2017

ELEVENTH ANNUAL

SUMMER RESEARCH PROGRAM UNDERGRADUATE ABSTRACTS



NYU TANDON SCHOOL OF ENGINEERING



2017 SUMMER RESEARCH

NYU Tandon School of Engineering's Undergraduate Summer Research Program provides a unique opportunity for NYU Tandon, NYU College of Arts and Science, NYU Abu Dhabi, NYU Shanghai, and other select students from outside universities to engage in research over the course of the summer. This program offers students far more than the traditional classroom experience. It allows them to work alongside faculty mentors on cutting-edge research projects and interact with other students of all different levels from various areas within NYU and otherwise. Close interaction with faculty and research staff promotes an educational experience that advances Tandon's i^2e model of invention, innovation, and entrepreneurship. Undergraduate students are afforded the opportunity to conduct research as paid interns during this 10-week period. The program aims to enhance and broaden students' knowledge bases by applying classroom learning to solve practical and contemporary problems and to better prepare them for lifelong learning.

Summer 2017 marked the eleventh year of the Undergraduate Summer Research Program. Since its inception, 692 students have participated, and a large number of faculty members from a variety of departments have contributed to the program. In addition to the students' work in labs, they attend multiple seminars focused on both academic and career development. Additionally, students participate in a poster session in collaboration with the NYU-MRSEC REU Program and the Summer Research Program for College Juniors, in which they present their work to other members of the research cohorts, faculty, staff, peers, and other outside attendees.

Tandon's faculty participation in this program is essential, as is the financial support provided by faculty mentors and the Tandon School of Engineering. The gifts from several alumni donors have also propelled the program's success. I would like to thank Dr. Joseph G. Lombardino '58Chem, James J. Oussani, Jr. '77ME, and Dr. Harry C. Wechsler '48CM, for their generous support of this year's program. Additionally, this year marked the sixth year of the Thompson Bartlett Fellowship. Ten of this summer's female researchers were graciously supported by this fellowship, made possible by Mrs. Dede Bartlett, whose father, Mr. George Juul Thompson, was a graduate of the Electrical Engineering program at the Polytechnic Institute of Brooklyn in 1930. Donors' gifts allow us to engage more student researchers and faculty mentors, and further strengthen this truly unique summer experience.

A special thanks also goes to Nicole Johnson, who volunteered her time to mentor the TB Fellows, providing them with additional programming and engagement throughout the summer. She remains in contact with these students over time and often brings them back to engage with younger TB Fellows. I would also like to acknowledge Sara-Lee Ramsawak, who coordinated this year's Undergraduate Summer Research Program and ensured that the program's daily operations ran seamlessly. She has coordinated the Program for the past four years and continues to develop and enhance it at every turn.

The abstracts published in this year's volume are representative of the research done over the summer and celebrate the accomplishments of the undergraduate researchers. Congratulations to all of the student researchers who participated in the 2017 Undergraduate Summer Research Program, and I look forward to future summers of more intellectual and scholarly activities.

Peter J. Voltz

Peter Voltz
Associate Dean for Undergraduate and Graduate Academics

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LINGXUAN GAO

BS Mathematics and Physics 2019

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NYU Tandon School of Engineering

APPLIED PHYSICS

MOTION OF GALAXIES IN THE EXPANDING UNIVERSE

In this paper, we explore the motion of a particle in the Universe, undergoing accelerating expansion influenced by the dark energy. The expansion of the Universe can be described by the 4-dimensional metric tensor found from the Einstein's Field Equation. In the simplest model, we ignore the stress-energy-momentum tensor. We consider the particle that is exempted from all the forces in the Universe except for the force produced by the expanding space. The velocity of the particle depends on time and can be calculated from the geodesic equation through the use of Christoffel Symbol.

Next, we explore the motion of a particle in the real Universe, taking into consideration effects of matter and radiation. In this circumstances, the stress-energy-momentum tensor is taken into consideration. Finally, we analyze the motion of the real galaxies and figure out the opportunity to compare this motion with our computations.



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CENTER FOR URBAN SCIENCE AND PROGRESS

INDEXING OF REMOTE AERIAL SENSING DATA

Advancements in LIDAR technology have allowed accurate and detailed datasets of urban environments. Aerial scanners from planes and drones, as well as terrestrial and mobile scanners can gather data cheaply and quickly. The point cloud data gathered can be used to model buildings and neighborhoods, thereby giving city planners better knowledge to manage urban development. However, point cloud datasets from LIDAR can reach upwards of a petabyte in size and current spatial index systems have difficulty storing and querying such large datasets. An efficient spatial index must preserve locality to minimize page access times. A spatial database system must also support spatial queries, such as point queries, ranged queries, and k- nearest neighbor queries.

Airborne lidar captures points on the exterior of buildings, while the interior of the building remains mostly empty. When representing the data with space driven indexes, this results in many cells remaining empty, while the cells on the periphery become overfull. The goal of this project is to create a new indexing method using polar coordinates to index the point cloud data. Urban buildings are generally made of regular shapes and can be represented with a few important points. By indexing the most important points and features, we can maintain an accurate depiction of the data while reducing storage overhead and query time. Additionally, polar coordinates have the added advantage of being able to index multiple dimensions with the need for more coordinates.



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STATISTICS-BASED RAPID CHANGE DETECTION FOR REMOTE SENSING DATA

The current strategies for rapid change detection on aerial remote sensing (ARS) data suffer from many problems including incompatible data granularity, vegetation-based interference, and computational expense. Different data cloud density and inconsistent point location also pose challenges to robust change detection strategies for Aerial Laser Scanning (ALS) datasets. Computing three-dimensional alpha-shapes is a potential solution to these problems, which involves approximating and quantifying the connectedness of 3D data clouds by alpha complexes based on Delaunay Triangulation. This method will be applied to the world's densest urban aerial laser scanning datasets (>225pts/m2 in 2007 and >335pts/m2 in 2015) for a portion of the center of Dublin Ireland.

To implement this, we will use modules from the Geometry Understanding in Higher Dimension (GUDHI) library to construct and represent the simplicial complexes computationally as parameters for evaluating the cloud points. The library also offers filtration values, computational algorithms, and tools for edge contraction simplification of the huge simplicial complexes. GUDHI and Javaplex will be used to derive data for a comparison between the 2007 and 2015 datasets, starting from simple subjects (e.g. trees, and buildings) to larger areas and more complex structures. The project will attempt to determine the best statistical predictor, minimum data density, and ideal geographic extent for robust implementation
of this approach.



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STATISTICS-BASED RAPID CHANGE DETECTION FOR REMOTE SENSING DATA

Current statistical methods for rapid change detection of aerial remote sensing data generally rely on black-box machine learning techniques or ones that are computationally expensive. In order to develop a robust and highly scalable approach for identifying urban change from remote sensing datasets, we derive and examine simple statistics as potential covariates. Our two datasets represent dense aerial laser scans (>225 points/m2) of Dublin Ireland, collected in 2007 and 2015. By clustering data points into cubes - a method called voxelization - the distribution of points within voxels can be directly compared. Along with basic exploratory statistics such as mean, variance, and skewness, we utilize other existing methods and tests to identify whether two voxels were sampled from the same underlying distribution, and hence, the same object. Using point density, Principal Components Analysis (PCA), and the Kolmogorov-Smirnov test, we quantitatively examine spatial data for differences in point distribution. If a voxel from 2007 appears to be different from its corresponding voxel in 2015, we have reason to believe that a change has occurred in that location.

In an urban setting, change can refer to newly constructed buildings, vegetation change, or building damage caused by human disturbances. However, the results of this research could be extended to non-urban environments, where change is a naturally occurring phenomenon. Achieving a robust and scalable solution to change detection in aerial remote sensing data could provide first responders and others involved in disaster response and mitigation timely tools to provide more effective intervention decisions.



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BUILDING INSPECTION DATA INTEGRATION

New York City requires by law that buildings taller than 6 stories must undergo a facade inspection every 5 years. This is known as Facade Inspection & Safety Program (FISP). Unfortunately, the information gathered from the FISP inspection is largely unavailable to the public with the exception of in-person requests to the Department of Buildings (DOB). Through the utilization of publically available databases such as NYC Open Data and DOB Building Information Search, it is possible to determine if there is an ongoing FISP inspection for a building. The information taken from these databases, however, does not provide enough detailed information on the fault/violations that were being inspected. Similarly, the analogue format of most of the records makes effective damage progression comparisons extremely difficult. As such, the purpose of this project is to create a database storage mechanism to facilitate temporal change detection and evaluation for facade inspection (e.g. looking at how a crack progresses). An octree data structure allows a dataset (e.g. a building) to be partitioned in space to store the most important features such as windows, doors, and facade deterioration. This would allow inspectors to check and determine whether any further action to repair a facade is needed.



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FAULT DETECTION FOR URBAN ACOUSTIC SENSORS

Current digital signal processing (DSP) techniques have yet to be regularly applied to microphone sensor fault detection. However, previous studies have explored loudspeaker fault detection with time-frequency (TF) representations—spectrograms—along with signal classification. Both microphones and loudspeakers are transducers (i.e. energy converters). A loudspeaker converts electrical impulses into sound, while a microphone converts sound waves into electrical energy. Although these devices serve different functions, DSP analysis involving TF representations can prove microphone fault detection. In the Sounds of NYC (SONYC) project at the Music and Audio Research Lab (MARL), a malfunctioning MEMS microphone produces audible harmonic distortion in its spectrogram. This is important, because a malfunctioning microphone leads to data loss, thereby becoming an impediment to SONYC's goal to monitor urban noise pollution. Microphone harmonics are currently identified manually by listening to the sound data files logged by an urban acoustic sensor. The acoustic sensor consists of a MEMS microphone, a Raspberry Pi, and a WiFi antenna, among other components.

This study seeks to identify microphone failure in situ by using spectral analysis techniques. In visual analysis, the presence of harmonics in the spectrogram can be mistaken for sudden urban sounds, such as a car honk or crash, if they have similar amplitudes. However, aural and visual observation of the data takes time, and a server-based robust algorithm would serve as a convenient built-in system test for each sensor. By labeling the faulty acoustic data and its features, an algorithm that utilizes TF classification theory can then be applied to microphone sound data to determine rapidly and robustly the health of any microphone sensor.



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SPARSE DECONVOLUTION OF FULL WAVE FORM DATA

LiDAR (Light Detection and Ranging) is a surveying technique that uses a laser to actively sample the surrounding visible surfaces. A combination of range and angular measurements obtained from laser scanners is used to deliver geometric representations of the target surface. Airborne Laser Scanning (ALS) systems also require Global Positing System (GPS) and Inertial Measurement Units (IMU) to position a platform with reference to the target surface. The range is measured based on the time-of-flight of spontaneous light pulses emitted by the scanners. The laser ranging data are then stored in two different formats: discrete point or full waveform.

This research project focuses on the relationship between the primary output of the laser scanner, the discrete points, and the more advanced method, the full waveform (FWF) data. A discrete point cloud dataset is a collection of 3D points described by x, y, and z coordinates. Each point also contains other attributes such as the intensity, time stamp and color. The time stamp is critical since it makes the data spatio-temporal. A full waveform dataset consists of points, waves, and pulses. The pulse data gives context to the wave through information such as wavelength and pulse width. The first and last echoes mark the two end points. While FWF data can capture long segments of laser backscatter, past tests have underscored its low precision. In an effort to alleviate waveform deconvolution and its possible errors, this research aims at developing a robust algorithm to characterize and statically describe the FWF returns on different geometries. The algorithm is tested on three datasets of 90 million, 360 million, and 1.15 billion points extracted from a 2015 aerial scan of Dublin city.



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SOUNDLESS CHEMICAL DEMOLITION AGENTS

Widely used demolition methods for rock and mineral fragmentation tend to be environmentally harmful and generate a large amount of vibrations that can damage nearby constructs. This subject is growing more prevalent as urban construction is continuously increasing, especially around sensitive structures and tunnel networks. Soundless chemical demolition agents, otherwise known as SCDAs, are cement mixtures which expand when mixed with water, generating a pressure strong enough to crack apart concrete when placed inside a borehole. This method is environmentally safe and creates minimal vibrations compared to its counterparts, such as blasting and heavy construction equipment.

The experiments done within this summer program look at the various impacts that insulation could have in heat retention within the SCDA material. This will be done through various layers of plastic lining. The primary factor that will be considered is the overall SCDA temperature, which is known to have a positive and substantial relationship with pressure. The plastic lining may have some impact on how well the temperature stays within the SCDA. Another factor being tested is the volume versus diameter of a container as there remains a lack of consensus within the published research as to whether it is more accurate to predict heat development based on hole diameter or hole volume. Testing will be done through monitoring with both thermocouples and thermal cameras.



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CHEMICAL AND BIOMOLECULAR ENGINEERING

SIMULATIONS OF THE ORIGIN OF LIFE

The Miller-Urey or Origins of Life Experiment conducted in the 1950s demonstrated the formation of complex organic molecules -- namely, amino acids -- from inorganic precursors, through simulation of primitive earth's atmosphere in the lab. Essential to life, Amino Acids come together to form a peptide bond between the Carbon atom of one molecule and the Nitrogen of another. Once this chain is formed, it folds into more complex proteins, which are responsible for carrying out essential biochemical reactions. In order to understand the role of these proteins in various biological processes, it is important to fully understand how they are formed on a molecular level. However, many educational tools that currently exist, are merely 2-dimensional textbook representations that fail to provide a clear visual idea of how these complex proteins come about. Consequently, there has been a call for more interactive software that can be used as teaching tools. Many standalone molecular visualization software programs, written in Python (an object-oriented programming language), interpret atomic coordinate or Protein Data Bank (PDB) files, to create three-dimensional images of molecules. Using the imaging capabilities of these software, a more interactive interface can be built in Python, allowing students to both understand how these bonds are formed and predict protein formation and functionality under various envir onmental conditions. In the future, such software can be implemented into classrooms, as well as expand into research, where predictions involving protein structure and interaction can be developed as a precursor to experimentation.



▲ Ariaki Dandawate is developing an interactive interface that explores the formation of complex organic molecules and predicts their structure and functionality.

STAFF OF GANDALF

According to the World Health Organization, there are currently over 285 million people around the globe who are classified as visually impaired, with 39 million being legally blind. Many of those who suffer from blindness continue to use a white walking cane, despite limitations and lack of advanced technology. The white cane has several disadvantages such as having limited reach around the user, and forcing an uncomfortable grip in congested areas, therefore the cane was redesigned with inspiration from The Lord of the Rings into the Staff of Gandalf. This form of Electronic Transport Aid (ETA) utilizes an array of ultrasonic sensors in order to detect objects using a wide angled approach. This allows for a full 180-degree coverage of the user's surroundings up to a range of about five meters. An Arduino microcontroller obtains information such as the range, distance, and angle of an obstacle, and delivers feedback in the form of a haptic panel. Prototypes that took the form of a cane, lantern, and staff were used to experiment with different sensors such as ultrasonic and infrared, while also exploring various feedback mechanisms including vibrating motors and solenoid pins. Ultimately, Staff of Gandalf aims to be a convenient, simple, and inexpensive ETA that safely and efficiently navigates the visually impaired.



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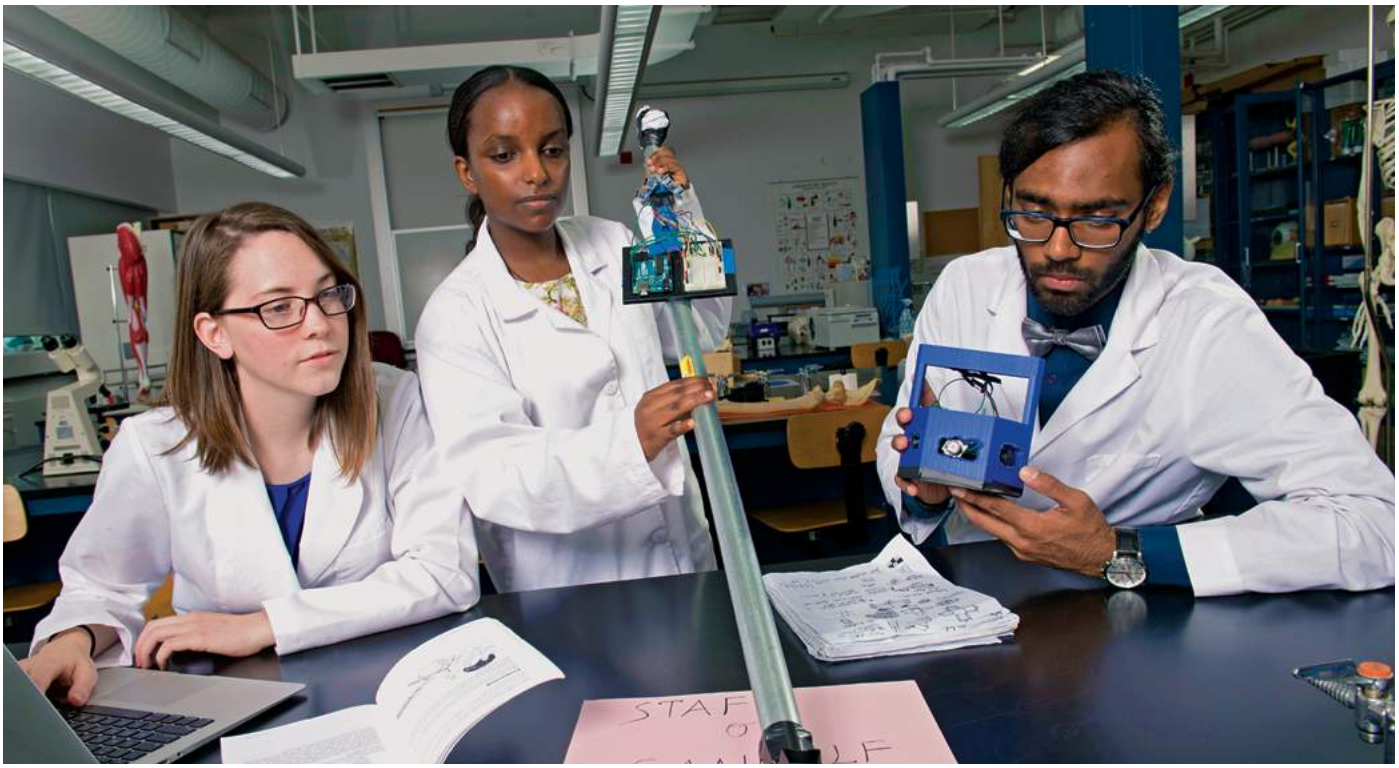
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▲ Morgan Fender, Aida Aberra, and Abhiroop Cvk (pictured left to right) are creating an Electronic Transport Aid with ultrasonic sensors to help the visually impaired better navigate their environment.



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DASH CAM

In the US, there is an average of 6 million car accidents annually. In a span of five years, 25% of all drivers will have been part of an accident, which means that any driver within the US is likely to have been involved in at least one car accident in their lifetime. A dash cam is a camera that records the front of the vehicle and if it were used in one of those accidents it can serve as an accountability tool for the driver.

With an easy and accessible Dash Cam app, any driver can use it whenever they are driving in case anything were to happen during their trip. The app will be created with Android Studios which is the primary development kit for android apps. Using this program, the app will be able to access both cameras at the same time and record the view from the front of the car as well as the interior, thus providing evidence that the driver was not driving recklessly, under the influence or doing anything that may impair their driving abilities. The video recorded by your phone will make it easier to prove innocence in legal and insurance proceedings. Dash cams may become a standard when driving to ensure absolute security when a person decides to drive and this app makes it much easier to obtain one. With its accessibility and multi-purpose application, the dash cam app seeks to not only lower driving related accidents but also become a part of everyday life as we gear towards a digitally reliant routine.



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BS Chemical and Biomolecular Engineering 2019

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MULTIVALENT PEPTIDE PROBES FOR THE DETECTION OF ß-AMYLOID AGGREGATES

The aggregation of ß-amyloid (Aß) is a key contributor to the characteristic neurodegeneration of Alzheimer's Disease. Aß, a 40-42 residue peptide, aggregates into toxic oligomers and fibrils species, mainly driven by interactions of the hydrophobic central domain (HCD), ^{16}KLVFFAE^{22}. Fluorescent peptide probes that can selectively bind to Aß oligomers and fibrils could aid in the early diagnosis of Alzheimer's Disease. Our lab has previously developed a fluorescein iso-thiocyanate (FITC) tagged peptide probe consisting of an analogous amino acid sequence, KLVFWAK, that can selectively bind to Aß oligomers and fibrils. An improved version of this probe containing multiple copies of FITC-KLVFWAK could result in stronger binding, greater selectivity between aggregate species, and amplified fluorescent signal, all due to a multivalent effect. This study focuses on designing, synthesizing, and characterizing bivalent and tetravalent KLVFWAK probes.

For the bivalent probe, two KLVFWAK peptides were joined by a 6-residue linker that forces a ß-hairpin turn conformation, tagged with FITC at the N-terminus. For the tetravalent probe, generation 0 polyamidoamine (PAMAM) dendrimers containing 4 amino surface groups were chosen as a scaffold for coupling 4 copies of the peptide. The C-terminus of the FITC-KLVFWAK peptides were linked to the amino surface groups in an EDC/Sulfo-NHS reaction. After the peptides were joined to the dendrimers, the resulting tetravalent probes were purified by size-exclusion chromatography (SEC), and characterized by matrix-assisted laser desorption/ionization (MALDI). The selective binding ability of the bivalent and tetravalent probes were tested with Aß monomers, oligomers, and fibrils in fluorescent and immunochemical competitive binding dot blot assays.



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BS Chemical and Biomolecular Engineering 2018

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EFFECTS OF IONIC STRENGTH ON MODEL MICRORNA-MORPHOLINO SOLUTION HYBRIDIZATION

MicroRNAs are non-coding RNA molecules that consist of sequences ranging from 19 to 25 nucleotides in length. Discovered in 1993, and referred to as miRNAs, they are a category of small RNAs vital to the control of human gene expression. MicroRNAs are also widely recognized as specific biomarkers for certain diseases, namely cardiovascular diseases. The goal of this research is to measure the binding affinity of hybridization between a model microRNA "target," and a complementary Morpholino oligomer "probe." By studying the behavior of miRNA in this context, we can gain insight into the potential application of Morpholino for miRNA analysis. Morpholinos are nonionic DNA analogs that can hybridize with nucleic acids; their polymer backbone consists of alternating phosphorodiamidate groups and methylenemorpholine rings with attached nucleic acid bases. By varying sodium chloride concentration in buffered hybridization solutions, one can examine the influence of ionic strength on probe-target binding affinity. To measure binding affinity, an ultraviolet-visible spectrophotometer is used to record the absorption of light at 260 nanometers as a function of temperature, which is cycled between a maximum and minimum value that captures the duplex thermal melting transition. Using the collected melting data, thermodynamic values such as the change in enthalpy (ΔH°), change in entropy (ΔS°), change in free energy (ΔG°), and the equilibrium constant, K, can be determined through application of a two-state hybridization model. The changes in the values of free energy and the equilibrium constant will assist us in answering the stated goal of the research.



JOHN UDARA MENDIS

BS Chemical Engineering 2018

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MODIFICATIONS OF PHOSPHOTRIESTERASES TO IMPROVE ACTIVITY AND STABILITY

Pesticides are frequently used for agricultural purposes such as combating insect infestations and food-borne diseases. Organophosphates (OPs), contained in most commonly used pesticides, inhibits acetylcholinesterase thus leading to an accumulation of acetylcholine which overstimulates muscles. Consequently, OPs have many negative impacts including fetal maldevelopment and several neurotoxic effects. Therefore, they require efficient and effective detoxification methods. Phosphotriesterases (PTEs) have been known to hydrolyze OPs; however, wild-type PTE lacks stability and shelf-life in addition to its limited activity to certain OPs. Herein, we optimize PTE via encapsulation and fluorination in order to improve its activity and stability. We apply lactose monohydrate (LM) co-crystallization to preserve PTE for prolonging its function over time. In addition, para-phenylalanine (pFF) is incorporated to stabilize the interface of PTE monomers in order to enhance the activity. Kinetic assays as well as structural studies on circular dichroism and differential scanning calorimetry are performed to assess the improvements.



▲ John Udara Mendis is optimizing phosphotriesterases to help make agricultural pesticide use safer.



DEANDRA WRIGHT

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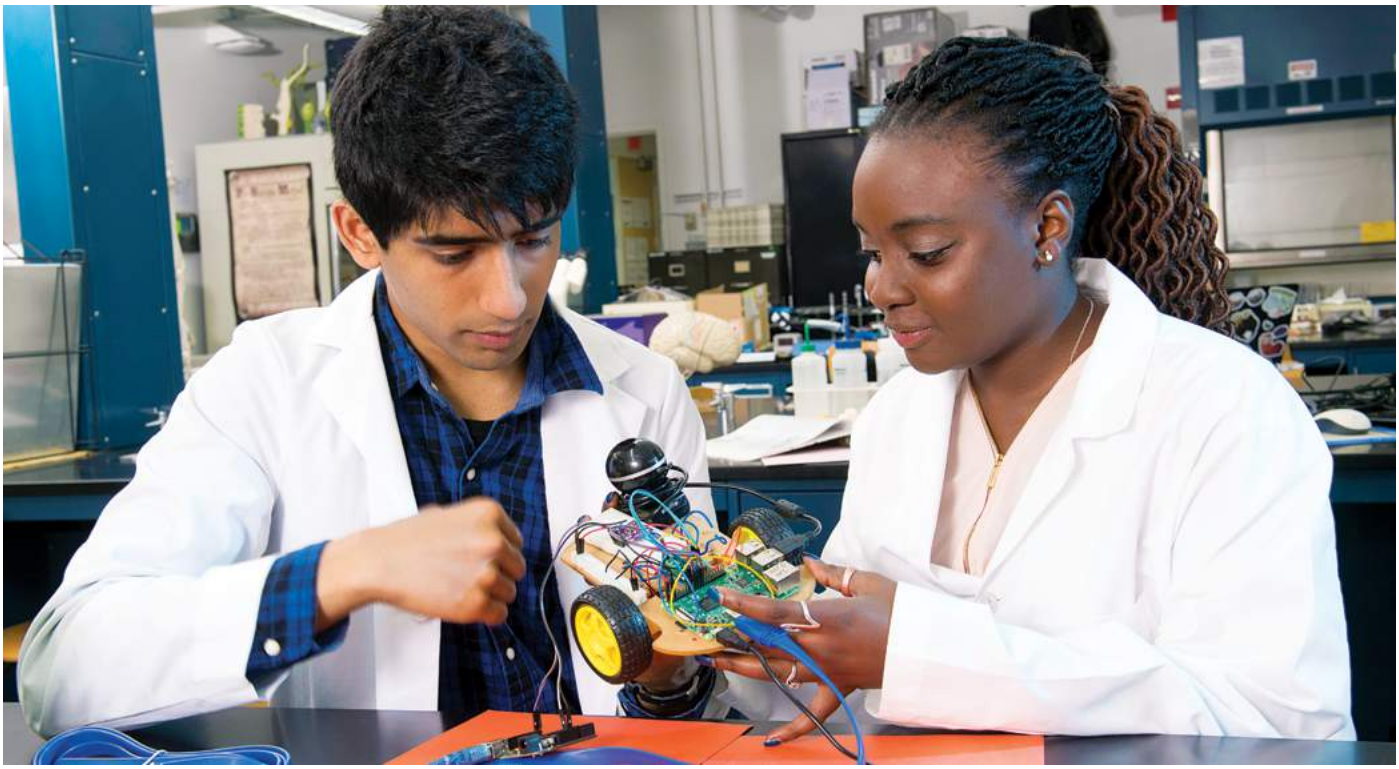
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▲ Rohan Chakraborty and Deandra Wright (pictured left to right) are developing a continuous health monitoring system that notifies elderly users and their physicians of their health status.

DEAD MAN WALKING

With recent advances in medicine, developed societies have reported a steady increase in lifespan with an accompanying decrease in mortality rates. As a result of this, the geriatric population is now the fastest growing demographic in modern society. This increase in size, however, has not been met with an increase in care facilities to address the complex chronic illnesses this population faces. The Dead Man Walking project strives to create a continuous health monitoring system that notifies elderly users, and their physicians, on their health status from their homes. By keeping an active record of vital signs, through facial recognition and infrared signals, the system will record the normal ranges, as well as alert emergency services in the case of adverse events. In addition, a wearable accessory will be designed for use outside of the home, syncing relevant data that is required to continue collecting accurate health records. The current model—a mobile robot with an infrared thermometer and facial tracking camera—uses infrared signals to collect accurate body temperature readings from regions on the face, while a Raspberry Pi computer will process thermal images from the infrared camera to non-invasively record a pulse rate (further additions will include recording respiration rate, as well as blood pressure). With this system, the geriatric community will ultimately be equipped with the knowledge to make informed decisions concerning their health, alongside their physicians, without being confined to a twenty-four hour health care facility.



GYU IK (DANIEL) JUNG

BS Biomolecular Science 2018

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Faculty
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CHARACTERIZATION AND COMPARISON OF CATALYTIC ACTIVITY OF RECOMBINANT PH-20 HYALURONIDASES

Hyaluronan (hyaluronic acid, HA) is a glycosaminoglycan that is found in the extracellular matrix, where it was observed to be involved in fundamental functions like cell signaling, cell migration, and wound repair. HA has been proposed as a biomarker for inflammation and indication of the malignancy of tumors. The microenvironment supported by HA around these diseased tissues are favorable for the proliferation of cancer cells due to breaching of cell-to-cell junctions, reducing access from external areas by increased osmotic pressure around blood vessels, enabling optimal conditions for development of the tumor in an isolated area.

Several therapeutic treatments for cancers, like follicular lymphoma and pancreatic cancer, have involved the use of hyaluronidases to increase the enzymatic cleavage of HA in these microenvironments and allow entrance by immune response-associated agents and administered chemotherapeutics. In vitro studies have been done with purified bovine testicular hyaluronidase (BTH), which showed hydrolytic capabilities but also induced inflammatory responses from treated cells. This pro-inflammatory condition is speculated to be caused by the low-molecular weight HA produced. Alternatively, corporate clinical trials have employed recombinant human (rh) PH-20 for drug delivery and as an overall therapy aid, and has recently been approved by the FDA for such application. PH-20 hyaluronidase is one of the most known forms of the enzyme in the field, and is commercially available as recombinant bovine (rb) or rhPH-20. The interest of this project lies on the enzymatic capabilities, if any, of the commercially found rbPH-20 and rhPH-20, and their specificity towards HA versus other unsulfated and sulfated glycosaminoglycans. Characterization of these proteins involves observing their kinetics under optimal and physiological conditions, and comparing the results with those for the widely-studied effects of BTH and its pro-inflammatory effects when treated to cells.



SARIN IAMSANGTHAM

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PANIC BUTTON

In order to both be safe and feel safe every day, a person should, among other things, be able to contact trusted individuals at a moment's notice. While systems, application, and features for this purpose exist, they have their flaws. For example, systems like LifeAlert require users to carry a pendant, but they stop working outside the area of the house, and other safety applications require the user to have their phone on hand and unlocked, and can drain battery very quickly. The Panic Button application seeks to mitigate these problems through its design while also performing as a less resource-intensive safety application. Users will be able to add and remove contacts from a list, and through the press of an onscreen button or a Bluetooth-connected button, they can send a customizable emergency message to the list of contacts, along with other vital information such as their last-known location, even while in sleep mode. This is for situations such as panic attacks where trusted individuals would be the preferred contact to something like the police. In more pressing situations, multiple button presses would allow for additional contact to numbers like a local police station or 911. Through this system, the user would not have to have their phone out at all times, and Bluetooth allows it to have a relatively large range of activation should the phone not be on the user's person. The application is currently in development for Android, however an iOS version is also planned; in either medium, the application will be free to download and use.



▲ Sarin Iamsangtham (pictured left) is working to design a safety application that is customizable and offers a wide activation range.



ERIKA DELGADO-FUKUSHIMA

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DOXORUBICIN-LOADED PROTEIN ENGINEERED FIBERS FOR POTENTIAL MRI-MONITORED DRUG DELIVERY

Iron oxide-based nanoparticles manifest magnetic properties, making them viable to magnetic manipulation, as well as superparamagnetic properties rendering them visible by magnetic resonance imaging (MRI). Previous studies have found that the templation of iron oxide nanoparticles by a drug carrying protein biomaterial can be potentially used for therapeutic applications monitored by MRI. Specifically, curcumin-bound azide-functionalized mesofibers are formed by the nanofiber-forming protein Q, an engineered mutant of the coiled-coil domain of the Cartilage Oligomeric Matrix Protein, which further assembles into mesofibers when bound to the hydrophobic molecule curcumin. To create an azide-functionalized variant, Q has been synthesized in the presence of the non-natural methionine analog azidohomoalanine. Drug-bound azide-functionalized Q is then capable of azide-alkyne cycloaddition to an iron templating peptide CMms6, derived from the magnetosome associated protein Mms6 found in magnetotactic bacteria. The conjugated protein formed from cycloaddition is capable of iron oxide templation and visible by MRI. Our group is currently focused on binding the chemotherapeutic agent doxorubicin (Dox) to the Q protein. Robust fiber formation occurs at a 1:5 Q:Dox ratio. Like with curcumin, we hypothesize that Dox binds to the hydrophobic pore of Q as well as between nanofibers, resulting in further assembly into drug-bound mesofibers. We aim to similarly evaluate of the ability of the Dox bound fibers to conjugate to the iron templating peptide CMms6 for subsequent templation of iron oxide nanoparticles. The resulting biomaterial has the potential to act as a Dox-delivery agent that can be monitored with MRI.



▲ Faculty mentor Jin Montclare and Erika Delgado-Fukushima (pictured left to right) are evaluating doxorubicin-bound fibers to produce an improved drug delivery system.



SINDHU AVUTHU

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▲ Sindhu Avuthu and Yevgeniy Reznikov (pictured left to right) are creating a method of visualizing complex molecules in an engaging video game environment.

CHEMTRIS III

Students taking a general chemistry course encounter macroscopic chemical concepts, such as observable reactions, that are generally intuitive to learn. However, once they enter Organic Chemistry and Biochemistry, more abstract chemical concepts are introduced that are less intuitive, that can be difficult for students to grasp. One of the most important skills that students need to develop in order to understand these concepts is molecular visualization, which courses traditionally teach through two-dimensional textbook models and three-dimensional physical models. These representations fall short in demonstrating inter- and intra-molecular chemical properties, and offer minimal interactive possibilities. Newly-developed computer molecular visualization softwares allow students to interact with molecular representations while simultaneously building an understanding of more complex chemical interactions. Chemtris aims to present molecular visualization in a video game environment, exposing students to molecular concepts in a way they find intuitive and interesting through Tetris-like gameplay. Tetris' gameplay involves spatial understanding of blocks' position and rotation, and expanding that to three dimensions lets the project teach three-dimensional spatial comprehension. The current Chemtris III project is a continuation of previous work, and has been rewritten in Unity from libGDX to aid project development. The current project also presents additional chemical concepts in its gameplay, such as polarity and chirality. Chemtris III will be presented on mobile and VR platforms that students already have access to, and will prove that learning chemistry can be just as fun and interactive as playing a game.



TINA (TZU-YI) CHEN

BS Biomolecular Science 2019

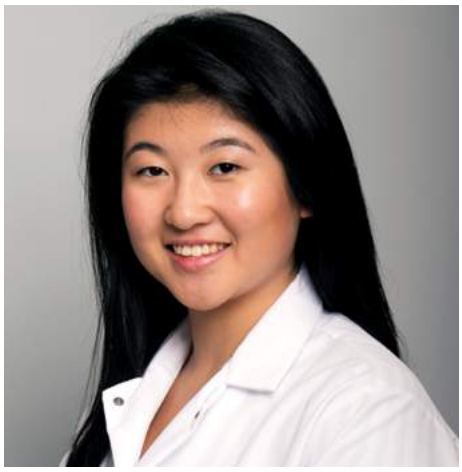
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EFFECT OF GOLD NANOPARTICLES ON LASER-INDUCED NUCLEATION

According to the previous research, Garetz et al. proposed the tendency of supersaturated aqueous solutions, for example glycine and urea, undergoing non-photochemical laser induced nucleation (NPLIN) when they are exposed to near-infrared pulsed lasers of high intensity. The different polarizations of the laser used could generate different crystal polymorphs. Unlike urea, supersaturated glycine solution could generate two forms of crystal polymorphs, a and g phase. When exposed to circularly polarized laser light, the NPLIN can cause the formation of a polymorph crystals. Likewise, when exposed to linearly polarized light, g phase crystals are obtained. This emphasizes the use of polarized lasers to create specific crystal polymorphs. This technique provides applications regarding separation and purification of material substances. The objective of the experiment is to observe the effect of gold nanoparticles on the NPLIN rate of the 1.5 supersaturated glycine solution. Before the addition of the gold nanorods, the experiments were first conducted on 1.5 supersaturated aqueous glycine, where 1064 nm near-infrared high intensity laser are employed for one minute exposure. Nucleation typically occurs in the time frame ranging from 30 minutes after laser exposure to 24 hours afterwards. The remaining experiment focuses on adding gold nanorods to the glycine solution. In theory, the interaction of the light with plasmon resonances of the gold nanoparticles would promote nucleation at lower intensities and at higher yields.



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▲ Claire Liu and Leo Potters (pictured left to right) are developing a protein-engineered hydrogel to improve treatment of post-traumatic osteoarthritis.

PROTEIN ENGINEERED INJECTABLE HYDROGEL FOR TREATING POST TRAUMATIC OSTEOARTHRITIS

Injectable hydrogels have gained increasing interest as smart biomaterials and are intensively being explored for various biomedical applications, such as tissue engineering and targeted drug delivery. Here, we are developing a drug-loaded self-assembling protein engineered hydrogel that exhibits smart sol-gel response at body temperature with enhanced biocompatibility and improved biodegradability. Our system is based on protein block polymer, EC, which consist of two self assembling domains-elastin like polypeptide (E) and the coiled-coil domain of cartilage oligomeric matrix protein (C). EC exists as sol at lower temperature (4°C) and has the ability to crosslink, with itself, forming a complex interconnected hydrogel network at physiological conditions (37°C). To further increase the mechanical strength of our hydrogels, we employ bis(sulfosuccinimidyl) suberate (BS3), a chemical crosslinker that covalently links free amine groups present in the protein. These hydrogels are further used to encapsulate a model protein, BSA and a therapeutic protein, progranulin (PGRN), known to have anti-inflammatory and chondroprotective effects in post-traumatic osteoarthritis (PTOA) patients.



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BLOCK COPOLYMER GRAIN CHARACTERIZATION USING DEPOLARIZED LIGHT SCATTERING

Block copolymers (BCPs) mixed with lithium salts have promising applications as a solid electrolyte in commercial lithium batteries. Their robust mechanical strength can impede detrimental dendritic growth, while their high ionic conductivity allows for low internal resistance. Although it has been recognized that BCP grain structure and local morphology determine their properties, such as shear strength and ionic conductivity, predictive expressions have not yet been derived for these relationships. To further understand these connections, our group has developed novel methods to measure parameters that characterize grain size and to study grain growth kinetics and thermodynamics, particularly in polystyrene-block-poly(ethylene oxide) (PSEO)/lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) mixtures.

In 2014, Wang et al. reported analytic expressions for the intensity of the diffraction patterns produced by light propagating through ellipsoid-grained polymer samples held in between crossed polarizers [1]. Using these expressions, grain growth and structure of ordered PSEO/LiTFSI mixtures have been examined through analysis of diffraction patterns from depolarized light scattering during annealing and quenching processes. From past experiments with neat PSEO samples, average grain volume was observed to increase monotonically during quenching [2]. However, in recent tests on PSEO/LiTFSI mixtures, grain volume was observed to first increase then decrease over time [1]. Our group intends to explore this phenomenon further in new PSEO/LiTFSI samples with different molecular weights and salt concentrations.

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REILLY CASHMORE

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▲ Reilly Cashmore and Radhika-Alicia Patel (pictured left to right) are designing experiments and protocols to determine the nutritional content of foods and drinks.

MOLECULAR NUTRITION

The challenges of living in an era with crash diets, confusing "superfood" trends, and an accessible abundance of overly processed, fatty foods make it difficult to maintain a healthy and balanced lifestyle. To combat this problem, the NYU Biomolecular Science Program is developing a Molecular Nutrition course. Molecular Nutrition is a field that combines knowledge of chemistry, biology, molecular systems, cellular activity, biochemistry, and biophysics to study the processing of nutrients in the body along with their health benefits and potential detriments. This project aims at selecting tests and developing protocols that will allow students to detect and quantify both macronutrients, like carbohydrates and proteins, and micronutrients, such as vitamins and minerals. Students will be able to explore the nutritional basis for so-called "superfoods" such as kale, chia seeds, and almond butter. Students will be encouraged to offer any basic foods or personal dietary foods for testing to maintain course relevance for each individual and to keep up with current health food trends. For example, students will be able to quantify carbohydrate and essential amino acid presence in different plant-based supplements and foods to analyze the nutritional differences between plant-based diets and carnivorous diets. Altogether, this project develops qualitative experiments and protocols for detection of substances that determine the nutritional content of food and drink with hopes of implementing these experiments in a laboratory-based course to expose students to the benefits and drawbacks of certain dietary choices.



TASFIA TASNIM

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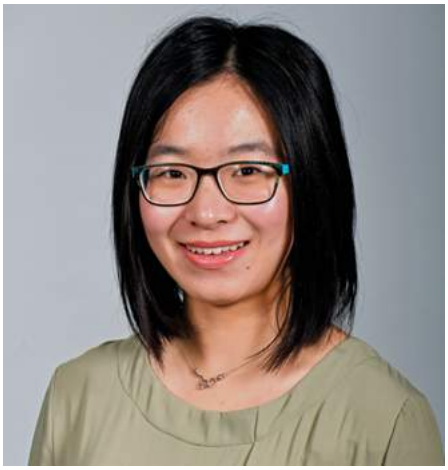
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LASER-INDUCED NUCLEATION OF MILLIMETER-SCALE DENSE LIQUID DROPLET IN AQUEOUS GLYCINE

Non-photochemical laser induced nucleation (NPLIN), discovered by Dr. Garetz and coworkers in 1996, demonstrated that supersaturated solutions can be induced to crystallize when exposed to high intensity laser pulses. They hypothesized that the electric field of the light helps to organize the molecules in solute aggregates aiding the crystallization process in a non-chemical way, forming different polymorphs for some solutes, such as glycine. In 2010, Dr. Yuyama et al. demonstrated the formation of single dense liquid droplet of glycine by tightly focusing a near-infrared continuous wave (cw) laser beam into a thin film of supersaturated solution of glycine in heavy water on a glass substrate. They proposed that photon pressure was trapping solute clusters in the focal region of the focused laser beam, resulting in the formation of a highly-concentrated solution droplet of glycine. The millimeter-sized dense liquid droplet was stable when the cw near-infrared laser beam was focused at the glass/solution interface, but immediately crystallized when the beam focus was moved to the solution/air interface. In this project, the optimal conditions for forming the dense-liquid droplet were explored by reproducing previous work, and investigated at a macro and micro scale using an endoscope camera and a CCD camera respectively. Parameters such as laser intensity, focal position, exposure time and concentration of solution were taken into consideration to understand the formation process of the dense-liquid droplet, which is possibly the early stage of a multistep nucleation process.



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VY-LINH GALE

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MARIA DOOLING

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▲ Xinyi Xu, Maria Dooling, Vy-Linh Gale (pictured left to right) are creating dynamic representations of neurons and bones that represent the integration of cellular structures.

3D MODELING OF NEURONS AND BONES

The goal of this project is to create and print dynamic representations of neurons and bones that push the envelope on static models and figures. 3D modeling for educational purposes serves as a profound enhancement to students' understanding of complex structures and concepts. Printing models of neurons and bones provides students with hands on learning through tactile communication. Using movable parts and novel designs, printed models are not only able to be held, but also interacted with in ways that traditional figures cannot be.

Traditional neuron models exist as simplified versions of reality, mainly consisting of 2D illustrations, which fail to fully capture the spatial dimensions of neurons. Neuron tracings from MRI scans were used to computationally build 3D models in the software, Neuronize. The 3D model was then modified in the softwares, Blender and 3D Builder, both for better printing and neuronal feature demonstration. The 3D printed neuron models not only portray important neuron structures and components, but are interactive and revolutionary in representing neuronal synapses and networks by emulating a jigsaw-like design.

Existing bone and osteon models are accurate in their depictions of substructures and organization, however there is a lack of variability in design or structural mobility. This 3D representation accurately showcases the bone's substructures and organization through dynamic features, which magnify the fractal nature of bone's molecular structure. The 3D building software, SketchUp and the laser cutting design technology, Adobe Illustrator, were used to create a detachable 3D printed long bone with a 2D cross section attachment. This innovative design uniquely demonstrates how each cellular structure is interconnected and integrated together within the bigger picture.



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MASS TRANSPORT ON SOLAR-H2 GENERATORS AND PROCESS OF ADIPONITRILE IN MAKING NYLON

Adiponitrile (ADN) is an important commercial intermediate for the production of Nylon 6,6 and, therefore, significant effort has been dedicated to the development of an efficient and suitable processes for its production. At the moment, it is mainly produced through hydrocyanation of 1,3 butadiene. However, this process has not been entirely satisfactory from both commercial and safety standpoints. The route not only consumes considerable amounts of energy but also gives rise to a variety of side reactions which tend to produce hazardous chemicals and reduce the yield of desired product. The predominant alternative route for the manufacture of adiponitrile is the organic electrosynthesis process that corresponds to the electrohydrodimerization of acrylonitrile (AN) to ADN in a divided or undivided electrochemical cell. During the electrohydrodimerization of AN, the oxygen evolution reaction takes place at the anode and the reduction of AN to ADN takes place at the cathode surface. Several side reactions can take place at the cathode surface, including hydrogen evolution and the generation of propionitrile (PN), 1,3,5 tricyanohexane and methylglutaronile as main byproducts.

This project is aimed at improving the performance of the cell by optimizing the electrolyte composition, mainly in terms of selectivity to ADN and current efficiency. For this, the effect of the presence and concentration of each of the electrolyte components will be studied. The quaternary ammonium salt is a key component in the electrolyte, as it maintains a compromise between selectivity to ADN and electrolyte conductivity. Several sizes of the substituting alkyl groups will be evaluated in order to understand their effect on the expulsion of water from the electrical double layer. The latter will hinder the hydrogen evolution and propionitrile production reactions at the cathode, increasing selectivity.



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▲ Mackensie Gross and Iain Wright (pictured left to right) are designing a three-dimensional model of the microscopic sarcomere structure that enables detailed visualization of its mechanisms.

3D MODELING OF SKELETAL MUSCLE

Macroscopic anatomical models, such as muscle models, are the primary teaching devices used in many anatomy courses. However, when it comes to microscopic anatomy, many structures are limited to expensive electron microscope images, two-dimensional artistic representations, or short video sequences. Visualization and tactile feedback are important constructs of learning, and physical models help students better grasp complex topics. Macroscopic skeletal muscle models exist only as gross body systems to identify muscle groups; there are very few options available that visualize the microscopic components of skeletal muscles in three dimensions. The arrangements of the sarcomere and its proteins are hard to grasp with two-dimensional representations.

By creating an accurate three-dimensional model of the microscopic sarcomere structure, students are able to visualize the connections, structures, and mechanisms present, gaining a greater understanding of their significance. 3D printing allows for a broad range of features in physical design, with customizable settings such as types of materials, quality of parts, and size. The final product is a professional, high-quality, and inexpensive model. SolidWorks and AutoDesk computer-automated design software was used to design representations of the proteins, which were 3D printed and assembled to form thin and thick filament that interact to simulate a contraction. The actin filaments have been designed and printed to scale, along with the myosin filament and accessory proteins. Magnets are integrated to represent the cross-bridge formation that occurs during contractile motion. The completion of this model gives students a new way of looking at microscopic anatomy that is both interactive and intuitive.



MYRIAM SBEITI

BS Chemical and Biomolecular Engineering 2018

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MODELLING SOLAR HYDROGEN GENERATORS

Fossil fuels are slowly being replaced by a variety of alternative energy sources due to their negative environmental effects, potential to cause political tensions, and limited availability. Renewable sources such as solar power are a promising alternative for large-scale implementation but still require many design improvements to become economically viable and deployable into broader markets due to their low efficiency and intermittency. An attractive solution to mitigate intermittent availability is to couple capture and storage in the same process, as do solar hydrogen generators, where solar panels provide energy to split water into storable hydrogen and oxygen gas, effectively converting solar irradiation into high energy density fuels. Despite these advantages, solar hydrogen generators still pose economic and implementation challenges: cost, efficiency, and safety are three major issues that can be solved with design-engineering. Parameters like gas crossover across separation membranes can lead to flammable mixtures of O2 and H2 and significantly reduce efficiency.
The goal of this project is to create a comprehensive model for solar hydrogen cells to better understand how different design-engineering parameters affect the rate of crossover over time, based on yearly solar irradiation in various locations around the globe. The results of this model will aid in creating an optimal design for maximum efficiency. In addition, this project explores potential solutions to limit crossover, notably through the use of REDOX shuttles. Shuttles serve two purposes: to lengthen the path of travel of the gases without increasing resistance, and to introduce a second phase and enable better separation of the gases.



ISAIAH MWAMBA

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CIVIL AND URBAN ENGINEERING

QUANTIFYING THE EFFECTS OF QUEUE JUMP LANES ON BUS SERVICE RELIABILITY

In an effort to improve the bus rapid transit service in New York City, the NYC DOT and MTA have for a few years now collaborated on implementing the select bus service (SBS) in the city. Features of the SBS include all off board fare collection, all door boarding, lower bus floors for easier and faster boarding, and the implementation of short dedicated bus lanes on approach to intersections, known as Queue Jump Lanes (QJLs). QJLs allow buses to jump ahead of other traffic on intersections and enhances their use of transit signal priority when available. Progress reports indicate that SBS is improving BRT around NYC, improving passenger comfort, reducing travel times, etc. SBS has even seen an increase in ridership over the recent few years (M86 SBS Progress report, 2017).

QJLs are by comparison to the other measures cited, the most expensive to implement. They also take up highly prized space and road infrastructure and are relatively new with majority of the research on them being done mainly using simulations and analytical models (Cesme et al., 2015; Troung et al., 2016). This research seeks to do an empirical study to evaluate the effects of the QJLs on the reliability of the SBS. By comparing two similar routes on the SBS, one with QLS and another without, two measures of reliability are proposed: the system's ability to meet its scheduled demand and capacity (Yin et al., 2004), and the severity of the wait passengers would endure. This will entail analyzing the bus schedules and actual bus data to assess the reliability as well as empirical field studies on passenger wait times. Such a study will pave way for studies of cost and benefit analyses and help drive policy decisions.

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▲ Isaiah Mwamba is working with his faculty mentor Joseph Chow (pictured left to right) to evaluate the effects of queue jump lanes on bus service reliability.



PYAY AUNG SAN

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Other Mentor
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DATA DRIVEN URBAN ENERGY MODELING AND DATA FOR CLIMATE CHANGE

How do physical infrastructure, socio-economic conditions, local ecology, and human behavior impact energy use and air quality in cities? This summer, I work at NYU's CUSP lab which uses data-driven models and computational methods to understand the interactions of physical, natural and social systems in multi-scalar urban environments, form building to the neighborhood to the city and even on a global scale. One of the main projects in the lab involves close collaboration with NYC Mayor's Office of Sustainability to achieve the city's aggressive mandate of reducing greenhouse gas and energy use. To meet the goal, we develop the analytical methodologies of the buildings' energy data to understand the nature of the usage and hence develop the new methodologies to identify and target efficiency.

"Data for Climate Action" is an open innovation challenge "to harness data science and big data from private sector to fight climate change" and CUSP group's proposal has passed the first round. This challenge is hosted by United Nation's Global Pulse, a flagship innovation initiative to accelerate discovery, development and scaled adoption of big data innovation for sustainable development and humanitarian action. With a selected group, I am working from data exploration, developing data modelling to gaining insights from big data sets provided by multiple industries such as BBVA, Plume, Waze, Orange, Twitter, etc.



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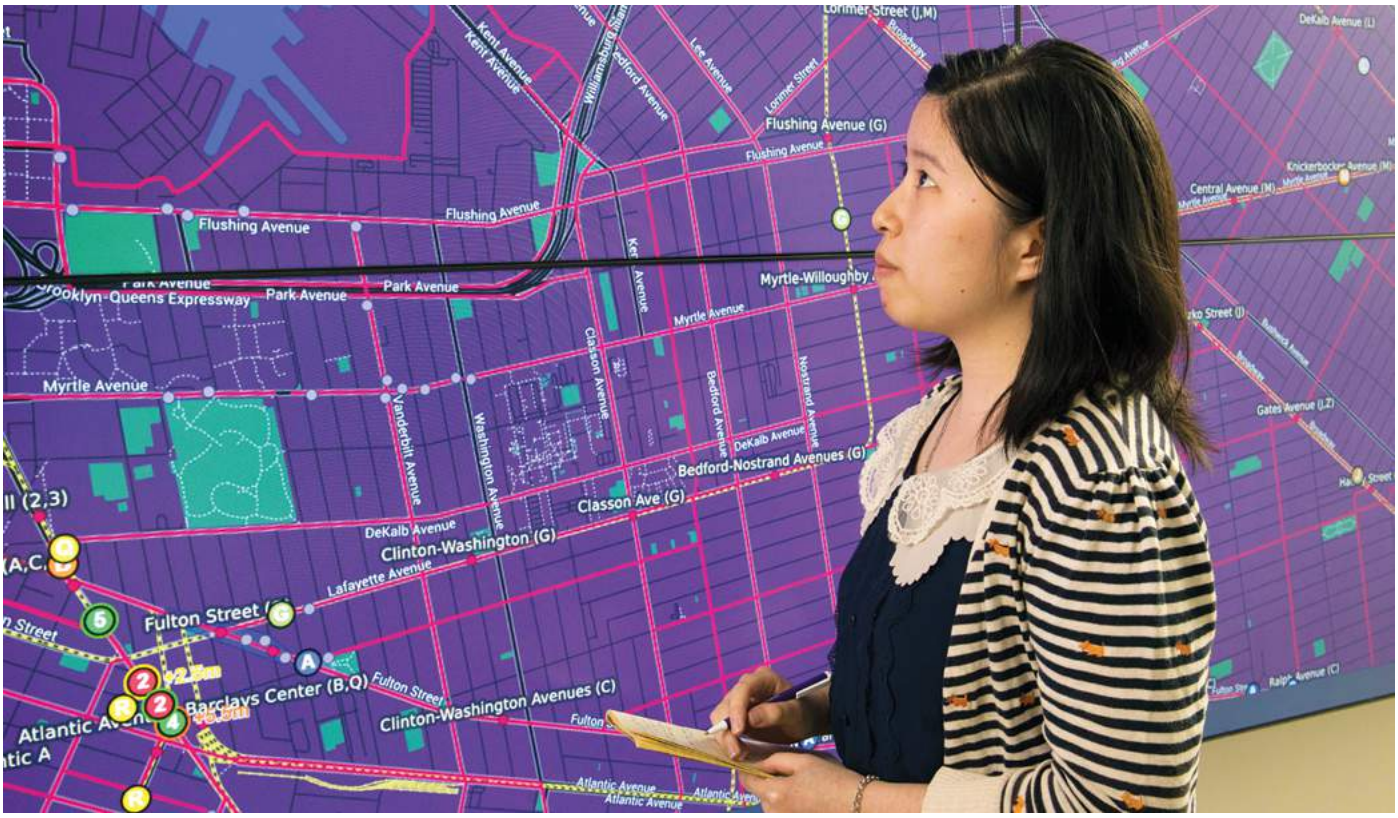
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MONITORING BUS ARRIVALS FOR HEADWAY CONTROL STRATEGIES

One of the primary problems in bus operations is bus bunching, a phenomenon that occurs when one bus gets delayed and ends up arriving at the same time as the following bus. This is problematic because the average wait times for travelers can increase significantly and ridership gets poorly distributed leading to further delays and frustration. Researchers have proposed strategies over the years (e.g. Newell, 1972; Daganzo, 2009; Bartholdi and Eisenstein, 2012) to control the headway to minimize the effects of bus bunching. Effective network-wide control strategies depend on having real time information available to make the decisions.

In these recent years, transit agencies like the NY Metropolitan Transportation Authority (MTA) have collected real time vehicle location data by installing the tracking devices on each bus. Each device sends out its location to the server automatically and records the location. While several tools have been developed by researchers for extracting bus locations and visualizing them on a GIS platform, no tool has been developed to monitor the bus arrivals at a bus stop. A method is explored to extract the location data and monitor bus arrivals at each stop of a transit route to allow for network-wide headway control strategies.



▲ Hio Kuan Kong is developing a tool to determine location data and monitor bus arrivals at each stop of a transit route to allow for implementation of better headway control strategies.



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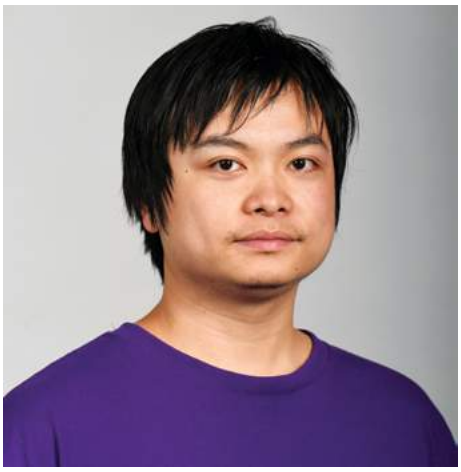
EVALUATION OF IMPACTS ON TRANSFERS FROM INTEGRATED REGIONAL TRANSIT NETWORK IN NEW YORK

The population in New York City is expected to increase by 2.5 million in 2040 and the transportation system is already experiencing overcrowding. Penn Station is known as the core of transit in New York with a capacity of 200,000 people per day. However, Penn Station currently faces an average of 400,000 commuters daily, serving as a terminal station for Metro-North, the Long Island Railroad, NJ Transit, and a few Amtrak lines. The resulting transportation system is not efficient for transfers. Regional integration (May and Shepherd, 2006) may address this problem.

One example is ReThinkNYC's plan to turn Penn Station into an entry point for the 400,000 commuters by creating new transit hubs for NJ Transit, Long Island Railroad, and Amtrak. This trunk line would then have access to all transportation networks and the new transit hubs in Secaucus Junction, Port Morris, and Sunnyside. It provides the availability to transfer from regional commuter rail to local transit, and vice versa. To analyze the effect the trunk line would have on commuters, a schedule-based transit assignment model (Nuzzolo and Crisalli, 2004), FAST-TrIPS (Khani, 2013), is developed and calibrated for the system. The model forecasts the routes taken by passengers so that comparisons between a base scenario and the scenario with the proposed trunk line can be made.



▲ Gisselle Barerra and her faculty mentor Joseph Chow (pictured left to right) are creating a model that will analyze the effect of a possible Penn Station trunk line on commuters.



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ONLINE INFERENCE OF CHARGING AND DWELL TIME ACTIVITIES FROM AUTONOMOUS ELECTRIC VEHICLE FLEET TRAJECTORY DATA

As the technology advances, abundant real-time and historical data for vehicles are available for analysis. This data is especially important in centralized, online control of autonomous vehicle fleets, as second-by-second vehicle location data can be made readily available for real time decision support. In order to run fleet level operational policies—routing, idle vehicle relocation, coordinating charging, coordinating transfers, etc.—a central system needs to be able to recognize the state of the network in real time. For example, an autonomous vehicle may know its own position, but the combined information of all vehicle locations is needed to infer the expected queue delay for passengers arriving at a terminal for pickup, or the drop-off requests that are leading to the routes made by the vehicles.

We develop such inference tools using inverse optimization (Xu et al., 2016) based on autonomous vehicle trajectory data shared by BestMile, a cloud computing company for autonomous vehicles. BestMile currently operates two electric autonomous-driving vehicles as a last mile service for a terminal station in Sion, Switzerland. To obtain deeper insight, we plan to further analyze the dataset of two vehicles with respect to more dimensions including times, vehicles' charge level and their real time speed, and then to develop an online inference model to estimate demand patterns and queue delay at the terminal station.



▲ Xuebo Lai and his faculty mentor Joseph Chow (pictured left to right) are creating an online inference model to estimate demand patterns and queue delays for vehicle fleets.

THE QUALIFIED COMMUNITIES AT HUDSON YARDS

With the increase growth of urban populations around the world, city agencies and local communities are keen to address the growing demand for efficient and sustainable services, as well as improving the quality-of-life for residents. The Quantified Community (QC) is a long-term research initiative that aims to collect data on the physical and environmental conditions of cities to assess how the built environment affects individual and social well-being. The QC aims to provide insight into solutions for sustainability and resiliency through analysis of data ranging from traffic to air quality.

As a part of the QC initiative, environmental sensors are being deployed in three New York City neighborhoods including Lower Manhattan, Red Hook and Hudson Yards. These low-cost environmental sensors provide real-time measurements of air quality, noise, air temperature, relative humidity and atmospheric pressure. Summer research has focused on the continued development of these devices including the implementation of a mobile Wi-Fi access point for remote access communication and the development of documentation and assembly instructions for distributed construction and further development. Using data obtained from these sensors, the project could reveal important insight and solution to some of NYC's urban challenges.



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COMPUTER SCIENCE AND ENGINEERING

SECURE SOFTWARE UPDATES FOR THE INTERNET OF THINGS

Internet of Things (IoT) industry is growing at unprecedented rates with industry leaders predicting 50 billion IoT devices to be in use by 2025. Software updates for Internet of Thing devices, such as industrial control systems, autonomous vehicles, medical devices, personal smart devices etc. could deliver significant benefits. However, if these updates are not implemented properly, they could lead to serious security vulnerabilities.

Software updates can address a myriad range of attack vulnerabilities and cyber attacks on the sphere of IoT devices that are compromising everything from power plants in Ukraine to pacemakers in hospitals in the United States to IP cameras around the world. These attacks are leading to more severe damage with every iteration.

Manufacturers have considered standard attacks and used common security practices, such as sending updates using Transport Layer Security to patch the devices, however, no existing solution considers more sophisticated and advanced attacks, such as the compromise of a repository distributing updates, a compromise at a supplier's site, or other similar attacks. Such attacks do not occur frequently but have previously been employed by rogue nation-state adversaries. And, the frequency of such attacks have significantly increased in the recent months.

Advanced solutions developed for regular PC software updates cannot be directly applied to IoT devices for two reasons: first, they do not address problems unique to these devices (eg. the minimal processing and storage capacities of IoT devices), and second, they do not address a scenario wherein an IoT device might be compromised, which causes it to malfunction, or worse, become unsafe (eg. automated medical supply systems from an industry leader in the US could be compromised to inject deadly amounts and combination of medicine into the patient's bloodstream). Thus, we are focusing on developing a flexible state-of-the-art software update framework that can be adopted by IoT devices, and designed together with leaders in the industry of IoT devices, to address IoT device-specific vulnerabilities and limitations.



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LIND

Virtual machines are widely used by software developers and computer engineers for various purposes, such as testing new programs on various distributions of operating systems, or isolating potentially malicious software from the host operating system. At the very core of every operating system, virtual machines included, is the kernel - the mother of all processes. If a vulnerability within the kernel is discovered and exploited via malware before it can be patched, important data can be lost, and the system could possibly be compromised. Such zero-day bugs could cause security problems.

Lind is a virtual machine design that is intended to be resilient to zero-day bugs, which are caused by vulnerabilities in kernels. By taking advantage of the fact that more popular paths correlate to triggering fewer zero-day bugs, Lind "locks" applications within these popular paths using a popular path based system design. By doing so, the chances of triggering a zero-day bug are drastically reduced. Lind's design implementation is complexified by constantly changing exploits, and the practicality of locking applications in popular paths, for both developers and users.

The purpose of this project was to determine the feasibility of a popular path based design. Using a modified version of the mouse and keyboard automation program XMacro, and the source code coverage analysis profiling tool, Gcov, kernel path data will be collected from virtual machines with operating systems running different versions of the Linux kernel. During the data collection process, packages from the Debian/Ubuntu Popularity Contest (popcon) will be run. By doing so, it will be possible to analyze kernel path trends across various operating systems, and culminate in a design that is both secure and useful.



▲ Parina Kaewrajang (pictured left) is developing a virtual machine model that examines the feasibility of a popular path-based design.

EFFICIENT INDEX UPDATES FOR WEB SEARCH ENGINES

Due to the constantly changing nature of the web, search engines have to deal with the issue of updating their index when documents change and become out of date. However, because documents are not usually completely replaced between changes, there is a significant amount of redundancy between document versions that can be exploited to make this update process much faster. Most of the research so far has been focused on taking advantage of redundancy between document versions in archival-like collections where all versions of a document are indexed. Our focus, on the other hand, is on indexing only the most recent version of a document, which is a less studied scenario, especially when we are also keeping track of positional information for indexed terms.

In this project, we develop a framework which will allow us to efficiently update an index with new versions of documents by only keeping track of the differences between the older and newer version. We first develop a document processing system that identifies an optimal set of common blocks of text to preserve by solving a variant of the Longest Common Subsequence problem, and then use that information to generate a tree representing the changes between the documents. We then create an index that can store the insertions and deletions specified by the tree, and buffer these changes into an auxiliary index located in memory to reduce random disk seeks. Finally, we make use of a re-merge strategy in order to merge the auxiliary index in memory with the main index on disk, and use a compression algorithm while merging that exploits the clustering nature of the terms in both indexes to save space.



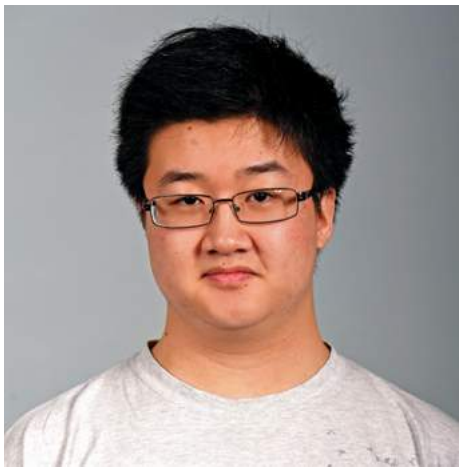
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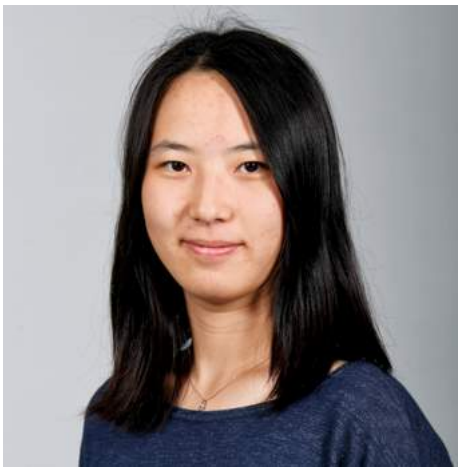
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IMPLEMENTING DISTRIBUTED HASH TABLE FOR DATA ADVERTISEMENT AND LOOKUP IN SEATTLE TESTBED

Seattle Testbed is an open-source, peer-to- peer platform designed for networking and distributed system research. It is free, community-driven, and operates on resources donated by users and institutions worldwide. Given the global distribution of its network, Seattle is ideal for applications in cloud computing, ubiquitous networking and distributed systems. Users can install and run Seattle in a sandboxed, isolated environment, which limits the consumption of resources such as CPU, memory, storage space and network bandwidth, and ensures the safety of other files and programs. These characteristics of Seattle allow users to run code without compromising the host machines' performance or security.

The purpose of this project is to provide an interface for using Distributed Hash Table (DHT) to announce and look up information pertaining to the operation of Seattle nodes. A DHT is a decentralized system commonly used in peer-to-peer software like BitTorrent; it provides a lookup service similar to that of a hash table – any participating nodes can retrieve the value associated with a given key efficiently from its peers. The first part of this project is to implement a DHT in Repy, Seattle's restricted subset of the Python programming language. The second step is to build a library that interfaces the DHT and directly provides Seattle users information advertisement and lookup functionalities. Since our implementation supports the extended BitTorrent protocol (BEP 44), it allows users to store and retrieve arbitrary data, making the DHT useful for more general purposes other than file sharing.



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SOCIAL GRAPH PARTITIONING ALGORITHMS

Graph partitioning is a well-known NP-hard problem that has no known efficient algorithm. Given its practical importance, many heuristic algorithms have been proposed. One example is METIS, a k-way multilevel partitioning algorithm, which can deliver good practical results. With the rise of social media, we see huge growth in social networks such as Facebook, Google+ and Twitter. The large amounts of user data make these social graphs impossible to be stored on a single machine. Thus, companies have built large distributed systems to store these graphs, and to run queries on them. However, due to bandwidth constraints and communication overheads, querying nodes across machines takes significantly more time than querying nodes locally. Hence, to minimize communication costs, data needs to be partitioned such that the total number of edges cutting across partitions is minimized while also satisfying constraints on the maximum amount of data that can be stored on each node.

In this research project, we study several methods proposed in recent papers, in particular, Balanced Label Propagation, LEOPARD, and a Bayesian Sharding approach. We implement these algorithms and run them on several large social graphs including LiveJournal, Orkut, and Pokec, each with millions of nodes and tens of millions of edges. We then compare and contrast the advantages and drawbacks for each algorithm. Finally, we further optimize the algorithms to improve partition quality.



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ELECTRICAL AND COMPUTER ENGINEERING

FAST SLAM FOR UNMANNED GROUND VEHICLES

For an Unmanned Ground Vehicle (UGV), Simultaneous Localisation and Mapping (SLAM) describes the problem of constructing a map of unknown surroundings, while being aware of the vehicle's location within the map. Given no information about the environment it is placed in, an autonomous vehicle must be able to extract and process data about its surroundings and subsequently navigate this environment based on this information. This task makes use of data from various sources. For example, image frames collected from on-board cameras are processed using computer vision techniques in order to recognize features in the environment, and Lidar (Light Detection and Ranging) sensors use frequent laser pulses to provide distances to obstacles so as to avoid collisions. Processing data from Lidar sensors, in particular, is a computationally intensive job that must be carried out on thousands of data points and can slow down navigation significantly. This presents itself as a prime candidate for the application of GPU processing power, amongst other computational speed-up methods. The goal of this project is to achieve fast and efficient data processing that will enable real-time navigation for UGVs.



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SENSOR FUSION AND CYBER-SECURITY OF EMBEDDED SYSTEMS

Cyber-security for embedded systems is a crucial part of any mechanical or electrical system. Any unauthorized change can cause numerous amounts of problems if it is not detected. The first part of this project involves verifying if the program in a programmable logic controller (PLC) had been altered in any way. The focus is to implement a technique that would extract the program from the PLC in an automated fashion, detect any differences in the program, and if discrepancies exist, to pinpoint where and what the changes are. The second part of the project involves working with an autopilot board with multiple microelectromechanical system (MEMS) sensors. The focus of this part is sensor fusion, combining data from several sensors in order to reduce the uncertainty that there would be if the sensors would perform separately. In the case of this project, sensor fusion can be used to estimate the pitch, yaw, and roll of an object to approximate the angular orientation. The cyber-security aspect of the sensors is also inspected. Methods to improve the resilience of the sensor fusion is looked into in order to prevent any altered sensor data or any other unwanted deviations.



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SECURING THE INTERNET OF THINGS

The Internet of things or IoT, for better or worse, is the way for the future. More and more devices are becoming connected to the internet. Many of these devices are simple, small, made to be low power, and are made with emerging technologies. None of these things are conducive to security. Security in IoT will be a major challenge for the security industry to solve in the coming years, both regarding conventional computer security concerns and new challenges specific to IoT security such as physical and hardware attacks.

There were three major goals of this research project. First to learn about common IoT devices and to create one. Then to explore the security flaws and potential attack vectors of the created device. Finally, to find and develop solutions to the security flaws and apply them to our device and expand them for application in the current IoT ecosystem.

We used the Arduino platform and cloud IoT data gatherers to create a standard IoT system. We looked at past attacks to understand the security concerns including, but not limited to, embedded system exploits and the Mirai virus (which was the virus responsible for the large outage in October 2016). We also looked at potential physical attacks such as a potential physical DDoS.



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LOAD BALANCING OF CITI BIKES

Citi Bike, like other bicycle-sharing systems around the world, is becoming increasingly popular as a means of transportation due to the flexibility that is offered to its users. Users can pick up or drop off bikes at any location or time they prefer. Because of this flexibility, there are often imbalances in the system such as the lack of bikes or parking docks at stations depending on the time of the day it is. For example, bikes tend to pile up downtown during early rush hour and on the outskirts during late afternoon. The current solution of Citi Bike is to use trucks to rebalance stations by carrying bikes from full stations to empty ones when the problem occurs. Instead of taking a reactive approach to the problem, our research aims to implement a proactive or preventive system that will more effectively meet the demand of the users.

This system will be implemented using a mathematical model called the Sequential Stochastic Assignment introduced by Cyrus Derman et al., where incoming tasks with random variable Xj (users) are allocated to objects (bike stations) with probabilities pi, based on the cumulative distribution function (CDF) of X and the values of p. The goal is to allocate the users to the stations of best fit or to maximize the total expected value ($\sum p \sum X$). The parameters p and X will be chosen in a way that will solve the load balancing problem. Our plan is to create a system that will incentivize users to fix the problem themselves by having a rewards-based system.



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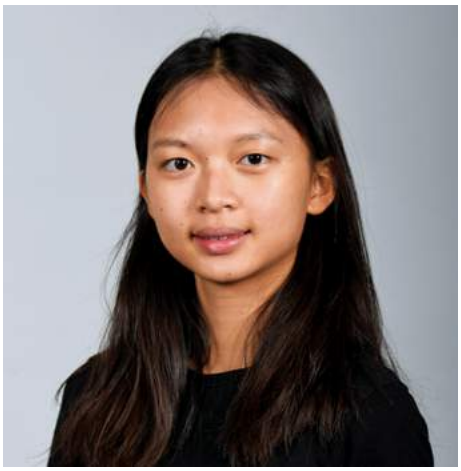
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ADVERSARIAL ATTACKS ON MACHINE LEARNING MODELS

Deep learning models have been widespread studied and proved to achieve high accuracy in various pattern recognition tasks, especially in image recognition. However, due to its non-linear architectures and high-dimensional inputs, its ill-posedness towards adversarial perturbations — small deliberately crafted perturbations on the input will lead to completely different outputs, has also attracted researchers' attention.

In order to study the adversarial attack on Deep Neural Networks(DNN) and build a more robust system, my work is split into two parts, first is to prove its vulnerability towards adversarial attacks by experiments, second is designing a mechanism for detecting adversarial attacks and defending the pattern recognition system — taking a traffic sign recognition system of a self-driving car. For the first part, my experimental results have clearly shown the vulnerability of the Convolutional Neural Networks(CNN) I built, adversarial samples crafted by both Fast Gradient Sign Method(FGSM) and Jacobian-based Saliency Map Approach(JSMA) can lower the model accuracy from above 95% to below 10%. For the detection of adversarial samples, I expect the statistical features of crafted adversarial samples and natural legitimate samples will be different. I expect the Density estimate and Bayesian uncertainty estimates of the sample's extracted features should help detect the adversarial samples. After detection, I expect a "human in the loop" mechanism will help correct the misclassification and quickly retrain the model using this adversarial sample, and an alternative recognition system will be working at that time, and after retraining, it should be able to defend the future adversarial samples crafted using the same algorithm. Therefore, a more robust and reliable recognition system can be established, which is essential for the safety of a self-driving car.



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BOARD GAME DESIGN ABOUT CYBER SECURITY

This project aims at designing an educational board game about cyber security. The potential players of the game can be kids and people without technology backgrounds that wish to have a basic knowledge of cyber security. The game also serves as a tool to raise people's awareness about cyber security.

The game tries to represent how the cyber attacks and regarding countermeasures work on the network level. By playing the game, the players would understand basic concepts of cyber security such as Virus, Distributed Denial of Service, Firewall, and Honeynet. Moreover, the players can experience some of the strategies involved in attacking or protecting cyber networks by playing the game.

This project involves developing the mechanics of the game, designing the visual style, digital fabrication and building an augmented reality mobile app. The game is a multiplayer board game. One of the player plays the role as an attacker, and the other player plays as a defender. Each player has a deck of hexagon cards with special functions. Through the game, the players take turns to put cards onto the table and develop a network. The objective for the attacker is to destroy the main server and the objective for the defender is to build a safe cyber network. The visual style of the game would be geometric design. All the concepts of cyber security would be visually represented with shapes and color. In the end, an augmented reality app would be launched and players can download the app and use their phones or tablets to scan the board game pieces. Some 3D representations of the game pieces and further explanation of the cyber security concepts would be shown on top of the pieces in the app to serve as an educational purpose.

MATHEMATICS



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EVALUATING ENVIRONMENTAL STRESSORS ON THE VULNERABILITY OF CORAL REEF ECOSYSTEMS USING THE MAHALANOBIS-TAGUCHI SYSTEM

Coral reefs are important for aquatic biodiversity and responsible for coastal protection. These coral communities have been declining in recent decades due to global climate change and increased sea surface temperatures. Environmental stressors such as light and rising nutrient concentrations also potentially correlate with thermal stress and further contribute to the vulnerability of coral reef ecosystem. There is a need to understand the effects of each environmental variable in coral communities. This study aims to investigate the significance of different environmental parameters on coral bleaching and mortality using the Mahalanobis-Taguchi System (MTS). MTS, a multivariate statistical method, is used to evaluate the most prominent ecological components that cause the coral reefs' detrimental health outcomes. The results are then compared with previously published multivariate models. By adding more potential indicators and using the MTS, we hope to broaden the present understanding of coral susceptibility and offer insight into future bleaching events and improving ecological resilience.



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ENERGY ANALYSIS FOR LOWERING CARBON EMISSIONS IN THE U.S., WHILE MINIMIZING EXPENDITURES

On June 1, 2017, the United States announced its plan to exit the Paris Agreement. The agreement was established by the United Nations to reduce global emissions of greenhouse gases. As part of the Paris Agreement, the U.S. committed to reducing emissions by 26 to 28 percent from its 2005 levels by 2025. Americans have criticized the withdrawal, with approximately 70% of them supporting the agreement. As of July 2017, 22 states have expressed support for the agreement. Compared to the rest of the country, nearly all of these states emit low carbon dioxide emissions per capita. This study aims to assist researchers in two ways: to gain a better understanding of the country's energy infrastructure and to formulate a plan to reduce greenhouse gases, especially for the states not supporting the Paris Agreement.

In 2015, carbon dioxide accounted for 82% of U.S. greenhouse gases emitted from human activity. Historical CO2 emissions and energy price data are used to develop energy source portfolios and budget estimates for each state. This would allow environmental and statistical models to be used to evaluate the distribution of different clean energy sources throughout the country. These models include Princeton University's Stabilization Wedges Model to develop energy portfolios and the Mahalanobis-Taguchi System to analyze the variation of the portfolios. The results of this study are compared with those of The Solutions Project's 100% renewable energy plans for each state and with those from a solar energy deployment study by Ryan Wiser, Galen Barbose, and Edward Holt.



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DETERMINING THE BEST PRACTICES FOR INCREASING TERRESTRIAL CARBON STORAGE AND SEQUESTRATION USING CURRENT SOIL DATA

For millennia, the Earth has successfully maintained a balance of carbon in the atmosphere, oceans, and terrestrial systems to create a climate suitable to sustain life. Global climate change is the result of increased concentrations of greenhouse gasses, such as carbon dioxide and methane, in our atmosphere. Anthropogenic carbon emissions from the burning of fossil fuels, deforestation, and land use change have been the main contributors to this increase, causing our planet to more effectively absorb and reemit energy back to the surface and warming the planet. As government agencies and industries continue to debate how best to reduce our global emissions, work can be done to create negative net emissions through carbon sequestration.

Two major sinks for carbon, terrestrial and biological systems, have been severely affected by deforestation and land use change practices. Old growth forests hold considerably more carbon in their biomass than the croplands with which they've been replaced. Increased tilling and plowing has removed entire layers of soil organic matter from agricultural land. While many farmers are already working to better their soil management practices, there is still tremendous room to expand these efforts. This research aims to determine the effects of different land practices by looking at soil data before and after conservation practices were introduced and identify which variables have the greatest impact on increasing carbon storage. Data from government databases regarding land use, soil properties, and agricultural practices will be analyzed using the Mahalanobis-Taguchi System. Working to increase soil organic content and carbon biomass will both reduce carbon emissions and create a sink for an estimated additional 150 to 430 Mton of carbon each year in the US alone.



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NONLINEARITY AND CHAOS IN THE EL NIÑO/LA NIÑA SOUTHERN OSCILLATION (ENSO) MODEL

The ability to accurately forecast climate events plays an essential role in the modern world. Forecasting the climate is complex and riddled with uncertainties; the goal of this paper is to investigate an nonlinear climate model that aims to do just that, the El Niño/La Niña Southern Oscillation (ENSO) model. This model explores the interaction between temperatures in the equatorial Pacific Ocean and the atmosphere. In this interaction, ocean temperatures influence the atmosphere which in turn influences ocean temperatures; this is known as a positive feedback loop, which leads to chaos.

Pioneered by the meteorologist Edward Lorenz, chaos is a phenomenon in which small differences in initial conditions lead to drastically different outcomes. It is no surprise, then, that chaotic systems have peculiar mathematical properties. In this research project, we will explore the chaotic properties of the ENSO model.



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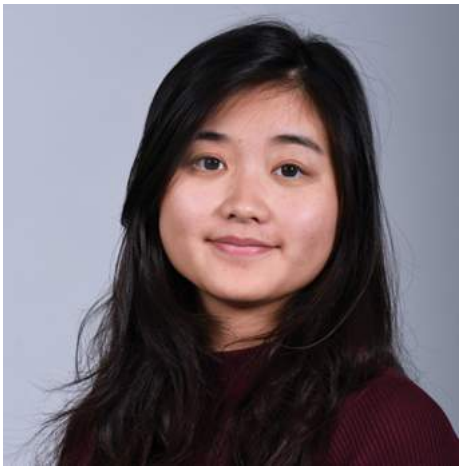
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MECHANICAL ENGINEERING

THE CHARACTERIZATION OF HIGH STRAIN RATE COMPRESSIVE BEHAVIOR OF CEMENTITIOUS SYNTACTIC FOAMS WITH HOLLOW GLASS MICROSPHERES

Syntactic foams are particulate composite materials composed of hollow particles dispersed mainly in a polymer or metal matrix. Owing to their lightweight and other desirable properties, they are extensively utilized in the aerospace and marine industry. This research is focused on a relatively novel composite material, called cementitious syntactic foam (CSF), which includes hollow glass microspheres (HGMs) in a cement paste matrix. The purpose of this study is to investigate the strain rate sensitivity of the compressive strength and failure mode of the different CSFs under a certain range of strain rates (~600–1000 s-1) using the Split Hopkinson Pressure Bar (SHPB) method. Samples of different CSFs with different density HGMs (0.38–0.60 g/cm3) and volumetric fractions (20–40%) of HGMs, and a baseline material with only the cement paste are cast in a cylindrical shape. To observe the time-dependent compressive behavior of CSFs half of the samples are tested on the 7th day following casting while the other half is tested on the 28th day. Following the SHPB experiments, the acquired raw data is analyzed using an in-house software to obtain the stress-strain and the stress-strain rate data. The analyzed data is then studied to determine important parameters such as compressive strengths, average strain rates, and the elastic moduli. The strain rate sensitivity of the compressive strength is expected to have a close relationship with the macro and micro scale failure modes. Therefore, a high-speed camera will be utilized to capture the failure mode on the macroscopic scale and this failure mode will be compared to that of the quasi-static tests. On the other hand, the failure mode on the microstructure level will be investigated with scanning electron microscopy and micro computed tomography.



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ENGINEERING 3D LEFT-RIGHT ASYMMETRY IN A CONTROLLABLE AND MULTIFUNCTIONAL VASCULARIZED MICROENVIRONMENT

Left-right asymmetry, one of the originals of asymmetrical organ formations, has been studied in a wide range of normal biological development in human bodies and other organisms. It is known that defects of LR asymmetry can lead to birth defects and numerous diseases. Instead of studying left-right asymmetry in in vivo, 2D in vitro cell chirality has been widely studied in recent decades. However, 3D in vitro left-right asymmetry is still largely unknown, due to the lack of available in vitro 3D microenvironments. We found the in vitro 3D endothelial cell (EC) chirality, and studied the different EC behaviors in an engineered 3D vascularized microenvironment with tunable matrix stiffness and composites, and controllable cell-matrix and cell-cell interactions. In addition, EC chirality in 2D and 2.5D environments were also achieved by using micropatterning techniques to parameterize the pattern shapes, sizes, and cytoskeleton arrangements in vitro. We propose that the engineered 3D microenvironments could potentially provide effective in vitro tools to observe, analyze and control more-like in vivo 3D LR asymmetry in cell populations, which could further benefit the understanding of disease mechanisms, such as birth defects in laterality, and tumor metastasis.



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ANALYTICAL SYSTEMS FOR THE STUDY OF CELL MECHANOBIOLOGY

Inflammatory breast cancer cells (IBC) is a form of breast cancer that is highly aggressive and lethal. Evidence suggests that cancer stem cells (CSC), which are cancer cells with stem cell-like properties, play a major part in the aggressive nature of IBC. Research has shown that the specific mechanical environment could contribute to its phenotypes and activities. Cell motility is also a key factor to the migration of invasive cancer cells. Factors analyzed in this project are specific to forces experienced by the cell, and the actin cytoskeleton structure. The regulation of the mechanical environment and cell motility could potentially lead to appropriate therapies for treating cancer.



▲ Fang Ni Zeng, Joyce Yan, and Kevin Guan (pictured left to right) are studying the effects of cancer stem cells, which may potentially lead to improved therapeutic treatments for breast cancer.

ANALYTIC STUDY OF MECHANICAL PHENOTYPE OF INFLAMMATORY BREAST CANCER STEM CELL

Inflammatory breast cancer (IBC) is the most aggressive and lethal form of breast cancer. Advances in the adjuvant treatment of breast cancer have not had a favorable effect on IBC patient survival rates because the underlying mechanisms which allow IBC to be so aggressively metastatic are still under study. Evidence indicates that cancer cells with stem cell-like properties, termed 'cancer stem cells' (CSCs), play a major role in the aggression of IBC. CSCs display distinct adaptive biomechanical properties that facilitate functional behaviors like self-renewal, epithelial–mesenchymal transition (EMT), and invasive and metastatic activities. In vivo, CSCs reside in a distinct microenvironment, the "CSC niche", in which a diverse array of mechanical/biophysical environmental factors contributes to the overall control of CSC phenotypes. Hence, this research examines how the distinct adaptive biomechanical attributes of IBC-CSCs, the so-called "mechanophenotype", such as cell stiffness, actin cytoskeleton (CSK) structure, and force contribute to the CSCs' tendencies toward tumorigeneses and metastases. Furthermore, our proposed research will specifically explore the role of the mechanotransductive regulatory networks involving Rho GTPase, actomyosin CSK and nuclear Hippo/YAP signaling in regulating the IBC to CSC. Understanding the unique role of the CSC mechanophenotype in IBC progression will enable the engineering of novel mechano-regulation platforms that would encode specific biomechanical cues to control IBC's stiffness, morphology, actomyosin CSK structures, and tensions. This added control will, in turn, modulate IBC's aggressiveness via its CSC subpopulation. Such a research is urgently needed for future therapeutic approaches to IBC.



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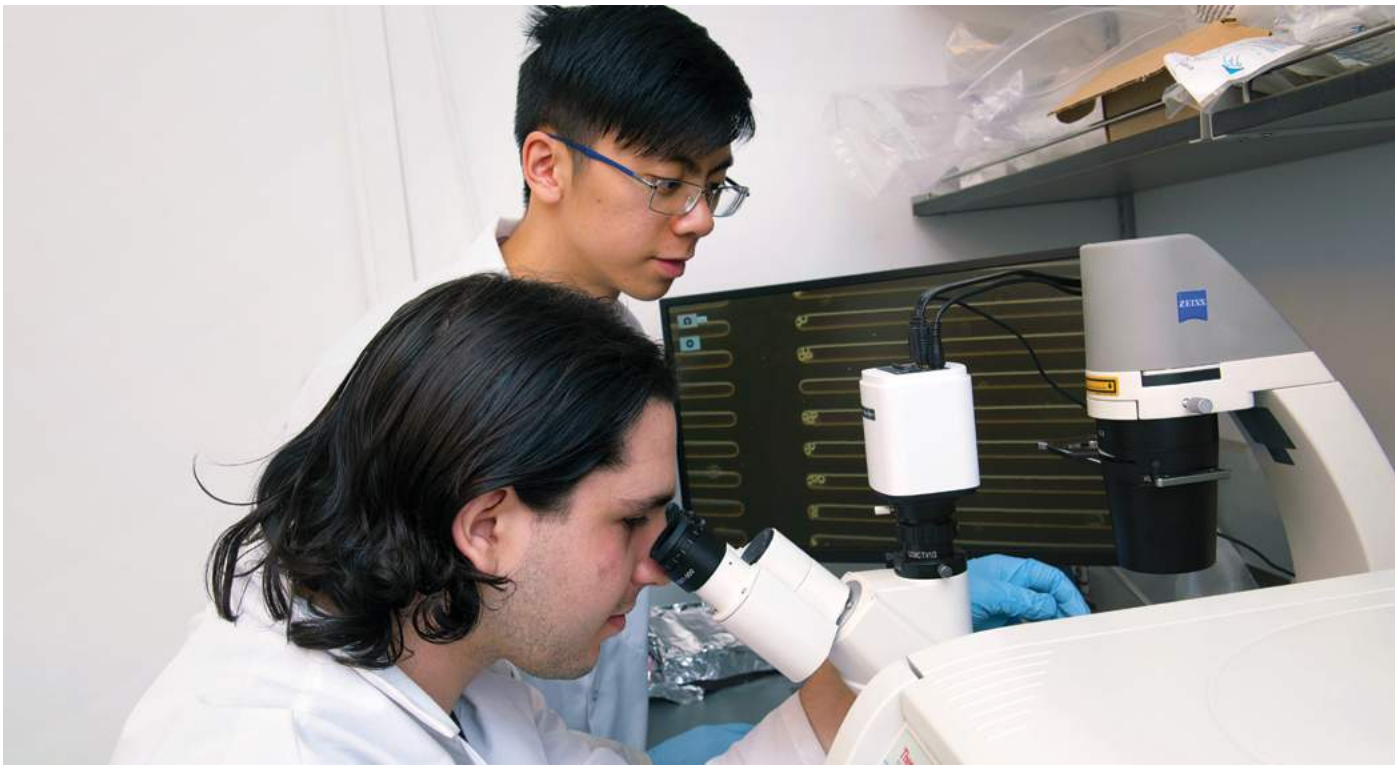
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▲ Adam Grosvirt-Dramen and Jiong Huang (pictured left to right) are designing a microfluidic platform to measure cytokine secretion profiles in blood to improve immune system monitoring.

PLASMO-FLUIDIC BIOSENSOR FOR REAL-TIME SINGLE CELL IMMUNOPHENOTYPING

The immune system defends the body through intercommunication between cells through signaling proteins called cytokines. It is crucial to determine individual cell's cytokine secretions as it directly relates to immune responses to infections, such as human immunodeficiency virus (HIV), and the development of cancer. Real-time measurement of immune responses is necessary to track disease progress and drug efficiency. The conventional method of cytokine analysis in clinical settings is Enzyme-Linked Immunosorbent Assay/Spot (ELISA/ELISpot), which is not suitable for real-time, multiplexed, dynamic detection of immune cytokines due to its time-consuming protocols and large sample volumes [~300uL]. In addition, the polyfunctional heterogeneous nature of immune cells shows the need of single cell profiling in clinical diagnostics and monitoring. Currently, we are developing a microfluidic platform incorporating localized surface plasmon resonance (LSPR) based optical biosensing and single cell microarrays to measure cytokine secretion profiles in smaller volumes [~1uL] of human blood to improve current diagnostic tools for immune system monitoring. The two-part device consists of a glass substrate patterned with an antibody functionalized gold nanorod (AuNR) barcode and a microwell-array for single cell capture. Cytokine-bound antibodies cause a shift in resonant oscillation of conduction electrons of the AuNRs. Consequently, the light intensity becomes greater; therefore, the concentration of cytokines can be determined by measuring this intensity shift using frequency filtered dark-field imaging. Single cell capture is done through applications of cell culture onto a microengineered microwell-array. The two components will allow for real-time biosensing of cytokine secretion based immunophenotyping of single immune cells.



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REPROGRAMMING MACROPHAGE PLASTICITY FOR OPTIMIZING GLIOBLASTOMA ANTI-ANGIOGENIC THERAPY

Despite aggressive treatment, Glioblastoma Multiforme (GBM), a refractory and fatal primary brain tumor, is characterized by tortuous neovascularization and potent immunosuppression. Like other solid tumors, GBM promotes angiogenesis, formation of new blood vessels from pre-existing vasculature, for survival and growth. The proven dependence of GBM tumor growth on neovascularization justifies a rationale for anti-angiogenic treatment. In addition, GBM continuously engages with neighboring and infiltrating immune cells during its progression. Among recruited immune cells, tumor-associated macrophages (TAMs) make up 30% of GBM tumor mass in remodeled vascularized networks and facilitate GBM immunosuppression for evading patient adaptive immunity. This suggests there is a synergic role of tumor immunity and vascular reorganization in GBM aggression.

This research involves engineering a biomimetic 3-D microfluidic vascularized glioma tumor microenvironment with directable biochemical signaling; controllable cell-cell interactions (immune, endothelial, and cancer cells); and tunable matrix mechanics. Cell-matrix interactions are tuned by repurposing a collagen matrix with Arg-Gly-Asp (RGD) peptides for promoted $\alpha_v\beta_3$ integrin expression, which is highly expressed by angiogenic endothelial cells. Employing our platform, we have shown that TAM plasticity contributes to *in vitro* tumor angiogenesis, such that anti-inflammatory macrophages (M2) promote angiogenesis and pro-inflammatory macrophages (M1) suppress angiogenesis. Harnessing this knowledge, we will screen the anti-angiogenic effects of $\alpha_v\beta_3$ integrin inhibition and/or TGF-β1-Receptor inhibition with the goals to, respectively, normalize GBM tumor vasculature and "re-educate" TAMs from a M2 to M1 phenotype. To further advance the clinical applications of our integrated microfluidic system, we hope to validate combinations of our proposed anti-angiogenic inhibitors along with immune checkpoint blockers to hack GBM tumor immunity and neovascularization.



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MECHANICAL ALLOSTASIS OF VASCULAR SMOOTH MUSCLE CELLS FOR CARDIOVASCULAR DISEASE MECHANOPHYNOTYPING

Allostasis is a fundamental biological process that living organisms utilize to maintain stability through physiological or behavioral changes to protect against variations of internal and external environments. Although physiological responses to environmental stressors has been extensively studied for vertebrates, understanding of allostasis in the subcellular level is still suboptimal. Smooth muscle cells (SMCs) of blood vessel are critical for promoting vascular health and development. Emerging clinical and experimental studies propose that SMCs in diabetes may be functionally impaired and thus contribute to the increased incidence of macrovascular complications. Unfortunately, cardiovascular disease is often established by the time diabetes is diagnosed. Here, by comparing the different allostasis processes of normal and type 2 diabetic SMCs, we will build an integrated phenotyping of SMCs for cardiovascular disease detection. We will use an integrated micromechanical tool capable of applying controlled mechanical stress on cells while simultaneously reporting dynamic responses of subcellular mechanics to study the distinct mechanical allostasis of normal and diabetic SMCs. We will reveal that cells subject to an emergent physical stress display mechanical allostatic response that caused the cells to change their shape, force, and energy distribution. Our analysis will be focusing on cellular free energy analysis, including cellular strain energy and the cellular interfacial energy that are responsible for cellular allostatic transformation. Together, our experimental and theoretical results will provide quantitative insights regarding the physical origin of single-cell mechanical allostasis, which will serve as sensitive mechanophenotyping for cardiovascular disease diagnosis and provide a subcellular view to understand the formation and progression of certain diseases or aging.



▲ Zijing Zhang (pictured left) is building an integrated phenotyping of smooth muscle cells to gain a subcellular understanding of the formation and progression of diseases.



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3D PRINTED AND LASER-CUT BIOSYSTEMS FOR CELL ANALYSIS

Soft lithography is the currently preferred manufacturing of microfluidic PDMS devices for Biosystems. It utilizes a multi-step process that is expensive and time consuming. Maker-Spaces are community driven spaces that provide low-cost access to rapid-Prototyping tools such as 3D printers, Laser-cutters/engravers, and other devices. The combination of technology and space allows for quick idea generation and execution. Having this in mind, the current project inquires whether Maker-Spaces can allow microfluidics devices to be prototyped and tested using much simpler and less time-consuming techniques than soft lithography. Current attempts at developing PDMS molds using 3D printing indicated that the accuracy and reliability of the material are the factors that affect the results most, with the most high-resolution 3D printer being able to print only within ~150Qm and higher. We also try to develop molds using laser-engraving and laser-cutting. Accuracy in laser-cutting is sufficient (1200 DPI or 25Qm), however designing the mold requires basic knowledge of Vector based design software such as Adobe Illustrator. Through this technique, we aim tackle the challenge of controlling the engraving and cutting depth as well as avoiding surface roughness of resulting PDMS devices.



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THE INVESTIGATION OF THE ALKALI SILICA REACTION OF HOLLOW GLASS MICROSPHERES WITH THE CEMENT PASTE IN A CEMENTITIOUS SYNTACTIC FOAM BASED ON C1260 MORTAR BAR EXPANSION METHOD

Lightweight cementitious materials with comparably high strengths are a research interest for many materials scientists. Recently syntactic foams, which are particulate composites with hollow particles, became popular amongst lightweight materials. In addition to polymeric and metallic composites, cementitious syntactic foams with hollow glass microspheres are also thought to have a potential for high specific strength. However, the amorphous silica of the hollow glass microspheres are likely to react with the highly alkaline cement paste of the cementitious syntactic foams. This reaction, which is called alkali- silica reaction (ASR) is known to lead to an expansive gel that causes cracking in other cementitious composites. The hollow geometry of the glass microspheres is expected to prevent internal stresses due to this ASR. The severity of ASR is commonly measured using the ASTM – C1260 standard method, which measures the expansion of the materials cured under high pH and high temperature (80°C) NaOH solutions. In this study, five different materials are tested for their expansion and compressive strength after ASR. The first two samples are two cementitious syntactic foams with different density hollow glass microspheres. Whereas the third and the fourth samples have solid glass inclusions with the same volumetric fractions (30%) and comparable particle size distributions. These solid inclusions are spherical for the third sample and angular for the fourth sample in order to observe the effects of the geometry on the ASR expansion. The last sample is the control group where a baseline material with only cement paste is tested. All of these materials will be tested for their compressive strength using six cubical samples, half of which will be subjected to the same high pH NaOH solution of the C1260 test and the other half will be cured under normal pH conditions. These compressive tests are expected to reveal the potential detrimental effects of the ASR on the compressive strength of the composites. Scanning electron microscopy will also be utilized to observe the microstructural changes due to the ASR reaction on all samples.



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TUNING GLIOBLASTOMA TISSUE MECHANICS FOR REGULATING TUMOR ANGIOGENESIS

Glioblastoma Multiforme (GBM) is the most prevalent and aggressive form of brain tumors, with a median survival period of 12-15 months despite aggressive therapy, and is characterized by malignant and aberrant angiogenesis. Given the poor clinical outcomes, it is critical to recreate a biomimetic in vitro microenvironment for examining the regulation of GBM aggression and tumor angiogenesis with tunable microenvironmental cues. Of the many microenvironmental parameters studied, mechanical signaling remains poorly understood. Gliomas develop within a mechanically-challenged microenvironment, characterized by extracellular matrix (ECM) remodeling and stiffening. Tumor tissue, like GBM, tends to stiffen during solid tumor progression and tissue stiffness is known to regulate cell behaviors such as proliferation, migration and cell-cell adhesion, which are prerequisite for angiogenesis. Also, GBM tissue stiffness can alter the stromal components present in the tumor microenvironment (TME), such as tumor-associated macrophages which facilitate inflammation in the GBM TME, as either pro-inflammatory or anti-inflammatory. We will investigate if alterable matrix rigidity can influence macrophage phenotype via polarization and tumor angiogenesis by employing a 3-D microfluidic vascularized brain TME. This multifunctional in vitro microfluidic system integrates glioma, immune and endothelial cells to recapitulate in vivo cell-cell interactions and incorporates controllable matrix stiffness to mirror in vivo biophysical tumor properties. The platform we report may provide a more physiologically relevant and controlled 3D in vitro model for elucidating the mechanosignalling mechanisms responsible in GBM progression.



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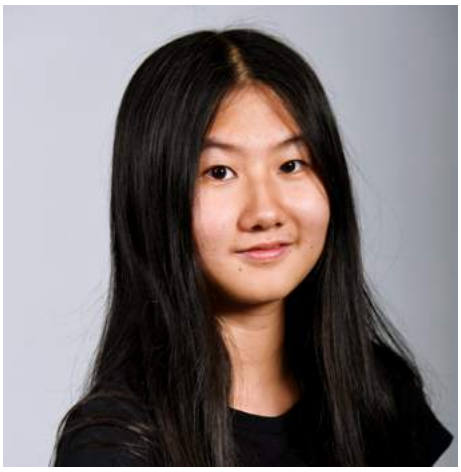
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MODELLING A VSD OCCLUDER DEVICE

Ventricular Septal Defect (VSD) is a congenital heart defect that occurs in newborns. It is characterized by an opening in the septum between the two ventricles of the heart. If the size of defect is large, VSD has to be treated surgically. Usually, this entails the deployment of medical devices to stop blood flow through the defect. These medical devices are defined as occluders, and are self-expandable double disc meshes made from braided wires of NiTinol. NiTinol is a Shape Memory Alloy that exhibits properties such as super-elasticity and Shape Memory Effect.

The left ventricle has a complex texture, which can present bundles of muscle fibers and trabeculae. Therefore, it is often difficult to locate the VSD and to deploy the occluder in a optimal position. This research focuses creating tools for planning a successful occluder deployment. Micro CT scans will be used to construct a 3D model of the occluder. Moreover, the mechanical behavior of the occluder will be simulated using a finite element analysis software such as ABAQUS∑. The overarching goal of this work is to create personalized simulations of occluder deployment for surgical planning and clinical decision making.



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PRODUCT SECURITY IN ADDITIVE MANUFACTURING

Additive manufacturing, also well known as 3D printing, has been adopted in fields as diverse as automotive, aerospace, architecture, dental and medical for many advantages including low tooling or assembly costs, and high customization as well as geometrical complexity. As a completely digital process chain from developing a CAD model to the final printing step, it is vulnerable to cyber-attacks such as intelligent property stolen, software or firmware sabotage, and other criminal intents at each of the manufacturing stage. Due to the increasing incidents of cybersecurity breaches worldwide, protecting the CAD models with embedded security features has become a priority in additive manufacturing. This project will design and implement a surface pattern on the product during the CAD stage for security purposes, which will make a counterfeit product easily identifiable if it is not authorized to be additively manufactured under the prescribed conditions. The secured product is then subjected to industrial computed tomography scanning technique to acquire the internal geometrical information and further reconstruct the embedded surface pattern. A pattern recognition and identification process will be developed to compare between the reconstructed and the original surface pattern. Deviation results from this pattern matching analysis will be used to evaluate and confirm the products' authenticity.



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DEVELOPMENT OF FIBER-OPTIC LOOP SENSOR FOR TEMPERATURE DETECTION

The fiber optic loop sensor (FOLS), invented at Composite Materials and Mechanics Lab, created by using a single-mode fiber detects transient changes in surrounding environments in which the transmitted intensity is monitored. The use of a single-mode fiber presents multiple intermediate peaks in the transmitted power allowing for a dual measurement range, very high sensitivity measurements in a short displacement range. A change in the radius of the optical fiber loop due to an applied force or displacement results in a change in the transmitted intensity; a smaller radius will present a much higher intensity loss than for a larger radius. The radius change occurs in two ways; the loop remains a perfect circle and one end is pulled by a translation stage to reduce the radius or the loop is deformed by applied pressure with a translation stage transforming it into more of an oval. The current research is focusing on detecting temperature, ranging between 0 and 100 degrees celsius by using the temperature as the parameter which changes the radius of the loop. Fiber optics are appealing due to their chemically passive and electrically immune properties. FOLS is a simple, inexpensive and sensitive design.

PREDICTION OF STRAIN RATE SENSITIVITY OF POLYMER MATRIX COMPOSITES USING DYNAMIC MECHANICAL ANALYSIS DATA

Recently, a large amount of research has been conducted to develop a method to relate data from dynamic mechanical analysis to the material's strain rate sensitive mechanical properties. This method is potentially valuable because it would greatly reduce the number of tests required to understand a material's behavior under a variety of temperature and loading rates. Applying the time-temperature superposition principle and the integral relations of viscoelasticity, the method is used to measure the time-domain relaxation function, which describes a material's response to a strain rate. This method relies on the assumption that the material is linear viscoelastic, which there is no general way to prove. The purpose of this study is to verify this method for composite materials beyond those materials previously studied by testing the method's ability to predict the strain rate sensitive response measured in separate tensile experiments.



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DEVELOPMENT OF LIGHTWEIGHT POLYMER MATRIX COMPOSITE MATERIALS

Lightweight composite materials like polymer matrix syntactic foams have been used ubiquitously in fields such as aerospace, marine and automotive industries for several decades due their high strength-to-density ratios. With the advent of additive manufacturing (AM) techniques or 3D printing, efforts are being made to manufacture parts from syntactic foams by using 3D printing, which offers flexibility in manufacturing such as quick prototyping, accommodating design changes, and fabricating complex geometries. New methods of recycling and reusing polymer-based syntactic foam offer economic and environmental potential. This project will investigate the degree of recyclability of thermoplastic-based syntactic foam to study the effects of processing on the constituents of the foam. HDPE and fly-ash cenosphere foam (40% wt. fly-ash) will be processed into filaments for fused deposition modeling (FDM). Thermoplastics undergo pressure and shear forces that might lead them to fail. Since the cenospheres provide the foam with a high strength-to-density ratio, the material will be analyzed for cenosphere breakage after it has been processed and extruded into filament. Three passes of extrusion will be conducted and cenosphere breakage will be calculated at the end of each pass

by performing micro CT scanning, and SEM will be used to characterize the microstructure. The filaments will be used to 3D print standard tensile samples and their strength will be compared with foam samples manufactured by injection molding to quantify the effects of recycling on mechanical properties. HDPE and glass micro-balloon syntactic foam will also be studied to compare recyclability of the two foams.



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REPAIRING ADDITIVELY MANUFACTURED PARTS USING ADHESIVE AND THERMAL BONDING TECHNIQUES

Advancements in the field of additive manufacturing (AM) techniques as means to fabricate components have made AM an attraction for several fields. Efforts are being made to use AM techniques or 3D printing to produce parts from lightweight composite materials in industries like marine, aerospace, and dental, among many others. While 3D printing can be used to produce parts with complex geometries (internal/external), one aspect of this process chain has enticed relatively less attention; the repairing of 3D printed parts. If a part is improperly printed or damaged during service, it should be possible to repair it instead of manufacturing the entire part altogether, which will add value to the process by saving cost and time. This research project investigates techniques of thermal welding to repair damaged/faulty parts while preserving the majority of its mechanical strength. This work focuses on finding optimum temperature, pressure and bonding materials to satisfy the repair requirements. Standard 3D printed tensile samples of Acrylonitrile Butadiene Styrene (ABS) with engineered defects are processed under thermal bonding methods to establish convincing results that justify the viability of such techniques. The repaired samples are then tested for their strength by conducting quasi-static tensile testing and compared against the strength of samples 3D printed without defects. Change in dimensions of the part are also studied and process parameters are optimized to achieve high strength and low dimensional variations.



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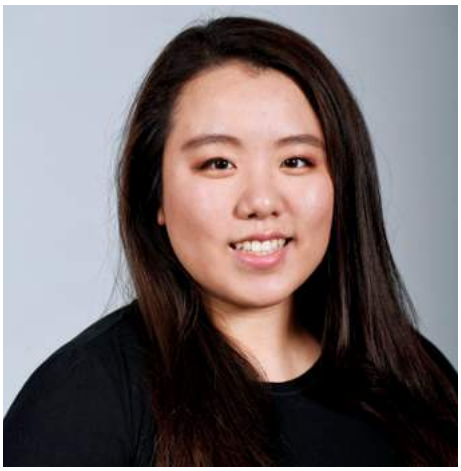
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ENERGY EXPENDITURE ESTIMATION IN BATTERY-POWERED MOBILE ROBOTIC SYSTEMS

Human reliance on mobile robots has increased in recent years. Their ability to perform dangerous and labor-intensive tasks has made them popular across different industries. A critical problem in mobile robotics is maximizing battery life so that robots can work for longer periods of time before needing to be recharged. One approach is to implement energy efficient motion planning, which optimizes the lifespan of the battery without requiring physical changes in battery design or construction. To develop an energetics model for use with optimization, energetics experiments were conducted on two robotic platforms: a two degree of freedom robotic arm and the Dynamic Anthropomorphic Robot with Intelligence – Open Platform (DARwIn-OP) humanoid robot, both powered by lithium-ion polymer batteries. The voltages and currents of cells in the battery and actuators of the robots were measured and collected during various tasks using a National Instruments CompactDAQ-9174 in order to compute the energy expenditure of typical activities. The state of charge (SOC) was then estimated from the voltage and current data using an extended Kalman filter, allowing the user to compute the energy expenditure of the battery based on the open circuit voltage (OCV) vs. SOC curve. This approach is studied and validated first using the robotic arm under arm-bending trials, and then using DARwIn-OP during walking trials. Future work includes energy optimal motion planning and energetics modeling in other robotic systems given their joint kinematics.



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PARAMETRIC ANALYSIS OF BALANCE STABILITY BOUNDARY VARIATION IN LEGGED SYSTEMS

Legged robots are favored due to their similarity to humans: they are better equipped than wheeled robots for rugged and human environments and are used throughout various industries. However, legged systems present a unique challenge in their control because of the added difficulty of avoiding falls while performing tasks, which requires knowledge of the system's stability characteristics. The stability of any legged system, human or robot, can be characterized with its balance stability boundary (BSB), a manifold that maps every center of mass (CoM) location to its velocity extrema. These are the maximum and minimum initial velocities such that the system, starting at the CoM location, can still reach a final balanced state under the given constraints. BSBs were generated for human subjects for varying gait phases and for an inverted pendulum model with a finite foot to study the effect of varying kinematic and dynamic system parameters on system stability. The velocity extrema were computed with a multibody dynamics solver programmed in C using the SNOPT 7 optimization package. Different variables such as foot size and torque were manipulated and studied to determine patterns in stability and test extreme velocities for the inverted pendulum model. Knowing the BSB of systems with different inertial and geometric parameters can lead to improvements in the design of robots, exoskeletons, and prosthetics with respect to stability.



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TRACKING NEMO: HELP SCIENTISTS UNDERSTAND ZEBRAFISH BEHAVIOR

Citizen science enables members of the public to participate in scientific research exploring real-world problems, often through web-based applications. It provides citizens opportunities to enhance their understanding of scientific work and offers an effective and efficient way for scientists to strengthen the infrastructure for scientific research.

The research objective of this project is to improve data collection of zebrafish swimming trajectories by leveraging distributed human participation in citizen science. Building upon our software that uses automated tracking algorithms for fish tracking, we will develop an entirely online platform for conducting manual tracking where human assistance is needed. For the frames of the video where assistance is required, a short task will be assigned to the user consisting of these frames along with their leading and trailing frames. Each task will consist of a minimal amount of frames: enough to provide the user with sufficient information to complete their task while avoiding excessive mental workload.

Further, we will incorporate features that resonate with intrinsic and extrinsic motivations to improve participant retention and contribution. The users will be able to track their progress and digital achievements, which reward them for their efforts. Additionally, a leaderboard system will encourage users to continue engaging themselves in scientific research by making their contributions noteworthy. This project will contribute not only to achieving the 3 Rs (Replace, Reduce, Refine) in animal experiments, but also engaging citizens in research.



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CHARACTERIZATION OF ZINC-MATRIX SYNTACTIC FOAMS

This research is based on determining compressive mechanical properties of Zinc matrix syntactic foam. Metal syntactic foams are composite materials that contain hollow particles in a metal matrix material. They are of high demand in aerospace and automobile industry, underwater vehicles and are also used as radar transparent materials due to their use in lightweight structures. One of the primary applications of syntactic foam composite materials is their use in energy absorption components. Therefore, understanding their compressive properties would provide innovative solutions to the real world challenges for industry. In this work, a Zinc-Aluminum Alloy (ZA8) syntactic foam filled S32 micro-balloons is being investigated. The microstructure of ZA8 syntactic foam is first observed under Optical Microscope and Scanning Electron Microscope. The material is then tested for Quasi-Static compression strength and a CT scan is conducted to understand mechanisms of deformation and fracture, which helps to develop quantitative relationships between structure property and predictive capability. The composite then undergoes high strain rate testing. This same testing procedure is followed for the matrix alloy which allows a comparison between the two and helps determine compositions/distributions of hollow particles in syntactic foam.



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INFORMATION FLOW IN ZEBRAFISH GROUPS DURING ESCAPE FROM A SIMULATED PREDATOR ATTACK

Zebrafish have attained an important role in behavioral studies investigating different cognitive and affective domains, guiding scientific research toward an understanding of the underlying processes of learning and memory. Social learning is defined as the process of acquiring new behaviors through the direct observation, and imitation, of other individuals. Several studies demonstrated that shoaling fish species are able to acquire anti-predator responses through social learning, as grouping provides protection against predators in virtue of numerous factors. This leads to the hypothesis that grouping individuals will follow the escape routes of others, with a small minority of fish capable of entraining a shoal of naive individuals. To test this hypothesis, we experiment on the avoidance behavior of zebrafish to an avian predator attack, simulated using a 3D-printed model of a heron head. A transparent acrylic "T-maze" with set escape routes is designed and constructed to observe two phenomena. We study firstly the escape latency for varying time-dependent levels of training and secondly the way the knowledge of the escape route is transferred among shoal members. The latter goal is achieved using transfer entropy, a construct that quantifies the potentially causal relationship between two distinct processes. Zebrafish swimming patterns is scored using a custom tracking system and these data will be analyzed to compute desired parameters for quantifying fish behavior and learning. The results will provide further insight into collective behavior in zebrafish, thus enabling the calibration of a data-driven model that could unravel the underpinnings of social learning.



▲ Avigael Sosnowik is experimenting on the avoidance behavior of zebrafish to gain insight into collective behavior and social learning.



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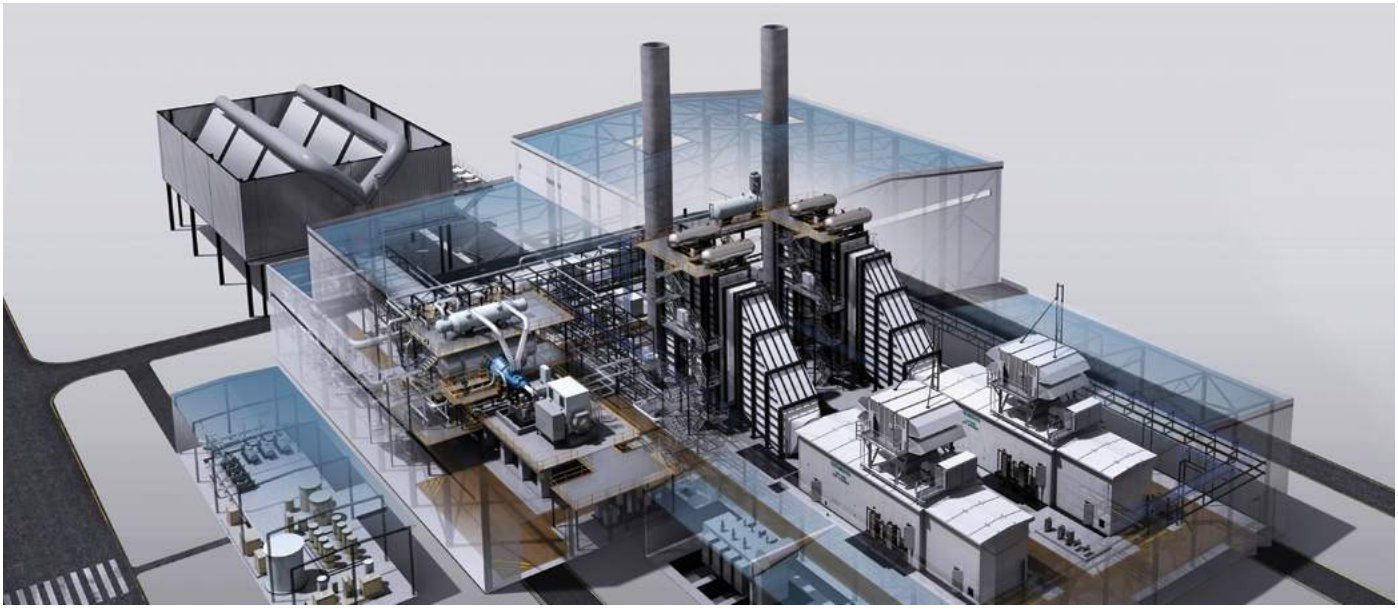
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3 ON 1 COMBINED CYCLE POWER PLANT SYSTEM OPTIMIZATION

Traditional fossil fueled thermal power plants mainly consist of pumps, boilers, steam turbines, and condensers. The thermal power plants are named based on the fossil fuel types combusted in their boilers such as coal fired thermal power plants, oil fired thermal power plants, or gas fired thermal power plants. Another widely available power plant is a simple cycle power plant (SCPP), which produces energy by combusting fuel which then causes a gas turbine's blades to turn (they are inspired from aircraft jet engines). Due to its compact size, short construction time, low emission, and mainly very fast startup, SCPPs became rapidly famous in the power generation business. Both thermal power plants and simple cycles, however, have efficiencies ranging from 33% to 48%. To increase efficiency and reduce thermal waste from exhaust, the combined cycle power plant (CCPP) was developed by the marriage of thermal power plants and SCPPs and is currently used worldwide as a source for base load power supplied to power grids.

Combined cycle power plants use parts of both systems and form them into one: fuel is combusted to turn a gas turbine configuration to generate power and the exhaust heat is then transferred into a Heat Recovery Steam Generator (HRSG – it is a boiler) which is connected to a steam turbine configuration. Both the gas turbine and steam turbine configurations are connected to generators. Combined cycle power plants have efficiencies of approximately 54% on average, though General Electric (GE) designed a plant in Bouchain, France that has an efficiency of 62.22%. Since efficiency determines how much energy is serviceable, it is important to increase the efficiency of any system.

This research aims to determine and design ways to increase the efficiency of a 3 on 1 combined cycle power plant. 3 on 1 CCPP configuration indicates that there are three gas turbines, three HRSGs, and one three-pressure-steam turbine (steam turbines are comprised of three smaller turbines which are distinguished by their operating pressure: high pressure (HP), intermediate pressure (IP), and low pressure (LP). By looking at different fuel configurations and input parameters, Balance of Plant (BOP) components such as piping and pumps are to be designed to maximize the efficiency of the overall system.



▲ Combined cycle power plant systems, such as this 2-2-1 CCPP, are being improved upon to increase their net efficiency.



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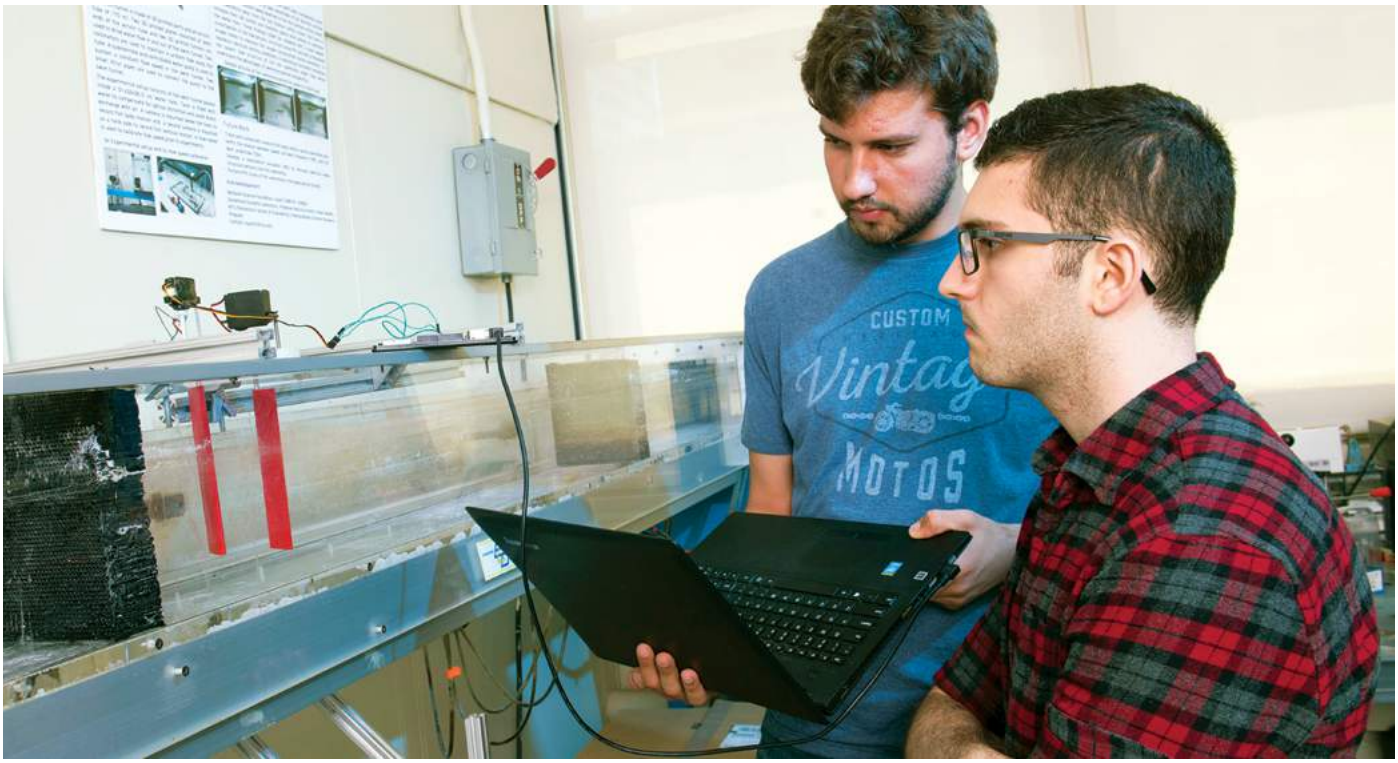
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▲ Antonios Gementzopoulos and Maxwell Rosen (pictured left to right) are utilizing transfer entropy as a method for quantifying interactions between structures in a fluid.

INFORMATION FLOW IN FLUID-STRUCTURE INTERACTIONS

The concept of entropy is well established in thermodynamics as a measure of a system's disorder, but has also been introduced in information theory to describe the uncertainty in the value of a piece of information. If there is a transfer of entropy in a leader-follower system, then the uncertainty of the leader is transferred to and compounds with the uncertainty of the follower. This is the concept behind transfer entropy (TE) - a powerful statistical method to determine the existence of a relationship between variables.
TE has been used to sort through networks of information transfer in fields such as finance, neuroscience, weather forecasting and collective behavior. This project aims to demonstrate the application of TE in a fluid-structure interaction system. In our experiment, two tandem airfoils are aligned in an axial water flow and confined to yaw rotation only. The upstream airfoil is controlled by a motor to rotate at a specified positive or negative angle at random times. Vortices are generated by the rotation of the upstream airfoil, inducing rotation in the downstream airfoil. This interaction between airfoils is quantified through tracking the rotation angles of each airfoil in time. TE is then calculated to determine the direction of information flow between the airfoils. Through this project, we aim to introduce TE as a novel tool to quantify interactions between structures in the fluid.



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FLOW VELOCITY AND PRESSURE QUANTIFICATION IN A WIND INSTRUMENT

Single-reed wind instruments, such as saxophones and clarinets, produce sound through a reed-mouthpiece system. Sound is produced due to the oscillation of the reed in the presence of an airflow, which involves an interaction between the reed and the airflow: the oscillation of the reed regulates the aerodynamics of this airflow, whereas the variation of the air velocity and pressure in the mouthpiece in turn influences the dynamics of the reed. This project aims to quantify the role of the airflow in the sound production process through fluid visualization techniques, particularly via particle image velocimetry (PIV).

Specifically, the aerodynamics in the mouthpiece will be visualized through high speed imaging of the airflow seeded with aerosolized tracer particles. Through analyzing the motion of the seeding particles illuminated by a laser, the velocity field of the airflow can be constructed. The aerodynamic pressure of the flow can then be derived from the governing equations of fluid motion. As an alternative way to obtain spatial pressure distribution, pressure-sensitive aerosol particles may also be used to realize simultaneous velocity and pressure measurements. Experimental visualization of this fluid-structure interaction process may improve our understanding of the sound production mechanisms in wind instruments.



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NETWORKED DYNAMICAL SYSTEMS IN SMALL GROUPS OF HUMANS

This project aims to understand the network dynamics that emerge through non-linear interactions between agents in small groups. Social network analysis offers a useful tool to understand the influence of network topology on individual and group-level properties. The applications can be seen in relatively large static networks and in fields such as spreading diseases, opinion formation, collaboration and leadership in collective movements. However, small networks are more common in a real-world setting, such as between friends, families, and teams. Within these small networks, members can obtain near perfect information about others. Considering that small networks are a fundamental component of complex networks, it is important to understand the dynamics and stability in small groups.

In this project, we seek to elucidate the dynamics of small groups and identify factors that predict the evolution of the network's properties. Using an individual-based model, we will investigate the effects of node properties and group compositions on the evolution of the network properties. Properties such as degree centrality and betweenness centrality are examined by simulating the process of network formation over parameter spaces. Furthermore, we will investigate the stability of a network by introducing perturbation of node properties to incorporate a higher degree of within-individual variability in humans. Conclusively, we will conduct an experiment with humans to validate the model. We will estimate parameters of individual traits from the observed data and compare them with the results from the simulation model. Combining the model and the experiment, this interdisciplinary study will contribute to our understanding of the networked dynamical systems in small groups.



▲ Elizabeth Krasner (pictured left) is working to elucidate the dynamics of small groups and predict patterns of their evolution.



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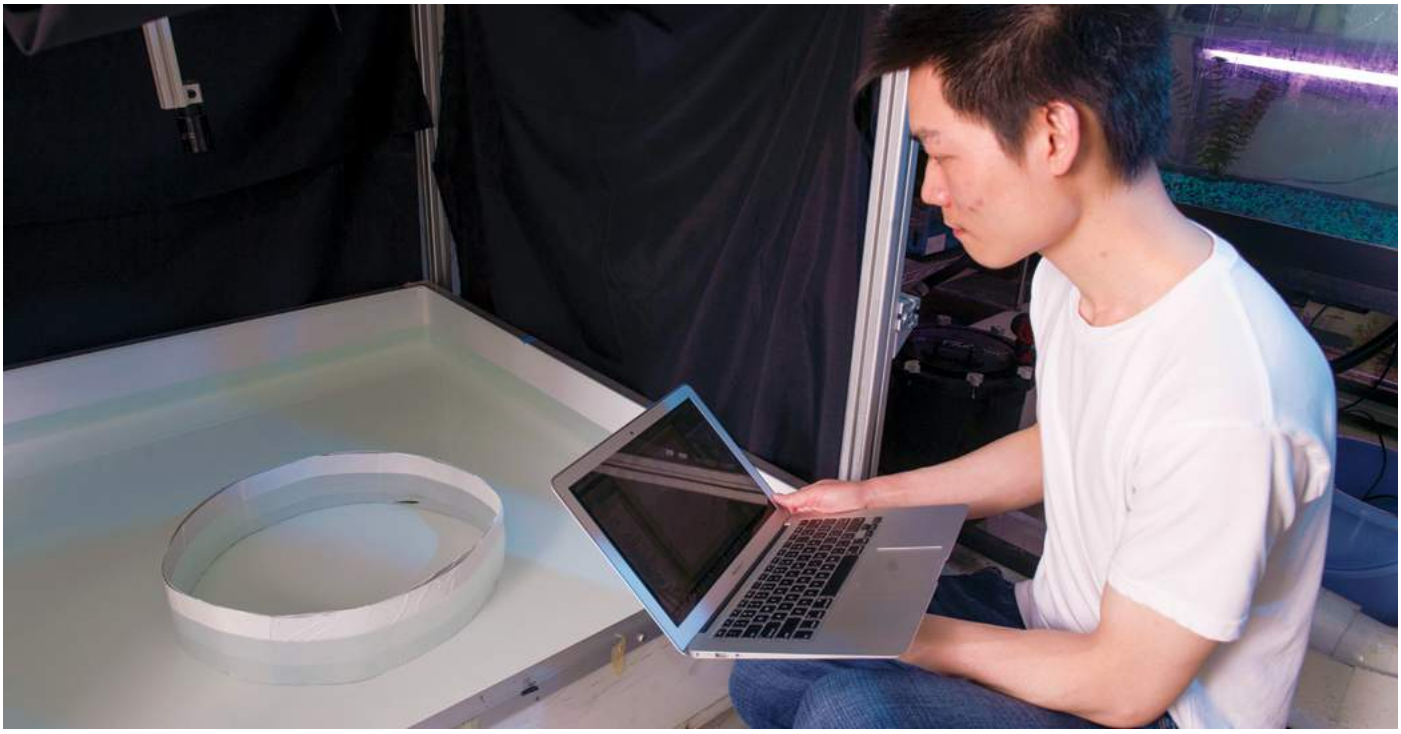
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VISIBLE IMPLANT ELASTOMER TAG INFLUENCE IN A GROUP OF FREE SWIMMING ZEBRAFISH

Neuro-behavioral experiments revolve around the estimation of parameters based on the position of one or more subjects during a trial. Recently, automated tracking systems allowed the possibility for high-throughput behavioral studies, increasing both efficiency and accuracy. However, these systems are often biased by occlusions, a phenomenon occurring when two or more distinct targets are so close to each other that the software cannot detect and maintain their identities. A possible solution to overcome occlusion and maintain a fish's identity is to tag the fishes with colorful implants. Amongst the broadly used tagging techniques for small fishes, the Visible Implant Elastomers (VIE, Northwest Marine Technology, Inc.) appears to be the most efficient method due to its relative simplicity and low invasive procedure. However, the effects of tags on fish social behavior are far from being fully comprehended. In this project, we investigate the impact of VIE tagging on zebra fish social behavior.

Fish trajectories are scored using an in-house custom made tracking software along with a color-based tracking toolbox. The tracking software uses state-of-the-art image segmentation techniques that allow a blob-detecting algorithm to robustly identify a target's center position. A Kalman filter algorithm is implemented to improve the position estimates. Fish trajectories are further checked and verified using a graphical user interface developed using MATLAB. Finally, data from the experiments will be used to compute salient observables of group shoaling tendencies, such as average inter-individual distance or group polarization.



▲ Jiazheng Wu is investigating the impact of using visible implant elastomer tagging on social behavior in zebrafish.



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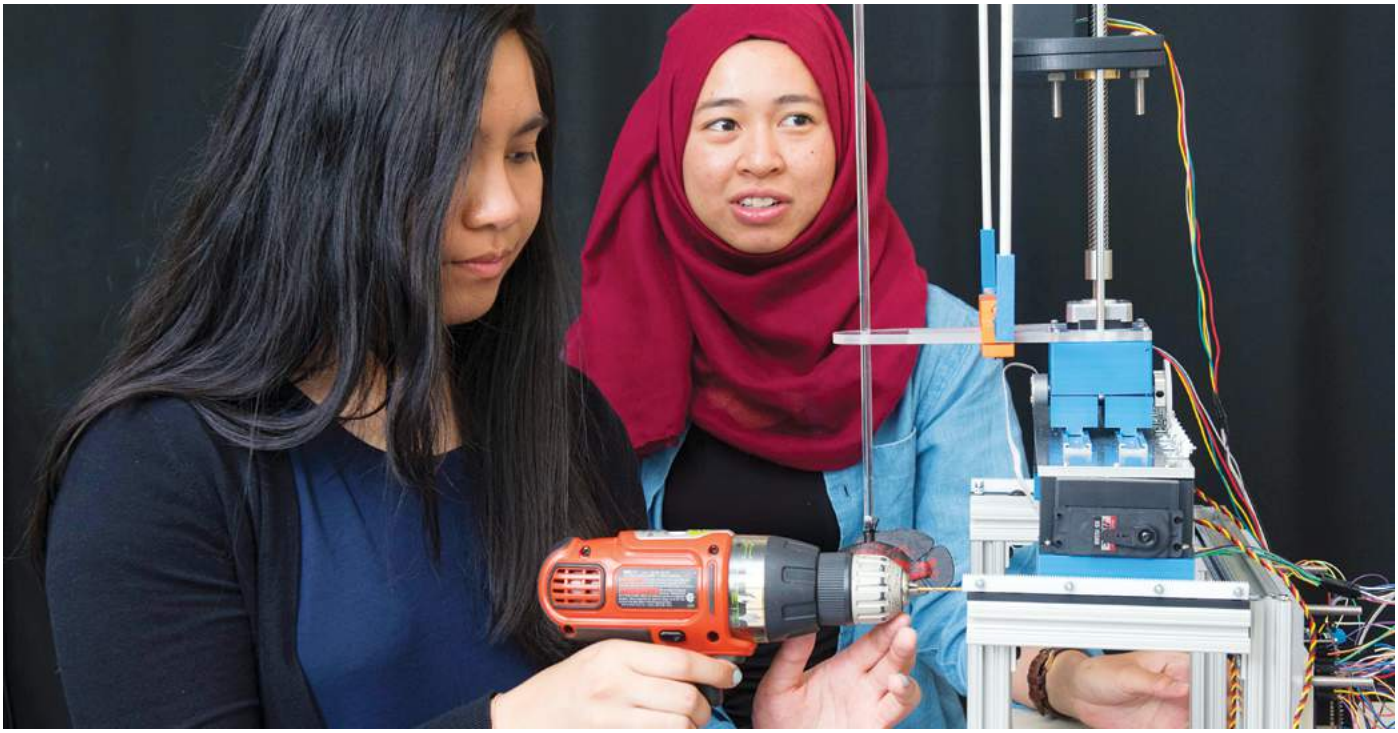
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DEVELOPMENT OF ROBOTIC PLATFORM THREATENING ZEBRAFISH IN A CLOSED-LOOP

Ethorobotics is the study of animal behavior through the employment of robotic stimuli. Even though robots enable the inspection of multiple variables involved in collective behavior by providing customizable and repeatable stimuli, little is known about the influence of control methods on these systems. As such, the majority of current platforms implement open-loop control systems of stimuli, which only permit information to flow directly from stimulus to focal fish.

The research objective of this project is to characterize, from an information-theoretic perspective, the fear response of a zebrafish to a predator by using a robotic platform that employs a closed-loop control system. Closed-loop systems show promise in simulating two-way interactions between stimuli and focal subjects. Building on previous studies conducted at the Dynamical Systems Laboratory, we seek to evoke fear-related response in zebrafish using a robotic predator. We improve our robotic platform by allowing the actuation of a biologically-inspired replica of a red tiger oscar fish, an allopatric predator to zebrafish, in three-dimensional space. The platform simulates the behavior of the predator, including a predatory attack in response to the real-time position of a focal zebrafish during experiments in a water tank; with the use of Arduinos and our custom-made real-time tracking software, we control the predator replica in a closed-loop. Finally, we analyze the data to obtain quantitative measurements of zebrafish fear-related behavior. This data will provide a compelling basis for future experiments quantifying the flow of information in fish shoals under the threat of a predator.



▲ Gabrielle Cord-Cruz (pictured left) is examining the fear response of zebrafish to a robotic predator in a closed-loop control system.



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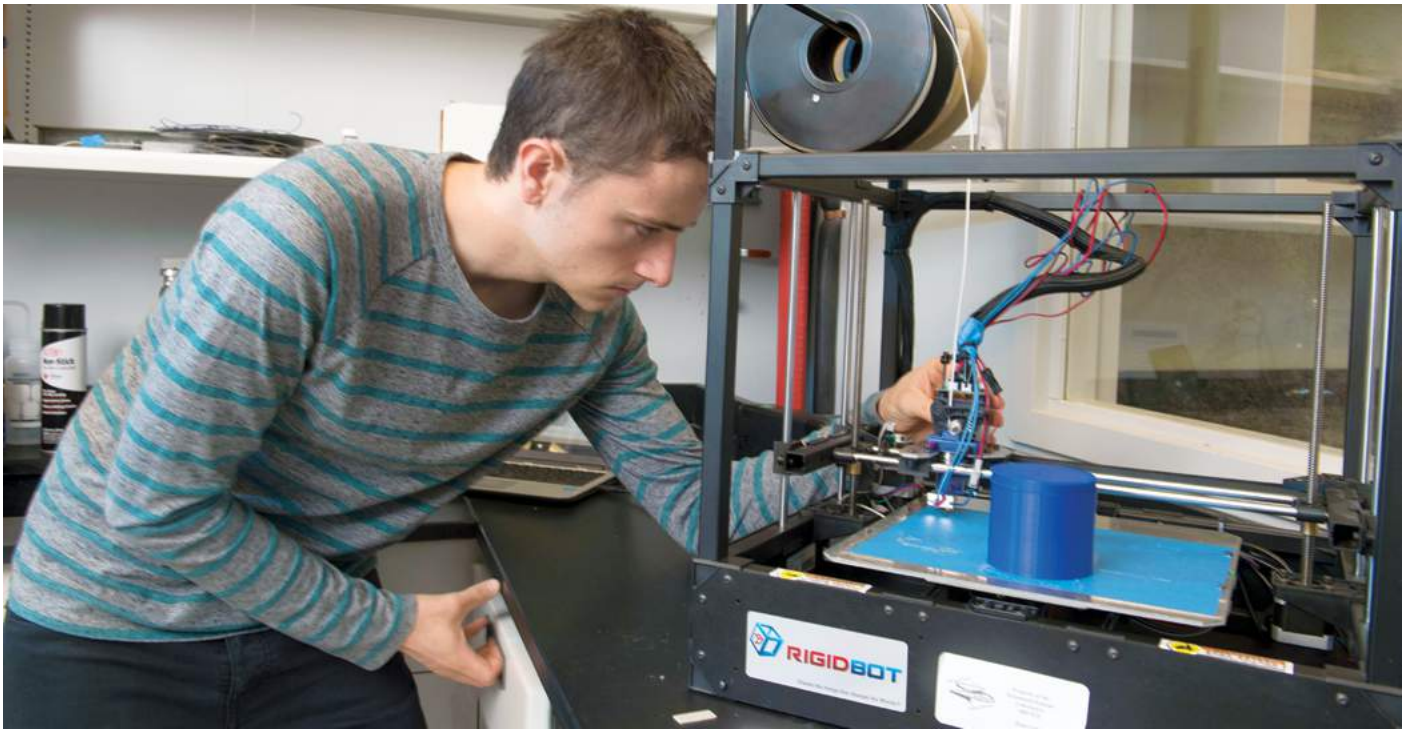
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FUSED DEPOSITION MODELING OF AQUIVION MEMBRANES FOR 3D PRINTING OF IONIC POLYMER METAL COMPOSITES

Ionic polymer metal composites (IPMCs) are a type of smart materials with the ability to deform under an imposed electrical voltage (actuation) and generate an electrical signal in response to a mechanical deformation (sensing). Due to their flexibility and low actuation voltage, IPMCs are being used in numerous engineering and biological applications as actuators and sensors. The current manufacturing procedure for IPMCs, however, takes several hours and significant human supervision, which is not suited for mass production. To address this limitation, we intend to use three-dimensional printing techniques to realize rapid fabrication of IPMCs. The goal of this project is to produce the ionomer membranes of IPMCs with fused filament deposition modeling, using filament made from the extrusion of precursor resin Aquivion pellets. The microstructure of the manufactured IPMCs will be imaged through a scanning electron microscope. The actuation and sensing performances of the IPMCs will also be tested. A number of factors in the manufacturing process, including the polymerization temperature and reaction time will be tested, and the optimal conditions will be determined. From this project, we expect to realize the free-form fabrication of IPMCs, with this project serving as an important step towards our goal of the mass production of IPMCs.



▲ Kyler Meehan is applying three-dimensional printing techniques to enable rapid fabrication of ionic polymer metal composites.



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INVESTIGATION OF BACK RELAXATION ON IONIC POLYMER METAL COMPOSITES (IPMC)

Ionic Polymer Metal Composites (IPMCs) have been developed as both efficient energy harvesters and actuators in biomedical and engineering applications. The Nafion and Aquivion based IPMCs have wide applications due to their lightweight, flexibility, and large mechanical deformation under low voltage. However, drawbacks in the dynamic behaviors, such as back-relaxation, have also been observed in past experiments, which compromises the performance of IPMCs as actuators. This project aims to quantify the back-relaxation phenomena of IPMCs through a series of experiments. Previous research has shown that the dynamic behaviors of IPMCs are influenced by a number of factors, including the structure of the backbone ionic polymer, the neutralizing cations, the metal electrodes, and the solvent. In this project, these effects on the back-relaxation behavior will be explored. First, IPMC samples will be fabricated with various number of platings, different types of cations (Na+, TBA+), and different ionomer materials (Nafion, Aquivion). The performance of the fabricated samples will then be evaluated quantitatively through impedance tests and actuation tests. This project may lead to an optimized material design that minimizes the back-relaxation effect, which can facilitate real life applications of IPMCs as artificial muscles.



▲ Quanhan Li is experimenting on the back-relaxation phenomena of IPMCs to develop an optimized material design to minimize this effect.



VERONIKA KORNEYEVA

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WHERE ROBOTICS MEETS MEDICAL RESEARCH IN THERAPEUTIC TREATMENT

This project aims to transform a traditional physical therapy practice by allowing patients to receive therapy sessions from the comfort of their own home. We will develop a system in connection with a low-cost, wearable, therapeutic device, whereby therapists and doctors will be able to monitor the progress of and control the treatments remotely for a range of diagnoses and symptoms, including postmenopausal bone loss, posture abnormalities, and muscle spasms among others.

The goal of this project is to provide remote physical therapy to patients through low-cost wearable devices, while allowing therapists to monitor and control the sessions. To achieve this, we will measure the usability and comfort of the device, application, and web-based server for both patients and therapists in a series of experiments. Further, we will test the effectiveness of the device in physical improvement.

Our envisioned system is applicable to a wide range of medical treatments customized for each patient over a secure network, to replace traditional medical treatments with cost-effectiveness and convenience for both patients and practitioners.



▲ Veronika Korneyeva is developing a vibrating device that will be embedded in a therapeutic shoe to stimulate an increase in bone mass for treatment of osteoporosis.



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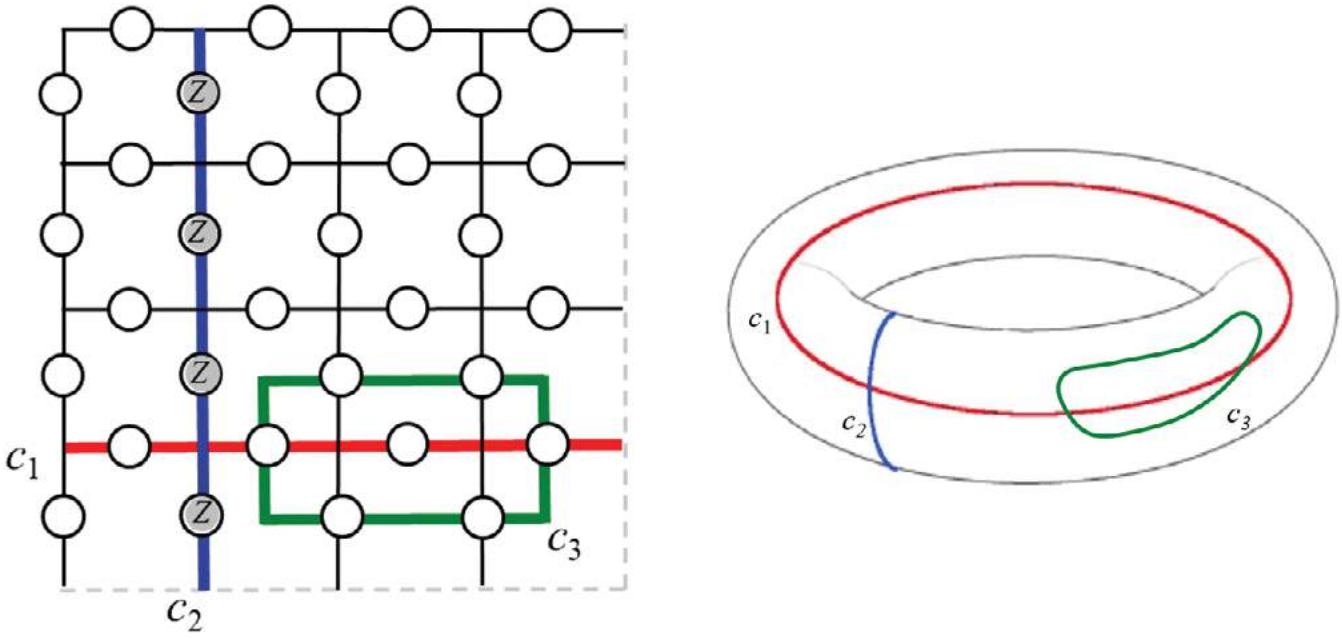
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TECHNOLOGY, CULTURE AND SOCIETY

NON-LOCALITY IN INTRINSIC TOPOLOGICALLY ORDERED SYSTEMS

Recent theoretical work in condensed matter physics has sought to define the notion of "intrinsic topological order" (ITO) (Wen 2013; Zeng & Wen 2015). ITO systems, such as those that exhibit the fractional quantum Hall effect, are characterized by two types of non-locality. The first type is associated with non-local topological properties, including degenerate ground states with the degeneracy depending on the system's topology, and low-energy excitations that obey fractional anyonic statistics. ITO systems are also characterized by a second type of non-locality associated with a particular kind of quantum entanglement, referred to as long-range entanglement. This project considers the extent to which topological non-locality is different from quantum entanglement non-locality, and whether, as some authors have suggested, the topological non-locality of an ITO system entails its quantum entangled non-locality. This is important insofar as recent work in quantum information theory has sought to exploit these two types of non-locality in ITO systems as a way to "topologically protect" the information encoded in entangled qubits from decoherence due to local errors. In particular, topological quantum error correction codes will be studied. The translation of the Knill-Laflamme condition from typical quantum error correction codes into topological quantum error codes and the mathematical motivations behind constructing such a code will be discussed. Finally, the relationships between systems that may be able to exhibit such non-locality and traditional quantum mechanical systems will be considered.



▲ In the toric code, information is stored in non-trivial elements c_1 and c_2. These cannot be disturbed by trivial element c_3, which is generated by local operators on the space.

DIGITAL HUMANITIES: AN INTERACTIVE MAP OF NEW YORK UNIVERSITY

With an overwhelming amount of information readily available on the Internet, how can a website encourage engagement with the humanities? This project sought to explore various answers and a possible solution to that question by following the Lean LaunchPad approach to customer development and examining the previous work on this project.

The goal was to create a location-based application that allows the user to explore both the current use and history of New York University buildings. The history of this city and the university are intertwined, as is exhibited by the history of many of the buildings in use today. After completing customer interviews, a need for better information on the location, details, and accessibility of most NYU buildings in one digital location was found.

In order to make this possible, each point of interest's address, coordinates, hours, history, and other relevant information were recorded and stored in a database. This information is retrieved from the database by Carto and Google Maps to build an interactive map, which may be accessed through the project website or using the mobile version of Carto. The map allows the user to filter for only relevant locations, get information about each of the points, and learn about the fascinating history of NYU along the way.

In the future, the hope is that this project grows beyond NYU to continue to encourage engagement with the various disciplines of the humanities. This format has the potential to be used as a template for similar projects for universities, archives, and cultural institutions, or for educational purposes.



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TECHNOLOGY, MANAGEMENT AND INNOVATION

HUMAN COMPUTER INTERACTION AND PERSONAL GENOMICS EXPLORATION

Personal genome sequencing has become cheaper than ever, leading to greater scientific research interest in the field. Such information is not only critical for medical professionals to access and interpret, but also important for non-experts to understand hereditary and biological risks that can be derived from their genomic data. Direct-to consumer genetic testing services such as 23andMe have helped with providing this data, but in unintuitive formats for non-experts. These services are meant for non-experts, but still require expert domain knowledge to read and interpret fully.

This project leverages human computer interaction methods to make this highly complex dataset easier to interpret by generating D3 visualizations and using reports from the Open Humans Project and Harvard Personal Genomics Project, funded by the National Science Foundation. Variant and participant data in VCF and JSON formats from ClinVar, Open Humans, GenNotes, and MyVariant.info were parsed and mapped using Python scripts to match variants using common data points. The mapping was done for a full deploy of Genomix on the Open Humans Project servers. This research aims to help non-experts interpret and act upon their own genomic data by providing novel tools that curate relevant information for users in an interactive and intuitive process.



▲ Generating D3 visualizations and utilizing reports from the Open Humans Project and Harvard Personal Genomics Project, this project enables better interpretation of complex data.

HUMAN COMPUTER INTERACTION FOR DECISION MAKING AND CONSUMER FINANCE

Can human-computer interaction help people make informed and effective decisions? Among a vast range of data, what are the quintessential data that help the user make a decision? Using HCI in investments management seems to be the most logical way to explore those questions.

When an individual makes financial decisions, taking selecting funds as an example, there are usually various indexes that the user could refer to, which all reflect segmental information of a fund. However, not all those data are equally important, and it is important to know how people would attach importance to each feature respectively. Hence, we build a website on tracing what features of a fund is the most valuable to the users, in this way, we could find the most efficient way to present information and help the process of decision making.



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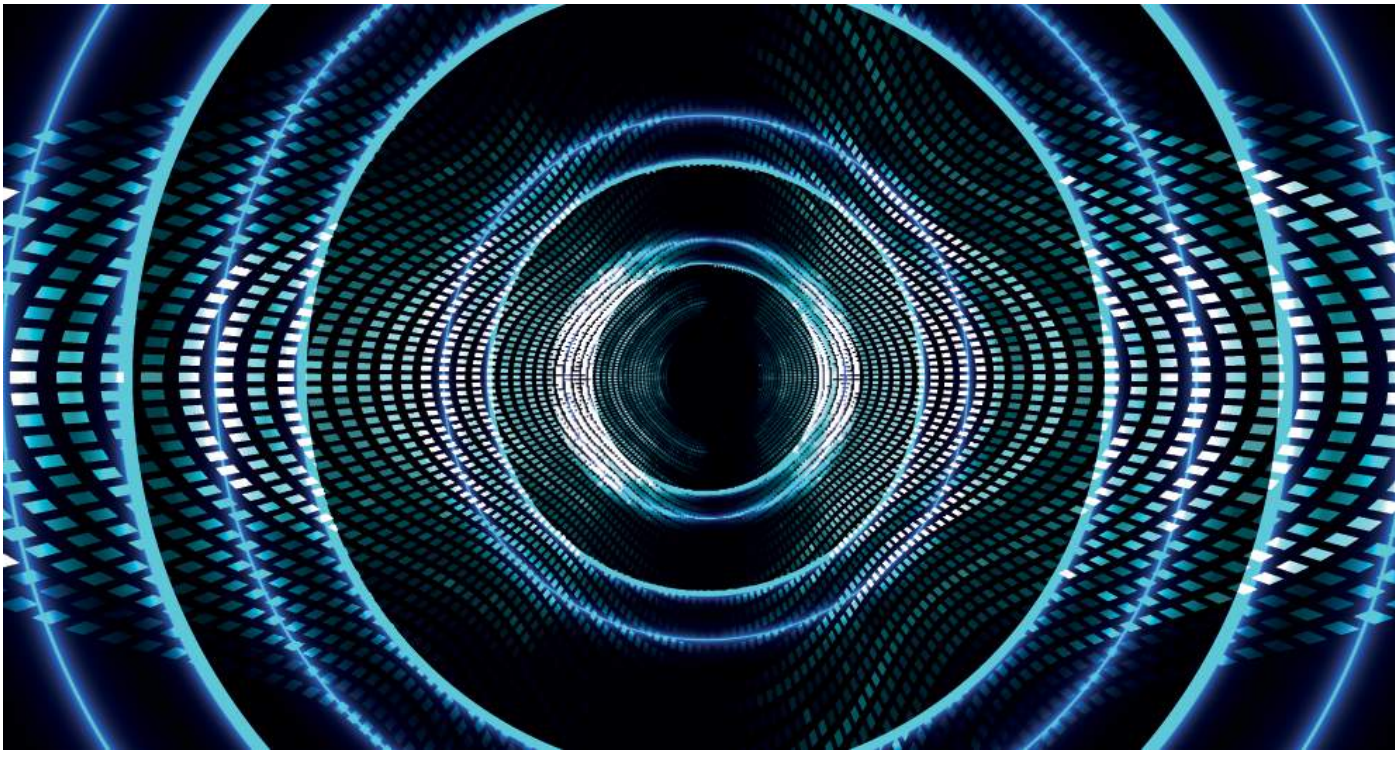
NYU Tandon School of Engineering

WIRELESS

OPTIMAL CHANNEL TRANSMISSION IN MILLIMETER WAVE NETWORKS

To satiate the demand for higher wireless data rates a larger available frequency spectrum is needed. Millimeter waves (mmW) range from 30GHz to 300GHz have over 70 times more unlicensed spectrum than traditional WiFi frequencies, thus providing the much needed room for expansion. mmW have shorter wavelengths limiting them to shorter transmission ranges for a given power and highly susceptible to propagation loss. MmW network coverage is consequently enhanced by placing larger number of access points (AP). With large AP density, the decision of which user-AP link to establish is presented. The goal of this project is to model a protocol through which the user may transmit to the AP delivering the highest throughput.

MmW requires beamforming to overcome propagation loss. Beamforming occurs after the initial access phase where a physical link is formed between the user and AP via channel probing. After probing a channel, the user may transmit via the last probed channel or recall a previous better channel probed with a given availability probability, which models the random nature of wireless networks, blockages, or network competition. Ideally, a user should probe the best channel first to minimize overhead. Using optimal stopping theory throughput maximization is balanced with overhead cost. The proposed protocol will be benchmarked through numerical analysis against current strategies. With their immense bandwidth allocation and alleviation of wireless traffic, mmW will enable the goals of 5G networks. The proposed protocol will serve as a stepping stone into the mmW network for optimal user-AP interaction.



▲ This project involves modeling a protocol for optimizing transmission to access points in millimeter wave networks.



SARA LEE RAMSAWAK

UG Summer Research
Program Coordinator

Associate Director of Academic Affairs
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NYU Tandon School of Engineering

Sara Lee Ramsawak has coordinated the Undergraduate Summer Research Program since the summer of 2013 and has expanded the program from 61 students to over 100. Faculty participation has also increased and expanded to include professors and research projects from NYU Wireless and the NYU Center for Urban Science and Progress. It now includes students from NYU Tandon, the NYU CAS 3+2 Program, NYU Shanghai, NYU Abu Dhabi, and select students from outside universities who participate in the Summer Research Program for College Juniors. Aside from the hands on research that students do with the faculty, they also attend career development, academic enhancement, and social events and gatherings, including engineering industry panels, Wasserman Center for Career Development and Graduate Admissions seminars, and poster sessions. Sara continues to dedicate herself to this program and all of the opportunities it affords students.

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