Home Compact Aquaponic Devices with 24×7 Observability on Hand.

S. Sridharan[1, a)], M. Sivakumaran[1, b)], K. Arunkumar[1, c)], M. Alaguvel[1, d)], Dr. S. Tamilselvi[1, e)]

[1]*Department of Electronics and communication Engineering, National Engineering College, Kovilpatti, India*

Abstract:

Aquaponics represents an environmentally conscious approach to food production, integrating aquaculture and hydroponics to cultivate fish and crops without traditional soil. It establishes a cost-effective symbiotic cycle between fish and plants. Within the aquaponic system, fish waste, primarily in the form of ammonia, is directed into the plant bed. Here, the plant bed serves as a biofilter, extracting essential nitrates required for the optimal growth of vegetation. This method underscores a sustainable and interdependent relationship between aquatic life and plant cultivation. This structure enables achieving self-sufficiency due to the fact that, with this approach, plants flourish at a rate three times faster than conventional farming, even within household gardens. Moreover, it eliminates the need for pesticides and fertilizers, while reducing water consumption by up to 90%, achieved by recycling the pristine and nutrient-rich water indefinitely. This initiative encompasses various functionalities, such as temperature monitoring and regulation through a heat source and cooling fan, identification of water pH using a pH sensor, and a pump for purifying and re-circulating the water. And in our product, we are goes to reducethe size of the device in a compact manner and control the level of pH by using some dilutes and acids which met how do Aquatic animals and green plants can be cultivated efficiently with minimum waste, space, and maintenance using the IoT based Observability across 24×7 on hand.

Keywords: Arduino Uno, Water level Sensor, Temperature sensor, Total Dissolved Solvent Sensor (TDS), pH Sensor, Micro Servo Motor.

INTRODUCTION

In an era characterized by burgeoning global populations and heightened environmental concerns, innovative solutions that address both food production and resource conservation have never been more critical. Aquaponics, a fusion of aquaculture and hydroponics, has emerged as a sustainable and efficient method for cultivating fish and plants while minimizing waste and conserving water. While the promise of aquaponics is substantial, the need for precision control and real-time monitoring has led to the development of a groundbreaking project: the "Aquaponic Monitoring System with 24x7 Observability on Hand." This project's integration of temperature sensor, water level sensor, pH sensor, UV sensor, Micro servo motor for fish feeding, TDS sensor, and real-time clocks sets it apart as a sophisticated and highly adaptable approach to home-based aquaponic systems. The "Aquaponic Monitoring System with 24x7 Controllability on Hand" represents a comprehensive solution for individuals interested in sustainable, home-based aquaponics. As the world grapples with food security issues and environmental challenges, this project embodies a forward-thinking approach that combines technology and agriculture. It provides the ability to create a closed-loop ecosystem that cultivates both fish and plants, all while offering unparalleled control and observability using a handheld device. This project's foundation lies in its seamless integration of various sensors, each serving a unique purpose in maintaining the aquaponic ecosystem Temperature Sensors: Monitoring the water temperature within the fish tank is crucial to ensuring the well-being of fish and plant species. Fluctuations in temperature can have a significant impact on growth rates and overall system health. Water Level Sensors: Maintaining the appropriate water levels in the system is essential to ensure proper nutrient distribution and prevent waterborne diseases. These sensors provide real-time data on water levels. pH Sensors: Maintaining optimal pH levels in an aquaponic system is critical for nutrient absorption by plants and the overall health of fish. pH sensor continuously monitors these levels. UV Sensor: Natural light is a cornerstone of photosynthesis in plants. These sensors monitor the UV light conditions in the environment where the aquaponic system is installed, enabling users to optimize plant growth. Micro Servo Motor: Automating fish feeding is a fundamental aspect of managing the aquaponic system. The micro servo motor precisely dispenses food to fish at set intervals, eliminating the need for manual feeding. Total Dissolved Solvent (TDS) Sensor: TDS sensors play a crucial role in determining the overall water quality. They provide data on the total nitrogen content in the fish tank water, ensuring that conditions are optimal for fish and plant growth. Real-Time Clock: The inclusion of a real-time clock allows users to schedule and control fish feeding based on a predefined timeline. This feature enhances the convenience and effectiveness of the aquaponic system. Controllability and observability**.** The hallmark of this project is its emphasis on controllability and observability. By integrating these sensors and actuators, users have the unique capability to manage and monitor their aquaponic systems via a handheld device. Whether it's adjusting the feeding schedule for fish, regulating water temperature, or optimizing lighting conditions, this level of control empowers individuals to customize their aquaponic setup according to their specific needs and preferences Crafted to cater to a diverse spectrum of users, this design holds promise for a multitude of applications across different areas. City Residents: People residing in urban settings frequently encounter restricted availability of fresh, locally cultivated produce. This initiative empowers urban dwellers to cultivate their own food in a space-efficient manner, fostering sustainability and self-sufficiency. Remote Areas: In remote or underserved regions where access to fresh food is limited, this technology offers the opportunity to establish small-scale, sustainable food production systems. Educational Institutions: Schools and educational institutions can utilize this project to teach students about sustainable agriculture and technology, fostering an understanding of environmental responsibility. Community Organizations: Community gardens and food cooperatives can implement this system to enhance their efforts to promote local, sustainable agriculture. Commercial Aquaponic Farms: Even large-scale aquaponic farms can benefit from the controllability and observability features, optimizing production and resource management. the "Aquaponic Monitoring System with 24x7 Observability on Hand" represents a pioneering approach to sustainable agriculture. By integrating a suite of sensors and control mechanisms, this project empowers individuals, educators, and communities to harness the benefits of aquaponics with unprecedented precision and convenience. With its potential to transform food production and enhance environmental responsibility, this project has the power to benefit a wide range of users and regions, contributing to a more sustainable and food-secure future.

LITERATURE SURVEY

Considerable research has been conducted on the aquaponics system, with a wealth of papers accessible, as indicated in the list of references. [1] to [10]. the realm of aquaponics and IoT-enabled monitoring systems [1], the integration of IoT technology proves instrumental in providing real-time monitoring, ensuring optimal conditions for fish and plant growth. Notably, An Internet of Things (IoT)-enabled aquarium monitoring device, proficient in capturing crucial parameters like water levels, broadens its utility to encompass extensive industrial applications, including the management of aquaponics fish and fish farming. The literature emphasizes the role of smart farming (SF) in sustainable agriculture [2], utilizing advanced technologies like sensors, communication, big data, and actuators to enhance crop quantity and quality with minimal labor interference. SF systems commonly involve remote surveillance, autonomous operation, and intelligent decision-making frameworks. Furthermore, the synthesis of aquaponics and IoT for sustainable development is explored, acknowledging aquaponics' contribution to resource utilization and environmental solutions [3]. Successful applications of IoT in aquaponics involve intelligent monitoring and control strategies to ensure the system's normal operation. Automation technologies, including fuzzy logic control, play a crucial role in controlling essential parameters such as electrical conductivity (EC) in aquaponics cultivation, ensuring optimal plant growth [4]. Fuzzy logic systems prove effective in controlling EC values without overshoot. The literature introduces an automated aquaponics system using IoT technology, addressing land scarcity and climate change concerns through continuous monitoring of parameters like pH value and temperature range [5]. The growth of an automatic aquaponics systems surpasses that of traditional fishkeeping and hydroponics, showcasing the efficiency of IoT-enabled solutions. Innovations in aquaponics, such as Integrated Multi-Trophic Aquaculture (IMTA), demonstrate advancements in addressing water flow challenges and wireless data transmission for siphon control [6]. Themes of variable pumping speeds and wireless control contribute to water level management and siphon functionality. In the context of urban aquaponics with ICT technology, the literature explores the transformation of commercial aquaponic systems into home/urban models to reduce food miles and carbon emissions [7]. The adoption of ICT transforms aquaponics systems into self-sustaining models, enhancing efficiency and sustainability. A focus on smart home aquaponics for food security [8] highlights systems equipped with sensors, actuators, and IoT connectivity to empower households in generating their own fish and plants. The efficacy of the system in monitoring, controlling, and recording water and air quality is emphasized Automated aquaponics systems utilizing emerge as solutions to manual control challenges, highlighting automated feeding, control of water quality, management of lighting, and regulation of temperature. [9]. Object detection algorithms, like YOLO, enhance efficiency by detecting excess fish feed and adjusting feeding rates, ensuring optimal fish health. Lastly, the application of fuzzy logic control systems in aquaponics cultivation for EC value control is discussed, demonstrating successful monitoring and adjustment of pump motor duration [10]. Fuzzy logic systems operate without overshoot, emphasizing their reliability in maintaining controlled EC values in aquaponics systems.

PROPOSED ARCHITECTURE

3.1 General architecture of the proposed system

The aquaponic device is generally composed of variety of sensors, and plays a crucial role in aquaponic devices by providing real-time data and enabling precise control over environmental conditions. These sensors help monitor various parameters to ensure the health and well-being of both fish and plants in the system. This technological synergy ensures a harmonious and efficient aquaponic setup, aligning with principles of sustainability and maximizing the benefits of this integrated farming approach. The suggested system frequently employs sensors and control algorithms to empower the aquaponic setup in sensing and influencing its surroundings. This may encompass sensors detecting temperature, water level, and pH, along with actuators regulating the water flow within the arrangement.

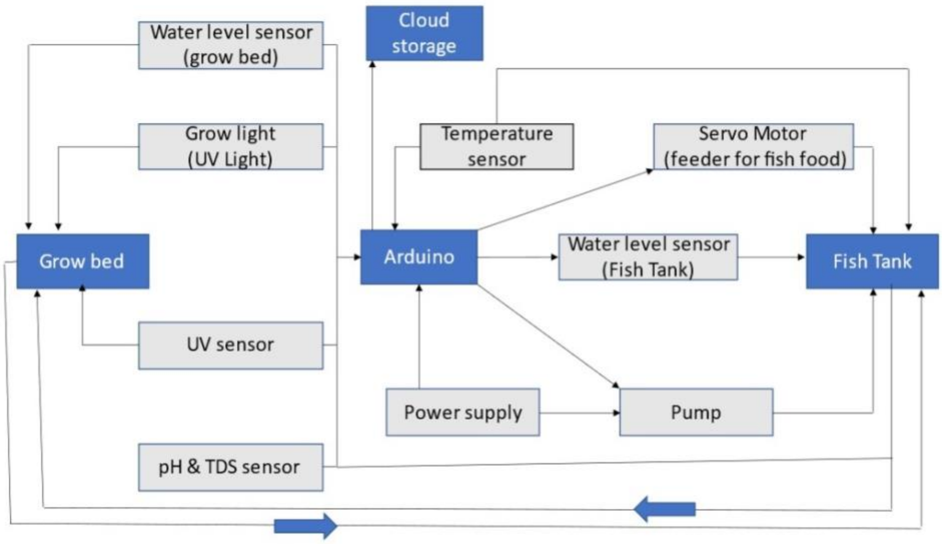

FIGURE 1. Aquaponic device architecture.

As depicted in Fig. 1. The Aquaponic Device depicted in the figure is structured into the following segments:

- Circuit connection of sensors with Arduino
- Components used
- Power Supply Board using PCB

3.2 Circuit connection of sensors with Arduino Uno

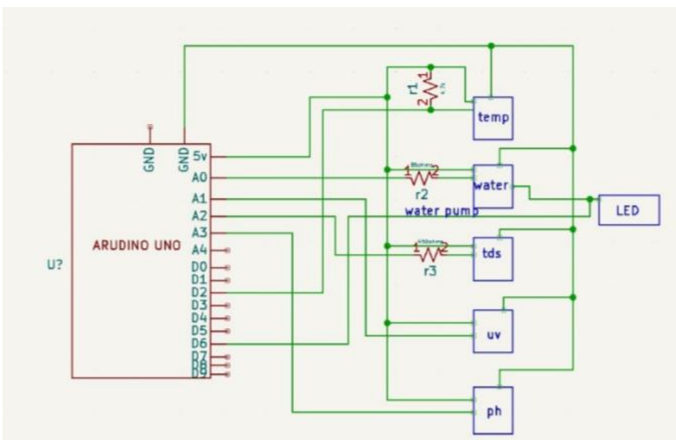

FIGURE 2. Sensors Connection with Arduino Uno

3.3 Components used

The Aquaponic device system encompasses the subsequent components:

- Microcontroller (Arduino UNO – R3)
- Leak detection sensor
- Temperature sensor
- pH sensor
- TDS senor
- Micro Servo motor

3.3.1 MICROCONTROLLER (ARDUINO UNO - R3)

Serving as the cornerstone of the Arduino system, the microcontroller board harmonizes seamlessly with the high-performance ATmega328P chip. This singular marvel of a chip operates at a robust 16 MHz and boasts indispensable features, including a ceramic resonator, six analog inputs, and 14 digital input/output pins, six of which can serve as Pulse Width Modulation outputs. Enabling connectivity, the microcontroller incorporates a power plug port, ICSP header, reset button, and a USB port pivotal for transmitting code from a computer to the Arduino. The default power supply for the Arduino stands at 5V, ensuring consistent and dependable performance. All essential components are meticulously integrated to bolster the multifaceted functionalities of the microcontroller. At the core of Arduino's functionality lies a user-friendly programming environment, allowing for the creation of efficient code, its upload onto the board, and the seamless interaction of the microcontroller with a myriad of components.

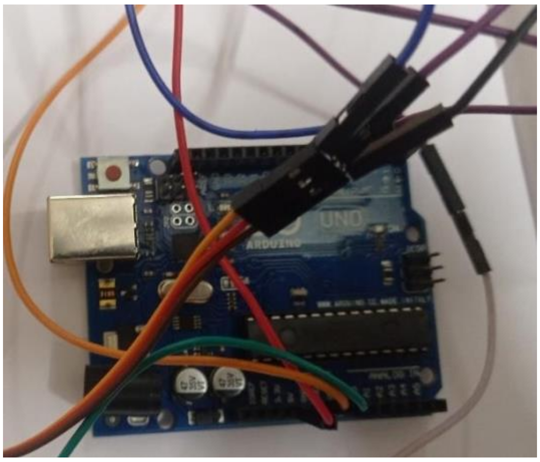

FIGURE 3. ARDUINO UNO R3

3.3.2 Leak Detection sensor

The water level sensor/leak detection sensor is a 3-pin module that produces an analog signal (typically ranging from 0 to 500), signifying the approximate depth of water submersion. When employed alongside a pull-up resistor, it can function as a digital device, signaling the presence of water. Operating at 5 volts, it delivers readings within the range of -30 to 50 degrees Celsius. The array of exposed parallel conductors collectively acts as a variable resistor, akin to a potentiometer, with its resistance adjusting based on the water level. The shift in resistance correlates inversely with the distance from the sensor's top to the water surface, providing a reliable indication of water height.

FIGURE 4. LEAK DETECTION SENSOR

3.3.3 Temperature Sensing Device

The DS18B20 is a digital temperature sensor widely employed on various applications due to its accuracy and versatility. designed by Maximum Integrated, this sensor operates on the One-Wire communication protocol, allowing multiple sensors to be connected in parallel while requiring only a single data line. The DS18B20 offers Temperature can be measured within a range spanning from -55°C to +125°C, exhibiting an accuracy of ±0.5°C across this range. Its compact and durable design, encapsulated in a waterproof stainless-steel casing, makes it suitable for applications in diverse environments, including aquaponics. Furthermore, the sensor's low power consumption, broad temperature range, and ease of integration with microcontroller make it a popular choice for monitoring and control systems. The DS18B20's versatility and reliability have positioned it as a go-to solution for precise temperature measurements in a wide array of industries and applications.

FIGURE 5. TEMPERATURE SENSOR

3.3.4 pH Sensor

The pH sensor serves as a vital instrument designed for the measurement and monitoring of acidity or alkalinity levels in solutions, especially in aqueous settings. Its significance extends across diverse industries, encompassing agriculture, environmental monitoring, and laboratory applications. Grounded on electrochemical principles, pH sensors identify the concentration of hydrogen ions in a solution, offering a quantitative assessment of its pH. The adaptability of pH sensors enables real-time monitoring, facilitating timely adjustments to uphold optimal pH levels tailored to specific processes or applications. And having an operating voltage like 5 voltages and current consumption of 5 to 10 mA. In aquaponic systems, the role of pH sensors is particularly pivotal, contributing to the regulation of water conditions and the creation of an ideal environment for both fish and plants. With their precision and responsiveness, pH sensors assume a pivotal role in sustaining the general well-being and thriving of aquatic ecosystems, along with their application in diverse industrial processes.

FIGURE 6. pH SENSOR

3.3.5 Total Dissolved Solvent Sensor (TDS)

The Total Dissolved Solvent (TDS) sensor is a crucial component within aquaponic devices, providing essential insights into water quality by measuring the concentration of dissolved substances. Operating on the principle of electrical conductivity, the TDS sensor detects inorganic and organic particles, including minerals and salts, offering real-time data for precise nutrient management in aquaponic systems. The sensor typically operates within a specific voltage range, commonly around 5 volts, making it compatible with standard microcontroller systems commonly used in aquaponic setups. Its low current consumption, often in the range of a few milliamperes, ensures energy efficiency and a prolonged sensor lifespan. In terms of design, TDS sensors are compact and durable, featuring a probe that can be immersed directly into the water. The probe design often includes materials resistant to corrosion, ensuring longevity even in aquatic environments. Some TDS sensors may come with waterproof enclosures, adding an extra layer of protection against moisture and potential damage. Their user-friendly design allows for easy integration into aquaponic monitoring systems, contributing to the efficient management of dissolved solids and supporting the overall health of both aquatic organisms and plants within the aquaponic ecosystem.

FIGURE 7.TDS SENSOR

3.3.6 Micro Servo motor

In aquaponics automation, and other domains requiring meticulous movement control, servo motors stand out as a common type of motor. Functioning as rotary actuators, they provide precise management over rotational angle, speed, and direction. A conventional servo motor comprises a gearbox, a control circuit, and a DC motor. Signals from the control circuit instruct the motor on the degree and direction of rotation. The gearbox plays a crucial role in amplifying the motor's torque, facilitating precise movement of substantial loads. Servo motors find widespread application in automated equipment, robotics, CNC machines, and 3D printers, among other technologies.

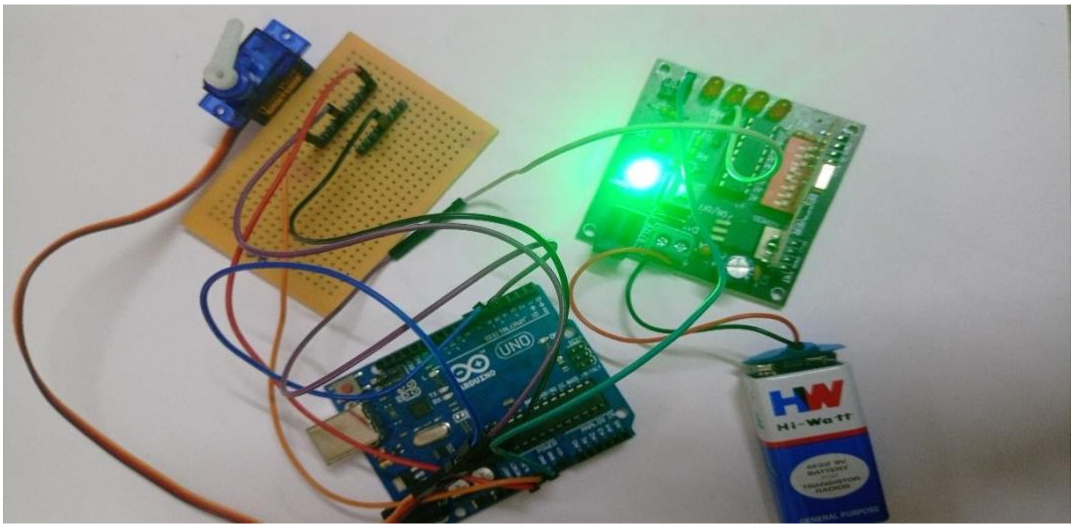

FIGURE 8. Interfacing of Servo Motor unit

3.4 Power supply Board Using PCB

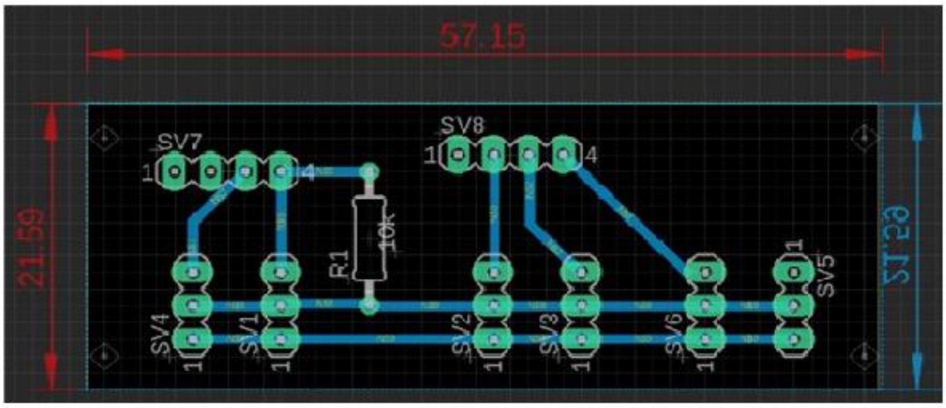

Fig 9. Power Supply Board Using PCB

RESULTS AND DISCUSSION

The aquaponic monitoring device, designed for 24x7 observability, yielded promising results in maintaining optimal conditions for both fish and plant components of the system. Continuous monitoring revealed stable pH levels (6.5-7.2) and well-regulated concentrations of ammonia, nitrate, and dissolved oxygen, ensuring a healthy aquatic environment. The device, consisting of required components interfaced with the Arduino Uno and interconnected with NodeMCU, as shown in the figure, effectively controlled water temperature within the optimal range, reducing stress on the organisms and contributing to system resilience. Nutrient uptake by plants demonstrated efficiency, fostering robust growth and a balanced nutrient cycling process. The system's real-time alarm triggers promptly detected anomalies, allowing for swift intervention and preventing potential issues. Additionally, the seamless integration of the device with cloud storage facilitated the storage of real-time data for future analysis. This capability not only enhances data security but also enables data-driven decision-making over extended periods. The prototype model, as shown in the figure, facilitated measurements carried out with the help of web apps, further highlighting the device's practical applicability. The discussion emphasizes the device's role in optimizing resource efficiency, enabling early issue detection, and facilitating data-driven decision-making. In conclusion, the aquaponic monitoring device with 24x7 observability proves instrumental in sustaining a productive and resilient aquaponic system, emphasizing its value in precision control, proactive management, and long-term data analysis for continuous improvement.

Fig 10. **The Overall Connection of Aquaponic Device**

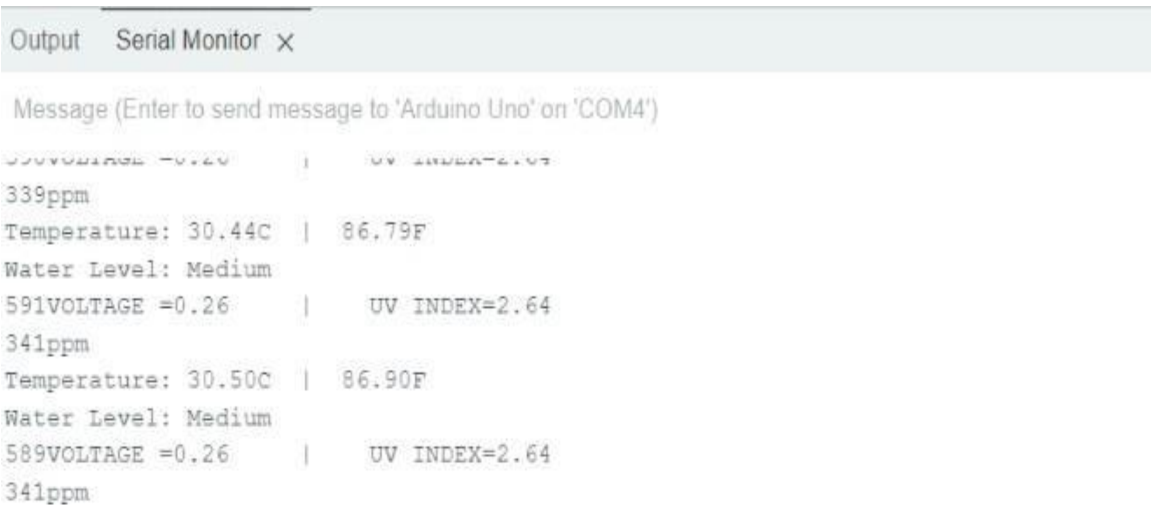

Fig 11. OUTPUT RESULT OBSERVED FROM ARDUINO UNO

CONCLUSION

In conclusion, the development of the aquaponic monitoring device with 24x7 observability represents a significant leap forward for aquaponic systems. Integration of water level sensors for the fish tank and grow bed, temperature sensors, a total dissolved solvent sensor, and pH sensors enables comprehensive monitoring. The addition of a micro servo for an automatic fish feeder not only enhances functionality but also contributes to reduced power consumption, showcasing commitment to sustainability. Overcoming drawbacks of past models, we achieved a 10-fold cost reduction, utilizing a compact Arduino Uno R3 board and eco-friendly components. The device seamlessly connects to cloud storage, ensuring secure real-time data storage, facilitating future analysis, and promoting informed decision-making. The successful prototype, as depicted, demonstrates the practical implementation of these technological enhancements. This project has yielded a sophisticated and efficient aquaponic monitoring system, laying the foundation for enhanced precision control, proactive management, and sustainable practices. With state-of-the-art sensor technologies and cloud storage capabilities, the device emerges as a valuable tool for researchers, practitioners, and enthusiasts in aquaponics. As we strive for progress, this project underscores the potential of technology to revolutionize aquaponic system management, promoting the health and productivity of aquatic life and cultivated plants. The product's design, with accurate measurements of temperature, pH value, and Total Dissolved Solvent, allows for cloud monitoring with minimal installation, enhancing accessibility and usability. In summary, this project marks a significant advancement in aquaponic technology, addressing past limitations, reducing costs, and providing a practical solution for efficient and sustainable aquaponic systems.

REFERENCES

[1] Ravi Kishore Kodali,” Aqua Monitoring System using AWS” 2022 International Conference on Computer Communication and Informatics (ICCCI), IEEE,2022.

[2] Mr. Mantari -Ramos “Design of an Automated System of PH and Water Level for an Aquaponic Module”, 13th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference, IEEE,2022.

[3] Zhixin Ke “Research Progress of Intelligent Monitoring and Control in Aquaponics”, International Conference on Information Science, Parallel and Distributed Systems (ISPDS), IEEE,2021.

[4] Rina Yuhasari, Rina Mardiati, Nanang IsmailSetia Gumilar Fuzzy Logic-Based Electrical Conductivity Control System in Aquaponic Cultivation, 7th International Conference on Wireless and Telematics (ICWT), IEEE,2021.

[5] Brahmantya Aji Pramudita, Muhammad Irfan Falih Mahdika, Ni Kadek Riya tika Pradnyandari Putri, “ArisHartaman, Irham Mulkan Rodiana Monitoring and Controlling System of Chili Aquaponics Cultivation Based on The Internet of Things”, IEEE,2022.

[6] Muhamad Asmi Romli, Shuhaizar Daud, Phak Len Eh Kan,Zahari Awang Ahmad, Sazali Mahmud.” Aquaponic grow bed siphon water flow status acquisition and control using fog server”. 13th Malaysia International Conference 31.

[7] Chao-Hsien Lee, Jhih-Hao Jhang” System Design for Internet of Things Assisted Urban Aquaponics Farming” ,8th Global Conference on Consumer Electronics (GCCE), IEEE,2019.

[8] Maheswaran.R, Andrew Keong Ng. “Smart and Sustainable Home Aquaponics System with Feature-

Rich Internet of Things Mobile Application", 6th International Conference on Control, Automation and Robotics (ICCAR), IEEE,2020.

[9] Jerry John, Mahalingam P. R "Automated Fish Feed Detection in IoT Based Aquaponics System"8th International Conference on Smart Computing and Communications (ICSCC), IEEE, 2021.

[10] Rina Yuhasari, Rina Mardiati," Fuzzy Logic Based Electrical Conductivity Control System in Aquaponic Cultivation "International Conference on Wireless and Telematics (ICWT), IEEE,2019.