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2014 SUMMER RESEARCH PROGRAM UNDERGRADUATE ABSTRACTS

EIGHTH ANNUAL UNDERGRADUATE SUMMER RESEARCH PROGRAM



NEW YORK UNIVERSITY

NYU | POLYTECHNIC SCHOOL OF ENGINEERING



INTRODUCTION

The NYU School of Engineering's Undergraduate Summer Research Program provides a unique opportunity for School of Engineering, NYU College of Arts and Science, and NYU Abu Dhabi students 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. Close interaction with faculty and research staff promotes an educational experience that advances the 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 a student's knowledge base by applying classroom learning to solve practical, contemporary problems and to better prepare them for lifelong learning.

Summer 2014 marked the eighth year of the Undergraduate Summer Research Program. Since its inception, 405 students have participated in and 172 faculty members have contributed to the program. In addition to their work in labs, students attend seminars on entrepreneurship, research posters, and diversity in STEM. Additionally, they present their work-in-progress to other members of the research cohort at a special luncheon dedicated to practicing presentation skills and fostering inter-group collaboration on current and future projects.

The program was an initiative of the late Professor Erich Kunhardt and Vice Dean of Academic Affairs Kurt Becker, who played a vital role in its success following its creation. The School of Engineering's faculty participation in this program has been essential, as is the financial support provided by faculty mentors. Gifts from several alumni donors have also propelled the program's success. I would like to thank Dr. Joseph G. Lombardino ('58 Chem), James J. Oussani, Jr. ('77 ME), and Dr. Harry C. Wechsler ('48 CM), for their generous support of this year's program. Additionally, this year marked the third year of the Thompson Bartlett Fellowship. Nine of this summer's researchers were graciously supported by this fellowship, which is made possible by Ms. Dede Thompson Bartlett, whose father, Mr. George Juul Thompson, was a graduate of 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. 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.

The abstracts published in this volume are representative of the research done over the summer and celebrate the accomplishments of the undergraduate researchers.

I congratulate all of the student researchers who participated in the 2014 Undergraduate Summer Research Program and look forward to future summers of intellectual and scholarly activities.



Iraj Kalkhoran

Associate Dean of Undergraduate Academics

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APPLIED PHYSICS



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NONLINEAR MECHANICAL SYSTEMS AND CHAOS

The double pendulum is a simple, yet physically rich, system to analyze. It's so simple that it can be built in a small lab but so rich in physical phenomena that one could spend years analyzing its subtleties. For this project, we are examining the double pendulum's chaotic motion and trying to calculate the border between the initial conditions that lead to non-chaotic motion and the ones that lead to chaotic motion.

We first used Lagrangian mechanics to come up with the equations of motion of the double pendulum and then modeled it on a computer using Mathematica. We next built a double pendulum in the lab, so we could see if our theoretical model matched the real pendulum. One of the things we are trying to do is to make a computer model that accurately simulates the motion of the pendulum in non-chaotic regimes that also takes into account air resistance and friction from the bearings.

Another part of our research involves conservation laws for nonlinear systems. Many nonlinear equations are impossible to solve for analytically and must instead be solved numerically. However, even if the equation is not solvable, one can analytically derive conservation laws, which can give a wealth of information about how the system evolves in time. We are using multiple techniques to derive conservation laws. One of them is the familiar Poisson bracket relation $[H,u]=\partial u/\partial t$; the other method is called the principle of neutral action. The Poisson bracket requires that the system have a Hamiltonian, while neutral action requires only that the system can be modeled as a differential equation.

CHEMICAL AND BIOMOLECULAR ENGINEERING



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BIOMOLECULAR ENGINEERING FOR LIGAND BINDING

Ligand-protein interactions are integral to many biological and industrial processes. The ligand is bound to the protein at its binding site by intermolecular forces, changing the protein's structural conformation and functional state. Ligands include substrates, inhibitors, activators and neurotransmitters. In an industrial environment, ligands may also include drugs, vitamins, flavors, and catalysts. Proteins are excellent carriers for the controlled delivery and uptake of ligands due to their selectivity for ligands. Current approaches towards modifying ligand-binding employ site-directed mutagenesis or random mutagenesis, where a few amino acids within an existing protein's DNA sequence are mutated to create protein variants with desirable qualities.

In this project, we explored the possibility of protein insertional fusion as a means of engineering ligand-binding affinity. Protein fusion complex (PfMBP-BLA177) has been previously developed where a guest protein domain, TEM 1 beta-lactamase from Escherichia coli (BLA), was inserted into the host protein domain, a thermophilic maltodextrin-binding protein from Pyrococcus furiosus (PfMBP) between the amino acids 177 and 178. The ligand-binding affinities of PfMBP-BLA177 with various sugar molecules, including those not strongly bound to the isolated wild-type PfMBP domain, were examined using Isothermal Titration Calorimetry.

In another project, an engineered peptide fragment was examined for its binding affinity to specific forms of protein aggregates. This peptide ligand was derived from beta amyloid, of which aggregation is implicated in the pathology of Alzheimer's disease. Using a dot blot assay, the binding affinities of the peptide ligand to specific forms of beta amyloid aggregates will be examined.



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CHEMICAL SHIFT AND STEREOELECTRONIC EFFECTS

The chemical shift is an important parameter in nuclear magnetic resonance (NMR) spectroscopy that provides information about the electronic environment around a given nucleus. The chemical shift is currently understood to result from diamagnetic and paramagnetic field effects. In some cases, the directional dependence of the magnetic field effect, such as the carbon-carbon bond magnetic anisotropy, plays an important role that can cause extensive chemical shift differences among hydrogen atoms. This detailed computational study focuses on the proton chemical shifts of cyclohexane and piperidine as a precursor to understanding the proton chemical shifts of larger cyclic molecules containing the piperidine moiety.

The Gaussian '09 (G09) software package can accurately compute proton chemical shifts but lacks the ability to distinguish between the contributions of neighboring orbitals that make up a particular chemical shift. Therefore, Natural Bond Orbitals 6.0 (NBO6) is used in conjunction with G09 to calculate natural atomic orbital (NAO) and natural bond orbital (NBO) populations, second order delocalization stabilization energies, natural Coulomb electrostatics (NCE), and natural chemical shifts (NCS), in order to analyze the chemical shielding tensors and the origin of their effects. In addition, isotropic surfaces are calculated using the Nuclear Independent Chemical Shift (NICS) NBO-NCS method, which provides a more thorough and visual analysis of the shielding fields at the proton under scrutiny. From these tools, we are able to accurately analyze the shielding effects produced by orbital overlap, such as hyperconjugation, or by bond magnetic anisotropy.



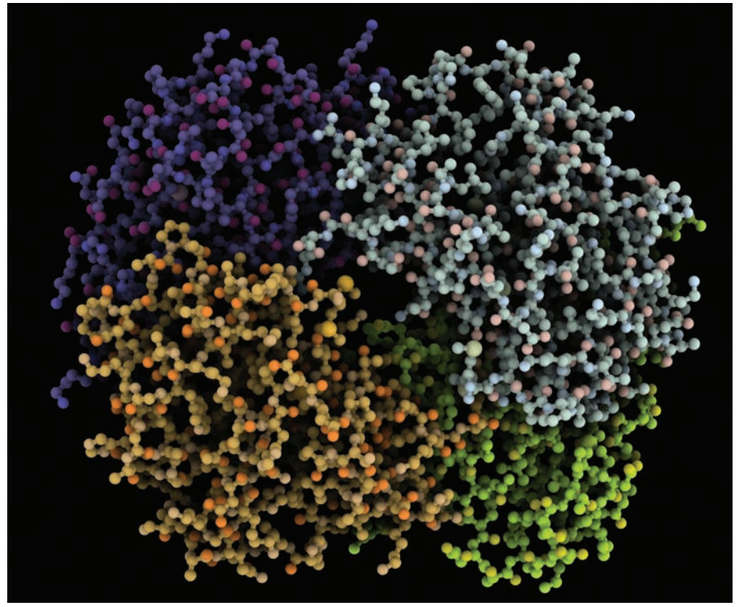
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▲ Alex Chew and Cody Dickinson calculate the intricacy of chemical shifting in nuclear magnetic resonance.



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DESIGN OF FLUORESCENCE MICROSCOPE UTILIZING GRIN LENSES FOR ANALYSIS OF DNA HYBRIDIZATION

DNA microarrays are diagnostic tools used in various applications, including pathogen identification and disease diagnosis, by measuring the expression levels of genes. The study of gene expression has led to many breakthroughs in the fields of medicine and science. Currently we use a TIRF (Total Internal Reflection Fluorescence) microscope to better understand DNA hybridization, the process that takes place on microarrays as well as in many other bio-applications. TIRF microscopy uses the reflection of a laser beam within a microscope slide with probe-DNAs immobilized on the slide. The reflection produces an evanescent electromagnetic field, which excites any labeled target-DNA (analyte) that is hybridized with the immobilized probe DNA on the surface. The intensity level emitted by these specimens correlates to the level of hybridization, with the fluorescence of the hybridized DNA captured using a camera.

To enable analysis of minute sample quantities, a metal pin is used to disperse a nano-droplet of a DNA sample over the slide, increasing the surface area where hybridization can occur. It is challenging to disperse the droplet symmetrically using the current set up. By using a gold slide instead of a glass slide, better defined, more tailorable surface chemistries than the currently used conventional glass supports are expected to improve assay performance. However, since gold is reflective, the TIRF microscope can no longer be used to observe the DNA hybridization. To overcome this challenge, a GRIN (gradient-index) lens based microscope was designed. GRIN lenses have a gradual variation of the index of refraction and can be used to press right against the slide, thus replacing the metal pin used in the TIRF microscope. The proposed design can be used to analyze hybridization on gold-coated slides, which have highly tailorable surface chemistry, as well as disperse droplets to increase the surface area of the hybridization.



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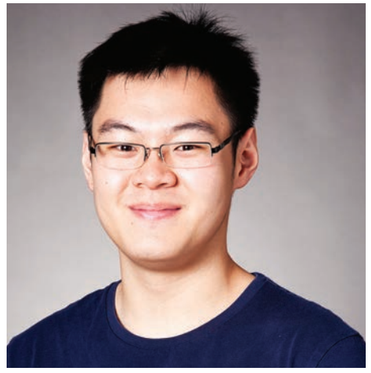
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DNA SURFACE HYBRIDIZATION THERMODYNAMICS

DNA microarrays and biosensors have been used as diagnostic tools in various bioanalytical applications, from pathogen identification to guiding cancer diagnosis and intervention. However, many aspects of the hybridization process at the heart of these technologies are still not well understood, making optimization difficult. These complications are primarily introduced by molecular crowding and interactions that arise in the interfacial environment in which the surface-immobilized "probe" DNA hybridizes with sample "target" nucleic acids from solution. In order to gain a better fundamental understanding of surface hybridization, an electrochemical method was developed in which ferrocene-labeled probe and target DNA is used to study the degree of hybridization. This allows the thermodynamics of surface hybridization to be rigorously established from melting curve analysis. Use of this method requires very stable immobilization chemistry for the probe DNA. Immobilization starts with the polishing of a gold electrode surface to clean it. Next, it is coated with a layer of poly(mercaptopropyl)methylsiloxane (PMPMS) polymer as an “anchor layer,” which is then reacted with a crosslinker. Crosslinking stabilizes the PMPMS film on the electrode, as well as provides reactive groups for the attachment of the probe DNA. Two main experiments are performed here. The first is a test in which the ideal concentration of the crosslinker to use is determined. The second is a thermostability test in which the one crosslinker (of four) that results in the most immobilized probe surface is determined, using the ideal concentration found in the first test. The four crosslinkers being used are 4,4'-bismaleimido-diphenylmethane (BMDPM), tris(2-maleimidoethyl) amine (TMEA), 1,11-bis(maleimido)triethyleneglycol (BM(PEG)3), and 1,6-bis(maleimido)hexane (BMH). The thermostability test is done by exposing the probe DNA to extreme temperatures to demonstrate the stability of the polymer crosslinking on the surface and the reversibility of the melting process. From these studies we seek to develop the most effective route to constraining the molecular organization of probe layers and thus advance fundamental studies of DNA surface hybridization.



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ENGINEERING COMP-BASED FLUORINATED COILED-COIL FIBERS

Over the past decade, considerable efforts have been made to develop protein and peptide based self-assembled systems. The α-helical coiled-coil proteins systems have been successfully engineered to develop structurally defined fibrils with potential application in the nanoelectronics and biomedical fields. Two rationally designed proteins, CC and Q54, derived from the coiled-coil domain of cartilage oligomeric matrix protein (COMPcc), have been designed to self-assemble into fibers. To improve the thermal and chemical stability of proteins and the assembly of fibers, we replace leucine from the hydrophobic core with 5,5,5-trifluroroleucine (TFL) by residue–specific incorporation. Successful incorporation of TFL is confirmed by MALDI Spectrometry. Circular dichroism results indicate that both the fluorinated proteins exhibit a stronger α-helical structure as compared to the wild-type protein. To investigate the fibers in solution, fluorescence microscopy is performed. In the presence of the small molecule, curcumin, which exhibits fluorescence upon binding to CCTFL and Q54TFL, fibers of approximately 600 nm in diameter are observed. The proteins are then subjected to BS3 cross-linking to further study their mechanical properties. The results indicate that fluorination is able to impart improved stability on the fibers and investigations on the mechanism of assembly are underway.



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ENGINEERING FLUORINATED BIOMATERIALS FOR TREATING METASTATIC BREAST CANCERS

The process of developing cancer therapies that utilize effective drugs is plagued by drug delivery inefficiencies. Use of doxorubicin in the early treatment of metastatic breast cancer, while effective for improving overall survival rate, is also highly cardiotoxic to healthy cells, and extensive use is limited by its poor solubility, tendency to degrade, and reliance on passive targeting. The efficiency of doxorubicin delivery is often difficult to track in real time, necessitating indirect or invasive measurements of treatment bioavailability. The objective of this project is to develop a magnetic resonance-traceable doxorubicin delivery vehicle that actively targets cancer cells.

The CE2-RGD block polymer is composed of the cartilage oligomeric matrix protein coiled-coil domain (C) and two elastin-like peptide domains (E) with an N-terminal hexahistidine tag for purification. The pentameric alpha helical C domain bears a hydrophobic core that is capable of encapsulating various small molecules, such as vitamin D3, vitamin A, curcumin and doxorubicin. The E domain permits thermoresponsiveness and further stabilizes the block polymer into a nanoparticle of optimal size for drug delivery purposes. The RGD tripeptide mutated into CE2 enables targeting to integrins that are known to be over-expressed in some breast cancer cells. Making use of 19F/1H MRI for semi-quantitative delivery measurements, CE2 was incorporated with either 5,5,5-trifluoroleucine or para-fluorophenylalanine. To synthesize the fluorinated CE2-RGD proteins, a plasmid bearing the gene of interest was transformed into strains of phenylalanine or leucine auxotrophic bacteria. Expression of the fluorinated protein was performed by IPTG-induction in the presence of the fluorinated amino acid analogues. CE2-RGD expression was confirmed by SDS-PAGE, followed by purification under increasing concentrations of imidazole. Further biophysical characterization experiments using circular dichroism, turbidometry analysis and 19F NMR of CE2-RGD are currently underway.



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GOLD NANOPARTICLE ENHANCEMENT OF NONPHOTOCHEMICAL LASER INDUCED NUCLEATION

While studying the process of crystallization, Garetz and his colleagues discovered that certain supersaturated solutions, when exposed to a high-powered near-infrared laser, would nucleate without absorption of laser light; this process was named nonphotochemical laser-induced nucleation (NPLIN). It was also later discovered that NPLIN of supersaturated solutions containing the amino acid glycine produced different polymorphs, that is, different crystal structures of the same compound, depending on laser polarization. We examined how other conditions affect the nucleation of glycine. Below are the results of trials carried out this summer testing the effect of the presence of 5 nm gold nanoparticles in supersaturated solutions of glycine in phosphate buffered saline (PBS).

Supersaturated solutions of glycine in PBS with 5 nm gold nanoparticles were prepared within a narrow range of concentration (c/c0 =1.45-1.55, where c is the solution molality and c0 is the solubility) After aging the solutions for one week, samples containing gold nanoparticles were twice as likely to spontaneously nucleate as the samples not containing gold nanoparticles. Then, the remaining samples were illuminated with the 1064 nm wavelength, linearly polarized output of the Victory 2A Nd:YAG laser for 5 seconds. The laser produced a 1pps train of 12 ns laser pulses with a peak power of 240 MW/cm2. Several hours after the laser exposure, some of the samples nucleated. The samples containing gold nanoparticles were ten times more likely to nucleate than samples not containing gold nanoparticles within a week of exposure.



▲ Audrey Goh works with Harun Ates and Professor Bruce Garetz to study how the crystallization process is affected by high-powered lasers.



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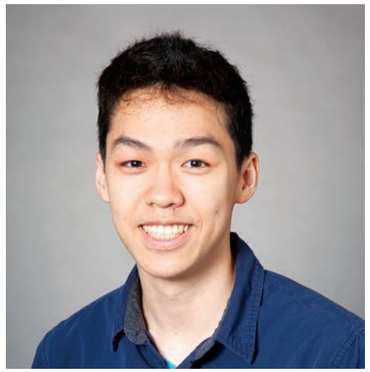
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STIRRING RATE: CONTROL OF NANOPARTICLES SIZE AND SHAPE

Nanoscale science and the synthesis of nanoparticles have become the central focus of numerous research studies in a wide range of fields due to their technological importance. Nanoparticles exhibit unique size-dependent magnetic, optical, and electrical properties, which can be useful in their application to drug delivery systems, data storage, catalysis, sensors, etc. A critical advancement in this area of scientific study is the expediting of industrial scale development. In order for the transition from lab-scale studies to large-scale production to occur smoothly, the reaction and reaction parameters must be studied closely so that the scale-up of the processes involved can be executed successfully.

In this project we are studying the effects that the stirring rate, in addition to other reaction parameters, has on nanoparticle size and morphology. The first step of this undertaking was to prepare, collect, and characterize iron nanoparticles. Iron pentacarbonyl, the nanoparticle precursor, interacts in organic solvent with Pluronics F-127, a triblock copolymer which functions as a surfactant by forming micelles. The use of other block copolymers as surfactants, such as poly(styrene-b-ethylene oxide) and poly(styrene-b-2-vinyl pyridine), has been investigated as well. Additionally, through preliminary studies on the rheological properties of polystyrene, we have drawn the conclusion that polystyrene or other viscous polymers may be used as a solvent to study the changes in shapes of the nanoparticles at different stirring rates, by eliminating shear effects as a determining factor in morphological changes. Future work on this project will include light scattering studies on various surfactant-solvent solutions using block copolymers of different composition and block length, as well as nanoparticle preparation at different stirring rates using various surfactant-solvent solutions.



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SYNTHESIS OF BINUCLEAR METAL COMPLEXES OF EXPANDED PORPHYRINS

Porphyrins, a group of highly conjugated heterocyclic macromolecules, consist of pyrrole subunits that bind metals to form complexes. The most common iron-bound porphyrin is heme, a component of hemoglobin found in the blood. A substantial amount of effort has been dedicated in recent years to the study of expanded porphyrins because of their potential applications, mainly as reaction catalysts, or their implications in photodynamic therapy due to their highly conjugated π-system. The goal of this project is to synthesize an expanded porphyrin that is completely planar and has the ability to form a binuclear complex using two metals. The scheme for the synthesis of the expanded porphyrin is to obtain 3,5-dipyrrolylpyrazole via dipyrrolyl diketone and condense it with 2,5-bisbenzoylpyrrole. The dipyrrolyl diketone was formed through treatment of pyrrole with malonyl chloride under freezing temperatures, and then refluxed with hydrazine hydrate to afford 3,5-dipyrrolylpyrazole and purified through recystallization from chloroform. 2,5-bisbenzoylpyrrole was obtained through a two-step reaction: 1) formation of 2,5-bis-(1,3-benzoxathiolyl)pyrrole using pyrrole and 1,3-benzoxathiolium tetrafluoroborate, 2) Cleavage of the protecting group using mercury(II) oxide in aqueous tetrafluoroboric acid. All of the chemicals were purified using thin-layer chromatography and flash chromatography, and structural data was confirmed using H-NMR.



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THERMODYNAMIC ANALYSIS OF MORPHOLINO SURFACE HYBRIDIZATION

Morpholino (MO) is a synthetic molecule that is often used as a DNA mimic. Morpholino provides an interesting approach to analyzing surface hybridization because it is an uncharged molecule, as opposed to DNA, which is negatively charged. Surface hybridization arises between an immobilized morpholino or DNA, called "probe," on a surface binding with complementary nucleic acids in solution, called "targets." Improved fundamental understanding of surface hybridization is needed for optimizing devices for diagnosing genetic diseases and for characterizing gene expression. Uncharged morpholino probes provide a way to eliminate electrostatic hindrances and thus to advance surface hybridization methods for analyzing nucleic acids.

Morpholino probes can be immobilized on the surface of gold-coated supports. Appropriately cleaned surfaces are then placed in a poly(mercaptopropyl)methylsiloxane (PMPMS) solution to form a PMPMS layer on the surface. This layer can provide a very stable surface for the attachment of biomolecules. Before the attachment of biomolecules, however, the PMPMS layer is typically first reacted with a crosslinker such as 4,4'-bismaleimido-diphenylmethane (BMDPM) to stabilize its molecular structure and to provide maleimide groups for the attachment of thiol-containing molecules such as proteins, morpholinos, or nucleic acids.

One of the goals of this project is to study this crosslinking reaction at several temperatures. After cross-linking, the PMPMS films will be placed in 6-(ferrocenyl)hexanethiol (Fc-C6-SH) solutions to determine their capacity for reacting with thiol-containing compounds. A CV scan will be used to measure the ferrocene signal and thus to determine the best temperature for creating films with the highest capacity for immobilization of biomolecules. Multiple trials will be conducted using two crosslinkers, BMDPM and another molecule called 1,11-Bismaleimido-triethyleneglycol (BM(PEG)3). A thermodynamic analysis using melting curves between PMPMS-immobilized morpholino, or DNA probes, and nucleic acid analyte in solution, will be used to examine the robustness of biomolecule immobilization at elevated temperatures.



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VIDEO IMAGING AND ANALYSIS OF NANOLITER-SCALE MICROPIN-PRINTED DROPLETS

DNA-based biosensors can be used for various diagnostic techniques, including genotyping, gene expression and the identification of other small molecules. Often, DNA biosensors are made by the robotic printing of nanoliter-sized droplets on a solid support, such as a microscope slide. Understanding interactions at the surface-solution interface is important to create a thermodynamically and chemically apt environment for the sensory probe molecule. In this experiment, nano-sized droplets were printed onto different surfaces using pins with diameters ranging in size from 80 to 300 microns and were observed with a high-speed camera equipped with a telecentric magnifying lens. Using programs such as MATLAB and LabVIEW, images from the camera were dissected, processed and analyzed.

Various parameters were tested in order to see the drying behaviors of nano-droplets printed while changing properties, such as local ion charge density, pH, and hydrophobicity. Different solvents such as water and sodium phosphate buffer were printed on glass slides, aldehyde-coated glass slides and gold-coated glass slides. The contact angle of the droplet to the surface, along with the height of the droplet, was calculated programmatically via MATLAB by thresholding and edge detection techniques, which then allowed for the shape of the droplet to be fitted to a circular arc (i.e. a 2D slice of a sphere; an assumption for droplet diameters well below the capillary length). In literature it has been reported that, in practice, droplets evaporate in a "stick slip" mode, at first exhibiting constant radius and then constant contact angle. The results of this experiment displayed similar outcomes, clarifying the understanding of non-uniformities that arise in coverages of immobilized molecules. The procedure was repeated with multiple droplet printing at a time in order to see the uniformity of the printed droplets. The results of this study will be used to further develop and test various sensors.

CIVIL AND URBAN ENGINEERING



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EFFECT OF DEICING MATERIALS ON ELECTRICAL POWER CABLES WITH THE EFFECTS ON INFRASTRUCTURE AND THE ENVIRONMENT

Deicing materials are used in a variety of pavements and snow-filled regions because they can benefit neighboring infrastructures and the environment. The materials are able to prevent the formation of ice and the formation of bonds between snow and pavement. Deicing materials also break those bonds and make the removal of snow easier, thus preventing slipping or any other inconvenience.

The New York-based electrical company Con Edison has decided to take the initiative in studying the effects of deicing products on electrical equipment and find alternatives. It has been documented that several deicing combinations can produce electrical arcing on the power cables located underneath manholes. Environmental impacts further caused from the use of the products on power cables will be evaluated. It is vital to come up with deicing alternatives that not just avoid harming the cable materials but also do minimum to no harm to the surrounding environment, including people, botanic life and animals.

Various deicing material composites will be compared in terms of their efficiency in in-situ scenarios. The effects of composites will be compared to those of regular salt used on roads. Although the effect on the cables in NYC will be studied in this research, the intent is to eventually release the results to other municipalities so that their agencies, including sanitation departments, can improve their own current deicing techniques.



▲ Student Carlos Santana Laraquent is researching how common deicing materials can be safely applied to electrical equipment.



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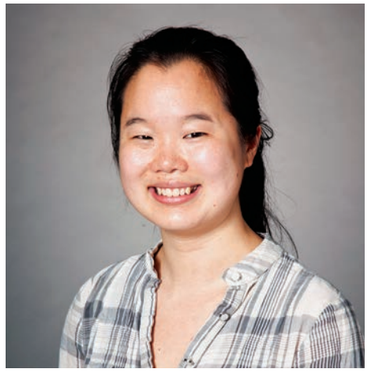
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THE STRAIN RATE DEPENDENCY OF THE STIFFNESS AND STRESS-STRAIN BEHAVIOR OF GRANULAR MATERIAL

The effects of strain rate on the mechanical properties of sand are important for different geotechnical problems, including blasting and earthquakes, soil-structure interaction, and pile driving and jacking, among others. Several studies on low-to-intermediate strain rate have resulted in controversial conclusions. Some of them concluded that the variation of strain rate does not produce significant variation on the mechanical parameters, whereas others have illustrated the opposite. Therefore, further experimental data, including stress-strain and stiffness measurements, are necessary to reassert the behavior of the sand under these conditions and to calibrate available models that are viscosity dependent.

In this research, an experimental program, along with analysis of shear strength in silica and calcium-based sands, was conducted from low-to-medium strain rate. Dry triaxial tests subjected to a confinement pressure of 400 kPa on dense samples were performed. Maximum and minimum densities were determined according to ASTM standards to achieve the targeted density. Triaxial samples were prepared using vibration techniques and placed under confinement by a combination of vacuum and air pressure. Four different strain rates, including 0.01, 0.1, 1 and 10%/sec, were employed. The resulting data were plotted to find out the stress-strain response. Particle crushing was also investigated through sieve analysis before and after testing. Comparison of results between silica and aragonite sand looked into the effects of particle composition and hardness. These observations allowed for the conclusion that strain rate plays an important role on the mechanical response of soil, especially when higher confinement pressures are applied. The effect of the strain rate is more pronounced in calcareous sand than silica sand.



JUDY MEI

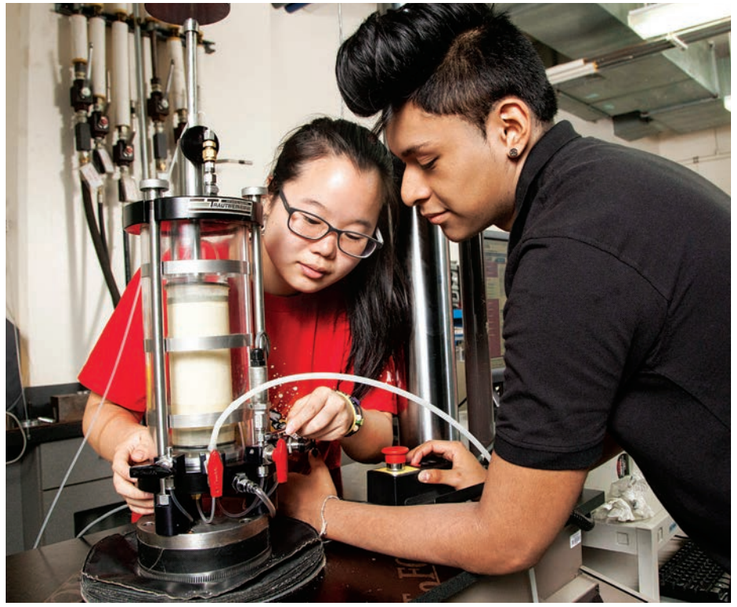
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Magued Iskander

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▲ Students Judy Mei and Jose Balbuena study how different levels of strain affect the mechanical properties sand.

COMPUTER SCIENCE AND ENGINEERING



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AUTHENTICATION METHODS FOR WEARABLE MOBILE DEVICES

Along with the advent of smartphones, the past couple of years have also been marked by the emergence of wearable mobile devices like smartwatches (Samsung Galaxy Gear) and optical head-mounted displays (Google Glass). As these devices gain popularity, it is important to consider their security risks. Traditional authentication methods employed on smartphones and tablets may not be appropriate for wearable devices due to the vastly different hardware specifications of each device. Our research involved developing authentication methods that accommodated the hardware limitations of these devices, specifically a smartwatch, while still being secure.

One of the methods implemented, Draw a Secret (DAS), attempts to add security to the standard pattern lock available on most Android devices in addition to making the passwords more memorable. Instead of being bound to a grid, users draw their passwords free form on a canvas. An app was developed for the smartwatch, and its security and usability were compared to that of the standard pattern lock.

Another method researched is Whisper Authentication (WA), which attempts to avoid the use of the smartwatch's small screen by allowing users to discreetly whisper a passphrase into the device to authenticate. Due to the noisiness of whispered voice signals, standard voice recognition algorithms are not enough to decode them. Instead, the correlations among different whispered signals in a sample set were analyzed, in the hope of determining a secure admittance threshold.



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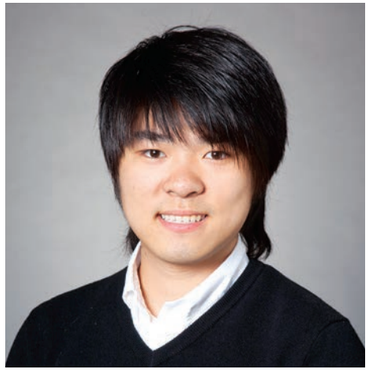
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▲ Computer Science students Salomon Idy and Anam Waheed are developing secure authentication methods that will work on wearable mobile devices, which generally have many hardware limitations.



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EVALUATING THE EFFECTIVENESS AND KERNEL FOOTPRINT OF LIND

Lind is a single process sandbox that executes programs in an isolated environment and maintains policies at process level. It allows the user to run untrusted code without compromising the integrity and security of the host system by monitoring the activities of the program and providing a separate, tightly controlled set of resources.

Lind is designed to run completely in the user space, avoiding the need for modified kernels. Most others, including Microsoft's Drawbridge and Apple's Sandbox, by comparison, require kernel modifications and thus have reduced portability across systems. Lind attempts to strike the balance between complete isolation (in the form of a virtual machine) and object-based isolation (which may not isolate resources between objects) by running compiled binary applications, while managing system access policies at process granularity, increasing its flexibility.

Lind, like it's meaning in Old English, "a shield constructed with two layers of linden wood," utilizes two sandboxing technologies, in order to provide efficient computing and ample system services. Leveraging Google Native Client for computation and Seattle Repy for system access, the resulting small trusted computing base (TCB) ensures the resilience of Lind.

Over the summer, to evaluate the effectiveness of the sandbox, test program for each possible systems access requests are run on Lind to observe its execution pattern. Methods to evaluate the kernel footprint of Lind in comparison to other sandboxing techniques are under development in connection to related works on kernel attack surface measurement.



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GOOGLE GLASS AUTHENTICATION

Google Glass is a wearable technology that stores and displays information, similar to a smartphone. As more personal information can be accessed using such devices, there is an increased need for secure and effective authentication mechanisms. The purpose of this project is to improve the built-in authentication mechanism of Google Glass through an additional security layer and enhanced usability under different conditions.

Our work presents three alternative authentication methods based on voice, hand gesture, and touchpad-based PINs, respectively, which use a 10-celled grid containing the digits 0-9. In the voice-based application, the user must say a dynamically generated red-colored digit associated with each digit of the PIN. In the hand gesture-based application the user must move his hand and place it on the randomly assigned cell of each digit of the PIN. In the touchpad-based application, the user must use horizontal swipes and simple taps to select each digit of the PIN.

The applications were developed using Android programming on the Glass platform. The voice-based application was implemented using CMU sphinx and Google API for speech recognition. The hand gesture-based application was designed using image-processing techniques in OpenCV. Additionally, various parameters, including the impact of background disturbance on usability and security, were analyzed during the development phase. A user study was performed to evaluate the security and usability of the authentication mechanisms by exploring the relative demands on user login time, effort, and error. The study also provided observations of user perceptions, strategies, and reactions to the authentication methods, collected using a System Usability Scale assessment tool.



SETH MILLER

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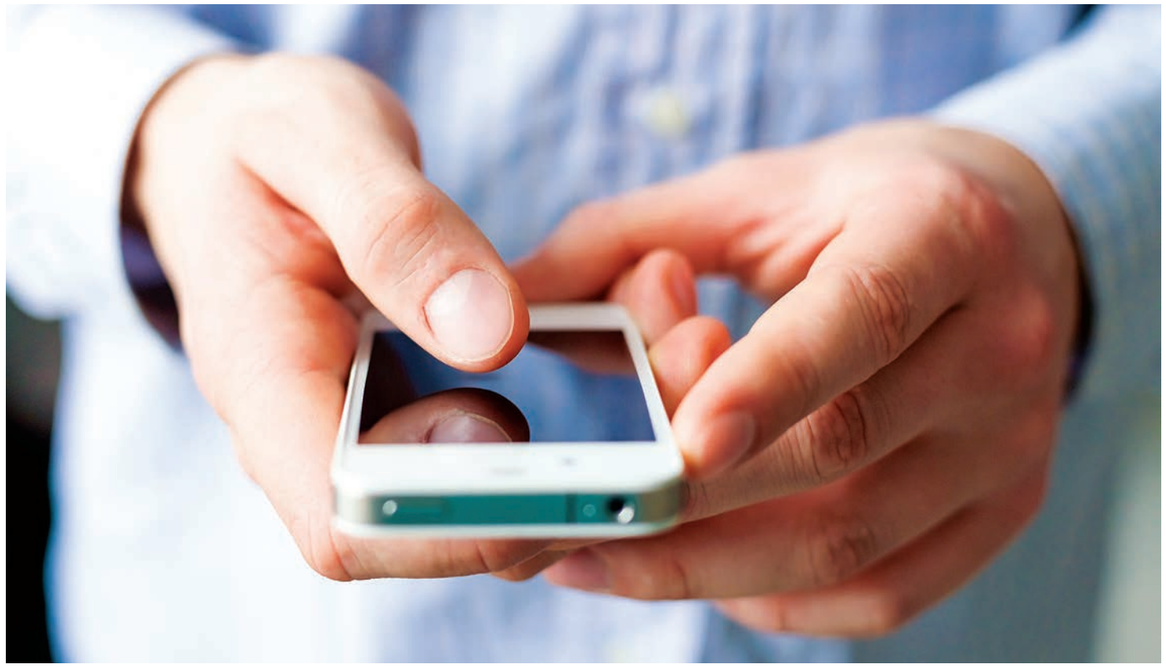
SENSIBILITY TESTBED: BUILDING A PLATFORM FOR SMARTPHONE SENSOR DATA AGGREGATION AND ANALYSIS

Modern smartphones and tablets come with a multitude of embedded sensors capable of recording how mobile users interact with their environments and proceed through everyday life. This information has vast, predominantly untapped potential across countless disciplines. Sensibility Testbed is a platform that seeks to provide researchers with the ability to instantly deploy programs. This allows researchers to draw on an existing user base, which improves science and benefits society as a whole.

Sensibility Testbed runs on Android devices and features a sandbox that limits access to device resources, programs, and files. By housing all sensor applications in a sandbox, the user is equipped with a level of protection and privacy not present elsewhere.

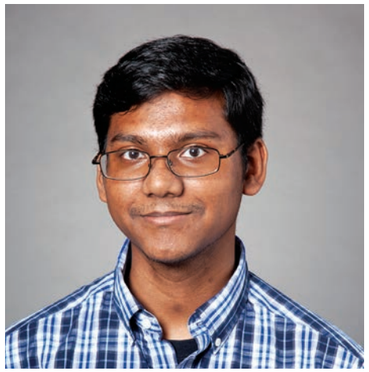
Applications safely obtain access to a device's cellular data, GPS, Bluetooth, accelerometer, and myriad other sensors in a manner that maintains the user's privacy.

The goal of this research is to set up a database into which sensor data can be backhauled; the data can then be analyzed and aggregated for further research or application purposes. This is being achieved with a non-relational database, specifically the NoSQL variety MongoDB. With its document-style storage, a NoSQL database offers scalability in addition to a form convenient for developers visualizing data in different environments. Django, a Python web framework, serves as an interceder between Sensibility Testbed and the database. As a result of this work, Sensibility Testbed will allow sensor applications to store and access data without having to manually create and open communication with a database.



▲ Student Seth Miller is tapping into embedded smartphone sensors to reveal how users interact with their devices and plans to apply the data across various disciplines.

ELECTRICAL AND COMPUTER ENGINEERING



KISHORE BISWAS

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A C-SCHEMATIC DESIGN APPROACH TO DIGITAL CIRCUITS ON VIVADO

Running applications on reconfigurable chips, such as field programmable gate array (FPGA) chips, is attractive because of their speed and programmability. These chips are speed competitive with custom chips and cost competitive with microprocessor chips, as manufacturers are developing high density FPGA chips, including the world's densest chips and the world's earliest 3-D chips.

FPGA chips have a speed advantage over microprocessor chips since they run applications on hardware. Also, hardware provides much more parallelism than software. FPGA chips also have an advantage over custom chips because they can run many different applications, while a custom chip can run only one application.

In order for FPGAs to be more competitive though, they must require little electrical engineering knowledge. Today, one needs to know hardware description languages (HDLs), such as VHDL, to use FPGAs. Writing a program in such a language for an application is the first step to using an FPGA. Nevertheless, there are now sophisticated tools that allow C, C++, LabVIEW and MATLAB programming for applications, meaning that anyone can do hardware development.

But, even on these tools, testing C/C++ programs and running them still requires electrical engineering. Our research addresses this and has two goals : acquire the skills to develop C/C++ programs for FPGAs and develop a graphical user interface (GUI) so that testing hardware and running applications on FPGAs is easier.

We use the Xiliinx Vivado tool to develop C/C++ programs. We develop the interface between the FPGA and the computer in two parts: a program that allows the communication between the FPGA and computer through the serial port and a GUI that controls and displays the contents of the FPGA on the computer screen. We show the results by developing games, such as tic-tac-toe, in C/C++ and then running them on an FPGA.



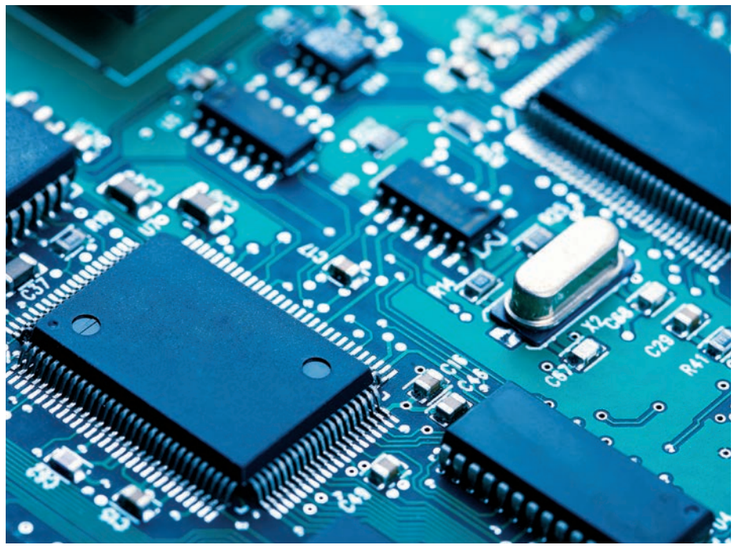
SHAHZAIB JAVED

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▲ Kishore Biswas and Shahzaib Javed are developing interfaces that will allow users to easily test hardware and run applications on more attractive reconfigurable chips.



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DEPTH-SENSING CAMERA AS FEEDBACK FOR ROBOTIC MANIPULATOR

To accurately position a robotic manipulator, real-time sensing of its position in 3D space is a necessity. Image Based Visual Serving (IBVS) is a feedback technique that uses vision sensors to locate the position of a manipulator's end effector, which can be used in a controller to improve tracking performance. This project uses a depth-sensing camera to provide measurements for a robotic manipulator in the form of three-dimensional coordinates of the end effector. Unlike IBVS with traditional cameras, the depth-sensing camera has access to depth information, which can be used to create an accurate three-dimensional end effector position, eliminating the need to estimate the position from a two-dimensional image.

For this project, the Creative Senz3D depth and gesture recognition camera was used to track the end effector position of a four-degree-of-freedom robotic manipulator. To achieve this objective, it was necessary to create a program using the raw depth and color data from the camera to locate the end effector of the manipulator and translate the data into usable three-dimensional coordinates. By tracking these coordinates, both position and velocity can be directly calculated. This information is then used to improve the controller for the manipulator to achieve a higher-level of positioning accuracy.



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DESIGN AND CONTROL OF A QUAD-ROTOR UNMANNED AERIAL VEHICLE

In recent years, the usage of quadrotor/quadcopter based unmanned aerial vehicles (UAV) has seen a steep increase. This is due to its numerous applications for both civil and military purposes and to the advances in the fields of electronics, mechanics, control, and automation. Because of their high maneuverability, quadrotors can be used for both indoor and outdoor applications and can be useful in many environments. The project being developed focuses on the control and navigation of a quadrotor UAV. It involves the data fusion of multiple sensors to estimate the UAV's position and angular orientation, which are then used for real-time feedback in a control system that generates the actuation signals to each one of the four propellers. The controllers were tested in a MATLAB Simulink model of the rotorcraft, having their structures directly implemented in Simulink as well as a real-time implementation using the C language. To achieve position control for the quadrotor regardless of having GPS signal, a set of cameras is utilized for localization purposes. Additionally, a simultaneous localization and mapping (SLAM) technique will be implemented on the quadrotor in future efforts.



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QUADRUPED PLATFORM FOR VARIABLE TERRAIN NAVIGATION

This project focuses on the ongoing development of the "BlueFoot" quadruped robotic platform. This platform has been constructed for the purpose of studying quadruped gaiting and rough-terrain navigation algorithms. Platform control has been implemented on a distributed processing architecture consisting of a dual-processor autopilot unit and an ODROID-XU quad-core computer. The autopilot unit provides full inertial sensing via an accelerometer, gyro and magnetometer combination. The autopilot is also responsible for gait-generation and adaptation. The ODROID-XU computer handles stereo camera inputs, as well as a laser distance sensor (LDS) and GPS unit. Furthermore, the robot is outfitted with decentralized serial-servo controllers, which provide position and loading feedback. Each of the robot's legs is fitted with contact sensors to provide touchdown detection.

Processed stereo image data will be used in concert with the LDS data to detect environmental features. Using C++ libraries, OpenCV and OpenPCL, the obtained images and point-cloud data will be employed in generating terrain models, as well as for mapping and localizing within arbitrary environments. Using central pattern generation techniques as the core of the platform's gaiting, higher-precision foothold adaptation will be incorporated through the use of the aforementioned terrain maps.Currently, the robot is capable of full-body color-blob tracking. To navigate, robot generates velocity and pose vectors that are updated with each new frame. These parameters are generated from the relative location and size of a blob within a processed frame.

MATHEMATICS



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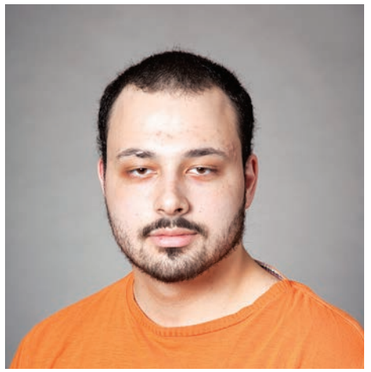
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MODELING ELECTRON-PHONON INTERACTIONS IN FULLERENES

The family of molecules known as "fullerenes"—molecules consisting entirely of Carbon atoms lying in a grid—is of interest in the field of nanotechnology. Applications vary through distinct fields of engineering, from electrical to optical to biomedical. Electrical engineers hope fullerene-based transistors will replace today's silicon-based ones and possibly provide high-temperature superconductors; cancer researchers hope to use fullerenes to aid in radiation therapy's accuracy; and optical engineers use fullerenes to make the blackest materials ever made.

It is thought that many of the unique properties exhibited by fullerenes that are of interest because of their wide array of applications are caused by phonon-electron interactions on the grid of Carbon atoms. We study a modified nonlinear Schrödinger equation modeling the phonon-electron interactions. As with many partial differential equations (PDE) that result from real-world study, the mathematical analysis is nontrivial. Analytical tools necessary for this study arise from the study of solitons in field theory and nonlinear analysis. Numerical solutions to the PDE are implemented via MatLab and Mathematica. Our objective is to give a complete analytical and numerical description of the solutions to the modified Schrödinger equation modeling the phonon-electron interaction. Additionally, we propose to implement the effects of a magnetic field into the model.



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SLEEP SPINDLE DETECTION USING CONVEX OPTIMIZATION

Sleep Spindles, characterized as sinusoids in the range of 12-14 Hz, are discrete and intermittent patterns observed in the human electroencephalogram. They are one of the hallmark characteristics of stage 2 of Non-REM sleep. It is observed that the onset of alternations in sleep spindle occurrences seem to have direct correlation to several mental illnesses, such as schizophrenia, autism, epilepsy, and other neurological disorders. As a result, the spindles can be invaluable as biomarkers. Traditionally, these spindles are detected by visual experts in sleep clinics. Several automated detectors have been designed to extract the spindles, but visual detection by the experts still remains a gold standard. We propose a sparsity based convex optimization approach in order to develop an algorithm that will have a lower rate of false positives. With the help of the Short Time Fourier Transform (STFT), the sleep spindles can be sparsely represented, and using mathematical tools such as variable splitting and the Alternating Direction Method of Multipliers (ADMM), we attempt to establish a solution to the convex optimization problem that will extract the sleep spindles.



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THE APPLICATION OF THE MAHALANOBIS-TAGUCHI SYSTEM (MTS) TO INSURANCE DATA

The Mahalanobis-Taguchi System is the statistical and forecasting method that classifies the data into normal and abnormal groups. Given a multi-dimensional dataset, the MTS first estimates the mahalanobis distances between the scaled normal data and the mean of the normal data, as well as the distances between the abnormal and the normal mean. Then, the Taguchi array is employed to calculate the average signal-to-noise ratio of each variable or feature and to carry out feature selections. Next, the mahalanobis distance is estimated again, but it only uses the selected features. The final analysis delivers a more interpretable result explaining the 'important' feature in the dataset that contributes to the classification between the normal and the abnormal group. In this research, the Mahalanobis-Taguchi System (MTS) was applied to the fire peril loss cost dataset that was publicly available from the Liberty Mutual Group Inc. This paper will demonstrate how the MTS system would make a clear separation between the group of the clients with the risk ratio less than 1 (the normal group) and the group whose ratios exceeded 1 (the abnormal group).

MECHANICAL ENGINEERING



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ACCELERATED ENVIRONMENTAL DEGRADATION AND RESIDUAL FELXUAL ANALYSIS OF CARBON NANOFIBER REINFORCED SYNTACTIC FOAMS

Syntactic foams are a class of composite materials that have been used extensively in underwater environments as thermal insulation for deep-sea drilling and buoyancy modules for submersibles. Hollow particles are dispersed in a matrix to create syntactic foams, which can be classified as closed-cell foams. Because the gas porosity is surrounded by the hollow particle wall, syntactic foams show very little water uptake and maintain their low density. In this work, carbon nanofibers (CNFs) have been used to reinforce syntactic foams and the environmental degradation mechanisms of these multiscale composites are studied.

Syntactic foams containing 15-50 vol.% glass microballoons (GMB) and 1-5 wt.% CNF reinforcement as well as CNF/epoxy composites containing 1-5 wt.% CNF were exposed to accelerated weathering by immersion in 90°C water for two weeks and characterized for their residual flexural properties. In the worst performing composites, a maximum weight gain of 3.5% and 10% was observed for CNF/epoxy and CNF/syntactic foam composites. The syntactic foams tested were observed to generally decrease in strength after weathering, with the exception of the foams containing 5 wt.% CNF, which were observed to increase in strength by 41% and 51% after weathering. The CNF/epoxy composite containing 5 wt.% CNF was also shown to increase in strength by 27% after weathering. Increased traction on the nanofibers due to swelling of the epoxy matrix is the likely cause of the strength increase in these composites after moisture exposure.



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BIOMECHANICAL MODEL OF AORTIC DISEASE

In an aortic dissection, the inner lining of the aorta is torn, and blood is forced between the aortic layers, tearing a long secondary channel. This often leads to rupture, and subsequently, death. The goal of this study has been to aid clinicians in selecting personalized treatments by developing computational methods for assessing stress distribution in patient-specific models of dissected aortas. The current focus is establishing methods for modeling the aorta in both diseased and healthy states to create highly accurate, unloaded, patient-specific volume meshes for stress analysis. The basis for the models were 3D CT scans from aortic dissection patients and from a healthy patient. Through sequential processing of the data in several programs (Simpleware, Meshmixer, Trelis, MATLAB, Abaqus), it was possible to create detailed, high-quality facet surface meshes of four aortas with complex dissection conditions. The models extended from the sinuses of Valsalva to the celiac artery and included the aortic branches up to the bifurcation of the first branch. A method for producing high-quality hexahedral volume meshes (as determined by element shape metrics) of healthy aortas was also established. Because the CT images show initial deformation due to the force from diastolic blood pressure, an iterative deflation algorithm is applied to the volume mesh to provide an unloaded specimen for stress analysis simulations. These models provide a realistic base for detailed comparison and investigation of how different means of intervention affect stress levels in the aortic wall. Future work will include further development on volume meshing for dissection geometries and investigations into the effects of different medications on stress distribution in the aorta.



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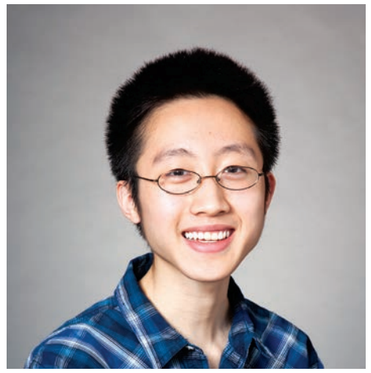
Faculty
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BIOMECHANICAL MODELING AND TESTING OF HUMAN KINEMATICS AND DYNAMICS

This research seeks to develop a general model that predicts human metabolic energy expenditure using kinematic data. Biological systems are by nature complex, and humans are no exception. Human movements are not actuated by simple motors but by complicated muscular systems involving the synchronized contraction of many muscle fibers. This complexity makes direct measurement of energy expenditure by monitoring individual muscle activity unfeasible. A kinematics approach requires less complexity because it focuses on the resultant movement actuated by muscular systems rather than the complicated internal behavior of these systems. As compared to monitoring internal metabolic activity, kinematic data is also easier to acquire.

The subjects that were recruited for this research were made to walk at different speeds while their oxygen uptake was monitored with a gas analyzer, and their motion was captured simultaneously using an infrared camera setup. The energy consumed during each trial of walking was determined through the levels of oxygen uptake and the kinematic data were extracted from the capture motion using Visual3D for motion analysis. The experimental data were mined using statistical tools to find correlations between energy use and kinematic variables, which were used to develop a biomechanical model using optimization techniques in MATLAB. The model was refined to incorporate subject specific parameters such as joint strength, body mass, age, and height, allowing it to predict energy consumption across a diverse range of individuals. This work represents an important step in providing a robust method for estimating human energy consumption, reducing the need for human experiments involving expensive equipment.



WILLIAM PENG

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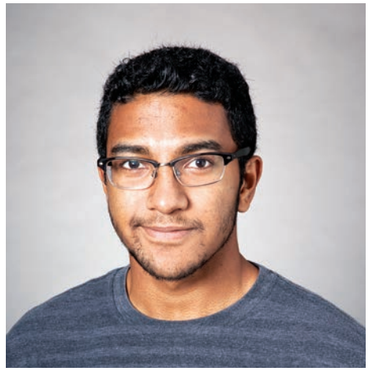
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▲ Zhen Xiang Chen and William Peng are developing a model that will predict energy consumption using kinematic data such as motion and oxygen intake.



STEPHEN CARTER

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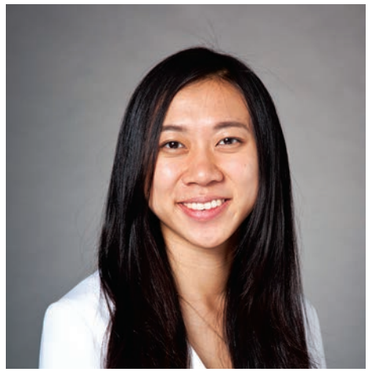
Faculty
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DEVELOPMENT OF WATER SURFACE-DWELLING ENERGY-HARVESTING DEVICES

This project focuses on energy harvesting through an ionic polymer metal composite (IPMC) undergoing deformation due to artificially induced waves. IPMCs are a novel class of smart materials that have received significant attention for their use as sensors and energy harvesters. As an IPMC bends, it produces an electrical output due to the change of the charge distribution within the polymer. In this project, an experimental setup consisting of floatation devices hosting an IPMC and a wave generator is used to harvest wave energy. Specifically, the IPMC is clamped between two anchored floatation devices such that it rests on the surface of the water. The wave generator is realized by a 3D printed wedge connected to a linear actuator that impacts the water. The movement of the linear actuator is controlled by an air compressor and a function generator. Wave amplitude and frequency can be varied by adjusting the outlet pressure of the air compressor and changing the frequency on the function generator, respectively. During the tests, short-circuit currents from the IPMC are measured and analyzed. From these results, it is possible to experimentally maximize the IPMC's harvested energy with respect to the incident wave amplitude and frequency. The results of this project could provide the ability to scavenge power from waves incident on floating buoys in the ocean.



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EVALUATION OF A NEW MAGNESIUM ALLOY FOR AIRCRAFT STRUCTURAL APPLICATIONS

Metals are widely used for various applications due to their high thermal and electrical conductivity as well as their high structural strength. In automotive structural and powertrain applications, steel has been replaced by lighter weight aluminum alloys. Use of lighter metals and alloys results in improvement in fuel economy and reduction in emissions. Magnesium alloys are now replacing even aluminum for further weight reduction, especially in aircraft structures.

WE-43 is a magnesium alloy consisting of Yttrium, Rare Earths and Zirconium incorporated into a Magnesium base. Magnesium alloys have low density and high strength per unit weight in comparison to steel and aluminum, and so are used in aircraft and sports cars. Thermo-mechanical analysis (TMA) and dynamic mechanical analysis (DMA) were performed on specimens of WE-43. This is done to determine its behavior at higher temperatures, up to 450 degrees Celsius. The results from DMA will also reveal the material's ability to dampen vibrations. The DMA is used to measure the change of the storage modulus of the material with temperature. It is observed that the modulus rises with higher temperatures, and further work is being done to analyze these results.



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EXPERIMENTAL STUDY OF UNDERWATER ACTUATION OF IONIC POLYMER METAL COMPOSITES

Ionic polymer metal composites (IPMCs) comprise a class of smart materials that feature a low activation voltage and power consumption combined with high flexibility and minimal weight. Such advantages make IPMCs a promising material for miniaturized underwater propulsion systems, especially for biomimetic robotic swimmers. This project focuses on the analysis of the thrust and flow field generated by an actuating IPMC as a function of the frequency of the applied voltage in a quiescent aqueous environment. The IPMC strip is actuated by a sine wave function generator. The thrust is measured using two methods: direct force measurements from a load cell and indirect measurements from particle image velocimetry (PIV). Specifically, the strain gauge in the load cell measures the thrust of the actuating, while PIV captures high-speed images of laser-illuminated tracer particles, which in turn are used to reconstruct flow field in the vicinity of the IPMC and estimate the thrust generated by the strip. The two estimations are compared and analyzed in detail. Quantifying the relationship between IPMC thrust and the applied voltage may provide a better understanding of the potential of IPMCs as underwater propulsors.



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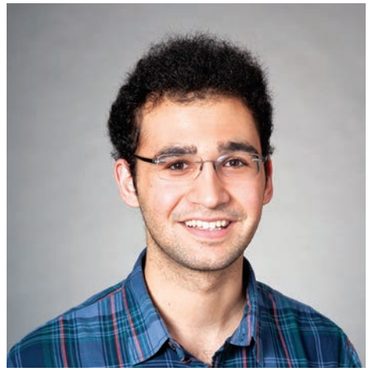
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EXPERIMENTAL STUDY OF UNDERWATER VIBRATIONS OF IONIC POLYMER METAL COMPOSITES

The goal of this project is to study the fluid flow in the vicinity of an Ionic Polymer Metal Composite (IPMC) vibrating underwater by using particle image velocimetry (PIV). IPMCs are novel electroactive materials composed of a polymer membrane sandwiched between two noble metal electrodes. Such materials have recently been utilized for the design of mechanical sensors and energy harvesters. Mechanical deformation of an IPMC produces a redistribution of mobile charge carriers within the polymeric core, which results in a detectable voltage across the electrodes. To fully characterize the interaction of the IPMC with the surrounding fluid and study the effect of the fluid on the electromechanical response of the material, PIV is used to reconstruct the flow velocity in the vicinity of the vibrating IPMC. PIV is a well-established experimental technique, enabling the measurement of the fluid flow from the motion of reflective particles that are illuminated by a laser and captured by a high speed camera. In this project, velocity data obtained through this technique are used to estimate the force exerted on the IPMC by computing the pressure in the fluid. This study aims to contribute to the understanding of the effects of fluid-structure interaction on IPMC underwater vibrations, with applications in fluid sensing and energy harvesting in underwater environments.



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HARVESTING USABLE ENERGY FROM FLUIDS USING SMART MATERIALS (DISK-TYPE IPMC)

Ionic polymer metal composites (IPMCs) are a novel form of smart materials that have received substantial attention in recent years in the field of energy harvesting. IPMCs produce an electrical output under mechanical vibrations and can be potentially used to power small electronic devices. IPMCs are distinguished from other soft smart materials for their aqueous nature, which makes them ideal for energy harvesting applications in water flows. The objective of this project is to study energy harvesting from the underwater vibration of an in-house fabricated disk-type IPMC. The IPMC is clamped to an oscillating rigid bar along its inner radius, while it is free at its outer radius. The base excitation of the bar is generated through a shaker mounted above a transparent water tank and connected to the IPMC via 3D printed fixtures. Using a function generator, the oscillation of the IPMC across a range of frequencies is simulated. The effect of the ratio between the inner and the outer radius is also studied by varying the clamped inner radius. The short-circuit current is measured via circular copper electrodes during the vibration tests. From this response, we obtain the resonance frequency of the IPMC. Finally, we parametrically vary the shunting resistance to elucidate the capabilities of the IPMC as an energy harvester.



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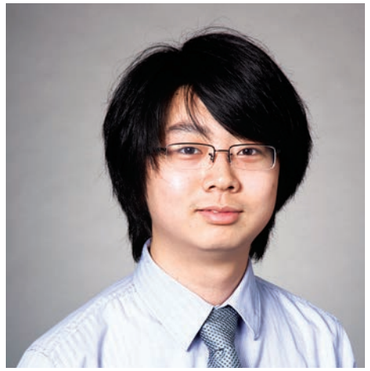
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IDENTIFYING COLLECTIVE BEHAVIOR IN US POLICY ADOPTION WITH MACHINE LEARNING

Due to a high mortality rate associated with driving under the influence of alcohol, American states have passed a variety of policies and legal measures intended to reduce the rates of these incidents. However, the number and type of enacted policies vary widely among states, and the underlying mechanisms that determine a state's health policy are not well understood. This project seeks to identify patterns in the laws passed by American states that reflect collective efforts in policymaking among them, which can aid in predicting and analyzing changes in policy. Specifically, the goal of this project is to use a machine learning classification technique to develop a lower-dimensional representation of a historical catalog of high-dimensional alcohol policy data. The results of this classification can be used to determine if the trends in states' laws exhibit collective behavior. Using the nonlinear dimensionality reduction algorithm Isomap, an embedding manifold corresponding to true alcohol policy data was created based on our computed distances between pairs of laws. Results indicate that the historical law data can be represented in two dimensions. However, simulated data that retained some statistical properties of the real alcohol data did not allow for the same simple representation. This suggests the existence of additional, state-specific factors that may be influencing the evolution of the laws. These results are expected to assist in further classification and predictive modeling of trends observed in state public health policy.



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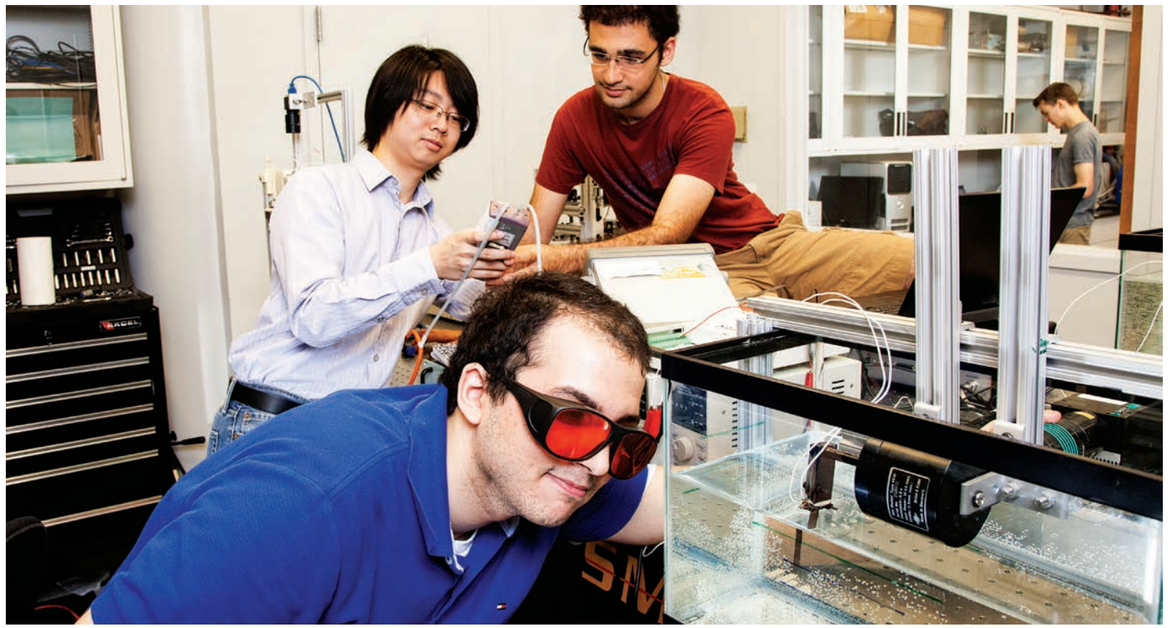
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IMAGE PROCESSING FOR MECHANOCHROMATIC ELASTOMERS

Mechanochromatic elastomers are characterized by a detectable color change due to mechanical deformation. The mechanical deformations induce a reorganization of the polymeric network, which in turn produces changes in the aggregation of dyes and pigments dispersed through the polymer. The objective of this project is to develop an image processing technique to assess the mechanical deformation and the fluorescent response of polymer. Results of this project may assist in the development of novel fluorescence sensors for biomedical and environmental applications.

A Digital Image Correlation (DIC) technique is adopted to characterize polymer mechanics during uniaxial and biaxial tests. DIC is a technique that enables determination of complex states of deformations in solids through correlation of sequences of images acquired during mechanical tests. To enable image correlation, an ad hoc sparkling technique has been developed through the application of a powder ink on the surface of the material. An open-source Matlab DIC code is used for processing the images acquired during the tests, and the custom Matlab routine is used to compute the polymer deformations.

To characterize the constitutive behavior of the material, results from uniaxial tensile tests are compared with biaxial deformations of an inflated dome. For this purpose, an experimental setup has been developed, which includes a manometer for recording pressure, a pumping motor, and the two high speed cameras to record dome deformations.



▲ Students Steven Osma, Liwei Zhou and Shervin Abdolhamidi study how the vibrations of ionic polymer metal composites can be applied to fluid sensing and energy harvesting in underwater environments.



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JET NOISE REDUCTION VIA FLUID INJECTION

Over the past half-century, high-speed jets have become one of the most efficient and powerful means of aircraft propulsion. Due to this, supersonic aircraft have been the object of numerous recent and ongoing design studies. One of the problems with supersonic aircraft's operation is excessive noise generation, associated with very high jet velocities used during take-off, and even more importantly. flying over communities near the airport. One of the primary causes of this noise radiation is an aeroacoustic phenomenon known as jet noise. For a supersonic aircraft at off-design condition besides jet mixing, shock associated noise can be the primary source of jet noise.

In this study we investigate the flow of an axisymmetric turbulent supersonic jet using the ANSYS Fluent package. The objective of this study is to inspect the supersonic flow developments in a converging/ diverging nozzle and to analyze the exhaust flow characteristics of an engine by altering specific parameters in order to investigate the supersonic jet flow field, shock wave structure and jet mixing enhancement for reducing the jet noise. The results of this study can help minimize jet engine noise in all types of jet engines.



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LIVER STIFFNESS ANALYSIS

Cirrhosis is the 12th most common cause of death by disease according to the National Institutes of Health and is characterized by the replacement of healthy liver tissue by scar/fibrotic tissue. It can be asymptomatic in the early stages but eventually causes various complications, including cancer. Diagnosis is made by observing the presence of conditions that may increase the risk of developing cirrhosis, including obesity and alcohol abuse, and is confirmed by procedures such as blood tests and biopsy.

Since biopsies are invasive procedures and may cause complications, physicians seek non-invasive alternatives. One of the most promising new methods is elastography, which measures the liver's stiffness by using an external device that generates transverse/shear waves and measures their propagation through the hepatic tissue.

This research aims to define a novel way to assess liver stiffness based on the natural deformation of the liver that occurs due to heart motion. Tagged MRI was used to measure this deformation and create a 3D model of the liver, which was used for an inverse finite elements analysis that sought the best material model to produce the same deformation as in the real liver. Using a custom optimization routine, the liver stiffness was evaluated and used to estimate the amount of fibrotic tissue present in it. We found a correlation between the values of liver stiffness obtained and the stage of cirrhosis progression. This approach costs less and provides more reliable results than elastography, as it will test the liver at a physiological strain rate. It also eliminates the need for biopsies.



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MACHINE LEARNING BASED DECISION-MAKING ONBOARD A ROBOTIC PREDATOR FISH

Studying onboard autonomous decision-making in a dynamic environment is challenging partly because it is difficult to model the complexities of a constantly changing scene from a camera viewpoint. Even if it were possible to track individual features, real-time interpretation of a dynamic environment is a computationally intensive task not easily implemented onboard small computer chips that can fit on small mobile robots. A recently proposed data-driven approach uses dimensionality reduction and manifold learning to extract global observables of collective behavior from images of fish shoals. This project aims to extend the same approach onboard a newly developed robotic fish for autonomous decision-making in an animal behavior study.

The goal of this summer project is to augment a robotic fish platform with onboard visual sensing capabilities to perform experiments in animal behavior. The robotic fish is modeled as the natural predator of the zebrafish to study the response of small fish shoals to simulated attack strategies. The experimental setup consists of the robotic fish darting towards a shoal of zebrafish separated by a glass partition. The experimental procedure consists of two attack strategies: one in which the robot randomly moves towards the side of the tank with the shoal of zebrafish, and a second in which the robot moves towards an isolated member of the shoal. The research activities include upgrading the robotic platform to conduct natural attack strategies, conducting behavioral experiments, extracting the trajectory data from existing experimental trials, computing the global observables of collective behavior such as cohesion and polarization from the trajectory data, and analyzing the resulting experimental dataset using statistical tools.



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MODELING AND ANALYSIS OF INTEGRATED SOLAR COMBINED CYCLE POWER PLANTS

Fast-growing industries throughout the world inevitably depend on the availability of electrical power. Today, the overall situation in the power sector is a bleak one; it is high time developing economies explore renewable energy resources. The Integrated Solar Combined Cycle (ISCC) power plant for one provides an optimistic view of our energy future. An ISCC power plant is the hybrid of a combined cycle gas turbine plant and a solar thermal plant. This conjunction allows solar energy to be used as an auxiliary energy source, increasing the power output without burning additional fossil fuel and ultimately cutting down carbon emissions compared to a traditional power plant.

Located 50 kilometers north of Duba, Saudi Arabia, Saudi Electricity Company's 550 MW Duba I project is a prospective ISCC power plant project that will burn natural gas as its main source and utilize Arabian Super Light as a backup fuel. This is the nation's first tangible step to initiating the solar industry in Saudi Arabia.

In response to Saudi Electricity Company's ambitious proposal, the objectives of this research are to schematically illustrate the system and to identify various input parameters as well as the overall process flow and design details of steam and gas turbine generator systems. Another objective that is worth noting is to define and analyze the thermal efficiencies of the Duba I independent power plant.



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RESPONSIVENESS OF LIVE ZEBRAFISH SHOALS TO ROBOTIC ZEBRAFISH SHOALS

With increasing opposition to the use of higher-order animals, the use of less sentient animals in laboratory studies is becoming a societal and ethical requirement. Within this framework, zebrafish are now considered as a valid alternative to laboratory mammals (e.g. rodents and primates) based on several characteristics: reduced neurological complexity, fully sequenced genome, elevated reproduction rate and stocking density. Additionally, zebrafish exhibit remarkably complex individual and social behaviors, thereby constituting a promising laboratory species for the preclinical modeling of human function and dysfunction.

Among the various hurdles to be overcome in the process of establishing zebrafish as a valid alternative, inter-individual phenotypic variation constitutes a principal issue that may hamper between-experiment data reproducibility. Social behavior in zebrafish, which may inform human conditions like autism and neurodevelopmental disorders, is generally addressed through the analysis of shoaling. Specifically, several studies investigate the response of a single individual to the presentation of a group of shoal-mates. The behavior exhibited by live stimuli remarkably depends on lab-specific idiosyncrasies (e.g. light conditions, circadian rhythms, dominance hierarchies, etc.). To standardize experimental protocols and increase between experiment reproducibility, we attempted to eliminate the variability of the shoaling zebrafish, replacing it with a fully controllable, three-dimensional model replica of a four-fish shoal. In this project, we attempted to optimize the shoal replica through a series of experiments in which we observed individual fish behavior in response to the presentation of several replicas. The experiment aims at testing which shoaling replica (varied in terms of the size of the robots composing the biologically inspired shoal) elicits the strongest approach response in the focal zebrafish.

Different sizes of replicas are used to determine the best size for behavior studies, including 2 cm, 3 cm, 4 cm, and 6 cm. The replicas have controlled movements that mimic overall zebrafish movement and morphology. The behavioral scoring conducted suggests that bio-inspired robotic replicas can elicit an approach reaction in live animals. In line with available literature indicating that live fish response to robotic stimuli is more consistent than that exhibited in response to live subjects, the present study may disclose novel avenues toward the development of test paradigms that can replace laboratory mammals, increase the reproducibility of experiments, and limit the use of live animals in preclinical research.



▲ Students Jasmin Li, Ashleigh Showler and Steven Carter study the responsiveness of live zebrafish shoals to robotic replicas.



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OPTIMIZATION AND CHARACTERIZATION OF ROBOTIC FISH WITH INTERCHANGEABLE COVERS

The development of robotic fish has traditionally focused on the biomimetic design of the fish shape and the implementation of its swimming locomotion. This focus has come at a cost of a coupling between the fish shape and the waterproofing mechanism that protects its interior circuitry. Most robotic fish have been built with an airtight external case, requiring a full redesign if a new fish with a different shape, but similar swimming pattern, is proposed. Herein, a novel robotic fish that decouples the fish shape, waterproofing mechanism, and swimming pattern is used to optimize and characterize the speed of the robotic fish based on a set of interchangeable covers. Specifically, several scaled-down, bio-inspired fish shapes were created with a rapid-prototyping machine, and particle image velocimetry (PIV) was used to determine the fluid flow around the exterior of the robotic fish. Analysis of the PIV measurements enabled calculation of the coefficient of drag for each fish body type. These values were also compared to those of the live fish after which the covers were modeled. Using a to-scale robotic fish, a speed characterization test is also performed using two fish covers designed after the scup (Stentomus chrysops) and Atlantic Bonito fish (Sarda sarda), and the influence of tail geometry on thrust is measured for both designs using a custom experimental apparatus. Results of this study are expected to aid in the reproduction of a larger variety of bio-inspired robotic fish exteriors.

TECHNOLOGY, CULTURE AND SOCIETY



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STEINFINDER: PUBLIC ENGAGEMENT IN THE HUMANITIES WITH LOCATION AWARE APPS

SteinFinder modifies the augmented reality interface Layar as a test-case for opening conversations about the humanities to a wider audience. Our customization allows users to add data points of interest about Gertrude Stein's life and publication history, as well as granting users the ability to discuss and analyze existing points with one another. These collaborative conversations can lead to a greater understanding of Stein's work.

After we spent the summer working with HTML5, CSS, PHP, and JavaScript, SteinFinder is able to be accessed across all platforms, with a new desktop version in addition to the mobile device version. The easy-to-use interface coupled with the interactive nature of SteinFinder cause it to be such a success. With more data points being added, more conversations surrounding the digital humanities have taken place. And from these conversations, the field has grown to include diverse views from people of all backgrounds, whether they are scholars proficient in the digital humanities or in Gertrude Stein and her works, or just fans of Stein's works.

SteinFinder provides a credible archive of information through its new and rigorous data validation process. By researching different data validation methods used by other successful crowd-sourcing projects, an effective method was found. Each newly entered point has its latitude and longitude verified, as well as its historical validity. This archive will serve as an example for the great historical preservation of authors and their works.

19TH-CENTURY CONCEPTIONS OF THE ELECTROMAGNETIC AETHER

Before the advent of special relativity, wave theories of light required the existence of an optical medium, called the "aether," through which light waves could propagate. In 1861, the famed physicist James Clerk Maxwell proposed a unified theory of electricity, magnetism, and optics by appealing to the mechanical conception of an electromagnetic aether. That is, he attempted to describe this aether as a physical system purely governed by Newtonian mechanics. Followers of Maxwell subsequently proposed their own mechanical models as aids in the understanding of electromagnetic phenomena, for both research and instructional purposes.

Our research in the history and philosophy of science considers how these mechanical models of the electromagnetic aether provide formal scientific explanations of electromagnetic phenomena, with respect to standard accounts of explanation in the philosophy of science. Based on our findings, we suggest that the type of explanations offered by Maxwell and his followers cannot be readily understood by any of these standard accounts; rather, we suggest a new type of "intertheoretic" scientific explanation that utilizes links between Maxwell's theory of electromagnetism and Newton's theory of mechanics. By suggesting this novel form of explanation, we hope to contribute to new growth between related scientific theories, for instance in quantum gravity with respect to general relativity and quantum mechanics.



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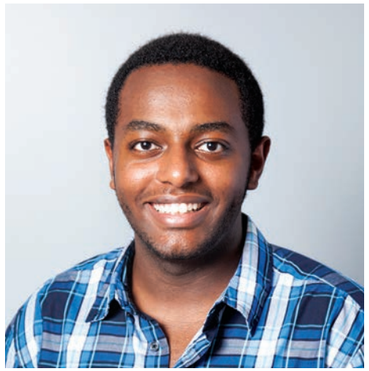
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INFORMATION RETRIEVAL TECHNIQUES TO MODEL DISCIPLINARY CHANGE IN THE HUMANITIES

Since the advent of the World Wide Web, online databases and search engines have provoked changes in the research techniques of the humanities. Disciplinary changes in research typically occur as new tools and technologies emerge, offering innovative ways of gathering and analyzing information. Although these disciplinary changes are generally welcomed, it is still important to understand and model the impact they are having. In order to accurately model these disciplinary changes, techniques from computer science, information science and the humanities were utilized to establish several methodologies.

The first methodology sought to quantify search engine effectiveness at retrieval of humanities resources. To simulate the expertise of hundreds of humanities researchers, a bibliographic gold standard was created for several research topics, ranging from simple to interdisciplinary. These lists were composed of quintessential sources that ideally should be displayed to search engine users inquiring about these topics. Online search engines and databases were then tested for their ability to retrieve these curated sources. Using the mean average precision (MAP) metric from information science, each search engine was assigned a precision score to quantify its effectiveness. This score was based on the number of relevant sources retrieved and their corresponding rank. The second methodology attempted to measure JSTOR's impact on information retrieval of humanities researchers. A three-part experiment was designed to model the information seeking behaviors of humanities researchers using JSTOR, measure JSTOR's information retrieval effectiveness, and determine the extent to which JSTOR encouraged interdisciplinarity and new research techniques. A tool was created to monitor graduate students in the humanities while they conducted simulated search tasks using JSTOR; this data was collected for analysis. After finishing the research, participants were then interviewed on their experience in seeking information using JSTOR.

Ultimately, we hope this research will help quantify disciplinary change in the humanities and be used as a basis to design a better tool of resource gathering for scholars, one that promotes interdisciplinary research but also reduces the limitations of current databases and search engines.



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TECHNOLOGY MANAGEMENT AND INNOVATION



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DEVELOPMENT AND IMPLEMENTATION OF A PAN-TILT CAMERA SYSTEM FOR AN AQUATIC ROBOT

This project entails the development of a pan-tilt camera system to enhance a robotics-based environmental monitoring and citizen-science project known as Brooklyn Atlantis, which focuses on the Gowanus Canal. In Brooklyn Atlantis, sensor-equipped aquatic mobile robots measure water quality and record image data throughout the canal. While the sensor data is easily analyzed by a computer, the image data requires a human to classify objects. To this end, individuals from the Brooklyn community and abroad take on the role of citizen scientists and tag the images collected by the robot through a web-based interface. To attract users and motivate the citizen scientists of Brooklyn Atlantis to continue tagging images, interesting and high quality photos of a wide variety of scenes must be captured. In this research project, the existing robotic platform is augmented to include high-resolution imaging hardware that is capable of panning and tilting a camera. Strategically capturing images, while panning and tilting, allows for the construction of photospheres, which are 360° panoramic virtual environments that can be fully manipulated by the viewer. The apparatus is used to collect a sequence of these photospheres along the length of the Canal in order to create a Google Streetview-like interface.



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INFRASTRUCTURE FOR QUANTITATIVE ANALYSES OF WIKIPEDIA DATA

As access to increasingly large amounts of data has become possible due to swift technological advances, a rapidly growing area of research is the analysis of such data, known as big data analytics. With exceedingly large data sets, traditional methods of data organization and analysis are difficult and inefficient to implement, and new, innovative methods must be introduced.

Consisting of millions of articles in a variety of languages, Wikipedia is one of the most remarkable information resources of our time and a prime candidate for big data analytics. As Wikipedia pages are created and revised on a daily basis, having the ability to organize and analyze the activity of the creation and edits of these pages is necessary in order to formulate a representative data model. Quantitative analyses involving this metadata can reveal meaningful and enlightening patterns of the inner workings of technology-mediated peer production.

WikiDAT is an open-source project whose aim is to create an extensible toolkit developed specifically for the purpose of Wikipedia Data Analysis. The source code, in Python and R, implements the data preparation/cleaning as well as the data analysis steps. The particular goal of the summer research project is to design the WikiDAT database using SQlAlchemy, which is a Python SQL toolkit that provides the necessary abstraction when dealing with large data sets like Wikipedia data dumps. SQlAlchemy helps optimize performance, as without SQlAlchemy, it would be difficult to handle very large data sets while retaining efficiency. Using SQlAlchemy, performance tests can be run in order to see how efficiently various database systems and various database engines handle bulk inserts of the data retrieved from the Wikipedia data dumps.

