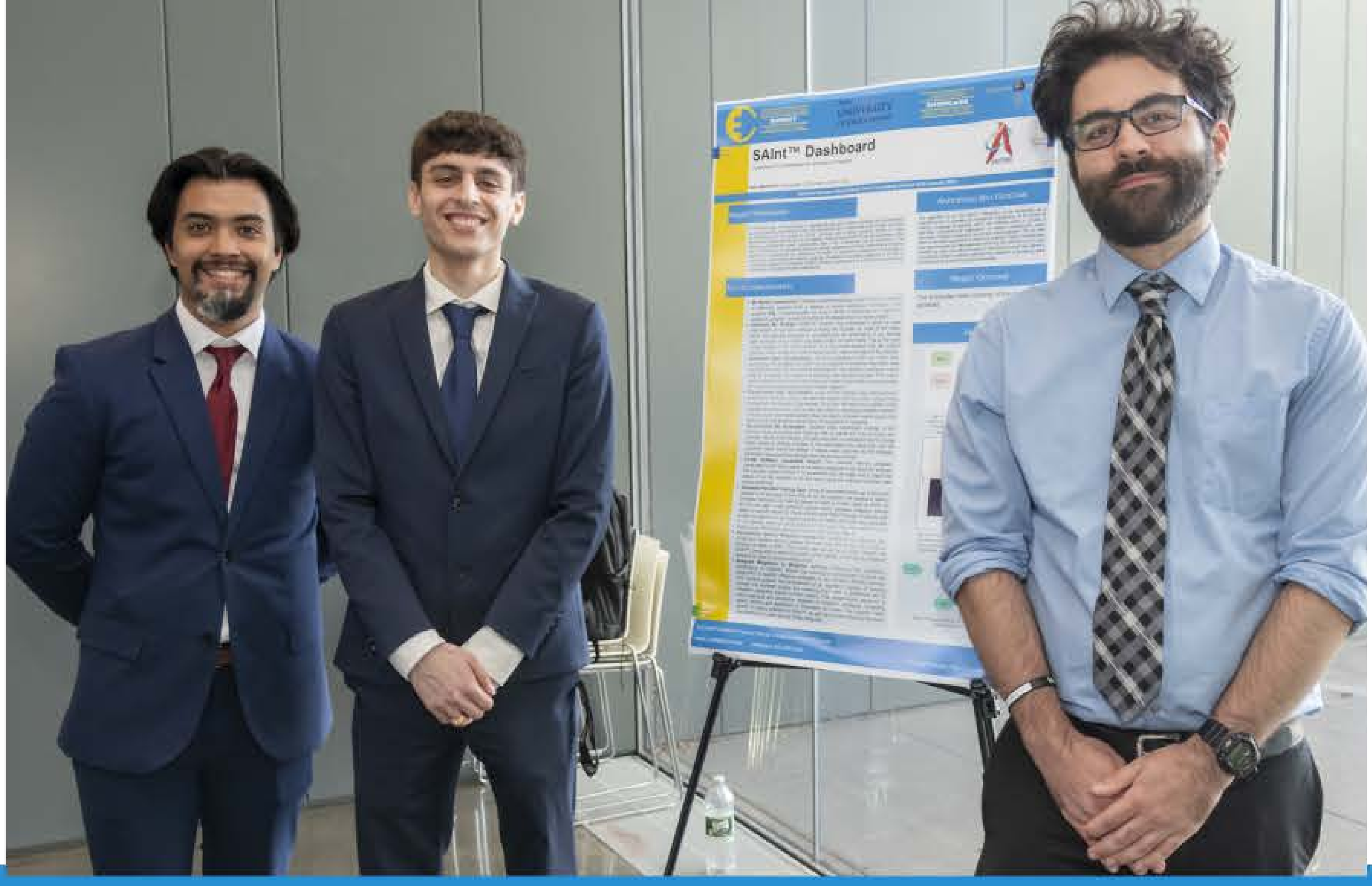

ELECOMP CAPSTONE
SUMMIT
TUESDAY, MAY 7, 2024

THE UNIVERSITY OF RHODE ISLAND

ENGINEERING
SHOWCASE
FRIDAY, APRIL 19th, 2024

THINK BIG WE DO™

SAInt™ Dashboard

Cybersecurity Database for Articles of Interest

Team Members: Kyle Nadeau (CPE), Mario Corado (CPE)

Technical Directors: Daniel DiMase (URI'89), Bronn Pav, Isabella Johnson (URI-ELECOMP '23), Jamie Gagnon (URI-ELECOMP '22)

Project Motivation

In the digital age, the significance of cybersecurity has gone beyond industries and governments, touching academia and everyday lives. The exponential rise in sophisticated cyber threats, motivated by geopolitics and the desire to disrupt, coincides with a digital revolution marked by rapid technological advancements and an increasingly interconnected world. These advancements, while offering unprecedented growth opportunities, also unveil vulnerabilities ripe for exploitation. The SAInt™ Dashboard, a collaborative endeavor between academia and industry, epitomizes a proactive approach to cybersecurity. By harnessing the wealth of open-source intelligence and leveraging cutting-edge technologies like Natural Language Processing, this project endeavors to provide a consolidated platform for actionable insights, equipping stakeholders to anticipate and combat the multifaceted challenges of modern cybersecurity.

Key Accomplishments

- **ML Model Construction:** Created a machine learning program which is capable of effectively learning from a dataset of purely text-based information. This program (**Fig. 1**) demonstrates the team's ability to effectively put together a usable ML program, as well as acting as the baseline for our entire project.
- **Optimized ML Program:** Initial ML program was enhanced to allow for more intervention on our end, instead of letting ML libraries do most of the heavy lifting. This allowed the team to pre-determine the dimensions of our training data, structure of our model, and exact output of metric data. This is the most critical update to the entire project, as if we moved forward with the original program, there would be no way of telling how to resolve an issue in ML training.
- **Generated Data Visualizations:** To truly understand how our mode was performing, we updated the output of our program to produce meaningful data visualizations showing the models performance. We utilized a confusion matrix (**Fig. 2**) to display this output in a simplistic and effective manner. This matrix easily displayed to us how many times our model could make a correct guess, and when there was a false positive or false negative.
- **Trained Mode With Test Dataset:** Once our ML program was optimized and produced a visualized output, the next step was to train the model multiple times to document the results of the training. To do this, the team put together a test dataset we could use for now to train the model in identifying mitigation articles. The ML model was trained several times, and each confusion matrix output from each tracing was saved to notice future improvements or setbacks.
- **Reconfigured ML Parameters:** Updated basic parameters involved in ML training, such as epochs and learning rate, to adjust the final accuracy and precision results of our training. The team was able to understand how to change these values by making changes to the parameters and observing how the confusion matrix would be altered. If results were improved by the changes, parameter values would be changed from the previous values.
- **Format Software Compatible Output:** The machine learning program constructed by the team needs to be easily integrable to the previous software that has been made for SAInt™. To accomplish this, we made sure to match the output of our ML program to be the same input the previous software was already expecting.
- **Generated Valuable Training Data:** While all accomplishments up to this point resulted in an accuracy of over 90% for our ML program, we needed to make a complete overhaul to our training dataset to reach a number closer to 100%. To do this, we used a web scraping program which gathered mitigation articles based on specific keywords. These articles were filtered through to identify only articles we deemed to be mitigation articles. All these valid links were uploaded to our dataset, where an equal amount of "not valid" links were added so the model could differentiate between the two during training (**Fig. 3**).
- **Successfully Identify Mitigation Articles:** By combining the optimized ML model and updated training dataset, the team was able to train the model to surpass its peak of 92%. This model now serves as a viable program for SAInt™, being able to determine exactly which articles to include as mitigation articles from a list of random articles online.
- **Assigned Mitigations to Mitigation Articles:** Following the successful identification of mitigation articles, the subsequent achievement involved the assignment of specific mitigation strategies to the correctly identified articles. This process entailed the development of an algorithm capable of parsing through the identified articles and matching them with a predefined set of mitigation categories based on their content. This categorization allows for a more organized and accessible database of mitigation strategies, facilitating easier retrieval and application of information for users This program relies heavily on legacy software for SAInt™, as well as the ever-evolving taxonomy tree detailing our cyber security threat categories.

Anticipated Best Outcome

Our aspiration is for the SAInt™ Dashboard to be recognized as a pioneering tool in cybersecurity intelligence. Capitalizing on the power of Natural Language Processing (NLP), the software aims to provide a real-time, comprehensive aggregation of relevant cybersecurity news, actionable mitigation measures, and current event analyses. This will offer users a seamless experience in discerning potential threats, vulnerabilities, and recommended countermeasures. Achieving this outcome will not only validate the meticulous efforts invested in this project but will also signify a monumental stride in proactive cybersecurity measures, empowering users in the face of an ever-evolving digital landscape.

Project Outcome

The anticipated best outcome of the project was achieved.

Figures

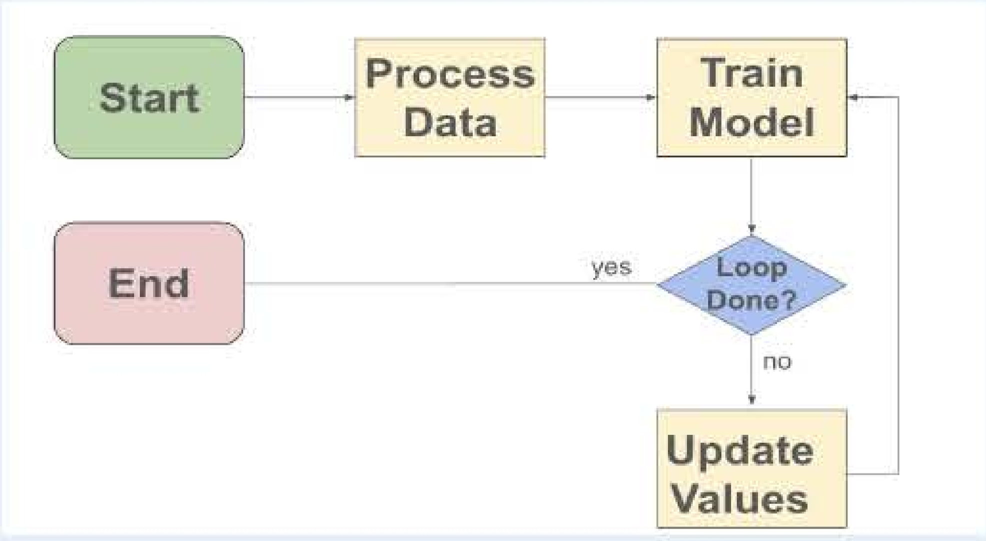

Fig. 1: This flowchart illustrates the iterative cycle of enhancing a machine learning model to accurately identify and categorize mitigation articles, through repeated processing, training, and parameter updates.

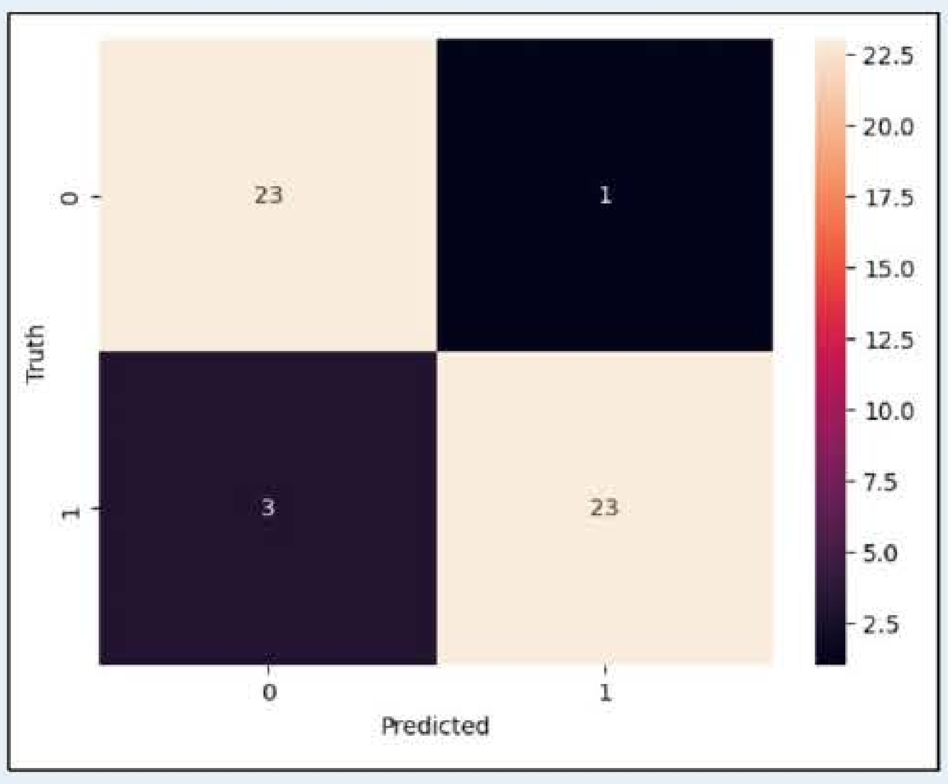

Fig. 2: Confusion matrix that highlights the accuracy of the first version of our machine learning model. The top left and bottom right boxes detail true negatives and true positives respectively, while the top right and bottom left detail false negatives and false positives.

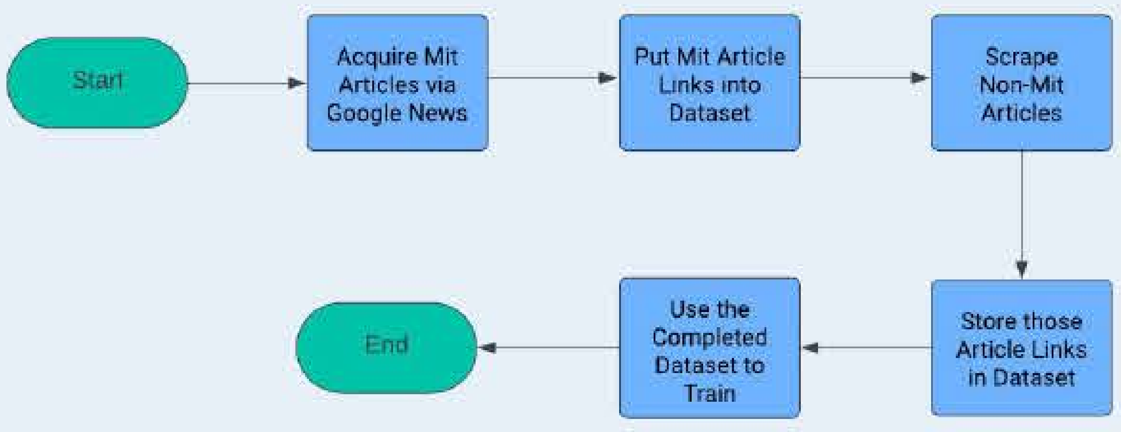

Fig. 3: Process in which we find links and articles to train our model. Generates fine tuning dataset.

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Joule Tome Battery Blaster

High Powered Dynamic Loading System For Next Generation Battery Development

EAGLEPICHER TECHNOLOGIES

Team Members: Alex Amado (ELE), Matthew St. Jean (ELE), Steven Kowalewski (ELE), Ryan Fish (CPE), Matthew Tabatneck (CPE/ELE)

Technical Director(s): Dan Wertz | Frank Puglia (URI'97) | Shawn Thurber (URI-ELECOMP '22)

Project Motivation

EaglePicher Technologies specializes in battery storage systems that are operated in the most extreme conditions on and even off the planet. From deep space to the deep sea, these batteries are required to deliver high amounts of power without fail. With custom battery chemistries and capacities, emerges the need to have custom test equipment capable of validating their performance. The formation of the Joule Tome Battery Blaster team from U.R.I.'s ELECOMP capstone Is tasked with developing a dynamic load control capable of dissipating power at a rate of 125 kilowatts per millisecond when the system is switched on.

Key Accomplishments

- **GUI:** Developed a front-end GUI, employing the Model-View-ViewModel (MVVM) architecture for efficient class setup, navigation, and input/output operations. This interface facilitates communication with the microcontroller, enabling the display of data in a user-friendly format. Adherence to Eaglepicher's standardized code conventions was maintained to ensure code readability and adaptability. In-depth research led to the adoption of a WPF application framework in C# within Visual Studio, chosen for its comprehensive libraries that support both the graphical interface and backend communication with the microcontroller.
- **Microcontroller:** Developed software to facilitate data transmission between the GUI and the system, enabling dynamic load adjustment according to user requirements. Utilized the STM32-H723ZG microcontroller integrated within the Nucleo-H723ZG development kit. Achieved data communication with a terminal application on the user's computer to interface directly with the GUI. Additionally, developed code to manipulate individual load branches and concurrently measure the total system load in the test design.
- **Load Dissipation:** Designed a load bank system with an integrated aggregate heat sink for efficient heat dissipation across eight channels, parametrically scaled to manage specific wattage levels. Engineered the resistive load system shown in to operate reliably at minimum and maximum battery voltage levels, incorporating a MOSFET for shared dissipation control. Developed a robust power transmission system capable of 400 amps continuous usage, featuring time-delay fuses and an emergency stop switch to ensure both active and passive safety.
- **Control Circuit:** Selected high-powered MOSFETs for load sharing in the battery discharge system within the control circuit. Incorporated an op-amp in a closed-loop negative feedback configuration to dynamically regulate current, ensuring stability throughout the battery discharge process, with rapid response time allowing for microsecond-level voltage transitions. Designed PCBs using Altium for the control circuit, that will integrate with the microcontroller functionality for channel selection.
- **Current Sensor & Eagle Li Platform:** Implemented a Hall-effect sensor, the LEM LA 205-S, rated for 200A to exceed well beyond the 70A minimum requirement, suitable for future scalability to higher currents. Validated small scale sensor functionality using an Arduino, with developed and tested code. The sensor, supporting various current ratings, was configured and tested on a protoboard. Also managed the integration of the Eagle Li platform for monitoring charge and discharge cycles of Eaglepicher batteries using the custom-designed AMBATS PCB.

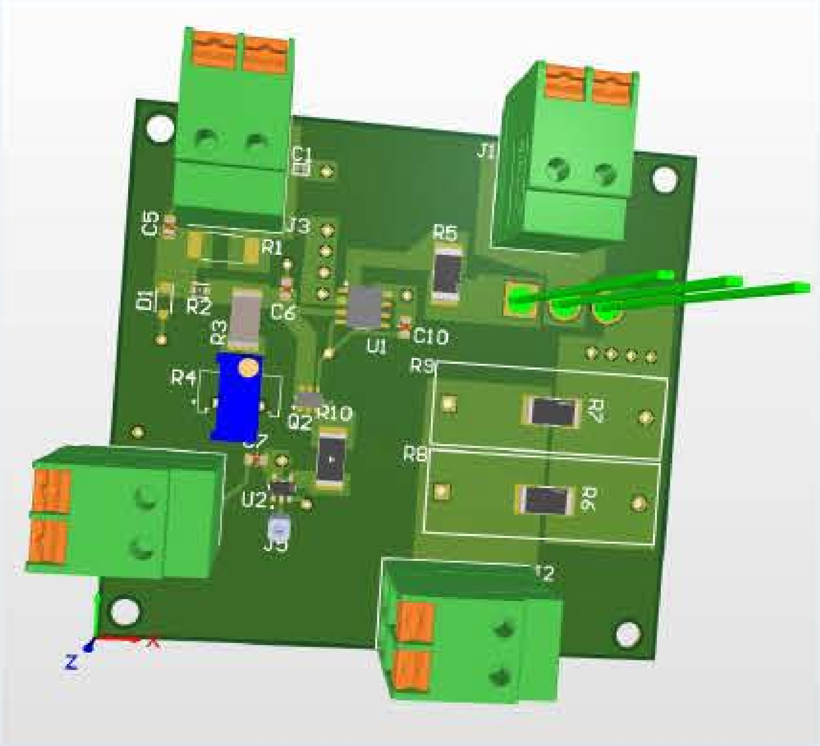
Anticipated Best Outcome

The best outcome is to have a dynamic load system that is not only capable of dissipating a large amount of energy but is also scalable in design. This will allow the flexibility to validate custom battery chemistries at higher or lower levels of power by providing a means for high fidelity data acquisition. The circuit response times are measured in volts per microsecond. It takes an average person 100 to 150 millisecond just to blink. The rate of change that is occurring in this dynamic load system is 1000 times faster than the blink of an eye.

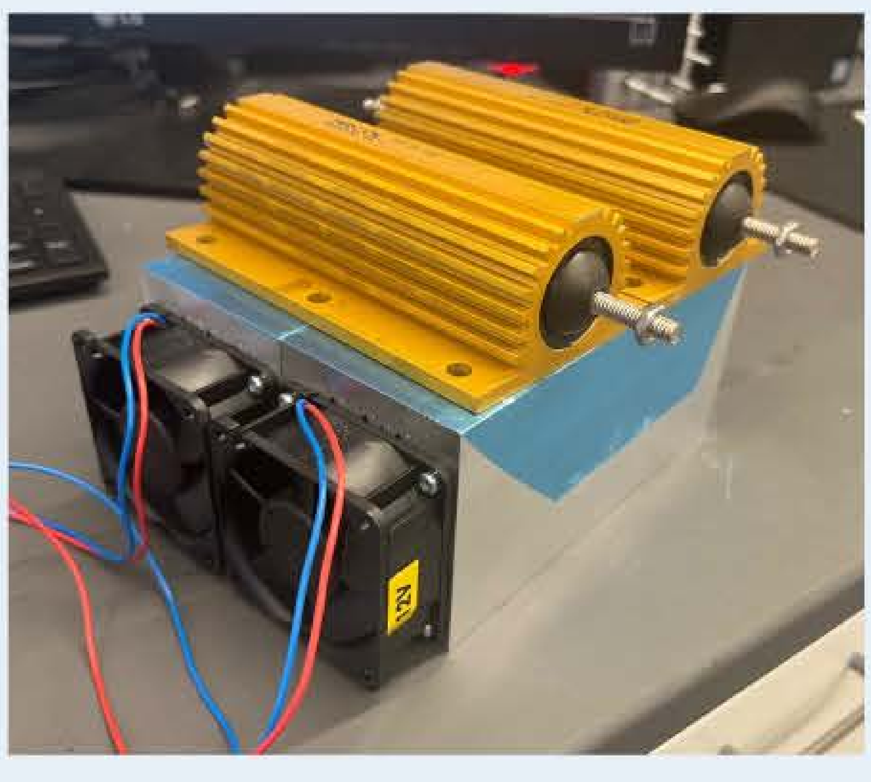
Project Outcome

The ABO is not currently achieved, though we plan to model a scaled down version.

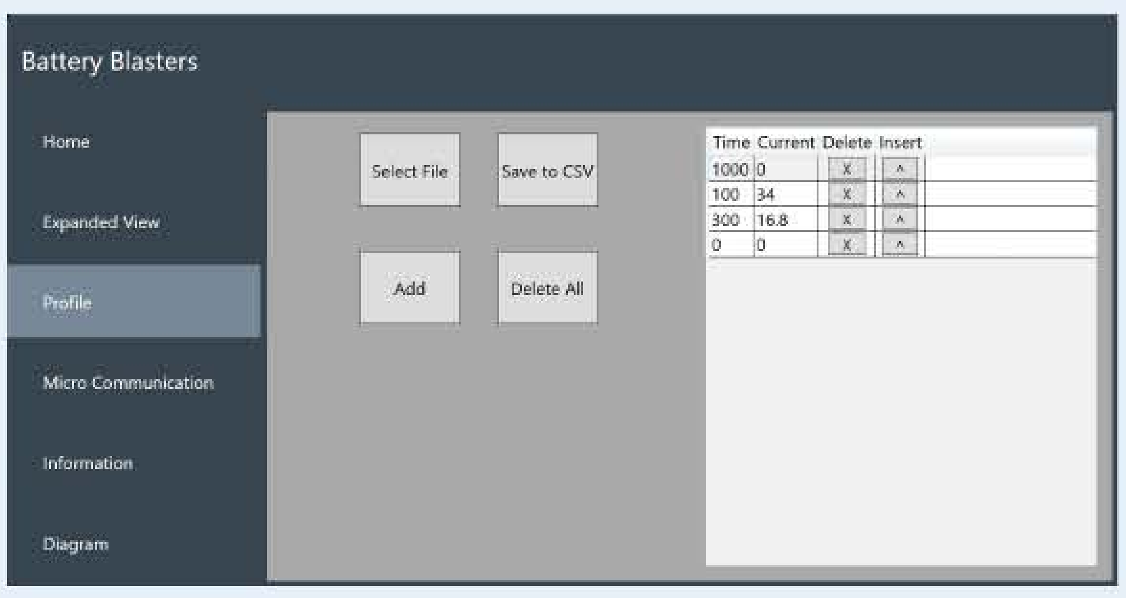
Figures



Hammer Board



Single Load Bank Channel Parts



Profile Manipulation in Graphical User Interface

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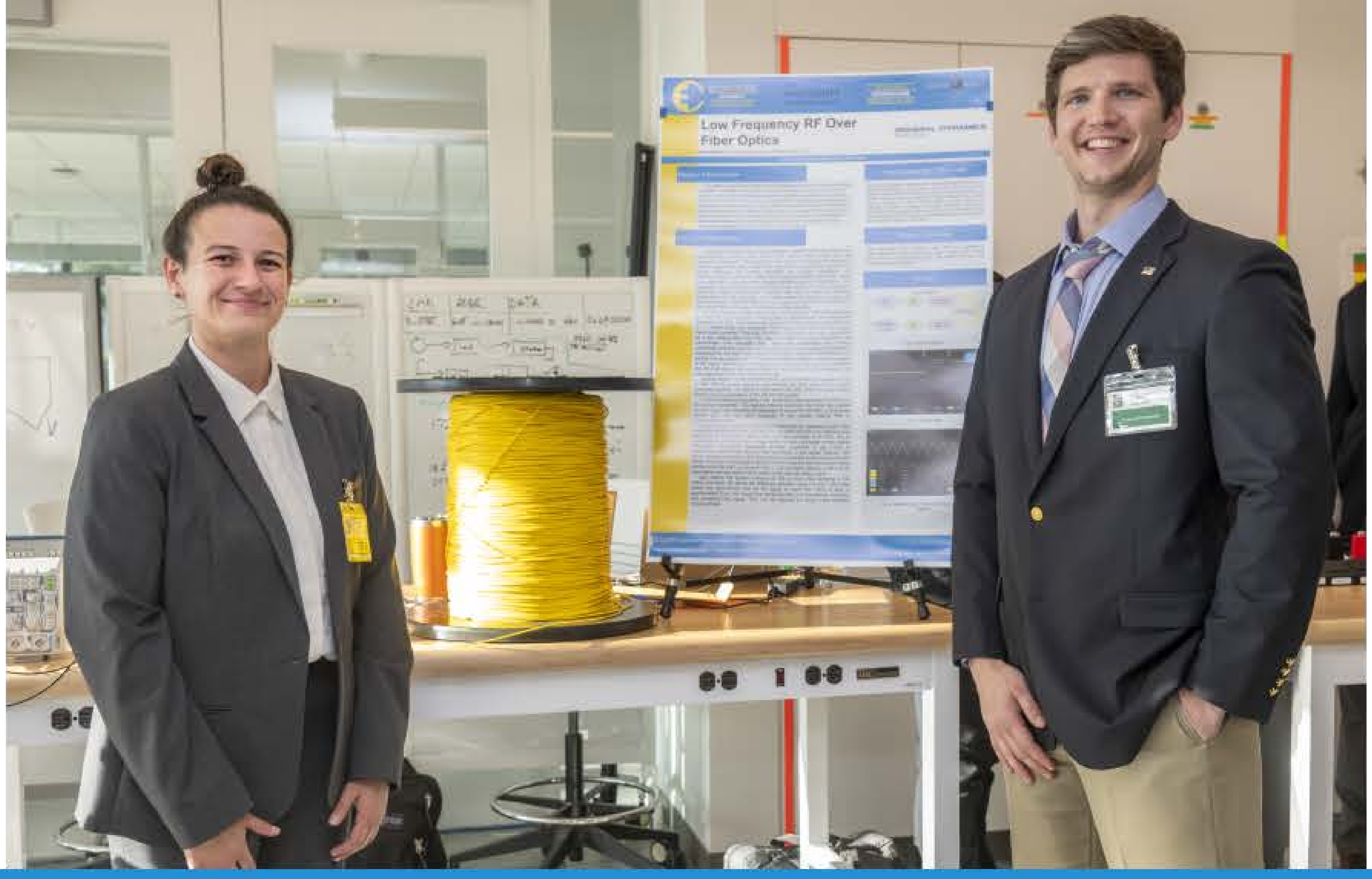

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Low Frequency RF Over Fiber Optics

GENERAL DYNAMICS Electric Boat

Team Members: Amanda Iadevaia (ELE), Zackery Hansen (ELE)

Technical Director(s): Mike Brawner, Mike Smith (URI'01)

Project Motivation

The ability to transmit low frequency radio frequencies over fiber will help reduce latency on vessels. The ability to transmit high frequency over fiber has been around for over a decade but the need for low frequency has been overlooked. Increasing the use of Fiber Optics improves system performance, increases platform compatibility and enables longer cable paths and platform flexibility. A major reason for the push to use fiber optic cabling is due to the electromagnetic interference (EMI) impact on coax cables. Fiber cables do not have to be carefully routed or shielded for EMI concerns. Thuse removing the impact of other nearby signals and the work of researching proper EMI requirements. This also removes the troubleshooting sources of EMI and failed shielding.

Key Accomplishments

In the initial stages of the project, extensive research was conducted on the fundamentals of fiber optics, delving into various fiber modes and their respective properties. This exploration was crucial in arriving at the decision to opt for single-mode fiber, owing to its capability to transmit light signals over longer distances with minimal dispersion. An in-depth investigation into Analog-to-Digital Converters (ADC) and Digital-to-Analog Converters (DAC) was undertaken, exploring their diverse applications and configurations. After evaluation, the MCP4822 and MCP3201 were chosen for their suitability to meet the project's requirements. Research was done to select the hardware components for the prototype, and helped make the decision to utilize two Arduino Megas, along with essential peripherals including the ADC (MCP3201), DAC (MCP4822), and a pair of optical transmitter/receivers.

For the simulation, MatLab was chosen as the platform. The code generated a 1 Volt, 50 kHz sine wave signal initially to demonstrate the transmission capability over fiber. The sample rate was set at 5 MHz, while an 8-bit ADC with a 1.1 voltage range was employed. The output of the ADC and the original signal were compared. Post-ADC conversion, the signal, previously represented by 8 bits ranging from 0 to 256, was converted into binary, preparing it for transmission over simulated fiber. Basic fiber parameters like 1550nm wavelength and a bit rate of 100 kHz were utilized for simulating transmission. Subsequently, the signal was directed to the DAC, also with 8-bit resolution, to restore it to its original form. To introduce realistic conditions, noise was added to the signal, accounting for imperfections. This step was crucial in validating that the 8-bit sample rate was sufficient to capture even minute changes in the input signal within the simulation framework.

A block diagram of the complete system and simulation can be seen in Fig. 1. The 100 Hz source signal is sent through the ADC and into the optical transmitter/receiver. The signal is then sent to the DAC where the output signal should come out equivalent to the 100 Hz input signal.

Coding consisted of two parts. First, the Arduino that controlled the ADC and the optical transmitter. The second Arduino controlled the DAC and optical receiver. Each was programmed separately to ensure functionality of both ends. Second part, the two were combined to one system utilizing fiber to communicate across.

Designing the prototype started with researching the necessary parts. After selecting the MCP4822 and MCP3201 for the DAC and ADC, the decision was made to use the Arduino Mega. The prototype, consists of an ADC that is connected to the first Arduino Mega which is then connected to the optical transmitter. The optical transmitter is then connected to the 1.5km of single-mode optical fiber which is next connected to the optical receiver. The optical receiver connects to the DAC which is connected to the second Arduino Mega. The initial input signal is sent to the ADC and the identical output signal comes out of the DAC as shown in Fig. 3. The top signal (yellow) is the 100 Hz input signal and the bottom signal (blue) is the identical output signal.

Upon testing the system a latency of 736 µs from initial sampling to the output recreation. By taking the difference between using 3m and 1.5km fiber spools the approximate time for the signal to travel the 1.5km of fiber is approximately 8 µs. This leaves the remaining 728 µs to processing, sampling, and recreating the signal. This can be reduced by using more powerful microcontroller.

Anticipated Best Outcome

As per the company's guidance the anticipated best outcome is a functioning prototype. The system should be able to prove the ability of transmitting low frequency signals across fiber optics. The system must be able to recreate an identical signal that traveled over a minimum of 1.5km of fiber cabling. Proper sampling is required to ensure a signal is properly replicated. Along with transmitting and receiving with very low bit loss and less latency than coaxial cable.The prototype should include new and emerging technologies to assist in this project.

Project Outcome

The anticipated best outcome was met by successfully transmitting low frequency RF over 1.5km of fiber optic cabling with no bit loss and less latency than coax cables. The input and output signals are identical.

Figures

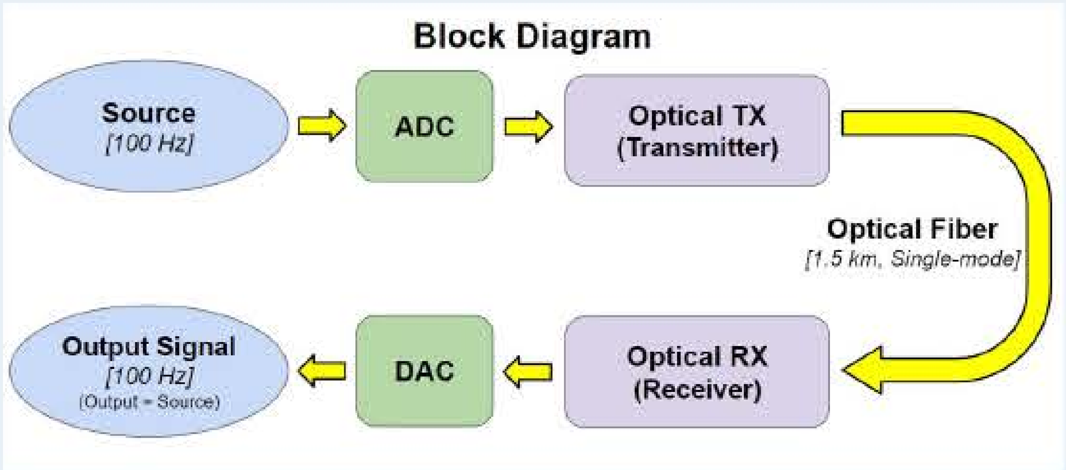

Fig. 1: Block Diagram

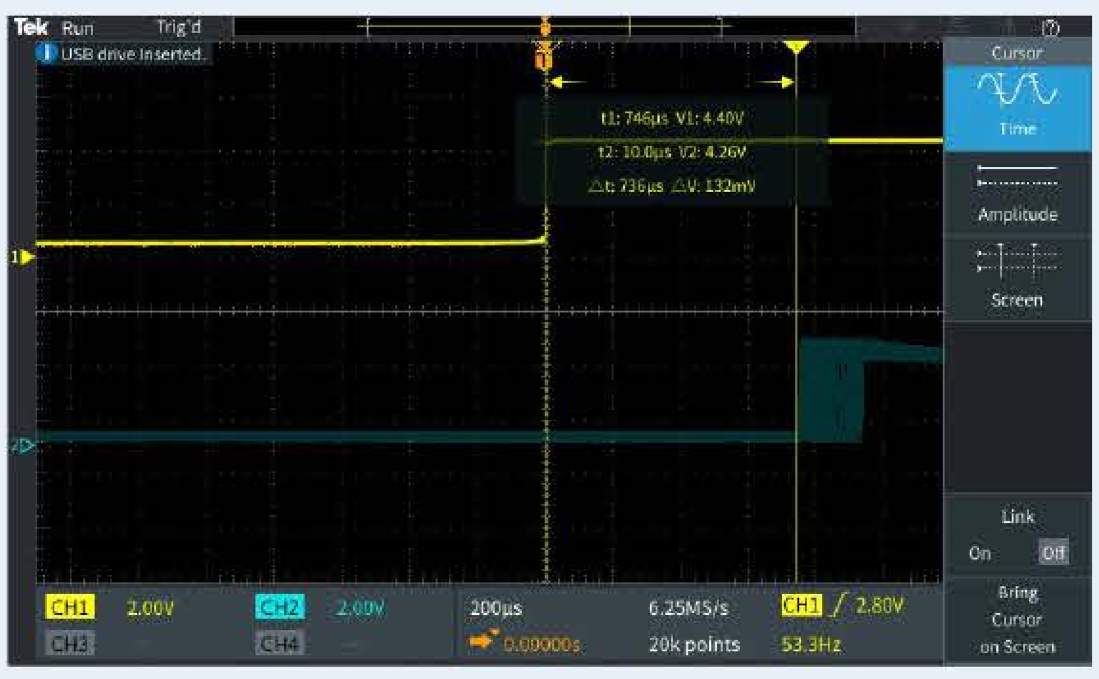

Fig. 2: Latency Test

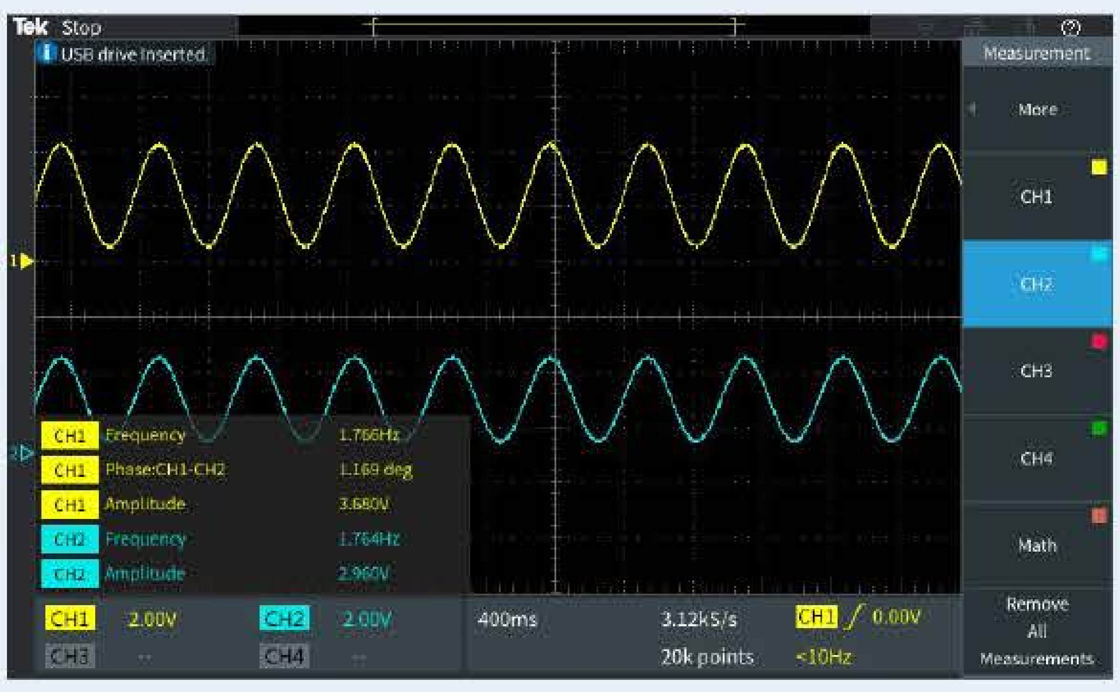

Fig. 3: Identical Input (Yellow) and Output (Blue) Signals

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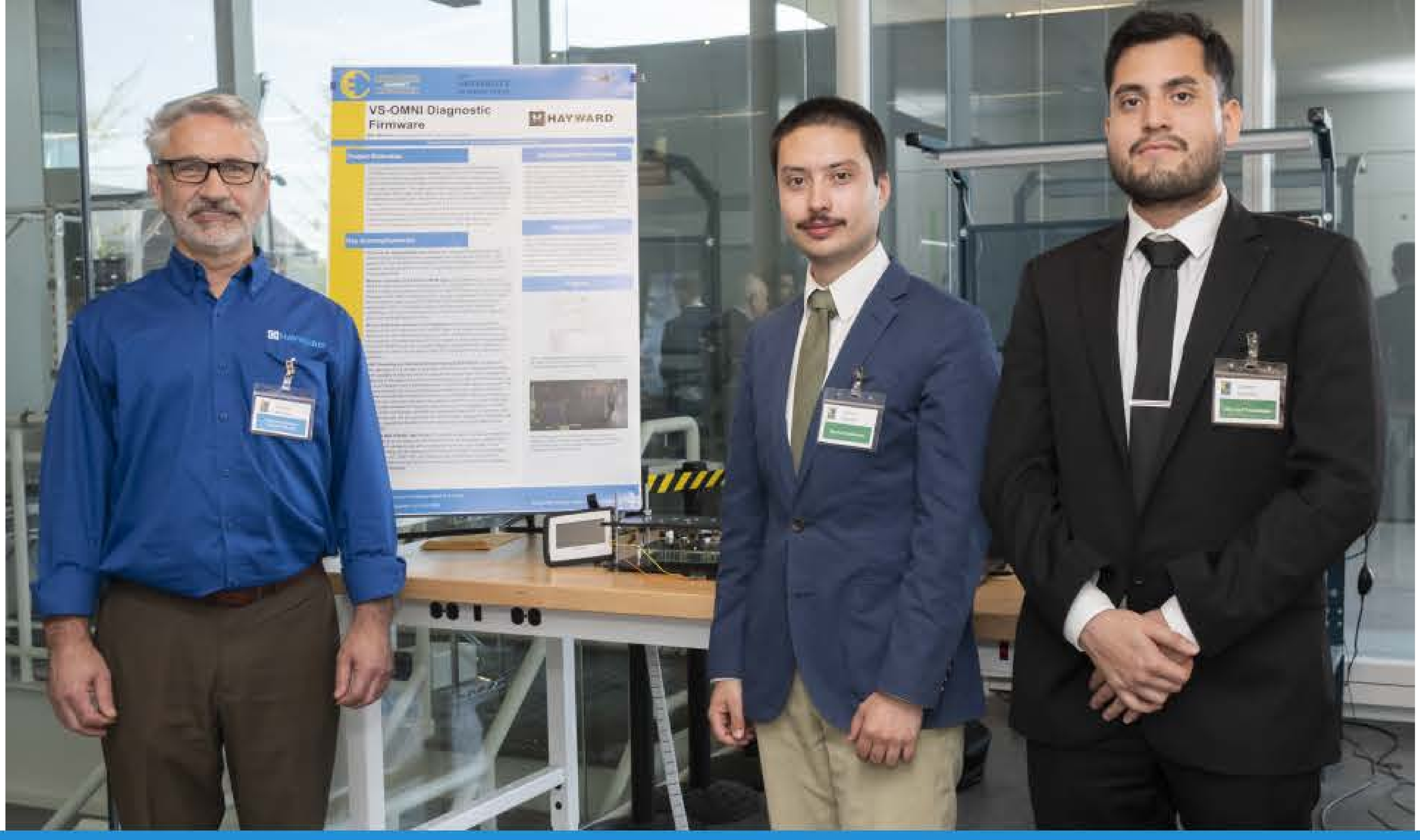

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VS-OMNI Diagnostic Firmware

HAYWARD®

Team Members: Beckett Maestas (CPE), Jayron Gonzalez (ELE)

Technical Director(s): Russell Buckley (URI'92, BS; URI'20, MBA)

Project Motivation

The manufacturing process for the computer system on Hayward Industries' VS-OMNI controller is susceptible variance in quality which is caused by factors which cannot always be predicted. To combat this problem, Hayward employs a team of engineers and technicians to troubleshoot and repair devices which fail to meet quality standards. This approach is time consuming and can create a backlog of assemblies which need further testing. Our goal is to reduce troubleshooting time by developing a toolset which technicians can use to quickly determine the source of a failure on the VS-OMNI controller. With this tool, we hope to be able to target every component of the controller's system and provide comprehensive diagnostic information to the user so that any faulty component can be replaced without the need to manually test its functionality. We hope to implement tests which run modularly and sequentially so that the entire system can also be verified.

Key Accomplishments

I^{2}C Driver for Reading Real-Time Clock: We created a bare-metal I^{2}C driver which enables reading and writing the Real-Time Clock on the VS-OMNI. This system can both validate the functionality of the I^{2}C interface which the i.MX283 supports, as well as allow for the RTC to be used to verify timing constraints for running other tests.

Memory Controller and External DRAM Tests: We implemented a driver which allows the Microprocessor to interface with the 1GB SDRAM IC which the VS-OMNI uses for reads and writes which exceed the 128kB of internal memory which comes standard on the i.MX28. Using this driver, we also implemented a set of four tests which target the data bus and I/O lines, the memory addressing and indexing capabilities of the IC, the ability to write to and then read from randomized addresses, and finally a retention test for ensuring that data corruption does not occur over extended periods of time.

SPI and NOR-Flash Interface from Raspberry Pi: Because the production version of the VS-OMNI boots from a NOR-Flash chip, proper functionality of this device can directly affect the performance of the VS-OMNI during startup. Due to the complexity of implementing a SPI driver based on the programming paradigms which the i.MX283 supports, we opted instead to implement a SPI interface on a Raspberry Pi, which can be used to verify the functionality of the NOR-Flash IC externally.

UART Encoding and Decoding Scheme Using DLE/STX/ETX: To reduce on false reporting errors caused by electrical interference, we implemented a system where packets of data are framed by sequences of start bytes which indicate the beginning of the sequence and the command which the user would like to issue, as well as a checksum and a transmission end. When the user issues a command, the firmware decodes the incoming packet and verifies that the packet's checksum matches the expected checksum. Once the communication has been verified, the firmware can utilize the data within the packet to perform one or many of the tests. The firmware provides the diagnostic data to the user. If the packet is corrupted during transit, the firmware can flush the buffer along the UART channel and issue a NAK to the user. By standardizing the communication protocol for this system, we have also opened the flexibility of the firmware's use via multiple different host applications.

Hardware Bed of Nails Test Fixture: To provide access to an SD card reader for devices which do not have that part populated, we had to create a system which could contact the test-points which correspond to the SC card reader on the VS-OMNI. During the development of this tool, we decided to also add physical interfaces for I^{2}C, UART, SPI, and power, so that a technician could affix the VS-OMNI PCBA to the test fixture and easily probe the communication busses to verify their functionality.

Anticipated Best Outcome

The ABO is a firmware package which can be quickly deployed to the VS-OMNI assemblies. The firmware shall communicate with the user on a host computer via the serial RS-232 DEBUG_UART port on the circuit board. Each test shall be issued by the user with a command. After running, the output will either display that the test has completed successfully, completed with a failure, or not completed. Our hope is to design this system such that it can easily be expanded to test other products in Hayward's catalog, and we will begin developing these tools if we reach the ABO.

Project Outcome

The full ABO for the project has not yet been reached since every VS-OMNI subsystem does not have a verified test completed, however, we have also expanded the utility of the project by creating a test apparatus which allows the user to supply test stimuli via external interfaces and written drivers for these uses which can stand in place of an internal firmware-based test.

Figures

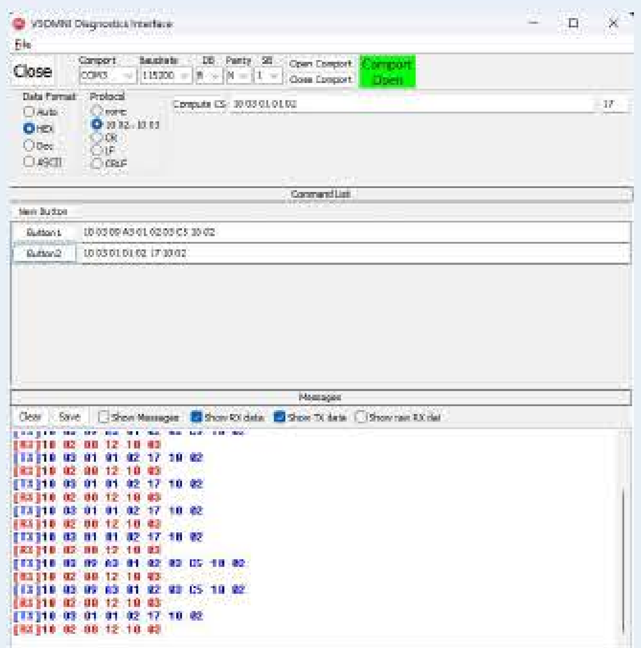

Fig 1. Using the Software on the host computer to communicate with the OMNI. Commands sent from the host are shown in blue and responses from the VS-OMNI are shown in red

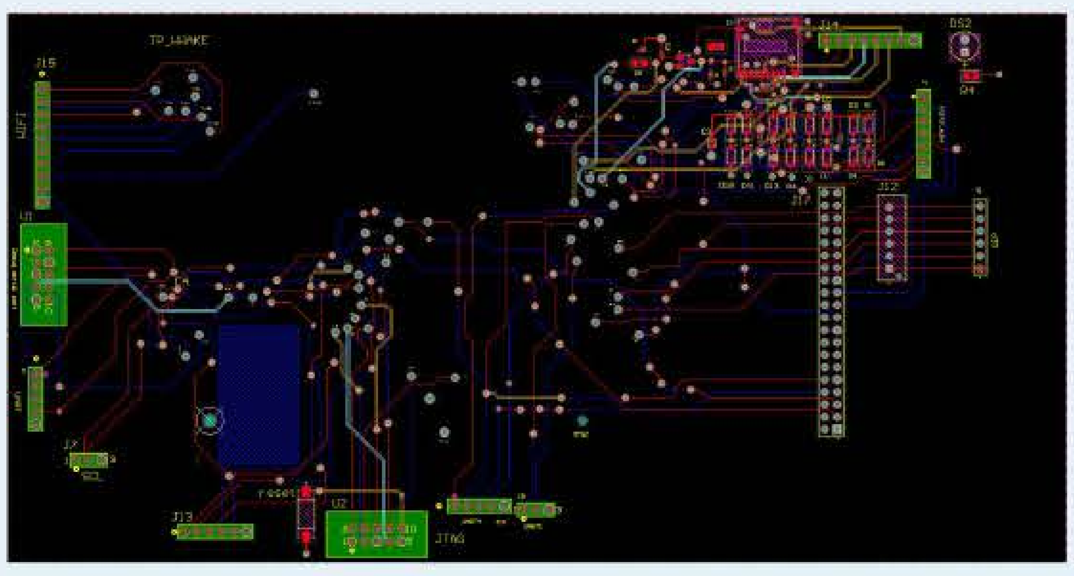

Fig. 2: PCB Layout for the final test fixture which shows the placement of each of the test points, headers for each individual communication line, a 40-pin header for interfacing with the Raspberry Pi, and the SD Card slot.

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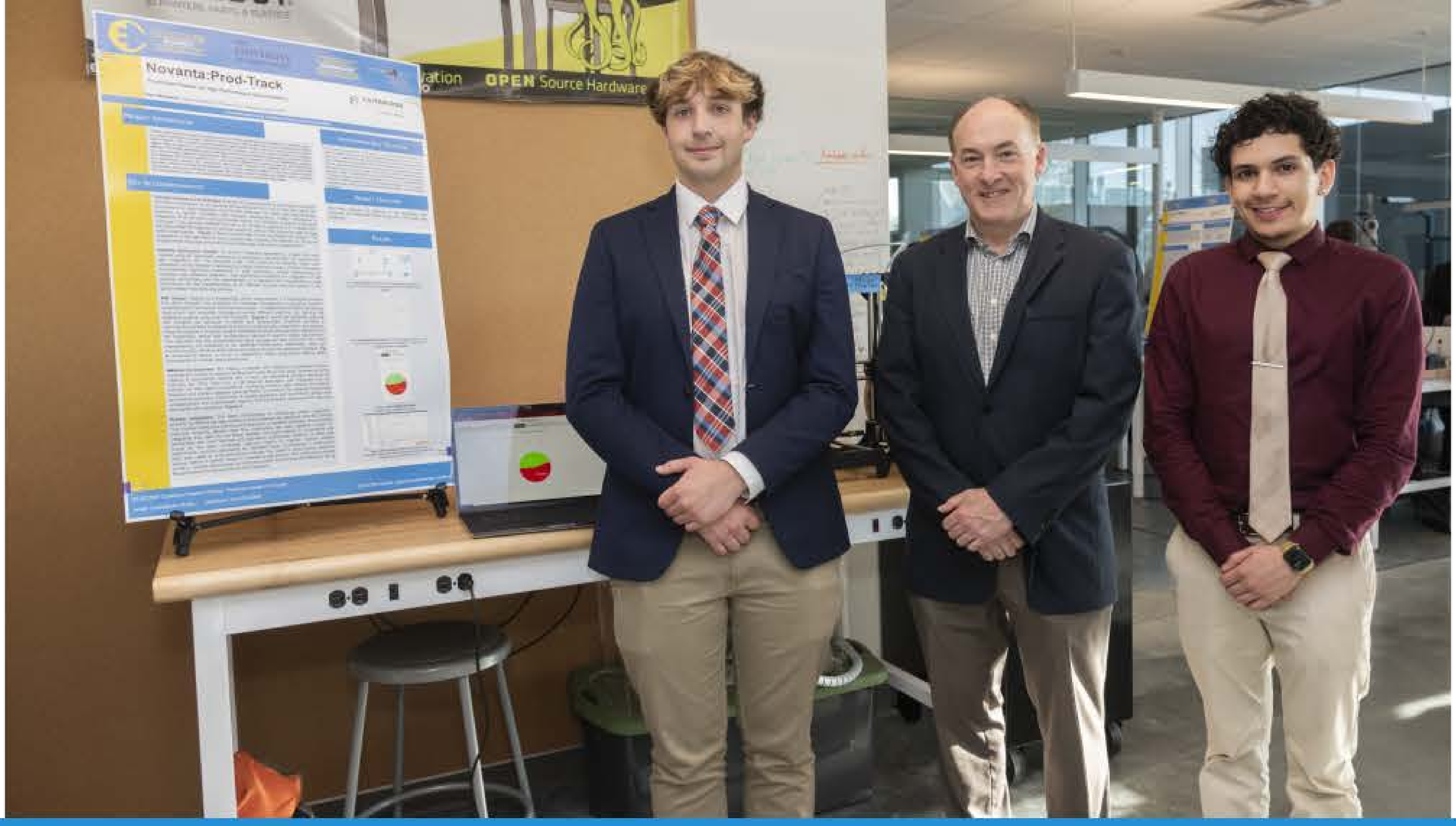

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Novanta:Prod-Track

Production Tracker for High Performance Galvanometers

CAMBRIDGE TECHNOLOGY
A Novanta Company

Team Members: Kaidan Campbell (CPE and ELE), Cristopher Quenes (CPE)

Technical Director(s): Jonathan O'Hare (URI'94, BS; URI'10, MBA) Jamie Gagnon (URI-ELECOMP '22)

Project Motivation

Crafting high-performance galvanometers demands intricate assemblies and operations for superior quality. As product complexity changes, adaptive manufacturing methods become crucial, emphasizing enhanced data collection. This includes capturing pass/fail data, failure modes, and cycle times across production stages. Manual data entry using keyboards proves inefficient, error-prone, and inconsistent in production settings. The project addresses these challenges with a two-fold objective: implementing a barcode scanner for crucial process steps and integrating its data into existing processes, forming a standardized database. This database will be the backbone for a user-friendly software tool, enabling graphical data visualization and streamlined querying. By overcoming manual input limitations, the initiative aims to improve data accuracy, enhance manufacturing efficiency, and provide valuable insights for informed decision-making. Anticipating optimized production processes, the project ensures meeting the highest quality standards, promising efficiency gains, and elevating the overall quality of the manufacturing process.

Key Accomplishments

Defined Hardware and Software: The key accomplishments of the project include the successful conversion of an existing Microsoft Excel form into a CSV file, laying the groundwork for data integration into the new database. Our team conducted thorough research to identify hardware and software requirements, initially considering a Raspberry Pi for an all-in-one touchscreen device but ultimately opting for a Windows computer. This decision dictated the use of QT Creator to develop a C++-based GUI, the Zebra DS2700 Scanner for barcode scanning, and an SQL server for data storage before web display. **Figure 1** shows a schematic of how our system will function. The integration of the QR scanner was a pivotal step, requiring the selection of C# as the programming language and overcoming challenges, such as an outdated SDK.

Desktop Application Design: In terms of back-end engineering, a basic GUI was created using QT Developer, serving as a prototype to test and learn QT functions for later integration with the back-end code. The focus on functionality rather than aesthetics proved integral to developing a robust back-end system. Overall, the project accomplished significant milestones in data conversion, closely collaborating on hardware and software selection. This partnership facilitated the integration of QR scanner functionality and the development of a backend GUI, establishing a solid groundwork for the implementation of an efficient barcode scanning system in the galvanometer manufacturing process.

SQL Design: Setting up a PostgreSQL server using Docker is a streamlined process that offers flexibility and scalability for database management. Leveraging Docker's containerization technology allows for the creation of isolated environments, simplifying deployment and ensuring consistency across different platforms. By defining the database schema using tools like DrawSQL, **Figure 2**, teams can efficiently organize and visualize the structure of tables and relationships. DrawSQL provides a user-friendly interface for designing schemas, enabling easy collaboration and iteration. Once the schema is finalized, Docker facilitates the quick and seamless deployment of the PostgreSQL server, with configurations tailored to specific project requirements. This approach not only streamlines the setup process but also enhances the overall manageability and scalability of the database infrastructure. Additionally, users can monitor the SQL server's performance and status through the dashboard interface, **Fig. 4**, empowering teams to focus on developing robust applications without being encumbered by complex setup procedures.

Website Development: For making a website, the milestone achievement involved completing a course on website development using React and Node, followed by jointly creating a user-friendly website with a basic yet responsive frontend structure by February 24, 2024. Data from a QR Scanner Application was integrated into the website via SQL Server connections, facilitating dynamic data retrieval and display. Relevant and realistic datasets were generated to enhance the website's functionality and testing scenarios. Additionally, a visually appealing and user-friendly design was conceptualized and implemented, aligning with the project's objectives and improving the overall user experience, **Figure 3.**

System integration: The team concentrated on enhancing system integration, primarily by refining the data transfer process between the application and SQL Server. This involved meticulous planning and execution to establish seamless communication channels, ensuring efficient data flow. Additionally, the team diligently worked on integrating SQL data into the React website, thoroughly testing for compatibility and functionality with cloud services and application components. Attention to detail was crucial as the team conducted rigorous checks to maintain optimal website performance, promptly addressing any identified issues. Furthermore, a collaborative effort was made to comprehensively evaluate the system's performance, analyzing various metrics to identify areas for potential enhancement. This meticulous analysis aimed to uncover opportunities for improving system functionality and efficiency, laying the groundwork for future development endeavors.

Anticipated Best Outcome

As the original specification of the project, the Anticipated Best Outcome is to deliver a project that uses a QR Scanner system implementation proof of concept that would replace current data entry methods. This proof-of-concept aims for a user to seamlessly input production data, with just a scan and a few clicks. The data the user inputs then would be stored in the cloud, where management could access the data through an admin portal, which would update the charts based on production week. The data stored on the cloud should be organized and integrated in a way for others to access for other projects in the future. The data gathered will empower informed decision-making, contributing substantially to the company's competitiveness, operational resilience, and long-term success in the manufacturing landscape.

Project Outcome

We have achieved all features of the anticipated best outcome. The Anticipated Best Outcome of the project was achieved.

Figures

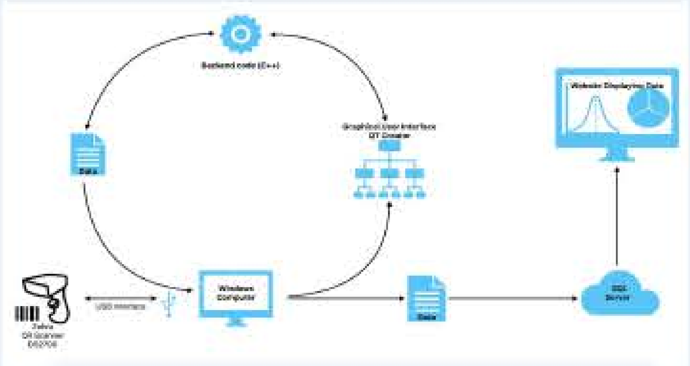

Fig. 1: Defined System: Shows the flow of concept from the starting point, scanning QR, to the endpoint where the data received is displayed on the website

Fig. 2: DrawSQL-defined tables: This shows the finished schema in SQL which provides a structured blueprint or framework for organizing and managing data within a database.

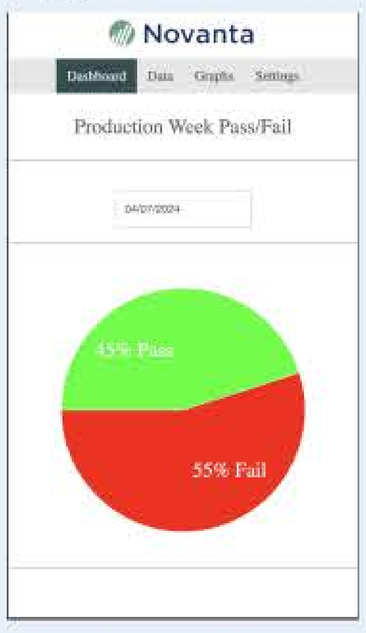

Figure 3: React Website Phone View: Shows the view of website from a phone

Figure 4.)SQL Dashboard: pgAdmin allows users to view databases, tables, views, stored procedures, functions, triggers, and indexes hosted on a SQL Server instance

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Digital Companion for Obesity

A combinational custom smartwatch and smartphone application platform for obesity management.

novo nordisk®

Team Members: Justin Watkins (CPE/ELE), Yashaswini Mandalam (CPE), Afolabi Abayomi (CPE), Dayla Olivo (ELE), Connor Vincent (ELE)

Technical Director(s): Mike Smith (URI'01), John Canevari, Karthik Kumar, Shabana Motlani, Fola Olabisi, Anubhav Srivastava

Project Motivation

In recent years, the prevalence of chronic conditions, such as obesity, has surged, posing a significant health risk to a substantial portion of the global population. As obesity rates continue to climb, the accompanying health complications, including cardiovascular risks, diabetes, sleep disorders, and elevated mortality rates, become increasingly common. Notably, obesity also exerts a profound mental impact on individuals, leading to struggles with issues like depression, self-image, and a diminished quality of life. These psychological burdens add a complex layer to the battle against obesity, making it as much a mental challenge as a physical one.

Key Accomplishments

- **PCB Prototype 2 Development:** Further development on the Prototype-1 device. Prototype-2 included a display and heart rate sensor but added an external battery, power management and connectors for further sensors. These improvements allowed for a more portable device that had increased sensor capabilities and user interface. This device utilized an Arduino Nano BLE to handle the embedded software of the device.
- **Front-End Creation:** Developed and implemented user interface, establishing front-end systems for real-time data displays, and encouraging seamless backend connectivity.
- **Large Life Contextual Description Model (LLCDM):** Developed a large language model with the ability to interpret video, audio, and health sensor data. It's being trained to describe the internal states, user actions, and external events going on from a user's perspective and to form a foundational model for identifying obesity related behaviors and physiological states.
- **Tools for Training Datasets:** Created a series of web scrapers, pdf extractors, and recreated the PVS-Gen health sensor synthetic data generation algorithm in order to create an intervention text corpus and to augment health sensor datasets to train the LLCDM.
- **Semantic Feature Extraction Library Models:** For the dual purpose of creating a training pipeline by making auto annotations for the LLCDM to train off of and providing direct user insights even in the early stages of development.
  - **Eating Activity Recognition:** Implemented a Convolutional Neural Network (CNN) coupled with Long Short-Term Memory (LSTM) architecture for eating activity recognition. This model utilizes the CNN to extract spatial features from raw sensor data, while the LSTM captures temporal dependencies, enabling rudimentary identification of eating behaviors and patterns.
  - **Stress Level Detection:** A bagged tree stress regression model is employed to assess stress levels, providing insights into potential triggers for overeating episodes. By aggregating predictions from multiple decision trees, this ensemble model offers robust stress estimation capabilities.
  - **Emotion Recognition Model:** created to understand the psychological aspects of obesity management. The algorithm analyzes 30 second voice clips to perform sentiment analysis.
- **AWS Backend:** Developed a GraphQL API which is connected to a series of DynamoDB tables, that store most of the backend information for the application. The health sensor data table is connected to a kinesis data stream which utilizes enhanced fanout to accommodate lambda functions for the stress regression machine learning model to make inferences on updated electrodermal and skin temperature data and sends it back to a stress inference dynamoDB table to allow the application to directly view these predictions on the user's current state.

3D generation shows our PCB Prototype 2.

Anticipated Best Outcome

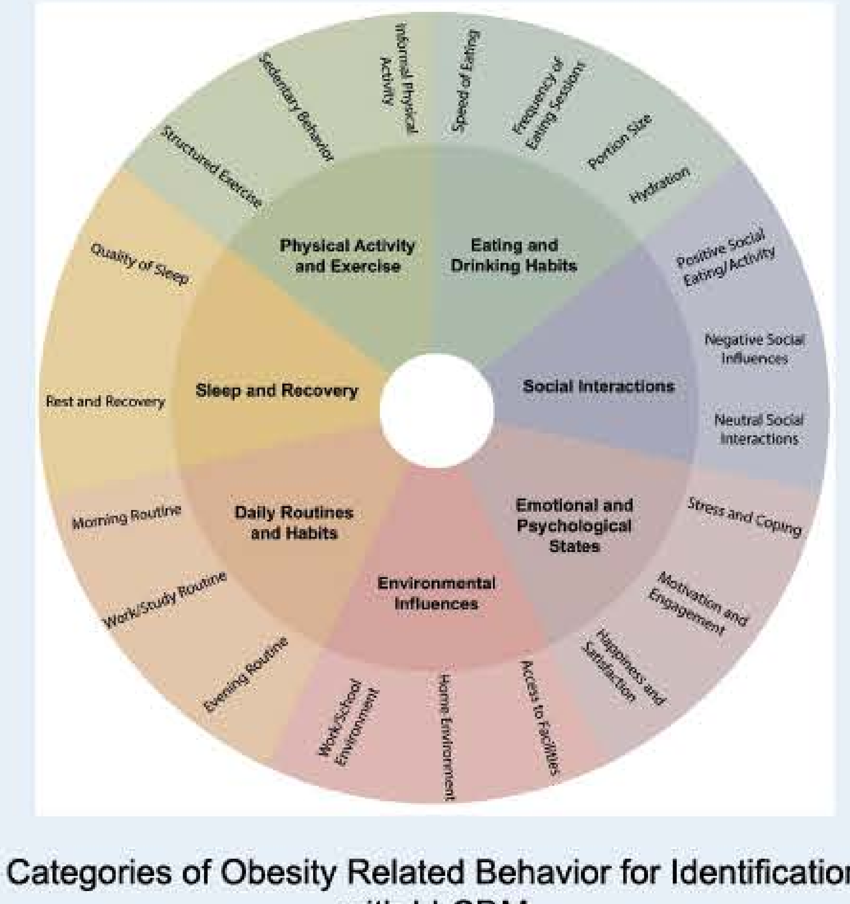
Personalized disease-state related outputs from the digital companion for the obesity patient to manage their condition. The creation of the digital companion as a smartphone application with the integration of a wearable device as well as sensor integration. Machine learning algorithm(s) with multiple data inputs providing the ability of the companion to train against the patient's inputs and biomarkers for advanced customization/personalization to help manage their condition.

Project Outcome

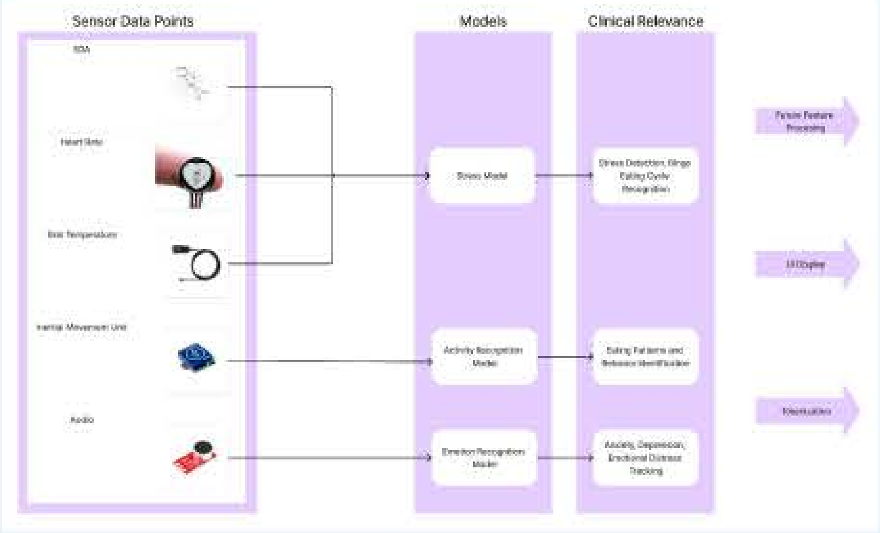
The combination of machine learning models and 6 different sensors incorporated with the platform lead to a deeper insight into the user's physiological states. Overall, a robust platform with the ability to both inform the user about their current health state and simultaneously provide more information for the LLCDM to be trained off of and to create a foundational model for creating personalized interventions.

Figures

Main Dashboard of smartphone application.



Categories of Obesity Related Behavior for Identification with LLCDM



Current Semantic Feature Extraction Library

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Project Outcome

The digital companion for obesity management is the beginning of a smartphone application that integrates a wearable device and multiple sensors, utilizing machine learning algorithms to personalize and enhance patient care. By training on patient inputs and biomarkers, the companion offers advanced customization to manage the condition effectively. The integration of six different sensors provides deep insights into the user's physiological states, informing them of their current health status while enriching the LLCDM for creating personalized interventions and foundational models.

Key Accomplishments

- **Hardware Sensor Choices and Development:** Sensor selection in the prototype was based on the necessity of sensors that would be able to detect stress in a user. PPG is essential as it allows the measurement of heart rate, heart rate variability and can act as the source for numerous insights for future machine learning models. IMU, ECG, EMG, EDA, PPG, Skin Temperature, and Audio were considered the most useful for future machine learning models to explore and give better insight into current user states in relation to obesity.

- **Semantic Feature Extraction Library Models:** For the dual purpose of creating a training pipeline by making auto annotations for the LLCDM to train off of and providing direct user insights even in the early stages of development.
  - **Eating Activity Recognition:** Implemented a Convolutional Neural Network (CNN) coupled with Long Short-Term Memory (LSTM) architecture for eating activity recognition. This model utilizes the CNN to extract spatial features from raw sensor data, while the LSTM captures temporal dependencies, enabling rudimentary identification of eating behaviors and patterns.
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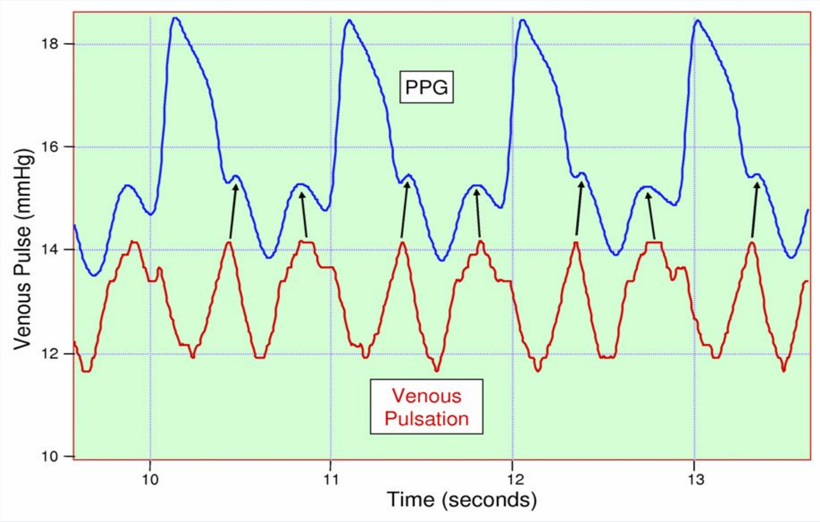


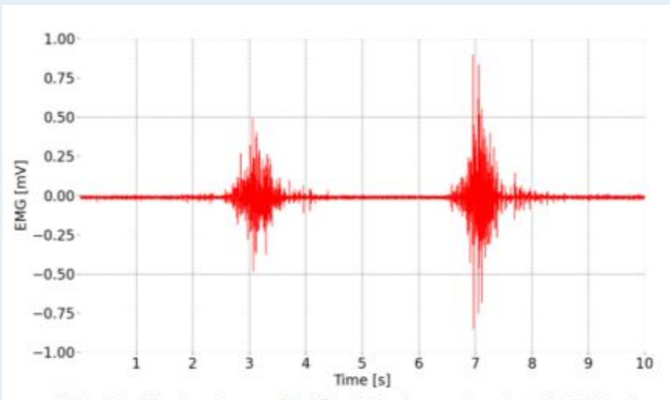


Fig. 3. Typical raw EMG data (acquired with BITalino (r)evolution) on the muscle biceps brachii with flexion of elbow and forearm in supination.

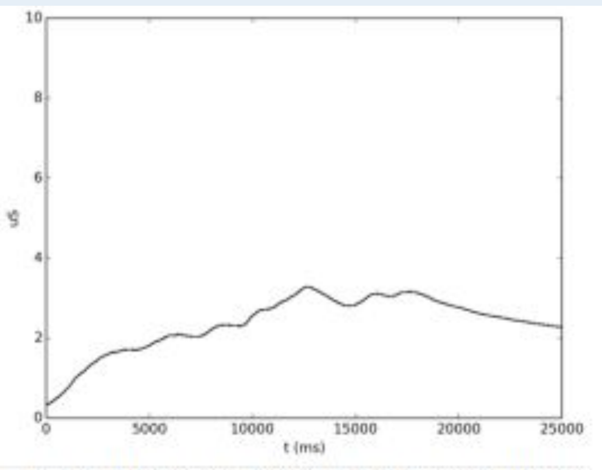
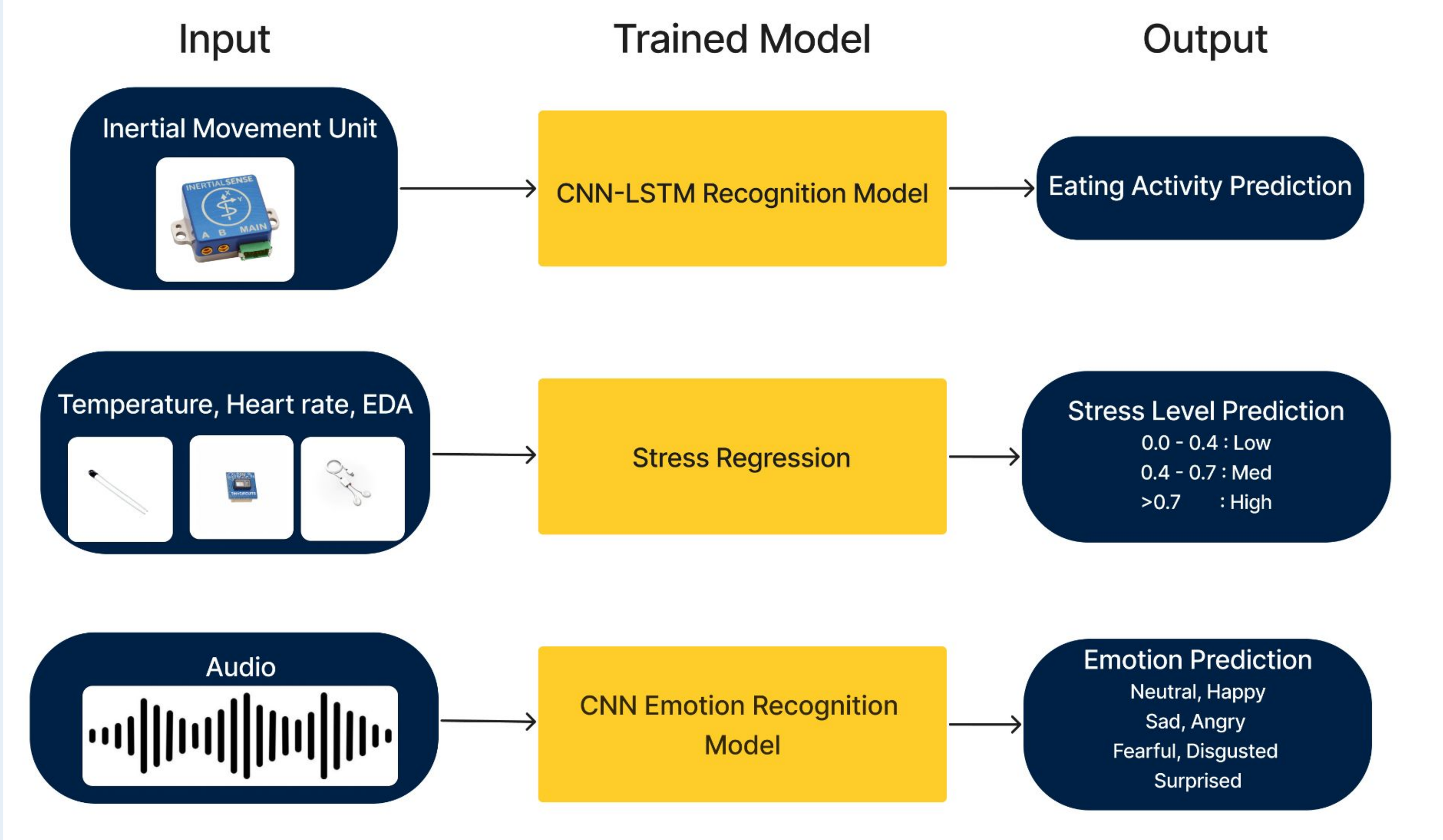
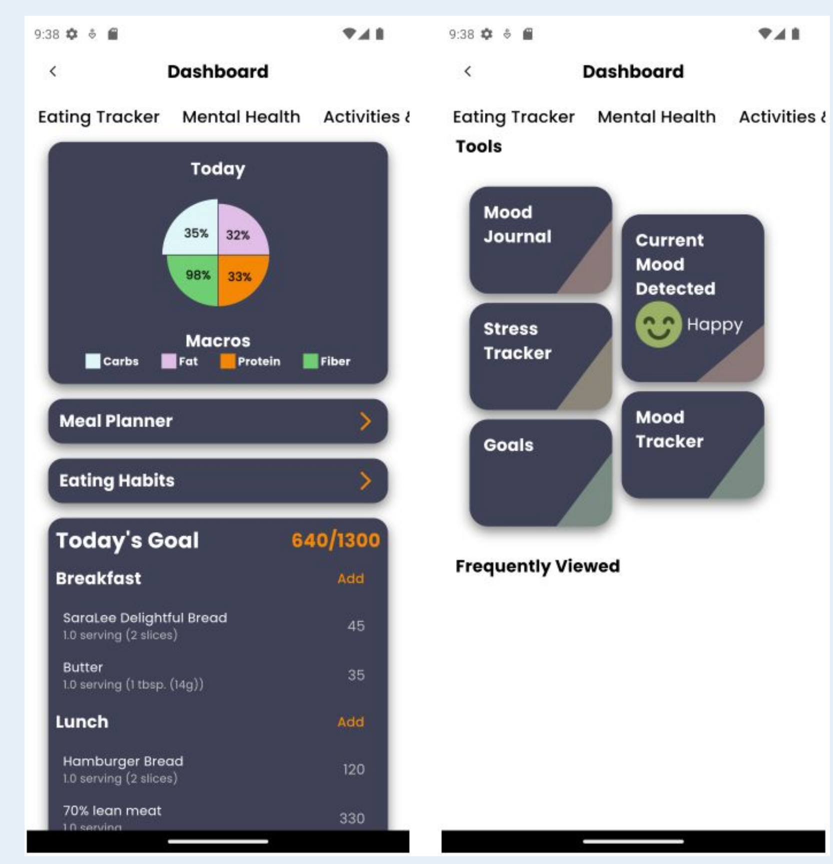


Fig. 2. Typical raw EDA data (acquired with BITalino (r)evolution).

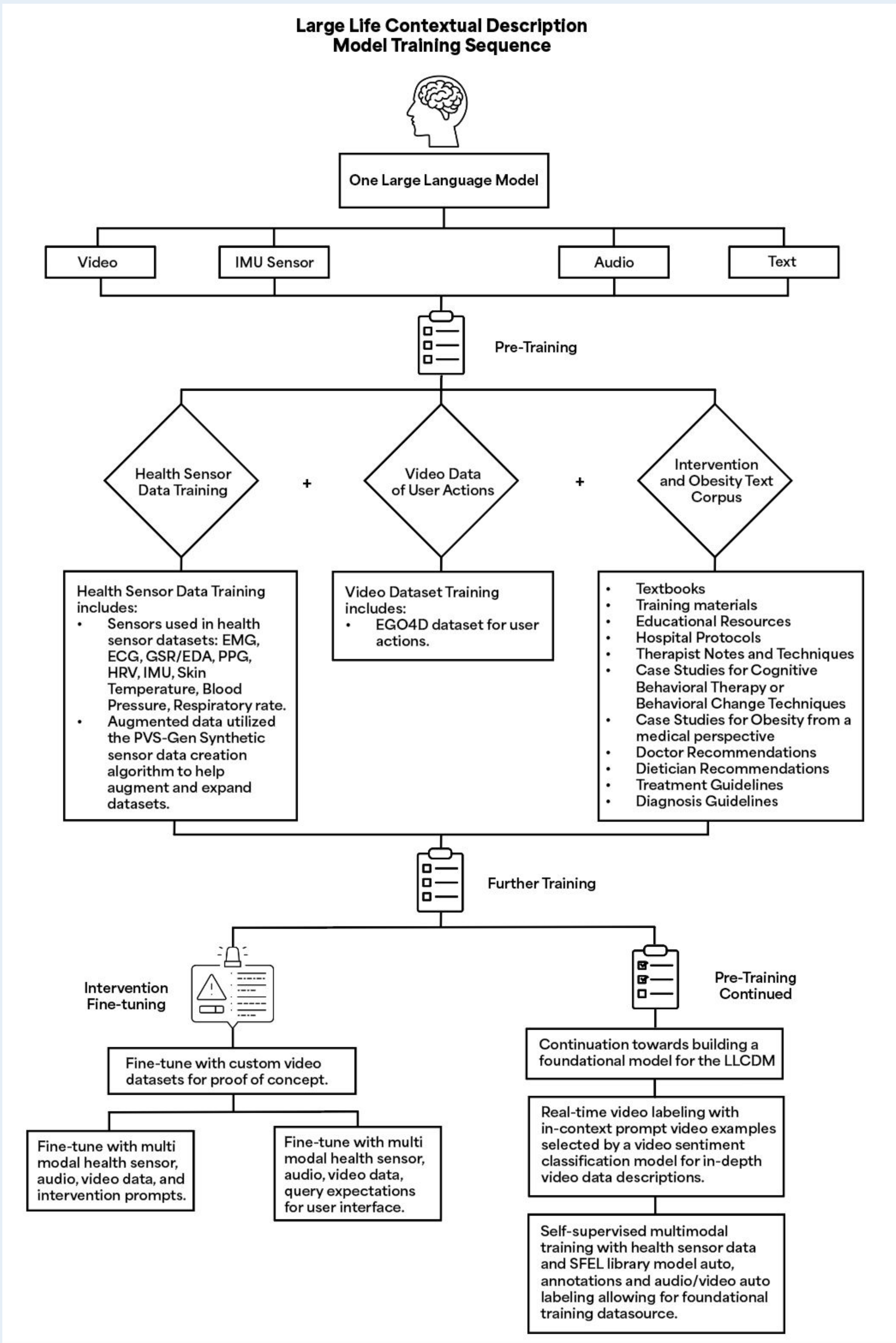
Health Sensor Outputs



Current Semantic Feature Extraction Library (above)



Main Dashboard of smartphone application (above)



Categories of Obesity Related Behavior for Identification with LLCDM (above)

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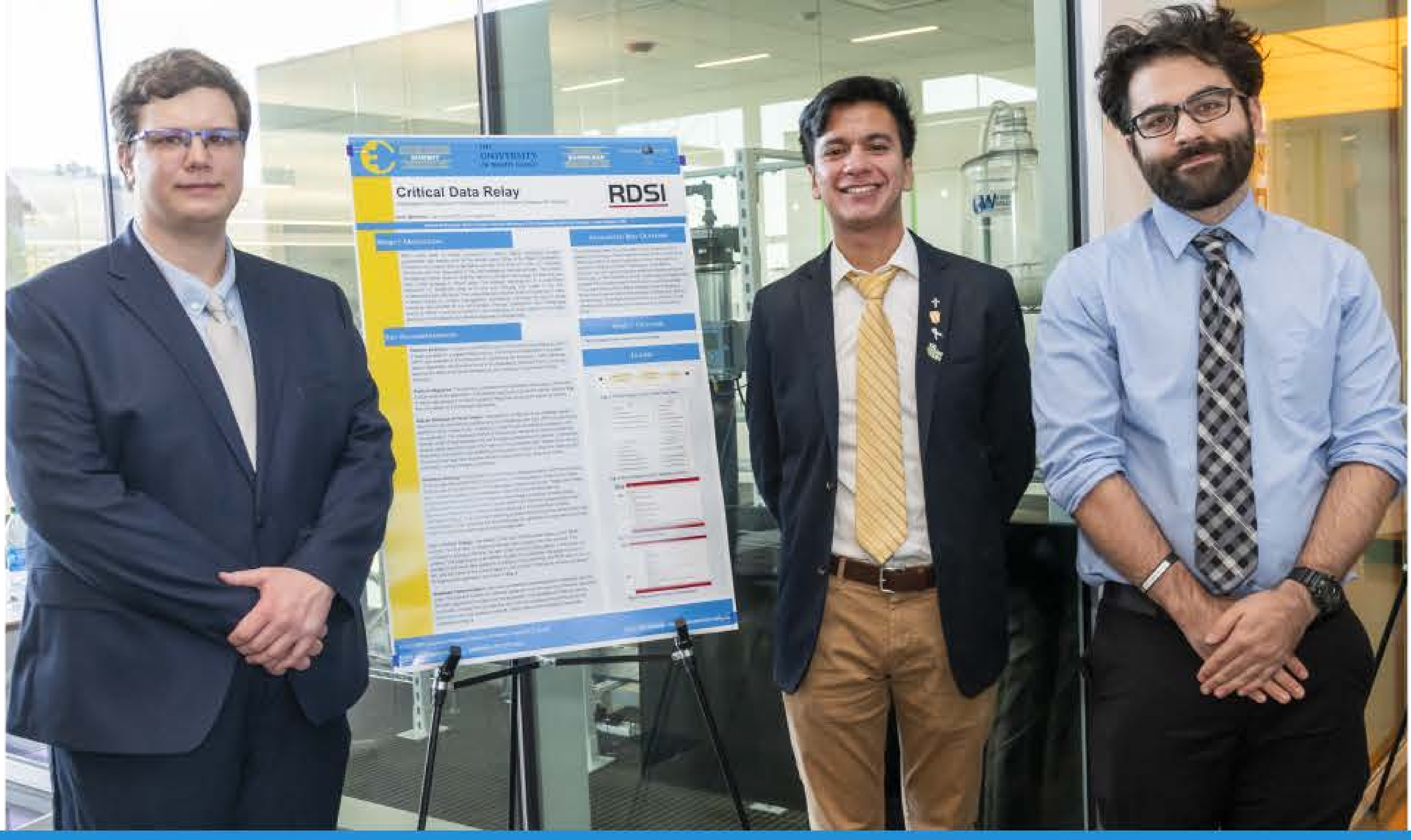

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Critical Data Relay

Aggregation of Data from First Responders to Windows Desktop API Display

RDSI

Team Members: Juan Cante (CPE), Erik Slader (CPE)

Technical Directors: Bruce Torman, Hannah Morrissey(URI-ELECOMP'23) | Consulting Technical Director: Jamie Gagnon(URI-ELECOMP '22)

Project Motivation

RDSI prides itself on robust connections in Public Safety, particularly through partnerships with entities such as the Rhode Island Office of the State Fire Marshal. President John Evans, also a dedicated volunteer Fire Chief for Lyme, CT, maintains strong ties with first responders in fire and emergency medical services. The incident management sector faces an ongoing need for innovative technology, an area that has seen limited progress in recent years. The strategic development of a specialized application for firefighters aims to fill this void, bringing their toolkit in line with contemporary field demands. This comprehensive initiative holds the potential to make a lasting impact on incident management, significantly improving the lives of those providing vital services to our communities. Through collaboration and cutting-edge solutions, RDSI is looking to transform the landscape of public safety for the better, ensuring a more efficient and effective response to emergencies.

Key Accomplishments

Platform Selection: In order to fulfill RDSI's vision of the Critical Data Relay as part of a larger package on a rugged laptop product, the Windows Presentation Foundation (WPF) was selected as the framework for developing the application. WPF offers the ease of application development found in its predecessor, Windows Forms, while also allowing the ability to produce professional user interfaces using modern design practices.

Platform Migration: The previous prototype phone application was used to model the Critical Data Relay application. The desktop application follows the activity diagram **Fig. 1**, which was derived from the Emergency Response Guide 2020 edition as well as from the design of the prototype application.

SQLite Database Schema Design: The selection of SQLite as the database system stems from its user-friendly interface and its compatibility with both WPF and WinForms platforms within Visual Studio, making it an ideal choice for seamless integration with the application. The database schema is meticulously designed to accommodate the diverse range of data necessary for the Emergency Response Guidebook. It comprises several tables tailored to store information on the guidebook itself, details about various chemicals, and specific data pertaining to evacuation ranges in case of a chemical spill. This structured approach ensures efficient organization and retrieval of crucial information during emergency situations.

Database Seeding: The process of populating the database begins with the acquisition of up-to-date data sheets from the Department of Transportation, reflecting the latest revisions as of the 2020 edition of the Emergency Response Guide. These data sheets serve as the foundation for the database content and are transformed into comma-separated variable (CSV) files for streamlined processing. A meticulously crafted C# script is then employed to parse these CSV files and systematically inject the relevant data into the database tables, adhering to the predefined schema illustrated in **Fig. 2**. This automated seeding process not only ensures the accuracy and completeness of the database but also enhances the application's readiness to provide timely and informed responses during emergencies.

User Interface Design: The design of the user interface was based on the RDSI website. The first step in designing the app was to design the main window. This consisted in adding a frame to the grid. Once the frame was added, a new page was created. The page layout is as follows; divided into quadrants, the page consists of content in the lower right quadrant, 4 buttons on the lower left, the RDSI logo in the top left, and the name of the current page on the top right. This layout remains consistent throughout the application as shown in **Fig. 3**.

Database Implementation: We have successfully implemented the database into the code. The placard number or chemical name can now be input into a textbox, and when the user submits this number into the application, the database will filter out all the chemicals. It would then provide the user with the corresponding chemical and its information such as potential hazards, public safety, and emergency response presented in **Fig. 4**.

Anticipated Best Outcome

The Anticipated Best Outcome (ABO) of the project will be to design and develop a near-finalized version of the Critical Data Relay application to assist firefighters in their response to a hazardous materials incident. Additionally, if the ABO is achieved, we will have produced a working prototype which we will be able to demonstrate technical functionality and determine possible future developments that should or could be added. The project will provide a digital rendition of the Emergency Response Guide as well as fast lookups for Response data by camera feed. The project will also serve as a platform for the development of future tools and applications developed by RDSI.

Project Outcome

The anticipated best outcome was achieved.

Figures

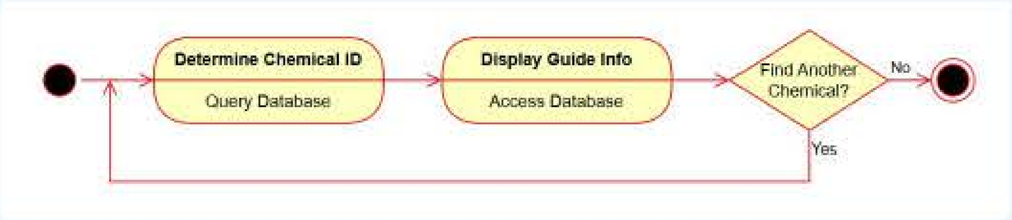

Fig. 1: Activity Diagram of the Critical Data Relay.

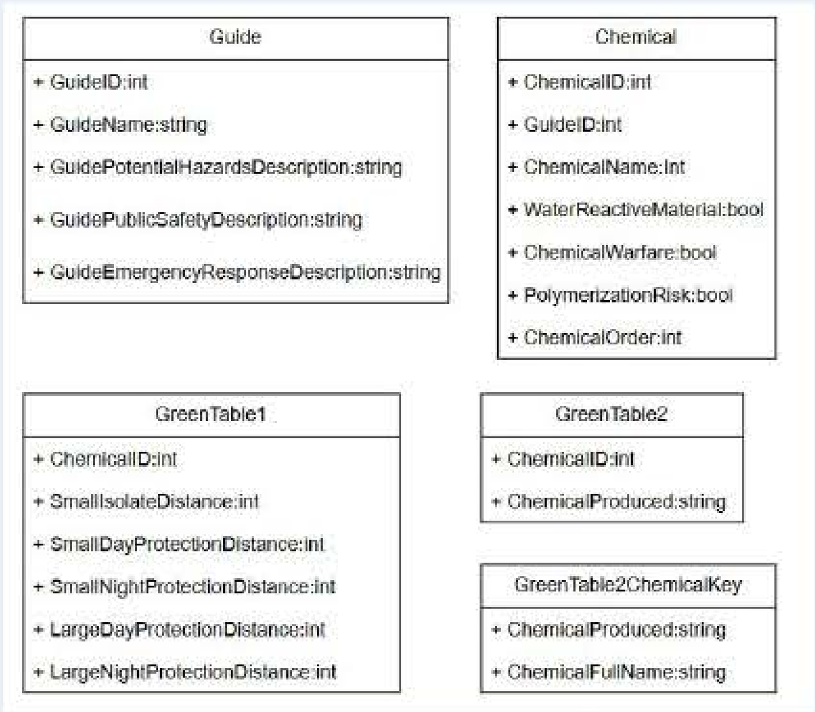

Fig. 2: Block diagrams of SQL database schema.

Fig. 3: Picture of Home Screen

Fig 4: Picture of the Placard ID Data screen

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On-Premises LLMs

Fine-tuning Large Language Models Using Proprietary Data

rite SOLUTIONS

Team Members: Demetrios Petrou (CPE), Sokpearoun Lorn (CPE)

Technical Directors: Jacob Wojciechowski (URI-ELECOMP '19), Thomas Santos, Alexander Moulton, Jamie Gagnon(URI-ELECOMP '22)

Project Motivation

LLMs have taken the tech world by storm because of their immense amount of potential applications. These models can intricately understand, process, and generate language in their own way, and most companies will be able to find a way to incorporate LLMs into their business in the form of a customer service chatbot, content summarizer, or really any other kind of language task. Rite-Solutions frequently seeks to acquire funding for projects, and the applications require lengthy and time-consuming proposals. With the power of LLMs, employees can save a great deal of drafting time to dedicate to more important tasks. Of course, these language models are not direct human substitutes. Rather, an LLM can support the drafting process by making the content more enriched and decreasing time spent writing. Human reasoning is still needed for proofreading and editing, but our project will still be a helpful tool in this early stage of applying LLMs.

Key Accomplishments

- **Model Design:** A study of LLMs was conducted to better understand the architecture and design requirements of the project. A flowchart representing the steps needed to produce a fine-tuned model is shown, starting with dataset generation, going into the fine-tuning and inference modules **(Fig. 1)**.
- **Selection Criteria:** A document was created to identify objective properties of different LLMs for the purpose of selecting a model to later evaluate in depth.
- **Pugh Matrix:** After deciding what aspects are used to evaluate the models, they are then given weighted scores to rank the models based on their overall compatibility with the project's design constraints. Models included in this matrix are grouped by their base model architectures, with several fine-tuned variants included within them. Various notes are appended to each model to include useful information that falls outside of the criteria. Models that are included into the matrix are pre-selected to remove various models that would automatically make it an undesirable choice such as those with proprietary licenses, those lacking sufficient documentation or information, or models that are uncensored.
- **Final Model Selection:** Utilizing the Pugh matrix developed previously, a list of top 5 models were chosen. These models are from three different architectures (Mistral, Llama, Falcon) to provide a variety of options should any of them turn out to be insufficient.
- **Dataset Curation:** A dataset with usable prompt/response pairs to train an LLM to output long-form responses in document format was first identified. In this case, we utilized arXiv.org, a large online database of academic articles. A large corpus of these articles are extracted from our ArxivScraper, which converts these PDF documents into plain text. The text is then inserted into the DatasetGen, which generates dataset pairs from the content.
- **Fine-Tuning:** With a base model and the generated dataset, we derived fine-tunes by placing them into the training module. The module tokenizes the dataset for easier processing then utilizes Parameter-Efficient-Fine-Tuning (PEFT) to maximize fine-tuning performance while only training on a small number of parameters. The resulting adapters are merged with the base model to produce a fine-tuned version. The training results can be observed through the training and validation loss **(Fig. 2)**.
- **Inference Module:** To satisfy the design requirements of an on-premises hosting solution, text-generation-webui was employed for local inference with our fine-tunes. It allows for easy loading of models and the ability to easily change hyperparameters. In addition, numerous extensions are available which can be enabled to enhance the output. One of these extensions include retrieval-augmented-generation (RAG).
- **Prompt Engineering:** The output of a model can be further enhanced through prompting techniques and additional changes. Experiments were run on key words and ways of defining the AI's role to include or exclude specific information. To this end, we focused on terminology that would force the outputs to follow the same style as that of a research paper. Through RAG, we can insert data into the model in real time as context to improve inference without explicitly referencing it in the prompt **(Fig. 3)**.

Anticipated Best Outcome

The inference pipeline is the central component of the ABO as it performs the document generation. At a high level, the system is built on top of the optimal LLM that minimizes memory needs and maximizes output quality. The LLM needs to be fine-tuned for the task of document generation, and fine-tuning can be performed on the fly with the use of the dataset generator functionality of the pipeline. The second part of the ABO is the three main parts of documentation for our project: installation and usage, prompt engineering, and a comprehensive evaluation. These are key to conveying the value of our project and its technical aspects.

Project Outcome

The ABO has been successfully met. Our work has helped Rite-Solutions begin development of an internal LLM tool to expedite document drafting and the necessary documentation to use and evaluate the system has been developed.

Figures

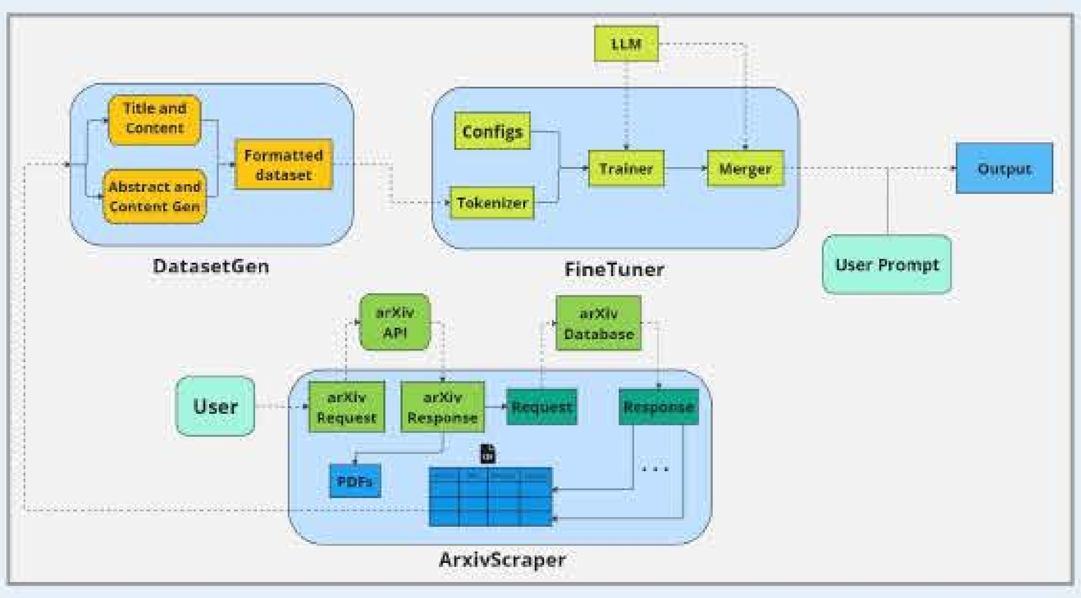

Figure 1: A visual representation of the LLM system from data collection to fine-tuning results and inference

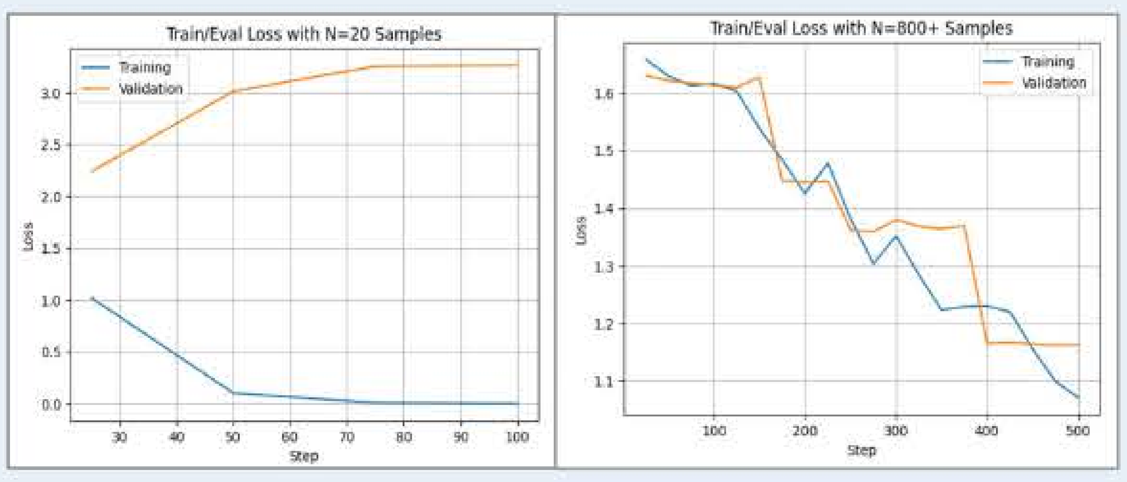

Figure 2: Training and evaluation data losses over a number of training steps with N=20 and N=800+ sample size datasets on the left and right, respectively.

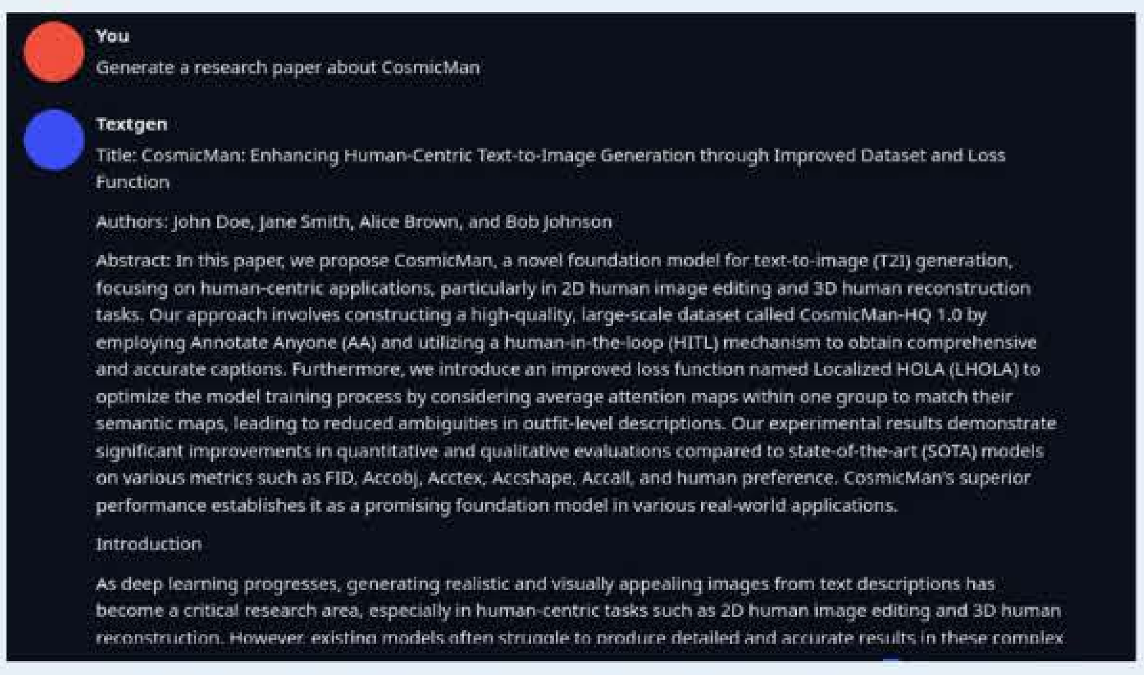

Figure 3: Example output in the style of a research paper using the 7B Mistral model WestLake

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Project Echo Mike 1

Post-Release Tracking Device for Small Mammalian Species

SANCTUARI

Team Members: Alexi Andresky (ELE), Grace Firth (ELE)

Technical Director(s): Joe Moreira and Chris Rothwell

Project Motivation

While there are some compact and lightweight devices available on the market that operate on very high radio frequency or various GPS technologies, there is a notable absence of mass-producible devices capable of adapting and optimizing themselves for specific environments by harnessing cellular and GPS technologies, particularly for small mammalian species. Currently, a substantial market exists for trackers designed for larger animals such as deer or elephants. Additionally, it is our belief that many companies specializing in animal tracking devices may not prioritize the potential impact of these trackers on the animals themselves. Our primary mission is to develop an unobtrusive device that seamlessly integrates with the animal, delivering long-lasting and precise results. The consumer demand for such small trackers from animal rehabilitation centers is substantial. This tracker would provide users the ability to track animals they have never been able to in the past, opening a new world of opportunities for rehabbers.

Key Accomplishments

- **Communication Protocol:** In this project, a crucial decision was selecting the appropriate communication protocol. IoT devices typically utilize MQTT for its continuous connection and efficiency in bandwidth and power usage. However, our device's design, which involves regular transitions between active and sleep states, made MQTT impractical. We turned to HTTP, a protocol well-suited for devices that frequently switch on and off, as it operates on a request-response basis and is highly compatible with the internet and cloud platforms. Given HTTP's advantages in energy efficiency and ease of integration, it was the preferred choice for our IoT device's GPS data transmission.

- **Acquiring and Delivering Location Data:** A vital aspect of our device's functionality is its precision in acquiring location data, with an accuracy of ±1 meter for position tracking. The device produces NMEA GPS data strings, which contains essential information such as longitude, latitude, time, velocity, and elevation. Within the scope of this project, our primary focus was on extracting the longitude and latitude data. We then converted these coordinates into a degree format to facilitate accurate interpretation by the endpoint, ensuring the location data was comprehensible and reliable for our application needs.

- **Sleep State Implementation:** An important aspect that required attention was how to effectively power down the device during sleep periods without fully turning it off. We implemented a system where the device would enter a sleep state based on a preset timer; for example, setting the timer for two hours meant the device would activate for a certain period every two hours. Refer to **Fig. 1** to better understand the timer cycle. We ensured that the GPS/LTE module was completely powered off and that most functionalities on the microcontroller were reduced to the lowest possible levels. During this phase, we carefully balanced modifying the code and measuring the power draw from the device, utilizing a power profiling kit to monitor the energy consumption effectively. Refer to **Fig. 2** to understand the integration of the modules into one device and how they effectively communicate with each other.

- **User Interface:** In this project, we utilized the Thingsboard IoT platform, known for its interactive 'widgets' that allow users to interact with various data types, including location and temperature readings. Specifically, we used a map widget to visually represent location data against a Google Maps backdrop, as shown in **Fig. 3**. Additionally, we leveraged a path mapping widget to illustrate the potential route of a tracked animal, piecing together multiple recorded position points to provide a clear trajectory.

- **Power Consumption Data Analysis:** Analyzing the module's power consumption was initially complex but eventually clarified. This analysis involved measuring energy usage during GPS searches and POST messaging, and identifying power-intensive, unwanted features, such as Bluetooth and LoRaWAN, to be deactivated on the microcontroller. Additionally, the power consumption analysis aimed to optimize factors like the trade-off between transmission size and the computational power needed to reduce that message size, among other considerations.

Anticipated Best Outcome

This project aims to create an integrated GPS and Cellular-compatible IoT tracking device designed for small animals. Ideally, this device should weigh approximately 5% of the animal's weight for the entire unit, ensuring it remains unobtrusive to the animals. This multifunctional tracker is envisioned to operate seamlessly in a wide range of environments, spanning urban, rural, remote, and unoccupied areas across the United States, and potentially the world. A paramount goal is to ensure that the deployment of this tracker does not impede the animal's natural movements and ability to carry out their tasks or lead their lives without interference, thereby allowing for discreet monitoring and research in various ecosystems.

Project Outcome

The anticipated best outcome was achieved.

Figures

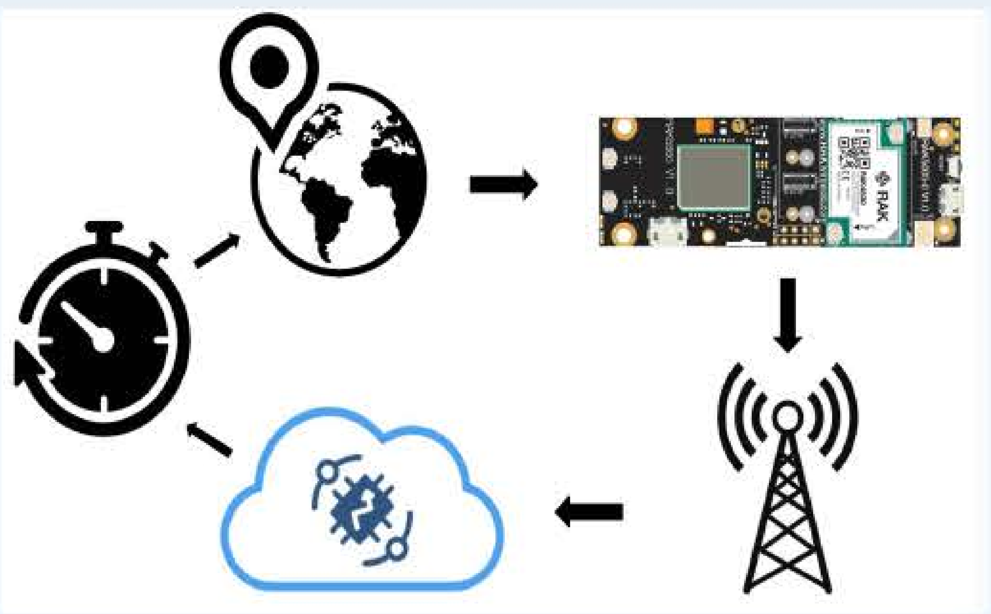


Fig. 1: This illustrates the module capturing location data, transmitting this data via the LTE network, and its subsequent display on the ThingsBoard Cloud user interface.

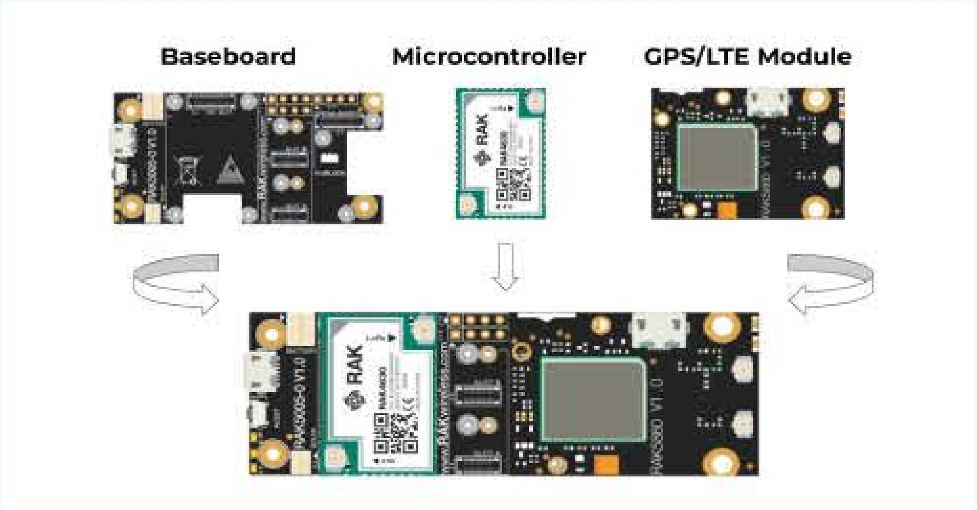


Fig. 2: This illustrates the device's three subcomponents: the baseboard, the microcontroller, and the combined GPS and LTE module.

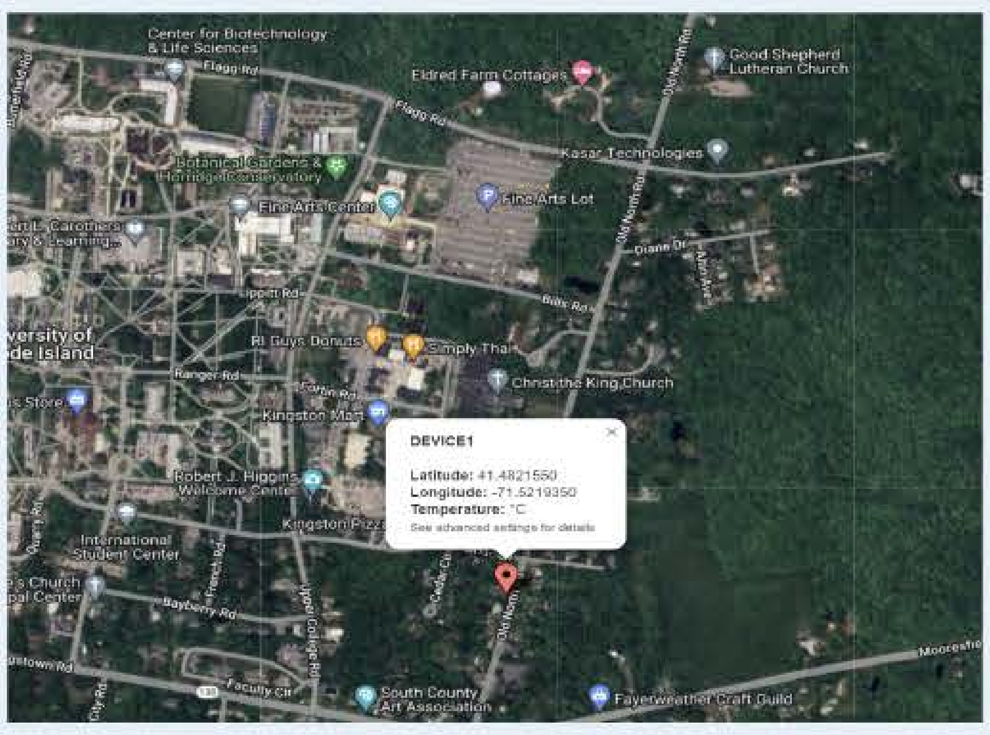
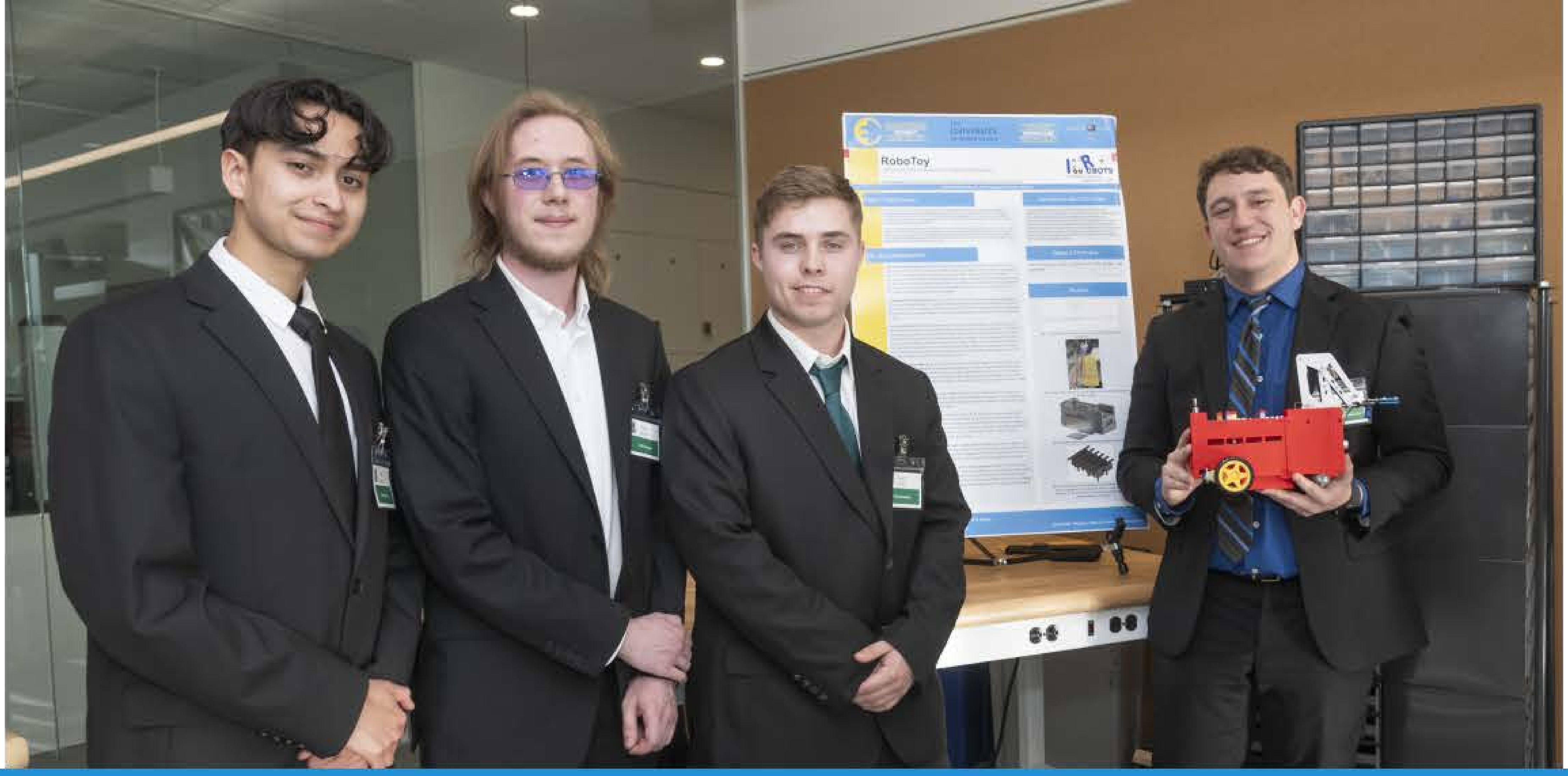


Fig. 3: This Thingsboard IoT map widget displays location data and its corresponding position on Google Maps.



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RoboToy

A Robotic Toy for K-12 Robotics and Programming Exposure

Team Members: Kyle DaSilva (CPE), Luis Medrano (CPE), Chris Glebus (ELE), Noah Doak (ELE)

Technical Director(s): Dr. Paolo Stegagno & Cam Amaral (URI-ELECOMP '23)

IC R OBOTS Intelligent Control and Robotics Lab

Project Motivation

Promoting and exposing kids to computer science by teaching them how to program will allow for a greater representation and access to technological professions. People with these skills will be able to have access to well-paying jobs that a community may not have been able to have access to prior. Along with this, increased participation by people from underrepresented groups in computing will promote diversity in the field and overall increase the number of workers in the field.

The tools for teaching programming and robotics in K-5 are still not as developed as they are in 6-12. Even though they have not exactly learned everything needed to do this, graphical programming tools have been introduced which allow learning programming foundational concepts in an easier setup. Developing this new robotic tool for early programming experiences will allow the best STEM education in Rhode Island as early as Kindergarten and specifically in the communities that need it the most.

Key Accomplishments

Instruction Scan Routine: When this project first began we were making the Arduino scan in each row and executing the command of that row. But we started to think of ways to change this and this is with reading in each row prior to executing them. These commands are read in through port c on the Arduino and then placed into an array. Once all the commands are scanned into the array the robot will begin executing the commands in order of the array. The bit strings in this array also hold the iterations with the commands. The first four bits of the string are the commands and the last four bits are the iterations.

DC Motors With Commands: When the robot is executing the commands these will trigger the DC motors in specific ways. For example, if the command is forward for 3 iterations this will tell the Arduino to turn on the servos moving forwards for 3 seconds. These commands can also tell the motors to go in reverse together or go in opposite directions depending on if it is turning left or right.

For Loop Command: When implementing a for loop into the available commands this would allow the robot to loop through however many commands that the user implements. The way this command would work is by having a for the block at the start of the loop and then an end block at the end of the loop with all the instructions wanted in between. When implementing this into a code we had to make sure the robot could loop through all these commands when it notices it is a for block. We implemented this by creating a vector that holds all the commands in this loop and this allows the for loop to have a dynamic amount of commands. The iterations on the "for" block will indicate the number of times this loop runs.

Ultrasonic Sensor With Arm: We created a function to find if an object is near the robot. This function has the ObsticleAhead variable automatically set to false unless the sensor detects an object 20 cm or less ahead. When there is an object detected the robot will stop in the middle of the current command and then it will trigger the arm to go down, grab the object, and move the object out of the way so the robot can move on. See the robotic arm and ultrasonic sensor in **Fig. 1**.

Start Button Code: A start button was implemented so that the robot wouldn't run before the coding blocks are fully inputted into the robot. When the button is pressed this will command the robot to begin reading in the commands and then execute these commands. This doubles as an emergency stop, in the event of an accident.

Design a PCB: The PCB, **Fig. 2**, is created to read in all 16 rows of 8-bit binary strings. Each row will connect to the output and each row represents its own command of the code. The buttons in this PCB were replaced with surface mount connections which would be connected by conductive material on the command blocks. When there is a connection this allows the bit to be read in as 1 otherwise that bit will be read in as 0. There are also LEDs on the PCB which indicates the row of the code that the robot is executing.

Chassis: The chassis is split into three parts to make assembly easier, as shown in **Fig. 3**. Two pieces make up the front, which contains the ultrasonic sensor, robotic arm, wheel bearing, and front bumper. The back chassis holds the Arduino Mega, On/Off switch, start/stop button, two motors, the PCB, power supply, power regulator, rear bumper, and any placed coding block.

Coding Blocks: These blocks are placed onto the PCB to operate the robot. The blocks have pins with a conductive material on the bottom. The pins complete a circuit within the matrix of the PCB, and depending on the circuit, the robot can do various commands. Most blocks have a command for what to do and a duration for how long to follow a command. Every block is labeled with its intended command, and most blocks have exchangeable duration segments. See **Fig. 4** for a visual representation.

Anticipated Best Outcome

The anticipated best outcome of the project is a fully functional prototype of a single robotic kit. This robotic kit includes a ground robot and coding blocks that can be replicated and delivered to K-5 classrooms around Rhode Island. This robot must be able to read a sequence of blocks that are inserted and execute the programmed blocks which could be going forward, going in reverse, or turning. Some special programming blocks will include for-loops and a robotic arm grab. The robot will also have sensors as well as include bumpers so the robot will avoid getting stuck.

Project Outcome

The Anticipated Best Outcome For this project was achieved.

Figures

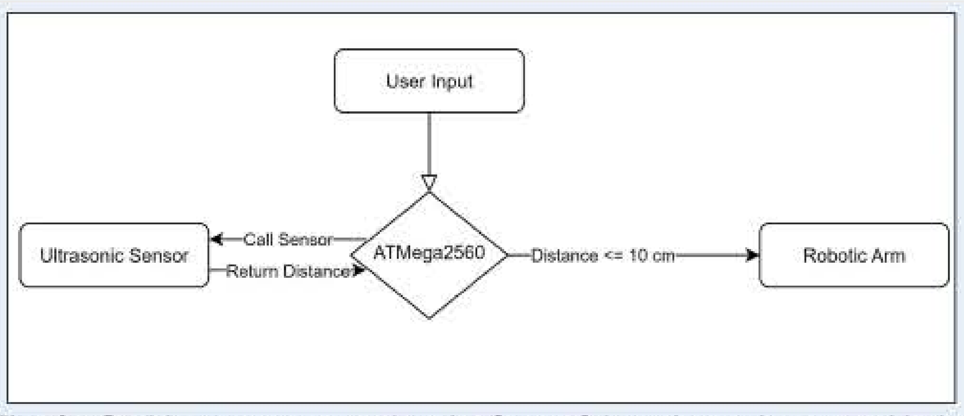

Fig. 1: Grabber arm mounted at the front of the robot to interact with the environment.

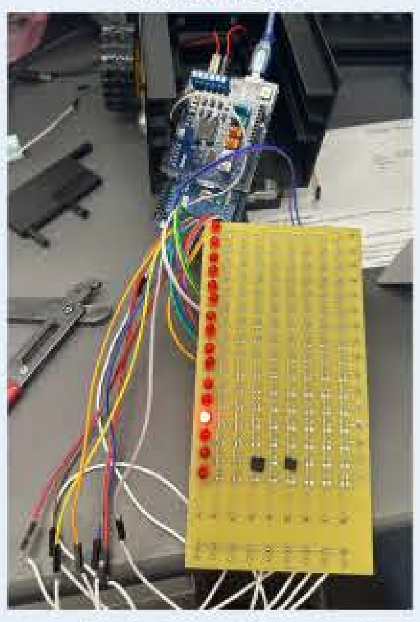

Fig. 2: PBA PCB connected to Arduino Mega, with conductive pads placed across contacts.

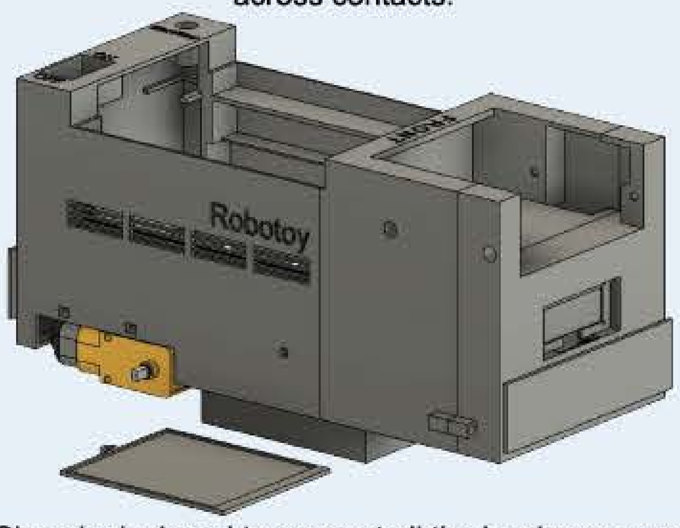

Fig. 3: Chassis designed to connect all the hardware components.

Fig. 4: Coding blocks with swappable duration sections. Here we have blocks to operate a for loop, right turn, left turn, move forward and backward. There are plans for more blocks to use the robotic arm, ultrasonic sensor, and buzzer.

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Standalone Cable Checker (SCC)

VICOR

Team Members: David Botelho (ELE), Anthony Cepeda (ELE), Nicholas Petrozzi (ELE)

Technical Director(s): Al Binder, Nathan Shake (URI-ELECOMP '20), Daniel Hartnett (URI-ELECOMP '21), Kristopher Keeble

Project Motivation

The motivation behind the development of the standalone cable checker lies in addressing the often overlooked but critical aspect of testing the connections from the Automated Test Equipment (ATE) to the Printed Circuit Board (PCB). In the intricate process of IC testing at Vicor, issues arising in these connections are typically resolved by replacing cables, contributing to wastage and increased expenses. The standalone cable checker aims to revolutionize this approach by offering a tool specifically designed to diagnose and transparently report issues within these connections. By providing a detailed and user-friendly interface, the cable checker not only expedites the debugging process for in-house Test Engineers but also serves as a remote diagnostic tool for Contract Manufacturer (CM) technicians. This innovation seeks to save both time and money for Vicor, ensuring efficient debugging, reducing cable wastage, and facilitating remote issue resolution, particularly in instances where CM testing occurs across different time zones.

Key Accomplishments

- **Finalized PCB Layouts with Altium Design:** We carefully designed the layouts of the Main Board and both Daughter boards using Altium Designer software, paying close attention to every trace, component placement, and signal routing to achieve optimal performance and compatibility.
- **Procured Boards from JLCPCB:** The Gerber Files and Drill Files for all three PCB Boards were compiled and forwarded to JLCPCB for fabrication.
- **Sourcing Electronic Components:** Through Digikey and Samtec, we selected each electronic component required for our project. Every item was chosen for its quality and compatibility, ensuring reliability of our system.
- **Assembly and Testing of Boards:** With the arrival of the sourced components, our team assembled and soldered all three boards. Additionally, VICOR replicated our assembly process for quality assurance purposes, subjecting each board to multiple tests, including continuity tests, to validate the integrity of connections and functionality.
- **Implemented Test Code for Cable Verification:** We implemented test code tailored specifically for verifying the integrity of all cables. This allowed for a foolproof Standalone Cable Checker (SCC), ensuring a flawless operation with a 100% success rate.
- **Modification of Housing Unit:** With precision tools, we began the process of modifying the housing unit to accommodate our electronic assembly. Every marking and cutout was meticulously guided by precise measurements and careful planning. A test fitting validated the accuracy of our modifications and ensured a seamless integration of components.
- **Final Touches and Delivery:** The housing unit underwent painting, to enhance its aesthetic appeal and durability. Also, labels were printed to bear essential information for end-users. With these details attended to, we were able to delivery the final product.

Anticipated Best Outcome

The best anticipated outcome was achieved. The project's focus was the development of a self-contained cable checker (SCC), featuring a custom PCB capable of accommodating diverse cable connections for comprehensive testing. The integration of a precision controller empowers the cable checker to conduct accurate tests, presenting operators with clear visual indicators—efficiently distinguishing between functional (good) and faulty (bad) cables. This streamlined tool aims to significantly enhance the testing and debugging process at Vicor, promoting efficiency by swiftly identifying cable issues. The anticipated best outcome underscores the creation of a user-friendly, versatile solution that not only expedites the debugging process for Test Engineers but also contributes to substantial time and resource savings in IC testing.

Project Outcome

The project successfully delivered the anticipated best outcome, creating a user-friendly, versatile self-contained cable checker (SCC) with a custom PCB and precision controller for comprehensive testing at Vicor. The streamlined tool efficiently distinguishes between functional and faulty cables, significantly enhancing the testing and debugging process for Test Engineers while promoting efficiency and substantial time and resource savings in IC testing.

Figures

Figure 1: Team VICOR's Standalone Cable Checker

Figure 2: Assembled Main PCB (top)

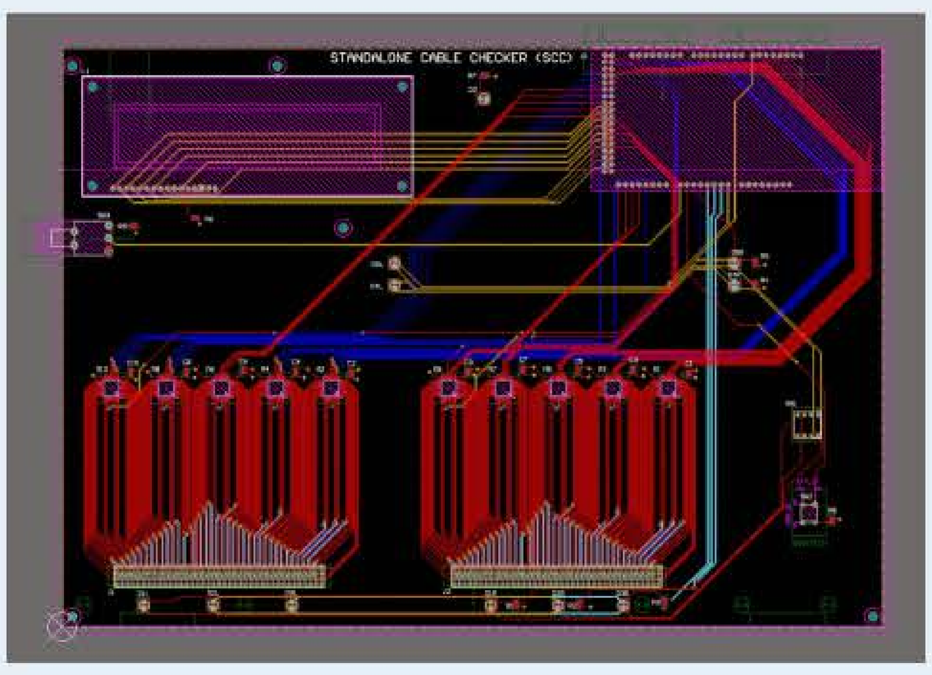

Figure 3: SCC Main PCB Altium Layout (top)

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Automated Cable Transitioning System (ACTS)

VOLTSERVER
DIGITAL ELECTRICITY™

Team Members: Andrew Brown (ELE), Brian Piwonski (ELE), Wesley Hardesky (ELE), Daniel Bradley (CPE)

Technical Directors: Andre Costa (URI-ELECOMP '23), Zach Chofay (URI-ELECOMP '23) Camilo Giraldo (URI-ELECOMP '17)

Project Motivation

Voltserver has developed a test procedure for cables in order to confirm compatibility with their Digital Electricity system, which consists of obtaining various characteristics of the cable by taking measurements of 100' increments up to 600' of total length. Each cable being tested is divided into 100', 200', and 300' sections, and these sections are combined to test 400', 500', and 600'. Currently, this process requires that someone is present in order to swap the lengths during various points of the test. Voltserver is looking to automate this process so that the tests can be run unattended, which will relieve employees from the distraction of having to interrupt what they are working on in order to change cable lengths. This will allow the Voltserver team to work more efficiently and will reduce the amount of time that the tests will take as well since they will no longer rely on someone interrupting their work in order to swap cable lengths.

Key Accomplishments

- **Labjack Logic Implementation:** The control system for the ACTS is centered around a Labjack T4 Data acquisition device, which will be controlled using C# based scripts hosted on a local computer. The Labjack T4 has much of the functionality that is required for the implementation of ACTS such as PWM capabilities and libraries for implementing I2C and SPI communications, and it also easily conforms to the current testing environment of Voltserver, which heavily revolves around other models of Labjack.
- **Design of System in CAD:** Before setting out to build the ACTS system, it was first necessary to design many custom components from scratch. Much of this work was done in SolidWorks, and this allowed the group to make many design decisions long before the assembly process started.
- **Realization of CAD Design:** Although the use of CAD software allowed for the creation of the custom parts required for ACTS, there were a few compromises that needed to be made in order to manufacture the components. One of the main issues faced by the ACTS team was the lack of access to a reliable large format 3D printer. Because of this, many of the 3D printed parts needed to be strategically broken up through the use of dovetails in order to allow them to be printed on smaller form factor printers while minimally altering the structural integrity of the system.
- **Design of Switching PCBs:** The design of ACTS revolves around a "main" multi layer PCB which is responsible for making the connections between cables, and eight smaller single layer "contact" PCBs which feed the cable into the system. The state of the cable length configuration is altered by rotating the main PCB 7.5º, after which it is forced against the smaller contact PCBs which allows the connections between the cable samples to occur resulting in the desired length.
- **Design of Hardware Control System:** Although the Labjack can be considered the "brains" of the ACTS, it is by itself incapable of driving the stepper motor and four linear actuators that are used in the system in order to make cable connections. Because of these different, incompatible motor types, there are two types of motor drivers in the ACTS system. The first is a stepper motor driver that is capable of micro stepping, a process which allows the inherent number of steps that a single revolution of a stepper motor is broken down into to be broken down into even more steps to achieve more positioning capability at the cost of speed. This is necessary, because most stepper motors have 200 steps, which would not allow for the desired 7.5º of rotation to be achieved. The second type of driver is a brushed DC motor driver designed specifically for the linear actuators that are used to raise the main PCB into position.

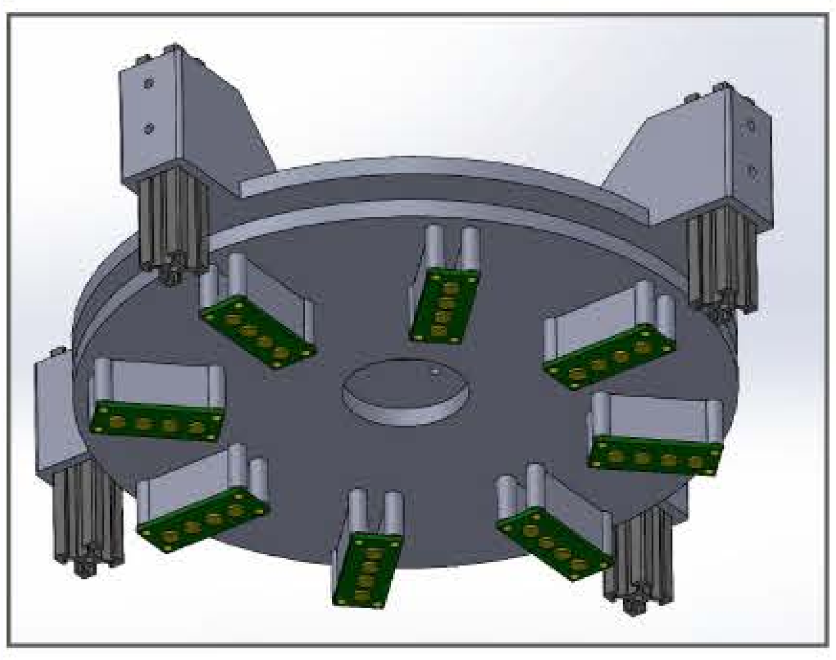

Figure 3: Split view of the ACTS assembly in SolidWorks, showcasing the top half with smaller "contact" PCBs mounted.

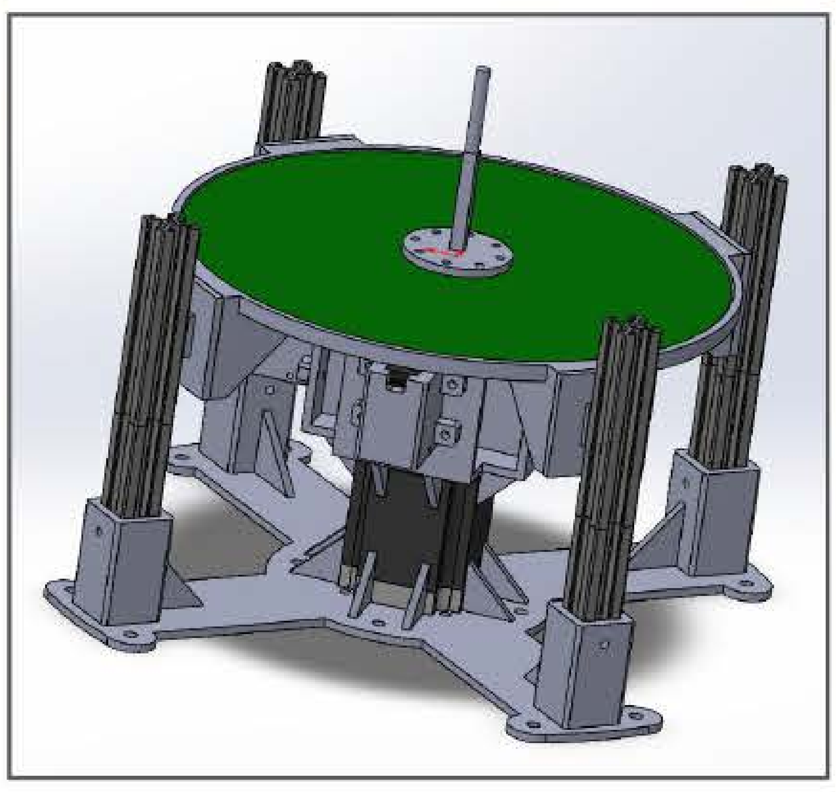

Figure 4: Split view of the ACTS assembly in SolidWorks, showcasing the lower half which contains the stepper motor, linear actuators, and main PCB.

Anticipated Best Outcome

The Anticipated Best Outcome is a functional prototype of a system which uses a Labjack measurement and automation tool to interface with Voltserver's cable tester to automatically change the length of cable during tests. This device must be able to connect single sections of cable to the tester as well as combine multiple sections in order to achieve longer lengths. The device must then be able to connect both ends of the length being tested to the cable tester. The ABO will also have the proper channels for communication with VoltServer's existing cable testing hardware.

Project Outcome

The ABO for this project has been achieved. We have demonstrated an automated cable switching prototype, as well as developed software to integrate with VoltServer's testing API. Moreover we achieved the reach goal for the system's size requirements. The extent to which the system affects the test measurements will be evaluated by VoltServer. .

Figures

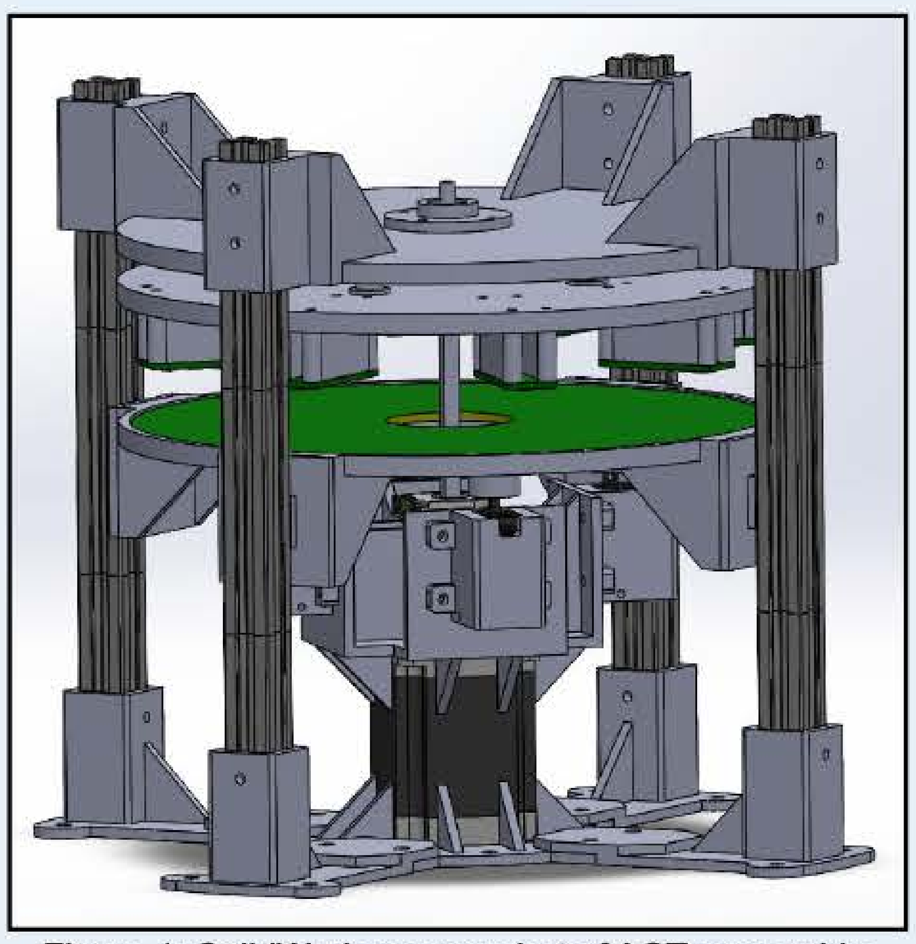

Figure 1: SolidWorks screenshot of ACTs assembly.

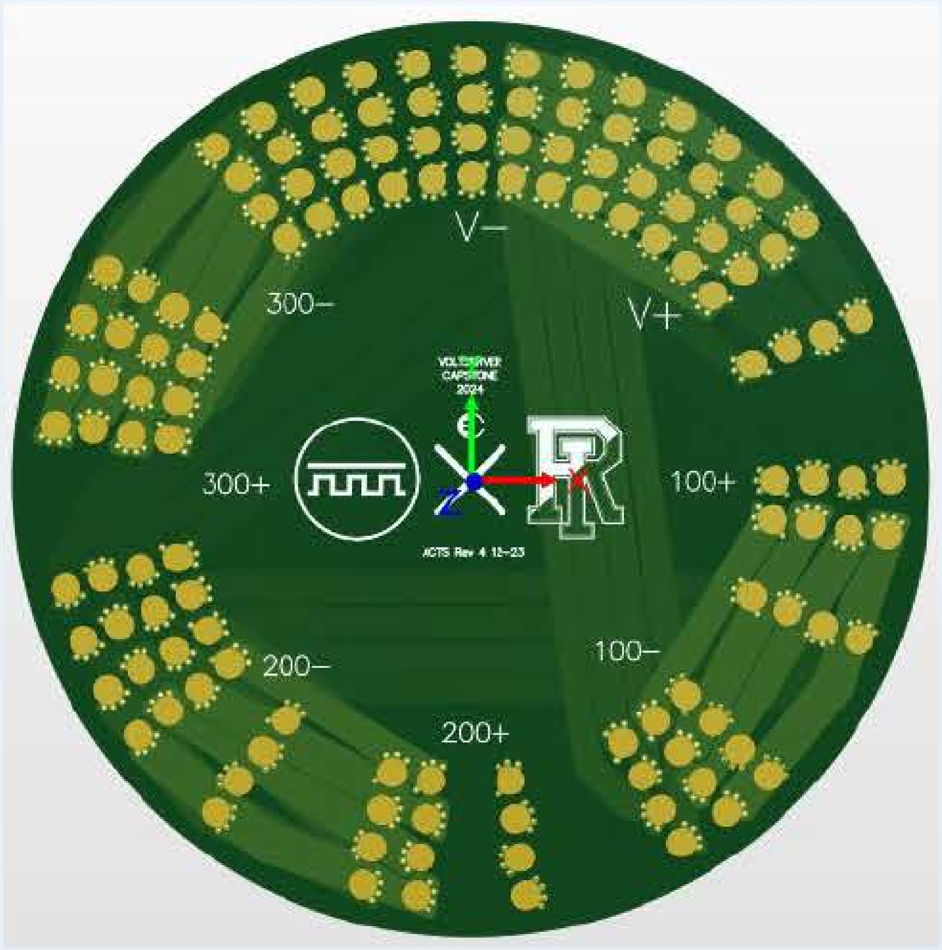

Figure 2: Altium Designer screenshot of the main PCB

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Vocal Motion

A Spatially Aware Voice Controlled 5-Axis Robotic Arm Powered by XCORE.AI

XMOS®

Team Members: Derek Raffetto (CPE), Mason Jacob (ELE)

Technical Director: Andrew Cavanaugh (URI'08) | Consulting Technical Director: Brenden Smerbeck (URI-ELECOMP '17)

Project Motivation

The Vocal Motion project is a result of collaboration efforts between the URI ELECOMP Capstone Design program and XMOS with the aim to demonstrate the capabilities of the XMOS xcore.ai processor. XMOS is currently shipping their 3rd generation of the xcore.ai, an advanced dual core microprocessor capable of parallel processing, neural network optimized computing, and high performance I/O in a low power and small footprint package. The latest generation adds a significant boost in AI processing power while retaining the deterministic, responsive IO processing that made their first generation so successful.

The goal of Vocal Motion is to construct a tangible AI enabled device that serves as a demonstration and embodiment of XMOS's engineering prowess and innovation. The project will showcase local speech recognition, motor/device control, and advanced AI capabilities of the xcore.ai and support both marketing and direct sales opportunities in the future.

Key Accomplishments

Development Container: To facilitate and expedite software development with the XMOS XTC toolkit and VOICE SDK, The team developed a docker development container running on the latest version of ubuntu with all the necessary tools installed, including GTKWave for simulated signal analysis.

Basic Voice Recognition: The team has generated a Sensory VoiceHub voice recognition model. Voicehub makes it easy to create these models, and a non-final sample model has been created for eventual testing purposes with the arm.

Basic Kinematics: Basic inverse kinematics have been created in software using the damped Jacobian method. The method boils down to partial derivatives and solving an inverse of a non-square matrix to find out which angles to change. It then repeats this process until the angles are appropriate to create the desired point in space. The damping factor alters this so the kinematic equations do not get stuck trying to create an angle orientation that is not allowed.

Debugging XMOS Development Board: We ran into an issue when trying to use the 3.3 volt breakout board. We needed this 3.3v signal because the TMC5160 runs on either 3.3v or 5v I/O voltage. The 3.3v breakout headers seemed to be off. However, using the 1.8v test connections, we were able to produce the correct signals. This led us to finding the physical level shifter on the development board. We found that the Enable Pin was off. After time and research, we discovered that this Enable Pin is enabled over I2C on the board. You may wonder how we had used the 3.3v previously. It turns out that the development board was pre-flashed with the SDK that had this Enable Pin set high. However, we flashed our own code, undoing this action. The solution was simply to reflash the SDK.

Debugging TMC5160T Stepper Motor Driver SPI Communication and Internal Ramp Generator: We ran into many problems when attempting to communicate with the stepper motor driver over SPI to drive the motor with the internal ramp generator, rather than having to supply a step signal and reducing the amount of expansion I/O we would have. We first found that the level shifter was not enabled on the XMOS dev board, and then after a lot of schematic and datasheet analysis discovered that the drivers we received were in the wrong mode by default from the factory. We were able to resolve this by removing a very small 0Ω resistor and solder bridging a different pad. Afterwards, we were able to successfully get full SPI communication with the internal ramp generator.

Porting TMCStepper Library: There already existed a robust and complete Arduino library for the TMC5160 digital drivers we used. The library was very well made in the capacity that it abstracts away low level functionality. Porting involved changing the Arduino specific calls and switching to the XMOS SPI communication implementation. We also had to make some simple architectural changes to combine C and C++ files together.

Parallel Execution: While we would have loved to use the SPI only mode offered by the TMC5160, we could not get it to consistently function. Instead we pivoted to using the STEP pin to manually send the STEP signal from the microcontroller. To send multiple step signals at the same time however, required using the robust and intuitive parallel functionality of the XCORE.ai. Each XCORE has 2 tiles, and each tile has 8 cores. That means we can use 5 of these cores to control the STEP pins, and a sixth core to send SPI signals to monitor the stallguard. We originally wanted two XCORE's so the other could be used for more imaging, but unfortunately, getting the TMC5160's to function properly proved more time consuming and difficult than originally thought.

Full Assembly of Robotic Arm: The arm was fully assembled. This consisted of using the original and outdated BOM for the BCN3D MOVEO and updating with new, easily accessible components. Furthermore, the components were ordered, and numerous 3D printed components were printed over multiple months. Linear rods were cut and turned on a lathe to a precise length, and the entire arm was assembled.

PCB: An in-depth schematic and PCB layout were created for the circuitry required to integrate the robotic arm with the XCORE.AI. A dual package setup was chosen, and TMC drivers with a common footprint were selected so that a board could be created in a modular fashion, allowing for hot-swapping of stepper motor drivers. The schematics were created with a hierarchical multi-channel design, allowing for repeated sections of the PCB to be copied and pasted. Any extra pins on the board were attached to an I/O expansion header to allow for further customization. The finished PCB was cut and assembled by JLCPCB.

Anticipated Best Outcome

Vocal motion aims to construct and fully implement the logic for successful control of a spatially aware voice controlled 5-axis robotic arm. The completed project will consist of the following components and specifications:

Hardware:

- 3D printed robotic arm
- a custom modular PCB with easy driver replacement and I/O expansion options
- camera and microphone peripherals

Software:

- forward and inverse kinematics
- speech recognition
- NLP (natural language processing) neural network
- object detection neural network
- G-CODE control interface.

Project Outcome

The anticipated best outcome of the project was achieved. A 3D printed robotic arm was built, a PCB was created, and a voice model to controlled the system was implemented.

Figures

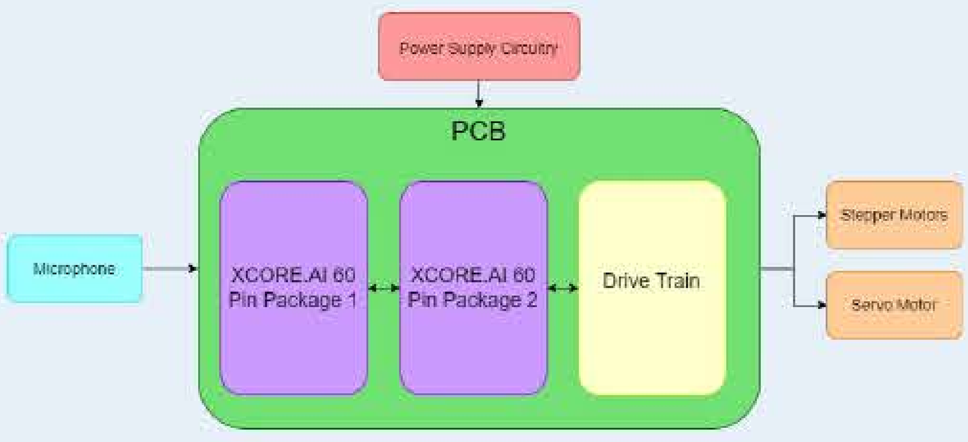

Fig. 1: Simplified Block Diagram. The voice commands are captured by the microphone as an input on the left, the XCORE.AI packages comprehend the command, make calculations to move the motors of the arm based on the commands, and then send the necessary commands to the stepper motor drivers to drive the motors.

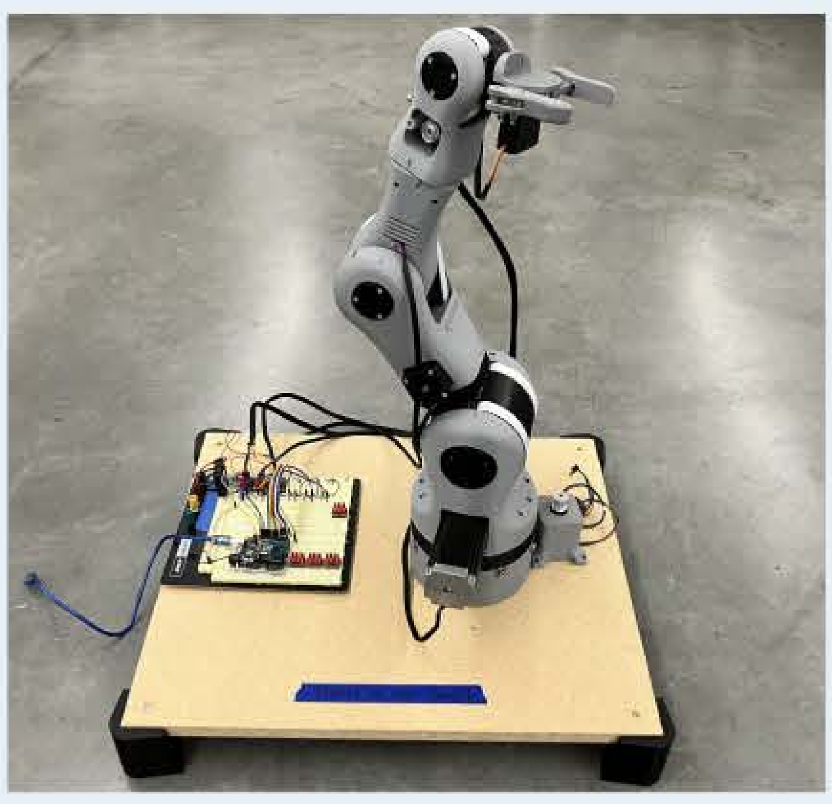

Fig. 2: Fully Assembled BCN3D MOVEO 5-Axis Robotic Arm. Components for the arm were sourced, all the large structural components were 3D printed, and the arm was assembled.

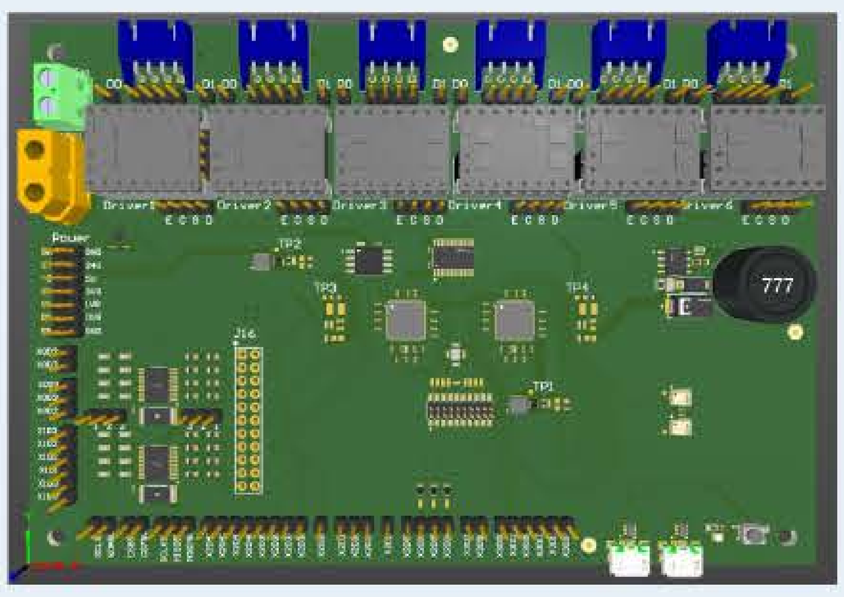

Fig. 3: 3D Render of the PCB in Altium Designer. The top of the PCB consists of the 6 stepper motor driver ports and outputs, which allows the dual 60-pin XCORE.AI packages to drive up to 6 motors at once. The perimeter of the board also includes numerous headers for I/O expansion, two USB ports for external powering and debugging, two SMD microphones, and power supply conversions from 24V to 5V, 3.3V, 1.8V, and 0.9V.

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Project Emilia

Wireless Enablement of Green Power Technologies for Edge Devices

ZEBRA

Team Members: Eddie Perez (CPE), Allen Liu (CPE), Andrew Ou (CPE), Alan Piwonski (ELE), Joseph Daiaa (ELE), Lucas Frost (ELE), Nick Fedorenko (ELE/CPE)

Technical Director(s): Joe Moreira and Bradley Willard

Project Motivation

Zebra Technologies is dedicated to advancing environmental and social responsibility through a project designed to meet stringent governance goals. The primary focus of this initiative is the substantial enhancement of the power efficiency inherent in Zebra products. This improvement is sought through the integration of converging technologies, with a special emphasis on wireless functionality. The project strategically utilizes wireless communication to facilitate data exchange and coordination among devices, eliminating the need for physical connections. Furthermore, a key aspect of the endeavor involves optimizing the timing of sensing and charging activities to align with periods of peak renewable or green energy availability. By synchronizing operations with environmentally favorable conditions, Zebra aims to significantly diminish the carbon footprints associated with millions of its devices across the globe. This project underscores Zebra Technologies' commitment to a sustainable and globally impactful approach to technology development, reinforcing the company's position at the forefront of environmentally conscious innovation.

Key Accomplishments

Prototype Board: A custom prototype board was designed, fabricated and assembled. This board integrates the entirety of the hardware components represented in the block diagram **Fig. 1** of our project. This has allowed us to program a singular system to run all the software applications, such as transfer data into a cloud server displayed to a web app. This component allows us to realize a proof of concept that our Emilia subsystem can establish a charge enable signal when the green energy found within a power grid is at its maximum.

Working WiFi MQTT Code: An application developed for the nRF7002DK board transmits telemetry data in JSON format to Azure IoT Hub using the secure MQTT protocol. Enhanced with nRF Connect and Zephyr for efficiency, it employs custom Certificate Authority chains for additional security, aligning with IoT communication standards.

Working Project Emilia Bluetooth LE service: A custom Bluetooth LE service for Project Emilia has successfully been created and implemented. The purpose of this service is to provide the method in which desired information about the Emilia subsystem can be broadcasted out via BLE, to be read and interpreted by an external application. Characteristics have been defined to broadcast data relating to voltage/current/power measurement data, timestamp information, charge enable signal status, wifi connection status, battery charge information, and renewable/non-renewable energy ratio. As shown in **Fig. 3**, the voltage/power/current measurement data can be successfully retrieved from the INA260 measurement peripheral using I2C and broadcasted out via BLE. All other characteristics broadcast predefined sample data stored in non-volatile storage upon initialization of the application.

Working Real-time Clock PCF8523: An external IC for the real-time clock was properly implemented with the nRF5340 DK board in communication via I2C. A basic small driver for the pCF8523 was also created with two functions. One to configure the time and date on startup of the system, and one to get and print out the current time and date in European time format. The purpose of the real time clock was to allow the Emilia subsystem to maintain the accurate time and date, including in the event of a power outage or system disconnection. This time and date was to be used for the timestamping of charge times for the user.

Watchdog Timer: Code for the watchdog timer was built and successfully flashed to the board. The watchdog timer is to be used to automatically reset the system in the event of a system failure or latch-up. The watchdog timer is infinitely fed a signal, periodically, to indicate the proper functionality of the system. If the watchdog timer does not receive a signal within a set time frame, the system will be initiated to reset in an attempt to correct the latch-up.

Azure API: The WattTime Application Programmable Interface was successfully implemented in the Azure API Management Service. The API can directly retrieve real-time data within the management service and outputs the various information such as the CO2 forecast, historical data, and more as depicted in **Fig. 2**.This data will be used to create a web application in order to visually display the data and determine charge times.

Web App: A web application, **Fig. 4**, visualizes battery analytics from the Azure IoT hub and energy production data from the EIA on user-friendly graphs. It compares renewable and non-renewable energy sources to trigger a charge enable signal to the board, enhancing energy efficiency.

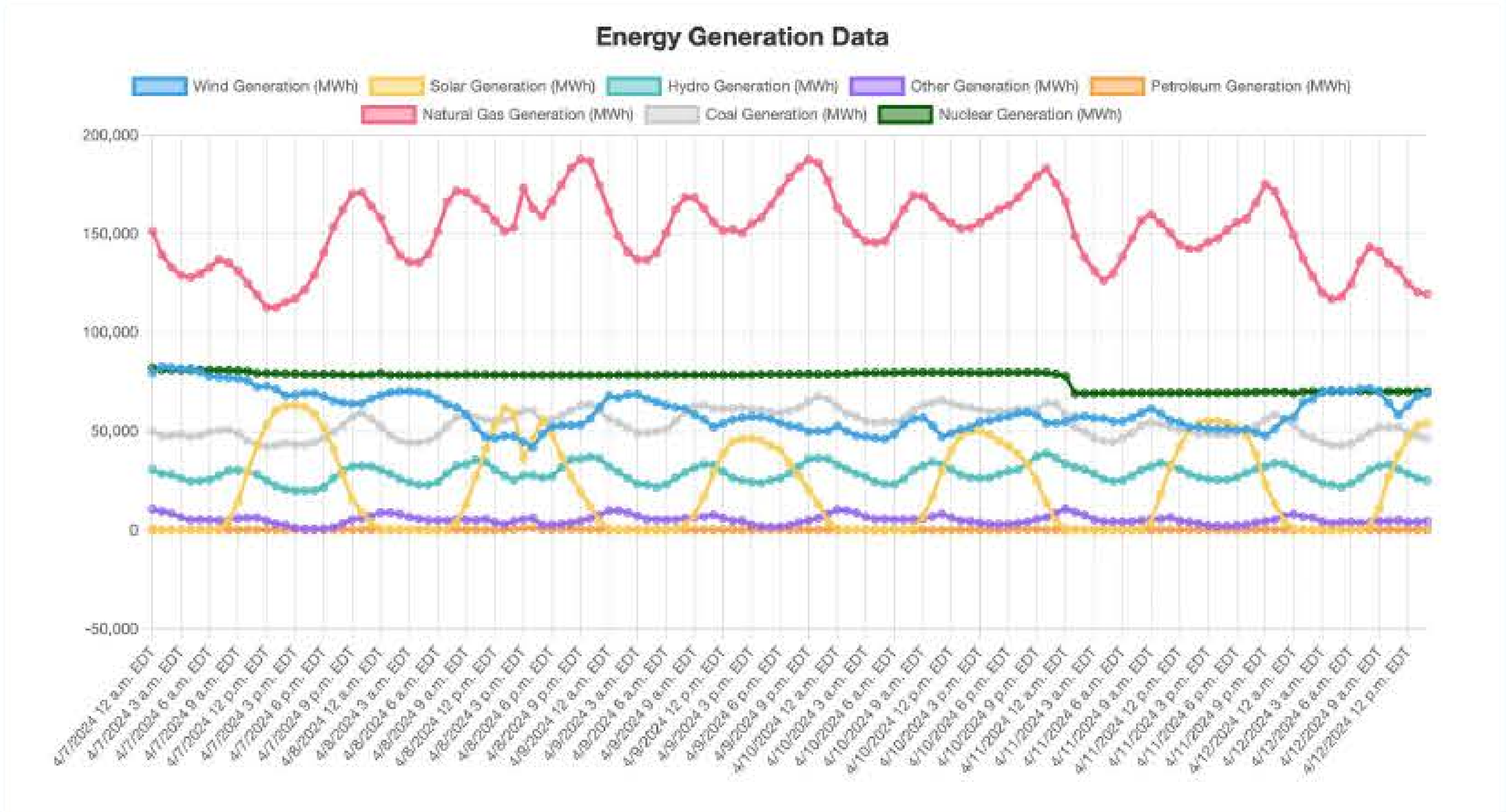

Figure 4: Energy Generation Graph from Web App

Anticipated Best Outcome

As initially defined in the project specification, the anticipated best outcome of the project was to fully realize working mockups of a dual Wifi/Bluetooth-based architecture at the test fixture and pre-EVT (Engineering Validation Testing) levels. This subsystem will be capable of determining the optimal time to charge batteries within Zebra products based on when renewable energy on the local utility grid is at a maximum. While charging, the subsystem will be able to track the energy charged into the battery and its renewable/non-renewable energy ratio. This information will be periodically updated into a cloud service provider and dashboard.

Project Outcome

We have partially achieved our ABO. The development of individual components has been successful, but the integration into one singular system has fallen short.

Figures

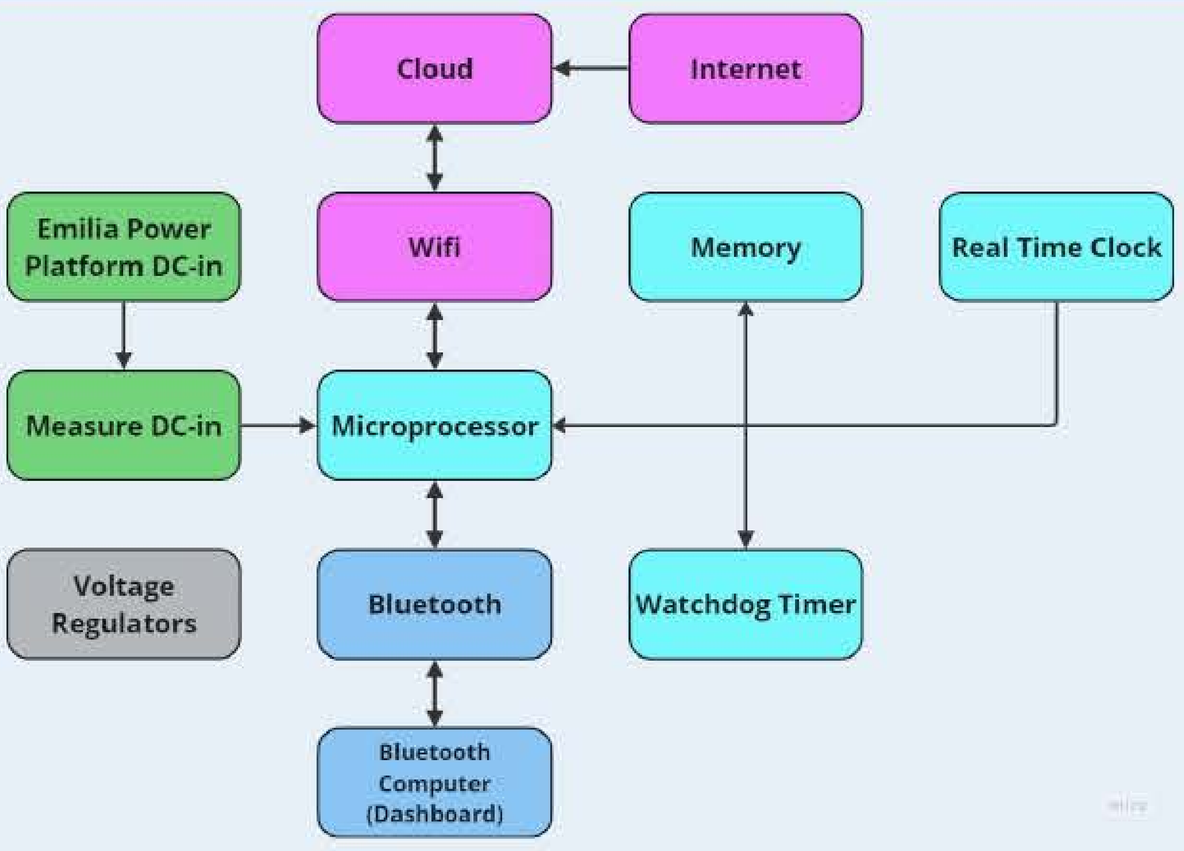

Figure 1: Functional block diagram of the Emilia sub-system

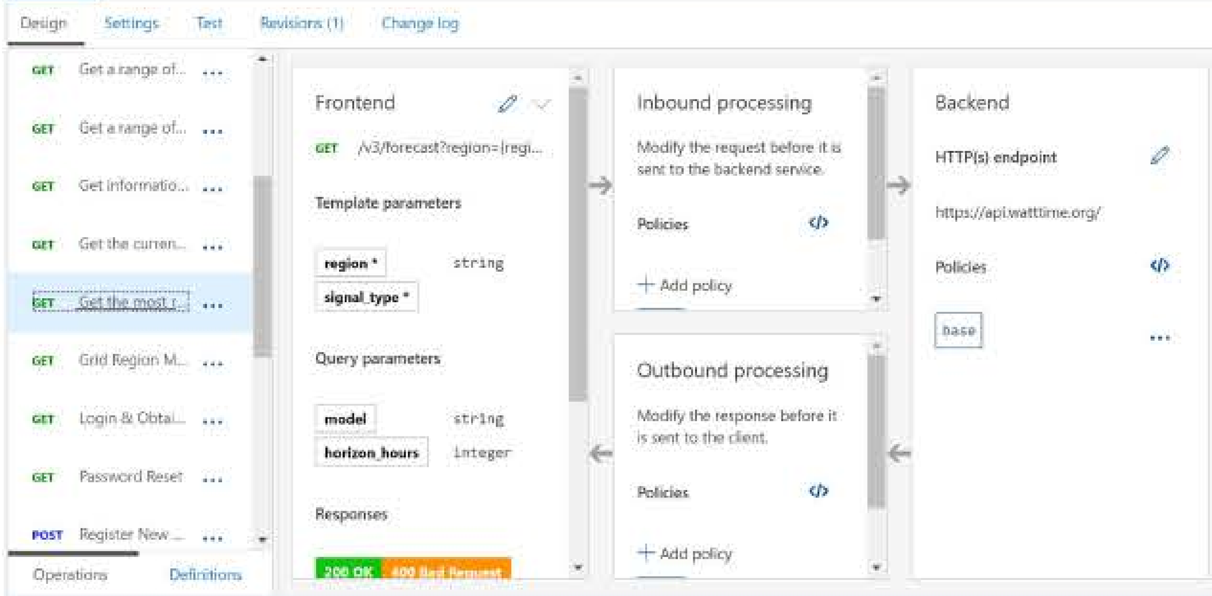

Figure 2: Azure API Management Service Functions

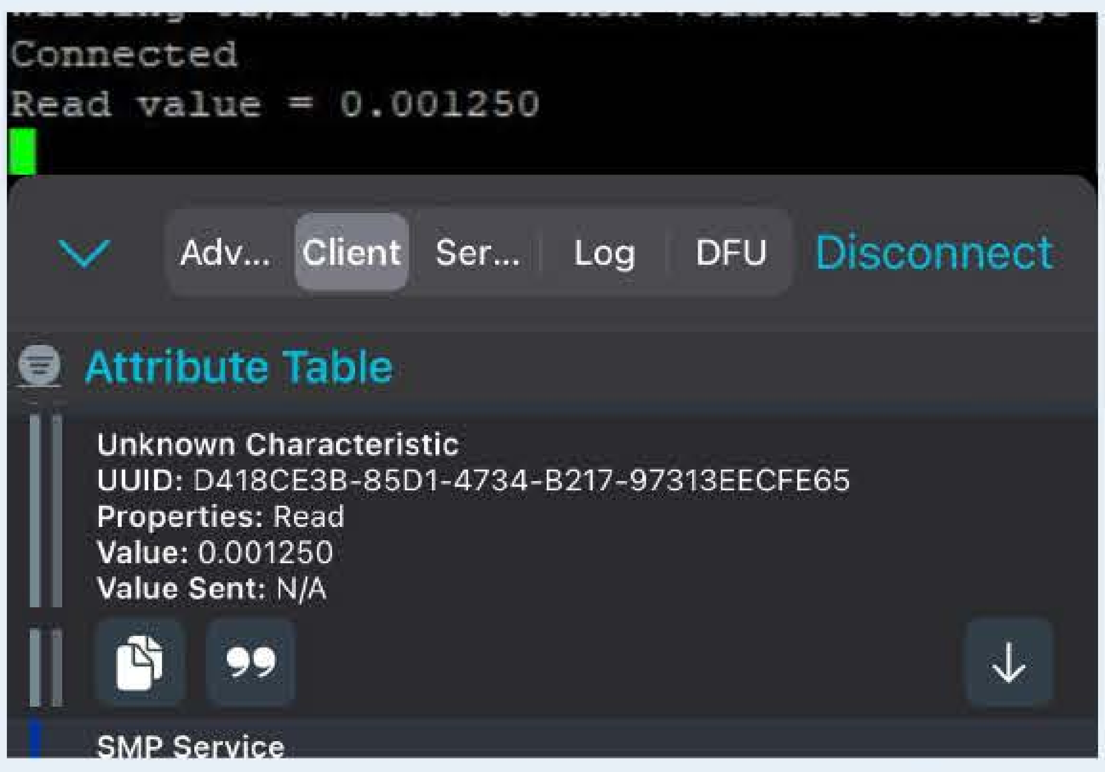

Figure 3: Voltage measurement data read from the INA260 being successfully broadcasted over BLE

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THE UNIVERSITY OF RHODE ISLAND

ENGINEERING
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FRIDAY, APRIL 19th, 2024

THINK BIG WE DO™

Blitz

Energy Harvesting (Photovoltaic) to Power a Patient Tracking Bluetooth Angle-of-Arrival Locator

ZEBRA

Team Members: Alexis Estrada (CPE), Fatima Lynch-Smith (ELE), Casimir Ryan (ELE)

Technical Director(s): Timothy Vermilyea, David Teal, and Mike Smith (URI'01)

Project Motivation

The Blitz Locator Project aims to establish a comprehensive patient tracking system within hospitals, integrating a Bluetooth beacon module into standard wristbands produced through a Zebra printer and a Locator. The beacon, affixed to a patient's wrist, utilizes Angle-of-Arrival (AoA) technology, boasting a minimum 14-day battery life. The primary objective is to achieve a 99% accuracy in precisely locating a patient's room. AoA Locators strategically placed on facility ceilings monitor the area for Beacons using an antenna array, calculating the signal's angle of arrival. These Locators transmit acquired angles, including azimuth and elevation, to a Positioning Engine via Wi-Fi. The Engine then computes X-Y coordinates, ensuring sub-meter precision, potentially as precise as 30 centimeters (12 inches), through a well-placed network of Locators. The Locator would utilize energy harvesting to ensure that installation time is kept under two minutes, eliminating the need for wiring.

Key Accomplishments

PV Cell Evaluations: Evaluated and analyzed technical datasheets from Ambient Photonics, Epishine, WSL, Exeger, Dracula Technologies, Panasonic, Solems, Lightricity, Trony, and Power Film. We are documenting PV cell specifications to use for a Pros and Cons list. We contacted manufacturers for data that was missing from the data sheets. We've collected information related to voltage and current at the maximum power point, open circuit voltage, short circuit current, and power density. This information will be valuable as we decide which PV cell is best suited for the Locator.

Lux Data Collection: We researched key information for light meters and selected a professional-grade lux meter for testing. We decided to use the HOBO MX1104 data logger. We developed a method to test lighting conditions for different areas of a hospital. We measured the area of the room and took lux measurements at various locations and angles. We conducted lux data collection in non-patient rooms and general areas at Rhode Island Hospital.

PV Cell Testing and Solar Simulator: We ordered WSL, GCell, PowerFilm, Dracula, Epishine, Exeger, Ambient Photonics, Lightricity, and Panasonic sample cells for testing**.** We've designed a prototype solar simulation box to test photovoltaic cells under controlled settings **(Fig. 1)**. The device is 3D printed and has a variable removable light source. and the box doesn't allow outside light to affect the PV cell. With this device, we determined PV cell performance under specific lux conditions that simulate real hospital conditions.

Energy Storage: We researched energy storage methods and have explored using supercapacitors in conjunction with a lithium-ion battery because supercapacitors are devoid of heavy metals and detrimental chemicals, decreasing their carbon footprint when compared to lithium-ion batteries. We also researched different circuit configurations and their applications.

PV Cell Selection: We conducted testing using a source and storage element circuit design. This design allowed us to gather the necessary data required to determine which PV cells perform the best under various lighting conditions and angles. This data resulted in our top contenders that will be competing for their final implementation in the Blitz Locator design. For testing, we used an RC circuit consisting of a 3.3k resistor and a 0.47 Farad supercapacitor **(Fig. 2)**. The Nordic Semiconductor Power Profiler Kit II was used for current measure
ments.

Designed Angled Test Fixtures: These test fixtures are designed to hold a small breadboard that contains all the necessary equipment for our data collection process. Each tester is fixed at an angle ranging from 25-50 degrees and is used to test PV cells in real world settings **(Fig. 3).** The PV Angler was affixed to the ceiling using a magnet. The Power Profiler Kit II was used to measure current and charge. The specific spot on the ceiling was marked for uniform testing **(Fig. 4)**.

Anticipated Best Outcome

The best outcome is :

- A thorough assessment of selected photovoltaic (PV) cells.
  - Evaluation of diverse lighting conditions, different light sources, orientations, and size/surface area variations.
- Identification of the top two leading candidates for PV cells.
  - Pricing information for the specific form factor will be obtained, and discussions with Zebra Commodities will be initiated.
  - Development kits and/or samples will be acquired from various suppliers.
- Testing of power production capabilities of the various PV cells.

Project Outcome

We were able to meet the anticipated best outcome. Zebra Technologies was provided with a full report outlining the testing process, test results, and top two contenders for the final design.

Figures

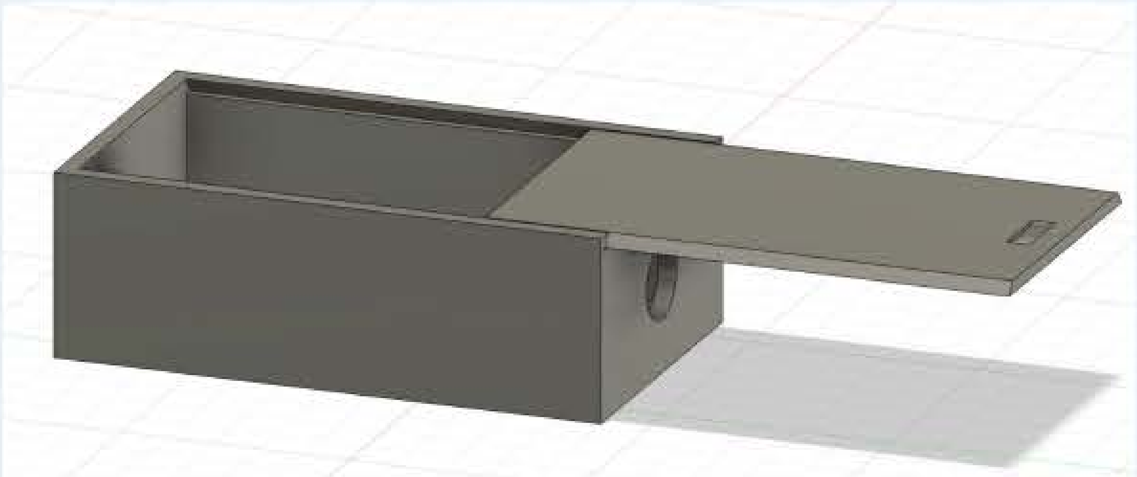

Fig. 1: Solar simulator box drawing in Fusion 360

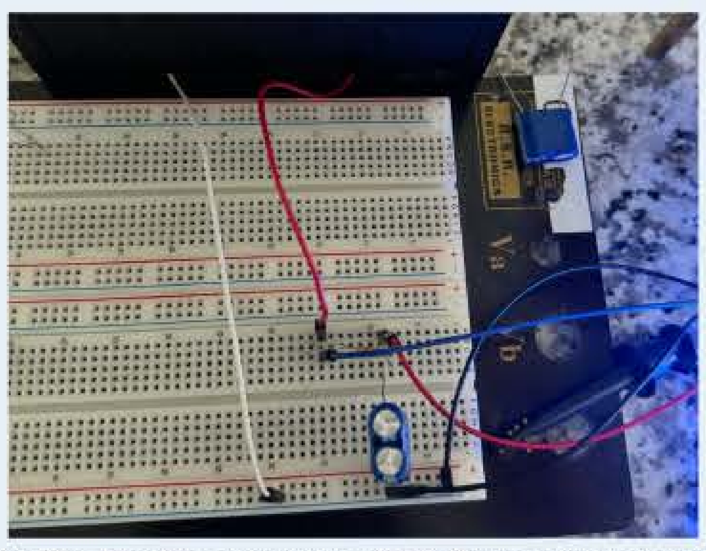

Fig. 2: RC circuit consisting of a 3.3k resistor and a 0.47 Farad supercapacitor

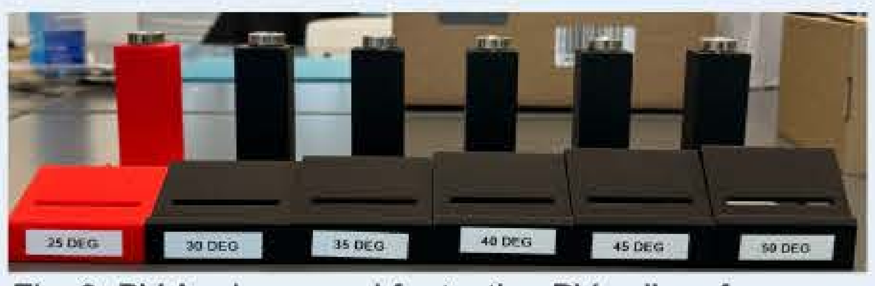

Fig. 3: PV Anglers, used for testing PV cell performance

Fig. 4: Testing a PV cell at a specific angle with the PV Angler and Power Profiler Kit II

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