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Development of an Aquaponics Farming Technology System Using Arduino Based on Internet of Things

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ABSTRACT

Aquaponics employs diverse biological and ecological strategies, integrating the cultivation of agricultural prawns and plants. A fundamental requirement for successful aquaponics systems is a reliable water source to ensure the stability and adequacy of essential nutrients for prawn and plant production. Managing an aquaponics system effectively necessitates the maintenance of factors such as pH level, water level, water temperature, and dissolved oxygen level. This paper addresses the challenges of aquaponics management by introducing a technology monitoring system based on an Arduino controller and Internet of Things (IoT). The Arduino IDE software facilitates interaction with various input sensors, output devices, and hardware components. The study evaluates four different sensors – dissolved oxygen, temperature, pH, and ultrasonic – and employs the ESP 8266-ESP01 Wi-Fi Module for IoT applications. The main finding of this research highlights the reliability of the proposed aquaponics farming technology monitoring system. The integrated Arduino-based IoT solution effectively monitors critical parameters, including pH, water level, water temperature, and dissolved oxygen level. By continually updating data, the system proves instrumental in enhancing productivity and streamlining management practices for agricultural prawns ÷and plant cultivation in aquaponics. This innovation addresses the pressing need for efficient monitoring and management in aquaponics systems.

1. Introduction

Water, as an ecosystem, not only sustains human life and the life of living organisms but also plays a crucial role in maintaining ecological processes and the environment. It stands as a unique ecological resource, forming the foundation for supporting and balancing ecosystems. Aquaponic systems, which integrate fish, prawns, aquatic plants, and hydroponic vegetables, depend on water as the medium through which essential nutrients and oxygen are supplied to plants and fish [1,2].

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Aquaponics represents the convergence of recirculating aquaculture and hydroponics, forming an integrated agricultural system [3,4]. In this system, aquaculture involves the farming and breeding of aquatic organisms, utilizing water instead of traditional land resources [5,6]. Modern aqua culturists employ advanced technologies such as closed-loop systems, where water is efficiently cleaned and recycled, contributing to sustainable and controlled aquatic environments.

The hydroponic subsystem, constituting the second element of aquaponics, facilitates plant growth without extensive soil usage [2,7,8]. This soilless approach minimizes the risks associated with soil-borne pests and diseases, enabling efficient reuse and sterilization of substrates between crops. Certain substrates offer superior water-holding capacity and oxygen supply compared to traditional soil, making them particularly suitable for intensive production.

A stable water source is critical for the success of aquaponics [8,9]. It acts as a medium for delivering necessary nutrients and oxygen to plants, fish, or prawns. Monitoring factors like pH level, water level, temperature, and dissolved oxygen ensures the maintenance of high-quality aquaponics water supply [10,11]. Freshwater from diverse sources, including lakes, rivers, swamps, irrigation, ditches, and ponds, is essential for supporting aquaponic systems. Freshwater, characterized by low concentrations of dissolved salts and other solids, is paramount for the optimal growth and production of desired organisms.

Beyond the realm of aquaponics, the sustainability of water management emerges as a formidable challenge. Sethu *et al.,* [12] advocate for urgent and serious measures to address water-related issues globally. Naidu *et al.,* [13] delve into the environmental impact of sewage treatment plant loading on river basins during movement control orders, proposing solutions to mitigate such effects. The work of Wang *et al.,* [14] provides a comprehensive exploration of water resource management, offering insights into advancements, challenges, and potential solutions.

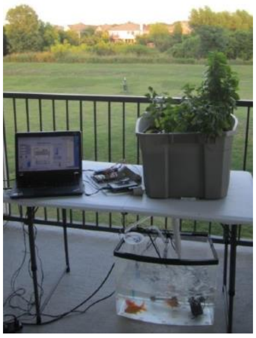
In the broader context of water management, technological innovations are being harnessed. Owen [15] explores the application of smart technologies in "Smart Water Management," utilizing data analytics, sensor networks, and the Internet of Things to optimize water systems. Margan [16] delves into technological advancements in water management, potentially within the context of the petroleum industry. Janardhanan's [17] chapter on "Water Management: A Key to Sustainable Development" provides a holistic overview of strategies essential for achieving sustainable development goals. Aiello *et al.,*'s [18] work on the "Internet of Things for Smart Management of Water Networks" explores the application of IoT in managing water networks. Krishnan *et al.,* [19] investigates the integration of artificial intelligence in optimizing water resource management.

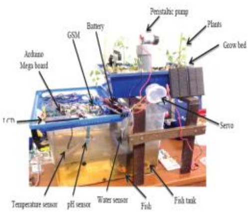
In conclusion, taking good care of the water quality is important to make sure the fish and plants in aquaponics stay healthy and grow well. Our research is to set up a smart monitoring system for aquaponics farming using Arduino and the Internet of Things. This highlights our commitment to adopting advanced and sustainable agricultural practices.

2. Project Background

Relevant projects that involve automation systems in research are presented, such as Arduino, a programmable logic control system, and an input and output mechanism to control water circulation. Table 1 shows the comparison of related projects for the Aquaponics Farming Technology System.

Table 1
Related project

No.	Tittle of The Project	Description	Comment
1	Aquaponics system [20] 	(a) Controller: (i) NI MyRIO (b) Input device: (i) Ultrasonic Distance Sensor (ii) Digital temperature sensor (iii) pH meter (iv) Flow meter (c) Output device: (i) Fountain pump (ii) Submersible Heater (d) Operation: (i) Throughout the cycle, the temperature, water level, and pH level of the fish tank are continuously monitored. (e) Software: (i) LabVIEW 2013 software	(i) This system is not sufficient to produce dissolved oxygen. (ii) The aquaponics system does not have to run continuously. However, the user can adjust the timing of the aquaponics cycle to obtain the optimal harvest and balanced power consumption.
2	pH control in an effluent treatment plant using PLC [21] 	(a) Controller: (i) PLC (Programmable Logic Controller, Allen Bradley Micrologix 820). (b) Input device: (i) Float Sensor (ii) pH Sensor (c) Output device: (i) Pump (ii) DC motor (iii) Valves (d) Operation: (i) These processes involved in the treatment of water for drinking purposes may be the separation of solids and physical processes. (e) Software: (i) CCW software (Connected Component Workbench).	(i) The effluent treatment plant is projected to be the PLC-implied control by PLC that is implemented in the discharging of contaminated and polluted water before it is returned to the environment. (ii) The advantage of this system is that it is very user-friendly for the operator or control engineer to troubleshoot the process.
3	Automated Aquaponics Design [22]. A similar automated aquaponics system can be found in the study by Basar *et al.,* [23]. 	(a) Controller: (i) Microcontroller (PIC18F4525) (b) Input device: (i) Ultrasonic Sensor (ii) Temperature Sensor (iii) Light Sensor (iv) Infrared Occupancy Sensor (c) Output device: (i) Water Pump (d) Operation: (i) To create an electronically monitored system capable of producing vegetables and fish for consumption. (e) Software: (i) Unstated	(i) The electronic system was proposed to perform all monitoring, error correction, and user alert actions necessary to maintain the unit ecosystem. (ii) The cause of death was likely overfeeding as the automatic fish feeder was not properly adjusted before vacation.

4	Design of an Aquaponics Water Monitoring System Using Arduino Microcontroller [24]. Similar PLC applications can be found in the study by Bakar *et al.,* [25]. 	(a) Controller: (i) Arduino Mega Controller (b) Input device: (i) Water Sensor (ii) pH Sensor (iii) Temperature Sensor (c) Output device: (i) Peristaltic pump (ii) Servo motor (d) Operation: (i) The developed system is capable of detecting pH values, water temperature, water level, hardware, and GSM to send a message to mobile phones. (e) Software: (i) Unstated	(i) The GSM result is obtained by observing the message sent by the GSM to the mobile phone. (ii) The message describes the condition of the water parameters.

3. Methodology
3.1 List of Components

The main components used to build the aquaponics farming system technology model of the aquaponics farming system technology are shown in Table 2.

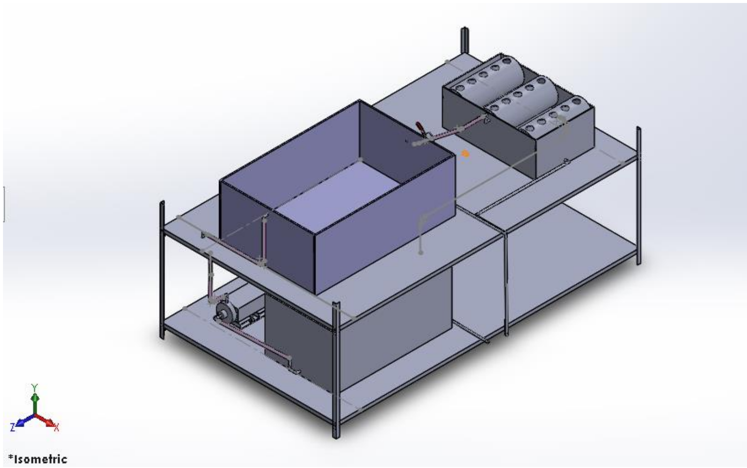
Table 2
List of components required for project development

No	Components	Description
1	Arduino Uno	The current version of Arduino Uno is equipped with a USB interface, 6 analog input pins, and 14 I/ O digital ports that are used for external electronic circuits. Of the 14 ports, 6 can be used for PWM output. In communication, Arduino Uno can communicate with a computer to transfer and upload the code. This board comes with fully integrated software and can be directly connected to the computer through a USB cable that is used to transfer code to the controller using IDE (Integrated Development Environment) software, mainly developed to program Arduino.
2	12V DC Brushless Water Pump	The water pump is used to allow water to flow from the reservoir tank to the prawn tank, which is enough to generate pressure. This is the main factor in producing the pressure of the water flow to recirculate the water in the reservoir tank and the aquatic tanks.
3	Motor Air Pump	The motor air pump is used to produce air bubbles that contain air (oxygen) from outside to supply aquatic life such as prawns for breath and survival.
4	Solenoid Valve	The usage of this solenoid valve is to regulate the water flow in the pipe in closed and open operation. This component needs 12 volts to supply its voltage in DC (direct current).
5	5V DC relay	The function of the component relay is used to protect the motor, the water pump, and the solenoid valve from failure. This is a relay that connects from the power supply source to the output port of the triggering switch.
6	Connecting wires	The purpose of connecting wires is to transfer current and signal signals, which include input and output devices. It also allows communication with devices at any port on various Arduino boards.
7	Wi-Fi Module ESP8266 ESP-01	The ESP8266 ESP-01 is a low-cost device to provide Internet connectivity to the project. This module works as a station and an access point, so it can easily retrieve data and upload them to the Internet to make things as easy as possible.
8	pH sensor	The input of the pH sensor detects and measures quality water with the reading of the pH value from 0 to 14. The pH sensor and the hardware of the signal

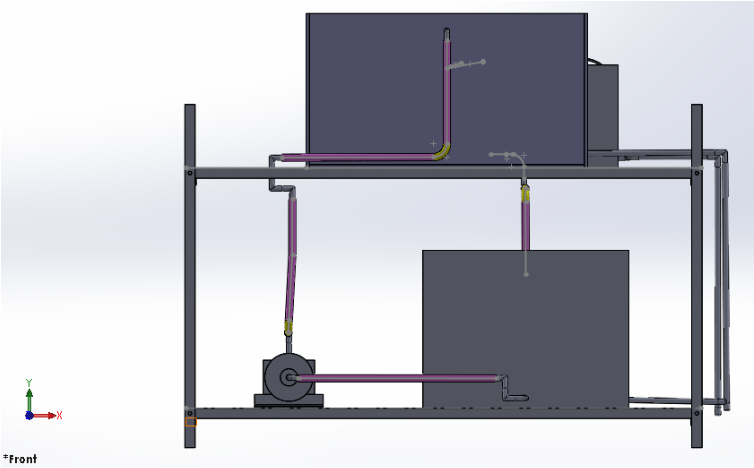
		converter module must be combined to interpret and become a readable data signal that is sent to the Arduino controller.
9	Temperature sensor	The temperature sensor is used to measure the condition of the temperature water in the tank. Normally, this type of sensor will use 5 volts for the power supply.
10	Dissolved Oxygen sensor	Dissolved oxygen (DO) is the amount of oxygen (O^2) sensor dissolves in water. The level of dissolved oxygen (DO) is the most critical variable in water quality. Dissolved oxygen levels can vary depending on the time of day, weather, and temperature.
11	Ultrasonic sensor	The ultrasonic sensor has 4 pins that are for the power supply, ground, echo, and trigger pin. This sensor is used to detect the amount or height of the water level in the tank. It is a contactless method to measure the distance between the liquid and the transceiver.

3.2 System Architecture

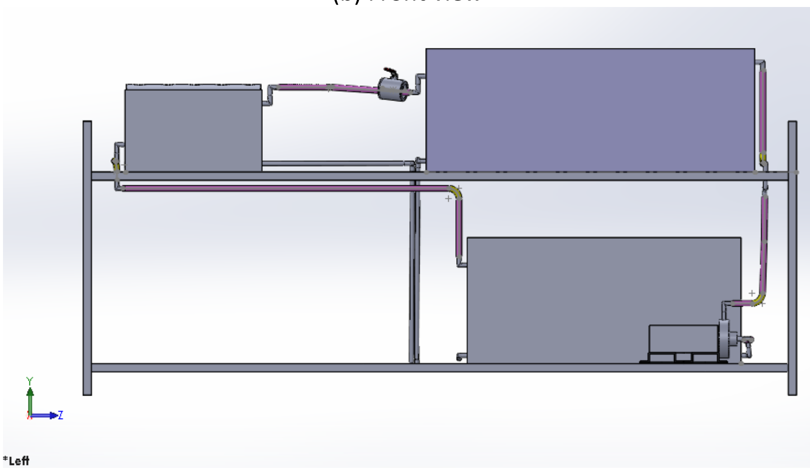
The structure of the Aquaponics project is shown in Figure 1. In particular, Figure 1(a), Figure 1(b), and Figure 1(c) illustrate the isometric front and side views, respectively. This project consists of 3 tanks, which are the aquatic tank and the aquaponics tank located in the upper part and the reservoir tank located in the lower part. The pipe is connected from the aquatic tank to the aquaponics tank. A solenoid valve is installed between the pipe from the outlet of the aquaponics tank and the water aquaponics tank inlet. Additionally, the hose is assembled and connected from the reservoir tank to the motor driver. The motor is mounted near the reservoir tank. The motor will pump the water from the reservoir tank and supply it to the aquatic tank. From the motor component, the hose is connected to the aquatic tank. Only the hose component is installed on the lower part. The real prototype of the aquaponics farming technology system is shown in Figure 2. More specifically, Figure 2(a) illustrates the front view, while Figure 2(b) shows the side view.



(a) Isometric view



(b) Front view



(c) Side view

Fig. 1. Design structure

(a) Front view (b) Side view

Fig. 2. Aquaponics Farm Technology System

3.3 System Integration

This system, as shown in Figure 3, consists of an Arduino Uno microcontroller, a pH sensor, an ultrasonic sensor, a temperature sensor, dissolved oxygen sensor, and relays that respond as a switch to control the operation. The pH sensor is used to sense the pH of water to maintain a sustainable environment in which fish and plants can live. The dissolved oxygen sensor is a crucial component of the electronic instrument to analyse the amount of oxygen in the water tank. The ultrasonic sensor is used to detect the height of water in the tank. Using the buzzer and the red led light to indicate the alarm system in the Blynk app. The ESP 8266 Wi-Fi module requires a power supply of 3.3 V from the Arduino Uno controller. The sensors continue to detect the water material to receive and return signals from Arduino Uno and the ESP 8266 Wi-Fi module ESP 8266 for transferring data over the Internet.

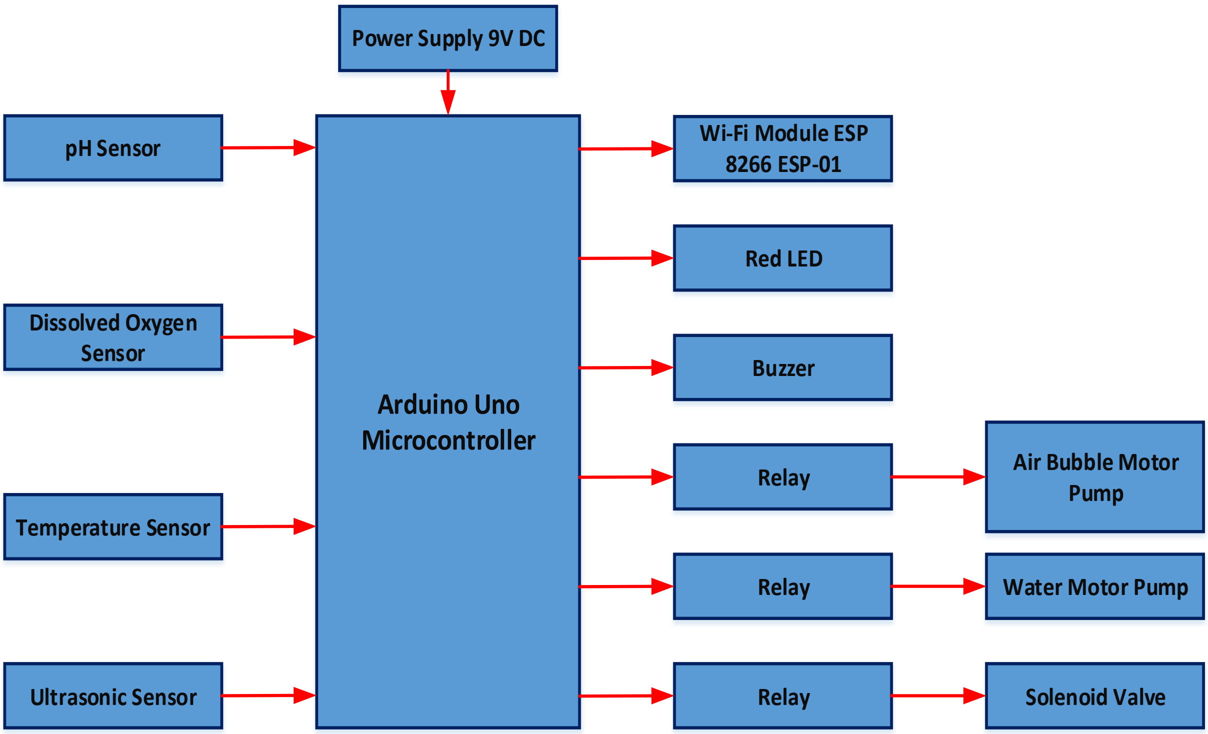


Fig. 3. Electronics Components Block Diagram

Figure 4 shows the hardware block diagram of the interface between Arduino Uno and the ESP 8266 Wi-Fi module. The Internet of Things (IoT) helps to gather and monitor information about conditions such as the pH level, temperature, the level of dissolved oxygen content, and the height of the water level. The Blynk App is a tool software that allows to control and act as a button for the output devices in auto and manual mode.

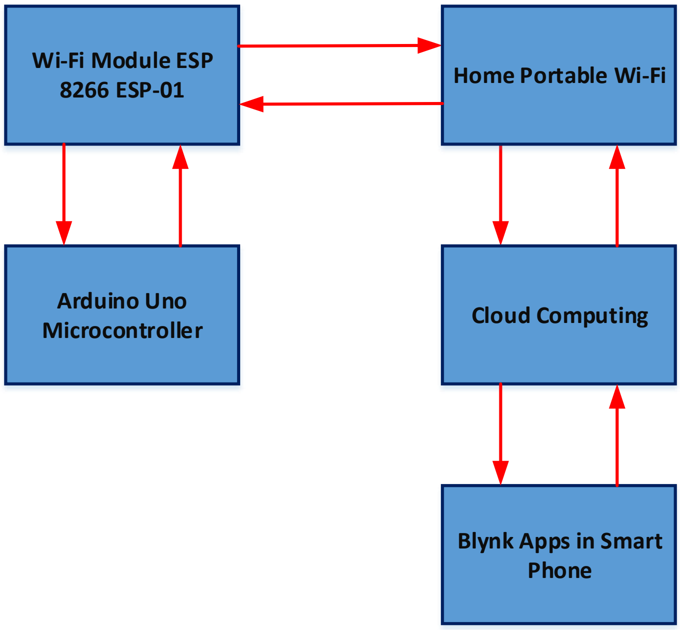


Fig. 4. The IoT Block Diagram

Figure 5 illustrates the flow chart for the development of an aquaponics farming technology monitoring system using Arduino based on IoT. Meanwhile, Figure 6 shows a circuit for the connection wiring diagram. This electrical wiring is used to transfer signal data and supply voltages, such as 5 volts, 3 volts, and 12 volts.

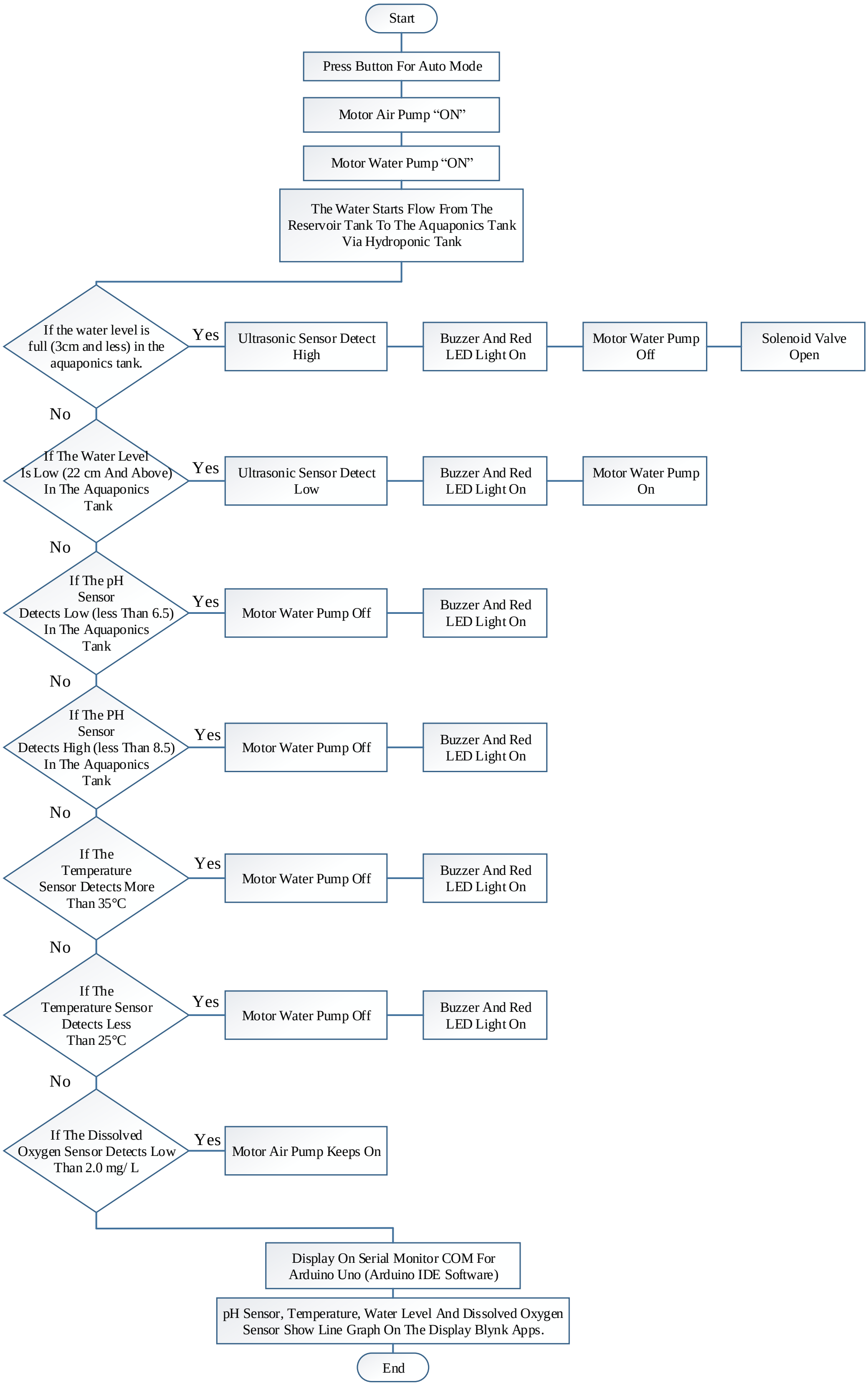


Fig. 5. Flow chart for the development of an aquaponics farming technology monitoring system

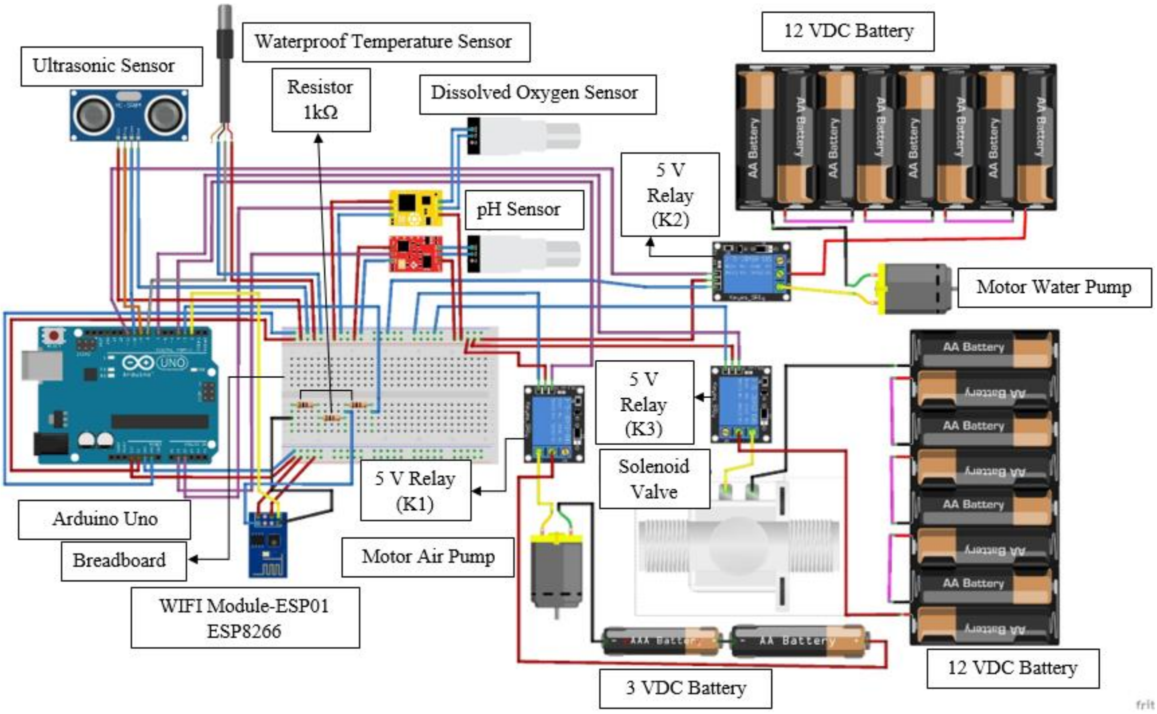


Fig. 6. Circuit Drawing

3.4 Prototype of Aquaponics Farming Technology

Figure 7 shows the general construction of the project with different views. The structure of the structure is made from wood except for the metal part that is used to support the sensor holder and the electrical part. The pipe is used to supply the water flow for the three tanks.

(a) Isometric View (b) Side View (c) Front View

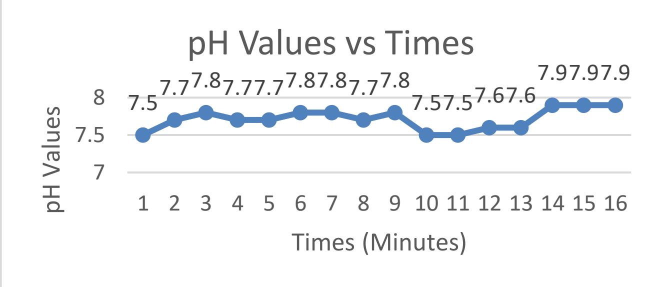
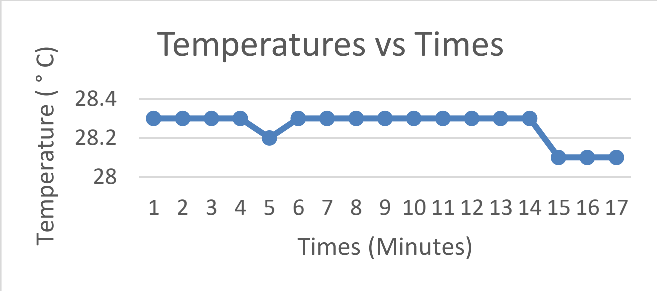
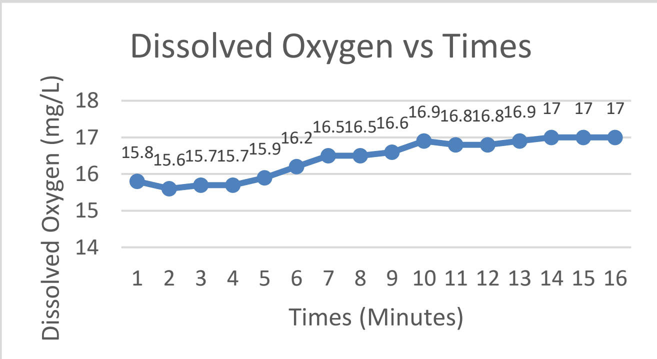
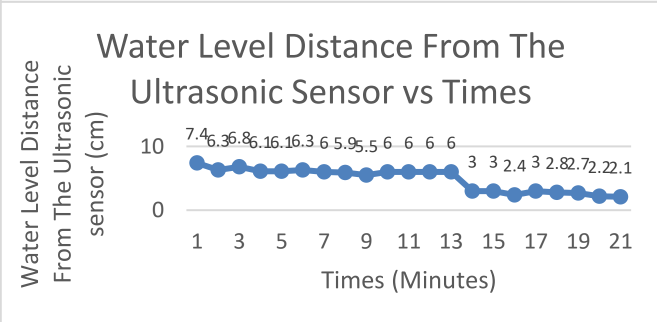
Fig. 7. Prototype of Aquaponics Farming Technology

4. Results and Discussion

4.1 Sensor Data

Table 3 shows the monitoring results based on four types of water quality in the aquaponics farming technology system. The pH values fluctuate as the condition of water is circulated, which contains leftover waste and prawn food. If the pH value is greater than 9 and less than 4, the prawn has a growth problem. Next, the temperature sensor is used to sense the constant temperature in water of about 28 ° C, but only the decimal point is different from the tolerance value. The dissolved oxygen graph shows the trend decrease from minute 1 until minute 4 due to the water that has been discharged from the aquaponics tanks and occurs when the roots of the plant are absorbing. When the water is refilled into the aquatic tank, the data show an increased rate of the amount of dissolved oxygen from minute 5 to minute 16. The water level graph shows the decrease in a small amount of loss of water during the water circulation. This happens when the water is in circulation in the three tanks, and sometimes the evaporation process occurs at any time.

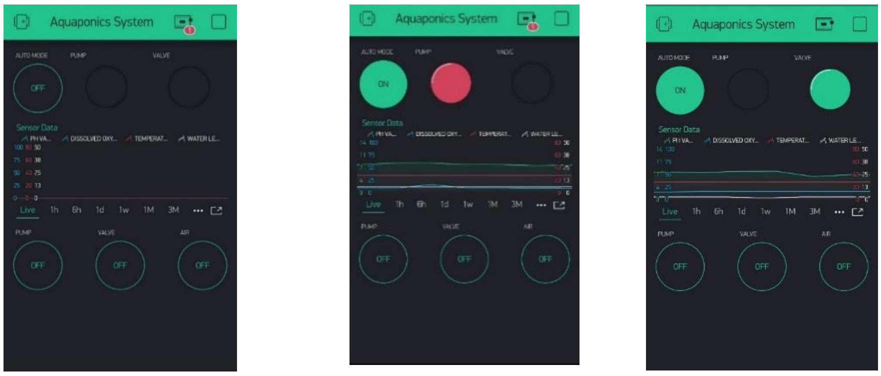
Table 3
Monitoring Results in Blynk App

No.	Type of sensor data	Graph
1	pH values	
2	Temperatures	
3	Dissolved oxygen	
4	Water Level	

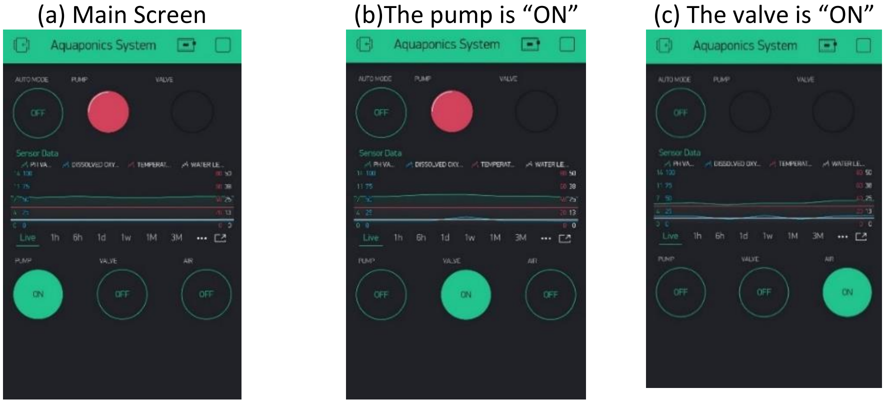
4.2 Controller Feedback in Blynk Application

The results of the water condition can be controlled, captured, and displayed on the Blynk app screen installed on the smartphone. The main controller consists of the “Auto Mode” button (upper screen) and the “Manual Mode” button (lower screen). The initial condition of the main screen is shown in Figure 8(a). When the “Auto Mode” is ‘ON’ (GREEN LED DISPLAY), the pump is ‘ON’ (RED

LED DISPLAY) and the valve is 'OFF' (NO COLOUR LED DISPLAY). This condition is shown in Figure 8(b) and Figure 8(c), respectively.



(a) Main Screen (b)The pump is "ON" (c) The valve is "ON"



(d) Manual Button for Pump (e) Manual Button for Valve (f) Manual Button for Air Pump

Fig. 8. Blynk App screen installed on the smartphone

Meanwhile, when the water approaches near the ultrasonic sensor about 3 cm from the surface water, the valve is 'ON' (GREEN LED DISPLAY) and the pump is 'OFF' (NO LED COLOUR DISPLAY). This condition is shown in Figure 8(b). Furthermore, when the "Manual Mode" is "ON" the manual button can be controlled separately. This condition can be seen in Figure 8(d), Figure 8(e) and Figure 8(f) for the manual buttons for the pump, valve, and air pump, respectively. Here, 'NO COLOUR DISPLAY' is 'OFF' while 'GREEN LED' is 'ON' to indicate that the auto mode is 'OFF' while the "GREEN LED" is 'ON', respectively.

5. Conclusions

The research introduces a technology monitoring system based on an Arduino controller and Internet of Things (IoT) for managing aquaponics systems. The study evaluates four different sensors - dissolved oxygen, temperature, pH, and ultrasonic - and employs the ESP 8266-ESP01 Wi-Fi Module for IoT applications. The main finding of the research highlights the reliability of the proposed aquaponics farming technology monitoring system, which effectively monitors critical parameters such as pH, water level, water temperature, and dissolved oxygen level. The integrated Arduino-based IoT solution proves instrumental in enhancing productivity and streamlining management practices for agricultural prawns and plant cultivation in aquaponics. The innovation addresses the pressing need for efficient monitoring and management in aquaponics systems.

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