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ORIGINAL ARTICLE

Smart Home Aquaponic System Monitoring and Control with Internet of Things Using Mobile Application

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ABSTRACT – Food security has been a recurrent concern for numerous nations, including Malaysia. Climate change and population growth exacerbate this issue by increasing necessity food. In past few years, aquaponics has proven beneficial for fish and plant production, based on the idea that if every household can generate its own fish and plants, the nation's overall food consumption will reduce. The suggested smart house aquaponics system comprises an assortment of internet-connected sensors, actuators, and ESP32 microcontrollers that continuously monitor, adjust, and record the water and air quality of the fish tank. The Internet of Things (IoT) mobile application feature can alert the user in the event of an abnormal system state in terms of maintaining the health and growth of fish and plants. The Internet of Things (IoT) mobile application feature can alert the user in the event of an abnormal system state in terms of maintaining the health and growth of fish and plants. When the pH and turbidity thresholds are surpassed, the pumps are actuated to either fill or drain the tank. The results show that the design for a smart aquaponics system that can be used in a home is able to monitor and control all the parameters that are needed to cultivate wholesome fish and vegetation.

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INTRODUCTION

Food security has been a problem throughout recorded history and is being made worse by the expanding global population and climate change [1]. Traditional farming practices also need more resources, including labour and land. As a result, conventional farming cannot solve the problem of food security on its own; instead, modern vertical farming is crucial.

Aquaponics may be a sustainable agricultural approach to a balanced and self-contained environment. Pesticides or fertilizers do not aid plant growth in this procedure. Aside from that, aquaponics can reduce water consumption since it produces less water wastage than other types of farming. When water is routinely recycled throughout the ecosystem, the system will produce nutritious foods because the fish and vegetables will grow without the use of fertilisers as well as pesticides or antibiotics [2-5].

A potential substitute for traditional farming is aquaponics, which combines hydroponics (plant growth without soil) and aquaculture (fish farming) in a symbiotic environment [3,6,7]. Fish eats their food and expel ammonia as waste. Different naturally occurring bacteria in the aquaponics ecosystem convert this ammonia to nitrite and then to nitrate. The nitrate is removed from the water by plants, which then circulates back to the fish tank. Compared to conventional farming, aquaponics uses 90% less water. Additionally, it uses soilless media to grow plants, producing crops free of soil-prone diseases. The crops being produced are also organic and chemical-free because the fish wastes are used as fertilizers. [5,8]. Around the world, there are hundreds of small-scale aquaponics projects. There are also a few larger-scale commercial or near-commercial operations; however, they are mostly found in the United States, particularly in Hawaii [9]. In addition to studies on aquaponics, a lot of work has been done on integrated multi-trophic aquaculture, which involves raising fish and plants in more open systems.

The research's main objective is to develop a smart aquaponics system that can monitor and automate control in a domestic setting using the Internet of Things (IoT) via a mobile application. The idea of precision farming, which is typically used in the context of traditional farming, is now being introduced, necessitating the use of sensing, smart, and Internet of Things technologies for the monitoring and control of its automated processes. In other words, the research aims to bring advanced technology to aquaponics, enabling precise monitoring and control for improved efficiency and productivity in a home environment [2,10-13]. The standard methods of controlling and monitoring the water level in aquaponics systems demand significant time spent manually monitoring the basic parameters. It also demands routine inspection to verify that the water parameters are consistent and in good condition. Urban farmers may monitor their crops at any time and location using automated methods and an IoT system, as well as acquire accurate parameter readings in real-time [14].

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Maintaining the ideal water quality parameters for fish, nitrifying bacteria, and plants is crucial for a robust and successful aquaponics system. Anomalies can be promptly fixed to stop productivity losses by routinely monitoring key water quality. Maintaining the ideal water quality parameters for fish, nitrifying bacteria, and plants is crucial for a robust and successful aquaponics system. Anomalies can be promptly fixed to stop productivity losses by routinely monitoring key water quality. One of the key parameters to sustain water quality is the water level in the fish tanks. This research explored the use of automation control and IoT to monitor water levels in the aquaponics systems as it will become a sustainable and bio-integrated food production system in the future. This work designed an algorithm for home aquaponic systems to monitor and automatically control the pH and turbidity at specific levels. IoT applications allow for the monitoring of all real data through mobile apps, Blynk, and Google Spreadsheet.

METHODS AND MATERIAL

The main objective of this system is to design and develop a smart home aquaponics system with online monitoring and control using an IoT that continuously measures and displays values through wireless networks. Real-time observations of the water inside the fish tank can be made to ensure that the fish and plants in the system grow and thrive in a healthy environment. In this work, a conventional aquaponics system with sensors and a microcontroller is used to gather sensor data for pH, water level, temperature, total dissolved solids (TDS), and turbidity and automate system functions makes up the IoT-based aquaponics system. The design was based on previous works which were built with IoT for online monitoring of aquaponic systems [11,12,14,15].

The fish tank and plant tray are assembled and then the light-expanded clay aggregates (LECA) are placed in the tray. The plant tray was placed on top of the fish tank for water circulation. The recycle pump is connected with a pipe between the plant tray and the fish tank. As indicated in Figure 1, sensors, a microprocessor, and wireless fidelity (Wi-Fi) were installed in the smart house aquaponics system. The temperature sensor located in the fish tank measures the water temperature; the TDS sensor measures the total concentration of dissolved substances in water; the pH sensor measures the pH level of the water; the turbidity sensor measures the turbidity of the water; and the ultrasonic sensor measures the water level in the fish tank. Figures 2 and 3 illustrate the system's sensors. Along with these, fish food is supplied into the fish tank using an automatic fish feeder.

Figure 1. Aquaponic setup of the system

The coding in the Arduino Integrated Development Environment or Arduino Software (IDE) was developed for each sensor's parameters. The key processing units for the smart home aquaponics system are the ESP32 microcontrollers with internet access. The developed programming for automation control using the Arduino IoT cloud is applied to the system.

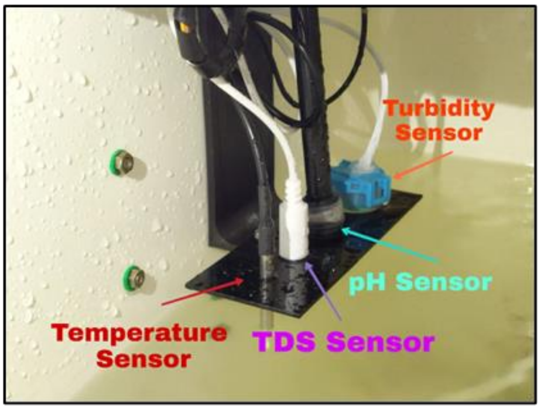


Figure 2. Temperature, TDS, pH, and turbidity sensors setup for the system

The reading of the water level and other parameters such as pH and turbidity are recorded and verified by comparing it with the value obtained using manual measurements and sensors reading.

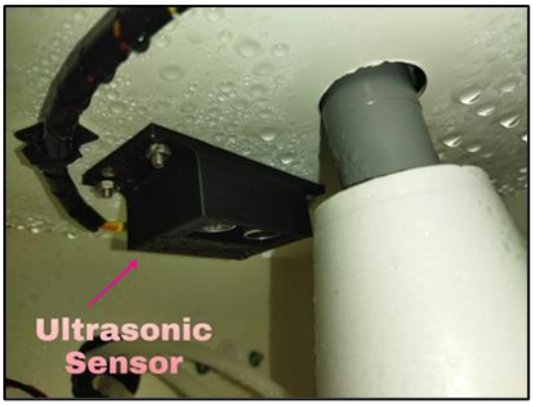


Figure 3. Ultrasonic sensors setup for the system

Water quality, such as pH and turbidity, must be maintained for fish, plants, and bacteria to thrive. Abnormalities in crucial water quality parameters can be detected early and corrected to avert production losses. The level of water in the fish tanks is one of the most effective ways to improve water quality. The fish tank's water level can help keep parameters like pH and turbidity in a safe range for both fish and plants to grow in.

Changing the water in the fish tank is needed in order to maintain the pH and turbidity, so they do not exceed the set point by triggering the pumps, as shown in Figure 4.

Figure 4. Pumps for changing water

If the value of the pH limit exceeds nine, there will be a change of the water in the fish tank. The same goes for turbidity. If it exceeds the limit of 1000 ppm, there will be a change of water. If both pH and turbidity are in the range, the program will continue to monitor the data by reading the parameters every 10 seconds. However, if it exceeds the limit, change water occurs with the empty pump being turned ON to evacuate the water in the fish tank until it reaches the low limit of 10 cm. Simultaneously, if the water level does not reach the low-level limit (10 cm), the empty pump will continue to turn ON. Then, the empty pump is turned OFF when the water reaches the low limit.

Then the tank will be filled when the ultrasonic sensor detects the amount of water at 10 cm until it reaches the high-water level limit (26 cm). Concurrently, if the water level does not reach 26 cm, the fill pump will continue to turn ON. Figure 5 shows the water flow from the fish tank and also the automatic fish feeder. The water from the plant tray that has been filtered by medium based light expanded clay aggregates (LECA) will circulate back to the fish tank as can be seen in Figure 6. The LECA had a greater filtration capacity, removing ammonium, nitrate, and orthophosphate, among other minerals and contaminants, and cleaning the water more effectively. The oxygen levels in the LECA bed were also found to be rather high, indicating that the plant development and the habitat for the fish created alongside the plant were both healthy.

Figure 5. Water flow from fish tank to the plant tray and automatic fish feeder

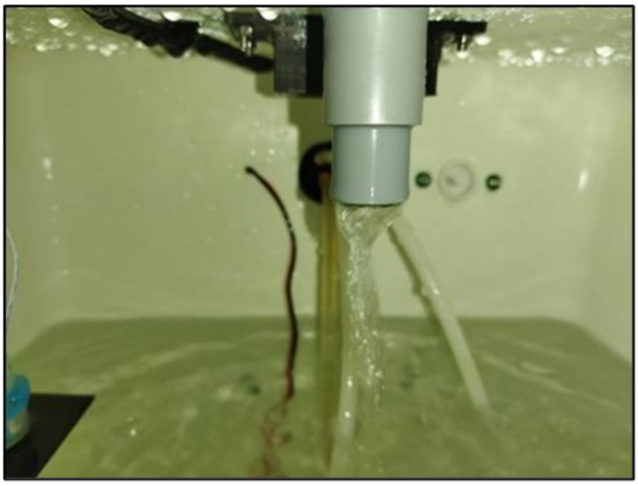


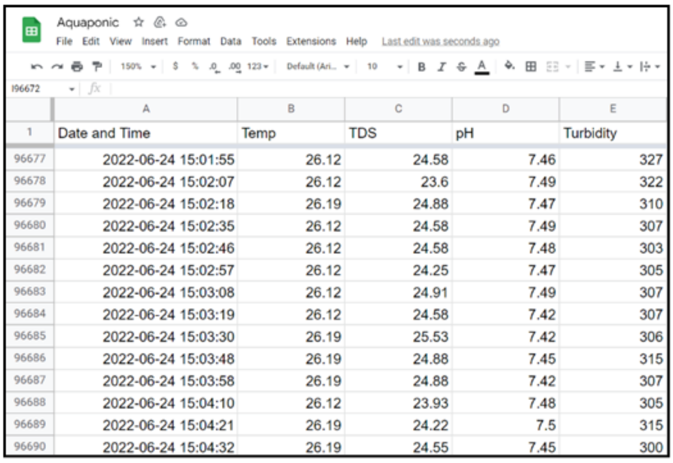
Figure 6. Water flow from plant tray to the fish tank

The reading can be monitored via the smart home aquaponic system's display panel, the Blynk apps, and an online spreadsheet. Blynk, an Internet of Things platform that enables users to freely build their mobile applications for hardware management and data analysis, is used to remotely monitor and control the smart home aquaponics system [12]–[15].

RESULTS AND DISCUSSION

This paper has designed a new IoT-based for home aquaponics system that is able to monitor real time parameters and automated control for water changing when the values of pH and turbidity is out of setting range. Monitoring was implemented to detect water temperature, pH level, TDS, and turbidity. The system was developed using the Arduino Software (IDE) with ESP32 microcontroller.

The developed home aquaponics system was tested in order to assess its performance and functionality. Data reading on the water quality from all sensors (water temperature, pH level, TDS, and turbidity) were sent continuously to the cloud server as long as the internet connection is good and the voltage supply to the microcontroller is not cut off. Figure 7 gives the real-time reading on the spreadsheet while Figure 8 shows the real-time data on the mobile application – Blynk.



Aquaponic
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	Date and Time	Temp	TDS	pH	Turbidity
96677	2022-06-24 15:01:55	26.12	24.58	7.46	327
96678	2022-06-24 15:02:07	26.12	23.6	7.49	322
96679	2022-06-24 15:02:18	26.19	24.88	7.47	310
96680	2022-06-24 15:02:35	26.12	24.58	7.49	307
96681	2022-06-24 15:02:46	26.12	24.58	7.48	303
96682	2022-06-24 15:02:57	26.12	24.25	7.47	305
96683	2022-06-24 15:03:08	26.12	24.91	7.49	307
96684	2022-06-24 15:03:19	26.12	24.58	7.42	307
96685	2022-06-24 15:03:30	26.19	25.53	7.42	306
96686	2022-06-24 15:03:48	26.19	24.88	7.45	315
96687	2022-06-24 15:03:58	26.19	24.88	7.42	307
96688	2022-06-24 15:04:10	26.12	23.93	7.48	305
96689	2022-06-24 15:04:21	26.19	24.22	7.5	315
96690	2022-06-24 15:04:32	26.19	24.55	7.45	300

Figure 7. Real time data on spreadsheet

The real data from the temperature sensor, TDS sensor, pH sensor, ultrasonic level sensor, and turbidity sensor is recorded for every 10 seconds on an online spreadsheet.

Figure 8. Real time data on mobile using Blynk apps

The water changing was successfully run when the value for pH and turbidity exceeded the pre-determine setting value, 9 and 1000 respectively. The contaminated water in the fish tank was pumped out until it reached a minimum level of 10 cm, and the clean water was pumped into the fish tank until it reached its maximum level, 26 cm.

CONCLUSION

A new IoT-based home aquaponics system that can monitor parameters in real-time and automatically change the water when pH and turbidity values are out of range (pH > 9; turbidity > 1000ppm) has been designed. The ESP32 microcontroller and Arduino Software (IDE) were employed to develop the system of the smart home aquaponics system with real time monitoring and control. Water temperature, pH level, TDS, and turbidity were all monitored continuously. The real-time data were sent to the online Google spreadsheet and the Blynk mobile apps because the ES32 allows the system to be IoT-based. Besides that, the parameters of the system also can be monitored in real-time at the display panel.

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