DESIGN OF A SMART PHOTOVOLTAIC GREENHOUSE WITH DISEASE DETECTION AND ENVIRONMENT MONITORING

By

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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.

Electrical and Electronic Engineering
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Electrical and Electronic Engineering
BRAC University
October 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 "Design of a smart photovoltaic Greenhouse with plant growth based Monitoring System" submitted by

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Summer, 2023 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on 16th October, 2023.

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Ethics Statement

We hereby certify that the project title "Design of a smart photovoltaic greenhouse with disease detection and environment monitoring" complies with the requirements for the Final Year Design Project (FYDP). All extra sources used for analysis, literature research, and data collection have been appropriately cited in this project, which was developed by our team. We have received assistance from Barc University and our supervisors in putting the project's contents into practice. Additionally, Sher-e-Bangla Agricultural University has provided us with field and structural support.

Abstract/ Executive Summary

Monitoring the growth of the plants with the help of disease detection in the greenhouse through image processing is an effective process in agriculture development. The monitoring procedure offers important information about plant health through percentages of the tomato leaf diseases. Also, tracking and balancing the internal environment of the greenhouse for better production employs sensor technologies to continuously monitor key environmental parameters such as temperature, humidity, light intensity, darkness, etc. Real-time data from sensors for temperature, humidity, light, and soil moisture enable accurate environmental control and show the data within the greenhouse at the same time. This research project combines a camera-based monitoring system with a wide range of sensors to guarantee the best scenarios for plant health status. In addition, to reduce dependency on electricity, solar system installation would be a helpful part of this project to make a hybrid energy system. Consequently, our research is utilized to establish a communication system among the components.

Keywords: Greenhouse; Image-processing; Plant health; Monitoring; Plant leaves; plant disease.

Acknowledgment

The head of our committee, Dr. Abu S.M. Mohsin, PhD, has our sincere gratitude for his invaluable assistance in meticulously assessing the project. We also acknowledge the assistance of Brac University lecturers Taiyeb Hasan Sakib and Ehsanul Karim, who provided guidance and recommended numerous guidelines that would strengthen the project. Abul Faiz Md. Jamal Uddin, PhD, is a professor in the horticulture department at Sher-e-Bangla Agricultural University who aided us by sharing his expertise to develop our project.

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Chapter 1: Introduction [CO1,CO2,CO10]

1.1 Introduction

The idea of a "smart greenhouse" comprises a typical greenhouse that is fitted with sensors that control temperature, humidity, and light to optimize plant development. This enables the crops that are being planted to mature more quickly and retain the greatest amount of nutrients. It is also referred to as an automatic greenhouse and is a high-tech, intelligent greenhouse built on an agricultural greenhouse environment with drip irrigation, a wet curtain/fan cooling system, a heating system, an insulation system, and a moveable skylight that is computer controlled. It might also play a role in identifying plant diseases. According to research by CR Technology Systems S.p.A., photovoltaic greenhouse systems connect solar panels with agriculture to increase energy yields and cut down on water use [1]. In greenhouses, solar panels employ renewable energy to power climate control systems, reducing energy use and harm to the environment. A combined online platform may be developed to collect and evaluate greenhouse data and build ideal circumstances, according to research published in the journal of Taibah University for Science. Make it possible for users to get remote notifications, ensuring real-time information on GHG dynamics for wise decision-making [2].

1.1.1 Problem Statement

Innovative solutions are required to address a variety of issues, including the need for seasonal foods, inadequate food production, a lack of suitable agricultural lands, a food scarcity crisis, and the effects of global warming. A greenhouse powered by solar energy and equipped with sophisticated environmental monitoring and disease detection machinery appears to be a possible solution to these critical issues [3]. Due to changing customer expectations and preferences, there is a substantial problem in meeting the demand for seasonal food. Concurrently, inadequate food production intensifies the problem, raising the possibility of food shortage calamities. Lack of sufficient agricultural land, which is a result of urbanization and land degradation, plays a significant role in this [4].

These difficulties are made more difficult by global warming, which disturbs conventional farming methods, results in unpredictable weather patterns, and lowers crop yields. The necessity of adaptable solutions to lessen the effects of climate change on agriculture is highlighted by this [5].

In this setting, integrating cutting-edge greenhouse technologies stands out as a comprehensive approach. Through the utilization of controlled surroundings, greenhouses provide a way to develop crops regardless of the weather outside and the amount of available land. Environment monitoring systems can control temperature, humidity, and other growth conditions to increase production and resource efficiency. Furthermore, disease detection systems can quickly spot and stop any outbreaks, protecting crops from harmful illnesses. These greenhouses can be powered by solar energy to ensure sustainability, reducing their reliance on traditional energy sources and their environmental impact. Technology, agriculture, and renewable energy working together in harmony demonstrate a comprehensive strategy for addressing the difficult issues of food production and security in the face of global warming and resource shortages.

So, we can contribute to our project to minimize those problems and provide valuable support in the economy.

1.1.2 Background Study

Agriculture is the use of domesticated plants or animals to produce things that improve or support human life. Crops and animal products are used by humans for food, animal feed, and non-food things. However, the future of global food security remains gloomy. According to the FAO's 2022 Global Report on Food Crises, 193 million people in 53 countries were food insecure and in need of immediate help in 2021. Millions more risk increasing food prices due to COVID-19-related supply chain disruptions, extreme weather events, and wars such as the war in Ukraine. Since 2019, the number of people experiencing acute food insecurity has increased from 135 million to 345 million, meaning that as many as 828 million people go to bed hungry every night. A total of 50 million people in 45 nations are on the verge of starvation. Domestic food price inflation remains quite high all over the world [4]. According to data from May to September 2022, nearly all low- and middle-income countries have high inflation; 88.9% of low-income nations, 91.1% of lower-middle-income nations, and 96% of upper-middle-income nations have experienced inflation levels above 5%, with many experiencing double-digit inflation. Food price inflation has reached 85.7% of high-income countries. A global food price crisis is forcing millions more people into extreme poverty and exacerbating hunger and malnutrition. Modern agriculture is a dynamic approach to agricultural discoveries and farming methods that enables farmers to increase output while using less natural resources to fulfill global food, fuel, and fiber demands. Among the various sectors of agricultural equipment employed, some of the most rising innovations from modern agriculture include the usage of greenhouses, agrivoltaics, plant growth-based image processing monitoring, automated sprinkler systems, and wireless communications. These many tools enable us to grow more nutritious and safe crops in a significantly more efficient and cost-effective manner [3]. Initially, the problem of land resource competition between food and energy production was addressed by dividing a plot of land for food and energy production, respectively. According to GHI (Global Hunger Index) scores from 2023, the third-highest degree of hunger exists in the West Asian and Africa's North region and their hunger level is adequate, which is a GHI score of 11.9 with a 2023. Nowadays, taking the case of the Agroforestry system as an example, we can combine food and energy production on the same piece of land in which the land resources can be used efficiently and result in a win-win situation of generating electricity Above and planting below. Agrivoltaics, the co-development of land for both agriculture and PV, is an innovative and increasingly popular approach to solar development. This deliberate co-location of agriculture and PV is intended to alleviate land use competition and boost revenues for landowners, among other benefits.Various empirical studies have been conducted to evaluate the technical viability of agrivoltaic systems, evaluating PV in conjunction with plant production. The use of agricultural land for agrivoltaic systems has been demonstrated to be both technically and economically feasible, with the ability to overcome the current separation of food and energy production while increasing land productivity by 35-73%.The plant image processing method was created to acquire information about plant growth for use in an online computer system for optimizing the cultivation environment [6].The combination of IoT and image-processing devices has opened a new era of plant health monitoring [27]. The image processing for plant health is done by inserting leaf images through an algorithm that gives results by detecting [28]. Plants require an appropriate quantity of nutrients to complete their life cycle. Sufficient levels of six macronutrients, including nitrogen, calcium, phosphorus, potassium, sulfur, and magnesium, are required for normal and healthy plant growth [7]. Plants struggle to carry out their daily functions due to nutrient deficiency or absence which has an influence on yield. We can construct a data set for deficient leaves and healthy leaves using image processing, which will help us identify the required nutrient deficiency.

1.1.3 Literature Gap

The literature on innovative solutions for addressing the challenges related to seasonal foods, inadequate food production, limited agricultural lands, food scarcity crisis, and the impacts of global warming has seen significant attention in recent years. However, there remains a notable gap in the research focusing on the integration of cutting-edge greenhouse technologies as a comprehensive approach to mitigate these challenges.

While there is existing research on various individual aspects such as greenhouse technology, solar energy integration, environmental monitoring systems, disease detection, climate change impacts on agriculture, and sustainable farming practices, there is limited literature that synthesizes these components into a holistic solution [8].

Specifically, the following literature gap can be identified:

- Existing research often explores individual aspects of greenhouse technology, renewable energy, or climate-resilient agriculture. There is a need for studies that comprehensively examine the integration of these components into a unified strategy to address multiple challenges simultaneously.
- While there are theoretical discussions on the potential benefits of advanced greenhouses powered by solar energy, there is a scarcity of empirical evidence and case studies demonstrating the practicality and effectiveness of such systems in real-world scenarios. Research that presents concrete data and success stories in different geographic and climatic contexts would be valuable.
- If we look into small-scale greenhouse or home farming or even rooftop farming, these require less space and if the monitoring of these can be done automatically in a very simple way can be efficient and there is no combined research that has been discussed on small-scale farming.
- There is a limited exploration of the social and cultural factors that may influence the acceptance and adoption of innovative greenhouse solutions. Understanding how

communities and stakeholders perceive and interact with these technologies is crucial for successful implementation.
- Many existing studies focus on large-scale greenhouse projects, but there is a lack of research addressing the scalability of these solutions for smallholder farmers or communities with limited resources. Investigating how these technologies can be made accessible and beneficial to a broader range of stakeholders is an important avenue for research.
- For image detection, colorwise detection is broadly used[27] but when it comes to simple level detection which can be very much convenient for small-scale farmers there is some noticeable gap.

Addressing these literature gaps would contribute to a more holistic understanding of the potential of modern greenhouse, rooftop farming, and small-scale farming technologies powered by solar energy as a comprehensive solution to food production and security challenges in the context of global warming and resource shortages. It would also provide valuable insights for policymakers, practitioners, and researchers seeking sustainable and resilient solutions for agriculture and food systems [9].

1.1.4 Relevance to Current and Future Industry

Agriculture is critical to both global food security and environmental sustainability. Plant diseases and the need for optimized greenhouse environments, on the other hand, have prompted the development of novel technologies. A balance across the generation of crops and energy should be considered when developing agrivoltaic systems while Pulling off a number of the solar power system components which could lead to this type of arrangement being much more fruitful [10]. This project focuses on using image processing techniques to detect plant diseases and monitor greenhouse environments, which is important in both the current and future agricultural industries.

Relevance to the Current Industry:

Precision Agriculture: As the world's population grows, so does the demand for increased agricultural productivity. Image processing-based disease detection allows for early detection of plant health issues, allowing for timely interventions to reduce yield losses [11]. Farmers can use targeted treatments to reduce pesticide use and sufficient resource allocation.

Sustainable Practices: Consumers are becoming more aware of agriculture's environmental impact. The project promotes sustainable practices by reducing chemical usage and limiting disease spread by detecting diseases early. This is consistent with the current industry trend of environmentally friendly and sustainable farming.

Adoption of Technology: The agricultural sector is embracing digitalization and technology adoption. Integrating image processing for disease detection and greenhouse monitoring aligns with the industry's shift toward automation, data-driven decision-making, and Internet of Things-based solutions [12].

Relevance to the Future Industry:

Smart Farming: The future of agriculture is smart farming, in which advanced technologies simplify operations. By providing real-time insights into plant health and greenhouse conditions, this project's approach aligns with the concept of smart farming. Predictive analytics and adaptive farming practices are made possible by these insights.

Data-Driven Agriculture: As agricultural data volumes increase, data-driven insights will drive decision-making. Image processing data from various sources, such as cameras and sensors, can be combined with machine learning algorithms to improve disease prediction, yield estimation, and resource optimization [12].

Climate Resilience: Traditional agriculture faces challenges as a result of climate change. Greenhouses allow for greater control over growing conditions [13]. This project contributes to the development of climate-resilient agriculture systems by monitoring and adjusting factors such as temperature, humidity, and CO2 levels using image processing [13].

1.2 Objectives, Requirements, Specification and Constraints

1.2.1. Objectives

We have some objectives that we want to achieve during the completion project. The primary objectives are listed below.

- Developing a way to detect the plant's present health by leaf image processing.
- Within the greenhouse chamber, key environmental parameters must be monitored and analyzed in order to stabilize growth conditions and resource consumption.
- Powering up the whole system using renewable energy as much as possible.
- Create an integrated method that provides real-time insights to farmers to help them make informed decisions.
- We aim a build up a system that is automatic and has less human interaction

We will have several subsystems working together to complete our overall system. Each of these subsystems has its own set of requirements and specifications.

1.2.2 Functional and Nonfunctional Requirements

Functional requirements:

Identification of plant growth and diseases: The system must be able to identify different stages of growth of the plant. Any potential illness or pest infestations must be able to be found by the system, which must then inform the user.

Analytic and proper information reports: The system must be able to provide detailed analytics and reports on the health of the crops. It must be capable of offering comprehensive data on soil fertility and nutrient content. It should provide a comprehensive overview of all crops being monitored in multiple locations. It has to analyze the collected data and provide real-time alerts for unusual or concerning trends.

Deliver alerts, notifications, and recommendations: The system must be able to provide recommendations for crop care and management based on collected data and analysis. It must be able to deliver alerts and notifications to the user in a timely manner. This can help farmers optimize their crops for maximum yield and health.

Provide recommended service to the crops: The system should provide the necessary nutrition and irrigation needed for the crops based on the collected data from sensors and devices installed in the greenhouse.

Non-functional requirements:

User-friendly and intuitive design: The system must have an intuitive and user-friendly interface for farmers to use. It must be able to handle data from multiple locations and farm sizes. It has to handle multiple users concurrently without performance degradation.

Security: The system must be secure and protect sensitive data from unauthorized access. The system must only be able to integrate with third-party sensors and devices for data collection after verification. The system must also have safety measures and a routine check can be done by professionals to keep updated on the successive functionality of the system.

Eco-friendly: We are powering the system with renewable energy sources, such as solar or wind power, to reduce the system's carbon footprint. The system should be designed to minimize resource consumption, such as by using low-power sensors and devices, to reduce the system's overall environmental impact.

1.2.2 Specifications

TABLE 1: System level details for functional and non-functional requirements

	System level	Components level
Functional	Conveyor Belt System	28BYJ-48 5V 4 Phase DC Gear Stepper Motor, ULN2003 Driver Board, B10k potentiometer, Arduino Nano V3.0, Limit Switch, GT2 Timing Pulley 16 Tooth, timing belt, SC8UU Linear Ball Bearing, push button.
	Image processing	Logitech C270 HD camera, PyCharm, Google colab.
	Irrigation system	Submersible water pump. Bendable pipes with a water valve. Water source(river/water tank/channel).

	light source	additional 40w LED light. lux intensity providing 4000 lumens.
	Greenhouse Chamber	Greenhouse Chamber Tempered glass Land area 1600 sq ft
	PV/ Solar panels	Solar panels Battery for power storage Converters for storing and dissipation of power
Non-Functional	Detecting Temperature, Humidity, Light, Soil moisture.	DHT-11 LDR sensor & soil moisture sensor.
	Notification System	Wifi Module GPS Module

TABLE 2: Details of the components

Name of the Component	Details	Purpose
DHT-11	Temperature and humidity sensor	Monitoring temperature and humidity in greenhouses.
LDR sensor	Light intensity Sensor	Detecting lightness and darkness facilities.in greenhouses.
soil moisture.	Resistive soil moisture sensor	Sensing soil dryness and moisture.
Additional Irrigation	Submersible water collector	Collecting water from the source and providing water when needed automatically.
Additional LED Light	40W LED Light (Providing 4000 lumens)	Detecting lightness or darkness inside the greenhouse and providing extra light by a relay when the sunlight can not reach inside the greenhouse.
Camera module	Webcamera (Logitech c270)	Take pictures of the leaves from plants by conveyor belt.
PV Panel	40W 12V (2 cells), solar charge controller, 12V 9 amp battery	Make a hybrid power system and get enough energy source in remote areas and minimize dependency on the grid.

1.2.3 Technical and Non-technical Considerations and Constraints in Design Process

Technical Considerations:

1. Image Quality and Acquisition: Use appropriate cameras or sensors to capture high-quality images. To capture accurate data, consider factors such as resolution, lighting conditions, and angles.

2. Extraction of Relevant Features: Select appropriate image processing techniques for extracting relevant features for disease detection and environmental monitoring. Color, texture, shape, and size of plant parts are examples of characteristics.

3. Algorithm Selection: Select appropriate algorithms for disease detection and environmental parameter monitoring. Machine learning algorithms such as CNNs (Convolutional Neural Networks) or SVMs (Support Vector Machines) could be used to detect diseases, whereas statistical methods could be used to monitor the environment.

4. Annotation of Training Data: Accurate annotation of training data is critical for machine learning models. Create a dependable annotation process for labeling images with disease status or environmental conditions.

5. Model Training and Validation: Use a diverse and representative dataset to train machine learning models. Perform rigorous validation using appropriate metrics to ensure model accuracy and generalizability.

6. Real-Time Processing: Consider the real-time processing requirements for greenhouse monitoring and disease detection. Efficient algorithms and hardware may be necessary to process data in a timely manner.

7. Integration with IoT: If applicable, ensure that IoT devices and sensors in the greenhouse are seamlessly integrated for real-time data collection and control.

8. Data Privacy and Security: Implement data security protocols, particularly if sensitive information is being collected. Take into account encryption, access controls, and data anonymization.

Non-Technical Considerations

1. Budget: Establish a budget for hardware, software, and personnel. Take into account the price of cameras, sensors, computing resources, and any third-party tools.

2. User-Friendly Interface: Design a user-friendly interface for farmers or users to access and interpret the collected data. The interface should provide clear insights and actionable information.

3. Ethical Considerations: Ensure that data is treated ethically, particularly if images of plants, farmers, or users are involved. Obtain proper consent and follow privacy laws.

4. Stakeholder Engagement: Involve stakeholders such as farmers, agronomists, and agricultural experts in project development to ensure the solution aligns with their needs and requirements.

5. Scalability: Consider scalability when designing the system. The project should be able to handle increased data volume and user load as it gains traction.

6. Maintenance and Support: After deployment, plan for ongoing system maintenance and support. This includes software updates, bug fixes, and customer support.

7. Compliance with regulations: Learn about relevant agricultural regulations and standards in your area. Check that your solution complies with these rules.

8. Environmental Impact: Consider the environmental impact of your solution. For instance, if the project involves hardware components, assess their energy consumption and disposal.

9. Partnerships and collaboration: To expand the project's reach and impact, consider potential collaborations with agricultural research institutions, government agencies, or industry partners.

Balancing these technical and non-technical considerations will contribute to the success, effectiveness, and long-term sustainability of your project.

Constraints:

- In our project, the solar system will provide the main power supply. So, if there is any insufficiency of sunlight then the solar panel may not be able to produce enough power throughout the project. In that case, we need grid power.
- The solar spectral irradiance is a measure of the brightness of the entire Sun at a wavelength of light. So, sunburn can occur due to solar irradiation on crops.
- In our project we will use some devices and sensors. If any vapor has been created inside the greenhouse chamber then it may break.
- Pest influence would be another constraint for crop production.
- Any unpredictable natural disasters such as storms, heavy rain, etc can affect our project. Also, it may break the chamber as well as the growth of the crops.

1.2.4 Applicable compliance, standards, and codes

TABLE 3: Applicable standards and codes

Working Sectors	**Technology**	**Standard Code**	**Standard title**	**Standard Information**
Notifications	Visual & Image processing	IEEE 610.4-1990	IEEE Standard Glossary of Image Processing and Pattern Recognition Terminology.	The terms used in the field of image processing and pattern recognition are defined in this glossary. There are established standards for those terms.
		IEEE 1858-2016	IEEE Standard for Camera Phone Image Quality	This standard covers measuring the performance of portable devices with cameras, with a focus on benchmarks and methods appropriate to the kinds of sensors, lenses, and signal processing routines found on such devices. It is not meant to serve as a general benchmark for the quality of images taken with expensive professional cameras, like Photos. Metrics include texture smudge, graphical interference, local geometric distortion, color uniformity, chroma level, and lateral chromatic displacement.
Communication	Signal Processing	IEEE 1858-2016	IEEE Standard for Camera Phone Image Quality	standard covers measuring the performance of portable devices with cameras, with a focus on benchmarks and methods appropriate to the kinds of sensors, lenses, and signal processing routines found on such devices.
Electronics	Rover/ Drone	IEEE 1936.1-2021	IEEE Approved Draft Standard for Drone Applications Framework	The guideline for drone application support is established by this standard. It provides information on drone applications, scenarios, and key application execution environments. For general drone application requirements, the flight platform, flight control system, ground control station, payload, control link, data link, takeoff and landing system are required. Among the requirements for drone safety and management are airworthiness, airspace, air traffic regulations, operator and staff qualifications,

				insurance, and confidentiality. Data classification, data collection and processing, data record and analysis, and data reference format are all stated in the operation record and report as general operation procedures that are similar to the operation results.
Energy Storage	Battery/Energy Supply	IEEE 1561-2019	IEEE Guide for optimizing the performance and life of lead-acid batteries in remote hybrid power system	Guidelines are provided for Lead-acid batteries, which are used as the energy storage part of remote hybrid power sources. The remote hybrid application serves a purpose in that the battery can usually be charged whenever and under conditions that may also be advantageous for the dispatchable generator due to its dual generator option, which includes both renewable and dispatchable generation.

1.3 Systematic Overview/summary of the Proposed Project

The proposed project seeks to revolutionize agriculture by incorporating advanced image processing techniques for accurate plant disease detection and efficient greenhouse environment monitoring. This comprehensive solution addresses critical farmer challenges by optimizing crop health, resource utilization, and overall agricultural productivity. The project recognizes the critical need for technology-driven, sustainable solutions in modern agriculture. The project intends to improve disease management strategies and greenhouse operations by leveraging the power of image processing, in line with the industry's shift toward precision agriculture. The project's main focus is on developing an image-based plant disease detection system using cutting-edge computer vision techniques. Cameras installed within the greenhouse will capture high-resolution images of plants. Deep learning algorithms will be used to process these images, allowing the system to accurately identify and classify various plant diseases such as fungal, bacterial, and viral infections. When diseases are detected, the system will notify greenhouse operators in real-time, allowing for quick intervention and reducing crop losses. In the meantime, the project will concentrate on greenhouse environment monitoring in order to create a favorable growth environment for plants [21]. Temperature, humidity, light intensity, and soil moisture will be measured using a network of sensors strategically placed. To maintain optimal environmental conditions, data from these sensors will be collected and analyzed. Advanced data analytics and machine learning models will be used to provide insights into crop-specific requirements, allowing for precise greenhouse environment adjustments. The proposed project is innovative in that it combines disease detection and environmental monitoring. The system will uncover potential causal relationships by correlating disease occurrences with environmental factors, assisting in disease prevention strategies. Furthermore, historical data will be used to forecast disease outbreaks based on environmental trends, allowing proactive measures to be implemented. The project is in line with emerging trends in precision agriculture, sustainable agriculture, and technology adoption. It addresses climate change and resource scarcity challenges, thereby contributing to the industry's efforts to ensure food security and environmental sustainability. To ensure that the developed solution meets real-world requirements, the project will involve close collaboration with agronomists, agricultural experts, and farmers. The combination of hardware components, software algorithms, and user-friendly interfaces will yield a complete solution that is ready for deployment. The project paves the way for future technological advancements as technology advances. Enhancing machine learning models, incorporating remote sensing techniques, and integrating the solution with larger agricultural management systems are all possible future developments.

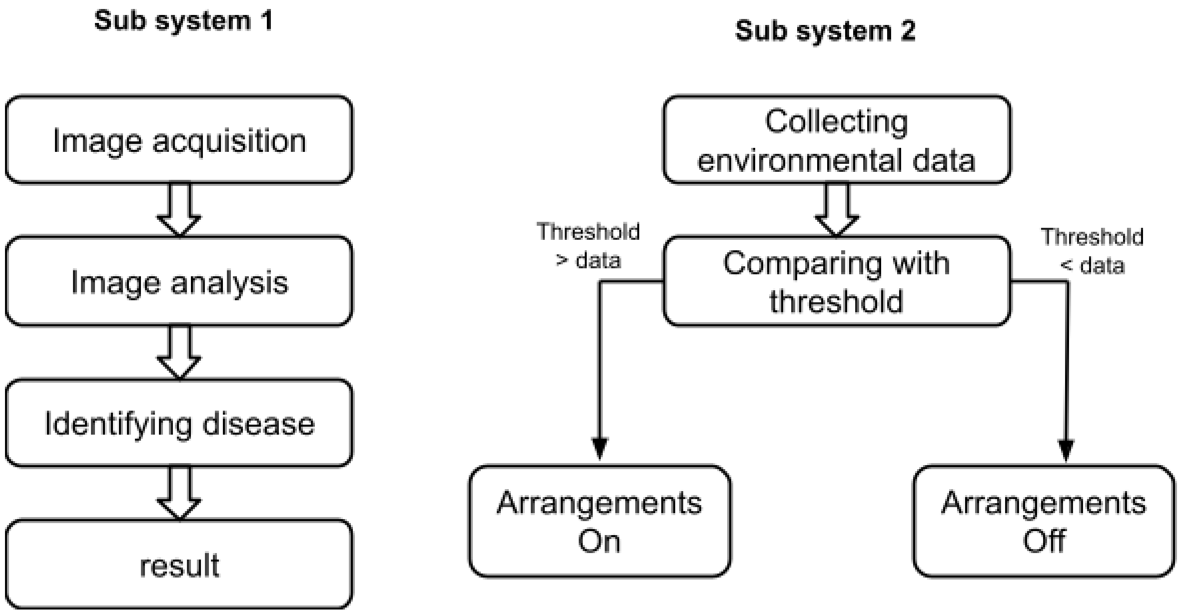


Figure 01: General functional diagram of the solution.

To summarize, the proposed project combines cutting-edge image processing techniques with agricultural practices to develop a novel solution for plant disease detection and greenhouse environment monitoring. The project aims to improve agricultural productivity, sustainability, and resilience in the face of changing global conditions by addressing key industry challenges.

1.4 Conclusion

In conclusion, addressing challenges in food production and security demands innovative solutions. Integrating advanced greenhouses powered by solar energy offers a holistic approach. Existing research gaps include the need for comprehensive studies, practical evidence, economic viability analysis, social factors, scalability considerations, and environmental impact assessments. Our project's objectives include early plant disease detection, real-time environmental monitoring, renewable energy utilization, and automation. By addressing these objectives and filling research gaps, we aim to contribute to sustainable and resilient agriculture solutions. Our approach enhances food production, reduces environmental impact, and supports the adoption of advanced agricultural technologies.

Chapter 2: Project Design Approach [CO5,CO6]

2.1 Introduction

In order to ensure the successful implementation of our project, we undertook a comprehensive exploration of several approaches to obtain a suitable solution. We have successfully aligned several designs that are highly suitable and capable of integration within our working environment. The project's design approach is influenced by the various yet harmonious characteristics observed in the plant kingdom. Similar to the coexistence and contribution of many plant species within an ecosystem, our study employs three diverse methodologies, each possessing its own unique qualities, in order to develop a comprehensive solution for greenhouse monitoring. In all of the methods, we had to ensure movability, sensor networks and data fusion, proper image collection, and error-free machine learning algorithm. Our designs are unique in most cases but in some cases, we had to keep similarity.

2.2 Identify multiple design approaches

We have designed three different approaches based on data collection methods. They are -

1. Manual data collection
2. Unnamed ground vehicle data collection
3. Top mounted automation bar

2.3 Describe multiple design approach

2.3.1 Approach 01: Manual data collection

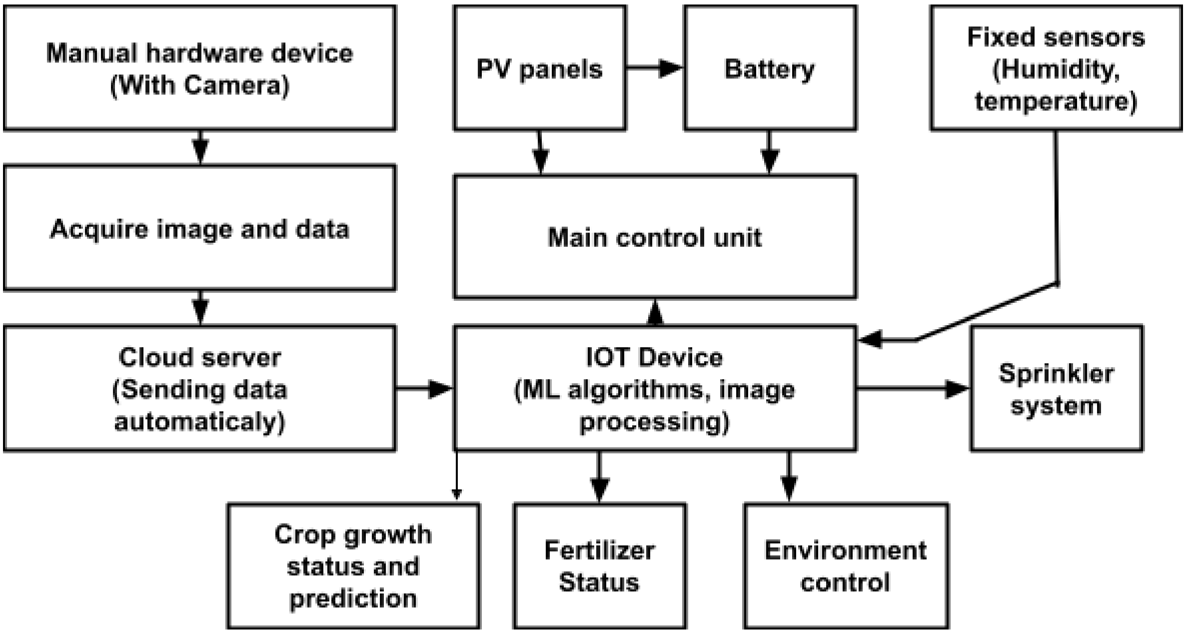


Figure 2: Block diagram of design approach 01

Explanation:

In this approach, we will have a fixed camera that will collect all the pictures of the plant. The camera needs to be moved manually. Also, we will have a solar panel with a charge controller. Also, there will be a water pump for irrigation and watering the plants and soil. Some sensors will be integrated inside which will monitor light, temperature and humidity, and soil moisture level.

Advantages:

- Easy setup and less cost.
- Camera can be moved anywhere.

Constraints:

- As the camera needs to be moved manually by the user, it will not be very efficient for large-scale implementation.
- The camera can't be powered by solar energy.
- Most time-consuming process.

2.3.2 Approach 02: Unnamed ground vehicle data collection

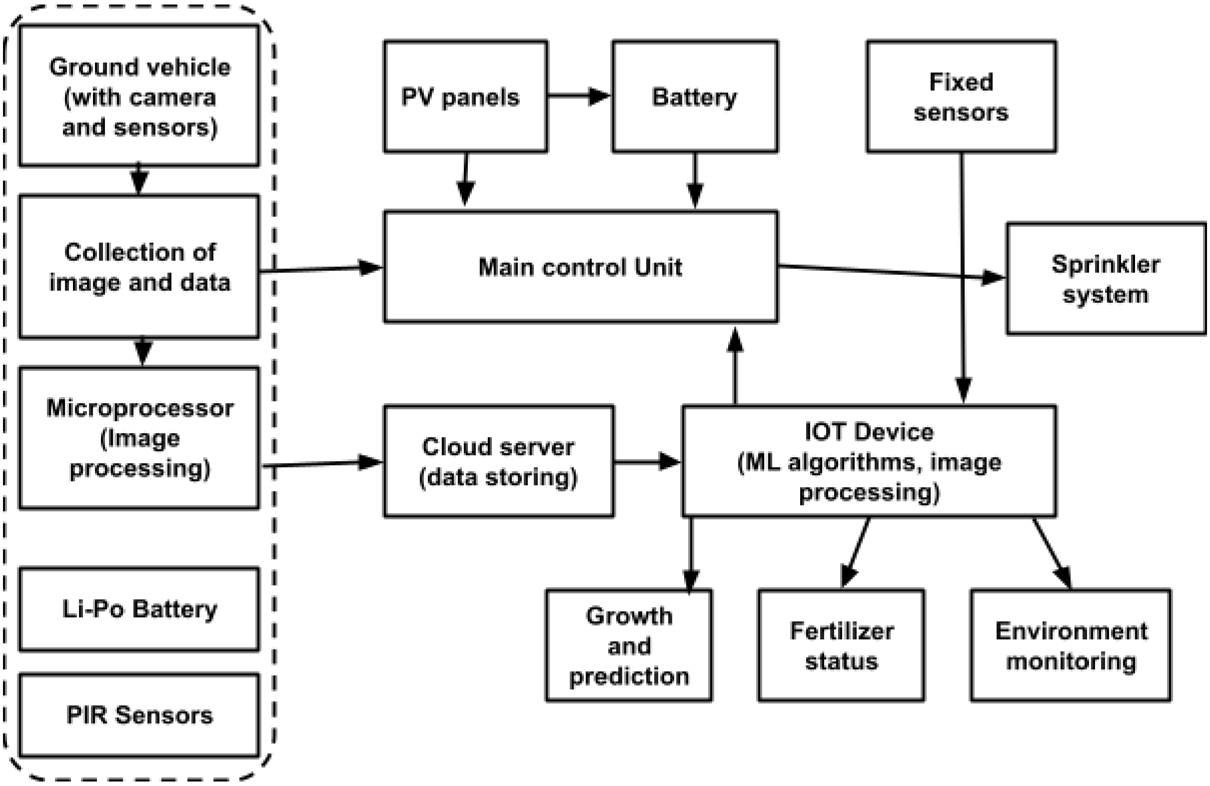


Figure 3: Block diagram of design approach 02

Explanation:

In this approach, we will be having a ground vehicle where the camera and storage device with an integrated microcontroller for the control of the vehicle and wifi module for data transmission will be available [15]. The vehicle will have a charging station where it can charge up its battery through solar energy. Also, real-time data can be derived from this process. There will be some fixed sensors to collect environmental data for monitoring and there will be a system available for the watering process.

Advantages:

- Much more efficient for data collection.
- Vehicles can take data from anywhere automatically.

Constraints:

- Having a vehicle inside a large greenhouse will require more than one vehicle as the battery will require recharge after an area of operation.
- In terms of muddy fields, the vehicle might not operate and get stuck which will require human supervision.
- the vehicle cannot take pictures properly if there is non-linearity in plant sizes.

2.3.3 Approach 03: Top mounted automation bar

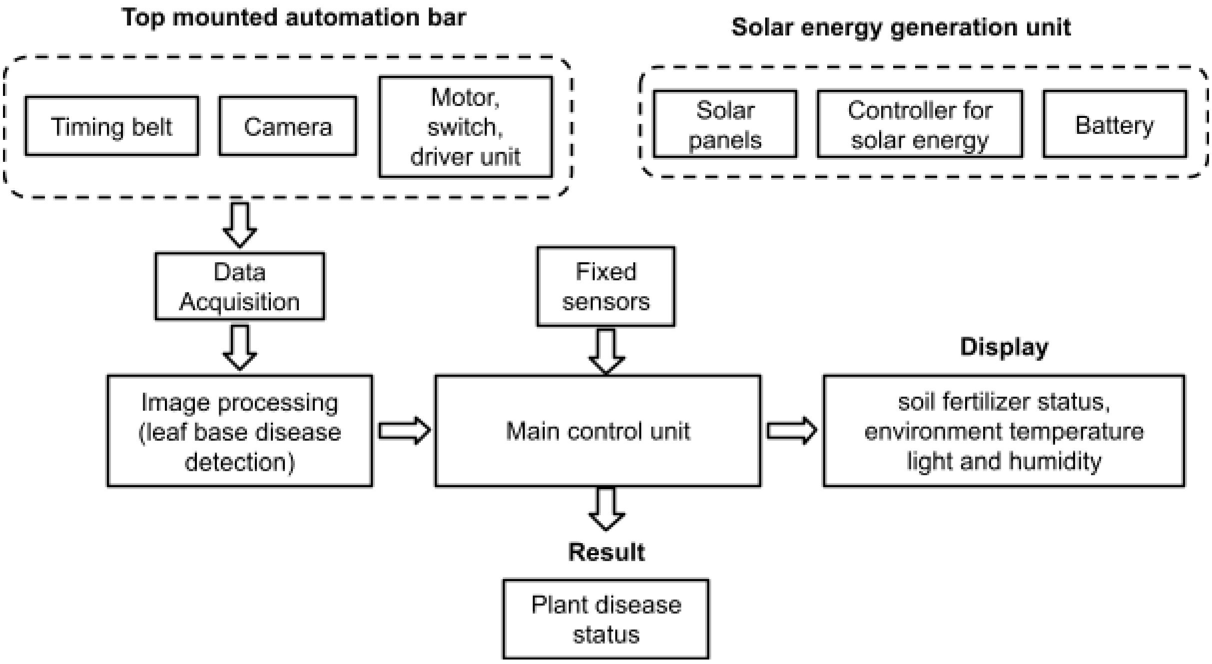


Figure 4: Block diagram of design approach 03

Explanation:

In this approach, we will have a device that will have a camera integrated with it. The device will operate through a stepper motor and it will have timing switches. The device will move linearly through a timing belt and it will be in the top-mounted position. Also, there will be a subsystem which is an environment monitoring unit. It will have fixed sensors and also there will be a water pump and light which will operate if the sensor data are below threshold level.

Advantages:

- Most reliable in taking data.
- As it will be top-mounted there will be no issue with plant size.
- Less time consuming.
- It can cover a whole field as it will work linearly.

Constraints:

- In terms of fields having different crops, different camera-integrated devices may be required.

2.4 Analysis of multiple design approach

Based on the following parameters a comparative analysis is done in the following table. It will highlight all the aspects of the designs.

TABLE 04: Comparative analysis of all the design approaches.

Parameter	Approach 01	Approach 02	Approach 03
Efficiency	This approach has a physical camera that needs to be moved manually by the user. If we consider time then this might be a hassle, considering mobility this will be good, again considering overall efficiency, the whole process is lengthy.	This approach has a vehicle that will move through the whole area where we'll draw the driving path for the vehicle, so the user rarely will operate the vehicle as it will operate automatically.	This approach has an automation bar on the top of the greenhouse and it will have a device containing a driver and camera. The whole device will move through a conveyor belt and it will be very convenient as there will be no obstacle.
Energy usage	The camera device needs to be connected to a battery through a converter (DAC) or directly connected to the ac power supply. The environment subsystem for all the	The vehicles will have li-po battery which can be charged up easily and li-po battery lasts long and stores a good amount of energy	The whole system will be directly connected to the battery and there will be a switchgear to change from battery power to grid power.

	approaches is quite the same. So considering this it will consume a lot of power.		
Portability	As the device can be moved freely so it is portable.	As the vehicle can be moved freely so it is portable.	The top-mounted bar and the device installed can't be moved freely. It will move through the conveyor belt.
Stakeholders' acceptance	The stakeholders think that moving a device by themselves is a hassle.	As the vehicle will move automatically so the stakeholders are okay with that but some of them feel uncomfortable having a movable object.	The stakeholders liked the conveyor belt most and it won't objectify anything.
Sustainability	The whole design is very fragile so there is a question of sustainability	The motor and the vehicle chassis is quite durable to operate in water dust and mud.	There will be less interruption which will make it more sustainable than other designs
Impact	The more easy and optimal our solution will be, the more impact it will create. As there is a manual operation to be done so the impact will be less.	There is less human interaction in this design and this will make the whole work easy for the user. It will have comparatively more impact.	There is very little human interaction in this design and this will make the whole work easy for the user. It will have comparatively more impact.
Safety	While operating in AC mode, there is a risk that cannot be denied.	The ground vehicle may create problems for the user as an object. Which is negligible in most cases.	There is so far no safety issue in this design but as the whole thing will be installed on the top proper installation must be done.
Recyclability	There are electrical components used so recyclability is possible unless it's damaged.	There are electrical components used so recyclability is possible unless it's damaged.	There are electrical components used so recyclability is possible unless it's damaged.

2.5 Conclusion

After a study of each of the three approaches derived from the weighted matrices, it has become clearly noticeable that Approach 3 is the one that is most suited to our project. Because it performs better in the majority of the functional parameters. Choosing it will be a viable option in terms of its efficiency.

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

3.1 Introduction

We use a variety of applications to do different tasks. We use MATLAB, Proteus, Pycharm, Python, Google Colab, PVSYST, solid work, and Adobe Illustration to simulate three models through the monitoring and detection system, optimization, performance evaluation, and animation. We finally settled on them based on their flexibility, use, and sustainability after some research and experimentation. In order to make our project hybrid in terms of power supply, we also selected a solar system.

3.2 Select appropriate engineering and IT tools

- **Sensor selection:**

For our system to work we need to have a collaboration with the threshold we will be setting up. These thresholds are basically standards that we will be using according to our plants' suitable parameters. To get the real-time data and then compare them with the threshold value we obviously need a few sensors that will acquire data from the field and plants. For the moisture level of the soil, we will be using a soil moisture sensor. Soil moisture sensors measure the water content in the soil. These sensors can help optimize irrigation systems and ensure plants receive the right amount of water. Humidity sensors can be incorporated to monitor and control humidity levels. For instance, in a greenhouse automation project, a humidity sensor can be used to regulate the watering system based on the moisture content in the air. To ensure the plants are getting enough light, LDR will be used to control the behavior of a circuit based on ambient light conditions. For example, it can be employed in a smart lighting system that adjusts the brightness of lights or turns on or off a light based on the surrounding light levels. For the temperature, we will be using temperature sensors to get an idea of present temperature values.

- **Solar Panel:**

From the beginning, we wanted to use renewable energy as much as possible. Also if needed we will be having grid connection as backup. Renewable energies are photovoltaic, wind, phizo etc. To make our project hybrid, we chose solar energy as this is more relevant as we will be working in a static environment. The open fields or rooftop is a good location for generating agro photovoltaic energy.So we will be using Solar panels to build a photovoltaic system that is made out of a series of photovoltaic cells arranged to generate energy using sunlight [14]. For this reason, we have used A-grade waterproof two solar panels which are rated at 20W each. With a power output of 20 watts, these panels are capable of generating ample electricity to charge batteries, power small appliances, and contribute to our energy needs. These panels are built to ensure longevity and consistent performance. The robust construction includes weather-resistant materials, making it suitable for a variety of environments, from urban rooftops to remote off-grid locations.

- **Microcontroller:**

A microcontroller is a compact integrated circuit that serves as the brain of embedded systems and electronic projects. Combining a processor, memory, and input/output peripherals on a single chip, microcontrollers provide a centralized control unit, enabling automation and intelligence in various applications. Microcontrollers are essential for our project as it requires real-time control. They efficiently process data, execute commands, and interact with external devices. Microcontrollers are designed to operate on low power, making them suitable for battery-powered devices or projects with energy efficiency requirements. As one of the objectives is to run the system with renewable energy, low power consumption of microcontrollers is very suitable. Also programming a microcontroller is comparatively easy.

- **Object detection:**

Our project required an object detection algorithm for detecting the diseases of a tomato plant. There are many detection algorithms for this purpose but we chose YOLO (You only look once) v8 for its real-time objective detection, simultaneous detection, object size handling, and many more. Yolo is renowned for its efficiency and speed, which makes it a good choice for real-time object detection. Yolo can make predictions fast because it processes the entire image in a single forward pass.YOLO is able to identify several objects in a picture at once. YOLO splits an image into a grid and forecasts bounding boxes and class probabilities for each grid cell rather than overlaying a window on top of the image. It is therefore effective in situations where it is necessary to detect multiple objects.YOLO can generate predictions in a single forward pass through the neural network thanks to its single-shot detection technique. Its speed is aided by its simplicity when compared to methods involving several stages or region proposals. As an open-source project, YOLO has a sizable user and contributor base. Gaining access to a multitude of resources and implementations, finding pre-trained models, and getting support can all be benefited from this. These were the main factors for which we have used YOLO for our object detection algorithm.

3.3 Use of modern engineering and IT tools

Google Colab: We have used Google Colab to train YOLO V8 as it offers several benefits, including- Training deep neural networks like YOLO requires a lot of computing power, especially for large datasets. Google Colab offers a free GPU that can be used to accelerate the training process and reduce the time required to train a YOLO model. Google Colab is a cost-effective option for training YOLO models as it offers a free GPU and does not require any additional hardware or software. This can be especially beneficial for researchers, students, and hobbyists who may not have access to high-performance computing resources. Google Colab is a cloud-based platform that provides a user-friendly interface for running

Python code. This makes it easy to set up and run YOLO training scripts, without having to worry about installing or configuring any software.Google Colab allows multiple users to work on the same notebook simultaneously, making it easy to collaborate with colleagues or share your work with others. Google Colab can be used to train YOLO models on datasets of any size, from small datasets to large-scale datasets like COCO. The platform can also be used to train multiple models in parallel, which can be useful for comparing different architectures or hyperparameters.

PyCharm: We have also used Pycharm to run YOLO V8 as it has several advantages, including that PyCharm provides an integrated development environment (IDE) for Python, which allows you to write, debug, and test the code all in one place. This can be very helpful for developing and debugging complex object detection algorithms like YOLO. PyCharm includes advanced code editing features, such as syntax highlighting, code completion, and code navigation. These features can help to write YOLO code more efficiently and with fewer errors. PyCharm includes powerful debugging tools that can help you track down and fix bugs in your YOLO code. You can set breakpoints in your code, step through code execution, and inspect variables and data structures to help identify the source of any issues. PyCharm includes built-in package management tools that can help you install and manage the required packages for YOLO. This can save you time and simplify the installation process.

Arduino IDE: Prior to Arduino, microcontrollers lacked a software IDE for loading code into the hardware. To upload the code into the hardware, one needed to use a different piece of hardware. This property of flexibility makes it simple to connect sensors to Arduino. The only hardware necessary to integrate these sensors with Arduino is the Breadboard and connecting wires because the microcontroller already comes with a software IDE for programming. In the Arduino IDE, code may be written and uploaded. For the interface, you'll need a power supply, a ground, a breadboard, and connection wires. The Arduino software includes a serial monitor that facilitates the straightforward exchange of text-based data with the connected board. The TX and RX LEDs on the Nano board will flash whenever data is being transmitted via the FTDI and USB connection to the computer. There are 14 digital pins and 8 analog pins. There are 6 PWM (Pulse Width Modulation) pins among the 14 digital pins. The 6 PWM pins in Arduino Nano are used to convert the digital signals into analog signals. The conversion takes place by varying the width of the pulse.

Proteus: Proteus includes an extensive library of electronic components with accurate simulation models. These models represent the behavior of real-world components, allowing users to simulate their interactions accurately. Here, we have used Proteus for our environment system. Proteus is used to simulate, design, and draw electronic circuits. We can easily add temperature, humidity, soil moisture, and light sensors. We can easily make two-dimensional circuit designs as well as change and control certain aspects (external lights, irrigation/watering system) of the environment automatically by Arduino uno (main board), and Arduino IDE for programming.

PVSYST: We have taken a suitable field for our project and by taking its latitude and longitude we have done some simulation in PVSYST software. PVSYST is a well-known software for getting solar irradiation and other data . It will give the complete profile of all the data we need for our project. We got our yearly energy data that will be generated from the PV panels. Also, our energy demand has been verified by the simulation.

Matlab: In Matlab, we have tried to find out the direction of the solar panel. Due to an accessible library, it was very suitable for us to simulate our desired structures. In Matlab, we have also found various types of PV cells. It has shown the approximate values of current, voltage, and power as well. During Matlab evaluation, we have found the voltage and power for implementing the solar system. It has also shown that the current supply is through solar cells and from batteries.

Solidworks: Using a parametric, feature-based, sketch-driven modeling methodology, SolidWorks enables users to produce 3D designs while preserving associativity and design intent. It consists of tools for structural and functional analysis design validation, parametric restrictions, and assembly design capabilities. SolidWorks is a software program that helps in engineering drawing generation, collaboration, add-in customization, and integration with other software products. It is a comprehensive solution for 3D computer-aided design, appropriate for a range of industries and product development stages, and it also handles design data and modifications.

3.4 Conclusion

We present a comprehensive system design that integrates various technologies, including sensor design in Proteus for environmental monitoring, the use of waterproof solar panels to create a photovoltaic system, the selection of Arduino UNO and Arduino Nano for microcontroller functionality, image processing with Google Colab and PyCharm for YOLO model training, and environmental monitoring via Proteus. Additionally, we employed PVSYST and Matlab for solar tracking and energy generation analysis. The synergy of these technologies creates a sustainable and versatile system with applications in smart agriculture and energy-efficient buildings, offering a promising pathway towards a greener and technologically advanced future.

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

4.1 Introduction

In this case, the project's best option from the three offered strategies has been chosen. While the three concepts demonstrate slightly different operational mechanisms, they ultimately accomplish a common objective. All three options have been evaluated with regard to specifications, requirements, cost, and standardization. Various methodologies can be employed to comprehensively examine and analyze the multiple approaches. Furthermore, based on feedback provided by consumers, consideration has been given and a weighted matrix has been developed to determine the ideal choices for design. Subsequently, software simulations and analyses were conducted to confirm the validity of the findings. Ultimately, drawing upon the outcomes of the conducted analyses, we have identified the most optimal approaches.

4.2 Simulation of multiple design approach

For the multiple design approach, the team chose three different alternatives which are “Manual data collection”, “Unnamed vehicle data collection” and “Top mounted automation bar”. For the optimization process, “Manual data collection” does not fully meet our requirements for automatic and less human interaction. “Unnamed vehicle data collection” is a good choice but considering the efficiency of its energy usage this might not be a good option as it requires more energy and also for large-scale implementation this might drop its efficiency. “Top mounted automation bar” This approach has a good number of pros, also as our target is to make the system off-grid so this approach will be feasible as it requires less energy. We have two subsystems in every approach, one is data collection which varies in different designs and another one is environment monitoring which is the same in every design. Also, we have PV for power input. We will be discussing the data collection subsystem of every design.

Manual Data Collection:

Figure 05: Camera model.

As discussed previously, This whole approach is based on human interaction. The user needs to move the camera on his own to take the picture and again the user needs to upload the taken data to the computer where the image data will be processed and the result will be given. This is very much time-consuming and less efficient. In the case of a very small-scale greenhouse where there'll be only a few plants this will be efficient. For optimizing this approach, the camera can be set up in a fixed position but that will not meet our engineering requirements.

Unnamed ground vehicle:

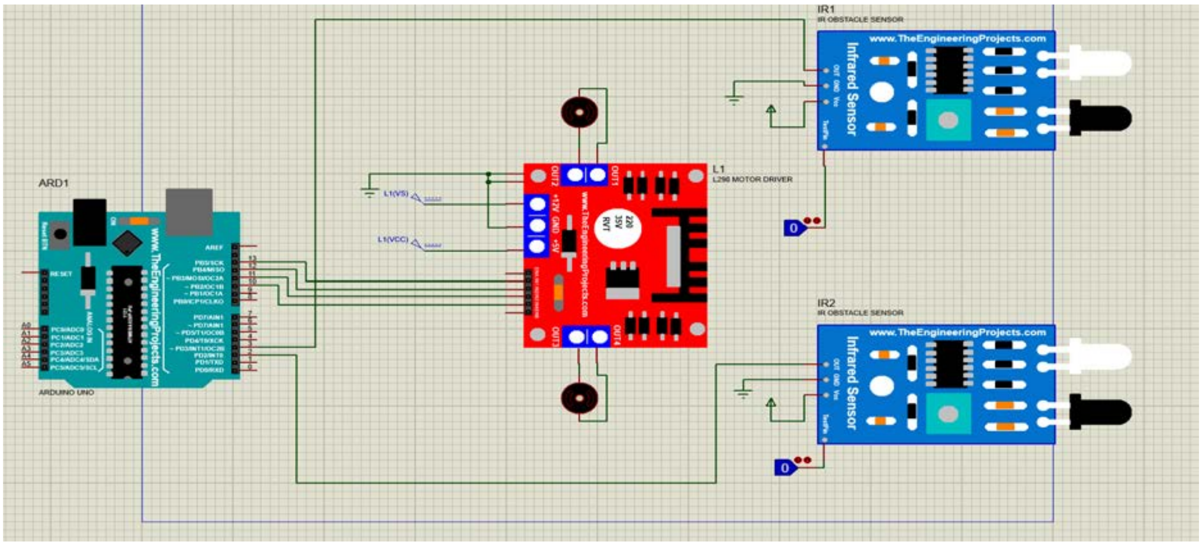


Figure 06: Simulation of Unnamed ground vehicle.

Here is the general simulation for the ground vehicle of approach 2. This simulation is inspired by a line following a robot and its basic mechanism. However, using a movable object inside of a field can be problematic due to the condition of paths/roads for the vehicle. Here two PIR sensors are used which will detect the marked line of the path/road. The vehicle will continuously move and take images of plant leaves. There will be a condition that will help the vehicle to detect its pathway.

Workflow of the simulation:

TABLE 05: Truth table for the vehicle operation.

V(left sensor)	S(right sensor)	Action
1	1	Forward
1	0	Left
0	1	Right
0	0	Stop

In this simulation we have added two sensors to detect the path for the vehicle to move. The truth table shows how the vehicle will move and in which direction. There is also a motor driver for maintaining the speed constant [15].

Figure 07: Chassis of the Unnamed ground vehicle.

This approach has an autonomous design, and It will ensure less human interaction. To optimize this design, we went through a few simulations, and the results were very satisfying. It can carry enough weight, so a good-quality camera and integrated drivers and sensors will work just fine. It operates on a DC battery, but it has huge energy consumption as it will be a four-wheel drive vehicle, which is a major drawback. Also, in terms of wet fields, it may get stuck. Changing its tires to off-road tires may be a solution, but again, that will increase energy consumption much more. And since we are aiming for an off-grid system, energy savings are a must for any of our designs.

Top Mounted Automation bar:

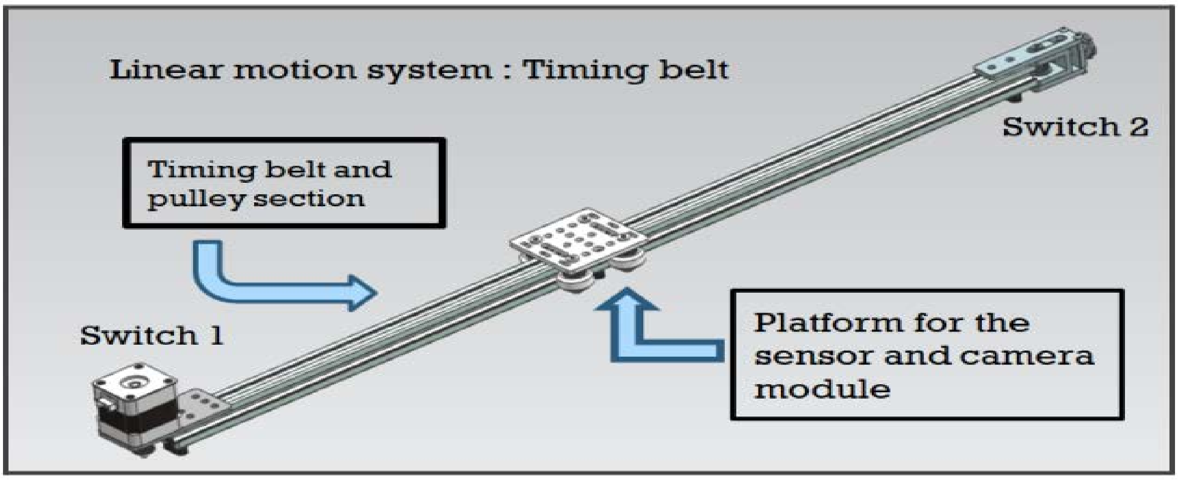


Figure 08: 3D model of a top-mounted bar.

In this approach, as previously mentioned, there will be a bar at the top of the greenhouse where a timing belt and motor will be placed. There will be a box on the bar containing cameras and sensors with integrated drivers. This design has the most efficiency and has satisfying results in the simulations. Also, large or small it can be integrated anywhere and this also has the potential to perform on industry-level tasks. As the whole system moves in a linear way there is less energy consumption than other designs.

Environment Monitoring System inside a GreenHouse Chamber:

Components used: Arduino uno, resistive soil moisture sensor, temperature sensor and humidity sensor(DHT11), light intensity(LDR), relays.

Before Simulation:

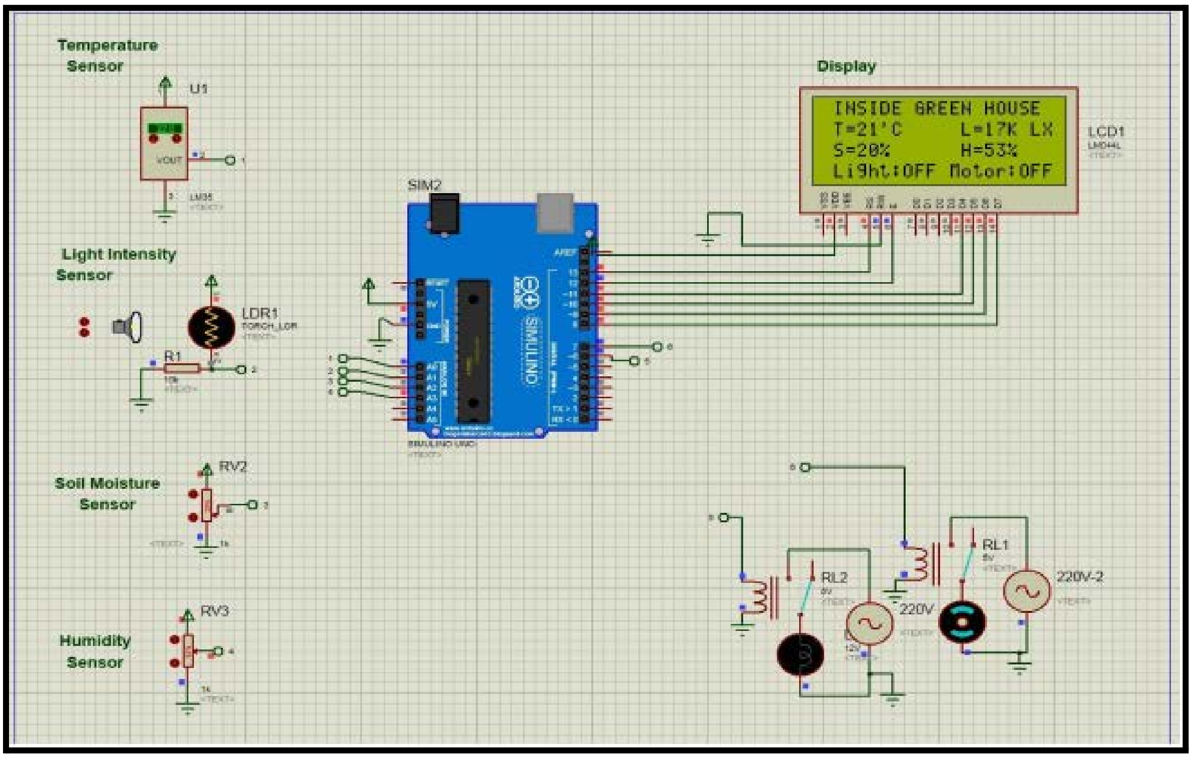


Figure 09: Before Simulation inside greenhouse

Here For the Circuit, we are using Proteus for circuit building where we use Arduino Uno as our main board and Arduino IDE for our Programming section. We are using the 20x4 display as our notification panel and some sensors to collect data. Resistive soil moisture sensor, temperature and humidity sensor, light intensity, and two relays for maintaining lightness and water. Here, we used the analog pins (A0, A1, A2, A3) of Arduino Uno. Firstly, We have connected the temperature sensor with the A0 pin of our Arduino board. Then added the LDR with the A1 pin of the Arduino board. Adding the soil moisture sensor

A2 pin of the Arduino board. We have connected the temperature sensor with the A0 pin of our Arduino board. We connected the humidity sensor with the A3 pin of our Arduino board. We have also used the two PD6 and PD7 Pins to connect with our relays. Here, PD6 is connected to the relay with a water pump and PD7 is connected to the external light. We have also connected the 20x4 display with the digital pins of PB0, PB1, PB2, and PB3 with the D7, D6, D5, and D4 pins of the display.

After Simulation:

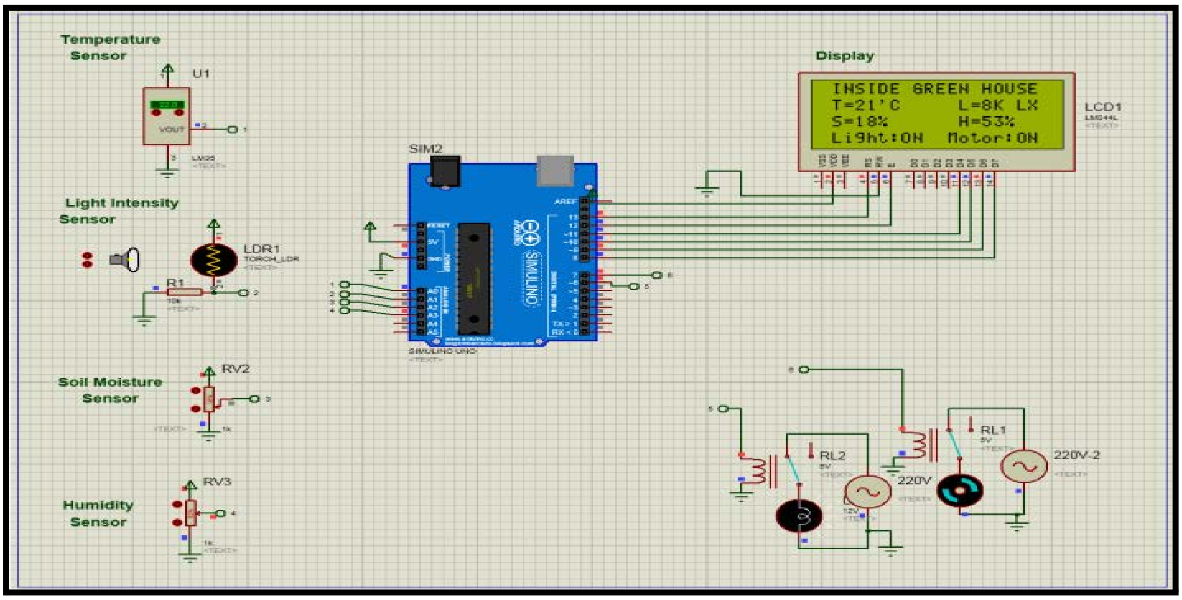


Figure 10: After Simulation inside the greenhouse.

After simulation, we can see that inside the greenhouse we are seeing temperature, humidity, soil moisture sensor, and light intensity sensor where we can see the temperature(c), humidity (%), soil moisture (%), and light intensity (LUX) inside the greenhouse chamber darkness or light intensity data in the Notification panel. In the relay, If the light intensity is less inside the greenhouse, then the external LED light will be turned on and if soil moisture is not appropriate, the automatic system will detect it and send water from the submersible water pump to make the soil sufficiently moisturized.

4.3 Identify optimal design approach

Based on our analysis through simulation (chapter 4.2) and from our analysis through the pros and cons of each design approach (chapter 2.3) also considering our stakeholder's priority and choices we have pointed out each of the design approaches on a scale of 10. These pointing systems will help us to find the optimal design approach for our problems.

TABLE 06: Point table for all of the design approaches.

Criteria	**Approach 01**	**Approach 02**	**Approach 03**
Efficiency	**6**	**7**	**7**
Energy usage	**5**	**9**	**7**
Portability	**8**	**8**	**7**
Stakeholders Acceptance	**4**	**4**	**8**
Sustainability	**5**	**6**	**8**
Impact	**5**	**7**	**8**
Safety	**6**	**6**	**8**
Recyclability	**7**	**7**	**7**

4.4 Performance evaluation of developed solution

In our project, we used three different types of design approaches and after evaluating each of them, we considered approaches 3 as the optimal solution and we developed our whole project based on it. In this section, we will be discussing the performance of the whole system.

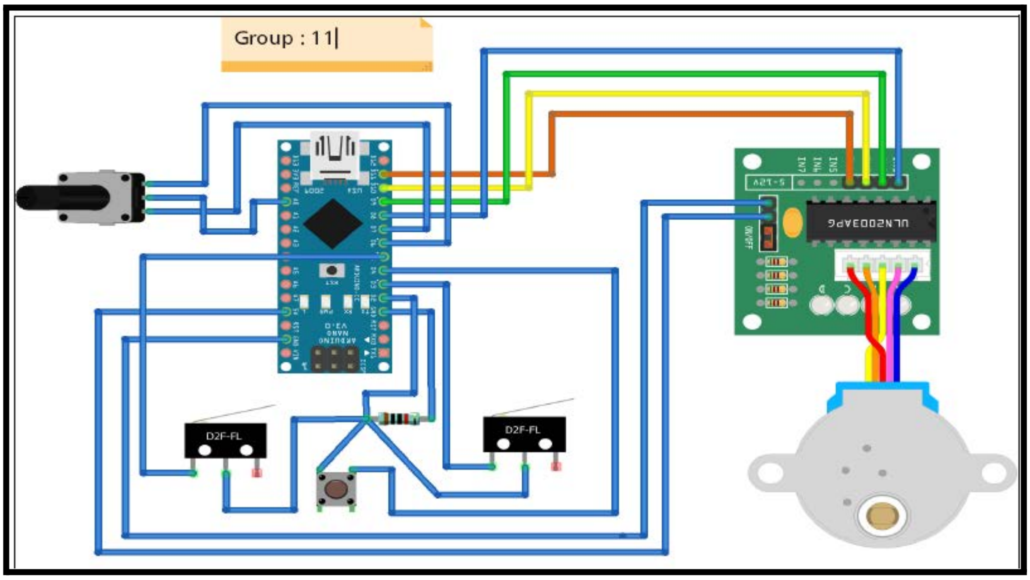


Figure 11: Motor-driver configuration of design approach 3

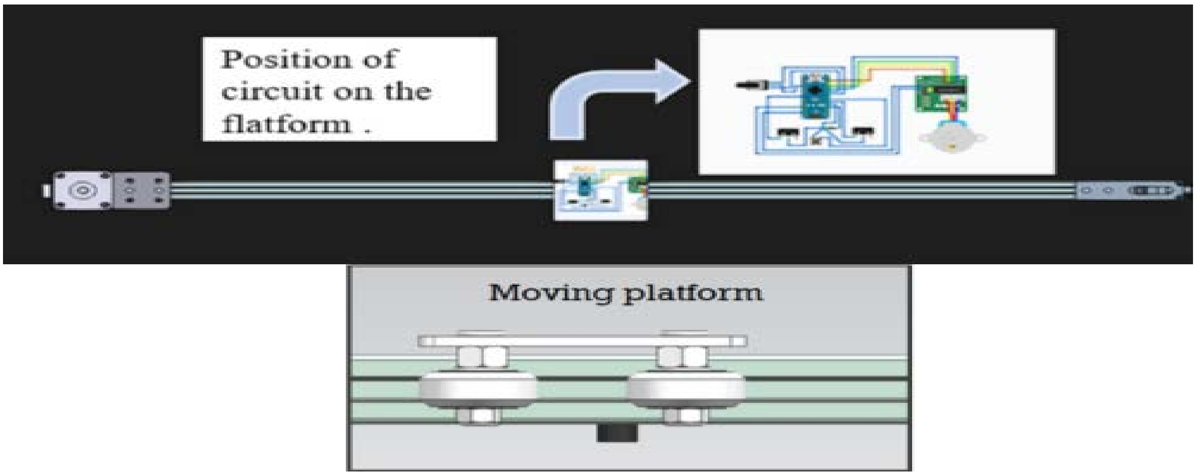


Figure 12: Motor-driver configuration of design approach 3

Here we can see the platform that will hold the camera at the top-mounted bar. The platform will move linearly and have two switches at both ends to ensure its pathway. The whole platform will be connected to a computer and battery.

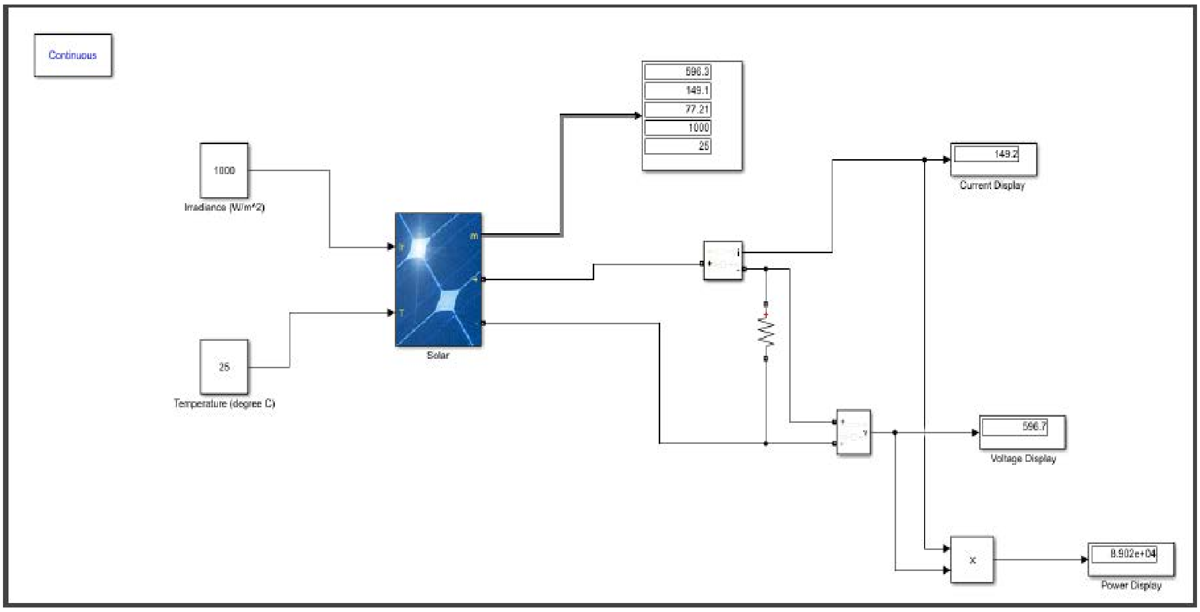
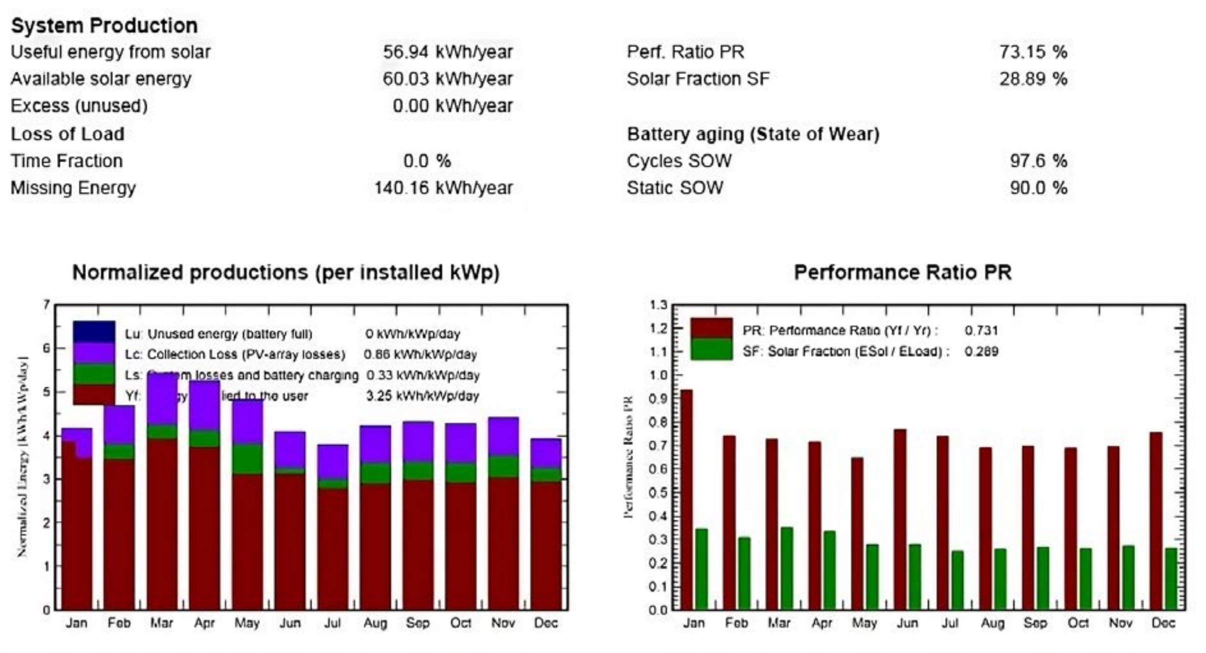


Figure 13: Solar system observation

Here, we have used a sunlight-based solar panel. In Matlab Simulink, we choose irradiance and temperature blocks to track the rays of the sun and their angles. For the result, we choose current, voltage, and power display to show the values from the solar panel. As the solar system is one of the sub-systems, we tried to measure the energy and observed the total power needed to run our prototype. In this simulation, we have selected the irradiance of

1100 W/m^2 means at our latitude, the value of the surface is approximately 1100 W/m^2 on a clear sunny day with a temperature of 25 degree Celsius. Then, we have seen the current (149.2-kilo amp) and voltage (596.7 V) in the displays. It is known that power=voltage*current [P=VI]. As a result, the power is 89.027kwatt which is enough for our overall system to run.. Through this process, we tried to understand the angle of the solar panels and from which side we could get the maximum energy from sunlight.



System Production

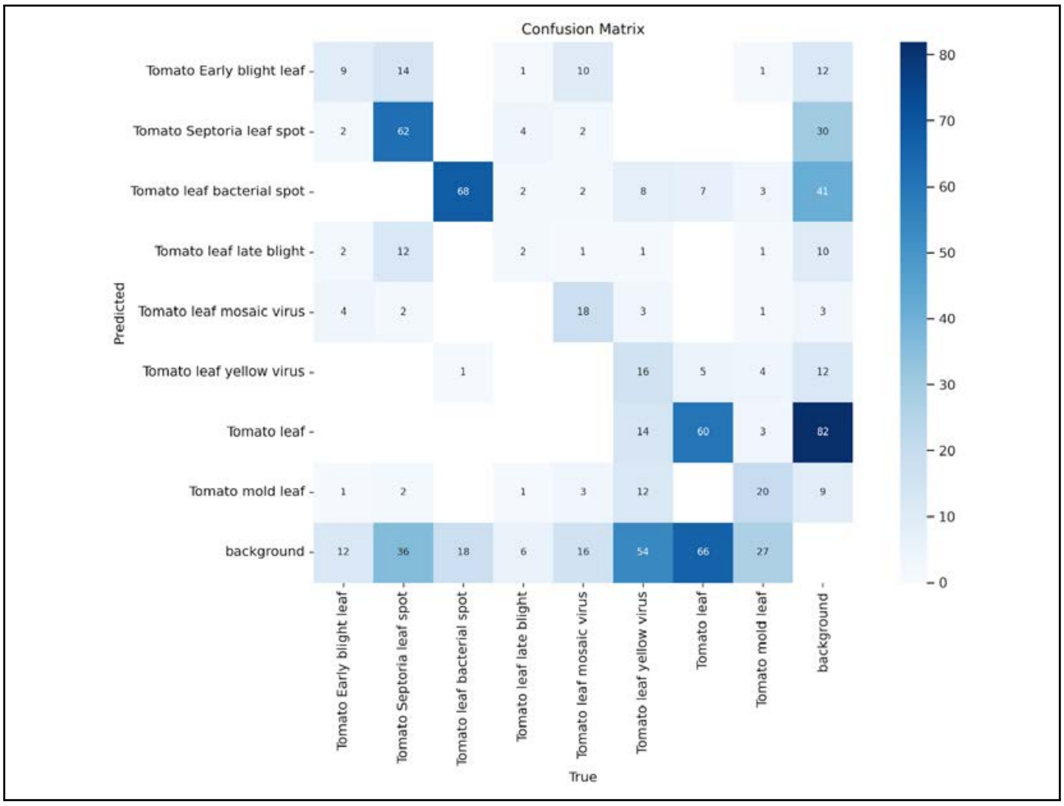
Useful energy from solar	56.94 kWh/year	Perf. Ratio PR	73.15 %
Available solar energy	60.03 kWh/year	Solar Fraction SF	28.89 %
Excess (unused)	0.00 kWh/year		
Loss of Load		**Battery aging (State of Wear)**	
Time Fraction	0.0 %	Cycles SOW	97.6 %
Missing Energy	140.16 kWh/year	Static SOW	90.0 %

Figure 14: Solar energy simulation results.

We have run a simulation to get an estimate for the amount of energy we will be needing throughout the whole year. From the simulation, we can get the idea that we will need 140.16 kWh of energy from other sources. So we came to the decision that we would need a grid connection to back up our whole system.

Results of disease detection using YOLO V8:

The effectiveness of the YOLOv8 model on the validation set is represented by the confusion matrix. The columns correspond to the projected classes, and the rows to the ground truth classes. The number of validation samples that were allocated to a particular ground truth class and predicted class is represented by each entry in the matrix. The number of accurate predictions for each class is represented by the diagonal elements, while the number of inaccurate predictions is represented by the off-diagonal elements.



Predicted \ True	Tomato Early blight leaf	Tomato Septoria leaf spot	Tomato leaf bacterial spot	Tomato leaf late blight	Tomato leaf mosaic virus	Tomato leaf yellow virus	Tomato leaf	Tomato mold leaf	background
Tomato Early blight leaf	9	14		1	10			1	12
Tomato Septoria leaf spot	2	62		4	2				30
Tomato leaf bacterial spot			68	2	2	8	7	3	41
Tomato leaf late blight	2	12		2	1	1		1	10
Tomato leaf mosaic virus	4	2			18	3		1	3
Tomato leaf yellow virus			1			16	5	4	12
Tomato leaf						14	60	3	82
Tomato mold leaf	1	2		1	3	12		20	9
background	12	36	18	6	16	54	66	27	

Figure 15: Performance matrix

The above graph shows us the validation curves of our YOLO model. Precision indicates the proportion of valid bbox predictions(True positives / (True positives + False positives)), while recall is the proportion of genuine bbox that was correctly anticipated(True positives / (True positives + False negatives)).

The mean Average Precision (mAP) at the 0.5 IoU (Intersection over Union) criterion is designated as "mAP_0.5." The average mAP over various IoU thresholds, from 0.5 to 0.95, is represented by the notation "mAP_0.5 to 0.95".

The YOLO loss function has three components:

1. box_loss — bounding box regression loss (Mean Squared Error).
2. obj_loss — the confidence of object presence is the objectness loss.
3. cls_loss — the classification loss (Cross Entropy).

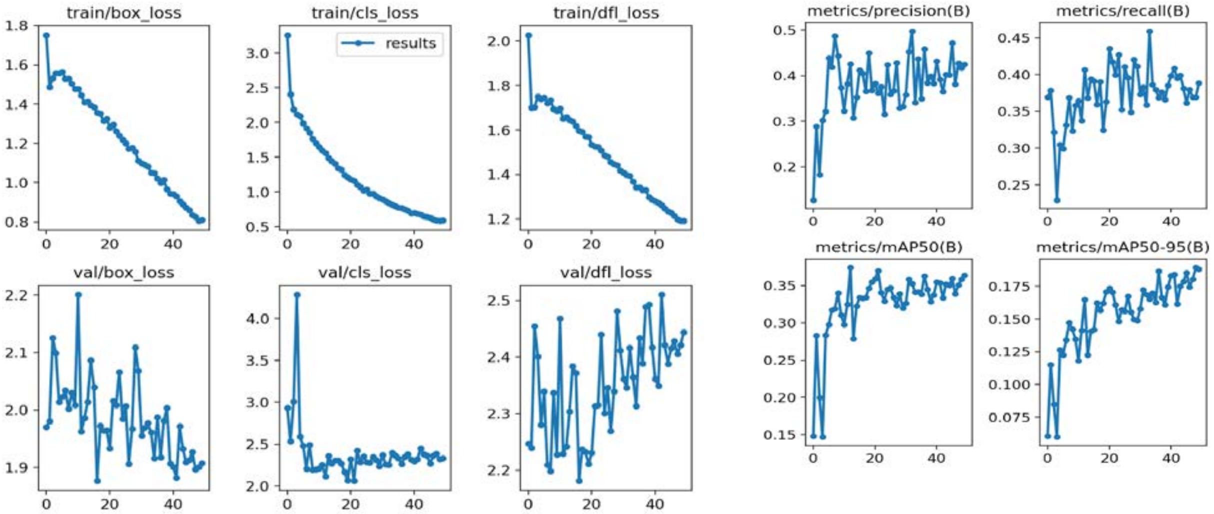


Figure 16: Validation curves from training.

The precision and recall are weighted and averaged to produce the F1 score. The formula for F1 score is:

F1 = 2 precision*recall / (precision+recall).

The F1 Curve:

The classification threshold is represented by the x-axis in this case. Moving along the x-axis adjusts the threshold for classifying an instance as positive. The F1 score is represented on the y-axis. The y-axis values represent the F1 score associated with each threshold. Analyzing the F1 vs Threshold Curve enables you to understand how the balance of precision and recall changes as the decision threshold is changed. It depicts the trade-off between false positives and false negatives at various confidence levels. Below we can see the curves for both simulations run at 50 epoch and 100 epoch accordingly.

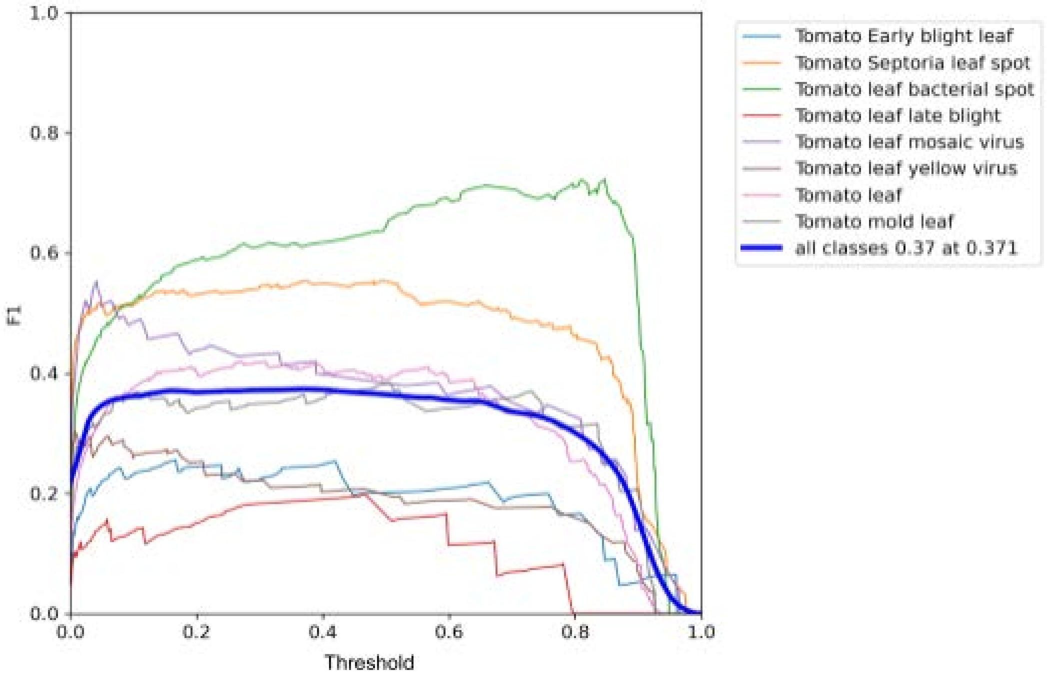


Figure 17: F1 curve for 50 epochs.

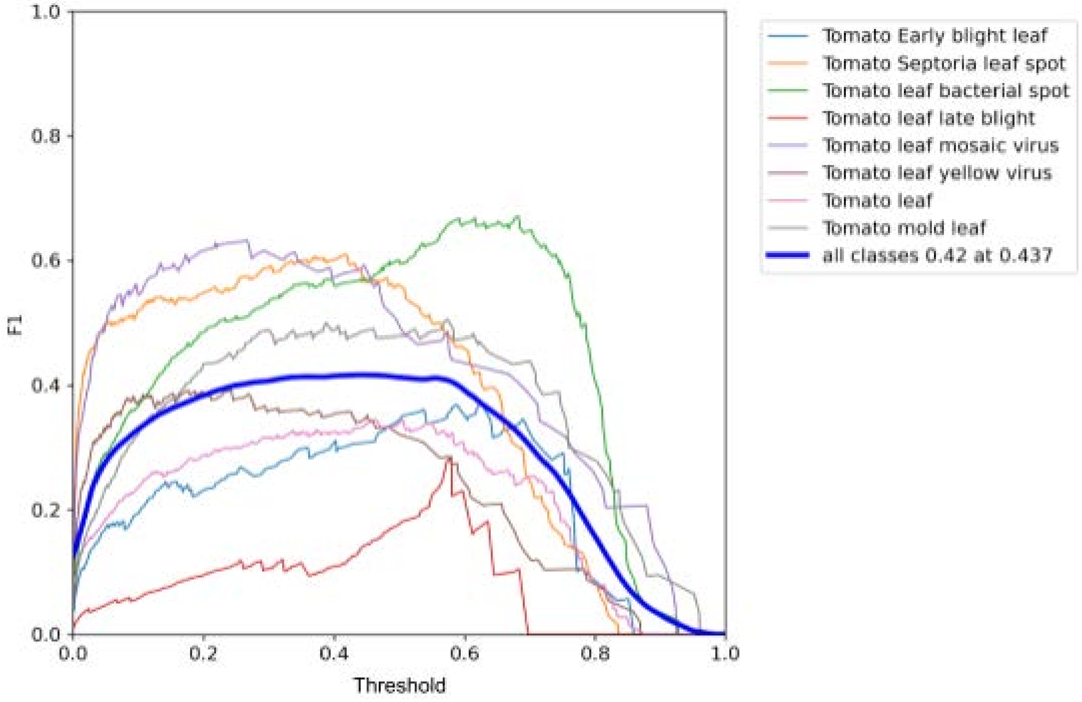


Figure 18: F1 curve for 100 epoch.

Precision-recall curve:

In a precision-recall curve, the relationship between recall (also known as sensitivity) and precision (also known as positive predictive value) is displayed for each possible cut-off. The recall (= sensitivity = TP / (TP + FN)) on the x-axis and the precision (= positive predictive value = TP / (TP + FP)) on the y-axis.

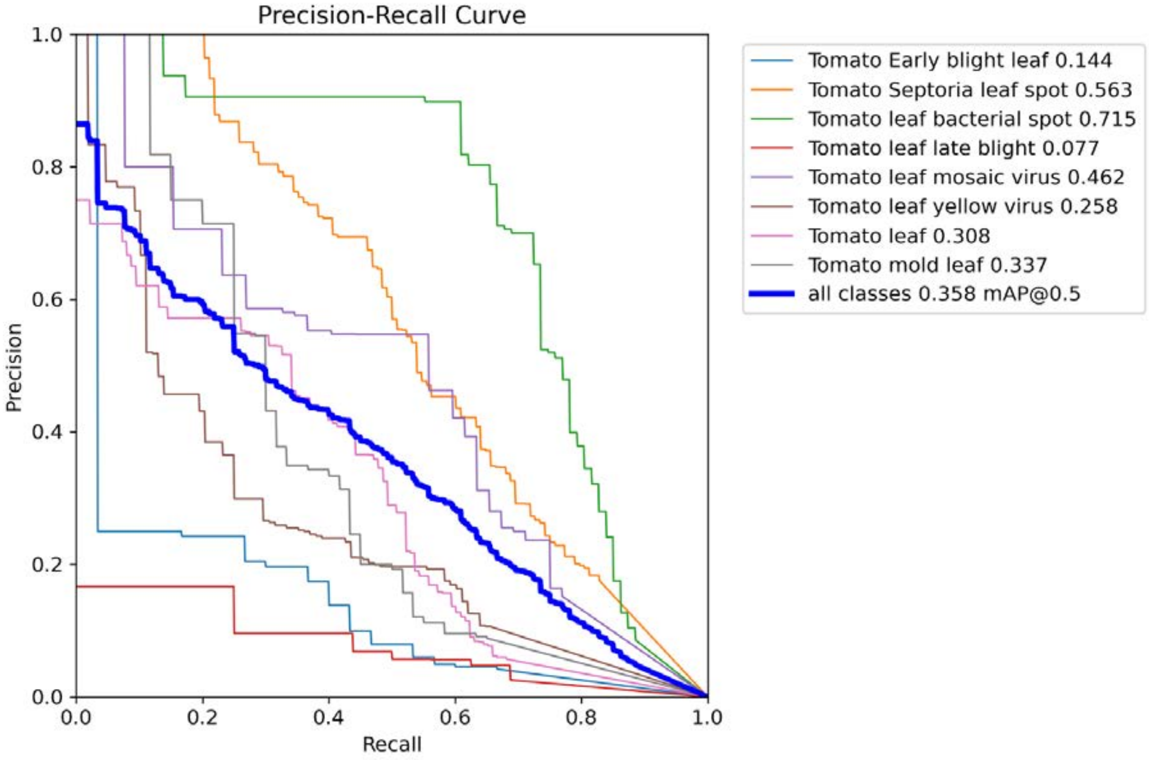


Figure 19: Precision-Recall curve obtained from Google Colab.

Recall-Confidence curve :

The classification threshold is shown by the x-axis in this instance. You adjust the threshold for classifying an instance as being positive as you advance along the x-axis. The recall (sensitivity) values are represented on the y-axis. The recall associated with each threshold is shown by the values on the y-axis. You can learn how your model's recall varies at various confidence levels by analyzing the recall-confidence curve. When assessing a model's accuracy in identifying positive instances and observing how this ability varies with different levels of confidence, this curve can be especially beneficial.

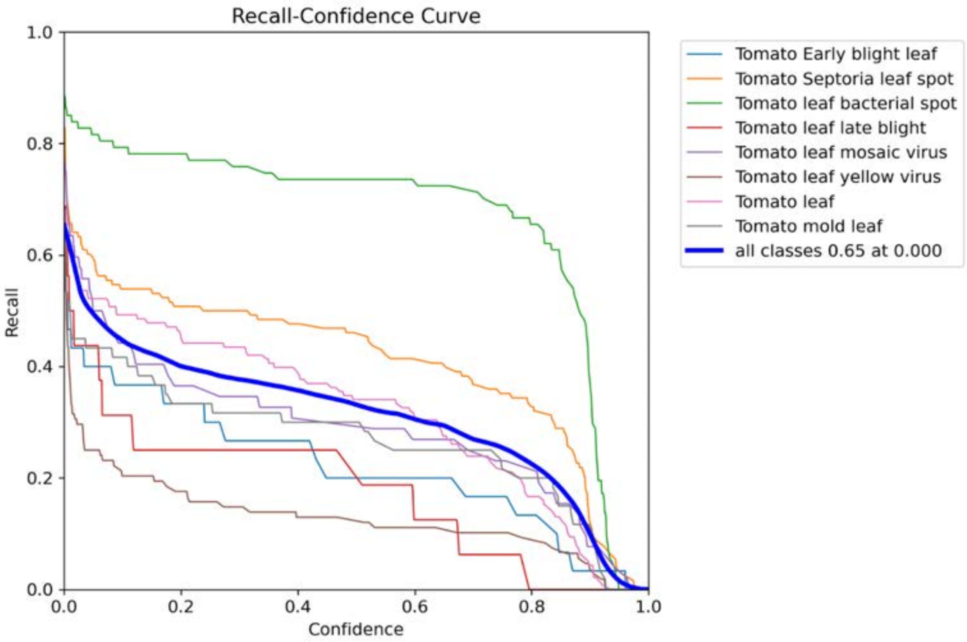


Figure 20: Recall-Confidence curve obtained from Google Colab.

Precision-Confidence curve :

The classification threshold is shown on the x-axis in this instance. You are changing the cutoff point for classifying an instance as positive as you advance along the x-axis. The precision values are displayed on the y-axis. The precision associated with each threshold is shown by the values on the y-axis. You can acquire how your model's precision varies at various confidence levels by analyzing the precision-confidence curve. This curve shows you how the accuracy of positive predictions varies according to the degree of confidence the model assigns. Precision is a measure of this accuracy.

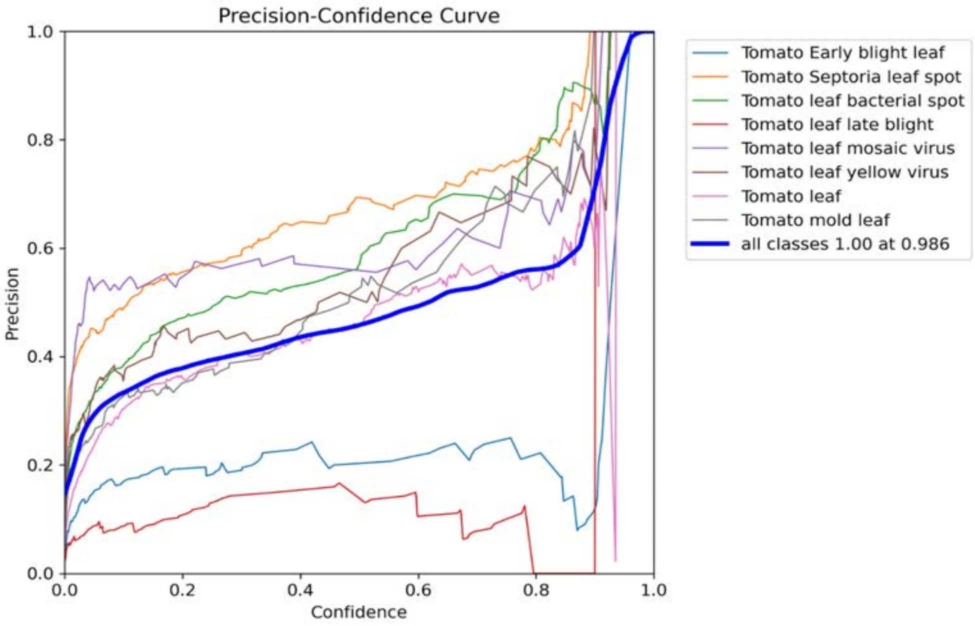


Figure 21:Precision-Confidence curve obtained from Google colab.

4.5 Conclusion

Optimization of multiple design approaches is really important to find out the best approaches. For this reason, we thoroughly analyze all the suggested approaches by comparing specifications, requirements, and budgets. To validate more, software simulations have been done. Finally, after taking into consideration the user’s feedback and all the analysis, approach 3- Top Mounted automation bar is selected as the most optimized and suitable for our project.

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

5.1 Introduction

This chapter, it discusses the completion process of the final design project and how the validation process occurs. After completing all the previous calculations with the help of simulated results and background theory from various papers and research materials, we sum up all the data from the theory with the real-life parameters to get the ultimate solution which is the final design of our prototype. To match the final data with our prototype result we have run our projects multiple times from data collection to result.

5.2 Completion of final design

There are a total of three sections in our final design;

1. Disease detection by machine learning.

2. Environmental monitoring & control system.

3. PV system for hybrid energy.

1. Disease detection by machine learning:

As we know, real-time object detection is a computer vision task that entails finding and identifying objects that are relevant in real-time video sequences while maintaining a minimal level of accuracy. We have tried to integrate object detection on a portable device to detect diseases on plants rather than objects [16]. We have built three subsections to build our model.

First, we needed a real-time object detection algorithm. For this, we chose YOLO v8 as YOLO v8 is incredibly quick and precise. YOLOv8 is comparable to Focal Loss in mAP measured at 0.5 IOU, but it is about four times faster. Additionally, you can easily compromise between accuracy and speed by simply altering the model's size; no retraining is necessary. We took our dataset, which had nine sets of annotated images for nine diseases and one set of images containing healthy plant images. We used tomatoes as our plant for disease detection. Then we used Google Colab to train our algorithm with the custom dataset. The process was done over 50 epochs. Then, for better accuracy, the process was done over 100 epochs. After that, Google Colab gave us various results regarding the accuracy and precision of our custom model. We required the Best.pt file, which contained the checkpoint with the best validation loss training so far.

Secondly, we needed an integrated development environment so that we could use Python as well as various other packages like userlytics, lap, open vision, and CVZ to run our custom model. We chose PyCharm for this purpose. We also used Python 3.10 for smoother package integration. After that, we put the best.pt file in the same directory as our Python project folder. Next, we imported YOLO, CVZONE, MATH, and TIME into our console. We then designate a camera with which the algorithm is going to run. We also selected our custom model for detection. Finally, we selected the proper parameters for the bounding box and class names to run our code. After pressing the run button , we were able to see active real-time detection of tomato diseases on tomato plants.

Finally, we needed a portable and movable device that would carry our camera [B] to get real-time scans of different parts of the tomato field. In order to do that, we chose a linear belt [C] system where the camera will be fixed on a platform, and the whole platform will be moving linearly from one end of the field to the other. The platform has a stepper motor (DC 5V Stepper Motor with ULN2003 Driver Board 28BYJ-48) [A] which is attached to a timing belt with a toothed gear. The platform moves on the timing belt from one end to the other. The platform has two limit switches [F] on both edges, which reverse the polarity of the motor so that the platform does not exit the length of the belt. The speed of the moving platform is controlled through a 10K potentiometer [D]. We have controlled the whole process with the help of the Arduino Nano [E]. Finally, we have used two 8mm solid stainless steel rods and two 6mm hollow stainless steel rods for the structural rigidity of the device.

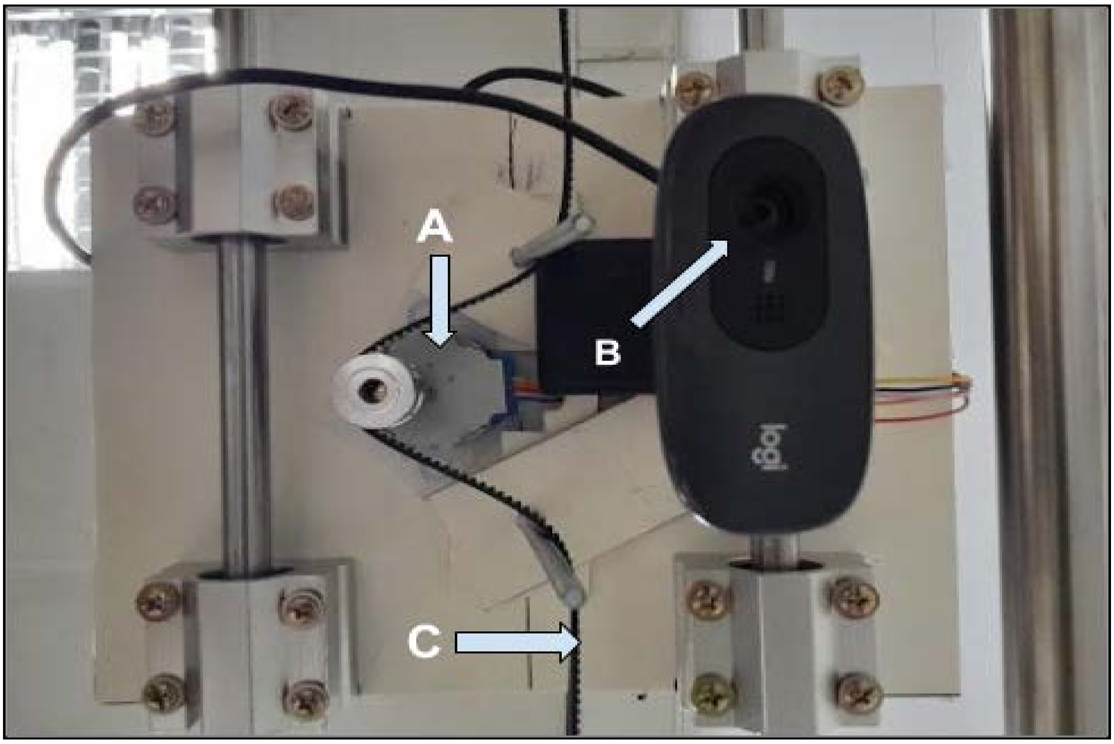


Figure 22: Taking pictures from the plants by the camera and running through a conveyor belt (A.Stepper motor, B.Web camera, C.Conveyor belt).

This is the setup for the camera module for taking continuous pictures. There is a belt (C) which is for moving the mounted platform. We can see the motor (A) and timing switch which combinedly work for the direction of movement. For better stability, high quality bearings and stainless steel pipes have been used. The camera (B) is able to take good pictures in enough light for the algorithm.

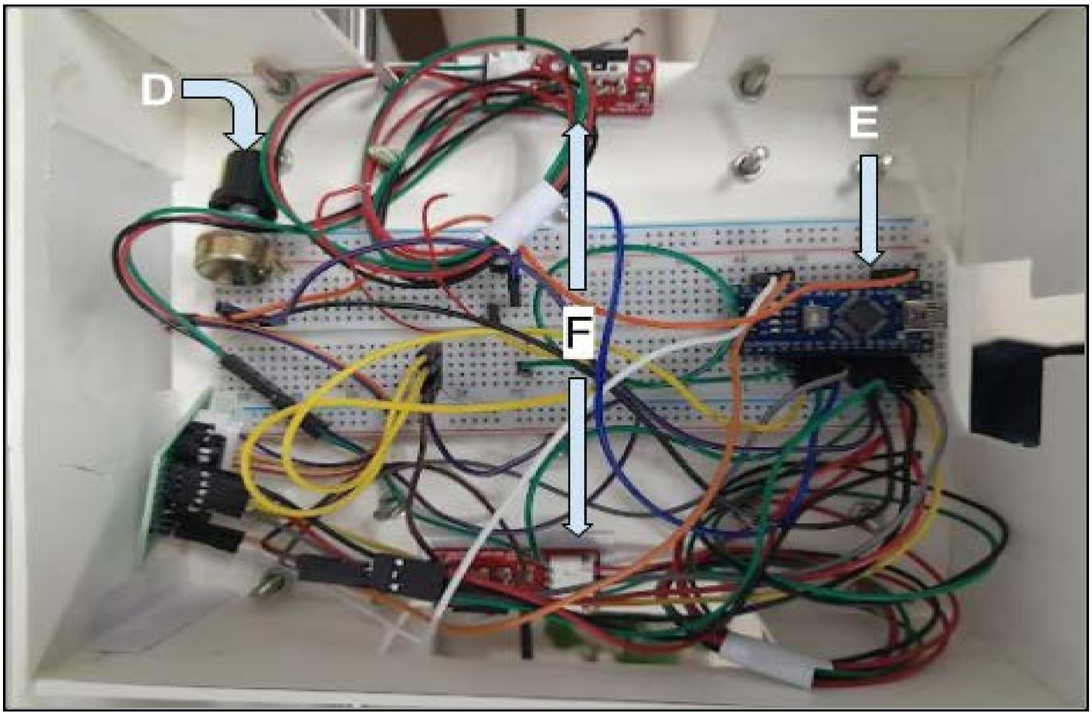


Figure 23: Internal circuit built of our conveyor belt system

In this Figure we can see 3 marked components. Here is a microcontroller (E) that is responsible for the whole control of the top-mounted subsystem. Two-timing switches (F) have been used for controlling the rotating direction of the motor. For controlling the movement speed we have used a regulating component (D) by using it we can vary the speed.

Figure 24: Prototype of our disease detection system on top of the timing belt device.

Figure 24 represents the physical demonstration of the prototype. It can take pictures of the plants even at a good height or distance. Also, by increasing the SS pipe we can install the whole system in larger greenhouses.

2. Environment monitor and control system:

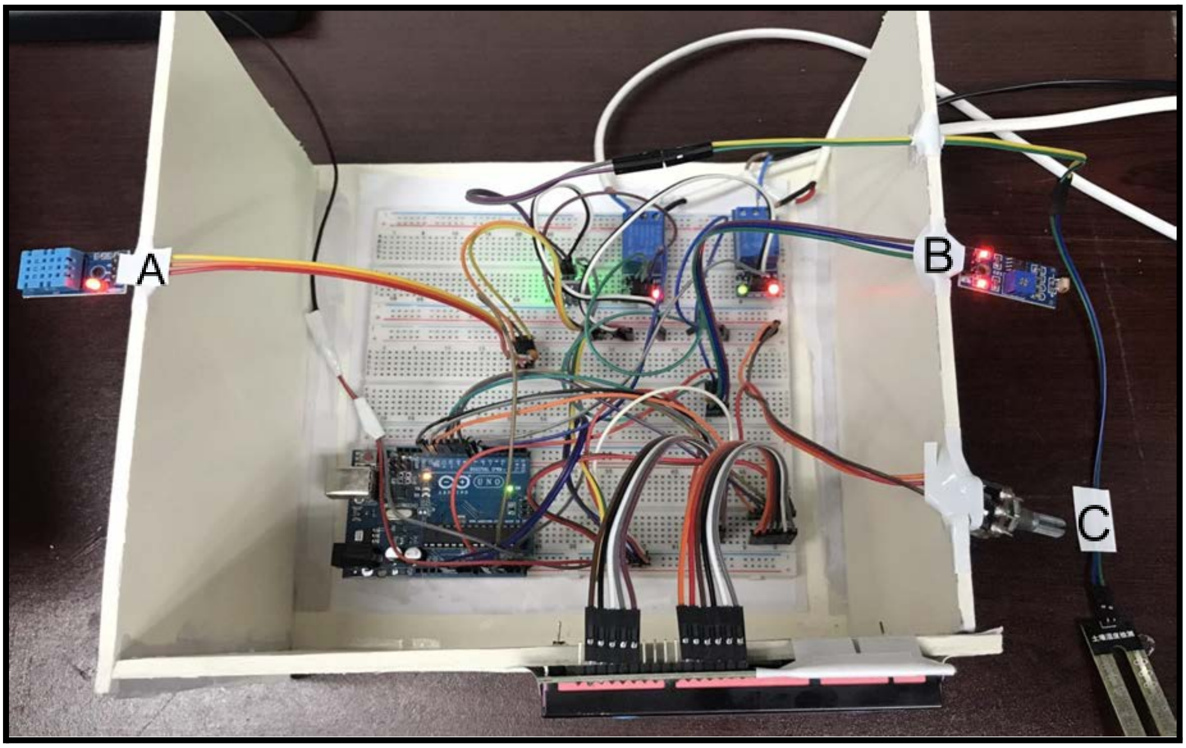
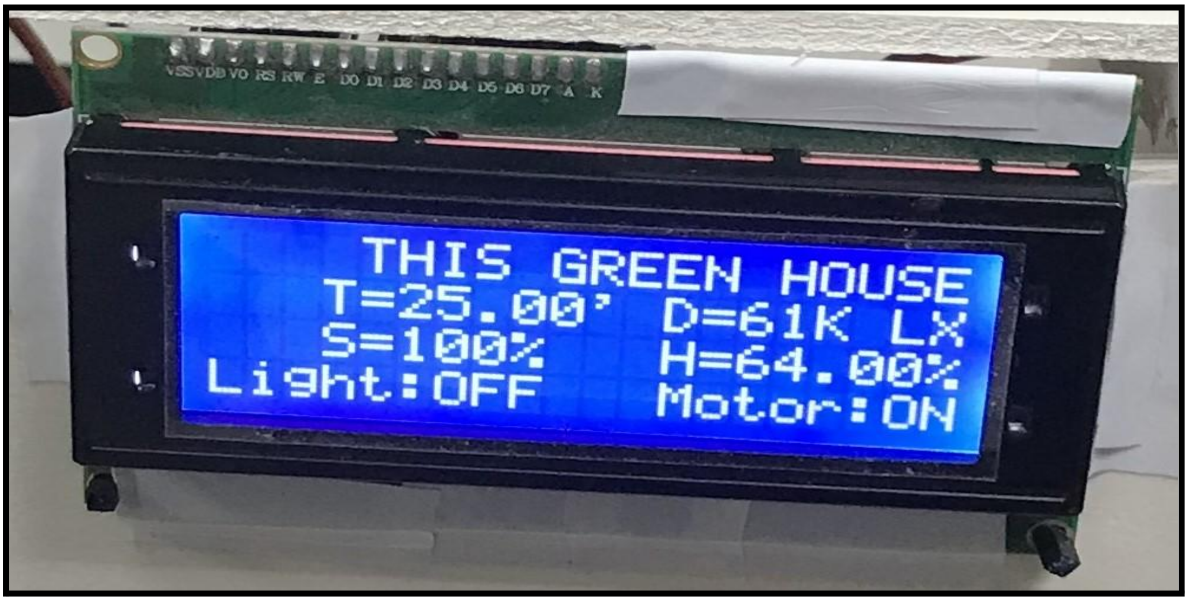


Figure 25: Sensor-based Environment Circuit (A) Temperature & Humidity.
(B) LDR Sensor.
(C) Soil Moisture.

This is the subsystem that is responsible for environmental monitoring inside of the greenhouse. We have a temperature & humidity sensor (A), LDR sensor (B) for detection of light intensity, and Soil moisture sensor (C) for detecting if water needs to be given or not. In the following figure 26, we have a display showing the Data collected from the sensors. It has been made really simple so that the user can read it easily. Also, the system can be easily troubleshooted if necessary.



```
THIS GREEN HOUSE
T=25.00'  D=61K LX
S=100%    H=64.00%
Light:OFF Motor:ON
```

Figure 26: Display for Environment System

Here, We can see the value of Soil dryness level or Soil moisture level, darkness or light intensity level, temperature and humidity level inside the chamber. Addition to that, we can see if the water motor / water pump is turned on or off, and the condition of external light is turned on or off.

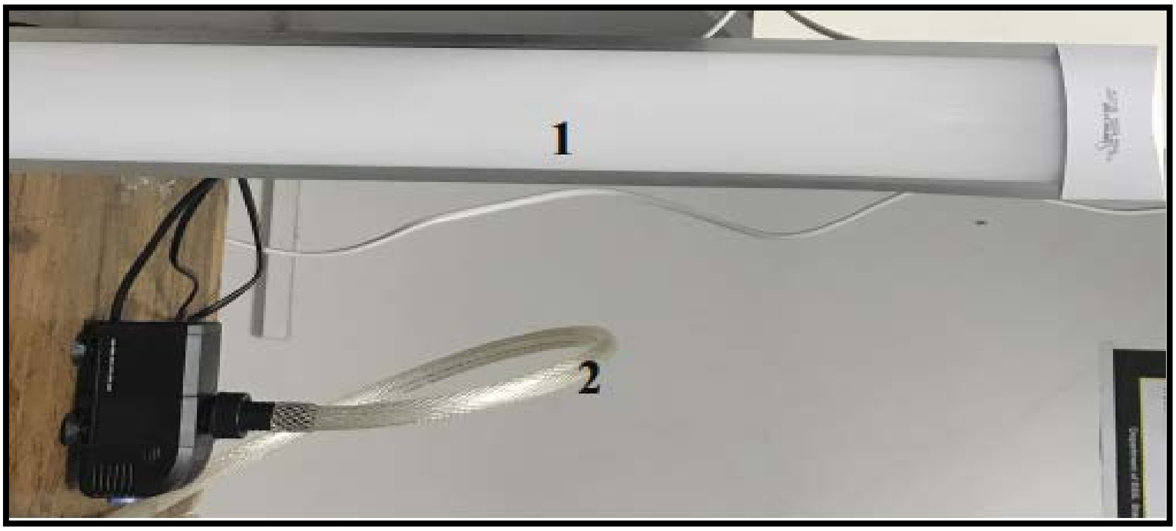


Figure 27: Additional Working Output for Environment.

Here, In figure 27: (1), we can see the additional led light (1) and submersible water pump (2). Both of them will be connected directly with the relay connected with the arduino uno and for both light and water motor will need to connect with ac power supply directly to work separately to get powered up and relay will take the decision if the led light or water motor needs to be turned on.

Complete Environmental Notifications and Monitoring control system :

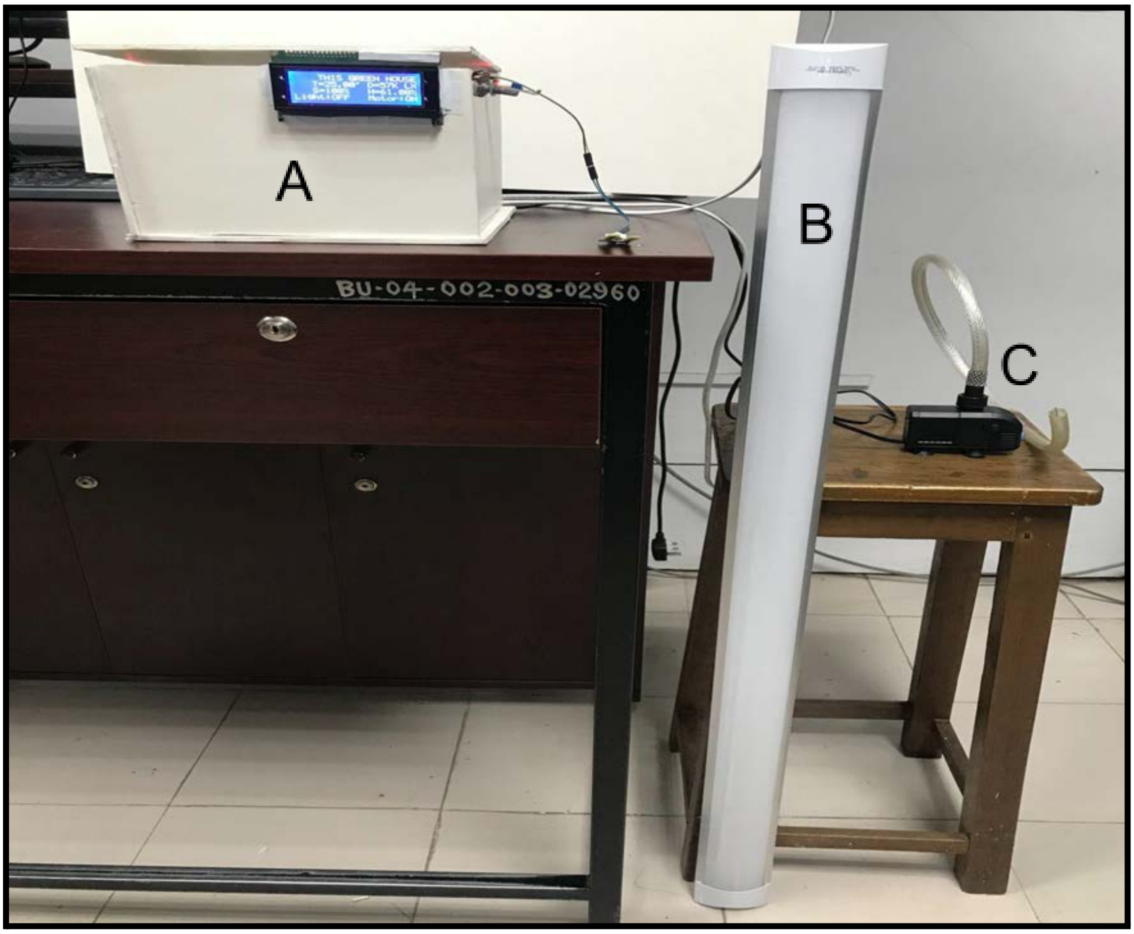


Figure 28: (A) Complete Environmental Notifications and Monitoring Control System with Notification Panels.
(B) Additional 40W LED Light &
(C) Submersible Water Pump.

Working principle of environment monitoring & control system of the greenhouse chamber:

Here, We are adding a notification panel as a display to show the system's current situation inside the greenhouse by displaying temperature, humidity, resistive soil moisture, light intensity factor For Better production and Tomato Growth, we know temperature should be (17-25c), Humidity (around 70%), Soil Moisture (below 60%), Light Intensity should be from 10k to 15k LUX inside a greenhouse chamber [17]. So, it is almost compulsory for a greenhouse chamber to remain in that certain atmosphere.

We know, for a greenhouse chamber the ideal value of temperature is 17-25°C, and humidity is 60-70% [18]. We used a DHT11 sensor for collecting data of temperature and humidity from the atmosphere inside the greenhouse chamber which is an important element to create a certain atmosphere inside the greenhouse [19]. Here, we have used a resistive soil moisture sensor (FC28) which has two exposed probes inserted into the ground to get the data and information from the soil of the greenhouse chamber. Now By using Arduino IDE, we can code and program our circuit to work automatically. Here, we basically used two sections to maintain the inside chamber. We have employed a cost-effective digital sensor and analog sensor, the LDR sensor module can measure and detect light intensity. LDR Sensor with an optical sensitive resistance light detecting responsive lDR sensor modules. The internal build (Light Dependent Resistor) on this sensor helps in identifying the presence of light. Its sensitivity to light can be changed by turning the potentiometer knob on the sensor.

To create an appropriate atmosphere, we have used two relays as our switching device with an Arduino board. To achieve enough light intensity and moisture level in plants, we added an External 40W LED light and a Submersible water pump for watering or irrigation purposes with our relay by which we can manage and control the additional LED Light and watering system automatically. Firstly, we have to maintain a watering moisture of below 60%. So, If the percentage of water moisture in the soil gets larger than 60%, The Soil sensor will automatically detect it, keeping the soil sufficiently wet till [18]. Secondly, whenever the sunlight is not sufficient, external light will get turned on inside the chamber. The minimum light intensity inside the greenhouse is 10k LUX which means 10000 LUX. Whenever the light fails to deliver 10k LUX inside the chamber, the external 40W LED will help the chamber to brighten up and help the tomato to get the perfect light it needs for photosynthesis.

3. Photovoltaic cells with battery:

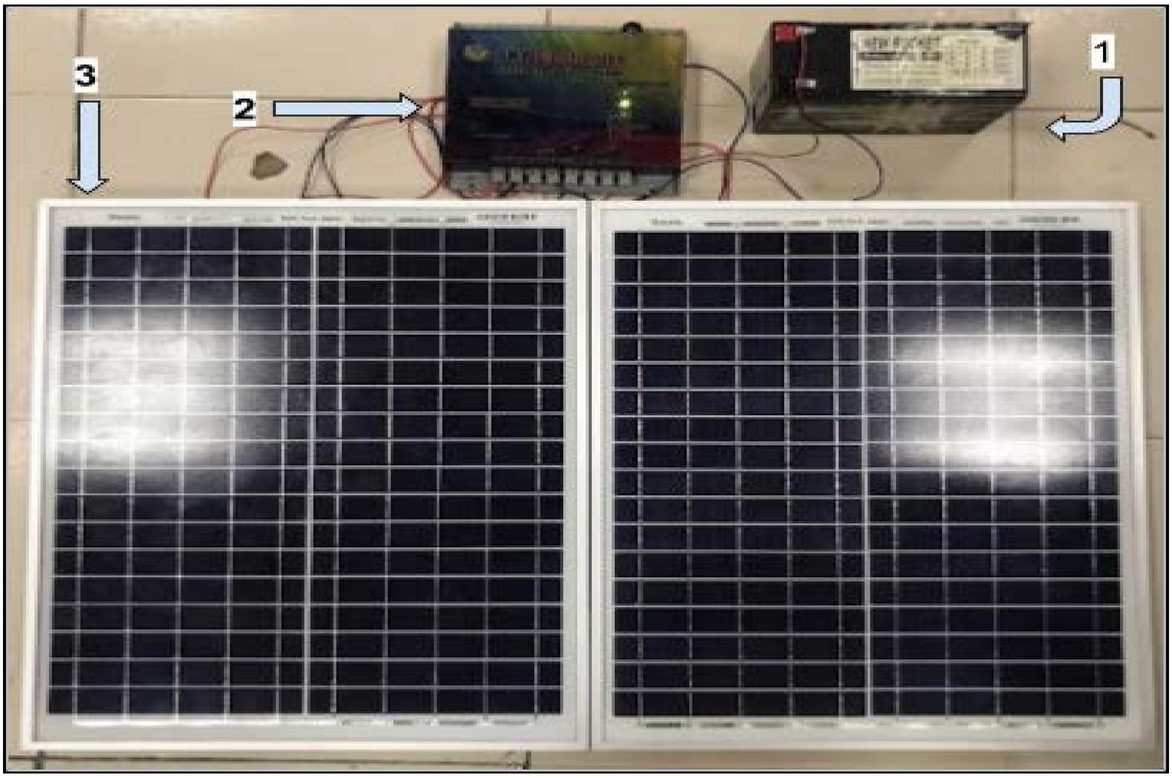


Figure 29: Solar Panel Installation (1.12V battery, 2. Solar charge controller, 3.20W solar cell).

Here we have our two solar panels each rated at 20W. For the control of the solar panels, we have a solar charge controller which is very easy to use, and also for storing the energy we have a battery. The energy we get from this is sufficient for our system to run. As mentioned before, we aim to run the whole project with off-grid energy and we choose PV as our power source [20]. We run the simulations for energy performance and we get the results that our energy needs can be fulfilled with PV energy, and we will have some extra energy left throughout the whole year. But in case of any absurd situation, we will have a grid connection as a backup [21].

Figure 30: A. Hardware prototype of the completed project, B. Controlling the dryness of the soil, C. Conveyor belt system, D. Sensing the light intensity of the environment, E. Photovoltaic cells with battery, F. Detection of disease.

5.3 Evaluate the solution to meet the desired need

As we ran the systems and observed the data, we did some field testing at Sher-e Bangla Agricultural University according to sensors and disease detection from greenhouse and tomato plants.

Results from disease detection through image processing:

The way we tested the whole system was first to collect a sufficient number of images of tomato plants from which the YOLO model is going to take proper information to generate the disease name with adequate confidence percentage. We took around 723 images from the testing field. Then we ran the individual image through the model. Each image gave us various confidence levels. We chose the best results as it already indicated that the plant had a specific disease.

Through our testing, we have come to the result that the plants had Tomato Leaf Bacterial Spots. The percentage of confidence level was ranging from 33% to 96%. The main reason for having a lower confidence level was that those specific images were either blurry or had too much imperfection to detect the proper disease. Most of our confidence level was higher than 65%. We also encountered some misdetection such as detecting other diseases (Tomato leaf late blight and Tomato mold leaf). The reason for this misdemeanor was also the same as that found in lower confidence levels.

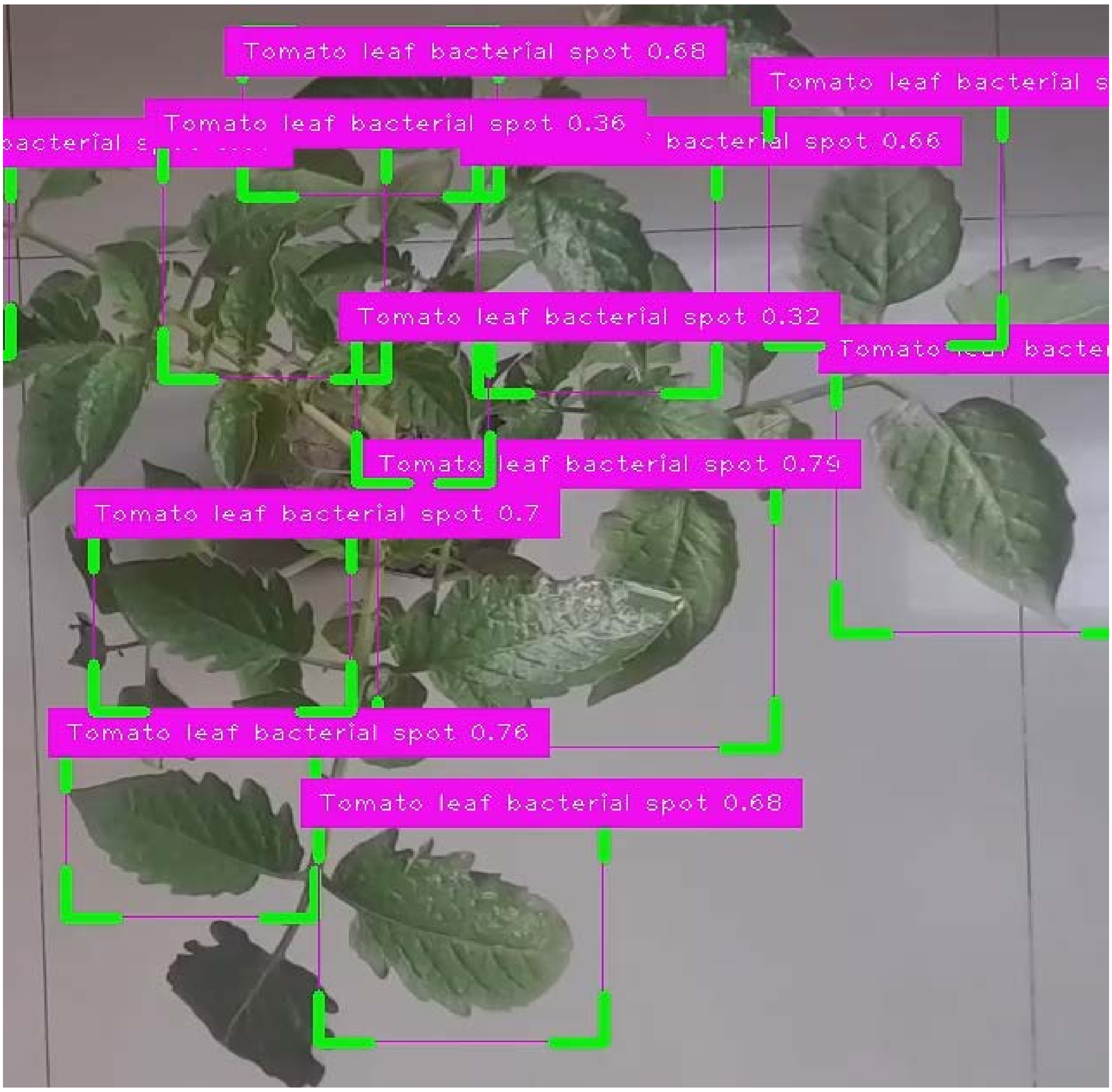


Figure 31: Collecting disease name and their designated confidence level from testing sample no.01.

Above is one of our detection result samples. Here we can see the active detection of individual leaves of a tomato plant. The bounding box is first capturing each leaf for possible diseases. Then if a disease is detected according to the algorithm the bounding box is going to display the disease as well as the confidence percentage to the exact position of the affected leaf. As we can see from the above picture the leaves are affected with tomato leaf bacterial spots. The confidence level is from 66% to 79% so there is a high probability that the plant is defective.

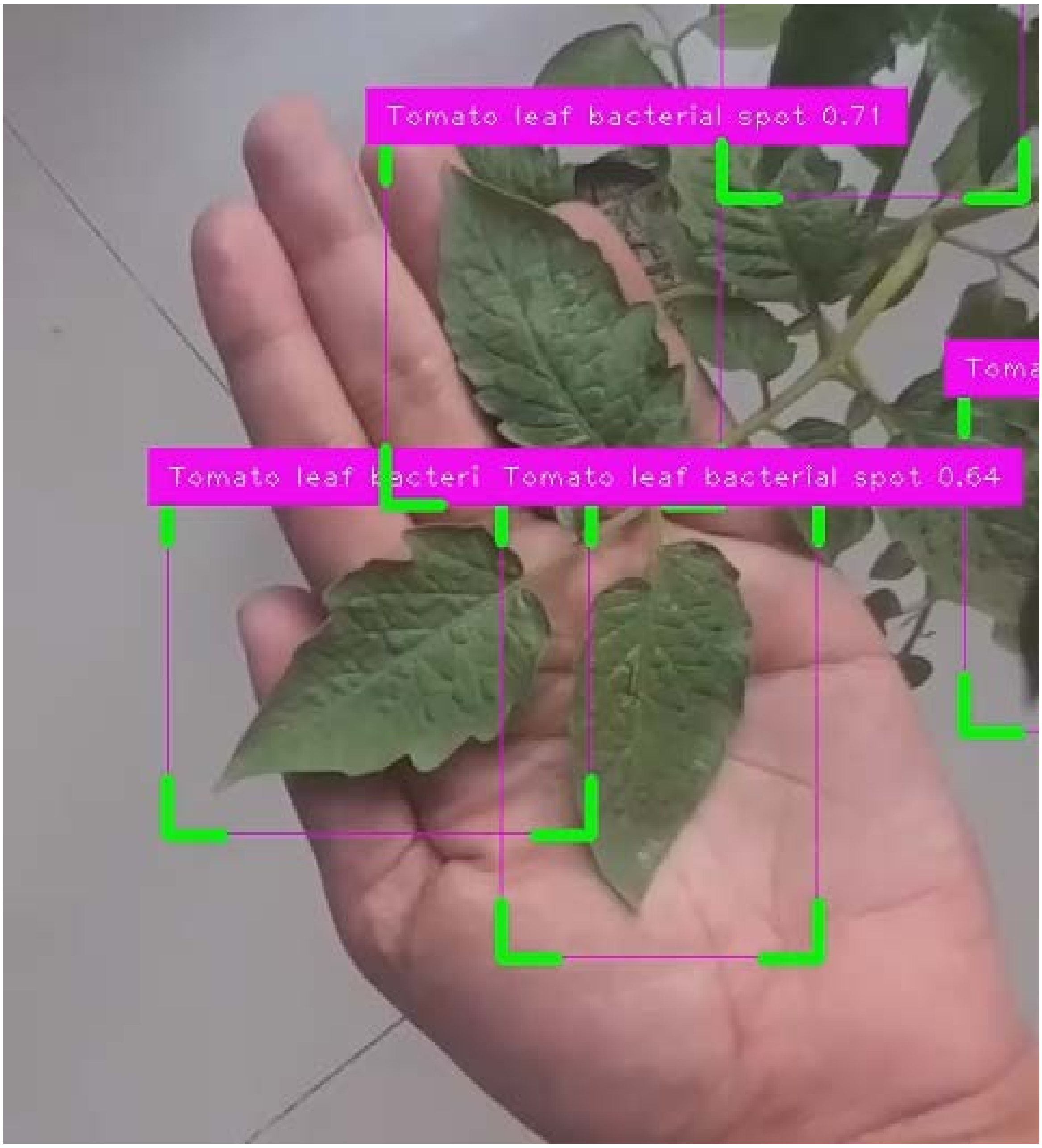


Figure 32: Collecting disease name and their designated confidence level from testing sample no.02.

Here we can see another sample from our tested images. We can also see that the algorithm is able to detect the same disease which is tomato leaf bacterial spot as we have seen in the previous sample. The proper confidence level is also attached to the allocated box. At the end, we scrutinized and summarized all the data and created a table with them. Below you will find the table containing the name of the disease detected and the confidence percentage.

Results of Environmental Monitoring:

TABLE 11: Environmental Data from the field.

No. of (Locations)	**Temperature (T=°C)**	**Humidity (%)**	**Darkness/ Light intensity (LUX)**	**Soil Moisture (%)**	**Soil Condition**	**External LED Light (ON/OFF)**	**External Submersible Water Pump or Motor-Pump (ON/OFF)**
1.	34	65	186K	88	Dry	Turned ON	Turned ON
2.	32	70	154K	54	Wet	Turned ON	TurnedOFF
3.	32	73	149K	57	Wet	Turned ON	Turned OFF
4.	30	69	71K	28	Wet	Turned OFF	Turned OFF
5.	29	80	64K	96	Dry	Turned OFF	Turned ON
6.	29	80	60K	57	Wet	Turned OFF	Turned OFF
7.	29	78	64K	61	Dry	Turned OFF	Turned ON
8.	29	77	63K	17	Wet	Turned OFF	Turned OFF
9.	29	76	66K	83	Dry	Turned OFF	Turned ON
10.	29	77	58K	65	Dry	Turned OFF	Turned ON
11.	29	76	61K	83	Dry	Turned OFF	Turned ON
12.	29	76	61K	82	Dry	Turned OFF	Turned ON
13.	29	77	64K	17	Wet	Turned OFF	Turned OFF
14.	29	79	67K	61	Dry	Turned OFF	Turned ON

We have collected some values from the display in a greenhouse. These values and data are very relative to our simulation data. As it is a prototype we tried to sort the standard data and represented them here. In the morning the temperature was so fine which is why we got the worthy data. We collected data from one location to another. In the greenhouse, there were three rows and one row had young tomato plants and another row had older tomato plants. We worked both on these. Also, we had to face some difficulties when the rain started. We measured the values on that atmosphere as well. The below figure (34,35) represents our field work.

Performance Evaluation of Environment Monitoring:

```
   THIS GREEN HOUSE
   T=28.00' D=58K LX
   S=102%   H=62.00%
Light:OFF   Motor:ON
```

Figure 33: Sensing the dryness of the soil and water motor getting on (1.Notification panel 2.Soil Moisture sensor. 3.Water Motor)

Here, we have used a resistive soil moisture sensor (FC28) which has two exposed probes inserted into the ground to get the data. Firstly, we have to maintain a watering moisture of below 60%. So, If the percentage of watering dryness of soil gets larger than 60%. That determines the plant is dry and it needs water. If we see figure 33, we will see the value of watering dryness is larger than 60% and that means the plant needs water. As a result, we will see the motor is on in the display and the water pump in the picture is on (Flowing water).

Figure 34: Sensing the dryness of the soil and water motor gets off (1.Notification panel 2.Soil Moisture sensor. 3.Water Motor)

Since we know, watering dryness should be below 60%. So, If we check the figure 34, we will see the value of Soil moisture is lower than 60% and that means the plant is wet enough. As a result, we will see the motor is off in the display and the water pump in the picture is getting turned off (Stop Flowing water).

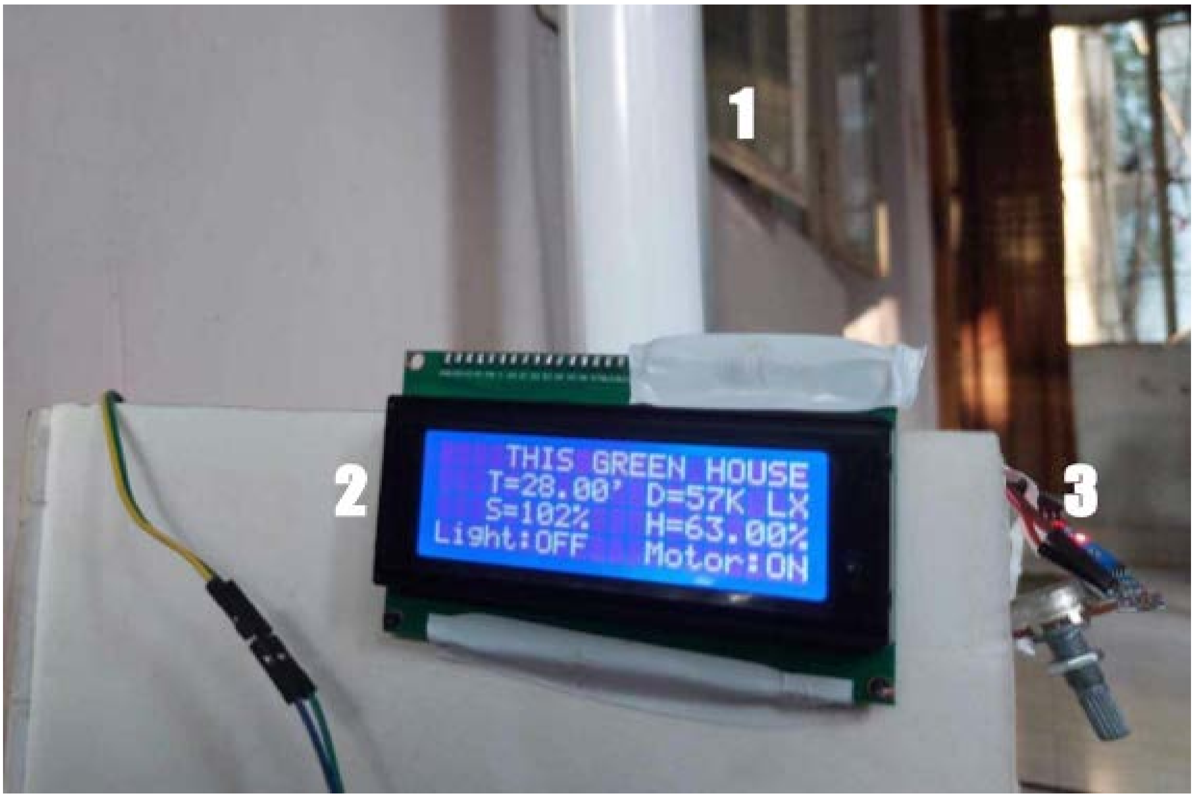


Figure 35 : Sensing the light intensity of the environment and External Light gets off (1.External Light .2.Notification panel 3.LDR sensor)

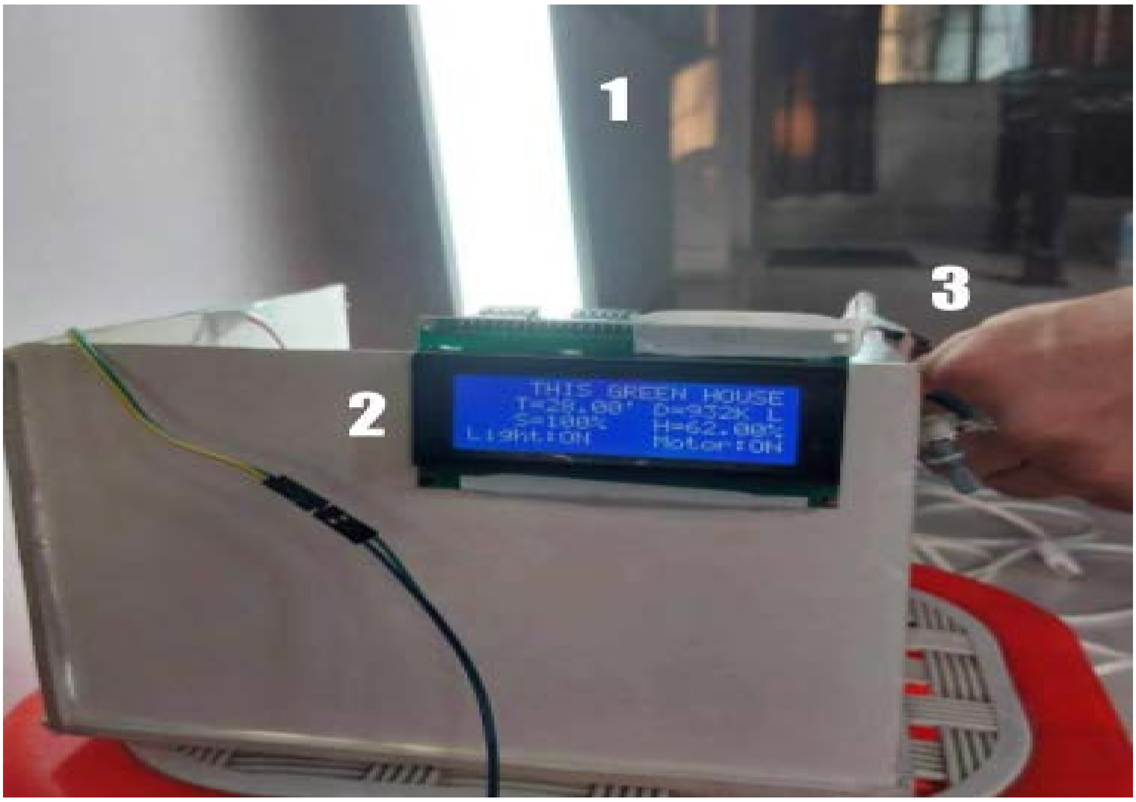


Figure 36 : Sensing the light intensity of the environment and External Light gets on (1.External Light 2.Notification panel 3.LDR sensor)

Here, By Sensing the darkness inside the greenhouse, if the sunlight is less means the darkness is bigger than larger than 100k LUX, External LED will be turned on. Then again, If the darkness in the chamber is lower than 100k LUX, then the chamber is sufficiently lightened up, so no external Light is required.
In figure 35 , the darkness is below the threshold value so, the external light is on and In figure 36 when the darkness is over the minimum value the external light will be turned off.

Solar tracking values:

TABLE 12: Results data of solar panel.

Time (h)	Voltage (V)	Current (A)	Power (W)
8 am	16.8	1.23	20.66
9 am	17	1.34	22.78
10 am	17.4	2.11	36.71
11 am	14.6	2.51	36.65
12 pm	19.4	2.64	51.23
1 pm	19.8	2.87	56.83
2 pm	16.2	2.28	37
3 pm	17.3	2.01	34.77
4 pm	12.5	1.20	15
5 pm	14.5	2.30	33.58

Here, the table shows the power variation of the solar panels according to time. As we will not be getting 100% efficiency from the panels, the energy results we got are satisfactory. We have measured the voltage and current by multi-meter and used the equation P=VI for power calculation. We have seen in the morning we can get enough power supply to run our overall system. But on that day, we had to face some difficulties during the rains. After 3 pm the rain started and we got less power. On the other hand, from 11 am to 1 pm we got maximum power which can be stored as well.

Total Completed Prototype of our final system:

Figure 37: Hardware prototype of the completed project
(1. Disease detection 2. Environmental monitoring 3. Solar system).

The solution presented for disease detection in greenhouse tomato cultivation through machine learning, along with the integration of a notification panel to monitor and control environmental parameters, demonstrates a comprehensive approach to optimizing tomato growth conditions. By maintaining temperature, humidity, soil moisture, and light intensity within specified ranges, the system aims to create an ideal atmosphere for maximum tomato production. The use of relays and an Arduino board to manage external LED lighting and irrigation effectively automates the process. Furthermore, the incorporation of off-grid energy generation through PV panels, with simulations confirming sufficient energy production, showcases a sustainable and eco-friendly approach. The provision for a grid connection as a backup ensures uninterrupted operation in unforeseen circumstances, adding a layer of reliability to the solution. Overall, this solution aligns well with the desired goals of optimizing tomato growth conditions while ensuring energy sustainability and reliability.

5.4 Conclusion

In conclusion, the integrated solution for disease detection in greenhouse tomato cultivation, coupled with an advanced environmental control system, represents a holistic approach to maximizing tomato production. Employing machine learning, it not only identifies and mitigates potential diseases but also maintains crucial environmental parameters such as temperature, humidity, soil moisture, and light intensity within optimal ranges. Automation via relays and an Arduino board enhances efficiency and precision in managing lighting and irrigation. What distinguishes this solution is its commitment to sustainability, exemplified by the integration of off-grid energy generation through photovoltaic panels and a reliable grid connection backup. This comprehensive approach effectively aligns with the overarching goals of optimizing tomato growth conditions while ensuring energy sustainability and operational reliability, all within an eco-friendly framework.

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

6.1 Introduction

We are developing a project that involves creating a greenhouse system with an integrated agricultural field. Above the greenhouse, solar panels will be installed to generate electricity, which can be used within the designated area and stored in batteries for emergencies. Our primary focus is on harnessing solar energy through photovoltaic cells while concurrently cultivating crops that thrive within the greenhouse environment, maximizing their utility. Through continuous monitoring, we will keep track of parameters such as greenhouse temperature, humidity, and soil moisture. This data will guide us in selecting and cultivating crops that are well-suited for optimal growth and yield. According to the FAO's 2022 Global Report on Food Crises, 193 million people in 53 countries witnessed food insecurity in 2021 and required immediate help [22]. Essentially, our project aims to efficiently utilize the available space by both capturing solar energy using solar panels and cultivating high-performing crops within the greenhouse enclosure. Our project might face some common problems but we can overcome them with the optimal solution.[16]

6.2 Assess the impact of solution

Social

The concept of agro-voltaic systems (AVS), which has gained popularity recently, can be used together to tackle the complications of producing food and electrical power [12]. The project's objective involves promoting plant growth through optimal warmth and moisture levels. It is recognized that for plants to thrive, a combination of moisture, heat, and light is indispensable. To achieve this, the strategy is to moderate the surrounding temperature and safeguard the plants against excessively cold weather conditions using a greenhouse structure.

By creating a controlled environment within the greenhouse, the project aims to ensure the stability of the growth conditions. This is particularly vital as fluctuating temperatures can negatively impact plant development. The greenhouse serves as a protective shield that prevents drastic temperature drops and extreme cold from affecting the plants.

An additional advantage of the project is its utilization of green energy sources. This approach has the potential to significantly reduce reliance on traditional power grids. As a consequence, there will be a noteworthy reduction in carbon emissions, which is a positive step towards environmental sustainability. The utilization of green energy aligns with the project's overarching goals, showcasing a commitment to eco-friendly practices. If even 1%

of farmland could be turned into an agrivoltaic system, the energy requirements of the globe would be covered by the sunlight's productivity. [11]

Importantly, the positive environmental impact achieved through reduced carbon emissions and sustainable energy practices has the potential to influence societal behavior. As people observe the tangible benefits of this system in terms of plant growth and reduced carbon footprint, there is a likelihood that they will be encouraged to adopt similar environmentally conscious approaches in their own lives. This ripple effect can lead to increased societal awareness about the importance of sustainable practices, fostering a broader culture of environmental responsibility.

Health

This environmentally conscious system generates minimal CO2 emissions, prioritizing our overall health and well-being. Furthermore, our initiative yields exceptionally nutritious and freshly harvested vegetables and fruits.

Environmental

Plants can feel protected in a greenhouse. It lessens the likelihood that pests and animals will be present that could harm or devour your plants. For higher standards of the harvest as well as generation, a regular checking arrangement for monitoring the status of nutrients in plants is required for enhancing productivity. [8] Extreme weather events like droughts and torrential rain are less common in this greenhouse climate. Also, we will supply the water and nutrition through a spraying system. So, it is a good way to reduce the wastage of fertilizers so that the environment can be youthful.Vegetables are cultivated in an agro-voltaic system on the same block of territory as solar panels that provide shading. [12]

In addition, in our optimal design, we will be using the top-mounted camera through a conveyor belt which has a timing belt and pulley section. This system is very effective at capturing pictures of the plant leaves. So, it would be easier to detect the disease properly.

Privacy

Other moral standards for our systems include protecting data privacy and confidentiality. The concept of "privacy" applies to the individual's ability to regulate how their personally identifiable information is utilized, shared, and preserved. Regulations and contractual obligations maintain privacy. On the other hand, privacy is protected by agreements that are governed by legislation. Lack of control over personal data and concerns regarding what data will be gathered from farms, how it will be used, and who it could be shared with are significant privacy concerns.

6.3 Evaluate the sustainability

Sustainability evaluation by SWOT analysis:

A SWOT analysis, which stands for evaluating Strengths, Weaknesses, Opportunities, and Threats, serves as a technique to comprehensively assess various aspects of a project. The main goal of conducting a SWOT analysis is to attain a deep understanding of all the factors associated with a project's implementation. This analysis functions as a valuable tool to examine the current status of a project and to formulate an effective roadmap for the future. By utilizing a SWOT analysis, we can identify recommendations and strategies that emphasize capitalizing on strengths and opportunities to address weaknesses and threats within our project.

TABLE 13: Sustainability analysis by SWOT analysis

Strengths ● Environment-friendly ● Plant growth monitoring ● Low maintenance cost ● Minimize CO2 ● Reduce dependency on electricity	**Weaknesses** ● Technical issues ● Power supply
Opportunities ● Smart photovoltaic greenhouse ● Plan for commercial project	**Threats** ● Natural disaster ● Safety hazards

Explanation:

Strengths

The system we're envisioning aims to be eco-conscious by adopting sustainable practices that minimize harm to the environment. This is achieved by reducing energy consumption, cutting down on carbon emissions, and promoting overall environmental health. It involves closely monitoring the growth of plants. This includes tracking parameters such as soil moisture levels, ambient temperature, humidity, and even plant growth rate by detecting diseases. Accurate monitoring provides valuable insights into the health and development of plants. The system is designed to be cost-effective in terms of maintenance. By utilizing smart and efficient technologies, it reduces the need for frequent maintenance interventions, ultimately saving both time and money. Also, this project incorporates strategies to minimize carbon dioxide (CO2) emissions. This could involve using renewable energy sources, employing energy-efficient components, and implementing intelligent algorithms that optimize energy usage. The system aims to reduce reliance on conventional electricity sources. This could be achieved by using alternative power sources like solar panels. Additionally, the system might incorporate energy storage solutions to ensure continuous operation even during periods of low energy generation.

Weaknesses

In our project, we have used many engineering tools such as Arduino, stepper motor, relay, sensors, LED light, camera, etc. That hardware equipment may be demolished and cause an interruption in this system. For example- if a motor driver breaks down then the camera can not take images from plants. Also, the discontinuation of the Arduino can not run the codes in Python. As we have mentioned before, we are trying to make a hybrid power system in our project. In remote areas the electricity is not available. So, this can be an obstacle to generating energy supply from the grid. Also, if we want to install solar panels, rain or shedding places may create interruptions so that the PV cells can not absorb the irradiance.

Opportunities

A Smart Photovoltaic Greenhouse combines traditional greenhouse farming with advanced technologies, such as photovoltaic solar panels, automation, and data analysis. This integration offers several opportunities across various domains. Incorporating photovoltaic panels into the greenhouse structure allows for the generation of clean and renewable energy. The panels can capture sunlight and convert it into electricity to power the greenhouse's operations, reducing reliance on external energy sources and decreasing operational costs. Smart systems can monitor and adjust environmental conditions to provide crops with ideal growing conditions. This precision cultivation can lead to higher yields and better-quality produce. Furthermore, we can elaborate a plan to implement our project in the commercial field. Our stakeholders will be the farmers who need to develop their agricultural sector to get more profit but invest less. This overall system will be more helpful for them than other systems which are already in the market.

Threats

Our project, despite its technological advancements, remains vulnerable to a range of natural disasters including extreme weather events like droughts, floods, and storms, as well as wildfire outbreaks, pest infestations, earthquakes, and soil degradation. These threats can damage crops, equipment, and infrastructure, disrupting operations and productivity. The side effects of absence are evaluated using multiple systems that utilize digital image processing, computer vision, and IOT significantly more rapidly than natural eyes could. While smart systems offer tools for monitoring and mitigation, such as early warning systems and data analytics, the inherent unpredictability of nature underscores the importance of disaster preparedness, resilient infrastructure, and adaptive farming practices to safeguard against these challenges. This system introduces safety hazards such as electrical risks from automation, potential collisions involving autonomous machinery, data privacy vulnerabilities, cyberattack threats, communication failures, ergonomic strains from extended digital interface interactions, over-dependence on automation, unintended consequences of AI decisions, weather-related dangers, and inadequate training Effective mitigation involves rigorous training, clear safety protocols, updated equipment maintenance, secure data handling, contingency planning, and a balanced approach that harnesses technology while prioritizing worker well-being and environmental integrity.

6.4 Conclusion

In summary, this project focuses on enhancing plant growth through controlled greenhouse conditions, driven by green energy sources. It not only ensures healthy plant development but also reduces carbon emissions, influencing wider adoption of eco-friendly practices. The initiative promotes health by yielding nutritious produce and safeguards the environment by mitigating extreme weather and minimizing waste. Privacy measures underscore its ethical stance. Overall, the project exemplifies a comprehensive and responsible approach to sustainable innovation with broad societal benefits. Also, our envisioned smart photovoltaic greenhouse demonstrates a commitment to environmental sustainability through reduced energy consumption and carbon emissions, while enabling precision cultivation and cost-effective operation. However, potential weaknesses lie in hardware reliability and hybrid power challenges. Seizing opportunities involves integrating advanced technologies for higher yields and commercial applications. Yet, threats including natural disasters and technological hazards underscore the need for robust disaster preparedness, safety protocols, and a balanced approach that marries innovation with resilience.

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

7.1 Introduction

The timely and cost-efficient execution of engineering projects depends heavily on effective engineering project management. Achieving certain engineering objectives, it entails coordinating and controlling resources. It takes technical, communication, and leadership abilities to oversee an engineering project from beginning to end, manage the project team, and keep all stakeholders updated as the project progresses. The importance of project management skills in engineering was emphasized and our Final Year Design Project (FYDP) was completed using these skills. Phases of the project included problem description, project planning, project management, and project implementation. To guarantee the project's timely and cost-effective completion, we used good project management techniques. Each member had a distinct assignment assigned to them based on their individual strengths since we were organized. Regular group meetings were organized to track progress, and regular contact was kept with our ATC panel to benefit from their insightful advice. This chapter gives a brief review of these phases and explains how effective project management techniques were used to complete the project on schedule and within the allocated budget and timetable.

7.2 Define, plan, and manage engineering projects

7.2.1 Defining project management

Determining a specific issue or demand and outlining a solution is the first step in defining an engineering project. We must take into consideration the project's goals, constraints, and resources while recommending a solution. The basis for effective project planning, management, and execution can be found in the definition of a project. A comprehensive project description aids in bringing stakeholders together, defining the project's scope, and establishing success factors. To manage an engineering project successfully, we need a thorough understanding of project management as well as some key competencies in stakeholder involvement, risk assessment, procurement, quality standards, continuous improvement, scheduling, pricing, and project scope. It is also necessary to have even a fundamental comprehension of technical engineering.

In our FYDP, we came to the realization that engineering project management requires strong project management capabilities in order to produce a project that will be successful and satisfy all pertinent requirements. To better manage our project, we gained a foundational grasp of engineering project management. From the start, our team demonstrated outstanding communication and an intense dedication to the task at hand. In order to maintain the project's standards, we made sure to employ high-quality materials and complete a risk assessment. We also keep expenditures in check so that our project is reasonable. We created a thorough plan during the FYDP's one-year period, and we remained patient for the entire project's duration. It started on 6th October 2022 and on 26th August 2023 it came to an end.

7.2.2 Project management in planning and proposal preparing phase

(FYDP-P): Flow diagram

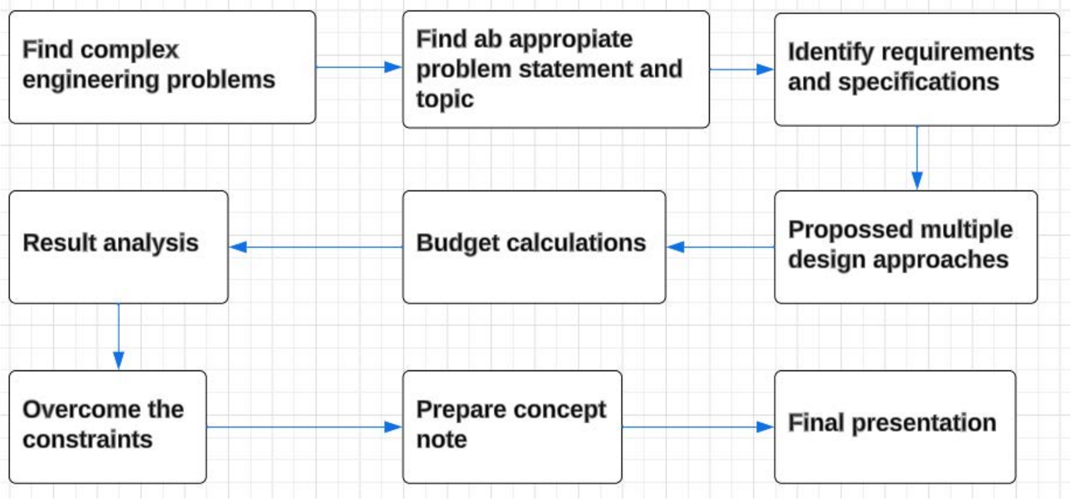


Figure 38: Workflow diagram of FYDP P

We conducted a brainstorming session to choose a challenging engineering issue in the field of agriculture that would be useful for observing plant growth utilizing technology as the foundation of our final year design project. With the aid of academic papers, we pinpointed the issue and performed a literature assessment to ascertain the requirements for the monitoring and detection system. Then, depending on our project, we presented three design alternatives and set project objectives. We then moved on to the design specification phase, where we produced a number of block diagrams and suggested alternatives while taking constraints into account. In addition, we determined the entire budget, evaluated sustainability, and made sure that pertinent standards and ethical issues were followed. Our ATC panel advised and guided us throughout the semester. Since the problem statements were difficult engineering problems, we adopted risk management strategies. We started our journey for the sophomore design project by looking for a challenging engineering issue that might be solved through creative and improvised engineering solutions. We looked at a variety of issues and available fixes while evaluating their drawbacks. Finally, we determine hybrid power sources for producing energy supply and develop a suitable problem statement. We then determined the project's requirements and specifications and suggested three different design trajectories, each with its own opportunities and difficulties. Finally, we determined the financial resources needed to implement each design strategy while also taking the risks, safety, and sustainability factors into account. Our FYDP trip was successfully completed as a consequence.

Gantt Chart for FYDP- P

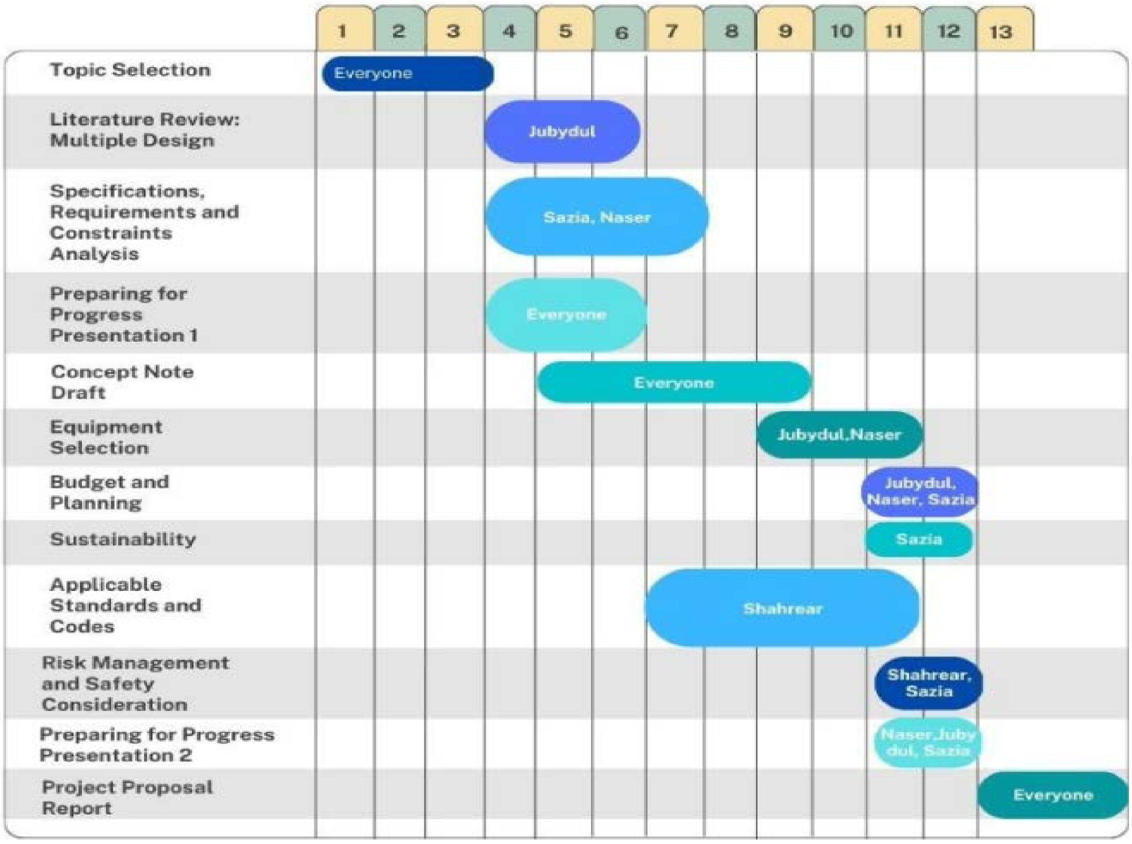


Figure 39: Project plan of FYDP- P

(FYDP- D) : Flow diagram

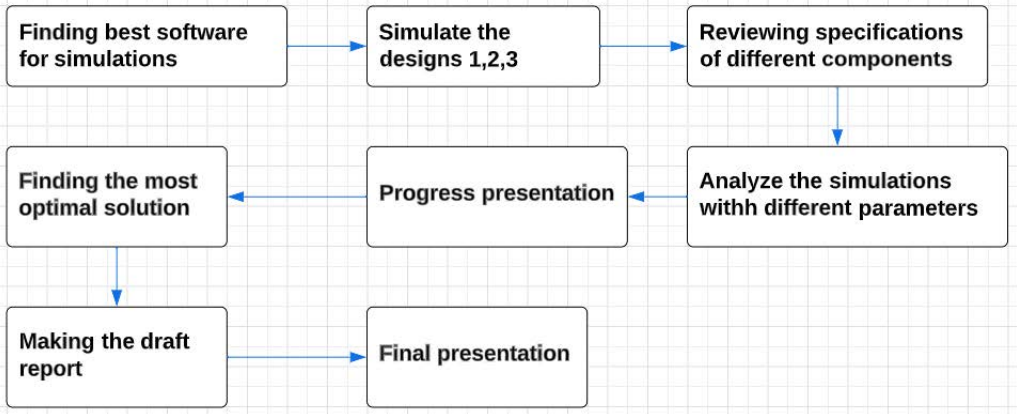


Figure 40: Workflow diagram of FYDP D

The FYDP-D phase is discussed in this text. The main problem we had during this phase was simulating each of the three design strategies using programs like MATLAB Simulink, Proteus, Google Colab, Pycharm, and PVSYST. The initial time we simulated all three concepts, we ran into some technological issues. Then, under the direction of our teachers, we made the necessary adjustments and re-simulated the systems in response to input from our ATC panel. Proteus has been used for both design approaches 1 and 2 and for monitoring the environment. On the other side, for the machine learning algorithm, we select Google Colab and PyCharm. Additionally, we measured the solar power, voltage, and irradiation using Matlab Simulink and PVSYST. Additionally, we utilized Solidworks to build the platform and timing belt for the third approach. During the investigation, we determined that Design Approach 3 was the optimal design. This design strategy includes an object detection system that uses a conveyor belt and a sensor-based monitoring system. Then, we worked to address each of the FYDP-D course outcomes, and we got ready to present to the ATC panel in both our practice presentation and our final presentation. In the end, we presented the ATC panel with our final simulation of our concept and our final report.

Gantt Chart for FYDP- D

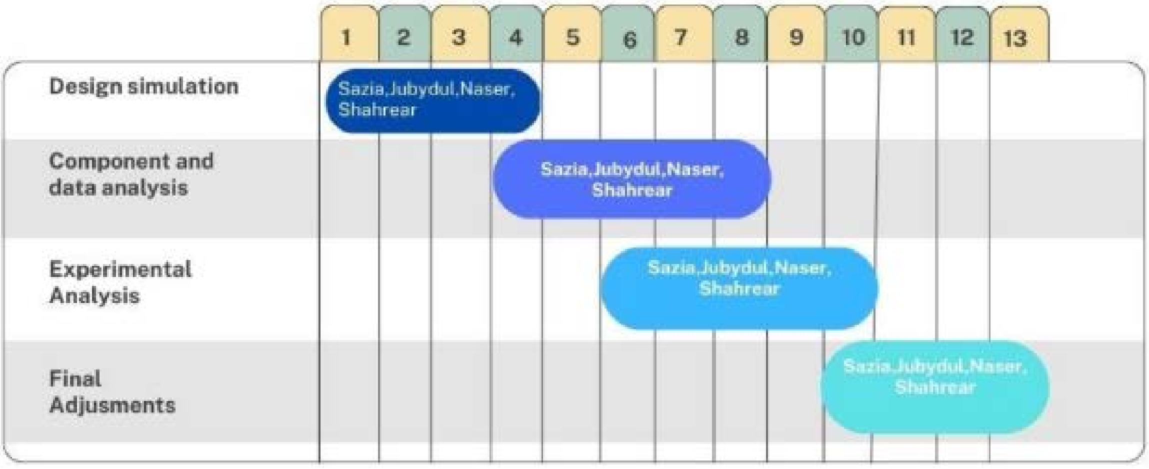


Figure 41: Project plan of FYDP-D

(FYDP- C) : Flow diagram

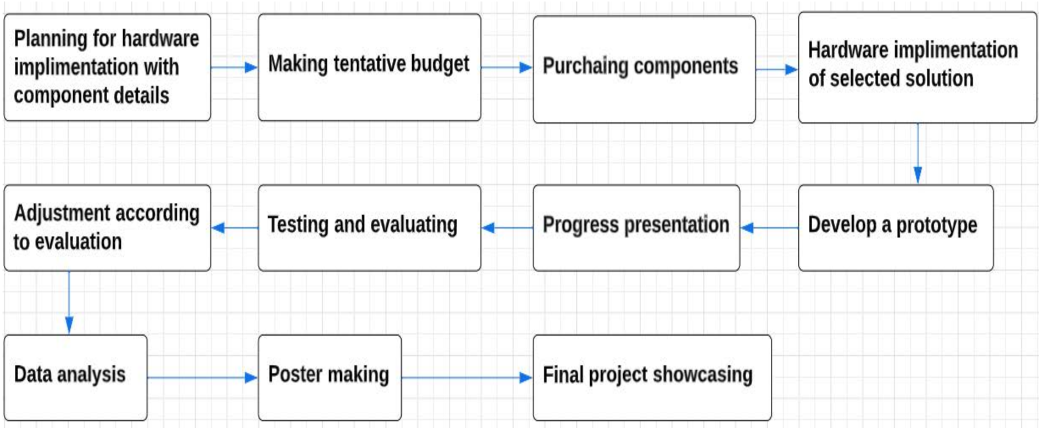


Figure 42: Workflow diagram of FYDP C

The last stage of our project is called FYDP-C. In this phase, the hardware implementation process has been finished. There are various steps to it. Making a budget and doing adequate preparation are the first steps in the process. After creating a component list, we forwarded it to the ATC panel for review. They gave us some insightful feedback. Before purchasing the components, we revised the list and sent it back to our ATC panel. They gave their okay, and we bought the parts we needed. We started using the chosen solution after purchasing the required parts. Then, we presented our development to our ATC panel for professional advice. They then provided us with some input regarding our development. We were able to expand the functionality of our prototype according to these comments. While developing our prototype, we encountered some challenges managing the 220v and AC current. That issue was resolved after a discussion with our ATC panel. Then, based on comments from our ATC panel, we tested and analyzed our prototype and made the necessary improvements. After that, we used the required tools to validate the final prototype. After doing a cost analysis, we produced a poster with the help of our ATC panel, followed by the submission of a preliminary project report. We then delivered our final presentation. These actions assisted us in establishing a consistent methodology for the hardware implementation process. This results in a project outcome that is successful.

Gantt Chart for FYDP- C

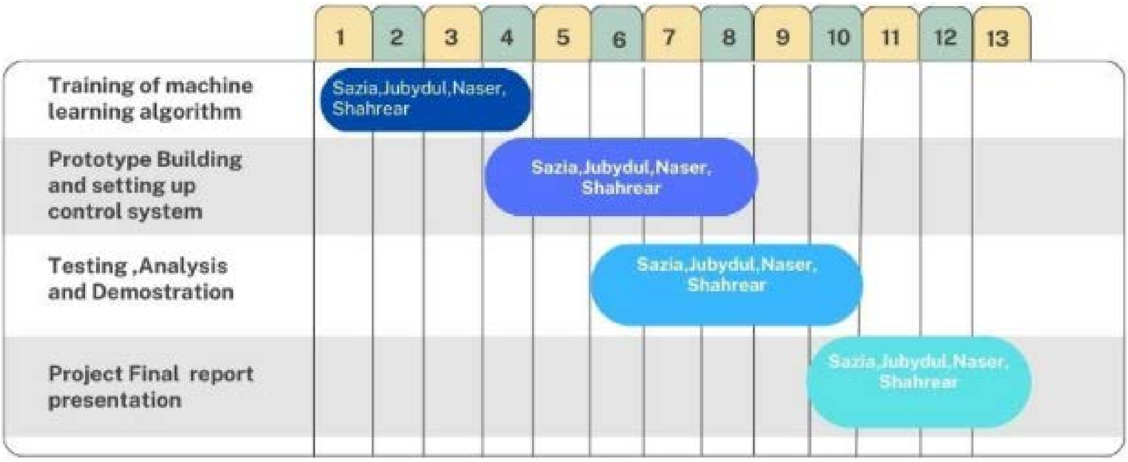


Figure 43: Project plan of FYDP-C.

7.3 Evaluate project progress

Our project's progress was driven by consistent communication through group discussions, attending meetings with the ATC panel, and adhering to a Gantt chart for each project phase. Through these steps, we tackled various issues and closely tracked each team member's advancement. Meetings with the ATC panel ensured they were informed about your progress, and their guidance was sought whenever challenges arose. They played a role in validating the project by evaluating your strategies. Maintaining efficient Gantt charts was a priority, with these charts being established before each project phase. The Final Year Design Project (FYDP) comprised three phases.

In the FYDP-D phase, we utilized software like MATLAB Simulink, PVSYST, Google Colab, PyCharm, and Proteus to simulate three design approaches. Our team faced and addressed challenges, adapting Design Approach 3 with input from our faculties. Ultimately, this approach was chosen, centered on a smart photovoltaic greenhouse, encompassing environmental monitoring and disease detection. Our criteria for selection included cost, sensors, image processing, efficiency, safety, and sustainability.

Moving into the FYDP-C phase, we successfully executed the hardware implementation. This encompassed planning, budgeting, generating a components list, prototype testing, and evaluation. This phase also involved submitting a preliminary project report and poster. The success of our project was a result of our cohesive working strategy and the valuable guidance provided by our ATC panel.

7.4 Conclusion

In conclusion, managing engineering projects is a critical step. To ensure the successful completion of a project, competent management abilities are required. We emphasized the need to employ effective project management techniques for the Final Year Design Project (FYDP). Problem definition, project planning, and project management are the three stages of the FYDP. The identification of a difficult engineering issue served as the impetus for the FYDP project. It was then followed by the suggestion of design strategies. Various pieces of software were used to emulate these design methodologies. The best design strategy was then chosen. We then created hardware to implement that. The ATC panel was our project's guide and gave us insightful suggestions. These recommendations and comments proved to be an essential aspect of the project's successful conclusion. Overall, we can state that for engineering projects, competent project management skills are essential, and a thorough strategy is required for project completion.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction:

For our FYDP, we have decided on a smart greenhouse system. To establish a project's long-term viability and sustainability, doing an economic study is crucial. Our endeavour is not an exceptional case. Assessing the costs and advantages of automation systems, identifying potential financial risks and rewards, and ensuring that resources are used effectively are all part of the economic study. Investors, policymakers, and project managers all heavily rely on the analysis when making decisions. Because it guarantees that a nation and its farmers get real advantages. We focus on the benefits, drawbacks, and potential risks of solar power systems, disease detection, and environmental analyses from an economic perspective. Making informed decisions would be made easier for stakeholders and project managers. In the final analysis, this procedure ensures effective resource allocation and increases the project's value for stakeholders.

8.2 Economic Analysis

TABLE 14: Budget for prototype system

System Number	Name of the Sub-sections	Name of the Components	Price (BDT)
1	Green House Chamber	Glass (tempered)	2100
		Truss (Aluminum) n)	1800
		Ventilator (Exhaust fan)	1200
		Total	**5100**
2	Environment Monitoring and Control System	DHT11 Sensor	150
		LDR Sensor	100
		Resistive soil moisture Sensor	150
		Arduino Uno	1000
		Capacitance 103	50
		LCD Display (20*4)	600
		Relay Module	170
		cables	170
		40W LED Light	600
		Submersible water pump	760
		Pipe and accessories	310
		Total	**4100**

3	Conveyor belt system	28BYJ-48 5V 4 Phase DC Gear Stepper Motor, ULN2003 Driver Board	200
		B10k potentiometer	30
		Arduino Nano V3.0	450
		Limit Switch	380
		GT2 Timing Pulley 16	250
		Timing belt	300
		SC8UU Linear Ball Bearing	1400
		Push button	20
		Total	**3030**
4	Image processing	Logitech C270 HD camera	2000
		Total	**2000**
5	PhotoVoltaic System	20W PV cell (2 piece)	2200
		Solar charge controller	650
		UPS battery 12V	700
		Total	**3550**

This table shows the pricing details of the components and overall system. Here, the total cost is (5100+4100+3030+2000+3550)=17780 Tk. However, we have used the greenhouse structure from Sher-e-Bangla Agricultural University. Also, we have used open source for image processing (python rsa,pycharm, google colab). So, our actual cost is (17780-5100)=12680 Tk.

TABLE 15: Budget for real system

System Number	**Name of the Sub-sections**	**Name of the Components**	**Price (BDT)**
1	Green House Chamber	Glass (tempered)	2100
		Truss (Aluminium)	1800
		Ventilator (Exhaust fan)	1200
		Total	**5100**
2	Environment Monitoring and Control System	DHT11 Sensor	150

		LDR Sensor	100
		Resistive soil moisture Sensor	150
		Arduino Uno	1000
		Capacitance 103	50
		LCD Display (20*4)	600
		Relay Module	170
		cables	170
		40W LED Light	600
		Submersible water pump	760
		Pipe and accessories	310
		Total	**4100**
3	Conveyor belt system	28BYJ-48 5V 4 Phase DC Gear Stepper Motor, ULN2003 Driver Board,	200
		B10k potentiometer	30
		Arduino Nano V3.0	450
		Limit Switch	380
		GT2 Timing Pulley 16 Tooth	250
		Timing belt	300
		SC8UU Linear Ball Bearing	1400
		Push button	20
		Total	**3030**
4	Image processing	Logitech C270 HD camera	2000
		Total	**2000**
5	PhotoVoltaic System	20W PV cell (2 piece)	1500
		Solar charge controller	650
		UPS battery 12V	700
		Total	**2850**

This table shows the cost of the real system which is 17080 Tk. It is not so expensive apart from our prototype cost. So, we can say that our project is budget-friendly.

TABLE 16: Manual Cost

System Number	Name of the Sub-sections	Name of the Components	Price (BDT)
1	Green House Chamber	Glass (tempered)	2100
		Truss (Aluminum)	1800
		Ventilator (Exhaust fan)	1200
		Set up accessories	1050
		Total	6150
2	Environment Monitoring and Control System	Pyrometers, thermocouples, and resistance thermometers (RTDs)	1700
		Marquis pressure boosting pump Set	6900
		Growth light	1600
		Pipe and other accessories	1000
		Total	**11200**
3	Disease Detection System	Agricultural expertise	1000
		Microscopy	1500
		Total	**2500**
4	Energy Source	Electricity bill	6000
		Total	**6000**

In the manual, we have seen that the total cost of a smart photovoltaic greenhouse is (6150+11200+2500+6000)=25850 Tk which is more than our project cost. So, we can say that our smart photovoltaic greenhouse is cost-effective.

8.3 Cost-Benefit Analysis

To conduct a cost-benefit analysis of our smart photovoltaic greenhouse project, we need to consider both the costs and the potential benefits it can bring.

Costs:

- Prototype - 12680 Tk
- Real system - 17080 Tk

- Manual - 25850 Tk

Benefits:

- Collect data on crop yield improvements, labor cost reductions, and energy savings over time.
- Determine how long it will take for the project's benefits to offset the initial costs. Divide the initial costs by the annual or monthly benefits.
- Consider potential risks such as system failures, maintenance costs, and market fluctuations that could affect the project's financial viability.
- Compare the costs and benefits of your smart photovoltaic greenhouse to alternative methods of greenhouse farming or other agricultural practices.
- Consider the environmental benefits of reduced energy consumption and sustainable agriculture practices. These benefits may not have direct monetary value but are important for long-term sustainability.

8.4 Evaluate Economic and Financial Aspects

To conduct a comprehensive cost-benefit analysis of your smart photovoltaic greenhouse project, consider both costs and benefits. Costs include prototype and real system expenses (12,680 Tk and 17,080 Tk, respectively), along with manual operation costs (25,850 Tk). Benefits encompass crop yield improvements, labor cost reductions, and energy savings, all of which should be quantified and assigned monetary values. Determine the payback period by dividing total initial costs by annual or monthly benefits, allowing you to estimate when the project will offset its costs. Assess risks, including system failures, maintenance expenses, and market fluctuations, and create mitigation plans. Compare your project to alternative farming methods, accounting for initial and ongoing costs. Additionally, recognize the environmental benefits, like reduced energy consumption and sustainability, and evaluate economic metrics like NPV, IRR, and ROI to assess financial viability.

8.5 Conclusion

In conclusion, the FYDP project project system's economic analysis demonstrates that it may be a workable and sustainable replacement for traditional detection, monitoring, and energy sources. The analysis shows the costs of manually setting up both prototype and real systems. The automation of a smart greenhouse system is said to provide advantages like less greenhouse gas emissions, monitoring the health of the plants and indoor environment, greater energy security, and cheaper operating expenses. But it also requires an upfront capital outlay. It also costs money to switch from a conventional energy source to a hybrid energy system. The system can be justified as a worthwhile investment if the advantages outweigh the disadvantages. Overall, the economic analysis of our project gives us important information that will help investors, decision-makers, and project managers work to maximize its potential.

Chapter 9: Ethics and Professional Responsibilities [CO13, CO2]

9.1 Introduction:

The importance of image processing, environmental monitoring, and solar energy has increased as we progress toward a more sustainable future [23]. However, conducting such initiatives needs not just knowledge of technology but also professional integrity and ethical concerns. In these circumstances, we'll discuss the ethical challenges and professional obligations that result from setting up an object detection setup in a field of plants. We'll talk about the requirement for stakeholder consent, safeguarding the privacy of personal data, and the significance of fairness in choosing the best design. We can help make sure that our project upholds moral standards and acts in accordance with ethical standards by looking at these topics.

9.2 Identify Ethical Issues and Professional Responsibility:

Our project required an open field and greenhouse where tomato plants are growing [23]. Because the image processing part detected the diseases through a camera from the plants. So, we have taken the permission from Sher-e-Bnagla Agricultural University (Horticulture department) and used their field and greenhouse structure. Moreover, we have to be concerned about the harm to the plants. When we run our hardware set up in the field, all of our group members have made sure that any plant does not get affected by our activities.

The next concern of our project is to get permission from the authority or the responsible person for collecting the soil sample. Also, our sensor-based environment monitoring part will be run into a greenhouse. Therefore, we have taken the consent from Sher-e-Bnagla Agricultural University and used their greenhouse shed.

Finally, in our project, we have tried to make the power system hybrid. Consequently, we have taken the authorization from Brac University to use their roof and install the solar system.

9.3 Apply Ethical Issues and Professional Responsibility

9.3.1 The research method used for designing

In order to ensure that our project's objective has not been compromised and to ensure that there are, consequently, no potential risks associated with the research strategy, we performed so by carefully examining the existing research and conforming to all appropriate IEEE standards and guidance.

9.3.2 Confidentiality

We understand the importance of maintaining the confidentiality of personal documents and data while designing our project, especially when dealing with our primary stakeholders, the farmers. We've taken steps to ensure that any information provided by our stakeholders will remain strictly confidential, and we will not share or grant access to their data under any circumstances. Additionally, we are committed to preserving the anonymity of all participants involved in our project.

9.3.3 Fairness in picking up the best design

We made every effort to select the design that would be ideal for the stakeholders we had in consideration. We had no intention of choosing a design that was simple to construct. Instead, we wanted to offer a design that would meet all pertinent sustainability standards. We achieved the greatest results for our stakeholders because it is our responsibility to provide the best for them. Therefore, we made every attempt to ensure that the best design would be implemented. For this, we agreed to a very specific decision.

9.3.4 Professional Responsibilities

As engineers, we have obligations to develop projects without risk. Furthermore, we must design a user-friendly system to ensure that individuals can use it safely. Additionally, we should make sure that we modify our system in accordance with customer feedback.

Risk identification and management:

risk management is a regular procedure that is established to identify risks to health and safety and assess the level of risk involved in project tasks [24].

Risks From Electrical Equipment:

The hazards arising from the use of electrical equipment are:

- **Electric shock:** Shock can be caused by the circuit and adapter or the AC-DC line.
- **Electric burn:** Burns can be caused by the motor we use for the rotation of the camera.
- **Interruption to essential services :** Interruption to essential safety equipment by disturbance of detection and monitoring.

Things To Do:

- Using proper insulation.
- Enough socket outlets to minimize the need for several adaptors or lengthy cords.
- Use a motor driver to protect the stepper motor from high voltage.

Risk From Sensors:

- Relatively slow response time to soil water changes.
- Excessive vibration can occur from the sensors.
- The water pump may overheat and cause heavy water flow due to any interruption.

Things To Do:

- Check the sensors over a week.
- Avoid oversizing the pump and limit pipework pressure loss.

Risk From Solar Panel:

- The panels can get hot (from the sun) with a (minor) risk of burns.
- There is a risk that the solar panel may break.

Things To Do:

We should use a proper frame to protect solar panels and we should maintain solar panels more often [25].

Risk matrix:

- Low = 1-5
- Moderate = 6-10
- High = 11-15
- Extreme = 16-20

TABLE 17: Risk management overview

Risk Identification	**Description**	**Likelihood**	**Consequences**	**Risk Factor**	**Contingency Plan**
Risk from electrical equipment	• Electric shock • Electric burn • Interruption to essential services	Unlikely Unlikely Likely	Major Major Minor	Moderate (6) Moderate (6) Low (4)	Self-awareness Use PPE and self-awareness Regular maintenance
Risk from sensors	• Low response to soil moisture sensor	Unlikely	Major	Moderate (6)	Change the sensors

	● Excessive vibration ● Pump overheat and heavy flow	Likely Unlikely	Minor Major	Low (3) Moderate (6)	Regular checking Limit pipe pressure
Risk from solar panel	● Over Heating ● Panel Breaks	Likely Likely	Minor Minor	Low (3) Low (2)	Regular maintenance Need to install a high-quality frame

9.4 Conclusion

In conclusion, the project involves moral considerations and professional obligations, including obtaining consent from all stakeholders, designing the system appropriately to ensure that the field area remains usable for other activities, advising stakeholders about risks and hazards, adhering to IEEE standards and guidelines for research methodology, maintaining the privacy of stakeholder information, and ensuring fairness when selecting the best design. These factors highlight the significance it is to carrying out projects in an ethical and responsible manner, putting stakeholders' welfare first.

Chapter 10: Conclusion and Future Work.

10.1 Project Summary/Conclusion:

Our project title is Design of a Smart Photovoltaic Greenhouse With Disease Detection and Environment Monitoring. To complete our project, first, we make a project plan and expected timeline. After that, we go through different publications regarding the same kind of topic. We gather their main ideas, simulations, and different software and applications. We set some objectives, functional and non-functional requirements, and specifications that we want to achieve through our project. According to that, we select three design approaches.

They are-

1. Manual data collection with auto processing
2. Ground Vehicle data collection with automatic sprinkler system
3. Top mounted Automation bar

After understanding those design approaches by gathering knowledge about those functional operations, we decided to Simulink. For simulation, we have used Matlab and Proteus. In Proteus, we have simulated our sensors and environmental system, and in Matlab, we have simulated the solar measures. Also, we have trained the process of image processing with the help of the data from Kaggle by Python rsa and Pycharm. We have also done some solar irradiation calculations on PVSYST. Our optimal solution is the design of a top-mounted automation bar. By this design, we can monitor the plants properly which can detect the diseases of the plants. Moreover, a submersible pump will be used for water supply. An approximate budget helps us to decide the optimal solution that we will implement in EEE400C and do some modifications in EEE400D.

Then, we acknowledged ethical, risk, social, cultural, legal, and safety concerns. We examine several complex engineering attributes to see if they meet standards for knowledge depth, analytical depth, issue familiarity, and other factors. We also examine the characteristics of complicated engineering tasks where we deal with a variety of resources, their effects on society and the environment, and our familiarity with them. Furthermore, we have implemented our overall system and are able to make a prototype. We have built up a sensor-based environment monitoring system that includes soil moisture, humidity, temperature, and LDR sensors.

After that, we have executed the disease detection part by image processing. Here, a camera will move in a double way by conveyor belt and collect images of the leaves. Also, a machine learning algorithm and dataset have been trained in pycharm and python rsa. Lastly, we have made a solar system for a hybrid power supply. To sum up, our project will be a great system in the agricultural sector and help to grow the plant without any affliction and in a suitable environment with an automated monitoring system in a greenhouse.

10.2 Future work

In the future, we can use high processing power to get more accuracy [26]. Here, we used a laptop to execute the image processing part and we got the accuracy about 79-81%. But from high GPO we can get the accuracy rate around 90-95%. Additionally, we can work on our project structure to make more stability so that we can utilize our prototype in a large field with various plants. The new IoT devices and nutrition the tester devices that collect data are utilized to feed patterns of leaf images through the Convolutional Neural Network (CNN) which system maintains and analyses data in the cloud, using CNN integrated with virtual machines to facilitate data input, processing, and sending of reports to the proper bodies.[7] Also, we may operate a ph sensor and NPK sensor to make the monitoring system more errorless.

Chapter 11: Identification of Complex Engineering Problems and Activities.

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

Attributes of Complex Engineering Problems (EP)

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

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

P1: Depth of knowledge required:

This proposal was conceived as a smart photovoltaic greenhouse with hybrid energy sources for the agricultural industry. We have a few goals for this project that we must achieve. We need to understand hybrid systems, object detection utilizing machine learning algorithms, and sensor-based environment monitoring in order to fulfill those. We also need to comprehend the ideal source-to-source managing method. Additionally, understanding the design we have chosen sustainability, cost, efficiency, and usability is needed.

P3: Depth of analysis required:

To learn more about practical design and control concepts, safety and security concerns, risk management, and health-related issues, we consult a variety of publications, journals, and simulation software. We approach our project with three possible designs based on that. Then we decide which control system is the most efficient. We chose the best option for our project after finishing optimization for several criteria, such as disease detection accuracy, hybrid system advantages, cost, and others. Once more, we chose an appropriate microcontroller and other relevant components for this project after extensive investigation and precise computations.

P4: Familiarity of issues:

Nowadays, increasing agricultural production in a greenhouse is a familiar issue. In our country, it takes a long time to detect the disease from the leaves and measure the parameters of moisture, temperature, humidity, etc. Also, in remote areas on grid power is mostly unavailable all the time in Bangladesh. In our project, we are dealing with hybrid sources finding out the tomato leaf diseases, and observing the internal environment of a greenhouse system.

P7: Interdependence:

Interdependence in a project refers to a relationship between member activities that can have an impact on one another's progress and significantly alter the overall project's progress. Our project's dependencies can be categorized as activities, technologies, processes, or resources. Our project's various components are all fairly dependent on one another.

11.3 Identify the attribute of complex engineering activities (EA)

Attributes of Complex Engineering Activities (EA)

	Attributes	**Put a 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 resources:

There are many sources of information on smart agro photovoltaic greenhouses. To gain a deeper understanding of the operation of some sensors for the environment and the workings of image processing in the context of disease detection, we consult various publications and documentaries. In order to comprehend the workings of automation approaches, we also read a few publications that use them.

A2: Level of interaction:

Our project can touch the interaction level. Because here the farmers have to be connected with different sectors of the maintenance process as well as fertilizer systems.

A4: Consequences for society and the environment:

We will bring abundant change in economic progress as well as bring equity in the farming community. The soil will be saved from excess pesticides and no harmful gas/element will be released. Also, solar cells will be another reason to be effective for the environment.

A5: Familiarity:

There are numerous farmers in Bangladesh who use or consult with expertise to develop their plant and crop production in a greenhouse manually. Here, we have tried to make an automation system in the agricultural field. It is common for developed countries but quite new and additional features are present in our country.

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Appendix

TABLE 1: The name of the detected disease and their confidence percentage.

1	Tomato leaf bacterial spot	70%
2	Tomato leaf bacterial spot	58%
3	Tomato leaf bacterial spot	60%
4	Tomato leaf bacterial spot	68%
5	Tomato leaf bacterial spot	65%
6	Tomato leaf bacterial spot	52%
7	Tomato leaf bacterial spot	30%
8	Tomato leaf bacterial spot	42%
9	Tomato leaf bacterial spot	87%
10	Tomato leaf bacterial spot	69%
11	Tomato leaf bacterial spot	54%
12	Tomato leaf bacterial spot	37%
13	Tomato leaf bacterial spot	74%
14	Tomato leaf bacterial spot	33%
15	Tomato leaf bacterial spot	75%
16	Tomato leaf bacterial spot	33%
17	Tomato leaf bacterial spot	70%
18	Tomato leaf bacterial spot	61%
19	Tomato mold leaf	53%
20	Tomato leaf bacterial spot	63%
21	Tomato leaf bacterial spot	39%
22	Tomato leaf bacterial spot	84%
23	Tomato leaf bacterial spot	54%
24	Tomato leaf bacterial spot	37%
25	Tomato leaf bacterial spot	74%
26	Tomato leaf bacterial spot	33%
27	Tomato leaf bacterial spot	33%
28	Tomato leaf bacterial spot	75%
29	Tomato leaf bacterial spot	70%
30	Tomato leaf bacterial spot	61%
31	Tomato leaf bacterial spot	63%
32	Tomato leaf bacterial spot	50%
33	Tomato leaf bacterial spot	54%
34	Tomato leaf bacterial spot	37%
35	Tomato leaf bacterial spot	54%
36	Tomato leaf late blight	39%
37	Tomato leaf late blight	84%
38	Tomato leaf late blight	57%
39	Tomato leaf late blight	72%
40	Tomato leaf bacterial spot	72%

41	Tomato leaf bacterial spot	70%
42	Tomato leaf bacterial spot	48%
43	Tomato leaf bacterial spot	49%
44	Tomato leaf bacterial spot	84%
45	Tomato leaf bacterial spot	40%
46	Tomato leaf bacterial spot	29%
47	Tomato leaf bacterial spot	26%
48	Tomato leaf bacterial spot	65%
49	Tomato leaf bacterial spot	39%
50	Tomato leaf bacterial spot	69%
51	Tomato leaf bacterial spot	51%
52	Tomato leaf bacterial spot	73%
53	Tomato leaf bacterial spot	66%
54	Tomato leaf bacterial spot	68%
55	Tomato leaf bacterial spot	50%
56	Tomato leaf bacterial spot	77%
57	Tomato leaf bacterial spot	43%
58	Tomato leaf bacterial spot	86%
59	Tomato leaf bacterial spot	48%
60	Tomato leaf bacterial spot	66%

61	Tomato leaf bacterial spot	69%
62	Tomato leaf bacterial spot	59%
63	Tomato leaf bacterial spot	54%
64	Tomato leaf bacterial spot	53%
65	Tomato leaf bacterial spot	63%
66	Tomato leaf bacterial spot	48%
67	Tomato leaf bacterial spot	50%
68	Tomato leaf bacterial spot	28%
69	Tomato leaf bacterial spot	52%
70	Tomato leaf bacterial spot	30%
71	Tomato leaf bacterial spot	51%
72	Tomato leaf bacterial spot	28%
73	Tomato leaf bacterial spot	63%
74	Tomato leaf bacterial spot	36%
75	Tomato leaf bacterial spot	40%
76	Tomato leaf bacterial spot	80%
77	Tomato leaf bacterial spot	65%
78	Tomato leaf bacterial spot	55%
79	Tomato leaf bacterial spot	67%
80	Tomato leaf bacterial spot	68%

81	Tomato leaf bacterial spot	32%
82	Tomato leaf bacterial spot	27%
83	Tomato leaf bacterial spot	53%
84	Tomato leaf bacterial spot	41%
85	Tomato leaf bacterial spot	46%
86	Tomato leaf bacterial spot	58%
87	Tomato leaf bacterial spot	53%
88	Tomato leaf bacterial spot	65%
89	Tomato leaf bacterial spot	59%
90	Tomato leaf bacterial spot	52%
91	Tomato leaf bacterial spot	53%
92	Tomato leaf bacterial spot	59%
93	Tomato leaf bacterial spot	56%
94	Tomato leaf bacterial spot	52%
95	Tomato leaf bacterial spot	26%
96	Tomato leaf bacterial spot	73%
97	Tomato leaf bacterial spot	78%
98	Tomato leaf bacterial spot	80%
99	Tomato leaf bacterial spot	84%
100	Tomato leaf bacterial spot	94%

101	Tomato leaf bacterial spot	58%
102	Tomato leaf bacterial spot	67%
103	Tomato leaf bacterial spot	68%
104	Tomato leaf bacterial spot	39%
105	Tomato leaf bacterial spot	70%
106	Tomato leaf bacterial spot	61%
107	Tomato leaf bacterial spot	45%
108	Tomato leaf bacterial spot	77%
109	Tomato leaf bacterial spot	68%
110	Tomato leaf bacterial spot	53%
111	Tomato leaf bacterial spot	74%
112	Tomato leaf bacterial spot	57%
113	Tomato leaf bacterial spot	74%
114	Tomato leaf bacterial spot	61%
115	Tomato leaf bacterial spot	62%
116	Tomato leaf bacterial spot	47%
117	Tomato leaf bacterial spot	74%
118	Tomato leaf bacterial spot	36%
119	Tomato leaf bacterial spot	70%
120	Tomato leaf bacterial spot	75%

121	Tomato leaf bacterial spot	51%
122	Tomato leaf bacterial spot	77%
123	Tomato leaf bacterial spot	56%
124	Tomato leaf bacterial spot	37%
125	Tomato leaf bacterial spot	46%
126	Tomato leaf bacterial spot	54%
127	Tomato leaf bacterial spot	55%
128	Tomato leaf bacterial spot	52%
129	Tomato leaf bacterial spot	75%
130	Tomato leaf bacterial spot	78%
131	Tomato leaf bacterial spot	79%
132	Tomato leaf bacterial spot	78%
133	Tomato leaf bacterial spot	74%
134	Tomato leaf bacterial spot	75%
135	Tomato leaf bacterial spot	76%
136	Tomato leaf bacterial spot	71%
137	Tomato leaf bacterial spot	75%
138	Tomato leaf bacterial spot	74%
139	Tomato leaf bacterial spot	73%
140	Tomato leaf bacterial spot	70%

141	Tomato leaf bacterial spot	63%
142	Tomato leaf bacterial spot	69%
143	Tomato leaf bacterial spot	59%
144	Tomato leaf bacterial spot	58%
145	Tomato leaf bacterial spot	36%
146	Tomato leaf bacterial spot	36%
147	Tomato leaf bacterial spot	54%
148	Tomato leaf bacterial spot	78%
149	Tomato leaf bacterial spot	59%
150	Tomato leaf bacterial spot	77%
151	Tomato leaf bacterial spot	37%
152	Tomato leaf bacterial spot	40%
153	Tomato leaf bacterial spot	28%
154	Tomato leaf bacterial spot	54%
155	Tomato leaf bacterial spot	61%
156	Tomato leaf bacterial spot	39%
157	Tomato leaf bacterial spot	48%
158	Tomato leaf bacterial spot	70%
159	Tomato leaf bacterial spot	74%
160	Tomato leaf bacterial spot	73%

161	Tomato leaf bacterial spot	31%
162	Tomato leaf bacterial spot	73%
163	Tomato leaf bacterial spot	36%
164	Tomato leaf bacterial spot	74%
165	Tomato leaf bacterial spot	65%
166	Tomato leaf bacterial spot	26%
167	Tomato leaf bacterial spot	34%
168	Tomato leaf bacterial spot	40%
169	Tomato leaf bacterial spot	43%
170	Tomato leaf bacterial spot	55%
171	Tomato leaf bacterial spot	66%
172	Tomato leaf bacterial spot	58%
173	Tomato leaf bacterial spot	78%
174	Tomato leaf bacterial spot	65%
175	Tomato leaf bacterial spot	56%
176	Tomato leaf bacterial spot	69%
177	Tomato leaf bacterial spot	69%
178	Tomato leaf bacterial spot	87%
179	Tomato leaf bacterial spot	66%
180	Tomato leaf bacterial spot	88%

181	Tomato leaf bacterial spot	78%
182	Tomato leaf bacterial spot	58%
183	Tomato leaf bacterial spot	96%
184	Tomato leaf bacterial spot	68%
185	Tomato leaf bacterial spot	84%
186	Tomato leaf bacterial spot	70%
187	Tomato leaf bacterial spot	75%
188	Tomato mold leaf	84%
189	Tomato leaf bacterial spot	63%
190	Tomato leaf bacterial spot	25%
191	Tomato leaf bacterial spot	36%
192	Tomato leaf bacterial spot	45%
193	Tomato leaf bacterial spot	65%
194	Tomato leaf bacterial spot	85%
195	Tomato leaf bacterial spot	90%
196	Tomato leaf bacterial spot	87%
197	Tomato mold leaf	55%
198	Tomato leaf bacterial spot	96%
199	Tomato leaf bacterial spot	38%
200	Tomato leaf bacterial spot	53%

201	Tomato leaf bacterial spot	39%
202	Tomato leaf bacterial spot	26%
203	Tomato leaf bacterial spot	59%
204	Tomato leaf bacterial spot	60%
205	Tomato leaf bacterial spot	85%
206	Tomato leaf bacterial spot	74%
207	Tomato leaf bacterial spot	36%
208	Tomato leaf bacterial spot	58%
209	Tomato leaf bacterial spot	68%
210	Tomato leaf bacterial spot	76%
211	Tomato leaf bacterial spot	69%
212	Tomato leaf bacterial spot	70%
213	Tomato leaf bacterial spot	70%
214	Tomato mold leaf	70%
215	Tomato leaf bacterial spot	59%
216	Tomato leaf bacterial spot	63%
217	Tomato leaf bacterial spot	68%
218	Tomato leaf bacterial spot	48%
219	Tomato mold leaf	77%
220	Tomato leaf bacterial spot	74%

221	Tomato leaf bacterial spot	47%
222	Tomato leaf bacterial spot	42%
223	Tomato leaf bacterial spot	50%
224	Tomato leaf bacterial spot	56%
225	Tomato leaf bacterial spot	68%
226	Tomato leaf bacterial spot	85%
227	Tomato mold leaf	87%
228	Tomato leaf bacterial spot	56%
229	Tomato leaf bacterial spot	53%
230	Tomato leaf bacterial spot	48%
231	Tomato leaf bacterial spot	47%
232	Tomato leaf bacterial spot	85%
233	Tomato leaf bacterial spot	82%
234	Tomato leaf bacterial spot	83%
235	Tomato leaf bacterial spot	65%
236	Tomato leaf bacterial spot	71%
237	Tomato leaf bacterial spot	44%
238	Tomato leaf bacterial spot	51%

Related code/theory

”””” CODE FOR Conveyor belt system””””

```
#include <Stepper.h>
const int stepsPerRevolution = 64;
Stepper myStepper(stepsPerRevolution, 8, 10, 9, 11);

#define potent_pin 0
int speed;
int direction;
int pinButton = 2;
int power1 = 3;
int power2 = 4;
int power3 = 5;
int power4 = 6;
int GND = 7;

void setup() {
 pinMode(pinButton, INPUT);
 pinMode(power1, OUTPUT);
 pinMode(power2, OUTPUT);
 pinMode(power3, OUTPUT);
 pinMode(power4, OUTPUT);
 pinMode(GND, OUTPUT);
 digitalWrite(power1, HIGH);
 digitalWrite(power2, HIGH);
 digitalWrite(power3, HIGH);
```

```
  digitalWrite(power4, HIGH);
  digitalWrite(GND, LOW);
}

bool flag       = LOW;
bool lastButton = LOW;

bool debounce() {
  bool current = digitalRead(pinButton);
  if (current != lastButton) {
    delay(10);
    current = digitalRead(pinButton);
  }
  return current;
}

void loop() {
  int currentButton = debounce();
  if (lastButton == LOW && currentButton == HIGH)
  {
    flag = !flag;
  }
  lastButton = currentButton;
  if (flag == LOW)
      direction = 1;
  if (flag == HIGH)
      direction = -1;

  speed = analogRead(potent_pin);
```

```
  speed = map(speed, 0, 1023, 1, 400);
  speed = constrain(speed, 1, 400);

  myStepper.setSpeed(speed);

  myStepper.step(direction);
}
```

”””” CODE FOR GREENHOUSE ENVIRONMENT SYSTEM ””””

```
// include the library code:
#include <LiquidCrystal.h>
#include <dht.h>
dht DHT;
#define DHT11_PIN A3
//LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
  LiquidCrystal lcd(13, 12, 11, 10,  9,  8);
const int L_Pin = 6;
const int M_Pin = 7;
const int lm35_pin = A0;  /* LM35 O/P pin */
void setup()
{
  lcd.begin(20, 4); // set up the LCD's number of columns and rows:
  lcd.setCursor(0,0); // set the cursor position:
  lcd.print("    THIS GREEN HOUSE");
  pinMode(L_Pin,OUTPUT);
  pinMode(M_Pin,OUTPUT);
}
```

```
void loop()
{
 //Temperature Sensing

  int chk = DHT.read11(DHT11_PIN);
  Serial.print("Temperature = ");
  Serial.println(DHT.temperature);
  Serial.print("Humidity = ");
  Serial.println(DHT.humidity);
  lcd.setCursor(0,1);
  lcd.print("   T=");
  lcd.print(DHT.temperature);
  lcd.print("'C     ");

  //Light Intensity
 // Read Light Intensity
  int LI=analogRead(A1);
  lcd.setCursor(11,1);
  lcd.print(" D=");
  lcd.print(LI);
  lcd.print("K LX       ");

  //Soil Moisture
  int S3=analogRead(A2);  // Read Soil Moisture
  int SM=S3/10;
  lcd.setCursor(0,2);
  lcd.print("   S=");
  lcd.print(SM);
  lcd.print("%      ");
```

```
//Air Humidity
lcd.setCursor(11,2);
lcd.print(" H=");
lcd.print(DHT.humidity);
lcd.print("%   ");

if(LI<100)
{
  digitalWrite(L_Pin,HIGH);
  lcd.setCursor(0,3);
  lcd.print("Light:OFF   ");
}
else
{
  digitalWrite(L_Pin,LOW);
  lcd.setCursor(0,3);
  lcd.print("Light:ON   ");
}

if(SM<60)
{
  digitalWrite(M_Pin,HIGH);
  lcd.setCursor(10,3);
  lcd.print(" Motor:OFF    ");
}
else
{
  digitalWrite(M_Pin,LOW);
```

```
    lcd.setCursor(10,3);
    lcd.print("  Motor:ON    ");
  }
delay(1000);
}
```

Custom Data training with YOLO V8:

```
!yolo task=detect mode=train model=yolov8l.pt data=../content/drive/MyDrive/Datasets/tomato/data.yaml epochs=50 imgsz=640
```

```
Downloading https://github.com/ultralytics/assets/releases/download/v0.0.0/yolov8l.pt to yolov8l.pt...

100% 83.7M/83.7M [00:05<00:00, 16.0MB/s]

Ultralytics YOLOv8.0.67 🚀 Python-3.9.16 torch-2.0.0+cu118 CUDA:0 (Tesla T4, 15102MiB)

yolo/engine/trainer: task=detect, mode=train, model=yolov8l.pt, data=../content/drive/MyDrive/Datasets/tomato/data.yaml, epochs=50, patience=50, batch=16, imgsz=640, save=True, save_period=-1, cache=False, device=None, workers=8, project=None, name=None, exist_ok=False, pretrained=False, optimizer=SGD, verbose=True, seed=0, deterministic=True, single_cls=False, image_weights=False, rect=False, cos_lr=False, close_mosaic=10, resume=False, amp=True, overlap_mask=True, mask_ratio=4, dropout=0.0, val=True, split=val, save_json=False, save_hybrid=False, conf=None, iou=0.7, max_det=300, half=False, dnn=False, plots=True, source=None, show=False, save_txt=False, save_conf=False, save_crop=False, show_labels=True, show_conf=True, vid_stride=1, line_thickness=3, visualize=False, augment=False, agnostic_nms=False, classes=None, retina_masks=False, boxes=True, format=torchscript, keras=False, optimize=False, int8=False, dynamic=False, simplify=False, opset=None, workspace=4, nms=False, lr0=0.01, lrf=0.01, momentum=0.937, weight_decay=0.0005, warmup_epochs=3.0, warmup_momentum=0.8, warmup_bias_lr=0.1, box=7.5, cls=0.5, dfl=1.5, pose=12.0, kobj=1.0, fl_gamma=0.0, label_smoothing=0.0, nbs=64, hsv_h=0.015, hsv_s=0.7, hsv_v=0.4, degrees=0.0, translate=0.1, scale=0.5, shear=0.0, perspective=0.0, flipud=0.0, fliplr=0.5, mosaic=1.0, mixup=0.0, copy_paste=0.0, cfg=None, v5loader=False, tracker=botsort.yaml, save_dir=runs/detect/train

Downloading https://ultralytics.com/assets/Arial.ttf to /root/.config/Ultralytics/Arial.ttf...

100% 755k/755k [00:00<00:00, 129MB/s]

2023-04-06 20:41:52.970935: I tensorflow/core/platform/cpu_feature_guard.cc:182] This TensorFlow binary is optimized to use available CPU instructions in performance-critical operations.

To enable the following instructions: AVX2 FMA, in other operations, rebuild TensorFlow with the appropriate compiler flags.

2023-04-06 20:41:53.982237: W tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Could not find TensorRT

Overriding model.yaml nc=80 with nc=8


                   from  n    params  module                                       arguments

  0                  -1  1      1856  ultralytics.nn.modules.Conv                  [3, 64, 3, 2]

  1                  -1  1     73984  ultralytics.nn.modules.Conv                  [64, 128, 3, 2]

  2                  -1  3    279808  ultralytics.nn.modules.C2f                   [128, 128, 3, True]

  3                  -1  1    295424  ultralytics.nn.modules.Conv                  [128, 256, 3, 2]

  4                  -1  6   2101248  ultralytics.nn.modules.C2f                   [256, 256, 6, True]

  5                  -1  1   1180672  ultralytics.nn.modules.Conv                  [256, 512, 3, 2]

  6                  -1  6   8396800  ultralytics.nn.modules.C2f                   [512, 512, 6, True]
```

```
 7                -1  1   2360320  ultralytics.nn.modules.Conv                [512, 512, 3, 2]
 8                -1  3   4461568  ultralytics.nn.modules.C2f                 [512, 512, 3, True]
 9                -1  1    656896  ultralytics.nn.modules.SPPF                [512, 512, 5]
10                -1  1         0  torch.nn.modules.upsampling.Upsample       [None, 2, 'nearest']
11           [-1, 6]  1         0  ultralytics.nn.modules.Concat              [1]
12                -1  3   4723712  ultralytics.nn.modules.C2f                 [1024, 512, 3]
13                -1  1         0  torch.nn.modules.upsampling.Upsample       [None, 2, 'nearest']
14           [-1, 4]  1         0  ultralytics.nn.modules.Concat              [1]
15                -1  3   1247744  ultralytics.nn.modules.C2f                 [768, 256, 3]
16                -1  1    590336  ultralytics.nn.modules.Conv                [256, 256, 3, 2]
17          [-1, 12]  1         0  ultralytics.nn.modules.Concat              [1]
18                -1  3   4592640  ultralytics.nn.modules.C2f                 [768, 512, 3]
19                -1  1   2360320  ultralytics.nn.modules.Conv                [512, 512, 3, 2]
20           [-1, 9]  1         0  ultralytics.nn.modules.Concat              [1]
21                -1  3   4723712  ultralytics.nn.modules.C2f                 [1024, 512, 3]
22      [15, 18, 21]  1   5588968  ultralytics.nn.modules.Detect              [8, [256, 512, 512]]
Model summary: 365 layers, 43636008 parameters, 43635992 gradients, 165.4 GFLOPs


Transferred 589/595 items from pretrained weights
TensorBoard: Start with 'tensorboard --logdir runs/detect/train', view at http://localhost:6006/
AMP: running Automatic Mixed Precision (AMP) checks with YOLOv8n...
Downloading https://github.com/ultralytics/assets/releases/download/v0.0.0/yolov8n.pt to yolov8n.pt...
100% 6.23M/6.23M [00:00<00:00, 266MB/s]
AMP: checks passed ✅
optimizer: SGD(lr=0.01) with parameter groups 97 weight(decay=0.0), 104 weight(decay=0.0005), 103 bias
train: Scanning /content/drive/MyDrive/Datasets/tomato/train/labels... 1536 images, 0 backgrounds, 8 corrupt: 100% 1536/1536 [14:44<00:00,  1.74it/s]
train: New cache created: /content/drive/MyDrive/Datasets/tomato/train/labels.cache
albumentations: Blur(p=0.01, blur_limit=(3, 7)), MedianBlur(p=0.01, blur_limit=(3, 7)), ToGray(p=0.01), CLAHE(p=0.01, clip_limit=(1, 4.0), tile_grid_size=(8, 8))
val: Scanning /content/drive/MyDrive/Datasets/tomato/valid/labels... 158 images, 0 backgrounds, 8 corrupt: 100% 158/158 [01:32<00:00,  1.71it/s]
val: New cache created: /content/drive/MyDrive/Datasets/tomato/valid/labels.cache
Plotting labels to runs/detect/train/labels.jpg...
Image sizes 640 train, 640 val
Using 2 dataloader workers
Logging results to runs/detect/train
Starting training for 50 epochs...
```

```
Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
 1/50      10.6G      1.754      3.264       2.04         94        640: 100% 96/96 [01:28<00:00,  1.08it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:06<00:00,  1.31s/it]
           all        158        619      0.152      0.295      0.131     0.0537

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
 2/50      10.7G      1.503      2.387      1.723        122        640: 100% 96/96 [01:26<00:00,  1.11it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.15it/s]
           all        158        619      0.188      0.381      0.202      0.075

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
 3/50      10.8G      1.522      2.185      1.697        105        640: 100% 96/96 [01:25<00:00,  1.13it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.13it/s]
           all        158        619      0.309      0.365      0.234      0.104

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
 4/50      10.7G      1.548       2.04        1.7        102        640: 100% 96/96 [01:24<00:00,  1.13it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:05<00:00,  1.04s/it]
           all        158        619      0.313      0.281      0.242      0.109

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
 5/50      10.8G      1.573      1.979      1.743        138        640: 100% 96/96 [01:23<00:00,  1.14it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.10it/s]
           all        158        619      0.329      0.304      0.247      0.115

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
 6/50      10.7G       1.56      1.912      1.716        100        640: 100% 96/96 [01:24<00:00,  1.14it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.13it/s]
           all        158        619      0.275      0.372       0.25      0.103

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
 7/50      10.8G      1.532      1.861      1.715        133        640: 100% 96/96 [01:24<00:00,  1.14it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:05<00:00,  1.02s/it]
           all        158        619      0.311      0.298      0.264      0.103

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
 8/50      10.7G      1.526      1.813      1.708        116        640: 100% 96/96 [01:23<00:00,  1.15it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.13it/s]
```

```
          all        158        619      0.303      0.392       0.29      0.108

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
       9/50      10.8G      1.499      1.775      1.699         89        640: 100% 96/96 [01:23<00:00,  1.15it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.14it/s]
                   all        158        619       0.32      0.407      0.322      0.146

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      10/50      10.7G      1.492      1.662      1.696        140        640: 100% 96/96 [01:24<00:00,  1.14it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:05<00:00,  1.04s/it]
                   all        158        619      0.391      0.416      0.373      0.152

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      11/50      10.8G       1.47      1.654      1.688        103        640: 100% 96/96 [01:26<00:00,  1.10it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:05<00:00,  1.00s/it]
                   all        158        619      0.357      0.386      0.332      0.145

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      12/50      10.7G      1.459       1.59       1.66        105        640: 100% 96/96 [01:25<00:00,  1.13it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.13it/s]
                   all        158        619       0.33      0.345      0.262      0.113

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      13/50      10.7G      1.429      1.524      1.628        135        640: 100% 96/96 [01:25<00:00,  1.12it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.15it/s]
                   all        158        619      0.349      0.362      0.315       0.15

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      14/50      10.7G      1.405      1.457      1.622        144        640: 100% 96/96 [01:24<00:00,  1.14it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.08it/s]
                   all        158        619      0.416      0.324       0.32      0.143

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      15/50      10.8G      1.394      1.421      1.622        151        640: 100% 96/96 [01:24<00:00,  1.14it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.14it/s]
                   all        158        619      0.364      0.351      0.319       0.15

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
```

```
16/50      10.8G      1.396       1.4      1.618        98       640: 100% 96/96 [01:26<00:00,  1.12it/s]
         Class     Images  Instances      Box(P          R       mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.13it/s]
           all       158       619       0.33      0.408      0.349      0.168

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
17/50      10.8G       1.37      1.357      1.605        88       640: 100% 96/96 [01:24<00:00,  1.14it/s]
         Class     Images  Instances      Box(P          R       mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.04it/s]
           all       158       619      0.311      0.406      0.312      0.124

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
18/50      10.7G       1.35      1.283      1.578       136       640: 100% 96/96 [01:23<00:00,  1.15it/s]
         Class     Images  Instances      Box(P          R       mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.16it/s]
           all       158       619      0.403      0.353      0.345       0.16

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
19/50      10.7G      1.319      1.243      1.551        92       640: 100% 96/96 [01:23<00:00,  1.15it/s]
         Class     Images  Instances      Box(P          R       mAP50  mAP50-95): 100% 5/5 [00:05<00:00,  1.04s/it]
           all       158       619      0.366      0.422      0.347       0.15

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
20/50      10.8G      1.298      1.209      1.558       105       640: 100% 96/96 [01:23<00:00,  1.15it/s]
         Class     Images  Instances      Box(P          R       mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.15it/s]
           all       158       619      0.391      0.382       0.35       0.17

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
21/50      10.8G      1.309      1.183      1.553       121       640: 100% 96/96 [01:22<00:00,  1.16it/s]
         Class     Images  Instances      Box(P          R       mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.16it/s]
           all       158       619       0.37      0.423      0.341      0.166

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
22/50      10.8G      1.275      1.141      1.513       121       640: 100% 96/96 [01:23<00:00,  1.15it/s]
         Class     Images  Instances      Box(P          R       mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.12it/s]
           all       158       619      0.374      0.424      0.363      0.184

Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
23/50      10.8G       1.26       1.08      1.494        72       640: 100% 96/96 [01:21<00:00,  1.17it/s]
         Class     Images  Instances      Box(P          R       mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.19it/s]
           all       158       619      0.371      0.425      0.377      0.167
```

```
Epoch   GPU_mem   box_loss   cls_loss   dfl_loss  Instances      Size

24/50      10.8G      1.259      1.102      1.506         97        640: 100% 96/96 [01:23<00:00,  1.15it/s]

         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.04it/s]

           all        158        619      0.336      0.362      0.303      0.152


Epoch   GPU_mem   box_loss   cls_loss   dfl_loss  Instances      Size

25/50      10.8G      1.208       1.03      1.472        147        640: 100% 96/96 [01:22<00:00,  1.16it/s]

         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.17it/s]

           all        158        619      0.385      0.394      0.375      0.179


Epoch   GPU_mem   box_loss   cls_loss   dfl_loss  Instances      Size

26/50      10.7G      1.192     0.9926      1.466        104        640: 100% 96/96 [01:22<00:00,  1.16it/s]

         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:05<00:00,  1.04s/it]

           all        158        619      0.415      0.403      0.359      0.162


Epoch   GPU_mem   box_loss   cls_loss   dfl_loss  Instances      Size

27/50      10.7G      1.187      0.981      1.455        102        640: 100% 96/96 [01:21<00:00,  1.17it/s]

         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.18it/s]

           all        158        619      0.468       0.31      0.342      0.156


Epoch   GPU_mem   box_loss   cls_loss   dfl_loss  Instances      Size

28/50      10.8G      1.166     0.9449      1.444        128        640: 100% 96/96 [01:22<00:00,  1.17it/s]

         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:05<00:00,  1.05s/it]

           all        158        619      0.417      0.376      0.338      0.162


Epoch   GPU_mem   box_loss   cls_loss   dfl_loss  Instances      Size

29/50      10.8G      1.137     0.9221      1.429        119        640: 100% 96/96 [01:21<00:00,  1.18it/s]

         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.16it/s]

           all        158        619       0.36      0.418      0.339      0.169


Epoch   GPU_mem   box_loss   cls_loss   dfl_loss  Instances      Size

30/50      10.7G      1.138     0.9063      1.413        150        640: 100% 96/96 [01:21<00:00,  1.18it/s]

         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.11it/s]

           all        158        619       0.43      0.359      0.355      0.177


Epoch   GPU_mem   box_loss   cls_loss   dfl_loss  Instances      Size

31/50      10.8G      1.116     0.8697      1.391         88        640: 100% 96/96 [01:22<00:00,  1.17it/s]
```

```
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.16it/s]
           all        158        619      0.398      0.381       0.35      0.181

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      32/50      10.7G      1.098     0.8551      1.386        112        640: 100% 96/96 [01:22<00:00,  1.17it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.11it/s]
           all        158        619      0.377      0.371      0.329      0.157

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      33/50      10.8G      1.082       0.85      1.378         94        640: 100% 96/96 [01:21<00:00,  1.18it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.18it/s]
           all        158        619       0.44      0.347      0.362      0.177

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      34/50      10.7G      1.063     0.7994       1.36        104        640: 100% 96/96 [01:22<00:00,  1.17it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.13it/s]
           all        158        619      0.467      0.436      0.386      0.192

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      35/50      10.7G      1.046     0.7838      1.345        104        640: 100% 96/96 [01:20<00:00,  1.19it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.17it/s]
           all        158        619      0.447       0.36      0.352      0.181

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      36/50      10.8G      1.016      0.781      1.337        110        640: 100% 96/96 [01:20<00:00,  1.19it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.18it/s]
           all        158        619      0.402      0.383      0.358      0.178

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      37/50      10.8G       1.01     0.7494      1.318        132        640: 100% 96/96 [01:25<00:00,  1.13it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.18it/s]
           all        158        619      0.406      0.444      0.376      0.193

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      38/50      10.8G     0.9878     0.7248      1.295        121        640: 100% 96/96 [01:26<00:00,  1.11it/s]
         Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:05<00:00,  1.03s/it]
           all        158        619      0.432      0.411      0.369      0.187
```

```
    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    39/50      10.8G     0.9772     0.7207        1.3        139        640: 100% 96/96 [01:24<00:00,  1.13it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.08it/s]
               all        158        619      0.451      0.385      0.364      0.183

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    40/50      10.8G     0.9474     0.6917       1.29         96        640: 100% 96/96 [01:25<00:00,  1.12it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.15it/s]
               all        158        619      0.377      0.395       0.34      0.171
Closing dataloader mosaic
albumentations: Blur(p=0.01, blur_limit=(3, 7)), MedianBlur(p=0.01, blur_limit=(3, 7)), ToGray(p=0.01), CLAHE(p=0.01, clip_limit=(1, 4.0), tile_grid_size=(8, 8))

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    41/50      10.7G     0.9324     0.5538       1.29         53        640: 100% 96/96 [01:14<00:00,  1.29it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.17it/s]
               all        158        619      0.365      0.425      0.353       0.18

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    42/50      10.8G     0.8986     0.5135      1.262         43        640: 100% 96/96 [01:11<00:00,  1.34it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.03it/s]
               all        158        619      0.483      0.369      0.357      0.185

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    43/50      10.8G     0.8708     0.4889      1.236         58        640: 100% 96/96 [01:11<00:00,  1.34it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.09it/s]
               all        158        619      0.439      0.412      0.377      0.192

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    44/50      10.8G     0.8401     0.4747      1.212         73        640: 100% 96/96 [01:11<00:00,  1.34it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.16it/s]
               all        158        619      0.472      0.375      0.373      0.183

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    45/50      10.8G     0.8282     0.4562      1.205         83        640: 100% 96/96 [01:12<00:00,  1.32it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.17it/s]
               all        158        619      0.454      0.427      0.411      0.205
```

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    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    46/50      10.8G     0.8123     0.4433      1.198         72        640: 100% 96/96 [01:11<00:00,  1.34it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.09it/s]
               all        158        619       0.46      0.415      0.393        0.2

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    47/50      10.7G     0.7837     0.4233      1.173         48        640: 100% 96/96 [01:11<00:00,  1.34it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.03it/s]
               all        158        619      0.451      0.427      0.391      0.197

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    48/50      10.8G     0.7633     0.4082      1.155         51        640: 100% 96/96 [01:11<00:00,  1.34it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.14it/s]
               all        158        619       0.45      0.422       0.38      0.196

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    49/50      10.8G     0.7443     0.4064      1.142         99        640: 100% 96/96 [01:12<00:00,  1.33it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.18it/s]
               all        158        619      0.461      0.415      0.386      0.199

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    50/50      10.8G     0.7398     0.3964      1.144         63        640: 100% 96/96 [01:11<00:00,  1.34it/s]
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:08<00:00,  1.78s/it]
               all        158        619      0.461      0.412      0.382        0.2

50 epochs completed in 1.228 hours.
Optimizer stripped from runs/detect/train/weights/last.pt, 87.6MB
Optimizer stripped from runs/detect/train/weights/best.pt, 87.6MB

Validating runs/detect/train/weights/best.pt...
Ultralytics YOLOv8.0.67 🚀 Python-3.9.16 torch-2.0.0+cu118 CUDA:0 (Tesla T4, 15102MiB)
Model summary (fused): 268 layers, 43612776 parameters, 0 gradients, 164.8 GFLOPs
             Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:09<00:00,  1.99s/it]
               all        158        619      0.454      0.428       0.41      0.205
Tomato Early blight leaf        158         30      0.273      0.375      0.217     0.0924
Tomato Septoria leaf spot        158        128      0.706      0.562      0.634      0.305
Tomato leaf bacterial spot        158         87      0.523      0.747      0.709      0.338
Tomato leaf late blight        158         16       0.12      0.312      0.185     0.0521
```

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Tomato leaf mosaic virus       158        52     0.702      0.442      0.569      0.353
Tomato leaf yellow virus       158       108      0.46      0.269      0.318       0.17
          Tomato leaf       158       138     0.361      0.362       0.29      0.127
      Tomato mold leaf       158        60     0.485       0.35      0.361      0.204
Speed: 2.2ms preprocess, 16.9ms inference, 0.0ms loss, 4.8ms postprocess per image
```

Team Log Book

Date/ Time/ Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
7.10.22	1.Sazia 2.Naser 3.Shah Rear 4.Jubydul	1.Need to research about topics 2.Need to find out some complex problems	Task 1 and Task 2: done by all members	
10.10.22	1.Sazia 2.Naser 3.Shah Rear 4.Jubydul	1.Proposed some topics 2.Discuss about approaches 3.Solar system	Task 1,Task 2 and Task 3 done by all members	

17.10.22	1.Sazia 2.Naser 3.Shah Rear	1.Green house based solar system 2.Water and nutrition monitoring 3.Image Processing 4.Crop selection with parameters 5.Soil moisture and weather monitoring with parameters 6.Designs with equipment	Task 1: All Task 2 and Task 6 : Sazia Task 3: Naser Task 4: Shah Rear Task 5: Jubydul	Gave idea of Precise cultivation and greenhouse agriculture as well as an automatic irrigation system with it . Suggested to check the datasheet for certain crops and study a few research papers on greenhouse.
24.10.22	N/A	Online meeting did not be arranged due to severe weather		
27.10.22 To Taiyeb Sir	1.Sazia 2.Jubydul	1.Discussed about the selecting crops while making concept note 2.Weather and temperature 3.Need to select some crops those can grow	All Members	Select some crops and observe the results in research paper

		in greenhouse environment		
31.10.22	1. Naser 2. Sazia	Draft Concept Note	All Members	Modifications on specifications and requirement
3.11.22 To Taiyeb Sir	All Members	Discuss about progress presentation feedback	All Members	Design name, specifications
7.11.22	1. Sazia 2. Jubydul 3. Shah rear	Discussion about concept note reports	Jubydul and Naser	Modification on design and objective
14.11.22	All Members	Discussion on designs and Applicable Standards	Jubydul and Shah Rear	Corrections on system level
21.11.22	N/A			
28.11.22	All Members	Discussion on some research papers	All Members	Adding IEEE Format referencing in our draft.
5.12.22	1. Naser	Showing some monitoring system and	Shah Rear	Advised us to work on the simulation

	2. Shah Rear 3. Jubydul	cultivations based on research papers and working on Risk factor	And Naser	parameters according to our green house system.
12.12.22	All Members	Mock Presentation	All Members	Modification on problem statement and specifications
14.12.22 To Taiyeb Sir	1. Sazia 2. Naser	Progress Presentation Slide	Naser, Sazia and Shah Rear	Modification on constraints and requirement
2.2.23	All Members	Discussion about softwares and functional operations.	All Members	Suggestions about those tools.
16.2.23	All Members	Showing some difficulties about image processing and environmental simulink	Naser and Shah Rear	Modifications on these problems
2.3.23	All Members	Progress Presentation	All Members	Getting More details on image processing
23.323	All Members	Discussion on 3D animation and sensor simulation	Sazia and Jubydul	Suggested some modern tool for 3D and

				modification on sensor simulink
6.4.23	All Members	Showing calculation for solar energy and simulation of environmental system, sensors	Jubydul and Shah Rear	Suggested for doing more elaboration of solar energy calculation
13.4.23	All Members	Showing the simulation of solar power, modified environmental system, trained system of image processing and 3D animation video	All Members	Modification on solar tracking, 3D of top mounted bar and image processing
27.4.23	All Members	Final Presentation	All Members	
19.5.23	All Members	Planning for the semester & clear about PO & CO	All Members	
2.6.23	All Members	Making a tentative budget for prototype	Sazia, Naser & Shahrear	Partially completed
8.6.23	Sazia, Shahrear	Need to make a components list	Naser, Shahrear & Sazia	Suggested to focus on best

		for the prototype		design and work with components' list.
9.6.23	All Member	Finding ways of hardware implementation & discussion about necessary components.	All Member	Ordered the components
16.6.23	All Member	Starting and planning of hardware implementation	All Member	Partially completed.
24.6.23	Sazia, Naser & Shahrear	Selection of the sensors & Machine learning algorithms	Naser & Shahrear	Suggested to work more for hardware setup.
27.6.23	All Members	Working on Planet disease detection & Sensor based environmental monitoring	Naser & Shahrear	Discussed about trouble shoots.
6.7.23	Sazia, Naser & Shahrear	Showing the hardware devices	Naser & Shahrear	Suggested to work on soil moisture sensor's working principle & Machine

				learning data set.
9.7.23	Sazia & Jubydul	Working on solar system implementation.	Sazia & Jubydul	Suggested to take different energy values at different times.
12.7.23	All Members	Moq presentation for mid progress	All Members	
13.7.23	All Members	Progress Presentation	All Members	Submitted slide & Noted the suggestions from Faculties.
18.7.23	All Members	Working with feedback & Collect more components	All Members	Completed
27.7.23	Sazia, Naser & Shahrear	Discussion about motor and platform	Naser	Suggested to change the motor model
3.8.23	All Members	Showing the video of the 3 parts of our project	All Members	Suggested to bring some changes & visit SAU

8.8.23	All Members	Discussion about SAU visit	All Members	Suggestion about data Collection.
10.8.23	All Members	Visited SAU	All Members	
17.8.23	Sazia	Discussion about Posted Making & updated from SAU	All Members	Suggestion about poster analysis
22.8.23	Sazia	Working based on feedback for poster	Sazia	Suggested to do some modifications.
24.8.23	Sazia, Naser & Shahrear	Showing final Poster & combined all the 3 parts.	Sazia, Naser & Shahrear	Suggested to work on abstract
25.8.23	Sazia, Naser & Shahrear	Collecting & Compiling Everyone's part together	Sazia, Naser & Shahrear	Completed
26.8.23	All Members	Projects showcasing	All Members	Noted the feedbacks and start the report writing

10.9.23	All Members	Showing the prototype and draft report	All Members	Suggested to bring some changes and visite SAU again
21.9.23	Sazia, Naser & Shahrear	Visited SAU and collected data	Sazia, Naser & Shahrear	
30.9.23	Jubydul, Sazia, & Shahrear	Discussion about report	All Members	Suggested to work on results more