Section II: Methodology

Role of Student vs. Mentor

Over the course of five months, the mentor provided guidance on critical questions like the probability of precipitation and the appropriate type of plants to grow. However, all the prototype building was done by the student, with occasional assistance from the mentor in troubleshooting.

Equipment and Material

The heart of the operation is an Arduino Giga with a 2.4GHz Mini Flexible WiFi Antenna. Connected to the board is a plethora of sensors and other components. These components include a Real Time Clock Module to keep track of the current date. There is also an L298N motor controller that is in charge of opening and closing the valves. The motor controller is powered by a 9-volt power supply or 9-volt battery. Then it is connected to a solenoid valve that can allow for water to pass through. I am also using a capacitive soil moisture sensor to determine how much moisture is in the soil. I am also using flexible tubing as well as fittings to allow for proper water flow. Please refer to the appendix for more information. Also being used are Wisconsin Fast Plant standard seeds, Osmocote, soil, and a white light.

Iteration 1

The initial version of the project utilized a soil moisture sensor, a valve, and a real-time clock. Its primary function was to monitor soil moisture, opening the valve when it fell below a preset threshold of 580. Once the moisture reached 630, the valve closed, and the duration it remained open was recorded on a USB stick. To generate sufficient pressure for the solenoid valve to open, a 120-volt AC pump was required. I initially attempted to increase the bucket's height to 6 feet, which would have provided approximately 3 PSI, as per the solenoid's specifications. However, this was still insufficient to allow full water flow. To prevent the pump from burning out, a smart plug with a side button was used. Three seconds before the valve opened, a servo flipped the button on the smart plug, enabling it to build pressure and open the valve.

Iteration 2:

Iteration 2 took what was learned in iteration one and expanded on it with the addition of weather analysis. Before water commences, the Arduino will reach out to the NWS Public Web API and return what it is seeing and store it in a JSON format. Once this JSON is received, the data is parsed down to the most current period, which is referred to as period 0, which contains data for the current weather. Then, it parses it down to just the change of precipitation as a percentage. It then stores this value in a separate variable and uses it for comparisons. Before the system is allowed to water, it compares its preset rain target value, and if the change of percentage, or the chance of precipitation, is higher than the current target value, it will not water. Then, it repeats back into the loop and continues the cycle of comparing to the weather. Refer to diagram 2A. The wiring diagram can also be seen in 2B. To simulate the rain conditions, a spray bottle was used to attempt to recreate the amount of rain that came into that area. This water was not counted into the total water used by the system as it was meant to not represent freshwater that was being provided. Both sets of whisking fast plants were grown under white light 24 hours a day. The set with my style of automatic irrigation was placed in the same style of cup as the other system; however, the other system sold by Carolina

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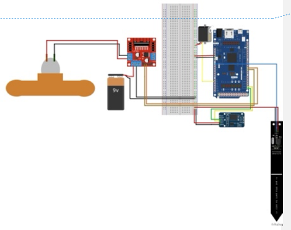
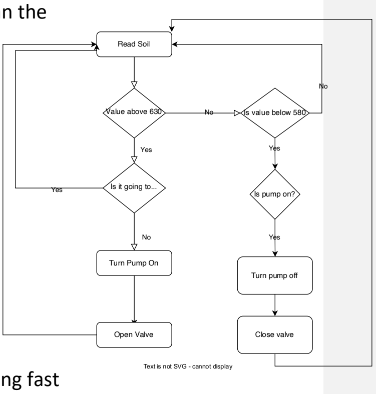
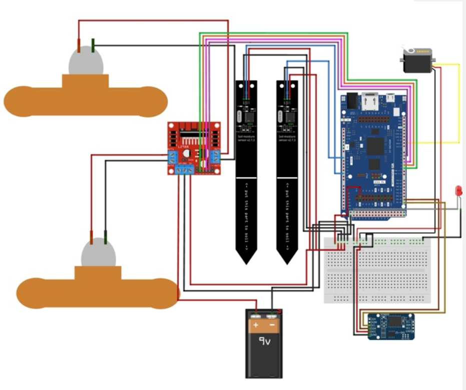


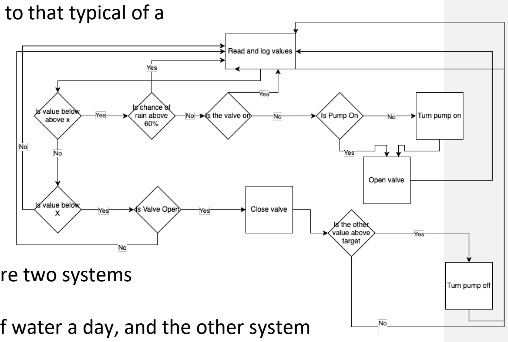


provided water at all hours of the day and also required additional irrigation on top of the soil. Later plants were baked in attempt to determine their masses with the water removed.

Iteration 3:

The third iteration takes the prior iteration and adds the ability for multiple sensors. The multiple sensors are crucial for hillside irrigation as hillsides often have runoff where the bottom of the hill will contain more water than the top of the hill. To add the second soilid valve and moisture sensor, the logic was slightly expanded to ensure that the pump was always on. The pump logic could be removed once the board is moved to a testing environment that has access to a water pressure similar to that typical of a regular garden hose. Refer to figures 3A and 3B for logic and wiring diagrams. These plants were being grown in fast-plant systems of the standard variety grown under 24-hour-a-day light. The soil used for them was a 1:1 ratio of peat moss and perlite. There were two systems that were used, one as a control, that received 500 ml of water a day, and the other system that was growing under the test system. Both of them were placed at an 8.38-degree angle from the horizontal to represent hillside irrigation. This angle was calculated by doing $sin^{-1}\left(\frac{3.5}{24}\right)$. Later, the plants were baked to determine their mass with the water removed..





Statistical Tests

The data that was being gathered was the moisture level of the soil from the sensor along with the amount of time the valve was open for in seconds. Then these seconds could be transformed into milliliters by knowing that the pressure reducer that is used reduces the pressure to approximately 0.25 gallons per hour.

Mann Whitney U Test

A Mann-Whitney U Test was used to determine the statistical significance of this project. A P valve of 0.0004 was found.

Section III: Results

The testing process involved meticulously recording the duration for which the valve remained open, as well as the soil moisture levels at intervals of every 10 seconds. By determining the duration of valve opening, we can apply mathematical calculations to ascertain the volume of water utilized. Data concerning the quantity of water used and the number of days it rained were primarily documented and subsequently compared, resulting in Figure 1.

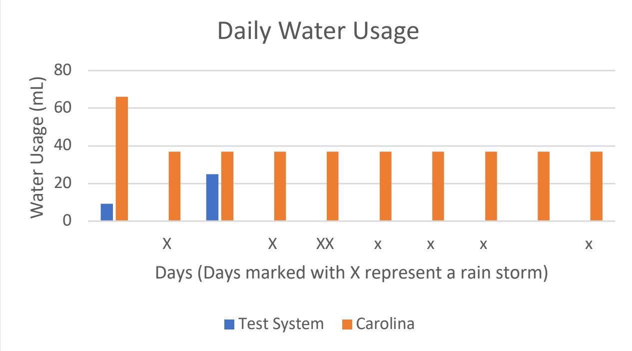


Figure 1: Daily water usage by both systems. This graph shows the amount of water used by both systems and when there was rain storms. The days with X marks represent days when there was a rain storm, and the days with two X marks represent two rain storms in one day.

Some data cleanup was necessary on the soil moisture records due to extraneous values caused by system restarts. Once the data had been cleansed, the refined results were depicted in Figure 2. The