RUTGERS–NEW BRUNSWICK
School of Engineering
Department of Electrical and Computer Engineering

RU ECE

Capstone Design Projects at a Glance

ECE CAPSTONE EXPO 2025

S25-01

Title: Smart Pill Box

Team Members: Anna Yeakel, Nikita Filippov, Siddharth Narayanan

Advisor(s): Dr. Sasan Haghani

Keywords Medication adherence, Pill tracking, Mobile app, Arduino, Bluetooth

Abstract:

Medication non-adherence remains a critical healthcare challenge, often leading to adverse health outcomes and increased medical costs. Many existing pill management systems are either too costly, overly complex or lack mobile integration—factors that hinder widespread adoption and ease of use. In this project, we present the design and implementation of a low-cost, portable smart pill-tracking device integrated with a mobile application to enhance adherence through real-time monitoring and reminders. The device is based on an Arduino microcontroller, supported by three weight sensors for independent pill tracking across three compartments, and features Bluetooth connectivity for seamless data synchronization with the app. The mobile application allows users to schedule customizable and recurring dosage reminders, receive refill alerts based on real-time consumption, and manage multiple medications efficiently. Designed for practicality, the device is powered by a rechargeable battery that lasts over two weeks, making it ideal for regular use without frequent maintenance. The enclosure was designed using CAD tools and 3D-printed in durable, lightweight plastic, featuring magnetic locks for secure yet accessible storage. The total build cost of $55 positions this system well below the price point of existing commercial solutions without compromising functionality or usability. Our prototype demonstrates that effective and affordable medication management is achievable through smart integration of software and hardware.

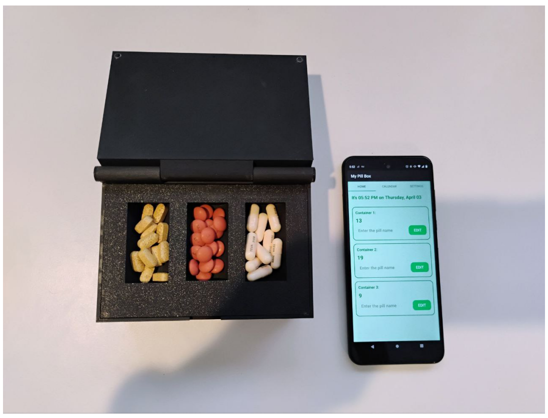


Figure 1: Smart Pill Box with Mobile App

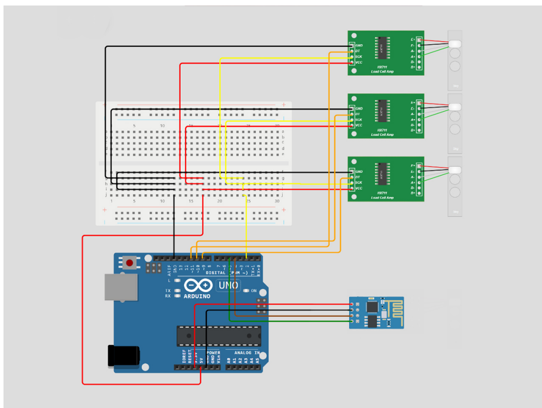


Figure 2: Internal Circuit CAD Model

S25-02	**Title: Smart Parking Assist System** **Team Members: Parshva Mehta, Aman Patel, Abhiram Vemuri, Rajeev Atla** **Advisor(s): Professor Kristin Dana**
Keywords	Computer Vision, Full-stack Development, Machine Learning, Data Pipelining/Manipulation
Abstract:	Universities increasingly struggle with parking due to growing demand, dynamic schedules, and limited staffing. Traditional solutions like automated valet systems are often too expensive, complex, and unreliable. As a result, drivers waste time circling crowded lots, increasing emissions and campus congestion. To address this, we developed a scalable Smart Parking Assist System using edge-based computer vision and a web app for real-time detection and guidance. A YOLO-based model, trained on public and custom Rutgers CoRE building images, runs on a Raspberry Pi with a high-resolution camera to detect parking occupancy on-device. The backend updates a central database and powers a front-end displaying real-time availability via a parking lot map. This end-to-end system offers a low-cost, deployable solution for university campuses and urban areas.

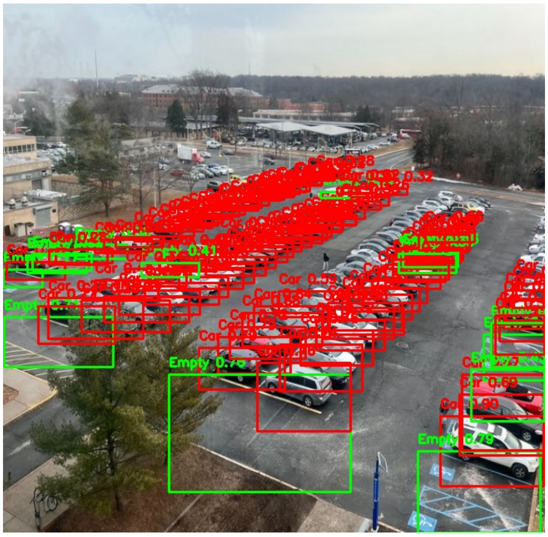


Figure 1: Machine learning output from the YOLOv11 model on EE parking lot.

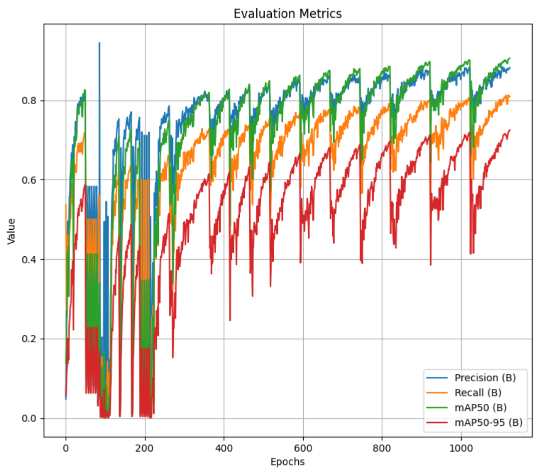


Figure 2: Evaluation metrics of the machine learning model. "Spikes" represent fine-tuning of the model. The model was trained until validation losses plateaued.

S25-03

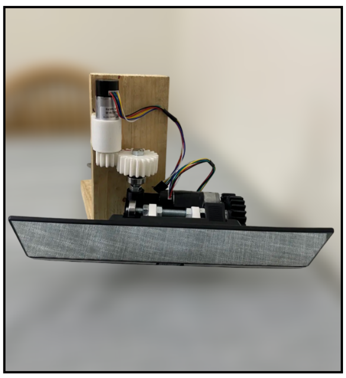
Title: Attention-Aware Adjustable Car Mirror

Team Members: Cristian Llerena, Michael Mogilevsky, Adarsh Narayanan, Muralii Krishnan Thirumalai, Hazem Zaky

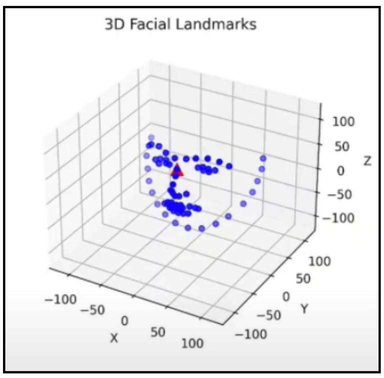
Advisor(s): Dr. Kristin Dana, Dr. Maria Striki, Dr. Zhao Zhang

Keywords Computer Vision, Machine Learning, Control Systems, Web App Development, 3D Design

Abstract: In today's automotive industry, driver safety and user convenience remain top priorities. Yet mirrors are often overlooked, despite their essential role in maintaining situational awareness. Misaligned mirrors can increase blind spots and increase the risk of accidents. This Capstone project addresses this issue by developing a self-adjusting rear-view mirror, powered by computer vision and mechatronics. The computer vision part involves the usage of stereo vision cameras, OpenCV & Dlib's 68-point facial landmarks model on a Raspberry Pi 5. The model detects key facial landmarks of the driver, to estimate their head orientation and position. These features are then triangulated into a 3D coordinate system via a Direct Linear Transform (DLT), from which the optimal angles for the rear-view mirror are computed and sent to the micro-controller through serial communication. An arduino micro-controller is used to implement a control system algorithm (PID Controller), which guarantees proper motion and control of the DC motors to place the mirror on the computed coordinates. The design for this dual-axis mirror device includes custom 3D-printed parts, and magnetic encoders as a feedback sensor. In parallel, a mobile application was developed to provide the user control over the position of the mirror. The app includes features for saving and loading presets, with a database hosted by Google Firebase. Ngrok was utilized to establish a secure HTTP tunnel between devices, aiming to avoid the leakage of the Raspberry Pi's public IP. Together, all these modules provide an user-friendly and intelligent device for rear-view mirror adjustments.

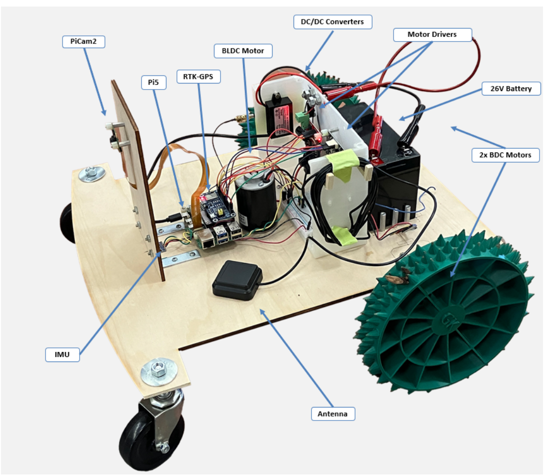


(a) 3D-printed dual-axis mirror assembly

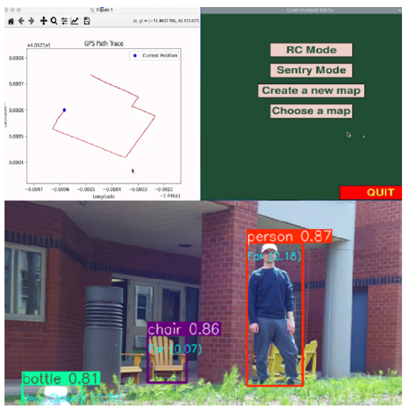


(b) Triangulated 3D facial landmarks

S25-04	**Title:** GreenKeeper Automower **Team Members:** Ian Christensen, John Lim, Erik Pacio **Advisor(s):** Dana Kristin, Sasan Haghani
Keywords	Robotics, Navigation, Computer-Vision, Lawncare
Abstract:	The objective of this project is to design and develop a cost-effective, fully autonomous, self-mapping robotic lawnmower that eliminates the need for physical boundary wires. Current budget-friendly robot mowers, priced between \$500 and \$1000, require time-consuming and costly wire installations, while higher-end models that use advanced navigation sensors like LIDAR or ToF are unnecessarily priced beyond reach for the average consumer. Our solution aims to bridge this gap by delivering high-end functionality at a significantly reduced cost, while maintaining all the safety benefits of automated lawn care. We utilize RTK-GPS technology with an L1/L5 antenna to map and assist in auto-pathing. Stable navigation is ensured with a PID controller utilizing an IMU & the given motor encoders, while a lightweight neural network including yolov8n & MiDaS handles obstacle detection with a PiCam2. Powered by PyGame, we employ a user friendly GUI for switching between the currently existing modes such as "Mapping, Pathing, RC, and Sentry." The project is open-source and encourages users to customize GreenKeeper to their own needs. Only costing around \$400 for a prototype and an estimated \$228.5 per unit (1000+ units), this project has shown that smart, boundary-wire free robotic mowing can be both affordable and practical for all types of homeowners.



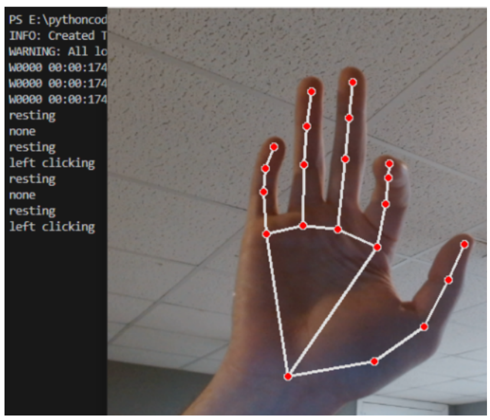
(a) GreenKeeper's Final Build



(b) GPS map of ECE parking lot, main menu, and CV processing results

S25-5	**Title: Touchless Interface Device** **Team Members: Joseph Dinh, Justin Pang, Henry Sprigle, Haojia Zhu** **Advisor(s): Prof. Sasan Haghani**
Keywords	Accessibility, Camera Recognition, Health, Software, Hardware
Abstract:	The use of computers has become an integral part of our everyday lives as we rely on them for almost everything we do from getting information to communication, shopping, and more. Because of this, people with physical limitations can be put at a severe disadvantage in society when it comes to productivity because they can not use computers as effectively. Our team recognizes that the use of computers is not ideal for people who only have one arm seeing as they can not type and use a mouse at the same time. Another challenge we hope to improve upon is general sanitation problems regarding automated service machines such as kiosks and ATMs (Automated Teller Machines) which come in physical contact with many people everyday. Our solution for both of these problems is to create a touchless interface device that will utilize cameras and sensors to gather information from hand gestures and movements of a user's hand and translate them into mouse inputs. Our device will have a mount that attaches itself to a desk. Its camera will look down onto the hand, track its movement, and match it to the computer's cursor. When the index finger is flexed, it will translate to a left click. When the middle finger is flexed, it will translate to a right click. Our device would allow for people with one hand to be able to seamlessly transition between using their mouse and keyboard with a single hand by removing the need to move their hand back and forth between input devices.

(a) Conceptual Design of Device



(b) Hand Recognition and Tracking

S25-06

Title: Whisker-Bot

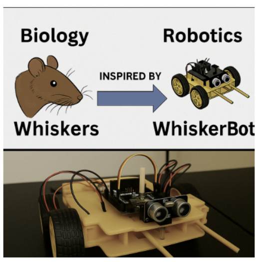
Team Members: Malik Soliman and Daniel Baver

Advisor(s): Professor Aggelos Bletsas

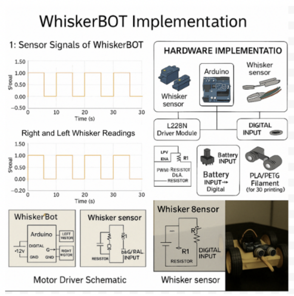
Keywords Dynamic Environmental Learning, Tactile Sensing, Multi-Modal Sensor Fusion, Real-Time Adaptive Navigation, Biologically Inspired Robotics

Abstract:

WhiskerBot is a biologically inspired mobile robot designed to navigate its environment using tactile sensing rather than traditional vision-based systems. In contrast to robots that rely on LiDAR or cameras, which can fail in dark, cluttered, or obstructed conditions, WhiskerBot uses physical contact to sense its surroundings. In that way, it is very much like animals such as rats, which use their whiskers to navigate and explore low-visibility settings. Our design uses whisker appendages wired directly to an Arduino Uno microcontroller, which interprets sensor input and adjusts motor control in real time. The drifting robot can pivot, reverse, or drive forward depending on which whisker detects contact. It achieves these behaviors, apparently quite well, with PWM-driven DC motors controlled by L298N drivers. All the electronics are mounted on a custom 3D-printed chassis. The robot was constructed to be modular, robust, and low-cost. We used PLA, PETG filament, and off-the-shelf components to build it. Its control software is written in embedded C++ and uses simple state-driven logic to give the robot responsive behavior in dynamic or confined test environments. Obstruction avoidance was properly demonstrated by WhiskerBot in real-world instances where vision systems would falter. The basic robot serves as a prototype for a more complicated obstacle avoidance system that could be used on an autonomous navigation platform with a greater variety of sensory inputs. With WhiskerBot, the team was able to harden an obstacle avoidance algorithm that could be used on an advanced navigation platform with a greater variety of sensory inputs.



(a) An Inspiration Graphic along with the final prototype design



(b) A Culmination of Sensor Data Compiled along with Hardware Implementation

S25-07

Title: Self-driving in Scale Multi-Car Environments

Team Members: Brandon Cheng, Tommy Chu, Adam D'Souza, Arya Shetty, Dylan Turner

Advisors: Ivan Seskar, Kristin Dana

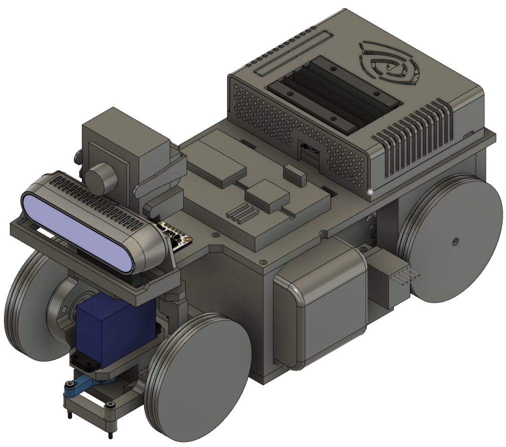
Keywords Autonomous Vehicles, Testing Platform, Deep Learning, Robotics

Abstract:

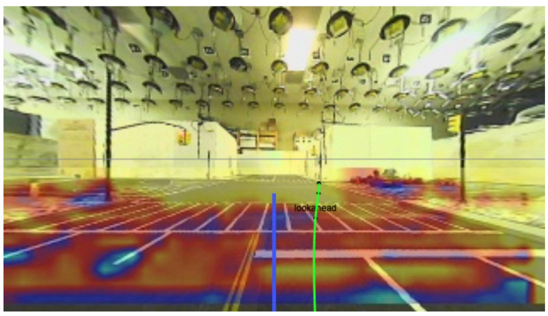
This project presents RASCAL: Robotic Autonomous Scale Car for Adaptive Learning, a 1/15 scale, 3D-printed car platform designed to be reproducible and precise. RASCAL mimics real car dynamics through its Ackermann steering and differential drive.

We aim to prove RASCAL's viability as a self-driving platform by designing and streamlining an entire self-driving pipeline with an interface for data collection and labeling, the ability to manage and experiment with multiple neural network models, and an integrated driving simulation for model testing and evaluation. Our interface also supports real-time interaction, allowing the runtime instance to pass decisions to the user to make high-level driving decisions. To test its open-source utility, a second RASCAL will also be constructed to produce documentation.

Using this pipeline, we collected data by recording human examples of driving using the two cars. With this data, we trained a neural network to drive with an understanding of valid trajectories for various driving scenarios. We also explored a variety of model types, including custom architectures and popular architectures with pretrained weights. We use autonomous vehicle metrics like collision frequency and driving accuracy to assess the simulation and real-world performance of our algorithms.

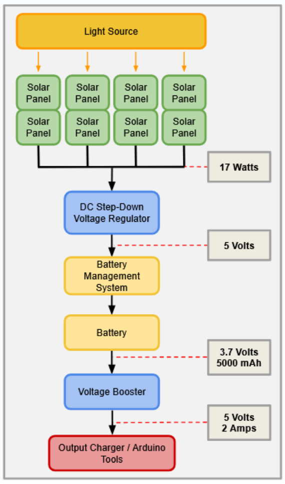


(a) CAD model of RASCAL



(b) Grad-CAM heatmap visualizes areas in the input image that are most important to the neural network model.

S25-08	**Title: Solar Umbrella** **Team Members:** Michael Finke, Ahmad Kamran, Nikhil Chandra, Yousef Nasr **Advisor(s):** Michael Caggiano
Keywords	Solar Power, Battery, Arduino, Sensors, Environmental Data, Portable
Abstract:	As of current, there is an increasing global need for sustainable energy solutions to reduce our growing carbon footprint. A major contributor to this issue is in the power sector, which still relies heavily on non-renewable sources like coal, gas, and petroleum to meet energy demands. In response, our Capstone Project focuses on reducing our dependency on fossil fuels by designing a device that helps ease daily demand on the power grid: the Solar Umbrella. The Solar Umbrella is an innovative, off-grid renewable energy solution designed to power small electronic devices while reducing carbon emissions. These devices include tools useful to scientists, farmers, inspectors, and other field professionals in addition to the average person. The project integrates solar panels, high-efficiency voltage regulation, and energy storage into a lightweight, portable structure. Arduino-based sensors enable environmental data collection, while wireless communication capabilities extend the umbrella's functionality beyond simply charging devices. Despite challenges such as hardware sourcing and difficulties with the modules, the prototype successfully delivers over 16 watts of solar power and supports a 5000 mAh battery, with key components operating at over 92% efficiency. With a total cost of $276, the Solar Umbrella presents a practical, multi-purpose tool with meaningful environmental impact for both everyday and specialized applications.

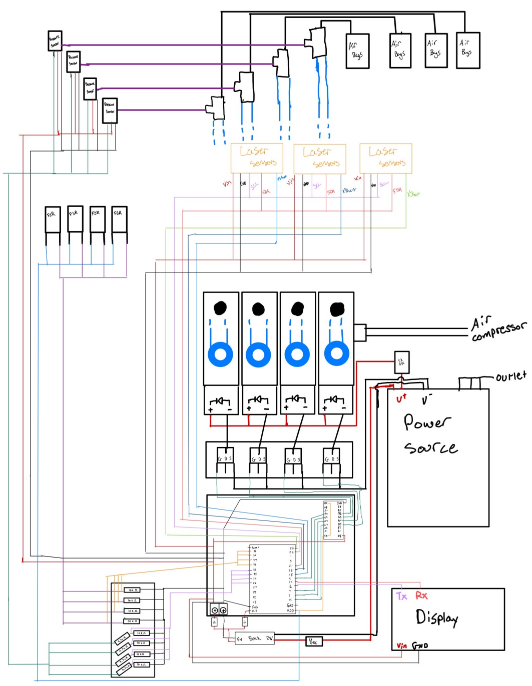


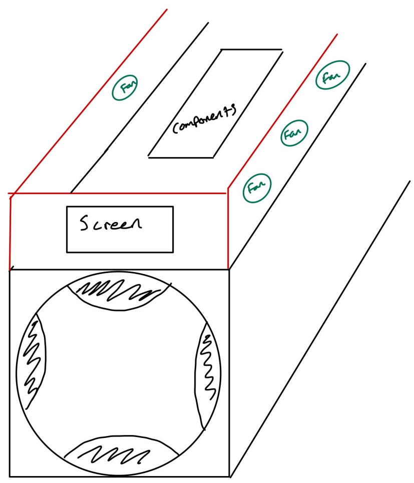
System Diagram

Closed Umbrella

Open Umbrella

S25-09	**Title: Rhythmic Shoulder Stabilization Simulator** **Team Members:Sharbel Sassine, Sahaj Singh** **Advisor(s): Sasan Haghani**
Keywords	Pneumatic Actuation, ESP32 Microcontroller, Motion Tracking, Rehabilitation Engineering, Force Feedback
Abstract:	This project involves the design and development of a rhythmic shoulder stabilization simulator intended to support physical therapy practices. The system automates a common rehab technique involving controlled perturbations to the shoulder joint using pneumatic air bladders. These bladders are inflated and deflated via solenoid valves powered by a 24V supply and controlled by an ESP32 microcontroller. Real-time feedback is gathered through laser distance sensors for motion tracking and force-sensitive resistors (FSRs) to monitor muscular stability. Pressure sensors inside the air bladders track internal pressure for safety and calibration. The system features a scoring algorithm that interprets movement data to quantify performance, displaying results on a 3.5" Nextion touchscreen interface. The complete device is housed in a custom-built wooden and PVC casing to support stability, portability, and user comfort. The design provides therapists with consistent, measurable data while reducing physical labor, and gives patients the opportunity to perform exercises safely and independently.





S25-10

Title: Early Wildfire Detection Drone

Team Members: Zakria Abdelaziz, Amar Abualhassan, Ahmed Alnadi, Haseeb Elkhouga

Advisor(s): Dr. Daniel Burbano, Dr. Sasan Haghani

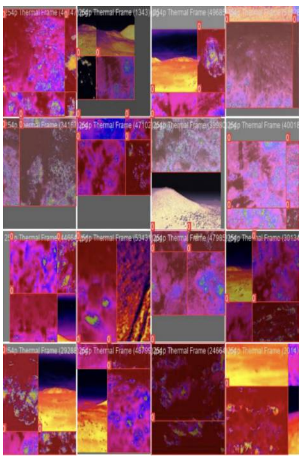
Keywords Wildfire Detection, Thermal Imaging, Drone, Machine Learning, YOLO

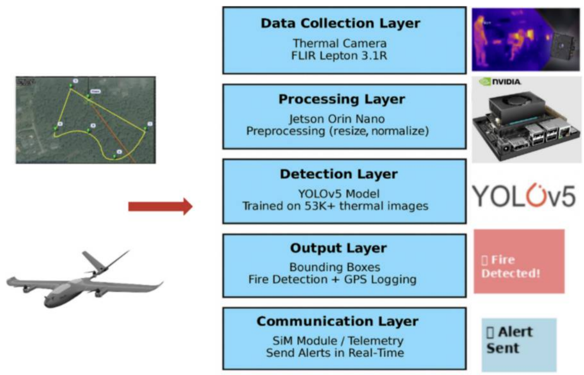
Abstract:

Wildfires are an increasing global threat, especially in remote or high-risk regions. Current detection systems often rely on satellite imagery or dual-drone approaches, which can introduce significant delays and hardware overhead. This capstone project proposes a cost-effective, single-drone system designed to autonomously patrol fire-prone areas and detect early-stage wildfires using onboard AI.

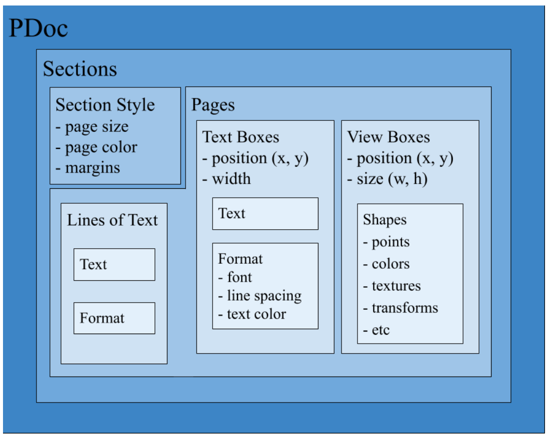
The drone integrates a FLIR Lepton 3.1R thermal camera and an NVIDIA Jetson Orin Nano compute module, running a lightweight YOLOv5 object detection model trained on over 53,000 labeled thermal images. The model is optimized for low-resolution imagery (160x120), enabling fast, accurate detection of fire hotspots. During flight, the drone follows a predefined path using ArduPilot, capturing and analyzing thermal video in real time. When a fire is detected, the system flags the event, logs GPS coordinates, and transmits an alert via onboard telemetry.

Unlike traditional systems that require external inference or cloud dependency, this solution runs entirely on the edge, improving responsiveness and reducing latency. The compact, integrated design lowers operational costs and simplifies deployment, making it ideal for rural municipalities, national parks, and resource-constrained regions. Future enhancements include support for human detection near fire zones, weather sensors for flight condition assessment, and expanded telematics to assist emergency services such as EMS helicopters.

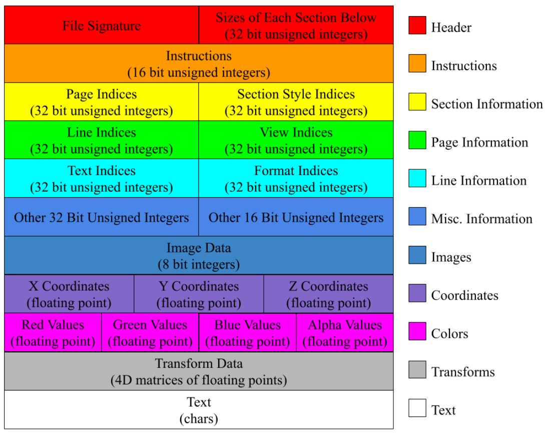




S25-11	**Title: PDoc** **Team Members: Michael Hanley, Maya Kalapatapu, Aarti Rao, Elisabeth Tam** **Advisor(s): Dov Kruger**
Keywords	Computer Graphics, Document and Text Processing, Compression
Abstract:	Adobe's PDF is widely used for creating and sharing online documents across many disciplines. Despite its ubiquity, the file format faces several notable issues, including but not limited to: easily embedded viruses, suboptimal compression, slow speed, and a small built-in font library. To rectify these issues, we have developed a new file format, PDoc. Programmed in C++, PDoc uses high-speed OpenGL rendering to render text (with TrueType, OpenType, and Type1 font support), images, and a large variety of 2D/3D graphics primitives. All primitives can be animated, and 3D primitives support full lighting. PDocs are structured in a hierarchy. Every page may contain lines of text, boxes of text, and a set of "view boxes," which define where on the page images and primitives should be drawn. By excluding PDF's ability to embed executable code from our own format, we have simply, but effectively, eliminated the massive virus and phishing attack vulnerability issues that PDF faces. PDoc is a binary file format, wherein information is de-interleaved to massively improve compression via LZMA. PDF stores text interleaved with coordinates, weakening LZMA's ability to predict bits and compress the document. By storing like-data with like-data, LZMA generally achieves a higher compression ratio with PDoc than with PDF, especially with documents containing a large amount of text. PDoc is portable across Windows and Linux. On devices with an NVIDIA GPU, text rendering is done via CUDA rather than OpenGL, improving text rendering speed.

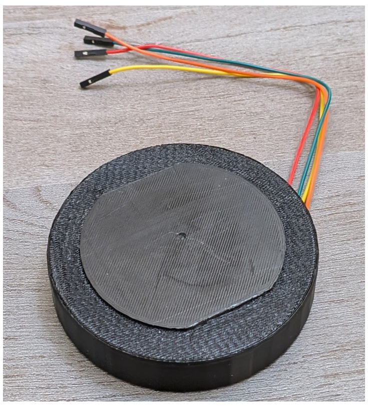


(a) PDoc Hierarchical Structure

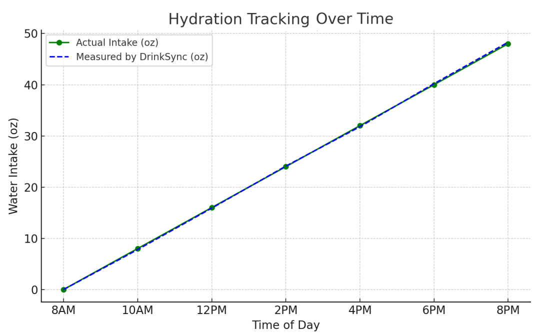


(b) PDoc Binary File Structure

S25-12	**Title: DrinkSync** **Team Members: Karim Smires, Kareem Kholaif, Mohammad Daoud** **Advisor(s): Sasan Haghani**
Keywords	Hydration tracking, sustainability, water intake, wearable technology, gamification
Abstract:	This project aims to develop an affordable, sustainable and versatile solution for tracking daily water intake. Unlike proprietary smart bottles, our product involves a water bottle sleeve or coaster equipped with sensors that can be used with any existing bottle. The system integrates with a smartphone app that uses gamification to motivate users to meet their hydration goals. The design incorporates load cells with controllers to precisely measure weight changes, ensuring accurate water intake tracking. In addition, a gyroscope improves the measurement by detecting bottle orientation during consumption. Data is transmitted via Bluetooth to a smartphone application, where users can monitor hydration trends in real time. Preliminary research indicates that existing hydration tracking solutions are based on proprietary bottles or manual input, limiting accessibility and user adoption. By introducing a universal sensor-equipped sleeve or coaster, our solution eliminates these constraints while promoting sustainability. The feasibility of the project will be evaluated through hardware testing, Bluetooth connectivity trials, and user feedback on the usability of the app. Future iterations may incorporate temperature sensors or ultra-wideband (UWB) tracking for enhanced user experience. This approach supports both personal health and eco-friendly practices.



(a) DrinkSync coaster prototype.



(b) Hydration tracking of DrinkSync prototype over 12 hours.

S25-13	**Title:** Custom Hardware Architectures for Accelerated ML Model Inference **Team Members:** Abdulwahab Malik, Damiano DiMaggio, Josh Green, Romany Ebrhem, Ruben Alias **Advisor(s):** Prof. Dov Kruger, Prof. Hang Liu
Keywords	FPGA, ASIC, Neural Network Acceleration, Embedded ML, Verilog
Abstract	In this project, we explore the design and implementation of custom hardware architectures to accelerate machine learning model inference, with a focus on embedded applications. Our approach utilizes a multilayer perceptron (MLP) model for MNIST handwriting recognition as a representative workload to evaluate the performance of different embedded system configurations. We implemented an MLP architecture using FPGAs and integrated it with camera and display modules for a real-time interactive system. By leveraging tools that convert PyTorch models into Verilog IP blocks, we achieved performance benchmarks of approximately 700,000 inferences per second. Our design process included extensive testing and debugging to ensure accurate real-time performance, followed by comparative benchmarks against commercial GPUs. Furthermore, we assess the potential of transitioning this design into an ASIC, evaluating both its technical feasibility and economic impact. While ASICs incur high non-recurring engineering (NRE) costs ($3.1 million), their unit cost can drop to $75 with sufficient scale. ASICs also offer significant benefits in power consumption and throughput, making them ideal for applications in defense, robotics, high-frequency trading, and aerospace. Our work demonstrates how tailored hardware can provide substantial gains in speed and efficiency over general-purpose processors, especially in real-time and power-sensitive environments. This project highlights the promising future of embedded ML hardware and offers a roadmap for scalable, efficient neural network inference systems.

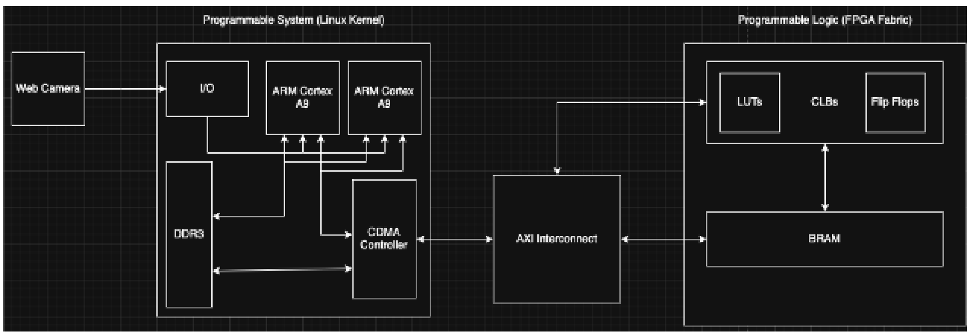


Figure 1: System Block Diagram

S25-14	**Title:** Smart Sole System (SSS) **Team Members:** Keanu Shah, Donovan Holgado, Abdul Qasir, Andrew Yu **Advisor:** Dr. Sasan Haghani
Keywords	Machine Learning, Assistive Technology, Actuation, Gait, App Development
Abstract:	Flat feet affects two billion people worldwide, and high arches affect another 1 billion people. These conditions increase the risk of developing prevalent musculoskeletal issues, such as lower back pain (LBP). Currently, over-the-counter inserts and custom orthotics are the most common treatments, but inserts lack customizability, and custom orthotics prolong discomfort through a lengthy design process. In lieu of these, we propose the Smart Sole System (SSS). The entire design is centered around an ESP32 microcontroller that acts as a WebSocket server for continuous data reception and transmission. It sits on a PCB containing power converters for proper power distribution to the ESP32, pressure sensor array, servos, and rotary encoders. When a user steps onto the pressure sensor array, a plantar pressure distribution mapping is generated. This can be visualized on a mobile application made using a React Native framework. The machine learning model will use the data gathered from the pressure sensors to detect whether the patient has flat feet, high arches, or normal foot structure. Based on the ML model's output, the ESP32 will configure the mechanical actuation system. This system consists of 6 servo motor-driven plates. Each servo drives a lead screw that pushes and pulls on the plates, effectively deforming the user's foot to correct any abnormalities. A gearing system and rotary encoders are also used, allowing the ESP32 to keep track of each plate's position.

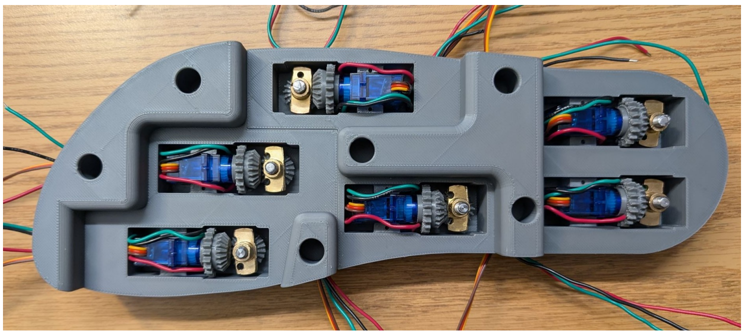


Figure 1: Shoe Sole with Mechanical Actuation System.

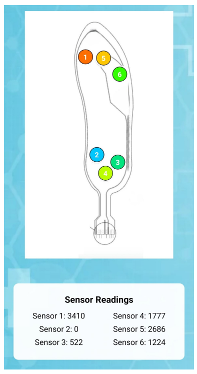


Figure 2: Pressure Distribution Map.

S25-15

Title: Synchronous American Sign Language Translator (SASLT)

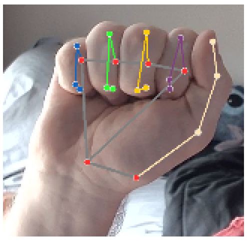
Team Members: Tyler Amalfa, Benjamin Friedman, John Greaney-Cheng, Jacob Liu, Nikash Rajeshbabu

Advisor(s): Kristin Dana

Keywords computer vision, american sign language translation, machine learning, neural network, generative ai

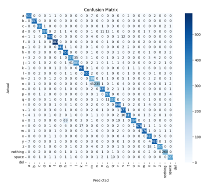
Abstract:

Deep learning and generative AI are cutting-edge technologies that are able to solve problems that are too complicated and abstract for humans, finding patterns and rules that would otherwise remain undiscovered. Our paper aims to explore the creation of a neural network capable of classifying ASL signs. This classifier will serve as the heart of our Synchronous American Sign Language Translator which will help people who work alongside deaf or hearing impaired individuals, who may not be fluent in ASL. We have created a model capable of identifying the signs of the English alphabet from real-time video with an overall average f-score of 0.94. We have utilized generative AI to draw hands, specifically for American Sign Language, in order to gain a better understanding of how machines "view" hands and hand signs in order to make our classifier more efficient and accurate. We plan to continue to evaluate this model by testing low quality images and using those evaluations to increase our model's robustness. We integrated a text-to-speech component API which allows simultaneous audio streaming of translated text to tie everything together. We will continue exploring generative AI by writing increasingly varied prompts and identifying successes and failures in generation so that we can innovate on our model's design.



Hand Landmarks for 'A' in ASL.

ASL "L" generated using generative AI, specifically with Dall-E 3.



Confusion Matrix showing our current model's performance.

S25-16

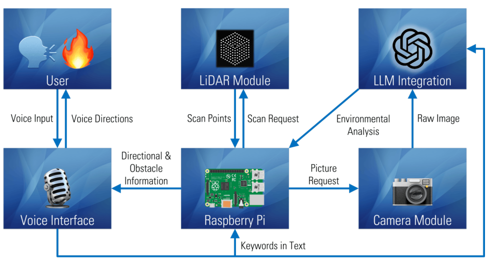
Title: LiDAR-Based Seeing-Eye Robot

Team Members: Tony Lu, Tong Tong, Yadi Lin

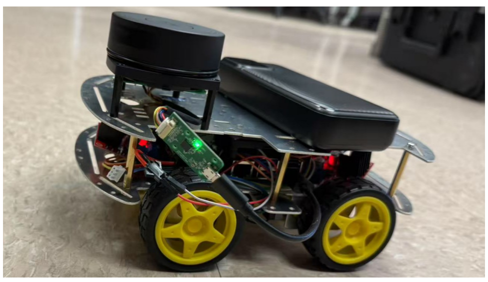
Advisor: Demetrios Lambropoulos

Keywords: LiDAR, Raspberry Pi, Voice Control, Autonomous Guidance, LLM Integration

Abstract: Our project addresses the navigation challenges faced by approximately 43 million visually impaired individuals worldwide. Traditional assistive solutions like canes offer limited functionality, as they primarily detect nearby obstacles and require constant user feedback for direction. Guide dogs, while highly effective, involve substantial cost, time for training, and long-term maintenance. To overcome these limitations, we propose a LiDAR-based seeing-eye robot as an affordable, scalable, and versatile alternative. The system integrates LiDAR technology with a Raspberry Pi microcontroller, creating a compact and efficient navigation platform that remains functional under all lighting conditions. The robot receives voice commands through a web-based interface. Users issue directional commands such as "forward" using a microphone input and processed using speech recognition software. The system identifies key command words and translates them into motion instructions. Meanwhile, the LiDAR module serves as the robot's primary sensory component, continuously executing 360-degree environmental scans to build and update detailed spatial maps of the surrounding area. When an obstacle is detected within a predefined proximity threshold, the robot stops and records the location of the obstruction. To enhance situational awareness, an additional camera module integrated with large language model (LLM) capabilities performs environmental analysis. All relevant navigation information is thus processed and converted into clear, real-time voice directions using browser-based text-to-speech tools, providing visually impaired users with reliable, intuitive, and responsive mobility assistance.



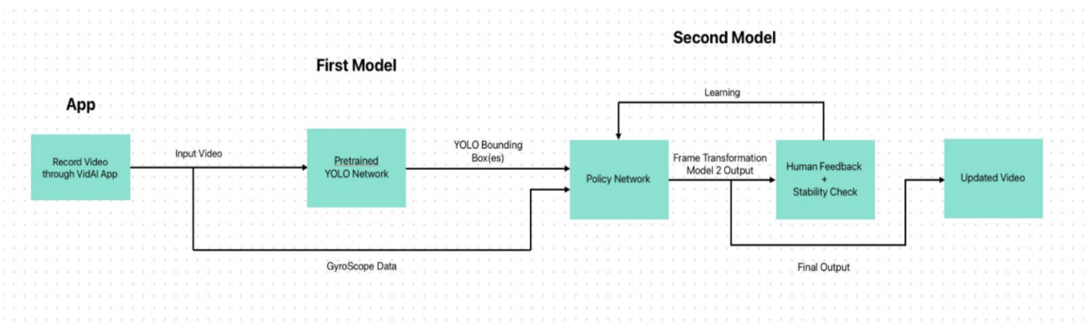
(a) Workflow in Block Diagram



(b) Prototype Robot

S25-17	**Title: Video AI** **Team Members: William DeIasi, Austin Fash, Martino Volcy, Owen Witt, Brandon Zheng** **Advisor(s): Minning Zhu**
Keywords	app building, computer vision, machine learning, neural networks, reinforcement learning
Abstract:	VidAI is a video player developed with the goal of enhancing the input video and providing a more dynamic, captivating video experience for the user. Traditional video players offer a routine playback experience to every viewer, static controls, fixed pacing, and no surprises, so audiences tune out or drop off early. The video player powered by VidAI will apply real-time adjustments and create a more enjoyable viewing experience, especially those created by non-professionals. Traditionally, such level of video editing requires lots of time and effort, however, by utilizing artificial intelligence, VidAI challenges the status quo of screen viewing. To realize the VidAI, we first created an iOS app to record sample videos while collecting both accelerometer and gyroscope data for model training. After training and testing, VidAI uses a YOLO-based neural network to detect the objects in frame and produces the coordinates of a bounded box around these objects. These coordinates are then synchronized with the accelerometer and gyroscope data and passed to the reinforcement learning model to get human feedback directly. While current outputs show occasional choppiness during transitions, ongoing training and model refinement are expected to significantly improve smoothness and continuity. VidAI has the potential to contribute to different areas of the entertainment industry, including short videos, stream videos, music videos, movies, TV shows, and sports broadcasting. This immersive enhancement from the video players not only captivates audiences but also provides creators with a powerful tool to retain viewer attention and improve content impact.

VidAi Data Workflow



S25-18

Title: CARMA - Car Active Recording and Monitoring Apparatus

Team Members: Jay Shah, Edwin Montesdeoca, Kevin Wang, Liam Mahon, Alexander Frederic

Advisor(s): Dr. Michael Caggiano

Keywords IoT, Embedded Systems, Mobile App, Security System, Modular

Abstract:

Car security remains a significant concern, with over a million vehicles reported stolen in 2023 alone, leading to billions of dollars in losses. Car owners also face rising threats of break-ins, vandalism, and hit-and-run incidents. Existing solutions, such as dashcams, car alarms, and GPS trackers, are often limited in scope, overly complex, or prohibitively expensive, pointing to the need for an innovative, affordable, and user-friendly security solution accessible to a wider audience.

The Car Active Recording and Monitoring Apparatus, or CARMA introduces a compact and cost-effective car security system that delivers wide-angle surveillance, real-time alerts, and intelligent threat detection using motion, audio, and object recognition. Unlike conventional systems, CARMA is designed to be portable, energy-efficient, and independent of the vehicle's internal power source. It utilizes hardware components such as an on-board computer, cameras, motion and audio sensors, and IoT connectivity to monitor and detect threats, alerting users via an intuitive mobile application.

It includes key features such as secure cloud storage, live push notifications, and YOLO-based object detection to minimize false positives. Its modular architecture ensures compatibility with various types of vehicles, while low-power components and a LiFePO4 battery enable extended operation without frequent charging.

In essence, CARMA bridges critical gaps in current car security offerings by being affordable, straightforward, and effective—providing a holistic approach to protecting vehicles from theft, vandalism, and unauthorized access.

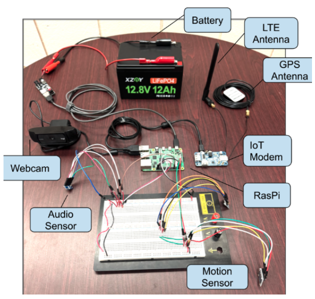


Figure 1: Hardware Setup

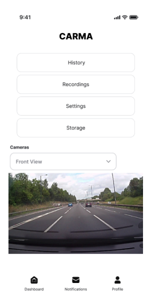


Figure 2: Front page of the mobile app with live feed

S25-19

Title: ML-Enhanced RF Signal Localization

Team Members: Sedat Guvercin, Sebastian Massella, Mark Moroney, Minskhy Roger

Advisor(s): Ivan Seskar

Keywords Machine Learning, Signal Processing, Simulation

Abstract:

Radio frequency (RF) based signal localization is critical in various fields, including telecommunications, emergency response, and wireless research. Traditional localization systems often rely on pre-existing infrastructure and multiple synchronized receivers, which can be inflexible, costly, and complex. This project aims to develop a portable, infrastructure-independent device capable of accurately locating signal sources in free space using only a single receiver. Our approach leverages machine learning to estimate signal directionality. Specifically, we train and compare multiple models, such as neural networks and tree-based algorithms, using data collected from controlled environments. A custom heuristic algorithm, inspired by human strategies for signal hunting, is employed to guide real-time localization and to generate structured training data. The algorithm enables efficient navigation and informs the model with realistic movement patterns by associating directional measurements with signal strength trends. The developed system integrates an antenna, a software-defined radio (SDR), and a compact computing unit capable of running model inference on-device. Emphasis was placed on identifying models that perform reliably under noisy, real-world conditions. Potential applications include search-and-rescue operations, optimal Wi-Fi router placement, and research use in unstructured environments. This device offers a low-cost alternative to traditional localization systems without sacrificing performance by reducing system complexity and increasing portability.

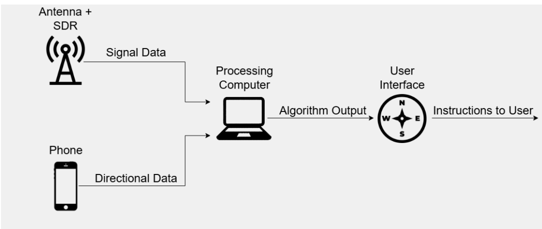


Figure 1. Conceptual flowchart of the RF signal detection system

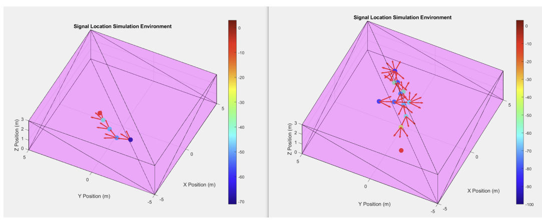


Figure 2. Simulation result - trivial case (left) and non-aligned case (right)

S25-20

Title:PulsePlay

Team Members: Qifan Zhuang, Luke Domingo, Seerat Kaur, Nowshin Rahman, and Peter Youssef

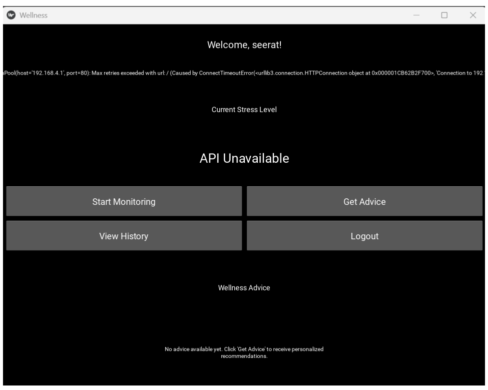
Advisor(s): Mehdi Javanmard

Keywords Machine learning, Stress Reducing, Healthcare, Mobile App Development, Micro Controllers

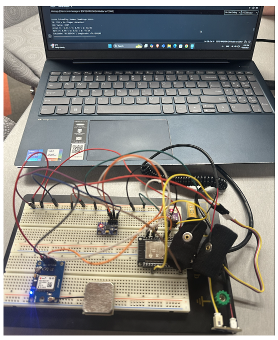
Abstract:

Stress is a major contributor to both mental and physical health problems, yet many people don't realize they're stressed until it's too late. We often ignore how our bodies are reacting to our surroundings, changes in heart rate, stress levels, or mood swings because we don't have an easy way to monitor those signs in real time. This lack of awareness can lead to burnout, anxiety, and chronic health issues.

Currently, stress management is addressed reactively through therapy, fitness apps, or general wellness advice but these tools don't personalize recommendations or track how stress physically affects the body. They also don't provide early alerts based on physiological data. To solve this, we developed PulsePlay, a system that combines a wearable sensor device with a user-friendly mobile app. The hardware tracks heart rate, motion, stress levels (using GSR), and location. This data is sent to the app, which offers personalized recommendations like calming exercises, stress-reducing foods, and breathing tools based on the user's current state. Our prototype gives users real-time insight into their well-being and actionable ways to feel better, something not possible with traditional apps alone. It helps people catch stress before it spirals, and empowers them to take control of their health with immediate, tailored support. PulsePlay makes proactive wellness simple, personal, and accessible.



(a) Figure 1: The App



(b) Figure 2: Hardware Components

S25-21	**Title: Accurate Soil Nutrient (NPK) Sensor with Photochemical Reactions** **Team Members: Jonathan Covell, Ryan Covell, Alexander Booth, Sathya Gopinath Thangamani** **Advisor(s): Dr. Aggelos Bletsas, Dr. Richard Howard**
Keywords	Plants, Nutrients, Sensor, Photodiodes, Microcontroller
Abstract:	Rapid and accurate measurement of soil macronutrients—nitrogen (N), phosphorus (P), and potassium (K)—is essential for optimizing crop yield and minimizing environmental impacts of over-fertilization. Traditional laboratory analyses are costly and slow (3–14 days turnaround at \$50–\$100 per sample), while at-home colorimetric kits provide only qualitative "low/medium/high" and require manual steps prone to human error. We present a low-cost (\$50), automated NPK sensor that delivers quantitative, same-day ppm readings in under 10 minutes. Our system combines reagent chemistry (Nessler's reagent for N; ascorbic acid assay for P; tetraphenylborate reaction for K) with photometry to determine macronutrient concentration. A flow cell with discrete LEDs tuned to reagent-specific absorbance peaks (548 nm, 880 nm, 850/940 nm) and matched Phototransistors captures multi-wavelength intensity data. An ESP32 microcontroller controls peristaltic pumps for sample extraction, dilution, reagent addition, and rinsing before recording stabilized optical signals. Calibration across 5–200 ppm for N, 10–100 ppm for P, and 20–200 ppm for K achieved R^2 values of 0.995, 0.990, and 0.970, with average errors of ±5%, ±7%, and ±10%, respectively. Incorporating k-means clustering and self-organizing map algorithms further reduces prediction error by $\tilde{1}0\%$. This automated, user-friendly platform empowers farmers and plant enthusiasts with rapid, precise nutrient profiling to inform targeted fertilization, reduce chemical runoff, and support sustainable agriculture.

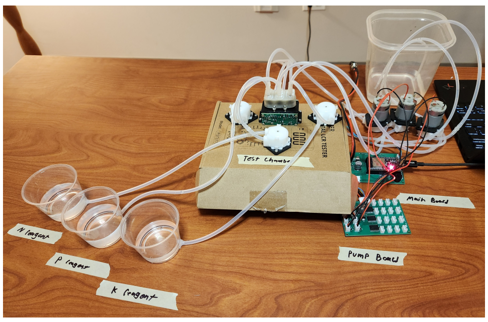


Figure 1: Sensor System

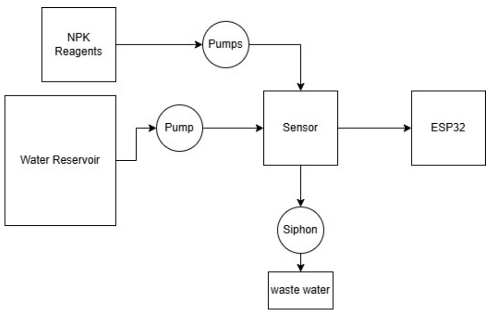


Figure 2: System Flow Chart

S25-22

Title: Ultrasonic Phased Array

Team Members: Gavin Cabida, Tenzin Kyizom, John Allen Manego

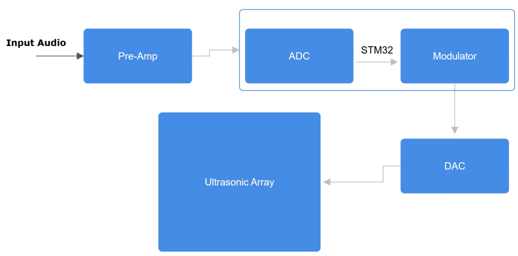
Advisor(s): Anand Sarwate

Keywords

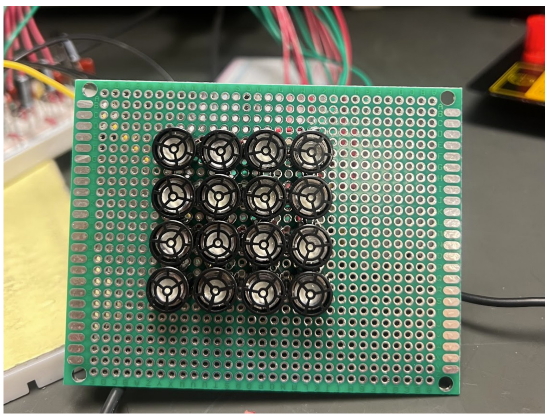
Beamsteering, Ultrasonic Array, Directional Audio, STM32 Microcontroller, Signal Processing, Modulation

Abstract:

This project focuses on the development of an Ultrasonic Phased Array for directional audio applications. Leveraging ultrasonic modulation where it transmits a sound, the project goal is to steer a narrow focus beam without physically moving the device. The design of this device incorporates a 3.55 mm audio input and an array of 16 ultrasonic transducers operating at a 40 kHz Carrier frequency. The degree of freedom this device offers is 45 degrees off boresight for both azimuth and elevation. Applications of this device span entertainment and informational settings such as museums and personal audio devices. Development began in STM32CubeIDE but was transitioned to ArduinoIDE for cleaner and simpler prototyping. An audio signal is first passed through a pre-amp and digitized using the internal ADC in the microcontroller. Through Arduino IDE, a modulation software is implemented and sent to our microcontroller, STM32F103C8T6. Two MCP4912 dual channel DACs receive the modulated signal and output phase-shifted output carrier signals. These signals are amplified via high speed MOSFET drivers and sent to the 16 transducers in the array. To test the effectiveness of the beamforming, we physically moved around the array and evaluated the perceived audio intensity at different positions. Although this is a subjective testing, it provided us with an efficient and quick demonstration of our system's beam steering behavior.



Block Diagram of Major Components of the System



16 Ultrasonic Phased Array

S25-23

Title: LyraAI

Team Members: Albi Gjini, Sparsh Patel, Arnav Patel, Beshoy Yacoub, Kalp Sheth

Advisor: Hang Liu

Keywords

Natural Language Processing, Text-to-Speech, Audio Translation, Deep Learning

Abstract:

Music is often described as a universal language, capable of connecting people across cultures and borders. However, linguistic differences continue to pose a barrier to fully understanding and appreciating songs from other regions. Our capstone project seeks to overcome this limitation by developing an AI-driven tool that enables seamless translation of songs into multiple languages while preserving the original artistic and musical integrity. The system integrates several advanced technologies, including text translation, voice synthesis, and audio alignment. The tool extracts the song's lyrics using the YouTube Transcript API, cleans and processes the text, and translates it into the target language. A text-to-speech model is then used to generate a new vocal track. The original audio is then processed to separate vocals from instrumentals. The final step analyzes the timing of the original vocals to synchronize the synthesized voice with the song's tempo. The result is a translated version of the original track that maintains the same rhythm and musical feel, but in a different language. This tool has significant potential within the music industry. It offers a cost-effective and scalable alternative to re-recording tracks in multiple languages, helping artists reach global audiences more efficiently. In the long term, the system could be integrated into platforms like YouTube and Instagram, providing users with multilingual listening experiences. Key challenges encountered during development include preserving vocal timing during translation and achieving natural-sounding tone in TTS outputs. Future enhancements will focus on improving tone matching, expanding language support, and refining vocal-melody alignment.

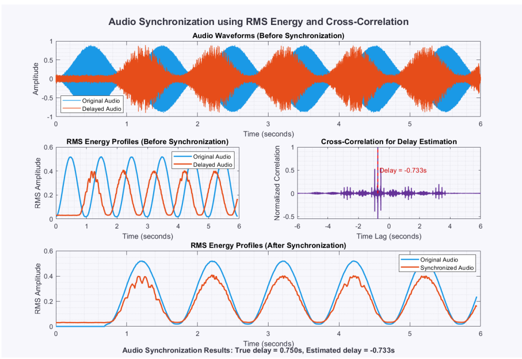
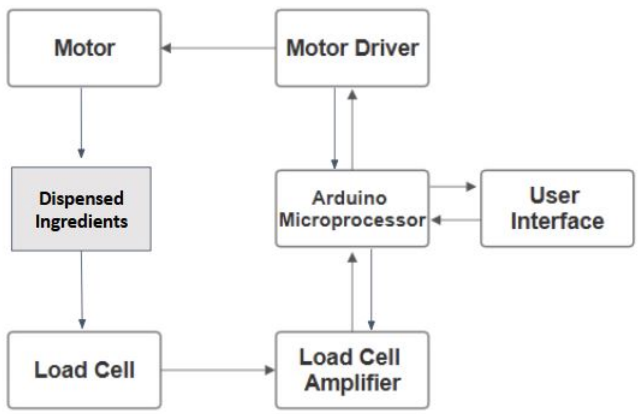
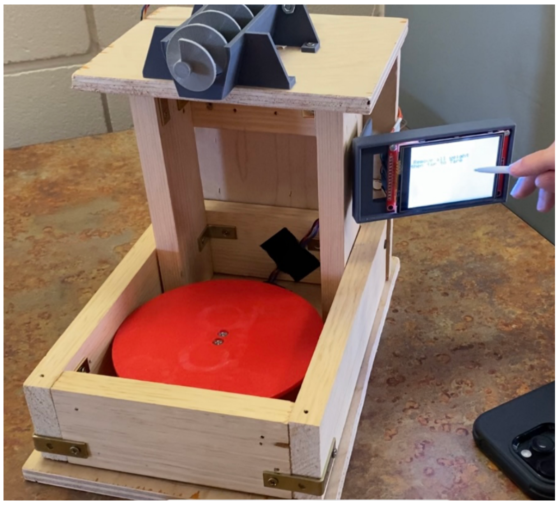


Figure 1: Audio Synchronization using RMS Energy and Cross-Correlation

S25-24	**Title: Baking Automatic Ingredient Dispensing Equipment (A.I.D.E)** **Team Members: Robert Wynne, Daniel Gerber, Francisco Aguirre, Diego Juarez** **Advisor(s): Dr. Michael Caggiano**
Keywords	Power Electronics, Accessibility, Utility, 3D Printing
Abstract:	Baking AIDE is an accessible and convenient baking tool designed to assist with measuring and dispensing of common dry ingredients used in home-baking. Traditional baking often requires precise measurements and steady hands, which can be difficult for individuals with limited fine motor skills. Baking AIDE addresses this challenge by automating a key part of the process: making baking easier, more inclusive, and less time-consuming for everyone. The device features an intuitive touchscreen display, allowing users to select the exact amount of a given ingredient they need with just a few taps. Once selected, the system dispenses the ingredient accurately and consistently, eliminating the need for manual scooping, leveling, or pouring. This not only helps reduce physical strain but also ensures that recipes are followed with precision, improving the quality and consistency of baked goods. By minimizing spillage and over-pouring, Baking AIDE also helps reduce food waste, making it both a practical and environmentally conscious solution. Whether someone is new to baking or has physical limitations that make traditional methods difficult, Baking AIDE empowers users to participate fully and confidently in the baking process. It brings the joy of baking to more people by removing common barriers and simplifying one of the most critical steps in the kitchen.

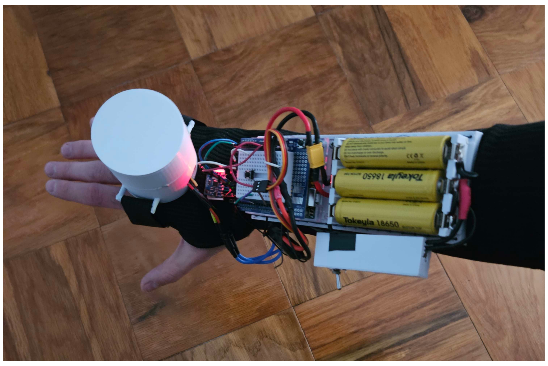


System Design of Baking A.I.D.E



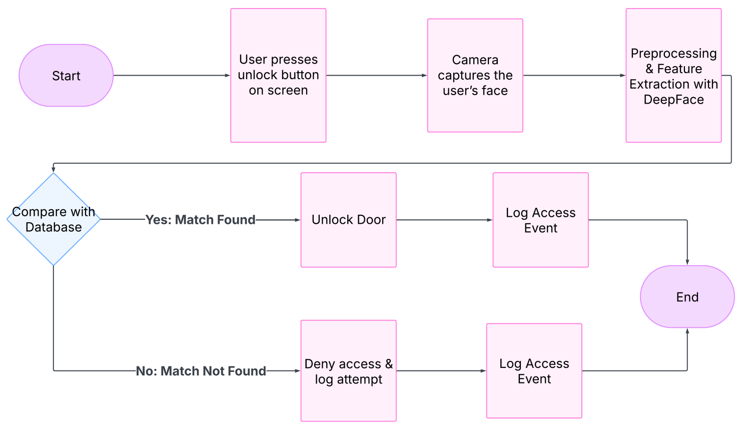
Completed construction of Baking A.I.D.E.

S25-25	**Title:** Low Cost Gyroscopic Glove for Hand Stabilization **Team Members:** Alec Bodnar, Devon Engelhardt, Esin Surmeli **Advisor(s):** Andres Guerrero (Blythedale Children's Hospital), Prof. Haghani
Keywords	Wearable Technology, Biomedical Engineering, Arduino
Abstract:	The Gyroscopic Glove was created as an affordable device to mitigate hand tremors in individuals with a condition known as ataxia. This was done in collaboration with Mr. Andres Guerrero from Blythedale Children's Hospital in an effort to assist young patients with this condition. Ataxia is considered a neurological disorder - one major symptom being substantial tremors in the hands and arms. These can vary in strength based on the action being performed and distance away from the body. The glove utilizes a powered gyroscope mounted to the back of the hand in order to improve motor control of the hands. Similar technologies currently exist on the market today, however they are primarily intended for those with Parkinson's Disease, which causes different tremors from those of ataxia. These devices are also prohibitively expensive (∼$6000) for the hospital to allocate funds for and test with. The primary objective of this project was to achieve similar functionality to the current market leaders at a substantially lower cost (< $300). The glove features variable levels of stabilization based on the strength of the tremors of the wearer. This was accomplished by implementing an accelerometer on the wrist to provide real time feedback to the motor controller. After testing and collaborating with physical therapists from the Children's Hospital, this prototype is in a functional state. Minor adjustments to component placement, gyroscope strength, and additional padding for comfort will lead to a final product that the hospital is highly interested in acquiring for their patients.



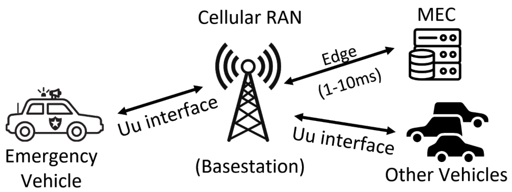
(a) Fully Built glove on hand

S25-26	**Title: Smart Dorm Room Lock Using Facial Recognition** **Team Members: Aditya Suresh, Daniel Aladeniyi, Michael Smeraglia, Tom Simon, Aditya Rajesh** **Advisor(s): Shirin Jalali, Kevin Wine**
Keywords	Facial Recognition, Security, Privacy, Convenience, Machine Learning
Abstract:	Traditional dormitory access methods like RFID cards, and keys are open to challenges related to **security**, **privacy**, cost and **convenience**. Physical keys can be easily stolen, duplicated or lost and trying to replace them can be very time-consuming and/or expensive for both students and housing administrators. This problem prompted us to step in and explore a modern alternative that can enhance user experience and safety.Our capstone project introduces a **facial recognition** based system that is designed to provide a more source, efficient and user-friendly solution for easy dorm room entry. By applying **machine learning** through software libraries such as proDlib, OpenCV, and DeepFace library, our system is capable of accurately being able to detect and verify faces using facial embeddings, with embeddings that are extracted from images and compared using cosine similarity to confirm identity. The hardware components integrate Raspberry Pi, Pi Camera Module, and servo motor to control the locking mechanism in real-time. To support real-world deployment, we wanted to have the solution designed with scalability in min. Our system is able to accommodate multiple users per door and remains cost-effective for implementation across academic housing. Our system helps to eliminate the need for physical access items such as keys or RFID cards, improving **convenience** for students while also minimizing administrative overhead.



Main Workflow Diagram

S25-27	**Title: Connecting Vehicles with Edge Computing** **Team Members: Steven Nguyen, Ji Wu, Vineal Sunkara, Damon Lin** **Advisor(s): Anthony Magnan and Sasan Haghani**
Keywords	App Development, Intelligent Transportation Systems, Edge Cloud Computing, 5G Networks, Amazon Web Services
Abstract:	On-board sensors in autonomous vehicles can be compromised by hardware obstructions and weather conditions. 5G cellular communication and edge computing offers a solution by enabling real-time vehicle communication for use in intelligent transportation systems (ITS). This project presents a Vehicle-to-Network (V2N) architecture that can leverage 5G networks and Multi-Access Edge Computing (MEC) using Verizon networks and AWS Wavelength EC2 instances. Using CARLA for traffic simulation and MQTT protocol for data communication, we demonstrate how edge computing may be used in real-time collision detection, emergency vehicle management, and driver alerts. A proof-of-concept Android application enables visualization and user interaction, aiming to bridge the gap between cutting-edge research and practical vehicular safety improvements.



(a) Example of a V2N system

(b) Example CARLA scenario

S25-28

Title: Gaitway

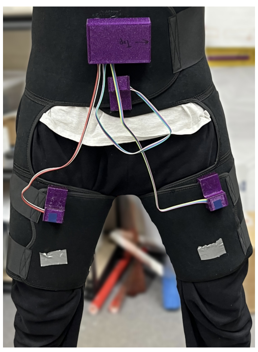
Team Members: Aaron Clarion, Michael Gibbons, Chris Hoskin, William Mejia, Yusuf Yaglidere

Advisor(s): Demetrios Lambropoulos

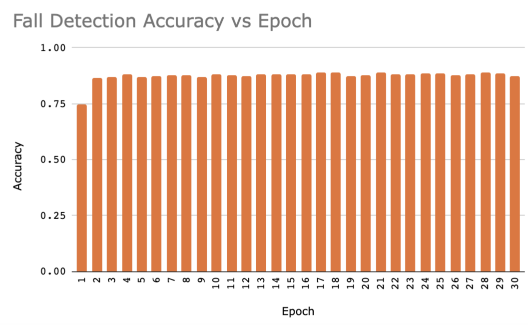
Keywords Assistive Technology, Biofeedback, Fall Detection, Motion Sensors

Abstract:

Children with cerebral palsy face many issues in life. Depending on the condition and which muscle groups of the child suffer from rigidity and lack of strength, several aspects of the lives of children will be affected. In particular, those who suffer from cerebral palsy that affect their ability to walk are of interest to our project. Looking to assist these children in their effort to gain normal locomotive function, our team is determined to design an mobility device with functionality built to aid the child in the process of learning to walk. This device consists of a hip brace to compensate for weakened hip flexor muscles and the weak core strength of the child. The novelty of Gaitway lies in the specially designed fall-detection and biofeedback system made to be used while wearing the physical device. Accelerometers and gyroscope sensors are placed on the mobility device to provide real-time data of the child's gait cycle that is then processed in a machine learning model in real time to accurately detect when the child will fall during the learning process of walking. The device is to be used as an assistive tool to aid in the process of the child learning to walk under the instruction and care of a pediatric physical therapist. The training graphs show that the model's validation accuracy steadily improves and stabilizes around **87.4%** by epoch 30, while the training loss consistently decreases, reaching a final value of **0.102**. This indicates effective learning and convergence without significant overfitting.



(a) Physical Implementation of Motion Sensors



(b) Accuracy of Fall-Detection per Epoch

S25-29	**Title:** AI-Powered Drone for Lawn and Weed Management **Team Members:** Noah Jacobson, Kalyan Cheruvu, Merrick Cai, Pengkai Li **Advisor:** Maria Striki
Keywords	Grass, Lawn, Drone, Weeds, Machine Learning
Abstract:	Lawn maintenance can be time-consuming, especially for larger areas where manually assessing plant health and identifying invasive species is challenging. Lawn owners often have limited resources, such as grass seeds and herbicides, making efficient weed management crucial. Invasive species pose a growing threat, particularly in New Jersey, where they endanger native plants. To address this urgent issue, we propose a smart solution to streamline lawn monitoring. Our project introduces a lightweight quadcopter drone equipped with a camera to survey lawns, capturing images of plant species. These images are mapped using GPS and displayed on a built-in website interface for easy access to study the health of the lawn and take the necessary action. To achieve this, we trained a YOLO model using machine learning. This is obtained from curating a dataset of plants using Roboflow, annotating plant species and dividing the images into training (70%), validation (20%), and testing (10%) sets. Once trained, the model is deployed to analyze plant health and detect invasive species efficiently on the lawn. To enhance accuracy, we incorporated color and shape detection techniques, allowing for precise species differentiation. Additionally, we designed a user-friendly website where captured images are processed through the trained model, enabling homeowners to quickly identify and address lawn issues. By integrating drone technology with machine learning, our project offers a faster, more efficient method to manage invasive plants, ultimately preserving lawn health and biodiversity.

Table1: Detectable Plant Species

Blue Violets	Broadleaf Plantains
Eastern Poison Ivy	Japanese Honeysuckle
Virginia Creeper	Chickweed
Common Ivy	Oxeye Daisy
Dandelions	Crabgrass
Common Purslane	Roundleaf Greenbrier

Figure1: Custom-built drone for lawn imaging

S25-30	**Title: Real-Time Eye Health Monitor** **Team Members: Daksh Khetarpaul, Liam Fox, Omar Talal, Nicholas Yim, Shrey Dobariya** **Advisor(s): Prof. Hang Liu**
Keywords	Eye Health, Blink Detection, Fatigue Management, Real-Time Analysis, Productivity insights
Abstract:	This project presents a conceptual design for a real-time drowsiness and stroke risk detection system based on eye-blink monitoring through computer vision and data analysis. The primary objective is to enhance safety by identifying early signs of eye fatigue, which, if left unaddressed, could lead to conditions such as dry eyes. The system utilizes a standard webcam to continuously capture facial data, employing facial landmark detection to compute the Eye Aspect Ratio (EAR)—a well-established metric for detecting blinks and eye closures. The conceptual design outlines the interaction between hardware components, image processing pipelines, decision logic, and audio feedback mechanisms. The software component, developed using Python libraries such as OpenCV, dlib, and NumPy, processes each video frame to detect subtle eye movements in real-time. Blinking patterns are tracked over fixed intervals to determine whether the frequency deviates from predefined thresholds. If an anomaly is detected, the system immediately triggers auditory alerts to notify the user.

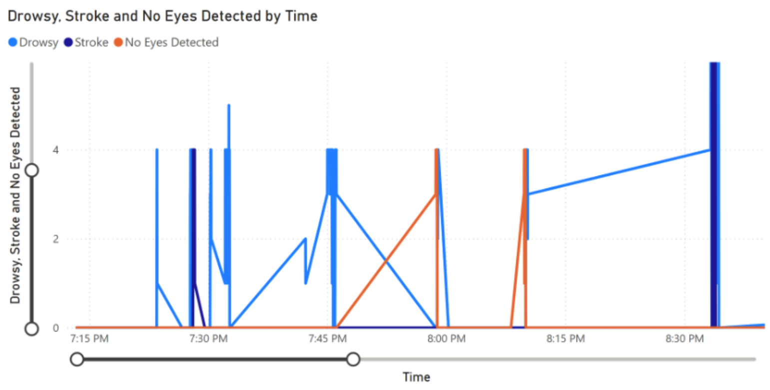


Fig. 1. Example of how behavior is monitored for a 30 min session via Power BI

S25-31

Title: PowerSentry

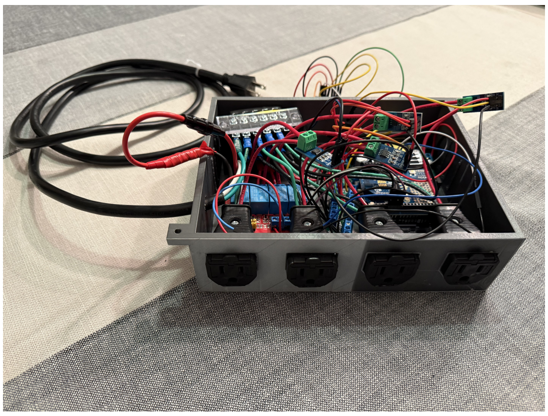
Team Members: Aryan Jain, Joshua Menezes, Keanu Melo Rojas, Thomas O'Connell

Advisor(s): Sasan Haghani

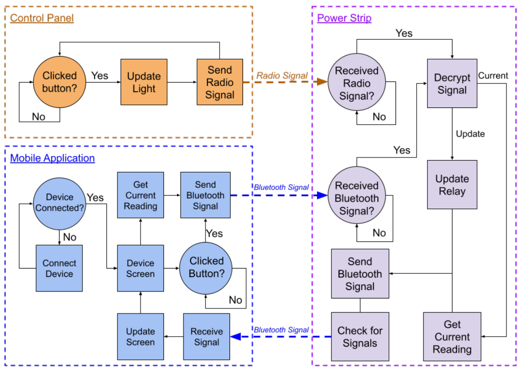
Keywords Automation, Energy Saving, IOT, Mobile App, Smart Home

Abstract:

PowerSentry is a system composed of a power strip, control panel, and a mobile app designed to monitor and control the energy consumption of connected appliances. Many devices are consuming power, even while idle. This "Phantom Power" is responsible for 15%-30% of the energy used for buildings, causing more waste and high costs. By offering flexibility and automation in shutting off unused appliances, PowerSentry results in less energy consumption and lower electricity costs. The control panel allows the user to control the power strip from a location of their choosing. The app can record, display the power readings from the power strip, and control the power strip. The usage of wireless communication, such as Bluetooth from the Arduino R4 and Zigbee Protocols from the Xbee modules, allows the system to be independent of Wi-Fi routers, unlike our competitors. The system is not reliant on a "smart home" environment, giving more flexibility to the user. The usage of the current sensor modules ACS712 5A allows the user to monitor their power readings, so they can stay informed about their electricity.



(a) Exposed Final Product of Power Strip



(b) PowerSentry's System Diagram

S25-32

Title: GrAIdient

Team Members: Sachin Ganpule, Taner Fetoski, Alexander Ruskulis

Advisor(s): Professor Dov Kruger

Keywords Education, Grading, Machine Learning, OCR

Abstract:

GrAIdient is an AI grader intended for the use of educators with the hopes of reducing the grading workload of teachers and professors. This allows for frequent low-stakes assessment, facilitating more kinds of question types and avoiding multiple choice while retaining easy grading by having the AI read and grade what the students write down. GrAdient works by conducting Optical Character Recognition (OCR) on text within a specific area of an uploaded PDF file designated by the teacher (as a bounding box) and assigning the correct answer to the associated question. Once it has its answers, it will assign grades to students based on what it has read from the students' writing. For any writing where the OCR is unsure (by assigning a low confidence level), it will ask for the teacher's assistance to determine what the student wrote by flagging the responses it is unsure of, appropriately updating the grade based on the teacher's edits. GrAIidient also allows teachers to create a list of students for an assignment that it can assign grades on behalf of the teacher. The AI model used was a fine-tuned version of Tesseract OCR, where we trained it to read handwritten words, numbers, and some special characters from datasets we found online. The User Interface was built on GTK 3.0 using Python. GrAIdient blends automation with educator oversight to streamline the grading process while supporting diverse question types.

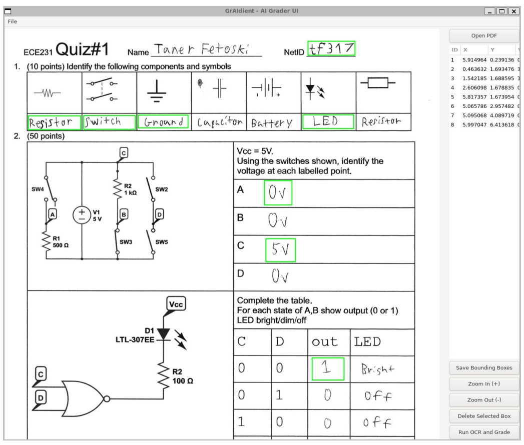


Figure 1: Creation of Bounding Boxes on Quiz

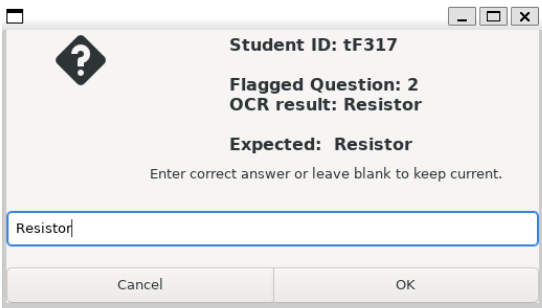
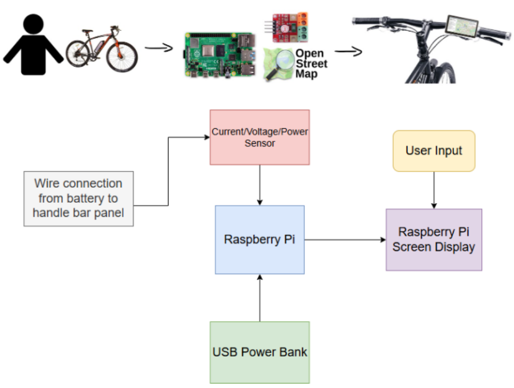
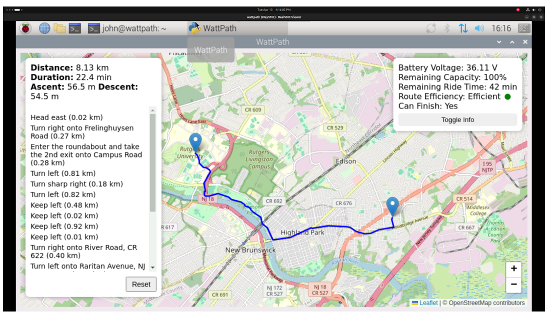


Figure 2: Question Flag and Correction Window

S25-33	**Title: WattPath - Efficient Route Planner for E-Bikes** **Team Members: William Jacas and John De Chavez** **Advisor(s): Sasan Haghani**
Keywords	Electric Bicycle, Raspberry Pi, Route Efficiency, Voltage Monitoring, App Development
Abstract:	E-bikes have risen in popularity over the past decade and provide an eco-friendly mode of transportation. But a major limitation is the uncertainty regarding battery life during a trip. Riders often face challenges in predicting whether their battery will last for the entire duration of a journey. There is a lot of support for battery efficiency with electric vehicles today, but riders do not have the same support with navigation systems that consider the specific energy consumption of their e-bike. Our project will give E-bike riders advanced information on their bike to help them plan and carry out their rides. The WattPath program will take in the information from the bike battery using a voltage module and inputs from the rider, including their weight, their origin, and their destination, to get the turn-by-turn directions, distance, and elevation of the route. This will give the rider an estimated ride time remaining, the most efficient route, and it will let them know if they will be able to reach their destination with the remaining battery they have left. With the rise of electric bicycles in recent years, we hope this project will help improve battery efficiency for users and make e-bikes a more reliable method of transportation.

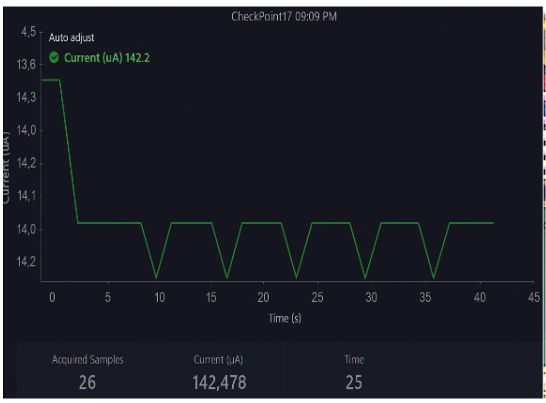


(a) Figure 1: System Design

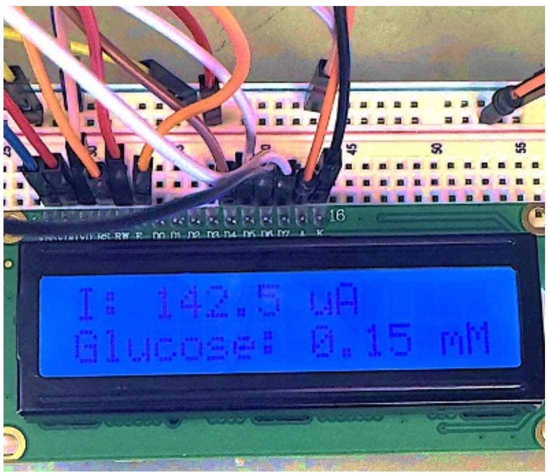


(b) Figure 2: Application Displaying Calculated Route

S25-34	**Title:** Analog Front End Circuit for an Electrochemical Sensor - Glucose Detection **Team Members:** Thahmidur Choudhury, Joel Arias, Aabid Azeez, Tanzir Ahmed, Christian Santos **Advisor(s):** Simiao Liu, Predrag Spasojevic
Keywords	Biomedical Signal Processing, Glucose Detection, Analog Circuit Design
Abstract:	The goal of this project is to design and fabricate an Analog Front End (AFE) circuit for an electrochemical sensor that can monitor glucose concentrations reliably and accurately. To measure current generated by glucose oxidation reactions, the system uses a three-electrode setup, consisting of a working, counter, and reference electrode. Advanced techniques including cyclic voltammetry (CV), square wave voltammetry (SWV), and amperometry are used to improve signal sensitivity and perform precise electrochemical analysis. The AD5941 AFE chip is crucial to the architecture, amplifying and processing weak signals with little interference. A microcontroller processes data from the AFE and transmits it via Bluetooth Low Energy (BLE) to a user-friendly LCD display, to offer real-time glucose readings and trends. The setup will include calibrating the sensor with a commercial glucose solution to demonstrate precise measurements and data presentation. Control group buffer solution and predetermined glucose concentration will be used in testing in order to determine the correct parameters needed for maximum accuracy. This project aims to advance accessible and effective health monitoring systems by solving issues in signal processing and system integration, setting the framework for future non-invasive and continuous medical diagnostic research, data collection, and improvements.



Amperometry Results of Glucose Concentration



Real Time LCD Display

S25-35

Title: Smart Pill Bottle

Team Members: Arvin K. Mui, Audrey Xiao, Jennie Nguyen, Thomas T. Vu, Veena A. Limbachiya

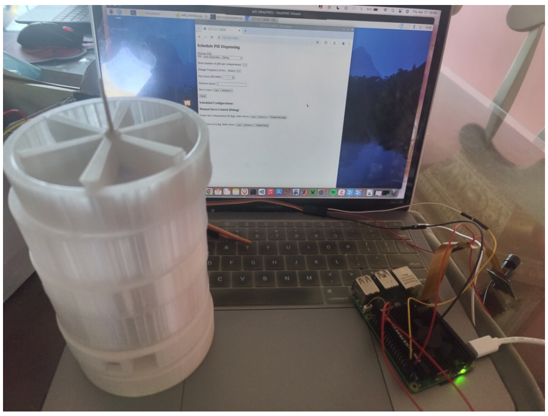
Advisor(s): Umer Hassan

Keywords Healthcare, Medical Management, Embedded Systems, Computer Vision, 3D Printing

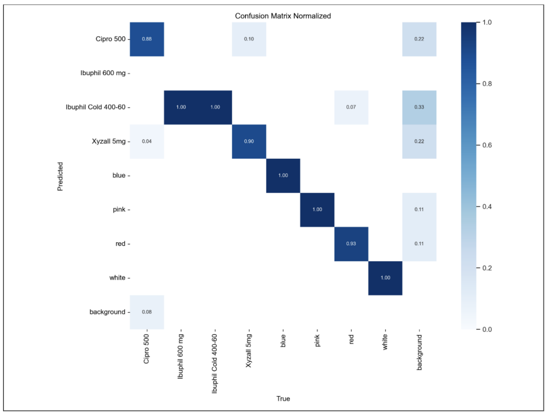
Abstract:

Medical non-adherence is a widespread issue that poses significant risks to individual health and adds a financial burden to the healthcare system. Many patients fail to take their medication as prescribed due to forgetfulness, and physical or psychological limitations. This is critical for medications like anticoagulants and antibiotics that require strict adherence for best effectiveness. To address this issue, this project proposes the design and implementation of a smart pill bottle that combines advanced technology with user-friendly features.

The proposed solution integrates an automated pill dispenser, user authentication, and wireless connection for real-time reminders and caregiver notifications. The bottle comprises of multiple layers to accommodate for multiple types of pills. Each layer consisting of multiple compartments to dispense the correct dosage. The bottle ensures precise dispensing of medication at scheduled intervals, eliminating the need for pre-sorting pills. Furthermore, we mitigate any potential pill dispensing errors through the usage of computer vision to identify the different pills in each compartment



(a) Figure 1: Overview of Pill Bottle Components, Web Interface, and Raspberry Pi



(b) Figure 2: Confusion Matrix of Computer Vision Model

S25-36

Title: PetPal: Intelligent Robotic Caretaker for Pets

Team Members: Katrina Celario, Jason Nguyen, Andy Pham, Jamie Solomon

Advisor(s): Kristin Dana

Keywords Pet Care, Automation, Internet of Things (IoT), Robotics, Mobile App Development

Abstract:

Pet owners often struggle to provide consistent care due to busy schedules, travel, or physical limitations. Existing solutions like boarding services, pet sitters, or single-purpose devices are often costly, limited in functionality, or lack comprehensive care. To address this, we developed PetPal: Intelligent Robotic Caretaker for Pets, a smart, all-in-one system designed to support pet well-being and owner convenience. PetPal consists of three main components: a Smart Care Station, a Mobile Robot, and a Mobile App. The Smart Care Station is powered by an Arduino Uno and connected to a Raspberry Pi, which manages communication and system-wide data flow. It automates feeding, hydration, and hygiene using a stepper motor-driven auger screw for food dispensing, a relay-controlled water pump, and a motorized potty pad system. The Mobile Robot engages pets through a servo-powered treat dispenser and a motorized bubble blowing system. It is controlled by an ESP8266 and an Arduino Uno, operating on two 3.4V lithium-ion batteries that recharge wirelessly via coils embedded in both the Robot and the Station. The Mobile App, developed with React Native, Expo Go, and Firebase, acts as the user interface for real-time monitoring, task scheduling, and manual control of all functions. Together, these components form a seamless and intelligent system that enhances pet care, reduces reliance on external services, and makes high-quality, automated care more accessible.

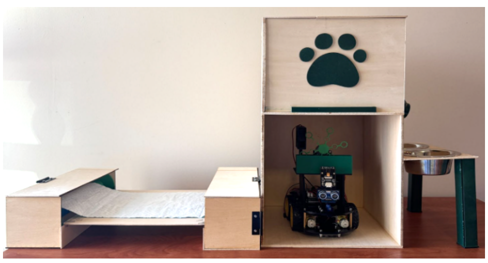


Figure 1: Final Prototype of the PetPal System

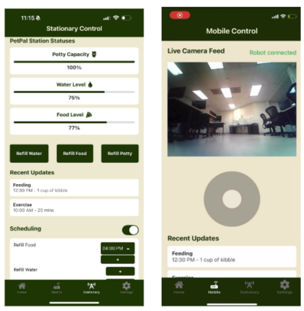
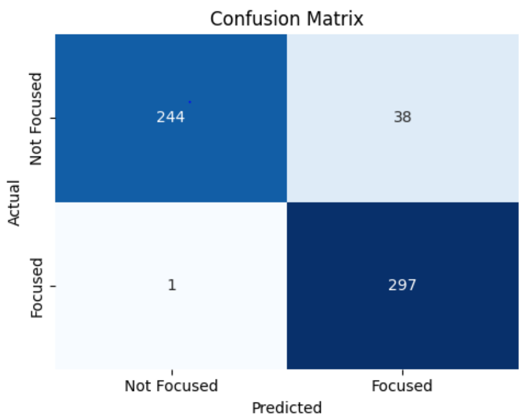
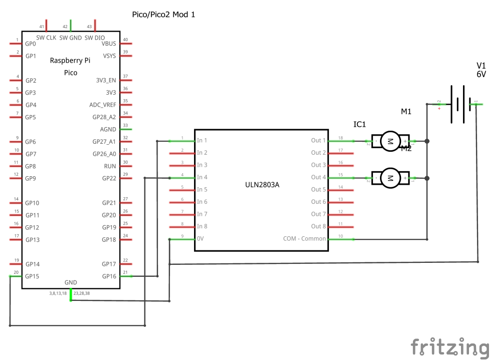


Figure 2: PetPal Mobile App

S25-37	**Title: Machine Learning Focus Assistant Glasses Attachment** **Team Members: Evan Ragone, Dizzy Hillocks, Chandler Dorce, Olavo Macedo** **Advisor(s): Sheng Wei**
Keywords	Machine Learning, Smart Glasses Attachment, Face Tracking, Wearable Technology, Focus Assistant
Abstract:	The need to be focused is something that has become increasingly important in our fast-paced, distraction-heavy everyday lives. Losing that focus during crucial moments can make life more difficult and at times even risks our lives. To help deal with this, we've developed the Machine Learning Focus Assistant Glasses Attachment, an attachment meant to help correct lapses in attention. We use Raspberry Pi NoIR cameras to track the eye in all lighting conditions. This visual data is analyzed using Facemesh, which accurately identifies the position and movement of the entire face. The data is then processed through our Machine Learning Model, built with TensorFlow, which identifies patterns in eye behavior and calculates a real-time focus score for the user. If the focus score predicts the user is not focused, a wireless signal is sent to a wearable necklace accessory, which buzzes gently to alert the user and encourage them to refocus and stay mindful. Designed for versatility, comfort, and user convenience, our Focus Assistant Glasses Attachment offers a proactive way to stay attentive when it matters most.



Matrix showing prediction accuracy



Schematic of alert device

S25-38

Title: Wildfire Risk Assessment Device

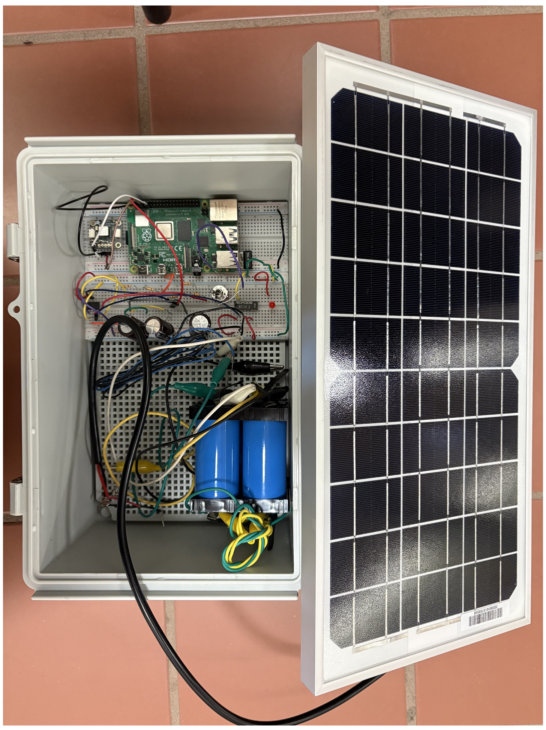
Team Members: Rumaysa Adnan, Muskan Aga, Avani Bhavsar, Nabil Lekmine

Advisor: Maria Striki

Keywords: environmental, machine learning, microcontrollers, Cloud, wildfires

Abstract:

The state of New Jersey is facing one of its longest periods of low precipitation, above-average temperatures, and drought. Our device aims to assist our own state with mitigating wildfires, integrating IoT sensors to collect environmental data, including CO_2 levels, temperature, and humidity, from any environment, namely forest and farmland. What makes our device unique is that it utilizes a machine learning model to train on data from specific areas to be able to accurately predict forest fires before they happen. During high risk conditions, it will alert the fire department so they are ready beforehand. Additionally, it will report forest fires that are in progress. The device utilizes a Raspberry Pi computer and Arduino on-board to communicate with our Google Cloud Services bucket, where it will send data collected from the sensors. The machine learning model will then poll constantly for new sensor data from the bucket, and predict "Fire" or "No Fire" per sensor sample. Our device also utilizes a complex power distribution system switching between a solar panel and rechargeable batteries to ensure that the device is almost never without power, which of course remains contingent on the state of sun exposure. Additionally, our sensors are cheap, in the case that they are destroyed by harsh wildfire conditions, so that they can efficiently and affordably be replaced. We hope that this device can effectively help mitigate damage caused by fires by utilizing newer machine learning techniques, and result in a step forward for environmental protection.



Device Hardware

Results of Various ML Models

Table 1: Synthetic Simulated Data

Model	Accuracy	F1 Score
Logistic Regression (LG)	55.5%	8.2474%
Random Forest (RF)	98.5%	98.4127%
Standard Vector Machine (SVM)	83.5%	78.9809%

Table 2: Real-Time Sensor Data

Model	Accuracy	F1 Score
Logistic Regression (LG)	84%	0%
Random Forest (RF)	84%	34%
Standard Vector Machine (SVM)	98%	87%

S25-39	**Title: Breeze Beam** **Team Members: Anmol Patel, Christian Verderosa, Rudrani Ghosh, Tomer Butbul** **Advisor(s): Yingying (Jennifer) Chen**
Keywords	Safety, Sustainability, Solar-Powered, Embedded-System, Smart-Gear
Abstract:	Breeze Beam is a solar-powered, wearable brake light system designed to enhance motorcyclist safety by improving rider visibility. Many accidents involving motorcycles are caused by inadequate visibility, particularly during night rides or inclement weather. Breeze Beam addresses this by using high-brightness LEDs mounted on wearable gear such as jackets or backpacks. These lights activate automatically when deceleration is detected, using data from an MPU6050 accelerometer and gyroscope module. An ESP32 microcontroller processes the data with adaptive filtering and dynamic thresholds to account for tilt, posture, and road vibration, ensuring accurate braking detection. The system is powered sustainably through a solar panel connected to a TP4056 charge controller and battery circuit. This setup eliminates the need for manual recharging and enables long-term use without compromising performance. All components are housed in a custom 3D-printed enclosure that ensures durability, accessibility to ports, and ease of attachment to multiple types of gear. The final prototype meets safety lumen standards and demonstrated reliable performance in real-world motorcycle and RC car testing. Compared to existing market solutions, Breeze Beam offers a lower-cost and self-sustaining alternative. Competing products either require frequent charging or do not use braking-specific triggers. Our smart gear bridges this gap by combining renewable energy, real-time sensing, and ergonomic design into a compact, affordable solution for riders.

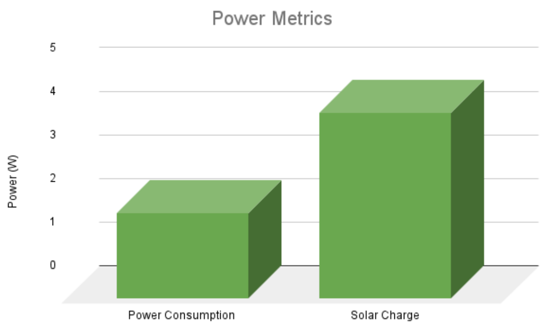


Figure 1: Power Metrics of the device components.

Figure 2: Breeze Beam testing on a Motorcycle Jacket.

S25-40

Title: Machine Learning for Musician Identification

Team Members: Harshini Ganapathi, Sabrina Jamil, Navya Malhotra

Advisor(s): Sasan Haghani

Keywords

Classical Music, Music Information Retrieval, Convolutional Recurrent Neural Networks, Audio Feature Extraction, Reinforcement Learning

Abstract:

This project investigates the application of deep learning to identify both the composer and performer of classical music recordings based on stylistic features such as phrasing, tempo, and articulation. While prior systems focus primarily on piece recognition, our model aims to distinguish subtle interpretive variations between performers, offering deeper insights into musical style.

Our system utilizes a two-stage Convolutional Recurrent Neural Network (CRNN) trained on a curated dataset of 150 labeled audio recordings. Mel-scaled spectrograms and MFCCs were extracted from each performance, allowing the model to learn both harmonic and temporal patterns. Evaluation results demonstrate high accuracy in composer classification, with a score of 0.80 across five classes—Beethoven, Chopin, Debussy, Liszt, and Mozart. Performer classification posed a larger challenge due to more nuanced differences. Misclassifications often indicated need for further data balancing. The confusion matrix reveals diagonal dominance, confirming that the model learned individual style signatures for several performers. The system includes a user interface for uploading audio, providing predictions along with descriptive feedback on phrasing and tone. These results demonstrate the promise of machine learning in analyzing performance style and enhancing research, education, and archival.

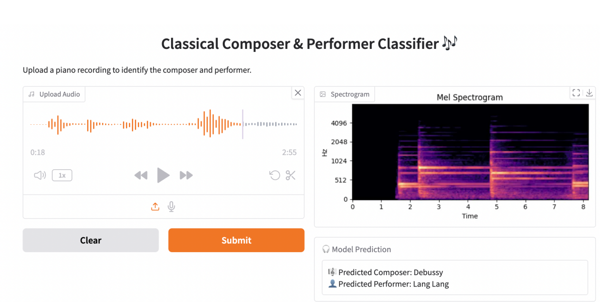


Figure 1: Functional UI with audio analysis and prediction output

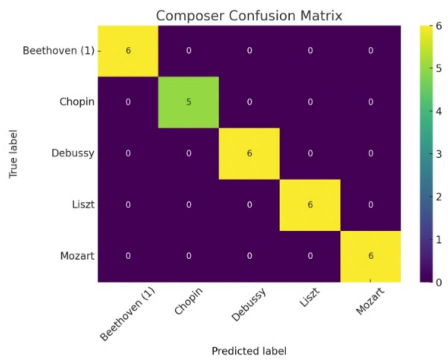


Figure 2: Confusion Matrix verifying prediction accuracy

S25-41

Title: Automated Line-Calling System for Pickleball

Team Members: Rick Patel, Gordon Toth, Alex Lee, and Vivek Shivakumar

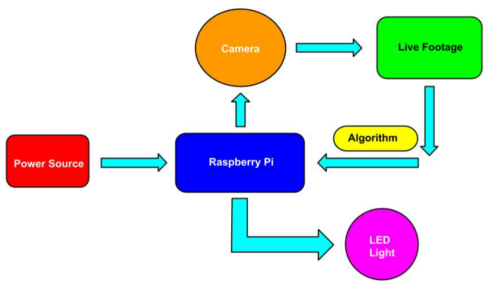
Advisor(s): Yuqian Zhang

Keywords Python, Computer Vision, Camera Sensor, Pickleball

Abstract:

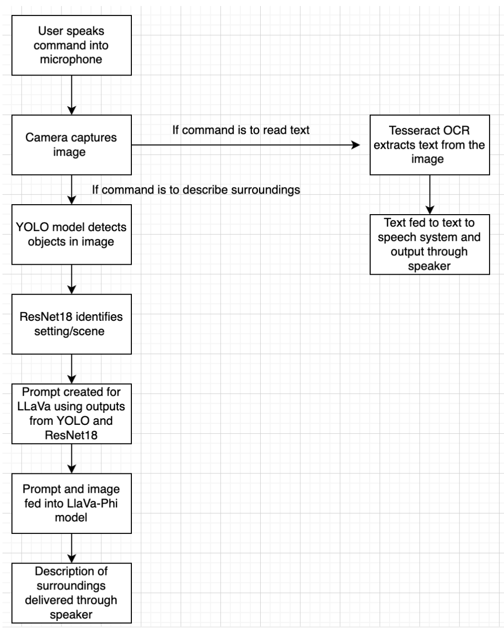
The popularity of Pickleball, a rapidly growing sport, has increased the demand for accurate and efficient line detection technologies to assist players, referees, and spectators in making quick and precise judgments during gameplay. Traditional methods rely on human judgment, which are prone to error and often leads to disputes, particularly in fast-paced matches. Advanced systems like Hawk-Eye, widely used in professional tennis, are prohibitively expensive and unsuitable for the smaller scale and unique dynamics of pickleball. To address this gap, the project 'Automated Line-Calling System for Pickleball' introduces an innovative and cost-effective solution that determines whether a ball lands within or outside of court boundaries. The proposed system employs 2 strategically placed high-speed cameras synchronized to capture real-time footage of the court. These cameras interface with a Raspberry Pi, which runs advanced image processing and computer vision algorithms to analyze ball trajectories and contact points with high precision. The system provides immediate feedback through a visual indicator, ensuring minimal disruption to gameplay. Key features include affordability, scalability, and user-friendly operation, making it accessible to recreational facilities, clubs, and amateur tournaments. By reducing human error, improving decision-making accuracy, and promoting fair play, the Pickleball Line Detector improves player satisfaction and the overall appeal of the sport. Furthermore, the integration technology with sports innovation represents a scalable framework that could be extended to other sports. This project demonstrates the potential for accessible technological advancements to revolutionize the way emerging sports are played.

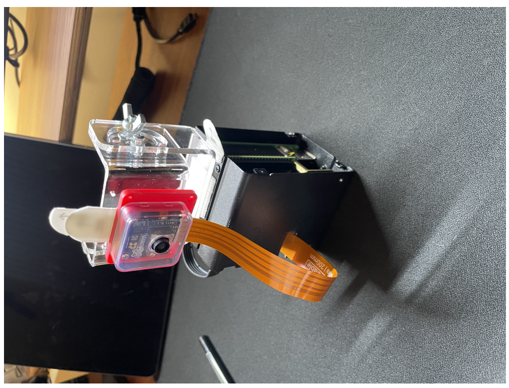
(a) Figure 1: Live Ball Detection



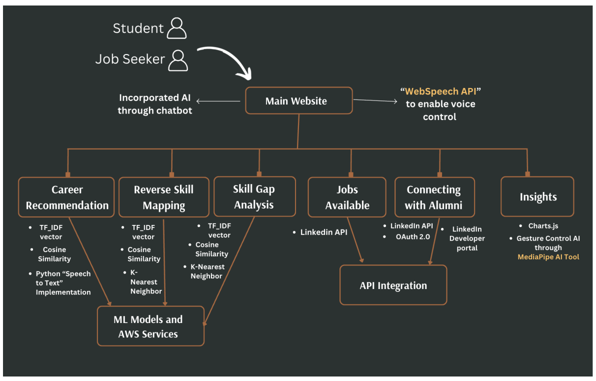
(b) Figure 2: System Flowchart

S25-42	**Title: Personal Assistant for the Visually Impaired** **Team Members: Sarmad Ahmed, Luis Castellanos** **Advisor(s): Sasan Haghani**
Keywords	Object Detection, Raspberry Pi, STT/TTS, Multimodal Neural Network, Residual Neural Network
Abstract:	Imagine navigating a busy street, an unfamiliar building, or local grocery store — all without the ability to see. For many visually impaired individuals, this is their reality. They face significant challenges such as navigating their environment, identifying objects, and interacting with their surroundings. While there exist simple solutions, such as walking dogs and canes, they lack the ability to provide detailed, real-time descriptions. This limitation is why there exists a need for an affordable and portable device that provides the user with a detailed description of their surroundings. Recent advances in machine learning and AI have enabled the development of complex computer vision and speech recognition systems. Convolutional neural networks (CNNs) are now capable of real-time object detection and scene understanding. STT and TTS systems have seen significant advancements in recent years, while Raspberry Pi makes it possible to deploy these models locally. This project aims to develop a portable AI-powered personal assistant that helps visually impaired individuals navigate and interact with their surroundings. The device will utilize STT and TTS to retrieve the user's commands and to provide audio feedback. Once a command is given, the device will perform a specific task such as identifying objects or reading text. The goal of this project is to create a cost-effective, efficient, and user-friendly personal assistant for the visually impaired.

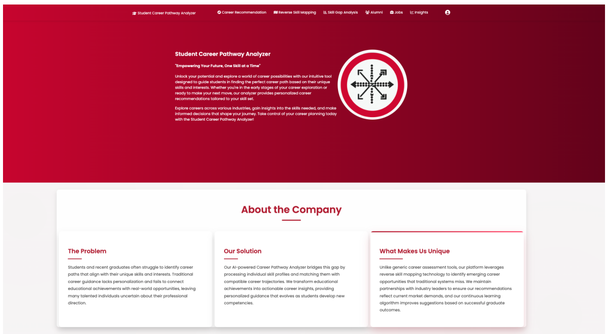




S25-43	**Title:** Student Career Pathway Analyzer **Team Members:** Neha Murthy, Nithya Bharadia, Mohnish Patel, Christina Yoo **Advisor(s):** Professor Sasan Haghani
Keywords	Career Recommendation, Skill Gap Analysis, Machine Learning, Computer Vision, AI-Powered Guidance
Abstract:	Student Career Pathway Analyzer (SCPA) is an AI-powered platform designed to provide personalized career recommendations, skill gap analysis, and reverse skill mapping. It addresses the growing disconnect between academic training and real-world industry demands, which often results in job mismatches, underemployment, and missed career opportunities. SCPA leverages machine learning models such as TF-IDF Vectorizer and Cosine Similarity to analyze job descriptions and match them with users' current skills, experiences, and interests. A built-in Resume Analyzer, powered by Natural Language Processing (NLP), extracts relevant information from user resumes to provide accurate career insights, suggestions, and skills the user has. The platform features a Reverse Skill Mapping module that uses a K-Nearest Neighbors (KNN) algorithm to identify similar job titles and their required skills. This empowers users to explore alternative career paths and recognize transferable skills. The Skill Gap Analysis tool compares users' existing skills against target job requirements, categorizing them into matched, recommended, and missing skills. This helps users prioritize high-impact skill development for improved employability. To enhance accessibility and engagement, SCPA integrates advanced AI-based interface options: 1) Voice Control, implemented using the WebSpeech API, allows users to navigate the platform through voice commands. 2) Gesture Control AI, developed with Google MediaPipe, a computer vision framework within AI, enables users to control pages using hand movements. Future enhancements aim to expand functionality across the platform. SCPA also features a LinkedIn Alumni Connection tool to help users build professional networks. By aligning education with industry demands, SCPA prepares students for the future.



(a) Project Design Flow



(b) Homepage of Student Career Pathway Analyzer Website

S25-44	**Title: Maestro** **Team Members: Gunjan Adya, Deshna Doshi, Melis Durgut, Haejin Song, Shreya Pandey** **Advisor(s): Jorge Ortiz**
Keywords	Reinforcement Learning, Internet of Things, Prompt Optimization, Large Language Model, Label Automation
Abstract:	The Internet of Things (IoT) generates vast amounts of sensor data, which often lacks descriptive metadata and contains irregularities, missing values, and noise. These challenges hinder effective data utilization, limiting potential insights that can be derived from smart environments. To address these issues, a network of Raspberry Pi-based sensor nodes, referred to as Maestros, was deployed in an office setting to collect high-resolution environmental data. The goal of this project is to enhance the reasoning capabilities of IoT systems by leveraging instruction-tuned large language models (LLMs). A novel framework is introduced, incorporating prompt optimization, data structuring, and synthetic sensor generation to enhance task reasoning and decision-making capabilities. The introduction of synthetic sensors enables richer feature extraction and contextual awareness. In conjunction with this, a dataset comprising over 20 hours of sensor data was developed, accompanied by an automated data labeling pipeline designed to facilitate efficient annotation at scale. Instruction-tuned large language models (LLMs) were integrated into the system to enable natural language interaction, allowing contextualized responses to user queries based on real-time sensor data. A mobile application interface, designed for usability, provides access to system outputs and supports user engagement. By embedding LLMs into the IoT data processing pipeline, the proposed approach bridges the gap between raw sensor data and actionable intelligence. This integration supports advanced automation and contextual reasoning within smart environments, contributing to the development of adaptive and responsive IoT systems.

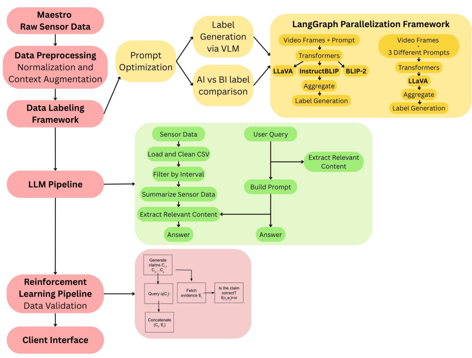
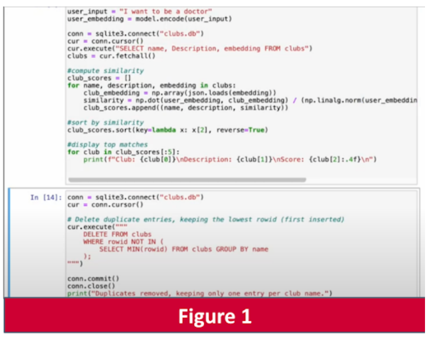
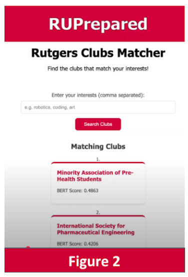


Figure 1: Maestro System Block Diagram

S25-45	**Title:** RU Prepared **Team Members: Bhavya Sahay, Gayathri Sajith, Amira Sekkouty, Eepsa Singh, Michael Walters** **Advisor(s): Dr. Hang Liu**
Keywords	Machine Learning, Natural Language Processing, Professional Development
Abstract:	Finding the right student organizations can be overwhelming, especially at large universities with hundreds of options. RU Prepared is an application designed to match students with organizations that align with their interests, skills, and experiences. Built using Python and the BERT API (figure 1), our system processes a fixed database of 1,000+ university clubs, analyzing club descriptions and student-inputted interests. It uses cosine similarity to measure the semantic closeness between student preferences and club descriptions, ensuring that recommendations go beyond simple keyword matching. This content-based filtering approach allows RU Prepared to generate relevant and personalized suggestions. The recommendation engine is seamlessly integrated with a React-based frontend (figure 2), providing an intuitive, interactive platform where students can explore their matches, filter results based on specific criteria (e.g., professional development, cultural involvement, recreational activities), and receive updates as their interests evolve. Designed for scalability and usability, RU Prepared simplifies the club discovery process, making it easier for students to engage with organizations that align with their goals. By leveraging advanced natural language processing (NLP) techniques, cosine similarity, and a modern web interface, our platform enhances student involvement, fostering deeper connections within the university community.Due to the current shortcomings in tools such as getInvolved, students are in need of a new tool to help guide their paths in college. Accordingly, RU Prepared transforms campus engagement by providing a data-driven, user-friendly solution to club selection, helping students find communities where they can thrive.

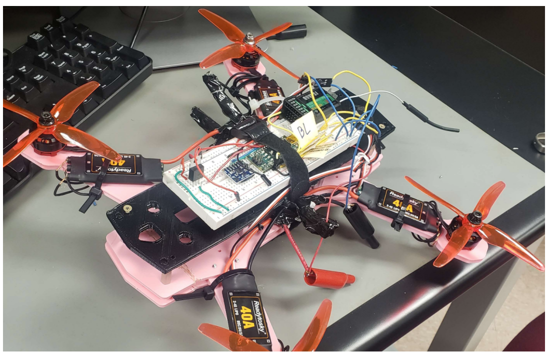


(a) Figure 1: Code Snippet



(b) Figure 2: Application UI

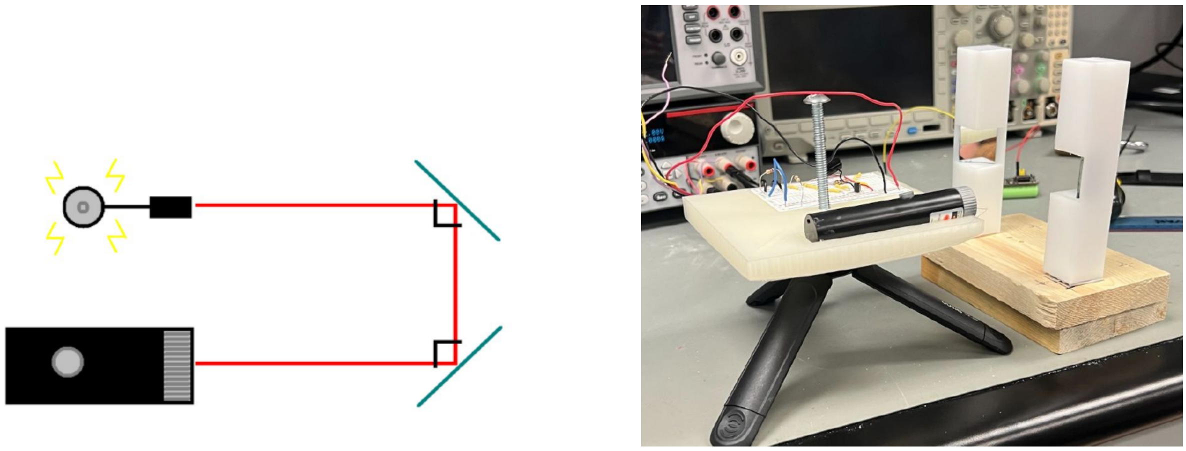
S25-46	**Title: Drone BEE** **Team Members: Evan Karolewski, Iyanna Norwood, Nihal Abdul Muneer, Sasha Gupta, Sahana Ranganathan** **Advisor(s): Dr. Sasan Haghani**
Keywords	Machine Learning, YOLO, Quadcopter, Drone Technology
Abstract:	Bees are the most prevalent pollinators on Earth, aiding in the development of food consumed by the human population. Along with other pollinators such as butterflies, bats, and hummingbirds, they are all under threat from human activities and global conditions. If bees were to go extinct, we would see drastic effects on the growth and development of food groups such as fruits, vegetables, oats, beans, and even livestock. Our objective is to utilize a drone that seamlessly integrates hardware with machine learning to aid the declining pollinator population. The drone designed is a quadcopter equipped with four motors, offering stability and maneuverability ideal for navigating diverse environments in various conditions. By leveraging deep learning models such as YOLO, flower detection can be achieved with high accuracy, offering a strong framework for future iterations of alternative technology to help out pollinators. Once a target flower is identified, a custom-designed pollen dispensing mechanism releases solution to the detected flower to replicate the natural pollination process. This approach offers a scalable, technological alternative to mitigate the decline of natural pollinators in our ecosystem.



(a) Constructed Drone

(b) YOLO model detecting sunflower

S25-47	**Laser Level: Metrology Solutions** **Team Members: Sami Siddiqi, Andrew Kemperman, Ramiro Lapola, Serazul Islam, Alfred Kuyateh** **Advisor(s): Michael Caggiano**
Keywords	Inclination Measurement, Photo-electric, Low Energy, Affordability, Laser.
Abstract:	The problem addressed in this project is to ensure the accurate measurement of inclination for various applications, such as construction, surveying, and equipment installation. Maintaining a precise angle is critical in these fields to ensure structural stability, precision, and safety. Current tools are extremely expensive and lack the ability to provide real-time measurements or adapt to changing conditions, making them impractical for dynamic environments or large-scale applications. Traditional tools like spirit levels and bubble levels are limited by human judgment, environmental factors, and the difficulty of measuring large or complex surfaces. This project seeks to develop an intuitive tool that utilizes an optical detection device to measure inclination with high accuracy and reliability while also being low-cost. By employing a low-power laser, optical reflectors, and a light-detecting resistor, our project can determine if a surface is level with high accuracy. This ensures that our tool is practical, easy to use, and affordable.



(a) Laser-mirror system in theory

(b) Laser-mirror system in practice

Figure 1: Plan and Implementation

SP25-48	**Title: RC Controlled Gesture Car** **Team Members: Kevin Jacob, Hasan Bhuiyan, Christopher Seo, Aidan Malixi** **Advisor: Bo Yuan**
Keywords	Gesture-Controlled Technology, RC Car, Accessibility, Motion Sensors, Assistive Technology
Abstract:	This capstone project aims to develop a gesture-controlled RC car operated via a gyroscope-equipped wristband. This system aims to provide an accessible solution for individuals with limited hand or finger mobility, enabling them to control the vehicle using wrist motions instead of traditional remote controls. The design incorporates a smartwatch equipped with an Inertial Measurement Unit (IMU), which captures wrist gestures and transmits them wirelessly to a Raspberry Pi microcontroller on the RC car. The Raspberry Pi processes these signals to control real-time motor output, direction, and speed. The project centers on creating a seamless and intuitive user experience by eliminating the need for conventional remote controllers. Our team is focused on building a lightweight, reliable prototype that prioritizes ease of use and fast response, emphasizing gesture recognition accuracy. Each gesture from the wristband directly corresponds to specific movement commands on the RC car, allowing users to navigate the vehicle naturally and responsively. Our prototype uses a Witmotion IMU sensor replicating most industry-standard smartwatches' gyroscope capability. This system is designed with accessibility in mind, targeting users who may not be able to interact with standard hardware interfaces. The modular nature of the design also allows for future expansion, such as different gesture mappings or integration with other wearable devices. The project provides a strong foundation for future assistive technologies. Ultimately, this project demonstrates how accessible hardware-software integration can make meaningful changes in how people with disabilities interact with technology.

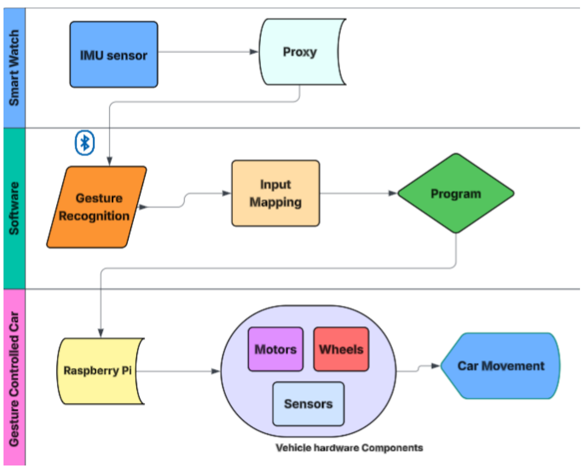


Figure 1: Run-Time System Implementation

S25-49

Title: FPGA Evolution of Radar Vital Sign Monitoring

Team Members: Brayden Casaren, Edwin Gonzalez, Joshua Loor, Raymond Lee

Advisor(s): Athina Petropulu, Minning Zhu

Keywords FPGA, PCB, Phased Array

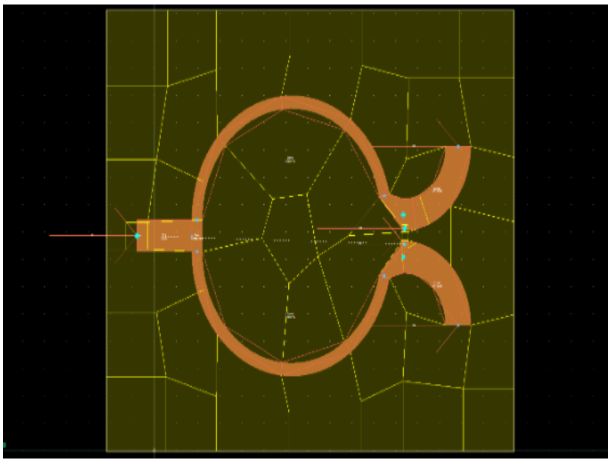
Abstract:

Traditional vital sign monitors rely on wired sensors that can be costly, painful (e.g., for burn victims), prone to placement errors, and unsuitable for continuous monitoring. Our project presents a low-cost, contactless radar system that uses a Double Phase Shifter (DPS) phased array to steer focused beams and measure heart and breathing rates remotely.

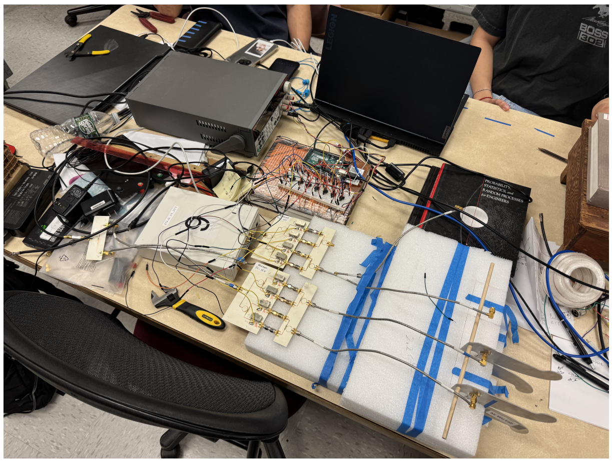
The initial prototype used a breadboard and separate PCBs. We transitioned to a custom PCB integrating phase shifters and antennas to reduce signal loss, improve performance, and minimize the system's footprint. Beam steering is automated with an Arduino Mega for analog PWM output and an FPGA for faster, scalable control. Amplifiers adjust the control voltages for the phase shifters.

Key challenges included fitting components into a compact PCB layout while maintaining signal integrity at 2.2 GHz, which limited trace design and spacing. The high cost of phase shifters and multilayer PCBs also restricted prototyping, requiring efficient and accurate design from the outset.

By combining contactless monitoring and automated beam control, our system offers a scalable, non-invasive alternative to traditional methods. While FMCW radar was not implemented, it remains a future goal to enable automatic target detection and tracking without preset beam angles.

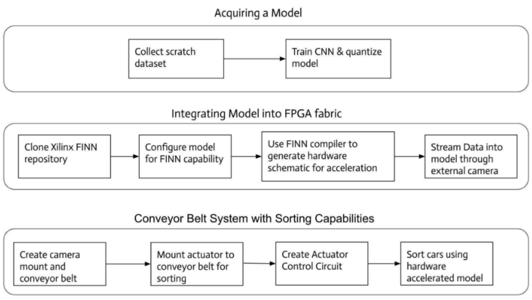


(a) Power divider design for PCB.

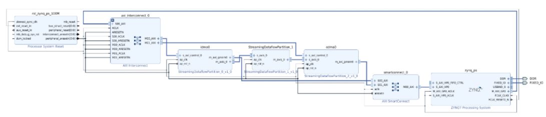


(b) Built out system for testing.

S25-50	**Title: FPGA based ML accelerator for Quality Assurance** **Team Members: Sameer Bhatti, Aseef Durrani, Christopher Caponegro, Nahum Arnet, Parth Karekar** **Advisor(s): Bo Yuan**
Keywords	FPGA, Hardware Acceleration, Low Latency, Bottlenecks, Computational Intensity
Abstract:	Machine Learning (ML) has gained traction in the present and will continue to gain traction in the coming years due to its inherent versatility and inferencing capabilities. However, bottlenecks exist among all emerging technologies. ML models, not discluded, are often synonymous with extreme computational intensity in metrics such as power, area, and cost. Various hardware architectures support ML models, but each has drawbacks. GPUs are fast but power-hungry and expensive. CPUs are cheaper but slower. ASICs are fast but inflexible and costly. FPGAs offer a balanced solution—they are reprogrammable, low-power, cost-efficient, and flexible. Our architecture leverages FPGAs to create custom hardware accelerators for ML models, helping small businesses efficiently detect defects in products and improve production pipelines.



(a) System Workflow



(b) FPGA Accelerator Architecture

S25-51

Title: Sun Tracker-Mobile Charging Station

Team Members: Quinn Gimblette, Yash Mathur, Minh Truong

Advisors: Kevin Wine, Sasan Haghani

Keywords

Solar Energy, Renewable Power, Public Access Charging, Arduino Microcontroller, Sun Tracking

Abstract:

As technology advances, people find themselves dependent on an array of mobile electronic devices for work and social purposes. However, with lives constantly on the go, mobile devices struggle to power through. It is rare for smartphones, tablets, or other common devices to make it through a day of constant use without needing to be recharged. Our solar charging station offers an eco-friendly way to power your devices by harnessing the sun's energy to keep you connected, on the go, anytime, anywhere. Using a photosensitivity sensor and an astronomical algorithm, our system improves solar absorption efficiency by 30% compared to static panels. It offers consistent mobile device charging through smart switching between solar and battery power sources, enhanced by a user-friendly interface. Designed with outdoor places in mind, such as parks, bus stops, train stations, campuses and train stations. Its rugged housing also has public environments in mind to protect the system from water, dust and possible vandalism. This eco-friendly solution promotes renewable energy use, reduces dependence on conventional electricity, and enhances outdoor experiences. The modular design allows for quick and easy maintenance as well as the potential for future upgrades. Future improvements include mobile app connectivity, charge status displays, and scalable designs for larger installations at an estimated mass production cost of $120 per unit.

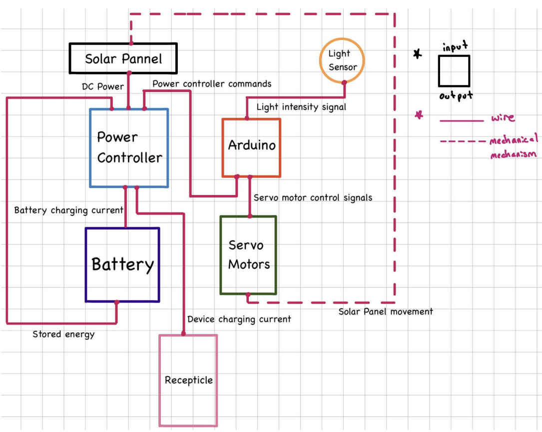


Fig. 1: System Block Diagram

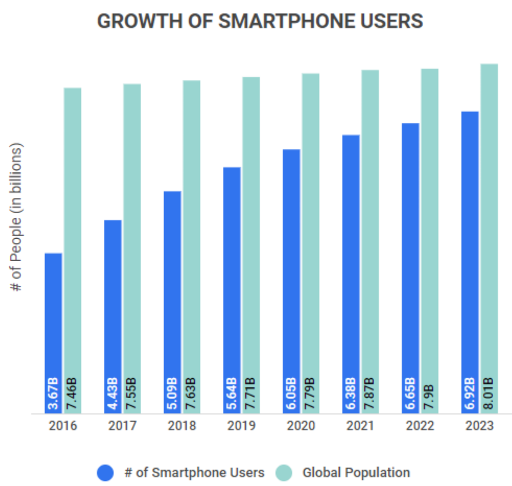


Fig. 2: Smartphone User Growth

S25-52	**Title: DEVCOM Wargame** **Team Members: Daniel Guan, Ethan Sie, Vincent Nguyen** **Advisor(s): Professor Shirin Jalali (ECE), Mathematician Grant Gallagher (DEVCOM)**
Keywords	Terrain Classification, Wargame Digitization, Image Segmentation
Abstract:	This capstone project converts physically scanned hexagonal wargame maps into an interactive digital platform with accurate tile identification and hover-based terrain information. The goal is to modernize a strategy wargame used by the U.S. Army DEVCOM into a functional video game. The project consists of three stages: digitizing the physical map, classifying hex tiles, and integrating everything into an open-source game engine. Digitization begins by detecting the center of each hexagon using contour analysis and circle fitting. Each tile is then cropped with a hexagonal mask that maintains transparent edges and accounts for staggered rows and edge tiles. A coordinate system (e.g., A1–Q11) is used to label each tile's position. Next, tiles are analyzed using their color composition and a comparison to chosen reference hexagons. The top five colors, in RGB, and their percentages are extracted from each tile and recorded. Each tile is compressed into a color vector and given a classification label based on the comparison using Euclidean distance to the selected reference hexagons. Finally, all data is stored in a structured JSON file used by the game engine to render the digital map. This creates an efficient pipeline for turning physical wargame maps into interactive, terrain-aware digital simulations. The program as a whole is able to create a digital replica of physical maps, allowing current maps and future maps to be adopted as a video game map for enhanced simulation experience.

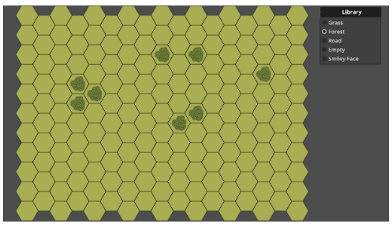


Figure 1: Digitized game map

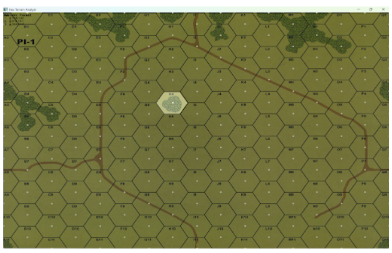


Figure 2: Original scanned map

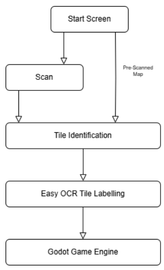


Figure 3: System flowchart

S25-53

Title: Unmanned Wireless Penetration Testing Device

Team Members: Ayaan Qayyum, Omar Hamoudeh, Harris Ransom, Gaetano Smith, Patrick Zong

Advisor(s): Professor Predrag Spasojevic

Keywords Autonomous Cybersecurity Systems, Portable Offensive Security Tools, LoRa Communication, Penetration Testing, Autonomous Systems

Abstract:

We have designed a self-contained system that can remotely hack into wireless networks. This Capstone project presents a proof-of-concept unmanned wireless penetration testing system for remote red-team cybersecurity audits. We developed a compact and modular embedded system capable of performing Wi-Fi and Bluetooth penetration tests while receiving commands from over a mile away.

The current prototype consists of a Raspberry Pi Zero 2W with Kali Linux mounted on a ground-based rover, featuring LoRa transceivers for long-range wireless communication, a motor controller, an onboard camera, and multiple power sources for system autonomy. A key aspect of this project was maintaining strict adherence to SWaP-C (Size, Weight, Power, and Cost) constraints to ensure portability and scalability. The resulting system supports real-time remote control and executes over ten key penetration testing scripts. Some features include the ability to crack an insecure network's Wi-Fi password or hijack available devices' Bluetooth connections.

With the design of a custom Unix-like scripting language, it is fully operable over the secure and long-range LoRa radio protocol. This prototype aims to lay the foundation for future drone-based open-source wireless auditing tools that can be deployed discreetly and efficiently. Ultimately, this work contributes to the limited unmanned wireless security testing research. We build a scalable open-source framework that enables organizations to enhance their cybersecurity posture through safer and more flexible red-team operations.

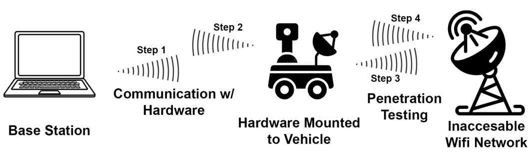


Figure 1: Remote Penetration Testing System Overview

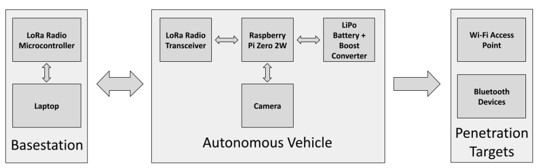


Figure 2: Remote Penetration Testing Block Diagram