AUTOMATED HEALTH MONITORING AND WATERING SYSTEM FOR PLANTS
(PLANT NURSING SYSTEM)

By

Rahatil Bin Mostafiz
18121105
Muhtasim Fuad
18121112
Hasan Sakib Sarker
18321049
Mushfique Ahmed
18321053

A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronics Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

Department of Electrical and Electronic Engineering
Brac University
December 2022

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Academic Technical Committee (ATC) Panel Member:

Dr. S M Rafi-Ul-Islam

Assistant Professor, Department of EEE, BRAC University

Mr. Tasfin Mahmud

Lecturer, Department of EEE, BRAC University

Department of Electrical and Electronic Engineering
Brac University
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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

Student's Full Name & Signature:

Rahatil Bin Mostafiz 18121105	**Muhtasim Fuad** 18121112
Hasan Sakib Sarker 18321049	**Mushfique Ahmed** 18321053

Approval

The Final Year Design Project (FYDP) titled “Automated Health Monitoring and Watering System for Plants (Plant Nursing System)” submitted by

1. Rahatil Bin Mostafiz (18121105)
2. Muhtasim Fuad (18121112)
3. Hasan Sakib Sarker (18321049)
4. Mushfique Ahmed (18321053)

of Summer, 2022 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on September 1, 2022.

Examining Committee:

Academic Technical
Committee (ATC):
(Chair)

____

Dr. S M Rafi-Ul-Islam
Assistant Professor, Department of EEE
BRAC University

Final Year Design Project
Coordination Committee:
(Chair)

____

Dr. Abu S. M. Mohsin
Assistant Professor, Department of EEE
BRAC University

Department Chair:

____

Dr. Md. Mosaddequr Rahman
Professor, Department of EEE
BRAC University

Ethics Statement

We, hereby, confirm that all the research, findings, data and results of our Final Year Design Project titled, " Automated Health Monitoring and Watering System for Plants (Plant Nursing System)" is our own original work. All the data and resources that we have used as references for our research are collected from several independent sources and were given proper citations in accordance with the IEEE standards. The project and all its work were reviewed and approved by our respected ATC (Academic Training Committee) panel and fulfilled all the requirements.

Abstract/ Executive Summary

The project aims to inspire an increasing number of people to participate in urban gardening activities. The project was created with the intention of helping those who, because of a hectic schedule or extended absence, are unable to care for indoor plants. While the system is capable of taking care of plants on its own, it was designed to act as a helper so that the user could continue to pursue their interest of gardening while also taking a break from their hectic city life. The entire system is responsible for carrying out a number of duties, including remote plant watering, pesticide application, and regular user updates.

Keywords: Arduino, automated, plant, system, soil moisture sensor

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List of Acronyms

AC	Alternating Current
API	Application Programming Interface
AWG	Atmospheric Water Generator
BDT	Bangladesh Taka
CAD	Computer Aided Design
CNC	Computer Numerical Control
CPU	Central Processing Unit
DC	Direct Current
DOF	Degrees of Freedom
EA	Engineering Activities
EEE	Electrical and Electronics Engineering
FYDP	Final Year Design Project
GPRS	General Packet Radio Services
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronics Engineers
IOT	Internet of things
IT	Information Technology
KPI	key performance indicators

NSPE	National Society of Professional Engineers
PCB	Printed Circuit Board
UPS	Uninterruptible power supply
Wi-Fi	Wireless Fidelity
WBS	Work Breakdown Structure
3D	Three Dimensional

Chapter 1 Introduction

1.1 Introduction

1.1.1 Problem Statement

Currently, cities and towns are home to more than 54% of the world's population. Larger cities with higher population densities than ever before are created as a result of a global population migration from rural to urban areas. Urbanization is spreading across the globe. Rapid expansion of cities is taking place without any land use planning strategy. So, this unexpected human pressure has highly damaging effects on green areas, landscapes, as well as forests. It’s harder to get space and grow a garden in city space. Urban gardening is a solution to solve this existing problem. Urban gardening can be done in limited space like balcony and rooftop. But people who live in cities are really busy. They don’t have enough time to take care of their plants on the balcony. People have to leave their home or apartment for business purposes and for many kinds of occasions for a certain period of time. For example, in Dhaka, most of the people leave their houses to enjoy the Eid vacation in the village. In this certain period of time there is no one to take care of plants. Planting trees and plants on rooftops and in balconies has a major problem, one needs to actively take care of these plants as these plants are planted in a limited space and these plants cannot intake water and minerals from deep within the earth's soil thus disrupting their natural growth. Taking care of plants takes time and human resources. So, we, as EEE engineers, want to make such a system which will automatically take care of our plants for us.

1.1.2 Background Study

After researching through various databases, it was found that most of the projects are designed to provide water and monitor the plants. But our project offers an innovative idea which will help identify some of the common diseases of plants that occur rapidly. There are projects based on the techniques utilized for the recognition of plant diseases utilizing the images of the leaves. But our project is merging this technology while offering additional features. This project will be unique according to its functionality.

Example 01

Name of the journal: Automated Irrigation System Using a Wireless Sensor Network and GPRS Module

Published in: IEEE Transactions on Instrumentation and Measurement (Volume: 63, Issue: 1, Jan. 2014)

This project's main objective is to make an automated irrigation system that was developed to optimize water use for agricultural crops. In our project, this is just a single part. Our project is offering much more than this. Our project is mainly focused on making a system which will monitor the plants health.

Example 02

Name of the journal: IOT Based Monitoring System in Smart Agriculture

Published in: 2017 International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT) This design is capable of taking pictures and monitoring temperature and humidity. On the other hand, our project has a broader range of functionalities that makes it more unique, particularly for balcony and rooftop gardening.

Example 03

Name of the journal: Smart watering of plants

Published in: 2019 International Conference on Vision Towards Emerging Trends in Communication and Networking (ViTECoN)

The project is designed to focus on watering the plants based on the soil moisture data collected with sensors and passed to Arduino. Our project, however, will use Raspberry Pi for an extended range of functionality to provide more accurate data for the watering system.

1.1.3 Literature Gap

A research gap, also known as a literature gap, is a subject that hasn't been thoroughly investigated but has the potential to be. It is a rare technology in the globe to find sophisticated equipment that can offer many supports to growing plants simultaneously. Most of the systems provide one or two subsystems to guard the plants. Either they provide a humidity monitor or a system that will be able to water the plants in a systematic way. However, with our innovative technology, not only a pesticide sprayer along with the water pumps are provided, they can be controlled remotely in order to leave no gaps. Additionally, with the raspberry pi and the pi zero camera, more support is provided as it will be solely responsible for capturing real-time images of the plants to deliver them to the users. With multiple subsystems integrated into one, the system has the potential to carry out any tasks even without any user instructions. To provide an added degree of security, the user is given the ability to control the system remotely to receive updates and to make decisions.

1.1.4 Relevance to current and future Industry

The use of automation has long been recognized as the most effective strategy for lowering the demand for manual labor. There are already examples of agricultural automation in the shape of tractors, harvesters, seeders, and even irrigation devices. But even that won't be enough to satisfy the skyrocketing need for personnel in the agricultural sector.

- Details of the structural and functional components of the robots, including their dimensions and organizational structures in their entirety

- The system's assets are its nimbleness, mobility, and flexibility.

- systems of electronic control that are reliable and have undergone extensive testing, as well as the power supply,
- Methods of remote communication and control that are both organized and very efficient
- decreasing the amount of human intervention that is required while increasing the amount of system automation

The agricultural community is prepared to make the shift to digital farming, and agriculture robots are well positioned to facilitate this change. The designs of agricultural robots of the future need to take into account all of the factors listed above, in addition to any new technologies that may emerge in the future.All through the year, pesticide-free vegetables may be harvested from indoor greenhouses. This immediately eliminates issues about the environmental effect of synthetic or natural pesticides used in commercial and organic agricultural production, the cyclical nature of conventional outdoor farming, and the advent of new weather related problems as a result of climate change. So,we are trying to bring something new to solve a particular problem in balcony gardening/indoor gardening. This sector is a rapidly growing sector.

1.2 Objectives, Requirements, Specifications and Constraints

1.2.1 Objectives

The main goal of this project is to provide assistance to people who love gardening but lack the will to pursue their hobbies. It is important to keep in mind that this is only an automated tool to support oneself while he or she is not nearby to take care of the plants. Even though this system can take care of plants on its own and provide updates remotely, the major goal is not to rob gardeners of the enjoyable aspects of their hobby.

The objectives of this project are as follows:

1. To motivate more and more people to do gardening
2. To provide real-time updates of the plants to the user remotely
3. To monitor soil humidity continuously and update information in real-time
4. To provide water and pesticides in accordance with user input
5. To enable the user to make decisions and perform operations to take care of the plants remotely after receiving updates

1.2.2 Functional and Non-functional Requirements

The requirement phase is basically divided into two categories: functional requirements and non-functional requirements. A system or one of its components is defined by a functional requirement. A software system's quality characteristic is defined by a non-functional need.

Functional Requirements:

1. The base should return to home after performing an operation by itself or by user input before any further operation.
2. The system will take user input remotely and act based on the input.
3. The Pi-Zero camera will take close images of plants to send them to the user through email.

Non-Functional Requirements:

1. The system works with a Wi-Fi module as, therefore, is able to provide real-time data over a long distance to the user.

2. The Pi-Zero camera's zoom capability is large enough to provide clear images of the plants to the user.

3. The soil moisture sensor will help in gathering accurate information about soil humidity and giving users updates.

1.2.3 Specifications

TABLE 1. DESIGN SPECIFICATIONS

Subsystem	Components	Details
Subsystem 1 The Plant Watering/Pesticide System	Water Pump/Watering Pipe	The system is responsible for providing water and pesticide according to user input.
	Pump Motor	
	Pump Motor Driver	
Subsystem 2 Image Capturing System	Raspberry Pi Zero W	This system will capture close image of plants and send them to the user through email.
	Raspberry Pi Zero Camera	
	Wi-Fi Module	
Subsystem 3 Soil Humidity Monitoring System	Arduino Mega	The system will provide updates about soil humidity levels.
	Soil Moisture Sensor	
Subsystem 4 Linear Motion System	Stepper Motor	This system will transform the positions of the linear axes to go to specific plant positions or return to home base.
	Stepper Motor Driver	

The overall device consists of the multiple subsystems mentioned above. Depending on user input, the system will be able to perform multiple tasks as all of the systems are interconnected to each other. Therefore, any task that needs to be done remotely can be done by the automated system.

1.2.4 Technical and Non-technical Constraints

The "Plant Nursing System", by itself, is a sophisticated system that can take care of plants. However, there are a number of constraints that are challenging to get around. Future innovations will help us get around these limitations. The constraints of the current designs are as follows:

1. Once the system has inspected through the conditions of the plants or provided water or pesticide to a specific plant, it must return to the home base before any other operations. Otherwise, the system will cause an overflow. It can be solved by introducing some additional variables to the system.

2. The system can pump water and provide to the plants by itself as soon as it gets a remote command; it, however, is unable to provide if the source of water is empty. Thus, the user may have to make sure beforehand so that the water tank never becomes empty.

3. The system is overly dependent on user input. As a result, even while the system is capable of making the optimal decision and acting on it, it may have to wait for user instructions. This problem can be solved by implementing complex AI algorithms through Machine Learning.

4. A continuous power source is required since the system must be able to deliver real-time updates. In other words, in the event of a sudden power failure, the system will undoubtedly be unable to send updates. An integrated mini solar panel can be a useful solution to this issue.

1.2.5 Applicable Compliance, Standards, and Codes

TABLE 2. APPLICABLE STANDARDS AND CODES

Standard Number	Title
IEEE 1801	Standard for Design and Verification of Low Power Integrated Circuits
IEEE 1547-2018	IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
IEEE 3007.3-2012	IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems

1.3 Systematic Overview/Summary of the Proposed Project

The system's primary responsibility is to process user inputs and act appropriately. The user has the option to request any plant's image, water the plants, or use pesticides. Additionally, the system regularly updates the user on the soil humidity level so they may choose how long to water the plants for. The Raspberry Pi is responsible for processing the images captured by the Pi-camera and delivering it to the user through mail. Arduino Mega, on the other hand, is in charge of changing the position of the axis and, if necessary, supplying water and pesticides.

1.4 Conclusion

The system is made with a very user-friendly functionality, to sum up. The ease of usage is taken into account throughout the entire design process. The user will find this application to be very convenient to use because of the straightforward User Interface created on Blynk.

Chapter 2 Project Design Approach

2.1 Introduction

As human beings we have different hobbies. Gardening is no exception. Gardening may be regarded as one of the widely popular hobbies of many people. With the ever growing population, the total land area of Bangladesh is not increasing. To accommodate such a huge population, people choose multi-storey buildings as an alternative solution to the limited land problems while building homes. So, it is easy to see that gardening as a hobby is an expensive one because of the very limited land area problem. As humans we do not just bury our dreams and hobbies, we find alternate solutions to all problems we face. There are balconies in our homes. Even multi-storey buildings have balconies. We Plant different plants in our balconies and make our hobbies of gardening a reality. But gardening inside balconies is an artificial one as the plants we plant are not directly connected to the earth. So, these plants cannot suck up water from underground and when it rains, the rain water cannot reach these plants as they are planted inside our home. So, we need to actively monitor and take care of our plants. But it is also impossible for many people to give time to take care of our delicate plants. We simply do not have enough time to waste on gardening. As such the plants we plant gradually die due to lack of care and maintenance. So, keeping this problem in mind we came to a conclusion on how to solve the problem. We had an idea of making such a system which will monitor the plants we planted inside our balconies, give water to the plants, determine the type of diseases the plants have contracted and give appropriate pesticide and medicine to the specific plant under consideration and inform the user about the plant health condition. So, keeping this idea in mind we set out to build such a system which could take care of our plants instead of us. After discussing and considering many plans, every member of our group came to a conclusion of how we were to build the system. We decided to build a Robotic arm which can take pictures of the plants inside our balconies, analyze the plant diseases, each plant has contracted, inform the user and give appropriate pesticide or medicine to the disease affected plants. We searched the internet to look for possible designs for the robotic arm and for the whole plant take care system. Some of the designs and models that we selected for the final product design will be discussed in this section. That is to say, this section will discuss the project design approach/multiple design approach. This section will give insight to the reader of which designs were selected for the final product and which got rejected.

2.2 Identify multiple design approach

After analyzing the problems we would face while building the system, the first thing we realized was that our system would consist of multiple subsystems. This is because we are building a system which would take care of plants without the intervention of a human being. As such we would need to water the plants periodically and so would need to build a water tank system with controlled water flowing inside and outside the tank. We also identified that we need to build a system which would periodically take pictures or scan each individual plant, notify the user about the plant's condition and give pesticide or medicine to each disease affected plant. To power everything we would need a power system. Therefore, we can see that we have approximately a total of 3 subsystems which come together to make the whole system which can then actively take care of plants without any human intervention. All the subsystems are discussed elaborately with multiple design approaches of each sub-systems.

a) Multiple Designs for the Water Flow Management System

We shall supply water to our system for watering our plants by taking water directly from the taps built in our homes. There will be a small tank where water will be stored and be used when needed. When the tank is empty, it can be filled up by using a hose pipe connected directly to the tap system in our homes. Another approach is to generate our own water using a separate device which can extract water from the environment using an atmospheric water generator (AWG) but such a system is costly and not efficient. So, taking water from the taps of our home is a cheap and viable option.

b) Multiple Designs for spraying pesticide and to scan the plants for disease detection

Another design approach to our system is, we need a camera for our system which will take photos of plants periodically and scan the images with image processing software's and determine the diseases and conditions of the plants. Approach one is to set up a camera at a specific location inside the balcony from where it will take photos. But taking photos from a fixed distance and angle may distort the image quality and not all photos can be taken from the correct angles. Thus, proper determination of plant health conditions cannot be made. So, our second approach is to fit the camera on top of a robotic arm which can move and thus enable our system to take photos of plants up close and from the correct angle. It will help us to take better and quality photos of plants and thus precise determination of plant diseases and plant health conditions can be made. But using a robot arm can be tricky and costly but it is a trade-off which can be made and we may include such a robot in our system for efficiency. Also, the robotic arm can be used to spray pesticides and medicines over the disease affected plants. We can attach a pesticide sprayer with the robotic arm to enable the user to spray pesticide over individual plants. The robotic arm helps to spray pesticide to every part of the plants which would otherwise not be possible without using a robotic arm.

c) Multiple Designs for the Power System

For our multiple design approaches first, we will give power to our system taking power directly from the national power grid. Another approach to giving power to our system is by using solar panels, as our system will be placed on rooftops and inside balconies thus getting much sunlight. Another design includes using piezoelectric transducers to generate energy for our system. Such transducers convert mechanical energy into electrical energy. We can make false tiles with piezoelectric transducers fitted at the bottom of the tiles. When someone walks over the tiles, it will transform the walking motion of a person into electrical energy thus powering our system. But among the three designs using solar panels to power our system may be the best choice as we get green and free energy and the cost of making such a system is cheap and easy to make.

2.3 Describe multiple design approach

As mentioned, and discussed previously, our project has 3 sub-systems. These sub systems are:

a. Power System

b. Water Flow Management System

c. Camera and Pesticide System

Initial discussions and analyzing the requirements, many of the designs and ideas which we came up with during the primary stage of our project and the designs we decided to go with are shown below.

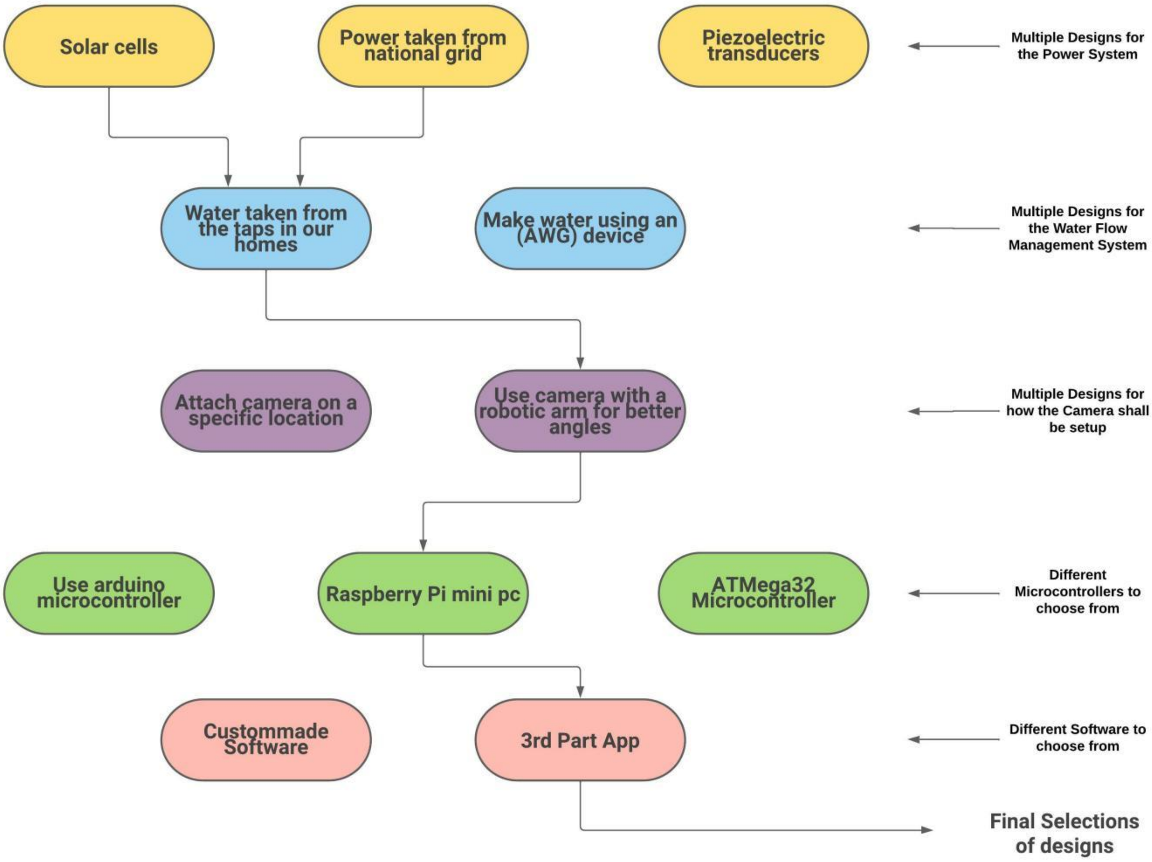

Fig 1: Selection of the best Sub-System designs from multiple designs in producing the best overall design

A. Power System

Approach 1:

we will give power to our system by taking power directly from the national power grid. Additionally, we will use solar panels in our system as our backup power system to avoid sudden power outages or load shedding

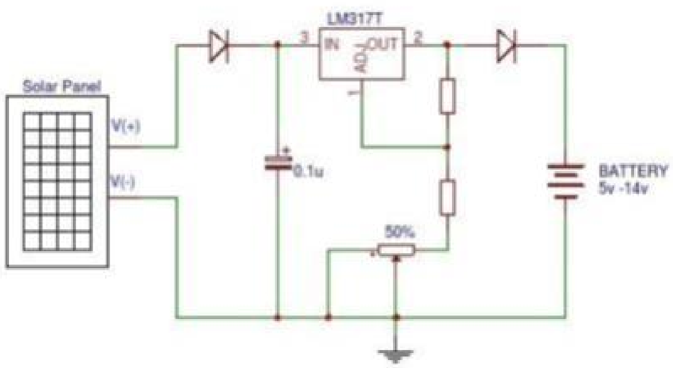

Fig 2: Approach 1

Approach 2:

For the backup power system, we can use a lithium ion battery which will be directly charged from the main grid.

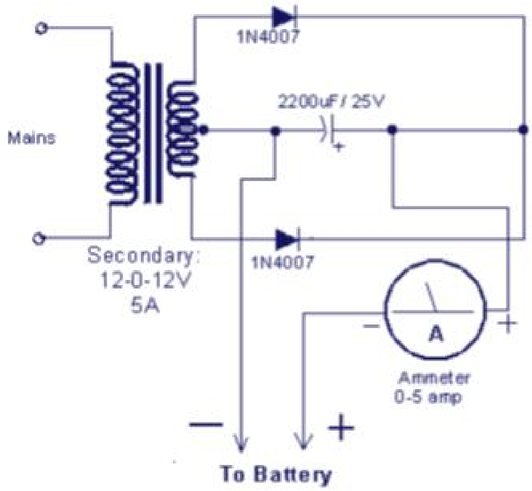

Fig 3: Approach 2

B. Water Flow Management System

Approach 1:

We shall supply water to our system for watering our plants by taking water directly from the taps built in our homes. There will be a small tank where water will be stored and be used when needed. When the tank is empty, it can be filled up by using a hose pipe connected directly to the tap system in our homes. After that we will supply water to the plant through gravity fed water tanks. Gravity fed system relies on gravity to help water flow through your home’s pipes.

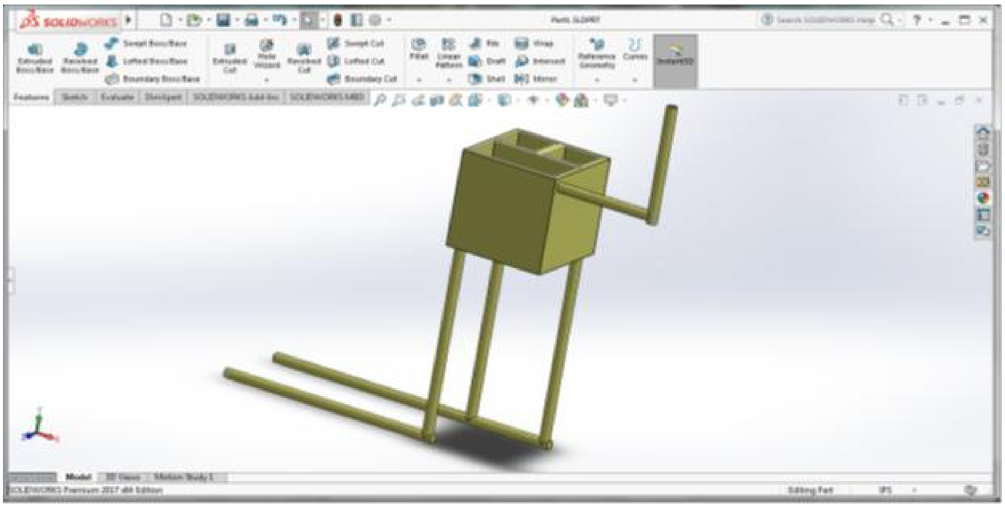

Fig 4: Gravity Fed System designed in Solid Works CAD Software

Approach 2:

Another approach is to generate our own water using a separate device which can extract water from the environment using an atmospheric water generator (AWG). All air contains at least a little water. On hot, muggy days, the air feels thick and uncomfortable because it's saturated with moisture. Water generators, also known as water makers, harvest the moisture suspended in humid air. An atmospheric water generator creates clean, fresh drinking water from the humidity in the air via a hyper-efficient condensing process. Water is created at the point of consumption, making this an environmentally-friendly and sustainable solution.

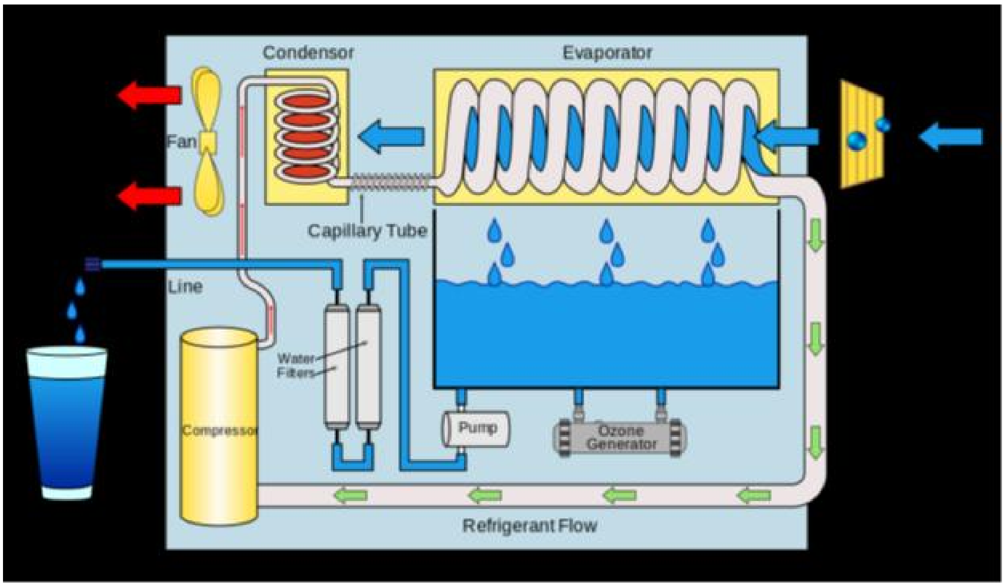

Fig 5: AWG

C. Camera and Pesticide system [The Robotic Arm]

Let us discuss the Camera and Pesticide system. All plants in their life span sometimes contract diseases and as such we need to give the appropriate pesticides and medicines to the plants. One engineering barrier we face in such a situation is how do we give the medicines to the plants? Also, we need to monitor the plants and so we need a closed-circuit camera. But fixing the camera to a fixed part of the balcony makes it difficult for us to take clear close up pictures of the leaves of the plants which we will later use to analyze the plants and determine what diseases it has contracted. So, we came up with the idea that we will build a Robotic arm which can move freely in space and on top of which we will attach a closed-circuit camera and a Pesticide Sprayer. As the Arm is able to move freely so it can move and take close up pictures of each individual plant and spray the medicines on every part of each plant.

Design 1 [3 DOF robotic arm]

After doing some research we came to the conclusion that we will build a 3 Degree of Freedom (3 DOF) robotic arm. 3 DOF robotic arms have 3 degrees of freedom. Meaning it has at max 3 joints which can rotate freely. 3 DOF robotic arm has 3 independent joints that can provide freedom of movement of the manipulator, either in a rotational or translational (linear) sense. Also, our plan was to attach the arm to a Linear Rail Guide System which can move along the horizontal axis thus allowing the arm to reach all parts of the balcony. The camera and the pesticide sprayer will be attached to the head on the robotic arm. Image of the 3 DOF robotic arm we planned to build is represented below.

Fig 6: 3 DOF Robotic Arm

Design 2 [Linear Axis Robotic arms]

Other designs we planned to use for building the robotic arm is to use Linear Axis Robotic arms which uses linear rail guides to move freely about the X, Y, Z axis and thus enabling it to move freely in space. One such example of a linear axis robotic machine is the CNC machine. In this design we came up with the idea that we will attach the camera and the pesticide sprayer on a platform and the platform will be able to move along the X, Y, Z axis rail guides allowing the platform to reach all parts of the balcony. In this design we will use linear rail guides which are available in the market to build the moving platform. In short, this CNC based linear axis robotic arm works together with a series of motors and drive components to move and control the machine axes, executing the programmed motions. Image of the linear axis robotic arm we planned to build is represented below.

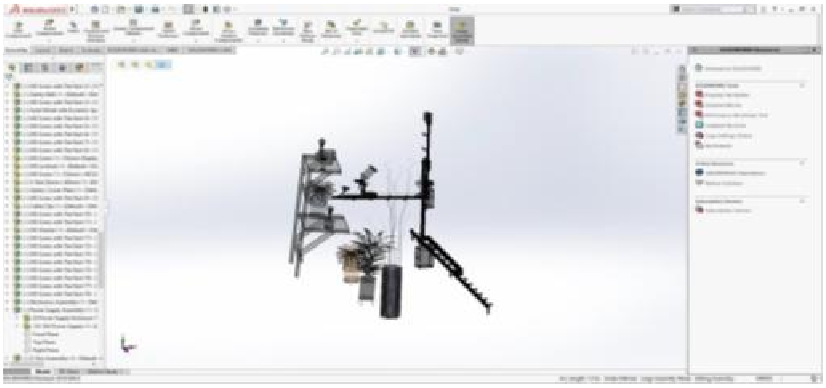

Fig 7: Linear axis robotic arms

Design 3 [Linear Axis Robotic Arm but with retractable and extendable parts]

The last design we decided to build is the Linear Axis Robotic Arm but with retractable and extendable parts along the Y and Z axis. That is to say this design will be similar to the previous design but instead of using a linear rail guide along the Y and Z axis to move the platform on which the camera and pesticide sprayer will be mounted to, we will attach the platform on a retractable and extendable arm which can extend like the head of an extendable antenna. Two hollow cylinders with different diameters will be fitted one inside the other like that of a syringe and the inside cylinder can extend making the platform move along the Y and Z axis. Such designs are called telescopic hydraulic cylinders. Such a design will allow us to make the arm compact and it will save space inside the balcony. Image of the linear axis robotic arm with telescopic hydraulic cylinders along the Y and Z axis is represented below.

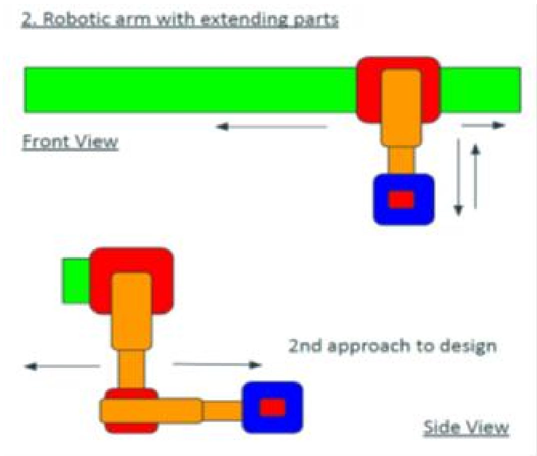

Fig 8: Linear Axis Robotic Arm but with retractable and extendable parts

2.4 Analysis of multiple design approach

2.4.1 Power management system

Some strong and weak points are shown for both the designs where we use solar panels or lithium ion batteries as backup power. Here we have used power from the national grid as the main source of power.

TABLE 3. COMPARISON BETWEEN A SOLAR PANEL AND LI-ION BATTERY AS BACKUP

Using Solar Panels	Using Lithium Ion batteries as UPS
Takes up a lot of space	Takes a little space
Solar panels have their batteries charged up by the sun	UPS has its batteries charged up by power supplied by the grid
Power generation rate is low	Does not generate power rather stores power from the grid
Can supply power to system for a long period of time in case of power outage	Supply of power is for a short time in case of a power outage
Supplied voltage is low	Supplied voltage can be regulated, from high voltage to low voltage

Here our system needs backup power for a very long period of time in case of a large power outage. UPS can supply power for a very short time but solar cells can supply power for a long time despite it producing power at a slow rate and voltage is low. But as our system requires low voltage about 12V and power consumption by the system is also low. So, for backup power using solar panels is the better option while using power from the grid as its main source of power supply. So, we use solar panels as the secondary power source for our project instead of using UPS.

2.4.2 Water flow management system

Some strong and weak points are shown for gravity fed water system and for AWG water system

TABLE 4. COMPARISON BETWEEN USING TAP WATER AND AWG AS WATER SOURCE

Using Tap water	Water produced by AWG
Water taken directly from taps present at our home	Water is produced from the atmosphere using atmospheric water generators
Very cost effective	Very costly to build
Water is taken from the tab so it is available 24/7	Rate of production of water is very low. Mostly in the winter season
Practically needs no electricity to fill up the tanks as water coming from the taps has high pressure.	Needs a lot of electricity to produce water and pump is used to fill up the tank

So, it is clear that supplying water to the tanks of our system using taps present in our homes as the main source of water is the better option. We only need to attach a solenoid valve in the tank to control the water flow. We do not need a pump also as water coming from the taps has high pressure and as such the tanks get filled when the valve is open. Also, as the tank is situated at a high place inside the balcony, water is also supplied to the plants with the help of gravity thus we call it gravity fed water system.

2.4.3 Robotic arms used for attaching the camera and pesticide

Some strong and weak points are shown for the three designs we made for the mechanical arms we designed as shown below.

TABLE 5. COMPARISON BETWEEN A 3-DOF, LINEAR AXIS ROBOTIC ARMS AND MODEL WITH EXTENDABLE PARTS

3 Degree of Freedom (3 DOF) robotic arm	Linear Axis Robotic arms	linear axis model with retractable and extendable parts
Complex and hard to build	Easy to build	Very complex and hard to build as it has many complex mechanisms inside
Cost effective	Cost effective	Costly to build
Has precise control	Has precise control	Control is not so precise
Software to control arm is complex	Software to control arm is easy to build	Software to control arm is easy to build
Takes up a lot of space	Takes up a lot of space	Takes up a little amount of space
Resilient to breaking	Can break due to more load Fragile structure	Can break due to more load Fragile structure

Therefore, considering all the points, we have decided to build the Linear axis robotic arm as our optimal solution. This is because, though this model is fragile and can break due to high load. But the weight of a small camera and a pesticide sprayer is very little so load is not a factor and if handled properly, the model will not break. Tough, it takes a lot of space but the model is easy to build, cost effective, has precise control and the software needed to control the model is easy to build. So, building the linear axis robotic arm for our project is the better and optimal solution.

2.5 Conclusion

In conclusion we as a team have decided to build our system based on the analysis done in this section of the article which is the multiple design approach. As mentioned earlier, our system consists of 3 sub-systems and these are a) Power Management system, b) Water Flow Management System and c) Camera and Pesticide System. For the power management system, we decided to build a simple power distribution system. It mainly consists of a power supply which converts the AC mains voltage of 220V/240V 50Hz to DC voltage of 12V. We will connect a lithium ion battery to the power supply using a simple UPS system so power is not interrupted during power outage. Next for the mater management system, we will use the simple tank, pipe and tap water system to supply water to the plants. The tank will be connected to the tap water via a water hose and a water hose coming from the tank will be connected to the pots of every plant. Flow of water will be controlled via solenoid valves. Lastly for the robotic arm we will build a linear axis model. The pesticide sprayer and the camera will be attached to the main body of the Robotic arm.

Chapter 3 Use of Modern Engineering and IT Tool

3.1 Introduction

One of the traits that must be nurtured in the graduating engineer is the ability to use "Modern Engineering Tools. Engineers have long been able to design useful products as a result of technological advancements. They were able to create wonderful works of art because of the tool-set or collection of technologies that comprised those technologies. However, the tools of yesteryear are no longer enough in light of the challenges that today's advances present. New technology can considerably boost the efficiency of modern engineers. Feature-Based Approaches are the most common way for altering models in order to evaluate different design options. However, as more elements are added to a model, more interrelationships are formed, which is an issue. As a result, the model becomes less adaptive to change, increasing the risk that it will fail. Engineers may end up dedicating a significant amount of time and effort on battling the CAD program rather than investigating other designs.

3.2 Select appropriate engineering and IT tools

We have taken the help of various modern engineering/IT Tools for the development of models and schematics. We have used Solidworks for the development of a 3D model of the mechanical arm. Furthermore, we used Proteus for the necessary schematics and Thonny IDE for programming that will be used to instruct the arm. Besides, we are also integrating our project with a server for the ease of image processing and data storage. This can be done using the API (Application Programming Interface) service of an app or any other storage devices. Raspberry Pi is our primary choice as a CPU as it suits our needs. However, we also have Arduino as a backup option if the need arises.

TABLE 6. LIST OF HARDWARES AND SOFTWARES FOR THE DESIGN

Hardware	Software
1. Raspberry Pi Zero W 2. Stepper Motor- Nema 17/ Nema 23 3. Timing Belt - 2mm Pitch 4. Coupler - 5mm to 8mm 5. Threaded Rod 8mm, 2mm pitch 6. Soil Moisture Sensor 7. Water Pump 8. Watering Pipe 9. Solenoid Valve 10. Aluminium Profile T-Slot 11. Power Supply - 12V 10 AMP 12. Stepper Motor Driver - DRV8825 13. Raspberry Pi Zero Camera 14. Camera Stand 15. Connecting Wires	1. Thonny IDE 2. Python 3. All the necessary library 4. Arduino IDE 5. Solidworks 6. Proteus

3.3 Use of modern engineering and IT tools

Software's for design and simulations

1. Solidworks: Used for designing CAD models for printing

2. Arduino IDE: Used to write code for the Arduino Mega

3. Proteus: Used for designing the simulation of the overall system

4. Thonny IDE: Used to write Python code for the Raspberry Pi

Hardware Components

1. Raspberry Pi Zero W: We used Raspberry Pi to take pictures and record live video of the plant to use it for disease detection purposes.
2. Stepper Motor: to move mechanical arms in different Axis.
3. Timing Belt: Timing Belt is used for moving the base along different axes.
4. Coupler: Coupler used to connect the Screw Belt to the Stepper Motor.
5. Threaded Rod 8mm, 2mm pitch:
6. Soil Moisture Sensor: This sensor is used to detect and measure the soil humidity of each of the plants.
7. Water Pump: The water pumps are used for carrying water to the plants.
8. Solenoid Valve: The valves are used to control the flow of water to individual plants.
9. Aluminium Profile T-Slot: The Al-Profile is used to build the base of the system.
10. Power Supply - 12V 10 AMP: Power supply is used for supplying power to the system.
11. Stepper Motor Driver: These motors are used to transform the positions of the axes.
12. Raspberry Pi Zero Camera: Pi-camera is used to capture the images of the plants and send them to the users.
13. WiFi Module: This module is used to connect the system to the internet.
14. Arduino Mega: This micro-controller is used to control the movements of the axes as well as controlling the entire water system.

3.4 Conclusion

Through research and analysis, the addressed design and the list of the components are found and are considered to be the final design. This design is tested through many simulations as well as trials and errors and found our desired output. In order to design unavailable parts, the CAD models are designed in SolidWorks. In order to program the Raspberry Pi and Arduino micro-controller, we used Thonny IDE and Arduino IDE respectively. Thus, we used the best modern engineering and IT tools for our project.

Chapter 4 Optimization of Multiple Design and Finding the Optimal Solution

4.1 Introduction

In the multiple design approach, we have discussed different designs for the sub-systems of our project. We discussed the Power Management system, the Water Flow Management System and the Camera and Pesticide System. Many designs were discussed for each of these sub-systems. Once again for the readers sake we will discuss the different designs discussed in the previous sections. Our project consists of 3 sub-systems. These are a) Power Management system, b) Water Flow Management System and c) Camera and Pesticide System.

The Power Management system included designs such as

I. To power the whole system, we decided to build a simple power distribution system. It mainly consists of a power supply which converts the AC mains voltage of 220V/240V 50Hz to DC voltage of 12V. We will connect a lithium ion battery to the power supply using a simple UPS system so power is not interrupted during power outage.

II. Another design also included a simple power distribution system. It mainly consists of a power supply which converts the AC mains voltage of 220V/240V 50Hz to DC voltage of 12V. But instead of connecting a lithium ion battery alone we will connect a Solar Cell array with the lithium ion battery to the power supply using a simple UPS system so power is not interrupted during power outage.

III. Another design includes using piezoelectric transducers to generate energy for our system. Such transducers convert mechanical energy into electrical energy. We can make false tiles with piezoelectric transducers fitted at the bottom of the tiles. When someone walks over the tiles, it will transform the walking motion of a person into electrical energy thus powering our system.

The Water Flow Management System include designs such as

I. To supply water to our system for watering our plants, water is directly taken from the taps built in our homes. There will be a small tank where water will be stored and be used when needed. When the tank is empty, it can be filled up by using a hose pipe connected directly to the tap system in our homes. That is to say, we will use the simple tank, pipe and tap water system to supply water to the plants. The tank will be connected to the tap water via a water hose and a water hose coming from the tank will be connected to the pots of every plant. Flow of water will be controlled via solenoid valves.

II. Another approach is to generate our own water using a separate device which can extract water from the environment using an atmospheric water generator (AWG) but such a system is costly and not efficient.

The Camera and Pesticide System include designs such as

To take clear and precise pictures of each individual plants for the purpose of analyzing and also to spray pesticides to each of the disease affected plants we decided to will build a Robotic arm which can move freely in space and on top of which we will attach a closed-circuit camera and a Pesticide Sprayer. As the Arm is able to move freely so it can move and take close up pictures of each individual plant and spray the medicines on every part of each plant. 3 designs were selected for the robotic arm. This are:

I. 3 Degree of Freedom (3 DOF) robotic arm. 3 DOF robotic arms have 3 degrees of freedom. Meaning it has at max 3 joints which can rotate freely. 3 DOF robotic arm has 3 independent joints that can provide freedom of movement of the manipulator, either in a rotational or translational (linear) sense. Also, our plan was to attach the arm to a Linear Rail Guide System which can move along the horizontal axis thus allowing the arm to reach all parts of the balcony. The camera and the pesticide sprayer will be attached to the head on the robotic arm.

II. Linear Axis Robotic arms which uses linear rail guides to move freely about the X, Y, Z axis and thus enabling it to move freely in space. In this design we came up with the idea that we will attach the camera and the pesticide sprayer on a platform and the platform will be able to move along the X, Y, Z axis rail guides allowing the platform to reach all parts of the balcony. In this design we will use linear rail guides to build the moving platform. In short, this CNC based linear axis robotic arm works together with a series of motors and drive components to move and control the machine axes, executing the programmed motions.

III. The last design we decided to build is the Linear Axis Robotic Arm but with retractable and extendable parts along the Y and Z axis. That is to say this design will be similar to the previous design but instead of using a linear rail guide along the Y and Z axis to move the platform on which the camera and pesticide sprayer will be mounted to, we will attach the platform on a retractable and extendable arm which can extend like the head of an extendable antenna. Two hollow cylinders with different diameters will be fitted one inside the other like that of a syringe and the inside cylinder can extend making the platform move along the Y and Z axis. Such designs are called telescopic hydraulic cylinders. Such a design will allow us to make the arm compact and it will save space inside the balcony.

4.2 Optimization and identification of multiple design approach

Analysis of the multiple designs of each sub-system in tabular forms gives us a clear idea as to which design is the optimal design. We shall see the strong points and weak points of each sub-system multiple designs.

4.2.1 Power Management system

TABLE 7. ADVANTAGES AND DISADVANTAGES OF EACH DESIGNS

Using Solar Panels	Using Lithium Ion batteries as UPS	Using piezoelectric transducers
Takes up a lot of space to build	Takes up little space to build	Takes up a lot of space to build
Systems using Solar panels have their batteries charged up by the sunlight. Clean energy source	UPS has its batteries charged up by power supplied from the grid. Electricity produced by The electricity generation companies are not clean	Systems using Piezoelectric transducers have their batteries charged up by conversion of mechanical energy to electric energy. Clean energy source
Power generation rate is low	Does not generate power rather stores power from the grid	Power generation rate is very low
Can supply power to system for a long period of time in case of power outage	Supply of power is for a short time in case of a power outage	Supply of power is for a short time in case of a power outage
Supplied voltage is low	Supplied voltage can be regulated, from high voltage to low voltage	Supplied voltage is very low
Cost to build the system is high	Cost to build the system is low	Cost to build the system is very high

Considering all the advantages and disadvantages in mind and also considering cost management as a key point while designing the system, we choose to build the power management system of the project using a simple power distribution system which mainly consists of a power supply which converts the AC mains voltage of 220V/240V 50Hz to DC voltage of 12V. We will connect a lithium ion battery to the power supply using a simple UPS system so power is not interrupted during power outage. We will not use any Solar cells nor any piezoelectric transducers to produce energy as customers do not want products which are costly and bulky in size.

4.2.2 Water flow management system

TABLE 8. ADVANTAGES AND DISADVANTAGES OF EACH DESIGNS

Using Tap water	Water produced by AWG
Water taken directly from taps present at our home using hose and pipes	Water is produced from the atmosphere using atmospheric water generators
Very cost effective practically zero cost	Very costly to build
Water is taken from the tap so it is available 24/7	Rate of production of water is very low. Mostly in the winter season
Practically needs no electricity to fill up the tank as water coming from the taps has high pressure which easily fills up the mini tank for storing water	Needs a lot of electricity to produce water and a pump is used to fill up the tank. Waste of power and electricity

Considering all the advantages and disadvantages in mind and also considering cost management as a key point while designing the system, it is clear that supplying water to the tanks of our system using tap water present in our homes as the main source of water is the better option. We only need to attach a solenoid valve in the tank to control the water flow. We do not need a pump also as water coming from the taps has high pressure and as such the tanks get filled when the valve is open. Also, as the tank is situated at a high place inside the balcony, water is also supplied to the plants with the help of gravity and using mini solenoid valves, thus we call it gravity fed water system.

4.2.3 Robotic arms used for attaching the camera and pesticide

TABLE 9. ADVANTAGES AND DISADVANTAGES OF EACH DESIGNS

3 Degree of Freedom (3 DOF) robotic arm	**Linear Axis Robotic arms**	**linear axis model with retractable and extendable parts**
Complex and hard to build	Easy to build	Very complex and hard to build as it has many complex mechanisms inside
Cost effective	Cost effective	Costly to build
Has precise control	Has precise control	Control is not so precise
Software to control the robotic arm is complex	Software to control the robotic arm is easy to build	Software to control the robotic arm is easy to build
Takes up a lot of space	Takes up a lot of space	Takes up a little amount of space, compact in size
Resilient to breaking	Can break due to more load Fragile structure	Can break due to more load Fragile structure

Considering all the advantages and disadvantages in mind and also considering cost management as a key point while designing the system, we have decided to build the Linear axis robotic arm as our optimal solution. This is because, though this model is fragile and can break due to high load. But the weight of a small camera and a pesticide sprayer is very little so load is not a factor anymore and if handled properly, the model will not break. Tough, it takes a lot of space but the model is easy to build, cost effective, has precise control and the software needed to control the model is easy to build. So, building the linear axis robotic arm for our project is the better and optimal solution. In short, we will build our system using a simple power supply with lithium ion batteries, gravity fed water system made using simple objects like water hose, pipes, mini water tank and small solenoid valves and lastly for the robotic arm for capturing pictures of plants and to spray pesticide to each plant we will build the linear axis robotic arm.

4.3 Performance evaluation of developed solution

After optimization and selection of the multiple design approaches, we started to build the project. Initially we thought to first build the linear axis robotic arm as it is the most complex build in our project. We need to build a mechanical robotic arm which can move freely in 3D space. As the name suggests, the arm rests upon 3 linear rail guides which guides and supports the whole arm. A linear axis robot has 3 axes of motion, namely the X-Axis, the Y-Axis and the Z-Axis. That is to say the arm has 3 axes: The X, Y, Z axis. The bottom part is the X axis. The vertical part is the Z axis and the last horizontal part is the Y axis on which a plate is mounted. The camera and the pesticide sprayer will be mounted on this plate. The plate moves along the Y axis. The Y axis moves along the Z axis and the whole Z axis moves along the X axis thus allowing the plate on which the camera and pesticide sprayer will be mounted to, to be able to move freely in any direction in space. Before starting to build the model, we first build a CAD model of the design in Solid Works. Solid Works is a well-known CAD Software for designing 3D models. Our initial models for the linear axis robotic arm done in Solid Works. Screenshots of the simulation and design of the models created in Solid-Works and later which we will build is shown below.

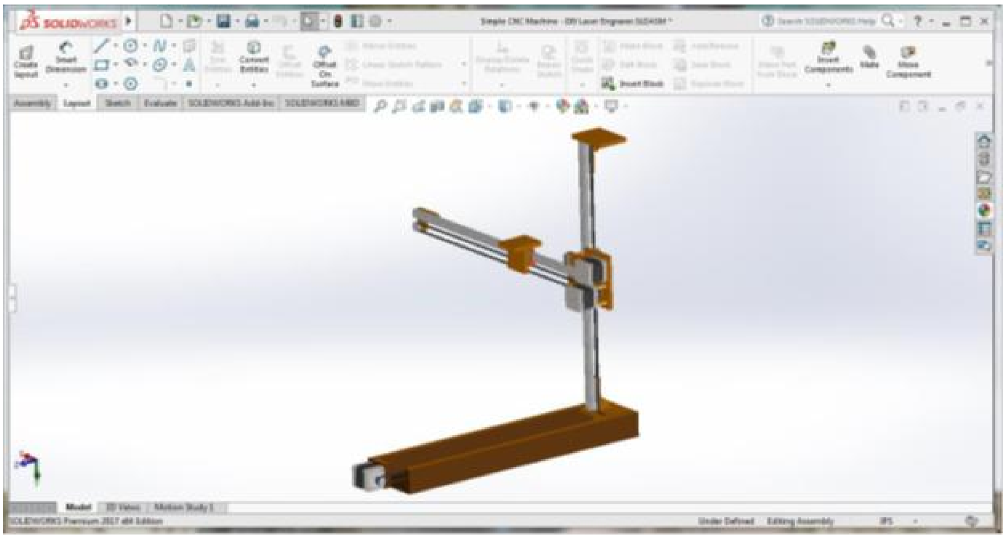

Fig 9: Design of the linear axis robotic arm

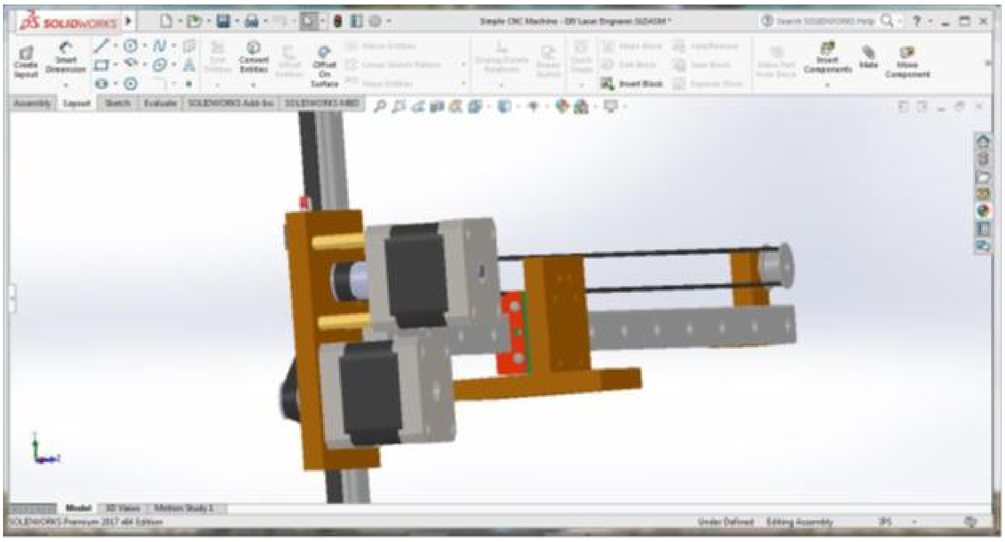

Fig 10: Design of the Y axis of the linear axis robotic arm

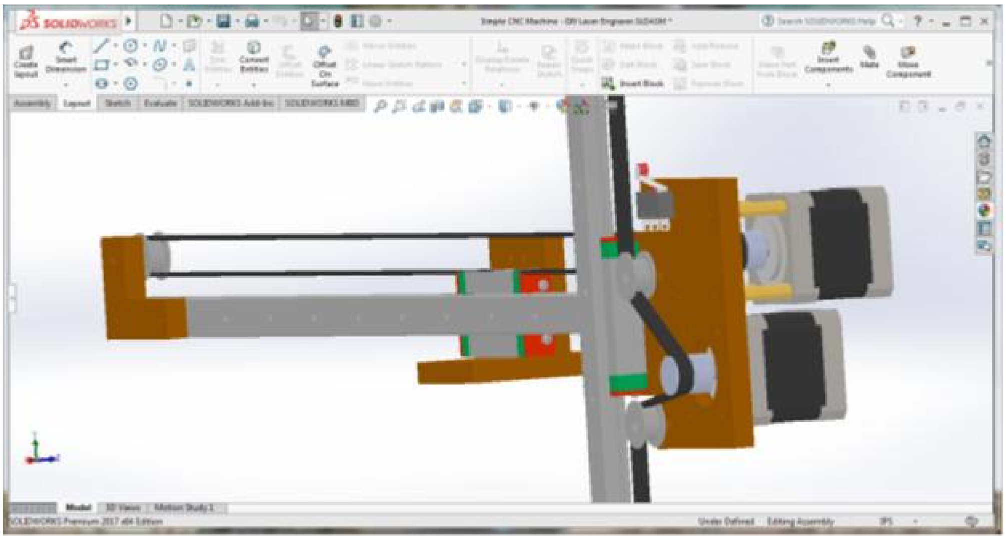

Fig 11: Design of the Z axis of the linear axis robotic arm

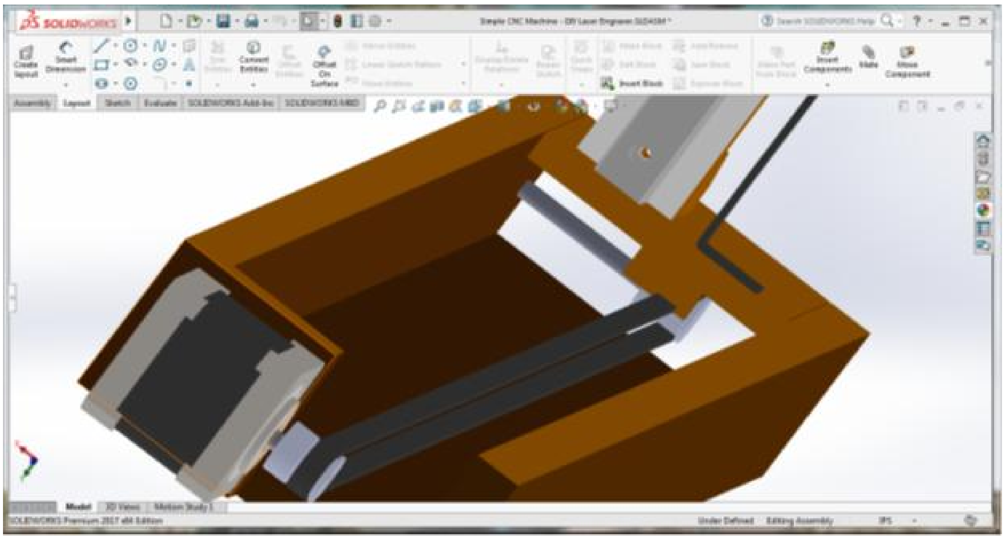

Fig 12: Design of the X axis of the linear axis robotic arm

After designing the initial model in CAD software, we started to build the robotic arm. The final product we built is shown below and we will discuss how we made the arm and which materials we used.

Fig 13: Linear axis robotic arm

Fig 14: Linear axis robotic arm

To build the X-Axis we first wanted to use aluminum rail guides but the current market price of such rail guides made for CNC type machines is just too high. So, we decided to build the X-Axis using wood. Wood is a durable material and we can cut it and give any shape we desire. After thinking and planning we made a U-shaped channel using wood. Then we attached two 36-inch aluminum rail profiles which we brought at a cheap price and attached the rails to the wood frame. To build the base on which the Z-Axis was to be built on and how the base was to move along the X-Axis, we attached 4 ball bearings which are used in traditional Thai Glasses or window frames to the base of the Z-Axis. The X-Axis frame works much like how the window frames in our home works. The sliding mechanism is the same. Then to make it move automatically, we attached a belt to the platform and attached the belt to a stepper motor. The drive belt and the motor mechanism enable the Z-Axis base plate to move along the X-Axis. To build the Z-Axis we bought a square aluminum profile and 3D printed some parts to make the Z-Axis. To move the plate on which the Y-Axis rests along the Z-Axis, we used a screw belt and a NEMA stepper motor to move the whole Y-Axis along the Z-Axis. When the stepper motor rotates, the Z-Axis moves up and down. The Y-Axis is built in a similar fashion like the X-Axis. That is to say, the Y-Axis is also built using a belt and motor drive system. Our robotic arms design is mainly based on the typical CNC based designs but with slight modifications. We have used an Arduino Mega as the brains of the motor control of the drive systems. This Arduino controls the stepper motors which are used to control the X, Y, Z axis motions. Thus, we can move the camera and the pesticide sprayer attached to the robotic arm in space to achieve our objective.

Demonstration video of our system with link is given: **https://youtu.be/JOiLCUb4Ajo**

The shield used to connect the Arduino to the stepper motors and the custom-made PCB to attach the ESP32 Wi-Fi module to send pictures captured by the raspberry Pi camera to the user is shown.

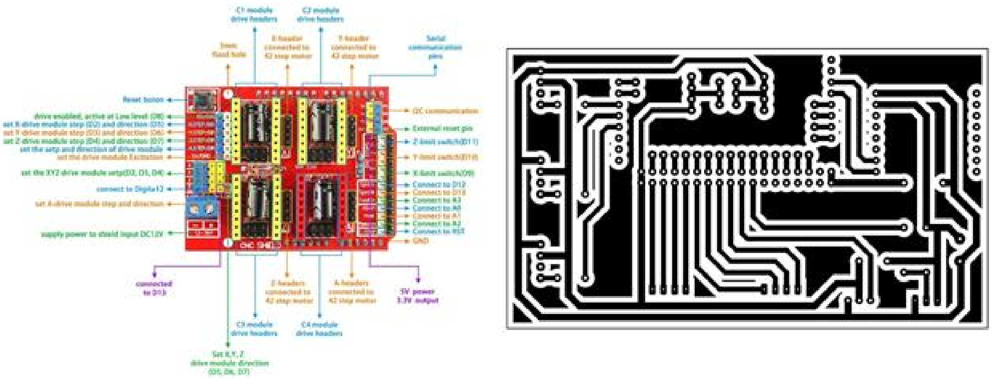

Fig 15: Drive shields and custom-made PCB

4.4 Conclusion

After conducting all experiments and running all the codes we find that our system is working perfectly. The system does not have to work with precision and so no-load test or any other graph related to load vs power consumption was made. As the system is fully automated and it only functions once every 24 hours so not much power is consumed by the system as it's not a continuous process. The system makes a lot of noise because of the stepper motors but that is also of little concern to us. Yes, improvement can be made on the overall design but to do that we need to use better and high-quality parts but as this is only a demonstration project so we chose not to spend too much money on the project. If better and quality materials are used to build the model then the system would be smooth and it would make much less noise. Frictional losses would be very low and as such power consumption will be low also. In summary the system is working as intended but it makes a lot of noise and frictional losses are high and the system cannot handle high load. But that is of no concern at all as our system is made light weight, load is very little and frictional losses can be removed is better and quality materials are used but we choose not to do so as doing so increases the cost and spending money for a demonstration project is a waste of money. But now as we have demonstrated that the system works, at the time of mass production we will be able to use high quality materials and production cost can also be kept at minimum.

Chapter 5 Completion of Final Design and Validation

5.1 Introduction

We have been working on the project for almost a year. During FYDP-P we initially planned what to build for the project. We after extensive research came up with the idea of the Automated Plant take caring system. Our objective was to build such a system which will take care of plants without any human interaction. That is to say it is an automated plant take -caring system as the name suggests. During the FYDP-D phase we thought of multiple designs which could achieve the same outcome though the designs, models and structure were different. We have talked about the multiple designs in the multiple design section. During FYDP-C we would start to build the real physical model to implement it into the real world. The designs we selected for the final product were discussed in the optimization and identification of multiple design sections. After optimization and selection of the multiple design approaches, we started to build the project. Initially we thought to first build the linear axis robotic arm as it is the most complex build in our project. We need to build a mechanical robotic arm which can move freely in 3D space. After building the Linear Axis Robotic arm, we built the water management system which is simply a tank connected to a pump and some solenoid valves with hose pipes for watering the plants. The pumps and the solenoid valves are controlled by the Arduino. Lastly we used soil sensors to monitor the soil water level of each plant. All these components work together to achieve our goal. Details of the project are discussed in the next section.

5.2 Completion of final design

Demonstration video of our system with link is given: https://youtu.be/JOiLCUb4Ajo

The video links to a YouTube video which is a demonstration video of our whole working system. But for those who cannot access the website, we will explain in details of the design and its completion. At first we built the robotic arm. The robotic arm is called 'Linear Axis Robotic Arm'. Its design is based on the standard model of a CNC machine used for different industrial uses. That is to say the arm is able to move in space. Before starting to build the model, we first build a CAD model of the design in Solid Works. After designing the initial model in CAD software, we started to build the robotic arm. To build the X-Axis we first wanted to use aluminum rail guides but the current market price of such rail guides made for CNC type machines is just too high. So, we decided to build the X-Axis using wood. Wood is a durable material and we can cut it and give any shape we desire. After thinking and planning we made a U-shaped channel using wood. Then we attached two 36-inch aluminum rail profiles which we brought at a cheap price and attached the rails to the wood frame. To build the base on which the Z-Axis was to be built on and how the base was to move along the X-Axis, we attached 4 ball bearings which are used in traditional Thai Glasses or window frames to the base of the Z-Axis. The X-Axis frame works much like how the window frames in our home works. The sliding mechanism is the same. Then to make it move automatically, we attached a belt to the platform and attached the belt to a stepper motor. The drive belt and the motor mechanism enable the Z-Axis base plate to move along the X-Axis. To build the Z Axis we bought a square aluminum profile and 3D printed some parts to make the Z-Axis. To move the plate on which the Y-Axis rests and moves along the Z-Axis, we used a screw belt and a NEMA stepper motor to move the whole Y-Axis along the Z-Axis. When the stepper motor rotates, the Z-Axis moves the base plate on which the Y-Axis rests, up and down. The Y-Axis is built in a similar fashion like the X-Axis. That is to say, the Y-Axis is also built using a belt and motor drive system. Our robotic arms design is mainly based on the typical CNC based designs but with slight modifications. We have used an Arduino Mega as the brains of the motor control of the drive systems. This Arduino controls the stepper motors which are used to control the X, Y, Z axis motions. Thus, we can move the camera and the pesticide sprayer attached to the robotic arm in space to achieve our objective. After building the Linear Axis Robotic arm, we built the water management system which is simply a tank connected to a pump and some solenoid valves with hose pipes for watering the plants. The pumps and the solenoid valves are controlled by the Arduino. We attached the hose pipes from the tanks to the robotic arm. Then we place the end of each pipe inside the pots of each plant. We also placed the soil sensors into the soil of each plant. So after running the codes when the soil moisture sensor detects that the water level of soil is below a certain threshold then the pumps would start and give water to the plants. Here it is to be mentioned that all plants are independent of each other. That is if one plant has dry soil but the other has wet soil. then only the plant with dry soil will get water. Again we have built a camera into the robotic arm which will take pictures of each individual plant and send the images to the user via mail. So after using a third party app and after determining if a particular plant has contracted any kind of disease then if the user commands the robotic arm would go to that particular plant and spray medicine over it. We have built an app to communicate with the device via Wi-Fi. We attached an ESP32 Wi-Fi module to the Arduino. The app is made with BLYNK. When the user sends commands, the device receives commands and acts accordingly.

5.3 Evaluate the solution to meet desired need

After uploading all the codes we find the device working perfectly. The criterion's that needs to be fulfilled and evaluated are discussed.

Movement of the linear axis robotic arm

When the device is turned on, it at first goes to its home position As intended by the makers. This is so to initialize the system. We have specified some specific locations where each plant is to be placed. We used Co_ordinate system location specifying while creating the codes. so when the user tells the device to go to a specific location like go to location 2 then the arm starts to move and goes to the specified location. After reaching the specified location it waits for the user to give the next command. After testing we find the arm is moving as we expected. The only problem is as it's just a demonstration so we used cheap materials and so frictional loss is high resulting in the stepper motors making loud noise. Also the device is slow because it is fragile so if it starts to move fast then it may break. But this is of no concern to us as precise control and fast working is not what we want. The objectives we set out to achieve are achieved.

Fig 16: Linear Axis Robotic arm

Capture image of plant or spray pesticide

After the robotic arm reaches its location it will wait. There are two commands the user can give. Either take pictures of the plant or spray medicine to the plant. The user can give commands to the device from his cell phone. Somewhere ever the user may be, he can still give commands to the device. The app used to control the device is made using BLINK. After testing we see that when we give the command to take a picture, the Raspberry PI camera installed onto the arm captures a picture of the plant and sends it to the user via Gmail. The user receives the image, uses a third party app to analyze the image and finds results if the plant has contracted any kind of disease or not. If he finds the plant is sick, then he gives the command to spray medicine over the plant. The device then executes the programme and sprays medicine over the plant. After spraying the medicine, the device returns to its home position. If no medicine needs to be sprayed then the user just tells the device to return to home position and it goes back to its initial position. After testing we find all is working perfectly. More advancement can be made into the device. The device has a lot of potential. If the code to run the machine is generated using more complex commands and machine learning is introduced then our device will have a lot of functions to work with. The BLYNK app interface for the user is shown below.

Fig 17: BLYNK UI

Measure soil water level and give water to the plants

We have attached many soil sensors to each of the plants. After testing we find that when we pick up the soil sensor from the pot of a particular plant and place it in dry soil, then the solenoid valves and motors of that plant turns on and water start pouring into the plant through a series of pipes and water comes directly from the mini tank placed into the balcony. When we place the soil sensor in wet soil, the pump and solenoid valve of that plant turns off and water stops coming out. After testing we find the watering system working fine. No problems there also.

5.4 Conclusion

So in conclusion we can say that our device is working perfectly. The codes we created, The device is executing all the commands perfectly. The only problem is the device makes a lot of noise while working and frictional heat loss occurs resulting in high power consumption. But that can be fixed by using high quality materials while building the device. Besides that the device works fine. It executes all the programme and when command is given, it goes to the specified location, takes pictures of the plants and if needed sprays medicine over the disease affected plants. Also depending on the soil dryness, the device decides whether to give water to the specific plant or not. In short the device works as we wanted, no problems seen so far.

Chapter 6 Impact Analysis and Project Sustainability

6.1 Introduction

Impact analysis is an evaluation and tracking of a proposed change to a project's scope. It attributes the outcomes and impacts to the operation of the project. In the project management industry, sustainability refers to a way of doing business that strikes a balance between the environmental, social, and economic demands of project-based work while still meeting stakeholder needs without endangering or overburdening future generations.

6.2 Impact Analysis

6.2.1 Societal Impacts

The project is designed with an intention to encourage more and more people into gardening. Since the system is able to update the user about the plants' condition, users will have no issues taking care of them remotely. Thus, even if they are not home, they do not have to worry about their plants' condition. Therefore, they will be motivated to get involved in gardening.

6.2.2 Health and Safety Impacts

The project is designed in order to encourage people to do urban gardening. Hence, it is ensured that the system does not raise any kind of health concerns. On top of that fact, the entire system operates at a low voltage making it harmless for the user or anyone else. All the components and the materials used to design the project are made sure to not hamper the lives of our neighborhood.

6.2.3 Environmental and Legal Impacts

The ecosystem is a critical part of our environment. Living species have their own ways of interaction with others as well as their surroundings. However, any external factor may be able to disrupt this ecosystem. Since all the living beings are part of this ecosystem, it is our responsibility to ensure no harm is caused to this system. Since our project encourages gardening, it will bring more balance to this system and, thus, will help in improving the conditions of our ecosystem. Also, the project is designed in a way such that it will pose no threat to the ecosystem of the environment.

6.3 Project Sustainability

6.3.1 Rooftop Gardening

As urban areas are expanding gradually, open spaces for plantations and gardening are becoming scarce. Gardening on the rooftops and balconies of urban buildings will be a viable option. Our project will be able to assist in this aspect.

6.3.2 Time Saver

People will find it tougher to find the time to care for their plants as their schedules with work and other obligations fill up. Their plants will be taken care of by our technology which will definitely inspire more people to garden.

6.3.3 Green City

Greenery in the urban areas is already evident. Green cities are essential given the speed of global warming. Our tool will readily contribute to giving the concrete and cement of city life some vitality, making it more livable for all of us. It will be beautiful and helpful in combating global warming for both the environment and the future of humanity. Stakeholders will have more than enough reasons to invest in this product as a result of the rising needs for green cities.

6.3.4 Efficient Design Structure

Both cost and performance efficiency were taken into consideration when designing the tool. With a multiple of systems integrated into the design, the tool will be able to do several tasks simultaneously. On the other hand, with multiple systems communicating with each other, the system will require less human input than necessary, improving the overall performance of the device.

6.4 Conclusion

The automated plant nursing system will be a solution to many problems the gardening enthusiasts encounter. It not only addresses the current state of plants, but also offers appropriate ways to solve them. Additionally, with minor improvements, this tool can become a necessity in the lives of every gardener.

Chapter 7 Engineering Project Management

7.1 Introduction

Any complex engineering project requires proper timing and planning for it to work smoothly. Keeping the ultimate objectives in mind and the available resources, the project plan should be followed accordingly. Risks should be taken where necessary and contingency planning should be done in case of any sudden mishaps. We formulated our plan accordingly for the final phase of the project based on the progress that we made previously. While formulating the plan, we adhered to five basic Project Management principles. They are:

7.1.1 Principle 1: Create clear and concise project goals

A project needs elaborate and measurable goals so that the progress can be tracked easily and the desired conclusion can be reached. We followed the best way, i.e., the S.M.A.R.T. criteria, which stands for:

Specific: Making sure the goal has a specific endpoint.

Measurable: Using KPIs to quantify the goals so that they are measurable.

Assignable: Assigning specific goals to respective individuals.

Realistic: Realistic goals that are attainable within a specific time-frame.

Time-related: Specific time frame for the members for achieving the goals.

7.1.2 Principle 2: Risk Management

Like every other project, ours was not free from risks. So, it was necessary to address the risks by team consultation, risk assessments, and planned responses. Here, the main idea is to make the project resilient in the likelihood of any unwanted circumstances. Since the goals were specific and realistic, risks were comparatively low for our project.

7.1.3 Principle 3: Performance baseline

The performance baseline is created based on:

1. Cost

2. Schedule

3. Scope

When planning out these three components, it's crucial to set baselines, also known as KPIs (key performance indicators), to measure them against. These three components all affect one another, so if the scope must change, so will the costs and the schedule in order to make room for that adjustment.

7.1.4 Principle 4: Establish and maintain healthy communication

Communication is one of the most crucial necessities for project success. Our team was constantly in touch with each other in various ways. We updated ourselves on the current progress, upcoming objectives and other necessary tasks. We encouraged open and consistent communication that helped us avoid any issues, anticipate risk, identify any existing problems and resolve any sort of conflict within the team. Our respected supervisors were also consulted from time to time in the need of any sort of assistance.

7.1.5 Principle 5: Clearly define team responsibilities

Team responsibilities were clearly defined using the RACI chart. This lead to proper distribution of everyone's roles in the team and actively point out everyone's role in the progress. RACI charts are an effective means for organizing the team and tracking tasks, milestones, or project decisions. It is essential for setting clear expectations from respective team members so that everyone is clearly informed about their roles.

RACI stands for:

Responsible: Who is responsible for the task?

Accountable: Who will delegate and review the task before it's completed?

Consulted: Who will help review about how current tasks will affect future ones?

Informed: Who will you keep in the loop about overall project progress?

7.2 Define, plan, and manage engineering management project

A project is a temporary, unique, cross-functional activity that is undertaken to introduce changes by a group of people who are skilled in different ways. Our project is a complex engineering project that needs proper planning to be executed. Over the course of the semester, we divided the main task into sub-tasks and assigned them to respective members of the team. In doing that, we kept the skills and expertise of the particular team member in mind so that the work can be done smoothly. For the ease of our purpose, we formulated a Work Breakdown Structure (WBS). A complex, multi-step project is visually outlined using a work breakdown structure (WBS) in project management. As the name implies, it deconstructs the structure of the work that has to be done, starting with the biggest goal and working down to the tiniest deliverable. A WBS is a form of the divide and conquer strategy since it enables project managers to work on one or a few deliverable at a time rather than finishing the entire project at once. The WBS divides a team's work into digestible parts by creating a hierarchy of the items the project will produce. Typically, there are two to four layers in the hierarchy. It makes clear exactly what will be delivered at the project's conclusion and demonstrates how those deliverable connect to one another. Teams have the knowledge they need to clarify the work that each employee is expected to do for every assignment thanks to this detailed perspective of the project. Without the WBS, it is probable that requirements will go unmet, and that the deliverable and possibly the entire project would also fall short of expectations. The project outcomes, the order in which tasks must be completed, and the necessary project deliverable are all clearly outlined in the work breakdown structure document. All team members may clearly understand the outcomes that must occur thanks to a WBS, and the work packages detail exactly what is involved.

The WBS of our project is given as follows:

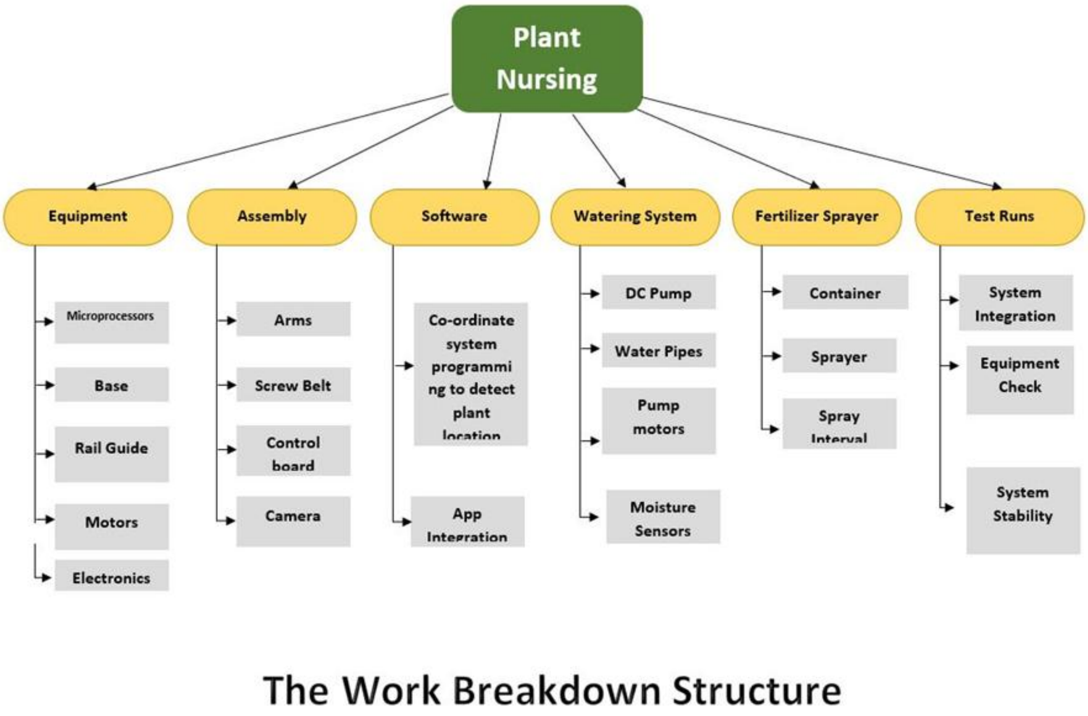

Fig 18: The Work Breakdown Structure

7.3 Evaluate Project Progress

Only proper planning is not enough. Rather, it is needed to be followed and evaluated accordingly. This needs to be done along if any changes are to be made. By complying with the principles of project management, we kept our project updated by forming a chart where we listed the project detail, and weekly progress reports and addressed issues like risk and probable mitigation plans. In doing so we were able to keep track of the status of the project and consult with the designated team members if the need arises. Besides, complying with the chart, we were smoothly able to resolve any wanted situations in a timely fashion. The progress chart of our project is as follows:

Project Title:	**Automated Health Monitoring and Watering System for Plants (Plant Nursing)**

Weekly Status Report

1 Project Details

Week Ending:	25.06.22
Project Manager:	All the team members
Project Summary:	Creating an automated model that will assist in taking care of plants in absence of the users.

2 Project Progress

Project Start Date:	29.07.22
Project End Date:	31.08.22
% Complete:	100%
Overall Budget Spent:	23k (approx.)

3 Task Status

Last Week's Events

Task	Status	Completion Progress	Notes
Finalizing the construction of the arms	On Track	100%	No issues.
Attaching the arms together	On Track	100%	Further checks for stability.
Test the functionality of the motors	On Track	100%	Reviewing the motor positions in terms of weight and generated torque.
Attaching the belt and screw system	On Track	90%	Multiple brackets are needed to keep them in place.

This Week's Events

Task	Status	Completion Progress	Notes
Preparing the codes for the co-ordinate system	On Track	75%	Needs to be reviewed for better accuracy.

Integrating the mobile app	On Track	100%	The SSID is needed to set up.

4 Key Issues, Risks, and Mitigation Plans

Project Issue	Project Risk	Mitigation Plan
Availability of the resources	Certain functions can't be performed	To look for alternate ways of collecting the item
The axis wheels notwithstanding the load	Arm can't reach designated places.	Changing the wheel type based on the load,
Z axis arm stability	While moving it may detach.	Using unconventional ways like zip ties to fasten it.
Wire management	Certain connections may disconnect.	Placement of the motherboard panel as close as possible to the main body.

Fig 19: Progress Chart

7.4 Conclusion

As our project is a very complicated one, its success heavily depended on the successful application of project management. We were able to accomplish that by clearly defining our project with the help of project management rubrics, adhering to its principles, proper division of the workload and successfully complying with the plan, and updating it along the way. All the team members successfully carried out their parts and there was clear communication among the team members all along the way. The risks were properly addressed and mitigation plans were thoroughly prepared. The main advantages of project management for engineering are the facilitation of successful project completion and a smooth project process. To establish a thorough project plan that they can utilize to keep the project on track, we incorporated technical engineering knowledge with non-technical project management strategies. As a result, we were able to deliver the required results within the designated time frame.

Chapter 8 Economical Analysis

8.1 Introduction

In order to determine if an engineering project is financially viable, engineers and economists research engineering economics. In turn, this raises the question, "Are the advantages worth the investment?" A major challenge of engineering projects is that costs tend to pile up quickly, but benefits may not become apparent for years or even decades. Engineering projects are investments with a lengthy time horizon; as such, they must be well planned out before being implemented. However, long-term investments provide their own unique challenges that must always be accounted for. Investing with a long-term horizon is difficult because people have a strong bias toward assigning lower future values to the same objects relative to their current worth. As a result, we now cherish the present more than we did before. This necessitates a fresh look at the financial implications. The possibility of ambiguity in the future is also cause for concern. Numerous factors are beyond anyone's control, including the weather, potential production issues, delays, and cost overruns, and so on. This is likely to reduce the expected value of the investment or make it less applicable to the situation. The benefits may be smaller than expected or may not materialize at all, but the situation can also reverse itself. We will go through a strategic plan with our project “Automated Health Monitoring and Watering System for Plants”. The name of the strategy is “Blue Ocean Strategy”. Let’s know what the Blue Ocean Strategy is. Overall, the blue ocean strategy demonstrates how the concentration of competition in certain industries has an effect on the profitability of new entrants in those industries. It is a sign of a highly concentrated market when there is a lot of competition for the same clients. This category of market is often referred to as "red" in figurative language. They "earn" these clients by strengthening the aforementioned four pillars through measures such as promotion and investment in the company's infrastructure. The quality of natural resources, for example, could have an impact on a consumer's purchase selections if those resources are of a better standard. On the other hand, the strategy encourages avoiding extremely competitive and crowded markets. Businesses need to concentrate their efforts on "blue oceans," which are markets that have little to no existing competition. Because there is no need to compete with other businesses for customers in these marketplaces, the potential for profit is much higher. Blue ocean strategy is just one of many different avenues that can be pursued to get a competitive advantage.

8.2 Economic analysis

We went through four phases to complete our project. Let's have a look

8.2.1 Phases of initiation and concept development

At this point in the process, it is quite necessary to collect the pertinent information because doing so will reveal whether or not it is beneficial to continue working on the project. Using the available data, one can do an analysis of the costs and benefits connected with the project in order to determine whether or not it is feasible to carry it out. If, for example, the cost of the project needs to be reduced or its value needs to be increased, making those adjustments at this point of the project is not only simple but also cost-effective.

8.2.2 The phases of planning and development

In this stage, the project's planning and design are developed in great depth. During budgeting, we break down how much money will be spent on various aspects of the project and tweak those estimates as you get more data. The evaluation of potential outcomes plays a pivotal role in the final decision.

8.2.3 Action Steps for a Successful Implementation

The majority of the work that has to be done in practice is carried out during the implementation phase. In terms of finances, there will be continuing analysis of data showing how much has been spent compared to estimates and how much is anticipated to be spent in the future. This comparison will be made against the total budget. With the use of these numbers, it will be possible to figure out which, if any, adjustments to the planned activities for the project need to be made in order to remain within the allotted budget. Total cost of our project is given below:

TABLE 10. BUDGET LIST FOR ALL THE COMPONENTS

Components	Quantity	Price
Power Supply 12V, 10A	1	650
Pump Motor(big)	1	650
PI Camera	1	1450
Stepper Driver	3	1140
CNC Shield	1	550
Buck Converter	1	100
Soil Sensor	3	360
IR Sensor	3	240
Stepper motor(YZ)	2	2600
Timing Belt	1	500
Stepper motor(X)	1	1200
Threaded Rod	1	750
Pulley	2	300
Mini Pump Motor	3	450
Motor Driver	2	500
USB Cable	1	200
Coupler	1	300
Stepper mount	2	300
Baller	2	160
Smooth ROD	1	300
Bearing	1	30

Screws	10	70
3D Print	15*164 gm	2460
Arduino Mega	1	2200
AC Cable	1	50
SD Card	1	350
PCB Board	1	1000
Limit Switch	3	60
Wires	1	200
WiFi Module	1	380
Pipe, Wood	1	120
Subtotal		19620

8.2.4 Phase of delivery or completion of the process

As the final phase of a building project, handover is concerned with giving the customer possession of the completed goods. Both the client and the contractors are involved in the process of determining whether or not errors or defects exist. If the new owners and the previous owners are happy with the arrangements, the project will be transferred to them. After all other tasks in financial management have been completed; an analysis of the project's cost outcomes will be conducted to determine where improvements can be made for future endeavors.

8.3 Cost benefit analysis

We have tried our best to keep it a low-cost purchasable setup and budget friendly. We evaluated our project’s multiple segments using a specific term which is value engineering. The goal of value engineering is to strike a good compromise between the price tag and the quality of a given facility or system. It is the belief that maximizing the performance of individual components of a system can be done without compromising the performance of the system as a whole that forms the basis for the major focus of value engineering. For instance, the sub-fields of architecture, structural engineering, mechanical engineering, and so on all share this characteristic. Because its goal is to develop ways to save costs while preserving or improving overall performance, value engineering considers all relevant subgroups when searching for optimal solutions. Top-down analysis means that value engineering will start with the whole system and work its way down through the subsystems. As an added bonus, this technique can be used to weed out superfluous subsystems. So, value engineering refers to the practice of analyzing systems to reduce costs while boosting functionality and thus increasing the product's worth. One simple approach to saving money is to minimize costs by lowering the quality of the product or service you provide. The use of

value engineering approaches, however, does not reduce the product's quality. Our project's maintenance is very low. It’s one time purchasable. After buying it, the user can manage everything on his own. We didn’t use any cloud drives. So the cost for cloud drive is zero. We choose the best products to minimize the cost of our project but functionally very sound.

8.4 Evaluate economic and financial aspects

Firstly, our project is one time purchasable. Users can use it easily without any hassle. We need to establish the "with project" and "without project" scenarios before we can determine the potential financial gains and losses from the proposed project. Therefore, the "without project" scenario is not always the "business as usual" case, as the status quo may be intolerable and mitigation actions may be necessary even in the absence of the proposed

project. Benefits and costs must be quantified in terms of dollars in the same years that the related outputs and inputs are manufactured. Whenever possible, it is also important to account for the project's external repercussions on the rest of the economy, such as positive or negative environmental impacts, that are not represented in market transactions. If you have a tiny piece of land and want to grow plants without giving extra time, the "Automated Health Monitoring and Watering System for Plants" is a robotic open hardware system that can help you with watering, testing the soil, and keeping it healthy. "Automated Health Monitoring and Watering System for Plants" describes the product. It's built using weatherproof components plus a Raspberry Pi, an Arduino, and other neat tech. Our approach will assist our consumers/customers in keeping their small balcony garden healthy and green without the need for additional time. Our project will cost between BDT12,000 -15,000 once it is in mass production. It will assist users in planting. If customers encounter any technological challenges or complications in the future, our assistance will be entirely free. If a component needs to be replaced, the consumer will only be charged for the cost of the component.

8.5 Conclusion

Therefore, in order to comprehend the different aspects that can affect an engineering project, one needs to have a good grasp of accounting for better management of the financial part of projects and fundamental economics in order to better manage the financial component of projects. Expenses are classified into several areas, including labor, materials, and overhead. An additional factor connected to threat assessment is an emergency. A safety net can be created by creating a plan for any unanticipated occurrences. The phrase "contingency" refers to the buffer included into an estimate to provide for unanticipated events such as faulty calculations, damaged delivery, and so on. In the client's eyes, this is the amount that must be set aside for the project in the event of errors, changes in scope, and so on, whereas in the contractor's eyes, it acts as a type of profit insurance. If the overall cost of the project exceeds the predicted cost, the profit will be reduced unless a buffer is established.

Chapter 9 Ethics and Professional Responsibilities

9.1 Introduction

Engineering is a valuable and sophisticated job. Engineers are required to uphold the highest standards of honesty and integrity as members of this profession. The quality of life of every individual is directly and significantly impacted by engineering. As a result, engineers must provide services with integrity, objectivity, fairness, and equity, and they must be committed to preserving the health, safety, and welfare of the general public. Engineers are held to a professional code of conduct that mandates adherence to the highest standards of moral behavior. Because an engineer's choices affect how safe the products and services are to use, the company's reputation and the goodwill of its shareholders, the public's and society's trust in the company's ability to provide for their needs, the law, which is concerned with how regulations affect the profession and industry, the engineer's job and his moral obligations, and about his moral values all need to be taken into account.

9.2 Identify ethical issues and professional responsibility

Worldwide engineering groups' codes of ethics generally share similar fundamental ideas, which helps to expand the code and offer more guidance. An illustration provided by the National Society of Professional Engineers (NSPE) is as follows:

In carrying out their responsibilities as professionals, engineers must:

- Prioritize the general public's welfare, health, and safety.
- Only provide services in the fields in which they are skilled.
- Only make sincere, unbiased statements to the public.
- Be faithful agents or trustees for each employer or client.

- Avoid misleading behavior.
- They behave responsibly, professionally, and morally.

We identified some ethical responsibilities following the above guidelines in our project. During our project development, we tried our best to align our work with the proposals and models that we developed prior to the development stage and deliver the exact things that we proposed. It is true that due to time constraints and some other complications, some key areas of our project were left underdeveloped, but we made sure that it doesn’t affect the core sectors of the project and worked our way around it so that we can provide the users exactly what they need. In future implications, we can incorporate those ideas and make this project even better by incorporating them with our project.

9.3 Apply ethical issues and professional responsibility

Naturally, gardening is a popular pastime among people. They experience contentment, joy, and health benefits from taking part in the act. The question of whether we will deprive them of them by automating this procedure may arise. No, is the response. Not all the work will be done by our project. It will be a useful tool that helps the owner of the plant take care of the plants. It will let the owners know if anything needs to be done. According to studies, 33.3% of urban dwellers claim that they are too busy with their jobs to have time for farming or gardening. Additionally, there are not many opportunities to learn about farming and technology. 25% of respondents claimed they are no longer interested in gardening and lack the necessary farming knowledge. In addition to providing customers with the necessary knowledge, our technology will take care of their cherished plants while they are away. It will serve as your personal aide. We shall have some obligations as professionals to install our equipment in structures in compliance with urban laws. We will safely reduce the likelihood of any risks by adhering to the building's structure and the relevant laws.

9.4 Conclusion

Our project is closely related to the environment. Besides, as it is aimed to work closely with people in their homes in the urban areas, the concerns for safety were paramount. We took that into consideration and complied with the ethical codes we adopted for fairness during the tenure of preparing, designing, and executing our model. Engineers play a critical role in society's sustainability, prosperity, and well-being. When engineering concepts are crucial, engineers must fully participate to hold their place in the decision-making process. To accomplish this, the engineering profession must continue to have public confidence. So, as future engineers, we tried to adhere to the same principles despite the challenges we faced.

Chapter 10 Conclusion and Future Work

10.1 Project summary/Conclusion

The product is intended to motivate people to engage in active gardening. The world's green beauty is dwindling. Not only that, but the rapid loss of greenery will have an influence on our environment by increasing global warming, and this is only a minor portion of the problem. It is our responsibility to protect the environment in which we live. As a result, even if we can help conserve our green nature by employing the technology that is improving every day, we will be able to hope for a better future. Even among the tiny number of city dwellers who are interested in gardening, lack of access to active care discourages them from even starting. That is where our product will be useful. It will allow individuals some breathing space while caring for the plants.

10.2 Future work

Auto Diseases and Pests Detection:

The presence of plant diseases and pests can have a significant impact, not only on the quantity, but also on the quality of a plant. The detection and diagnosis of plant diseases and pests is made possible by the utilization of digital image processing. The world's food supply is under grave danger from the proliferation of dangerous plant diseases. In the subject of picture categorization based on leaves, there has recently been an explosion of innovative, accurate algorithms that have produced startling results. In recent years, considerable breakthroughs have been made in digital image processing, with deep learning proving to be significantly more effective than earlier approaches to the problem. The application of deep learning to the study of plant diseases and the detection of plant pests has emerged as a significant topic of research. In the field of machine vision, one of the most important areas of research is looking at how to identify plant diseases and pests. This technique makes use of machine vision equipment to examine photographs of plants that have been gathered in order to search for indications of diseases and pests. To a considerable extent, the traditional way of recognizing these issues by eye has been largely replaced in agriculture by machine vision-based plant disease and pest detection technology, which has recently undergone first implementation.

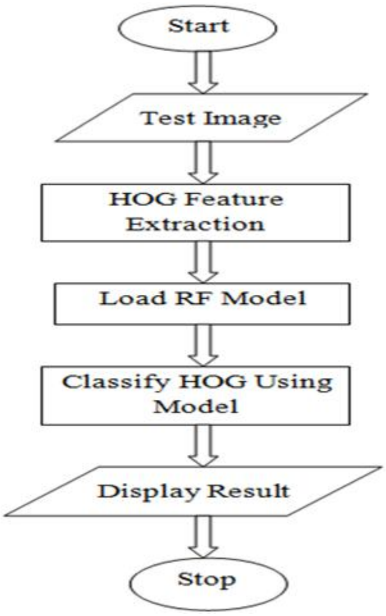

Fig 20: Classification flowchart

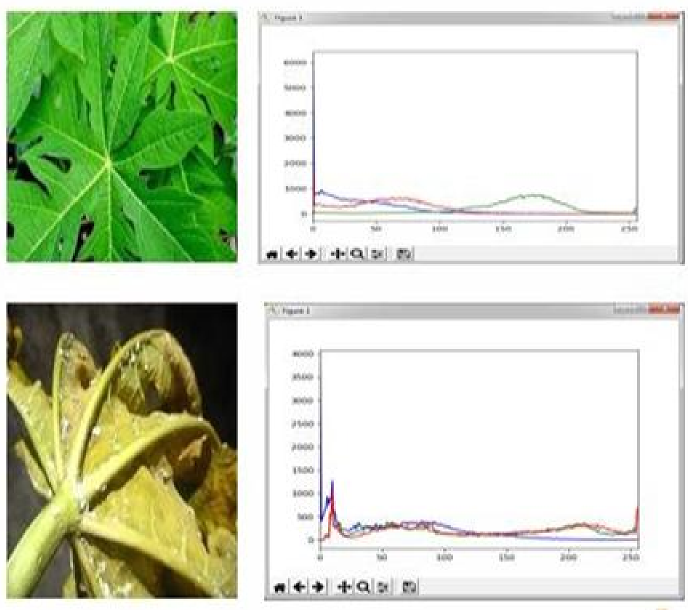

Fig 21: Histogram Plot

The goal of the algorithm is to identify irregularities in greenhouse or outdoor plant life.

Solar Panel Implementation:

Utilizing alternative forms of energy demonstrates that we are concerned about the health of the natural world. As a consequence of this, consumers who are concerned about the state of the environment will have a greater propensity to make purchases from our company. If you include solar panels in our goods, you will have a competitive advantage over other buyers due to the fact that the cost of installing solar panels is decreasing with time. To utilize solar electricity, all that is required is exposure to sunshine; this eliminates any geographical restrictions. Installing solar panels may provide a variety of benefits, one of which is reduced reliance on electricity supplied by the utility company. Our project will be less sensitive to power outages as a result of this, which will have a lesser influence on the overall production as a result of this. When energy is stored, it becomes available for use at a later time as a secondary source of power in the event that the original source of power becomes inoperable. Using renewable energy communicates our commitment to sustainability. This will attract environmentally conscious customers towards our product. Integrating the solar system in our product will therefore give you a competitive advantage.

Chapter 11 Identification of Complex Engineering Problems and Activities

11.1 Identify the attribute of complex engineering problem (EP)

Attributes of Complex Engineering Problems (EP)

	Attributes	***Put tick (√) as appropriate***
P1	*Depth of knowledge required*	√
P2	*Range of conflicting requirements*	
P3	*Depth of analysis required*	√
P4	*Familiarity of issues*	√
P5	*Extent of applicable codes*	
P6	*Extent of stakeholder involvement and needs*	√
P7	*Interdependence*	√

Note: Project must have P1, and some or all from P2-P7

11.2 Provide reasoning how the project address selected attributes (EP)

11.2.1 Depth of Knowledge Required

In order to find a sophisticated answer to our problem, we studied and explored through a number of articles. We researched a number of automated home gardens and green roof systems in order to come up with a suitable solution and strategy for our design [3][4][5]. We also considered several methods for integrating multiple systems so that they can communicate with one another. In order to approach our design, we accumulated extensive expertise by reading pertinently researched publications.

11.2.2 Depth of Analysis Required

The best design is selected from among several designs based on cost and performance. Additionally, in order to maintain quick performance and response time, additional architectural complexity is minimized. Through many tries and errors, the ideal system is created. Although everything is now functioning as intended, we intend to add more features and enhance the system.

11.2.3 Familiarity of Issues

As cities expand quickly, open spaces are getting smaller and smaller until there is nowhere left to plant trees. However, the loss of a green environment is contributing to the slow but steady increase in global warming. Despite the fact that rooftops and balconies can be used for gardening, the majority of us are deterred by the notion that the plants won't be cared for frequently due to their hectic schedule. As a result, despite being garden enthusiasts, many people avoid participating in these activities. It is our system's responsibility to occasionally relieve them of plant care.

11.2.4 Extent of Stakeholder Involvement and Needs

The final design of the "Plant Nursing System" is the most optimal system chosen from the multiple design approaches that is the most cost efficient among all others. Furthermore, the system is already a part of contemporary urban gardening as it combines numerous existing systems into one that are already interconnected in order to produce the most effective outcome. Therefore, the design has a possibility to catch the interest of many stakeholders with or without any additional developments.

11.2.5 Interdependence

The entire system is divided into small individual systems. These systems are, however, linked internally to each other. As a result, the system can carry out multiple activities concurrently with minimal human involvement.

11.3 Identification of the attribute of complex engineering activities (EA)

Attributes of Complex Engineering Activities (EA)

	Attributes	***Put tick (√) as appropriate***
A1	*Range of resource*	√
A2	*Level of interaction*	
A3	*Innovation*	√
A4	*Consequences for society and the environment*	√
A5	*Familiarity*	√

Note: Project must have some or all of the characteristics from attributes A1 to A5

11.4 Provide reasoning how the project address selected attribute (EA)

11.4.1 Range of Resource

The range of resources is planned according to our design specifications. The finances are also allotted, and all the supplies and components are listed appropriately. The budget and component list are both reasonably small since the system is overall optimal.

11.4.2 Innovation

Integration of multiple tools in a single unit and enabling them to communicate with each other while providing updates to the user requires innovative use of engineering principles and knowledge. The individual systems are not only responsible for their respective jobs, as they are linked to each other, but they also exchange information internally back and forth so that the tool can operate as intended.

11.4.3 Consequences for society and the environment

Urban gardening will advance through the introduction of the "Plant Nursing System". While improving the addressed problems, it will also provide more opportunities for development. Not only will we be able to retain the natural beauty, we will also be able to protect our environment in the most effective way possible. Additionally, the motivation to continue gardening is an added benefit.

11.4.4 Familiarity

The project deals with a familiar area for electrical engineers. There have been previous projects for assistance in gardening. Our project redefines the idea and improves on earlier creations.

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Appendix A.

Arduino code to control 3 linear axes, water pumps, pesticide spraying pump and soil moisture sensors

```
#include <AccelStepper.h>
// Serial commands
//-----------------
// P1, P2, P3
// HOME
// SPRAY
// RESET
// S=000, 001, 011, 111
// Maximum Axis Limits
#define MAX_X 1000
#define MAX_Y -2800
#define MAX_Z 10200
// setting s
#define SPEED
80 // Steppers
#define SOIL_LEVEL 50 // %, SAFE
#define SPRAY_TIME 10 // second, SAFE
#define WAIT_TIME 5 // second, SAFE
#define ESP Serial2
// Plant 1 location, Changable
#define PLANT1_X 700
#define PLANT1_Y -500
#define PLANT1_Z 1000
// Plant 2 location, Changable
#define PLANT2_X 700
#define PLANT2_Y -1500
#define PLANT2_Z 2000
```

```
// Plant 3 location, Changable
#define PLANT3_X 700
#define PLANT3_Y -2500
#define PLANT3_Z 4000
// Motor Driver 1
#define pumpA1 51
#define pumpA2 49
#define pumpB1 47
#define pumpB2 45
// Motor Driver 2
#define pumpC1 43
#define pumpC2 41
#define pumpD1 39
#define pumpD2 37
// Others Connection
#define moisPin1 A10
#define moisPin2 A11
#define moisPin3 A12
// Stepper Motor Connection
#define stepX 2
#define dirX 5
#define limitX 9
#define stepY 3
#define dirY 6
#define limitY 10
#define stepZ 4
#define dirZ 7
#define limitZ 11
#define enPin 8
// macros functions
#define pin(x) digitalRead(x)
#define pinW(x, y) digitalWrite(x, y)
```

```
AccelStepper stepperX(AccelStepper::DRIVER, stepX, dirX);
AccelStepper stepperY(AccelStepper::DRIVER, stepY, dirY);
AccelStepper stepperZ(AccelStepper::DRIVER, stepZ, dirZ);
int timer;
long prevMs;
bool reached;
String isPlanted = "000"; // default plants
void setup() {
Serial.begin(115200);
ESP.begin(115200);
pinMode(pumpA1, OUTPUT);
pinMode(pumpA2, OUTPUT);
pinMode(pumpB1, OUTPUT);
pinMode(pumpB2, OUTPUT);
pinMode(pumpC1, OUTPUT);
pinMode(pumpC2, OUTPUT);
pinMode(pumpD1, OUTPUT);
pinMode(pumpD2, OUTPUT);
digitalWrite(pumpA1, 0);
digitalWrite(pumpA2, 0);
digitalWrite(pumpB1, 0);
digitalWrite(pumpB2, 0);
digitalWrite(pumpC1, 0);
digitalWrite(pumpC2, 0);
digitalWrite(pumpD1, 0);
digitalWrite(pumpD2, 0);
stepperX.setMaxSpeed(SPEED);
stepperY.setMaxSpeed(SPEED);
stepperZ.setMaxSpeed(SPEED);
stepperX.setSpeed(SPEED);
stepperY.setSpeed(SPEED);
stepperZ.setSpeed(SPEED);
```

```
pinMode(limitX, INPUT_PULLUP);
pinMode(limitY, INPUT_PULLUP);
pinMode(limitZ, INPUT_PULLUP);
pinMode(enPin, OUTPUT);
pinW(enPin, LOW);
Serial.print("Going Home...");
home();
Serial.println("OK");
prevMs = millis();
}
void loop() {
checkBlynk(ESP);
checkBlynk(Serial);
if (millis() - prevMs >= 1000) {
soilAutomation();
if (reached == 1) {
timer++;
if (timer == WAIT_TIME) {
reached = 0;
ESP.println("P=MOVING...");
home();
}
}
prevMs = millis();
}
}
void checkBlynk(Stream &serial) {
if (serial.available()) {
String cmd = serial.readString();
cmd.replace("\r\n", "");
Serial.println("ESP: " + cmd);
if (cmd.indexOf("SPRAY") != -1) {
```

```
Serial.println("SPRAYING");
digitalWrite(pumpD1, 1);
for (byte i = 0; i < SPRAY_TIME; i++) delay(1000);
digitalWrite(pumpD1, 0);
reached = 1;
timer = 0;
}
else if (cmd.indexOf("HOME") != -1) {
home();
reached = 0;
timer = 0;
}
else if (cmd.indexOf("RESET") != -1) {
reached = 1;
timer = 0;
}
else if (cmd.indexOf("P1") != -1) {
gotoPosition(PLANT1_X, PLANT1_Y, PLANT1_Z);
}
else if (cmd.indexOf("P2") != -1) {
gotoPosition(PLANT2_X, PLANT2_Y, PLANT2_Z);
}
else if (cmd.indexOf("P3") != -1) {
gotoPosition(PLANT3_X, PLANT3_Y, PLANT3_Z);
}
else if (cmd.indexOf("S=") != -1) {
int i = cmd.indexOf("S=");
cmd.remove(0, i + 2);
isPlanted = cmd;
}
}
}
```

```
void soilAutomation() {
int soil1 = analogRead(moisPin1);
int soil2 = analogRead(moisPin2);
int soil3 = analogRead(moisPin3);
soil1 = map(soil1, 0, 1023, 100, 0);
soil2 = map(soil2, 0, 1023, 100, 0);
soil3 = map(soil3, 0, 1023, 100, 0);
String data = "M=";
data += (String) soil1 + ",";
data += (String) soil2 + ",";
data += (String) soil3 + ",";
ESP.println(data);
Serial.println(data);
if (isPlanted[0] == '1' && soil1 < SOIL_LEVEL) {
digitalWrite(pumpA1, 1);
}
else digitalWrite(pumpA1, 0);
if (isPlanted[1] == '1' && soil2 < SOIL_LEVEL) {
digitalWrite(pumpB1, 1);
}
else digitalWrite(pumpB1, 0);
if (isPlanted[2] == '1' && soil3 < SOIL_LEVEL) {
digitalWrite(pumpC1, 1);
}
else digitalWrite(pumpC1, 0);
}
void gotoPosition(long x, long y, long z) {
Serial.println((String)"X=" + x + ", Y=" + y + ", Z=" + z);
stepperX.moveTo(x);
stepperY.moveTo(y);
stepperZ.moveTo(z);
stepperX.setSpeed(SPEED);
```

```
stepperY.setSpeed(SPEED);
stepperZ.setSpeed(SPEED);
ESP.println("P=MOVING..");
pinW(enPin, 0);
while (true) {
long cX = stepperX.currentPosition();
long cY = stepperY.currentPosition();
long cZ = stepperZ.currentPosition();
if (cX != x) stepperX.runSpeedToPosition();
if (cY != y) stepperY.runSpeedToPosition();
if (cZ != z) stepperZ.runSpeedToPosition();
if (cX == x && cY == y && cZ == z) break;
}
pinW(enPin, 1);
stepperX.setCurrentPosition(x);
stepperY.setCurrentPosition(y);
stepperZ.setCurrentPosition(z);
ESP.println("P=REACHED");
}
void home() {
stepperX.setSpeed(-SPEED);
stepperY.setSpeed(SPEED);
stepperZ.setSpeed(-SPEED);
ESP.println("P=MOVING..");
pinW(enPin, 0);
while (true) {
if (pin(limitX)) stepperX.runSpeed();
if (pin(limitY)) stepperY.runSpeed();
if (pin(limitZ)) stepperZ.runSpeed();
if (!pin(limitX) && !pin(limitY) && !pin(limitZ)) break;
}
pinW(enPin, 1);
```

```
stepperX.setCurrentPosition(0);
stepperY.setCurrentPosition(0);
stepperZ.setCurrentPosition(0);
ESP.println("P=AT HOME");
}
```

Arduino code to connect the system with Blynk User Interface

```
#define BLYNK_TEMPLATE_ID "TMPLjDxM0dV5"
#define BLYNK_DEVICE_NAME "IOT Tree Nursing"
#define BLYNK_AUTH_TOKEN "GnvA-p81KdmAkppjPcsz2CU1kf7Ia0qN"
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp8266.h>
char ssid[] = "Hello";
char pass[] = "11223344";
#define TERMINAL V0
#define PLANT1 V1
#define PLANT2 V2
#define PLANT3 V3
#define SOIL1 V4
#define SOIL2 V5
#define SOIL3 V6
#define STATE1 V7
#define STATE2 V8
#define STATE3 V9
#define CAPTURE V10
#define SPRAY V11
#define HOME V12
#define piCap D1
int i, soil[3] = {0};
String isPlanted = "000";
bool stateChanged = 0;
```

```
void setup() {
Serial.begin(115200);
Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
pinMode(piCap, OUTPUT);
}
void loop() {
Blynk.run();
if (Serial.available()) {
String cmd = Serial.readString();
cmd.replace("\r\n", "");
if (cmd.indexOf("P=") != -1) {
i = cmd.indexOf("P=");
cmd.remove(0, i + 2);
Blynk.virtualWrite(TERMINAL, cmd);
}
else if (cmd.indexOf("M=") != -1) {
i = cmd.indexOf("M=");
cmd.remove(0, i + 2);
getValue(cmd, soil[0]);
getValue(cmd, soil[1]);
getValue(cmd, soil[2]);
Blynk.virtualWrite(SOIL1, soil[0]);
Blynk.virtualWrite(SOIL2, soil[1]);
Blynk.virtualWrite(SOIL3, soil[2]);
}
}
if (stateChanged == 1) {
stateChanged = 0;
Serial.println("S=" + isPlanted);
}
}
void getValue(String &cmd, int &val) {
```

```
val = cmd.toInt();
int i = cmd.indexOf(",");
cmd.remove(0, i + 1);
}
BLYNK_CONNECTED() {
Blynk.syncAll();
Blynk.virtualWrite(TERMINAL, "CONNECTED");
Serial.println("S=" + isPlanted);
}
BLYNK_WRITE(PLANT1) {
int state = param.asInt();
if (state == 1) Serial.println("P1");
}
BLYNK_WRITE(PLANT2) {
int state = param.asInt();
if (state == 1) Serial.println("P2");
}
BLYNK_WRITE(PLANT3) {
int state = param.asInt();
if (state == 1) Serial.println("P3");
}
BLYNK_WRITE(STATE1) {
int state = param.asInt();
if (state == 1) isPlanted[0] = '1';
else isPlanted[0] = '0';
stateChanged = 1;
}
BLYNK_WRITE(STATE2) {
int state = param.asInt();
if (state == 1) isPlanted[1] = '1';
else isPlanted[1] = '0';
stateChanged = 1;
```

```
}
BLYNK_WRITE(STATE3) {
int state = param.asInt();
if (state == 1) isPlanted[2] = '1';
else isPlanted[2] = '0';
stateChanged = 1;
}
BLYNK_WRITE(CAPTURE) {
int state = param.asInt();
if (state == 1) {
digitalWrite(piCap, 1);
delay(1000);
digitalWrite(piCap, 0);
Serial.println("RESET");
}
}
BLYNK_WRITE(SPRAY) {
int state = param.asInt();
if (state == 1) Serial.println("SPRAY");
}
BLYNK_WRITE(HOME) {
int state = param.asInt();
if (state == 1) Serial.println("HOME");
}
```

Arduino code to the camera for taking pictures and to send the image to the user via mail

```
# Import modules
import subprocess
import ipaddress
# Prompt the user to input a network address
```

```
net_addr = input("Enter a network address in CIDR
format(ex.192.168.1.0/24): ")
# Create the network
ip_net = ipaddress.ip_network(net_addr)
# Get all hosts on that network
all_hosts = list(ip_net.hosts())
# Configure subprocess to hide the console window
info = subprocess.STARTUPINFO()
info.dwFlags |= subprocess.STARTF_USESHOWWINDOW
info.wShowWindow = subprocess.SW_HIDE
# For each IP address in the subnet,
# run the ping command with subprocess.popen interface
for i in range(len(all_hosts)):
output = subprocess.Popen(['ping', '-n', '1', '-w', '500',
str(all_hosts[i])], stdout=subprocess.PIPE,
startupinfo=info).communicate()[0]
if "Destination host unreachable" in output.decode('utf-8'):
#print(str(all_hosts[i]), "is Offline")
pass
elif "Request timed out" in output.decode('utf-8'):
#print(str(all_hosts[i]), "is Offline")
pass
else:
print(str(all_hosts[i]), "is Online")
```