Self-Watering Plant Pot

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by

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Abstract:

The topic expressed in this paper relates to the automation of a plant pot. Many people own house plants, and a lot of plant owners face similar issues relating to over watering or underwatering plants. This is not good for the plant and will likely kill the plant forcing the owner to buy another with the fear of doing the same thing. This often draws people away from owning plants since they do not have the time or money to purchase a new plant due to their busy lifestyle and inability to give the plant the sunlight and watering the plant requires daily. This leads to the construction of a plant pot that will take care of the plant for you whether you are home or away.

1. Problem Statement

Many people struggle to keep plants healthy, that is due to irregular watering by either forgetting to water them or overwatering. These inconsistencies lead to poor plant growth and health. A solution to these issues is a pot that could water and maintain plant growth. A self-watering plant pot with a built-in water reservoir and moisture sensor could automatically regulate water release, providing an easy, low-maintenance way to keep plants healthy, especially for busy or forgetful individuals.

2. Research

a. Background of the Problem

Inconsistent plant watering has been a persistent issue for both casual plant owners and professional gardeners for decades. Historically plant care has been entirely manual, requiring individuals to water plants on a regular schedule. However, human error, such as forgetting to water or overwater, has always been a significant challenge. In 2021 State of the Industry report garden centers reports that house plants saw a 22% growth (1). The increase in house plant sales indicating a growing market and there are more house plant owners than ever.

For plant owners, improper care of plants can result in significant financial losses. On average, houseplant owners in the U.S. spend over $120 dollars a year on plants and related products (2). Beyond financial cost, there are other resources wasted, including water, fertilizers, and time spent on attempts to salvage unhealthy plants. Not to mention the emotional investment people will make with the plant being a houseplant, houseplants are often associated with mental well-being and interior aesthetics.

If this issue continues to be improperly addresses, it will lead to waste of resources and increased frustration for plant owners, many plants to fail to thrive or even die to insufficient watering, this discourages new plant owners from continuing gardening efforts. Over time, this could cause fewer people to maintain their plants in homes or offices, undermining the numerous health and environmental benefits that these plants provide.

There are currently a few options that exist, but each has its own limitations. Traditional solutions include watering pots, water globes, and more advanced irrigation systems. One newer solution uses AI to display how the plants' current health is based on its water level and moisture. The issue with this solution is how expensive it is. Other solutions are unable to provide proper amounts of water and cause over or underwater. Over watering causes root rot, which is a plant disease that causes a plant's roots to deteriorate and die, which can eventually kill the plan (3). These gaps leave room for innovation, particularly in the development of a more efficient, aesthetically pleasing self-watering plant pot that uses advanced moisture sensors to accurately maintain optimal soil moisture levels

b. Applicable Standards

- UL 508A: Industrial Control Panels
- UL 1310: Class 2 Power Units
- IEC 61131: Standards for programmable controllers
- ISO/IEC 27001: Information security management

c. State of the Art

The evolution of self-watering plant pots and systems is seen using technology. Several self-watering systems are available, each with different approaches to automating plant watering. These technologies include traditional self-watering pots, water globes, capillary mat systems, and new moisture-sensor based irrigation systems.

1) Reservoir System

This approach has a built-in water reservoir at the base that provides waters to the plants roots through capillary action. As the soil dries up the water is drawn up from the reservoir, providing a consistent water supply.

Pros:

- Low cost and widely available
- Low maintenance after setup
- Helps prevent underwatering by providing a consistent water supply

Cons:

- No moisture sensing capability, leading to potential overwatering
- The water supply may become stagnant over time, leading to mold or bacterial growth
- Limited control over water flow, and the pot needs refilling periodically.

This traditional reservoir system is an improvement over manual watering, but this system lacks the ability to adjust water supply based on its actual needs. These systems still suffer from overwatering issues.

2) Water Globes (Passive Watering System)

Water globes are simple glass or plastic devices filled with water and inserted into the soil. As the soil dries, water is slowly released from the globe into the plant's roots.

Pros:

- Very low cost and easy to use
- No electrical components or complex setup
- Simple, compact design that fits into most pots

Cons:

- No way to regulate water flow, leading to inconsistent watering
- Prone to overwatering or clogging in some soil types
- Unsuitable for larger plants or those requiring more precise care

Water globes provide an ultra-simple solution but lack the sophistication needed to accurately regulate water based on soil moisture. They are more suitable for small plants and short-term use but do not offer the reliability of more advanced systems.

3) Capillary Mat Systems (Passive Irrigation)

Capillary mats are placed beneath pots and wick water up from a water reservoir into the soil. They use capillary action to automatically water plants as needed.

Pros:

- Ideal for use with multiple pots simultaneously.
- Efficient for consistent watering without over-saturating soil.
- Passive system with no electrical components needed.

Cons:

- Can lead to waterlogging if not monitored.
- Requires flat surface placement, limiting the number of plants that can benefit.
- The system is often bulky and difficult to integrate into home decor.

Capillary mats are useful for small-scale indoor gardening or greenhouse setups but lack the flexibility and adaptability needed for more dynamic plant care. They are also more suited to large plant collections rather than individual houseplants.

4) Moisture Sensor-Based Irrigation Systems

These systems use moisture sensors inserted into the soil to monitor water levels. Based on real-time data, they automatically activate a pump or release water when the soil becomes too dry.

Pros:

- Real-time moisture monitoring.
- Prevents both overwatering and underwatering by only delivering water when needed.
- Can be connected to smart home systems for automated control and monitoring.

Cons:

- Higher initial cost and more complex installation.
- Requires regular maintenance of sensors and electronics.
- Battery-powered systems may need frequent recharging or replacement.

Moisture sensor-based systems offer the most precise and advanced plant care but come with higher costs and maintenance requirements. They are ideal for users who want detailed control over their plant watering schedule but may be overkill for casual users.

d. End User

The people that will benefit from solving the problem of inconsistent plant watering is a busy urban living professional who enjoys having plants at their home and or work but struggles to keep the plant healthy due to busy schedules. This person has limited time, knowledge or interest in regularly monitoring and watering their plants. The understand the health, environmental, and aesthetic benefits that come from houseplants but are discouraged by them due to the challenges of keeping them alive.

e. Summary of Research

Through my research, I learned that the main issue faced by plant owners, especially busy professionals and those with limited knowledge or time, is the inconsistently watering and attending to plants properly. Many of the current solutions are either overwater or underwater due to the lack of precision and adaptability. Traditional and advanced automated systems currently exist but they have their issues and or either to simplistic and imprecise or overly complex and expensive. There is a clear need for a more accurate, affordable, and adaptable solution for watering plants.

f. Customer features

- Moisture Sensing Technologies
- Water Reservoir with automated release
- User-Friendly Interface
- Battery or Solar Powered
- Stylish Design
- Environmental Consideration in materials used.

3. Quality Function Deployment

a. Survey Methodology and Results

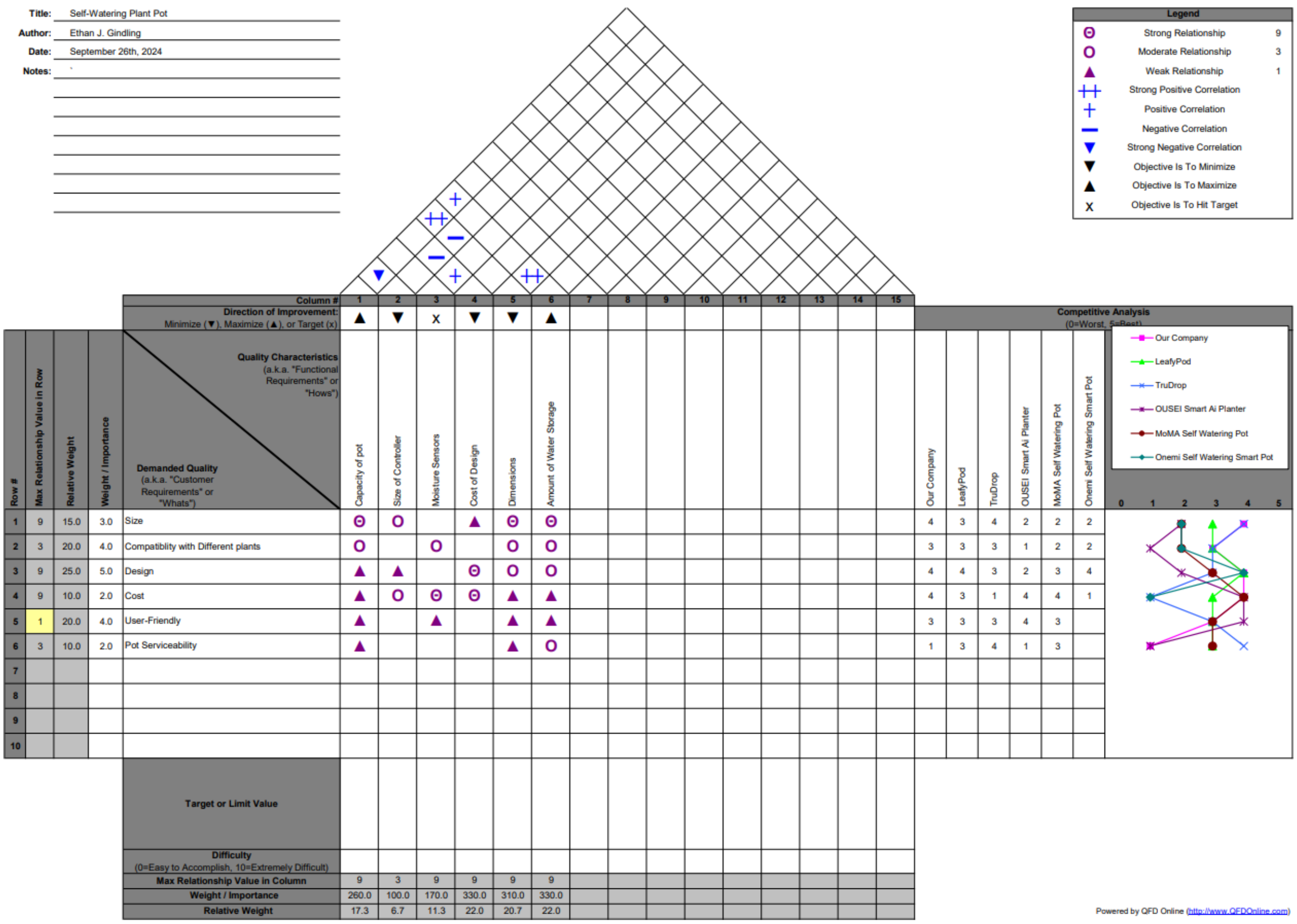
When conducting this survey, I picked out a small sample of people from friends and family that has indoor plants. Each of them said on the survey they had killed plant from either over watering or under watering, none of them were familiar with self-watering plant pots but knew they existed. The survey then asked how important each feature was. I found that the design of the pot is the most important.

		Importance of the feature		Satisfaction with the feature in the current technology	
Customer Feature	**Total Surveyed**	**Average Rank**	**Standard Deviation**	**Average Rank**	**Standard Deviation**
Size	29	3.69	0.67	1.89	0.56
Compatibility with several plant types	29	3.77	0.62	2.33	0.47
Design	29	4.12	0.67	2.56	0.49
Investment Cost	29	2.94	0.57	2.67	0.47
User Friendly	29	3.85	0.62	2.33	0.67
Pot Serviceability	29	2.60	0.49	2.44	0.49

b. Engineering Characteristics

Using resources and information from surveys and through internet forums, I decided the Engineering Characteristics below.

- Capacity of Pot
- Size of controller (number of I/O and other ports)
- Moisture Sensors
- Cost of Product
- Dimensions
- Amount of Water Storage



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Capacity of pot	Size of Controller	Moisture Sensors	Cost of Design	Dimensions	Amount of Water Storage	Our Company	LeafyPod	TruDrop	OUSEI Smart Ai Planter	MoMA Self Watering Pot	Onemi Self Watering Smart Pot
				Column #	1	2	3	4	5	6						
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	▼	x	▼	▼	▲						
1	9	15.0	3.0	Size	Θ	O		▲	Θ	Θ	4	3	4	2	2	2
2	3	20.0	4.0	Compatiblity with Different plants	O		O		O	O	3	3	3	1	2	2
3	9	25.0	5.0	Design	▲	▲		Θ	O	O	4	4	3	2	3	4
4	9	10.0	2.0	Cost	▲	O	Θ	Θ	▲	▲	4	3	1	4	4	1
5	1	20.0	4.0	User-Friendly	▲		▲		▲	▲	3	3	3	4	3	
6	3	10.0	2.0	Pot Serviceability	▲				▲	O	1	3	4	1	3	
7																
8																
9																
10																

	Capacity of pot	Size of Controller	Moisture Sensors	Cost of Design	Dimensions	Amount of Water Storage
Target or Limit Value						
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)						
Max Relationship Value in Column	9	3	9	9	9	9
Weight / Importance	260.0	100.0	170.0	330.0	310.0	330.0
Relative Weight	17.3	6.7	11.3	22.0	20.7	22.0

c. Product Objectives:

Based on our House of Quality the engineering characteristics are listed below in order of importance, with the first on the list being most important. I will prioritize these characteristics according to their percentage of importance:

1. Cost of Design (22%)
2. Water Storage (22%)
3. Dimensions (20.7%)
4. Capacity of the Pot (17.3%)
5. Moisture Sensors (11.3%)

6. Size of controller (number of I/O and other ports) (6.7%)

7. Concepts Design

Throughout the process of this proposal, I determined the most important features for a successful design are, in their respective order, budget friendly total cost, large water capacity, medium sized design with added components, a high-capacity pot, moisture sensing technology, and a compact housing service for controller components.

It is important for this pot to feature a budget friendly design with new technology features such as smart moisture sensing technology, compatibility with many plants and a water capacity that will last a couple of weeks. Current technology on the market each have their limitations whether that be a small capacity, expensive, or limitations with the type of plant.

Function #1

Large Water Basin with small electric pump

Function #2

Moisture sensing technology

Function #3

Create an app that will allow users to track trends in moisture and water cycles.

Final Design

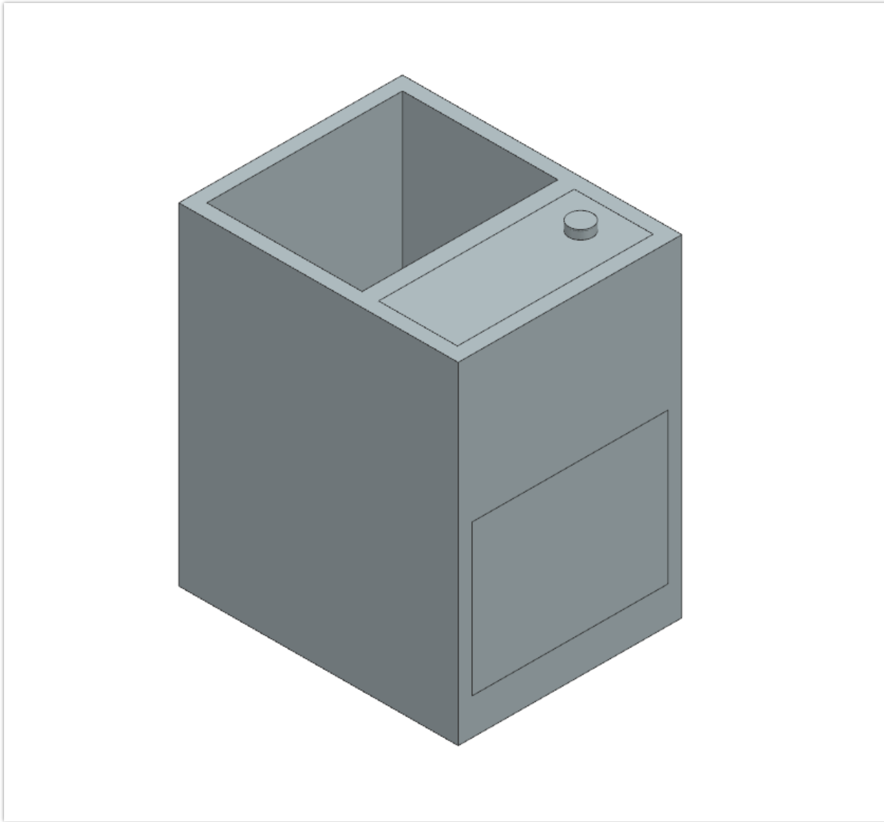


Figure 1: Final Assembly

8. Project Management

a. **Team Members and Responsibilities:**
   i. **Ethan Gindling**
b. **Project Budget Limit:**

The actual cost does not include the original set of moisture sensors I had purchased for the project. I also ended up changing the controller for a raspberry pi that I had already, but I did include that cost in there. This project could also have been completed using Arduino but that didn't provide me with wireless access to the controller to monitor the system. The submersible pump and moisture sensors were purchased from amazon each coming in a pack of four. Some future purchases for this project will be a PV module and Battery so the system can operate without wall power.

Parts / Assembly	Proposed Cost	Actual Cost
Frame (Pressure treated wood)	$45	$49.40
Water Pump (4 pack)	$10	$6.99
Water Tubing + Fittings	$20	$9.41
Controller (Raspberry Pi 4)	$50	$62.99
Capacitive Moisture Sensor (4 pack)	$50	$10.99
Misc. Parts (screws, nuts, bolts, wire, etc.)	$15	$32.54
Total	$190	$172.32

c. **Key Milestones:**

When it came time to assemble, I faced a few issues, the first being faulty moisture sensors. This issue related to the data that was being transmitted back to the raspberry pi, the data for the few readings would seem correct but the rest of the data seemed to have a lot of interference. I tried to make it work but every idea I had to resolve the problem didn't change readings, so eventually I bought different sensors that were able to read in accurate enough data to where I could adjust the threshold of the sensor. After that issue was resolved I began the assembly of the outer shell where I used treated wood and sanded the inside down to apply multiple layers of waterproofing stain and used a rubber sealant along the cracks, once I had completed that I had let it cure for few days and began testing in the box, a few days of letting the system run on its own I noticed a leak and applied some flex tape to the inside of the box to further prevent leaks. Once I was certain it would not leak again, I continued testing.

Task	**Planned Date**	**Actual Date**
Order Remaining Components	1/6/2025	1/16/2025
Assembly Start	1/20/2025	2/5/2025
Finish Assembly	2/15/2025	2/26/2025
Begin Testing	2/25/2025	3/7/2025

Sustainability and Material Usage:

There are a few factors that could have made this project more efficient. Firstly I could have used a different controller that would have been cheaper and contained most of the wiring and electrical components that were required for this project, some options included an Arduino. The second change that could have been made to this project was the box material selection. Since I went with wood, I knew the dangers that could have come with leaks and such of using as a material with water, I could have found some sort of plastic material that would have been cheaper and lighter than the wood used. The last thing I would change about this project is the moisture sensor, I faced issues with the sensor early leading me to purchase a different, the sensors that are currently being used work but the sensor seems to corrode after being exposed to damp soil for long periods of time.

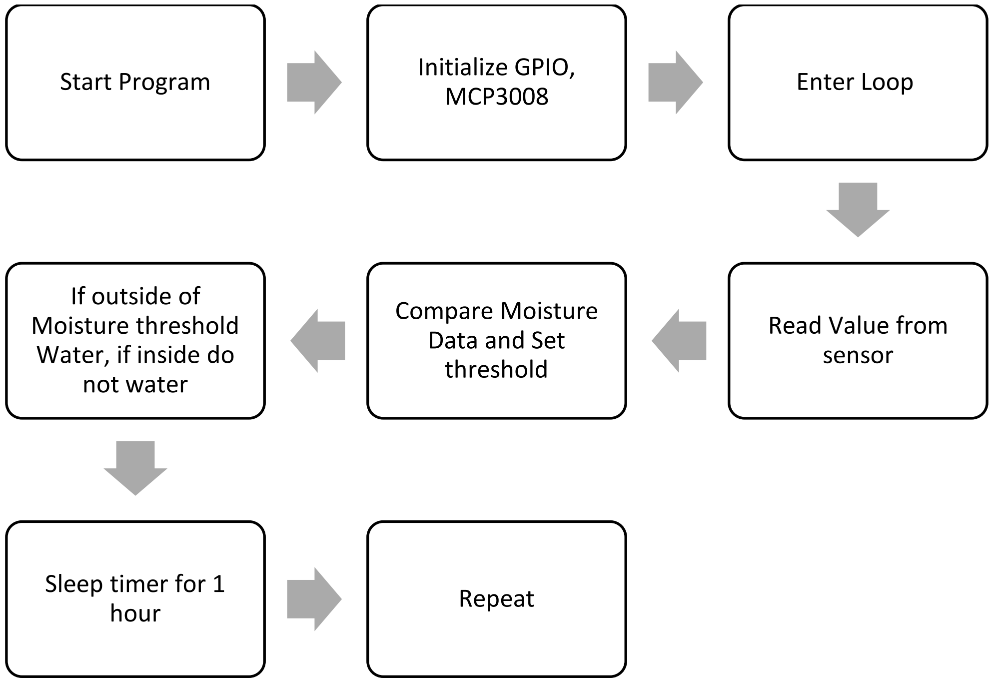


Figure 2: Python Code Flow Chart

Figure 3: Final Product

Figure 4: Shell

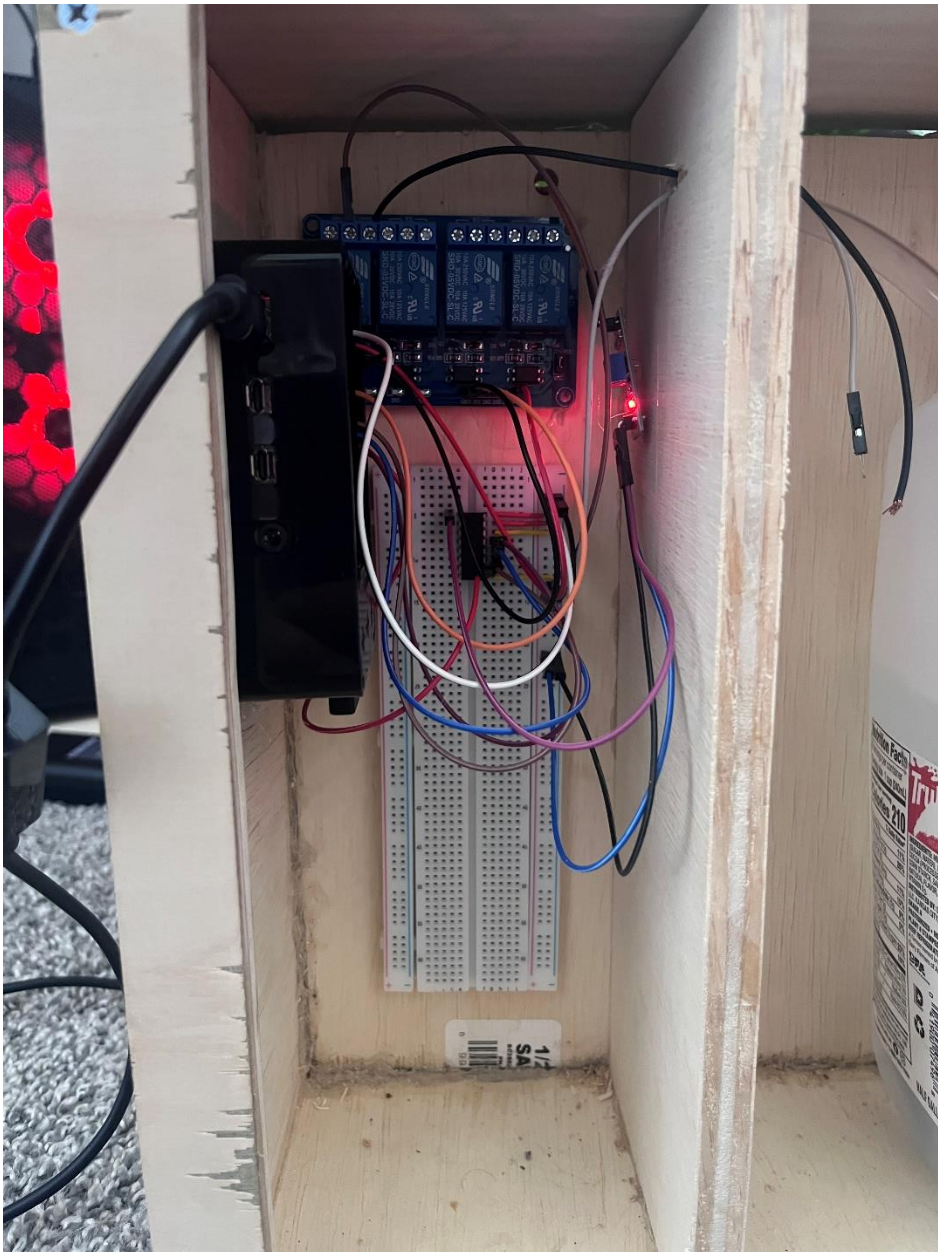


Figure 5: Raspberry Pi, Relays, and breadboard Configuration

Figure 6: Temporary Water Storage Solution

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Appendices

$Inner\ diameter\ of\ piping\ (Dp): 7\, mm\ = 0.007\, m$

$Flow\ rate\ (Q): 1.4\ \frac{L}{s} =\ 0.0014\ \frac{m^3}{s}$

$Nozzle\ angle\ (\theta): 45°\ (assumed\ optimal\ for\ horizontal\ range).$

$Gravitational\ acceleration\ (g): 9.81\, m/s2$

$Pot\ Dimensions: L \times W \times H = 0.3937\, m\ \times 0.3048\, m \times\ 0.3175\, m$

$A_{Inner\ pipe} =\ \pi \times \frac{0.007^2}{4} = 3.85 \times 10^{-5} m^2$

$v_{in\ pipe} =\ \frac{Q}{A} = \frac{0.0014}{3.85 \times 10^{-5}} = 36.4 \frac{m}{s}$ **This idealized velocity is unrealistically high for most systems and suggests that friction, turbulence, and pump limitations significantly reduce velocity in practical applications.*

Range: $R = \frac{{v_{in\ pipe}}^2 \times \sin{(2\theta)}}{g} =\ \frac{2^2 \times \sin{(2(45°))}}{9.81} = 0.41\ m$

Energy Usage (*assume optimal conditions*): $Daily\ Energy = (5V * 2.5A) * 2.5hr + (4.5V * 0.18A) * 2.5hr = 33.275 \approx 35\ \frac{W*hr}{day}$

Watering Schedule table: will be based on soil moisture content measured by probe placed in soil, goal is to preserve water and only water based on conditions of the soil.

Moisture Level (%)	Soil Condition	Watering Action	Watering Duration (seconds)
0–20	Extremely Dry (Wilting)	Immediate watering	20–30
21–40	Dry	Water required	10–15
41–60	Moderately Moist	Light watering if needed	5–10
61–80	Moist (Optimal)	No watering	0
81–100	Overwatered (Saturated)	No watering	0

Components and Material Selection:

- Exterior Design and Frame: Made up of 2x4 frames and plywood for frame walls.
- Recycles metals/plastics for aesthetics
- Environmentally safe plastic tubing
- Water Pump:
  - Voltage Scope (DC): 3.3V
  - Current: 0.18A
- Raspberry Pi 4 model B:
  - Voltage Scope (DC): 5V
  - Current: 2.5A
- Analog Moisture Sensor: 0-100%RH