SuperComputing Challenge Interim:

Autonomous Hydroponic System

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Executive Summary

We propose modular hydroponic basins mimicking an "ebb and flow" design interconnected with multipurpose rails capable of accommodating a robot. This robot will have the ability to maintain plants in the hydroponic system by monitoring temperature, humidity, pH, and plant condition. Furthermore, an ideal robot should be capable of harvest, pruning, and general upkeep. Combining monitoring with physical interactions should make it an autonomous hydroponic system, or AHS. AHS will include the following four technologies: hypersonic ranging for 3D modeling of plants, heatmap rendering of multi-point recordings of temperature/humidity, real time graphing of Total Dissolved Solids, pH, and other hydroponic fluid parameters, and visual recognition of plant ailments using machine learning.

Keywords: hydroponics, robotics, machine learning.

STEM Challenge 2023: Autonomous Hydroponic System

Background Research

"Zero Hunger," the second of seventeen Sustainable Development Goals, outlined by the United Nations Department of Economic and Social Affairs, should be viewed as a shared struggle for a better future. About 271,210 people in New Mexico face food insecurity. Many of the foundational crops necessary to the average food processing network do not grow on mass within the state (Feeding America 2020). Furthermore, nearly 13.3% of our food worldwide is lost from farm to consumer (UN DESA 19). By moving the source of our food closer to home and adopting adequate food resource management we can greatly reduce food waste, ultimately bringing more people out of food insecurity.

Hydroponic Systems

A hydroponic system, or hydroponics, is a method of growing plants using mineral nutrient solutions in water without the use of soil (Son E. J., Kim H. J., Ahn T. I. 2019). There are various types of hydroponic systems, but for this project we decided to mimic an ebb and flow system. Ebb and flow systems allow for intermittent flooding of plant roots, preventing "drowning" and allowing for aeration of nutrient solution (Pure Greens Container Farms 2022). Two variations of the ebb and flow system are DFT and NFT. DFT, or Deep Flow Technique, grows crops by pumping aerated nutrient water from a reservoir, which stores the water and nutrient solution, into one side of a tray, which is built to hold plants in a hydroponic system. Plants are suspended with their roots hanging inside the tray. When the water is pumped into the tray it delivers nutrient rich water to the plants. The used water then travels to the opposite end of the tray and is drained back into the reservoir for future use (Pure Greens Container Farms 2022). NFT, or nutrient film technique, is quite similar to a DFT system. An NFT system also utilizes trays and water pumps to deliver nutrient water to plant roots. Although these systems share similarities there is a contrast in how they function. DFT trays are deeper than NFT systems because in NFT "only a thin film of nutrient water passes through at a time" (Pure Greens Container Farms 2022). NFT systems also rely more heavily on a water pump because the tiny amount of water that passes through the tray cannot sustain the plants for an extended period, so if the pump malfunctions and no more water is pumped the plants could die (Pure Greens Container Farms 2022). By mimicking an ebb-and-flow hydroponic system, we hope to simulate a plant factory to make the overall plant manufacturing and growing system more efficient. By simulating a plant factory, we can create an artificially controlled internal environment that aids plant growth regardless of outdoor conditions (Ministry of Economy, Trade, and Industry).

The environmental aspects which plant factories control include "light, temperature, humidity, carbon dioxide concentration, and culture solution" (Ministry of Economy, Trade, and Industry). By using a plant factory in tandem with an autonomous robot our model will control these variables in our system without the need for human labor common in harvesting and agricultural care found in other Hydroponic systems. In general, hydroponic systems and plant factories are maintained "manually by monitoring the nutrition such as acidity or basicity (pH) value, the value of total dissolved solids (TDS), electrical conductivity (EC), and water

temperature" (Herman, Adidrana, Surantha, Suhajito 2019). By controlling the environment with the framework of a plant factory, we hope to remove the human aspect and maintain plant health using robots that monitor temperature, humidity, pH, and plant condition.

Monorail Development

The early design philosophy of the AHS Robot (AHS-R) ensures modularity and scalability. A large-scale implementation of AHS-R would require a diverse range of applicable sizes and tolerances. AHS-R should be capable of serving homes, schools, and agricultural centers with equal effectiveness.

3D Printing

Importing and Slicing

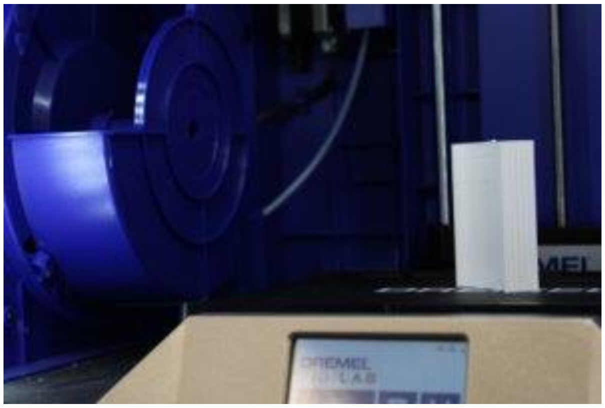
Our 3D printing process begins with importing the model (STL) from the modeling software to the Tinkercad application to ensure full compatibility with the printer. Following that the model is then imported to the Dremel online application. After importation we use the repair tool in Dremel to ensure the model is fully ready to print. Our final step before physically printing is to use the slice tool in Dremel which simply transcribes the online computer model into instructions for the printer. Initially we did not use Tinkercad because we thought that we could import the model straight to Dremel. However, when doing that we found that the model would not render properly. After trying a few methods, we ultimately decided to import the model to Tinkercad first and then to Dremel. The process of reslicing in Tinkercad fixed the printing error.

Printing

After using the slice tool on the printer we are ready to print. We always made sure to go to the layout page to make sure everything would print the right way and on the right place. The printer does the rest of the work from there. Depending on the printing speed we choose, the printing time varies anywhere from 1.5 hours to 4 hours. We found that slowing down the printing speed helped us by increasing the quality of the print. Attached below are some prototypes of the rail model:

Troubleshooting

Our team could not print the full design, but steps to analyze problems and engineer solutions still occurred. Two issues that faced the 3D printing process: accuracy when printing, and design tolerances with fittings and final prints. Our 3D printer, The Dremel 3D40, could achieve adequate accuracy when printing, but only under specific circumstances. The printer must extrude the plastic slowly, and with a greater quantity of layers for high accuracy. Upwards to four hours per monorail piece was necessary, with a layer count of 826. Alongside time and layering, the filament header must be cleaned for consistent accuracy. The pins that interlock the monorail pieces together often fell to the problem of poor accuracy, since the pin design size was less than 0.1 inches. This small size posed an issue to both accuracy and tolerances.



Design tolerances, or “the total amount a specific dimension is permitted to vary,” became an unwieldy issue for the monorail printing, and would likely present itself for all other designed pieces (The American Society of Mechanical Engineers 2019). The size of the interlocking pins did not give enough leeway to properly fit with other pieces.

Part List

Title of Part	**Price per unit**	**Quantity**	**Total cost**
Multi Colored PLA Filament	$0.09 per gram of PLA	Approx. 500 grams	$45.00
Raspberry Pi 2 Model B	~$30 (part is deprecated)	1	$30.00
90 RPM Micro Gearmotor	$13.95	4	$55.80
65mm Wheel Rubber Wheel Pair	$3.50	2	$7.00
Ultrasonic Distance Sensor	$4.50	4	$18.00
140 RPM Planetary Gearmotor	$6.50	4	$26.00
RPi Camera Module	$50.00	1	$50.00
RPi 6mm Camera Lens	$25.00	1	$25.00
DHT20 Humidity/Temperature Sensor	$6.50	2	$13.00
GRAND TOTAL			$269.80

Collaboration and Division of Labor

The philosophy of our team's division of labor is a consistent circle of feedback.. Each section (engineering, biology, and integration) has three levels: a lead with a strong sense of the project's end goal, collaborators capable of acting on ideas presented by their section's lead, and reviewers capable of research to introduce new ideas and oversee their section's ideas.

Essentially, reviewers should find breakthroughs, cutting-edge technology, and solutions relating to their field and present them to their section lead. Afterwards the section lead will determine the viability and value of an idea in context of their section and the project. If the section lead finds an idea to be viable, they'll present tasks to collaborators who will work alongside the entire section to produce overall project advancement. While this cycle endures, the section of integration shall ensure no conflicts arise between sections (non-operable designs, bloat, etc.), establish the needs of each section, and document the progress of the project. For example, if the section of engineering needs DC motors, then the section of integration will find the best source to fit the requirements of a request.

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