Dwight Look College of
ENGINEERING
TEXAS A&M UNIVERSITY

ECEN 404 Final Presentation
Team 41: Roombotics

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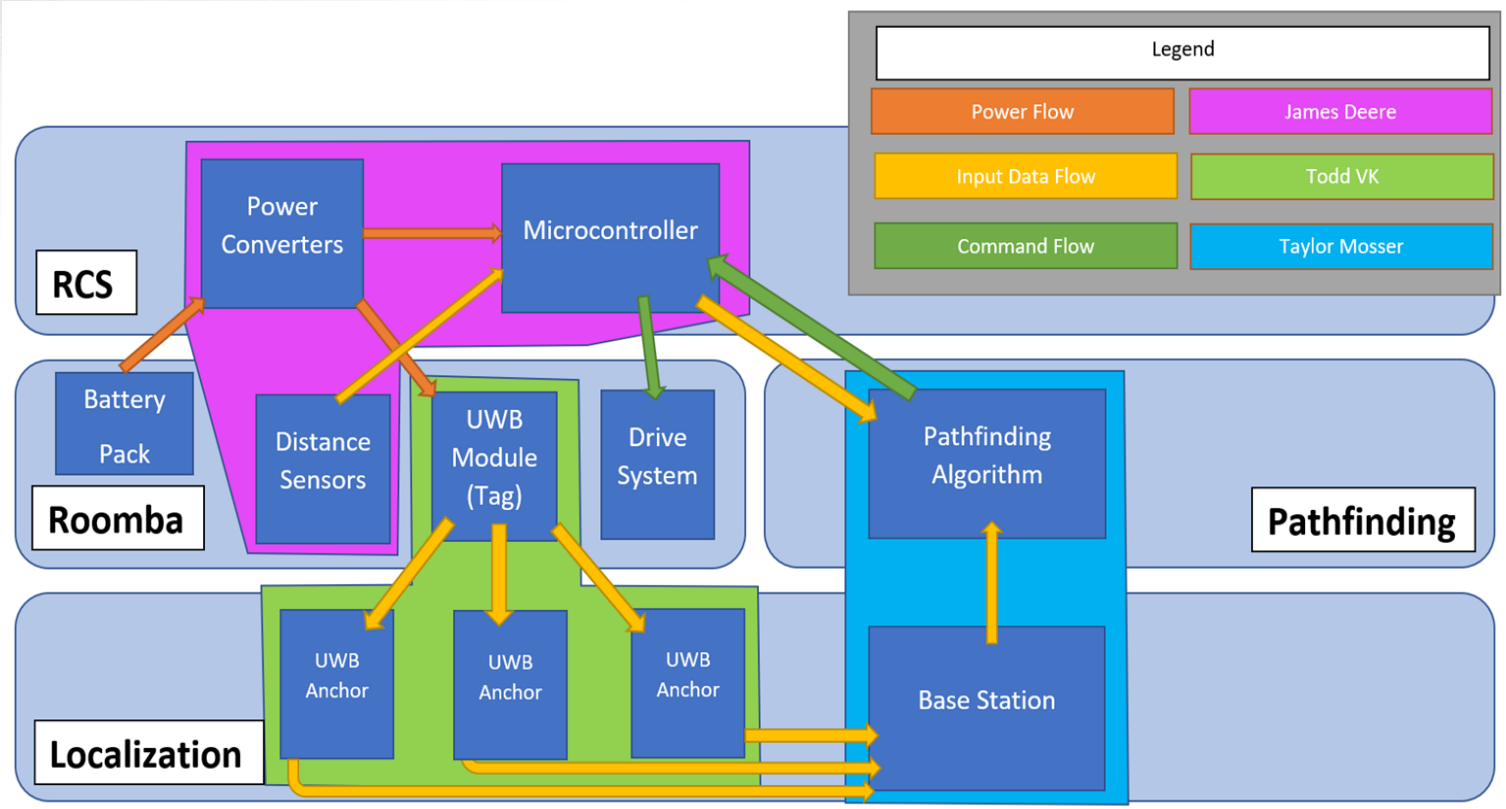
Roombotics Project Overview

Problem: iRobot Roombas do not follow a specific path when cleaning a room and are prone to repeatedly cleaning the same areas or avoiding other areas altogether. While the Roombas can map the layout of a room, they do not have strategic methods of navigating the space to clean quickly and efficiently.

Additionally, one Roomba can be ineffective in cleaning larger spaces due to its small size. This system will allow for more than one Roomba to be deployed in a space in which they can work together to cover all area in the room.

Solution: Roomba navigates a space using the A* pathfinding algorithm to calculate lowest cost path from one point to another. Path calculation is performed based on the location of the Roomba and any obstacles in the room. Roombas do not interfere with each other's assigned cleaning spaces and avoid colliding with each other.

Integrated Project Diagram



Project Deliverables:

- Roomba can detect static and dynamic obstacles in environment.
- Location of Roomba is tracked and sent to base station.
- Path calculated based on localization and obstacle detection data.
- Manual control can be used for testing Roomba.

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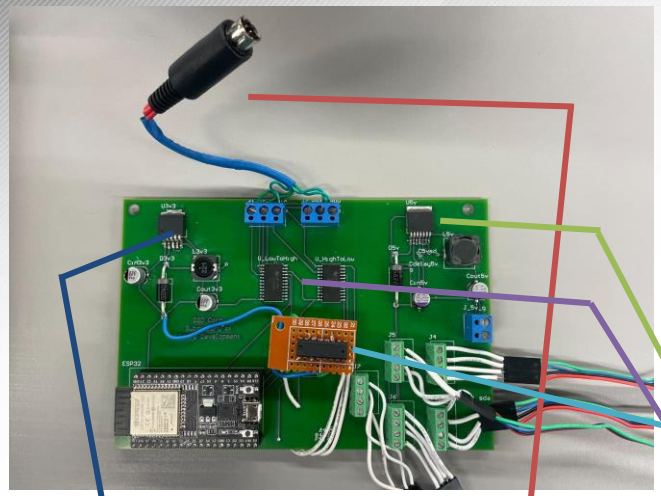
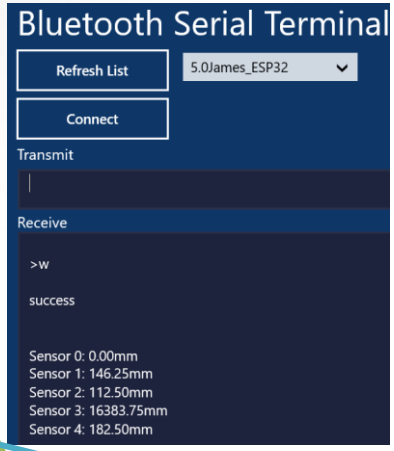
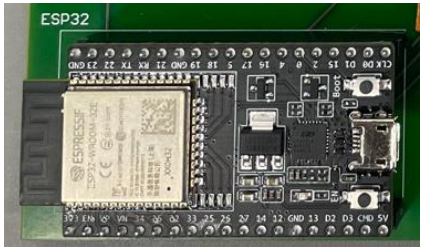
Roomba Control Subsystem



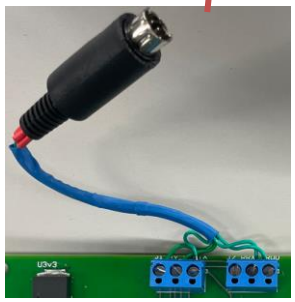


Serial terminal showing output from 5 distance sensors over bluetooth



ESP32 runs firmware to control Roomba

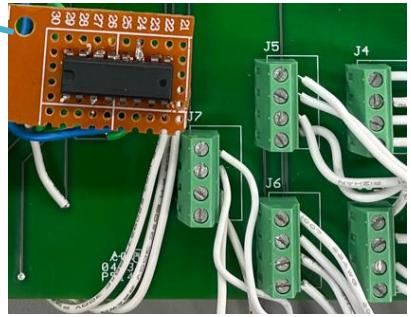
3.3V @ 1A buck converter from Roomba battery to power ESP32, sensors, level shifters



Mini Din7 allowing for connection with Roomba

5V @ 0.75A buck converter from Roomba battery to power level shifters, localization

Level shifters allowing for serial communication between 5V and 3.3V logic level devices



Switching multiplexer and distance sensors (connected to terminals) allow for obstacle detection and avoidance

Roomba Control Subsystem Challenges and Solutions

Challenges	Solutions
• IR Distance sensors used are non-addressable • ESP32 uses 3.3 volt level logic and Roomba uses 5 volt level logic • Multiplexer used on pcb was not working as desired • Occasional spikes in sensor data causes Roomba to stop and jerk when no obstacle is present • Creating PCB for the first time	• Switching multiplexer used to make addresses • 3.3V to 5V level shifters are used to translate voltage levels • A new switching multiplexer was put on a perfboard and soldered onto PCB using Altium files and vias • Rolling average is implemented in firmware to stop momentary spike in values to effect data • A lot of research in how to use Altium and how to make footprints

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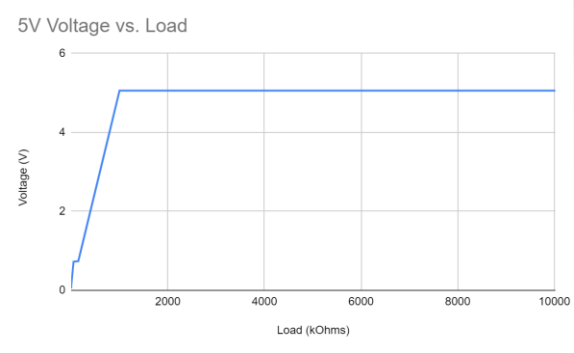
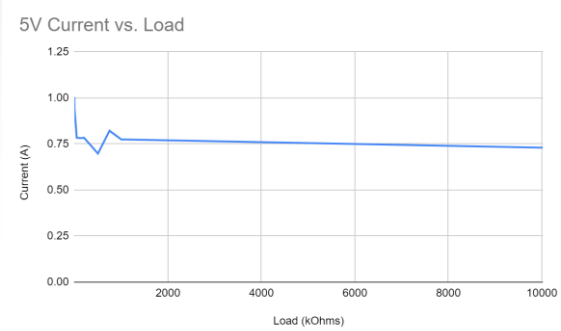
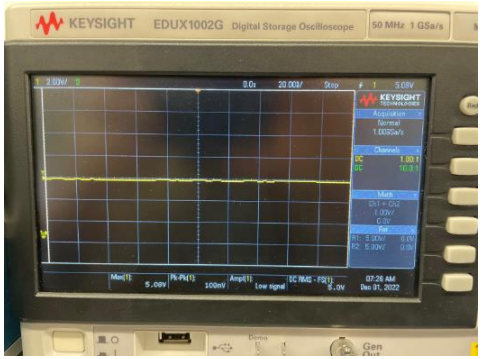
Roomba Control Subsystem Power Converter Validation



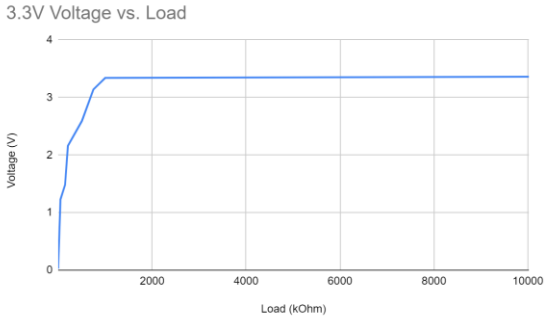
5V Buck Converter stabilizing at 5.06V with E-load



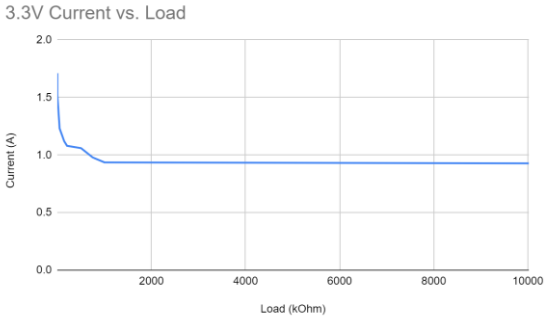
5V Buck Converter stabilizing at 750 mA with E-load



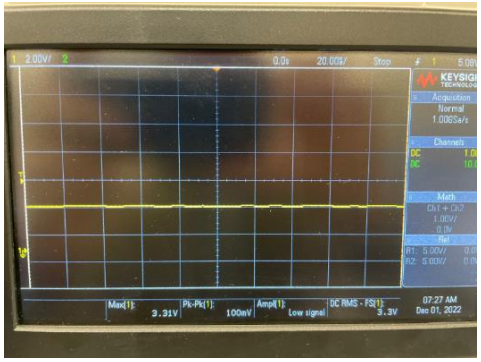
5V Buck Converter output shown on oscilloscope



3.3V Buck Converter stabilizing at 3.34V with E-load



3.3V Buck Converter stabilizing at 940 mA with E-load



3.3V Buck Converter output shown on oscilloscope

Roomba Control Subsystem Results

Item	Met
Connects via Bluetooth (115200 baud rate)	Yes
Accepts Commands via Bluetooth	Yes
Command: Forward Continuously	Yes
Command: Forward 3 cm	Yes
Command: Forward 4.25 cm	Yes
Command: Turn Right Continuously	Yes
Command: Turn Left Continuously	Yes
Command: Turn Right 45, 90, 135, 180 degrees	Yes
Command: Turn Left 45, 90, 135, 180 degrees	Yes
Command: Turn Right specified degrees	Yes
Command: Turn Left specified degrees	Yes
Command: Stop	Yes
Cycle Through 5 Distance Sensors	Yes
Temporarily Stop When Obstacle is Within 4in	Yes
Send Alert of Obstacle When Static for 5s	Yes

Pathfinding Subsystem Overview

Simulation Phase

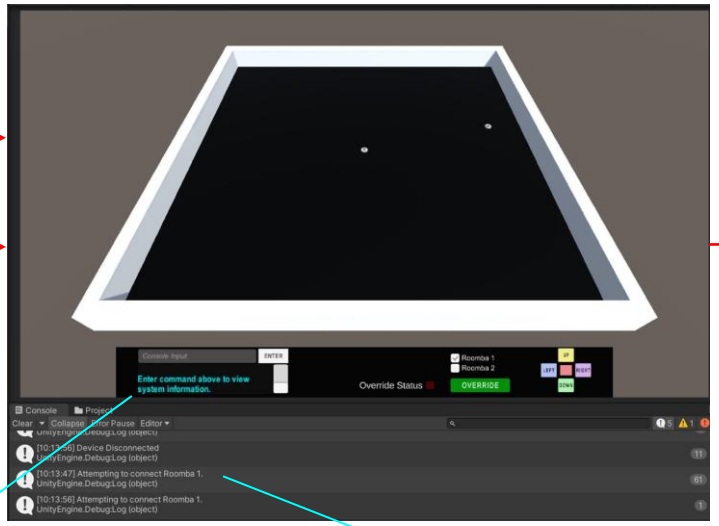
A* pathfinding algorithm originally designed and tested in Unity 3D simulated environment.

Design Phase

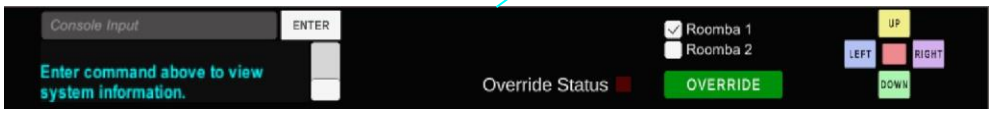
PATH CALCULATION AND COMMANDS

LOCATION DATA

OBSTACLE DETECTION



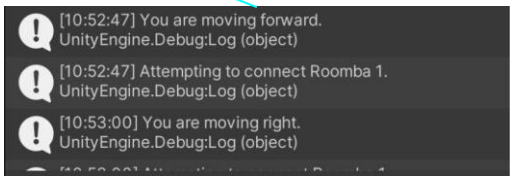
ROOMBA CONTROL



User can find information about current locations of the Roombas, status of Override Mode, and other helpful information about the system during operation.

Indicator light shows user whether Override Mode has been enabled or not. User chooses device to be controlled.

Directional buttons can control Roomba movement when in Override Mode.



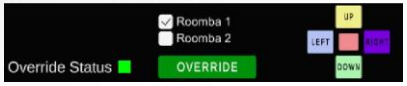
Status of Roomba connection, obstacle detection, and current direction are shown here. Success or failure in path calculation is also displayed.

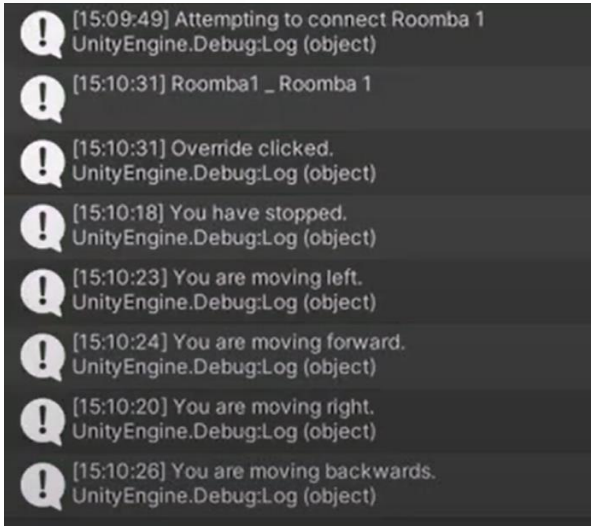
Pathfinding Subsystem Challenges and Solutions

Challenges	Solutions
- Obstacle detection response (stop commands) overrides commands in pathing script - Cannot exit Override Mode once it has been enabled; Roomba does not stop operation - After exiting Override Mode, pathing script becomes obsolete - Bluetooth connection issues in Unity	- Data from sensors read directly in Unity and all commands only sent by pathing script or override buttons - Stop command automatically sent to Roomba when entering or exiting Override Mode - Roomba continues on predetermined path based on current location - Separate scripts for each Roomba device that could be used in the system

Pathfinding Subsystem Results

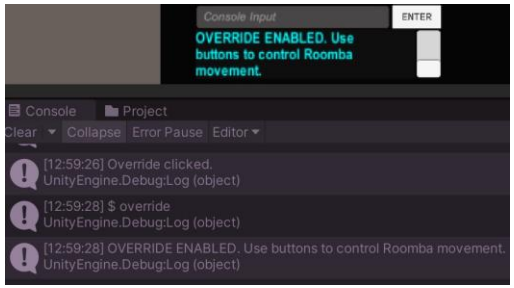
Override Mode



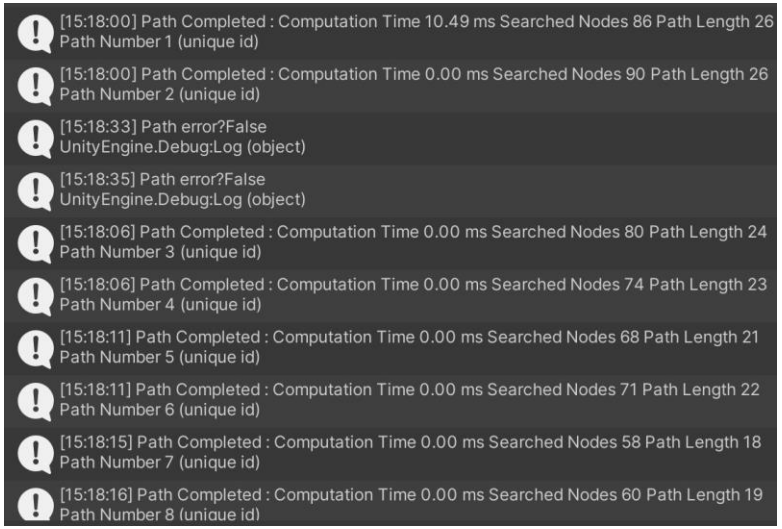


Roomba can be manually controlled through just directional buttons.

Console gives information on direction traveled, Roomba selected, and Override Mode status.



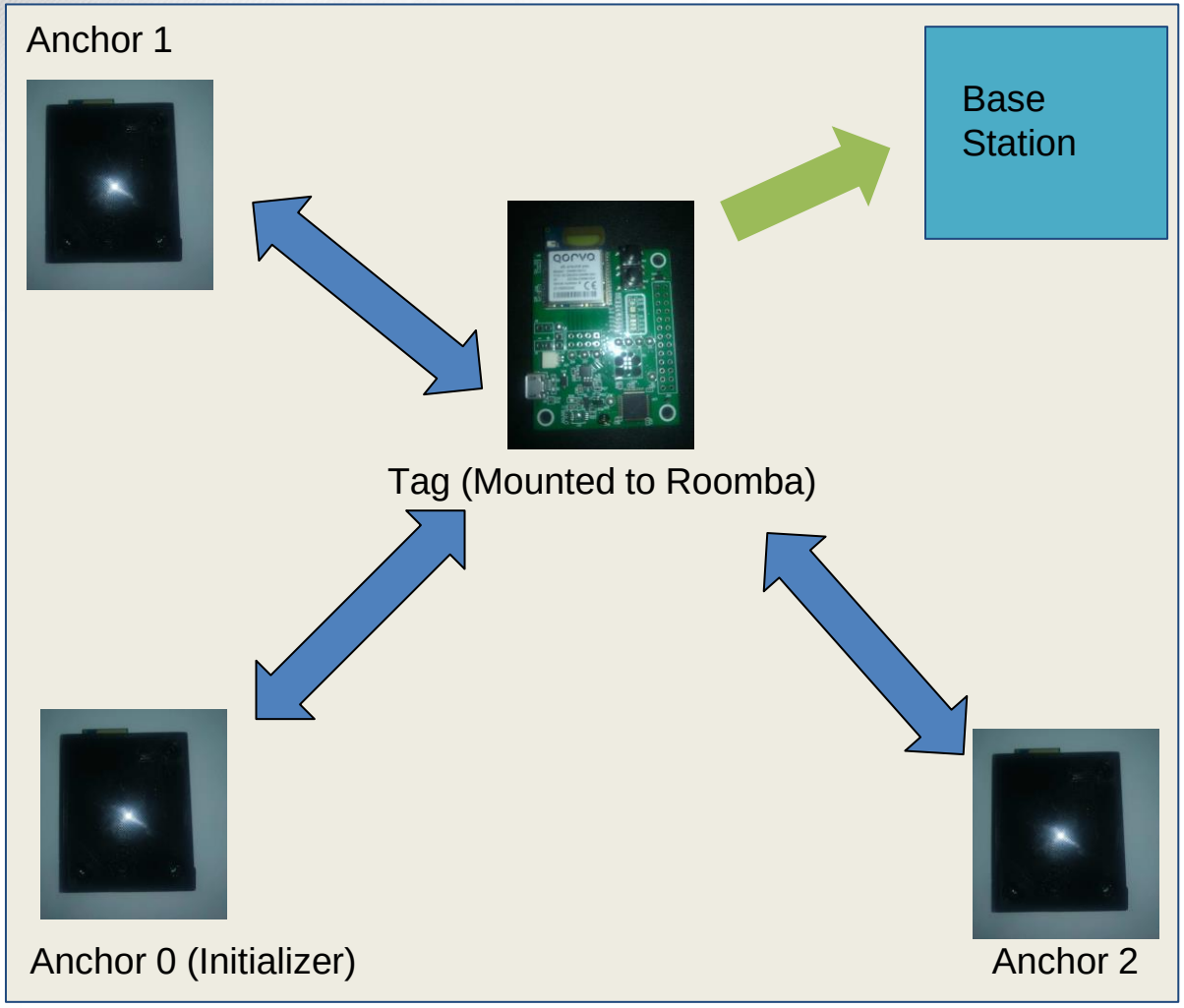
Unity Pathfinding



All nodes explored and lowest-cost path calculated from starting node to ending node. There is no path calculation error and the pathing is updated during operation.

If obstacle encountered, path calculation is changed.

Localization Subsystem Overview



UWB Ranging Send & Request

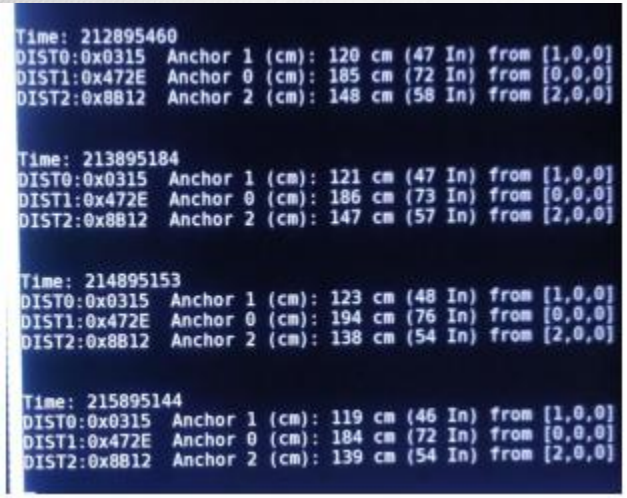
Location data

- Anchors are wall mounted and only require power via a 5v USB connection.
- The Tag sends out a range request; each anchor timestamps an appropriate reply and sends it.
- The Tag then calculates the distances, trilaterates its position, and outputs the location.
- Anchors have individual housings, and the Tag is housed with the control board.

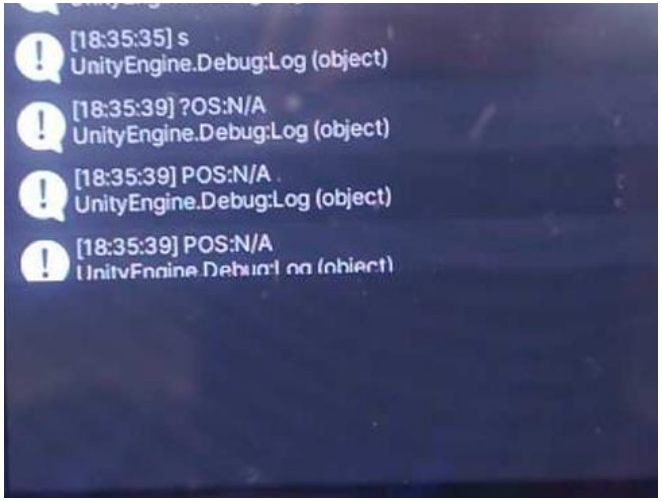
Localization Subsystem Challenges and Solutions

Challenges	Solutions
- Localization only gathers distance, not angle of vector between points. - Ranging attempts have high variation for each measurement. - Low accuracy of determined location. - Localization degrades when operated inside the FEDC. - Transfer of location data slow to transmit from Tag to Anchor to Base station. - Primary UART connection used a different protocol that basic serial.	- System uses trilateration, not triangulation. - Rolling average method adopted to absorb small errors / variations. - Multiple training of antenna delays in RF intensive environments. - Changed data from to Anchor to ESP to Base Station using UART and Bluetooth. - Switched attachment to secondary UART chip, with flag set in firmware to use simple serial at 115200 baud.

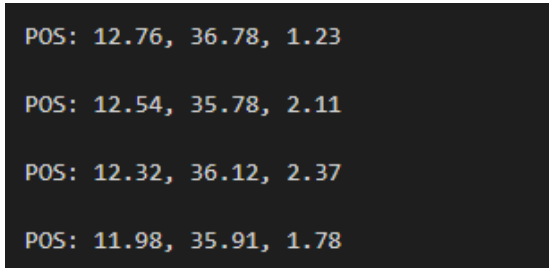
Localization Subsystem Results



Localization in individual reading mode. Each distance is displayed here to show individual conditions.

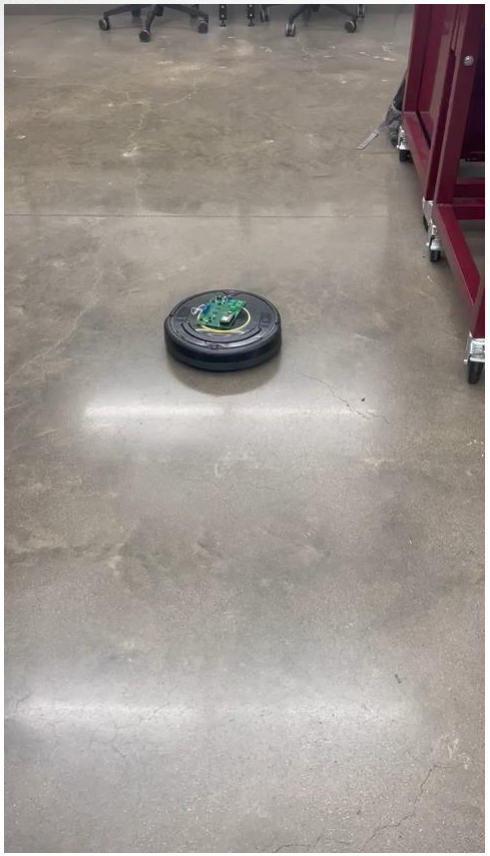


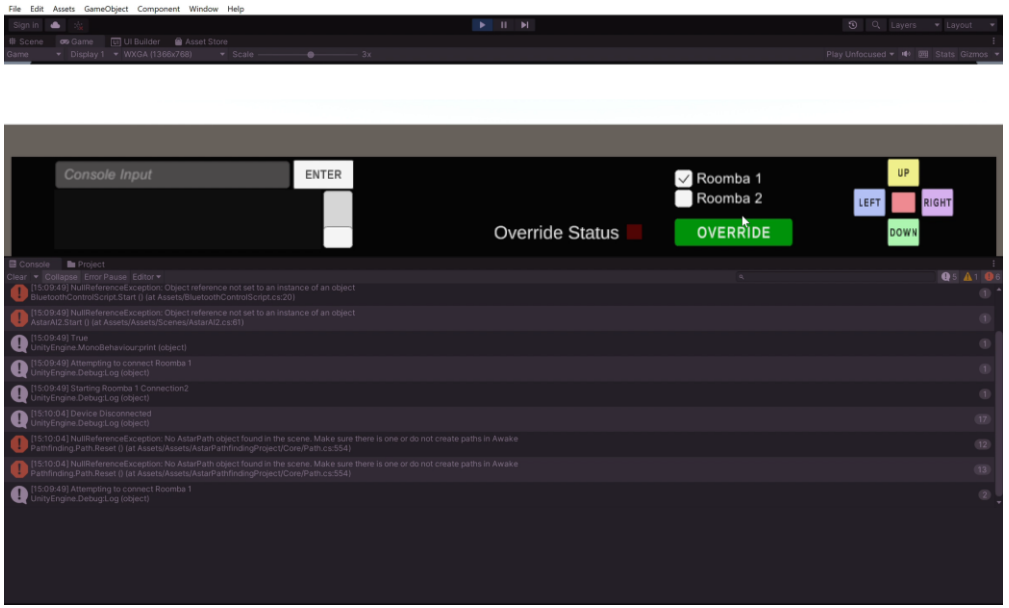
Localization outputting data over UART and Bluetooth. When all anchors are non functional, N/A is displayed.



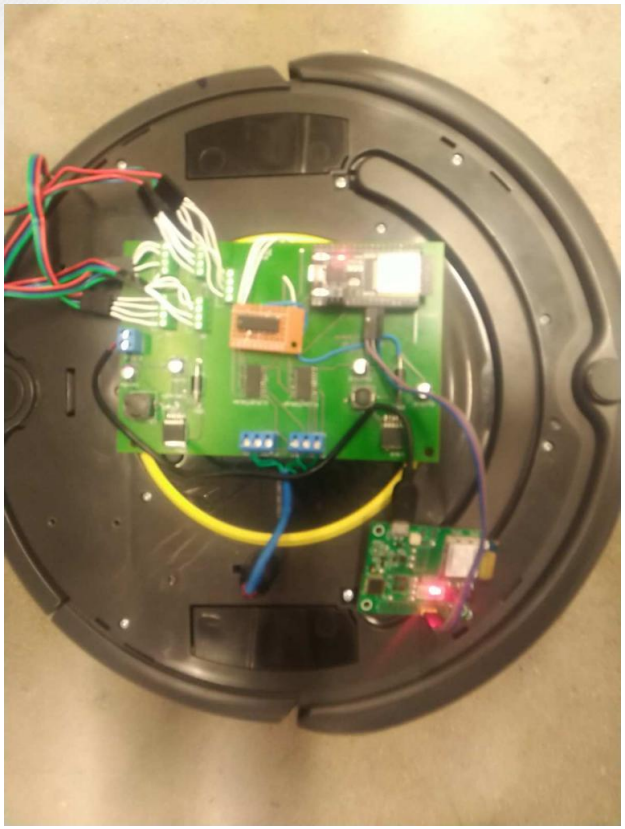
Localization being read on a UART terminal directly showing the output (in Inches) of the system when all 3 anchors are powered up and responding to requests.

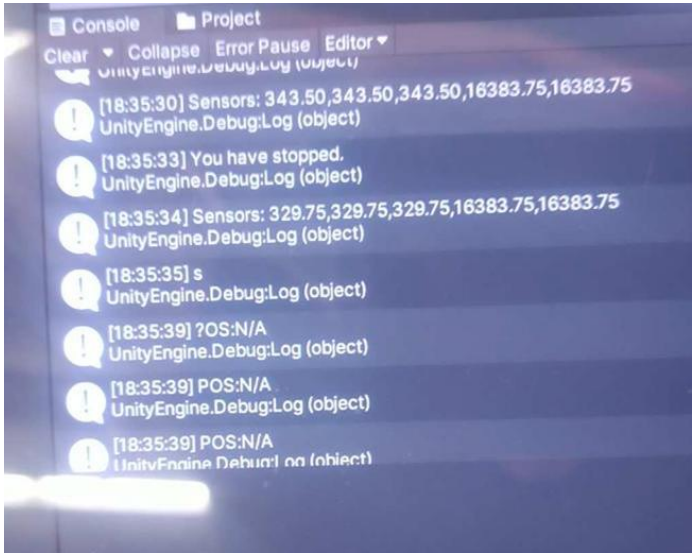
Integrated System Results





Integrated System Results





All location data is sent to Unity during Roomba operation. Sensor data is sent directly to Pathfinding to determine direction commands.

Conclusions

- All systems integrated and controlled in Unity
- Need to continue testing automatic pathing on Roomba
- Need to perform a full cleaning in an environment with static and dynamic obstacles, path updates
- Mounting system is currently printing and will be done by Friday