UCF Senior Design 1 Divide & Conquer Document

Functioning Lighting and Optimal Watering for Environmental Regulation System (F.L.O.W.E.R.S.)

Group 20

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2 Project Description

2.1 Background and motivation

Plants are essential to life, providing the foundation for the food we consume and the air we breathe all while enhancing the well-being of our environment itself. They contribute to biodiversity, the reduction of carbon dioxide levels, and overall, create a healthy outside environment, so it is no surprise that they have been integrated as an indoor addition as well, to bring those benefits directly into homes. Beyond ecology, plants offer numerous benefits for individuals, as planting and gardening have been regarded as fulfilling and productive activities which can lead to improved mental health, reduction of stress, and increased productivity. For humans, the nurturing of plants has been linked to the promotion of feelings of increased importance due to a greater sense of responsibility, relaxation, and have even proved to be a form of therapeutic remedy.

Despite the well-documented benefits listed above, many individuals are hesitant to engage in plant care or gardening tasks. Those with busy schedules or limited knowledge of plant care may find the challenges of gardening daunting, further deterring them from engaging in such activities. There is a common misconception that successful gardening requires a “green thumb”, but there is no innate ability embedded within humans to understand and care for plants effortlessly; plant care is a skill that must be learned. For those with demanding schedules, keeping up with the watering requirements and conditions many plants require in excess, can quickly become overwhelming. This is why many people avoid plant care as a whole or experience setbacks which prevent them from trying again in the future, which can cause the home to drop regarding health benefits as well as lack desired aesthetic appeal. This is why many home decor stores and supermarkets usually have reserved multiple aisles with dozens of fake plants, since these items can deliver on the latter. However, the largest benefit which greenery can offer inside is improved air quality, which these plastic placeholders are unable to fulfill.

Our team, consisting of four college students who balance rigorous engineering coursework with jobs and extracurricular activities, have personally faced these challenges. While we each appreciate the idea of hosting plants in our homes, both for the beneficial and aesthetic aspects, our hectic schedules have discouraged each of us from successfully bringing real plants to live with us. On top of a busy lifestyle, the addition of watching your plants fail to grow and having to compensate or restart again can be highly frustrating.

This project seeks to address these barriers by automating the more complex aspects of garden maintenance. Via our smart garden project, users will find gardening more accessible and appealing, empowering them to embrace this rewarding activity with greater ease and confidence. Some of the most time-consuming and tedious tasks such as watering, soil moisture monitoring, and repositioning for prime lighting will no longer need to be repeated by plant parents. This project aims to bridge some of the larger gaps between technology and nature, to ensure plant care can become effortless and enjoyable.

2.2 Existing Products

There are a few existing products that try to tackle a similar concern as our smart garden, however these projects tend to have great diversity in implementation, since environments can integrate differing combinations of: light exposure, RGB LED spectrum altering, watering systems, multiple/single simultaneous environments, heating elements, etc. However, there are notably quite few environments which offer the ability for the user to change and specify the specifications for plants that have critically different demands in the regard of light and soil requirements.

Marketed products are vast, with a multitude of companies and approaches. For example, the ‘Click & Grow’ company offers multiple similar products along this scope, offering products like the “Smart Garden 9” and the “Smart Garden 3”. These products offer automatic watering and lighting services for the plants within. Even though the “Smart Garden 9” offers increased space to allow different plants to cohabit the same environment, there is no separation or regulation to maintain the growth needs of plants with notable differences between their nutrition, watering, and heat requirements. “The Smart Garden 9” has reusable pots for each plant, in these pots Click & Grow adds their own soil mixture so that the plant gets the proper amount of nutrients. The “Smart Garden 9” has a height extension for the lighting of the pot. The purpose of this is to give the plants the most lighting possible when they’re a seedling and then once they have grown enough you are able to move the lighting further away from the plant as needed, they also use white and red LEDs. For watering, each of the pots sit above a water reservoir where a rod sticks into both the water and the soil and absorbs the water which then goes into the soil. The user will have to manually refill the reservoir once it gets low.

Another similar product is the ‘LetPot’ “Hydroponics Smart Growing System,” one of Amazon’s top sellers and top rated in this category. This product actually has a much closer correlation to the aspects of our project plan. Noteworthy features of this indoor gardening assistant include a directed water pump, light spectrum to encourage different growth responses from plants, and support multiple plants. From the app, the user is able to control the LED mode based on whether they want to grow veggies/plants (changes the RGB values in the LED), change the light intensity, see the water volume, and see the power consumption of the system. It is important to note that even though this product more closely represents the goals of our systems, and has the convenient user interface to boost the goals outlined in our project, the system still does not allow for multi-environment support, as the plants all share a common soil and watering environment. ‘LetPot’ costs less than the previous product and can have the same amount of plants when compared to the previous product from ‘Click & Grow’. Even though the product from ‘LetPot’ has the same amount of features as the product from ‘Click & Grow’, as well as an app feature. The product from ‘Click & Grow’ seems to be the high quality product and the one worth buying.

2.3 Goals and Objectives

We expect our design to alleviate the problems mentioned above; specifically, our design will provide a minimal maintenance solution to growing plants indoors, using plant pots or small planters. These plant pots will be stacked vertically on shelves for space saving reasons. Maintenance requirements will be minimized in order to prioritize user's upkeep as well. Therefore, the goals for our project are as follows:

Project Goals

- **Goal One:** To build an optimized and efficient indoor growing environment for plants, that takes into account a given species' ideal water and light intake
  - Basic Goal: To deliver water to the plants in accordance with the ideal amount of water for that particular species
  - Basic Goal: To provide sufficient spectral power density to the plants to ensure optimal growth
  - Basic Goal: To measure the soil moisture and soil temperature at the plant pot for feedback control
  - Advanced Goal: Use a programmable light that can output at a variety of frequencies for optimum plant growth
  - Advanced Goal: To send the collected data through a wireless bluetooth connection to the MCU
  - Advanced Goal: To utilize duty cycle control and extended on/off periods for the LED lights to simulate day and night cycles
  - Stretch Goal: The moisture/temperature sensor should be such low power that the battery on the PCB only needs to be replaced twice a year, assuming constant use

- **Goal Two:** To develop a user friendly app that will allow the user to manually input ideal growth conditions for a given plant
  - Basic Goal: Allow the user to input the ideal soil moisture level and lighting values
  - Basic Goal: Allow the user to see real time information about the soil moisture and temperature
  - Advanced Goal: Create a small database within the app that comes with preset ideal values for the most common potted plants grown in Florida
  - Advanced Goal: Notify the user when a soil moisture or temperature critical low/high has been measured
  - Stretch Goal: The app will consider what stage of growth a plant is currently in (seedling, budding, flowering), and modify the amount of water delivered for even more optimized growth, depending on the plant species

Project Objectives

- **Water System Objectives**

- ➢ To deliver water to the plants via a small water pump and electronically controlled solenoid valves
- ➢ To respond to inputs from the MCU to know when to open the solenoid valves, and for how long to do so.

❖ **LED Light Fixture Objectives**
- ➢ To use a surface mount light emitting diode to provide light to the plants
- ➢ To maintain relatively low power consumption to add minimal load and cost to the user
- ➢ To change the color of the programmable LED light to output the ideal growth frequency

❖ **App/UI Objectives**
- ➢ To create a user friendly interface that allows the user to create plant "profiles"; it will store the user input values for ideal soil moisture level and optimal spectral frequency, and communicate with the MCU to control these values
- ➢ To communicate to the MCU via Bluetooth
- ➢ To report the listed data values, like current moisture and temperature values, to the user
- ➢ To notify the user if any values of the critical conditions fall below or above a certain threshold

❖ **Capacitive Moisture/Temperature Sensor Objectives**
- ➢ To accurately measure the moisture and temperature of the soil in which the plant is growing
- ➢ To consume very little power in order to remain functional for long periods without recharging, ideally half a year or more
- ➢ To communicate via Bluetooth to the MCU the current values

❖ **MCU Objectives**
- ➢ To facilitate communication between the various peripheral devices
- ➢ To receive real time information from the sensors via Bluetooth
- ➢ To open/close the solenoid valves in response to the real time soil moisture level
- ➢ To duty cycle control the LED lights in order to provide the ideal power spectral density

2.4 Features and Functionalities

Overall growth conditions vary tremendously for various phyla of plants throughout the world, and therefore our design will be geared towards plants that are able to grow in the outdoors environment found in the earth's tropic and subtropic zones (between 0 and +-35 degrees of latitude), and which expect to see fresh water, as opposed to brackish or salt water. However, even in this reduced category of greenery, growth can occur under a large range of conditions; however, optimal conditions for different types of plants have been well established in the scientific literature. Our goal is to optimize the plant growth by providing the ideal amount of water, as well as providing exactly the ideal frequencies of light, for the ideal amount of time. Of course, these values will generally vary slightly, or sometimes largely, based on which specific type of plant that is currently being put on the shelf. Therefore, our design will also implement an app that will allow the user to input which type of plant is in which of the three shelf locations. From the app, the user will be able to input the ideal amount of water the plant should receive over the course of a single day, as well as the ideal frequency of light at which photosynthesis is most efficient for that given species.

The functionalities can be listed as follows:

- **Overall System Functionality**
  - The system will only require the maintenance of refilling the water tank when the tank starts to run low
  - An accompanying app will track which type of plant is currently on which of the 3 shelf positions
  - After the ideal water and light data has been entered into the app, the system will automatically deliver the correct amount of water and light to that location

- **App Functionality**
  - The app will allow the user to select one of three plant positions, being top, middle, and bottom, and then specify which type of plant is in that position
  - The app will have preset values for some of the most common plants grown in Florida, allowing a large percentage of users to simply use preset values
  - The app will allow for users to create their own plant preset, which will allow for ideal water data, as well as the ideal light data, to be added
  - The app will also have the capability of sending alerts to the user if any of the three critical conditions reach critical highs or lows; this would be for soil temperature, soil moisture, and light density per square meter
  - The app will provide a small step by step checklist for when the user switches plants on the shelf; this will include a reminder to move the moisture/temperature sensor, as well as a reminder to seat the water line correctly
- **Soil Moisture/Temperature Sensor Functionality**
  - The system will come with three “plug and play” sensors, which simply need to be inserted in the plant pots on the shelf
  - The sensors will detect the soil moisture/temperature at a location near the roots, and will send the MCU a value every 10 minutes
  - For seamless connectivity, the sensor will send its data via Bluetooth to the MCU
- **Water System Functionality**
  - The system will come with a 12 Volt self regulating water pump which will keep the pvc lines at a constant pressure
  - A built in, inline pvc water regulator will ensure that water pressure stays low enough to meet safety standards

- ➢ Electronic PVC solenoid valves will regulate the flow of water into each pot; these will be entirely independent of each other
- ➢ When the MCU determines that the soil moisture is ideal for a given plant, the solenoid valve for that plants water line will close immediately

❖ **LED Lighting Functionality**

- ➢ The system will come with high power, 120V surface mount, and programmable LED fixtures
- ➢ These fixtures will be duty cycle controlled in order to moderate the spectral density incident onto the plant
- ➢ These fixtures will also be programmable, and will emit a range of light that is ideal for a given plant
- ➢ The lights will also come with a dimming feature, which allows the light to operate at a more comfortable intensity for the human eye; in this mode, the lights will stay on for longer in order to still meet the ideal needs for the plants

❖ **MCU Functionality**

- ➢ The MCU will both process data from other systems, as well as act as the input to other systems within the total framework of the design
- ➢ The MCU will read data values for soil moisture, soil temperature, and light per square meter incident onto the plant
- ➢ The MCU will receive data from the app which informs it of which plant is in which position on the shelf
- ➢ The MCU will receive data from the app which informs it of the ideal amount of soil moisture for the plant; the MCU will compare the value read from the sensor and the ideal value, and
- ➢ The MCU will receive data from the app about the ideal lighting conditions for the given plant type in one of the three location; based on this information, it will have the LED operate at a specific operating frequency, as well as duty cycle control the light as to give the plant both the ideal frequency and amount of light energy
- ➢ The MCU will provide the app with data from the sensors so that the user can be sent critical information about their plants, in the event a critical condition value is outside of the acceptable range

2.5 Specifications

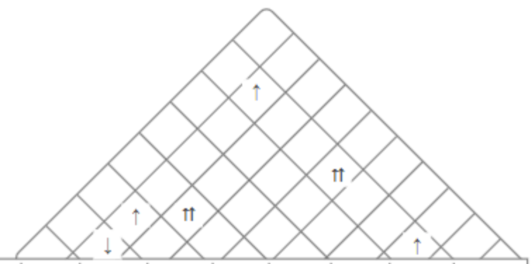
Table 1 below shows the design specifications and engineering requirements for this project. From this table we will be demonstrating three of these requirements which will be highlighted. These features that have been listed below are what are important for our project to be successful.

Table 1: Engineering Specifications

Specifications Table	
Specification	**Requirement**
App Data Refresh Rate	App information updates at least once every hour
Volumetric Water Content Accuracy	Within 5% accuracy
Soil Moisture Polling Rate	At least once per minute
Environments Maintained Simultaneously	At least 3
Maximum Power Supplied (120V LED lights)	Between 100 and 200 watts
Electronic Solenoid Valve Response Time	0.1s-0.5s
GPM of Water Pump	At least 1 GPM (Gallon per Minute)
PSI of Water Pump	At least 50 PSI at the highest plant pot on shelf
Battery Life (Moisture Sensor, Minimum polling rate)	At least 180 days
Battery Life (Water Pump)	4 hours of continuous draw from pump
Water Pump Maximum Power Consumption	Less than 75 watts
Maximum Shelf Size	4'x 6'x2'
12V system Safety	15 Amp Breaker trip time between 30 and 100 milliseconds
120V Lighting system Safety	15 Amp Breaker trip time between 30 and 100 milliseconds

2.6 House of Quality

Symbols	Description
↑	Positive Correlation
↓	Negative Correlation
↑↑	Strong Positive Correlation
↓↓	Strong Negative Correlation
+	Positive Polarity
-	Negative



Marketing Requirements / Engineering Requirements	+/-	Battery Capacity	Dimentions	Temperature Measurement	Humidifier Sensor	Cost	Response Time	Maintainable	Data Transfer Accuracy
		+	-	+	+	-	-	+	+
User Interface	+		↓			↓	↑↑		↑↑
Battery Life	+	↑↑							
Portability	+	↓	↓			↑			
Water Capacity	+		↑↑					↑	
Affordability	+	↑			↑			↑↑	
Reliability	+			↑			↑↑	↑↑	↑↑
Target for Engineering Requirements		4 hours	4'x6x2'	once every 10 minutes	once per mintue	$500-$1000	0.1s-0.5s	100% accuracy	Every 30 days

Figure 1: House of Quality

2.7 Block Diagram

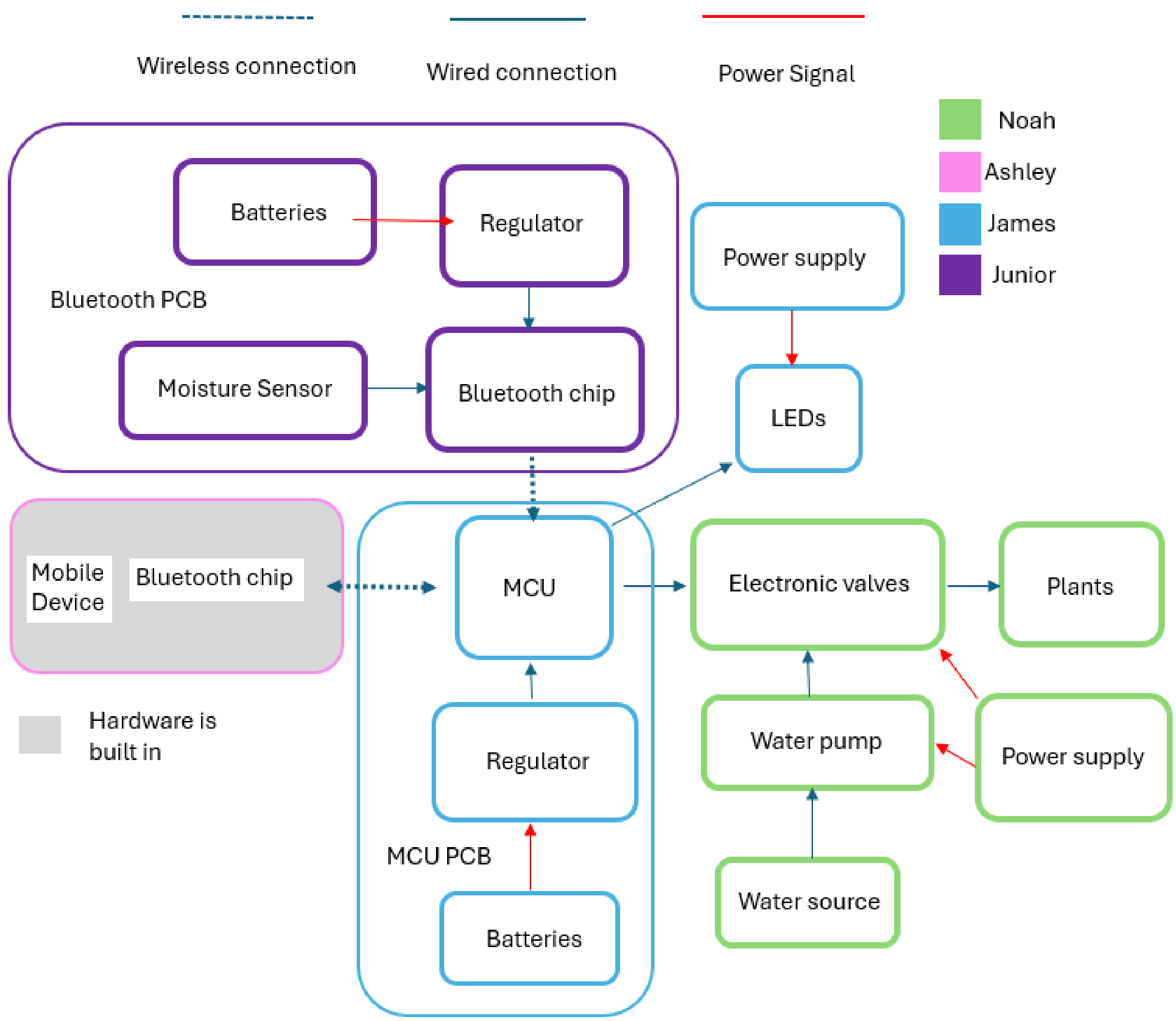


Figure 2: Block Diagram

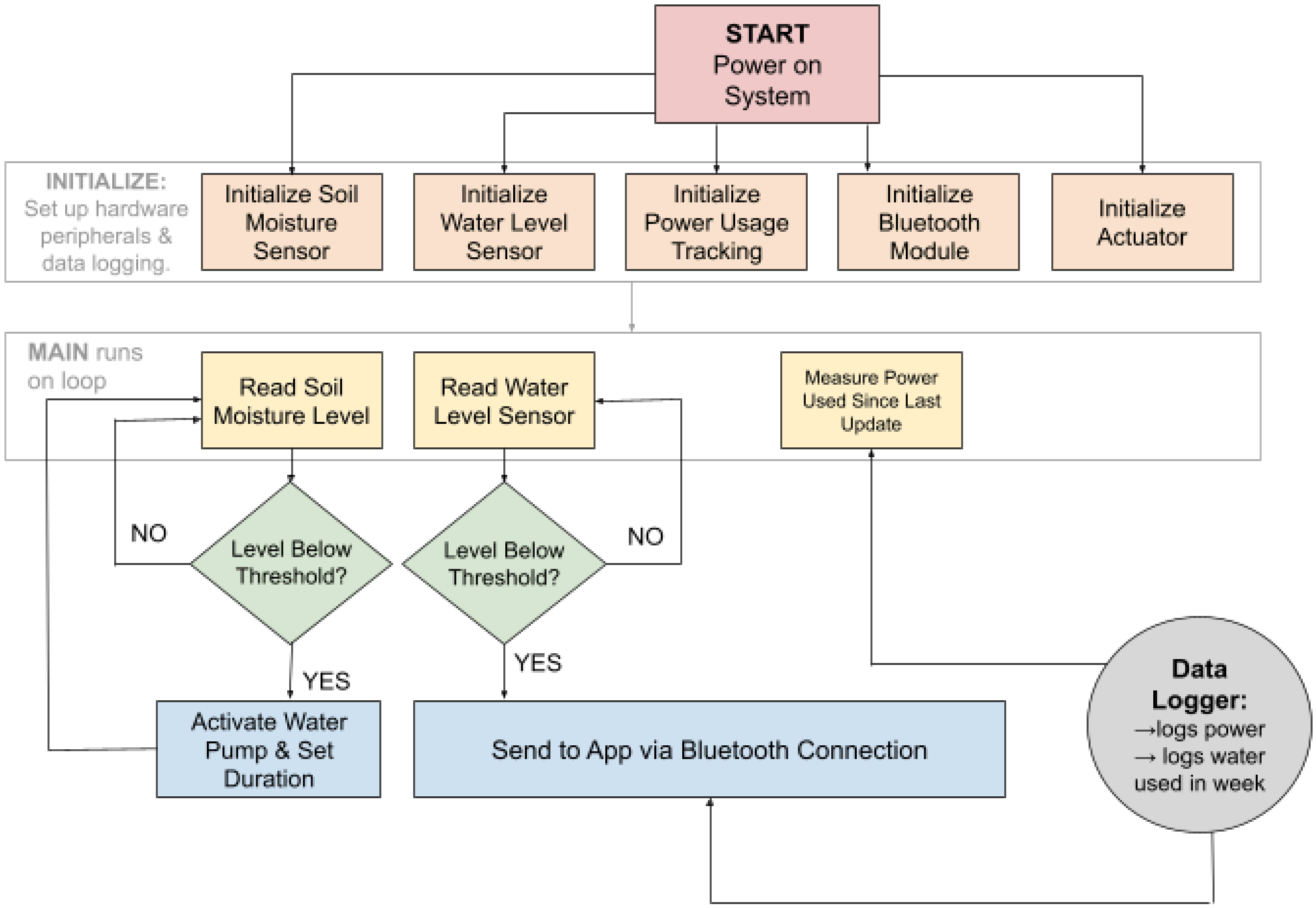


Figure 3: Embedded software flowchart

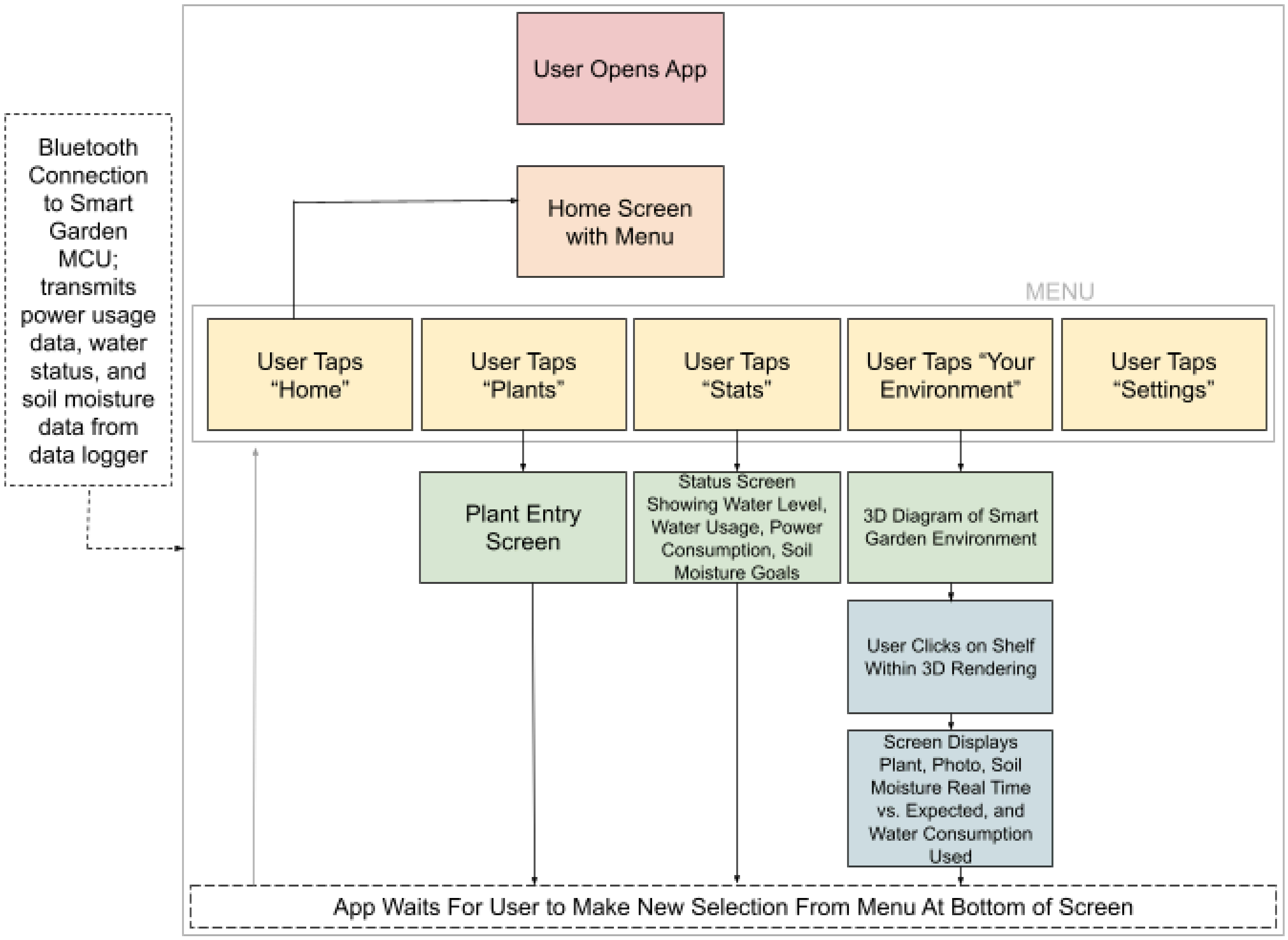


Figure 4: App Logic Flowchart

10 Administrative Content

10.1 Budget and Financing

This project will not have a sponsor external to the group members, and therefore, the entirety of the cost of development will be divided equally between the four members. We will construct the budget table by dividing the components into the following sub-systems: The safety features, capacitive moisture/temperature sensor, the app, the MCU, the water system, and the lighting system.

10.2 BOM

	Bill of Materials EEL 4914		Total Cost	$375.22		
Part Name	Part Number	Vendor	In stock?	Unit Price	Delivery Date	Total
12V DC Water Pump	Pauline CY/711202470378	Amazon	Yes	1 for $19.99	Not Yet Purchased	$19.99
Schedule 40 1/4" PVC pipe	PVC 07200 0600	Home Depot	Yes	15ft at $1.37/ft	Not Yet Purchased	$20.55
4' x 8' 23/32" CDX Plywood	303564747	Home Depot	Yes	4 Sheets for $36/sheet	Not Yet Purchased	$144.00
ESP32 Home chip	1965-ESP32-WROOM-32E-H4DKR-ND - Digi	DigiKey	N/A	3 for $2.68	Not Yet Purchased	$8.04
40 Gallon Plastic Tank	40 Gallon Heavy-Duty Storage Tote	Amazon	Yes	1 for $20	Not Yet Purchased	$20.00
Electronic Solenoid Valve	Digiton ROCON-341	Amazon	Yes	3 for $7.50/valve	Not Yet Purchased	$22.50
Garpsen LED Growth Lights	BL-G40A	Amazon	Yes	4 for $8.75/Light	Not Yet Purchased	$35.00
12V 18Amp*h Battery	B0B3MHJXLF	Amazon	Yes	1 for $38	Not Yet Purchased	$38.00
Wood Varnish	N/A	Home Depot	Yes	1 for $20	Not Yet Purchased	$20.00
1/4" O.D Clear Vinyl Tubing	N/A	Home Depot	Yes	20ft at 25cents/ft	Not Yet Purchased	$5.00
Cell Batteries	CR2032AB/10B	Amazon	Yes	10 for $1/battery	Not Yet Purchased	$10.00
Temp/Humidity Sensor	SHTC 3	Sensirion	Yes	3 for $3.27/chip	Not Yet Purchased	$9.81
10k resistor	RC1206FR-0710KL	DigiKey	Yes	12 for $0.10/resistor	Not Yet Purchased	$1.20
.470k resistor	13-RC2512FK-07470RLDKR-ND - Digi-Reel	DigiKey	Yes	3 for $.32/resistor	Not Yet Purchased	$0.96
1M resistor	P1.00MHDKR-ND - Digi-Reel	DigiKey	Yes	3 for $0.1/resistor	Not Yet Purchased	$0.30
32khz Oscillator	CFS-20632768DZBB	DigiKey	Yes	3 for $.20 each	Not Yet Purchased	$0.60
3.3V regulator	TPS613222ADBVR	DigiKey	Yes	4 for $.58/regulator	Not Yet Purchased	$2.32
Tandem 15A Circuit Breakers	N/A	Home Depot	Yes	1 for $16.95	Not Yet Purchased	$16.95

We can reference the BOM above and categorize the budget for each subsystem listed below. As always, there will be some amount of unaccounted for costs in development; for example, pcb development costs can be highly variable and cannot be known until the PCB design is complete. Therefore, in our budget, we will allocate some amount of funds for these miscellaneous development costs. Furthermore, the table below will double count a few items, as some components are used in multiple sub systems, like the CR2032 batteries. This give us:

Table 3: Budget table

Sub-System	Sub-System Cost	Running Total Cost	Percentage of allocated Budget
Capacitive Moisture Sensors	$25.19	$25.19	4.3%
Shelf Frame	$164	$189.19	28%
MCU	$19.64	$208.43	3.3%
Water System	$126.04	$334.47	21.5%
Lighting System	$35	$369.47	6%
Safety Features	$16.95	$386.42	2.9%
Misc Development	$200	$586.42	34%

10.3 Project Milestones/Schedule

Table 4: Senior Design 1 Tentative Schedule

Tentative Schedule For Senior Design 1 - Spring 2025		
Task	**Timeline**	**Responsibility**
Form Group	**Week 1**	**Everyone**
Brainstorm Ideas	**Week 1**	**Everyone**
Final Decision on Project	**Week 2**	**Everyone**
Divide and Conquer Document	**Week 3 (Fri, Jan. 24)**	**Everyone**

Review Divide and Conquer with Advisor	**Week 4 (Weds, Jan. 29 - 3pm)**	**Everyone**
Research Bluetooth Chip	**Weeks 5/6**	**Ash/Junior**
Research the User Interface/Methods of Implementation	**Weeks 5/6**	**Ash**
Research MCU	**Weeks 6/7**	**Ash**
Research the Batteries	**Weeks 5/6**	**James/Junior**
Moisture/Temperature Sensor	**Weeks 5/6**	**Junior**
Water Pump Parts Acquisition	**Weeks 10/11**	**Noah**
PCB Design	**Weeks 10/11**	**Junior**
PCB Review and Order	**Week 12/13**	**Junior/Everyone**
Power Supply (12V battery)	**Week 10/11**	**Noah/James**
Acquire LEDs	**Week 14**	**James**
Acquire Electronic Valves	**Week 14**	**Noah**
60 Page Draft	**Week 12**	**Everyone**
Project Prototype	**Week 13/14/15**	**Everyone**
120 Page Final Document	**Week 16**	**Everyone**

Table 5: Senior Design 2 Tentative Schedule

Tentative Schedule For Senior Design 2 - Summer 2025		
Task	**Timeline**	**Responsibilities**
Cutting, Painting, Staining, Coating, and Assembling Wooden Base	**SD2 (While PCB out for order)**	**Everyone**
Building App and Developing the UI	**SD2**	**Ash**
Order 2nd PCB	**Week 5/6**	**Everyone**
D Day	**Week 12**	**Everyone**