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IoT-Enabled Autonomous Smart Plant Box for Precision Agriculture

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Abstract: IoT-Enabled Autonomous smart plant box for Precise agriculture mainly aims on developing a self-controlled environment for plant using IoT. A Raspberry Pi plays as the controller Role by processing data from sensors to automate the plant requirement like watering, lighting, and air circulation and more. This involves many sensors to monitor and control environmental conditions like temperature, soil moisture, light intensity and humidity. This reduces human involvement and water wastage during the plant growth and development. A web dashboard gives with real-time data monitoring and remote controlling abilities of the Plant environmental conditions and development. This involves the electronics, coding, IoT, and biology. This makes it a platform for STEM learning and scientific research and development.
Keywords: IoT (Internet of Things), Sensors, Raspberry Pi, Controlled Environment Agriculture, Plant Monitoring, Automation, Precision Agriculture

I. INTRODUCTION

In the modern world, the relationship between technology and sustainable living is becoming increasingly important. Urbanization has resulted in the shrinking of green spaces, while the pace of daily life leaves little time for plant care. Yet, the presence of plants indoors and in urban environments offers significant benefits, including improved air quality, reduced stress, and enhanced aesthetic value. However, successful plant growth demands consistent monitoring and timely actions such as watering, lighting control, and ventilation—tasks that many people find difficult to manage regularly due to time constraints or lack of gardening knowledge.

Traditional plant care methods require manual attention, making them impractical for individuals with busy schedules or limited horticultural experience. Furthermore, plants are living organisms with specific and sometimes delicate needs. Factors such as soil moisture, temperature, humidity, and light intensity must be continuously maintained within suitable ranges for optimal growth. If these factors are neglected, even briefly, the plant's health can quickly deteriorate.

The need for intelligent, automated systems that can monitor and manage the plant's environment without constant human intervention has led to the conceptualization of the IoT-Enabled Autonomous smart plant box for Precise agriculture. This project aims to merge simple automation principles with environmental sensing to create a self-regulating system that adapts its behavior to the plant's changing needs.

II. METHODOLOGY

1) System Design and Planning
- Define the scope and objectives of automating plant care using sensor-based environmental control.
- Identify essential environmental parameters required for optimal plant growth (e.g., temperature, humidity, light, soil moisture).

2) Hardware Selection
- Use Raspberry Pi as the central controller for data processing and device management.
- Select and integrate necessary sensors: Temperature and Humidity Sensor. Water Level Sensor. Light Sensor.

3) Sensor Integration and Data Collection
- Connect sensors to the Raspberry Pi using appropriate GPIO interfaces.
- Program the Raspberry Pi to read real-time environmental data from the connected sensors at regular intervals.

4) Web Dashboard and Cloud Integration
- Develop a Flask-based web application to act as a user interface.
- Display real-time sensor readings and system status on the dashboard.

5) Data Logging and Analysis
- Store sensor data and system logs in a cloud database for further analysis.
- Use collected data to identify trends and refine control strategies over time.

6) Testing and Calibration
- Calibrate sensors to ensure accurate readings.
- Test each component individually, then test the entire system in a controlled environment.

III. OBJECTIVES

1) To Design an Automated Plant Care System: Reduce human effort by automating core plant care tasks such as watering, lighting, and environmental control. Adapt the system to meet the specific requirements of different plant types.
2) To Implement Smart Water and Environmental Management: Use real-time sensor data (e.g., moisture, temperature, humidity, light) to control irrigation and environmental conditions. Integrate AI-based adaptation techniques to optimize plant growth and minimize water wastage.
3) To Develop a Remote Monitoring and Control Platform: Enable users to monitor plant conditions and control system functions via a smartphone application or web interface. Provide real-time alerts, system status, and manual override features for convenience.
4) To Establish a Data Collection and Analytics Framework: Continuously record environmental and system performance data. Analyse trends to provide actionable insights for improving plant care routines and optimizing system behaviour over time.

IV. IMPLIMENTATION

A. Block Diagram

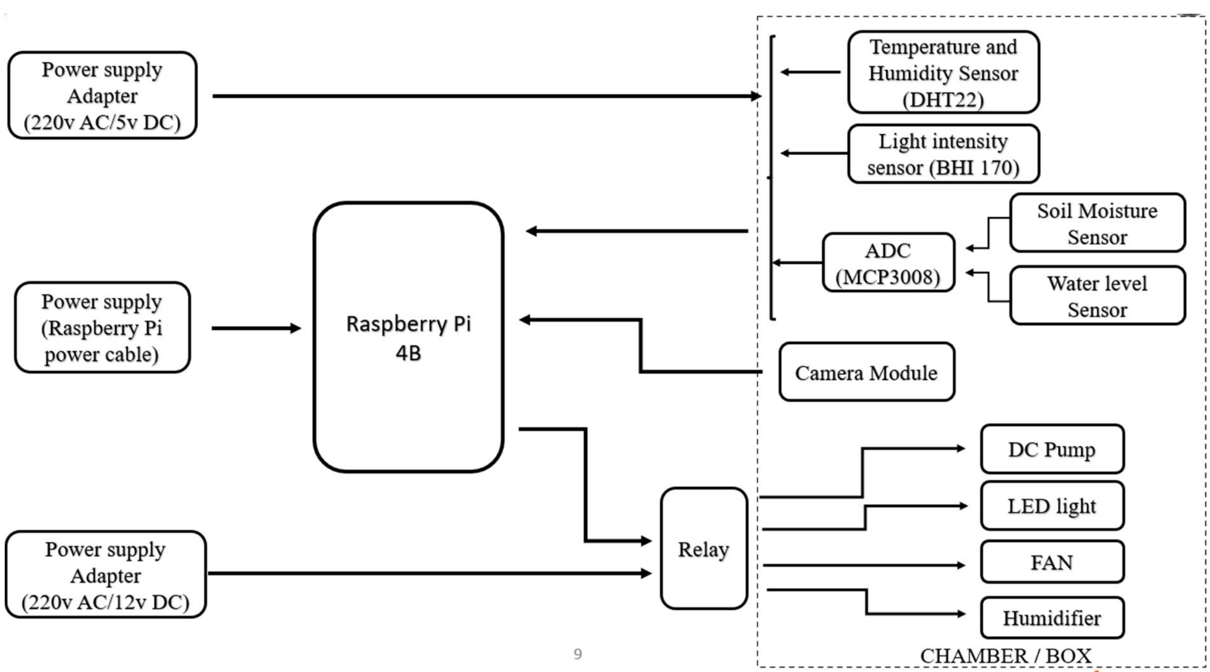

Fig 4.1: Block Diagram

B. Components Used With Specifications

SI. N0	Components	Description	Specification	Function
1.	Raspberry Pi	A series of small, low-cost, single-board computers designed to be accessible for learning and various projects from IoT and Robotics	Operating Voltage: 5V/2.5A DC Storage: Micro SD port I/O pins: Extended 40-pin GPIO header Additional inputs: Power-over-Ethernet (PoE) support (requires separate PoE HAT)	It is used to receive and analyses data from various sensors and perform required correction in the system
2.	Light sensor	It is a component used to measure the light intensity in the plant box	Operating Voltage:3.3V to 5V Measurement Range: 1 to 65,535 lux Accuracy: ±20%	It is used to measure light intensity inside the box
3.	LED Grow Light	Blue-red LEDs are used for indoor plant growing	Operating Voltage: 12V Spectrum: Blue (450–470 nm) for vegetative growth Red (620–660 nm) for flowering	It is used to provide sufficient light for optimal plant growth in a closed environment
4.	DC Water Pump	An electric water pump powered by Direct current	Operating Voltage: 12V DC Maximum Flow Rate: Up to 300 L/h Pump Type: Submersible	It is used to supply water to the plant
5.	DHT22	A digital temperature and humidity sensor module that uses a capacitive humidity and thermistor to measure environmental conditions.	Operating Voltage: 3.3V to 6V Accuracy: ±2-5% RH Temperature Range: -40°C to 80°C	It is used to measure the humidity and temperature around the environment
6.	Soil moisture sensor	It measures the volumetric water content in the soil. It helps determine whether the soil is dry, moist, or wet	Operating Voltage: 5v Moisture Range: 0-100% Sensor type: Resistive	Measures the electrical conductivity of the soil. Sends data to MCP3008
7.	Water level sensor	It detects the presence or absence of water at different levels in a tank	Operating Voltage: 5v Detection Method: Contact based.	Detects water levels in containers. Used to alert when levels are too low.
8.	Humidifier	The ultrasonic humidifier uses high-frequency vibrations to produce a fine mist, making it ideal for plant growth chambers or indoor climate control.	Operating Voltage: 5v Water mist output: 30-350ml/h Working Principle: Ultrasonic piezoelectric Transducer.	Converts water into a mist using ultrasonic waves. Increases humidity in a closed space. Helps maintain ideal humidity levels tropical plants.
9.	MCP3008	It is an ADC chip used to read analog signals from sensors (like soil moisture or light sensors) and convert them into digital values readable by digital-only	Operating Voltage: 5v Interface: SPI (Serial peripheral interface) Conversion Time:8.5 µs	Reads analog sensor values. Converts analog signals to digital. Commonly used with Raspberry Pi (which lacks built-in analog inputs).
10.	A camera module	It captures still images. It's used in plant box for visual monitoring,	Sensor: 5MP pi Camera module Video Resolution: 320p Field of View: 62°	Captures images for Plant growth monitoring Time-lapse photography

C. Working

In this project Raspberry pi acts a main processor, monitoring device and storage. It takes various parameters (Temperature, Humidity, Water Level and Moisture) from the sensors and acts accordingly to maintain optimal conditions in the chamber (box) for the plants to grow efficiently with minimal resources. Uploads the received data to cloud for long term analysis.

- DHT22, Light sensor, Moisture sensor and Water level sensor are used to monitor the conditions of the plant box. LED lights, Fan, DC Water pump and Humidifier are used to provide optimal conditions for the plant.
- Pi camera module is used to time lapse images of the plant which is controlled and stored using raspberry pi.
- Relay is used as an intermediate device for raspberry pi to control various devices in the Plant Box.
- Power adapters are used to supply power for all the components. 5V power adapter is used as supply for sensors, 12V is used for equipment's which is controlled by the relay and a Raspberry pi power cable is used to supply for Raspberry Pi.

V. MODEL PERFORMANCE ANALYSIS

A. Prototype Performance

The prototype performance of the IoT-Enabled Autonomous smart plant box for Precise agriculture is driven by its high-efficiency and control parameters. The Key performance indicators include ability to access real-time data accuracy from its sensors e.g., precise temperature, humidity, and moisture and the reliable execution of tasks, such as ON and OFF of the water pump or adjusting lighting to maintain specific environmental conditions. the prototype performs well in remote accessibility, consistently logging data to the cloud dashboard and providing timely alerts for critical conditions, which together validate its potential to significantly enhance plant health and yield while minimizing resource utilization over manual.

B. Data Logging and Monitoring

The Data Logging and Monitoring, main feature of the IoT plant box is to display all environmental and data in real-time on the web dashboard and with upload it to the cloud. This continuous, data collection and parameters like humidity, soil moisture, light intensity and temperature. serves a critical function by allowing the system to identify trends, detect diseases, and remote decision-making by the user to improve plant health and productivity.

VI. RESULTS

The project successfully demonstrates automated control over essential environmental parameters like soil moisture, light, temperature, and humidity using various sensors and actuators governed by a Raspberry Pi-based system. This minimizes human intervention while ensuring optimal growing conditions for plants. The system addresses common challenges of traditional plant care through data logging, real-time monitoring, and intelligent control mechanisms, offering a sustainable, precise, and convenient solution. The project leverages automation, IoT, and data-driven control to promote efficient plant care and reduce reliance on manual supervision. It represents a step towards smart home gardening and precision agriculture, where technology enhances natural growth processes for better sustainability and convenience.

Fig 6.1: Plant Box Image

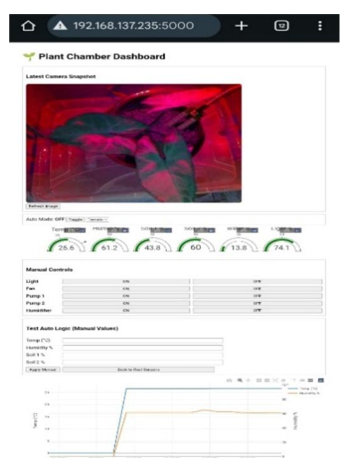

Fig 6.2: Dashboard Output

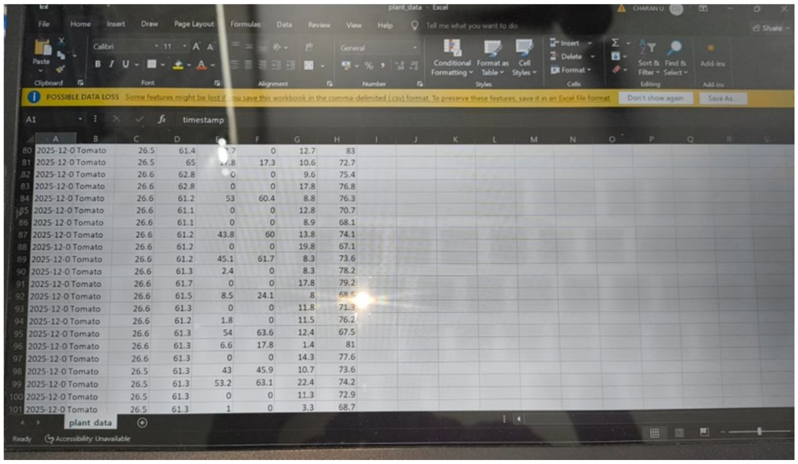

Fig 6.3: Saved data on Raspberry Pi

VII. CONCLUSION

The IoT-Enabled Autonomous smart plant box for Precise agriculture gives a successful implementation of a Controlled Environment platform driven by IoT technology. The prototype effectively includes a Raspberry Pi controller with different sensors and actuators to achieve real-time monitoring and automated control of environmental factors like humidity, light intensity soil moisture, and temperature. This system has its operational web dashboard, which shows reliable data logging and remote accessibility. By achieving precise resource management and continuous environmental optimization, the project fulfils its main objectives of enhancing plant health and productivity while laying a strong basement for future expansion into AI-driven predictive control, advanced nutrient management.

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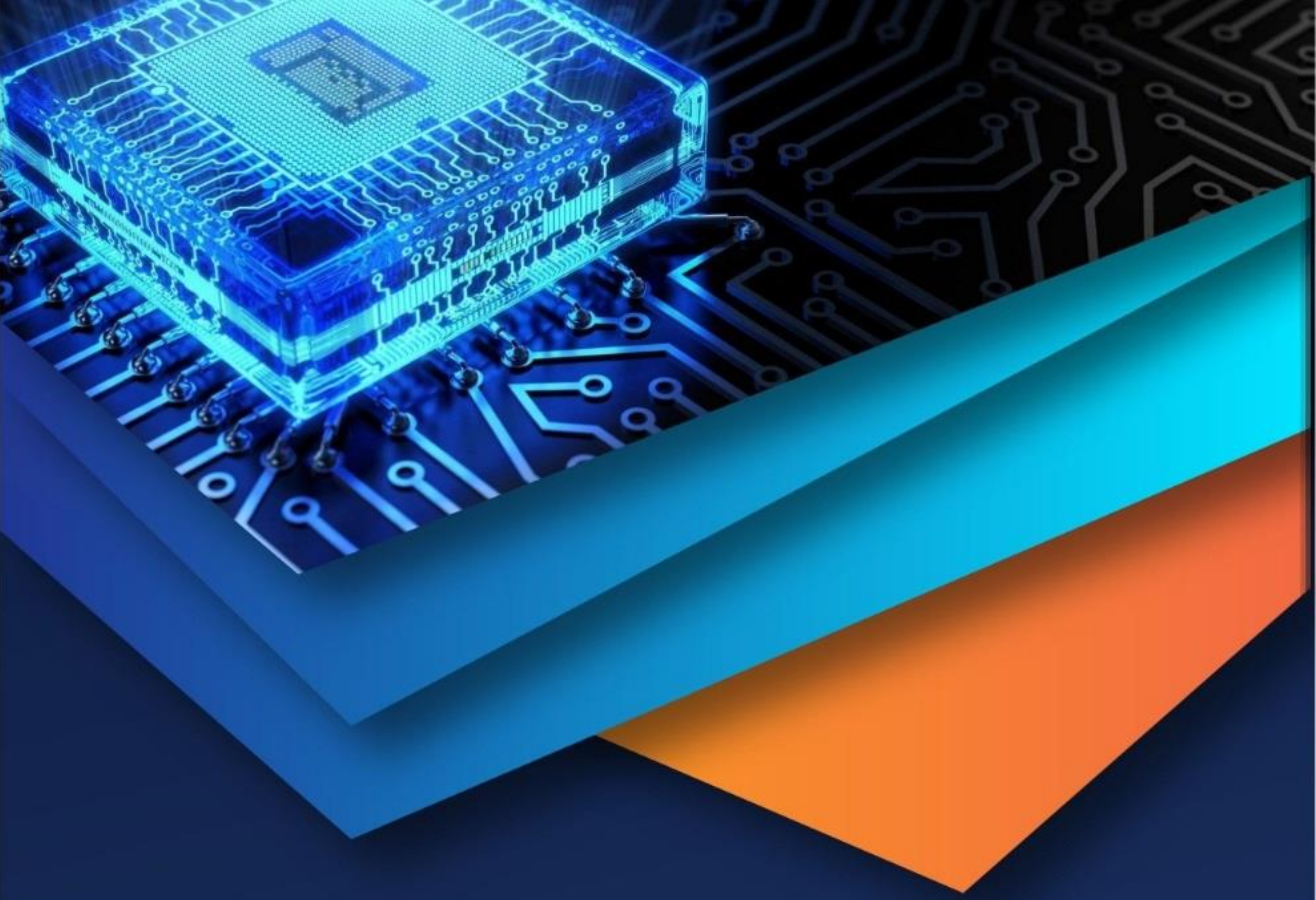

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