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Special issue:
Science & Engineering Senior Projects and Internships, Semester II Abstracts

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Journal of Science & Engineering
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United States

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From the cover: Science & Engineering class of 2025.

Special issue: Science & Engineering Senior Projects and Internships, Semester II, June 16, 2025.

Science & Engineering Learning Center
Senior Projects and Internships
Semester II
June 16, 2025

S Currie – Principal
J Komitas – Program Supervisor
E Levin – Project Mentor
D Evangelista – Project Mentor
B Boyce – Internship Representative

Monmouth County Engineering Traffic Safety Division internship

Aadarsh Kumar
Science & Engineering
Manalapan High School
Englishtown, NJ
425akumar@frhsd.com

Abstract

Civil engineering is a dynamic and evolving field that has to constantly adapt and change to accommodate new challenges and address the concerns of the government and its citizens to ensure the proper and safe function of all physical elements of the public sector. Monmouth County Engineering is a public works organization that designs, builds, and maintains the entirety of Monmouth County's transportation network and buildings. The Traffic Safety Division in particular deals with signals, signs, roads, and road markings.

This internship has given me valuable experience in civil engineering and the various systems and methods engineers use to keep our roads safe. During my time at Monmouth County Engineering, I gained in-depth experience regarding the work and day-to-day functions and duties of a public works organization. My work included on-site inspections, signage designations, planning roadway changes, and striping estimates.

Index Terms

traffic safety, Monmouth County Engineering, civil engineering, internship, transportation systems, public sector, public works

Girl in Space Club (GISC) internship

Victoria Collemi
Science & Engineering
Manalapan High School
Englishtown, NJ
425vcollemi@frhsd.com

Cameron Karabin
Science & Engineering
Manalapan High School
Englishtown, NJ
425ckarabin@frhsd.com

Sabrina Thompson
Girl in Space Club
sabrina.thompson@girlinspaceclub.com

Abstract

Girl in Space Club is a clothing brand established by NASA engineer Sabrina Thompson that produces astronaut-grade and fashion flight suits for the analog astronaut (people who participate in crewed simulated space missions on Earth), female astronaut candidates, and STEM enthusiast communities. Since the corporate mission is to make STEM fun, fashionable, and creative, we were tasked with designing a "Build Your Own Flight Suit" app that enables customers to individualize their flight suits. To develop the website's functionality and aesthetics, we employed the web development languages of HTML, CSS, and JavaScript. The foundation for our website layout and "flow" was based on Ms. Thompson's design philosophy of "putting the user's experience first". During our presentation, we will present the (1) user engagement principles and logic behind our website structure; (2) the evolution of the website's GUI (graphical user interface) and backend code; and (3) a preview of the website. We will also discuss the issues we encountered during the website's development and future additions that can be made to our work.

Index Terms

Girl in Space Club, web development, frontend, backend, UI, UX, GUI, HTML, CSS, JavaScript, flight suit, internship

Optimizing the fabrication process of microspheres for extended-release drug delivery

Jake Schatz
Science & Engineering
Manalapan High School
Englishtown, NJ
425jschatz@frhsd.com

Abstract

In the pharmaceutical industry, numerous drugs are required to be released over extended periods of time for diverse applications. Microspheres, microparticles that contain drugs encapsulated by polymers, have special characteristics that make them optimal for these applications. The quality of microspheres is characterized by their physical shape/size and drug encapsulation rates. My goal is to optimize the fabrication process's efficiency and improve the quality of microspheres produced by these techniques by producing microspheres that have an average diameter of about $10\,\mu\mathrm{m}$ to $20\,\mu\mathrm{m}$ and have as high of a drug encapsulation rate as possible.

In the first semester of my internship at ACON Pharmaceuticals, I primarily focused on testing the emulsion-evaporation fabrication technique. Using this time-consuming method, which involves the evaporation of an emulsified drug-polymer solution over 2-3 days, I found that the microspheres were suboptimal, often consisting of excess polymer and low drug encapsulation rates.

For my second semester, I tested using the phase-separation method of fabrication, where I rapidly induced the formation of microspheres within minutes by adding a liquid to the emulsified drug-polymer solution. This method proved to be time-efficient without sacrificing the quality of the microspheres. To optimize for mass production, I aimed to enhance the drug encapsulation efficiency of this process by testing adding a base, and I also aimed to minimize the amount of materials used, while also scaling up and making larger batches. Furthermore, I began drug dissolution studies on the produced microspheres to measure the extended-release rates for drug delivery.

Index Terms

microspheres, emulsion-evaporation, phase-separation, polymer, encapsulation rates

T&M Associates heating, ventilation, and air conditioning (HVAC) internship

Steven Perkins
Science & Engineering
Manalapan High School
Englishtown, NJ
425sperkins@frhsd.com

Abstract

T&M Associates is a national engineering firm headquartered in Middletown, New Jersey that specializes in many different fields of engineering. Throughout the past semester, I have had the opportunity to collaborate with Mechanical, Electrical, and Plumbing (MEP) engineers at T&M, working on computer-aided design (CAD) drawings of heating, ventilation, and air conditioning (HVAC) systems. These drawings play a crucial role in the construction process, guiding contractors through the installation of the HVAC systems of a building.

Index Terms

T&M Associates, internship, HVAC, heating, ventilation, and air conditioning, mechanical, electrical, and plumbing, MEP, CAD, professional engineer, engineer-in-training, EIT, piping system, computer aided design

Identifying data-driven trends to support research quality and insight

Nathan Gershteyn
Science & Engineering
Manalapan High School
Englishtown, NJ
425ngershteyn@frhsd.com

Abstract

During my senior internship at Columbia University Irving Medical Center, I was responsible for organizing, managing, and analyzing structured research data to support operational insights and inform decision-making. My internship emphasized key components of the data analysis pipeline, including data cleaning, normalization, integration, and exploration. I worked within a research-driven environment where identifying patterns, trends, and relationships between variables was essential to improving study outcomes and informing future protocols. A significant part of my work involved summarizing complex data in a meaningful and accessible way through visualizations, descriptive statistics, and exploratory analysis techniques. I learned how to refine large datasets, draw correlations, and develop interpretations that could influence research direction or operational improvements. My role required a strong focus on attention to detail, iterative refinement, and analytical thinking to ensure findings were both accurate and useful. In addition to the analytical aspects, I gained valuable experience in workflow optimization, data-driven problem solving, and applied research support. This internship provided a foundation in best practices for managing research data, interpreting results in a broader context, and contributing to continuous improvement in data collection and analysis strategies. This experience taught me a well rounded skill set in data literacy, strategic thinking, and evidence-based analysis within a real-world research setting.

Index Terms

data analysis, research operations, trend identification

Commvault internship: automated summaries of Update Center

Srikar Baru
Science & Engineering
Manalapan High School
Englishtown, NJ
425sbaru@frhsd.com

Ryan Edwards
Science & Engineering
Manalapan High School
Englishtown, NJ
425redwards@frhsd.com

Abstract

In order to work efficiently, employees need to be able to access information regarding different products quickly and easily. During our internship at Commvault, we worked on optimizing the Update Center which employees use to access information regarding various Commvault files and specific updates regarding these files. The information includes an update summary of all changes made, all bugs found, and all bugs fixed. We created a page where employees can input the specific form and update that they want information on, then have that information extracted using SQL and sent to a generative AI to create a summary and 20 unique test cases for the data for the user to use, as well as the ability to compare the differences between two or more specific updates.

Index Terms

Commvault, internship, Update Center, SQL, Python, automated summary, generative AI

Neurotrace: a brain visualization learning tool

Chloe Li
Science & Engineering
Manalapan High School
Englishtown, NJ
425cli@frhsd.com

Ryan Cohen
Science & Engineering
Manalapan High School
Englishtown, NJ
425rcohen@frhsd.com

Abstract

This project focuses on visualizing physiological stress using heart rate variability (HRV) data and mapping it to a 3D model of the human brain. HRV, a measurement of the variation in time between heartbeats, is a known biomarker of stress and autonomic nervous system activity. Lower HRV typically corresponds to higher stress levels, while higher HRV indicates lower stress. The project began by exporting HRV data from the Apple Health app in XML format. Using Python (with libraries such as xml.etree.ElementTree, pandas, and seaborn) it was possible to convert, label, and plot the data over time. Each data point was categorized into high, moderate, or low stress based on standard HRV thresholds.

Although real-time interaction is not yet implemented, the current version establishes a foundation for integrating HRV data into a responsive, browser-based 3D visualization. This tool could eventually be used to demonstrate how physiological stress manifests in the brain using color and animation. The final goal is to create a platform that accepts HRV data from any user and visually represents their stress level in real time.

Index Terms

brain, learning, heart rate variability, visualization

A purely Python computational origami library for scientific studies

Pooja Thaker
Science & Engineering
Manalapan High School
Englishtown, NJ
425pthaker@frhsd.com

Abstract

Origami, traditionally an artistic endeavor, has evolved into a significant area of study within scientific concentrations such as genomics, materials science, and structural engineering. Computational tools like Rabbit Ear have facilitated the exploration of origami's mathematical properties; however, their utility in scientific research is limited due to their focus on creative coding and reliance on the JavaScript ecosystem. My research introduces PyOri, a novel Python library designed to bridge this gap by adapting the principles of computational origami for scientific studies. Developed as a pure Python package, PyOri ensures compatibility with a wide range of scientific computing environments and is available for installation via PyPI & pip. The library provides functionalities for modeling and visualizing origami structures, including graph-based crease pattern generation, conversion to SVG and FOLD formats, and interactive 3D visualization. By integrating with widely-used scientific Python libraries such as NumPy, SciPy, and PyTorch, PyOri offers a versatile platform for simulating and analyzing foldable structures in various scientific contexts.

PyOri employs the FOLD format, a mesh-based structure, to represent origami models, containing information on vertices, edges, faces, and interrelations. This format allows for detailed manipulation of origami structures, including the creation and traversal of crease pattern graphs. Users can convert these patterns into scalable vector graphics (SVG) and FOLD files for visualization purposes. The library supports interactive 3D visualization of origami at different stages of foldability, facilitating a comprehensive understanding of the folding process. Additionally, PyOri enables the creation of folds using foundational principles such as the Huzita–Justin axioms and includes functionality for conducting flat-foldability checks on crease pattern graphs. Future developments aim to incorporate advanced meshing techniques and mesh manipulation capabilities, further enhancing the library's applicability in scientific research. This work ultimately aims to bridge the gap between computational origami and scientific research, enabling the exploration of complex systems through the lens of foldable geometries and is published for use on pip & PyPI.

Index Terms

computational origami, languages, mesh, FOLD format, fold, rabbit ear, pyori, svg, graph, traversal, crease pattern

Implementing Simultaneous Localization and Mapping (SLAM) onto a mobile robot

Saketh Ayyagari
Science & Engineering
Manalapan High School
Englishtown, NJ
425sayyagari@frhsd.com

Abstract

A common problem in autonomous navigation of robots is the ability to both map and consistently know its location in an unknown environment, more commonly known as the Simultaneous Localization and Mapping (SLAM) problem. Localization is a robot's ability to estimate its position and orientation with respect to the world given a predetermined map of an environment, and mapping is its ability to construct an accurate map, assuming it knows its pose (position and orientation). This semester, I focused on implementing a SLAM algorithm in both a simulated and a physical environment. I first implemented the algorithm within Gazebo, a robotic simulation environment, on a similar model of the robot I intended to build. Afterwards, I built the robot and equipped it with a 360° LiDAR for mapping and an Inertial Measurement Unit (IMU)/wheel encoders for localization. The physical robot was powered with a Raspberry Pi 4B and programmed using Python and the Robot Operating System 2 (ROS2) framework, which contains different algorithms and packages for robotics and data processing.

Index Terms

localization, mapping, SLAM, robot, ROS2, mobile robot, Gazebo, IMU, wheel encoders, LIDAR

SimuMine: a web-based Bitcoin mining efficiency simulator

Krish Shah
Science & Engineering
Manalapan High School
Englishtown, NJ
425kshah@frhsd.com

Krish Patel
Science & Engineering
Manalapan High School
Englishtown, NJ
425kpatel@frhsd.com

Abstract

Bitcoin mining is highly energy-intensive, and improving its efficiency is critical for both economic and environmental sustainability. This project presents a web-based simulation tool that models key aspects of Bitcoin mining, including the SHA-256 hashing algorithm, nonce iteration, and target difficulty checks. The computational backend is integrated with real-time power and thermal models, enabling the simulator to reflect how hash rate influences energy consumption and temperature. Interactive controls for frequency, voltage, and resistance, along with graphical visualizations of power usage over time, allow users to explore trade-offs between energy efficiency and mining performance. The simulation also includes a financial trade-off analysis feature and supports extended runtime testing to evaluate long-term behavior under varying operational conditions.

Index Terms

bitcoin mining, SHA-256, energy efficiency, ASIC simulation

5G Edge cloud application

Dilan Gandhi
Science & Engineering
Manalapan High School
Englishtown, NJ
525dgandhi@frhsd.com

Shreyas Musuku
Science & Engineering
Manalapan High School
Englishtown, NJ
425smusuku@frhsd.com

Abstract

This project investigates the potential of 5G Edge computing to improve vehicular safety through ultra-low latency communication and real-time data processing. With human error accounting for the majority of traffic accidents, our system leverages the proximity of edge servers to 5G base stations to transmit critical vehicle telemetry between nearby cars using MQTT protocols and Docker-based deployment. We designed and tested two key safety scenarios—following vehicle and head-on collision detection—demonstrating reliable, low-latency performance under simulated conditions using OBD-II emulators. Our work also includes a documented framework for scalable deployment and real-time data streaming. Looking forward, we aim to integrate machine learning for predictive maneuvers such as lane changes and environmental adaptation, enhancing the system's robustness in complex traffic environments.

Index Terms

5G Edge computing, vehicle-to-vehicle communication, autonomosu vehicles, real-time data, MQTT, low latency, traffic safety, OBD-II emulator, Docker deployment, collision avoidance, connected vehicles, intelligent transportation systems

Towards neural control of a prosthetic arm

Vikram Choudhury
Science & Engineering
Manalapan High School
Englishtown, NJ
425vchoudhury@frhsd.com

Abstract

I prototyped an inexpensive prosthetic arm that is able to be controlled in a straightforward manner using electroencephalography (EEG), which is a method to measure electrical activity in the brain. EEG signals contain information related to motor function as well as information related to other actions that the brain is responsible for. As motor function signals are predominantly found in the 12 Hz to 100 Hz range, I applied a digital filter to the EEG signal, using a Fourier transform that ignores all parts of the signal outside of the 12 Hz to 100 Hz passband. EEG signals are also very sensitive to noise, disruptions to a signal, caused by motor function of head muscles. For two electrodes in close proximity, the noise induced by the motor function of head muscles would be similar, so I used an instrumentation amplifier, a type of amplifier that subtracts two input signals, to take the difference between the readings from two electrodes, decreasing the impact of the common mode noise caused by head muscles. For the prosthetic arm hardware, I based my design off of the inMoov2 prosthetic, with some adjustments made to increase the space for servo motors, allowing for each phalange (finger bone) to be controlled independently, increasing the functionality of the prosthetic.

Index Terms

electroencephalography, EEG, fast Fourier transform, FFT, neural control, prosthetic

Design and construction of a vacuum tube guitar amplifier

Danyal Ahmad
Science & Engineering
Manalapan High School
Englishtown, NJ
425dahmad@frhsd.com

Henry Villaseñor
Science & Engineering
Manalapan High School
Englishtown, NJ
425hvillasenor@frhsd.com

Abstract

This project focused on the design, simulation, and physical construction of a fully functional vacuum tube guitar amplifier. Modeled in LTspice and built by hand, the amplifier features a high-voltage power supply based on the Hammond 270FX transformer, a dual-triode 12AX7 preamp, a phase inverter, and a push-pull 6L6-based power stage. Both diode-based and subcircuit models of the 5U4GB rectifier tube were implemented to evaluate performance trade-offs. A center-tapped RC-filtered power rail supplies each stage with progressive ripple reduction, and transformer windings were tuned in simulation to replicate the real transformer's behavior. In addition to simulation and testing, the final amplifier was physically assembled and housed in a hand-crafted wooden chassis. Voltage measurements, output signal behavior, and tonal character were analyzed throughout the signal chain. This project deepened our understanding of analog electronics, amplifier design, and high-voltage safety while blending engineering with musical creativity.

Index Terms

vacuum tube, amplifier, push-pull, rectifier, preamplifier, power amplifier, guitar amplifier, LTSpice, 5U4GB, 12AX7, 6L6, Hammond 270FX, analog design, tube audio, power supply, chassis fabrication

Refining intraday futures strategy through ICT concepts: a real-time trading performance analysis

Justin Hammer
Science & Engineering
Manalapan High School
Englishtown, NJ
425jhammer@frhsd.com

Nirvik Patel
Science & Engineering
Manalapan High School
Englishtown, NJ
425npatel@frhsd.com

Abstract

This project documents the ongoing development and refinement of a live intraday futures trading strategy, primarily focused on the E-mini S&P 500 (ES) contract. Utilizing core principles from Inner Circle Trader (ICT) methodology—including Fair Value Gaps (FVGs), liquidity sweeps, breaker blocks, and higher timeframe market structure—the strategy aims to capitalize on high-probability trade setups during key market sessions. Over the course of February to May 2025, we implemented structured execution protocols, strict session filters, and continuous journaling to improve consistency and reduce impulsive behavior. Performance metrics showed an overall net gain with reduced drawdowns and an enhanced risk-reward profile. This iterative process highlights the importance of disciplined decision-making, contextual market understanding, and systematic journaling in the evolution of a professional trading strategy.

Index Terms

futures trading, ICT concepts, fair value gap, FVG, liquidity sweep, market structure, breaker block, trading psychology, day trading strategy, risk management, E-mini S&P 500 (ES), intraday analysis

Ultrasonic device for rapid air bubble removal in automotive coolant systems: the saga continues

Anirudh Khanna
Science & Engineering
Manalapan High School
Englishtown, NJ
425akhanna@frhsd.com

Nareshsanjay Muthukumar
Science & Engineering
Manalapan High School
Englishtown, NJ
425nmuthukumar@frhsd.com

Abstract

The efficiency and longevity of automotive engines are heavily influenced by the proper operation of cooling systems, which can be compromised by the presence of air bubbles. Traditional methods of removing air bubbles, such as system bleeding, are time-consuming and often ineffective. This project introduces an ultrasonic device designed to rapidly and efficiently eliminate air bubbles from automotive coolant systems. Using a 555 timer chip to create an ultrasonic wave, and several forms of amplification, the device powers an ultrasonic transducer that emits sound waves to promote the coalescence and removal of entrained gases within a coolant system. Preliminary tests show that this ultrasonic method is faster and more efficient than conventional techniques while ensuring compatibility with existing automotive systems. The device improves engine efficiency by enhancing coolant flow and reducing the risk of overheating due to trapped air and foaming. Potential applications include faster maintenance, reduced labor costs, and enhanced system performance. This device could be applicable to a wider range of fields, such as milk pasteurization, oil rigging, and material sciences.

Index Terms

ultrasound, bubbles, automotive, coolant system, degas, feed-and-bleed, fluid system, noncondensable gases, air-intrusion, piping system

Naval architecture and hull design

Kevin Tomazic
Science & Engineering
Manalapan High School
Englishtown, NJ
425ktomazic@frhsd.com

Abstract

Naval architecture is the study of ship design, focusing on overall balanced design considering the functional requirements, with special focus on the hull, including buoyancy; centers, moments, and stability; structural integrity; resistance and powering, etc. I examined the design of a small $1\,\mathrm{m}$ LOA hull intended for a model or autonomous sailing craft. To design the hull and obtain volumes and centers for stability calculations, I used Autodesk Fusion. To physically construct the hull, I used additive manufacturing (3D printing), using several hull sections in order to satisfy manufacturability constraints due to bed length of the tooling.

Index Terms

naval architecture, CAD, computer aided design, Fusion 360, hull design, stability, buoyancy, resistance and powering, sailboat, sailbot, autonomous sailbot, 3D printing, additive manufacturing

Automatic detection of microexpressions using an image classification model

Eshan Handique
Science & Engineering
Manalapan High School
Englishtown, NJ
425ehandique@frhsd.com

Nathan Martin
Science & Engineering
Manalapan High School
Englishtown, NJ
425nmartin@frhsd.com

Abstract

Polygraph tests determine if someone is lying by comparing differences in their biometric data with their responses to a set of questions. However, this method of lie detection is not very effective and is open to misuse for intimidation and abuse. Because of this, we aimed to create a new functional form of lie detection. This was done by analyzing one's microexpressions: the uncontrollable expressions that appear on someone's face for a short amount of time, expressing their true feelings. These microexpressions are thought to give a more truthful indication of the emotional state of the subject. We used an image classification model to automatically detect microexpressions on someone's face in a live feed, allowing us to decide whether or not they are lying based on their answer in relation to their microexpressions. We will continue to refine the model to try to get the lie detector as accurate as possible in the future.

Index Terms

polygraph, lie detection, microexpressions, image classification

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