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# A Rotary Hydroponic Gardening System

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## ABSTRACT

Gardening has risen to a popular household activity, but it is challenging due to factors that many beginners are incapable of thinking of. Hydroponics has risen to a popular method of gardening both in backyard gardens and in farms, for it provides many benefits not offered by traditional soil farming. However, many factors including temperature, humidity, and proper nutrient supply stand in the way of ensuring optimal conditions. In the case of a rotating machine, power consumption also becomes an issue.Despite efforts for ensuring proper amounts of light exposure and proper nutrient supply, different factors and different plants often have proven it to be a formidable task for achieving consistency. In this study, a smaller scaled Rotary Hydroponics Garden was created through the use of digital fabrication technology, along with a network of sensors and processing to maintain high quality conditions. The rotary system optimizes spacing and speed through the limitation of gravitational force on plants. Additionally, the digital fabrication process allows for rapid prototyping, enabling adaptability in terms of sizing, space, and duty cycle, factors which depend on the plant that is being germinated. This approach offers a highly adaptable solution to the challenges faced by previous designs, while maintaining optimal growth parameters and allowing for a household size spinning garden. Although not able to handle plants larger in size, this adaptable garden overcomes many barriers that exist with traditional household gardens, particularly through the productive manufacturing techniques of digital fabrication.

## Introduction

Hydroponics is an innovative method of growing plants that eliminates the need for traditional soil-based cultivation. In hydroponic systems, plants are grown in a soilless medium while receiving a nutrient-rich solution directly to their root systems. This technique offers numerous benefits and has gained popularity in both commercial and home gardening settings. The basic principle behind hydroponics lies in providing plants with optimal conditions for growth and development. By removing the soil from the equation, growers can have greater control over important factors such as nutrient uptake, water availability, and oxygen levels.

**Figure 1.** Hydroponic Gardening Farm

This precise control allows for faster growth rates, higher yields, and the ability to grow plants in areas with limited space or poor soil quality. In a hydroponic system, plants are supported by various soilless growing mediums such as perlite, coconut coir, rockwool, or vermiculite. These mediums provide stability and ensure that the plants' roots have access to oxygen. Instead of relying on soil nutrients, plants receive their required minerals and elements from a carefully formulated nutrient solution. This solution, consisting of water and a balance of essential macro and micronutrients, is delivered directly to the roots via a pump or irrigation system.

## Literature Review

### Increase in Hydroponic Farms

Hydroponics are a controlled environment, making it better for indoor environments and gardens. Outer gardens and soil-based cultivation are affected by dramatic changes in our world, including climate change, increased urbanization, and depletion of natural resource deposits. Hydroponics is a means to bypass these complicating factors relating to traditional agricultural systems. However, this requires technology to control the sustained environment, often going off a threshold of values unique to the types of plants being grown. Sensors, for one, measure the amount of nutrient content and environmental factors such as temperature, humidity, pH, etc. The book SYLVA SYLVARUM by Francis Bacon printed in 1627 was the first published work to popularize the idea of growing terrestrial plants without using soil. Since then, hydroponics has been applied to modern farming, and has gained popularity given its ability to bypass the environmental threats that exist with traditional agriculture. The United Nations (UN) estimates that the world population will reach 10 billion by the year 2050. Already in 2019, 124 million people faced food shortages due to climate-related threats including flooding, and nutrient supply shortages.Hydroponic farm projects have since been under mass experimentation, especially with NASA's experiment on growing plants under optimal conditions with limited gravity, leading to the introduction of the rotational system within hydroponic gardens.

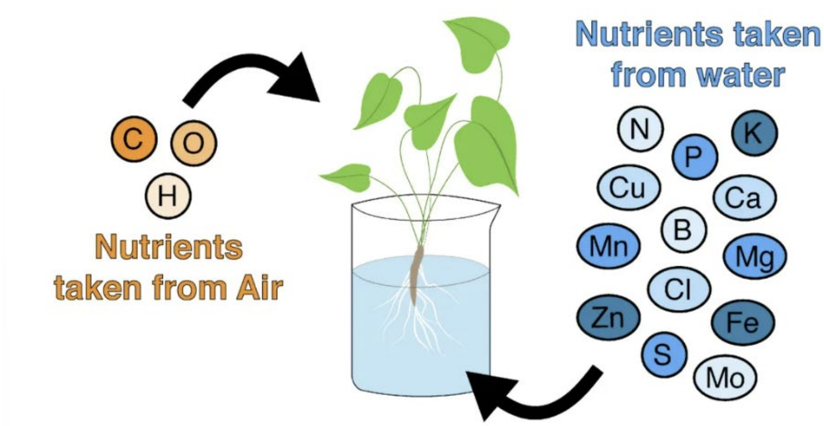


**Figure 2.** Nutrient Solution Diagram

### Hydroponic Gardening Methods and Development of Rotary Hydroponics Systems

Julius Sachs dedicated a career to understand the elements plants need to best survive. Realizing that while nutrients are crucial, soil is not necessary for the cultivation of plants, he created a "nutrient solution" formula which set the foundation for modern hydroponic systems. Many different modern hydroponic systems have since been created. Some of the most popular include the Nutrient film technique, the Ebb and Flow technique, and the Wick technique. The NFT system possesses a channel which pumps nutrient solutions to a container. They don't use a grow medium and require an air pump. The Ebb and Flow allows plants to be flooded with the nutrient-filled water, and when the water is pumped, it then is drained back to the reservoir to be reused. The Wick system is simple, where plants are grown in medium such as sand or wool, and a string runs up to the plant from the reservoir. There is no use of any pump, electricity, or other components.

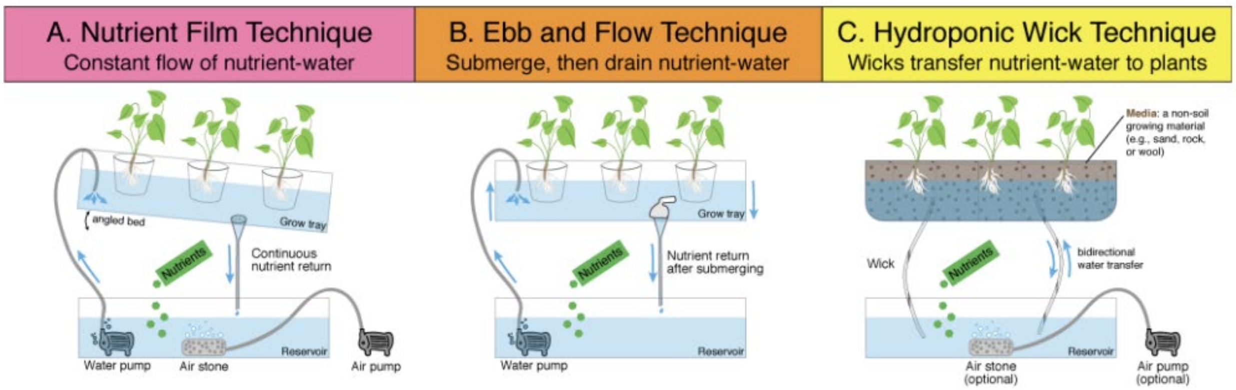


**Figure 3.** Different Hydroponic Gardening Systems

The rotary hydroponics system is usually smaller than the other systems, being able to effectively conserve spacing issues. Although there is higher power consumption, it is usually outweighed by the more efficient growth capabilities of the plants being germinated. Additionally, NASA's research has proven to optimize speed through limiting gravity on the plants, speeding up the process. A plant physiologist at Kennedy Space Center's Space Life Science Lab has said that hydroponics will be able to create advantages in space travel, and possess abilities to support the system of growth in space. Many rotary hydroponics gardens utilize a gear system for the rotational mechanism with the reservoir located at the bottom, alongside lighting in the center of the system.

## Working Methodology

### Objective

The main objective of this project is to create a digitally fabricated Rotary Hydroponics Gardening system that utilizes a central microcontroller based system to parse sensor data, and based off a threshold, will display data on an OLED screen to the user so that the user can uphold optimal conditions for the plants. Additionally, the microcontroller will also be assigned with the task of controlling a motor driver to control a Stepper Motor. This motor will be used to control the duty cycle, and can be turned on and off with a button, an ideal design given that different plants may require different cycles of time in the air and different levels of contact with the nutrient solution placed in the bottom water reservoir. This whole process will enable an optimized hydroponics system that overcomes fluctuations in the environment, by allowing for an easily scalable and adaptable system that can grow a variety of plants. Additionally, the small sizing will reduce power consumption. The optimization of this test will be done through the testing of plants using the finalized fabricated outcome.

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## Fabrication Process and Assembly

### *Design and Modeling*

The design for the project was first scaled and created on the software program FUSION 360. This enabled parametric solving, allowing for accurate sizing of the optimized time. Additionally, Fusion 360 allows for separation of different components, allowing for the organization and expiration of the designs, especially crucial for making the fabrication process reliable and efficient. The image below (Figure 4) displays the base reservoir at the bottom, with the back containing a stable metal bar where the motor will rest and allow the plants to spin properly.

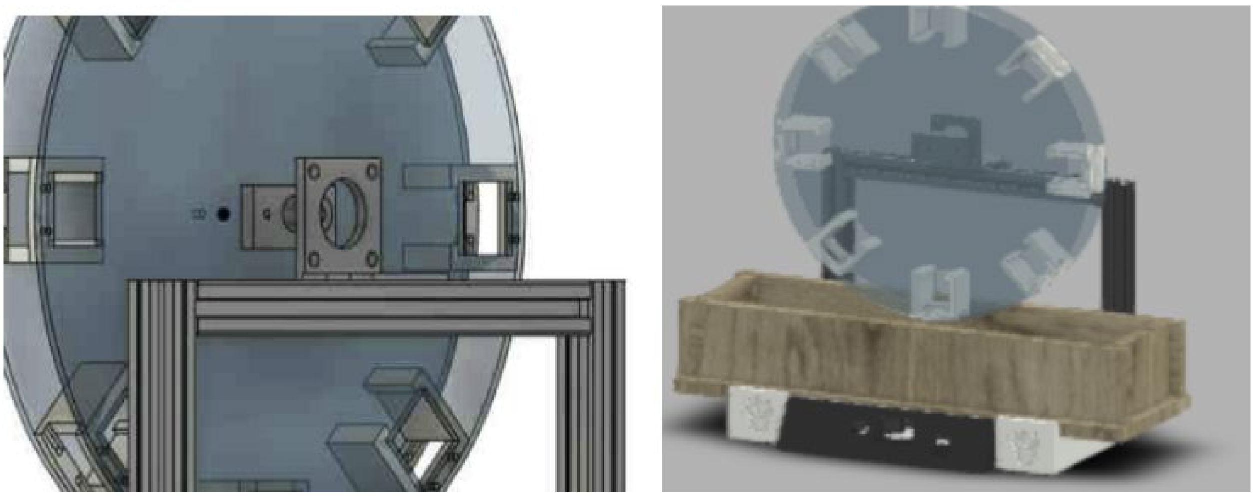

**Figure 4.** Fusion 360 Model Render

### *Electronics*

The electronics were made from a mini CNC (computer numeric control) machine, using g-code to perform subtractive manufacturing. This enabled an electronic design where components could be soldered on. The manufacturing was done on copper boards.

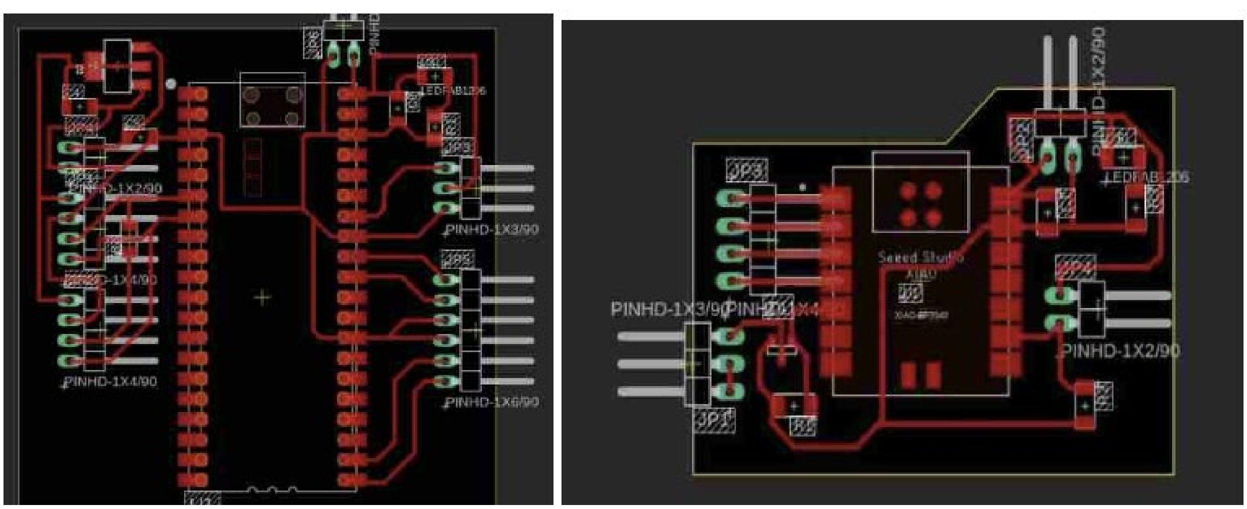


**Figure 5.** Board Design and Model

The XIAO model of the RP2040 chip which was used for motor driver control, together with a Raspberry Pi Pico Chip which was used for the main sensor network, were embedded beneath the entire support to avoid potential water contact. The RP2040 chip is a highly capable processor with great memory storage, allowing for a safe amount of program to be stored. The DHT 20 temperature/humidity sensor along with an Electrical Conductivity Sensor were used. An OLED connected to the Pico displayed the information necessary to the users.The greatest challenge came within the code of the Electrical Conductivity Sensor, which was using a calculation of the median voltage to parse and relay information about the nutrient supplement. However, using the Arduino IDE, the libraries allowed for easy programming of the chips, which were uploaded directly via a USB cable.

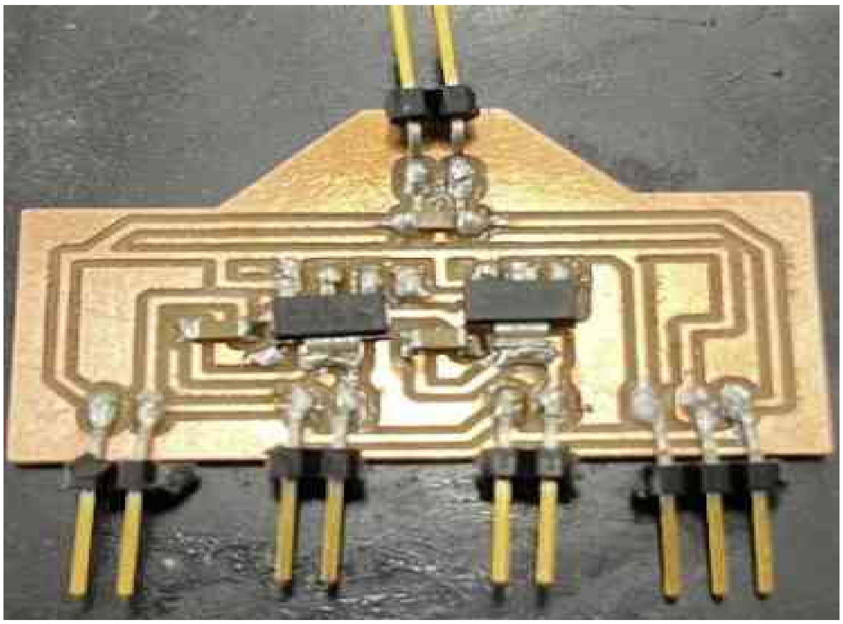

**Figure 6.** Power Distribution Board

An additional board for power distribution was made, with a main connector for a 12 volt power supply, and two regulators filtered by capacitors to supply power to the microcontrollers.

### *Circular Holders with Rockwool Medium/ Outer Casing*

**Figure 7.** Rockwool Medium Holders

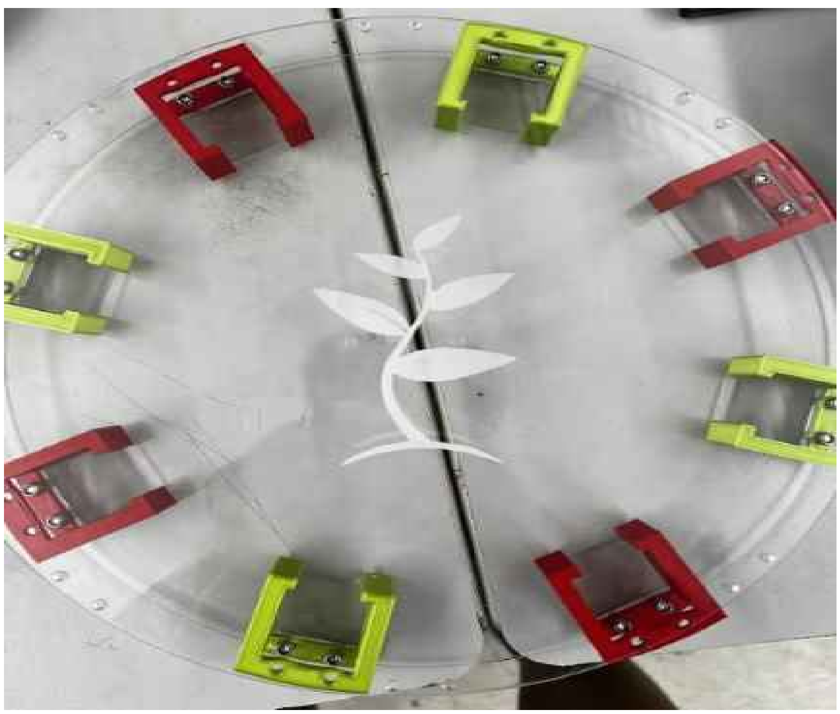

**Figure 8.** Cube Holders Attached to Outer Casing

This portion of the design was fabricated via 3D printing and laser cutting. The main challenge was to create an adaptable and resizable system that would overcome the problems of power consumption and environmental fluctuation. Given these considerations, this stage of the design was conducted with as few connections as possible.The outer casing was cut with holes that held screws to connect the 3d printed Medium Holders. In this test, we used Rockwool, a highly popular medium used in hydroponic gardening, and we scaled the circular holders to fit the rockwool medium. However, in the designs provided, the parametric tools of CAD softwares allows for easy resizing, which can be easily designed and fabricated again to fit plants of different sizes.

**Figure 9.** Rockwool Medium

### *Base Reservoir*

The base reservoir was cut using a big CNC machine, with ¼ inch wood. A plastic container which would hold the nutrient solution sat flush within the reservoir.

**Figure 10.** Wooden Base Reservoir

## Observations and Results

The Rotary Hydroponics System was left running to evaluate the efficiency of the system. With power consumption and optimal growth conditions being the main focus of hydroponic systems, certain criteria were set. Therefore, the observations tested the reliability of the sensors and display system, along with the mechanical motor system. If the motor driver went too hot, then power consumption would be a problem. Therefore, using lettuce seeds as the test, the garden ran for multiple days, being evaluated based on the success of the electronics, and the ability to successfully germinate the seeds. To test the efficiency of the final product, a couple of tests were evaluated. The first were the functionality of the sensors on the OLED display. Testing different solutes, the Electrical Conductivity Sensor was tested over different liquids filled with either 100, 50 or no mg of solutes. As each test was probed, the outcome displayed a difference, in which the display successfully relayed the message.


**Figure 11.** OLED displaying Information

The Temperature/Humidity Sensor was also tested through different temperature surroundings, relaying a difference in values and again proving its functionality. Next was the functionality of the motor and the duty cycle. The button shifted the duty cycle for different instances of plants or grow mediums, and this functionality worked smoothly too. As the duty cycle changed, the motor's speed and cycling of rotary action changed as well, proving to be useful for plants placed in it in the future. Using rockwool medium, a couple of seeds were tested and sprouted, proving growth and full functionality of the digitally fabricated rotary hydroponics garden.

**Figure 12.** Successful germination after two weeks

## Conclusion

From the successful fabrication of the rotary hydroponics gardening system above, it has been proven that a small scaled hydroponics system that spins on a motor is capable of sustaining optimal conditions, being adaptable to different plants, and possessing the ability to germinate seeds. Every unique garden possesses benefits, and future technological advancements might allow smoother driving of the motor, a more optimal lighting system, and more space for plants in turn for less power consumption. Hydroponics, which has been an alternative to traditional agriculture for a while now, has been proven to be useful in overcoming difficult environmental obstacles to successful cultivation, and has become much more popular in the gardening world.With new technological advancements and studies being used to further optimize the efficiency, adaptability, and capabilities of the hydroponic systems, like the rotary garden project above, it is vital for gardeners to pursue new methods that optimize the growth of plants, especially with so many environmental threats in the uprise.

**Figure 13.** Functioning Rotary Hydroponic Garden System

## Acknowledgments

I would like to thank my advisor for the valuable insight provided to me on this topic.

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