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IOT-Based Automated Aquarium Care System

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Abstract: Fishkeeping is a fun and well-established hobby with a vast variety of marine lives to be kept and enjoyed. Fishkeeping can also be psychologically and emotionally comforting as watching aquarium can help people to relax and make beautiful decoration. However, maintaining an aquarium requires consistent effort and knowledge, which can be challenging for aquarists who are not always able to monitor their fish tanks. To address this problem, an IoT-based Automated Aquarium Care System was developed with the objective of developing a system that is reliable and maintains the aquarium's health even in the owner's absence. The system incorporates an auto-feeder, battery-powered aerator, and water change mechanism, all controlled and monitored through the Blynk app. The project successfully achieved its objectives, enabling precise feeding, vital oxygen exchange, and water quality maintenance through rigorous testing and implementation. Moreover, the system operates efficiently during power outages, ensuring continuous functionality. With remote monitoring and control capabilities, users can easily access the system through the Blynk app. The IoT-based Automated Aquarium Care System provides a reliable and efficient solution, alleviating the burden of aquarium maintenance while promoting the health and safety of marine life. This project highlights the significance of automation in aquarium care and contributes to a sustainable and thriving aquatic environment.

Keywords: Auto-Feeder, Battery Powered Aerator, Water Change Mechanism, Blynk Application, Automated Aquarium System

1. Introduction

Fishkeeping is a popular hobby, practiced by aquarists, keeping fish in a home aquarium or garden pond. People tend to keep fish because a pet fish in an aquarium or pond can provide decoration for a home, to be psychologically and emotionally comforting as watching aquarium can help people to relax, thus as a result many people now keep them. In fact, in a survey in the United States in 2020, it was found that of all pets, the proportion of people keeping pet fish was the largest, as shown in Figure 1[1]-[2]. In addition, the types of fish, aquatic plants and types of water animals need different care techniques

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and knowledge to maintain the ecosystem in the aquarium. However, the common factors that contribute to an aquarium ecosystem are food, oxygen and water quality.

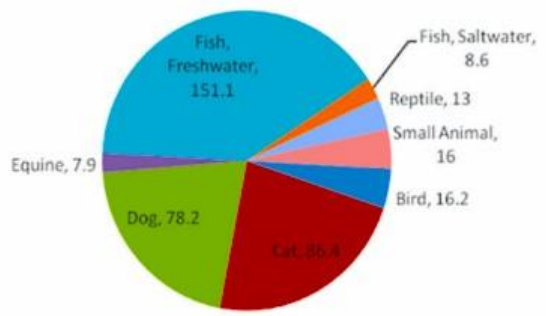

Figure 1: Proportions of different kinds of pets kept by people in the USA in theperiod 2017–2020 [1]-[2]

The main problems identified in aquarium maintenance include proper feeding, oxygenation, water quality, and power outages. Inconsistent feeding practices can result in malnutrition or overfeeding, negatively impacting the health of fish and other aquatic organisms[3]. Maintaining adequate oxygen levels in the aquarium is vital for the well-being of fish, as inadequate oxygenation can cause stress, illness, and even mortality. Ensuring consistent oxygen exchange becomes crucial during periods when the owner is absent[3]. Monitoring and maintaining water quality parameters such as pH levels, water hardness, and the nitrogen cycle are essential for a healthy aquarium ecosystem. The accumulation of harmful substances, such as nitrates, can have adverse effects on fish health[3]-[4]. However, regular water changes can be time-consuming and inconvenient for aquarists. Power outages pose a significant risk to aquariums as they can disrupt essential equipment and lead to adverse consequences for aquatic life. Ensuring continuous operation during power outages is vital to maintain a stable and healthy environment for the aquarium inhabitants.

Some similar project works have been studied to aid with the development of IoT based automated aquarium care system. Firstly, "Aquarium Monitoring System Based on Internet of Things[2]" focuses on using IoT technology to monitor and control aquariums. It gathers data from sensors and transmits it through a wireless network for real-time access. However, it lacks battery power and water-changing functionality. Secondly, "Aquarium Monitoring System[5]" utilizes a Raspberry Pi computer to monitor and maintain indoor aquariums. It offers features like water level measurement, water change, and alerts for leaks. But it lacks battery power and aeration capabilities. Thirdly, "Smart Aquarium Design Using Raspberry Pi and Android Based[6]" enables control and monitoring through an Android application. It supports features like decorative lights and auto feeding but lacks battery power, aeration, and functional decorative lamps. Lastly, "Fishtalk: An IoT-Based Mini Aquarium System[7]" uses IoT technology for monitoring and controlling aquarium parameters. It includes features like video monitoring, water temperature control, and aeration. However, it requires complex connections and is costlier. The proposed IoT-based Automated Aquarium Care System combines advantages from these studies, such as battery power, adjustable aerator, automated water changes, and remote monitoring. However, it lacks pH measurement, water temperature control, video monitoring, reverse osmosis filtration, and decorative lamps.

In that case, the project that will be developed is IoT based Automated Aquarium Care System with the objectives to develop an automated system to maintain an aquarium's health, to develop a reliable aquarium monitoring system for user, to develop an automated aquarium system that will able to make informed decisions and actions on its own during critical situations and to ensure the ecosystem in the aquarium is maintained in case of power outage. Thus, this system will automatically servethe needs of the aquarium and user can monitor the aquarium from anywhere in the world and be able Auto feed lives using auto feeder, provide oxygen exchange in aquarium using lithium ion batteries[8]-[9]

powered aerator and make a water change according to the user's preference.

2. Materials and Methods

3.1 Materials

The materials used in the automated aquarium care system include an Arduino Uno microcontroller board, an ESP01S WiFi module, two ultrasonic sensors for monitoring water levels in the main and backup tanks, a motor driver for controlling the aerator (DC motor), another motor driver for operating two DC water pumps, and a servo motor used as an auto-feeder. The Arduino Uno serves as the central control unit, while the ESP01S module enables internet connectivity and IoT functionality[10]. The ultrasonic sensors provide accurate water level measurements, ensuring proper water management. The motor drivers facilitate control over the aerator and water pumps, essential for maintaining oxygenation and dc water pump aid with water change. The servo motor automates the feeding process, dispensing the right amount of food at scheduled intervals. These components, powered by appropriate batteries, work together to create a comprehensive automated aquarium care system, ensuring continuous operation during power outage and allows remote monitoring and control via the internet.

3.2 System Block Diagram

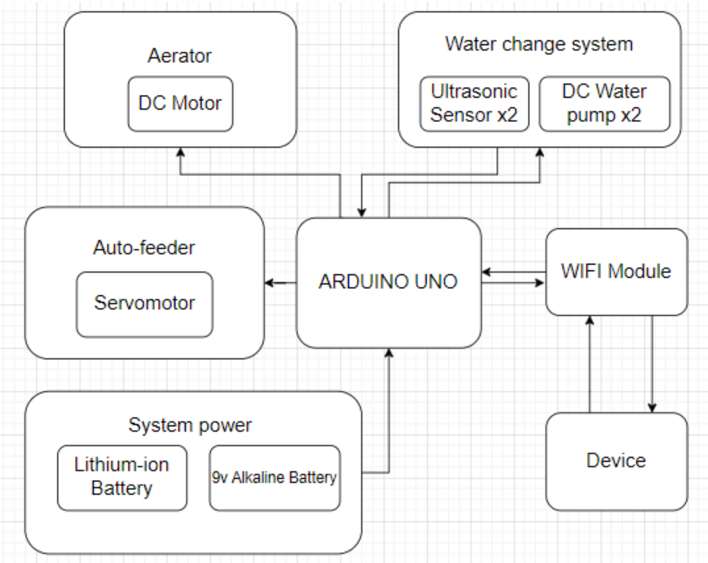

Figure 2: Block Diagram of the project

Figure 2 show the block diagram of the project. The system operates with microcontroller Arduino Uno. Firstly, the aerator runs with a dc motor. Secondly, the water change system runs 2 water pump (one to reduce water another one to refill water) and there is 2 ultrasonic sensor measure water volume and avoid overflow. Thirdly, the auto feeder runs with a servomotor that moves when triggered, stay open for the delay set then move back to original position. Fourthly, the WIFI module will provide data of the system to user via their device, allow them to control the system and. User can also automate the time and number of feeding they prefer to do using their device. Lastly, the system will be battery powered to avoid power outage.

3.3 System Flowchart

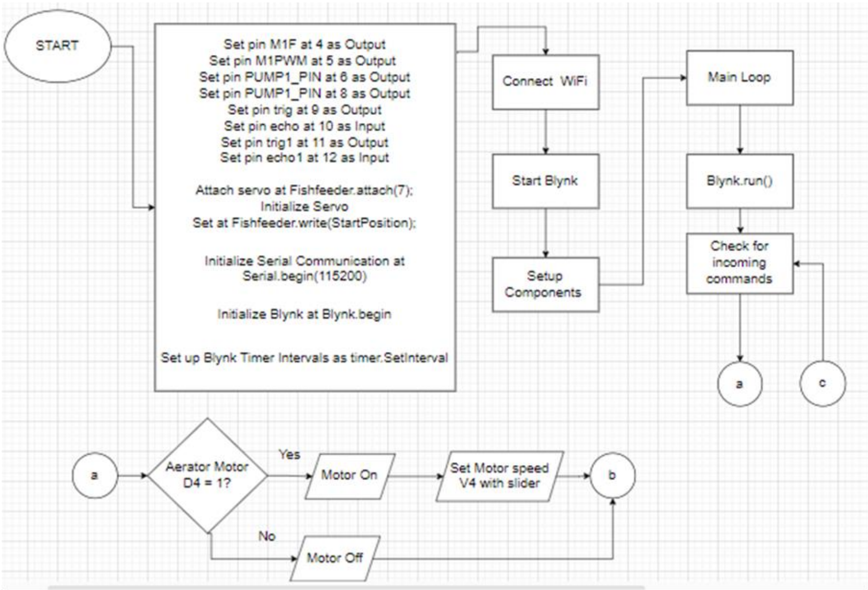

Figure 3: Flowchart of the project 1

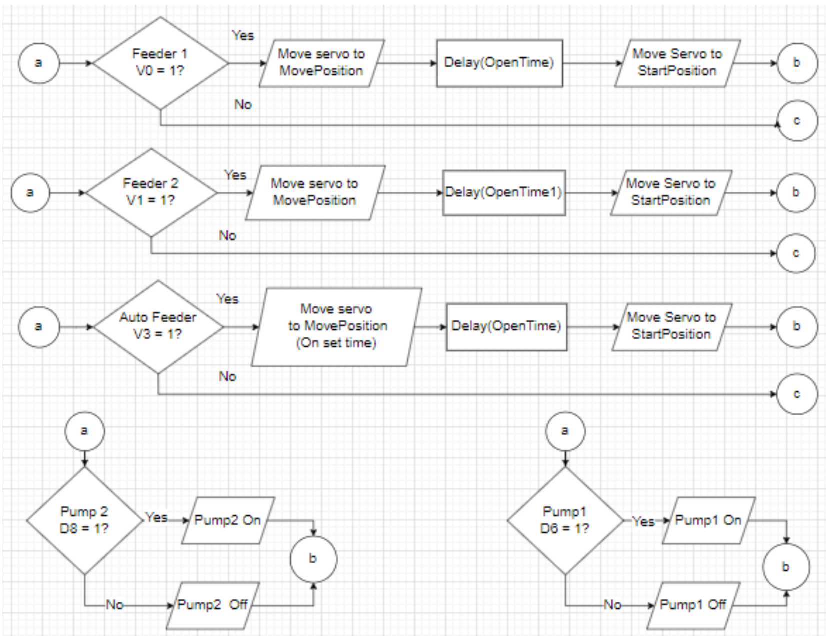

Figure 4: Flowchart of the project 2

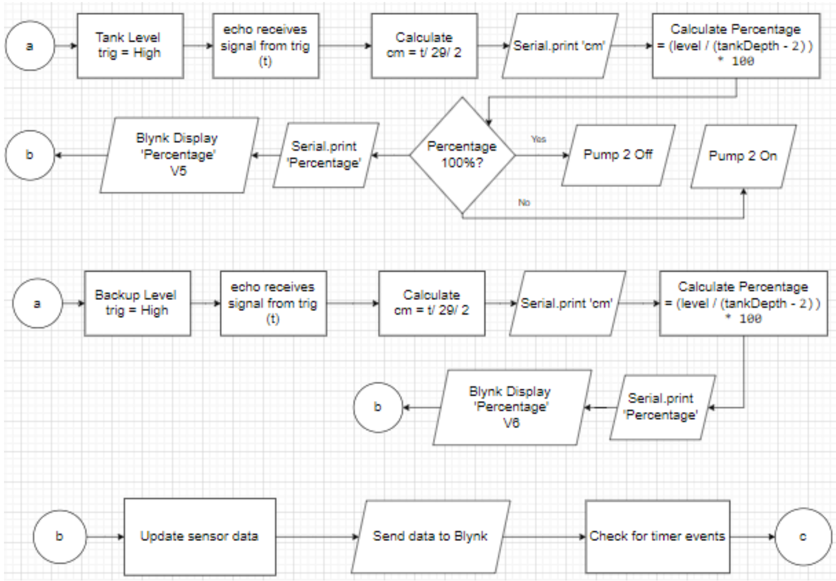

Figure 5: Flowchart of the project 3

Figure 3, Figure 4 and Figure 5 shows the flowchart of the system. The flowchart depicts the operation of an automated aquarium care system. It starts with pin initialization for various components, including motors, sensors, and the servo motor. Serial communication is established at 115200 baud rate, and Blynk is initialized with timer intervals set for Blynk operations. The system then connects to WiFi and begins the Blynk connection. In the main loop, the system handles incoming commands from Blynk. It checks the status of D4 pin to switch on and off aerator motor also checking status of V4 to control the speed of aerator motor and updates sensor data for monitoring. For the auto-feeder (V0, V1, and V3), the servo motor moves to dispense food at the specified intervals. The system also manages the water pumps (Pump 1 and Pump 2) based on D6 and D8 pin values. Ultrasonic sensors (trig/echo and trig1/echo1) measure water levels in the main and backup tanks, respectively. The calculated percentage of water level is displayed on Blynk using virtual pins V5 and V6. The system continuously updates sensor data, handles Blynk commands, and checks for timer events to maintain automated aquarium care.

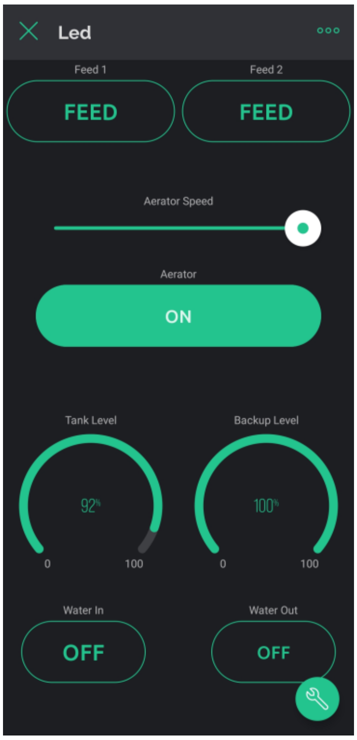

Figure 6: Blynk application for IoT based automated aquarium care system

Figure 6 shows the actual Blynk app developed to control the system. The coding template is obtained at examples.blynk[11] where else the data stream and widget are set up at blynk.cloud[12]. Feed 1 represents the feeder function to feed on Opentime and Feed 2 represents the feeder function to feed on Opentime1. The Aerator speed slider is used to control the speed of aerator to obtain desired surface agitation. The switch below the slider labeled "Aerator" is used to switch on and off the aerator. The gauge labeled "Tank Level" is used to measure and monitor the water level in the main tank where else gauge labeled "Backup Level" is used to measure and monitor the water level in the backup tank. Last but not least, the "Water Out" switch is used to draw water out of main tank and "Water In" switch is used to add water in the main tank from the backup tank. The water level of both tanks can be monitored during this process, resulting in an effective water change.

2.3 Equations

The ultrasonic sensor transmits and receive sound waves to measure distance,the trig (trigger) pin is an input pin that is used to initiate the measurement process. To start measuring distance, you send a short pulse (typically 10 microseconds) to the trig pin. This pulse triggers the sensor to emit a burst of ultrasonic sound waves. The echo pin is another pin on the sensor, which serves as an output pin. After the sound waves are emitted, they travel through the air and bounce off objects in their path. When the reflected waves reach the sensor, the echo pin is activated, and it outputs a high-level signal.

By measuring the duration of the high-level signal on the echo pin, you can calculate the time it took for the sound waves to travel to the object and back. This time measurement is crucial for distance calculation using the speed of sound formula. The sensor measures the time between sending the trigger pulse and receiving the echo pulse. This time interval represents the roundtrip time of the sound waves. Since the sound waves travel at a known speed in air (approximately 343 meters per second), dividing the roundtrip time by two gives the time it took for the waves to travel one way. Multiplying this time by the speed of sound and dividing by 2 gives the distance to the object [13]-[14]-[15].

$$\boldsymbol{Distance} = \frac{\boldsymbol{Speed\ of\ Sound\ x\ Time}}{\boldsymbol{2}}$$

3. Results and Discussion

The water level monitoring, feeder, aerator and battery efficiency and reliability will be tested to analyze the strengths, limitations and accuracy of the system. The results are compared to actual equipment such as a multimeter, ruler and timer to relate to the accuracy of system.

4.1 Water level monitoring

Table 1: Main tank water level monitoring

Serial Monitor Tank Depth (cm)	Serial Monitor Tank Percentage (%)	Tank Depth (cm)	Blynk App Gauge Water Level Main (%)	Pump 2 Off = 0 On = 1
17	0	0	0	1
12	23	12	23	1
10	38	10	38	1
7	61	7	61	1
3	92	3	92	1
2	100	2	100	0

Table 1 shows the main tank water level monitoring system testing results. The serial monitor is coded to show the tank depth in cm and the tank percentage in %. Thus, the results shown in (Serial Monitor Tank Depth (cm)) and (Serial Monitor Tank Percentage (%)) is obtained from the serial monitor. The tank depth is 17cm and it determined with a ruler to ensure the depth varies with the depth shown in serial monitor. The gauge at Blynk app is observed to ensure it varies with the percentage shown in serial monitor. Lastly, to prevent overflow pump 2 is coded to stop when gauge reaches 100% thus the result being output = 1 until 100% and output = 0 when percentage is 100%.

Table 2: Backup tank water level monitoring

Serial Monitor Tank Depth (cm)	Serial Monitor Tank Percentage (%)	Tank Measurement (cm)	Blynk App Gauge Water Level Main (%)
15	0	0	0
10	20	10	20
8	40	8	40
6	60	6	60
3	90	3	90
2	100	2	100

Table 2 shows the backup tank water level monitoring system testing results. The serial monitor is coded to show the tank depth in cm and the tank percentage in %. Thus, the results shown in (Serial Monitor Tank Depth (cm)) and (Serial Monitor Tank Percentage (%)) is obtained from the serial monitor. The tank depth is 15cm and it determined with a ruler to ensure the depth varies with the depth shown in serial monitor. The gauge at Blynk app is observed to ensure it varies with the percentage shown in serial monitor.

The code consists of two functions, "waterLevel" and "waterLevel1," which are part of a water level monitoring system utilizing ultrasonic sensors. Each function is responsible for measuring the distance between the sensor and the water level in a tank. In both functions, the trig and echo pins are defined to control the ultrasonic sensor. The sensor emits ultrasonic pulses and measures the time it takes for the pulses to travel to the water surface and back. Based on this measured time, the functions calculate the distance in centimeters.

For "waterLevel," the depth of the tank is set to 17cm, but this value can be adjusted according to the user's preference. The calculated distance represents the remaining water level in the tank. The functions then calculate the percentage of the tank that is filled based on the remaining water level. If the calculated percentage is equal to or greater than 100, it indicates that the tank is full or overfilled. In such a case, the code turns off a pump connected to a specific pin (PUMP2_PIN). The calculated percentage is displayed on the Serial monitor, and it is also sent to a Blynk virtual pin (V5) for further processing or visualization. If the water level is zero or negative, indicating an empty tank or an error, the code sends a value of 0 to the Blynk virtual pin.

Similarly, for "waterLevel1," the depth of the tank is set to 15cm, and again, this value can be adjusted according to the user's preference. The function calculates the remaining water level and the percentage of the tank that is filled. However, in this case, there is no cut-off for the pump (Pump_1), meaning that the user can remove any amount of water from the tank without triggering an automatic pump turn-off. The calculated percentage is displayed on the Serial monitor and sent to a different Blynk virtual pin (V6) for further processing or visualization. If the water level is zero or negative, indicating an empty tank or an error, the code sends a value of 0 to the Blynk virtual pin. Figure 7 shows Serial monitor display main tank percentage and depth and Figure 8 shows the Blynk gauge display water level in main tank. This gauge and serial monitor reading is done for both main tank and backup tank.

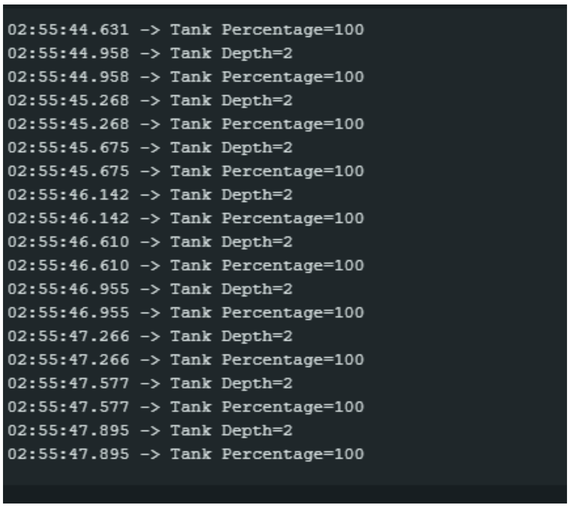

Figure 7: Serial monitor display main tank percentage and depth

Figure 8: Blynk gauge display water level in main tank

3.2 Auto feeder testing

In this data collection session, the feeder is tested to analyze the convenience, reliability and consistency of the feeder. Firstly, the consistency and reliability of the feeder will be testing with three feeding attempts. Other than that, the convenience is analyzed with automated feeding where the time of the day is set and observed.

Table 3: First feeding attempt

Feed	Open time	Actual time	Feeding Status	Amount of Feeding
1	0.5s	0.5s	Done	Medium
2	1s	1s	Done	High

Table 4: Second feeding attempt

Feed	Open time	Actual time	Feeding Status	Amount of Feeding
1	0.5s	0.5s	Done	Medium
2	1s	1s	Done	High

Table 5: Third feeding attempt

Feed	Open time	Actual time	Feeding Status	Amount of Feeding
1	0.5s	0.5s	Done	Medium
2	1s	1s	Done	High

Based on the functionality at table 3, table 4 and table 5 of the feeder, when Feed 1 is pressed the servo moves to move position delays the Open time which is 0.5s then move back to start position. When Feed 2 is pressed the servo moves to move position delays the Open time which is 1s then move back to start position. During all three attempts to feed with Feed 1 and Feed 2 the consistency to feed was good. The Open time and actual time are compared, where the actual time is measured with a timer and it varies with the actual time. The amount of feeding at 0.5s is less compared to 1s which completed the aim, being the more the open time of feeder, the more food is feed. That said, it is convenient as the results are similar on all three attempts.

Table 6: Automated feeding based on time

Time to Feed	Day to feed	Open Time	Actual Open Time	Actual Feeding Time
14.00pm	1	0.5s	0.5s	2.00pm
14.15pm	1	0.5s	0.5s	2.15pm
14.30pm	1	0.5s	0.5s	2.31pm
14.45pm	1	0.5s	0.5s	Not done
15.00pm	1	0.5s	0.5s	3.00pm

Table 7: Automated feeding based on day

Time to Feed	Day to feed	Open Time	Actual Open Time	Actual Feeding Time
14.00pm	1	0.5s	0.5s	2.00pm
14.00pm	2	0.5s	0.5s	2.00pm
14.00pm	3	0.5s	0.5s	2.00pm

At table 6, accuracy of feeding on set time and amount of food feed during automation is tested. The test is done on the same day but with different feeding time. The feeding time was set to run once thus after every automation, the next time is set again for the next automation. The time to feed was set at 14.00pm, 14.15pm, 14.30pm, 14.45pm, 15.00pm and all the feeding was done on time except the 14.45pm feeding as Blynk app disconnected due to unstable internet connection. Mobile hotspot was used to connect to Blynk, this might be the cause as mobile hotspot can be unstable. Other than that, the open time and actual time indicates the time the feeder was open to feed thus the time being 0.5s for both open time and actual time, it can be considered to feed approximately same amount of feed during the open time.

At table 7, automated feeding on specific day and accuracy of feeding is tested the time to feed is the same at 14.00pm but the feed will be done in a 24 hours' gap. The automation is set for 3 days. To set this automation, the run once feature at Blynk app must be turned off and days of the week feature will appear thus the automation can be set on any days in a span of a week. The feeding was done on time on the three consecutive days and the amount of feeding is also approximately similar as the open time and actual time varies. Anyhow, the system was not left online for 3 days, it was turn on during the set time and the results was measured. Results might differ if the system was on for 3 days. That said, it is recommended to a stable internet connection to avoid loss of signal and inaccurate results. Other than that, the open time can be changed to increase or decrease amount of food to feed.

3.3 Aerator and lithium-ion battery

Table 8: Aerator PWM (140)

Time	Input Voltage (Battery)	DC Motor (ON/OFF)	Pulse Width Modulation (PWM)	Slider Placement	Output Voltage (Out1&Out2)	Surface Agitation
7.40 pm	11.40V	ON	140	Max (Figure 4.	6.04V	Very High
7.50 pm	10.45V	ON	140	Max (Figure 4.	5.50V	High
8.00 pm	7.62V	ON	140	Max (Figure 4.	3.10V	Medium
8.10 pm	6.70V	ON	140	Max (Figure 4.	2.50V	Slow
8.12 pm	6.50V	OFF	140	Max (Figure 4.	2.20V	None

The data collected at table 8 shows that the aerator operates for about 32 minutes with the lithium-ion battery on high PWM setting of 140. The surface agitation of the water was very high at first because of the high PWM contributing to high dc motor speed but eventually decrease to high, medium, and slow as the battery deplete and stops at 6.50V.

Table 9: Aerator PWM (70)

Time	Input Voltage	DC Motor (ON/OFF)	Pulse Width Modulation (PWM)	Slider Placement	Output Voltage	Surface Agitation
10.10 pm	11.80V	ON	70	Medium	6.20V	Medium
10.30 pm	10.60V	ON	70	Medium	5.90V	Medium
10.50 pm	8.04V	ON	70	Medium	4.0V	Medium
11.10 pm	6.90V	ON	70	Medium	3.20V	Slow
11.22 pm	6.40V	OFF	70	Medium	2.16V	None

The data collected at table 9 shows that the aerator operates for about 1hour 12 minutes with the lithium-ion battery on high PWM setting of 70. The surface agitation of the water was medium at first because of the medium PWM contributing to medium dc motor speed but eventually decrease to medium, medium, and slow as the battery deplete and stops at 6.40V.

Table 10: Aerator PWM (10)

Time	Input Voltage	DC Motor (ON/OFF)	Pulse Width Modulation (PWM)	Slider Placement	Output Voltage	Surface Agitation
12.00 am	11.90V	ON	10	Min	6.50V	Slow
12.40 am	10.90V	ON	10	Min	6.00V	Slow
1.20 am	9.04V	ON	10	Min	5.06V	Slow
2.00 am	7.50V	ON	10	Min	3.90V	Slow
2.45 am	6.36V	OFF	10	Min	2.37V	None

The data collected at table 10 shows that the aerator operates for about 2 hours 45 minutes with the lithium-ion battery on low PWM setting of 10. The surface agitation of the water was slow because of the low PWM contributing to slow dc motor speed but eventually stays slow and decrease in voltage as the battery deplete and stops at 6.36V.

Based on the table 8, table 9 and table 10, it can be concluded that higher PWM settings lead to faster motor speeds and more vigorous surface agitation. However, higher motor speeds also consume more power, causing the battery to deplete faster. Conversely, lower PWM settings result in slower motor speeds, gentler surface agitation, and extended battery life. Other than that, the min and max of PWM can be set at Blynk data stream. The min limit is 0 and max limit is 255 thus the aerator is set at min 10 and max 140 because at 255 the aerator speed is impractical as it depletes battery too fast and vibrates vigorously. Figure 4. shows the slider V4 data stream and the min and max setting.

Therefore, the choice of PWM setting for the aerator's dc motor should consider the desired surface agitation, required battery life, and the capacity of the lithium-ion battery. Higher PWM settings may be suitable for situations requiring intense agitation for instance large tanks and low oxygenated tanks but with shorter operating times, while lower PWM settings are more suitable for longer operating times with less vigorous agitation, suitable for smaller tanks and semi-naturally agitated tanks.

4. Conclusion

In conclusion, the results analysis revealed important findings regarding the main tank level, backup level, feeding attempts, automated feeding, aerator speed, and battery life. The water levels in both main and backup tanks were precisely recorded by the ultrasonic sensors, enabling accurate monitoring and management. The automated feeding system performed consistently and effectively, with the open time of the feeder directly influencing the amount of food dispensed. The automated system successfully maintained the health and safety of marine life in the aquarium, providing essential functions such as feeding, surface agitation, and water change.

The project's contributions to others include the development of an IoT-based automated aquarium care system that can serve as a valuable and reliable tool for aquarists. The system's ability to make informed decisions and take actions during critical situations, even in the absence of the user, enhances the overall management and maintenance of the aquarium. In addition, the system is battery powered as backup mechanism to guarantee the stability of the ecosystem in the event of a power outage.

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