Green Wave Technologies

An Integrated Hydroponic Solution to Staggering Population Growth in the Modern Day

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Design Prompt

To produce enough food for an ever-burgeoning world population with a massive ecological footprint, humanity must develop sustainable farming practices that can keep up with its growth.

Vertical farming is one such practice. Unlike traditional cultivation, it reduces the need to create additional farmland and can multiply a farm's crop yield by a factor of 4 to 6; this increase depends on the crop due to year-round productivity and seasons in which certain crops grow best.

We seek to establish a robotic-centric approach to agriculture that takes advantage of modern engineering simulations, mathematics, revolutionary sensor technology, controlled environment agriculture, fertigation, and indoor farming techniques to transform modern food production into a crop-churning juggernaut. It will consist of an 18-floor cylindrical structure, and our goal is to optimize it to produce 1,500 tons of strawberries annually.

Overview

Water is vital to life. With the world's population steadily increasing, the demand for accessible clean water for human use such as irrigation is vital to humanity's sustainability and prosperity. Specifically, the system presented in this paper will take water from a water source, extract impurities and harmful pathogens, and will treat the water supply in order to provide the best possible conditions water can provide for growth. A centrifugal pump, which requires a continuous supply of water to run and promote a quality flow rate, will pump ocean water from the Upper Newport Bay. In order to remove floc, salt, bacteria and pathogens from the water, electrocoagulation, solar thermal distillation, and a forward osmosis with a hydrophilic polyethersulfone membrane will be used, respectively. To add the necessary nutrients needed, will be added. Finally, an acid/base injection system will be integrated into the process to adjust pH of the water as needed.

Beginning in the 19th century, the world population and its population growth rate grew much more than they did in previous times. Humanity has ballooned from roughly 900 million people in 1800 (Kremer) to over 7 billion people in 2019, thanks largely to advances in healthcare, agricultural practices, and sex education (Lenntech). Yet the human population is beginning to grow at a rate that is far quicker than one our agricultural practices and our planet's resources can support. In fact, a 2017 United Nations report on the world's population predicted that 11 billion humans would inhabit the planet by the end of 2100. This jaw-dropping conclusion challenges us to manifest an effective response to such a massive acceleration in population growth.

Our response to that growth is an automated strawberry cultivation robot of our own design, paired with a hydroponic system of revolving PVC pipes of strawberries on a motorized shelf; the robot can plant, water, and harvest strawberries on the bottom pipe as the shelf of pipes cycles to strawberries that need such delicate care. This solution is effective for two reasons; the strawberry pipe shelves' vertical orientation allows farmers to plant more strawberries per square mile -- and in the case of AGRIspire, more strawberries per floor -- and hydroponics has proven time and time again to be more efficient and environmentally friendly than practices from conventional agriculture.

The robot's design phase posed several major challenges, including establishing communications among the robot's various parts, deciding how to move the robot with conveyor belt wheels, determining the structure of the revolving shelf, and producing a complete assembly of the system on SOLIDWORKS in just one afternoon. While we were able to solve most issues after some thought, redoing mates in SOLIDWORKS consumed much of what little time we had to complete the project.

Precision farming is a developing field of agriculture that aims to reduce waste and increase crop yield. Using precision farming to improve vertical farming can result in a massive biomass yield. However, one current problem with vertical farming is its high cost and the maintenance needed to keep it working properly. With the power of software and artificial intelligence we can combat this issue and bring an even higher yield to extend vertical farms as they exist now. We envision a future in which vertical farming is the main supply of food for the world and new innovations in technology can help us achieve this goal. Green Wave Technologies is the realization of this autonomous vertical farming future.

Green Wave Technologies! employs sensors and cameras mounted throughout the different floors of the vertical farm, periodically logging information about the environment. The collected information is sent to a centralized database system which is accessible by users via a user-friendly platform. Information that is collected in the database can be analyzed in order to determine favorable factors for maximum crop yield, enabling research and development.

Integral to our concept is the application of low power systems and design. This means that both hardware and software should be managed to reduce our energy footprint as much as possible.

One of our primary challenges was understanding how to solve our issue of long processing times for sending our information from the sensors to the central server. Another issue was how to create an applicable neural network that could be scaled up to extremely large farms, which contain many more data points than a standard small-scale farm.

We also integrated computer vision to monitor the health of the strawberries, and reinforced our wired sensor network to be more robust against hijacking or software attacks.

Background

While traditional horizontal farming has been the most commonly globally utilized source for large scale agriculture, farming inefficiencies such as pesticide limitation, water runoff waste, insufficient crop yield, and scarcity of nutrient rich plants have presented to the challenge of how to best address the shortcomings from traditional farming by seeking alternative forms of farming.

The design created for a vertical sky farm shows potential in solving these issues since it allows for a larger population to efficiently be fed strawberries while at the same time minimizing the material cost. Innovations such the use of facade windows help address excessive energy consumption. However with all high story structures in California, the increased probability of seismic activity also require the use of the team’s third innovation of a rotational friction dampener to provide reduction of the structure’s vibration when subjected to natural frequency seismic loads.

Innovations

The facade, which lines the exterior of the building, is a technology that allows for the automated regulation of not only airflow but also heat, light and shade. Due to this it minimizes electricity use short term and long term to then improve energy efficiency. The rotational friction dampener, located beneath the building, rotates against one another in so that it converts the mechanical energy to heat which therefore reduces structure vibration.

Solution

- Circular structure of the sky farm reduces the drag coefficient of seismic forces on our building
- Self-healing concrete base provides a solid and sustainable foundation for the structure
- Rotational friction dampers secured beneath the base of the building allows building to withstand seismic acceleration of up to 1.5 G's
- LED light fixtures evenly spaced throughout the cultivation area ensures that the plants are growing under a full light spectrum, providing a helpful and nurturing environment for the plants during their sprouting and fruiting phases.

Major Challenges

There was difficulty in calculating surface areas necessary to determine static loads and moment distributions due to unorthodox shape of structure. The team struggled with finding a viable means of irrigating plants, as well as spacing the hydroponic gardens such that the harvesting machines could reap the plants with maximum efficiency. To find the surface area of the building, the team broke down the exterior building into constituent parts, took the measurements for each respective part, and summed the areas of each respective shape. The team resolved the spacing of the hydroponic gardens by arranging the plants into shelves that staggered upwards to an elevation of 8.5 feet. This allows for the distribution of light to become more even, increasing the likelihood of an optimal yield.

Special Facts

Glass facades are placed on the outer circle to reflect sunlight and prevent temperature fluctuations from harming potential yield of crops. The circular design minimizes the drag coefficient for seismic forces in the presence of earthquakes, as well as provide an intersecting point for all members within to interconnect, providing excellent structural support for each floor in the building.

Goals

The goal is to transport water from an abundant source, extract impurities, add nutrients and deliver it to a farm at a pH for optimum crop health and growth, all in a cost-efficient manner.

Build a robot capable of planting strawberry seeds, pulling weeds, performing soil analysis, and harvesting ripe strawberries. However, our team deviated from this goal slightly by dividing the automation among a robot and a hydroponic shelf of revolving strawberry PVC pipes.

Create a software based solution to increase crop yield, monitor environment levels, and gather data on crops in order to allow for more efficient vertical farms and help research.

The design of the building aimed to accommodate the farming installations necessary to produce at least 1500 tons of strawberries in a year. The design process prioritized efficiency, maximizing yield, low environmental impact, and cost minimization.

Objectives

The team sought to accomplish several design objectives:

- Remove particles of all sizes such as floc, pathogens, and contaminants
- A centrifugal pump will take saline-rich ocean water will extract floc, pathogens, salt, and contaminants
- Since a desired water pH range of 5.5-6.5 is needed for maximum growth possible, an acid/base injection system equipped with ammonium sulfate and limestone will be used to control the pH
- To design a mobility system that allows the robot to move about the garden as nimbly as possible.
- To design a robot that can plant strawberry seeds, pull weeds, analyze soil, and harvest ripe fruit.
- To produce a detailed model of the robot and shelf in SOLIDWORKS.
- To detail the costs of the robot and shelf's components and keep the total cost of the project as low as possible.
- Design a building at least 18 floors that houses hydroponic farming systems, provides general UCI office space, and finally complies with structural safety regulations.
- Primary Goal: Design building dimensions to fit hydroponic farming structures that have the capacity to produce 1500 tons of strawberries.
- Incorporate technological solutions that minimize environmental impact, including:
    - Glass facades that maximize natural sunlight.
    - Earthquake dampener to increase structural security.

Project Outline

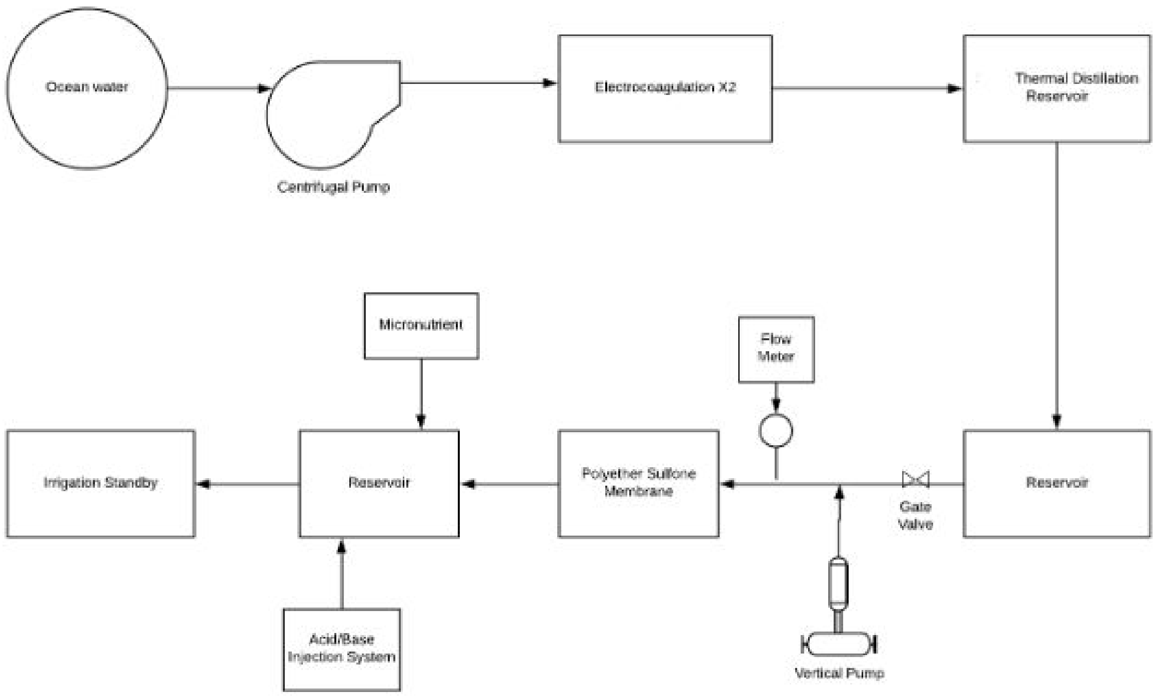


Figure 1: Water System Outline

Through a centrifugal pump connected by a system of pipes, the unfiltered salt-water will travel from a main body to a prefiltration system where it will be treated with electrocoagulation, a type of electrochemical water treatment. Then, the treated water will be thermally distilled using solar power. After vaporization, the steam will then condense and pass through a polyethersulfone (PES) membrane to perform forward osmosis to remove microparticles.

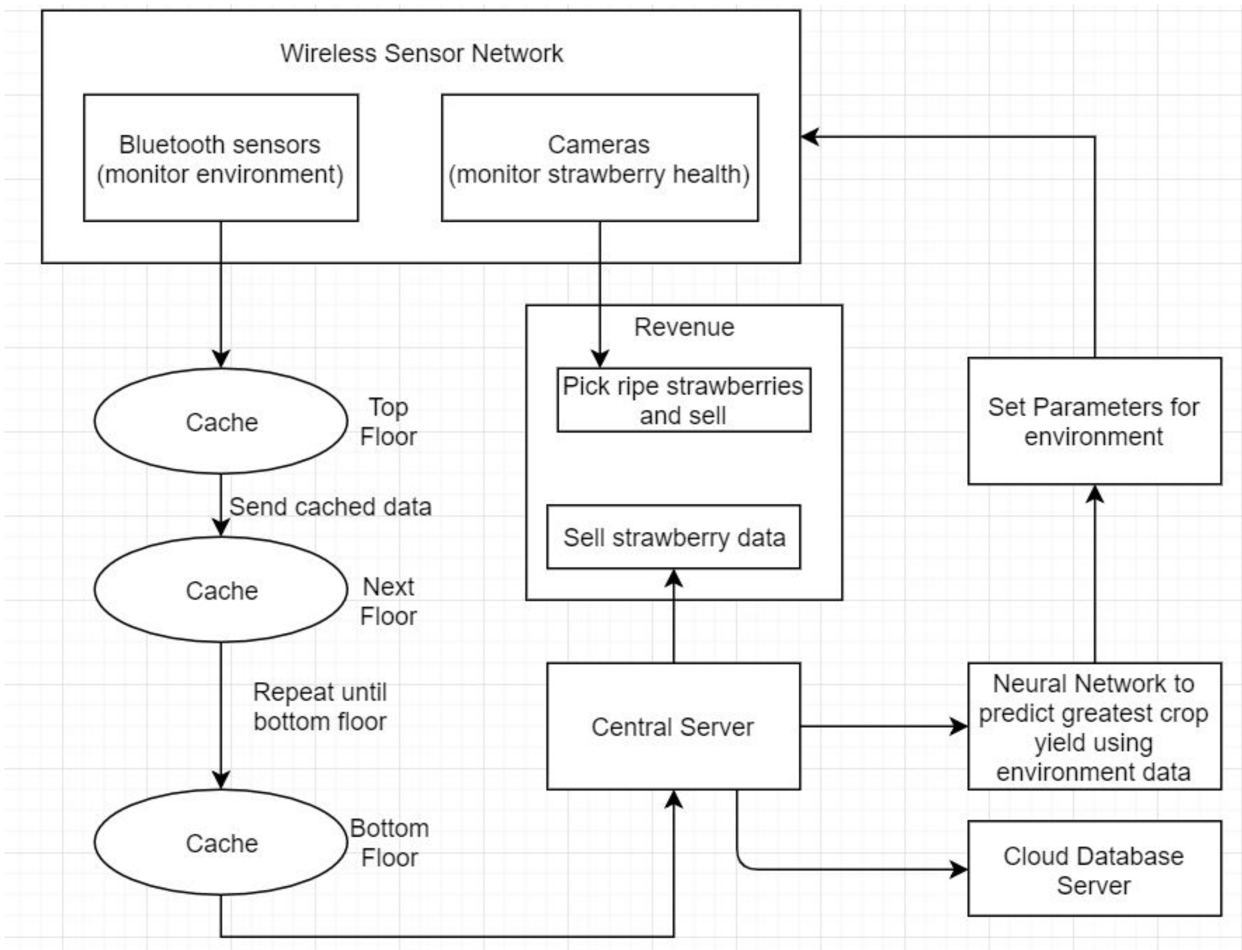


Figure 2: Software Design Outline

First, sensors and cameras make up our sensor network. The sensors monitor the environment data, while the cameras monitor the strawberry health. This happens once every three hours as the robots make their rounds around the floors.

Next, the gathered environment data is stored in a cache that is local to the robot it was collected from. When every rack has data stored into the cache and the robot returns to its charging station and sends its cached information to its base station, the base station cache begins collapsing top to bottom to the server. The cached data from the top base station is collapsed into the cache of the station beneath it, and this collapsing continues until it reaches the server at the bottom.

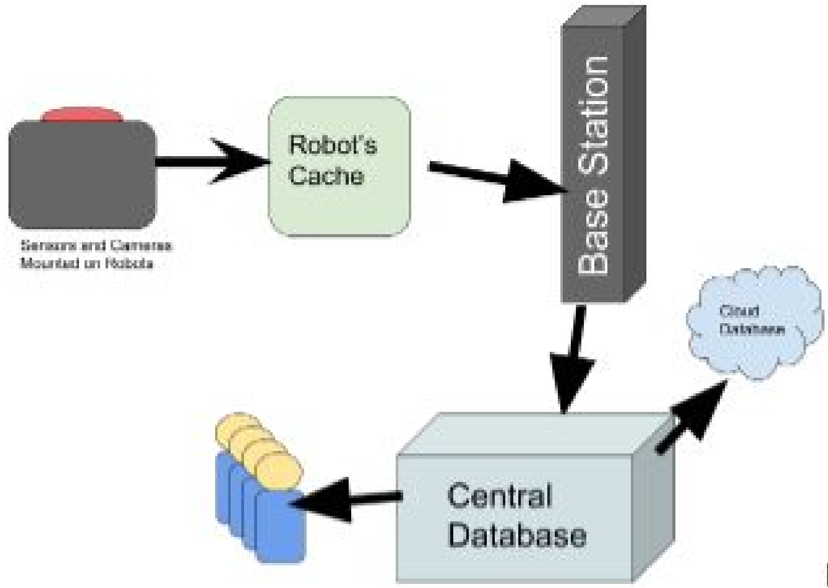
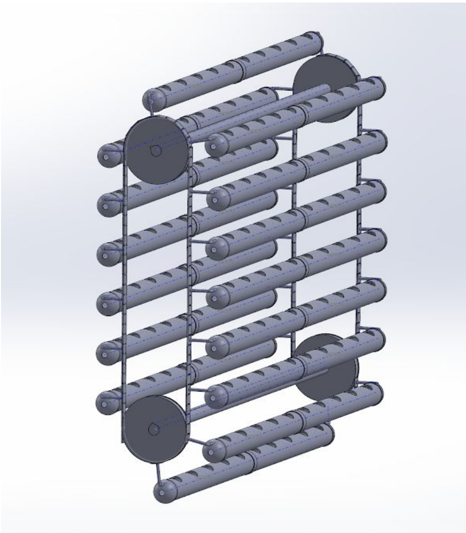
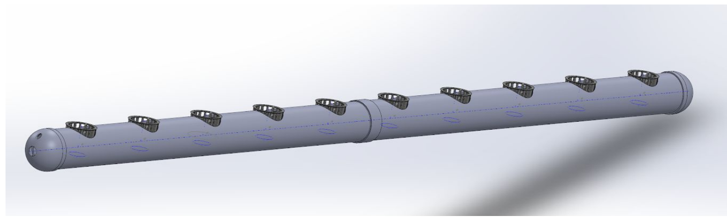


Figure 3: Data Transmission System

The central server then communicates with the neural network system. The neural network takes the environment data and number of strawberries to predict what environment parameters will produce the greatest crop yield. These parameters are then communicated to the central planting system (created by the building designers) at the end of the planting season.

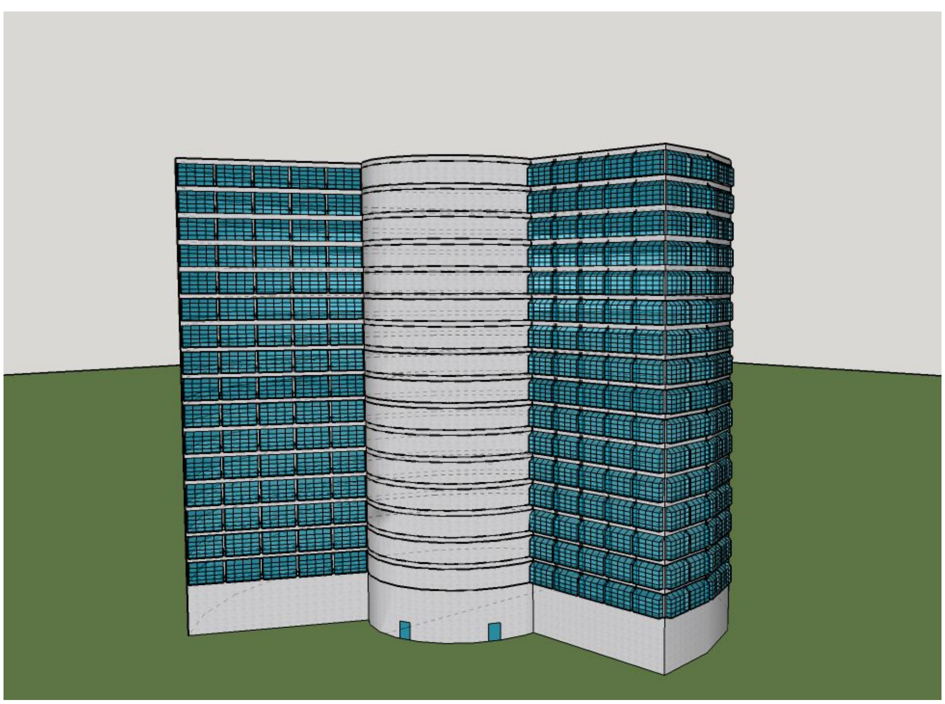
In order for our server to store all of its lifetime data, it is sent to a cloud based database (MongoDB) at the end of the day, and the server data in order to ensure space is always available.

In order to generate revenue, the farm will sell data collected on the health of the berries and the strawberries when they are almost ripened. Our target audience will be companies that use strawberries in their products.

From left: SOLIDWORKS screenshots of the shelf assembly and the PVC pipe that serves as a tray for the strawberry seeds.

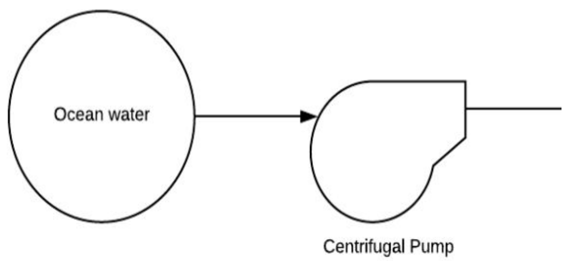
The design of the hydroponic farming system consists of two major components: the strawberry cultivation robot and the revolving hydroponic PVC pipe shelf. The strawberry cultivation robot, named Agri-ZOT, will travel down a rail and tend to the strawberries on the bottom pipes of the shelf, planting strawberry seeds and harvesting the ripe fruit that grow from them. The pipes on the shelf will periodically cycle along the motorized conveyor belt, depending on which pipe contains strawberries that require Agri-ZOT's care; the pipe containing these strawberries will move down the belt to the bottom of the shelf for the cultivation robot to perform its work.

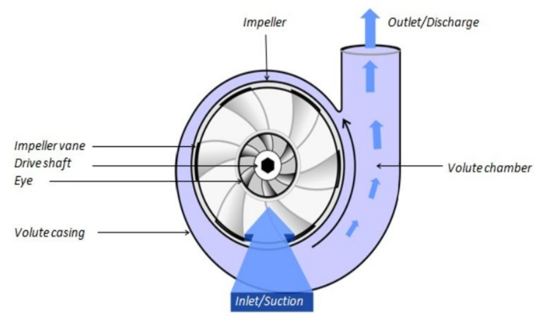


Separation of semi-cylindrical structure into 18 floors; Floor 1 is a designated loading zone, while Floor 2 contain processing and packaging equipment that will allow for quick shipping to the trucks. Floors 3-18 are dedicated to cultivating the strawberries, with offices located along the inner core of the building for floors 3 through 6. The upper floors of the inner core have minimal personnel and can be designated for other purposes should any such need arise. The exterior of the building is lined with double-layered glass, with the interior layer composed of Low E glass, which reflects incoming sunlight back to the outside. Elevator shafts installed inside the building allows for efficient transportation of both personnel and product.

Design Breakdown

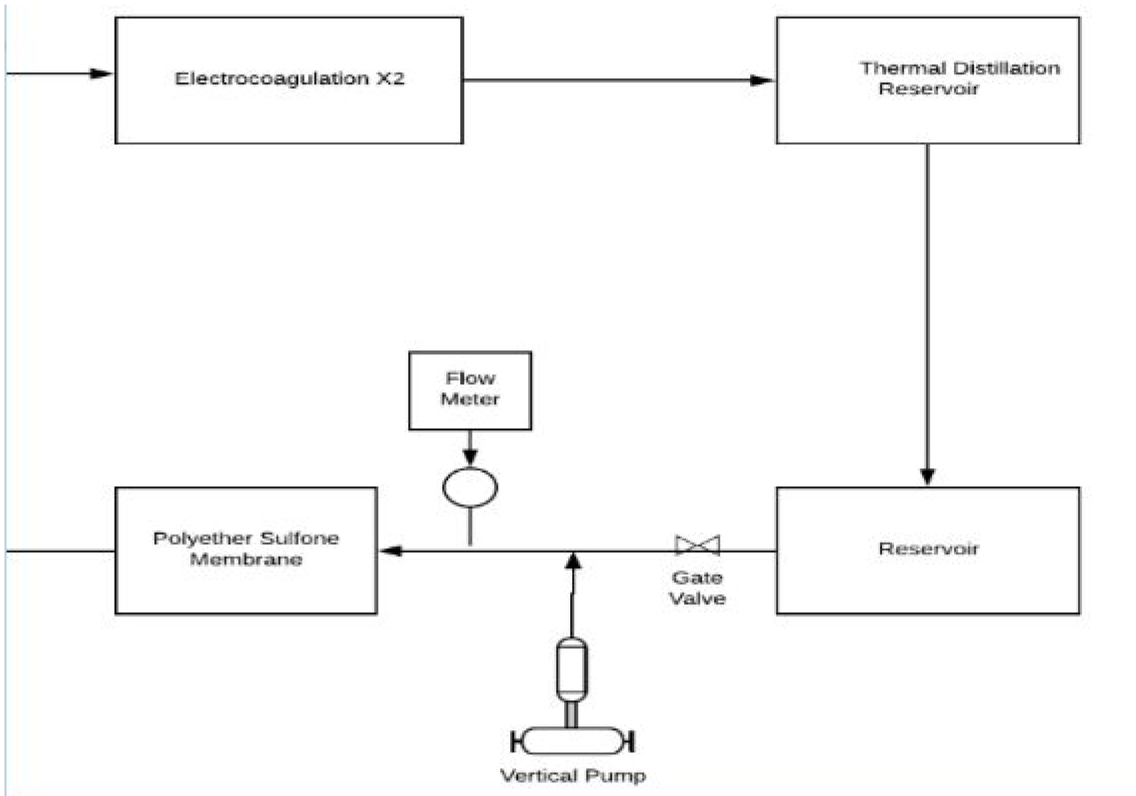
Water Extraction:





- We chose our water source based off of availability and to minimize the damage to ecosystems. The ocean has an inconsistent and unknown flow rate so we were able to manipulate this by using a centrifugal pump and a distinguished pipeline made of cost-efficient PVC plastic piping.
- Due to a stable climate, we established that PVC would not wear away or be exposed to extreme temperatures.
- Our pump has the maximum flow rate of 105 gallons per minute (~6300 GPH) with only an inch diameter. The flow rate is within the desired range, which is from 4,000 to 9,000 GPH (gallons per hour).
- Centrifugal pumps were efficient because of the ability of the impeller vanes to produce a rotational motion accelerating the salt water out and increasing pressure towards the outlet. Compared to positive displacement pumps, they have higher flows and are more geared for less viscous liquids like water. Centrifugal pumps also need to have a continuous source of water and oceans will satisfy that need.

Water Filtration:



- Our unfiltered saltwater will run through an electrochemical treatment called electrocoagulation twice to remove large sediments, heavy metals, bacteria, and dissolved contaminants
- Electrocoagulation involves the use of many parallel metal plate electrodes, which, at low voltage, use high current densities to destabilize electrical charges. This disrupts the suspension of particles, which then coagulate and clump together to make flocs. Heavier and insoluble particles fuse and rise in the cell, separating from the clean water. It produces hydrogen and oxygen gas bubbles that help the coagulated solids and coalesced hydrocarbons float. Then, the cells use an upward flow to clear all bubbles and discharge sediment and floc into flotation/sedimentation tanks for filtration.
- Electrocoagulation allows for continuous flow and a hydrodynamic design, which is proven to be cost effective and low in energy consumption. A two-stage electrocoagulation system is used to improve the accuracy of contaminant removal.
- Then we will use Thermal Distillation to isolate the salt from the water by electricity-powered vaporization. The steam will then travel to a 100,000 gallon reservoir so that we can store the desalinated water.
- This allows us to control the flow of the water with a water valve and a pump. The flow meter checks on the water flow as it moves towards the Polyethersulfone membrane (PES) for forward osmosis.

- The pressurized pump, which controls the valve and the flow meter between the reservoir and PES, has the maximum flow rate of 24 gallons per minute (~1440 GPH).

$$J = \frac{Q_p}{A_m}$$

- J = 40 - 100 L/m^(2)/hr (range of desired flux)
- Q = 1440 GPH (flow rate(controlled) into PES)
- A(area of PES filter) = Q/J
- The unknown value is the area of the RES filter, which should have a high flux along with flow rate, and be considered cost efficient.
- The area of the filter will be used to calculate the diameter of the filter, as well as the total cost used for the process.
- min J:

  A = 1440 GPH/ (40 L/m^(2)/hr) = (36 Gm^(2) / L)(3.7854 L/ 1 G) = 136.27 m^(2)

- max J:

  A = 1440 GPH / (100 L/m^(2)/hr) = 14.4 Gm^(2) / L = 54.51 m^(2)

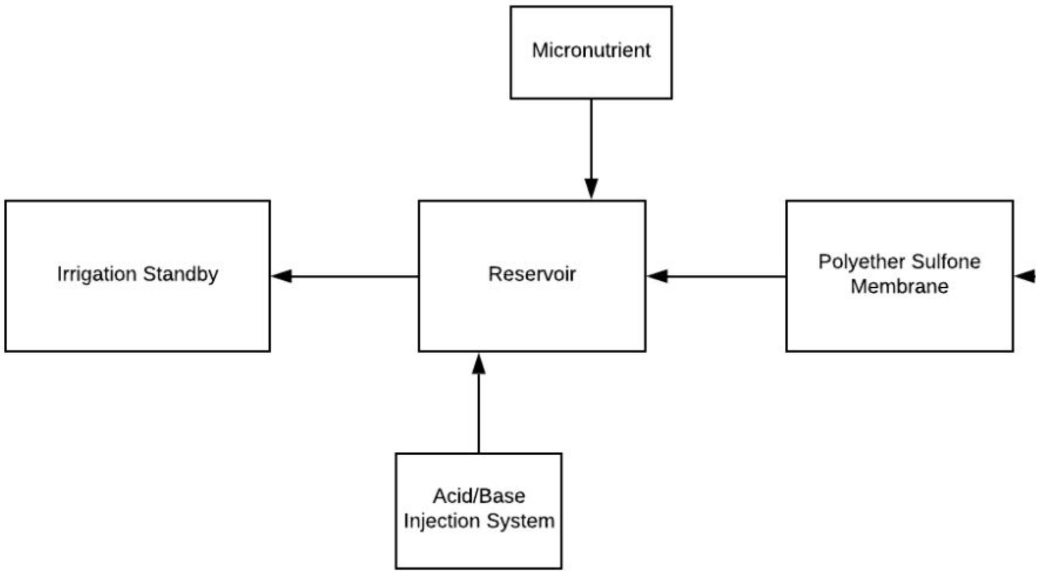
  - To make this more cost efficient for the PES membrane, we needed to use the max flux.

    [54.51 m^(2)]/[0.0674 m^(2) per disk)] = 809 disks

    (809 disks)/(25 disks per pack) = 33 packs

- A hydrophilic Polyethersulfone membrane has the ability to remove fine particles, bacteria, fungi, has low protein binding, isolates yeast and mold colonies, and removes viruses. Forward osmosis is possible because it has a high water flux.

pH Control System and Micronutrient Optimization System:

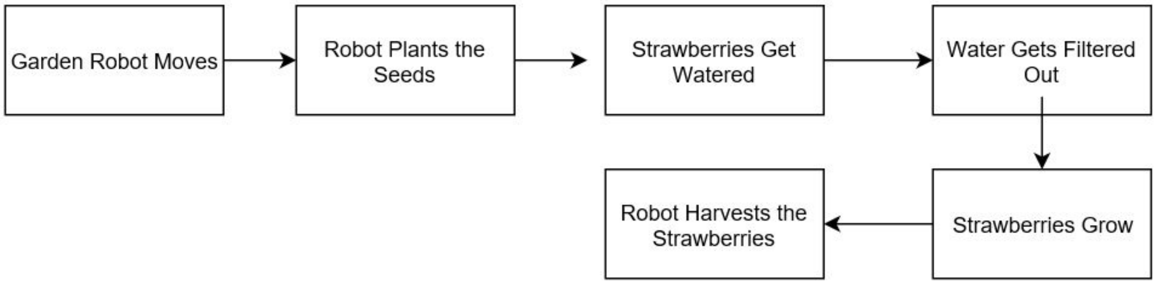


- Given constraints: Building is 100 x 100 ft^(2) to 300 x 300 ft^(2). 18 stories tall and 70% overall cultivation
- Area
  min: 10000 ft^(2) (or 0.229 acres) ⇒ (considering restraints) = 2.892 acres
  max: 90000 ft^(2) (or 2.066 acres) ⇒ (considering restraints) = 26.033 acres
- Strawberry micronutrients
  Nitrogen, N: 120 lb/acre
  Potassium, K: 200 lb/acre
  Phosphorus, P: 30-60 lb/acre
  Calcium: 0.5 - 1.5%
  Magnesium: 0.25 - 0.45%
  Sulfur: 0.15 - 0.40%

Micronutrient	**Amount (lbs)**
Nitrogen	347.04
Potassium	578
Phosphorus	115

- A Nitrogen: Phosphorus: Potassium (NPK) ratio of 3:1:5 is needed.
- A fertilizer available commercially with an NPK ratio of 3:1:1 will be used.
- Although the N:P ratio matches exactly to the one that is needed, there is a deficiency of Potassium. To compensate for the lack of potassium, a separate fertilizer of 0:0:60 NPK ratio will be used to fulfill this deficiency.
- A pH control system needed to be put in place to stabilize the pH of water (ideally between 5.3 and 6.5) for the crops to grow by using clean, environmentally-friendly chemicals.
- An acid-base injection system will be put in place to act as a buffer whenever an increase or a decrease in pH strays away from the ideal pH. Ammonium sulfate is used if the water is too basic, and pH needs to decrease, while limestone is used when pH needs to be increased.
- Limestone is an alkaline agent with the ability to neutralize strong acids, by adding hydroxide ions, as well as to add both calcium and magnesium to the soil.
- Ammonium sulfate is a common inorganic fertilizer for alkaline soils. Not only does it release acid, therefore more hydronium ions, it also contributes essential nitrogen to improve plant growth. It reacts fast to alter the pH.
- The total ammonium sulfate needed to bring the pH of the filtered water to a pH of 6 is approximately 17.26 g. This calculation came from multiplying the total concentration of hydrogen ions when pH=6, ([H]=1×10^{-6}), times the molar mass of ammonium sulfate, times the flow rate in one day, (24 gallons/min).
  grams needed in one day=0.000001mol/L x 132.14 g ammonium sulfate/mol x 24 gallons/min x 3.78L/gallon x 1440 min/day x 1 day.

Farm Harvesting/Monitor System



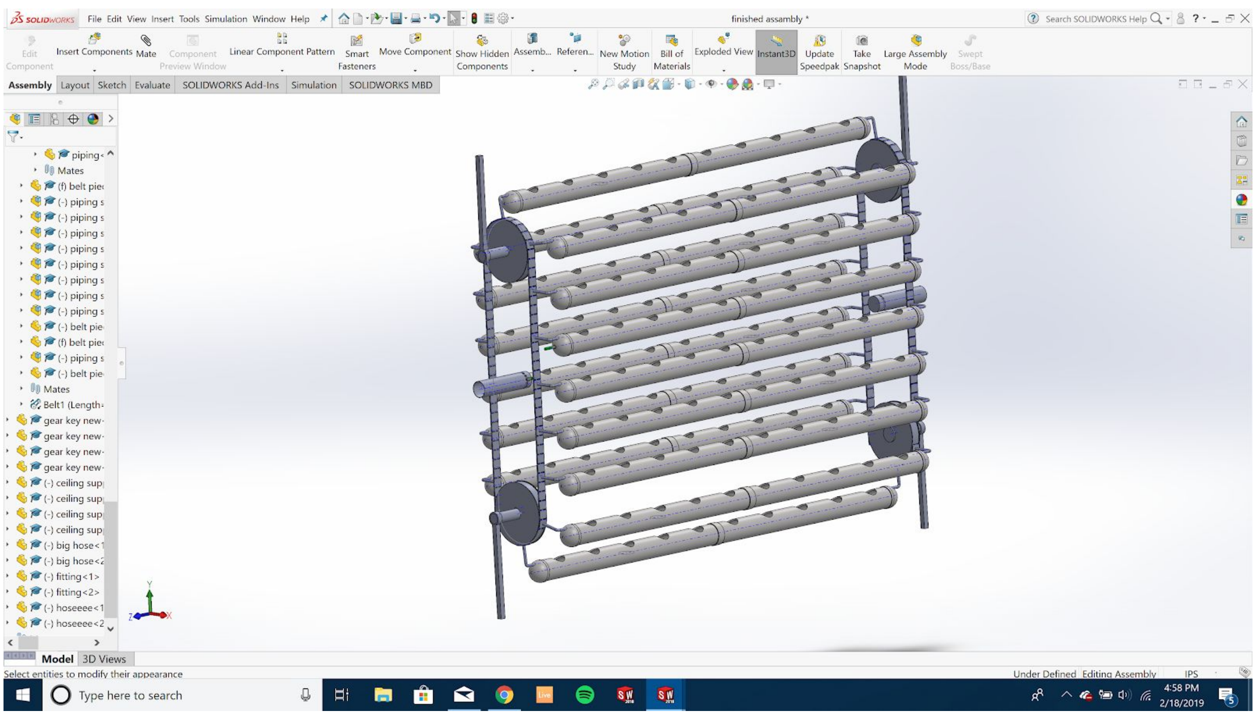
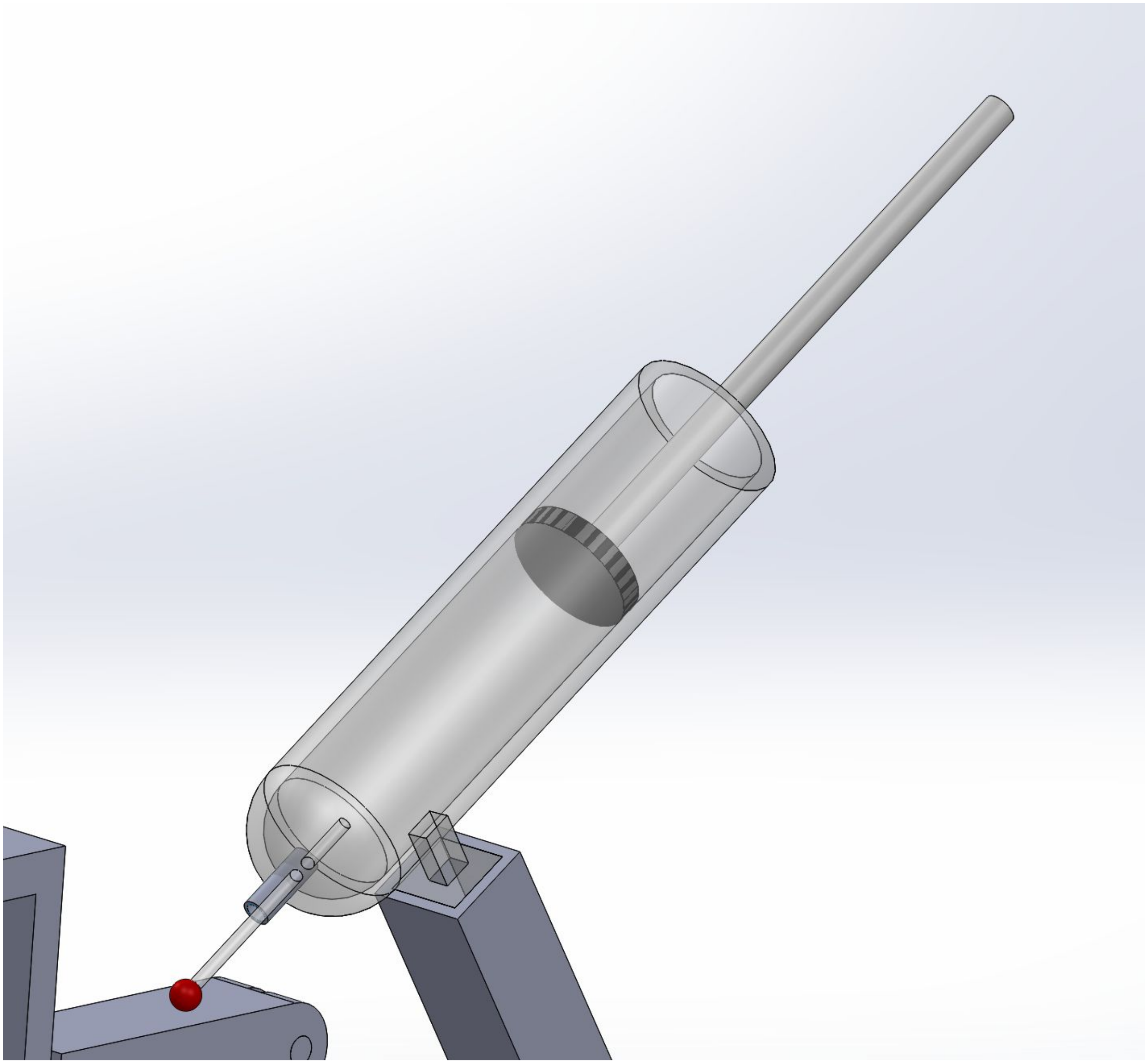


Figure 1. Solidworks Assembly of revolving shelf



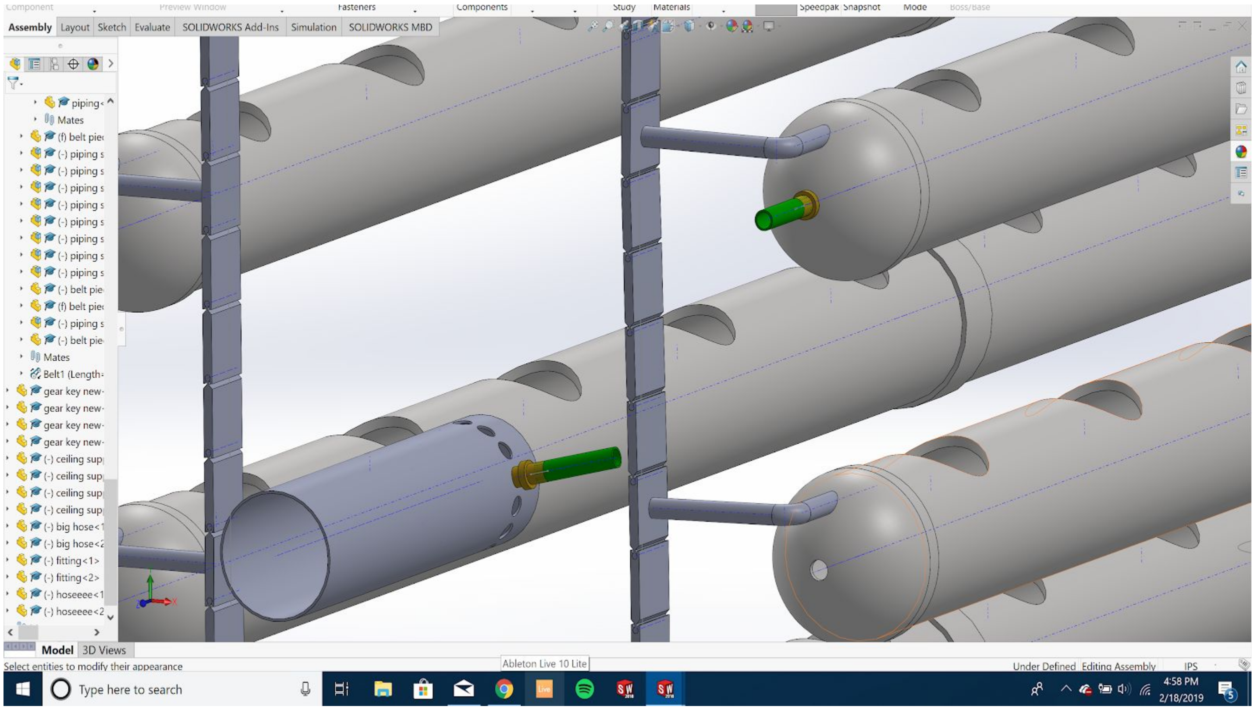


Figure 2. Close-up of fluid system in revolving shelf

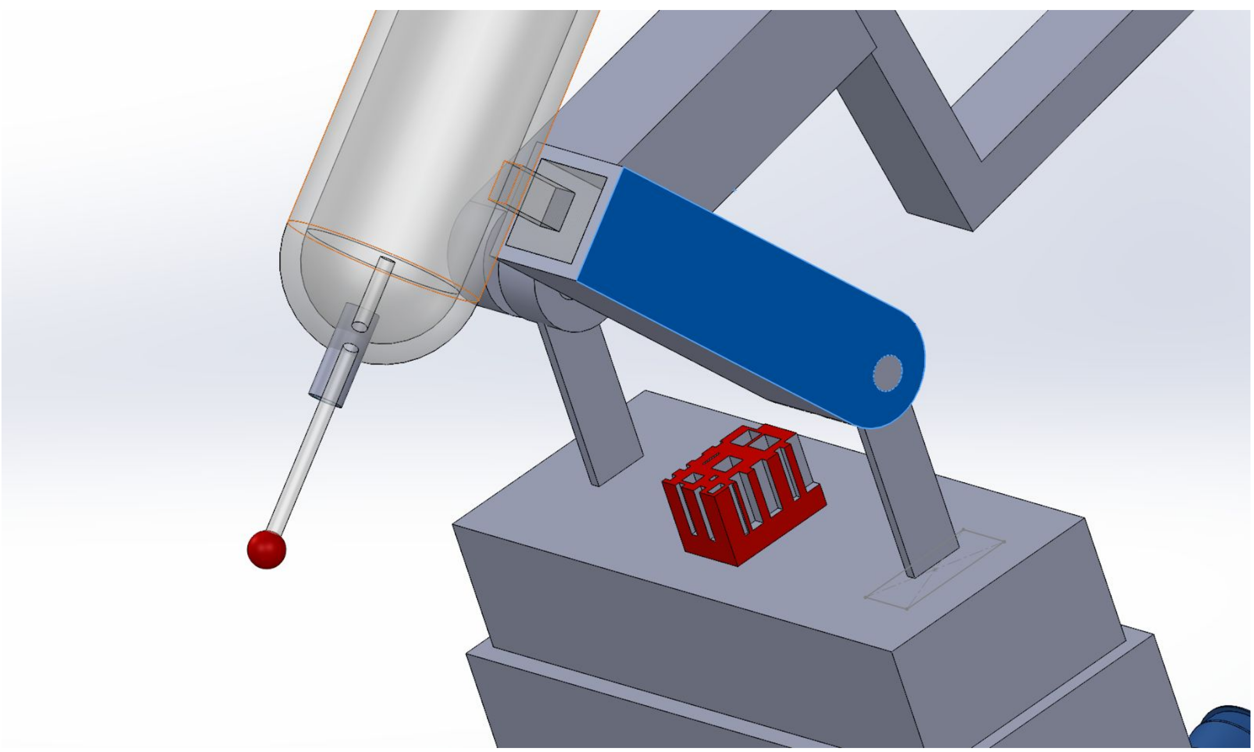


Figure 3. Close-up of Robot mechanical arm

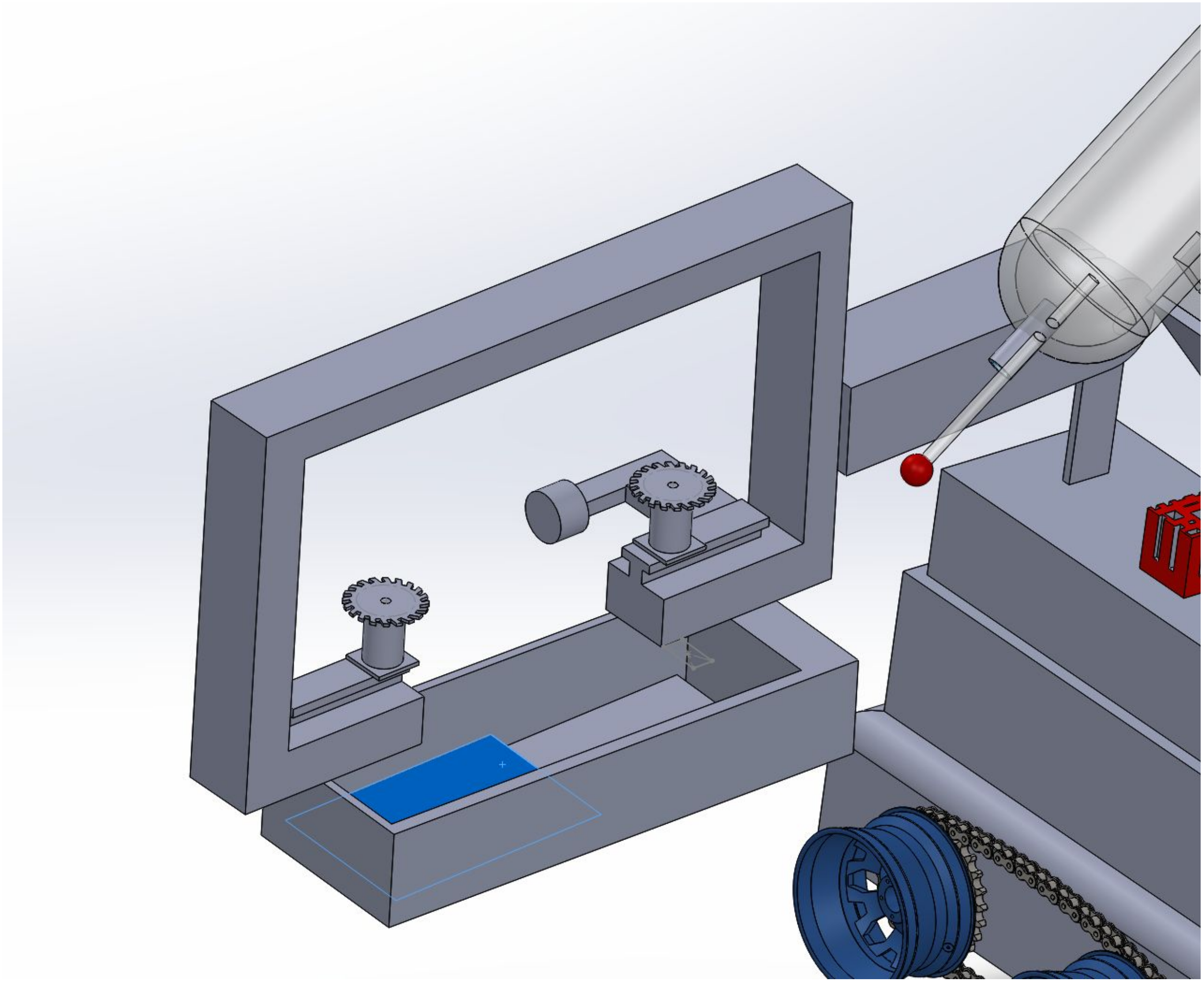


Figure 4. Basket and strawberry removal arm on robot

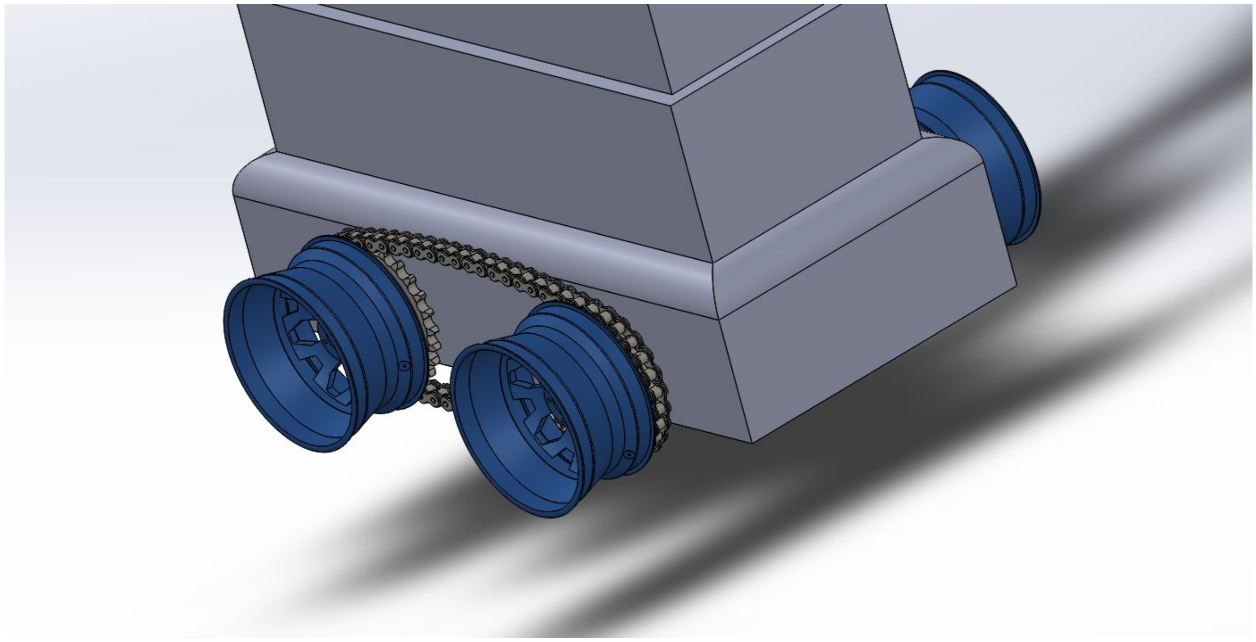


Figure 5. Robot wheels (connection to railing system)

The team met the design requirements with a two-body system consisting of a motorized revolving shelf of strawberries and a moving robot with arms that can plant and harvest the strawberry seeds, which moves on a floor railing that traverses the entire floor. This allows for the robot to tend to multiple units throughout the level.

The hydroponic motorized revolving shelf is the most versatile planting medium, as it requires no soil and optimizes the amount of strawberries that can be grown for each floor, vertically and horizontally. Meanwhile, the robot moves about the rows of pipes, planting and harvesting the strawberries in the bottom shelf as they cycle.

Each row consists of an 8-inch-diameter PVC pipe that carries flowing water and strawberry plants placed in 6-inch-diameter openings. The 8-inch-diameter pipe allows the strawberry plants' roots ample room to grow, and the 6in diameter opening at the top of the horizontal pipe allows the strawberry plant to grow outward as much as it can.

Each row also moves periodically, and the robot may move them when it needs to work with the strawberries at the bottom shelf.

System Design

Sensor Network:

The robot carries around a temperature sensor and humidity sensor that collects data every time a strawberry is scanned, wirelessly. On the robot is also camera that collects data on the strawberry's health and maturity, to see when it would be harvested. When the robot reaches the end of its monitoring cycle and returns to its charging dock, the data stored locally on the robot is sent to a cache that is based on the floor. On each floor, a water pH sensor measures the pH level of the water that is sent to all of the strawberries on its floors.
Since the information is being through wire transmission when the robot docks, this creates a secure loop that prevents attackers from hijacking or accessing the network.

Computer Vision:
Images collected by cameras on each floor will be processed using computer vision. The computer vision program divides the image into many square tiles. A kernel, or a small matrix that encompasses a patch of pixels, will move across the image to determine a number for each tile based on the sum of the gradient differences between the center pixel and the surrounding pixels in the matrix. A sharper gradient difference implies an edge; a gradient difference of zero implies solid color. The values in the matrix are collapsed into a histogram, represented by an array. Next, the program is fed images of a particular object, such as a strawberry. A small portion, around 15-25%, of the images are set aside for testing, while the program uses the others as training data, assigning weights to each part of the histogram. The weights are tested on the testing data and adjusted, and are then used with further images to determine if an object looks like a strawberry. Computer vision will be used in this project to count the number of strawberries in each zone.

Data Storage:

Each floor is populated by racks of rows of rotating trays, arranged in concentric arcs. A robot on rails will periodically traverse the rows of racks, scanning the QR code identifying each specific tray within a rack, then scanning each strawberry in the tray, collecting an image and data via sensors, storing the information in a local cache on the robot, and harvesting the berry if it meets the conditions specified for ripeness by an intelligent algorithm. A one time water sample will be collected per tray via a siphon at the end of the robot's arm. Mounted on the robot's body are a thermometer and hygrometer, tracking the differences in ambiance. The robot will store this information until it returns to its charging base upon completion of its sweep of the floor, upon which it will connect to a base station (located every few floors throughout the farm depending on range) via fiber optic cable, clearing its cache.

An additional water meter will be installed in the reservoir to track pH, temperature, and nutrient content, which provides secondary data to cross reference with water information collected from trays, in the event of troubleshooting water contamination.

The datasets collected by each base station are passed to a cache in a cascade from top to bottom, which waits until all base stations have supplied their data, at which point all data is dumped at once into the MongoDB document database system and cleared from the cache. This data storage method provides the advantage of segregating data from each zone into individual BSON documents, allowing each data dump to quickly add data to an existing sheet. If the database needs to be expanded, horizontal scaling enables addition of server space without having the system go offline, eliminating server downtime. Every 24 hours, a copy of the central server's logs are sent to a cloud server acting as a backup data source in the event of natural disaster or server destruction.

```
Floor 1

{
 "Time":
 "Tray": A1
        "Srndg":
                "hdty": __
                "tmp": __
        "Crop":
                "Ph": __
                "Img":
 "Tray": A2
        "Srndg":
                "hdty": __
                "tmp": __
        "Crop":
                "Ph": __
                "Img":
}
```

Figure 1: JSON Representation of BSON Entry in Database

Authorized users (technicians, Research and Development, system admins, clients) will access the data through a portal, which is supported on mobile, tablet, and desktop platforms. Every registered platform will receive automatic data downloads from the central server throughout the day when new data is received by the database. To minimize server load, downloads will be grouped into staggered batches. This enables users to view local copies of the database, reducing load to the server by searching within a local copy instead of making a call to the database. In the event that a user needs to access a recent dataset that has not been automatically imported, they may refresh the log via an icon at the top of the UI.

To access data, the user enters the floor number into a search field, which makes a request to the specific document in the local copy of the database that contains the information. The BSON data is parsed via Python's PyMongo API library and presented in a formatted view in the user interface can then be filtered by time, tray, and/or other fields. Every automatic server request is stored locally in the user's application for one week, but entries can be cleared if the user wishes.

If a query result is not in the user's local copy, a query request can be made to the server. Since this will likely only be used if the user is accessing older data, server requests are minimal and latency will be low, allowing for quick response times.

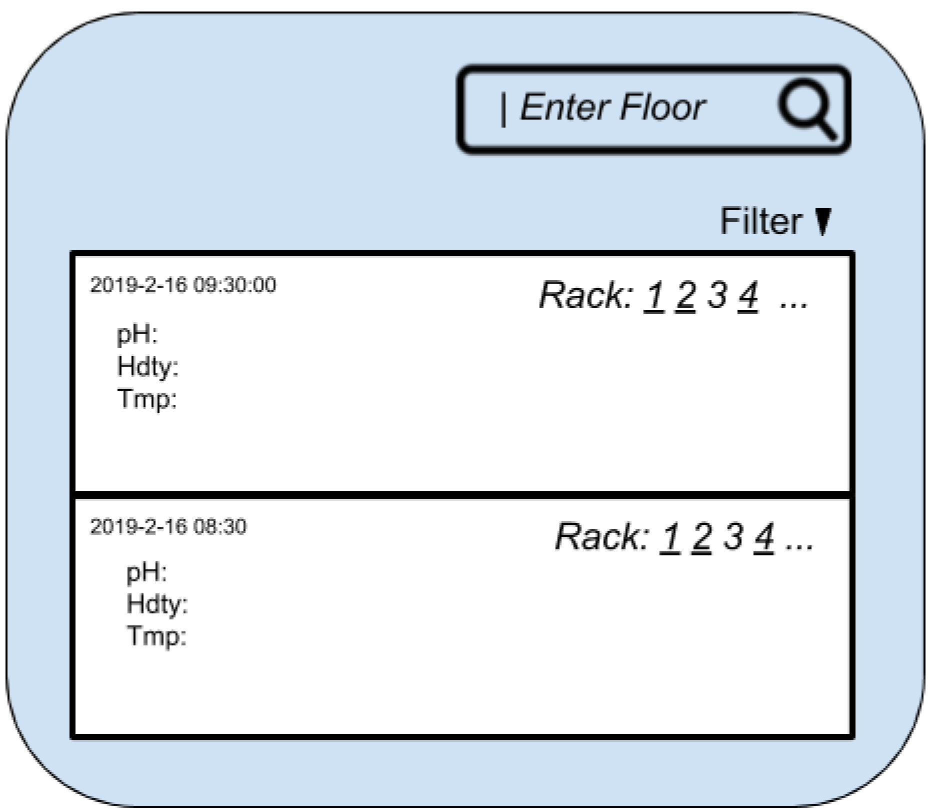


Figure 2: Example User Interface

Intelligent Algorithm:

In our prediction for biomass yield (crop yield), we decided that to predict the effect of individual factors, we would need to produce a curve using a plotting library and data points from our different controlled groups. We decided to have our factors include water hydration, fertilization amount, soil nutrient content, pH content, temperature, density of crops per square meter, and humidity. A plotting library would allow us to predict the individual effect of these factors to almost 100%.

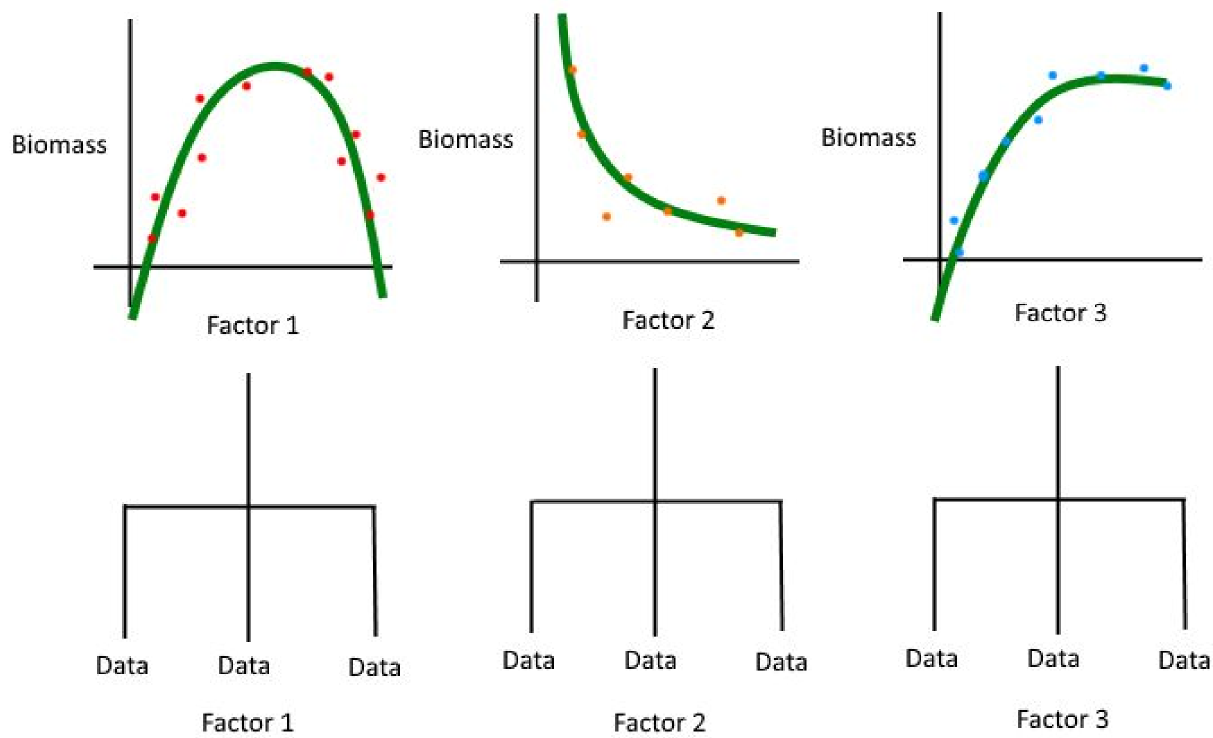


Figure 3: Examples of Lines of Best Fit showing factors affecting Yield

However, when we integrate our software into the vertical farm, we will need to adapt our data sets into a custom neural network that accepts a set of variables. These variables will be the factors of agriculture that affect growth. The problem with a default neural network is that it does not consider the nonlinear effects of our variables on biomass yield. This is because in agriculture, the factors of growth are not independent from one another. For example, humidity will affect the water saturation in the soil, and vice versa. Therefore, we need to find a way to normalize our data, which can be done through a series of 1+ hidden layers. The hidden layers will be able to process the effect multiple variables will have on each other. Though this will take time with such a large set of data points, the end result will allow us to predict the output yield to a degree of almost 100%.

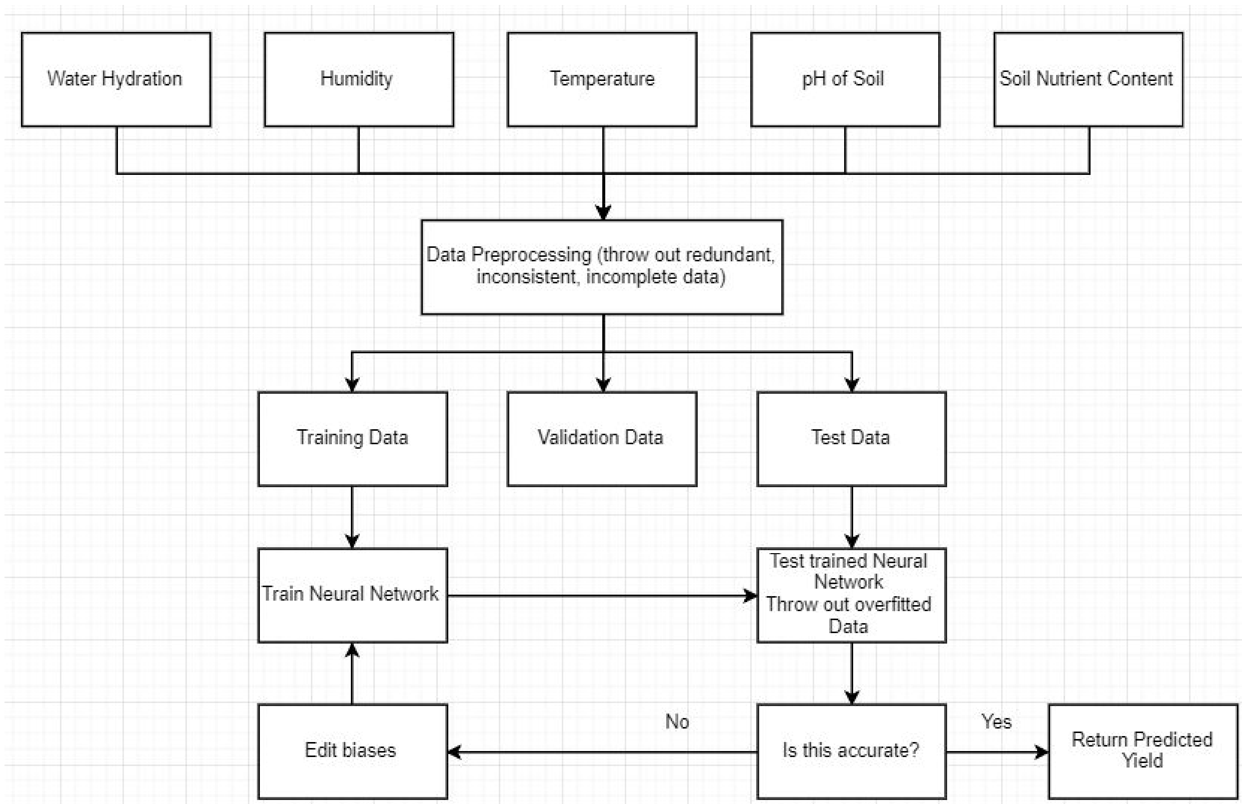


Figure 5: Feedforward Multilayer Neural Network

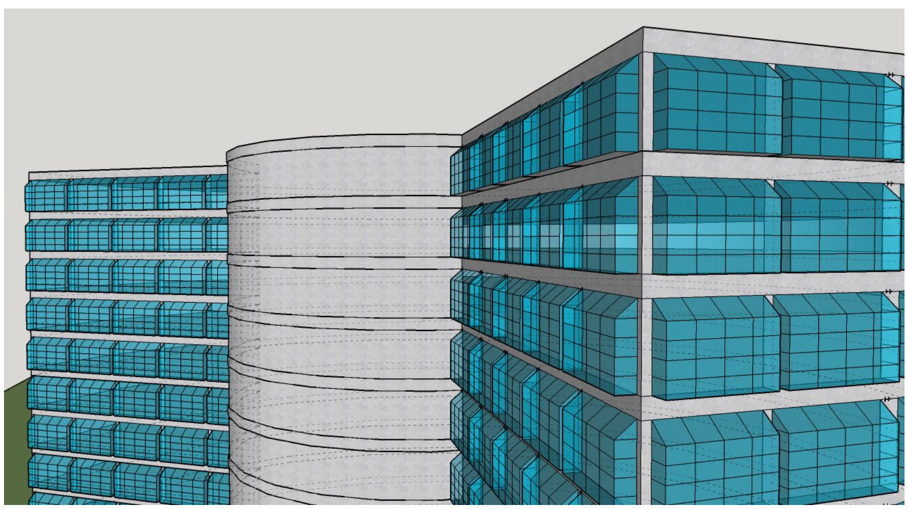
User Interface*:*

The main source of revenue will be sales to large companies that use strawberries in production (ie. strawberry jelly producer). This is because, based on our research, individual consumers tend to buy groceries from local grocery stores rather than online ones. Therefore, we decided to sell our products to companies that demand large quantities of strawberry for their production line instead of to the individual consumers. This allows us to sell our mass-produced products in large quantities and lower prices to an appropriate buyer. Moreover, we decided to further increase our revenue by selling the data that we collect through our sensors to researchers, soil producers, fertilizer producers, and any others who would be interested in our data to further improve their product. Data purchasing and strawberry purchasing could be separated through the user portal, and allow for our customers to more quickly reach the product they desire. Potential use cases of the E-Commerce system are outlined in Figure 6. The E-Commerce system will allow us to use the increase in biomass yield to produce revenue for our company and further improve future vertical farms.

Use Cases	*Actors(User/Admin)*
Fill out the form	*User*
Access the form	*Admin*
Receive notification	*User*
Login/logout	*User/Admin*
Purchase data collected	*User*
Place purchase request for strawberries	*User*

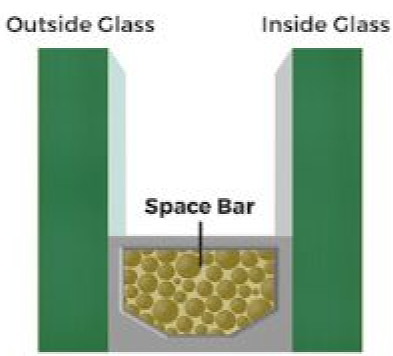
Use Case Diagram

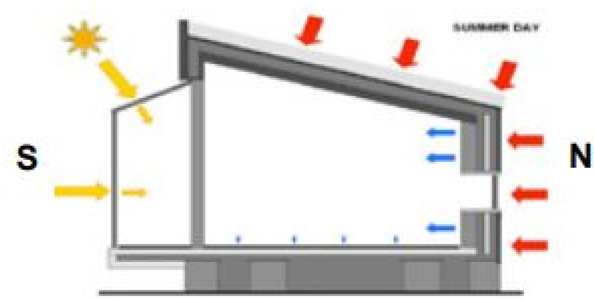
Construction



Aerial 3D model of structure

A hydroponic system was utilized to maximize the yield of strawberry crop and reduce costs. Planting strawberry crops required significantly more surface area than a hydroponics system. Planting also required soil, which would present a much higher cost than the materials required in a hydroponics system. Soil is also a much denser material than water - the primary material required in a hydroponics system - and would increase the load that the building's structure would have to bear, which would only furthen the cost of materials necessary to support the building. The building design included the infrastructure required to distribute the products yielded. The ground floor included features such as storage space and a loading bay. The storage containers were refrigerated to assure maximum quality of produce. The loading bay was designed to comply with federal regulations, and facilitate the maneuverability of the products. The loading bay is also in proximity to the service elevator that connects the entire building. The service elevator was designed to accommodate larger cargo than the personnel elevator in the central part of the building. The building was designed with a circular shape because circular forms have a minimal drag coefficient and increases the overall stability of the building due to the members of the building converging on its vertical axis. Reports have shown that circular structures typically outlast rectangular structures, provided the same basis.

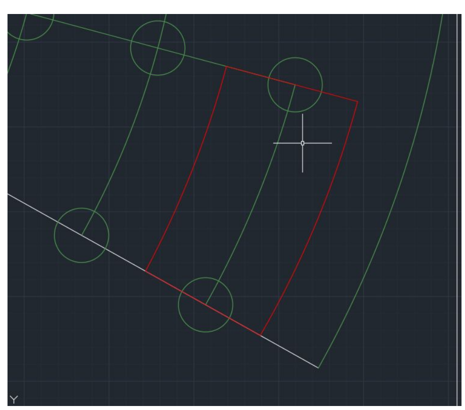




Double Annealed Glass

Building Design Calculations:

Girder Subjected To Maximum Loading:



Tributary Area of Distributed Weight

Girder Tributary Area: 692.69 ft^2.

Assumed Dead Load: 100 psf

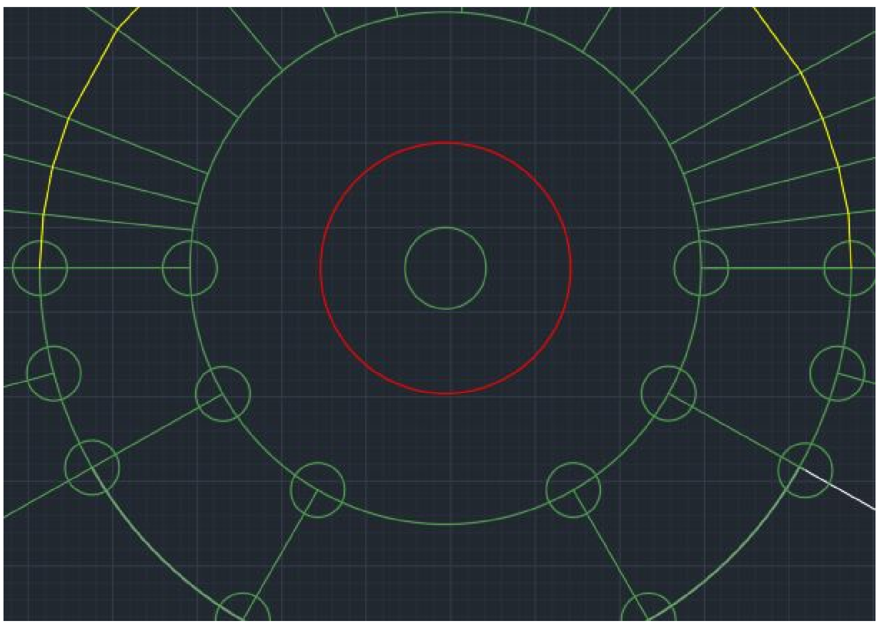
Calculation for Maximum Load:

$$Load = Assumed\ Dead\ Load * Tributary\ Area : 69.26\ kips$$

Recommended W-Shape For Girder:

W16-35

Column Subjected To Maximum Loading:



Cross sectional View of Column

Column Tributary Area:1075 ft^2.

Assumed Dead Load: 100 psf

Maximum Load:

$$Load = Assumed\ Dead\ Load * Tributary\ Area : 107.5\ kips$$

$$Maximum\ Load = Load * Number\ of\ Floors = 1935\ kips$$

Seismic Design Force For RC Concrete Building

Risk Category = Category II

Seismic Importance Factor = 1.00

Fv= 1.5 Site amplification factor at 1.0 second

Fa=1 Site amplification factor at 0.2 second

Sms = 1

Sm1 = 1.5

Sds = ⅔

Sd1 = 1

Risk Category III

Site Class: D - Stiff Soil

R =8

Cs = .166

Effective Seismic Weight: 647,970,335 lb

Seismic Base Shear V : 107,563,075 lb

Distribution Exponent K: 1

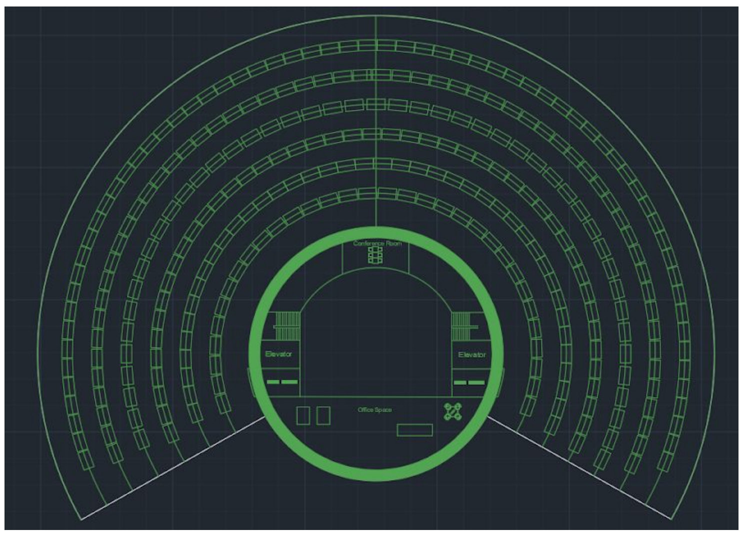
Floor	Height (ft)	Wall load (lb)	Floor load (lb)	Offices (lb)	Total (lbs)
Concrete base	0.5	N/A	N/A		
1	15	578,338,272.00	25707105	1901428	605,946,805.00
2	15	546208368	24278932.5	1426071	571913371.5
3	15	514078464	22850760	950714	537879938
4	15	481948560	21422587.5	475357	503846504.5
5	15	449818656	19994415		469813071
6	15	417688752	18566242.5		436254994.5
7	15	385558848	17138070		402696918
8	15	353428944	15709897.5		369138841.5
9	15	321299040	14281725		335580765
10	15	289169136	12853552.5		302022688.5
11	15	257039232	11425380		268464612
12	15	224909328	9997207.5		234906535.5
13	15	192779424	8569035		201348459
14	15	160649520	7140862.5		167790382.5
15	15	128519616	5712690		134232306
16	15	96389712	4284517.5		100674229.5
17	15	64259808	5712690		69972498
18	15	32129904	2856345		34986249

Live and Deadload Calculations per Floor

Dead loads are taken at 100 psf, live loads taken at 25 psf

Floor Load Calculations
Surface Area: 57126.9 ft^2 Thickness: 1 foot
Circumference of building: 214199.36 ft
Area of inner circle (office) : 9507.14 sq.ft
Thickness of glass: 12.5 psf

Farm Layout



Cross Sectional View of Floor

The cultivation area was 47619.76 sq.ft. THe strawberries were produced in a hydroponics system composed of PVC pipes.Each floor is designed to fit 247 structures per floor, with 6 ft. of space between them to allow maneuverability. One structure contains 12 rows that accomodate 10 plants each. Each floor produces approximately 266000 pounds of strawberries annually. The 16 floors dedicated to cultivation have the capacity to produce 2135 tons per year. The cultivation area is sectioned off from the inner circle by a pressurized airlock system, which prevents foreign contaminants like bacteria from entering the agricultural area.

Integrated Bill of Materials

Item	*Description*	*Link*	*Manufacturer*	*Price per unit*	*Quantity*	*Total price*
Motor	UAV Brushless Motor MS2814	Link	TMotor	$34.77	64	$2225.28
Motor	Motor, ¼ HP, Split Ph, 1725 RPM, 115V	Link	Dayton	$74.88	9600	$718,848.00
Aluminum Sheet	Cold Finish Aluminum Square 2024 T351 12” length	Link	OnlineMetals	$237.86	256	$60,892.16
Aluminum Sheet	Aluminum Bare Sheet 2024 T3 12”x12”	Link	OnlineMetals	$8.94	256	$2288.64
Tracks and Wheels Set	MLT-JR Pair of Molded Spliceless Tracks and Wheel Set	Link	SuperDroid Robots	$189.00	16	$3024.00
PVC Hose	1-1/4" ID x 1.40" Nominal OD CVLD Blue PVC Hose	Link	Hi-tech Duravent	$1.88	224,000	$380,324.00
MongoDB Subscription	Database Fees	Link	MongoDB	$129,570	Annual Subscription	$129,570
Texas Instruments HDC2010YPAR	Humidity Sensor	Link	Texas Instruments	$1.26	36	129,570
Maxim Integrated DS18B20+	Temperature Sensor	Link	Maxim Integrated	$3.06	36	110
pH electrode LE407	Water pH Sensor	Link	Mettler Toledo	$111.00	54	9
ATMEGA328P-AU	Microprocessor	Link	Atlens	$1.84	36	5,994
Arlo Camera System	4-Camera System Kit	Link	Arlo	$70	9	66

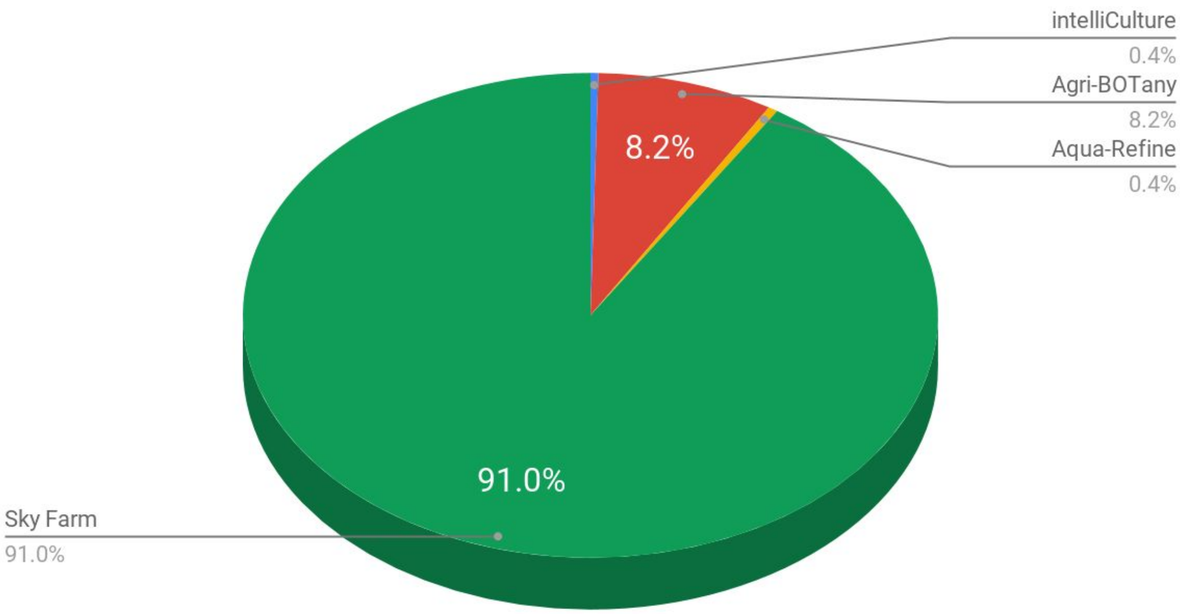
Dell Business Desktop Computer	Main Nodes	Link	Dell	$300	10	630
304 Stainless Steel Sheets, Bars, and Strips	Pulley	Link	Mcmaster	$122.67	4	$490.68
Corrosion-Resistant Tungsten 420ft	Railing system	Link	Mcmaster	$19.77	420	$531,338.24
UHMW Film	Robot casing	Link	Mcmaster	$9.84	1	$9.84
L Series Dust-Free Timing Belts	Conveyor Belt	Link	Mcmaster	$20.72	2	$41.44
Insulated Glass with LowE(Pilkington)	Two layers of glass separated by a vacuum that allow minimal heat to get through	Link	Fab Glass and Mirror	$414	9,450	$3,912,300
Corrugated Steel	Steel panels	Link	M&K metal co.	$22	20000	$440,000
Self Healing Concrete	Self-healing concrete base provides solid foundation with minimal maintenance	Link	Basilisk	$33-44/sq. meter	85564 sq.ft	$ 3,421,194.4
PVC pipe	Pipe used to distribute water and hold the strawberry plants		Home Depot	$8 /sq ft	290	$7,888,000
Bar Reinforcing Steel	Rebar used to reinforce concrete columns which are at risk of being subjected to eccentric loadings	Link	Alamillo	#4 rebar (.5 in by 20 ft) $6.55 each 4x69*18*6.55	4968	$32540

Pressurized Airlock	Chamber that pumps pressure through a low-energy fan unit, preventing cross-contamination between cultivation areas and external sources	Link	Terra Universal	$10,635 /unit	1	$10,635
PhytoMAX 2 LED Grow light	Large grow lights that enhance the plant's growth through different spectrums of light allow for more budding and growth potential	Link	Black Dog LED	$1500/unit	12,456	$ 18,684,000
Water Pump	70P Centrifugal Pump	Link	Oberdorfer	$448.00	1	$448.00
Chemicals	Limestone ($CaCO_3$) 50 lbs	Link	Mississippi Lime Company	$8.80	1	$8.80
Chemicals	Ammonium Sulfate 50 lbs	Link	Seed World	$18.95	1	$18.95
Reservoir	10,000 gal reservoir	Link	Norwesco	$5824.99	4	$23299.96
Pressure Booster	Simer 4075SS 24 GPM	Link	Simer	$429.99	1	$429.99
Flow Meter	NPT Flow Meter 3-30 GPM	Link	Flomec	$134.55	1	$134.55
Pipes	PVC pipes 1 in x 10 in	Link	Home Depot	$3.97	31680	$125,769.60
PES Membrane	Polyethersulfone Membrane Media Disc Cartridge 293 MM Diameter, 25/pk	Link	Serv A Pure	$388.96	33	$12,835.68

Fertilizer 3:1:1	Fertilizer	Link	Amazon	$51.69	47	$2,429.43
Fertilizer 0:0:6	Fertilizer	Link	Amazon	$18.16	129	$2,342.64
Tank Stirrer	0.5 HP Tank Stirrer	Link	Fusion Express	$1665.00	1	$1,665.00
Water Valve	Water Solenoid Valve	Link	Automation Direct	$384.00	1	$384.00
Charlotte Pipe 8-in x 20-ft 160 Schedule 40 PVC Pipe				$203	4800	$974,400
Carbon Steel Beam				102	9600	$979,200

Total

$38,347,895.57


intelliCulture
0.4%
Agri-BOTany
8.2%
Aqua-Refine
0.4%
8.2%
91.0%
Sky Farm
91.0%

Conclusion

We successfully designed a sustainable autonomous cultivation system for an 18-floor mixed-used business office and strawberry greenhouse. Thanks to its hydroponics technology, automated farming process, unique building design, and water filtration systems, our sustainable strawberry farm produces food that is safe for all to eat and can yield crops in a soil-free environment nearly anywhere, especially in areas with serious soil deficiencies and given the fact that conventional farming methods often risk yielding soil-borne diseases with their crops.

Ultimately, the strawberry greenhouse that we designed is a feasible food production powerhouse that can not only keep up with the exponential and relentless growth of the world population, but also influence agricultural practices towards mass automation to meet the ever-growing food demands of the human populace. While its total cost is upwards of $35 million, maintaining the greenhouse will be relatively cheap, and the profits that we can recoup from selling the crops produced in it will make it a financially viable long-term solution to excessive human population growth.

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