C.H.A.N.O.S.

Controlled Hydration Automated Nutrient Optimization System

Revised Divide and Conquer Document

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2 Project Description

2.1 Motivation and Background

Since transitioning to agriculture thousands of years ago, gardening has been a central part of human society. Even today, when most people do not perform agricultural labor, gardening can provide joy, relieve stress, and build confidence. Particularly, the care of indoor and outdoor plants is ubiquitous and can even develop a deep human-plant relationship.

However, the busy schedule of modern life and long work hours thwart many people's abilities to garden and effectively tend to plants. Sadly, this loss is only one of many disruptions between people and nature, a trend which is correlated with reduced cognitive function and increased anxiety and depression.

Meanwhile, many technological advancements have occurred within electrical and computer engineering. Robotics has helped automate menial tasks which previously required human intervention. New sensors provide these robots with information imperceptible to humans. Microelectronics and internet-of-things have permitted these tools to be affordable and convenient to use within the home.

It should come as no surprise, then, that these technological advancements have been used to implement products that assist in gardening without direct human intervention. However, many of these products have a narrow scope or do not exploit the full potential of these technologies, which lead to oversight of the nuances of gardening and plant biology. Furthermore, many commercial applications of new technologies have recklessly increased the power consumption within a person's life and home.

Thus, there is a clear need for a product which maximizes the potential of modern electronics to intricately care for plants commensurate with the compassion and experience of dedicated horticulturists. Despite additional complexity, this product should attempt to mitigate the environmental disadvantages of common electronic commodities.

2.2 Existing Products

An automatic irrigation system is not a novel idea. These systems already exist for horticultural (household) and agricultural (industrial) purposes. The distinction between these systems include the processes used to control the system and the sensors used to collect data about the plant, soil, or environment.

An article written by Moss et al. from Oklahoma State University describes two types of controllers, evapotranspiration and soil moisture sensor based, and three types of sensors–soil moisture, rain, and wind [2]. Evapotranspiration, or climate-based, controllers use data about the soil-to-air or plant-to-air movement of water to regulate the irrigation of an area of soil. The costs of these controllers were reported to be in the hundreds or thousands of dollars. Controllers based on soil moisture sensors use data collected about water content in the soil to regulate the irrigation of the area. The location of these controllers must be carefully chosen. The efficacy of these controllers were reported as possibly higher than ET controllers, and the cost was similar to non-professional ET controllers.

The latter half of the article described three types of sensors which could be integrated into existing irrigation systems to increase efficiency. Many existing irrigation systems are timer-based, so the integration of soil moisture sensors can help classify whether a plot of soil must be watered at the specified time or if the soil is already sufficiently irrigated. These sensors are significantly cheaper than the aforementioned soil moisture sensor controllers (~ $100-$200). Rain/freeze sensors detect whether it is raining or frozen in the environment. In either case, further irrigation of the soil risks overwatering the plant or crop or freezing and damaging the roots/soil. Wind sensors measure the wind speed in the environment; high winds can hinder the efficacy of irrigation by spreading the water horizontally across the soil rather than vertically into the soil. Rain, freeze, and wind sensors are similar in cost to a soil moisture sensor.

Commercial automatic irrigation systems for indoor gardening were researched via a search on Google Shopping. An initial search was performed using the keyword “automatic plant watering system”. The cost of these systems widely varied from about $30 to more than $100. All of the systems observed were primarily controlled by a timer, irrigating the plant/soil at time intervals and for watering durations set by the user. Additionally, these systems were powered by either power adapter cord or a battery. Most of these systems did not collect any data about the soil contents or environment surrounding the plant. However, one lower-cost system did have a separate irrigation setting based on the humidity of the surrounding environment. The lack of sensors or data collection is likely due to a tradeoff between number of plants that can be watered and the precision of care. In order to control irrigation based on the contents of soil, a sensor is required to place in the soil, so in order to irrigate multiple plants based on soil content, a large number of sensors would be required, increasing the cost and complexity of the system’s electronics.

In fair consideration of all options for data-based automatic irrigation controllers, further research was conducted regarding evapotranspiration controllers. One of the most common ET controllers is a lysimeter–a device which calculates the evapotranspiration of water in a plot of soil by measuring the amount of water collected then lost in a small sample of the plot. Weighing lysimeters specifically measure the weight of a sample to calculate the amount of water gained and lost. A specific study of low-cost weighing lysimeters was performed by Dong and Hansen at Michigan State University and published in *Smart Agricultural Technology* [3]. The paper found that four accurate weighing lysimeters could be custom designed and manufactured for an average cost of $327 per lysimeter. Although this cost is drastically lower than professional-grade lysimeters, it is still high relative to the cost of a soil moisture sensor.

After developing many of our goals and objectives, multiple YouTube videos were found which described similar automatic gardening or irrigation systems. The first YouTube video was 10 years old and received about 3.2 million views. It described a "Arduino Garden Controller", which used soil moisture and temperature sensors and a photoresistor to collect data about and automatically irrigate the creator's garden [4]. The second YouTube video was 3 years old and received 50 thousand views. It showcased Flaura, a custom 3D-printed pot which held a pot above a water supply [5]. Using water level and soil moisture sensors, Flaura automatically waters the soil and uses an ESP32 microcontroller to communicate with a mobile app where the user can change and track certain parameters of the system. Flaura also used a rechargeable battery, and the creator mentioned adding solar power supply.

2.3 Goals, Objectives, and Features

Basic Goals

The first basic goal of this project is to design and create a system which automatically waters and nourishes a plant. A second basic goal is the automatic drainage of the water runoff. A third basic goal is the system should be adaptable to a plant and pot of the user's choosing. There must be a way for the user to define the parameters relevant to the plant being watered, such as the required minimum and maximum values for soil moisture, temperature, electrical conductivity, or other characteristics.

Advanced Goals

An advanced goal is to reduce the environmental footprint of the design. This entails both low energy consumption and use of sustainable energy sources. This advanced goal will be met in the final product design.

Stretch Goals

A stretch goal is the integration of the automatic watering system into the users' smart home system as an internet-of-things (IoT) device.

Objectives

To achieve the first basic goal, the first objective is collection of information about the plant that indicates when it must be watered. The cheapest and easiest form of this objective is measurement of the soil moisture using sensor technology. If the soil moisture is below a certain threshold, a pump is activated which transports water from a supply container to the soil. Other characteristics of the soil, such as temperature, may also help indicate whether the plant must be watered.

The objective for the second basic goal is the transport of the runoff from the pot to a separate container. An objective for the third basic goal is the design of a web or mobile app where the user can either select preset information for some common plants or define specific requirements for each characteristic. This would require the microcontroller to have features such as bluetooth or WiFi capabilities in order to communicate with the mobile/web app.

Multiple objectives are required for the advanced goal. A low energy consumption can be achieved by periodically sampling measurements every hour using timer based interrupts. Additionally, selection of lower voltage components, such as certain microcontrollers, pumps, and motors, can also reduce energy consumption. The use of sustainable energy can be achieved by using a solar-powered battery, because the plant and system will be positioned in the sunlight.

An objective which helps achieve the basic and advanced goals is the reuse of water runoff as a source of irrigation/nourishment, which can be accomplished via a filter. The runoff from the soil/pot would be filtered and transferred back to the water supply tank.

An objective for the stretch goal is the communication between C.H.A.N.O.S. and other smart home devices via bluetooth or other wireless communication protocols. For example, the system may communicate with and close smart home curtains when the plant has received a sufficient amount of sunlight. The system may also communicate with a smart home thermostat in order to measure or control humidity or temperature.

Features & Functionality

Based on the basic goals and objectives, a custom pot system/design was determined to be most convenient for the user, instead of a system which would be attached to a pot chosen by the user. This would limit the interconnections that the user is required to make and increase stability and reliability of the product. This custom pot system is planned as a 3D-printed design.

A soil moisture sensor is one of the key components of the product. The data from this sensor will determine if the plant must be watered. In addition to a soil moisture sensor, a solar sensor will also be connected to the system. This sensor will measure how much sunlight the plant has received and determine when the plant has received sufficient sunlight or when it must be rotated to receive sunlight on its other sides. An ultrasonic sensor will be placed by the water supply tank and determine if the tank is low on water and must be refilled by the owner.

These sensors will be connected to a microcontroller. Based on sensor data, the microcontroller will determine when a pump must be activated to water the plant. The water pump will be connected to the water supply tank. Additionally, the microcontroller will determine when the pot must be rotated and when curtains must be moved to shade the plant. These tasks will be performed by motors connected to the microcontroller.

The microcontroller also communicates with a web app via Wi-Fi. The microcontroller sends data regarding the soil moisture levels, the water level/volume in the supply tank, and the solar sensor. The user can view this information, but can also enter data on the web app for the particular plant that is in the pot. This data includes the minimum and maximum soil moisture values for the plant, which the user can determine by manually entering or selecting a preset from a database of common plants.

In addition to the web app, the stretch goal described above requires additional communication features. A feature which helps meet these objectives would include a framework that streamlines the integration of C.H.A.N.O.S. with an existing smart home infrastructure. ESPHome, developed by Open Home Foundation, is an example of such a framework, which focuses on ESP microcontroller as well as providing desktop support. ESPHome cooperates with Home Assistant, a free, open-source software, which would detect and manage existing smart home devices.

The final feature of the system is the power supply, consisting of a solar panel, solar charge controller, and battery. The charge controller sends power to a voltage regulator and data to the microcontroller. The regulator distributes this power to the electronic components of the system, such as the microcontroller and water pump.

2.4 Required Specifications

Table 2.4.1 Specification for components

Component	**Parameter**	**Specification**
Soil Moisture Sensor	Measurement accuracy	± 3% VWC
Water Pump System	Flow rate	0.5-1.0 L / Min
Solar Panel	Power output	0.5-1.0 W
Battery	Backup operation time	24 hours
Ultrasonic Sensor	Water level accuracy	±1 cm
Container & Battery	Temperature	< 42 C (107.6 F)

Table 2.4.2 Specifications for System

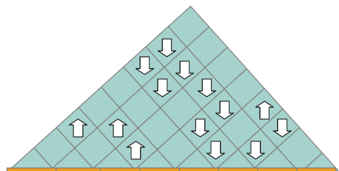
System	**Parameter**	**Specification**
Web application	Update frequency	Every 1 min
Microcontroller	Sampling of sensor data frequency	Every 15 mins
Battery	Power usage	<1.5Wh/day

2.4.1 House of Quality Table

The house of quality table allows us to extrapolate between meeting our customers expectations with the design specifications needed to accomplish it. Comparing the tradeoffs between these allows us to view the potential impact of changing certain parts or aspects of the project. Below is a table with what we identified as the most important marketable aspects and design requirements for C.H.A.N.O.S.

Table 2.6, House of Quality

Symbols	Meaning
+	Maximize
−	Minimize
⇧⇧	Very Positive Correlation
⇧	Average Positive Correlation
⇩	Average Negative Correlation
⇩⇩	Very Negative Correlation



		Soil Moisture Sensor Accuracy	Water Pump Flow Rate	Web-App Update Freq	Ultrasonic Sensor Accuracy	Solar Panel Output	Cost	Power Consumption	Dimensions
		+	+	+	+	+	−	−	−
Cost	−	⇩⇩		⇧	⇩⇩	⇩	⇧⇧		
Reduced Water Usage	+	⇧⇧	⇧	⇧	⇧		⇩⇩		
Durability	+						⇩⇩		⇩
Easy UI	+			⇧					
Appearance	+						⇩		⇩⇩
Supports Plant Variety	+	⇧⇧		⇧⇧					
Minimal Maintenance	+			⇧	⇧				
Auto Drainage	+						⇩		⇩
		+- 3% VWC	0.5 - 1.0 L/min	Information Update Every 1 min	+- 10%	0.5 - 1.0 W	~ $300	< 1.5 W	1 ft 4 inch base, 1 ft 6 inch width, 1 ft 3 inch height

2.5 Block Diagrams

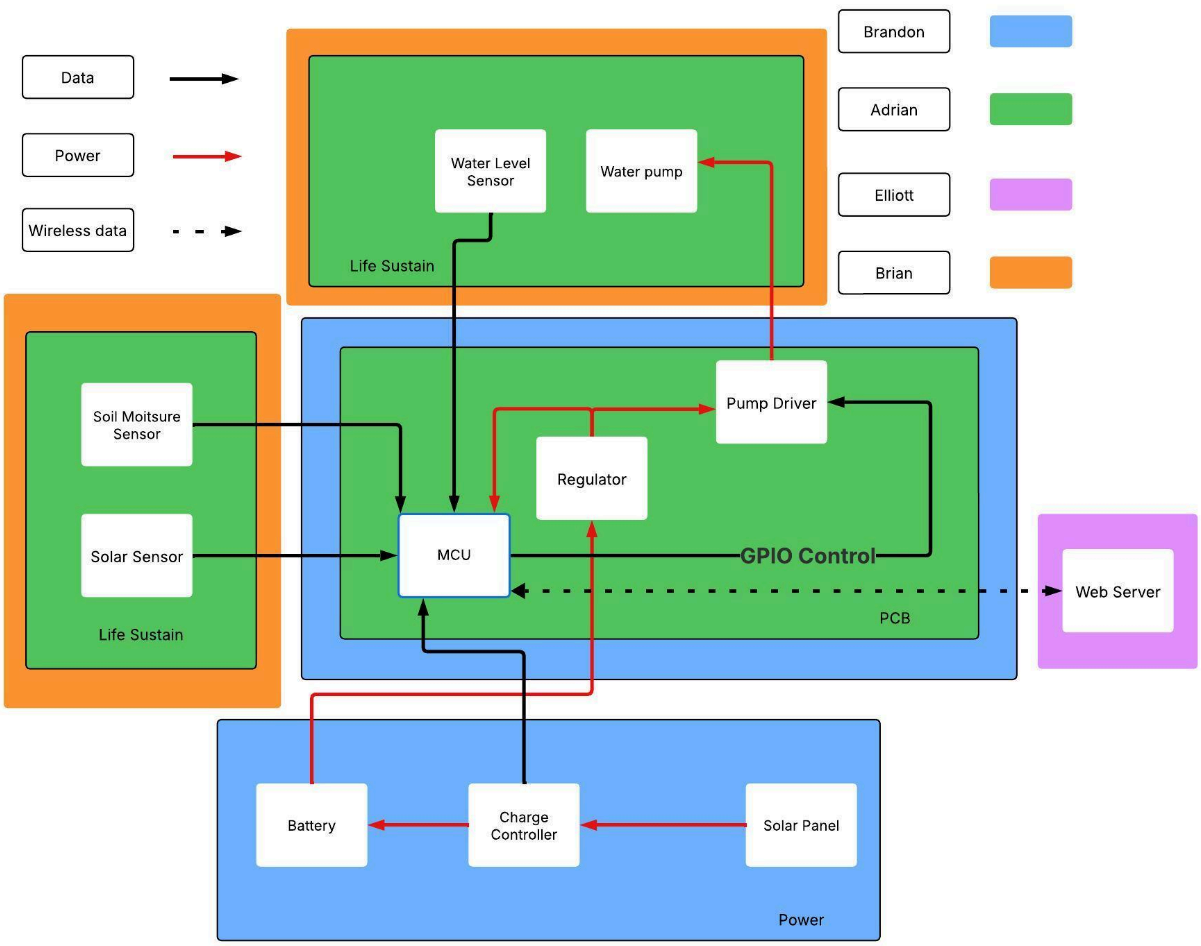
2.5.1 Hardware

This block diagram represents the architecture of a solar powered plant life support system. The goal of this system is to maintain soil moisture using sensors and a water pump. As well as provide wireless updates to the user about the plant's life status.

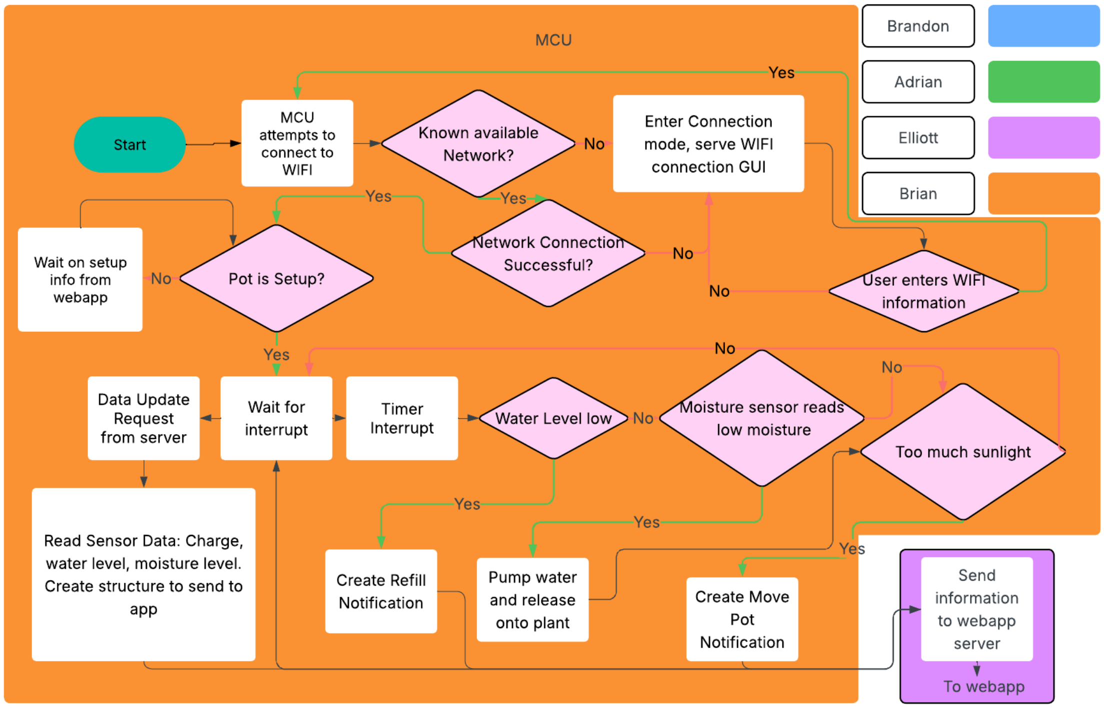
We will be using an ESP32 microcontroller to monitor and control the various sensors and life sustaining systems. The sensors we plan to use are the following - light sensor, ultrasonic water level sensor and capacitive soil moisture sensor. These sensors will both provide information to the mcu to make automated systems activate and provide data to the user.

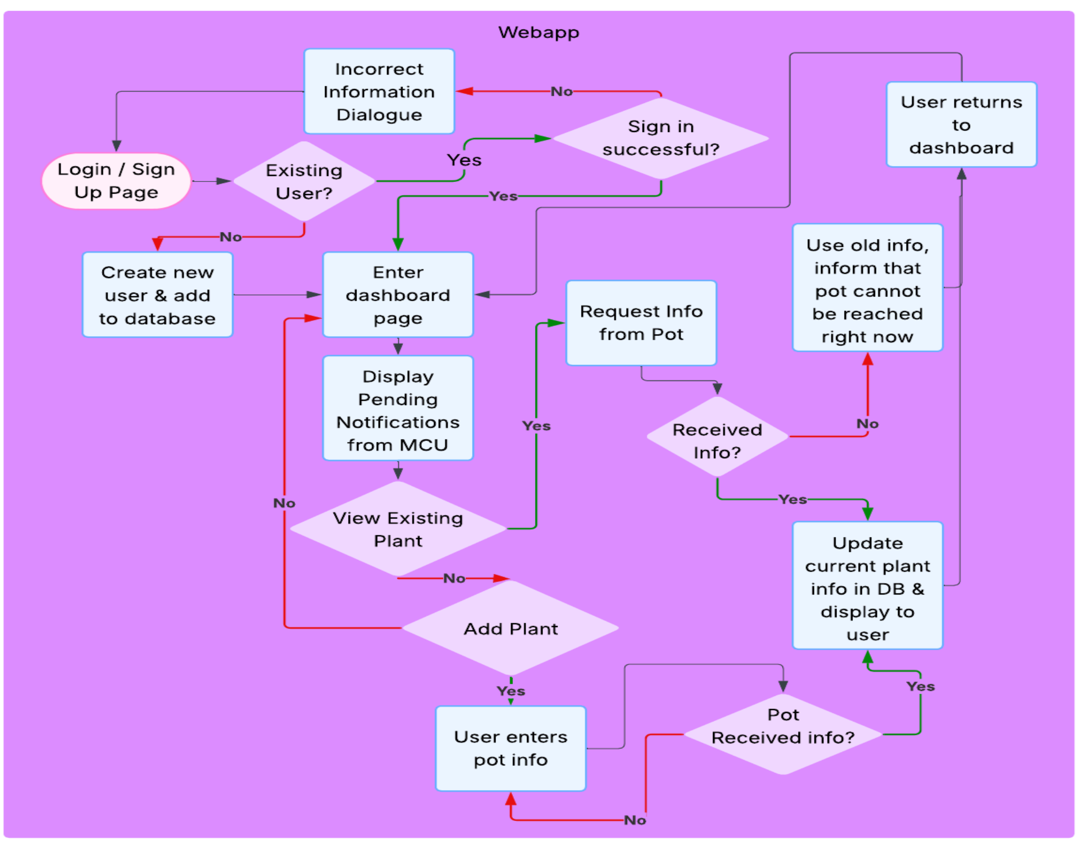
Each of the blocks - life sustain, power and pcb will all be separate boards. The soil moisture sensor and solar sensor will be custom designed boards along with the water level sensor. The power block will also be its own board all feeding into the main pcb board label PCB on the diagram.

The hardware design aspects will primarily be done by the two EE - Brandon and Adrian. While the software components will be handled by the two CPE Elliott and Brian.

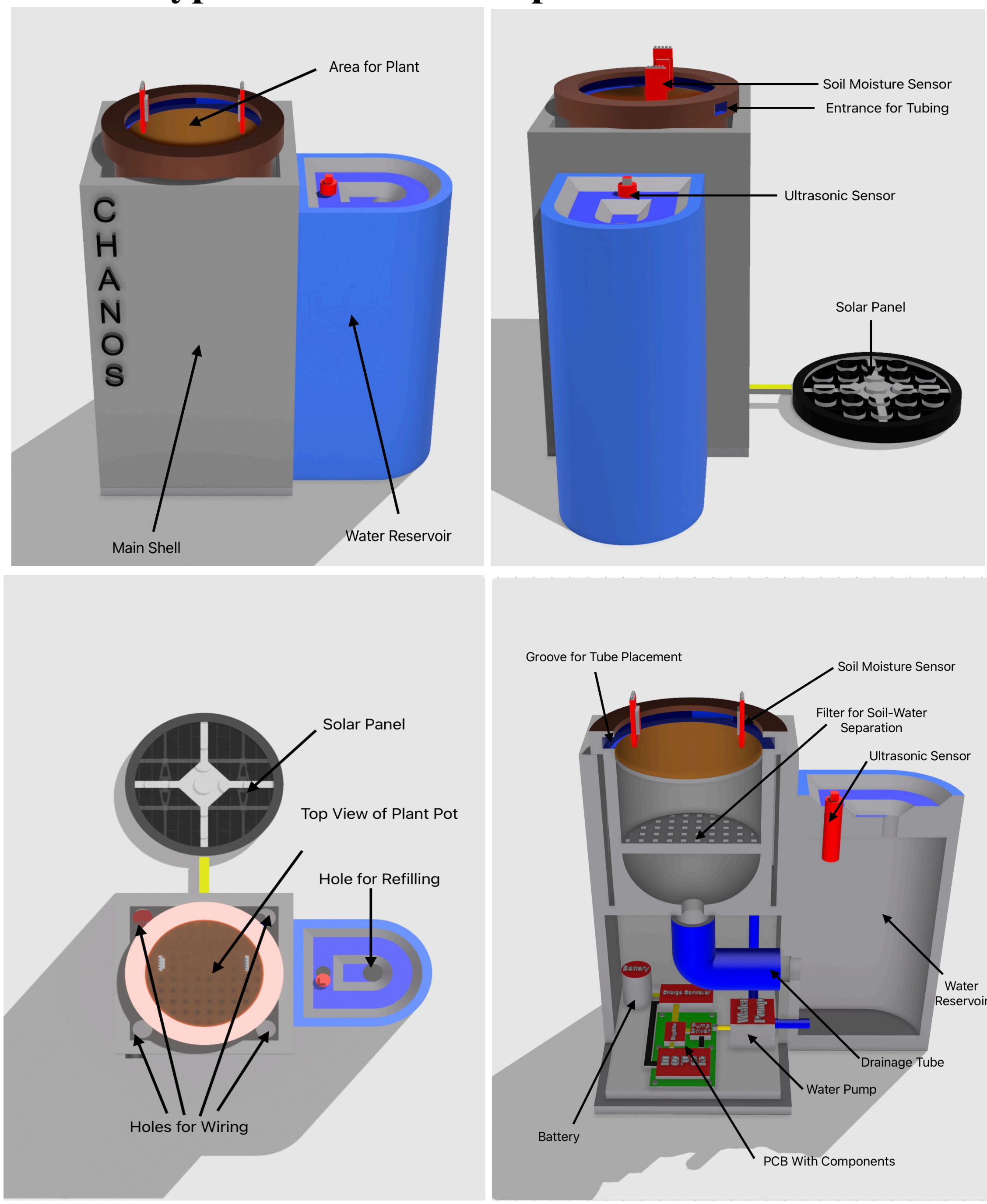


2.5.2 Software





2.7 Prototype illustration/blueprint



Visual 2.7, top left, front view (a), top right, side view (b), bottom left, top view (c), and bottom right, internal view (d), of C.H.A.N.O.S.

The above visuals show several views of the C.H.A.N.O.S. prototype. Breaking the color scheme down, we can loosely identify electrical components as anything highlighted in red, blue for anything related to water, green for the PCB, brown for the pot the plant would be put in, and grey as the overall shell. We will start with explaining the area around where the pot would be. In this area we have our soil moisture sensor (red) and a groove (blue) that extends around the inner perimeter of the pot. This groove is meant for the end section of the tubing where water would be shooting out in a 360 degree fashion, making sure it reaches all parts of the soil in a semi-even way. In side view (b) you will see a small rectangular cut out on the outer perimeter of the pot where the tubing would enter. The remaining part of the tube, which is connected to the pump, can be seen in (d) behind the drainage tube also highlighted in blue.

Continuing slightly under where the pot is positioned you will see a mesh where a potential filter would be placed, seen above the drainage tube in (d). This is meant to separate the soil so that clean water can return to the reserve shown on the right in figure (a) in blue. For the reserve, you can see on most visuals a hole where new water would enter to refill it. In (d) we can more easily see the potential placement of where the ultrasonic sensor could be in order to accurately measure water levels. Staying with visual (d) in mind, we can see a small tube, towards the bottom, in blue going from the reserve straight to the pump located in the central part of the shell.

The lower part of the shell is located straight below where the plant would be and houses most of the electrical components needed for the project to function. In green we have our PCB with the MCU, voltage regulator, and pump driver. Outside the PCB we have the actual pump, charge controller, and battery. Finally, behind the shell, seen more clearly in visual (b) and (c), we have our solar panel which will be our main energy source for the project.

3 Budget Estimate

Table 3.1 Budget estimate

Sub System	**Budget**
Power delivery and solar	$80
PCB/ microcontroller	$30
Sensors	$30
PCB and other materials	$100
3d Prints	$25
Total	$265

Table 3.2 Bill of Materials - in progress

Category	Component	Subsystem	Quantity	Cost	Total
MCU	ESP32	PCB			
Battery		Power			
Solar Panel					
Soil Sensor					
Light Sensor					
Pump					
Diode	Schottky Diode	Power			
Total					

4 Milestones and Responsibilities

The milestones have been set with the information provided so far. We don't have much information about deadlines for SDII. The process for setting deadlines involves us targets 1-2 weeks ahead of the actual deadline to give us adequate time in case of unexpected events.

Item	Start Date	TCD	Due Date
Bootcamp Assignment	05/13/25	05/23/25	05/23/25
Divide & Conquer Document and Committee Formation	05/13/25	05/30/25	05/30/25
DiscoveryKITForm	05/13/25	05/31/25	05/31/25
Divide & Conquer (D&C) Document Revision	06/02/25	06/05/25	06/06/25
Assignment on Standards	06/02/25	06/18/25	06/20/25
Midterm Milestone Report	05/13/25	06/21/25	07/07/25

Final Report - Draft	05/13/25	07/12/25	07/29/25
Final Report - Final	07/12/25	07/26/25	07/29/25
Mini Demo Video	07/12/25	07/26/25	07/29/25

Table 4.1 Senior Design 1 Project Documentation Milestones

Item	Start Date	TCD	Due Date
Individual System Design	06/06/25	06/14/25	06/18/25
Individual System Testing	06/18/25	07/12/25	07/26/25
Breadboard Prototyping	06/18/25	07/12/25	07/26/25
PCB Design/Ordering	07/26/25	08/05/25	08/12/25
Component Selection	06/06/25	06/10/25	06/14/25

Table 4.2 Senior Design 1 Project Design

Item	Start Date	TCD	Due Date
PCB Testing	TDB-SDII	TDB-SDII	TDB-SDII
System Integration/Testing	TDB-SDII	TDB-SDII	TDB-SDII
Practice Project Demo	TDB-SDII	TDB-SDII	TDB-SDII
Finalize Documentation	TDB-SDII	TDB-SDII	TDB-SDII
Practice Final Presentation	TDB-SDII	TDB-SDII	TDB-SDII
Final Presentation	TDB-SDII	TDB-SDII	TDB-SDII

Table 4.3 Senior Design 1I Project Documentation Milestones

The following will be the specific sub systems and other design aspects that each person will be responsible for.

Electrical Engineering	Responsibility
Brandon James	PCB Design and fabrication
	Solar and other power delivery

	3d printing pot design
Electrical Engineering	Responsibility
Adrian Vergara	PCB Design and fabrication
	Water pump system
	Solar, soil moisture and water level sensor
	3d printing pot design
Computer Engineering	Responsibility
Brian Ericson	MCU software design
	Sensor design support; MCU/Sensor interfacing
	Web app support
	Smart home integration
Computer Engineering	Responsibility
Elliott D'Amato	Web app
	MCU Networking & web app connection
	MCU Software support

Table 4.4 Distribution of roles

Appendix A - references

1. We have used Chatgpt for creating the image on the document as well as other proofreading.
2. Moss, Justin Quetone, et al. "Smart Irrigation Technology: Controllers and Sensors." OSU Extension, Oklahoma State University, 1 Feb. 2017, https://extension.okstate.edu/fact-sheets/smart-irrigation-technology-controllers-and-sensors.html. Accessed 29 May 2025.
3. Dong, Younsuk, and Hunter Hansen. "Development and design of an affordable field scale weighing lysimeter using a microcontroller system." Edited by Stephen Symons. *Smart Agricultural Technology*, 8 Dec. 2022, https://doi.org/10.1016/j.atech.2022.100147.
4. Hillhouse, Grady. "Arduino Garden Controller - Automatic Watering and Data Logging." *YouTube*, uploaded by Practical Engineering, 2 April 2015, https://www.youtube.com/watch?v=O_Q1WKCtWiA.
5. Uhlmann, Martin. " Flaura – Automatic, Smart Plant Pot (Self Watering, DIY Project, 3D Printed, Arduino) INTRODUCTION." *YouTube*, uploaded by Flaura - Smart Plant Pot, 6 July 2021, https://www.youtube.com/watch?v=rHHFL17ncnc.

Appendix B - copyright permission

1.

Hello,

I am a Computer Engineering student at the University of Central Florida. I am currently working on a senior capstone project for an automatic houseplant watering and nourishment system. I read your 2017 OSU article on Smart Irrigation Technology and it contains some information on smart irrigation controllers and sensors that I would like to cite in my capstone report. We are required to obtain written permission from the authors/creators for the content we use and cite in our report. I have CC'ed the other members of my capstone group for transparency.

Would we be permitted to use and cite your article in our report?

Thank you,
Brian Ericson

Moss, Justin Quetone<mossjq@okstate.edu>
To: Brian Ericson; malarie.gotcher@okc.gov; saleh.taghvaeian@unl.edu; +1 **other** Sat 5/24/2025 5:36 PM
Cc: Brandon James; Adrian Vergara; Elliott D'Amato

Retention: UCF Delete after 10 Years (10 years) Expires: Tue 5/22/2035 5:36 PM

Yes, please proceed.

Justin Quetone Moss
405.744.5415

2.

3. https://doi.org/10.1016/j.atech.2022.100147 ↗

Hello,

I am a Computer Engineering student at the University of Central Florida. I am currently working on a senior capstone project for an automatic houseplant watering and nourishment system. I watched your YouTube video on your Arduino Garden Controller and it contains some information on automatic watering sensors and systems that I would like to cite in my capstone report. We are required to obtain written permission from the authors/creators for the content we use and cite in our report. I have CC'ed the other members of my capstone group for transparency.

Would we be permitted to use and cite your video in our report?

Thank you,
Brian Ericson

Grady Hillhouse <grady@practical.engineering>
To: Brian Ericson
Cc: Brandon James; Adrian Vergara; Elliott D'Amato
Tue 5/27/2025 10:46 AM

Retention: UCF Delete after 10 Years (10 years) Expires: Fri 5/25/2035 10:46 AM

Brian,

Glad that video is still being seen! Feel free to use it in your report. As long as the video isn't downloaded and rehosted elsewhere, it's not a problem. Best of luck on your project.

4. Grady

5. This is a detailed introductory video to Flaura, my Do-It-Yourself, Open-source project.

Appendix C - etc