2025 BOOK OF ABSTRACTS

New Jersey Institute of Technology

2025 UNDERGRADUATE SUMMER RESEARCH AND INNOVATION SYMPOSIUM

JULY 23-24, 2025

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BIOSCIENCE AND BIOENGINEERING

Modeling the Role of Nuclear Strain in Regulating Transcription Factor Transport: A Multiscale Computational Study

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Abstract: The mechanical environment of a cell, including how it spreads and the stresses it experiences, plays a vital role in determining its function and fate. Cells maintain their structural integrity by continually sensing, interpreting, and responding to external cues, which are instrumental in regulating cellular behavior. Mechanotransduction—the process by which cells convert mechanical stimuli into biochemical signals—has been shown to involve the cytoskeleton, the nucleus, and nuclear pore complexes. In recent years, research has highlighted how these components coordinate to translate external forces into precise molecular responses. Studies have demonstrated that stress anisotropy, or the direction-dependent distribution of mechanical stress, is a key regulator of fibroblast activation and mechanical memory. Transcription factors such as YAP or Yes Associated Proteins have emerged as mediators within these pathways, shuffling between the cytoplasm and nucleus in response to mechanical cues. However, the specific relationship between nuclear strain and its role in transcription factor transport remains unclear. In this project, I will investigate how nuclear shape and the directionality, or anisotropy, of mechanical strain affect the opening of nuclear pores and regulate transcription factor transport. To do so, I will work in close collaboration with experimental groups at Virginia Tech and WashU, utilizing their data to develop comprehensive cell & fiber models. These computational models will establish a biophysically accurate baseline model to simulate nuclear morphology and nuclear strain fields under varying mechanical conditions. Then, to begin investigating downstream effects on nuclear transport, I will couple nuclear strain to nuclear pore opening to derive a permeability-strain relationship which will then be used to simulate transcription factor (e.g. YAP) dynamics under different pore opening conditions. After measuring YAP accumulation levels, computational projections will be compared with experimental observations to test predictions. The expected outcome includes the submission of a manuscript detailing a validated computational model that links nuclear shape, strain fields, pore permeability, and tissue engineering. This model will serve as a predictive tool for studying how mechanical cues influence gene regulation, helping guide the development of biomaterials and tissue engineering scaffolds that control cellular behavior through pore regulation. Additionally, this model will have potential applications in fibrosis and cancer by providing insight on how to optimize therapeutics by targeting mechanotransduction pathways.

Spinal Cord Injury Recovery in Zebrafish Through Exercise and Immobilization

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Spinal cord injury (SCI) can result from traumatic force to the spine, resulting in lesioned areas of the spinal cord which reduce motor function for many patients who experienced traumatic injury (Alizadeh et al., 2019). To uncover cellular pathways behind neural regeneration of the motor synaptic network in SCI, zebrafish have been used as a common model organism due to their neuroregenerative capabilities and genetic similarities in regard to neural development with humans. Additionally, multiple laboratory methods have been established to induce SCI in larval zebrafish, including mechanical transection of motor nerves, crush injuries, and infrared laser lesions. However, the relative contributions of exercise or immobilization to the neural mechanisms behind zebrafish SCI recovery have not been sufficiently studied. To answer this question, we utilize a surgical lesioning procedure in an experimental group of zebrafish while maintaining a control group of non-lesioned fish. We will exercise or immobilize both lesioned and non-lesioned zebrafish to encourage natural movement or suppress it, specifically through manipulation of the zebrafish optomotor response inducing swimming, and agarose gel for whole body restraint, respectively. Following the recovery period, larval movement will be tracked via a high-speed camera to measure swimming speed, and kinematic features of body movement. As a result, we hope to determine the optimal level of exercise or immobilization for SCI recovery, allowing us to not only visualize motor circuit recovery in zebrafish but also uncover treatments for recovering SCI patients at the non-invasive level in a model system amenable to live neuronal imaging.

Surface modification of lipids nanoparticles with ligands and click chemistry for targeted cellular delivery to cancer cells

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Recent advancements in mRNA vaccines and delivery systems have popularized the use of RNA for cancer therapy. RNA therapeutics for cancer therapy have proved to be a promising field, with research demonstrating advantages in specificity, low toxicity, and decreased costs compared to conventional treatments such as radiotherapy or chemotherapy. Currently, the most advanced and popular RNA delivery vehicle is the lipid nanoparticle (LNPs), but there is a massive challenge in accurately targeting cell types. LNPs tend to accumulate in the liver and spleen due to macrophages in these organs filtering out LNPs from the bloodstream. This leads to RNA being delivered to nontarget tissues, so the antitumor efficacy of the treatment becomes severely reduced. As a result, there is a growing demand for research into engineering LNPs to target particular tissues. Improving the targeting efficacy of LNPs will bring nucleic acid cancer therapy one step closer to being applicable in the clinical setting.

Our project will seek to combine ligand proteins that will target specific cell receptors with LNPs and study their effectiveness in cell targeting in the Laboratory of Nanomedicine and Healthcare Materials at the New Jersey Institute of Technology. These ligand proteins will allow LNPs to bind to and be absorbed by specific tissues. The first specific objective of this study is to develop a surface-modified LNP platform and determine its efficacy for safe and effective cellular delivery of mRNA by mixing self-assembling lipid components in a solvent with an aqueous solution containing the RNA. To create our targeting ligand, we are going to engineer a scFv-linked fusion protein where one side uses a loop-friendly molecular glue protein to form a spontaneous iso-peptide bond capable of specific distal attachment to LNP surfaces. This combined fusion protein assembly will allow for spatial control of antibody fragment orientation on the surface of the LNP and accessibility to receptor sites on tumor-specific cells. The second specific objective of this study is to evaluate the effectiveness of receptor or transporter-mediated LNP delivery for improved cellular targeting or improved cellular-specific uptake. To evaluate the effectiveness of delivery, we will evaluate the cellular specific uptake via in vitro co-cultures with antigen-expressing target cells and nonspecific cells and measure it through FACS cell sorting and quantification experiments.

This project will be a proof-of-concept study that analyzes the success of using fusion proteins to conjugate cellular-specific antibody domains for cell receptor targeting and targeted cellular delivery. If results demonstrate the viability of this approach, this will be a huge step towards improving LNP targeting technology for nucleic acid drug delivery for cancer and other diseases. Improved LNP targeting will allow for less off-target toxicity and increased anti-cancer efficacy. To build off this project, further research can be conducted to analyze the targeting efficacy towards a broader range of cellular-specific targets, and eventually, in vivo, testing in mice can be explored as well. More specifically, future research can focus on targeting specific liver cancer cells, breast cancer, and melanoma cancer mice and human cell lines in mice models.

Piezoelectric Biopsy Sensor for Tumor Detection

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Abstract: Biopsies are the gold standard for diagnosis, but current methods are not infallible, which could delay life-saving treatment. Cancer cells can affect the tissue extracellular matrix (ECM), causing side effects, such as abnormal stiffness; for example, while normal breast tissues are soft, malignant tumors can be up to ten times stiffer. Designing effective sensors proves essential to biopsy needles for detecting tumors early in the medical world. However, current methods are not suited to assessing irregularities in tissue that are less obvious. A piezoelectric device using a biocompatible copolymer, poly(vinylidene fluoride-trifluoroethylene) (P(VDF-TrFE)), is proposed to react to the level of stiffness in tissue. The distortion in the surrounding tissue following the needle's penetration converts the mechanical strain into an electric signal, allowing real-time quantitative analysis of suspicious lesions. This mechanism enhances the precision of conventional biopsy needles. The device was constructed in a sandwiched structure, with electrospinning P(VDF-TrFE) as the functional material, followed by layers of carbon nanotube (CNT) electrodes. Finally, the device was encapsulated with biocompatible polydimethylsiloxane (PDMS) film on each side. Mounted onto the tip of the biopsy needle, this flexible sensor makes for an easy integration to a clinical setting. By improving the detection of benign and malignant tumors, this piezoelectric device can minimize unnecessary measures and detect signs of cancer earlier.

Characterization of the Tumor Microenvironment Using Imaging Mass Cytometry

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Abstract: Colorectal cancer (CRC) is the third most common cancer worldwide and is the second leading cause of cancer-related death among men and women in the United States. On average, 150,000 people are diagnosed with the disease per year, and trends show an increasing incidence in younger populations. In 2020, the cost of this disease was $24.3 billion, and CRC had the second highest annual expense of any type of cancer, making up 11.6% of all cancer costs. Like other cancers, symptoms of CRC do not appear until the tumor has progressed to a later stage, and current treatment options are proving to be inadequate. Thus, to understand why current treatment options are not proving effective, a characterization of the tumor tissue composition is necessary. An emerging imaging technology called IMC can be leveraged to do this, in which antibodies conjugated to heavy metal isotopes are used to generate bioinformatic data about marker expression on a single-cell level. These data are then analyzed through a standard bioinformatics pipeline, which, after segmenting the cell boundaries, allows quantitative analysis of the features of the CRC tumor microenvironment (TME). Such quantitative analysis includes the spatial proximities of various cell types (tumor epithelial, macrophage, CD8, CD4, and fibroblasts) and immune infiltration into tumor regions. Specifically, as immune cells are key to an anti-tumoral response, one of the most important spatial features is classifying the tissue into "immune-hot" and "immune-cold" regions, and analyzing spatial interactions within them to understand why immune cells fail to infiltrate certain tumors. Furthermore, owing to the paired patient samples, consisting of both primary CRC tumors and corresponding metastatic lesions from the peritoneal organs, a pairwise analysis between primary and metastatic tumors is expected to give unique insights into how primary tumors influence the composition and TME of corresponding metastases. Ultimately, insights derived from such spatial analysis, paired with single-cell RNA sequencing analysis, will guide new understandings of cell-cell interactions in the TME, as well as yield novel targets for immuno-oncological (IO) therapies.

Effects of Caffeine on the Collective Panic Responses of Larval Zebrafish *Danio rerio*

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Mass panic is the communicable spread of distress among a group or population. Studying mass panic in larval zebrafish allows us to analyze the neurobiological factors that contribute to catastrophic mass panic events in humans, such as the Astroworld stampede in Houston, Texas, which resulted in several injuries and fatalities. Studies show that in confined, high-density environments, larval zebrafish exhibit circling behavior, otherwise perceived as panic-like behavior, around the confined space. This project seeks to determine if the administration of the stimulant caffeine will affect the frequency and intensity of the panic episodes. Caffeine is a widely consumed substance in everyday beverages, foods, and desserts, and understanding how it impacts large groups has implications for animal welfare and crowd management. As caffeine has been linked to anxiety-inducing behavior and stress in individual fish, we hypothesize that it will increase the frequency of panic responses in a large group setting. To test this hypothesis, we will administer a dose between 50 mg/L and 200 mg/L caffeine by bath application and record high-speed videos of swimming larvae at high densities to observe their behavioral responses for both control and caffeinated groups. Results will be analyzed using optical flow to detect frequency and intensity differences between the groups.

Targeting ST3GAL4 Gene in Glioblastoma Cells Using CRISPR-Cas9 to Investigate Sialic Acid's Role in Cancer Progression and Immune Evasion

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Glioblastoma (GBM) is the most aggressive and deadliest type of brain cancer. What makes GBM particularly dangerous is not only its rapid growth rate but also its ability to evade the immune system. Unfortunately, GBM is notoriously difficult to treat, as these cancer cells are often resistant to both chemotherapy and radiation. This makes typical cancer therapy techniques not a viable option for many glioblastoma patients. One possible approach is to modify the cells to reduce their ability to spread, which may lower the risk of aggressive tumor growth and enhance the effectiveness of other cancer treatments

This project aims to reduce the cells' ability to proliferate and escape the immune system. Although there are many factors that lead to rapid cell growth and immune resistance, one likely cause is an abnormal glycocalyx. The glycocalyx is a thin layer of proteoglycans, glycolipids, and glycoproteins outside the cell membrane. In normal cells, these proteins and lipids work together to monitor adhesion and signaling, but in cancerous cells, they can facilitate immune evasion and tumor growth. The cancer glycocalyx is marked by high expression of sialic acid, a negatively charged sugar molecule that caps the above proteins and lipids. When these sialic acid units are added, cancer cells can trick the immune system and thereby escape immune surveillance. Sialylated glycocalyxes also activate growth signaling pathways and create a protective barrier that can cause cancer cell detachment. The ST3GAL4 gene codes for ST3Gal4, a sialyltransferase protein that adds sialic acid to protein and lipids. It can be removed to reduce sialic acid expression in the glycocalyx.

To remove the ST3GAL4 gene through a knock-out, gene editing tool CRISPR-Cas9 will be used. CRISPR-Cas9 acts as a molecular scissor that cuts the DNA at specific sites. After the cut, cells that try to repair the mistake will only end up causing more errors that deactivate the gene. CRISPR-Cas9 is guided by a specifically designed RNA sequence, also known as a sgRNA. Two sets of primers, deletion and non-deletion, which are created to verify the gene deletion are added to the sgRNA. Once the sgRNA is complete, it is inserted into a plasmid that already contains the Cas9 enzyme. This plasmid is then introduced into E.Coli bacterial cells to amplify. Once the bacterial colonies are large enough, plasmids from selected colonies will be transfected into glioblastoma cells using lipofectamine. Now, the complete CRISPR Cas9 cassette, with the help of sgRNA, can go into the DNA of the cancer cell and delete the ST3GAL4 gene. Fluorescent proteins inside the plasmid will help identify edited cells, which are then tested at the DNA, RNA, and protein level to ensure gene deletion. The anticipated results are glioblastoma cells with lower sialic acid levels in the glycocalyx, resulting in slower cell growth, enhanced immune recognition, and increased sensitivity to chemotherapy. These effects could support the development of gene-editing-based cancer therapies and lead to more effective treatment outcomes in glioblastoma patients.

Absolute Quantitation of Phosphopeptides by Coulometric Mass Spectrometry (CMS)

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Protein and peptide quantitation using mass spectrometry (MS) is an advantageous analytical method due to its high sensitivity to compounds. It can be used to monitor protein and peptide expression levels, which are important for studying many diseases. Most traditional absolute peptide quantitation methods involve isotope-labelled peptide standards or making calibration curves using peptide standards, which are both expensive and time-consuming methods. Therefore, a method that can eliminate the need for using such standards would benefit this area of research. Recently, our lab developed coulometric mass spectrometry (CMS) which is used to quantify peptides that are oxidizable (e.g., those containing tyrosine or tryptophan) without using a peptide standard. The method is based on electrochemical oxidation of peptides followed by MS measurement of the oxidation yield. However, it cannot be directly used to quantify peptides without oxidizable residues. To extend this method for quantifying peptides/proteins in general, in this study, we adopted a derivatization strategy in which a target phosphopeptide is first tagged with an electroactive reagent such as 2,5-dioxo-1-pyrrolidinyl 3,4-dihydroxybenzene propanoate (DPDP), followed with quantitation by CMS. To further test this method we will be quantifying specific phosphopeptides through CMS to develop a further understanding of this method and its applications. One manuscript on this research is currently being accepted for publication (Md Tanim-Al Hassan, Yongling Ai, Bhavya Deshaboina, Timothy Yaroshuk, Arjun Sharma, Quentin Young, Howard D. Dewald, Hao Chen, *ACS Measurement Science Au*, 2025, in press).

Understanding Call Interaction Dynamics in Vocalizing Animals

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Understanding the complex social and behavioral intricacies and dynamics of animal call interactions can be studied through many different species in order to get an understanding of general interaction dynamics on a larger scale. In this study, we are examining marmoset call timing using a data set available through a prior paper published in 2024 by T. Varella et al. This paper studied optimal call duration between marmosets who could not see each other but could hear each other. The authors used Bayesian inference models to simulate dyadic call interactions and found that marmoset co-vocalizing resembles a form of question-and-answer. Through the provided Github, we were able to access and analyze data based on thousands of vocalizations between six individual marmosets (three pairs) in different situations: alone, visually occluded, visible close, and visible far. With this data, we were able to calculate the inter-onset intervals (IOI) for sequential vocalizations and response latencies between the different pairs of marmosets. The aim of the current analyses is to link the Bayesian inference approach with computational approaches, such as coupled-oscillator models, that focus on the interaction mechanisms generating calling exchanges. As we continue to pursue an enhanced grasp on the complicated dynamics of marmoset calls, we hope to extrapolate marmoset call dynamics to other species.

Comparing Methods for Predicting Circadian Gene Expression in scRNA-seq Data

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Circadian phase, the internal "time" of a cell's molecular clock, plays a critical role in regulating gene expression and has implications in areas such as drug efficacy, neuroscience, immunology, and developmental biology. However, accurately inferring circadian phase from single-cell RNA sequencing (scRNA-seq) data remains challenging due to sparse sampling and technical noise. These challenges are compounded by the fact that core clock genes responsible for keeping cir- cadian time are only moderately expressed, while the more abundant clock-controlled genes vary across cell types and are unknown beforehand.
Our research explores the use of scNODE[2], a deep learning model that approximates continuous gene expression using neural ordinary differential equations, to aid circadian phase inference in scRNA-seq time-series data. By omitting selected timepoints during training, we use scNODE to interpolate gene expression at the removed intervals. We then apply Tempo[1], a probabilistic method for circadian phase inference, to both the original and scNODE-augmented datasets. Comparing Tempo's predictions allows us to assess whether generative modeling can enhance phase estimation in noisy, temporally sparse single-cell data. This work presents a novel application of deep temporal modeling to circadian biology and may help improve temporal resolution in studies of heterogeneous tissues.

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A 3D-Bioprinted Hydrogel-based Model of Chronic Fibrosis

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Abstract: Approximately 45% of deaths in developed countries are caused by a condition known as fibrosis, characterized by excessive extracellular matrix (ECM) deposition and fibrous tissue remodeling, which can lead to organ malfunction. Despite advancements in regenerative therapies, current treatments lack long-term efficacy due to uncontrolled fibrosis, inconsistent cellular responses, and complex biomechanical forces experienced during organ function. This project will engineer a hydrogel-based fibrosis model to study ECM remodeling. The main objective is to establish a physiologically relevant biomimetic platform for future development. It is hypothesized that natural hydrogels and 3D bioprinting will allow the creation of fibrosis models to study ECM-cell interactions. During this URI project, we will optimize the 3D hydrogel model based on gelatin methacryloyl and a layer-wise gradient of stiffness and pore size to replicate the microenvironment of fibrosis tissue. We will find the best- optimized set of hydrogels by observing human fibroblast behavior that reflects the fibrotic tissue. The findings will contribute to personalized, biomechanical-based therapeutic strategies, addressing a critical gap in tissue engineering and regenerative medicine.

Cross-Scale Analysis of the Protocadherin Gene Cluster: Serotonergic Self-Avoidance in PCDHαC2 Mouse Models and Mutation Enrichment in Human Populations

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Neurodevelopmental disorders such as autism spectrum disorder (ASD) impact millions of individuals and remain poorly understood despite decades of research. Increasing evidence suggests that genetic factors play a key role in these conditions. Among these genetic candidates are the protocadherin (PCDH) genes, which are essential for building the brain's neural circuitry. These genes help neurons distinguish "self" from "non-self" by expressing stochastic combinations of adhesion proteins, enabling proper neural patterning during development. Current studies have shown that disrupting a single PCDH gene in mice leads to defective serotonergic neuron tiling and altered brain architecture. However, the field lacks the understanding of the mechanism through which patient-derived mutations in the protocadherin gene affect this self-avoidance process at the molecular and cellular level. The PCDHαC2 gene, part of the protocadherin cluster, is a distinct isoform that has specific mutation data available. This project investigates two rare PCDHαC2 variants: D249V (discovered in a patient with ASD) and M435R (predicted to alter critical protein interfaces). Plasmids were successfully cloned to generate lentiviral and adeno-associated viral systems for gene delivery, enabling replacement of wild-type genes with variants in mouse neurons. Confocal imaging revealed altered neuronal organization and unexpected nuclear localization of mutant proteins. In parallel, a population-level Poisson enrichment analysis using the Deciphering Developmental Disorders (DDD) dataset was conducted. Protein-truncating and missense variants showed enrichment in a subset of genes, but PCDH cluster genes did not reach significance, suggesting isoform-specific impacts rather than cluster-wide burden. Findings suggest that rare point mutations in PCDHαC2 may disrupt neural circuit assembly through disruptions in tiling. This work offers a step toward comprehending the genetic underpinnings of neurodevelopmental disorders and sets the stage for future investigations into targeted, precision-based therapies.

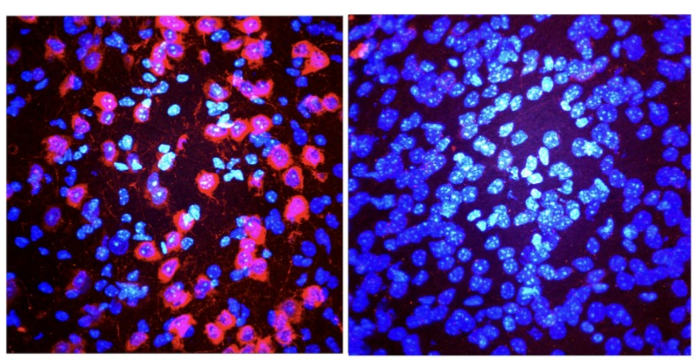

Figure 1. Confocal imaging of PCDHαC2 mutant expression in primary cortical neurons. AAVs encoding D249V (left) and M345R (right) PCDHαC2 variants were transduced in PCDH-deficient mice. HA-tag (cyan) confirms successful transduction, SERT (red) labels serotonergic neurons, and DAPI (blue) labels nuclei. Both variants exhibit HA signal in the nucleus, unexpected for a cell-surface protein, suggesting mislocalization potentially providing further insight on PCDH function.

AI-Based Predictive Framework of Solid Tumor Cell Invasion Under Fluid-Pressure Gradients

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Abstract: Cancer remains a major cause of death in the United States, mainly due to the metastatic potential and recurrence of tumors after treatment. Existing xenograft models are not able to reproduce the complex mechanical environment of solid tumors, i.e., high interstitial fluid pressure (IFP) and flow-induced shear stresses that have significant effects on tumor invasion and drug resistance. The goal of this research is to design an AI-assisted pressurized hydrogel bioreactor capable of dynamically replicating physiological pressure and flow conditions. Tumor cells are embedded within a PEGDA-GelMA composite hydrogel and subjected to controlled hydrostatic and perfusion pressures using a multi-layered acrylic, PDMS sheets, and bath chambers to build up pressure. Over the summer, we used laser cutting and 3D printing techniques to fabricate a modular bioreactor, progressively improving chamber geometry, sealing, and syringe pump integration in an effort to reduce leakage and consistent flow. At the same time, supervised machine learning algorithms—Random Forest, Support Vector Classification, Logistic Regression, and XGBoost—are used to predict hydrogel mechanical behavior, print parameters, and simulate cell invasion under varying pressure conditions. This multidisciplinary approach, combining computational prediction and experimental bioreactor design, will lead to a biologically informative in vitro tumor model of greater fidelity for probing mechanobiological response. Future and current work will include validating predictions made with AI against live cell data, refining scale-up of the chambers, and applying this platform to general cancer and drug screening research.

Using Light To Stimulate *Dmrt3a* Neurons, A Genetic Class of Spinal Interneuron, In Zebrafish Larvae To Determine Its Functional Role In Locomotor Behavior

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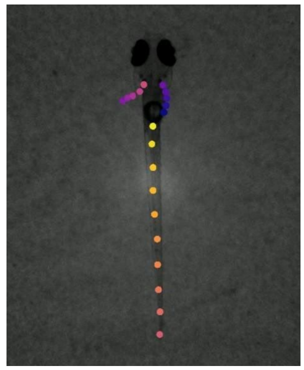

Figure 1. Image of larval zebrafish (rostral at top) with overlap of successful tracking by DeepLabCut where the two pectoral fins (left is abducted, right is adducted) and the tail are visible. The fish is approximately 4 mm long. Image from Severi Lab.

Neurons work together in neural circuits to control locomotor functions from a simple step to swimming. Deciphering neural circuits allows for a broader understanding of the essential components necessary for movement and provides a foundational understanding necessary to develop novel treatments for movement disorders. This study focuses on a class of spinal interneurons identified by expression of the *Dmrt3a* gene, and their role in coordinating movement across the body. Mutations of the *Dmrt3a* gene in fish and the homologous DMRT3 gene in mammals were found to impact locomotor coordination within the spinal cord and limbs across the body, including the appearance of a novel gait in mutant horses. We hypothesize that *Dmrt3a* neurons are vital for effective locomotion in larval zebrafish by permitting coordination of their limbs, the pectoral fins, with their axial body. We will test this hypothesis by optogenetically activating these neurons with light, observing and quantifying the movement of the pectoral fins, and comparing the effects of larval zebrafish with and without activating the interneurons. By observing how the zebrafish move their pectoral fins and tails when these neurons are activated or silenced, we hope to uncover how these neurons facilitate gaits used in locomotion.

Optimization of freeze-gelation to fabricate aligned, mechanically robust scaffolds for Volumetric Muscle Loss (VML) repair

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Volumetric muscle loss (VML), affecting 65.8 million Americans annually, results in irreversible tissue damage with limited surgical solutions. Standard treatments such as muscle transfers and physical therapy share a crucial concern: the lack of complete muscle recovery. For the most effective treatment, one must utilize tissue engineering and target the body's muscle regeneration process itself. Biomaterial based scaffolds must replicate skeletal muscle's aligned extracellular matrix (ECM) to guide cell integration and force transmission. Freeze-drying is a widely used method to fabricate biomaterials, however it faces critical limitations: surface skin formation, which causes structural collapse and results in a dense outer layers of material that hinder cell infiltration, and scalability as energy-intensive lyophilization (48–72 hrs) limits cost-effective production. Freeze-gelation offers a scalable alternative by combining phase separation and crosslinking during freezing. Despite its promise, few studies have systematically explored dual crosslinking (EDC/NHS + $CaCl_2$) or temperature-dependent pore tuning for muscle regeneration. This project aims to optimize freeze-gelation parameters (e.g., freezing temperature, degree of crosslinking) to fabricate aligned, mechanically robust scaffolds for VML repair. The goals for this project include developing protocols for scalable, aligned scaffold production, a dataset linking freezing temperature to pore alignment/mechanics, and the proof-of-concept for minimally invasive VML therapy. Currently, we have found that both the reduction of freezing temperatures and the addition of crosslinkers helps the scaffolds in gaining structural stability. Further successful outcomes could advance translational solutions for 176,000+ annual VML cases.

Quantifying Instantaneous Base of Support During Gait to Determine Dynamic Postural Stability

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Holistic analysis of gait and postural stability ultimately serves to benefit various populations suffering from balance-related health issues. By collecting motion data during a gait cycle using a 3-D motion capture system, several parameters of balance can be analyzed and integrated to help form the larger picture of stability–the most important of these parameters being the base of support (BoS). BoS is a key concept to postural stability and is defined as all the possible coordinates in the horizontal (transverse) plane that the center of pressure can draw from; this area also aligns with all the areas of contact the feet make with the ground and any areas connecting the feet (Figure 1). The standard visual analysis of gait abnormalities is subjective; populations struggling with balance due to musculoskeletal disorders will benefit from research producing an accurate tracking of their BoS during a walk. This project undertakes the task of quantifying instantaneous BoS during gait using existing 3-D marker trajectories captured from able-bodied adults during walking. A combination of foot markers and ground reaction forces will be analyzed to differentiate between phases of the gait cycle and calculate the area and location of instantaneous BoS, center of mass (COM), and other variables of postural stability. Understanding dynamic stability is the first step to a series of research that will aid populations suffering from conditions affecting locomotion and imbalance and to potentially minimize the incidence of falls in the elderly population.

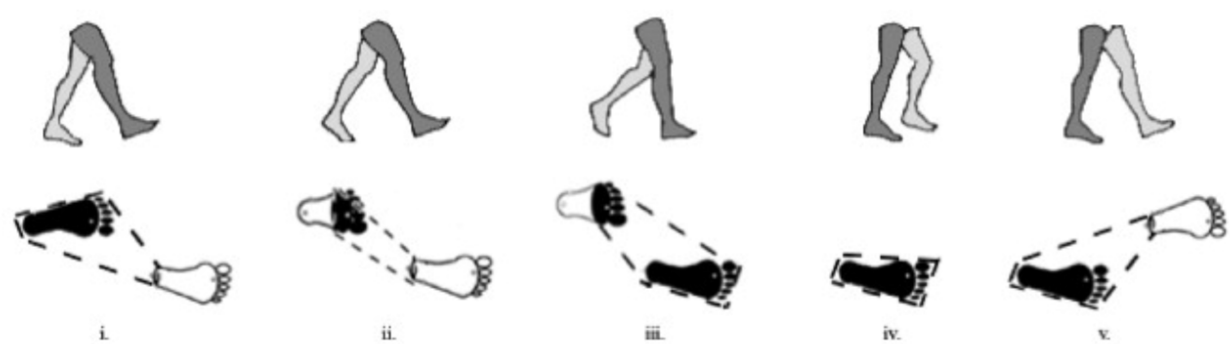

Figure 1: The changing BoS perimeter during gait [1]

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Elucidating the cannabinoid biosynthesis in liverworts

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Phytocannabinoids are a class of plant-derived compounds with significant pharmaceutical potential. While primarily known from *Cannabis sativa*, cannabinoid production has independently evolved in other plant species, including the liverwort genus *Radula*. Investigating cannabinoid biosynthesis in *Radula* may provide insights into novel biosynthetic pathways yet to be elucidated. It has been predicted that synthesis of cannabinoids in *Radula* is similar to the pathway present in *C. sativa*, utilizing homolog enzymes that act on different "building blocks" to create remarkably similar products. We hypothesize that *Radula* utilizes the amino acids phenylalanine or tyrosine as initial substrates in cannabinoid biosynthesis. This project aims to confirm our hypothesis by feeding plants with stable isotopically labeled amino acids L-Phenylalanine and L-Tyrosine. The incorporation of such derivatives in the chemical backbone of *Radula* cannabinoids will be monitored by High-Performance Liquid Chromatography-Mass Spectrometry. Moreover, we will explore whether we can induce or suppress cannabinoid production in *Radula* through an abiotic stressor like UV radiation. This will allow us to later correlate cannabinoid content with the expression levels of polyketide synthase (PKS) genes. Ultimately, this research will help pave the way for knowledge on unique cannabinoids synthesized by the only non-seed plant capable of producing them and elucidate this puzzling case of convergent evolution of natural products with potential pharmaceutical applications.

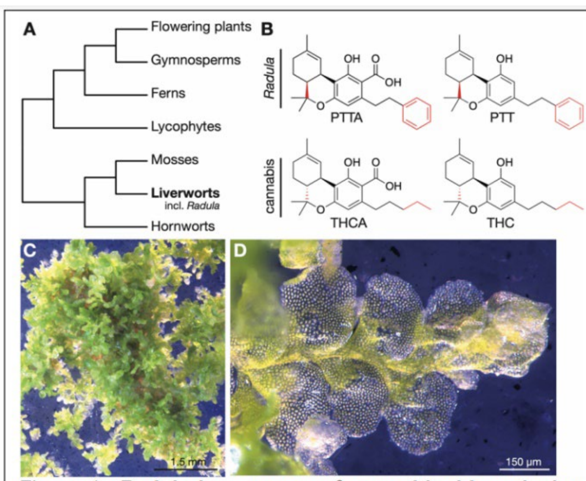

Figure 1. ***Radula* is a genus of cannabinoid-producing liverworts**. (A) Phylogeny of land plants highlighting the evolutionary distance between *Radula* and flowering plants. (B) Structural comparison of *Radula* PTTA/PTT and cannabis THCA/THC; chemical differences are depicted in red. (C) *Radula obconica* in tissue culture in our laboratory. (D) A close-up of *R. obconica* thallus.

Figure 1: *Radula* is a genus of cannabinoid-producing liverworts. (A) Phylogeny of land plants highlighting the evolutionary distance between *Radula* and flowering plants. (B) Structural comparison of *Radula* PTTA/PTT and cannabis THCA/THC; chemical differences are depicted in red. (C) *Radula obconica* in tissue culture. (D) A close-up of *R. obconica* thallus.

AI-Enhanced Optimization of Bioprinted Solid Tumor Models: Regulation of Bioink Biophysical Properties

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Cancer cells can adopt a range of morphological states linked to distinct functional behaviors during tumor progression, including the epithelial-mesenchymal transition for migration and matrix degradation for intravasation. Some remain in a proliferative state, forming tight clusters; others detach and elongate into an invasive state; and some retain a rounded amoeboid form with minimal matrix adhesion. However, factors that determine which morphological state a cell adopts remain poorly understood. Using a combined theoretical and experimental framework, we showed that extracellular matrix (ECM) mechanics regulate cancer cell morphology in three-dimensional (3D) environments. The local microenvironment of a cell, the ECM, has specific biomechanical properties that are key steps in the metastatic cascade of the tumor and its response to therapy. Dr. Miri's collaborator developed a theoretical model based on the principle of minimum energy, which predicts that a cell will adopt the morphological state—rounded, elongated, or clustered— that minimizes the total energy of the cell-ECM system. Using MDA-MB-231 breast cancer cells, we established a reliable protocol for encapsulating cells into 3D naturally-derived hydrogels that will monitor physical changes during breast cancer progression. To control the transition of cells into a morphological state, we applied AI-driven optimization to tunable bioink properties such as stiffness and porosity, enhancing the fidelity of bioprinted tumor models and enabling more precise replication of in vivo conditions. We validated the model's predictions *in vitro* over an extended culture period. In soft ECMs, cells transitioned over time to an elongated morphology, while in stiff ECMs, cells favored clustered configurations. These transitions were governed by the physical–rather than chemical–properties of the hydrogel-based ECM, as confirmed by using matrices with different chemical but similar mechanical properties. The theoretical modeling and AI can be used to study stage-dependent cancer models that provide a tool to study the mechanisms of triple negative breast cancer. Through monitoring of the ECM remodeling, the aim is to develop noninvasive real-time monitoring techniques for cancer progression diagnosis which will have implications on potential drug screening.

Early-stage Endometrial Uterine Cancer Detection using an Electrochemical Sensor that utilizes a Shear-Enhanced, flow-through, nanoporous, Capacitive Electrode

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Abstract: Every woman deserves a fighting chance to battle endometrial uterine cancer. However, far too many women from underrepresented communities are being diagnosed at a later stage, where survival outcomes are significantly lower. Endometrial uterine cancer, often treatable if found at an early stage, continues to illustrate unusually high mortality rates in African American women due to aggressive tumor biology and delayed diagnosis. Strikingly, p53 gene abnormalities are linked to the more aggressive type of endometrial cancer, and is more commonly found in African American women. Machine learning techniques are shown to be excellent at diagnosing cancer through the analysis of data and images. An Electrochemical Sensor that utilizes a Shear-Enhanced, flow-through, nanoporous, Capacitive Electrode (ESSENCE) is proposed to integrate machine learning and enable high sensitivity and rapid early detection of endometrial uterine cancer. The proposed microfluidic platform was designed to detect cancer biomarkers such as P53 and PTEN proteins by functionalizing the capture material with the relevant antibodies. Electrochemical Impedance Spectroscopy (EIS) was used to measure the biomarker binding and find the concentration of the target analyte (cancer biomarkers) in the sample of interest. Machine learning was then applied to analyze signal patterns and enhance detection accuracy. The combination of microfluidics and machine learning has the potential to detect endometrial uterine cancer early and provide life-saving diagnostics to women who have previously been overlooked.

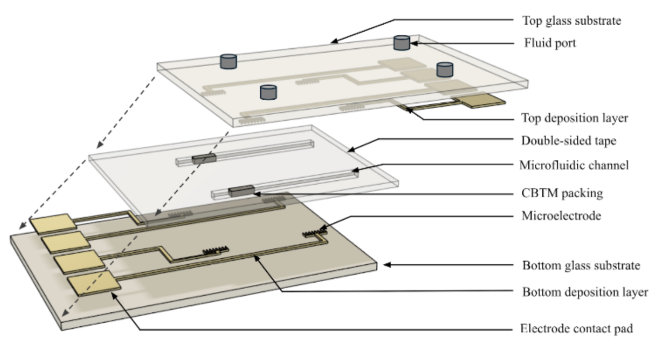

Figure 1: ESSENCE Platform Breakdown used to capture protein by Electrochemical Impedance Spectroscopy (EIS).

Machine Learning Integrated with Molecular Modeling to Develop Inhibitors of the Mitochondrial LONP1 protease for Cancer Therapeutics

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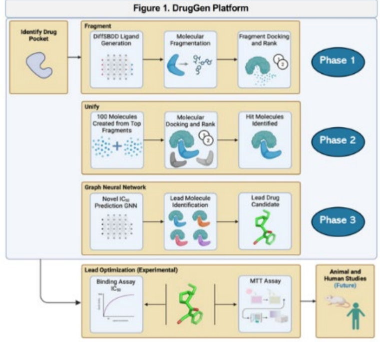
Cancer is a leading cause of death worldwide, resulting in approximately 10 million deaths in 2022. In the United States, nearly 20 million new cases of cancer were identified in 2022 with 9.7 million deaths from cancer. The common forms of cancer are breast, prostate, lung, and colorectal cancers. Cancer research focuses on understanding the mechanisms driving cancer cell survival and proliferation, and the development of innovative strategies for killing cancer cells using pharmacological agents, immunotherapy, or gene therapy. The oncogenesis and uncontrolled growth of cancer cells is driven by DNA damage or altered gene expression. Cancer cells require tremendous amounts of energy for survival and growth, which is produced by mitochondria. Mitochondrial LONP1 protease has emerged as a potential anticancer drug target, crucial for mitochondrial metabolism, energetics, and proteostasis. Previous work from Dr. Suzuki's laboratory demonstrated that pentacyclic triterpenoid CDDO (2-cyano-3,12-dioxoolean-1,9(11)-dien-28-oic acid) and its derivatives inhibit the mitochondrial protease LONP1. More recent data from the Suzuki lab have shown that, in addition to CDDO derivatives, another pentacyclic triterpenoid, Celastrol, also inhibits LONP1's ATPase activity. In this research project, we aim to identify selective allosteric inhibitors of LONP1 by targeting its ATPase regulatory site.

The Machine Learning based drug discovery platform, DrugGen, developed by Dr. Kamal Singh, will be implemented to identify and develop small molecule inhibitors of LONP1 with binding specificity and high affinity. DrugGen will be enhanced for compound generation targeting LONP1 with the integration and optimization of DiffSBDD (Differentiable Structure-Based Drug Design), a deep learning–based framework combining generative modeling with structure-based drug design principles. To guide model training and validation, molecular modeling and structural data will be incorporated. The identified compounds will be ranked by strength and specificity of docking, and evaluated using biochemical and cell-based assays to determine efficacies in disrupting mitochondrial function and eliciting cancer cell death. The expected outcome of this project is the development of drug-like inhibitors of LONP1 with translational potential for anticancer therapeutics.

Figure 1. DrugGen Platform



Investigating the Role of Cytokines in Secondary Brain Injury: Neuroinflammation, Neuronal Death, and Cognitive Decline Following Traumatic Brain Injury

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This research proposal is aimed at exploring the role of various cytokines including Interleukin-6 (IL-6), Interleukin-1β (IL-1β), and Interleukin-18 (IL-18) in secondary brain injury with neuroinflammation, neuronal death, and cognitive deterioration following traumatic brain injury (TBI). Secondary injury, occurring after primary mechanical trauma, is a complex progression of brain injury through cellular and inflammatory events. This project's goal is to illuminate the pathway through which IL-6 contributes to neurodegeneration and behavioral dysfunction post-TBI. This study will employ a murine model of TBI where mice will be exposed to controlled blasts/fluid percussion injuries (FPI), and subjected to behavioral tasks to determine changes in cognition and anxiety. These behavioral tasks include open field tests, novel object recognition, elevated plus maze, and sucrose splash that will assess the depressive and anxiety-related effects following mild neurotrauma. These animals will be euthanized and perfused. The brains will be harvested and examined for cytokine expression through analysis using the ImageJ software for quantitative analysis of IL-6, IL-1β, and IL-18 expression by measuring expression of IL-6 staining in the dentate gyrus of the hippocampus. We hypothesize that IL-6, IL-1β, and IL-18 will increase after blast injury in the hippocampus, the increase of IL-6 will worsen the secondary injury following blast injury, and the treatment with the anti-IL-6 approach will improve the behavioral outcome and restore neuronal function. This proposal aims to dissect the role of cytokines in post-TBI neurodegeneration and investigate it as a possible therapeutic target for overall functional recovery in patients with TBI.

Currents in Control: Computational Characterization of Neuromodulated Stability

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Abstract: Neurons are able to maintain stable electrical activity, and this stability arises from ionic current interactions flowing through multiple types of ion channels. Despite the variability in the strengths of these currents (ion channel conductance) from neuron to neuron, circuits can maintain a consistent output–indicating the co-regulation and individual circuit logic used to preserve each neurons identity necessary for biological system maintenance. Neuromodulatory inputs normally help enforce this homeostasis by tuning ion channel conductivity and constraining the high-dimensional space (parameter space). In the stomatogastric ganglion (STG) of the crab Cancer borealis , for example, neuromodulators are responsible for the oscillatory rhythmic motor pattern. When this regulatory input is removed (by decentralization), the neuron must then rely solely on intrinsic mechanisms to sustain their rhythmic activity, raising the question of how stable output is maintained in the absence of neuromodulatory constraints. However, the classical Hodgkin-Huxley model has provided a biophysical foundation for describing ion channel kinetics–while powerful for describing those dynamics– do not capture modulatory influence, leaving a gap in understanding neuronal stability under neuromodulator loss. To address this, we combined computational modeling with physiological data to trace ion channel current changes over time in STG neurons. Using a custom MATLAB Hodgkin and Huxley based modeling tool, a global parameter fit with bounded optimization replacing the conventional practice of averaging conductance values, along with fitting the conductance-based models to voltage-clamp recordings from identified neurons at 0 hours and 8 hours after neuromodulatory input removal (decentralization). And by comparing the fitted ion conductances between these time points, we can observe how populations of ionic currents co-vary as the neuron adapts in the absence of neuromodulation, noting patterns of increases and decreases in different parameters Iplasticity) that allow the neuron to maintain their homeostatic mechanism. Interpreting this co-regulatory dynamic will deepen the understanding of neuronal identity under normal and abnormal conditions.

Optimizing Xenon Microbubble Therapy for Neuroprotection in a Rat Model of Traumatic Brain Injury

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Traumatic brain injury (TBI) poses significant challenges for treatment, mainly due to the complexity of delivering therapeutics across the blood-brain barrier (BBB). TBI is a significant public health issue, affecting approximately 69 million individuals globally each year, and it is especially common among athletes, military personnel, and victims of falls or vehicle accidents (Gardner & Yaffe, 2015; Taylor et al., 2017). Despite its prevalence, effective pharmacological treatments remain inaccessible, and patients often suffer long-term cognitive, emotional, and physical impairments.

While xenon gas has shown promise as a neuroprotective agent, its clinical utility is affected by the impractical nature of inhalation-based delivery (Shin et al., 2023). This project aims to evaluate the effectiveness of xenon-loaded microbubbles as an alternative delivery method in mitigating TBI-induced neuropathology. These lipid-based gas carriers can be injected intravenously and selectively ruptured using ultrasound to deliver xenon to targeted brain regions. Specifically, we will determine the optimal xenon dosage by testing various concentrations in rat models of TBI. Behavioral assessments will be conducted to evaluate locomotor activity, anxiety-like behavior, and short-term memory, which all prove to be common deficits following brain trauma. In addition, we will perform immunohistochemical analyses of brain tissue, targeting key biomarkers such as GFAP for reactive astrocytes, Iba1 for activated microglia, ZO-1 for BBB integrity, and Connexin-43 for gap junctional communication.

By establishing a dose-response relationship, we seek to understand whether the protective effects of xenon scale linearly or follow a saturation curve. This research not only contributes to the development of non-invasive, targeted delivery systems for TBI therapy but also lays the groundwork for translational applications given xenon's FDA-approved status (Duhamel et al., 2001). The results will directly inform future long-term studies on xenon's therapeutic timing and mechanisms, with implications for broader neuroprotective strategies.

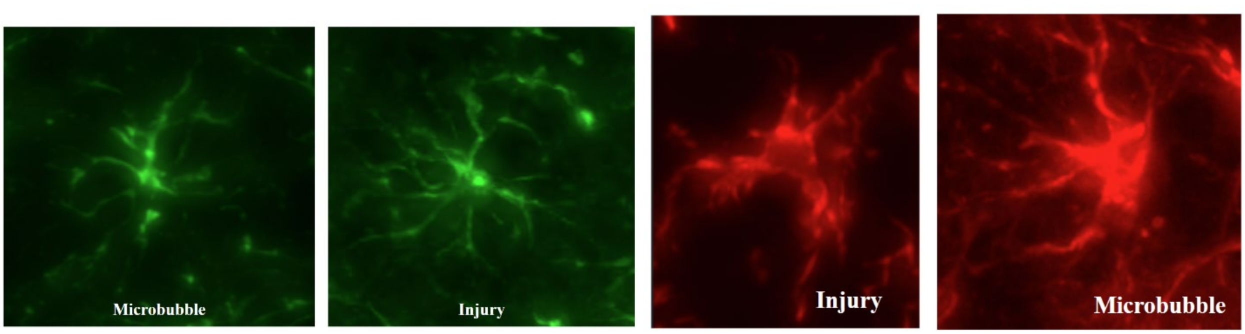

Figure 1. GFAP (green) and Iba1 (red) staining show astrocytes and microglia in injured rats with and without XeMB treatment. XeMB-treated cells exhibit more branched, resting-like morphologies, while injury-only cells appear activated.

Acute Neuronal Degeneration following Repeated Blast and Blunt Traumatic Brain Injuries

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Based on recent data from the Center for Disease Control, there were approximately 214,000 TBI-related hospitalizations and 69,500 TBI-related deaths in 2020 and 2021 respectively.[1] A large portion of those who suffer from TBI are soldiers with over 430,000 service members being exposed since the year 2000.[2] Severe and moderate TBI that soldiers in the field experience have been studied at length but one area of TBI research that has been somewhat neglected is low-level repeated injuries which military personnel in training, law enforcement, and low-level blunt injuries athletes are regularly exposed to. This study aims to examine low-level blunt TBI and repeated blast TBI and its impact on acute neuronal degeneration. For the experiment, adult male C57/BL6 mice will be exposed to mild fluid percussion injury (FPI), single blast and repeated blast injuries, and sacrificed at the PID1 (Post-Injury Day 1). Neuronal degeneration will be examined using FluoroJadeC and TUNEL (Terminal deoxynucleotidyl transferase dUTP nick end labeling) will be used to detect apoptotic cells by identifying DNA fragmentation. Free-floating immunohistochemistry using IBA1 to stain for microglia and CD68 will be applied to stain for activated microglia which show macrophage-like activity in response to injury. Fiji image analysis software will be used to quantify TUNEL+ cells. It will also be used to assess the morphological differences in microglia between injured and sham animals. In order to make volumetric estimations and ensure accuracy and unbiased results, stereology techniques using the MBF Biosciences Stereo Investigator will be used to quantify microglial activation by counting colocalized Iba1+CD68+ cells in the dentate gyrus (DG) of the hippocampus. The DG was chosen as the region of interest because it is highly vulnerable to injury and is a major site for neurogenesis. TBI will impact neurogenesis and result in the onset of neurodegenerative conditions where microglia are a major contributing factor.[3] In the future, this work will be expanded upon by using stereology to examine glutamatergic and GABAergic neurons and their contribution to neuronal loss.

[1] CDC, 2024
[2] Howard, J. T., et al., 2022
[3] Navabi et al., 2024

Is Smartphone-based (Markerless) Motion Capture a Feasible Alternative to Marker-based Motion Capture Systems?

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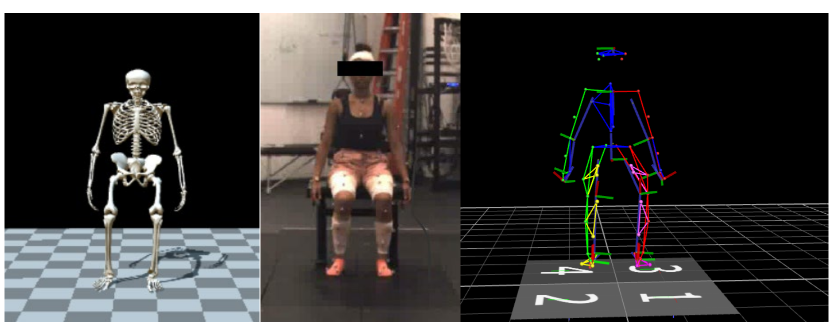
Motion capture is a valuable technique in biomechanics, providing data that lays a foundation for further research in health, rehabilitation, and injury prevention. Traditional marker-based motion capture, the gold standard for three-dimensional (3-D) motion tracking, involves carefully placing reflective markers on specific anatomic landmarks, a highly controlled environment, and expensive, specialized equipment. These markers are susceptible to shifting, falling off, or becoming completely occluded. Designed to overcome these limitations, OpenCap has emerged as a web-based application that estimates 3-D dynamics of human movement using videos from two or more iPhones. This technique is significantly faster, cheaper, and more portable because it does not rely on specialized hardware, allowing for greater versatility in capturing movements within more realistic settings. Given the limited literature comparing this novel form of motion capture to marker-based methods, this project intends to evaluate the value and accuracy of OpenCap by recruiting three able-bodied participants to perform four common daily movements: walking, squatting, stand-to-sit, and sit-to-stand. Each trial will be recorded simultaneously using both the Vicon Nexus Processing System and OpenCap, within the NJIT Life Sciences Motion Capture Lab. 3-D motion data will include simultaneous measurements of 3-D marker trajectories and OpenCap videos from two iPhones. Hip, knee, and ankle angles from both motion capture techniques will be compared using the root mean square error (RMSE). A low RMSE will indicate that OpenCap can record motion data with comparable accuracy to marker-based motion capture, making it a more efficient and feasible alternative to standard techniques. The speed, affordability, and flexibility that this new technology offers will enable future research to be conducted in real-world environments, greatly increasing opportunities for kinematic data collection and facilitating the development of more useful assistive devices and advancements in biomechanical research.



(A) **(B)** **(C)**

Figure 1: A representative sit-to-stand trial shown through the (A) video camera view, (B) marker-based avatar from Vicon Nexus, and (C) subject-specific musculoskeletal model from OpenCap

Cardiac Injury Treatment Using the Noble Gas Xenon Microbubbles

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Abstract: Current treatments for cardiac injury have limitations in fully repairing or preventing myocardial damage, demonstrating the growing need for innovative and precise approaches that address unmet medical needs, reduce treatment risks, and improve patient outcomes. Xenon, a type of noble gas, is known for its anesthetic and neuroprotective properties in brain injuries like traumatic brain injury, stroke, and cerebral ischemic injury. Although the potential of xenon in reducing cardiac injury from ischemia-reperfusion has been discussed in previous studies, the exact impact of xenon gas in heart tissues is unknown. This study investigates the effects of xenon microbubbles on heart tissue function after a hypoxic (low oxygen) condition, similar to a myocardial infarction or heart attack. Three-dimensional human cardiac tissue models were created from cardiomyocytes derived from induced pluripotent stem cells (iPSCs) and cell culturing. Four experimental groups were established: a non-hypoxia control, a hypoxia control, and two hypoxic groups treated with xenon microbubbles. The treated tissues were targeted with three xenon microbubble injections each, which is a more efficient and localized treatment compared to gas inhalation. After 24 hours, tissues were analyzed through reverse transcription polymerase chain reaction (RT-PCR) to evaluate cell survival, viability, and expression of cardiac-related genes like *HIF-1α, BAX,* and *GLUT-1*. It is anticipated that the xenon-treated tissues will show reduced inflammation, decreased changes in calcium handling, and less mitochondrial damage. Specifically, the tissues injected with a moderate amount of xenon gas are expected to suffer less cell damage and have a higher survival rate. Overall, the study will highlight the effectiveness of noble gas treatment on cardiac tissues by determining cell function and damage. The results of this study will contribute to the development of novel targeted therapies for cardiac injury that can be used in clinical trials and human applications.

Movement and Reward are Encoded in the Cerebellar Signals to the Substantia Nigra Dopamine Neurons

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Department of Chemical Engineering, Universidad Nacional del Sur, Argentina
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A previous study titled "The cerebellum directly modulates the substantia nigra dopaminergic activity" analized and described functional monosynaptic projections from the cerebellum to the substantia nigra dopaminergic nucleus. This is an important distinction because previously, they were known to participate in movement and reward systems independently in the brain; however, this study was able to describe a link between them. In order to study this further, the focus shifted to Cb-SNc activity from Pavlovian conditioning, encompassing movement-related, sensory, and reward-related components.

In order to record the neural activity of mice, their brains were injected with a virus. These viruses cause groups of neurons in specific regions of the brain to produce fluorescent proteins. This fluorescence can then be read as an analog to neural activity. A recording of the mouse as it licks is also graphed over time. Each lick represents a single spike, and the trials are averaged to create a clear graph similar to how the fluorescent signals are averaged. At the moment, the fluorescent data is being exclusively used as the neurological readings. However, an article titled "Accurate spike estimation from noisy calcium signals for ultrafast three-dimensional imaging of large neuronal populations in vivo" has potentially provided a means of translating the fluorescent signals into spike rates. The MLspike system is able to provide a predicted spike train from the fluorescence recorded. The system is able to do so by utilizing a physiological model for indicators in conjunction with provided or predicted parameters. This new method can assist in understanding the connections to a better degree.

I have reviewed literature, including Theoretical Neuroscience by Peter Dayan and L.F. Abbott, for self-study and to create a background of information. I have independently reviewed the results and participated in conversations discussing them, helping to solidify my understanding of the material. Through extended research into the MLspike system, I have been able to utilize what I am learning and further the research. From this we can create a better understanding of the connection between the cerebellum and substantia nigra. Participating in this study, I have been exposed to research in a manner I had not previously experienced. Through being integrated into the group and participating in meetings, I have been able to gain a better understanding of the material and how research functions.

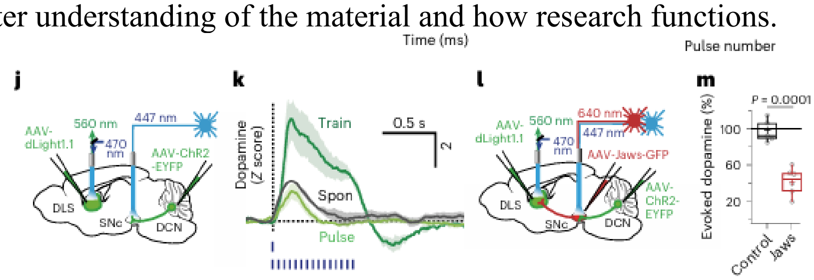

Figure 1. Virus expressions within different sections of the brain in conjunction with optogenetic pulses from optic fibers

Washburn, S., Oñate, M., Yoshida, J. et al. The cerebellum directly modulates the substantia nigra dopaminergic activity. Nat Neurosci 27, 497–513 (2024). Figure 1.

Longitudinal Oculomotor and Symptoms Data with Persistent Post-Concussive Symptoms Convergence Insufficiency

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Convergence Insufficiency (CI) is a vision disorder marked by an impaired sense of binocular vision, affecting about 10% of the population. Individuals who suffer from the condition experience headache, nausea, and eye strain when completing tasks requiring binocular focus such as studying, reading, or using a computer. CI often manifests during developmental years, also known as typical CI, or arises following a traumatic brain injury, or Post-Concussive Syndrome-related CI (PPCS-CI). CI can significantly hinder individuals ability to read, use electronic devices, or study, thereby affecting individuals' everyday lives. However, despite advances in modern medicine, symptoms such as headache, dizziness, and nausea and CI often persist in individuals experiencing such injuries. Contemporary optometric and therapeutic studies lack a specific protocol dedicated to reducing symptoms and treating PPCS-CI. Our current study proposes a potential protocol to treat CI and other clinical symptoms. This potential protocol may entail an improvement in the clinical ability to treat CI, leading to increased academic and work-related performance as well as quality of life improvements.

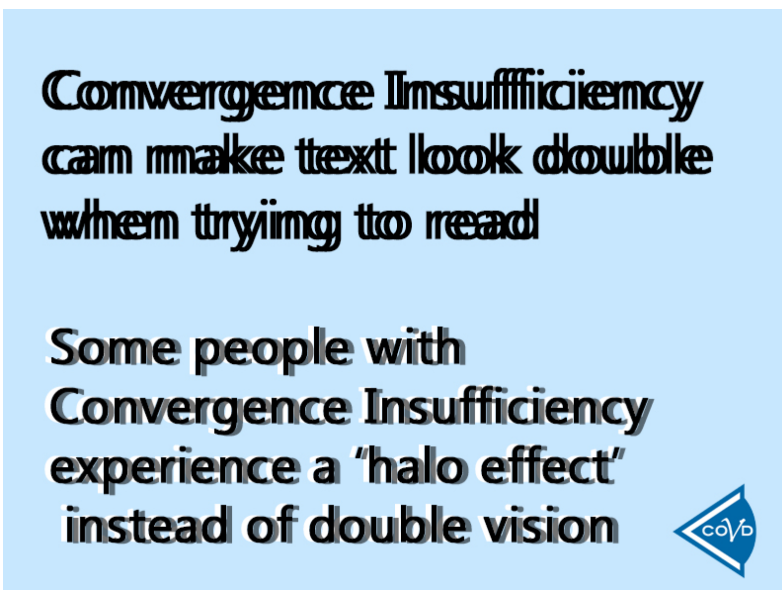

Figure 1: Example of Double-Vision (top) or Halos (bottom) as a Result of Reading with Convergence Insufficiency

Fast Antibody Characterization via Microdroplet Digestion with Novel Enzymes and Mass Spectrometry

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Monoclonal antibodies (mAbs) are popular biotherapeutics used for the treatment of diseases, such as cancer, infections, and neurological disorders. Exploiting the target specificity of antibodies, cytotoxic small-molecule drugs are sometimes attached to antibodies to form a class of targeted therapeutics known as antibody-drug conjugates (ADCs). To evaluate the safety and efficacy of these therapeutics, bottom-up or middle-up proteomic approaches are generally employed. Typically these approaches use enzymes to digest/break the proteins into smaller fragments. Mass spectrometers (MS) are then used to analyse the fragments to obtain information about the protein. Enzymatic digestions can take hours, however, it has previously been demonstrated that enzymatic reactions in microdroplets can reduce the reaction time to microseconds. This capability was capitalized previously by using Agilent's Jet Stream Source (AJS), which is an ionization source for Agilent's mass spectrometers. This study will therefore use AJS coupled with a quadrupole time-of-flight mass spectrometer to characterize ADCs. Additionally, this study will evaluate various enzymes, such as GingisKHAN and IdeS Xtra from Genovis, that can be used for these bottom-up and middle-up approaches. To assess digestion efficiency, the MS signals of the antibody digest produced by both microdroplet and traditional in-solution reactions will be compared. Next, to ensure clean and simplified MS signals, enzymatic sugar removal or deglycosylation of the ADCs will be assessed with the AJS source. Moving forward, this work can facilitate quantifying the amount of drugs attached to the antibody, otherwise known as the antibody-to-drug ratio (DAR).

Development of a novel male contraceptive using lariat peptides to inhibit sperm function

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Almost half of all pregnancies are unplanned, with >60% of these events resulting in termination. The contraceptive market is dominated by female reproductive options, with options for males being limited to condoms (with a 15-20% failure rate) or vasectomy. ***The overall objective of this study*** is to meet the unmet need for male-focused, non-hormonal contraceptive options through development of a peptide-based, male-focused contraceptive that (i) is highly tolerated and non-immunogenic with minimal side effects, (ii) has excellent shelf stability, (iii) is readily reversible, and (iv) is low cost to manufacture. 'Lariat' peptides are bifunctional, with one cyclized, functionalized domain fused to a second functionalized extended linear domain. We hypothesize that cyclized inhibitory domain fused to a sperm-targeting extended domain will facilitate cell-specific delivery of a contraceptive peptide that inhibits post-meiotic spermatogenesis and sperm function thus representing a safe, effective, and reversible male contraception option. Therefore, ***specific goals and objectives for the summer*** are to design the lariat peptides that specifically target developing sperm cells and block spermatogenesis-dependent proteins to suppress fertility. Future work will focus on testing promising peptide candidates in animal models of fertility. Preliminary data will be the foundation for applications for grants through the NIH R01 submission.

Studying the Migration Dynamics of Cancer Cells in a 3D Model

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The progression of cancer metastasis is influenced not only by tumor cell properties but also by the distinct microenvironments of secondary tissue. Primary tumors regulate extracellular matrix (ECM) remodeling at distant sites, forming a pre-metastatic niche even before metastatic cells migrate. Despite growing interest, the specific roles of the ECM in regulating cancer cell migration and growth within these niches remain unclear. This project aims to address the biophysical cues within the ECM that influence metastatic behavior. Collagen-methacrylate (CMA) hydrogels with fibrous and nonfibrous architectures are analyzed to characterize fibril formation dynamics and mechanical properties. Turbidity and rheological measurements inform the design of hydrogel-based microenvironments fabricated using multi-material light-assisted 3D printing, with gelatin-based hydrogels optimized for stiffness through controlled polymerization. These microenvironments will be fabricated using multi-material light-assisted 3D printing, with gelatin-based hydrogels optimized for stiffness through controlled polymerization. Cell density will also be optimized for spatial patterning. MDA-MB-231 breast cancer cells, known for their high invasiveness, will be encapsulated within these hydrogels to model candidate pre-metastatic niches. Cell migration will be monitored using fluorescence microscopy, and image analysis will assess how ECM mechanics and topographical features influence tumor cell dynamics. The ultimate goal is to design and validate a bioink-based, tumor-on-a-chip platform that replicates metastatic behavior in physiologically relevant ECM settings. This system holds strong translational potential for evaluating ECM-targeting therapies and personalizing treatment by modeling patient-specific tumor microenvironments.

Leveraging AI to resurrect ancient life

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Ecological specialization is an essential component of biodiversity and functionality of the Earth's ecosystems. As species go extinct, some ecological roles are lost, potentially leaving ecosystems more vulnerable to collapse. Analyzing the ecologies of extinct species can identify modern species that are prone to extinction as targets for conservation efforts. On the island of Hispaniola, a rich history of fossils provides a unique window into studying extinct ant species in addition to their modern counterparts. Ants are an ideal system to study extinction as they are ubiquitous and perform many essential duties in their environments. Due to their diversity in morphologies and behaviors, ants can be viewed under the lens of extinction in many different contexts, such as how specialist species extinction rates compare to those of generalists. Modern ant ecology can be observed in nature, but studying the ecology of extinct ant species presents challenges as comparisons between modern and extinct species are not always accurate indicators of ecology. By using a novel machine-learning framework, key morphological characteristics of fossil ants will be utilized to predict their ecology. Results will reveal how extinction has shaped ecosystems on Hispaniola and establish a new pipeline for paleontology in the era of AI.

Assessing Predictive Musculoskeletal Simulations for Exoskeleton-Assisted Movement

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Exoskeletons designed with modeling approaches often use generic musculoskeletal models to predict assistance for walking, but do not consider the unique anatomy and neuromuscular variability of each user. In this research, we show a subject-specific predictive simulation pipeline for the derivation of optimal hip–knee exoskeleton torques for overground walking. Self-paced walking trials were completed by two healthy adults and captured by a 10-camera motion-capture system and force plates. An OpenSim musculoskeletal model was anatomically scaled using gap-filled marker trajectories. Following this, predictive simulations of unassisted walking will be done using OpenSim Moco. Ideal torque actuators will be added at the hip and knee once simulations finish. This research allows for more tools for finding the personalized assistive torque profiles and innovates the tuning and validation of walking assistance for exoskeletons.

Investigation of ST3Gal5 in Regulating Neutrophil Adhesion and Migration via Sialyl Lewis-x Expression

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Abstract: Neutrophils are the first line of defense in acute inflammation and infection, including common life-threatening conditions such as sepsis. The neutrophil recruitment to sites of inflammation is a strictly coordinated process that is governed by selectin-mediated adhesion, which depends on the expression of specific glycan structures, sialyl Lewis-x (sLeX) on neutrophil surface. When there is dysregulated neutrophil adhesion and trafficking, it can lead to excessive inflammation, tissue damage, autoimmune diseases, and sepsis. Although several sialyltransferases have been studied and are found to be key regulators of sLeX biosynthesis, the role of ST3Gal5 is undefined in neutrophil migration. The only role that is well-defined is it plays a role in glycosphingolipid synthesis. The project addresses the need to have a deeper understanding in the glycan-mediated immune regulation by investigating the impact of ST3Gal5 on neutrophil adhesion and migration.

The goal of this project is to determine how ST3Gal5 overexpression and knockout influence the sLeX expression, and how it influences neutrophil adhesion and migration. To achieve this goal, HL-60 cells are differentiated with DMSO to model mature neutrophils. The ST3Gal5 gene is cloned into a lentiviral plasmid in E. coli where they will encode viral proteins and be able to create the virus that will be used to transduce the HL-60 cells. The cells are then separated into successfully modified populations that either express ST3Gal5 or do not express it. Then, using flow cytometry and lectin binding assays to analyze the changes in the glycosylation surface of the cell. Migration assays will also show how the changed glycosylation impacts the neutrophil, model, adhesion to P and E selectin substrates.

The anticipated outcome of this project is that the ST3Gal5 overexpression will increase the sLeX expression on the cell surface, which will then help the with neutrophil adhesion and migration. For the ST3Gal5 knockout, the anticipated result will be the opposite, where the sLeX expression will decrease, leading to difficulties in neutrophil adhesion and migration. These research findings will be substantial to neutrophil trafficking and may offer innovative solutions for controlling inflammatory diseases. Overall, this project aims to advance the understanding of glycosylation in immune cell behavior and create new therapeutics for inflammatory disorders.

Impact of Combined Exposure to Nanoplastics and Phthalates on Placental and Fetal Development

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In recent decades, the use of single-use plastics has significantly increased. Less than ten percent of plastics are recycled, and the remaining plastics slowly degrade into micro- and nanoplastics (MNPs), which studies indicate may interfere with female reproductive processes. Additionally, plastics leach phthalates, chemical additives that improve plastic durability, which are known reproductive toxicants. Both phthalates and MNPs can translocate to organs throughout the body, including the placenta, which is a vital organ developed during gestation to support the embryo. While humans are exposed to both nanoplastics and phthalates on a daily basis, there are currently no studies that have analyzed the impacts of co-exposure on placental health. To test our hypothesis that co-exposure to phthalates and nanoplastics will have a significantly larger negative impact on fetal development as opposed to exposure to phthalates or nanoplastics individually, we will orally dose pregnant CD-1 mice with either vehicle control, 200 nm secondary lab-generated polyethylene terephthalate (PET) nanoplastics at 2 mg/kg/day, a phthalate mixture at 200 μg/kg/day, or a combination of nanoplastics and phthalates for 10 gestational days. The placentas and fetuses will be collected following the dosing period to identify exposure-related changes to the size and weight of the fetuses and placentas. This research will help determine if co-exposure to nanoplastics and phthalates has additional negative impacts on placental and fetal development. Future studies should analyze the impacts on the transforming growth factor beta (TGF-β) pathway, a critical pathway in the development of the placental structure, immune response, and trophoblast invasion in order to understand the impact of nanoplastics and phthalates at the genetic level. This study provides insight into the potential negative health impacts as a result of co-exposure to both phthalates and nanoplastics.

Effects of Exoskeleton-Assisted Walking Therapy on the Dynamics and Metabolic Cost of Walking in Post-Stroke Patients

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Abstract: Patients who suffer from stroke often experience significant gait impairments, diminishing their quality of life and independence. Addressing these challenges requires a strong understanding of gait biomechanics and effective therapeutic interventions. Robotic exoskeletons present a promising yet underutilized approach to restoring mobility in patients with neurological impairments and other conditions causing immobilization. While prior clinical studies have explored treatment outcomes, few have investigated objective, quantitative gait parameters. This project combines controlled experiments with computational modeling to quantitatively assess the effects of exoskeleton-assisted walking therapy in post-stroke individuals. Conducted collaboratively between NJIT and the Kessler Foundation's Center for Mobility and Rehabilitation, the study will measure differences in force output and energy expenditure pre- and post-intervention to provide a framework for optimizing rehabilitation strategies. Anticipated outcomes include detailed characterization of gait improvements and reduced metabolic cost with exoskeleton use, offering valuable insights for personalized rehabilitation. Future work will explore long-term effects and integration with other therapies to further enhance mobility restoration post-stroke.

Modeling in-vitro Releases of Crystalline API from HPMC Matrix Formulations

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Controlled drug release systems are designed to sustain stable therapeutic drug concentrations to ensure proper dosage ensuring the mitigation of adverse effects associated with inconsistent treatment profiles, including nausea, dizziness and toxicity. Hydroxypropyl methylcellulose (HPMC) is a common hydrophilic polymer utilized in controlled-lease drug delivery systems valued for its ability to modulate different drug release profiles with a market projected to reach USD 2.25 billion by 2026, growing at 4.4% annually (Industry Arc, 2021-2026). HPMC matrix formulations are a popular method for compressed tablet solid dosage forms since the Active Pharmaceutical Ingredients (API) release profile can be fine-tuned by adjusting key material attributes including molecular weight and polymer concentration. The HPMC swells dramatically upon contact with the dissolution media and forms a thick gel layer that delays API diffusion. This research addresses these challenges by creating a database of crystalline API *in-vitro* release profiles from HPMC matrices to further develop a release model for future predictive capabilities. Techniques include assessing the compaction behavior of the desired direct compressed tablet formulations for a range of crystalline API solubilities, API loading, and HPMC molecular weight grade. The experimental API release profiles will be obtained by performing USPI dissolution and UV-VIS analysis to quantify the API release rates across formulations, revealing differences in release kinetics. In addition, water uptake experiments on the HPMC tablets will quantify matrix swelling rates, providing insight to their impact on diffusion pathways. Anticipated results from this study are expected to demonstrate that HPMC formulations with higher viscosity grades, such as K100M, will exhibit slower and more controlled drug release profiles compared to lower viscosity grades like K4M, due to K100M's greater gel layer viscosity and reduced water uptake rate. Several API release quantitative models from literature will be implemented and nonlinear regression will be applied to determine the model fitting parameters to characterize the various formulations of interest to reveal difference in diffusion mechanisms. This systematic approach aims to provide efficient HPMC formulation development guidelines by identifying key material attributes by characterizing a diverse range of controlled release formulations with several predictive models to reduce costs and enhance therapeutic efficacy, significantly improving patient outcomes by ensuring consistent drug delivery in an expanding pharmaceutical landscape.

How is Microglia Morphology Related to Adolescent Social Isolation?

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The COVID-19 pandemic brought unprecedented levels of social isolation, particularly affecting adolescents during a critical window of brain development. Adolescent social isolation (ASI) is a psychosocial stressor that disrupts decision-making by shifting behavior from goal-directed action to habitual response; it is linked to neuropsychiatric disorders like substance addiction, eating disorders, and obsessive-compulsive disorder. However, the underlying biological mechanisms behind these changes remain poorly understood. Microglia, the brain's resident immune cells, play essential roles in neurodevelopment, synaptic pruning, and behavioral regulation, with their morphology shifting dynamically to reflect their functional state (Figure 1). Disruptions in microglial function during adolescence can influence neural development and have long-term behavioral consequences. While early-life stressors such as maternal separation and resource scarcity have been shown to impact microglia morphology, the specific impact of ASI as a stressor remains unexplored.

This investigation examines how ASI influences microglial morphology within the dorsal striatum, a brain region involved in both goal-directed and habitual behavior. Mice are bred in-house and weaned at postnatal day (PND) 21 into either single housing (ASI) or group housing (GH, control), then euthanized at PND 28, 42, and 56. At each time point, twelve mice (n = 12) are analyzed. Their brain tissues then undergo immunohistochemistry with anti-IBA1 and anti-CD68 antibodies. IBA1 will be utilized to assess microglia morphology and activation status using the MicrogliaMorphology plugin in ImageJ, while CD68 expression will be manually scored to evaluate lysosomal activity, an indicator of immune function.

We anticipate that ASI will produce measurable morphological and functional changes in microglia within the dorsal striatum, reflecting a heightened neuroimmune response. These changes would provide a cellular basis for long-term behavioral shifts associated with ASI. By identifying early biomarkers of stress-induced neuroinflammation, we aim to clarify the connection between socialization and brain development, ultimately informing therapeutic approaches for neuropsychiatric disorders.

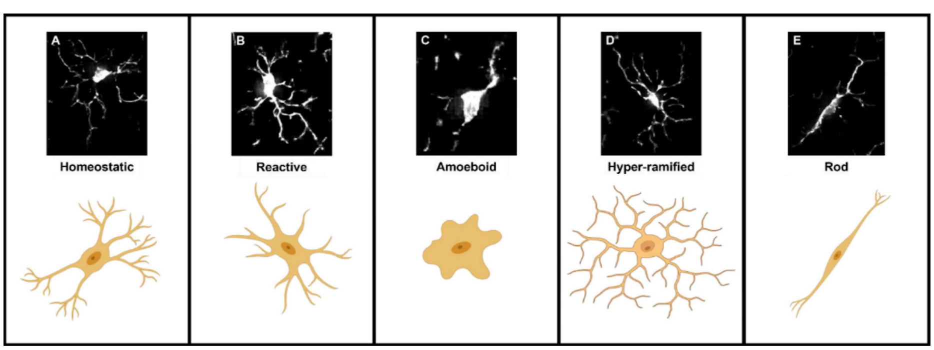

Figure 1: Microglia activation can be assessed through its morphological shifts between homeostatic, reactive, amoeboid, hyper-ramified, and rod states, reflected in the size and complexity of the somas (cell bodies) processes (branches).

Characterizing Diversity in Macrophage Immunometabolism Profiles With High-Throughput Automation

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Macrophages are innate immune cells that regulate inflammation and tissue homeostasis. Macrophages become functionally active by sensing extracellular molecules and are typically classified into M1 and M2 cell states. These subsets exhibit distinct metabolic profiles, with M1 macrophages utilizing glycolysis to cause inflammation, while M2 macrophages utilize oxidative phosphorylation and fatty acid oxidation for tissue repair. A key immune function of macrophages is cytokine secretion, including inflammatory mediators such as IL-1 and anti-inflammatory cytokines like IL-10. However, the link between their metabolic states and immune function remains poorly understood. To investigate the relationship between the metabolic changes in macrophages and their immune responses, I propose to develop a high-throughput platform for studying macrophage immune responses, such as IL-1 and IL-10 secretion, to 86 physiologically relevant stimuli. I will first build automation protocols on Agilent BioTek Multiflo Fx and Biospa to automate IL-1, IL-10, glucose, and lactate assays to characterize cytokine secretions and metabolic changes in different macrophage activation states. I will analyze the correlation between different treatment-induced activation states and the secretion of cytokines such as IL-1β and IL-10 to identify immune signatures associated with pro-inflammatory and anti-inflammatory macrophage responses. This project will establish a systematic relationship between macrophage metabolism and function, providing insights into immunometabolic regulation.

Computational Analysis of the Reactivity of Polysulfides Toward Hydrolysis

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Polysulfides (R-S_n-R′, where n > 2) are critical sulfur-containing compounds with a significant biological role in sulfur metabolism and redox biochemistry and thus implicit in human health. The disruption of biological polysulfides is associated with neurological disorders, cardiovascular disease, and cancer. Reactive sulfur species like HS_2H and persulfides (R-S_n-R′, where n = 2) are in dynamic equilibrium with other polysulfides. Despite their recognized importance, the innate reactivity of polysulfides in biological systems remains insufficiently characterized**.** Direct experimental studies are challenging due to the kinetic and thermodynamic instability of polysulfides and the rapid interconversion of sulfur species. As such, the intrinsic reactivity of polysulfides with water is not yet defined.

This research will employ computational methods to systematically elucidate the detailed mechanisms of polysulfide hydrolysis, thereby contributing to a deeper understanding of their stability and reactivity in an aqueous environment. Each structure will be optimized using Density Functional Theory (ωB97XD/aug-cc-pVDZ) and the SMD implicit solvation model for water. Comparing the reaction and activation free energies, we have determined the most favorable pathways under biological conditions and quantified their predicted rate. Our results show that across the inorganic and cysteine-derived polysulfide systems, certain hydrolysis pathways are more kinetically or thermodynamically accessible. All hydrolysis pathways proceed via an SN_2like nucleophilic attack, with increasing reactivity for each additional sulfur atom. The underlying chemical behavior favors the nucleophilic attack on the terminal sulfur in both systems. However, organic polysulfides have greater energetic variability, with various lower activation barriers and many selective pathways. Computational calculations confirm hydrolysis trends and will advance our understanding of the potential reactivity of reactive sulfur species and their biological role in sulfur pathway, and guide future experimental work.

Flexible Piezoelectric Sensor for Real-Time Cardiotoxicity Monitoring in Cancer Therapy

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Abstract: Cardiotoxic side effects from cancer therapies affect up to 40% of cancer patients and significantly increase the risk of cardiovascular complications, highlighting the need for continuous, real-time cardiovascular monitoring during treatment. To address this need, we propose a wearable sensing system based on flexible piezoelectric sensors placed on the wrist, neck, and chest to detect early signs of cardiotoxicity. The sensors are fabricated from P(VDF-TrFE), a flexible, biocompatible, and lightweight piezoelectric polymer, capable of converting mechanical stress into electrical signals, enabling self-powered operation. The wrist mounted sensor records the radial pulse wave and calculates the augmentation index, a key indicator of arterial stiffness and wave reflection. The neck sensor, positioned over the carotid artery, captures and monitors specific waveform characteristics. Changes such as a reduced secondary peak or altered timing between peaks can indicate developing arterial stiffness or cardiac stress. The chest sensor detects seismocardiogram signals, allowing for continuous monitoring of heart rate, cardiac contractility, and timing intervals between cardiac events; deviations or delays in these intervals indicate early signs of myocardial dysfunction. By integrating data from these three anatomical sites, this comprehensive sensing system promptly identifies subtle indicators of cardiotoxicity before clinical symptoms appear. This non-invasive, low-cost platform thus equips clinicians with real-time, data-driven insights, enabling timely adjustments to cancer therapies, minimizing cardiovascular risk, and improving overall patient outcomes.

Analyzing Interior Density in Army Ant Bivouacs Using Computer Vision

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Abstract: Understanding the collective problem-solving behavior of social species, such as army ants, can provide valuable insights into adaptive, self-organizing strategies with applications in robotics and computer science. Army ants build dynamic, self-assembled structures called bivouacs, constructed from the bodies of living workers, which function as temporary homes. This complements the nomadic nature of the ants by allowing them to conduct foraging raids in different areas. Despite extensive research on swarm intelligence and decentralized decision-making among different species, very little is known about the internal density distribution within these bivouacs. This study aims to analyze the density of army ants in the interior layers of bivouacs using a large dataset of CT scans. By using image processing through ImageJ, the study is designed and executed using an automated script (programmed with a JavaScript-derived language) to record the density and occurrence of ants at different bivouac depths. The goal is to produce histograms of pixel brightness values, which will be processed statistically to identify density changes of ants between layers, including comparison among bivouacs differing in size and construction time. The expected outcomes include a refined method for bivouac analysis, insights into collective/swarm army ant behavior, and applications in robotics for adaptive swarm-based problem-solving.

Figure 1: Army ant bivouac in nature. Image courtesy of Daniel Kronauer

Brain Network Connectivity in Epileptic Individuals

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Abstract: Temporal lobe epilepsy (TLE) affects over 50 million people worldwide. While treatment options include medication and surgery, approximately 30% of patients are drug-resistant. Though surgery is the best option for these individuals, only about half achieve long-term seizure freedom. These poor outcomes likely result from the complexity and subjectivity of interpreting intracranial recordings and the limited spatial sampling they provide. There is a critical need for validated, quantitative methods to guide surgical decision-making and improve outcomes.

Recent evidence suggests that epilepsy arises from abnormalities in brain connectivity. To study these connections, this study compares healthy individuals and patients with TLE using two modalities: functional magnetic resonance imaging (fMRI), which captures indirect neural activity across the entire brain via hemodynamic signals, and intracranial electroencephalography (iEEG), which directly records electrical activity at a high temporal and spatial resolution. While previous studies have typically used fMRI and iEEG independently, this study integrates both modalities to combine the electrophysiological signals from iEEG and structural aspects of fMRI, allowing for more complete whole-brain visualizations. Functional connectivity determines the statistical dependence between signals from different brain regions, offering insight into how different parts of the brain communicate with each other. These associations will be computed from fMRI data, and network metrics such as community structure, participation coefficient, node strength, and distinguishability statistics are extracted. Parallel analyses are performed on iEEG data to enable cross-modality comparison (Figure 1). We hypothesize that combining both modalities will produce different network representations of epileptic regions in temporal lobe epilepsy (TLE).

By integrating iEEG and fMRI into a unified network framework, this model aims to overcome current limitations in surgery. If reproducible network signatures of epileptogenic zones can be identified across patients, they may support the development of brain network models, guiding epilepsy surgeries and even early diagnosis.

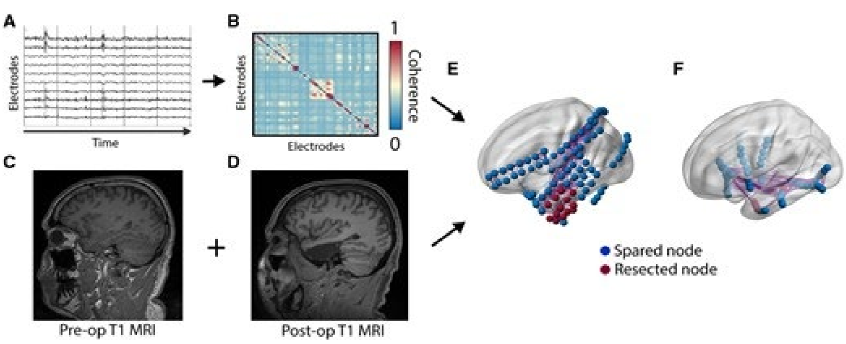

Figure 1: Depicts the process going from time series of iEEG scans(A) to create a coherence- based connectivity matrix that is paired with anatomical MRI scans before and after surgery to differentiate healthy(spared) and seizure-related (resected) tissue

The Influence of Rapid Repeated Fluid Percussion Injury

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Abstract:

Traumatic brain injury in individuals can result in devastating after effects ranging from the onset of neurodegenerative diseases to hospitalizations and fatalities. Many cases of traumatic brain injury are misdiagnosed and can remain untreated. To this end, this study aims to investigate the influence of rapid repeated fluid percussive blows on behavioral patterns and tissue damage in order to increase the understanding of Traumatic Brain Injuries, its causes and methods towards prevention. Rapid repeated fluid percussion injury may better model certain instances of trauma, and as such, information regarding these will serve to aid in better defining the causes and risks of traumatic brain injuries.

The Voice Coil method for fluid percussion injury would be adapted into a novel system for the purposes of the study. This method of injury involves use of the *QCI-S3-IG Controller*, the *BEI LAS28-53-000A Linear Actuator*, the *TONIC T103x RTLC-S Linear Encoder System*, the *PCB Electronics Model 102B06 Pressure Sensor*, and our computer system with the installed *QuickControl* Software. In the standard method for injury, the Controller, guided by the computer system, controls a Motor that drives a piston. This piston is in direct contact with fluid in an sealed, watertight, acrylic mold with an opening controlled by a valve on one side. The encoder measures the distance traveled by the piston and the pressure sensor measures the pressure as the experiment progresses(Figure 1). In this way, a subject, for example an *adult male C57/BL6 mice(20-30g)*, after having undergone a craniotomy, can be subjected to traumatic brain injury while the pressure can be strictly monitored. The addition to the previous design that this study has focused on is the addition of an intermediate piece between the piston and fluid to allow for rapid repeated injury.

The creation of this modified fluid percussion injury device has been the primary focus of the study thus far. The next steps include characterization of the device to determine optimal ranges for injury in subjects, and following this, use of the device to conduct a study comparing a control group, single or traditional fluid percussion injury, and rapid repeated fluid percussion injury.

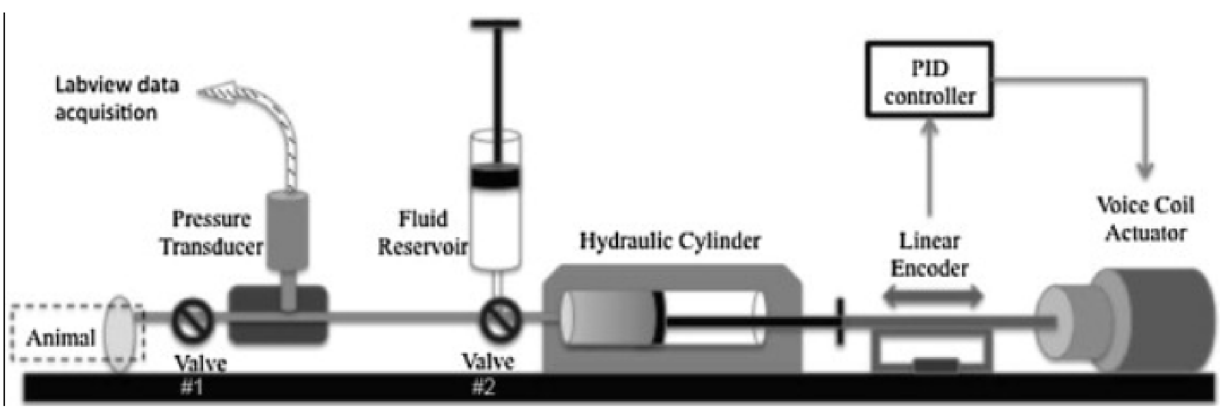

Figure 1: Traditional Fluid Percussion Injury Model, https://doi.org/10.1016/j.jneumeth.2015.03.010.

The Impact of Bharatanatyam Expertise and Training on Visual Crowding: A Comparative Analysis of Dancers and Non-Dancers

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Abstract: Globally, at least 2.2 billion people live with vision impairments and of these, 1 billion cases could have been prevented or remain untreated. As the demand for accessible, non-invasive strategies to support these individuals grows, one promising approach involves enhancing peripheral vision perception. Visual crowding is a phenomenon in which clutter in the visual field makes it difficult to recognize objects, specifically in the periphery. It is not a vision impairment itself but a limitation in visual perception that can significantly reduce function, especially in individuals with existing impairments. Prior studies suggest that dancers may have superior peripheral vision compared to non-dancers due to their reliance on spatial awareness and coordination while dancing. However, most research has focused on Western dance styles, leaving Indian classical dance forms like Bharatanatyam largely unexplored. Bharatanatyam is unique in that it incorporates eye movements not only intro choreographed dance but also through dedicated eye exercises, where isolated eye movements are repeatedly practiced solely to train eye control. This heavy emphasis on eye movement suggests that having Bharatantyam training may strengthen peripheral visual processing, potentially reducing the effects of visual crowding. The goal of this study is to investigate whether individuals with Bharatanatyam training demonstrate improved performance in recognizing objects in their periphery under crowded conditions, compared to non-dancers. Participants from both groups will complete a letter recognition test, in which they will identify letters in crowded and uncrowded settings. It is hypothesized that dancers will show higher performance in crowded conditions, indicating that dance experience and possibly eye-movement training improve visual perception. The findings may inform future research in developing vision therapies that are non-invasive and accessible for mitigating the impact of vision-related impairments.

Macrophage mediated efferocytosis regulates immune suppression in cancers

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Cancer has remained one of the leading causes of death worldwide, impacting millions of lives annually. Despite many breakthroughs in therapeutics, such as chemotherapy, immunotherapy, and other targeted molecular treatments, many forms of cancer still persist and thrive by evading immune detection and suppression. One area of potential exploration is efferocytosis, or clearance of apoptotic cells, mediated by the recognition of externalized phosphatidylserine (PS), a membrane lipid that incorporates on the outer membrane in cells marked for cell death. Macrophage mediated efferocytosis is the engulfing of cells by macrophages, or professional phagocytes that act as the body's defense. Currently, PS exposure is recognized through apoptosis management in normal cell conditions, but in the tumor microenvironment, it is externalized in tumor cells and WBCs and acts as an immunosuppressive signal that inhibits effective anti-tumor responses. This study seeks to fill that gap by investigating the role of PS externalization and associated macrophage mediated efferocytosis in tumor progression and immune suppression. Through a combination of various biochemical assays, such as live imaging, Western blot, qPCR, and flow cytometry, this study will effectively assess the role of externalized PS and related efferocytosis in immunosuppressive signaling. Our project further explores therapeutic interventions that target PS directly, inhibit PS receptors, or deliver signaling molecules via engineered PS-binding biologics (Gas-Interferons). Findings from this study will enhance our understanding of how PS-mediated signaling sustains immune evasion in cancer and will support the development of next-generation immunotherapies aimed at reversing this suppression. Ultimately, this research will contribute to a more effective and targeted approach in the treatment of cancer.

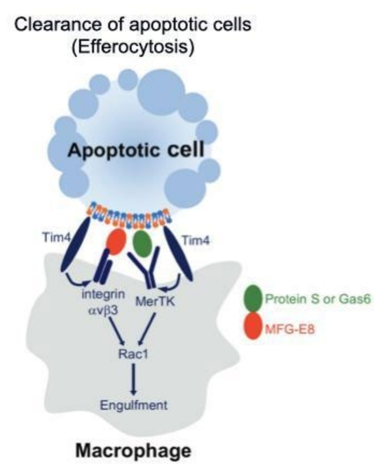

Fig. 1. Efferocytosis (the phagocytosis of apoptotic cells) is mediated by the recognition of externalized PS on dying cells by receptors on phagocytes including TAM receptors such as Mertk, and TIM receptors such as TIM4.

Effect of Theranostic Nanodroplet Phase-Separation On Cell Droplet Interaction

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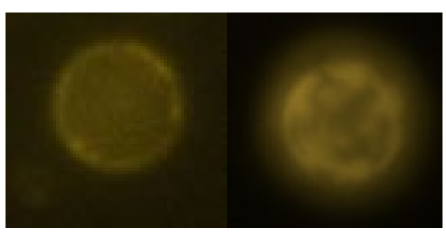
Cell membranes undergo lipid phase separation to allow for clustering of membrane proteins and receptors for better ligand-receptor interactions. Similar to cell membranes containing lipid rafts, phase separation can be observed in biomedically engineered perfluorocarbon (PFC) nanodroplets. These nanodroplets can be employed for a range of applications, which includes the manipulation of them as ultrasound contrast agents and as carriers for drug delivery. Specifically, as an ultrasound contrast agent, these droplets convert into high contrast microbubbles when they are exposed to high intensity focused ultrasound. Additionally, as drug delivery carriers, the size of these nanodroplets allows them to extravasate into tumors and accumulate at their target site. Phase separation has been experimented with liposomes, which are a different type of lipid structures, but never experimented with lipid nanodroplets. This project aims to investigate how phase-separated domains in PFC nanodroplets might have differential interactions with cells. Specifically, this study will investigate the ratio of liquid-disordered to liquid-ordered domains on nanodroplet membranes, droplet-cell incubation times, concentration ranges, and how these interactions will vary with distinct cell types. This will be done by first viewing microdroplets created with different ratios of lipids and fluorescent dyes that contribute to each domain from the same stock utilized to create the nanodroplets. The specific compositions will contain ratios of 2:1, 1:3, and 3:1 of liquid-ordered to liquid-disordered domain lipids. Next, the nanodroplet samples containing different ratios of lipids will be incubated with distinct cell types to view the uptake amount and efficiency of the distinct nanodroplet samples. The amount of nanodroplets uptaken into the cells will be viewed by flow cytometry to quantify the amount of fluorescence attached to the cells. This data will help design ultrasound-activatable nanoparticles for enhanced target cell uptake which could enhance treatments in therapeutics and diagnostic technology.



A B

Figure 1: Figure 1A shown above is a 2:1 liquid-ordered to liquid-disordered domain PFC nanodroplet with apparent specific phase separation on its membrane. Figure 1B shown above is a control droplet with an ordered domain on its membrane.

Portable Readout System for Microfluidic-Based Multiplex Biosensor for Alzheimer's Disease

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Abstract: Early diagnosis of Alzheimer's disease (AD) is crucial for starting treatments and improving patient outcomes. With more than six million Americans living with AD, the economic impact of AD treatment costs is projected to exceed $1 trillion in the US by 2050, placing an immense financial and emotional burden on families and caregivers. However, many current diagnostic methods, such as MRI or PET imaging, are expensive (ranging from $1300 to $3000), time-consuming, and not accessible to everyone. This gap can be filled by the creation of a point-of-care (POC) diagnostic device for early detection of AD biomarkers such as amyloid beta-42. A microfluidic-based multiplex biosensor that identifies various AD biomarkers by detecting the capacitance changes of the functionalized interdigitated electrodes is proposed. The objectives are to 1) develop and build a portable readout system capable of measuring capacitance changes through the use of an Arduino microcontroller that replaces traditional laboratory equipment and supports POC use; and 2) design the circuit to enhance detection accuracy of the Arduino system so that it is comparable to the traditional LCR (inductance, capacitance, and resistance) meter. This was done by building a circuit combined with the Arduino, programming the system to detect capacitance of the biosensor alongside integrating a display, and building a 3D-printed prototype to miniaturize the system and for portability. A compact, 3D-printed prototype that incorporates the Arduino circuit system and allows for real-time capacitance measuring was developed. Additionally, improvements to the circuit design enhanced the sensitivity of the biosensor's capacitance sensing, bringing it closer to the performance of traditional LCR meters. The system also includes a display module for the instant visualization of capacitance data. A low-cost Arduino circuit system that can function as an effective readout system for capacitive biosensors and can be used as a key alternative to traditional laboratory equipment is possible. The combination of hardware, software, and enclosure design indicates the feasibility of real-time, portable biomarker detection in POC environments. Future study will focus on improving the system's sensitivity to detect capacitance values less than 10 pF which is crucial for early-stage biomarker detection. Additional efforts will focus on full integration of the display interface. These recommendations will improve the accessibility and applicability of diagnostic tools, allowing for early intervention in Alzheimer's disease and broadening their usage to other diseases with detectable biomarkers.

Quantifying Joint Forces during Exoskeletal-Assisted and Unassisted Stand-to-Sit and Sit-to-Stand Maneuvers to Reduce Fractures in Persons with Spinal Cord Injury

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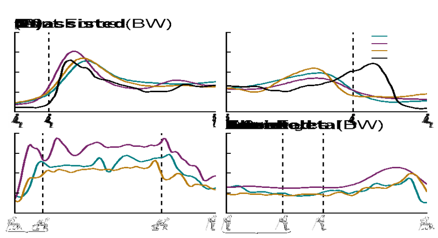
Wearable robotic exoskeletons are currently the only way to restore upright locomotion in persons with spinal cord injury (SCI). However, an important secondary consequence of SCI is severe osteoporosis, which exposes the population to a greater risk of bone fracture during exoskeletal-assisted locomotion (EAL). The growing demand for wearable robotic exoskeletons emphasizes the need for the quantification of lower-limb joint forces during EAL. Experimental, or *in vivo*, measurements of joint forces are invasive to collect. Accordingly, the goal of this research is to develop a computational framework to quantify the hip, knee, and ankle joint forces of an able-bodied person. Three-dimensional (3-D) motion data were collected from one motion capture session at the Life Sciences Motion Capture lab while the participant performed exoskeletal-assisted and unassisted sit-to-stand and stand-to-sit maneuvers. 3-D motion data included simultaneous measurements of 3-D marker trajectories, ground reaction forces, electromyography (EMG), and exoskeleton encoder data. EMG-tracked muscle-driven simulations were performed to compute hip, knee, and ankle joint forces using four simulation conditions of increasing complexity. The first simulation condition excludes all exoskeletal contributions (No Interactions). The second simulation condition prescribes the exoskeleton motor torques directly to the hip and knee joints (Prescribed Torques). The third simulation condition applies exoskeletal interaction forces modeled as linear spring-damper systems at regions of exoskeleton support cuffs and bands (Bushing Forces). The fourth simulation condition applies both the prescribed torques and bushing force conditions (Prescribed Torques + Bushing Forces). Preliminary data shows the right knee joint forces during exoskeletal-assisted (No Interactions) and unassisted stand-to-sit and sit-to-stand trials (Figure 1). Future work will consist of using the developed framework to compute hip, knee, and ankle joint forces for additional able-bodied and SCI subjects performing stand-to-sit and sit-to-stand movements.



References: [1] Kutzner
et al. (2010), J Biomech 43(11).

Entomological Photonic Sensing

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Abstract: Mosquitoes are a uniquely problematic insect for human health as they serve as vectors for disease and cause an estimated 700,000 deaths annually. Current methods utilize physical traps to monitor mosquito populations but may have implicit biases and are costly and time-consuming. The implementation of photonic methods is likely to enhance responsivity and improve the effectiveness of population monitoring and control efforts. However, optical sensing alone generally has a low taxonomic accuracy; notably, it has been shown that photonic identification of mosquito species, sex, and gravidity significantly improves when wingbeat and depolarization ratios are collected. This study assesses the application of near-infrared polarimetric measurements to identify and characterize insects in a transmission configuration under laboratory conditions. Polarization sensitive detectors record transmission intensity to obtain the wingbeat frequency and depolarization ratios of the wings and body of an insect. This data is then processed using an unsupervised machine learning classifier to evaluate mosquito species, sex, and gravidity.

Evaluation of Bioactive Collagen Sponge Implantation for Muscle Regeneration and Scar Reduction in Volumetric Muscle Loss (VML) Injuries

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Abstract: Volumetric muscle loss (VML) is a condition in which a large portion of skeletal muscle tissue is lost or destroyed, leading to permanent disability. VML is typically caused by traumatic incidents such as battlefield injuries or automobile accidents. Current treatments for VML, such as muscle free flap transfer, are limited by complications including poor graft integration, donor site morbidity, and incomplete recovery of function. Thus, there is a need for alternative treatments. Our lab has developed a bioactive collagen sponge that has been biochemically and structurally optimized to promote skeletal muscle tissue regeneration. This project aims to determine the ability of our bioactive scaffold to promote muscle regeneration in a VML defect using histological analyses. Over the summer, the goal has been to analyze mouse muscle tissue which received a VML injury and subsequently was treated with bioactive collagen sponges. The collected tissue was sectioned and stained using hematoxylin and eosin (H&E) and Masson's trichrome to visualize collagen deposition (scar formation), new myofiber formation, and infiltration of muscle cells into the scaffold. The stained tissue was evaluated to determine whether the scaffold has integrated with the remaining muscle tissue, and whether new muscle fibers have formed within the scaffold area. Our results show that collagen content was significantly lower in the treatment group 2 months after injury, which indicates successful muscle regeneration, as mature muscle tissue replaced the collagen-rich scaffold. Trichrome staining showed a significant reduction in defect size at 2 months compared to 1 week for the treatment group while control groups revealed no changes in defect size, which suggests successful regeneration of the experimental scaffold into the injury site. Integration of the scaffold with host tissue also improved over time, with more seamless boundaries between the host and scaffold observed. Analysis of fatty infiltration and fibrosis suggests a reduction in adipose presence and fibrotic response in the treatment group, which are both positive indicators of muscle regeneration. In future work, scaffolds will be implanted into a murine VML model and regeneration will be evaluated at 6 months post-implantation instead of 2 months to observe further scaffold degradation and regeneration. This project ultimately aims to determine the efficacy of this scaffold as an implantable, off-the-shelf treatment for VML for future use in clinical settings.

Investigating the Effects of IGF-1- and IGFBP-5-Loaded Collagen Scaffolds for Treatment of Volumetric Muscle Loss In Vivo

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Volumetric muscle loss (VML) is a clinical condition in which large amounts of muscle tissue are lost, typically more than 20% of a muscle's total mass, resulting in permanent disability. VML poses a significant challenge in both civilian and military populations, incurring diminished patient quality of life and substantial healthcare costs. Our long-term goal is to develop an off-the-shelf acellular scaffold that can provide better outcomes than conventional treatments like autologous tissue transfer, where muscle tissue from a donor site is surgically grafted to the injury site. Around 10% of all muscle grafts for VML have complications like graft rejection and infection, leading to adverse outcomes and scar tissue formation. Instead we seek to use readily implantable scaffolds that utilize endogenous regeneration processes for better outcomes. Our approach investigates the integration of insulin-like growth factor-1 (IGF-1) into acellular collagen scaffolds for VML treatment. IGF-1 promotes both the proliferation of myoblasts and their differentiation into muscle fibers. To facilitate a longer release of IGF-1, we incorporated IGFBP-5 to form a complex with IGF-1. In this project, our goal was to evaluate the cellular infiltration in response to IGFBP-5/IGF-1 loaded scaffolds in VML injuries to evaluate treatment efficacy. Collagen sponges were chemically crosslinked with heparin, loaded with IGF-1 and IGFBP-5, and were implanted into a VML defect in the tibialis anterior muscle of mice. Tissue was harvested at 1 and 8 weeks post-injury. Immunohistochemical staining was performed to evaluate satellite cell infiltration (Pax7), myofiber formation (myogenin), vascularization (CD31), and macrophage infiltration (F4/80). Imaging and quantitative analysis using ImageJ will compare the expression of these markers across treatment groups to determine the scaffold's effect on muscle regeneration. We expect that scaffolds loaded with the IGFBP-5/IGF-1 complex will show enhanced cellular recruitment, improved muscle tissue regeneration, and increased vascularization compared to control scaffolds and untreated injuries. Some preliminary data collected shows that markers of Pax7, CD31, and myogenin are higher in the treatment groups than the defect-only negative control at 1 week, indicating that regeneration was occurring. At the 8 week mark, myogenin and Pax7 was elevated only in the hep/bp5/igf treatment group, suggesting continued regeneration in the scaffold of interest. Further investigation will demonstrate the scaffold's ability to support muscle tissue growth. By investigating the use of an IGFBP-5/IGF-1-loaded collagen scaffold, this project contributes to the development of a viable off-the-shelf treatment for VML. The results of this project will provide guidelines for future strategies regarding growth factor delivery in regenerative biomaterials, and may support continued development toward functional, scalable solutions for traumatic musculoskeletal injuries.

Establishing an Assay for Visual Desensitization in Larval Zebrafish for Understanding Synaptic Plasticity

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Synaptic plasticity is the ability of neurons to modify their strength of connections based on experience. It is a key mechanism underlying visual desensitization in larval zebrafish, a form of neural learning that influences escape behavior. Synaptic plasticity is also crucial in humans as it helps with learning, memory, and overall brain function. While previous studies have focused on habituation, a decrease in responsiveness due to repeated exposure to the same stimulus, our research focuses instead on desensitization, a learned response in which repeated exposure to a weak, subthreshold version of a stimulus reduces the response to a strong, suprathreshold version. We developed a novel experimental setup tailored to investigate how zebrafish respond to visual stimuli of varying intensities and frequencies, simulating looming threats. Control and experimental groups are tracked in real time using high-speed cameras and specialized software to precisely measure behavioral responses. Our results reveal a decrease in responsiveness after repeated exposure to sub-threshold stimuli, consistent with desensitization. Future work will incorporate closed-loop tracking to enhance temporal and spatial resolution. By advancing our understanding of sensory-motor integration and behavioral adaptation, this research sheds light on fundamental principles of learning and plasticity. In the long run, these findings could help uncover mechanisms behind neurological disorders and inform new approaches to their treatment.

Quantitative Assessment Using Peak Velocity in Virtual Reality Vision Therapy for Convergence Insufficiency Patients

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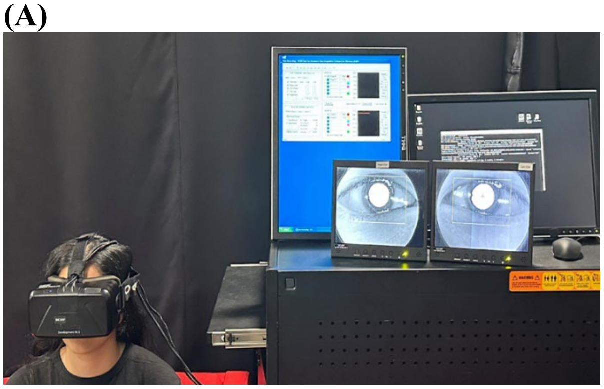
Abstract: Convergence insufficiency (CI) is a binocular vision disorder in which individuals are unable to focus their eyes on nearby objects, leading to difficulty and fatigue during everyday tasks such as reading and computer work. Traditional vision therapy is approximately 75% effective in treating CI, but many individuals lack access to this care due to cost, location, or limited provider availability. This project focuses on understanding the neuromuscular mechanisms behind virtual reality (VR)–based vision therapy, a novel and potentially more accessible treatment option for CI. Participants (n = 10), all previously diagnosed with CI, completed an eye movement protocol involving vergence and saccadic eye movements. Recordings were collected before and after twelve weeks of VR vision therapy. MATLAB will be used to analyze changes in peak velocity and final amplitude between the two time points. We expect to see increases in both metrics following therapy, along with a strong correlation to symptomatic improvement. These outcomes are anticipated to be comparable to those achieved through traditional therapy. Looking ahead, this study lays the groundwork for developing scalable, home-based VR interventions that could be distributed through consumer headsets or integrated into telemedicine platforms. Such an approach has the potential to expand access to vision therapy for underserved populations, including children in rural areas, older adults, and individuals in resource-limited settings. By highlighting both the efficacy and the broader applicability of VR therapy, we aim to contribute to the future of accessible, technology-driven vision care.

(A)



(B)

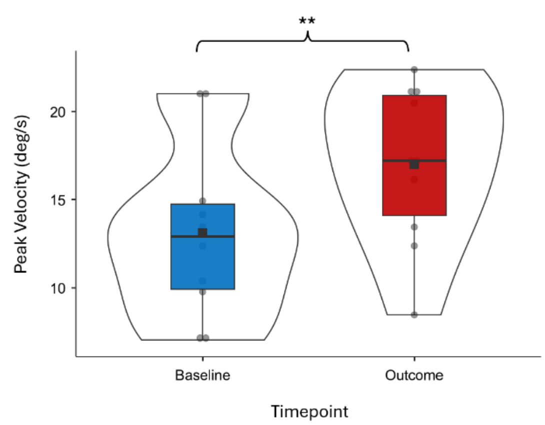


Figure 1. (A) Virtual reality vision therapy setup. (B) Violin plot showing significant increase (**p < 0.01) in binocular peak velocity for four degree convergence movements following vision therapy (n = 10).

Are Neuronal Capacitance Changes due to Neuronal Size Changes? A Confocal Microscopy and Fiji Imaging Approach

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Neuronal signal transmission relies on a number of core components. One of these components is membrane capacitance, a measure of the cell's ability to store electric charge. Membrane capacitance is a fundamental property of all cells, and it is especially crucial in neurons because it changes the time course that cells respond to signal input. Membrane capacitance directly influences the speed and frequency of signal reception and signal generation as it impacts the time constant τ, which is the product of the electric resistance of the membrane multiplied by its capacitance ($\tau = RC$). This research aims to uncover measurable factors behind observed fluctuations in neuronal membrane capacitance and how these changes affect signal transmission and basic neural activity. Capacitance has been previously believed to be a stable property that does not fluctuate over time. However, fluctuations in capacitance over a 24-hour period were recently discovered in excitatory pyramidal cells from the visual cortex in mice. Capacitance is directly linked to the surface area of cells. Thus, this study assesses how surface area might contribute to the observed fluctuations. Using Fiji imaging software, we trace 3D images obtained using confocal microscopy to create reconstructions of the neurons. I will obtain measurements of cell surface area derived from dendritic length and synaptic spine count in order to assess possible correlations with measured changes in capacitance. The findings produced by this study can be applied to applications of memory, cognition, and capacitance-induced synaptic integration. The anticipated outcomes are measurable parameters that explain fluctuations in membrane capacitance and an enhanced understanding of synaptic integration and signal transduction. Ultimately, the study will reveal if the regulation of surface area explains changes in capacitance and synaptic integration.

Membrane capacitance is a fundamental property of all cells, and especially neuronal cells, which use electricity in order to communicate. Neuronal capacitance is a measure of the neuron's ability to store electricity. The neuron relies on this for the generation of action potentials, which allow signals to be transmitted in response to signal reception.

The Search for Ctenophore Vitellogenins: Towards Understanding the Evolution of Lipid-Rich Animal Eggs

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Abstract: Vitellogenin (Vtg) is a lipoprotein essential for embryo development, where it supplies lipids and nutrients from the yolk of an egg to the embryo. However, Vtg has yet to be identified in Ctenophores, the earliest-diverging animal lineage. Research on this topic remains limited or untried, and any existing data lacks validity due to limitations in older sequence-based protein search algorithms such as BLAST and HMMER3. This study is designed to apply more modern tools, such as MMseqs2 for more sensitive and faster protein sequence comparison, AlphaFold for structural prediction, and Foldseek for structural alignments, to find Vtg or a Vtg-like candidate gene. In addition, RNA sequencing of dissected ctenophore gonads will be used to provide temporally regulated gene expression patterns, which can uncover candidate genes that aren't able to be detected by sequence similarity alone given the evolutionary divergence of ctenophores from any other animal known to possess Vtg. This research aims to resolve whether Vtg or a Vtg-like gene exists in ctenophores, providing insights into lipid transport evolution and embryonic development across early-diverging animal lineages. If Vtg is indeed found, it enables the use of VitelloTag, a gene editing tool that provides a better alternative to the conventional method of microinjection, and suggests an earlier evolutionary origin for the vitellogenin family of lipid transport proteins, potentially predating the last common ancestor of animals. If Vtg is absent in ctenophores, it would indicate an independent evolutionary path for yolk nutrient transport in them, opening new directions in the study of early animal evolution. Both results pave a further path into lipid transport evolution and embryo development across early-diverging animal lineages.

Tracking Changes in the Brain's White Matter Throughout Pregnancy: A Longitudinal Study

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Abstract: Pregnancy is an extremely complicated stage of life, where an individual's body undergoes many changes for the coming of a baby. Some of the most crucial changes occur in the brain, both anatomically and functionally. Current research has shown changes in neuroplasticity in both animal and human models, with the percent change in grey matter from conception to 6 months postpartum being described as a "U-shaped curve" through the preprocessing and analysis of scans obtained by functional Magnetic Resonance Imaging (fMRI). However, very little is known about how the white matter in the brain changes throughout pregnancy. In the brain, white matter acts as the communication pathway, allowing for the transmission of nerve signals. This connects various parts of the brain, allowing them to work together to perform neurological functions, making white matter especially important for problem-solving, balance, and learning. White matter is not only crucial for communication, but also important in changes in mood and mental health. Therefore, tracking the change in white matter can communicate to scientists if there are certain periods of the pregnancy where women are more likely to develop mental health disorders such as anxiety, childbirth related PTSD, and depression, as well as if there are ways to prevent the onset of these conditions. This project aims to track and model the change in white matter over the course of pregnancy within specific regions of interest (ROIs) by using MATLAB, SPM (Statistical Parametric Mapping), and AFNI (Analysis of Functional NeuroImages) in order to analyze data from MRI scans of pregnant women. By plotting and understanding the trajectory of white matter throughout pregnancy, we can better support pregnant women before, during, and after their pregnancy, as well as their babies. Understanding how the brain changes can allow for future work such as treating neurological and psychological disorders like childbirth-related PTSD and postpartum depression with a more profound understanding of brain function during this time period.

Investigating the Impact of a Clickable Phthalate on Gene Expression in Ovarian Follicles

Valarie Malty

Advisor: Dr. Genoa Warner

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Abstract

Phthalates are endocrine-disrupting chemicals (EDCs), which have a presence in the environment and potential health impacts. Ovarian follicles are essential for reproduction as they allow for the release of eggs during ovulation and produce hormones. This study focuses on the effects of phthalate exposure on gene expression in ovarian follicles, specifically genes that are responsible for oxidative stress, inflammation, and follicular development. By using a phthalate designed to be used for click chemistry, which will allow for reactions to occur without cross-interactions with other biological processes, we aim to better understand the mechanisms that phthalates cause disruption of ovarian function. This phthalate was designed to only react with the intended biological targets without interacting with other proteins or chemicals which allow for a precise investigation into specific effects on gene expression in ovarian follicles. Studying this is crucial to determine the mechanism that is disrupting ovarian follicles. We hypothesize that the targeted phthalates will alter genes that are related to oxidative stress, inflammation, and follicular development in a dose-dependent manner compared to DINP and DNOP. Female CD-1 mouse ovarian follicles will be cultured and treated with the phthalate treatment groups and then compared to positive control culture treatments such as diisononyl phthalate (DINP), Dimethyl Sulfoxide (DMSO), and di-n-octyl phthalate (DNOP). Following treatment, RNA will be extracted from the different follicle treatment groups, including DINP, DNOP, and DMSO, followed by cDNA synthesis and analysis using quantitative polymerase chain reaction (qPCR). Gene expression changes will then be analyzed, with expectations the synthesized phthalate will have the same toxicity as the positive controls, more specifically the genes involved in processes such as steroidogenesis and follicular development. This study aims to identify how phthalate exposure disrupts gene regulation in ovarian follicles and assist in our understanding of reproductive toxicity mechanisms.

Engineering Tunable Protein-Only Nanoparticles with Multifunctional Capabilities for High-Efficacy Antifungal Therapy

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Most of us coexist peacefully with fungi, but for the immunocompromised, that peace can turn fatal. Fungal infections pose a growing threat to these communities worldwide as 7% of U.S adults have weakened immune systems in contrast to the 3% in 2013. As fungal pathogens grow increasingly drug-resistant, current treatments often fail and have a small half-life. We need antifungal therapies that not only work, but stay in the body longer, target the infection precisely, and can surpass evolving resistance.

Ongoing studies indicate antifungal treatments rely on a few broad-spectrum drugs, such as polyenes, azoles, and echinocandins, which are often associated with toxicity and low efficacy because of the rising treatment resistance. There is a growing interest in nanoparticle-based drug delivery to reduce off-target effects and improve efficacy of antifungal treatments. Prior research has shown that oleosin-based micelles offer a promising platform due to their self-assembling design, hydrophobic core for drug encapsulation, and customizable hydrophilic surface for functionalization. Building on this, we engineered micelles by expressing recombinant oleosin in E. coli, followed by purification and assembly with antifungal peptides. These micelles were then tested against drug-resistant fungal strains using in vitro growth inhibition assays to evaluate their efficacy and therapeutic potential.

While current findings are promising, more research is needed because many existing approaches remain inadequate for clinical use. The nanoparticles are unstable under physiological conditions, difficult to manufacture or modify, and lack the versatility needed to address diverse fungal strains. There is a clear need for a delivery system that is both biologically robust and functionally adaptable, particularly for vulnerable populations where treatment failure is not an option.

By leveraging the natural behavior and properties of oleosin, we can combine it with the targeted power of antifungal peptides. Initial findings indicate that these micelles reduce fungal growth significantly in resistant strains, suggesting their effectiveness as a delivery system. This research could lead to a breakthrough therapeutic platform—one that is not only effective against drug-resistant fungi but also adaptable for future applications. In a clinical setting, this could translate to lower drug dosages, fewer side effects, and improved outcomes for patients who currently have limited treatment options.

Enhancing Language Learning with Transcranial Magnetic Stimulation

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This project, which aims to stimulate the brain's linguistic functions through transcranial magnetic stimulation (TMS) to enhance language learning, has the potential to improve the lives of individuals with language impairments significantly. By targeting TMS to brain areas identified on magnetoencephalography testing in a large sample of healthy individuals, we seek to answer the specific question of the optimal time to stimulate these brain areas for the language task. Our ultimate goal is to assess the efficacy of TMS in improving language learning, thereby evaluating its potential as a therapeutic tool to aid individuals with language impairments. This research, if successful, could bring hope and relief to many individuals and their families.

Stroke, brain injury, brain infection, and other neurological disorders, such as Alzheimer's disease and dementia, can cause aphasia. Aphasia is a severe language impairment caused by damage to the parts of the brain that control language. It can affect various aspects of language, including speaking, understanding speech, reading, and writing. This sudden breakdown in communication impacts an individual's ability to function independently in society. Healthy native English speakers (18-65 years old, right-handed, with normal or corrected vision) are invited to participate. Two TMS conditions are employed: priming (stimulation administered before the task) and inhibition (stimulation administered during the task).

Additionally, both reaction times and accuracy in sentence-processing tasks will be measured. The first phase of this project tested three sentence types using priming and inhibition to assess their effects on linguistic processing. Inhibiting the frontal lobe increased reaction times for normal sentences and reversed sentences but had little impact on inner transpositions. Priming the posterior temporal lobe accelerated responses to inner transpositions, thereby facilitating the processing of ungrammatical sentences. Inner transpositions were least affected by inhibition but benefited most from priming.

We will confirm the substantial effects that TMS induces on language function in one individual and a larger sample of individuals. Within our pilot study, we observed promising results that depicted how TMS can highly impact language processing. This project enables us to conduct research on a larger scale with more participants, thereby confirming these findings. The results will validate our initial study and provide a solid foundation for exploring the use of TMS as a crucial tool for enhancing language processing.

The next phase will target TMS to brain areas identified by magnetoencephalography in a large sample of healthy individuals. This phase aims to determine the optimal timing for brain area stimulation during language tasks. We will evaluate whether TMS should be applied before or during task performance to strengthen linguistic performance.

According to the National Aphasia Association, approximately 2 million people are currently living with aphasia in the US, and each year, about 180,000 new cases are diagnosed, showing an emphasis on top-down grammatical knowledge that intercepts sentence understanding. At the end of this project, the anticipated result is to understand at which time points, concerning these processes, we should apply TMS to enhance the brain's ability to perform language tasks.

Detecting Impaired Movements of Stroke Patients From Motion Sensor Data Using Machine Learning

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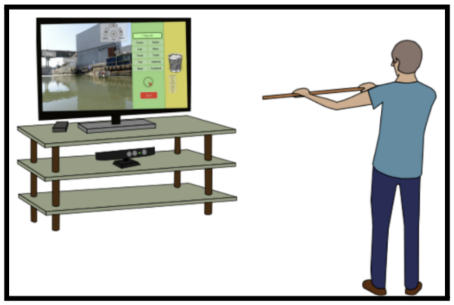

Figure 1: Set-up of telehabilitation platform.

Stroke is a leading cause of long-term disability, with over 795,000 cases annually in the United States. Approximately 80% of stroke survivors experience hemiparesis, significantly limiting their mobility and independence. Telerehabilitation, where patients perform physical therapy outside of the clinic, offers a promising solution by enabling remote monitoring of motor recovery using motion sensors. However, analyzing movement data remains a challenge, often requiring advanced manual interpretation by technicians. This project aims to develop a machine learning model that automatically detects impaired movements from camera-based sensor data, providing real-time, clinically interpretable feedback. Data were previously collected on healthy subjects and stroke patients who performed bimanual training in front of a Microsoft Kinect sensor. Key features that capture the range of motion, limb coordination, and movement symmetry will be extracted and used to train algorithms that distinguish between healthy and impaired movements. The machine learning model will be evaluated using cross-validation and performance metrics such as accuracy, precision, and sensitivity. Automating movement assessment in telerehabilitation will improve accessibility, streamline clinical decision-making, and enhance rehabilitation outcomes for stroke patients. Beyond stroke, this technology has the potential to benefit individuals with other motor impairments, making rehabilitation more efficient and widely available.

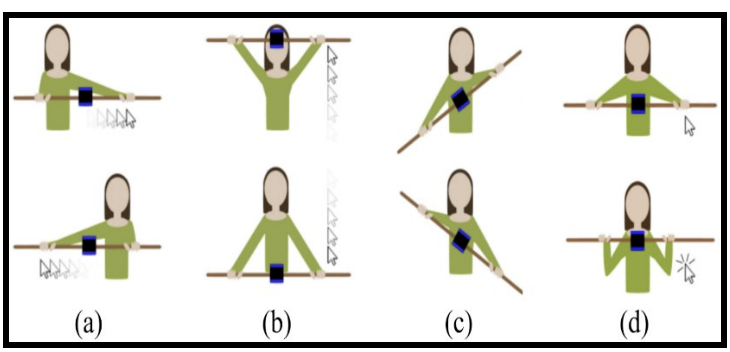

Figure 2: The eight bimanual movements performed by subjects using a dowel, shown left to right: (a) Left and right shoulder abduction–adduction, (b) Upward and downward shoulder flexion–extension, (c) Clockwise and counterclockwise rotation, (d) Elbow flexion–extension.

The Effect of Exosomes on Collagen Production in Human Cardiac Fibroblasts

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Abstract:
Fibrosis, the replacement of dying heart tissue with permanent, non-contractile fibrotic tissue, is a major cause of heart failure, the leading cause of death in the world. There is currently a lack of therapies addressing cardiac fibrosis, and its mechanism is poorly understood. Exosomes, naturally produced, nano-sized cellular vesicles, have emerged as a promising treatment for their ability to carry miRNA and proteins. They have exhibited cardioprotective properties including reduced apoptosis and inflammation, though fibrosis has not been independently studied. This study aims to determine whether human induced pluripotent stem cell (hiPSC)-derived exosomes secrete anti-fibrotic factors. Since fibrosis is only a transient stage in regenerative hearts in neonatal mice, it is hypothesized that hiPSC-derived exosomes may induce similar cardioprotective properties. A MI model will be simulated in fibroblasts by inducing their differentiation into myofibroblasts using TGF-β1 *in vitro*. The anti-fibrotic properties of exosomes will be measured by the effect of exosome treatment on levels of collagen secretion before and after differentiation, allowing comparison between the effects of pre-ischemic and post-ischemic treatment. Secretion of fibroblast-activating genes and cardioprotective factors will be measured using RT-qPCR. If exosomes are indeed anti-fibrotic, the expected outcome would be less differentiation into myofibroblasts compared to control groups, and reduced collagen secretion. Optimally, more cardioprotective proteins will be secreted as well. By targeting fibroblasts, this study focuses on exosomes' effect on fibrosis specifically, with minimal confounding factors, helping to clarify mechanisms and develop treatments of pathophysiological fibrosis in the future.

ENVIRONMENT AND SUSTAINABILITY

Project FloodLens: Holographic Flood Simulation for Disaster Risk Assessment

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Natural disaster planning and preparation are crucial for community safety, minimizing property damage, and expediting recovery efforts. Flooding is a significant global issue that has seen rising frequency and intensity due to climate change and urban development. It may lead to severe consequences like property damage, erosion, and unfortunate loss of life. Traditional disaster models and planning methods, such as maps and cardboard models, are outdated, struggling to accurately represent flooding's complex nature and often overlooking climate change impacts. These models often function in a stationary manner, which makes it challenging to accurately capture terrain details and drainage interactions in urban environments.

On a constructive note, recent advancements in display technology offer exciting, innovative opportunities for enhanced visual communication. We propose developing an interactive projection system for simulating flood scenarios, projecting dynamic floodwater onto a surface integrated with 3D-printed building models and simulated moving elements like vehicles and people. This holographic-style display is based on projected imagery onto a surface, creating the visual illusion of a flood simulation. The goals include designing and 3D-printing models, setting up a projection system, developing a simulation of moving elements, and exploring interactive capabilities. A 3D scan of the NJIT campus was utilized to accurately represent the scene, and the buildings were 3D printed to enhance realism. The simulated movement of vehicles and people within the projected floodwater adds an extra layer of immersion to the experience. By combining tactile physical models with dynamic holographic projections, this approach improves disaster planning and community education to increase user engagement and understanding of emergency preparedness. Users can customize variables like the amount of rainfall and number of obstacles, enabling exploration of various flooding scenarios and improved evacuation planning. Community workshops can use this technology for discussions on preparedness, and urban planners can better assess mitigation plans. Schools can raise environmental awareness, while local governments can engage the public through dynamic presentations. Overall, this system empowers communities to strengthen resilience against flooding.

The objective of this project is to create a functional interactive holographic flood simulation prototype that effectively showcases the viability of this approach. This prototype illustrates a dynamic flood scene, complete with the simulated movement of objects and people. We conducted a preliminary evaluation to assess the effectiveness of this method for flood simulation, using qualitative observations and gathering user feedback. The insights gained from this research evaluate both the advantages and limitations of employing interactive holograms for flood simulation in educational contexts and public awareness initiatives. This project pioneers a versatile, low-cost simulation platform that can revolutionize how we visualize and respond to a wide range of complex emergencies, from natural disasters and pandemics to economic crises like the 2008 financial crisis. By transforming abstract data into immersive, interactive experiences, this platform amplifies education, planning, and decision-making at scale.

The Role of Localized Weather Data in Urban Building Energy Efficiency and Compliance

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Abstract: Weather data is a critical factor in Building Energy Modeling (BEM), influencing heating and cooling load calculations, Heating, Ventilation, and Air Conditioning (HVAC) system sizing, and overall building energy performance assessments. However, many BEM studies rely on publicly available historical weather data from airports rather than localized urban measurements, which can lead to inaccuracies due to microclimatic differences. Therefore, this study aims to characterize and analyze discrepancies in weather data by comparing measurements from the Weston Weather Station, located on the roof of Weston Hall at NJIT in Newark, with data from the nearest airport, Newark Liberty International Airport, while also incorporating additional meteorological databases. The project has been conducting a comparative analysis of key weather parameters, including temperature, humidity, wind speed, air pressure, and solar radiation, to quantify variations caused by the Urban Heat Island (UHI) effect. For example, the analysis has focused on three representative months that reflect seasonal conditions: July for the cooling season, October for the transitional season, and January for the heating season, in order to capture seasonal patterns. Preliminary results indicate both seasonal and diurnal trends in temperature differences between the two weather stations (Figure 1), which are being compared to the results of other UHI studies. In addition, the project plans to integrate these variations into EnergyPlus whole-building energy simulations using the U.S. Department of Energy (DOE) Commercial Reference Building models to evaluate their impact on building energy consumption predictions. By demonstrating the extent to which airport-based data can affect BEM accuracy, this study will contribute to improved urban energy modeling, supporting more resilient and energy-efficient building designs.

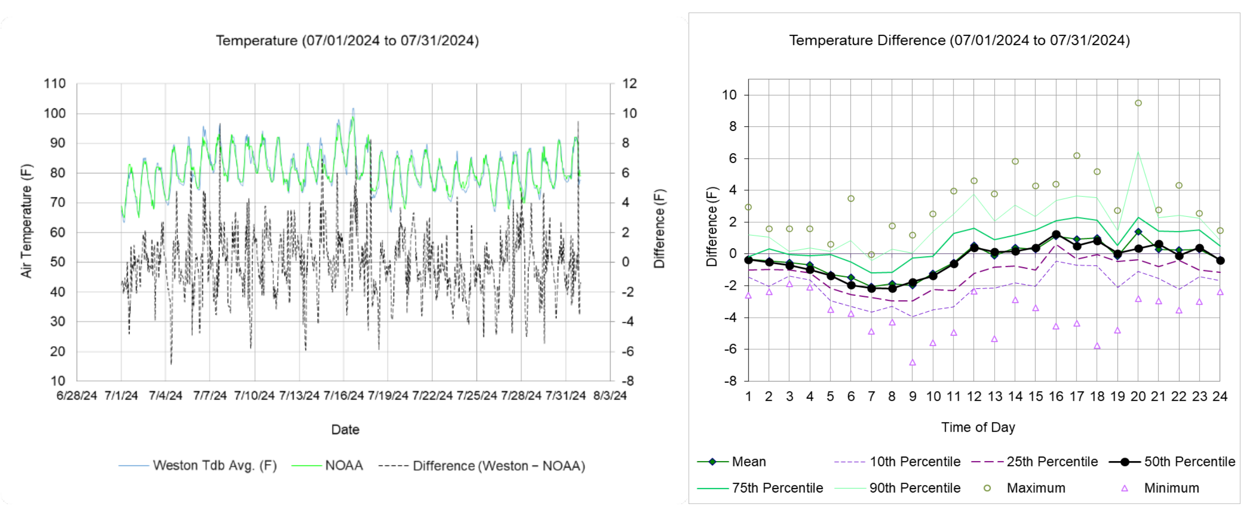

Figure 1: Time-Series (left) and Time-of-Day (right) Outdoor Temperature data from Weston and Newark International Airport weather Stations for July 2024

Impact of Combined Exposure to Nanoplastics and Phthalates on Placenta Morphology

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Plastic production has been increasing exponentially over the past few decades, yet only about 10% of the plastics ever produced have been recycled. The remaining 90% of plastics remain in the environment and landfills, where they degrade into smaller particles known as nanoplastics. Nanoplastics have become a large public health issue as they have been measured in nearly every part of the human body and the most remote areas of the world. However, we are not only exposed to nanoplastics when plastics degrade, instead, we are also exposed to chemical additives that leach during the degradation process, known as phthalates. Phthalates are added to plastics to make them durable and flexible, and they are also added to personal care products to stabilize fragrances. Both nanoplastics and phthalates have independently been found to permeate placental tissue, a temporary structure developed during pregnancy to support the developing fetus. The presence of these compounds within the placenta alone is especially concerning due to potential influence on fetal health and research to understand their impact is urgent. The impact of both nanoplastics and phthalates on placenta and potentially fetal development is heavily understudied. To address this gap, we will orally doses pregnant CD-1 mice with either vehicle control (corn oil), polyethylene terephthalate (PET) nanoplastic particles at 2 mg/kg/day, a relevant phthalate mixture based on phthalate exposure in pregnant women at 10 µg/kg/day, or a combination of phthalates and nanoplastics from gestational days 7 to 15. Placentas will be sectioned and stained using hematoxylin and eosin to identify placental structures. I will measure the area of the decidua, basal, and labyrinth zones of the placental for all groups to compare anatomical differences as a result of exposure as each section has their own role in fetal development. Additionally, I will compare the sizing of the fetal and maternal blood spaces to identify changes in placental vasculature. The ratio between them is critical for ensuring proper nutrient and waste exchange. Ultimately, this study will be useful in understanding if combined exposure heightens alterations to placenta morphology given that this is one of the first studies to address the impact of combined exposure on placental health. Results will be useful in identifying molecular targets related to the disrupted anatomical features to streamline the process of understanding the impact of plastic degradation on placental health.

Assessing Toxicity of Benzyl Paraben (BzP) in Mouse Ovarian Follicles

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Endocrine-disrupting chemicals (EDCs) are prevalent in consumer and industrial products, posing significant public health risks and contributing to the onset of endocrine and reproductive related diseases. EDCs mimic and or interfere with the body's hormonal pathways, and can further affect vital reproductive organs such as the ovary. The ovary, the female reproductive organ, is essential for the processes of steroidogenesis, the production of hormones, and folliculogenesis, the process of ovarian follicle maturation. Follicles are small, fluid-filled sacs that secrete hormones and contain immature eggs (oocytes). Matured antral follicles eventually burst to release the oocyte for fertilization. Among EDCs, parabens, a common class of preservatives and antimicrobial agents in cosmetics and pharmaceuticals, have been the subject of increasing concern due to their potential endocrine-disrupting effects. Despite its widespread use, the extent to which a member of this class, benzyl paraben (BzP), affects the reproductive system remains insufficiently studied, particularly its effects on the ovary. The goal of this study was to determine whether BzP can disrupt gene expression and impair normal hormonal pathways, thus acting as an EDC. To conduct this research, cultured mouse antral follicles were exposed to BzP in vitro over a 96-hour period. At the end of the culture period, total RNA was extracted from treated follicles to perform quantitative polymerase chain reaction (qPCR) to analyze expression of genes related to steroidogenesis, cell cycle regulation, and apoptosis (cell death). From our collected results thus far, there was a reduction in cell growth at 0.1 µg/mL of BzP, which leads us to expect an increase in apoptosis markers, such as *Bad*. We also expect decreased expression of hormone-related genes, such as *Hsd17b1* and *Cyp19a*. Using mammalian models to investigate the potential to disrupt gene expression will contribute to the urgently needed body of research on chemicals that can cause adverse health effects such as infertility, early menopause, and more. These findings will help provide important evidence that BzP functions as an endocrine disruptor and shed light on its toxic effects, supporting the need to re-evaluate its usage and safety in consumer products and strengthen regulatory guidelines.

Interactive Characters in Simulated Environments to Promote Empathy for Endangered Animals

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Abstract:
The red wolf (*Canis rufus*) is the most endangered canid in North America and is one of the most endangered canid species worldwide with fewer than twenty individuals remaining in the wild as of February 2025. Although public support for conservation exists, efforts to protect the species often fail to gain much attention or emotional investment. This project looks at how animated and interactive digital experiences can encourage empathy for endangered species by presenting their stories in a relatable and visually engaging format, whilst realistic and scientifically rigorous.

The research centers on a speaking red wolf avatar placed in a semi-natural digital environment that reflects the real-world challenges the species faces. The animated wolf communicates directly with users, sharing insights into its behavior, habitat, and the obstacles it encounters. All visual and environmental elements—such as the wolf model, animation sequences, and habitat design—are created for the animation component of the project with careful attention to realism, ensuring that the character's movements and expressions feel grounded while still being expressive enough to support communication. Information provided by Dr. Joey Hinton and Dr. Regan Downey at the Wolf Conservation Center informs both the artificial intelligence integration developed by Simon Ogorek and the design of the red wolf's visual behavior and environment.

To support this interaction, Ogorek has developed a virtual reality (VR) environment utilizing Unity game engine and large language models (LLMs), such as ChatGPT, to facilitate real-time unscripted, yet knowledge-based verbal interactions between a human player and virtual avatar. This enables guided conversations in which the avatar shares information, reacts to questions, and reinforces key wildlife conservation messages. The use of a stylized red wolf avatar, intends to create a strong emotional bridge helping to turn abstract conservation facts into a memorable personal encounter.

The experience combines storytelling, animation, and real-time interaction to assess whether such formats can improve audience empathy. Before and after the simulation, participants will complete a short survey designed to see shifts in how they think or feel about red wolves. Following this, this approach could also be used to tell the stories of other endangered species, especially in places like classrooms or museums, where an emotional connection can help make conservation feel more real.

Life on the River: Exploring Water Toxicity and Its Health Impacts

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The Passaic River is known for being one of the most polluted rivers in the country. The river's historical and current proximity to industrial corporations and sewage treatment facilities make it a frequent target of irresponsible dumping of toxic substances and combined sewer overflows (CSOs). Many residents of the communities surrounding the Passaic River experience adverse health effects as a result of being exposed to the toxic contaminants found in the river. Some contaminants found in the river, including mercury, lead, and DDT, are known to cause reproductive issues, cancer, developmental issues, weakened immune systems, and many other health problems. The EPA has been conducting cleanups for decades, based on studies focused on the sources of pollution and the many types of contaminants found in the river. However, there is still a long way to go in terms of completing cleanups at certain points of the river, performing regular reviews on the effectiveness of past cleanups, and implementing new designs and strategies to prevent pollution and continue cleanup efforts. In order to test the health of the Second River, which flows into the Passaic River, water samples will be collected at different points of the river to test for the following contaminants: PFAs, EE2, PCBs, furans, glyphosate, lead, arsenic, and DDT. Better understanding the contaminants of concern (their concentrations, their most prominent locations, and their impacts on human health) allows the contaminants to be traced back to their sources, which is important in addressing the root cause of pollution. It also allows for the development of a targeted solution, which will be addressed through a biochar water filtration system. Biochar, a form of charcoal derived from biomass, has promising adsorption properties. Using isotherms and rapid small-scale column testing (RSSCT), biochar's maximum and kinetic adsorption rates will be determined for various contaminants. The filtration apparatus will use PVC pipes and plastic disks, leaving space for biochar, which the water will flow through. Determining the contaminants of concern and understanding the effectiveness of this biochar filtration system, especially in comparison to other designs, can be useful for the EPA's upcoming cleanup initiatives by addressing causes and solutions to the pollution problem. The tested filtration systems can be scaled up and applied to the Second River and Passaic River to reduce the impact that the rivers have on human health.

Omni-directional Windmill

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Professor N.M. Ravindra
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This research seeks to improve the novel O-Wind Turbine concept's durability and efficiency for urban wind energy applications. The fundamental research topic is the application of passive magnetic bearings and magnetic transmission to lower maintenance requirements and frictional losses in omnidirectional wind turbines while preserving high energy conversion efficiency. By examining how these technologies affect mechanical performance, energy capture efficiency, and operational stability, the study will concentrate on their viability. Designing a CAD model of the modified turbine, conducting a thorough literature review on urban wind energy and friction reduction mechanisms, and running Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) simulations to evaluate wind flow and structural integrity are some of the main goals in the project. Precision machining and 3D printing will be used to create a working prototype, which will then undergo controlled wind tunnel testing to assess durability, power output, and rotational efficiency in turbulent environments. The anticipated result is a verified prototype that exhibits enhanced performance and decreased mechanical resistance, providing a workable low-maintenance wind turbine option for urban settings. The outcomes will support the development of scalable decentralized urban power integration and sustainable energy technologies.

Investigation of the Mechanism of Solar Irradiance Variations

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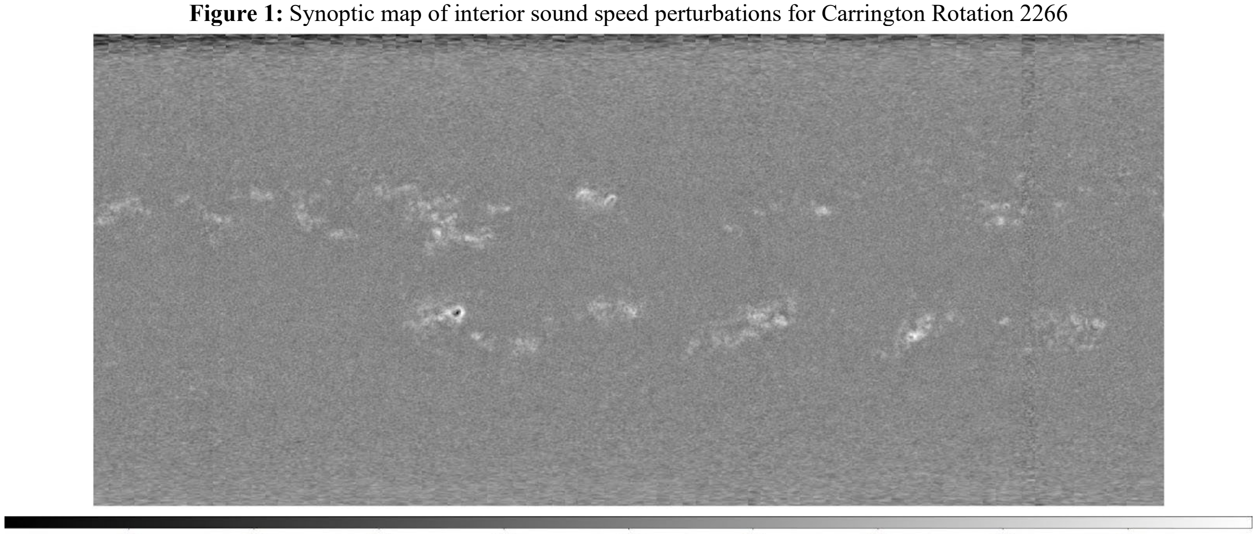
Abstract: Studies have revealed that variations in solar irradiance over the Sun's 11-year activity cycle have a significant effect on Earth's atmosphere and climate. Variations in solar irradiance are related to the dynamo-generated magnetic flux. It can inhibit irradiance in some areas, causing sunspots, or it can increase irradiance, causing faculae. However, the magnetic field also affects energy transport within the Sun, making them hidden from direct observation. As a result, current models of solar irradiance are unable to explain observed changes in solar energy output fully. The main goal is to visualize the hidden sources of these changes, which may lie within the solar interior, and analyze their connection to other solar properties, such as irradiance and the magnetic field. The data used to construct these visualizations is captured by the Helioseismic and Magnetic Imager(HMI) onboard the Solar Dynamics Observatory(SDO) satellite and is obtained through the Joint Science Operations Center(JSOC) database. These instruments enable the use of time-distance helioseismology to infer properties of the solar interior. In particular, images of interior sound speed perturbations at different depths are analyzed because they have yet to be researched and because sound speed is proportional to temperature, making them useful for understanding internal energy transport mechanisms. These images are then processed and used to construct synoptic maps and butterfly diagrams through Python libraries, such as Sunpy. The diagrams are compared to analogous diagrams of the magnetic field and irradiance to inspect for differences between them. Studying these diagrams will enhance our understanding of variations in solar irradiance, which can help us predict changes in Earth's environment. Additionally, the diagrams will be available on the JSOC database, allowing for further research into solar interior mechanisms. Future work will involve analyzing other interior solar properties, such as subsurface flows.

Figure 1: Synoptic map of interior sound speed perturbations for Carrington Rotation 2266



First Principles Study of Hydrogen Adsorption on Calcite in Shale and Its Role in Shale Softening

Nwanebu Laura Udochukwu, Supervisor: Dr Jay Meegoda, Dr Perera Duwage.
Department of Civil and Environmental Engineering.

The increasing global demand for sustainable energy solutions has positioned underground hydrogen storage (UHS) as a promising technology for managing energy supply and demand. Due to their caprock integrity and geographic abundance, shale formations are being evaluated as potential hydrogen (H_2) reservoirs. However, the long-term viability of H_2 storage in shale is contingent upon a thorough understanding of how H_2 interacts with constituent minerals, particularly calcite ($CaCO_3$), which is a common component of carbonate-rich shales. While previous studies have shown that gases like carbon dioxide weakly physisorb onto calcite surfaces, the adsorption behavior of H_2 remains insufficiently understood. Due to its low molecular weight, high diffusivity, and potential to induce charge redistribution, H_2 may significantly affect calcite's structural and mechanical stability, potentially leading to shale softening.

This research project focuses on modeling and analyzing the adsorption of molecular hydrogen on the calcite (104) surface using first-principles methods based on Density Functional Theory (DFT). The calcite(104) surface is chosen due to its thermodynamic stability and prevalence as the natural cleavage plane of calcite. The study will involve constructing a periodic slab model of calcite from crystallographic data sourced from the Materials Project database. The surface model will be visualized and prepared using VESTA software. Subsequent geometry optimizations, electronic structure calculations, and adsorption studies will be performed using Quantum ESPRESSO 7.1 as the calculation tool, employing ultrasoft pseudopotentials and a plane-wave basis set with energy cutoffs appropriate for surface simulations.

The project is organized into three phases: Weeks 1 and 2 will focus on literature review, software setup, understand and calculate the adsorption energy using a predicted theoretical model, and slab construction; Weeks 3 through 6 will involve DFT simulations, including adsorption energy calculations for hydrogen placed at multiple surface sites and various coverage levels; Weeks 7 through 10 will be dedicated to charge density analysis using the Bader method, data interpretation, and report compilation. The objective is to determine the most energetically favorable adsorption configurations, quantify the charge transfer between hydrogen and calcite, and evaluate whether adsorption leads to surface reconstruction or weakening of the crystal lattice. Outcomes from this study will inform risk assessments and design protocols for hydrogen containment in geologic formations, contributing to the broader field of clean energy infrastructure.

A Clear Window into Bird Collisions: Inexpensive Devices for Monitoring Strikes

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One billion birds die each year in the United States due to bird-window collisions (BWC), an environmental tragedy of incomprehensible proportions (Kornreich et al., 2024). The severity is highest in urban environments due to the multitude of windows (Hager et al., 2017). However, current research methodology—consisting of simply observing a bird corpse on the ground—fails to capture the majority of instances of strikes as most don't result in death, or the corpse is moved before it can be logged (Samuels et al., 2022). This method also fails to provide any additional information on the strength of the strike or its spatial location. At the New Jersey Institute of Technology (NJIT), our group in the Urban Ecology Lab (UEL) will combat this issue by developing an easy-to-deploy automated collision detector (ACD) based on inexpensive technologies like microcontrollers and MEMS accelerometers. We have developed a functional prototype and will begin testing it in Weston Hall, fine-tuning the signal processing and data-collection code.

This new ACD will enable a far more accurate dataset of BWCs in urban environments than any prior study to date. The larger goal of this proposal is to empower future studies on BWCs via a more comprehensive dataset on the frequency and nature of strikes. A goal achievable by designing this ACD for mass-production and with open source code so that anyone can build their own.

Data collected at NJIT will be used in future studies to uncover the exact qualities that cause some windows to be greater collision hazards than others, and to accurately test commonly proposed deterrence methods—a feat yet to be achieved. Our project will be pivotal in ending the mass mortality of birds not only at NJIT, but in urban environments everywhere.

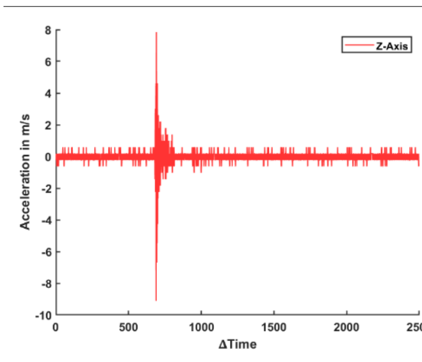

Figure 1: Mid-assembly of the ACD

Figure 2: Example of window collision using a preserved bird

Bio-Inspired Routing for Dynamic Material Transport in the Construction Industry

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Abstract: The construction industry plays a critical role in developing our modern infrastructure, yet worker productivity lags behind other industries mainly due to a lack of automation. To address inefficiencies in dynamic transport networks, I have worked on developing a novel, bio-inspired routing algorithm in the Spring 2025 semester for optimally moving buses through cities dynamically, based on passenger demand. The algorithm is inspired by the slime mold *Physarum polycephalum*, which is a single-celled organism that can use decentralized communication methods to efficiently transport its biomass to high-demand locations. To build on these findings, we aim to address the issues of inefficiency in the construction industry by producing a construction site simulation in Python over the summer. This will allow us to demonstrate the benefits of robot swarms that can dynamically navigate through complex sites. Construction sites are vastly different from city automation due to the mix of fungible and non-fungible goods, as well as the dynamic changes in the workspace. This means that significant adaptation to the simulation and algorithm will be required. This simulation will add further nuance to ongoing work by Drs. Swissler and Garnier regarding material transport in complex environments, and provide deeper insight into the broader applications of our bio-inspired algorithm.

Antiviral MXene–Laser-Induced Graphene for Composite Antiviral Air Filters

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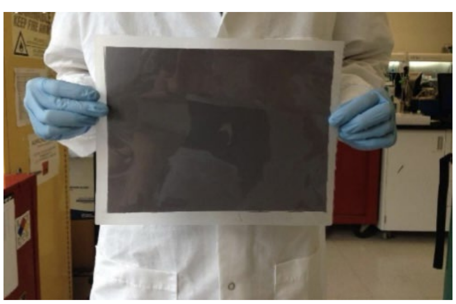
Abstract: Airborne viral transmission continues to pose serious public health challenges, especially in healthcare and densely populated indoor settings. This research focuses on developing a multifunctional air filtration system with M-Xene and laser-induced graphene (LIG) composite surface coatings on commercial air filters, aiming at capturing and potentially neutralizing viruses. The objective is to create a lightweight, conductive, and antiviral air filters that integrates two advanced materials to enhance viral particle entrapment and inactivation.

The project involves synthesizing a 2 mg/mL $Ti_3C_2T_x$ MXene solution using sonication and spray-coating it onto a porous graphene layer fabricated by laser-scribing polyimide film. The combination of MXene's 2D surface functionality and LIG's high surface area and electrical conductivity is expected to provide strong filtration capabilities. So far, we have successfully synthesized the $Ti_3C_2T_x$ MXene solution, achieved the uniform coating of M-Xenes on commercial air filters with different loadings, and evaluated the electrical conductivity of the M-Xene coated air filters. During the following weeks, we will continue to fabricate the MXene-LIG coated air filters and carry out the air filtration tests to evaluate their antiviral performance using MS2 bacteriophage as the typical viral aerosol simulation.

We anticipate that this composite will demonstrate strong antiviral potential due to the synergistic physical and photothermal effects of both materials. The long-term goal is to integrate this filter into a scalable air purification prototype for biomedical and commercial use.

a)



b)

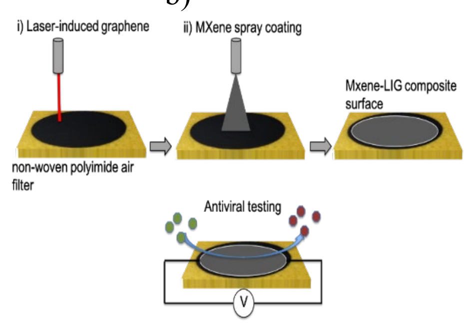


Figure a. Coated M-Xene/LIG air filter developed during the project. Figure b: Schematic showing the fabrication of MXene- LIG composite surface for antiviral air filters.

Continuous Sensing and Machine Learning Analysis of Lead Occurrence in Drinking Water

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Abstract: The leakage of lead and other heavy metals into drinking water supplies poses a significant health risk, with neurological defects especially present in children and infants. It is estimated that at least 170 million Americans were exposed to harmful lead levels in early childhood. In buildings built before 1986, corrosion of lead infrastructure is still an ongoing challenge, as seen in Newark and other cities. Difficult to detect without off-site lab equipment, it presents a need for onsite, cost-effective lead monitoring. In collaboration with engineers at the University of Michigan, we developed a simple four-electrode sensor containing only inert platinum electrodes for the real-time, continuous detection of lead and other heavy metals, such as zinc, copper, and iron, that are commonly present in contaminated drinking water. The sensors can be embedded in water service lines for long-time use until lead or other heavy metals are detected, operating on two 1.5 V batteries and drawing a small current on the order of microamps. The sensors can be fabricated at a low cost (about $.10/sensor) and are ideal for long-term use. We also developed a PCB (printed circuit board) module for transmission of sensor data, which integrates into existing infrastructure for the detection of water pH, temperature, and electrical conductivity. This work provides a path to developing machine learning techniques to correlate water quality indicators, helping further understanding of lead pollution and promote environmental sustainability.

Assessing the Effectiveness of Biochar for Sediment and Water Treatment

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Newark's long history of industrialization has led to the staggering pollution of key waterways, rendering the lower 8.3 mile stretch of the Passaic River an EPA superfund site. The Second River in Newark, NJ, a tributary to the Passaic River, is contaminated with harmful substances such as heavy metals, pesticides, herbicides, and industrial waste products. Despite past and ongoing cleanup efforts, the contaminants remain largely present, continuing to impact both environmental and human health. Communities near these rivers, often historically underserved and predominantly composed of low-income residents, may be at heightened risk of exposure, yet localized water quality data remains limited. Currently, the most prominent sediment remediation strategies are dredging and capping, which are time consuming and extremely expensive projects. In light of these challenges, researchers have begun to explore alternative solutions. An emerging method is the use of biochar, a novel and inexpensive water and sediment remediation treatment. Produced through the pyrolysis of organic biomass, biochar possesses adsorptive properties that can capture contaminants such as heavy metals and organic pollutants. While its primary application has been in soil treatment, its potential in water and sediment remediation remains underexplored and warrants further investigation to evaluate treatment in the field. This project seeks to address that gap. It assesses the health of the Second River through the collection and testing of water and sediment samples for pH levels, dissolved oxygen levels, and major contaminants to be compared against EPA health-based thresholds. These samples along with controlled factors are then treated with biochar to evaluate the efficiency of contaminant removal and immobilization, primarily aiming to propose a solution to the pollution of the Passaic River. By connecting water quality data to public health and environmental justice concerns, this research will offer insight into current risks and provide a foundation for future advocacy, infrastructure improvements, and environmental engineering solutions.

Applications of Nanobubbles in Circulating Cooling Water for Scale Prevention

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Scaling in circulating cooling water systems presents a significant challenge across industries, reducing heat transfer efficiency, increasing energy consumption, and leading to costly maintenance. Traditional chemical scale inhibitors, such as phosphonates, pose environmental risks due to toxicity and limited biodegradability. This project explores an innovative, sustainable alternative: gas nanobubbles, which exhibit long residence time, high mass transfer efficiency, and localized scouring effects that can prevent scale formation. Specifically, we will investigate the roles of CO_2 and air nanobubbles in modulating water chemistry and their impact on calcium carbonate ($CaCO_3$) precipitation.

The research will focus on three objectives: (1) generating and characterizing nanobubbles in cooling water systems, (2) evaluating the effects of CO_2/air nanobubbles on $CaCO_3$ formation under varying pH and Mg^{2+}/Ca^{2+} ratios to elucidate how the acidic CO_2 nanobubbles may slow down or prevent the alkalinity-induced precipitation of $CaCO_3$ crystals or solid, and (3) assessing nanobubble performance in a simulated cooling system to compare against conventional inhibitors. Using advanced analytical techniques, we will determine the influence of nanobubbles on nucleation, crystallization, and thermal transfer properties. This study aims to establish nanobubbles as a scalable, environmentally friendly solution for scale prevention, reducing reliance on chemical inhibitors and enhancing industrial cooling system efficiency.

Fabrication and Characterization of 2D MoS_2-based Electronic Nanosensors for Harmful Algal Bloom Monitoring

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Cyanobacterial harmful algal blooms (HABs) pose a threat to water resources across the United States due to their generation of hazardous cyanotoxins during their growth process. These cyanotoxins pollute drinking water and can cause a wide range of health problems in humans and wildlife. There is therefore a need for sensors that can effectively monitor cyanotoxin levels in water and rapidly detect new HABs. In this project, we proposed a novel 2D MoS_2-based field-effect transistor (FET) electronic nanosensor for HAB monitoring. FET devices contain source, drain, and gate electrodes, a dielectric layer, and a semiconducting channel material connecting the source and drain electrodes. Our model utilizes two-dimensional (2D) molybdenum disulfide (MoS_2) as the channel material, and a combination of an hBN intermediate layer and a pyrenebutyric acid N-hydroxysuccinimide ester (pyrene-NHS) linker to connect DNA-based probe molecules to the channel region. The adsorption of cyanotoxins to the probe molecules induces changes in the charge transport of the FET, which can be measured and compared to control conditions, thereby allowing for cyanotoxin detection. Our nanosensor will be capable of detecting three major cyanotoxins: geosmin (GSM), 2-methylisoborneol (MIB), and microcystin (MC). At this stage, we have optimized the parameters for synthesizing high-quality MoS_2 and hBN and fabricated the electrodes needed for FET device assembly. During the coming weeks, we will continue to functionalize our FET devices with DNA probe molecules and assess the sensing performance of the as-fabricated nanosensors for the detection of target cyanotoxins. We anticipate that our 2D MoS_2-based FET electronic nanosensor will accurately detect GSM, MIB, and MC in water sources, thus enabling fast, accurate, and economical real-time HAB monitoring.

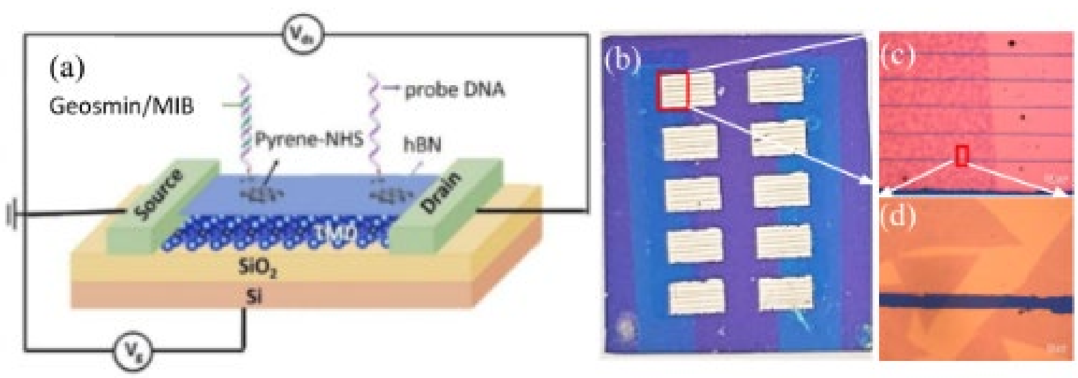

Figure 1: 2D MoS_2-based FET nanosensor for harmful algal bloom monitoring: (a) Schematic of device components. (b-d) MoS_2 and hBN applied to electrode and photographed at increasing levels of magnification.

Exploring Patterns of Pollutants in the Passaic River through a Map-Based Model

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This project aims to create an accessible computerized water pollution pattern map of the Second River, a tributary of the Passaic River that flows through Newark, NJ. Environmental contaminants in the Second River are of growing concern due to their ability to, even at low concentrations, interfere with the biotic organisms around them, including humans. There remain gaps in the research body for tailor made efforts to combat the unique contaminants along with their sources present in the Second River. This project combines historical research, water sampling, online computational resources, and detailed methods of analysis to help understand this problem.

To begin addressing this knowledge gap, this study will focus on water sampling at multiple points along the Second River. Sampling locations will be selected based on proximity to known or suspected sources of pollution. The procedures by which the water samples will be tested will depend on the specific contaminants meant to be examined. After testing, a detailed analysis will be conducted to understand the implications for such levels found. In conjunction to this, the data found will be geographically mapped, incorporating the sample results and photos of the location at which the sampling was done, modeled after Google Street View.

There is great importance in mapping how these pollutants appear and vary along the course of the Second River. The research conducted in this study will contribute to a broader understanding of how contaminants move through the river. That, along with photographs showcasing where water sampling was conducted will provide a unique and innovative on the ground view of the Second River. These efforts will help showcase a clearer picture as to where intervention may be most needed, helping save time and money and allowing for efforts to be as effective as possible. The ultimate goal of this research project is to lay the groundwork for future water remediation strategies tailor made for the Second River to better its ecosystem and surrounding community, which will in turn help the greater Passaic River as well.

User-Centered Design for Reducing Food Waste in University Dining Halls

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University dining halls are designed to serve students by offering convenient access to nutritious and satisfying meals. Despite this intent, they frequently present design-related challenges—such as overwhelming food choices, irregular portion cues, limited dietary accommodations, and operational inefficiencies—that inadvertently contribute to excessive food waste. Traditional food waste interventions, including tray removal, reduced plate sizes, and educational campaigns, typically place responsibility for waste reduction onto students. Although these approaches show moderate effectiveness, they often lead to dissatisfaction and fail to sustainably engage students. Recognizing these limitations, this research project frames food waste as primarily a service design problem rather than a behavioral one.

This project aims to improve food waste outcomes by applying human-centered design principles, as articulated by Don Norman in "The Design of Everyday Things," to the dining hall context. A comprehensive literature review was initially conducted to understand the intended functions of university dining services and identify common points of failure in supporting sustainable student behavior. Subsequently, the New Jersey Institute of Technology (NJIT) dining hall was selected as a case study for in-depth analysis. Interviews and guided observations were conducted with dining hall staff and students to map existing pain points and system inefficiencies. These qualitative insights guided the iterative design and development of a low-fidelity prototype of a user-facing interface aimed at intuitively supporting appropriate portion selection and improved meal planning.

The anticipated outcome of this research is a validated, user-centered prototype that significantly reduces cognitive and operational barriers contributing to food waste. Preliminary usability testing and feedback sessions will inform ongoing refinements. Ultimately, future research will measure the effectiveness of this prototype through food waste audits comparing pre- and post-intervention conditions during the academic year. This project underscores the necessity of shifting the burden of sustainable practice from students to better-designed dining experiences. The findings will have broader implications for universities across America, potentially informing scalable interventions to combat the 7.2 billion pounds of food waste produced annually by students across American university campuses.

An Analysis of Historical Development and Perspectives of the Lower Passaic River

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The Lower Passaic River has seen increasing levels of urbanization and development in the Newark area over hundreds of years. Following this, the river has been subject to extremely high levels of contamination and pollution, creating one of the greatest health risks in the United States for the populations surrounding it. The river has been studied extensively from a scientific approach but rarely from a sociological and historical one. By integrating the historical, cultural, and environmental relationships between the Passaic River and its surrounding populations throughout its development, context can be provided for new policy. Current studies of the Passaic River are incomplete without the lived experiences of Native tribes, which can be crucial to understanding how to successfully steward the restoration of native lands. Therefore, the Lenni-Lenape tribe will be integrated into a novel environmental and historical view of the river. Additionally, this study explores the contemporary public perceptions of the river's pollution in riverside neighborhoods to inform future environmental solutions. Survey topics include concerns about current and future environmental policies, public use values of the river, and knowledge of the river's pollution. Using a literature analysis of Native and industrial histories as well as interviews with the Nanticoke Lenni-Lenape Nation, a general timeline and map of the river's social and environmental history will be created. Accompanying this will include a public opinion brief discussing the results of the neighborhood surveys and how knowledge gained from Lenni-Lenape interviews connect with them. Through this approach, a novel methodology will be developed for implementation in future environmental projects.

Standardizing Historical Ca II K Spectroheliograph Images from the Kodaikanal Solar Observatory for Solar irradiance Analysis with Machine Learning

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Abstract: Historical Ca II K spectroheliograms from the Kodaikanal Solar Observatory (KSO) are valuable for studying long-term solar activity but suffer from inconsistencies that limit their scientific utility. EUV irradiance data is only available for around two decades, which is not enough to study its long-term effects on Earth and space weather. This project addresses the need to standardize these images for accurate analysis and enable machine learning-based reconstruction of historical extreme ultraviolet (EUV) irradiance.
Extending EUV irradiance records beyond the satellite era is essential for understanding long-term solar variability and its effects on space weather. The primary goals include preprocessing the data, evaluating the preprocessed results, inputting the preprocessed data into SemNet (a deep learning model trained on modern PSPT data) to produce synthetic EUV irradiance, and evaluating the output from that model.
The preprocessing pipeline includes normalization, contrast correction, and correction of limb darkening. To validate the integrity of the preprocessed data, we generate scatter plots, histograms, and butterfly diagrams, and calculate pearson correlation coefficients between the raw and preprocessed data to confirm that the integrity of the data has been maintained through preprocessing. Once validated the preprocessed data will be used as input to the SemNet model, a deep learning framework that is trained on modern PSPT data, to predict synthetic EUV irradiance across solar cycles.
This project contributes to improving the scientific useability of historical Cal II K spectroheliograms to expand the study on EUV irradiance past the satellite era to reconstruct synthetic EUV irradiance using machine learning. Future work includes expanding the pipeline to other solar archives and refining model accuracies.

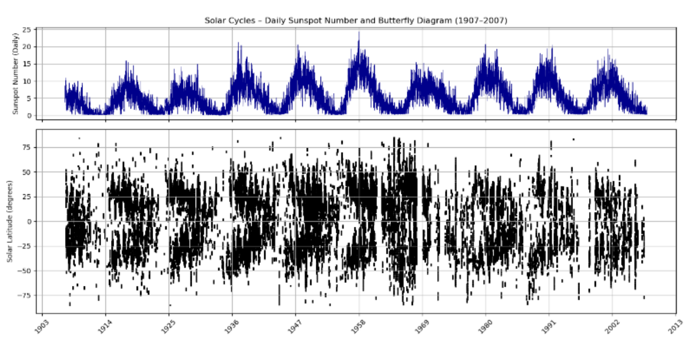

Figure 1: Butterfly diagram showing the latitudinal distribution of sunspots detected from preprocessed Ca II K images. This visualization confirms the temporal and spatial consistency of the standardized data and supports its scientific integrity for modeling long-term solar activity.

Construction of an Anaerobic Biodigester Prototype

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According to the US Environmental Protection Agency, over half of greenhouse gas emissions from landfills come from food waste. To address this issue, common approaches include incinerating or composting the food waste. Incineration recovers energy, but not nutrients, and composting recovers nutrients, but not energy. However, in order to recover both, there's another option: anaerobic digestion recovers energy through the production of biogas and nutrients from the resulting digestate. Biogas can be burned as a form of renewable energy and turns methane that would otherwise escape from landfills to the atmosphere into a less potent greenhouse gas, carbon dioxide. Because of the nutrients in the digestate, it can be used as soil amendments, fertilizer, or livestock bedding. The mechanism to take advantage of this form of digestion is called an anaerobic biodigester.

Incorporating this technology into NJIT will allow the college to save money, reduce emissions from waste transportation, and increase the percentage of renewable energy used on campus. Looking at existing options, most anaerobic biodigesters are either very large scale or specialized to specific industry waste products and do not accept outside material. Some companies offer small scale biodigesters that NJIT could buy, but starting the design from scratch allows us to integrate the latest research from the field and ensure it will seamlessly incorporate into existing systems. The primary goal is to develop a functional prototype by the end of summer 2025 to incorporate into the faculty dining hall in fall 2025. While there is no fixed target for the methane output of this prototype, the system will be optimized for production during the design and testing stages. An energy balance for the system will also be completed to estimate the methane and energy production from full operation. Testing will be conducted using food waste collected from NJIT's summer Educational Opportunity Program, which will be stored inside at room temperature in covered plastic bins. Future research can use the information that will be collected in the fall to work on further refining the prototype design to make it more efficient, more automated, and have a smaller physical footprint. In the long term, additional systems can be developed to process food waste from the main NJIT dining hall and be integrated into daily operations, with the aim of processing the majority of the university's food waste by 2028.

Establishing Anthropogenic and Other Site Contexts for the Effective Implementation of Built Interventions on the Second River

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Abstract: The Second River is a tributary of the Passaic River flowing through the north end of Branch Brook Park in the city of Newark. The Passaic itself carries a number of broad environmental concerns, namely soil and water contamination from industrial-era pollutants, as well as flood risks. Within the Passaic River Basin, this impacts the some 2.5 million people and 20,000 residential, industrial, retail, commercial and office properties that are located there. Likewise, the smaller microcosm of the Second River sees a similar dynamic between the surrounding local community and the river, one whose critical analysis as a case study in this project can beget both immediate benefit for the local community and longer-term frameworks for cleanup and development efforts on the larger Passaic River. Previous such endeavours have focused on other stretches of the Passaic, and related projects have addressed similar notions of community-riverfront revitalization, but there has not been an explicit analysis of the Second River area.

Accordingly, this project seeks to determine the relevant anthropological, environmental, and municipal site contexts of the Second River area that may inform the needs that the future service-learning ENGR 493H course and others will work to address. It then also aims to qualify how and where solutions should be implemented to be most effective and cognizant of these factors. In order to accomplish this, the project will review a mix of background municipal, community, and literature documentation surrounding this site, and conduct site visits and assessments of existing site conditions. Further, this project will coordinate with local community organizations, stakeholders, and residents to understand their needs and concerns, as well as incorporate analysis of similar past riverfront projects as precedents.

This initial site-contextual assessment will inform future efforts to address the dynamic between community and environmental stakeholders and the Second River as well as the Passaic. These range from the ENG 493H course's further investigation of designing and deploying relevant engineering solutions, to community group advocacy, City of Newark redevelopment plans, and federal cleanup efforts. Additionally, expansion of the findings and approaches of the project may in turn serve broader ventures, from community and environmentally-conscientious private riverfront development to municipal public use and infrastructural improvement initiatives. As potentially vital arterial components of global cities in an increasingly environmentally-charged era concerned with livability, pollution, urban heat effects, flooding, and sustainability, rivers become a key point to address in the greater urban planning schema. Each step to more vibrant and effective riverfront communities in turn informs more successful city / urban developments on the global scale.

Biochar Water Remediation

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Abstract. Water pollution is a major problem in the United States. Roughly 20% of Americans, 68.4 billion, drink water that contains "forever" chemicals, such as atrazine, glyphosate, metolachlor, furan, PCBs, and PFAS, which take hundreds, if not thousands of years to break down, as seen in the Passaic River. The best way to remove contaminants is through water remediation, or filtration. Activated carbon has been extensively studied and shows promising adsorption capabilities, but is very expensive, and many communities with water pollution, including those along the Passaic, cannot afford it. A possible remediation alternative is biochar, which can be readily formed through the pyrolysis of organic material, and is much cheaper than activated carbon. Many studies focus on the mechanisms of biochar adsorption, but do not reveal its capacity for remediation of specific contaminants. This research will investigate the adsorption capabilities of biochar for a variety of common contaminants in order to evaluate its cost effectiveness as an alternative water remediator and how it can be applied to the Passaic River. To achieve this, Langmuir isotherms and RSSCTs were used to evaluate the potential and kinetic adsorption properties of biochar, respectively. The isotherms were conducted with a stirring plate at room temperature with varying concentrations, with adsorption capacities being compared. The average for glyphosate (Roundup) was $3g*g^{-1}$, removing up to 74% of the glyphosate from the lightly contaminated samples. RSSCTs were carried out under the same conditions using a water pump and filtration column with parameters from Poddar et al. By understanding the adsorption capabilities of biochar, we can harness them for water remediation, using it to clean rivers, lakes, and groundwater reservoirs, increasing the availability of clean water.

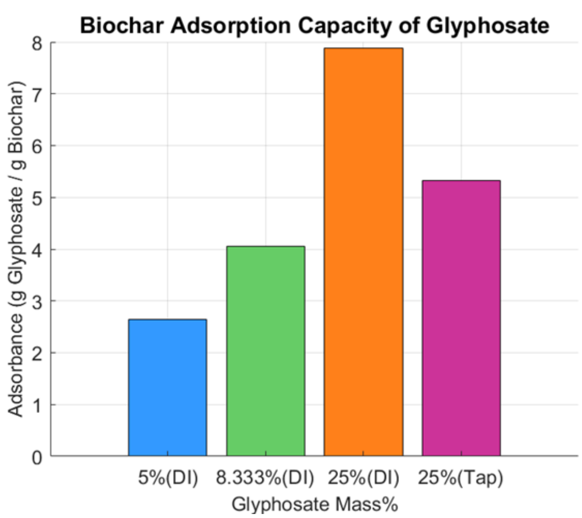

Figure 1: The adsorption capacity of 5g samples of biochar in different water/glyphosate mixtures, measured in g/g.

Developing Policy Solutions for the Passaic River Pollution: Synthesizing Health Research, Community Advocacy, and Legal Principles

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The Passaic River is recognized as one of the most polluted rivers in the entire nation. It is an 80-mile-long river that flows through Morris, Somerset, Union, Essex, Passaic, Bergen, and Hudson counties in New Jersey. The pollution in the river has various impacts, including health risks for humans, especially vulnerable populations like older adults, pregnant women, and young children. Cancer, developmental and neurological effects, and immune system damage are some of the detrimental health risks caused by the pollution in the river; these health risks can significantly affect the quality of life of those affected by them. Several efforts and legislation have been underway to reduce the pollution in the river, one of which is the "Lower Passaic River Restoration Project," which aims to address the contamination in the lower 8.3 miles of the river using various methods; however, this effort is expensive, is still in the design and implementation phases, and can take several years to fully function. In order to prevent the mass health destruction of the people, stronger legislation and legal efforts must be advocated for, which leads to clean-up efforts to take place efficiently. By reviewing several journals and research articles about the health impacts caused by the contaminants in the Passaic River, and gaining first-hand insight from talking to community members who live near the river, this project aims to compile the research regarding the health impacts from the river along with the community insights into a comprehensive policy brief, which will be delivered to lawmakers and organizations. The goal of the project is to influence the policy-making process and the development of future legislation that works towards addressing the health risks caused by contamination in the Passaic River in an efficient manner.

Artificial Intelligence, Machine Intelligence and Robotics

Automating Silicon Photonic Circuit Design Using Large Language Models

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Abstract: The recent advancements in Large Language Models (LLMs) have enabled significant breakthroughs in the automated generation of text, code, images, and even electronic circuit design. Despite these successes, the application of LLMs in the generation of Photonic Integrated Circuit (PIC) design remains largely unexplored. The manual design of PICs is labor-intensive, repetitive, time-consuming, and highly susceptible to human error, thus, highlighting a strong need for automation in this domain. For this reason, our research aims at leveraging the promising capabilities of LLMs to automate the generation of PIC netlists, thereby reducing design time, improving reliability, and streamlining scalability. In order to automate PIC netlist generation, we are developing a framework that integrates three key components: (i) the construction of a diverse dataset of PIC netlists for LLM training and testing, (ii) the use of photonic circuit simulators to test the syntactic validity and functional performance of generated designs, and (iii) the implementation of an optimization pipeline to refine circuit outputs. We are investigating dataset generation via prompt engineering and Retrieval-Augmented Generation (RAG) techniques, while simulators such as SAX (based on the JAX framework) and PhotonTorch (based on PyTorch) are being explored for their compatibility with automated testing and optimization workflows. We anticipate that this approach will demonstrate the potential of LLMs to produce syntactically correct and functionally viable and optimized photonic circuit designs. Future work will involve scaling the dataset, refining prompt strategies, and benchmarking performance across different LLM architectures to evaluate robustness, efficiency, and creativity in circuit generation.

Defending Latent Space Jailbreaking Attacks in Large Language Models

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The rapid development of Large Language Models (LLMs) has revolutionized content generation, yet it brings critical security challenges, particularly in safeguarding user data and proprietary prompts. A major concern is the potential for cloud-based service providers to observe client inputs and generate sensitive code, posing threats to intellectual property. To address this, our research investigates the detection of jailbreaking prompts, malicious inputs designed to bypass LLM safety protocols. Specifically, we train a classifier within the latent space of an autoencoder to differentiate between adversarial and benign prompts. Our methodology includes building a carefully curated dataset, employing adversarial training to boost model robustness, experimenting with padding strategies, and testing multi-block classification. We also explore a novel direction: using one LLM to evaluate and classify the outputs of another. While grounded in the theoretical foundation of adversarial robustness in NLP, this project also presents practical implications. Our findings could inform the development of more secure generative AI systems, with scalable applications across industries that rely on proprietary or sensitive prompt inputs, such as healthcare, finance, and enterprise software. Ultimately, this research contributes to academic understanding and real-world tools for enhancing trust, compliance, and safety in LLM deployments.

Development of an Assistive Ankle Exoskeleton for Enhanced Mobility and Rehabilitation

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Abstract:

This proposal presents an enhancement to a previously developed ankle exoskeleton system, originally designed by a prior capstone team, with the goal of improving user mobility by reducing the metabolic energy cost of walking. The improved design maintains the core function of providing assistive plantarflexion torque during the push-off phase of gait, but introduces a more secure and stable foot shell to better interface with the user's shoe. Rather than using an insole or one-size-fits-all approach, this enhanced version employs a detachable, external foot shell that fits a range of standard shoe sizes and wraps around the outside of the foot. This adjustment improves load transmission and user comfort while preserving the lightweight, minimally invasive nature of the system. An external torque motor continues to serve as the actuator, positioned to minimize distal weight and maximize torque effectiveness. Simulation-based control and ergonomic refinements ensure better fit and responsiveness. A biologically inspired control strategy remains integral to the system, synchronizing actuator output with the user's natural gait cycle for seamless biomechanical integration. By combining improved foot securement with established control methods, this enhanced ankle exoskeleton supports more stable walking assistance, better adaptability to uneven surfaces, and improved rehabilitation potential. The project demonstrates a cost-effective, wearable robotic solution aimed at promoting functional independence and mobility for users requiring ankle assistance.

Towards achieving safe LLM through rectified penalty using RLHF

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Abstract: Large Language Models (LLMs) have revolutionized the way we approach tasks such as writing, programming, and general knowledge generation. Their ability to understand and generate human-like text has enabled a wide range of applications across industries, education, and research. However, as these models become more integrated into everyday tools and decision-making systems, ensuring their safety and reliability becomes critically important.
One of the most pressing concerns is the susceptibility of LLMs to jailbreaking prompts—carefully crafted adversarial inputs that can manipulate the model into producing unsafe, biased, or otherwise harmful outputs. These vulnerabilities not only pose ethical and societal risks but also hinder the adoption of LLMs in sensitive domains such as healthcare, law, and education. In this project, we aim to build a safer and more robust LLM by leveraging Reinforcement Learning from Human Feedback (RLHF) within a constrained reinforcement learning framework. Unlike traditional approaches that focus solely on optimizing helpfulness or informativeness, our method explicitly incorporates safety constraints by treating harmful behavior as a measurable cost. To guide the model's learning process, we introduce a rectified penalty-based mechanism that penalizes unsafe outputs while still encouraging useful, high-quality responses.
Anticipated Goals: The primary goal is to design and evaluate a fine-tuned LLM that consistently produces helpful and safe responses, even when faced with jailbreaking prompts. Our method aims to outperform current state-of-the-art safety-tuning techniques.
I will be responsible for:
1. Conducting a comprehensive review of relevant literature to inform the design;
2. Implementing the fine-tuning process for the LLM using constrained RLHF;
3. Developing a dataset of prompts, including curated jailbreaking examples and their expected safe responses;
4. Evaluating model performance and iterating based on results.
Future work: The future work will aim to make the model adaptable to the ever-changing jail-breaking prompts and test it on a broader database.

Utilizing Artificial Intelligence for Calibration-Free Predictions in Electrochemical Breath Sensors for Cancer Diagnostics

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Abstract: Lung cancer was the leading cause of cancer-related mortality worldwide, responsible for over 1.8 million deaths annually. Early detection dramatically improved survival rates, yet current diagnostic tools remained invasive, costly, and inaccessible for routine screening. Volatile organic compounds (VOCs) in exhaled breath are promising non-invasive biomarkers of lung cancer, but detection methods such as gas chromatography–mass spectrometry (GC-MS) rely on centralized laboratory infrastructure, making them unsuitable for point-of-care (POC) use. This project builds on the development of a portable electrochemical sensing platform for real-time VOC detection. The prototype consists of three main components: a microfluidic sensor chip, a computer-controlled system for signal acquisition and interpretation, and a Machine Learning (ML) driven data analysis pipeline. The prototype functions as the physical interface that houses the chip and enables the readout and interpretation of sensor data through an integrated electrochemical setup. To ensure reliable performance across real-world conditions, an artificial intelligence (AI) model based on multilayer perceptron (MLP) regression model is developed to interpret complex electrochemical impedance spectroscopy (EIS) data. The model is designed to account for variability introduced by different sensor calibrations and environmental noise, improving generalizability and diagnostic accuracy. Simulated EIS data, incorporating noise and error, was used to pre-train and test the system. Other models, such as convolutional neural networks (CNNs), were also evaluated for their ability to make these predictions. By enabling fast, non-invasive detection of breath-based biomarkers without relying on centralized laboratories, this work advances a scalable platform for early-stage lung cancer diagnostics and sets the foundation for broader applications in respiratory and metabolic disease screening. Future work may focus on validating the system with clinical breath samples and further improving model robustness and diagnostic accuracy across diverse environmental conditions.

Deep Neural Network Adaptation For Photonic Hardware

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[2]Department of Electrical and Computer Engineering, New Jersey Institute of Technology, Newark NJ 07102

Abstract: Transformer architectures, neural networks that excel at understanding relationships in data, underpin the modern AI revolution and dominate computer vision benchmarks through Vision Transformers (ViTs). Unfortunately, their intensive compute requirements confine real-time inference to energy-hungry data centers. Photonic acceleration offers a promising solution for edge deployment, using light for low-power, faster computation of the extensive mathematical operations required in deep learning models. Yet current optical ViT prototypes forfeit much of this advantage due to complex nonlinear operations that cannot be performed optically, forcing costly conversions between optical and electronic domains with each conversion consuming 10-100× more energy than the optical computation itself. Recent studies show that replacing these nonlinear operations with simpler operators and retraining using knowledge distillation (KD) , where a simpler model learns from a complex teacher model, can recover accuracy with minimal performance loss. Existing optical implementations, however, only offload linear operations to optics, still routing each layer through extensive conversions to achieve nonlinearity.

To address these limitations, we introduce AffineViT: The first ViT architecture whose entire prediction pipeline consists exclusively of simple linear transformations that map directly onto photonic hardware as efficient operations. AffineViT eliminates conversion bottlenecks through four innovations: i) Linearized self-attention that processes and compares image parts without requiring softmax normalization, ii) Simplified feed-forward networks where multi-layer structures collapse into single linear transformations, iii) Minimal conversion architecture that confines nonlinear operations to electronic boundaries, preprocessing before optical entry and classifying after optical exit, requiring only single conversions while keeping intensive operations in the photonic domain, and iv) Multi-objective KD that transfers understanding from teacher to student models through logit matching, attention transfer, and feature alignment.

We anticipate that AffineViT will reduce electronic-optic conversions from ~200 to just 2 per inference, cut total operations and parameters through architectural simplification, slash energy and latency substantially relative to reported optical ViTs, and maintain accuracy within 5 percentage points of traditional baselines. AffineViT marks a decisive step toward truly end-to-end optical vision models, enabling low-power, high-throughput AI inference on edge devices like smartphones, drones, and IoT systems.

Enhancing Forensic Science Education Through XR

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Advisors: Dr. Margarita Vinnikov[2], Dr. Kevin Parmelee[3], Professor David Fisher[3]

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2. Department of Informatics
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Crime scene investigation (CSI) is a crucial part of university-level forensic science curricula. It is through CSI training that future forensic scientists learn to document and categorize evidence, operate equipment, and communicate their results and findings, but traditional in-person training sessions can be costly in terms of time, money, and laboratory space. Physical crime scenes can only be explored by one or a small group of users at a time and may present accessibility barriers for students with specific educational needs, limiting the opportunity for individual student growth and learning. Using Unity, a game development engine, we are building upon a virtual reality (VR) program called CSIxR, in which students can traverse a digital crime scene, collect and analyze evidence, and hone their investigative skills. By creating virtual versions of these crime scenes, students and teachers can revisit and customize these scenes an indefinite number of times, allowing students to practice CSI at their own pace. Users with limited mobility can still access and move around the VR application using a headset and controllers. Using a preexisting complimentary application, teachers can easily populate the crime scene with different types of evidence to simulate various scenarios. Virtual assets, such as fingerprints, bloodstains, and other pieces of evidence will be created to diversify current data sets and increase the number of options that educators will have to customize the scene to their discretion. To accomplish this, we will first communicate with faculty members of the forensic science department at NJIT to get a better understanding of what assets are needed. Then, we will employ artificial intelligence tools like ChatGPT, Gemini, and Grok to generate the necessary crime scene elements. In addition to increasing dataset variability, our goal is to improve the user interface and functionality of CSIxR through Unity development to give students and educators a smoother learning experience. We expect to increase the variability and usability of the CSIxR platform and to make it an effective tool for teaching and learning crime scene investigation for the future use of NJIT forensic science students.

Embracing the Empirical Advantages of AI-Driven Motion Capture

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Abstract

Artificial intelligence is rapidly integrating itself into the design world. With this development comes the question of balance between two practices – using AI as a replacement versus using it as a tool. With the exponential improvement of AI systems' ability to recognize human patterns of movement, body tracking technology is constantly perfecting itself. The recent emergence of AI-driven markerless motion capture (Mocap) technology, such as Autodesk's brand new Flow Studio (formerly known as Wonder Studio), allows greater creative possibilities, workflow efficiencies, and cost reduction for the production process. Users can process live-action footage through Autodesk Flow Studio and quickly generate 3D Mocap data. Tight budgets and time constraints are often obstacles to utilizing standard Mocap technology, especially in educational settings such as NJIT's Digital Design studios, making this innovation groundbreaking for the average user. However, compared to traditional Mocap platforms, there is little existing scholarship on this particular technology, which only emphasizes the need for this research. I will be experimenting with optimal workflows and best practices for this cutting-edge technology to evaluate how it could scale within NJIT's animation-focused Digital Design curriculum. I will then test and apply this research to the initial stages of a larger project, *Smiõr*, an NJIT-produced animated short film with screenplay and creative direction by Associate Professor Richard Thompson.

Automation in Plumbing: Kinematics and Leak Detection

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Abstract: Water leaks in residential homes occur often, leading to water waste and costly repairs for the homeowner. Many water leaks originate behind walls, making the source of the leak difficult to find and costly to repair. In many cases, finding the source of a leak requires extensive removal of drywall leading to many holes in the walls and ceilings of the home. This, in turn, leads to an even higher cost of repair for the customer. It is estimated that water leaks cost homeowners in the United States a collective $34.30 billion dollars annually (IPManagement, 2025). A leak detection tool that minimizes damage done to the home during a leak repair could save homeowners hundreds or thousands of dollars per repair. This research project aims to create a user-friendly leak detection tool using robotics and automation that minimizes the need for home deconstruction and will enable the plumbers or homeowners to detect and repair the leak. The two goals of this project are as follows:

1. Create a small, compact design that will traverse the outer diameter of a 0.75 inch copper pipe.
2. Equip this kinematic design with a leak detection system that will communicate the location of the leak to the user.

To achieve the goal of a small and compact design that will traverse the pipe, the robot will utilize a combination of a rack and pinion mechanism and two clamp mechanisms. The rack and pinion will facilitate the movement of the robot as the clamps stabilize the mechanism. The movement will be similar to that of an inchworm. Creating a mechanism that traverses the outer diameter of a pipe is novel, and could serve as inspiration for other use cases. The second goal will be achieved by developing a control system that will detect moisture and determine the most likely location of the leak based on the concentration of water in all areas of the pipe. This system will be able to communicate the location determined by the system in a user friendly manner.

Expedited Virtual Film Production: Enhancing Real-Time Feedback and Immersive Interaction with an emerging AI Tool

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As AI technology continues to evolve, its applications expedite many laborious or costly processes across many industries, and offer new opportunities to streamline workflows. In film and animation studios, machine learning tools are being considered for potential use in the storyboarding and visualization process for upcoming projects. On a larger scale, further research seeks to combine virtual production techniques with AI tools by developing a comprehensive framework to maximize efficiency and preserve creativity. As such, current students in design-based fields must gain experience with these latest advancements in order to further their careers.

This study will explore the efficiency, usability, and potential impact of Autodesk's AI-driven Wonder Animation platform (still in beta) in academic and professional settings. Wonder Animation promises to create 3D scenes from video "shoot a scene with any camera, in any location, and turn the sequence into an animated scene with CG characters in a 3D environment." With this technology, students and independent users would be able to complete some of the more technical and intensive processes more efficiently, and hone in on their creativity.

Evaluating Sensor Configurations for Human Activity Recognition Using Machine Learning

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Developing accurate models that can recognize daily human movements and actions is significant in fields of rehabilitation, robotics, and assistive technology, where systems must be able to classify and monitor physical activity with high accuracy. Previous studies demonstrate a limited understanding of the relationship between sensor count, sensor placement, and classification accuracy. This research aims to understand the relationship between the quantity of sensors and precision of models, investigating how many sensors are required to accurately recognize and characterize different human actions. Understanding the minimal viable sensor configuration and identifying which body placement contributes most to accurate classification can be used to increase data efficiency and increase comfort for users. This project will be explored in two phases: data collection and model development. Data collection includes collecting a dataset of ten human actions, such as picking up an object or placing an object on a surface, obtained through SparkFun OpenLog Artemis IMU sensors. Sensors will be worn by a participant to emulate body parts, specifically on hands, upper arms, torso, and head. The second phase involves developing robust machine learning models to recognize and classify the human motions through classification algorithms, such as support vector machines and decision trees, and using the collected data for training, testing, and validating. Model performance will be assessed on accuracy, evaluating the quantity of sensors required and their correlation, which can contribute to developing more efficient and user-comfortable recognition systems.

Time Series Forecasting with Large Language Models

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Time series forecasting is an important challenge across various scientific and industrial disciplines such as finance, healthcare, and climate. Such tasks involve analyzing data with complex temporal dependencies, structural variability, and seasonal trends usually under conditions of uncertainty and noise. Traditional approaches, like autoregressive statistical models and rule-based systems often fail to capture the intricate, nonlinear dynamics involved in real-world time series data, especially when applied at scale.

Recently, large language models (LLMs), which were originally developed for natural language processing tasks, have shown great potential beyond their initial use. LLMs have an incredible ability to capture complex patterns, contextual relationships, and long-term dependencies in textual data, making them a promising approach in processing time-series data. The key problem in adapting LLMs for time series forecasting lies in the ability to align the languages used for LLMs with the numerical nature of time series signals.

Recent progress has addressed this issue by developing ways to feed numerical time-series data into forms that LLMs can naturally interpret. Such strategies include tokenization, embedding, and prompt engineering that aim to reframe time series data into structural texts or symbolic sequences. This process is called modality reprogramming, and it enables LLMs to process temporal data without requiring retraining for domain specific time series tasks.

This project will investigate the capabilities of LLMs for time series forecasting with a focus on performance benchmarking and reproduction of results. One LLM we will use is TimeLLM, an architecture that reprograms frozen LLMs for forecasting tasks without needing to retrain the LLM from scratch. TimeLLM uses the pre trained capacity of large language models by inputting temporal data into their existing architecture using prompt and embedding strategies. This approach enables the reuse of powerful LLMs in the time series without the need for extensive parameter tuning and specialized training pipelines.

We aim to evaluate TimeLLM on publicly available time series datasets by utilizing the official inference pipelines provided in the TimeLLM repository. We will evaluate benchmark performance using common regression metrics, such as the mean average error (MAE), the root mean squared error (RMSE) and R-squared, with a focus in short and long horizon forecasting accuracy. We aim to understand the generalization behavior of LLMs in structured prediction tasks by reproducing and analyzing reported results.

This work contributes to a growing body of research that reimagines LLMs as not only tools for natural text processing, but as general-purpose predictors across modalities. By using frameworks that isolate the use of LLMs for time-series forecasting, this project provides insight into their limitations, strengths, and potential for replacing or complementing traditional time series forecasting methods.

Optimization and Characterization of Low Power In-Memory Computing Devices

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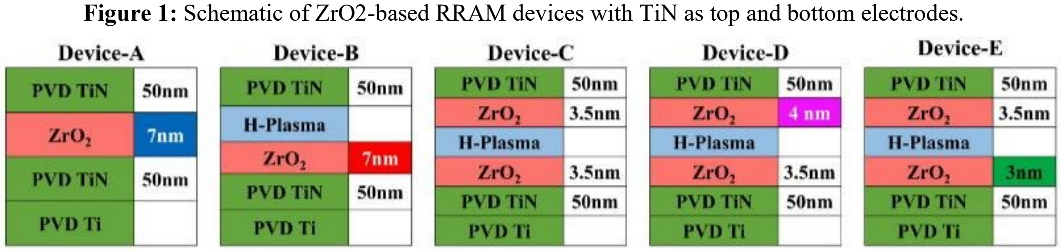
Abstract: Modern computing systems demand memory technologies that are both energy efficient and scalable. Resistive Random Access Memory (RRAM) and Metal-Insulator-Metal (MIM) devices present an alternative to the conventional von Neumann architecture where the memory and central processing units are separate. In MIM devices, both of these units exist and communicate in the same space, causing a potential for high-speed, low-power, and non-volatile operation. The significance of this work lies in its potential to improve device stability and reliability in next-generation memory systems. Our research focuses on these MIM RRAM devices utilizing zirconium dioxide (ZrO_2) as the active switching dielectric layer due to its simple structure and CMOS compatibility and titanium nitride (TiN) as the metal electrodes because it is a good oxygen reservoir. We aim to evaluate and improve the characteristics of these devices by exploring structural variations and pulse testing protocols. As we conduct this project, we assess different ZrO_2 based configurations, such as 3.5 nm ZrO_2 / H-plasma treatment / 4 nm ZrO_2, and evaluate how these different configurations affect endurance performance under repeated switching conditions. Each device undergoes an initial forming process, wherein an electric field is applied across the MIM device to induce resistive switching. This is applied slowly in order to prevent a hard breakdown and encourage a soft breakdown. The applied electric field drives oxygen ions toward the top electrode while the bottom electrode remains grounded, resulting in the formation of oxygen vacancies within the dielectric layer. These vacancies create conductive paths that enable the device to switch between high and low resistance states. Following successful forming, we conduct endurance testing via a series of pulse operations. We apply repeated voltage pulses of varying pulse widths (i.e. 2 µs, 10 µs) across the device. The resulting resistance state transitions between set and reset tests are monitored across ~10,000 cycles to evaluate device degradation or device failure. Ideally the resulting resistance states form an increasing staircase pattern in graphical outputs, reflecting stable switching in a device. We expect that certain structure modifications, specifically those involving oxide thickness, will yield improved endurance and switching consistency. We also believe that by changing the parameters for the pulse operations, specifically the pulse widths and the applied voltage, we will be able to see what constraints push the limits for the different devices. This research will inform the design of more robust RRAM devices and guide future fabrication and application strategies for in-memory computing.

Figure 1: Schematic of ZrO2-based RRAM devices with TiN as top and bottom electrodes.



Predictive model of the spread of the spotted lanternfly in the continental United States using machine learning

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The introduction of the spotted lanternfly (*Lycorma delicatula*) to the continental United States in 2014 caused statistically significant agricultural losses annually due to the insect's parasitism of plants grown for food, timber, paper, and ornament. Two major aspects of the spotted lanternfly make the species one of the fastest-spreading foreign insect invasions: (1) the variety of plants that *L. delicatula* parasitizes and (2) their capacity to use land vehicles to rapidly disperse over long distances. Predicting where spotted lanternflies will travel next and where they are most likely to cause significant damage is vital to the economy. Machine learning techniques are already used to predict the diffusion of invasive species around the world, and this project aims to use machine learning to classify the risk of plant damage caused by spotted lanternflies per county and state. Pre-existing Python libraries helped create these decision tree ensembles and neural networks following training, validation, and testing. All models made in this project are intended to predict a general attack risk (to a county or state in the continental United States over the year of 2025 and 2026) or specific risk to all plants grown for the same purpose. Each model uses predictors like local climatological factors, the abundance of predators and host plants, and the high-speed land traffic in each area. The target classes are integers correlated with increasing risk of *L. delicatula* damaging the plants in the area. The predictors selected for each model in design will be limited in later iterations of each model because not all aspects of climate, ecology, and traffic should improve model accuracy and prevent overfitting. "Final" models, data, and additional commentary will be made available on a public repository. The results will help inform U.S. residents of the high damage potential of *L. delicatula* and allow agricultural managers to make informed decisions for the end of 2025 and the year 2026.

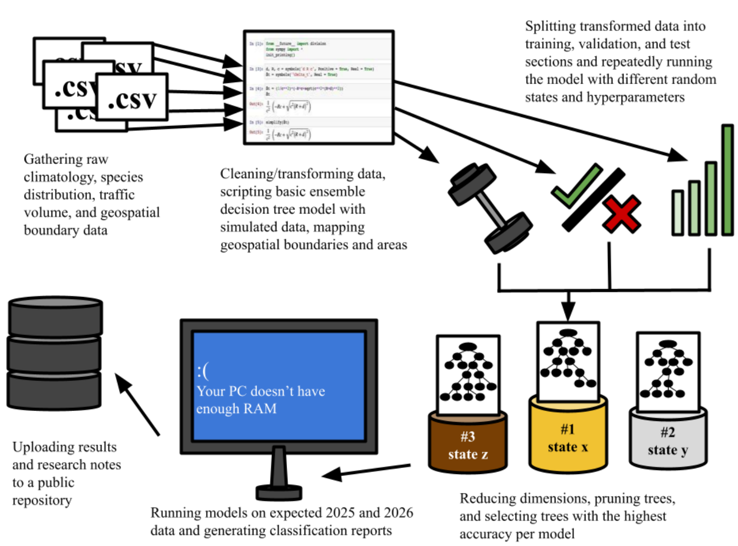

Figure 1: Summary of the research process for decision tree modeling.

Machine Learning for Exploring Sounds for Live Music

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Abstract: Musicians are always looking for novel sounds that they can use when playing music, whether for song production, playing live, or just playing for fun. Recent advancements in machine learning (ML) can allow musicians to explore new sounds using this technology. One such example is using ML to change the timbre (or character) of a sound to something else (for example, taking a guitar and making it sound like a piano). Current tools that use ML in sound applications include tools such as Realtime Audio Variational autoEncoder (RAVE) and Differential Digital Signal Processing (DDSP). DDSP allows the user to create a deep learning model with outputs filtered through layers based on traditional digital signal processing (DSP) elements, such as synthesizers, wavetables, and filters. However, the kinds of sounds DDSP can make are naturally constrained by the DSP components it includes. RAVE trains on a dataset of sound samples and produces audio similar to the sound samples it was trained on, either through sound generation or timbre transformation. In addition, both of these tools are difficult to use, and require more technical knowledge than most musicians have. The end goal of this research project is to have a program that creates neural networks (NNs) that will change the timbre of an instrument's sound to something novel. The NN can be loaded into a patch for a program called MaxMSP, which is how audio input and output will be handled. This patch can be converted to a plugin that can be used in a digital audio workbench when recording or producing songs. The primary difference between prior tools that use ML and this tool is that this tool is focused specifically on creating unique sounds. This approach is also intended to be simple enough for musicians who do not have a background in computer science to use, by allowing users to download an existing neural network from the internet or train their own NNs with minimal hassle. Focusing on accessibility and originality will allow musicians to explore new sounds without needing technical expertise, allowing them to focus on creating and playing music.

A Novel Method to Transfer Human Movement with Mobility Aids to Virtual Avatars

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Marker-based optical motion capture (MoCap) is extensively used in research studies and the entertainment industry to translate human movement into virtual environments. However, conventional MoCap workflows struggle with issues of occlusion and atypical movement patterns introduced by the use of mobility aids such as wheelchairs, canes, and walkers. This challenge typically necessitates expert intervention, creating barriers to capturing accurate motion data from everyday users of mobility devices. Consequently, there is a lack of available datasets that authentically represent individuals with disabilities, hindering their inclusion in virtual applications such as video games, human ergonomic simulators, and scientific visualizations.

This project addresses these limitations by developing an optimized MoCap pipeline tailored specifically for recording mobility aid users. Utilizing the Vicon optical MoCap system, the novel workflow includes customized marker sets designed for various assistive devices, modified skeleton templates accommodating seated positions, missing limbs, or asymmetric movement patterns, and adjusted procedures to accurately record authentic gait cycles. The pipeline was validated using real-world volunteers who routinely use mobility aids, rather than non-disabled actors approximating such movements.

Special attention was given to the way different mobility aids uniquely influence user movements, requiring distinct animation states and smooth transitions to produce realistic virtual characters. The resulting system integrates behavior tree blending tools and locomotion state machines, designed for easy integration into 3D game engines and human simulation software. This comprehensive approach ensures that constrained and device-assisted movements are accurately represented. The study contributes open-source documentation of a user-friendly pipeline empowering non-experts to capture high-quality MoCap data of mobility-aided human motion. Additionally, it provides a diverse database of virtual characters generated through these methods, significantly broadening the representation of varied movement forms in simulated environments.

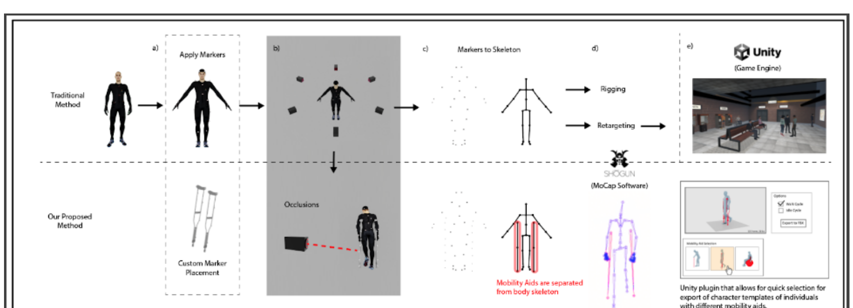

Figure 1. Overview of Project Design

Figure #1: Overview of Project Design

Deep Learning for the Study of Particle-Cell Interactions

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Abstract: Understanding how particles and cells interact with each other is critical for advancing targeted drug delivery and improving treatments. Phase imaging allows for label-free visualization of these biological interactions and enables precise tracking of particle movement. The U-Net model, a deep learning method used for image segmentation, assists with developing automatic, accurate predictions from labeled data. Prior deep learning methods applied to phase imaging have focused exclusively on cell segmentation, overlooking particle detection. This research aims to manually label particles in phase images, train a U-Net segmentation model using phase augmentation techniques, and evaluate the model's performance in identifying particle-cell interactions. Phase images have been acquired from a novel imaging technology previously developed in this lab, called Modulated Optically Computer Phase Microscopy (M-OCPM). Particles in these images will be manually annotated to produce training data. U-Net will then be trained using phase-augmented images, in which global phase shifts are introduced to account for phase wrapping artifacts. This augmentation strategy is essential because it teaches the model to distinguish real particle features from artificial edges caused by phase wrapping. These methods should result in improved accuracy in identifying particles from wrapped phase images and in successfully distinguishing them from surrounding cells and background. It is expected that the results will demonstrate that deep learning segmentation techniques developed for cell analysis can be effectively extended to particle detection, with the goal of enabling accurate identification from wrapped phase images while avoiding the need for phase unwrapping. This work highlights how deep learning approaches can simplify particle analysis and support future research on particle-cell interactions.

Cloud-Based Autonomous Driving: Leveraging Sensor Data and Machine Learning for Real-Time Driving Decisions

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Abstract: Autonomous driving offers significant technological advancement to the transportation industry; however, this technology is quite disadvantaged when it comes to dependency on stable network connectivity, upgradeability, and costs. These vehicles rely heavily on sensor data, which requires significant computational power and storage capabilities. While cloud computing offers scalability and ease of software updates, it introduces latency issues when connectivity is poor. This research proposes a hybrid of cloud and edge computing to improve real-time performance while minimizing costs and enabling remote upgrades. Edge computing is a new-generation type of computing that accesses data at the "edge" of the network, instead of utilizing a centralized cloud or data center. To implement this design, a one-tenth scale car will be built. This vehicle will act fully autonomously, use onboard edge computing for real-time decision-making, and cloud computing for model updates. A trained machine learning model will be used to control vehicle functions such as braking and steering based on summarized sensor inputs. To test this vehicle, it will be placed on a to scale track involving multiple turns. The desired product of this experiment is that the vehicle will avoid all obstacles and act on its commands under the lowest latency possible.

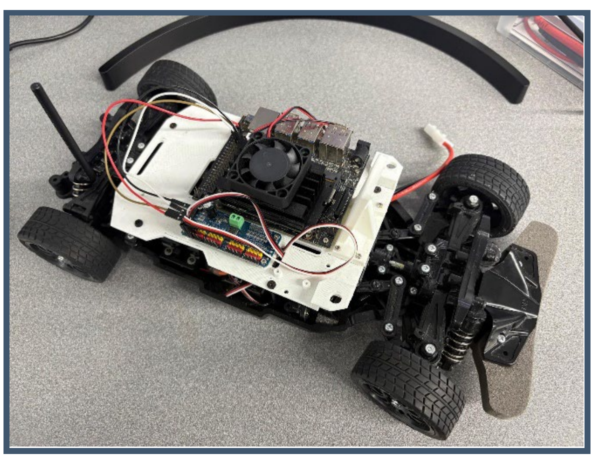

Figure #1: This figure shows a prototype of the final product.

Evaluating Usability and Accuracy of Different Methods to Align and Place Digital 3D Wounds

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Abstract: With 10.5 million Medicare beneficiaries affected by chronic wounds, there is an ongoing demand for more precise and consistent tools for wound measurement. In current clinical practice, the most common methods of wound measurement are 2D imaging and the ruler and Q-tip; these methods have limitations due to visual bias and low inter-rater reliability. By incorporating 3D imaging wound measurement software with a manual alignment feature, clinicians can enhance accuracy by reducing visual estimation errors and improving consistency across different users. Accurate wound tracking is critical for patient care, as clinicians rely on consistent measurements to determine whether a wound is healing properly. Improving the reliability of these assessments directly affects patient outcomes and reduces the risk of complications. Addressing these problems can improve the accuracy and efficiency of wound assessment, which is especially important for patients with diabetic ulcers, pressure ulcers, and other chronic wounds or related conditions. 3D wound measurement software provides clinicians with greater control during the wound placement process. This functionality allows users to adjust measurements directly, helping to reduce visual bias and improve consistency in wound tracking. This research aims to examine the usability and accuracy of a wound placement feature in a 3D wound measurement system. This study aims to evaluate how effectively this interface supports ease of use, user control, and overall satisfaction. The study will focus on a small pilot of 10 college students from non-technical backgrounds to understand how users interact with the system. Participants will observe or interact with the software, then complete a structured usability survey to provide feedback on clarity, control, and interface design. Both quantitative data and qualitative insights will be collected to assess how intuitive and flexible the system feels to users. It is expected that most participants will find the interface user-friendly, with the manual adjustment feature offering valuable control and flexibility. This research contributes to the improvement of user-centered medical simulation tools by promoting accessibility and usability, ensuring the software is usable for all users, regardless of their technical experience.

Detection of Solar Radio Bursts with Machine Learning

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Co-mentors: Anastasia Kuske[2], Prof. Bin Chen[2], Mengjia Xu[2]
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Solar Radio Bursts (SRBs) are generated by solar activity, often associated with extreme space weather events like solar flares and coronal mass ejections (CMEs). Accurate detection of these events is crucial for understanding space weather and its impact on Earth's technological infrastructure. Studying SRBs plays a vital role in monitoring solar flares and CMEs and enhances our ability to forecast potential space weather impacts. This research focuses on composing a dataset using solar radio observation from the Owens Valley Radio Observatory - Long Wavelength Array (OVRO-LWA) and training a model based on the YOLO machine learning architecture to detect and classify Type III and Type IIIb SRBs. By carefully annotating and labeling, and training the model with the labeled data. The goal is to achieve high-accuracy, non-manual detection. The resulting dataset and model can be used to collect events from a huge amount of historical observations and also be implemented for real-time observation for nowcasting reports of radio bursts.

Optimizing Dielectric Layers for Power-Efficient RRAM Devices

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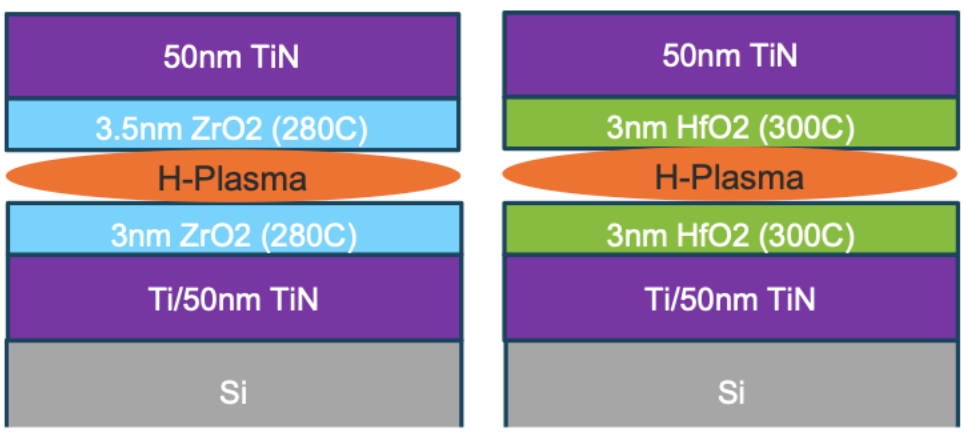
Abstract: The growing demand for energy-efficient memory devices for AI hardware and in-memory computing has led to increased interest in optimizing resistive random-access memory (RRAM) technology. Current technologies such as static random-access memory (SRAM) and dynamic random-access memory (DRAM) require significantly more power to operate, as they rely on changing the charge of the device to store data, while RRAM relies on changing the physical properties of the device to store data. In order to optimize these RRAM devices, our focus is on engineering the dielectric layer. There are many different factors regarding the dielectric layers which can be adjusted; our research will focus on the material of the layer as well as the application of H-plasma treatment. We will be testing ZrO2 devices as well as HfO2 devices (Figure 1). Testing both of these devices will identify which material results in a more optimized oxygen vacancy concentration and distribution. The devices which have a more optimized oxygen vacancy concentration and distribution will be more power efficient, contributing to the development of more effective and more efficient non-volatile memory solutions. Optimizing the power consumption of these RRAM devices will pave the way for the next generation of artificial intelligence hardware and in-memory computing solutions.

Figure 1: Schematic of ZrO2 and HfO2 RRAM devices



Developing a Terrain-Aware Reinforcement Learning Controller for Robotic Exoskeletons

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New Jersey Institute of Technology, Newark NJ 07102

Locomotive mobility of the human body plays a crucial role in an individual's quality of life. Many existing exoskeletons, already used in limited clinical and rehabilitation settings, offer adaptive assistance for those with mobility impairments and those whose performance is hindered, possibly due to aging or injury. Often reliant on rigid, preprogrammed controllers and limited testing environments, these models are already developed to help people walk on flat, consistent surfaces. However, they often struggle with real-world situations involving more complicated environments like stairs, ramps, or uneven ground. This lack of adaptability presents a clear issue: current exoskeletal approaches are not ready to dynamically respond to varying terrains users would face, which restricts their usability and safety in real-world applications. As a result, there is a growing need to explore solutions that enhance exoskeletons' adaptability across diverse environments. To address this limitation, my research focuses on developing a terrain-aware reinforcement learning (RL) controller for robotic exoskeletons. Under the guidance of Professor Zhou, I investigate how adjustments to simulated training environments affect controller performance on unpredictable surfaces. I identify the metrics that accurately represent successful adaptation and apply them to make exoskeletons smarter, safer, and more useful. My focus includes coding and testing RL-based models with terrain locomotion challenges, recording and visualizing results for patterns and improvement, and documenting the process for continued development. This research, by addressing terrain variability through simulation, contributes to the development of exoskeletons that can support user mobility with greater safety and adaptability in everyday environments.

Democratizing Quantitative Motion Capture for Ubiquitous Use: Evaluating an Artificial Intelligence-based OpenCap Markerless System in Comparison to a Traditional Marker-based Motion Capture System

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Abstract: Human motion capture digitally records and maps human body movements into computer character animation for analysis. Currently, marker-based motion capture is the scientifically-approved method for quantifying 3-D motion data. However, a limitation to this standard technique is marker occlusion during complex maneuvers aside from typical gait, affecting the accuracy of results. Markerless motion capture is an effective alternative due to the elimination of concern for marker occlusion. OpenCap is a markerless motion capture tool that calculates both the kinematics and dynamics involved in human movement. But, our knowledge on the accuracy of markerless against traditional marker-based motion capture systems is limited. This study aims to assess the accuracy and reliability of markerless OpenCap in comparison to ground-truth marker-based motion capture during the complex movements of Bharatanatyam, a dance form characterized by flexion of the ankles, knees, and hips. This complexity mirrors that of intricate movements required to be analyzed for physical rehabilitation, making Bharatanatyam an ideal context for assessment in this study.

We recruited one participant to perform a diverse set of Bharatanatyam movements at the NJIT Life Sciences Motion Capture Lab. We recorded simultaneous measurements of 3-D marker trajectories, electromyography (EMG), and OpenCap videos while the participant performed Bharatanatyam *adavus* (basic motions) at 3 different speeds (slow, medium, and fast). The OpenCap software identified anatomical landmarks on the body and calculated 3-D positions over time to quantify joint kinematics, kinetics, muscle activation, and musculoskeletal forces. The Vicon Nexus software was employed to process the coordinates of the markers throughout the motion and tailored post-processing algorithms were employed on the 3-D motion data to enable the analysis of the same measures quantified by OpenCap. The results from markerless OpenCap will be compared to those from the marker-based motion capture system. If OpenCap proves to be comparable to marker-based motion capture, the findings of this study may provide more accurate measurements for complex movements, such as in sports rehabilitation and exoskeletal-assisted walking, which must be analyzed without the risk of marker occlusion. This may further present a more efficient alternative for research facilities, allowing motion capture in real-world environments of patients, such as outdoor settings.

(A) (B) (C)

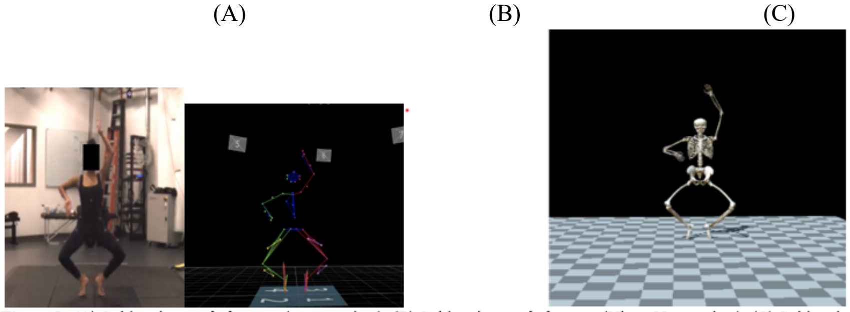

Figure 1: (A) Subject in *paychal* stance (camera view). (B) Subject in *paychal* stance (Vicon Nexus view). (C) Subject in *paychal* stance (OpenCap view).

Mycelium to Machine: Exploring Hybrid Intelligence Through Cyberpsychology

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Current AI development centers the belief that intelligence is individual, rational, and human-like. However, this view limits our ability to envision AI systems whose intelligence and ethics emerge through ongoing interaction with people, environments, and other systems—what is referred to as co-evolving AI. Rooted in methodological individualism, this prevailing paradigm treats intelligence as the property of isolated agents. It often leads to anthropocentric design, where human cognition becomes the default template for machine reasoning and ethics. Inspired by mycelium, this project explores an alternative model for AI grounded in decentralized, cooperative intelligence. Mycelium exhibits a form of non-hierarchical intelligence, as it shares nutrients, adapts to local conditions, and sustains life through decentralized cooperation. Rather than following top-down commands, it coordinates activity through responsiveness and connectivity. These networks prioritize coherence over correctness and relational feedback over rigid control. To explore these properties, this project involves a behavioral experiment that observes how mycelium responds to environmental changes. Petri dishes will be used to cultivate fungal networks under varying conditions (e.g., contamination, nutrient richness), and the researcher will document adaptive behaviors such as rerouting, clustering, or stalling. Observations will be analyzed both qualitatively (e.g., patterns of behavior) and quantitatively (e.g., rates and directions of growth) to develop a prototype of a distributed model of decision-making. These insights will be compared with emerging models of hybrid intelligence that challenge isolated models of cognition, instead viewing intelligence as distributed across human, machine, and environmental relations. Emerging from the mycelial metaphor, the project proposes a framework for AI systems that evolve through interaction rather than isolation.

Al-Powered Carbon Credit Verification: A Data-Driven Approach to Optimizing Market Efficiency.

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The carbon offset market plays a critical role in climate mitigation but suffers from credibility issues due to unverifiable claims and inconsistent methodologies. This project presents a scalable, AI-powered framework to automate the verification and valuation of carbon offset projects using satellite imagery, machine learning, and public market data. Leveraging the Google Earth Engine platform, environmental indicators such as NDVI (Normalized Difference Vegetation Index) and rainfall were extracted for over 1,600 land-based Verra-registered projects. These features, along with project metadata, were used to train a supervised learning model (Random Forest) that estimates annual carbon sequestration in metric tons. A verify_project() function was developed to dynamically validate new project claims using geospatial inputs.

The model shows promising accuracy for land-based project types such as Afforestation/Reforestation (ARR), Reduced Emissions from Deforestation and Degradation (REDD), and Agricultural Land Management (ALM). Future work will generalize the model to accommodate clean energy and industrial projects by integrating emissions displacement metrics, and introduce a pricing engine using real-time carbon credit market data (e.g., ICE EUA). Additional layers such as ESG scores and NLP-based sentiment analysis may be integrated to adjust credibility weighting, improving transparency and pricing accuracy in voluntary and compliance carbon markets.

Inference of LOS Magnetic Field and Velocity in the Weak-Field Regime

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Draft: Researching the quiet Solar areas has been a major challenge within the field of Solar astronomy due to many factors. Previously used models such as Milton-Eddington Inversion rely on full Stokes I,Q,U, and V parameters which are unreliable in the quiet solar regions. In order to be able to measure the potency and direction of a Line of Sight magnetic field in quiet Sun regions, this project focuses on using the Center of Gravity (CoG) Approximation method. Likewise, the end goal of this project is to standardize a CoG based pipeline to derive LOS magnetograms from Stokes I and V profiles in BBSO/NIRIS databases, and afterward to apply this approach to data from the period during the joint observations of BBSO and Parker Solar Probe for regions of corona hole boundaries. To accomplish these objectives, data from BBSO is being put through code using Visual Studio Code in order to test CoG's effectiveness in creating magnetograms of LOS magnetic fields in various solar regions, with close attention to variations when testing quiet solar regions. Variations will be further examined with direct comparison with LOS magnetogram from other space-based instruments. Additionally, using a Monte Carlo simulation and calculating the standard deviation, CoG approximations will be tested on how well they respond to ambient noise.

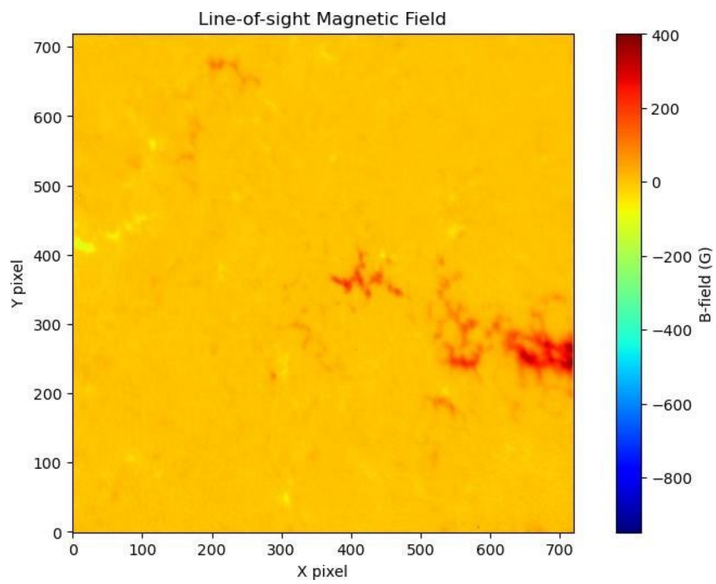

Figure #1: LOS Magnetic field output for a weak Solar magnetic field region

Investigating EMIC Wave Conjunctions: Linking Ground-Based and Space Observations

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Abstract: Electromagnetic Ion Cyclotron (EMIC) waves are low-frequency plasma waves that travel through the Earth's geomagnetic field environment, called the magnetosphere, and interact with high-energy particles. These interactions can scatter radiation belt particles into the ionosphere, affecting the dynamics of Earth's magnetosphere and contributing to space weather phenomena. Space weather can impact satellites, astronauts, and even ground-based infrastructure, highlighting the need for a deeper understanding of Earth's space environment and predictive tools to prevent potential risks.

EMIC waves are typically measured by spacecraft in the magnetosphere and ground-based instruments. However, the occurrence rate obtained from spacecraft data is extremely low. Thus, a space-ground conjunction study is essential. This project aims to improve our understanding of EMIC wave occurrence by starting with ground-based magnetometer observations and identifying corresponding space-based events using Geostationary Operational Environment Satellite (GOES) spacecraft data. To analyze these relationships, we will apply a Random Forest binary classification model in Python, using datasets that contain solar activities and geomagnetic activities, as well as statistical surveys of wave occurrences in space and on the ground. By evaluating feature importance, this study will identify key factors influencing EMIC wave generation, providing new insights into their occurrence and potential for predictive modeling.

The anticipated outcome of this research is an improved understanding of the conditions that lead to the successful propagation of EMIC waves from space to ground, as well as a model for predicting wave activity in space. Future work will include expanding the dataset with more ground stations and spacecraft, which will improve model accuracy.

Advancing the Usage of Edge Intelligence in Autonomous Driving

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Abstract: The current network structure is known as the cloud infrastructure. The system has worked as a whole, but as real-life applications, such as autonomous driving, continue to advance, the demands placed on cloud infrastructure grow. These demands are massive volumes of data to make real-time decisions, decisions required by the sensors, such as LIDAR, cameras, GPS, radar, and onboard computing systems. In these strenuous demands on the cloud, the real-life applications become ineffective as the cloud cannot provide the needed support. The solution proposed to this issue is Mobile Edge Computing (MEC) is a crucial part of the modern network architecture as it plays a key role in enabling real-time, low-latency applications. By bringing together the data processor with the source of data itself, Mobile Edge Computing would reduce latency and ease the load from the centralized cloud systems. This research aims to answer how federated machine learning can be utilized to automate and optimize network management in mobile edge computing systems. Through conducting this research, the simulator software CARLA, alongside the real-world RoboRacer AI platform, will be utilized to evaluate the performance, reliability, and responsiveness of edge intelligence within autonomous vehicles compared to cloud infrastructures. In CARLA, federated machine learning is utilized as artificial intelligence in the simulation. CARLA also allows for a cloud-based infrastructure simulation. The CARLA simulator will be leveraged as a testing field to create a comparison between both infrastructures. Both experiments will simulate urban driving with network latency ranging between 10 ms - 200 ms, bandwidth constraints, and sensor configurations. There are also environmental conditions that are systematically varied to test robustness; these conditions range from dark skies, fog, rain, low visibility scenarios, and lightning storms.

The anticipated results would demonstrate that the edge-intelligence structure as a whole allows for autonomous driving to perform better when compared to a cloud structure. In the simulation, tasks increase in complexity from basic lane-following to dynamic obstacle avoidance and pedestrian interaction. Each task is completed in both edge-local and cloud-based infrastructure. To piggyback off these simulations, Roboracer AI serves as the physical manifestation of edge-only AI that must make instantaneous decisions under real-world constraints. These constraints include sensor interference, onboard hardware limits, and track noise. This experiment validates the simulation findings while also highlighting the viability of edge intelligence placed in operational AV systems. Through both forms of experimentation, system performances are compared in terms of decision latency, task success rate, and safety-critical event response. Anticipated results are to demonstrate that edge intelligence deployment into operational AVs will prove superior to cloud-based deployment.

On Emergent Emitter Dynamics in the Covariance Matrix Adaptation MAP-Elites Algorithm

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Abstract: There is an ongoing challenge in finding a diverse collection of high-quality solutions within complex continuous domains. This challenge is especially important in fields such as robotics and automated design, where systems must perform well and adapt to a variety of situations. Quality diversity (QD) algorithms like MAP-Elites address this need by encouraging both performance and behavioral diversity, but they typically require many evaluations to effectively explore large search spaces. Covariance Matrix Adaptation MAP-Elites (CMA-ME) builds on this approach by combining the self-adaptive optimization of Covariance Matrix Adaptation Evolution Strategy (CMA-ES) with MAP-Elites' archiving and mapping mechanisms. CMA-ME uses a population of emitters—variants of CMA-ES instances—that guide the algorithm to search for solutions using one of three strategies: random direction, improvement-based, or optimizing. While CMA-ME has demonstrated promising results in prior research, these findings were limited to homogeneous emitter populations that utilized only a single search strategy at a time, leaving open questions about its search dynamics, comparative advantages, and convergence behavior with respect to CMA-ES and MAP-Elites. This project aims to clarify the specific mechanisms by which CMA-ME enhances performance and to investigate how introducing heterogeneous emitter populations—combining multiple search strategies—influences exploration, solution diversity, and convergence efficiency. Early experiments aim to show how different emitter types interact, offering insight into how to design future algorithms that more effectively balance performance and variety. This research contributes to building smarter, more adaptable AI systems that can better solve real-world problems where a single solution is not enough.

Crowdsourcing Closed Caption Quality Ratings with Intrinsic Motivation

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While automatic speech recognition has improved the accessibility of many videos for d/Deaf and hard of hearing (DHH) people, many accessibility challenges remain. For example, while ASR has aided in the creation of captions for spoken content, only a small fraction of videos (estimated to be less than 4%) have captions containing non-speech information (NSI), such as music, sound effects, and environmental sounds. This information can be critical for DHH viewers' understanding of video content. As a result, DHH viewers' access to many videos is diminished, and additionally, many DHH viewers may have difficulty finding videos that contain sufficient captions. While the AI task of automated audio captioning promises to address this problem, current datasets are unfortunately not designed to meet the needs of DHH viewers.

To address the lack of NSI-inclusive captions and the difficulty DHH users face in identifying well-captioned content, this project aims to construct two tools: a browser plugin that gathers user feedback on the caption quality of videos, and a website that recommends videos with good-quality captions based on crowdsourced ratings. The plugin allows users to contribute directly to the evaluation of caption quality, turning passive consumption into active feedback. Meanwhile, the recommendation site serves as a resource for discovering well-captioned videos, allowing users to save their time and energy in search for such content. The website is populated with videos based on ratings submitted by the DHH community through the plugin, further incentivizing its use. The gathered data will fuel future research, including the development of accessible automated captioning datasets and the development of captioning standards that better reflect the needs of the DHH community.

Development Platform for Prototyping and Testing Swarm Robotic Algorithms

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Abstract: This research explores the design, development, and evaluation of a hybrid simulation platform for swarm robotics. This enables virtual and physical agents to coexist within the same testing environment. Throughout the 10-week development cycle, we identified critical insights into the challenges of scaling swarm behavior, the limitations of purely virtual or purely physical testing methods, and the value of hybrid experimentation.

Our key learning was that hybrid simulations greatly improved both debugging efficiency and behavioral accuracy. Simulated agents allowed for rapid iteration and stress testing of flocking algorithms, while physical devices introduced realistic constraints such as communication dropouts and sensor variability. This dual-layer feedback loop exposed flaws in naive alignment and cohesion logic that would not have emerged in isolated simulation.

We also discovered that human-operated proxies, guided via mobile phones acting as surrogate robots, offered a low-cost and effective method for testing swarm dynamics in real-world spaces. This approach allowed us to simulate complex environmental interactions without deploying expensive robot fleets.

This discovery also demonstrated the effectiveness of using mobile phones to teach individuals about swarm robotics. This smartphone system can help teach the fundamentals of swarm robotics which is otherwise impossible without costly hardware. By allowing users to participate as mobile agents within a swarm, the system teaches the users about swarm systems. This is done by bridging the gap between theoretical models and real-world behavior, making it a powerful educational tool for classrooms, workshops, and outreach programs.

Our open-source application now serves as a functional proof-of-concept, demonstrating that hybrid simulation accelerates algorithm development, reduces hardware costs, and offers a scalable solution for studying emergent behavior in swarm robotics.

Using self-organizing maps to decipher whale song battles

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Humpback whales repeat complex, fluctuating sequences of song patterns for hours at a time but the overall function of their songs and purpose of song modulation is contested. The standard belief currently is that humpbacks exclusively use song as a mechanism for attracting mates, however this may not be the case. Using recordings of singing humpback whales off the coast of Hawaii, this project aims to identify how duetting whales vocally interact as compared with solo singers. This comparison is important to demonstrate that the time-varying characteristics of songs produced by co-singers are not stochastic. If singers coordinate song production to avoid interference, this would suggest that there may be advantages to a whale doing so, outside of mating purposes. Self-organizing maps (SOMs), a type of artificial neural network, are a promising tool for approaching these questions, as they possess the ability to provide unsupervised quantitative analyses of songs in order to identify detailed interactions between singing whales.

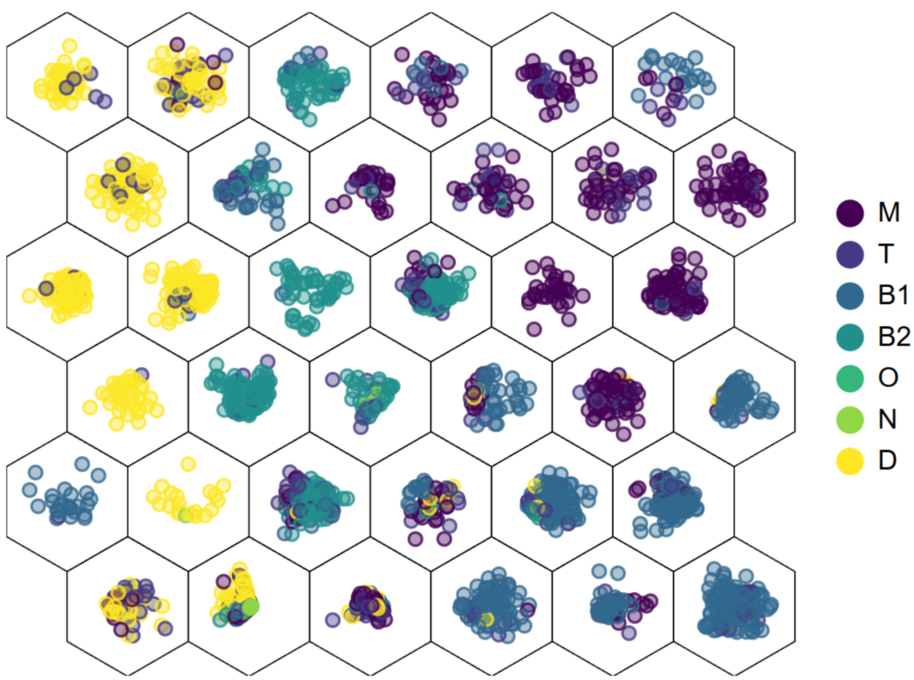

Figure 1: A hexagonal cloud plot of a SOM trained on a single song session, each circle representing an observation within a cell. Each color corresponds to a distinct section of a humpback whale song: D (units with descending frequencies), M (alternating units), B1 (broader range of alternating units), B2 (broadband units), as well as additional labels: N (silence), O (non humpback whale noise), T (transitional phrases between sections).

AI-Driven HPC Optimization for Triangle Counting in Graph Analytics

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Abstract: Graph analysis plays a key role in real-world problems—from detecting fraud rings in financial transactions to mapping protein functions in biology, identifying community structures in social media, and filtering spam on the web. All of these rely on triangle counting, a fundamental algorithm that looks for groups of three connected nodes (triangles) in a graph and helps reveal tightly connected regions, making it useful for spotting communities, feedback loops, and network clusters. Today's graphs are becoming larger and more complex, and differences in graph structure or computing hardware often require manual tuning of algorithms. No single triangle counting method performs best in all situations—what works well on dense graphs or CPUs may fail on sparse graphs or GPUs. As graphs and hardware keep evolving, we need smarter systems that adapt automatically to stay fast and efficient. By combining runtime monitoring with reinforcement learning, an adaptive system can automatically select and adjust triangle counting algorithms based on graph structure and hardware behaviour. Designed for high-performance computing (HPC), the system runs on NJIT's Wulver supercomputer and monitors hardware metrics like cache usage, instruction throughput, and processing rate. A machine learning model, trained on past performance data, predicts the most efficient configuration for new and unseen workloads. Future work will apply this AI-based framework to more graph algorithms to test its flexibility. The goal is to make graph analytics faster and easier to deploy across diverse computing environments.

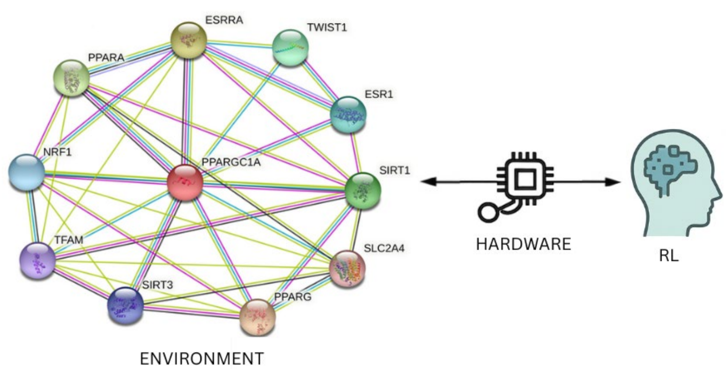

Figure 1: Protein–protein interaction (PPI) network showing triangle patterns in a real graph. Nodes represent proteins and edges denote interaction strength; triangles highlight tightly connected motifs detected by triangle-counting algorithms. Runtime signals from the graph and hardware guide the reinforcement learning (RL) agent.

Search Functionality for Virtual Reality Ontology Editor

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Abstract: This project extends the functionality of the VROOM (Virtual Reality Ontology Object Manipulation) system. An ontology is a linked dictionary of terms from a specific domain. VROOM was designed for medical ontologies. Medical ontologies are large systems, often containing over 100,000 medical terms. Ontologies are structured like a network of nodes and links. The nodes represent the medical terms, and the links represent relationships between pairs of terms. The most important links are called subclass or IS-A links. They express generalization — for example, pneumonia is more general than viral pneumonia. Due to the size of a medical ontology, a graphics display of its network is overwhelming. The VROOM system addresses this problem by spreading out the network display in THREE-DIMENSIONAL space surrounding the viewer (Fig. 1). This is achieved by using an Oculus Headset for VR. The user interacts with the display using a game controller in each hand.

Currently, VROOM has no search functionality. In this project, the search functionality will be implemented from scratch. This includes supporting substring search — for example, typing "Can" will return "Lung Cancer," "Skin Cancer," and other related terms. A search bar and keyboard in 3D space will be implemented. The user can type parts of a medical term and the system shows all matching terms. Then, the user can choose the desired term with the game controller. As a result, the user can be teleported in VR space to float in front of the desired term. He can then edit the term or delete it. If time permits, an existing voice search functionality will be re-integrated.

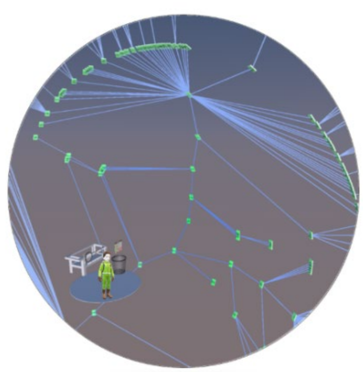

Figure 1. An Avatar for the user standing on a mobile platform that is floating in VR space. The green dots are the medical terms. The blue lines the generalization links. By implementing this search functionality, the VROOM system will become much user-friendlier.

Historical He I 10830 Å Dataset Generation via Deep Learning for Solar Cycle Studies

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One of the biggest problems in solar physics is that we lack full-disk He I 10830 Å images for most of solar observation history. These images are obtained using the He I 10830 Å spectral line—a critical wavelength for studying the Sun's upper chromosphere and lower corona. He I 10830 Å images are scientifically important but technically hard to capture because getting these images requires specialized infrared instruments, which didn't exist in the early 1900s (primarily started in 2006 by SOLIS). In contrast, Hα observations, which trace a lower layer of the solar atmosphere, have been collected daily at well-known observatories worldwide since the early 20th century. This mismatch in spectral data availability restricts our ability to analyze historical solar flares, magnetic fields, and coronal structures.

Therefore, the goal of our project is to bridge this gap and reconstruct He I 10830 Å full-disk images from historical Hα data using a deep learning model known as pix2pixHD, a high-resolution conditional generative adversarial network (GAN). This approach allows us to bypass complex radiative transfer simulations by learning visual mappings directly from paired image data. The said Hα data was collected from Kanzelhöhe Solar Observatory (KSO) and Synoptic Optical Long-term Investigations of the Sun (SOLIS), spanning from 1973 to 2025. Then, the data went through the preprocessing phase, which included converting raw FITS files to grayscale PNGs, resizing them to 1792×1792 pixels, and systematically eliminating corrupted or incomplete data frames based on desired quality parameters using Python scripts. These processed images will be used as inputs to generate synthetic He I 10830 Å images through the pre-trained pix2pixHD model.

The anticipated outcome of this project is to develop the backend database that stores both original Hα and synthetic He I 10830 Å data. Similarly, we also plan to build an interactive web interface (like NJIT's SolarDB) that enables users to visualize, query, and download data by date, solar features, or observatory. Future works would include refining and updating the reconstruction model, validating output across several other renowned observatories, and expanding the database as a whole.

Collective Motion and Effective Vision in the Emergence of Panic Waves in Zebrafish

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Abstract: Understanding how visual perception shapes collective motion and threat response in zebrafish schools represents a fundamental question in biological systems, with broad significance for fields such as robotics, artificial intelligence, and crowd management. The main goal is to uncover the mechanisms by which zebrafish detect, process, and react to threats within a school, and to understand how vision influences their ability to synchronize movement and generate panic waves, especially in confined environments. To achieve this, we are developing and validating computational models that incorporate the visual field constraints of zebrafish, adapting the ray-projection method originally used for bird flocking to the more limited "cone of sight" characteristic of fish, and integrating experimental trajectory data provided by collaborators in Severi's Lab at NJIT. Our modeling approach accounts for physical boundaries like tank walls and non-mechanical interactions such as social and visual cues, aiming to more accurately reflect the environment and sensory inputs experienced by zebrafish. The experimental design includes simulating zebrafish schools in racetrack-shaped confinements and tracking both individual and group trajectories during normal swimming and induced panic waves, with the prototype being a scalable simulation framework capable of reproducing key features of group dynamics and predicting collective responses under varying sensory and environmental constraints. Anticipated outcomes include identification of the main mechanisms by which zebrafish use vision to coordinate movement and respond to threats, development of a validated computational model that predicts synchronization patterns, and general insights into the similarities and differences between fish and human collective dynamics under stress. This work is expected to advance our understanding of collective behavior in biological systems and inform the design of engineered systems for crowd management and autonomous robotics. In conclusion, this research will contribute to the fundamental understanding of visually driven group behavior in confined spaces, with future directions including extending models to more complex environments, performing cross-species comparisons, and exploring applications in autonomous systems and emergency response protocols, ultimately aiming to reveal the principles underlying collective motion and coordination in animal groups.

Enhancing LLMs in Voice-Based Smart-Home Technologies for Users with Mild Cognitive Impairment (MCI)

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Abstract: Medication non-adherence among individuals with mild cognitive impairment (MCI) is a widespread but often overlooked issue, contributing to over 100,000 preventable deaths and $300 billion in healthcare costs annually. While smart-home technologies such as Google Home offer potential support, current systems fall short — their rigid, command-based designs often feel impersonal to this user demographic, undermining user autonomy. Existing approaches typically rely on scheduled alerts or passive reminders that fail to account for emotional sensitivity or variability in expression or communication styles. This research proposes a smart assistant prototype that integrates with Google Calendar to learn a user's personalized medication schedule and uses proximity sensors and natural, empathetic verbal prompts to encourage adherence with motivational nudges grounded in executive function and wellness benefits (e.g., "Let's take our medication to help us stay sharp for tomorrow's plans"). Interaction data is logged daily to help track medication intakes while respecting user autonomy. This system anticipates improving both adherence and user well-being by making the reminder experience more emotionally attuned and personalized to the user's communication style. Beyond medication adherence, this work points to a broader application of enabling users to tailor smart assistants to support a variety of personal goals for users across varying demographics.

Query Planning with Agentic AI

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Abstract: In many real-world applications, we need to find the best way to rank a set of items - like choosing the top products, hotels, or job candidates. Quite often, we rely on LLMs to provide us with such top-k ranking results. But as uncertain as LLMs are, those results are not deterministic. Instead they are probabilistic. With the growing number of items, the number of possible rankings increases exponentially, making exhaustive search using LLMs extremely expensive. This project explores a smart and interactive system that uses AI agents (LLMs) to help break down the user's request into a series of atomic queries that can eventually lead to extracting the top-k result in a cost-effective manner.

The system in this project includes a main AI agent (called the Supervisor) and several smaller helper AIs (called Tool LLMs). Each LLM tool can look at a small number of items at a time and give useful feedback about the probable ranking of these items based on a user's request. This can be used to compute the probability of a particular overall ranking encompassing all the items. The Supervisor decides which subset of items to show to which Tool, and uses their responses to update its belief about the best overall ranking. This process repeats until one possible ranking becomes highly probable. The queries to the tools are made in a cost-effective manner as each LLM call gets more expensive depending on the prompt.

By doing this, we not only take into account an LLM's inherent non-deterministic nature but also avoid checking every possible ranking, and instead use smart planning and learning to reach the right answer in a much cheaper and more explainable manner.

From Uniform Grids to Graphs: A Generalized Wavelet Diffusion Neural Operator Approach for PDE Modeling on Irregular Domains

Presenter: Varsha Narayanan[1]
(Advisor) Dr. Mengjia Xu[1,2]
(Co-advisors) Dr. Amit Chakraborty[3] **and Dr. Yu-Chin Chan**[3]
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Abstract:

Many real-world physical systems—such as weather dynamics, fluid flow in porous media, and biological processes—are governed by partial differential equations (PDEs) defined over *complex and irregular domains*. Traditional PDE solvers, as well as recent deep learning-based neural operators such as the Wavelet Diffusion Neural Operator (WDNO), typically assume that data resides on static, uniform grids. This assumption limits their applicability to unstructured or non-Euclidean domains, including triangular meshes and graph-based sensor networks. This project aims to overcome these limitations by developing **GraphWDNO**, a novel extension of WDNO designed to operate on “irregular grids” using graph-based inputs.

This research builds on WDNO’s core innovations—wavelet-domain generative modeling and multi-resolution training—while adapting them to graph-structured data. Specifically, it replaces the convolutional architecture in WDNO with graph neural networks (GNNs) to better *capture spatial dependencies*, and incorporates geometric wavelet transforms to enable *multiscale representation on graphs*.

The proposed method will be implemented using PyTorch Geometric and PyTorch Wavelets, and evaluated on graph-discretized versions of classical PDE benchmarks, including the Burgers' equation and incompressible fluid dynamics. Anticipated outcomes include improved modeling of long-term dynamics with sharp transitions, robust generalization to higher-resolution discretizations, and superior performance on complex geometries compared to mesh-invariant neural operators such as the Fourier Neural Operator (FNO).

By the end of the summer, we expect to demonstrate that GraphWDNO can effectively simulate and control physical systems on irregular domains, while preserving the interpretability and resolution scalability of the original WDNO framework. Future work will focus on applying this approach to real-world datasets (e.g., weather forecasting, molecular dynamics) and integrating physics-informed constraints into the generative process to enhance both accuracy and physical consistency.

Characterizing Mathematical Skills In Language Models

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Abstract: Modern language models demonstrate remarkable proficiency at solving arithmetic tasks, often achieving near-perfect accuracy on benchmark datasets. Yet the underlying mechanisms by which they perform these computations remain largely hidden, within a "black box." This lack of transparency makes it difficult to predict model failures or improve them—posing a serious challenge for building AI systems that are both reliable and interpretable.

Recent research made a breakthrough by discovering that simple neural networks learning modular arithmetic (e.g.,. 7 + 8 = 3 in mod 12) develop surprisingly organized internal structures—using just six repeating frequency patterns to represent all their computations. However, this discovery focused on one type of network and a single, basic operation, leaving critical questions unanswered: Can these patterns inform more robust model design, and do they appear across architectures and more complex problems?"

To explore these questions, this research expands in two directions to test whether these patterns generalize. First, it examines whether similar frequency-based patterns emerge across different types of neural networks, including recurrent networks, transformers, and newer state-space models (S4 and Mamba). These models process sequences in distinct ways, making them a strong environment for evaluating how model architecture affects internal structures. Second, it broadens the range of math operations beyond simple addition to include modular subtraction, multiplication, division, and more using comprehensive datasets built over a range of prime numbers (e.g., 97 to 113). Using mathematical tools such as Fourier transforms and targeted removal experiments, we analyze learned structures and test their importance by removing components and measuring performance impact.

This research advances the foundational understanding of how different neural networks learn structured approaches to mathematical reasoning. By demonstrating whether these patterns reflect universal principles of learning, the work contributes to the development of AI systems that are not only interpretable and reliable in their reasoning processes—an essential step toward AI systems we can understand and trust.

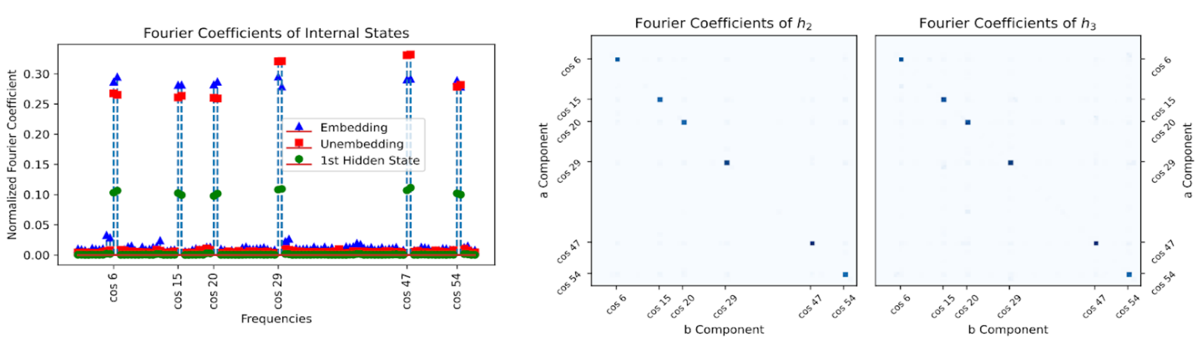

Figure 1: Tracking the Fourier coefficients of every node in the computational graph

DATA SCIENCE AND MANAGEMENT

Verifier Guided Refactoring for Nullability

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Static nullness analysis tools (e.g., NullAway) and annotation generators (e.g., NullAwayAnnotator) help developers avoid null-pointer exceptions in Java code by detecting and labeling potentially nullable references. However, these tools frequently miss complex or indirect references, especially in situations where a variable's non-nullness is implied via indirect checks that hide the original reference, such as by representing a value's nullness through the use of boolean flags, integer values, and more. This forces the developers who use these tools to manually annotate their code bases, thereby defeating the original purpose of the tools. To mitigate this problem and encourage developers to adopt nullability verifiers, we introduce Verification-Guided Refactoring (VGR), an automated approach that rewrites these indirect checks into direct null checks while preserving semantics. Prior research has shown that developers make semantic code changes as they annotate[1], leading to a decrease in the kinds of complex code that these tools struggle with. Likewise, by making nullability conditions explicit through semantic refactoring, VGR enables more accurate annotation inference and reduces superfluous warnings in static analysis in the same way human developers do, leading to an overall decrease in false-positive warnings. We provide a catalog of common null-check patterns—ranging from simple boolean flags to embedded assertions—and demonstrate how VGR transforms each. An empirical evaluation on several large Java codebases commonly used in production environments shows that VGR lowers false positives reported by NullAway, making nullness verification more reliable and developer-friendly.

Figure 1: Code utilizing an implicit nullness check before (top) and after (bottom) undergoing refactoring

```java
public class BooleanFlagTest {
    public void test(String x) {
        boolean isNull = x == null;
        if (isNull) { // Nullness Check for x
            x = new String();
        }
    }
}
```

```java
public class BooleanFlagTest {
    public void test(String x) {
        boolean isNull = x == null;
        if (x == null) { // Nullness Check for x
            x = new String();
        }
    }
}
```

References

[1] Karimipour, N., Arvan, E., Kellogg, M., & Sridharan, M. (2025). A new approach to evaluating nullability inference tools. *Proceedings of the ACM on Software Engineering.*, *2*(FSE), 358–379. https://doi.org/10.1145/3715732

Decomposing Type Inference

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Pluggable type systems allow software developers to write safer code by catching more bugs at compile time. Specifically, they enable us to *prove* that certain classes of bugs do not exist in a piece of software. We care about catching bugs as early as possible because it is significantly easier and cheaper to fix a mistake when it is made, as opposed to later in the development process. Importantly, pluggable type systems also allow us to provably prevent certain classes of security vulnerabilities, such as SQL injection attacks. Many companies, including Uber, Meta, and Amazon, have successfully used pluggable type systems in industry. One of the largest advantages of pluggable type systems is that they can be applied to languages that developers are already familiar with and to projects that already exist, integrating formal methods into workflows they are already comfortable with.

To use pluggable type systems, software developers must insert hints to the type checker, known as annotations, into their programs. Unfortunately, manually annotating an existing project is tedious work, which serves as a high barrier to adoption. To solve this problem, prior research has developed automated annotators, called type inference tools. These extant tools are either effective at annotating but limited to only one type system, thereby decreasing their applicability, or generic over type systems but ineffective in practice.

We propose a tool that overcomes this limitation, being generic over the type system and effective. We use the novel approach of decomposing the input program into slices which can be annotated independently, annotating each slice, and then combining the annotations from each slice to annotate the whole program. The primary advantage of this approach is that the space of possible annotations is exponentially reduced by splitting the program up into slices, and so we can apply traditional artificial intelligence techniques to the problem of annotating each slice. We will compare with the extant tools what proportions of warnings we can remove on untyped projects, both for nullness and other type systems. This tool will significantly lower the cost of using pluggable type systems for existing projects, helping software developers write safer, more secure code.

Comparisons using simulations of copula graphic estimators of survival functions based on dependent censored survival data.

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Abstract: In traditional survival analysis, the widely used Kaplan–Meier estimator assumes that the event of interest and censoring are independent. However, this assumption often fails in real-world settings, such as clinical trials where patients may drop out due to health-related factors. When censoring is dependent on survival time, this can introduce significant bias into survival estimates. To address this, a simulation framework using Archimedean copula models (Clayton, Hougaard, and Frank) was implemented to estimate survival functions under dependent censoring.This project applies the complete set of derivations and estimations formulas from the novel work of my advisor to simulate dependent survival data and apply copula graphic estimators in this context. Dependent censored survival data is generated using statistical software (R) and evaluates the performance of each copula model by comparing their estimated survival curves. The goal is to assess which copula model offers the most reliable and unbiased survival function under different dependence structures. Anticipated outcomes include identifying models that perform robustly even when the true dependence is unknown or misspecified. This research provides a foundation for more accurate survival analysis in biomedical, engineering, and social science applications. Future steps include applying these techniques to real-world datasets and expanding the methodology to more complex copula families.

Beyond Usability: How Aesthetic and Functional Design Influence User Preference in Web Interfaces

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While usability plays a crucial role in effective web design, the relationship between aesthetic appeal and functional efficiency in shaping user preferences remains unexplored. This study will investigate how visual aesthetics and functional design elements collectively influence user engagement and satisfaction in web interfaces. The significance of this research lies in its potential to shift modern design patterns, ensuring interfaces are not only usable but also visually compelling, enhancing user retention and interaction. The study employs a mixed methods approach, combining quantitative user testing with qualitative feedback. Participants interact with different web interface prototypes, one varying in aesthetic and the other functional designs. Metrics such as task completion time, number of mouse clicks, and self reported satisfaction are analyzed to assess performance and preference. Anticipated outcomes include identifying design configurations that optimize both aesthetic appeal and usability, revealing user trade offs between visual attractiveness and functionality. Past findings suggest that while highly aesthetic designs initially attract users, functional efficiency significantly impacts long-term preference. Future work will expand the sample size and incorporate tasks to find throughout each interface, and calculate the amount of time it takes them in order to further analyze visual attention patterns. This research contributes to an understanding of web design, informing best practices for developers and designers seeking to balance form and function.

Design and Implementation of a Secure Document Processing System Using Intel SGX

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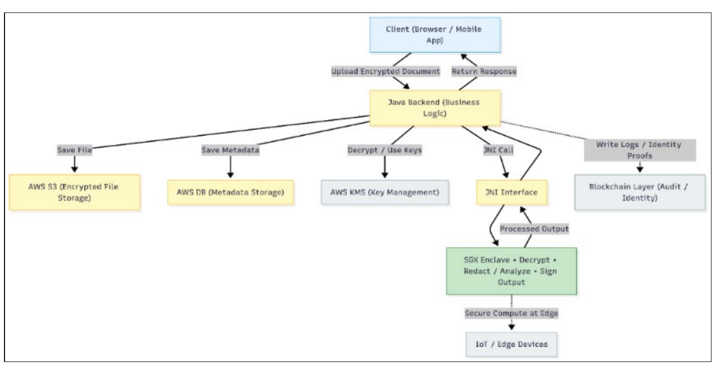
Abstract: The recent leak of over 16 billion compromised credentials, including passwords from major platforms like Google, Facebook, and Apple, highlights the urgent need for robust, privacy-preserving solutions that protect sensitive data from unauthorized access—even in untrusted cloud environments. These incidents reveal a critical vulnerability in conventional software-only security models and demand trusted, hardware-backed frameworks for data protection.

This research presents the design and implementation of a secure document processing system that leverages Java for application logic, Amazon Web Services (AWS) for scalable cloud deployment, and Intel Software Guard Extensions (SGX) to create hardware-based trusted execution environments (TEEs). The system ensures end-to-end confidentiality and integrity of sensitive documents during processing, even in the presence of privileged threats.

The methodology involves developing a Java-based backend integrated with SGX enclaves via the Java Native Interface (JNI), isolating critical operations such as encryption, decryption, and redaction within secure enclaves. A simulated SGX environment is used for prototyping, followed by deployment on AWS to evaluate performance and real-world applicability. The system architecture (Fig. 1) incorporates secure data transmission (e.g., AWS KMS) and enclave-attested processing to mitigate cloud-level risks.

Anticipated outcomes include a working prototype that validates secure enclave-based processing of documents and data, with performance benchmarks under SGX constraints. The system will demonstrate practical integration of TEEs in real-world backend workflows using Java and cloud services.

Future work will explore extending the framework to secure processing in IoT and blockchain-integrated systems, enabling trusted automation in areas such as self-driving cars, industrial robots, and critical infrastructure. This convergence of SGX, cloud computing, and decentralized trust aims to build resilient systems that can operate securely even in adversarial environments.



Installation and First-Light Observations of an He I 10830 Synoptic Telescope

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Solar eruptive events, like flares and coronal mass ejections, can significantly impact Earth and its near-Earth environment – a phenomenon known as “space weather.” To better understand the space weather’s origin, NJIT and California State University, Northridge (CSUN) have jointly developed a synoptic solar telescope. This new instrument operates in the near-infrared at the Helium 10830 Å, providing high-cadence, high-sensitivity polarimetry measurements of the solar chromosphere across a 320" by 256" field of view. This REU project involves the installation and precise calibration of a Paramount ME telescope mount, the installation and first-light observations of the new telescope, and preliminary processing and analysis of scientific data.

Developing Biodegradable Mulch for Sustainable Agriculture

Camila Martinez, Advisor: Dr. Lisa Axe, and Mentor: Nikki Rodriguez, PhD Student

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Abstract: The practice of mulching in agriculture has been an integral part of human cultivation techniques since well before 500 BC. Since 1948, poly(ethylene) (PE)-based mulch films have been widely used globally. PE mulch is a significant source of microplastic pollution in soil fauna, subsequently integrating into our food chain. Microplastics have been found in human tissues such as the placenta and arteries. The accelerating growth of the human population will exacerbate this issue as a result of higher food demand. For this reason, the need for durable, biodegradable mulch films, which can be directly tilled and degraded in the field, has emerged. However, biodegradable options currently available fail to meet the durability that PE offers; furthermore, the degradability of these films requires further analysis. The overarching objective of this research is to develop an optimized composition of a biodegradable film comprised of microcrystalline cellulose (MCC) and hydroxyapatite (HA) particles intercalated in a polymer matrix of poly(lactic acid) and poly(butylene adipate terephthalate) that exhibits properties similar to PE. Films were melt-mixed in a double-arm mixing unit fitted with roller mixing blades and then hot-melt pressed to produce homogeneous, reproducible samples. Films were then subjected to mechanical testing, ultraviolet (UV) accelerated aging, and water absorption simulations to identify the optimal composition for enhanced durability and environmental performance. Uniaxial mechanical tensile testing was performed to characterize stress at break and elongation at break. Biodegradable mulch films must exhibit a high tensile strength (≥ 18 MPa in machine direction, ≥ 16 MPa in transverse direction) and a high percentage elongation ($\geq 200\%$ in machine direction, $\geq 350\%$ in transverse direction) according to commercial standards. The UV accelerated aging setup uses high-intensity fluorescent lamps to simulate 3 months of sunlight over 9.7 days. Preliminary results show that MCC concentrations strongly affect water absorption, which is important in biodegradation after tillage. However, added MCC and HA particles can compromise the ductility of the film. Therefore, we hypothesize that there will be a composition where properties are balanced for meeting agriculture requirements while undergoing degradation once tilled into the soils within a 6-month period. Future work seeks to identify the optimal composition, compare its properties with PE and biodegradable films currently on the market, and evaluate the films in field studies to ensure commercial viability.

Leveraging Digital Twin Technology to Model Human-Geography Interactions

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On the surface, societal actions appear extremely unpredictable and are highly dependent on the situations encountered by the masses. The way one group acts in Situation A can differ significantly from how that same group behaves in Situation B. However, recent research has introduced the emerging concept of a *digital twin*—a virtual replication of an environment that allows for simulations to observe human behavior. While it may never yield 100% accurate results, a well-designed digital twin can provide critical insights into population dynamics, potentially leading to groundbreaking societal advancements. Understanding this concept can assist urban planners in designing better cities, enable law enforcement to allocate resources more effectively, and support event organizers in maintaining safety, security, and enjoyment for large crowds—among a multitude of other benefits.

Our team aims to research these processes by first creating a simplified, low-level digital twin of NJIT. This involves selecting appropriate software to map NJIT's buildings, analyzing human flow into and out of different areas, and identifying key hotspots of social interaction and physical engagement. Once the mapping is complete, we will begin running simulations using the acquired data to analyze various behavioral characteristics. We plan to focus on targeted simulations—such as an active shooter drill or a large concert—to assess how the campus would respond to such scenarios.

After conducting enough simulations, we hope to determine the appropriate hyperparameters that would allow us to extrapolate our findings to untested situations and assess whether our digital twin model is applicable across the entire search space.

Overall, the potential use cases of this technology are vast. We hope that our research will enhance campus safety and help students feel more secure in the face of potential threats. Additionally, it could support improvements in campus design, resource allocation, amenity placement, and event planning by providing deeper insight into human behavior in this environment.

While this research is initially focused on NJIT, we envision it as a stepping stone toward implementing digital twins in larger environments, such as suburban towns and cities. Unlocking this potential could become a major asset for governments and businesses working to improve our society.

Unifying Design: Facilitating Interdisciplinary Collaboration with OpenUSD

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Abstract: Large-scale design requires collaboration and coordination between many individuals, uniting diverse strengths to build a complete project. However, communication between experts from different disciplines can be difficult, as each utilizes various tools, often with unique ecosystems to complete their tasks, but must bring all the materials together during the process. A common medium for files and information is needed to address this issue, but currently, there are few tools to allow communication between software of different types. The project aims to increase the efficiency of interdisciplinary work within the College of Architecture and Design and beyond, by introducing a standard file type and framework for housing and editing assets across design tools and software ecosystems: OpenUSD (Universal Scene Description). OpenUSD is an open-source software suite developed by Pixar, which enables uniformity in structure across multiple software platforms and workflow pipelines. It facilitates simple transfer together with version control systems, to reduce the complexity and difficulty of moving files across diverse systems. Using industry-standard software from across design disciplines, the project aims to restructure the workflow of an ongoing collaborative project, Smiõr, an animated short film, to evaluate OpenUSD's potential for inclusion within HCAD, and create instructional material for future students to utilize the framework. Integrating a standard interface will facilitate communication between members of project teams, elevating the level of student collaboration to that of professional studios. The quick transfer and swapping of files in a smooth manner will prepare students for high-level collaboration within design industries.

Title: Investigating ionospheric activities during solar eclipse using radio observations

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Abstract: The ionosphere (60–1000 km) is an ionized layer of Earth's upper atmosphere that has a significant impact on radio astronomy by causing phase delays, refractive shifts, and signal distortions that impact observational accuracy, especially for low-frequency instruments (< 300 MHz) such as the Owens Valley Radio Observatory Long Wavelength Array (OVRO-LWA). This project aims to characterize ionospheric effects on low-frequency radio images by analyzing shifts in radio source positions during the October 2023 annular solar eclipse using astrometry and complementary Global Navigation Satellite System (GNSS) data to correlate total electron content (TEC) gradients of observed radio source shifts. Using the eclipse as a natural laboratory allows for analysis of deionization, non-linear recovery and dynamic gradients to gain greater insight into ionospheric response during rapid change in solar flux. Preliminary analysis shows measurable frequency-dependent source displacements that are consistent with the expected inverse square relationship with frequency, confirming ionospheric refraction as the primary mechanism for radio image distortion. Next steps in correlating ionospheric parameters from radio-based positional shifts to GNSS-derived TEC gradients are expected to reveal complementary spatial and temporal variations in electron density. By using low-frequency radio imagery as a medium to study the ionosphere, this research is expected to improve understating on how ionospheric behavior is altered during localized solar events.

Exploring Pre-erupting Configuration of Magnetic Fields in Solar Active Regions

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Non-recurrent geomagnetic storms have been identified as a prime result of Coronal Mass Ejections (CMEs). In observing the evolution of solar active regions (ARs), specifically through the use of magnetic flux ropes (MFRs), a different approach to the already existing predictive models can be constructed to better define the time and location of a CME. This project aims to explore and parameterize the pre-eruptive magnetic configurations in solar ARs by detecting signatures of MFRs using extrapolated coronal magnetic field data. By utilizing extrapolated magnetic field data obtained from the Helioseismic and Magnetic Imager (HMI) aboard NASA's Solar Dynamic Observatory, the twist flux and intensity flux of the solar ARs can be analyzed in Python. In plotting flux over the time of the solar AR, a clear indication should be displayed as to when the eruption occurred, resulting in a potential proposal to a new predictive method of observing the evolution of solar ARs. For the purpose of this project, past data collected over the years was used to test the predictive scheme. Going forward, being able to incorporate this approach for real-time data is the goal.

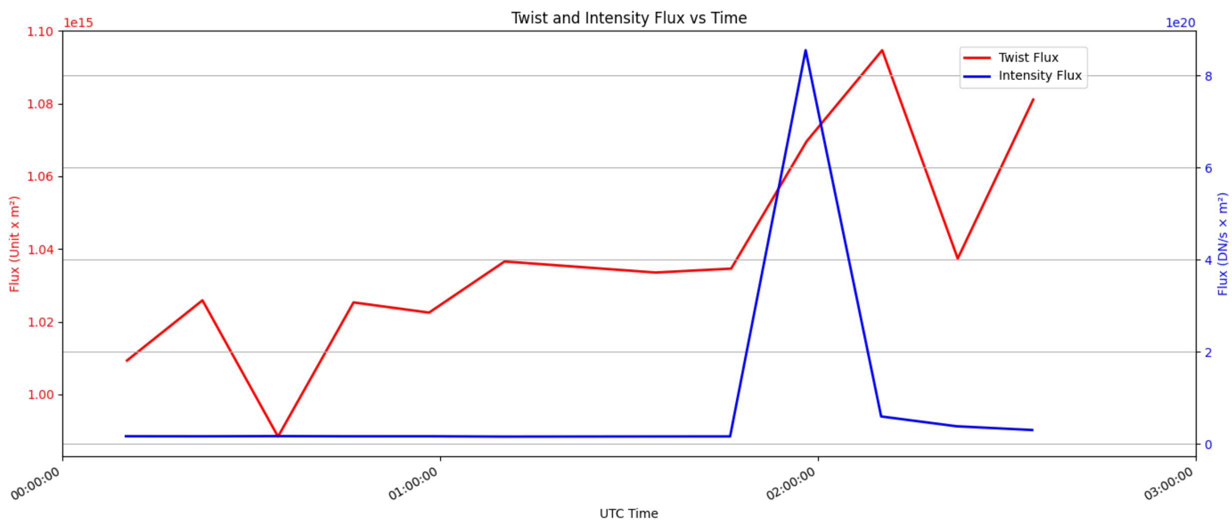

Figure 1. Comparison of twist flux and intensity flux with respect to the lifespan of a solar active region on 2011-02-15.

Virtual Reality Ontology Object Manipulation (VROOM)

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Ontologies are structured knowledge representations that can enhance efficiency and consistency in biomedical reasoning by standardizing vocabulary and conceptual relationships, supporting more accurate diagnoses. However, their current format as two-dimensional drop-down style menus in user interfaces can potentially result in misinterpretation of the ontological structure and content. To address these limitations, Virtual Reality Ontology Object Manipulation (VROOM) introduces a three-dimensional virtual reality software for immersive ontology visualization, exploration, and manipulation. Previous studies have highlighted the need for virtual reality media to support multi-user collaboration for the facilitation of effective data delivery. This study compares the usability and user experience of VROOM in single- versus multi-user virtual reality environments, which is done using a singular session for subjects divided into three blocks. The first block consists of a virtual demographics survey and a short lecture on ontology. The second block involves hands-on interaction with the virtual reality systems, with participants assigned to either single- or multi-user sections to complete predetermined tasks designed to evaluate the usability of graph visualizations and the constructional tools used when authoring an ontology. The third and final block will include a brief interview to assess the user experience for subjects in both groups. The outcomes of this study will contribute to improving data navigation and knowledge representation in biomedical informatics. Ultimately, systems like VROOM could enable more accurate, collaborative, and efficient diagnostic processes, reducing errors from misinterpreted data and supporting the advancement of precision medicine.

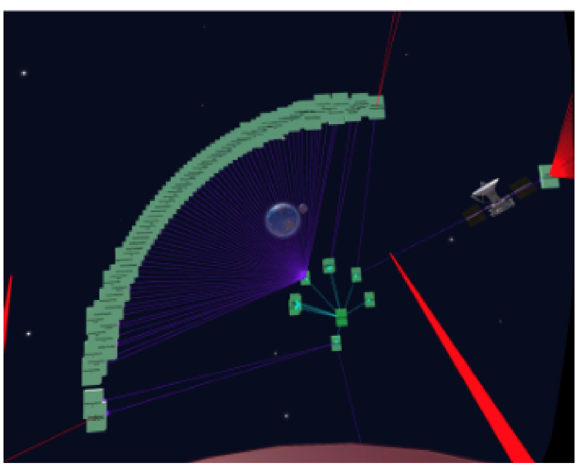

Figure 1: Immersive ontology representation within the VROOM system as viewed through an Oculus VR Interface

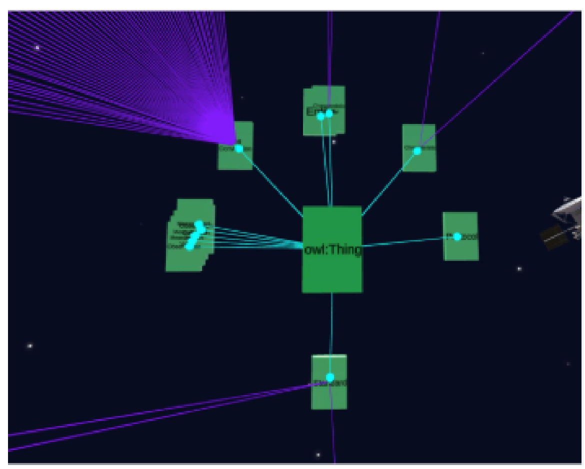

Figure 2: The scope zoomed into a specific section of the ontology

Informed Design of a Social Fitness Platform for the Visually Impaired

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It is estimated that nearly 2 billion people across the world live with a visual impairment (VI), with at least 4 million residing in the US. People living with VI experience loneliness at higher rates than sighted people, and the risk increases with age and other illnesses. Despite the risks of comorbidities being highly prevalent among them, persons with VI often fail to comply with prescribed exercise regimens due to safety concerns, lack of accessible transportation, and fear of being ridiculed when exercising. Thus, new and improved methods to engage this at-risk population in physical exercise are necessary. A social platform that combines exercise and social connections could create a welcoming atmosphere that both tackles mental health issues and promotes long-term engagement in physical health activities. However, little is understood about the design factors that would lead to consistent use of such technology. This project will inform the design of a social fitness platform through a survey inquiring about the interests and preferences of persons with VI in three overall categories: social interactions, fitness/exercise, and technology use. Questions from the survey will aim to understand the common experiences of persons with VI, and the possible impact of VI on their exercise routines. The survey will be administered to 30 persons with VI, and a similar survey will be administered to persons of similar backgrounds not experiencing VI. By comparing the responses of these two populations, the magnitude of differences and preferences for technology-based social exercise will be examined. The results will contribute to the current body of literature in assistive technology and serve as a benchmark for a social fitness app. It is anticipated that the findings will provide insight into the usability of technology, the barriers surrounding physical activity, and the methods of experiencing exercise information. The survey will be made publicly available, and its results will be published in a peer-reviewed journal.

How An Increase In Data Analysts Maximizes the Potential of FIFA Teams

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With the 2026 FIFA World Cup on the horizon, 48 squads will compete for one common goal. As odds are stacked against each specific team at different levels, a growing number of data analysts could help close the gap, making this outcome more exciting. Although teams from Europe and South America have been dominating the stage for multiple years, nations from other continents have begun to rise in influence, driven by the growing impact of data science. Not only are analysts tasked with creating pre-match lineups, but they are also responsible for other important tasks, such as in-game adjustments, advising players during training, and predicting match outcomes before they occur, considering several variables. The primary objective of this project is to demonstrate how data analysts can utilize methods that many successful teams have employed in recent years, while also gaining insight into which squads are likely to adopt these approaches in 2026. This study will examine how Goldman Sachs analysts nearly predicted an improbable 2018 World Cup result, the application of data in specific leagues to inform national team development, the understanding of rule changes, and the utilization of models such as the Poisson distribution, as well as the impact of forecasting. For instance, 9% of Goldman Sachs' data analysts picked France to win the World Cup, based on stadium conditions and FIFA ratings, compared to 2% of the general public.

As France and Spain emerge as up-and-coming dynasties, their teams were initially shaped by analysts who have completely revolutionized their domestic leagues as well. La Liga was not as prominent 20 years ago. Analysts developed apps like La Liga Tech and the Barca Innovation Hub, which helped the league become more competitive beyond just the rivalry between FC Barcelona and Real Madrid. By using these apps that tracked every advanced statistic of players, teams like Atletico Madrid became more successful due to their ability to predict future player values. These tools not only helped identify talents from other countries, such as Dani Alves, but also transformed raw data into actionable metrics, enhancing their capability to discover players like Andres Iniesta, Lamine Yamal, and Pedri, who contributed to their victory in the 2010 World Cup and three European Cups. Noticing that France is capable of developing apps like Goaltime, which tracks player speed to the ball, analysts from Skillcorner, an AI-based tool that creates variations of live footage, have successfully contributed to the development of clubs like PSG, while identifying key players that have taken them to two World Cup finals in a row. These included Kylian Mbappé and Ousmane Dembélé, with another batch of superstar players now also arriving.

Considering the information presented so far, analysts are leveraging modern technologies to build teams and enhance their understanding of prediction methods. With more resources at their disposal, these teams can gain a significant advantage. In my future work, I plan to examine the strategies employed by Morocco and Japan in 2022. This analysis will also help me assess how countries like Saudi Arabia, Qatar, and others might perform, all under the overarching theme of how analysts will influence emerging teams in the 2026 Cup.

Small-scale Ejections and Eruptions from the Solar Chromosphere

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Small-scale eruptions may play a key role in heating the corona and driving solar wind acceleration. These events are dynamic and are often associated with the magnetic network of the Sun. While they are generally attributed to small-scale magnetic reconnection, driven flows and vortex-induced upflows one specific type of small scale eruption, known as a mini-filament eruption, has become an important subject of study due to its relatively larger size and clearer structure compared to spicules or small jets. This makes them ideal for detailed observational analysis. This study focuses on a mini-filament eruption observed on August 31, 2018, using high resolution H-alpha images from the Goode Solar Telescope (GST) at Big Bear Solar Observatory for the period between 16:45 and 18:15 UT. High-resolution chromosphere images from GST/VIS were processed using image derotation and alignment to remove solar rotation and track the evolution of the eruption. Time-distance (TD) maps were constructed using multiple slits to investigate both eruption and pre-eruption plasma flow dynamics. Dopplergrams will be used to examine line-of-sight velocities in the chronosphere and coronal counterparts using extreme ultraviolet (EUV) data from the Atmospheric Imaging Assembly (AIA) onboard NASA's Solar Dynamics Observatory. Differential emission measure (DEM) analysis will be used to determine the coronal plasma's temperature structure. Additionally, magnetic field data from SDO's Helioseismic and Magnetic Imager (HMI) will be used to model the magnetic environment surrounding the mini-filament. The goal of this research is to investigate mini filament eruptions and how they drive wave activity such as torsional motions and vortex flows that may contribute to coronal heating and solar wind generation. Through the analysis of multi-wavelength and multi instrument solar data, this project aims to advance our understanding of how these small scale events connect the lower solar atmosphere to the outer corona.

Efficient quadrature for nearly singular integrals in potential theory

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Abstract: Some physical models include components that fluctuate wildly. This occurs within many fields, such as electrostatics. For example, when two particles of opposite charge are nearly touching, the force of attraction between them approaches infinity. In most practical circumstances, integrating these models would be accomplished as an approximation due to feasibility and efficiency. However, most current methods to approach such problems are dependent on the type of observed singularity. That is, such methods are only efficient for one family of fluctuating phenomena. As a potential solution, this project aims to design a quadrature that can accurately approximate the integrals of any nearly singular families of functions. To accomplish this, we will begin by implementing the generalized Gaussian quadrature (GGQ) algorithm of [Bremer 2010] in MATLAB, which entails function family discretization, function compression (utilizing the SVD), building a Chebyshev quadrature, and applying nonlinear optimization to down-sample the points. The quadrature rules are efficient for low rank families of functions, and likely will be effective for nearly singular functions after some parameter tuning is performed. Our goal will be to accurately approximate integrals of logarithmic and polynomial singularities. Lastly, the code will be arranged into a function that can allow other researchers to investigate families of functions of their choice accessibly and effectively. With this, researchers studying a nearly-singular mathematical model can apply our coding package to grasp how their phenomenon metrics act cumulatively over time, space, or other independent variable.

Resolving the Distribution of Ionospheric Irregularities

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The Earth's ionosphere is a region of the upper atmosphere between 50 km and 1000 km that contains a high density of plasma. Ionospheric irregularities, characterized by fluctuations in plasma density, are an important part of space weather dynamics and significantly impact modern technological systems, including satellite communications and radar operations. Despite the importance of understanding these irregularities, we currently possess limited knowledge of their distribution, formation, and evolution. The primary goals of this research are to: (1) quantify how solar and geomagnetic drivers impact these irregularities, and (2) characterize the spatial scales of ionospheric irregularities. Using high-resolution Swarm spacecraft data taken in Earth's ionosphere, this research will quantify the distribution and spatial-scales of irregularities through sorting plasma data by parameters such as magnetic latitude, magnetic local time, and season. Then, utilizing ground-based SuperMAG magnetometer observations of the Earth's magnetic field and Geostationary Operational Environmental Satellites (GOES) spacecraft observations of the Sun, this work will determine what solar or geomagnetic activity leads to different irregularities. The findings from this research will be imperative for understanding space weather and plasma physics - both of which will help mitigate the impact of space weather on critical spacecraft technologies.

Materials Science and Engineering

Development and Optimization of microfluidic membrane contactor for gas sensing application

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Abstract: Microfluidic gas sensors offer a promising pathway toward compact, sensitive, and selective environmental sensing platforms. In this work, we explore the benefits of using a microfluidic membrane contactor as an electrochemical gas sensor. The architecture consists of two microchannels, one for gas flow and another for confining the sensing liquid, separated by a hydrophobic membrane. These microchannels are sandwiched between two glass substrates, with the bottom glass substrate comprising interdigitated microelectrodes in contact with the sensing liquid. We developed a theoretical model to analyze the mass transfer behavior of this system and found that above a certain threshold gas flow rate, mass transfer is no longer rate-limiting. Experimental validation using CO_2 as the model gas and [EMIM][2-CnPyr] ionic liquid as the sensing element confirmed these findings. We further examined the benefits of using microchannels for both gas transport and liquid confinement. The model demonstrated that directing the gas through a microchannel significantly enhances mass transfer of the target analyte compared to macrochannel configurations, a result corroborated by experimental data. Lastly, we demonstrated that confining the ionic liquid—the sensing medium—within a microchannel enhances the sensor's sensitivity and response time for a fixed volume of analyte, compared to macrochannel-based designs. Together, we showed that a microfluidic membrane contactor architecture for gas-liquid significantly enhances the performance of a gas sensor. These studies lay the groundwork for next-generation microfluidic gas sensors.

Keywords: Microfluidics, Ionic Liquids, Electrochemical Impedance, Gas–Liquid Interface, CO_2 Sensing

Predicting Printability of Hydrogel Bioinks Using Machine Learning

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Abstract: The organ shortage has long been a universal healthcare problem, with only half of those on the waiting list for an organ transplant in the US receiving one. Tissue engineering using 3D bioprinting has emerged as an innovative solution to this problem, as it allows personalized tissues to be created from a patient's cells. A major barrier, however, lies in the printing of the hydrogel scaffolds, as the hydrogels must meet specific material conditions to print properly, and these conditions are only identified through extensive trial and error. Machine learning (ML) models that predict the printability of the hydrogels based on their properties have the potential to greatly streamline the research process. However, current ML models fail to take into account material-dependent characteristics, such as rheological behavior, which greatly influences print quality. This project seeks to address this gap by creating a ML model that is able to predict hydrogel printability based on different rheological characteristics, like viscosity and crosslinking kinetics. To achieve this, different MeAlg hydrogels will be synthesized and tested for rheology and printability. This data will be used to train the ML model. Other hydrogels, like MeHA and Pluronic, will be used to test the model's ability to generalize to other bioinks by comparing experimental results to the model's predicted results. In the future, we hope to also include cell viability tests as data for the ML model to help predict hydrogel function. An accurate and successful ML model could greatly streamline the research process, as it would reduce experimental guesswork. In turn, we could move tissue engineering closer to clinical application by allowing researchers and clinicians to optimize hydrogel formulations tailored for specific applications.

A Numerical and Experimental Study of Faraday Waves on Two Free Surfaces in a Two-Fluid system

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Abstract: When an open container filled with fluid is vibrated externally, standing wave patterns appear on the surface known as Faraday waves in certain frequency envelopes, dependent on the magnitude of forcing. Through numerical and experimental analysis, the nonlinear dynamics of Faraday waves in a two-layer fluid system, within an open container subjected to vertical vibrations, can be observed and modeled. The findings will advance understanding of nonlinear wave interactions in stratified fluids, with potential applications in geophysical fluid dynamics, oceanography, and microfluidic technologies, specifically when density-stratified fluids interact with an external force. Faraday waves, first observed by Michael Faraday in 1831, are standing wave patterns that emerge when a fluid is parametrically excited at specific frequency ratios. Current research describes ways to map the nonlinear nature and effects of damping, surface tension, and other factors that contribute to nonlinearities. Previous studies have examined these interactions in a closed tank, which introduces different dynamics compared to systems with two free surfaces. The governing equations for each layer are modeled as coupled nonlinear Mathieu-type equations, incorporating viscous damping and cubic nonlinearities to capture finite-amplitude effects. Numerical simulations using a 4th-order Runge-Kutta method will predict the system's response under varying forcing frequencies and amplitudes, focusing on three key scenarios: (I) surface-wave-driven internal waves, (II) internal-wave-driven surface waves, and (III) simultaneous excitation of both modes. Each of these will be excited under different frequencies based on the density of the fluids. With two free surfaces, direct energy exchanges between the fluids increase, leading to instabilities that can be examined. Laboratory experiments will validate these predictions using a glass tank filled with two immiscible fluids of differing densities, vibrated via a motor-controlled mechanism. By analyzing wave motion images, we compare the results with theoretical predictions. This study aims to elucidate the energy exchange mechanisms between the two wave modes and their stability under parametric resonance, supported by an approximate numerical model to predict nonlinearities.

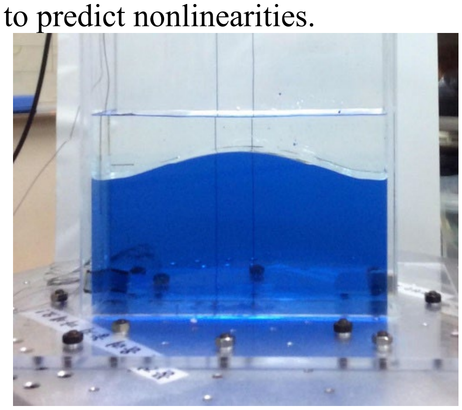

Figure 1: Experimental setup for the internal wave mode in a two-layer system

Investigation on the Effects of Nitrogen-doped Graphene (N-G) Nanomaterials on Thermal Properties of Phase Change Materials (PCM)

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Abstract: Phase Change Materials (PCM) have attracted attention due to their potential to store/release relatively large amounts of latent heat during phase changes. This capability has great promise in multiple enterprises, especially those involving thermal management and energy storage. The material also has applications across external industries related to cold-chain packaging, construction, electronics, and many others. Previous studies have shown that adding carbon based support materials have increased thermal conductivity; however, it came at the expense of decreased latent heat absorbed. For our project, we synthesized several samples of nitrogen-doped graphene (N-G) to serve as support materials for PCMs. The N-G was produced using a nanoscale, high-energy wet ball milling technique, in which precursor materials were placed in a grinding jar, using zirconia balls as the grinding media. The PCM composite was subsequently combined with nitrogen-doped graphene (N-G) via sonification. Multiple ratios of N-G to PCM were synthesized and the resulting N-G/PCM composites were then evaluated for its performance using techniques such as differential scanning calorimetry and various spectroscopy methods. The results indicate promising outcomes, as the composite demonstrates an increase in thermal conductivity as well as an increase in latent heat. Further studies will concentrate on enhancing the quality of support materials and fine-tuning the N-G to PCM ratio for improved composite functionality.

Investigation of Quasi-Periodic Pulsations in Long-Duration Solar Eruptive Flares

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Advisors: Dr. Sijie Yu and Dr. Xingyao Chen
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Quasi-periodic pulsations (QPPs) are bursts of energy that exhibit variable periodicity and are often observed in microwave and X-ray emissions from solar eruptive flares. Although they are common, current QPP models don't fully agree on the main mechanisms that drive such phenomena. This project aims to investigate the relationship between QPPs and the morphology of CMEs (i.e. large-scale solar eruptions) in long duration solar flares. The significance of this work lies in potentially supporting a magnetism-based QPP model with experimental results using the latest data gathered from the Expanded Owens Valley Solar Array (EOVSA), a suite of NASA spacecraft and the Heliospheric Observatory (SOHO) coronagraph. The morphology of the associated CMEs will be examined using multi-wavelength imaging and white-light data, from where spatial parameters will be derived. The obtained measurements will be statistically analyzed along periodicity data obtained from a wavelet transform of QPP spectrograms to construct QPP-CME correlation case-studies. The current hypothesis is that the QPPs' periodicity and the associated CME's current sheet length may have a positive correlation. The work to test this hypothesis is ongoing.

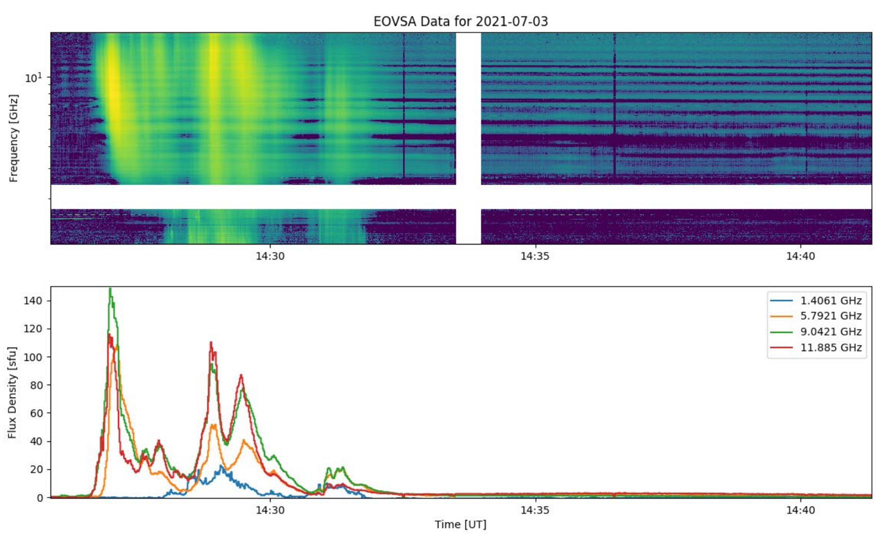

Figure #1: Microwave spectrogram of a quasi-periodic pulsation event on Jul 3, 2021.

Chadley Gede

Abstract:

PFAS (per/poly-fluoroalkyl substances) are linked to infertility, accelerated puberty, and increased risk of cancer. A 2015 study found that approximately 97% of Americans have PFAS in their blood. PFAS may mimic fatty acids in the body and are strongly correlated to dyslipidemia; dyslipidemia is associated with cardiovascular disease. PFAS are resilient and pervasive environmental contaminants. They are most commonly consumed from groundwater-connected sources such as well water and tap water. Once ingested, they linger in the body from days to decades. PFAS encompasses a large number of molecules that require highly specific processes. Therefore, cost-effective PFAS water treatment is difficult to implement. Lab testing is the conventional method to reliably test for PFAS. Sending water samples to a lab can cost hundreds of dollars, and results are prepared after multiple days. Testing for PFAS is important for individual consumers of water to judge the quality of their drinking water. However, high cost and long waiting times are inconvenient for stakeholders.

As an aid to the issue, a capacitive sensor comprised of a gold electrode coated in a polyaniline-chitosan composite detects varying concentrations of PFOA (perfluorooctanoic acid) in deionized water. The polyaniline-chitosan composite facilitates the capture of PFOA molecules and the transfer of charge to the electrode to be read on the capacitance meter. Electrostatic forces between chitosan and PFOA facilitate the capture and sensing of PFOA. Chitosan is known as a high-quality, environmentally friendly adsorbent. Polyaniline facilitates the movement/transfer of electrons via the benzene rings present in emeraldine salt (the specific iteration of polyaniline used in this composite).

The sensor is expected to detect PFOA in deionized water within the part per billion range. Successful selective detection of PFOA implies cheaper, more accessible PFAS testing for stakeholders. Future research involves modifying the sensor for increased selectivity and sensitivity. The ideal sensor can ignore other substances and ions in water to detect PFOA alone. The maximum contamination level of PFOA in water is 4 parts per trillion; thus, future research involves developing a sensor capable of detecting lower concentrations of PFOA.

Towards Effective Numerical Methods for Earthquake Simulations

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Understanding the internal forces of the Earth's crust is essential for accurate earthquake modeling. Beneath the ground exists an array of tectonic forces applying stresses and strains on different layers of rock, culminating in a delicate balance. By sampling data along layer boundaries and solving the elastostatic equations with said boundary data, it is possible to gather information about the interior of these geological layers. Traditional numerical methods struggle with certain sharp geometries, particularly at regions of dislocation, where abrupt changes in rock displacement occur. Additionally, there is the added constraint of requiring the same type of data for all the boundaries when working with traditional boundary integral methods. Recent advancements in boundary integral equation methods offer promising solutions, but existing approaches do not fully support mixed boundary conditions, limiting their robustness and flexibility. This research seeks to develop a numerical scheme to extend boundary integral equation methods to problems with mixed boundary conditions at corners, while maintaining stability and accuracy. The method will be first tested on the Laplace equation as a prototypical case before being applied to a special case of the elastostatic equations. This work lays the foundation for a generalized algorithm for the standard traction boundary condition. Although motivated by earthquake applications, the mathematical techniques developed here have broad relevance, with potential applications in materials science and other areas where understanding deformation and stress is essential.

Electrohydrodynamic co-jetting of particles for self-assembly and drug delivery applications

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Conventional drug delivery faces various biological barriers, such as premature clearance by a patient's immune system, an inability to control a drug's release, and an inability to release multiple synergized drugs that can circulate within a patient's system long enough for targeting. Thus, there is a clinical need for drug carrier systems that are capable of multi-drug loading, independent compartmentalization, extended blood circulation, and targeted delivery. Needs that can be met through the use of biphasic Janus particles, fabricated through electrohydrodynamic co-jetting (EHD co-jetting). Other multifunctional particle carrier systems have typically resulted in isotropic particles whose functionalities target the same area. Multifunctional particles fabricated from EHD co-jetting can incorporate different functions into distinct areas of the particle, thus resulting in particles that can target different areas without having their functionalities compromised or weakened. In EHD co-jetting, two side-by-side syringe pumps feed two chemically distinct solutions to a grounded collector plate. When a high voltage is applied to the dual needles, the droplet at the tip of the needles elongates into a sharp Taylor cone that ejects a jet, which evaporates in flight. Upon reaching the collector, the droplets precipitate into biphasic particles that mirror the jets' co-flow. The particles were then characterized by using scanning electron microscopy (SEM) and nanoparticle tracking analysis (NTA). The particles fabricated with this technique are expected to be able to carry multiple drug types, with the potential of being able to accomplish site-specific release, which is critical for combination therapies and drug administration.

Predicting Crack Arrest Fracture Toughness of Structural Materials through Multimodal Data Analysis

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Abstract: The aging and accidental damage of structural materials can lead to catastrophic failure in critical infrastructure, such as oil drilling facilities and nuclear power plants, posing an enduring threat to social and economic security. It is essential to assess and monitor the risk of catastrophic failure throughout the lifecycle of a structural material. Crack arrest fracture toughness, which characterizes a material's ability to halt an advancing crack, provides an effective metric for risk assessment. However, experimental measurement of crack arrest fracture toughness remains technically challenging and economically impractical for widespread application. To overcome this limitation, we aim to develop a machine learning (ML)-based model to predict crack arrest fracture toughness using more readily accessible material information, including composition, heat treatment history, and microstructural features, and to deploy this model as an engineer-friendly, web-based application. The success of this project hinges on compiling a multimodal dataset of crack arrest fracture toughness through a comprehensive review of scattered literature and training an ML model by making full use of the collected data. The ML-based model for predicting crack arrest fracture toughness developed in this project can offer valuable insights into the physics underlying crack arrest phenomena, enable rapid risk assessment of structural materials, and inform the development of guidelines for enhancing crack arrest fracture toughness. This project is intended to serve as a steppingstone toward future research on fracture management and risk control in aerospace and hypersonic materials under extreme environments.

Molecular Mechanisms of Interaction between PFAS and Surfactants

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Abstract: Perfluoroalkyl and polyfluoroalkyl substances (PFAS) have a wide range of applications: in industrial mining, food production, firefighting foam etc. However, these applications result in the contamination of groundwater with PFAS which can lead to exposure to humans. Methods like foam fractionation can be used to remove long-chain PFAS molecules from water. Cationic surfactants such as cetyltrimethylammonium chloride (CTAC) can be added to improve the efficiency of removal of short-chain PFAS. In this study, we investigate the molecular interactions of long-chain PFAS such as perfluorooctanesulfonic acid (PFOS), and short-chain perfluorobutanoic acid (PFBA) and perfluorobutanesulfonic acid (PFBS) with CTAC using molecular dynamics simulations. We will determine possible sites of interaction between PFAS and single CTAC molecules, as well as interactions of PFAS with CTAC micelles. The interaction energies as well as the contribution of electrostatics and hydrophobic interactions will be obtained. These insights can help compare the mechanisms of different PFAS compounds, such as PFOS, PFBA, and PFBS and develop better strategies for purification of water contaminated with PFAS.

Miniature Peptide Synthesizer

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Insulin, made of 51 amino acids, is the first peptide ever synthesized, and its synthesis is an extremely monumental innovation in drug discovery. Since then, it has been able to increase the production of the drug to treat people suffering with certain types of diabetes. Therapeutic peptides can act as hormones, growth factors, ion channels, and other biological structures[1], therefore making their synthesis valuable in the pharmaceutical industry as they have the opportunity to treat several different diseases, such as cancer.

Solid phase peptide synthesis (SPPS) is a method of peptide synthesis that builds peptides connected to a resin. 9-Fluorenylmethyloxycarbonyl (FMOC) chemistry is a widely used method of SPPS. It works by using an FMOC group to protect an R-group of an amino acid to orient it correctly when bonding with another amino acid. This FMOC group is then washed away, leaving another R-group available to bond with another amino acid. This process is repeated until the desired peptide is created. Peptide synthesizers like the Liberty Blue uses FMOC chemistry, along with microwave technology, to synthesize peptides.

However, the Liberty Blue can cost between $25,000 to $50,000 even disregarding maintenance costs. Furthermore, its installation requires a certified technician and mandatory training resources from the manufacturer. It also creates very toxic waste that must be handled under a fume hood with the user being required to wear suitable protective equipment.

The objective of this research is to make a miniature peptide synthesizer that can address these concerns. The synthesizer will have 32 different slots for 32 *possible* amino acids, it should be small enough for transport and point-of-use, and it will require no special training to install and operate.

To create the prototype of the synthesizer, it was divided into 4 sections: the first-selector valve, the reactor, the second-selector valve, and the output container, which contains the waste, the product, and recycled material like dimethylformamide (DMF) and dichloromethane (DCM). The first selector valve has 4 separate areas with 8 spots each that house the amino acids, the selection of which is controlled by an Arduino-powered stepper motor and software. The reactor is a hollow half-cylinder with multiple shelves inside to increase surface area for the purpose of increasing the productivity of the reaction. The second selector valve is where the products are separated, with 3 areas for the finished peptide, the waste,

It is expected that the miniature peptide synthesizer is able to separate waste and product effectively without leaking or wearing down the material after continued use. It is also expected to be fully automated using stepper motors. This device should be used in areas where therapeutic peptides would be needed, but there is no space for or access to a traditional peptide synthesizer, like on spaceships or areas far from hospitals.

Microfluidic Production and T_g Analysis of PLGA Nanoparticles for Drug Delivery Applications

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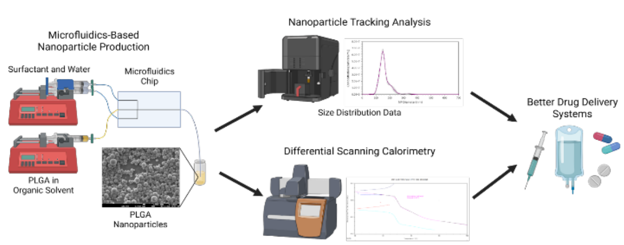
Conventional cancer treatments (ex. chemotherapy) are very limited because they harm both tumors and healthy cells. Meanwhile, a targeted drug delivery system would safely transport drugs through the bloodstream to act only on cancer cells while leaving the rest of the body unharmed. This system would improve patients' physical health, mental health, and quality of life. Poly(lactic-co-glycolic) acid (PLGA) nanoparticles are of especial interest as drug vehicles because they are long-lasting in the body, cross biological barriers, and break down into safe, biodegradable molecules. However, a significant issue with PLGA vehicles is burst release, where a large amount of drug rapidly leaves the vehicle instead of releasing slowly and consistently at its intended destination. Burst release is related to the glass transition temperature (T_g) of the PLGA vehicles. T_g is the temperature at which a molecule changes from a rigid, "glassy" state to a flexible, rubbery state. If the body heats the PLGA vehicle above its T_g, drug molecules rapidly escape, reducing the drug's efficacy and increasing the risk of toxicity. As of now, the relationship between T_g and particle size in PLGA is under-researched. To determine how size affects T_g, we want to produce PLGA nanoparticles of various diameters. Traditional production methods use surfactant to avoid particle aggregation but leave irregular amounts of surfactant on the finished nanoparticles, distorting T_g measurements. To solve this problem, we chose microfluidics, a novel approach for both controlled particle production and constant residual surfactant levels. Using the methodology developed through the 2024 URI Phase 1 Seed Grant, we vary microfluidics parameters (ex. PLGA concentration, flow rates) to produce nanoparticles with a range of diameters. After processing particles, we collect data on size distribution using Nanoparticle Tracking Analysis (NTA). We then measure T_g using modulated Differential Scanning Calorimetry (mDSC). Statistical analysis will reveal the effect of particle size on T_g, which is crucial information for designing PLGA nanoparticles that control for burst release. This advancement would be a critical step in producing functional targeted drug delivery systems, with the potential to transform medicine, pharmacology, and cancer therapy.

Figure #1: Schematic of PLGA Nanoparticle Production, Experimental Data Collection, and Future Applications



Theoretical Study of Droplet Electrophoresis

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Abstract: This project concerns motion of a small fluid electrolyte drop in a host electrolyte fluid driven by an external electric field, which is known as electrophoresis. Electrophoresis is a fundamental phenomenon that occurs at the microscopic or nanoscopic scale, and has a wide range of applications from the separation of components in bulk fluid mixtures to microfluidic chemical and biochemical laboratory analysis (nucleic acid and protein separation). Results of an analytically tractable but physically realistic electrokinetic model for the time-dependent motion of a single drop that starts from rest when an external electric field is applied will be explored numerically. This will show the dependence of features such as the droplet's electrophoretic or translational speed, the flow field pattern, and the electric field and charge distribution. The behavior of these features will be explored for a range of parameters that include the viscosity, permittivity, ion concentration of the two fluids, the applied field strength, and ion diffusivities. Graphical visualization of the results and model predictions will play a key role in this study. They will be developed using Matlab's plotting and simulation features to accurately display the behavior of this electrokinetic model. The model is expected to more accurately predict the behavior of droplet electrophoresis in relatively weak electric fields. Future work on this project includes accounting for the membrane potential, a buildup of charges that may be interchanged on the membrane. This is a common occurrence among biological samples. Another addition to the project is to consider an AC applied electric field as opposed to the DC field of this model.

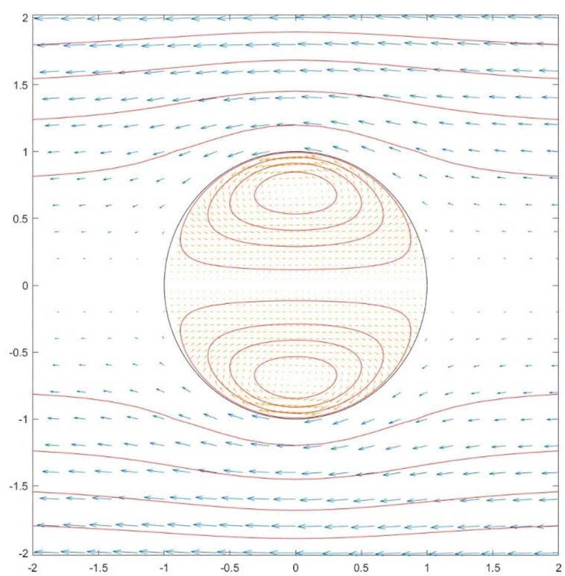

Figure 1: Velocity field and contours of stream function for drop translation

Developing Biodegradable, Safe, and Optimized 3D Printable Biomaterials for Alternatives to Consumer Product Applications

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Micro- and nanoplastics have emerged as environmental and public health threats, with evidence linking their presence in food and consumer products to gastrointestinal, immune, and endocrine disruptions. This research addresses the need for safe, biodegradable alternatives to plastic in kitchenware, packaging, and consumer goods by formulating novel biomaterials compatible with 3D printing. The goal is to develop optimized, structurally reliable, and food-safe materials that do not release harmful particles during use.

This project focuses on the formulation and testing of three biodegradable material blends created using bio-based ingredients. These blends are evaluated through rheological analysis, flow and extrusion testing using syringes, layering stability, and structural integrity tests, including penetrometer hardness, compression strength, thermal resistance, water resistance, and drying shrinkage rates. Key performance criteria also include biodegradability in soil environments, dissolvability, and the recyclability of dried biomaterial samples or print waste.

Anticipated outcomes of this research include identifying one or more candidate biomaterials that demonstrate consistent printability, moderate structural and mechanical durability, optimized material properties, and verified health and environmental safety. These findings will support the development of a functional prototype designed for the most suitable application that is relevant across plastic-reliant industries. Potential use cases range from food containers and disposable utensils to various forms of packaging and storage products.

In the long term, this work may serve as a foundation for ongoing material research at NJIT, with the potential for institutional adoption in student labs or design studios as an incentive to support sustainable design practices. Future directions include publishing the results in peer-reviewed journals, exploring the possibility of FDA food safety validation to expand potential applications, and collaborating with NJIT's sustainability and innovation programs to optimize and scale the materials for broader consumer or industrial use. This project contributes to advancing the role and competitiveness of bio-based 3D printing in reducing plastic waste, protecting human health, and supporting circular design practices.

Analyzing Polymer Nanoparticles in Blood Plasma for Drug Delivery Applications

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The key challenge with chemotherapy treatment in cancer is that healthy cells are also affected by the therapy while targeting cancer cells, leading to increased toxicity levels in patients. This is a significant safety issue with chemotherapy and other non-targeted treatment approaches, resulting in a need for more targeted therapies. Delivering drugs directly to target cells using nanoparticles (NP) has been an evolving field of science and has recently shown great promise in the fields of biomedicine.

However, while NPs are a great tool for targeted therapies, they still need to be researched further, specifically within biological systems. A common occurrence when NPs are introduced into biological systems is aggregation, which is the formation of clusters. This is due to the NPs interacting with the many proteins and other biological compounds found within the blood plasma. The interaction between these proteins and NPs can lead to the formation of a protein corona around the NP, which is a layer of protein that surrounds the particle when it is introduced into a biological environment. When these particles aggregate, it can lead to the decreased effectiveness of the drug being carried by the NP. This occurrence needs to be further researched and better understood for the creation of more effective targeted drug therapies.

The aim of my research is to study the interactions that occur between blood plasma and polymer nanoparticles using nanoparticle tracking analysis (NTA). The NTA is a piece of technological equipment that works by shining a laser beam onto a flow plate that has been loaded with particles suspended within a solution. The particles that interact with the laser beam reflect the light and are captured by a camera. The videos produced by the NTA are then analyzed by the machine, tracking the particles' movement in solution. This data will serve to fill the gaps in previously collected data from my lab and provide more insight into the interactions between NPs and the biological environment.

The purpose of this research project is to understand how polymer nanoparticles interact with goat and bovine (cow) blood plasma in alsever's and sodium citrate anticoagulants in various dilutions with saline to see its effects on protein corona formation. The use of these blood plasmas allows this research to effectively translate to humans due to the great number of similarities between humans and these animals. My goal is to see how this information can be applied to creating an effective targeted drug delivery mechanism with nanoparticles to be used in the human body.

Microfluidic Device for Rapid and Sensitive Electrochemical Detection of mRNA for Cancer Prognostics

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Abstract: Cancer is a leading cause of death, afflicting nearly 1 in 6 people globally. One of the most powerful targets for early detection of cancer is messenger RNA (mRNA), as its gene expression in the body changes after only hours of pathophysiological stimuli. However, mRNA detection is a costly and time-consuming process with the current methods of qPCR and fluorescence labeling. Electrochemical biosensing devices, on the other hand, offer an affordable and label-free alternative to current methods. ESSENCE is a highly sensitive and specific modular electrochemical biosensing platform with functionalized single-walled carbon nanotubes (SWCNTs) transducer material packed into a channel between gold non-planar interdigitated microelectrodes. Shear enhancement reduces matrix interferences and increases selectivity. When a sample flows through the channel, the target mRNA sequence binds to complementary single-stranded DNA probes bound to the SWCNTs through EDC/NHS chemistry. The hybridization event obstructs ion transport near the electrode surface, leading to an increase in charge transfer resistance measured with electrochemical impedance spectroscopy (EIS). By comparing impedance responses across the conditions of blank sample, target mRNA, and non-target mRNA, the biosensor demonstrates an unprecedented picomolar sensitivity and high specificity. Future work will build on this proof-of-concept to enable clinicians to directly run blood samples for oncogenic mRNA transcripts and ultimately transform cancer prognosis in the earliest, most treatable stage.

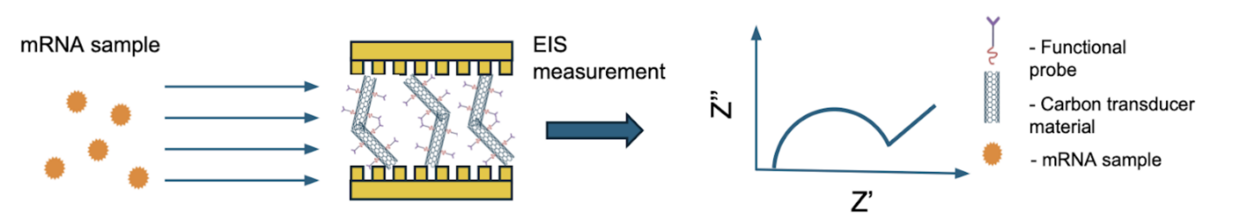

Figure 1. Schematic of the electrochemical detection for mRNA. The data acquisition protocol illustrates the flow of mRNA through the ESSENCE chip, generating Nyquist plots through EIS.

Chemical Vapor Deposition Synthesis of Nitride MXenes for Energy Storage Applications

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Abstract:

MXenes, a large family of two-dimensional (2D) transition metal carbides and nitrides, are attracting increasing attention due to their unique physical and chemical properties. Compared to the carbide MXenes, the synthesis of nitride MXenes has always been a significant challenge in the MXene research field due to their relatively poor chemical stability. This project aims to advance the synthesis and application of nitride MXenes for energy storage, specifically targeting their use as anode materials in lithium-ion batteries (LIBs). The primary objective is to explore and optimize the chemical vapor deposition (CVD) method for synthesizing various nitride MXenes, including Ti_2NCl_2 and V_2NCl_2. The investigation primarily involves optimizing the CVD process and characterizing the resulting product, with the goal of identifying the most effective setup for maximizing both the quality and yield of nitrides MXenes. So far, we have successfully achieved the reliable synthesis of Ti_2NCl_2 MXene on Ti foils by CVD as shown in **Figure 1a and b**. During the following weeks, we will further optimize the growth parameters for Ti_2NCl_2 MXene and achieve the growth of V_2NCl_2 MXene. The obtained nitride MXene powders will finally be fabricated into LI-ion battery anodes and evaluate their electrochemical performance. This information will give a clear picture on the potential nitride MXenes for energy storage applications.

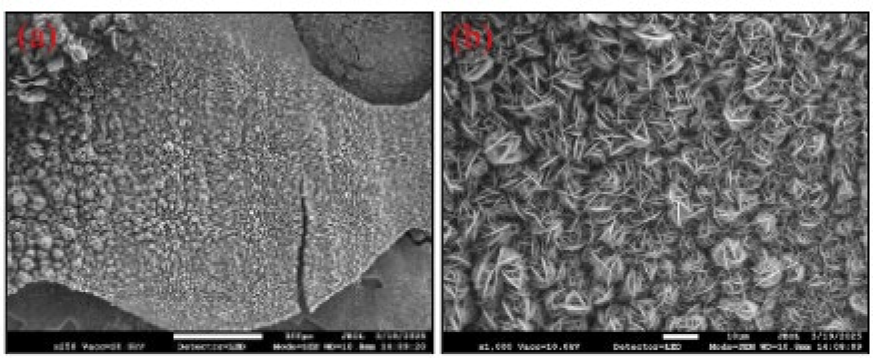

Figure 1. (a) Low magnification and (b) high magnification SEM images of as-synthesized Ti_2NCl_2MXene by CVD.

Spectroscopic characterization of a microfluidic membrane mimic system under dynamic conditions

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Abstract: Target DNA sensing is the detection of the presence, concentration, and/or identification of a specific DNA sequence. This process is important for disease diagnostics, as it is the process that identifies the genetic mutation or pathogen pertinent to the disease. This project focuses on the development of an electrochemical biosensing platform for the detection of single-stranded DNA (ssDNA) using a microfluidic membrane mimic system (MMM). Studying the binding of ssDNA helps us to better understand how DNA replicates and repairs, specifically how diseases caused by mutations start. A biosensing platform can be applied to lab-on-a-chip technologies and biomolecular diagnostics in tissue engineering. The sensor operates through a pair of microelectrodes that measure impedance changes caused by biomolecular interactions within a microchannel under electrochemical impedance spectroscopy (EIS). The exothermic binding of complementary ssDNA strands generates detectable energy shifts. These shifts can be captured using EIS, allowing for a direct correlation between ssDNA concentration and impedance response. The core innovation lies in modifying a two-electrode, flow-through MMM into a three-electrode MMM utilizing a gold-coated polyester membrane. The membrane serves a dual purpose: acting as both a filter and a working electrode that when optically transparent, enables integration with surface-enhanced Raman spectroscopy (SERS). SERS, which signals are enhanced by the gold surface, provides molecular specificity similar to NMR and IR techniques. When this three-electrode MMM and SERS are combined, the application of the system broadens to many applications, like the detection of biofouling on the membrane.

Infrared Photoconductive Photodetectors Based-on Colloidal Semiconductor Nanocrystals

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Abstract: Low-cost, uncooled detectors operating in the mid-wavelength infrared (MWIR) region are in high demand, and their scarcity in the infrared detector market presents a technology gap. Imaging applications such as night driving assistance and missile guidance may not be feasible without such detectors. Lead selenide (PbSe) has the potential to bridge this gap due to its ability to operate at room temperature without the need for large, expensive cooling systems. A cost-effective method for fabricating PbSe thin films involves the use of colloidal quantum dots, which can further reduce manufacturing costs compared to conventional techniques. Regardless of the fabrication method, it is well-documented that a process known as sensitization (oxidation and iodization annealing) is required to achieve high MWIR responsivity in PbSe films. However, its mechanism is still debated, which has hindered the optimization and standardization of process parameters. The goal of this research is to investigate how variables such as annealing temperature, grain size, ligands, and metal contacts influence sensitization, which could lead to more effective film fabrication. A better understanding of this process is expected to enhance MWIR responsivity and enable PbSe films to compete with state-of-the-art technologies.

Digital Twin and Smart PPE for Enhancing Safety within Automated Construction

Yugyel Lhamo

Abstract: One of the riskiest job sectors in the world is still construction, where workers are frequently exposed to hazardous tasks and high-risk environments. In order to create a safer working environment, technological advancements continue to focus heavily on safety. As a result, sensor-based systems and modern software are used to detect hazards, collect data, and send alerts during or even before an occurrence. Such a sensor-based system is developed in this research for a construction hard hat, which, apart from its original purpose, also monitors the real-time health of workers on active construction sites and provides safety alerts using a digital twin system. The biometric sensors are incorporated with the helmet to measure biological parameters such as heart rate, core body temperature, and galvanic skin reaction (GSR) while engaging in physically demanding activities such as climbing, repetitive lifting, or maintaining extended stationary postures. The data collected through these sensors provides crucial insights into the workers' health, enabling the early detection of heat stress, fatigue, or overexertion during work. This information is subsequently shared with a Digital Twin, a real-time virtual representation of the building site to display alerts and enhance visualization of both biometric data and the working environment. Future research will focus on field testing of the smart helmet in real and simulated construction environments, enhancing system responsiveness using machine learning algorithms, and integrating with more emerging safety management technologies in the industry.

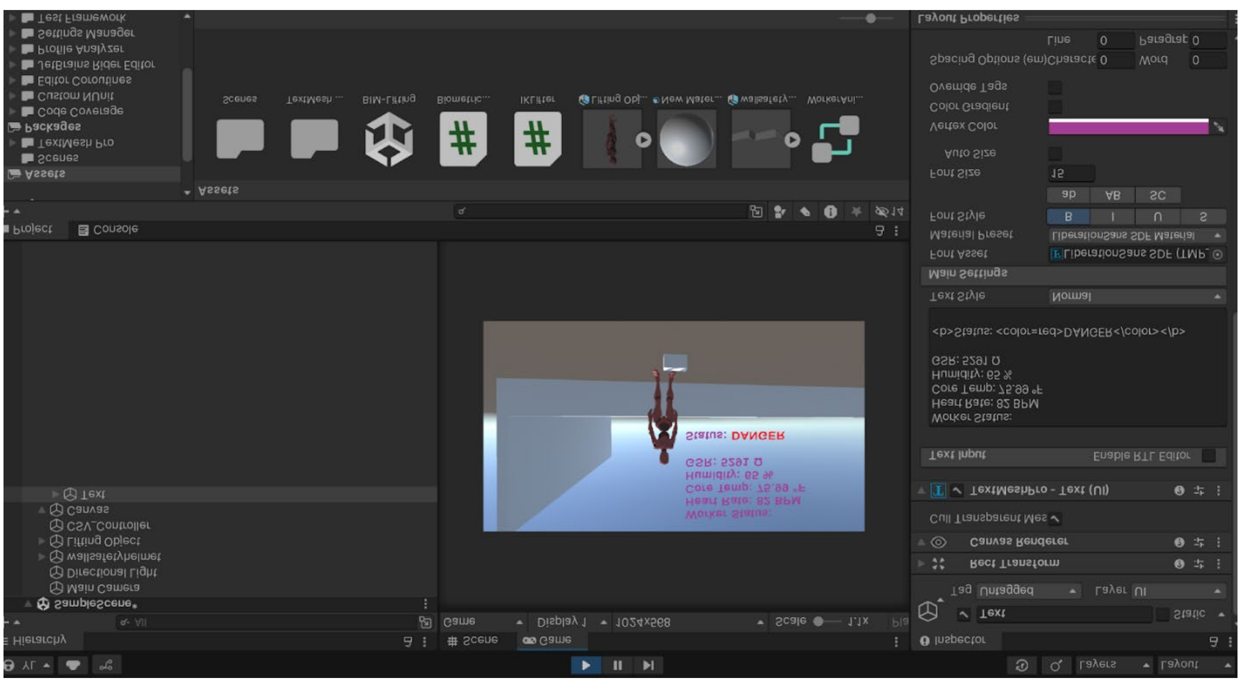

Figure 1: A digital twin system of a construction worker lifting a brick

Platinum Nanoparticles as a Therapeutic for Breast Cancer

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Abstract: Breast cancer remains one of the leading causes of cancer-related mortality among women worldwide, highlighting the ongoing need for more effective and less toxic treatment strategies. According to the World Health Organization, over 10 million fatalities were attributed to cancer in 2020, with 2.26 million instances of breast cancer recorded, exceeding other predominant solid tumors such as lung, colorectal, and prostate cancers. Platinum-based chemotherapeutics such as cisplatin are widely used, but their clinical utility is often hindered by toxicity to healthy cells and drug resistance. Platinum nanoparticles (Pt NPs) represent a promising alternative due to their unique physicochemical properties, including enhanced cellular uptake and potential to generate reactive oxygen species (ROS). Pt NPs in breast cancer treatment, including their use as direct anticancer agents, drug delivery vehicles, and agents for photothermal and radiation therapies, is explored. The Pt NPs are synthesized using a chemical reduction method. Platinum nanoparticles were synthesized by mixing 5 mL of 0.02 M K_2PtCl_4 with 1 mL of 0.0448 M Brij58 and sonicated for 5 minutes. After adding 5 mL of 0.1 M L-ascorbic acid, the solution was sonicated for 1 hour, then centrifuged for 40 minutes. The pellet was washed three times with ultrapure water, frozen at -80°C, and freeze-dried to yield dry Pt NP powder.The synthesized nanoparticles were characterized using Transmission Electron Microscopy (TEM) and Nanoparticle Tracking Analysis (NTA). TEM provided information on particle size, shape, and morphology, while NTA offered quantitative data on size distribution and concentration. These techniques are critical for verifying the consistency and quality of the Pt NPs, as well as their suitability for biomedical applications.Pt NPs are anticipated to offer improved tumor selectivity, reduced systemic toxicity, and synergistic effects when combined with existing treatment modalities. Due to their capacity for functionalization, Pt NPs may enable active targeting of tumor cells and evasion of drug resistance mechanisms. While preclinical evidence suggests considerable promise, continued research is essential to optimize synthesis methods, improve biodistribution, and validate safety and efficacy in clinical settings. My research outlines the current landscape and future directions for Pt NP-based therapies as a transformative approach in breast cancer treatment.

Production of Vanadium-Based MXenes by Chemical Vapor Deposition for Zn-Ion Batteries

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Two-dimensional transition metal carbides and nitrides (MXenes) are relatively novel material with various unique electrical and chemical properties and applications. The use of a selective etching process to form them has been well studied with many papers on the topic, but a new technique, Chemical Vapor Deposition (CVD), has recently become an emerging competitor to selective etching, due to its ease, direct MXene products, and significantly reduced production time. MXenes have also become a viable alternative for high-performance electrode compounds in Zn-Ion batteries (ZIBs) due to their excellent cations storage capacities and superior electrical conductivity. ZIBs themselves and general electrode materials of high energy, conductivity, and appropriate surface morphology have been a promising alternative to more conventional Li-ion batteries. The purpose of this paper specifically is to investigate and optimize the use of the CVD process to produce vanadium-based MXenes, specifically V_2CCl_2, for high-performance ZIBs. So far, we have carried out the preliminary optimization process on the CVD growth and successfully achieved the reliable growth of V_2CCl_2 MXenes on V foils (**Figure 1a and b**). During the following weeks, we will continue to further optimize the CVD process to produce the V_2CCl_2 MXenes in a large quantity, which will be then used to fabricate the ZIB electrode to investigate their applications as cathode materials in ZIBs (**Figure 1c**). This project will provide a strong foundation for a reliable CVD synthesis process for vanadium-based MXenes, improve understanding of their electrical, chemical, and physical properties, and demonstrate their potential as high-performance electrodes in ZIBs.

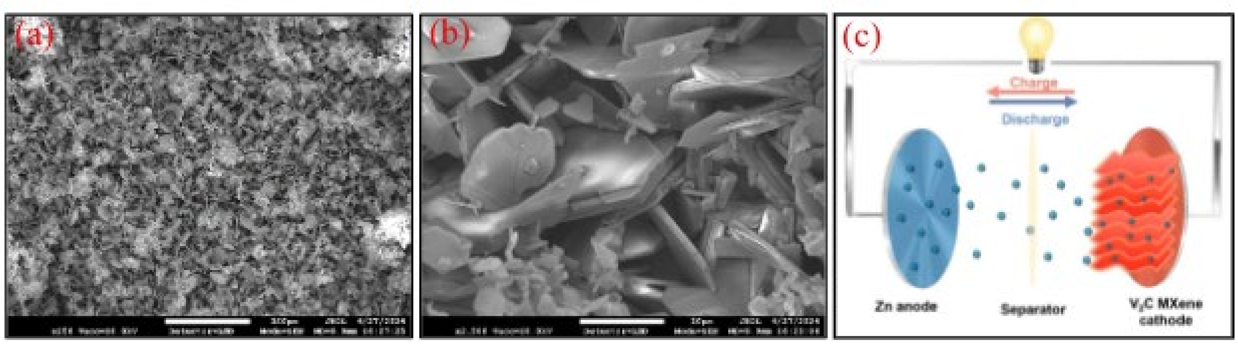

Figure 1. (a) Low magnification and (b) high magnification SEM images of as-synthesized V_2CCl_2MXene by CVD, (c) A schematic illustrating the potential use of MXenes in ZIBs [1]

References:

[1] M. Jenitha, D. Durgalakshmi, S. Balakumar, and R. A. Rakkesh, "Vanadium-based MXenes: synthesis, structural insights, and electrochemical properties for Zn-ion battery applications: a beginner's guide," *Emergent Mater*, 2024, doi: 10.1007/s42247-024-00916-6.