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AN INTELLIGENT GREENHOUSE MONITORING AND CONTROLLING SYSTEM WITH AGRI-VOLTAICS OPTIMIZATION

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ABSTRACT

"An Intelligent Greenhouse Monitoring and Controlling System with Agri-Voltaics Optimization" project revolves around the powerful combination of agri voltaics and image processing to create a sustainable and efficient solution for greenhouse management, powered by Raspberry Pi. Agrivoltaics, which integrates crop cultivation with solar energy generation, optimises plant growth while reducing energy consumption. Real-time data collection through sensors, along with image processing techniques using PiCam, enables monitoring of plant health and early disease detection. The system also includes solar tracking technology to maximise solar energy generation. Actuators such as fans, heaters, LEDs, and a pump for drip irrigation are controlled based on sensor data, ensuring precise environmental control for optimal crop growth. The remote monitoring and control capabilities through a user-friendly Blynk dashboard enable farmers to conveniently access and manage the greenhouse conditions from anywhere. This comprehensive approach to greenhouse farming promotes sustainable practices, reduces energy usage, and increases crop yields.

Keywords: Greenhouse Management, Agrivoltaics, Internet Of Things(Iot), Remote Controlling, Solar Tracking, Plant Disease Detection.

I. INTRODUCTION

Greenhouse agriculture has become an essential component of modern agriculture, providing controlled environments for optimal crop growth and protection from external factors. However, traditional greenhouse systems often face challenges such as high energy consumption and limited monitoring and controlling mechanisms, leading to inefficiencies and unsustainable practices. To address these challenges, the integration of renewable energy sources, such as solar energy, with greenhouse operations has gained attention. One promising approach is the use of agri-voltaics, which involves the co-locating of solar panels with crops, creating a symbiotic relationship where solar energy is harvested while providing shade to the crops.

In recent years, advancements in technology, such as image processing, Internet of Things (IoT), and microcomputing platforms like Raspberry Pi, have opened up new possibilities for creating intelligent greenhouse monitoring and controlling systems. These systems can leverage real-time data collection, analysis, and control to optimise greenhouse operations, including energy usage, environmental conditions, and crop health monitoring.

In this context, this research paper focuses on the development of an intelligent greenhouse monitoring and controlling system with agri-voltaics optimization. The system aims to create a sustainable and efficient solution for greenhouse management, powered by Raspberry Pi and incorporating image processing techniques for plant health monitoring. The integration of agri-voltaics with image processing and IoT technologies holds the potential to optimise crop growth while reducing energy consumption, resulting in more sustainable greenhouse operations. The system also includes solar tracking technology to maximise solar energy generation, and actuators to control environmental conditions based on real-time sensor data. Additionally, the system provides remote monitoring and control capabilities through a user-friendly dashboard, enabling farmers to conveniently manage greenhouse conditions from anywhere.

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This research paper will present the methodology, experimental setup, and results of the proposed intelligent greenhouse monitoring and controlling system. The paper will also discuss the potential benefits of the system, including promoting sustainable practices, reducing energy usage, and increasing crop yields. Furthermore, the limitations, challenges, and future research directions will be addressed to highlight the significance and potential impact of the proposed system in the field of greenhouse agriculture.

II. LITERATURE REVIEW

Study was conducted on Agro Voltaics farming, it is one of the options to increase the contribution of renewable energy in power generation and enhance income generation. It will enable the integration of photovoltaic (PV) panels on the Greenhouse which will conserve water, provide electricity for rural electrification, and reduce the temperature of the crop during the summer.[1]

The primary aim of this researchers includes an intelligent greenhouse management system, based on the (IoT) which can monitor and optimise the microclimates by utilising the agriculture photovoltaics system as a standalone power source, while still maintaining the minimum supply of solar sun radiation for the plants inside so they can grow with optimum water loss as minimum as possible.[2]

The main aim of the system is to send the info to the server wherever the correct call is taken for automation. Since the aim is to scale back the maximum amount of human involvement as potential this technique supports, the web of things must be created intelligent and intuitive. The system delineates optimised water utilisation on the premise of plant's water wants rather than cultivator's assumptions by acting on static information like plant and soil kind and surroundings dynamic information gathered from sensors. The info has been tested for algorithms like Naïve Bayes, C4.5 and SMO (svm).[3]

In this paper, proposed system receives three parameters from the sensors and activates the actuators if the actual values are more than the threshold values andalso stores these values in the cloud database enabling them to be accessed from anywhere, anytime. This paper also sheds light on the automatic control over the climatic conditions inside the greenhouse. There are different seasonal crops which can be grown only under certain conditions. Onions, garlic, shallots etc. are the winter crops which require cold conditions for their growth. Cucumbers,melons etc. are the summer crops which require moderate or hot climatic conditions.[4]

The primary aim of this paper includes an intelligent greenhouse management system, which incorporates; check the water level, humidity and measure moisture soil with control primarily based on real-time area data. Making the use of intelligent and IoT techniques. The Controlling of all these duties can be via smartphone application related to the internet and the duties can be achieved via interfacing wi-fi modules, sensors and actuators with a microcontroller in order to decrease the lab work and humans to make a cost efficient system.[5]

In this paper an Arduino based greenhouse monitoring and controlling System is designed. DHT11 sensor, Soil Moisture sensor, LDR sensor and pH sensor are the main sensors used in this Project which give the exact value of temperature,humidity, Moisture content, light intensity and soil pH respectively. This system is designed for controlling and monitoring Environmental parameters in the greenhouse by a simple SMS From anyplace via the GSM network. Ethernet is also used to send the data parameters to mobile phones which eliminates the SMS charges.This system reduces the power consumption, maintenance and complexity. This Project can be used in the agricultural field, in the nursery and in the botanical garden.[6]

This project describes an automated agricultural monitoring system using IoT. This system will sense all the mentioned parameters and send the data to the user. The user will take controlling action according to it. This asset allows the farmer to enhance the cultivation in a way the plant needs. It leads to higher crop yields and better quality crops[7]

Describes that Aeroponics is the new plant growing system of new-age agriculture. In the system, the plant cultivates under complete control conditions in the growth chamber by feeding a small mist of the nutrient solution in replacement of the soil. The paper gives significant knowledge about sensors like Temperature Sensors- which measure the real-time temperature reading through an electrical signal. Water sensors detect the liquid level PH sensors -to measure the acidity or alkalinity of a soil and many different sensors. The sensors sense their respective parameters and then convert them into electrical signals, the output of the

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sensors is connected to the Microcontroller. Then the microcontroller displays the information to the user and according to the user the parameters are controlled. Thus, the system helps the planter to keep a 10 watch and control the aeroponic system using the mobile app. The review also provides a wide range of information that could be essential for plant researchers and provides a major understanding of how the vital parameters of aeroponics relate with plant growth in the system.[8]

The main goal of this paper is to develop a low-cost, high-performance, and flexible distributed monitoring system with increased functionality. Wireless connection-based smart sensors network combines sensing, computation, and communication into a single, small device. The three main wireless standards used are: WiFi, Bluetooth, and ZigBee. Firstly they used acquisition sensors for field signals, an MCU as the front-end processing device, and several amplifier circuits to process and convert signals of field parameters into digital data. Secondly, the Zigbee module was used to transmit digital data to the SoC platform in a wireless manner. Finally, an SoC platform, like a Web server additionally, was used to process field signals.[9]

Research study was categorised into three groups such a Iot Based monitoring and controlling of a greenhouse secondly an intelligent AI based system and the lastly is energy based greenhouse systems In simple monitoring and controlling based system , the main objective is to gather the environmental factors and according to that the controller device is actuated by the user to maintain the optimum environment [4] [5] [6] [8] [7] [9]

In second intelligent ai based system it works like simple green house monitoring system in addition to it the collected data from the sensor and stores in the cloud which then by using ml the user can able to analyse the growth cycle of plants as well thereby the user can optimise the system [3]and last system were based on energy saving greenhouse system in this system the main objective of this system is to make the greenhouse self sufficient by using solar panels in this solar panels are fitted on the top of greenhouse in such a manner that it does not interfere with the sunrays as well as the land consumption is also minimised the greenhouse energy parameters can be studied by using software such as pvsyst and solidworks [1] [2]

III. METHODOLOGY

A. System Overview

In this section, the architecture of the proposed system is described. The proposed system consists of greenhouse and several subsystems:

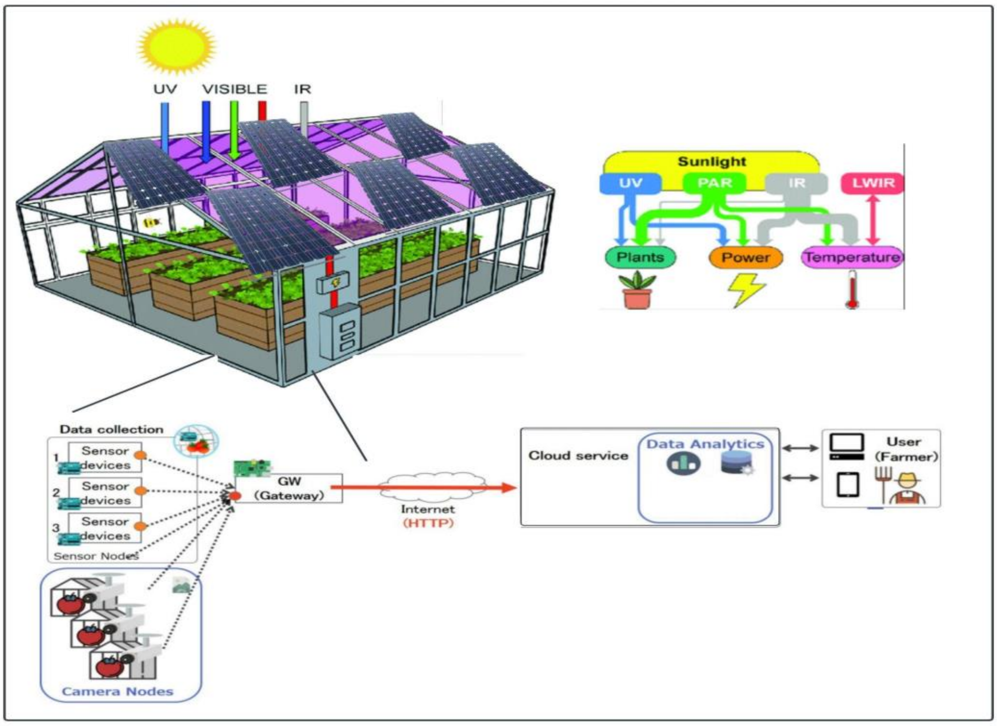

Figure 1: Proposed system

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1. **Greenhouse:** A Greenhouse is a building that functions to modify the climate based on a plant's need. It is used to produce food crops and flowers outside the normal season. For the research purpose we have chosen some crops for our greenhouse. They are Tomato, Broccoli, and Sunflower. In the proposed model solar panels are also placed on the roof of the Greenhouse in such a manner that plants will get a sufficient amount of light and at the same time electricity is generated to power the greenhouse. The parameters of the greenhouse environmental conditions measured are temperature inside the greenhouse, air humidity, soil moisture, light conditions and air quality inside the greenhouse. The specifications for the Greenhouse and the crops for the proposed model is shown in Table 1.

Table 1. Greenhouse and crop specifications

Type	Rectangular, Even-span		
Covering material	Polyethylene		
Length	44 cm		
Width	33 cm		
Height	65 cm		
Surface Area	1452 sq.cm		
Different Types of Crops for eg. Vegetables and Flowers.			
Crops	**Tomato**	**Broccoli**	**Marigold**
Preferred temperature	21°C-24°C	17°C-23°C	18°C-30°C
Water requirement	little over one litre of water per day	1-2 inches of water are required per week	18.7milliliter per week
Stage of crops	Saplings	Saplings	Saplings
Time for harvest	60-65 days	60-85 days	100-110 days
Soil type required	Well-drained, sandy or red loam soils rich in organic matter with a pH range of 6.0-7.0	Broccoli grows best in soils with a pH between 6.0 and 6.8.	Soil with the pH value 6.0 - 7.5

2. **Photovoltaic subsystem:** It consists of solar panels and a battery that serves as a standalone power resource so that all devices can work. The solar panels are placed on the roof in an alternate manner so that plants can get an adequate amount of sunlight and to create enough energy to charge the battery to power the sensors and the loads. The specification of the solar panel and the loads are shown below

Table 2. Solar and Load specification

Load Specifications				Solar Specifications	
Load	**Voltage**	**Current**	**Power**	**Length**	7 cm
LDR	3.3-5V	15mA	50mW	**Width**	5 cm
Soil moisture sensor	3.3-5V	15mA	50 mW	**Thickness**	0.3cm
Dht 11	3-5V	2.5mA	13mW	**Area**	49 sq.cm
Gas Sensor(MQ)	5V	150mA	750 mW	**Current**	100mA
Exhaust fan	12V	220mA	7W	**Voltage**	4-6 V
Pump	12V	600mA	3W		
Lamp	220V	9A	15W		
Motor	12V	180mA	2.1W		

3. Data Acquisition subsystem: In this subsystem, data collected from various sensors, such as humidity, temperature, light intensity, CO_2 level, images of the crop are recorded. These data are captured continuously from the sensor to monitor the environmental status of the greenhouse. These captured data will be send to the controller to process and take appropriate action.The information about the sensors used in the system are as follows:

1) Temperature and Humidity Sensor(DHT11): DHT11 sensor is one type of sensor that can measure the temperature and humidity of the air around plants that can affect the rate of biochemical processes. The DHT11 sensor is a sensor composed of capacitive polymer elements used to measure humidity, and a temperature sensor. There is a calibration memory that aims to store the calibration coefficient of measurement results inside the sensor. The data generated from this sensor is in the form of digital logic that can be accessed serially. DHT11 is a temperature and humidity sensor that has a measurement range of 20-90% Relative Humidity (RH) and degree Celcius. The sensor works on two cables namely data and Serial Clock (SCK). The data obtained in the form of environmental temperature measurement data

2) Soil Moisture Sensor: This sensor soil works in the measurement range of 0 to 100% with an accuracy of ±5% RH. These sensor alarms work based on the principle of the capacitive sensor. There are two capacitor plates separated by a dielectric. Soil moisture will change the dielectric permittivity between capacitor plates which is proportional to the generated voltage.

3) LDR(Light Dependent Resistor): LDR (Light Dependent Resistor) as the name states is a special type of resistor that works on the photoconductivity principle that means that resistance changes according to the intensity of light. Its resistance decreases with an increase in the intensity of light.

4) Gas level sensor(MQ6): The gas sensor module consists of a steel exoskeleton under which a sensing element is housed. This sensing element is subjected to current through connecting leads. This current is

known as heating current through it, the gases coming close to the sensing element get ionised and are absorbed by the sensing element. This changes the resistance of the sensing element which alters the value of the current going out of it.

5) Pi Camera Sensor: High Definition camera module compatible with all Raspberry Pi models. Provides high sensitivity, low crosstalk and low noise image capture in an ultra small and lightweight design. The camera module connects to the Raspberry Pi board via the CSI connector designed specifically for interfacing to cameras. The CSI bus is capable of extremely high data rates, and it exclusively carries pixel data to the processor.

4. Gateway subsystem: To forward data from the sensor subsystem so it can be collected by the Microclimate optimization subsystem and Image processing subsystem for processing and also monitored by users via smartphones or laptops using the internet network.

5. Microclimate optimization subsystem: With the help of algorithms, sensor data collected through the gateway will be processed, analysed, and then controlled to maintain optimal conditions for plants.

6. Image processing subsystem: The image data gathered by the sensor through the gateway will be processed to predict the disease.

B. System Design

The system can be considered as a combination of several subsystems or modules - Power Unit, Input Devices(Sensors), Controlling unit, Output devices(Actuators), Server(Cloud). The block diagram of the system is shown in Figure 2.

In the power unit, solar panels are arranged in an alternate manner on the roof of the Greenhouse such that there are gaps between two solar panels. When the solar rays are incident on the panels, it converts the incident sunlight into DC electricity to charge the battery. This electricity is fed to the battery via a charge controller which ensures the battery is charged properly and not damaged. Sensors and load can be powered directly from the solar panel in the presence of sunlight and from the battery in the absence of sunlight.The output voltage from the solar panel can be stepped-up using a boost converter.

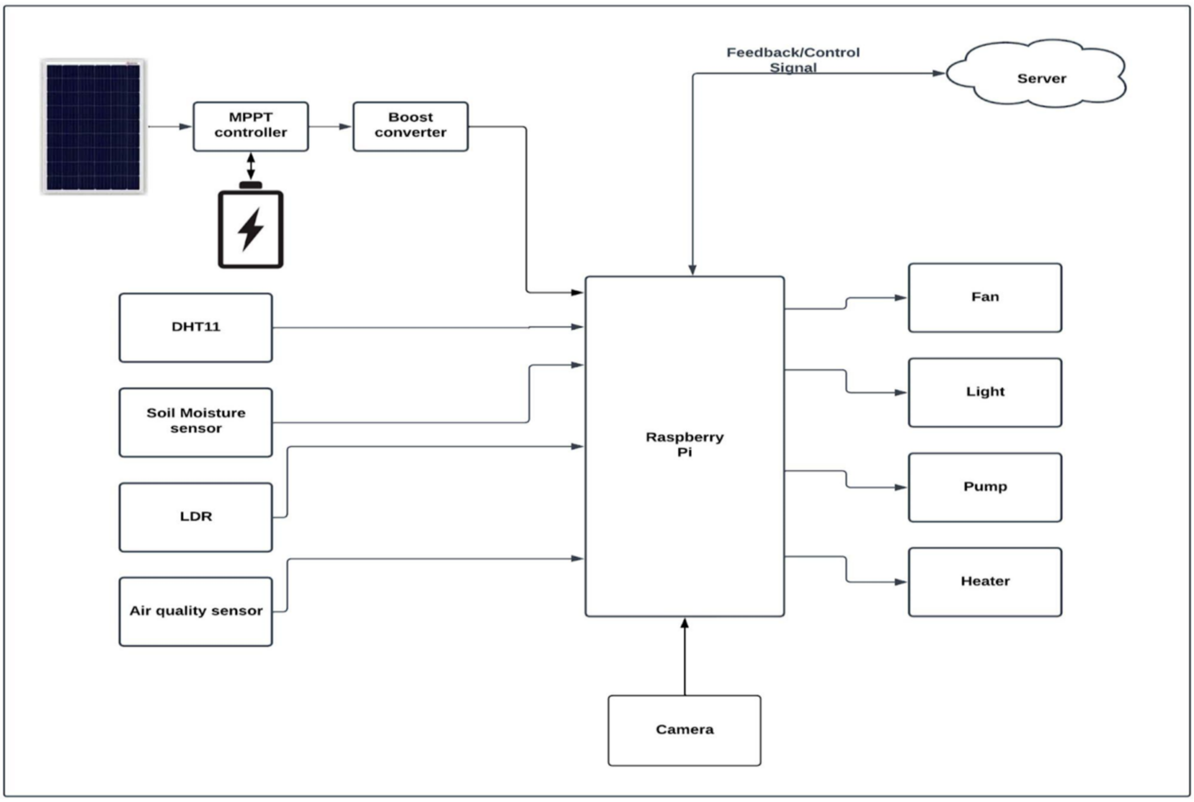

Figure 2: Block Diagram

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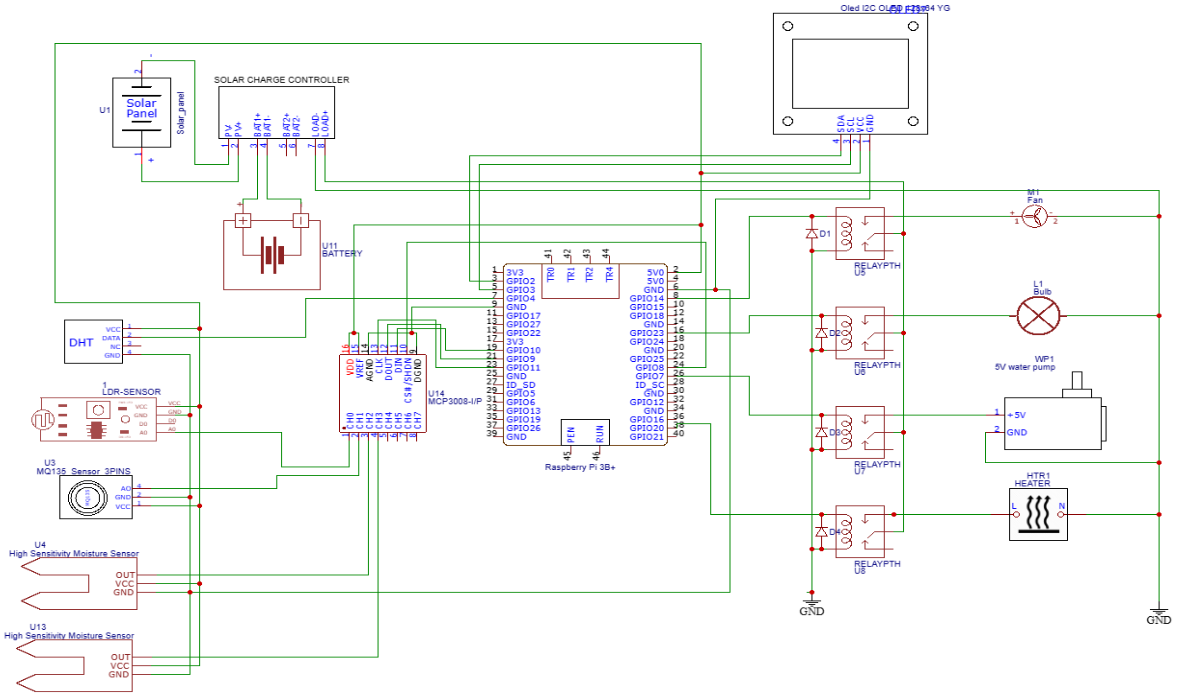

Figure 3: Circuit Diagram

In the sensing unit, different sensors such as DHT11, Soil moisture sensor, LDR, RPi camera module and Air quality sensor will be used for data collection by sensing the environment conditions inside the Greenhouse continuously. The collected data from the sensor will be sent to the controlling unit.

The received data from the sensors will be processed by RPi based on the ML algorithms, which will help to make decisions to control the actuators to maintain the required climate conditions inside the greenhouse. To control different parameters in greenhouse separate actuators are used. For e.g. Fan will be turned on for ventilation or cooling when the sensed temperature value is greater than the threshold value, Similarly other actuators are controlled by RPi to maintain the favourable conditions for the crop inside the greenhouse.

The camera module will be installed at a fixed location and will take periodic snapshots of the crop. The sensor data along with image data will be sent to the cloud for visualisation and further processing of image data to predict the growth rate of the crop. With the help of cloud platforms, users can access, monitor the data and control the devices remotely.

Solar Tracking Panel

A solar tracking panel is a type of solar panel that is designed to follow the movement of the sun across the sky. The purpose of solar tracking is to maximise the amount of sunlight that the solar panel receives, which in turn increases the panel's efficiency and power output.

There are two types of solar tracking systems: active and passive. Passive systems use a fluid or gas-filled cylinder that expands or contracts based on the temperature to move the panel. Active systems, on the other hand, use sensors or algorithms to detect the sun's position and move the panel accordingly.

The tracking system is powered by a small motor that adjusts the angle of the panel to ensure it is always facing the sun directly. This maximises the amount of sunlight that hits the solar cells, which increases the panel's efficiency and power output.

By following the sun's movement across the sky, solar tracking panels are able to receive a higher amount of direct sunlight than fixed panels that are stationary throughout the day. This results in a higher overall energy output and greater efficiency, making solar tracking panels a popular choice for both residential and commercial solar energy systems.

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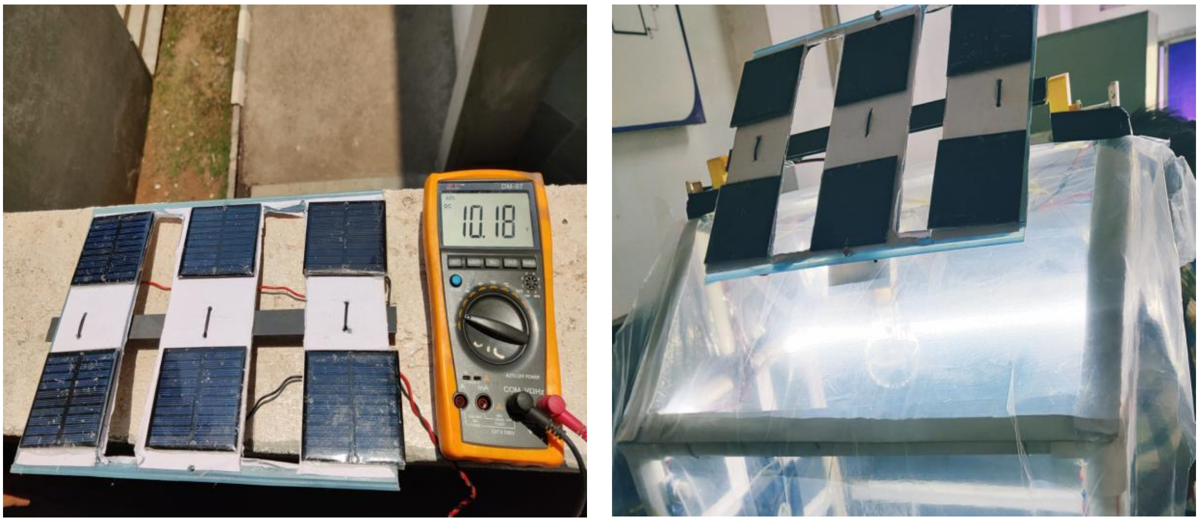

Figure 4: Solar Tracking Panel

Image processing

The Disease detection system works in this way, the code sends the processed image to the predictor. The images are taken by the camera module attached to raspberry pi, then resized in the specific size needed for the predictor. The predictor is a deep learning model based on the Convolutional Neural Network.

The predictor model is designed using flowing setups:

1. Importing Dataset and creating groups

The project uses a tomato plant dataset with images of diseased leaves. Tensorflow's "image_dataset_from_directory" function creates a dataset by taking parameters like image location, size, and batch size. Image size is the size of all images, and batch size is the number of images processed together to reduce resource requirements.

2. Dividing the dataset into train, validation, and test

To train and validate the model, a certain amount of data is required, followed by additional data for testing. The recommended practice is to divide the dataset into three groups: 80% for training, 10% for validation, and 10% for testing. During training, the model uses training data to learn and validation data to test and improve itself. Test data is used to evaluate the model's performance after it has been trained.

3. Preparing the Model and build it

Model preparation involves arranging layers in sequence, where each layer processes images in the dataset in a linear manner. The preparation typically includes a convolution layer, which extracts features from images using a kernel matrix and an activation function, such as ReLu. The output is a feature map that is then passed through a pooling layer, which reduces the image size while retaining the important features. There are different types of pooling, such as max pooling. The resulting feature map is flattened and fed into dense layers, which are the hidden layers in the model. The output figures are then transformed into probabilities between zero and one using the Softmax function.

4. Set the optimizer

The concept of optimizers is used in Neural Networks to increase the accuracy of the model's network by manipulating the weights for every epoch. The Adam optimizer, short for Adaptive Moment Estimation, is commonly used when there is a large amount of data and parameters. It is an upgraded version of the gradient descent method and is popular among developers of neural networks.

5. Compile the Model

We can use the fit() function provided by Tensorflow to train or fit our model. During this process, the model is trained with a fixed number of iterations, also known as epochs, using the provided dataset. This process updates and sets the model weights after each epoch.

6. Testing the Model

The testing phase of the model is done by using the dataset that was separated in the initial step. The function model.predict() is used to classify the images into their respective categories. The accuracy of the model can be checked using the model.evaluate() function or by plotting the performance graph of the training and validation data.

7. Exporting the Model

The model export feature allows a trained model to be exported for direct application on a device with less processing power. This can be achieved using the model.save() function provided in TensorFlow.

IV. RESULT OF IMAGE PROCESSING

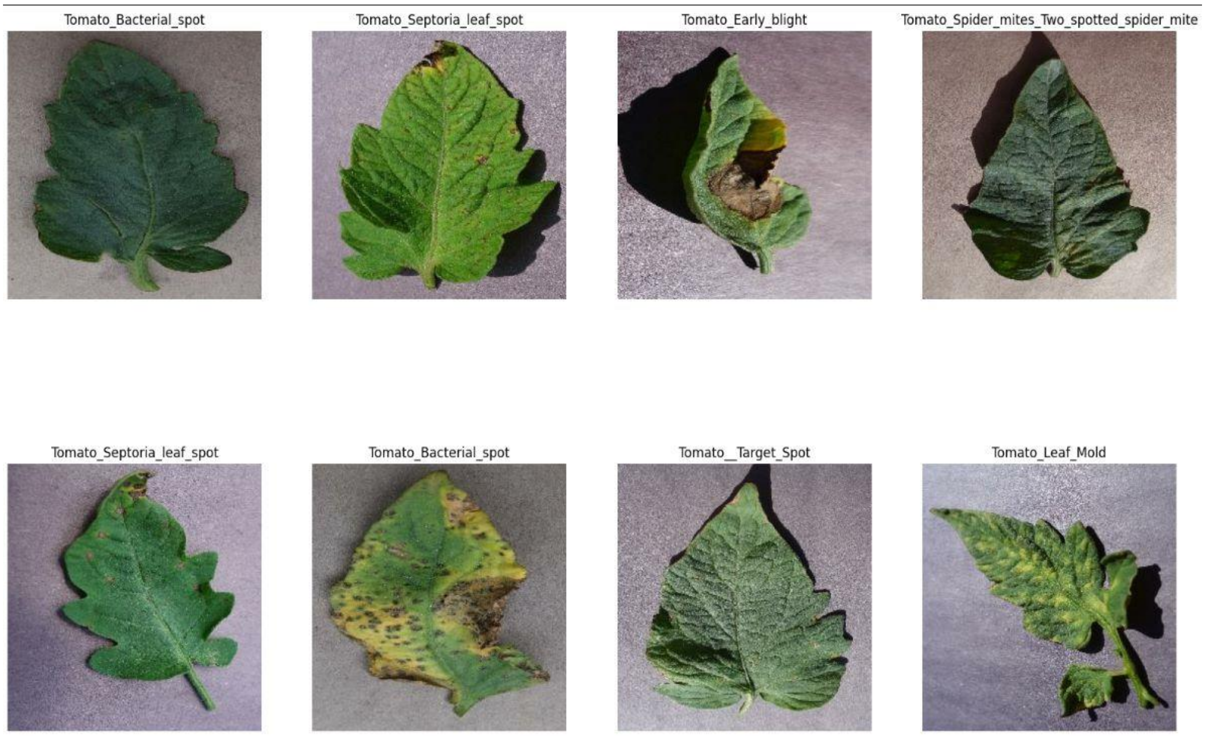

Figure 5: Disease Detection

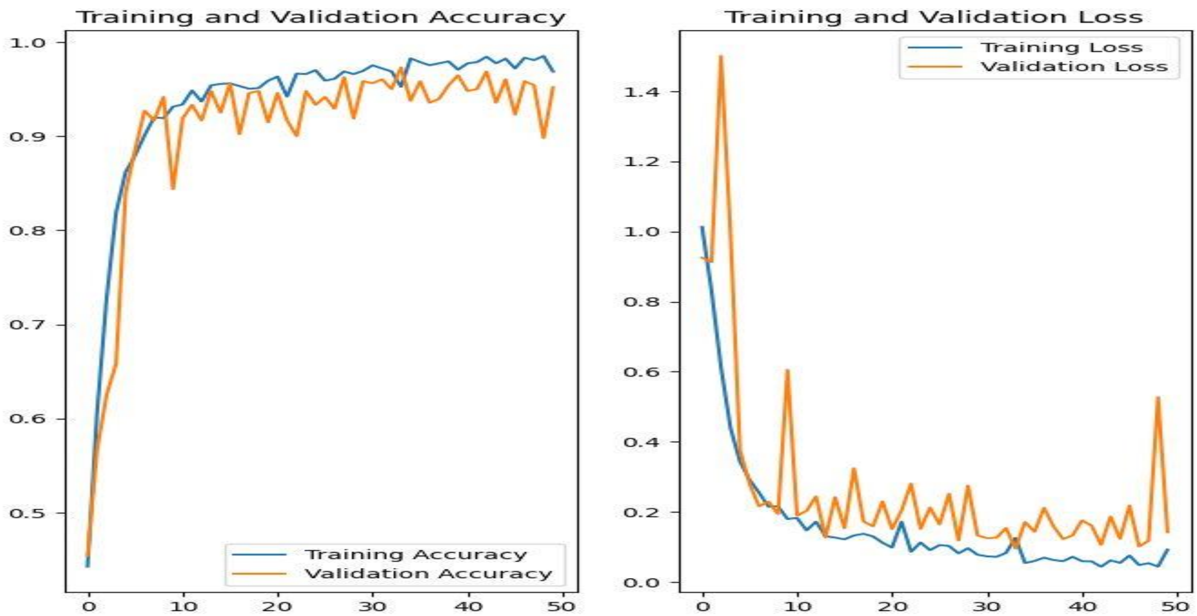

Figure 6: Plant Disease Detection Algorithm Accuracy

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V. MODEL AND ANALYSIS

A. Testing

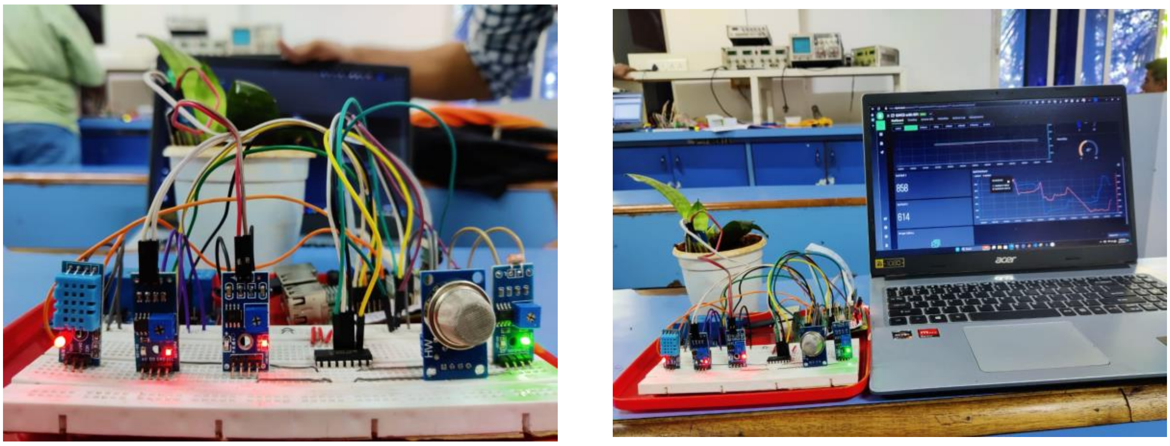

Figure 7: Testing on Breadboard

The project is tested with the simulator, before being hooked up with the hardware to avoid any mistakes and that may damage the hardware and software. The integration process needs to be carried out as safely as possible. The testing was conducted by constructing the circuits using a breadboard, before applying a suitable power supply and manipulating the circuit as per the real applications.

B. Final Model

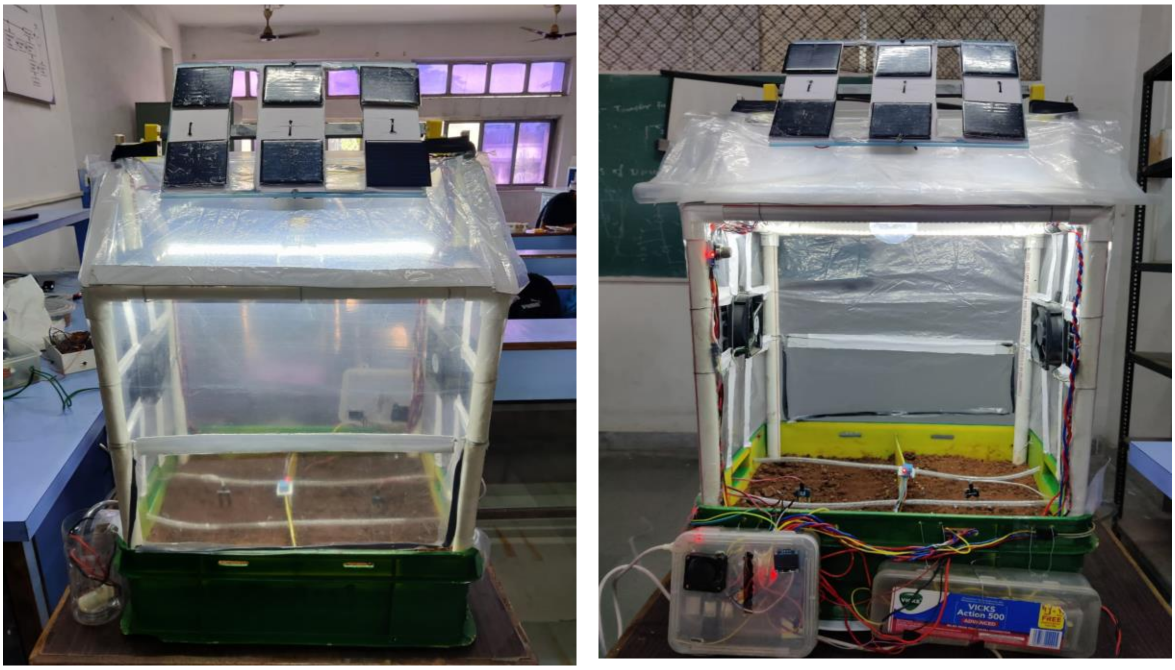

Figure 8: Model with all connections

The model is prepared as per the design using the technique of agrivoltaics, which involves utilizing solar panels on the same land where crops are grown. To ensure maximum efficiency, the solar panels are equipped with solar trackers that optimize their orientation towards the sun, powering the Raspberry Pi (RPi) and the sensors connected to it, as well as the actuators.

The sensors continuously collect data from the greenhouse environment, which is then processed by the RPi to control the actuators and maintain an optimal climate for the crops. The collected data is utilized to make informed decisions about when to activate or deactivate the actuators, such as the pump, fan, light, or heater, to ensure the greenhouse conditions are ideal for crop growth.

Furthermore, the collected data and system control options are made accessible to the user through the Blynk Cloud platform. The user can monitor the greenhouse conditions, view real-time data, and control the system through an intuitive dashboard provided by Blynk (discussed below). This allows the user to have remote access and control over the greenhouse operations, ensuring convenient and efficient management

C. Blynk Dashboard

The project presented in this research paper incorporates a cutting-edge web and mobile dashboard, developed using the Blynk platform. The dashboard serves as a central hub, allowing users to securely log in and remotely access real-time data, control actuators, set up automation rules, receive notification alerts, and visualise historical data. The seamless integration of web and mobile dashboards provides users with versatile and accessible means to manage greenhouse parameters, making it a comprehensive solution for modern Greenhouse Management.

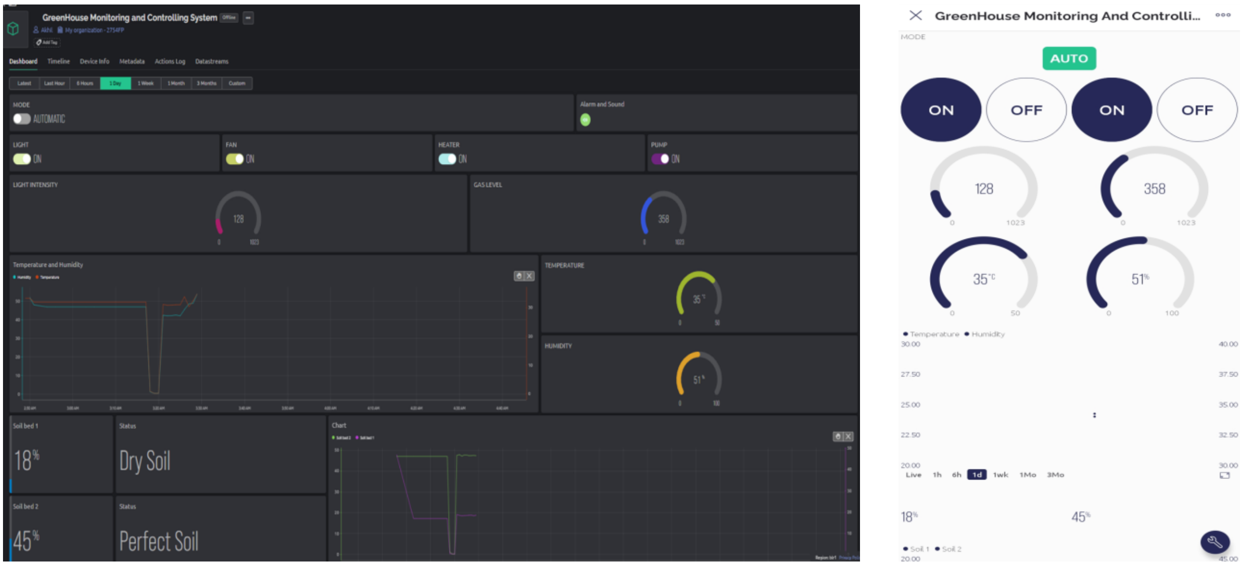

Figure 9: Web and Mobile Dashboard

Features:

- **Secure Login:** Users can securely log in to the Blynk dashboard to access the greenhouse monitoring and control system, ensuring data privacy and security.
- **Parameter Monitoring:** Real-time data from sensors installed in the greenhouse, such as temperature, humidity, light intensity, etc., can be viewed to monitor the environmental conditions.
- **Actuator Control:** Users have the option to manually control the actuators (fan, light, heater, pump) from the dashboard based on their requirements or set them to automatic mode to be controlled by sensor readings and preset threshold values.
- **Automation:** Automation rules can be set up based on sensor readings and thresholds to automatically control the actuators, ensuring optimal environmental conditions in the greenhouse.
- **Notification Alerts:** Users can receive notifications via the Blynk platform in case of emergencies, such as temperature/humidity exceeding preset limits, ensuring timely response to critical situations.
- **Graph Visualisation:** Historical data can be viewed in graphical form, allowing users to analyse trends, patterns, and insights for better decision-making.

VI. CONCLUSION

The intelligent greenhouse project has incorporated advanced technologies such as photovoltaic cells, batteries, Agri-voltaics, and disease detection APIs to create a sustainable and efficient solution for crop cultivation. With continuous monitoring of real-time environmental parameters, automated climate control, and early disease detection capabilities, the greenhouse has been optimized to maximize crop yield while minimizing energy and resource consumption. The intuitive dashboard provides easy access to collected data, empowering users with greater control and understanding of the greenhouse's operations. Through these advancements, a sustainable and productive greenhouse has been created, contributing to the future of agriculture.

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