DISEASE DETECTION SYSTEM OF MANGO LEAVES

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

Department of Electrical and Electronic Engineering
Brac University
December 2023

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December 2023

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.

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Approval

The Final Year Design Project (FYDP) titled "Disease Detection System of Mango Leaves" submitted by

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of Fall 2023 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of B.Sc in EEE on 14th December 2023.

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Ethics Statement

For our project “Disease Detection System of Mango Leaves,” we have tried our best to fulfill all the requirements of the Final Year Design Project. To complete the project report we have used information from a huge number of journals, articles, and research papers by summarizing and citing accordingly. By using the plagiarism detector, we get the index result of this report to be 16%.

Abstract/ Executive Summary

This work aims to design and implement a disease detection system for mango leaves. We have proposed two design approaches for the disease detection system for mango leaves. From these two design approaches, we have performed simulation and analysis to get the best design approach. The best design approach includes a pest disease detection system with a rover body. We have trained our model to detect 9 types of pest diseases in mango leaves with the help of available datasets. We have performed the test of the pest disease detection system with the rover body in a particular field. In that field, we have got 3 diseases that were detected by our rover body system successfully. Our pest disease detection system can easily expand up to the required height for the particular testing field and can detect successfully the pest diseases of the mango leaves which completes our entire project.

Keywords: rover, scissor lift, mango leaves pest disease detection, image processing, agricultural robotics, agriculture

Dedication

We want to dedicate our work to our parents, who have encouraged and supported us in our project so that we can finish the project successfully. We also want to dedicate our work to our ATC panel members who guided us throughout this journey. Their unwavering motivation has kept us on track and inspired us to achieve our goals for this project. Besides, we want to dedicate this work to every person who has helped us to implement our project till now.

Acknowledgment

We would like to express our gratitude towards our ATC panel members for their unwavering support and guidance. We also want to thank our Professor, Dr. Md. Khalilur Rahman (Associate Professor, Department of CSE Brac University), for his invaluable help in constructing the rover body. We extend our gratitude to Professor, Abu Noman Faruq Ahmmed (Professor, Sher-e-Bangla Agricultural University) and Lead Agriculturalist Shamiran Biswas (Dr. Chashi app) for allowing us to gain knowledge about mango leaf diseases. We would also like to thank Engr. Golam Mowla for giving us permission to work on his land and collect the data and parameters that we needed for our project.

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Chapter 1: Introduction- [CO1, CO2, CO10]

1.1 Introduction

Agriculture is a very important and crucial sector in Bangladesh. In this sector, the fruit production rate increases each year. Bangladesh is now among the largest tenth tropical fruit-producing countries in the world. Among all the growing fruits in Bangladesh, mango is the most highly valued and highly produced fruit. However, due to pest disease on mango trees, it costs money to buy pesticides, and farmers use more pesticides than necessary, as they are unaware. This problem can create harmful effects on human health and the environment and decrease the crop yield of mango crops. Designing a disease detection system is crucial so that farmers use the required amount of pesticides, increase the crop yield of mango trees, and decrease the harmful effects on humans and the environment.

1.1.1 Problem Statement

Mango is a vital fruit crop in Bangladesh that significantly contributes to the economy and the livelihoods of millions of people. The majority of the production comes from small-scale farmers, and it is one of the most popular and high-value fruit crops grown in the country. Mango cultivation occurs in almost all parts of Bangladesh, ranking seventh among mango-producing countries globally [1]. In Rajshahi and Chapainawabganj districts, 85% of the population is directly or indirectly dependent on mango[2]. Bangladesh produces around 1.5 million tonnes of mangoes annually, with a market value of Tk10,000 crore[1]. In 2021, farmers produced 25 lakh tonnes of mangoes, and in 2022, the production was 23.5 lakh tonnes [3]. According to the Department of Agricultural Extension (DAE), mango exports reached 1,737.83 tonnes in 2022 from 791 tonnes in 2021, more than doubled in a year [3].

Table 1: Ranking of Mango Production [4]

SL. No.	Problem items	PCI	Rank order
1	Insect and disease infestation	429	1st
2	Dropping of fruits and flowers	409	2nd
3	Scarcity of better varieties/ Seedling/ grafts etc	387	3rd
4	Climate change	276	4th
5	Lack of modern technology	193	5th

Table adapted from [4]

Early detection and treatment are therefore necessary to stop the spread of these insects, pests, and diseases and lessen the harm they cause to crops. Additionally, early treatment can be more efficient, lowering the number of pesticides and other chemicals needed to control the disease. Nevertheless, insect pests and diseases in mango crops pose a significant threat to the health and productivity of the crops. In [4], it was mentioned that insect and disease infestation is ranked as 1st order problem for mango production, and this is also demonstrated in Table 1. However, traditional techniques for monitoring and spotting pests and diseases can be both time-consuming and labor-intensive. Thus, developing a system for detecting diseases might significantly increase its effectiveness and accuracy, leading to better crop management techniques and higher yields.

1.1.2 Background Study

Due to the attack of insect pests and diseases, the production of mango crops has decreased in Bangladesh. This loss of production is seen everywhere, not only in Bangladesh but also in other countries. Insect pests can also act as vectors of plant diseases, such as powdery mildew and anthracnose, which can spread rapidly to other mango trees and crops[5],[6]. This causes economic losses to the farmers and other stakeholders and also affects the country's food security. To control insect pest infestations, farmers use pesticides. According to [4], the majority of the farmers, or (69%) respondents, believed that growing mangos required higher pesticide use than growing other crops. However, most pesticides harm the environment and human health and may increase production costs.

An automated disease detection system can detect and control the disease that can damage the mango crops. The system can increase the yield and the quality of the mango crops. To control the disease of the mango leaves, high doses of pesticides, which are expensive and harmful to the environment and humans, are used. With a disease detection system, we can detect diseases early and take action to control them, which can reduce the excessive use of pesticides [7]. In previous times, the detection of diseases in the mango crops was done manually by the farmers. Still, image processing and machine learning tools are currently used to automate the monitoring system.

Using deep learning techniques, several crop diseases were identified and were successful. In case mango leaves detection using CNN was done, and this model was trained with 100 images per class, there were six classes, and it was seen by testing 600 images that the testing accuracy was 96.67% [8]. The success rate for this monitoring system is huge. It reduces the labor cost and the usage of pesticides, which is why this method is used in many countries for wheat, tomatoes, and cucumbers. In the future, the accuracy will be improved with the advancement of models. A study shows a plant disease detection system was built using a pre-trained deep learning model called AlexNet. The system was designed to identify abnormalities and patterns associated with fungal, bacterial, or viral diseases in grape and mango leaves. The model was trained with 1266 mango leaf images from real-life cultivation land and 7,222 grape leaves from the Plant village. The study results showed that the proposed model achieved an accuracy of 99.03% in detecting previously unseen grape leaves and 89% in detecting insect pests and diseases in mango leaves. To prevent the harmful effects of infectious diseases and economic loss, this low-cost disease detection system on a smartphone can help farmers detect early stapled abnormalities in plants [9].

1.1.3 Literature Gap

Most research focuses on broad disease categories; however, diverse species call for diverse monitoring strategies and models. A research gap exists in evaluating these systems' practical deployment in real-world scenarios since their performance varies between controlled laboratory settings and the actual world. There is a lack of discussion on the challenges of using algorithms for disease detection. The studies mention challenges with image acquisition, but there is no discussion on data quality issues, model interpretability, and generalizability. The datasets from research papers do not show whether they represent the real-life scenario. The studies also did not address the cost-effectiveness and usability issues if we use machine learning models to detect diseases on mango leaves [9], [10].

1.1.4 Relevance to Current and Future Industry

In the current industry, some companies offer automated insect and pest detection systems. The following two are the companies:

1. **Xarvio Digital Farming Solutions** is a BASF brand that uses machine learning, image recognition technology, and advanced crop and disease models to provide accurate and timely recommendations, enable farmers to track crop growth stages, and detect pest and disease infestations [11].

2. **Taranis** is a system that uses deep-learning technology and high-speed crewless aerial vehicles (UAVs) that solve farmers' problem of losing crop yield to 30-40% due to crop diseases, insects, and weeds [12].

3. **Dr.chashi** is an app focused on agriculture of Bangladesh which helps the farmers to detect the diseases of the fruits and vegetables and gives them solutions to reduce the infections of the diseases. It uses AI technology which has 92% accuracy[53].

4. **Plantix** is an AI-based company that was founded in 2015 for the detection of diseases of fruits and vegetables and gives them solutions [54].

The companies mentioned above are using machine learning and deep-learning technology to detect and identify the presence of insect- pests, and diseases and also provide accurate and timely recommendations to reduce problems, diseases, and other threats to crops.

1.2 Objectives, Requirements, Specification, and Constant

1.2.1. Objectives

Our objective is to design a disease detection system for the mango leaves that will identify the type of disease on the mango leaves and give suggestions for remedies according to the diseases.

1.2.2 Functional and Nonfunctional Requirements

Functional Requirements:

- Detection of the diseases from the mango leaves.
- After detecting diseases on mango leaves, identify the type of the diseases.

Non-Functional requirements:

- Gives solutions to the users on how to prevent the spread of diseases.
- The rover can travel to any place as the wheels are strong and well-designed.

1.2.2 Specifications

- The system can reach a maximum height of 7 feet.
- The rover's speed on a plain surface is around 40 ms^{-1} and on an uneven surface is 20 ms^{-1}.
- The weight of the rover is around 50 kg.
- The system can detect nine types of diseases on mango leaves. We have trained the system with 9 types of disease detection. But in our own dataset, there are 3 types of pest diseases that we have detected and trained in the model.

The diseases that the system will detect are:

1. Anthracnose
2. Bacterial Canker
3. Cutting Weevil
4. Die Back
5. Gall Midge
6. Powdery Mildew
7. Sooty mold
8. Honey dew
9. Scale insect

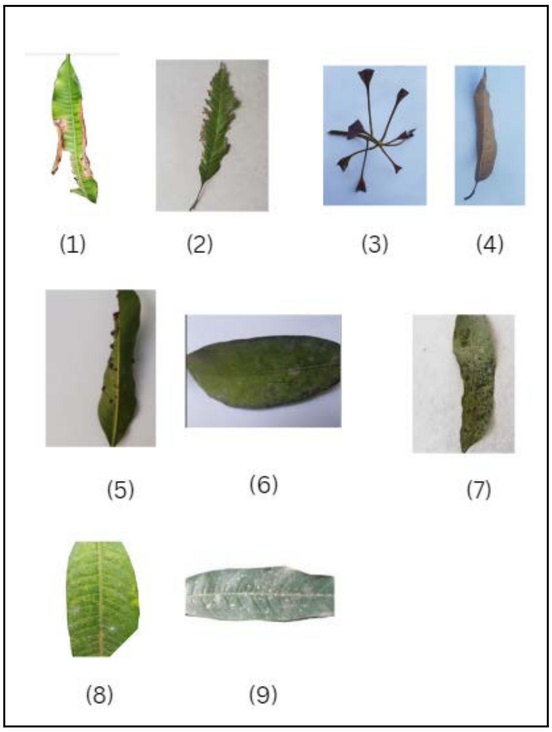


Figure 1:Diseases on mango leaves that our system will detect [10]

1.2.3 Technical and Non-technical consideration and constraint in the design process

Constraints:

- **Weather issue:** In gloomy and rainy weather, the system may have problems performing well due to capturing the pictures of the leaves.
- **Light:** Due to insufficient sunlight, it is hard to capture images through the camera.
- **Dust:** The dust on the outer surface of the camera can obstruct the camera from capturing images of the mango leaves.
- **Burry image:** Due to the system's movement, images could be blurry and might hamper the detection process.

1.2.4 Applicable compliance, standards, and codes

Table 2: Applicable compliance, standards, and codes

SL	Element/Product/System	Name of Standards
1	LoRa module	IEEE standard code P1451.5.5 defines the smart sensor interface with the LoRa.This standard code maintains higher accuracy, interoperability, and harmonized performance of the LoRa system [13].
2	Machine Learning	The legitimacy of machine learning (ML) for safety certification is still up for debate despite its growing

		importance in modern car services like driver assistance and autonomous driving. We examine what may be done to limit the impact of machine learning in software on the ISO 26262 safety lifecycle. We then present a series of suggestions for modernizing the standard to include machine learning [14].
3.	Camera	IEEE 1858-2016 quantifies the performance of the image with the camera-equipped phone devices[15].

1.3 Systematic Overview/summary of the Proposed Project

Farmers use a lot of pesticides for mango leaves and pest diseases as a result they spend a lot of money, health hazards occur to humans, and also harmful to the environment. We have designed and implemented a pest disease detection system. The pest disease detection system will detect the pest diseases of the mango leaves and notify the farmers regarding the remedies for the pest diseases. This system will help the farmers to prevent the pest diseases of the mango leaves and early detection can help to use fewer pesticides and increase the mango crop yield.

1.4 Conclusion

To conclude, this chapter includes a discussion of the problem statement and background study of the project titled ‘Disease Detection System for Mango Leaves.’ To find a complex engineering problem, we had to go through several literature reviews, and from there, we had to find the literature gaps, which are also documented in this chapter. Along with that, the relevance of the project to the current or future industry is also presented here. The major part of the project is the objective, requirements, specifications, and constraints identified and stated with explanations.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction

This section includes the multiple design approaches that we have chosen for our problem solution and their description, analysis, and comparison among the multiple design approaches.

2.2 Identify multiple design approaches

For our mango leaf disease problem, we have two design approaches for the solution. Design Approach 1 (Drone System) and Design Approach 2 (Rover System).

1. **Drone system**: We use drones to capture pictures of the diseased mango leaves. Since it is an off-board system, we insert all the pictures from the SSD into the laptop to detect the pest disease.

2. **Rover system:** With this system, the pictures of the diseased mango leaves are taken with the help of a rover. The mobile phone is attached to the rover's body to capture pictures of the diseased mango leaves. We are taking pictures of the diseased mango leaves by controlling the phone camera with the help of the laptop that we have selected for our pest disease detection. The pictures are automatically saved on our laptop as we take pictures of the diseased mango leaves with the phone attached to the rover body.

2.3 Describe multiple design approaches

Design Approach 1:

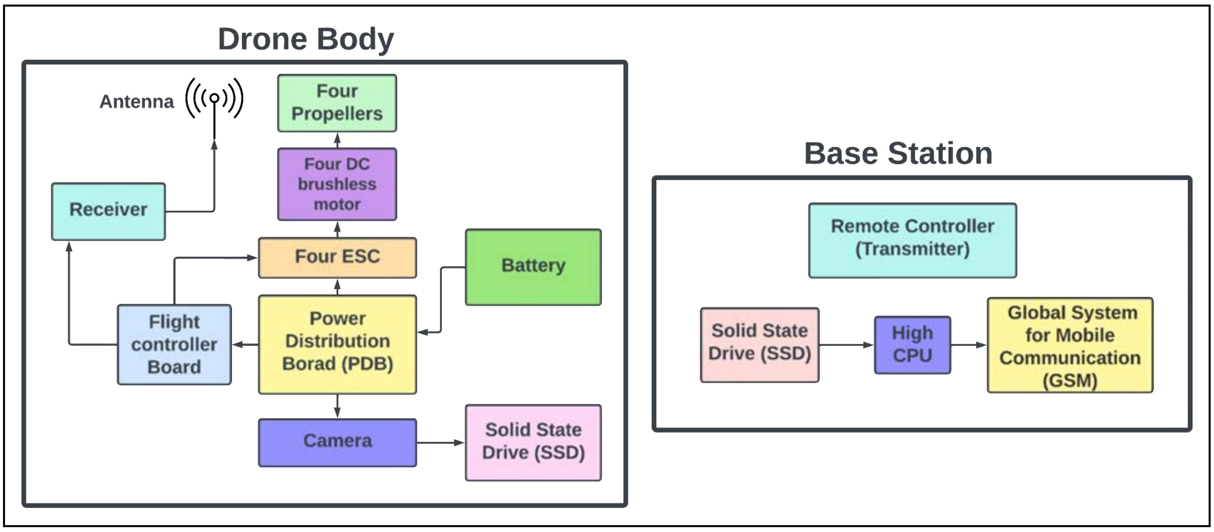


Figure 2:System Level Diagram of Design Approach 1

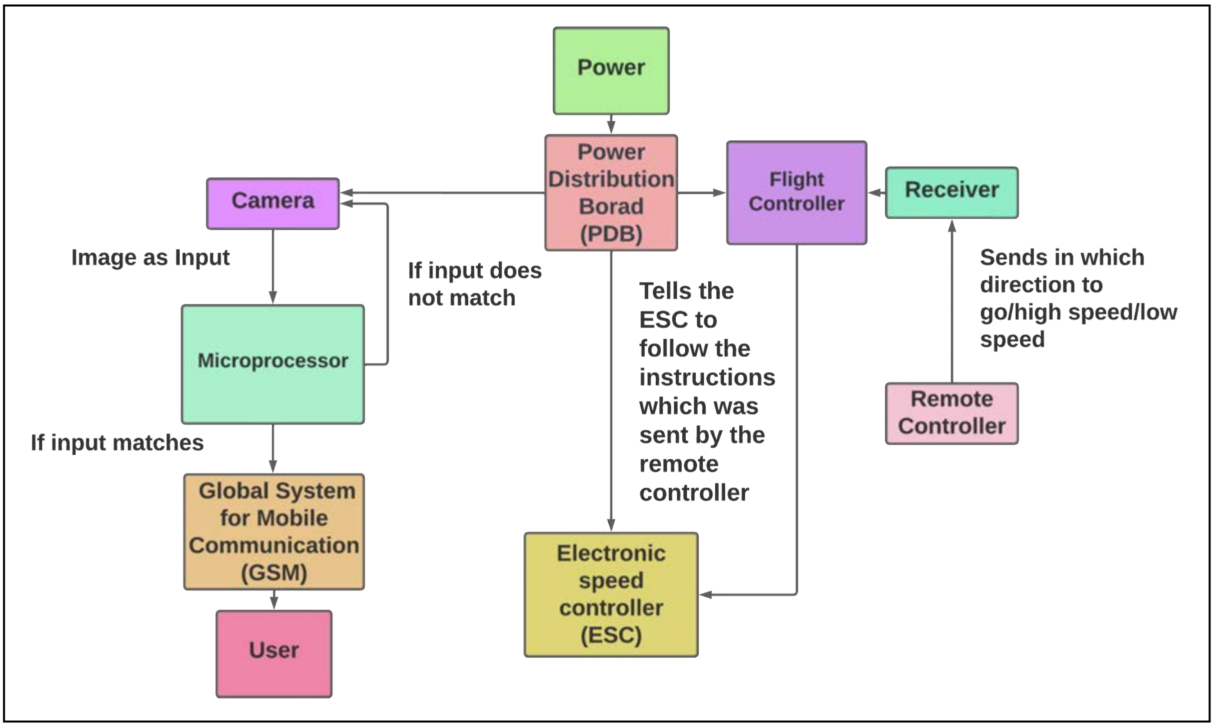


Figure 3: Block Diagram of Design Approach 1

Fig. 2. demonstrates the System Level Diagram of Design Approach 1. This design consists of two parts. Firstly, the drone body and then the base station. The drone body battery supplies power to the Power Distribution Board (PDB). Then, this PDB distributes the power to the camera, flight controller board, and the four Electronic Speed Controllers (ESC). The remote controller in the base station is responsible for directing and controlling the speed and the direction of the drone. The remote controller transmits instructions to the drone's receiver

to control the drone. Then, the receiver will send the instructions to the flight controller, which operates the ESC based on the instructions to control the movements of the four brushless motors. The four brushless motors are responsible for spinning the four propellers. Additionally, the camera takes pictures of the mango leaves and stores them in the Solid State Drive (SSD). Since this is an off-board system, we manually insert the SSD in the high CPU where the user places the base station. The model will match the images with trained images, as shown in Fig. 3. The high CPU is connected to a GSM module. If the pictures match, then with the help of the GSM module, the users will be notified about disease detection and receive suggestions for preventing the diseases.

Design Approach 2:

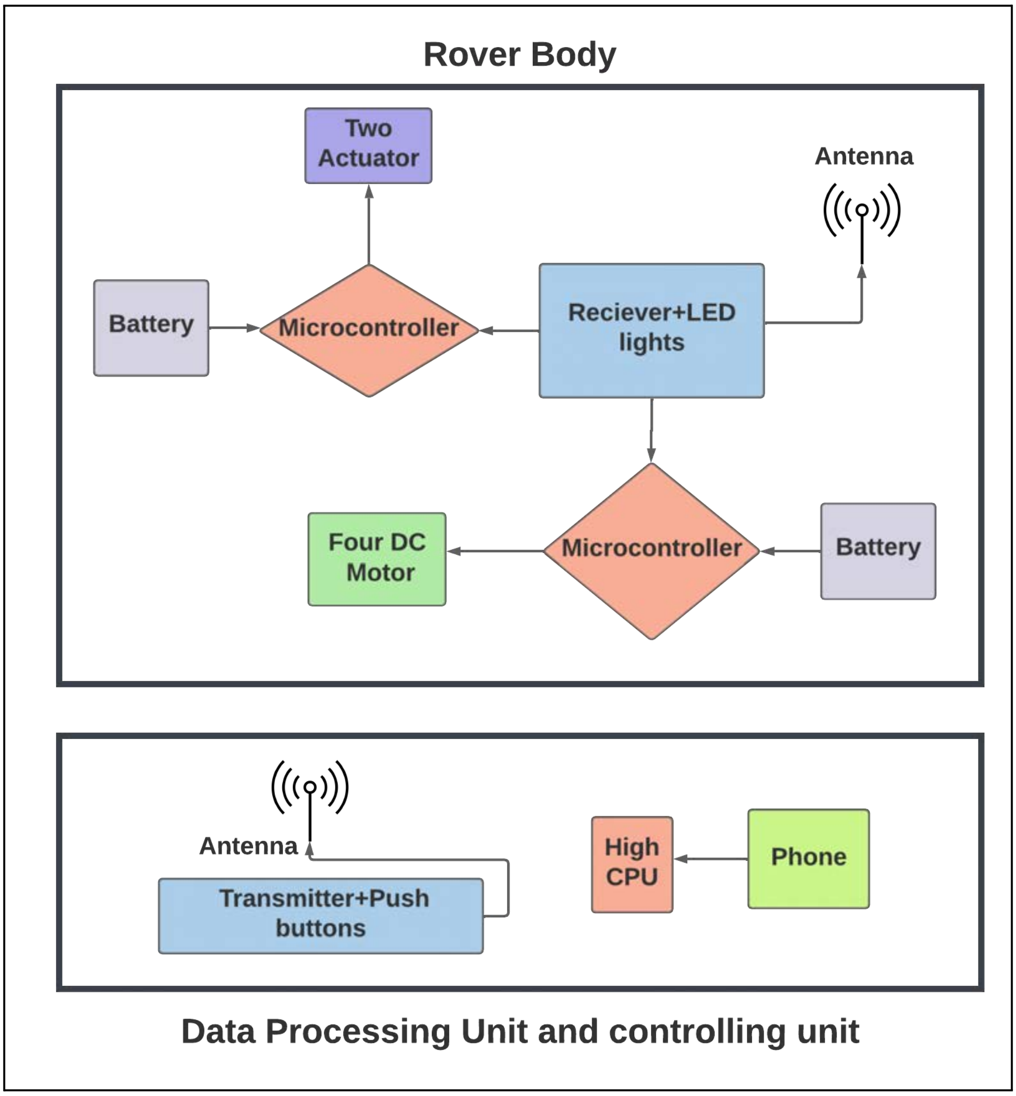


Figure 4: System Level diagram of Design Approach 2

Fig. 4. System Level diagram of Design Approach 2. This design consists of three parts. Firstly, the control unit which is required to control the whole system. The control unit includes the push buttons and transmitter for controlling the two actuators and motor wheels

which are connected by the microcontrollers of the rover body. Secondly, we have the rover body. Here, the receiver with LED lights is connected to the two microcontrollers. One microcontroller is connected to the two actuators and another to the four DC motors. These four DC motors are connected to the four wheels of the rover.

On the other hand, a primary concern we addressed in our system is the necessity to reach the height of the mango trees, typically around 8 feet. To solve this problem, we have integrated a scissor lift as a ladder onto the rover body, allowing the camera to ascend to the required height to capture images of the mango leaves. Hence, the actuator is required for the scissor lift. Thirdly, the data processing unit will process the input images and generate the output through the laptop. This unit consists of a phone camera controlled by the laptop. We will use the Python deep learning model for this data processing. This model ensures the system provides accurate outputs, which will notify the user. The figure below represents our software's algorithm.

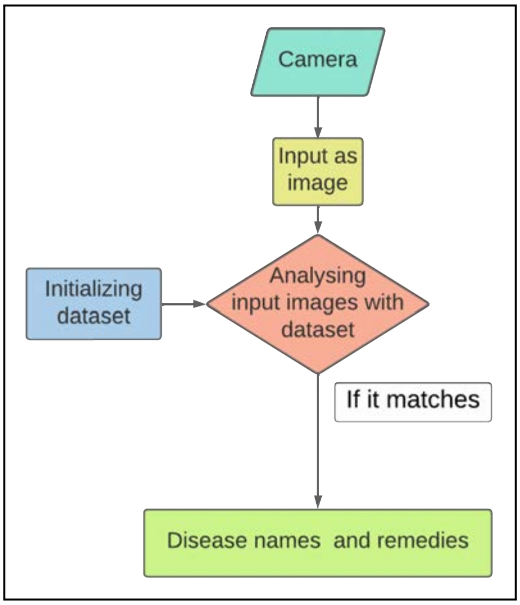


Figure 5: Algorithm of Design Approach 1 and Design Approach 2.

In this software part, as shown in Figure 5 we have developed a deep-learning model named ResNet-18, also known as a Residual Network. We have used the same algorithm for both of our designs. The ResNet-18 model is trained using the datasets we have made on our own and found from Kaggle.

For deep learning, we always face the vanishing gradient, a challenge encountered in neural networks, particularly in deep learning models, where gradients diminish or "vanish" as they propagate backward through the network during the training process.

However, Resnet, which is a residual network, is also a deep-learning model, but it uses the skip connection. In the case of a regular Deep learning network, it is directly connected to each of the neurons and depends on the previous layer which is given in Figure 6.

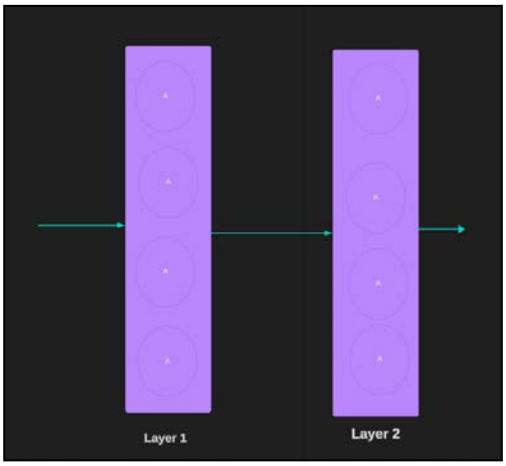


Figure 6: Deep learning network

But in terms of skipped connection we actually used the algorithm given in Figure 7.

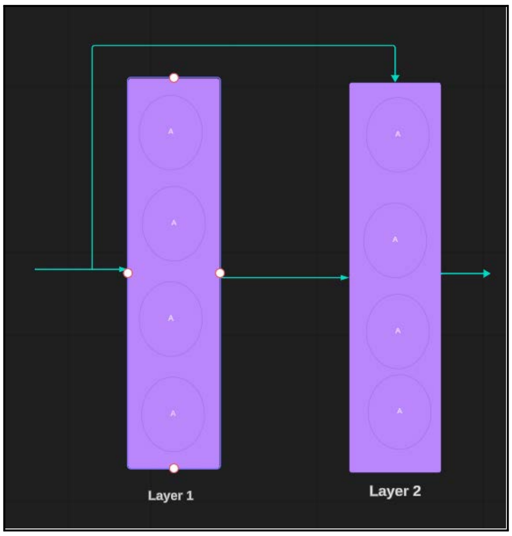


Figure 7: Residual network

As a result layer 2 depends on the original input. Using this skipped concept, ResNet can solve the vanishing gradient issue. Because our goal is to detect the images so that it will help us to compare the original image with the output images.

Initially, the camera captures the images of mango leaves. These images are sent to the ResNet-18 model. The model then attempts to compare these input images with the trained images. Suppose there is a match between the input images and the trained images. In that case, the model identifies the disease and provides an output confirming the detection along with the name of the disease and suggests the remedies required to prevent the disease. The model does not identify the disease if there is no match.

2.4 Analysis of multiple design approaches

Design Analysis:

Table 3: Design Analysis of Design Approach 1 and Design Approach 2

Comparison topic	Design Approach 1	Design Approach 2
Accuracy	62.97%	93.37%
Recall	69%	93.47%
Precision	62.26%	94%
F1 score	61.73%	92.91%
Type	Drone system	Rover system
Cost	BDT 1,27,000 (approx)	BDT 71000 (approx)
Power given by battery	4.18 W per hour	525.28 W per hour
Method of analyzing data	Storing the images in SSD and detection using ResNet18	controlling phone using laptop to capture images and detection using ResNet18
Method of taking input	Using camera from certain altitude and angle	Using camera by moving alongside the plant
Controlling system	Flight control based wireless system	Movement control based wireless system
Flexibility	High flexibility with mobility	High flexibility with camera placement
Scalability	High due to comprehensive monitoring	Can be easily replicated into multiple rovers
Safety	Not that safe due to the flying nature of drones	More safer than design approach 2 but still precaution is required due to ground movement.

Quantitative Assessment:

Table 4: Quantitative Assessment of Design Approach 1 and Design Approach 2

Criteria	Weight (%)	Design 1 (out of 5)	Ratio	Ratio * Weight	Design 2 (out of 5)	Ratio	Ratio * Weight
Accuracy	20	2	0.4	8	4.5	0.9	18
Expense	20	3	0.6	12	4	0.8	16
Eco-friendly	15	4	0.8	12	3	0.6	9
Usability	15	3	0.6	9	4	0.8	12
Maintenance	20	3	0.6	12	4	0.8	16
Durability	10	3	0.6	6	4	0.8	8
Result:	100			59			79

Scoring is done by the group members.

2.5 Conclusion

By analyzing the two design approaches, we can sum up that design 1 is the drone body that requires taking pictures from a higher altitude and distance and is more prone to atmospheric conditions. As a result, the pictures are hazy, and the result of the detection of pest diseases of mango leaves with the help of a drone is very low compared to the rover system as the drone system takes pictures from a very small distance apart and as it is on the ground it has a stable movement. Design 1 requires very little power as it is a small device rather than design 2. Design 2 consists of very high torque motors for rover movement and expanding and shrinking of the scissor lift, which consumes much more power than design 1.

From the design analysis and quantitative assessment we can see that the score for Design Approach 1 is 59, and the score for Design Approach 2 is 79. Even from the design analysis perspective ie- accuracy, cost, safety, and method of analyzing data design approach 2 is the optimal solution.

Chapter 3: Use of Modern Engineering and IT Tools. [CO9]

3.1 Introduction

This chapter focuses on selecting engineering and IT tools for developing the "Disease Detection System of mango leaves." These tools, categorized into software and hardware, were strategically chosen to facilitate various aspects of the project, ranging from circuit simulation to 3D modeling and wireless communication.

We use the selected engineering and IT tools for the system's simulation, programming, and physical implementation. The subsequent sections delve into the specifics of each tool's purpose and its comparative advantages within the chosen toolset.

3.2 Select appropriate engineering and IT tools:

Table 5: Select appropriate engineering and IT tools [14]

Tools Type	Engineering Tools	Purpose
Software Tools	Proteus 8.13	Circuit Simulation
	Arduino IDE 1.8.10	To develop the code for Arduino
	Google Collab	To execute the code of the detection system
	Autodesk Fusion 360	3D Modeling
	Altium designer	PCB Design
	Codevision AVR	To develop the code of ATmega32 & Lora
Hardware Tools	Arduino Uno	To control the motor & wheel of the rover body
	Arduino Mega	To control the lifting of the scissor lift
	BTS 7960 motor driver	To connect the motor with the microcontroller
	12V wiper motor	To move the wheel of the rover body
	12V 300mm DC actuator	To lift the scissors lift
	Lora SX1278 433mhz transmitter & receiver	To create a wireless communication

3.3 Use of Engineering and IT tools Software and IT tools

- **Proteus 8.13**

As shown in the Table above, various engineering/IT tools were used to design our project. We have used Proteus 8.13 for the circuit simulation. We have chosen Proteus for our circuit simulation despite other popular circuit simulation software like Tinker, PSpice, Matlab, and many more. In the Table below, we have compared the two most famous simulation software.

Table 6: Comparison of Proteus and TinkerCAD

Feature	Proteus	TinkerCAD
Ease of Use	user-friendly	user-friendly
Simulation Capabilities	Analog and digital	Analog and digital
Microcontroller	A wide range of various MCUs available	Limited to basic MCUs
Component Library	15M components	Limited to basic components
3D PCB Design	Available	Not available

Adapted from [16], [17]

The reason for choosing Proteus is that it is an all-in-one software that can simulate, design circuits, and create PCBs. Additionally, it has more than 15 million component libraries that offer features such as differential pair routing, group length matching, and remote front panel design for Arduino and Raspberry Pi microcontrollers which Tinkercad does not offer, as shown in the above Table 6 [16], [17].

- **Arduino IDE 1.8.10**

Arduino IDE is an open-source software designed by Arduino and mainly used for writing, compiling, and uploading code to almost all Arduino Modules. The environment of IDE mainly contains two essential parts called Editor and Compiler, where the user has to write the required code. It has to compile and upload the code into the given Arduino Module. In the environment, we can use both C and C++ languages.

In our project, we have used Arduino Uno and Arduino Mega to control the wheel and scissor lift of the rover body. We have chosen to use the Arduino IDE 1.8.10 to develop the code for Arduino in the circuit simulation and implementation of the project operation because it is easy to use, and anyone without any prior knowledge can also develop code [18].

- **Google Collab**

The Basics Collaboratory, also known as Google Collab, is a product from Google Research. The collab allows anybody to write and execute arbitrary Python code through the browser and is incredibly well suited to machine learning, data analysis, and education.

For this reason, we use Google Collab to implement the detection system, as we build this system based on machine learning. To build the code, we use the programming language Python. This language helps to develop the deep learning algorithm, as Python is the best programming language for machine learning. Python has a simple syntax that is easy to understand and write code. Similarly, it has a massive collection of libraries that makes complex tasks like developing deep learning algorithms smooth and easily implemented. Since we used Google Colab to run Python code, we could easily collaborate with our group mates in the same file, which enhanced our productivity [19].

Furthermore, to build the detection system, we have used Resnet-18. Residual Network is a deep learning model used for computer vision applications, which is a convolutional Neural Network(CNN) architecture [20]. It supports hundreds or thousands of convolutional layers. In this case, 18 represents 18 layers of a deep convolutional network. Through this model, we have figured out which design approach would be more appropriate through the Accuracy, F1 score, Recall, and Precision values. As we are working in agriculture, we need to have a good idea of the common diseases that occur on mango leaves, and we have chosen them with the help of research papers. In chapter two, we mention how the model of the detection system works, and it says that the model compares the input images captured with the rover body's camera and detects [19].

- **Autodesk Fusion 360**

We have used Fusion 360 to design a 3D model of our system. Two of the most popular 3D modeling tools are Fusion 360 and Blender. We have chosen Fusion 360 as the platform for 3D designing because this system offers collaboration with groupmates, whereas Blender does not. Furthermore, anyone can use the design in Fusion 360 from anywhere with an internet connection. Fusion 360 also offers the ability to create parametric models and CAM integration. However, Blender does not provide any of these features, as shown in Table 7. [16], [17]

Table 7: Comparison of Blender and Fusion 360

Features	Blender	Fusion 360
Ease of use	suitable for animators and artists	ideal for engineers and designers
Parameter Modeling	Not available	Available
Collaboration	Not available	Available
Cloud-based	Not available	Available
CAM integration	Not available	Available

Adapted from [16], [17]

- **Altium designer**

Altium Designer is a PCB and electronic design automation software package for printed circuit boards. Based on the complexity and size of our project circuit, we have chosen Altium as the designer for the PCB design of the transmitter and receiver circuit. Proteus and Altium Designer are two very well-known software for PCB designing. The Table below presents the reasons for choosing Altium in more detail.

Table 8: Comparison of Proteus and Altium Designer

Feature	Proteus	Altium Designer
Ease of Use	user-friendly	user-friendly
Component library	15M components and some library components in the paid version	A wide range of libraries for components
Features	Advanced features available on the paid version	A comprehensive set of features available on both free and paid versions
Availability	Free version fully functional	Free version available and functional
Affordability	Paid version expensive	The paid version is significantly more affordable
3D PCB Design	Used for smaller and less complex projects	Used for larger and more complex design

Adapted from [22]

- **CodeVisionAVR**

CodeVisionAVR is the only Integrated Development Environment on the market that features an Automatic Program Generator. To implement wireless communication, we have used Lora as a transmitter and receiver, and in this circuit, we have used atmega32 as a microcontroller. So, for developing the code of atmega32 and Lora, we have chosen CodeVisionAVR as it is easy to use with the knowledge of C programming language [23].

Hardware Tools

- **Arduino UNO**

Figure 8: Arduino UNO R3

Arduino UNO is a low-cost, flexible, and easy-to-use programmable open-source microcontroller board. Arduino boards can interface with other Arduino boards, shields, and Raspberry Pi and can control relays, LEDs, servos, and motors as an output. For this reason, we have chosen this microcontroller to control the motor of the rover body.

The external power and The USB connection can power the UNO R3. External power can come either from an AC to DC adapter or battery. The board can operate on an external supply of 6 to 20 Volts. If supplied with less than 7V, however, the 5V pin may give less than 5V, and the board may be unstable. Besides, we can use each of the digital pins on the Uno as input or output, using pinMode(), digitalWrite(), and digital Read() functions. Due to all the discussed characteristics, we have chosen UNO for our project implementation [24].

- **BTS 7960 motor driver**

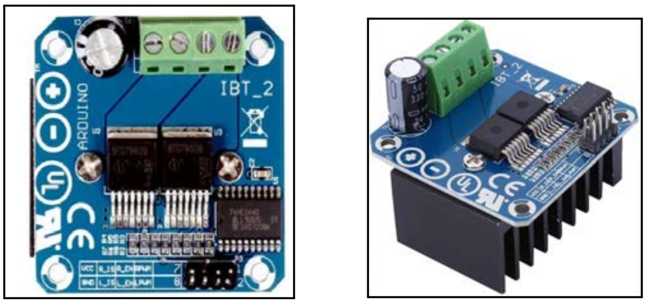


Figure 9: BTS7960 Motor driver

BTS7960 43A H-bridge High power motor driver module is a fully integrated high current H bridge for motor drive applications using the BTS7960 high current half bridge. The motor driver can operate input voltage 6 to 27 Voltage. Besides interfacing with a microcontroller made by the motor driver, IC features logic level inputs, diagnosis with current sense, slow rate adjustment, dead time generation, and protection against overtemperature, overvoltage, undervoltage, overcurrent, and short circuits. Because of all of the characteristics of the BTS7960 motor driver, we have chosen the BTS7960 motor driver [25].

- **12V 300mm DC actuator**

Figure 10: 12V 300mm long stroke Linear Actuator

The miniature Linear Actuator Stroke Length 300mm, $15ms^{-1}$, 500N, 12V is an electric push rod and an ideal solution for industrial, agricultural, machinery, construction, clean sweeping, vehicles, vessels, cargo, and many other applications. This electric push rod is a kind of electric driving device that transforms the motor's rotary motion into the linear reciprocating motion of the push rod. It can be used in various simple or complex processes as executive machinery to realize remote control or automatic control. The electric push rod is composed of the drive motor, reduction gear, screw, nut, guide sleeve, pushrod, sliding seat, shell, and micro-motion control switch. With the help of this actuator, our scissor lift can reach 7 feet in height for capturing photos.

There are many features of this actuator. Due to the features, we have chosen the actuator. For example, the actuator is an aluminum frame and extension tube. It is a compact design. Besides, it has a built-in limit switch, low noise, and moisture-proof Surface [26].

- **LoRA 100mW SX1278 433mhz**

Figure 11: LoRA 100mW SX1278 433mhz

LoRa is a wireless technology that offers long-range, low-power, and secure data transmission. We have chosen Lora 100mW SX1278 as the transmitter and receiver to implement our wireless communication system. Due to the features below, we have used the technology [27].

- The Communication distance tested is up to 3km. The maximum transmission power of 100mW, software multi-level adjustable
- Support the global license-free ISM 433 MHz band
- Support air date rate of 0.3kbps～19.2kbps
- Support new generation LoRa technology based on SX1262
- Low power consumption for battery-supplied applications；
- Support 3.3V~5.5V power supply, power supply over 5.0 V can guarantee the best performance
- Industrial grade standard design, support -40 ~ 85 °C for working over a long time
- IPEX and stamp hole optional, suitable for secondary development and integration.

3.4 Conclusion

In conclusion, the judicious selection and proficient use of various engineering and IT tools in software and hardware domains have successfully developed the "Disease Detection System of mango leaves." From circuit simulation to 3D modeling and from code development to physical implementation, tools like Proteus, Arduino IDE, Google Collab, Autodesk Fusion 360, and various hardware components mutually contributed to the project's efficiency and effectiveness. This chapter underscores the pivotal role these tools played in achieving simulation accuracy, facilitating collaborative coding, and ensuring precise physical control, underscoring their significance in the comprehensive realization of the project objectives.

Chapter 4: Optimization of Multiple Designs and Finding the Optimal Solution. [CO7]

4.1 Introduction

In this chapter, we will simulate and do the necessary calculations of design approach 1 and design approach 2. We will also show the data of our conducted experiments on the selected design approach and how we troubleshoot the experimental faults. We will also analyze the system with graphical representations and try to make our selected design optimal.

4.2 Optimization of multiple design approaches.

- **Design Approach 1:**

Following the procedure according to [29], [30], [31]

Weight of the drone along with Camera = 2 kg
Drone thrust to weight ratio = 2:1
Number of motors (Quadrocopter)= 4
Total thrusts required for our drone = Total weight * Drone thrust to weight ratio
= 2* 2:1
= 4 kg

Thrust per motor = Total Thrust /No of motors
= 4 kg/4
= 1 kg
Therefore, each motor requires 1 kg of thrust to get the drone up in the air.

For DJI TELLO, the battery has a capacity of 1.1 Ah with a voltage of 3.8V.
Power consumption by the battery= 3.8 V * 1.1 Ah
= 4.18 Wh of power.
Therefore, the battery will consume 4.18 W per hour.

A calculator was used for this process from [32].

- **Design Approach 2:**

In the project for various sub-systems, we used different types of batteries and did the power calculation:

Table 9: Battery used for each component

Subsystem	Battery used
Wheel of Rover body	Series of 12V 7mAh & 12V 9mAh rechargeable sealed lead acid Battery
Actuator of Scissor lift	12V 9 mAh rechargeable sealed lead acid Battery
Microcontroller of controlling system	Series connection of two 3.7V 6400mAh rechargeable lithium-ion Battery
Transmitter and receiver of wireless & communication system	Both side series connection of three 3.7V 6400mAh rechargeable lithium-ion Battery

Power consumption of Rover Body wheel:

From our product testing in a mango yard, we observe that the rover body can sustain one hour with the 24V DC rechargeable battery.

In that case the total current of the battery after being connected in series: 8Ah

The power consumption = 24V * 9Ah = 216Wh

Power consumption of the actuator of the Scissor lift:

For the actuator, a 12V 9Ah is used. So the power consumption: 12V * 9Ah = 108Wh

Power consumption of the microcontroller (controlling system):

In the power supply of the microcontroller, the series connection of two 3.7V 6400mAh lithium-ion rechargeable batteries is used. So the voltage of this connection is 7.4V and the current is 6800mAh or 6.8Ah

The power consumption of the microcontroller: 7.4V*6.8Ah = 50.32Wh

Power consumption of transmitter & receiver:

- Transmitter power consumption:

The voltage of the power supply by cascading three lithium-ion: 3*3.7V =11.1V

The current from the battery: 6800mAh=6.8Ah

The total power: 11.1V * 6.8Ah =75.48Wh

- Receiver power consumption:

In the receiver end, the same kind of battery as the transaction end is used for the power supply. For this reason, the receiver's power supply is as similar as the transmitter's. So the power consumption is 11.1V.

Now the total power consumption of our product: 216Wh + 108Wh +50.32Wh +75.48Wh + 75.48Wh = 525.28Wh

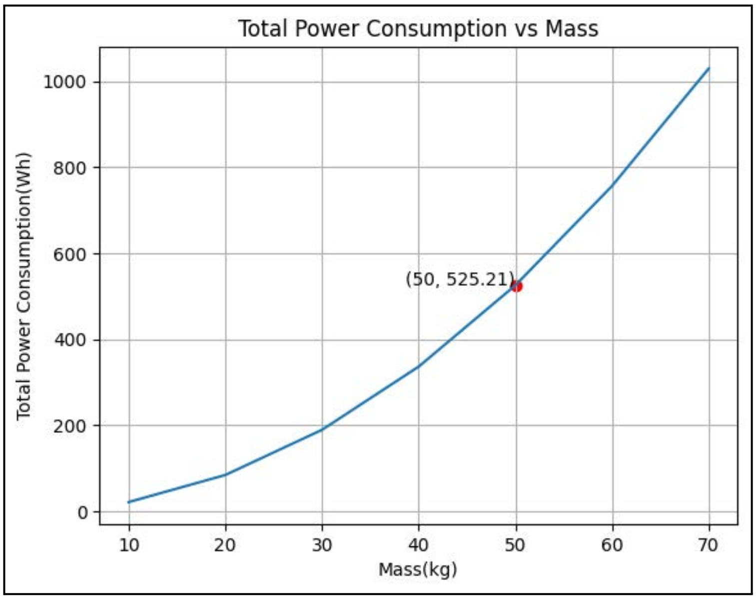


Figure 12:Total power consumption of our rover body with respect to mass

Functional Verification:

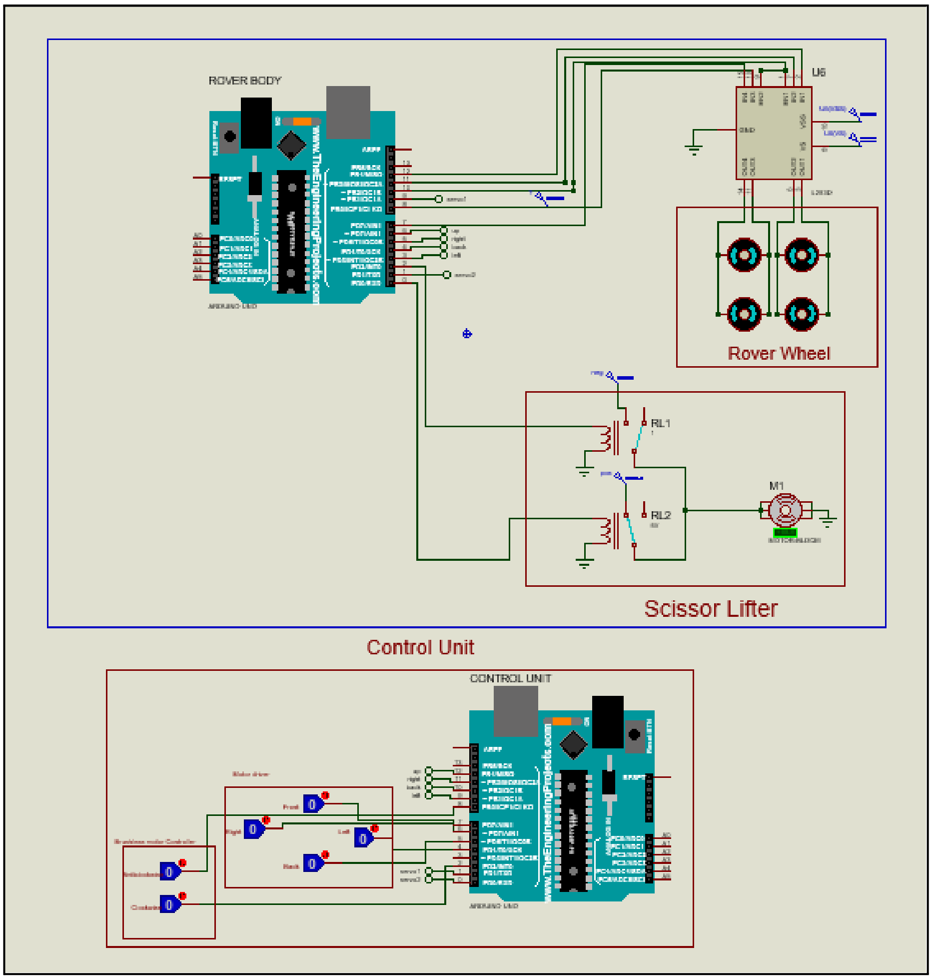


Figure 13: Simulation Circuit for Design Approach 2 [See Appendix B for code details]

Fig. 13. illustrates the circuit of proteus simulation for Design Approach 2. Design Approach 2 is a rover-based system. In this design, we have used two Arduino boards. The control unit is responsible for controlling the whole system.

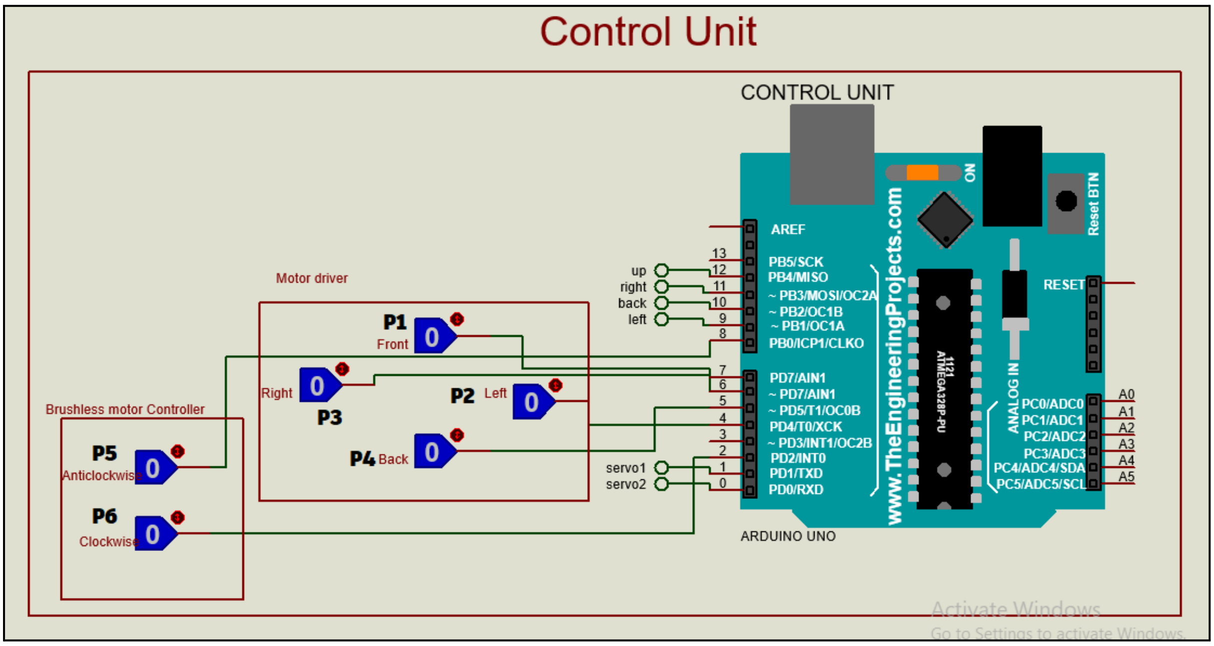


Figure 14: Control Unit of Design Approach 2 [[See Appendix B for code details]

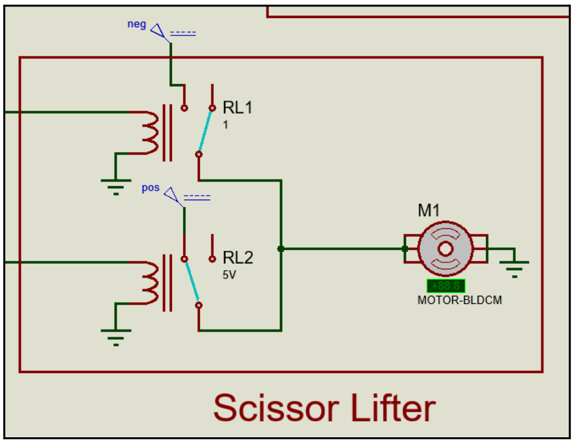


Figure 15: Scissor Lifter of Design Approach 2 [See Appendix B for code details]

Fig. 14. and Fig. 15. show the control unit and scissor lifter from the rover body. Firstly, we have used this brushless motor for the scissor lifter. In this case, the brushless motor will rotate both clockwise and anti-clockwise. As a result, to rotate it clockwise, we need to provide positive voltage and for the anti-clockwise rotation, we need to provide negative voltage. However, using Arduino can only provide positive voltage. For this reason, we have used two relays and they are connected with two different pins. To control the relay, we have used 2 buttons. When button no. 5 is on the first relay will become on and it will supply positive voltage to the brushless motor and it will start to rotate clockwise. On the other hand, when button 6 is on the second relay will become on and it will supply negative voltage to the brushless motor and it will start to rotate anti-clockwise. That is how we control the brushless motor.

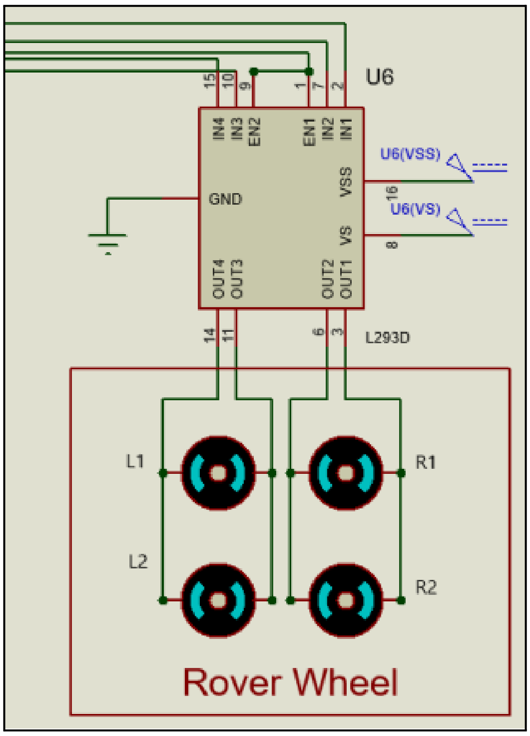


Figure 16: DC motos for the Rover wheels in Design Approach 2 [See Appendix B for code details]

For moving the rover body, we have 4 push buttons to control the motors as shown in Fig. 14. For the simulation case, we have considered that if the motor is rotating clockwise then the rover is moving front, and if the motor is rotating anti-clockwise then the rover is moving back. To drive it to the right, we have made a logic which is given in Table 5.

Table 10: Working Principle of the DC Motors

	L1	**L2**	**R1**	**R2**
Front	Clockwise	Clockwise	Clockwise	Clockwise
Back	Anti-Clockwise	Anti-Clockwise	Anti-Clockwise	Anti-Clockwise
Left	Anti-Clockwise	Anti-Clockwise	Clockwise	Clockwise
Right	Clockwise	Clockwise	Anti-Clockwise	Anti-Clockwise

To move it to the right, the left wheel will rotate clockwise and the right wheel will rotate anti-clockwise. As a result, for the center of the mass, the rover will rotate right.

4.3 Identify optimal design approach

- **Design Approach 1:**

Drone dataset description:

As we were not getting any pictures of diseased mango leaves captured through drones, we used insect-infected soy leaf pictures captured through drones for our analysis.

Table 11: Design Approach 1 dataset description

How data were acquired	The images were captured with 3 (three) different pieces of equipment, an Unmanned aerial vehicle (UAV), and two smartphones equipped with a 48mp AI triple camera.
Data format	The images are in JPEG format with a standard size of 500 × 500 pixels.
Description for data collection	Photographs were shot on sunny, windy, and cloudy days. The images focus on the upper part of the insect-infected soy leaves and healthy leaves.
Data source location	All photos were captured in the State of Mato Grosso, Brazil. More specifically, we chose two locations: (I) farms located in the municipalities of Lucas do Rio Verde - Latitude 13◦ 01′ 59″ longitude 55◦ 56′ 38″ and (II) farms located in the municipality of Nova Mutum - Latitude 13 ◦ 05′ 04″, longitude 56◦ 05′ 16″.

Dataset taken from [33]

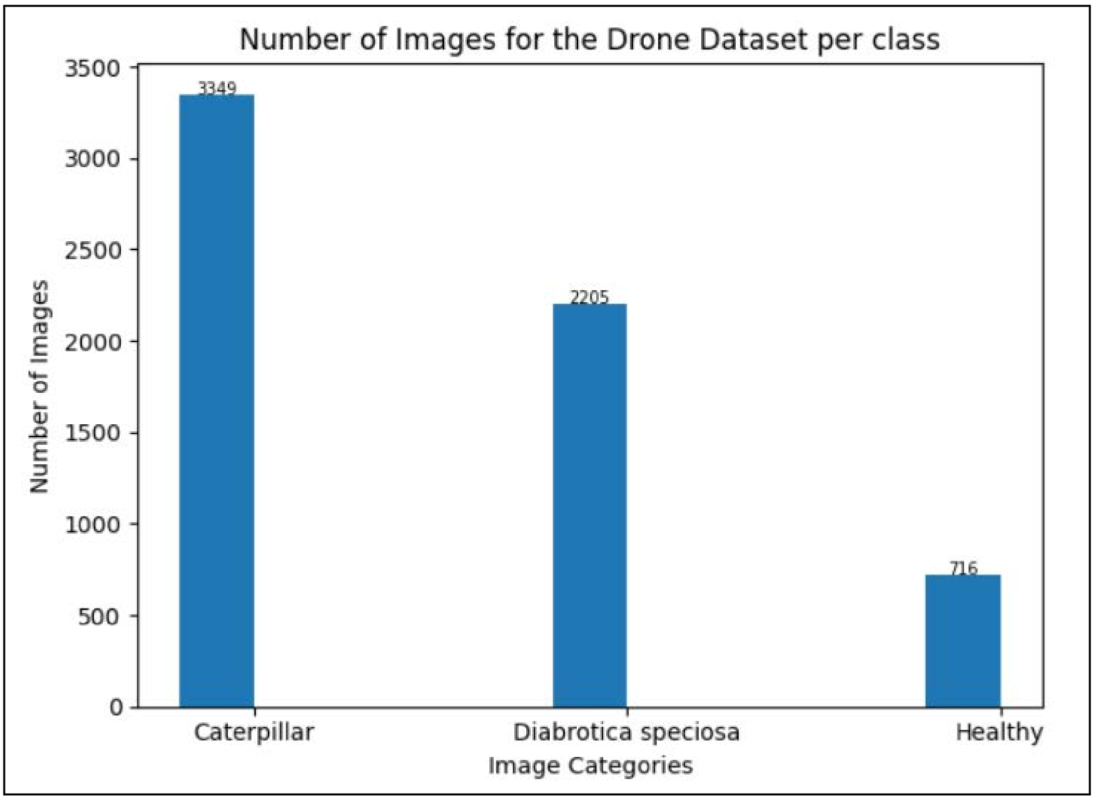


Figure 17..Initial distribution of the drone dataset per class[See Appendix C for code details]

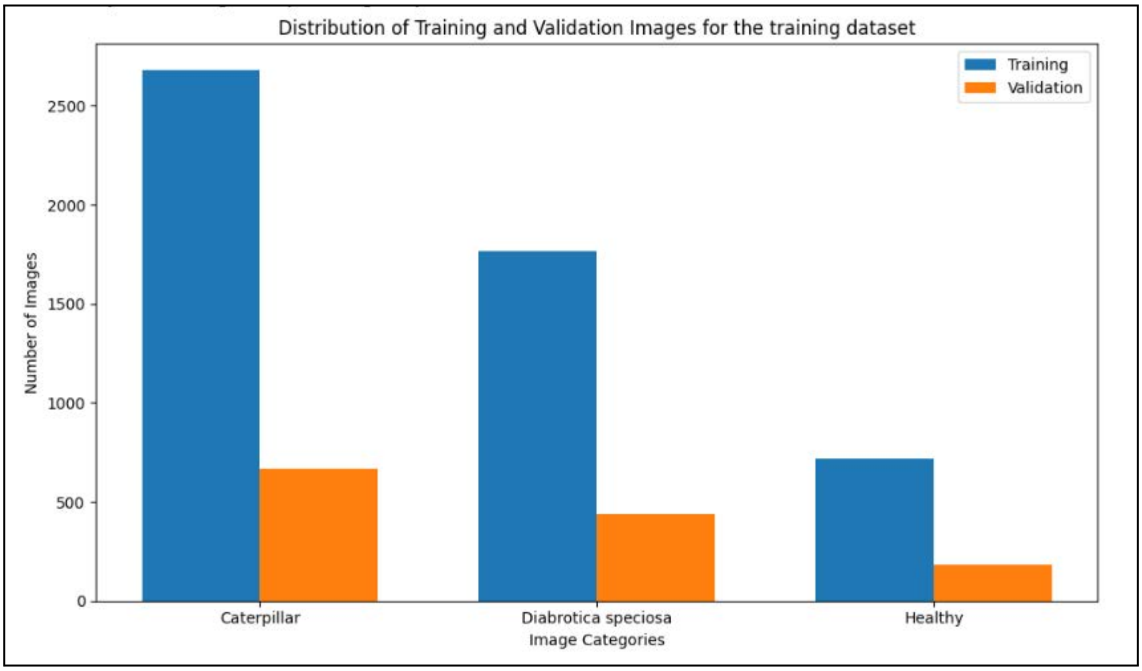


Figure 18. After splitting, the distribution of training and validation images for the training drone dataset [See Appendix C for code details]

Here the dataset is imbalanced, so we have to fix this issue. As a result, we have taken a limited amount of images per class (500 images for each class).

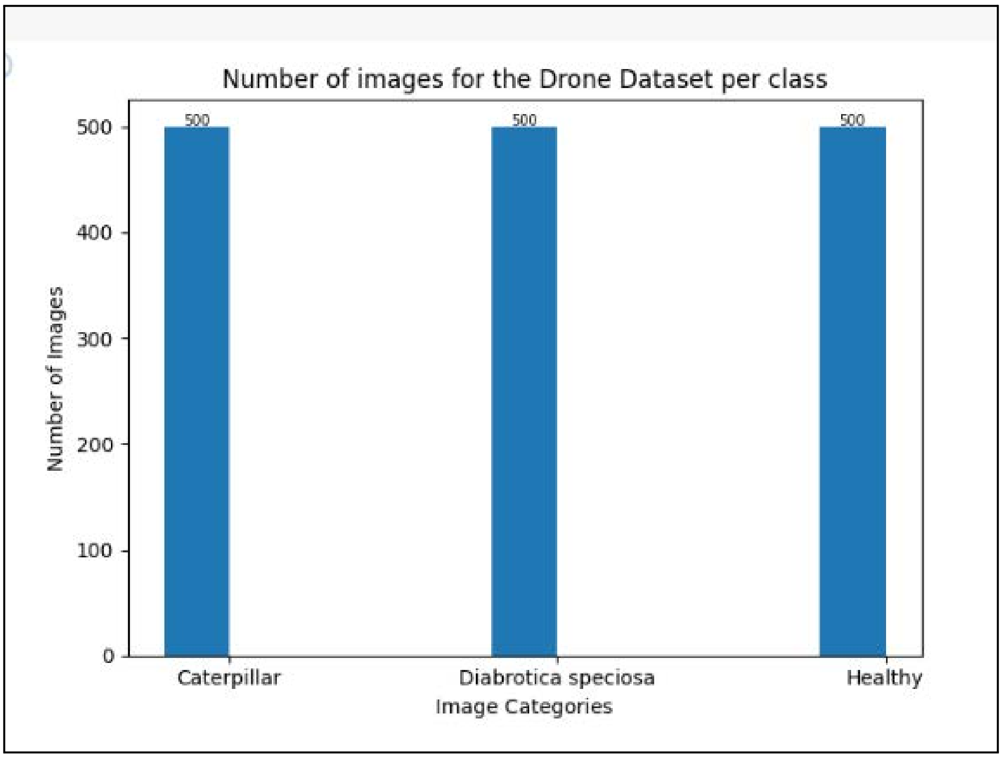


Figure 19. The distribution of the drone dataset per class for fixing the imbalance dataset [See Appendix C for code details]

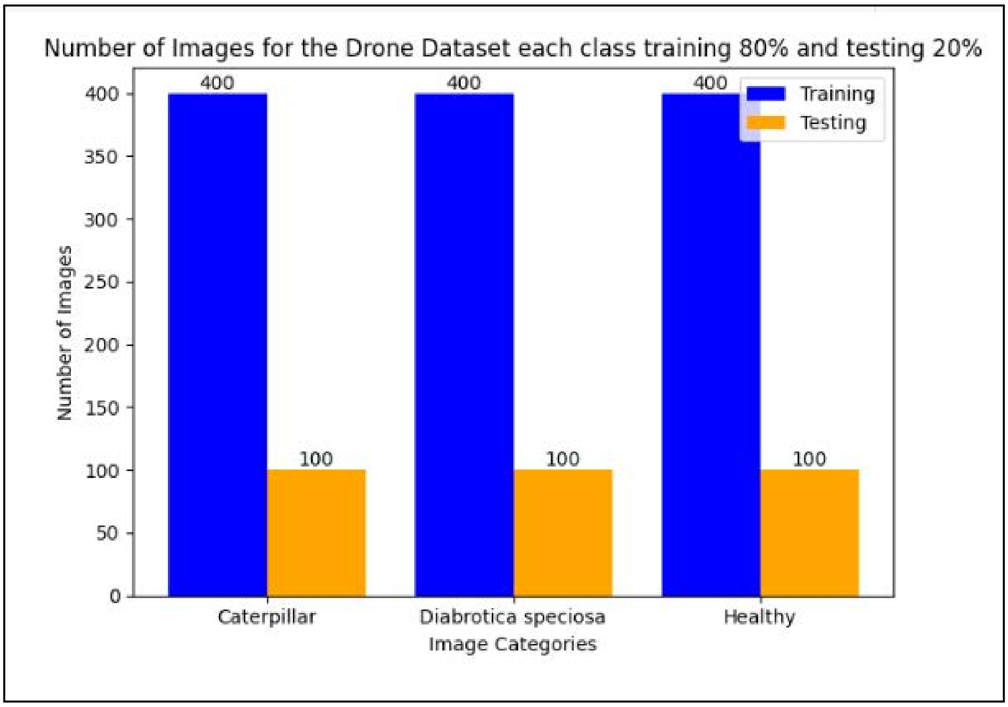


Figure 20: Number of images for the Drone dataset per class (training 80% and testing 20%) [See Appendix C for code details]

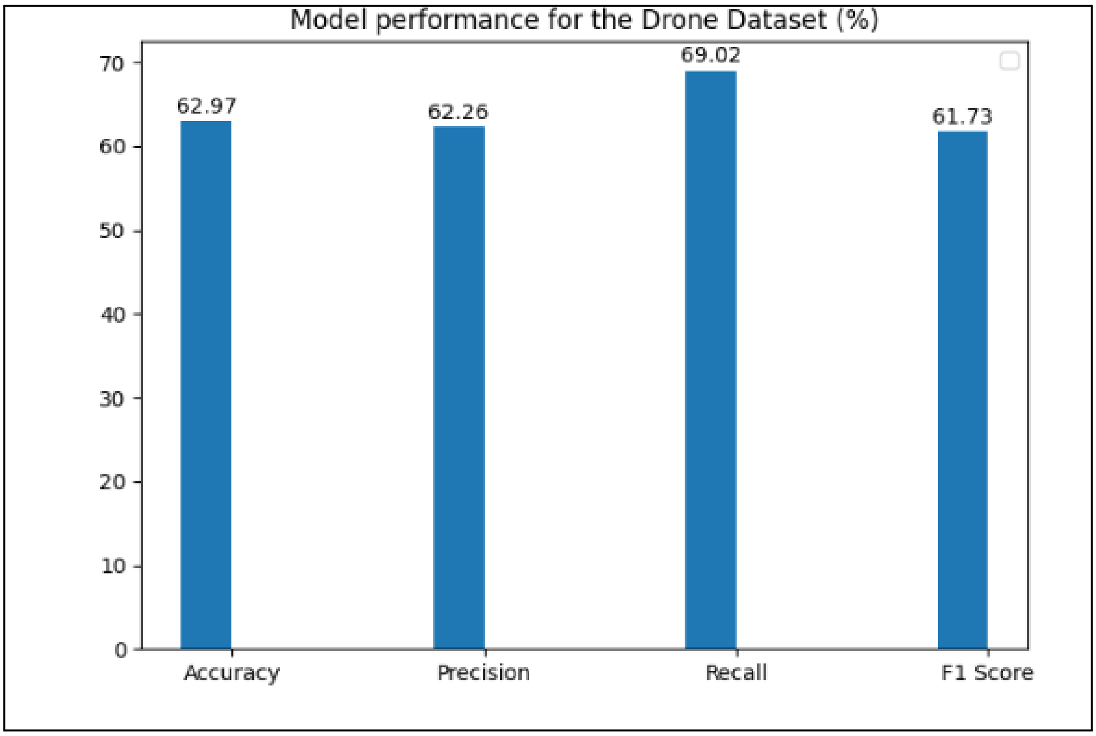


Figure 21: Model performance metrics of the drone dataset in percentage
[See Appendix C for code details]

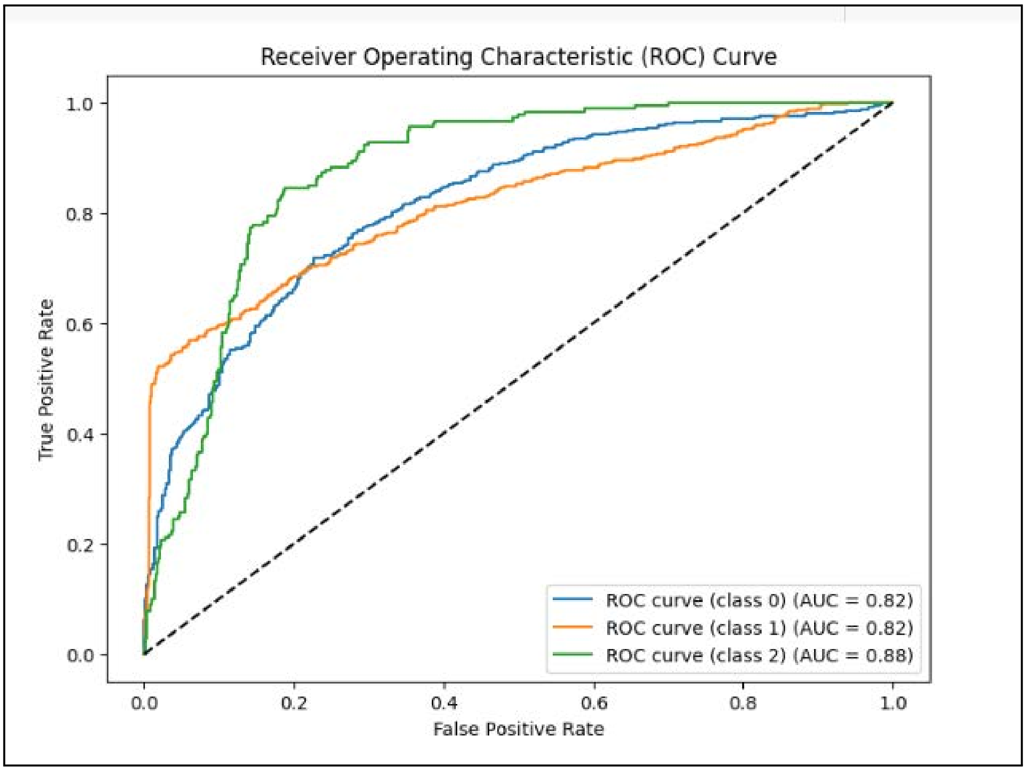


Figure 22: ROC curve for the drone dataset
[See Appendix C for code details]

Here, the accuracy of 62.97% means that 62.97% of the predictions from the total instances are correctly classified by the model. The recall of 69% means that the model captures 69%

of the actual positive instances. The precision of 62.26% means that 62.26 % of the instances that the model predicted as positive are actually positive. 61.73% of the F1 score indicates that the model is a better balance between precision and recall. The ROC is the measure of the ability of the model to distinguish between positive and negative instances. Here the model gives <0.9 which starts from 0.8 so it means that the model has a high discriminative power.

- **Design Approach 2:**

Design Approach 2 dataset description:

Table 12: Design Approach 2 dataset description

Type of data	**240x320 mango leaf images.**
Number of images:	4000 images. Of these, around 1800 are of distinct leaves, and the rest are prepared by zooming and rotating where deemed necessary.
Diseases considered:	Seven diseases, namely Anthracnose, Bacterial Canker, Cutting Weevil, Die Back, Gall Midge, Powdery Mildew, and Sooty Mold.
Number of classes:	Eight (including the healthy category).
Distribution of instances	Each of the eight categories contains 500 images.
Data source locations:	Four mango orchards of Bangladesh, namely Sher-e-Bangla Agricultural University orchard, JahangirNagar University orchard, Udaypur village mango orchard, and Itakhola village mango orchard.

Dataset taken from [34]

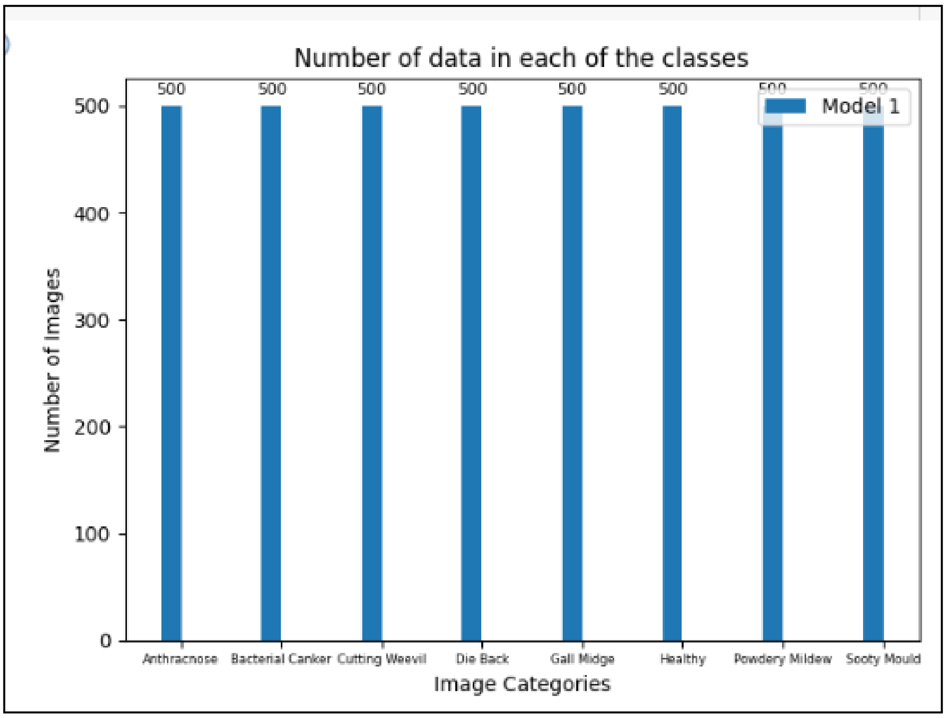


Figure 23:Number of data in each of the classes of the Kaggle dataset
[See Appendix D for code details]

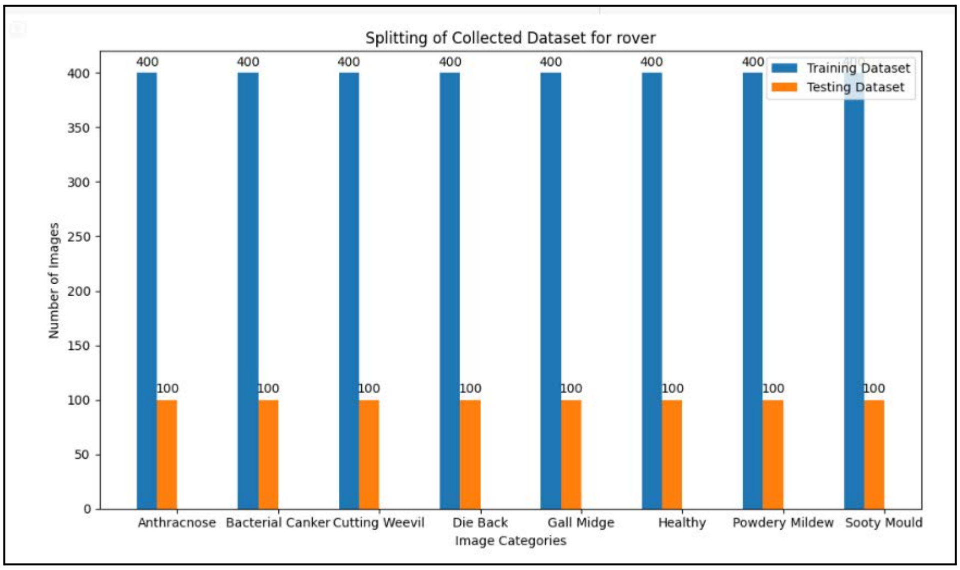


Figure 24:Splitting of the Kaggle dataset for rover
[See Appendix D for code details]

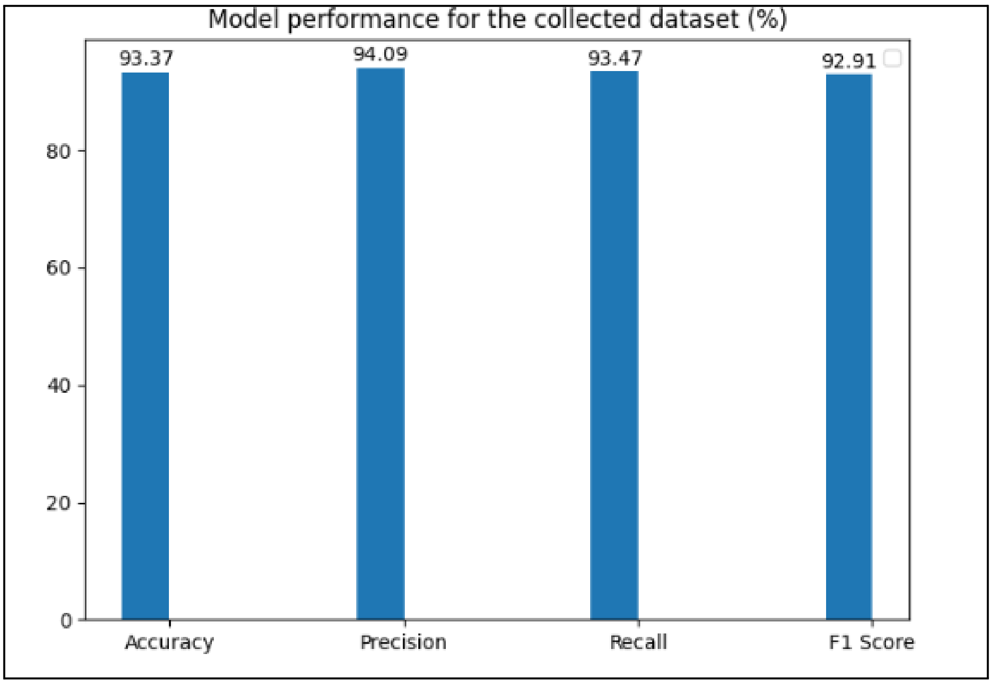


Figure 25:Model performance metrics for the Kaggle dataset
[See Appendix D for code details]

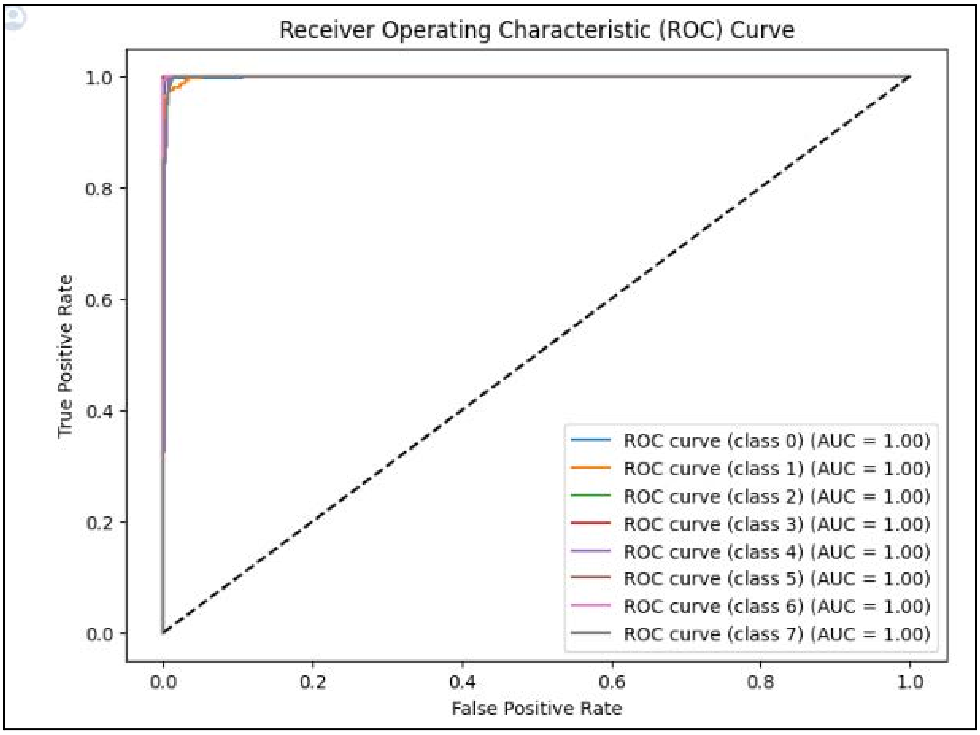


Figure 26: ROC curve for the Kaggle dataset
[See Appendix D for code details]

Here, the accuracy of 93.37% means that 93.37% of the predictions from the total instances are correctly classified by the model. The recall of 93.47% means that the model captures 93.47% of the actual positive instances. The precision of 94% means that 94% of the instances that the model predicted as positive are actually positive. 92.91% of the F1 score indicates that the model has a better balance between precision and recall. The ROC is the measure of the ability of the model to distinguish between positive and negative instances. Here the model gives 1 so it means that it has a 100% true positive rate and 0% false negative rate across all discrimination thresholds. That means that the model can distinguish all false and negative instances correctly.

From the drone dataset and Kaggle dataset, it is evident that the Kaggle dataset performs better because the rover takes pictures in a stable condition and atmospheric conditions are less compared to the drone. We could also see a comparison between the drone and Kaggle dataset performance metrics which is given below-

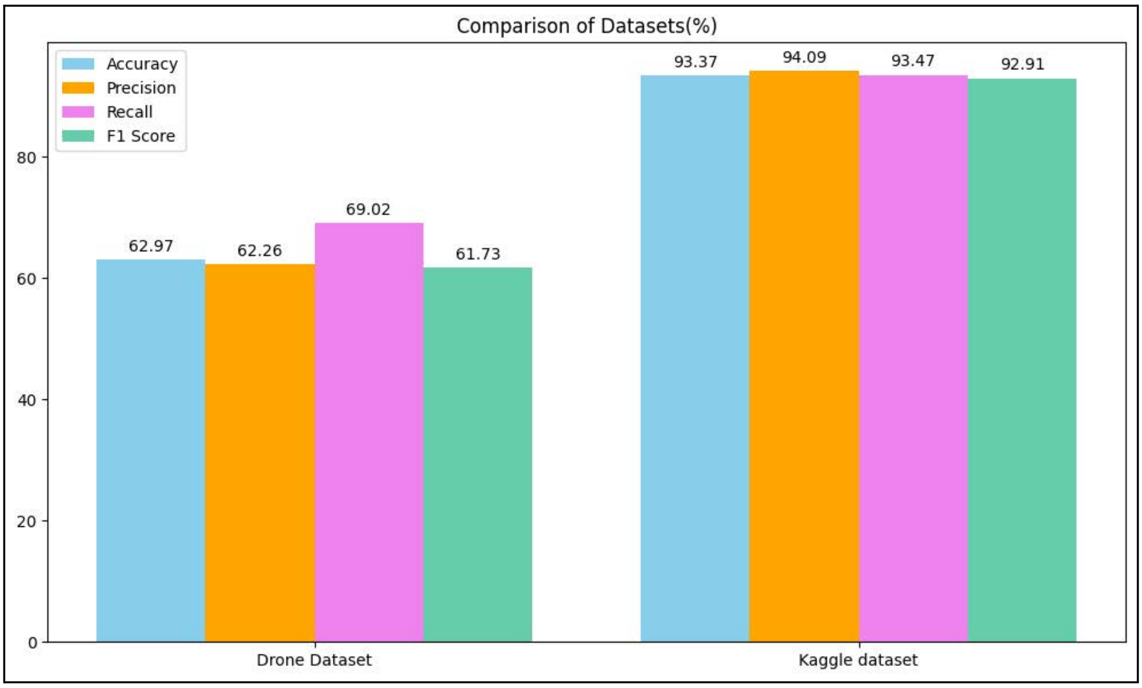


Figure 27: Performance metrics comparison between drone and Kaggle dataset
[See Appendix D for code details]

Hardware structure:

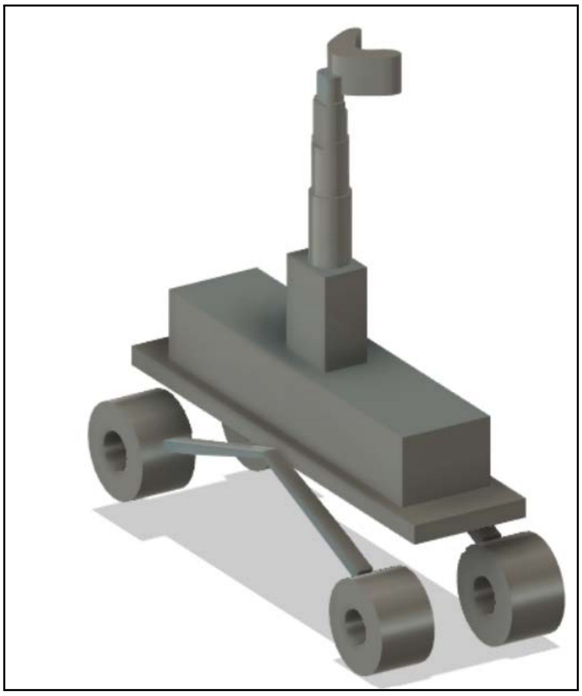


Figure 28: Initial 3D design of our rover body system

4.4 Performance evaluation of developed solution

Table 13: Experimental faults and troubleshooting process

Experimental Faults	Troubleshoot process implemented by us::
Balancing the stability of the system	The main concern of the rover body was the height required for the system to capture the pictures. The rocker-bogie we have designed has manufacturing facility issues and it is not stable when it expands as the center of mass is not located within its base. For this structure, we require more than 2 actuators which is costly. For this, we have developed a scissor lift system along with the rover body so that there should be no stability issue and it requires only 2 actuators with less complexity.
Microcontrollers not getting enough voltage	Initially 7.4V of the lithium-ion battery was given to each microcontroller individually but the microcontrollers were not working then we made the series connection of (3.7+3.7)V of lithium-ion battery to make the two microcontrollers work. The reason for this problem could be the DC jack cable problem or battery casing problem.
Fault in LoRa SX1278	As this LoRa module Ra-02 SX1278 was very delicate to work with for some reason it was not working then we tried to interchange MISO and MOSI pins, it was still not working so we switched

	to LoRa SX1278 UART.
The cables started to catch fire	We used 14AWG 15 A wire for the whole rover body and when we used a different rating than this, a fire started to become explosive. We have troubleshooted this problem using 14 AWG 15 A wire.
Actuator could not work with 12 feet height scissor lift	We have made an actuator calculation for a 12 feet height system but in a real scenario, the actuator could not operate with 12 feet height. The reason could be there is a difference between theoretical and hardware calculation. We needed to include the correct angle, and degree so that it could be close to the real-life implementation. Then we had to make the system height around 7 feet to operate the actuator smoothly.
Dataset problem	We had an unbalanced dataset for the drone body, we had to solve it by taking a fixed number of data per class to solve this problem.
Dataset problem	We had a dataset of diseased mango leaves but the pictures were not captured in bunch leaves form, it was individual diseased pictures, as a result the model would not perform well as the rover system will capture pictures of collective leaves. So, we have made our own dataset for training the model.

4.5 Conclusion

In this chapter, we have found our optimized design and have performed experiments with the optimized design. There were many experimental faults while running the rover body and also running the model and we have tried to troubleshoot them. We have implemented a scissor lift for the stability of the design of the rover body and made our own dataset for the better performance of the model as the system will not perform well with the existing dataset. The existing dataset does not have any bundle form leaves so it will create a problem for our model.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

In this chapter we will show our final design. We have performed experiments and had many experimental faults and we have troubleshooted them. We will now show the completed final design and development of the solution with adjustments required for performance evaluation. This section includes a full-depth description of our final design after all the required modifications.

5.2 Completion of final design

Figure 29. 3D Design of the rover body

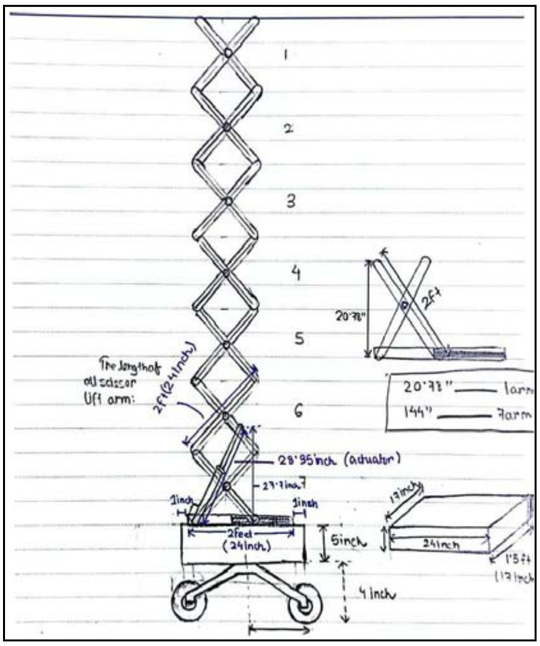


Figure 30: Rough sketch of the rover body with measurements

Figure 31: PVC design of the scissor lift

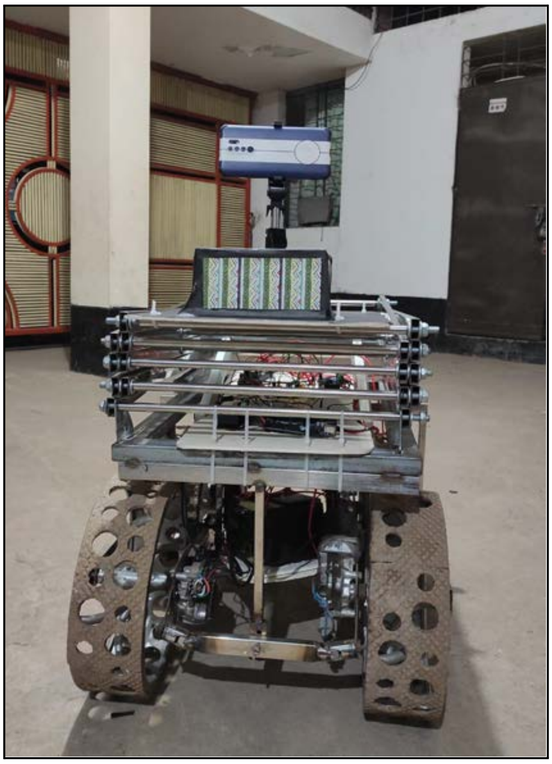


Figure 32:Scissor lift while in shrink stage (1.79 feet)

Figure 33:Scissor Lift while expanding (7 feet)

We have developed the scissor lift with two actuators and here the system is very stable compared to the previous structure that we have decided on due to the center of gravity.

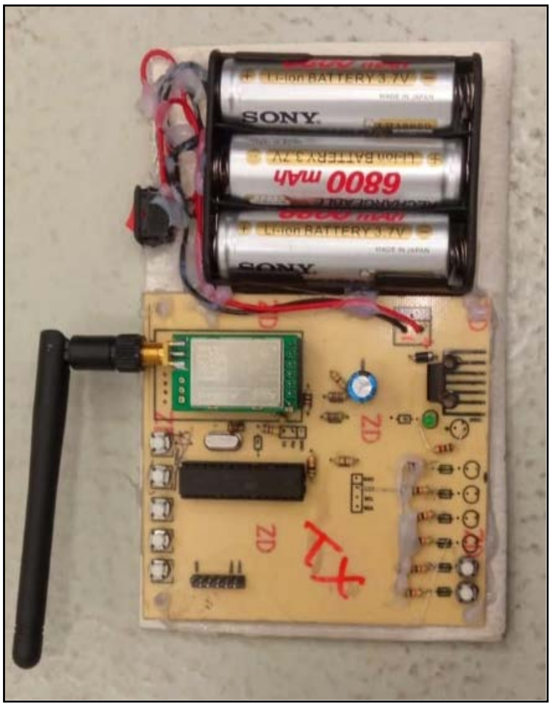


Figure 34:Transmitter

Figure 35:Receiver

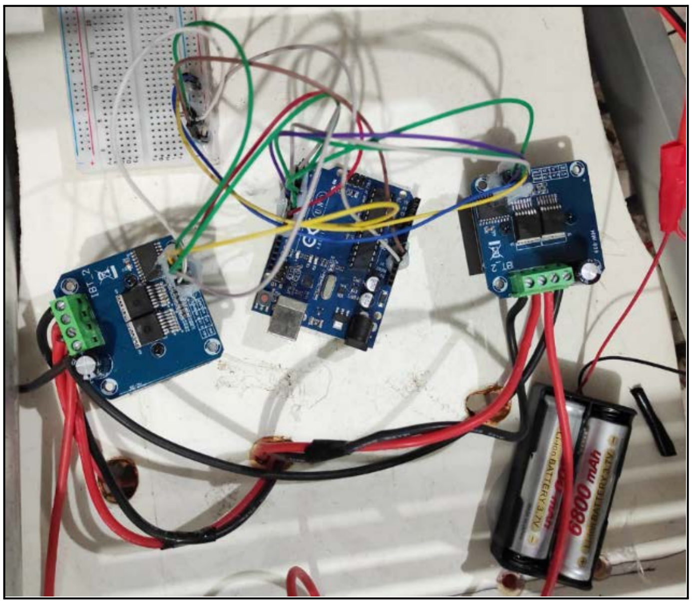


Figure 36: Arduino UNO connection with motor drive

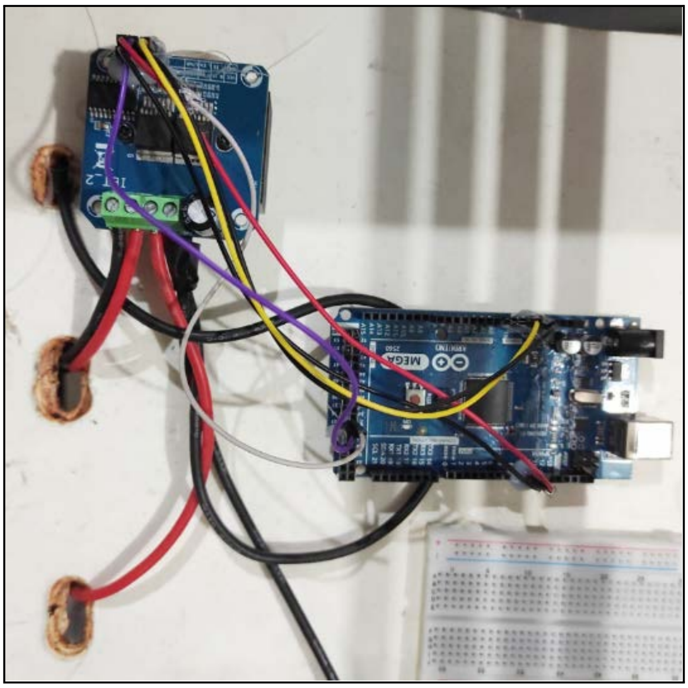


Figure 37: Arduino Mega with motor driver circuit

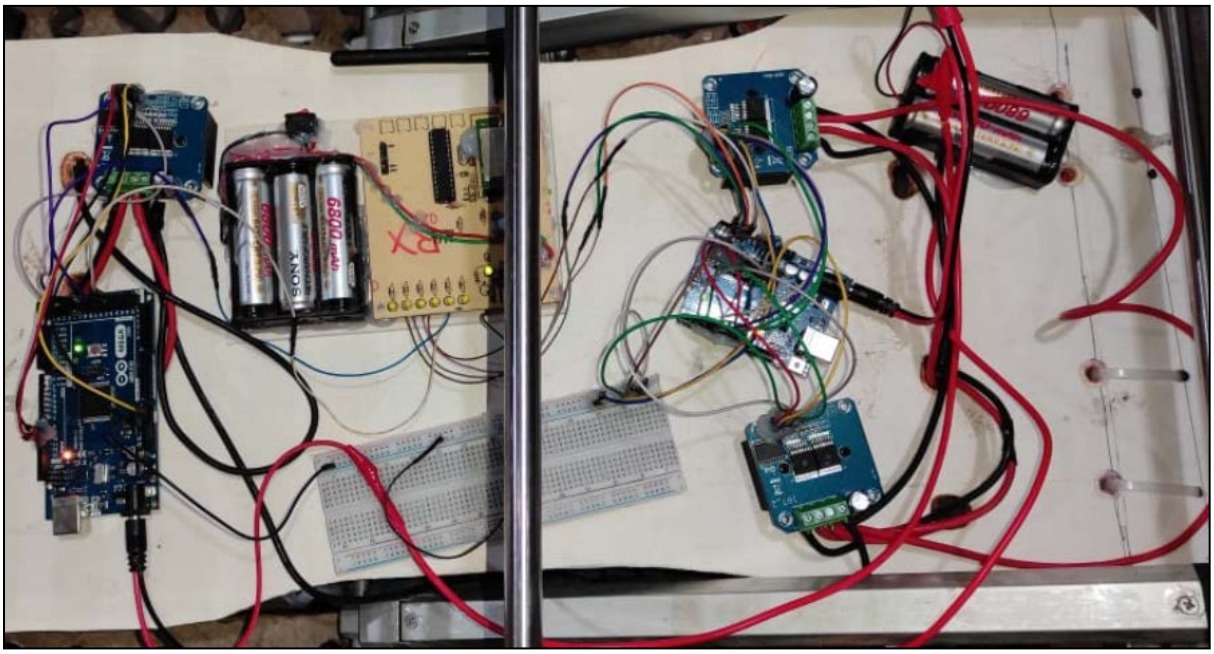


Figure 38: The whole circuit of our rover body system

Here, we are controlling the motors of the wheels and the actuator of the rover body with the help of our transmitter. The receiver will receive the signals from the controller and move the rover body wheels and actuator according to the command that is received. We have used push buttons on the transmitter side and LED lights on the receiver side so that we can visually see that the push buttons are pressed. For example, if a pushbutton is pressed from the transmitter side then on the receiver side the rover will light up the LED light and then the action of moving forward will be performed by the motors. There are two microcontrollers which will control the actuator and motors of the wheels. We are taking pictures with the help of a phone camera. The phone camera is controlled by AirDroid software on the laptop. Then the data are saved on the computer and from the computer we will give input of the captured images by the rover to our model for the detection of diseased mango leaves.

5.3 Evaluate the solution to meet desired needs

1. The system met the specification of the height as it was required. The height of the mango trees for which we were testing was around 5-7 feet. With the scissor lift, we can reach a maximum height of 7 feet.

2. Real-time practical Measurement from the rover body:

Table 14: Real-time practical Measurement from the rover body

Component	Measurement
Motor drive	The Motor drive gets 12 V from the battery and the actuator gets 11V from the motor drive
Wiper motor	● When freely moving, it consumes 0.5 A

	current. ● When with our rover body system it consumes 1.125A current ● When with the rover body moving with the uneven surface it consumes over 2A current.
Actuator	DC motor drive voltage=12 V maximum current draw =2 A Maximum Power consumption=12 V*2A =24 W per hour

3. The rover can travel any path, even uneven surfaces very easily, the wheels are very powerful for the rover to move to any path. We have calculated the velocity of the rover by calculating the time the rover takes to travel a particular distance.

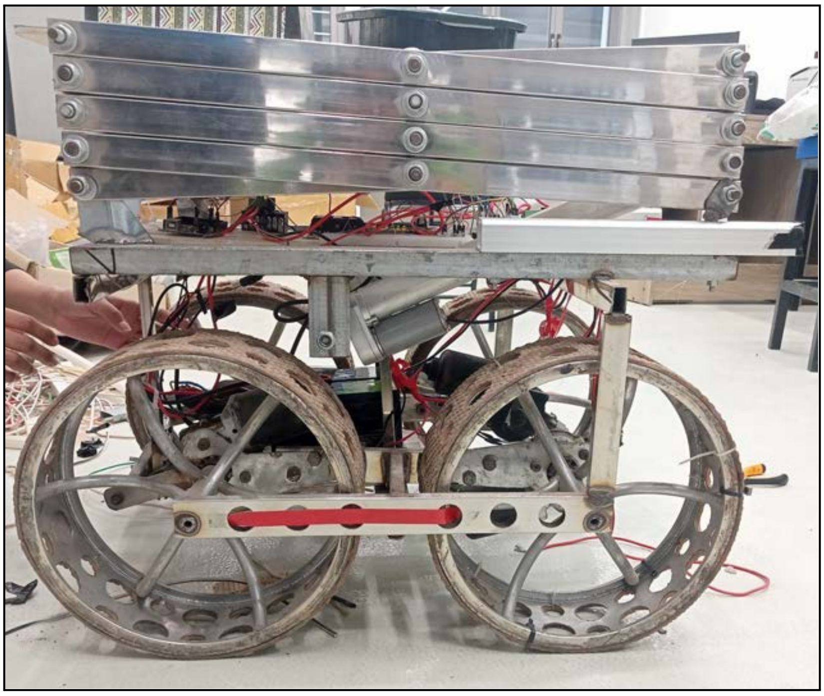


Figure 39:Wheels of the rover body

Table 15: Rover speed

Path	Speed
Plain surface	$40ms^{-1}$
Uneven surface	$20ms^{-1}$

4. We have taken the pictures with the help of our mobile camera. The AirDroid software on the laptop controls the mobile camera. The pictures are then transferred to the laptop as we can control the mobile phone [35].
5. We have performed the experiment by training with our dataset. The system can detect pest diseases accurately.

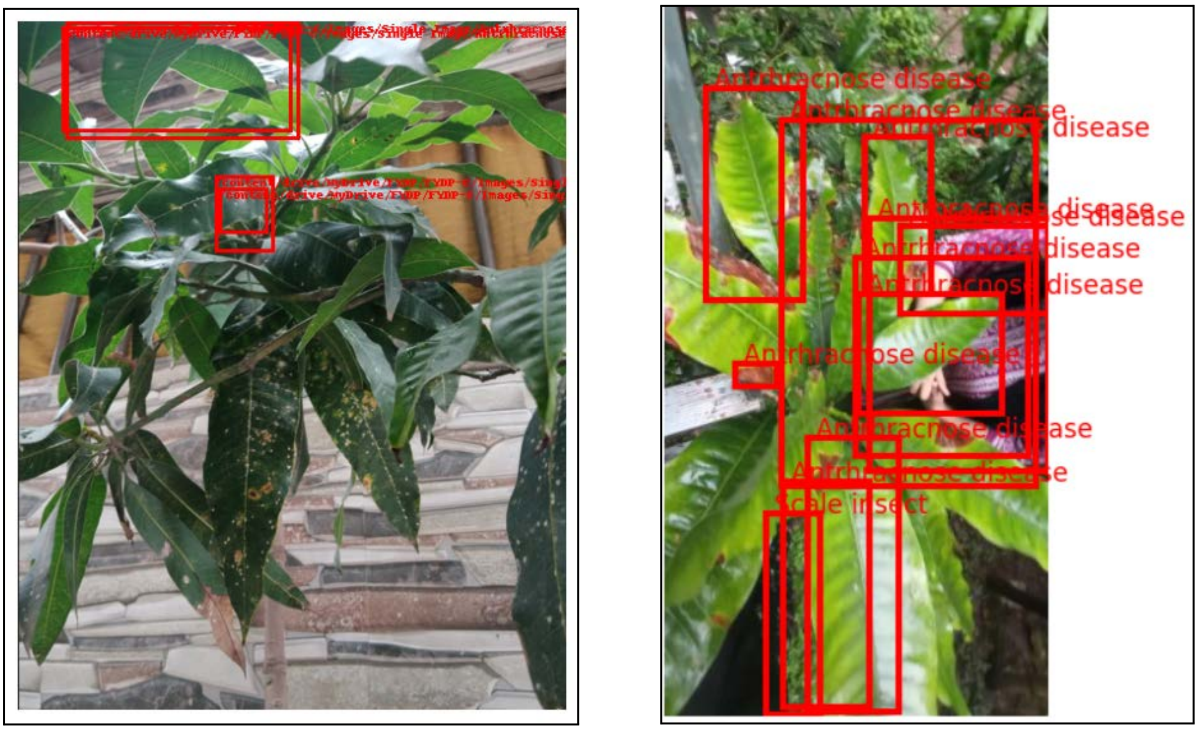


Figure 40: Disease Detection by Resnet 18.

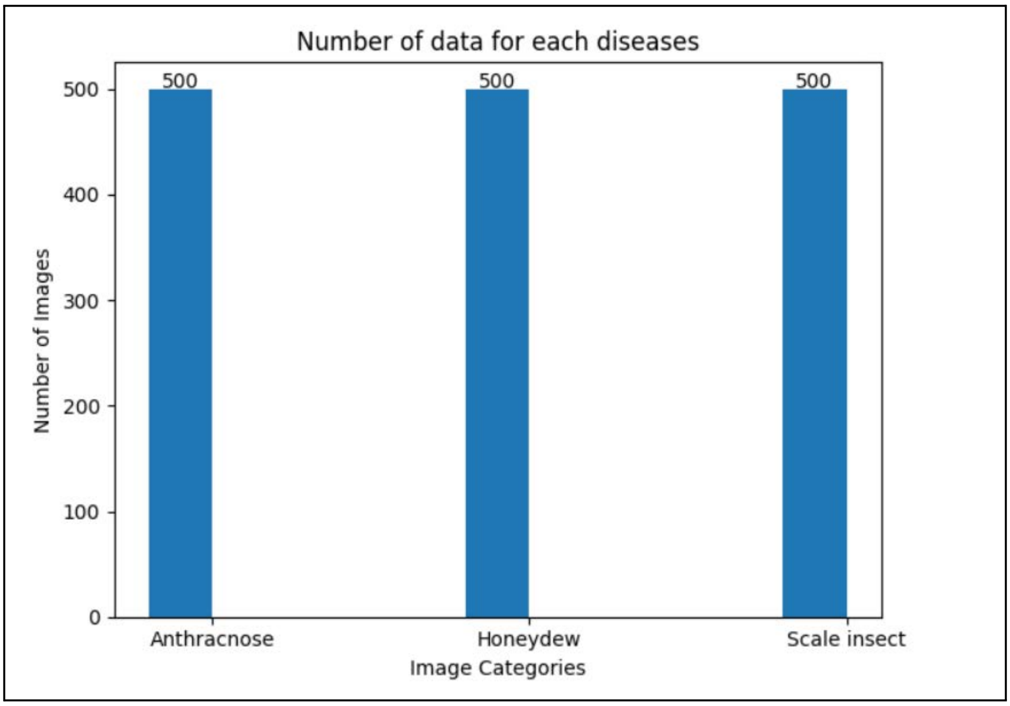


Figure 41:Number of data in our own data set per class
[See Appendix E for code details]

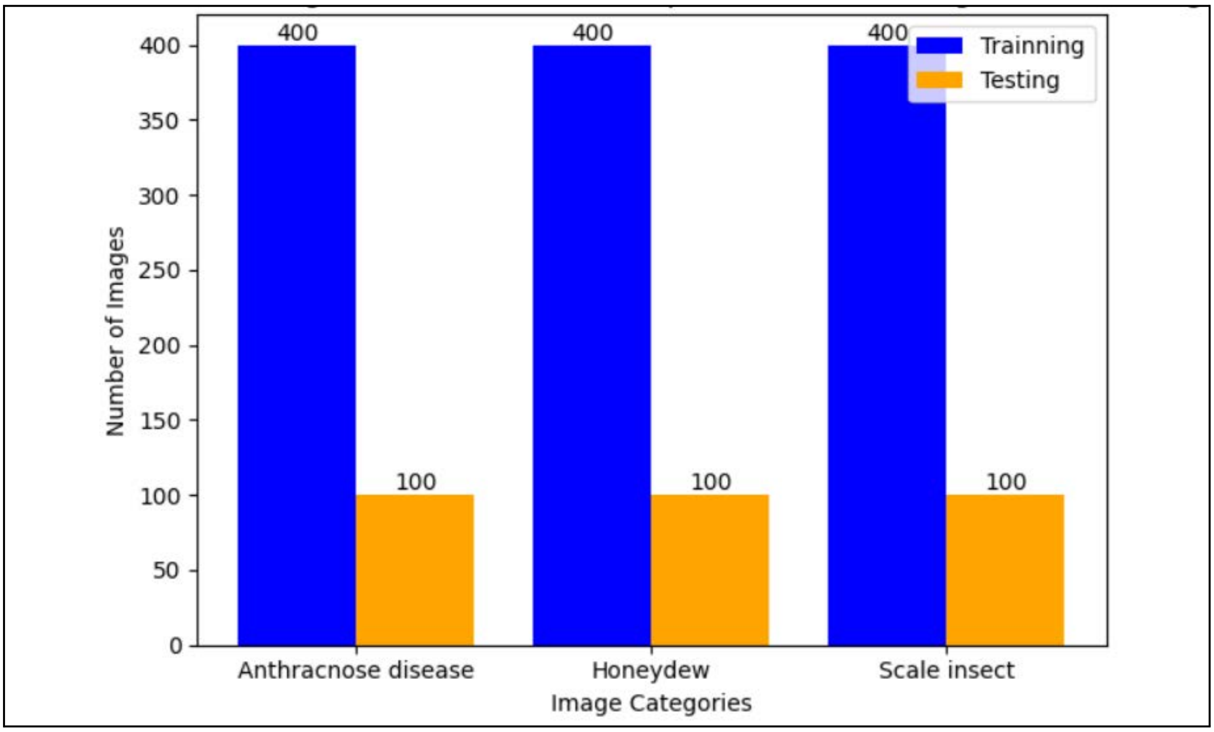


Figure 42: Number of images for our own dataset per class 80% training and 20% testing
[See Appendix E for code details]

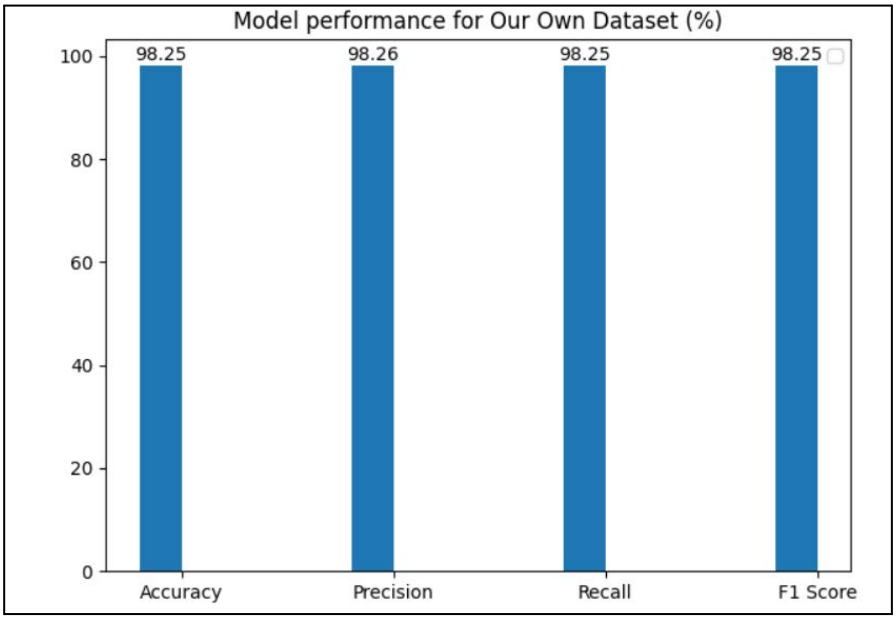


Figure 43: Model performance metrics of our own dataset
[See Appendix E for code details]

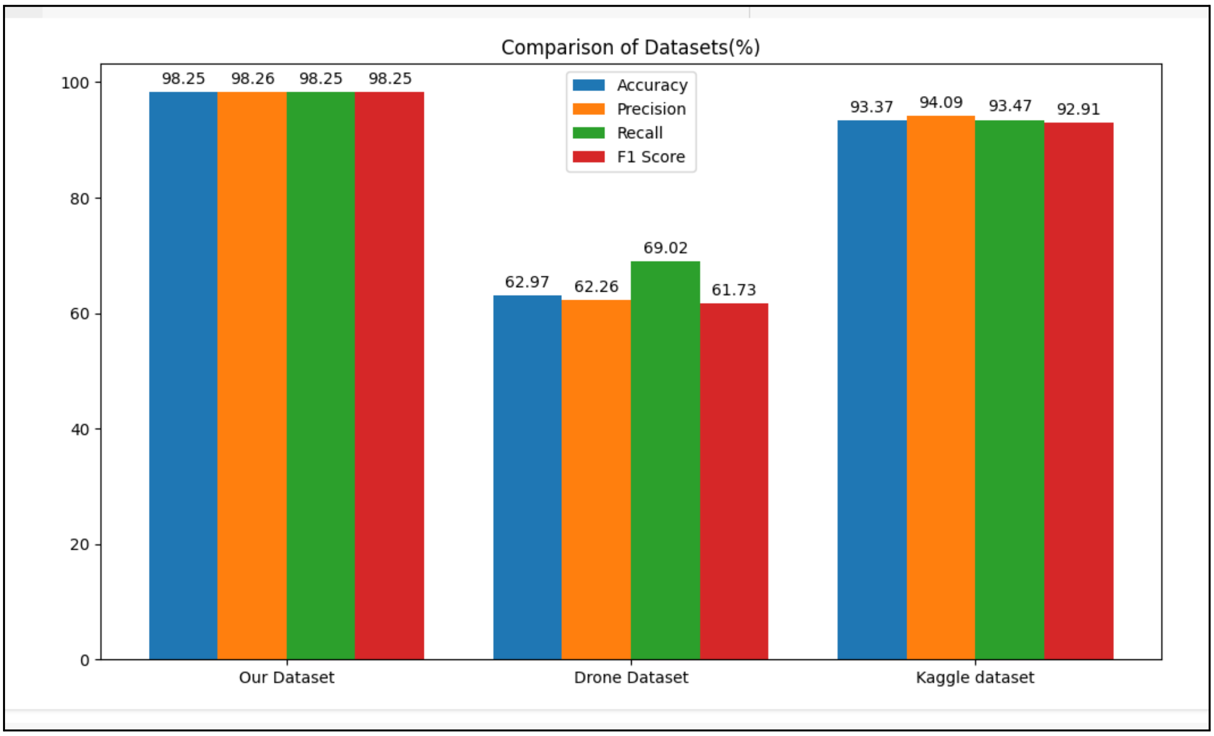


Figure 44:Performance metrics comparison
[See Appendix E for code details]

Here, the accuracy of 98.25% means that 98.25% of the predictions from the total instances are correctly classified by the model. The recall of 98.25% means that the model captures 93.47% of the actual positive instances. The precision of 98.26% means that 98.26 % of the instances that the model predicted as positive are actually positive. 98.25% of the F1 score indicates that the model has a better balance between precision and recall. The performance metrics results are comparatively good but we can get more accurate results if there is a large number of datasets.

6. After detecting the diseases of the mango leaves the model will give us the measures to remove the infestations. We have verified our prevention measures with the help of the Plantix app and the Dr.Chashi app. The remedies that the system will provide are given below-

1. Anthracnose:

- Burn the affected areas
- Mango farm should be clean
- Use fertilizers twice a year
- In each liter of water mix 1 ml of propiconazole or 1gm of copper oxychloride in each liter of water or 2 gm of topspin or 2 gm of dimethoate per liter of water with an interval of 12-15 days.(remedies given by Lead Agriculturist Shamiran Biswas)

2. Bacterial Canker:

- Regular spray of copper oxychloride
- Biocontrol agents like Acinetobacter baumannii can reduce the population of X.citri.

- Sprays containing thiophanate-methyl or benzimidazole can be applied to control Bacterial canker [36].

3. Cutting Weevil:

- Apply Cypermethrin of 1 ml per liter of water or Sevin of 2gl in per liter of water when leaves are 3 cm wide.
- Chlorpyrifos +Cypermethrin and Cypermethrin could be applied to control the infection of the mango leaves [37].

4. Die Back:

- Remove the infected parts of the leaves
- Apply oxychloride at 0.3% on the wounds. Apply Bordeaux mixture twice a year to reduce the infection rate.
- Sprays containing fungicide thiophanate-methyl have been proven to get rid of B.rhodina [38].

5. Gall Midge:

- KINGCODE ELITE® 50EC (10 ml in 20 Liters of water)
- LEXUS® 247SC (8 ml in 20 Liters of water)
- TOMARADO® 500SC (10 ml in 20 Liters of water) [39].

6. Powdery Mildew:

- We have to plant trees in dry and ventilated areas
- Prune plants and remove tall weeds to reduce the incidence of the fungus
- Avoid high nitrogen fertilization
- Apply fertilizers of potassium phosphate [40].

7. Sooty Mold:

- Infections are killed by spraying with carbaryl or phosphamidon 0.03%.
- We can also spray a dilute solution of starch or 5% maida. When the solution gets dried the starch comes off in flakes and it removes the black moldy growth of the fungi.
- We can spray the Bordeaux mixture 1%
- Spraying of wettable sulfur methyl parathion+gum acacia (0.2+0.1+3%) at 15days intervals reduces the sooty mold incidence [41].

8. Honeydew:

- A strong blast of water can be given to remove the infestations
- Neem oil, white oil, or insecticidal soap can be useful to remove infections [42].

9. Scale insect:

- Pruning of the heavily infested plant parts and their immediate destruction followed by two sprays of Monocrotophos (0.04 %) or Diazinon (0.04 %) or Dimethoate (0.06 %) at an interval of 20 days have been found very effective in controlling the scale population [43].

5.4 Conclusion

In conclusion, our final design met the requirements of the desired needs of the solution. We have shown our system can reach up to 7 feet in height and capture pictures of the mango leaves. As this system is an off-board system after taking the pictures with the help of a phone camera, the data is saved in our computer. From the computer, we will input the pictures into our model and detect the pest diseases of the mango leaves.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

This chapter marks a pivotal exploration of the impact and sustainability of the "Disease Detection System of Mango leaves." Beyond its technological features and economic benefits, the report searches into the societal, health, and safety dimensions that our solution inherently influences. The social impact is evident in the system's ability to provide consumers with more significant quantities of high-quality mango fruits while simultaneously elevating farmers' profits through early disease detection and optimized pesticide use. Furthermore, the health impact extends beyond consumers to environmental well-being, as the system minimizes toxic pesticides, positively affecting water ecosystems.

In the legal and cultural contexts, our system faces the challenge of integrating with traditional farming practices deeply rooted in manual control methods. However, its alignment with increasing environmental regulations positions it as a sustainable farming solution. The SWOT analysis provides a comprehensive overview of internal strengths and weaknesses, external opportunities, and threats. Based on the United Nations' Sustainable Development Goals, the sustainability matrix illustrates how our project actively contributes to global objectives, from food security and reduced diseases to sustainable agriculture and economic growth. This section illuminates the broader impact of our implemented Disease Detection System of Mango leaves, showcasing its role not only as a technological innovation but as a catalyst for positive change in agriculture and its interconnected domains.

6.2 Assess the impact of the solution

Social impact:
Our solution gives the consumers more quantity and good quality mango fruits as, due to early disease detection, we can solve our problems. It helps produce abundant mango fruits, and the farmers increase their profits by selling them. In earlier times, farmers required more workers and pesticides to invest in mango crops. However, with our solutions, the user can automatically monitor and detect diseases in mango fields and use the appropriate amount of pesticides, so the farmers' profit would increase dramatically. Food security could be obtained through this solution as detection at an early stage ensures preventive measures, and taking these preventative measures at an early stage could reduce crop loss and ensure a stable supply of mango crops [44].

Health impact:
Our solution lessens the pesticides used for mango production, positively impacting consumers' health. Also, the toxic pesticides are washed out with rainwater and go to the water bodies, affecting the fish and freshwater. Still, with our solutions, the amount of pesticides can be lessened, so when the consumers consume water, fish will positively impact health [45].

Safety:
Our detection system can reduce the need to use harmful and toxic chemicals and pesticides by farmers. As our solution can provide accurate data regarding the attack of diseases, it minimizes exposure to harmful chemicals and pesticides for living bodies.

Cultural context:
In agricultural practices, disease control management is a part of farming, and the traditional manual control method has existed for a long time. So, it will be hard for the farmers to believe in the effectiveness and accuracy of the automated pest monitoring system and why it will be beneficial and effective for them.

Legal context:
Our optimal solution will minimize the negative impact of agricultural practices on ecosystems, which will increase environmental regulations. The solution promotes sustainable farming methods by using fewer pesticides.

Swot Analysis:
Swot analysis identifies and analyzes any incident based on strengths, weaknesses, opportunities, and threats. The table below presents the SWOT analysis of our project.

Table 16: Swot Analysis

Strength	Weakness
• Detection of diseases more accurately and efficiently • Environment-friendly as less usage of pesticides • Early detection of disease outbreaks • Gives solution of pest diseases	• Weather issues • Light • Dust • Blurry images
Opportunities	**Threats**
• Improve pest management strategies and reduce pesticide usage for which sustainability increases • The data from the system can be important data for the pest management research • The system can be built for other crops too.	• Emerging companies with the same system but cost-friendly • New technology may seem unknown to mango garden owners • Technical issues can affect the movement of the rover body

6.3 Evaluate the sustainability

Project relation with sustainability matrix:

Table 17: Sustainability matrix

Select SDGs	Goal description	Primary dimension Focus	Indicators
SDG-2: No hunger	• Food Security • Reduce crop loss • Improve nutrition and promote sustainable agriculture	Social	• Crop damage assessment • Pest population control • Percentage of growing mango
SDG-3: Good health and well-being	• Decrease diseases causing for excessive pesticide • Reduce to transmit diseases from insect to animal	Social	• Percentage of crop affected by pests • Reduction pesticide uses
SDG-8: Decent work and economic growth	• Decrease economic losses • Increase profit of farmers	Economic	• Increase in crop yield • Reduction of losses

The Sustainable Development Goals (SDGs) are 17 goals adopted by the United Nations in 2015 to end poverty, protect the planet, and ensure prosperity for all.

One SDG relevant to an insect pest monitoring system is SDG 2, Zero Hunger. This goal aims to end hunger and improve sustainable agriculture by achieving food security. There is a need to develop efficient monitoring systems to identify and control pest outbreaks resulting from insect pests significantly affecting crop yield and food security.

Besides, SDG 3 focuses on ensuring healthy lives and promoting well-being for all, including reducing disease burden and addressing other health challenges. One key note related to SDG 3 and insect pest monitoring systems is that these systems can help reduce the use of pesticides and other harmful chemicals that can negatively impact human health. By identifying and managing pests more precisely, farmers can use fewer chemicals, reducing exposure for farmers and consumers.

Furthermore, the monitoring system for insect pests can help with SDG-8 by promoting sustainable food and agricultural systems. Pest insects can seriously harm crops, resulting in financial losses for farmers and decreased food output. Farmers that use efficient pest monitoring systems can identify pest outbreaks and take the necessary precautions to limit or prevent damage.

Overall, insect pest monitoring systems can contribute to several SDGs, particularly food security, sustainable production, and biodiversity conservation [46].

6.4 Conclusion

In summarizing the impact and sustainability analysis, the narrative unfolds across social, health, safety, cultural, and legal realms. Socially, the system promises increased high-quality mango yields, empowering farmers for greater profits and reinforcing food security. On the health front, it reduces pesticide use, benefiting consumers and safeguarding freshwater ecosystems. The safety aspect is marked by minimized farmer exposure to harmful chemicals. The Mango Leaves Disease Detection System emerges as a technological feat and a catalyst for sustainable agriculture, harmonizing prosperity, health, and environmental balance.

Chapter 7: Engineering Project Management. [CO11, CO14]

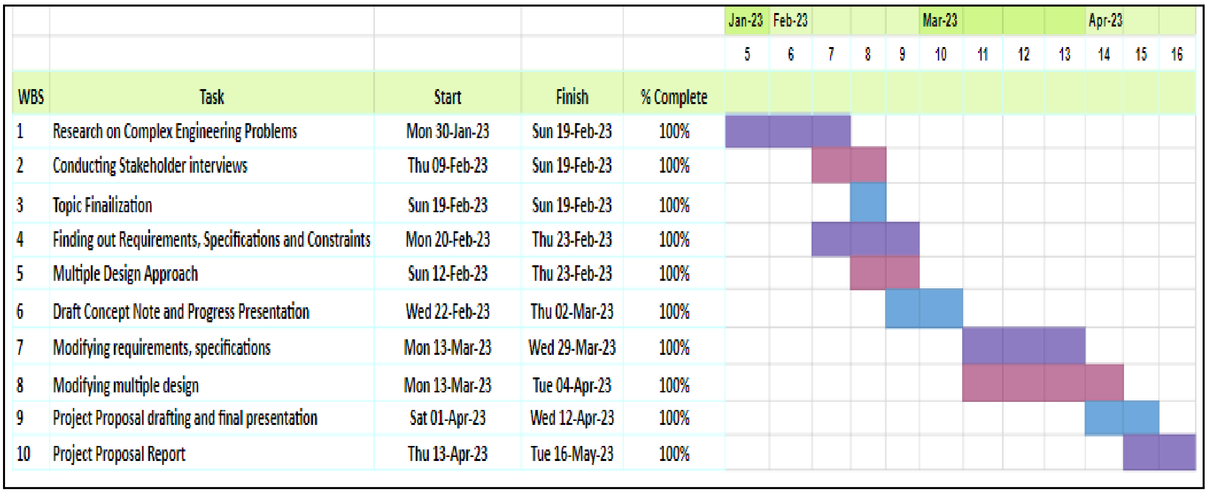
7.1 Introduction

Engineering Project Management requires fundamental knowledge and skills to navigate a project from its initial to completion stage. The goal is to ensure the completion of the project by fulfilling the objective, requirements, and specifications within the given timeframe. Our Final Year Design Project is tentatively a yearlong project divided into three parts for three semesters. Firstly, in the EEE400P/EE499P (Problem Identification and Project Proposal) course, we have to choose a topic on complex engineering problems and then find a maximum of three approaches to solve this problem. Secondly, we have EEE490D/EEE499D (Design and Development) course, where we implement our design approaches in simulation and 3D models to identify the optimal design. Lastly, we build a prototype of our optimal design in the EEE490C/EEE499C (Validation and Project Completion) course.

Throughout the project, we have maintained a Gantt chart each semester to anticipate our workload and plan accordingly. This has contributed to the efficient planning, execution, and monitoring of our project. Additionally, one of the most important parts of project management is the communication between group members and the ATC Panel. We had a weekly meeting with our ATC members, where we have shared our queries and updates on our project. Similarly, we had a fixed time allocation for meeting with our group members thrice a week and many instant meetings whenever needed. Another important part of project management is the involvement of stakeholders. For our project, we met three stakeholders who shared their expertise in their respective fields, which helped us complete our project successfully.

7.2 Define, plan, and manage engineering project

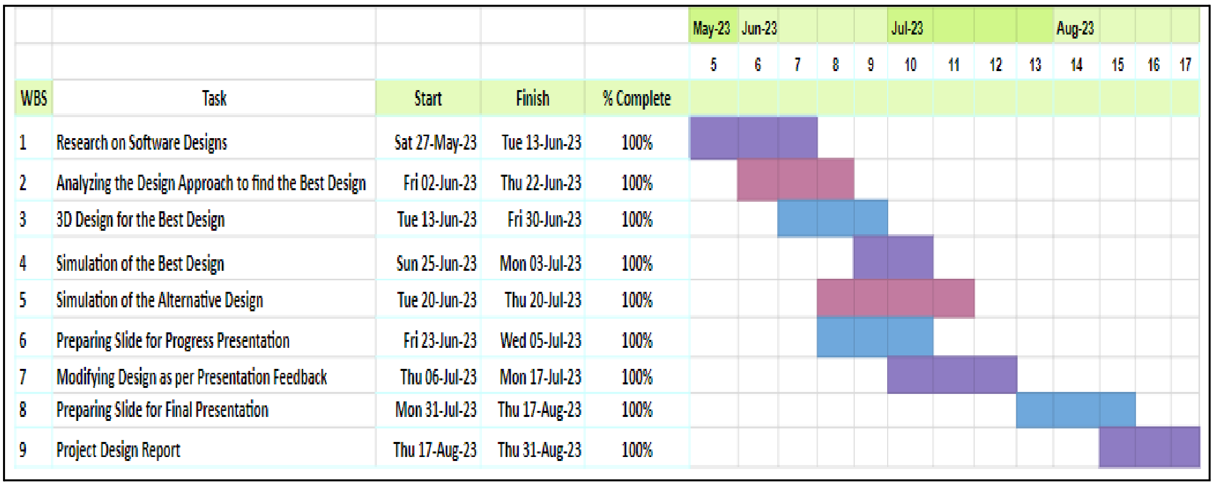
- Gantt chart for EEE499P, Spring 2023:



WBS	Task	Start	Finish	% Complete
1	Research on Complex Engineering Problems	Mon 30-Jan-23	Sun 19-Feb-23	100%
2	Conducting Stakeholder interviews	Thu 09-Feb-23	Sun 19-Feb-23	100%
3	Topic Finalization	Sun 19-Feb-23	Sun 19-Feb-23	100%
4	Finding out Requirements, Specifications and Constraints	Mon 20-Feb-23	Thu 23-Feb-23	100%
5	Multiple Design Approach	Sun 12-Feb-23	Thu 23-Feb-23	100%
6	Draft Concept Note and Progress Presentation	Wed 22-Feb-23	Thu 02-Mar-23	100%
7	Modifying requirements, specifications	Mon 13-Mar-23	Wed 29-Mar-23	100%
8	Modifying multiple design	Mon 13-Mar-23	Tue 04-Apr-23	100%
9	Project Proposal drafting and final presentation	Sat 01-Apr-23	Wed 12-Apr-23	100%
10	Project Proposal Report	Thu 13-Apr-23	Tue 16-May-23	100%

Figure 45:Gantt chart for EEE499P, Spring 2023

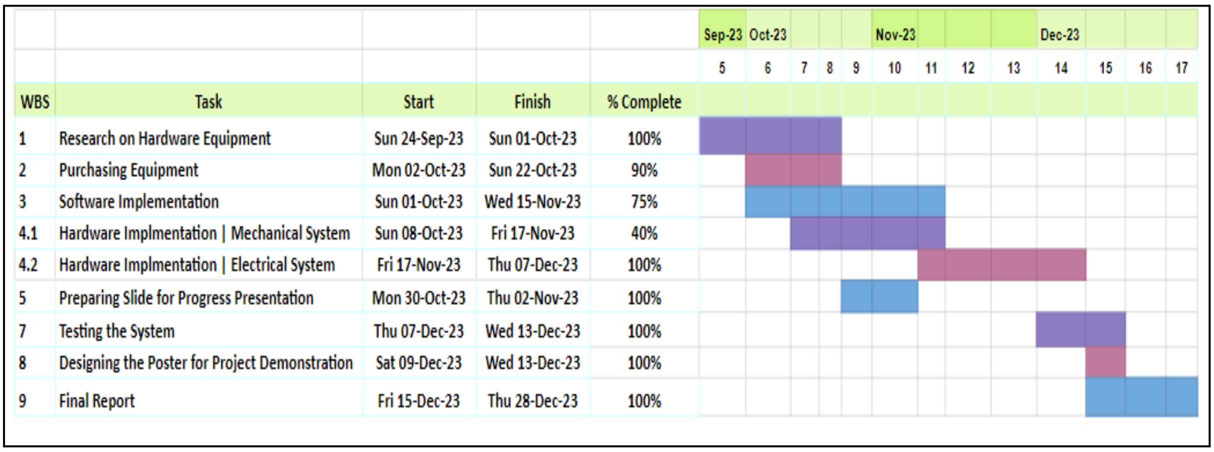
- Gantt chart for EEE499D, Summer 2023:



WBS	Task	Start	Finish	% Complete
1	Research on Software Designs	Sat 27-May-23	Tue 13-Jun-23	100%
2	Analyzing the Design Approach to find the Best Design	Fri 02-Jun-23	Thu 22-Jun-23	100%
3	3D Design for the Best Design	Tue 13-Jun-23	Fri 30-Jun-23	100%
4	Simulation of the Best Design	Sun 25-Jun-23	Mon 03-Jul-23	100%
5	Simulation of the Alternative Design	Tue 20-Jun-23	Thu 20-Jul-23	100%
6	Preparing Slide for Progress Presentation	Fri 23-Jun-23	Wed 05-Jul-23	100%
7	Modifying Design as per Presentation Feedback	Thu 06-Jul-23	Mon 17-Jul-23	100%
8	Preparing Slide for Final Presentation	Mon 31-Jul-23	Thu 17-Aug-23	100%
9	Project Design Report	Thu 17-Aug-23	Thu 31-Aug-23	100%

Figure 46: Gantt chart for EEE499D, Summer 2023

- Gantt chart for EEE499C, Fall 2023:



WBS	Task	Start	Finish	% Complete
1	Research on Hardware Equipment	Sun 24-Sep-23	Sun 01-Oct-23	100%
2	Purchasing Equipment	Mon 02-Oct-23	Sun 22-Oct-23	90%
3	Software Implementation	Sun 01-Oct-23	Wed 15-Nov-23	75%
4.1	Hardware Implmentation | Mechanical System	Sun 08-Oct-23	Fri 17-Nov-23	40%
4.2	Hardware Implmentation | Electrical System	Fri 17-Nov-23	Thu 07-Dec-23	100%
5	Preparing Slide for Progress Presentation	Mon 30-Oct-23	Thu 02-Nov-23	100%
7	Testing the System	Thu 07-Dec-23	Wed 13-Dec-23	100%
8	Designing the Poster for Project Demonstration	Sat 09-Dec-23	Wed 13-Dec-23	100%
9	Final Report	Fri 15-Dec-23	Thu 28-Dec-23	100%

Figure 47: Gantt chart for EEE499C, Fall 2023

Involvement with Stakeholder:

Table 18: Details of the stakeholders

Name of the stakeholder	Interests	Role	Estimated Priority
Engr. Golam Mowla, Mango Garden owner	Effective pest control.	Directly affected by leaf diseases as it is related to crop yield .	1
Agricultural Researcher Professor Abu Noman Faruq Ahmmed of Sher-e-Bangla Agricultural University	Interested in scientific detection and technical aspects of the detection	He is involved in providing us with knowledge about mango leaves diseases and gave our project method validation.	2
Lead Agriculturist Shamiran Biswas at Dr. Chashi	Interested in the development of agriculture	Providing us with knowledge about mango leaves diseases and measures with his practical experience.	3

7.3 Evaluate project progress

First of all, in the EEE490P/EEE499P course, our group opted to address a complex engineering problem within the agricultural field. For a better understanding of the problems within this field, we arranged a meeting with Professor Abu Noman Faruq Ahmmed, the Chairman of the Department of Plant Pathology at Sher-e-Bangla Agricultural University. During this meeting, the Professor discussed various problems, and among them, one of the problems intrigued us. It was the problem regarding the diseases on mango leaves, which reduces the crop yield, and excessive use of pesticides poses risks to human health and the environment. Following the meeting, our group went through intensive research on this topic by reviewing journals, articles, and papers to learn more about this problem. Based on our findings, we proposed this topic to our ATC Panel. Our ATC panel approved our chosen topic and guided us in beginning our project proposal writing. Then, we initiated our work on the project proposal by dividing the task among our group members with a clear timeframe. Any issues or confusion regarding our project were first attempted to be solved among our group mates at regular group meetings. If not solved by us, then during weekly meetings with our ATC Panel, they consistently guided us to solve a problem adequately.

Second of all, in the EEE490D/EEE499D, we had to simulate the design approaches we found in EEE490P/EEE499P, and from that, we had to identify an optimal solution for our project through different types of analysis. Similarly, we again assigned responsibilities to each group member within a timeline for each task. Along with simulation of the design approaches, we also designed a 3D model of the system to give a proper visualization of how our system should look, and we also worked with the software algorithm for image processing. Meanwhile, we kept updating our progress on our work, the issues we faced during the weekly meeting with our ATC Panel, and their valuable feedback helped us choose the right path.

Last but not least, in the EEE490C/EEE499C, the final stage of our project was to implement the hardware system based on optimal design. We began by thoroughly researching the equipment we needed and the shops that would be best to make our purchase. After that, we started purchasing the equipment. At the same time, one of our group mates was successful in conducting a meeting with Shamiran Biswas, a Lead Agriculturist at Dr. Chashi. Mr. Shamiran helped us by sharing his knowledge regarding mango leaf diseases in our country. Moreover, we received support from Mr. Golam Mawla, a mango field owner who was generous enough to allow us to conduct our project in his field. This cooperation with Mr. Mawla helped us to create our dataset for training them in our algorithm and also gave us the chance to assess the performance of our system upon its completion. Furthermore, with the assistance and guidance of Professor Md. Khalilur Rahman and Mr. Monir we successfully completed the construction of the mechanical system of our body.

Afterward, we began working on the electrical part of our project. The electrical part required several trial and error processes, which consumed much time and tremendous effort until completion. After the completion of our system, we took it to the mango field for testing. The system was able to fulfill the requirements. It also captured pictures of mango leaves, which were then analyzed through our algorithm to detect the diseases and recommend appropriate remedies.

7.4 Conclusion

To conclude, project management plays a major role in efficiently completing any project. For instance, managing a Gantt chart helped us pre-plan our work and gave us enough time to work with any unforeseen event. Similarly, regular meetings with group members and the ATC members allowed us to discuss the progress, determine the problems, and figure out the solutions, thus helping us to continue the project according to the schedule. Most importantly, the collaboration with stakeholders helped us in various ways to complete our project successfully.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

The ninth chapter of the comprehensive report discusses the economic aspects underlying the Mango leaf disease detection system. In the initial chapters, we laid the groundwork by introducing the project, elaborating its technological innovations, and highlighting the significance of this advancement in mango cultivation practices. Now, to present the practical and rational view of the implementation of our project, our attention is to analyze the detailed evolution of the economic landscape.

This chapter serves as a bridge, connecting the broader narrative of the project with the specific economic insights that will follow. In this chapter, we resolve the cost and benefits of our implemented system and evaluate the financial and economic aspects of the project. By the end of this chapter, we hope to provide a comprehensive understanding of how the Mango Leaves Disease Detection System stands as a technological milestone and a potential catalyst for positive economic change within the agricultural sector.

8.2 Economic analysis

Economic analysis, in the context of our project, involves a systematic study of the financial implications, costs, and benefits of implementing the Mango Leaf Disease Detection System. This process requires a detailed exploration of the economic viability, market dynamics, and potential financial returns. As we explore this analysis, the chapter unravels the costs and benefits of the implemented system. Moreover, it involves a comprehensive evaluation of the financial and economic aspects of the project, shedding light on its potential to influence positive economic change within the agricultural sector.

In the first step of the analysis, the table below shows the production cost of our project. From the previous chapters, we know that for building our project, we use different electrical and mechanical components to implement the subsystem of our system. The table represents the cost of the equipment used in our project.

Table 19: The product cost

Subsystem	Component	Price (BDT)
Rover Body & Scissor Lift	SS Box (3)	6575
	10mm screw rod (64′)	2880
	10mm Lock nut (60′)	840
	Metal Washer (150′)	900
	10mm drill bit (1)	450
	½ cross pipe (60′)	2700
	Chanel (2′)	300
	Slide wheel	500
	Making Scissor	2500
	12V 400 RPM Motor (4)	6400
	Wheel (4)	5000
	12V DC Long-stroke actuator (2)	14700
Power system	12V 9 mah Rechargeable Battery (1)	1400
	12V 7 mah Rechargeable Battery (1)	1400
	Battery charger of rechargeable Battery	600
	3.7V Rechargeable Battery (5)	500
	Battery charger of lithium battery	450
Control & Communication	Arduino UNO R3 (1)	810
	Arduino Mega (1)	1650
	BTS 7960 motor driver (3)	1350
	Breadboard (2)	180
	Lora (4)	2200
	PCB making of Lora circuit	3000
	Switch (4)	20

Miscellaneous	DC jack (3)	120
	Lithium Battery case (3)	170
	Jumper wire	180
	14AWG silicone wire (16 feet)	144
	Total	**71000**

So, in this case, the production cost of our project is 71,000 tk. However, with this market and other shifting costs, our product price is almost 75,000tk.

Due to the convenience of our product, transportation problems, the current situation of our country, and the limitation of funding and accessibility, we choose a mango yard area of 1400 square meters. However, our product is applicable and practical for large mango yards. For this reason, we do our economic analysis of our project from the information of 2000 square meters of mango yard in Chapainawabganj, Rajshahi, mentioned in "the Daily Star" newspaper. The mango grower has almost 200 mango trees in the mentioned mango yard. Almost all of the trees in this yard are Fazli mango trees. From an adult Fazli mango tree, almost 200 to 300 mangoes are produced during the summer, meaning the grower gets almost 40,000 to 60000 mangoes from this yard [47].

In the summer, the average price of Fazli is 70tk. If we calculate, we get that from this 2000 square feet yard. The grower earns almost 30 lakh taka from selling mangoes. Besides, research from another article on 'Business standards' we know that to save against mango diseases and pests, mango growers have to use a good number of pesticides, which cost almost 2-3 lakhs taka [48].

We also know that growers use pesticides 17-18 times before harvesting. In a research paper "Present Scenario of Insecticides and Fungicides Use in Largest Mango Cultivation Area in Bangladesh" we find the pesticides used by the mango growers are such as Mancozeb, Dithane M-45 (Mancojeb), Indofil M-45 (Mancojeb), Nativo (Tebuconazole + Trifloxystrobin 100), Knowing (Carbendazime), Penncozeb (Mancojeb) and Power blast (Azoxitrobin+ Diphenoconajol). However, about 39.6% of mango growers know little about insecticides/fungicides, and 60.4% do not know about insect use and side effects [49]. So, the excessive use of insecticides indicates a waste of money and causes dangerous health issues. So, in this case, our product is used in the mango yard to detect diseases and provide solutions to the attacked diseases; it is possible to save the high cost of the mango yard from using excessive insecticides, which is 1-1.5lakh.

Furthermore, for the small mango yard of less than 1000 square meters, we do our analysis based on providing service, another business aspect. In this circumstance, the cost of our service system is considered as 10000 tk/per day with the shifting cost. If we assume the

1000 square meter mango yard has 100 trees by planting trees within 10m distance. After 3-4 years from planting, the adult mango trees produce almost 20-30 thousand mangoes. The market price of these mangoes during summer is 10 lakh taka. Using our product detection service system for 2-4 days, mango growers can save excessive money on pesticides.

8.3 Cost-benefit analysis:

In the economic analysis section, we analyze our product cost, which is almost 75 thousand taka. By using the product, it is possible to increase the revenue and decrease the labor and environmental impact.

Increase the revenue

From our research, we find that economic loss occurs every summer season in Bangladesh due to the detected diseases by our system. Anthracnose at 60%, Scale insects at 10%, and Honeydew at 50%. In this case, we analyze the diseases found in our selected testing field project. Our product can decrease the loss of the affected diseases[50]. We have analyzed the economy of the 2000 square meter mango yard mentioned in this chapter's section 8.2. The graph below shows the revenue with and without our system [51].

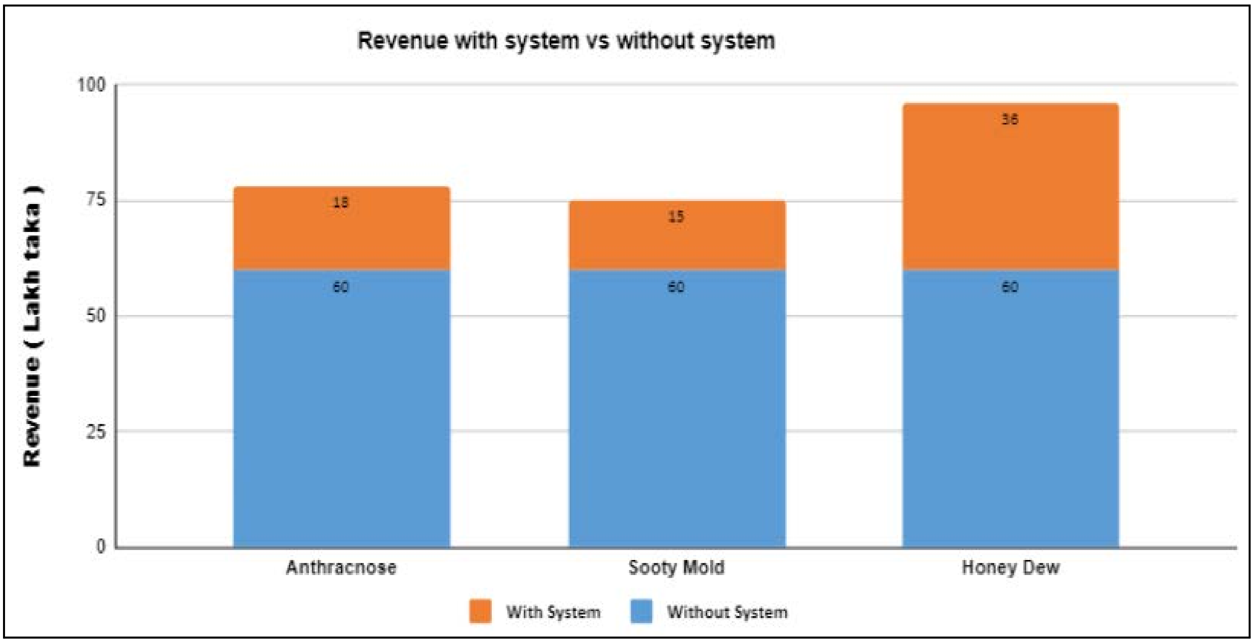


Figure 48: 2000 square feet mango yard revenue with system vs without system

The chart shows that our detection system with the rover body can increase revenue by a considerable amount. Besides the previous section, we also get from our analysis that usage of our product can save excessive pesticide amounts of 1-1.5lakh taka.

Decrease the labor cost

Our detection system is more advantageous for large mango yards as the user can control the rover body from 2.5-3 km. So, preventing the rover system from a base station is easy and convenient. With the invented system, we can easily move quickly in a large and uneven yard, which is tough and more time-consuming to reach physically. On the other hand, to monitor and nourish the mango yard, the growers need some human resources, but using our product, they can deduct the labor cost. In our analysis of the 2000-square-meter mango yard, the grower needs 3-4 laborers to monitor the yard. If the monthly salary of each laborer is 9-10 thousand taka, the grower has to spend almost 1.2 lakh taka after a year. However, as the users can control our product from a distance and monitor the health of mango leaves, 1-2 laborers can easily monitor the yard with the help of the rover body. So in this way, our product can save almost 50 thousand labor costs.

Environmental impact

To implement our project, we aim to reduce excessive amounts of pesticide in the mango yard and save human health from dangerous diseases. In a research paper "Pesticide exposures towards health and environmental hazard in Bangladesh: A case study on farmers," analysis of the side-effects of using pesticides over appliers that 17% of farmers in Savar Upazila and 16% of farmers in Meherganj Upazilla reports general weakness. Some farmers also reported vomiting, feelings of unconsciousness, stomach ache, weakness, skin problems, and effects on the eyes. However, the farmers with mild pesticide poisoning often do not report because treatment services are costly and inaccessible or because they fear that drawing attention to themselves may result in losing employment opportunities. Besides, healthcare professionals in rural areas often fail to diagnose poisoning correctly, as many related symptoms are pretty general or mimic other common health problems (e.g., headaches, dizziness, vomiting). Using our system makes it possible to reduce farmers' health problems [51].

Furthermore, from an article in 'The Daily Star,' we find that growers use excessive chemical pesticides to increase the production of mangoes. Eating these chemical fruits causes deadly diseases, for example, cancer, hypertension, and congenital disabilities. Nevertheless, our detection system can help to produce a good number of mango fruits, which helps to increase profit and save the farmers and the general people from dangerous diseases.

8.4 Evaluate economic and financial aspects

Section 8.4 shows that our product can generate considerable revenue from a 2000-square-foot mango field. The analysis shows that the earning revenue by using our system is much higher than the mango selling revenue without revenue. The product cost of our system is almost 75 thousand taka. If our analyzed 2000 square meter mango field has diseased with Anthracnose, Sooty mold, and honeydew, using our product, the grower can make more than 60 lakh taka, almost eight times more than the product cost. In this analysis, to earn more revenue, using the product is helpful to the growers.

On the other hand, our product is more practical to use in a large mango yard. Our product cost is more than 70 thousand, so it is not profitable for use in small mango fields. The growers of large mango fields can benefit from using the product and monitoring the mango leaf, detecting diseases, and getting the solution accurately with less manpower and less timing.

8.5 Conclusion

In conclusion, the economic analysis of the Mango Leaf Disease Detection System underscores its transformative potential in mango cultivation, particularly for larger yards facing disease challenges. The cost-benefit analysis reveals significant economic advantages, emphasizing the system's ability to increase revenue, reduce labor costs, and contribute to environmental sustainability. Beyond its technological innovation, the system emerges as a catalyst for positive change in agriculture, providing a clear pathway to economic prosperity and more sustainable farming practices. The findings presented here lay the foundation for informed decision-making, encouraging stakeholders to embrace innovative solutions that harmonize technology with economic sense.

Chapter 9: Ethics and Professional Responsibilities CO13, CO2

9.1 Introduction

Ethics and Professional Responsibilities are one of the major responsibilities that should be prioritized for any project. In this chapter, the identification and application of ethical and professional responsibilities have been discussed according to the National Society of Professional Engineers Code of Ethics for Engineers [51].

9.2 Identify ethical issues and professional responsibility

- **Privacy and data protection:** According to the Rules of Practice No. 1c) from the NSPE Code of Ethics for Engineers [51], engineers cannot disclose any information without the client's or employer's prior consent. In our project, we collaborated with stakeholders who discussed valuable information to support our project. Therefore, it is essential to keep that information confidential and use it only for our project. Similarly, we have worked in a mango field to create our dataset and test the system we have built. These datasets must also be kept private and restricted to the purpose of our project. Furthermore, the location of the mango field should also be dealt with privacy.

- **Consent to be involved in the project:** Consent is crucial to any project. It is an ethical and professional responsibility to get permission from the stakeholders before they share their knowledge or support us by any means. This approval by the stakeholders indicates their willingness to participate in our project. Before asking for permission, it is also important to brief them about the project and what we are trying to achieve and thus enable them to decide whether they would like to participate. Furthermore, referring to the Rules of Practice as discussed in point 1 [51], for future work or any other project, if we need the information and datasets we have gathered by obtaining permission from the stakeholders, then we need to get their consent again [See Appendix F for application and consent form details].

- **Transparency:** The Rules of Practice No. 4 [51] said that Engineers should remain faithful to their employers and clients. In our Project, we are honest about anything regarding the project with the stakeholders, ATC members, and group members. Additionally, the Rules of Practice No. 4c [51] also describes that Engineers should have open communication about any matter so that their judgment or quality of their work is not affected by any present or potential conflicts of interest. In our case, we have disclosed all the factors regarding our project to stakeholders and ATC members.

  Likewise, we should not have any communication gap between our groupmates regarding anything on the project. Moreover, in the future, if we get the opportunity to use the system as a subscription-based system, we must let our clients have clear information regarding how the system works, how it can be used, and how it gives suggestions on the remedies for the diseases.

- **Environmental Impact:** Any electrical or mechanical system does have numerous environmental impacts. For instance, in an electrical system, one of the vital pieces of equipment needed to experiment is a Battery. The production of batteries consumes much energy, generates greenhouse gasses, and requires the extraction of natural resources. Similarly, battery disposal can also contribute to environmental pollution when not disposed of properly. On the other hand, electrical projects require numerous trial-and-error methods that can cause the generation of waste materials. If these waste materials are not disposed of properly, then this can also negatively impact the environment [52].

- **Risk Management and Contingency Plan:** Following Fundamental Canons no.1 [51], Engineers should prioritize the safety, health, and well-being of the public first before everything else. Thus, proactive approaches and emergency plans such as risk management and contingency plans should be included for every project.

9.3 Apply ethical issues and professional responsibility

- **Privacy and data protection:** As per the Rules of Practice No. 1c) from the NSPE Code of Ethics for Engineers [51], engineers are not allowed to disclose any information without the client's or employer's prior consent. We have acknowledged the potential sensitivity of information shared by the stakeholders and thus promised to keep the confidentiality and use of information restricted to the project's purpose only.

- **Consent to be involved in the project:** Consent is vital in showing ethical and professional responsibilities. Thus, while communicating with any stakeholders throughout the project, we have asked for their consent first to know whether they agreed to share their expertise with us. We have taken a written document for approval to work on the mango field [51]. However, for various reasons, it was not always possible to have written documentation of this agreement. We have tried our best to communicate clearly to let them know about the goal and objective of our project.We have given application to the mango field owner for asking permission to use the mango field for our project purpose [See Appendix F for application and consent form details].

- **Transparency:** Maintaining the Rules of Practice no. 4 and no. 4c) [51], we have tried communicating clearly and honestly with stakeholders, ATC members, and groupmates. Additionally, regarding the subscription-based system, we have planned to create documentation and training materials to ensure that the clients know how the system works, how data is gathered, and how it is utilized.

- **Environmental Impact:** For our project, we tried using rechargeable batteries instead of single-use batteries so that it has a less environmental impact. Additionally, the disposal batteries and other waste materials from our project are recycled, and if could not be recycled then are given to the hazardous waste collection company. [52]

- **Risk Management Plan:** For the Risk Management Plan of our project, we have created a qualitative risk assessment.

    - ❖ **Natural Calamities:** The electrical system must be unsafe in various weather conditions. Rain can cause damage, so it should not be operated during cloudy weather. Strong winds are also dangerous, significantly when the scissor lift rises. If the scissor is extended to 7 feet during windy weather, the equipment could become unbalanced and harm the system. Thus, monitoring weather forecasts and potentially a balancing mechanism to the bottom of the rover for stability during the wind.

    - ❖ **Electrical Risk:** Batteries are used to power the system. However, inaccurate load calculations may result in insufficient voltage to operate our system or excessive voltage that could be harmful. Calculating the correct load requirement is crucial to mitigate this risk. Additionally, implementing safety features such as MCBs can help safeguard the system from voltage fluctuations.

    - ❖ **Monitoring time:** Our device may not be effective if used at night because it cannot detect leaf diseases. Therefore, we should operate the system at night and continue to improve our chances of finding the insect as a solution to this issue.

    - ❖ **Physical Damage:** The system risks various forms of damage, including falling stones and falls. Similarly, the device may also experience damage due to the uneven terrain of the fields, which may not be suitable for operating a rover system. Therefore, caution must be exercised to prevent stones from falling onto the rover.

Table 20: Qualitative Risk Assessment

Frequency of Circumstances	**Risk**		
	Low	**Medium**	**High**
High Certainty	Not Applicable	Electrical Risk	Natural Calamities
Medium Certainty	Monitoring time	Physical Damage	Not Applicable
Low Certainty	Not Applicable	Not Applicable	Not Applicable

- **Contingency Plan:**

Table 21: Contingency Plan

Risk level	Trigger	Response	Reason	Responsible
Natural Calamities	The rover & scissor lift system may be damaged and stop working	Monitor the weather forecast and check all connections if vital call the technicians	Due to heavy storms or strong wind	Sabrina
Electrical risk	The disease monitoring system would not operate properly and cause voltage fluctuations	Turn off the MCB	Inaccurate load calculation and voltage up-down not enough power production along with battery failure	Oishe
Physical damage	The system will be in operation unless any major problem occurs	Cleaning the terrain clean, Hardware repair and component replacement needed	Falling the rover due to stone and damage and occur short circuit	Fiza, Apurba

9.4 Conclusion

In conclusion, this chapter includes the identification and application of ethical and professional responsibilities. These ethical and professional responsibilities are mostly according to the standard rules of the National Society of Professional Engineers Code of Ethics for Engineers [51]. Maintaining these responsibilities ensured the successful completion of the project.

Chapter 10: Conclusion and Future Work.

10.1 Project Summary/Conclusion

Our project aims to create a disease-detection system for mango leaves. The system will identify the type of disease on the leaves and provide suggestions to the user on how to manage it. The system can detect nine diseases and will notify the user of remedies. The project has proposed two design approaches to solve the complex engineering problem. The project requires implementing the design approach simulation to analyze the optimal solution. ResNet 18 architecture has been used for image processing in both approaches. These design approaches have been further analyzed through different factors such as the performance matrix of the algorithm, power consumption of the battery, controlling system, a method to take pictures, etc., to get the optimal design.

To implement the hardware system, the power consumption for the scissor lift, the motor of the scissor lift, and the total power consumed by the scissor lift have been calculated. Then, the height of the scissor lift was also calculated to construct the mechanical part of the system. Likewise, 3D and PVC models of the system have been designed to visually represent how the system will look once completed. After the implementation of the hardware system, it has been proved that the system fulfills the objectives and requirements of our project. For instance, the system can reach the height of the mango field. Additionally, the system can detect diseases as trained by the algorithm and suggest remedies as required.

The report includes the use of modern Engineering and IT tools and the analysis of why specific tools were best for our project. The report also outlines impact analysis and project sustainability along with economic analysis. Moreover, the impact analysis includes different impacts of the project along with SWOT analysis, and the sustainability matrix has also been explained in the sustainability analysis. Lastly, the project document consists of Engineering Project Management and Ethical and Professional responsibilities which are the essential factors to complete a project.

10.2 Future work

By analyzing the project outcomes, the strengths and weaknesses are identified, which can be further utilized and developed as future work. For example, the system can be trained with the dataset of other fruit leaves and mango leaves; through this, the system will be able to address the problem of other fruit diseases. The system can also be designed in such a way that it will be able to spray the required amount of pesticide automatically based on the detection. This design will reduce the excessive use of pesticides and the need for human labor. Additionally, the system can be improved with high-functioning multi-sensors that can determine the humidity, temperature, and nutrition levels of the plants. Hence, this functionality of the system will be able to monitor the health of the plant. Furthermore, the system can also be implemented to have autonomous navigation; with this, the system will be able to navigate around any location by itself. This will again reduce the use of manpower which was required to navigate the system. Lastly, the system can be upgraded to real-time data analysis and reporting, which means the system will be able to detect the disease instantly along with suggestions for remedies. Hence, this will be able to enhance the efficiency of the outcomes of the system.

Chapter 11: Identification of Complex Engineering Problems and Activities.

11.1: Identify the attribute of complex engineering problem (EP)

Attributes of Complex Engineering Problems (EP)

Table-22: Provide reasoning how the project address selected attribute (EP)

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

11.2: Provide reasoning how the project address selected attribute (EP)

P1. Depth of knowledge required: Completing the project required a comprehensive understanding of many things, from identifying a complex engineering problem to finding the topic of our project till the completion of the project; we have to gain enough knowledge on numerous things through researching and talking to experts. Additionally, we had to learn how to use microcontrollers, energy storage systems, communication systems, and, most importantly, machine learning algorithms.

P2. Range of Conflicting Requirements: Every project aims to develop a cost-effective solution with high accuracy. In our project, we had to face the issue of choosing a cost-effective solution without compromising accuracy. However, choosing the optimal design approach through various analyses still helped us mitigate this issue.

P3. Depth of analysis required: This project required depth of analysis in various stages. Such as the analysis of design approaches, analysis of calculation to choose the power required for the system, analysis to calculate the height of the scissor lift for the system, and analysis of the performance matrix for the system.

P4. Familiarity of issues: The project topic is based on the agricultural field; thus, this topic was unfamiliar.

P6. Extent of stakeholder involvement and needs: Throughout the project, we collaborated with a few stakeholders who helped us tremendously to complete our project. In Chapter 6.2, we have discussed the collaboration with stakeholders (Table 18).

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11.3 Identify the attribute of complex engineering activities (EA)

Attributes of Complex Engineering Activities (EA)

Table-23:Attributes of Complex Engineering Activities (EA)

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

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

A1. Range of resource: As mentioned above in P1, we had to go through various resources such as research articles, journals, papers, and books to gain knowledge of the project to complete it successfully.

A2. Level of interaction: We have mentioned in Chapter 6 about the interaction with stakeholders throughout the project. The immense support we have received from the stakeholders helped us complete the project (Table 18).

A4. Consequences for society and the environment: Excessive use of pesticides negatively affects human health and society. Our project aims to reduce this excessive use of pesticides and, thus, reduce the harmful effects of pesticides on human health and society.

A5. Familiarity: The project topic is based on the agricultural field. Hence, this topic of the project is unfamiliar, as mentioned in P4.

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Appendix A: Logbook

FYDP C Fall 2023 of Team Log Book/ Journal

	Final Year Design Project-C Fall 2023		
Student Details	**NAME & ID**	**EMAIL ADDRESS**	**PHONE**
Member 1	Apurba Paul 20121033	apurba.paul@g.bra cu .ac.bd	01792213077
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Member 1	Md. Mahmudul Islam	mahmudul.islam@ br acu.ac.bd	
Member 2	Abdulla Hil Kafi	abdulla.kafi@bracu .a c.bd	

Date/Time /Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
25/9/2023	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Planning on purchasing the components Task 1:Purchase actuator and battery Task 2:Purchase steel, aluminum sheet, nuts, and bolts	Task 1:Apurba and Oishe Task 2: Fiza and Sabrina	Task 1. Completed Task 2: Completed
1/10/2023 (ATC Meeting)	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Design analysis and scissor lift construction Task 1: Analyze the design of the scissor lift Task 2: Do the calculation for the desired design Task 3: Make the scissor lift with PVC	Task 1: Apurba and Fiza Task 2: Fiza and Sabrina Task 3:All	Task 1: Completed Task 2: Partially Completed Task 3: Partially Completed
7/10/2023	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Test the actuator and complete building the scissor lift	Task 1: All	Task 1: Completed
14/10/2023	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Planning for constructing the whole machine	Task 1: All	Task 1: Completed
20/10/2023	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Collect datasets Task 2: Purchase other components	Task 1: Sabrina Task 2: Apurba and Fiza	Task 1: Completed Task 2: Completed
22/10/2023 (ATC meeting)	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Shift the rover body with a scissor lift near our testing field.	Task 1: All	Task 1: Completed
28/10/2023	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Understand all the component connections	Task 1: All	Task 1: Completed
1/11/2023	1. Sabrina 2. Apurba	Task 1: Test to operate the actuator with the switch	Task 1: Oishe and Fiza	Task 1: Completed

	3. Oishe 4. Fiza	Task 2: Test to operate the rover body movement with the switch	Task 2: Apurba and Fiza	Task 2: Completed
14/11/2023 (ATC meeting)	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Add Lora module to operate Task 2: Designing the transmitter and receiver	Task 1: Apurba and Sabrina Task 2: Oishe and Fiza	Task 1: Completed Task 2: Completed
21/11/2023	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Create the data set with sample Task 2: Software part completion	Task 1: Apurba and Sabrina Task 2: Oishe and Fiza	Task 1: Completed Task 2: Completed
1/12/2023 (ATC meeting)	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Video transmitting and processing	Task 1: All	Task 1: Completed
3/12/2023	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Testing	Task 1: All	Task 1: Completed
3/12/2023 (ATC meeting)	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Work with mid-presentation feedback Task 2: Poster	Task 1: All Task 2:All	Task 1: Completed Task 2: Completed
14/12/2023	1. Sabrina 2. Apurba 3. Oishe 4. Fiza	Task 1: Final presentation	Task 1: All	Task1: Completed

Appendix B: Code for Microcontroller

Code of Arduino Mega:

```
// Analog pins for inputs
int act_up_analog_pin = 44;
int act_down_analog_pin = 45;
int r_en_act = 32;
int l_en_act = 33;
int r_pwm_act = 5; // PWM
int l_pwm_act = 6;
void setup() {
  pinMode(r_en_act, OUTPUT);
  pinMode(l_en_act, OUTPUT);
  pinMode(r_pwm_act, OUTPUT);
  pinMode(l_pwm_act, OUTPUT);
  // No need to set analog pins in pinMode for reading
}
void loop() {
  int actuator_up= digitalRead(act_up_analog_pin);
  int actuator_down = digitalRead(act_down_analog_pin);
  // Up actuator
  if (actuator_up==LOW && actuator_down==HIGH) {
    digitalWrite(r_en_act, HIGH);
    digitalWrite(l_en_act, HIGH);
    analogWrite(r_pwm_act, 1000);
```

```
    analogWrite(l_pwm_act, 0);
  }
  // Down actuator
  else if (actuator_up==HIGH && actuator_down==LOW) {
    digitalWrite(r_en_act, HIGH);
    digitalWrite(l_en_act, HIGH);
    analogWrite(r_pwm_act, 0);
    analogWrite(l_pwm_act, 1000);
  }
  // Actuator hold (neither up nor down)
  else if (actuator_up==LOW && actuator_down==LOW) {
    digitalWrite(r_en_act, HIGH);
    digitalWrite(l_en_act, HIGH);
    analogWrite(r_pwm_act, 0);
    analogWrite(l_pwm_act, 0);
  }
  // Actuator hold (neither up nor down)
  else if (actuator_up==HIGH && actuator_down==HIGH) {
    digitalWrite(r_en_act, HIGH);
    digitalWrite(l_en_act, HIGH);
    analogWrite(r_pwm_act, 0);
    analogWrite(l_pwm_act, 0);
  }
}
```

Code for arduino Uno:

```
int r_en_rit = 8;
int l_en_rit = 7;
int r_pwm_rit = 6;
int l_pwm_rit = 5;
int r_en_lft = 3;
int l_en_lft = 4;
int r_pwm_lft = 10;
int l_pwm_lft = 9;
void setup() {
  pinMode(A0, INPUT);
  pinMode(A1, INPUT);
  pinMode(A2, INPUT);
  pinMode(A3, INPUT);

  pinMode(r_en_rit, OUTPUT);
  pinMode(l_en_rit, OUTPUT);
  pinMode(r_pwm_rit, OUTPUT);
  pinMode(l_pwm_rit, OUTPUT);

  pinMode(r_en_lft, OUTPUT);
  pinMode(l_en_lft, OUTPUT);
  pinMode(r_pwm_lft, OUTPUT);
  pinMode(l_pwm_lft, OUTPUT);
```

```
}
void loop() {
 int rover_front = 5*analogRead(A0)/1023;
 int rover_back = 5*analogRead(A1)/1023;
 int rover_right = 5*analogRead(A2)/1023;
 int rover_left = 5*analogRead(A3)/1023;
 // front
 if (rover_front  >0 && rover_back<=0 && rover_left <= 0 && rover_right <=0) {
  digitalWrite(r_en_rit, HIGH);
  digitalWrite(l_en_rit, HIGH);
  digitalWrite(r_en_lft, HIGH);
  digitalWrite(l_en_lft, HIGH);
  analogWrite(r_pwm_rit, 3000);
  analogWrite(l_pwm_rit, 0);
  analogWrite(r_pwm_lft, 3000);
  analogWrite(l_pwm_lft, 0);
 }
 // back
 else if (rover_front <=0 && rover_back >0 && rover_left<=0 && rover_right<=0) {
  digitalWrite(r_en_rit, HIGH);
  digitalWrite(l_en_rit, HIGH);
  digitalWrite(r_en_lft, HIGH);
  digitalWrite(l_en_lft, HIGH);
  analogWrite(r_pwm_rit, 0);
```

```
  analogWrite(l_pwm_rit, 3000);
  analogWrite(r_pwm_lft, 0);
  analogWrite(l_pwm_lft, 3000);
}
// left
else if (rover_front <=0 && rover_back <=0 && rover_left >0 && rover_right<= 0) {
  digitalWrite(r_en_rit, HIGH);
  digitalWrite(l_en_rit, HIGH);
  digitalWrite(r_en_lft, HIGH);
  digitalWrite(l_en_lft, HIGH);
  analogWrite(r_pwm_rit, 0);
  analogWrite(l_pwm_rit,3000);
  analogWrite(r_pwm_lft,3000);
  analogWrite(l_pwm_lft, 0);
}
// right
else if (rover_front  <= 0 && rover_back <=0 && rover_left <= 0 && rover_right > 0) {
  digitalWrite(r_en_rit, HIGH);
  digitalWrite(l_en_rit, HIGH);
  digitalWrite(r_en_lft, HIGH);
  digitalWrite(l_en_lft, HIGH);
  analogWrite(r_pwm_rit, 3000);
  analogWrite(l_pwm_rit, 0);
  analogWrite(r_pwm_lft, 0);
```

```
    analogWrite(l_pwm_lft, 3000);
  }

 // Stop or default case
  else {
    // Stop or default logic
    // Set appropriate pins for stopping or default behavior
    digitalWrite(r_en_rit, LOW);
    digitalWrite(l_en_rit, LOW);
    digitalWrite(r_en_lft, LOW);
    digitalWrite(l_en_lft, LOW);
    analogWrite(r_pwm_rit, 0);
    analogWrite(l_pwm_rit, 0);
    analogWrite(r_pwm_lft, 0);
    analogWrite(l_pwm_lft, 0);
  }
}
```

Appendix C: Code for detection of pests by the drone

```
import matplotlib.pyplot as plt

metrics = ['Caterpillar', 'Diabrotica speciosa', 'Healthy']

model1_values = [3349, 2205, 716]

bar_width = 0.2

index = range(len(metrics))

fig, ax = plt.subplots()

bar1 = ax.bar(index, model1_values, bar_width)

plt.xlabel('Image Categories')

plt.ylabel('Number of Images')

ax.set_title('Number of Images for the Drone Dataset per class')

ax.set_xticks([i + bar_width / 2 for i in index])

ax.set_xticklabels(metrics, fontsize=10)

for i, v in enumerate(model1_values):

    ax.text(i, v + 1, f'{v}', ha='center', fontsize=7)

plt.tight_layout()

plt.show()

import os

import matplotlib.pyplot as plt

DIRECTORY =
'/content/drive/MyDrive/Code_fydp/Drone_dataset/The_photos/bycbh73438-1'

image_folders = ['Caterpillar', 'Diabrotica speciosa', 'Healthy']

training_images = {}

validation_images = {}

for folder in image_folders:
```

```
    folder_path = os.path.join(DIRECTORY, folder)

    if os.path.exists(folder_path):

        images = os.listdir(folder_path)

        num_images = len(images)

        # Splitting

        count_train = int(0.8 * num_images)

        count_val = num_images - count_train

        training_images[folder] = count_train

        validation_images[folder] = count_val

        print(f"For: {folder} - Total Images: {num_images}, Training: {count_train},
Validation: {count_val}")

    else:

        print(f"{folder} folder does not exist.")

        training_images[folder] = 0

        validation_images[folder] = 0

training_counts = [training_images[folder] for folder in image_folders]

validation_counts = [validation_images[folder] for folder in image_folders]

plt.figure(figsize=(10, 6))

bar_width = 0.35

index = range(len(image_folders))

plt.bar(index, training_counts, bar_width, label='Training')

plt.bar([i + bar_width for i in index], validation_counts, bar_width, label='Validation')

plt.xlabel('Image Categories')

plt.ylabel('Number of Images')

plt.title('Distribution of Training and Validation Images for the training dataset')
```

```
plt.xticks([i + bar_width / 2 for i in index], image_folders)
plt.legend()
plt.tight_layout()
plt.show()
```

The dataset is imbalance.Now we will balance the dataset.

```
import matplotlib.pyplot as plt
metrics = ['Caterpillar', 'Diabrotica speciosa', 'Healthy']
model1_values = [500,500,500]
bar_width = 0.2
index = range(len(metrics))
fig, ax = plt.subplots()
bar1 = ax.bar(index, model1_values, bar_width)
plt.xlabel('Image Categories')
plt.ylabel('Number of Images')
ax.set_title('Number of images for the Drone Dataset per class')
ax.set_xticks([i + bar_width / 2 for i in index])
ax.set_xticklabels(metrics, fontsize=10)
for i, v in enumerate(model1_values):
    ax.text(i, v + 1, f'{v}', ha='center', fontsize=7)
plt.tight_layout()
plt.show()
import os
import shutil
training_image_paths = [
```

```
    '/content/drive/MyDrive/Code_fydp/Drone_dataset/Train/Caterpillar',

    '/content/drive/MyDrive/Code_fydp/Drone_dataset/Train/Diabrotica speciosa',

    '/content/drive/MyDrive/Code_fydp/Drone_dataset/Train/Healthy'

]

test_image_paths = [

    '/content/drive/MyDrive/Code_fydp/Drone_dataset/Test/Caterpillar',

    '/content/drive/MyDrive/Code_fydp/Drone_dataset/Test/Diabrotica speciosa',

    '/content/drive/MyDrive/Code_fydp/Drone_dataset/Test/Healthy'

]

for path in training_image_paths:

    if not os.path.exists(path):

        os.makedirs(path)

    folder_name = os.path.basename(path)

    source_images =
os.listdir(f'/content/drive/MyDrive/Code_fydp/Drone_dataset/The_photos/bycbh73438-1/{fol
der_name}')

    for img in source_images[:int(len(source_images) * 0.8)]:  # 80% for training


shutil.copy(f'/content/drive/MyDrive/Code_fydp/Drone_dataset/The_photos/bycbh73438-1/{
folder_name}/{img}', path)

for path in test_image_paths:

    if not os.path.exists(path):

        os.makedirs(path)

    folder_name = os.path.basename(path)

    source_images =
os.listdir(f'/content/drive/MyDrive/Code_fydp/Drone_dataset/The_photos/bycbh73438-1/{fol
der_name}')
```

```
    for img in source_images[int(len(source_images) * 0.8):]:  # 20% for testing

shutil.copy(f'/content/drive/MyDrive/Code_fydp/Drone_dataset/The_photos/bycbh73438-1/{folder_name}/{img}', path)

import matplotlib.pyplot as plt

metrics = ['Caterpillar', 'Diabrotica speciosa', 'Healthy']

model1_values = [400, 400, 400]

model2_values = [100, 100, 100]

bar_width = 0.4  # Increase the bar width to accommodate two sets of bars

index = range(len(metrics))

fig, ax = plt.subplots()

bar1 = ax.bar(index, model1_values, bar_width, label='Training', color='blue')

bar2 = ax.bar([i + bar_width for i in index], model2_values, bar_width, label='Testing', color='orange')

plt.xlabel('Image Categories')

plt.ylabel('Number of Images')

ax.set_title('Number of Images for the Drone Dataset each class training 80% and testing 20%')

ax.set_xticks([i + bar_width / 2 for i in index])

ax.set_xticklabels(metrics, fontsize=10)

ax.legend()

for i, v in enumerate(model1_values):

    ax.text(i, v, f'{v}', ha='center', va='bottom', fontsize=10)

for i, v in enumerate(model2_values):

    ax.text(i + bar_width, v, f'{v}', ha='center', va='bottom', fontsize=10)

plt.tight_layout()
```

```
plt.show()

from google.colab import drive

drive.mount('/content/drive')

import os

import matplotlib.pyplot as plt

DIRECTORY =
'/content/drive/MyDrive/Code_fydp/Drone_dataset/The_photos/bycbh73438-1'

image_folders = ['Caterpillar', 'Diabrotica speciosa', 'Healthy']

training_images = {}

validation_images = {}

for folder in image_folders:

    folder_path = os.path.join(DIRECTORY, folder)

    if os.path.exists(folder_path):

        images = os.listdir(folder_path)

        num_images = len(images)

        # Splitting

        count_train = int(0.8 * num_images)

        count_val = num_images - count_train

        training_images[folder] = count_train

        validation_images[folder] = count_val

        print(f"For: {folder} - Total Images: {num_images}, Training: {count_train},
Validation: {count_val}")

    else:

        print(f"{folder} folder does not exist.")

        training_images[folder] = 0
```

```
        validation_images[folder] = 0
training_counts = [training_images[folder] for folder in image_folders]
validation_counts = [validation_images[folder] for folder in image_folders]
plt.figure(figsize=(10, 6))
bar_width = 0.35
index = range(len(image_folders))
plt.bar(index, training_counts, bar_width, label='Training')
plt.bar([i + bar_width for i in index], validation_counts, bar_width, label='Validation')
plt.xlabel('Image Categories')
plt.ylabel('Number of Images')
plt.title('Distribution of Training and Validation Images for the training dataset')
plt.xticks([i + bar_width / 2 for i in index], image_folders)
plt.legend()
plt.tight_layout()
plt.show()
import torch
from torchvision import transforms, datasets, models
from torch.utils.data import DataLoader
import torch.nn as nn
import torch.optim as optim
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score
import os
data_transforms = transforms.Compose([
    transforms.Resize(256),
```

```
    transforms.CenterCrop(224),
    transforms.ToTensor(),
    transforms.Normalize(mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225]),
])
train_data_path = '/content/drive/MyDrive/Code_fydp/Drone_dataset/Train'
val_data_path = '/content/drive/MyDrive/Code_fydp/Drone_dataset/Test'
if not os.path.exists(train_data_path) or not os.path.exists(val_data_path):
    pass
train_data = datasets.ImageFolder(train_data_path, transform=data_transforms)
val_data = datasets.ImageFolder(val_data_path, transform=data_transforms)
train_loader = DataLoader(train_data, batch_size=32, shuffle=True)
val_loader = DataLoader(val_data, batch_size=32)
model = models.resnet18(pretrained=True)
num_ftrs = model.fc.in_features
model.fc = nn.Linear(num_ftrs, 3)
criterion = nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(), lr=0.001)
num_epochs = 5
for epoch in range(num_epochs):
    model.train()
    for images, labels in train_loader:
        optimizer.zero_grad()
        try:
            outputs = model(images)
```

```
            loss = criterion(outputs, labels)

            loss.backward()

            optimizer.step()

        except FileNotFoundError as e:

            print(f"FileNotFoundError: {e}. Skipping this batch.")

            continue

    model.eval()

    val_loss = 0

    correct = 0

    total = 0

    with torch.no_grad():

        for images, labels in val_loader:

            try:

                outputs = model(images)

                loss = criterion(outputs, labels)

                val_loss += loss.item()

                _, predicted = torch.max(outputs.data, 1)

                total += labels.size(0)

                correct += (predicted == labels).sum().item()

            except FileNotFoundError as e:

                print(f"FileNotFoundError: {e}. Skipping this batch.")

                continue

    print(f"Epoch [{epoch + 1}/{num_epochs}], Val Loss: {val_loss / len(val_loader)}, Val Accuracy: {(correct / total) * 100}%")

test_loader = DataLoader(val_data, batch_size=32)
```

```
model.eval()
test_predictions = []
true_labels = []
with torch.no_grad():
    for images, labels in test_loader:
        outputs = model(images)
        _, predicted = torch.max(outputs.data, 1)
        test_predictions.extend(predicted.tolist())
        true_labels.extend(labels.tolist())
accuracy = accuracy_score(true_labels, test_predictions)
precision = precision_score(true_labels, test_predictions, average='macro')
recall = recall_score(true_labels, test_predictions, average='macro')
f1 = f1_score(true_labels, test_predictions, average='macro')
print(f"Accuracy on Test Set: {accuracy * 100:.2f}%")
print(f"Precision on Test Set: {precision:.4f}")
print(f"Recall on Test Set: {recall:.4f}")
print(f"F1 Score on Test Set: {f1:.4f}")
import matplotlib.pyplot as plt
metrics = ['Accuracy', 'Precision', 'Recall', 'F1 Score']
model1_values = [62.97, 62.26, 69.02, 61.73]  # Add placeholder values for the last 4 metrics
bar_width = 0.2
index = range(len(metrics))
fig, ax = plt.subplots()
bar1 = ax.bar(index, model1_values, bar_width)
```

```
ax.set_title('Model performance for the Drone Dataset (%)')
ax.set_xticks([i + bar_width / 2 for i in index])
ax.set_xticklabels(metrics, fontsize=10)
ax.legend()
for i, v in enumerate(model1_values):
    if i < 4:
        ax.text(i, v + 1, f'{v:.2f}', ha='center', fontsize=10)
plt.tight_layout()
plt.show()
import torch
from sklearn.metrics import roc_curve, auc
import matplotlib.pyplot as plt
import torch
from torchvision import transforms, datasets, models
model.eval()
test_probabilities = []
true_labels = []
with torch.no_grad():
    for images, labels in test_loader:
        outputs = model(images)
        probabilities = torch.nn.functional.softmax(outputs, dim=1)
        test_probabilities.extend(probabilities.tolist())
        true_labels.extend(labels.tolist())
fpr = dict()
```

```
tpr = dict()

roc_auc = dict()

num_classes = len(train_data.classes)

for i in range(num_classes):

    fpr[i], tpr[i], _ = roc_curve([1 if label == i else 0 for label in true_labels], [prob[i] for prob
in test_probabilities])

    roc_auc[i] = auc(fpr[i], tpr[i])

plt.figure(figsize=(8, 6))

for i in range(num_classes):

    plt.plot(fpr[i], tpr[i], label=f'ROC curve (class {i}) (AUC = {roc_auc[i]:.2f})')

plt.plot([0, 1], [0, 1], 'k--')

plt.xlabel('False Positive Rate')

plt.ylabel('True Positive Rate')

plt.title('Receiver Operating Characteristic (ROC) Curve')

plt.legend(loc="lower right")

plt.show()
```

Appendix D: Code for kaggle dataset (for rover body)

```
from google.colab import drive

drive.mount('/content/drive')

import matplotlib.pyplot as plt

metrics = ['Anthracnose', 'Bacterial Canker', 'Cutting Weevil', 'Die Back', 'Gall Midge',
'Healthy', 'Powdery Mildew', 'Sooty Mould']

model1_values = [500, 500, 500, 500, 500, 500, 500, 500]

bar_width = 0.2

index = range(len(metrics))

fig, ax = plt.subplots()

bar1 = ax.bar(index, model1_values, bar_width, label='Model 1')

plt.xlabel('Image Categories')

plt.ylabel('Number of Images')

ax.set_title('Number of data in each of the classes')

ax.set_xticks([i + bar_width / 2 for i in index])

ax.set_xticklabels(metrics, fontsize=6)

ax.legend()

for i, v in enumerate(model1_values):

    ax.text(i, v + 10, str(v), ha='center', fontsize=8)

plt.tight_layout()

plt.show()

import matplotlib.pyplot as plt

import numpy as np

# Metrics for the three models
```

```
models = ['Anthracnose', 'Bacterial Canker', 'Cutting Weevil', 'Die Back', 'Gall Midge',
'Healthy', 'Powdery Mildew', 'Sooty Mould']

accuracies = np.array([400, 400, 400, 400, 400, 400, 400, 400])

precisions = np.array([100, 100, 100, 100, 100, 100, 100, 100])

# Plotting the bar chart

bar_width = 0.2

index = range(len(models))

fig, ax = plt.subplots(figsize=(10, 6))

bar1 = ax.bar(index, accuracies, bar_width, label='Training Dataset')

bar2 = ax.bar([i + bar_width for i in index], precisions, bar_width, label='Testing Dataset')

# Function to label bars with their values

def label_bars(rects):

    for rect in rects:

        height = int(rect.get_height())

        ax.annotate(f'{height}',

                    xy=(rect.get_x() + rect.get_width() / 2, height),

                    xytext=(0, 3),

                    textcoords="offset points",

                    ha='center', va='bottom')

label_bars(bar1)

label_bars(bar2)

plt.xlabel('Image Categories')

plt.ylabel('Number of Images')

ax.set_title('Splitting of Collected Dataset for rover')

ax.set_xticks([i + 1.5 * bar_width for i in index])
```

```
ax.set_xticklabels(models)
ax.legend()
plt.tight_layout()
plt.show()
import os
import shutil
import random
source_directory = "/content/drive/MyDrive/Code_fydp/Kaggle_dataset/The_photos"
destination_directory = "/content/drive/MyDrive/Again"
image_folders = ['Anthracnose', 'Bacterial Canker', 'Cutting Weevil', 'Die Back', 'Gall Midge',
'Healthy', 'Powdery Mildew', 'Sooty Mould']
num_images_to_copy = 200
for folder in image_folders:
    source_folder_path = os.path.join(source_directory, folder)
    destination_folder_path = os.path.join(destination_directory, folder)
    os.makedirs(destination_folder_path, exist_ok=True)
    files = os.listdir(source_folder_path)
    random.shuffle(files)
    for file in files[:num_images_to_copy]:
        source_file = os.path.join(source_folder_path, file)
        destination_file = os.path.join(destination_folder_path, file)
        shutil.copyfile(source_file, destination_file)
print("Images copied successfully!")
import os
import shutil
```

```
DIRECTORY = "/content/drive/MyDrive/Again"


image_folders = ['Anthracnose', 'Bacterial Canker', 'Cutting Weevil', 'Die Back', 'Gall Midge',
'Healthy', 'Powdery Mildew', 'Sooty Mould']

training_image_paths = [

    '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Train/Anthracnose',

'/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Train/Bacterial Canker',

'/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Train/Cutting Weevil',

'/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Train/Die Back',

'/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Train/Sooty Mould',

'/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Train/Gall Midge',

'/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Train/Healthy',

'/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Train/Powdery Mildew']

test_image_paths = [

    '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Test/Anthracnose',

    '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Test/Bacterial Canker',

    '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Test/Cutting Weevil',

    '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Test/Die Back',

    '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Test/Gall Midge',

    '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Test/Healthy',

    '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Test/Powdery Mildew',

    '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Test/Sooty Mould'

]

for folder_path in training_image_paths:

    if not os.path.exists(folder_path):
```

```
        os.makedirs(folder_path)
    folder_name = os.path.basename(folder_path)
    source_folder = os.path.join(DIRECTORY, folder_name)
    source_images = os.listdir(source_folder)
    for img in source_images[:int(len(source_images) * 0.8)]:
        img_path = os.path.join(source_folder, img)
        if os.path.isfile(img_path):
            shutil.copy(img_path, folder_path)
for folder_path in test_image_paths:
    if not os.path.exists(folder_path):
        os.makedirs(folder_path)
    folder_name = os.path.basename(folder_path)
    source_folder = os.path.join(DIRECTORY, folder_name)
    source_images = os.listdir(source_folder)
    for img in source_images[int(len(source_images) * 0.2):]:
        img_path = os.path.join(source_folder, img)
        if os.path.isfile(img_path):
            shutil.copy(img_path, folder_path)
import torch
from torchvision import transforms, datasets
from torch.utils.data import DataLoader
import torch.nn as nn
import torch.optim as optim
import torchvision.models as models
```

```
import torch

from torchvision import transforms, datasets

from torch.utils.data import DataLoader

import torch.nn as nn

import torch.optim as optim

import torchvision.models as models

from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score,
roc_curve, auc

import matplotlib.pyplot as plt

data_transforms = transforms.Compose([

    transforms.Resize(256),

    transforms.CenterCrop(224),

    transforms.ToTensor(),

    transforms.Normalize(mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225]),

])

train_dir = '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Train'

val_dir = '/content/drive/MyDrive/Code_fydp/Kaggle_dataset/Test'

allowed_extensions = ['.jpg', '.jpeg', '.png', '.ppm', '.bmp', '.pgm', '.tif', '.tiff', '.webp']

train_data = datasets.ImageFolder(train_dir, transform=data_transforms,
is_valid_file=lambda filename: any(filename.lower().endswith(ext) for ext in
allowed_extensions))

val_data = datasets.ImageFolder(val_dir, transform=data_transforms, is_valid_file=lambda
filename: any(filename.lower().endswith(ext) for ext in allowed_extensions))

train_loader = DataLoader(train_data, batch_size=32, shuffle=True)

val_loader = DataLoader(val_data, batch_size=32)

model = models.resnet18(pretrained=True)
```

```python
model.fc = nn.Linear(model.fc.in_features, 8)
criterion = nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(), lr=0.001)
num_epochs = 3
for epoch in range(num_epochs):
    model.train()
    for images, labels in train_loader:
        optimizer.zero_grad()
        outputs = model(images)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()
    model.eval()
    val_loss = 0
    correct = 0
    total = 0
    with torch.no_grad():
        for images, labels in val_loader:
            outputs = model(images)
            loss = criterion(outputs, labels)
            val_loss += loss.item()
            _, predicted = torch.max(outputs.data, 1)
            total += labels.size(0)
            correct += (predicted == labels).sum().item()
```

```
    print(f"Epoch [{epoch + 1}/{num_epochs}], Val Loss: {val_loss / len(val_loader)}, Val Accuracy: {(correct / total) * 100}%")
test_loader = DataLoader(val_data, batch_size=32)
model.eval()
test_predictions = []
true_labels = []
with torch.no_grad():
    for images, labels in test_loader:
        outputs = model(images)
        _, predicted = torch.max(outputs.data, 1)
        test_predictions.extend(predicted.tolist())
        true_labels.extend(labels.tolist())
accuracy = accuracy_score(true_labels, test_predictions)
precision = precision_score(true_labels, test_predictions, average='macro')
recall = recall_score(true_labels, test_predictions, average='macro')
f1 = f1_score(true_labels, test_predictions, average='macro')
print(f"Accuracy on Test Set: {accuracy * 100:.2f}%")
print(f"Precision on Test Set: {precision:.4f}")
print(f"Recall on Test Set: {recall:.4f}")
print(f"F1 Score on Test Set: {f1:.4f}")
import matplotlib.pyplot as plt
metrics = ['Accuracy', 'Precision', 'Recall', 'F1 Score']
model1_values = [93.37, 94.09, 93.47, 92.91]  # Add placeholder values for the last 4 metrics
bar_width = 0.2
index = range(len(metrics))
```

```
fig, ax = plt.subplots()

bar1 = ax.bar(index, model1_values, bar_width)

ax.set_title('Model performance for the collected dataset (%)')

ax.set_xticks([i + bar_width / 2 for i in index])

ax.set_xticklabels(metrics, fontsize=10)

ax.legend()

for i, v in enumerate(model1_values):

    if i < 4:

        ax.text(i, v + 1, f'{v:.2f}', ha='center', fontsize=10)

plt.tight_layout()

plt.show()

num_classes = 8

class_probs = torch.nn.functional.softmax(torch.tensor(test_predictions).reshape(0,
num_classes), dim=1)

fpr = dict()

tpr = dict()

roc_auc = dict()

for i in range(num_classes):

    fpr[i], tpr[i], _ = roc_curve([1 if label == i else 0 for label in true_labels], class_probs[:,
i].numpy())

    roc_auc[i] = auc(fpr[i], tpr[i])

plt.figure(figsize=(8, 6))

for i in range(num_classes):

    plt.plot(fpr[i], tpr[i], label=f'ROC curve (class {i}) (AUC = {roc_auc[i]:.2f})')

plt.plot([0, 1], [0, 1], 'k--')
```

```
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver Operating Characteristic (ROC) Curve')
plt.legend(loc="lower right")
plt.show()
```

Appendix E: Code for our own dataset(For Rover body)

```
from google.colab import drive

drive.mount('/content/drive')

import os

DIRECTORY = "/content/drive/MyDrive/Code_fydp/Own_dataset/The_Photos"

number_of_images = {}

for item in os.listdir(DIRECTORY):

    item_path = os.path.join(DIRECTORY, item)

    if os.path.isdir(item_path):

        number_of_images[item] = len(os.listdir(item_path))

    else:

        print(f"{item} is not a directory and will be skipped.")

print(number_of_images.items)

import matplotlib.pyplot as plt

metrics = ['Anthracnose', 'Honeydew', 'Scale insect']

model1_values = [500, 500, 500]

bar_width = 0.2

index = range(len(metrics))

fig, ax = plt.subplots()

bar1 = ax.bar(index, model1_values, bar_width)

plt.xlabel('Image Categories')

plt.ylabel('Number of Images')

ax.set_title('Number of data for each diseases')

ax.set_xticks([i + bar_width / 2 for i in index])
```

```
ax.set_xticklabels(metrics, fontsize=10)

for i, v in enumerate(model1_values):

    ax.text(i, v + 1, f'{v}', ha='center', fontsize=10)

plt.tight_layout()

plt.show()

import matplotlib.pyplot as plt

metrics = ['Anthracnose disease', 'Honeydew', 'Scale insect']

model1_values = [400, 400, 400]

model2_values = [100, 100, 100]

bar_width = 0.4  # Increase the bar width to accommodate two sets of bars

index = range(len(metrics))

fig, ax = plt.subplots()

bar1 = ax.bar(index, model1_values, bar_width, label='Trainning', color='blue')

bar2 = ax.bar([i + bar_width for i in index], model2_values, bar_width, label='Testing',
color='orange')

plt.xlabel('Image Categories')

plt.ylabel('Number of Images')

ax.set_title('Number of Images for the Drone Dataset per class 80% training and 20%
testing')

ax.set_xticks([i + bar_width / 2 for i in index])

ax.set_xticklabels(metrics, fontsize=10)

ax.legend()

for i, v in enumerate(model1_values):

    ax.text(i, v, f'{v}', ha='center', va='bottom', fontsize=10)

for i, v in enumerate(model2_values):
```

```
    ax.text(i + bar_width, v, f'{v}', ha='center', va='bottom', fontsize=10)

plt.tight_layout()
plt.show()
import os
import shutil
# Directories for training and testing images
training_image_paths = [
    '/content/drive/MyDrive/Code_fydp/Own_dataset/Test/Antrhracnose disease',
    '/content/drive/MyDrive/Code_fydp/Own_dataset/Test/Honeydew',
    '/content/drive/MyDrive/Code_fydp/Own_dataset/Test/Scale insect'
]
test_image_paths = [
    '/content/drive/MyDrive/Code_fydp/Own_dataset/Train/Antrhracnose disease',
    '/content/drive/MyDrive/Code_fydp/Own_dataset/Train/Honeydew',
    '/content/drive/MyDrive/Code_fydp/Own_dataset/Train/Scale insect'
]
for path in training_image_paths:
    if not os.path.exists(path):
        os.makedirs(path)
    folder_name = os.path.basename(path)
    source_images =
os.listdir(f'/content/drive/MyDrive/Code_fydp/Own_dataset/The_Photos/{folder_name}')
    for img in source_images[:int(len(source_images) * 0.8)]:  # 80% for training
```

```
shutil.copy(f'/content/drive/MyDrive/Code_fydp/Own_dataset/The_Photos/{folder_name}/{i
mg}', path)

for path in test_image_paths:

    if not os.path.exists(path):

        os.makedirs(path)

    folder_name = os.path.basename(path)

    source_images =
os.listdir(f'/content/drive/MyDrive/Code_fydp/Own_dataset/The_Photos/{folder_name}')

    for img in source_images[int(len(source_images) * 0.8):]:  # 20% for testing


shutil.copy(f'/content/drive/MyDrive/Code_fydp/Own_dataset/The_Photos/{folder_name}/{i
mg}', path)

import torch

from torchvision import transforms, datasets, models

from torch.utils.data import DataLoader

import torch.nn as nn

import torch.optim as optim

from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score

import os

data_transforms = transforms.Compose([

    transforms.Resize(256),

    transforms.CenterCrop(224),

    transforms.ToTensor(),

    transforms.Normalize(mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225]),

])

train_data_path = '/content/drive/MyDrive/Code_fydp/Own_dataset/Train'
```

```
val_data_path = '/content/drive/MyDrive/Code_fydp/Own_dataset/Test'
if not os.path.exists(train_data_path) or not os.path.exists(val_data_path):
    raise FileNotFoundError("Train or Validation data path does not exist")
train_data = datasets.ImageFolder(train_data_path, transform=data_transforms)
val_data = datasets.ImageFolder(val_data_path, transform=data_transforms)
train_loader = DataLoader(train_data, batch_size=32, shuffle=True)
val_loader = DataLoader(val_data, batch_size=32)
model = models.resnet18(pretrained=True)
num_ftrs = model.fc.in_features
model.fc = nn.Linear(num_ftrs, 3)
criterion = nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(), lr=0.001)
num_epochs = 20
for epoch in range(num_epochs):
    model.train()
    for images, labels in train_loader:
        optimizer.zero_grad()
        outputs = model(images)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()
    # Validation loop
    model.eval()
    val_loss = 0
```

```
    correct = 0
    total = 0
    with torch.no_grad():
        for images, labels in val_loader:
            outputs = model(images)
            loss = criterion(outputs, labels)
            val_loss += loss.item()
            _, predicted = torch.max(outputs.data, 1)
            total += labels.size(0)
            correct += (predicted == labels).sum().item()
    print(f"Epoch [{epoch + 1}/{num_epochs}], Val Loss: {val_loss / len(val_loader)}, Val Accuracy: {(correct / total) * 100}%")
test_loader = DataLoader(val_data, batch_size=32)
model.eval()
test_predictions = []
true_labels = []
with torch.no_grad():
    for images, labels in test_loader:
        outputs = model(images)
        _, predicted = torch.max(outputs.data, 1)
        test_predictions.extend(predicted.tolist())
        true_labels.extend(labels.tolist())
# Calculate evaluation metrics
accuracy = accuracy_score(true_labels, test_predictions)
precision = precision_score(true_labels, test_predictions, average='macro')
```

```
recall = recall_score(true_labels, test_predictions, average='macro')
f1 = f1_score(true_labels, test_predictions, average='macro')
print(f"Accuracy on Test Set: {accuracy * 100:.2f}%")
print(f"Precision on Test Set: {precision:.4f}")
print(f"Recall on Test Set: {recall:.4f}")
print(f"F1 Score on Test Set: {f1:.4f}")
import matplotlib.pyplot as plt
metrics = ['Accuracy', 'Precision', 'Recall', 'F1 Score']
model1_values = [98.25, 98.26, 98.25, 98.25]
bar_width = 0.2
index = range(len(metrics))
fig, ax = plt.subplots()
bar1 = ax.bar(index, model1_values, bar_width)
ax.set_title('Model performance for Our Own Dataset (%)')
ax.set_xticks([i + bar_width / 2 for i in index])
ax.set_xticklabels(metrics, fontsize=10)
ax.legend()
for i, v in enumerate(model1_values):
    if i < 4:
        ax.text(i, v + 1, f'{v:.2f}', ha='center', fontsize=10)
plt.tight_layout()
plt.show()
import torch
from sklearn.metrics import roc_curve, auc
```

```
import matplotlib.pyplot as plt

import torch

from torchvision import transforms, datasets, models

model.eval()

test_probabilities = []

true_labels = []

with torch.no_grad():

    for images, labels in test_loader:

        outputs = model(images)

        probabilities = torch.nn.functional.softmax(outputs, dim=1)

        test_probabilities.extend(probabilities.tolist())

        true_labels.extend(labels.tolist())

fpr = dict()

tpr = dict()

roc_auc = dict()

num_classes = len(train_data.classes)

for i in range(num_classes):

    fpr[i], tpr[i], _ = roc_curve([1 if label == i else 0 for label in true_labels], [prob[i] for prob
in test_probabilities])

    roc_auc[i] = auc(fpr[i], tpr[i])

plt.figure(figsize=(8, 6))

for i in range(num_classes):

    plt.plot(fpr[i], tpr[i], label=f'ROC curve (class {i}) (AUC = {roc_auc[i]:.2f})')

plt.plot([0, 1], [0, 1], 'k--')

plt.xlabel('False Positive Rate')
```

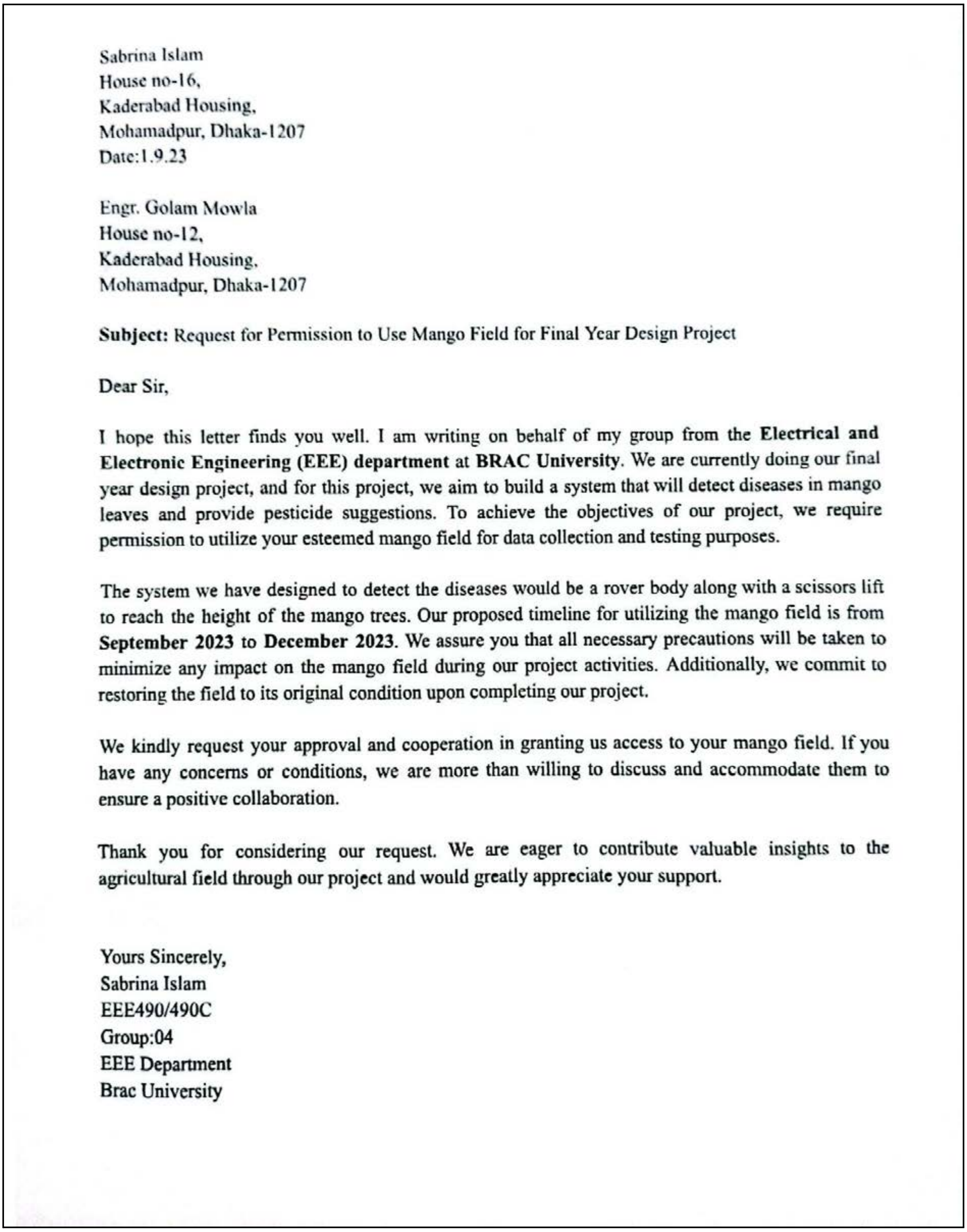
```
plt.ylabel('True Positive Rate')

plt.title('Receiver Operating Characteristic (ROC) Curve')

plt.legend(loc="lower right")

plt.show()
```

Appendix F: Application and Consent Form



Sabrina Islam
House no-16,
Kaderabad Housing,
Mohamadpur, Dhaka-1207
Date:1.9.23

Engr. Golam Mowla
House no-12,
Kaderabad Housing,
Mohamadpur, Dhaka-1207

Subject: Request for Permission to Use Mango Field for Final Year Design Project

Dear Sir,

I hope this letter finds you well. I am writing on behalf of my group from the **Electrical and Electronic Engineering (EEE) department** at **BRAC University**. We are currently doing our final year design project, and for this project, we aim to build a system that will detect diseases in mango leaves and provide pesticide suggestions. To achieve the objectives of our project, we require permission to utilize your esteemed mango field for data collection and testing purposes.

The system we have designed to detect the diseases would be a rover body along with a scissors lift to reach the height of the mango trees. Our proposed timeline for utilizing the mango field is from **September 2023** to **December 2023**. We assure you that all necessary precautions will be taken to minimize any impact on the mango field during our project activities. Additionally, we commit to restoring the field to its original condition upon completing our project.

We kindly request your approval and cooperation in granting us access to your mango field. If you have any concerns or conditions, we are more than willing to discuss and accommodate them to ensure a positive collaboration.

Thank you for considering our request. We are eager to contribute valuable insights to the agricultural field through our project and would greatly appreciate your support.

Yours Sincerely,
Sabrina Islam
EEE490/490C
Group:04
EEE Department
Brac University

Application for asking permission to use the mango field

Project Consent Form

Project Details:
Project Name: Disease Detection System For Mango Leaves
Duration: September 2023 to December 2023

Group Members Details:

Name: Oishe Roy Chowdhury	**ID:** 19121130
Name: Apurba Paul	**ID:** 20121033
Name: Sabrina Islam	**ID:** 20121011
Name: Fahmida Akhter Fiza	**ID:** 20121007

Department: Department of Electrical and Electronic Engineering, Brac University

Mango Field Details:
Owner Name: Engr. Golam Mowla
Location: Road-05, Kaderabad Housing, Mohamadpur, Dhaka-1207

Permission Requests:

1. Do you grant permission for our team to take pictures of mango leaves?
- [✓] Yes
- [ ] No

2. Do you grant permission for our team to test the system, including the rover body and scissor lift, within your mango field during the project duration?
- [✓] Yes
- [ ] No

3. Do you permit us to share the findings and outcomes of our project, including any pictures or information related to your mango field, for educational and presentation purposes?
- [✓] Yes
- [ ] No

Your cooperation is invaluable to the success of our project. We assure you that all activities will be conducted with utmost care, and your property will be respected.

Respondent's Name: Engr.Golam Mowla
Respondent's Signature:
Date: 01.09.23

Consent form for our project testing