Autonomous Hydroponic System

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Elevator Pitch-We are senior design engineering students creating a self-regulating system using soil-less conditions to grow vegetation anytime, anywhere!

Executive Summary

The self-regulating food growing system is designed to grow crops anywhere, anytime regardless of the time of the year, environment, resources, etc. This system will use the least amount of resources necessary to produce a healthy crop meaning the places that have a limited amount of water or soil that is non-arable, one would be able to grow food in an environment that does not require soil.

Currently, the planet is facing issues such as climate change, non-arable land, increase in population therefore increase in demand for food. In order to address all these issues, our system will use innovation and hydroponics to grow healthy food without soil, enough resources etc. This system will be able to grow any vegetation anywhere, anytime. The system will be soil less, will use the water instead. The water will have minerals in it so therefore there will be no need for soil. The system will use artificial light instead of sunlight so it can be used in places that barely get any sunlight or sometimes do not get sunlight for days. The system will produce healthy organic crops without the use of any pesticides. This system will help eliminate the use of an excessive amount of resources needed to produce crops.

The demand for food that is not only healthy but is easier to grow is increasing day by day. People are more inclined towards food that is organic more than ever before. The healthier the food, the healthier are those that have access to it therefore the idea is to make sure everyone has access to healthy organic food rather than the food produced using pesticides and other hazardous chemicals.

The goal is to bring this system to reality to help tackle several global concerns such as food demand for growing population, climate change, making sure food can be grown in hostile environments such as non-arable soil, water scarcity. Another goal is to make this product available in every part of the world, especially the parts where the production of food is scarce, food is not healthy, and where hunger is a concerning issue.

***Abstract*—The self-regulating food growing system is a solution that will let humans grow any crop in soil less (Hydroponics) hostile environment. The system will consist of several different things to achieve its goal. Some of the things such as sensors will be used to measure temperature, humidity in the air etc. The system will also have a self-regulated irrigation system, artificial light. This system will utilize all the sensors and every other technological device to produce healthy crops anytime anywhere.**

***Keywords*— Hydroponics, irrigation, greenhouse, climate change, Sustainable foods, soil degradation, non-arable.**

I. INTRODUCTION

This report will provide an insight of hydroponic farming, which is growing plants without soil. In this documentation, we attempt to explain what hydroponics is and what are the various advantages of using this system. Along with that, we will show the main societal problems such as increase in global population, climate change, soil degradation, water scarcity in certain areas etc and how hydroponics system would serve as a better alternative. This report will further go over the Autonomous Hydroponics built by Team 3 of Senior Design. The report will cover all aspects of the project such as funding, project milestones, parts, its features, work breakdown structure, risk assessment, and marketability forecast

II. SOCIETAL PROBLEM

A. Awareness

According to an article, "A World Without Hunger," it has been estimated that the world population will increase drastically by 2050 to 9.2 billion and trying to sustain the growing population with food will require a significant increase in agricultural production. A number of agricultural and ecological scientists believe that a large-scale shift towards organic farming would not only increase the world's supply but might be the only way to eradicate hunger sustainably [11].

If we are able to sustainably increase and distribute food production, we might just be able to create a world without hunger, but we will not be able to sustain it without also eliminating extreme poverty. However, it is found that sustained improvements in agricultural productivity is central to socioeconomic development and studies have also shown that rapid reduction of extreme poverty is only possible when the incomes of smallholder farmers are increased [5].

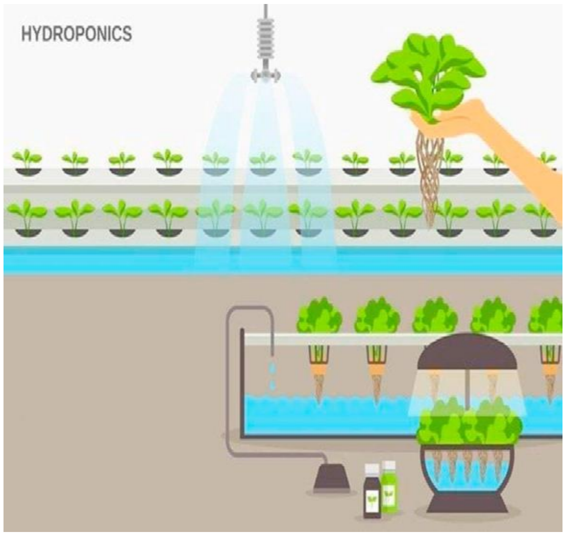
B. Why Hydroponics

Due to the increase in food demand, labor cost, unpleasant environmental conditions (such as soil erosion), and less area for agriculture, there is a major increase in motivation for indoor farming such as hydroponics [6]. With the world population growing rapidly every year, the demand for food is also increasing immensely. In order to keep up with the high demand for food new technologically innovative methods are being tested. These methods will be able to not only help the high demand for food but also the increasing labor cost and give us an alternative for the unpleasant environmental conditions as well as the lack of agricultural land. Soil is generally the most accessible developing medium and plants ordinarily develop in it. Continuing development of harvests has brought about poor soil fruitfulness, which ultimately has diminished the open doors for normal soil ripeness developments by organisms. Hydroponics provides solutions for these various problems and with more testing and newer technology it can become the next innovation for farming.

C. What is Hydroponics

Hydroponics is a subset of hydroculture, which is the growing of plants in a soil less medium, or an aquatic based environment. Hydroponic growing does not use soil but instead uses mineral nutrient solutions in water to feed the plants [2]. These nutrients are supplied to the roots in a solution that can either be flowing or stationary. By using hydroponic you can lessen the amount of water a plant requires and also the labor when compared to traditional farming.

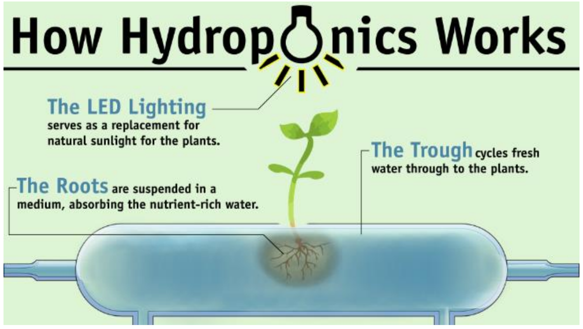
Besides soil, hydroponics uses a porous growing aggregate that includes sand, vermiculite, gravel, coconut coir, gravel, clay ball or perlite [2]. The nutrients and water required by the plants are fed directly to the roots which enable the plant to spend more of its energy growing above the soil rather than having to push through soil to gather the needed nutrients [6].



[2] Figure 1: Hydroponics

D. Advantages

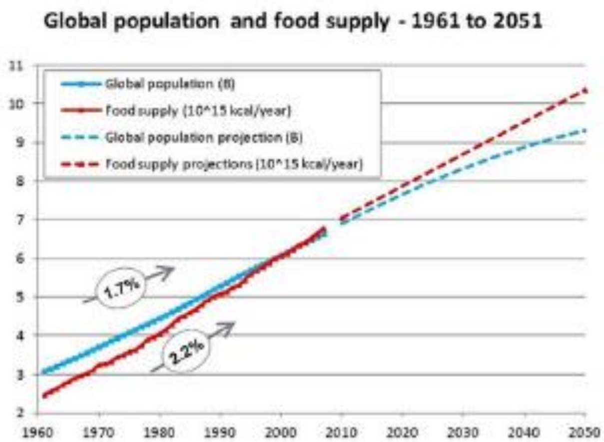
There are many other advantages to hydroponics besides using less water and labor. By using hydroponics, you can avoid many of the problems that affect soil-grown plants such as cutworms and soil-borne diseases that can ruin your crops which means that the use of herbicides and pesticides can be avoided [1]. With hydroponics you have a lot more control over the nutrients that your plants receive, and you are also conserving space because the plants can be grown very close to one another since their roots are much smaller. This means that everything grows at a much faster rate and produces higher yields within a smaller space [1].



[2] *Figure 2: How Hydroponics Works*

Innovation is changing the way we live our lives. We use technology and computers all day long. From when we wake up to making our breakfast. We use it to get to work or school and use it at both. Technology is even used for our sleep. It makes tasks easier and more efficient. Computers give humans the infinite possibility to create anything they imagine.

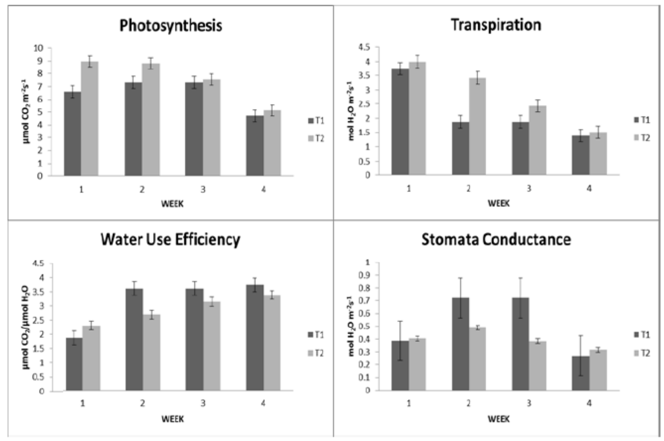
For this reason, technology and innovation are integral to use in agriculture, so that we can feed the growing population and bring crop growing to places where we couldn't before.



[5] Figure 3: Population vs. Food Supply

Information technology and communication can be used to manage and analyze the process of developing vegetation [7]. One concept farmers can do is use smart devices for intelligent farming. They can use devices to turn on and off sprinklers, calculate their crop yield, measure soil moisture levels, observe soil chemical levels like nitrogen and carbon, water ph levels, water usage, and even infrared crop health sensors*. These technological advances make growing crops faster, easier and way more intelligent. Another concept farmers can use is precision farming to observe, measure, calculate and respond to crops in sample sizes. The goal of precision farming is to optimize crop yield while minimizing the use of resources. The resources include labor, water, soil, and many more factors to farming. The two biggest factors to precision farming are environmental conditions like climate and water allocation. This way is more data and analytics-driven compared to smart farming. However, precision farming and smart technology to gather data. They both are the key factors in information technology and communication to manage and analyze agriculture.

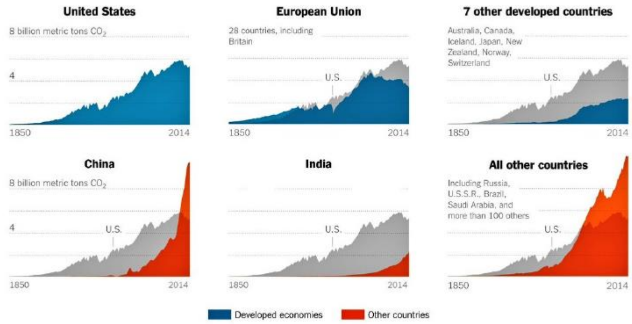
Another way innovation and technology can improve agriculture is optimizing the growing process. In [3] variable intensity and far red LED treatment were used to optimize plant growth. The experiments were conducted using Red / Blue / White (RBW) LEDs and Red / Blue / Far Red (RBFR) LEDs to grow plants indoors. This technology shows significant difference on flowering with the Far Red LEDs.



[3] Figure 4: RBW(black) vs. RBFR (grey)

Figure 4 shows the RBFR LEDs on the plant was more efficient with photosynthesis and used less water in the future weeks. The transpiration* levels were a lot higher and the stomatal conductance* was much lower. This evidence demonstrates the Far Red LEDs are much more effective in plant growth than the RBW LEDs. This Far Red technology can be used to grow vegetation in controlled environments where optimal sun energy isn't an option.

One important way we need to innovate in agriculture is the efficient use of water. Freshwater conservation is an integral part of farming intelligently. A simple but proficient way of saving water is using drip system technology. First of all, there are 4 main types of irrigation [8]. They are surface (flood and furrow), sprinkler, drip (including low-volume micro-sprinkler), and subsurface. Surface irrigation tends to lose the most water and is being replaced by drip system technology. However, for crops like rice, drip system technology would not be as effective as surface flooding. Other crops like most trees and standing plants can be watered with drip systems. In [7] Ren Ji explains how drip irrigation technology can use 35%-75% less water than sprinkler irrigation. This technology uses drip heads to drip water slowly to the soil with low pressure. This is more effective than sprinklers because the drips directly go to the plants and the roots. While sprinklers can miss the plants and shoot where water is not needed. Using drip system technology is an easy and effective way to save water while making sure the crops are getting watered enough.



[10]Figure 5: C02 emission trends

Climate change will continue to affect agriculture and food production in the world. The use of greenhouses and controlled environments are key to battling climate change along with the conservation and effective use of water.

[5] Figure 6: Influence of Soil Degradation

Influence of soil degradation on the main grape yield components over different farms across Europe.

Country	Farm	Bunches/vine (n)		Bunch w[b] (g)		Yield/vine (kg)		100 berries w (g)		TSS[c] (°Bx)		TA[d] (g/l)		pH	
		D[e]	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND
Italy	Fontodi	4.9B[a]	7.0A	144B	209A	0.71B	1.45A	180	193	24.5A	22.3B	6.19	6.20	3.15	3.12
	San Disdagio	6.5B	9.8A	99B	190A	0.81B	2.06A	156B	193A	24.9A	22.6B	5.01b	5.80a	3.4a	3.21b
France	Maison Blanche	7.5B	12.3A	124	176	0.97B	2.35A	121	142	–	–	–	–	–	–
	Pech Redon	5.9B	13.3A	73	153	0.53B	2.05A	128	174	–	–	–	–	–	–
Spain	Bodegas Puelles	9.1	9.3	184B	334A	1.72b	3.09a	210b	254a	25.1A	22.1B	–	–	3.30A	3.16B
Slovenia	Bonini	–	–	–	–	–	–	–	–	22.8A	19.7B	5.10b	5.41a	3.31B	3.41A
	Prade	–	–	–	–	–	–	–	–	18.3A	21.9B	6.69	5.99	3.18b	3.39a
All sites	*Mean*	6.1B	*10.1*A	122B	194A	*0.80*B	2.00A	151A	175B	*24.0*A	*22.0*B	*5.68*	*5.92*	*3.28*	*3.20*
	CV[f]	*56*	*30*	*49*	*41*	*80*	*46*	*27*	*24*	*9*	*6*	*15*	*8*	*5*	*4*

[a] For each yield component, means followed by different letters are statistically different (lowercase, $p \leq 0.05$; uppercase, $p \leq 0.01$; uppercase-bold, $p \leq 0.001$).
[b] w: weight.
[c] TSS: total soluble solids (sugar).
[d] TA: titratable acidity.
[e] D: Degraded soil ND: Non-degraded soil.
[f] Coefficient of variation (%).

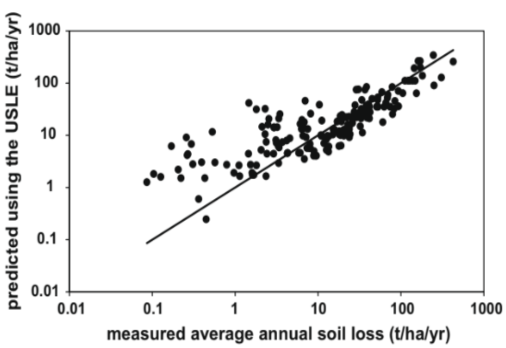
E. Climate Change

Another important concept that ties into the societal problem is climate change. With changing climates, food production is going to change. The places that are currently farmed may become arid and the soil could be infertile. Our major countries currently produce a lot of Carbon Dioxide. If things do not change our food production will have to adapt. Figure 5 [10] shows the trend in C02 emissions in the biggest countries.

F. Soil Erosion

We are living in the era of choice, and economies that are capitalism centered. In this era of choice, we are neglecting some key issues in the field of agriculture that can lead to farming lands being not good enough for growing crops due to soil erosion. Soil erosion tends to be the most overlooked issue when we consider the factors that are leading to land loss and soil loss, hence leading to a decrease in the overall agricultural production.

Soil erosion generally results from the natural elements such as wind and running water, but can also be the product of human activities such as tilling. There are other factors as well such as over cultivation, deforestation and overgrazing by animals. All the above listed factors are slowly leading to lands that are incapable of yielding the same amount of crops as they could in the past. To measure the rate of soil loss and predict future soil loss, an equation was developed. Universal Soil Loss Equation is the most widely used analysis tool to assess soil loss in a given area and also predict future soil loss depending on current and past data. Many studies have been conducted using USLE and have helped scientists better understand soil erosion and its effects on farming and agricultural yield.



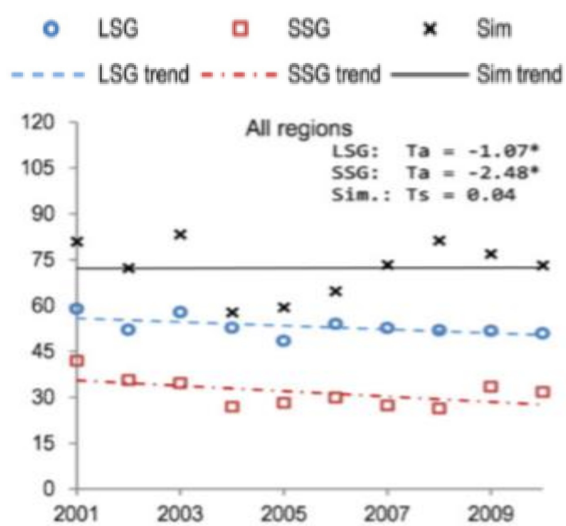
[5] Figure 7: Average Soil Loss

Figure 6 shows us a USLE graph that compares measured vs predicted soil loss based on theUSLE.

Today we have much accurate charts that can predict soil erosion which help us understand its implications. Using such methodologies, studies were conducted that showed the degrading effects of soil erosion. Study shows that degraded areas in nineteen organically farmed European and Turkish vineyards resulted in producing significantly lower amounts of grapes and excessive concentrations of sugar. Plants suffered from decreased water nutrition, due to shallow rooting depth, compaction, and reduced available water capacity, lower chemical fertility, as total nitrogen and cation exchange capacity, and higher concentration of carbonates **[5]**. Figure 7 shows the impact of soil erosion on the overall yield of grapes in various different sites in the world.

Soil erosion is mostly a result of natural elements but inefficient farming such as over cultivation have also contributed to an acceleration in soil erosion and has led to land loss leading to a decrease in the overall crop yield. Over cultivation or soil exhaustion due to repeated plantation of same crops leads to a deprivation of essential soil nutrients and provides no way Figure 7:

to replenish them. As observed in a study conducted in the South African sugar industry, there was a decline in the sugar yield over a period of ten years and the major reason was concluded to be soil degradation due to over cultivation of the same crop **[13]**. Figure 7 shows the trend of yield for large scale growers (LSG), small scale growers (SSG) and simulated trends.



[10] Figure 8: Trend

The data shown above gives us enough evidence for the fact that land loss is a real thing and is leading to a decline in overall agricultural yield which is adding to our existing and ever increasing issue of world hunger. The issues of not having land to farm on that can produce a sufficient yield of crop to directly or indirectly support a community is becoming real. To address this issue, we need to come up with a global solution that helps us correct this deficiency of crop yield and also can be done in an inexpensive way.

Using hydroponics can be one of the best ways to address the issues of land loss and decreased crop yield. Hydroponics is a soil less system that is efficient in water usage, uses less to no pesticides and leads to a greater controlled yield throughout the year. The soil less system consists of a mixture of essential nutrients in water or an inert medium **[10]**. This method completely eliminates our dependence on natural elements and helps us produce desired crops in hostile environments that normally wouldn't support farming. Hydroponics brings the ability to grow our own food in our backyard irrespective of the fact if it is a concrete backyard or a degraded land. This methodology becomes more revolutionary with automation and plant growth being expedited and maintained using sensors and algorithms. Our project will be able to execute and function in an autonomous way while maintaining the essentials of a hydroponic environment. It will be an example of very little human interference and utilization of available technology for generating a better crop yield in areas that can't fathom growing that crop in their natural environment.

G. Features

This system will have many features that will help it grow soil-less food. Those features are a watering system, sensors, artificial light, and filters. The watering system will have pipes that have minerals and nutrients rich water in them. Instead of using soil, the system will use mineral rich water to grow plants. The system will also include sensors that will help detect moisture in the air, pH levels, temperature. There will be different types of sensors that will be used to conduct these different measurements to make sure the growth of the plants is as perfect as it can be. The system will also deploy artificial light instead of using the sunlight, this will help control the amount of light needed to grow the crop; this will also help it grow in areas where there is less sunlight. The artificial light is much easier to control than the actual sunlight which makes it easier and a better choice for the system. The system will also use filters to clean the water that has already been used. The watering system will be pushing the same water in a loop and there will be filters deployed in the system that will clean the water to make sure it does not carry anything from the previous loop.

III. DESIGN IDEA

A. How does our idea address the problem?

Our design idea is to create a food growing system that can lead to crop production in areas where the soil doesn't have the ability to yield enough crop to sustain the local population and also to have a system that has no dependence on local weather. By allowing people to grow food anywhere and anytime will address the many problems that we are facing in our agriculture today. The convenience of being able to grow food in any type of environment will solve the issues of soil degradation and excessive water usage.

Our product is essentially about bringing forth a better and more efficient way of growing food faster. Our mini greenhouse farm will be able to grow any piece of produce from start to finish. To achieve food growth, we will be using Hydroponics to grow our crops. The greenhouse will use water or an inert medium to supply the necessary nutrients to the plants for their growth. This system can be further made more efficient by having sensors to maintain the chemical level for optimum growth per the targeted crop. We will be picking a single target crop to grow in our mini greenhouse farm. Using hydroponics we will be able to create our farm in an aquarium because the plants will not need a huge amount of space to grow and also we have a lot more control over the nutrients and the amount of water the plants receive.

Maintaining the right temperature is the next element that we will be addressing by either having a wind circulation system or by using continuous copper coil loops running under the water. Our ideal priority is to use the closed loop copper coils which will run under the water and will be externally cooled using a refrigerant and a compressor exhaust. Such a system proves to be 40% more efficient than a regular air conditioning system. If this system doesn't come to fruition then we can always fall back to a wind circulation system that can provide the desired temperature control but will be using more energy.

Having a light source is another component needed for our design. Having the right amount of light is going to be crucial to growing healthy plants. A plant has to be able to do photosynthesis to live. This is where the plant takes in light and converts it into a chemical so that it can be used to give the plant food and water. This process converts carbon dioxide to oxygen. For our design we will be using an LED growing light. This light will be controlled by a microcontroller. It will be able to change intensity levels (dimming) and also colors. The ideal light colors will be either red or blue. Depending on the plant we will control the light intensity and color. We will also need the microcontroller to control when the light turns on and off. We are going to aim to give the plant 14-16 hours of light a day and around 8 hours to rest. The disadvantage of having an incandescent light is that it gives up too much heat. This might pose a problem with our prototype because we will need to control the temperature. LEDs give off heat, but most of that heat is concentrated to the lightbulb itself and doesn't affect the environment like an incandescent light bulb would.

By combining the above mentioned technologies, our design idea will be able to tackle the societal problem that is at the heart of our project. Our design will be able to provide the ability to grow food anywhere and anytime with very little human intervention. The problems brought about by soil loss and climate change that adversely affect agricultural production in many areas, will no longer be an issue if we eliminate our dependence on them. This is exactly what our design idea will accomplish and hopefully we will be able to have a large scale application of such a product to see our vision become a reality.

B. What Technologies are needed for our design?

Our design idea will be heavily reliant on the sensor technology. We will be using multiple sensors that will be there to measure temperature, humidity, chemical level and pressure. Furthermore, we will be using a microcontroller to automate our system. Using a microcontroller helps us minimize the design cost and make it more compact and eliminates complexities of higher level systems. A key part of our design will be the closed loop copper coils for cooling and maintaining the temperature. This is a relatively new technology but it is 40% more efficient than other temperature control systems out there. If the application of such a system doesn't come to fruition, then we will revert back to a simple wind circulation fan to regulate the temperature. As we will also need a light source for our plants, we will be relying on the LED growing light. This technology helps us eliminate the dependence on sunlight and we will be able to provide our plants with a much controllable light source that will provide light for at least 14 hours a day.

C. What is unique about our idea?

Similar ideas have been attempted before but none offered the ability to control all the elements that are needed for optimum plant growth. One of the ideas was very similar to ours where IOT(internet of things) were being used to control the growth of plants in a controlled system. This system would be using sensors just like us and then feeding the data to a program to adjust the appropriate control elements**[15]**.We are not sure if it was ever implemented but it certainly resembled our project but our idea is still unique. This system was still reliant on sunlight and was using just water sprinklers and air flow to regulate the temperature. We will be using a closed loop coil system for regulating the temperature and would be using LED growing lights to eliminate dependence on sunlight.

Another similar idea was being implemented which was also based on hydroponics but was using neural networks for regulating the system. Use of a deep neural network system is a clever way of improving the efficiency and optimization of the system**[6]**. This system exhibited the same applications as us but again it was dependent on sunlight and didn't have a dedicated temperature management system.

In doing our research we have come across many systems that were similar to our idea. They also mimicked our design to a point where we were worried that our system might not be unique enough. Doing further research, we were able to accomplish that indeed our system is unique and will be more efficient than previously employed ideas. Our system will be an autonomous system requiring minimal human interference while maintaining and regulating optimum plant growth. It will be using less energy as compared to other greenhouse systems out there and will provide the ability to grow food anywhere and anytime using a self-controlled environment.

1. *Feature*

This system will have many features that will help it grow soil-less food. Those features are watering system, sensors, artificial light, and filters. The watering system will have pipes that have minerals and nutrients rich water in them. Instead of using soil, the system will use mineral rich water to grow plants. The system will also include sensors that will help detect moisture in the air, pH levels, temperature. There will be different types of sensors that will be used to conduct these different measurements to make sure the growth of the plant is as perfect as it can be. The system will also deploy artificial light instead of using the sunlight, this will help control the amount of light needed to grow the crop; this will also help it grow in areas where there is less sunlight. The artificial light is much easier to control than the actual sunlight which makes it easier and a better choice for the system. The system will also use filters to clean the water that has already been used. The watering system will be pushing the same water in a loop and there will be filters deployed in the system that will clean the water to make sure it does not carry anything from the previous loop.

2. *Hardware*

There are several hardware components we will need for this project. We will need an artificial light panel, a pump to pump water throughout the pipes, a light sensor that will help detect when the time is for light and therefore will turn on the light. We will also need a sensor to measure humidity in our greenhouse. Another sensor will be needed to measure temperature as well. We will also need a sensor to measure pH levels as well as another sensor to measure the levels of nutrients in the water. We will need a filter to keep the water clean running through the pipes. We will use the artificial light panel in our system instead of using the actual sunlight as this will give us full control over the environment of the greenhouse hydroponics system.

3. *Software*

We will be using an IDE to program the microcontroller(s). Depending on the microcontroller used we will select the IDE. The languages that will most likely be used are C and Python. We will also be using Microsoft Excel to save data and keep track in order to help us understand how the system is working as a whole. This will help us grow vegetation more efficiently.

IV. FUNDING

part or company	cost
Digikey	$20.67
Amazon	$196.21
Sparkfun	$38.75
Original chiller	$12.50
Amazon	$52.19
2nd relay	$26.64
Chiller	$92.43
Potentiometer	$9.49
Pizza	$49.75
Petsmart	$32.61
Fryes	$6.51
Home depot	$37.56
Aquarium	$93.08
Total	$668.39
cost per person	$133.68

[16] *Figure 9: Total cost*

Parts Provided	Provider
DHT11	Akash
Raspberry pi	Taranjit
Arduino uno	Akash
Mouse	Akash
Keyboard	Akash
Wires	Akash
Monitor	Navjot
Electronic parts	Navjot
Voltmeter	Navjot
Fan	Navjot

[16] *Figure 10: Parts*

V. PROJECT MILESTONES

The table below shows the major milestones regarding the completion of the project. Each milestone was a pivotal step towards the completion of the system. The milestones include research, development and testing.

Major milestone	Milestone date
Societal Problem	09/2019
Design Idea	09/2019
Feature Set Contract	10/2019
Ordering Parts	10/2019
Humidity Sensor	10/2019
Relay Switch	10/2019
Water Temperature	10/2019
pH Sensor	11/2019
TDS Sensor	11/2019
LED Intensity	11/2019
Heater/Chiller	11/2019
Dispenser Working	11/2019
Dispenser Automation	11/2019
Working Prototype	12/2019
Device Testing	02/2020
New pH Sensor	02/2020
Marketability Review	02/2020
Automation Reached	03/2020
Deployable Prototype	04/2020

[16] *Figure 11: Milestones*

VI. WORK BREAKDOWN STRUCTURE

Work Breakdown Structure is one of the most important parts of the project, it goes over every single part and feature that everyone worked on. It also helps keep track of the progress of the project and which parts require and required more work and time than the other parts did. Each individual's work was assigned and then once they completed the assigned work, they wrote their hours down as to how much time it took them to finish that certain part of the project. This also includes project schedule including milestones and events that were significant to the project. It basically covers hours aspect of the project as to how many hours each individual worked, and which features of the project they worked on.

Tasks assignments needed to complete each feature including summary (by feature) of hours in total and by team member

Full WBS

Task	Duration	Hours	start	end	Assigned to	completion
All parts ordered	6 days	48	Mon 10/21/19	Sat 10/26/19	Team	100%
Designing the circuits	6 days	20	Mon 10/21/19	Sat 10/26/19	Team	100%
Setting up chiller/heater + pump	6 days	5	Mon 10/28/19	Sat 11/2/19	Navjot	100%
Custom lid with leds + exhaust fan	6 days	20	Mon 10/28/19	Sat 11/2/19	Satwinder	100%
Adding foam + making cut outs	6 days	3	Mon 10/28/19	Sat 11/2/19	Parmvir	100%
Circulation pump setup	6 days	10	Mon 11/4/19	Sat 11/9/19	Akashdeep	100%
TDS/EC +pH coding	6 days	5	Mon 11/4/19	Sat 11/9/19	Taranjit	100%
Relay Setup	6 days	5	Mon 11/4/19	Sat 11/9/19	Satwinder	100%
Testing + Fixing code for recorded data	6 days	10	Mon 11/11/19	Sat 11/16/19	Parmvir	100%
Temperature and Humidity sensor setup	6 days	10	Mon 11/11/19	Sat 11/16/19	Akashdeep	100%
Testing for measurements	6 days	25	Mon 11/18/19	Sat 11/23/19	Parmvir	100%
Getting ready for demo	6 days	20	Mon 11/25/19	Sat 11/30/19	Team	100%
Testing measureable +fixing	6 days	20	Mon 11/25/19	Sat 11/30/19	Team	100%
Demo ready	1 day	5	Fri 12/6/19	Fri 12/6/19	Team	100%
Testing and Fixing	48 days?	25	Mon 12/9/19	Sat 1/25/20	Team	100%
Plant the Plant	6 days	5	Mon 1/27/20	Sat 2/1/20	Team	100%
Name the Plant(Germinating)	6 days	1	Mon 1/27/20	Sat 2/1/20	Team	100%
Adjusting nutrients and pH	6 days	5	Mon 2/3/20	Sat 2/8/20	Navjot	100%

Humidity+Temp+light intensity Range refinement	6 days	5	Mon 2/10/20	Sat 2/15/20	Akashdeep	100%
Water flow control	6 days	5	Mon 2/17/20	Sat 2/22/20	Satwinder	100%
Temp adjustment	6 days	8	Mon 2/17/20	Sat 2/22/20	Parmvir	100%
Taking measurements & adjusting	6 days	20	Mon 2/24/20	Sat 2/29/20	Satwinder	100%
Program Automation	6 days	30	Mon 3/2/20	Sat 3/7/20	Taranjit	100%
Building GUI	6 days	20	Mon 3/9/20	Sat 3/14/20	Navjot	75%
Design measurables testing	34 days	20	Mon 3/23/20	Sat 4/25/20	Taranjit	100%
Showcase	1 day	5	Fri 5/8/20	Fri 5/8/20	Team	0%
3-Work Breakdown Structure Report	8 days	10	Mon 10/14/19	Mon 10/21/19	Team	100%
4-Project Timeline	8 days	10	Mon 10/21/19	Mon 10/28/19	Team	100%
5-Risk Assessment Report	8 days	10	Mon 10/28/19	Mon 11/4/19	Team	100%
6 – Project Technical Review	29 days	10	Mon 11/4/19	Mon 12/2/19	Team	100%
7 - Laboratory Prototype Presentation	5 days	10	Mon 12/2/19	Fri 12/6/19	Team	100%
8 - Revised Problem Statement	27 days	10	Wed 1/1/20	Mon 1/27/20	Team	100%
9 - Device Test Plan Report	8 days	10	Mon 1/27/20	Mon 2/3/20	Team	100%
10 - Market Review	22 days	10	Mon 2/3/20	Mon 2/24/20	Team	100%
11 - Feature Report	8 days	10	Mon 2/24/20	Mon 3/2/20	Team	100%
12 - Mid-term Progress Review	22 days	10	Mon 3/2/20	Mon 3/23/20	Team	100%
13 - Deployable Prototype Technical Review	29 days	10	Mon 3/23/20	Mon 4/20/20	Team	100%
14 - Final Documentation Report	8 days	10	Mon 4/20/20	Mon 4/27/20	Team	100%
1-Problem Statement Report - Individual	8 days	10	Mon 9/2/19	Mon 9/9/19	Team	100%
1-Problem Statement Report - Team	15 days	10	Mon 9/9/19	Mon 9/23/19	Team	100%
2-Design Idea Report	8 days	10	Mon 9/23/19	Mon 9/30/19	Team	100%

[16] *Figure 12: Full WBS*

Task	Hours	Assigned to	completion
All parts ordered	48	Team	100%
Designing the circuits	20	Team	100%
Getting ready for demo	20	Team	100%
Testing measureable +fixing	20	Team	100%
Demo ready	5	Team	100%
Testing and Fixing	25	Team	100%
Plant the Plant	5	Team	100%
Name the Plant(Germinating)	1	Team	100%
Showcase	5	Team	0%
3-Work Breakdown Structure Report	10	Team	100%
4-Project Timeline	10	Team	100%
5-Risk Assessment Report	10	Team	100%
6 – Project Technical Review	10	Team	100%
7 - Laboratory Prototype Presentation	10	Team	100%
8 - Revised Problem Statement	10	Team	100%
9 - Device Test Plan Report	10	Team	100%
10 - Market Review	10	Team	100%
11 - Feature Report	10	Team	100%
12 - Mid-term Progress Review	10	Team	100%
13 - Deployable Prototype Technical Review	10	Team	100%
14 - Final Documentation Report	10	Team	100%
1-Problem Statement Report - Individual	10	Team	100%
1-Problem Statement Report - Team	10	Team	100%
2-Design Idea Report	10	Team	100%
Total hours	299		

[16] *Figure 13: Team*

Task	Hours	Assigned to	completion
Circulation pump setup	15	Akashdeep	100%
Temperature and Humidity sensor setup	10	Akashdeep	100%
Humidity+Temp+light intensity Range refinement	5	Akashdeep	100%
Total hours	30		

[16] *Figure 14: Akashdeep*

Task	Hours	Assigned to	completion
Setting up chiller/heater + pump	5	Navjot	100%
Adjusting nutrients and pH	5	Navjot	100%
Building GUI	20	Navjot	75%
Total hours	40		

[16] *Figure 15: Navjot*

Task	Hours	Assigned to	completion
Adding foam + making cut outs	3	Parmvir	100%
Testing + Fixing code for recorded data	10	Parmvir	100%
Testing for measurements	20	Parmvir	100%
Temp adjustment	8	Parmvir	100%
Total hours	41		

[16] *Figure 16: Parmvir*

Task	Hours	Assigned to	completion
Custom lid with leds + exhaust fan	10	Satwinder	100%
Relay Setup	5	Satwinder	100%
Water flow control	5	Satwinder	100%
Taking measurements & adjusting	20	Satwinder	100%
Total hours	40		

[16] *Figure 17: Satwinder*

Task	Hours	Assigned to	completion
TDS/EC +pH coding	5	Taranjit	100%
Program Automation	15	Taranjit	100%
Design measurables testing	20	Taranjit	100%
Total hours	40		

[16] *Figure 18: Taranjit*

VII. RISK ASSESSMENT

INTRODUCTION

In any Project, there are always unpredictable outcomes that pose risk to the project or certain parts of the project. These uncertain events can include both negative and positive impacts, but one must be ready if it does have negative impacts on the project. Knowing these risks gives us an idea as to what to expect and the solutions for those risks. The goal of the risk assessment is to figure out all the potential risks and find solutions for them so when and if they ever pose any problem, we can be ready with alternate solutions.

A. Heating system

In order to make sure the conditions for the plant growth are found, we have to make sure the water temperature inside the aquarium is at a certain level. In order to do this, we decided to use a 150W heater to heat the water. Our goal was to change the temperature in a certain amount of time but the 150W heater was not enough so we decided to use more than one but even that will not be enough as it took more than an hour for one heater to raise the temperature about 7 degrees. So in order to make sure the temperature stays where we want and can be raised when needed, we came up with another solution after talking to Professor Levine. The solution was that if the heating system doesn't work then we can use the bucket that sits outside the aquarium and heats water at slow rate and when temperature needs to be raised, a pump would take water from the bucket and spill it in the aquarium thus change the water temperature to ideal temperature that needs to be at.

B. Failure of Raspberry Pi

We are using raspberry pi to run our code, to collect data, to interact with sensors, with relay systems. Our project depends on the critical work of Raspberry pi and if it does not work, it can have a major impact on our project; it can jeopardize the whole project. The likelihood of this is very low as we've never had a problem with raspberry in our previous projects and so far, we haven't had any problem with it in our project. In case this problem does occur, we have figured out a solution for it. Instead of using Raspberry pi, we will then be using either Asus Tinker Board or ODroid XU4.

a. Asus Tinker Board

Asus Tinker board is an alternative option for Raspberry Pi, it carries the same DNA as raspberry pi. Built by Asus, one of the biggest manufacturers of hardware in the world, has everything one needs in Raspberry pi. It has the same layout, size, feature set, and a 40-pin connector. It has 2GB RAM. Asus Tinker Board is about $30 more than Raspberry Pi but one gets more in it too **[2]**.

b. ODroid XU4

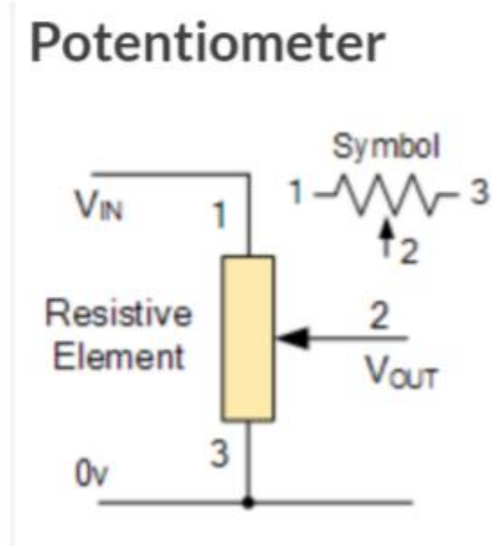
Another replacement for raspberry pi would be ODroid XU4, built by and using Samsung's 8-core CPU. It can run Android 4.4 (kitkat), 5.0 (lollipop) and 7.1 (Nougat) **[2]**.

c. Banana Pi-M64

This is another replacement for Raspberry pi that can be used in case our Raspberry pi fails. It can run Android, Ubuntu, and Debian, and several other operating systems. It has a dual-core GPU, a 2 GB Ram. It also has a 8 GB onboard storage which can be expanded using microSD **[2].**

C. LED light system

Since our aquarium can be anywhere and most likely won't be getting any sunlight, we needed to have artificial light for the plant to do photosynthesis. So, for our project, we chose an LED light system to use. We were running into one problem, that was to change the intensity of the light for our plant. For that problem, our solution is a potentiometer. Potentiometers create a change in resistive value when a connected shaft is rotated. Below is the image of the potentiometer with a resistive element showing. Potentiometer is three-terminal mechanically device; they are passive meaning they do not require external power supply or additional circuitry in order to perform their function **[1]**.



[15] *Figure 19: Potentiometer*

D. Designing the Circuit

Designing the circuit layout is a critical element for our project. If not done right, many risks might arise. For our project, there are multiple circuits that are needed to execute various distinct parts in harmony. Following are the circuits that we are key in receiving the inputs for our project elements:

1. Circuitry for LED intensity adjustment using a potentiometer
2. Circuitry for the temperature sensors
3. Circuitry for the humidity sensors

The risks that may arise can range from a simple wiring issue to the usage of too small of a resistor leading to higher voltages than expected. These issues can result in overheating, short circuit or permanent damage to elements such as temperature sensors. Risk likelihood is very low, but the impact will jeopardize the project. Risk mitigation can be achieved by designing the circuits and then testing it out using PSPICE or OrCad lite. This way, we will be able to observe the expected voltages and current in the circuit without jeopardizing actual physical elements. Furthermore, we can track the implementation of risk mitigation by testing the circuit using a voltmeter in real time to assess any wiring mishaps that can happen by mere unexpected contact between two or wires bare wires.

E. Failure of one or more Sensors

Our design is heavily dependent on sensors for inputs that are necessary to trigger elements such as LEDs, exhaust fan, heating and cooling of mixture and nutrient levels. Following are the sensors and risk associated with them:

a. Temperature Sensors: Temperature sensors are being used to measure the temperature of the mixture and use it as an input in triggering the heater or cooler. A failure of the temp sensor can lead to overheating or cooling of the mixture. Risk likelihood is very unlikely, and the risk impact is limited as well.

b. Humidity Sensor: Humidity sensor acts as an input for triggering the exhaust fan. The failure of this sensor can lead to the exhaust fan never turning on or never turning off. This can lead to a humidity level that will be outside our design measurables and can be critical to the growth of the plant. The risk likelihood is 6 very unlikely as well and the impact is limited as well.

c. TDS/EC sensor: TDS/EC sensor is used to detect the nutrient level and the pH level for our mixture. Failure of this sensor can lead to an unwanted amount of nutrients in the mixture and a pH out of the expected range. This can negatively impact the growth of the plant and does have a high impact. The risk likelihood is very unlikely, and the impact is limited as well.

F. Dispenser

The dispenser is the key element in maintaining the required pH and nutrient level in our hydroponic system. It will be dispensing nutrients and pH solutions into the main water chamber in small bursts with a preadjusted volume. There are multiple risks that can arise which are listed as follows:

a. Excess volume being dispensed
b. No dispensing happens despite the triggers from the Rpi
c. Complete failure of the dispensing unit

G. Risk Mitigation:

The TDS and EC sensors will be able to point out any irregularities in the system if excess or no volume is being dispensed. This will help us catch the issue promptly. We will be setting up alarms in our code in case irregular levels are detected over a longer period than normally expected after dispensing nutrients into the mixture. Additionally, we will have extra dispensing nozzles on hand to further mitigate the risk in case of nozzle failure. The risk likelihood is low, and the impact is limited as well. Detection of a complete failure of the dispensing unit will also fall on to the TDS and EC sensor. This is a high impact failure which depends on the reliability of the product. To mitigate this risk, we will have an additional dispensing unit on hand which can be quickly used to replace the failed dispenser. The risk likelihood is very unlikely, and the risk impact is really high. In order to make sure this does not happen, we will be tracking the risk to make sure we detect it before it happens.

H. Risk Tracking:

Risk Tracking would play a mjor role in the success of the product as it could help us track some of the risks that are posed and help us resolve those risks before they end up halting the project. Risk Tracking will work using Risk mitigation which is discussed above. Again, Risk Tracking will be performed by usage of a TDS/EC sensor. Software will be our key-way to alert us of any irregularities that are observed and appropriate action will be taken as discussed in risk mitigation above.

I. Aquarium

The aquarium is where everything will be sitting, but with everything in it, if it breaks, it could be a problem. The likelihood of this problem is very low but the impact even though it is limited is still big; it would require a whole new aquarium that is much stronger and much more durable. Another problem we can run into is the fact that the Aquarium is gonna have a lot of gaps on the top where things such as fan, pipes from dispensers will be going in; we will have to make sure that nothing else goes into the aquarium through those gaps. In order to make sure nothing like that happens, we will have to make sure all the gaps are sealed and secured.

A. Personal Issues

We all have life outside the school, and some of us have family to take care of. If there is ever a family issue in one of our houses, others will help do that as individuals part in order to make sure we stay on track and finish the project on time. Some of the issues were directly the result of covid-19, which made it harder for us to work together as well put health and safety of not ours but our family members at risk which is something we had to consider.

K. Sensors

In any Project, there is always a need to run tests to check all of its features and parts to make sure everything runs the way it is supposed to. In our project we had several features such as temperature sensor, humidity sensor, pH sensor, and TDS sensor. Risk Assessment helped us realize some of the potential risks we can run into. There were several risks that we thought we might run into so in order to avoid those, we made sure to have solutions ready for them. During the fall semester we realized that our original ph sensor was not showing accurate readings. We were using the default code that the sensor came with. In the code the sensor was pre calibrated with an equation that would convert the voltage recorded to a ph value. This equation was written in y = mx+b format.

```
float phValue=(float)avgValue*5.0/1024/6; //convert the analog into millivolt
phValue=-3.5*phValue + 22.45;                   //convert the millivolt into pH value
Serial.print("    pH:");
Serial.print(phValue,2);
Serial.println(" ");
digitalWrite(13, HIGH);
delay(1000);
digitalWrite(13, LOW);
```

[16] *Figure 20: pH calibration*

We then again tested pH for the Gatorade and water. The readings were close at first. We then tested it using a different liquid which was milk. The pH reading was way off. After this we measured the Gatorade and water again and the readings were not close anymore.

	ph value (post calibration)	actual
water	6.7	6.8
gatorade	3.1	2.9
milk	5.5	6.6

[16] *Figure 21: pH results*

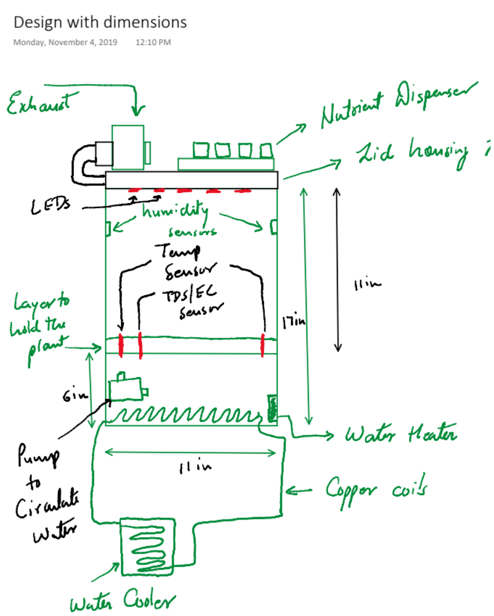
This caused us to come to the conclusion that our ph sensor is not working correctly. We ended up purchasing the Gravity: Analog pH Sensor/Meter Kit V2. This sensor was a lot more reliable and a lot more expensive. We decided we needed something more reliable and the price did not matter. It came with buffers that were ph levels of 4 and 7. These buffers were used to calibrate the new sensor. All we had to do was run a program that reads the initial ph value and calibrate it to the actual ph buffer reading. We did this with both the 4.0 and 7.0 ph buffers.

L. Unanticipated Events

There are always unanticipated events that could happen during a project time period. One can be prepared for certain events that could be connected to the project but if there are any unanticipated events that indirectly affect the project, one would not be prepared for that. There were several risk assessments that we made based on the project but the one we never thought of was a global pandemic. Covid-19 posed so many difficulties in the progress of the project. First school got shut down due to the virus and then soon after the city followed with shelter in place order which meant that we could not come to Navjot Benipal’s house where our project was to work on. We had to finish everything the day before shelter in place was put on. It also led to another issue which is that we could not get a LCD display because it would take too long to arrive and it would not be safe for us to come over and help on the project after that day.

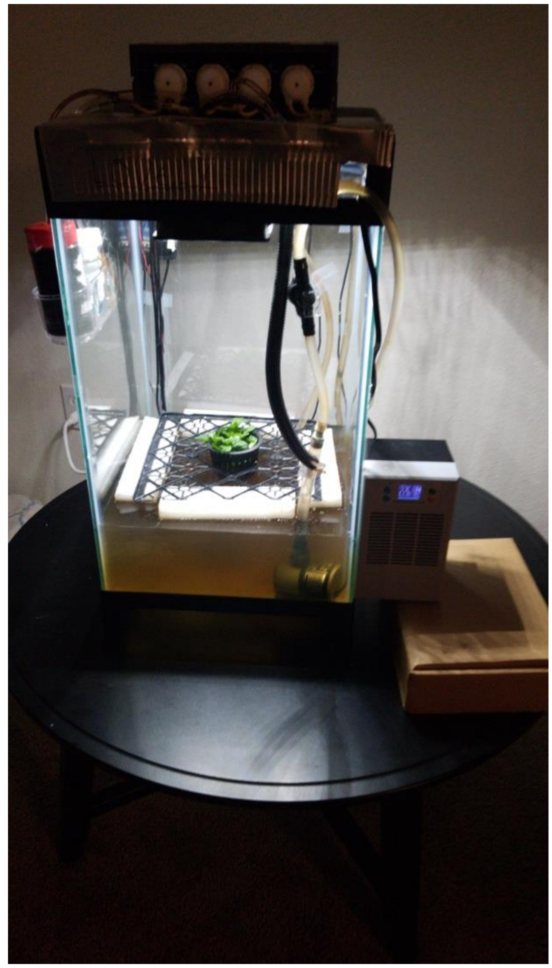
“VIII. DESIGN PHILOSOPHY”

When we first decided to do Autonomous Hydroponics System, we did not have it in mind as to what the design of the project would look like. We had the idea that it would be something that would not be too big so we could display it easier as well it would be a small prototype that can be made into as big of a project as one would want. So we decided to get together and draw some rough drawings of what the prototype could look like. One of the first drawings we made is attached below, although we did make several changes as to when it comes to hardware and design.



[16] *Figure 22: Early Design of the Project*

So, after few more discussions with the team, we all decided to go with a small aquarium (refer to page 21). First, we decided to add an exhaust fan that was big in size but after realizing that it does not meet the design standards, we decided to change it for the Spring semester. So in spring semester we installed an exhaust fan taken from an old CPU. Below is the pic of the design at the end of the project.



[16] *Figure 23. Final Design*

"IX. DEPLOYABLE PROTOTYPE STATUS"

The status of the deployable prototype as of the ending of the Spring term is almost as we hoped it would be but of course it is not at the exact level that we had hoped to achieve due many altercations that we faced this semester. The prototype is performing accurately and is able to maintain and grow the plant efficiently. Our new ph sensor, the Gravity: Analog pH Sensor/Meter Kit V2, is working a lot better and performing more accurately compared to our old ph sensor. There was no need to adjust the readings or look for a better temperature sensor because the temperature sensor that we have is displaying fairly accurate data. The TDS sensor is also working well and sends a signal to the dispenser once the nutrient level goes below the set level just like the ph sensor. Lastly, the humidity sensor is working effectively as well and anytime the humidity increases in the tank it sends a signal to the arduino which turns the fan on to level the humidity.

This semester we decided to incorporate everything on one microcontroller instead of two. We decided to shift everything on the arduino because it was going to make it easier for us to display everything on a screen if we had all of the stuff on one microcontroller. However, we were not able to get the display screen due to the unexpected pandemic. So because we were not able to get the right display screen we were not able to display anything on our prototype but instead we used a monitor which did almost the same job as the GUI. That was the only part of our desired design idea that we were not able to meet but besides that the deployable prototype fully meets the desired design idea. Our design is far more refined and presentable this semester than it was in the fall semester.

“X. MARKETABILITY FORECAST”

The deployable prototype has made great strides since the laboratory prototype. The changes include extensive testing improving reliability for the sensors. A change in the pH sensor which since the previous one was not reliable. The system has also moved over to one microcontroller instead of two. Also, the mechanical changes have made the system nicer to look at and decrease electricity usage along with reducing the noise to provide a greater experience for the customer. There have been many changes within this span of time.

The design has made great progress between the laboratory and deployable prototypes, but much more has to be done to bring this product to market. First of all, a floatable tray needs to be made that can hold four grow cups. This allows for maximum potential for plant yield.

Next, the graphic display will need to be improved. Due to Covid-19 an alternate solution was made because of the shelter in place. As of now the display is a monitor and the user selects the plant via keyboard. This works for now because it does still meet the design feature set for the deployable prototype. With more time a small screen will be made on the bottom of our design that shows the live measurements instead of the monitor doing that. The GUI will be a touch screen so the user can select which plant they would like to grow. The program will then use this plant's optimal growth parameters throughout the growing process.

Another feature that could be added is an app or notification system for when liquids need to be replaced or the plant(s) are ready. It can even have a camera to show daily growth which can be seen on the application. This will also help with data collection. The user can see when the plant is ready to be harvested. A portable user interface would greatly enhance the user experience.

The last and most pivotal part of our design is creating an algorithm that grows any plant to its optimal levels autonomously.

This will require vast testing to find the optimal growth levels for every plant. Once these levels are found then the algorithm will know what to use as the parameters. Also, the parameters need to change throughout the life cycle of the plant in order for the plant to be optimally grown. So if a plant needs to have a higher humidity in the beginning of the growing process, the algorithm will adjust the parameters accordingly. This will grow the best and fastest plant possible. These studies for optimal plant growth have already begun. The current plant being tested is peppermint. Levels are being adjusted with prior experiments used as a base for parameters for the plant..

Although the design has come a long, there is still work to be done for the design to be marketable. Design specs that need to be added or changed are the floatable tray, Graphic User Interface on the physical device, a software application to view your plants progress and help aid in the growth of the plant, and more data and testing for optimally growing different types of plants.

“XI. CONCLUSION”

Hydroponic Farming aims to reduce human interference by using the available technology and generating produce without the use of natural resources. It would result in getting yield in those areas which were earlier unable to produce because of lack of resources. Along with that, it solves the problems of climate change and soil erosion. In order to create this project, we will need several different types of parts as well as funding to fund the project. For right now, we are looking at somewhere around $500 for the project. We will need that funding to buy parts such as microcontrollers, LED lights to provide light instead of sunlight, sensors to measure temperature, pH levels, nutrients, moisture in the air. We will also need a fish tank for the project. Other things that we will need are copper coils, voltage controllers, wires, heating and cooling system, plants and feed, water filter.

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References are present and appear to follow the IEEE guidelines.

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[16] Sandhu Taranjit; Benipal Navjot; Singh Parmvir; Singh Satwinder; Jida Akashdeep, Produced by one or more members of CSUS 2019-2020 Senior Design Team 3

GLOSSARY

Appropriate list of technical terms, specialized jargon or other items specific to your
project and this report.

Self-regulating: Having power to produce and to carry its own activities.

Non-arable: Land which is unsuitable for farming.

Sustainable food: Food which is healthy for consumers and produced in an ecologically and socially responsible way

Hydroponics: It is a method to grow plants without using soil and instead using mineral nutrient solutions in water solvent.

Soil exhaustion: Poorly managed soil which is no longer able to support or grow plants.

Greenhouse: A glass building in which plants are grown that need protection from cold weather.

Socioeconomic: Relating to the interaction of social and economic factors

Transpiration: The process where moisture is carried through plants from roots to small pores on the underside of leaves

Infrared Crop Health Sensors: Plants that are healthier tend to reflect more green light than red light, which is why they look green

Appendix A. User Manual

Step 1:
The system has three power outlets for the whole design. The three parts should be connected to a surge protector to protect against an unwanted spike in voltage. The three parts are the microcontroller, heater/chiller, and the relay switch.

[16] Figure A-1 Surge Protector

Step 2:
Pour 20 litres of water into the system. Make sure to pour directly into the chamber. It is recommended to use a funnel. The system recycles the water so there is no need to add water after this for the life of the plant.

Step 3:
Pour the pH up, down, and the nutrients in each dispenser bottle. The bottles are labeled and need to be in the correct order to dispense the correct liquid.

[16] Figure A-2 Liquid dispenser bottles

The leftmost bottle is for the nutrients. The middle is to increase the pH. The rightmost is to decrease the pH. Refill the bottles as needed.

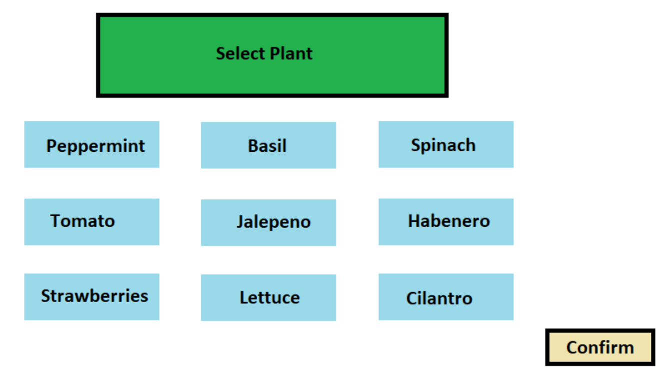
Step 4:

Lift the lid and insert the plant inside the cup. Make sure roots are spread out and at least touching or going through the holes in the bottom of the cup. It is recommended to start the seed in a peat to allow the plant to sprout enough to stand on its own in the cup. The peat can be inserted inside the cup. This is recommended for optimal growth, but not mandatory.

[16] Figure A-3 Young Plant in Peat

Step 5:

Using the graphic user interface select which plant you are growing. Once selected the system will automatically adjust the pH and nutrient level for optimal growth. How does it do so? Magic? No way! The algorithm gets the optimal parameters for growth and adds nutrients to the needed levels. It also balances the pH level! Once the plant is selected nothing else needs to be done other than refilling the bottles. It will take about 20 minutes for the nutrients to reach the appropriate TDS level for the plant. Initially check the bottle to make sure it's not full. The water will not look clear anymore.



[16] Figure B-4 Plant Selection

Appendix B. Hardware of the deployable prototype system

Hardware

There are several hardware components we used for this project. We used Arduino UNO, an artificial light panel, a pump to pump water throughout the pipes, a light sensor that helps to detect when the time is for light and therefore will turn on the light. We used a sensor to measure humidity in our greenhouse. Another sensor needed to measure temperature as well. We also need a sensor to measure pH levels as well as another sensor to measure the levels of nutrients in the water for which we used a dp-4 dispenser. We will need a filter to keep the water clean running through the pipes. We will use the artificial light panel in our system instead of using the actual sunlight as this will give us full control over the environment of the greenhouse hydroponics system.

A. Arduino UNO

Arduino UNO is the brain of our project. We used Arduino UNO 3 for our project implemented code on it to be an autonomous system. pH sensor, Humidity Sensor, TDS/EC Sensor, Relay system, water temperature sensor, LED light, exhaust fan and nutrient dispenser is connected to Arduino.

[16] Figure B1: Arduino

B. pH Sensor

A pH sensor is one of the most essential tools that’s typically used for water pH measurements. This type of sensor is able to measure the amount of alkalinity and acidity in water and other solutions. pH sensors are able to ensure the safety and quality of a product and the processes that occur within a wastewater or manufacturing plant[2].

[16] Figure B2: pH sensor

This project utilized DM PH 4502C Liquid pH value detection sensor. It detects pH value of water. If pH is less than 5.5, it will send signals to Arduino, which turns on the dispenser motor. The dispenser motor then dispenses base from the acid/base container. If the pH is greater than 6.6 then the dispenser motor dispenses acid from the acid/base container.

C. Water Temperature Sensor

This is a pre-wired and waterproofed version of the DS18B20 sensor. Sensor is good between 100-125°C, it is a 1-wire digital temperature sensor that is fairly precise (±0.5°C over much of the range) and can give up to 12 bits of precision from the onboard digital-to-analog converter. Sensor works with any microcontroller using a single digital pin and can even connect multiple ones to the same pin. Usable with 3.0-5.0V systems [4].

[16] Figure B3: DS18B20 Digital Temperature Sensor

It detects Water temperature. If temperature is greater than 68 F, it will send signals to Arduini UNO, which turns on the Cooler/Heater using relay.

D. Relay

If we were to have an autonomous system where features of our design would not have to be manually controlled by a user, the most important part of our project is getting a relay switch to kick on and power on a certain part of our design. We had an exhaust fan that was using a standard plug outlet. We needed a way to turn this fan on demand and automatically. In order to do this we found the IOT Relay switch. Figure 1 IOT relay switch This switch has the capability of turning two outlets on by switch and one outlet off. We controlled this with the raspberry pi. We set the signal high and it would turn the switch on.

[16] Figure B4: IOT Relay Switch

E. Water cooler/heater

At first, we were invited by Professor Lavine to come see his coil system that's implemented throughout his house and it works really good and efficiently but we decided not to use it because it was too expensive and was out of our budget so then we got the regular water heater which did not work as well as it did not meet our design measurables, we figured this out after several different tests that we ran. Then after that failed we ordered this chiller heater which was implemented through Arduino using python and set up a range of temperature using the temperature sensor in the nutrient mixture. So the temperature sensor would send a digital signal of the temperature value to the raspberry pi which in turn would send a signal to the chiller heater and then it would set the temperature according to.

[16] *Figure B5: Water Chiller box*

F. TDS/EC Sensor

TDS stands for total dissolved solids and represents the total concentration of dissolved substances in water. TDS is made up of inorganic salts, as well as a small amount of organic matter. Common inorganic salts that can be found in water include calcium, magnesium, potassium and sodium, which are all cations, and carbonates, nitrates, bicarbonates, chlorides and sulfates, which are all anions. Cations are positively charged ions and anions are negatively charged ions [3].

[16] Figure B6: Gravity Analog TDS Sensor

For this project, we used Gravity Analog TDS Sensor. It detects the conductivity of water. If conductivity is less than 1260 PPM, it will send signals to Arduino, which turns on the dispenser motor. The dispenser motor then dispenses nutrients from the nutrient container.

G. Humidity Sensor

A humidity sensor (or hygrometer) senses, measures and reports both moisture and air temperature. The ratio of moisture in the air to the highest amount of moisture at a particular air temperature is called relative humidity. Relative humidity becomes an important factor when looking for comfort [5].

[16] Figure B7: DHT22 Humidity Sensor

At first, we used a DHT11 sensor which failed due to wiring error. Then we used a DHT22 sensor. This sensor detects humidity and temperature of air. If humidity is greater than 65, it will send signals to Arduino Uno, which turns on the exhaust fan using a relay.

H. Connecting Sensors

Finally, all four sensors connected together using a breadboard. We used resistors for humidity and water temperature sensor while TDS and pH sensor were connected directly to Rpi.

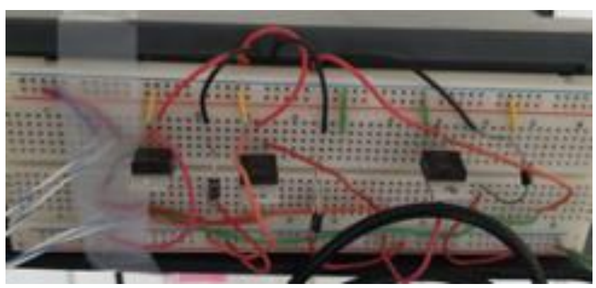
[16] Figure B8: Wiring Sensors

I. Dispenser

The dp-4 is a new, affordable dosing pump with 4 dosing heads. Each pump can be programmed to come on up to 24 times a day and dispense a precise amount of solution, which allows a user to keep their tank parameters stable and removes the need for mixing supplements daily [6].

[16] Figure B9: Dispenser Setup

Original dispenser had a weird feature set. It used to dispense liquids at certain times, but we required it to dispense acid/base and nutrients at particular times when required by our plant. In order to control the circuit according to our project requirements, We opened the box and took out the original board. We used the motors and created our own circuit. Earlier, We tried to use a relay but got the wrong one for 12 V signal input. Then We used BJT but that too failed within a day due to lack of required current. Finally, MOSFETs work since they work on the principle of voltage.



[16] Figure B10: Dispenser Connections

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[1] TAHERI, F, ET AL. “A WORLD WITHOUT HUNGER: ORGANIC OR GM CROPS?” SUSTAINABILITY, VOL. 9, NO. 4, 201

[2] C. P. &. W. F. TOM HARRIS, "How Light Emitting Diodes Work," 31 January 2002. [Online]. Available: https://electronics.howstuffworks.com/led.htm.

[3] Hancock, N. and Hancock, N. (2020). *TDS and pH — Safe Drinking Water Foundation*. [online] Safe Drinking Water Foundation. Available at: https://www.safewater.org/fact-sheets-1/2017/1/23/tds-and-ph [Accessed 6 Mar. 2020].

[4] Industries, A. (2020). *Waterproof DS18B20 Digital temperature sensor + extras*. [online] Adafruit.com. Available at: https://www.adafruit.com/product/381 [Accessed 6 Mar. 2020].

[5] Electronics For You. (2020). *Humidity Sensor: Basics, Usage, Parameters and Applications*. [online] Available at: https://www.electronicsforu.com/resources/electronics-components/humidity-sensor-basic-usage-parameter [Accessed 6 Mar. 2020].

Appendix C. Software of the deployable prototype system

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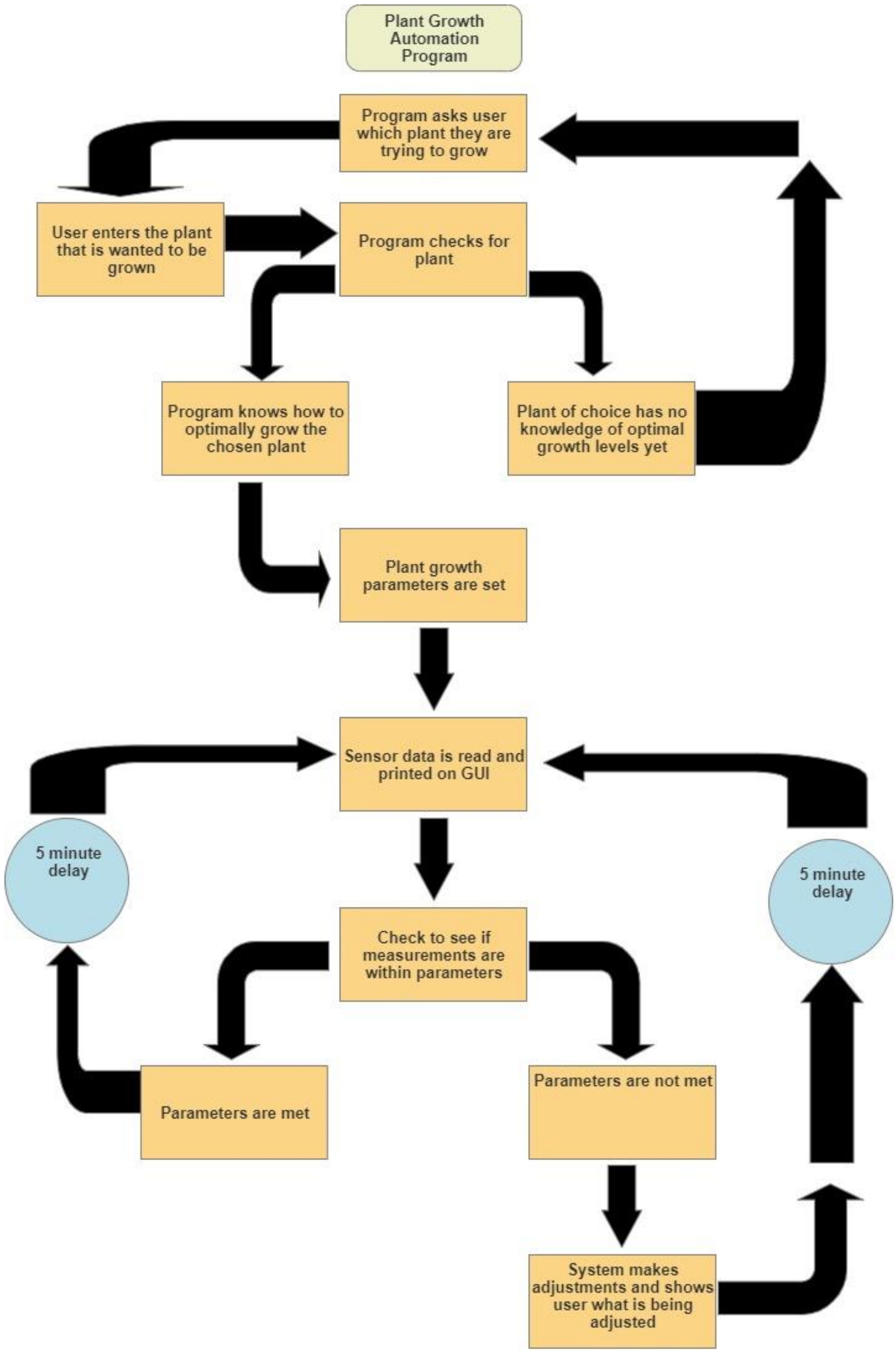
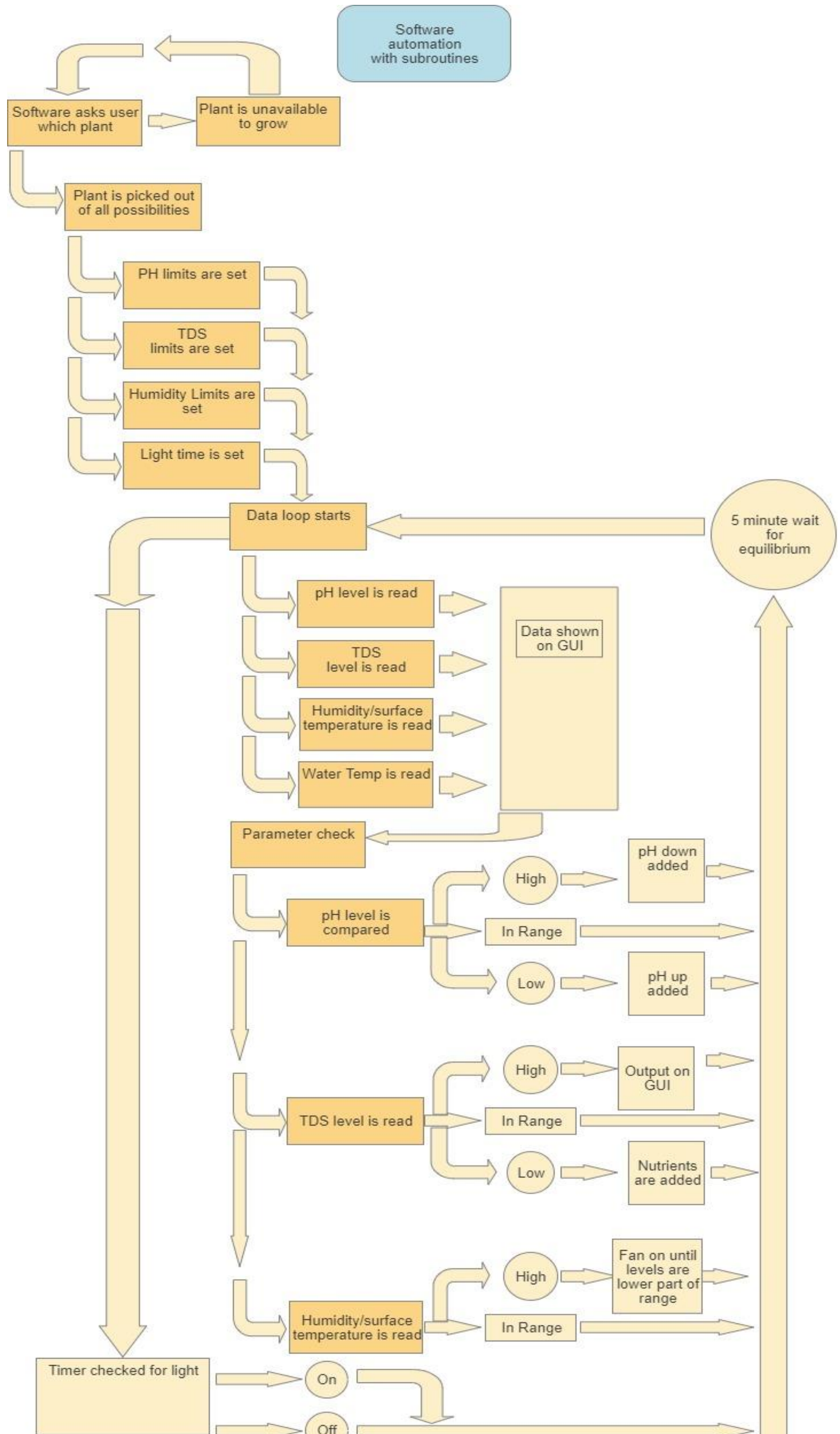


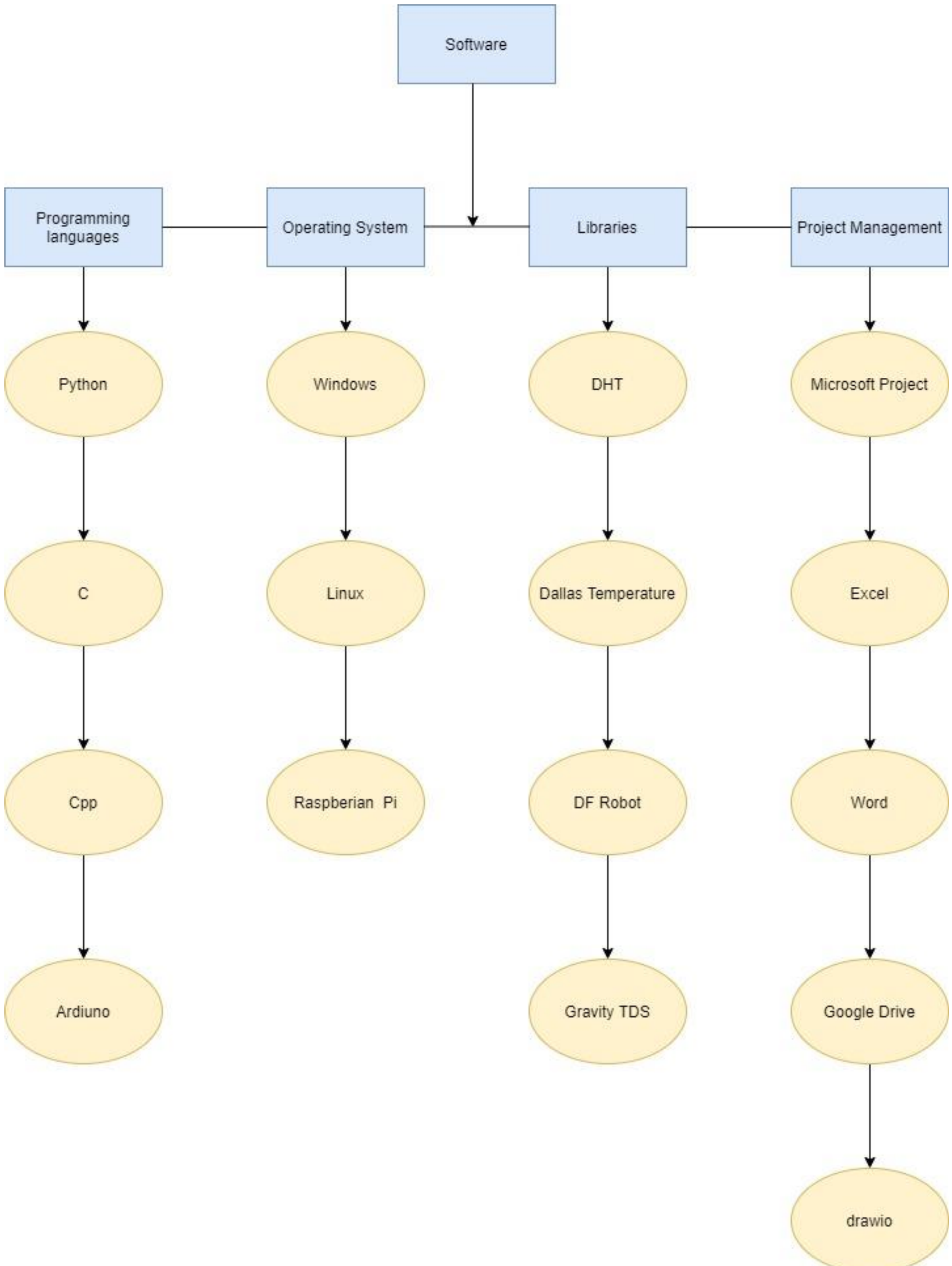
[16] Figure C1 Block Diagram



[16] Figure C2 Subroutines

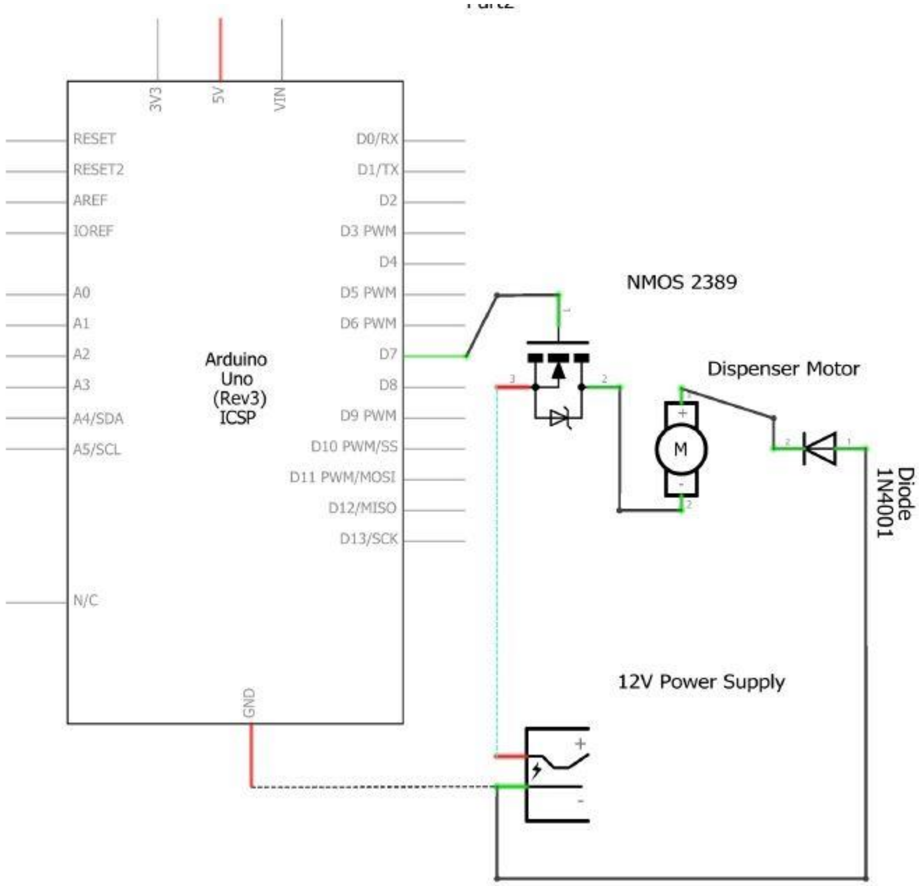
```
int humlow = 0;
int humhigh = 0;
double phlow = 0;
double phhigh = 0;
int tdslow = 0;
inlcude libraries for sensors
define pin inputs
int chk;
float hum;  //Stores humidity value
float temp; //Stores temperature value

void setup()
{
set frequency
begin sensors
set pin outputs
}

void loop()
{
//ask user to select a plant
//get plant from user
//check plants optimal growing parameters
//set to appropriate values:
        int humlow
        int humhigh
        double phlow
        double phhigh
        int tdslow
        int lighttime
//turn light on
////read and print sensor measurements to GUI
//check humidity and turn fan on if needed
//check pH and turn correct motor on if needed
//check tds and turn correct motor on if needed
//check time and turn light off if needed
//wait 5 minutes for system to reach equilibrium
}
```

[16] Figure C3 Pseudo Code

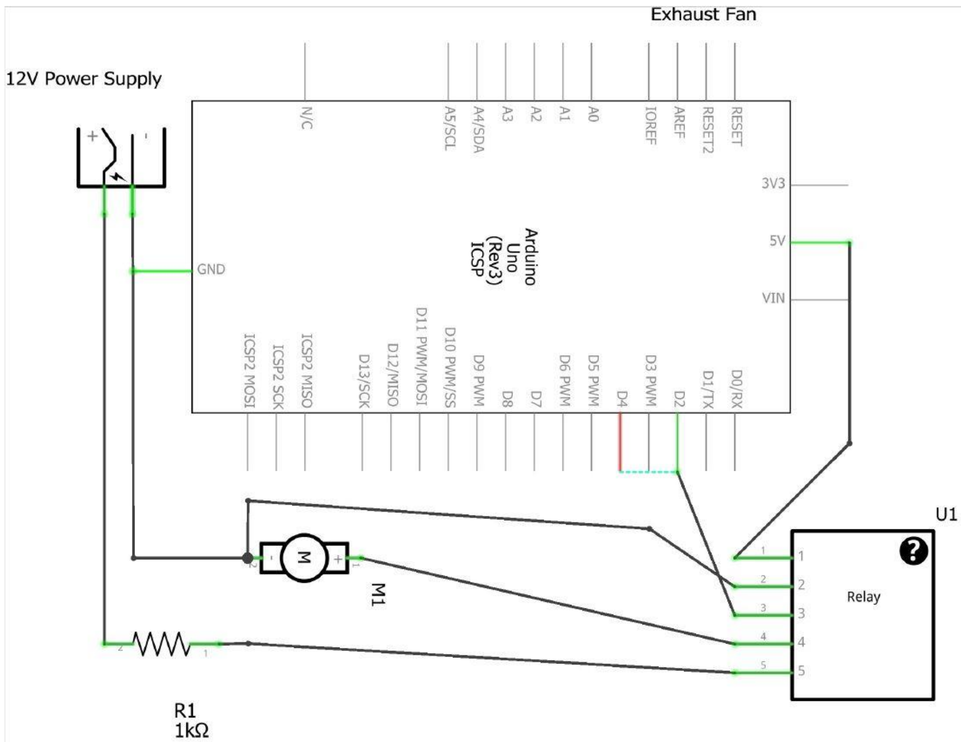


[16] Figure C4 Software Used

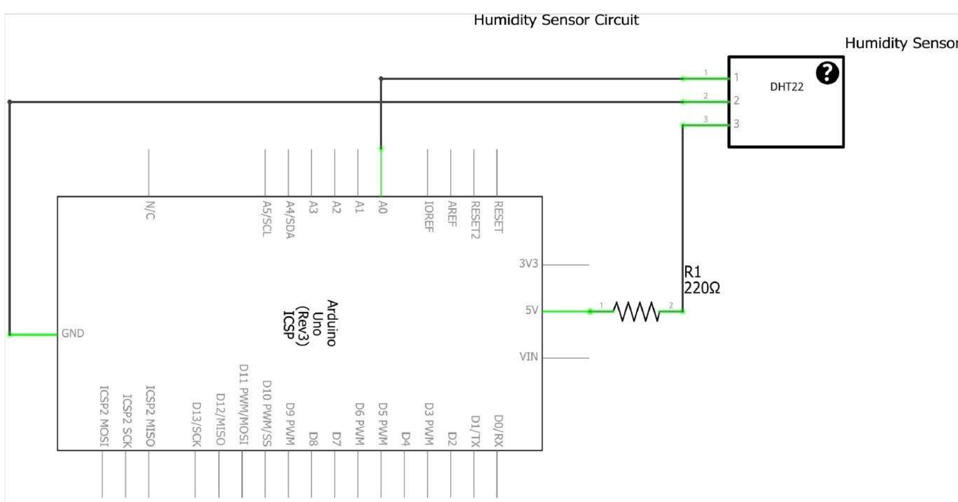
Appendix D. Mechanical Aspects of the deployable prototype system



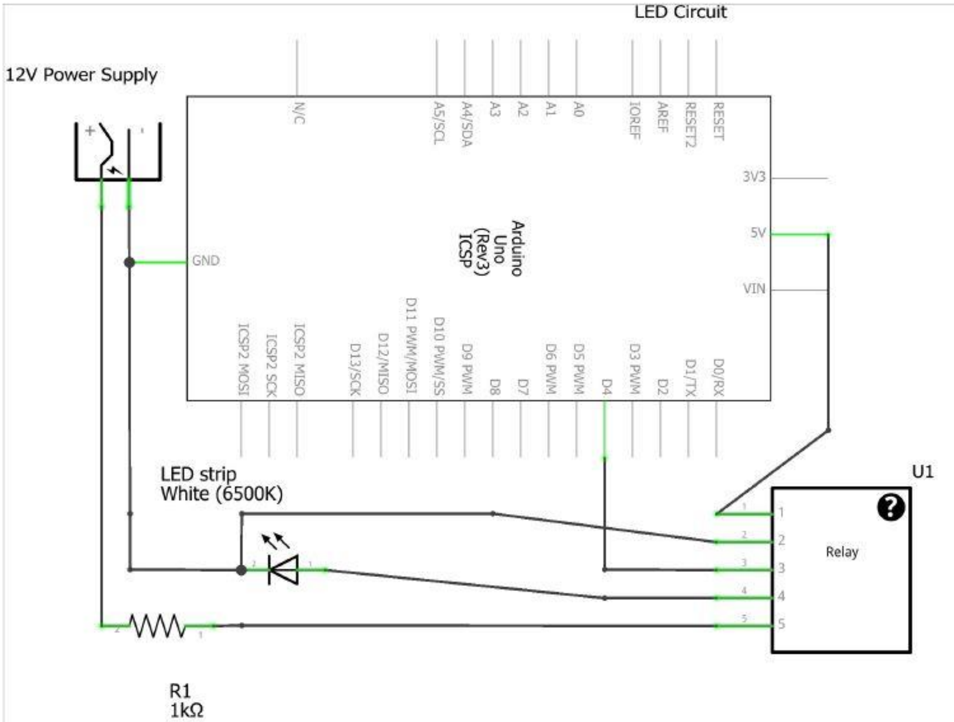
[16] Figure D1. Dispenser Schematic



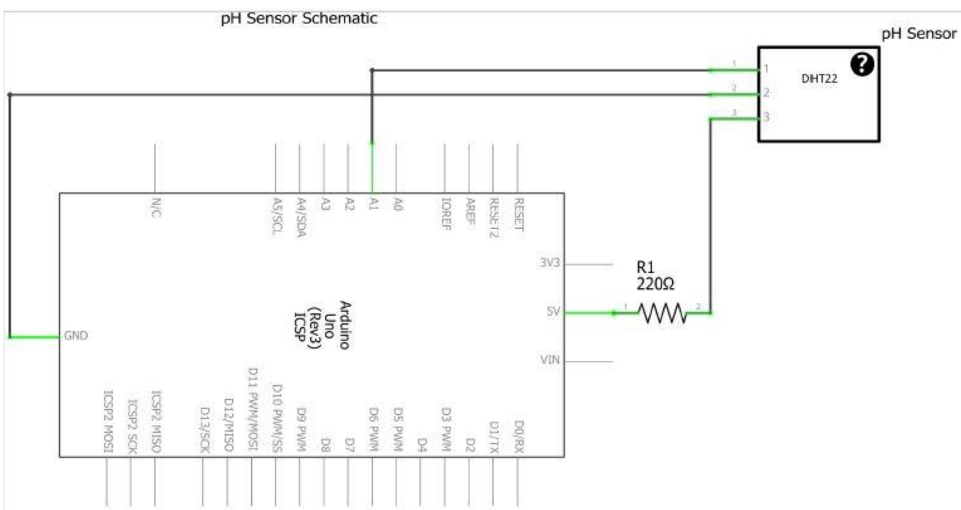
[16] Figure D2. Exhaust Fan Schematic



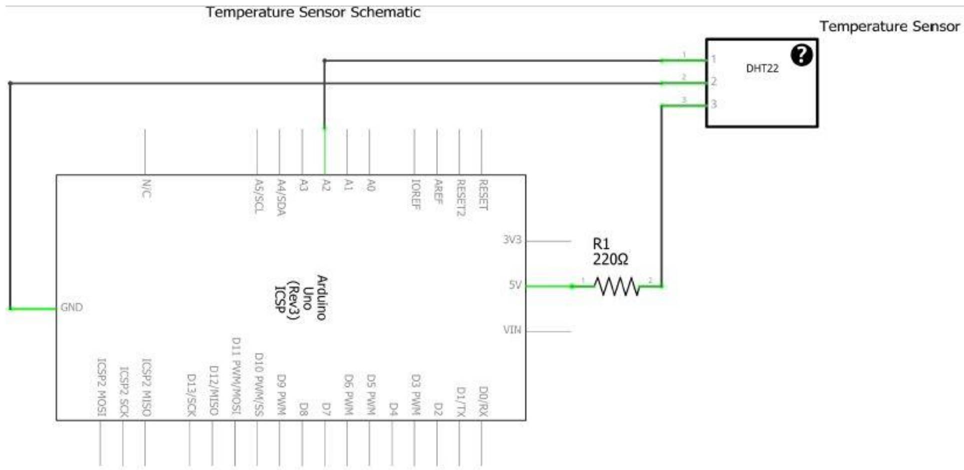
[16] Figure D3. Humidity Sensor



[16] Figure D4. LED Schematic



[16] Figure D5 pH schematic



[16] Figure D6. Temperature Sensor Schematic

Appendix E. Vendor Contacts

One of our technical advisors was Professor Levine. We needed a solution to our heating and cooling system. One possibility that Professor Levine gave us was a closed loop copper heating and cooling system. This is not common, and a lot of people are not aware of this as we initially had no idea. Basically, the copper coils heat or cool the system by being placed on the walls. For his example he showed us his copper coil system in his house. We went to his house and documented the system.

[16] Figure E-1 Hot and Cold Pipes

[16] Figure E-2 Control System

[16] Figure E-3 Cold Water Copper Piping

This visit gave us great insight on what we wanted to do with our design. It showed us a great way to control the temperature of the water and atmosphere. Sadly, it was expensive to implement because of the need to heat and cool the water individually. This idea is better suited for a large scale design. Even though we did not implement this into our design we did use some of the ideas. The main idea was aligning the pipes the water is flowing through on the glass so that the glass will also feel the same temperature as the water ultimately leading to the water and atmospheric temperature to reach the parameters faster.

Appendix F. Resumes

Continued (Next Page)

TARNJIT SANDHU

sandhutaranjit@gmail.com · www.linkedin.com/in/tarnjitsandhu

Full-time student pursuing a B.S. in Computer Engineering, while also working part time. Looking to apply school coursework and work experience to an environment in which I would like to start my career in.

EXPERIENCE

2013 – 2016

OFFICE TECHNICIAN, WEST COAST XPRESS

During my time at West Coast Xpress, I performed tasks that included creating data reports using excel on factoring data, creating graphs and performing statistical analysis on load payments vs. cost of load, and entering information to the database using file maker.

2018

STUDENT ASSISTANT IT, CALTRANS

While working in the IT department, I have learned how to image computers, troubleshoot software, follow and improve procedural documents, create ad-hoc reports, query data in Microsoft Access, update databases, move phone lines, and activate network ports.

2019-PRESENT

STUDENT ASSISTANT DATA MANAGEMENT, CALTRANS

At Data Management, I have created numerous web applications that are used by hundreds of users. The programming languages I have used are HTML, JavaScript, php, and MySQL. I have used data from PRSM and QMRS which are in the MySQL databases I have created. During my time here I have also learned to create BI visualization for dashboards using Tableau and presented to upper management numerous times on my own.

EDUCATION

2016 – Spring 2020 (Expected Graduation)

COMPUTER ENGINEERING, CSU SACRAMENTO

I am currently a 4th year student with a 3.16 G.P.A. while completing 133 units. Relevant coursework includes programming, software engineering/software development life cycle, network engineering, statistics, economics, and probability.

SKILLS

- Experience with the following languages: Java, C, Python, HTML, JavaScript, PHP, and SQL
- Microsoft excel, word, access
- Tableau
- Windows and Linux OS
- MySQL, Oracle databases
- Data Analyzation
- FTP server (FileZilla)

Navjot Benipal (Navi)

(916) 595-3553 | benipalnavi@outlook.com

Objective

To obtain a position with your esteemed organization where I can apply my education and experience in achieving the company's mission, vision and values.

Experience

LEADERSHIP AND TEAM WORK | SENIOR DESIGN PROJECT | AUTONOMOUS HYDROPONICS

- Designed, developed, tested, debugged and managed an autonomous plant growing system using hydroponics with a 5-person team in course of 3 months
- Arduino and raspberry-pi were used as microcontrollers to operate self-designed circuits and remotely transfer collected data such as temperature, humidity and pH into a database

SENIOR LAB ASSISTANT | SUTTER MEDICAL FOUNDATION | MAY 2012 - PRESENT

- Ensured Quality Assurance and performed required Quality control analysis
- Trained new hires and students according to the company guidelines
- Performed all job duties in compliance with company policies leading to multiple recognitions

Skills & Abilities

LANGUAGES

- C
- C++
- Verilog
- VHDL
- Linux/Unix Programming
- Oracle

OPERATING SYSTEMS

- Windows
- Linux

TOOLS

- Logisim
- Multisim
- PSpice
- Quartus Prime
- MPLab
- Xilinx Vivado

HARDWARE

- STM32
- Raspberry Pi
- Arduino

Education

BACHELOR OF SCIENCE | 2015-PRESENT | CALIFORNIA STATE UNIVERSITY, SACRAMENTO

- Major: Computer Engineering (Expected Graduation: May 2020)
- GPA: 3.5
- Dean's list: Fall 2018, Fall 2019
- Related coursework:
  - Advanced Logic Design
  - Network Analysis
  - Computer Interfacing
  - Signals and Systems
  - Data structures
  - Algorithm Analysis
  - Computer Hardware Design
  - Database Management
  - Adv Computer Organization

Satwinder Singh

OBJECTIVE

To obtain a professional position in the Computer Science and Engineering industry utilizing my relevant experience, technical expertise, and problem solving skills.

EDUCATION

California State University, Sacramento, CA
Bachelor of Science in Computer Engineering, Expected May 2020 GPA: 3.07

Selected Coursework: Computer Interfacing, Database Management Systems, Advanced Logic Design, Network Analysis, Data Structures and Algorithm Analysis, Computer Hardware Design, Senior Design

SKILLS

- *Coding:* Python, C/C++, Java, Perl x86 assembly, Verilog, VHDL
- *Technologies/Environment*: Windows, Linux, Raspberry Pi, FPGA
- Application Design using Database technology: SQL, Entity-Relationship (ER) model
- Proficient in Microsoft Excel, Microsoft PowerPoint, Microsoft Word, Diagramming Applications

PROJECTS

Autonomous Hydroponics System (Fall 2019-Spring 2020) – Senior Project
- Breadboard Wiring: pH sensor, Humidity Sensor, TDC/EC sensor
- Wrote applications for Arduino in Python
- Set up LED’s using MOSFET

Ping Application (Fall 2019) – Computer Networks and Internets
- Developed my own Ping Application
- Used Python Script
- Used ICMP (Internet Control Message Protocol)

Four-Way Traffic Light System (Fall 2018) – Final Project for Computer Interfacing.
- Breadboard Wiring: LED’s, Piezo Speaker, Resistors.
- Wrote an application in C on SimpleIDE
- Mainly implemented LED’s with timer.

Seven-Segment Display with Piezo Speaker (Fall 2018)- Computer Interfacing
- Coded in Python to display numbers on propeller board
- Also coded to play different sounds on piezo speaker
- Used Propeller Board, Piezo Speaker, LED’s, coded in python in IDE.

ACTIVITIES/CLUBS

SWE, CSUS, Member (2017- PRESENT).
- Help with events and activities.

Sikh Student Association, Member (2017-PRESENT)
- Club to spread awareness about Sikh faith and equality
- Helped manage events, events, and Community Service

PARMVIR SINGH

OBJECTIVE:

Actively seeking an internship/job in the areas of Hardware, Firmware, or Software Engineering.

EDUCATION:

Bachelor of Science, Computer Engineering ***Expected:*** May 2020

California State University, Sacramento, CA

Overall GPA: 3.24 ***Major GPA:*** 3.34

WORK EXPERIENCE:

Cashier and Cook ***Mountain Mikes Pizza*** ***August 2015 - December 2015***

- Engaged with customers warmly and provided immediate and dedicated assistance.
- Assisted customers with prompt and polite support in-person and via telephone.

Prime Now Associate ***Amazon*** ***October 2017 – February 2020***

- Worked in a super-fast paced environment to meet daily goals.
- Provided services efficiently with high level of accuracy and problem solved minor technical difficulties.

SKILLS-LANGUAGES, TOOLS, PLATFORMS:

Punjabi, Hindi, C, C++, Verilog, Python, JavaScript, Java, VHDL, x86 Assembly, ARM Assembly, HTML/CSS, Oracle SQL, PHP, Eclipse IDE, Xilinx Vivado Design Suite, Multisim, OrCAD PSpice, Cadence Virtuoso, Control, DOS, Windows (XP, Vista, 8.1, 10), MS-DOS, UNIX, Linux (Ubuntu, Debian), VMWare,

RELATED PROJECTS:

Senior Design Project

- *Semi-Autonomous Hydroponic Greenhouse:* Currently involved in designing and building a Semi-Autonomous Hydroponic Greenhouse with 4 other team members. The team consists of 1 Electrical Engineer (EE) and 4 Computer Engineering (CpE) students. Directly assisting with designing the Control System for all sensors and implementing the desired measurables in code for these sensors.

Java/C Projects

- *Multi-threading:* Experimenting with the performance impact of multithreading using real time measurements using the POSIX thread library on a UNIX system. I was in charge of writing a program that sorts an array of random integers first sequentially and then using multi-threading.
- *User-level Threading:* Implementing context switching using *sisetjmp* and *silongjmp.* Also, implementing two preemptive scheduling algorithms: Round-robin and Lottery scheduling and designing data structures for thread entities.

Computer Hardware Designs

- *Direct Mapped Cache Design*: In Verilog, designed and simulated a cache controller module that utilized the direct mapping scheme to store data onto cache blocks. The controller would be able to interface between a CPU and Main Memory to perform read or write operations.
- *PCI Bus Arbiter:* In Verilog, designed and simulated a PCI Bus Arbiter that performed bus arbitration among multiple master devices on a PCI Bus. The bus arbiter utilized the Round-Robin Priority Scheme to designate the PCI Bus to the appropriate master device.
- *Multi-cycle Datapath Model*: Designed and simulated a multi-cycle data path that performed either the RTN $R \leftarrow A + B + C - D$ or the RTN $R \leftarrow A - B + C + D$. A control unit (FSM) was also created to provide the proper control signals to the data path.

AWARDS/CLUBS:

Deans Honor List ***Spring 2017 – Spring 2019***

MEP, *Member* ***Fall 2017 – Spring 2020***

SWE, *Member* ***Fall 2017 – Spring 2020***

SSA, *President/Member* ***Fall 2017 – Spring 2020***

AKASHDEEP SINGH JIDA

asjida@csus.edu
(530)-713-2858
United States
linkedin.com/in/akashdeep-jida-69725125

Currently pursuing my Bachelor's in Electrical and Electronics Engineering. Aspire to work for an organization where my skills and ideas are utilized as well as enhanced.

LANGUAGES

VHDL/VERILOG
C/C++
Python
MATLAB

TOOLS

Cadence Virtuoso
Xilinx Vivado
ModelSim
PSpice
Quartus
Altera
Advanced Design System
Microstrip Lines
PCB Soldering
Circuit Designing
PCB Design
Microsoft Office Suite

HARDWARE

NEXYS4 FPGA, Raspberry Pi
Parallax propeller
Arduino Max32
STM32
Function Generator

COURSEWORK

Advanced Logic Design
Computer Hardware Design
CMOS and Vlsi
Power Electronics
Computer Interfacing

EDUCATION

Bachelor of Science in Electrical and Electronics Engineering
California State University, Sacramento *01/2018 – 05/2020*
3.50 GPA
Dean's Honor List (*Spring 2019)*

Associates in Mathematics
Fresno City College, Fresno *08/2013 – 06/2017*

WORK EXPERIENCE

Customer Service - Dining Commons
California State University, Sacramento *02/2018 – Present*
- Delivered exceptional customer service to all customers by connecting with customer
- Discovered and responded to customer needs
- Maintained regular and consistent attendance and punctuality
- Followed health, safety and sanitation guidelines for all products

Instructional Student Assistant - Tutor
Fresno City College, Fresno *09/2017 – 12/2018*
- Provided appropriate tutorials to meet each students' needs.
- Documented tutorial sessions and monitored students' progress.
- Marked and provided appropriate feedback to the students.

ACADEMIC PROJECTS

Hydroponics System *08/2019 – 05/2020*
- Currently Working on an Autonomous Hydroponic system in which Plants will grow by adding Nutrients in water.

Simulation of Verilog Designs using FPGA *01/2018 – 05/2018*
- Simulated Verilog and Test bench in ModelSim to get waveform and implemented the code on FPGA.

Four-Way Traffic Light System *05/2019 – 06/2019*
- Created a circuit using breadboard and implemented coding to blow lights.

Arduino Ultrasonic Sensor Radar *11/2018 – 12/2018*
- Designed ultrasonic sensor radar using Arduino UNO, HC-SR04 Ultrasonic Sensor, Servo, broadband and Wire Jumpers with implementation in C++.

Microcontroller based heart rate measurement using fingertip sensor *04/2018 – 05/2018*
- Developed a pulse detector system to measure heart rate using a PIC Microcontroller.

Computer Hardware Designing *08/2019 – 12/2019*
- Designed an 8kB Replay buffer, Arbiter, Cache Memory, PCI bus PIC Microcontroller.

Cadence Virtuoso Layout *08/2019 – 12/2019*
- Designed Layout for Invertor, DFF, NAND, USR and Mirror Adder

Appendix G. Plant Pictures

Figure G1: Day 20

Figure G2: Day 25

Figure G3: Day 35