Smart Garden System

FINAL REPORT

Team: 25

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Executive Summary

Summary of Requirements

The Smart Garden Monitoring System (SGMS) requires many hardware components as well as a software to display the analyzed data to the user.

Functional:

- Monitor temperature of the environment in order assure plant health
- Time the growth of the plant
- Water the plant using a timed water pump
- Give the plant light using an led plant light

Resource:

- Funds to purchase seeds & soil
- A location to host our project
  - The senior design lab and our physical greenhouse
- This project must be completed by the end of April 2022(constraint)
- Sensors and circuitry to observe the plant and communicate findings to the user

Economic/Market:

- This project must cost under $1000 to create and operate (constraint)

Environmental:

- A small greenhouse will be constructed to avoid temperature variations while testing the prototype

User Interface:

- The user should be able to see all signals charted clearly with an automatically analysis of the plant's health and remaining time until maturity if starting from a seed

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1 Introduction

1.1 Problem Statement

Growing plants can be not only a time consuming task, but a very sensitive one as well. With our smart garden monitoring system, we hope to automate as much of the plant growing process as feasibly possible in order to make it more consistent and manageable for the user. Doing so will save time and money, and will in turn make growing plants a more accessible task for a wide range of potential users. So our goal was to make a prototype for a smart relatively affordable greenhouse.

1.2 Requirements & Constraints

The Smart Garden Monitoring System (SGMS) requires many hardware components as well as a software to display the analyzed data to the user.

Functional:

- *Monitor temperature of the environment in order assure plant health*
- *Time the growth of the plant*
- *Water the plant using a timed water pump*
- *Give the plant light using an led plant light*

Resource:

- *Funds to purchase Seeds, & Soil*
- *A location to host our project*
- *The allocated amount of space offered for this project may constrain the size of our prototype*
- *This project must be completed by the end of April 2021(constraint)*
- *Sensors and circuitry to observe the plant and communicate findings to the user*

Economic/Market:

- *This project must cost under $1000 to create and operate (constraint)*

Environmental:

- *A small greenhouse will be constructed to avoid temperature variations while testing the prototype*

User Interface:

- *The user should be able to see all signals charted clearly with an automatically analysis of the plant's health and remaining time until maturity if starting from a seed*

Other:

- *Soil should be treated properly to reach a state of chemical balance and obtain maximum plant growth*

1.3 Engineering Standards

Some common standards needed to follow are IoT standards regarding security and communication protocols. These standards may also coincide with bluetooth standards which we could use for short distance wireless communication and wifi/ethernet standards which would be used for long distance communication. The short distance bluetooth is useful for wireless probes or other tools/features, whereas the long distance communication is useful for controlling the system with a cellphone or computer that is located in a different location.

1.4 Intended Users and Uses

Due to not having a client, despite our best effort of trying to get one, the only real users of this project at the current time will be us. That being said, the design of something like this would be very beneficial to be able to produce food in a small environment with a busy schedule. Our design has the potential to be used in the future to a food shelf or a family that needs it. All this includes that it will help the user grow healthy food which will: save on money, time, and lead to healthier available food options. They would use it to grow food for themselves or those who need it but do not have time or a green thumb to grow it themselves.

Beneficiaries from our project:

- On a smaller scale:
    - Hobby Gardeners
    - Educational tool
- On a larger scale:
    - Food insecure populations
    - Humanitarian efforts

Use cases:

- Grow plants for hobby gardeners
- Work as an educational tool for students
- Grow healthy food for a family in need, shelter, or food shelf
- Present healthier food options to the user
- Help grow a space, plants, in which the user takes comfort in
- It should be able to be used to track and monitor the levels of water, light, temperature and growth time of the plant.
- Display crucial information on the application, and ability to adjust based on the information that is being given.
- If one goes into the application they can check the level of water, and light that the plant has been given for the past week
- They are able to track, write down on the application if they can see new growth on the plant to track if the light and water levels are working

2 Design

2.1 Design Context

2.1.1 Broader Context

Area	**Description**	**Examples**
Public health, safety, and welfare	The users of this product are able to grow healthier foods right from their own home. This also includes being able to share that food with their neighbors and family.	An example includes: being able to grow food and make healthier measles rather than having to go out and get fast food to be able to afford food for their families.
Global, cultural, and social	Growing food and being able to supplement it relates to many cultures, religions, and values to be able to name them all. It also strengthens families and communities when that resource can be shared with others Which in turn helps make those ties that are needed to survive in our world.	If a family has leftover food they can share with that neighbor who just moved to town and knows nobody this creates a community and friendship that was not previously available.
Environmental	The impact our smart garden system will have are being able to grow your own produce which helps lessen plastic waste that otherwise could be used. It also will have an electricity timer so that the light is not powered on in order to preserve those resources.	By using it families will no longer need to buy as much veggies at the grocery store and that will save on plastic that goes back in the environment/ocean
Economic	Our product will help lessen the need for users to buy food from the market. It will also be economically efficient for our client and will be a good saving time so that it doesn't cost them anymore than needed.	It will need to be able to efficiently and safely grow food to be able to provide what is needed. It will also need to be able to turn the light off when needed to save on electricity.

Figure 1: This table shows analysis of the broader context of our project.

2.1.2 User Needs

Note: We really only have one user group, those who are purchasing the product.

Purchaser's of this product need a way to grow food in their own home because of the rising expense of food.

2.1.3 Prior Work/Solutions

Smart Garden Monitoring Ideas

Things plants need to grow:
Sunlight, water, air, proper temperature, nutrients

A guide on what plants need:
What Makes Plants Grow?

University of Florida. (1997, May). *3 what makes plants grow? plant ... - university of Florida*. What Makes Plants Grow? Retrieved October 17, 2021, from https://edis.ifas.ufl.edu/pdf/4H/4H36000.pdf.

Things to measure in garden:

- Sunlight
  - UV lights for plant, simulate day + night if needed
- Water
  - Soil moisture, some sort of watering system to keep regulated (misting system?)
- Air
  - Humidity
  - Temperature, need like a tiny space heater or temp regulator

- ➔ All of these are subject to change, depending on what you are growing.
  - ◆ If we can find optimal numbers for a variety of plants, it will be easy to control what we can control
- ➔ Might be best to create a system that can take values for measurables and adjust behavior based on that.

Best produce to grow:

1. Lettuce - Its hardy, grows quickly, and we do not need to do anything to prep the soil
2. Radishes - fastest growing vegetable so if we mess up, there's a quick turnaround time
3. Kale - hardy, grown in a variety of temperatures. Can be harvested at many different stages depending on wh taste you are going for

2.1.4 Technical Complexity

Our project involves multiple parts to make a product that is sufficient for consumer use, causing it to be complex. The system required knowledge from multiple areas including embedded systems, user interface development, networking, and web application development. All of these components were combined with each other, using communication between team members, to create an adequate product.

2.2 Design Details

2.2.1 Project Evolution

During the course of this semester we have had a couple decisions that we had to talk about and decided as a group.

First off as the semester progressed we realized that the camera functionality of our original design should be removed. There were coding issues on the website and we realized that Google Photos was not able to connect to our website in the way that we thought it would. Google photos API was a verify difficult to work with and eventually the challenges of implementing the camera outweighed the benefits and as a group decided it needed to be removed from design.

Some things we added to our design was spray foam and vinyl. The first was spray foam on the top of the greenhouse used for insulation and protection. The second thing we added to our design was vinyl on the inside as a way to allow for as much soil as the user might need. The last thing we added was a lock to the greenhouse, this was to increase physical security to our greenhouse. Which helps verify not only will the door not open when it's not expected to, but it will also allow the user to have a sense of safety when away from the greenhouse. We did not categorize security for the microcontroller since all it can control is the functionality of the greenhouse. The biggest risks of this are having all the controllable aspects of the greenhouse on at all times, which would take more power than normal and, depending on the amount of water in the reservoir, flood the greenhouse.

2.2.2 Design Visual and Description

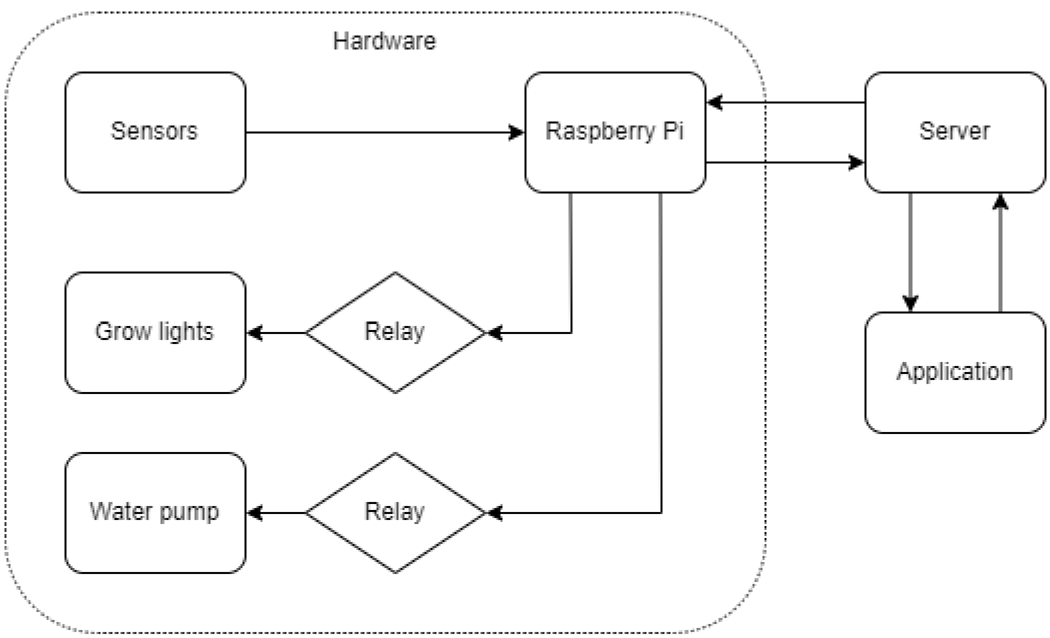


Figure 2:

This block diagram above describes a general overview of our smart garden design. All the hardware was placed in our mini greenhouse testbed. A temperature sensor and camera is outputting the data to the relay. The temperature is placed into a table to be analyzed. The water pump and grow light can be individually switched on and off. Based on the user input into the application on, the water pump and grow light will automatically switch on and off at predetermined intervals of time.

2.2.3 Functionality

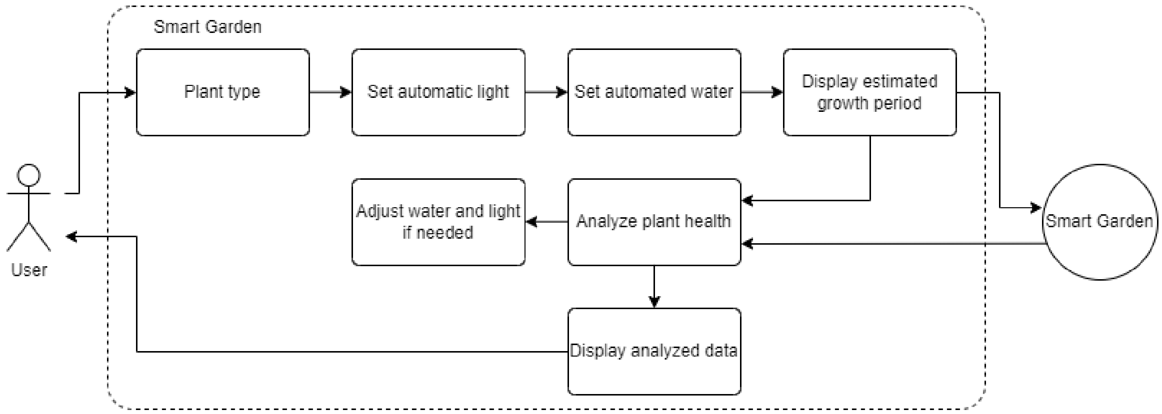


Figure 3:

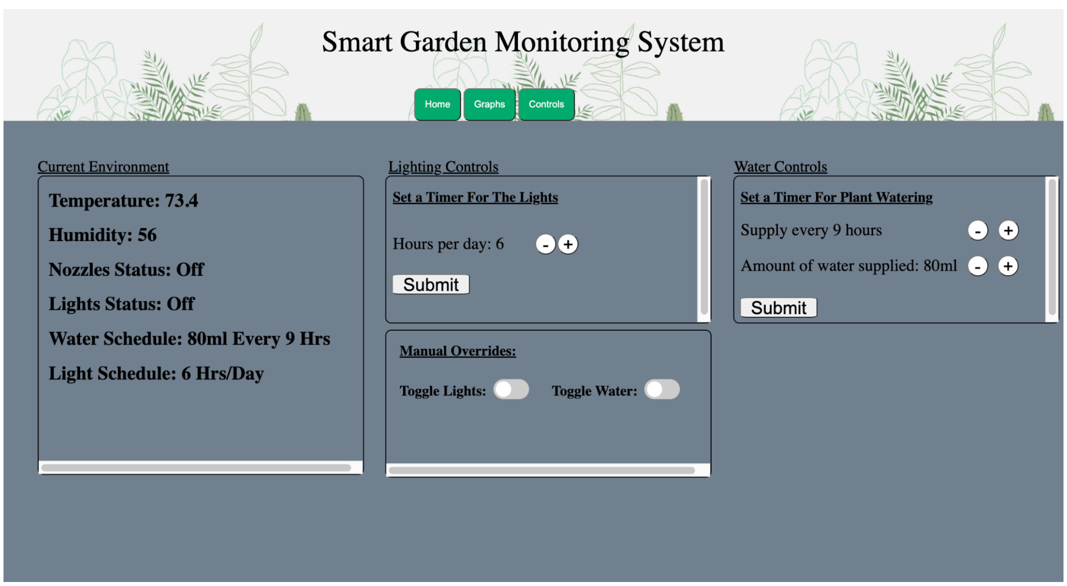


Figure 4:

Above is the use case diagram for the Smart Garden. Figure 3 outlines what we wanted in our greenhouse and the functionality that we wanted to displayed. In figure 4 we can see the final implmeneation of that as displayed in our control page. This includes the controls for the watering system, Lighting, which allow you to set the automatic default, as well as have a manual override for those systems. And in figure 5 below there is the display of the analized data, the way we chose to do this is in the form of a graph, along with a table for ecah of the 4 plants that will be in the greenhouse.

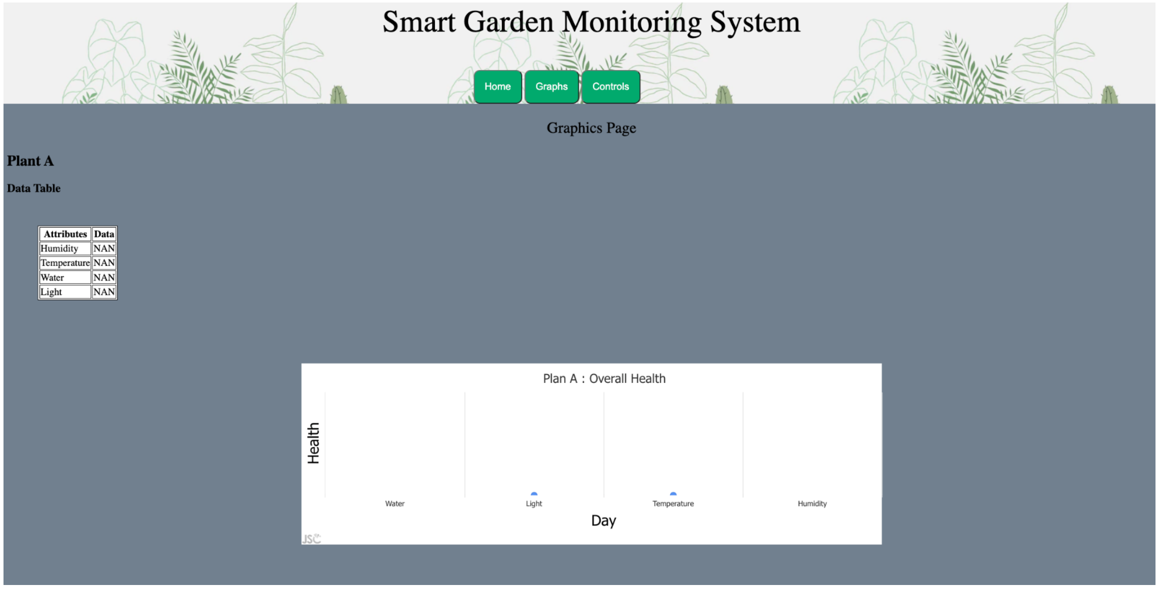


Figure 5

2.3 Technology Considerations

For the budget and experience available, much of this project was for the most part cheaper than versions of technologies already available. Strengths of this include simplicity of design and implementation. Weaknesses include cheaper supplies that may need to be replaced at some point and possible oversights in efficiency.

2.4 Design Analysis

Upon further analysis we reworked our design through small corrections. These included adjustments for the necessary energy requirements of the hardware. The initial design served more as an estimate to our final prototype. Now our design is more thought out as we know what our hardware requirements are for our various monitors. We tried our best to limit the cost of the parts utilized in our design. We also looked into various other monitors to add to our design as we gained a better understanding of a plant's necessities.

2.5 Design Overview

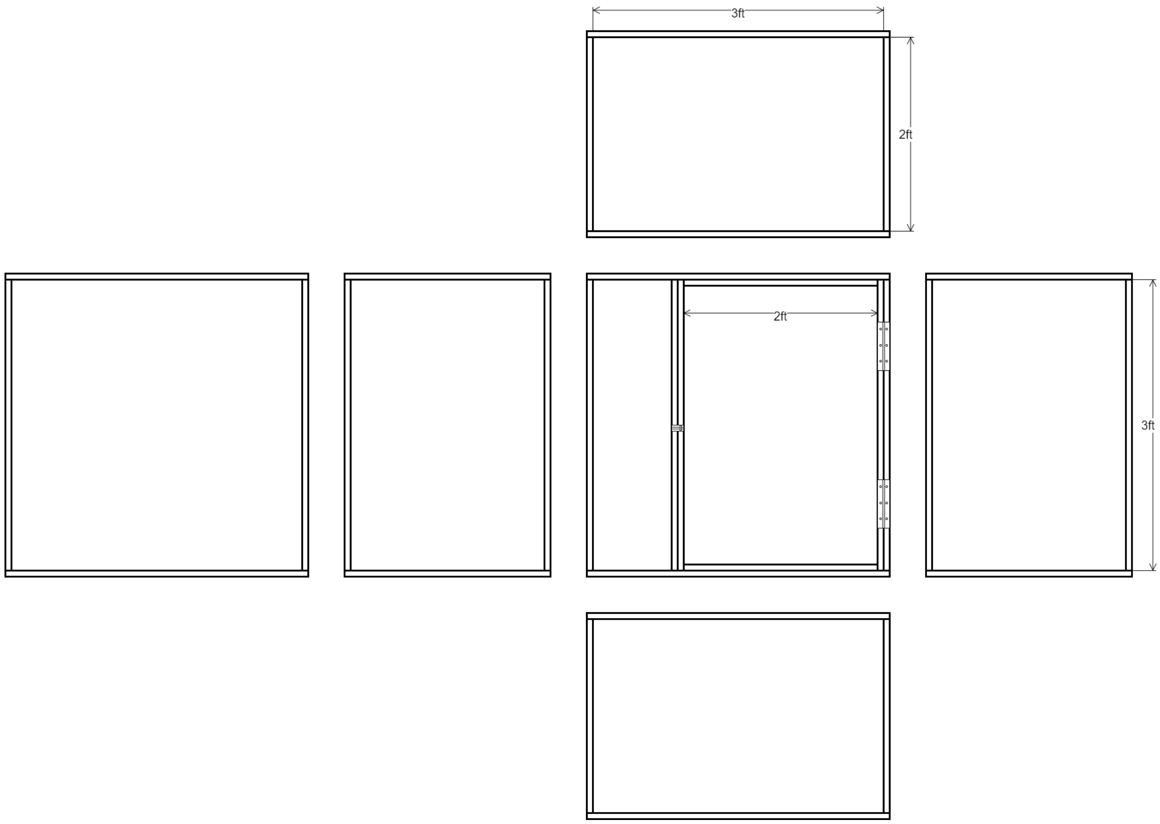


Figure 6:

The plant enclosures a wooden frame with clear vinyl windows. The top and bottom of the enclosure will be plywood. The inside of the enclosure will be accessible through a hinging door, with vinyl also covering part of the entrance to this door to allow users to add as much soil as needed without it spilling out. Wiring is passed through holes that have been drilled in the clear vinyl windows and connect to the raspberry pi and relays which are above the container in a protective box.

Inside the enclosure the grow lights, plant mister are mounted to the celling. There is a sensor placed inside the greenhouse to read the currently temperature and moisture levels of the greenhouse. The rest of the space will be used to grow multiple plants at a time, and the room doing so will require,

3 Testing

The general flow of testing followed the figure below. We developed each part of the system individually with given specifications, and then measure to make sure that the communication between each works as expected.

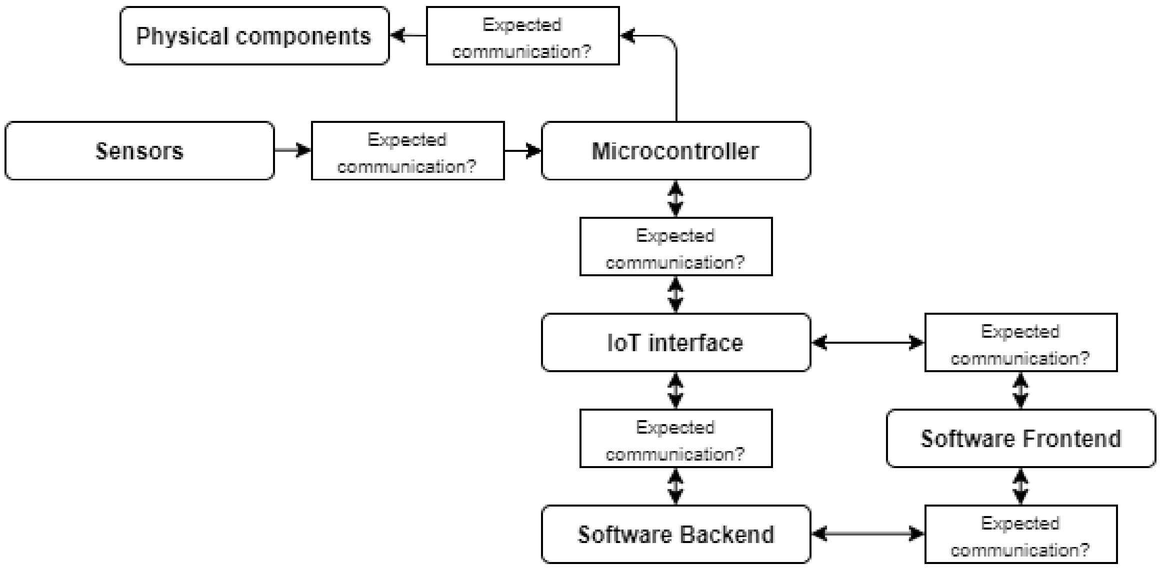


Figure 7: Testing Flowchart

3.1 Interface Testing

As we created the website application we went in and added values through the database and use that as a connection to test the front and back end funonality of the website while the senors where still being developed.

3.2 Integration and Regression Testing

As our project developed we tested each component to verify its functionality. After we verified the singular functionality we tested the overall functionality of it as a whole system. Using an agile approach when we pushed new devlopmenets, like the control page, the entire system as a whole was tested to verify we did not break any existing functionality.

As our project develops and we integrate more parts into the project, we will test each component. As the project grows, we will need to perform system integration testing, testing the system as a whole to make sure all parts are working together.

3.3 Results

Testing of every subsystem during and after development yielded successful results. Each part of the smart garden functions as expected, as well as the communication between them. While each subsystem was tested and verified to work properly, large scale testing of the system as a whole remains to be done. Given the time that we as a group had to work on the project however, we are satisfied with the results. The next phase of development for the greenhouse would be to begin long term plant growth testing and tuning of the subsystems according to what results in the best plant growth.

4 Implementation

Build Greenhouse

- Ordered wood and plastic paneling for assembling a greenhouse skeleton
- Ordered auxiliary components (nozzles, tubing, pump, lights, etc.)
- Assembled greenhouse frame
- Attached all necessary components
- Validated functionality of each component
- Validated full-scale functionality

Implement Embedded System

- Designed and ordered custom PCBs for controlling greenhouse components
- Connected control components and run tests without backend input
- Connected backend with Raspberry Pi controller
- Wrote handling and scheduling algorithms on Raspberry Pi
- Integrated algorithms with backend input
- Write data to backend for use on frontend
- Ran full scale integration tests from frontend input

Implement Backend

- Created mySQL database to store necessary data
- Create a Node.js app to interact with the database
- Create endpoints for both frontend and embedded system
- POST & GET endpoints so either side can read/write data
- Run integration tests on each endpoint to verify accuracy

Implement Frontend

- Acquired a domain name and hosting site
- Created an initial skeleton for differing website pages (Home, Camera, Graphs, Controls)
- Connected each page to the backend endpoints
- Created UI features on each page so user can interact with the greenhouse
- Ran tests verifying connection to backend
- Make any necessary adjustments to have the website looking and functioning better
- Removed Camera Page due to issues with Google Photos API - see 2.2.1 Project Evolution

Final Tests

- Run integration testing on each component of the greenhouse
- Validate temperature & humidity levels are at optimal values
- Run full-scale stress testing on the system
- Run user-input edge cases through frontend

5 Closing Material

5.1 Conclusion

As the semester wraps up to a close, looking back on this project it has allowed us space to learn what the process for building, designing and implementing a full scale project such as this will take. We found this to be valuable experience, that taught us how to use our strength, and work together as a team. We also learned how to address some set backs, red tape, we might have to go through in order to accomplish our mission. Overall we have learned a lot from this project, and this semester, and are happy to present the final prototype for our Smart Garden Monitoring System!

5.3 References

Related work we have looked at are garden systems. Some of those include:

Triple Family Garden

Single Family Garden

Aero Garden

Appendix

Appendix I: Operation Manual

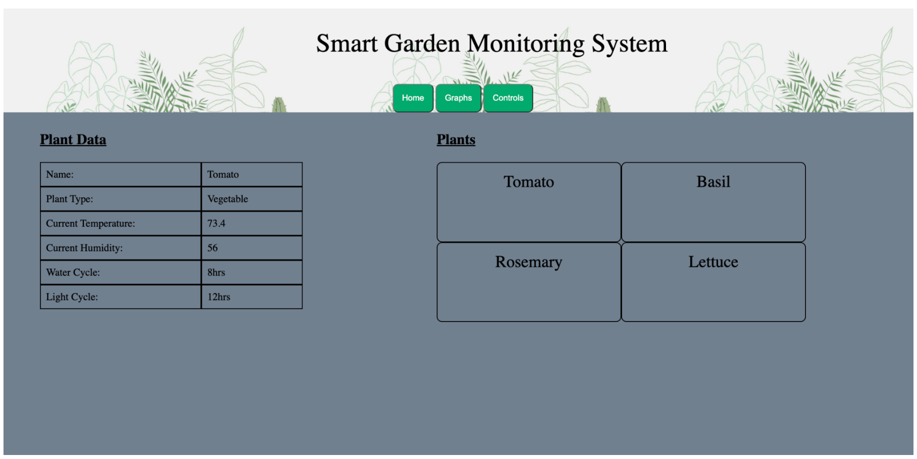
First off, The greenhouse itself should already be assembled. All you should have to do as a user is add water to the bucket and put the pump back into the bucket.

To grow plants you will need the following that are not included in the smart greenhouse:

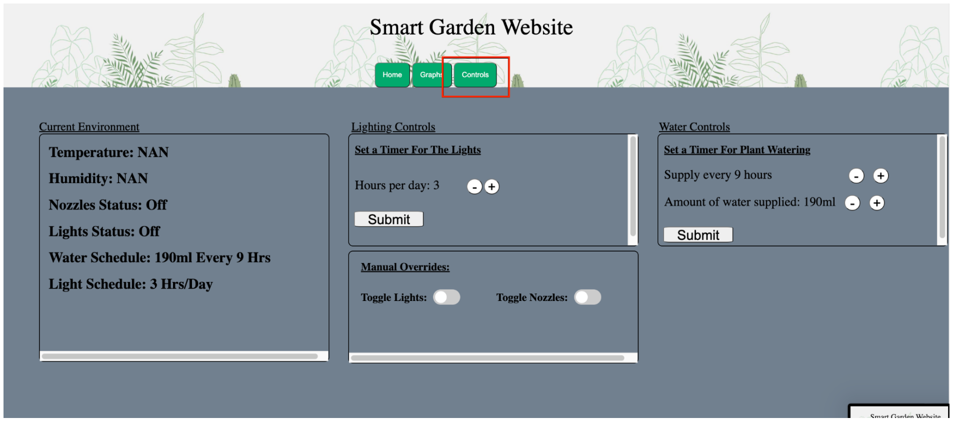
- Soil
- Water
- Seeds
- Access to the Internet

How to set up your seeds for success:

Note: when choosing seeds this greenhouse is intended for use with seeds that require similar temperatures and environments.

1. Connect to the internet and access the website via the url :
   a. http://macrotrackingsupremo.com/
2. After Navigating to the Url you should be brought to the home page which looks like the following:
   a. 

3. Navigate to the control page on the website : By clicking the control button, which is highlighted in a red Box below. After doing this the page shown will appear.



4. Next thing we have to do to get the greenhouse operational is to set the default hours per day for the lights and water

   a. To set Default lights:

      i. In the light Controls page we will see minus and plus buttons. Click the minus and plus to add or subtract to get the desired default amount.

      ii. After that click submit.

   b. To set the default water settings

      i. On the water Controls Pannel, click minus and plus buttons next to the hour or amount setting.

      ii. Once the amount of water you want every x hours is set click the submit button

5. To view what the current default settings are look to the current environment panel. Upon completing the steps above they will be automatically updated and can be changed at any time by repeating Step 3.

6. Toggle buttons:

   a. the manual override switches will override your current settings and perform that action, whether it be having the lights on or watering your greenhouse until they are turned back off.

7. Your Greenhouse should now be all set up through our website give it time running before adding plants. This is to make sure the temperature, and moisture both rise to appropriate levels before adding plants

8. Adding soil: a plastic covering has been protected on the inside of the greenhouse, this is to protect soil from spilling out and allowing the user to put as much soil as is necessarily for the plants.

Testing the system:

To test the water is working:

1. Navigate to the control page shown in figure [x]
2. click the toggle next to to the "toggle nozzles" text. This Should turn the sprinkler system on. This should be located in the manual override panel on your screen
    a. You should also see the Current environment panel be updated, the nozzle status should have changed from off to on
3. Click the toggle again to turn the water off

To test the lights are working:

1. Navigate to the control page
2. click the toggle next to the toggle lights text. This should be seen in the manual override panel on your screen.
    a. You should now see the current environment panel be updated by the"light status" now being set to on.
    b. And the lights should now be turned on in the greenhouse
3. Click again to turn the lights off
    a. You should now see the current environment pane be updated by the"light status" now being set to off.
    b. And the lights should be turned off in the greenhouse