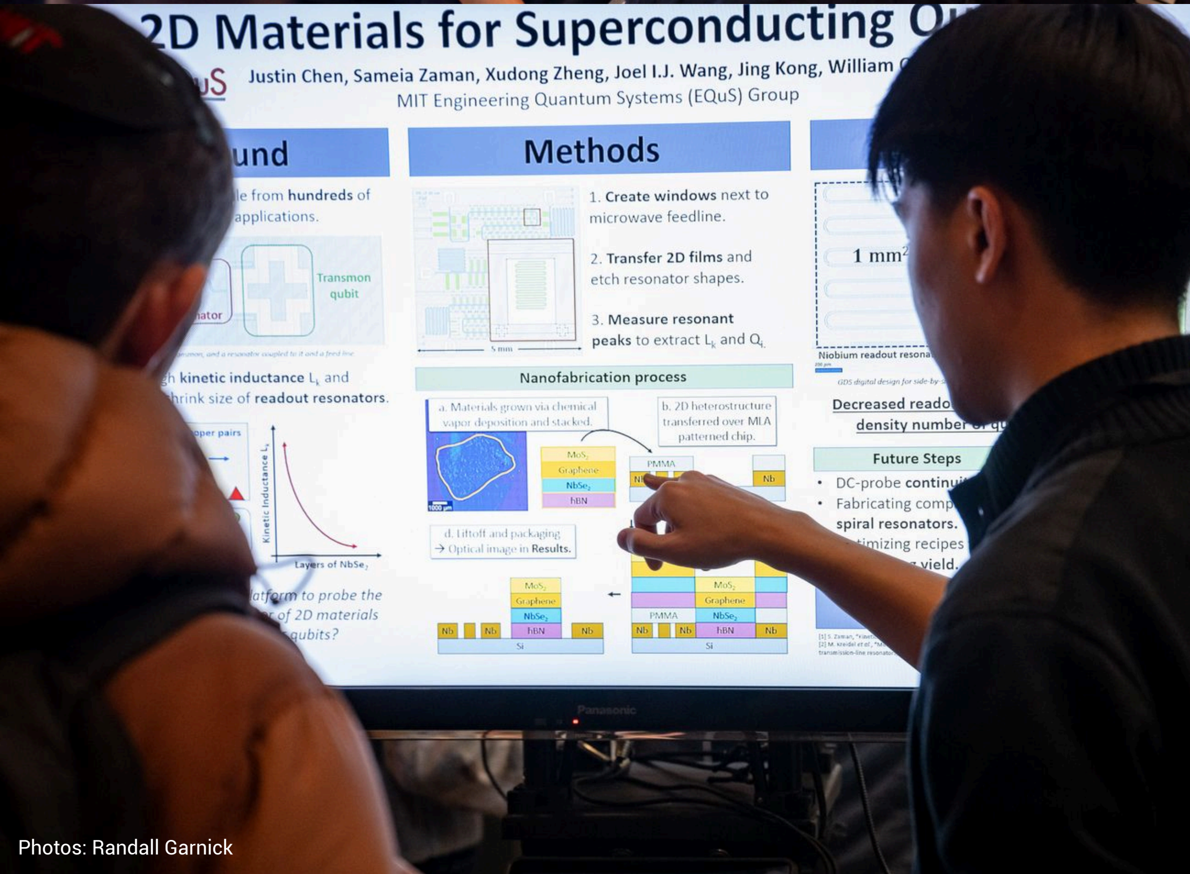
SuperUROP

Advanced Undergraduate Research Opportunities Program

2025-2026 Research Guide



Photos: Randall Garnick

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SuperUROP tackles the most pressing challenges facing our world today and sets the stage for our students to pursue careers in research, 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
MIT Provost
Vannevar Bush Professor of Electrical Engineering and Computer Science

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 1,390 undergraduates with the research tools they need to tackle real-world problems by giving them the chance to engage in yearlong 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. This 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, MIT Provost 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 374 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

Photos: Randall Garnick

New Initiatives

New SuperUROP funding advances MIT's institutional priorities

MIT's President, Sally Kornbluth, recently unveiled two major new initiatives focused on important issues of the day: MIT's Health and Life Sciences Collaborative (MIT HEALS) and The MIT Generative AI Impact Consortium (MGAIC).

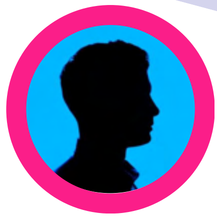
MIT HEALS supports the convergence of world-class expertise across MIT and creates connections with industry leaders in biotechnology, pharmaceuticals, and hospitals—to catalyze discovery, innovation, and impact for human health.

MGAIC brings together faculty, students, and industry partners to harness the power of generative AI for the public good.

Both MIT HEALS and MGAIC are now collaborating with SuperUROP to fund student projects in alignment with their goals. While MGAIC's funding will focus on research in generative AI, responsible AI, and applications that drive societal benefits, MIT HEALS's funding will support research at the intersection of health, well-being, equity, and technology.

New Initiatives

You can find MGAIC- and HEALS-funded projects throughout this booklet; look for student portraits marked with the hot pink circle:



The new SuperUROP projects offer the opportunity for research groups and students alike to advance MIT's strategic priorities, whether developing open, collaborative AI solutions, or catalyzing discovery, innovation, and impact for human health.

Scholars

Eric and Wendy Schmidt Center Funded Research and Innovation Scholars

Kyra M. Henriques
Jeffery Lin
Aarushi Mehrotra
Amanda T. Miyares
Anisha Parsan
Sora S. Shirai

MIT AeroAstro | Boeing Undergraduate Research and Innovation Scholar

Trevor E. Johst

MIT | Tang Family FinTech Undergraduate Research and Innovation Scholar

Akshata Tiwari

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

Victor Gabriel Dominguez
Elian Kai Juarez
Diego Alejandro Temkin

MIT CEE | Undergraduate Research and Innovation Scholar

Tananya Prankprakma

Scholars

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

Julia Casey
Amanda Cheng

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholars

Justin Chen
Stanley Chen
Kieran N. Dunn
Gwyneth Liu
Matan Z. Yablon

MIT EECS | Boeing Undergraduate Research and Innovation Scholar

Michelle J. Wang

MIT EECS | Citadel Undergraduate Research and Innovation Scholars

Arul Kolla
Shirley T. Xu

Scholars

MIT EECS | Fano Undergraduate Research and Innovation Scholars

Benson Zhan Li Lin

Ashley Y. Zhang

MIT EECS | Guillemin Undergraduate Research and Innovation Scholars

Jonathan Tjandra

Nicole Z. Xu

MIT EECS | Hudson River Trading Undergraduate Research and Innovation Scholar

Yaman Bora Otuzbir

MIT EECS | Landsman Undergraduate Research and Innovation Scholars

Arnav Aggarwal

Noah J. Wiley

Katherine Xie

MIT EECS | Mason Undergraduate Research and Innovation Scholars

Nethaka (Ne) S. Dassanayake

Hannah Y. Gao

Scholars

MIT EECS | Morais and Rosenblum Undergraduate Research and Innovation Scholar

Carolina Moura Valle Costa

MIT EECS | Nadar Foundation Undergraduate Research and Innovation Scholars

Daria Kryvosheieva

Alicia Li

MIT EECS | Philips Undergraduate Research and Innovation Scholars

Eric Alfaro

Alexander K. (Alex) Franks

Sophie L. Wang

MIT EECS | Quick Undergraduate Research and Innovation Scholars

Jeewoo Kang

Marshall N. Taylor

MIT EECS | Sam Goldwasser Undergraduate Research and Innovation Scholar

Jue Gong

Scholars

MIT EECS | Takeda Undergraduate Research and Innovation Scholar

Anastasia Dunca

MIT EECS | Tenev Family Undergraduate Research and Innovation Scholar

Megha M. Hegde

MIT EECS | Undergraduate Research and Innovation Scholars

Isha Agarwal
Jay Matthew Bhan
Evan Eunjae Kim
Johlesa Miyheak Orm

Scholars

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholars

Nupur Ballal
Annie-Minyi (Minyi) Chen
Jasper Lee
Charikleia (Hara) Moraitaki
Janina Ojeiduma
Roshni Parulekar-Martins
Krishna Parvataneni
Monica Ann Petulla
Diya Lakshmi Ramesh
Keonna Charlize Simon
Magdalena (Maggie) Slowikowski
Tiffany Stephens
Sophie M. Thompson
Zuri Mary Vallery
Jason Christopher Wang
Josephine Wang
Clara Y. Zhu

Scholars

MIT MechE | Sea Grant Undergraduate Research and Innovation Scholar

Ved Ganesh

MIT MechE | Undergraduate Research and Innovation Scholars

Florida Mahano Cishesa
Sarah Habona
Christiana Pak Nguyen
Mario Javier Sanchez Mendez

MIT MGAIC | MIT Generative AI Impact Research and Innovation Scholars

Cheuk Hei Chu
Arthur De Los Santos
Harrison Liang
Nilay Mishra
Serena H. Pei
Greycen Ren
Manxi (Maggie) Shi
Joel Junyao Tan

Scholars

Undergraduate Research and Innovation Scholars

Thomas Watson Brewitt
David Burke
Abdel Kareem Abdallah Dabbas
Can (Rachel) Jiang
Eugene Y. Jiang
Varun Sangtani
Aditya Shrivastava
Unyimeabasi Usua
Alexandra Valdepenas
Medha Venkatapathy
Isabella Yunfei Zeng

Isha Agarwal

MIT EECS | Undergraduate Research and Innovation Scholar

A Mechanistic Analysis of LLM & User Persona Interaction Bias

Supervisor: Marzyeh Ghassemi

Personas, simulated roles assigned to Large Language Models (LLMs), have emerged as a useful tool for task personalization as the popularity of LLMs has risen. In addition to adopting their own personas, LLMs have also been shown to maintain and update an internal user model based on user inputs. While prior work has studied these aspects of personalization in isolation, we propose that the interaction between the LLM persona and its internal user model captures crucial behaviors and biases. We use linear probing and representation analysis to explore how interactions between the LLM persona and user profiles are embedded in each layer of the network. Through this analysis, we demonstrate that the interaction between the persona and user model impacts both the internal LLM processing and downstream responses to user queries. Furthermore, we provide evidence that, based on user interactions, an LLM changes how it internally represents and relates its own personas. These results underscore the potential harms and biases that LLMs propagate in trying to maximize personalization.

By participating in SuperUROP, I hope to gain more hands-on experience completing an end-to-end research project. I'm particularly excited to apply my prior research experience in mechanistic interpretability from UROPs and summer programs to debiasing research. I look forward to learning more about interpretability and bias in AI while making a meaningful contribution in this space.

Arnav Aggarwal

MIT EECS | Landsman Undergraduate Research and Innovation Scholar

Predicting EEG Spectrograms from fMRI to Identify Brainwide Activity Underlying Neural Rhythms

Supervisor: Laura D. Lewis

Simultaneous EEG-fMRI combines the high temporal resolution of EEG and the high spatial resolution of fMRI, allowing us to investigate the spatiotemporal dynamics of electrophysiological neural rhythms that underlie cognition and vigilance. However, the complex relationship between fMRI and EEG signals and the substantial inter-subject variability in how these signals are related make jointly analyzing the two challenging. As a novel approach for analyzing EEG-fMRI, we developed a machine learning framework to decode EEG spectrograms (0-17.1 Hz) from brainwide fMRI data. By predicting spectrograms, our model leverages the covarying structure of neural oscillations. Our model consists of an RNN encoder and a nonlinear fully-connected decoder. We created a Subject Generalization model that predicts EEG spectrograms for unseen subjects, and a Subject Specific model that learns individualized EEG features. We applied this approach to an EEG-fMRI dataset of 27 subjects transitioning through wakefulness and non-REM sleep stages, brain states which are defined by neural rhythms. We found that the Subject Generalization model accurately decoded EEG spectrograms. The Subject Specific model significantly improved decoding for all frequencies above 6 Hz, demonstrating that inter-subject variability in the EEG and fMRI relationship is smaller in slower frequencies. To determine which brain areas contain predictive information, we trained models on each gray matter region. We found that certain networks, such as arousal systems, broadly decoded all frequencies, whereas others were selectively predictive of specific rhythms, such as the visual network predicting alpha (8.5-12 Hz). However, decoding benefited from learning simultaneously from all brain regions, demonstrating that they contain complementary information. Our results show that fMRI contains rich information about neural rhythms that allow decoding EEG dynamics, and that this information is distributed across large-scale brain networks. Additionally, this approach enables investigation of brainwide dynamics underlying oscillatory activity in a variety of experimental paradigms.

I am participating in SuperUROP because it is an amazing opportunity to bolster my research experience, specifically learning how to solve problems that have not been solved before. Additionally, I am interested in the intersection of machine learning and neuroscience, specifically how we can use machine learning to learn more about the brain and cognitive processes. I believe this SuperUROP will help me start answering this question.

Eric Alfaro

MIT EECS | Philips Undergraduate Research and Innovation Scholar

Real-time Processing and Visualization of Brain Signals to Enable Screening of Cognitive Impairment

Supervisor: Richard R. Fletcher

Recent developments in wearables have made it possible for consumers to monitor their brain data through electroencephalography and functional near-infrared spectroscopy, but few tools exist to process that data into useful information. The goal of this project is to design algorithms to transform physiological data from wearables into metrics that measure brain health and evaluate cognitive function and impairment. To make these metrics accessible to both consumers and clinicians, this project will focus on two main areas: (1) Designing efficient signal processing and screening algorithms that can be implemented in real-time on a mobile device and (2) Creating brain data visualizations that enable biofeedback by making the aforementioned metrics understandable by non-clinicians.

I am participating in SuperUROP because I want to develop my research skills while creating technology that can positively impact personal health. I hope to apply my background in video game development towards research that is immediately accessible and tailored to the needs of individuals who would benefit from cognitive screening.

Nupur Ballal

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Leveraging Sparse Labeling to Characterize Airway Intrinsic Neurons

Supervisor: Sara Prescott

Airway-intrinsic neurons (AINs) are essential to coordinating breathing and protecting the airways. AINs have historically been difficult to study due to their sparseness and location along the airways, but recent technological developments enable us to study AINs with molecular resolution. The Prescott lab generated the first unbiased profile of the molecular diversity of AINs, however these data lack spatial context. Our goal is to employ new methods of fluorescently sparse labeling AINs using adeno-associated viruses to enable visualization of the projection patterns of key neuronal subtypes. Understanding AIN subtype morphology and projection patterns allows us to hypothesize about their specific roles in regulating airway physiology and disease phenotypes.

As part of the SuperUROP program, I'm thrilled to further my research with world-class mentors while also thinking critically about communicating my work to the broader scientific community. I look forward to building upon my surgical, imaging, and computational abilities as well as the scientific writing skills that will help me in my future career as a neurosurgeon and physician-leader.

Jay Matthew Bhan

MIT EECS | Undergraduate Research and Innovation Scholar

New Bounds for Zarankiewicz Numbers via Reinforced LLM Evolutionary Search

Supervisor: Srinivasan Raghuraman

The Zarankiewicz number Z(m, n, s, t) is the maximum number of edges in a bipartite graph G(m, n) such that there is no complete K(s, t) bipartite subgraph. We determine for the first time the exact values of three Zarankiewicz numbers: Z(11, 21, 3, 3)=116, Z(11, 22, 3, 3)=121, and Z(12, 22, 3, 3)=132. We further establish lower bounds for 41 more Zarankiewicz numbers, including several that are within one edge of the best known upper bound, and we match the established value in four more closed cases. Our results are obtained using OpenEvolve, an open-source evolutionary algorithm based on Large Language Models (LLMs) that iteratively improves algorithms for generating mathematical constructions by optimizing a reward signal which we tailored for this specific problem. These findings provide new extremal graph constructions and demonstrate the potential of LLM-guided evolutionary search to contribute to mathematical research. In addition to presenting the resulting constructions, we report the generation algorithms produced, describe the relevant implementation details, and provide our computational costs. Our costs are remarkably low, at less than $30 for each Zarankiewicz parameter combination, showing that LLM-guided evolutionary search can be an inexpensive, reproducible, and accessible tool for discovering new combinatorial constructions. For the full work, see https://arxiv.org/abs/2605.01120.

I've really enjoyed working on this SuperUROP project. The power that AI has to make mathematical discoveries is truly unprecedented, and I can't wait to see how this technology continues to grow over the next few years.

Thomas Watson Brewitt

Undergraduate Research and Innovation Scholar

Investigating Audio and Visual Modality in Physics Parcels

Supervisor: Nancy Kanwisher

The physics network (PN) is a set of brain regions engaged when people make physical rather than descriptive judgments on visual stimuli. All studies of this region have measured PN response to visual input, while one can make physical judgments based on auditory cues (the 'ting' of a wine glass or the 'splash' of water). The goal of my project will be to investigate the role of the auditory modality in the PN to determine whether the network is a vision-driven system for scene-understanding or if it integrates across modalities to generate a physics model. I will use several task-based fMRI studies to measure neural responses during physical and non-physical audio tasks, applying both univariate and multivariate analysis methods to determine relative PN activity for each condition.

In this SuperUROP, I hope to continue developing my research and experimental design skills so that I can pursue a future career in science. I have been working on related studies with the Kanwisher Lab since my Freshman IAP term, and have found the experience to be extremely educational and rewarding. I look forward to continuing to see this project through to completion and receiving more formal research instruction with this program.

David Burke

Undergraduate Research and Innovation Scholar

Developing VR and Mobile Apps to Screen for Brain Injury and Neuropathology

Supervisor: Richard R. Fletcher

There exists a need to create new tools that can scan for brain injury and neurological impairment using portable and low-cost tools such as mobile phones and Virtual Reality headsets. Such technologies have found modern applications in sports and military training, as well as in schools monitoring for ASD, ADHD and Dyslexia. This research will advance the development of a virtual reality (VR) platform for neurocognitive health assessment by integrating immersive cognitive tasks with real-time multimodal physiological monitoring. The platform will combine analytic algorithms, machine learning techniques, and multimodal neuroimaging data to support both clinical and research applications.

Bringing my background in the armed services and skills in software development, I feel fortunate to be able to apply myself developing tools to assist in cognitive health assessment that may find applications across many domains. I look forward to gaining experience bridging the gap between user-facing software development and data collection and analysis for health research.

Julia Casey

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

Modeling Diffusion Across a Clear Zone Assay for Understanding Biodegradability of Polymers

Supervisor: Bradley D. Olsen

Although plastics have only been used on an industrial scale since the 1950s, the rate of production and use of plastics has risen exponentially, with polymers now infiltrating every aspect of our lives. One potential solution is biodegradable plastics, which are designed to be broken down by living organisms after disposal. However, understanding the complete degradation kinetics of polymers in the environment remains an unanswered fundamental challenge. Development of degradation models – from initial fragmentation to biodegradation and biological uptake – remains key to understanding the end-of-life fate of polymers and the design of environmentally benign, sustainable polymer materials. This project will use existing work modeling enzyme diffusion and add enzyme-polymer interactions.

I am participating in SuperUROP because I want to continue learning research skills and problem-solving techniques. Last year, I learned advanced transport topics that I'm looking forward to applying to the next steps in my project. By the end of the program, I hope to have developed scientific writing skills enough to be able to concisely build a narrative surrounding my research.

Annie-Minyi (Minyi) Chen

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Mapping DNA Damage and Inflammatory Signaling in Liver-Immune Co-Cultures Exposed to N-nitrosodimethylamine

Supervisor: Forest M. White

Decades of industrial activity in Wilmington, MA contaminated groundwater with N-nitrosodimethylamine (NDMA), a probable carcinogen that causes DNA damage, oxidative stress, and inflammation in the liver. This project investigates how immune-liver interactions influence cancer progression after NDMA exposure. First, I will determine if immune cells interact with liver cells in ways that amplify cancer-related processes (e.g. promoting liver cell DNA damage and inflammation). Then, I will apply mass spectrometry-based phosphoproteomics to map signaling changes in co-cultures of hepatocytes and immune cells. The goal of this project is to reveal how cross-talk between cell types drives inflammation and disease in populations exposed to environmental toxins.

My previous work in the White Lab showed me how powerful mass spectrometry-based phosphoproteomics can be for uncovering disease mechanisms. I'm excited to apply these skills to study how environmental contaminants impact human health. Through this project, I hope to better understand these effects and contribute to helping people who have been exposed.

Justin Chen

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar

A Contactless Superconducting Waveguide Platform for Probing the Kinetic Inductance in 2D Superconductors

Supervisor: William Oliver

Realizing superconducting quantum computing platforms requires advances in material science, fabrication techniques, and circuit design. In qubit devices, charge and flux variations typically cause rapid quantum states to decay and limit performance. Devices made of superconductors with high kinetic inductance can help suppress such fluctuations. In the past, circuit quantum electrodynamics (cQED) platforms that probe kinetic inductance required transparent electrical contacts that came with a high experimental overhead. We propose a circuit design to measure the kinetic inductance of coplanar waveguide resonators made of 2D superconductors without galvanic contact. This architecture will enable the exploration and the characterization of 2D superconductors for novel quantum devices.

I am participating in the SuperUROP program to pursue my interest in quantum technology and create findings that can benefit the broader physics community. Classes such as 6.2540 exposed me to the nanotechnology techniques in MIT.nano and 8.05 prepared the much-needed mathematical foundations for this project. I am excited to dive deeper into this project and learn more about my peers' research along the way.

Stanley Chen

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar

Accelerating Erasure Detection for Dual-Rail Qubit Architectures

Supervisor: Kevin P. O'Brien

Dual-rail qubit architectures naturally bias toward erasure errors, which are easier to correct than Pauli errors. A major challenge, however, is the slow speed of erasure detection, which limits the scalability of fault-tolerant protocols. To accelerate erasure checks, we propose an architecture that enhances coupling between qubits and readout ancilla while preserving coherence. We will design native gate sets and erasure check schemes, evaluate robustness under fabrication variances, and benchmark coherence, fidelity, and detection speed. The ultimate goal is a scalable hardware platform enabling faster, lower-overhead quantum error correction.

By participating in SuperUROP, I look forward to engaging in the full research process, particularly presenting and writing papers, while gaining exposure to more advanced research. Building on my prior projects on superconducting qubits in the QCE group, my goal is to produce publication-level research and develop the skills to prepare for a future academic career.

Amanda Cheng

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

Investigating 2D Polyaramids as a Protection Layer for Air and Moisture Sensitive Perovskite Materials

Supervisor: Michael S. Strano

Two-dimensional polyaramids (2DPAs) are covalently bonded polymers with exceptional strength, stability, and gas barrier properties. This project explores how structural variations, particularly end-group modifications, affect 2DPA solubility, film formation, and interfacial behavior through the synthesis and characterization of different films. These films will be spin-coated onto $MAPbI_3$ perovskites, and their resistance to ambient degradation will be evaluated using XRD. The broader goal is to advance fundamental understanding of 2DPA design principles and their potential as versatile protective barriers for sensitive materials, with perovskites serving as one example of interfacial protection.

Through this SuperUROP, I intend to strengthen my research skills in polymer chemistry and chemical engineering, building on the content I learned in organic chemistry and Course 10 classes. I am excited to explore polymer engineering applications that can contribute to efficient and sustainable solutions. I also hope to further develop my problem-solving skills and apply chemical engineering principles to real-world challenges.

Cheuk Hei Chu

MIT MGAIC | MIT Generative AI Impact Research and Innovation Scholar

Mechanistic Interpretability of Modern Vision-language Models

Supervisor: Phillip Isola

Multimodal foundation models like CLIP have demonstrated powerful generalization capabilities across vision, language, and retrieval tasks. However, how these models represent concepts internally, and how information flows through their components, such as attention heads, MLPs, and residual streams, remains insufficiently understood. Mechanistic interpretability seeks to move beyond input-output probing, aiming to reverse-engineer the internal computations of neural networks to understand how and why they produce certain behaviors. This project applies those principles to multimodal models, with the goal of understanding the storage of interpretable features and semantic directions across modalities, and studying the flow of multimodal information through model components.

I am participating in SuperUROP because I want to gain experience conducting serious research in computer vision. I took 6.7960 (Deep Learning) and 6.8300 (Advances in Computer Vision) last year and I was inspired by the cutting-edge advancements researchers have made in the last decade. I am excited to learn more about the field and contribute to an active field of research.

Florida Mahano Cishesa

MIT MechE | Undergraduate Research and Innovation Scholar

Real-Time Sit-to-Stand and Stand-to-Sit Recognition for Assistive Mobility

Supervisor: Neville J. Hogan

This research builds on the probabilistic approach for recognizing Sit-to-Stand (Sit2St) and Stand-to-Sit (St2Sit) transitions using a single Inertial Measurement Unit (IMU) sensor [1]. The primary objective is to develop an intelligent, real-time recognition system capable of identifying sitting, standing, and transitional movements with high accuracy in younger and older adults. The goal is to leverage this capability to enhance users' experience with Sit2St wearable assistive technologies. A Bayesian classifier was trained on filtered IMU data and tested on raw signals to ensure generalizability and resilience to noise [1]. An angular threshold approach was employed to segment the transition regions of Sit2St and St2Sit into three transition phases. The system achieved 100% accuracy in recognizing both activities and phases using only one sensor. The classifier was deployed on a microcontroller, demonstrating standalone operation and suitability for exoskeletons. Future steps of this research study involve exploring biological indicators of transition phase breakpoints and integrating the algorithm into an exoskeleton while maintaining semi-passivity. In addition to algorithm development, the study explored age-related variations in Sit2St and St2Sit transitions across different age groups ranging from 18 to 95 years old. Metrics such as the duration of Sit2St and St2Sit transitions, acceleration, acceleration standard deviation, and frequency content were analyzed, revealing that transition duration may be more informative of mobility status than age alone. The goal of this study is to determine the quality of the subject's mobility and to quickly identify whether assistance is needed.
Reference: [1] Martinez-Hernandez, U., and Dehghani-Sanij, A. A., 2019, "Probabilistic Identification of Sit-to-Stand and Stand-to-Sit with a Wearable Sensor," Pattern Recognition Letters, 118, pp. 32-41. https://doi.org/10.1016/j.patrec.2018.03.020.

Bridging technology and human motion to enhance lives across ages.

Abdel Kareem Abdallah Dabbas

Undergraduate Research and Innovation Scholar

Infrastructure for Multimodal LLM Training

Supervisor: Paul Liang

Multimodal models are rapidly becoming the way people use AI, bringing together language, vision, audio, and video. Yet most training stacks are siloed and brittle, and each new pairing of modality and model takes too much custom work. This project aims to build a fast, modular infrastructure for any to any multimodal training. It will offer a generic interface that lets researchers attach new modalities to models of any backbone, while handling heterogeneous data types and sizes in a consistent way, while targeting performant, scalable training across setups. The focus is on performance, scalability, and ease of use for large-scale training. The goal is an open source toolkit with clear documentation and examples that reduces boilerplate, improves throughput, and makes multimodal experimentation straightforward.

Through this SuperUROP, I plan to draw on my background in computer science and mathematics to build practical, high-performance tools. I am especially excited to apply these skills to develop infrastructure that makes any to any multimodal LLM training fast, consistent, and scalable. More broadly, I enjoy tackling problems that span disciplines and turn solid theory into systems that work in practice.

Nethaka (Ne) S. Dassanayake

MIT EECS | Mason Undergraduate Research and Innovation Scholar

Exploring Scalable Molecular Representations for Interaction Aware Design

Supervisor: Connor W. Coley

The Coley group has previously worked on ShEPhERD, an SE(3)-equivariant diffusion model that performs 3D interaction-aware drug design via joint diffusion of molecular structure with other chemically relevant features, such as a shape and electrostatic point cloud. Owing to both the graph neural network (GNN) based and equivariant denoising modules, ShEPhERD is quite slow, and it becomes intractable to train and sample from larger chemical spaces. This project aims to create a non-equivariant version model admitting a scalable mechanism for interaction-aware drug design. Currently, we are working on developing this via representing shape and electrostatics as voxelized grids and augmenting the data with random SE(3) transforms to bypass the need for equivariance or GNNs.

My background has evolved from pure chemistry to include computer science while at MIT. I have had a great experience in the Coley lab and the structure offered by the SuperUROP program seems very useful to me. I intend on both becoming more versed in relevant literature and modern machine learning research methods throughout this project, which is the perfect intersection of the passion I have for both the natural sciences and computer science.

Arthur De Los Santos

MIT MGAIC | MIT Generative AI Impact Research and Innovation Scholar

Physical AI: Robust Vision-Language Navigation

Supervisor: Daniela L. Rus

Vision-Language Navigation links natural language and robotic navigation, enabling agents to follow instructions in complex environments. Existing frameworks like MiniNav achieve this efficiently by fusing frozen vision-language features with lightweight policy heads, but use static plans that fail to adapt to scene changes or ambiguous intent. We propose a minimalist VLN system for real-world deployment that integrates real-time formal reasoning modules to validate plan step feasibility and goal-adherence, and interactive feedback mechanisms to request clarifications or suggest alternatives when confidence is low. This preserves computational efficiency while enabling adaptive, cooperative disambiguation in dynamic settings, paving the way for scalable, trustworthy human-robot interaction.

I chose to participate in a SuperUROP to enhance my problem-solving skills and apply them to cutting-edge research in my field. My two prior ML-based UROPs and my work at Telexistence this past summer (perception for autonomous warehouse robots) have prepared me for this research. I aim to deepen my knowledge of physical AI and the full research cycle, and I am most excited to see our work realized in a physical system.

Victor Gabriel Dominguez

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

Synthesizing Origin-Destination Data for Mobility Applications

Supervisor: Gioele Zardini

Origin-destination (OD) data is fundamental to mobility and transportation analysis, providing critical insights into travel demand patterns, infrastructure planning, and mobility algorithm performance evaluation. However, real-world OD datasets are often sparse, inconsistent, or inaccessible due to privacy constraints. This project addresses these challenges by synthesizing OD data, enabling enhanced benchmarking and reproducibility in transportation research. Our proposed approach comprises two complementary synthesis methodologies: forward and backward. The forward synthesis method focuses on developing generative algorithms that produce realistic OD demand patterns from static datasets or high-level properties. Given inputs such as population density, census data, and a city's transportation network, we aim to generate mobility demand data that is spatially and temporally consistent with these inputs. This enables controlled scenario generation, allowing researchers and practitioners to evaluate mobility solutions under diverse conditions. On the other hand, the backward synthesis method operates on existing OD demand datasets, either decomposing them into multiple datasets with varying characteristics or extending them to enhance spatial and temporal granularity. Decomposition acts as a form of down-sampling, extracting distinct demand patterns from dense datasets, while extension enables up-sampling, refining aggregated or incomplete datasets to integrate multiple sources and improve analytical fidelity. By advancing OD data synthesis, this project enhances the reproducibility and accessibility of mobility research. A key outcome is the development of an open-source tool that democratizes access to high-quality, synthetic mobility datasets, facilitating robust algorithm benchmarking and broader adoption in transportation modeling.

I am participating in SuperUROP for the opportunity to advance my knowledge in the transportation field specifically as it relates to transportation modeling & data generation. Through this program, I want to apply my experience from previous UROPs and my urban planning background in order to develop a platform for mobility data synthesis. I'm excited to participate and contribute to this project.

Anastasia Dunca

MIT EECS | Takeda Undergraduate Research and Innovation Scholar

CortexLang: A Domain Specific Language and LLM Framework for Modeling Neural Circuits

Supervisor: Wojciech Matusik

A Domain-Specific Language (DSL) is a programming language tailored to a specific field to solve problems more effectively. In neuroscience, current tools for modeling neural circuits are often too rigid (predefined model classes) or opaque (black-box neural networks). NeuroCircuitDSL addresses this by introducing a flexible DSL for representing neural populations, synaptic interactions, and network dynamics. This approach offers a more transparent and customizable alternative to existing models, supporting deeper insights into brain function and disease. Additionally, this project will contribute to the growing field of computational neuroscience by leveraging advanced machine learning techniques to generate novel neural circuit architectures.

I'm always excited to investigate problems in applied computer science! I took a compilers class (6.110) last year which exposed me to the beauties of computer language construction. This project is a very unique opportunity to explore all of my interests: computational biology, computer languages, and natural language processing. In doing so, I hope to make a significant contribution to domain specific language and neuroscience research.

Kieran N. Dunn

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar

Nanotechnologies for Brain-Inspired Computing

Supervisor: Farnaz Niroui

My research explores novel neuromorphic computing architectures using nanoscale memristors to overcome the memory-computation bottlenecks of CMOS-based AI hardware. Memristors, which retain resistance states and enable in-memory computing, offer high density, low power, and analog functionality ideal for matrix-vector multiplication. Building on recent advances in molecular memristors, this project will (1) design system-level architectures tailored to specific machine learning tasks, and (2) implement and characterize prototype systems to evaluate performance gains over conventional approaches, paving the way for energy-efficient, scalable AI hardware.

I am participating in the SuperUROP program to gain better research experience, deep dive into a next generation compute solution for our ever growing digital world, and become experienced in presenting and writing about research.

Alexander K. (Alex) Franks

MIT EECS | Philips Undergraduate Research and Innovation Scholar

Modeling Distributed Learning in Cortico-basal Ganglia and Cortico-cerebellar Loops During Locomotor Adaptation

Supervisor: Nidhi Seethapathi

The neural computations underlying gait adaptation to environmental conditions remain poorly understood. Recently, computational models have captured locomotor adaptation behavior by specifying objectives like energy minimization and symmetry. However, these models and their hypothesized objectives have not been linked to the underlying neural computations. I will design a spiking neural network model of cortico-basal ganglia-thalamo-cortical loops, the cerebellum, and brainstem, to provide a neural grounding for these computational models. I will use Artificial Neural Networks Architect as a framework for running SNNs. This research aims to provide a computational framework to model the neural basis of neuromotor disorders, rehabilitation, and their influence on locomotor adaptation.

I am participating in SuperUROP because after taking neuroscience and machine learning classes, I am excited to apply what I have learned to building models of neural circuits. I am interested in applications of neural algorithms to both improve deep learning methods and design brain computer interfaces for rehabilitation. The SNN simulation data analysis I will gain experience with are important for these applications.

Ved Ganesh

MIT MechE | Sea Grant Undergraduate Research and Innovation Scholar

CFD Based Optimization and Analysis of Artificial Reef Structures

Supervisor: Andrew Bennett

Coastal erosion causes over $500 M in annual U.S. property losses, yet mitigation is a zero-sum challenge: inducing deposition in one area requires downcoast erosion. Effective, targeted interventions require a suite of structures tuned to different levels of deposition. This project develops 3D-printable concrete reef units generated via multi-objective Bayesian optimization in a nested-loop proposal-validation workflow. Physical testing in MIT's 30 m wave tank replaces costly multiphase CFD, enabling broader exploration of the design space. The end goal is a portfolio of pareto-optimal mass-to-deposition reef geometries for precise, community-specific shoreline protection.

Growing up in Houston, especially in the wake of Harvey, coastal erosion was a highly visible problem. I'm excited to combine research tools, like tow tank testing, that I picked-up in previous UROPS, with coursework on optimization, that I got from classes like 2.086 and 2.155, to address a problem I've been interested in since high school.

Hannah Y. Gao

MIT EECS | Mason Undergraduate Research and Innovation Scholar

Enabling Visual Thinking and Reasoning in Multimodal LLMs

Supervisor: Antonio Torralba

When solving complex or multi-step problems, humans often benefit from visual aids for reasoning, including sketching diagrams or graphs. As visual diagramming can be a powerful tool for advanced reasoning, we aim to equip multimodal models with the ability to reason through free-form sketching. To enable multimodal models to create natural and versatile sequence-by-sequence sketches, I will help develop a suitable dataset for teaching multimodal models the desired sketching behavior, design a pipeline for incorporating sketching behavior into the model's reasoning process, and train or fine-tune a multimodal model to perform visual-based reasoning. This model will serve as a new baseline for future work in visual chain-of-thought reasoning.

I am participating in SuperUROP because I have really enjoyed my time in AI classes and AI-related research projects at MIT, and I want to continue to build off the skills I have developed in these experiences through an immersive research experience. I am excited to learn more about state-of-the-art multimodal models and get a better sense of a career in academia.

Jue Gong

MIT EECS | Sam Goldwasser Undergraduate Research and Innovation Scholar

Sensor for Rapid Detection of Climate Stress in Agriculture

Supervisor: Rajeev J. Ram

Plant stress monitoring is vital for improving crop productivity and sustainability, but traditional methods focus on superficial traits like leaf color and plant height, missing underlying causes. Recent developments show that Raman spectroscopy enables optical and thereby non-invasive probing of biochemical constituents and stress markers. Nonetheless, current systems face trade-offs: precise but bulky, or compact but noisy. My project will focus on developing a scalable and farmer-friendly Raman instrument that is both lightweight and sensitive—by mounting a lightweight telescope on a robotic manipulator while keeping the heavy optical instruments at the base. After creating the device, we will test its performance in a range of real-world conditions and develop design improvements.

I am excited to combine my love for both engineering and physics to develop a device with real-world impact on energy and agriculture! After learning about optics/photonics at research talks and in classes like Quantum Mechanics (8.04) and Circuits (6.2000), I became interested in both the field's theoretical frameworks and potential applications. Hence, through the SuperUROP, I hope to deepen my understanding of this research area and apply its core ideas, while also honing my collaboration and communication skills.

Sarah Habona

MIT MechE | Undergraduate Research and Innovation Scholar

Design and Validation of a Portable Holographic Microscope for Early Detection of Harmful Algal Blooms

Supervisor: David R. Wallace

This project addresses the lack of low-cost, real-time tools for monitoring aquatic microbial communities by developing a submersible, low-cost microscope. The device uses digital in-line holographic microscopy (DIHM) to capture high-resolution images of microorganisms, offering real-time insights into ecosystem dynamics and enabling the detection of harmful algal blooms (HABs). The system's low cost allows for deploying multiple units in a spatial grid to monitor microorganism distribution. The goals are to refine the hardware for reliable, multi-day field use, validate its performance for early HAB detection of key cyanobacteria species, and demonstrate its utility through field deployments, providing a scalable method for continuous aquatic microbiome monitoring.

I am participating in SuperUROP to learn how to structure my design process and formalize research into a communicable manner. I'm most excited to apply my skills while gaining a deeper theoretical understanding of digital holography and seeing how the device's deployment informs future iterations. This project will allow me to contribute to early harmful algal bloom detection efforts while developing a more holistic research perspective.

Megha M. Hegde

MIT EECS | Tenev Family Undergraduate Research and Innovation Scholar

Semantic Watermarking for Large Language Models

Supervisor: Vinod Vaikuntanathan

This project addresses a structural vulnerability in current watermarking schemes for large language models. We are proposing a modification to the prefix-free binary encoding tree used in the Christ-Gunn PRC construction, grouping semantically similar tokens into synonym clusters so that all cluster members share a common watermarked path from the root, with the intra-cluster token choice left free. Synonym substitutions change only the un-watermarked portion of the encoding, leaving the PRC signal intact by construction. Synonym clusters are derived offline from cosine similarity in a pre-trained embedding space, requiring no modification to the underlying language model. We evaluate the scheme against embedding-based synonym substitution, Dipper paraphrase, and GPT-4 rewriting, comparing against the standard Christ-Gunn scheme and SemaMark, and demonstrate improved robustness while preserving the PRC framework's formal undetectability guarantee.

I am participating in SuperUROP to deepen my understanding of cryptography and its connections to machine learning security. My background in theoretical computer science and mathematics, along with prior exposure to coding theory, prepared me for this research. I hope to learn how to bridge formal cryptographic guarantees with practical robustness in real systems.

Kyra M. Henriques

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar

Integrating Deep Image Embeddings and Single-Cell Transcriptomics to Elucidate Adipocyte Differentiation and Cardiometabolic Risk

Supervisor: Caroline Uhler

This project integrates high-content cellular imaging and single-cell RNA sequencing to investigate adipocyte differentiation and cardiometabolic disease risk. Linking cell morphology with gene regulation remains a major gap in understanding how genetic and environmental factors influence adipocyte function. Data from adipose-derived mesenchymal stem cells across 120 human donors, profiled under multiple stimulations, include features from LipocyteProfiler and single-cell transcriptomes. Modality-specific embeddings are aligned in a shared latent space across genetic variation, CRISPR perturbations, and compound treatments. This integration, enabled by ML-based embedding models, reveals how risk factors and therapeutic interventions alter adipocyte biology. It also establishes a scalable framework that not only advances research in adipocyte differentiation and cardiometabolic disease but also extends to other biological systems and diseases, enabling cross-modal insights with therapeutic and translational relevance.

I am excited about my SuperUROP as it offers me the unique opportunity to conduct collaborative and impactful research at the intersection of computer science and biology. I have always been passionate about applying computational and machine learning approaches to solve complex biological problems, and I am grateful to be able to build my technical, professional, and communication skills while contributing to research that improves human health.

Eugene Y. Jiang

Undergraduate Research and Innovation Scholar

AI-Driven Robotic Discovery in Quantum Information Science & Technology

Supervisor: Dirk R. Englund

Simulation plays a vital role in advancing quantum physics, where direct experimentation is often limited by cost, fragility, and technological feasibility. However, traditional simulations frequently rely on idealized assumptions that limit their predictive accuracy in real-world conditions. This project addresses this gap by developing an integrated robotic platform for autonomous quantum experimentation. We use a Franka Research 3 robotic arm, which will interface with a QuantenKoffer photonic toolkit to construct and reconfigure optical quantum experiments. Using reinforcement learning, agentic programming, and physics-informed world models, the system will propose, simulate, and refine experimental designs in a closed feedback loop. GPU-accelerated simulations will generate high-fidelity priors to guide reinforcement learning toward physically realizable outcomes, such as maximizing entanglement fidelity. By coupling robotic automation with simulation-informed learning, this work aims to create a self-improving system that bridges the divide between theoretical predictions and experimental implementation, accelerating the design and execution of quantum experiments.

I am super excited to join Dr. Englund's lab and explore how digital twins and reinforcement learning can transform quantum optics experimentation. By combining Omniverse-based simulations with physics-informed models and robotic automation, I hope to learn how to bridge the gap between idealized theory and noisy, real-world systems, ultimately accelerating the design of reliable, autonomous quantum experiments.

Can (Rachel) Jiang

Undergraduate Research and Innovation Scholar

Improving Reliability in Nanofabrication: A Systematic Approach to Failure Analysis and Process Optimization

Supervisor: Tomás Palacios

Modern nanofabrication relies on complex tools, where small process deviations can lead to significant yield loss and wasted time. Despite this, current workflows depend heavily on manual logging and experience-based troubleshooting, limiting process visibility and making root-cause analysis slow and inconsistent. To address this, we propose a data-driven framework for structured troubleshooting and process monitoring. We collect user-reported data on failure modes, frequency, and time loss to identify high-impact issues across nanofabrication tools. Then, we evaluate structured validation steps as practical interventions to reduce failures. By replacing trial-and-error debugging with systematic, data-informed workflows, this work aims to improve diagnostic efficiency, reduce downtime, and enable more scalable and reliable nanofabrication processes.

I chose to participate in this SuperUROP because it is interdisciplinary, combining my interests in AI and semiconductor technologies. I am interested in exploring how data-driven approaches can improve hardware reliability in nanofabrication. I hope to deepen my understanding of areas such as anomaly detection and system-level diagnostics, while gaining hands-on experience working with real-world process data. My goal is to contribute meaningfully to our group's efforts to improve tool reliability and develop more systematic, efficient approaches to troubleshooting in nanofabrication environments.

Trevor E. Johst

MIT AeroAstro | Boeing Undergraduate Research and Innovation Scholar

Beyond the Graph: Far-field Reasoning About Spatial and Semantic Concepts using 3D Scene Graphs

Supervisor: Luca Carlone

The autonomous operation of mobile robots benefit from a detailed metric and semantic understanding of their environment. Typical mapping approaches rely heavily on depth measured directly by sensors or estimated with parallax. These depth values typically become unreliable at far distances, so mapping is often limited to the robot's local area. We utilize frame-to-frame tracking and cross-observation association to sparsely localize far-field landmarks. Each landmark is attributed an open-set semantic descriptor and location range allowing them to be used for high-level planning.

My SuperUROP project will give me the chance to contribute towards more capable and robust robotic systems. I look forward to developing and testing my work, and pushing towards more useful robots for the future.

Elian Kai Juarez

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

Remote Sensing-Based Air Pollution Mapping with Coupled Bayesian and Gussian Processes

Supervisor: Haruko M. Wainwright

Air pollution is a leading cause of premature deaths, and detailed tracking of its distribution at a local level is a significant priority in terms of policy and long-term reductions. While low-cost sensors, satellite products, and other data sources are able to track certain gases, they often differ in spatial and temporal coverage. This study will develop a Bayesian data integration approach with Gaussian Processes using data from low-cost sensors and other globally available datasets. Our focus is to integrate new remote sensing data products from the TEMPO satellite and explore the use of an atmospheric chemistry & transport model (WRF-Chem) to add physical constraints in forecasting. The resulting integrated map and emulator will enable rapid predictions and policy recommendations.

In high school, I enjoyed delving into atmospheric modeling using open-access data. However, I was limited by my computer's computational power and (lack of) access to advanced physics-based models. I am now excited to work on a project involving these tools, as well as learn from others doing research on pollution at MIT.

Jeewoo Kang

MIT EECS | Quick Undergraduate Research and Innovation Scholar

Optimizing Device Design for Enhancement-Mode Low Voltage GaN HEMTs

Supervisor: Tomás Palacios

This project seeks to address these gaps through the experimental characterization and optimization of highly scaled GaN HEMTs fabricated at MIT.nano, specifically targeting low to medium-voltage (10–100V) applications with an emphasis on high-temperature reliability. The study will systematically investigate the role of passivation layers, field plates, and device geometries in enhancing device performance, leveraging various deposition techniques such as atomic layer deposition (ALD), plasma-enhanced chemical vapor deposition (PECVD), and low-pressure chemical vapor deposition (LPCVD). Key electrical characterization methods will include DC-IV, pulse-IV, Hall effect, transmission line measurements (TLM), capacitance-voltage (C-V), and S-parameter measurements to extract a comprehensive set of physical device parameters.

By participating in this SuperUROP, I hope to gain more experience in modeling and simulations. While I have done a lot of experimental characterization, broadening my knowledge through simulations will help me better understand GaN transistors. I also hope to produce meaningful results that lead to fabricated transistors that replicate the behavior predicted in my simulations.

Evan Eunjae Kim

MIT EECS | Undergraduate Research and Innovation Scholar

Scaling Latent Novel View Synthesis Models

Supervisor: Vincent Sitzmann

In this project, we focus on studying the scaling of latent novel view synthesis models. For a while, novel view synthesis solutions have involved explicit 3D representations, but recent work has shown that this inductive-bias is unnecessary. However, there is yet to be a thorough analysis of these sorts of models, which we aim to do across several architectures and several scales of compute and data. We'll then use this analysis to introduce several refinements to existing latent novel view synthesis architectures and training schemes.

I am participating in SuperUROP in order to strengthen my general research and communication skills while deepening my computer vision knowledge through my particular project. With a background in machine learning research across both academic and industry settings, I'm excited to apply my experiences in a scaling focused project that can offer valuable insights for other academic researchers.

Arul Kolla

MIT EECS | Citadel Undergraduate Research and Innovation Scholar

Efficient Generative AI Inference via Nonlinear Kernel Approximation

Supervisor: Anantha P. Chandrakasan

Modern accelerators excel at linear operations, but nonlinearities take up a significant portion of compute for both datacenter and edge deployments. We propose a co-design approach that (1) develops approximation algorithms for key nonlinear functions in generative models and (2) maps these approximations to efficient hardware on server/edge GPUs and domain-specific accelerators. We will compare families of approximations and study their effects on accuracy, fine-tuning convergence, and robustness under distribution shift. On the hardware side, we will analyze how each method composes with existing compute primitives and propose microarchitectural extensions to reduce latency, area, and energy. Our evaluation combines analytical models with prototype implementations to quantify trade-offs across area, delay, and energy. The outcome is a systematic recipe for algorithm–hardware co-design that closes the nonlinear bottleneck in large-scale AI systems.

Through this SuperUROP, I aim to translate theory into working systems by prototyping hardware-friendly approximations for nonlinear layers and validating them end-to-end on real-world models. I'm excited to apply my knowledge of ML from classes like Hardware Architecture for Deep Learning (6.5930) to real-world systems. My goal is to publish practical techniques that accelerate both datacenter and edge inference.

Daria Kryvosheieva

MIT EECS | Nadar Foundation Undergraduate Research and Innovation Scholar

Task-Level Performance Prediction in Agentic Coding Benchmarks

Supervisor: Yoon Kim

As the focus in LLM-based coding shifts from static single-step code generation to multi-step agentic interaction with tools and environments, there is a growing need to understand what evaluations of coding agents tell us. At present, agent performance is typically measured by aggregate pass rates on benchmarks, but single-number metrics obscure the diversity of tasks within a benchmark. We present a framework for predicting success or failure on individual tasks tailored to the agentic coding regime. Our approach augments Item Response Theory (IRT) with rich features extracted from tasks, including issue statements, repository contexts, solutions, and test cases, and introduces a novel decomposition of agent ability into LLM and scaffold ability components. This parameterization enables us to aggregate evaluation data across heterogeneous leaderboards and accurately predict task-level performance for unseen benchmarks, as well as unseen LLM-scaffold combinations. Our methods have practical utility for benchmark designers, who can better calibrate the difficulty of their new tasks without running computationally expensive agent evaluations.

I am participating in this SuperUROP because I am interested in crafting better evaluations for coding agents. I aim to develop efficient methods for (1) estimating the capabilities of agentic systems and their underlying components (LLMs and scaffolds), and (2) estimating the difficulties of novel coding tasks. I hope that those methods will prove useful for practical use cases, such as designing benchmarks or scaffolds, or selecting training tasks of appropriate difficulty in RL training rollouts.

Jasper Lee

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Developing a High-throughput Functional Assay for Neuromuscular Drug Screening

Supervisor: Ritu Raman

Neuromuscular diseases including muscular dystrophies, sarcopenia, and ALS severely limit mobility and quality of life. However, in vitro skeletal muscle cultures have proven to be valuable preclinical models to test mobility-restoring drugs. This SuperUROP will adapt the Raman Lab's STAMP muscle culture method to 96-well plates to systematically study how substrate stiffness, chemistry, and topography affect muscle maturation and function. We will quantify muscle fiber morphology (fiber width, length, alignment), function (contractile force and dynamics), and gene expression. Optimized parameters will enable high-throughput screening of investigational drugs to evaluate the assay's predictive value for pharmaceutical discovery.

Having cultivated C2C12 mouse muscle cells and adapted the Raman Lab's 'STAMP' growth method to various well-plate formats for optimization, I have been inspired by the potential in vitro skeletal muscle cultures offer. From advancing preclinical disease models to powering biological actuators for robotics, I aim to continue pushing these frontiers, contributing to innovations at the intersection of bioengineering and technology.

Alicia Li

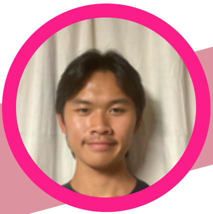
MIT EECS | Nadar Foundation Undergraduate Research and Innovation Scholar

Chunked Bidirectional Attention Transformers for Long Context Reasoning

Supervisor: Yoon Kim

Planning and sequential decision-making remain fundamental challenges for large language models (LLMs). Prior work has shown that vanilla transformer architectures are limited in state-tracking tasks, and that chain-of-thought (CoT) reasoning, while improving expressivity, incurs inference-time costs at long horizons. Bidirectional attention offers a promising alternative by producing richer contextual representations, but existing efficient implementations restrict bidirectional context to the prompt region, leaving reasoning traces causally attended. We propose chunked bidirectional attention, a novel architecture that extends bidirectional representations into the reasoning trace by recomputing full bidirectional attention once per fixed-size chunk rather than at every token. This design achieves enhanced expressivity with only constant-factor overhead during training and minimal overhead at inference. We initialize from pretrained Qwen3-0.6B weights and fine-tune on the OpenMathReasoning dataset, expecting our architecture to outperform standard fine-tuning of the base causal transformer on complex reasoning benchmarks.

I'm participating in SuperUROP because I want to work on novel NLP architectures. Specifically, I'm interested in planning capabilities, which is inspired by my previous UROP in robot planning and learning. I'm excited to learn more about NLP architectures and hoping to publish a paper.



Harrison Liang

MIT MGAIC | MIT Generative AI Impact Research and Innovation Scholar

Federated Learning Methods for Design and Manufacturing

Supervisor: Faez Ahmed

The rise of AI in engineering design and manufacturing has accelerated development cycles and reduced costs, but its full potential is limited by fragmented and sensitive datasets spread across organizations. Federated learning offers a solution by enabling collaborative model training without exposing proprietary data. This project focuses on developing and implementing federated learning models suitable for engineering applications. I will evaluate different federated learning architectures and integrate techniques such as horizontal federated learning, secure model aggregation, and synthetic data generation to enhance efficiency and data security. The outcome will be open source methods and practical guidelines to support secure, collaborative manufacturing workflows.

I am participating in SuperUROP because I'm interested in how AI can assist in the design process. I've previously worked on a project where I generated a synthetic dataset of airfoils intended to train machine learning models for optimizing aerodynamic design. I'm excited to build on this foundation and explore how machine learning can drive innovation in engineering design and manufacturing.

Jeffery Lin

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar

Causality-based Learning of Gene Regulatory Networks With Prior Knowledge

Supervisor: Caroline Uhler

Causal graphs provide a promising framework to understanding biological systems, especially in building more interpretable ML models when applied to hard biological tasks like understanding the mechanism through which a drug or therapy works. However, biological networks are extremely vast and complicated, meaning that the amount of quality data to develop such causal graphs is almost never available. Therefore, the incorporation of prior biological knowledge is likely needed to efficiently build such causal graphs. Using data driven approaches on a variety of dataset such as Perturb-Seq combined with prior knowledge such as known protein-protein interactions, I will develop scalable algorithms that learn meaningful causal graphs of gene regulatory networks (GRNs) despite noisy, limited data and incomplete, noisy prior knowledge. Then, I will benchmark these learned GRNs on downstream tasks such as gene perturbational outcome to determine if such networks are biologically meaningful and can be incorporated into biology-inspired machine learning.

Through this SuperUROP, I plan to learn more about causal inference – an area of research that is new to me but very promising as it has applications to more interpretable and causality-based methods in applying machine learning to biology. This project will inform and provide inspiration for my future research and career as I hope to develop causal-based AI / ML methods that are able to incorporate known biology for more interpretable and powerful models.

Benson Zhan Li Lin

MIT EECS | Fano Undergraduate Research and Innovation Scholar

A Hardware Accelerator for Datalog

Supervisor: Adam Chlipala

Datalog is a declarative logic programming language with applications in databases and formal verification. While GPU Datalog engines such as GPULog have shown performance gains over CPU-based systems like Souffle, further specialization at the architectural level may yield greater efficiency. This project aims to design a hardware accelerator for Datalog, beginning with a custom processing element for Datalog operations. We then build a software simulator to validate correctness and evaluate throughput. If time permits, this will be followed by an RTL-level implementation in SystemVerilog. We can then test an FPGA implementation of key components to obtain realistic performance results and measure the accelerator's effectiveness on real-world workloads.

I am participating in SuperUROP to explore high-performance hardware architectures and deepen my research experience. Courses in performance engineering (6.1060), formal verification (6.S057), and FPGAs (6.2050) have prepared me to tackle challenges across the software-hardware stack. I am eager to learn how to conduct long-term research and am most excited by combining rigorous mathematical frameworks with efficient hardware implementations.

Gwyneth Liu

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar

Gradient Dynamics for Quantifying Model Uncertainty

Supervisor: Nir N. Shavit

Reliable uncertainty estimates are essential for deploying machine learning systems in settings with distribution shift and limited data, where models must both recognize uncertainty and oftentimes adapt efficiently from few examples. Gradient-based optimization drives modern machine learning, yet most uncertainty quantification (UQ) methods rely only on information at the final trained parameters, ignoring the structure of the training trajectory. We propose a dynamics-centric framework that models training as a stochastic dynamical system. This enables a decomposition into stable and plastic directions and supports propagation of uncertainty through the learned dynamics. Using this idea, we guide few-shot adaptation as a constrained control problem, where update directions and magnitudes are informed by the learned dynamics and associated uncertainty. We demonstrate the performance of our methodology on out-of-distribution classification and few-shot adaptation tasks, such as the Camelyon-17 dataset.

I'm doing SuperUROP to gain experience with carrying out a year-long independent project. This is a really exciting opportunity to study more of the mathematical foundations of ML and contribute to more trustworthy ML models.

Aarushi Mehrotra

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar

Multi-omics Characterization of Cancer Tumors and Cell Lines

Supervisor: Caroline Uhler

Can we read a tumor's mutations from its gene expression and use that to predict which genes it depends on to survive?

Nilay Mishra

MIT MGAIC | MIT Generative AI Impact Research and Innovation Scholar

Building Generalist Multimodal Reasoning Agents

Supervisor: Paul Liang

Puzzles are challenging, multimodal tasks that require interpreting ambiguous hints, such as text, visuals, and tabular data, without any explicit instructions. This makes them ideal for training large-language models to tackle complex, open-ended tasks. This SuperUROP project aims to develop a system of multimodal reasoning agents to collaboratively solve these types of puzzles. Ultimately, the hope is to contribute towards models that not only excel at puzzle-solving, but also demonstrate improved performance on downstream tasks involving logical and mathematical reasoning.

I am participating in SuperUROP because I am excited to explore cutting-edge research on multimodal AI and on enhancing LLM reasoning capabilities. Through this program, I can deepen my understanding of these topics through an extended research experience, applying technical skills from my ML coursework and industry experience.

Amanda T. Miyares

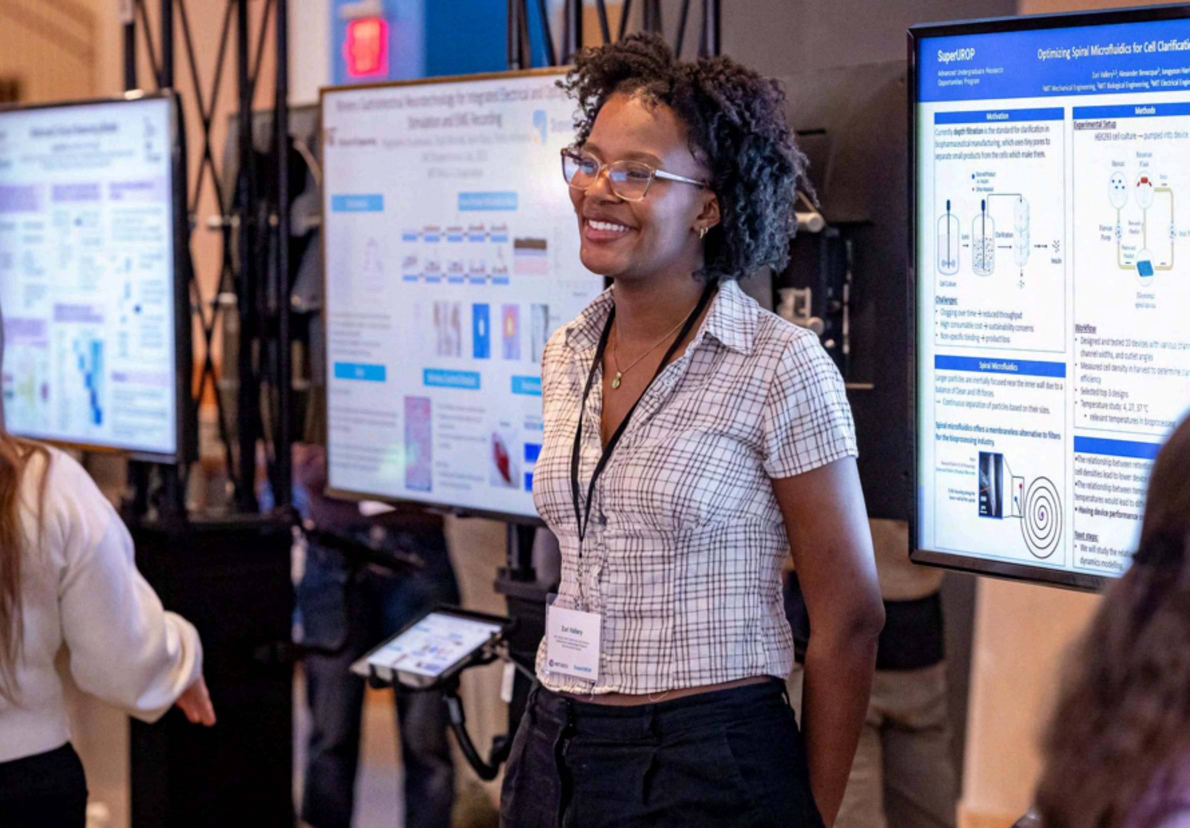
Eric and Wendy Schmidt Center Funded Research and Innovation Scholar

Investigating the Role of Transcription Factors Snail and Twist in Epithelial-Mesenchymal Transition

Supervisor: Adam Martin

Epithelial-mesenchymal transition (EMT) is a process in which cells transition from an adhesive state within a cohesive tissue to a migratory, individualistic phenotype. This project investigates the roles of the transcription factors Snail and Twist in inducing EMT when expressed ectopically in Drosophila embryos. Using a GAL4-UAS system to drive overexpression, along with fluorescent markers to visualize expression patterns, we examine how these factors influence cellular behaviors such as adhesion, cytoskeletal organization, and migration. By analyzing proteins including actin, myosin, and E-cadherin, we aim to characterize the mechanistic changes underlying EMT and determine whether cells migrate in coordinated groups or disperse individually. Additionally, we compare the effects of combined versus individual expression of Snail and Twist to better understand their distinct and cooperative roles. Ultimately, this work seeks to provide a more detailed, mechanistic understanding of how these transcription factors regulate EMT.

I am participating in SuperUROP because I want to gain research experience in machine learning and computational biology, enabling me to contribute to real-world biomedical challenges and develop skills that are essential for graduate school and an academic career.



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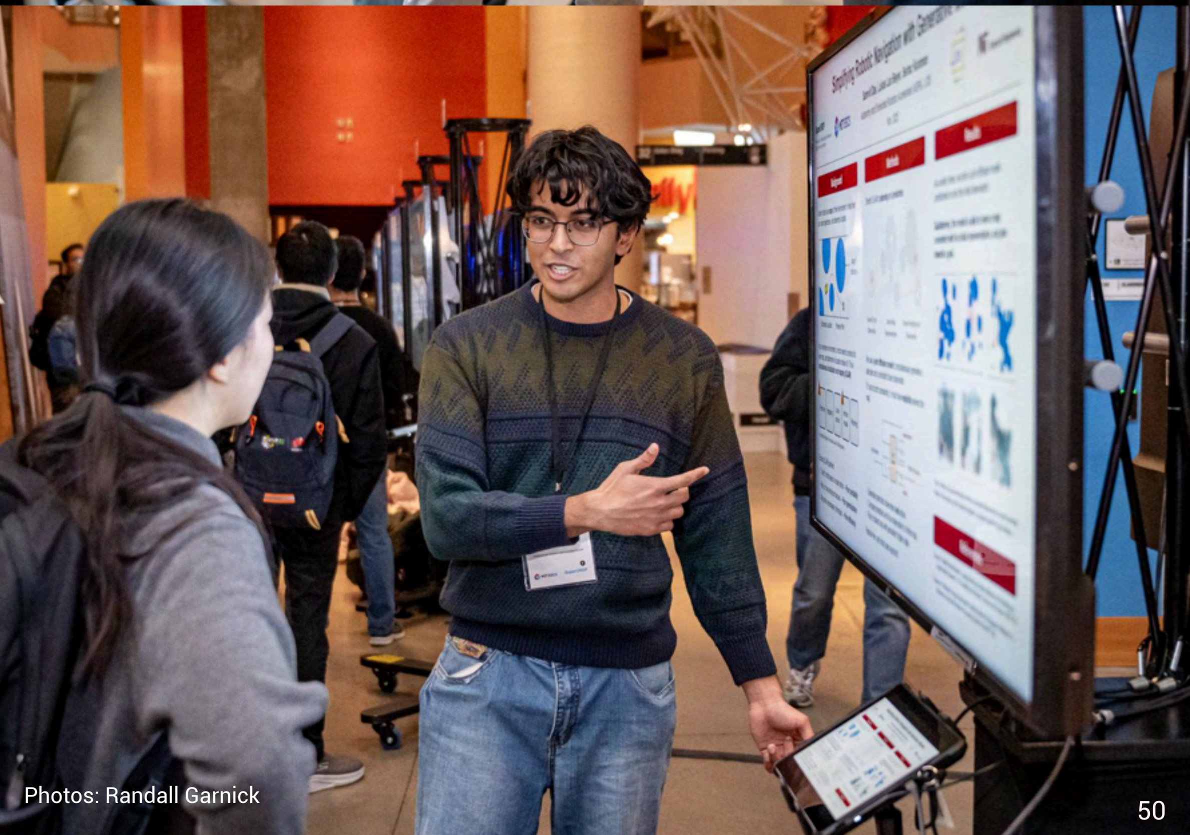


Photos: Randall Garnick

Charikleia (Hara) Moraitaki

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Multimodal Learning for Early Prediction of Endometriosis

Supervisor: Marzyeh Ghassemi

Endometriosis affects 5–10% of reproductive-aged women but faces diagnostic delays of 6–11 years, contributing to prolonged suffering and healthcare inequities. Current diagnostic approaches rely on single data sources and fail to capture the complex, multifaceted nature of this disease. This project develops a multimodal machine learning framework that fuses three complementary data streams: structured longitudinal electronic health records, patient-generated symptom reports from a menstrual-tracking application, and unstructured clinical notes. We apply large language models to extract clinical entities from free-text notes and systematically compare unimodal and multimodal architectures to understand how different data sources contribute to early risk prediction. Critically, our approach incorporates fairness auditing across demographic subgroups to address documented disparities in endometriosis diagnosis and care. By integrating these heterogeneous modalities, we aim to shorten diagnostic delays and enable earlier, more equitable interventions for all patients.

I am participating in SuperUROP because I am drawn to research where methodological innovation meets real-world impact. Women's health remains critically underserved, with millions of patients facing years-long diagnostic journeys and fragmented data. This project gives me the chance to develop novel approaches for fusing heterogeneous data sources while working toward tools that could improve patient outcomes.

Carolina Moura Valle Costa

MIT EECS | Morais and Rosenblum Undergraduate Research and Innovation Scholar

Rethinking Software Development

Supervisor: Daniel N. Jackson

Current LLM-based workflows either aid developers with granular coding tasks or use free-form prompts to generate full applications ("vibe coding")—but neither abstracts low-level tasks enough or scales effectively for complex projects. This research introduces a modular design methodology: we decompose software into self-contained modules that communicate only via defined synchronizations. This way, we avoid monolithic generation, simplify maintenance, and exploit common coding patterns learned during LLM pretraining. In this project, we're going to build tools that embed LLMs in code generation, design a domain-specific synchronization language, and perform case studies and prototype development for both instructional and real-world applications.

With the advent of LLMs, and haven taken several HCI classes at MIT, I found myself constantly reflecting on the future of software. In this SuperUROP, I'm excited to bring my experience both as an HCI enthusiast and as a user of all kinds of AI coding assistance tools into Prof. Jackson's concept design research.

Christiana Pak Nguyen

MIT MechE | Undergraduate Research and Innovation Scholar

Human-Centered Evaluation and Design of Novel Sleep Apnea Therapies: Insights from the User Experience

Supervisor: Ellen Roche

Humans rely on intuitive interactions with devices to manage health, and for individuals with obstructive sleep apnea, usability, comfort, and convenience are key drivers of consistent therapy. While our novel negative-pressure device shows promising therapeutic potential, participants face challenges with noise, setup, and other barriers common across existing treatments such as CPAP. This project uses semi-structured interviews to explore patient experiences across the full spectrum of OSA therapies, capturing motivations for seeking treatment, daily routines, perceived effectiveness, and key pain points. Responses are systematically analyzed to identify design opportunities, preferences, and trade-offs that influence long-term adherence. Insights from this holistic evaluation guide iterative improvements to device design, comfort, and usability, ultimately aiming to enhance patient experience, support consistent use, and inform broader strategies for human-centered sleep apnea therapies.

I am participating in SuperUROP to strengthen my skills in user-centered design and multi-modal research methods. By conducting structured interviews and analyzing participant feedback, I aim to identify key design challenges and develop practical improvements that enhance usability, comfort, and adherence. This experience will help me bridge engineering design with human-centered evaluation to create more effective technology.

Janina Ojeiduma

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Animate Biosensors for Toxic Chemical Detection and Characterization

Supervisor: Bevin P. Engelward

Animate biosensors offer a practical and innovative approach for detecting toxic chemicals, leveraging the sensitivity and specificity of engineered mammalian cells to assess environmental hazards. This research centers on developing mammalian cell-based biosensor platforms capable of identifying a range of hazardous chemicals, including nitrosamines, per- and polyfluoroalkyl substances (PFAS), and flame retardants. By introducing specific metabolic enzymes, particularly cytochrome P450 isoforms, we mimic human metabolic activation pathways, improving the physiological relevance of our models. This approach enables comprehensive detection of DNA damage and repair events following environmental exposures, supporting chemical safety assessment and public health efforts.

Through this SuperUROP I aspire to characterize the effects of a key class of toxins on liver cell line physiology and genomic integrity. I am determined to work towards elucidating genotoxic interactions at a granular level, and hopefully uncover findings which advance our knowledge of the intersection between toxin exposure and human physiology at the cellular level.

Johlesa Miyheak Orm

MIT EECS | Undergraduate Research and Innovation Scholar

Robotic X-Ray Vision for Sensing and Manipulation

Supervisor: Fadel Adib

Advances in AI and computer vision have allowed robots to gain a better understanding of their environment and accomplish complex manipulation tasks. However, traditional robotic systems struggle with occluded environments, where visual sensors provide limited information. In my project, I aim to create a first-of-its-kind robotic grasping system capable of grasping objects in fully occluded environments (e.g., under packaging materials). I will build on recent work which uses millimeter-wave (mmWave) signals to create 3D reconstructions of hidden objects and investigate new machine learning architectures to predict optimal grasp points for this new modality. This work can open up new possibilities in robotic perception and manipulation, with potential uses in warehouses and smarthomes.

My goals for participating in this SuperUROP are to gain high-level research experience in preparation for an MEng, and to deepen my knowledge in machine learning (ML), sensing, and robotic manipulation. With my project, I am able to regularly apply skills that I had learned from my courses, such as ROS and ML. Ultimately, I am motivated by the potential for my research to advance robotic applications in both domestic and industrial settings.

Yaman Bora Otuzbir

MIT EECS | Hudson River Trading Undergraduate Research and Innovation Scholar

Data-driven Mathematical Modeling of the World Trade Network

Supervisors: Justin Solomon & Joern Dunkel

In this project, we perform data-driven analysis and modeling of international trade, using the historical trade data between nations. Our approach combines dynamical systems identification with graph theory to capture both the temporal evolution of trade flows and the network of interdependencies they form. Emphasis is placed on interpretability: rather than building opaque predictive models, we aim to construct representations that can be understood and related to the economical and political data. First of all, we adapt statistical dynamics identification methods to explicitly incorporate the network structure, and we will calibrate them using synthetic data. Secondly, we apply these methods to the data collected by the World Trade Organization in order to extract meaningful patterns.

Through this SuperUROP, I want to apply my skills in an interdisciplinary project that takes a mathematical approach to an economics based problem. This project lies in the intersection of my two majors, 18 (Math) and 6-14 (CS, Econ, and Data Science). Having taken classes on networks (6.326), dynamical systems (18.353), and high dimensional statistics (18.656), I'm excited to apply the knowledge I gained from these classes to real world data.

Anisha Parsan

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar

AF3Design: De Novo Protein Design with AlphaFold3

Supervisor: Caroline Uhler

De novo protein design is a central challenge in computational biology, with broad applications in therapeutics, diagnostics, and enzyme engineering. Recent advances have shown that AlphaFold-based confidence metrics, such as ipTM and pTM, correlate strongly with experimental measures of binding affinity and structural stability, motivating their use as surrogate losses in protein optimization frameworks. Building on these insights, new approaches such as BindCraft have introduced additional differentiable proxies (e.g., pLDDT, contact-based losses, radius of gyration loss) that capture structural fidelity and biophysical plausibility. This project focuses on developing AF3Design, a protein design framework that directly leverages the speed and accuracy of AlphaFold3. A key research direction is to incorporate diverse loss functions into the design loop – including energy-inspired metrics (pTMEnergy, pAEnergy), confidence-based losses (pLDDT), structural regularizers (contact loss, radius of gyration), and potentially novel AF3-specific surrogates – to provide a flexible optimization landscape that balances stability, foldability, and function. In parallel, the project will systematically explore different search algorithms for navigating protein sequence space. Current experiments have shown that evolutionary search with AF3 can already generate high-confidence nanobody and miniprotein candidates. Building on this, we will investigate reinforcement learning, discrete gradient descent in energy landscapes, and hybrid strategies that integrate proteinMPNN-based mutation operators or active-learning loops. By benchmarking these algorithms across miniprotein, nanobody, and enzyme design tasks against existing methods (BindCraft, RFAntibody, RFDiffusion2), we aim to clarify which combinations of losses and search strategies yield the most efficient and generalizable design pipeline.

I am doing SuperUROP because I am deeply interested in generative approaches in structural biology and genomics, and in how optimization methods can be used to frame these problems in new ways. What excites me most is the potential of deep learning not just to build powerful models, but to ask the right biological questions and to lead to tangible improvements in experimental settings. More broadly, I see this project as a way to explore what research could look like for me long term—whether that means pursuing a PhD or working in industry—and it feels like a strong model for both paths. I would also love to work toward writing a paper by the end of this experience.

Roshni Parulekar-Martins

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Functional Connectivity Mapping of Hippocampal Neuron Circuits in the Brain Using Voltage Imaging

Supervisor: Sixian You

How do we think and form memories? Understanding this requires mapping neuronal firing and synaptic dynamics in the hippocampus, the brain's center for learning and memory. Voltage imaging, which records neural activity via fluorescent genetically encoded voltage indicators (GEVIs), enables functional readout of these processes. While prior work has focused on structural reconstructions or broad behavioral dynamics, few have used voltage imaging to infer synaptic strengths. This project develops a pipeline to reconstruct hippocampal circuits from voltage imaging movies and track how repeated stimulation reshapes connection weights, offering new insights into the neural basis of learning and memory.

I am excited to conduct research on the "final frontier," understanding how our brains work. SuperUROP will be an amazing opportunity to learn hands-on experimental and computational techniques, deepen my understanding of brain function, and contribute to a project that could one day impact BCIs, AI, and treatments for memory disorders.

Krishna Parvataneni

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

An AI-enabled tool for Peri-Procedural Patient Risk Stratification for Hemodialysis Patients Undergoing Interventional Procedures

Supervisor: Polina Golland

Hemodialysis is a common treatment for End-Stage Renal Disease (ESRD). To filter blood, it requires vascular access procedures such as thrombectomy and fistuloplasty, which carry elevated risk of infection, cardiovascular events, and mortality. This project aims to develop a model that predicts peri-procedural morbidity, readmission, and mortality for hemodialysis-related interventions, filtered from the ACS-NSQIP surgical database using CPT and ICD codes. Models including Random Forest and TabPFN will be trained and evaluated on AUROC, precision, recall, specificity and sensitivity. Results will be stratified by age, race, and sex to ensure fairness and transparency. The goal is to improve care by helping clinicians identify high-risk patients and deliver personalized, timely care.

I am participating in SuperUROP to gain experience applying machine learning to real clinical data. My background in AI and biomedical coursework prepared me for this research, and I am excited to learn how data-driven tools can improve patient outcomes and support clinical decision-making.

Serena H. Pei

MIT MGAIC | MIT Generative AI Impact Research and Innovation Scholar

Enhancing Biodiversity Image Datasets with Generative AI for Improved Species Classification

Supervisor: Sara Beery

Biodiversity conservation efforts increasingly rely on large-scale image repositories for species classification and monitoring. This project addresses issues of class imbalance in such repositories to support more effective classification. My role involves balancing datasets through synthetic data generation and determining optimal strategies for integrating generative AI in biodiversity research. I'll experiment with different diffusion model architectures and dataset parameters in generation, then quantify outcomes through model accuracy and generalization on out-of-distribution data. The goal is to introduce a validated biodiversity dataset, evaluate the potential of GenAI in ecological contexts, and propose best practices for data augmentation.

My goal through participating in this SuperUROP is to actively contribute to biodiversity conservation efforts using state of the art generation models. Being able to take more ownership of a project will allow me to grow my passion for research and practice both technical skills in computer vision and soft skills in communication.

Monica Ann Petulla

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Unbiased Discovery of Binding-fusion Complexes to Deliver Diverse Cargo to Any Cell Type in the Body

Supervisor: Kristin Knouse

Gene therapy holds great promise to treat disease, but current delivery systems lack the precision and efficiency needed for safe use. My project develops a modular, in vivo cell-targeting platform by engineering lentiviral vectors with viral fusogens, which enable entry, and nanobodies, which provide specificity. I have used yeast surface display to identify high-affinity nanobodies across multiple murine cell types and conducted an in vivo delivery screen of nanobody-fusogen pairs. These studies revealed novel targeting interactions, offering new insights into delivery system design. Moving forward, I will investigate avidity effects and extend this platform to other delivery vehicles, aiming to enable programmable, cell-specific gene delivery for safer, more effective therapies.

I am participating in SuperUROP to experience the complete research and publication process while bridging my interests in biological engineering and translational medicine. My background in molecular biology and engineering has prepared me to tackle viral vector design, and I am excited to explore the therapeutic potential of my delivery platform.

Tananya Prankprakma

MIT CEE | Undergraduate Research and Innovation Scholar

Building a Geospatial Decision-Making Tool for Climate Beneficial Biomass Reuse

Supervisor: Desiree Plata

Agricultural residues are produced on the gigaton scale annually, and a portion of those burnt or left on the field could deliver climate benefits if redirected to bioenergy or carbon sequestration pathways. I am developing a geospatial tool that maps residue availability and integrates location-specific life cycle analyses for fuel production and carbon storage pathways. This enables the spatially specific visualization of environmental and economic tradeoffs, informing infrastructure and policy decisions. The tool aims to assess potential climate impact from a holistic, life-cycle point of view and identify locations with high potential impact. We plan to pilot this tool with stakeholders such as farmers and carbon removal startups to gather feedback and identify further research goals.

I am participating in the SuperUROP program to develop my ongoing research. My interest in having a positive impact on energy systems and classwork as a civil engineering major prepared me to take on this project. I hope to become a more independent researcher and am excited for the potential of developing a tool for real-world impact.

Diya Lakshmi Ramesh

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Characterizing Cancer Cell Dependency on Methionine Synthase (MTR) in Low-Lipid Environments

Supervisor: Matthew G. Vander Heiden

Cancer cell metabolism is significantly influenced by microenvironmental factors such as nutrient availability, which can vary across different tissues and introduce exploitable therapeutic vulnerabilities. Our findings indicate an increased dependency in cancer cells on the folate and methionine cycles in low lipid conditions. A direct connection between these pathways is not known. So, this project aims to characterize the nature and mechanism of this dependency through a variety of experimental techniques, including proliferation assays with relevant metabolites or pharmacologic agents, measurement of altered metabolic profiles, and quantification of changes to key metabolic pathways (such as lipid synthesis) through methods like gas chromatography-mass spectrometry.

I am participating in SuperUROP to further develop my research experiences in the field of cancer metabolism. As an aspiring physician-scientist, I am passionate about bridging the bench with the bedside through biomedical research that has direct patient impacts. This project perfectly aligns with my goals by enabling me to explore the basic science behind fundamental biochemical pathways that are also known to have roles in cancer progression.

Greycen Ren

MIT MGAIC | MIT Generative AI Impact Research and Innovation Scholar

Structural Elucidation Through Self-supervised Learning of Molecular and Spectral Representations

Supervisor: Connor W. Coley

Complete metabolic studies require the ability to systematically label and quantify the entire collection of molecules within a sample. Current labeling methodologies with liquid chromatography-tandem mass spectrometry (LC-MS/MS) require comparison to a reference library, providing poor coverage over the chemical space. This project hopes to advance the computational metabolomics pipeline by developing a bimodal foundation model. By leveraging vast corpora of unlabeled data, we aim to learn rich spectral and molecular representations through self-supervised learning. Then, using labeled spectral/molecular pairs as supervision, we hope to align the latent space across the two modalities, enabling robust molecule-to-spectrum fragmentation and spectrum-to-molecule generation.

I am participating in SuperUROP to gain a more intensive research experience at the intersection of machine learning and the biomedical sciences. Though I have explored machine learning through my coursework, my background is primarily in biochemistry. This project excites me as an opportunity for computational approaches to make a meaningful contribution to modern problems in biology research, such as metabolomics.

Mario Javier Sanchez Mendez

MIT MechE | Undergraduate Research and Innovation Scholar

Developing a Device for In-Situ Detection of Microplastics in Water

Supervisor: Andrew Bennett

Plastic pollution has become a significant issue facing today's oceans. This contamination is complicated further by the presence of small particles (including microplastics), which can either be released directly into the environment or broken down from larger plastic components. A promising, lower-cost approach for detection of microplastics involves the implementation of the Nile Red dye. This ongoing research presents a design seeking to address some of the existing complications with Nile Red as a low-cost method for in situ microplastic detection. This approach implements a machine learning based fluorescence imaging approach. Nile Red dye is able to stain plastics and fluoresce under blue light, making plastics more easily identifiable to a standard camera. Plastics were left to stain in a dark room for 30 minutes in a mixture of 3 μg/mL of Nile Red dye. These plastics were then moved to a tubing setup connected to a reversible pump, which oscillated between moving the plastics in each direction. This tubing setup was then lit by blue LEDs, and recorded by a phone camera using an orange filter to block out the blue light while allowing through the fluorescence spectra. These tests were done with different known masses of plastics, with each test being run for one minute at 240 frames per second. The frames of the video were run through an image labeler, using a script to detect plastic pieces based on their colors and shape. This was then used as the data set to detect any plastics in frame. In order to detect the plastic concentration in a video, the presence of microplastics was detected in each frame using a deep learning algorithm trained on the plastic image data set. The total pixel area covered by microplastics across the entire video was calculated, and then averaged over the total pixel area of the entire video. This could then be plotted against videos of known microplastic concentrations, allowing for new videos to be analyzed and receive a microplastic concentration estimate. Although still ongoing, this project has the potential to expand the possibilities for lower cost microplastic analysis.

Varun Sangtani

Undergraduate Research and Innovation Scholar

Simplifying Hardware Design

Supervisor: Daniel Sanchez

A central challenge when designing CPUs or accelerators is managing the control logic surrounding pipeline hazards. Syncopy is a new HDL that addresses this by decoupling timing-sensitive control logic from functional units and supporting reusable hazard-handling strategies as first-class constructs. Building on this foundation, my research will focus on designing, implementing, and evaluating complex hazard-resolution abstractions in Syncopy that go beyond simple pipelines to support more aggressive microarchitectural features, such as out-of-order execution and shared caches.

During this SuperUROP, I hope to gain a deeper understanding of the complexities behind modern processor and accelerator architecture by automating (in some sense) some of the more complex parts of their design.

Manxi (Maggie) Shi

MIT MGAIC | MIT Generative AI Impact Research and Innovation Scholar

Bridging Statistical Physics and Generative AI

Supervisor: Marin Soljacic

This project applies statistical physics to generative AI, exploring how concepts like entropy and the renormalization group (RG) can yield more principled models. We focus on two directions. The first is adaptive temperature scaling to maintain constant entropy across text length. Current methods violate this, degrading generation quality in longer texts. We aim to control per-token entropy as a measure of creativity vs. determinism while preserving quality. The second is applying RG ideas to design diffusion models that capture multiscale feature emergence. Natural data often show scale-invariant, power-law behavior, but current models lack such structure. Our goal is to formalize links between statistical physics and generative AI, advancing interpretability, efficiency, and robustness.

Through SuperUROP, I hope to build on my coursework and prior research by tackling a more intensive project. I am excited to deepen my understanding of generative models through physics-inspired approaches and to contribute meaningful research in this rapidly evolving field.

Sora S. Shirai

Eric and Wendy Schmidt Center Funded Research and Innovation Scholar

Exploring Explainable Graph Neural Network Options for Microbiome Data Integration and Biomarker Discovery

Supervisor: Caroline Uhler

The human microbiome plays a critical role in health and disease, but extracting reliable biological insights from multi-omics datasets remains challenging due to high dimensionality, sparsity, noise, and compositionality. This project proposes the development and application of graph neural network (GNN) models to enhance the reproducibility of microbiome analyses. Using structural learning techniques in PyTorch Geometric, the project aims to build graph-based models that more reliably capture underlying biological patterns than traditional correlation-based methods. Beyond applications to the microbiome, the approaches developed through this project have potential for broad applicability to other domains involving complex biological networks, such as cancer genomics and immunology.

I am participating in SuperUROP to expand my foundation in experimental biology into computational research. My experiences with research in synthetic biology through MIT iGEM and cancer immunology at Dartmouth-Hitchcock have prepared me with strong biological intuition to guide hypotheses. I am excited to gain hands-on experience with machine learning in a biomedical context and to connect computation with biology.

Aditya Shrivastava

Undergraduate Research and Innovation Scholar

Improving the Visual Reasoning Abilities of AI for Education

Supervisor: Paul Liang

This study investigates methods to enhance large language models (LLMs) with robust capabilities for visual reasoning in the context of education. While LLMs demonstrate strong performance on symbolic reasoning tasks, their inability to reliably interpret diagrams in domains such as geometry and calculus often results in erroneous explanations, thereby undermining their effectiveness as tutoring systems. Typical errors include misidentifying geometric relationships—for instance, inferring intersections between disjoint circles or misclassifying the location of a labelled point relative to a region. To address these limitations, we aim to propose a framework for augmenting LLMs to integrate visual understanding with formal reasoning, with the objective to establish an AI tutoring system capable of delivering precise, visually grounded feedback that supports learning while minimizing instructional error.

I am excited to pursue this SuperUROP in order to develop my research skills, and to apply what I have learned to further the field of artificial intelligence and education.

Keonna Charlize Simon

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Morphology-Aware ML Model for CycIF-Based Cell Typing in the Medulloblastoma Tumor Microenvironment

Supervisor: Regina A. Barzilay

Imaging medulloblastoma tumors presents several challenges, including tissue autofluorescence, low signal-to-noise ratios, and the complexity of distinguishing immune cells within densely packed tumor regions. Current analysis methods rely largely on signal brightness and frequently confuse true biology with autofluorescence or spectral overlap. My work develops a morphology-aware machine learning model that uses visual structure and texture, rather than brightness alone, to distinguish real marker expression from these artifacts. By improving how cells are identified and classified, my approach seeks to produce more reliable cell typing.

Through this SuperUROP, I hope to gain hands-on experience applying machine learning and image processing techniques to biological data, which will complement my lab experience in experimental biology. I am eager to enhance my understanding of advanced statistical analyses and imaging pipelines, which will be crucial for my long-term interests in disease research and public health.

Magdalena (Maggie) Slowikowski

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Wireless Gastrointestinal Neurotechnology for Integrated Electrical and Optogenetic Stimulation and Gastrointestinal EMG Recording in Small Animals

Supervisor: Polina Anikeeva

Disruptions in gut-brain communication are linked not only to gastrointestinal disorders like IBS but also to neuropsychiatric disorders like anxiety and depression, making the gut-brain axis a critical target in neurophysiological research. However, current research on the gut-brain axis remains limited due to a lack of adequate tools capable of both modulating GI activity at the organ level while recording GI physiology in real-time. We aim to address these limitations by developing a full gastrointestinal stimulation and recording system—implantable devices that are capable of interfacing seamlessly with the gastrointestinal tract along with a wireless control module that is capable of driving electrical and optogenetic stimulation along with gastrointestinal EMG recordings.

I am participating in SuperUROP because I want to help make advancements in the types of tools available for neurophysiological research. Having worked in the Bioelectronics Lab for 3 years, along with taking numerous circuit design, programming, and microfabrication classes, I feel prepared to design and fabricate my own fully integrated, multifunctional system for studying the GI tract. I am excited to create a new tool for others to use!

Tiffany Stephens

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Improving Immunotherapy for Ovarian Cancer Treatment By Inducing Tumor Cell Stress and DNA Damage

Supervisor: Michael B. Yaffe

Ovarian cancer grows deep in the abdomen, producing vague symptoms in its early stages. It is most often diagnosed at a late stage, limiting treatment efficacy. This project aims to evaluate how the integrated stress response in tumor cells undergoing DNA-damaging chemotherapy treatment increases immune cell activation. In murine melanoma models, we have shown that combining immunotherapy with intratumoral injection of DNA-damaged tumor cells successfully activated an anti-tumor response and resulted in tumor regression. By probing proteomic and transcriptomic changes of DNA-damaged tumor cells, we can investigate signaling pathways necessary for immune recognition and elimination of tumor cells. We hope to successfully combine DNA-damaging chemotherapy with immunotherapy in cancer models.

SuperUROP will give me the opportunity to uncover an unknown and misunderstood biological phenomena in a topic that I am deeply passionate about; immunology. It will give time and support to do good and meaningful research as a student. I hope to learn about presenting and communicating research findings in a convincing and effective way. I am most excited about how interdisciplinary my project is, offering many possible directions.

Joel Junyao Tan

MIT MGAIC | MIT Generative AI Impact Research and Innovation Scholar

Human-AI Collaborative Music Generation

Supervisor: Anna Huang

The Anticipatory Music Transformer (AMT) is a model that generates symbolic music (i.e. score generation such as MIDI) given user inputs, such as generating an accompaniment for a melody. Its name stems from the fact that during generation it anticipates user inputs in the near future, with the idea that better predictions are made with this additional context. While the original AMT (Thickstun et al.) is able to generate music, it only takes into account the duration and pitch of notes, but not the expressive aspects such as dynamics. The aim of the project is to continue this development and evaluate its performance, with the goal that such a model can be deployed onto a Disklavier (an acoustic piano with recording and playback functionality) to enable live accompaniment generation.

As a Computer Science student who is currently learning about the quick developments in AI and a pianist myself, I am curious how AI can be used to collaborate with pianists, and wish to see the strengths and weaknesses of different models that accomplish this task. Unlike many other applications of AI, there is a large creative focus to music and seeing how the current models may be able to mimic this creativity interests me.

Marshall N. Taylor

MIT EECS | Quick Undergraduate Research and Innovation Scholar

Real-Time Detection and Reconstruction of Smell

Supervisor: Paul Liang

The goal of this SuperUROP is to develop machine learning models and datasets capable of recognizing and interpreting mixtures of smells. Existing approaches focus on identifying single substances, but real-world odors are complex combinations of volatile compounds that interact non-linearly. We will collect sensor data from controlled mixtures across categories such as fruits, herbs, spices, and household chemicals to create a benchmark dataset for mixture reasoning. Using this data, we will train attention-based and multi-label models to classify mixtures, estimate composition, and generalize to novel combinations. Building on our previous work SmellNet, this project aims to advance mixture-aware AI for smell, with all datasets and models released as open-source resources to support the broader olfactory machine learning community.

I chose to pursue SuperUROP to gain structured research experience while working on groundbreaking projects. My previous UROP experiences prepared me to undertake a SuperUROP. This year, I hope to learn more about multimodal learning, the process of publishing, and collaboration. I am most excited for how much I will grow from this experience and for opportunities to publish.

Diego Alejandro Temkin

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

Using Category Theory to Create a Generalizable Framework for Bus Network Redesigns Incorporating Equitable Factors

Supervisor: Gioele Zardini

By 2050, over 60% of the global population will live in cities, making public transit not just essential but foundational to the functioning of modern society. Yet, despite advances in mobility technology, cities still struggle to design bus systems that are efficient, adaptable, and that meet evolving urban and community needs. This project aims to develop a novel framework for co-designing and modeling urban bus systems using applied category theory, addressing challenges when planning city-scale transit networks. By creating a modular, extensible simulation platform and partnering with transit agencies, we will rigorously capture technical and stakeholder dynamics, test our models on real-world data, and explore AI-driven approaches for optimizing bus routes and service design.

Through this SuperUROP, I'm really excited to applying novel ideas to solve age-old problems, like transit, through a long-term research project. This project combines so multiple different disciplines into one, and I'm ready to tackle that head on!

Sophie M. Thompson

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Optimization of Natural Fiber Prosthetic Socket Manufacturing Method for Sierra Leone

Supervisor: Hugh M. Herr

Less than 10% of patients globally have access to orthotic and prosthetic medical care, and thus have barriers to managing the effects of their disability and to maximizing their mobility. For prosthesis users, the prosthetic socket, the interface between the residual and prosthetic limb, is the most critical component of the device to maintain. The socket requires frequent adjustments and replacement to ensure the health of the residual limb and painless ambulation. Sockets are typically made from carbon-fiber mesh, supported by acrylic resins. Acquiring materials to fabricate carbon-fiber sockets —"the gold standard of care"—is logistically difficult and prohibitively expensive in locations like Sierra Leone, West Africa. Research studies by Nigerian scientists proved the feasibility of using natural fibers from locally-grown plants, like banana trees, as carbon-fiber alternatives to produce natural fiber prosthetic sockets for use in similar environments. However, data on clinical safety of these sockets and guides informing fabrication processes for clinicians are limited. Therefore, this project aims to optimize a step-by-step manufacturing method for fabricating natural fiber sockets including material testing, fabrication, and mechanical testing at MIT, in a simulated tropical environment, and in Sierra Leone, followed by clinical trials. Chemical and manual extraction methods were tested, with a combination of water retting and 5% NaOH solution providing the optimal result. Mechanical testing has ensured that the natural fibers equate to carbon fiber in terms of characteristics like tensile strength and bendability. The preliminary results are promising and indicate the potential for adoption in numerous limited resource environments, thus improving the prosthetic management of care post-amputation and enabling mobility for patients who benefit from this innovation.

I joined SuperUROP because I wanted to gain more experience translating my research out of the lab into a presentation setting. I look forward to the different workshops and exercises in SuperUROP that I will be able to apply back to my research.

Akshata Tiwari

MIT | Tang Family FinTech Undergraduate Research and Innovation Scholar

Domain-Specific Language and Trained LLM Copilot for Financial Instrument Design

Supervisor: Wojciech Matusik

This project develops a concise domain-specific language and AI assistant for designing and validating financial instruments. The system connects developers in financial contexts—quant developers, risk/trading teams, and integration engineers—to pricing engines, market data, booking, and reporting systems. It aims to compile natural language requests into specifications, including payoffs, schedules, and valuation settings. This pipeline aims to produce shorter time-to-market, fewer back-and-forths, and decisions that meet regulatory restrictions in a range of financial settings. The DSL standardizes how ideas are specified and reviewed, while the assistant surfaces edge cases, explains trade-offs, and produces answers and rationale that teams can trust.

This SuperUROP gives me the opportunity to bridge the gap between CS, machine learning, and finance, and study how modern ML can promote problem-solving in the fintech domain. Having experience working on models and designing systems in settings from academia to market-making firms and exchanges, I am interested in translating well-founded techniques into fintech capabilities and learning to frame research questions into tools that can make an impact in a range of financial contexts.

Jonathan Tjandra

MIT EECS | Guillemin Undergraduate Research and Innovation Scholar

Leveraging Synthetic X-Ray Projections for Accurate Lung Nodule Detection

Supervisor: Polina Golland

Lung cancer is the leading cause of cancer-related deaths worldwide, underscoring the importance of early detection. While CT is the gold standard for screening, chest X-rays remain vital due to their accessibility, affordability, and lower radiation exposure. This project explores how machine learning can enhance X-ray based diagnosis using synthetic radiographs generated from CT data. Initial work will focus on detecting and localizing lung nodules, but the scope also includes broader directions such as data augmentation, multi-view projections, and comparisons across imaging modalities. The goal is to assess both opportunities and challenges of applying AI in medical imaging and generate insights for future clinical applications.

I am participating in SuperUROP to gain real-world professional research experience and prepare for future projects such as an MEng thesis. My coursework in machine learning and computer vision has equipped me with strong technical foundations, and I am excited to deepen both my technical and communication skills. I look forward to exploring new ideas and contributing to impactful research in this field.

Unyimeabasi Usua

Undergraduate Research and Innovation Scholar

Mitigating Hallucinations in Finance Based Multi-Agent Large Language Model Systems

Supervisor: Amar Gupta

This project explores the development of privacy-preserving, multi-agent AI systems that use large language models and differential privacy. The goal is to design decentralized agent frameworks that can collaborate and reason collectively while maintaining strict data protection. We intend to develop a unique system aimed to support complex decision-making tasks across sensitive domains, building toward safer, fairer, and more transparent AI applications.

I am doing SuperUROP because I want to continue my research in privacy and ethical AI at a deeper level by pursuing a more involved project with my lab. I want to be able to present interesting and impactful work and publish something meaningful to my community.

Alexandra Valdepenas

Undergraduate Research and Innovation Scholar

Biocompatible Gel for Cell Encapsulation

Supervisor: Xuanhe Zhao

For people with type 1 diabetes, the destruction of insulin producing β-cells causes an imbalance in glucose levels. This necessitates lifelong insulin therapy via subcutaneous infusion pumps or multiple daily injections. An alternative and promising solution for cellular replacement is through islet cell encapsulation, where cells are enclosed in polymeric membranes that allow the selective passing of insulin while blocking immune attacks. This project will explore the material design for such biocompatible membranes, with the end goal of a robust protocol for the fabrication of these devices.

I am excited to be part of SuperUROP and improve both my research and communication skills. With the potential for real impact in healthcare, I hope to make the most out of this project through the program. I am looking forward to exploring how research in mechanics and materials can solve some of the most challenging problems in medicine.

Zuri Mary Vallery

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Optimizing Spiral Microfluidic Devices

Supervisor: Jongyoon Han

Suspension cell culture is commonly used for the manufacturing of biopharmaceutical products. One of the unit operations of downstream processing, called cell clarification, describes the separation of biopharmaceutical products from the cells which produce them, and the use of filters for clarification generally leads to large product losses. We use spiral microfluidic technology as a passive, continuous, and label-free method of separating cells from products. In this project, we will optimize the channel geometry and process conditions that lead to a cell-free harvest collection. This year, we will investigate how temperature and fluid viscosity influence device performance, and we will explore computational modeling of flow dynamics and particle focusing to guide future device designs.

I am participating in SuperUROP to gain experience with a longer-term research project and to strengthen my skills in device development. Through NEET, I was first introduced to microfluidics, which sparked my interest in this field. I am especially excited to learn how to iterate effectively when working with a system that involves such a large number of variables.

Medha Venkatapathy

Undergraduate Research and Innovation Scholar

Optimizing the Muon Optimizer

Supervisor: Jacob Andreas

The Muon optimizer is a recent and faster neural network optimizer that uses momentum with an additional orthogonalization step based on the Newton-Schulz iteration. My project focuses on improving post-training methods for large language models, evaluating Muon's stability and efficiency compared to standard optimizers, and exploring how it improves the fine-tuning performance on hidden weight layers.

I am excited to pursue SuperUROP to deepen my understanding of natural language processing, a field I believe will be important for many years. My background includes linguistics coursework and research with the LIGO group, which prepared me to explore a niche subject over an extended period.

Michelle J. Wang

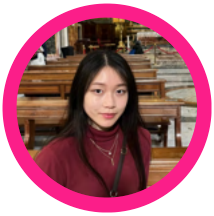
MIT EECS | Boeing Undergraduate Research and Innovation Scholar

SoftMimic: Learning Compliant Whole-body Control from Examples

Supervisor: Pulkit Agrawal

We introduce SoftMimic, a framework for learning compliant whole-body control policies for humanoid robots from example motions. Imitating human motions with reinforcement learning allows humanoids to quickly learn new skills, but existing methods incentivize stiff control that aggressively corrects deviations from a reference motion, leading to brittle and unsafe behavior when the robot encounters unexpected contacts. In contrast, SoftMimic enables robots to respond compliantly to external forces while maintaining balance and posture. Our approach leverages an inverse kinematics solver to generate an augmented dataset of feasible compliant motions, which we use to train a reinforcement learning policy. By rewarding the policy for matching compliant responses rather than rigidly tracking the reference motion, SoftMimic learns to absorb disturbances and generalize to varied tasks from a single motion clip. We validate our method through simulations and real-world experiments, demonstrating safe and effective interaction with the environment.

I am participating in SuperUROP to gain hands-on experience in robotics and AI research. I am excited to learn more about reinforcement learning, modeling the physical world, and humanoid robots over the course of a longer-term project. I hope that this project will contribute towards safer, more functional robots.



Josephine Wang

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

World-grounded Pose Estimation for Identifying Motor Abnormalities in Children

Supervisor: Nidhi Seethapathi

Pediatric locomotion analysis holds potential for early detection of neurodevelopmental disorders; however, current methods for data collection in toddlers are costly and challenging. We present a computational pipeline for extracting gait metrics from standard 2D videos. The pipeline integrates state-of-the-art pose estimation models, world-coordinate alignment via WHAM, and gait metric validation against Motion Capture ground truth. Applied to videos of toddlers walking, we will evaluate whether early gait markers detected by the pipeline correlate with later autism spectrum disorder diagnoses. This approach enables motion analysis without specialized equipment, expanding pediatric motor control research and supporting earlier intervention for disorders with motor manifestations.

I have worked in the Seethapathi lab for two years, gaining experience in computational methods for studying motor control and its clinical translation. Through SuperUROP, I aim to secure dedicated time and mentorship to explore the diagnostic potential of my computer vision pipeline. I hope to enhance my project leadership skills, refine my research practices, and develop a tangible product while collaborating closely with my lab.

Sophie L. Wang

MIT EECS | Philips Undergraduate Research and Innovation Scholar

Words That Make Language Models Perceive

Supervisor: Phillip Isola

Large language models (LLMs) trained purely on text ostensibly lack any direct perceptual experience, yet their internal representations are implicitly shaped by multimodal regularities encoded in language. We test the hypothesis that explicit sensory prompting can surface this latent structure, bringing a text-only LLM into closer representational alignment with specialist vision and audio encoders. When a sensory prompt tells the model to 'see' or 'hear', it cues the model to resolve its next-token predictions as if they were conditioned on latent visual or auditory evidence that is never actually supplied. Our findings reveal that lightweight prompt engineering can reliably activate modality-appropriate representations in purely text-trained LLMs.

I'm excited to work on open-ended problems in representation learning and to continue growing as a researcher. Deep learning is evolving rapidly, and I'm grateful for the opportunity to explore this field through the SuperUROP program, with the support of Philips and my lab.

Jason Christopher Wang

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Engineering Immunogen Trafficking in Immune Cells

Supervisor: Bryan Bryson

To enhance antigen presentation and CD4 T-cell priming, this project aims to engineer transferrin-receptor (TfR) lysosome-targeting chimeras that deliver the M. tuberculosis immunogen Ag85B into the endo-lysosomal pathway. Constructs will fuse EsxG to either a TfR-binding module or a designed EndoTag, then be benchmarked against EsxG alone for lysosomal trafficking and MHC-II presentation. This work aims to establish a modular strategy for programming immunogen trafficking in immune cells and a next-gen TB vaccine platform.

I am joining SuperUROP for the mentored research experience paired with training in communication. My work in the Bryson lab for the past two years, as well as my industry R&D internship, has prepared me for this project. I hope to deepen my abilities as a scientist in experimental design, writing, and presentation. I'm excited to translate immune engineering ideas into a testable vaccine strategy.

Noah J. Wiley

MIT EECS | Landsman Undergraduate Research and Innovation Scholar

Hardware-Software Co-Development for Energy-Constrained Robotic Platforms: Optimizing Perception

Supervisor: Vivienne Sze

Energy-constrained robots, such as those used in environmental monitoring and space robotics, must balance actuation and computation costs, which are often of similar magnitude. Prior work in the Low-Energy Autonomy and Navigation (LEAN) lab has reduced these computation costs through motion-planning and perception algorithms, including Compute Energy Included Motion Planning (CEIMP) and DecTrain for efficient deep learning. Building on this foundation, we enabled vision-based perception on robotic car test platforms and refined experiments to evaluate algorithmic efficiency. This project extends that work by co-designing hardware and software: deploying a metareasoning perception algorithm, accelerating it with FPGA-based hardware, and validating energy savings through hardware-in-the-loop experiments on miniature robotic vehicles.

Research at the intersection of hardware design, machine learning, and energy efficiency excites me. I am eager to apply and expand my experience across low- and high-level systems to optimize crucial tasks end-to-end in the fast-paced field of autonomous navigation. The SuperUROP program offers a unique opportunity to deepen my research skills and make meaningful contributions to the field, and I am excited for the journey ahead.

Katherine Xie

MIT EECS | Landsman Undergraduate Research and Innovation Scholar

Multi-Cohort Evaluation of Inclusive Polygenic Scoring (iPGS) Model

Supervisor: Manolis Kellis

Advances in genetics research have improved our ability to understand disease risk, but current prediction models often fail to capture the diversity of human populations. Polygenic scores, which estimate genetic risk, are usually trained on data from individuals of European ancestry and perform poorly for others. My project evaluates the inclusive polygenic score (iPGS) model, a machine learning approach designed to address this gap. iPGS has shown superior performance for non-European individuals in the UK Biobank. In the project's first phase, I will extend this work by testing the model in the U.S.-based All of Us dataset, comparing performance across traits and ancestry groups. The second phase will be to refine the model, contributing to advancing equitable genomic medicine.

I am participating in SuperUROP to build on my previous work in statistical genetics and bioinformatics and to gain more experience working with large-scale data and computational research methods. I am looking forward to learning more about the publication process and contributing a paper based on this project. What excites me most is that my project advances genetic risk prediction in a way that is more inclusive and clinically useful.

Shirley T. Xu

MIT EECS | Citadel Undergraduate Research and Innovation Scholar

The Biomechanics of Piano Playing

Supervisor: Anna Huang

This SuperUROP aims to develop an assessment system for piano performance integrating expert qualitative evaluations with quantitative computational analysis. Performance data will be collected using Disklavier MIDI output and synchronized audio/video recordings, allowing the capture of both technical (e.g., timing and movement) and expressive aspects of performance. The project will involve collecting performance data, applying computer vision methods, and using Python for MIDI data processing and event detection. An evaluation rubric will be designed using criteria from prestigious competitions and established pedagogical frameworks. By comparing expert assessments with computationally derived metrics, we seek to reveal correlations between human judgment and computational models.

Through this SuperUROP, I want to build hands-on experience in research that connects computer science and the arts. As a pianist, I am excited to apply my technical, research, and music skills to this project while deepening my understanding of interdisciplinary work. I look forward to learning, collaborating, and working with other pianists in this unique research setting.

Nicole Z. Xu

MIT EECS | Guillemin Undergraduate Research and Innovation Scholar

Simple and Fast Differentiable Simulator

Supervisor: Mina Konaković Luković

Partial differential equations (PDEs) underpin many existing physical phenomena, including heat conduction, fluid flow, and electromagnetic behavior. In many contexts, one may wish to optimize geometric configurations to achieve a desired physical outcome, such as improving thermal performance or minimizing electromagnetic interference. The aim of this project is to develop a differentiable PDE solver that enables gradient-based optimization with respect to geometric parameters. Existing approaches either require remeshing and boundary tracking or rely on Monte Carlo methods with slow convergence rates. We instead propose to draw upon techniques in differentiable rendering to develop a lightweight, easy-to-implement, and fast optimizer that can handle any geometric representations (so long as a distance function exists). By achieving efficient and stable optimization for a wide range of geometric primitives, this framework makes PDE-based design more practical and accessible for real-world applications.

I hope to apply the skills I have developed through prior classes and internships during this SuperUROP project and strengthen my abilities as a researcher. I am particularly excited to continue my work in the Algorithmic Design Group and deepen my understanding of how optimization techniques can be leveraged to tangible problems in the design domain!

Matan Z. Yablon

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar

Improving the Thermalization of Superconducting Qubits

Supervisor: William Oliver

Superconducting circuits are a leading platform for quantum computing. Although they are cooled down inside of dilution refrigerators, the circuits themselves only reach 30 or 40mK at best, due to thermal noise. Improving the thermalization of these circuits is an ongoing challenge that impacts qubit initialization, control, decoherence and measurement. Full thermal modeling of these systems is difficult and thus experimentation is required to optimize circuit temperatures. I will experiment with different filtering, thermalization and attenuation techniques to minimize qubit coupling to thermal noise, as well as investigating how antenna modes of qubit geometry couple to high-frequency noise.

This SuperUROP is a unique opportunity to apply theory I have learned from physics classes, including the quantum mechanics sequence 8.04-8.06, in a laboratory setting. Moreover, I hope to become proficient in all the intricate details that go into designing good superconducting qubits, and I am most excited to test hypotheses and see what happens.

Isabella Yunfei Zeng

Undergraduate Research and Innovation Scholar

Scavenger-Submerged Microfluidics Reveal Oxygen Gradient-Driven Control of Organoid Architecture

Supervisor: Scott R. Manalis

Physiological oxygen gradients are essential regulators of epithelial organization and cancer progression, yet current organoid models expose tissues to uniformly high or static low oxygen levels that diverge sharply from in vivo profiles. We developed a submerged microfluidic platform that integrates real-time optical oxygen sensing with an external sodium sulfite scavenger to generate stable, tunable oxygen gradients across 3D organoid cultures. Applied to patient-derived colorectal cancer organoids and mouse intestinal stem cell organoids, the system revealed that spatial oxygen gradients, rather than uniform hypoxia, drive inward tumor-like growth, polarity inversion, and cytoskeletal remodeling. This platform provides a robust engineering solution for recapitulating physiologic oxygen microenvironments and demonstrates that spatial oxygen dynamics are key determinants of epithelial architecture and disease-relevant behavior.

I am participating in SuperUROP to deepen my experience at the intersection of clinically relevant modeling and biological engineering. I'm excited to take on more independent research and to develop tools that advance translational biology.

Ashley Y. Zhang

MIT EECS | Fano Undergraduate Research and Innovation Scholar

Generative AI for Music Visualization and Interpretability

Supervisor: Anna Huang

Generative AI has begun to transform music creation, with transformer-based systems able to improvise alongside human performers. However, the inner workings of these models remain difficult to interpret, making it challenging for musicians to understand how past notes or motifs influence the output. This project develops on a real-time visualization system that retrieves, downsamples, and transmits attention weights from a transformer music model, allowing its decision-making to be represented in an interpretable way during live performance. In addition to visualization, the work focuses on detecting repetition in token sequences through attention analysis, generating multiple futures for musicians, and quantifying how 'surprising' a note to aid interpretability. While music performance is the primary application, the methods aim to contribute more broadly to real-time interpretability and human–AI collaboration with generative transformers.

I am participating in SuperUROP to gain a more intensive undergraduate research experience. I hope to apply machine learning research to music, a field I have been passionate about my entire life. My goal is to develop tools that make generative AI more interpretable for musicians, with the aim of culminating in a live in-concert demonstration. I also hope to deepen my understanding of the research process, from project proposal to publication.

Clara Y. Zhu

MIT HEALS | MIT Health and Life Sciences Collaborative Undergraduate Research and Innovation Scholar

Mechanisms of Cell Envelope Maintenance in a Human Tickborne Pathogen

Supervisor: Becky Lamason

Vector-borne bacterial pathogens in the Rickettsia genus cause a variety of vascular febrile illnesses in humans. Because these pathogens cannot survive outside the host cell, they are highly adapted to the host environment and are thought to encode novel cell envelope factors, including the 17kDa surface antigen, which we hypothesize acts as a tether between the outer membrane and cell wall that stabilizes the rickettsial cell envelope. I aim to identify residues of 17kDa that are critical for its cell wall-binding ability and investigate this protein's role in cell envelope morphology via cryo-electron tomography. An improved understanding of rickettsial cell envelope biology may reveal new targets for therapeutics that are needed to combat emerging infectious diseases.

I have always been interested in infectious diseases, and this project has been a great way to apply this interest in a research-based setting and learn more about host-pathogen interactions. I am excited to continue this project through SuperUROP, further strengthening my research skills.

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