ECE 445
Team 13
Autonomous Gardening Rover
Fall 2024

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1 Introduction

1.1 Problem

Soil monitoring is a challenge for both hobbyist gardeners and farmers. A lot of solutions out there use stationary probes that have to be placed at regular intervals across the field, but setting them up can be a hassle, especially when dealing with plots of different sizes or layouts. On top of that, maintaining these probes is tricky since they're prone to electrical issues and physical damage, making traditional soil monitoring a bit of a headache when things go wrong or need adjusting.

On the other hand, companies like John Deere are taking a more high-tech approach with solutions like their autonomous tractor. Instead of relying on stationary probes, these tractors can move around the field, gathering real-time data as they go. This makes it easier to monitor soil conditions across different areas without all the manual setup and maintenance. It's a much more flexible and efficient way to manage soil health, giving farmers and gardeners better insights into their fields.

1.2 Solution

We propose to create an autonomous rover that is able to collect soil analysis data at certain points in a field, and upload the data to a web application.

A full scale commercial extension of our project would ideally be able to cover a variety of tasks, such as automated watering, planting, and plowing, as well as more crop monitoring capabilities such as visual crop analysis, and nutrient monitoring.

1.3 Visual Aid

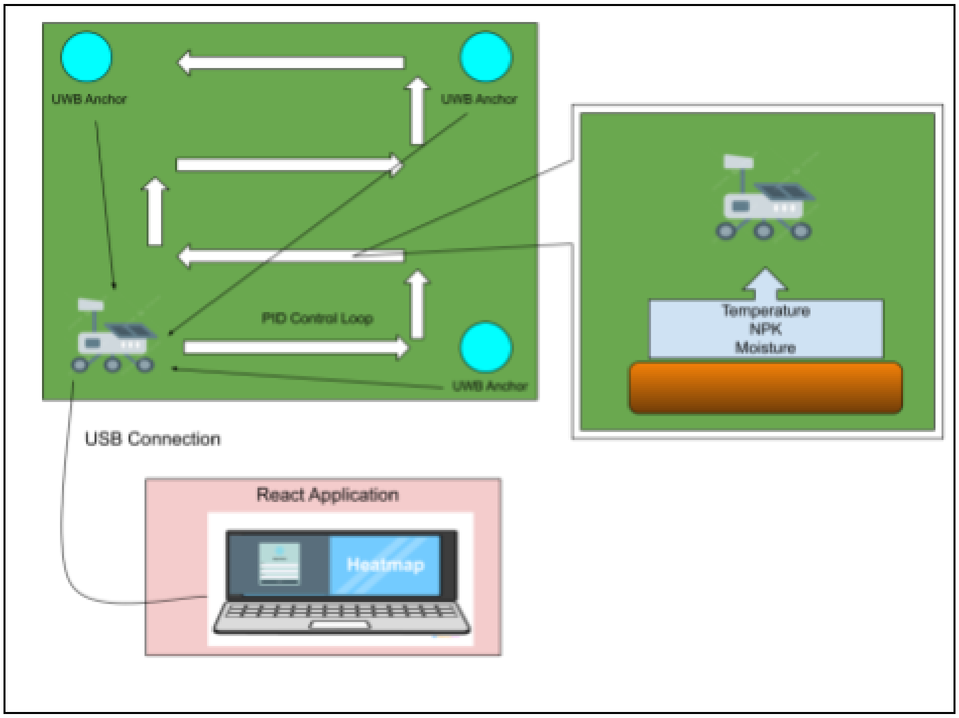

Figure 1: Gardening Rover Visual Aid

1.4 High-Level Requirements

- Root Mean Squared Error(RMSE) of 20% of the predefined motion plan based on PID control algorithm and time-of-flight corrections.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Predicted_i - Actual_i)^2}{N}}$$

- Soil Monitoring Subsystem should be accurate within 25% for all moisture, pH, and temperature measurements compared to stationary probes used as reference.
- Users are able to input plot dimensions and intervals through React application and flash this configuration to the rover within 2 minutes. Users are able to retrieve and observe soil quality profile in web application in 2 minutes upon retrieving rover.

2 Design

2.1 Block Design & Physical Drawing

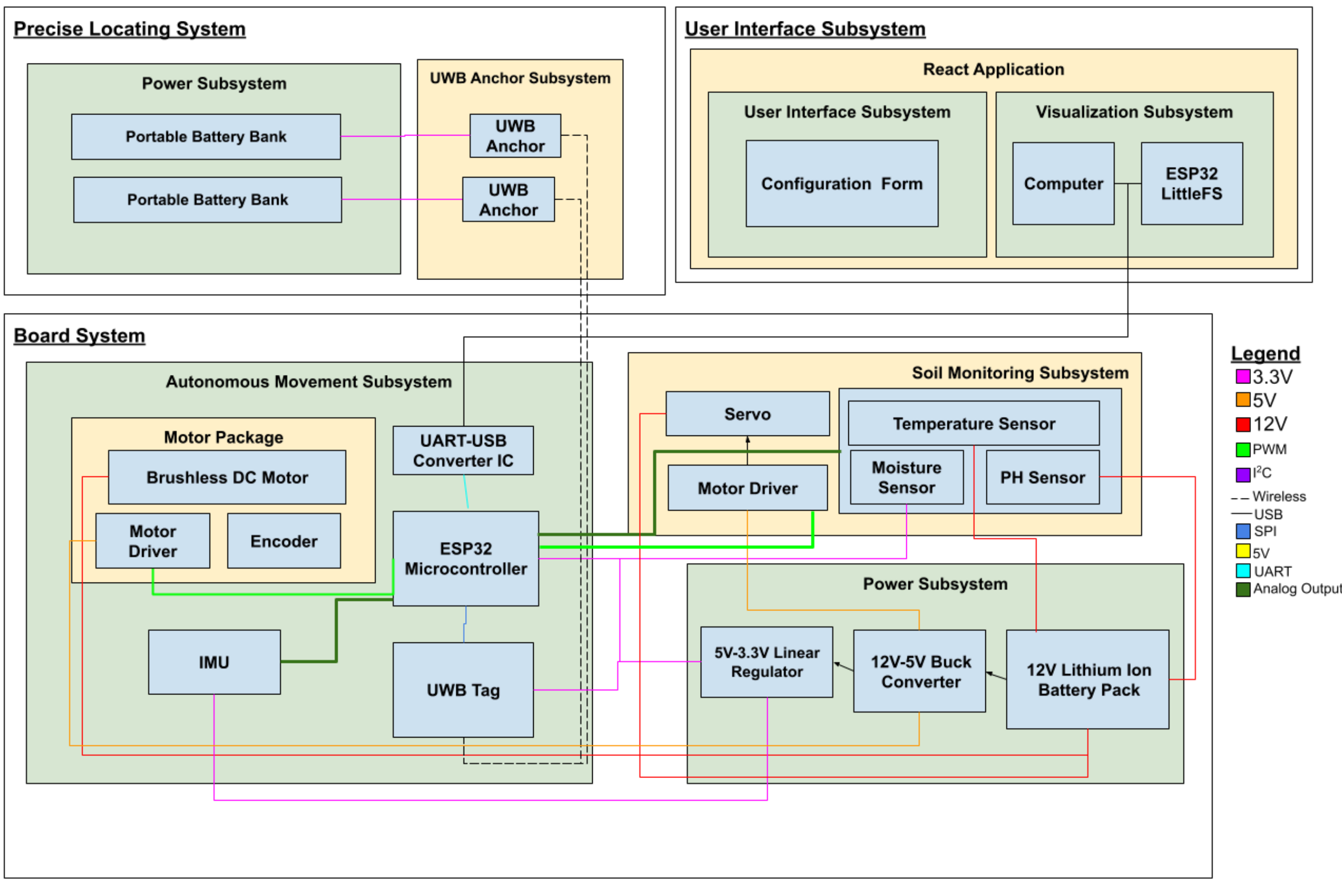

Figure 2: Block Diagram

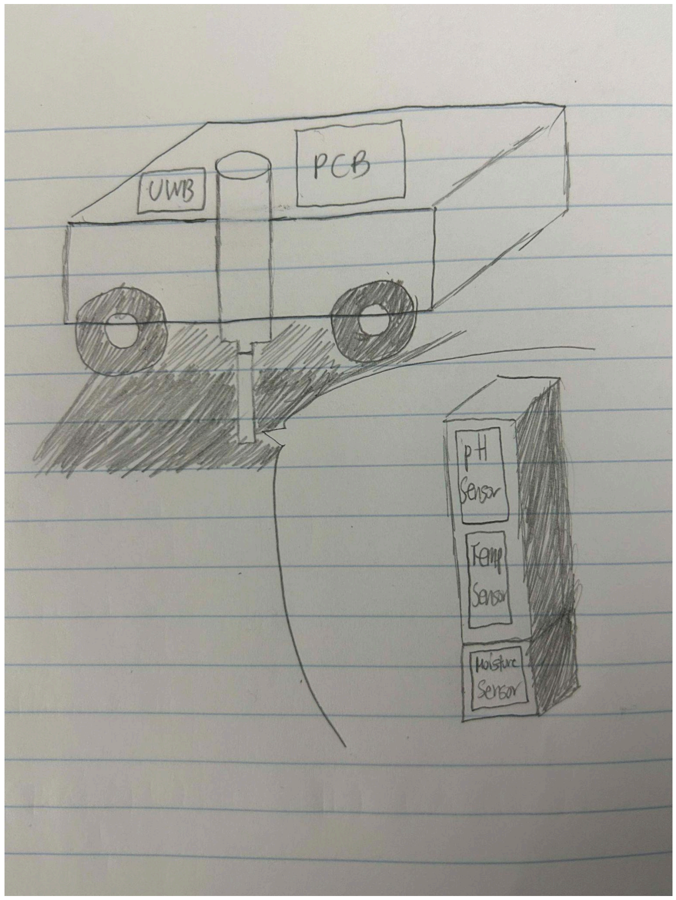

Figure 3: Soil Quality Probe Visual Aid

2.2 Subsystems

2.3.1 Autonomous Movement Subsystem

This subsystem is responsible for the movement and orientation of the rover. It consists of 4 wheels, 4 brushless DC motors, encoders for each of the motors, 2 motor drivers, and an inertial measurement unit(IMU). Lastly, there will be a chassis that will be manufactured in the machine shop. This chassis will be designed to accommodate the numerous subsystems and the physics of the rover's traversal. We decided to use brushless DC motors since they are more power efficient and run for a longer duration. The encoders are necessary for the PID control loop, which will calculate the error with respect to a predefined traversal path. We will supplement the PID control loop with inertial measurement unit(IMU) readings in order to accommodate the uneven terrain of the soil. More specifically, the gyroscope and accelerometer will be used to stabilize the rover by supplying pitch/roll information to the PID controller. The IMUs accelerometer will be used to adjust the motors speed in events like turning, driving, or stopping. The controller will be run on the ESP32 microcontroller, which will read the sensor data. The ESP32 will generate a PWM signal with varying duty cycle which will be an input to the motor driver. The motor driver employs a number of power transistors to switch the phase of the voltage supply to the motor, effectively setting the voltage in response to a PWM signal. The motor driver is used for brushless motors and also handles the motor's commutation using hall effect sensors, which prompted us to use it.

The movement of the rover will also be corrected through the UWB sensors, which is elaborated in the Precise Location Subsystem Section. Figure 4 demonstrates how the brushless DC motor will be connected to the ESP32. Since the motor driver is on the motor, the ESP32 can be directly connected to the motor.

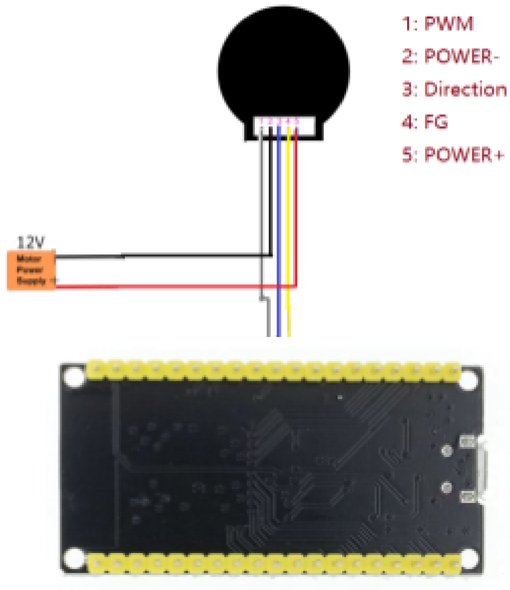

Figure 4: ESP-32 Encoder connection

The PID controller will be governed by the following equation in Figure 5 below.

$$u(t) = K_p \cdot e(t) + K_i \cdot \int_0^t e(\tau)d\tau + K_d \cdot \frac{d}{dt}e(t)$$

Figure 5: PID Control Loop

u(t) is the control signal(PWM signal sent to the motor driver)
e(t) is the error at time t
K_p is the proportional gain, K_i is the integral gain, K_d is the derivative gain

The error will be calculated as a weighted average as demonstrated by the equations below in Figure 6, with the position and heading measurements given by the encoder and IMU, respectively:

$$e_{\text{position}}(t) = \text{Waypoint Position} - \text{Actual Position}$$

Figure 6: Position Error

$$e_{\text{heading}}(t) = \text{Setpoint Heading} - \text{Actual Heading}$$

Figure 7: Heading Error

$$e(t) = W_{\text{position}} \cdot e_{\text{position}}(t) + W_{\text{heading}} \cdot e_{\text{heading}}(t)$$

Figure 8: Error Weighted Average

Our IMU of choice is a MPU-6050 Six-Axis Motion Tracking device. It is equipped with an accelerometer and gyroscope, which inform the control algorithm, specifically the current speed. The speed will also be a PID variable much like the position. The uneven terrain of the soil demands a gyroscope that can make measurements up to 1000°. Additionally, it has programmable interrupt support for tap and shake detection, which we imagine will be useful on the soil. The pinout diagram and table are below in Figure 9 and Figure 10, respectively[6].

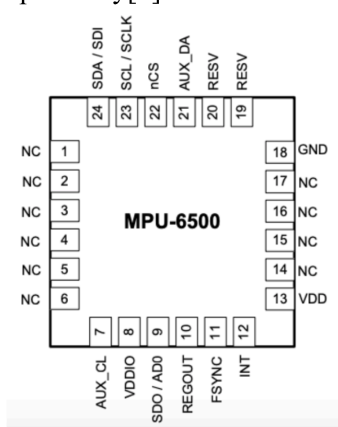

Figure 9: MPU-6500 Pinout

Pin Number	Pin Name	Pin Description
7	AUX_CL	I^2C Master serial clock, for connecting to external sensors
8	VDDIO	Digital I/O supply voltage
9	AD0 / SDO	I^2C Slave Address LSB (AD0); SPI serial data output (SDO)
10	REGOUT	Regulator filter capacitor connection
11	FSYNC	Frame synchronization digital input. Connect to GND if unused.
12	INT	Interrupt digital output (totem pole or open-drain) ***Note: The Interrupt line should be connected to a pin on the Application Processor (AP) that can bring the AP out of suspend mode.***
13	VDD	Power supply voltage and Digital I/O supply voltage
18	GND	Power supply ground
19	RESV	Reserved. Do not connect.
20	RESV	Reserved. Connect to GND.
21	AUX_DA	I^2C master serial data, for connecting to external sensors
22	nCS	Chip select (SPI mode only)
23	SCL / SCLK	I^2C serial clock (SCL); SPI serial clock (SCLK)
24	SDA / SDI	I^2C serial data (SDA); SPI serial data input (SDI)
1 – 6, 14 - 17	NC	No Connect pins. Do not connect.

Figure 10: MPU-6050 Pinout

As the table indicates, the MPU-6500 communicates through both I2C and SPI. The I2C interface is preferable since it adheres to Master-Slave communication principles and consumes less power by running at 100KHz in standard mode.

This subsystem interacts primarily with the power subsystem since the motors are connected to the 12V battery and the user interface subsystem by way of the ESP32, which will store the traversal information. It fulfills the first requirement which is concerned with the position of the rover. The PID solution is intended to correct for errors, so RMSE <= 20% will be an accurate measurement of this.

Requirements	Verification
RMSE of acceleration and yaw readings is 25%	Use a ruler to measure distances and calculate RMSE of acceleration after complete run
RMSE of position estimations are 20%	Use a ruler to measure errors and calculate RMSE after complete run
RMSE of position across all waypoints is 20%	Use a ruler to measure errors and calculate RMSE after complete run

Table 1: R&V Table for Autonomous Movement Subsystem

2.3.2 Soil Monitoring Subsystem

The soil monitoring subsystem will consist of a linear actuator that will insert a complex of sensors that take measurements of the soil including temperature, moisture, and pH. The temperature measurement requires a LM35 Precision Centigrade Temperature Sensor, which has the following pinout.

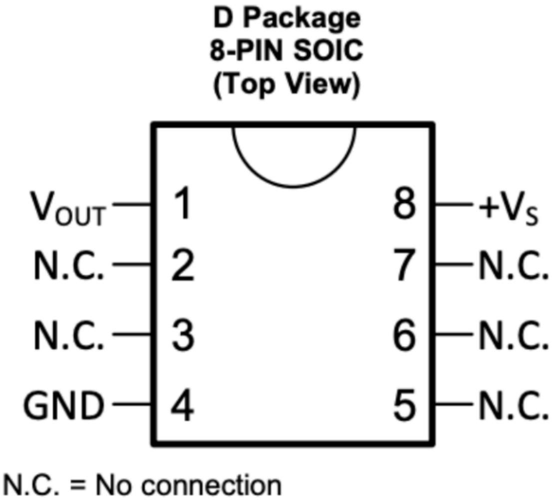

Figure 11: LM35 Pinout

$$V_{\text{out}} = 10 \times T_{\text{Celsius}}\, \text{mV/C}$$

Figure 12: Voltage-Temperature Relation

The LM35 outputs a voltage that is directly proportional to the ambient temperature, as the formula above shows. We selected this sensor because it provides an analog voltage, which is more precise. It is also rated for temperatures between -55°-150°, which works for our application. Lastly, it is low self-heating(+0.08°C) which ensures more accurate measurements which come in direct contact with the soil. The sensor will be attached to the linear regulator and connected directly to the GPIO pin headers on our PCB.

The subsystem will also consist of a pH sensor. The following equation gives the pH of a soil sample in the equation below (Figure 12).

$$E = E^0 + \frac{RT}{F}\ln(a_{H^+}) = E^0 - \frac{2.303RT}{F}\text{pH}$$

Figure 12: Current-pH relation

The equation shows that the current is directly proportional to the pH, which makes sense since pH is the potential of hydrogen, which is given by the number of hydrogen ions that induce a charge. We plan to use an ENV-30-pH sensor, which is 4.5” in length and only needs to be immersed <1”, which is ideal for our applications. It is said to be commonly used for soil pH measurements, which is why we selected it.

The next sensor we are adding to the soil monitoring subsystem is a moisture sensor, designed to be implemented on a PCB. This circuit measures soil moisture levels by converting the soil’s resistance into a corresponding voltage, which a microcontroller (ESP 32) for monitoring data can then process. The moisture sensor is built using a combination of resistors and operational amplifiers to ensure precise readings and reliable performance in the compact PCB format. The circuit that we are planning to build is in the figure below (Figure 13).

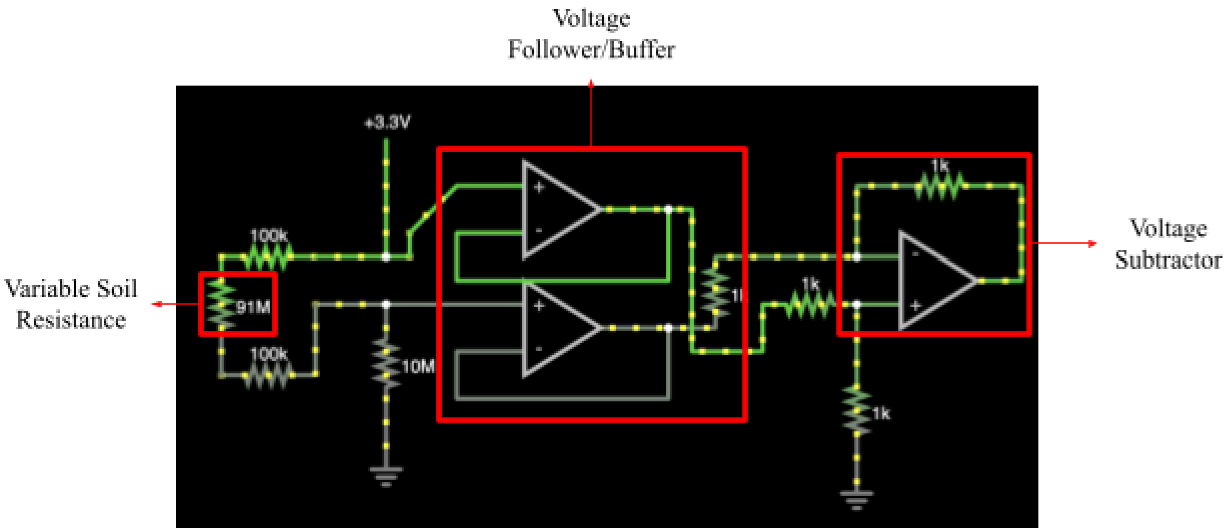

Figure 13: Moisture Sensor Circuit Diagram

Variable Resistance: The first part of this circuit is the variable soil resistance. In the circuit above, the soil resistance is set to 91M as an arbitrary value. The value of this resistance will change depending on the soil moisture level. Dry soil offers high resistance, while wet soil presents lower resistance. The resistance value fluctuates as the moisture level changes, forming the foundation of the sensor's measurement.

Voltage Divider Network: The resistors (91MΩ and 100KΩ) and the variable soil resistance form a voltage divider. The output voltage from the diver is related to the soil resistance. The voltage divider is the fraction of the input voltage scaled by the ratio of the two resistances. In our case, the two resistance values are the fixed resistors and the variable soil resistance.

Op-Amps (Voltage Buffer and Subtractor): The voltage follower (buffer) amplifies the signal without loading the circuit to essentially ensure that the voltage coming from the divider remains accurate without any voltage drop. It pushes it through the last stage of the processing, which is a voltage subtractor. The voltage subtractor compares the two voltages and outputs the difference, which is fed into GPIO bits.

These sensors will be attached to a linear actuator that inserts the sensors 4" into the soil. The linear actuator was chosen because we can control the speed directly which limits the impact on the rover. This subsystem is connected to the power subsystem which supplies 5.5V and 3.3V from the buck converter and linear regulator respectively. This subsystem also connects to the ESP32 in the autonomous movement subsystem since the measurements need to be stored there. This subsystem fulfills the RMSE of 20% for the motion plan by way of the PID algorithm we plan to implement.

Requirements	Verification
Observe probe is inserted 4” into the soil and can retract after data measurement is completed	Use a ruler to measure the length that the actuator is inserted into the soil. Observe through inspection that the probe retracts after.
Temperature measurements are accurate within 25% of stationary probe of choice across 75% of intervals	Use thermometer to measure temperature at each interval and compare accuracy to rover measurement
pH measurements are accurate within 25% of stationary probe of choice across 75% of intervals	Use stationary pH probe to measure pH at each interval and compare accuracy to rover measurement
Moisture measurements are accurate within 25% of stationary probe of choice across 75% of intervals	Use a stationary moisture sensor to measure moisture quantity and compare accuracy to rover measurement.

Table 2: R&V Table for Soil Monitoring Subsystem

2.3.3 Precise Locating Subsystem

The UWB subsystem requires the use of 3 UWB modules from MakerFab. These have built in power management, so we will be powering these with either our laptops or a portable battery bank. To determine the precise location, we will be using Time of Flight calculations to find the precise distance between the rover and two anchors placed at known locations in the field. The PCB on board the rover will be connected to one UWB module via SPI. This UWB module will act as our tag. The other two UWB modules will be placed at the bottom left and bottom right of the field and will act as our anchors, as represented in Figure 14.

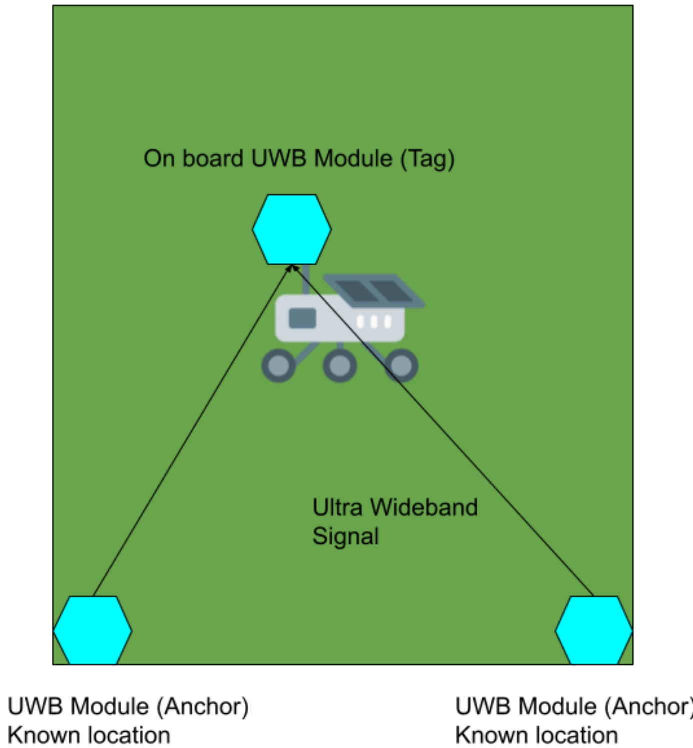

Figure 14: UWB Anchor-Module Relation

The time of flight calculations are as follows:

$$d = c * (t_f - t_i)$$

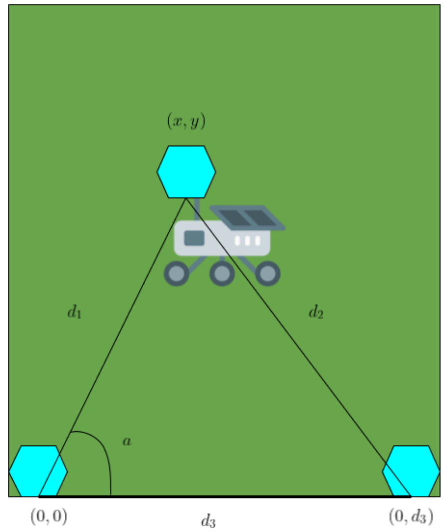

Figure 15: UWB Triangulation

The distance between two UWB modules is calculated as the speed of light (c) times the time it takes for a packet to travel.

Using this, we can calculate the location relative to the two anchors. Assume our field is on a coordinate plane. With the law of cosines as displayed in Figure 16:

$$a = \cos^{-1}(\frac{d_1^2 + d_3^2 - d_2^2}{2d_1d_3})$$

Figure 16: UWB Location Calculation

Then, we see that $y = \sin(a)$ and $x = \cos(a)$

Requirements	Verifications
Establish between UWB tag and two anchors.	Print out the device address of each anchor on the tag if a packet is received.
Receive accurate distance data from tag to each anchor.	Print out ten values of the calculated distances. Measure actual distance using measuring tape and analyze error. Recalibrate the calculations until values are within 10%.

Output the data through SPI and receive data through SPI on main ESP32 controller	Print the data being outputted on the UWB module and print the values being received on the main ESP32 controller. Verify that the values being outputted are the same as the values being received.

Table 3: R&V Table for Precise Locating Subsystem

2.3.4 Power Subsystem

Our system requires the use of 12V, 5V, and 3.3V power rails. Thus, we will achieve this by using a 12V battery, a 12V-5V buck converter, and a 5V to 3.3V linear regulator. We will be using a commercially available charger for the 12V battery, along with buck converter and linear regulator ICs.

Requirements	Verification
The buck converter should be able to steadily produce a 5V output.	Connect 5V power rail to oscilloscope. Monitor output for 3 minutes. Ensure that voltage stays within 5V ± 5%
The linear regulator should be able to steadily produce a 3.3V output.	Connect 3.3V power rail to oscilloscope. Monitor output for 3 minutes. Ensure that voltage stays within 3.3V ± 5%

Table 4: R&V Table for Power Subsystem

2.3.5 User Interface Subsystem

The fields populated in the form will be transmitted to and from the ESP32 through the following design:

- USB-to-UART Interface on PCB
    - PCB will have a USB-to-UART converter chip to convert USB data to a format ESP32 can read through UART pins.
- USB UART Communication
    - ESP32 will have handler to listen to incoming serial data
- ESP32 Storage
    - LittleFS on ESP32’s flash memory(which can store JSON)

The user interface will consist of a form where the user will configure the plot size, intervals, and starting point. The soil quality measurements will be displayed in a number of heatmaps Below is an HTML mockup of form and an illustration of a potential heatmap:

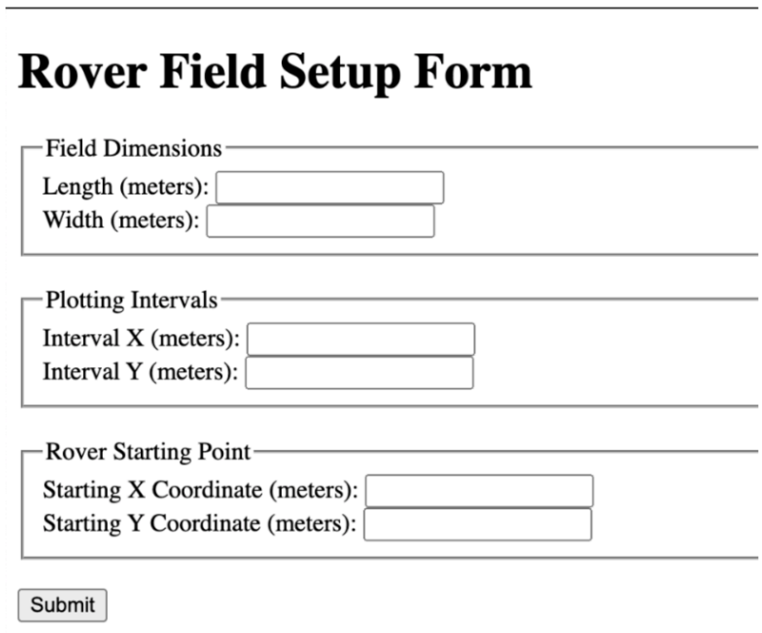

Figure 17: Rover Field Setup Form

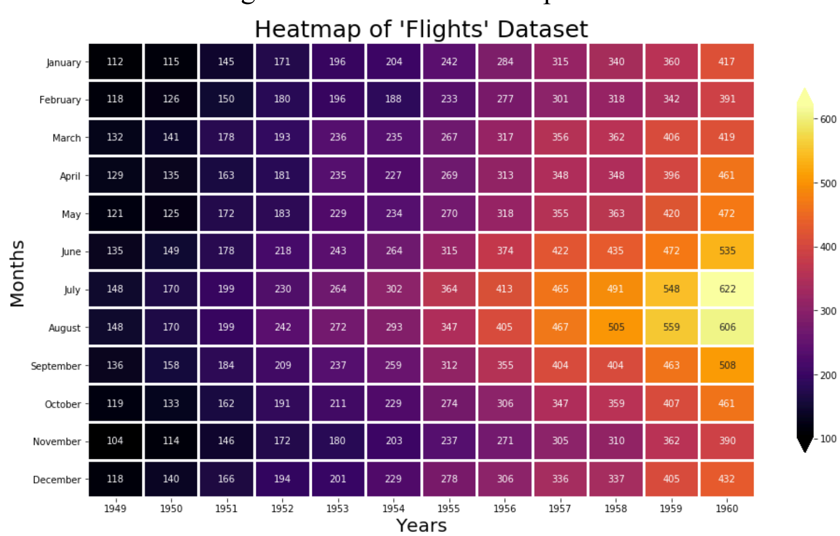

Figure 18: Sample Heatmap

This subsystem collects measurements from the soil monitoring subsystem and the ESP32 which has the measurements stored in LittleFS or flash memory. This subsystem fulfills the third high-level requirement by enabling the user to flash the configuration and observe the heatmaps.

Requirements	Verifications

Observe that ESP32 handler is triggered at least once upon data write to UART pins	Look at IDE logs to see print statement in handler is observed
Observe that measurements reside in LittleFS after ESP32 is powered off, observe measurement data is reflected in 3 heatmaps after rover completes rover run	Turn off the ESP32 and plug in the USB to the PCB and turn on the rover. Observe the heatmaps update on the web application.

Table 5: R&V Table for User Interface Subsystem

2.3 Tolerance Analysis

Using the LM1117 linear regulator, we can calculate the junction temperature to see if it is reasonable. Only the ESP32, moisture sensor, and IMU require 3.3V input from the linear regulator.

ESP32 Current Draw: 500mA

Moisture Sensor Current Draw: 15mA

IMU Unit: 7.3mA

$$T_j = i_{out}(v_{in} - v_{out})(\Theta_{ja}) + T_a$$

Variable	**Value**
$\max(T_j)$	150C
i_{out}	515mA
v_{in}	5v
v_{out}	3.3v
Θ_{ja}	23.8 C/W
T_a	Assume around 38C

$T_j = 0.515(5 - 3.3)(23.8) + 38 = 58.84$, which is within our operating range.

3 Cost and Schedule

3.1 Cost Analysis

We estimate the labor costs as 3 * ($83.33/hr) * 200 hours = ~$50,000 in total. The machine shop quote is based off of a conversation we had where we explained our design.

Chassis	Self Made	M		
Wheels	https://www.sparkfun.com/products/13259			
BDCM w/ Encoder & Motor Driver (x4)	https://wiki.dfrobot.com/FIT0441_Brushless_DC_Motor_with_Encoder_12V_159RPM#target_1	$19.79	4	$79.16
IMU	https://invensense.tdk.com/products/motion-tracking/6-axis/mpu-6500/	$6.12	2	$12.24
12V Battery	https://www.servocity.com/12v-nimh-nested-battery-3000mah-mh-fc-xt30-connector/	$50.00	1	$50.00
12V Battery Charger	https://www.servocity.com/12v-nimh-nicad-smart-battery-charger-with-xt30-connector/	$13.00	1	$13.00
Buck Converter	https://www.digikey.com/en/products/detail/dfrobot/DFR1015/18069278	$5.30	2	$10.60
Linear Regulator	https://www.digikey.com/en/products/detail/texas-instruments/LM1117IMPX-3-3-NOPB/3440160	$1.15	5	$5.75
Linear Actuator	https://www.amazon.ca/Stroke-Actuator-Electric-Mounting-Bracket/dp/B0D1288FTF?th=1	$43.12	1	$43.12
pH Sensor	https://www.digikey.com/en/products/detail/atlas-scientific/ENV-30-PH/16003028?utm_adgroup=&utm_source=google&utm_medium=cpc&utm_campaign=PMax_DK%2BProduct_Product%20Categories%20-%20Rapid%20Growth%20Categories&utm_term=&utm_content=&utm_id=go_cmp-19872190497_adg-_ad-__dev-c_ext-_prd-16003028_sig-CjwKCAjwgfm3BhBeEiwAFfxrG9QwHt67C9aamr9VFLrkbsLeGhxqCf-Po7PUqy1jqNXfuvMfuEs7IRoC1DkQAvD_BwE&gad_source=1&gclid=CjwKCAjwgfm3BhBeEiwAFfxrG9QwHt67C9aamr9VFLrkbsLeGhxqCf-Po7PUqy1jqNXfuvMfuEs7IRoC1DkQAvD_BwE	$49.99	3	$149.97
Moisture Sensor	Self Made			$0.00

Temperature Sensor	https://www.ti.com/product/LM35	$14.58	3	$43.74
Op-Amp (LM741)	https://www.digikey.com/en/products/detail/texas-instruments/LM741CN%2FNOPB/6322	$0.91	3	$2.73
100kOhm Resistors (PCB)	https://www.digikey.com/en/products/detail/yageo/RC0402FR-07100KL/726526	$0.10	2	$0.20
1kOhm Resistors (PCB)	https://www.digikey.com/en/products/detail/yageo/RC0603JR-7W1KL/12698996?utm_adgroup=Yageo&utm_source=google&utm_medium=cpc&utm_campaign=PMax%20Shopping_Supplier_Yageo&utm_term=&utm_content=Yageo&utm_id=go_cmp-17816160916_adg-_ad-__dev-c_ext-_prd-12698996_sig-CjwKCAjwgfm3BhBeEiwAFfxrG5eLxbfMlblbFNTB_LwUrL1JVp3wQICUGgQwDyIodTzWYMHdBpbRpBoC6_cQAvD_BwE&gad_source=1&gclid=CjwKCAjwgfm3BhBeEiwAFfxrG5eLxbfMlblbFNTB_LwUrL1JVp3wQICUGgQwDyIodTzWYMHdBpbRpBoC6_cQAvD_BwE	$0.10	3	$0.30
10MOhm Resistors (PCB)	https://www.digikey.com/en/products/detail/vishay-dale/CRCW060310M0DHEAP/3593891	$0.27	1	$0.27
3x UWB Board	https://www.makerfabs.com/esp32-uwb-ultra-wideband.html	$40.00	3	$120.00
Group Labor		$50,000.00	1	$50,000.00
Machine Shop Quote		$2,500.00	1	$2,500.00
	Total			$53031.08

3.3 Schedule

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8/26		First class meeting 4:00p - 5:50p ECEB 1002		Initial Web Board Post due 11:59p			

9/2		Second class meeting 4:00p - 5:50p ECEB 1002	Early Project Approval due 4:45p Laboratory safety training due 11:59p		CAD assignment due 11:59p		
9/9	Add/Drop Deadline due 11:59p	Third class meeting 4:00p - 5:50p ECEB 1002		Project approval due 11:59p			
9/16	Soldering assignment due 4:45p	First team meetings with TAs 4:00p ECEB 3081		Proposals due 11:59p	Initial Conversation With Machine Shop (required if using the shop) due 4:00p ECEB 1047 Team Contract due 11:59p		
9/23							
9/30				Design Document due 11:59p	Proposal Regrade due 11:59p		

10/7	Design Review 8:00a - 6:00p With Instructor and TAs Design Review Fliflet: ECEB 2070 Design Review Fang: ECEB 2072	Design Review 8:00a - 4:00p With Instructor and TAs Design Review Fliflet: ECEB 2070 Design Review Fang: ECEB 2072 Design Review Yu: ECEB 2074	Design Review 8:00a - 6:00p With Instructor and TAs Design Review Fliflet: ECEB 2070 Design Review Fang: ECEB 2072	**Finish PCB Design Schematic** **(EVERYONE)**	PCB Review 3:00p - 5:00p ECEB 3081 **Order PCB Parts and Rover Manufacturin g** **(EVERYONE)**	**Fix PCB after Review** **(EVERYONE)**	
10/14		First Round PCBway Orders (MUST PASS AUDIT BY TODAY) due 4:45p **Order PCB**	Teamwork Evaluation I due 11:59p **Breadboard Prototype Power Subsystem(Ba ttery + Buck Converter + Regulator) — DAY 1**	**Breadboard Prototype Power Subsystem(Batt ery + Buck Converter + Regulator) – DAY 2** **(TANISHQ)**	Last day for revisions to the machine shop due ECEB 1048 **Breadboard Prototype Power Subsystem(Ba ttery + Buck Converter +**	**Breadboard Prototype Soil Subsystem – DAY 1** **(TANISHQ)**	**Breadboard Prototype Soil Subsystem – DAY 2** **(TANISHQ)**

			(TANISHQ)		**Regulator) – DAY 3** **(TANISHQ)**		
10/21	**Breadboard Prototype Soil Subsystem – DAY 3** **(TANISHQ)**	Second Round PCBWay Orders (MUST PASS AUDIT BY TODAY) due 4:45p **Prototype Autonomous Movement Subsystem – DAY 1** **(DHRUV)**	**Prototype Autonomous Movement Subsystem – DAY 2** **(DHRUV)**	**Prototype Autonomous Movement Subsystem – DAY 3** **(DHRUV)**	**Prototype Autonomous Movement Subsystem – DAY 4** **(DHRUV)**	**Prototype Autonomous Movement Subsystem – DAY 5** **(DHRUV)**	**Prototype Autonomous Movement Subsystem – DAY 6** **(DHRUV)**
10/28	**Prototype Autonomous Movement Subsystem – DAY 7** **(DHRUV)**	Third Round PCBway Orders (MUST PASS AUDIT BY TODAY) due 4:45p **Reorder Fixed PCB**	**Solder Autonomous Movement + Soil + Power Subsystem onto PCB** **(EVERYONE)**	**TEST** **(EVERYONE)**	**TEST** **(EVERYONE)**	**TEST** **(EVERYONE)**	**TEST** **(EVERYONE)**

11/4	**Prototype Precise Location Subsystem – DAY 1** **(RYAN)**	Fourth Round PCBway Orders (MUST PASS AUDIT BY TODAY) due 4:45p **Prototype Precise Location Subsystem – DAY 1** **(RYAN)**	Individual progress reports due 11:59p **Prototype Precise Location Subsystem – DAY 1** **(RYAN)**	**Prototype Precise Location Subsystem – DAY 1** **(RYAN)**	Design Doc Regrade due 11:59p **Prototype Precise Location Subsystem – DAY 1** **(RYAN)**	**Prototype Precise Location Subsystem – DAY 1** **(RYAN)**	**Prototype Precise Location Subsystem – DAY 1** **(RYAN)**
11/11	**Build User Interface Subsystem** **(TANISHQ)**	Fifth Round PCBway Orders (MUST PASS AUDIT BY TODAY) due 4:45p **Build User Interface Subsystem** **(TANISHQ)**	**Build User Interface Subsystem** **(TANISHQ)**	**TESTING + Documentation** **(EVERYONE)**	**TESTING + Documentation** **(EVERYONE)**	**TESTING + Documentation** **(EVERYONE)**	**TESTING + Documentation** **(EVERYONE)**

11/18	Mock demo During weekly TA mtg	Mock demo During weekly TA mtg	Mock demo During weekly TA mtg	Mock demo During weekly TA mtg	Mock demo During weekly TA mtg Team Contract Fulfillment due 11:59p		
11/25	Fall Break	Fall Break	Fall Break	Fall Break	Fall Break		
12/2	Final Demo With Instructor and TAs	Final Demo With Instructor and TAs	Final Demo With Instructor and TAs	Mock Presentation With Comm and ECE TAs	Mock Presentation With Comm and ECE TAs Extra Credit Video Assignment due 11:59p		
12/9	Final Presentatio n With instructor and TAs	Final Presentation With Instructor and TAs	Final papers due 11:59p	Lab checkout 3:00p - 4:30p With TA Award Ceremony 4:30p - 5:30p Grainger Auditorium Lab Notebook Due due 11:59p			

Responsibilities:
Autonomous Movement - Dhruv

Precise Location & User Interface Subsystem - Ryan
Soil Monitoring & Power Subsystem - Tanishq

4 Ethics and Safety

The Autonomous Gardening Rover project raises a few ethical and safety concerns that must be addressed during the robot's development and use cases. These issues include compliance with safety standards, responsibility for technology and data, and considerations for environmental impact. This project aligns specifically with the IEEE Code of Ethics and ACM, particularly by prioritizing safety, environmental sustainability, and responsible use and privacy of data. However, some inherent potential ethical breaches must be avoided and assessed.

One of the main issues that we will address is **data privacy**. The soil quality data collected by the rover should only be used for soil monitoring for its plot of garden and land. Misusing this data, such as sharing it without the user's consent, would violate ethical standards, especially regarding data security in the ACM 1.6 Code of Ethics [7]. To address this, if our product were to be commercially produced, we would need to ensure our software is protected by proper encoding and firewall.

Environmental responsibility is also a main concern in the Code of Ethics. As a device used in outdoor environments, the rover should not harm the surrounding ecosystem. Its operation should not result in environmental degradation, such as chemical spills or soil contamination, as referred to in ACM 1.1 Code of Ethics [7] and IEEE Code of Ethics I-1 [8]. To address this, we will have to ensure that our rover has a low failure rate, as the robot contains components such as batteries that can harm the environment. We will use a battery management IC to ensure the batteries do not fail and cause harm to the environment. Additionally, we will have to design the rover to use rechargeable batteries so that it can rely on renewable energy sources.

To further mitigate safety concerns associated with our project, we will reference established safety procedures outlined on the MIT website for lithium batteries [9], which include guidelines for handling batteries. Our design decisions will be justified to demonstrate that they sufficiently protect users of the product and the designers from unsafe conditions arising from the project. These measures will ensure that our rover operates safely in various environments, minimizing risks to people, wildlife, and the ecosystem while maintaining compliance with safety standards.

5 Citations

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[6] “MPU-6500 | TDK.” https://invensense.tdk.com/products/motion-tracking/6-axis/mpu-6500/

[7] IEEE, “IEEE Code of Ethics,” *ieee.org*, Jun. 2020.
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[8] “ACM Code of Ethics and Professional Conduct,” *Association for Computing Machinery*, Jun. 22, 2018. https://www.acm.org/code-of-ethics

[9] “Lithium-Ion Battery Safety Guidance,” MIT EHS. Available:
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