Team Hydroponics

The automation of any plant’s complete needs utilizing hydroponic techniques, peristaltic pumps, pH sensor, EC sensor, and a water level sensor.

CS 121- Computer Organization- James Eddy

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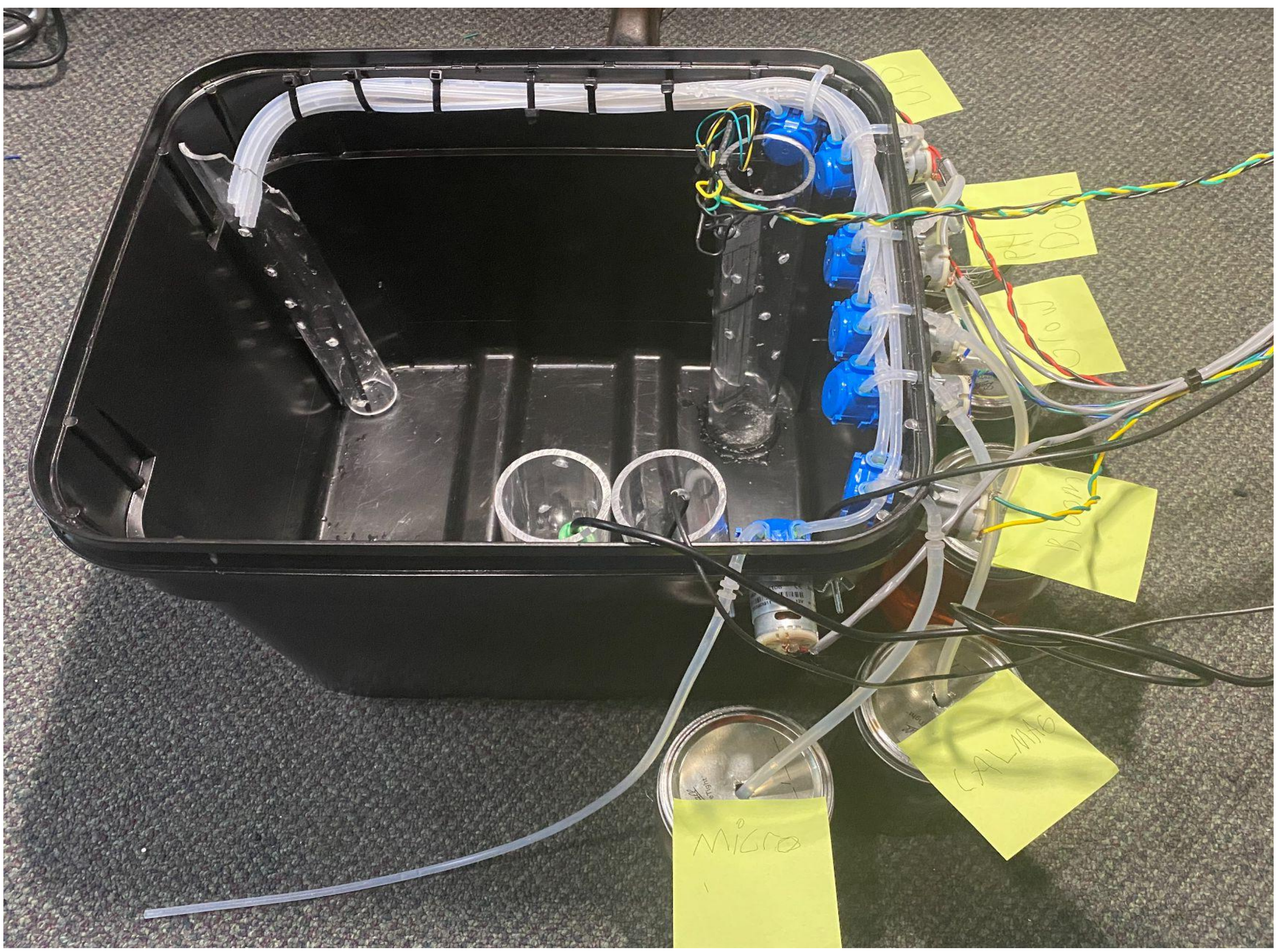

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Introduction:

With the ever-increasing need to provide more food for a growing planet with a limited amount of resources, researchers are investigating new efficient growing techniques. One such technique is hydroponics-- growing plants in containers with no soil. Inert material (like clay pellets) holds the plant in place, and nutrient-infused water allows the plants to grow. As the plants are enclosed in watertight containers, preventing water from draining away, hydroponics can reduce the water used for farming by over 80%! Hydroponics also enables the growth of plants in areas without soil, useful for growing fresh food in urban centers, allowing barren islands to become life sustaining, and even feeding future colonies in outer space!

One difficulty with hydroponics is that it requires regular adjustment and maintenance. Water levels, nutrient concentrations, and PH must be regularly adjusted. Neglecting hydroponically grown plants will quickly lead to their death. If you combine this with the fact that hydroponics already requires the use of electrical equipment to circulate or aerate the water, hydroponics becomes a natural target for automation. We intend to create an automated hydroponic system that will be able to maintain correct growing conditions for the plants with only occasional adjustment from the owner, making hydroponic farming more accessible to ordinary, time-constrained consumers.

We have completed this complete hydroponic automation utilizing a raspberry pi, 2 motor drivers running 7 pumps, 1 temperature sensor, 1 e-tape water level sensor and analog to digital converter, 1 pH and 1 EC sensor from Atlas Scientific.

Logic of our program:

Startup (occurs once):

1. Pump lines are primed
2. New water is drawn in with a large pump according to user value and e-tape sensor height

3. Nutrients are dosed evenly with pumps according to EC sensor and user value
4. pH is balanced to user value according to pH sensor
5. Sensors are kept calibrated using the temperature sensor

After startup (and for rest of plant life):

6. Check water level is below for the next fillup procedure and keep the pH within set range
7. Next fillup:

- Find the difference between the EC of the previous fillup and the current EC and add new water, nutrients, and pH
    a. Ex: First fillup ppm: 200, Second fillup ppm: 275: add -75 to initial ppm: 125: and use that as new nutrient dosing measurement to compare to next time
        i. The change in ppm means the plant ate less (more ppm) and thus should be fed less food next time
    b. Ex 2: First fillup ppm: 200, Second fillup ppm:130: add 70 to initial ppm: 270: use that as new nutrient dosing measurement to compare to next time
        i. The change in ppm means the plant ate more (less ppm) and thus should be fed more food next time

Definitions, Acronyms, and Abbreviations:

- Hydroponics- A unique method of growing plants where only water is used, and no soil is present at all to hold the roots, only an inert material like clay pellets
- Peristaltic pump, a pump that pushes water through a flexible tube using rollers.
- pH- stands for the potential of hydrogen- very important- too high or low for the plant will cause nutrient deficiency issues.
- EC- stands for electrical conductivity- directly relates to how much nutrients are in the water
- PPM- Another measurement of EC
- I2C- Inter-Integrated Circuit, a two-wire bus for embedded devices
- Raspberry Pi- an ARM-based single board computer

Project Details:

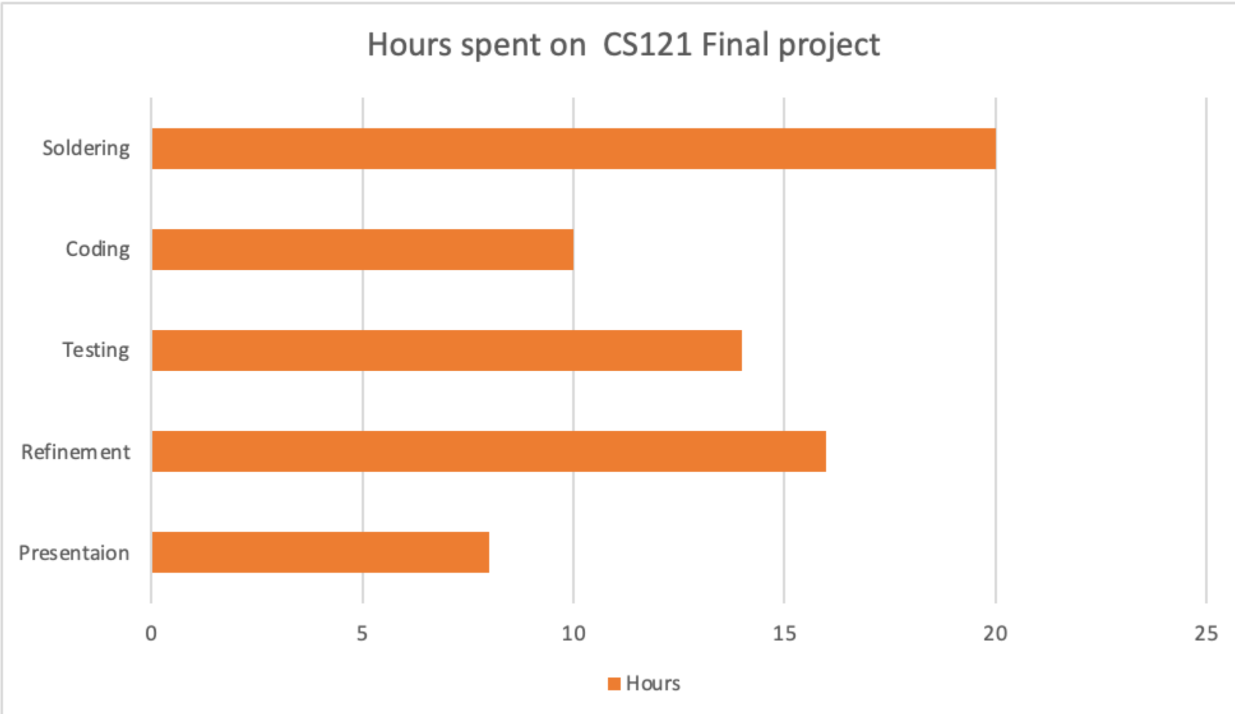
Our system will monitor 3 properties: water level, ph, and nutrient concentration, and regulate 4 of them, the preceding 3 + air concentration using an air pump. It will control liquid pumps to add water and nutrients to the container and an air pump to add air. Our system controls these autonomously, only needing user input on initial startup.

Project Plan:

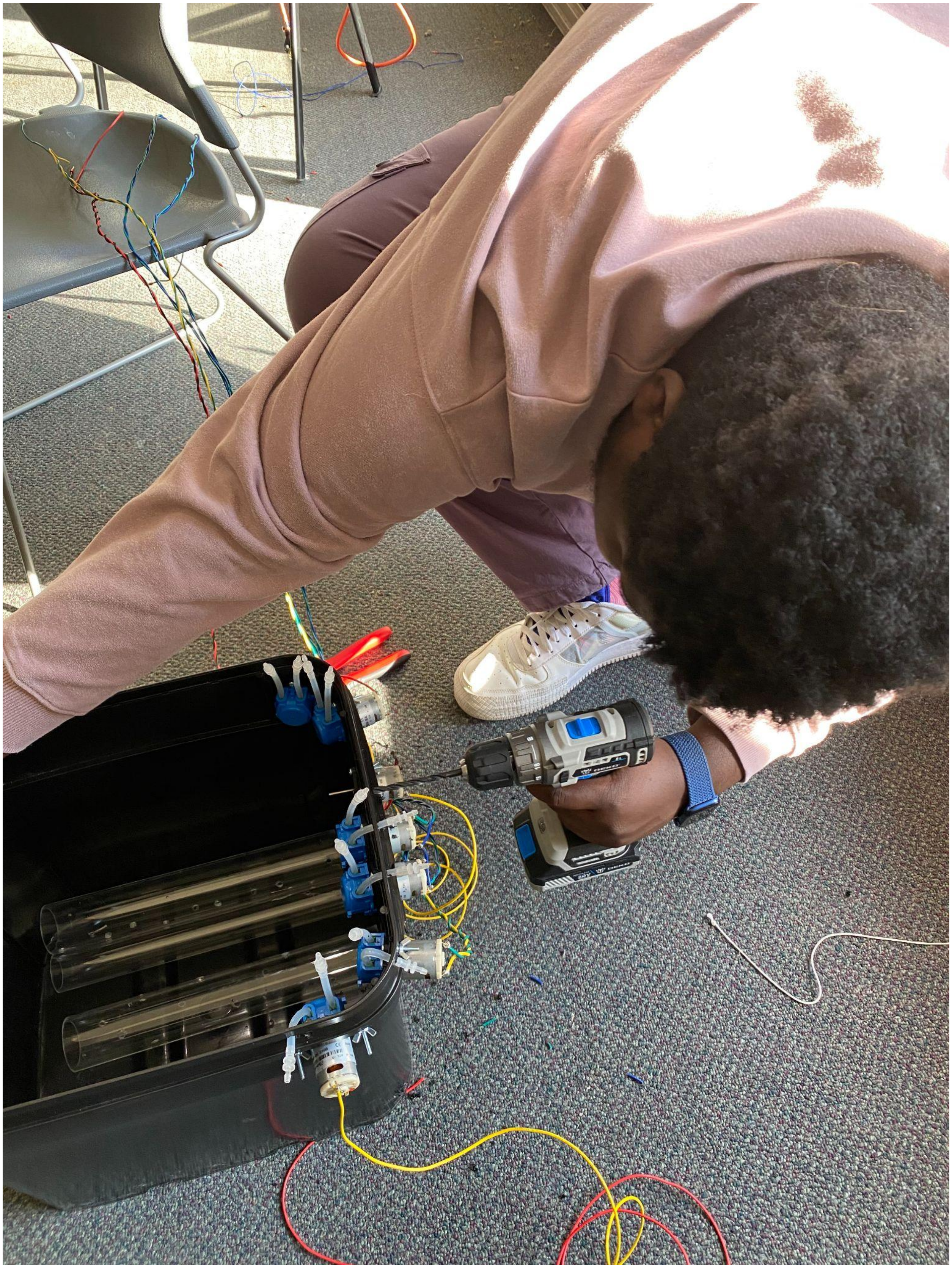
The system will be monitored and controlled by a raspberry pi. Water level will be measured using an eTape resistive sensor connected to an I2C digital to analog converter. PH and nutrient levels will be measured using Atlas Scientific PH and electrical conductivity probes connected over I2C. Nutrients and water will be delivered with peristaltic pumps controlled with an Adafruit DC & Stepper Motor Hat.

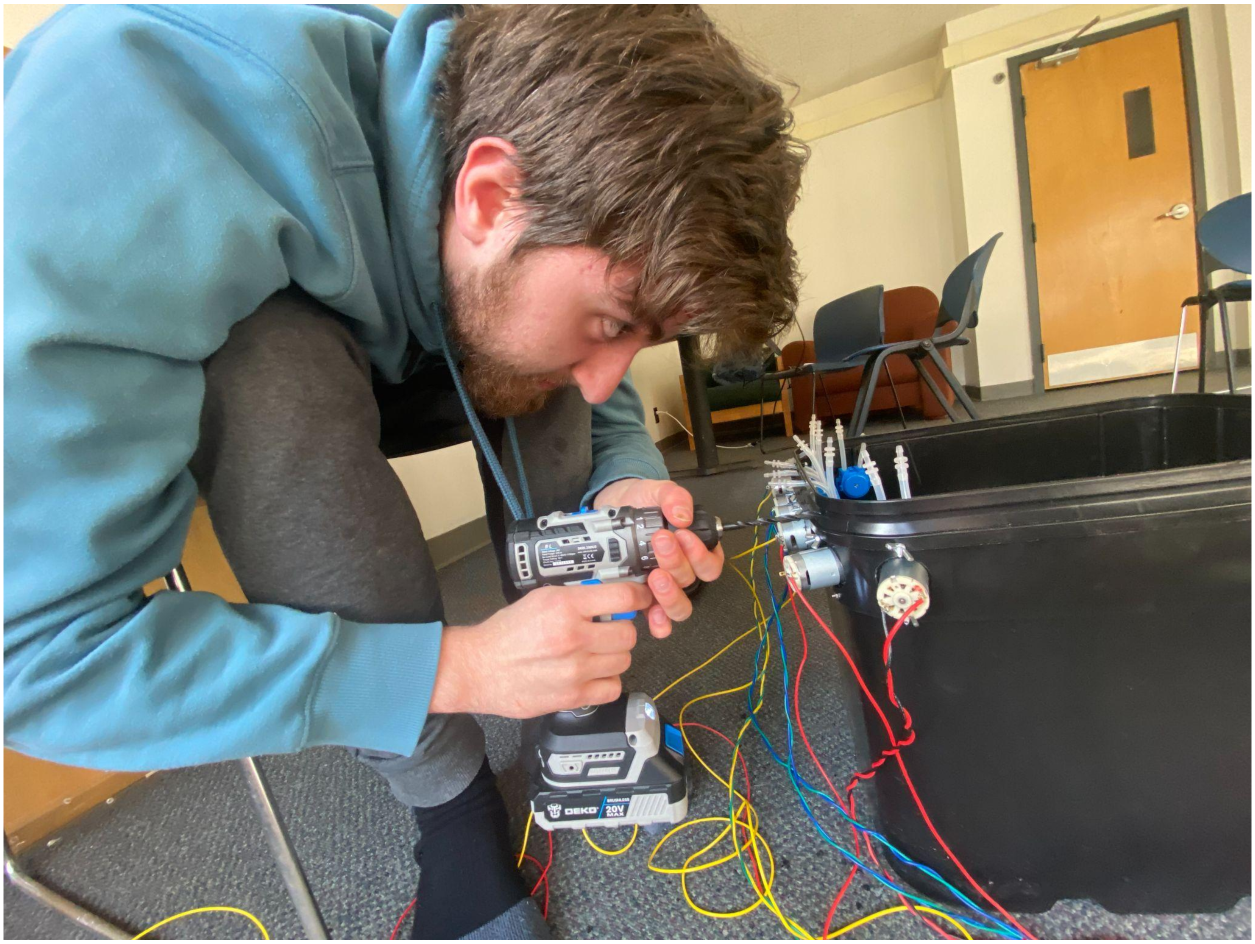
We initially had Sean as lead hardware engineer and Michael as lead software engineer, but as the project progressed and their strengths were revealed, they naturally switched places and executed their roles perfectly. Leon took care of gathering the items, watching over the project, gathering the team members, and ensuring everything ran smoothly overall. Sean did most of the coding and troubleshooting, and Sean and Leon did most of the soldering, while Michael and Leon worked on embedding the items in the bucket and attaching the items to the wooden board (very difficult).

Updated Gantt Chart:



Pictures from Project:

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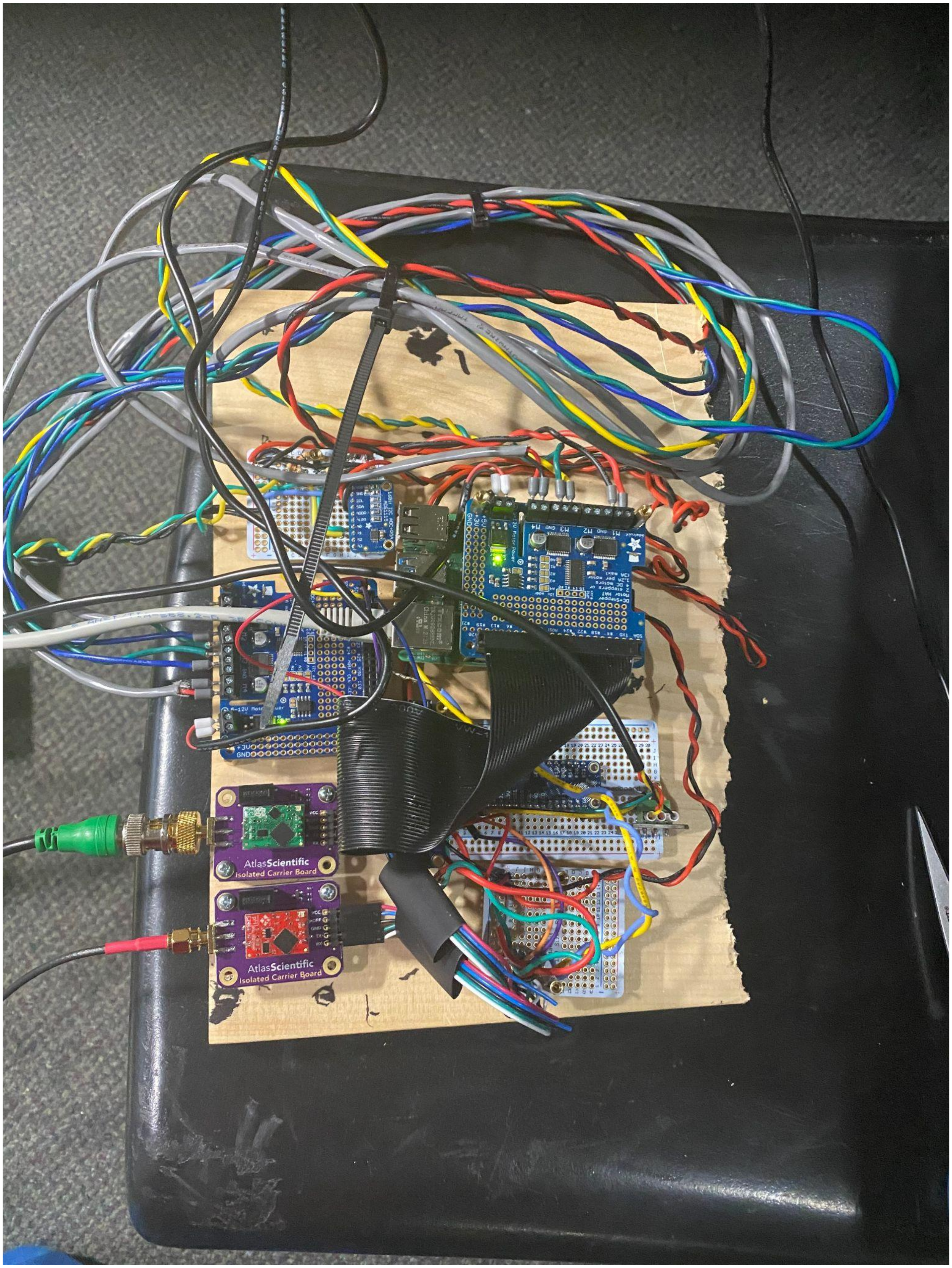
Atlas Scientific
Isolated Carrier Board
Atlas Scientific
Isolated Carrier Board

Updated Budget:

1. **Water level sensor-**
    a. $40
    b. https://www.adafruit.com/product/463?gclid=Cj0KCQjw29CRBhCUARIsAOboZbInXtvQWV8bQK_XdaBoVP_iNadhUSkqk8EUgvKV9OhsmLkcY-z6fXMaAgdrEALw_wcB
2. **Wire stripper-**
    a. $7
    b. https://www.amazon.com/gp/product/B073YG65N2/ref=ppx_od_dt_b_asin_title_s02?ie=UTF8&psc=1
3. **(Multistrand) Pack of wires-**
    a. $16
    b. https://www.amazon.com/gp/product/B01LH1FQJ0/ref=ppx_od_dt_b_asin_title_s02?ie=UTF8&psc=1
4. **Heat shrink pack-**
    a. $7

   b. https://www.amazon.com/gp/product/B09B1644SX/ref=ppx_od_dt_b_asin_title_s00?ie=UTF8&psc=1

5. **Atlas Scientific PH probe-**
   a. $50
   b. https://atlas-scientific.com/probes/consumer-grade-ph-probe/
      i. **Voltage isolator**
         1. $30
         2. https://atlas-scientific.com/carrier-boards/electrically-isolated-ezo-carrier-board-gen-2/
6. **Atlas Scientific EC probe-**
   a. $45 from ebay
      i. **Voltage isolator**
         1. $30
         2. https://atlas-scientific.com/carrier-boards/electrically-isolated-ezo-carrier-board-gen-2/
7. **12 volt AC adaptor-**
   a. 3.99*2= $8
8. **5 volt USB-**
   a. 3.99*2= $8
   b. (Not needed) - Returned
9. **Peristaltic pump-**
   a. 11*7= $77 from eBay
10. **Pi cobbler-**
   a. $8 from Adafruit
   b. https://www.adafruit.com/product/2028?gclid=Cj0KCQjw29CRBhCUARIsAOboZbIbzLVH-TUgsJZqs8u4swSLSRnkQWUEAcqZZPnN4IftcYotEAZ_QMwaAiwHEALw_wcB
11. **Motor driver-**
   a. 22.5*2= $45 from Adafruit
   b. https://www.adafruit.com/product/2348
   c. Another one was needed due to a capacitor being torn off ($30- was reimbursed)
12. **Analog to digital converter-**
   a. $10
   b. https://www.adafruit.com/product/1083?gclid=Cj0KCQjw29CRBhCUARIsAOboZbJ3FTn03I7n8muR1XlnQwf8BGlN6qQdHW7rQUOPMlmctCYTkHmwq6waAkclEALw_wcB
13. **Raspberry PI B+**
   a. $120 from Uvm bookstore

14. **Another one was needed due to it being lost- 16 bit ADC-**

   a. $20 from Amazon
15. **IOT Relay to control ac outlet using GPIO pin:**
    a. $100 from eBay (usually $30 but massive shortage)
16. **Soldering Iron+ wire, desoldering copper, brass cleaner, etc-**
    a. $80 from Harbor Freight
17. **4 Clear PVC tubes for holding sensors-**
    a. $25 from plasticsupply.com
18. **Epoxy Glue-**
    a. $10 from Amazon
19. **Wood board-**
    a. $10 from Home depot
20. **8 Gallon Black bucket and lid-**
    a. $30 from ZenHydro
21. **Silicone 3mm tubing-**
    a. $10 from Amazon
22. **Wire crimper and crimps-**
    a. $20 from Amazon
23. **Temperature Sensor and Circuit-**
    a. $10 from Amazon
    b. https://www.amazon.com/BOJACK-Temperature-Waterproof-Stainless-Raspberry/dp/B09NVWNGLQ
24. **Protoboards-**
    a. $15 from Adafruit
    b. https://www.adafruit.com/product/1609?gclid=CjwKCAjwjtOTBhAvEiwASG4bCNp5riGsfJZqeVbm3JXM7-Q0UUli5bg2nMJSJLBxqdZsE-VeTWK3TBoCKPgQAvD_BwE
25. **Mason Jars-**
    a. $10 from Target
26. **Raspberry pi Screw (2.5m) set-**
    a. $10 from Amazon
27. **Long screws for pump attachment-**
    a. $10 from Amazon
28. **Zip ties-**
    a. $5 from Amazon
29. **Single Strand Pack of Wires-**
    a. $16 from Amazon
30. **Large fresh water pump-**
    a. $15 from ZenHydro

Total Cost Estimate before Completion:

40 + 7 + 16 +7 + 50 + 30 + 45 +30 + 8 + 77 + 8 + 45 +10 + 120 = $493

Total After Completion cost:

$493 + 20 + 100 + 80 + 25 +10 +10 + 30 +10 +20 +10 +15+ 10 +10 +10+ 5 +16 +15 = $889

Comments on Budget:

We were definitely low-balling the cost of all the components initially as we merely did not know the scale of volume of items needed to complete this project. We were off on the price by almost half, but this is to be expected with such a large and ambitious project. Each item played a vital purpose in the completion of this project.

Updated Labor-

- Leon- 5 hours soldering, 2 hour coding, 10 hours understanding project, 7 hours buying components, 5 hours on bucket and wooden board, 2 hours on status updates
    - $21*31 hours= $651
- Sean- 5 hours soldering, 10 hours coding, 5 hours understanding project, 2 hour on bucket and wooden board
    - $25*22 hours= $550
- Michael- 2 hours soldering, 2 hours coding, 5 hours understanding project, 10 hours on bucket and wooden board, 1 hour on presentation
    - $22*20= $440
    -

Group Member Contribution:

Leon: Worked on collecting the multitude of items needed to complete the automatic hydroponics, worked on developing the pseudocode for automation on the pi, worked on the bucket- assisting in attaching the peristaltic pumps, wires from the motors, attaching circuitry to the wood board, soldering to the circuits and troubleshooting the sensors (including the e-tape).

Michael: Worked on the bucket- drilled some of the peristaltic pump holes, attached the pumps to the bucket, glued in the pipes for the water level sensor, pH probe, EC probe, connected the wires from the peristaltic pumps to the motor drivers, attached the circuits to the board, soldered onto some boards, attached the silicon tubing to the peristaltic pumps on both sides, worked on the final report, etc.

Sean:

I did a significant proportion of the soldering, including the i2c board, which combined the i2c connections for another and converted Leon's pseudocode into python code, combining example code for various sensors and using Excel to develop a voltage-depth curve for the depth sensor and calculate a function to turn raw voltage levels into depth readings. I tested all other sensors and calibrated the EC sensor (PH and temperature sensors did not require calibration).

Target Market:

Small scale farming and home growing is widening its score to include hydroponics. The hydroponics technology can be successfully incorporated into a business model for farmers to save cost and generate revenue especially during harsh or tropical months. People at home can utilize hydroponics to grow any plant they want with the ease of just adding water. Hydroponics using a closed-loop water circulation system to grow vegetables provides significant challenges without the aid of automated dosing of nutrients and of water. The rewards are worth it however, It not only leads to considerable water savings but also increases crop yields all year round, especially during really dry weather. It also provides more intimate control of the plant's root system to allow farmers and growers at home to understand exactly what their plant is doing that they normally wouldn't see in soil. Anyone trying to understand and grow a plant would be in the market for an automatic hydroponics pot!

Final Reflection:

Leon:

This idea of mine to completely control and raise a plant- with full transparency and understanding of what's going on internally with the plant, and then to automate that completely has been a dream of mine since I was 15. I never did like how plants grew in soil, never knowing what was going on internally, just assuming the water I'm adding is enough to sustain it.

This project truly enabled me to play around with something I love passionately, and I am very thankful for that. I got to solder, play around with code, discuss hydroponics, explain the purpose of each item, and overall teach others while also teaching myself.

My wonderful teammates Sean and Michael worked diligently to assist me, and while there were plenty of hiccups, (Sean breaking the motor driver board, me losing the ADC, etc), in the end my goal was reached exactly as I wanted it, and that's all I could ask for. Without their help, there is no way I could have gotten it done in the amount of time that we did. This is a truly comprehensive project, and was a lot of fun. Now, I get to see any plant I desire roots, how it likes the nutrients, how it changes the water's pH, how much water it drinks in a given time, etc.

The algorithm for the plant's nutrients dynamic dosing may seem simple, but it took me weeks and weeks of trial and error to come up with that. It essentially boils down the entire hydroponic growth experience into a few lines of code. Michael did an excellent job of applying what I needed to the buckets and to the board, while Sean was very good at deciphering the code and then integrating it. Overall this has been a very informative and fun project that taught me a lot in ways I never expected at all.

Michael:

This was a long but interesting project, and everything was fresh to me. Communication and patience were really significant factors. It was essential to communicate and discuss with the group, while being patient.

I started this project with very little knowledge of Hydroponics and now, I can get into an argument over it. This project opened my eyes to an alternative way of growing plants, not just the traditional method. This way you let a plant grow with little to no effort from you.

On the other hand, there were challenges with getting some of the parts we needed, when they came in we discovered they were the wrong parts and had to order the right ones with some of them not even working right, and fixing errors in code.

In the end we got everything done in time to complete and test the hydroponics prototype. The project was a learning experience. I have now become very familiar with hydroponics and the huge positive impact it can have in the agricultural sector if it is wildly used. I got exposure to the topic and now learnt a great deal about hydroponics, and it has shaped my way of thinking.

Sean:

The number one lesson that we learned during this project was not to leave everything to the last minute! We delayed starting to put the project until a week and a half before it was due, and as is usually the case with this kind of project, everything had unexpected complications. The second lesson was to buy high-quality tools. When we first started soldering, with a $12 soldering iron and some no-name solder, we couldn't get the solder to fully melt and all of the joints were cold. We bought a $50 iron and some higher quality solder, and suddenly soldering was trivally easy. The third lesson was to as soon as possible make sure your parts are present and working. When we were halfway through the project, we discovered that our DAC had gone missing and that some of the screw terminals provided with our motor drivers were too small to fit the crimped wires. We managed to order another DAC at the last minute and to find a way to crimp the wires small so that they could fit in the tiny screw terminals, but either of these issues could have ruined the project.

References:

Raspberry Pi motor driver hat:

- Ada, L. (n.d.). *Adafruit DC and Stepper Motor Hat for Raspberry Pi*. Adafruit Learning System. Retrieved May 5, 2022, from https://learn.adafruit.com/adafruit-dc-and-stepper-motor-hat-for-raspberry-pi
-

Atlas Scientific pH + Ec sensor + voltage isolator + circuit

- *Raspberry pi sample code raspberry pi - files.atlas-scientific.com*. (n.d.). Retrieved May 5, 2022, from https://files.atlas-scientific.com/pi_sample_code.pdf

Etape water level sensor:

- Porrey, D. (2019, September 16). *Etape liquid level sensor on MCP3008*. Hackster.io. Retrieved May 5, 2022, from https://www.hackster.io/porrey/etape-f4b457
- DiCola, T. (n.d.). *Smart measuring cup*. Adafruit Learning System. Retrieved May 5, 2022, from https://learn.adafruit.com/smart-measuring-cup?view=all

Why hydroponics is better than soil:

- EspirituFounder, K. (2019, October 3). *Hydroponics vs. soil: 7 reasons hydroponics wins*. Epic Gardening. Retrieved May 5, 2022, from https://www.epicgardening.com/hydroponics-vs-soil/

16 bit ADC code reference:

- DiCola, T. (n.d.). *Raspberry Pi analog to digital converters*. Adafruit Learning System. Retrieved May 5, 2022, from https://learn.adafruit.com/raspberry-pi-analog-to-digital-converters/ads1015-slash-ads1115

Temperature sensor code reference:

- *Raspberry Pi DS18B20 Temperature Sensor Tutorial*. Circuit Basics. (2021, November 14). Retrieved May 5, 2022, from https://www.circuitbasics.com/raspberry-pi-ds18b20-temperature-sensor-tutorial/