Design Review Presentation

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C.E.L.P. GARDENS
Smart Plant Monitoring

Problem Statement

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- C.E.L.P. Gardens aims to revolutionize plant care with an inexpensive, autonomous solution.
- Various sensors will measure factors impacting plant health including humidity, temperature, and soil moisture.
- Data can be accessed through a desktop application for easy monitoring, accurate to within 10 minutes.
- Self-watering system provides right amount of water at the right time, saves resources, and maintains optimal plant health.

Project Goals

Objectives

- Provide up-to-date data (polling rate 10 minutes) on soil moisture and temp/humidity levels for a small potted house plant.

- Feature a self-watering system capable of maintaining a soil moisture percentage within 5% of the researched optimal moisture level (values shown later) for the observed plant.

- Functional for a range of plant containers: >6” diameter pots.

- Store recorded data locally to microcontroller, to be accessed and analyzed via micro-usb by a desktop application.

- Operates independently of a wired power source through use of a battery for at least 7 days.

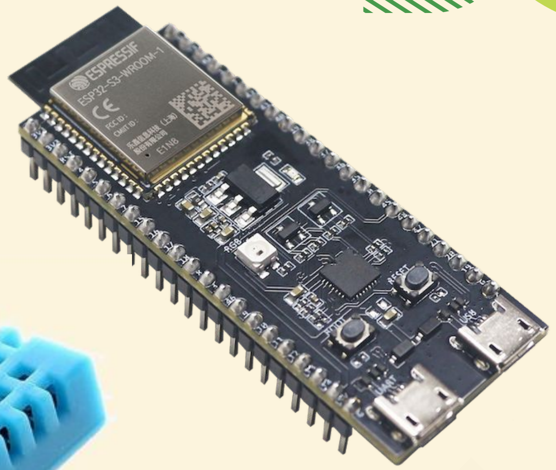
Stretch Goals

- Over the course of development, bluetooth and wireless data transmission to a user device has become a stretch goal rather than an expected feature.
- Incorporate additional sensors to the array, such as a carbon dioxide sensor.
- Build a more aesthetically pleasing housing for the device.
- Make device capable of autonomous operation for 1 month or more rather than 7 days.
- Achieve higher resolution watering, ie keep moisture within smaller range for daily watering.

Design Specifications

Hardware Components

- Microcontroller: ESP32-S3-DevKitC-1 v1.1
- Temp./Humidity Sensor: DHT11
- Soil Moisture Sensor: B07SYBSHGX
- Diode: COM-08589
- Pump: ALAMSCN
- Device Case: Zulkit Waterproof Plastic Project Box ABS
- Power Solution: 4x AA Batteries



Dimensions

- Height: 100 mm
- Width: 68 mm
- Depth: 50 mm
- Weight: Less than 5 lbs
- IP Rating: IP54
- Operating Temperature: 1℃ - 45℃

Power Solution

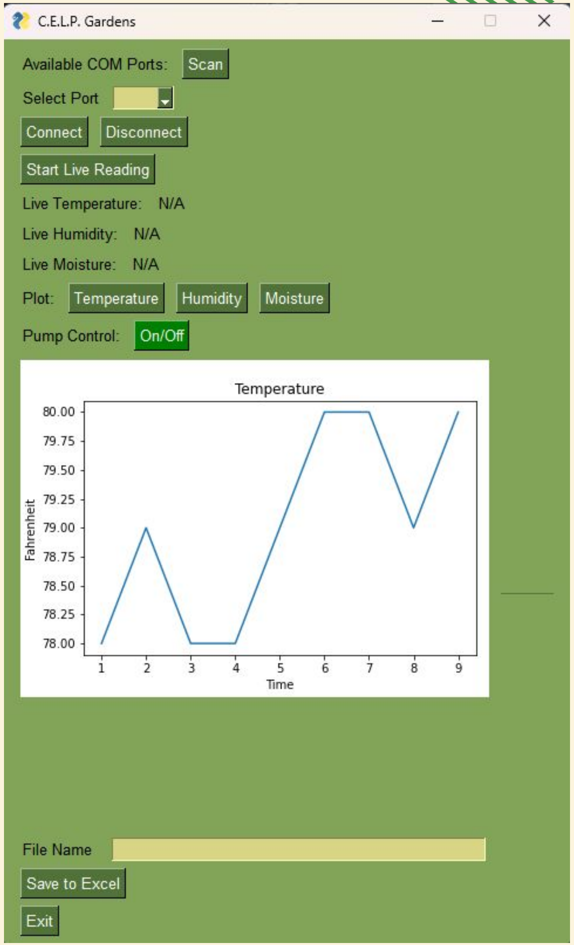
- 4x AA Batteries
  - Batteries Voltage: 1.5V each
  - Battery Capacity Each: 2850 mAh

Data Storage/Sensor Accuracy

- Data Storage Capacity: 8 MB Flash memory
- Relative Humidity Repeatability: ±1%
- Relative Humidity Accuracy: At 25℃, ±5%
- Temperature Repeatability: ±0.2℃,
- Temperature Accuracy: At 25℃, ±2℃
- Moisture Sensor Range: 514 Points

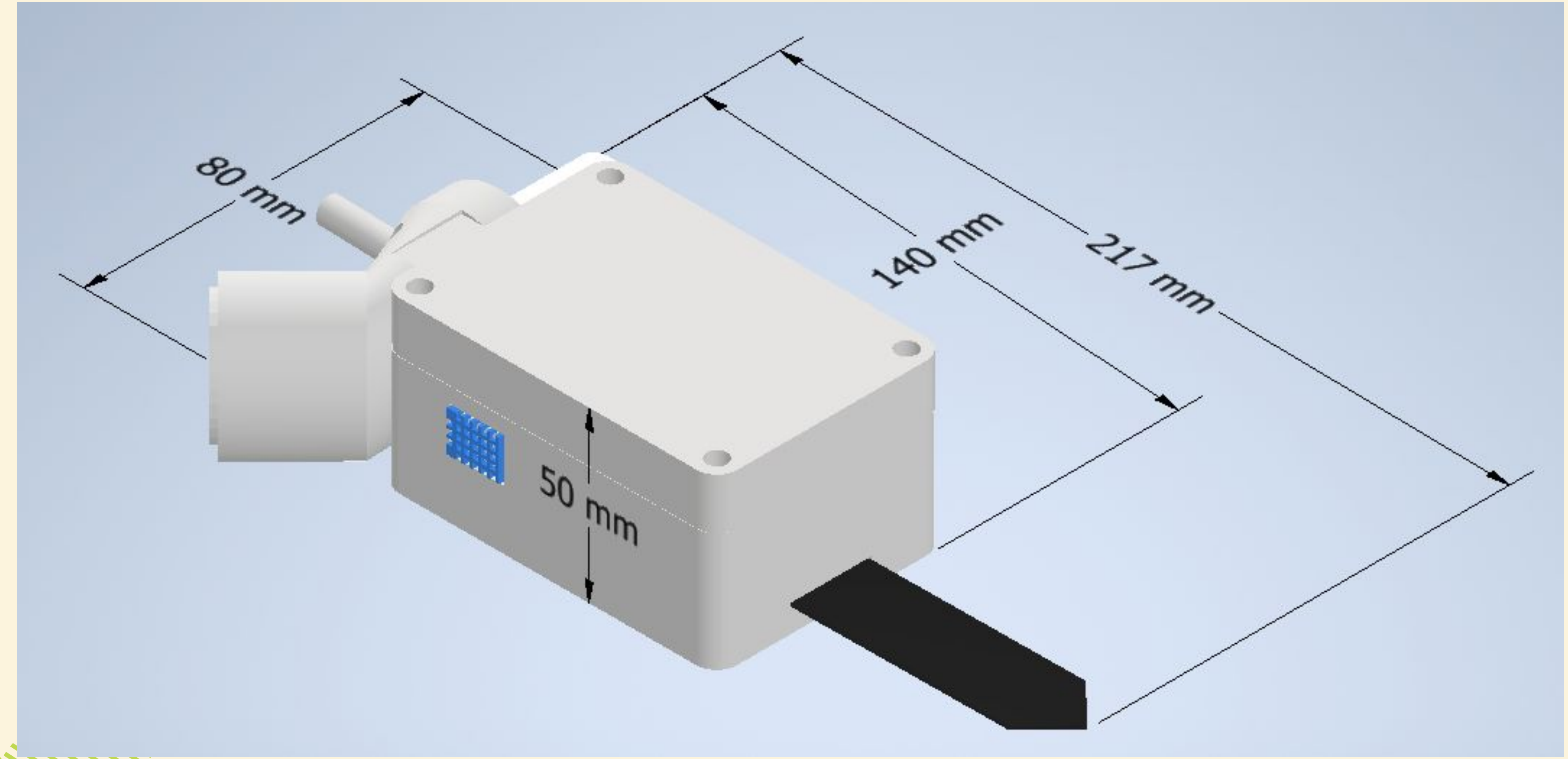
Software Applications

- Sensor Data Handling: C++
- Graph Creation/Data Analysis: Microsoft Excel
- GUI: Python
- Serial Data Transmission

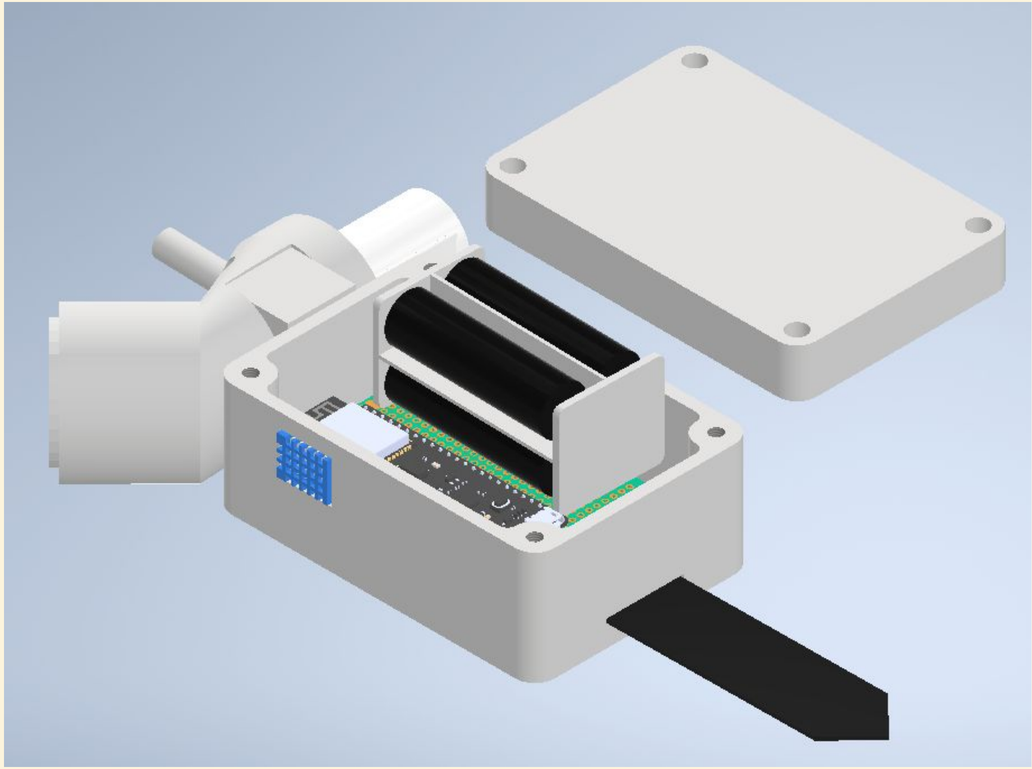


Configuration and Diagrams

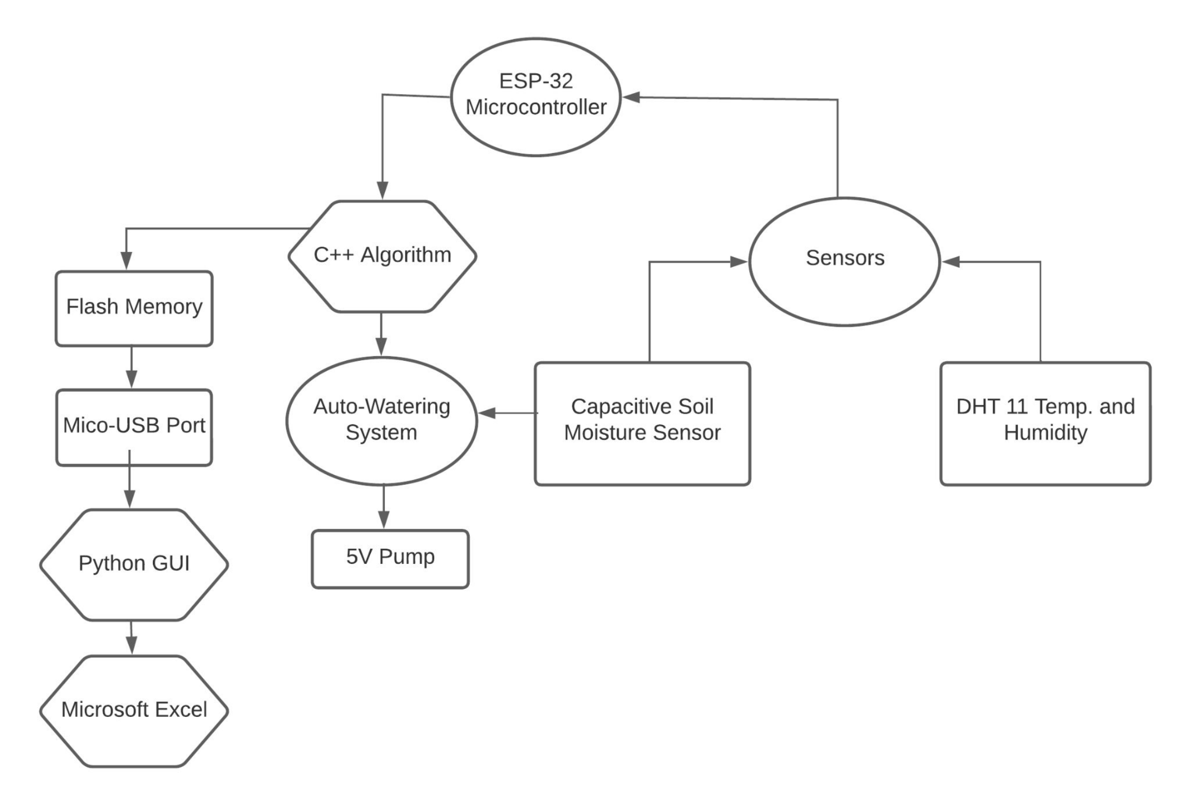
CAD Model



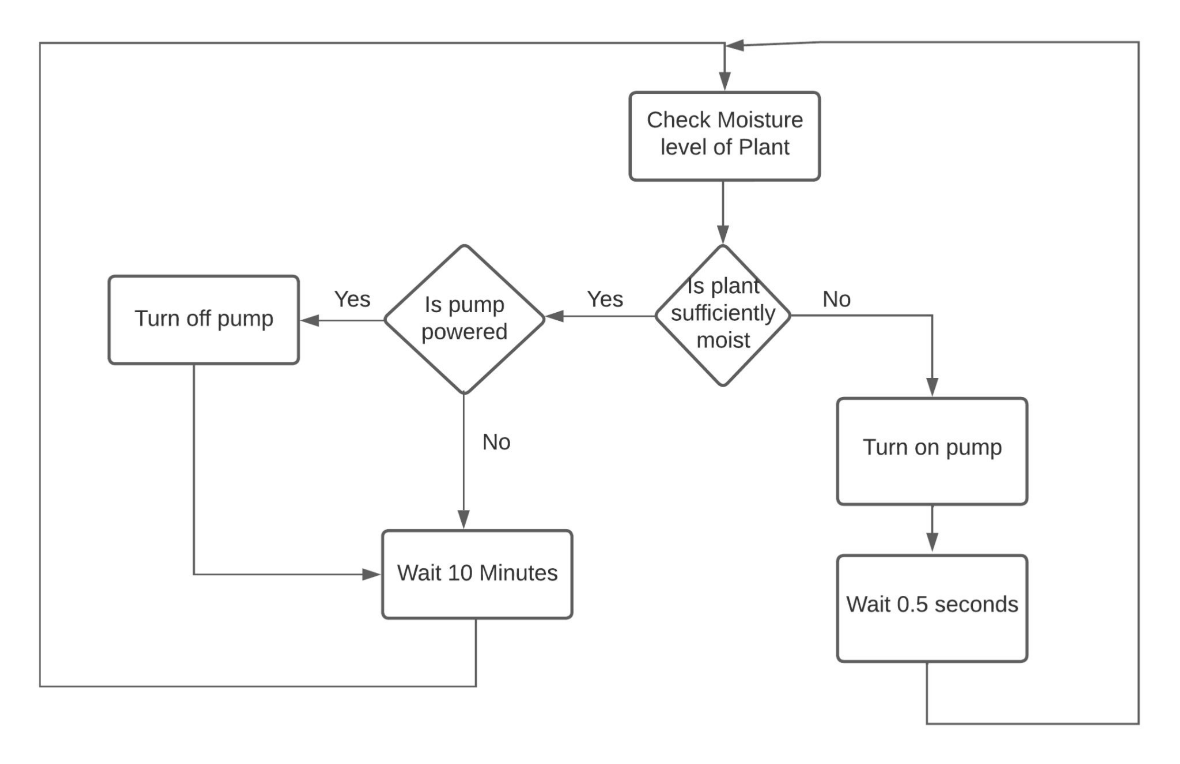
CAD Model Cont.



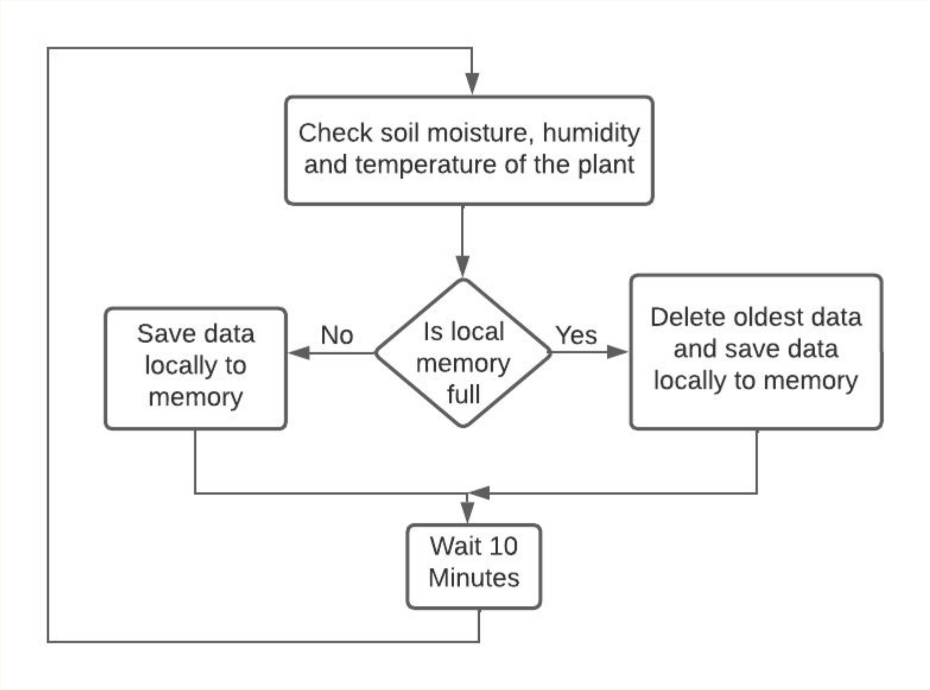
System Diagram



Hardware Feedback System



Data Storage Algorithm



Testing Plan

Testing Schedule

Bench Test
By March 17

- Assembly of components in the lab, components will not be fixed in place inside of the housing.
- Testing in ideal, controlled conditions (dry, fully charged batteries)

Environment Test
By March 24

- Components will be fixed in place inside of the housing
- Testing will be in the intended environment, which may contain hazards such as exposure to sunlight, dust, and water sprays at 60 degrees for up to 5 minutes.

Field Test
By March 31

- Testing in intended environment, with a focus on ensuring autonomous operation for at least 7 days with debugging complete.

Bench Test Plan

A successful test would require:

- Seamless power system operation (no downtime or need for rebooting during use).
- Sensor data ≥90% accurate, to be confirmed with testing equipment in lab.
- Sensors capable of polling data every 10 minutes.
- GUI displays data correctly with accompanying graphical display.
- Software algorithm operating according to schematic, actuating the auto-watering apparatus when moisture falls below acceptable levels.
- Calculated power draw would allow for at least a week of autonomous operation.

Anything short of these requirements would denote a test failure.

Environment Test Plan

A successful test would require:

- Operation to the satisfaction of previous testing in a controlled environment (checking the box on every Bench Test requirement).
- Housing and sensor ingress protection rated at least IP54 (checking IP rating test requirements).
- Sensors operating normally when device is constructed, minimal difference in the accuracy of data when inside housing.

Anything short of these requirements would denote a test failure.

Field Test Plan

A successful test would require:

- Device successfully operates without failure or need for human intervention for at least 7 days
- Reservoir is sufficiently large in volume to maintain soil moisture within 5% of the optimal value for the observed plant (see next slide for values).
- Power draw/battery capacity is sufficient to maintain operation for the required length of time.
- Ensure low battery capacity doesn’t impact device operation.

Anything short of these requirements would denote a test failure.

Proposed Test Plants

A “watering session” is ~0.5L of water

- Aloe Vera - Requires watering session every 3 weeks, ~0.167L of water/week
- ZZ Plant - Requires watering session every 2 weeks, ~0.25L of water/week
- Orchid - Requires watering session every week, ~0.5L of water/week

Analysis and Simulation

Power Draw

- Microcontroller Input Voltage: 3.3V - 6.5V
  - Operating Current Draw: 36mA; Power Draw: 180 mW
  - Deep Sleep Current Draw: 0.9mA; Power Draw: 4.5 mW
- Pump Input Voltage: 3V-5V
  - Operating Current Draw: 400mA; Power Draw: 2W
- Temp./Humidity Sensor Input Voltage: 3-5.5V
  - Operating Current Draw: 3.5mA; Power Draw: 17.5 mW
- Soil Moisture Sensor Input Voltage: 3.3-5.5V
  - Operating Current Draw: 6mA; Power Draw: 20 mW
- Theoretical Runtime: 3479 hours or 145 days

Analysis and Simulation

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Humidity (%): 54.00
Temperature   (F): 82.40

ADC analog value = 511
ADC millivolts value = 430
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Example Data Readouts

Sensors Accuracy Test Method

- Humidity/Temperature Sensor
    - Will be tested using lab equipment at DEVCOM facilities.
    - Lab equipment accuracy: 0.1% Humidity and ±0.1℃
    - This test will be run 20 times, 10 times with the sensor covered by the environmental fabric, and 10 times in open space, at a temperature range from 10-30℃ and a humidity range from 30-60% to mimic household conditions.
    - Sensor will be run through an environment testing chamber, with the readout from the sensor being compared to the readout from the testing equipment.
    - We are looking for at least 90% accuracy in the results from the temperature and humidity sensor and the environment testing parameters.

Sensors Accuracy Test Method Cont.

- Soil Moisture Sensor
    - Comparison of accuracy will be determined using gravimetric/volumetric analysis

Steps for Testing:

1. Weigh empty 200 mL container and zero scale
2. Spread out soil on wax paper and dry out in oven at 150 degrees
3. Fill 200 mL container with soil
4. Weigh soil
5. Calculate bulk density of soil by dividing weight of soil by volume of soil
6. Wet soil with 20 mL of water through use of spray bottle
7. Distribute wet soil evenly throughout container
8. Take soil moisture sensor reading
9. Weigh soil
10. Calculate gravimetric soil water content with below formula
    a. Gravimetric Soil Water = (wet weight – dry weight) / (dry weight) * 100
11. Calculate volumetric water content with below formula
    a. Volumetric Water Content = (Gravimetric Soil Water) x (Bulk Density)
12. Compare results with soil moisture sensor reading and ensure accuracy to within 90%
13. Repeat process 2 times and then increment by 20 mL, to ensure linear readings of soil moisture sensor

Pump Test Method

- We will run the pump continuously for 5 minutes while submerged in water, and monitor the current draw and volume output to ensure that there isn't a drastic change that would denote degradation of the device.
- We will allow the pump to rest for 5 minutes between test cycles, and run this test for 10 cycles.
- A current draw change of more than 50% or a volume output change of more than 25% will be unacceptable.

Enclosure Test Method

- Our enclosure for the module is rated for IP54 water and dust protection.
- This means our case should withstand water and dust that will not interfere with the part’s functionality, ie any electronics inside the case.
- We will test the enclosure by exposing the case to an oscillating spray from all directions for a minimum of 10 minutes.
- The case passes when there is limited ingress with no harmful effects, ie all pins and external devices run as expected, voltage and current distributed correctly, and no shorts, sparks, or overheating on the board
- This will be tested again after any modifications to the case have been made.

Updated Data

Design Changes/Decisions

- Originally the power solution discussed was an array of coin cell batteries, which was quickly replaced with two 9V batteries. Eventually, we settled on an array of 4 AA batteries, as it better fit our needs in voltage output, capacity, and size.

- The C.E.L.P. Gardens module was supposed to support wireless transmission of data to the serial app on a user device, but this was relegated to a stretch goal due to problems with the bluetooth capabilities of the ESP-32 microcontroller that was chosen.

Design Changes/Decisions Cont.

- The module housing has gone through many revisions, as we discovered not only that more space was needed, but also that the sensors would need to have access to their environment in order to provide accurate data.

- We've introduced the idea of using waterproof mesh fabric to protect the external sensors from any hazards.

- When proposing the idea of this product, a light sensor was intended to be included in the sensor array, but this was abandoned due to it being seen as redundant in the intended setting.

- At first, the watering solution was to be driven by a solenoid valve, but there were problems with the required water pressure that necessitated swapping to a pump, which wouldn't require as much, if any, gravity assistance.

Project Constraints

Cost	Product should not exceed $50 in total parts cost. Bulk buying will reduce the cost of components.
Maintainability	Must maintain operation autonomously without human intervention for at least 7 days. Sufficiently waterproofed to keep the device functional indefinitely. IP Rating: IP54
Manufacturability	Only accounts for one plant per unit, so some customers may have a need for more than one. Can be easily assembled with no need for proprietary tools.

Project Constraints Cont.

Legal	Must be unique enough to not violate copyright/patent law in the U.S., where it would be distributed.
Aesthetics	Must maintain a sleek, inline appearance with no visible sensors or electronic components. Housing will sit inside the pot, with only an external water reservoir.
Schedule	Initial testing demonstrating operation under intended conditions should be done by March 17th, and final testing/debugging must be complete by March 31st.

Legal Code/Standard Concerns

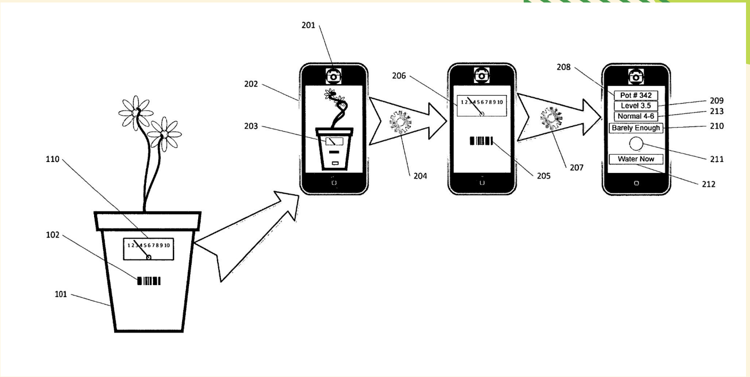
If the C.E.L.P. Gardens module were to fail in its purpose and a user's houseplant were to die, or if the auto-watering apparatus were to malfunction and cause flooding in the home, then we could be subject to liability under tort law. This would mean that we could be responsible for damages caused by the product's malfunction or design flaw, and could be required to compensate affected parties. Thus, it is very important that the device meet the requirements and regulations laid out by organizations such as the Consumer Product Safety Commission (CPSC) and the Institute of Electrical and Electronics Engineers (IEEE).

Namely, IEEE 1725, which has to do with safety requirements for rechargeable batteries in portable devices, and IEEE 1596, which is a standard regarding devices that are designed to be used in harsh environments--which is important because the C.E.L.P. Gardens module will be subject to occasional sprays of water while performing its function. Either of these codes, if the requirements are not met, could cause a malfunction that could be a liability.

Updated/Final Budget

C.E.L.P. Gardens	Part Number	Part Description	Retail Price	Vendor
Hardware	ESP32-S3-DevKitC-1-N8R8	Microcontroller	$15.00	mouser.com
	DHT11	Temp./Humidity Sensor	$3.15	amazon.com
	B07SYBSHGX	Moisture Sensor	$2.00	amazon.com
	ALAMSCN	Pump	$2.85	amazon.com
	COM-08589	Diode	$0.25	mouser.com
	Zulkit Waterproof	Device Case	$4.86	amazon.com
	SCYarn	Breathable Fabric	$0.20	amazon.com
	Alkaline	4x AA Batteries	$1.81	amazon.com
	B0858Y4JPL	Battery Holder	$3.75	amazon.com
	LAMPVPATH	Micro USB Port Plug	$0.20	amazon.com
Total			**$34.07**	**(Prev. Total: $37.22)**

Patent Research



U.S. Patent US9271454B1 - Intelligent Gardening

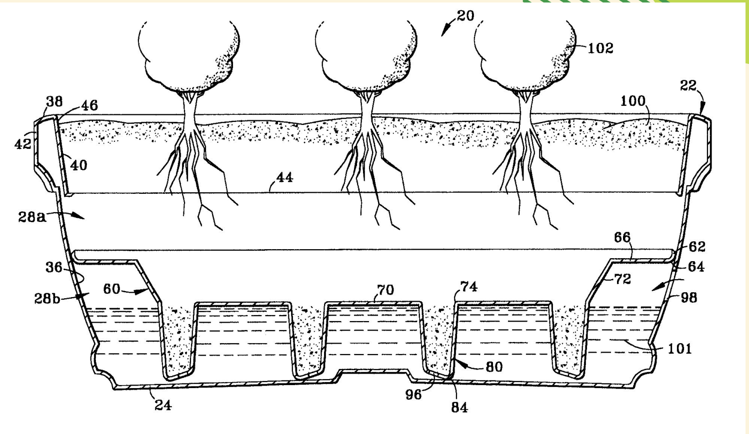
An intelligent gardening system and method for monitoring and analyzing a moisture level in individual gardening pots and/or containers is provided. A system comprises a moisture measuring sensor integrated into a pot/container. A gardener can read moisture-related data using a mobile device, a computer, or a tablet, or directly from built-in display. The gardener can send the moisture level-related data along with other data (such as, a type of a plant, a soil type, size of a pot, a plant size, location, current weather, an air temperature, etc.) to a central server connected to a central gardening database or to a cloud service and receive gardening recommendations. The gardening recommendations can include other recommendations pertaining to a particular plant and gardening conditions.

This patent is similar to our project, but it is missing some facets of the design. The C.E.L.P. Gardens module will include a self-watering system that will rely on the data provided by the moisture sensors. Additionally, it would provide alerts to a device wirelessly when conditions are outside of acceptable limits.

Patent Research Cont.

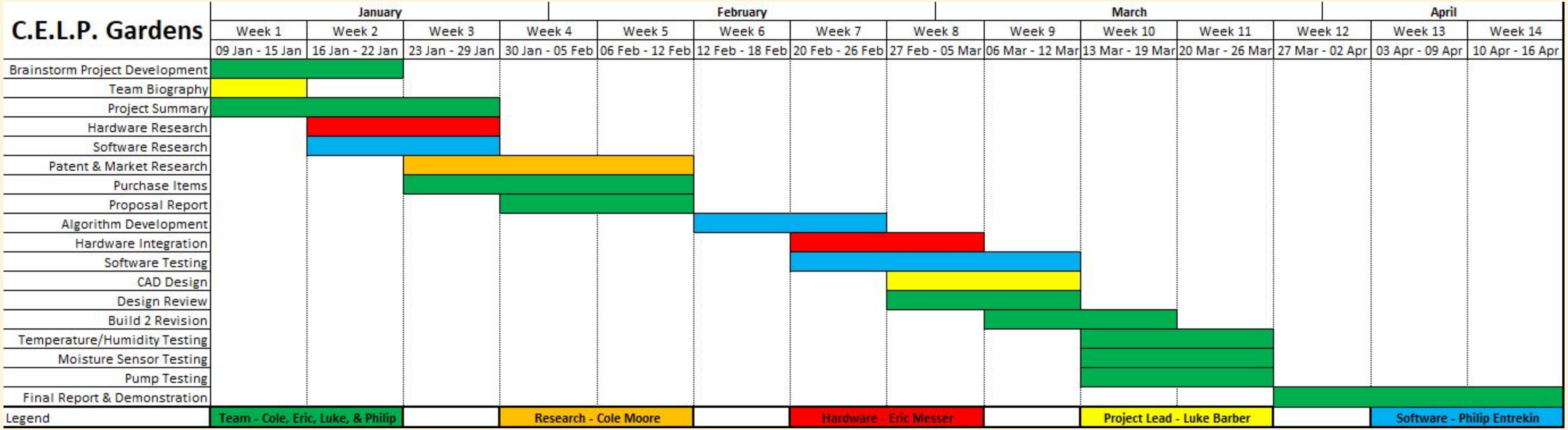
U.S. Patent US6357179B1 - Self-Watering Planter

A self-watering planter having a container and a floor structure . The latter includes one or more troughs that extend downwardly from the floor . When manufacture of the planter is complete, a chamber portion for receiving planting medium is provided above the floor. This chamber portion includes interior regions of the troughs. A lower chamber portion is provided beneath the floor structure for receiving water. Openings in bottom ends of troughs permit water in the lower chamber portion to be wicked up into the planting medium in the troughs, which in turn is wicked up into planting medium in upper portions of the upper chamber portion. The planter is designed to be manufactured with a single mold in a single molding operation.

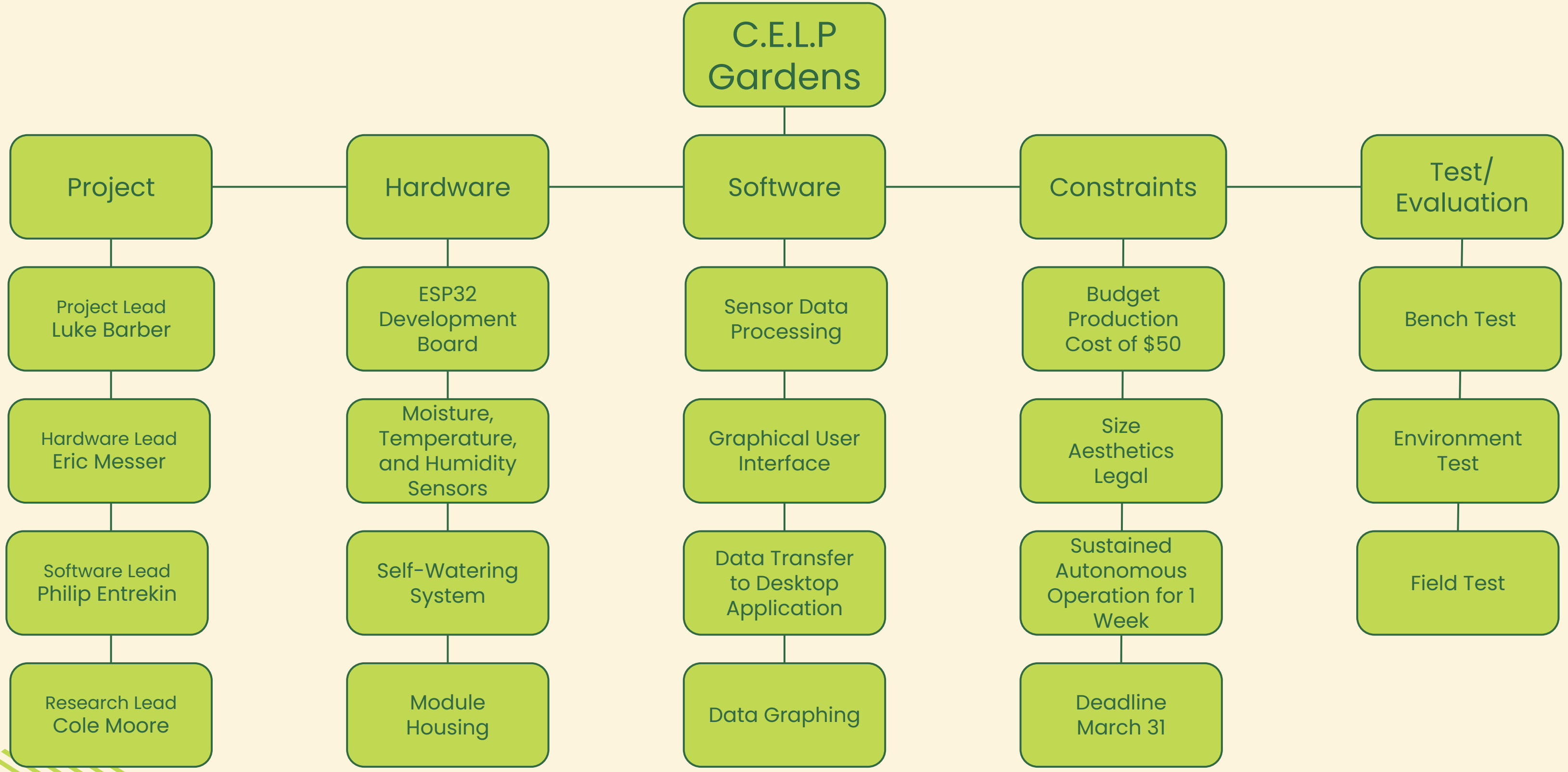


This patent is similar to our idea for a self-watering system, but it fails to include the integration of sensor data with wireless transmission or any kind of notification system/user accessible GUI.

Task Schedule



Work Breakdown Structure



Team Composition

Luke Barber - Project Lead

- As Project Lead, Mr. Barber will manage the design and scheduling necessary to complete the project correctly and on time. He will oversee all areas to make sure components of the project are assembled and operate according to design specifications.

Philip Entrekin - Software Lead

- As the software lead for the plant sensor project, Mr. Entrekin's main responsibilities include overseeing the development and implementation of the desktop application and wireless communication technologies used to transmit data from the sensors to the user. He will also ensure that the mobile application is user-friendly and easy to understand.

Eric Messer - Hardware Lead

- As the Hardware Lead, Mr. Messer will be responsible for overseeing the design and implementation of the physical components required for the project. This includes tasks such as sourcing, assembling, and storing components.

Cole Moore - Research Lead

- As Research Lead, Mr. Moore will organize any research data pertinent to the project such as hardware component specifications and software requirements. He will also ensure that the project does not violate any existing patents and identify the nature of the differences in design between our project and any existing ideas. Additionally, he will collect and quantize any necessary market research.