Automatic Aquarium Water Change System With Real Time Monitoring Through IoT

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***Abstract*— As Malaysia pandemic is coming to an end, all the hobbyists will begin to return to their respective work life which some even includes travelling overseas. This will leave their aquatic pets unattended, their pets might starve to death or even worst got poisoned by the dirty tank water which leads to death of fishes as well. The main aim of this project is to create a self-sustainable aquarium system through real-time IoT control using Arduino and ESP 32 as microcontroller. The system implemented will be well equipped with a feeding system, water parameter monitoring and a water change system. The methodology used will be using user-based input feeding system that can control the amount of food being dispensed to prevent any overfeeding. It is observed that the food being dispense is more consistent compared to human feeding manually. Besides there will be a water quality monitoring system where the temperature and the PH value is being kept at optimal level. Whenever the water parameters exit the optimal condition, respective actuators will be turn on to return the water quality back to optimal conditions. All the parameters will also be displayed on a web and mobile application platform whereby user can get real time streaming and live situation from the application. Some future enhancement that can be performed on this project will be using more specific sensor and actuators to create a more precise and accurate system.**

Keywords*— *Automated Aquarium, Feeding System, Blynk IoT, Arduino, ESP 32

I. Introduction

Interactions with non-human animals (hence referred to as "animals") have been linked to a variety of psychological advantages in humans. Some researchers mentioned that it is a good solution to overcome some psychological interventions to a wide range of emotional problems which includes depression, loneliness, grief, trauma, somatic concerns, sleeping problems, eating disorders and substance abuse. Besides pet owners experience greater physical and psychological wellbeing. Pets may act as a buffer against the negative impact of stress. One study found that pet owners who were present with their pet during a math test had lower heart rates and blood pressure reactivity than those who were not. Pets can help lower susceptibility to serious illnesses such as cancer and heart disease (Ronald J. DeVries, 2020), the author has also suggested that aquariums in the home can help children with ADHD to calm down and regulate their emotions.

As the COVID-19 pandemic continues to spread and individuals remain confined to their own houses, many are looking for new hobbies and activities. With a large portion of the population seeking what fits them best, many have turned to home aquariums to keep themselves occupied and engaged during this pandemic period. Based on the owner from Premier Pet Supply, there was a spike in number of individuals consulting information about home aquariums (Manning, 2021). But as pandemic come to an end human are returning to their normal working lifestyles which will be a problem to current aquatic pets' owner as some might need to work outstations.

Feeding management is a significant barrier to aquaculture growth. It is a poor practise for fish owners to provide extra food to the fish in the tank before to their absence, since this may result in the fish being overfed which will kill the fish. Additionally, the food degrades in the water, producing proteins and nitrites, reducing the quantity of oxygen in the water, which is detrimental to the survival of fish (Balaji et al., 2020). Fish have a daily feeding routine, which makes it difficult for the fish owner to be away from home. As a result, there is a requirement for an automated system capable of consistently feeding a fish. Thus, an automated fish feeder may be utilised to ensure adequate feeding at specified times while also monitoring and maintaining the environment suitably. For example, whenever the pH level and temperature of the water fall below the minimal values, an automated system should be present to fix the water parameters issues.

The current available method, which is dependent on timers, is incapable of controlling the amount of food delivered to the tank. This results in an insufficient/excessive amount of food, which both result in the death of aquatic organisms. The most frequently made statement by fish raising enthusiasts is issue of feeding the fish when they are away from home for a long amount of time or are unable to keep a regular feeding schedule due to their hectic schedule. The situation deteriorates further during Eid, Puja, or other holidays when they are required to depart for an extended period of time (Ali et al., 2020).

The current monitoring system available do not have a phone app to control the entire system. If devices from various manufacturers do not adhere to the same standards, integration between these devices will be more challenging. To create an IoT application, a variety of information and communication technologies in the form of hardware and software must be integrated (Pasha Mohd Daud et al., 2020).

The current system available only has the ability to alert the fish owner whenever water level has reached a minimal level but not an automated system to perform water change. Water change is a crucial part of fish keeping as it do not just remove dilute nitrate concentration but also eliminate dirt, debris, and sludge build-up. Hence whenever water conditions change dramatically in almost every measurement a water change process should be conducted (Lucas, 2020). Automatic Aquarium Water Change System has become a hot topic of research where many researches have been carried on IoT-Based Smart Aquarium Monitoring System (Pasha Mohd Daud et al., 2020a, Suhaimi et al., 2021, Rewatkar et al., n.d., Cheng et al., 2019), (Patel et al., n.d.). The Internet of Things (IoT) is an intelligent network which It is an extension and expansion of Internet-based network, which expands the communication from human and human to human and things. Many smart technologies will be embedded into a variety of applications (Faiyaz et al., 2022, Haziq et al., 2022, Rasheed et al., 2021)

(Jasim et al., 2021) conducted research on Implementation of an Automated Fish Control and Monitoring System Based on Internet of Things Technique. The proposed system will be fish can be fed automatically twice day using a servomotor. The feeding subsystem can be adjusted by adjusting the servomotor's degree of rotation (the motor degree directly proportional with amount of food). Numerous sensors, including ultrasonic, temperature, and PH sensors, have been used to create a suitable and healthy habitat for the fish by sensing the amount of water, the temperature degree, and the water pH value. Sensor data is wirelessly displayed on the mobile phone using the BLYNK application via IoT. Additionally, they are exhibited concurrently on the on-site Liquid Crystal Display (LCD). When the Ph value is greater than 8 but less than 6.5, the water can be replaced because this range is more suited for fish life. Additionally, if the water temperature is less than 20degree Celsius, the 220v heater is turned on. The water level is detected using an ultrasonic sensor, and if it falls below a pre-set setting, a pump is activated to re-fill it to the needed level.

(Hardyanto et al., n.d., 2019) conducted research on smart aquarium based on internet of things. The reason of this research is due to e provision of fish feed that is still manual. It will be very troublesome if the fish owner has a very high activity, so the risk of forgetting to feed fish is very high. Hence it is important to have an aquarium system that is eye catching and completely automated. This smart aquarium is equipped with automatic lighting, automatic feeders, and automatic water content measurement. The hardware consists of a microcontroller of Arduino Mega 328 which can acquire date from sensors. In this case, the sensor used will be light sensor, humidity sensors and water level sensors. It also consists of web-based interface that allows user to control the aquaponic system.

(Prangchumpol, 2018) conducted research regarding A Model of Mobile Application for Automatic Fish Feeder Aquariums System. The implementation was broken down into 4 steps. Step A was to study problems and possibility. Research paper was reviewed to gather data and system development. Step B was design and develop automatically fish aquarium. This step was separated into 2 parts. First part was to design the system while second part was to design mobile application. Firstly, system design was written down, such as the PH measurement, feeding system and lighting. In this case raspberry pi was proposed as the microcontroller of the system. Second part was to design the program to use PH value measurement as water changing factors, The optimal range was set at 6.5 to 9.0. Third part was to set up for feeding process. Users can determine the specific amount of food and time. Forth part was developing the lightning system to control turn on and turn off of bulbs in a fish aquarium using raspberry pi. Lastly, a mobile application was designed so that raspberry pi can be paired with wireless devices. Step C was regarding an automatically fish feeding system (phase 1). Using C# language, a mobile application was created. The application will be able to control sensors in fish feeding, PH value measurement and lightning. The data can be retrieved in real time allowing users to check current information. Step D will be regarding the Automatically Fish Feeding System (phase 2). This section will be more focused on testing. Again, this part was separated into 2 sections, accuracy, and satisfaction toward an automatically aquarium system.

(Hutabarat et al., 2022) conducted a study on smart system for maintaining aquascape environment using internet of things-based light and temperature controller. This intelligent device assists users in maintaining the plant aquarium's environmental conditions. An mobile application was then developed which will enable the user to connect to the system through internet. This system provided functions for maintaining the aquascape's properties, most notably the light intensity and water temperature. It is envisaged that with this tool, plants would thrive in accordance with the light level and water temperature requirements of the aquarium plants. There were 2 main block diagrams for this system, controllable LED and temperature controller. (Khairunisa et al., 2021) conducted research on Smart Aquarium Design Using Raspberry Pi and Android Based. The main component selected was Raspberry Pi as a microcontroller which controls the connected devices. Servo motor act as a valve which is used to control the fish food valve. And lastly relay were used as connecting switch and an electric circuit breaker in decorative lamps.

(Reynaldi & Hamdani, 2021) conducted research towards a Aquarium Automation System Using a NodeMCU. The purpose of their research was to tackle the problem where fish enthusiasts busy with matters that take a long time to handle so they do not have time to take care for their pet fish. NodeMCU is utilised as a temperature sensor data reader, pH, ultrasonic, and servo data receiver, as well as a relay to control valves, pumps, heaters, and fans. The data analysis findings will be wirelessly sent to cellphones via the Blynk application. The study's outcome is a system capable of feeding fish on a predefined timetable, replacing water based on the acidity of the water's pH, and adjusting the temperature to the fish's natural environment. Thus, this automated solution will be beneficial for users who are frequently out from town for days on end.

(Naj & Sanzgiri, 2021) conducted a study on water quality monitoring system. The suggested model, water quality monitoring in aquaculture using IoT, is used to identify various characteristics of water such as pH value, turbidity, and temperature in order to detect water of poor quality that may cause illness or have a harmful effect on a living creature. As a result, it is critical to identify the water's quality in order to have safe drinking water for a healthy living. Traditional procedures involve the collecting of samples manually using a sophisticated process that is ineffectual due to the length of time required, the high cost, the absence of real-time monitoring, and the testing is performed later in the laboratory. The data is computed and sent to the cloud using a variety of sensors. The system is built on the ThingSpeak platform, an IoT platform service that enables cloud-based data processing, storage, and display using MATLAB. Subsequently, IFTTT applets are utilised to notify the owner. In short the advantages of this system will be no need for manual collection, ease of use, cheap and quick process and real-time monitoring. As for hardware selection, NodeMCU was selected as an microcontroller. It will be used to control sensor such as temperature sensor, PH sensor and turbidity sensor. As for software selection, Arduino IDE was used to code the NodeMCU, ThingSpeak is an open-source Internet of Things (IoT) analytics platform that provides various functionalities like, aggregate, and analyse live data steam, storage of data in the cloud, and visualization of data through MATLAB programming and finally IFTTT applets which will be used to program various responses for events of different kinds.

The aim of this project is to create a self-sustainable aquarium system through real-time IoT control, with the objectives of: design an auto feeding system with based on user input, develop an IoT based water parameter control (pH, temperature, lighting, water level) system, and develop an automated water change system with Arduino microcontroller. Fish are opportunistic and are constantly on the lookout for food. Overfeeding is the most common error that fish owners make, as uneaten food pollutes the water. Indeed, fish can easily survive several days without food, and moderate underfeeding has minimal adverse effects. When free ammonia is being built up it is advised to feed fish no more than once per day to reduce the waste productions (Lin & Tseng, 2019). Hence due to all these different scenarios it is very crucial to create a user-friendly application or system that can handle different amount of fish food being dispensed into the fish tank.

Besides due to lockdown coming to an end it is also important to have a control system that can observes and control the parameters such as PH values. PH fluctuations, particularly abrupt ones, can be detrimental or even lethal to fish. Breeding happens exclusively within a narrow pH range in certain fish species. (Pasha Mohd Daud et al., 2020a). This has proven the significance of having an automated water change system which is embedded in an app which can simplify the tank owner. Besides, the actuators that will be implemented such as fans and heater can provide an optimal temperature of the aquatic organisms to survive and thrive in the tank.

II. System Implementation

A. Block Diagram

Fig 1. demonstrates the block diagram of the entire Smart Aquarium system. The three main components or microprocessor used will be Arduino MEGA 2560, ESP 32 Dev module and ESP 32 CAM. Serial communication was performed between these microcontrollers to establish the communication process for the sensor's data. The input data for this sensor will include current sensor, PH sensor, temperature sensor, 2 ultrasonic sensors, and voltage sensor. The data will then be sent to ESP 32 for further processing to activate respective relays/ actuators. There will also be other information present in ESP 32 which includes the Wi-Fi speed, MCU temperature and actual time. There will be a total of 6 actuators in total for the system. Fan and heater were used to control the temperature. Water pump was used to control water change system. LED to control the lights and finally servo motor to control the feeding of the fishes. All the data of the sensors will be feedbacked and sent to an Blynk IoT platform data logging and sensor monitoring. Besides the livestreaming of the ESP 32 CAM will be done via the BLYNK mobile application.

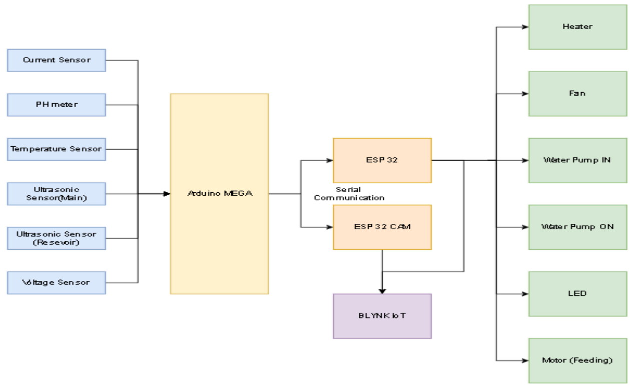

Fig. 1. Block diagram

B. Flowchart

Fig 2. shows the flowchart for Arduino. All the sensor data was processed through this microcontroller as there was insufficient pins present in ESP 32. The sensors' detected value will first be gathered in a string format and sent it to ESP 32 for further processing. Values will constantly be uploaded via serial communication until the power for the Arduino MEGA is cut off.

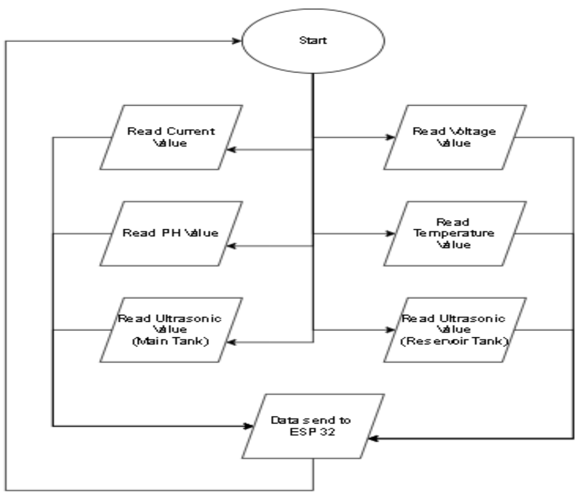

Fig. 2. ESP 32 main flowchart

Fig 3. demonstrates of code for ESP 32. The first action done was to connect the device to Wi-Fi network. The time variable was also obtained via a NTP server online. Then the program proceeds with multiple subsystems as shown in figure and will be further elaborate below. After the process of each subsystem, the data will be sent to BLYNK IoT for monitoring and also data logging.

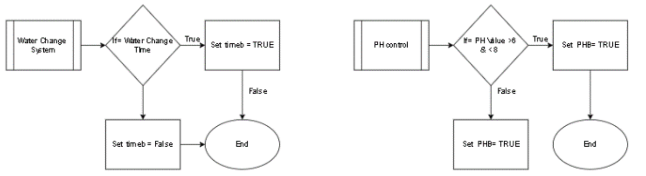

Fig. 3. Water output flowchart

Fig 4. shows the entire process flow of water change process. It can be seen the water change when either one of the variables is activated, hence this will prevent contradicting scenarios.

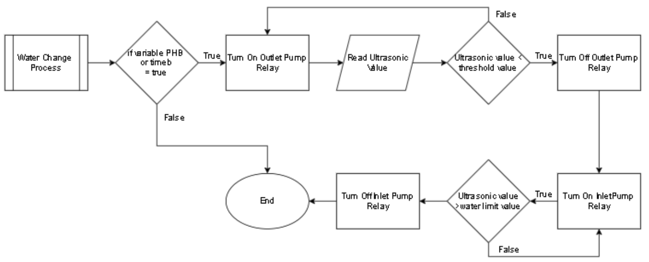

Fig. 4. Water Change Process Flowchart with variables

Fig 5. shows the flowchart for lighting system. The LED will only be turned on when either one of the conditions is fulfilled. While Fig 6 and 7, shows the flowchart for feeding and temperature control system.

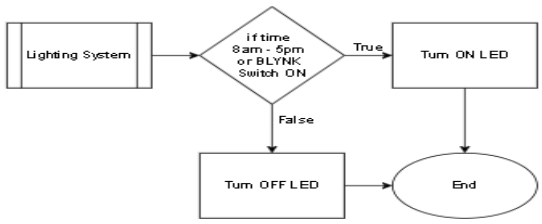

Fig. 5. Lighting System

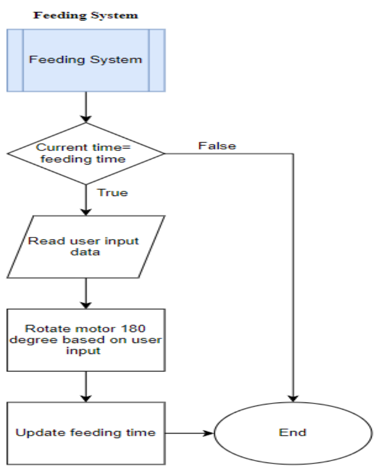

Fig. 6. Feeding system

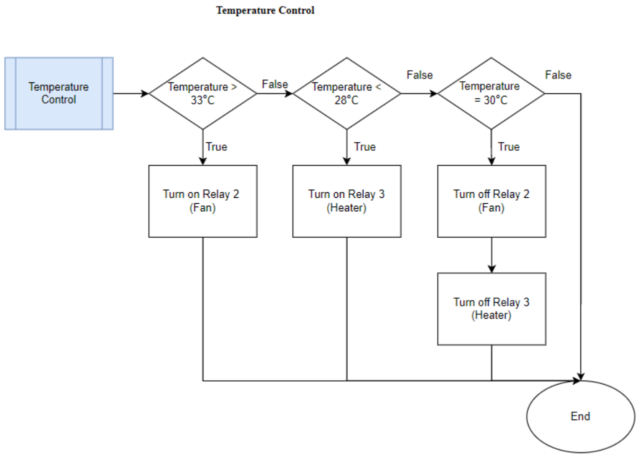

Fig. 7. Temperature control system

C. Design Specifications

Fig 8 and 9 shows the dimension and design of the rack used for this system. It will act as the main support for aquarium tank. The dimension for this rack will be 60cm x 30cm x 150cm. There will be 3 layers for this rack, the bottom level for reservoir tanks, second level for main aquarium tank and lastly the upper level will be used for component placement and storage area. The final assembly of all the drawing parts will be shown in Fig 10. The smart aquarium will be mainly consisting of 6 main parts. 2 water reservoirs for clean and dirty water, an aquarium tank, a self-made pipping, components' box and finally rack for the entire system.

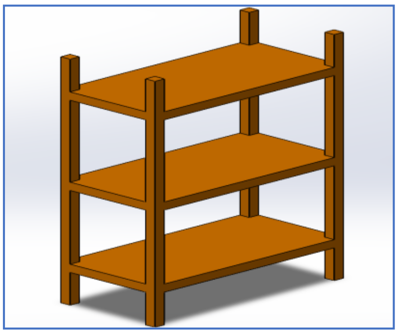

Fig. 8. 3D Drawing for Rack

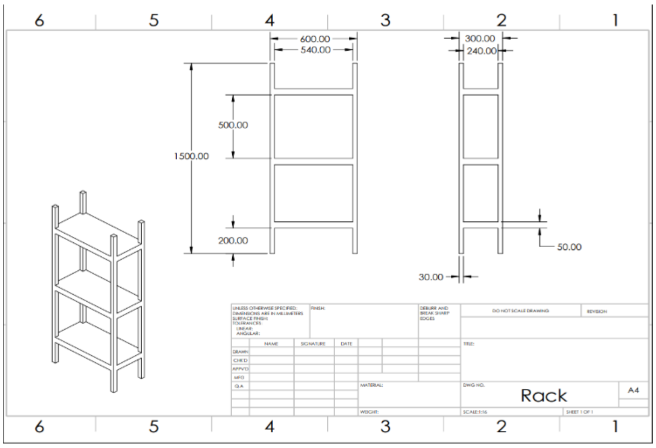

Fig. 9. 2D Drawing for Rack

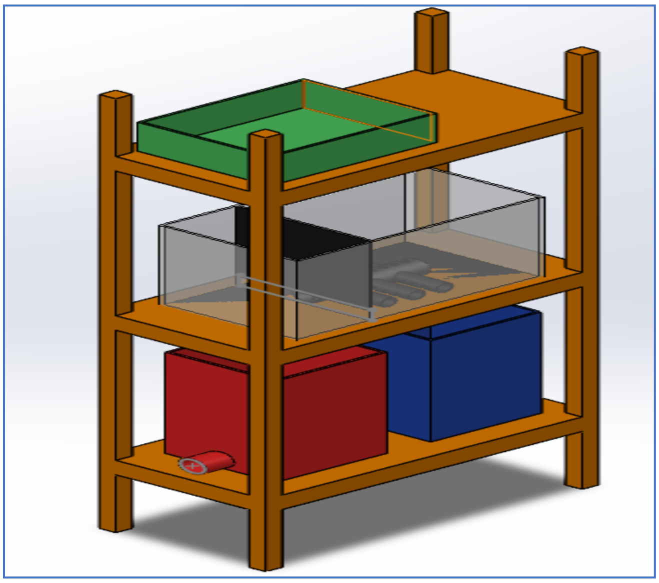

Fig. 10. Assembly for all components

D. Hardware Results

Fig 11. demonstrates the final prototype for the proposed system. There will be total of 3 levels in the system. First level demonstrates the circuits and wiring, the second level demonstrates the main tank with all the essential sensors and finally third level shows the reservoir and wastewater tank. Fig 12, 13 and 14 demonstrates the individual diagram of each level in details.

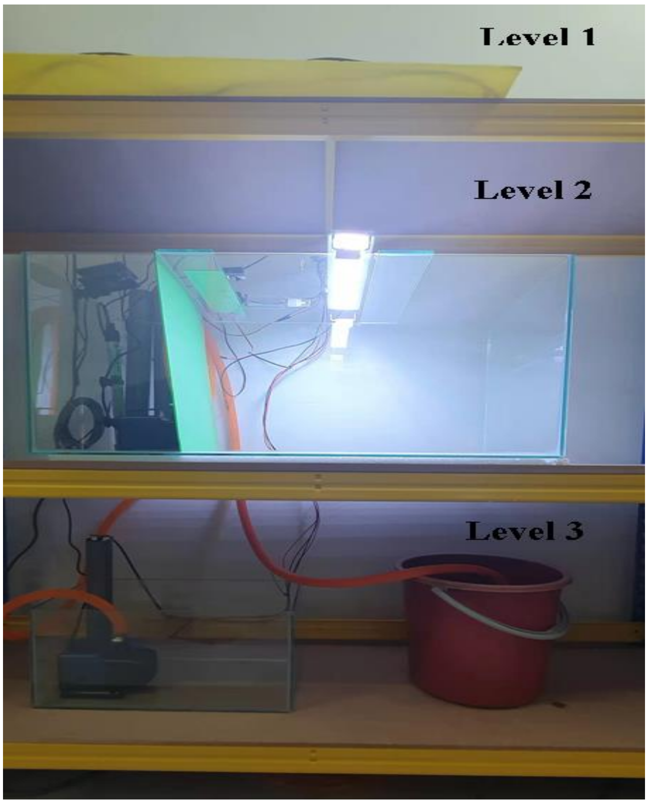

Fig. 11. Final Prototype

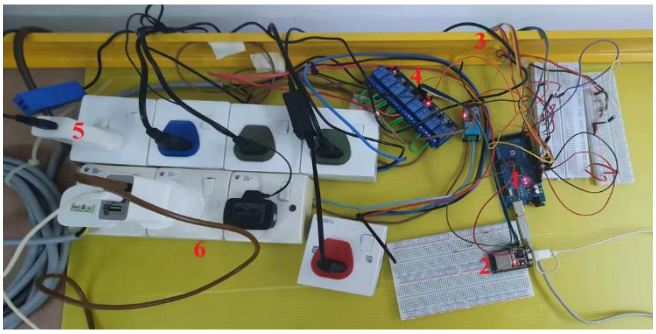

Fig. 12. Level 1 diagram

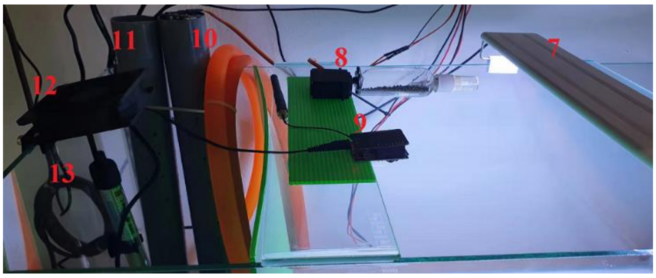

Fig. 13. Level 2 diagram

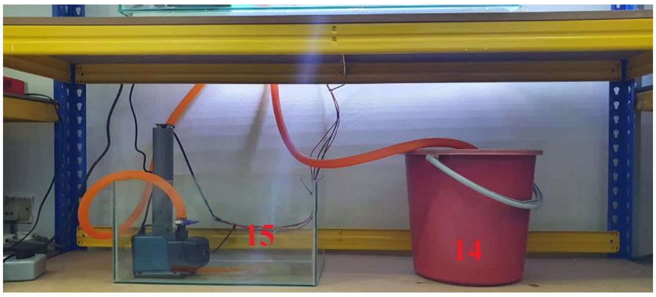

Fig. 14. Level 3 diagram

E. Software Results

Fig 15. demonstrates the IoT Dashboard created with BLYNK that was embedded together with the sensor data via virtual pins. Each block shown in the figure has their respective virtual pin which was bind to respective readings obtained by the ESP 32 unit.

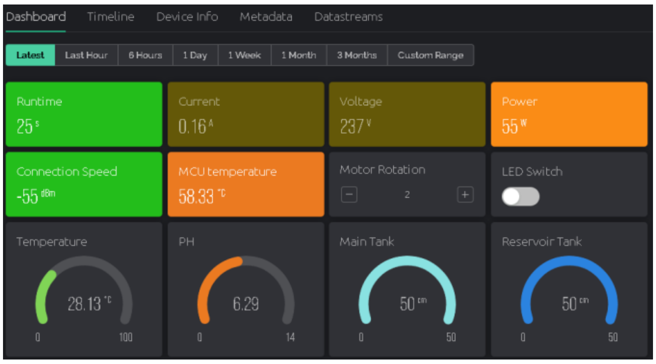

Fig. 15. BLYNK IoT Web dashboard

III. Testing of the Proposed Design

A. *Feeding System Test*

This test was performed to experiment on the stability and accuracy of the fish food dispensing mechanism. 5 sets of data were collected by rotating the servo motor and each time the number of pallets discharged was calculated. The ideal output of the feeding system is 10 pallets per rotation. This test was done so that the system is free from overfeeding the fishes. The number of pallets dispense after each rotation was recorded and tabulated in Table I**Error! Reference source not found.**. A total of 5 number of tests conducted for this subsystem to obtain its accuracy.

TABLE I. Feeding Test Results

Test	No of pallets dispensed
1	10
2	9
3	10
4	12
5	11

Based on the data collected it can be seen that the output was not consistent. Using simple efficiency calculation, the accuracy percentage can be obtained and tabulated in Table II.

TABLE II. Accuracy Testing Results for Fish Feeding System

Test	Accuracy
1	100%
2	90%
3	100%
4	80%
5	90%

Based on the obtained data, it can be calculated the accuracy of the entire system has reach an accuracy of 92% which was acceptable. The error percentage may be due to size of fish pellets being too small hence affecting the number of dish pallets being dispensed into the tank.

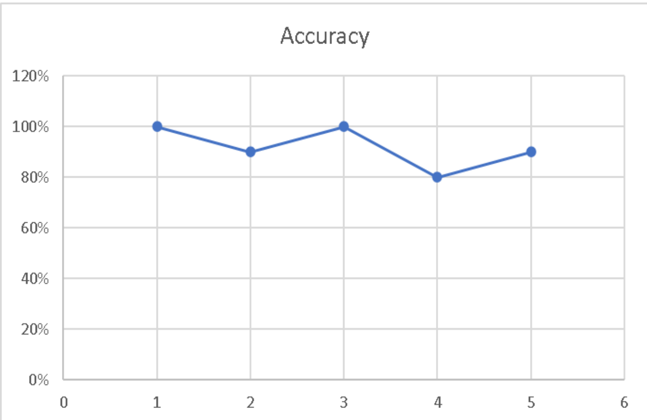

Fig. 16. Accuracy graph for feeding system

B. *LED lamp output accuracy test*

This test was performed to identify all the possible outcome for the lightning system. As mentioned in the programming part of the codes, there will be 2 conditions that affect the output of the LED lamp, this test conducted will be simulating all possible scenarios using logic gates concept. There is a total of 2 input for the LED system, hence a total of 4 test was conducted to make sure that the LED achieved the expected output. The results collected were tabulated in table III.

TABLE III. LED Lamp Outputs Based on Different Inputs

Test	Timer	Manual Switch	Output
1	False	On	Lights On
2	False	Off	Lights Off
3	True	On	Lights On
4	True	Off	Lights On

Based on the results obtained in Table III. It can be seen that the system has worked as expected based on the coding. Hence the results of this test will be 100% accurate and it can be represented with a OR gate logic whereby when 1 input is TRUE, the LED will be turned on.

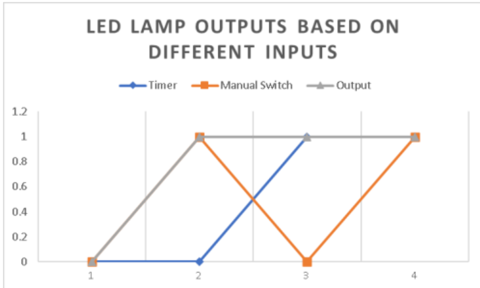

Fig. 17. Graph of LED lamp outputs based on different inputs

C. *Number of Water Change Cycle Test*

This testing was conducted to calculate the amount of water change cycle that can be perform by water change system as shown in Fig 18. The test was conducted when the main tank is empty while the reservoir tank is at its full capacity. The test was conducted assuming the main tank is full at 30 cm and reservoir tank is full at 20cm.

	Initial Condition	Final Condition
Reservoir Tank	 20cm	 12cm
Main Tank	 0 cm	 4 cm

Fig. 18. Water level tests

Based on the observed data, it can be seen that a 13.33% water change will take up to 40% of the reservoir tank. Hence it can also be concluded that the reservoir tank can last for 2 complete water change cycle. Each water change will be performed once every month. Hence if water quality remains optimal, hence the entire reservoir tank can last for 2 months. As mentioned, this system is very customizable hence to increase the complete water change cycle, the user can change the reservoir tank to a larger volume.

IV. Conclusion

In summary, the proposed idea to create a automatic aquarium water change system with real time monitoring through iot has been proven to work. With the preliminary results it has also shown that each of the sensors can produce the desired outcome. This project's aim and objectives have been met with an complete operational system. Serial communication was a major success which was used to communicate with sensor data. With the sensor data, only the actuator can be initiated to work accordingly. Besides all the data were also able to be written to the online IoT platform for monitoring purposes. All the programming were done using Arduino IDE using C programming language.

Hardware limitations were one of the sources that causes the fluctuations of the sensor data, some sensors such as ultrasonic sensor were providing inconsistent values that contribute to random actuators triggering. Another limitation that was present in this system includes the tank size. The reservoir tank can be larger to accommodate more water storage in reservoir so that the refilling process can be perform less frequently.

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