EEL 4914 SENIOR DESIGN I:
Divide and Conquer Version 2.0

Department of Electrical Engineering and Computer Science
University of Central Florida

Smart Herb Garden

Sponsor: DC Carpet

Group 11

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Project Narrative

The interest in growing one's own fresh herbs is a desire that may easily be left unpursued due to a variety of inconveniences such as the guesswork involved in growing plants, a busy schedule, or a window that doesn't receive an optimal amount of sunlight. A garden that offers features for automated watering and plant lighting provides an easy-to-use solution to bring fresh herbs to your fingertips year-round taking green thumb out of the equation.

Our Smart Herb Garden will offer multiple modularized features which allow the consumer to choose a Smart Herb Garden setup which involves the features that make sense for their specific needs. The base model will feature an automated watering system which waters the herbs depending on the moisture level detected in the soil. Once the soil moisture level reaches a low reading, the herbs will be watered without any assistance from the consumer. This is perfect for those times one will find themselves absent from home for an extended period, as well as a solution for those who find themselves busy or forgetful.

The automated water feature is composed of an XY Motion robot attached above the planters. The software will plot the positions of the plants in an XY grid, while the mechanism will move the hose using stepper motors. This motion will be dictated by the moisture sensor which will give an alert once a low moisture level has been reached. This will initiate the motion of the robot moving the hose and watering the plant until it has reached a sufficient moisture level. The hose will be connected to a water pump submerged in a tank that will need to be refilled by the user every 1-3 weeks based on the number of plants in the garden.

Prefer your garden housed indoors? No natural light available? Our product offers the ability to attach an automated plant light to the garden, which runs on a schedule. Namely, this lighting will be on for the proper number of hours to ensure adequate sunlight for the plants. This way, one can grow any herb year-round without the dependence of access to the outdoors, or changes in season or weather. And since this lighting component is an optional attachment, if there come times where it is preferred the plant be outdoors or under natural sunlight, the plant lighting module to the garden can be easily removed.

Conveniently, our smart herb garden comes with a companion web application that allows a user to view the historical and live data gathered from the garden such as soil moisture. Also, one can opt in for SMS push notifications for a variety of different important notices. This includes but is not limited to when the watering system is going off, or when the water tank needs to be refilled. This is another feature perfect for those who find themselves away from the garden but still desire to be up to date with their herbs.

Thanks to our sponsorship DC Carpet, a local flooring and tiling company, this project is made possible. DC Carpet plans on donating the necessary tools and materials needed to complete this project. This company is interested in the project because they are dedicated to creating more convenience in the home.

Specifications

Requirements for Hardware - Absolute Requirements

The Smart Herb Garden's physical structure shall be no greater than 6 feet in length, 6 feet in width, and 6 feet in height.

Data collected from the moisture sensors shall be accurate (sensors shall be accurate within +/- 5% range)

Stepper motors will carry tubing to allow water flow in both x and y bringing water to plants as determined by the moisture sensor

Tubing must not be obstructed by movement of robotic arm

Stepper motors will respond to input provide by different sensors and traverse to different plants accordingly

- This will allow for the correct plants to be watered

The Smart Herb Garden system shall be able to send sensor data to the API for the Web Application

- This will allow for users to view data for their Smart Herb Garden

Any electrical components that are not water resistant must be encased in a watertight seal

- This is allows for the system to be resistant to water

The Smart Herb Garden structure shall be able to hold at minimum 2 plants

The microcontroller shall be able to send the correct signals to the motors to move the robotic arm in the correct position

The microcontroller shall be able to activate the water pump or valve to initiate or hault the water flow

The microcontroller shall be able to shut off the water in < 5 seconds in case of a fault or error

The robotic arm shall not damage or knock over the plants.

Requirements for Hardware - Soft Requirements

Lighting module will be able to operate according to data inputted by the user

- Light is important for the livelihood of herbs and will be a great addition to the system
- Various plants have high lighting requirements that cannot be met by the environment that they are in, thus must have additional supplementary lighting

Two moisture sensors will be implemented to ensure all readings are accurate and eliminate random errors

- This addition will yield a more accurate result, if needed.

The sensors and motors will have the ability to be remotely operated through the web application

- If time and budget allow, an interactive interface will give the user a more customizable experience. This experience would involve customizing specific times to water plants, not based only on moisture levels. Some plants must undergo a delay period before being watered again, and so the interface would allow for such options.

The Smart Herb Garden System shall be modular and be able to accommodate for more than two plants, but less than 13 plants if the user desires

The Smart Herb Garden shall include a light sensor

- A light sensor shall be included to read the amount of light the plants are receiving

The Smart Herb Garden system shall connect to an online weather API (Tentative)

- If time and budget allow, the system shall connect to an online weather API and warn users of weather than may harm their Smart Herb Garden

The Smart Herb Garden shall include a temperature sensor

- A temperature sensor shall be included to read immediate surrounding temperature

The Smart Herb Garden shall include a humidity sensor

- A humidity sensor shall be included to determine if the plants are receiving enough humidity.

Any resistance to the robotic arm should mean that there is an obstruction and the plants should not be knocked over.

The system will detect position of plants using camera

- If time and budget allow, the system can use a camera to detect position of plants and aim the water directly in the correct location

Requirements for Software - Absolute Requirements

The web application shall be synced with the hardware via wireless network

- The integration of IoT will allow for better user interfacing with the hardware and allow more info to be relayed to the user

The web application shall be able to read information from the moisture sensor(s)

- The microcontroller used will allow for wireless transmission of data to the user so that info can be retrieved and displayed

The web application shall be able to read information from the water level sensor

- This will allow for the user to monitor the water level wirelessly from the web application

The web application shall be able to display information gathered from sensors

- This allows users to view information on all sensors

All communications with the API shall be done with the HTTPS protocol

- This protects the integrity and confidentiality of data

The database shall never be out of date with the user interface

- This promotes data synchronization, and keeps the data consistent through every record

The user interface must not have direct access to the database

- To ensure security, the user must not have access to the database.

The software on the microcontroller should be able to correctly position the robotic arm in the correct location

The software on the microcontroller should be able to process the data in an efficient, timely manner

Each user should be able to create their own account for their greenhouse

Each user shall be able to log in to their account

- Equips the user with security, allows the program to manage roles and retain user information

Each user shall be able to log out from their account

All interaction with the web application must have immediate feedback, even if it is only showing an operation is in-progress

Requirements for Software - Soft Requirements

The web application shall be able to send an SMS notification

- Updating the user through SMS notifications will keep the user interested and invested in their herb garden.

A user shall be able to opt in to receive SMS notification

The web application shall be able to connect to and manage more than one garden

- Management for multiple gardens will give our product the expansion needed for future advancements.

The web application should be able to run properly on a mobile device such as a smartphone or tablet

- The web application shall be responsive and able to be viewed from a browser on a mobile device

An admin of the web application shall be able to log in

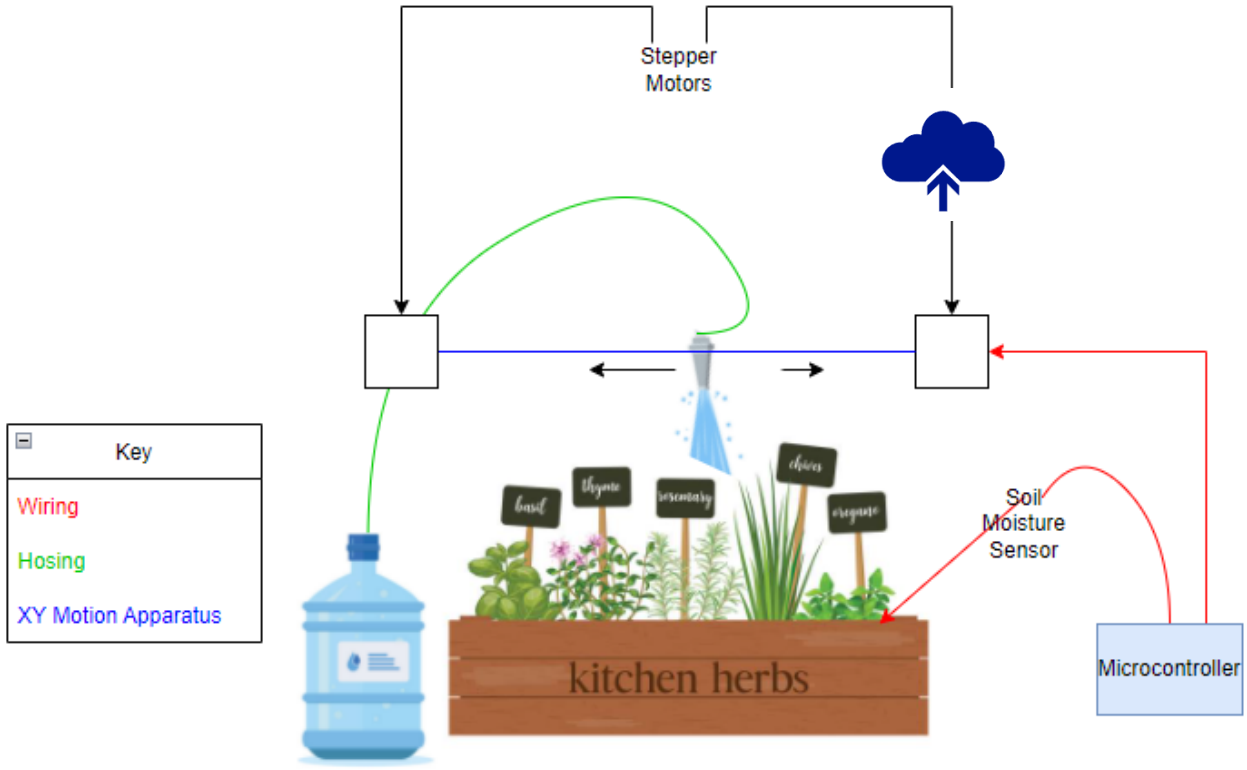
The user interface shall be permission aware

- Information or functionality that are available only for an admin role, shall not be displayed to a regular user

The web application should work with Chrome and Firefox

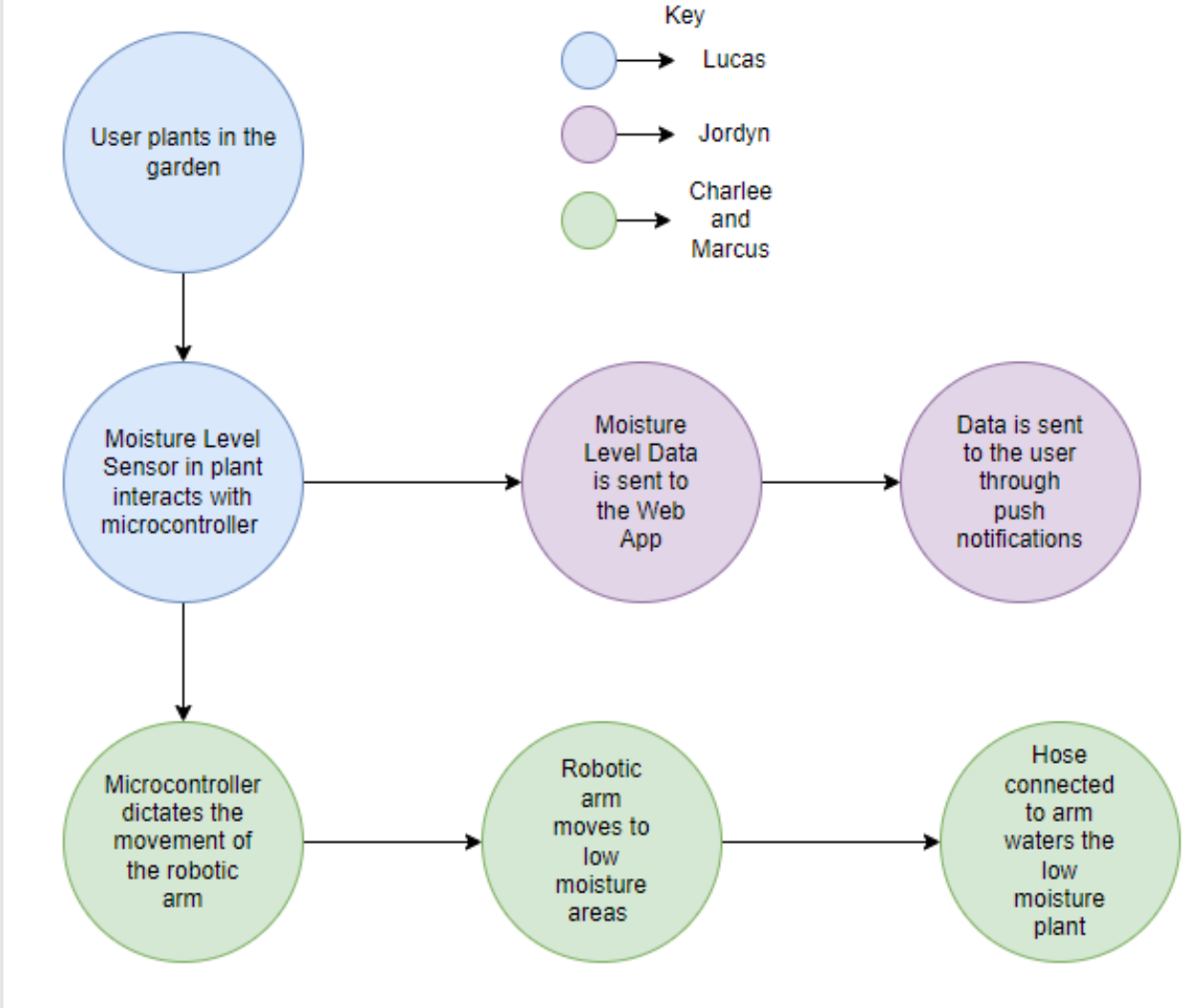
Prototype Illustration

Figure 1: Prototype Illustration



Block Diagram

Figure 2: General High Level Project Block Diagram



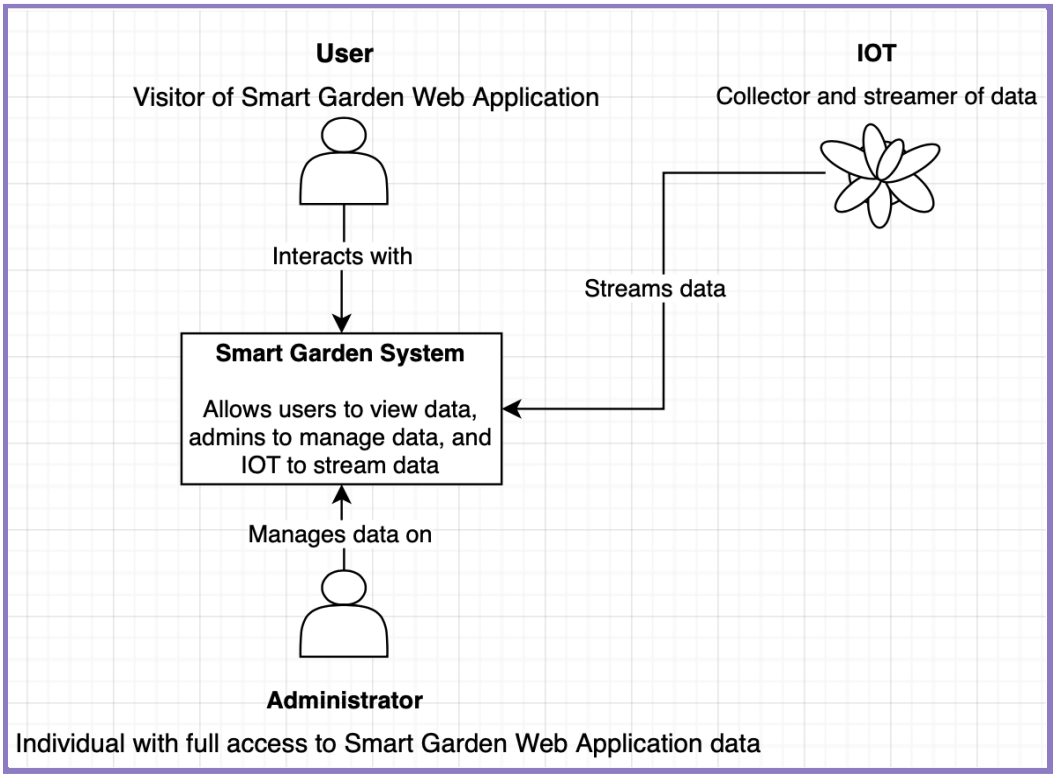
Status of each block as of 02/03/2022:

- Moisture Level Sensors have been purchased
- Supplies for planter has been donated
- XY Motion Robot still being researched and designed
- Web Application is being researched and designed
- None of the blocks have been completed or prototyped

Web Application Block Diagram

(Responsible for this section: Jordyn Hayden)

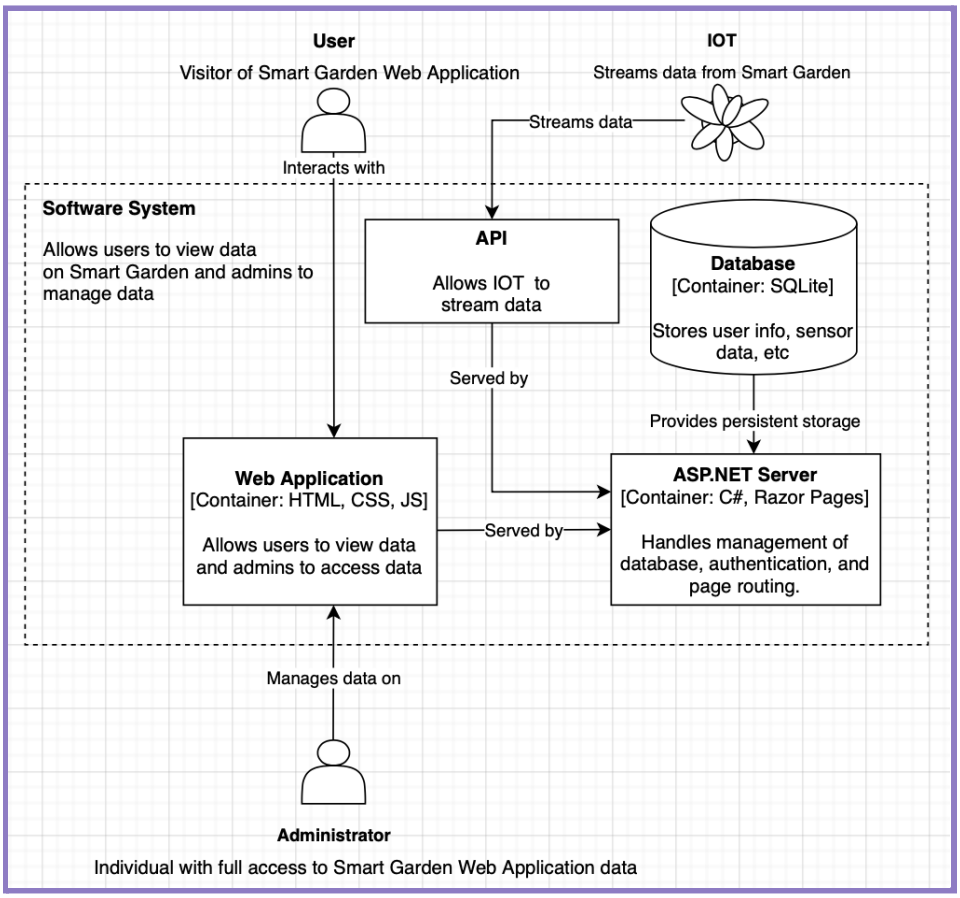
Figure 3: Web App System Context Diagram



Displayed in Figure 3, above, the Smart Herb Garden system appears as one monolith to both admins and users. The incorporation of administrators is described in the soft requirements for the software component of the project. The integrity, and security of users is a priority for the system.

Acronym Legend:
API – Application Programming Interface
EF – Entity Framework
IOT – Internet of Things

Figure 4: Web App Container Diagram

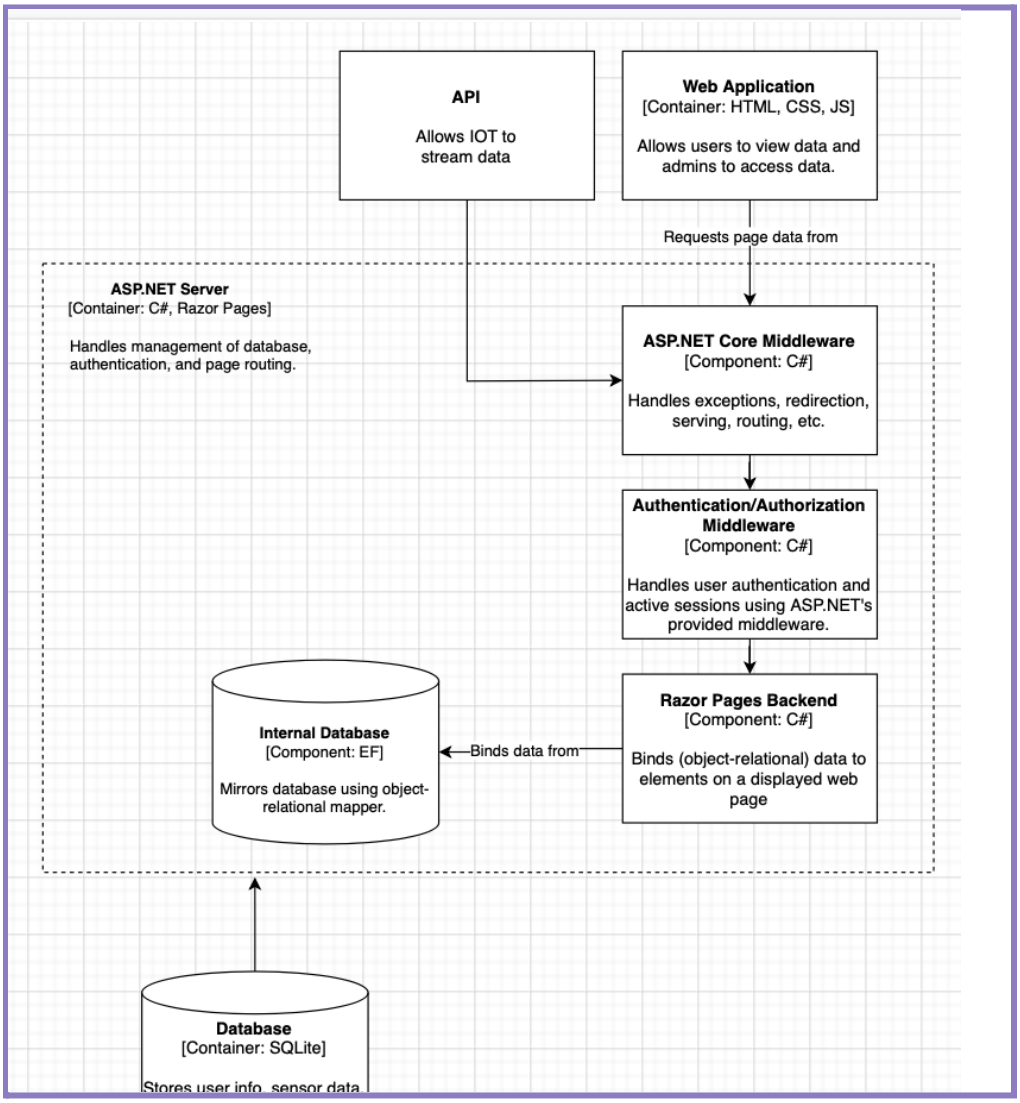


Detailed in Figure 4, above, the user will interact with a web-based application served from the ASP.NET server. The data served with the page is handled internally with both the administrator-facing and user-facing pages.

ASP.NET was chosen for its ability, utilizing the .NET Entity Framework, to communicate with a database model directly mapping database entries to objects. Jordyn Hayden has a prior level of experience in using the framework within the group members, which is the reason behind this choice.

Acronym Legend:
API – Application Programming Interface
EF – Entity Framework
IOT – Internet of Things

Figure 5: Web App Component Diagram



Shown in Figure 5, above, upon a running server, the ASP.NET middleware adresses exceptions, routing, and authorization, amongst others, with the intent to work on the main user-facing product atop a robust solution. As a part of .NET Entity Framework, database entries are instilled with an object-relational (OR) mapper, which makes for accessing entries as though members of a C# class.

Using this set of components specifically is a choice made simply thanks to the structure of the ASP.NET framework, as building off of it is not necessarily a difficult task.

Acronym Legend:

API – Application Programming Interface
EF – Entity Framework
IOT – Internet of Things

Budgeting and Financing

Table 1: Estimated project budget and financing.

Item	Quantity	Price
Moisture Sensor	3-4	$6-$20
Hose Tubing	1-2	$4-$10
Microcontroller with wireless communication capabilities	1	$20-$40
Power Source	1	$20-$40
Stepper Motors	2	$14-$28
Stepper Motor Driver	1	$20
Bluetooth Module	1	$14
Custom PCB	1	$30-$50
Plants	2-3	$5-$10
Plant Growth Light	1	$30-$80
Total (Estimated)	N/A	$153-$302

Table 1, above, displays our estimated budgeting and financing for the Smart Herb Garden project. Our project will at minimum be estimated to cost $153 and maximum $302. All costs will be fulfilled and satisfied thanks to our generous sponsor DC Carpet. Although a sponsor is in place, the team has a goal to keep reduce cost where possible.

Project Milestones

Table 2, below, illustrates the tentative schedule of the project progression namely in Senior Design 1. The Smart Herb Garden Project will adjust these tentative dates accordingly as the semester progresses. The main focus of Senior Design 1 is to research and prepare for the implementations that will be done in Senior Design 2. Creating project milestone goals for Senior Design 1 will aid in the project's development, success, and allow the team to stay on track. Weekly check-ins will occur to assess our productivity, allow for adjustment of the tentative dates, and attain status of team members.

Table 2: Initial project milestone for Senior Design 1 (Tentative)

Milestone	**Week Number (Date Range of Week)**
Form Groups	Week 1 (01/10/2022 - 01/14/2022)
Brainstorm Ideas for a Project	Week 2 (01/17/2022 - 01/21/2022)
Brainstorm Ideas for a Project	Week 3 (01/24/2022 - 01/28/2022)
Initial Divide and Conquer Paper Submission	Week 4 (01/31/2022 - 02/04/2022)
Research Project and Meet with Dr. Lei Wei	Week 5 (02/07/2022 - 02/11/2022)
Divider and Conquer Paper V 2.0 Submission	Week 6 (02/14/2022 - 02/18/2022)
Research and Design	Week 7 (02/21/2022 - 02/25/2022)
Research and Design	Week 8 (02/28/2022 - 03/04/2022)
Research and Design	Week 9 (03/07/2022 - 03/11/2022)
Research and Design	Week 10 (03/14/2022 - 03/18/2022)
60 Page Senior Design 1 Documentation Submission	Week 11 (03/21/2022 - 03/25/2022)
Research and Design	Week 12 (03/28/2022 - 04/01/2022)
100 Page Senior Design 1 Documentation Submission	Week 13 (04/04/2022 - 04/08/2022)
Research and Design	Week 14 (04/11/2022 - 04/15/2022)
Research and Design	Week 15 (04/18/2022 - 04/22/2022)
Final Documentation Submission	Week 16 (04/25/2022 - 04/29/2022)

Project Milestones

Table 3, below, illustrates the tentative schedule of the project progression namely in Senior Design 2. The Smart Herb Garden Project will adjust these tentative dates accordingly as the semester progresses. The focus of Senior Design 2 is to implement the goals, and requirements set in place during Senior Design 1. We will build from the research and budget conducted. The work that was done in Table 2 will help the project progress in a timely, and productive manner. The goal is to finish prior to the final deadline in order to complete necessary documentation, and allow time for testing. Weekly check-ins will occur to assess our productivity, allow for adjustment of the tentative dates, and attain status of team members.

Table 3: Initial project milestone for Senior Design 2 (Tentative)

Milestone	Week Number (Date Range of Week)
Acquire Supplies	Week 1 (08/22/2022 - 08/26/2022)
Acquire Supplies	Week 2 (08/29/2022 - 09/02/2022)
Acquire Supplies	Week 3 (09/05/2022 - 09/09/2022)
Smart Herb Garden Structure Build	Week 4 (09/12/2022 - 09/16/2022)
Sensor - Microcontroller Interface	Week 5 (09/19/2022 - 09/23/2022)
Microcontroller - Robotic Arm Interface	Week 6 (09/26/2022 - 09/30/2022)
Establish Web Application User Interface	Week 7 (10/03/2022 - 10/07/2022)
Sensor - Microcontroller Interface	Week 8 (10/10/2022 - 10/14/2022)
Microcontroller - Robotic Arm Interface	Week 9 (10/17/2022 - 10/21/2022)
Web Application Development	Week 10 (10/24/2022 - 10/28/2022)
Prototype Testing	Week 11 (10/31/2022 - 11/04/2022)
Continue to Build Prototype	Week 12 (11/07/2022 - 11/11/2022)
Continue to Build Prototype	Week 13 (11/14/2022 - 11/18/2022)
Test and Finalize Prototype	Week 14 (11/21/2022 - 11/25/2022)
Senior Design 2 Documentation	Week 15 (11/28/2022 - 12/02/2022)
Senior Design 2 Documentation	Week 16 (12/05/2022 - 12/09/2022)

House of Quality

The House of Quality is a design tool that allows for identification and classification of end-user requirements and demonstrates their correlation with engineering requirements. The chart below, Figure 6, demonstrates the interactions among end-user requirements and how they impact the engineering requirements, and vice-versa along with a corresponding key in Fig. 7. Below the house of quality is a table containing a key identifying the symbols in the table. The polarity refers to the desired direction. For example, a minus symbol appears for power consumption, indicating that our goal is to reduce power consumption. The arrows indicate positive or negative correlation. For example, two double downwards arrows for "ability to expand size of garden" means that it has a strong negative correlation to power consumption. In other words, the more we expand, the more power we use. By analyzing this table, we can determine how design choices can impact both the engineering requirements and the end-user requirements.

Figure 6: House of Quality

			Engineering Requirements								
			Sensor Precision	Watering Position Precision	Modularity	Cost	Simplicity	Watering Speed	Water Use	Power Consumption	Durability
			+	+	+	-	+	+	-	-	+
End-User Requirements	Sensor data processing	+	↑↑	↑↑	↑	↓	↑	↑↑	↑	↓	
	Robot motor movement to correct position	+	↑↑	↑↑	↑↑	↓	↑↑	↑↑	↑↑	↑↑	↑↑
	Ability to expand size of greenhouse	+		↑	↑↑	↓	↓	↓↓	↓↓	↓↓	↑↑
	Low cost	-	↓↓	↓↓	↓↓	↑↑	↓↓	↓↓	↓↓	↓↓	↓↓
	Ease of Use	+	↑	↑	↑↑	↓	↑↑	↑		↑	↑↑
	Speed of watering	+	↑	↓	↓	↓	↑	↑↑	↑	↓	↑
	Web interface	+				↓	↑↑			↓	
	Customization	+		↑	↑↑	↓	↑↑			↓	↑
	Low water usage	-	↑↑	↑↑	↓	↓	↑	↓	↑↑	↑↑	↑
	Low power usage	-	↓		↓	↓	↑	↓↓	↑	↑↑	↑
	Minimal disturbance of plants	-	↑	↑↑	↑↑	↓	↑	↓	↑↑	↑↑	↑↑
	System water resistance	+	↑	↑		↓	↑	↓	↓	↑↑	↑↑
	Goal for engineering requirements		< +/- 5% error	< +/- 2.5% error	Max 500 possible modules interconnected	< $100 for single module	Less than 10 parts per component	< 30 seconds per plant	< +/- 100 mL water given to plant	< 1000 watts	Materials made to withstand 100lbs, temps of 0F – 140F, water and chemicals

Figure 7: House of Quality Key

Key	
+	Positive polarity
-	Negative polarity
↑	Positive correlation
↓	Negative correlation
↑↑	Strong positive correlation
↓↓	Strong negative correlation
	Does not apply N/A

Steps Going Forward

Clearly, based on all of the details described, the Smart Herb Garden is an excellent solution that solves the problem of large-scale plant based management. Our system will automatically water plants when their moisture levels are low, alert users of undesired environmental conditions and actions the Smart Herb Garden takes, and allow for modular customization and expansion. As time spent developing the project continues, our goal is to implement the absolute requirements and basic functionality a user can expect to experience. Only if time allows, the team shall add more advanced features. Our project currently involves robotics, sensors, microcontrollers, and a web application. Further strictly potential capabilities include wireless communications, solar powered sensors, and more. In the end, our Senior Design project will be an excellent demonstration of the skills that we have acquired throughout the years. Our Smart Herb Garden has a lot of potential and is clearly a unique one-of-a-kind solution to large-scale plant based management.

Citations / Research

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Moisture sensor research -
https://www.mentalfloss.com/article/581946/verdmo-plant-soil-moisture-sensor

https://maker.pro/arduino/projects/arduino-soil-moisture-sensor#:~:text=How%20Does%20the%20Arduino%20Soil,to%20measure%20the%20moisture%20value.

XY Robotic Arm implementation -
https://www.instructables.com/How-to-make-a-XY-plotter-with-Makeblock/

Hose Tubing Research -
https://learn.eartheasy.com/articles/drip-irrigation-vs-soaker-hoses-which-is-better-for-your-garden/

Smart Herb Garden Research -
https://blog.constellation.com/2021/06/14/smart-devices-for-managing-and-automating-your-garden/#:~:text=What%20is%20smart%20gardening%3F,producing%20food%20or%20decorative%20plants.

Example Microcontrollers -

- Jetson Nano

https://www.nvidia.com/en-us/autonomous-machines/embedded-systems/jetson-nano/

- Arduino sensors collection

https://store-usa.arduino.cc/collections/sensors-environment

- Arduino IOT collection

https://store-usa.arduino.cc/collections/iot

- Texas Instruments MSP430FR6989

https://www.ti.com/product/MSP430FR6989