AEROPONICS AGRICULTURE USING IOT

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***Abstract*—Aeroponics is a technologically advanced cultivation method that requires no soil and provides nutrients to plants by spraying a mist directly onto the roots, thus reducing the consumption of water and nutrients. This paper proposes an IoT-based smart aeroponics system that uses a variety of sensors, including temperature, humidity, light, water level, TDS, and pH sensors, to receive and analyze data about the growing conditions in real time. The system is based on an ESP32 microcontroller, which is responsible for data collection and Wi-Fi communication with the Blynk platform for control and monitoring. This research is aimed at advanced food production technologies in agriculture, making it possible to apply sustainable practices.**

***Index Terms*—Aeroponics, ESP32, Blynk, IoT**

I. INTRODUCTION

The increase in food demand, contrasted with challenges like climate change, water scarcity, and soil degradation, has intensified the need for innovative agricultural practices. Traditional soil-based farming often struggles with resource-use efficiency, leading to lower productivity levels and environmental concerns.

Aeroponics emerges as a viable alternative, wherein nutrients are delivered to plant roots in the form of a fine mist. This approach maximizes water and nutrient efficiency while accelerating plant growth. The integration of IoT technology enables real-time monitoring and automation of environmental parameters such as temperature, humidity, light intensity, water level, and nutrient concentration, ensuring optimal growing conditions while reducing resource wastage.

This research presents an IoT-based aeroponics system featuring an ESP32 microcontroller, which collects data from multiple sensors and transmits it wirelessly to the Blynk platform for remote monitoring and control. A relay-based automation mechanism is implemented to regulate nutrient spraying and maintain ideal growing conditions. This proposed system aims to enhance precision agriculture, making it more efficient, scalable, and cost-effective for urban and commercial farming.

II. LITERATURE REVIEW

Aeroponic farming, a highly advanced *soilless cropping technique*, has gained significant attention due to its *efficiency, sustainability, and programmability*. Several studies have explored the role of **IoT, automation, and environmental monitoring** in aeroponic system management. This section discusses major contributions to *smart aeroponics*, identifies challenges, and highlights open research questions.

Technology Adoption in Aeroponics

Garzo´n et al. (2023) conducted a *systematic review* of aeroponics technology and introduced the **Technology Adoption and Integration in Sustainable Agriculture Model**. Their work highlights how aeroponics **increases yield, optimizes water use, and incorporates IoT for precision farming**. However, challenges such as *high initial costs and limited technology accessibility* remain barriers to adoption [1].

A. Smart Aeroponics for Indoor Farming

Fasciolo et al. (2023) described a *smart aeroponic system* for **sustainable indoor farming**, emphasizing its potential for **urban agriculture**. Their study demonstrates how **enclosed environments, coupled with IoT-based automation**, can enhance **crop growth efficiency** while reducing reliance on traditional soil-based methods [2].

B. IoT-Based Smart Agriculture for Food Security

Qureshi et al. (2022) examined *smart agriculture using IoT* and its impact on **food security**. Their study highlights how IoT optimizes irrigation, monitors plant health, and automates nutrient delivery, significantly reducing the need for manual labor [3].

C. Automation in Aeroponic Farming

Singh et al. (2023) investigated *automated aeroponic farming*, where **sensors and actuators** regulate **nutrient mist- ing, humidity, and temperature**. Their results indicate that **automation enhances productivity, minimizes water and nutrient usage, and enables ideal plant growth**, making aeroponics scalable for large-scale agriculture [4].

D. Identification of Research Gaps

Despite advancements in **automation and optimization of aeroponic farming**, several challenges remain:

- **Limited Scaling:** Most studies analyze small-scale aeroponic systems, but large-scale deployment remains underexplored.
- **Cost Barriers:** The high cost of IoT sensors and automation systems limits widespread adoption.
- **Data Integration Issues:** Further research is needed to improve **cloud-based data management and AI-driven analytics**.
- **Nutrient Optimization:** The impact of **nutrient composition** on different plant species in aeroponic systems requires further investigation.

III. OBJECTIVE

The goal of this research is to develop a smart aeroponics system that incorporates IoT technology to improve plant growth efficiency and optimize resource utilization. This study focuses on designing and implementing an automated aeroponics system that employs multiple sensors—including temperature, humidity, light, water level, TDS, and pH sensors—to continuously monitor and adjust environmental conditions [1], [2].

Using an ESP32 microcontroller for data collection and wireless communication with the Blynk platform, the system enables remote monitoring and control, minimizing the need for manual intervention [3], [4]. Additionally, a relay-based mechanism automates nutrient misting, ensuring accurate nutrient delivery to plant roots [5]. Experimental testing assesses the system's ability to maintain optimal growth parameters while minimizing resource waste [6]. Ultimately, this research aims to contribute to precision agriculture by offering a scalable, cost-effective, and sustainable solution for urban and large-scale farming [7], [8].

IV. PROPOSED DESIGN

The developed IoT-based aeroponics system enhances plant growth efficiency by automating the monitoring and control of environmental factors. The system architecture integrates multiple components, including environmental sensors, a microcontroller, a relay-controlled misting mechanism, and a cloud-based monitoring platform.

A. System Architecture

The IoT-based aeroponic system is designed to automate plant growth monitoring and control. It consists of four key components: the **sensor module**, **microcontroller unit**, **communication module**, and **actuation system**. These elements work together to gather real-time data, analyze conditions, and adjust parameters accordingly.

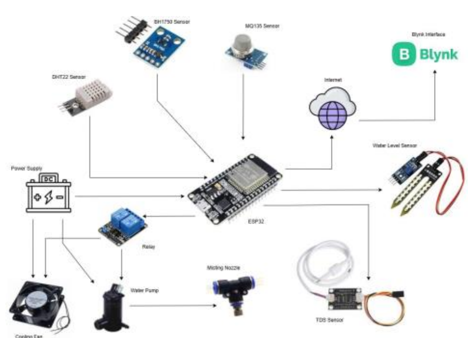

Fig. 1. Block diagram of IoT workflow

B. Sensor Module

To maintain optimal growing conditions, the system continuously collects data using various sensors:

- **DHT22 Sensor:** Monitors temperature and humidity to ensure a stable environment.
- **BH1750 Light Sensor:** Measures light intensity to regulate artificial lighting.
- **Water Level Sensor:** Prevents water depletion by detecting reservoir levels and sending alerts.
- **TDS Sensor:** Ensures proper nutrient concentration in the water for plant growth.

C. Microcontroller Unit (ESP32)

The **ESP32** serves as the system's central controller, processing sensor data and making necessary adjustments. It continuously monitors environmental conditions and communicates with the cloud via built-in **Wi-Fi**, allowing remote access through the **Blynk IoT platform**.

D. Communication Module

The system employs **Wi-Fi-based communication** to transmit sensor data and receive user commands. The **Blynk app** provides a user-friendly interface for real-time monitoring and manual control. Future upgrades may integrate the **MQTT protocol** to enhance scalability.

E. Actuation System

The system automates necessary actions based on sensor readings:

- **Water Sprayer:** A relay-controlled pump mists plant roots at regular intervals.
- **DC Fan:** Activates when temperature or humidity exceeds predefined limits to improve airflow.
- **Future Scope:** Future implementations may include an automatic nutrient and pH regulation system.

F. Power Supply Management

The system is built around an ESP32 microcontroller, which is responsible for managing various sensors and actuators. To ensure continuous and stable operation, a well-regulated power supply is essential.Furthermore, the power supply unit plays a critical role in delivering the required voltage and current to support the connected sensors, relays, and motors. The custom-designed PCB circuit for the ESP32, along with its power management components is shown below

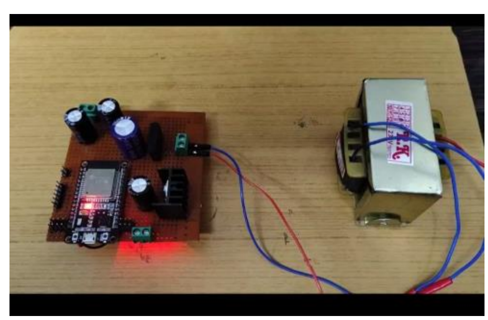

Fig. 2. Power Supply Circuit for ESP32 and Actuators in Aeroponics System

V. METHODOLOGY

The IoT-based aeroponic system is designed to automate plant growth monitoring and control using sensors, a microcontroller, and wireless communication. The system operates in several key phases, ensuring efficient and real-time environmental regulation.

A. Hardware Setup

The system is built around an ESP32 microcontroller, which is responsible for managing different sensors and actuators.The power supply unit ensures that all components receive a stable voltage, preventing fluctuations that could impact performance. Several capacitors and voltage regulators are integrated into the circuit to maintain consistent power delivery. Additionally, a cooling fan is included to prevent overheating of crucial components.This prototype allows for testing and debugging before finalizing the PCB design, ensuring that all connections and functionalities operate correctly. The setup includes temperature, humidity, water level, and gas sensors, which help monitor environmental conditions in the aeroponics system.

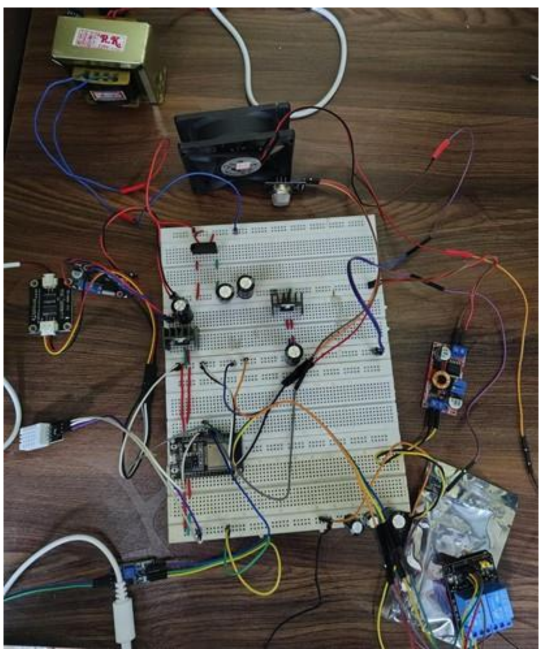

Fig. 3.Hardware setup of Aeroponics System

B. Data Collection through Sensors

The system continuously monitors environmental parameters using multiple sensors. The **DHT22** records temperature and humidity, while the **BH1750 light sensor** detects ambient light intensity. A **water level sensor** ensures sufficient water availability, and the **TDS sensor** monitors the concentration of dissolved nutrients in the water. The collected data is processed in real-time by the ESP32.

C. Automated Control Mechanism

Based on sensor readings, the system takes necessary actions to maintain optimal conditions. If the temperature or humidity exceeds a predefined threshold, a **DC fan** is activated to regulate airflow. When the water level drops below a set point, a **relay-controlled water pump** is turned on to replenish the system. This automation minimizes manual intervention while ensuring an optimal growing environment.

D. Wireless Communication and Monitoring

The ESP32 connects to the **Blynk IoT platform** via Wi- Fi, allowing real-time monitoring and control through a mobile app. Users can view sensor data, receive alerts when thresholds are exceeded, and manually override system actions if needed. Future improvements may integrate **the MQTT protocol** for enhanced scalability and device communication.

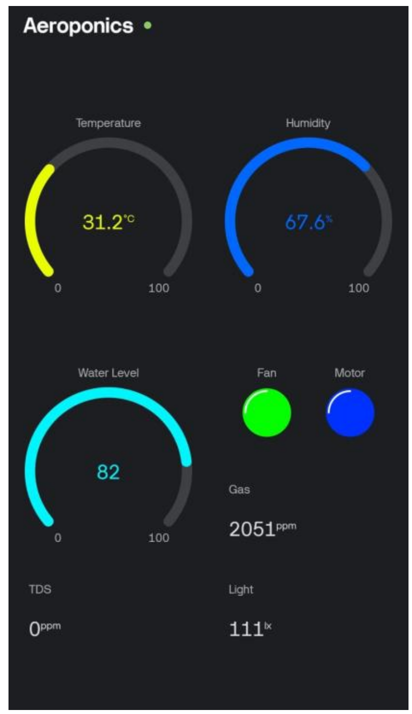

Fig. 4. Blynk data

E. Conclusion

This methodology ensures efficient and automated aeroponic system operation. By leveraging IoT, users can remotely monitor and control the system, reducing manual effort and ensuring optimal plant growth conditions.

VI. APPLICATIONS

The IoT-based aeroponic system is an advanced agricultural solution designed to optimize plant growth through automation. It has various practical applications that enhance efficiency, sustainability, and ease of farming. One major application is in **urban and indoor farming**, where traditional soil-based cultivation is not practical. By utilizing a nutrient-rich mist instead of soil, this system is ideal for **vertical farms, rooftop gardens, and hydroponic setups**. Continuous monitoring ensures plants receive optimal conditions, leading to improved yield and quality. Another key application is in **precision agriculture**, where automation helps regulate water, nutrients, and airflow with minimal manual intervention. IoT integration allows farmers to monitor and adjust growing conditions remotely, reducing labor while maximizing productivity. The system also sends **real-time alerts** when environmental factors exceed set thresholds, enabling quick corrective actions.

Additionally, the system is useful in **agricultural research and education**. Researchers and students can study plant growth under controlled conditions, collecting real-time data for analysis. This helps in understanding plant health, growth patterns, and environmental impact, contributing to advancements in agricultural science.

For regions experiencing **water scarcity**, this system offers an effective solution. By delivering nutrients directly to plant roots in a fine mist, it significantly reduces water consumption compared to conventional irrigation methods. This makes it highly beneficial for **drought-prone areas** and **sustainable farming projects** where water conservation is essential.

VII. Future Scope

The IoT-based aeroponic system has significant potential for further development, enabling greater efficiency, automation, and sustainability in modern agriculture. Several advancements can be integrated to enhance system performance and expand its applications.

One promising improvement is the integration of **AI and machine learning algorithms** to analyze historical sensor data and predict optimal environmental conditions. By implementing predictive analytics, the system can make intelligent adjustments to water, nutrients, and airflow, reducing waste and improving crop yield.

Another potential enhancement is the incorporation of **automated nutrient and pH regulation**. By adding sensors and actuators for real-time monitoring and correction, the system can maintain precise nutrient concentrations, reducing human intervention and ensuring optimal plant health.

The adoption of **solar-powered systems** can further increase energy efficiency, making the system viable for remote locations and off-grid farming. Renewable energy integration will enhance sustainability and reduce dependency on conventional power sources.

Additionally, expanding **IoT connectivity with MQTT protocols and cloud-based data storage** can improve system scalability and remote accessibility. Advanced communication protocols will allow seamless data exchange between multi- ple aeroponic units, enabling large-scale, automated farming networks.

Overall, continued advancements in IoT, AI, automation, and renewable energy will shape the future of aeroponic farming, making it more intelligent, efficient, and sustainable.

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