hospitalizations and try to avoid outbreaks. In this project, we will develop a model using Convolutional Neural Networks (CNNs) to track and forecast the regional spread of COVID-19. We also plan to implement a binary 'pre-classifier' to account for skewed data in rural areas where daily case counts are often near zero and infection rates are lower. This model will be used to predict hospitalizations as well as future outbreaks on a county-by-county basis for Montana, Wyoming, South Dakota, North Dakota, and Idaho.

Prototyping a point-of-care system for extracellular vesicle detection using magnetics
Mentor: Prof. Anja Kunze (1–2 students)

The use of extracellular vesicle (EV) detection strategies for highly sensitive point-of-care systems and liquid biopsy has shown great potential to gain further insights into human disease diagnostics. One major challenge of EV-based diagnostics is the small scale of the carrier, limiting light-based detection and analysis methods. This limitation further results in low sample throughput and low specificity regarding cell-specific detection of disease markers. One way to overcome these challenges is to combine EV extraction methods with magnetic trapping systems such as magnetic micropores, magnetic gradient devices, or localized magnetic traps. This project aims to develop a rapid in situ on-chip EV size profiling assay using the concept of magnetic traps. Depending on the REU student's background and interest, this project can be developed in two directions. It either can focus on a prototype design using CAD software with finite-element simulations (FEM, COMSOL Multiphysics). Alternatively, it can also be more hands-on, using cleanroom-based fabrication of magnetic trapping features that can be utilized as a proof of concept. Throughout the project, the REU student will be exposed to cutting-edge methods for extracellular vesicle-based detection methods, which are used to detect neurodegenerative disease markers. If a successful prototype emerges from the student work, the chip can be used to detect, sort, and analyze EVs carrying hallmarks of Alzheimer's and other neurodegenerative diseases. Furthermore, the student will be embedded in a vibrant lab dynamic in the Kunze Neuroengineering Lab, consisting of several graduate and undergraduate students. Strong communication skills, weekly participation in lab meetings, as well as team-working attitudes, are expected. At the end of the REU project, the student will have gone through the design approach for point-of-care systems using micro- and nanotechnology in the sector of neurodegenerative diseases.

Encapsulation of Optical Devices through Glass Frit Bonding
Mentors: Dr. Andrew Oliver, Prof. David Dickensheets (1–2 students)

Microelectromechanical systems, or MEMS, is the technology of building sophisticated mechanical structures at micro-scale - so called "micromachines." MEMS micromirrors for laser beam scanning have emerged as enabling components for medical endoscopes, virtual reality headsets and LIDAR (LIght Detection And Ranging) cameras for smart and autonomous cars. Researchers at MSU are designing and building new types of micromirrors and optical sensors for many applications, including long-range LIDAR.

This is an exciting opportunity for a hands-on undergraduate student to help develop this next generation of optical sensors and devices. Specifically, we are looking for an undergraduate student to help develop a packaging and encapsulation process for optical devices. Currently, our microfabricated optical MEMS need a sealing technology for environmental protection that keeps out dust and dirt. Many of our devices also need to be sealed in vacuum so that air will not slow down the movement of tiny micromachined mirrors. Glass frit can achieve these goals and is screen printed onto substrates and then dried and solidified the glass at temperatures above 300 C (572 Fahrenheit). The student will then bond the glass frit coated wafer to silicon or glass wafers at forces greater than 500 Newtons (112 lbf). The glass frit will only be visible in a microscope since it will be only eight thousandths of an inch wide and one thousandth of an inch thick. Students will be exposed to the high-tech semiconductor, electronics, and sensor industry. They will learn about laboratory techniques, microscopy and metrology tools, vacuum technology, integrated circuit and sensor fabrication technology, learn clean room protocols, process development and control techniques and even beginning statistics.

Nanofabrication of Optical Devices
Mentor: Prof. Wataru Nakagawa, Prof. David Dickensheets (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, optical imaging, and LIDAR. 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 cleanroom 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.

Backscatter Lidar for Atmospheric Studies
Project Mentor: Prof. Kevin Repasky (1 student)

Light Detection and Ranging (Lidar) is a remote sensing technique used to understand the state of the atmosphere. Backscatter lidar provides a tool for understanding the aerosol distribution in the lower troposphere that are important drivers of many weather and climate phenomena as well as an important factor in many public health issues. During this project, the student will work on developing a compact eye-safe micro-pulse backscatter lidar. Furthermore, the student will work on analyzing backscatter lidar data to better understand the spatial and temporal distribution of atmospheric aerosols. The student will gain experience with optical systems and lidar instruments. The student will also gain experience with processing and interpreting lidar data.