Front Cover Photos

Top row
SuperUROP Showcase, Charles M. Vest Student Street, Stata Center, December 2018. Photo: Justin Knight

Middle row, left to right
Left: Christabel Jemutal Sitenei, a senior in EECS, worked on a project using artificial intelligence and cell phone data to help drive financial inclusion in East Asia. Photo: Justin Knight
Right: Taylor V’Dovec, a senior in mechanical engineering, worked on a project designed to help reduce drag reduction in aerial and aquatic transportation. Photo: Gretchen Ertl

Bottom row
Left: EECS senior Faraaz Nadeem’s project involved using computers to automatically transcribe musical performances involving multiple instruments. Photo: Gretchen Ertl
Center: EECS junior Joshua Noel’s SuperUROP explores the tradeoffs involved in superscalar design decisions on RISC-V processors. Photo: Justin Knight
Right: EECS senior Haripriya Mehta’s project in artificial intelligence and machine learning is designed to help assist storyboard artists when they are running out of ideas. Photo: Gretchen Ertl

“SuperUROP in its design is so quintessentially MIT, particularly because it builds on MIT’s tradition of mens et manus [“mind and hand”], and it is aligned with the Institute’s priorities of discovery, innovation, and making the world a better place.”

–Cynthia Barnhart
Chancellor
Ford Professor of Engineering

“SuperUROP embodies MIT’s learning-by-doing ethos. When students participate in frontline research, they touch the future – and by providing a structured way to learn the ropes of research with faculty mentors, SuperUROP gives them a head start on their own futures, too. I am inspired by the program’s impact on our students and by the way it inspires them to help make a better world.”

–L. Rafael Reif
President, MIT
SuperUROP Continues to Thrive

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

Since the program began in EECS in 2012, it has equipped undergraduates with the research tools they need to tackle real-world problems by giving them the chance to conduct innovative, publishable research.

This year’s SuperUROP class includes about 130 students from throughout the School of Engineering and, for the second year, from the School of Humanities, Arts, and Social Science. We are grateful to the anonymous donor whose generous gift supported this ongoing collaboration between the two schools.

SuperUROP scholars engage in yearlong supervised research projects and complete a seminar that exposes them to the essentials of research. 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. Throughout the year, they receive access to research facilities that are typically available only to graduate students. Some publish their research results in respected journals or present 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 at MIT and beyond. Our students are supported by the Research and Innovation Scholars Program (RISP), a named scholars program that funds the students’ work and provides some associated discretionary funding for the host research group. This program relies on generous support from its sponsors, including corporations, foundations, individual alumni, and friends, all of whom are committed to growing the SuperUROP program and enhancing the student experience at MIT. I would like to extend my sincere thanks to SuperUROP’s sponsors, contributors, and other supporters, who are highlighted elsewhere in this brochure.

Once again, I wish to acknowledge Anantha Chandrakasan, Dean of the School of Engineering and Vannevar Bush Professor of Electrical Engineering and Computer Science. As EECS Department Head, he pioneered and oversaw SuperUROP for its first several years, and he remains among the program’s strongest champions. Hundreds of current and past SuperUROP Scholars have benefited from his efforts, and everyone involved with the program is grateful for his initial vision and ongoing support.

In the long term, I look forward to seeing where these bright young researchers go in their careers. Meanwhile, I invite you to discover more about the impressive research projects highlighted in these pages and learn about SuperUROP in general at superurop.mit.edu.

Sincerely,

Asu Ozdaglar
Department Head, Electrical Engineering and Computer Science
School of Engineering Distinguished Professor of Engineering
MIT AeroAstro | Boeing Undergraduate Research and Innovation Scholar
Gabriel Margolis

MIT AeroAstro | Lincoln Laboratory Undergraduate Research and Innovation Scholars
Eswar Anandapadmanaban
Arjun Raj Gupta
Hung-Jui Huang
Milo Henry Lovelace Knowles
Sebastian A. Lopez-Cot
Puneeth NSK Meruva
Rose Elizabeth Wang

MIT BE | Microbiome Undergraduate Research and Innovation Scholar
Rebekah Costello

MIT CEE | Undergraduate Research and Innovation Scholar
Stephanie Chin

MIT ChemE | Undergraduate Research and Innovation Scholars
Naomi S. Bright
Sarah Coleman
Michal Lukasz Gala
Jesse Hinricher
Yara Jabbour Al Maalouf
Zachary David Schmitz

MIT EECS | Advanced Micro Devices Undergraduate Research and Innovation Scholars
Cynthia Tianqing Liu
Sophie Mori
Joshua Eron Noel
Domenic Nutile
Grace Yin

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholars
Alan De-Hao Cheng
Nancy Hung
Shreyan Jain
Yukimi Morimoto
Ashisha Nirupa Persad
Megan Yamoah
Yunyi Zhu

EECS senior Ramya Durvasula’s SuperUROP project involved predicting gene function via hyperbolic space embedding.
Photo: Gretchen Ertl
As an industrial sponsor, Analog Devices explores opportunities to collaborate with MIT students and faculty on research topics of continual interest and provides insights into the relevance of research to real-world applications. Analog Devices is excited to further strengthen our relationship with students and faculty through the SuperUROP program.

– Raymond S. Stata ’57, SM ’58 Chairman and Co-Founder, Analog Devices, Inc.
MIT EECS | Hudson River Trading Undergraduate Research and Innovation Scholars
Alyssa Chen
Nazar Ilamanov
Sophia Luo
Luke Shimanuki
Christabel Jemutai Sitienei
Christine Soh

MIT EECS | Keel Foundation Undergraduate Research and Innovation Scholars
Matias Hanco
Cory John Lynch
Jesse Michel
Hoang Nguyen
Ravi Rahman

MIT EECS | Landsman Undergraduate Research and Innovation Scholars
Tugsbayasgalan Manlaibaatar
Aman S. Patel
Phuong Mai Pham

MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholars
Akhilan Boopathy
Nithin Buduma
William Peebles
Michal Shlapentokh-Rothman
Mike Meichang Wang
Ethan Weber
Elizabeth Wei

MIT EECS | Mason Undergraduate Research and Innovation Scholars
Arsen Vasilyan

MIT EECS | MITRE Undergraduate Research and Innovation Scholars
Ebrahim Al Johani
Basil N. Saeed

MIT EECS | Morais and Rosenblum Undergraduate Research and Innovation Scholar
Kunal Tangri

MIT EECS | Nutanix Undergraduate Research and Innovation Scholars
Jenna Hong
Endrias Kahssay
Severyn Kozak

MIT EECS | Quick Undergraduate Research and Innovation Scholars
Suchan Vivatsethachai
Mattie Frantz Wasiak

“This is usually something graduate students would do. It’s really awesome to be able to work on this as an undergraduate.”

– Patrick Tornes, Mechanical Engineering
MIT School of Engineering | Quest Undergraduate Research and Innovation Scholar

“What I’ve been able to accomplish in one semester is inspiring!”

– Ronit Langer, EECS
MIT EECS | CS+HASS Undergraduate Research and Innovation Scholar
AMD is excited to sponsor MIT’s SuperUROP program because it provides the best and brightest undergrads with the opportunities to tackle important, real-world problems. I grew up as a UROP student at MIT and AMD looks forward to working with our next generation of innovators through the SuperUROP program.”

–Lisa Su ’90, SM ’91, PhD ’94; President and CEO, Advanced Micro Devices
I am interested in this SuperUROP project because it will provide me with the opportunity to work in multiple machine learning paradigms and to put the theory I have been studying in my classes to practical use. I hope to learn the subtleties of causal inference and time series modeling of medical data while simultaneously improving my own implementation and research abilities.

Using photonic crystals to enhance the efficiency of optical devices has been a widely discussed concept since its advent in the early '90s. The focus of this study is on detector enhancement using resonant cavity structures. Cavity resonators confine light such that it allows recycling of unabsorbed photons; this simple mechanism enhances the detector's efficiency without directly changing the device's parameters. In this work, we will assess the enhancement factor of 1088 different structures. In addition, we will build a model in a semiconductor device simulation software that will highlight the structural effects on absorption. With a focus on the near infrared band, the implementation of photonic structures in Silicon will allow for low-cost infrared sensors and LIDAR technologies.

"For the past two years, I have been gradually becoming more exposed to research in optics. After working for more than four semesters, I feel ready to take that experience to a more challenging setting. Also, the idea of applying the knowledge I've gathered so far into one cohesive work is something I hope to gain from this SuperUROP."

Modern-day biological experimentation often necessitates extensive gene expression profiling across a variety of cell types, which in turn implies an expensive and prolonged experimental schedule. Our research aims to reduce the cost and time required to collect such gene expression data via computational methods. In particular, by leveraging the framework of "compressed sensing" and by taking advantage of the underlying relationships between genes, we can recover the desired gene expression data while significantly decreasing the number of empirical measurements that must be collected. Using both deep and classical machine learning techniques, we hope to optimize this scheme so that it can be employed reliably and scalably to facilitate biological experimentation in a variety of settings.

"I’m participating in SuperUROP to hone my research skills as well as to broaden [and deepen] my understanding of both biology and computational science. I have accrued practical experience via my UROP projects in the past year as well as academic knowledge through coursework in computational biology (6.047) and deep learning (6.883), and thus I’m excited for the opportunity to combine the two by participating in SuperUROP."

Machine learning has vast untapped potential for helping medical professionals by predicting a patient’s response to a treatment. However, many machine learning techniques are not able to effectively quantify uncertainty. This leads to unjustified recommendations that the medical industry is hesitant to adopt in practice. The goal of this project is to design an algorithmic framework for estimating individual treatment effects from observational data that incorporates sensitivity analysis from the start. We use an extrapolation-based approach to quantify regions of the population space for which our treatment effect estimates are applicable. This allows us to make treatment recommendations that are valid despite uncertainty in the causal effect.

"I am interested in this SuperUROP project because it will provide me with the opportunity to work in multiple machine learning paradigms and to put the theory I have been studying in my classes to practical use. I hope to learn the subtleties of causal inference and time series modeling of medical data while simultaneously improving my own implementation and research abilities."

The day we put people on Mars, they will require much higher levels of autonomy. A mission to Mars would have significant bandwidth limitations and communication delays as long as 20 minutes one way. Providing astronauts with all of the intelligence possible is important, but equivalently important is how they will access and use that information. A proper informatics system integrated within the space suit is required. This project will explore using in-helmet augmented reality (AR) for exploration missions. It will expand a previous AR navigational tool prototype and explore hardware prototypes for in-helmet displays. The second component is to test the efficacy of the high-fidelity prototype with human subjects to understand the benefits of using AR during exploration missions.

"Having worked on this project previously as a UROP student, SuperUROP gives me the opportunity to dive deeper into researching Augmented Reality (AR) for exploration missions. I have been working on AR interfaces during my time at MIT and specifically on AR for analog EVA missions during the past three semesters. This research could help engineers design and envision the next suits for Mars, which makes it very exciting to work on."
apply what I have already learned to further advance my group and field.

Soft robotics last year, I want to take my research to the next level and creation and take ownership of a project. After working on a UROP in "I am participating in SuperUROP to further develop high-level system."

controller and demonstrate the capabilities of a large-scale soft robotic nonlinear motions. We will evaluate the mechanical properties and a novel sensor feedback system capable of measuring and controlling muscles that bend when negative pressure is applied and implements reconfigurable robotic system. The module is made from foam artificial build soft robotic modules capable of being combined in a large-scale work with fluid-driven, origami-inspired artificial muscles to design and to their rigid counterparts. For this project, we expand on our previous interactions with humans and greater degrees of freedom compared focused on robots made from soft, flexible materials, touted for safer interactions with humans and greater degrees of freedom compared to their rigid counterparts. For this project, we expand on our previous work with fluid-driven, origami-inspired artificial muscles to design and build soft robotic modules capable of being combined in a large-scale reconfigurable robotic system. The module is made from foam artificial muscles that bend when negative pressure is applied and implements a novel sensor feedback system capable of measuring and controlling nonlinear motions. We will evaluate the mechanical properties and controller and demonstrate the capabilities of a large-scale soft robotic system.

"I am participating in SuperUROP to further develop high-level research skills and continue to learn about and contribute to the field of soft robotics. I am excited to design, build, and code my own soft robot creation and take ownership of a project. After working on a UROP in soft robotics last year, I want to take my research to the next level and apply what I have already learned to further advance my group and field of study."

"I want to use the SuperUROP to familiarize myself with the path that researchers follow to derive applications from theoretical knowledge. I learned about photonic materials in my lab for 3.024 [Electronic, Optical, and Magnetic Properties of Materials], and I saw their promise and their potential. It will be an amazing learning opportunity to create a new photonic material from my understanding of the fundamentals and to expand on that along the way. I’m excited about the applications of the new material."

"SuperUROP is a great opportunity for me to apply my expertise in physics and cell and molecular biology while gaining writing and oral skills to work on a project that is tackling one of the most intriguing problems. I am also very excited to attend 6.UAR lectures while being supervised, advised, and taught by an amazing group of scientists, designers, and thinkers. I hope that SuperUROP will help me make a tangible contribution to the field."

"My academic experience at MIT has provided me with a solid foundation in various topics in the field of EECS. By participating in SuperUROP, I have the opportunity to apply my academic experience to real-world problems that are awaiting solutions, without the guidance found in the classroom environment. My time will be spent coming up with novel solutions to unsolved problems, and that is exciting to me."
David Anthony Bau  
MIT EECS | C5+HASS  
Undergraduate Research and Innovation Scholar  
Project: Interpreting the Operation of Neural Question-Answering Models  
Supervisor: Regina A. Barzilay

Deep neural networks have become state-of-the-art for many tasks, but because they are trained end-to-end, interpreting their inner operations is a challenge. This is a salient problem for natural language question-answering models. These models have become very complex, but there are many open questions about what that complexity does in practice. The goal of this project is to build tools to interpret the internal neurons in question-answering models. This will involve building both visualizations and quantitative tests for behaviors and functions. We hope these tools will help determine whether and where real language comprehension occurs in question-answering models and assist in debugging and improving these models with a greater understanding of how they encode information.

“I am interested in language and in making complex systems understandable. I have worked before on interpreting neural machine translation models, and I am excited to apply what I have learned to a new task. I hope to gain some insight both into language and into the neural models that process it and to gain some comfort with the research process and community.”

Akhilan Boopathy  
MIT EECS | Lincoln Laboratory  
Undergraduate Research and Innovation Scholar  
Project: Analysis and Quantification of the Robustness of Neural Networks  
Supervisor: Luca Daniel

Neural networks have become an increasingly popular and effective tool for a variety of machine learning tasks, including classification of images and text. However, recent research has shown that neural networks are susceptible to adversarial attacks. In critical applications, networks susceptible to attack could result in fatal accidents and/or unfair discrimination. Improving the robustness of neural networks to attack enhances safety and has positive social implications. Recent work has been done on empirically finding attack-agnostic robustness guarantees for neural networks. This project aims to build off of prior work to find even stronger robustness guarantees so that future neural networks can be made more robust for safety and security critical applications.

“I am participating in SuperUROP to gain experience working on an applied machine learning project that will allow me to use some of the theoretical concepts I have learned while taking 6.867 [Machine Learning] last year. I hope to get a better understanding of working on a long-term research project with many open-ended directions for exploration. I’m very excited to work on a project that could potentially have tremendous applications in the medical world.”

Naomi S. Bright  
MIT ChemE | Undergraduate Research and Innovation Scholar  
Project: Optimization of Microalgae for Lipid Production  
Supervisor: Jean-Francois Hamel

Microalgae have the potential for mass cultivation that will allow us to supply our energy demand as fossil fuel availability decreases. However, to do this, we must identify the reactor type that allows for maximum lipid production. This research is focused on the efficacy of Schizochytrium Limacinum (S.limacinum), a type of microalgae, for lipid production in perfusion versus batch culture for biodiesel applications. Here, we culture S.limacinum in a perfusion reactor using a novel microfluidics device after characterizing the microfluidic device efficiency at separating the cells from media. The batch and perfusion method will be compared based on the quantity of lipid produced per gram of dry cell in order to identify which cultivation method should be used moving forward.

“I am participating in SuperUROP in order to hone my research skills in the area of renewable energy and participate in research at a level similar to what is expected in graduate school.”

Sooraj Boominathan  
MIT EECS | Fairbairn  
Undergraduate Research and Innovation Scholar  
Project: Prediction of Patient Antibiotic Resistance Profiles  
Supervisor: David Sontag

The growth of antibiotic resistance is one of the most pressing medical problems facing the world, placing the lives of millions at risk. Currently, antibiotic prescription for patients is largely based on manual assessments of medical data and a doctor’s past experience. These decisions do not always produce the optimal choice given a patient’s condition and past antibiotic exposure. However, the abundance of electronic records and data about patients’ antibiotic resistance profiles may make it possible to construct a more rigorous framework for predicting antibiotic resistance. In this project, we plan to use machine learning techniques to develop accurate models of antibiotic resistance in patients that will help doctors make decisions about antibiotic usage in a more systematic manner.

“I am participating in SuperUROP to gain experience working on an applied machine learning project that will allow me to use some of the theoretical concepts I have learned while taking 6.867 [Machine Learning] last year. I hope to get a better understanding of working on a long-term research project with many open-ended directions for exploration. I’m very excited to work on a project that could potentially have tremendous applications in the medical world.”
Nithin Buduma
MIT EECS | Lincoln Laboratory
Undergraduate Research and Innovation Scholar
Project: Information Sharing Among Distributed Neural Networks
Supervisor: Dorothy W. Curtis

Neural networks perform well when they are built for a specific task and the set of inputs and set of outputs are well defined. However, these accomplishments are very limited in scope, and communication between different neural networks to share knowledge that will lead to the performance of more general tasks is still inadequate. We propose to utilize independent sets of neural networks while allowing knowledge transfer between each of the neural networks. The idea is based on computer network architecture. The idea will similarly allow each neural network to specialize in its own task while transferring and receiving information from other neural networks. This will allow different neural networks to be plugged in as an open platform.

“I am participating in SuperUROP because I want to apply the knowledge I have gained through taking classes covering machine learning and systems in my research. I am excited to learn how to present and communicate research more effectively.”

Thomas Raymond Carotti
Undergraduate Research and Innovation Scholar
Project: Implementing Additional Functionality for a Verified Compiler
Supervisor: Adam Chlipala

My project will involve adding additional functionality to the Bedrock 2 project. The goal of the Bedrock 2 project is to have a formally verified compiler for a low-level, C-like language. This allows for reasoning about compiler behavior — and, therefore, trust — surrounding compiled programs. Part of my work will be to develop proofs about the worst-case execution of compiled programs. This will allow for software to be compiled in a manner such that it is both provably correct and has provable performance characteristics.

“Through this SuperUROP project, I am hoping to use my prior experience in compiler development applied in a much more focused area of research. I am really excited to learn more about the area of verification and be able to use it for practical applications within the compiler.”

Alyssa Chen
MIT EECS | Hudson River Trading
Undergraduate Research and Innovation Scholar
Project: Real-Time Planning Support for ICU Work Rounds
Supervisor: Roger Mark

Intensive care units (ICUs) provide lifesaving treatment for critically ill patients. Within the ICU, health care providers routinely meet for a scheduled discussion where the clinical data for a patient are reviewed and a care plan is developed. These discussions, or rounds, allow individual providers to contribute to the overall care plan based upon their specific expertise and familiarity with the patient. I plan to explore various predictive algorithms that can provide data-driven perspectives of patients to ultimately facilitate communication about patient status during rounds, inform the development of care plans, and improve patient outcomes.

“I am participating in SuperUROP to gain more experience in biomedical informatics research. Last year, I took 6.872 (Biomedical Computing) and really enjoyed the final project, during which I had the opportunity to be mentored by Alistair Johnson, a postdoc in Professor Mark’s lab. Through SuperUROP, I look forward to working with Alistair in Professor Mark’s lab again, gaining insight from ICU patient data and improving my research skills.”

Melanie Chen
MIT EECS | Hewlett Foundation
Undergraduate Research and Innovation Scholar
Project: Exposing the Invisible Surveillance Behind Everyday Web-Browsing Activities
Supervisor: Ilaria Liccardi

Privacy has become an increasingly important issue in today’s internet age. This project addresses the surveillance that happens online in daily browsing activity in which websites collect metadata from unknowing users. We aim to build a tool that will reveal to users what sorts of metadata a website would collect from them and then conduct experiments to examine how this awareness of surveillance affects users’ browsing habits.

“I am participating in SuperUROP because I hope to gain experience in conducting research on topics that are tangible to more people and because I believe internet privacy is an important issue that requires more attention. I will apply my background in web development to develop our primary tool for tracking metadata, and I am incredibly excited to learn from the results of our experiment.”
Xinyi Chen
MIT SoE | Quest Undergraduate Research and Innovation Scholar
Project: Optimizing Performance on Graph Applications with a High-Performance Graph DSL
Supervisor: Saman P. Amarasinghe

This project focuses on the use, case implementation, and evaluation of GraphIt, a new high-performance graph domain-specific language (DSL). The first phase of my SuperUROP project will be to implement several larger algorithms in the GraphIt DSL to test if additional operators are needed for GraphIt. Currently, we have planned to implement the following algorithms: community detection, delta-stepping, and Stochastic Approach for Link-Structure Analysis (SALSA). The second phase of my project will be to evaluate the algorithms’ performance when implemented with GraphIt and compare it to the performance of existing frameworks, including Ligra, GraphMat, and GraphMarl. The evaluation will be based on the runtime performance as well as scalability measures with regards to both data size and processor count.

“I’m participating in SuperUROP because I want to gain more advanced research experience in computer science. I have learned during my previous UROP what to expect in SuperUROP, and I have gained a lot of programming experience from my previous summer internships, which will help me do my SuperUROP project better. I want to learn about both performance programming and the research process, and I hope to publish a paper by the end of my SuperUROP experience.”

Stephanie Chin
MIT CEE | Undergraduate Research and Innovation Scholar
Project: Classifying Traffic Camera Data at Scale for Transportation System Resilience
Supervisor: Amin Saurabh

There is a growing need for efficient transportation operations and communication, especially for urban emergency evacuation scenarios such as natural disasters and severe weather conditions. The goal of this SuperUROP project is to build a convolutional neural network using the Python-based tensorflow framework for traffic-related objects using publicly-available semi-unstructured camera data from MassDOT and CalTrans. The model will be used to classify over a million images for future transportation modeling research about disruptions in critical transportation facilities due to natural events.

“I am participating in SuperUROP for the opportunity to apply machine learning techniques I have learned in 6.036 (Introduction to Machine Learning) to real traffic data. I hope to improve my programming skills and machine learning knowledge and contribute to interesting research about urban transportation.”

Alan De-Hao Cheng
MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar
Project: A Depth-Estimation Platform for Low Power Time-of-Flight Imaging
Supervisor: Vivienne Sze

Depth sensors are useful in a variety of mobile applications, ranging from robotics to augmented reality, by providing 3D information about a scene. One type of depth sensor is a time-of-flight (TOF) camera, which measures depth by emitting light and measuring its round-trip time. TOF cameras are appealing because they obtain dense depth measurements with minimal latency. However, one drawback is its illumination source, which is power hungry and limits the battery life of mobile devices. The goal of this project is to reduce the power consumption of depth sensing using TOF cameras by obtaining depth in a more energy-efficient manner. We propose to build a system that uses RGB images from a digital camera and previous depth measurements to estimate depth without illuminating the scene.

“Since high school, I’ve been interested in working in both FPGA prototyping and computer vision. This SuperUROP opportunity, found through my final project in 6.111 [Introductory Digital Systems Laboratory], perfectly combines both of these fields. I hope to further my knowledge not just in these two topics but also in their fusion — how hardware can be used to efficiently help improve image processing.”

Sarah Coleman
MIT ChemE | Undergraduate Research and Innovation Scholar
Project: Optimal Phosphor Construction for the Light-Emitting Plant (LEP)
Supervisor: Michael Strano

This SuperUROP project is focused on increasing the amount of time that a plant infused with nanoparticles can emit visible light, with proof of concept previously published by the Strano group. To this end, I am working with Dr. Pavlo Gordiichuck to characterize and effectively separate phosphors with new techniques to get a very narrow sizing distribution. We hypothesize that phosphors which can emit light at a higher intensity will allow the light emitting plant to be brighter and for longer. Light-emitting plants, if able to luminesce long enough, are an attractive alternative to conventional light because plants possess the capability for autonomous self repair, are independent energy generators, and therefore are a carbon-footprint friendly solution.

“I have really enjoyed all my research experiences at MIT and was initially drawn to SuperUROP so I could be given more roles and responsibilities with my research. SuperUROP has connected my research and writing capabilities in a way that no other MIT program has and provided me an in-depth look into what research is like beyond the undergraduate level.”
Rebekah Costello
MIT BE | Microbiome
Undergraduate Research and Innovation Scholar
Project: Effect of Enteric Mucins on the Transport and Antimicrobial Activity of Human Defensins
Supervisor: Katharina Ribbeck

Gaining a greater understanding of the complex interactions between our immune systems and gut microbiome could help explain how our bodies regulate intestinal ecology and potentially uncover the causes of serious health problems such as Crohn’s Disease. The goal of my research is to further characterize the behavior of an antimicrobial peptide called human α-defensin 5 (HD5) that is released by our bodies into the gut mucosa as part of the innate immune response. Specifically, I plan to study how the protective mucus layer of the intestine, which houses the microbiome, alters the antimicrobial activity of these defensins and affects their diffusion towards potential targets. I will run a series of antimicrobial and microfluidic transport assays to quantify these changes.

“I am participating in SuperUROP because I enjoyed my previous research experiences and want to tackle a challenging, independent project. My participation in the NEET Living Machines thread introduced me to the exciting frontier of human microbiome research, and my BE classes have provided me with the tools to approach a scientific problem. I am most excited about the idea of producing novel data about the microbiome and publishing a paper.”

Steven Diles
MIT EECS | CS+HASS
Undergraduate Research and Innovation Scholar
Project: Using Eye Tracking and Pen Movement to Detect Solution Strategies For Maze Solving
Supervisor: Randall Davis

A simple pen and paper task, called the Clock Drawing Test, has been used for more than 50 years as an accepted method for detecting cognitive impairment, such as that seen with Alzheimer’s, Parkinson’s, and other neurological disorders. Decades were spent improving this test using a digital pen and machine learning. The intent of this project is to improve upon this detection by combing eye tracking with the existing pen tracking then analyzing how subjects think about a maze as they solve it. Using data gathered from local volunteers and subjects with impairments at the Lahey Clinic, we will use data display and exploration tools, such as combined playback, to detect solution strategies used by subjects.

“I’d like to use SuperUROP as an opportunity to gain a better understanding of high-level research methods. I already have some experience applying machine learning to open-ended research questions, attempting to improve educational curricula using software tools to model mathematical representations. I am excited to expand my practical application of machine learning and modelling techniques to analyze human thought processes.”

Ali Rami Daher
MIT SoE | Quest Undergraduate Research and Innovation Scholar
Project: Brain Tumor Modeling and Learning
Supervisor: Pierre Lermusiaux

Glioblastoma multiforme, or GBM, is a fast-growing, aggressive type of central nervous system tumor that develops from glial cells and forms on the supportive tissue of the brain. These tumors are biologically aggressive and present unique treatment challenges due to the lack of comprehensive understanding of the dynamics of tumor evolution. The project attempts to initiate the mathematical modeling of the evolution of glioblastoma multiforme (GBM), using the existing rigorous partial differential equation-based machine learning framework of the MIT MSEAS (Multidisciplinary Simulation, Estimation, and Assimilation Systems) group in the mechanical engineering department.

“This is my first time working on anything that uses mathematical modeling to help trace the evolution of a biological phenomenon like the evolution of Glioblastoma multiforme in the brain, and I am very excited. I hope to gain high-level research experience through such an interdisciplinary project and hopefully make a positive contribution to my group.”

Ramya Durvasula
MIT EECS | Undergraduate Research and Innovation Scholar
Project: Predicting Gene Function Via Hyperbolic Space Embedding
Supervisor: Bonnie A. Berger

The ability to predict gene function has far-reaching applications, and recent research shows that gene function can be inferred from experimentally derived associations of other genes. These networks of associations are formed via metrics such as physical binding and genetic interaction. The Berger lab recently detailed a novel method to combine information from many networks by learning gene embeddings based on patterns in individual networks and then applying standard machine learning methods to infer gene function. The goal of my project is to improve this method by embedding the functional labels of gene networks in hyperbolic space. With hierarchical representations, I am to create a tool that is valuable for biological and translational research.

“My excitement about computational biology research at MIT is what initially inspired me to apply to this school, and with SuperUROP, I actually have the opportunity to pursue interdisciplinary research with guidance from some of the leading experts in the field. I’m looking forward to being able to use cool math and machine learning techniques to hopefully make an impact in the world of health technology.”
Secure data transfer is becoming increasingly important as more and more data pass through the internet. Traditional RSA encryption requires larger key size for more security. However, many embedded devices have limited memory and computational power. Hence, elliptic-curve cryptography (ECC) is used. The current hardware implementation implements the protocol in hardware and has counter measures against side-channel attacks, one of the known vulnerabilities of ECC. I will assess its security against side-channel attacks and determine statistics to quantify its security. The ultimate goal is to achieve energy-efficient cryptography for embedded devices.

“I’m participating in SuperUROP because I want to contribute to security research while also gaining hands-on experience. Some courses I’ve taken in both math and computer science have touched on security briefly, fueling my curiosity to learn more through research. I’m excited to work on real-world applications in hardware and software during this SuperUROP.”

Thermodynamic considerations suggest electrochemical lithium-mediated ammonia synthesis as viable alternative to the currently used Haber-Bosch process that eliminates its high capital cost and reliance on gaseous hydrogen produced from fossil fuels. In my SuperUROP project, I will investigate the role of hydrogen sources in the process, providing insights into the effect of steric and electronic factors on the kinetics and thermodynamics of electrochemical synthesis of ammonia. The understanding obtained will be used to find the set of properties the optimal proton source should have. I hope this will find application in the design of well-defined catalysts that would allow us to run the process under milder conditions, making water a cheap and sustainable hydrogen source.

“I study chemical engineering because I want to apply chemical knowledge to solve important problems. My SuperUROP project does exactly that by combining several relatively simple reactions into a well-behaved catalytic ammonia synthesis process. I believe my courses in chemistry and thermodynamics, together with the lab classes I have taken, give me a decent background in the field, and I hope to get interesting results by the end of the year.”

“I’m participating in SuperUROP because I wish to apply the knowledge I acquired from 6.875 (Cryptography and Cryptanalysis) to a long-term research effort. I hope to learn more about theoretical cryptography and find out if I will enjoy research in cryptography through this project.”
Intuition, with tasks requiring challenging hierarchical planning. In pursuit of this goal, we explore applications of this abstract reasoning, using program induction to facilitate symbolic modeling behavior through symbolic abstraction. We seek to offer a possible methodology that facilitates a more robust form of general abstract reasoning, using program induction to facilitate symbolic reasoning. In pursuit of this goal, we explore applications of this paradigm to a block-stacking environment demanding robust physical intuition, with tasks requiring challenging hierarchical planning.

“Through SuperUROP, I want to gain experience in all aspects of the scientific process, from data collection and analysis to communication of results through presentations and papers. I want to use the skills I acquired from taking 9.40 and 9.66 (Introduction to Neural Computation and Computational Cognitive Science) to process imaging and electrophysiology data from mice I’ve helped train and perform surgeries on. I am excited to help demystify nature’s most powerful computer —the brain!”

“I decided to participate in SuperUROP to apply the knowledge I have gained during university to real-world research problems. I chose this project as I have experience applying recently conceived adaptive signal processing techniques to analyze EEG/ECG data. I would like to learn to apply machine learning techniques to biological data. I am keen to apply my knowledge to acquire useful results and, if possible, publish the findings in a paper.”

“I hope that through this SuperUROP project, I will learn how to write a publication for an academic conference. Before this, I’ve had multiple research opportunities in machine learning and the application of neural networks, but none have led to a tangible publication. I am excited to explore a more novel area of deep learning and work towards tangible products that demonstrate my research experience and prepare me for graduate-level study.”
“I am participating in SuperUROP so I can devote myself to a long-term research project as an undergraduate student, specifically at the intersection of applied ML and neuroscience. Prior research experience and classes I have taken have both prepared me for this opportunity, and my project feeds into my interests in music, mathematics, machine learning, and beyond. I’m excited to learn more about the field and see what results my project may yield!”

“Before autonomous vehicles can reach a higher level of functionality, they need the ability to not only quickly and accurately evaluate situations, but also make good predictions for future planning, even in new situations. Current algorithms use explicit definitions of traffic rules and models for pedestrian prediction, but in order for autonomous driving to become more robust, the vehicle must be able to extract these rules from the scenes it is exposed to. The goal of this research is to develop an algorithm for scene understanding and prediction that enables the car to determine the rules and relationships between traffic objects in real time.

“I have been doing research at MIT since the spring semester of freshman year, and I have recently become interested in autonomous car research. When I learned about SuperUROP, I thought it was a fantastic opportunity to apply the knowledge I have gained through my machine learning coursework to the field of autonomous driving. I hope to do some great work, and I am excited by the opportunity to possibly publish a paper about my research.”

“I am participating in SuperUROP because I hope to gain valuable research experience in the computer science field. I have been participating in UROPs for the past two years, and I am excited to take on this new project. I hope to learn more about neural networks and their intersection with feature-extracting algorithms.”

“Human audition has largely been studied from a neurological and psychoacoustic lens, but with the advent of powerful computational tools, human audition and other sensory systems in the brain can now be studied via deep learning systems. Neural networks in particular have been shown to be successful in predicting brain activity and neural responses to visual stimuli but are less studied in the context of audition. Thus, the overall aim of my project is to leverage machine learning tools trained on human tasks to see whether we can build intelligent systems that replicate human audition and if there are biological insights to be gleaned from these models.

“This project is the marriage between my two favorite things: formal methods and protecting people’s privacy. Coming from my background in binary analysis, I’m excited to learn more about applying formal reasoning to complex systems and push the field forward. SuperUROP gives me the opportunity to dedicate a large portion of my time to intensive research.”

“This research project is building a new way to specify security policies for complex applications and prove that implementations fit the applications’ policies. This involves building semantics for describing policies and implementations in Coq, a runtime system, tooling to support proving properties about policies, and providing example applications to demonstrate its usefulness. Previous work in information flow control focuses on scenarios where programmers just want to improve confidence that their system does not leak data. However, users are increasingly interested in strong guarantees of their privacy, rather than blindly trusting third parties. Our system achieves the best of both worlds, protecting against untrusted application builders while allowing for performance on par with traditional methods.”

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Matias Hanco  
MIT EECS | Keel Foundation  
Undergraduate Research and Innovation Scholar  
Project: Filtering Database Entries in STO  
Supervisor: Barbara H. Liskov

My project adds a feature to a system utilizing Software Transactional Objects (STOs). STOs began with the idea that being able to handle concurrency control within methods of objects allows for more optimizations when dealing with multicore machines. STOs have been used to implement a high-performance database system. However, when a transaction commits, the commit protocol considers all objects used by the transaction. The goal of this project is to support a new kind of transaction, one in which the first phase filters out irrelevant data, and the second phase carries out the requested computation using the remaining data. We expect that the use of two-phase transactions will significantly improve performance because the work that must be done at commitment time is reduced.

“I’m participating in SuperUROP to better understand what the research process consists of and how to communicate findings to those who are researchers and those who aren’t. I like the project because it has some useful applications to databases in industry.”

Helen He  
MIT EECS | Hewlett Foundation  
Undergraduate Research and Innovation Scholar  
Project: Extrapolating Information from Facebook Wall Data  
Supervisor: Ilaria Liccardi

Facebook has accumulated a wealth of information about our lives, but we aren’t necessarily aware of the depth or details of what other people can see about our relationships with others. The project will involve scraping wall data off Facebook and formulating a survey about the nature and details of the content, and then giving this survey to the people of these walls. I will then analyze the results of these surveys to glean insights about what people think of their data.

“I’m participating in SuperUROP because I realized during my internships that I’m happiest implementing things closest to research areas, and I’d like to learn more about research itself. I have a strong interest in human-computer interaction (HCI), which lends itself to this subject matter, and I’m excited to both see the findings and learn how to present them because social media and privacy are very relevant concerns today.”

Jesse Hinricher  
MIT ChemE | Undergraduate Research and Innovation Scholar  
Project: Thermogalvanic Flow Cell for Waste Heat Recovery  
Supervisor: Fikile Brushett

The United States consumed 97.7 quadrillion BTUs of energy in 2017, of which 68 percent was rejected as waste heat. Conventional therlectric generators use solid-state inorganic components which have coupled ion and thermal conductivities ultimately limiting device performance. My project seeks to develop an alternative thermogalvanic generator based on electroactive organic molecules and redox flow battery (RFB) architectures. This approach offers the opportunity to decouple ion and thermal conductivity while maintaining durability, safety, and scalability. To that end, my research efforts will include prototyping a thermogalvanic flow cell with redox-active organic molecules, modeling the system using a techno-economic analysis, and optimizing the system to reduce cost.

“My research in the Brushett group has exposed me to a wide array of electrochemistry and energy storage technologies. This SuperUROP project will allow me to more thoroughly develop my research skills. I’m excited to create new technology and contribute to improving energy efficiency. In doing so, I will learn about materials development, energy economics, and system modeling.”

Helen Ho  
MIT EECS | Fairbairn  
Undergraduate Research and Innovation Scholar  
Project: Computer Graphics for Improving AI  
Supervisor: Frederic P. Durand

Current image recognition algorithms developed for self-driving cars rely primarily on deep learning. Such models must be trained on large datasets to perform well, but datasets of well-annotated images can be limited in size and expensive to acquire. The goal of my project is to use 3D graphics to create large, annotated, synthetic datasets of city scenes to train image-recognition algorithms for self-driving cars. Specifically, I will be working on diversifying rules for generating buildings, roads, and people, and making the rendered city scenes more realistic. The flexibility of a synthetic dataset also allows researchers to study other aspects of deep learning, such as a model’s capability to generalize, and the effects of image label quality on a model’s performance.

“By participating in SuperUROP, I hope to gain more substantial research experience, learn more about computer graphics, and familiarize myself with current technology and software. I have previously taken computer graphics and machine learning courses, and I am excited to apply what I’ve learned to a more long-term project.”
Hung-Jui Huang
MIT AeroAstro | Lincoln Laboratory
Undergraduate Research and Innovation Scholar
Project: Navigation in Unknown Environment Using Visual Feature
Supervisor: Nicholas Roy

We, as humans, navigate efficiently in novel environments with the help of our prior knowledge about the semantic meaning of the environment. We also create a high level abstraction of maps and actions to take when making decisions during navigation. For example, entering a room will probably not lead us to a faraway goal but to a dead end, and walking through a hallway is probably faster. However, classical robot navigation methods do not use the knowledge above. The main goal of this project is to have our robots navigate in novel environments to a specified location as quickly as possible.

“I am participating in SuperUROP because I hope I can extend my knowledge about the bleeding edge of robotics research. I am super-excited to study more advanced technology in robotics.”

Jenna Hong
MIT EECS | Nutanix Undergraduate Research and Innovation Scholar
Project: A Multimodal Memory Augmentation Interface: Unlocking Human Cognition Behind Story Memorability
Supervisor: Patrick H. Winston

Memory serves a key cognitive function in human story understanding and storytelling, which sets apart human intelligence from that of machines. This project explores the memorability of stories to create an intelligent assistive interface with possible applications in online learning or early intervention for Alzheimer’s disease. I will be working on building an artificial intelligence system that identifies key features of memorable story events and subsequently predicts episodic memorability from physiological and emotional responses. From there, I hope to contribute to the field of augmented cognition by building an AR environment that allows users to perceptually manipulate their “mind palace” via audiovisual cues, creating stronger mental associations for new and fading memories.

“I’m passionate about how technology can enhance our understanding of human intelligence and how we can reverse engineer the mind to create innovative technologies. With SuperUROP, I hope to gain skills in research and communication to answer meaningful questions at the intersection of computer science and cognitive science. I’d love to complete my project from ideation to publication, with results contributing to further applications of AR in learning and memory.”

Louisa Ruixue Huang
MIT EECS | Himawan
Undergraduate Research and Innovation Scholar
Project: Developing RNA-Based Synthetic Biology Circuits
Supervisor: Ron Weiss

Synthetic biology brings together a broad range of disciplines across biology and engineering to design and construct novel biological circuits or modify existing biological systems. Over the course of my research project, I will be developing RNA-based circuits using a library of RNA endonucleases that cleave in the middle of RNA polynucleotides to disrupt function in combination with other RNA constructs. I will work with both computational models and modular wet lab experiments to build up these circuits. RNA-based systems limit the amount of exogenous proteins, reducing load and stress on the cell and also avoid immune responses to these proteins. Development of circuits using these RNA switches opens up the tool to many future applications, especially for therapeutic intervention.

“I’m looking forward to applying the skills I learned in 6.129 [Biological Circuit Engineering Laboratory] to designing and building synthetic biology circuits in a new context. This research has the potential for therapeutic applications and is also at the forefront of the synthetic biology field. I’m excited about learning about the tools and techniques being currently used in the field and about helping develop new tools.”

Eileen Hu
MIT EECS | Himawan
Undergraduate Research and Innovation Scholar
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Quantum sensing exploits the sensitivity of quantum systems to the environment for high precision measurements. However, unwanted environmental noise can also corrupt the sensitive system easily. For quantum sensors to work over a practical timescale, quantum error correction, the process of preserving the state of the quantum system over time, is indispensable. This project is focused on measuring and optimizing the robustness of quantum error correcting codes (QECCs) under various sources of uncertainty by applying the framework of robust optimization. Starting from investigating the simplest system and noise model, we will incrementally incorporate more relevant features from quantum sensing and its implementation into the model.

“I am participating in SuperUROP because I hope to apply skills I learned from previous classes to gain insights into a problem that is both useful and interesting. The implementation of quantum sensing presents a broad range of physics and engineering challenges. I am excited to learn more about the quantum phenomena involved and to apply computational methods to study important properties of the quantum error-correcting systems.”
**Nancy Hung**  
MIT EECS | Analog Devices  
Undergraduate Research and Innovation Scholar  
**Project: Developing a Multipurpose Automated Platform for Quantitative Cellular Imaging**  
**Supervisor: Joel Voldman**

This project seeks to develop deep learning models that accurately predict and classify immune cells. Existing solutions have limited breadth because they do not account for staining techniques and cell functions. We will build, train, and test a CNN model that identifies cellular and sub-cellular regions on diverse cell types and contexts. We will collect datasets of cellular movies and develop computer vision models that process and analyze such datasets. We will test this tool with specific case studies relevant to the field and generate data visualizations that are user-friendly to researchers in a biology lab setting. This software platform will enable researchers, clinicians, and pathologists to conveniently understand disease-relevant cell properties from their own image sets.

“Through SuperUROP, I hope to learn how to perform image processing with computer vision, which I learned about from previous machine learning classes. This will also help me determine whether I’d like to pursue graduate school and work on something I believe is impactful.”

**Yara Jabbour Al Maalouf**  
MIT ChemE | Undergraduate Research and Innovation Scholar  
**Project: Development of a CBD-Protein, a Fusion Protein for Antibody Paper Based Assays**  
**Supervisor: Hadley Sikes**

Antibodies are widely used in many biological applications, particularly in diagnostics. The goal of this project is to create and test a fusion protein construct that would allow for the rapid, high-density and oriented immobilization of antibodies on unmodified cellulose paper. Immobilization of antibodies on paper can decrease the number of false positives and nonspecific binding events. If this construct proves to be effective, it can be integrated in a full immunoassay that can be utilized to design and test a variety of paper-based diagnostics.

“I am participating in SuperUROP in order to strengthen my background in protein engineering and the biological applications of chemical engineering. I hope to provide a meaningful contribution to my lab that can be used in future work. I also look forward to the opportunity to work on my own independent research project.”

**Satvat Jagwani**  
Undergraduate Research and Innovation Scholar  
**Project: Map Update Using GPS Data**  
**Supervisor: Hari Balakrishnan**

Accurate online road maps are required in the modern world for many purposes, such as location-based mobile services, disaster relief, and autonomous vehicles. However, making these maps is a task primarily done by humans, and is therefore slow and tedious. To speed up and automate the map making, we will create a system which takes an existing road map and a set of GPS trajectories and suggests new roads to the user based on the trajectories that are not covered in the map. We will adapt existing algorithms such as k-means clustering and RoadRunner for the purpose of updating maps, rather than inferring from scratch. The system will be tested on maps in the United State and in Qatar. We aim that the system would infer most of the roads, avoid inferring any extra roads, and have proper road connections.

“Through SuperUROP, I want to get deep into research and learn skills such as writing papers and giving presentations. Both will prepare me for graduate school and industry. I have taken courses in software development and algorithms, and I am therefore prepared to work on this project of online street maps. I feel excited about implementing algorithms that can detect accurate information about the road network with the given noisy data.”

**Nazar Ilamanov**  
MIT EECS | Hudson River Trading  
Undergraduate Research and Innovation Scholar  
**Project: The Psychophysics of Hands**  
**Supervisor: Boris Katz**

The goal of my project is to develop novel approaches for hand recognition. This could be used in robot gesture recognition for understanding commands from a human. Hand recognition also has many applications ranging from sign language to inferring shapes of objects. We built a vision system that can recognize 3D structure of hand poses from pictures in a controlled setting. In order to improve the performance of the system and make it more robust, we decided to understand how humans recognize hands in pictures. We are currently analyzing the psychophysics of human hand recognition by running experiments on Amazon Mechanical Turk. Once we understand the psychophysics of how humans recognize hands, we will be able to build better hand recognition systems.

“I am participating in SuperUROP because this is a great opportunity to apply what I’ve learned throughout my studies. I have taken machine learning and computer vision classes which will help me a lot in this project. I hope to learn about how computer vision is used to solve problems.”

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Alex Kimm
MIT EECS | CS+HASS
Undergraduate Research and Innovation Scholar
Project: Application of Artificial Data Generation to Deep Learning-Based Sentence Error Correction
Supervisor: Dorothy W. Curtis

One of the main problems in designing a good machine learning model is selecting an appropriate set of training data. When the pool of applicable data is small, creating a satisfactory model can be challenging. The goal of our project is thus to determine whether adding systematically produced sample data can improve the quality of the final model. In particular, we will determine whether machine-generated sentence pairs can improve the accuracy of a Seq2Seq neural network in translating between errored and correct Japanese sentences. The final application of this project is to create an online training tool to provide beginning language-learners with prompt and useful feedback on their mistakes.

"By participating in this SuperUROP project, I am aiming to gain experience in solving a problem that combines my fields of interest. I am excited to apply my background in machine learning to a long-term research project, which I hope will deepen my understanding of natural language processing."

Endrias Kahsay
MIT EECS | Nutanix Undergraduate Research and Innovation Scholar
Project: Performance Engineering Cilksan: A Provably Correct Race Detector
Supervisor: Charles E. Leiserson

Writing correct parallel code is notoriously difficult because of data races. Race detectors alleviate this, but most are "best-effort" and can miss rare races, resulting in mysterious data corruption and crashes. To address this, a provably correct race detector called Cilksan was developed at MIT. Unfortunately, Cilkan is too resource-intensive to use in practice. The goal of this project is to significantly improve Cilksan’s performance through parallelization and performance tuning, as well as reduce its memory usage by decreasing the 16x-per-byte overhead by coalescing memory accesses and leveraging hardware. By significantly improving Cilksan, we hope to provide developers a fast tool to aid them in writing correct parallel code with confidence.

"I am participating in SuperUROP because I want to gain experience in conducting research in performance and multicore, which are areas I am passionate about. I also want to go through all aspects of research: brainstorming, implementing, and writing a paper. My two favorite classes at MIT were 6.172 (Performance Engineering of Software Systems) and 6.816 (Multicore Programming). I am looking forward to applying the knowledge I learned from them to my project."

Shreyan Jain
MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar
Project: Evaluating Robustness of Neural Networks for Graph Structured Data
Supervisor: Luca Daniel

Neural networks are quickly becoming the algorithm of choice for a variety of machine learning tasks. However, the vulnerability of these models to adversarial attacks presents a challenging security concern that must be addressed. Networks trained on graph-structured data are particularly vulnerable to such attacks, because these networks are typically deployed in an online setting where user accounts can be manipulated by malicious attackers. Despite that fact, there has been a lack of research on the robustness properties of popular graph networks. We aim to fill this gap by proposing an approach for calculating certified lower bounds on the minimum distortion needed to generate adversarial examples in the graph setting. In so doing, we hope to identify graph network architectures that can be safely deployed on the web without compromising the security of the model.

"After taking graduate classes in machine learning and security last year, I have a growing interest in tackling problems at the intersection of these two disciplines, which is what drew me to this SuperUROP project. I hope to not only expand my technical knowledge and mathematical maturity, but also to improve my communication skills and get a better understanding of the entire research pipeline, from formulating an idea to presenting my work."

Milo Henry Lovelace Knowles
MIT AeroAstro | Lincoln Laboratory Undergraduate Research and Innovation Scholar
Project: Robust Data Association for Object-Level SLAM
Supervisor: Nicholas Roy

We conduct a comprehensive performance comparison of descriptor-based data association methods for object-level SLAM. Based on our findings, we design a visual bag-of-words descriptor from Oriented FAST and Rotated BRIEF descriptors extracted from object bounding boxes. To disambiguate between perceptually similar objects and improve the efficiency of our algorithm, we incorporate a heuristic for filtering associations based on geometric information from the robot pose and object map. We show that our bag-of-words approach with geometric filtering outperforms the precision, recall, and runtime of baseline descriptor matching methods on 21 challenging driving sequences from the KITTI Tracking Dataset.

"Working as a UROP student in the Robust Robotics Group for the past two years has given me a lot of exposure to current research in autonomous robotics, especially perception. I’m excited to continue exploring this area of robotics through SuperUROP and publish or present results."

Supervisor: Dorothy W. Curtis
The fundamental question behind most online algorithms is to determine how to deal with uncertainty of future data. In broad terms, this can be done in two ways. First, in the classical competitive analysis case, we seek an algorithm that gives a guarantee of an expected competitive ratio. The second method is to use techniques from machine learning to predict future data. If this prediction is correct, it is as if we have an offline problem instead of an online one, and we can often construct a simple and optimal solution. However, it is not immune to errors. We reconcile these two methods for a variant of the “ski rental problem.” In our variant, we allow the skier access to a black-box machine-learning algorithm that provides an estimate of the probability that there will be at most a threshold number of ski-days. We derive a class of optimal randomized algorithms to determine the strategy that minimizes the worst-case expected competitive ratio for the skier given a prediction from the machine learning algorithm, and analyze the performance and robustness of these algorithms.

Parallelism is critical to modern high-performance software. Cilk is a parallelization framework and runtime for C/C++ applications that allows the programmer to easily parallelize their code with composable, high-level building blocks. This reduces the number of implementation errors that parallel programming is notorious for, and can also yield better performance than poorly written code that uses lower-level primitives. This project focuses on identifying and investigating performance anomalies in Cilk. For instance, we assess how well Cilk scales on manycore NUMA (non-uniform memory access) machines, and how variably it performs on identical workloads.

“I enjoy working on low-level systems, software performance, and parallel computing. I have hands-on experience from past projects, internships, and classes, such as 6.172 (Performance Engineering of Software Systems), and hope to gain some research experience and insight into academia from this SuperUROP project. I’m excited to learn loads of new material and work on a promising and challenging software project.”
Ashley Jieun Lee
MIT EECS | Undergraduate Research and Innovation Scholar
Project: Learning to Generate 3D Point Clouds
Supervisor: Justin Solomon

“I am interested in applying the knowledge from classes, internships, and research experience I acquired during my three years at MIT to real-life applications. I have always been interested in machine learning and computer vision and graphics and want to delve deeper into the field. Through this SuperUROP project, I hope to better understand various techniques of machine learning and how they can be applied to modeling the real world.

“I am excited about SuperUROP because it will allow me to gain a yearlong experience in academic research. This project interests me a lot because it lies in the intersection of robotics and artificial intelligence. Having worked as a software engineer, I look forward to utilizing my engineering skills and diving deeper into the optimization of robotic control with the aid of machine learning.”

Toru Lin
MIT EECS | Aptiv Undergraduate Research and Innovation Scholar
Project: Learning Particle Dynamics in Partially Observable Scenes
Supervisor: Antonio Torralba

The goal of this project is to build a model that is capable of generating particle representation and predicting the dynamics of partially observable physical scenes. This is a step forward from Dynamic Particle Interaction Networks (DPI-Net), a particle-based simulator that can only learn object dynamics and make predictions based on fully observable scenes. Upon successful implementation of the new model, we will be able to create robots that can quickly adapt to new environments with unknown dynamics and accomplish various real-world control tasks using less computation.

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Calvin Lee
Undergraduate Research and Innovation Scholar
Project: Extending Generalization Theory to Include Adversarial Robustness
Supervisor: Aleksander Madry

Standard generalization theory focuses on bounding generalization error, which measures a model’s ability to handle never-before-seen examples which are sampled at random. In this project, we plan to explore a new theory of robust generalization, which will instead measure a model’s ability to handle adversarial examples intentionally chosen to fool it. Previous research has already shown that this robust generalization requires more data than standard generalization. By re-examining the tools of standard generalization theory, such as Rademacher complexity, and extending them, we hope to develop theory and insights into this new notion of robustness. Ideally, the project will culminate in a theoretically-grounded technique for training robust, human-like AI.

“I am excited to work on a project where I can draw on both my theoretical background in algorithms and my practical experience contributing to machine learning projects at top industry labs. I hope to contribute to the field of deep learning by understanding existing methods’ robust generalization properties, then inventing new methods which are both theoretically grounded and highly effective.”

Cynthia Tianqing Liu
MIT EECS | Advanced Micro Devices Undergraduate Research and Innovation Scholar
Project: Alignment as an Indicator for Two Distinct Training Regimes
Supervisor: Aleksander Madry

Deep learning is quickly becoming more prevalent in both research and industry. To make use of deep learning models, we must train a model on some task. While there are many optimizers and schedulers designed to improve training results or increase convergence speed, there is little understanding as to why these methods work. To fill this gap, we hypothesize that the training process of deep nets can be separated into two distinct phases: a generalization phase and a convergence phase. To provide evidence for this hypothesis, we observe a metric called “alignment,” which measures whether our training steps are moving us towards the solution minima during training. We hope to use this metric to demonstrate that there are two distinct phases of training, and potentially suggest a new training scheduler that takes advantage of this fact.

“Through this SuperUROP project, I would like to explore deep learning while applying machine learning and mathematics to real-life problems. I previously conducted research in applied machine learning and reinforcement learning. This SuperUROP project will let me expand on that experience and tackle machine learning from a more theoretical angle, while allowing me to utilize principled reasoning skills learned in classes such as 18.100B [Real Analysis] and 6.046 [Design and Analysis of Algorithms].”

2018–2019 Scholars
Researchers in the field of deep reinforcement learning have shown that network architectures such as deep Q-learning (DQN), deep deterministic policy gradients (DDPG), and asynchronous actor-critic agents (A3C) can produce well-trained agents to play several Atari games using only the game’s pixel array as input and the game of Go, which has an incredibly large state-space. The primary goal of this research is to understand how modeling these networks while factoring in natural language instructions might lead to more performant and explainable agents. The initial approach will be to borrow methods from hierarchical reinforcement learning to break goals into sub-goals for the agent to learn and then map an underlying language model to such a hierarchy of sub-goal execution choices.

“I am participating in SuperUROP because I want to gain experience as a researcher before starting a master’s-degree program. I have participated in the UROP program for two years and have enjoyed it very much. I am very interested in the field of deep learning and how it can be used to solve old problems in a new way. I also hope to get to better know the people in my lab through SuperUROP.”

Cory John Lynch
MIT EECS | Keel Foundation Undergraduate Research and Innovation Scholar
Project: Privacy-Preserving Data Aggregation on the Decentralized Web
Supervisor: Lalana Kagal

Solid is a decentralized platform for the web where data are managed separately from the application. Users store their own data in personal data stores, and can individually grant access to applications. A large number of users on this network provides an opportunity for computing aggregate statistics across user data. However, much of this data may be potentially sensitive, such as medical information. This project will investigate a method of aggregating data, while preserving the privacy of every user. Specifically, using homomorphic encryption, we will be able to securely compute aggregates without knowing the unencrypted value for any user. By implementing this system on the Solid framework, we will demonstrate the practicality of calculating various aggregate statistics, such as sum or average, and how this could be extended to more generalized queries.

“Through this SuperUROP, I am excited to apply my experience in web development in a research project that could change application architecture on a fundamental level. Without a doubt, this investigation will give me exciting insight for my future programming endeavors.”

Sophia Luo
MIT EECS | Hudson River Trading Undergraduate Research and Innovation Scholar
Project: Modeling and Predicting Investor Trading Behavior Using Media Sentiment
Supervisor: Andrew Lo

The rapid integration of information sharing platforms has dramatically impacted the financial markets and sparked many questions about the relationship between media sentiment and alpha signals. Current research investigates the effects of sentiment on liquidity, stock returns, and market movement. To the best of our knowledge, there is no study that explores the relationship between market sentiment and individual trading behavior. In this study, we will investigate the impact of news sentiment on investor trading behavior with a large novel data set of brokerage accounts and RavenPack News Analytics data. We will extract features from trading activity for each investor, compute aggregate sentiment scores for each time period, and investigate correlations between the two. Then, we will attempt to predict how individuals will react to changes in market sentiment.

“I am excited to gain insight into a wide variety of topics during guest lectures and experience the research process firsthand throughout this SuperUROP project. Moreover, I hope to increase my understanding of financial economics, develop my skills in data analytics, and apply machine learning concepts from class to the real world.”

Jingwei Ma
MIT EECS | Angle Undergraduate Research and Innovation Scholar
Project: Analyzing 3D Reconstruction of Cameras and Spatial Information in Movies and Building a Deep Learning Model to Improve Current Algorithms
Supervisor: Antonio Torralba

Extracting 3D information from 2D has been a growing focus. With recent progress and more 3D datasets made available, it is possible to extract more complicated 3D information. Our research will focus on 3D reconstruction from movies using methods, such as structure from motion, stereo, and orbslam. Movies provide diverse and complicated information, difficult for machine to understand. We want to start with extracting 3D shape and location of objects from single frames then use sequential frames to 3D reconstruct. And because movies focus mostly on people, we can use trajectory, face, or pose to constrain the base 3D reconstruction. This project can contribute to creating VR simulations, reconstructing heritage, and helping machines learn from the immensity of available video data.

“I have been working on this project in the past year. The number of real world applications our research can unlock always makes me feel excited. Through participating in SuperUROP, I hope to strengthen skills, such as writing papers and doing presentations. I also hope to fill in knowledge gaps, such as computational geometry and computer vision algorithms.”
With increased renewable energy, natural gas power plants have become key players due to their relatively low fuel costs and ability to ramp up in response to changes in wind and solar resources. The focus of this project is to develop computational models that will evaluate the impact of increased renewable adoption on New England’s coupled electric-natural gas system. I will examine whether the current natural gas infrastructure is appropriately sized and operated to fulfill shortfalls in renewable generation. Both physical and economic system domains will be studied, with a focus on developing recommendations to more efficiently manage the joint electricity-natural gas system and accommodate the growth of renewable generation.

“I hope to gain experience in modeling and optimizing energy systems. I hope to apply knowledge about energy economics from my Energy Economics and Policy class, about the electric grid from my Fundamentals of Smart and Resilient Grids class, and on modeling physical systems my previous UROPs and internship. This will allow me to gain insights on how one form of energy generation affects other electric generation plants and infrastructures.

“I am majoring in 6-3 (Computer Science and Engineering). The classes I have taken at MIT prepared me for SuperUROP. By doing this project, I hope to learn more about performance engineering and gain more practical skills. I am excited about the many challenges that the project will bring.”

In this project, we are implementing the high-performance version of the triangular counting algorithm that can work efficiently on big systems using Graphit, a new domain specific programming language suited for graphs that generates fast implementations from high-level algorithm specifications. Then, we are planning to compare the result with previous works done in this field. If time permits, we will extend our project to implement different highly optimized graph algorithms in Graphit and work towards improving the current version of Graphit.

“Autonomous science robots encounter coupled planning and modeling challenges when placed in an unknown environment. When little prior information is provided about a survey domain, many exploration algorithms are prone to exhibit behavior resembling random exploration or local gradient-following. Furthermore, a data-collecting agent’s belief about its environment is often modeled as a continuous, uncertain Gaussian process, which makes the definition of policies for the agent a complex task. To address these challenges, we propose an autonomous agent that learns about the conditional relationships between multiple variables or features over a survey field in the form of a graphical model. We demonstrate that such an agent can overcome the problem of weak priors by making inferences, and we define an active learning policy for such an agent to intelligently gather information about variable dependencies. Our method has applications in learning with side information, transfer learning, multi-agent coordination, and surveillance of nonstationary domains.

“I am participating in SuperUROP because I want to gain experience doing scientific research in robotics. I hope to gain a better understanding of predictive and model-based algorithms and techniques to learn how to develop, evaluate, and express my ideas, and to contribute towards the research goals of my group.”
Brooke McGoldrick
MIT EECS | Hewlett Foundation
Undergraduate Research and Innovation Scholar
Project: Inferring People’s Personal Traits from Location Traces
Supervisor: Ilaria Liccardi

This project focuses on the type of personal traits that can be inferred about an individual based on their location data. Factors affecting inference accuracy include the length of time over which data is collected from participants and the frequency of location points recorded over the collection period. To gather data, I will develop a mobile app which participants will allow to sample their location at random points throughout the day and ask the users to give some context about the points collected. Other participants will then be asked to infer general information about those individuals using some of their location data. This project’s results have major implications in user privacy, especially on social media, and they may make users and corporations more aware of potential risks.

“I have enjoyed working on different UROPs in the past, and I am excited to spend more time researching through SuperUROP. User privacy is a new field for me and has a big impact today, so I look forward to using my experience in user interface design and data analysis to explore this topic. Through SuperUROP, I would like to learn more about communicating research results rather than just producing them in a lab.”

Haripriya Mehta
Undergraduate Research and Innovation Scholar
Project: Paper Dreams
Supervisor: Pattie Maes

Perhaps all storyboard artists have faced “artist’s block” at least once in their lifetimes. What happens when storyboard artists feel an absence of creativity? Our project, Paper Dreams, focuses on augmenting the artist’s creativity by providing potential ideas for storylines to artists when they are running out of ideas. We utilize cognitive processes of artists to determine when they are lacking creativity and to determine machine learning algorithms to recognize what they are drawing. Then the underlying neural network of our app draws an object in the scene. Our goal is to take our existing neural network model and modify it so that the produced doodles are more relevant to the existing storyline and to the artist’s emotional state and are in the style of the artist.

“I am participating in SuperUROP because I would like to go deeper in my research about augmenting creativity with artificial intelligence. While I have spent most of my time last semester making the user interface for Paper Dreams, this year, I would like to focus more on understanding and refining the machine learning models relevant to our project. I hope to submit a paper for publication.”

Puneeth NSK Meruva
MIT AeroAstro | Lincoln Laboratory
Undergraduate Research and Innovation Scholar
Project: End-to-End Learning of Perception Data for Autonomous Vehicles
Supervisor: Sertac Karaman

One common trend in autonomous vehicles is that no amount of data of real drivers is sufficient to train autonomous vehicles so that they can cover all edge-cases in addition to the more simple, common tasks. Therefore, it is critical to develop robust simulation and training engines that can produce and learn from artificial training data. In this project, we develop an end-to-end simulation and training engine based on LIDAR and camera data to train autonomous vehicles. The engine takes as an input dataset a video of a normal human-controlled drive (a base trajectory for the vehicle as a starting point) and predicts new steering-wheel angles by combining LIDAR data with the images in the trajectories, transforming the data to produce numerous artificial trajectories, and applying reinforcement learning techniques upon the new trajectories.

“I have been interested in robotics and the autonomous vehicles space for more than six years. This project will allow me to acquire the knowledge necessary to excel in this field. I feel that my past internships at Uber, BMW, Microsoft Research, and the Carnegie Mellon Biorobotics Laboratory, as well as my enrollment in 6.141 (Robotics: Science and Systems) and 6.036 (Introduction to Machine Learning) have given me the necessary skills in autonomy and control to succeed in my upcoming research project.”

Antonis Michael
MIT EECS | CS+HASS
Undergraduate Research and Innovation Scholar
Project: Reasoning About Emotions – Building Generative Models of Emotional Intelligence
Supervisor: Leslie P. Kaelbling

Humans readily make nuanced and abstract inferences about the unobserved contents of others’ minds, including their beliefs, values, and emotions. Professor Saxe’s Lab has begun to develop probabilistic models of people’s intuitive reasoning about others’ emotions. The goal of my project is to extend these Bayesian models to capture observers’ cognition about others’ emotions in a range of more complex social games and ethical dilemmas. This will involve designing behavioral experiments, collecting human data, and building generative models of observers’ emotion attributions. This investigation of people’s intuitive theory of emotion aims to advance both our understanding of human social cognition and our ability to recapitulate these functions in artificially intelligent systems.

“I am participating in SuperUROP because I’m interested in understanding more about our social cognition and applying the skills I’ve acquired through my classes and past research projects to model such processes and potentially implement them in artificial agents.”
Low precision training of neural networks has been shown to improve training time and save energy. However, there is a performance cost incurred from the corresponding loss of information. We explore fine-grained mixed precision training of neural networks. Specifically, given an assignment of operators to float precisions in the computation of forward propagation and back propagation, we try to minimize truncation, while maintaining test set performance. Furthermore, we compute probabilistic bounds for our allocation in order to provide guarantees of the overall precision of the computation.

“My interest in participating in SuperUROP came from my desire to spend more time doing research during the semester and to learn more from Professor Michael Carbin and PhD student Ben Sherman. My research with them last semester touched on some related topics. I want to explore the ways to represent rationales on computers and to understand the corresponding effects on computation. I like that this area of research has rich theory and interesting applications.”

Creating a static HTML web page is simple enough for beginners, but developing a fully functioning web application requires jumping through many hurdles. There is a need to learn scripting, backend technologies, data management schemes, and so on. We aim to lower this barrier for anyone who wishes to create data-driven applications to solve various tasks in their daily lives. Often, those people may not be traditional programmers, but they have experience keeping track of and performing calculations on data in a spreadsheet. Spreadsheets are also limited by their flat structure for data representation. Thus, we work on creating a tool with a familiar spreadsheet-based interface that allows a user to create custom, computationally flexible web applications for hierarchical data without the need to write any templating or scripting code.

“I am interested in exploring how we can lower barriers to programming and application development, and I also enjoy creating usable tools in general. Through SuperUROP, I hope to learn more about how different people use computational tools and what working in a research environment is like.”

The goal is to deposit and characterize few-nanometer-thick superconducting films which are the material used in the fabrication of sensitive photonic devices, especially superconducting nanowire single photon detectors (SNSPDs). The performance of SNSPDs is dependent on the materials. In this project, I investigate the superconducting properties of few-nm-thick bilayer films and wires fabricated on them. There are three main projects for this SuperUROP: 1) fabrication of wires on NbN-Ti bilayer film and measurement of superconducting properties of the wires, 2) fabrication of Nb-Au bilayer film and measurement of superconducting properties of the material, and 3) fabrication of bilayer film with different materials and thickness and measurement of superconducting properties.

“I am participating in SuperUROP because I am very interested in the applications of superconductors. I have worked on this material for a UROP project, but as I learn more about it, I find more things I don’t know about. I am excited to learn more about fabrication methods and applications of bilayer superconductors.”

The goal of my SuperUROP project is to be able to automatically transcribe musical performances with multiple instruments using computers. In general, the task of music transcription is about listening to a piece of music and writing down all of its musical elements using some sort of notation. The current state-of-the-art models use deep learning to transcribe live piano performances to sheet music. I am working towards extending this research to be able to work with any combination of instruments, instead of just the piano.

“I’m concentrating in music, and I’m very involved in the dance community at MIT. So I’m especially excited about this SuperUROP project because I have the opportunity to help computers develop an understanding of the complex layers that underlie the overall sound of a song in the same way humans compose music in parts or dance to different musical elements!”
Moin Nadeem  
MIT EECS | CS+HASS
Undergraduate Research and Innovation Scholar  
Project: Fact-Checking and Reasoning  
Supervisor: Jim Glass

Our goal is to develop an automated solution which accomplishes three tasks: 1) When given a document, it differentiates which sentences are making substantive claims that require verification and which do not; 2) When given sentences, it detects whether it agrees or disagrees with some evidence (for example, given the evidence "The bear scared off the baby that was attacking him," does it agree or disagree with the claim "The bear is scary"); and 3) When given a claim, it provides evidence from a large corpus, such as Wikipedia, that agrees or disagrees with that claim (for example, given the claim "The bear is scary," it should be able to provide documents that prove or disprove this claim).

“I’m participating in SuperUROP because it’ll help provide a great venue to do some substantial research at MIT. I feel sufficiently prepared by a combination of classes and side projects. I hope to learn a lot about the state of natural language processing research; particularly, its applications in industry. Fake news is also something that really excites me, and I couldn’t be more grateful to work on it.”

Joshua Eron Noel  
MIT EECS | Advanced Micro Devices Undergraduate Research and Innovation Scholar  
Project: Exploring the Design Space of Superscalar RISC-V Processors  
Supervisor: Arvind Mithal

This project aims to summarize the tradeoffs of superscalar design decisions on RISC-V processors by quantifying the power, performance, and area of implemented processors. The RISC-V processors will differ in the sharing and duplicating of hardware resources, scheduling policy, and the width of the superscalar pipeline. To evaluate these designs, they will all be able to boot Linux and run a suite of benchmarks on FPGA. Area and power will then be evaluated by synthesizing the designs to ASICs. This research will result in an overview of superscalar design and the tradeoffs of various choices. This summary can then be used to introduce students familiar with basic computer architecture to the possibilities offered by superscalar design.

“I am participating in SuperUROP to obtain research experience while also gaining a deeper understanding of, and contributing to, the field of computer architecture. In the past, I have taken classes related to architecture, completed a CPU-GPU fluid dynamics UROP, and completed a GPU architecture internship at NVIDIA. I aim to utilize and build upon my experience while also gaining exposure to conducting self-guided research.”

Hoang Nguyen  
MIT EECS | Keel Foundation Undergraduate Research and Innovation Scholar  
Project: Development of Feature-Cue Based Speech Analysis System  
Supervisor: Stefanie Shattuck-Hufnagel

In recent years, there has been an increase in demand for, as well as innovation in, speech-analysis services. Unfortunately, many of the techniques and services are dependent on high volumes of quality data to perform well. My research with the MIT Speech Communication Group aims to solve data dependency problem for development of speech analysis system. We combine linguistic knowledge and computer science techniques to train and evaluate modules that recognize linguistic contrastive parameters in languages. From the detection results, we can use linguistic constraints to infer intended distinctive features and subsequently recognize phonemes and words from the extracted speech signal.

“I joined this project in my sophomore year in college. I really like the linguistic aspect of the research and am particularly interested in working with machine learning. I hope to continue learning a lot of technical skills and research skills through SuperUROP. I am very excited to see the result at the end of my research project.”

Domenic Nutile  
MIT EECS | Advanced Micro Devices Undergraduate Research and Innovation Scholar  
Project: Profiling Execution of Auto-Parallelized Programs in the Swarm Architecture  
Supervisor: Daniel Sanchez

While the performance improvements of single-core processors have recently stagnated, the Swarm architecture has demonstrated novel advancements in the performance and scalability of program parallelization across a multi-core architecture. In my project, development of a generalized compiler for the architecture has begun, which will allow any program to automatically take advantage of these performance gains. The goal of my project is to design and implement tools to profile and parse data about how these programs are automatically parallelized and executed, such as how loop iterations are scheduled, or how function calling is organized, to better understand how a program is best converted into a Swarm program to maximize parallelism and performance.

“I am participating in this SuperUROP because of my interest in computer architecture and low-level software. I believe that this project is very exciting and at the forefront of development in these fields, and I feel my experience in these areas from classes such as 6.175 (Constructive Computer Architecture) will help me make a meaningful impact on the project. I also hope to gain valuable research experience and further my knowledge and understanding of computer architecture.”
Ellen Bridget O’Connell
MIT MechE | Lincoln Labs
Undergraduate Research and Innovation Scholar
Project: Soil Analysis
Supervisor: Douglas Hart
Soil nutrient analysis provides information that is used to prescribe fertilizer, but the standard method for soil analysis is labor-intensive, time-consuming, and cost-ineffective because samples must be sent to labs for analysis. This research will be focused on validating a new approach to soil nutrient analysis that reduces the amount of soil needed for samples and allows for rapid, in-field analysis. Factors such as grain size and the method of sample preparation will be studied further. Additionally, we will construct calibration curves and will run experiments on the effects of moisture content in the soil samples.

“I am participating in SuperUROP to experience a longer-term, interdisciplinary research project. Through this research, I hope to further my understanding of how to design a mechanical system for a specific context and how to structure a research project. In 2.014 (Engineering Systems Development), I worked on the predecessor to this research and I am excited to continue research that combines my interests in mechanical design and chemistry.”

David Pacheco
MIT EECS | Undergraduate Research and Innovation Scholar
Project: Linguistic Analysis of Wikipedia for Question Answering
Supervisor: Boris Katz
Currently, Wikipedia is one of the biggest, if not the biggest, source of information portrayed in the form of both unrestricted text and linguistic values associated with certain attributes. Many of the important and classifying data that Wikipedia contains can be found in the first sentence of an article as well as its infoboxes. This tagged data can prove very useful when it comes to question answering and so our goal is to create a seamless question-answering system that can integrate Wikipedia infoboxes. Some of the steps needed to achieve this include: 1) creating a robust database retrieval and storage system; 2) deciding what is relevant to a particular question through decomposition; and 3) allowing our system to understand multiple references to the same object.

“This SuperUROP experience will enable me to learn what it is like to carry out a research project for an entire year. I’ve taken 6.031 (Elements of Software Construction) and 6.806 (Advanced Natural Language Processing), so I’m excited to put what I’ve learned to the test. I also plan on doing a Master’s in Engineering (MEng) degree, and SuperUROP will certainly prepare me for writing a research paper.”

Fernando Andre Ortiz-Soto
MIT EECS | CS+HASS
Undergraduate Research and Innovation Scholar
Project: Sampling in the Space of Redistricting Plans
Supervisor: Justin Solomon
Gerrymandering has plagued the American electoral process since the country’s foundation, but has attracted increasing attention in recent years. By making elections uncompetitive, this practice has decreased voter engagement and trust in our democratic institutions. The goal of this SuperUROP project is to develop and implement an algorithm that can generate electoral districts with uniform probability on an electoral map. Such an algorithm would make it possible to characterize the “distribution” of electoral maps. This could then serve as a tool to make statistical arguments in the courts about whether a given electoral map was gerrymandered. This would hopefully lead to the removal of these partisan maps and the use of maps drawn with less human bias.

“I see SuperUROP as an opportunity to get meaningful experience as a researcher and gain very specialized expertise, specifically in the fields of graph algorithms and probability theory. Moreover, my project allows me to combine my passions for math and computer science and apply them to work on bringing positive change to this country. This is also a great opportunity to explore whether I would like to pursue a future in research.”

Aman S. Patel
MIT EECS | Landsman
Undergraduate Research and Innovation Scholar
Project: Determination and Prediction of Histone Modification Covariance Structures
Supervisor: Manolis Kellis
This project aims to better understand modifications of histone proteins, which are essential in regulating gene expression. Sequencing methods exist to study this process, and determining the covariance structures of the data produced (essentially, correlations between sequencing output from different cells) could provide vital information about the patterns behind histone modifications. First, using epigenomic sequence data, covariance structures will be built across several cell types and hundreds of individuals. Machine learning models will then be used to predict covariance structures more accurately, thus creating a versatile tool to study disease and gene expression. Finally, this project will focus on studying histone modifications in autoimmune diseases.

“I see SuperUROP as an exciting next step in my research career. Conducting research since my first semester at MIT has imparted me with an appetite to explore more, and I am very excited about the potential implications of my project. I also believe SuperUROP’s emphasis on communication through papers, posters, and presentations will prove highly beneficial and allow me to hone several undoubtedly essential skills.”

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The advent of deep learning has led to dramatic improvements in algorithms for conditional image generation. Yet, the problem of creating videos from images remains extremely challenging — most existing methods enforce strong priors on video datasets, require multiple frames as input, or generate videos that are blurry and incoherent. To overcome these limitations, I am exploring a new, multimodal domain of video generation where models are conditioned on one image, which sets the scene, and a sentence, which specifies how the video should unfold by describing the actions of objects in the image. My goal is to develop neural networks for use in this setting and train them to synthesize coherent, high-quality video.

“Most of my prior experience in vision and deep learning came from UROPs and an internship at NVIDIA. The 2018 version of 6.883, which provided a critical analysis of popular evaluation metrics for deep generative models, also helped prepare me to do competent research in the field. I joined SuperUROP as it provides a great opportunity to get more experience implementing and critically evaluating novel architectures.”

Alzheimer’s disease (AD) is one of the leading causes of death worldwide for people over 65 years old because of its complex pathology and latent symptoms at its early stage. To date, early diagnosis of AD requires invasive and complicated methods, which have low sensitivity and are not readily perceptible with current technologies. This project will tackle this problem by seeking to develop a noninvasive blood-based diagnosis for early detection of AD. We will apply the current technologies and research in cell-free DNA (cfDNA) to identify predictive biomarkers for AD. Two types of statistical models, marker-based and tissue-proportion-based models, will use these selected biomarkers as predictors to infer the disease status of an individual. These models are trained using various machine learning algorithms on a cohort of 50 individuals with cfDNA methylation proles. We perform simulation to evaluate the choice of markers and cross-validation to evaluate the accuracy and precision of different disease-prediction models.

“Through SuperUROP, I want to apply my background in computer and data science, and molecular biology in conducting independent research. I hope to broaden my knowledge in life science and I am excited to contribute to the development of Alzheimer’s disease research.”
The state-of-the-art vision algorithm for self-driving cars uses deep learning, which requires a lot of data to train the models and to test their robustness in different environments. However, obtaining extensive photographs of streets and the corresponding ground truth annotations is extremely expensive and sometimes impractical. Our approach is using computer graphics to generate large annotated datasets by rendering scenes in different controllable lighting and environments. This opens up opportunities to study various aspects of deep learning, such as how well neural network models generalize, and how to make the learning invariant to lighting conditions. Another challenge is making the virtual world realistic while also optimizing the performance of the algorithm.

"As a computer science student and photography enthusiast, I'm interested in research areas where the two fields overlap. This SuperUROP project is a great opportunity for me to gain more experience in machine learning and computer graphics research. I hope to improve my understanding of these topics, to learn how to collaborate on a successful project, and to make an impact with real-world applications."

A "smart contract" is a piece of code that is stored on a blockchain, triggered by blockchain transactions and that reads and writes data in that blockchain's database. We would like to develop a high-level language for specifying data-sharing contracts that bridges the gap between programming languages (currently used for smart contracts) and natural language (currently used for legal agreements). These contracts will focus on enabling the sharing of sensitive information such as health care information. The contracts will describe responsibilities of both the subject and consumer of the data, tie parties to their duties, ensure payment, when applicable and hold violators accountable.

"Through this SuperUROP project, I want to learn how to develop blockchain-based applications. I previously worked on blockchain projects, and I am very interested in this area of research. I hope to share my results by releasing open-source libraries and publishing a paper."

"I'd like to participate in a research project where I hold a great deal of the responsibility, and I think going through this program in this lab will provide the necessary mentorship for me to be successful in doing that."
Zoos are an illustration of the extreme disconnect between humans and other species, often criticized as entertainment sources that restrict natural animal behaviors and fail to provide meaningful human-animal interactions. However, many of these institutions have transformed into safe havens to protect and improve the quality of life of animals and increase scientific and public understanding and respect of other species. To further these efforts, we will reimagine how we use voices and sound to design and create interactive voice-based experiences to stimulate animals’ auditory senses, the dominant sense for many species. We will then evaluate the effect of these enrichments in improving interspecies and intraspecies connectivity, quality of life for captive animals, and caregiver monitoring.

“I’m excited to be participating in SuperUROP because I hope to gain a deeper understanding for rigorous research, and because I believe music and the voice have the power to enrich the lives of not just people, but animals as well. I will apply my background in programming and music to approach the interesting design challenge of creating interfaces and experiences for non-human users.”

In the field of natural language processing, we express the semantic content of a word using a high-dimensional embedding in Euclidean space. Many improvements in the field have come from engineering embedding methods that preserve notions of semantic distance and additivity. However, for specific tasks, recent research has shown that a flat manifold may not accurately represent the true distance relationships between words. In particular, for language tasks that involve clustering (like word sense disambiguation and topic modelling), we want to induce regions of locally high curvature on the underlying manifold. In this project, we will explore techniques to generate such embeddings and apply them to domain-specific tasks.

“I am participating in SuperUROP because I want to gain valuable experience in the field of numerical optimization, especially as it applies to simulations. I have taken several high-level computer science and math courses, and I am excited to apply my knowledge towards my research!”

The primary effort in this SuperUROP project consists of writing additional Python modules to take full advantage of the capabilities of an Opentron robot for biological engineering endeavors. For example, these modules could focus on streaking colonies, performing BCA (protein concentration) and Bradford assays, and conducting other assays in order to minimize researchers’ time spent on repetitive tasks. This work could provide a template with which chemical engineers could mold their own protocols for high-throughput experiments using a more economical platform in their research endeavors than is currently the industry standard.

“I am participating in SuperUROP to best contribute to my lab’s ability to conduct high-throughput research while gaining technical competencies not normally covered in a chemical-biological engineering curriculum. My previous research in quantitative trait locus-mapping drew my attention to the importance of automating lower level processes to best focus my efforts on high-value activities.”

In today’s world of extensive data-collection, privacy of users is ever more important. Even the so called “anonymized” datasets can be de-anonymized given external records. The notion of differential privacy makes concrete mathematical guarantees and is far more desirable. Through this SuperUROP project, I will be working to develop a fully scalable, fault-tolerant, automatically managed privacy-preserving machine learning framework. Such framework would be indispensable for analysts and developers, as it would allow a low-barrier, easy-to-use-and-manage solution for ensuring user privacy while providing high utility at the same time.

“Through this SuperUROP project, I want to gain more experience in machine learning and privacy research, in addition to making a meaningful contribution to my research group. I’ve taken classes in machine learning, software systems, and algorithms, and I want to expand on that knowledge with an interesting application. I also hope to publish a paper by the end of SuperUROP experience, aiming for significant results.”
large databases. However, searching such databases for files with specific properties poses a challenge because unique addresses contain limited information about the file and make it difficult to find all files with a given property without individually sequencing every strand. We are working on developing an addressing system in which short DNA tags provide information about a file that makes it searchable by a complementary DNA probe. The limited specificity of DNA binding allows for the development of a “fuzzy” addressing system in which a search for a specific property will find most files with the property exactly matching the search term and some files with similar properties.

“I am excited to participate in SuperUROP to learn skills in research planning and execution. I hope that I can apply the lab skills I have learned in previous research experiences to a project that I am able to help design. The project I am working on is also more computational than research I have done in the past, so I am excited to work on my abilities in that area.”

“We consider the problem of robots planning for complex, long-horizon tasks. Several algorithms exist to solve arbitrary planning problems, but their running time scales poorly with the plan length. However, knowledge learned from experience can be used to guide planning to more quickly find a sequence of actions leading to the goal. We generalize the convolutional neural network to apply to graph-structured input and train it to learn the cost of reaching a goal from a given state encoded as a graph. This heuristic can be integrated with a conventional planning algorithm to pick intermediate goals that are likely to eventually lead to the final goal. As a result, the planning algorithm never has to plan all the way to the goal, leading to faster plan generation. We implement and evaluate this approach in a simulated 3D environment and eventually on a physical robot.

“I am participating in SuperUROP because I want to continue to build on my prior research in robotics and learning and eventually determine a path forward for graduate school and beyond.”

“Automating excavation in mining and construction applications is crucial today, as the supply of skilled operators cannot match market demand. To make control decisions for autonomous excavators, gaze-tracking can be employed by solely extracting key information that skilled operators use in the field during a digging task. A subject will wear a camera that looks into both the eye and the surroundings to collect data. After characterizing the human attention points of skilled operators using optical flow, this information will serve to identify appropriate inputs in the control decision process.

“I am participating in SuperUROP because I would like to gain advanced research skills within robotics to apply to graduate studies. Last year, I was a UROP student in the D’Arbeloff Lab, and I also took 2.671 (Measurement and Instrumentation), a class that has prepared me to present my research results effectively. I’m excited by the opportunity to learn more about the software aspects of robotics and training neural networks to improve the robot’s intelligence and ability to mimic human behavior.”
Cybersecurity is a growing threat that can have profound impacts on people’s lives. My project uses evolutionary algorithms to create robust network system configurations that are better able to withstand attacks. The end goal is to create a deployable configuration that can be transferred to existing systems and help network administrators best determine how to set up their network.

“After taking 6.034 (Intro to Artificial Intelligence), and 6.033 (Computer Systems Engineering), I became interested in both machine learning and security. Through participating in SuperUROP, I am excited to learn more about research in both fields and how machine learning can help make more secure systems. Additionally, I am looking forward to gaining experience in working on a long-term research project.”

Access to finance remains a huge problem for East Africa, mostly because a majority of the population is unbanked. Having been born and raised in Kenya and knowing what artificial intelligence can do, I believe that I’m in a unique, privileged position that will allow me to fully research and understand this problem and possible solutions.

“SuperUROP allows me to bring together all my coursework, personal interests, and professional experience into a single project. I have always been interested in the human side of technology, understanding how it can be used to evoke emotions and provoke thought. This program gives me the ability to create and take ownership of a project that is meaningful to me, and I hope that will start a discussion on how we engage with media.”

We are exposed daily to thousands of images presented by various media outlets, social networks, and corporations. The danger with this ubiquity of visual media lies in the ease with which we accept and digest an image — how quickly a picture can equate reality. This project aims to understand how tropes of racial, ethnic, and sexual minorities within digital media can impact the perception of these demographics in real life. Affective computing techniques will be used to track the emotional and psychological responses of individuals as they are presented images that directly contradict these tropes. In doing so, this project hopes to reveal how engagement with digital media impacts implicit biases, and if it can be used to reverse these biases through sustained and deliberate exposure.

“I am excited about participating in SuperUROP with a project that combines my majors of computer science and linguistics and that will help me make a real change in the world. I have taken courses in phonology, algorithms, and artificial intelligence, and I look forward to using all the skills and knowledge I acquired in those classes in the context of research. I also hope to grow more as a researcher during the program.”
Rechargeable batteries are suited for energy storage due to their high energy density and efficiency. However, these devices are limited to using electrodes less than 300 µm thick to avoid diffusion losses, which results in higher cost due to the inclusion of inactive components. Transitioning to thicker electrodes requires novel electrode and cell architecture to enable sufficient ion and electron transport through the electrode. I will investigate the permeability and wettability of different engineered electrodes and the compatibility of various electrode-electrolyte combinations in order to develop low-resistance, thick electrodes. Specifically, I will examine electrolyte surface tension and viscosity as well as electrode microstructure to determine the effect on battery performance.

“Through this SuperUROP project, I hope to apply knowledge from my previous courses in an effort to provide a viable solution for improving the stability of renewable energies. Additionally, this research will provide me with invaluable laboratory experience as I complete my undergraduate academic career and transition into the next stage of my career.”

The aim of this project is to derive estimations of the blood pressure (BP) variation based on pulse arrival time by using a novel unobtrusive sensing technique instead of a conventional ECG sensor as proximal timing reference. Monitoring based on magnetic induction allows measurement of vital signs in a noncontact way even through several layers of clothing. This could enable more convenient and immediate BP monitoring in medical emergencies. The course of this project is separated into 1) building a magnetic induction sensor based on existing electrical layouts; 2) conducting measurements, including test protocol definition, setup of the experiment, and actual data recording; and c) analyzing the data.

“I am very excited about this SuperUROP project. I think this product will not only be a great medical tool that saves lives, but also a unique learning opportunity for me to apply my classroom knowledge to a practical project. It covers a wide range of subjects that interest me, from PCB design to signal processing, and will introduce me to new areas in microcontroller programming and biomedical technologies.”

“I am participating in SuperUROP because I want to get more hands-on experience with projects outside of classwork. I took 6.831 [User Interface Design and Implementation], and I really enjoyed building user interfaces for various applications. I hope to learn more about the back-end side of web development as well as experience research in the HTI field.”
controls, which could transform both fields.”

“I am participating in SuperUROP to gain experience researching controls before I attend graduate school and continue to do more controls research. SuperUROP will provide me with the planning, writing, and presentation skills I will need to effectively communicate my work whether it be in graduate school or afterwards. Furthermore, the project I am working on brings together machine learning and controls research. SuperUROP will provide me with the planning, writing, and presentation skills I will need to effectively communicate my work whether it be in graduate school or afterwards. Furthermore, the project I am working on brings together machine learning and controls, which could transform both fields.”

Drag reduction has long been studied as a way to decrease viscous effects and allow objects moving through air or water to operate more efficiently. A key component in drag reduction is the boundary layer, the thin layer of fluid that touches the surface of an object and has high viscous effects. The ability to have more control over the boundary layer and prevent or minimize the effects of turbulence and flow separation is the ultimate goal of drag reduction. Biomimetics, specifically the motion of fish, has presented possible solutions to improve boundary layer control. This project intends to use embedded actuators and novel manufacturing techniques to explore the feasibility of introducing standing waves in the boundary layer as a way of improving the performance of hydrofoils.

“Fluid dynamics has been a growing area of interest for me because it is a relevant subject in so many fields, and yet there is still uncertainty about how exactly fluids work. The opportunity to delve deeper into this field while also utilizing my skills as a mechanical engineer through SuperUROP is an amazing opportunity.”

Quantum state tomography, or the reconstruction of the density matrix of a quantum state via measurements, is critical to ensuring the proper functionality of qubits and quantum operations in a quantum computer. Currently, there exist tomography implementations for use of 1- and 2-qubit systems in our superconducting quantum processor. In this work, we aim to develop quantum state tomography for a 3-qubit system. This will be achieved through a variety of statistical and machine learning techniques. Ultimately, this will be implemented as a code suite and integrated in the analysis software toolbox for the quantum processor. The code will be tested and verified on real data from state-of-the-art qubit experiments. If time permits, work will be done to extend tomography to n-qubit systems.

“Through this SuperUROP project, I hope to explore the field of quantum computing in depth. I want to go to graduate school and would like to see if this is a field I would be interested in researching long-term. I have had various research and UROP experiences but hope that SuperUROP will provide an even more intensive research experience and help me improve my communication skills.”

With the development of quantum computers that have the computing power to break current cryptographic methods, there is a threat to cryptography. To demonstrate security solutions for the quantum future, my lab is implementing energy-efficient hardware that supports lattice-based cryptography, which is considered impenetrable to quantum computers and a prime candidate for standardization by NIST. This is particularly important for Internet of Things (IoT) devices that need to do encryption and authentication but are extremely resource-constrained in terms of computation. I will be working on implementing different variations of lattice-based cryptographic protocols in software and using the specialized hardware so that we can benchmark the efficiency of the hardware.

“I was drawn to this SuperUROP project because I had heard that quantum computers make the current cryptographic standards obsolete. I was surprised to hear that algorithms exist to compensate for that, so I will enjoy learning how the different lattice-based algorithms work as I implement them for the chip.”
Arсен Василиян  
MIT EECS | Mason Undergraduate Research and Innovation Scholar  
Project: Testing Fourier Properties of Boolean Functions in Sublinear Time  
Supervisor: Ronitt Rubinfeld  

Recent data sets have become so large that even the time for reading the whole dataset is prohibitive. In order to tackle this challenge, the subfield of sublinear time algorithms has been developed. In practice, it often happens that the data can be represented as an input-output relation of a function. Fourier analysis of Boolean functions is an important tool for characterizing various properties of functions. In this project we plan to investigate sublinear time algorithms that allow us to estimate some of these Fourier properties.

“Having taken a class with Professor Rubinfeld that covered Fourier analysis of Boolean functions, I am very excited for this chance to apply my knowledge and gain research experience. This project will give me an opportunity to develop my skills in research and, perhaps, to contribute to human knowledge.”

Suchan Vivatsethachai  
MIT EECS | Quick Undergraduate Research and Innovation Scholar  
Project: Transfer Learning Across Hospitals by Discovering Latent Patient-Hospital Sub-mechanisms  
Supervisor: David Sontag  

Hospitals with abundant patient records can train supervised machine learning models that provide effective medical prediction, but other hospitals with less data cannot do so. Transfer learnings are being developed to build models that perform well across hospitals. However, machine learning models trained using one hospital’s data may not perform well in others due to organizational differences. Thus, we must develop methods allowing models trained in source hospitals to transfer to target hospitals. We have developed a new algorithm that combines topic modeling with a logistic regression model. Our algorithm exploits the assumption that source and target domains are mixtures of latent sub-mechanisms to learn from source-dominant models that perform well on target domains. In this work, we implement a new type of machine learning algorithm for transfer learning.

“SuperUROP gives me an opportunity to work on a full-scale project with both technical and communication guidance, and a sense of what it’s like to study for a doctorate. This project on machine learning in causal inference will be a good blend of knowledge I have received from previous classes in machine learning, inference, and econometrics.”

Rohil Verma  
MIT EECS | Draper Laboratory Undergraduate Research and Innovation Scholar  
Project: Investigating the Confidence of Deep Neural Networks  
Supervisor: Daniela L. Rus  

Deep learning is reshaping machine learning in many domains such as robotics and medicine. Although these algorithms can approach or exceed human accuracy at certain tasks, they lack interpretability. This makes it difficult to assess result accuracy in practical applications, which often have high costs of error. This makes it key that we develop rigorous methods of evaluating the confidence of these networks in their outputs. In this project, we will first explore scenarios under which state-of-the-art networks struggle with confidence and then develop specific measures of confidence under these scenarios. We will then attempt to generalize results across these different scenarios. Finally, we will attempt to extend any results into the more general field of neural network confidence.

“I’m working on a SuperUROP project because I’d like to explore what I can achieve through a focused yearlong program in a fascinating research area: autonomous driving. I’ve taken theoretical machine learning classes and would like to bring that rigor to this field to ensure that prospective solutions are as safe as they are flashy. Beyond my work, I’m most excited about being able to learn about what successful, long-term research requires.”

Mike Meichang Wang  
MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar  
Project: An Interlock for Self-Driving Cars  
Supervisor: Daniel N. Jackson  

A crucial milestone in the development of self-driving cars is giving them the ability to detect and react to dangerous environments such as slippery roads due to ice or snow and pedestrian-dense urban environments. This project aims to create a safety controller for self-driving cars that can take in data from various onboard sensors, parse the data to detect hazardous driving conditions, and issue driving commands to minimize the possibility of collision. The software will be written to interface with existing sensor and control software in the industry-standard Robot Operating System (ROS) and will be tested in simulation using Drake, a robotics simulation tool developed in CSAIL and used extensively in collaboration with the Toyota Research Institute.

“I have taken 6.141 (Robotics: Science and Systems), where I worked with LIDAR-mounted racecars and ROS, and participated in MIT’s IAP robotics competition MASLAB. Robotics is a field that I am interested in exploring in a master’s degree at MIT and as a career. Through this SuperUROP project, I hope to gain further experience in working with industry-standard tools and software, such as ROS and Drake. I also hope to hone my research skills in preparation for a master’s project.”
Rose Elizabeth Wang  
MIT AeroAstro | Lincoln Laboratory  
Undergraduate Research and Innovation Scholar  
**Project:** Vision-Based Approach to Localization and Mapping in Autonomous Vehicles  
**Supervisor:** Jonathan How

In the near future, coordinated autonomous vehicles will heavily impact the transportation of people and goods. The vehicles must communicate and cooperate with each other to perform efficiently, but pre-defined protocols must be agreed upon by all vehicles/companies. This work instead develops reinforcement learning (RL) algorithms, where simulated, heterogeneous agents explore possible communication and cooperation strategies to maximize the overall team performance.

“Through this SuperUROP project, I want to gain more experience in robotics research and make a positive contribution to my lab. Robotics is a fascinating field to be in. Especially considering the potential it has to improve our lives, I’m excited to bring together ideas from the computer vision and graphics communities and learn more about the problems in this research domain.”

Ziheng Wang  
MIT EECS | Himawan  
Undergraduate Research and Innovation Scholar  
**Project:** Deep Learning Biological Ensembles  
**Supervisor:** David K. Gifford

Many problems in biology, such as predicting gene expression and protein folding, share a crucial common feature: dynamics of interest are governed by a complex energy landscape. Constructing these landscapes ab initio often times requires inaccessible data, such as accurate measurements of reaction rate parameters. On the other hand, we are often presented with a huge number of samples drawn from the landscapes, either from molecular dynamics simulations or single-cell RNA sequencing. This raises the possibility of empirically learning these landscapes through specifically designed deep learning architectures, which is the goal of this project.

“I am participating in SuperUROP to pursue my interest in applying deep learning to understand the natural world. My previous experiences in computational chemistry and deep learning research were instrumental in establishing this interest. I hope to provide new methods for understanding gene expression and protein folding.”

Mattie Frantz Wasiak  
MIT EECS | Quick Undergraduate Research and Innovation Scholar  
**Project:** Leveraging Clinical Data Sets to Optimize Oxygen Delivery to Newborns  
**Supervisor:** Thomas Heldt

Tight oxygen titration in the preterm neonate is a key aspect of neonatal intensive care due to the mortality associated with hypoxia (low oxygen saturation) and the morbidity associated with hyperoxia (high oxygen saturation) in this vulnerable population. Despite these known complications of sustained oxygenation outside target ranges, most Neonatal Intensive Care Units (NICUs) fail to reliably maintain infants’ oxygenation saturations within target range. The primary goal of this project is to leverage large volumes of physiological data streams collected in the NICU to identify clinical, demographic, physiological, and workflow factors that place preterm infants at risk for hypoxia and hyperoxia.

“I am participating in SuperUROP to gain more exposure to research that applies data analytics to health care. I have developed a passion for this field through previous interesting research experience, and I am excited to continue pursuing health care and learn how to contribute to it. I hope to learn a lot about the research process and improve my presentation skills in order to ultimately become more prepared for the Master’s in Engineering (MEng) program.”

Ethan Weber  
MIT EECS | Lincoln Laboratory  
Undergraduate Research and Innovation Scholar  
**Project:** Perception for Robotic Manipulation  
**Supervisor:** Russell L. Tedrake

Recently, perception algorithms based on deep learning have been on the rise, and these techniques are being applied to robotic manipulation tasks with promising results. In these manipulation tasks, perception is important to know the location of every object in order to plan and control for desired trajectories. This project focuses on using RGB-D images to best represent the state of the world for robotic manipulation. Our work plans to automatically detect key points that can be used for pose estimation and tracking. We aim to achieve results on both real-world data and meaningful tasks.

“I’m participating in SuperUROP because I’m eager to gain research experience as I prepare for graduate school. After doing robotics UROPs in my freshman and sophomore years, I’m excited to commit to this longer project with hopes of contributing to the fields of computer vision and robotics.”
difficult as the growth of dataset sizes outpaces the growth of CPU processing power. For that reason, GPU-accelerated databases are an increasingly popular idea. However, two major issues that GPU-based systems face are data movement overhead and relatively expensive, limited memory. Our project focuses on solving both issues by implementing the delta binary packed encoding scheme for integer columns’ compression on GPUs, while assuming that the dataset is resident on the GPUs.

“I am excited about SuperUROP because it lets me apply what I have learned from classes I have taken in previous terms, such as 6.824 (Distributed Computer Systems Engineering), 6.172 (Performance Engineering of Software Systems ), and 6.828 (Operating System Engineering of Software Systems ), and 6.828 (Operating System Engineering), to a project with real-world load and resource constraints. This project will help me further understand the modern CPU/GPU architectures and how to program them efficiently.”

Elizabeth Wei
MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar
Project: Optimizing Lossless Compression on GPUs
Supervisor: Samuel R. Madden

Efficient data analysis is increasingly important in our own applications and devices, is a popular topic of discussion today. One example is the existence of smart IoT devices in our homes. There is a disconnect between what consumers expect from the companies that provide services through these devices and what the companies want to gain from the consumers’ use of their devices. This project aims to shed light on this matter. It further tries to explore what consumers may feel or perceive about their devices now and what can be changed to give them more assurance and trust for their smart devices. This project seeks to find a way to inform consumers of the tradeoffs and of the extent to which their data may be collected for the functionality of the device.

“SuperUROP offers me the opportunity to deeply explore a subject that interests me: multi-modal devices and user privacy. I have taken classes internships that focus on this area and believe that this project is a great platform for me to continue working in this area. Along the way, I also hope to become more familiar with the processes involved in carrying out a full formal research project.”

Wei Hou Wu
MIT EECS | Hewlett Foundation Undergraduate Research and Innovation Scholar
Project: Investigative Privacy Preferences, Expectations and Behaviors of Voice-Activated Devices
Supervisor: Daniel Weitzner

Privacy, especially in our own applications and devices, is a popular topic of discussion today. One example is the existence of smart IoT devices in our homes. There is a disconnect between what consumers expect from the companies that provide services through these devices and what the companies want to gain from the consumers’ use of their devices. This project aims to shed light on this matter. It further tries to explore what consumers may feel or perceive about their devices now and what can be changed to give them more assurance and trust for their smart devices. This project seeks to find a way to inform consumers of the tradeoffs and of the extent to which their data may be collected for the functionality of the device.

“SuperUROP offers me the opportunity to deeply explore a subject that interests me: multi-modal devices and user privacy. I have taken classes internships that focus on this area and believe that this project is a great platform for me to continue working in this area. Along the way, I also hope to become more familiar with the processes involved in carrying out a full formal research project.”

Megan Yamoah
MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar
Project: Microwave Dielectric Loss of Hexagonal Boron Nitride in the Low-Temperature, Single-Photon Regime
Supervisor: Terry P. Orlando

The use of 2D van der Waals (vdW) heterostructures in quantum computing devices, due in part to the potential of combining different materials with epitaxial precision, has begun to merge the superconducting and 2D material platforms. Hexagonal boron nitride (hBN), a vdW material widely used as an ultra-clean substrate, gate dielectric, and protection layer in vdW heterostructures, may be used in building high-quality qubit elements. VdW materials have been extensively studied in the DC and optical regimes, but understanding their response to microwave excitations is vital to introducing them into superconducting circuits. We study hBN in the microwave regime by integrating the material in a superconducting LC resonator to extract its loss tangent. Our scheme can be used for characterizing not only the electromagnetic properties of hBN, but also other 2D materials.

“SuperUROP provides a unique opportunity to gain experience working on my own research project in a specific subfield of applied electrical engineering applicable to my professional goals from start to finish while learning the invaluable skills of presentation and communication. I have worked with my SuperUROP supervisor for the past two years as a UROP student and am excited to pursue a more individual project in the coming year.”

Jesse Widner
MIT EECS | Fano Undergraduate Research and Innovation Scholar
Project: Bayesian Conditioning on Gaussian Mixture Models for Automatic Speech Signal Analysis
Supervisor: Stefanie Shattuck-Hufnagel

Current automatic speech-recognition system approaches tend not to use information about speech production when analyzing speech signals. This project focuses on making improvements to an automatic speech-recognition system that uses acoustic cues and speech signal features to generate the words spoken from a signal. The goal of my project is to improve the system’s accuracy by finding ways to integrate new information into the system’s model. One way of achieving that is by using formant frequencies to infer different properties about the speaker and using Bayesian conditioning to update the probability distributions used by the model.

“I am participating in SuperUROP because I would like to gain more research experience and apply what I have learned from previous research to the current project. I hope to learn more about acoustic signal analysis and how to apply this knowledge to the project. I am very excited to learn more about the applications of machine learning to natural languages and signals.”
Grace Yin
MIT EECS | Advanced Micro Devices Undergraduate Research and Innovation Scholar
Project: Bundling Variables in Auto-Parallelized Swarm Programs
Supervisor: Daniel Sanchez

Though multicores are widely used, multicore programming is difficult. Auto-parallelizing compilers attempt to solve this problem, but have limited success on existing hardware architectures. Swarm is a new multicore architecture with an execution model based on small tasks to be run in parallel, speculatively and out of order. For this project, we implement a new Swarm C/C++ compiler (SCC) optimization pass that bundles variables for efficient allocation. We privatize and pad variables to improve parallelism and reduce task overheads in SCC-compiled programs.

“I’m participating in SuperUROP because I’m interested in multicore programming and looking to gain more research experience. I have taken 6.172 (Performance Engineering of Software Systems) and 6.816 (Multicore Programming), which have given me a sense of the potential and limitations of multicore programming, making this project all the more exciting. I’m looking forward to both working on the Swarm compiler and getting a fuller picture of what researching is like.”

Mikael Yunus
Undergraduate Research and Innovation Scholar
Project: Design of Quantum Photonic Device Components Using MEEP
Supervisor: Dirk R. Englund

With the impending end of Moore’s law, we must investigate novel ways to process information. Quantum technologies are one such avenue, with practical applications in computation and communication. The nitrogen-vacancy (NV) center in diamond is a quantum memory with exceptional properties, including a long quantum coherence and spin-coupled optical transitions. The Englund group aims to integrate this memory into solid-state and scalable photonic devices for large-scale quantum information processing. This research aims to design two critical components of such a platform: First, grating couplers will be designed to maximize the coupling between a photonic mode and a free-space mode. Second, the interface between cladded and uncladded waveguides will be optimized to maximize transmission.

“I am particularly excited about working in Professor Englund’s lab because of the implications of his research. If his project succeeds, we will be closer to having quantum computers operating at room temperature with the power to outperform every standard digital binary computer combined. I am honored to be a part of Professor Englund’s team and thrilled that I will be able to play a part in the search for quantum supremacy.”

Yunkun Zhou
MIT EECS | Undergraduate Research and Innovation Scholar
Project: Shortest Vector Problem
Supervisor: Vinod Vaikuntanathan

The Shortest Vector Problem on integer lattices has been widely studied during the last few decades. There are many cryptographic constructions whose security assumes the worst-case hardness of the approximation version of this and related problems. This project focuses on improving the known results of this problem: our goal will be to either discover a new algorithm that improves the best known space and/or time complexity, or demonstrate an improved hardness result.

“In this project, I would like to learn more about the problem itself and gain research experience. I am double majoring in mathematics and computer science, so I think this project allows me to apply knowledge from both disciplines. I believe that the material covered by 6.875 and 18.425 (Cryptography and Cryptanalysis) will be relevant to this project as well.”

Yunyi Zhu
MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar
Project: 3D Printed Breadboard for Customizable Electronics Prototyping
Supervisor: Stefanie Mueller

This project involves creating a physical adaptive learning system that adjusts difficulty levels according to the learner’s performance. More specifically, it builds a smart bicycle that teaches beginners how to ride by gradually moving the training wheels inwards. This way, it uses a parametric design software to achieve a steady increase of the difficulty level of riding a bicycle until the training wheels are no longer needed.

“Through this SuperUROP project, I want to gain experience on human-computer interaction. I have gained prior knowledge in object-user interface guidelines through classes in design, and I have learned about software implementation through various software engineering and machine learning classes. I’m excited to combine my knowledge and create some meaningful products.”
Compared to conventional silicon, gallium nitride (GaN) is much more capable of operating under high temperatures, high voltages, and high power levels due to its superior material properties. Transistors fabricated with GaN have shown to have a higher efficiency, and their breakdown field is also an order of magnitude higher. Although existing GaN transistors have already been proven to have much better performance than conventional transistors, they are still far from their theoretical limits. In this project, GaN high-electron-mobility transistors (HEMTs) will be stressed under different experimental conditions to help understand their breakdown mechanisms and develop models for GaN devices to push their operating limits.

“I am really interested in semiconductors and power electronics and their promising applications, and I am very excited to have the opportunity to work on GaN transistors that have great potential to change the future. Through my SuperUROP project, I would like to gain more hands-on research experience in the field and apply what I’ve learned in class to real-world applications.”
Undergraduate researchers finished their first half of their yearlong research experience by discussing their projects at a well-attended poster session.

By Kathryn O’Neill
Contributor, Department of Electrical Engineering and Computer Science

If one overarching message emerged from the December 2018 SuperUROP Showcase, it was this: MIT undergraduates can do just about anything.

The lively poster session, which marked the halfway point in the annual Advanced Undergraduate Research Opportunities Program (SuperUROP), featured more than 130 poster presentations by students on topics ranging from DNA-based memory storage to adaptive flight control and from image recognition to the automated correction of grammatical errors in Japanese.

Capping the event was the SuperUROP Community Dinner, which featured a keynote address by Tom Leighton PhD ’81, the CEO and co-founder of Akamai, a $2.5 billion technology company that was born at MIT. Leighton’s talk, “The Akamai Story: From Theory to Practice,” was designed to inspire the undergraduates in attendance. It centered, as Leighton put it, on “taking a UROP project and forming a company and having some success with it.”

SuperUROP builds on the success of MIT’s flagship UROP program. While traditional UROP experiences last just one term, SuperUROP involves research projects spanning the full academic year and includes a two-term class on conducting and presenting research, including writing journal-style papers as their final assignments.

Typically, the impact of SuperUROP experience extends well beyond the course, says Anantha Chandrakasan, dean of the School of Engineering and Vannevar Bush Professor of Electrical Engineering and Computer Science.

“The fact that it’s yearlong is crucial,” says EECS senior Faraaz Nadeem, who is trying to automate the transcription of music featuring multiple instruments, a task he finds quite time-consuming. “The extra time and the way the class is structured, with deadlines, is pretty helpful.”

Launched in 2012 within EECS, SuperUROP later expanded to the full School of Engineering. In 2017, thanks to a generous grant from an anonymous donor, the program began supporting research involving the School of Humanities, Arts, and Social Sciences (SHASS). Nadeem is among this year’s nine CS+HASS Undergraduate Research and Innovation Scholars, who work on projects combining computer science with the humanities, arts, and social sciences.

“SHASS is so excited to have students involved in SuperUROP,” says Agustín Rayo, associate dean of SHASS, who attended the fall poster session. “I think our undergraduates are really at the vanguard.”

This year, SuperUROP also included eight scholars funded by the School of Engineering and the MIT Quest for Intelligence, a campus-wide initiative launched in February 2018 to advance human understanding of intelligence.

“The research goes beyond EECS. We have a really broad spectrum,” says Piotr Indyk, the Thomas D. and Virginia W. Cabot Professor of EECS and one of three faculty members who teach the SuperUROP class 6.UAR (Seminar in Advanced Undergraduate Research) with the support of eight teaching assistants.

EECS faculty member Thomas Heldt, who has served as an advisor for several SuperUROP students in the past few years, pointed out that the yearlong program enables undergraduates to really dig into their topics.
“Usually it’s a more meaningful experience than a regular UROP because we’re working with students for nine months and there’s a formal program of classwork,” noted Heldt, who is the W.M. Keck Career Development Professor in Biomedical Engineering and an associate professor of electrical and biomedical engineering. “The experience is fantastic.”

Students agree. “This is usually something graduate students would do,” says Patrick Tornes, a senior in mechanical engineering and School of Engineering/Quest scholar who is creating adaptive controls for drones so that the devices can better navigate the variable conditions of the real world. “It’s really awesome to be able to work on this as an undergraduate. In the spring, I’m looking forward to implementing the controller on a hexacopter and seeing how it actually performs.”

EECS senior Sky Shin, also a School of Engineering/Quest scholar, says SuperUROP is helping her decide what path to take in her future.

“I think [SuperUROP is] testing how I’ll fit in grad school,” says Shin, who is working in the Computational Cognitive Science Group to enable computers to classify images based on just a few examples. “This is very extensive research.”

The poster session gave students the chance to practice presenting technical material to a technical audience — one of the key skills taught in the SuperUROP program, says Dina Katabi, the Andrew & Erna Viterbi Professor of EECS and another 6.UAR instructor. “This is a very different class from anything other universities do. It’s a class that believes that research and presentation should go hand in hand,” she says.

Austin Garrett, a senior double-majoring in EECS and physics, says the SuperUROP class assignments — from developing a research topic to creating a poster and giving a presentation — have been useful in helping him plan his research.
“I’ve realized how difficult it is to develop a project,” says Garrett, a School of Engineering/Quest scholar whose research goal is to embed an intuitive understanding of physics into artificial intelligence. “It’s easy to get lost in the sea of possibilities.”

What many students say they like best about SuperUROP, however, is the chance to pursue independent research in an area that really interests them. “I’ve been given a lot of freedom in how I approach the problem. It’s really self-driven,” says Alex Kimn, a senior double-majoring in EECS and physics and another School of Engineering/Quest scholar. Kimn is using neural modeling to address grammatical errors to aid students of Japanese — work motivated by his interest in education.

Ronit Langer, a junior in EECS, meanwhile, has pursued her interest in “how we can take biological knowledge and, using computer science, develop things that can be deployed to help people.” Specifically, she’s trying to develop a protein sensor that will alert first responders to the presence of fentanyl, a powerful synthetic opioid, in possible drug-overdose cases. “What I’ve been able to accomplish in one semester is inspiring,” says Langer, a CS+HASS scholar.

The December showcase gave just a taste of things to come; students will next present the results of their research at the April 2019 SuperUROP Showcase poster session. However, it was clear that MIT undergraduates have the potential to produce great work, as Leighton underscored in his keynote dinner presentation.

As Leighton recounted the story of Akamai’s founding at MIT, its meteoric rise during the dot.com era, and its near total collapse in 2001, he attributed much of the company’s success to the work of MIT students. Teams of students worked to get the company launched and later helped it rebound from disaster, he said.

“We got through it, led by people just like you: MIT undergraduates.”
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EECS senior Helen Ho’s SuperUROP project focused on using 3D graphics to create large, annotated, synthetic datasets of city scenes to train image-recognition algorithms for self-driving cars. Photo: Gretchen Ertl
“We are pleased to sponsor SuperUROP because the program provides undergraduates with unparalleled opportunities to immerse themselves in research. It’s exciting to know that they’re gaining the knowledge and skills needed to succeed in our industry. We look forward to seeing what these young scholars accomplish this year — and in the future.”

– Prashant Lal ’99, Partner, Hudson Riving Trading Co.

“SuperUROP and MIT play an important role in preparing Aptiv’s future talent with the skills needed to deliver solutions to some of society’s biggest challenges. We are happy to sponsor the SuperUROP program, as it provides our future scientists and engineers the expertise needed to develop safer, greener, and more connected solutions that enable the future of smart mobility.”

– Statement from Aptiv

“As an alumnus, I was happy to extend an existing donation to assist the SuperUROP program. It’s gratifying to know that a small additional gift can do so much to support undergraduate research opportunities. I look forward to hearing about the results of the SuperUROP scholars’ work – and to seeing where they go in their future careers.”

– R. Franklin Quick Jr. ’70, SM ’70

EECS senior Garrett Souza’s SuperUROP project explores the effects of visual media on implicit human biases. Photo: Gretchen Ertl
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“Our undergraduates have the opportunity to work shoulder-to-shoulder with researchers and tackle the toughest problems on the planet. SuperUROP and related efforts are a hallmark of an MIT education. These programs deliver skills, build confidence, and foster a life of learning.”

– Ian A. Waitz, Vice Chancellor and Jerome C. Hunsaker Professor of Aeronautics and Astronautics, MIT
The SuperUROP program brings students and faculty together to work on a yearlong research project. It’s a great opportunity for students to take the lead on a project that they care deeply about, and to see it through to a meaningful conclusion.”

– Dennis Freeman, EECS Education Officer and Henry Ellis Warren (1894) Professor of Electrical Engineering
Nearly 130 undergraduates discussed the results of their yearlong research projects during the high-energy spring SuperUROP Showcase at MIT’s State Center on April 25, 2019.
For complete coverage, including photos and links to videos, visit eecs.mit.edu.

All photos from the spring 2019 SuperUROP Showcase are by Gretchen Ertl.
"I am always thrilled to hear from members of previous SuperUROP classes about the exciting new directions they are taking, benefiting from their experience in the program. Many are now earning advanced degrees at major universities, making an impact in industry, or working as part of the team at cutting-edge early-stage startups. Their research has set very high standards."

–Anantha Chandrakasan
Dean, School of Engineering, MIT
Launched in 2012, SuperUROP is an expanded version of MIT’s flagship Undergraduate Research Opportunities Program (UROP). The yearlong program gives juniors and seniors the chance to conduct publication-worthy research and learn the essentials of research. SuperUROP is hosted by the School of Engineering and administered by the Department of Electrical Engineering and Computer Science. This year, the school included students from the following MIT schools and departments:

School of Engineering
- Department of Aeronautics and Astronautics
- Department of Biological Engineering
- Department of Civil and Electrical Engineering
- Department of Chemical Engineering
- Department of Electrical Engineering and Computer Science
- Department of Mechanical Engineering

School of Arts, Humanities, and Social Sciences