INTEGRATED DESIGN FOR AEROPONIC PLANT CULTIVATION SYSTEM USING IOT

1.K.R.Gokul Anand, 2. G. Jayamurugavel, 3. V. Jaga vishnu, 4. K. Ranjith Kumar 5.K. Kaviyarasu
Department of Electronics and Communication Engineering,
Dr. Mahalingam College of Technology, Tamilnadu, India,

Abstract- The integration of Internet of Things (IoT) technologies into aeroponic plant cultivation systems offers a promising avenue for advancing precision agriculture. This project aims to design and implement an integrated aeroponic cultivation system that leverages IoT sensors and actuators for real-time monitoring and control of environmental parameters. Utilizing tools such as Arduino Uno, NodeMCU, and various sensors and modules including ultrasonic sensors, temperature sensors, air quality sensors, water pump modules, and relay modules, the system seeks to optimize resource utilization, automate critical processes, and enhance crop yield and sustainability. Through remote monitoring, data analytics, and automated decision-making, this project aims to foster a more resilient and technologically advanced approach to aeroponic farming, thereby contributing to the advancement of precision agriculture and sustainable food production. Keywords: Aeroponic cultivation, Internet of Things (IoT), Precision agriculture, Remote monitoring, Automation, Sustainability.

Keywords- IOT (internet of things), Aeroponic plant, Data analytics, Sensors-Air Quality sensor, Water Pump Module, Temperature Sensor

I.INTRODUCTION

In recent years, there has been a growing interest in sustainable and efficient methods of agriculture to meet the increasing demand for food production while minimizing resource consumption and environmental impact. Aeroponic systems have emerged as a promising solution, offering efficient nutrient delivery to plants while using minimal water and space compared to traditional soil-based methods. Integrating Internet of Things (IoT) technology with aeroponic systems further enhances their capabilities by providing real-time monitoring, control, and optimization, thus maximizing yields and resource utilization. This project aims to develop an integrated design for an aeroponic plant cultivation system utilizing IoT technology. By combining aeroponics with IoT, we seek to create a smart and automated solution for optimized plant growth, which can be remotely monitored and managed. The integration of IoT into aeroponic systems offers several advantages. Firstly, it enables precise monitoring of environmental variables such as temperature, humidity, pH levels, and nutrient concentrations, allowing for immediate adjustments to optimize growing conditions. Secondly, IoT facilitates remote access to system controls, enabling users to monitor and adjust parameters from anywhere with an internet connection. Thirdly, IoT technology enables data collection and analysis, providing valuable insights into plant growth patterns and system performance over time, thus supporting informed decision-making and continuous improvement. This project will involve the design and development of both hardware and software components. The hardware will consist of sensors for monitoring environmental variables, actuators for controlling system parameters such as nutrient delivery and airflow, and a microcontroller or single-board computer to interface between the sensors, actuators, and IoT platform. The software will encompass the development of an IoT application or platform for data visualization, remote monitoring, and control of the aeroponic system. Overall, this integrated design for an aeroponic plant cultivation system using IoT holds significant potential for revolutionizing modern agriculture by offering a more efficient, sustainable, and technologically advanced approach to plant cultivation. By harnessing the power of IoT, we aim to create a system that not only maximizes yields but also minimizes resource consumption, labor requirements, and environmental impact, ultimately contributing to a more resilient and food-secure future.

RELATED WORK

Dr. Krishna Gopal Singh: Dr. Singh [1] has published several research papers and articles on IoT applications in agriculture, including aeroponic systems. His work often focuses on integrating IoT sensors and actuators into agricultural systems to improve crop yield and resource efficiency.

Dr. Ramesh C. Gupta: Dr. Gupta [2] is known for his research in both aeroponics and IoT. His work often explores the optimization of aeroponic systems using IoT technology for real-time monitoring and control. He has published extensively on topics related to smart agriculture and precision farming.

Dr. Simon Blackmore: Dr. Blackmore's [3] research primarily focuses on agricultural automation and robotics. He has contributed significantly to the development of IoT-enabled farming systems, including aeroponic cultivation setups. His work often emphasizes the use of sensor networks and data analytics for optimizing crop production.

Dr. Lammert Kooistra: Dr. Kooistra's [4] research intersects aeroponics, IoT, and remote sensing technologies. He has worked on projects involving the integration of IoT devices with aeroponic systems to collect data on plant health and environmental conditions. His work also explores the use of machine learning algorithms for predictive analytics in agriculture.

Dr. Manoj Kumar Arora: Dr. Arora's work [5] includes research on IoT-based smart farming systems, with a focus on aeroponics. He has explored the development of IoT-enabled platforms for monitoring and controlling aeroponic farms remotely. His research often addresses challenges related to data acquisition, communication protocols, and decision support systems in smart agriculture

II. SYSTEM ARCHITECTURE

A. *Integrated design combines hardware components with Arduino*

The integration of various components such as a switch, 16x4 display, water pump module, exhaust fan, humidity sensor, and air quality sensor into an Arduino Uno board forms the backbone of a sophisticated aeroponic plant cultivation system. This system is designed to provide optimal growing conditions for plants while leveraging IoT capabilities for remote monitoring and control. At the heart of the system lies the Arduino Uno board, acting as the central processing unit and orchestrating the operation of all connected components. The switch serves as a manual input mechanism, allowing users to toggle specific functions or modes of operation. The 16x4 display provides real-time feedback and information display, offering insights into various parameters such as temperature, humidity, nutrient levels, and system status. The water pump module is responsible for delivering nutrient-rich water to the plant roots in a controlled manner, ensuring proper hydration and nutrient uptake. An exhaust fan helps regulate air circulation within the growing environment, preventing stagnation and maintaining optimal oxygen levels. Additionally, the humidity sensor and air quality sensor continuously monitor environmental conditions, allowing the system to adjust parameters accordingly for optimal plant growth. In terms of system architecture, the Arduino Uno board acts as the central hub, interfacing with each component through digital or analog input/output pins. The sensors provide real-time data to the Arduino, which then processes this information and triggers appropriate actions based on predefined thresholds or user-defined settings. For example, if the humidity sensor detects a decrease in humidity below a certain threshold, the Arduino may activate the water pump module to irrigate the plants and increase humidity levels. Similarly, if the air quality sensor detects elevated levels of pollutants, the Arduino can activate the exhaust fan to improve air circulation and quality within the growing environment.

.

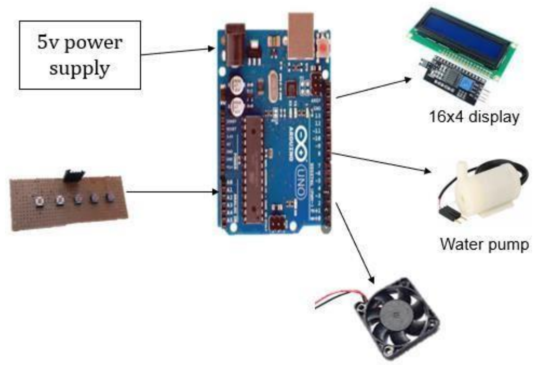


Fig. 1. Functional block diagram of Arduino connection

A. *Integrated design combines hardware components with NodeMCU*

The ultrasonic sensor is connected to the NodeMCU's GPIO pins for both trigger and echo signals. These waves bounce off nearby objects, including the plants, and return to the sensor. By timing how long it takes for the waves to come back, the NodeMCU can figure out how far away the plants are. This helps in understanding the proximity of the plants and adjusting the LED light accordingly for their optimal growth. The plant grow LED is connected to another set of GPIO pins on the NodeMCU. The NodeMCU controls the LED's brightness and duration based on the measured distance from the plants and predefined lighting requirements for optimal growth. The NodeMCU runs a firmware that includes code for reading data from the ultrasonic sensor, controlling the plant grow LED, and handling Wi-Fi connectivity for remote monitoring and control. Optionally, the NodeMCU can be connected to a Wi-Fi network to enable remote monitoring and control of the system. Users can access a web interface or a mobile application to view real-time data from the ultrasonic sensor and adjust the LED settings as needed

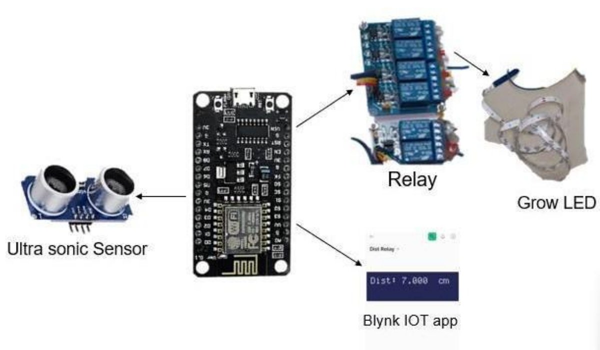


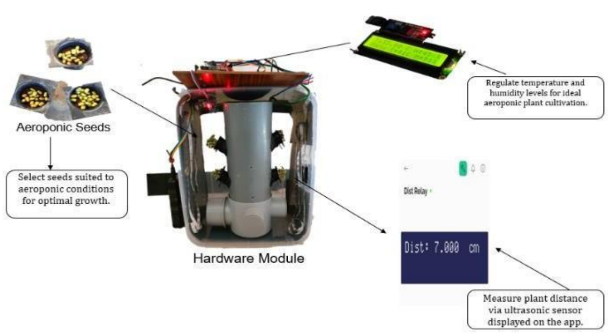
Fig 2 Functional block diagram of NodeMCU connection

A. *Blynk app connection to NodeMCU*

The IoT eyeblink sensor project, where an app monitors ultrasonic values, the system architecture revolves around the utilization of a NodeMCU microcontroller. The NodeMCU is interfaced with both the eyeblink sensor and the ultrasonic sensor, acting as the central processing unit for data acquisition and transmission. The eyeblink sensor detects eye movements, while the ultrasonic sensor measures distances. These sensor readings are then processed by the NodeMCU, which sends the data to a designated mobile application through Wi-Fi connectivity. The mobile app serves as a monitoring interface, displaying real-time ultrasonic values to users. This setup allows for remote tracking of ultrasonic data, enabling users to monitor environmental conditions or object distances from their smartphones or tablets

III.SYSTEM DESIGN

Fig.2 shows the proposed project aims to develop an innovative sensor based Aeroponic Plant Cultivation System Using IOT. The integrated design offers numerous functionalities and benefits for both farmers and consumers. By leveraging IoT technology, farmers can remotely monitor and manage the cultivation environment, thereby reducing the need for manual intervention and maximizing operational efficiency. Real-time data analytics enable proactive decision-making, minimizing risks associated with environmental fluctuations and ensuring consistent crop quality. Moreover, the system promotes resource efficiency by optimizing water and nutrient usage, leading to significant cost savings and environmental sustainability. From a consumer perspective, the adoption of aeroponic cultivation supported by IoT ensures access to fresh, pesticide-free produce year-round, meeting the growing demand for healthy and locally sourced food.



.

Manual Mode Operation:

- In manual mode, the system operates continuously without temperature threshold checks.
- Relay control is solely based on manual button inputs for temperature and humidity adjustments.

4. Sensor Data Processing:

- Collected data is displayed on the LCD screen, facilitating real- time monitoring.
- Air quality readings are obtained from the air quality sensor, influencing relay control based on predefined thresholds.

5. Ultrasonic Distance Sensing:

- Ultrasonic sensor readings determine proximity to plants, controlling another relay for supplementary actions like lighting.
- Actions are executed based on predefined distance thresholds, ensuring optimal environmental conditions for plant growth.

Return bounding boxes, confidences, and class IDs

6. Data Logging and Serial Output:

- Sensor readings, including temperature, humidity, air quality, and ultrasonic distance, are logged and printed via the serial interface.
- This facilitates debugging and monitoring of system performance, aiding in fine-tuning and optimization.

The pseudo code of the system is as follows.

1. Setup and Initialization:

- The code begins by including necessary libraries and defining constants for pins and sensor parameters.
- Pins are initialized for sensors, buttons, and relay control, alongside setting initial temperature and humidity values.

2. Main Loop Execution:

- Within the loop, sensor data is collected for temperature, humidity, and ultrasonic distance.
- If operating in auto mode, the relay controlling the aeroponic system is triggered based on temperature thresholds.

The hardware model of the proposed system comprises several key components. Firstly, a series of sensors, such as temperature and humidity sensors, are deployed within the aeroponic chambers to monitor the immediate growing conditions. Additionally, nutrient sensors are integrated into the nutrient delivery system to ensure precise nutrient levels are maintained Furthermore, actuators, including pumps and valves, are employed to regulate the delivery of nutrients and water to the plants based on the data received from the sensors. This enables the system to automatically adjust parameters such as nutrient concentration and water flow rates to optimize plant growth and health. Moreover, IoT-enabled controllers serve as the central processing unit of the system, facilitating communication between the various sensors and actuators. These controllers are equipped with microprocessors capable of running sophisticated algorithms for data analysis and decision-making. They also provide connectivity to the internet, allowing users to remotely monitor and control the cultivation system via a smartphone app or web interface

.

The hardware model is designed to be modular and scalable, allowing for easy expansion and customization based on the specific needs of the user. Additionally, the use of IoT technology enables seamless integration with other smart agricultural systems, such as weather monitoring stations or automated pest control systems, further enhancing the efficiency and productivity of the overall farming operation.

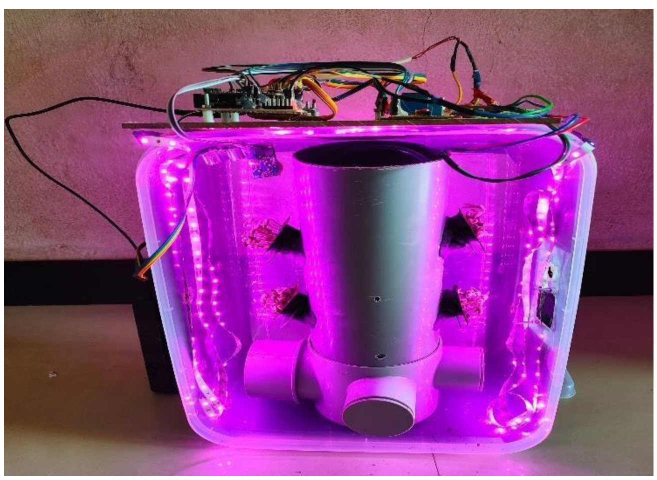


Fig.4. Final output

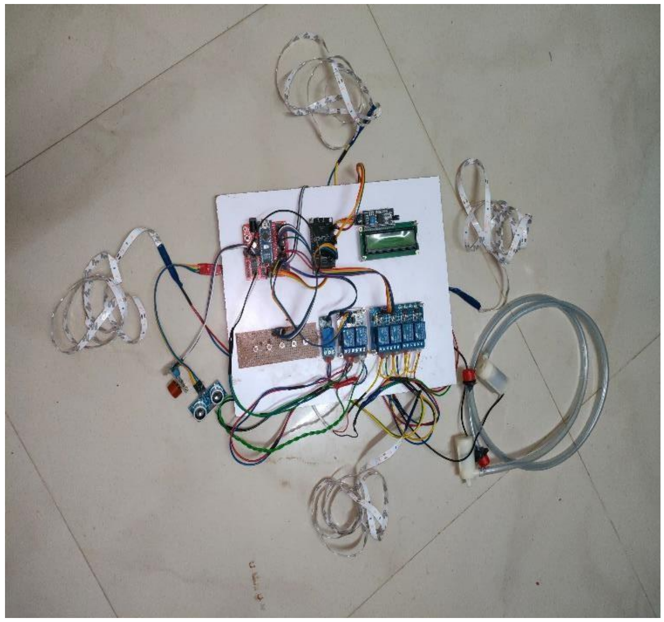


Fig. 3. Hardware module

V.CONCLUSION

In conclusion, the integrated design of the aeroponic plant cultivation system using Arduino, NodeMCU, grow LEDs, sensors, and IoT technology demonstrates a robust solution for optimized plant growth and management. By leveraging IoT, real-time monitoring and control of environmental variables such as temperature, humidity, nutrient levels, and light intensity are facilitated. The synergy between Arduino and NodeMCU enables efficient data processing and communication, while the incorporation of grow LEDs ensures tailored light spectra for enhanced photosynthesis. Overall, this system offers a scalable and automated approach to aeroponic cultivation, paving the way for sustainable and high-yield agricultural practices.

REFERENCES

[1] Wang X, Gao X, Liu Y, Fan S, Ma Q "Progress research on the regulatory pathway of the plant shade-avoidance syndrome. Front Plant" Sci 11:439,2020

[2] Gokul Anand. K. R, Rajalakshmi. N. R, Karthik.S "Hydroponics a Sustainable Agriculture Production System" ISSN: 2278-3075, Volume-9 Issue-6, April 2020

[3] S.Boopathy ,Gokul Anand.K.R ,N.R.Rajalakshmi "Smart Irrigation System for Mint Cultivation through Hydroponics Using IOT" ISSN: 0193- 4120 Page No. 13706 – 13714. May – June 2020

Zheng L, He H, Song W "Application of light-emitting diodes and the efect of light quality on horticultural crops: a review"
[4] HortScience 54:1656– 1661,2019.

[5] Herman and Nico Surantha "Intelligent monitoring and controlling system for hydroponics precision agriculture", 7th International Conference on Information and Communication Technology (ICoICT) Kuala Lumpur, Malaysia. 2019

[6] M. A. Romli, S. Daud, P. L. E. Kan, Z. A. Ahmad and S. Mahmud, (2017)"Aquaponic growbed siphon water flow status acquisition and control using fog server," 2017 IEEE 13th Malaysia International Conference on
[7] Communications (MICC), Johor Bahru, pp. 224Thakare et al., (2018) "Decision Support System For Smart Farming With Hydroponics Style"- International Journal of Advanced Research in Computer Science Volume 9, No. 1.

[8] Tanabut Changmai et al., (2018) "Smart Hydroponic Lettuce Farm using Internet of Things"- 10th International Conference on Knowledge and Smart Technology (KST) 31 Jan.-3 Feb. 2018.

[9]M. A. Romli, S. Daud, P. L. E. Kan, Z. A. Ahmad and S. Mahmud, (2017)"Aquaponic growbed siphon water flow status acquisition and control using fog server," 2017 IEEE 13th Malaysia International Conference on Communications (MICC), Johor Bahru, pp. 224-228.

[10] Olaf Witzel, Stefan Wilm, Divas Karimanzira, Daniela Baganz,(2019) "Controlling and regulation of integrated aquaponics production systems – An approach for a management execution system (MES)" Information Processing In Agriculture 6 - 326–334.

[11] Brandon Yep, Youbin Zheng (2019) "Aquaponic trends and challenges- A review" Journal of Cleaner Production 228 -158