*Undergraduate Research Fellowship*

**Research Project Description List**

Fall 2024

**PLEASE NOTE: Many of the below projects are interdisciplinary and are seeking undergraduates from outside of the faculty’s department. Be sure to check the “desired academic majors” for each project to determine your eligibility. This list will be updated weekly with new projects, so check back frequently.**

**Project #1**

**Department:** Mechanical Engineering

**Faculty:** Tiwei Wei

**Faculty Website:** <https://s-pack.org/?_ga=2.179754467.633491757.1707929290-1025564542.1707929290>

**Project description:** Project objective is to develop a method/approach that can reliably and accurately 3D print small capillary structures using stereolithography technology. Mentee's role will be iteratively experimenting with different print settings, resin materials, and CAD design to find the best way to print small capillaries, while also formulating a theoretical explanation as to why that setting or method works. This project is impactful in that the design of many jet impingement coolers contains small capillary structures, which often fail to print during rapid prototyping. If a method can be developed that can reliably fabricate these structures, it would make the design and fabrication of new coolers easier and faster.

**Desired Academic Majors:** Mechanical Engineering or Mechanical Engineering Technology

**# of hours/week: ~**8 to 9 hours (3 credits of independent research)

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**Project #2**

**Department:** Mechanical Engineering

**Faculty:** Eckhard Groll

**Faculty Website:** <https://engineering.purdue.edu/ME/People/ptProfile?resource_id=11748>

**Project Description:**

The research project aims on designing a high temperature heat pump (HTHP) that can provide a temperature of up to 200 C. Since this temperature level is not covered yet, the project provides a variety of cutting-edge research opportunities:

- A fluid or fluid mixture needs to be defined to operate in that temperature level

- A system architecture needs to be developed and optimized for maximum efficiency

- A completely new compressor type will be developed and tested

The mentee can help out during the testing process and with the test stand design (CAD drawing, etc.) but also with less sophisticated coding and modeling activities. It provides the mentee a great opportunity to get some insight into thermodynamic research and at the same time get guidance during the learning process. The impact of this research has the potential to be monumental. The U.S. government aims for a carbon neutral industry by latest 2050. HTHP's are essential in this move to replace fossil fuel driven furnaces in heat and energy efficient processes such as e. g. pulp and paper industry. Our research can help to make this giant leap and to safe the United States world-leading role in industry while securing jobs and preventing from more severe impacts of global warming.

**Desired Academic Majors:** Mechanical Engineering, Civil Engineering, Mechanical Engineering Technology, Environmental Engineering

**Preferred skills:** Python coding skills are very helpful but are not a critical criteria.

**# of hours/week: ~** 6 hours (2 credits of independent research or more if interested)

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**Project #3**

**Department:** Mechanical Engineering

**Faculty:** Pavlos Vlachos

**Faculty Website:** <https://vlachosresearch.org/?_ga=2.252434828.403533464.1708355263-1025564542.1707929290>

**Project Description:** Cardiovascular diseases are one of the leading causes of death globally, accounting for a significant proportion of mortality worldwide. The goal of the project is to analyze cardiac flow for determining cardiac function. The mentee will help in analyzing the flow and perform statistical analysis. Our analysis would help us better understand the hemodynamics of the circulatory system.

**Desired Academic Majors:** Mechanical Engineering, Biomedical Engineering

**# of hours/week:** **~** 6 hours (2 credits of independent research or more if interested)

**Preferred skills:** If a student has some basic knowledge of MATLAB or Python, it would be advantageous but it's not a strict requirement. Students who lack a basic knowledge in them can learn during the semester as needed.

**Project #4**

**Department:** Mechanical Engineering

**Faculty:** Pavlos Vlachos

**Faculty Website:** <https://vlachosresearch.org/?_ga=2.252434828.403533464.1708355263-1025564542.1707929290>

**Project Description:**

*Snake Tongue Flicking: A Fluid Mechanics Perspective*

The research project focuses on examining snake tongue flicking behavior through a transport mechanics lens. This involves utilizing a setup in a water tank to approximate the snake tongue's geometry to two cylinders. The fluid mechanics surrounding the tongue's oscillations are studied using Particle Image Velocimetry (PIV), with actuation achieved via a stepper motor.

The mentee’s role will entail enhancing the setup's actuation system. This includes refining the Arduino code, exploring alternative actuation methods, and researching materials for the tongue, such as soft materials. Additionally, you will conduct experiments and analyze results to determine velocity fields and advanced hydrodynamics measurements, thereby quantifying the flow characteristics.

'Why do snakes flick their tongues?' has only been explored through a chemosensory behavior perspective. Investigating the physics not only opens up a new insight into an old question (we know they do it to smell, but how do the molecules move around the tongue?). This work has the potential to develop new techniques in the field of bio-inspired sensing (remember SONAR?). Exploring such a question can have a broad reach on the scientific community, being one that is easily asked, but not entirely explained.

**Desired Academic Majors:** Open to all majors in the College of Science and College of Engineering.

**# of hours/week:** ~ 6 hours/week (2 credits of independent research or more if interested)

**Preferred skills:** Basic knowledge of Python and/or MATLAB.

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**Project #5**

**Department:** Mechanical Engineering

**Faculty:** Pavlos Vlachos

**Faculty Website:** <https://vlachosresearch.org/?_ga=2.252434828.403533464.1708355263-1025564542.1707929290>

**Project Description:**

*Phonation Signal and Image Processing for Detecting and Classifying Dysphonia*

We are examining simultaneous high speed videoendoscopy images of vocal fold vibration and audio, of subjects suffering from some vocal fold pathology (this can vary depending on the dataset we have in the future, currently we have one of a patient with tremor - involuntary movements of muscle groups). The aim is to extract features from audio and video signals which can distinguish healthy vocal fold vibrations (and thus healthy audio) from pathological. We want to develop methods to pick up subtle irregularities in vibrations and audio signals which could be missed by trained professionals. The variability of audio data and the shortcomings of HSV (grayscale images, no live feed, rigid endoscope) have prevented them from becoming clinical standard for diagnoses. There is potential for developing novel processing algorithms, software, and classification methods using machine learning further down the line.

The mentee’s role for this project will be to research signal processing techniques like Hilbert transform, wavelets, etc., and assist in extracting fundamental properties of noisy signals. Decomposition methods used extensively in data science for physics (such as POD) may also be explored. This project will involve extensive programming (MATLAB or python may be used).

Research in medical imaging and data analysis directly contributes to improving the human condition. Our voice is our identity, and is therefore priceless (well, some have placed a monetary value on it, like singers who insure their voices to the tune of millions of dollars). Despite years of research in the areas we mentioned, these methods are not clinical standards. The consequent numerous uncomfortable laryngeal examinations (endoscope in your mouth ?!), and perhaps even missed diagnoses are impactful when one could risk losing regular vocal function. Using mathematics and engineering to pick out subtle indications of voice pathologies, this work can revolutionize the way vocal examinations are conducted in the near future.

**Desired Academic Majors:** Open to all majors in the College of Science and College of Engineering.

**# of hours/week:** ~ 6 hours/week (2 credits of independent research or more if interested)

**Preferred skills:** Basic knowledge of Python and/or MATLAB.

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**Project #6**

**Department:** Biomedical Engineering

**Faculty:** Leopold N. Green

**Faculty Website:** <https://engineering.purdue.edu/BME/People/ptProfile?resource_id=256061>

**Project Description:** The undergraduate students will participate in a research project to develop RNA-based feedback controllers as a new therapeutic approach for sepsis (a serious condition in which the immune system responds improperly to an infection). The project's main objective is first to design and test these controllers using fluorescent proteins and further optimize the circuit to produce therapeutic cytokines to regulate the immune response to sepsis. Engineered circuits will be characterized using engineered sepsis cell lines.

**Desired Academic Majors:** Biomedical engineering, chemical engineering, microbiology, mechanical engineering, agricultural engineering, computer science

**# of hours/week:** ~ 9 hours/week (3 credits of independent research)

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**Project #7**

**Department:** Civil Engineering

**Faculty:** Jinha Jung

**Faculty Website:** <https://engineering.purdue.edu/CE/People/ptProfile?resource_id=222078>

**Project Description:**

This project aims to estimate soil moisture using S-band SAR sensor, multispectral, and hyperspectral data collected via an airborne UAV system, with the eventual goal of expanding the methodology to satellite data to produce a high-resolution soil moisture map for the entire US. The mentee's role involves participating in data collection if needed, managing image processing tasks, and attending virtual team meetings. Additionally, if interested, the mentee can contribute to training data for deep learning models and analyzing the results. The mentee will be trained on how to process the data, and access to all processing machines will be provided. The mentee does not require any specific system of their own to process the data. The outcomes of this research are valuable for agricultural irrigation management and hydrological studies, including flood prediction.

**Desired Academic Majors:** Civil engineering, agricultural and biological engineering, and mechanical engineering. Other engineering majors interested in working with remote sensing data, image processing, and deep learning are welcome.

**# of hours/week:** ~6 hours (2 credits of independent research or more if interested)

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**Project #8**

**Department:** Physics and Astronomy

**Faculty:** Stephen Durbin

**Faculty Website:** <https://www.physics.purdue.edu/people/faculty/durbin.php>

**Project Description:** The project will be for student(s) to develop an understanding of Hong-Ou-Mandel interferometry as it pertains to implementations in physical systems. Student(s) will be responsible for developing a theoretical understanding of the subject, developing skills in software required to use the detectors and systems necessary for implementation, and developing soft skills as it pertains to presenting research topics (both to an experienced and layman audience) with a broader overall emphasis on learning how to take complex, research specific ideas and how to best communicate them depending on your audience.

**Desired Academic Majors:** Physics, Mathematics, Electrical Engineering, Computer Engineering

**# of hours/week:** ~3 hours (1 credit of independent research or more if interested)

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**Project #9**

**Department:** Biological Sciences & Forestry and Natural Resources

**Faculty:** Andrew DeWoody

**Faculty Website:** <https://www.purdue.edu/fnr/sites/dewoody/>

**Project Description:** The research project will be determined based on the mentee's interests.I have diverse research projects ranging from landscape analyses to bioinformatics. 1) *Landscape Analysis:* we will explore suitable habitats of endangered birds, and how the habitats will be shifted according to climate change. The mentee will collect occurrence data of the focal species and relevant environmental data and validate the data's accuracy. The mentee will read associated papers to gain background knowledge. The result of this project will help conservation agencies to plan their management programs for the focal species. 2) *Bioinformatics*: The mentee will learn some basic coding/scripting knowledge if not readily available. The mentee will then write scripts and run them to explore genomics structure of endangered species. We will address how genetic variants of them are associated with environmental adaptation or are changing with demographic events. The results will help identify conservation units within the focal species for future management plans.

**Desired Academic Majors:** Ecology and Evolutionary Biology; Computational Biology; Agricultural and Biological Engineering; Genetics; Forestry and Natural Resources; Natural Resources and Environmental Science; Agricultural Systems Management

**# of hours/week:** ~6 hours/week (2 credits or more if interested)

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**Project # 10**

**Department:** Mechanical Engineering

**Faculty:** Marcial Gonzalez

**Faculty Website:** <https://web.ics.purdue.edu/~gonza226/>

**Project Description:** The overarching research question is understanding how macroscopic properties of solid granular (heterogeneous) materials depend on the evolution of microstructure under different external fields (i.e., stress, temperature, electromagnetic). The microstructure comprises of specific small-scale material properties that affect macroscopic behavior in nontrivial ways. Using that understanding, we intend to engineer new material structures that are resilient under different applications. The student will focus on applying a statistical/probabilistic framework developed by our lab group to predict how material properties evolve under different loading conditions.

The mentee's roles will involve data analysis of numerical simulations and experimental image data. The student will be able to learn and extend their understanding of concepts from solid mechanics, materials science, and probability/statistics. The student could also assist with training a neural network that is constrained by mechanistic considerations to predict different microstructures that satisfy different performance requirements according to applications of interest (i.e., pharmaceutical tablets, batteries, semiconductor chips). There is also an opportunity to explore experimental instrumentation (i.e., micro-CT imaging) and apply computer vision to extract statistical information in real-time design of these materials.

While the details of the project are amenable depending on student interest, the overall idea is for the student to apply some of the frameworks we are developing in the lab to practical applications in continuous manufacturing and quality by design of engineered products.

**Desired Academic Majors:** Would prefer a student outside of Mechanical Engineering who wants to explore an interdisciplinary project that can extend/apply their major-related knowledge. Some preferred majors include (but not limited to):

(1) Electrical and Computer Engineering/Computer Science/Data Science

(2) Physics/Applied Mathematics (with some coding experience)

(3) Materials Science/Aerospace/Industrial Engineering (with some coding experience)

**# of hours/week:** ~ 6 hours/week (2 credits or more if interested)

**Preferred Skills:** (1) Looking for a student who will be in their 3rd year in Fall 2024. Needs familiarity with coding in C/Python/MATLAB. Some knowledge of data structures/algorithms/discrete math would be a plus (i.e., ECE 264, ECE 269, ECE 20875).

(2) More importantly, a general curiosity to learn and explore topics outside of their curriculum, and an interest in applying concepts in machine learning/computer vision to design of materials-based products. Furthermore, an interest in applying probability/statistics to physical systems would be plus.

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**Project # 11**

**Department:** Computer Science

**Faculty:** Milind Kulkarni

**Faculty Website:** <https://engineering.purdue.edu/~milind/>

**Project Description:** *Accelerating database queries using GPU Ray Tracing Architecture* - GPU architecture is suitable for accelerating regular data structures such as lists or matrices. However, there is a wide range of applications that use irregular data structures such as trees or graphs. This project introduces new techniques to accelerate irregular computations by effectively mapping a target application to the operations accelerated by the GPU Ray Tracing Architecture. The objective is to leverage the GPU architecture to speed-up spatial database queries such as selection and join. Mentee’s responsibilities include:

a) Understand the application (database queries) and part of the GPU architecture that we use (Ray Tracing Architecture).

b) Code, test, or benchmark the algorithms/techniques the mentor formulates.

**Desired Academic Majors:** Computer Science or Engineering, Computer and Information Technology, or Computer Systems Analysis and Design

**# of hours/week:** 9 hours/week (3 credits of independent research)

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