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Automatic Hydroponics Farming System with Image Processing Based Smart Nutrients System

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Abstract - *This project presents an automated irrigation system for Hydroponic farming based on IoT sensors which are integrated with plant lifecycle monitoring through image processing Hydroponic farming is the technique of plant cultivation without using the soil. This technique ensures that the plant receives all nutrients from the water-soluble nutrient solution and doesn't need to grow extensive root systems to obtain the nutrients they need are circulating hydroponic system can conserve up to 85% water compared to standard farming making it good for the environment. Irrigation system is integrated with nutrients system. To operate nutrients system, one should have expertise in botany science which is not available to local farmers so we are developing a software that used image processing to comment on plant lifecycle status based on controller will be decided to the amount of nutrients should supply this process makes the irrigation system and nutrients system automatic and can be done by ruler farmer without the need of learning botany in depth.*

Key Words*: *Automatic Hydroponic farming, IOT, PLC, Image Processing.

1.INTRODUCTION

The Greek words "hydro" (which means water) and "ponos" (which means labour) are the roots of the word "hydroponics." A new farming method called hydroponics produces crops without the use of soil via nutrient solutions. To survive, humans need a living environment, food, and water.

Automatic hydroponics farming system with image processing-based smart nutrients system is an advanced approach to growing plants without the use of soil. Hydroponic systems are becoming increasingly popular due to their numerous advantages over traditional soil-based agriculture they offer precise control over environmental factors reduce water usage and can increase crop yield and quality.

As developments in sensors and processors continue to present more chances to automate, automation has gained a stronger foot hold around the world.

The proposed system employs image processing to analyze the plant's growth and determine their nutrient requirements. A camera captures images of the plants at regular intervals and image processing algorithms analyze the images to identify various growth parameters such as plant height, leaf area, and color. Based on this analysis the system automatically adjusts the nutrient supply to ensure that the plants always receive optimal nutrition.

The system is also fully automated reducing the need for manual intervention and making it ideal for large-scale commercial operations. The smart nutrient system ensures that the plants receive the nutrients they need when they need them resulting in healthier plants and higher yields.

Automatic hydroponics farming system with image processing-based smart nutrients system is an innovative solution that combines the benefits of hydroponics with advanced technology to produce healthy, high-quality crops with minimal environmental impact.

1.1 What is hydroponics?

Hydroponics is a branch of hydro culture, which is a method of growing plants without using soil i.e., replacing it with a controlled nutrient water source.

The plants maybe grown with only their roots exposed to the mineral solution or the roots

Maybe supported by inert medium, such as NPK (Nitrogen, Phosphorus, and Potassium).

In this project have focused on ways of conducting hydroponic farming using a compact modular setup with least possible methods of treatment.

2. RELATED WORK

Hydroponics is a soilless cultivation technique that provides plants with a nutrient-rich water solution, allowing them to grow in a controlled environment. Several hydroponic systems are commonly used, each offering unique advantages and limitations. Here, we will review three popular hydroponic systems: Nutrient Film Technique (NFT), Deep Water Culture (DWC), and Drip Irrigation.

Hydroponics is a type of agriculture that involves growing plants without soil, using nutrient-rich water instead. This method of farming has become increasingly popular in recent years, particularly in urban areas where space for traditional farming methods is limited.

The concept of hydroponics has been around for centuries, with early examples dating back to the ancient Babylonians and Aztecs. However, it wasn't until the 20th century that modern hydroponic systems began to emerge, using advanced technology and techniques to optimize plant growth.

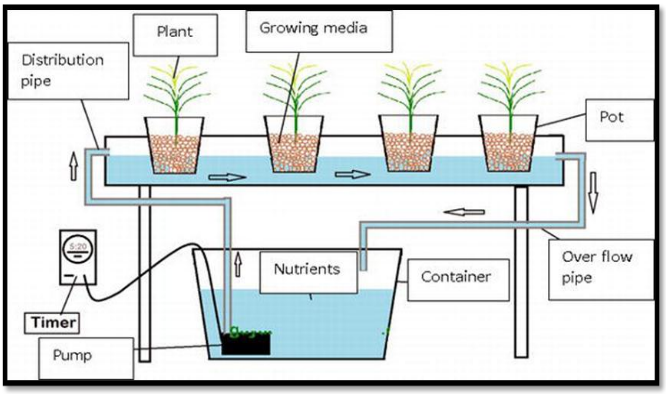


Fig -1 : Hydroponic Farming System of Structure Design

The main advantage of hydroponic farming is that it allows for precise control over growing conditions, including nutrient levels, pH, and temperature. This can lead to faster growth rates, higher yields, and better-quality produce compared to traditional farming methods. Additionally, hydroponic systems use less water than traditional farming methods and can be set up in a variety of locations, from urban rooftops to indoor facilities.

Hydroponic farming has the potential to revolutionize the way we grow food, offering a sustainable and efficient solution to the challenges of modern agriculture.

3. METHODOLOG

3.1 Nutrient Film Technique (NFT)

Nutrient Film Technique (NFT) is a type of hydroponic farming system that is popular for growing crops with short growth cycles, In an NFT system; plants are grown in channels or troughs that are slightly tilted to allow a thin film of nutrient-rich water to flow over the roots of the plants.

NFT is a hydroponic system where a thin film of nutrient solution continuously flows over the roots of the plants. The roots are placed in channels or gutters with a slight downward slope to allow the nutrient film to flow. The excess solution is collected, reoxygenated, and recalculated to maintain a constant flow.

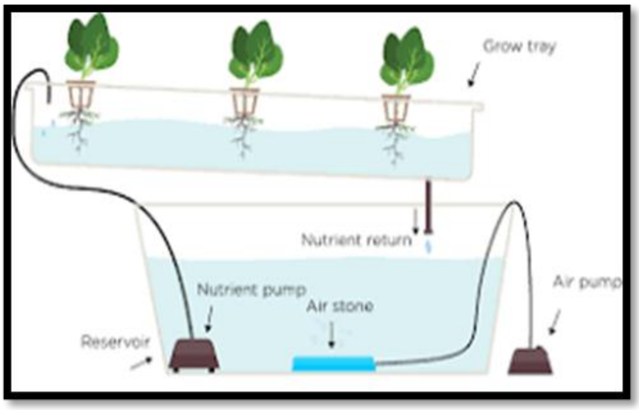


Fig -2: Nutrient Film Technique (NFT)

The nutrient solution flows over the roots; it delivers the necessary nutrients to the plants while also providing oxygen and removing waste products. The excess nutrient solution is collected at the end of the channel and returned to the reservoir for recirculation.

NFT systems require careful monitoring of the nutrient solution pH and electrical conductivity (EC) to ensure that plants receive the correct balance of nutrients. Temperature and humidity levels must also be maintained within a specific range to promote optimal plant growth.

The Nutrient Film Technique is a popular and effective hydroponic farming system for producing high yields of healthy and nutritious plants.

Advantages

Water and nutrient efficiency: NFT systems are highly efficient in their use of water and nutrients.

Space-saving: NFT systems can be set up in small spaces, making them ideal for users who have limited land or indoor space. This makes them suitable for urban farming and other situations where space is at a premium.

Reduced use of pesticides: Since NFT systems are typically grown indoors or in controlled environments, they are less susceptible to pests and diseases. This means that users can reduce their use of pesticides and other harmful chemicals.

Low maintenance: NFT systems require less maintenance compared to traditional farming methods. They do not require tilling, weeding, or other labor-intensive tasks, making them easier to manage for users.

Efficient use of water and nutrients: The thin film of nutrient solution provides a highly efficient nutrient uptake for the plants.

Oxygenation of roots: The exposed roots in the film receive ample oxygen, promoting healthy growth.

Suitable for smaller plants: NFT is ideal for smaller plants with shallow root systems, such as lettuce and herbs.

Space-efficient: The design of NFT systems allows for high plant density, making it suitable for commercial applications.

Limitations

Limited crop selection: They may not be as effective for crops that require longer growing periods or have deeper root systems.

Nutrient balance: The nutrient solution in NFT systems must be carefully monitored and adjusted to ensure that the plants receive the correct balance of nutrients.

Nutrient imbalances: The continuous flow of nutrient solution can lead to pH and nutrient imbalances if not closely monitored and managed.

Power supply: NFT systems require a reliable source of electricity to power the water pump and other components.

Susceptibility to system failures: If the flow of the nutrient film is disrupted, it can cause rapid plant stress and damage.

Limited suitability for larger plants: NFT may not provide sufficient support for larger plants with extensive root systems.

3.2 Deep Water Culture (DWC)

DWC is a hydroponic system in which plant roots are submerged in a nutrient-rich solution. The roots are supported by floating platforms or net pots, allowing them to access the solution.

An air pump or diffuser provides oxygenation to the solution to prevent root rot. Oxygenation is critical in DWC systems, as plants require oxygen to survive and grow. Air stones or other aeration devices are typically used to ensure that the nutrient solution is properly oxygenated.

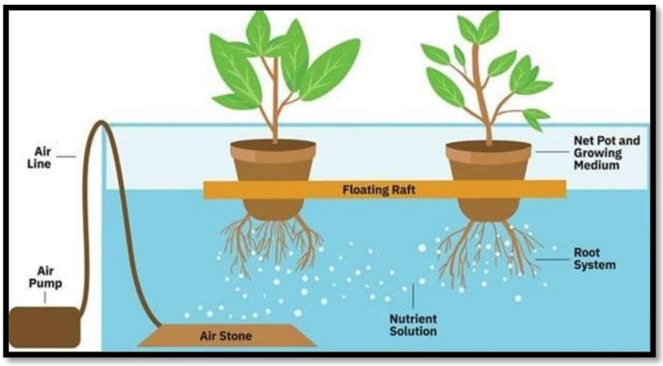


Fig -2 : Deep Water Culture (DWC)

Deep Water Culture is a simple and efficient hydroponic farming system that is well-suited for home gardeners and hobbyists. With proper maintenance and monitoring, DWC systems can produce high yields of crops in a relatively small space. However, it is important to be aware of the limitations of the system and select crops that are well-suited for this type of hydroponic farming.

Advantages

Efficient nutrient uptake: DWC systems allow plants to directly access a nutrient-rich solution, resulting in faster and more efficient nutrient uptake. This can lead to faster growth rates and higher yields compared to traditional soil-based farming methods.

Optimal oxygenation: DWC systems provide optimal oxygenation to the root zone, which is critical for plant growth and development.

Low water usage: DWC systems use less water compared to traditional soil-based farming methods, making them more environmentally friendly and cost-effective.

Low maintenance: DWC systems do not need soil preparation or ongoing monitoring, hence they require less maintenance than conventional soil-based farming techniques. Lower lab our expenses and more profitability may result from this.

Simple setup: DWC systems are relatively easy to set up and require minimal equipment.

Excellent oxygenation: The roots are constantly immersed in oxygenated water, promoting rapid growth and high yields.

Suitable for a wide range of plants: DWC can accommodate both smaller and larger plants, making it versatile for various crops.

Good water and nutrient retention: The large volume of water in DWC systems helps maintain stable nutrient concentrations.

Limitations

Increased risk of root diseases: If the oxygenation is insufficient or water quality is poor, root diseases can occur.

Challenging pH and nutrient management: The nutrient solution in DWC systems requires frequent monitoring and adjustment to maintain optimal pH and nutrient levels.

High water usage: DWC systems may require more water compared to other hydroponic systems due to the large volumes required to immerse the roots.

4. Image Capture Robotic Structure

At the top of the system, there is a robotic structure made of aluminum and iron sticks. This structure incorporates pulleys on two sides, along with silicon packing, which ensure smooth movement.

Fig -3: Working of Image Capture Robotic

A fibred rope is bound with the robot using an aluminum sliding door mechanism that enables free sliding along the railing. The movement of the rope is actuated by a 12 RPM, 12-volt DC motor connected individually with a power adapter. This one-axis robot is controlled by an ESP32 CAM, which provides the necessary functionality for controlling its movement.

Hardware Setup: Connect the camera module to the ESP32-CAM board using the camera interface. Ensure that the connections are secure.

Programming: Write the firmware or code for the ESP32 microcontroller. You can use the Arduino IDE or ESP-IDF to program the ESP32. The code should include instructions to initialize the camera module and configure it for capturing images.

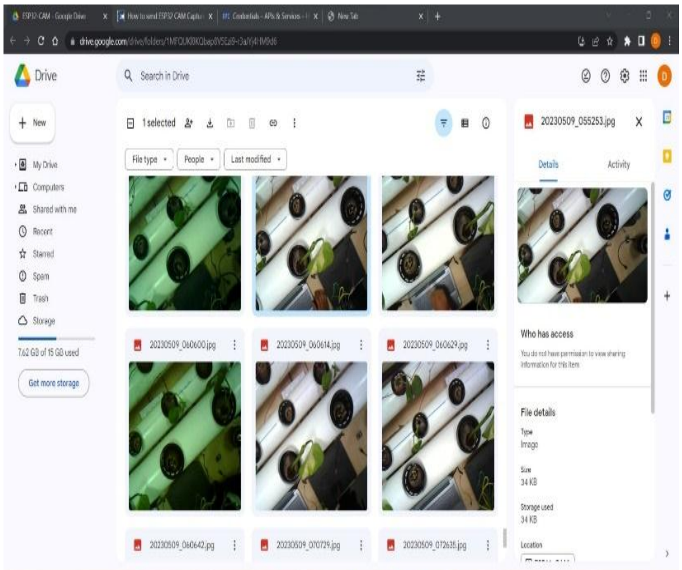
Image Capture: Once the firmware is uploaded to the ESP32, it can start capturing images. You can trigger image capture by sending a command to the ESP32 or by setting up a specific interval for capturing images automatically.

Image Processing: After capturing an image, the ESP32 can perform various processing tasks such as image filtering, resizing, or applying algorithms for image recognition or object detection. The processing capabilities depend on the complexity of the algorithms implemented and the available resources on the ESP32.

Image Transmission: Once the image is captured and processed, it can be transmitted over the Wi-Fi connection. You can choose to send the image to a remote server, save it on an SD card, or stream it to a connected device such as a Google drive and computer.

Control Mechanism: Depending on the design of your robot, you may have additional components such as motors or sensors. These components can be controlled by the ESP32 to move the robot, adjust the camera angle, or perform other actions based on the captured images.

4.1. Output of google drive image



5. MicroLogix 1200 PLC Controllers for working

This project, we have used Allen Bradley MicoLogix 1200 trainer kit as PLC Controller. The Allen-Bradley M 1200 is a compact and modular programmable logic controller (PLC) manufactured by Rockwell Automation. It belongs to the Micro800 series and is designed for small to medium-sized industrial applications.

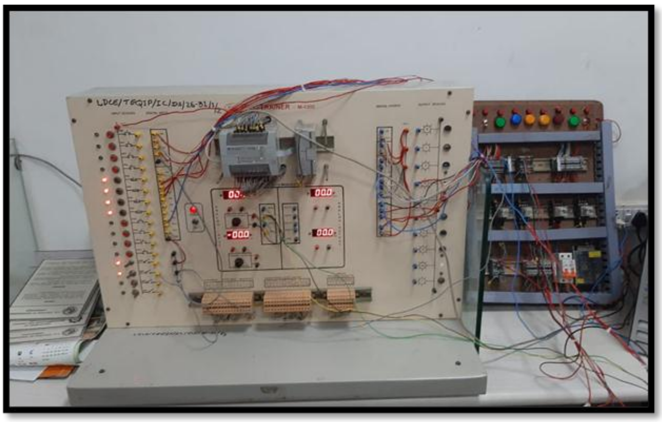


Fig -4: PLC Trainer Kit

The M 1200 features a compact design that allows it to fit into tight spaces. It offers modular expansion options, enabling users to customize their system configurations and accommodate future upgrades. The PLC supports a variety of embedded I/O modules, including digital, analog, and specialty options, facilitating connectivity with sensors and actuators.

Program the controller using the Allen-Bradley programming software, the MicroLogix 1200 controller is programmed to monitor the sensor data and control the system accordingly. The programming can be done using ladder logic, function block diagrams, or structured text.

The automated hydroponic farming system is monitored regularly to ensure that it is functioning correctly. Any issues that arise are addressed promptly to avoid damage to the plants or system.

5.1 Control Panel

The MicroLogix 1200 PLC Controllers can be used as the central control unit for the hydroponic farming system's control panel. The control panel typically includes a combination of input devices, such as toggle switches, push buttons, and sensors, and output devices, such as relays, lights, and motors.

The PLC program can be designed to read input signals from the various input devices and process them to control the output devices.

For example, the program can read the sensor values to determine the nutrient levels and adjust the nutrient dosing accordingly using the output relays. Similarly, the program can control the water flow to the plants by turning the water pump on/off based on the input from the water level sensor.

The PLC Controllers for the hydroponic farming system's control panel can provide a flexible and efficient solution for controlling and monitoring the various aspects of the system.

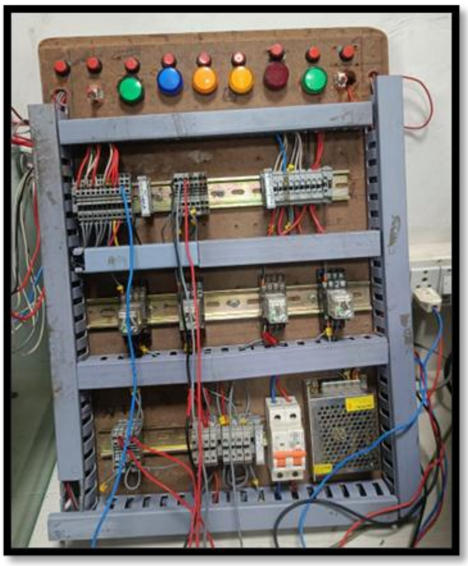


Fig -5: Control Panel

The code of the plc is based on timers, MOV instruction, LIM instruction, toggle switch and push buttons as the input.

5.2 PLC Control Panel specifications

INPUT NO.	INPUT	OUTPUT NO.	OUTPUT
I0	Stop Hydroponics	O0	Green Light
I1	Start Hydroponics	O1	Motor
I6	Stop (Expansion)	O6	Yellow Light
I7	Start (Expansion)	O7	Light Yellow Light
I8	Master Reset	O8	RED Light
I 12	Float Switch	O9	Buzzer
I 13	Bypass Buzzer		

Table 1: Control Panel

5.3 PLC Code Explanation

In this PLC program, each input and output have a specific purpose and function.

Input Signals

I0: "Stop Hydroponics" - This input is used to signal the need to stop the hydroponics system.

I1: "Start Hydroponics" - When activated, this input initiates the start of the hydroponics system. The System runs for 30 minutes ON and 30 minutes OFF, and the system runs until and unless resented using I0.

I6: "Stop (Expansion)" - This input is associated with stopping an expansion module or additional functionality.

I7: "Start (Expansion)" - When activated, this input starts an expansion module or additional functionality.

I8: "Master Reset" - This input triggers a master reset, typically used to reset the entire system.

I12: "Float Switch" - This input is connected to a float switch, which detects the liquid level or presence of liquid. If the water level is less than defined value a buzzer is runged

I13: "Bypass Buzzer" - This input indicates whether to bypass or disable the buzzer function.

Output Signals

O0: "Green Light" - This output activates a green light as an indicator when the hydroponics system is running

O1: "Motor" - When activated, this output controls a motor that is part of the hydroponics system.

O6: This output activates a Yellow Light as an indicator when the additional system is running.

O7: This output activates a Light-Yellow Light as an indicator when the additional system is Stopped.

O8: This output activates a RED Light as an indicator when the system is resented.

O9: This output activates a Buzzer as an indicator when the water level is low.

6. Results

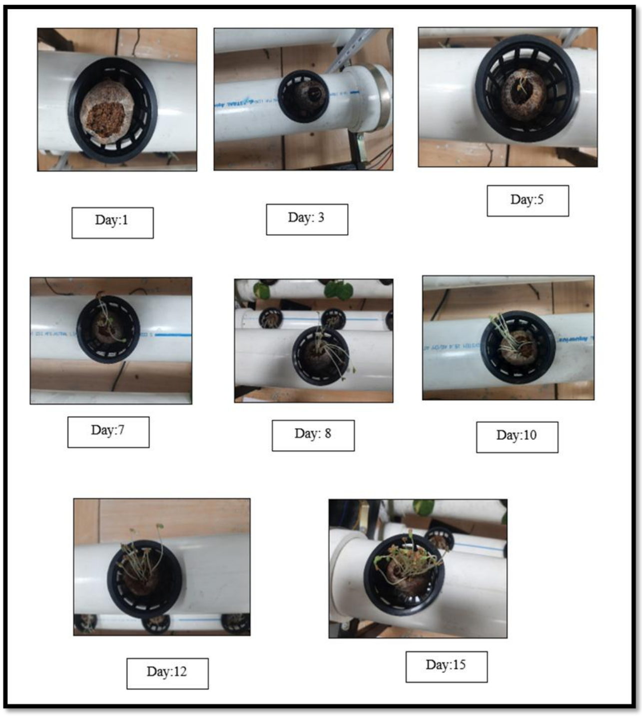


Fig -6: Final Image Capture

6.1 Calculation of leaf area by image processing method and plotting a growth graph

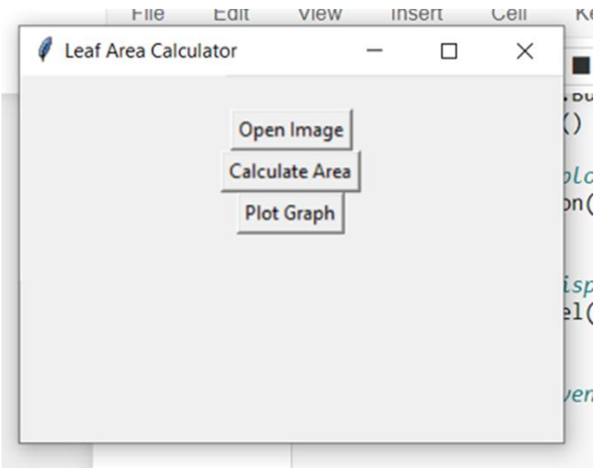


Fig-7: Leaf area Calculator GUI

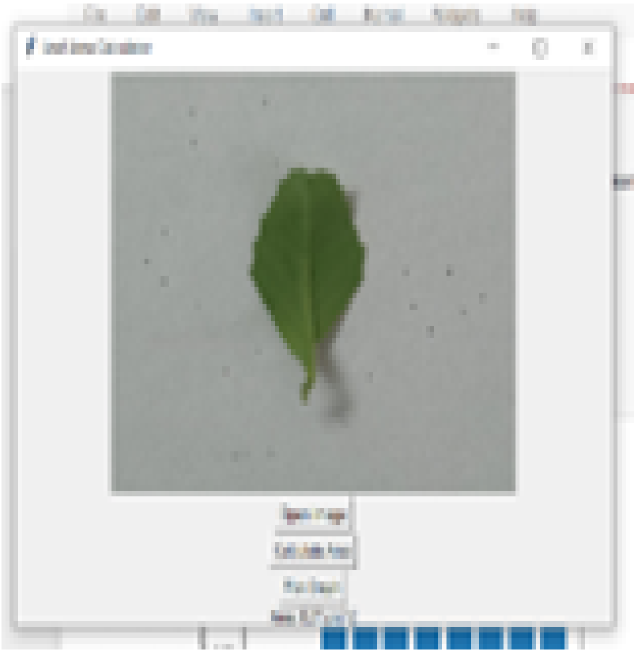


Fig -8: View of The Leaf and Its area

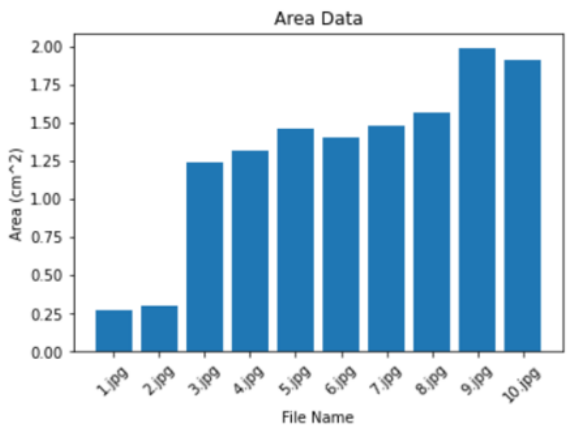


Fig -9: Plot of area calculated of sample leaf

7. Conclusion

In conclusion, the implemented automatic hydroponics farming system, featuring a PLC controller, an automatic robot for image capture, and a Python-based application for leaf area calculation and graph plotting, presents a comprehensive solution for monitoring and managing plant growth. The integration of hydroponics methodology allows for efficient water and nutrient delivery, ensuring optimal plant development. The PLC controller acts as the central control unit, orchestrating the water and nutrition supply to the plants, as well as providing essential measurements and adjustments to maintain an ideal growing environment. The inclusion of an automatic robot equipped with a camera further enhances the system's capabilities. By capturing photos of the plants at regular intervals and uploading them to Google Drive, the system enables remote monitoring of plant growth. This integration of the Internet of Things (IoT) technology adds convenience and accessibility to the monitoring process. The Python-based application serves as a powerful tool for data analysis and visualization. By calculating the leaf area from the captured images, it provides valuable insights into plant growth and system efficiency. The generated graphs offer a clear representation of the growth trends, aiding in decision-making and performance evaluation.

Looking ahead, the suggested future enhancement of incorporating machine learning for real-time monitoring and area calculation of the entire plant bush holds tremendous potential. By leveraging live camera feeds and advanced algorithms, the system can offer up-to-the-minute information on plant growth and health, facilitating proactive decision-making and precise system management.

Overall, this implemented system demonstrates the successful integration of multiple technologies to create an automated hydroponics farming solution. It showcases the benefits of combining robotics, IoT, and data analysis for effective plant cultivation and optimization of agricultural practices. With further advancements and refinements, this system has the potential to revolutionize modern farming methods and contribute to sustainable agriculture.

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