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IoT Enhanced Smart Aeroponics System

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Abstract: ***Recently, urban farming has gained popularity as people become more aware of the quality of their food. Aeroponics is an urban farming technique that uses air as its growing medium. Compared to traditional farming and hydroponics, aeroponics offers a significant reduction in water usage while increasing yield. This study introduces an aeroponics system integrated with Internet of Things (IoT) technology for real-time and automated monitoring. The system maintains the pH level of the nutrient solution using a pH sensor and monitors temperature and humidity with an A DHT sensor. A peristaltic pump, coupled with a ultrasonic sensor, regulates the tank's liquid level. All these processes are accurately timed and shared on the ThingSpeak Platform and Blynk App for user interaction, facilitated by the ESP 32 Micro controller.***
Keywords: Aeroponics, Ultrasonic sensor, ESP 32 CAM, Ph sensor, Esp 32 MC.

I. INTRODUCTION

The cornerstone of organic farming is healthy soil. However, soil degradation and nutrient pollution are detrimental effects of traditional soil-based agriculture on the environment. These challenges have spurred the development of urban farming methods. Among them, aeroponics stands out as a promising approach. Aeroponics replaces soil with air or mist as the growing medium, eliminating the need for soil or bulky substrates. The term "aeroponics" originates from the Greek words for "air" and "labour," namely "aero" and "ponos." Unlike traditional hydroponics, aquaponics, and plant tissue culture, aeroponics offers a distinct approach to cultivation. While hydroponics and aquaponics rely on water, fish waste, and liquid nutrient solutions as growing mediums, aeroponics uses mist or air. Though nutrients are delivered through a water-based mist in aeroponics, it's sometimes considered a subset of hydroponics. The shift in the food industry over the last two decades has been influenced by a growing global awareness of health and food quality. The public is increasingly concerned about nutrition and food safety. Urban gardening has gained momentum as people grow more aware of the food quality they consume. Aeroponics, an urban farming technique that utilizes air as its growing medium, has emerged as a notable method. Unlike hydroponics or conventional farming, aeroponics offers a substantial reduction in water usage while increasing yield. This study utilizes the Internet of Things (IoT) to develop and deploy an aeroponics system equipped with online and automated monitoring features.

II. LITERATURE REVIEW

Modern agricultural technologies have become increasingly sophisticated, leveraging resources such as labor, land, and natural resources more efficiently. The latest advancements in automation for aeroponic systems have gained widespread recognition and adoption due to their innovative approach to cultivation, requiring specialized expertise and technological support. Significant research efforts have been invested in automating aeroponic systems. The study [1],introduced an independent automated system designed for indoor small-scale farming in urban settings, eliminating the need for soil or manual watering. This automation enables consistent delivery of fresh produce to individuals not actively involved in gardening. Additionally, it facilitates real-time system monitoring through a web service that offers parameter data. The authors concluded that integrating a pH sensor to assess the nutrient solution's quality would enhance the system's accuracy and efficiency, further automating its functionality. The paper [2], proposed an Internet of Things (IoT) Hydroponics Agriculture system using web and mobile applications. This system enables monitoring, control, and delivery of plants' nutritional and water requirements through IoT technology. The research findings indicated that the plants thrived under the specified nutritional and environmental conditions over a six-week period, as evidenced by visual inspections and computer vision analysis of plant growth. The paper[3], developed and implemented an IoT system for real-time monitoring of temperature and light levels in an aeroponics chamber. Without controls, the root chamber temperature reached 32.9°C. However, with careful control, the temperature was maintained at an average of 28.8°C, which is optimal for plant growth. Water spinach was chosen as the test plant, and the results demonstrated that the plants thrived within the aeroponics chamber.

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The paper [4] Based on the information gathered, it is evident that integrating automation into the existing

1) The current system lacks monitoring and feedback mechanisms for temperature, humidity, and pH levels.
2) The growth rate is relatively slow compared to other systems.
3) The water supply to the plants is not automated through a timer.
4) There is no automatic refill mechanism for the tank's water level.
5) To address these challenges, I have outlined my proposed solutions, which will be detailed in the subsequent chapters of this project.

III. EXISTED MODEL

In the current aeroponics approach, plants are typically housed in a plastic container that fits into holes on a platform positioned above a reservoir. Due to the lack of traditional root zone material, support collars are essential to hold the plant stems securely. These collars need to be sturdy yet flexible, allowing space for root growth while maintaining the plants' upright position and securing the roots. The pump system generate mist by atomizing the nutrient-rich solution, spreading mixture of water, nutrients, and growth hormones into the plastic container. This mist envelops and nourishes the exposed plant roots.

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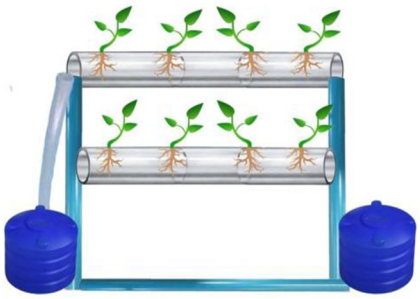


Fig1: Existing System

The project aims to achieve the following objectives:

1) Create a prototype capable of automatically maintaining pH, temperature, and water levels.
2) Design the system to operate without requiring any user interaction once it is turned on.
3) Develop an IoT-based monitoring system that generates daily reports to minimize user maintenance.
4) Design the prototype to be environmentally friendly, relying solely on stored electricity in its battery.
5) Provide a compact space for optimal plant growth.

IV. PROPOSED MODEL

The ESP32 microcontroller orchestrates the operations of the entire system, providing precise timing and control to various components based on the uploaded program. Relays are employed to deliver power signals to output devices such as pumps .depending on the signals received from the microcontroller. An ESP32 Wi-Fi module serves as an intermediary, transmitting sensor data to both the ThingSpeak platform and the ThingView app. A pH sensor is utilized to monitor and regulate the water's pH level, ensuring it remains neutral. Additionally, a Temperature & Humidity sensor gauges the ambient air temperature. Lastly, an ultrasonic sensor is deployed to monitor and manage the water level in the tank without making direct contact with the water.The system comprises the following key components

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V. HARDWARE CMPONENTS

A. ESP 32 Microcontroller

In this project The ESP32 micro controller used as it is a powerful and versatile chip that combines Wi-Fi and Bluetooth capabilities with a dual-core processor, making it suitable for a wide range of applications. It offers low power consumption, high performance, and a rich set of peripheral interfaces, making it ideal for Internet of Things (IoT) projects, home automation, wearable devices, and more.

B. ESP32 CAM and Wi-Fi Module

The ESP32 micro controller, combined with a camera module, can create a powerful IoT device capable of capturing and transmitting images or video over Wi-Fi or Bluetooth connections. The ESP32's built-in Wi-Fi and Bluetooth capabilities make it an excellent platform for developing camera-based IoT applications.

C. Potential of Hydrogen (pH) Sensor

pH stands for "Potential of Hydrogen," representing the concentration of hydrogen ions in a solution. A pH sensor measures the acidity or alkalinity of a substance on a scale ranging from 0 to 14pH. In our project, we use a gravity analog pH sensor with a response time of less than a minute and an accuracy of 0.1pH. To connect with the micro controller and capture the pH sensor's input signal, the sensor is equipped with a BNC connector.

D. Ultrasonic Sensor

An ultrasonic sensor is a type of sensor that uses sound waves with frequencies higher than the human audible range to measure distance to an object or detect its presence. These sensors emit ultrasonic waves and then measure the time it takes for the waves to bounce back after hitting an object. Based on this time measurement, the sensor can calculate the distance to the object.

E. 2-channel Relay

A 2-channel relay is a device that allows you to control two separate circuits using a single control signal. Each channel can independently switch on or off a circuit 2-channel relay typically has two separate circuits (channels).Each channel has three terminals: Normally Open (NO), Normally Closed (NC), and Common (COM).When the relay is activated by applying a control signal (usually a low voltage or current), it switches the connection between the NO and COM terminals, effectively closing the circuit.

F. Temperature/Humidity Sensor Module

The AM1011A is a cost-effective digital temperature and humidity sensor. It utilizes both a thermistor and a capacitive humidity sensor to accurately measure the humidity levels in the air. The sensor provides a digital output signal through its data pin. Known for its accuracy, long-term stability, and ease of use, the AM1011A is a reliable choice for monitoring environmental conditions.

G. Submersible Pump

In this project, I've employed the Sunsun JQP 1000 series submersible pump, which is directly installed inside the tank. This pump draws the nutrient solution from within the tank. It has a power **c**onsumption of 14 W, a flow rate of 1000 L/hr, and can lift water up to a height of 1.4 meters.

H. HW Batteries

In this project,we use Hardware batteries, often referred to as hardware-embedded batteries, are built-in power sources found in various electronic devices, particularly laptops, smartphones, and tablets. These batteries are designed to be non-removable and are integrated into the device's hardware.

I. Software Requirements

In this project, we used the Arduino IDE for programming the Arduino the ThingSpeak online platform for data visualization, and the ThingView App to display both current and previous sensor readings and easy Eda tool for schematic diagrams of the project
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VI. WORKING

A. Block Diagram of the Proposed System

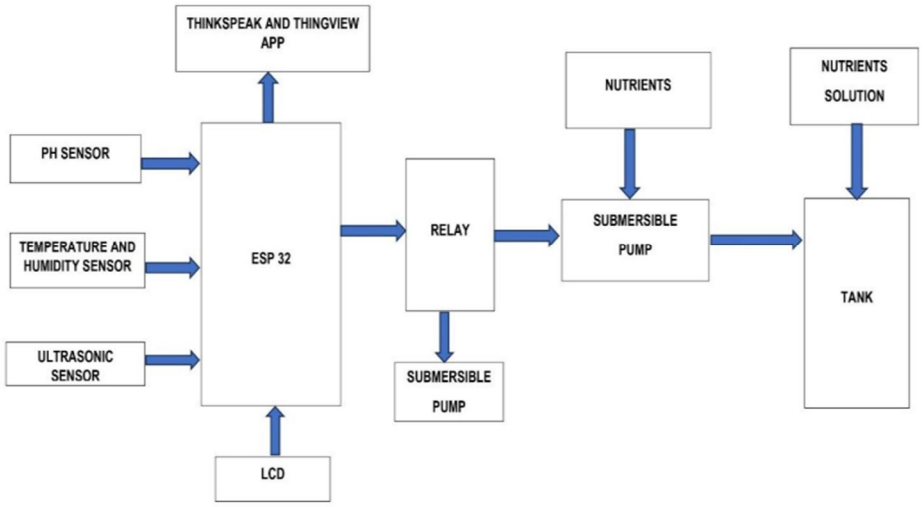


Fig 2: Circuit daigram

In this system, the ESP32 micro controller controls all the operations, providing proper timing and instructions to the corresponding components based on the uploaded program. Relays are employed to supply power signals to output devices such as pumps and fans, according to the micro controller's signals. The ESP32 Wi-Fi module acts as an intermediary, transmitting sensor data to both the ThingSpeak platform and the ThingView app. A pH sensor is utilized to measure the water's pH level and maintain it at a neutral point; any pH value changes trigger the activation of a peristaltic pump to normalize it. Additionally, a Temperature & Humidity sensor monitors the air temperature within the system. Lastly, a non-contact Liquid Level sensor is employed to manage the water level in the tank without direct contact with the water.

In this project, the pH level of the nutrient solution is measured using a pH sensor. . The ultrasonic sensor ensures that the submersible pump maintains the correct head level. If the level decreases, second submersible pump is activated to restore it. To maintain a consistent temperature, the AM1011A sensor is paired.Relay mechanisms control the opening and closing of circuits. The submersible pump is activated by a relay circuit with a 20-second ON and 2-minute OFF time sequence. For user interaction, an ESP32 CAM is used. The Thing View app shows real-time pH, temperature, and humidity values, while the ThingSpeak web platform displays daily charts of pH, temperature, and humidity.

VII. RESULTS

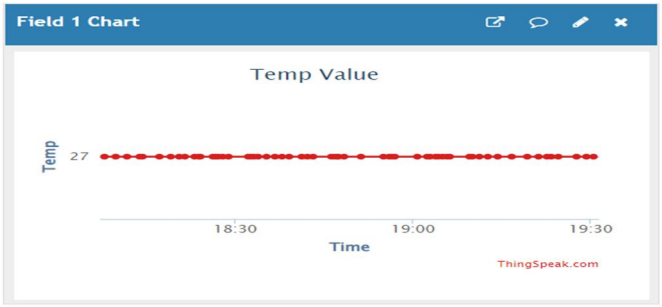
After conducting multiple tests on the automation system, it was observed that the micro controller successfully gathered data from all connected sensors and devices. This data was then transmitted to both the ThingSpeak web platform and the ThingView app.During the conducted tests, the ESP32 CAM successfully collected and transmitted essential data regarding plant growth to the mobile application. By connecting to the IP address 192.168.81.39 through a web browser, live video streaming of the farms is possible. I planted four different varieties—Mint, Cowpea, Ladyfinger, and Chili—to assess their compatibility when grown using the same nutrient solution. The results indicate that they can thrive together using the same formulation, as all responded positively. The growth of these crops was monitored and controlled for a period of 15 days. The plant growth evaluation utilized computer vision based on data acquisition and application by the ESP32 CAM micro controller. Figure 16 displays the results of the plant growth evaluation.The platform displays the real-time temperature, humidity, and pH values. During the conducted tests, these sensors reliably gathered and transmitted the required data to the micro controller.

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Fig.3 Final Setup of project



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Fig :4 Atmospheric Temperature Sensor Data

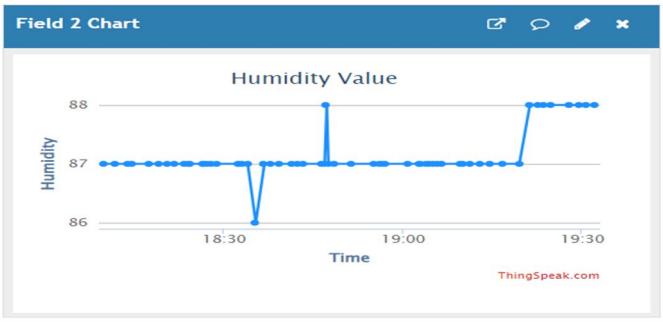


Fig :5 Relative Humidity SensorData

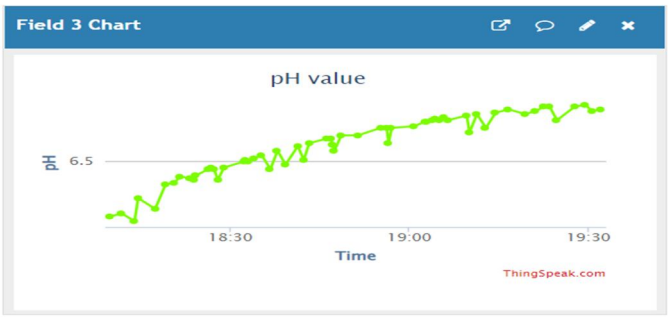


Fig :6 pH Sensor Data

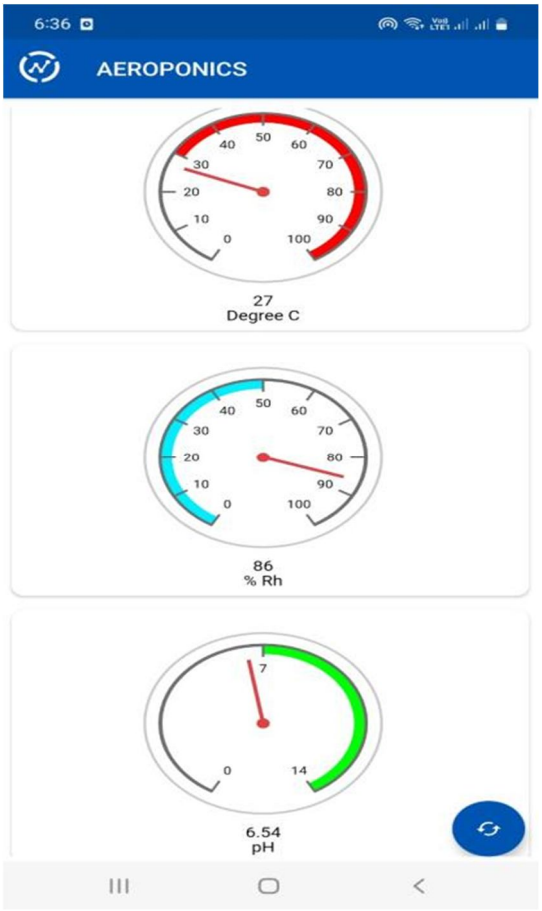


Fig :7 ThingView Domain Data

VIII. ADVANTAGES

1) The pH level is preserved.
2) The temperature is managed.
3) The water level is retained.
4) User engagement is high.
5) Requires less attention.
6) The Space consumption is low

IX. APPLICATIONS

1) Vertical Farming
2) Urban Agriculture
3) Remote Monitoring and Control
4) Data Analytics and Optimization
5) Hybrid Systems
6) Data Analytics and Optimization
7) Integration with IoT Devices

X. FUTURE SCOPE

Looking ahead, there are several avenues for further research and development in the field of aeroponics and IoT-enabled urban agriculture. Firstly, there is a need for continued innovation in sensor technology, data analytics, and automation systems to improve the reliability, scalability, and affordability ,of IoT-integrated aeroponic systems. Additionally, research efforts should focus on optimizing nutrient formulations, plant genetics, and environmental control strategies to maximize crop productivity and quality.Future research could focus on optimizing the integration of IoT technology within aeroponic systems to further enhancetheir performance and unactionality. This could Involve developing more advanced sensor networks, improving data analytics algorithms, and refining automation processes to achieve greater precision and efficiency in monitoring and control.There is scope for exploring advanced environmental monitoring techniques, such as hyperspectral imaging and remote sensing, to provide more detailed insights into plant health, growth patterns, and nutrient uptake in aeroponic systems. By leveraging these technologies, farmers can make more informed decisions and optimize growing conditions for maximum productivity. As cities become increasingly interconnected and data-driven, there is an opportunity to integrate IoT-enabled aeroponic systems with broader smart city initiatives. This could involve leveraging urban data platforms, sensor networks, and predictiveanalytics to optimize resource allocation, transportation logistics, and urban planning strategies for more sustainable and resilient urban food systems. While aeroponics offers numerous benefits, there is still room for exploring novel growing techniques and hybrid systems that combine aeroponics with other methods such as hydroponics, aquaponics, or vertical farming. These integrated approaches could leverage the strengths of each method to further enhance resource efficiency, crop diversity, and overall productivity.

Efforts should be made to enhance the accessibility and affordability of aeroponic systems, particularly in undeserved urban areas and developing regions. This could involve developing low-cost, modular solutions, providing training and support for small-scale farmers, and exploring innovative financing models to facilitate widespread adoption and impact. Future research should also focus on developing supportive policy and regulatory frameworks to incentivize the adoption of aeroponic systems and promote sustainable urban agriculture more broadly. This could involve implementing incentives for urban farming, establishing standards for food safety and quality, and integrating urban agriculture into broader urban planning and development strategies.

XI. CONCLUSION

Moreover, as urbanization continues to accelerate and the global population grows, the demand for sustainable food production solutions in urban environments will only increase. The integration of aeroponics with IoT technology offers a scalable and adaptable approach to meeting these challenges head-on.

Looking forward, there is immense potential for further innovation and refinement in the field of aeroponics and IoT-enabled urban agriculture. Continued research and development efforts can focus on optimizing system design, enhancing sensor technology, and improving data analytics ,algorithms to maximize efficiency and productivity

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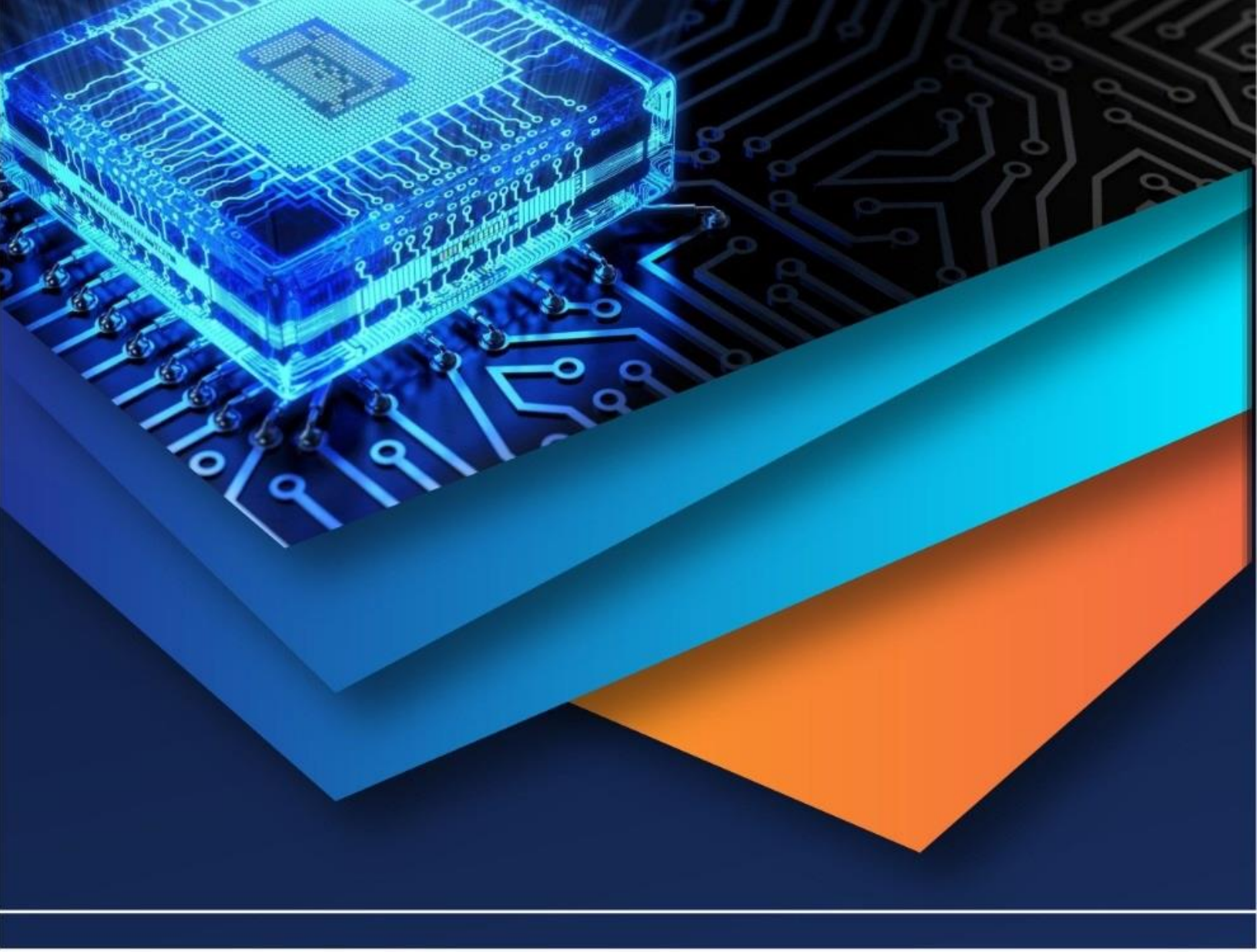
Additionally, exploring synergies with other emerging technologies such as artificial intelligence, block chain, and renewable energy can further enhance the sustainability and resilience of urban agriculture systems. Collaborative initiatives involving researchers, practitioners, policymakers, and community stakeholders will be essential in driving progress and ensuring the widespread adoption of these innovative solutions.

In conclusion, the integration of aeroponics with IoT technology holds great promise for creating more sustainable, resilient, and equitable food systems in urban areas. By harnessing the power of technology, interdisciplinary collaboration, and community engagement, we can pave the way for a brighter future where urban agriculture plays a central role in addressing the challenges of food security, environmental sustainability, and socioeconomic development.

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