“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
SuperUROP Update

As the new Department Head of the MIT Department of Electrical Engineering and Computer Science, I’m pleased to report on the continued success of the Advanced Undergraduate Research Opportunity 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 opportunity to conduct innovative, publishable research.

This year’s SuperUROP class includes 130 students from throughout the School of Engineering and, for the first time, from the School of Humanities, Arts, and Social Science. We are grateful to the anonymous donor whose generous gift supported this new 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 the program ends. Many go on to earn advanced degrees at top research universities, work at industry-leading companies, or join exciting 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 and other contributors, who are highlighted on page 42.

I also want to acknowledge Anantha Chandrakasan, Dean of the School of Engineering. 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.

I am very excited about this year’s projects and look forward to seeing where these young researchers go in their careers.

Sincerely,

Asu Ozdaglar
Joseph F. and Nancy P. Keithley Professor of Electrical Engineering and Computer Science
Department Head, Electrical Engineering and Computer Science
MIT AeroAstro | Boeing Undergraduate Research and Innovation Scholar
Tingxiao Sun

MIT AeroAstro | Lincoln Laboratory Undergraduate Research and Innovation Scholars
Aaron Huang
Jeremy Stroming

MIT AeroAstro | Northrop Grumman Research and Innovation Scholar
Sean Patrick Kelley

MIT BE-Microbiome Undergraduate Research and Innovation Scholars
Iva Monique Tejero Gramatikov
Daniel Osorio
Surya Tripathi
Vivian Zhong

MIT CEE Undergraduate Research and Innovation Scholars
René Andres Garcia Franceschini
Eric Wong

MIT ChemE Undergraduate Research and Innovation Scholars
Erika Ding
Yannick Eatmon
Brook Eyob
Emily Penn

MIT EECS | Advanced Micro Devices Undergraduate Research and Innovation Scholars
Megan Chao
Zoe Gong
Siyu [Zoe] Lu
Natalie Mionis
Nur Muhammad Shafiullah

MIT EECS | Analog Devices Undergraduate Research and Innovation Scholars
Mark Chounlakone
Driss Hafdi
Carolyn Lu
Helmuth John Naumer
Cattalyya Nuengsikkapian
Diana Wofk

Q & A Session, SuperUROP Community Dinner, December 2017
"Cisco is committed to driving innovations in networking and information technologies that transform the way we work, live, play, and learn. The network is undergoing the largest architectural shift in decades. We are thrilled to participate in MIT’s SuperUROP program to work with SuperUROP scholars, faculty, and staff to create innovations for the next generation of networked experiences."

— Susie Wee ’90, SM ’91, PhD ’96 VP and Chief Technology Officer of Networked Experiences, Cisco
“Engineering possibilities has been the cornerstone of Draper capabilities throughout its more than 80-year history supporting national security and commercial customers. With the enhanced experience SuperUROP provides to students, they appreciate more fully the value and importance of continuing to push the envelope of possibilities in the field and their subsequent impact on our lives.”

— Kaigham J. Gabriel
SCD ’83, President and CEO, Draper
“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
Many web applications feature similar concepts including reviews, ratings, and marketplaces, which are implemented in unique ways with the context of the application in mind. If we could exploit this similarity, we could accelerate web application development. Though content management systems (CMSs) make it easier to develop web applications, users are restricted to a subset of simple applications because their components and plugins lack a compositional mechanism. As a result, any desired interaction between them must be programmed. Déjà Vu, a new software paradigm developed by the MIT CSAIL Software Design Group, aims to allow end-users to create complex and multifaceted web applications by abstracting implementation details into modular concepts, known as clichés, and widgets, an array of interactive components. Each cliché has its own user interface elements, and maintains state and domain logic in the backend. To evaluate the current prototype, I will build sample applications from the catalog of existing clichés, add new clichés through solving design problems, and extend functionality of existing clichés as necessary. Future users will be able to create applications with an interface builder, without writing any code.

“After taking Software Studio (6.170) and User Interface Design and Implementation (6.813), I decided to participate in SuperUROP to explore my interests in system design and human computer interaction. I hope this research experience will be the stepping stone towards my MEng thesis, and I am excited to develop a tool that enables inexperienced and experienced programmers alike to construct complex web applications.”

Privacy policies are commonly used in modern technologies to alert and inform people of how services handle their personal data. This includes the usage and sharing of the accessed personal data either implicitly or explicitly. This project will analyze how privacy policies have changed over time. In particular, we would like to identify and compare policy changes that individual companies have implemented and the implications of these changes for users and their personal data. We will compare changes in policies within and across various services (social news, retail, financial, and so on). We will discuss the implications of our findings in the context of privacy preservation and provide guidelines to policy regulators or civil organizations to help preserve and safeguard personal privacy.

“I am interested in online privacy policies and the implications for personal data. While abroad at Cambridge University, I became interested in statistics and machine learning. I will create a dataset of privacy policies over time and employ natural language processing and machine learning techniques to compare, cluster, and investigate the changes and implications for users. Communication of results is a key to the research process, so I hope to write a paper.”

To study the cellular basis of disease, researchers must have a way to probe the internal state of both healthy and diseased cells. Analyzing how different perturbations, such as drugs or genetic modifications, affect this internal cell state gives researchers more information about how the cell behaves under abnormal conditions, allowing them to study potential therapeutics. One way to examine this behavior is to see which genes are most affected by each perturbation. To accomplish that, researchers need a better understanding of the regular expression levels of these genes. This project will use machine learning methods to determine an empirical null distribution of gene-expression data and use this distribution to perform hypothesis testing and examine relationships between genes in perturbed samples.

“I have always been interested in health care. When I was first introduced to artificial intelligence and machine learning through classes at MIT, I was excited by the current and potential future applications for machine learning in the healthcare field. I decided to participate in the SuperUROP program because it is an ideal opportunity to gain skills in machine learning, contribute to a meaningful area of research, and work closely with incredible mentors.”
Archis R. Bhandarkar
MIT EECS | Angle Undergraduate Research and Innovation Scholar
Project: Designer Neuronal Networks: Studying and Guiding Neuronal Differentiation with miRNA-based Genetic Circuits
Advisor: Ron Weiss

Stem-cell technologies hold promise for treating a variety of neurological disorders. However, protocols for the differentiation of stem cells into neurons have low efficiency and provide scientists with little flexibility to custom-produce neurons of particular subtypes. The focus of this project will be to apply tools from synthetic and systems biology to develop better techniques for controlling stem cell differentiation. In particular, we plan to develop microRNA (miRNA) sensors that are capable of stably integrating into the genome of stem cells and dynamically detecting the state of stem cells undergoing differentiation. Through creating these miRNA sensors, we expect to achieve the first step in a platform for controlling the behavior of stem cells at any point in differentiation.

"The SuperUROP program excites me as an opportunity to dive deeper into the synthetic biology research I have conducted in the past. As a double major in electrical and biological engineering, I am thrilled by how synthetic biology allows me to blend what I have learned from the coursework I have seen in both my majors. I look forward to helping to develop technologies that have an impact on patients' lives and continuing to grow as a researcher."

Emma Bingham
MIT EECS | CS+HASS Undergraduate Research and Innovation Scholar
Project: Does Democracy Cause Free Trade?
Advisors: Caroline Uhler and In Song Kim

When countries become more democratic, they typically lower barriers to trade. Reducing tariffs encourages trade by making imported products more affordable for consumers. We have a data set of billions of tariffs spanning 28 years, 179 countries, and millions of products. Using this data, we will conduct a causal inference analysis about the effects of democratic political institutions on trade liberalization. How do trade patterns change over the years, especially as polity scores change? Which products or categories of products are driving the trends and how can that be interpreted? Through this study, we hope to help revise the current understanding in political science of the connection between the development of countries and the shifting of trade patterns.

"Last semester, I was working on a UROP in political science and we were looking for new computational methods. So when I heard about the Computer Science and Humanities, Arts, & Social Sciences (CS+HASS) SuperUROP offering, I knew it was an opportunity I wanted to pursue. I am excited to bring together the techniques from two different fields to try to discover something interesting."

Srilaya Bhavaraju
MIT EECS | Quick Undergraduate Research and Innovation Scholar
Project: Using Locality-Sensitive Hashing on ECG Waveform Data
Advisors: Una-May O’Reilly and Erik Hemberg

Locality sensitive hashing (LSH) addresses the nearest-neighbor search problem of machine learning. The essence of LSH involves hashing similar input items to the same buckets with high probability and without the need for model-based learning. This project aims to explore the applications of LSH in health care by efficiently finding patients with physiological waveforms similar to a reference waveform. A given similarity set can then be exploited for future or diagnostic extrapolations to the patient of reference. Through this project, I will investigate LSH in prediction problems such as ECG ECG and ABP and explore extensions of LSH, such as whether hashing families can be combined or whether different hashing families should be used for different predictions.

"As a student whose interests lie at the intersection of technology and medicine, I find that this project falls perfectly into that intersection. I have had experience applying machine learning techniques to social media data and am excited about exploring machine learning applications within health care as well as gaining more insight into the problems affecting health care."

Jake Ryan Burga
Undergraduate Research and Innovation Scholar
Project: Generalized Learning Through Video Games
Advisor: Joshua Tenenbaum

Video games have recently been used to train and test artificial-intelligence (AI) algorithms that learn to behave effectively in a wide array of environments. Deep RL approaches reach good asymptotic performance on certain classes of video games. But unlike humans, they require large amounts of data and generalize poorly to even slight changes to their environments. This project aims to explore the idea that having a human-like capacity to learn requires building a closely-fitting model of the world. The specific aim of this project is to develop a language that is sufficiently rich and flexible to be able to describe a wide range of possible game-worlds and to develop inference procedures for learning a good game description given actual game-play data.

"This SuperUROP will be a continuation of the work I have been doing this summer with the lab, where we have been developing this video-game description language. While the UROP gave me the chance to develop a wide range of skills in computer science, this SuperUROP project will allow me to focus on the really interesting and more challenging aspects of AI and reinforce the learning I have been wanting to do since joining this lab."
Caitlin Cassidy
MIT EECS | Draper Laboratory Undergraduate Research and Innovation Scholar
Project: Glanceable Code History: Visualizing Student Code for Better Instructor Feedback
Advisor: Max Goldman

Programming exercises in computer science classes can be difficult to grade because a student’s code at the end of an exercise is often not reflective of what the person learned and discovered throughout the exercise. This SuperUROP project will design and implement glanceable visualizations of coding exercises completed by students. These visualizations will show detailed data about a student’s actions during the exercise in a comprehensive and easy-to-understand way, allowing teachers to more quickly parse students’ final code, give better feedback, and better assess learning and progress.

“I had a fantastic experience in Software Construction (6.031) using Constellation for collaborative programming. This SuperUROP is a great opportunity for me to make Constellation even better for future MIT students. Taking 6.031 has shown me the sorts of challenges 6.031 staff face, and taking User Interface Design & Implementation (6.813) has given me a good foundation for user interface design. I’m most excited to test my interfaces in a live environment.”

Megan Chao
MIT EECS | Advanced Micro Devices Undergraduate Research and Innovation Scholar
Project: Designing Software for Creating 3D Interactive Displays
Advisor: Stefanie Mueller

We would like to free displays from their current 2D rectangular form and enable the fabrication of freeform 3D displays of any shape. By transforming any object surface into a canvas for visual output, we create a new class of user interfaces with increased learnability, efficiency, and safety. We will focus on displays that work via electroluminescence, as they can be created from only four base materials: electroluminescent paste, conductive silver paste, dielectric paste, and conductive silicone paste. A custom hybrid 3D printer will print these materials in one integrated process, and design software will allow users to draw displays onto 3D geometry, automatically decomposing it into the four layers of material and generating instructions for the 3D printer to print the full display.

“I would like to apply the skills I’ve learned from my technical classes and personal pursuits in 3D modeling to a real-world project through the SuperUROP program. I hope to acquire research experience in human-computer interaction and related fields, as well as experience working in a collaborative environment. I want to make a meaningful contribution to my lab while having fun doing research!”

Jesse Chang
Undergraduate Research and Innovation Scholar
Project: Video Atomic Force Microscopy
Advisor: Kamal Youcef-Toumi

The atomic-force microscope (AFM) is a powerful tool that produces images in the nanoscale world. Currently, large-range AFMs are capable of producing 8–10 images per second. But to attain truly real-time imaging speeds, the system must be improved so that it can produce at least 25 frames per second without reducing the size of the area being imaged. My project focuses on improving the existing implementation of an AFM faster more compact and the electronics system more robust to noise. To increase imaging speed without risking damage to the cantilever probe or the sample, a new controller must be designed with a fast response and little error in the actuation of the piezos controlling the probe.

“I am participating in SuperUROP because I would like to apply the concepts from classes I’ve taken to a longer-term research project. As an electrical engineering major and mechanical engineering minor, I hope to combine what I’ve learned in both disciplines in a meaningful way.”

Nicholas Charchut
MIT EECS | Nutanix Undergraduate Research and Innovation Scholar
Project: Road Understanding with Deep Learning
Advisor: Daniela L. Rus

Autonomous driving is an emerging industry, garnering sponsorship and attention from almost all big-name car brands and attracting scientists as well. However, most current autonomous driving approaches rely on highly detailed prior maps, which are extremely time-consuming to generate, maintain, and extend to other regions. This project aims to create a system capable of real-time application while actively quantifying uncertainty in any autonomous decision or segmentation through the use of Bayesian deep learning. Coupled with light detection and ranging (LIDAR), the pipeline will allow for a quickly trainable neural network capable of operating on any properly equipped vehicle.

“SuperUROP appeals to me because of the intense learning I will achieve through research, experimentation, and execution – even more so than the courses at MIT that have taught me the fundamentals. What prepared me for research is a growing drive to apply what I know and extend it to enhance autonomous driving. I am excited for the constant struggles, sporadic victories, but most important, the potential of this project and how it could impact the world.”
Today’s communication networks face large amounts of traffic and congestion from increased usage of video applications and big data analytics. The dynamic nature of these sessions means that the network state changes constantly. My SuperUROP project will explore how to design, develop, and analyze innovative network management and control systems in scenarios with imperfect state knowledge. I will start by using a variety of analytical and algorithmic solutions to model a communication network. Then I will leverage tools from various disciplines — such as machine learning, optimization, and control theory — to design suitable network-management protocols. Finally, I can evaluate my protocols through simulating network-protocol conditions.

“I am participating in SuperUROP to gain hands-on research experience and prepare for further education in computer science. What excites me most is the ability to take knowledge from my classes and apply it to a real-world problem in an area of my interest. I want to learn how to take technical concepts from my research and present them in an understandable, engaging manner.”

Sharlene Chiu
Undergraduate Research and Innovation Scholar
Project: Exploring the Future of Urban Mobility with Scenario Discovery
Advisor: Moshe Ben-Akiva

Current transportation infrastructure may struggle to support the long-term needs of growing urban populations. The Mobility of the Future project will gain insight into how different transportation policies impact the carbon footprint of cities over time. These insights will be gained by running simulations of these policies within virtual environments. My research is in scenario discovery and outcome analysis. Scenario discovery entails generating different combinations of city parameters, such as fuel prices and median population age. The goal of the outcome analysis is to develop methods for determining which parameters lead to low estimates for carbon emissions. A simulator will run different transportation policies inside virtual cities that take on the parameters of input scenario samples. The developed analysis methods will be used to determine how the input scenario parameters impact the simulation outcomes. This analysis will provide insight into how cities should design transportation policies to minimize their carbon footprint.

“I like transportation. Through SuperUROP, I can dive into research that combines my interests and studies. I hope to apply what I’ve learned from my computer programming and transportation modeling classes, and I want to better understand how models and simulations reflect urban trends. But above all, I’m excited to contribute to research that takes a computational approach to improving sustainable public policy.”

Kevin Kyung Bum Cho
MIT EECS | Hewlett Foundation
Undergraduate Research and Innovation Scholar
Project: Automated Safety Verification Toolbox for Autonomous Cars
Advisor: Daniela L. Rus

Self-driving cars have fascinated the world for some time. However, a major question remains: how will people know whether to trust the software that runs all the autonomous behaviors? This project will deal with various optimization problems involved with verifying the safety of self-driving cars. The optimizations will deal with making the verification run faster and more efficiently. The biggest problem with verification is that it takes a very long time. This project will help shorten the time needed for verification.

“I chose to participate in SuperUROP to gain a better understanding of what research is like and to learn more about my topic of autonomous cars. Through this project, I hope to not only acquire good research skills, but also learn a lot about what it means to do a full verification and about self-driving cars.”

Run Chen
MIT EECS | CS+HASS
Undergraduate Research and Innovation Scholar
Project: Eye-Tracking Experiment on Reading Patterns of Non-Natives
Advisors: Boris Katz and Suzanne Flynn

The project utilizes eye movement patterns as an indication of parsing from linear streams into hierarchical structures. Fixation variables including landing sites and saccades disclose mental processing of English sentences in a multilingual brain. A uniformity in reading patterns across various languages and their writing systems will lead to a conclusion on constructive effects of L1 on L2 converging UG.

“I’m a Course 24 (Linguistics and Philosophy) and Course 6 (EECS) student, so this SuperUROP project is combining both my interests into one. I have been working with the eye-tracking group for a year and it is really fascinating. I am intrigued by the number of things that could be looked into.”

Shivani Chauhan
MIT EECS | Lincoln Laboratory
Undergraduate Research and Innovation Scholar
Project: Managing and Controlling Networks Under Uncertainties and Imperfect State Knowledge
Advisor: Vincent W. S. Chan

Today’s communication networks face large amounts of traffic and congestion from increased usage of video applications and big data analytics. The dynamic nature of these sessions means that the network state changes constantly. My SuperUROP project will explore how to design, develop, and analyze innovative network management and control systems in scenarios with imperfect state knowledge. I will start by using a variety of analytical and algorithmic solutions to model a communication network. Then I will leverage tools from various disciplines — such as machine learning, optimization, and control theory — to design suitable network-management protocols. Finally, I can evaluate my protocols through simulating network-protocol conditions.

“I am participating in SuperUROP to gain hands-on research experience and prepare for further education in computer science. What excites me most is the ability to take knowledge from my classes and apply it to a real-world problem in an area of my interest. I want to learn how to take technical concepts from my research and present them in an understandable, engaging manner.”

Sharlene Chiu
Undergraduate Research and Innovation Scholar
Project: Exploring the Future of Urban Mobility with Scenario Discovery
Advisor: Moshe Ben-Akiva

Current transportation infrastructure may struggle to support the long-term needs of growing urban populations. The Mobility of the Future project will gain insight into how different transportation policies impact the carbon footprint of cities over time. These insights will be gained by running simulations of these policies within virtual environments. My research is in scenario discovery and outcome analysis. Scenario discovery entails generating different combinations of city parameters, such as fuel prices and median population age. The goal of the outcome analysis is to develop methods for determining which parameters lead to low estimates for carbon emissions. A simulator will run different transportation policies inside virtual cities that take on the parameters of input scenario samples. The developed analysis methods will be used to determine how the input scenario parameters impact the simulation outcomes. This analysis will provide insight into how cities should design transportation policies to minimize their carbon footprint.

“I like transportation. Through SuperUROP, I can dive into research that combines my interests and studies. I hope to apply what I’ve learned from my computer programming and transportation modeling classes, and I want to better understand how models and simulations reflect urban trends. But above all, I’m excited to contribute to research that takes a computational approach to improving sustainable public policy.”
Zareen Choudhury  
MIT EECS | Angle Undergraduate Research and Innovation Scholar  
Advisor: Daniela L. Rus

Cloud robotics is an exciting field that has the potential to greatly enhance robot development by providing access to large datasets, supporting cloud computing, and enabling collaboration between robots. Canopy is a new open-source cloud robotics platform for inter-robot communication and cloud computing. It is intended to integrate seamlessly with the Robot Operating System (ROS), the most widely used robotics software library. This project focuses on enhancing the current Canopy software to ready it for use by the robotics community. Our objectives include optimizing message transmissions, supporting multiple clients, fully developing the cloud computing platform, incorporating continuous test integration, and producing end-to-end demonstrations of the system.

“I hope to explore and gain experience in distributed robotics through SuperUROP to be better informed and to help make future career decisions. I have previously done an internship in distributed systems and am taking higher-level systems courses. I am excited to apply the skills I have gained to contribute to the cutting-edge research in my lab.”

Nichole Imani Clarke  
MIT EECS Undergraduate Research and Innovation Scholar  
Project: Democratizing Cross-Platform Mobile Development with MIT App Inventor  
Advisor: Harold Abelson

App Inventor has been around for eight years and now has 6.8 million users worldwide. However, App Inventor currently targets only Android development, excluding the 20 percent of users who use Apple devices, including schools that are deploying iPads for classroom use. As part of my SuperUROP project, I will work to understand the differences between the Android and iOS platforms in terms of architectural design. In so doing, I will help develop the iOS version of App Inventor, leading to App Inventor democratizing cross-platform mobile development for both Android and iOS.

“I’m participating in SuperUROP because, after a semester of working with App Inventor, I knew that I wanted to continue on with them. I knew that I wanted to make a difference. I hope that this year I’m able to make that difference by helping create App Inventor for iOS. On top of that, I’m excited about the challenges that this will present and all that I can learn from it.”

Mark Chounlakone  
MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar  
Project: Automated Amperometric Immunoassay  
Advisor: Joel Voldman

In 2016, the estimated global mortality rate of newborns in the first month of life was 7,000 deaths per day. Fifteen percent of these deaths were due to sepsis, or bacterial bloodstream infection. Many newborns could be saved if sepsis were rapidly diagnosed. The conventional diagnostic blood test can take days to produce results because samples must be transported to remote labs where equipment is available. In addition, only a small amount of blood can be drawn from a newborn. The Voldman lab is developing a portable device that can test small volumes of blood quickly and reliably. This device leverages the small scale of microfluidics to reduce the amount of blood required for a blood test, and its small form factor makes it more viable to store and use locally. While this device takes only 15 minutes to perform a blood test, preparing the device takes two days of manual labor. This project aims to automate this process so that devices can be prepared ahead of time in large quantities. The final product should be able to run the device independently from preparation to testing. This will make the device more viable as a rapid diagnostic tool in hospitals.

“The device I’m working on is a biosensor that has the potential to improve the speed and quality of blood tests. My role in this project will require an understanding of interdisciplinary concepts. I’m excited to work on a high-impact project while extending my knowledge of other science and engineering fields.”

Emily Damato  
MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar  
Project: Applications of Machine Learning for Cryo-Electron Microscopy (Cryo-EM)  
Advisor: Cathy Drennan

Discovering the structure of large biomolecules to atomic resolution is critical for understanding biological processes and developing new medicines. One increasingly popular method of structure discovery is to directly image particles with an electron microscope (EM) and computationally reconstruct the macromolecule 3D structure from these 2D projections. However, this process is time-consuming and places a significant computational burden on biochemistry labs. For my SuperUROP project, I plan to use machine learning and other statistical techniques to replace the steps in the EM image-analysis pipeline that normally require expert human intervention. My goal is to streamline the reconstruction pipeline to make EM a more approachable technique for research groups.

“In the past, I have enjoyed UROPs in molecular biology and coursework in computer science. I am excited to explore an intersection of these two fields through my SuperUROP project. This year, I look forward to diving into a fascinating research project and working with the wonderful people in the Drennan Lab.”
Ronald Davis
MIT EECS | Texas Instruments
Undergraduate Research and Innovation Scholar
Project: Controlling Diamond Spin with a Microscale CMOS Inductor
Advisor: Ruinan Han
Quantum computers use qubits (quantum bits) to perform calculations. Qubits can be created by manipulating the spin states in quantum systems with magnetic fields. One major problem in the development of quantum computers is making qubits scalable. Hence, the quantum system must be constructed so that tens to hundreds of them can be physically imbedded into a single chip to form the basis of a quantum computer. One promising quantum system is the diamond nitrogen vacancy [NV] center. Current methods of controlling NV centers are not scalable, so adding multiple NV centers to a quantum computer design is difficult or infeasible. My SuperUROP project involves designing a CMOS microscale solenoid that emits microwave frequency magnetic fields to drive a single NV center. The solenoid should produce a strong magnetic field, yet be uniform enough so that several of them can be placed on a single chip without interfering with one another. The development of a scalable quantum system will pave the way for placing hundreds of qubits on a single chip.

“I am participating in SuperUROP because it is a great opportunity to gain research experience. My background in both physics and electrical engineering has helped prepare me for this research. I am excited to learn more about the applications of quantum mechanics, practical electrical engineering skills, how to conduct quality research, and how to communicate and write about my research.”

Hannah Diehl
MIT EECS | Draper Laboratory
Undergraduate Research and Innovation Scholar
Project: Qubit Factory: Developing Light-Matter Interfaces
Advisor: Dirk R. Englund
Quantum computation is becoming an increasingly important field at the interface among computer science, electrical engineering, and physics. Quantum algorithms are known to solve problems faster than any known classical algorithms. Yet, for these algorithms to be practically realized they must be implemented on physical quantum computers. A group within Professor Dirk Englund’s lab has been researching the implementation of quantum information processing using the optically active defects in diamond structures. My project will involve designing and simulating the light-matter interfaces for these quantum systems which provide the basis for manipulating and reading the qubits used in computation.

“I have chosen this SuperUROP project because it combines my interests in physics and computer science. It will allow me to apply the skills I have acquired from previous physics research and classes in a new field that I became interested in through classes in complexity theory and quantum computation. I look forward to learning the methods and approaches within this field and comparing them with my previous experiences.”

Erika Ding
MIT ChemE | Undergraduate Research and Innovation Scholar
Project: Protein Purification by Reversible Solvent-Induced Phase Transitions
Advisor: Bradley Olsen
Directed evolution can drastically modify the catalytic activity of protein enzymes for use in various artificial applications. By immobilizing an enzyme to make a solid material, we can unlock longer material lifetimes, greater ease of use, and the ability to reuse the material. The goal of this SuperUROP project is to use directed evolution techniques to monitor and select for activity in the material itself, to achieve higher activity levels, or improve other features of interest in the material. Specifically, we will develop methods to efficiently and robustly express and purify Cal-B — an enzyme widely used in industrial processes like biowaste breakdown — immobilize it into solid films, and then use directed evolution to optimize its catalytic activity in solid-film form.

“I am participating in SuperUROP because I have enjoyed the UROP research I have done thus far and I would like to delve more deeply into a problem at the intersection of biology and chemical engineering. I hope to make a positive contribution in developing processes that have a wide scope of real-world applications.”

Leo de Castro
MIT EECS | Lincoln Laboratory
Undergraduate Research and Innovation Scholar
Project: Efficient Two-Party Computation from Plaintext-Ciphertext Homomorphic Operations
Advisor: Vinod Vaikuntanathan
As cloud computing becomes more powerful, solutions for securely outsourcing computations on sensitive data become more necessary. Homomorphic encryption schemes have tremendous potential to provide analytical access to encrypted data while still maintaining privacy. Modern homomorphic schemes are fully functional, but have yet to be implemented in practical applications. Moreover, the asymptotic efficiency of homomorphic schemes is not well understood in the context of complex circuits, and comparisons can be difficult as different schemes have different potential optimizations through single-instruction multiple-data (SIMD) operations. This project will compare the efficiency of the BGV and FV homomorphic schemes when running three fundamental circuits for data sharing: ARGMAX, SETDIFF, and INTERSECTION, with the goal of creating an efficient suite of functions for secure genome analysis.

“My SuperUROP project is in the field of lattice-based cryptography. Previous classwork and meetings with my professor (who is now my SuperUROP supervisor) led to my interest in this project. I hope to learn more about lattices and their cryptographic applications, as well as how to better communicate and share my results. I am excited to use these skills both in this project and in future work.”
Archive research has changed dramatically as the world has become more digital. But existing digital-annotation and media-exploration tools don’t fulfill the research need to understand individual documents within an archive’s larger context. We propose the construction of Spectacles, a digital humanities tool that uses natural language processing (NLP) techniques to help researchers perform speculative analysis by creating an “active archive” from any digital-text repository. Previous tools focused on helping researchers answer known questions or helping students understand individual texts in classroom settings. Spectacles will analyze source texts and related annotations created by researchers in different disciplines who are using the same repository for different purposes. The active archive can make recommendations to direct researchers to previously unconsidered questions and answers. The collaborative, cross-disciplinary contextualization and the recommendation techniques will aid researchers in performing speculative analysis of digital archives.

“I’m excited and optimistic about the potential for computational techniques to aid human understanding of the world. The research I’ll be doing this year will allow me to gain a better understanding of modern natural language processing; but by using NLP to build tools for humanities research and archive exploration, I hope to also gain a better understanding of how humans relate, and have related, to each other and the world.”

Recent advances in computer vision have led to remarkable and even superhuman performance on tasks such as image prediction. 3-D scene understanding is more difficult with many parts of objects occluded or hidden. In this project, we seek to predict semantic labels and occupancy for voxels in rooms using shape primitives and recurrent convolutional networks from a single depth map of the scene.

“I decided to participate in SuperUROP to get a more immersive experience in research. In the past, I have tried several deep learning-based projects in natural-language processing [NLP] computer vision and reinforcement learning. I am really excited to get a better understanding of where we are in 3-D computer vision and to hopefully improve our performance on 3-D computer vision tasks.”

Change in the input can alter the solution. Through testing various neural network models and comparing their performances both with each other and with the performance of networks evaluating the MNIST dataset, we hope to gain further insight into the extent to which neural networks can be relied on to tackle similar classification problems.

“I view Super UROP both as a chance to further enhance my experience with research and an opportunity to continue my exploration into machine learning. I have had some prior experience using neural networks, and I hope to emerge from this project with an even better understanding of their behavior. Above all, I am excited for the opportunity to study the lesser-known aspects of a neural network’s capabilities and shortcomings.”

Countries have traditionally placed tariffs on foreign products that enter their country for sale. The rationale behind this import tax is that it allows countries to protect their domestic industries and workers and is also a way for them to assert international dominance over rival countries and economic competitors. It’s curious, then, given these shared rationales for the tax, so substantially between countries, across products, and over time. This project endeavors to apply machine learning and big data analysis methods to a dataset of more than 10 billion tariff rate observations spanning 30 years, 130 countries, and 6,000 products for the purpose of detecting, measuring, and analyzing various economic and political determinants of tariff rates and trade volumes.

“By engaging in this SuperUROP project, I hope to gain exposure to a longer-term, multidisciplinary research endeavor. I am majoring in Course 6-3 and minoring in economics. Having done internships in both fields, this project gives me a unique opportunity to apply machine learning techniques in the context of an economic phenomenon, a problem that requires an understanding of both artificial intelligence and global economic trends.”

“...a challenging problem in machine learning due to the property that a small...”

“...in an “active archive” from any digital-text repository...”
Yannick Eatmon
MIT ChemE | Undergraduate Research and Innovation Scholar
Project: Studying Liquid Transport Through Small-Diameter Carbon Nanotubes
Advisor: Michael Strano
As science continues to advance, there is always an emphasis on nanoscale processes — for example, nanoscale mass transport, which has been recently revolutionized by carbon nanotubes (CNTs). These are nearly one-dimensional hollow tubes with diameters ranging from approximately 0.5 – 10 nm. Currently, interactions between molecules and the exterior of the nanotube are relatively well studied; however, discoveries about the interactions with the interior of the tube remain to be made. The hollow geometry of CNTs make them permeable to ions and molecules of appropriate sizes. Currently, liquid flow through small diameter nanotubes is not well controlled, but being able to reliably flow molecules through single-walled carbon nanotubes (SWNTs) will have many applications such as micro-channels, small-scale drug delivery, nanoscale plug flow reactors, and more. Previous work proves that liquid filling in small-diameter tubes is possible and can be controlled. For this study, I intend to first study spontaneous water filling in carbon nanotubes by using Raman spectroscopy to track liquid movement. Then I will attempt to control the flow of water through nanotubes using potential differences across tubes.

“I have been a UROP student for almost two full academic years. During this time, I have gained valuable knowledge in various areas of research, as well as experience in how to be a focused and efficient researcher. I am participating in this program because I believe I am ready for the responsibility of working on my own project, and the experience I will gain will be helpful as I pursue a PhD following graduation.”

Logan Engstrom
EECS Undergraduate Research and Innovation Scholar
Project: A Rotation and a Translation Sufficient: Fooling CNNs with Simple Transformations
Advisor: Aleksander Madry
Research has shown that neural networks can be fooled by small changes to images. Current research fails to consider a reasonable space of changes. Most works use the “l_infty” norm or the “l_2S” norm to constrain the space of possible adversarial examples, but neither norm includes rotations, translations, or skews. We propose two metrics to better capture the space of possible adversarial examples: VGG Distance (from the Oxford Visual Geometry Group) and Madry Distance. VGG Distance uses a VGG-19 feature extractor to find adversarial examples and Madry Distance uses composed “l_infty” and “l_2S” norm application along with rotations and translations. Using these two metrics, we can better defend against a wide range of adversarial attacks on the MNIST dataset.

Patrick Ikedi Egbuchulam
MIT EECS | CS+HASS Undergraduate Research and Innovation Scholar
Project: Dynamic background Music for Action-Adventure Video Games
Advisors: Adam Hart and Michael Scott Cuthbert
Imagine playing through your favorite video game for the 20th time—an exciting and tough adventure game. While the dynamic gameplay adapts to you as the player, the soundtrack hasn’t changed since your very first play-through. A game that responds to your controls should also have responsive music. We propose a system that will fit the music to your current experience (be it triumphant victory, inevitable defeat, or something in between). This project will solve three challenges to creating such a system. First, we’ll use our music theory knowledge to take a background theme input and output a variation to fit the player’s state. Second, we’ll use machine-learning techniques to predict the game’s state from the engine. Finally, we’ll use audio engineering to replace the game’s audio engine with our own.

“I’ve had the opportunity to take many music classes while at MIT, including Professor Eran Egozy’s Interactive Music Systems (21M.385), after which I realized that I want to continue doing substantial work that combines music composition with my computer science major. I’m very excited to be able to work on building a new music system with Professor Michael Cuthbert through the SuperUROP program.”

Brook Eyob
MIT ChemE | Undergraduate Research and Innovation Scholar
Project: Kinetics and Product Distribution of Bimolecular Radical Reactions Relevant to Combustion
Advisor: William Green
Reaction Mechanism Generation [RMG] software is a powerful tool for understanding chemical reaction pathways. However, RMG lacks experimental data to validate its prediction for certain sensitive radical reactions related to the formation of harmful polycyclic aromatic hydrocarbons (PAHs) during combustion. This project’s goal will be to experimentally study the kinetics and product distribution of these elementary bimolecular reaction pathways to extend the accuracy of the RMG’s models. Laser absorption spectrometry (LAS) and mass spectrometry (MS) will be used to measure both the kinetics and the product distribution of these reaction networks. Quantitatively understanding how PAHs are produced during combustion can allow us to design systems that limit their production.

“I am taking part in SuperUROP to gain more experience in kinetics and energy research. I enjoyed taking Chemical Kinetics and Reactor Design and want to further develop my understanding of the subject matter through independent research. I look forward to using state-of-the-art reaction-measuring tools to better understand complex chemical processes.”
As autonomous vehicles start to enter the public space, it is important for them to be able to justify their actions with a human-readable explanation. The reasonableness monitor, formed in the CSAIL Toyota Research Center, is a proof of concept designed to help autonomous vehicles justify their actions. Currently, the system can only determine the reasonableness of a (subject, object, verb) triple. However, my work looks to extend its capabilities to determine reasonableness among compound sentences with an added context. By having human-readable explanations, this reasonableness monitor will make people more comfortable with allowing autonomous machines into their sphere.

“Participating in SuperUROP gives me the opportunity to explore artificial intelligence while gaining research experience. I am excited to apply the knowledge I have gained from my Course 6 classes and previous research in autonomous vehicles on my project.”

The U.S. federal government considers the timely detection and repair of public infrastructure a top priority for both national and financial security. Because of their ease of maneuverability and low personnel risk, small Unmanned Aerial Systems (sUASs) are an increasingly popular choice for assessing infrastructure. While there is plenty of work on efficient routing of vehicles through known networks, comparatively little work has been done in routing of vehicles where physical constraints, such as GPS or communications coverage, are dynamically incorporated. Our proposed solution combines previous work in Vehicle Routing Problem (VRP) and Orienteering Problem (OP) formulations to address the problem of near-optimal routing of sUASs along nodes that need to be inspected in communication constrained environments. This solution provides a novel model where the system is learning the real connectivity of the network as it is exploring it, allowing for the possibility of dynamic re-planning if needed.

“I am participating in SuperUROP to obtain a more focused experience in providing clear deliverables as a result of research. I hope to apply my knowledge of systems engineering to a problem that I find very fascinating which is the detection of faults in pipe networks. I also want to learn about the process of writing and publishing a high-quality paper.”

“After hearing about SuperUROP I figured it would be a great way to get my hands dirty with legitimate research. I will be working in computation architecture a field very different from my previous software experiences. Planning on pursuing an MEng at MIT I find it extremely valuable to have the opportunity to explore this field with the safety of a mentor and the SuperUROP program to guide me through.”

Deep neural networks are a powerful tool that have made many difficult problems tractable. However, their internal mechanisms are opaque, and it is usually necessary to treat them as black boxes which makes debugging them difficult and raises ethical concerns about algorithmic transparency. This research will use statistical methods to analyze populations of trained deep networks. By comparing and contrasting the internal states of multiple networks we hope to develop metrics that will allow us to effectively characterize their interpretability by humans. We will investigate the effects of different architectures data sets and training algorithms on our metrics. We hope to develop networks that are highly human-interpretable while still retaining good test-set performance.

“Through this SuperUROP project, I hope to gain more experience in machine learning research. I’m looking forward to apply my data visualization and statistics experience to problems without established solutions as well as working in a high-performance scientific programming environment. I think interpretability is an important area of the deep learning field and I hope to make a useful contribution.”
Zoe Gong
MIT EECS | Advanced Micro Devices Undergraduate Research and Innovation Scholar
Project: Simulating Application Fault Tolerance Under First-Class Execution Models
Advisor: Michael Carbin

Modern processors are more prone to errors than ever due to rapid scaling of technology. It is no longer practical to simply ensure fully reliable execution and, in addition, programs gain efficiency by allowing occasional errors. Developers can leverage faulty hardware to increase the efficiency of their programs, but also need to verify the safety of their programs. The verification system Leto gives developers the ability to specify and verify the correctness of assertions relating the reliable and relaxed semantics of their program. This project aims to build an interpreter for Leto, allowing developers to run their programs under a simulation of faulty conditions, letting them empirically verify the safety of their programs.

“I am participating in SuperUROP to gain research experience and see whether I’m interested in doing a PhD and pursuing a career in research. This past summer, I worked on a research and development team at Siemens Healthineers. I hope to learn more about the research process since I’m not very familiar with it, and I hope to learn whether I enjoy it. I think the project has many exciting practical applications.”

Iva Monique Tejero Gramatikov
MIT BE | Microbiome
Undergraduate Research and Innovation Scholar
Project: Machine Learning and In Silico Peptide Design
Advisors: Timothy K. Lu and Cesar de La Fuente Nunez

A grand challenge in medicine today is the inability to rationally manipulate the human microbiome. Despite its established importance in both health and disease, we currently lack tools to precisely engineer these microbial communities. Recently, we have generated synthetic peptides that can be used to manipulate the human microbiome. We have synthesized and performed functional screening of peptide libraries designed to combat infectious diseases and engineer the microbiome. This SuperUROP project’s goal is to leverage machine-learning algorithms to extract structure-function relationships from the datasets generated thus far, perform biophysical and biochemical investigations, and to design next-generation peptides in silico that may serve as the basis for future medicines.

“Since coming to MIT, I’ve become very interested in the application of electrical engineering and computer science to biology. It was eye-opening to see that breakthroughs in fields such as genetics and microbiology could be attributed to principles founded in circuits or machine learning. I have participated in research that works to analyze biological systems, but look forward to working on a project where I will be creating something completely new.”

Claire Sinetar Goul
Undergraduate Research and Innovation Scholar
Project: Efficient Cellular Delivery of DNA Nanoparticles
Advisor: Mark Bathe

Cell-penetrating peptides (CPPs) have recently emerged as one of the most effective tools for drug delivery in various cell types, in particular in tissue compartments that are difficult to access. CPPs can facilitate both cell entry and escape from intracellular degradation. However, the mechanisms by which CPPs enter cells and escape degradation are not fully understood, largely due to the differing physicochemical properties, size, and concentration of CPPs or CPP-cargo conjugates. Nonetheless, these factors can play a significant role in efficiency of cell entry and escape of degradation. DNA origami nanoparticles can address these challenges by serving as a bioorthogonal vehicle with easily tunable stoichiometric attachment of CPPs. Moreover, cell-targeting ligands can be simultaneously conjugated to the nanoparticle to allow for cell type-specific delivery while reducing intracellular degradation. This project will investigate how tuning CPP number and spacing can limit particle degradation. Using CPPs conjugated to tetrahedral DNA nanoparticles in conjunction with cell targeting ligands, we will identify optimal parameters to enhance the efficacy of therapeutics.

“I am eager to take advantage of the SuperUROP opportunity to continue my current bioengineering UROP project. I look forward to growing as a presenter, thinker, and researcher through the program and hope to work towards a publication from my SuperUROP work. I’m most excited about the project because enhanced targeted cellular delivery would be an impactful advance for DNA nanotechnology-based therapeutics.”

Dylan Grullon
MIT EECS | Hewlett Foundation Undergraduate Research and Innovation Scholar
Project: Resilient Networking Over Unreliable Substrate
Advisor: Vincent W. S. Chan

The Internet was designed and matured under a non-adversarial paradigm for networking and transport. While networks today are well-equipped to mitigate benign failures, many problems remain in terms of addressing adversarial attacks, including so-called Byzantine failures. This project seeks to explore ways of modelling these coordinated attacks over complex networks to gain insight into ways of developing algorithms for adaptive network reaction. The project’s ultimate intention is developing tools to efficiently model networks and attacks, as well as exploring different potential approaches to the problem of network security.

“I am participating in SuperUROP because I want to gain additional research experience before my time with MIT comes to an end and I move to industry. I very much enjoyed my distributed systems class and want to continue exploring the complex and abstract problems it can lead to, specifically, Byzantine attacks in untrusted network communication.”
radio frequency (RF) localization have shown immense potential for a wide range of applications. Professor Dina Katabi and her group have developed a particularly promising device. It has achieved unseen levels of accuracy and has been shown to measure faint signals that can be used in seamless medical diagnostic, such as breathing rate or even heart rate. However, its range, resilience to metallic obstacles, and multi-person tracking are limited. This would represent a significant challenge if the device were to be used in constrained densely populated environments, such as assisted living facilities. The problem could be solved by enabling multiple devices to operate in the same environment. However, the devices would interfere with each other and the performance would degrade. Therefore, this project will tackle this challenge by first introducing a simple time-based synchronization scheme. Later, it aims to obtain more information by synchronizing the devices’ clocks. Doing so will permit each device to listen to and differentiate the signals from the other devices. The additional information will be used to enhance the overall performance of the system.

“I am participating in SuperUROP because I want to strengthen my knowledge in communications systems development on field-programmable gate arrays (FPGA) and radio frequency (RF) circuit design. Working with this lab in the past year has increased my interest in the subject substantially, and I hope to further my abilities to carry meaningful research within it.”

Jeffrey Hu
MIT EECS | Lincoln Laboratory
Undergraduate Research and Innovation Scholar
Project: Active Learning for Semantic Segmentation
Advisor: Antonio Torralba

Semantic segmentation is a computer vision problem that involves classifying the pixels of an image into meaningful categories. While networks have achieved human-level performance on tasks such as image classification, segmentation performance lags due to the relatively small size of available datasets. In this work, we bypass this problem by training a secondary network to predict when the segmentation network is correct. We hypothesize that the task of recognizing where the segmentation network is wrong is easier than the original task of segmentation. If true, we can use the secondary network to select good predictions from unannotated images. By treating these as ground truth, we can use orders of magnitude more pseudo-training data to train the original network.

“Originally, I thought computer science was the most unnecessary field in which to get a PhD. Recently, however, I’ve found that the people doing the most interesting work in machine learning seem to have PhDs. I took the SuperUROP program to get a jumpstart in higher education and research for the fields I’m interested in.”

Driss Hafdi
MIT EECS | Analog Devices
Undergraduate Research and Innovation Scholar
Project: Synchronization of Multiple RF Tracking Devices
Advisor: Dina Katabi

Recent developments in sensorless radio frequency (RF) localization have shown immense potential for a wide range of applications. Professor Dina Katabi and her group have developed a particularly promising device. It has achieved unseen levels of accuracy and has been shown to measure faint signals that can be used in seamless medical diagnostic, such as breathing rate or even heart rate. However, its range, resilience to metallic obstacles, and multi-person tracking are limited. This would represent a significant challenge if the device were to be used in constrained densely populated environments, such as assisted living facilities. The problem could be solved by enabling multiple devices to operate in the same environment. However, the devices would interfere with each other and the performance would degrade. Therefore, this project will tackle this challenge by first introducing a simple time-based synchronization scheme. Later, it aims to obtain more information by synchronizing the devices’ clocks. Doing so will permit each device to listen to and differentiate the signals from the other devices. The additional information will be used to enhance the overall performance of the system.

“I am participating in SuperUROP because I want to strengthen my knowledge in communications systems development on field-programmable gate arrays (FPGA) and radio frequency (RF) circuit design. Working with this lab in the past year has increased my interest in the subject substantially, and I hope to further my abilities to carry meaningful research within it.”

Aaron Huang
MIT AeroAstro | Lincoln Laboratory
Undergraduate Research and Innovation Scholar
Project: Fast Multi-Vehicle Path Planning with Decentralized Heuristics
Advisor: Brian Williams

NASA is interested in investigating the liquid water ocean hidden under the icy surface of Europa for conditions suitable for life using multiple underwater autonomous vehicles. However, concurrently planning paths for every vehicle using a single system is computationally difficult because the problem’s complexity increases exponentially with each additional vehicle. This project focuses on developing a distributed-path planning algorithm that plans each vehicle’s optimal physical path in a computationally reasonable manner while ensuring that vehicles will be safe and that maximum scientific knowledge is obtained during the mission. At a high level, this is accomplished by detecting when interactions between vehicles can be ignored, producing distinct problems to be individually solved.

“I am participating in the SuperUROP program to further my interest in applying my computer science background to social science issues, as well as to develop the skills needed to do research in the long term and communicate my findings effectively.”

Jacob Higgins
MIT EECS | CS+HASS
Undergraduate Research and Innovation Scholar
Project: Video Games for Social Issues
Advisor: Fox Harrell

My research will focus on computational modeling of social categorization and the user experiences based upon it. This work will be based in artificial intelligence approaches developed in the Imagination, Computation, and Expression Laboratory directed by Professor D. Fox Harrell. The goal is to enable developers of interactive narrative systems such as videogames and virtual-reality works to create more dynamic, engaging, and customized content. An additional aim is to create content to support pedagogy involving sociological phenomena such as bias and diverse cultural identities of learners.

“I am participating in the SuperUROP program to further my interest in applying my computer science background to social science issues, as well as to develop the skills needed to do research in the long term and communicate my findings effectively.”

“As a 2017-2018 Scholar, I am excited to work on the multiple-vehicle coordination project with direct application to a visionary under ice exploration mission to Europa. I expect to gain intensive research experience and connect with world-class faculty, which are both critical to my goal of gaining admission to grad school and achieving a doctorate degree.”

“I am participating in the SuperUROP program to deepen my understanding of automated path-planning and activity-scheduling by taking on a multivehicle coordination project with direct application to a visionary under ice exploration mission to Europa. I expect to gain intensive research experience and connect with world-class faculty, which are both critical to my goal of gaining admission to grad school and achieving a doctorate degree.”
Andrew Ilyas  
**Undergraduate Research and Innovation Scholar**  
**Project:** Training GANs with Optimism  
**Advisor:** Constantinos Daskalakis

The goal of this project is to characterize the convergence of two-player optimization dynamics. Our initial investigation is into convex-concave (saddle point) functions, where we investigate the convergence of the optimistic mirror descent algorithm. When this result is explained, we can continue to investigate general properties of optimization dynamics in potentially multidimensional games. Specifically, the project is inspired from earlier papers that characterize the optimization dynamics in terms of average-convergence to equilibria in two-player table games. In our research, we hope to extend these works to show final-step convergence, as well as extend beyond table games into the realm of general convex-concave functions.

“In doing this SuperUROP project, I hope to apply the mathematics and computer science I’ve learned in classes such as Inference and Information (6.437) and Topics in Algorithmic Game Theory (6.853) to explore and develop new methods and results. I’m excited to dive into deep theoretical work with many interesting applications!”

Kritkorn Karntikoon  
**MIT EECS | Lal Undergraduate Research and Innovation Scholar**  
**Project:** Climate Networks and Ricci Curvature  
**Advisor:** Stefanie Jegelka

We propose a method to reconstruct and analyze the global climate network via the geometric lens of Ricci curvature. The global climate can be seen as a large, evolving network between different grid points on the globe. Modern network analysis techniques are increasingly applied to understand this network by measuring mutual information and centrality of the network. However, existing techniques are often limited because of scalability and limited applicability to only unweighted networks, so we will combine Ricci curvature with the old method to solve the constraints. Ricci curvature is a geometric property (in some sense measuring shape) that can be discretized to (weighted) graphs via Ollivier-Ricci curvature and Forman-Ricci curvature. These graph curvatures have already been applied to social, brain and economic networks, and are shown to give insights into structural properties of these networks. Using Ricci curvature, we will perform a mathematical analysis to extract and observe the property of the climate network in more scalable and applicable way.

“I am interested in this SuperUROP project because it is a combination of discrete mathematics, theoretical computer science, and machine learning. I think it will be enjoyable to use my knowledge in these fields to create a visualized result. I also hope that, by doing this project, I will be able to develop my skills and help solve real-life problems involving the global climate.”

Abigail Katcoff  
**MIT EECS | Angle Undergraduate Research and Innovation Scholar**  
**Project:** An Enhanced Mechanistic Model for Capnography, with Application to CHF-COPD Discrimination  
**Advisor:** Caroline Uhler

Capnography, a noninvasive monitoring modality that records the partial pressure of carbon dioxide in exhaled breath as a function of time or volume, produces a capnogram — that is, a graph that reflects characteristics of the lung and is useful for diagnosis of cardiorespiratory conditions. Others in our group have recently developed a simpler mechanistic capnogram model than those described in the literature. Promising results have been obtained for identifying patients with chronic obstructive pulmonary disease using the model parameters that are fit to the time-based capnogram. The goal of this project is to refine the mechanistic model to capture specific characteristics of the capnogram in congestive heart failure and asthma for eventual use in developing simple and effective diagnostic procedures.

“I am participating in SuperUROP because I am planning to do a PhD and think that working one-on-one with a professor will be a great preparation. In my sophomore and junior years, I did active research in the Graybiel Lab and enjoyed it greatly. I am very excited that this project involves the biomedical applications of EECS and want to learn more about these applications, since I am considering further studies in this field.”

Ekin Karasan  
**MIT EECS | Mason Undergraduate Research and Innovation Scholar**  
**Project:** An Enhanced Mechanistic Model for Capnography, with Application to CHF-COPD Discrimination  
**Advisor:** George C. Verghese

Each of the approximately 200 cell types in the human body shares the same DNA but expresses a different set of genes. The specific genes expressed by a cell are determined by a process called cell differentiation, in which physical and chemical signals from a cell’s environment guide the cell through epigenetic transitions. The goal of this SuperUROP project is to use inference methods such as graphical models to learn how geometries and stiffness constraints imposed by surrounding tissues during cell differentiation affect chromosome organization and gene expression. Establishing a map between chromosome organization and gene expression is key to further understanding cell differentiation and other processes, including the genomic processes underlying diseases such as cancer.

“I am participating in SuperUROP to explore an area that interests me: statistical inference applied in the expanding area of computational biology. This SuperUROP project will give me the opportunity to apply inference methods I learned in Introduction to Inference (6.008), which has been one of my favorite classes so far. I also believe that participating in SuperUROP will allow me to become a better researcher and programmer in general.”
Srinivas Kaza
MIT EECS | Mason Undergraduate Research and Innovation Scholar
Project: Interactive Sound Propagation via a Hybrid Numerical Simulation and Geometric Acoustics Approach Using Signed Distance Functions
Advisor: Frederic P. Durand

Geometrical Acoustics (GA) is a popular family of methods for simulating acoustics in virtual environments. Unfortunately, most GA techniques fail to take into account the effects of diffraction—an important physical effect that involves some of the wave-like properties of sound. Because geometric acoustics is founded on the approximation that sound travels like a ray rather than a wave, diffraction can be difficult to accurately model. We propose using a signed distance function as a heuristic to help determine how to simulate diffraction. In this project, we endeavor to explore various models of diffraction to see how we can minimize aliasing while still running the simulation at interactive rates.

“In this SuperUROP project, I want to gain more research experience in the field of computer graphics. I have been interested in computer graphics and systems engineering for a couple of years, and this year, I am taking Computer Graphics (6.837). I am excited to continue work with the Computer Graphics Group, especially because of the focus on performance engineering that this project will entail.”

Houssam Kherraz
MIT EECS | Angle Undergraduate Research and Innovation Scholar
Project: Toward an Unbiased Dataset
Advisor: Boris Katz

Current machine-learning models for action recognition operate either by first extracting features such as keypoints and bounding boxes and then classifying the action, or by performing full-frame action classification. Recent work exploring how humans interpret images and recognize actions show that we are capable of identifying and localizing a high number of semantic features and parts in images. Our research plans to use the best of both worlds: extract semantically-relevant features from pertinent bounding boxes (full interpretation in a temporal context). The focus will be on a subset of actions performed by hand, which poses the challenge of obstruction and occupying a small number of pixels in real-life images.

“I am participating in SuperUROP because I am very interested in artificial intelligence (AI) and want to be involved in furthering the state of the art. I believe AI will be a big part of the solutions to humanity’s problems in the 21st century and I want to be part of that effort. I have done research in natural-language processing (NLP) and interned at an AI startup. I hope to learn a lot through this program and publish an impactful paper.”

Sean Patrick Kelley
MIT AeroAstro | Northrop Grumman Undergraduate Research and Innovation Scholar
Project: Electro-Aerodynamic Propulsion for Fixed-Wing Aircraft
Advisor: Steven Barrett

While engine efficiency has seen dramatic improvement, environmental impact and noise pollution remain major problems facing the aviation industry. A promising solution to eliminating these negative aspects is the development of electric propulsion systems. Near-silent and requiring no onboard propellant, my research will focus on the application of electro-aerodynamic (EAD) propulsion, which requires no moving parts, on a fixed-wing prototype airframe. In addition to altering thruster integration methods to improve aerodynamic efficiency, we will explore such techniques as varying electrical discharge and implementing electric flow control. After experimenting with these different strategies, we will demonstrate a more practical and effective use of EAD thrust for fixed-wing aircraft.

“I am participating in SuperUROP because I am passionate about conducting more in-depth research in aerospace engineering and expanding my undergraduate experience. From past projects, including my involvement in this research as a UROP during my sophomore year, I have grown fascinated by aerodynamics and electric propulsion technology. I look forward to contributing to the project again moving into my final year.”

Jin Woo Kim
MIT IMES Undergraduate Research and Innovation Scholar
Project: Quantification of Calcium Deposits for Transcatheter Aortic Valve Replacement: Imaging Software Development
Advisor: Elazer Edelman

Aortic stenosis is a life-threatening heart condition that is a leading cause for invasive, valvular surgery in Western countries. Transcatheter aortic valve replacement (TAVR) is a non-invasive, alternative procedure that can curtail the risks involved in traditional open-heart surgeries, but careful prior interventions need to be planned beforehand using computed tomography (CT) to visualize the calcium deposit on the aortic valve. This has traditionally been a manual and qualitative process, in which doctors obtain a general understanding of the calcium distribution on the aortic valve, but we aim to introduce a more consistent, quantitative approach to quantify the calcium deposit. A current algorithm developed by previous researchers at the Edelman Lab uses 2D slices of the CT to identify and quantify the calcium, but non-calcium artifacts are difficult to distinguish at the 2D level. I will improve upon the current algorithm by incorporating 3D capabilities to capture the contiguous calcium deposit on the aortic valve and eliminate irrelevant artifacts. We expect to achieve a more accurate quantification of calcium deposits, which we will verify by comparing to the cohort of patient data manually analyzed by trained cardiologists.

“Through SuperUROP, I want to combine my passion for technology and medicine, and contribute to this interdisciplinary study. I am excited to use the software skills I have developed to conduct clinical research.”
Sharon Jerop Kipruto  
MIT EECS | Morais and Rosenblum  
Undergraduate Research and Innovation Scholar  
Project: Improving Maternal Healthcare Outcomes in Kenya  
Advisor: Peter Szolovits  

Maternal mortality rates in Kenya are of great concern. As of 2015, there were 510 maternal deaths per 100,000 live births, as estimated by the World Bank. The common causes of such maternal deaths are severe bleeding, infections, unsafe abortions, and high blood pressure. However, these causes could be mitigated through access to reliable maternal health information and resources that provide opportunities to reduce the risk factors. Kenya has a 93 percent rate of mobile-phone penetration that we can leverage to provide mothers with reliable maternal health care information from medical practitioners providers. This SuperUROP project aims to improve maternal health care outcomes in Kenya by building a telemedicine application that provides health care information to women in Kenya on their mobile phones.

“I am participating in SuperUROP because I would like to apply my computer science knowledge to build a telemedicine application to improve maternal healthcare outcomes in Kenya. I have taken relevant computer science classes and I have ‘on-the-ground’ knowledge of Kenya. I hope to gain advanced research experience through SuperUROP.”

Ma Czarina Lao  
MIT EECS | Landsman  
Undergraduate Research and Innovation Scholar  
Project: Déjà Vu: A Conceptual Software Design Method for Web Applications  
Advisor: Daniel N. Jackson  

Though applications differ vastly in purpose, they tend to have many fundamental concepts in common, such as posting, up-voting, and events. These recurring concepts are what we call clichés. Déjà Vu is a new platform that allows developers to build applications without writing code by assembling clichés from a library. A prototype has already been built and used to recreate some simple web applications. My project’s goal is to explore a possible niche type of website such as shopping or forum-style sites and further develop Déjà Vu according to that niche. The project aims to measure Déjà Vu’s success by recreating existing, more complex web applications of the target type. It will also assess how Déjà Vu affects the application development process.

“Through the SuperUROP program, I hope to gain valuable research experience and guidance and become more capable of producing new creative ideas. I am particularly drawn to my project because I am interested in exploring and improving software engineering and design methods. I hope to contribute significantly to my project using my experience in designing systems and developing web applications from past internships and classes such as Software Studio (6.170).”

Jun Jie Joseph Kuan  
MIT EECS | Keel Foundation  
Undergraduate Research and Innovation Scholar  
Project: Between-Ride Routing Algorithms for Private Transportation Service  
Advisor: Mardavij Roozbehani  

The market for mobile-based ride services such as Lyft and Uber is growing rapidly, especially in urban areas. When drivers of these services drop off a passenger, they often have to decide where to go next, taking into account peak prices, fuel cost, and travelling time. Suboptimal decisions can lead to increase in urban traffic and greenhouse gas emissions. The aim of this project is to develop a fast and effective between-ride routing algorithm to advise drivers on what to do between rides. Afterwards, we will implement the algorithm to test how well it works in a real-life situation and make any corresponding adjustments if necessary. Ultimately, we hope that the final product will be a significant improvement over the current algorithms used by transportation services.

“I am participating in SuperUROP as it allows me to apply what I have learnt from classes to a more practical setting. I am interested in algorithms and optimization problems, and I believe the material from the algorithms classes I have taken (6.086, 6.046, 6.854) will be relevant to the project as well. As a double major in computer science and mathematics, this project is also a good fit for me because it requires knowledge from both disciplines.”

Quang Le  
MIT EECS | Lincoln Laboratory  
Undergraduate Research and Innovation Scholar  
Project: Improving Human-Robot Interaction  
Advisor: Julie A. Shah  

Current research on planning human-robot interaction is mostly based on sampling-based or human demonstration-guided motion planning, in which robots learn from a set of human demonstrations to generate plans for avoiding obstacles or performing an assistive task. However, simulating human motion is a complex problem due to the redundancy of the human musculoskeletal system; thus, it increases the cost of the solution/planning to manipulate the robot’s motion. Our research will focus on developing new task-based dynamic motion planning using single or multi-objective optimization techniques that eliminate basic physical and kinematical constraints of simulating human motion.

“Through this SuperUROP project, I want to gain professional research experience in the robotics field. I’m interested in applying my knowledge in machine learning and computer vision to improve human-robotic interaction. I hope to publish a paper by the end of the SuperUROP project if I have meaningful results to display.”
I appreciate this opportunity to see how the models can be applied to a theoretical aspect of machine learning in Artificial Intelligence (6.034), people to make better nutritional choices. After learning about the language processing to a practical objective of making it easier for optimizations in a language-agnostic and framework-agnostic way. Rhino — the proposed SuperUROP project — builds on top of the compiler-level parallel structure knowledge afforded by Tapir and implements automatic parallel code optimizations in a language-agnostic and framework-agnostic way.

“Through this SuperUROP program, I want to work with the START system to see how a system can understand words as knowledge. I will be working with natural-language annotations and learning to understand the START system. I am excited about this project because I have always been curious to see how a machine can understand the words we speak.”

Jiahao Li
MIT EECS | Keel Foundation Undergraduate Research and Innovation Scholar
Project: Rhino: The Optimizing Parallel Program Compiler
Advisor: Charles E. Leiserson

Modern computation applications rely heavily on multicore systems. However, today’s compilers are weak at optimizing parallel programs compared to serial ones. One reason for this weakness is a lack of ways to express parallel constructs at the level of the compiler’s intermediate representation (IR) and consequently a lack of knowledge of the program’s parallel structure at the compiler level. Previous solutions including Tapir have addressed the lack of IR-level expressiveness but do not allow the use of common parallel optimization patterns. Rhino — the proposed SuperUROP project — builds on top of the compiler-level parallel structure knowledge afforded by Tapir and implements automatic parallel code optimizations in a language-agnostic and framework-agnostic way.

“I am interested in participating in this SuperUROP project because I love having the opportunity to apply machine learning and natural language processing to a practical objective of making it easier for people to make better nutritional choices. After learning about the theoretical aspect of machine learning in Artificial Intelligence [6.034], I appreciate this opportunity to see how the models can be applied to a real-life situation.”

Ka Wai (Joanne) Lee
MIT EECS | Keel Foundation Undergraduate Research and Innovation
Project: Generating Annotations from Wikipedia to Answer Questions
Advisor: Boris Katz

Much information on the Internet exists in the form of text. In Wikipedia, specifically, there are textboxes called “infoboxes,” with mappings of attributes to values that contain highly condensed information. We are trying to organize that data for improved, more natural data access. This project focuses on generating annotations, or small, understandable facts, from Wikipedia infoboxes. I will use morphological analysis of relations and other natural language processing (NLP) techniques to automatically generate annotations. The algorithm will then be used to scour Wikipedia pages to generate annotations that will contribute to the START Natural-Language Question Answering System, which answers natural-language questions by searching in its knowledge base.

“Through this SuperUROP program, I want to work with the START system to see how a system can understand words as knowledge. I will be working with natural-language annotations and learning to understand the START system. I am excited about this project because I have always been curious to see how a machine can understand the words we speak.”

Jiayi Lin
Undergraduate Research and Innovation Scholar
Project: Learning to Speak by Inverting and Composing Motor Programs
Advisor: Joshua Tenenbaum

Human speech learning is remarkably versatile. We are able to recognize and imitate new words after exposure to just one or a few examples, correct how we speak according to feedback, and learn new languages without “catastrophically forgetting” the languages we have previously learned. To perform the complex speech learning tasks that come so naturally to us in adulthood, we must understand what our representations of speech look like in the first place, and how the same representations can be versatile enough to be used with a variety of contexts and examples. To this end, we propose a computational model of how humans learn to speak from scratch, starting with just the basic components available to an infant: the ability to produce and perceive sounds. Given a perceived speech utterance, the system learns to invert the sound into its underlying articulatory latents, compose primitive articulatory motor programs to create an arbitrarily complex utterance, and update its representation by listening to itself and adapting with a reinforcement learning paradigm.

“I’ve enjoyed conducting speech research with Professor Josh Tenenbaum’s group for the past year. I’m excited to continue exploring how humans learn and building on these insights to engineer cognitively plausible models for artificial intelligence.”
“First used as a platform for bitcoin, blockchain’s use has now expanded to identity management transaction processing and chain of ownership documentation. In the summer of 2016, while an intern at NASDAQ, I had the chance to develop a proxy voting protocol on blockchain. This SuperUROP project is an opportunity to apply and further advance my knowledge of blockchain technology and vastly improve current standards of healthcare data sharing between providers.”

“Past UROPs have helped me find my interest in computer graphics and tools and have helped me feel prepared for future work with research. I am excited about the opportunity this SuperUROP project provides for me to do work that matches my interests. I hope to apply the skills I have learned in class and to gain expertise in the fields I am interested in by creating a finished product in this project.”

“Epitomizing MIT’s motto of mens et manus (“mind and hand”), this SuperUROP project provides me with a great opportunity to apply my academic knowledge and skills in solving real-world problems. I look forward to integrating my double-major background in computer science and mechanical engineering to advance the development of autonomous vehicles.”

“I have worked with the Speech Communications Group in the past and found both the work and the goal of the research interesting and impactful. Moving forward, I would like to help make the speech system come to fruition by improving the system’s detection rates alongside of deploying it for use.”
Varun Raj Mangalick
MIT EECS | Lincoln Laboratory
Undergraduate Research and Innovation Scholar
Project: Inference and Generation of HTTP-Based Web Application Program Interfaces
Advisor: Martin C. Rinard

Software engineering increasingly involves creating programs using simple core computational logic but running on platforms with complex interfaces. These platforms provide functionality including distributed computation, widespread web deployment, and extensive security measures. Due to platform complexity, much of software engineering time is spent trying to adapt existing work to make a core computation work in target contexts. A tool developed by the Rinard Lab at MIT aims to solve this problem inputting seed program written in the developer’s language of choice and inferring the functionality of the program. It then regenerates this functionality into code using a platform of the user’s choice. My project is to add a JavaScript Open Notation (JSON)-based application program interface (API) as a platform choice.

“Through this SuperUROP project, I hope to learn about programming language implementation and compiler design. I’ve taken a course in computer systems engineering and would like to apply the principles I’ve learned towards a deeply focused and intellectually satisfying project. By the end of this SuperUROP project, I hope to have created a language unique and complete enough that it can viably be used to solve some database problems.”

Cheahuychou Mao
MIT EECS | Keel Foundation
Undergraduate Research and Innovation Scholar
Project: Using Wikipedia Infoboxes for Natural Language Question-Answering
Advisor: Boris Katz

START is a natural-language question-answering system developed at the Computer Science and Artificial Intelligence Laboratory (CSAIL). The system parses incoming questions into ternary expressions and matches the parsed queries against its knowledge base of natural language annotations also stored as ternary expressions. This project aims to provide an automatic way to generate high-precision annotations for Wikipedia articles to enable START to answer a broader range of questions. That includes finding a way to extract necessary information from many sources within Wikipedia and to generate annotations that will indeed match the potential queries and designing a robust system that can search efficiently across the whole of Wikipedia to allow quick real-time question-answering and that can compile data and generate annotations at adequate speed.

“I am participating in SuperUROP because I want to gain more research experience and to contribute to a project that is valuable and fascinating for both InfoLab and myself. The project involves many aspects of computer science within my interests, such as natural language processing, potentially machine learning, and system design. I am excited to apply my knowledge and interests to my project.”

Tarek Mansour
MIT EECS | Angle Undergraduate Research and Innovation Scholar
Advisor: Regina A. Barzilay

Mammograms contain a lot of information that the human eye can’t see or decipher. Using deep learning can help detect very subtle changes and low-level patterns. The current aim of this project is to work on deep learning models that can correctly predict whether or not a patient has a risk of developing cancer. We are currently utilizing density, birads, and other scores to make such predictions.

“I am hoping to get serious hands-on research experience with machine learning. My interest in machine learning and my work in Professor Barzilay’s lab in the past year helped prepare me for the job. I am trying to learn more about machine learning and how to apply it to real-life problems. To me, the best part of the project is that I will be working on solving cancer-related problems!”

Akaki Margvelashvili
EECS | Angle Undergraduate Research and Innovation Scholar
Project: Identifying Cancer on Breast X-Ray Images
Advisor: Regina A. Barzilay

Breast cancer is obviously a major medical issue today. Doctors need to be well-trained to successfully diagnose breast cancer from x-ray images, but they are still nowhere close to being perfect in doing so. This project’s goal is to build a machine learning algorithm that will successfully detect and locate cancer regions in a given breast X-ray image.

“Participating in SuperUROP is a great way for me to work on an important project using the Machine Learning knowledge I gained from Machine Learning (6.867) and the UROP I did with Professor Regina Barzilay last year. It will help improve my research work ethics and skills.”
This project will focus on the outcome of patients with sepsis in an intensive care unit (ICUs) setting. Particular outcomes of interest include: cardiac dysfunction, septic shock, acute kidney injury, and liver failure. We will identify physiological factors that lead to risk of organ failure in sepsis using the MIMIC III database. From there, we will characterize septic patients with different outcomes. We will then use this labeled dataset to build predictive models using machine learning techniques such as logistic regression and neural networks. The overall goal of the project is to explore the feasibility of implementing an early warning system to alert clinicians about patients at high risk of developing organ dysfunction.

“Through the SuperUROP project, I hope to gain more experience working on a long-term, impactful research project. I am excited to apply the machine-learning techniques I have learned in my coursework to a real clinical dataset. With this project, I will use my knowledge to help people while improving my own skills.”

Barry Anthony McNamara
MIT EECS | Draper Laboratory Research and Innovation Scholar
Project: Responsive Layout Generation
Advisor: Daniel N. Jackson

Déjà Vu® is a software-development platform that aims to take advantage of the observation that much of software design is simply recombining pre-existing concepts in novel ways. Déjà Vu provides a library of clichés — components that are pre-implemented by experts — with which designers can construct richly featured web applications. Currently, we have about a dozen clichés and a handful of sample applications that use them. Throughout the next year, we plan to work on the automatic generation of HTML and CSS based on the clichés chosen by the user, along with a basic description of the application layout. This will decrease the technical knowledge required to build apps using Déjà Vu, bringing us closer to our goal of abstracting design from implementation details.

“I am participating in SuperUROP because I have heard from friends that it is a great experience and the best way to do research as an undergraduate. I found my project as a result of Software Studio (6.170) last fall, the content of which relates directly to my project. I hope to gain a deeper understanding of software design and am excited to be working on a single project for an extended period of time.”

Edgar Minasyan
MIT EECS | Lal Undergraduate Research and Innovation Scholar
Project: Parametric Inversion of Non-Invertible Functions
Advisor: Armando Solar-Lezama

Many of the most important problems in artificial intelligence can be formulated as inverse simulations of computer programs; however, only rarely are programs literally simulated in reverse. Inverse simulation is hard because (a) non-injectivity of the forward program renders the inverse grossly ill-posed, and (b) it requires search over complex, highly constrained spaces. We introduce parametric inversion in response to both of these concerns and present algorithms to simulate non-trivial programs in reverse. A parametric inverse is a generalized inverse function; it uses a parameter to disambiguate between the multiple inputs that a non-invertible forward function maps to the same output.

“During my three years at MIT, I have developed a strong passion for research, so I want to participate in SuperUROP. I’ve already been doing UROP for my whole junior year and will continue extensive research with the same group and graduate student. Eventually, I hope the experience I gain from this program will help me in my pursuit of graduate degrees.”

Elizabeth Ella Martin
MIT EECS | Himawan Undergraduate Research and Innovation Scholar
Project: Predicting Outcomes of Sepsis in Intensive Care Units (ICUs)
Advisors: Roger Mark and Elizabeth Martin

This project will focus on the outcome of patients with sepsis in an intensive care unit (ICUs) setting. Particular outcomes of interest include: cardiac dysfunction, septic shock, acute kidney injury, and liver failure. We will identify physiological factors that lead to risk of organ failure in sepsis using the MIMIC III database. From there, we will characterize septic patients with different outcomes. We will then use this labeled dataset to build predictive models using machine learning techniques such as logistic regression and neural networks. The overall goal of the project is to explore the feasibility of implementing an early warning system to alert clinicians about patients at high risk of developing organ dysfunction.

“I am participating in SuperUROP because I have heard from friends that it is a great experience and the best way to do research as an undergraduate. I found my project as a result of Software Studio (6.170) last fall, the content of which relates directly to my project. I hope to gain a deeper understanding of software design and am excited to be working on a single project for an extended period of time.”

Miranda Nicole McClellan
MIT EECS | Cisco Undergraduate Research and Innovation Scholar
Project: WebRTC-Based Network Performance Measurements
Advisor: David Clark

Network speed tests are used to understand the viability of the connection between a user’s local machine and another point in the internet. Current browser-based speed tests measure performance metrics such as the ping time, the time to deliver a message and receive a reply, the download speed, and the upload speed. However, differences in assumptions and methodologies cause discrepancies in the results. I will build and analyze a set of network performance tests using a variety of network metrics such as bulk transport capacity, latency, and loss. The tests will utilize WebRTC, an application program interface (API) and communication protocol provider, for real-time communication for browsers and mobile apps.

“I am excited to participate in SuperUROP because I took a networking course that sparked my interest in computer systems. I want to know more about communication between machines on peer-to-peer networks, the process and metrics used to evaluate network performance, and how these metrics are used in policy and marketing decisions.”
Natalie Mionis
MIT EECS | Advanced Micro Devices Undergraduate Research and Innovation Scholar

Project: Power/Accuracy Tradeoff in FPGA Low-Resolution Neural Network
Advisor: Anantha P. Chandrakasan

I will be developing a binary neural network on a field-programmable gate array (FPGA). Binary neural networks have 1-bit coefficients, which may greatly reduce their power usage compared with real-valued networks. Although slightly less accurate, binary neural networks with low power consumption may be appropriate for certain use cases and contexts. I will start by implementing a common real-valued neural network on an FPGA. Once I understand the implementation of real-valued neural networks on an FPGA, I will begin developing a binary neural network. By replacing multiplications with binarization power of two shifting and bit packing, I will build a binary neural network. If time allows, I would like to research the relationship between coefficient bit size, accuracy, and power consumption on an FPGA.

“I am participating in SuperUROP because I am very interested in applying my hardware knowledge to machine learning. In Introductory Digital Systems (6.111), I learned about Verilog code and FPGAs. I am excited to apply this knowledge to develop a neural network on an FPGA platform, particularly for the purpose of emotion detection. Because I have an electrical engineering background, I hope to learn more about machine learning in my SuperUROP project.”

Mikayla Ida Murphy
MIT EECS | CS+HASS Undergraduate Research and Innovation Scholar

Project: Digital Governance: Using Big Data to Measure Government Transparency Online
Advisors: Sam Madden and Daniel Hidalgo

Local governments play an important role in Americans’ lives but relatively little attention is paid to how these governments operate and disseminate information such as budgets meeting minutes and salaries. MIT GOV/LAB has developed a machine learning pipeline to automatically evaluate local government websites, enabling us to complete the first comprehensive set of transparency ratings for local governments in the United States. Via data visualizations and other publicity methods, we plan to use these transparency ratings to inform government officials and citizens about the relative transparency of their local government and assess which methods are most effective in improving such transparency.

“I’m excited for the opportunity to combine my interests in political science and computer science into this research project. I hope this project will encourage local governments to be more transparent and, in the process, improve the lives of citizens across the United States.”

Katy Muhlrad
MIT EECS | Draper Laboratory Undergraduate Research and Innovation Scholar

Project: Using GelSight to Identify Objects by Touch
Advisor: Russell L. Tedrake

Despite recent advancements in robotic manipulation and heightened interest in pick and place applications, robots still struggle with basic manipulation tasks. With millions of industrial robots worldwide performing manipulation tasks that rely on computer vision, it is crucial to identify and improve upon weaknesses in their systems. To improve a robot’s tactile perception ability, we want to augment traditional computer vision with tactile data from a GelSight touch sensor. The first part of this project will focus on developing motion planning methods to construct a labelled database of what different objects feel like to a robot with a GelSight sensor. The second will focus on migrating from recognizing objects with computer vision to recognizing them with only the GelSight.

“I am participating in SuperUROP because I am excited about being able to combine my background in both computer science and mechanical engineering to a robotics project where the software that the robot is running is equally important to how the robot is physically interacting with the world.”

Helmut John Naumer
MIT EECS | Analog Devices Undergraduate Research and Innovation Scholar

Project: Vasculature Graphical Model Extraction: A Framework for Inference
Advisor: Max Shulaker

Circuits fabricated from carbon nanotube (CNT) field-effect transistors (CNFETs) are projected to achieve over an order of magnitude benefit in energy efficiency compared to silicon-based circuits. However, due to challenges with fabricating this emerging nanomaterial, experimental demonstrations of CNFET-based circuits to date have been small-scale, with severely limited performance. This research aims to develop robust manufacturing processing for CNFET-based circuits, which also addresses some of the major CNFET-based challenges that exist with current fabrication techniques. The project will begin by demonstrating the feasibility of depositing densely aligned CNTs across large substrates and will move to using these methods to design, fabricate, and test complex digital CNFET-based systems.

“I first met Professor Max Shulaker in his course on devices in fall 2016. Rather than just improving devices, his research focuses on building full systems. As I am still narrowing down my passion, I like that this group includes everything from devices to network analysis in its goals. I worked in the group over the summer, and SuperUROP is a way to continue devoting my time to research.”
Tensor algebra is a powerful tool with applications in machine learning, data analytics, engineering, and the physical sciences. The combinations of possible tensor operations are infinite, so it is impossible to manually implement and optimize kernels for every operation of interest. The Tensor Algebra Compiler ("taco") is an open-source C++ library that automatically generates performant kernels to compute any compound tensor algebra operation with the use of compiler techniques. My research will focus on improving the performance of taco by exploring different performance-engineering approaches, such as vectorization and parallelism. The goal of taco is to provide performance competitive kernels for any possible tensor operation.

“I am participating in SuperUROP to get a feel for what it is like to do computer science research. As my time at college comes to an end, I have to decide whether I want to continue my studies through graduate school or focus my career elsewhere. I believe SuperUROP is the perfect opportunity to do that while contributing to an important open-source project. I look forward to learning what compilers are all about.”

Movement detection and object recognition provide various applications to improve our lives. Recently, Professor Dina Katabi’s group created the sensor-generating wireless signal that can pass through a wall, allowing us to locate people and detect their movements within their homes. Some of its applications include monitoring the elderly, detecting falls, analyzing heartbeats for health issues, and remotely controlling lights, among others. However, there are two main problems: fictitious human detection caused by wall reflection, and time-consuming setup caused by manually measuring and drawing floor plans. The goals of my SuperUROP project are to detect the walls and differentiate between signals from real humans and those from wall reflection, and to automate the generation of floor plans using the sensor’s data.

“I am participating in this SuperUROP project because I like its innovative ideas about using wireless signals to detect people’s movement and differentiate objects. Moreover, I am very interested in computer vision after taking Advances in Computer Vision (6.869) last year. I want to develop my knowledge and research-level skills. I would like to publish a paper and come up with some additional useful applications from this SuperUROP project.”

Graph coloring has long stood as an important computer science problem. The different approximation techniques for the NP-complete problem represent a trade-off between approximation accuracy and efficiency. Previous work had parallelized many of these methods, however the Saturation Degree heuristic algorithm, one of the most accurate but of the slowest as well, remains hard to parallelize. This is because, the order of the program execution is assigned dynamically. In this SuperUROP project, I will use Swarm, an architecture designed in MIT for ordered parallelism, to parallelize this algorithm. Swarm is capable of speculating different graph coloring orders in parallel, and later disregard the invalid orderings, effectively parallelizing the algorithm while behaving as the serial algorithm would. This project aims to speed up the approximation of an important problem in computer science, in addition to contributing to the novel Swarm architecture.

“From my point of view, research is an essential complement to classes. This research project provides me with an opportunity to work closely with two different fields I am passionate about: performance engineering and computer systems design. I am looking forward to learning more about the workflow of research, from the brainstorming stage through implementation, ending with production.”

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Afika Nyati
MIT EECS | Keel Foundation
Undergraduate Research and Innovation Scholar
Project: Flow Presentation: An Alternative Text Presentation for Digital Reading
Advisor: Dorothy W. Curtis

Patricio Noyola
MIT EECS | Keel Foundation
Undergraduate Research and Innovation Scholar
Project: Improving the Performance of the Tensor Algebra Compiler
Advisor: Saman P. Amarasinghe

Cattalyya Nuengsigkapian
MIT EECS | Analog Devices
Undergraduate Research and Innovation Scholar
Project: Practical Multi-Camera System for Indoor Localization and Human Identification
Advisor: Dina Katabi

Omar Obeya
MIT EECS | Draper Laboratory
Undergraduate Research and Innovation Scholar
Project: Parallelizing Saturation Degree Heuristic for Graph Coloring Using Speculative Parallelism
Advisor: Daniel Sanchez

Afika Nyati
MIT EECS Undergraduate Research and Innovation Scholar
Project: Flow Presentation: An Alternative Text Presentation for Digital Reading
Advisor: Dorothy W. Curtis

With the rise of information production resulting from society’s gradual shift towards a globalized social system and increased use of connected devices, there is a greater responsibility today to remain well-informed about current affairs and news as a means of facilitating better decision-making and learning. For this reason, we face a greater pressure to consume more information — despite the fact that our time resources prove to be restricted, along with the reality that our methods of information consumption have remained unchanged. Moreover, most information is consumed in textual form. My research seeks to explore ways in which to enhance an individual’s reading ability through the utilization of alternative textual representations designed to improve reading by eliminating undesirable reading habits and efficiently guiding an individual through a textual passage. Through this research, I hope to preserve time spent reading by optimizing a reader’s rate of information acquisition.

“Due to my interests in human-computer interfaces and information design, I am drawn to the role that information representations play in organizing knowledge and aiding in effective and efficient understanding of data. With natural language being the chief modality of information transfer today, I found the lack of development in the area of alternative textual representations peculiar. I am participating in SuperUROP because I see it as an appropriate context for learning about hypothesis development with the guidance of leading professionals.”
With the advent of high-resolution photography, the film industry has grown rapidly due to advances in aesthetic quality while the theater industry lags behind. While theater should be at the forefront of helping confront critical social issues such as racism, it is currently not effective in doing so. This is due to a lack of a standardized communication infrastructure. This research will focus on understanding the problem and designing Theatryc, a system that we hope will address the issue by providing a platform through which theater producers can advertise, collaborate, staff, attract sponsorship; and provide the public at large a forum for discussing theater works and world happenings.

“I recently picked up theater as my Humanities, Arts, & Social Sciences (HASS) concentration. Realizing that I could leverage my technical background in computer science to drive innovation in the theater arts motivated me to be part of the SHASS-SuperUROP. I hope to gain a better understanding of the scope of the communication breakdown within the theater field and, consequently, revolutionize how theater is received by society.”

To integrate renewable energy technologies into the existing grid, large-scale energy storage systems are necessary to ensure that power can be stored until it is needed. The Redox Flow Battery (RFB) has shown potential for this application but requires improvements in efficiency and cost. By optimizing the electrode, RFB efficiency can be improved by reducing charge transfer resistance, mass transfer resistance, and ohmic overpotentials via modifications in surface chemistry, electrode micro-structure, and conductivity. This project will selectively modify the surface of the porous electrode by adding polymers with desired properties such as wettability and electrical conductivity. We will first characterize the properties of the modified electrode, then determine its effects on RFB efficiency.

“Through my SuperUROP project, I want to gain more experience with the research process and apply what I’ve learned in class to a real-world application. I’m excited to learn more about energy storage, flow batteries, and porous media, and hope to find ways to improve electrodes for redox flow batteries.”
This project focuses on verifying correctness of Spark’s SQL operations and optimizations via Coq, a formal proof-management system. The first part of this project was done in my previous UROP experiences, which involved formalizing translation of SQL operations to builders, a core feature behind Spark for back-end optimization. After successfully developing the basic formalization, the goal of this SuperUROP project is to prove some optimizations for the formalized Spark’s SQL operations so that we can translate SQL queries to our formalized and optimized builders for fast querying while preserving the correctness of the output.

“I’m participating in SuperUROP because I want to research and explore program verification – that is, how to ensure that a program is semantically correct and runs as intended. I also want to learn more about tools and techniques for formalizing correctness of a program.”

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ConcertCue brings the traditional music program to life: it is a real-time program web application for concerts. Users are provided relevant information at precisely timed moments of a live performance, thus enhancing the concert. Currently, these timed moments are manually synchronized during a concert. This project will focus on adding automatic synchronization of live music to the prerecorded annotated music. The typical approach to synchronizing two pieces of music Dynamic Time Warping (DTW) is offline requiring all audio data a priori. However, as we need real-time synchronization, the goal of this project is to create a real-time variant of DTW. I will analyze the performance of the current variants, develop other techniques, and identify the best approach to take in the end.

“This project embodies what I love about computer science — its interdisciplinary nature — and combines with another passion: music. I have studied some basics of signal processing, and I am excited about this opportunity to learn more about it and related topics through my SuperUROP project. It will also be a wonderful way to explore the intersection of music and technology, particularly how we can use technology to improve our musical experiences.”

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Energy Equalization (EEQ) is a signal-processing scheme that combats the reduced dynamic range of hearing-impaired listeners. It reduces amplitude fluctuations of noisy speech without introducing excessive distortion by normalizing the fluctuating short-term signal energy to be equal to the long-term average signal energy, thus amplifying low levels of speech. Our research focuses on implementing a Voice Activity Detector (VAD), which will classify signals as speech or noise prior to EEQ processing, with the goal of implementing EEQ only when speech is present. We will incorporate MATLAB’s VAD G729 algorithm into the current algorithm and compare EEQ processed signals with and without VAD. We will conduct acoustic analyses of both types of processed signals to evaluate the effect of VAD.

“This SuperUROP project, I want to gain more experience in signal processing and contribute to a field I am interested in. I have taken signal processing courses and I want to expand on that knowledge with real-world applications. I hope to publish a paper by the end of the SuperUROP and become a better researcher.”

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The human perceptual system can solve many vision tasks; however, current computational models are largely specialized for a single task. In this project, we aim to solve the multitask perception problem by mitigating the catastrophic forgetting observed in sequential learning of different visual problems. We will use Hierarchical reinforcement learning (RL) and elastic weight consolidation (EWC) in an effort to solve this problem, which is simplified and constrained to the Atari 2600 games.

“I’m participating in SuperUROP because I want to learn to approach any new problem that my curiosity brings to me. I also think having the resources in the class will help me learn how to be more successful in a research environment. In my project, I am specifically interested in learning more about deep reinforcement learning and how it applies to solving games. Solving games and making artificial intelligence (AI) models that can compete with humans is cool.”
Every day, we are confronted with decisions. We want to understand the biological basis of decision making, but doing so by trying to understand the nervous system is an extraordinarily complicated task.

We have previously shown that there is reason to believe that bacteria could feasibly act as an analog for neurons in a computational sense. To better understand decision making, we therefore consider the stochastic binary choice to become competent (the ability to uptake extracellular bacteria) in Bacillus subtilis, a well-characterized model bacterium, through stochastic and deterministic mathematical models that are then implemented in a computational agent-based model. Our agent-based model is supplemented by wet-lab work being done to determine the diffusion limitations of an extracellular signal called ComX that helps cells become competent. We hope that this work will help elucidate in a mathematical, computational and biological sense the competence binary choice B. subtilis cells undergo and also provide the foundation for further examination of the similarities between ways in which decisions are made by organisms in the natural world.

"I’m participating in SuperUROP because I’d like to spend time on a research project. I have a background in biology and neuroscience, which really complements my EECS/machine learning background and helps me see where biological principles can be applied to the networks I’ll be working on. I’m honestly excited to be working on my project! It’s my first time working without grad/postgrad supervision."

"SuperUROP is a great opportunity to focus on research as an undergraduate. I have worked with this lab as a UROP participant and am really excited about its members’ work. I hope to apply and develop my current knowledge of machine learning and system design as well as practice my communication and presentation skills."

WiTrack is a device that uses wireless signals and their reflections to track 3D motion without requiring the use of any additional sensors. It has already been used in smart-home applications such as non-intrusive health monitoring to track a user’s breathing and heart rate and allowing users to control household appliances. To expand the capabilities of WiTrack as a smart-home device, I will be adding a machine learning system to accurately count the number of people in a home, despite WiTrack’s limited range, and make inferences about the setup of a room or house. In addition, the system will recognize specific users, allowing personalized control of the home.

"Electric vehicles will be the future of the automobile industry. Through this project, I want to identify and develop effective charging strategies that minimize costs and the impact on the electric grid. In addition, I hope to explore the economic question of what is preventing electric cars from gaining precedence today. I am also excited to indirectly contribute to the departure of reliance on fossil fuels and the attenuation of climate change."

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Andrew Rouditchenko  
Undergraduate Research and Innovation Scholar  
**Project: The Sound of Pixels**  
*Advisor: Josh McDermott*

Our research focuses on developing machine learning models that learn the relationships between vision and sound. In the first part of our project, we aim to make a model that separates multiple audio sources in the same video. This work has numerous applications that range from improving audio smart devices to enhancing recorded videos.

“Through this SuperUROP, I aim to have a quality research experience combining my passions for computer science and audio technology. I will apply the skills I have learned from courses in machine learning, signals and systems, and music technology. I am interested in pursuing a graduate degree in computer science and I hope to use this experience to refine my research interests and develop relationships in the research community.”

Helen A. Sakharova  
MIT EECS | Himawan  
Undergraduate Research and Innovation Scholar  
**Project: Computer-Guided Engineering of Neuronal Circuits**  
*Advisor: Ron Weiss*

The ability to create a precisely specified neuronal circuit in a cell culture would provide valuable opportunities to investigate ideas about the development and function of neuronal networks. My project will focus on genetically engineering neurons to form high-level neuronal circuits in response to computer-controlled light signals. This will be done through optogenetically controlled axonal and synaptic pruning, apoptosis, and neurotransmitter type change. The project will also involve the creation of an algorithm to process images of neuronal circuits and issue the optogenetic commands needed to achieve the desired arrangement of cells. The goal of this project is, starting from a random group of neurons, to be able to achieve a specific configuration of cells using optical signals.

“Through this SuperUROP project, I hope to gain practical experience in both genetic engineering and computer vision. I have significant background knowledge in both biological research (from previous UROPs) and computer science. I am excited for the opportunity to apply these two skill sets, learn more about neuroscience, and pursue an independent research project.”

Christopher Shao  
MIT EECS Undergraduate Research and Innovation Scholar  
*Advisor: Adam Chlipala*

One challenge of building software systems that handle sensitive information is ensuring that their components meet certain security policies, describing what information each component is allowed to access and pass on. In complex systems where information may flow through many different components, it’s difficult to reason about all possible flows of information and check that a policy is satisfied in every case. This project aims to develop a framework to specify security policies, build larger systems from user-provided implementations of components, and automatically verify that these systems adhere to their policies. This framework will be formalized in the Coq proof assistant, allowing users to derive machine-checked formal proofs showing that the security policies are satisfied.

“I became interested in formal verification and interactive theorem proving after doing a UROP project with Professor Chlipala. Through this SuperUROP project, I hope to learn more about the different ideas and challenges in applying formal methods to larger-scale problems.”
systems function usefully, but operate very differently from human speech perception. This project involves work on a speech signal-analysis system that is modeled more closely on what we know about human speech processing. We will work to develop a consolidator module to integrate acoustic, lexical, and prosodic information derived from the signal into a preliminary hierarchical structure for the entire phrase or utterance even before the speaker’s intended words are fully recognized.

“I’m participating in SuperUROP because I’m extremely interested in pursuing novel research. My preparation for this particular project includes having taken Algorithms for Inference [6,438], but I still have a lot to learn about even the basics of causal inference. I hope to learn everything from the fundamentals to the latest research and applications. I’m most excited about my potential to help surmount current limitations in the field.”

Anna Sinelnikova
MIT EECS Undergraduate Research and Innovation Scholar
Project: How the Tolerance Principle Plays into Language Acquisition
Advisor: Robert C. Berwick

If we are to understand the full scope of language acquisition, we must understand how linguistic rules and exceptions are acquired. Professor Charles Yang formulates a Tolerance Principle to describe the point at which children learn a rule to apply to all items presented instead of memorizing each one by one as an exception. The number of exceptions a child can tolerate without relinquishing the grammar rule is: “n/log(n),” where “n” is the number of words heard at that point (Yang 2016). This project will further study the Tolerance Principle from an empirical and conceptual point of view and test its versatility and extensions across a wider range of child acquisition construction types, such as the English past-tense formation and alternation patterns in verbs (Levin 1993).

“I’m participating in SuperUROP because I’m extremely interested in researching exceptions. I’ve been pursuing further education and research in computational linguistics and seeing whether this is an area where I would like to do further research.”

Chandler Squires
MIT EECS | Angle Undergraduate Research and Innovation Scholar
Project: Direct Estimation of Differences in Causal Graphs
Advisor: Caroline Uhler

Many diseases, including schizophrenia and cancer, are caused by complicated, abnormal interactions between genes. One way to model the function of genes is a directed network of random variables corresponding to the expression of each gene. Often, the task of learning the exact structure of such a network is intractably complex due to the number of interactions taking place. However, it can be much more efficient to learn the difference between two networks when that difference is sparse – that is, most of the structure is the same between the two networks. I will join a project to develop/test algorithms to learn the difference between two such networks, using simulations and real data on gene-regulatory networks from the Broad Institute to prove the accuracy and efficiency of the approach.

“I’m participating in SuperUROP because I’m most excited about my potential to help surmount current limitations in the field.”

Jeremy Paul Stroming
MIT AeroAstro | Lincoln Laboratory Undergraduate Research and Innovation Scholar
Project: Earth Speaks: A Digital Ocean Platform for Citizen Engagement
Advisor: Dava Newman

In the spirit of Buckminster Fuller’s “Operating Manual for Spaceship Earth,” EarthThinx is an envisioned operating system for Spaceship Earth. The system will empower every person to act every day to heal and preserve our planet. The technology platform will use cognitive computing, artificial intelligence, data mining, pattern recognition, and natural language to survey and diagnose Earth’s four subsystems (land, oceans, atmosphere, and near-space) in near real-time and offer solutions for everyone to take action through technologies such as smart phones, smart watches, digital assistants, and social media. EarthThinx will be a cognitive, visually engaging tool for global citizens, businesses, and governments to make smarter economic and environmental decisions on a daily basis.

“MIT celebrates and facilitates a culture of bold propositions to solve complex problems, and EarthThinx is the epitome of that mindset. I see this SuperUROP project as a chance to explore my own capabilities and apply my learning towards solving a real-world challenge in an academic research setting while building strong relationships with inspiring faculty mentors and industry advisors. I want to produce work that I will be proud to sign my name to.”
Among the novel renewable energy technologies, a new class of wind energy converters, Airborne Wind Energy Systems (AWES), is rapidly growing. This new generation of technology employs aircrafts to capture high altitude winds that are inaccessible to traditional wind turbines. The project aims to apply the techniques of machine learning to the task of autonomously controlling the aircraft in order to optimize its trajectory and maximize the system’s energy efficiency. An airborne wind energy system prototype with a fixed ground station and a non-powered soft kite is manufactured and is used as the testing platform for this project. The final part of the project involves building a demo system that implements the RABBIT protocol on a custom-designed chip and a field-programmable gate array (FPGA).

"I want to participate in SuperUROP to work on an interesting long-term research project in the fields of transmissions and security. My UROP projects, as well as previous work in classes such as Introduction to Algorithms (6.046), Design and Analysis of Algorithms (6.046), and Computer Systems Engineering (6.033) helped me prepare for this. I hope to learn more about the cutting edge in security techniques and the IoT and gain valuable developer skills that will allow me to be more involved in future EECS projects."

"SuperUROP offers a great opportunity to immerse myself in research as an undergraduate. It will allow me to explore cutting-edge research areas in depth and will help me figure out whether I’m interested in pursuing a career in academia. I’m really excited to combine my knowledge of computer science and aerospace engineering and apply them onto a real-world application that could potentially make an impact on how we think about renewable energy."
Christopher Sweeney
MIT EECS | Angle Undergraduate Research and Innovation Scholar
Project: DeepSim: A Learned Approach to Generating Realistic Synthetic Depth Images
Advisor: Russell L. Tedrake

Modern perception systems are highly complex. They operate on high-dimensional data and often use black-boxed approaches such as deep learning to make sense of the world. The complexity and lack of understanding in these perception systems are tolerable in many settings, but when deploying these systems on robots with real-world consequences, it is essential to ensure expected behavior in all environments. This project will strengthen robust perception from the context of robotic manipulation. To achieve this goal, we will generate synthetic vision data using model-based and data-driven methods to adversarially test modern perception systems. Then, with a better understanding of inputs that cause perception failures, we will develop new systems that can provide guarantees for robust behavior.

“I am participating in SuperUROP because I want to use skills learned from previous UROPs and classes such as Robotics: Science and Systems [6.141] to dive deeper into robotics research. I have always had an interest in robotics for the multidisciplinary skills the field requires. Through this project, I hope to contribute to cutting-edge research in robotic perception.”

Brian Tom
MIT EECS Undergraduate Research and Innovation Scholar
Project: Learning Program Embeddings with RNNs
Advisor: Michael Carbin

Establishing a metric to compare the similarity of two pieces of code in terms of style, functionality, and performance is essential to creating systems that can automatically perform optimizations, generate code from specifications, and simply search through a code base. However, current approaches still only rely on edit distance from either characters or from the abstract syntax tree. This representation, while easy to implement and relatively performant, is unable to compare code across different languages or code that has the same functionality but very different structural arrangements. For this SuperUROP project, I am attempting to use neural networks to learn an optimal representation for code that can efficiently and accurately be used for common code-search related applications.

“I am participating in SuperUROP because, after three years at MIT, I have finally figured out that research is the heart and soul of MIT undergraduate education. My background in compilers through my internships is directly related to the approach that my advisor and I are taking with this project. I hope to learn more about machine learning and the processes that are the most effective at tackling an open ended problem. This is also what I find the most exciting about the project.”

Tristan Andrew Fraser Thrush
MIT EECS Undergraduate Research and Innovation Scholar
Project: Learning Intuition for Problem-Solving with K-Line Theory
Advisor: Patrick H. Winston

The Genesis Story Understanding System has problem-solving resources, but currently doesn’t learn from previously seen problems. Genesis needs that ability to provide a computational model of high-level symbolic human intelligence (our research group’s goal). Currently, Genesis attempts to solve a problem by looking up an insight, which provides mapping from a question structure to an intention (action) that may answer the question. Genesis can have multiple insights for the same question structure; a single insight may lead to many intentions without a solution. Sometimes Genesis may need to follow a path of insights, but if Genesis has many insights for a question, finding that path ne infeasible. I hope to enable Genesis to learn a path of insights to use for a novel problem by recovering partial mental states from previously solved problems. Essentially, I hope to implement Minsky’s notion of K-lines in Genesis, producing a robust reinforcement learning system that takes example problems and insights, bootstraps a learning process by experimenting until it solves problems efficiently, and learns from and solves novel problems with the same question structure as the examples.

“I am fascinated with the idea of creating a human-level artificial intelligence (AI) and believe that developing a robust problem-solving apparatus is essential to doing so. Humans can leverage their memory to gain insights when solving novel problem. After working on the Computer Science and Artificial Intelligence Laboratory (CSAIL) Genesis story-understanding system, I hope to learn about how I can give it this ability as well.”

Loc Q Trinh
MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar
Project: Semi-Supervised Learning for Clinical Phenotyping
Advisor: David Sontag

My project aims to learn the phenotype of a patient, consisting of hundreds of different clinical state variables based on routinely collected, unlabeled, and “noisy” clinical data available in Electronic Medical Records (EMRs). These state variables help describe the patient and provide answers to high-level questions, such as whether the patient has an infection, an altered mental state, or a history of alcoholism, which are not obvious or directly observable from the clinical records. Obtaining these labeled descriptions for a supervised learning algorithm is often expensive and requires extreme efforts from clinicians. We hope to be able to efficiently and accurately infer these phenotypes from unlabeled clinical data in a semi-supervised manner, incorporating specialist expertise as guidance.

“Through this SuperUROP project, I want to gain more experience in health care research and make a positive contribution to my group. I have taken machine-learning courses and I want to expand on that knowledge with real-world applications, creating a social impact with my work. To me, even a 1 percent improvement in the field means a lot. I hope to publish a paper by the end of the SuperUROP project, if I have meaningful results to display.”
Surya Tripathi
MIT BE | Microbiome Undergraduate Research and Innovation Scholar
Project: Understanding the Early Infant Micro-Biome Selection Forces
Advisor: Ramnik Xavier

Mother’s milk has human milk oligosaccharides (HMOs), which a baby cannot digest but which are utilized by its gut bacteria. It is being established in research that a person’s microbiome highly stabilizes during the first three years of life and HMOs might have a role to play in shaping that microbiome. I will examine any personalized match between a mother’s milk and her child’s gut by utilizing HMO-utilizing bacteria from infant stool. I will then identify the genes which enable HMO-utilization based on transcriptional induction across many strains. Finally, I will try to deduce HMO composition given the microbiome of a child. This bidirectional matching will help me establish whether human milk continues to shape child microbiome for the first few years of life.

“I want to learn about the human gut microbiota and produce publishable results within the timeframe of one year. During the last 16 months at the Yilmaz lab in Koch, I have been part of two research projects and I presented my work at a UROP symposium in January 2017. I have learned to ask a question, design experiments, analyze the results, and answer the question. My long-term goal is to apply these skills to solve microbiome-induced obesity.”

Alexander Matthew Turner
MIT EECS | Lal Undergraduate Research and Innovation Scholar
Project: Introducing Backdoors in Neural Networks with Data Poisoning
Advisor: Aleksander Madry

Deep neural networks have shown remarkable performance even on extremely complex, highly nonlinear problems such as classifying objects in images, language translation, and robotics. Training these neural networks, however, takes vast amounts of time. A major factor increasing this time is the need to tune various higher-level parameters (hyperparameters) of the network. Testing each set of hyperparameters typically requires training the network from scratch, making the search very computationally expensive. This project aims to develop a principled understanding of hyperparameter search from the perspective of continuous optimization using a mixed theoretical and experimental approach to study the training of deep neural networks and the impact of hyperparameter settings.

“I am participating in SuperUROP because I have enjoyed previous research projects and I would like to expand my knowledge of machine learning while applying what I have already learned. I hope to publish a paper if my research has interesting results.”

Justin Daniel Tunis
MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar
Project: Indoor Localization via Sensor Fusion of UWB, IMU, and Camera Data
Advisor: Moe Win

Recently, a reliable solution for indoor localization has been heavily pursued. Ultra-wideband radio frequency (RF) has shown promising results as a technology for providing accurate indoor localization data. This project looks at combining this data with image data from cameras to set the foundation for potential applications to augmented reality (AR). Existing computer vision techniques will be used to identify optical markers in the image of the camera. These 2-D features will then be associated with a known 3-D coordinate of the optical marker. The output of the computer vision algorithm will be used in a data-fusion algorithm, along with the ultra-wideband (UWB) and inertial data, to achieve the final result. In future commercial indoor localization applications, optical markers can be replaced by 3-D indoor maps stored in a database.

“Indoor localization has been a topic that has interested me for a few years now, going back to freshman year when I wanted to develop a better way to be guided around grocery stores when shopping. I’m excited to explore new techniques in the space with potential applications to AR as that is another fascinating space. I love the research process and I’m excited about what this SuperUROP project has in store for me.”

Jason Giovanni Vellanueva
MIT EECS | Lincoln Laboratory Undergraduate Research and Innovation Scholar
Project: Improved State Estimation in Autonomous Vehicles
Advisor: Jonathan How

The AeroSpace Controls Lab (ACL) uses Vicon camera tracking technology to test its robots. Though capable and accurate, the indoor camera space limits many other projects that the team could potentially work on outdoors due to space restrictions and the lack of an accurate method for state estimation outdoors. Inherent in this is losing the ability to make autonomous complex maneuvers, or drifting in position or orientation over a prolonged period. I will explore methods for sensor calibration to confidently collect accurate data as well as implementing performance-optimized odometry and attitude algorithms to open up a new realm of experimentation for the ACL, both indoors and outdoors.

“Through this SuperUROP project, I want to contribute to research in clever ways that my education will allow. I’m currently taking Performance Engineering of Software Systems (6.172) and hope this coupling with research in C code will allow the IMU to function and become useful for tracking. What excites me most is the potential that this project has for opening new research doors.”
Aaron Richard Vontell  
MIT EECS | Texas Instruments  
Undergraduate Research and Innovation Scholar  
**Project: Accessibility of Mobile Applications**  
**Advisor: Lalana Kagal**  
This research studies the use of an ARTIQ-controlled field programmable gate array (FPGA) to produce TTL pulse sequences, which control various electromagnetic (EM) fields (microwave sources and visible lasers) that are resonant with relevant nitrogen-vacancy (NV) state transitions in diamond. It is also used to monitor emitted photons (using an avalanche photodiode) to determine when the pulse sequence has been successfully executed. These pulse sequences are then used to initialize NV-based qubits and perform computations. This work also provides a programmatic foundation for the development of a quantum repeater.

“I am participating in the SuperUROP program to further develop my research capabilities in preparation for graduate school. My background in internships and previous UROPs has prepared me for this research. I hope to learn more about the hardware that controls quantum computation in preparation for industry and graduate school. Writing a paper and contributing to my lab’s research is what excites me most about this project.”

Thuy-Duong Vuong  
Undergraduate Research and Innovation Scholar  
**Project: Fixed-Length Cycle Detection in Directed Graph**  
**Advisor: Virginia Williams**  
Fixed-length cycle detection is an interesting problem in algorithmic graph theory. This research aims to improve upon known algorithms to detect fixed-length cycles. At this stage, we are trying to prove a conjecture on the runtime of an algorithm to detect fixed-length cycles using matrix multiplication, a conjecture made by R. Yustre and U. Zwick in 2004.

Eric Joseph Wadkins  
MIT EECS | MITRE Undergraduate Research and Innovation Scholar  
**Project: Self-Driving Microscopy: Bayesian Inference for Instrument Tracking and Localization**  
**Advisor: Dirk R. Englund**  
The movement of laboratory instruments results in a certain degree of error, which can make precise localization difficult. Techniques such as Bayesian inference allow for an improved localization process — one that takes into account the inherent error arising from the use of physical instruments. Using my previous work for the Quantum Photonics Laboratory, including a real-time system for automated detection and focusing of location-encoded QR codes, I will design and implement a system using Bayesian updating with the aim of improving the existing localization process used by the lab. It is hypothesized that such an improvement will reduce the time required to seek the lab’s confocal camera.

“After completing a UROP project with the Quantum Photonics Laboratory in spring 2017, I wanted to continue my research by working on an extension of my previous work. SuperUROP provided me with the perfect opportunity. I hope to learn new approaches to the problems at hand that will allow my work to have an even greater impact within the lab, all the while making the valuable connections that I’m certain SuperUROP will provide.”

Katherine Yuchen Wang  
MIT EECS | Cisco Undergraduate Research and Innovation Scholar  
**Project: Creating a Database Log History Page for Cloud Components in App Inventor**  
**Advisor: Harold Abelson**  
CloudDB, an experimental feature of the MIT App Inventor Platform, allows users to send data across several different machines using tag-value pairs. However, currently with CloudDB, users, by deploying several blocks, can only view lists of their data tags and high-level information about individual tag-value pairs. Since App Inventor places emphasis on the usability of its program, we plan to implement a website where users can view the entirety of their CloudDB data buckets. The user would be able to see his/her tags, the corresponding stored data, and a brief history of that data. By bringing all of the data and its history into a viewable apparatus, this extension of CloudDB can potentially be used to answer research questions on data trends and help users learn about cloud data storage.

“By participating in SuperUROP, I hope to gain more exposure to the research process at MIT. My project allows me to not only learn more about data storage tools, but also incorporate my passion for CS education into my work. Since I have experience in app development, I am especially excited that I can learn about another aspect of it through my project.”
Larry Z. Wang  
MIT EECS | Lal Undergraduate Research and Innovation Scholar  
**Project: Kernel Functional Maps**  
*Advisor: Justin Solomon*  

Functional maps introduced to the computer-graphics community in 2012 by Bosanko et al are popular tools for expressing correspondences between shapes. These make use of linear algebra to represent a map from one surface into another. In this project, we will formulate and implement a kernelized version of functional maps, using ideas from kernel methods in machine learning. The hope is to improve the quality and reliability of correspondence algorithms.

“I am super-excited to be working with Professor Justin Solomon on this SuperUROP. Because his computer graphics class piqued my interest in computer graphics, I can’t wait to delve deeper. Through this SuperUROP project, I hope to get a deeper understanding of mathematics and numerical algorithms as well as learning whether research is something I want to pursue.”

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Xin Wen  
MIT EECS | Texas Instruments Undergraduate Research and Innovation Scholar  
**Project: FitFab: Varying Infill of 3D Printed Food to Reduce Calorie Intake**  
*Advisor: Stefanie Mueller*  

People often fail to control their calorie intakes because doing so requires conscious effort. While research on effects of sensory factors on food perception exist, manipulating these factors manually is challenging. However, recent advances in fabrication — for example, 3-D printing and laser cutting — now allow for automating modification of gustatory perceptions. We present FitFab, a food-fabrication technique that automates food-perception tricks to reduce calorie intake. We will investigate a computational model that estimates perceived satiety over food based on user psychophysical experiments, and build a prototype FitFab system that automates food-perception tricks to control calorie intake. We hypothesize that FitFab will help reduce calorie intake without sacrificing user perception of satiety.

“I decided to participate in SuperUROP because I wanted to learn more about research in academia and the end-to-end process of conducting an independent research project. I am very excited to dive into the human-computer interface field and be able to tinker with both hardware and software in this project.”

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Wendy Wei  
MIT EECS | Cisco Undergraduate Research and Innovation Scholar  
**Project: Decoding the Hidden Language of a Deep Neural Network**  
*Advisor: Antonio Torralba*  

Deep neural networks, widely used for pattern recognition tasks such as vision classification problems, are often regarded as “black boxes.” For deep neural networks to be interpretable, efforts have been made to uncover and visualize the types of features learned by each neuron. Previous work by the lab has provided a Network Dissection framework, which uses Borden, a labeled dataset, to align each neuron’s activations with human-interpretable concepts. I will use this framework and its interpretability metric to catalogue how various training methods affect a network’s interpretability. Using this understanding, I hope to ultimately propose practical methods for deep learning that maximize interpretability while producing competitive results.

“When I took Advances in Computer Vision (6.819) some semesters ago, I became interested in machine learning. After doing a few related projects in classes and internships, I am excited to now use this SuperUROP project as an opportunity to dive deeper and to be able to work on a problem I personally find unique and fulfilling.”

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Lindsay Westlake  
MIT EECS | Himawan Undergraduate Research and Innovation Scholar  
**Project: Decoding Human Visual Processing**  
*Advisor: Aude Oliva*  

To understand the visual world, the human brain must tie together simple features into complex wholes through a process called binding. Research to date has shown that the rhythmic firing of neurons in the gamma band (30–80 Hz) is associated with this process. Using MEG, we can observe these oscillations, and with a multivariate approach aided by support vector machines, we are able to interpret these data to obtain a fine characterization of the gamma response to a variety of stimuli. For this project, we will be focusing on Kanizsa figures, a class of illusions that cause the human brain to bind contours to form a shape. This would allow us to better understand the process by which the human brain binds features and is able to process its visual surroundings.

“As a student in the Computer Science and Molecular Biology Program [6-7], I am very interested in interdisciplinary research that applies computer science and mathematical principles to life-science questions. This project presents the opportunity to apply some of what I have already learned to an exciting discipline that I rarely get to see in my coursework.”
**Diana Wofk**  
MIT EECS | Analog Devices  
Undergraduate Research and Innovation Scholar  
**Project:** Energy-Efficient Deep Neural Network for Depth Prediction  
**Advisor:** Vivienne Sze

Depth-sensing is a key aspect of navigational systems in autonomous robots. The ability to reconstruct a dense depth map of a scene from RGB imagery and sparse depth data is necessary for obstacle detection and motion planning. Since deep convolutional neural networks (DNNs) have achieved high accuracy rates in image classification and regression, recent work has focused on designing DNNs for depth prediction tasks. However, the high accuracy of DNNs comes at the cost of high computational complexity and energy consumption, and current designs are unsuitable for low-power applications in miniaturized robotics. This project seeks to address this gap by applying recently developed methodologies for estimating and improving the energy-efficiency of DNNs to an existing depth-prediction DNN.

"I enjoyed courses in signal processing and digital system design and have developed an interest in multimedia applications. This project will allow me to learn more about vision deep learning and energy-efficient hardware architectures. I am excited to work on a long-term project that may lead to a publication. I am participating in SuperUROP to benefit from the rigor of the program and to improve my project and presentation skills."

**Eric Wong**  
MIT CEE | Undergraduate Research and Innovation Scholar  
**Project:** Structural Implications of the Bone-Periodontal Ligament-Cementum Complex  
**Advisor:** Admir Masic

Earthquakes are among the most destructive natural disasters, causing billions of dollars in damage each year in the United States alone. Engineers have several tested seismic designs that have had relative success. However, there is no universal design and what works in certain cases does not necessarily translate to others. With that in mind, this research project aims to provide constructors with another seismic design— one inspired by the connection found between the tooth and the jaw bone.

"This SuperUROP project provides a once-in-a-lifetime opportunity to pursue a funded research position on an original topic. Addressing the question at hand, I have a unique chance to influence how and when this research will progress."

**Sarah Wooders**  
MIT EECS Undergraduate Research and Innovation Scholar  
**Project:** Improving Image Alignment Through Localized Recomputation  
**Advisor:** Nir N. Shavit

Many problems, such as in-image alignment, require localized recomputation on sub-inputs to effectively fine-tune a result. This project aims to implement a MapReduce-like parallel framework for computational problems with the following characteristics: (1) A “divide-and-conquer” approach is applicable to solve the problem, whereby the input of the problem is recursively partitioned. (2) Errors in computation cannot be detected until the stage where partitions are being merged back together. In this case, when we find an error while merging, we have to recurse again on the erroneous portion of the output, possibly by running a slower, more accurate version of our computation on the piece, or partitioning in a different way.

"I’ve enjoyed participating in UROPs in the past because it’s a great way to get involved in research and get to work on interesting problems. I’m really interested in algorithms and parallel computation, so I’m excited to get to apply my coursework and experience in those areas to my SuperUROP project."

**Kifle Woldu**  
MIT EECS Undergraduate Research and Innovation Scholar  
**Project:** Personalized Web Page Recommendations Using Browsing Activity  
**Advisor:** David R. Karger

We propose to extend Eyebrowse, a web-browser extension that gathers information about web-browsing activities and shares that information (under the users’ control) with others for mutual benefit. Potential applications we hope to also explore include: discovering interesting new web sites based on users’ friends’ browsing activity, improving web navigation by blazing trails to the important parts of websites, supporting chance encounters when users and their friends are visiting the same website, browsing the web collaboratively, identifying missing links between pages, reporting on global web-activity trends, tagging sites and pages according to the interests of people who visit them, and whatever other exciting applications that emerge.

"I wanted to do SuperUROP to apply my acquired knowledge working on an interesting year-long research project. Going forward, I look forward to realizing the numerous useful applications browser activity data has to offer and applying my application and user interface development skills."
Albert Wu
Undergraduate Research and Innovation Scholar
Project: Implementing an Ankle Exoskeleton to Reduce Running Metabolic Cost
Advisor: Hugh Herr

Exoskeletons are wearable robotic devices that can enhance or restore human functions. Among the challenges of modern exoskeletons is the fact that reducing wearer metabolic cost creates a fundamental obstacle to producing a practical device. In this research, an ankle exoskeleton with novel design will be proposed and implemented. The ultimate purpose is to demonstrate that exoskeletons can successfully reduce metabolic cost. Results from this research can pave the way for developing future exoskeletal devices that further enhance or restore human functions without a metabolic burden on the user.

"I seek to explore the interdisciplinary field of robotics with SuperUROP. In addition, I want to apply what I learned in real life. I am very excited to learn more about exoskeletons and look forward to the upcoming research work."

Yinzhan Xu
MIT EECS Undergraduate Research and Innovation Scholar
Project: Deductive Synthesis of Linear Algebra Formula in Coq Proof Assistant
Advisor: Adam Chlipala

Fiat is a Coq framework for refining specifications into efficient programs on which my work will be based. Although currently there are already many platforms to process linear algebra formulas, the users usually cannot choose the way they want to process the formula. In some cases, the user might be able to change the open-source code to support more powerful calculations. But after the change, the code isn’t guaranteed to still be correct and even before the change, the code isn’t proven to be correct. In contrast, using Fiat to do linear algebra can help us overcome this difficulty. My research project involves working on this platform and focusing especially on formulas that people are interested in.

"I am participating in SuperUROP because I want to see how real research in computer science is like. I have been working with Professor Chlipala during the past spring and was quite interested in the area he is working on. I hope through this SuperUROP experience I can create something that’s useful and guaranteed to be true."

Yuancheng Yu
MIT EECS Undergraduate Research and Innovation Scholar
Project: New Bounds for Approximating Extremal Distances in Directed Graphs
Advisor: Erik D. Demaine

The diameter radius and node eccentricities of a graph are fundamental topological parameters that have many important practical applications in real-world networks. For a-multiplicative B-additive approximations with expected $O(n^a \cdot \text{polylog}(n))$ time, there is a natural tradeoff between $a$ and $\beta$? Cairo et al proved lower bounds under the Strong Exponential Time Hypothesis (SETH) of Impagliazzo et al, and upper bounds for undirected graphs. This project investigates the various techniques employed in relevant literature to generalize the results in Cairo et al to obtain new bounds for approximating extremal distances in directed graphs.

"I am intrigued by the elegance of combinatorial and algebraic algorithms, and I would like to investigate interesting open problems in the field."

Erica Ji Yuen
MIT EECS Undergraduate Research and Innovation Scholar
Project: Creating Data Visualization Features in App Inventor
Advisor: Harold Abelson

App Inventor is an educational-outreach initiative whose vision is to make computer science education more accessible and easy to learn. The platform provides users with an introduction to programming via an intuitive drag-and-drop block interface. My role in this project will consist of two parts. The first is designing and developing data visualization features that will allow students to visualize collected data of mobile apps that they create. By providing these features, students will be able to increase their applications’ potential impact. The second part is creating a curriculum to help students and teachers learn computer science concepts using App Inventor. This project will expose students to computational thinking early, ultimately helping to create a generation of better problem-solvers.

"My SuperUROP project gives me the opportunity to apply my computer science education on a high-impact long-term project. I enjoyed learning about the UI design process in User Interface Design & Implementation (6.813) and look forward to applying that experience in creating data-visualization features for App Inventor. Research with the App Inventor team aligns very well with my interest in making computer science education more accessible globally while contributing to my technical growth."
Inflammatory bowel diseases (IBDs), which affect 3 million Americans each year, have been shown to alter the gut microbiome. Gut-bacteria-containing fecal-matter transplants (FMT) from healthy donors to diseased recipients is a highly successful treatment for the antibiotic-resistance disease C. difficile infection (CDI), but less success has been seen in applications for other gastrointestinal diseases such as IBD. The clinical standard for processing FMT samples is under aerobic conditions; however, most gut bacteria are anaerobic, and there is evidence that aerobic processing results in more bacterial death than anaerobic processing. We seek to determine whether sample-processing conditions affect donor bacteria engraftment to inform more effective use of FMTs to treat IBD.

“I got my first taste of the computational side of biology in a previous UROP project, and I’m excited to hone it further through analyzing large, complex datasets in my SuperUROP project. The field of microbiome research is fascinatingly new and filled with unexplored questions. I hope to contribute to the field with a paper as well as learn how to ask and address insightful questions in the midst of so much that is unknown.”

How do we as humans develop intuition about the physical world around us? It is obvious that letting go of an apple causes it to fall, but it is harder to predict the trajectories that result from two billiard balls colliding. Regardless, we seem to have developed some mental intuition for what will likely happen. Our project seeks to model this cognitive process from an evolutionary computing perspective by introducing genetic programming methods to the development and learning of transferrable physical intuition. By searching over a space of possible programs, the model should be able to generate its own simple forms and respond to novel situations subject to noise and various heuristics. We seek to reinforce the idea that humans possess an abstract framework for physical learning.

“I’ll be developing cognitive models of physical concept learning as part of my research in SuperUROP. I’ve been researching computational theories of mind for more than a year now, and I’m glad to be able to continue working in such an interdisciplinary field and advancing our knowledge about human thought.”

Vivian Zhong
MIT BE | Microbiome
Undergraduate Research and Innovation Scholar
Project: Effect of Oxygen Exposure on Bacterial Colonization in rCDI Patients’ Post-Fecal Microbiota Transplant
Advisor: Eric J. Alm

Liang Zhou
MIT EECS | MITRE Undergraduate Research and Innovation Scholar
Project: An Intuitive Constraint-Based Model of Physical Dynamics
Advisor: Una-May O’Reilly

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Sharon Kipruto knew giving birth was a precarious endeavor. In her home country of Kenya, the maternal death rate is more than 10 times higher than in the United States — 510 versus 23 deaths per 100,000 live births. In part, that’s because there aren’t enough doctors to meet patient demand. And without visits, women aren’t getting prenatal information that could potentially save their lives.

Kipruto realized this was a problem ripe for intervention. Instead of relying on doctor visits to disseminate information, she thought: “Why not send the information directly to the women?” This year, she’s working on a project that runs with this idea: sending informative, automated text messages. About 88 percent of people in Kenya have mobile phones, so that could be an effective way to give pregnant women information they need, when they need it, says Kipruto, an MIT senior in EECS.

Kipruto is among more than 130 students participating in the 2017-2018 Advanced Undergraduate Research Opportunities Program, better known as SuperUROP. Launched by EECS in 2012, the program was later expanded to all departments in the School of Engineering; this year, for the first time, the program was open to students from the School of Humanities, Arts, and Social Sciences (SHASS) as well.

SuperUROP scholars’ diverse projects include investigations to improve our health, keep us better informed, and make technology more attuned to our feelings.

“It is remarkable in how many fields the students are contributing,” says Dirk Englund, an associate professor of EECS and instructor of 6.UAR, the 12-unit seminar course that all SuperUROP students take.

Many student projects focus on approaches to better treat disease. Claire Goul, a junior in EECS, for example, is investigating a tiny biomedical delivery system: DNA nanoparticles. Made of single-stranded DNA, these nanoparticles fold themselves into biological containers, which can transport therapeutic molecules into cells.

Part of maintaining our health is our ability to access and share our detailed medical histories. But right now, the process isn’t very streamlined, says Kevin Liu, a senior in mathematics and EECS. “Health-care data is not really in the hands of patients. It’s in the hands of doctors, hospitals, and health care insurance companies,” Liu says. “We want to be able to move this data back to patients, and let patients decide who to share it with.”

To do that, Liu is working with blockchain technology, the system that underlies the celebrity digital currency Bitcoin. What makes blockchain so useful is that it keeps track of transactions. When applied to medical records, patients would be able to know who sees their data. An innovative add-on to blockchain code, a feature called “smart contracts,” would also allow patients to determine who they want to share data with, as well as who has the ability to update that data. Liu is hoping to build a web interface that makes this technology easy and intuitive to use, even for people who have never coded before.

Information made visible

Other students are looking into ways to harness information to benefit society.

Mikayla Murphy, a senior in civil and environmental engineering, is using information to hold people accountable. She’s visualizing data collected by an MIT GOV/LAB-developed machine learning pipeline, which analyzes city government websites to determine whether those governments are being transparent.

There’s reason to look. In 2010, the Los Angeles Times published an exposé on the exorbitant salaries of city administrators of Bell, California (population 38,000). Bell’s city manager was paid a whopping $800,000 per year — the
nation’s highest salary for someone in that role, according to the investigation. Murphy says that practices such as publishing city budgets and meeting minutes online can help citizens keep their representatives, and their payrolls, in check.

“I’ve been really happy working on this project because it’s something I’ve been interested in this entire time here at MIT: how to apply data science skills for social good,” Murphy says.

Jeremy Stroming, a senior in aeronautics and astronautics, is also working toward a better world — literally. Stroming is building a platform for visualizing trends in Earth’s subsystems, such as oxygen levels in the oceans, melting sea ice, or changes in average surface temperature.

Stroming’s project aims to find ways to better communicate what’s happening to the earth so users can “have a conversation” with the planet. Not only could people better understand the planet and its systems, especially those going awry, but they could also find out about actions they can take using the platform, Stroming says. These might include recommendations for how to adjust diet, support sustainable businesses, or contact government representatives to advocate for change.

Stroming recognizes that learning about the Earth’s ills can be intimidating. He hopes to make it inviting and empowering. He has been planning a hackathon to make the portal as irresistible as possible, “so that it sucks you in, like Facebook.”

**Mood music**

With its versatility, technology can also improve our leisure. Patrick Egbuchulam, an EECS senior, wants to enhance video game play by making the music responsive to what a player is experiencing.

Most of the time, video game music is precomposed, fixed, Egbuchulam says. Yet a person could have a totally dif-
ferent experience of the game, with different attendant emotions, from the first time playing to the tenth. Egbuchulam’s project is to make the soundtrack match player experience in real-time. This could include making the music slower and darker for tense, serious moments, or brighter and faster, for exciting, hopeful ones, by changing musical traits such as the melody’s key, tempo, and mode (major or minor, for example). With this approach, he says, “the music is as unique as a game play.”

As the fall term closed, SuperUROP scholars showcased their work at Proposal Pitch, a poster session, followed by the annual SuperUROP Community Dinner. There, they heard guest speaker Katie Rae, CEO and Managing Partner of the Engine, describe the challenges facing startup founders who are developing “tough technologies” – that is, breakthrough concepts that require extensive time and funding to bring to market. “Tough-tech companies have historically been underserved and underfunded, leaving many breakthrough inventions stuck in the lab,” Rae told the students. The Engine, an MIT-backed organization launched in 2016, provides long-term capital, equipment, lab space, and other support for such companies.

At that point, SuperUROP participants were only halfway through the year-long program, but they’d already come a long way. “I am deeply impressed about their progress in their research projects and their ability to communicate them,” Englund says. Scholars returned to their labs and classrooms in February, preparing for the annual SuperUROP Showcase poster session in April and awarding of certificates in May.

Katie Rae, CEO and Managing Partner of The Engine, spoke about entrepreneurship at the SuperUROP Community Dinner in December 2017.
SuperUROP is made possible by the generous support of the following industrial sponsors and donors.

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- R. Franklin Quick, Jr. ’70, SM ’70
- Anonymous

SuperUROP Showcase poster session, April 2018
“Engaging in research gives our undergraduates the confidence to push boundaries and solve problems that no one has ever solved before. The skills students gain from SuperUROP and related programs are about more than learning how to be a researcher or academic. They provide a foundation for whatever they end up pursuing.”

— Ian A. Waitz
Vice Chancellor and Jerome C. Hunsaker Professor of Aeronautics and Astronautics, MIT

“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
Our thanks to the following for their support of and contributions to SuperUROP 2017-2018.

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Amir Karamlou (Spring 2018)
Tally Portnoi (Fall 2017, Spring 2018)
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“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, Henry Ellis Warren (1894)  
Professor of Electrical Engineering and  
MacVicar Faculty Fellow
“MIT Lincoln Laboratory strives to develop innovative technical solutions for very difficult national security problems. The SuperUROP program has been a great way for us to strengthen our relationship with outstanding MIT students and faculty and to find very creative new ideas for advancing the programs we have. We have really benefited by being involved.”

— Eric Evans
Director, MIT Lincoln Laboratory

“As an industrial sponsor, Analog Devices will look for opportunities to collaborate with students and faculty on research topics of continual interest and provide insights into the relevance of research to real-world applications. Analog Devices is excited about exploring new possibilities to strengthen our relationship with MIT students and faculty through the SuperUROP program.”

— Raymond S. Stata ’57, SM ’58
Chairman and Co-Founder, Analog Devices Inc.
More than 130 undergraduates discussed the results of their year-long research projects during the high-energy spring SuperUROP Showcase at MIT’s Stata Center on April 26, 2018.
For complete coverage, including photos and links to videos, visit eecs.mit.edu.
All photos by Gretchen Ertl.
Front Cover Photos

Top row
Ronald Davis, a senior in EECS, is working on a project involving both quantum mechanics and electrical engineering.

Middle row, left to right
Left: Emily Penn, a senior in chemical engineering, is working on a project for improving energy storage, specifically involving electrodes for redox flow batteries.
Right: Elizabeth Ella Martin, a senior in EECS, is focusing on ways to improve the outcomes for patients with sepsis in intensive care units (ICUs).

Bottom row
Left: Nicholas Charchut, a junior in EECS, is applying deep learning to autonomous driving.
Center: Smriti Pramanick, a senior in EECS, is creating a variant of Dynamic Time Warping (DTW) to enable real-time synchronization of music.
Right: Jesse Chang, a senior in EECS, is working on a project to help improve the imaging speeds of atomic-force microscopes (AFMs).

All photos in brochure are by Gretchen Ertl unless otherwise noted.

“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 provides a tremendous opportunity for MIT’s engineering students to gain meaningful research experience in world-class labs. I have been delighted to observe the program’s impact in shaping how our students understand the role research plays in addressing important challenges.”

— L. Rafael Reif
President, MIT
Launched in 2012, SuperUROP is an expanded version of MIT’s flagship Undergraduate Research Opportunities Program (UROP). The academic yearlong research program gives juniors and seniors the opportunity to conduct publication-worthy research and provides a primer on issues surrounding modern research. SuperUROP is hosted by the School of Engineering, and this year included students in the following MIT schools and departments:

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

School of Humanities, Arts, and Social Sciences