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MIT School of Engineering

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SUPERUROP 2024–2025 RESEARCH GUIDE

SuperUROP

Advanced Undergraduate Research Opportunities Program

2024–2025 Research Guide

MIT

SuperUROP tackles the most pressing challenges facing our world today and sets the stage for our students to pursue careers in research, in industry, and beyond. Through a meaningful research experience and opportunities for interdisciplinary exploration, SuperUROP helps to shape how our students see the role of research in addressing challenges, regardless of their pursuits: earning advanced degrees at major research universities, making an impact in industry, or applying the lessons of their creative research within early-stage startups. SuperUROP uncovers a host of exciting new directions and possibilities.

—Anantha P. Chandrakasan
Dean, MIT School of Engineering
Vannevar Bush Professor of Electrical Engineering and Computer Science

Photo credit: Randall Garnick


Photo credit: Randall Garnick

As head of the MIT Department of Electrical Engineering and Computer Science, I'm pleased to report on the continued success of the Advanced Undergraduate Research Opportunities Program, better known as SuperUROP.

Since its debut in EECS in 2012, SuperUROP has equipped over 1,300 undergraduates with the research tools they need to tackle real-world problems by giving them the chance to engage in year-long supervised research projects and complete a seminar that exposes them to the essentials of research in a supportive and structured environment. They learn to choose and develop research topics, design experiments, collaborate, write technical papers, and present their work. They also study entrepreneurship, ethics in engineering, and other critical topics. Some publish their research results in respected journals or present them at important conferences. SuperUROP alumni continue to thrive long after their time in the program has ended. Many go on to earn advanced degrees at top research universities, win major scholarships and fellowships, work for industry-leading companies, or join exciting new entrepreneurial ventures.

Hosted by the School of Engineering and administered by EECS, SuperUROP is a collaborative effort involving many other departments, both within the School of Engineering and beyond. Their collaboration helps bridge the gap between the sciences and humanities through innovative, creative interdisciplinary research.

This program relies on generous support from EECS, alumni, corporations, foundations, and friends, all of whom are committed to growing SuperUROP and enhancing the student experience at MIT.

Once again, I wish to acknowledge Anantha Chandrakasan, Dean of the School of Engineering and Vannevar Bush Professor of Electrical Engineering and Computer Science. As EECS Department Head, he pioneered and oversaw SuperUROP for its first several years, and he remains among the program's strongest champions. I also wish to acknowledge the contributions of our 359 SuperUROP faculty supervisors over the years.

In the long term, I look forward to seeing where these bright young researchers go in their careers. They have already chosen challenging and difficult questions; I believe the flexibility and creativity they have displayed will carry them far. I invite you to discover more about the impressive research projects highlighted both within these pages and at superurop.mit.edu.

Sincerely,

Asu Ozdaglar
EECS Department Head
Deputy Dean of Academics, MIT Schwarzman College of Computing
MathWorks Professor of EECS

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Mahmoud Abdelmoneum

MIT EECS | Takeda Undergraduate Research and Innovation Scholar

Personality, Environment, Pathology, and Regulatory Networks: A Molecular Examination

Supervisors: Manolis Kellis and Li-Huei Tsai

Personality is an abstract description that attempts to explain tendencies in how individuals view and respond to the world around them. It is an excellent example of the complexity of human complexity, and the five-factor model of human personality has enabled us to assess personality in a more quantitative way. An individual's personality largely dictates the trajectories and outcomes of their life experiences, and recent literature has established strong correlates between personality and various pathologies, notably Alzheimer's disease (AD) and psychiatric disorders such as schizophrenia, as well as significant relationships between environmental factors and personality traits. Nevertheless, despite the critical importance of personality in the human experience, the molecular mechanisms underpinning personality remain poorly understood. Limited genetic correlates have been found, but a more extensive picture of the underpinnings of personality in the brain have yet to be painted. Through both genetic and epigenetic approaches I aim to elucidate the molecular underpinnings of personality, understanding how environment modulates personality, and subsequently understanding how personality might predispose individuals to Alzheimer's disease as well as psychiatric disorders such as schizophrenia. To do so I will perform Genome-Wide Association Studies (GWAS) as well as Mendelian randomization analyses to find genetic correlates of personality as well as to understand whether they are causally implicated in the five-factor personality traits. I will then conduct transcriptomic analyses (via single-nucleus RNA sequencing of human prefrontal cortex tissue) of the five-factor personality traits, as well as of some environmental conditions that may affect personality, most notably adverse childhood experiences (ACEs), social isolation (SI), and early-life enrichment. Using the results of these genetic and transcriptomic analyses, as well as genetic and transcriptomic hits from previous analyses of AD and schizophrenia, I will conduct a networks-level analysis to understand how environmental factors may modulate personality, and how personality may predispose individuals to AD and schizophrenia.

I am participating in the SuperUROP program because I wanted to expand the work that I was already doing into a more interdisciplinary project between BCS and EECS where I could continue to build on my neuroscience research skills while gaining more advanced computational mentorship. Additionally, I wanted to gain more mentorship in writing and presenting in the research world. I feel prepared for this research by almost two years of neuroscience research (including computational workflows) as well as extensive CS, biology, and neuroscience coursework. I am hoping to learn more advanced statistical/computational approaches to developing a more comprehensive picture of biological processes in the brain from multi-omic data.

Ekaterina Arutyunova

MIT EECS | Quick Undergraduate Research and Innovation Scholar

Transport Layer Protocol for Quantum Networks

Supervisor: Vincent W. S. Chan

Transport Layer Protocols are crucial for data exchange between multiple devices within the network, with classical protocols like TCP/IP designed for traditional communication systems. Quantum transport protocols are needed for quantum networks, which use qubits (instead of classical bits) that can be affected by quantum decoherence and transmission losses, leading to errors. Quantum error correction codes (QECC) and quantum automatic repeat requests (ARQ) are used to control and correct these errors, but both of these algorithmic methods have their own inefficiencies. The goal of this project is to combine these algorithms into a single one, designed to improve the efficiency of quantum information transmission within quantum networks. The effectiveness of the proposed algorithm will be validated through a simulation.

Participating in the SuperUROP would provide me with the opportunity to work on a theoretical project in the quantum communication field—an area I am interested in exploring further. Through this program, I aim to apply the quantum technology knowledge and skills I've developed through my MIT coursework and past research experiences, while also learning new methods and techniques for conducting theory-driven research. I am excited to contribute to my project and share my progress and ideas with others!

Maxim Noel Attiogbe

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar

Enhancing Genetic Structural Variant Discovery with Deep Learning

Supervisor: Caroline Uhler

Accurate mapping of genomic structural variants (SVs) is crucial for advancing biomedical research and understanding genetic diversity. Deep learning is a promising approach for interpreting complex SV signatures in DNA sequencing data. Using data from the Human Genome SV Consortium, we will develop a convolutional neural network to detect SVs from short-read sequencing data, building on existing architectures for smaller mutations. We will then integrate the model into the Talkowski lab's GATK-SV pipeline, creating a scalable, cloud-based workflow for structural variant filtering in large-scale genomic studies. This integration aims to enhance the accuracy and efficiency of identifying disease-causing genetic variants in research and clinical settings.

I am pursuing this project to gain experience combining research and engineering to develop a high-impact, production-ready healthcare application of machine learning. I aim to expand upon my ML research experience from CSAIL and SWE/ML industry experience from Microsoft and LinkedIn. This project will inform my ML research project choice for my MEng, which I plan to start in fall 2025, and my graduate school or industry decisions afterwards.

Ishaq O. Balogun

MIT CEE | Undergraduate Research and Innovation Scholar
A Phylogenetically Informed Tool for Pangenome-Wide Association in Bacteria
Supervisor: Tami Lieberman

Phage Defense Genes (PDGs) are the building blocks of the bacterial immune system. Although recent research has identified numerous new PDGs, their mechanisms of action and evolutionary dynamics are still largely unknown. To deepen our understanding, we focus on studying the interactions between PDGs as a way to further classify these systems. Unlike traditional statistical models, which assume sample independence, our approach corrects for the phylogenetic relationships between observations. This allows us to uncover evolutionary correlations and negative associations between PDGs. The insights gained will help generate hypotheses about the true mechanisms of PDGs. Moreover, this method can be applied to any binary character on a phylogeny, such as linking genes to disease phenotypes.

Through this SuperUROP I wish to improve my ability to computationally analyze biological data and learn to use these results to generate concrete experimental findings. Hopefully this will prepare me to be an effective researcher who can bridge discovery and application.

Ayyoob Berhane

MIT EECS | Undergraduate Research and Innovation Scholar
How Did We Get Here? Steering Schrödinger Bridges
Supervisor: Justin Solomon

We explore a generalization of the Schrodinger Bridge Problem (SBP), which steers a probability distribution with prior nonlinear dynamics from an initial to final state, building an optimal controller for a broad set of prior dynamics. Specifically, we design a numerical solver for a pair of partial differential equations (PDEs) describing the generalized problem. Our framework of the SBP has applications to physics, computer graphics, and computer vision, with prior works utilizing special cases of the PDEs for smooth shape interpolation, digital animation, generative modeling, and seismic exploration. Using our generalized solver for the aforementioned applications, we develop improvements to sample generation and interpolation.

I'm interested in dynamical system modeling and optimal transport, as well as their many applications across the sciences. In developing optimization techniques for generic systems, my SuperUROP will expose me to a variety of numerical and theoretical tools used for controls. I hope to synthesize my computational and communication skills to solve real-world problems in nonlinear system modeling.

Daniel Timothy Brown

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar
Isolated Piezoelectric-Based Power Converter Design
Supervisor: David J. Perreault

Power electronics are critical components of many electric energy systems. For example, power converters can be found in anything from consumer electronics to renewable energy generation. New applications demand smaller, lighter, and more efficient power converters. However, scaling down these parameters is often bottlenecked by magnetic energy storage elements: not only are they typically the largest element on the circuit, but they are also the least efficient at small volumes. Piezoelectric materials are a promising alternative energy storage device, but piezoelectric-resonator-based power converters are a relatively new development. The goal of this project is to develop, design, construct, and test novel piezoelectric-based converter designs.

I'm participating in SuperUROP to deepen my understanding of power electronics. I took 6.222 (Power Electronics Laboratory) last year and I really enjoyed engineering power converters for tangible purposes. I hope to learn more about how I can effectively communicate engineering-oriented research to a wide audience.

Jing Cao

Undergraduate Research and Innovation Scholar
Using Foundation Models to Solve TAMP Problems
Supervisor: Leslie P. Kaelbling

This project integrates Large Language Models (LLMs) and Vision Language Models (VLMs) into Task and Motion Planning (TAMP) to enhance robotic planning. Traditional TAMP requires explicit logical specifications, often limited by closed-world assumptions. We propose a framework where LLMs generate action sequences that are verified by a constraint satisfier (CSP) for physical and geometric feasibility. This iterative process refines plans, ensuring they align with real-world constraints, thereby improving the adaptability and effectiveness of autonomous robots in dynamic environments.

I am participating in SuperUROP to gain hands-on experience and apply my machine learning knowledge to robotics. I aim to deepen my expertise in AI by working on this project, where I'll develop a framework to enhance robotic planning and execution. This project excites me because it represents a significant step toward creating adaptable, intelligent robotic systems capable of solving complex, real-world challenges.

Lee Chen

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar

Understanding Gene Expression Dynamics of Brain Aging and Neurodegeneration

Supervisor: Manolis Kellis

Aging is understood as a risk factor for many neurodegenerative diseases, including Alzheimer's disease, Parkinson's disease, and amyotrophic lateral sclerosis. Using single-cell sequencing methods, we're able to investigate the gene expression and accessibility of brain neurons in individuals across different ages. This allows us to understand the changes in how cell types communicate with each other, repair their own genetic material, and move through their environment. We hope to reveal the nature of cellular brain aging and offer possible points of therapeutic intervention.

I am participating in SuperUROP to gain experience in carrying out an independent project. I have worked with similar datasets and enjoyed the explorative nature of bioinformatics research. I'm excited to explore the effects of aging on the brain.

Steven-Shine Chen

Undergraduate Research and Innovation Scholar

Interactive Sketchpad: A Multimodal Tutoring System for Collaborative, Visual Problem Solving

Supervisor: Paul Liang

Humans have long relied on visual aids like sketches and diagrams to support reasoning and problem-solving. Visual tools, like auxiliary lines in geometry or graphs in calculus, are essential for understanding complex ideas. However, many tutoring systems remain text-based, providing feedback only through natural language. Leveraging recent advances in Large Multimodal Models (LMMs), this paper introduces Interactive Sketchpad, a tutoring system that combines language-based explanations with interactive visualizations to enhance learning. Built on a pre-trained LMM, Interactive Sketchpad is fine-tuned to provide step-by-step guidance in both text and visuals, enabling natural multimodal interaction with the student. Accurate and robust diagrams are generated by incorporating code execution into the reasoning process. User studies conducted on math problems such as geometry, calculus, and trigonometry demonstrate that Interactive Sketchpad leads to improved task comprehension, problem-solving accuracy, and engagement levels, highlighting its potential for transforming educational technologies. All code is available at: https://stevenshinechen.github.io/interactivesketchpad.

SuperUROP allows me to leverage my machine learning skills, gained from experience with large language models, machine learning courses, and previous UROP work, in a longer-term research project. I aim to advance my knowledge of multimodal AI and develop strong research skills, hoping to publish my results. I believe enhancing generalized reasoning is key to advancing artificial general intelligence, and my project is a step in that direction.

Alex Dang

MIT EECS | Fano Undergraduate Research and Innovation Scholar

Inverting Generative Diffusion Models

Supervisor: Justin Solomon

Generative diffusion models have recently revolutionized computer vision due to their ability to create realistic, detailed images. By using billion-size training datasets these models learn to map noise to images based on text prompts. Multiple recent works reported that the opposite map (from signal to noise) captures rich information about images, allowing for applications like image editing, out-of-distribution correction, and 3D shape generation. In practice, however, these inversion maps are shown to have weak numerical stability. Our research aims to analyze the numerical errors of diffusion inversion in multiple practical settings. If successful, this has the potential to greatly improve multiple diffusion-based methods and enhance understanding of generative diffusion models.

I am participating in SuperUROP because I'm eager to apply what I've learned from machine learning (ML) courses to an extended research project. As ML techniques have advanced, I've become deeply interested in being able to explain why these methods work intuitively from a mathematical standpoint, and I'm excited that my project will both let me explore my interest while gaining experience in conducting research, especially in computer vision.

Gozel Dovranova

MIT CEE | Undergraduate Research and Innovation Scholar

Utilizing Naturally Abundant Zeolite for Effective Mitigation of Low-Level Methane Emissions

Supervisor: Desiree Plata

Methane is a potent greenhouse gas, with a global warming potential 120 times greater than that of carbon dioxide on a per-mass basis. Mitigating methane emissions offers a critical opportunity for rapid and significant climate action, but a major challenge is that 80% of these emissions are dilute. This research will optimize a copper-zeolite catalyst for mitigating low-level methane emissions through oxidation. The catalyst effectively uses the porous structure of zeolites to store metal ions and enhance oxidation. While synthetic zeolites are common, natural zeolites are more abundant, sustainable, and cost-effective. This project will explore the potential of natural zeolites to improve methane oxidation and their practical benefits.

I am excited about this SuperUROP opportunity because it will help me develop the skills for independent, advanced research. I look forward to applying the technical knowledge from my coursework and previous projects. Contributing meaningful research in the field of climate change is both rewarding and inspiring to me.

Luc Gaitskell

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar
Scalable Efficient Distributed Graph Sampling for GNN Learning
Supervisor: Charles E. Leiserson

Graph Neural Networks (GNNs) have been discovered to model certain systems with particularly high accuracy, such as chemical molecules and relationship networks. However, due to the scale of individual input graphs in useful training sets, they cannot be processed on current hardware without sub-sampling. The intensive graph sampling process can be seen to take around 50% of training time. As a result, recent research has been conducted into methods to improve sampling efficiency, which allows training with more data and gives headroom for larger models. However, this research has yet to focus extensively on effectively utilizing multi-GPU training systems. Efficiently distributing sampling across GPUs could deliver further performance improvements, enabling larger, more capable models.

Through this SuperUROP, I'm looking forward to applying my experience in machine learning and hardware architecture from previous courses and working in the industry. With the least of my experience in software performance engineering, I look forward to learning through my research and alongside 6.1060 next semester. I hope to expand my understanding of all three areas by exploring the intersection.

Rodrigo Garza Garcia

MIT EECS | CS+HASS Undergraduate Research and Innovation Scholar
Augmenting Lobbyist Data for Political Research
Supervisor: In Song Kim

The lobbying industry involves billions of dollars and plays a crucial role in American politics, yet existing datasets suffer from critical limitations that hinder robust analysis. The goal of my research is to address some of these challenges by developing methods to disambiguate and augment lobbyist data through computational techniques. This involves implementing algorithms that can identify duplicate lobbyist entries and enrich profiles with relevant information such as government employment history, political donations, and party affiliations. The enhanced dataset seeks to make the analysis of lobbying influence more accurate and reliable, as well as provide a clearer picture of the relationships between lobbyists, legislators, and policy outcomes, ultimately working toward a more transparent view of how corporate lobbying influences American governance.

Through SuperUROP, I'll be able to learn what it's like to go through the process of dedicated research and writing a full research paper. In previous UROPs, I've conducted research that served an important purpose, but taking that to the next level and presenting this research to others is what I hope to get in SuperUROP. I want to inform people about the elusive lobbying industry and gain crucial academic and research skills in the process.

Charalampos (Charis) Georgiou

MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar
Conformal Prediction for Optimization-Informed Keypoint Placement
Supervisors: Pulkit Agrawal and Luca Carlone

Accurate keypoint placement is crucial for robotics applications such as pose estimation and trajectory optimization. Current keypoint detectors, however, lack guarantees on output accuracy, leading to propagated errors in pose estimation algorithms. To address this, we propose training a diffusion model tailored to a specific category of objects to standardize keypoint selection. This approach aims to enhance pose accuracy across all objects within the category. We plan to integrate robust pose estimation algorithms directly into the training process using differentiable optimization layers. This will allow us to simultaneously optimize pose error and optimization tightness. Additionally, by utilizing conformal prediction, we can provide statistical guarantees on keypoint accuracy and predict their impact on pose estimation algorithms.

Through this SuperUROP, I aim to tap into my background in computer science and mathematics to come up with innovative solutions. I'm particularly eager to apply my skills to develop algorithms that improve robotic efficiency and precision. In general, I enjoy attempting problems that bridge multiple disciplines, and which benefit from closing the gap between theoretical knowledge and practical application!

Janka Franciska Hamori

MIT Tang Family FinTech Undergraduate Research and Innovation Scholar
Do LLMs Synthesize Technical Information Like Humans?
Supervisors: Andrew W. Lo and Antonio Torralba

My project investigates how large language models (LLMs) lose critical technical information during information synthesis, and how these gaps vary across different scientific fields. By categorizing the errors, we identify consistent challenges in handling theoretical foundations and performance evaluation, with computer science showing the most significant decline in accuracy. The findings emphasize fundamental limitations in LLMs' ability to process and retain critical scientific knowledge, offering a foundation for targeted improvements in AI-assisted scientific analysis.

I am participating in SuperUROP to connect my main interest areas—AI, mathematics, and finance—through high-level research. This is a great opportunity for me to do work in the intersection of my majors, Business (15-2) and AI (6-4), while learning more about financial markets and how to work with LLMs. I am also interested in LLM capability research, particularly how their use in everyday life influences larger systems and drives broader societal changes.

Yeabsira Lanior Hawaz

MIT Tang Family FinTech Undergraduate Research and Innovation Scholar
NOC for a Hardware Accelerator for Sparse Iterative Solvers on FPGAs
Supervisor: Daniel Sanchez

Solving sparse systems of linear equations is a crucial component in many science and engineering problems, like simulating physical systems. We present an architecture for accelerating sparse matrix factorization algorithms. However, a specific concern is network topology. Chip network topology is the arrangement and organization of interconnects within a chip controlling communication between different parts of the chip, like the processor cores, memory elements, and I/O controllers. The topology determines the pathways for data transmission, affecting the performance, efficiency, latency, and scalability of the chip. We plan on designing and optimizing a network on chip architecture that gets the best performance out of our hardware accelerator for sparse matrix factorization algorithms.

I am participating in this SuperUROP because I think digital systems are really intriguing and I loved optimizing processors in classes like 6.192 (Advanced Computer Architecture) and 6.191 (Computation Structures). I am hoping to gain more experience writing RTL code and designing digital systems from scratch.

Almog Hilel

MIT EECS | Landsman Undergraduate Research and Innovation Scholar
Reverse Engineering the Mind
Supervisors: Leslie P. Kaelbling and Joshua B. Tenenbaum

How do we make guesses about minds? How do we share these guesses using natural language? How do we convey so much information with so few words? We aim to investigate the cognitive mechanisms underlying theory of mind and language generation. This process can be described in three steps: (1) observe– actions of the other, (2) infer– a probabilistic model underlying those actions, and (3) share– this model using language to enable a listener to reconstruct it in their own mind. Compressing an inferred model into a few words is a non-trivial task. To investigate this cognitive mechanism we use computational tools tailored for a close-domain controlled game scenario: We develop a Bayesian model architecture to (1) observe virtual players' actions, (2) infer their RL model, and (3) generate language to share that model through natural language to a listener. The model achieves this entirely through its architecture, for a specific controlled environment, without any training on human data. To evaluate our computational model we compare its natural language guesses to humans prompted with a similar stimulus. Our results highlight that by incorporating theoretical constructs from the communication literature—balancing accuracy, informativity, and relevance—the Bayesian model demonstrates better alignment with human explanations. Preliminary lab experimentation with humans shows that the Bayesian model generates natural language guesses that closely match how humans articulate their guesses when exposed to similar visual stimuli in our specific lab-controlled setting.

Reverse engineering one of the most beautiful and intricate systems known to exist: the human mind.

Vivian S. Hir

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar
Using Deep Learning to Construct a Pan-Cancer Blueprint of Tumor Spatial Organization
Supervisor: Caroline Uhler

The objective of the project is to construct a pan-cancer atlas of cellular neighborhoods and their spatial assembly. We aim to analyze the impact of two adjacent cellular neighborhoods on patient survival, as well as the relevant genes correlated with these significant neighborhoods. Furthermore, we plan to do an analysis of shared clusters across different gastrointestinal (GI) cancers. We will apply a foundation model to extract image features from whole-slide imaging data of GI cancers in the Cancer Genome Atlas (TCGA), and apply the tissue schematics framework to find cellular neighborhoods and map their spatial assembly. By leveraging the clinical, gene expression, and mutation data in TCGA, we can decipher the functional mechanisms and impact of this assembly.

I am participating in this SuperUROP because I am interested in computational biology research, specifically in the field of cancer. This project excites me because of its medical and clinical applications. Taking on this project will not only help me better understand computational histopathology, but also further develop my research and communication skills.

Erin Hollis Hovendon

MIT MechE | Undergraduate Research and Innovation Scholar
Enabling Flux Exchange Measurements for Marine Carbon Dioxide Removal
Supervisor: Thomas Peacock

The ocean serves as a vital global carbon reservoir and emissions buffer. As atmospheric carbon dioxide levels rise, the potential to enhance marine carbon storage capacity has become an invaluable research topic. Marine carbon dioxide removal (mCDR) is an electrochemical approach that promotes carbon uptake and improves long-term sequestration. This project explores a novel measurement approach for quantifying air-to-seawater carbon dioxide flux, a critical metric in evaluating the efficacy of marine carbon capture. Research in the ENDLab combines hands-on lab experiments with numerical modeling, and our results will inform crucial technological development in the mCDR field.

I am excited to participate in this SuperUROP because mCDR is a new and developing technology, and our work can address critical challenges in climate mitigation in real time. I also hope to gain valuable research skills relevant to my future endeavors in mechanical and environmental engineering.

Janvi Huria

MIT EECS | Takeda Undergraduate Research and Innovation Scholar

Early Detection of Cholangiocarcinoma with Diagnostic Nanoparticles

Supervisor: Sangeeta Bhatia

Cholangiocarcinoma (CCA) is a deadly bile duct cancer that can be challenging to distinguish from benign fibrotic conditions. To improve detection, we developed activatable zymography probes (AZPs), peptide-based agents that bind to cancer cells after being cleaved by dysregulated proteases. I have screened 29 AZPs in a murine CCA model and identified 5 with significantly higher binding to CCA tumors compared to fibrotic lesions. Now, through this project, I will determine the specific proteases involved in AZP cleavage, develop a new peptide that requires two cleavage events for activation, and test an enhanced AZP6 for PET imaging. Additionally, I will improve our quantification pipeline with new scripts for detailed pixel-by-pixel colocalization analysis.

I am participating in SuperUROP because I want to further my research interests at the intersection of biological engineering and computational techniques. I am interested in developing new tools to address clinical difficulties in diagnosing cancer. I have enjoyed and am excited to expand my work in nanoparticle engineering while developing new analytical protocols.

Bryan Jangeesingh

MIT EECS | Takeda Undergraduate Research and Innovation Scholar

Generalized Clinical Data Pipeline for Enhanced Health Records Analysis

Supervisor: Collin M. Stultz

This project aims to enhance an existing clinical data-modeling tool by integrating support for unstructured text data, focusing on large-scale datasets such as the MIMIC database. The enhancement will enable comprehensive multimodal modeling by incorporating both time-series clinical data and text-based data like clinical notes. We will also explore injecting domain knowledge from clinical textbooks and knowledge graphs to enrich the data representations, thereby improving the model's predictive accuracy. The tool's effectiveness will be evaluated in a transfer learning context, optimizing its applicability across diverse clinical tasks.

Through this SuperUROP, I aim to deepen my understanding of representation learning and machine learning, building on my experience from previous machine learning engineering internships. I also want to improve as a researcher, developing the intuition necessary to make groundbreaking discoveries in applied AI. This project excites me because it offers the opportunity to contribute to real-world advancements in healthcare.

Andrea Y. Jia

MIT EECS | Mason Undergraduate Research and Innovation Scholar

Characterizing Neural Dynamics of Internal State Switching and Swimming Behavior in *Clytia hemisphaerica*

Supervisor: Brandon Weissbourd

Many species exhibit internal state switching, where shifts in neural activity patterns produce distinct behavioral states. The mechanisms of state-switching and their extent of evolutionary conservation are unknown; thus, studies across diverse species provide valuable points of comparison. With established transgenesis and optical advantages, the jellyfish *Clytia hemisphaerica* offers a highly tractable state-switching model consisting of active swimming and quiescence states. I will record neural activity in restrained *Clytia* via transgenic GCaMP6s expression, then use computational methods to identify and model neural populations correlated in time with behavior state transitions. Studying state-switching in *Clytia* may yield meaningful insights on how neural activity governs behavior.

Having UROP-ed since freshman year, I think SuperUROP is a great way to gain a more immersive research experience. My project combines computation with neuroscience in a jellyfish model, which is really exciting to me as a sort of start to pursuing my own research interests. Through SuperUROP and beyond, I hope to explore the fundamental principles behind how simple and complex nervous systems might arise from well-made connections.

Pinqian Jin

Undergraduate Research and Innovation Scholar

Hardware Accelerator for Sparse Matrix Computation with Iterative Method

Supervisor: Daniel Sanchez

This project aims to prototype computer architecture designs that require massive SRAM resources using FPGAs, which have abundant SRAM for effective execution of iterative solver algorithms. The focus is on automating the prototyping process, optimizing tile distribution to minimize boards needed and reduce latency, enhancing scalability for varying algorithms, and exploring trade-offs in processing element generality versus resource utilization.

I'm participating in SuperUROP to deepen my understanding of digital system designs, especially FPGAs. Having worked on small FPGA projects, I'm eager to tackle a larger, more complex project to further explore this field.

Samir Kadariya

Undergraduate Research and Innovation Scholar
Tracing Trade Policies of the US Over the Last 250 Years Using Machine Learning
Supervisor: In Song Kim

This project aims to systematically trace the evolution of US trade policies from 1789 to the present using advanced machine learning techniques, particularly natural language processing (NLP). By analyzing legislative bills, we will assess changes in trade policies and their underlying political dynamics over time. A key focus involves developing an NLP-based algorithm to standardize historical tariff items by assigning Harmonized System (HS) codes, converting disparate tariff rates into comparable ad valorem rates, and adjusting past monetary values to current equivalents. The project also envisions creating user-friendly applications, including a mobile tool for real-time HS code classification, facilitating data access and analysis for researchers and policymakers.

I am participating in SuperUROP to gain experience in machine learning research and its applications in historical data analysis. Having previously worked in this lab using NLP algorithms for HS code tariff description matching, I am excited to further my research in this area and also develop tools that offer insights into US trade policies and to gain valuable experience for my future career in research and industry.

Jack G. King

MIT EECS | Undergraduate Research and Innovation Scholar
Statistical Features Govern Temporal Straightening in Large Language Models
Supervisor: Evelina Fedorenko

Building on a theory of predictive coding that suggests large language models (like ChatGPT) straighten their representation of language to more easily predict the next word in a sentence, I will explore the internal representations that characterize straightening and next-word prediction. I will apply both mechanistic interpretability and computational cognitive science techniques in an effort to understand how and why models straighten language trajectories. This builds on a new but quickly growing geometric/dynamics analysis paradigm for modeling human/artificial neural networks. Characterizing straightening will inform our understanding of how large language models produce the output they do, and it may shed some light on the computation underlying temporal prediction in general.

I am participating in SuperUROP to continue my exploration of machine learning/computational cognitive science research with more independence. Not only is this an opportunity to explore a field that greatly excites me, but I hope to gain much more experience bringing a cohesive research project into fruition. I am most excited about the opportunity to explore a question that has implications for intelligence in both minds and machines.

Angelica J. Knudsen

MIT MechE | Undergraduate Research and Innovation Scholar

How Hummingbird Feathers Make Light Dance and Water Bounce

Supervisor: Irmgard Bischofberger

Hummingbirds are unique in that their feathers boast two extraordinary properties simultaneously: superhydrophobicity and iridescence. These properties are hypothesized to be linked to the intricate structure of hummingbird feathers, characterized by microscopic barbs and barbules. We propose to reveal the geometry of the hummingbird's hierarchical feather structure and how it leads to combined superhydrophobicity and iridescence. Using this information, we will also build an experimental model system of the feather structure using glass capillaries to precisely link the splashing characteristics to the angle of the barbules.

I am participating in this SuperUROP because it allows me to combine my two favorite things: engineering and ornithology. My fascination with birds and their intricate mechanisms dates back to my high school years, where I developed a deep curiosity about their inner workings. I am excited to apply my background in mechanical engineering and ornithology to reveal the mechanisms that make hummingbird feathers unique.

Jeffrey J. Kwon

MIT EECS | Morais and Rosenblum Undergraduate Research and Innovation Scholar

Implementing a Human Speech Perception Model Based on Acoustic Cues: Distinguishing Between the /s/ and /sh/ Phonemes

Supervisor: Stefanie Shattuck-Hufnagel

Lower-level acoustic characteristics are intrinsically linked with the phonemes comprising a language, and have distinct acoustic patterns (which can be analyzed using spectrogram data) that are especially useful for phonological classification models. I will be working on furthering an existing SB (spectral burst/noise) detection module to detect the types of turbulence noise that are characteristic of obstruent consonants, specifically to distinguish between the spectral burst noise of the /s/ and /sh/ phonemes. Our approach is to implement and test a GMM (Gaussian mixture model)-based SB detection module that is able to replicate results from human listening experiments for these sounds.

I hope to learn more about high-quality research practices as well as effective communication techniques. Having analyzed speech acoustics in English phonemes using spectrograms, I am excited to learn more about how humans can distinguish between various sounds.

Adrienne Wing Suen Lai

MIT MechE | Sea Grant Undergraduate Research and Innovation Scholar
Design and Analysis of a Hydrodynamic Sensor Inspired by Harbor Seal Whiskers
Supervisor: Michael Triantafyllou

Harbor seals have unique wavy whiskers with asymmetric oscillations along the profiles and an elliptical cross section. This shape is key to their high sensitivity; harbor seals can track a fish with a 30s head start in front of them using solely their whiskers for sensing. An artificial whisker sensor with the unique hydrodynamic properties of a seal whisker would enable an underwater vehicle to sense and maneuver without emitting sound or light, reducing energy requirements and being less obtrusive. These sensors have the potential to be low cost, power efficient, and highly sensitive. The goal of this study is to analyze the behavior of the whisker geometry in laminar and turbulent conditions to understand the nuances in tracking hydrodynamic patterns to improve the sensor accuracy.

I hope to improve my communication skills and ability to steer a research project toward future innovation. I am excited to learn about research outside of my field—I can't wait to see how I am able to incorporate the new technologies and methods I learn from my peers into my own work. With my project, I have only studied fluids in the classroom prior to this work, so I am excited to apply that knowledge to an unsolved question.

Paridhi (Pari) Latawa

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar
Exploring the Functional Diversity of the L7-like Ribosomal Protein
Supervisors: Regina A. Barzilay and Feng Zhang

In response to viral infection, bacteria have antiviral phage defense systems that facilitate the bacterial response to phage attack. Various phage defense systems have been previously identified, but the behavior and functionality are not fully characterized. This research focuses on exploring phage defense systems such as the Class 2 UG Reverse Transcriptase (RT) defense system through computational and wet-lab analysis. By further understanding the mechanism of RT systems, we can engineer them to produce desired proteins or express activities of interest.

The SuperUROP experience will be an engaging opportunity to explore computer science and biology through hands-on, cutting-edge, collaborative research. Through this experience, I hope to integrate my knowledge in AI/ML and biology together in a research setting with real-world applications while gaining mentorship and guidance through SuperUROP!

Trent R. Lee

MIT MechE | Undergraduate Research and Innovation Scholar

Optimization of the Synthesis of Solid-State Electrolytes with Flame-Assisted Spray Pyrolysis

Supervisor: Sili Deng

Solid-state batteries are a promising alternative to lithium-ion batteries, offering enhanced safety with non-flammable solid-state electrolytes (SSEs), higher energy densities using lithium metal anodes, and potentially longer lifespans due to stable chemical components. Flame-assisted spray pyrolysis (FASP) is a scalable, cost-effective synthesis method for SSEs, involving the atomization of a precursor solution and its decomposition in a flame. Our research will optimize FASP parameters such as solution composition, droplet size, and flame conditions to improve SSE performance and consistency, advancing their application in battery technology.

Through this SuperUROP, I hope to combine my classroom interest in thermodynamics with my previous work in batteries. I'm eager to further my understanding of energy storage systems and refining manufacturing techniques, and I'm thrilled to contribute to sustainable energy solutions.

Hengzhi Li

Undergraduate Research and Innovation Scholar

Towards Socially-Intelligent Nonverbal Foundation Models

Supervisor: Paul Liang

Socially intelligent AI that can understand and interact seamlessly with humans in daily life is increasingly important as AI becomes more closely integrated with people's daily activities. However, current works in artificial social reasoning all rely on language-only or language-dominant approaches to benchmark and train models, resulting in systems that are improving in verbal communication but struggle with nonverbal social understanding. To address this limitation, we tap into a novel source of data rich in nonverbal and social interactions—mime videos. Mimes refer to the art of expression through gesture and movement without spoken words, which presents unique challenges and opportunities in interpreting non-verbal social communication. We contribute a new dataset called MimeQA, obtained by sourcing videos from YouTube, through rigorous annotation and verification, resulting in a video question-answering benchmark. Using MimeQA, we evaluate state-of-the-art video large language models (vLLMs), and reveal their limitations in understanding imagined objects and subtle nonverbal interactions. We hope to inspire future work in foundation models that embody true social intelligence capable of interpreting non-verbal human interactions.

I am participating in the SuperUROP to gain thorough research experience. I have done several UROPs in the past, mostly joining existing projects. The SuperUROP allows me to independently explore a research question from start to finish, with the guidance of expert mentors and peers. I am excited to gain deeper insight into conducting research, build on existing works in the field, and hopefully push the boundaries a bit further!

Jada Jiaxing Li

MIT EECS | Undergraduate Research and Innovation Scholar

Improvement of Human-Stem-Cell-Derived Cortical Organoid Maturation Through Reduced Necrosis

Supervisor: Kwanghun Chung

Cortical organoids recapitulate many features of the growing human cortex, including the formation of ventricular units. However, such crucial ventricular structure cannot be maintained beyond 12 weeks under the current organoid culture condition. A recent breakthrough in strategy in the Chung lab has elongated the lifespan of ventricular structures in organoids until up to 20 weeks, which has led to a remarked increase in organoid size among other significant phenotypes. This project aims to develop strategies to quantitatively analyze those phenotypes with computational pipelines and machine learning tools. Work in this SuperUROP project will significantly help our understanding of the mechanisms contributing to such enhanced organoid culture, in addition to corticogenesis in general.

Through this SuperUROP, I hope to deepen my understanding of how computational pipelines can accurately quantify significant phenotypes in vitro. My coursework in machine learning and experience in wet-lab research have prepared me to approach this project from both analytical and experimental perspectives. I am most excited to engage in hypothesis-driven discussions and scientific decision-making throughout the research process.

Arthur X. Liang

MIT EECS | Takeda Undergraduate Research and Innovation Scholar

Substructure-Aware Protein Representation Learning for Reasoning Over Proteins with Large Language Models

Supervisor: Manolis Kellis

We focus on harnessing the high-level reasoning capabilities of large language models to accelerate scientific discovery of proteins. In particular, we train large language models to utilize protein embeddings generated by state-of-the-art protein sequence and structure encoders. By infusing a large language model with the ability to directly reason over this richer representation of protein function, we produce a model that has both the flexibility and generalizability of a natural language interface as well as the grounding in fundamental biology that comes from protein sequence and structure rather than arbitrary gene names. With this model, scientists will be able to answer complex queries over the protein space as well as engage in hypothesis generation.

I am participating in SuperUROP to deepen my research experience and contribute to cutting-edge advancements in AI. With my background in machine learning, particularly in representation learning and computational neuroscience, I hope to explore new methodologies, collaborate with experts, and refine my problem-solving skills.

Katherine Lin

MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar

Data-Efficient Skill Reconstruction for Complex, Long-Horizon Tasks

Supervisor: Leslie P. Kaelbling

This project focuses on the development of a robotic planner that can learn to perform complex manipulation tasks, emphasizing the detection and application of precise forces and pressures during interaction with objects. One of the core challenges in robotic manipulation is enabling robots to execute delicate maneuvers, such as inserting a spatula under a pancake to flip it. This requires not only advanced control mechanisms but also the ability to generalize from limited data. As collecting large datasets to complete very specialized and niche tasks is often impractical in real-world scenarios, this research aims to explore data-efficient learning strategies for robotic planning and control.

I am participating in SuperUROP to leverage the experience I have gained in my previous research to work this problem. I am excited to apply my knowledge and experiences to formulate and propose my own solutions to interesting and challenging problems in robotics and planning. I aim to contribute to the field through the work I do in this coming year.

Erin Yang Y. Liu

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar

Automated fsfMRI Voxel Segmentation for Cerebrospinal Fluid Flow

Supervisor: Laura D. Lewis

Cerebrospinal fluid (CSF) plays a vital role in maintaining brain health, clearing waste, and transporting nutrients. With the development of the fsfMRI by the Lewis Lab, researchers can visualize CSF flow through the 4th ventricle along both spatial and temporal dimensions. However, manually identifying and analyzing voxels displaying CSF inflow is time-consuming and labor-intensive. This project proposes an automated system for segmenting voxels displaying CSF inflow in the 4th ventricle using machine learning techniques. First, the system will automatically segment all the voxels corresponding to the 4th ventricle. Then, it will mark the regions containing CSF flow by analyzing patterns in the spatial progression of flow across three cross-sections within the ventricle. Finally, it will extract the temporal oscillation intensity in these CSF flow regions, allowing researchers to automatically visualize CSF flow patterns from fsfMRI scans.

This SuperUROP project allows me to apply my background in machine learning with my interests in neuroimaging and brain health. As a double major in AI and neuroscience, this will be my first opportunity to combine these two disciplines together. I hope to deepen my understanding of both fields and discover how my skill set can best contribute to the amazing research at the Lewis Lab.

James Liu

MIT EECS | Nadar Foundation Undergraduate Research and Innovation Scholar
Training-Free Activation Sparsity in Large Language Models
Supervisor: Yoon Kim

Activation sparsity can enable practical inference speedups in large language models (LLMs) by reducing the compute and memory-movement required for matrix multiplications during the forward pass. However, existing methods face limitations that inhibit widespread adoption. Some approaches are tailored toward older models with ReLU-based sparsity, while others require extensive continued pre-training on up to hundreds of billions of tokens. Existing training-free approaches do not obtain substantial model-wide sparsity (around 25%). We aim to develop a method that obtains high training-free model-wide activation sparsity, and translate this to end-to-end wall-clock speedup.

I'm participating in SuperUROP to gain more exposure to the intersection of efficient machine learning with Large Language Models—a field that I have previous exposure to, but am looking to immerse myself more deeply in.

Kate Lu

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar
Genomic Analysis of Diffuse Large B-cell Lymphoma to Predict Treatment Response
Supervisor: Caroline Uhler

Detecting cancer at early stages and monitoring disease progression during treatment are critical to improving the chance of cure and decreasing cancer morbidity and mortality. However, early detection of cancer remains challenging, as most traditional methods are costly and only able to detect sizable tumors. Thus, we aim to develop a cost-effective and minimally invasive computational approach for pan-cancer detection and tumor burden estimation using data from ultra-low-coverage whole-genome sequencing of plasma-cell-free DNA (cfDNA). In this project, I will work on developing and implementing statistical inference algorithms that integrate different cfDNA measurements such as CNV and fragment length to distinguish tumor-derived from normal-derived cfDNA and estimate tumor fraction.

I am participating in SuperUROP because I want to gain research experience in computational genomics. The topic and aims of this project are aligned with my interests in cancer biology and copy number variation analysis. I am excited to learn skills needed for conducting computational research. I also hope to apply and expand upon knowledge I have learned in biostatistics and machine learning classes by working on real-world applications.

MAHMOUD ABDELMONEUM

Photo credit: Randall Garnick

EKATERINA ARUTYUNOVA

Photo credit: Randall Garnick

Photo credit: Randall Garnick

MAXIM ATTIOGBE

Photo credit: Randall Garnick

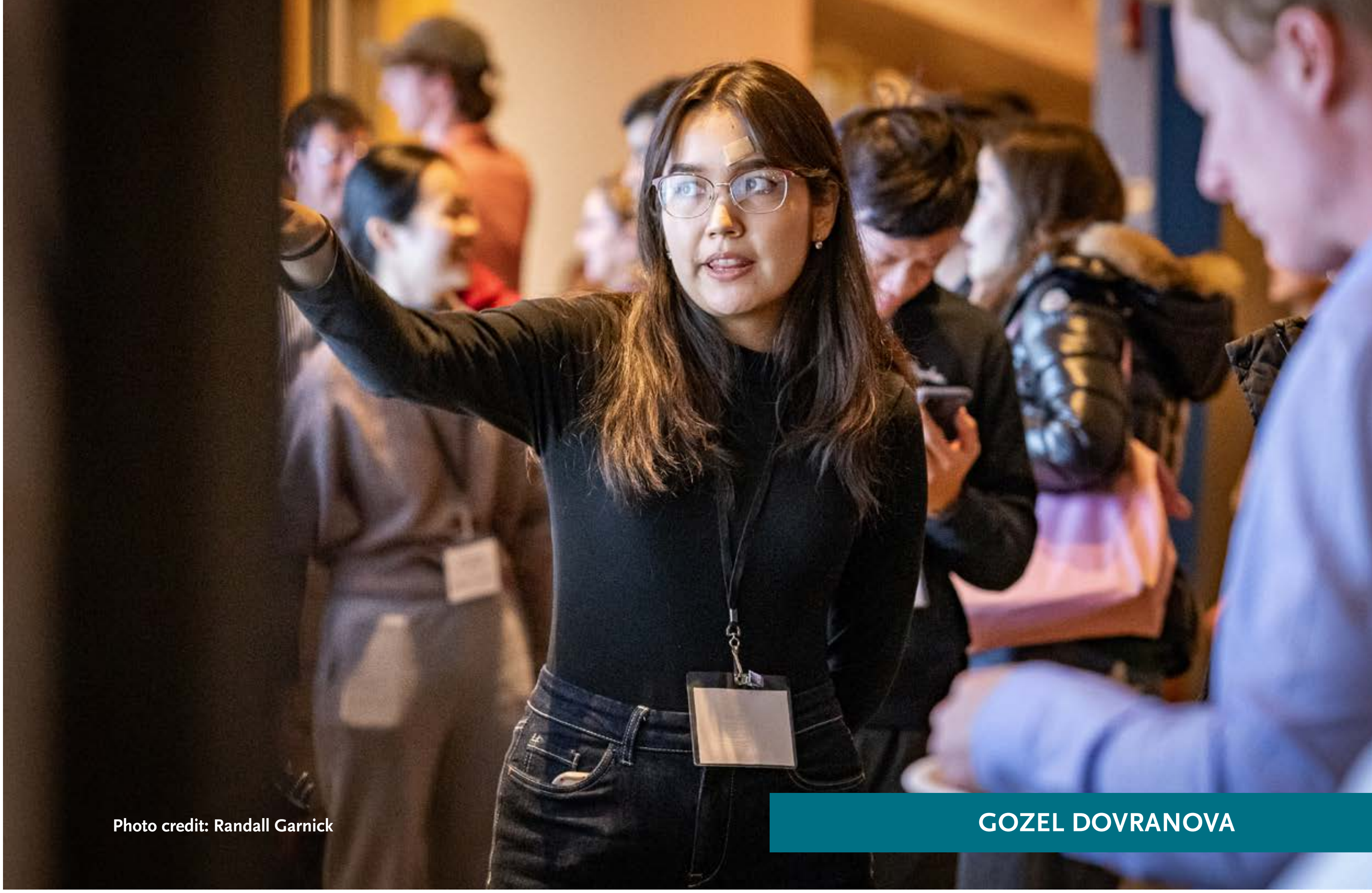
AYYOOB BERHANE

LEE CHEN

Photo credit: Randall Garnick

ALEX DANG

Photo credit: Randall Garnick



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GOZEL DOVRANOVA

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CHARIS GEORGIOU

ALMOG HILEL

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JACK KING

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ANGELICA KNUDSEN

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HENGZHI LI

JADA LI

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QUINN PERIAN

MISHAEL QURAISHI

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TITUS ROESLER

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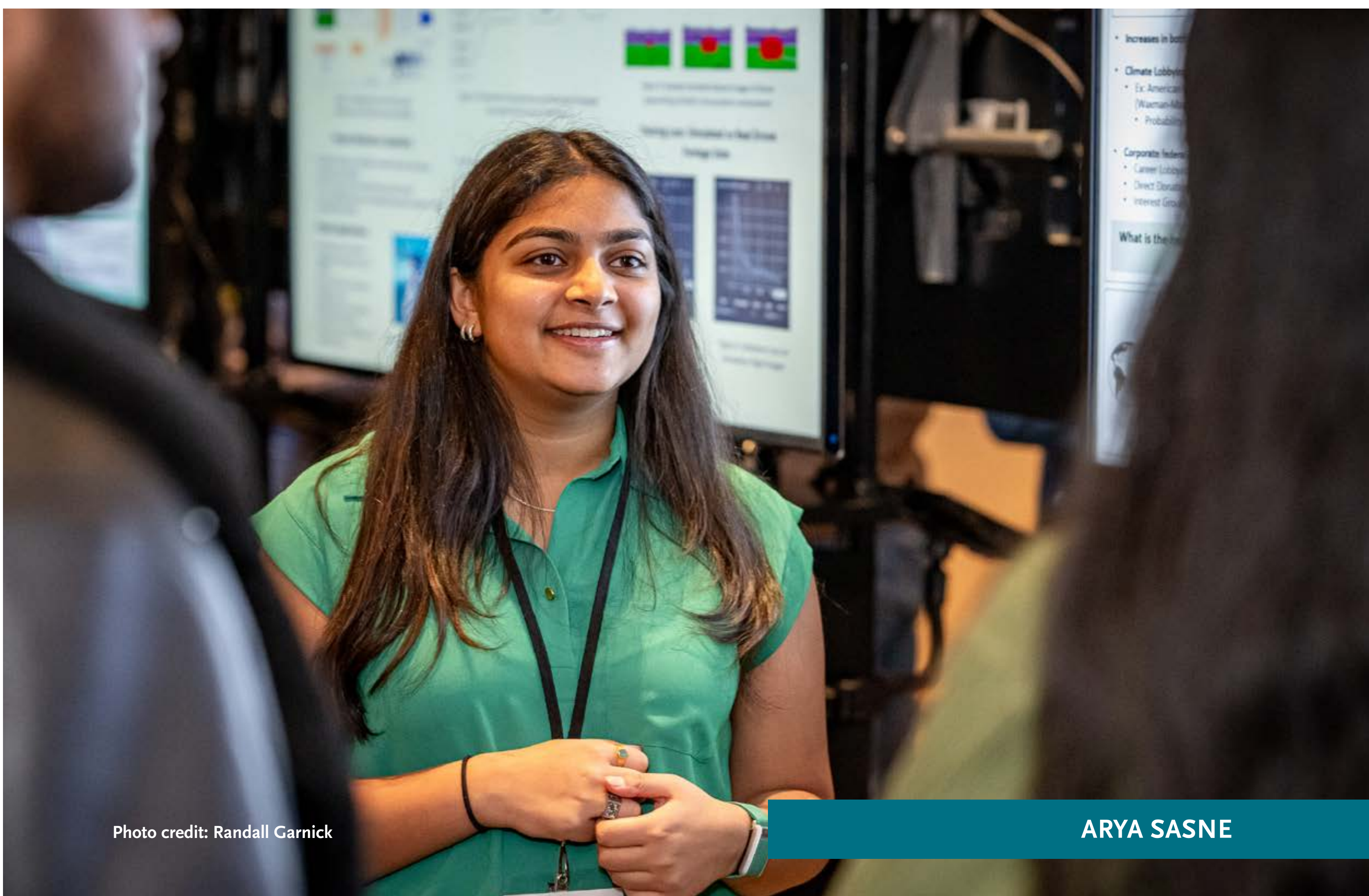
Photo credit: Randall Garnick

COLE RUEHLE



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ARYA SASNE

MAANAS SHARMA

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JULIE STEELE

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Photo credit: Randall Garnick

INIMAI SUBRAMANIAN

Photo credit: Randall Garnick

PETER ZHOU

Malachi G. Macon

MIT MechE | Undergraduate Research and Innovation Scholar

Characterizing and Mitigating Seismic Noise in Gravitational Measurements

Supervisor: Vivishek Sudhir

To further advance knowledge in modern physics, an experiment is being developed to evaluate if gravity is quantum through measuring the interactions between milligram-mass objects prepared in quantum states. The impact of outside noise sources must be mitigated to conduct such an experiment. The first focus of this project is to characterize seismic interference (for instance, vehicles, footsteps, and tides) and its impacts on the experiment using various power spectrum estimate techniques. Next, active and passive control techniques, potentially involving a mechanical suspension system or controls of an optical table, would be explored to isolate the experiment from any significant interference.

From my previous experience in developing a hardware upgrade for a linear ion accelerator used in nuclear fusion diagnostic development, I'm looking to further expand my research skills in mechanical engineering and controls through this project. I hope to gain more insights as to the process of developing experiments and am excited to put my skills to the test.

Kasra Mazaheri

MIT EECS | Quick Undergraduate Research and Innovation Scholar

VFXR: Virtual-Reality-Powered VFX & Animation Editing

Supervisor: Justin Solomon

Visual effects (VFX) and 3D animation, while ever-growing industries, remain challenging tasks with steep learning curves, due to the complexity of a myriad of things: the VFX pipeline, lack of visualization of live-action sets within VFX environments, editing realistic motion in 3D character animation. Our work introduces VFXR, a novel virtual reality system that transforms the way animators interact with CGI by merging spatial and temporal editing in a truly immersive 3D space. By allowing users to directly manipulate character joints with intuitive hand gestures and visualizing keyframes as spatial anchors within the 3D environment accompanied by ghosting effects for real-time feedback, VFXR alleviates the cognitive burden of traditional, timeline-based methods where animators have to use multiple views to work on a single CGI element. Moreover, by integrating Gaussian Splatting to reconstruct photorealistic real-world sets directly from the live-action footage, our system aims to provide a seamless, context-aware editing environment that bridges the gap between digital characters and their real-world settings during the animation/VFX process. Designed to empower both novices and seasoned professionals, VFXR aims to offer an innovative, hands-on approach that enhances motion editing and paves the way for more immersive and realistic VFX workflows.

My research interest in computer graphics stems from my passion for animation and storytelling. As an animation enthusiast myself, I have experienced firsthand the challenges of animation tools, which are often complex and hard to pick up. Therefore, I want to contribute to the animation process and the art of storytelling by designing intuitive, streamlined systems that allow anyone to bring their creative visions to life. My research tackles this massive challenge from the motion editing and scene visualization perspectives, leveraging the power of virtual reality as well as recent advances in Gaussian Splatting to make 3D animation more approachable and empower both beginners and professionals to tell their stories with greater ease and expressivity.

Jacob R. McCarran

MIT EECS | Undergraduate Research and Innovation Scholar
State Estimation and Control of Many-Body Quantum Systems Using Deep Learning Transformers
Supervisor: Dirk R. Englund

We investigate novel quantum control algorithms utilizing deep learning transformers within reinforcement learning (RL) frameworks for quantum control. Transformers excel at capturing correlations across multiple qubits and representing entanglement in large quantum systems. By employing transformers to dynamically adjust and optimize control parameters in real time, we aim to outperform existing techniques in preserving entanglement and coherence, advancing quantum computing technologies. We will compare how our transformer's attention mechanism represents a quantum state compared to information theoretic bounds such as Bayesian estimators and belief propagation, demonstrating their effectiveness in heralded optical links of spin qubits within an RL framework.

I am excited to join Prof. Englund's group for SuperUROP and learn more about using reinforcement learning to control quantum optics setups. I hope to further my knowledge in quantum engineering and use my previous UROP experience simulating Rydberg arrays to help build improved quantum control algorithms.

Camila Moran-Hidalgo

MIT EECS | Morais and Rosenblum Undergraduate Research and Innovation Scholar
Constraining Lexical Candidates in a Landmark-Based Model of Speech
Supervisors: Stefanie Shattuck-Hufnagel and Jeung-Yoon Elizabeth Choi

This research project focuses on enhancing the understanding of human speech perception by examining acoustic cues and their relationship to phonological categories. Building on the foundational work of Shipman and Zue (1982), this project aims to demonstrate that acoustic cues can effectively constrain lexical candidates, thereby advancing models of speech perception. Through the development of a computational algorithm that incorporates phrase-level information, we will calculate the likelihood of lexical candidates based on observed acoustic cues. This approach not only improves automated speech recognition and language processing systems but also offers valuable insights into the cognitive mechanisms underlying human communication.

I chose to participate in SuperUROP to enhance my ability to communicate research findings and explore a career in academia. Growing up trilingual sparked my interest in language, and this project allows me to merge that background with my academic pursuits. I'm excited to deepen my understanding of inferential algorithms by applying them to linguistics, aiming to uncover new insights into human speech recognition.

Kateryna Morhun

MIT EECS | Morais and Rosenblum Undergraduate Research and Innovation Scholar

AI-Curated Democratic Discourse

Supervisor: Jacob Andreas

Traditional social media sites tend to prioritize showing their users what will achieve the most "engagement," thereby exacerbating echo chambers and affective polarization. Drawing inspiration from cultural and political sociological theory, this project imagines a new, more prosocial way of engaging on social media, in news comment sections, and on public fora. User interfaces shape user behavior, and an alternative user interface can support more productive, enlightening discussions where new ideas can come to the forefront. We will use large language models as well as traditional NLP/ML methods to visually supplement the current conversation with selected supplemental posts from other conversations, and to give users a preview of how their messages may be received by others before they send them.

I aim to develop technology that serves the public interest. This SuperUROP will equip me with a deeper understanding of both the technically rigorous methods of designing and evaluating complex AI systems currently being used in academia and industry and the opportunities that exist to apply those methods in unexpected and beneficial ways in the real world. My background lies in web design and development and in ML model uncertainty and bias mitigation, and I'm excited to synthesize these skills and supplement them with NLP to build my researcher and developer toolkit.

Lauren Norell Nichols

MIT CEE | Undergraduate Research and Innovation Scholar

Data-Driven Decision-Making for Sustainable Forestry

Supervisor: Saurabh Amin

My research project aims to address the critical issue of illegal and unsustainable deforestation in Indonesia, driven by timber logging and palm oil cultivation. By leveraging fine-grained remotely sensed data and geospatial analysis, I will infer the network structure of strategic interactions between concession owners. I will then use game-theoretic models and random network simulations to analyze the impact of economic factors and network topologies on deforestation practices. Finally, machine learning models will be developed to design intervention policies, promoting sustainable forestry and penalizing illegal activities. The project's ultimate goal is to contribute to more effective data-driven decision-making for sustainable forestry.

I'm participating in SuperUROP to apply and expand my skills in data analysis, machine learning, and geospatial modeling to tackle environmental challenges. I have previous background in programming in Python and R. I am beyond excited to delve deeper into sustainable forestry practices and see how these tools can be leveraged to make a real-world impact and contribute to innovative solutions that protect our planet's forests.

Caitlin Christine Ogoe

MIT EECS | Nadar Foundation Undergraduate Research and Innovation Scholar

Navigating Credit Attribution in Human Group–Generative AI Systems

Supervisor: Randall Davis

DesignAID, a generative-AI-based tool for fostering creative idea generation, was created to assist designers in tackling large, open-ended problems that require extensive creative exploration and development. By presenting designers with visualizations generated by a text-to-image diffusion model based on their textual descriptions of the design space, DesignAID was able to significantly improve inspiration in comparison to traditional image search and gathering methods. However, as it stands, subsequent iteration on generated inspiration is difficult and requires the user to perform their own prompt engineering. In this project, we aim to address this challenge by creating an intuitive interface for users that allows them to identify key aspects of the system output that inspired them, enabling the user to pass that content forward to iterate and refine the idea space. This improvement should better mesh with the human creative process, furthering the utility of AI to designers.

My favorite part of computers are the people who use them, and through this SuperUROP project, I hope to empower those wonderful humans to achieve their creative aspirations.

Lucas Ospina-Quintero

Undergraduate Research and Innovation Scholar

Plant Nanobionics for Carbon-Negative Methane Conversion

Supervisor: Michael Strano

Methane is a greenhouse gas that contributes significantly to global warming, making its sustainable usage critical to climate change efforts. Plants are capable of naturally metabolizing CO_2 but not methane; however, plant nanobionics offers the possibility of engineered methanotrophic plants by using nanomaterials to introduce this non-native function. This project aims to convert methane into plant-metabolizable products (formaldehyde, methanol) using visible-light-activated nanocatalysts in H_2O_2 systems within plants, where H_2O_2 is supplied by basal plant levels or generated beyond natural levels using H_2O_2-forming enzymes within lipid vesicles. The project's ultimate goal is to develop the first ever methanotrophic plant for sustainable methane phytoremediation of contaminated sites.

Through this SuperUROP I want to apply the knowledge from my chemical engineering and material science courses to develop a novel solution to sustainability. My interdisciplinary background has given me an understanding of nanotechnologies that I hope to enrich through this independent project. Specifically, I am most excited to optimize my system such that my plants can live. I like plants!

Rishab X. Parthasarathy

MIT EECS | Citadel Undergraduate Research and Innovation Scholar
An FPGA-Based Spatial Accelerator for Sparse Matrix Operations
Supervisor: Daniel Sanchez

While current hardware accelerators, like GPUs, excel on standard matrix operations, they fail to exploit one key matrix property—sparsity—when matrices consist of mostly zeros. One such application of sparsity is reducing the computational cost of solving massive systems of linear equations, which are found in scientific computing from circuits to urban planning. Hence, in this project, our work aims to implement a custom spatial accelerator for solving these sparse linear systems. We will first develop processor elements for sparse matrix-vector multiplies and triangular solves, which will be connected via a custom networking protocol. Then, this system will be transformed into a real-world implementation on FPGAs, which we will compare to the current state-of-the-art accelerators.

Through this SuperUROP, I want to gain experience working with practical hardware applications. Drawing from my background in ML and ML Systems, I want to transfer the theoretical knowledge I acquired in Computer Systems Architecture (6.5900) to learn how to build optimized real-world accelerators for scientific computing applications. I'm very excited to expand my knowledge of digital hardware design and hopefully be able to publish my work.

Quinn Perian

MIT EECS | Takeda Undergraduate Research and Innovation Scholar
Intersectional Debiasing for Vision-Language Models (VLMs)
Supervisor: Marzyeh Ghassemi

While large language models have become increasingly prevalent, these models have been repeatedly found to display concerning racial and gender bias in a wide array of contexts. Of debiasing techniques that have been developed in attempting to address these discrepancies, most do not address motivation behind choices of gender/racial categories and representations that these techniques rely on. In my project, I test whether debiased models still show improvements when using measures of bias that rely on alternative racial categorization schema or different gender/race-related features. In so doing, I aim to examine the need for more contextually-specific debiasing algorithms that rely on race/gender features and categorization schema most pertinent to the application at hand.

Coming from a background in critical gender and race theory, I'm excited for the opportunity to be able to bring critical theory to bear on technical questions relating to debiasing in machine learning. I hope to deepen my existing background in machine learning (and natural language processing) to better understand the state of the field and how the needs of affected marginalized groups can be centered in debiasing techniques.

Mishael A. Quraishi

MIT CEE | Professor Wilson H. Tang (1966) Research and Innovation Scholar

Multi-Scale Characterization of Egyptian Blue Pigment

Supervisor: Admir Masic

Egyptian blue, the oldest synthetic pigment in human history, was first manufactured in Egypt around 3300 BCE and used widely in artwork throughout the Mediterranean until the Middle Ages. Known for its chemical stability and luminescence, this copper-based pigment holds promise in modern applications, including forensic imaging and solar-reflective paints. While its general production process is understood, gaps remain in the regional and temporal variations of these methods, particularly at the atomic scale. This study aims to address these gaps by examining ancient Egyptian blue samples from Egypt, Cyprus, and Pompeii, alongside modern replicas. Multi-scale characterization techniques, culminating in transmission electron microscopy (TEM) at unprecedented spatial resolution, will be used to investigate nanoscale structural defects and image down to individual atoms of the pigment's crystal lattice. By comparing geographical production methods from across timescales, this study seeks to uncover new insights on the materials, techniques, and energy requirements of ancient Egyptian blue production, as well as knowledge exchange across different cultures. Ultimately, this project seeks to deepen understanding of ancient craftsmanship and explore how these insights can inform modern innovations in sustainable materials engineering.

I am undertaking this project to deepen my knowledge of materials characterization while sharpening my skills as an interdisciplinary researcher. My interests lie in bridging archaeology and materials science, with an emphasis on how learning from ancient techniques can make modern practices more sustainable. Through SuperUROP, I hope to gain a comprehensive understanding of developing and fully executing a research project. I am excited for the year!

Krithik Ramesh

MIT EECS | Undergraduate Research and Innovation Scholar

Developing Efficient and Expressive Subquadratic Primitives for Biological Sequence Modeling

Supervisors: Caroline Uhler and Pardis Sabeti

Deep learning tools such as convolutional neural networks (CNNs) and transformers have spurred great advancements in computational biology. However, existing methods are constrained architecturally in terms of context length, computational complexity, and model size. We present Janus, a novel subquadratic architecture for sequence modeling, and discover for the first time that state space models can efficiently learn polynomial functions—a property that makes them inherently suited for modeling epistatic interactions in biological sequences. By integrating this mathematical insight with projected gated convolutions, Janus achieves state-of-the-art performance across diverse tasks including protein fitness landscape prediction, RNA structure analysis, and CRISPR guide design. Notably, Janus does this with significant performance improvements, both in speed and orders-of-magnitude reduction in parameters, compared to recent biology foundation models. This dramatic reduction in computational requirements enables training on consumer-grade hardware in hours rather than requiring specialized GPU clusters for weeks, democratizing access to sophisticated sequence analysis and positioning Janus as a promising tool for biological sequence modeling.

Not everyone has the computational resources to train large language models, especially biologists. My work is driven by the belief that creating efficient architectures rooted in biological principles can democratize AI insights for all.

Shruthi Ravichandran

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar

Raman Spectroscopy for Accurate and Rapid Analysis of Cell Therapy Products

Supervisors: Loza Tadesse and Sangeeta N. Bhatia

Immunomagnetic beads are used in cell therapy manufacturing for cell isolation and gene activation. Before downstream processes, beads must be magnetically removed to not exceed 10 beads per 300,000 cells, ensuring patient safety upon cell infusion. Currently, quantification requires sampling products and manually counting beads using brightfield microscopy. This process is time-intensive and prone to human error. Raman spectroscopy is a technique that captures the inelastic scattering of light to identify the molecular composition of a sample. Immunomagnetic beads have strong Raman signatures, enabling this technique to be used as a noninvasive and rapid approach to quantify low concentrations of beads in cell therapy products. Here, immunomagnetic beads of five serial dilutions of stock concentration were dropcast onto a gold-coated slide. The Raman spectra of these dried droplets was measured using a WiTech Raman system, equipped with a 732 nm laser and 10x objective lens. Single spectra were acquired using 3 mW of power with 5 second integration time and 30 accumulations. The resulting spectra were pre-processed for cosmic ray and fluorescence background removal. The maximum intensity values from three distinct peaks (1000 cm-1, 1350 cm-1, 1600 cm-1) for each spectrum were calculated. These were averaged across replicates for each sample concentration and used as features in a linear regression model. The resulting model was trained to predict the concentration based on these three features and achieved a mean squared error of 0.004 beads. Our results show Raman spectroscopy as a promising noninvasive and rapid method for quantification of magnetic beads. With ongoing research to measure lower concentrations, this work has the potential to improve the safety of cell therapy products, integrating well with existing manufacturing pipelines.

I am passionate about using EECS tools to create diagnostics for low-resource areas to make healthcare more widely accessible. I am excited to continue working with the Tadesse and Bhatia labs on their work toward the goal of diagnosing and treating childhood pneumonia. I look forward to learning more about the research process and skills through participating in SuperUROP!

Estefano Alejandro Reyes Madriz

MIT CEE | Professor Wilson H. Tang (1966) Research and Innovation Scholar

Identifying Keystones and Gatekeepers on Vaginal Microbiome Dynamics Using Causal Inference

Supervisor: Serguei Saavedra

The vaginal microbiome is a dynamic ecosystem vital to women's reproductive health, yet its regulatory mechanisms remain poorly understood. This study aims to identify keystone (positive regulator) and gatekeeper (negative regulator) species to reveal microbial interactions and their roles in maintaining ecosystem stability. By finding the connectivity of species within their regulatory network and using causal inference methods such as Average Causal Effect (ACE), the study quantifies interaction patterns, captures the strength and directionality of interactions, and evaluates species' influence on community dynamics. To validate these causal insights, microbial population dynamics are simulated using generalized Lotka-Volterra models with noise to mimic ecological perturbations. By comparing synthetic interaction patterns with causal models derived from real-world data, the study seeks to assess the robustness and interpretability of inferred microbial interactions. The research aims to provide insights that could inform targeted therapeutic strategies and improve diagnostics, contributing to a deeper understanding of microbial community dynamics and advancing knowledge in women's health.

How do we know what we know is true?

Titus K. Roesler

MIT EECS | CS+HASS Undergraduate Research and Innovation Scholar
Harmonic Source Separation in Single-Channel Audio Music
Supervisors: Eran Egozy and Dennis M. Freeman

Source separation refers to the process of extracting constituent source signals from one or more mixture signals. Access to high-quality musical sources separated from an audio mixture may facilitate downstream audio processing and music information retrieval tasks, such as audio enhancement and equalization, automatic music transcription, and content-based audio retrieval. In this project, we consider four-part chorales performed by predominantly harmonic musical instruments, such as the bassoon and clarinet. The tones produced by such instruments are often well-approximated by a superposition of sinusoids oscillating at a fundamental frequency and its harmonics. We exploit musical structure to track the time-varying fundamental frequency of each source. Using these estimated fundamental frequency trajectories, we design time-varying filter banks to extract each source.

> *I'm looking forward to tackling an open-ended signal processing problem that I find fascinating. I hope to get more experience not only with conducting independent research, but also with communicating technical concepts clearly and concisely.*

Cole Hayden Ruehle

MIT EECS | CS+HASS Undergraduate Research and Innovation Scholar
LobbyView: Exploring the Lobbying Industry with AI
Supervisor: In Song Kim

LobbyView is a data-driven project designed to analyze and visualize the influence of lobbying activities on US legislative outcomes. By leveraging machine learning, natural language processing, and large-scale government data, LobbyView aims to identify connections between financial contributions from interest groups and the subsequent legislative actions taken by members of Congress.

Arya K. Sasne

Undergraduate Research and Innovation Scholar
Analyzing US Lobbying Action Across Climate Supply Chains
Supervisor: In Song Kim

The connection between government and industry is one that is immensely complicated but highly impactful, with lobbying and campaign donations often driving change. In Song Kim's lab has developed a high-dimensional database that sheds light on the relationships between individuals, politicians, companies, and industries. In Song Kim's lab works to highlight and analyze these connections that ultimately shape public policy. By understanding the networks that connect business and politics it becomes possible to gain a clearer understanding of how society is molded. I hope to utilize my passion for climate policy and skills in computer science to create models and frameworks that analyze the relationship between climate value chains and lobbying behavior.

> *I am super passionate about climate and energy—especially the intersection of sustainable energy, business, and technology. Studying urban studies, computer science (11-6), and business (15-1); interning at the Department of Energy; and doing research, have shown me the importance of effective energy policy. Utilizing my training and experiences, I hope to be able to analyze how energy policy and decisions are made and influenced via lobbying.*

Maanas K. Sharma

MIT EECS | Landsman Undergraduate Research and Innovation Scholar
Dialect Debiasing LLMs Using Biased Character Trait Associations
Supervisor: Marzyeh Ghassemi

Large language models (LLMs) have exploded in usage, but have significant problems with social biases, misinformation, security, and more. This project examines dialect discrimination, specifically in how LLMs codify stereotypes and discriminatory decision-making against users of African American English. We propose a new method that uses biased character trait associations in large language models to decrease dialect bias in downstream use cases, including in decision-making scenarios.

> *I am excited to continue my forays into machine learning, especially in safety and fairness, through the SuperUROP program. I feel best prepared for this project by the class 6.S977, a prior UROP with my supervisor, and two years in the SERC Scholars program. I am grateful for this opportunity, and am eager to use this experience to continue working in the ML space!*

Divya Padmalatha Shyamal

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar
Experimental Design for Combinatorial Interventions with Dosages
Supervisor: Caroline Uhler

Finding an optimal intervention through sequential experimental design is a problem with many important applications in medicine and other fields. In sequential experimental design, one is repeatedly allowed to apply an intervention and observe its effects. The choice of the next intervention should depend on our observations from previous interventions—the goal is to most effectively choose the intervention at each step to help us converge toward the optimal intervention. To help us choose interventions, an estimate of how well an intervention will perform is very useful. To this end, we construct a doubly robust estimator. This estimator has been used in reinforcement learning settings. We extend it to a causal model, where the intervention can be arbitrarily "upstream." We then construct high-probability bounds for this estimator, which will inform us on how to choose successive interventions in sequential experimental design. To design a procedure, we draw inspiration from algorithms used for multi-armed bandit problems.

This project excites me for two reasons: it is strongly motivated by applications, and I get to use advanced mathematical concepts from my coursework. I am really excited to continue working on this project this year as a SuperUROP!

Shruti Siva

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar
Accelerating RTL Simulation
Supervisor: Daniel Sanchez

RTL simulation is a core stage in the chip design process that provides key debugging and performance information. However, this process is agonizingly slow and bottlenecks most chip design workloads. Though the code can be broken down into many simple tasks, each task requires large amounts of synchronization to communicate its inputs and outputs to the next module, which negates the benefits of parallelism. Accelerator of Simulated Hardware (ASH) proposes a new architecture and compiler to 1) schedule individual tasks as operands become available, and 2) selectively simulate only tasks where inputs have changed, using dataflow execution to reap the full benefits of parallelism.

My first experience with hardware outside of an academic context was writing protocol checkers for ARM's (Advanced RISC Machines) new cache coherence protocol, and I spent the summer dealing with the bane of every hardware engineer's existence: RTL simulation times. Working on this SuperUROP is a chance to solve this problem and improve the experience of hardware devs across the board.

Anson So

MIT EECS | Undergraduate Research and Innovation Scholar

Investigating the Microbiome to Uncover the Mechanisms of Inflammatory Bowel Disease

Supervisor: Manolis Kellis

Inflammatory Bowel Disease (IBD) is a chronic inflammatory condition of the gastrointestinal tract that affects millions worldwide. Though research has made strides in identifying factors contributing to IBD pathogenesis—most prominently immune dysregulation and gut microbiome composition—the causes and mechanisms of IBD remain largely unknown. Genome-wide association studies (GWAS) have successfully identified over 240 loci in the human genome associated with IBD, providing crucial insights into disease susceptibility. However, GWAS studies primarily capture IBD from the perspective of human genetics, completely overlooking the essential role of the microbiome in disease causation. Therefore, we propose conducting a Microbial-wide Association Study (MWAS) based on a clinical study of 5,000 patients at MGH, which represents the largest microbiome metagenomic dataset of IBD patients to date. This project aims to analyze the evolution of bacterial genes and mutations in IBD patients and their corresponding interactions with the human gut, using an unprecedented level of detail to explore the fundamental question: "What causes IBD?"

Kiwhan Song

MIT EECS | Nadar Foundation Undergraduate Research and Innovation Scholar

History-Guided Video Diffusion

Supervisor: Vincent Sitzmann

In this project, we develop the next version of Diffusion Forcing, a general sequence diffusion model with unique capabilities. Through several technical improvements such as latent diffusion, our goal is to showcase its enhanced performance across multiple domains such as video, natural language processing, and planning. We aim to highlight its unique features, particularly compositionality, which is challenging for baseline models, including standard diffusion models. Additionally, we will investigate the application of Diffusion Forcing in video-related tasks, including text-to-video and novel view synthesis.

Through SuperUROP, I aim to deepen my research in generative models and computer vision, collaborating closely with our talented group. With a background in machine learning research, I am excited to not only demonstrate our framework's capabilities and publish our findings, but also to provide the research community with impactful, practical open-source codes and models.

Julie Steele

MIT EECS | Nadar Foundation Undergraduate Research and Innovation Scholar
Unrestricted Adversarial Training
Supervisor: Nir N. Shavit

Currently all machine learning models are easily fooled by an adversarial perturbation to the input. Adversarial images are any images unanimously indentified as one class by humans, yet classified as another by the image model. While the field has improved on adversarial robustness against small bounded perturbations, adversaries are not constrained. Our research applies, trains, and evaluates binary adversarial training in the unrestricted adversarial setting. Binary adversarial training contrasts with regular adversarial training by penalizing entering an adversarial target-class instead of rewarding staying in the original image class. In addition, we extend binary adversarial training to multiple classes. We evaluate with suites of gradient-based image attacks.

I love research because I love puzzling over hard problems. I'm excited to think creatively about how to solve this unsolved problem of training a robust image classifier, and to gain more hands-on experience training models and crafting research directions. In addition, I hope to improve my technical communication through SuperUROP. I hope research in adversarial robustness can get us closer to building trustworthy AI models.

Inimai A. Subramanian

MIT EECS | Landsman Undergraduate Research and Innovation Scholar
Fixed Parameter Sparse Expansion
Supervisor: Nir N. Shavit

Previous scaling laws for sparsity have shown that, for the same parameter count, larger sparse models outperform smaller dense ones. Furthermore, there has been significant work in the realm of neural network growth—using a small, pretrained model to seed the training of a larger neural network, without having to train the large one from scratch. However, growing a smaller network into a larger network while keeping the parameter count fixed has not previously been explored. We duplicate the neurons in a layer and apply sparse masking techniques such that each original weight appears exactly once across the expanded neurons. This maintains the parameter count while allowing for increased representational capacity through additional neurons. Doing so would allow additional performance at a negligible increase in training and inference cost. This is as opposed to the other two avenues, where post-training sparsification requires a significant amount of training compute, and where unconstrained network growth requires additional inference cost. We have shown initial promising results in toy models, and are working to bring our findings into more state-of-the-art systems, such as language models.

The SuperUROP program will allow me to deepen my knowledge in machine learning and take ownership of a project. Having built a machine learning tool in an internship and taken related classes, I hope to apply my skills to advanced research, further my understanding of developing intelligent systems, and provide meaningful contributions to the field. The hands-on experience gained will prepare me to tackle future engineering challenges.

Ayantu Mulugeta Tamene

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar

Advancing Cancer Dependency Prediction Through Integration of Novel Genomics Features

Supervisor: Caroline Uhler

Gene sequencing reveals potential causative variants and gene expression patterns for further follow-up studies of gene expression and regulation mechanisms. The Cancer Dependency Map (DepMap) project uses functional genomics to pinpoint essential genes for cell growth in cancer models, aiding in new therapeutic development. DepMap identifies dependencies via CRISPR screening to find genes linked to specific cancer phenotypes. My aim for this project will be to pinpoint mutations causing cancer-driven alternative splicing and integrate this data into our model to explore its connection to cancer dependency and other genomic features, which could inform new therapeutic strategies.

Through this SuperUROP, I aim to enhance my research skills in computational biology and improve my ability to communicate findings. I am particularly interested in using machine learning to tackle complex biological problems. I look forward to applying knowledge from my computer science, biology, and bioengineering courses to identify cancer dependencies that can lead to the development of more precise and effective cancer treatments.

Grace Tian

MIT EECS | Undergraduate Research and Innovation Scholar

LLM Fine-Tuning with Insights from Optimization

Supervisor: Justin Solomon

Large language models (LLMs) are typically pre-trained on extensive datasets and subsequently fine-tuned on smaller, task-specific datasets. One common method of fine-tuning is low-rank adaptation (LoRA), which uses low-rank updates of matrix parameters. However, the impact of changing the rank of LoRA during fine-tuning remains poorly understood. Understanding LoRA rank dynamics is a crucial step toward making LoRA more efficient. This project examines the influence of changing rank during LoRA using insights from optimization theory, aiming to provide both theoretical grounding and experimental results.

Through SuperUROP, I want to apply my machine learning knowledge from past coursework and projects to complete a longer research project. I am excited to expand my understanding of machine learning and large language models, and to learn more effective communication for presenting my work. I hope to keep up with this fast-moving field, and to contribute meaningfully.

Srinidhi Venkatesh

MIT EECS | Quick Undergraduate Research and Innovation Scholar
Nanotechnologies for Brain-Inspired Computing
Supervisor: Farnaz Niroui

Improving the speed and efficiency of modern-day computing systems has been a goal of the technological world since the inception of computers. My project aims to reduce the bottleneck between memory and computing in traditional von Neumann computing architectures by directly embedding computing into the memristive behavior of nanoscale devices. Next steps in our project include in-depth characterization and testing of the fabricated memristors through the use of various lab testing equipment to extract data about device behavior. Upon analyzing factors such as the frequency and bias windows under which these devices function optimally, the project will focus on bridging the gap between high-level electrical properties of these systems, and designing devices for specific applications.

I am researching as a part of SuperUROP because I am interested in researching the intersection of electrical properties of nanotechnologies with computing. I have previously worked on nanoscale device characterization and hope to learn more about how such devices can be understood and applied in usable circuitry and systems.

Will M. Vu

MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar
High-Power Microwave Vector Modulator for Interference Cancellation
Supervisors: Negar Reiskarimian and Kenneth E. Kolodziej

Expanding spectrum usage and needs for in-band full duplex transceiver capabilities requires increasing levels of receiver isolation from unwanted emissions. My research focuses on the development of a high-power vector modulator for use as signal taps in an active interference canceller. Creating this device will involve novel techniques for pushing RF device linearity at extreme power levels and wide bandwidths, while maintaining a small form-factor suitable for integration as a drop-in component in existing radio transceivers. Such findings will help further the development of next-generation electronic protection and joint radar-communications technologies. My work will be demonstrated as part of a radio front end to display its capacity to reject unwanted interference.

SuperUROP is providing me with the opportunity to engage in advanced research with resources to help me succeed and prepare me for future endeavors in academia and industry. I have been prepared for this project through my previous research at MIT Lincoln Laboratory and I am excited that I am able to continue to work with them through SuperUROP, where I hope to better understand the formal research process.

Michelle Wang

Undergraduate Research and Innovation Scholar

Electrochemical Formation of N-nitrosamines in Agriculturally Impacted Waters

Supervisor: Desiree Plata

Electrochemical water treatment technologies offer a promising approach to contaminant degradation without chemical additives. However, concerns about harmful byproduct formation remain underexplored. This study reports the electrochemical formation of N-nitrosodimethylamine (NDMA), a probable human carcinogen, from waters containing nitrite and nitrate, even at concentrations regulated by the US Environmental Protection Agency (USEPA), through reactions with dimethylamine (DMA). Observed NDMA yields (200–300 ng/L) significantly exceed the EPA screening level (0.11 ng/L), presenting a notable risk for electrochemical treatment deployment in nitrate/nitrite-impacted waters, particularly in agricultural regions. The study contextualizes the electrochemical potentials that facilitate NDMA formation by comparing them against methyl orange degradation, a model anionic azo dye frequently used to assess oxidative electrochemical processes. NDMA formation was examined using a novel 3D-printed flow cell equipped with high-surface-area carbon nanotube electrodes, allowing for rapid and environmentally relevant observations. More broadly, this work demonstrates that electrochemical screening can serve as a predictive tool for byproduct formation, offering a faster, more scalable alternative to traditional chemical oxidation tests, such as uniform formation condition methods. These findings highlight the need for careful optimization of electrochemical treatment conditions to mitigate unintended nitrogenous byproduct formation and ensure the safe application of these technologies in water treatment.

I'm excited about this SuperUROP opportunity because it will help me develop the skills needed for independent research. Through this project, I aim to apply my coursework to create an innovative solution for addressing water contamination and improving water treatment sustainability.

Jinhee Won

MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar

Exploring Computer Vision and Machine Learning Models to Better Predict Infections in Surgical Wounds

Supervisor: Richard Fletcher

Wound infections, particularly Surgical Site Infections (SSIs), represent a major healthcare challenge globally, especially in low-resource settings. This project aims to develop a mobile-based machine learning model for accurately detecting SSIs from wound images by utilizing both RGB and thermal data. Building on previous research, I will explore and optimize various machine learning models, incorporating advanced techniques such as feature engineering and transfer learning. I will also evaluate the performance of these models across different computational platforms, including laptops, servers, and Android devices. The ultimate goal is to create a robust, scalable model that can be deployed widely, helping to reduce the incidence of SSIs and improve patient care worldwide.

I am participating in SuperUROP to gain in-depth research experience and apply my knowledge in machine learning to a challenging problem in healthcare. My background in computer science, particularly in image processing and AI, has prepared me well for this project. I'm excited to learn more about the research process, refine my technical skills, and work toward publishing a paper.

Elisa T. Xia

MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar
Computer Vision for Endotracheal Intubation
Supervisor: Thomas Heldt

Endotracheal intubation (ETI) is a high-stakes, lifesaving procedure that is necessary when patients need assistance in breathing effectively. The procedure involves the insertion of a breathing tube through the mouth or nose to keep the airway open and to deliver oxygen. Failure to complete the procedure correctly could lead to a high risk of death or permanent neurologic impairment. With the use of video laryngoscopy for ETI, there are sizable data archives of successful and failed intubation attempts. The goal of this SuperUROP project is to use these data archives to develop a computer vision model to aid physicians in the ETI procedure. The model will automatically detect anatomical landmarks in real time and suggest trajectories for optimal placement of the endotracheal tube. This project involves a collaboration with colleagues from Boston Children's Hospital.

I joined SuperUROP because I am interested in applying hands-on what I have learned through my coursework at MIT through my own research project. Through my SuperUROP experience, I hope to advance my knowledge in computer vision, learn fundamental research-based skills, and grow as an independent researcher. I believe there is great potential in the application of AI in healthcare to enhance patients' lives, and I hope to be part of future advancements in this promising field.

Vanessa Xiao

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar
Towards Latent Disentanglement of Multi-Modal Cell Painting Data with Drug Perturbations
Supervisor: Caroline Uhler

Drug discovery and mechanistic biology both hinge on our ability to link chemical structure to cellular response. However, high-content imaging modalities such as cell painting assays often blend captured shared and channel-specific signals, obscuring the precise morphological changes induced by chemical perturbations, hindering interpretability and downstream analysis. To address this, we introduce a modular pipeline that employs 1) APOLLO, a variational autoencoder with partially overlapping latent spaces, to disentangle shared versus channel-specific morphological features; 2) uses fully connected neural networks trained on these latent embeddings to detect and localize perturbation effects; and 3) integrates molecular embeddings to highlight functional substructures driving phenotypic changes. Applied to the large-scale JUMP CP dataset and an independent collaborative cell painting dataset, our approach separates control and treated cell profiles, isolates morphological alterations across chromatin and other organelle channels, and pinpoints key molecular motifs linked to observed effects. This framework enhances the interpretability of cell painting data and provides a scalable strategy for mapping compound chemistry to cellular phenotypes.

Having done undergraduate research at MIT these past two years, I'm excited to embark on a more intensive research journey through SuperUROP this academic year within the field of computational biology. I'm interested in gaining more experience in representation learning for multi-modal data, and I hope to publish a paper on my work given any significant results.

Grace Yang

MIT ChemE | Raj. V. Tahil (1981) Research and Innovation Scholar

Engineering Electrochemical Whole-Cell Biosensors for Detection of Soil Nutrients

Supervisor: Ariel Furst

Of the nutrients present in soil, 18 have been identified as essential for plant growth. These include phosphate, nitrate, potassium, calcium, magnesium, manganese, zinc, copper, and boron, which are necessary in different quantities. To measure soil health for plant growth, it is important to measure nutrient levels within the soil and ensure it remains in the necessary range for plant growth. In light of this, we propose to engineer *Shewanella oneidensis* to create an electrochemical sensor platform to monitor nutrient levels in soil. This platform will hinge on engineering the EET pathway of *S. oneidensis* such that electron transfer occurs in the presence of and proportionally to the amount of a certain nutrient, allowing electrical signal to be used as a proxy for nutrient quantity.

Through SuperUROP, I am looking for the opportunity to immerse myself in research. I want to apply the theoretical knowledge I have gained from coursework, as well as the technical skills earned through past UROP projects and internships, to carry through an engineering-based project.

Maggie Huili Yao

MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar

Latent Vision-Aided Sensor Recalibration in Soft Robotic Systems

Supervisor: Daniela L. Rus

Nature and evolution have produced remarkably capable organisms, inspiring engineers and researchers to create robots that replicate the versatility and resilience from the highly complex and functional physiologies of the natural. As a result, soft and bio-inspired robotics have emerged as a promising area of innovation in recent years because of their unprecedented flexibility and adaptability, but their continuously deformable structures pose significant challenges for modeling and control. Machine learning has emerged as a powerful tool for soft robot perception, enabling proprioception and control through sensor-driven neural networks. However, these approaches face two key challenges: performance degradation over time due to material wear and sensor shifts, and the difficulty of learning meaningful representations in highly underactuated systems as onboard sensors may not provide a signal informative enough. Our research systematically investigates how neural network performance deteriorates as system parameters change, using soft robotic simulations of a trunk and a cable-actuated gripper. We additionally propose a novel latent vision-aided sensor recalibration framework that utilizes vision-based latent encodings to fine-tune sensor models without requiring full retraining or continuous visual input during deployment. This approach retains the benefits of vision systems while mitigating their computational and environmental limitations, improving the adaptability of learning-based soft robot models and reducing the need for costly and time-intensive retraining.

I am participating in the SuperUROP program because I am interested in exploring the intersection between machine learning and robotics. I am excited to be able to develop additional research skills as well as to pursue a more independent project. I have previously taken subjects in the domain and performed machine learning research, and so I hope to leverage my knowledge toward real-world applications.

Alexander Zhang

MIT EECS | Mason Undergraduate Research and Innovation Scholar
Learning Generative Models for 3D Molecule Generation
Supervisor: Wojciech Matusik

Generative AI technologies have proved their usefulness in several information processing applications, but struggle with complex tasks such as spatial reasoning and complex design problems. As a result, they are inadequate for a truly transformative impact in the design and manufacturing domain due to a variety of shortcomings, including those with creating unrealistic 3D models. We combine deep learning with the symbolic graph grammar framework to tackle the inverse design problem for 3D shapes. We develop a versatile infrastructure for this system, including building and pre-processing a high-quality, comprehensive 3D shape dataset, advancing grammar learning algorithms, and refining 3D shape generation and analysis method, to produce geometry- and topology-aware 3D shapes.

I am participating in SuperUROP because I would like more experience in research. I worked on computational geometry research projects in high school and would love to delve deeper into this field. I believe 3D shapes are very important for a lot of growing fields, such as VR and robotics, so I'm excited to work on cutting-edge techniques to generate accurate 3D models.

Eileen Zhang

MIT MechE | Undergraduate Research and Innovation Scholar
Electrolyser Sensitivity to Intermittent Renewable Energy Systems
Supervisor: Amos Winter

Green hydrogen is a sustainable alternative to diesel fuel because it has high energy density and can be used to generate electricity without emitting carbon dioxide. It is produced using renewable energy via electrolysis, a process where electricity separates water molecules into hydrogen and oxygen gas. While green hydrogen has the potential to decarbonize many industry sectors, one challenge preventing its adoption is the inability of electrolysers to produce hydrogen at scale. This project focuses on reducing the cost and improving the efficiency of electrolysers by assessing methods for reducing air bubble formation on cathode/anode plates and creating ideal conditions for electrolysis reactions to take place. Using these insights to form design requirements and investigate limitations of current electrolyser designs, this project aims to develop an improved electrolyser system.

I am excited to explore my interests in energy and develop my capabilities as a researcher through the SuperUROP program. As I learn and contribute to this project, I hope to uncover meaningful insights and help advance green hydrogen usage in the future.

Ellen Zhang

MIT EECS | Takeda Undergraduate Research and Innovation Scholar
Diagnosing Orthostatic Hypotension from Nocturnal Breathing Signals
Supervisor: Dina Katabi

Orthostatic Hypotension (OH) is a valuable biomarker for neurological diseases such as Parkinson's disease and Alzheimer's. It is known that OH can be caused by autonomic dysfunction, one of the early markers of neurodegeneration. However, the current diagnosis of OH is quite tedious and infeasible in a clinical setting; therefore, it is vastly underdiagnosed, despite its value. Our goal is to detect OH using machine learning transformer models using data from 1) EEG signal, 2) respiration signal, and 3) wireless-signal-based respiration signal. This would allow for a simple and accurate at-home test for OH.

I am interested in the potential of AI when applied to healthcare because of its practical uses and the large amount of data available. In particular, our research involves signal processing, transformer architecture, and data analysis, and I hope to be able to gain a pragmatic understanding of these areas. I hope that through the research process, I will develop my critical thinking and awareness of the current field, while creating and exploring the application of AI in medical diagnosis.

Jason Zhang

MIT ChemE | Undergraduate Research and Innovation Scholar
Improving Template-Based Retrosynthesis Predictions with Reaction Context
Supervisor: Klavs Jensen

Retrosynthesis is the process of recursively simplifying a desired target molecule into smaller and less complex starting materials. Retrosynthesis is a cornerstone for organic chemistry, offering pathways or synthetic routes to create important chemicals such as medicines and novel materials. Previous template-based approaches have used ML to predict the precursors given a target compound. This work demonstrates that the addition of pathway level information improves the accuracy of the retrosynthesis model.

Through this SuperUROP, I want to use computational approaches to tackle chemistry problems. I wish to apply my classroom knowledge from chemistry and engineering to discover pathways to synthesize a target compound. I am excited about tackling chemistry problems from a computational angle, and I hope to improve my presentation skills and publish a paper after completing this program.

Xenia Zhao

MIT EECS | Morais and Rosenblum Undergraduate Research and Innovation Scholar
Mapping Tree Species in Drone Imagery
Supervisor: Sara Beery

Mapping plant species in forest ecosystems is crucial to advancing our understanding of forest ecology, invasive species mitigation, carbon sequestration potential, and more. UAV-based surveys both have high resolution and are economically scalable, but are not often used in natural scenes due to matching ambiguity and articulated geometry (e.g., due to wind). The goal of this project is to research adapting ML-based species mapping approaches to use unprocessed UAV imagery. This project seeks to (1) develop approaches for sampling of informative views while (2) minimizing duplicate manual labeling effort and (3) computing geolocation by reconstructing geometry, with the end goal of (4) accurately labeling and categorizing plant species or health.

I'm participating in SuperUROP because I want to work on interesting research problems, and this is a great opportunity to learn from the experts in the field. As an AI major who has taken Advances in Computer Vision, I feel lucky to be able to use computer vision in my project on such an impactful topic as mapping forests.

Renggeng (Reng) Zheng

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar
Finding Efficient Fungible Buffer Data Placements
Supervisor: Joel Emer

Data movement is a significant component of the energy consumption for most computer architectures. Fungible buffers, a group of multiple small buffers abstracted into a larger buffer, have been proposed to reduce the cost of data movement, as there is a positive relationship between buffer size and per-data energy access cost. A challenge of fungible buffers is that data placement within the physical buffers impacts the distance data has to move, meaning poor data placements can undermine the benefit in energy per access from smaller buffers. Our work aims to optimize data placements in fungible buffer systems, building off of a newly developed efficient fungible buffer simulator, to quantify their benefit when implemented on existing architectures.

I want to pursue computer architecture industry research, which this SuperUROP will give me experience in, as it involves modifying and using Nvidia Timeloop. My two years spent UROPing in the MIT EEMS group under Professors Emer and Sze gave me the knowledge needed for this project. I'm excited to do more simulation work to gain intuition on what makes a good computer architecture and to learn more about efficient research processes.

Zixiang (Peter) Zhou

MIT EECS | Nutanix Undergraduate Research and Innovation Scholar

Approximate Nearest-Neighbor Search with Filters

Supervisor: Charles E. Leiserson

Various data types can be mapped into high-dimensional embedding vectors through deep learning models. The ability to query the closest vectors to a given query vector enables semantic search, which has numerous applications in recommendation systems and machine learning. Since an exact solution is computationally infeasible, many approximate nearest-neighbor search (ANNS) systems have been developed. However, real-world applications may impose structured label constraints on the desired search results, a variant of ANNS known as filtered search. Despite the smaller search space, it is challenging to integrate filters with vector search efficiently, and existing methods waste a lot of computation processing irrelevant vectors. This project aims to improve previous filtered search systems and build a vector database that scales to billion-scale datasets.

> *Through this SuperUROP, I hope to apply my background in theoretical algorithms (e.g., from 6.5210 Advanced Algorithms) and C++ programming to a long-term research project with real-world applications. I hope to learn more about performance engineering and parallel computing as well as develop valuable skills required in academic research.*

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