SMART AGRICULTURAL SYSTEM FOR CROP MONITORING AND SOIL ANALYSIS

By

Bristy Das

ID: 19121123

Tahmid Zarif Ul Hoq Sayor

ID: 19121015

Rubyat Jahan Nijhum

ID: 19121111

Mehnaz Tabassum Tishun

ID: 19121024

A Final Year Design Project (FYDP) submitted to the Department of Electrical & Electronic Engineering in partial fulfillment of the requirements for the degree of
B.Sc. in Electrical & Electronic Engineering

Department of Electrical & Electronic Engineering
Brac University

December 2022

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Academic Technical Committee (ATC) Panel Member:

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

Taiyeb Hasan Sakib
Lecturer, Department of EEE, BRAC University

Ehsanul Karim
Lecturer, Department of EEE, BRAC University

Department of Electrical & Electronic Engineering
Brac University
December 2022

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:

Tahmid Zarif Ul Hoq Sayor
ID: 19121015

Bristy Das
ID: 19121123

Rubyat Jahan Nijhum
ID: 19121111

Mehnaz Tabassum Tishun
ID: 19121024

Approval

The Final Year Design Project (FYDP) titled "SMART AGRICULTURAL SYSTEM FOR CROP MONITORING AND SOIL ANALYSIS" submitted by

1. Tahmid Zarif Ul Hoq Sayor (19121015)
2. Bristy Das (19121123)
3. Rubyat Jahan Nijhum (19121111)
4. Mehnaz Tabassum Tishun (19121024)

Fall, 2022 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of B.Sc. in Electrical & Electronic Engineering on December 15, 2022.

Examining Committee:

Academic Technical Committee (ATC):
(Chair)

____

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

Final Year Design Project Coordination Committee:
(Chair)

____

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

Department Chair:

____

Md. Mosaddequr Rahman, PhD
Professor and Chairperson
Department of EEE
Brac University

Ethics Statement

The team working on this project is dedicated to carrying out its duties in a way that upholds the highest ethical standards. We always operate in a way that is consistent with the fundamental principles of our company, and we make an effort to be sincere, polite, and fair in all of our interactions. We work hard to make sure that every choice is taken with the interests of our stakeholders and the general public in mind. As part of our efforts, we also make sure that all applicable rules and regulations are followed when working on our projects.

Abstract/ Executive Summary

Agriculture is the base of the economy in Bangladesh, however, 90% of the farmers are not familiar with modern-technological tools. That is the reason why we see very-little usage of modern tools in farming in our country which limits crop production significantly.

Hence to address this, a smart monitoring system is proposed to introduce farming robots to bring a strong revolution to the existing primitive systems. The proposed system will include a range of sensors, including cameras and probes, to detect ripe vegetables and harvest them, as well as analyze soil conditions and provide advice to farmers. The system will use image processing techniques and an NPK sensor.

The primary objectives of the project are to reduce labor requirements and improve the efficiency of agricultural production. Advancements in technology will enable modern farms and agricultural businesses to utilize cutting-edge tools, robotic systems, and precision farming methods to become more successful, productive, safe, and environment friendly. Automated navigation and harvesting, crop growth monitoring, and crop disease detection can be achieved through the use of sensors, robotic arms, and machine learning algorithms, respectively. However, these advancements require sufficient data to train the machine learning models, making them a long-term goal for the future.

Keywords: Rover; NPK Sensor; Inverse Kinematics; Robotic Arm; Harvesting; Soil Analysis; Tomato; Image Processing; Ripe; Navigation

Dedication

To our families,

This project is dedicated to you. You have been our source of strength and support throughout our lives. You have been there for us in times of joy and sorrow, and you have always encouraged us to reach for our dreams. You made such a great deal of sacrifices for us, and we will always be appreciative of the support and love you gave us. We are hoping that you will enjoy and be proud of this endeavor as much as we have.

Acknowledgement

We would like to express our deepest gratitude to the Almighty for giving us the strength and courage to complete this project. We also acknowledge the assistance and support we received from our supervisors Dr. Abu S.M. Mohsin, Taiyeb Hasan Sakib, and Ehsanul Karim. Finally, we want to express our gratitude to our families for their unwavering love and support. This paper would not have been possible without their support and compassion. Thank you all for your invaluable contributions.

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List of Acronyms

MCU	Microcontroller Unit
NPK	Nitrogen, Phosphorus, and Potassium
LIPO	Lithium Polymer
IDE	Integrated Development Environment
ROS	Robot Operating System
NodeMCU	Node Microcontroller Unit

CHAPTER 1: INTRODUCTION- [CO1, CO2, CO10]

1.1 Introduction

Bangladesh is a predominantly agricultural nation, accounting for nearly one-third of the GDP. The majority of our population relies on it as their main source of income. However, Bangladesh cannot produce as much food as it could since it still uses the conventional agricultural system. Because of this, agriculture robots are gaining importance as a means of enhancing sustainability in the industry. Robotics can help reduce the labor and water requirements for food production and energy and water consumption. We propose an agriculture-based robotic project that can smartly navigate, detect ripe tomatoes, harvest them, and analyze soil conditions. The robot will have a range of sensors, including cameras and probes for soil analysis. It will be equipped with a robotic arm that can identify ripe tomatoes and harvest them. The rover bot will also be capable of evaluating the soil's condition and providing farmers advice on how to best take care of their crops. Farmers will be able to utilize less labor while increasing productivity thanks to this project. Using this robotic technology, agricultural output productivity may be raised.

1.1.1 Problem statement

Today's world is dominated by robotics. The advancement of technology permeates every aspect of life. However, especially in our agriculture sector, our nation has not yet fully embraced these revolutionary advancements. The majority of farmers are uninformed of the improvements in agricultural technology, even though agriculture is the foundation of our nation's economy. Most farmers in our country struggle with a lack of technological knowledge of soil analysis and its importance. While many countries are implementing agricultural robots to improve life quality, make tasks easier, and increase crop yields.

Making life simpler, quicker, and more productive is something that technology always greatly influences. Robotics and technology have the potential to significantly impact agricultural growth, as evidenced by statistics from technologically advanced nations. Technical development in China is to blame for 15.7% of the rise in agricultural output. This percentage is relatively low when compared to other countries. Between 1960 and 1980, technological advancements were responsible for a 47.4 percent rise in overall performance in Japan and an increase of 84.2 percent in the United States [1].

On the other hand, Bangladeshi farmers are in a very precarious situation in this rapidly evolving business. Again, despite the high unemployment rate in the nation, many of the youth still find agriculture unappealing because it requires more effort and hard work. These days, it is difficult for farmers to find workers to carry out harvesting tasks. This is a serious issue since it delays the timely harvest of crops, which costs farmers money. Agriculture is linked to numerous other social problems and difficulties because it has such a significant economic impact on our nation. The younger generation will be more motivated to work in this field if robotics are included, and smart agriculture may even assist Bangladesh in lowering its unemployment rate. Agriculture robotics will also undergo a revolution.

1.1.2 Background Study

It's crucial to understand the project's primary goal and its relevance in the present robotics sector before moving on to describe the project's overall system and goal. In terms of the project's major goal, we wish to include a new component known as a smart monitoring system to revolutionize the way Bangladeshi agriculture operates. The world is not entirely new to this reality. Many advanced economies have put a lot of effort into the research and development of this agricultural technology. As seen by several of their remarkable initiatives, they have streamlined the planting, monitoring, and harvesting processes. The works associated with this industry in many nations are presented here.

A robotic method is developed for picking tomatoes in greenhouses where the main technology is the effective detection of ripe tomatoes against a complicated background [2]. The ripe tomato is segmented using the L*a*b* color image and K-means clustering. The shape-based method is used to eliminate noise and manage the conditions of tomato overlaying and shelter to obtain single-integrity ripened tomatoes.

Using computer vision and image processing techniques, the estimation of maturity and counting of tomato fruit is implemented in this study where the user chooses to execute the additional processing for image improvement to improve accuracy in inclement weather [3]. The majority of the work is done in the HSV color space and binarization is used here as it is efficient. The image was subjected to noise suppression and morphological processing to develop masking that accurately detects ripe and turning tomatoes and hence counts the fruits found.

In this study, an NPK sensor will be used here to detect the soil nutrients. The results identified by the sensor will be delivered in the form of analog signal data to NodeMCU, which will be processed and presented on the screen [4]. The NPK sensor tool's job is to measure the nutrients in the soil for citrus seedlings, and the data will be communicated to Thingspeak online.

The developed system in this study is an automatic watering system with a watering duration limit that is based on the value of soil moisture. The soil moisture sensor YL-69 is used to determine the soil moisture value, and the DS1302 RTC is used to determine the watering start and end limits [5]. The center of the automatic watering controller is an Arduino Uno microcontroller unit, which is used in this system. A sensor and an RTC are connected to the microcontroller, and the output is a DC water pump. If the sensor detects that the moisture value of the soil is below the humidity level that the tomato requires, the system will water the tomato and keep the humidity level between 70 and 80 percent.

This study describes the development of a four-wheel-drive agricultural mobile robot for collecting crop and soil information in broad fields [6]. The control command generator is an industrial computer with a touch screen. The robot has six motors, four of which are in-wheel motors that provide movement, and the other two are steering motors. The industrial computer will generate both linear velocity orders and steering commands. The linear velocity commands will be sent to the motor driver circuit, which will alter the revolving speed of the in-wheel motors.

The suggested work is in the field of agriculture, which is ideally suited to conventional agricultural practices. The goal of this study is to develop an agribot that can do tasks such as plowing, seeding, watering, and fertilizing crops [7]. The four wheels of the agribot are controlled by the Arduino Mega (2560) based on the input from the IR sensor. The Android application receives the user's command], such as which mode (automatic or manual) to use or which operation to conduct, and sends it to the Wi-Fi module. The Arduino Mega is also intended to transmit commands to the motors that will do the tasks.

1.1.3 Literature Gap

This paper proposes a ripe tomato extraction technique based on color clustering and mathematical morphology [2]. There are various disadvantages to the suggested method for ripe tomato extraction. For example, consider the failed sample. The ripe tomato is only taking up a small portion of the picture, resulting in incorrect cluster segmentation for the ripe tomato. To ensure that the correct ripe tomato is always included in the input images, the ripe tomato detective should be used. Another significant issue is the calculating time, which may be reduced by using a high-performance computer. However, optimizing the extraction method remains an essential task for future research.

Using computer vision and image processing techniques, the estimate of ripeness and identification of tomato fruit is implemented in this study [3]. Although the findings appear to be satisfactory, the counting might be easily incorrect if the fruits overlap. Again if more than one fruit appears in the frame which one will be detected first and what will be the action then was not briefly mentioned in this study? Furthermore, adding more ripeness levels to detect and indicate the expected time for harvesting for each class can improve the outcomes.

This research focuses on developing a soil nutrient measurement tool that makes use of NPK soil sensors and IOT [4]. This work is really useful for testing soil nutrients. In terms of future work, this work might be a study issue if this toolbox can also provide essential suggestions for fertilizers for that soil based on the NPK ratio existing in the soil.

This paper demonstrates a watering system device used to keep the soil moisture of a specific plant at a constant level [5]. The watering system in this system employs a soil moisture sensor to obtain the idea, however, the main drawback of this project is that the soil moisture will be checked manually. The research would be more productive if the system was automated in compliance with the soil moisture sensor checking requirement.

This study describes the development of a four-wheel-drive agricultural mobile robot for collecting crops/soil data in vast farmland [6]. However, other applications of such robots could be implemented. The experiment was bounded for only soil data collection however this could have also been used for other purposes such as suggesting fertilizer.

The preceding research of IoT technology application and its implementation in the field with the assistance of Arduino, together with the right monitoring system of sensors and cameras, results in an effective recommended system [7]. In terms of the research gap and future work in this research, the solar panel can replace the battery power source to reduce recharge costs and provide electricity on the field itself. In this technique, weeding and harvesting are also included.

1.1.4 Relevance to Current and Future Industry

To achieve food security, all governments must prioritize agriculture, and most developed countries are employing robotics and automation systems to increase food production. One of Bangladesh's ambitions is to become a digital nation. The agricultural industry is one of "Digital Bangladesh's" top goals. Mechanization is emphasized to boost labor productivity, earnings, and food security [8]. Unfortunately, Bangladesh still uses traditional ways of agriculture. The research and technical progress are very low in comparison to other countries. Labor shortage can be seen in Bangladesh during the harvesting season [9].

Introducing smart harvesting into agriculture is the goal of our suggested concept. Because it will be a smart system, it will eliminate the need for farmers to perform manual labor during the harvest. This project is currently focused on a single vegetable, but with a few design modifications, it might be utilized for other vegetables or crops in the future. Additionally, this project allows for the completion of soil analysis, providing farmers with information about the state of their fields. These kinds of technologies are improving the lives of farmers in rich nations, but they are challenging to adopt in a low-income nation like Bangladesh due to high production costs. This project aims to introduce a cost-effective smart harvesting system and soil analysis system which will be sustainable and easily accessible to farmers.

Bringing up recent research that is pertinent to the projects, Japan, China, and the United States are just a few developed nations that have already implemented robotic harvesting systems to cut labor costs while raising crop or vegetable productivity rates. Numerous private farming enterprises in Japan have adapted this technique for their harvesting procedures. The use of robotics systems in private agricultural farms is also extremely common in China. If we develop our agriculture in this way, it will significantly improve our economic situation.

1.2 Objectives, Requirements, Specifications and Constraint

After proper identification of the problem, we have to think of solving the problem. In order to accomplish this we set certain objectives for our project, targeting how we are going to mitigate our identified problem.

To fulfill the objectives we carefully selected the requirements. In other words, how the objectives of our project will be achieved. Again, we note the components we require for our design in the specification part. Finally, we accounted for the constraints we might be facing while creating, testing, or using our design.

1.2.1. Objective

Our project's main objectives are to incorporate smart farming into Bangladeshi agriculture and to improve the practicality and enjoyment of farming. To do this, we are thinking about creating a robotics system that can perform crucial soil and atmospheric assessments for the majority of crops or vegetables and reduce harvesting stress by performing smart harvesting.

We are going to develop this system targeting one certain crop or vegetable. Our objective has been divided into several areas, which are shown below-

Smart Harvesting System: Developing a smart harvesting system will be one of our main objectives. In terms of our system, we will have a part for identifying ripe vegetables and plucking them when the time is right. Thus we can assure harvesting of that certain vegetable or crop is occurring at an adequate time.

Soil Analysis: There will be a section in the system to do the necessary soil analysis. We know before cultivating anything in the soil we need to test the soil nutrient rate available in the soil. If the soil is adequate for that plant or not. Nitrogen, Potassium, and Phosphorus are the three main soil nutrients to check. There will be a sensor box calibrated with all the necessary sensors needed to perform these soil analyses.
After the soil analysis, the system will send back the data and make necessary decisions.

1.2.2 Functional and Non-Functional Requirements

Functional Requirements:

System Level:

The main tasks here are to detect the ripe vegetables using image processing, harvesting the vegetables, and doing soil smartly. All these tasks will be achieved by a smart robotic system.

For Vegetable Harvesting:

The basic goal here is to use image processing to recognize ripe vegetables and then pluck or harvest them.

To perform the first task, we will take an image of the vegetables first and then through image processing, we will spot the ripe vegetable. Firstly, the input images will be rescaled as the images are very high in quality. The images will be resized afterward [3]. Then the color space will be changed to Hue Saturation Value (HSV) and based on the HSV value images will be thresholded. After that, we will get binary images of ripe and turning vegetables and the original images will be masked. Finally, for every identification, a contour will be detected to draw an ellipse.

To cut the ripped vegetables a robotic system will be designed which will be operated using ROS and inverse kinematics to find the exact position of the ripe vegetable camera coordinated with a communication module.

To implement all these objectives there will be some subsystems in the mechanical structure. These are-

i) Electronics: This part will contain the necessary circuits and PCB. In this section, there will be all necessary electronic components like motor drivers, boosters, relay, buck, circuit modules, and sensors for processing purposes.

ii) Power Unit: For the power distribution purpose there will be a power distribution board called the power unit, providing the necessary power to the whole system. This power distribution board will contain the necessary components like a battery.

iii) Control Panel: In this project, we will also need a control panel for controlling the whole system and for sending the necessary commands according to time. This unit will not be connected to the mechanical structure. There will be a control station for sending the commands.

iv) Communication Board: In this project for sending the necessary data, we will need a communication board, which will ensure the perfect communication ambiance of the system body with the control station.

v) Sensor Box: There will be a section in the mechanical structure called the sensor box containing all the adequate and important sensors fulfilling the tasks of soil analysis. This section will be connected with the controlling unit, electronics unit, and communication unit.

Component Level:

1. OpenCV/YOLO v5
2. Microprocessor & Microcontroller
3. 3 Finger claw
4. Buck & boosters
5. Connectors
6. Motor
7. Motor Driver
8. Inverse Kinematics
9. Camera
10. Mechanical Body

For Soil Analysis:

To perform the second task, we will design a probe with an NPK sensor that will be able to measure the soil nutrient [4]. The measured data will be sent to NodeMCU for processing. From there it will be displayed on the screen.
To measure the soil moisture and water autonomously a microcontroller will be used. The soil moisture sensor will give data based on the soil resistance [5]. If the soil resistance is high that means the soil is dry.
To perform these tasks we will have some subsystems which will be attached to the mechanical structure of the system.

Component Level:

1. NPK Sensor
2. Soil moisture sensor

Summary:

TABLE 1. Summary of Functional Requirements

Type	System Level	Component Level
Functional	Ripe detection & harvesting system ● Using image processing to find the ripe vegetable ● Using ROS & Inverse Kinematics for plucking the ripe vegetable.	OpenCV, YOLO v5, Microprocessor, HSV Color space, 2 Finger claw, Actuator, Motor, Motor Driver, ROS, Inverse Kinematics Sharp sensor, stereo vision camera.

	Soil analysis ● Finding soil nutrients using NPK soil test ● Checking soil moisture through soil sensor	NPK Sensor, Soil moisture sensor

Non-Functional Requirements:

System Level:

Greenhouse Environment

Here, our task is to grow winter vegetables in the Summer season too. To do this, we will be creating a greenhouse environment where temperature can be controlled. For example, to grow a certain vegetable we need a nominal temperature of 21°C. If the temperature is above 21°C., the DC fan will be on and it will bring down the temperature. If the temperature is below 21°C., the DC fan remains off [10]. For creating this ambiance there will be a different system called the greenhouse system.

Another non-functional requirement is to maintain adequate soil moisture rate according to the necessity. To do that there will be an automated watering system facility.

i) Greenhouse System: The greenhouse system will contain all the necessary components to create an adequate atmosphere for the plants. This system will be connected to the mechanical system with the communication board. Moreover, there will be a circuit box attached to the system, containing the necessary components.

ii) Smart Watching System: To maintain the adequate soil moisture rate for better production there will be a smart watering system. This system will consist of a DC pump motor which will operate whenever the soil moisture rate is less than adequate. So, the microcontroller will use this soil analysis data to turn on the water pump and will water the soil till the soil moisture level reaches between 70% - 80% [5]. As soon as the moisture level is at 70% - 80%, the microcontroller will deactivate the water pump.

Component Level:

1. DC Fan
2. Transparent roof
3. DC water pump
4. Relay module
5. Spray

Summary

Table 2 described below is the summary of the nonfunctional requirements

TABLE 2. Summary of Non-functional Requirements

Type	**System Level**	**Component Level**
Non-Functional	Smart watering system ● Using water pump to bring adequate soil moisture	Relay module, Water spray
	Greenhouse environment to increase crop production ● If temperature > necessary one, DC fan will be on ● If temperature < necessary one, DC fan will be off	DC fan, Transparent Roof

1.2.3 Specifications

1. **Crop:** This system is designed to be applicable to some vegetables and fruits such as tomatoes, oranges, strawberries, or any plants similar to 3 to 4 feet tall. The mechanical structure will be the same for this case, we just need to change the software data-related parts if we want to make it applicable to other plants. But for our experimental analysis, we are planning to choose one certain crop or vegetable similar to a tomato.

2. **Land:** For the testing purpose of our system we are planning to work on a 3600- 4800 square feet field or 0.1-acre land. The system will be developed to be functional having 3-5 hours of battery life. Now, if we want to use it in bigger lands, the system needs to be redesigned according to necessity. Our target will be to collaborate with agriculture research institutes, and private farming spaces to manage crop fields.

3. **Mechanical Structure:** Assuring all the objectives there will be a certain mechanical structure containing all the necessary subsystems like electronics, network & communication, sensor box, and others. After analyzing the multiple designs described below we are going to choose the adequate structure for the system. However, up until now according to the necessity of the subsystems and the project the mechanical structure will be 0.8-0.9 m long and 0.5-0.7m wide.

4. **Controlling Unit:** There will be a controlling unit for sending the necessary commands which will be connected with the mechanical body through the necessary communication systems and will be operating the whole system. Basically, it will be considered the brain of the whole system.

1.2.4 Technical and Non-Technical Consideration and Constraints in Design Process

Any project has constraints and hazards that must be managed for it to be successful in the long run. In this project, the constraints are divided into mainly two parts.

1. Technical constraint
2. Non-technical constraint

Technical Constraints:

i) Proper Track: One of the major constraints we have is that we need proper track in the farmland to operate the Rover. Hence, the farm needs to be well-planned and organized where sufficient space is available between each row of crops.
However, unfortunately, we don't have plenty of such farms in Bangladesh. So it is a limiting factor in our remedy to the old agricultural system, which we may not be able to implement on every production farm.

ii) Maintaining Precisions: Another constraint is to maintain precision while detecting ripened vegetables through image processing. If precision is not maintained then the system may harvest vegetables too early, eventually curtailing the production. However, it is difficult to maintain such precision as we would rely on the color of the vegetable solely.

iii) Data Set: To make our system effective we need enough data sets to comfortably use machine learning algorithms. Otherwise, our system might worsen the scenario. For example, if the system is plucking immature vegetables due to some faults of machine learning, it might hinder production further. That goes to the importance of the data set. But the problem here is that it is hard for us to find a proper place to run our bot and teach it. We need to have enough samples to build a proper data set.

iv) Mechanical Difficulties: Designing the mechanical harvesting system to pluck the correct vegetable is tricky. We would need a proper 'Euclidean distance metric' to detect the crop distance from the rover appropriately. Hence, calibrating the mechanical harvesting system would be challenging also we are bounded by limited distance for plucking.

Non-Technical Constraints:

Provide Training: Using robotic technology in the agriculture sector is relatively a new concept. We need to give proper training to everyone who is involved with farming. As almost 80% of the total people of Bangladesh are connected with agriculture, it is a challenge to provide proper training to this huge population. We do not have this much manpower to properly train and inform people about the advantages of using robotic technology in their farmland. Initially, it might seem difficult but not impossible.

1.2.5 Applicable Complaints, Standards and Codes

Codes, standards, or requirements applicable to the work set forth or stated in an attachment in any applicable Law, are referred to as Applicable Codes and Standards. Standards are written documents that outline the requirements and practices for the supplies, products, processes, and/or services that people often use. Standards include a wide range of subjects, including but not limited to protocols that promote consumer safety and public health, improve product functioning and compatibility, and enable interoperability. Standards provide the basis for product development by offering defined protocols that can be understood and used by everyone. This facilitates product interoperability and compatibility while also streamlining product development and cutting down on time to market. It's also easy to understand and compare competing items because of the standards. In our final year design project, we are going to follow some laws, standards, and codes according to IEEE standards, ISO standards, and IEC standards regarding various purposes such as wireless communications, control purposes, and crop selection. Some of the codes and standards are stated below in Table 3.

Table 3 : Applicable Standards and Codes

Subsystem	**Standard**	**Definition**	**Purpose**
WiFi Network	IEEE 802.11	All of these functions over a range of about 30 meters (150 feet), speed will be Mbps (1 million bits per second) and frequency will be 5 GHz or 2.4 GHz. **[11]**	For wireless communication
Bluetooth	IEEE 802.15.1	Frequency will be 2.4 GHz **[12]**	For wireless communication

Machine Learning	ISO 18497:2018	forestry applications, mobile, semi-mobile, or stationary machinery used for farmyard or barn operations **[13]**	For control purposes
Agricultural electronics	ISO/TC 23/SC 19	This ISO technical committee creates agricultural electronics standards. **[14]**	For maintaining International codes and standards
ROS	ISO 10218-1:2011	Non-industrial robots are not covered by this standard, however, the safety principles outlined in ISO 10218 can be used for them. **[15]**	For control purposes
Internet of Things, (IoT)	ISO/IEC 30141	Non-functional requirements of your system must be highlighted, such as maintainability, reliability, usability, high availability, and scalability. **[16]**	For communication and control purpose
Microprocessor	ISO 11783	standardize the method and format of data transfer between sensors, actuators, control elements, and display **[17]**	For control purpose
Fertilizers and soil conditioners	ISO/TC 134	bulk density of various forms of fertilizer, as well as standards specifying the basic vocabulary, sampling methods,	For Crop selection

		and test protocols for assessing the quantities of compounds in fertilizers such as nitrogen, ammonium nitrate, phosphorus, and potassium. **[18]**	

1.3 Systemic Overview/Summary of the Proposed Project

The major goals of our project are to increase the efficiency and fun of farming while integrating smart farming practices into Bangladeshi agriculture. For that, we are proposing a system that can smartly detect ripe crops and harvest them. At the same time, it can check soil nutrients to increase crop production more efficiently. To detect ripe tomatoes, we will be using Hue Saturation Value (HSV) and as for the algorithm, we will be using YOLOv5. After detection, a robotic arm will harvest those ripe tomatoes using Inverse Kinematics. For soil analysis purposes, we will be using an NPK probe which will measure the soil nutrients like Nitrogen, Phosphorus, and Potassium. To accomplish these tasks, our whole system will be divided into different subsystems which are electronics, power unit, control panel, communication board, and sensor box.
But while implementing this system there are several difficulties we might encounter. For instance, we need a proper track where there is enough room between each row of crops so that our rover can navigate properly. We require a large enough data set to effectively apply machine learning methods for our system to be effective. Also, it is difficult to design a mechanized harvesting system that will pick the right vegetable. To determine the crop's distance from the rover, we would require an appropriate "Euclidean distance measure". Moreover, the application of robotic technology to the agricultural industry is a relatively recent idea. As over 80% of Bangladesh's population is involved in agriculture. We lack the staff to effectively train people and inform them of the benefits. It could appear challenging at first, but it's not impossible. Also, we have followed all the standardized protocols that are easily understood and used universally. This facilitates product interoperability and compatibility while also streamlining product development and cutting down on time to market.

1.4 Conclusion

Technology is bringing revolution to almost every aspect of our lives by changing how we do things. The primary goals of investing in technology are to increase efficiency and effectiveness, improve product quality, and lower manufacturing costs. Agriculture is one of the areas that is seeking to increase from smart technologies. The use of IoT in agriculture is known as smart farming or smart agriculture. Using data from a variety of sources, smart farming focuses on managing agricultural activities (historical, geographical, and instrumental).

Our group is focusing on this industry for the final year design project in the hopes of bringing about some revolutionary improvements in Bangladesh agriculture. The main goal of this project is to create a system that will reduce some of the most significant issues in farming.

Like harvesting on time and autonomously decreasing labor-management issues, soil analysis, atmospheric analysis, and soil moisture maintenance by watering plants timely and implementing an embedded greenhouse system. For that system, we have thought about multiple designs and after doing further analysis and research on cost-effectiveness and availability we will choose the best design and will implement that. These are mostly used for harvesting in the industrial sector. We can further optimize these systems to meet our goals.

CHAPTER 2: PROJECT DESIGN APPROACH [CO5, CO6]

2.1 Introduction

The first phase of the project lifecycle, project design, is when concepts, processes, resources, and results are thoroughly mapped out. Throughout the project design process, concepts, processes, and deliverables may all be aligned. Early on in the process, it typically takes place before a project plan or charter. Despite being iterative, the design process follows a set of predetermined steps, some of which may need to be reviewed before going on to the next. Although the steps of the engineering process are not always followed in the exact same sequence, it is customary for us to first outline the problem and produce ideas before creating a prototype test that is then adjusted and enhanced until the solution meets the project's criteria. Here, we will be describing the block diagrams of different designs and analyze them thoroughly. By doing these, we can get a clearer idea about our systems and which one is a more suitable answer for our project

2.2 Identify the Multiple Design Approach

As was already mentioned, our main objective, in this case, is to create a smart agricultural system that will make farming easier and more productive. Consequently, to meet our needs, we must first design a system that will let us effectively monitor the field and increase production. This includes items like soil analysis, mainly NPK testing, and environment monitoring [4]. Farmers will benefit from greater input on crop choices in this way.
Additionally, we are putting a lot of effort into developing a system that includes image processing, which will increase the scope for figuring out how the vegetables are doing.
As a result, a mobile device that can roam over the field and photograph the vegetables while monitoring the soil and other pertinent factors are needed. Additionally, delivering those data remotely to the user.
To serve the objectives, we are planning to design three multiple approaches-

i) Rover bot
ii) Unmanned aerial vehicle (UAV)
iii) Science box

Building a Rover bot [Figure 2.3.1] is one of the design options we have as a potential solution to this issue. It will be a transportable automated vehicle. It can therefore move along the field. It can watch over the field while being fitted with cameras and sensors. Another important aspect of this is that the rover bot may transport an automated harvesting robot arm, requiring less human labor overall.

Designing an unmanned aerial vehicle (UAV) is another option [Figure 2.3.2]. In this manner, a flying unit can quickly monitor fields. However, it is more expensive and can only support a certain amount of weight.
We could create a scientific box in its place for monitor purposes now [Figure 2.3.3]. The required sensors will be included in this. To remotely check on the state of the farm, we might place the science box at various locations in the field.

2.3 Describe the Multiple Design Approach

i) Rover Bot:

We want to build devices that will meet our demands, and a Rover bot is one of them. A bot is powerful and can easily lift a small burden. As a result, there is no need to worry about the weight of having several sensors. With more sensors, it can monitor the farms more efficiently.
Additionally, because it is mobile and transportable, it can document the conditions under which vegetables grow as it moves. Again, the rover robot is suitable for harvesting and analyzing soil.
Because it is unable to fly and take images of large areas, the bot must travel further to gather all the data. In contrast, because it will be closer to the ground, it will be simple to collect soil samples from various places across the field.

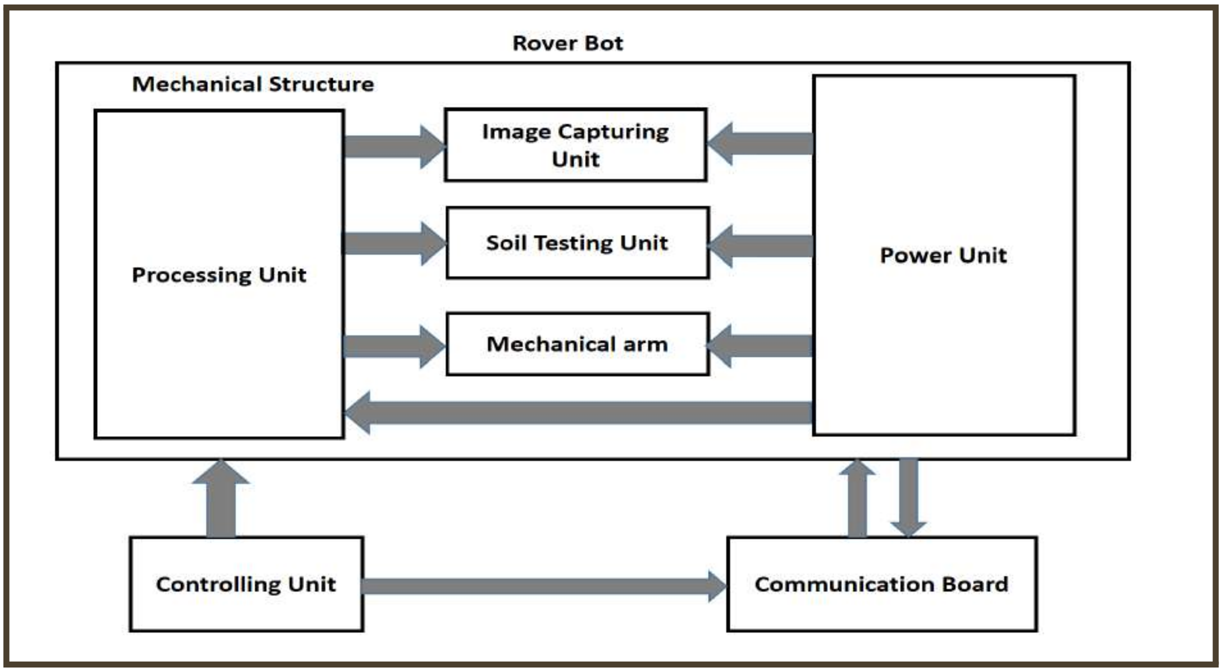


Fig. 2.3.1. Rover-bot block diagram

Figure 2.3.1 makes it obvious that a power unit will use electricity to run every part of the rover bot. At the following level, every component of the rover bot will be under the control of the processing unit. This contains the soil testing tool, which monitors the condition of

agricultural soil and has sensors for soil testing. In addition to other types of soil data, this instrument will also record the soil moisture.
It also has an image processing element for taking and manipulating vegetable photos. This image-based data will be used to locate the ripe vegetables that will later be plucked by the mechanical arm.
The bot will be managed by remote-control hardware. It will once more send the data gathered to a cloud server that can be contacted remotely via its communication board.

ii) Unmanned Aerial Vehicle (UAV):

Unmanned aerial vehicles (UAVs) could be an excellent tool for helping us achieve our objectives. Photos obtained by a UAV from above show a large area of agriculture. In this situation, we primarily target UAVs that resemble copters rather than aircraft. This is so that it can effectively gather information by remaining stationary in certain places.
The problem is that it will need more thrust to fly if we put heavier objects in it, which might result in a reduction in power efficiency. UAVs must also be handled carefully because they are fragile.
The mechanical claw on the UAV might not be as efficient at harvesting as the rover bot, too. Again, it is impractical for soil analysis because it must land to test the soil.

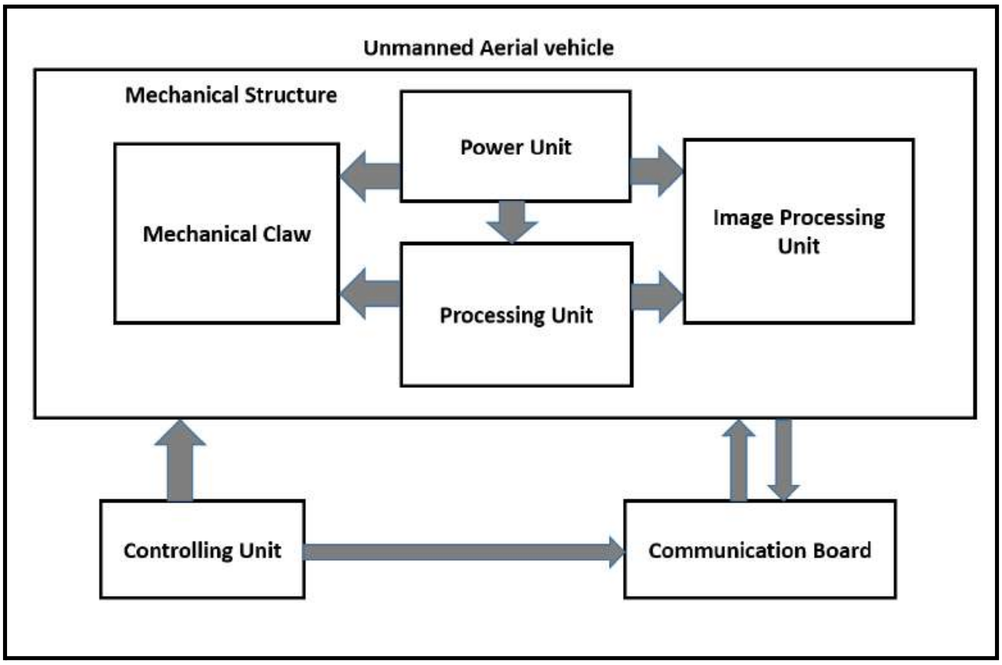


Fig. 2.3.2. Unmanned aerial vehicle block diagram

Similar to the rover bot concept, the UAV will contain a power and processing unit [Figure 2.3.2]. However, because it is a flying device, soil testing will not be suitable for it. The rover bot's robotic arm would be replaced with a mechanical claw. UAVs will once more be able to communicate remotely.

iii) Science Box:

A Science Box could also be used for monitoring and sensing. It will be a stationary device However, it can be a practical, affordable choice for keeping an eye on farmlands and taking the necessary action as a result. It is more of a streamlined version of the rover bot and the UAV. It is less mobile than its counterpart, but this allows it to carry more weight without reaching the maximum capacity.

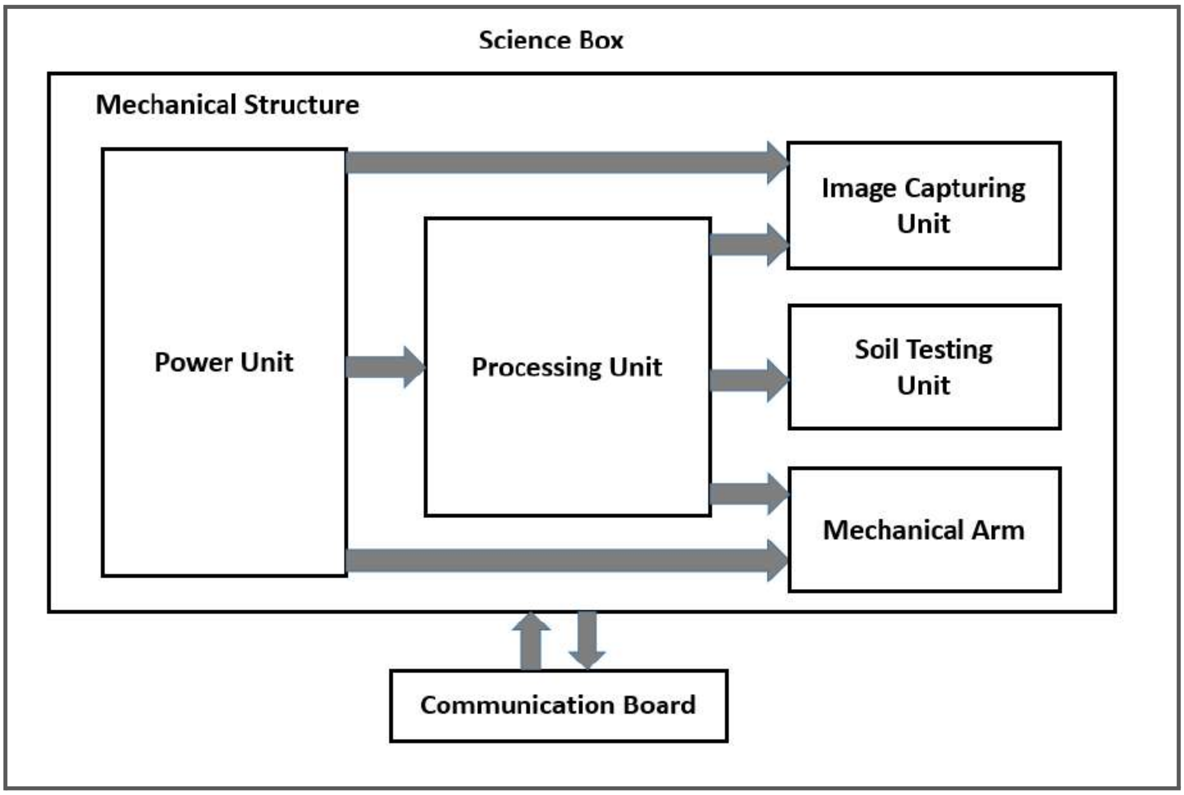


Fig. 2.3.3. Science box block diagram

The science box mechanical structure has a power & processing unit, just like the UAV and rover bot [Figure 2.3.3]. This, however, will be sensor-based for monitoring since it is an immobile low-cost option. Locating the ripe vegetables that will subsequently be picked by the mechanical arm will be done using this image-based data. Due to the field's limited agility, we also need to adjust it. Additionally, using its connectivity facility, it will be passing the farming test data.

2.4 Analysis of Multiple Design Approach

We can see that a smart agricultural system can be implemented in several ways to reduce the need for human labor in farming.

First, if we compare their durability and weight lifting capacity, the science box has literally no weight limit as we are keeping it immobile. On the other hand, UAV is sensitive to the weight we add, as it might increase the power consumption and stability of the UAV overall. In this regard, the Rover bot falls in between.

Now although the science box is a cheaper solution that has fewer power requirements, however as it is immobile hence it can only be used for monitoring purposes. UAV on the other hand being a flying unit provides a vast opportunity for image-based monitoring however it requires more power to operate. And again weight carrying capacity is limited for the UAV. Moreover, it is harder to teach the machine due to its Three-dimensional movement compared to the Rover bot which is limited to Two-dimensional movement.

In comparison, the rover bot is a mobile unit and is ideal for soil testing and environmental monitoring. Meanwhile, it can conduct image processing-based actions too. With an integrated robot arm, it can also do the work of harvesting, curtailing human efforts further. Again, as discussed above it is easier to teach the rover to move than to teach a UAV.

2.5 Conclusion

The design of the project is crucial to its successful execution. Here, through our block diagrams of different systems, we have compiled the required data and materials and brought our vision to life. Looking through the diagrams, one can easily understand the project motive and also can have a better understanding of how different systems work and also about their pros and cons. This is why the project design approach is undeniable.

CHAPTER 3: USE of MODERN ENGINEERING and IT TOOL [CO9]

3.1 Introduction

Engineers use scientific concepts, technical expertise, and creative creativity to design a mechanical building, machine, or system that performs certain duties with the maximum level of economy and efficiency. Key steps in the design process include the defining of objectives and criteria, as well as synthesis, analysis, constructing, testing, and assessment. Using IT technologies to create our prototype enables us to select the optimal design from a range of alternatives. Additionally, it enables us to investigate hypothetical situations without having to test our hypotheses on the actual system. It aids in your understanding of the factors that affect system performance the most.
For our project, we have three alternate designs. Based on some parameters, we modeled our alternate designs on modern engineering tools to determine the optimal solution.

3.2 Select Appropriate Modern Engineering and IT Tools

As our project is related to robots we had to consider various IT tools to simulate our design and realize our prototype. Therefore, we tried out various software tools , figuring out the best, suitable and efficient ones among them. Then we selected the appropriate ones to be used. All the softwares , IT tools we consider are listed below.

- ☐ MATLAB Simulink
- ☐ Proteus
- ☐ Blender
- ☐ ROS
- ☐ Arduino IDE
- ☐ Pycharm
- ☐ Roboflow
- ☐ Raspberry Pi OS

Now let’s look at our findings while testing the tools. Furthermore , the reasons why choose or reject using the software.

MATLAB Simulink:

System design using multi-domain models, simulation prior to hardware deployment, and deployment without writing code are all done in the block diagram environment known as MATLAB Simulink. It offers simulation, automated code generation, continuous testing and verification of embedded systems, and system-level design. Simulink includes a graphical editor, extensible block libraries, and solvers for modeling and simulating dynamic systems.

We can test out new concepts in MATLAB Simulink, and it enables us to do quick, repeatable tests.

Hence we selected MATLAB Simulink for the ‘stability’ test of our designs. With the help of the built-in Simulink blocks which incorporate many mathematical calculation processes as a whole, we could quickly create the testing environment. Again we needed to calculate the physics of our designs and the possible environment around them. MATLAB Simulink is effective in such scenarios, which accomplish complex calculations in short periods of time. Moreover, Simulink also provides the tools to visualize the simulation results rather than providing the numeric values of calculated output.

Therefore, for stability testing of our designs, we selected MATLAB Simulink to be the most appropriate tool for us, considering its scope and simplicity.

Proteus:

Proteus is an all-encompassing platform for product development that handles everything from ideation through design execution. Its advantages include automated wiring and PCB layout, intelligent principle layout, accurate hybrid circuit analysis, single-chip software debugging, and co-simulation of single-chip and peripheral circuits.

We chose Proteus to simulate the Soil analysis part of our simulation. To test this criterion we needed software that could simulate the processing of the data sensed by soil analysis sensors. The 3D simulation was not necessary here; rather, the simulation needed to properly simulate how the subsystem circuitry works. Considering the importance of circuit simulation here over physics or visual simulation, in this case, we selected Proteus as the appropriate tool.

Blender:

Blender is an open-source 3D creation suite. The whole 3D workflow is supported, including modeling, rigging, simulation, rendering, and compositing. Along with the modeling and sculpting, the simulation can be animated and analyzed in this software environment.

For our simulation purpose, some of the testing criteria are vegetable detection, navigation, harvesting, and image clarity testing. Any 2D simulation environment is not effective to test the mentioned test criteria. . In order to simulate our design to validate these testing criteria, we needed a proper 3D simulation environment. Therefore, we choose Blender as the simulation software to fulfill the tests in navigation, vegetable detection, harvesting, and image clarity.

Again, Blender also provides the facility to motorize the 3D model. To simulate the navigation and harvesting ability we needed the simulation to be dynamic rather than static. Hence for our navigation and harvesting tests, Blender suits here nicely too due to its animation feature.

ROS:

Robot Operating System (ROS) is an operating system designed to operate softwares suitable for robot programming. Although it is an operating system, it provides software frameworks for robot software development. Again, ROS can also incorporate many different add-ons and plugins related to robotics.

As our designs are closely related to robotics initially we planned for implementing the simulation part in ROS. ROS can run Gazebo plugin which is a handy tool to simulate the Robot design in 3D while incorporating necessary physics models such as including gravity. Thus, it could have been a great tool for 3D simulation for stability, harvesting and image processing tests.

However, although being a powerful software and providing a lot of scope it comes with its drawbacks. ROS requires powerful hardware to run properly hence making it less suitable to work with. Again , it is sometimes too complicated to work with while such simulations can be performed more efficiently by MATLAB or Blender. Hence for software simulation we refrained from using ROS after experimenting with it.

Apart from the simulation purpose ROS can also be used for controlling the Robotic system. However, again the performance issue comes in here. As our design is supposed to be controlled remotely hence a portable micro-processor may find it too heavy to be runned by ROS. Again as we plan for using Arduino microcontrollers hence it is easier to incorporate with Arduino software that ROS.

Therefore, after experimenting with it we did not choose to use ROS.

Arduino IDE:

The Arduino IDE is a great software to write programs for Arduino microcontrollers. It contains a text editor where programs can be written in C++ language. Moreover, it can connect to the Arduino hardware to upload programs and communicate with them.

So we considered choosing it as an IT tool to use while implementing the hardware part of the project. As we are planning to use Arduino chips as the microcontroller of our project hence Arduino IDE is a great tool for that. Moreover,it is open source and easy to use. It also incorporates many built in libraries to communicate with a wide range of hardware modules. Again, the built-in functions make it easier to code, summing up many lines of code in a single line. Hence, considering the scope of our project we choose Arduino IDE as an IT tool to be used in hardware development of our project.

Pycharm:

Pycharm is an IDE for python programming. Thus this can be used to incorporate Python codes with our project.

The benefits of using Python is that Python being a high-level language programming language provides a wide range of scopes for software development which can be implemented using any Python IDE such as Pycharm.

Hence first we tried to use it for simulation purposes. Integrating it with ROS to program our simulation model. However, Python being a high level language and general purpose language hence it is way slower than other programming languages or domain specific programming languages. Therefore, we realize it would not be a good idea to use Python for simulation purposes.

Yet, we choose Pycharm as a modern IT tool to use it to verify our mathematical models during hardware development. As in Python it is efficient to code and also compiling it provides instant output in the console, therefore Pycharm is a great tool to verify our mathematical models before implementation.

Roboflow:

Roboflow is used for a variety of computer vision tasks, including image processing. In this project, image processing will be used to train the system for the detection of ripe and unripe vegetables.

In roboflow there are opportunities for annotating and labeling the dataset along with performing tasks with the annotated and the labeled ones. The roboflow allows you to easy the work for whole image processing by providing the fundamentals code format. In the format the user can just modify the code according to the requirements. Using this platform anyone can easily avoid the extra work. No other platforms provide such a sorted environment for image processing purposes.

Raspberry Pi OS:

A Unix-like operating system called Raspberry Pi OS is designed for the Raspberry Pi series of small single-board computers and is based on the Debian Linux distribution.

This is a platform for communicating with the processor remotely through any controller. Using the Raspberry Pi OS, the user can create a remote screen to operate the Pi. Like uploading codes and other controlling tasks. No other platform is much more efficient than the Raspberry Pi OS to operate the processor.

Summary: Table 4 is described below as the summary of the selection of our modern engineering /IT tools in order to analyze the multiples

TABLE 4. Summary of the selection of our modern engineering /IT tools in order to analyze the multiples

Softwares	Rover Bot	UAV	Science box	Software Simulation	Hardware Implement-ation	Reason
Matlab	✓	✓	✗	✓	✗	• Ideal for mathematical simulation • Specialized robot control algorithms • We used for position estimation
Blender	✓	✓	✓	✓	✗	• 3D environment design • Visual effects & Animation design • Simulated the harvesting mechanism
Proteus	✓	✓	✓	✓	✗	• Can be used to design two-dimensional circuits. • Various advantages over making circuits in the real world. • Takes less time than the actual fabrication of the circuit • Simulated overall soil analysis subsystem
ROS	✗	✗	✗	✗	✗	• Provides a lot of Robot software development scope. • Requires powerful hardware resources • Complicated interface and time consuming
Arduino IDE	✓	✓	✓	✗	✓	• Can communicate with hardware (Arduino microcontrollers) • Text editor interface to write codes • Varieties of built in libraries and functions making it easier to code and integrate various hardware modules.

Pycharm	✓	✓	✓	✗	✓	• Quick and easy to use Python IDE • Great tool to validate mathematical models before integrating with hardware • Handy feedbacks to quickly debug problems
Roboflow	✓	✓	✓	✗	✓	• Can be used for dataset creation, annotation, labeling purpose • A combined organized platform for image processing tasks.
Raspberry Pi OS	✓	✓	✓	✗	✓	• Helps to create a remote desktop platform for operating the processor • Will be used to send commands to the processor using Wifi communication.

3.3 Use of Modern Engineering and IT Tools

Usage of MATLAB Simulink:

In accordance with our selection criteria, in MATLAB Simulink we implemented two different designs for the rover bot and UAV for the stability test. For the stability testing, we needed to build an electromechanical model. Then, after the simulation, we could analyze the performance of the designs from the perspective of stability.

Here, in MATLAB, we built two different electromechanical systems for Rover and UAV. For the Rover bot, we used the simscape model of MATLAB where we could easily get the blocks and components for automobile systems. By using and modifying those blocks and components, we developed the system for our Rover Bot. UAVs also used mathematical blocks and diagrams for building the electromechanical system of UAVs. As MATLAB gives us the facilities to verify our system design mathematically by using necessary formulas, we adapted these methods to formulate the UAV system. Our models were simulated, and the results were obtained for each design. Step input was taken into consideration for our systems' input, and we also received a step signal as their output. Here, the step signal is basically giving us an overview of the performance of each design in certain criteria. The Roverbot system's curve is critically damp, while another is underdamped, as shown by the graphs. We may assess the stability of our implemented design using the overshoot of the curves. The stability test is not necessary for a science box as it will be a stationary device.

Usage of Blender:

We used Blender for vegetable detection, navigation, harvesting, and image clarity testing for three alternate designs. In this software, we created three different 3D environments of farmland according to the optimal field configuration per design approach. We tested how the captured image might look from the camera perspective of the designs. This way we get an idea about the captured image clarity.

We also designed a 3D rover bot, UAV, and science box and dynamically simulated the 3D models with the help of animation. This enabled us to simulate how the designs may navigate in the farmland in a real scenario. Again how effectively the designed systems can harvest the vegetables upon detection. Through the simulation, we showed that the rover bot and the UAV can navigate their way to the ripe vegetables and harvest them with the help of its mechanical arm/ mechanical claw. Based on these parameters, we can compare the vegetable detection, navigation, harvesting, and image clarity of our three implemented designs.

Usage of Proteus:

Proteus being our engineering tool for sub-circuit simulation was used mainly to show how the soil analysis subsystem will work. Here the main reason for choosing proteus as our simulation tool is, in proteus, we can get a variety of sensors and processors. As in soil analysis, we need calibrated sensor system, proteus could be the right choice here to create such an environment. In proteus, we can easily access the necessary hardware needed for the simulation purpose and then to testify the performance through data collection methods and all. However, as we could not get any NPK sensor (Nitrogen (N), Phosphorus (P), or Potassium (K)) or calibrated NPK sensors here so we showed the soil analysis using a soil moisture sensor only. To vary the soil moisture in the proteus, we used a potentiometer. Varying the potentiometer we can consider different cases of soil moisture and it can be displayed on LCD. The NPK data would be processed in a similar manner.

Usage of Arduino IDE:

As we are preferring to use Arduino as the microcontroller for our project hence it is Arduino IDE has a significant role to be played as an IT tool. It is used to develop the software part of our final prototype. We used it to write the code and communicate with the Arduino hardware microchip . Thus Arduino IDE enables us to properly implement the soil analysis, harvesting and navigation of our system.

Usage of Pycharm:

As Pycharm is a great IDE to run python code hence it is used to build the mathematical models for our project swiftly . As it is easier to develop the necessary mathematical model with python as it is a high level coding language. Moreover, the console here in Pycharm provides quick output to easily debug the model.

Therefore to make the calculations easier for our project and quickly solve complex calculations to efficiently develop our system we used Pycharm as a suitable software tool.

Usage of Roboflow:

In this project, image processing is one of the most fundamental requirements for the ripe vegetable detection, so, one platform is required for the dataset preparation and for the system training purposes. Roboflow is being used for this system detection purpose in this project.

In this project, we are using tomatoes as our testing vegetables. So a dataset consisting of sufficient images of ripe and unripe tomatoes will be prepared. Then the images will be annotated and labeled according to the conditions. These whole procedures can be done in one platform only. From there, the file can be exported to the notepad of the YOLOv5 Pytorch notepad for further training purposes.

Thus, Roboflow will be used for image processing.

Usage of the Raspberry Pi OS:

For the operation of the microprocessor that is going to be implemented in this project, one operating screen is needed. This operating screen will be used for giving commands to the microprocessor. As we are using the Raspberry Pi as the microprocessor, one screen will be needed to operate this.

For operating the Raspberry Pi the Raspberry Pi OS will be the most perfect environment. As in this platform using the wifi connection any desktop screen can be used as the raspberry Pi operating screen or can be used as a remote desktop.

Thus the necessary command will be provided to the Raspberry Pi using this platform.

3.4 Conclusion

By now, it is clear that we completely agree with the fact that performing simulations is a must before implementing a design. This saves us time, money, and the effort required. However, in order to extract desired simulation outcomes, it is necessary to ensure the simulation environment is appropriate. Hence we emphasized selecting proper engineering tools before simulating the design and obviously before implementing the designs.

Initially, we identified the criteria we wanted to test and divided our design into sectors relating to the criteria in order to properly distinguish the simulation outcome and perform a fair comparison among the designs. Our simulation part was sectorized as a stability test, image-based detection, and harvesting, soil analysis. Again, to properly execute the simulation in each sector we choose MATLAB Simulink, Blender, and Proteus as simulation tools respectively.

We performed the simulation of the stability testing way quicker than it is supposed to thanks to the MATLAB Simulink feature block model that integrates complex mathematical calculations without manually writing the codes or formulas. Hence we could simulate the basic real-world physics for the stability testing purpose.

Secondly, for Image-based detection and harvesting purposes, a 3D environment was required. Hence, Blender was used to properly create such an environment to perform the simulation in this sector. Another important aspect was that this simulation sector required the simulation to be dynamic. Here again. blender remained appropriate for its animation features.

Finally, as proper circuit simulation was required for the simulation of the soil analysis sector, Proteus was used as it provided an appropriate environment for such simulation.

Apart from the simulation purpose where selection and usage of modern IT tools is required , these tools are also extremely important to realize the system in hardware. This includes communicating with the hardware and programming it appropriately.

Hence firstly, Arduino IDE is used as our design includes the Arduino as the microcontroller. This will enable us to effectively communicate with the hardware .

Moreover, the Pycharm helped us develop mathematical models for our system. Roboflow helped train the image processing model. Lastly, Raspberry OS is a great operating system to make our design controllable remotely.

Executing the software simulation in all these sectors we extracted enough data to compare our design approaches effectively. Which is further elaborated in the following chapters.

CHAPTER 4: OPTIMIZATION of MULTIPLE DESIGN and FINDING the OPTIMAL SOLUTION. [CO7]

4.1 Introduction

To satisfy a common set of requirements, many engineering design circumstances call for the creation of several designs. The presented approach makes use of and advances both the specialized design methodology and the general task approach to knowledge-based systems [19]. To test a particular set of functions three design approaches are proposed here. We simulated all of the ideas using various engineering IT tools rather than developing a hardware method, which may be time-consuming and expensive. We compared them based on the results of their simulations, and we ultimately settled on the design that can best meet our needs. This process assisted in selecting the best design for this project. Additionally, the data and information we required will be helpful in order to build the prototype.

4.2 Optimization of Multiple Design Approach

Developers must implement a product's functional needs in order for consumers to be able to do their tasks. Features and functions frequently describe how a system will act in specific situations. Using those features, we can optimize our design approaches. We also have additional functional criteria for our project that apply to the other solutions. They are -

1. **Smart harvesting system**
2. **Soil analysis**

1. Smart Harvesting System:

In the smart harvesting process our objective is to design the system in such a way that it can detect the ripe vegetables through image processing and can harvest them. To ensure the tasks here we divided the whole verification process into different categories for our three designs. They are-

- Vegetable detection
- Harvesting
- Navigation
- Image Clarity
- Stability

These five categories will be the tools for analyzing the performances of the three designs of this project. Through this, we will evaluate the performances of their functionality. The elaborative explanation for this is given below.

Rover Bot:

Here we will discuss the methodology and the process of performing all the criteria for a smart harvesting system.

i) Vegetable Detection:

Our system is built to recognize and pick up ripe vegetables. We will use a robotic arm with a claw mechanism that can move in five dimensions as the mechanical system. The arm system is made up of a laser sensor and a stereo-vision camera. Using precise three-dimensional coordinates and the size of the vegetable, the robotic arm may be instructed to pick up the ripe fruit or vegetable [2]. We will detect ripe vegetables using picture segmentation and processing. The following procedures will now be provided for vegetable identification and recognition, including pre-processing techniques, image segmentation, color conversion, feature extraction, and training/classifying algorithms. In order to expedite processing, images are resized and depending on whether the resizing is growing or decreasing, interpolation is applied [3]. The color space conversion most frequently depends on the kind of classification algorithm employed, and the extraction feature is dependent on color and form. Then, camera images will be converted from RGB to L*a*b color space, where L stands for brightness and represents black as white, a* as green, and b* as blue. The filters are then applied, and the image is downscaled and resized [3]. That's how the image processing segment of this segment will work. In short, explaining the rover will first detect the tomatoes, then after detecting them through inverse kinematics technique it will reach that particular point. We have assured the verification of the technique using the 3D simulation in blender. [20]

Fig. 4.2.1. Rover bot locating vegetables using three-dimensional coordinates and laser sensors

From figure 4.2.1, we can see that the rover bot is shooting lasers at the vegetables and detecting their coordinates. After detecting the exact location of the vegetables, the mechanical arm can reach the vegetables.

Fig. 4.2.2. Rover bot harvesting ripe vegetables using picture segmentation

In figure 4.2.2, we can see that there are green tomatoes (unripe) and red tomatoes (ripe), and using the picture segmentation process, our system classifies which tomato to harvest. Utilizing camera vision, the device will estimate and detect the ripening level (OpenCV). A camera will be attached to a Raspberry Pi in order to travel and monitor the system as part of ongoing work on ripeness detection.

ii) Navigation

A rover bot can navigate in many approaches but here we will be using a vision-based approach. We abstract vegetable-specific characteristics like spacing and periodicity by modeling vegetable rows as an arbitrary planar parallel texture. From a simulated overhead perspective, a novel technique is used to extract the direction of the dominant parallel texture, which is utilized to track the lateral offset of the vehicle [21]. To increase processing speed, the camera will first be stabilized before the images are pre-processed and downsized. We will employ IMU, which will detect the image's horizon, to determine the roll and pitch of the vehicle. To obtain a general view, we will stabilize and warp the image. Then, by determining the dominant parallel texture's direction in the overhead image, the vehicle's heading for the crop rows can be determined. By skewing the image with the anticipated heading, we can adjust the heading in the overhead view. By skewing the image using the anticipated heading and creating a frame template by adding the columns of the skewed photos, we may adjust the heading in the isometric perspective.

Fig 4.2.3: Roverbot navigating through the field

To obtain a general view, we will stabilize and warp the image. Then, by determining the dominant parallel texture's direction in the overhead image, the vehicle's heading concerning the crop rows can be determined. By skewing the image with the anticipated heading, we can adjust the heading in the overhead view. By skewing the image using the anticipated heading and creating a frame template by adding the columns of the skewed photos, we may adjust the heading in the isometric perspective. When tracking starts, the robot is positioned in the center of a local coordinate frame that is centered at that location and aligned with the rows. This way, our rover can navigate through the field and find its position relative to the vegetable lanes.

Their robotic design employs an IMU, two high-accuracy differential GPS units, and these devices to precisely locate where the seeds should be planted. To minimize the seed planting mistake, the path tracking algorithm closely watches movement. [20]

Localisation Technique:

A more precise understanding of the robot's location is obtained by localization, which is accomplished in two methods. Localization is initially done incrementally using odometry data, which is then fine-tuned by reading landmarks in the form of passive RFID tags incorporated into the carpet by an RFID reader attached to the bottom of the robot. These fixed landmarks aid in detecting the robot's direction [6] and are absolute. This method successfully achieves a degree of localization that is adequate to provide accurate navigation in inhabited spaces [22]

Driving Forward Paths:

Elastic Band Analyzer, Elastic Band Driver, and Point Approach module capabilities allow for forward movement along pathways. The shortest route between a source and a destination is the one that the Path Planner has designed. Following those instructions to the letter may force the robot to approach some barriers too closely, which would slow it down and make it more difficult for it to get where it was going. Elastic Band [12] has been utilized to avoid this situation. The Point Approacher receives the relevant path points one at a time from the Elastic Band Driver after reading the path from the blackboard. The access to the blackboard is therefore contained within it, and it also provides extra functionality, such as the ability to reverse the order of the route points or to hop forward or backward to other locations.[22]

Driving Backward Paths:
Driving backward will be possible by taking robot velocity into account after a given amount of time. When a point's velocity exceeds a certain threshold, the robot can move about in a safe area. In case the robot has to return, the present location is marked as a safe spot. There are two scenarios in which the velocity may fall below the threshold. First, it's possible that the robot is navigating a narrow hallway with several obstructions in its path. Second, the robot is stuck somewhere and is unable to go ahead or turn around. In the first scenario, the robot can resume its fast speed after passing through the corridor.[22]

iii) Image Clarity:

Here, in this test case, we will analyze the vision of the rover's camera. We will see an image taken from the perspective of the rover.

Fig. 4.2.4. Field view from a rover's perspective

From figure-4.2.4 we get an overview of how the rover's camera is going to do the visionary work to detect the ripe vegetable. This picture basically shows us how the field is going to be shown in the rover's camera. In this picture, we can see a clear horizontal view of the field. This means that the rover camera will get clear views for image detection and ripe vegetable location detection. Also, as the rover can independently navigate throughout the field, it will be easier for the rover to get more clear images. In this image, the hidden vegetables behind the leaves are also visible. Additionally, as the rover can navigate through the middle of the lanes, the vegetables hanging on both sides will be visible. This gives a positive affirmation of having image clarity for the rover bot.

iv) Harvesting:

After detecting the ripe vegetable the main task of the rover will be harvesting that ripe vegetable. To harvest or to pluck that vegetable, the rover bot will precisely determine the axis and the position of that ripe vegetable through inverse kinematics. After moving towards that point it will move its arm to reach that position. The claw will be used to pluck that vegetable. The claw will be built up in that mechanism so that the vegetable doesn't get squished. In [figure 4.2.5] we are showing the vegetable harvesting process of the rover bot.

Fig. 4.2.5: Vegetable harvesting, Rover-bot

In this figure 4.2.5 we can see that the rover bot is plucking the ripe vegetables and after plucking them it's putting it into a basket. After keeping it, it will do this task again. Detecting the ripe ones, reaching them, harvesting them, and putting them in the basket. That will be the harvesting property for the rover bot.

v) Stability:

By stability we mean are going to analyze if the rover bot is stable enough to implement. What will be its performance on velocity, and position testing? In this test case, we will develop an electromechanical system, which will give us a graphical representation by which we can justify the stability performance of the rover.

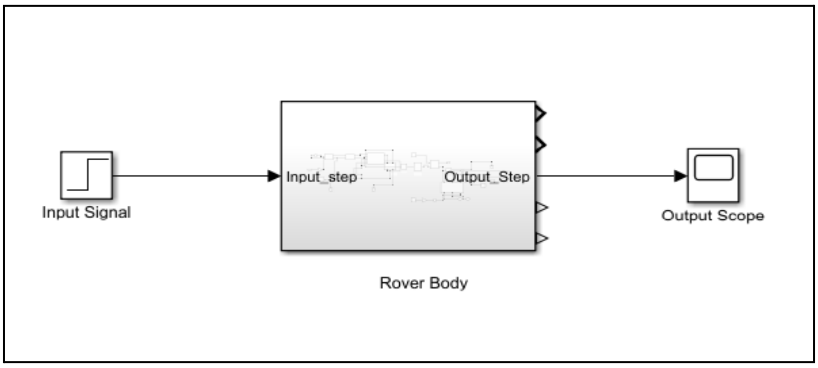


Fig 4.2.6: Schematic Diagram of Rover Bot (Top Diagram)

Here, we have developed an electromechanical system using MATLAB (Simscape Model). Fig 4.2.6 is the schematic diagram of the top model. Here, as an input signal, we give a step signal. Our main motive here is to analyze the performance of the rover from the perspective of this step signal. If the step signal is getting distorted or not we will see it in the output signal.

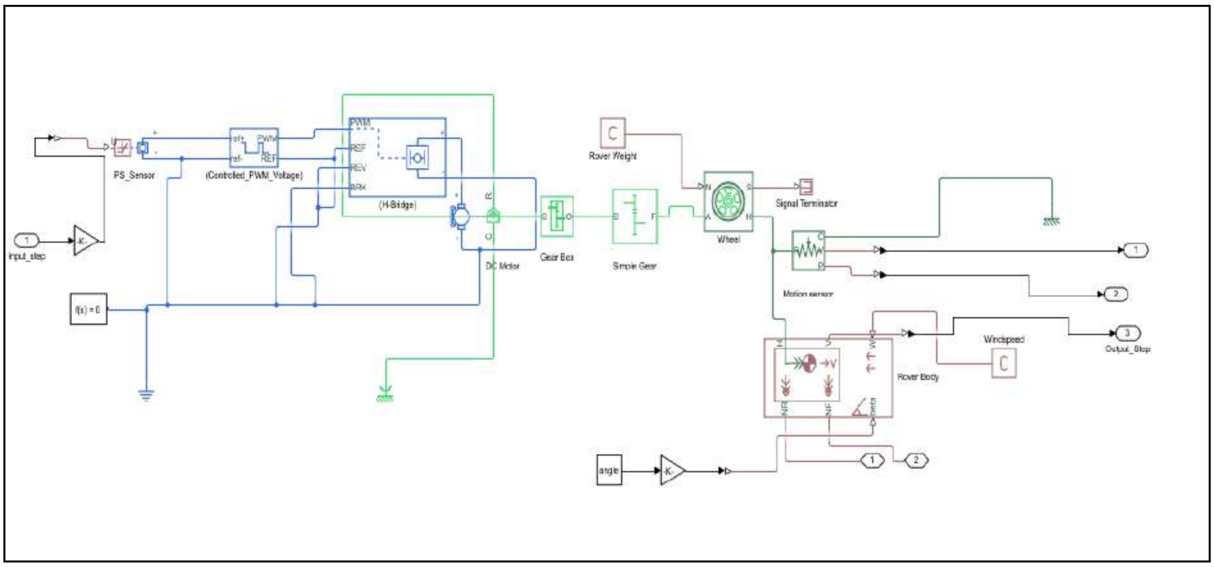


Fig 4.2.7: Schematic Diagram of Rover Bot (Subsystem Diagram)

Figure 4.2.7 is the subsystem of the rover bot. Here using the simscape model we modified an electromechanical system used for automobiles. We modified this component to use for the rover. The rover bot is connected to a wheel. The wheel is again connected with a DC motor, using a gear mechanism. Here the PS sensor converted the signal to controlled PWM voltage which is again connected to the DC motor with H-Bridge. Then from the wheel using a motion sensor, we will get the expected output.

Here, in this model, we have defined the component values as variables, so that this model can be used for every type of rover having different weights, gravity, windspeed, torque, voltage, and all. We have considered all these parameters as variables so that in future if we need, we can change the values accordingly.

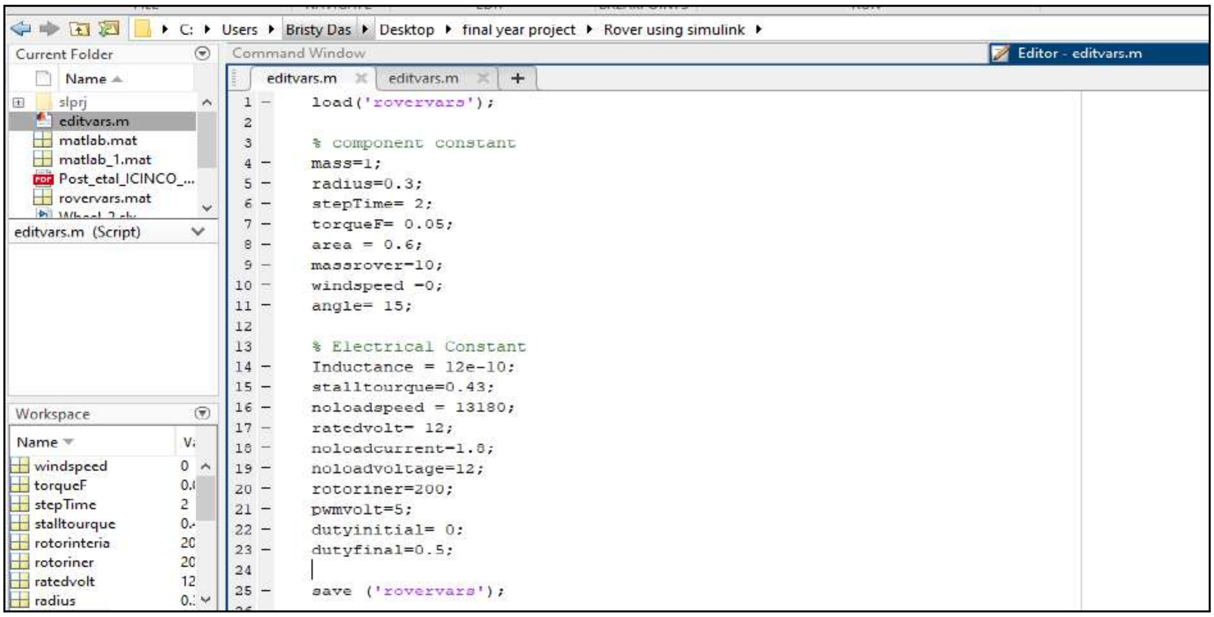
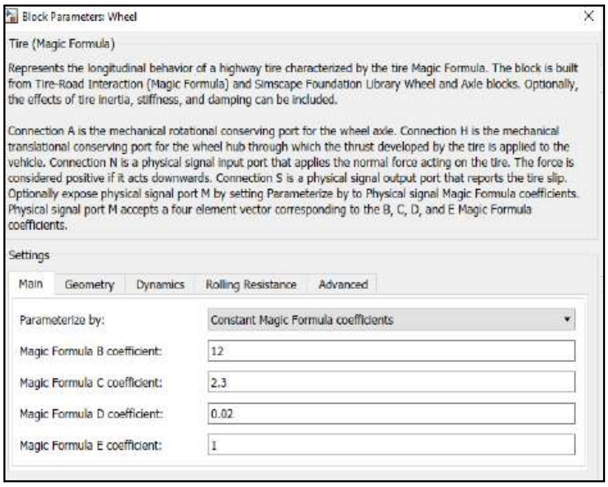
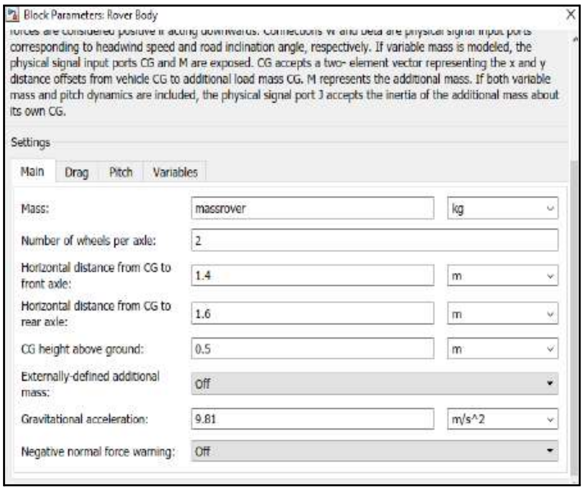


Fig. 4.2.8: Variable values for all parameters (In MATLAB editor window)

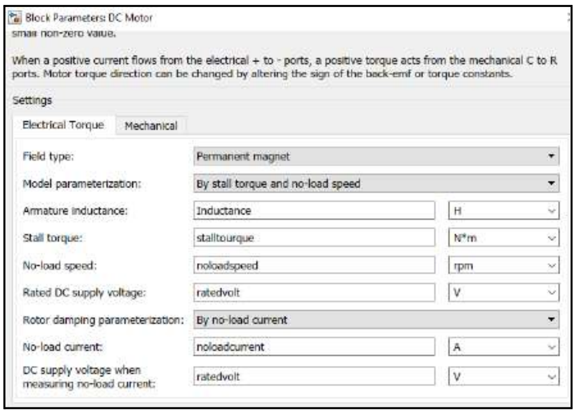
These are the parameters defined in the MATLAB Editor section, connected with the Simulink file. Here, we have mentioned the component variable values and electrical component values accordingly.



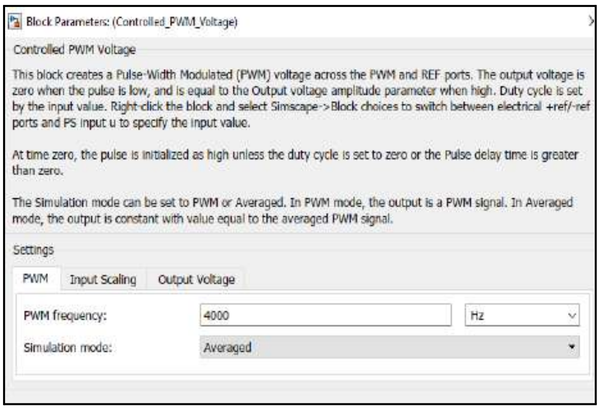
[A]



[B]



[C]



[D]

Fig 4.2.9: Variable values for rover body, wheel, DC motor, PWM voltage

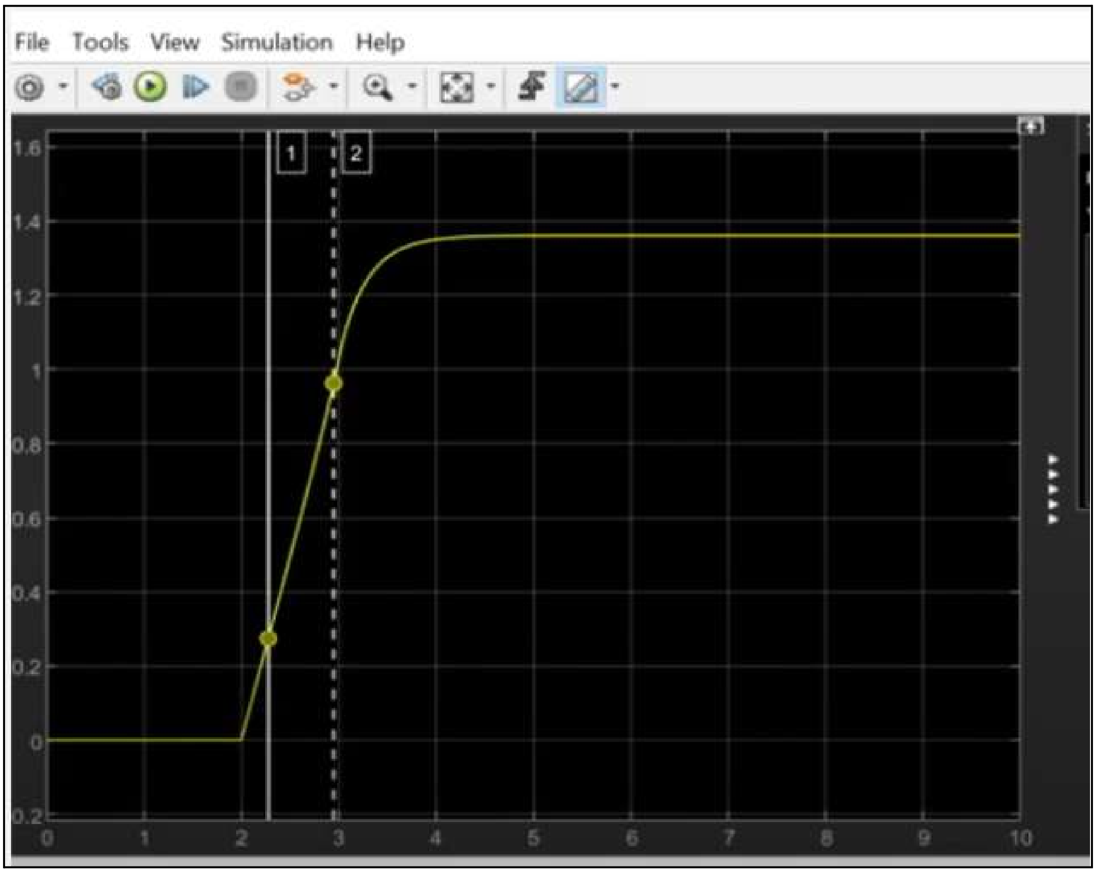


Fig. 4.2.10: Output Curve after simulating rover bot circuit

After simulating the circuit we will get the output curve like figure 4.2.10. In this figure, we can see a step signal-like curve as an output. This curve basically shows how stable the rover is going to be. In this curve, there is no overshoot. Though the output graph will not be as sharp as the input signal, still the graph we are getting, still, the output we are getting is almost close to the input one, which states that the design we choose can be implemented in hardware and we will get a similar output. There will be no issues in the navigation like overshoots and all.

Unmanned Aerial Vehicle (UAV):

i) Vegetable Detection:

The UAV is also designed in a way that it will identify the ripe vegetable and pluck it. To identify and recognize vegetables, the following processes will be provided: pre-processing methods, image segmentation, color conversion, feature extraction, and training/classifying algorithms.

Fig. 4.2.11. UAV locating vegetables using three-dimensional coordinates and laser sensors

From figure 4.2.11, we can see that a stereo vision camera and laser sensors are attached to the claw. With the help of these, the system is able to determine the exact location of the vegetables.

When we get the exact coordinates of the vegetable, the UAV is lowered down to the position so that the claw can grab the vegetable and pluck them.

Fig. 4.2.12. UAV harvesting ripe vegetables using picture segmentation

By segmenting and analyzing images, we can find ripe vegetables. We will be using the same procedure as the rover bot which is discussed earlier. Using image segmentation and classification algorithms, ripe vegetables are detected. From figure 4.2.12, it can be seen that only red tomatoes (ripe) are detected and harvested with the help of a mechanical claw.

ii) Navigation

Here we will talk about the navigation process of UAVs.

Fig.4.2.13: UAV navigating through the field

The navigation system for the UAV will be GPS based. Drones equipped with GPS can locate themselves in relation to an orbiting satellite system thanks to their GPS module. Although certain drone GPS modules will lock on to up to seven or eight different satellite signals for best performance, GPS normally employs three or four satellite signals to compute relative location and speed [23]. By connecting to signals from these satellites, the drone may do actions including position hold, altitude hold, return to home, and waypoint navigation.

Position and Altitude Hold

The drone can recognize and keep track of its position in a fixed location when it can lock on to a GPS signal. With GPS, the drone will be able to maintain its position even in the presence of a light breeze if we do not provide it with any controls at all [23]. It will immediately correct itself and fly back to the same point if it notices that it has strayed from its original position. Altitude hold is not always dependent on GPS because many drones employ onboard barometric sensors or image sensors to measure proximity to or distance from things directly below. The drone makes a difference.

Return to Home

One of a pilot's best friends is the return to home feature. A foot or two from where it took off, the drone will recall and land exactly where it was. This is obviously only possible with GPS, which can inform the drone of both its starting location and current location.

Way Point Navigation

If we preplan a flight path for our drone, we can accomplish this by instructing it to find specific GPS waypoints along the route. We can program a GPS drone to follow the predetermined route using the autopilot feature. The drone may be instructed to hover for a predetermined period of time at each waypoint using autonomous flying instructions [23].

iii) Image Clarity:

This parameter allows us to view the picture from the position of a UAV.

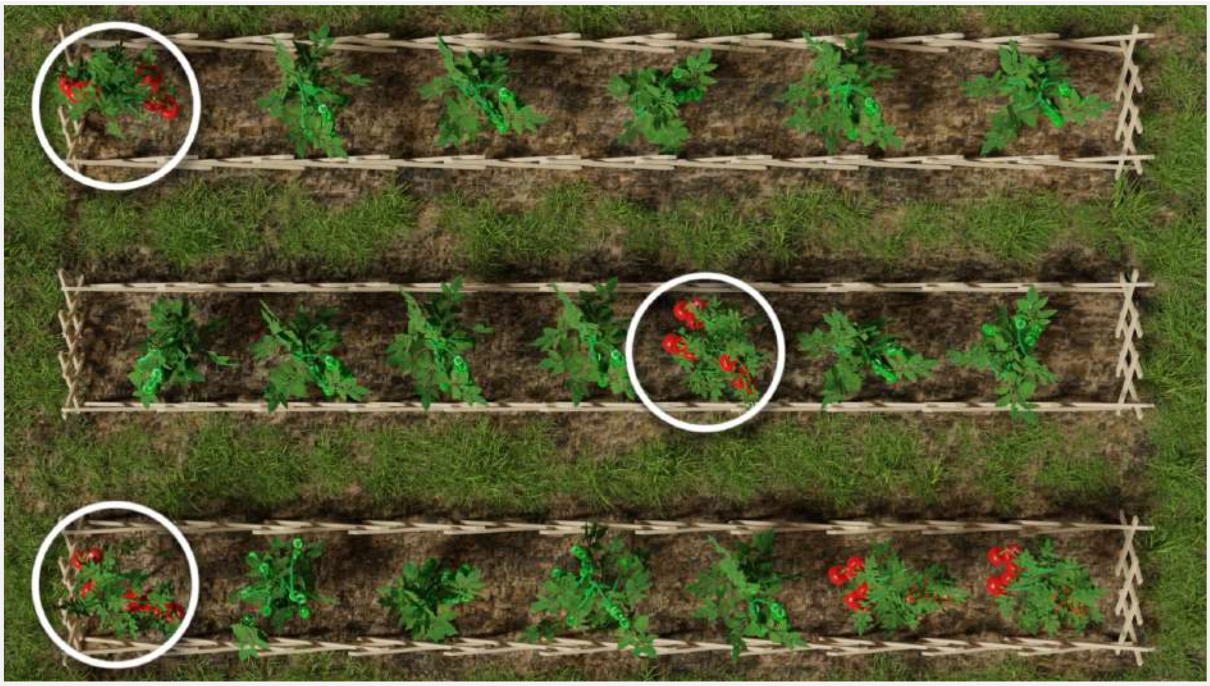


Fig. 4.2.14. Field view from UAVs perspective

Here, figure 4.2.14 provides an outline of the innovative work that the UAV camera will perform to identify the ripe vegetable. In the figure, we can see that the vegetables can be behind the leaves and also can be hidden from view. To have a clear view a UAV must go near the plants but it cannot go too near to the vegetables as the propellers of the UAV might damage the plants. So, the UAV needs to hover from a certain distance. As a result, vegetables might get undetected from the UAV's viewpoint which could lead to errors while detecting ripe vegetables.

iv) Harvesting

The UAV's primary goal will be together the ripe vegetable after it has been located. The UAV will use inverse kinematics to precisely determine the centerline and location of that ripe vegetable in order to harvest or pluck it. After detecting the exact location of the ripe vegetables the position of the UAV will be lowered so that it can reach the vegetables. To pluck or harvest the vegetables a claw will be used. In order to prevent the vegetable from being crushed, the claw will be strengthened in that mechanism. Also due to payload limitation, the UAV will have to harvest only one vegetable at a time. So, this system has to fly back and forth to keep the harvested vegetables.

Fig. 4.2.15: UAV harvesting ripe vegetables

From figure 4.2.15, we can see that the UAV is lowering its position to reach the ripe vegetables. With the help of a claw, it will do the harvesting. It will fly to the basket to store the ripe vegetables after harvesting.

v) Stability

As the UAV is a dynamic system. Hence, its stability is crucial. We tested the UAV stability in MATLAB.

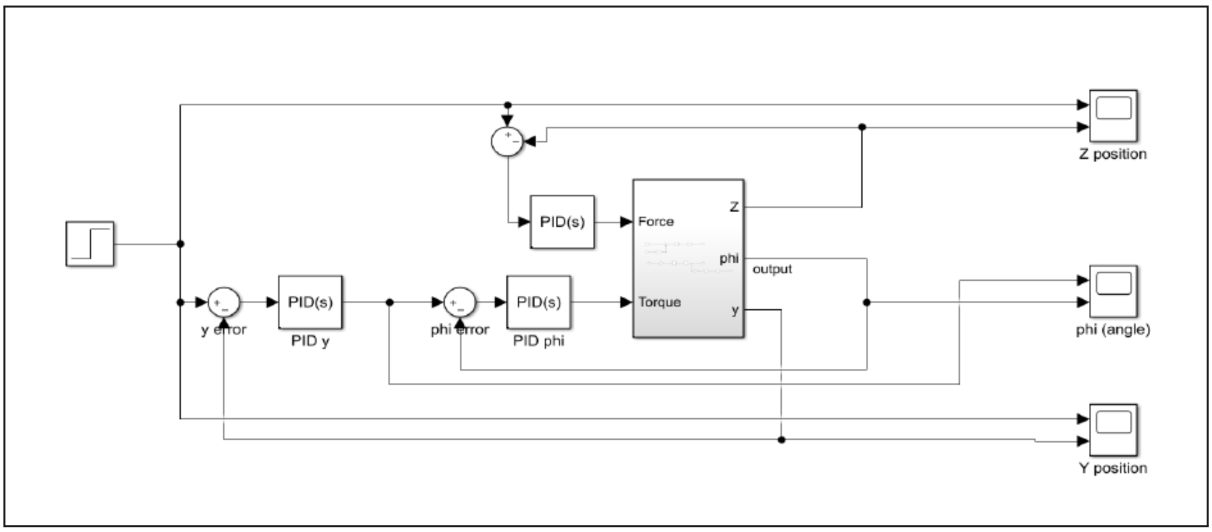


Fig. 4.2.16: UAV stability testing main circuit

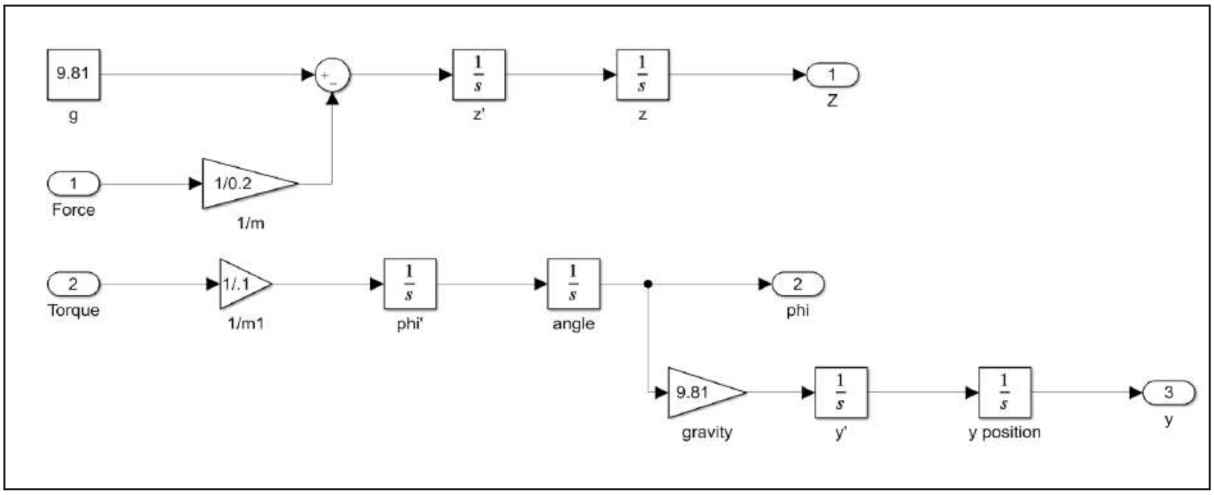


Fig. 4.2.17 : UAV stability testing subsystem circuit

For this simulation the UAVs movement is considered to be along the vertical(Z) and horizontal(Y) axis along with its tilting angle. For simplicity, we are ignoring the other horizontal axis(X).

To control the UAV or to move we will basically be providing a force or thrust. The simulation shows us how much stability the UAV would be maintained in accordance with the force. Here, the gravity is considered to be 9.81 m/s^2

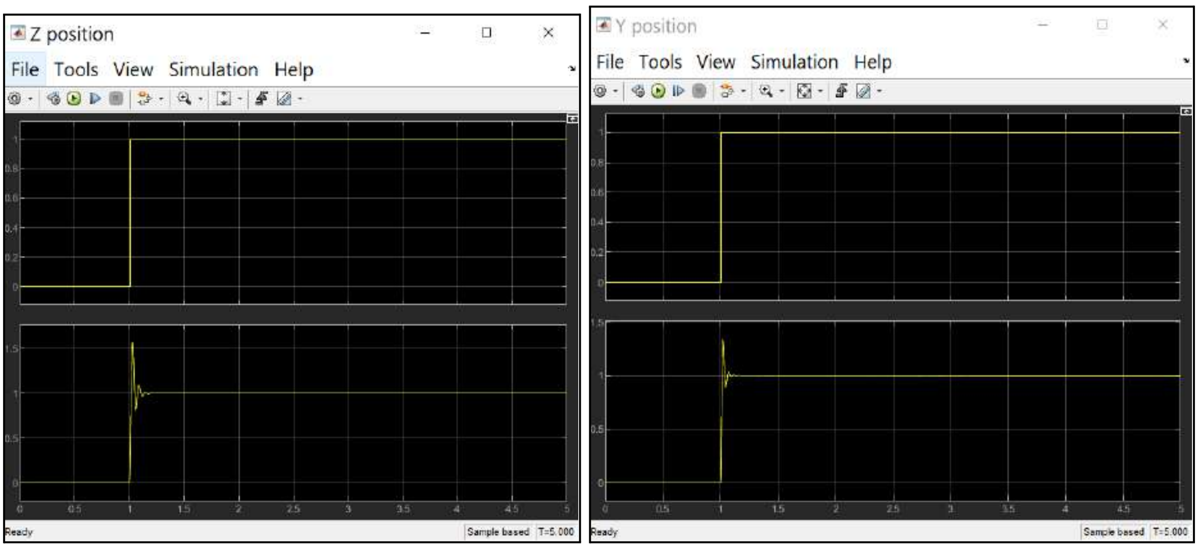


Fig. 4.2.18: UAV stability testing Simulation output

The simulation output graph (Figure -4.2.18) shows the step response of the UAV if moved in the vertical or horizontal direction. For both cases, an overshoot can be observed. This indicates that the UAV is a bit unstable. Although the PID controllers quickly eliminate the error hence the output follows the input in later parts.

Science Box:

i) Vegetable Detection:

Our last alternate design science box is built such that it can detect ripe produce and harvest it. As for the mechanical system, we'll employ a claw mechanism on a robotic arm that can move in five directions. Like the rover bot, the claw system is made up of a laser sensor and a stereo vision camera.

Fig. 4.2.19. Science box locating vegetables using 3D coordinates and laser sensors

Figure 4.2.19 shows how the rover robot is using lasers to target the vegetables and locate them using their coordinates. But there is an interesting thing to notice that the plants are not planted in a traditional way. The whole vegetable field has to be modified in order to make our device work as the device is not transportable. As the science box is stationary, so the field has to be customized in a way so that the mechanical arm can reach the vegetables and harvest it precisely.

Fig. 4.2.20. Science box harvesting ripe vegetables using picture segmentation

The same process as the rover bot will be used to identify ripe vegetables. Vegetables that are ripe are identified using picture segmentation and classification algorithms. Only red tomatoes (ripe) are identified and collected using a mechanical claw, as can be seen in figure 4.2.20.

ii) Navigation

Science box cannot navigate through the field. It is a nonmoving system. This system will be installed at the different lanes of the field and it will be controlled manually. Only the mechanical arm attached to the system will move. The arm will be able to move 360° so that it can harvest the maximum number of vegetables.

Using geometric analysis the motion trajectory of a robot arm is calculated. Here the Kinematics equations are used in order to make the robot arm achieve the exact grasping object. In order to make the end-effector of the robot arm more accurate to reach the target, firstly, carry on kinematics and inverse kinematics to find out the solution [24]. The arm will contain five degrees of freedom . Servo motors are to be used to achieve this. The robot arm comprises the shoulder joint, elbow joint, lower arm, wrist, and the end-effector.
In order to make the robot arm navigate properly at a 360° angle, it is necessary to obtain the kinematics equation at the same time with the geometric structure and the homogeneous transformation matrix to control the robot arm.

Fig. 4.2.21: Science box arm navigation

iii) Image Clarity

Now we will analyze the vision of the Science box's camera.

Fig. 4.2.22. Science box image clarity in a modified field setting

The science box would be getting a clear horizontal view of the plants from its camera perspective. This way it should get a clear image of the plants to a satisfactory level. Again, the science box's camera would be close enough to maintain the image resolution to a maximum level. However, if we consider the circular arrangements of the vegetable, in another word the modified field for the science box, this way the devices will be getting the plant's images from the inner circle only. Vegetables that are oriented in the outer circle might not be clear from such a perspective. This remains a drawback for the science box, in its most productive field arrangement.

iv) Harvesting:

Unlike the rover bot and UAV, the science box will do the harvesting being stationary to a point. The harvesting will be done using a mechanical arm. In order to do the harvesting the science box needs to locate the ripe vegetables first and this detection will be done using the Kinematics equation. After locating the vegetables, the arm's claw will reach out to pluck the vegetables and it will be stored in the basket near it. As it will be an immobile system, so to harvest the maximum number of vegetables the arm will be able to move 360°.

Fig 4.2.23: Science box harvesting vegetables

From figure 4.2.23, we can see the whole process of harvesting. Here, we can see that the ripe vegetables are being detected. After the detection, the mechanical arm is reaching towards the ripe vegetables to pluck it. The harvesting system will be built up in that mechanism so that the ripe vegetables do not get crushed.

v) Stability

The science box we are considering is a static system. As it is immobile hence it does not suffer from stability issues that much. Hence, we ignored the stability simulation for the science box.

The only movable part here for the science box is the Robotic-arm. As long as the stability of it is maintained with proper use of forward and inverse kinematics the science box should not be facing any major stability issues. Hence, we may declare the science box to be a stable system.

2.Soil Analysis:

The second major criterion of our functional analysis is Soil analysis, after the Smart harvesting system. For the soil analysis part, our approach is to verify the functionality of the soil moisture test and NPK test.

The functionality is similar in all three design approaches for the soil analysis part. So in this section, the verification is described in a generalized manner. What differs in the design approaches is how the sensors are integrated into the designs.

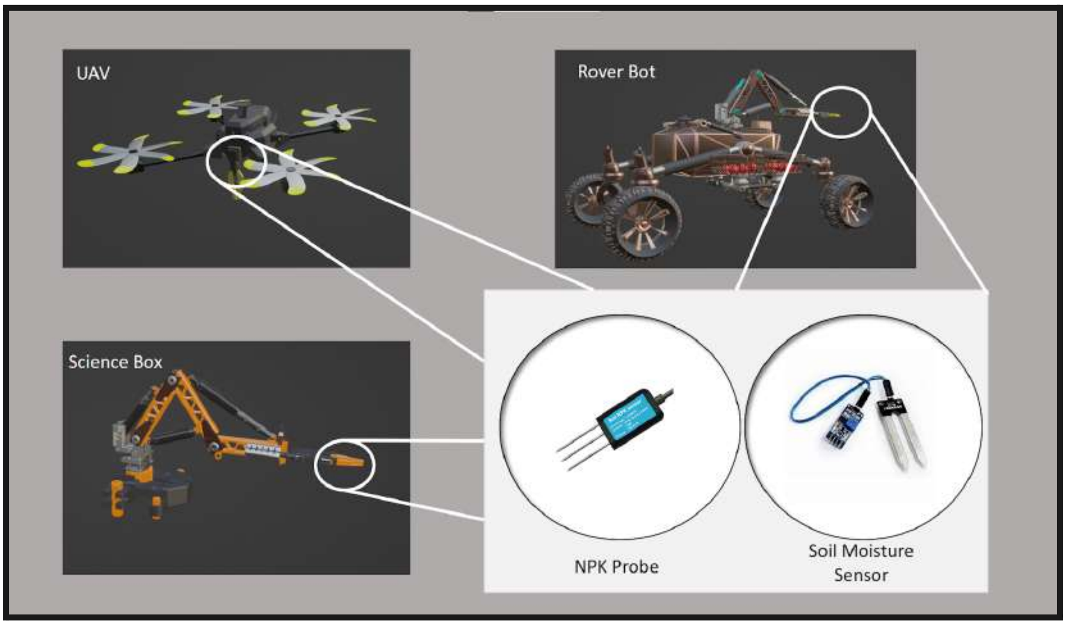


Fig. 4.2.24: Position of Soil analysis sensor

For UAV the sensors would be integrated near its claw. While the Rover bot and the Science box it would be integrated into their robotic arms.

Soil Moisture Testing:

In order to simulate the functionality of soil moisture we used Proteus as the simulation environment.

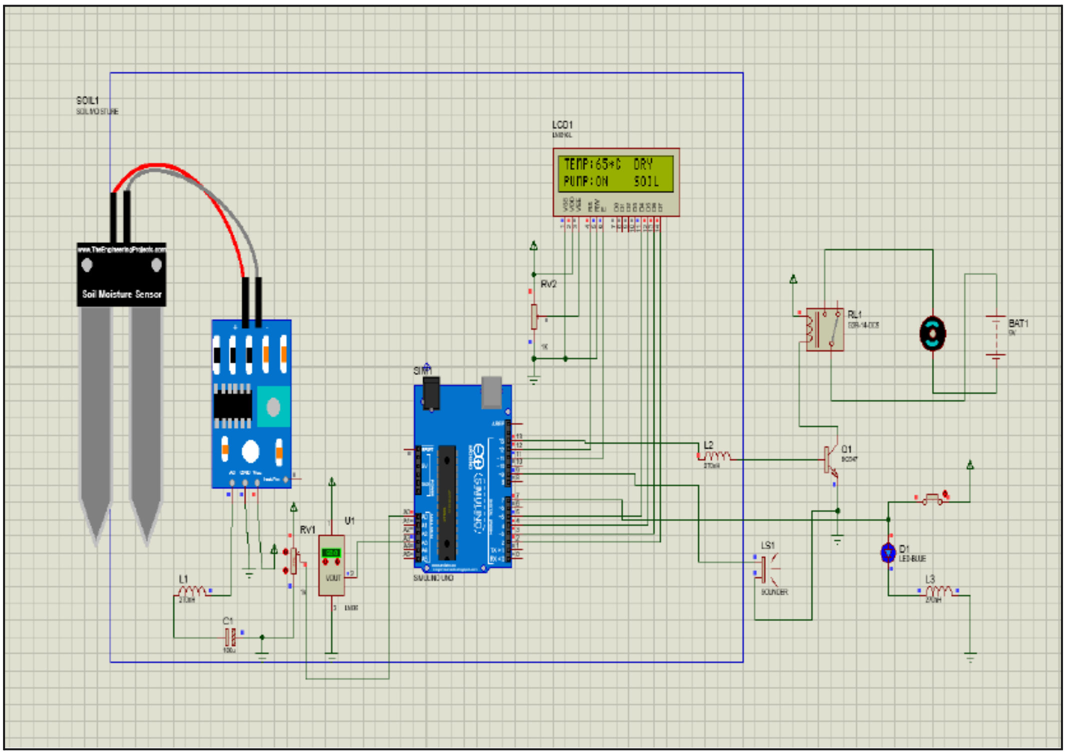


Fig. 4.2.25: Soil Moisture testing simulation, circuit diagram.

Here in this simulation the soil moisture sensor is measuring the moisture of the soil and is sending the data to the microcontroller. Which activates the watering pump based on the dryness of the soil. If the moisture goes below a certain threshold , the system will spray water trying to retrieve the moisture to a satisfactory level.

NPK Testing:

For the NPK testing, the simulation could not be performed due to the lack of calibrated NPK probe in the software. However, it can be implemented in the hardware. The process is illustrated with the help of the following block diagram (fig 4.2.26).

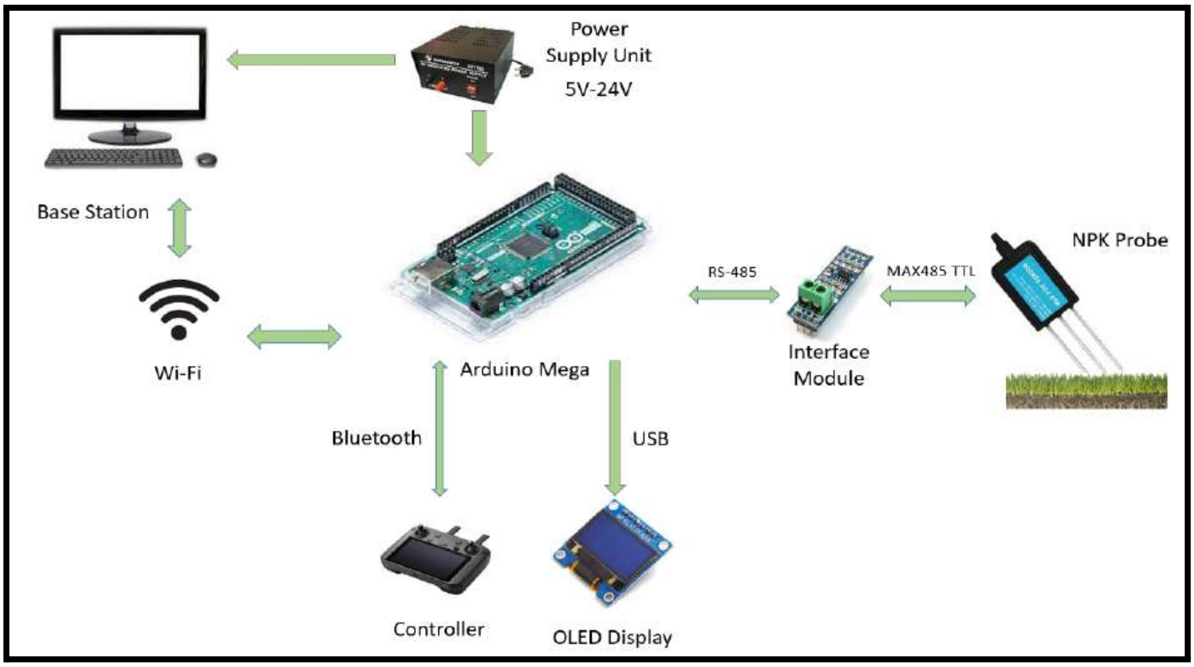


Fig. 4.2.26: Workflow diagram of NPK testing

First the controller will signal the microcontroller to start taking data on the soil nutrients using the NPK probe. The interface module translates the sensor data into microcontroller language for processing purposes. After that, the collected data will be sent to the base station for the user.

4.3 Identify Optimal Design Solution

We have established some guidelines or test cases on the basis of which we will evaluate our designs in an effort to discover the best answer for our project. To clearly grasp all of our alternative designs, we have established a few test cases. After analyzing the factors, we will be able to identify the benefits and drawbacks of each of the three designs and select the best option. The parameters we have considered for our projects are mentioned and described below:

1. Image Clarity

Through this parameter we will see if our system can maintain image clarity and identify vegetables hidden behind the leaves for proper detection.

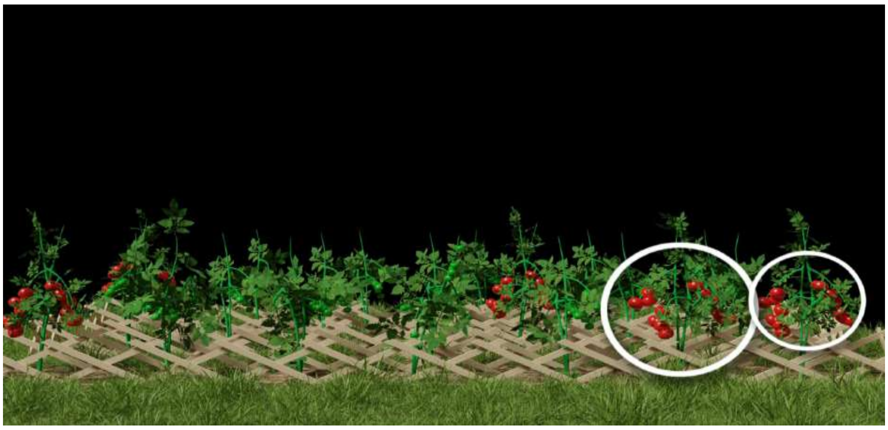


Fig. 4.3.1. Image clarity and filed view for rover bot

Fig. 4.3.2. Image clarity and filed view for UAV

Fig. 4.3.3. Image clarity and filed view Science box

We know, sometimes in a field vegetables can be out of sight as it can be hidden behind the leaves. In (figure 4.3.1), it can be seen that even if some vegetables are out of sight, the rover can easily navigate through the lanes and can reach the closest to the vegetables. As opposed to that, the drone is only able to get an upper view or a bird eye view of the vegetables (figure 4.3.2). Due to this, if some vegetables are hidden under the leaves, the UAV cannot detect it. Furthermore, the science box can also reach close to the vegetables and detect it (figure 4.3.3).

To briefly put it, we can say that in terms of image clarity, the rover bot and science box works better than UAV.

2. Ripe Vegetable Detection:

This test case can be used to see if our system will be able to navigate and reach inaccessible vegetables to detect ripe one's properly.

Fig. 4.3.4. Rover bot detecting vegetables

Fig. 4.3.5. Uav detecting vegetables

Fig. 4.3.6. detecting vegetables

From figure 4.3.4, we can see that the rover bot can go to the closest to the vegetable and can detect the vegetables easily whereas the UAV in figure 4.3.5 can detect all the vegetables properly as some of the vegetables might be out of sight due to the leaves. As the UAV is only getting a birds eye view, it cannot detect all the vegetables properly. For the science box in figure 4.3.6, we can see that the system can only reach those vegetables which are reachable to arm's length. So, to detect all the vegetables, we need another science box in every two or three lanes depending on the arm length of the system.

So, from here, we can conclude that the system rover bot is a better approach than the other two designs in order to detect the vegetables.

3. Harvesting:

All the designs will be able to pick the ripe vegetables and this harvesting technique will be compared using this parameter.

Fig. 4.3.7. Rover bot harvesting ripe vegetables

Fig. 4.3.8. UAV harvesting ripe vegetables

Fig. 4.3.9. Science box harvesting ripe vegetables

As the rover bot can go closest to the vegetables so it can harvest the ripe vegetables properly using picture segmentation process (figure 4.3.9). UAVs also can harvest vegetables but it is somewhat difficult for the system to go to the closest plants as its propellers can damage the plants. On the other hand, the harvesting system for the science box is limited to 2-3 lanes as one science box cannot cover the whole field. So, we need multiple science boxes in different lanes in order to cover the harvesting of the whole field.

From here also we can see that the rover performs better than the other two designs.

4. Navigation:

With this parameter, we will be analyzing the transportability of our design.

Fig. 4.3.10: Rover, UAV , Science-box navigating through the field

In terms of transportability the UAV is the best solution to navigate around the field. The UAV can move across the field in a 3D plane. Moreover, by adjusting the thrust of the propellers it can quickly change its course. However, the Rover bot's movement is restricted to 2D plane. Again, it would be difficult to navigate the Rover in congested areas. The rover

would require plenty of space in between the tree to navigate properly. While the UAV can navigate through narrow spaces .

On the other hand, as the science box is immobile its navigation process is only limited to the 360° movement of its robotic arm.

Furthermore, turning the rover's body would require further space. While the UAV can easily rotate, tilt, and move in any direction without much of a hassle.

This way in terms of navigational scope the UAV performs better than the rest of the design approaches.

5. Stability:

The stability tests were performed on our dynamic systems (Rover Bot, UAV) and the science box being a static system was ignored for this test criteria.

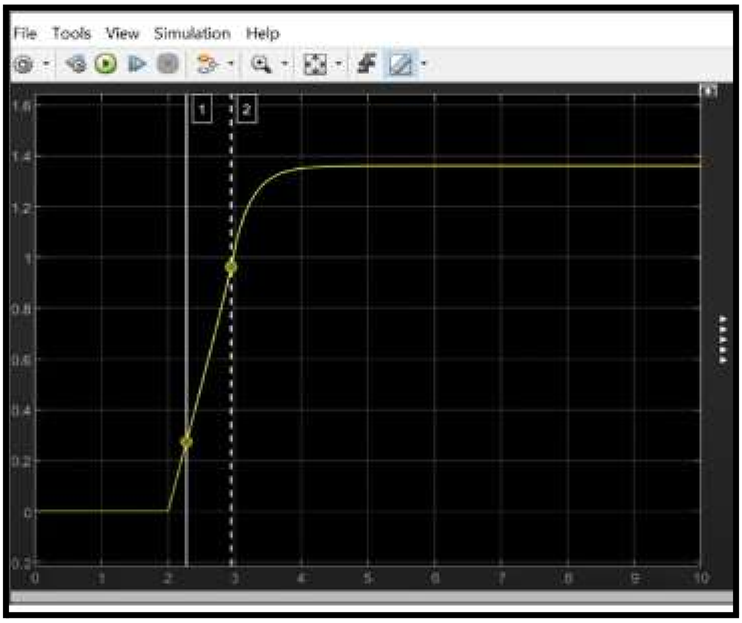


Fig. 4.3.11: Rover bot stability testing in MATLAB (simulation output)

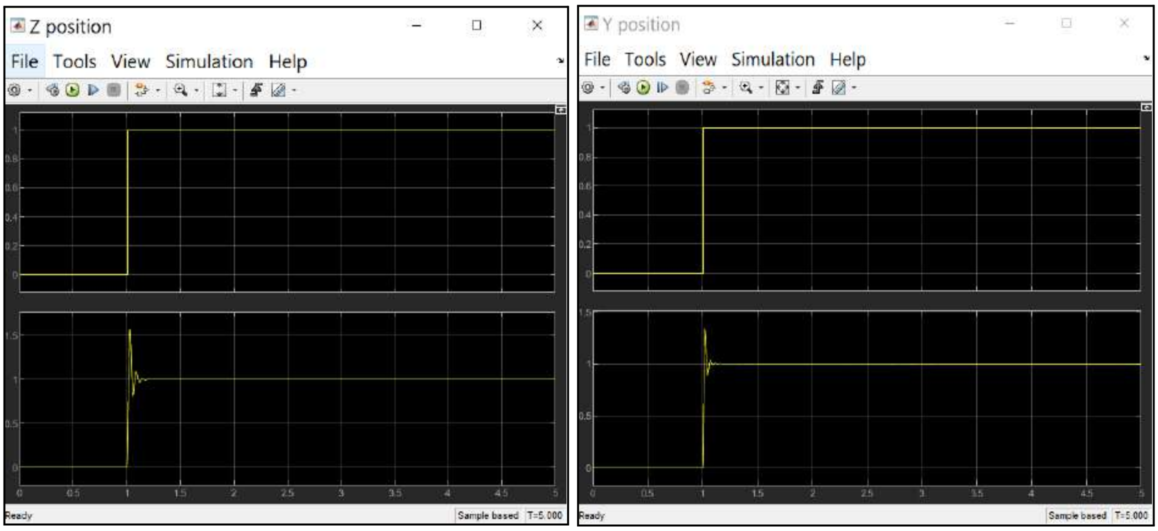


Fig. 4.3.12. UAV stability testing in MATLAB (simulation output)

From figures 4.3.11 & 4.3.12 we see, unlike the rover bot which has critically damped stable output the UAV output graph, is not as stable. For a step input in both vertical and horizontal direction, the response has significant overshoot. This suggests the system is not as stable as the rover bot.

6. Weight Limitation:

This argument can be used to determine and compare how much weight our systems can carry.

Fig. 4.3.13. Rover bot carrying harvested crop

Fig. 4.3.14. UAV carrying harvested crop

Fig. 4.3.15. Science box carrying harvested crop

From figure 4.3.13, it can be seen that the rover bot is harvesting vegetables and the system is carrying the harvested crops along with it as there is no weight limit. On the other hand, UAV has weight limiting capacity so it harvests only one plant at a time (figure 4.3.14). In (figure 4.3.15), we can see that the science box has no limitations for weight capacity but it cannot harvest all the lanes at once.

To put it simply, it can be said that in terms of weight capacity the rover bot is the better choice.

7. Soil Analysis:

Soil moisture and soil nutrients like Nitrogen (N), Phosphorus (P), and Potassium (K) will be analyzed by our systems and this will be observed by this parameter.

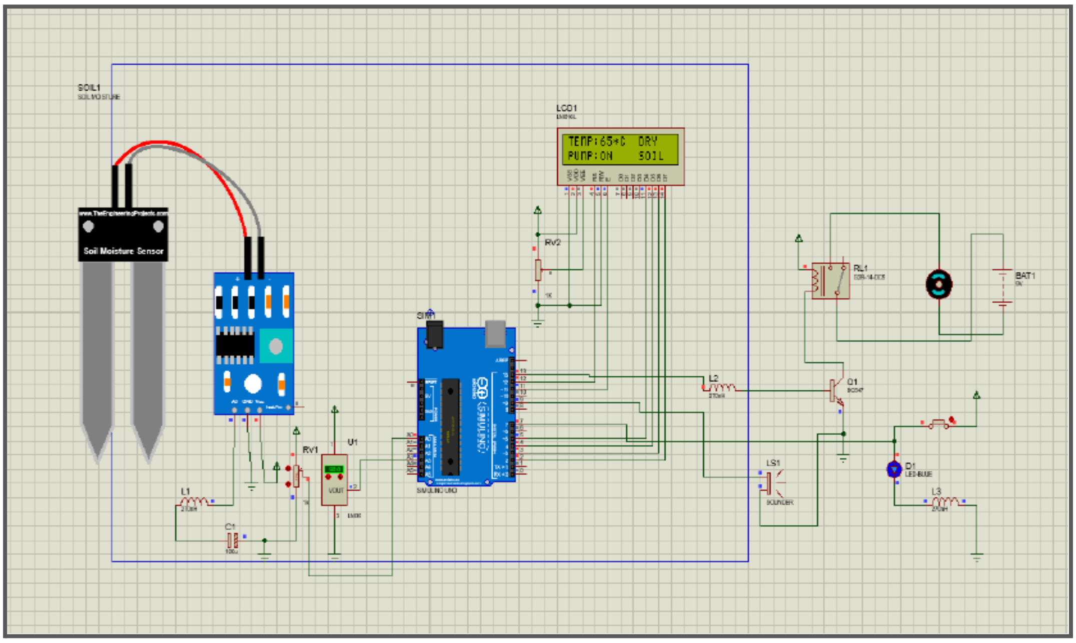


Fig. 4.3.16. Dry soil, pump On

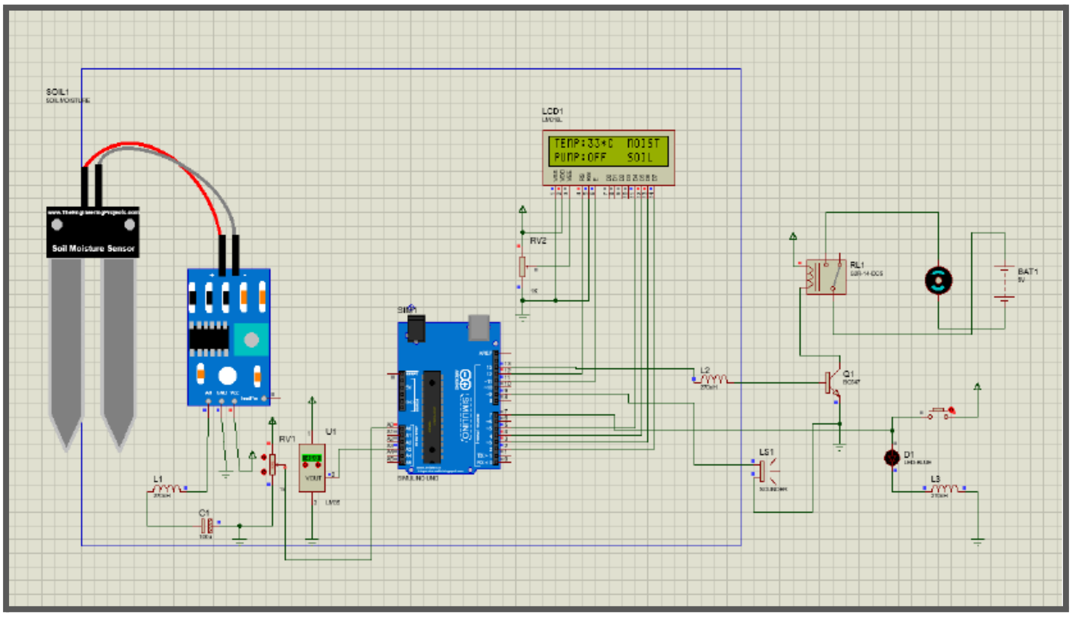


Fig. 4.3.17. Moist soil, pump Off

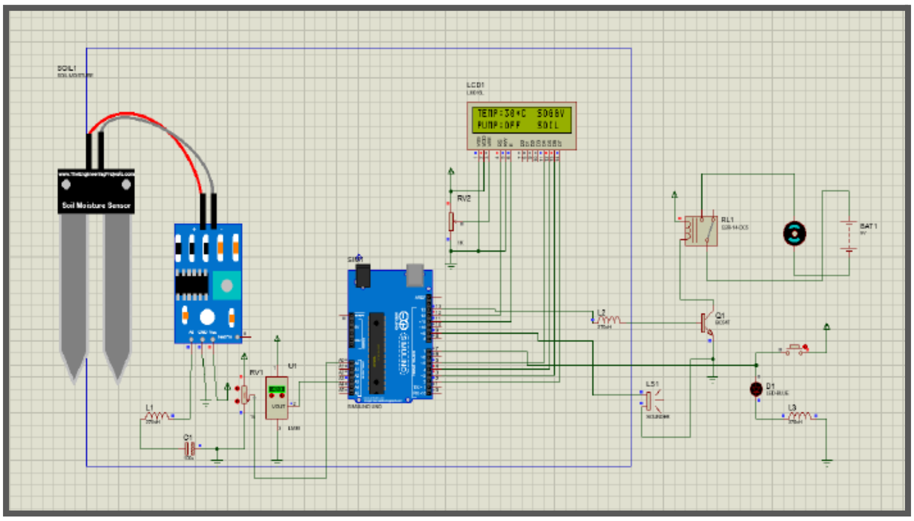


Fig. 4.3.18. Soggy soil, pump Off

From the figures, we can see that with this system we can check the soil moisture. If the soil is dry, the microcontroller sends the signal to the water pump to turn it on (figure 4.3.16). When the soil's moisture level is adequate, the microcontroller again sends the signal to the water pump to turn it off (figure 4.3.17). The water pump remains off if the soil is soggy (figure 4.3.18).

Here, we only showed the soil moisture test through our designs because the NPK test is not possible in software simulation as there is no calibrated NPK probe available in softwares.

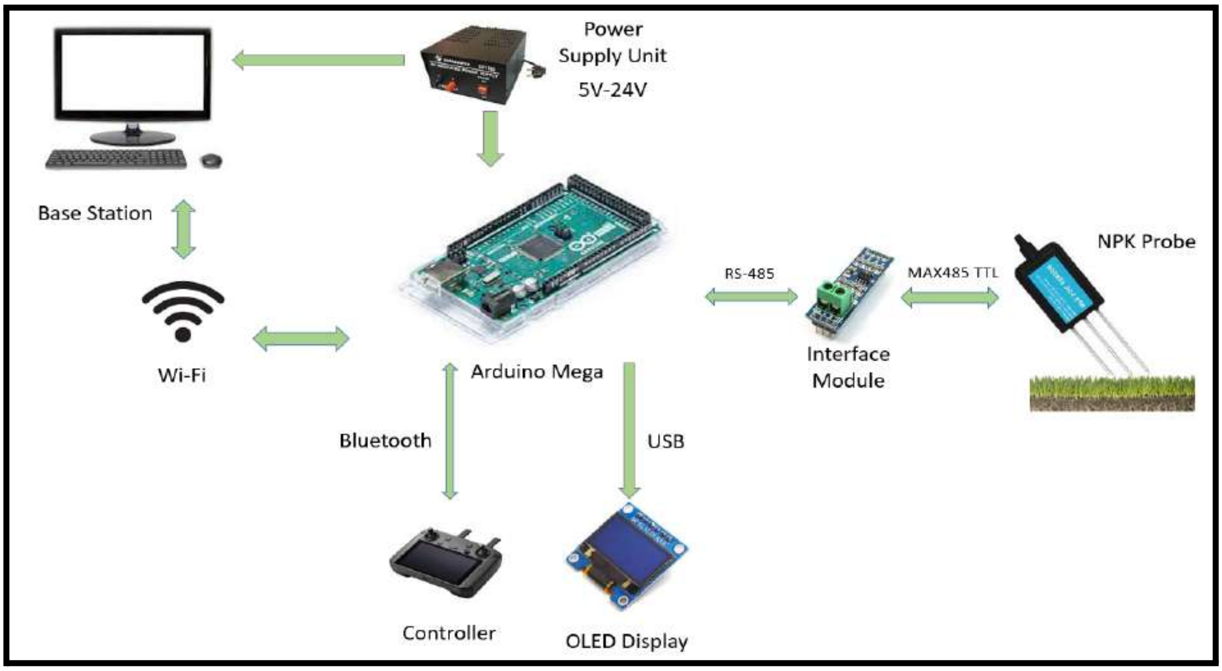


Fig. 4.3.19: NPK test block diagram

Due to the scarcity of calibrated NPK probes in , the NPK testing can be only implemented in hardware. So, rather than using an NPK probe, a soil moisture sensor is used here to verify our design. Moreover, through the block diagram, the whole process is displayed which will be implemented in hardware. (figure 4.3.19)

8. Field Modification:

Through this parameter, it will be observed if our designs can work on the traditional field or if we need to modify the land in accordance with our design.

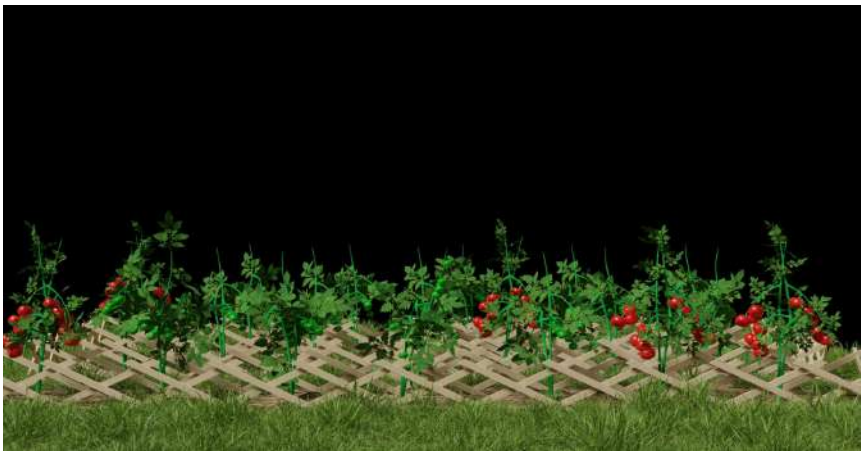


Fig. 4.3.20. Traditional filed for rover bot

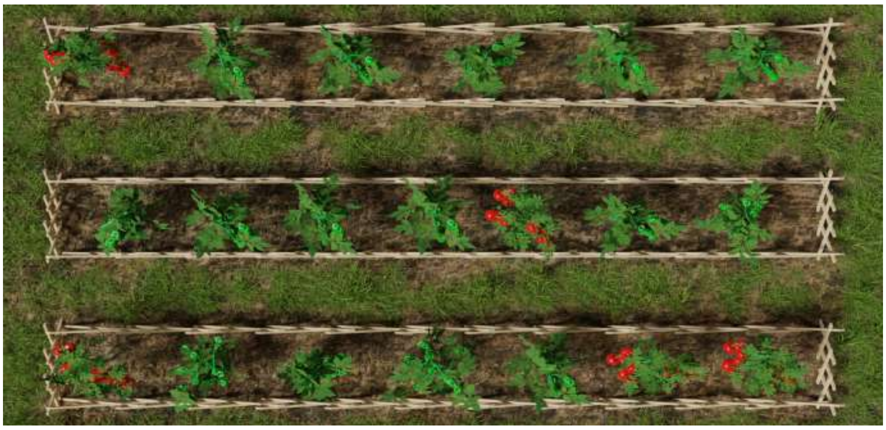


Fig. 4.3.21. Traditional field for UAV

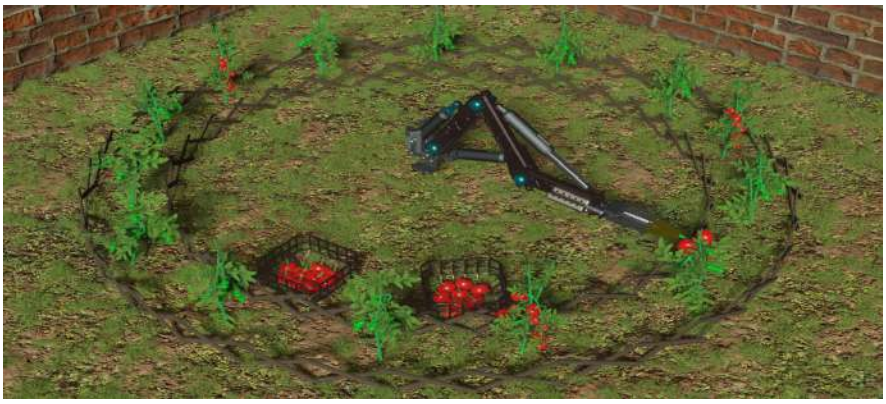


Fig. 4.3.22. A traditional field for science box

From Figures 4.3.20 and 4.3.21, we can see that our system rover bot and UAV can work with traditional farming land but for the science box, we need to modify the conventional farming land so that the mechanical arm can reach as many vegetables as possible. (figure 4.3.22)

As we need to modify the conventional farming land for the science box to work so instead of this system, rover bot and UAV would be better options for us.

Table 5 is described below as the summary of the comparison of multiple design solutions in order to find the optimal solution.

TABLE 5. Summary of the comparison of multiple design solution

Test Cases	Rover Bot	Unmanned Aerial Vehicle	Science Box
Image Clarity	Can reach the almost inaccessible vegetable more efficiently	Not able to reach vegetable easily due bird eye view	Not able to reach all the vegetables at once in the properly
Ripe vegetable detection	Stable device, easier image capturing and detection	Less stable device for image capturing and ripe fruit detection	Limited for image capturing and ripe fruit detection as human-controlled
Navigation	Able to navigate through the field freely	Being controlled by PID controller, not able to navigate independently	Not able to navigate
Harvesting	Harvesting, soil analysis gets easier for having 6-degree freedom based arm	Claw is used for harvesting and soil analysis	Attached scissors is being used for harvesting
Stability	Stable dynamic system to a satisfactory level	Unstable to a certain degree. Having high overshoot in response	Static system hence stable
Weight Limitation	Can harvest a good amount of vegetable altogether for having less weight limit	Able to harvest one vegetable at one time due to weightage limit	Not able to harvest all the vegetables at once
Field Modification	Can work properly with a traditional field, no need to modify field	Can work properly with a traditional field, no need to modify field	Field modification needed so that the system's arm can reach to the vegetable
Soil Analysis	Soil analysis procedure will be the same for all three designs. In software simulation only the soil moisture tests can be simulated, NPK tests cannot be simulated in software as there is no calibrated NPK sensor. It can be only implemented in hardware		

4.4 Performance Evaluation of Developed Solution

In accordance with what we analyzed so far the following table is prepared.Where we rated all the designs based on different criteria. The weights of these criteria are adjusted according to how much the selection criteria relate to our desired objectives.

TABLE 6: Rating the design approaches

Selection Criteria		Design Approches		
	Weights	**Rover Bot**	**UAV**	**Science box**
		Score	**Score**	**Score**
Image Clarity	15	15	10	15
Ripe Vegetable Detection	20	18	15	18
Navigation	15	12	15	5
Harvesting	20	15	10	15
Stability	10	8	5	10
Weight Limitation	5	4	2	5
Field Modification	5	4	5	2
Soil analysis	10	10	10	10
Total Score	100	86	72	80
Optimum solution		YES	NO	NO

For the image clarity and the vegetable detention part the UAV has a lower rating than the rest of the design approaches because from the bird's eye view some of the vegetables are most likely to be hidden behind the tree leaves. On top of that, the image taken from the UAV would most likely be less clear due to stability issues.

However, in terms of navigation, the UAV is the best solution, while the science box is the worst as it needs to be moved manually. Although UAV lags behind in stability criteria. The science box being a static system is the most stable among the three.

For harvesting purposes, the science box and the roverbot having similar integrated arms get similar ratings. However, for the UAV the claw will not be as effective in harvesting.

As the science box is static and does not have to carry weights, hence it is free from weight limitations. However, due to its immobility, field modification is required to make maximum use of it. Field modification might be required for the Rover Bot too as it requires a proper track to move. However, UAVs in this case can work with most of the field configurations.

After going through all criteria and rating the design approaches the Roverbot gets the highest rating (TABLE 6). This way we may conclude that the Rover bot is the best design solution for our project.

4.5 Conclusion

Different test cases were taken into account, which enabled us to examine the three designs side by side in order to select the best option for the project. We got to the conclusion that the rover bot was the best option for our project after comparing them only on the basis of picture clarity, ripeness detection, harvesting, navigation, stability, weight limitation, soil analysis, and field modification. In order to select the winning design for the project, we also used a scoring matrix. The next step will be to do the necessary calculation and execute our chosen ideal solution into hardware.

CHAPTER 5: COMPLETION OF FINAL DESIGN and VALIDATION. [CO8]

5.1 Introduction

The next step is to implement the best design into operation after selecting it based on all performance criteria. According to our prior investigation, Rover Bot was the best design. To put this approach into practice, we must construct the mechanical framework and design the electronic circuit with all the necessary sensors and drivers. In order to improve things, some modifications will be made. Afterward, verify if the system meets all of the system requirements by comparing it to the predicted results.

5.2 Completion of Final Design

The overall system's development has taken place in stages. like the development of mechanical structures, training of image processing models, electrical circuit development, and control system development. In this section, all development stages and their corresponding substages are explained in detail.

i) Mechanical Structure Development:

The mechanical structure of the rover body was designed with stability and a strong core in mind so that it can perform well in all rocky terrain and under all conditions. There are many components of the structure. The details of those parts are described below.

a) **Chassis Body:** For the chassis body, a tracked tank-based chassis has been used made

of aluminum alloy. The track is made of engineering plastic, which essentially ensured the rover body's good elasticity, outstanding damping effect, and substantial road grip. This lightweight, responsive, and agile-tracked chassis is simple to use. The high-quality crawler design enables rapid movement of the rover body to any location. There are ten wheels, five on each side, with a plastic strap around them.

Fig 5.2.1: Mechanical Chassis.

b) Motor: There are two motors that have been used to run the rover body. They are 12V

gear high torque DC motors. The RPM of the motors is 300. The rated torque of the motors is 4 Kg-cm. The motors have a 1.2A full load current and 0.2A no load current. The shaft type of the motors are D.

Fig 5.2.2: Mechanical Motor

c) Mechanical Arm: For the mechanical arm of the rover, a six DOF arm is being used.

The arm is made of aluminum. To operate the mechanical arm there will be 6 servos connected with every degree of freedom. There is a 2 finger claw attached to the arm for the harvesting purpose. The claw has 2 blades attached to the fingers so that it can cut the brunch easily.

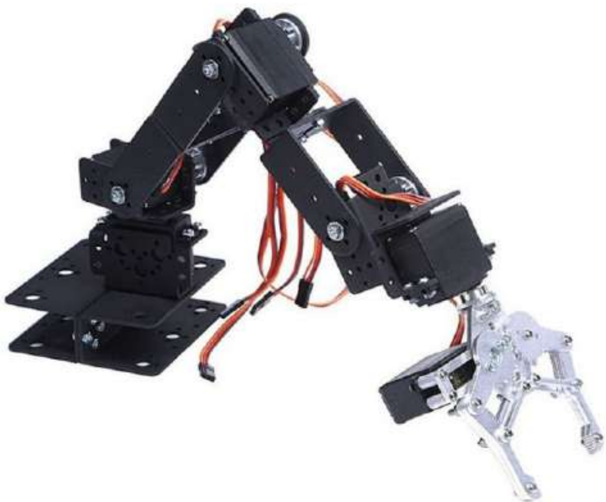


Fig 5.2.3: Mechanical Arm

d) Arm Motor: For the arm motor MG996R servo has been used. This servo is able to carry a maximum 10 kg weight. Altogether 6 servos have been used in all six sections of the arm. The operating voltage of these six servos are 6-7V. Current consumption rate is 0.3A for one servo.

Fig 5.2.4: Mechanical Arm Servo

ii) Image Processing Model Training:

In this project, one of the requirements is detecting the ripe vegetable for harvesting purposes. For detecting the ripe vegetable image processing method will be used. In image processing, a model will be trained to detect the expected object. The dataset creation, annotation, labeling has been used in online image processing platform "Roboflow'.

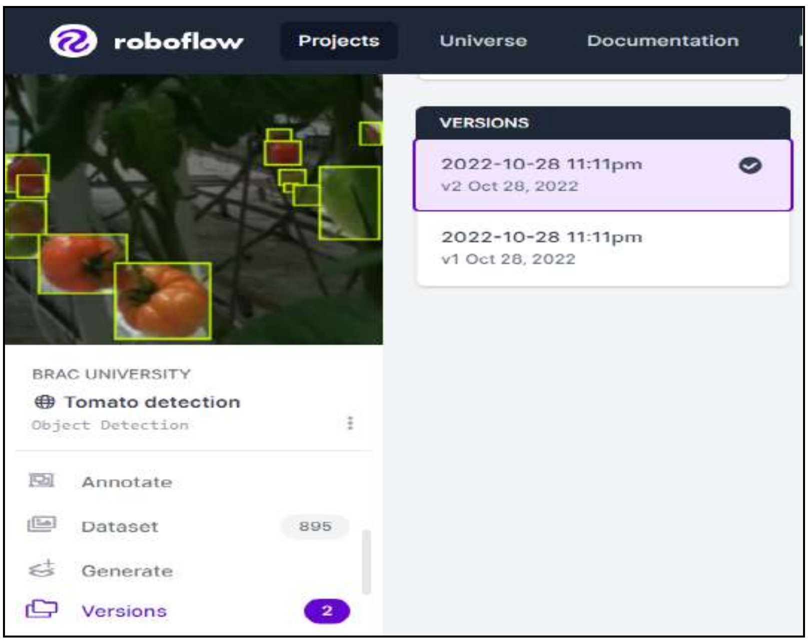


Fig 5.2.5 :Roboflow Platform

The steps of performing image processing for ripe tomato detection are given below.

a) Creating Dataset: First, a dataset is prepared for training the system. In our project,

We used a public dataset for the image training purpose from kaggle [25]. We used a dataset of 895 images. In which, 626 images will be used for training purposes, 179 will be used as validation sets and 90 images will be used as testing sets. Here the ratio for the training set, validation set and testing set is 70% , 20% and 10% accordingly.

Fig 5.2.6: Image for Training Set

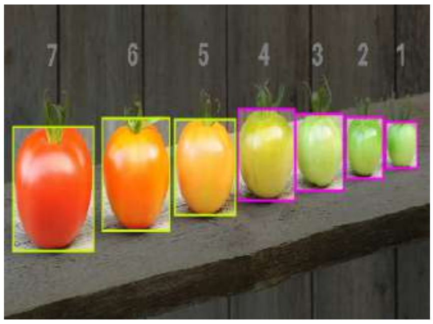


Fig 5.2.7: Image for Validation

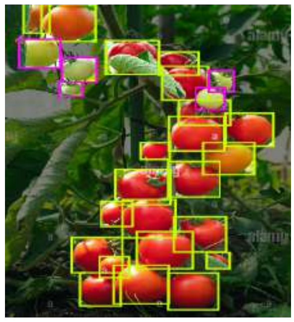


Fig 5.2.8: Image for Testing

b) Labeling and Annotation: After selecting the dataset the images needs to be labeled

and annotated for further training purposes. After the annotation part, the system will be able to recognize the ripe and unripe tomato models accordingly. In this project, the ripe tomatoes have been annotated as ‘0’ and the unripe tomatoes have been annotated as ‘1’.

c) Selecting a Model: Then a model needs to be selected for training purposes. In this project, YOLOv5n has been used as the training algorithm. Compared to the other algorithm, this one has better performance in object detection. Performance wise the YOLOv5 model performs better than the other models. Here the system trains in a nano version instead of the small one to have better frame rate while using any remote processors.

d) Training: The next step is to train the model. For training the model the first step is to

install all necessary requirements. Then after that assembling all the dataset. Then the system will be ready to be trained. To train the model, 150 epochs have been used, which tested the training performances and increased the rate of precision. After completing the training we will get a weight training file which will be used for deployment in any processor.

e) Deployment and Evaluation: After training the model, the weight file will be used to deploy the model in any processor for further evaluation. After deploying the system can do real time analysis in any processor. As the raspberry pi 4 is being used here as the processor the necessary environment has been created with all necessary software to operate the onboard image processing.

After that, the system will be fully functional for object detection. In this project, we are using raspberry pi 4 as our main microprocessor, so the weight file will be stored in the main processor, and thus the image processing task will be conducted. A USB camera will be connected with the processor for object detection purposes.

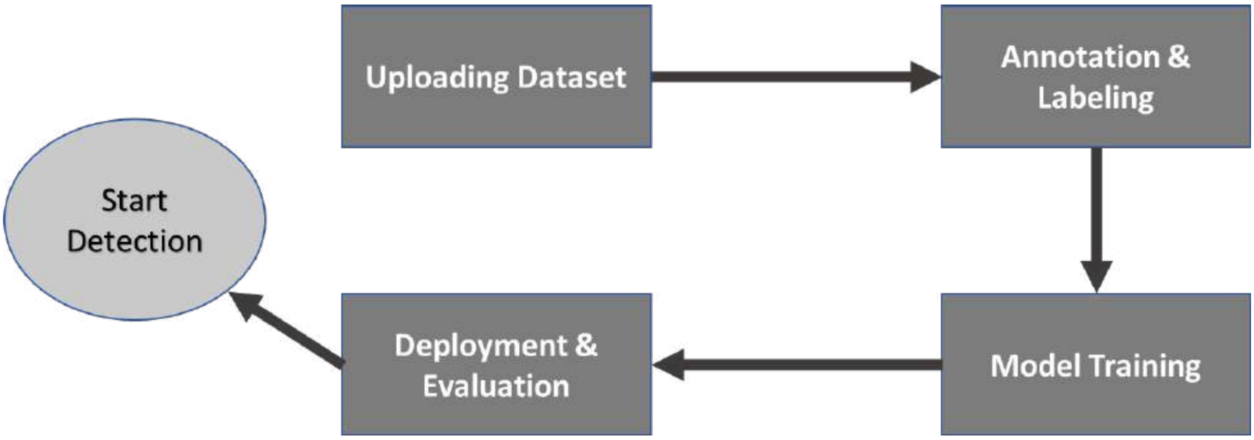


Fig 5.2.9: Workflow Diagram of Image Processing Method

iii) Electrical Circuit Connection Development:

For the electrical circuit connection development, different types of components have been used. There will be 2 different circuits connected with each other for 2 different purposes. One circuit will be for rover operation reasons, and the other will be used for soil analysis purposes. The detailed design of the circuit for these two operations is demonstrated below.

a) For a Rover Operation: In this Rover system there are two motors. For the two motors a monster motor driver has been used for driving the two motors. As the motor driver has two channels it can operate two motors at the same time. Then the motor driver will be connected to the controller.

There will be six servos used for operating the arm. After analyzing it has been found out that, to operate the arm fully 6.5 v power will be needed. So another 11.1 V battery will be used. This battery will be connected to a buck converter to regulate the input voltage and will bring it down to 6.5V after converting.

The PCB design of the operating circuit is given below. This PCB consists of the controller, motor driver, buck converter, battery port, and servo ports. The main source of power here is a 12V battery. The battery is giving power to the motor driver and the buck converter . The motor driver is then again connected with the arduino. The arduino then will control the motor driver accordingly. Again, for operating the arm there are six servo's connection pins given. Each servo connection point consists of 3 pins. One for VCC, one for signal and another for ground. So in total there are six VCC pins, six signal pins and six ground. All the grounds are connected commonly with the arduino ground. All the signal pins are connected with the arduino PWM pins and all the VCC pins are connected commonly with the converted voltage that we get from the buck converter.

Furthermore, the arduino is connected to the Raspberry pi processor through a USB cable, and the processor is getting power from the external power bank. Here the processor has not been placed in the PCB for obvious reasons. This will be stacked above the circuit board and will be also connected with another microcontroller for the controlling purpose.

Thus, the arm and the wheel of the rover have been connected for the rover operation purpose.

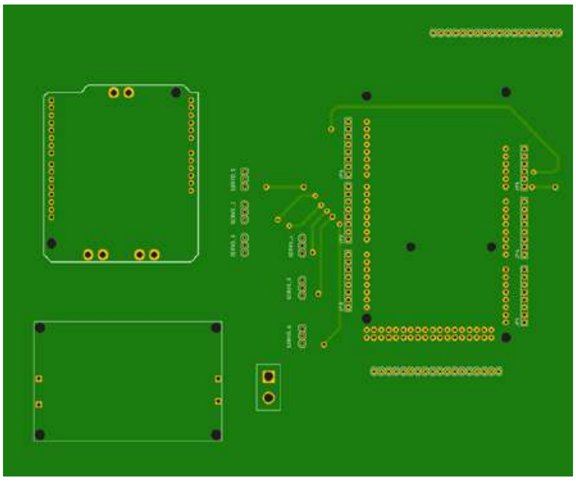


Fig 5.2.10: PCB Top Layer

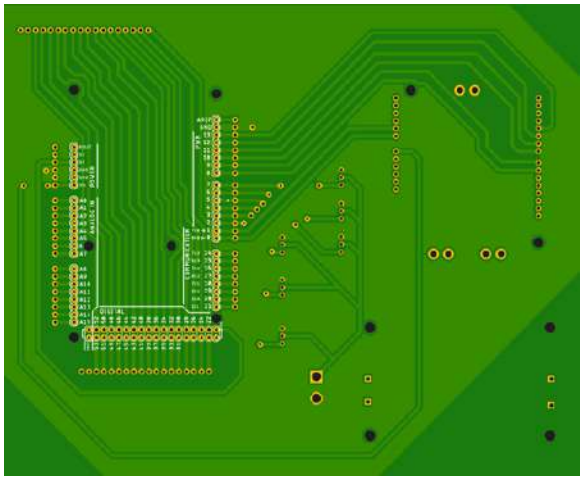


Fig 5.2.11: PCB Bottom Layer

b) For Soil Analysis: For the soil analysis purpose, there will be another circuit consisting of another PCB. This circuit will consist of a NPK sensor connected to a 12V battery supply and will be controlled by a controller. The sensor will be connected to the controller through an interface module (RS485).

In the PCB design of this circuit, the module (RS485) is connected with tthe arduino and the "A" and "B" part of the NPK sensor is connected with the module. The VCC of the NPK sensor is connected with the 12V battery source and the GND is connected commonly with the arduino ground. There is also another connection given for the LCD screen if necessary to show the data value. Here the (RS485) module is working as the interpreter of the sensor. The NPK sensor gives analog data. Here the module interprets the analog data and makes it readable to the arduino.

Thus the NPK sensor is connected with the controllers. Here different controllers have been used for this purpose as for serial communication of the NPK sensor and for the rover operations sufficient digital pins were not available in one microcontroller.

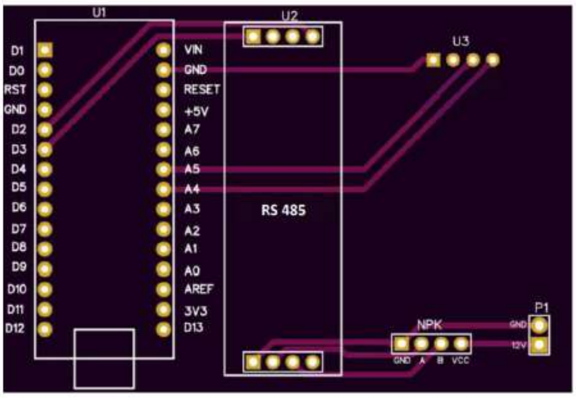


Fig 5.2.12: PCB Top Layer

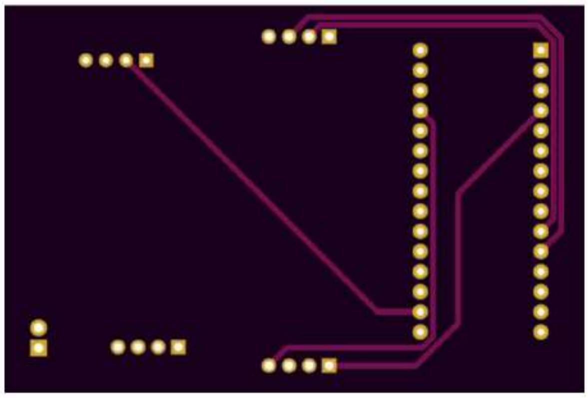


Fig 5.2.13: PCB Bottom Layer

iv) Control System Development:

For the control system of the rover, onboard processors and controllers have been used which will control and will communicate with the user using a remote desktop via a wi-fi communication network. For the onboard processor, raspberry pi 4 is being used and for controlling purposes the Arduino Mega and UNO is being used.

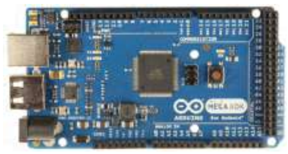
a) **Raspberry Pi 4:** The raspberry pi is a small single board computer that processes the controllers. In our project raspberry pi will be the heart of the system. This will operate the controllers and the controllers will operate the other sensor. To power up the pi one power bank will be used. The pi will be connected to a wifi network. By connecting any desktop with that same wifi network anyone can easily use that desktop or monitor as the remote desktop to control the pi.

b) **Arduino Controllers:** In this project, two types of Arduino microcontrollers will be used. One is Arduino Mega and the other one is Arduino Nano. The arduino Mega will be used for operating the wheel and arm and the nano will be used to operate the soil sensor. Both of the controllers will get power from the microprocessor that is being used.

The table below shows all the components that are being used.

Table 7 : Components

Name	Specification(Rated/Max)	Function	Diagram
LiPo Battery	12V ; 3300mAh	Supplies power to motor driver	

Power Bank	5V ; 10000mAh	Supplies power to microprocessor	
Microprocessor (Raspberry Pi 4)	5V ; 3A	Works as a brain for our rover. Allow us to control it remotely from a desktop	
Microcontroller (Arduino Mega)	5V ; 50mA	Works as memory space for the wheel and the arm	
Motor	12V ; 0.23A, 160 rpm	Converts the rover's electrical energy into mechanical energy so that the wheel may move.	
Motor driver (Monster Moto Shield)	15V; 30A	Acts as an interface between motors and the control circuits	
NPK Sensor	12V; <0.15W	Detecting the content of nitrogen, phosphorus, and potassium in the soil.	
USB Camera	5V; 900 mAh	For image processing purposes	

Buck Converter	4A; 1.25V-32V DC	Curtails the voltage making it tolerable for the servo motors.	
Microcontroller (Arduino Uno)	5V; 20 mA	Works as memory space for the soil analysis unit	
Servo Motors	6V, 0.3A	Works as the operating motor for the mechanical arm.	

Methodology:

Now as all the components used in our system are mentioned above. Let's go through how the components make up the whole functional Rover-bot system.

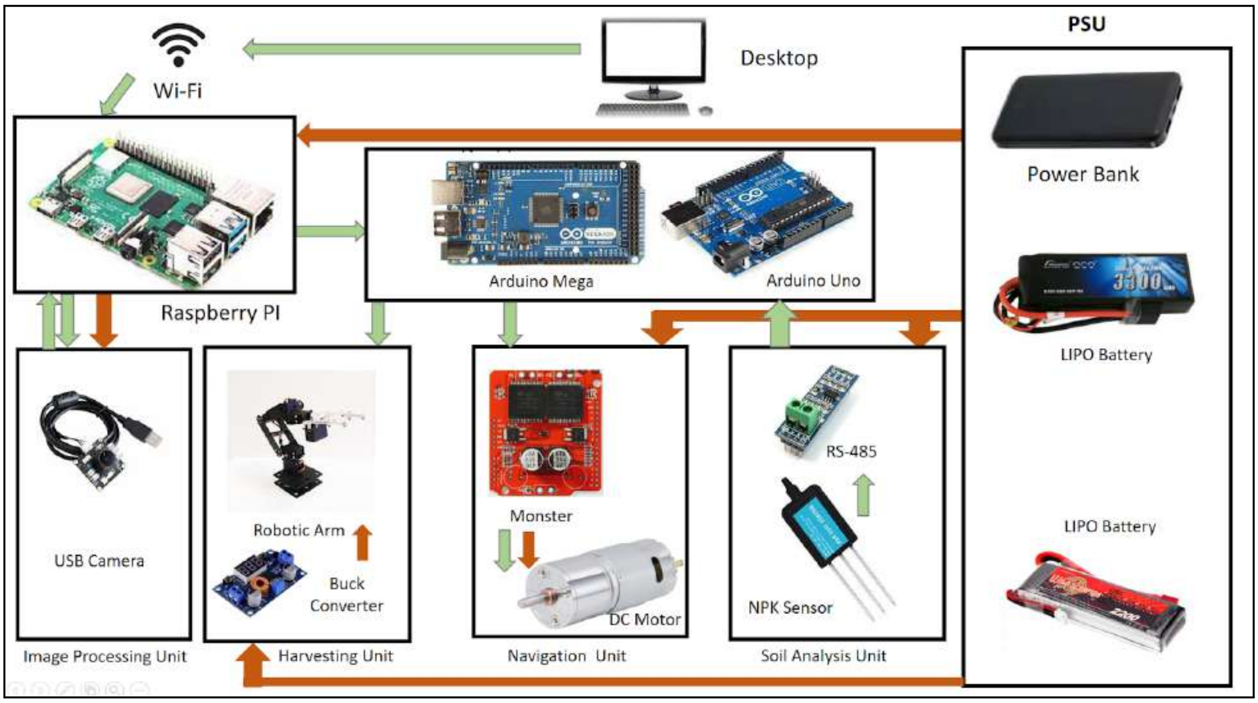


Figure: 5.2.14 : Rover bot System Overview

Here as we can see from the figure (5.2.14) how each component is connected to each other. How they are powered and how they are synergized. The Green arrows indicate the flow of signal and data while the Red arrow indicates how each component is powered.

Our system consists of mainly four actuator sub-circuit. These include the Image processing Unit, Harvesting Unit, Navigation Unit & the Soil Analysis Unit. Again, the sub-circuit is controlled directly or indirectly by the Microprocessor or through the Micro-controllers. The microprocessor here (Raspberry PI) can be controlled remotely through a wifi network. This makes the system wirelessly controllable. The system will also carry a power bank to keep the microprocessor running.

Coming to the subsystems, the Image processing unit which consists of a USB camera is directly controlled by the microprocessor, unlike the other sub-circuit. Again being connected through a USB cable this unit does not require to be powered externally.

In terms of navigation of our Roverbot, the DC motor on the conveyor belt on both sides enables our system to move in a 2D plane. These motors are powered by the LIPO battery and signaled by the Arduino Mega microcontroller. However, they are driven by a Motor driver (Monster) instead of a microcontroller as they require more power than the microcontroller itself can provide.

The NPK sensor transmits the soil data to the microcontroller in a soil analysis device. However, the soil data must first be transformed so that the microcontroller can understand it. This is done by the RS-485 module which works as an interpreter between the microcontroller and the NPK sensor. Again, similar to the Navigation unit the Soil analysis unit is also powered by a LIPO battery. The Robotic arm which is the main component of the harvesting unit is controlled by Arduino Mega. Actually, the 6-servo motors connected to it are being controlled by the MCU. However, the servo motors here require an ample amount of current to hold their position under heavy load. That is why we used a separate LIPO battery for the Harvesting unit to make this unit draw power separately and don't limit the runtime significantly. As the servos in the Robotic arm operate at around 6-7V. Hence the extra voltage from the LIPO battery is curtailed by the Buck Converter to make it suitable for the servo motors.

5.3 Evaluate the Solution to Meet Desired Need

Now in this chapter, we will evaluate the designed system performance on the basis of our specifications. Our objective is to detect the ripe vegetables, harvest them, and do the soil analysis. In this chapter, the performance of the whole rover will be analyzed on the basis of these specifications.

I) Detecting Ripe Vegetables:

Ripeness detection is one of our main objectives. After doing the ripeness detection the system will proceed to the harvesting process. We can do the evaluation of the model that has been used for training the model. For the evaluation purpose , the precision curve and the loss curve can be used. After completing the training, we got the precision curve and the loss curve. These two curves describe how well the system is performing while detecting the ripe vegetables.

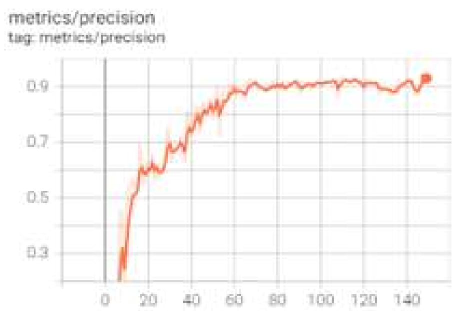


Fig 5.3.1: Matrix vs Precision Curve

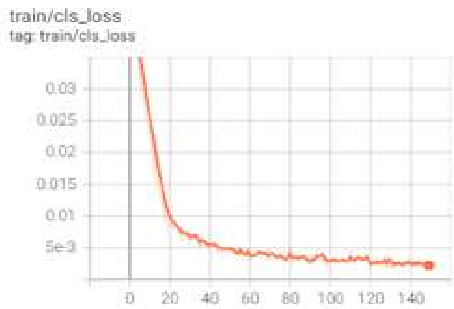


Fig 5.3.2: Train class vs Class Loss Curve

After deploying the model in the processor when we use the USB camera we get the feed for the object detection something like this.

For the evaluation purpose we created an environment where we put some ripe and unripe tomatoes together so that we can verify if the system works properly when many tomatoes are in a bunch.

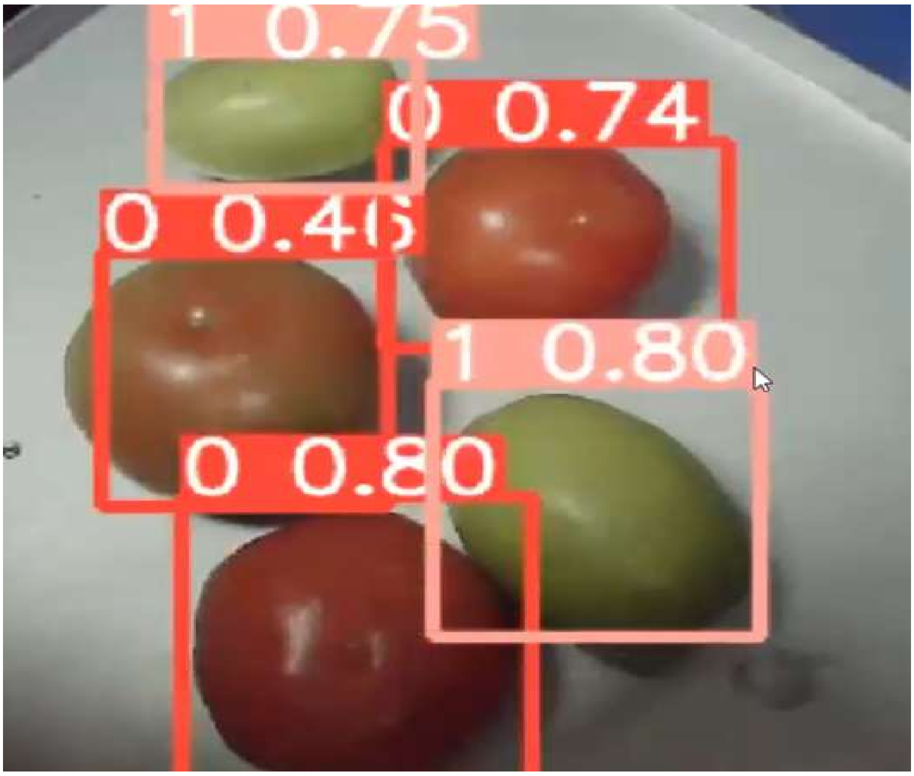


Fig 5.3.3: Ripe & Unripe Tomato Detection.

Here in fig 5.3.3, we can see how the system is detecting ripe and unripe tomatoes. Whenever the system will see ripe tomatoes it will label it as ‘0’ and whenever it will see an unripe tomato it will label it as ‘1’.

The system is also skilled at detecting the color intensity of the object. The parameter that is shown along with the labeling parameter is the color intensity value. In this figure, we can see the color intensity value of the very ripe tomatoes is more than 0.7. The same goes for the unripe tomatoes as well. By checking the color intensity value, we can easily determine which tomatoes are ready to harvest. The tomatoes that have the labeling value "0" and a color intensity value of more than 0.7 are ready to harvest and are finally ripe.

II) Harvesting:

For the purpose of evaluating the harvesting procedure, we created an environment in a room where we strung together some ripe and unripe tomatoes using some brunches. To identify the tomatoes, the rover first went through the room. Once it had located the tomatoes, it determined which were ripe and which were unripe. After determining which tomato was ripe, it moved closer to that tomato and started harvesting. That was the adjustment we made in order to assess the rover's harvesting procedure.

Now, elaborating on the whole harvesting process, first the rover will detect the ripe tomato. Upon detection of the ripe tomato, the Roverbot will harvest the ripe tomatoes. The actuator for this process would be the 6-DOF robot arm inserted over the Roverbody.

Fig 5.3.4: Harvesting Process

The robotic arm is equipped with claws to pluck the ripe tomatoes. We may consider it as an end effector for the robotic arm. The rest of the servo motor will help the arm reach its destination.
Now the problem arises when we try to make the robotic arm's end effector reach a certain point. We are required to translate the coordinate value to joint space or angle values of the servo motor, to make the 6-servo motors reach the destination point altogether.

To ensure this we are required to apply a mathematical model called 'Inverse kinematics to make the end effector of the Robotic arm reach the position. This requires all the servo motors to synchronize properly.

Kinematics

Without taking into account the forces or moments that create the motion, kinematics investigates how bodies move. The analytical study of robot manipulator motion is called robot kinematics. To understand the behavior of industrial manipulators, it is essential to create a suitable kinematic model of the robotic mechanism. In kinematics, two distinct areas are primarily utilized.

Cartesian space and Quaternion space are two modeling frameworks for manipulators. Rotation and translation are the two components that make up the transformation between two Cartesian coordinate systems.

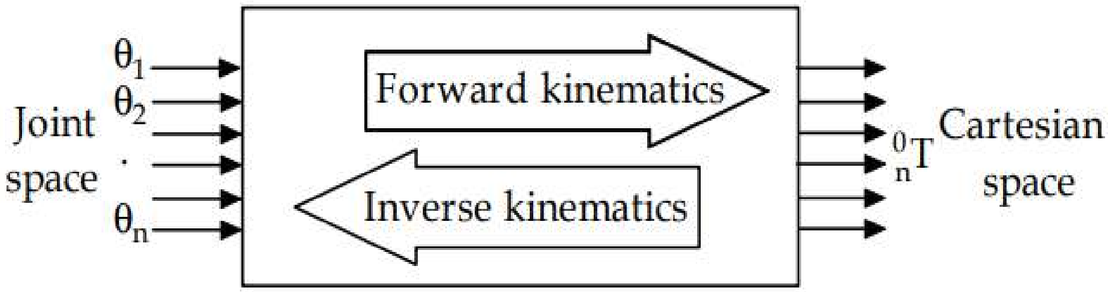


Fig 5.3.5: Inverse kinematics illustration

Forward kinematics take Joint space variables into account and yield the position of the end-effector in Cartesian space. While Inverse-kinematics simply do the opposite. Meaning it takes Cartesian coordinates into its account , in another word it takes the desired position of the end-effector as an input and provides values for Joint-space variables that eventually leads the end effector to its desired position.

Inverse-Kinematics

As mentioned before our objective with kinematics here is to drive our Robot-arm to a certain position to pluck the ripe tomato. Clear the type of kinematics we need to apply here is inverse kinematics. To clarify, after applying inverse kinematics we would have the servo orientations to make our Robotic-arm's end effector go to a certain location or the location where ripe tomato is detected.

Now how we apply inverse kinematics or the equations of "Cartesian space to Joint space conversion" may vary depending on the robotic arm itself. In other words, the orientation of the servos connected to the Robotics-arm, and its degree of freedom affect the inverse kinematics calculation.

Hence in the following sequence, we will explore how we calculated the inverse kinematics for our Robotics-arm such that it can convert the Cartesian coordinates into Joint space values, thus
calibrating the servo positions in such a way as to make the end effector meet the Cartesian coordinate values.

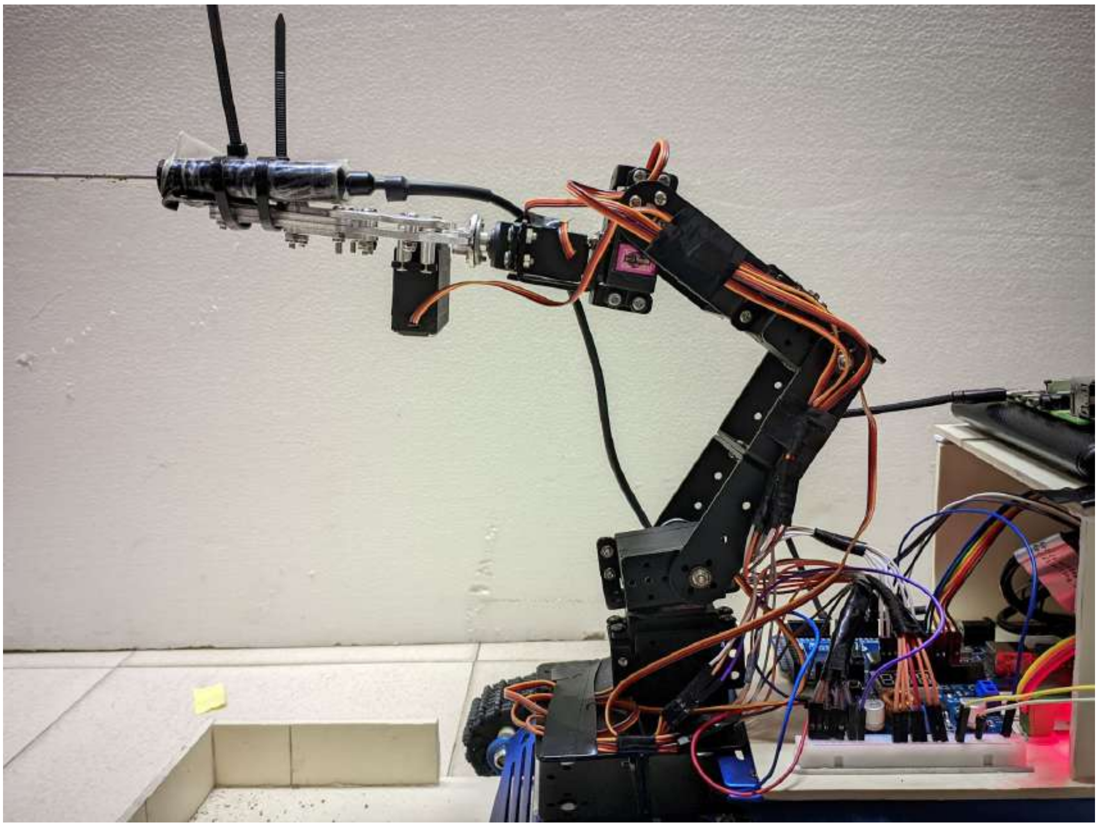


Fig 5.3.6: DOF Robotic Arm

From figure-5.3.6 we see the robotic arm we are using consists of 6-Servos meaning it has Six degrees of freedom. In terms of implementing the inverse kinematics, we are actually calculating the Servo angles in order to make the End-effector of the robot arm reach the specific Cartesian Point.

Two servos are connected to the claw of the robotic arm, which has virtually no impact on the end effector position. As one is being used to open or close the claw in the arm, another one is being used to rotate the claw around its axis. Thus, not ending up distorting the end effector position.

Then we are left with 4 servo motors to meet the Cartesian point by calculating the required servo positions. The servo at the base controls the arm position along the horizontal plane, and the immediate upper 3-servos can move along the vertical plane.

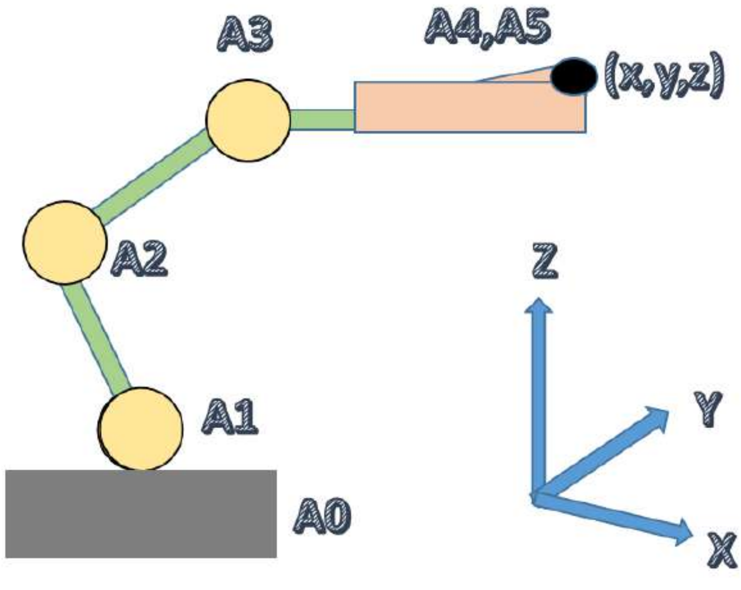


Fig 5.3.7: Inverse Kinematics

From figure-5.3.7 we see the servo at the base controls the robotic arm along the x,y axis. Hence, the cartesian x,y value is enough to extract its angle value(A0).

As the claw is not doing much to distort the final end-effector position we may just ignore the A4 and A5 angles. Hence, We are left with 3 servo angles to be found. A1,A2 and A3.

The Problem is when we are trying to find a 3-angle for actuators to reach a point that would yield infinitely many solutions. Hence, we needed to finalize an angle first among A1,A2 & A3.

As we can see from figure-5.3.7 we would make the servo3 (A3 angle) till the end-effector remain parallel to the ground. To make the claw hold a suitable position for harvesting. Then we just need to calculate the A1,A2 angle. The horizontal axis for this vertical plane (x', z) is already yielded by the A0 angle in the horizontal plane(x,y).

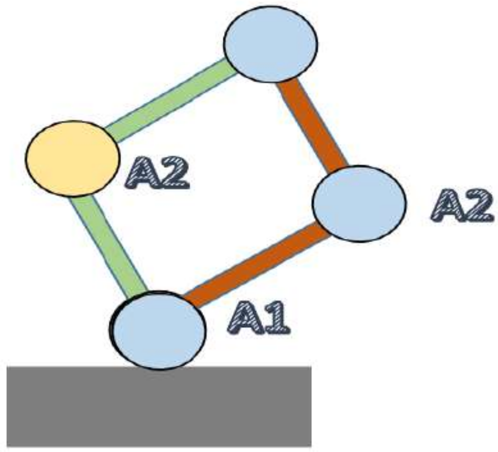


Fig 5.3.8 : Possible solutions

Now while determining the A1, and A2 position we have two possible solutions (Figure-5.3.8). We choose the upward facing solution in order to put less weight on the servo1 (A1). After that, all we needed is to inverse the A1, and A2 angle to determine the A3 angle controlling all the way up to the end effector. Thus keeping the claw parallel to the horizon.

Equations:

Joint space variable equations for the robot arm are discussed below.

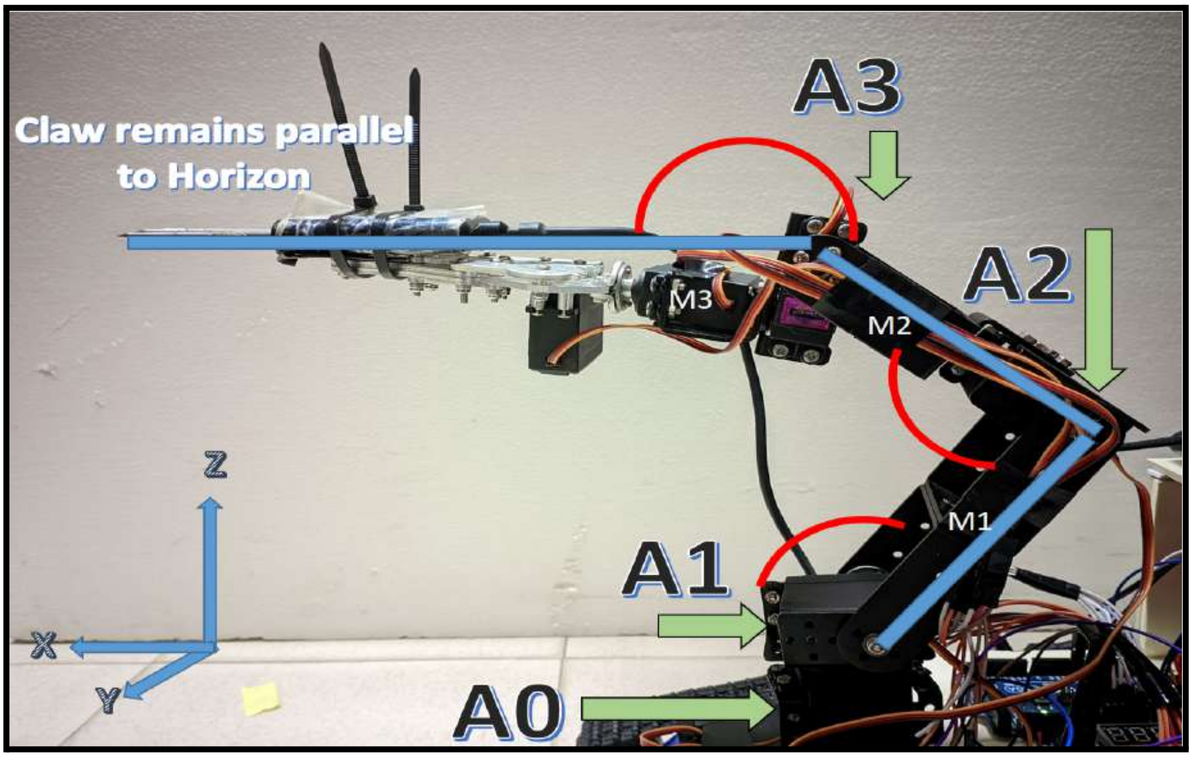


Figure 5.3.9: Robot arm annotated , Inverse kinematics

As per the methods stated above we calculated the equation to measure the Joint angles for the 4-servo motors that relates to the position of the robot arm . (Figure 5.3.9).

The servo at the base(A0) controls the position of the arm in the horizontal plane. So the angle for the base servo A0 will simply be

$$A_o = tan^{-1}(\frac{y}{x})$$

Now the base angle determines where the horizontal axis of the vertical plane will be. Let's call the horizontal axis as x'.

Then-

$$x' = \sqrt{x^2 + y^2}$$

Now that the position of our vertical plane is determined , all that is left is to find the equations of the remaining 3 angles A1, A2 and A3. Here M1,M2,M3 indicates the length. Now for simplicity of the equations lets deduct M3 from x' and update the x'.

$$x' = x' - M_3$$

As mentioned previously the angle A1,A2 is determined in such a way so that the sevo over the base remains in upward position rather than downward position among the 2 possible solutions for it. This way the angle for A1,A2 servos-

$$[P = x'^2 + z^2]$$

$$A_2 = \pi - (cos^{-1}((-p + M_1^2 + M_2^2) / (2 M_1 M_2)))$$

$$A_1 = tan^{-1}(z/x') + tan^{-1}((M_2 \sin(A_2)) / (M_1 + M_2 \cos(A_2)))$$

Now as we want the claw to remain parallel to the ground A3 will simply minimize the A1 and A2 angles. Hence,

$$A_3 = -A_1 + A_2$$

This is all about how Inverse kinematics is applied to make the 6-servos automatically coordinate among themselves to reach a certain point. In other words, make the claws reach the tomatoes.

III) Soil Analysis:

Testing soil samples to ascertain their physical and chemical characteristics is the process of soil analysis. Soil analysis is a crucial component of soil science that is used to evaluate the soil's fertility and identify any contaminants. It can be used to ascertain the soil's nutrient content, pH level, heavy metal presence, and organic matter content. For our system, we will be only measuring the vital soil nutrients which are Nitrogen (N), Phosphorus (P), and Potassium (K). For this, we will be using an NPK sensor. Measurement of the soil's nitrogen, phosphorus, and potassium levels is done with an NPK probe. It is a crucial tool for farmers and gardeners because these three components are necessary for the establishment of healthy plants. The soil loses its fertility since many farmers do not conduct laboratory soil tests and continue to produce the very same crop on the exact plot of land. The electrical conductivity of the soil, which is impacted by the presence of these elements, is measured using the NPK probe. A reading is taken once the probe has been put into the ground. To assess the quantities of nitrogen and phosphorus, the reading is then compared to a chart [26, Table 8] which is shown below.

TABLE 8. Rating Chart for Soil Test Data [26]

Nutrient	Low	Medium	High
Available nitrogen (N)	< 240 Kg/ha	240- 480 kg/ha	> 480 Kg/ha
Available Phosphorus (P)	< 11.0 Kg/ha	11 – 22 Kg/ha	> 22 Kg/ha
Available potassium (K)	< 110 Kg/ha	110-280 Kg/ha	> 280 Kg/ha

Here, in table 8, the values of NPK are given in Kg/ha but from the NPK sensor we get the values of soil in mg/Kg unit. It is difficult to relate the values of the mentioned table and NPK sensor as the units are different. That is why we can measure the ratio of NPK to assess the quality of the soil. Moreover, the nutrient content of the soil varies from soil to soil. It also depends on different farming stages. An NPK ratio of 4:2:1 in the soil boosts crop production and overall soil health[27].

In order to assess the effectiveness of the rover's NPK testing, we set up an environment utilizing a flower pot and checked the NPK data for that specific plant. The rover drove to that pot, inserted the NPK sensor using its robotic arm into the soil, and then conducted a soil analysis. We can ensure the task's functionality by constructing this specific environment and carrying out the activity there.

The NPK sensor basically operates at 12 volts. So we used a 12V, 3300mAh LiPo battery to power the sensor. For the microcontroller, we used an Arduino UNO, and to interpret the data, we used a module named RS485.

Using the 6DOF-based arm, the probes of the sensor are dipped in the soil, and it collects the data. But as the data is in analog form, the RS485 module converts it to digital data so that Arduino UNO can process it.

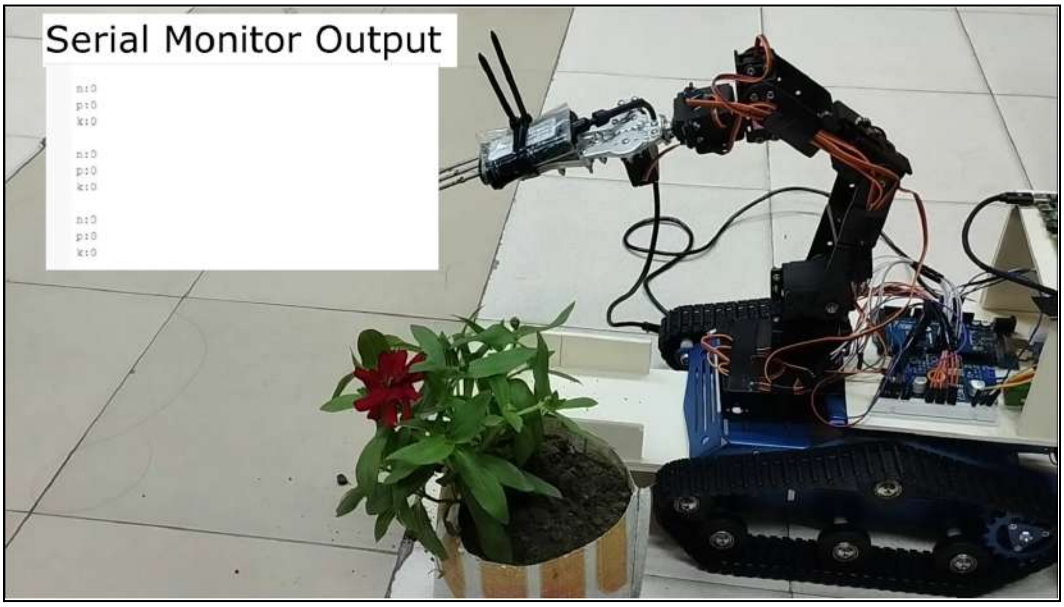


Fig 5.3.10- NPK sensor and Serial Monitor

After processing the data, we can see the values of Nitrogen (N), Phosphorus (P), and Potassium (K) in the remote desktop.
From Fig 5.3.10 we can see that the probe is not plunged into soil yet. That is why in the serial monitor, we can see that the values of nitrogen, phosphorus, and potassium are zero.

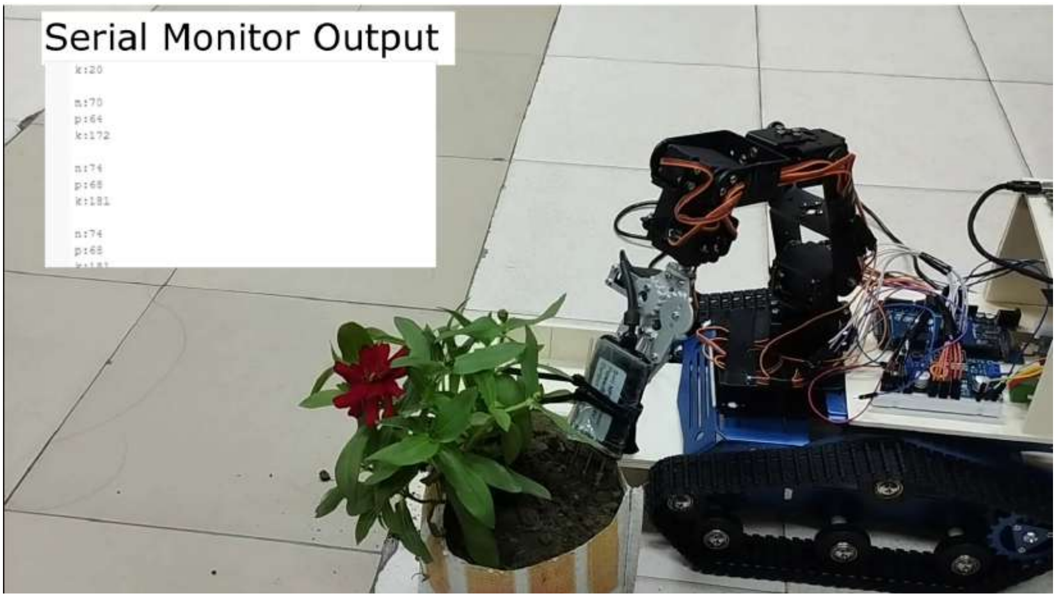


Fig 5.3.11- NPK sensor and Serial Monitor

From Fig 5.3.11 we can see that the probe is plunged in soil, and in the serial monitor of our remote desktop, the values of Nitrogen (N), Phosphorus (P), and Potassium (K). The values of soil nutrients are given below.

Nitrogen = 74 mg/kg
Phosphorus = 68 mg/kg
Potassium = 181 mg/kg

To validate these values, we also used a marketed device from Aqualink, which also measures NPK data in the soil.

Fig 5.3.12: Marketed NPK device

From Fig 5.3.12, we can see nitrogen, phosphorus, and potassium values from the same soil. The values of soil nutrients are given below.

Nitrogen = 54 mg/kg
Phosphorus = 73 mg/kg
Potassium = 172 mg/kg

The accuracy rate of the NPK sensor that we used is **+-2%** and the accuracy rate of the device that we used is also **+-2%.**

After comparing both values, we can see that both NPK sensors give values in a similar range. The variation of values are mostly because the depth of NPK probes dipped in soil and due to the accuracy issues. However, using this method we can get an idea of the nutrients that are present in the soil. Last but not least, soil analysis can assist farmers in seeing possible difficulties before they turn into larger ones, enabling them to take preventative actions to preserve their crops.

5.4 Conclusion

Our fundamental goal is to develop an agricultural system technology that enables intelligent harvesting and uses image processing and the Soil NPK(Nitrogen, Phosphorus, Potassium level of the soil) test to determine when a crop (in this case, a tomato) is ripe. During the execution of the concept, we ran upon a few problems that required revisions. We resolved them, changed the design, and then finished the implementation. Then we began to examine our apparatus. We started assessing each of our many subsystems to see if they were achieving the expected results. After that, we started testing multiple subsystems simultaneously to see if they can communicate with one another. Finally, we assessed the entire system. At each level, we tested the systems to make sure they were producing the outcomes we were hoping for. After a lot of testing, trial and error, it is obvious that our project has effectively complied with the subject's goal and requirements.

CHAPTER 6: IMPACT ANALYSIS and PROJECT SUSTAINABILITY. [CO3, CO4]

6.1 Introduction

An impact is a noticeable result or influence. This could involve adjustments to societal, health, safety, legal, cultural, or other contexts. The impact we have on the environment is a crucial issue in today's society. For that reason, we must enhance environmentally friendly operations through sustainable practices and renewable technologies. The ideal degree of sustainability is one that actively works to reduce waste, resource consumption, and environmental effect. But the challenge in improving sustainability is that it has to be done at a fundamental level.True sustainability is more of a group endeavor, supported by the entire team or organization. It is crucial to consider a project's sustainability and the influence it will have on numerous factors while it is being built. The talk that follows gives a quick overview of the patient effect we want to have and the sustainability we hope to achieve after project implementation.

The Rover-bot, our chosen design option, is anticipated to have some effect in the aforementioned domains. Some of these are the consequences we may not be able to prevent, while others are our planned effects based on the goals we wish to accomplish with it.

6.2 Assess the Impact of Solution

Societal Impact

Due to the high population growth rate and overpopulation unemployment rate is growing in Bangladesh. It would be a challenge to decrease the unemployment rate as our economy is majorly based on agriculture which is underdeveloped. Approximately 50% of our population is primarily employed in the agriculture sector. Nowadays, our youth is showing disinterest in farming as it is arduous and unpredictable.
However, our Agricultural Rover-bot may inject a noticeable impact in this regard. Operating the machine for detection & harvesting purposes would surely be less Arduous than doing it manually. Hence by making farming easier, the youth may find interest in farming, thus our project might minimize the unemployment rate.
Moreover, with the Rover-bot being able to differentiate between ripe & unripe vegetables, farming productivity is expected to rise which surely may introduce societal impact.

Health:

The Rover-bot is expected to have few health impacts on the farmers who work in the fields. With the help of the Rover-bot, we are opting to mitigate health risks during farming. For example, farmers have to work under the scorching sun for a very long time which can cause dehydration, heat stroke, skin disease, etc. It might also cause skin cancer. Luckily as the Rover-bot can be controlled remotely, it will reduce the health risks in this regard to some extent.

Cultural Context:

World population is continuously growing and it is set to grow by 9 billion by 2050. So, in recent times, one of the biggest challenges will be to ensure food safety. Achieving self-sufficiency for a nation is important because it makes a country stable. With the Rover-bot being selective in harvesting due to the image-based detection it is expected to perform, thus we can ensure higher crop productivity. It also helps to develop the country industrially. Using the Rover-bot can also lead to reducing the labor shortage in the harvesting season.

Legal Impact:

Several legal approvals need to be obtained to launch this project. The legality of an act, agreement, or contract refers to its compliance with the law and whether it is legal or illegal in a particular field. It's also a power structure. Since this is an agricultural device, we must obtain authorization and register it before we can test it at "Sher-e-Bangla Agricultural University."

6.3 Evaluate the Sustainability

Utilizing resources in a sustainable manner means meeting present demands without endangering the ability of future generations to meet their own requirements. It is a style of life that aims to lessen our negative effects on the environment and guarantee that our activities do not restrict opportunities for future generations. Sustainability is a multifaceted idea that affects many facets of our life. It involves how we utilize energy, create and consume commodities, etc. We must ensure that our system continues to function for many years because it will be used for agricultural purposes.

- The chassis of our system is made of Aluminum. Aluminum is a lightweight, very durable material that finds employment in almost every aspect of a contemporary building due to these special qualities. Because it is lightweight, the environmental effect and transportation expenses are reduced [28] It is very malleable and can be molded or bent into countless patterns. Instead of years, the lifespan of aluminum items is measured in decades. The world's most environmentally friendly building material, aluminum is also highly recyclable. The recycling method yields aluminum of excellent grade that retains all of the physical attributes of primary aluminum while using only 5% of the energy required to produce primary aluminum. Because of this, aluminum is regarded as the most sustainable building material available.

- For our 6 DOF-based arms, we are using 6 servo motors. A servo motor is a closed-loop device with a positional feedback system to control rotational/linear speed & position [29]. Servo motors are more effective than stepper motors because of their unique design and manufacturing processes. The permanent magnets' strength is another significant distinction. Stronger magnets can easily shorten the motor by 20%, resulting in a torque boost of at least 50% . Servo motors are efficient by over 85%. Additionally, servos are reasonably priced, small in size, and extremely dependable. So servos are unquestionably superior and more environmentally friendly than torque motors.

- Usually, during farming, Bangladeshi farmers cannot measure soil nutrients due to a lack of technology. They rely on their age-old knowledge for preparing the soil for crops. That is why we used an NPK probe in our system. An NPK probe is used to evaluate the soil's amounts of nitrogen, phosphorus, and potassium. Given that these three components are crucial for the establishment of healthy plants, it is a useful tool for farmers and gardeners. The electrical conductivity of the soil, which is impacted by the presence of these elements, is measured using the NPK probe. A reading is obtained once the probe has been placed into the ground. The levels of nitrogen and phosphorus are then determined by comparing the reading to a chart. Affordable, fast response, high precision, portable NPK sensors use 316 austenitic steel probes that are resistant to rust, salt-alkali, and electrolytic reactions while allowing long-term, corrosion-free operation. The probe is corrosion resistant, strong, and recyclable, making it environmentally friendly.

These are the project's sustainable factors that support the aspect of sustainability. Now to prove the validity of the sustainability theory, we can also perform another method called SWOT analysis.

SWOT Analysis

A SWOT analysis is a technique for identifying and evaluating internal strengths and weaknesses, as well as external opportunities and threats, that affect current and future operations and help formulate strategic objectives. A SWOT analysis can also be used to set personal growth goals and engage in productive self-reflection. In order to develop the strategic goals for our project, we have also analyzed the strengths, opportunities, weaknesses, and threats of our optimized design. After analyzing all three alternate designs, we have chosen the rover bot as our optimal design, so we will be analyzing the strengths, weaknesses, opportunities, and threats of this design.

Strength:

The biggest strength of our project is that it can complete a series of tasks in a very short time whereas it will consume a lot of time if it is done manually. For instance, the rover bot can navigate through the fields and can detect ripe vegetables. It can differentiate between ripe and unripe vegetables and harvest it perfectly. At the same time, with the help of an NPK probe and soil moisture sensor, it can check the nutrients and the moisture of the soil respectively. If we were to do these tasks manually, it may take up a lot of time and there is always room for error. However, our designed robot has the potential to have significant economic and societal effects. Due to the dependence of traditional farm machinery on crops and topologies, researchers are concentrating more on various farming operational aspects to create intelligent agricultural vehicles and this rover bot can be a fantastic solution for efficient farm management.

Weakness:

There are certain flaws or shortcomings in our project. The farmers in our nation are not particularly economically developed because we are a developing nation. It will be challenging for us to industrialize its popularity among all farmers. It can be quite difficult for us to make robotics widely accessible on an industrial scale because it is largely unknown in rural society. Again, even if we are creating the system in the most economical manner, many farmers who are below the poverty line may find it difficult to afford. Even if we make it available to the farmers, the farmers need to go through extensive training in order to operate it in the fields.

Opportunity:

Our project's primary goal is to bring technology to agriculture. Because the unemployment rate is rising daily despite the fact that the literacy rate is currently approaching 75%. Numerous factors could be at play, but one of the most significant ones is that people tend to have a particular spectrum of professional interests. Agriculture has traditionally been a major source of employment, but due to a lack of development and the fact that farming requires considerably more physical labor than other professions, employment in this sector has been drastically declining over the past few decades. The youth will feel much more intrigued and inspired to pursue a profession in this industry if we introduce technological advances in these industries.

Threat:

Even while our project has the potential to generate wonderful opportunities, there are some threats to be aware of. Like many people, they support themselves by working in the labor force. Our project will take the place of the laborers who previously worked on other people's land for harvesting purposes because it does harvesting tasks freely. In this way, our project may pose a danger to those who do farming in a traditional way. Another potential threat to our project exists. China and Japan, two industrially advanced nations, are already developing this system. Other nations may pose some challenges to us if we attempt to industrialize or build a market for harvesting devices.

TABLE 9: SWOT Analysis

Strength (S): ● It can do multitask at a very short time ● Increases efficiency, boosts productivity in the long run	**Weakness (W):** ● Initially may not be affordable for all farmers ● Training of the farmers is a must to adapt the use of rover bot in farmland
Opportunities (O): ● Introducing new technological perspective in Bangladesh agriculture ● Attracts youths towards farming	**Threat (T):** ● Can replace the jobs of labor workers. ● Will be challenging to survive on an industrial level with other developed countries.

6.4 Conclusion

An important effect and sustainability analysis of the design project, a smart agricultural system for crop monitoring and soil analysis, is given to us through the investigation and debate in this chapter. According to us, the project's positive effects will represent a significant achievement for the agriculture sector. Finally, while keeping an eye on the financial viability of the design and production, we evaluated the sustainability factor by comparing several surveys that took into account the condition and requirements of the patient. With greater advantages for the environment, human health, and society, this solution is more affordable than traditional ones. As a result, we are confident that our project will have a reliable influence that will last for a very long period. Finally, a SWOT analysis has been done to identify the strengths, weaknesses, threats, and opportunities our design would have in the current market.

CHAPTER 7: ENGINEERING PROJECT MANAGEMENT. [CO11, CO14]

7.1 Introduction

Engineering project management carefully prepares and communicates this strategy to the engineering team. Along the project's lifespan, there are several obstacles that might prevent it from being completed effectively. This toolkit will demonstrate how the ability to effectively use insights may enable you to execute excellent projects on time and create a team that is eager to support you in prevailing. This includes identifying project goals and checkpoints and creating different scenarios and backup plans. Project management requires making the most of a unique group of people; you must assess them and select the most effective method of communication with them. Clear and concise communication is often regarded as the core principle of project management. If you have strong communication skills, you will have an advantage over your competition in project management. Project management principles and concepts are commonplace ideas that help projects get done. Although every project is different, you may apply these fundamental ideas to most, if not all, of them. Reading these principles will give you a general idea of the direction you may take to lead and complete projects successfully, while some of them may need to be modified to meet the specifics of your project. Successful delivery of the piece depends on the leader giving clear instructions. Gaining the team's trust is crucial to getting them to pay attention to what you have to say. If team members respect and trust in your statements, they are more likely to desire to make the project successful for you. Building relationships with the team and taking the time to understand them while making it simple for them to comprehend you is the best strategy for winning their trust. Creating a codified framework is the first of the listed principles. By providing your project with a formal structure, you can better manage and maintain control over it. You might start by creating an outline that highlights the main components and aids in carefully organizing the details. The following are some additional elements that might aid in defining a formal project structure: A project charter, A project plan, A project budget, A project goal, etc. Four of us participated in a conversation about how we would create our goals for each semester and assign our tasks during our first week of FYDP. To make healthy communication with all the members we selected Bristy Das as our group leader who leads throughout the timeline and also maintained a very friendly atmosphere to make a good bonding with all of us. And she along with all of us first made a project timeline to finish our project in a certain timeline. This made it easier for us to keep everyone informed about the project and focused on our daily tasks. Additionally, it enabled us to constantly update our ATC panel on our weekly progress. Because engineering is a complex and ever-evolving industry, engineers also need to develop and adapt management abilities in order to effectively manage any project, which is essential to their professional careers. The majority of engineers view themselves as technical experts in their disciplines, but in the workplace, it is necessary to manage people, deadlines, and budgets, which calls for a basic grasp of project management techniques. The fundamental criteria you must adhere to in order to properly manage projects are the project management principles. To guarantee that the result meets the client's expectations, a project must have well defined structure, goals, and tools. If these principles are not followed, the project might incur harm. Additionally, remember that a successful team relies heavily on excellent communication. Team members' alignment on project objectives is ensured via effective communication. Additionally, it helps to build trust, which makes it possible for everyone to work together more successfully from beginning to end.

7.2 Define, Plan and Manage Engineering Project

First, a project plan was created in the first half of FYDP(P) in order to execute the tasks effectively and complete it on time. We provided a thorough timeline of the project in that project plan.

We first planned out all the tasks. To keep the task inside a deadline, we separated the work into several steps and distributed it amongst ourselves. The work plan was then created in accordance with the guidelines for each semester. Like in FYDP(P), we planned the project topic and conducted a background analysis to determine the issue's viability. Therefore, we organized the entire project and assigned duties in accordance with the specifications. The aim of FYDP(D) was then to analyze software tools and select the optimum design. Therefore, we created a schedule for that as well and divided the tasks properly. Additionally, we have to use the optimum design for FYDP(C). As a result, we created a schedule for the work to be done in accordance with what we had planned as the main tasks. Throughout this workframe we decided that we collaboratively work and distribute the different tasks with all. As per schedule, we tried to maintain all the tasks that our ATC panel announced with a time limit.

In FYDP (P) in the very first week we developed a plan and gave it the format of a gantt chart. The Gantt chart that follows highlights our preparation for how we will assign tasks to each other and how much time each task will take. From this gantt chart we got the general idea what will be the tasks in our upcoming semesters and in what time we had to complete it. The Gantt chart is given below in table 10.

Table 10: Project Gantt Chart

PROJECT TIMELINE													
	Task	**Responsible Member**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
FYDP-P	**Topic Identification**	Bristy, Rubyat, Zarif, Mehnaz											
FYDP-P	**Research & Documentation**	Bristy, Rubyat, Zarif, Mehnaz											
FYDP-P	**Design & Approach**	Bristy & Zarif											
FYDP-P	**Codes & Constrain Analysis**	Rubyat & Mehnaz											
FYDP-D	**Software Simulation**	Bristy, Rubyat, Zarif, Mehnaz											
FYDP-D	**Component Analysis & Calculation**	Bristy, Rubyat, Zarif, Mehnaz											
FYDP-D	**Experimental Analysis**	Bristy, Rubyat, Zarif, Mehnaz											
FYDP-C	**Protype Building (Mechanical)**	Bristy, Rubyat, Zarif, Mehnaz											
FYDP-C	**Control Setup**	Bristy & Zarif											
FYDP-C	**Communication Setup**	Rubyat & Mehnaz											
FYDP-C	**Testing & Analysis**	Bristy, Rubyat, Zarif, Mehnaz											
FYDP-C	**Final Documentation**	Bristy, Rubyat, Zarif, Mehnaz											

Then, after performing this gantt chart month-by-month study, we also thoroughly examined the work timeframe in weeks-by-semester, such as FYDP(P), FYDP(D), and FYDP (C). We were able to monitor whether or not we were on time thanks to this thorough investigation. We always made an effort to keep this chronological foundation. The detailed plan is given below in table 11.

Table 11: Project Plan Week Wise

Semester	**Tasks**	**Time (Weeks Per Semester)**
FYDP (P)	Background Research & Topic Selection	Week- 1,2,3
	Concept Note	Week- 3,4,5
	Proposal Note	Week- 6,7,8,9,10
FYDP (D)	Selecting IT Tools	Week - 1,2
	Software Simulation	Week- 3,4,5,6.7
	Project Report	Week- 6,7,8,9,10
FYDP (C)	Buying Components	Week-1,2,3
	Mechanical Structure development	Week-3,4,5

	Whole system development Completion	Week-5,6,7
	System Testing	Week-6,7,8
	Report Writing	Week- 8,9,10

In FYDP (P) the first duty is to select a topic and then to do background study. We planned to do the background research in week-1,2,3. Then in week 3,4,5 we had to complete our concept note and to give the progress presentation. Then after the concept note the final task of that semester was to write the proposal note with selected multiple design approaches.

In FYDP (D) the most important task is to finalize the optimum design. To do so first we needed to select the IT tools that will be used for analyzing the best design. As the designs were simulated in softwares so in week 1 and 2 we compared the IT tools and selected the necessary ones accordingly. From week 3-7 the simulations for the analyzing part of the designs were to be done. After completing the simulation the next task was to complete the report writing from week 6.10.

In FYDP (C) the main task is to implement the final design.For that we needed to buy the components. So we planned to buy the component in the first 2 weeks. Then after buying the components we planned to develop the mechanical structure in the next 3 weeks. Also we thought to make the whole system fully functional by the 7th week so that we can use it for the testing purpose and for the data collection purpose. Then on the week 8,9,10 we planned to complete our report writing.

The project started on 10th Feb and was expected to end the project by 15th December.

Table 12: Project Timeline

Project Starting Date	10th February, 2022
Project Ending Date	15th December, 2022

Thus, at the beginning of the FYDP(P) semester, we finished the planning process for our project. which aided in our ability to stay inspired and finish our assignment on schedule.

7.3 Evaluate Project Progress

In the previous section the expected project timeline was proposed and in this section we will evaluate the project progress by comparing our task completion time with the proposed one. This section is to evaluate our work skill and work management skill. Here we will evaluate the project progress semester-wise and then evaluate it with the proposed ones.

FYDP(P)

Table 13 : FYDP(P) Tasks

Section	Name of Task	Assigned To	Week
Concept Note	Topic Selection	All	1
	Background Research, Tentative Problem Statement	Sayor, Tishun	2
	Tentative Objective, Constraints	Bristy, Nijhum	3
	Requirements, Specifications	Nijhum, Bristy	4
	Multiple Design Approach	All	5
	Applicable Codes & Standards, Conclusion	Tishun, Sayor	6
Proposal Note	Project Plan, Gantt Chart	All	7
	Methodology, Expected Outcome	All	8
	Impact, Sustainability	All	9
	Budget, Ethical Consideration, Risk management, Safety Considerations	All	10
	Conclusion, Slide	All	11
Peer Assessment		All	12

In our FYDP(P), we first selected a couple of cutting-edge issues, then we discussed those with our ATC panel, and lastly, we selected a topic from all of those topics that would be appropriate for our project. And on the basis of this topic, we looked through various study papers and publications in order to develop some additional innovations. We also developed some concepts and put into practice various functional and non-functional requirements as well as set 3 multiple Designs. We then established certain goals and made progress in accordance with them. Our progress presentation was held in the seventh week, and we then worked on our proposal note and completed everything we had planned. Finally, in the eleventh week, we held our final presentation, concluding our FYDP (P).

Evaluation:
If we compare our progress with the proposed one then we can certainly say that in this semester all our tasks were performed in time, maintaining the schedule. This shows the proficiency of the project management skill for the first step of this project.

FYDP(D)

Table 14 : FYDP(D) Tasks

Name of Task	Assigned To	Week
Selecting Appropriate Tools	All	1
Background Research, Survey	All	2
Software Learning	All	3
Software Learning	All	4
Software Simulation	All	5
Software Simulation	All	6
Software Simulation	All	7
Software Simulation	All	8
Report Writing	All	9
Report Writing	All	10
Preparing Slide	All	11
Peer Assessment	All	12

We had begun FYDP(D) after finishing FYDP(P). Here, we've simulated our three design strategies, and after finishing them all, we've decided on our Optimal design on the basis of the simulations' final results and an analysis of them. First, it took us two weeks to choose our simulation platforms. Then, it took us three to four weeks to do all of our simulations. After that, we created a 3D design with the help of Blender for every design approach to help us separate our goals from the other ideas.

We divided the entire time frame into a few weeks to accomplish it as we had to do software simulations this semester. First, during the first week, we selected several softwares. After doing further study on them, we selected which software would perform effectively for our design approaches in week 2. Additionally, we were inexperienced with those softwares, so we had to study them between weeks three and four. Then, we set to work on those, trying to get the best outcome possible. Week 9 was when we finally discovered our ideal answer. In this manner, we completed our FYDP (D).

The ATC panel then gave their clearance. Following that, we worked on our FYDP(D) report and presentation slides. We gave our progress presentation in the midst of the Summer 2022 semester, and in the 12th week, we had our final presentation. In that way we have completed our FYDP(D).

Evaluation:
Now comparing the progress of this semester with the proposed one again, we can see that the works were completed timely according to the plan. The IT tool selection, simulation, and report writing were all finished within time. Even though the 3D simulation took a little longer than anticipated, the work was nevertheless completed on schedule.

FYDP(C)

Table 15 : FYDP(C) Tasks

Name of Task	Assigned To	Week
Component Selection	All	1
Budget Making	All	2
Purchasing Components	All	3
Purchasing Components	All	4
Implementation of Prototype (Mechanical Structure)	All	5
Implementation of Prototype (Mechanical Structure)	All	6
Implementation of Prototype (Electronics Circuit)	All	7
Implementation of Prototype	All	8
Implementation of Prototype	All	9
System Testing	All	9
System Testing	All	10
Report Writing, Slide	All	10
Report Writing	All	11
Peer Assessment	All	12

Here, we have chosen a few suitable components for putting our Optimal Design into practice (Rover Bot). We then created a budget and placed an order for the prototype's parts. After all the parts were delivered, we began putting our prototype into practice.

As none of the internet suppliers offer individual items but rather wholesale, we had to deal with a few challenges throughout the component gathering process because we were unable to acquire them online by the suggested deadline. We had to gather the component independently as a consequence. We purchased a few parts from Patuatol markets and electronics stores. It takes a while to finish the entire approval and authorization procedure. Following the component collecting procedure, we needed to locate a suitable testing site, which we found at Sher-e-Bangla Agricultural University. However, taking into account these shortcomings, we created a final project plan at the beginning of our EEE400C and followed it. Our project is currently complete. Everyone in our group contributed to the project and helped with the follow-up responsibilities. Everyone engaged as required under the guidance of recognized ATC members and the FYDP committee because all of the tasks had been allocated among us so that we could comprehend every phase of the project. By email, we kept in touch with our designated ATC Sir Abu S.M. Mohsin and updated him as needed. Moreover, we have communicated with each committee member for a number of approval-related reasons.

Evaluation:

If we want to evaluate the progress of the work done in this semester we can see also that the work has been done timely. Also, we were able to manage our engineering project within the deadline with little to no problem thanks to the use of a logbook to record meetings and agendas and the Gantt chart for all three stages of the project to analyze our project advancement.

7.4 Conclusion

This prototype project's main goal was to create an agricultural rover that could harvest and pick tomatoes after ensuring ripeness via image processing. We first had to create the algorithm for the prototype before creating a software prototype to work out any technical issues. Then, we constructed the hardware project in accordance with the software project. We encountered various challenges in implementing the hardware to satisfy our objectives. We were finally able to perform those objectives once we had finished all the tasks. As a result, our developed solution complies with the final design. Finally, it is clear that we completed our project under a range of time constraints. Even though we think that such a project would take more time to complete, we were nevertheless able to create an industrial-level design. We need an additional 3–4 months for training and testing to ensure the maximum level of accuracy.

CHAPTER 8: ECONOMICAL ANALYSIS. [CO12]

8.1 Introduction

The budget has been prepared in order to ensure the project is sustainable or not according to it's efficient level. The major goal of our project is to develop a project that is both economical and will perform like a smart rover at a very affordable manufacturing cost, making it feasible for individuals from all socio-economic backgrounds. Mentionable, we have constructed this project within the price range of a robotic body that is developed for picking tomatoes in greenhouses where the main technology is the effective detection of ripe tomatoes against a complicated background.

8.2 Economic Analysis

The process of determining the economic effects of a specific situation or choice is known as economic analysis. Assessing or studying subjects or situations from an expert's point of view is the process of economic analysis. The study of economic systems is called economic analysis. It might also be a study of an industry or a method of production. The analysis seeks to ascertain how efficiently the economy, or some aspect of it, is functioning. For instance, the primary emphasis of an economic analysis of a product is the amount of profit it generates.It entails weighing the advantages and disadvantages of a particular course of action in order to choose the most effective strategy for achieving a specific goal.

It is a crucial tool for maximizing resources and helping organizations, governments, and people make wise decisions. Economic analysis has grown even more crucial with the development of robotics because robots are being utilized more frequently across a range of businesses.
Due to its importance to our project and the necessity for the creation and sale of the product, we have taken into account the following project expenditures.

1. **Investment Cost:** This one includes several costs like robot purchase cost, engineering cost, installation cost, special tooling, and miscellaneous cost. For our proposed system prototype, we have prepared a budget of 61,055 BDT and it includes the cost of the prototype, special tooling, and miscellaneous. As we have designed the project of our own so we do not have to consider the cost of engineering. Furthermore, we do not need any supplies nor any special arrangements to implement our rover on farmland. So, we also do not have any installation costs.

2. **Training Cost:** As we want to introduce robotic technology in agriculture, this is comparatively a new concept for our farmers. This is why, before using this system we need to give proper training to the farmers on how to operate the rover and in case of any malfunction how to handle it. That's why we have included training costs.

Since much of the training needed for installation will be included in the first cost of the installation, training may be viewed as an investment expense.

3. **Maintenance Cost:** The cost of maintenance should be taken into account when acquiring any item. The cost of maintaining a product in excellent functioning order includes the price of parts, labor, and other costs. Depending on the system and the sort of maintenance required, maintenance costs might vary substantially. Regular maintenance can increase a system's lifespan and lower its overall ownership costs. For our proposed design, we do not need any maintenance on a larger scale. For example, after running on the field for several hours, the batteries need to be charged. The batteries we have used in the design, all of them are rechargeable. So after some basic training, the owner himself can charge those batteries easily and the rover will be good to go.

4. **Estimating Costs:** The original investment as well as yearly upkeep and repairs are included in the price. There are several methods to design a project, and each has an impact on the project's life and expenses of both kinds. To accomplish the management objectives, a respectable range of project designs might be created. Cost estimates for each design are available.

5. **Feasibility Analysis :** Three fundamental techniques are used to determine the economic viability once costs and benefits have been estimated:

- Internal Rate of Return (IRR)
- Present Net Worth(PNW)
- Benefit-Cost Ratio (B/C)

The same data is used by all three techniques. When calculating PNW and B/C, the analyst must know what discount rate to apply, but when calculating the IRR, the analyst must know what interest rate to use as a benchmark. The PNW technique is probably the most effective, although the others are also helpful.

A description of the many possibilities for an engineering project's options based on its total expenses is known as an engineering economic analysis. These analyses enable businesses to select the solution that maximizes their profits before starting the project. An engineering economic analysis often examines a project from two fundamental angles: the time needed to finish the project and the physical expenditures, such as materials and labor. For the design method, we have used two different parts to consider one is the body (Chassis) and another one is the 6 Degree Of Freedom Mechanical Robotic ArmWe looked up the Arm and Chassis elements that we utilized in our design model at stores and markets. The product characteristics vary among online and physical stores, and the pricing ranges likewise rely on the attributes. We researched the most recent market prices for comparable items. For instance, Amazon, Aliexpress, Indiamart, daraz etc. According to indiamart.com , the Industrial 6 DOF arm price is almost 3.67lac BDT (2.92lac Rupees). Also, according to Aliexpress, the Robotic Arm price is BDT 717,983.32 The pricing range for this remote control chassis is around 3000-5000 USD, which translates to approximately 311,400–519,000 BDT including shipping costs. One of the most expensive Chassis is this one. Additionally, it will meet our needs.

Now coming to our planned budget vs our final budget,

Table 16: Initial Planned Budget for Prototype

Subsystem	Components	Quantities	Tentative Cost per Items (BDT)	Total Cost (BDT)
Mechanical Subsystem	12V DC Gearbox electric motor 150RPM	4	842	3368
	4S 50C 5000mAh Lipo battery	2	3628	7256
	Stainless steel 36 inches	2.5 ft	1290 (2ft)	1290
	Plywood	2ft	860(2ft)	860
	Stepper motor NEMA 17	4	1290	5160
	Gear Motor Box	1	630	630
Control Subsystem	Raspberry Pi Expansion Board	1	1880	1880
	Raspberry PI 4 8GB	1	14800	14800
	Arduino Mega Board	1	1650	1650
	Wifi module	1	500	500
	Transmitter	1	280	280
	Receiver	1	70	70
Processing/ Electrical Subsystem	Soil Moisture Sensor Module	3	165	495
	Soil NPK Sensor Module With Power Supply	1	12,500	12,500
	A4988 StepStick Stepper Motor Driver	4	350	1400
	Motor driver 43A BTS7960	4	680	2720
	Stereo Vision Camera	1	2450	2450
	Buck Converter	10	250	2500

	Relay Module	8	100	800
Miscellaneous		-	-	5000
Total				**65609**

This is the budget of our optimal design (Rover Bot). We define our budget with some subsystems, for example, the Mechanical system, control system, and electrical system. This is not the budget for our Prototype. This is the budget for our model. Finally, this budget is summed up to almost 65 thousand Taka..

Table 17 : Our Final Budget for Prototype

Components	Quantities	Cost per Items (BDT)	Total Cost (BDT)
RS485 To TTL Module	1	1050	1050
Soil NPK Sensor Agricultural RS485/Modbus	1	11990	11990
MAX485 RS-485 Module TTL	1	454	454
XIAOR Tracked Tank Chassis	1	8960	8960
6 DOF Aluminium Mechanical Robotic Arm Clamp Claw Mount Robot Kit	1	3555	3555
Metal Servo Horn	7	140	980
Raspberry Pi 4 Computer (Made in UK)	1	13,999	13,999
ARDUINO MEGA 2560 ADK	1	3443	3443
Lipo Battery 2200mAh 11.1V 3S	1	1870	1870
Lipo Battery 3300mAh 11.1V 3S	1	2599	2599
MG996R 10 kg Servo (Fully Metal)	7	445	3115
M3 STAINLESS STEEL NUTS (10MM)	40	7	280
16-CHANNEL 12-BIT PWM SERVO DRIVER MODULE PCA9685	1	466	466
ARDUINO NANO ATMEGA328P	1	754	754
DC-DC ADJUSTABLE STEP-DOWN BUCK CONVERTER XL4015 4A - WITH VOLTAGE METER	1	326	326
SUNSHINE INTELLIGENT ADJUSTABLE TEMPERATURE SOLDERING IRON	1	1400	1400
THIRD HAND SOLDERING STAND WITH MAGNIFIER MAGNIFYING GLASS 3 LENS 5 LED LIGHT	1	750	750

MECHANIC 150G 63/37 TIN LEAD ROSIN CORE 0.3MM 1.2% FLUX REEL WELDING LINE SOLDER WIRE LOW MELTING POINT	1	754	754
BAKU BK-150 ADVANCED SOLDERING PASTE	1	53	53
YAXUN 109 ELECTRONIC PLIERS WIRE CUTTER	1	175	175
PRO'SKIT ORIGINAL DP-366D DESOLDERING PUMP ANTI-STATIC SOLDER SUCKER REMOVAL	1	265	265
BREAK AWAY FEMALE HEADERS	1	35	35
USB TO RS485 FT232RL FTDI TTL SERIAL CONVERTER ADAPTER	1	420	420
BREAK AWAY MALE HEADERS - RIGHT ANGLE	1	35	35
SOLDERING TOOLS DAMP SPONGE	2	21	42
Miscellaneous	-	-	3285
Total			61,055

Therefore, our final budget has been summed up to an amount of 61,055 BDT which meets our Initial budget plan. But we could make it less but we failed to manage it as the current Dollar rate is increased due to global inflation which is why the product prices are also increased.

Main Budget:

Table 18 : Our Final Budget for Main Design

Components	Quantities	Cost per Items (BDT)	Total Cost (BDT)
RS485 To TTL Module	1	1050	1050
Soil NPK Sensor Agricultural RS485/Modbus	1	11990	11990
MAX485 RS-485 Module TTL	1	454	454
Self Designed Chassis for Final design	1	30000	30000
Self Designed 6 DOF Aluminium Mechanical Robotic Arm	1	10000	10000

Metal Servo Horn	7	140	980
Raspberry Pi 4 Computer (Made in UK)	1	14000	14000
Arduino Mega2560 ADK	1	3443	3443
Lipo Battery 2200mAh 11.1V 3S	1	1870	1870
Lipo Battery 3300mAh 11.1V 3S	1	2600	2600
10 kg Fully Metal Servo	7	445	3115
PWM Servo Driver ModulePCA9685	1	746	746
Arduino Nano	1	754	754
Step Down Buck Converter with Voltage Meter	1	326	326
Adjustable Temperature Soldering Iron	1	1400	1400
3rd Hand Soldering Stand with Magnifier	1	750	750
150g Rosin Core	1	754	754
Soldering Paste	1	53	53
Electronic Plier Wire Cutter	1	175	175
Anti-static Solder Sucker Removal	1	265	265
Break away Female Headers	1	35	35
USB to RS485 FT232RL FTDI TTL SerialConverter Adapter	1	420	420
Break away Male Headers - Right Angle	1	35	35
Soldering Tools Damp Sponge	2	21	42
Miscellaneous	-	-	5000
Total			**90257**

After calculating all the components that we will use in our Final (Main) design, the whole budget comes out to BDT 90,257. It will fluctuate between 90,000 to 1 lac BDT. We tried to make this budget plan in a cost effective manner. But the recent breakdown of the current market rate for the dollar is a hindrance to make it more effective. But according to our plan we can tell that this is still feasible.

Fig 8.2.1: Price Comparison of Similar Products

In figure 8.2.1, we can see the graphical representation of similar kinds of products for different countries. Here, we can clearly see that the price of our proposed product is much lower than other marketed products.

8.3 Cost-Benefit Analysis

The manufacturing cost of the project, including miscellaneous costs, appears to be around BDT 60000 BDT. When production is at a high level, a significant amount of miscellaneous costs can be eliminated. Because it is customized based on the field size, the chassis price is set.

It is clear that the project may be completed within BDT 100000 when taking the various cost reductions into account. And we can produce the product from our prototype in BDT 60,000. After setting up the final design components we made a new budget list where we will use our self designed Arm and the chassis body which will make our Final design more effective with the objectives. And the total amount came out at 90,257 BDT. Which can be in the range of 90,000 to 1 lac BDT. In order to benefit the farmers and make it affordable, we will set the purchase price very low after understanding the user's needs. We think that because repairability is simpler, repairability costs will also be reasonable.
Based on research, the functional element was often purchased for between BDT 70,000 and BDT 20 Lac. Our project (the overall design) can be sold for BDT 1,20,000 to 1,50,000 if we

compare it to the price of a single robotic arm, which can cost anywhere between BDT 2,00000 and BDT 800,000.
Also, the Chassis Cost will be included which can be cost anywhere between BDT 15000 and BDT 40000. This demonstrates that the overall cost can be reduced to a very impressive range of the following,

Table 19: Market Price vs Our Design

Product	Lowest Range in BDT	Highest Range in BDT
Market Product	2,15,000	8,40,000
Our Design	1,20,000	1,50,000
Cost Different	95,000	6,90,000

8.4 Evaluate Economic and Financial Aspects

The expenditure of buying and sustaining a robot, the cost of training staff to operate the robot, the possible cost benefits from employing the robot, and the potential revenue earned from increased crop production are some of the economic and financial aspects of a robot used for agriculture. In addition, one must take into account the economic and financial ramifications of how the robot will affect employment, the environment, and the regional economy. The expense of the robot must be compared to the possible advantages it can offer to the agricultural sector, such as increased crop production, lower labor costs, and increased productivity.

According to the aforementioned cost evaluation, it is clear that the development's original costing was a little high because we had to gather the components individually. When the pricing was normal, the initial design budget was made. However, the recent price hike has had an impact on our overall spending plan. It will have an impact on the project's construction budget in the meantime. Based on the current situation, the overall manufacturing price, which variously estimated to be between 60,000 and 65,000 BDT for the prototype, and the Final Design’s Budget to be between 90,000 and 1,00,000 BDT but with some product reduction, our budget could meet 80,000-85,000 BDT but for the current situation potentially reach 90257 BDT.

8.5 Conclusion

In order to keep our Sustainability Plan price range as cost-effective as possible, we have tried to minimize it. Our system saves a lot of money and is expensive on the main unit. We believe that because we used a simple robotic arm alternative, it will be affordable for farmers who cannot afford a rover due to the cost being many times higher than the price we developed.

CHAPTER 9: ETHICS and PROFESSIONAL RESPONSIBILITIES CO13, CO2

9.1 Introduction

Engineering is a valuable and specialized profession. As members of their profession, engineers must adhere to the highest professional and ethical standards. Technology has a direct and major impact on people's quality of life. Engineers must therefore be dedicated to maintaining the health, welfare and safety of the public and must provide their services honestly, objectively, fairly, and equally. The Code of Professional Conduct for Engineers prescribes adherence to the highest ethical standards. When researching and managing projects, ethics must be taken into account. Stakeholder acceptance of the project is ensured by adherence to ethical principles set forth in policies established by accredited or accredited organizations. According to the policy everywhere, it is unethical to harm resources or the health of stakeholders. Because it is an agricultural system, we must follow specific laws and rules to develop, test, collect data, and train the system. Certain guidelines, permits, and standards must be followed before developing a system for production or industrial use. Some of the ethical considerations that may apply to our projects are as follows.

9.2 Identify Ethical Issues and Professional Responsibility

- A system designer's first and most crucial responsibility is to construct the system in the most efficient and effective manner feasible. To avoid harming any living thing, the system will be created. Because the system will be used directly on fields for harvesting purposes, it will be constructed with the premise that it cannot hurt any crops or be harmful in any manner to anything associated with the field.

- The major goal of this research is to find the most economical approach to commercialize this system so that any farmer can use it. To do this, we will be in touch with several companies to discuss manufacturing it in accordance with all applicable regulations and standards. For consent, permissions, and principles, we will need to make some official arrangements.

- Agroterrorism is a form of terrorism that involves the intended tampering with or destruction of agricultural or food supplies. The safety of the world's food supply is seriously threatened. The susceptibility of the food supply system and the possibility of significant economic and social disruption are contributing to the growth of this hazard. Agroterrorism can also be carried out with the proposed device. For instance, if this device goes in the wrong hands, it can be used to run over crops and vegetable fields which can destroy crops. It will significantly reduce agricultural productivity.

Moreover, this will cause chaos in the social and economic spheres as well as dread and panic. To prevent this we must watch over and secure the food facilities. Additionally, we must instruct and train staff on how to identify potential agroterrorism risks and take appropriate action.

- For testing purposes, we will require a certain area of land for that particular vegetable. For this reason, we shall file a formal statement. As a result, everything will be formal and official. Additionally, we are restricted by the fact that throughout the testing and data processing phase, nothing pertaining to the field or crops will be hindered.

- Since this is an agricultural project, we will contact the Sher-e-Bangla Agricultural University for aid with data analysis, testing, land management, and validation. If we conduct this study under their direction, it will be accredited and simple to industrialize. In this context, we have formally contacted the Department of Horticulture of Sher-e-Bangla Agricultural University.. The application will be submitted on behalf of our advisors.

- There may be safety issues associated with the use of robotic technology in agriculture that need to be considered. Concern for stakeholder safety is crucial when it comes to agricultural robots. Because of this, we must keep safety in mind while designing and developing this rover. Prior to being used in the field, it must undergo rigorous testing and be developed to the required standard of reliability and safety. Furthermore, all software and hardware systems should also receive frequent updates.

9.3 Apply Ethical Issues and Professional Responsibility

Our study followed all ethical guidelines for doing research. While writing this project report, we did not employ any unethical tactics or references without due attribution or citation. We created a design that is original and distinct from other works or publications. We'll talk about moral concerns including secrecy, informed consent, and anonymity. Through a permission form, we have attempted to address these ethical concerns. So, in order to participate in the study, individuals must read and accept the permission form's requirements. Duplication of work was strictly avoided, and if data from other researchers were used, proper credit was given through citation. When required, recognized worldwide standards were consulted to guarantee that the study was of the highest caliber.

9.4 Conclusion

Engineers must adhere to the highest ethical standards consistent with their code of professional conduct. All applicable laws, rules, and policies, including those that control the environment, commercial power generation, renewable energy, etc., will apply to any project undertaken below. We monitor compliance with intellectual property and patent laws. In addition, plagiarism was carefully avoided and citations were used to properly credit other researchers when their data was used. As a new and innovative initiative, our mission is to ensure that safety and ethical considerations are taken into account during project implementation. We have reviewed every conceivable code of behavior an engineer must adhere to by identity and application. Engineers must be encouraged to develop projects in the field, and stakeholders must be encouraged to take an interest in the project, through its ethical ethos. In short, we are aware of our ethical obligations and have strived to honor them throughout our duty.

CHAPTER 10: CONCLUSION and FUTURE WORK

10.1 Project Summary/Conclusion

In Bangladesh, agriculture is the base of the economy. As Bangladesh is more developed in this era, especially in the Technological sector, many of the farmers are ignorant of this advancement of technological tools. For that reason, they face difficulties while farming where technology is needed. However, the developed countries use technical tools in every sector, even in agriculture to make their tasks easier, faster, and more handy as well as improved crop production. Most Bangladeshi farmers are illiterate so they are unable to use those technologies which is why they are the hindrance to conduct their harvesting system smartly. As a result, Bangladesh has fallen into a very poor position compared to other smart countries. To overcome this, we can introduce farming Robots which can bring a strong revolution to these primitive systems. So, our main objective is to introduce an advanced automated monitoring system in Bangladesh Agriculture. To bring this we can set up an example which can be a Robotic method for picking Tomatoes by detecting Ripe vegetables. By using image processing techniques and computer vision maturing and counting vegetables will be estimated and the main tasks will be done using HSV color space. To detect soil nutrient level, an NPK sensor will be used. To ensure our objectives we designed three multiple approaches (1) Rover bot, (2) Unmanned Aerial Vehicles (UAV), and (3) Science box. Firstly, the Rover bot is a transportable automated vehicle that can move along the field and transport a robotic arm for harvesting to ensure less human labor. Secondly, UAV is a flying monitor and it is rather expensive. Also, we created a science box for checking on the state of farming. For our design project, we meet various modern engineering tools or simulation tools. We basically use those IT technologies to create our prototype to help us select the optimal design from a range of alternatives and investigate hypothetical situations. For instance, In MATLAB Simulink, we implemented our two different designs for Rover Bot and UAV. We used Proteus to implement our Science Box. As we could not find any NPK sensors so we showed soil analysis by a Soil Moisture sensor. Lastly, by Blender, we compared the vegetable detection, navigation, harvesting and image clarity of our three implemented designs. To find an optimal solution, for our project we have set some parameters or test cases for example image clarity, mobility, ripe vegetable detection, weight limitation, stability, navigation, etc based on which we will analyze. The Rover bot and science box performed well rather than the UAV in Image Clarity. Rover bot and UAV performed well in field modification. In ripe vegetable detection, Harvesting, and water limitation Rover bot performed well rather than the other two approaches. Therefore, the Rover bot's performance is exemplary in most cases rather than others.

In FYDP(P) and FYDP(D), we focused on doing research and working to identify the best and optimum design solutions based on those three design performance criteria as well as certain test cases. The Rover-Bot, which was our best design, was then created. As a result, we decided to set up the design in FYDP (C). As a result, we began gathering information to process our prototype. We prepared a budget as soon as we decided on the final parts we would utilize for the rover. We purchased some of them from Patuatuli, Farmgate, and some from different internet vendors throughout the course of the following several days. We began working to complete it on schedule after obtaining all of the necessary parts.

10.2 Future Work

Bangladesh is mostly an agricultural nation, hence this industry employs the most people. Modern farms and agricultural businesses work substantially differently from those from a few decades ago as a result of technological advancements. Modern agriculture frequently makes use of robots, temperature and moisture sensors, aerial photography, and GPS technologies. These cutting-edge tools, robotic systems, and precision farming methods may help businesses become more prosperous, productive, safe, and environmentally friendly. Water, fertilizer, and pesticides are no longer required to be applied uniformly over whole fields by farmers. Instead, they might use the very bare minimum, concentrate on a very tiny area, or even treat specific plants differently.

Automated Navigation:

We may make the Roverbot more suitable to work with by making it navigate automatically around the field. This requires the Rover to detect obstacles in front of it and shift its course upon the detection of the obstacle.

This can be done in various ways using proper sensors. Such sensors may include IR sensors, Ulta-sonic sensors etc. Or another method can be making it a line follower Robot. Thus following a certain reference line across the field and navigating automatically.

Automated Harvesting:

The tools required for Automated harvesting are different from Automated navigation. Here, we would require to find the distance of the Ripe tomato in order to pluck it when the Ripe tomato is detected.

After finding the position the Robotic arm can make the Claw reach up to the detected tomato by the help of inverse kinematics that we already implemented.

However, due to budget issues, we could not include a Stereo Vision camera that can provide the Coordinates to the robotic arm. If we can Integrate it , that way may enable automated harvesting for our design.

Crop Growth Monitoring:

We have already implemented Image-based detection in our System. For now, it is limited to ripeness detection.

However, with the help of proper training in machine learning models, we can realize crop growth monitoring in this system that closely relates to our primary objectives. This, however, requires sufficient data of crops in order to train the model. Hence, would require a lot of time to implement. Therefore for now it is something we may consider doing in the future.

Crop Disease Detection:

Similar to the crop growth monitoring , crop disease detection can be implemented in our system by the help of machine learning algorithms. Again, this would require sufficient data to train the machine learning model.

CHAPTER 11: IDENTIFICATION of COMPLEX ENGINEERING PROBLEMS and ACTIVITIES.

11.1: Identify the Attributes of Complex Engineering Problem (EP)

Table 20: Attributes of Complex Engineering Problem

	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	

11.2: Provide Reasoning How the Project Addresses Selected Attribute (EP)

As per the requirements our project follows five different complex engineering attributes. However, every attribute will not be applicable to our projects. The major ones which will be appropriate as per the system are shown by giving a tick mark on the table. The justification for following those attributes are as follows:

- **P1 (Depth of Knowledge Required)→** The depth of information is the first and most crucial criterion for constructing the system. We won't be able to create the system precisely if we don't understand the issue and how to fix it. The quality is relevant to our project since we thoroughly examined the problem before developing a strategy or approach to creating a system to tackle it. This process involved reviewing relevant literature and looking at related works.

- **P3 (Depth of Analysis Required)→** In our project, this aspect of analytical depth is also present. We must investigate every part of the process in order to identify ripe veggies and create a harvesting system, which will eventually enable us to create the system. to conduct analyses of the soil and the atmosphere. Once more, we need to have a strong analytical foundation in this field**.**

- **P4 (Familiarity of Issues)→** Many of the difficulties in this project are new to us, but we are familiar with the standards for tackling them. We will be able to address these new difficulties using the information we have gained. For instance, what technique would be ideal for picking vegetables while keeping the right amount of pressure so as not to squash them while picking them. As a result, our project also adheres to the attribute of issue familiarity.

- **P6 (Extent of Stakeholder Involvements and Needs)→** According to our goals, we wish to provide all farmers with access to the system on an industrial scale. Now, in order to accomplish this, we will get in touch with the appropriate businesses and organizations that produce agricultural technology systems. The improvements will be made so that the system may be produced commercially and in accordance with their demands and specifications. As a result, the attribute of having stakeholders involved in the project is qualified.

11.3 Identify the Attributes of Complex Engineering Activities (EA)

Table 21: Attributes of Complex Engineering Activities

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

11.4 Provide Reasoning How the Project Addresses Selected Attribute (EA)

While executing the system plans we are going to follow four different complex engineering activities. The reasons for following these EAs are as follows:

A1: Range of Resources- In order to complete our project, we need to access a variety of resources, including money, lands, hardware tools, technology, software, data, and information. Thus, these engineering tasks are followed in our project.

A2: Level of Interactions- This activity is followed by this project. We must maintain various degrees of interactions with various individuals while we work on this project. Such as interactions with the collaborative partner, the land and equipment owners, people related to data management, stakeholders, and investors.

A4: Consequences for Society and Environment- We intend to add a revolutionary component to agricultural technology through our initiative. With the implementation of an automated harvesting system, a novel idea will be brought to agriculture in our nation. Hopefully, it will have a good impact on society by making farming easier and more sociable..

A5: Familiarity- The use of novel principles that we haven't seen previously is necessary for our endeavor. Using machine learning methods, for instance, to teach our system to recognize novel ripe veggies. In addition, we occasionally learn new concepts, such as inverse kinematics for the robotic arm or Euclidean distance measurement for picture capture.

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APPENDIX

CODES:

(Operational)

```
#include <Servo.h>

Servo myservo0;
Servo myservo1;
Servo myservo2;
Servo myservo3;
Servo myservo4;
Servo myservo5;

int pos0=120;
int pos1=142;
int pos2=83;
int pos3=131;
int pos4=50;
int pos5=30;
int i=0;

#define motor_right 0
#define motor_left 1

#define BRAKE 0
#define CW    1
#define CCW   2
#define CS_THRESHOLD 15

#define CURRENT_SEN_1 A2
#define CURRENT_SEN_2 A3

#define EN_PIN_1 A0
#define EN_PIN_2 A1



#define motor_1a_PIN 11
#define motor_1b_PIN 12

#define motor_2a_PIN 8
#define motor_2b_PIN 13

#define PWM_motor_right 9
#define PWM_motor_left 10


short usSpeed = 150;
unsigned short usMotor_Status = BRAKE;

void setup()
{
  pinMode(motor_1a_PIN, OUTPUT);
  pinMode(motor_1b_PIN, OUTPUT);
```

```
  pinMode(motor_2a_PIN, OUTPUT);
  pinMode(motor_2b_PIN, OUTPUT);

  pinMode(PWM_motor_right, OUTPUT);
  pinMode(PWM_motor_left, OUTPUT);

  pinMode(CURRENT_SEN_1, OUTPUT);
  pinMode(CURRENT_SEN_2, OUTPUT);

  pinMode(EN_PIN_1, OUTPUT);
  pinMode(EN_PIN_2, OUTPUT);

  myservo0.attach(2);
  myservo1.attach(3);
  myservo2.attach(4);
  myservo3.attach(5);
  myservo4.attach(6);
  myservo5.attach(7);

 /* myservo0.write(pos0);
  myservo1.write(pos1);
  myservo2.write(pos2);
  myservo3.write(pos3);
  myservo4.write(pos4);
  myservo5.write(pos5);*/

  Serial.begin(9600);
  Serial.setTimeout(6000);
  Serial.println();
  Serial.println("Enter number for control option:");
  Serial.println();


  /*Serial.println("0. STOP");
  Serial.println("1. FORWARD");
  Serial.println("2. Left");
  Serial.println("3. Right");
  Serial.println("4. Backward");
  Serial.println("+. INCREASE SPEED");
  Serial.println("-. DECREASE SPEED"); */
  Serial.println();
}


void loop()
{
  char user_input;



  while(Serial.available())
  {
    user_input = Serial.read();
    digitalWrite(EN_PIN_1, HIGH);
    digitalWrite(EN_PIN_2, HIGH);

    if (user_input =='o')
    {
      Stop();
    }
```

```
else if(user_input =='i')
{
 Forward();
}
else if(user_input =='j')
{
 left();
}
else if(user_input =='l')
{
 right();
}
else if(user_input =='k')
{
 Reverse();
}
else if(user_input =='+')
{
 IncreaseSpeed();
}
else if(user_input =='-')
{
 DecreaseSpeed();
}
else if (user_input =='q')
{
  Forward0();
}
else if(user_input =='a')
{
 Backward0();
}
else if (user_input =='w')
{
  Forward1();
}
else if(user_input =='s')
{
 Backward1();
}
else if (user_input =='e')
{
  Forward2();
}
else if(user_input =='d')
{
 Backward2();
}
else if (user_input =='r')
{
  Forward3();
}
else if(user_input =='f')
{
 Backward3();
}
else if (user_input =='t')
{
  Forward4();
}
```

```
  else if(user_input =='g')
  {
   Backward4();
  }
  else if (user_input =='y')
  {
    Forward5();
  }
  else if(user_input =='h')
  {
   Backward5();
  }
  else if(user_input=='p'){
   habijabi();}
  else if(user_input=='m'){
  Position_ask();
  }
  else if(user_input=='n'){
   Inpos();
  }
  else if(user_input=='z'){
   Npkin();
   }
  else if(user_input=='x'){
   Npkout();
  }
  }

 }


void Position_ask()
{
 float x=0;
 float y=0;
 float z=0;
 float m=0;
 float l1=10.5;
 float l2=9.8;
 float l3=16.5;
 float th0=0;
 float th1=0;
 float th2=0;
 float th3=0;
 float mind=0;
 float d=0;
 float pi=3.1416;
 Serial.println("Value of x");
 while (Serial.available()==0){}
 x=Serial.parseFloat();
 Serial.println(x);

 Serial.println("Value of y");
 while (Serial.available()==0){}
 y=Serial.parseFloat();
 Serial.println(y);

 Serial.println("Value of z");
 while (Serial.available()==0){}
 z=Serial.parseFloat();
```

```
Serial.println(z);
z=z-14.5;


d=sqrt(x*x+y*y);

d=d-l3;


th2=(pi-(acos((-(d*d)-(z*z)+(l1*l1)+(l2*l2))/(2*l1*l2))));

th1=((atan(z/d))+(atan((l2*sin(th2))/(l1+l2*cos(th2)))));


th2= (180*th2/pi);

th1= (180*th1/pi);

th3=-th1+th2;

th0=(atan(y/x)*180/pi);

Serial.print("Servo0 pos   =");
Serial.println(th0);

Serial.print("Servo1 pos   =");
Serial.println(th1);

Serial.print("Servo2 pos   =");
Serial.println(-th2);

Serial.print("Servo3 pos   =");
Serial.println(th3);

th0=th0+90;
th1=th1+11;
th2=th2;
th3=th3+87;
Serial.println(th0);

 while(pos0>th0+2 || pos0<th0-2){
  if(pos0<th0){
  pos0+=1;
  myservo0.write(pos0);
  delay(30);}
  else{
  pos0-=1;
  myservo0.write(pos0);
  delay(30);}

 }


  while(pos2>th2+1 || pos2<th2-1){
  if(pos2<th2){
  pos2+=1;
  myservo2.write(pos2);
  delay(30);}
  else{
  pos2-=1;
```

```
   myservo2.write(pos2);
   delay(30);}
  }

   while(pos3>th3+1 || pos3<th3-1){
   if(pos3<th3){
   pos3+=1;
   myservo3.write(pos3);
   delay(30);}
   else{
   pos3-=1;
   myservo3.write(pos3);
   delay(30);}
  }

   while(pos1>th1+1 || pos1<th1-1){
   if(pos1<th1){
   pos1+=1;
   myservo1.write(pos1);
   delay(30);}
   else{
   pos1-=1;
   myservo1.write(pos1);
   delay(30);}
   }

  Serial.print("Servo0 pos   =");
  Serial.println(pos0);

  Serial.print("Servo1 pos   =");
  Serial.println(pos1);

  Serial.print("Servo2 pos   =");
  Serial.println(pos2);

  Serial.print("Servo3 pos   =");
  Serial.println(pos3);

/*  while(pos5>101 || pos5<99){
   if(pos5<100){
   pos5+=1;
   myservo5.write(pos5);
   delay(30);}
   else{
   pos5-=1;
   myservo5.write(pos5);
   delay(30);}
   }
  delay(1500);
  while(pos5>21 || pos5<19){
   if(pos5<20){
   pos5+=1;
   myservo5.write(pos5);
   delay(30);}
   else{
   pos5-=1;
   myservo5.write(pos5);
   delay(30);}
   }*/
```

```
}

void Npkin(){

  Serial.print("Npk in");
  while(pos0>143 || pos0<141){
   if(pos0<142){
   pos0+=1;
   myservo0.write(pos0);
   delay(30);}
   else{
   pos0-=1;
   myservo0.write(pos0);
   delay(30);}

  }

   while(pos1>77 || pos1<75){
   if(pos1<76){
   pos1+=1;
   myservo1.write(pos1);
   delay(30);}
   else{
   pos1-=1;
   myservo1.write(pos1);
   delay(30);}
   }


 }
void Npkout(){
  Serial.print("Npk Out");

  while(pos1>142 || pos1<140){
   if(pos1<141){
   pos1+=1;
   myservo1.write(pos1);
   delay(30);}
   else{
   pos1-=1;
   myservo1.write(pos1);
   delay(30);}
   }

  while(pos0>91 || pos0<89){
   if(pos0<90){
   pos0+=1;
   myservo0.write(pos0);
   delay(30);}
   else{
   pos0-=1;
   myservo0.write(pos0);
   delay(30);}

  }
```

```
  }

void Inpos(){
pos0=98; //inpos
pos1=142;
pos2=61;
pos3=0;
pos4=50;
pos5=100;

  myservo0.write(pos0);
  myservo1.write(pos1);
  myservo2.write(pos2);
  myservo3.write(pos3);
  myservo4.write(pos4);
  myservo5.write(pos5);

}


void habijabi()
{
 for(i=0;i<=15;i++)
 {
  pos0+=5;
  myservo0.write(pos0);
  pos2-=1;
  myservo2.write(pos2);
  pos3+=4;
  myservo3.write(pos3);
  pos5-=2;
  myservo5.write(pos5);
  delay(200);
  }

 delay(200);
 for(i=0;i<=15;i++)
 {
  pos0-=5;
  myservo0.write(pos0);
  pos2+=1;
  myservo2.write(pos2);
  pos3-=4;
  myservo3.write(pos3);
  pos5+=2;
  myservo5.write(pos5);
  delay(200);
  }

}


void Forward0()
{
  Serial.println(pos0+11);
    for (i = 0; i <= 10; i += 1)
    {
    pos0+=1;
    myservo0.write(pos0);
    delay(15);
```

```
    }
}


void Backward0()
{
  Serial.println(pos0-11);
    for (i = 0; i <= 10; i += 1)
    {
    pos0-=1;
    myservo0.write(pos0);
    delay(15);
    }
}

void Forward1()
{
  Serial.println(pos1+11);
    for (i = 0; i <= 10; i += 1)
    {
    pos1+=1;
    myservo1.write(pos1);
    delay(15);
    }
}


void Backward1()
{
  Serial.println(pos1-11);
    for (i = 0; i <= 10; i += 1)
    {
    pos1-=1;
    myservo1.write(pos1);
    delay(15);
    }
}
void Forward2()
{
  Serial.println(pos2+11);
    for (i = 0; i <= 10; i += 1)
    {
    pos2+=1;
    myservo2.write(pos2);
    delay(15);
    }
}


void Backward2()
{
  Serial.println(pos2-11);
    for (i = 0; i <= 10; i += 1)
    {
    pos2-=1;
    myservo2.write(pos2);
    delay(15);
    }
}
```

```
void Forward3()
{
 Serial.println(pos3+11);
   for (i = 0; i <= 10; i += 1)
   {
   pos3+=1;
   myservo3.write(pos3);
   delay(15);
   }
}


void Backward3()
{
 Serial.println(pos3-11);
   for (i = 0; i <= 10; i += 1)
   {
   pos3-=1;
   myservo3.write(pos3);
   delay(15);
   }
}
void Forward4()
{
 Serial.println(pos4+11);
   for (i = 0; i <= 10; i += 1)
   {
   pos4+=1;
   myservo4.write(pos4);
   delay(15);
   }
}


void Backward4()
{
 Serial.println(pos4-11);
   for (i = 0; i <= 10; i += 1)
   {
   pos4-=1;
   myservo4.write(pos4);
   delay(15);
   }
}
void Forward5()
{
 Serial.println(pos5+11);
   for (i = 0; i <= 10; i += 1)
   {
   pos5+=1;
   myservo5.write(pos5);
   delay(15);
   }
}


void Backward5()
{
 Serial.println(pos5-11);
   for (i = 0; i <= 10; i += 1)
```

```
  {
  pos5-=1;
  myservo5.write(pos5);
  delay(15);
  }
}

void Stop()
{
 Serial.println("Stop");
 usMotor_Status = BRAKE;
 motor_control(motor_right, usMotor_Status, 0);
 motor_control(motor_left, usMotor_Status, 0);
}

void Forward()
{
 Serial.println("Forward");
 usMotor_Status = CW;
 motor_control(motor_right, 1, usSpeed);
 motor_control(motor_left, 2, usSpeed);
}

void Reverse()
{
 Serial.println("Backward.");
 usMotor_Status = CW;
 motor_control(motor_right, 2, usSpeed);
 motor_control(motor_left, 1, usSpeed);
}

void right()
{
 Serial.println("Right");
 usMotor_Status = CW;
 motor_control(motor_right, 2, usSpeed);
 motor_control(motor_left, 2, usSpeed);
}

void left()
{
 Serial.println("Left");
 usMotor_Status = CW;
 motor_control(motor_right, 1, usSpeed);
 motor_control(motor_left, 1, usSpeed);
}

void IncreaseSpeed()
{
 usSpeed = usSpeed + 10;
 if(usSpeed > 255)
 {
  usSpeed = 255;
 }

 Serial.print("Speed +: ");
 Serial.println(usSpeed);

 motor_control(motor_right, usMotor_Status, usSpeed);
 motor_control(motor_left, usMotor_Status, usSpeed);
```

```
}

void DecreaseSpeed()
{
 usSpeed = usSpeed - 10;
 if(usSpeed < 0)
 {
  usSpeed = 0;
 }

 Serial.print("Speed -: ");
 Serial.println(usSpeed);

 motor_control(motor_right, usMotor_Status, usSpeed);
 motor_control(motor_left, usMotor_Status, usSpeed);
}

void motor_control(uint8_t motor, uint8_t direct, uint8_t pwm)          //Function that controls the variables: motor(0 ou 1), direction (cw ou ccw) e pwm (entra 0 e 255);
{
 if(motor == motor_right)
 {
  if(direct == CW)
  {
   digitalWrite(motor_1a_PIN, LOW);
   digitalWrite(motor_1b_PIN, HIGH);
  }
  else if(direct == CCW)
  {
   digitalWrite(motor_1a_PIN, HIGH);
   digitalWrite(motor_1b_PIN, LOW);
  }
  else
  {
   digitalWrite(motor_1a_PIN, LOW);
   digitalWrite(motor_1b_PIN, LOW);
  }

  analogWrite(PWM_motor_right, pwm);
 }
 else if(motor == motor_left)
 {
  if(direct == CW)
  {
   digitalWrite(motor_2a_PIN, LOW);
   digitalWrite(motor_2b_PIN, HIGH);
  }
  else if(direct == CCW)
  {
   digitalWrite(motor_2a_PIN, HIGH);
   digitalWrite(motor_2b_PIN, LOW);
  }
  else
  {
   digitalWrite(motor_2a_PIN, LOW);
   digitalWrite(motor_2b_PIN, LOW);
  }

  analogWrite(PWM_motor_left, pwm);
 }
```

```
}
```

(NPK Analysis)

```
#include <ModbusMaster.h>
#include <SoftwareSerial.h>
SoftwareSerial modbus(10,11);    //5 is rx, 6 is tx, change accordingly


ModbusMaster node;


int read_n();
int read_p();
int read_k();

void setup() {
  // put your setup code here, to run once:

  Serial.begin(9600);

  modbus.begin(9600);

}

void loop() {


  //0-1999mg/kg or ug/g
  int n = read_n();
  int p = read_p();
  int k = read_k();

  Serial.print("n:");
  Serial.println(n);
  Serial.print("p:");
  Serial.println(p);
  Serial.print("k:");
  Serial.println(k);
  Serial.println(" ");
```

```
  delay(2000);
}


int read_n() {
  uint8_t result;
  int value;
  node.begin(1, modbus);

  result = node.readHoldingRegisters(0x1E, 1);
  // do something with data if read is successful
  if (result == node.ku8MBSuccess) {
    value = node.getResponseBuffer(0);
    //Serial.println(value);
    return value;
  }
  return -1;
}

int read_p() {
  uint8_t result;
  int value;
  node.begin(1, modbus);

  result = node.readHoldingRegisters(0x1F, 1);
  // do something with data if read is successful
  if (result == node.ku8MBSuccess) {
    value = node.getResponseBuffer(0);
    //Serial.println(value);
    return value;
  }
  return -1;
}

int read_k() {
  uint8_t result;
  int value;
  node.begin(1, modbus);

  result = node.readHoldingRegisters(0x20, 1);
  // do something with data if read is successful
  if (result == node.ku8MBSuccess) {
    value = node.getResponseBuffer(0);
```

```
    //Serial.println(value);
    return value;
  }
  return -1;
}
```

LOGBOOK

It is important to note that we made the whole Prospect proposal report rapidly by means of thorough consultation with our ATC panel. According to their suggestions, we updated our report throughout the semester.

In the logbook, we included all the meetings we attended with our ATC panel. Again, we included some of the major meetings we had among us.

FYDP(P)
Timeline: Spring-2022

Date	Place	Attendee	Summary of the meeting	Responsi-ble	Comment by ATC	link	About
10 Feb 22 , Thu	Online meeting	Mohsin sir	We introduced with Mohsin sir and sir gave a short brief of FYDP-P	Everyone	-	gle.com/dqc	Introductio n
16 Feb 22 , Wed	Online meeting	Mohsin sir	To find a suitable topic	Everyone	Suggested research more and find a topic	meet.goog le.com/dq d-uakt-jhc	Topic selection
21 Feb 22 , Mon	Online meeting	Taiyeb Sir	We discussed about our research for finding topic	Everyone	-	meet.goog le.com/dq d-uakt-jhc	Topic selection
22 Feb 22 , Tue	Online meeting	Mohsin sir	Discussed everyone's gathered ideas about E-Waste, UAV, Cansat and finally chose a Cansat based Project	Everyone	Recommend gather more ideas and make a project using both Cansat and UAV	meet.goog le.com/dq d-uakt-jhc	Topic selection
25 Feb 22, Fri	Online meeting	All members of fydp	Discussed about Cansat and UAV	Everyone	-	Meet - Group-5 FYDP :3 (google.co m)	Cansat
28 Feb 22 , Mon	Online meeting	Mohsin sir	Sir send us some papers about Cansat, we discussed about some limitations of UAV and Cansat	Everyone	Suggested to refinement and finalize our topic	meet.goog le.com/dq d-uakt-jhc	Topic selection
1 Mar 22 , Tue	Offline meeting	Mohsin sir	Finalize our topic using Rover Bot	Everyone	Recommend to start our further tasks and take preparation for	meet.goog le.com/dq	Topic selection

					presentation	d-uakt-jhc	
3 Mar 22, Thu	Online meeting	All members of fydp	Researched on Agricultural Project Papers	Everyone	-	Meet - Group-5 FYDP :3 (google.com)	Rover Bot
6 Mar, Sun	Online Meeting	All members of fydp	Discussed on Presentation and Prepared Slides	Everyone	-	Meet - Group-5 FYDP :3 (google.com)	Presentation
7 Mar 22 , Mon	Online meeting	Mohsin sir	We discussed about our presentation ideas and slides	Everyone	Gave us important feedback regarding slides and gave advice about presentation	meet.google.com/dqd-uakt-jhc	Presentation
8 Mar 22, Tue	Online Meeting	All members of fydp	Prepared for Presentation	Everyone	-		Presentation
9 Mar 22, Wed	Online Presentation	All ATC Members	Presentation	Everyone	Got Feedback for multiple design approach	https://meet.google.com/aic-ammn-vnd	Presentation
18 Mar 22, Fri	Online Meeting	All members of fydp	Made a draft concept Note and discussed on Budget	Everyone	-		Concept Note
21 Mar 22, Mon	Online meeting	Mohsin sir, Taiyeb Sir	Discussed about concept note	Everyone	Got Feedback about concept Note, we need to add Literature review, Literature Gap, Current & Future relevancy of the project, summary table of functional & Non functional work, Gnatt chart, budget, IEEE Citation format, improvising applicable codes, cites references	meet.google.com/dqd-uakt-jhc	Concept Note
26 Mar 22, Sat	Online Meeting	All members of fydp	Discussed on choosing components and preparing plans and made a budget	Everyone	-	Meet - Group-5 FYDP :3 (google.com)	Concept Note
28 Mar 22, Mon	Online meeting	Taiyeb Sir	Specifying land area, budget, log book	Everyone	-	meet.google.com/dqd-uakt-jhc	Concept Note & Log book
29 Mar 22, Mon	Offline meeting	Mohsin sir	Requirements, Crop selections, land area specifications,	Everyone		meet.google.com/dqd-uakt-jhc	Concept Note and Project Proposal
4 Apr 22, Mon	Online meeting	Mohsin sir	How to write collaboration letter and discussed about Prototype	Everyone	-	meet.google.com/dqd-uakt-jhc	Collaboration Letter
9 Apr 22,	Online	All	Worked on project	Everyone	-	Meet -	Project

Sat	meeting	members of fydp	proposal			Group-5 FYDP :3 (google.com)	Proposal
15 Apr 22, Fri	Online meeting	All members of fydp	Preparing slides for mock presentation	Everyone	-	Meet - Group-5 FYDP :3 (google.com)	Mock Presentation
18 Apr 22, Mon	Online meeting	Taiyeb sir	-	Tahmid Zarif Ul Hoq sayor	Got feedback about project proposal	meet.google.com/dqd-uakt-jhc	Project Proposal
20 Apr 22 , Wed	Online meeting	All members of fydp	Prepared for mock presentation	Everyone	-	Meet - Group-5 FYDP :3 (google.com)	Mock Presentation
21 Apr 22, Thu	Online Meeting	Mohsin Sir, Taiyeb Sir	-	Everyone	Got suggestion about slides and some key points of presentation	meet.google.com/dqd-uakt-jhc	Mock Presentation
23 Apr 22, Sat	Online Meeting	Everyone	Preparing Slides for Mock Presentation and practicing presentation	Everyone	-	Meet - Group-5 FYDP :3 (google.com)	Mock Presentation
25 Apr 22, Mon	Online Meeting	Mohsin Sir, Taiyeb Sir	Presentation	Everyone	Got feedback about our presenting criteria and some mistakes of slides	meet.google.com/dqd-uakt-jhc	Mock Presentation
26 Apr 22, Tues	Online Meeting	All members of Fydp	Preparing Final presentation slides and practicing Presentation	Everyone	-	Meet - Group-5 FYDP :3 (google.com)	Final Presentation

FYDP(D)
Timeline: Summer-2022

Date	Place	Attendee	Summary	Responsible	Comment by ATC	About
13 June 2022, Monday	Meeting Room	Mohsin Sir, Taiyeb Sir	We discussed about our Preparation of simulation works and what softwares would be used for our design	Everyone	-	Simulation
15 June 2022, Wed	Google Meet	-	Did research on simulation	Everyone	-	Simulation
16 June 2022, Thu	Google Meet	-	Did research on simulation	Everyone	-	Simulation
20 June 2022, Mon	Meeting Room	Mohsin Sir, Taiyeb Sir	Discussed our progress of simulation. Gazibo, MATLAB, Proteus will be used and Taiyeb sir suggested us to go through with Mathworks	Everyone	-	Simulation
21 June, 2022 Tues	Google Meet	-	Simulation work	Everyone	-	Slide and Simulation
25 June, 2022 Sun	Google Meet	-	Prepared slide	Everyone	-	Slide
27 June 2022, Mon	Meeting Room	Mohsin Sir, Taiyeb Sir	Sir checked our progress presentation slide, gave feedback and advised us to change some components and update the slide and what would be the topic of our presentation	Everyone	Got suggestion about slides and some key points of presentation	Slide and Presentation
29 June, 2022 wed	Google Meet	-	Updated slides and prepared for presentation	Everyone	-	Slide
30 June 2022 Thu	50303	All ATC members	Presentation	Everyone	-	Presentation
19 July, 2022 Tues	Physical Meeting	-	Purchased components	Everyone	-	Hardware components
20 july 2022 Wed	Meeting Room	Mohsin sir	We informed sir about our hardware components that we will purchase and gave update about simulation progress	Everyone	-	Hardware components, simulation
26 July, 2022 Tues	Google Meet	-	Discussed about components	Everyone	-	Hardware component
28 July, 2022 Thu	Physical Meeting	-	Discussed about simulation	Everyone	-	Simulation
1 aug 2022 Mon	Meeting Room	Mohsin Sir, Taiyeb sir, Ehsan Sir	Show our 3D environment, we will use Blender instead of Gazebo and sir wanted to know the update of our	Everyone	-	Simulation and report

			hardware components also talked about the report			
3 Aug 2022, Wed	Google Meet	-	Prepared report	Everyone	-	Report
7 Aug 2022, Sun	Google Meet	-	Updated simulation simulation and report	Everyone	-	Simulation and Report
14 aug, 2022 Sun	Google Meet	-	Discussed about Report	Everyone	-	Report
16 aug 2022 Tues	Meeting Room	Mohsin sir	Checked out simulation	Bristy Das	-	Simulation
17 Aug 2022, wed	Physical Meeting	-	Discussed about report and simulation	Everyone	-	Report and Simulation
20 Aug 2022, sun	Google Meet	-	Prepared Slide and updated simulation	Everyone	-	Simulation and Slide
25 aug, 2022 thu	Physical Meeting	-	Discussed about report and updated slide	Everyone	-	Slide and Presentation
29 aug 2022 Monday	Meeting Room	Taiyeb Sir, Ehsan Sir	Gave feedback of our slide and advised us to change some specifications on our slide, need to change ethical consideration, conclusion part, change in analyze part also other key points and what should be the focused area during our presentation	Everyone	Suggested to refine and finalize our slide. Gave us important feedback regarding slides and gave advice about presentation	Slide and presentation
31 aug 2022, wed	Google Meet	-	Prepared for presentation and updated slides	Everyone	-	Presentation
1sept 2022	30403	All ATC Members	Final Presentation	Everyone	-	Presentation

FYDP(C)
Timeline: Fall-2022

Date	Place	Attendee	Summary	Responsible	Comment by ATC	About
5 Oct, 2022 Wed	Meeting Room	Mohsin Sir, Taiyeb Sir, Ehsan Sir	Discuss about how to build up our ideas	All	-	-
8 Oct, 2022 Sat	Online	-	Making budget and ordered components	All	-	-
9 Oct, 2022 Sun	Online	-	Learning image processing and ML	All	-	-
12 Oct, 2022 Wed	Offline	-	Learning image processing and ML	All	-	-
16 Oct, 2022 Sun	Offline	-	Learning image processing and ML	All	-	-
19 Oct, 2022 Wed	Meeting Room	Mohsin Sir	Gave update about our progress to prepare prototype	All	-	-
20 Oct, 2022 Thu	50101	-	Preparing Arm	All	-	-
22 Oct, 2022 Sat	50101	-	Preparing Arm and Chassis	All	-	-
23 Oct, 2022 Sun	Online	-	Preparing Slides	All	-	-
24 Oct, 2022 Mon	Online	Mohsin Sir	Slides and progress presentation	All	Gave feedback about slides	Progress Presentation
26 Oct, 2022 Wed	50101	-	Making some video of the prototype	All	-	Progress Presentation
2 Nov, 2022 Wed	Online	-	Modify slides	All	-	Progress Presentation
3 Nov, 2022 Thu	Conference Room	-	-	All	-	Progress Presentation
15 Nov, 2022 Tue	Meeting Room	Mohsin Sir, Taiyeb Sir	About Sher-e-Bangla visit	All	Gave stakeholders information	-
17 Nov, 2022 Thu	50101	-	Rover testing	All	-	-
20 Nov, 2022 Sun	50101	-	Rover testing	All	-	-
21 Nov, 2022 Mon	50101	-	Rover testing	All	-	-
23 Nov, 2022 Wed	Sher-e-Bangla Agricultural University	Mohsin Sir	Rover testing	All	-	-
30 Nov, 2022 Wed	50101	-	Modifying Arm with connect blades in the claws	All	-	-

3 Dec, 2022 Sat	50101	-	Starting NPK testing	All	-	-
4 Dec, 2022 Sun	Online	-	Making slides and report	All	-	-
5 Dec, 2022 Mon	Online	-	Making slides and report	All	-	-
7 Dec, 2022 Wed	Online Meeting	Mohsin Sir, Ehsan Sir	We gave our final update of our work and presentation slide to our ATC and	All	-	Presentation
8 Dec, 2022 Thu	50101	-	NPK Testing	All	-	-
11 Dec, 2022 Sun	50101	-	NPK Testing	All	-	-
13 Dec, 2022 Tue	50101	-	Recheck our prototype And update the slide	All	-	-
14 Dec, 2022 Wed	Online	Mohsin Sir, Taiyeb Sir, Ehsan Sir	Gave mock presentation	All	Gave Valuable feedback regarding slides	Mock Presentation
15 Dec, 2022 Thu	Conference Room	-	We presented our final presentation and showcasing our prototype	All		Final Presentation

ASSESSMENT GUIDELINES for FACULTY

[The following assessment guideline is for faculty ONLY. **This portion is not applicable for students**.]

ASSESSMENTS TOOL and CO ASSESSMENTS GUIDELINES

	Distribution of assessment points among various COs assessed in different semesters														
PO →	l	c	f	g	c	b	d	c	e	l	k	k	h	i	j
CO →	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	CO 7	CO 8	CO 9	CO 10	CO 11	CO 12	CO 13	CO 14	CO 15
EEE 400C/ ECE 402C (Out of 100)							30	24	6	4	4	6	7	7	12
Project Final Report/ Project Progress Report							x	x	x	x	x	x	x		x
Demonstration of working prototype							x								x
Progress Presentation/ Final Presentation								x			x				
Peer-evaluation*													x	x	
Instructor's Assessment*													x	x	
Demonstration at FYDP Showcase								x							x

Note: The star (*) marked deliverables/skills will be evaluated at various stages of the project.

MAPPING of CO-PO-TAXONOMY DOMAIN & LEVEL- DELIVERY-ASSESMENT TOOL

Sl.	**CO Description**	**PO**	**Bloom's Taxonomy Domain/Level**	**Assessment Tools**
CO7	**Evaluate** the performance of the developed solution with respect to the given	d	Cognitive/ Evaluate	• Demonstration of working prototype

	specifications, requirements and standards			• Project Progress Report on working prototype
CO8	**Complete** the final design and development of the solution with necessary adjustment based on performance evaluation	c	Cognitive/ Create	• Project Final Report • Final Presentation • Demonstration at FYDP Showcase
CO9	**Use** modern engineering and IT tools to design, develop and validate the solution	e	Cognitive/ Understand, Psychomotor/ Precision	• Project Final Report
CO10	**Conduct** independent research, literature survey and learning of new technologies and concepts as appropriate to design, develop and validate the solution	l	Cognitive/ Apply	• Project Final Report
CO11**	**Demonstrate** project management skill in various stages of developing the solution of engineering design project	k	Cognitive/ Apply Affective/ Valuing	• Project Final Report • Project Progress presentation at various stages
CO12	**Perform** cost-benefit and economic analysis of the solution	k	Cognitive/ Apply	• Project Final Report
CO13	**Apply** ethical considerations and professional responsibilities in designing the solution and throughout the project development phases	h	Cognitive/ Apply Affective/ Valuing	• Peer-evaluation, • Instructor’s Assessment • Final Report
CO14**	**Perform** effectively as an individual and as a team member for successfully completion of the project	i	Affective/ Characterization	• Peer-evaluation • Instructor’s Assessment
CO15**	**Communicate** effectively through writings, journals, technical reports, deliverables, presentations and verbal communication as appropriate	j	Cognitive/ Understand Psychomotor/ Precision Affective/ Valuing	• Project Final Report • Progress Presentations,

	at various stages of project development			• Final Presentation • Demonstration at FYDP Showcase

Note: The double star (**) marked CO will be assessed at various stages of the project through indirect deliverables.